Development of a Southern Vilnius Standard Photometric System

by

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Abstract

The Vilnius Standard Photometric System is said to have several advantages over other photometric systems; reduction procedures free of systematic errors, a homogeneous set of standard stars, accurate dereddening, spectral classification and calibration of physical parameters for normal stars, and a good detection rate of abnormal stars. To investigate these, two southern, open star clusters (Omicron Velorum and Kappa Crucis) have been measured in the Vilnius system. The observations were used to derive astrophysical parameters such as age $((45 \pm 15) \times 10^6$ and $(10 \pm 3) \times 10^6$ years respectively), composition (both solar metallicity), distance to the clusters ($m-M = 5^m.94 \pm 0.02$ and $12^m.18 \pm 0.05$), interstellar reddening along our line of sight to the clusters ($E_{Y-V} = 0^m.00 \pm 0.02$ and $0^m.31 \pm 0.09$), and cluster membership probabilities for the individual stars. These compared favorably with the consensus of similar analyses made by observers using other photometric systems, with one exception being the distance to Kappa Crucis ($\langle m-M \rangle = 11^m.59$).

As no stars further south than declination -26° have been measured in the (original) Vilnius System, it was necessary to calibrate the local system to the standard system by measuring equatorial stars common to both. To alleviate this problem in the future, suitable southern stars were measured to form a southern standard system. Initially bright stars evenly spread across the sky were calibrated - this will ensure any future observing programme will have nearby standards. The next phase of the programme was to calibrate the E-region stars - this is a set of stars in common use as southern standards in other photometric systems. The final phase was to calibrate a sequence of stars near the south celestial pole - producing a set of stars so that the same standards can be observed at any time during the year. This southern standard system could not be completely established in the time available (it is approximately 50% finished), due to the larger than expected uncertainties in the measurements largely caused by the atmospheric effects of the Mount Pinatubo eruption.

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Chapter 1

Introduction to Photometric Systems.

1.1 Possible information found from Spectroscopy.

Some possible sources of information about stars and interstellar material are electro-magnetic radiation (of all wavelengths, for example gamma rays, X-rays, ultra-violet (UV), visible light, infrared, or radio waves), cosmic rays (consisting of high energy electrons, protons, and heavier nuclei, plus neutrons and mesons, with some anti-matter), neutrinos and anti-neutrinos, and, perhaps one day, gravitational waves. Traditionally most measurements have been made of e-m radiation, with observations in the optical region having the longest history. Generally e-m observations give information only about the surface of stars, while neutrinos give complementary information about stellar cores. As this work concerned a visible light measuring system, a brief outline of the information that can be found from this region will be given next — any university undergraduate textbook on quantum mechanics or e-m radiation should be referred to for more detail.

A 'black body' is defined as any object that absorbs all incident light (at all wavelengths) and reflects none. It is also a perfect emitter of light, producing a continuous spectrum in a way that only depends on its temperature;

$$E(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1} \quad (1.1)$$

E is the energy emitted per second, per unit wavelength interval, per unit (surface) area of the black body, into a unit solid angle, h is Planck's constant, k is Boltzmann's constant, c is the speed of light, λ is the wavelength and T is the (absolute) temperature. Black bodies do not actually exist¹ but any hot, opaque solid, liquid or (compressed) gas will behave approximately like one.

Two important results for black bodies are best seen in the following equations (which can

¹If Quantum black holes exist, they are expected to radiate as a black body via quantum fluctuations in the size of their event horizon

be derived from equation 1.1). The first is Wien's displacement law

$$\lambda_{max}T = 2.9 \times 10^7 \quad (\lambda \text{ in } \text{\AA}) \quad (1.2)$$

which states the black body emission has its maximum intensity at the wavelength λ_{max} , and this 'peak' wavelength shifts to shorter wavelengths as the temperature increases. The second result is Stefan's law

$$I = \sigma T^4 \quad (1.3)$$

which states that the total energy emitted (i.e. over all wavelengths) per second per unit area (I) increases (rapidly) with temperature, where σ is Stefan's constant.

Thus the temperature of a black body can be measured in three ways; fitting a black body curve to the measured spectrum, measuring the maximum intensity wavelength, or measuring the total energy emitted (over all wavelengths). The latter is not generally used due to difficulties in calibrating the measurements in absolute units, measuring the radius or angular size of the object (which is difficult for stars) and covering a sufficiently large wavelength range (to approximate the complete range).

If a star is spherical (radius R) and has the same temperature over its entire surface, then the total energy emitted by the star is

$$L \propto IR^2 \quad (1.4)$$

Approximating the star as a black body with an effective surface temperature (T_e) gives

$$L \propto T_e^4 R^2$$

Normalizing by dividing with solar units (subscript $\odot$) gives

$$\frac{L}{L_\odot} = \left(\frac{T_e}{T_{e\odot}} \right)^4 \left(\frac{R}{R_\odot} \right)^2$$

This is more commonly used in logarithmic form

$$\log \frac{L}{L_\odot} = 4 \log \frac{T_e}{T_{e\odot}} + 2 \log \frac{R}{R_\odot} \quad (1.5)$$

An alternative form uses the surface gravity (g)

$$\log \frac{L}{L_\odot} = 4 \log \frac{T_e}{T_{e\odot}} + \log \frac{\mathcal{M}}{\mathcal{M}_\odot} - \log \frac{g}{g_\odot} \quad (1.6)$$

vis $g = G\mathcal{M}/R^2$, where G is the universal gravitational constant and $\mathcal{M}$ is the mass of the star. These relationships are expected to hold when a star is in energy equilibrium (for example, on

Black Body Spectra

Figure 1.1: Black Body emission spectra at different temperatures over the optical wavelength region. The temperatures correspond to the effective surface temperatures of M0 V (3900 K), K0 V (5050 K), G0 V (5940 K), F0 V (7290 K), A0 V (9590 K), and B0 V (31480 K) stars — Temperatures taken from Appendix 3 of Straižys (1992). The emitted energy is plotted using the logarithm (to base 10) as the maximum energy (for each temperature) varies by a factor of 10^4 .

the main sequence) — if the star is non-spherical or has a non-uniform temperature distribution, then the radius or temperature may be replaced by effective parameters (averaged over the star's surface).

Light can be described by both wave and particle models,² with the connection between the models given by

$$E = h\nu = hc/\lambda \quad (1.7)$$

where E is the energy of the particle (called a photon), h is Planck's constant, c is the speed of light through the medium (usually a vacuum), and ν, λ are the frequency and wavelength respectively of the e-m wave. This is often used in alternate form

$$E = \hbar\omega \quad (1.8)$$

where ω is the angular frequency ($\omega = 2\pi\nu$) and $\hbar = h/2\pi$.

²What are normally considered particles, for example electrons or atoms, can also be described by both particle and wave models.

This particle/wave duality has important consequences when combined with the quantum nature of matter. The energy states of atomic and molecular systems are found to only occur in certain discrete values (i.e. they are 'quantized') rather than being free to take any value from a continuous range. To change the state of a system, it must absorb (or emit) energy corresponding to the difference in energy between its initial and higher (or lower) final energy state. Thus a system can only absorb a photon if the photon's wavelength corresponds to a energy, via equation 1.7, that will excite the system to a higher level from its current state. The converse applies when an excited system decays to a lower energy level by emitting a photon; the photon's wavelength corresponds to the difference in energy levels.

However, quantum systems may have some energy states so closely spaced together that they merge to form a continuous energy band, with the system able to take on any energy level within the band. This is more common in larger systems, as, according to the correspondence principle, any quantum system behaves more like a classical system (which can have any energy from a continuous range) as its size increases.

The energy states of concern here are the 'bound' electrons which orbit the nucleus of an atom. An electron excited to a higher energy state moves to another orbit which is, on average, further from the nucleus than the initial orbit.³ If the electron receives enough energy that it escapes from the attraction of the nuclei's electric field, the atom is said to be ionized. Such 'free' electrons are actually then part of a much larger quantum system (of all the neighboring atoms and other free electrons) which has an continuous energy band from the ionisation energy upwards. Further, the energy levels of the atom change when it becomes ionized and changes again each time it loses another electron.

The quantum states (and transition probabilities) are unique to each element, meaning the resulting pattern of absorption (or emission) lines allow that element to be identified. However the absence of an element's absorption lines (in a star) does not mean the element itself is absent as the star's surface may not be at the right temperature and pressure to maintain a large enough population of atoms excited to the right energy levels that the lines can be seen (in the wavelength region observed).

Consider the hydrogen atom; to a good approximation its energy levels are

$$E \propto \frac{1}{n^2} \quad (1.9)$$

where n is the quantum state, ranging from the ground state ($n = 1$) to the ionisation level ($n = \infty$). Thus the wavelength of a photon arising from a transition from the n_i initial state

³The electrons don't follow well defined orbits (in the sense of planets orbiting a star) but instead have their position given by a probability function, in keeping with their dual particle/wave nature.

Example of the hydrogen Balmer series

Figure 1.2: Example of the hydrogen Balmer series of absorption lines. The star is θ Vir, an A0 V type star, whose spectrum was measured by Gunn & Stryker (1983).

to the n_j final state is

$$\frac{1}{\lambda} \propto \frac{1}{n_i^2} - \frac{1}{n_j^2}, \quad (1.10)$$

the photon being absorbed if $n_i < n_j$ or emitted if $n_i > n_j$. For instance, the Balmer series of lines arises when one of the quantum states is $n = 2$ and the other is $n > 2$. Given that the first line in the Balmer series (H_α , between the $n = 2$ and $n = 3$ energy levels) corresponds to $\lambda = 6564 \text{ \AA}$, the next lines in the series occur at $H_\beta = 4861 \text{ \AA}$, $H_\gamma = 4342 \text{ \AA}$, $H_\delta = 4102 \text{ \AA}$ etc. The lines become increasingly packed together (in wavelength) as the series increases, ultimately stopping at $\lambda = 3646 \text{ \AA}$ when the atom is ionized. As the electron can take on a continuum of energies above the ionisation level, this absorption ‘line’ spreads out over all wavelengths for $\lambda < 3646 \text{ \AA}$. An example of the Balmer series in a star is shown by Figure 1.2.

Clearly the Balmer series is only seen in stars which are hot enough to maintain a large population of hydrogen atoms (on the star’s surface) excited to the first energy level. However, if the star is too hot then most of the hydrogen is ionized and the Balmer series is not seen. Hence the intensity of the Balmer lines indicate the temperature of the star’s surface; unfortunately the strength initially increases with temperature and then decreases again with further temperature increases. The lines also sharpen, and so increase their strength, with increasing pressure (i.e. surface gravity — see later). However each series of lines shows a similar tem-

perature dependence over a different temperature range — also each element shows a different temperature dependence. Thus the ratios of the line strengths between different elements can indicate the surface temperature of the star.

The absorbed/emitted photons for such atomic transitions generally have wavelengths in the UV and visible regions. However a molecule has additional energy states available, due to rotations of the entire molecule or vibrations of the component atoms. These energy levels are generally spaced more closely together than the atomic states, hence the corresponding photons have longer wavelengths and occur in the infrared or far-infrared regions for vibrational or rotational transitions respectively. Note that most molecules will break up before any of their component atoms can become ionized and so are only found in the cooler stars.

The conditions which give rise to a continuous spectrum, or discrete emission or absorption lines can be summarized by the following rules found empirically by Kirchoff;

1. A hot and opaque solid, liquid or highly compressed gas emits a continuous spectrum.
2. A hot, transparent gas produces an emission line spectrum.
3. If a continuous spectrum passes through a transparent gas at a lower temperature, then the gas produces absorption lines in the spectrum.

Thus the interior of a star produces a continuous spectrum, approximately described by a black body function, while the cooler, more transparent atmosphere produces absorption lines. Note that emission lines may also be seen, originating in the corona where the temperature increases again.

The Heisenberg uncertainty principle is also important for this discussion. This states that the product of the uncertainties of two complementary variables can not be less than Planck's constant, for instance energy and time ($\Delta E \Delta t \gtrsim h$). Each transition between energy levels in a quantum system has an associated probability of occurring. If the transition has a high probability, then the average time the system will spend in the initial state before undergoing the transition is small. Hence the uncertainty in that time is also small, and so the uncertainty of the change in energy is large. Thus the frequency of an emitted (or absorbed) photon is not a precise value (ω_0) but described by a intensity function of the form

$$I(\omega) \propto \frac{a}{a^2 + (\omega - \omega_0)^2} \quad (1.11)$$

whose intensity and line width is determined by the constant 'a' (which depends on the transition probability). Thus less probable energy state transitions give narrower, more intense absorption (or emission) lines.

This 'natural' line width is seldom seen, as a variety of processes act to broaden it. For

instance, collisions between atoms can stimulate an energy transition, i.e. increase the transition probability and hence increase the line width. This can give a measure of the absolute temperature (T) and pressure (P) of the gas; the collision rate (R_c) can be found by $R_c = n\bar{v}\sigma$ where n is the density of atoms in the gas, $\bar{v}$ is the average velocity of the atoms, and σ is the effective cross-sectional area of an atom. Combining this with the kinetic theory relation

$$\frac{1}{2}m\bar{v}^2 = \frac{3}{2}kT \quad (1.12)$$

and the ideal gas law

$$n = \frac{P}{kT} \quad (1.13)$$

gives

$$R_c = \frac{\sigma P}{kT} \left(\frac{3kT}{m} \right)^{\frac{1}{2}}, \quad (1.14)$$

where m is the mass of an atom and k is Boltzmann's constant. In other words, as the temperature decreases or pressure increases (of the region from which this line originates), the (frequency) line width increases. Astronomers usually measure the local gravity (g) rather than the pressure — these are related via the hydrostatic equilibrium equation

$$\frac{dP}{dr} = -ng, \quad (1.15)$$

where r is the radius from the center of the star.

However, in tenuous interstellar gas clouds, collisions are rare and so these sharp 'natural width' lines may be seen provided they are not hidden by lines from the star illuminating the clouds. If a cloud is predominantly hydrogen, interstellar lines are most easily seen when the star is sufficiently hot that all its hydrogen is ionized, and thus has no hydrogen lines of its own. Further, the low density of the clouds means so-called 'forbidden' lines may be seen. These are actually very low probability transitions, such as simultaneous two photon emission, which require the excited atom to be left undisturbed sufficiently long that it can spontaneously decay to a lower energy level via this particular transition. These sharp lines may allow individual clouds along the observer's line of sight to be resolved by their radial velocities and temperatures via the Doppler effect (see later discussion).

Thermally re-emitted light (for example from a dense gas cloud) is un-polarized. However, if the interstellar material are metallic grains, or elongated grains aligned by some process (for example by an electric field), then the scattered light is polarized.

In the previous discussion, many of the energy levels are actually the combination of several quantum states which have the same energy — these are called 'degenerate states'. However, in the presence of an electric field (from a neighboring atom say) or magnetic field these quantum

states will split into different energy levels, closed spaced above the degenerate energy level. This is known as the Stark effect or Zeeman splitting for electric or magnetic fields respectively. There are now many possible transitions (between these energy states) with very similar changes in energy, which can appear to blend together and increase the line width. Fortunately some of the different energy states produce photons with different polarizations, so splitting the light through a polarizer can allow the individual lines to be resolved. As these effects are proportional to the field strength (for weak fields; a quadratic term becomes important in stronger fields), it may be possible to measure the field strength if it can be untangled from the other broadening processes. For example, Jaschek & Jaschek (1987) give the line width ($\Delta\lambda$) due to Zeeman splitting as $\Delta\lambda \propto \lambda^2 H$, where H is the field strength.

Another important process is the Doppler effect; when an object is moving with a velocity $\mathbf{v}$ relative to an observer, any waves emitted by the object appear to the observer to be shifted in frequency compared to the frequency seen when the object is stationary. The 'relativistic' Doppler effect is

$$\frac{\Delta\nu}{\nu} \propto \frac{v}{c} \frac{1}{\sqrt{1 - (v/c)^2}}, \quad (1.16)$$

where v is the magnitude of the velocity. For objects not moving at a significant fraction of the speed of light, the 'classical' Doppler effect is sufficiently accurate

$$\frac{\Delta\nu}{\nu} \propto \frac{v_r}{c} \quad (v \ll c) \quad (1.17)$$

where v_r is the velocity component of the axis between the object and the observer (the 'radial' velocity). An object approaching the observer has a negative velocity and hence the wave is 'blue-shifted' to a lower frequency, with the converse case of a receding object being 'red-shifted' to a higher frequency.

If the object consists of a collection of smaller objects all emitting (or absorbing) waves and moving with different velocities (described by some statistical distribution), the Doppler effect results in a smearing out of the wave's frequency as what is actually seen is the combination of the individually Doppler shifted waves of all the (smaller) objects. For instance, the velocity distribution of atoms in a gas is given by the Maxwell-Boltzmann distribution (if they collide frequently) so the average radial velocity ($\bar{v}_r$), which is measured from an absorption line width, is related to the temperature by $\bar{v}_r^2 = kT/m$. The same line broadening effect can occur on the larger scale of micro-turbulence; consider a small cell of gas moving relative to other cells of gas (where a cell is a region in which the atoms can be described by a particular velocity distribution). Yet larger scales of turbulence can be found, right up to full-blown convection of the star.

The largest scale for which Doppler broadening can occur is in the case of a rotating star;

a quarter of the star is approaching the observer while another quarter is receding — the remaining half is on the ‘back’ side of the star out of sight of the observer. This broadening is proportional to $v \sin(i)$, where v is the rotation rate and i is the inclination angle (the angle between the rotation axis of the star and the axis connecting the observer to the star). As the inclination angle is not usually known, statistical studies of large numbers of stars must be used to gain information about rotation rates. There is also the added difficulty that for stars with very fast rotation rates, the lines become so broad and shallow that they are difficult to resolve from the continuum. Another effect of high rotation is that the centripetal force makes the star bulge out around its equator, and so the local gravity and temperature varies across the star’s surface.

Finally, the Doppler shift of the star’s lines gives the radial velocity of the star. If the star is sufficiently close to the observer that its proper motion⁴ can be measured, then its actual velocity may be found.

In a binary star system, the velocity curves of one, or both components, of the system may be found, which gives the period of the orbits and the total mass of the system. If the system’s orbital plane is nearly edge on to the observer’s line of sight, then measurements of the continuum during a complete orbit can give the angle of inclination of the system, the relative brightness of the component stars and their mass ratio. Combining this with the velocity curves gives a complete description of the system’s orbit and the masses of the individual components. Alternately, if the star is sufficiently close to the observer that the component stars can be resolved (so its proper motion and trigometric parallax can be measured), the orbit and individual masses may again be found.

Most of the previous discussion assumed that all the light from a star originates from the star’s ‘surface’, which is characterized by one combination of temperature, pressure and chemical composition. However the opacity of a star’s atmosphere varies with wavelength, so measurements in different wavelength regions will see to different depths and hence regions of different temperature, pressure and composition.

1.2 Why do photometry?

Given the information about stars and interstellar material that can be gleamed from spectroscopy, why then are so many measurements made using photometry instead? Spectroscopy, due to the low photon arrival rate per unit wavelength interval, requires very large telescopes and/or is restricted to very bright stars to get a sufficient signal in the limited time available

⁴The proper motion of a star is the transverse motion of the star, measured against the background of very distant (and therefore apparently motionless) stars.

for an observation (at most the duration of a night⁵). Further, large telescopes are expensive and difficult to obtain observing time on, and most stars are fainter than can be measured spectroscopically. Finally, much of the spectrum (of normal stars) contains redundant information (Bessell 1993), for instance only two or three points on the continuum are needed to derive the effective temperature. Thus the first question to answer is if the planned investigation requires the wavelength resolution of spectroscopy or will photometry suffice.

Assuming photometry is adequate, the next question is which of the existing photometric systems are suitable, or will a new system need to be designed. As each photometric system is (usually) designed to investigate a particular question (which accounts for the large number of systems, for example, the UBV system (and its clones and extensions), Washington, Geneva, DDO, Strömgren, Walraven, Borgman, Wing, and Vilnius systems to name but a few), there does not exist a single 'best' system — indeed many observers do not believe an 'ideal' system is even possible as it would have to satisfy many, often contradictory, requirements. Other observers however believe it is possible, with subsets of filters from the 'ideal' system selected to suit each investigation and having the added advantage of needing only one set of standard stars (Straižys 1966). To help explain why the Vilnius system was chosen for this study, two other photometric systems (the popular Johnson and Strömgren systems) will be described later and compared with the Vilnius system.

One important characteristic of a photometric system is the typical bandwidth of its filters. These are usually sub-divided into the three categories given below;

$$\begin{array}{ll} \lambda_1 - \lambda_2 < 90 \text{ \AA} & \text{narrow} \\ 90 \text{ \AA} < \lambda_1 - \lambda_2 < 300 \text{ \AA} & \text{intermediate} \\ 300 \text{ \AA} < \lambda_1 - \lambda_2 & \text{wide (or broad)} \end{array}$$

according to Strömgren (1963, 1966), where λ_1 and λ_2 are the minimum and maximum wavelengths through which the filter will transmit light. However it should be noted that these thresholds are only approximate. Figure 1.3 shows a selection of stellar spectra measured at spectroscopic resolution while Figures 1.4 and 1.5 show the same spectra seen at wide and intermediate bandwidth resolution respectively. Clearly broadband systems can only measure the largest features of a spectrum, such as the continuum and the Balmer discontinuity, while intermediate systems can measure additional features such as molecular absorption bands and some of the strong (single) absorption lines.

Another important characteristic of a photometric or spectroscopic system is its purity. Consider a photometric system with n passbands, so a measurement of a star can be thought of

⁵Some early photographic observations were made over several nights by re-exposing the same film with the same star field each night (Dodd 1994).

Spectra

Figure 1.3: Spectra of various Main Sequence stars, taken from the Gunn & Stryker (1983) catalog, de-reddened and normalised to the effective wavelength of the Standard Johnson V filter.

defining a point in an n -dimensional space. The measuring errors means a precise point is not defined, but rather a 'fuzzy' region known as a photometric box (Golay 1974, Jaschek & Jaschek 1987).⁶ Thus all stars falling in the same box are identical according to that photometric system even though they may in fact have different properties. The purity of each box is defined as the number of stars in the box having the desired property divided by the total number of stars in the box (Jaschek & Frankel 1985). The total number of stars in a box is usually increased by using dereddened colours (as a colour index cancels the inverse square law reduction of the star's intensity with distance), giving an $n - 1$ dimensional space.⁷

A necessary preliminary to the investigation is to pre-select stars of the appropriate type, so increasing the purity of the photometric system. This is often done as a survey with a form of spectroscopy using coarser resolution but covering a wider wavelength range than discussed previously, for example the $100 \text{ \AA/mm}$ dispersion of the MK classification system. The survey system is not usually suitable for the investigation itself as it gives qualitative information (i.e. by grouping similar stars together), while photometric systems give quantitative information. However some photometric systems can be used for both the survey and measurement

⁶These are also known as stellar or Golay boxes.

⁷An n passband system has $n!/(n-2)!$ possible colours but only $n-1$ independent colours.

Spectra smoothed by Standard Johnson V filter

Figure 1.4: Convolution of various Main Sequence spectra with Johnson V filter. Spectra taken from the Gunn & Stryker (1983) catalog and V filter response from Straižys (1992).

Spectra smoothed by Standard Vilnius V filter

Figure 1.5: Convolution of various Main Sequence spectra with Vilnius V filter. Spectra taken from the Gunn & Stryker (1983) catalog and V filter response from Straižys (1992).

phases, for instance the Vilnius system can correctly classify 95% of all stars in the MK scheme (Straižys & Philip 1994) and measure effective temperatures etc. (see section 1.7).

1.3 Designing a Photometric system.

A brief outline of the design of a photometric system is given next. As an example, consider a hypothetical system designed to measure the effective (surface) temperature of stars (T_e). It would be advantageous to situate the filters in the wavelength region of the star's maximum intensity, which can be estimated from Wien's law ($\lambda_{max}T_e = \text{constant}$) or Table 4.3 of Jaschek & Jaschek (1987). However for ground based observatories, the filters must be placed in an atmospheric 'window' of low extinction and avoid regions with highly variable extinction (for example water absorption bands — see Figure 2.12).

The bandwidth of the filters (i.e. narrow, intermediate or broadband) is set as a compromise between the need to reduce bandwidth effects (for example on heterochromatic extinction — see section 2.7) and increase the limiting magnitude of the system. Note also that the placement and shape of the filter responses becomes more crucial as the bandwidth decreases — for instance the effect of excluding a spectral feature by a filter which is slightly narrower or shifted in wavelength from what was intended (i.e. the standard filter) becomes more important as the feature occupies a larger fraction of the filter's bandwidth.

The number of filters in the system is similarly a compromise between the need to maximize information about the star's spectra ($E(\lambda)$) and minimize the time required to observe a star. For instance, a minimum of two filters (placed in continuum regions well approximated by a black body function) are required to measure the effective temperature — the ratio of the intensities cancels the inverse square law reduction of the star's intensity with distance to the observer. However if the stars are not nearby, they are likely to be reddened by interstellar extinction. Therefore more filters would be required to measure this effect, perhaps with one in the red or near-infrared where the reddening is weaker.

Another consideration is the wavelength spacing between the filters relative to their bandwidth, i.e. their overlap. Young (1988, 1992a, 1994) has found that it is vital the filters are spaced no further than their Full Width at Half Maximum (FWHM) apart so transformations (such as the heterochromatic extinction or from the local system to the standard system) for any star is free of systematic errors. This spacing is equivalent to satisfying the critical sampling theorem, i.e. to adequately sampling the spectrum so it can be fully described at the resolution level set by the bandwidth of the filters. As most photometric systems are designed for restricted sets of stars (for example early stars in the *uvby* system) which all give approximately the same systematic errors, this requirement has usually been ignored. Unfortunately most

photometric system have been extended to sets of stars for which they were never intended (Jaschek & Jaschek 1987), with the ensuing systematic transformation errors being different for each local system.

The reduction procedure used to convert the raw observations into measurements in the standard system (for example, see Chapter 2) must also be given. This ensures any systematic errors in the reduction procedures are the same for all observers, hopefully cancelling out when comparing results from local copies of the standard system.

In addition to the astrophysical factors discussed above, there are several practical considerations. Clearly the technology (i.e. filters, detectors) must be available and affordable. The filters need to be chosen to provide the highest transmittance possible consistent with the required effective wavelength and bandwidth.

The stability of the filters and detector is another important consideration; for instance interference filters cost more, have a smaller temperature sensitivity but are less stable (due to water vapour entering the layers), hence having a shorter lifetime, and produce narrower passbands (with high transmission) than glass filters (Young 1974). Each filter must be measured over a wide wavelength range to check for 'leaks' outside the intended passband — often these leaks can be removed by choosing a detector which is only sensitive over the intended wavelength range of the system, otherwise a blocking filter must be added. If observing near a city, or other light source, the system will need to avoid the wavelength(s) of the light and/or make frequent measurements of the sky background.

The system's properties, such as its purity, may be explored during the design stage using magnitudes and colours synthesized by convolving the passband response curves with stellar spectra (from either spectroscopic measurements or stellar atmosphere models). Further, reduction and dereddening procedures may be investigated. Synthesized magnitudes are also useful after the system has been implemented, reducing the number and variety of stars that need to be measured to calibrate the system and its reduction procedures (for example, see section 1.7 describing the Vilnius system).

A full description of the original (standard) system must be given, including the instrument (for example a 61 cm Aluminum coated mirror in a f13 Cassegrain telescope), the receiver (for example a photon counting 9558B PhotoMultiplier Tube (PMT) at -1500 V and cooled to -10° C , with an amplifier/discriminator) and filters (for example the U filter consists of 1 mm thick Schott WG355 glass glued to 7 mm thick Schott UG11 glass with Canadian Balsam). This will give other observers a starting point for their own local implementations of the system; however the definitive description is given by the transmittance curves of the entire system for each filter. These are usually calculated by convolving the measured transmittance curves of each filter with the receiver's response (often taken as the typical response from the

manufacturer's catalog) and the reflectance/transmittance curves of any optical elements in the telescope and photometer. An alternative is to measure some stars whose spectra are known (either by spectroscopic measurements or from a stellar atmosphere model). The response curve for each passband is convolved with the spectra and least squares fitted to match the measured magnitudes of the stars. To reduce the number of data points used in the fit, each response curve can be approximated by a cubic spline fitted to 4-5 points or Fourier series of 4-5 sine functions (Jaschek & Jaschek 1987), using the calculated passbands as a starting point. This works best if there are no strong spectral features within the passband of each filter, i.e. use O-B stars with various amounts of reddening if the filter is not situated on the continuum.

As standard light sources for calibration of photometric systems are very difficult to produce in an observatory situation (Young 1974, Straižys 1992, Bessell 1993), a set of (non-variable) 'standard' stars are normally used for this purpose. These should be well distributed across the sky, cover a large magnitude range and the spectral and luminosity classes for which the system was designed (and preferably the complete range of spectral/luminosity classes and peculiar stars). In general both reddened and unreddened stars should be included. If the receiver is subject to fatigue effects (for example dead-time in PMT's), very bright stars should be excluded. When establishing a new photometric system it is helpful to include a set of circumpolar standards for internal calibration using the same stars through-out the year (as the original filters will change with age, and PMT characteristics drift on all time scales).

Finally, the photometric system must be calibrated against stellar parameters such as the effective temperature, surface gravity, chemical composition etc. As there are few large, homogeneous samples of such calibrated stars (Jaschek & Jaschek 1987), it is more common to calibrate using approximate quantities such as spectral type, luminosity class, [Fe/H] ratio etc. These also have the advantage of being model-independent, so will not have to be revised every time stellar models are improved. The calibrations may be tested by deriving the distance modulus of the individual stars in a binary or cluster — these should all be the same if the calibrations are correct (assuming the stars are all at the same distance, have the same [Fe/H] ratio, interstellar reddening and the cluster membership is known).

1.4 Characteristics of photometric system.

The intensity measured through a filter in a photometric system is

$$E_m = \int_{\lambda_1}^{\lambda_2} S(\lambda)R(\lambda)d\lambda \quad (1.18)$$

where $S(\lambda)$ is the spectral function of the light incident on the receiver system $R(\lambda)$, over the wavelength interval $[\lambda_1, \lambda_2]$ where the receiver's response is non-zero. The incident light

$S(\lambda)$ includes the star's intrinsic intensity $E(\lambda)$, the inverse square law reduction in intensity due to the distance ' r ' between the star and the receiver, the transmission function $I(\lambda)$ of interstellar matter along the light of sight and the transmission function $A(\lambda)$ of the Earth's atmosphere. These functions are usually grouped together (as $S(\lambda)$) because they vary from one measurement to another, while the receiver system is assumed to be stable.

If the star's spectrum ($S(\lambda)$) is continuous and the receiver's response function does not change sign in the interval $[\lambda_1, \lambda_2]$, then the mean value theorem says the measured (heterochromatic) intensity E_m corresponds to the monochromatic intensity at one, or more, wavelengths in the interval, i.e.

$$E_m = \int_{\lambda_1}^{\lambda_2} S(\lambda) R(\lambda) d\lambda = S(\lambda_i) \int_{\lambda_1}^{\lambda_2} R(\lambda) d\lambda, \quad (1.19)$$

apart from a constant factor ($\int R(\lambda) d\lambda$). This is known as the isophotal wavelength(s) (Golay 1974), and is different for each star, and even different measurements of the same star due to the atmospheric function $A(\lambda)$ changing. Unfortunately the isophotal wavelength requires knowledge of the star's spectrum (which is what we wish to measure) before it can be calculated.

If $S(\lambda)$ is continuous and its derivatives are continuous in the interval $[\lambda_1, \lambda_2]$, then it may be expanded in a Taylor series about $\lambda_0 \in [\lambda_1, \lambda_2]$

$$S(\lambda) = S(\lambda_0) + \frac{(\lambda - \lambda_0)}{1!} S'(\lambda_0) + \frac{(\lambda - \lambda_0)^2}{2!} S''(\lambda_0) + \dots \quad (1.20)$$

where the primes are differentiation with respect to wavelength. This expands Equation 1.18 to

$$E_m = S(\lambda_0) \int_{\lambda_1}^{\lambda_2} R(\lambda) d\lambda + S'(\lambda_0) \int_{\lambda_1}^{\lambda_2} (\lambda - \lambda_0) R(\lambda) d\lambda + \frac{1}{2!} S''(\lambda_0) \int_{\lambda_1}^{\lambda_2} (\lambda - \lambda_0)^2 R(\lambda) d\lambda + \dots \quad (1.21)$$

Rewriting the equation for brevity by dropping the integral limits, the explicit wavelength dependence and denoting the evaluation of a function at λ_0 by a subscript zero gives

$$E_m = S_0 \int R d\lambda + S'_0 \int (\lambda - \lambda_0) R d\lambda + \frac{1}{2!} S''_0 \int (\lambda - \lambda_0)^2 R d\lambda + \dots \quad (1.22)$$

By rearranging slightly, the equation can be further abbreviated using the normalised n^{th} moments

$$\mu_n^n = \frac{\int (\lambda - \lambda_0)^n R d\lambda}{\int R d\lambda} \quad (1.23)$$

producing

$$E_m = S_0 \int R d\lambda \left\{ 1 + \frac{S'_0}{S_0} \mu_1^1 + \frac{1}{2!} \frac{S''_0}{S_0} \mu_2^2 + \dots \right\} \quad (1.24)$$

The wavelength λ_0 may be chosen so the first moment vanishes, i.e. $\mu_1^1 = 0$, which requires

$$\lambda_0 = \frac{\int \lambda R d\lambda}{\int R d\lambda}. \quad (1.25)$$

This is known as the effective wavelength (King 1952) (or the equivalent wavelength (Strömberg 1937), or mean wavelength (Golay 1974)). This is significant because if the second order and higher derivative terms are negligible, then $E_m = S_0 \int R d\lambda$, i.e. the effective wavelength equals the isophotal wavelength. In practise, the higher order terms only converge slowly (Young 1992b) and the effective wavelength accurately estimates the isophotal wavelength if the star's spectrum has a point of inflexion in the interval $[\lambda_1, \lambda_2]$ (Golay 1974).

Consider the case where the spectrum is free of strong features, so that only the second and/or third derivative terms are important say, and can be well approximated by an assumed function such as the Black Body equation. Then the following

$$\lambda_e = \frac{\int \lambda S R d\lambda}{\int S R d\lambda}, \quad (1.26)$$

is considered to give a better estimate of the isophotal wavelength than the effective wavelength.⁸ The only parameter required for the black body equation is the temperature, being here the effective surface temperature of the star. An iterative process of fitting a black body equation to the star's intensity through two different filters to derive the temperature,⁹ which then gives an improved estimated of the filters isophotal wavelengths for that star using equation 1.26 can be done.

In general, a single absorption line will not have a detectable effect on a photometric measurement (consider a 1000 Å passband filter giving measurements to a precision of $\pm 1\%$ and an absorption line with an equivalent width less than 10 Å). However the cumulative effect of many absorption lines can be significant. Thus, to ensure the effective wavelength accurately gives the isophotal wavelength restricts filters to being placed on the continuum. This is difficult to satisfy for all stars, especially late-type stars which have so many absorption bands that the regions with only weak features are considered a pseudo-continuum. In these cases the spectrum is split into a smooth continuum $S^*(\lambda)$ and the energy removed by absorption features $s(\lambda)$. The fraction of energy removed from the continuum is

$$\eta(\lambda) = \frac{\int_{\lambda-\epsilon}^{\lambda+\epsilon} [S^* - s] d\lambda}{\int_{\lambda-\epsilon}^{\lambda+\epsilon} S^* d\lambda} \quad (1.27)$$

⁸This is also called the effective wavelength by some authors, for example King (1952). Here the term 'effective wavelength' will refer to equation 1.25 unless explicitly stated otherwise.

⁹An effective temperature derived by fitting a black body to a colour index is appropriately known as a 'colour' temperature.

with the wavelength range of the integrals usually being $\varepsilon = 5 - 50 \text{ \AA}$ (Jaschek & Jaschek 1987). This gives the 'blocking coefficient' as

$$\gamma(\lambda) = 1 - \eta(\lambda) = \frac{\int s d\lambda}{\int S^* d\lambda}, \quad (1.28)$$

which increases rapidly with spectral type, luminosity but decreases with increasing wavelength (Ardeberg & Virdefors 1975). Some photometric systems have filters designed to measure this blocking coefficient and thus the star's metal abundance.¹⁰

However, if the star is in energy equilibrium this blocked energy must be re-emitted but not necessarily at the wavelength which it was originally absorbed. This effect is known as 'back-warming' as most of the energy is re-emitted in the continuum, which increases the effective temperature of the continuum as shown next. The integrated blocking coefficient

$$\gamma_{int} = \frac{\int_0^\infty \gamma S^* d\lambda}{\int_0^\infty S^* d\lambda}$$

is the total energy left after blocking, hence the original effective temperature (T_{e1}) is related to the back-warmed effective temperature (T_{e2}) by $T_{e1}^4 = \gamma_{int} T_{e2}^4$, i.e.

$$T_{e2}^4 = \frac{1}{\gamma_{int}} T_{e1}^4 > T_{e1}^4$$

as $0 < \gamma_{int} < 1$. Both effects (blocking and back-warming) are together referred to by the term 'blanketing'.

A special case of blocking is when a filter is situated on a single, isolated strong line, such as H_β . The removed energy (s) is now the line profile and η measures the equivalent width (W) of the line. An additional wider passband filter centred on the line, or filters on each side of the line, is necessary to measure the continuum S^* . The first case, where the two filters have (nearly) the same isophotal wavelength has the additional advantages of having the same interstellar and atmospheric extinction, which can then be cancelled out (Jaschek & Jaschek 1987).

In photometry it is conventional to use a magnitude scale rather than intensity. The original magnitude scale was based on the visibility of stars during evening twilight (Sterken & Manfroid 1992a). The time between sunset and full darkness was divided into six equal intervals, with stars of the first magnitude being visible in the first interval and stars of the sixth magnitude becoming visible in the last interval. Around 1850 it was found that this approximately corresponded to a logarithmic scale with one magnitude step being a factor of 2.5 in intensity. Pogson

¹⁰Photometrists use the term 'metal abundance' to refer to all elements/molecules causing absorption features, while spectroscopists use the term 'metallicity' to refer to actual metals and stellar interior modelers use that term to refer to all elements other than hydrogen and helium (Jaschek & Jaschek 1987).

(1856) choose the value 2.512, as this is the fifth root of 100 and so the base 10 logarithmic scale could be used.

Therefore the modern magnitude scale is defined by

$$\begin{aligned} \frac{E_1}{E_2} &= 2.512^{m_1 - m_2} \\ \Leftrightarrow m_1 - m_2 &= -2.5 \log \left(\frac{E_1}{E_2} \right) \end{aligned} \quad (1.29)$$

where E_1, E_2 are the measured intensities (of either two stars through the same passband or one star through two passbands, denoted by the numeric subscripts) and m_1, m_2 are the corresponding magnitudes. By normalizing to some intensity (equivalently, setting some magnitude to zero), the magnitude scale of a star becomes

$$m = -2.5 \log(E) + C \quad (1.30)$$

where C is a constant chosen for the normalization, known as the 'zero-point'. Similarly, a 'colour' (or 'colour index') was defined as the difference in magnitudes (measured at different wavelengths) for the same star, giving

$$c_{12} = m_1 - m_2 = -2.5 \log \left(\frac{E_1}{E_2} \right). \quad (1.31)$$

The 'apparent' magnitude measured by the observer is fainter than the star's actual magnitude due to the inverse square law reduction of intensity with distance between the star and observer. To correct for this effect, the 'absolute' magnitude (denoted by M , or m_0) is defined as the star's magnitude measured at a distance (ρ) of 10 *parsecs* from the star, which, assuming no other causes of light reduction, gives

$$m - M = -2.5 \log \left(\frac{E/\rho^2}{E/10^2} \right) = 5 \log(\rho) - 5 \quad (1.32)$$

where $m - M$ is called the 'distance modulus'. Note that a colour is independent of the star's distance, i.e. $c = c_0$ as $c_{12} = m_1 - m_2 = (M_1 + 5 \log(\rho) - 5) - (M_2 + 5 \log(\rho) - 5) = M_1 - M_2 = c_{012}$.

The presence of interstellar material will also reduce the star's apparent magnitude, producing

$$m - M = 5 \log(\rho) - 5 + A$$

with A being the interstellar extinction as will be shown next. If x is the optical thickness of the interstellar material and $k(\lambda)$ is its absorption coefficient, then the measured intensity

(equation 1.18) becomes

$$E_m = \int E(\lambda) e^{-k(\lambda)x} R(\lambda) d\lambda \quad (1.33)$$

where $x = 0$ corresponds to no extinction and $x = 1$ corresponds to complete extinction.

In the case of a narrow passband filter such that $k(\lambda) \approx \text{constant}$, k say, then

$$E_m = e^{-kx} E_{m_0} \quad (1.34)$$

where E_{m_0} is the star's intrinsic intensity ($\int E(\lambda) R(\lambda) d\lambda$). Converting to magnitudes gives

$$\begin{aligned} m &= -2.5 \log(E_m) \\ &= m_0 + ax, \quad \text{where } a = \frac{2.5}{2.3026} k \\ \text{or } &= m_0 + A, \quad \text{where } A = ax \end{aligned}$$

with m_0 being the star's intrinsic magnitude and A is the interstellar extinction. In terms of colours, this gives

$$\begin{aligned} c_{12} &= m_1 - m_2 \\ &= (m_{01} + a_1 x) - (m_{02} + a_2 x) \\ &= c_{012} + E_{12}, \quad \text{where } E_{12} = (a_1 - a_2)x = A_1 - A_2, \end{aligned}$$

with c_{012} being the star's intrinsic colour and E_{12} is the colour excess. In general the extinction decreases as the wavelength increases, so a star's observed colour is larger (i.e. redder) than its intrinsic colour, hence the term 'reddening'.

The extinction at one wavelength can be written in terms of that at another wavelength, i.e. $A_1 = f A_2$, so

$$\begin{aligned} E_{12} &= A_1 - A_2 = f A_2 - A_2 \\ \Leftrightarrow A_2 &= \frac{1}{f-1} E_{12} \\ &= R E_{12} \quad \text{and } A_1 = (R+1) E_{12} \end{aligned}$$

where R is the 'ratio of extinction to colour excess' and is only dependent on the form of the interstellar extinction law, i.e. independent of the amount of interstellar material (as $R = 1/(f-1) = A_2/E_{12} = a_2/(a_1 - a_2)$). This ratio can be used to calculate intrinsic magnitudes, for example from the UBV system $V_0 = V - R E_{B-V}$, or reddening free magnitude parameters, for example $P = V - R(B-V)$ also from the UBV system.¹¹

¹¹ It can be easily shown that P is equivalent to $P = V_0 - R(B-V)_0$, which is free of reddening as it can be

These ideas can be extended to colours for systems with two or more colours, via the 'colour excess ratios'

$$\chi_{123} = \frac{E_{12}}{E_{23}} \quad \text{or} \quad \chi_{1234} = \frac{E_{12}}{E_{34}} \quad (1.35)$$

which are also dependent only of the form of the interstellar extinction law (as $\chi_{123} = (a_1 - a_2)/(a_2 - a_3)$). It follows from the above definition that the intrinsic colour can be calculated by

$$c_{012} = c_{12} - \chi_{123}E_{23} \quad (1.36)$$

and reddening free colour parameters from

$$Q_{123} = c_{12} - \chi_{123}c_{23} \quad \text{or} \quad Q_{1234} = c_{12} - \chi_{1234}c_{34} \quad (1.37)$$

as the 'Q parameters' (also known as 'Q factors') are easily shown to be equivalent to $Q_{123} = c_{012} - \chi_{123}c_{023}$ etc.

All of the above colour excesses and excess ratios assumed the monochromatic case (i.e. narrow passbands). In the general case, the colour excesses depend on the star's spectrum (i.e. spectral and luminosity class), the optical thickness of the interstellar material (x), and the particular form of the extinction law followed by the interstellar material along the line of sight to the star, with the dependence increasing as the filter bandwidths increase. The colour excess ratios also depends on the star's spectrum and the form of the extinction law. Finally, these all depend on the effective wavelength of the filter so correct transformation of measurements to the wavelengths of the standard system is crucial (Manfroid 1992).

1.5 Development of the UBV Photometric System.

In the late 1940's, Johnson and his co-workers measured photoelectrically (using wide-band blue and green filters) stars in the North Polar Sequence (NPS) and three Kapteyn regions which were standard stars in the International System of photographic (M_{pg}) and photovisual (M_{pv}) magnitudes (Stebbins et al. 1950). Their intention was to investigate how to duplicate, and improve on, the International System using a photoelectric system, and develop a system closely tied to the MK spectral classification scheme. It was found that the two filters gave non-linear, multi-valued transformations to the International System. This was due to the inclusion of different amounts of the Balmer jump between the blue filter and M_{pg} , as shown by further observations with several blue filters with different UV cut-offs in their response functions. Hence, a third filter (to measure the UV) is required for linear transformations.

expressed in terms of intrinsic magnitudes and colours.

Based on the above results, Johnson proposed the UBV photoelectric system consisting of an ultra-violet U filter (Corning 9863 glass), a blue B filter (Schott GG13 and Corning 5030 glass) and a green V filter (Corning 3384 glass) with an uncooled Antimony-Caesium RCA 1P21 PMT. The UV cut-off of the U filter is determined by the response of the PMT's glass envelope and the (steeply increasing) atmospheric extinction. The red cut-off of the V filter is set by the long wavelength response of the PMT. Observations in this system (to establish standard stars etc.) were started in the winter of 1950/51 using 32 cm and 2 m Cassegrain telescopes with Aluminized mirrors and balsam cemented quartz-fluorite Fabry lens. The response functions of the system were calculated from room temperature double-beam monochromator measurements of the filters transmissions and the PMT's sensitivity — the effects of the mirrors, Fabry lens and change from room temperature to the Observatory's ambient temperature were ignored (Johnson & Morgan 1951). Further, the response functions were never given in numerical form but only shown in graphical form.

In the summer of 1951, the Fabry lens was replaced with a crystalline quartz lens and the PMT cooled with dry ice (Johnson 1962). The resulting 'summer' system was then transformed back to the 'winter' system, which was considered the standard system (even though it no longer existed). The U and B filters were found to have red 'leaks' at $\lambda > 6800 \text{ \AA}$ and $\lambda > 7200 \text{ \AA}$ respectively, with the B filter's red leak being an order of magnitude less than the U filter. Johnson & Morgan (1953) corrected the observations for the red leak of the U filter only.

The zero-point of the V magnitude was adjusted to correspond to the photovisual system via measurements of nine NPS stars (which became primary standards of the UBV system). The earlier observations by Stebbins et al. (1950) had already established that there was no colour equation between V and M_{pv} . The remaining zero-points were set by taking the average colours (U-B, B-V) of un-reddened A0 V stars (based on six stars) as zero. Further standard stars were given by Johnson & Harris (1954), and later by Johnson (1955).

Six stars were also used to investigate the atmospheric extinction corrections (see section 2.7), taken as

$$\begin{aligned} V_0 &= V - (k'_V + k''_V(B-V))X \\ (U-B)_0 &= U-B - k'_{U-B}X \\ (B-V)_0 &= B-V - (k'_{B-V} + k''_{B-V}(B-V))X, \end{aligned} \tag{1.38}$$

where k''_{U-B} is defined as zero. This has caused many problems as the extinction in wide-band systems (especially in the UV) strongly depends on the star's temperature and luminosity, plus the amount of interstellar and atmospheric extinction — this is a result of the higher order terms of the Taylor expansion of the star's spectrum (equation 1.22) being significant. Thus

Table 1.1: Characteristics of the Standard UBV System Passbands.

filter	$\lambda_{R_{max}}$ (Å)	FWHM (Å)	λ_0 (Å)	μ_2^2 (m^2)	μ_3^3 (m^3)	μ_4^4 (m^4)
U	3730	440	3760	4.29×10^{-15}	1.24×10^{-21}	4.11×10^{-28}
B	4280	1010	4450	1.32×10^{-15}	1.32×10^{-23}	4.41×10^{-30}
V	5280	820	5500	1.35×10^{-15}	3.95×10^{-23}	6.86×10^{-30}

setting $k''_{U-B} = 0$ gives errors dependent on the airmass, which were seen by Johnson (1963) as declination effects (as the southern stars were always seen at large airmasses).

Therefore each standard star has its own colour equation (or equivalently, its own response function) dependent on the average airmass through which it was observed. This problem is made worse as part of the response functions of the U and V are determined by the PMT, which is considerably less stable than a glass filter. Further, the PMT was un-cooled, i.e. left to drift with the observatory's ambient temperature, giving seasonal variations which would probably be seen as Right Ascension (RA) effects. All of this leads to systematic errors in transforming a local system (typically with an internal precision of $\pm 0^m.01$) to the standard system of up to $\pm 0^m.05$ in U-B, and makes it difficult to do synthetic magnitude studies.

Several investigations have been made of the UBV response functions, for example Melbourne (1960), Arp (1961), Sharov (1962), Matthews & Sandage (1963), Johnson (1965a), but have still ignored the effects of the mirrors, lens, temperature or red leaks. Later investigations based on matching synthesized colours to observed colours, for example Ažusienis & Straižys (1969), Bessell (1990), should give more accurate results, but are still only correct for the average airmass through which the system was observed — see Figure 1.6. Although the filters overlap in wavelength, they do not meet the critical sampling theorem which will lead to further systematic errors in extinction and standardisation transformations. Some of the system's characteristics are given in Table 1.1; $\lambda_{R_{max}}$ is the wavelength giving the maximum transmittance for each filter, the FWHM was measured directly from Figure 1.6, λ_0 is the effective wavelength and μ_2^2 etc. are the moments of the filter passbands.

The B-V colour serves as a temperature (spectral type) indicator while the U-B colour measures the size of the Balmer jump, which depends on both the temperature and surface gravity (luminosity class). Unfortunately the long wavelength response of the U filter extends into the Balmer jump itself so does not give an accurate measure of the intensity on the short wavelength side of the jump. The spectral sequences for different luminosity classes is shown in Figure 1.7. Notice the bends in the sequences (around A0 – G0, and after M0) and the shallow angle between the reddening line and the sequences — this means heavily reddened early type stars can fall in the same position in the diagram as un-reddened later type stars (or white dwarves or sub-dwarves). Further, the sequences intersect at several points on the diagram,

Figure 1.6: Transmission Response curves of the UBV Photometric System, normalised and spline fitted. Taken from Straižys (1992).

for example G2 I, G5 III, and K2 V stars are all in the same position, giving ambiguous results when classifying stars in the diagram.

These factors give rise to three cases when trying to classify stars in the UBV system; Firstly, if the reddening is known, or is small enough to be neglected, then the star's (de-reddened) observed colours equal it's intrinsic colours and the star may be classified using the diagram (subject to the ambiguities due to different luminosity classes). Secondly, if the luminosity class is known, then the star may be de-reddened by extrapolating it's observed colours back to it's intrinsic colours using a colour excess ratio (or equivalently, it's Q factor may be calculated). However ambiguous results are still possible, for example an apparently un-reddened G9 V star may in fact be a reddened F0 V star or a heavily reddened B7 V star. Only in the third case, when both the reddening and luminosity class of the star is known, can it's spectral class be uniquely determined. This also allows another factor, such as the star's metallicity, to be found (although this may still give ambiguous results due to other factors such as rotation or binarity).

This is further complicated by the bandwidth effect on the reddening which means the slope of the reddening line in the U-B, B-V diagram (i.e. the colour excess ratio) depends on both the star's spectrum and the amount of interstellar material. According to Straižys (1992), A_V and A_B are approximately linear with $(B-V)_0$ for $0 < (B-V)_0 < 1$ and is approximately

Figure 1.7: The Johnson System's intrinsic U-B, B-V sequences of luminosity V (solid line), III (short-dashed line), and I (long-dashed line) stars, the black body line, and the positions of white dwarves, metallic-line stars and sub-dwarves. Taken from Straižys (1992).

independent of luminosity. However A_U shows a bend around $(B-V)_0 = 0$ due to the Balmer jump and separate sequences for different luminosities. They all show a quadratic dependence on the amount of interstellar material (for $0 < x < 1$) and so the reddening line is not linear (approximately parabolic for small reddening) and its slope depends on $(B-V)_0$. Finally, the red leaks have a strong effect on the reddening line for late type stars.

Despite its problems, the UBV system was quickly adopted and is still widely used today, with at least 90,000 stars observed to date (Mermilliod 1987*a, b*) — see Straižys (1992) for further references to catalogues. Possible reasons for its popularity are the large number of standard stars spread across the (northern) sky established by Johnson, its wide bandwidths meaning faint stars may be observed, and that the system can be easily realized for photographic sky surveys (after-all, it was intended to duplicate a photographic system).

There are also several clones or extensions of the system in use (Bessell 1986). For instance, Johnson (1965*b*) extended the system by adding the red and infrared filters R, I, J, H, K, L, M, N. These suffer smaller blanketing effects and interstellar reddening than the bluer UBV filters and are better temperature indicators for late type stars (as they are nearer the maximum emission of these cooler stars). Straižys (1973 *a*) proposed a W filter to replace the U filter, which was designed to a) reduce the long wavelength response into the Balmer jump (giving a

better measure of the size of the jump in conjunction with the B filter), b) remove the red leak, c) determine an accurate response function and d) correct the $(W - B)$ colour for atmospheric extinction allowing for the spectral type, luminosity class and reddening of the star. A final example is the U_CBV variant produced by the Cape Observatory of South Africa, generally known as the Cousins system as most of the standard stars (predominately from the Harvard E regions of stars evenly spaced in RA at Declination $\sim -45^\circ$) were observed by Cousins (Menzies & Laing 1988, Menzies et al. 1989). One major difference between the systems is that $(U_C - B)$ is not (incorrectly) transformed outside the atmosphere as was done by Johnson but corrected to an airmass of 1.1. The resulting (V) magnitude and colours are then corrected to the UBV system via multi-valued non-linear transformations.

1.6 Development of the *uvby* Photometric System.

In the 1960's an intermediate bandwidth photometric system was developed by Strömgren (1963, b, 1966) to measure the Balmer discontinuity, temperature and metallicity of B, A and F stars. It consisted of four filters, with the *u* filter being 8 mm of Schott UG11 glass cemented to 1 mm of WG3 Schott glass, and the remaining three (*v*, *b* and *y*) made of interference filters. The *v* magnitude was adjusted to approximately correspond to Johnson V, while the colours were left in the instrumental system of the original photometer. The filters are spaced in wavelength so they measure approximately equal increments in interstellar extinction, hence the reddening nearly cancels when taking differences in colours (Jaschek & Jaschek 1987).

The ultraviolet *u* filter is placed between the atmosphere's extinction cutoff (at $\sim 3000 \text{ \AA}$) and the beginning of the Balmer jump, overcoming the two major problems with the Johnson U filter. The violet *v* filter measures the flux at $\sim 4000 \text{ \AA}$, being centred near the H_δ line, with the other Balmer lines falling in the short wavelength tail of the response function and so having little effect. However in late type stars, this filter is strongly effected by blanketing. Centred at $4600 \text{ \AA}$, the blue *b* filter is situated between the H_γ and H_β lines with the long wavelength tail slightly overlapping the H_β line. This filter also avoids the interstellar absorption band at $4430 \text{ \AA}$, and is only weakly effected by blanketing. The yellow *y* filter is essentially a narrower Johnson V filter, having nearly the same effective wavelength. It is placed in a region largely free of spectral features, and gives a good apparent magnitude measurement. For F and G stars, this filter has approximately the same blanketing as the *b* filter.

The response functions of the filters were initially given by Crawford (1966), with slightly different functions found by Matsushima (1969), again by Crawford & Barnes (1970), and Stokes (1972, b). Olson (1974) also included the 1P21 PMT in his calculations, which has only a minor effect as the passband responses are nearly completely defined by the filter responses

Figure 1.8: Transmission Response curves of the *uvby* Photometric System, normalised and spline fitted. Taken from Jaschek & Jaschek (1987).

Table 1.2: Characteristics of the Standard *uvby* System Passbands.

filter	$\lambda_{R_{max}}$ (Å)	FWHM (Å)	λ_0 (Å)	μ_2^2 (m^2)	μ_3^3 (m^3)	μ_4^4 (m^4)
<i>u</i>	3460	360	3470	1.50×10^{-16}	$+1.36 \times 10^{-25}$	5.20×10^{-32}
<i>v</i>	4100	200	4110	8.04×10^{-17}	-1.28×10^{-27}	2.30×10^{-32}
<i>b</i>	4660	180	4670	7.50×10^{-17}	$+2.67 \times 10^{-26}$	2.22×10^{-32}
<i>y</i>	5460	240	5460	9.64×10^{-17}	-5.27×10^{-27}	2.81×10^{-32}

(Manfroid & Sterken 1987). The passbands shown in Figure 1.8 are from Jaschek & Jaschek (1987), and were originally taken from Lamla (1982). Some of the system’s characteristics are given in Table 1.2; $\lambda_{R_{max}}$ is the wavelength giving the maximum transmittance for each filter, the FWHM was measured directly from Figure 1.8, λ_0 is the effective wavelength and μ_2^2 etc. are the moments of the filter passbands.

The system is often used with two extra filters; a narrow (β_N) and wider filter (β_W) both centred on the H_β line (Crawford 1958, 1960). As these have (nearly) the same effective wavelength, the beta index (in magnitudes, $\beta = \beta_N - \beta_W$) is free from interstellar reddening, and, for simultaneous measurements through both filters, atmospheric extinction (Crawford &

Mander 1966). As the strength of the Balmer lines change in proportion to each other,¹² the β index can be used to correct for the effect of the H_δ line in the v filter (Golay 1974). The β_N and β_W response functions have been given by Crawford (1966), later revised by Crawford & Mander (1966), and also given by Stokes (1972, b).

The bandwidths of the filters are sufficiently small that higher order terms in the Taylor expansion of the star's spectrum (equation 1.22) are negligible, except for the c_1 and $u-b$ which shows a complicated dependence of the star's spectrum and reddening (Straižys 1992) — see later for a definition of c_1 . However it was assumed that all the colours had negligible higher order terms, so the reduction procedure used to correct for atmospheric extinction results in systematic errors for c_1 and $u-b$ colours. Further, as the filters do not overlap in wavelength, significant systematic errors when transforming measurements to the standard system are possible.

For early stars b and y are approximately blanketing free, while for late stars they have nearly the same blanketing (Hendon & Kaitchuck 1990). Thus the $b-y$ colour is free of blanketing effects and serves as a temperature indicator in a similar manner to Johnson B-V. The v filter is in a strong blanketing region but clear of the Balmer lines so the difference between the actual $v-b$ colour and what it would have in the absence of blanketing (estimated by $b-y$) gives the metallicity $m_1 = (v-b) - (b-y)$, as can be seen in Figure 1.9. The u filter's intensity is reduced by both blanketing and the Balmer jump (c_1). As the blanketing of the u filter is approximately twice that of the v filter, Figure 1.9 shows that $(u-y) - c_1 - 2m_1 = 3(b-y)$ which reduces to the Balmer jump $c_1 = (u-v) - (v-b)$. Finally, as described in section 1.4, the β index measures the equivalent width of the H_β line (see Golay (1974) for a proof of this). For B and early A stars this width is correlated with the absolute magnitude of the star, while for late A and F stars it is a function of temperature (Straižys 1992). Hence the following parameters

$$\begin{aligned}
 &b-y \\
 m_1 &= (v-b) - (b-y) \\
 c_1 &= (u-v) - (v-b) \\
 \beta &= \beta_N - \beta_W
 \end{aligned} \tag{1.39}$$

are more commonly used than the other colour indices.

These parameters still depend slightly on interstellar reddening (Strömgren 1966) so the

¹²The shorter wavelength lines are actually slightly more sensitive to luminosity (i.e. gravity) than the longer wavelengths, via the Stark effect (Golay 1974).

Figure 1.9: Schematic explanation of c_1 and m_1 in the $uvby$ system. Adapted from Golay (1974) and originally given by Crawford.

following reddening free parameters are used;

$$\begin{aligned}
 [c_1] &= c_1 - \frac{E_{c_1}}{E_{b-y}}(b-y) \\
 [m_1] &= m_1 - \frac{E_{m_1}}{E_{b-y}}(b-y) \\
 \text{and sometimes, } [u-b] &= (u-b) - \frac{E_{u-b}}{E_{b-y}}(b-y) = [c_1] + 2[m_1],
 \end{aligned} \tag{1.40}$$

where $[u-b]$ is useful as a temperature indicator in very hot (B type) stars (Budding 1993). The filter bandwidths are sufficiently narrow that the reddening lines are nearly straight as the extinction increases. However the slopes of the lines, and hence the value of the colour excess ratios, do depend slightly on the star's spectrum. Typical values are $E_{c_1}/E_{b-y} = 0.19$, $E_{m_1}/E_{b-y} = -0.33$, and $E_{u-b}/E_{b-y} = 1.53$, while synthesized ratios are given by Straižys (1992, Table 34) for different spectral and luminosity classes.

In an attempt to minimize the variations of local versions from the $uvby$ system, Crawford of Kitt Peak Observatory (KPO) bulk ordered filters which were then supplied to different observers (Bessell 1993, Straižys 1992). Unfortunately a manufacturing error resulted in some of the v filters having the wrong FWHM, being too narrow, which has caused systematic errors in c_1 and m_1 colours. Mount Stromlo and Siding Springs Observatories received two of these wrong filters (Eggen 1976), as was shown by comparison of the transmission with that of the standard filter (Eggen 1982). The transformation errors were so severe that Eggen (1976, 1977, 1978, 1982) decided to use their instrumental system as a new $(b-y, M_1, C_1, \beta)$ standard

system. Eggen (1976) also extended this system for use with late type stars.

Another variant of the *uvby* system used a spectrophotometer, where the light was spread into a spectrum using a prism or diffraction grating, split into the required passbands by slots in a mask and the passbands measured simultaneously by four PMT's. One version used *uvby* filters between the slots and PMT's (Grønbech et al. 1976) but the tails of the passbands were cutoff by the slots and the passbands themselves did not closely match the standard passbands so this system did not transform well to the standard system (Manfroid 1985, Manfroid & Sterken 1987, Young 1988). The other version did not use filters but instead defined the passbands by the slots, resulting in rectangular response curves which had severe transformation problems (Olsen 1983).

In general, observers get high internal precision in the *uvby* system (typically $\pm 0^m.005 - 0^m.009$) but need multi-valued, non-linear transformations to the standard system and still have large systematic errors. For instance, there are differences of $\pm 0^m.03 - 0^m.05$ in c_1 and m_1 between catalogs of the northern and southern hemisphere (Straizys 1992). Thus there seem to be at least two *uvby* systems; the original system defined by northern hemisphere standard stars (Grønbech et al. 1976, Grønbech & Olsen 1977, Olsen 1983) and the southern hemisphere E region standards measured by Cousins (1987), including H_β standards (Cousins 1989), and extended to fainter stars by Kilkenny & Laing (1992). A large number of stars (Hauck & Mermilliod (1980, 1985) list approximately 40000 stars in their catalogue) have been observed in this system, which is second in popularity to only the UBV system.

Several procedures have been developed for classifying stars in this system, with a good description given by Straizys (1992), so only an outline will be given here. First it is assumed that only the stars for which the system was designed (B, A and F stars) have been observed.¹³ Figure 1.10 shows the intrinsic sequences in a $b-y$, c_1 diagram, with the sequences of different luminosities have similar shapes but being shifted down and to the right slightly. Thus reddened main sequence stars can overlap with supergiants and heavily reddened B stars can overlap with the A and F stars. Therefore a star has to be grouped in it's approximate spectral and luminosity class before this diagram can be used, with various other diagrams such as $(b-y, m_1)$ or (m_1, β) available for this.

Once separated into the approximate spectral group, the $b-y$ and c_1 colours may then be de-reddened using an iterative method. For instance, with B III-V stars the observed c_1 value gives an estimate of the intrinsic c_0 colour, which is then used to look up an improved estimate of the intrinsic $(b-y)_0$ colour in a table of intrinsic $(b-y)_0, c_0$ colours. This then gives the colour excess $E_{b-y}(= (b-y) - (b-y)_0)$, leading to the colour excess E_{c_1} via the colour excess ratio

¹³Some qualitative and quantitative schemes have been developed for the restricted case of un-reddened G and K III-V stars.

Figure 1.10: The Strömberg $b-y$, c_1 diagram, taken from Straižys (1992).

E_{c_1}/E_{b-y} , and resulting in an improved estimate of the intrinsic c_0 colour. The process is repeated until the values converge, usually only requiring a few iterations. Similar procedures can be used for most of the other groups, with the A stars being most difficult to classify due to their position in the turning point of the sequence.

An alternative procedure is to use the Golay box method, comparing the unknown stars with reference stars taken from a catalog and occupying the same $(b-y, c_1, m_1$ or $(b-y)_0, c_0, m_0$) box. Either procedure results in similar accuracy, correctly classifying the stars to within $\pm 1-2$ spectral subclasses and ± 1 luminosity classes. Calibrations to physical parameters have been found by Crawford (1975, 1978, 1979).

Various types of peculiarities may be recognized with success rates varying from 50 – 75%, with the lower rates due to stars with a mild form of the peculiarity occupying the same position on the diagrams as normal stars. For instance, metallic line (Am) stars can be separated with a 75% success rate using m_1 , $b-y$ or m_1 , β diagrams. Some Blue Horizontal Branch (BHB) stars may be recognized, while white dwarves can be separated about half the time and both components of a binary can usually be classified. In some restricted cases, the effects of metallicities (in clusters), rotation or micro-turbulence may be detected.

1.7 Development of the Vilnius Photometric System.

According to Straižys (1973 *b*), in the 1960's a chaotic situation existed with many intermediate and narrow bandwidth filter systems in use. These were usually very specialized in design and limited in the temperature range, luminosity and population type that could be classified (using dozens of proposed methods) and all needing extensive sets of standard stars for transformation (of local implementations of the filters to the standard system) and calibration (Straižys 1973 *b*). The situation was not helped as it was becoming clear that transformations (both from the local to standard system and between different standard systems) were plagued by systematic errors. The Vilnius group felt there was a need for one general system, based on astrophysical needs (rather than availability of the filters) and in particular, a system which could derive a star's spectral type, luminosity and reddening using only the photometric measurements from the system. In addition to requiring standard stars for only one system, this would allow many more stars, in particular fainter stars or stars in dusty regions, to be classified than could currently be done by spectroscopic means. Some applications of such a system could be statistical studies of stellar populations or investigations of interstellar dust and gas. Further, specialized studies could be possible by taking a subset of the general system.

The development of such a system became possible with the photoelectric measurements of energy distributions of stars of different types and the (mean) interstellar dust transmission curve in the 1960's. Synthetic colours and Q factors could be calculated and by changing the effective wavelength, FWHM and shape of the response curves, optimum passbands could be derived. A trade-off between bandwidth effects and limiting magnitude implied the use of intermediate bandwidth filters (bandwidth $\sim 400\text{\AA}$).

Initially Straižys (1964) investigated existing filter systems for their ability to measure reddening and found they could only do so if the stars all belonged to the same group (for example a cluster or association) and had the same reddening. Further, due to a 'break' in the colour-colour diagrams, the reddening lines (for early stars) would intersect the sequence of (later-type) unreddened stars and stars of different luminosities formed their own sequences. Straižys (1963, 1964) found that the ideal system met three conditions; 1) there is a large angle between the sequence of unreddened stars (the intrinsic sequence) and the reddening lines, 2) the intrinsic sequence does not have large changes in slope, especially towards the reddening lines, and 3) the intrinsic sequences of different luminosities lie close together on the diagram. To achieve this requires the following three filters; X ($\lambda_0 \sim 4000\text{\AA}$, bandwidth $\sim 400\text{\AA}$), Y (at the breakpoint of the interstellar reddening line when plotted against λ^{-1} , i.e. $\lambda_0 \sim 4500\text{\AA}$, bandwidth $\sim 400\text{\AA}$) and Z ($\lambda_0 = 5000 - 6000\text{\AA}$, bandwidth $\sim 500\text{\AA}$).

This allowed reddening to be determined for early-type stars (Zdanavičius & Straižys 1964) but the addition of an S filter was required to find the reddening and classify late-type stars

Figure 1.11: Transmission Response curves of the Vilnius Photometric System, normalised and spline fitted. Taken from Straižys & Zdanavičius (1970) and Straižys (1992) for the new S response curve (dashed line).

and a T filter to separate the K and M stars (Straižys & Zdanavičius 1965). Finally, the U and P filters were added to classify early-type stars (Straižys 1965).

The proposed system was tested in 1966 using interference filters and confirmed the theoretical calculations (Zdanavičius & Nikonov 1967). However, as interference filters are not stable, are hard to manufacture to a required transmission curve and have too small a bandwidth, they were replaced (except for the S filter) with glass filters (Kakaras et al. 1968). The T filter was dropped (it was only required to separate the K and M stars, which can also be done using combinations of the remaining filters) and a V filter added to form the standard system. The transmission response curves of the standard system are given by Straižys & Zdanavičius (1970), listed in Table 1.3 and shown in Figure 1.11. Some of the system's characteristics are given in Table 1.4; R_{max} is maximum transmittance for each filter (in arbitrary units), $\lambda_{R_{max}}$ is the wavelength of the maximum transmittance, the FWHM was measured directly from Figure 1.11, λ_0 is the effective wavelength and μ_2^2 etc. are the moments of the filter passbands. The response curve of the S filter was modified by Straižys (1992), and is labelled as the 'new S' filter in Table 1.3 and shown as a dashed curve in Figure 1.11. As the new S response curve became available partway through this thesis, much of the analysis uses the response curves of Straižys & Zdanavičius (1970).

Table 1.4: Characteristics of the Standard Vilnius System Passbands.

filter	R_{max}	$\lambda_{R_{max}}$ (Å)	FWHM (Å)	λ_0 (Å)	μ_2^2 (m^2)	μ_3^3 (m^3)	μ_4^4 (m^4)
U	180	3480	400	3440	2.07×10^{-16}	-4.70×10^{-25}	1.05×10^{-31}
P	238	3760	270	3740	1.08×10^{-16}	-1.28×10^{-25}	3.24×10^{-32}
X	229	4070	220	4050	1.64×10^{-16}	$+2.12 \times 10^{-24}$	1.46×10^{-31}
Y	288	4590	260	4660	1.64×10^{-16}	$+1.99 \times 10^{-24}$	1.05×10^{-31}
Z	360	5140	220	5160	1.40×10^{-16}	$+1.36 \times 10^{-24}$	1.41×10^{-31}
V	215	5420	230	5440	1.41×10^{-16}	$+2.19 \times 10^{-25}$	5.21×10^{-32}
S	169	6530	120	6530	5.53×10^{-16}	$+1.24 \times 10^{-23}$	2.37×10^{-30}

The initial calibration of the system was based on observations of normal and peculiar stars made during 1967–70 (Zdanavičius et al. 1969, Straizys & Sviderskienė 1972) although improvements have continued to the present date, for example (Sūdžius et al. 1970, Bartkevičius et al. 1973), with the current calibrations given by Straizys (1992). The method used to correct for atmospheric extinction was described by Zdanavičius (1970) and standard star sets established in the northern hemisphere (Zdanavičius et al. 1969, Straizys et al. 1970, Zdanavičius & Cerniene 1985, Černis et al. 1989, Černis & Jasevičius 1992). These, and all other observations, were collected together by North (1980) in a catalog available on magnetic tape from the Centre de Données Astronomiques de Strasbourg (CDS). A more up-to-date catalog (containing 7445 stars) recently became available (Straizys & Kazlauskas 1993) and was used for the later analysis in this thesis.

In addition to being able to classify the spectral type and luminosity of normal B–M stars with any degree of reddening, the Vilnius system was found to detect stars with certain types of peculiarities; subdwarfs (Bartkevičius & Straizys 1970a) and late-type metal deficient giants (Bartkevičius & Metik 1969, Bartkevičius & Straizys 1970c, Bartkevičius et al. 1992, Bartkevičius & Lazauskaitė 1994), Am, Ap and Be stars (Bartkevičius & Straizys 1970b), white dwarfs, double stars (Kakaras & Straizys 1969), carbon and barium stars (Šleivytė 1992), Herbig Ae/Be stars, and T Tauri stars. It has been estimated that this system can classify 90 – 95% of the stars in any galactic field (Straizys & Philip 1994).

A brief discussion of the rationale for the placement of each filter follows; The U filter is placed on the ultraviolet side of the Balmer Jump to measure the minimum intensity of the Jump, and hence, in combination with the P or X filters, measure the size of the Jump which is sensitive to the temperature (or spectral type) of an early-type star. However the filter must be at a sufficiently long wavelength to avoid atmospheric extinction which increases rapidly for $\lambda \lesssim 3500$ Å and is highly variable due to Ozone. The FWHM is increased to ~ 400 Å to improve the limiting magnitude to which a star can be measured through the filter.

The P filter measures the absorption lines of the higher members of the Balmer series,

whose depths are sensitive to the surface gravity of early stars. Thus for supergiants the P filter measures the maximum intensity of the Balmer Jump while for main sequence stars it measures the bottom of the Jump.

As described earlier, the X, Y and Z filter measure reddening due to interstellar dust and gas. It is desirable to place the X and Z filters far away (in wavelength) from the Y filter to satisfy the three conditions for an ideal X-Y, Y-Z diagram. However the X filter must avoid being on the Balmer Jump or the ultraviolet side of the Jump (as this would give a strong non-linearity in the diagrams) and hence is placed between the H_γ and H_ϵ absorption lines. It also measures the maximum intensity of the Balmer Jump for early stars (especially main sequence stars) and blocking by metal lines in late-type stars.

The Y filter is shifted slightly from the interstellar reddening breakpoint to avoid an interstellar absorption band at 4430 Å.

The Z filter has a wide wavelength range available in which it can measure interstellar reddening and so it is placed to also measure a wide absorption feature (the Mg I triplet and MgH molecular band) in late-type stars whose depth is sensitive to surface gravity (or luminosity).

The V filter is an analog of the Johnson V filter, having nearly the same effective wavelength. There is no colour term in the transformation between the filters except for K-M stars. This was intended to allow the Johnson V magnitudes to be adopted as the Vilnius V magnitudes and reduce the work required to set up the Vilnius system of standard stars. It is also the long wavelength side of the absorption feature measured in the Z filter, so Z-V measures the depth of this feature and partly replaces the function of the T filter.

Finally, the S filter is centred on the H_α line and can measure any emission in early stars (separating B and Be stars). For late-type stars, it measures a pseudo-continuum (actually it is the next intensity maximum of the TiO band measured by the T filter), helping to give the spectral and luminosity classes of a late star.

A variant of the standard system, the VilGen system, was made by merging the Vilnius and Geneva photometric systems as several filters have similar effective wavelengths and functions. The Geneva system has wide bandwidths, and hence fainter limiting magnitudes, so several of the Vilnius filters were widened and/or replaced by the equivalent Geneva filter. Theoretical and observational experiments were made on the proposed system by Straižys (1977, 1979) and North (1978). Preliminary intrinsic colours and calibrations for normal stars were measured by Straižys et al. (1982) and some peculiar stars (subdwarfs, metal deficient giants, metallic line, and Ap stars) by North et al. (1982). This system has the advantage that all VilGen colours can be easily obtained from the original Vilnius and Geneva colours (except for M-type, carbon and emission stars). A brief discussion of the system is given by Straižys (1992).

1.8 The Q-Search Classification Method.

One of the methods used to classify the spectral and luminosity types of stars measured in the Vilnius system is the 'stellar box' method of Geneva astronomers (Straižys 1992) — this has also been called the 'sigma-Q' method (Smriglio et al. 1986, 1988, 1991).

The following value is calculated for each program star using a reference list of stars with known spectral and luminosity types

$$\sigma_{\Delta Q} = \left[\sum_{i=1}^n \frac{\Delta Q_i^2}{n} \right]^{\frac{1}{2}} \quad (1.41)$$

where ΔQ is the difference in the Q factors between the program star and a reference star, and n is the number of Q factors used (usually five — there are at most five independent Q factors as there are only six Vilnius colours).

To determine the spectral class, the spectral types of the three reference stars with the smallest $\sigma_{\Delta Q}$ must agree within one class range (for example A5–F5). The assigned spectral class is the weighted mean of these three stars, with the weights being $1/\sigma_{\Delta Q}$. Similarly, the luminosity classes of the three closest matching reference stars must lie within two consecutive luminosity classes (for example IV–V). Thus, at least two of the three reference stars have the same luminosity class and this class is assigned to the program star. Two or three iterations will be needed as the colour-excesses used to calculate the Q factors depend slightly on the spectral and luminosity class of the star. Initially a G0 V type star is assumed.

A variation on the general method, referred to here as the 'Q-Search' method, was used and is described next. In line with the literature, the following five Q factors were used; Q_{UPYV} , Q_{PXVY} , Q_{XYV} , Q_{ZVYV} , and Q_{VSYV} . However, instead of searching for the three best matching reference stars, all reference stars with $\sigma_{\Delta Q}$ less than or equal to some minimum are listed and the average spectral and luminosity classes calculated from this list. The averages are weighted by $1/(\sigma_{\Delta Q}^2 + 0.001)$ — the 0.001 is added to avoid 'divide-by-zero' errors. At least five matching reference stars must be found before an average is calculated. This has the advantages of an adjustable and generally less stringent criteria (the minimum $\sigma_{\Delta Q}$ required was usually 0.020 to get five or more matching reference stars, although up to 0.060 was sometimes needed for K stars) and allows the standard deviations of the assigned spectral and luminosity classes to be calculated. The (northern) catalog of Vilnius stars (North 1980) was used for the reference list. If a star has multiple entries in the reference star list, only the first entry is considered for the search.

To test the **QSearch** computer program, tables of mean Vilnius intrinsic colours (Straižys 1992, Sūdžius & Bobinas 1994) were used as program stars. It was found that the spectral type of early (O–B) and late (K–M) stars, particularly supergiants, were mis-classified with

small systematic errors. Examination of the reference star lists used to calculate the mean spectral class revealed this was due to the spectral type of these stars (with approximately the same Q factors) varying with luminosity class. To reduce this effect, the weights for the mean spectral type were multiplied by an additional weight, the reciprocal of the absolute difference in luminosity classes between the program and reference star, i.e. $1/(|\Delta Luminosity| + 1)$ — the one is added to avoid 'divide-by-zero' errors. This requires the Q -search to be iterated at least once, to calculate the luminosity class first.

The tests were repeated with the revised program, with the results shown in Figure 1.12. The additional weights did reduce the luminosity effect on the spectral classifications but not entirely eliminate it. The standard deviations give a good estimate of the possible difference between the actual and calculated spectral and luminosity classes. Typical standard deviations are ± 1.4 spectral sub-classes and ± 0.8 luminosity classes, with the giants and supergiants having slightly larger standard deviations (± 1.6) in the spectral classifications. As can be seen in Figure 1.12, M-type stars may not be accurately classified — this is due to the small selection of M stars in the reference list so the search criteria must be widened to find enough stars for an average. The search then also finds many K stars and hence the average is forced towards an earlier (in-correct) spectral class.

1.9 The Q-Spectra Classification Method.

Another method of spectral classification in the Vilnius system is that of the 'Q-curves' (also referred to as 'Q-Spectra' or 'Q(λ) functions'), described by Straižys (1974, 1992). For monochromatic magnitudes, the following reddening free energy distribution curve is calculated

$$Q_{m_\lambda m_1 m_2} = (m_\lambda - m_1) - \frac{E_{m_\lambda - m_1}}{E_{m_1 - m_2}} (m_1 - m_2) \quad (1.42)$$

for the program star and compared to a set of standard curves similarly calculated for different spectral types, luminosities, metallicity, peculiarities etc. According to Straižys (1974), the program stars may be classified by "simple graphical shifting of their Q-curves up to best coincidence with one of the standard curves". The method may be extended to the heterochromatic magnitudes of a photometric system by setting λ in turn to the effective wavelength of each filter.

As the shape of the Q-curve is similar to the star's intrinsic energy curve if $m_1 - m_2$ represents the colour-temperature only, i.e. the yellow-red spectral region, the Vilnius system usually uses

$$Q_{\lambda VS} = (m_\lambda - V) - \frac{E_{m_\lambda - V}}{E_{V - S}} (V - S) \quad (1.43)$$

Test of Classification methods

Test of Classification methods

Figure 1.12: Test of the Q-Search Spectral classification method. The top figure shows the results for all luminosity classes, while the bottom figure includes only the supergiants. The error bars on the bottom figure are the standard deviations of the calculated spectral classes.

This means seven Q-factors may be calculated (Q_{UVS} , Q_{PVS} , Q_{XVS} , Q_{YVS} , Q_{ZVS} , Q_{VVS} , and Q_{SVS}) but as $Q_{VVS} = Q_{SVS} \equiv 0$, only the first five can be used. As the Vilnius system defines the colours of unreddened O-type stars to be zero, the Q-Spectra for an O-type star is flat (i.e. $Q_{\lambda VS} \equiv 0$). Examples of standard Q-Spectra are shown in Figures 1.13 and 1.14, illustrating the variation with spectral and luminosity classes.

The standard curves used here are calculated from Straižys (1992) tables of mean intrinsic colours for normal stars. The **QSpectra** computer program calculates the absolute difference between the program star's Q-Spectra and each of the standard Q-Spectra ($= \sum_{\lambda=U}^S |\Delta Q_{\lambda VS}|$), the standard Q-Spectra with the minimum difference giving the spectral and luminosity classes of the program star. A large absolute difference for the best matching standard Q-Spectra indicates either that there are errors in the photometry of the program star, or a standard Q-Spectra of the appropriate type has not been included. When used to classify stars in the southern Vilnius system, $|\Delta Q_{UVS}|$ and $|\Delta Q_{PVS}|$ were given half the weight of the other absolute differences as the U and P measurements generally had larger errors (see Chapter 3).

To test the **QSpectra** program, the Aquila and Cygnus Standard Stars (Zdanavičius et al. 1969) were used as program stars. As it was not clear what Straižys meant by "simple graphical shifting of the Q-curves", both possibilities

$$Q(\lambda)_{\text{prog}} = (1 + a) \left[(m_{\lambda} - V) - \frac{E_{m_{\lambda} - V}}{E_{V - S}} (V - S) \right] \quad (1.44)$$

or

$$Q(\lambda)_{\text{prog}} = (m_{\lambda} - V) - (1 + a) \frac{E_{m_{\lambda} - V}}{E_{V - S}} (V - S) \quad (1.45)$$

were tested. The coefficient a is normally zero but could be set to other (small) values to improve the fit of the program star's Q-Spectra to a standard Q-Spectra. It was found that equation 1.44 gave only slight improvements (as measured by the average difference between the calculated and actual spectral and luminosity classes of the program stars) to that of $a \equiv 0$. However equation 1.45 gives a significant improvement (nearly a factor of two) and is equivalent to correcting any random errors in V-S (which produce systematic errors in the Q-Spectra). Based on the 57 stars in the Aquila and Cygnus regions, the Q-Spectra method allows stars to be classified to a standard deviation of ± 1.0 sub-classes of their actual spectral type and ± 0.3 luminosity classes.

1.10 The Q-Isolines Classification Method.

The 'Q-isolines' method of classifying stars also uses five independent Q factors (usually Q_{UVS} , Q_{PVS} , Q_{XVS} , Q_{YVS} , and Q_{ZVS}) and returns the effective surface temperature (T_e) and surface

Figure 1.13: Variation of pseudo-Q-spectra with spectral class for main-sequence stars. The top figure shows the Q-Spectra for G-K stars, while the bottom figure shows K-M stars.

Figure 1.14: Variation of pseudo-Q-spectra with luminosity class. The top figure shows the Q-Spectra for O-A supergiants, while the bottom figure shows main-sequence stars of the same spectral classes.

Figure 1.15: Examples of Q-isolines classifications. The left figure gives $\theta_e, \log(g)$ data points (for Q_{UVS}) which are used to plot the Q-isolines in the right figure. Taken from Straižys (1978).

gravity (g) of the star (Straižys 1978, 1992). This works by plotting in a $\theta_e (= 5040/T_e)$, $\log(g)$ diagram five curves (Q-isolines) corresponding to $Q_{UVS} = \text{constant}_1$, $Q_{PVS} = \text{constant}_2$ etc., with the constants being the Q factors of the star to be classified. Each isoline is defined by three – four $\theta_e, \log(g)$ points which can be read from the intersections of a $Q = \text{constant}$ line with $\log(g) = \text{constant}$ curves in diagrams such as Figure 1.15. The five isolines will intersect at a point corresponding to the θ_e and $\log(g)$ of the star, as shown by two examples also in Figure 1.15.

Due to calibration and observational errors, the isolines will seldom intersect in one point, but will instead form a region whose area depends on the size of the errors. The $\theta_e, \log(g)$ ‘point’ defined by this region is given by weighted means, with the weights being the errors in each Q factor. According to Jasevičius (1986), this method agrees with the Q,Q classification method with mean square errors of ± 0.8 spectral sub-classes and ± 0.6 magnitudes. However, the method only works for normal stars as stars with peculiar energy distributions (for example subdwarves, metal-deficient stars, metallic-line stars, Ap stars, white dwarves or double stars) also give a larger intersection area. Fortunately a “trained investigator” can decide from the “character of deviations of different lines in the diagram” the peculiarity type of the star (Straižys 1978).

Figure 1.16: The X-Y,Y-Z diagram is used to roughly classify the spectral type of a star. The curves indicate intrinsic sequences for main sequence (solid), giants (short dashes) and supergiants (long dashes). The parallel lines are reddening lines for B0 V, A0 V, F0 V, G0 V and K0 V stars. The two-segment broken line separates M-type stars from earlier stars. The hatching indicates the blue limits of Be- and Am-stars and subdwarfs. Taken from Straizys & Sviderskienė (1972) (or Straizys (1992)).

Figure 1.17: Separation of M-type stars from mixture of K and M stars found below the two-segment broken line in Figure 1.16. All M-type stars have $Q_{ZTS} < -0.2$. Taken from Straizys & Sviderskienė (1972).

1.11 The QQ-diagrams Classification Method.

The final classification method is called the 'QQ-diagrams' method as it uses calibrated diagrams of various Q factors after sub-dividing into approximate spectral classes and removing peculiar stars, and is described by Straizys & Sviderskienė (1972) and Straizys (1992).

The first step is to sub-divide the stars into approximate spectral classes using the star's (reddened) X-Y and Y-Z colours, as shown in Figure 1.16. The design of the Vilnius filter system ensured that the intrinsic sequences of normal stars (in this diagram) do not intersect any reddening lines, the reddening lines are at a large angle to the sequences and that Q_{XYZ} is (approximately) a function only of spectral class.

The major exception to this are M-type stars, whose sequences show strong luminosity effects and bend back towards the X-Y colours of earlier stars, and so may overlap with earlier stars that are reddened or of a different luminosity class. As M-type stars are only found below the two-segment broken line in the diagram, stars which satisfy

$$(X-Y) > \min \begin{cases} 1.68 - 0.4(Y-Z) \\ 3.0 - 2.1(Y-Z) \end{cases} \quad (1.46)$$

(here referred to as 'possible M stars') must be checked if they are M stars before proceeding with the spectral groups classification.

The prototype Vilnius filters included a T filter, whose effective wavelength at 6250 Å coincides with one of the TiO absorption bands found in M stars. Combining this with the S filter, which lies between two TiO bands, gives the depth of a TiO absorption band which increases with the spectral class (of M stars). To correct for reddening, a Q factor (using T and S) is needed — Straizys & Sviderskienė (1972) use Q_{ZTS} to separate M stars from earlier stars ($Q_{ZTS} < -0.2$) in the group of 'possible M stars', and even approximately classify M stars, as shown in Figure 1.17.

However the final Vilnius system did not include the T filter, possibly because late M stars may be separated using combinations of the remaining filters. Straizys (1992) states that Q_{YSYV} may be used for this, but the top diagram in Figure 1.18, using all 'possible M stars' from the Vilnius catalog (North 1980, Straizys & Kazlauskas 1993), does not support this. However, other Q factors were found to allow separation of (late) M stars, for example Q_{UXY} , Q_{PXY} , Q_{PYZ} , Q_{PYS} , Q_{XVS} , Q_{ZVS} , and the bottom diagram of Figure 1.18. The discrimination between the M stars and others is slightly improved by combining two of the above Q factors, as shown by Q_{ZVS} , Q_{UXY} in Figure 1.19, where only 5% of the stars between $-0.55 < Q_{ZVS} < +0.05$ and $Q_{UXY} > 0.4 - 0.6Q_{ZVS}$ are mis-classified as M-type stars.

Once a star has been identified as a M star, its spectral type and absolute (V) magnitude (or effective surface temperature and gravity) may be read off the calibrated Q_{XYZ} , Q_{XZS} diagrams shown in Figure 1.20.

After the M stars have been classified, the remaining stars may be placed in one of the four spectral groups according to

$$\begin{array}{ll} \text{B} & Q_{XYZ} \leq 0.16 \\ \text{A - F} & 0.16 < Q_{XYZ} \leq 0.40 \\ \text{G} & 0.40 < Q_{XYZ} \leq 0.66 \\ \text{K} & 0.66 < Q_{XYZ} \end{array} \quad (1.47)$$

which are the reddening lines shown in Figure 1.16.

Figure 1.18: Alternative separation of M-type stars from mixture of K and M stars found below the two-segment broken line in Figure 1.16. The curves indicate intrinsic sequences for main sequence (solid), giants (long dashes) and supergiants (short dashes). Most late M-type stars have $Q_{UXY} \geq 0.5$.

Figure 1.19: Alternative separation of M-type stars from mixture of K and M stars found below the two-segment broken line in Figure 1.16 continued. The M-type stars are crosses and the others are squares.

Figure 1.20: Calibrated Q_{XYZ} , Q_{XZS} diagrams for M star classifications, calibrated in spectral class and absolute magnitudes. Taken from Straizys (1992).

The B group consists of normal O and B stars, A supergiants, Of, Be, Bp stars, OB subdwarfs, white dwarfs and extreme F subdwarfs. First the Be stars and F subdwarfs must be separated — the B group stars are divided in two groups B1 ($Q_{XYZ} \leq 0.10$) and B2 ($Q_{XYZ} \geq 0.10$). The B1 group is plotted in a Q_{XYZ} , Q_{XZS} diagram to separate the Be stars — see Figure 1.21. The B2 group is plotted in a Q_{UYV} , Q_{UXY} diagram to separate the extreme F subdwarfs (Bartkevičius & Straižys 1970a, Straižys 1992) — see Figure 1.22. The Bp stars (of Si type) may be separated in a Y-S, Q_{YZS} diagram (Figure 1.23) and the white dwarfs in a Y-V, U-P diagram (Figure 1.24). The remaining stars are considered normal and are classified in calibrated Q_{PYV} , Q_{UPY} diagrams (Figure 1.25).

The A-F group consists of normal A and F stars, Am and Ap stars, F and G subdwarfs and white dwarfs. The Am stars are recognized in a Y-V, Q_{XYV} diagram (Figure 1.26) and for greater reddening, in Q_{XYV} , Q_{UPY} and X-Y, U-X diagrams (Bartkevičius & Straižys 1970b). The Ap stars (of CrSrEu type) can be recognized in Figure 1.23. The white dwarfs and F-G subdwarfs may again be separated in Figures 1.24 and 1.22. The remaining normal stars are classified in the calibrated Q_{XYV} , Q_{UPY} diagram in Figure 1.27. As the spectral type or temperature isolines are too close together or overlapping for A5-7 III-V stars, these are classified in a Q_{UPYV} , Q_{UXY} diagram instead (Figure 1.28).

The G group consists of normal G type stars, G and K subdwarfs, metal-deficient giants, CH and barium stars. The subdwarfs may be separated as before using Figure 1.22. Barium and CH stars are separated in a Q_{XZS} , Q_{UPYV} diagram (Figure 1.29). The metal-deficient giants are separated using Q_{UXY} , Q_{UYV} and Q_{PYZ} , Q_{XYZ} diagrams (see Figure 1.30). All the subdwarfs found earlier (in the B, A-F and G groups) may be classified in T_{eff} and $[\text{Fe}/\text{H}]$ using a calibrated Q_{UXY} , Q_{UYV} diagram (see Figure 1.31). The remaining normal G stars are classified using calibrated Q_{XZS} , Q_{UPY} diagrams (Figure 1.32).

The K group consists of normal K dwarfs, G8-K giants, G5-K supergiants, K subdwarfs, metal-deficient giants, and R, CH and barium stars. The subdwarfs, metal-deficient giants and carbon rich stars are separated using the same diagrams as before (Figures 1.22, 1.30 and 1.29 respectively). The remaining normal stars are classified in a calibrated Q_{XYZ} , Q_{XZS} diagram (see Figure 1.33).

Initially a G0 V spectral type is assumed for each star, so the colour excesses may be found (see Table 1.5) and the Q factors calculated. The classification procedure is then repeated using the spectral type found in the previous iteration. More precise colour excess ratios (for the later iterations) are given in Appendix J, copied from Straižys (1992) and Kurilienė & Sūdžius (1974).

The different Vilnius classification methods have largely complementary strengths and weaknesses, so classifications will generally be made using as many of the methods as possible and

Figure 1.21: Separation of Be stars (circles) from normal B stars (dots) of different luminosities. The dashed line shows the limit of normal stars. Taken from Straižys & Sviderskienė (1972) (or Straižys (1992)).

Figure 1.22: Separation of subdwarves from normal stars. The arrow is the blanketing vector for the Sun. Taken from Straižys (1992).

Figure 1.23: Separation of Ap and Bp stars from normal stars. Here $Q_{YZS} = Y - Z - 0.54(Z - S)$. The normal stars of luminosities III, IV, and V are between the dashed lines, and the positions of the main sequence spectral classes are marked. Taken from Straižys (1992).

Figure 1.24: Separation of white dwarfs from normal stars. The main sequence and black body curves are shown. The triangles are extreme F subdwarves. Taken from Straižys (1992).

Figure 1.25: Classification of normal B stars using Q_{PYV} , Q_{UPY} diagrams calibrated in spectral class and absolute magnitude (top figure) and effective temperature and gravity (bottom figure). Taken from Straižys (1992).

Figure 1.26: Metallic-line, Ap and Bp stars. The normal stars of luminosities III, IV, and V are between the dashed lines, and the positions of the main sequence spectral classes are marked. Taken from Straizys (1992).

an average taken for the spectral class.

1.12 Summary.

Much information about stellar surfaces and material along the observer's line of sight can be gained from the electro-magnetic radiation emitted by a star. Ideally the entire e-m spectrum should be measured at fine wavelength resolution (spectroscopy). In practice, only limited wavelength ranges can be measured (due to high opacity wavelength regions in the Earth's atmosphere and the need for a variety of detectors for different wavelength regions). Further,

Sp.	$\frac{E_{U-P}}{E_{P-Y}}$	$\frac{E_{P-Y}}{E_{Y-V}}$	$\frac{E_{X-Y}}{E_{Y-V}}$	$\frac{E_{X-Y}}{E_{Y-Z}}$	$\frac{E_{X-Z}}{E_{Z-S}}$	$\frac{E_{U-X}}{E_{X-Y}}$	$\frac{E_{U-Y}}{E_{Y-V}}$	$\frac{E_{P-Y}}{E_{Y-Z}}$
B	0.43	1.12	0.75	1.16	1.16	1.15	1.60	1.73
A	0.45	1.09	0.73	1.14	1.15	1.15	1.59	1.69
F	0.41	1.11	0.73	1.14	1.15	1.15	1.58	1.74
G	0.38	1.15	0.73	1.13	1.13	1.18	1.58	1.79
K	0.37	1.15	0.70	1.11	1.12	1.23	1.57	1.79
M	0.35	1.14	0.70	1.06	1.10	1.20	1.54	1.77

Table 1.5: Approximate colour excess ratios for initial spectral classification. Taken from Straizys (1992, Table 75).

Figure 1.27: Classification of normal A-F stars using Q_{XYV} , Q_{UPY} diagrams calibrated in spectral class and absolute magnitude (top figure) and effective temperature and gravity (bottom figure). Taken from Straižys (1992).

Figure 1.28: Classification of normal A5-7 III-V stars using Q_{UPYV} , Q_{UXY} diagrams calibrated in spectral class and absolute magnitude (top figure) and effective temperature and gravity (bottom figure). Taken from Straižys (1992).

Figure 1.29: CH (crosses), barium (circles) and R-type (dots) stars. The curves are the main sequence (solid), giant sequence (short dashes) and supergiant sequence (long dashes). Taken from Straizys (1992).

Figure 1.30: Separation of metal-deficient giants from normal stars. Pluses are CN stars, triangles CH, circles $-0.3 > [\text{Fe}/\text{H}] > -0.7$, and dots are $-0.7 > [\text{Fe}/\text{H}]$. The main sequence (solid line), giant sequence (short dashes) and supergiants (long dashes) are also shown, and the shaded region are subdwarves. Taken from Bartkevičius & Straizys (1970c).

Figure 1.31: Classification of subdwarves using a Q_{UVY} , Q_{UV} diagram calibrated in metallicity and effective temperature. Taken from Bartkevičius & Straižys (1970a).

to obtain adequate signal to noise in the time available only the brightest stars can be measured at fine resolution in these wavelength 'windows' and only by using large telescopes (which are expensive and difficult to obtain observing time on). Thus many observers are required to make measurements with coarse wavelength resolution (photometry) using smaller telescopes.

There are a large number of photometric systems in use, most being designed to investigate a particular question and so being restricted to use on a small subset of types of stars (if the 'purity' of the system is not good, then a survey phase will be needed to reject the stars for which the system was not intended). To allow a meaningful analysis of measurements made in any photometric system, and to enable other observers to duplicate the original system, a system must be described (numerically) by the transmission spectrum through each filter. In addition, a description of the components making up the system – telescope/mirrors size and type, filter composition (glass or interference filter type and thickness), detector type and operating conditions – is useful as a starting point to duplicate the system. Further, the reduction procedure to transform the raw measurements to those equivalent to the original system (but above the Earth's atmosphere) must be described – this will depend on the bandwidth, number of filters and wavelength spacing between the filters and requires a large number of stars accurately measured in the original system for use as 'standard' stars. Finally, measurements in the system should be calibrated against astrophysical parameters relevant to the investigation, for instance the surface temperature, gravity, chemical composition, rotation rate, and/or magnetic field strength of stars.

To illustrate these points, and to allow a comparison with the photometric system chosen for this study (the Vilnius system), two of the most commonly used systems (the Johnson and Strömgren systems) were reviewed together with the Vilnius system. The Vilnius system is

Figure 1.32: Classification of normal G stars using Q_{XZS} , Q_{UPY} diagrams calibrated in spectral class and absolute magnitude (top figure) and effective temperature and gravity (bottom figure). Taken from Straižys (1992).

Figure 1.33: Classification of normal K stars using Q_{XYZ} , Q_{XZS} diagrams calibrated in spectral class and absolute magnitude (top figure) and effective temperature and gravity (bottom figure). Taken from Straižys (1992).

notable as being the first designed for MK classification and measurement of the main physical parameters of all normal stars, using the then recently available stellar spectra to synthesize magnitudes and colours to investigate the system's properties. It was also found to have a high detection rate of peculiar stars (i.e. high purity), virtually eliminating the need for a survey phase of any investigation. The MK classification can be done via several complementary methods based on the reddening-free Q factors.

A summary of the differences between the three photometric systems is given in Table 1.6. The wavelength range of each system is taken as the difference in effective wavelengths of the bluest and reddest filters. Some of the comparisons are necessarily subjective, but show why the Vilnius system was chosen for use at Victoria University of Wellington (VUW) and Carter Observatory. The only major shortcoming of this system (relative to the others) is the small number of stars observed and lack of standard stars in the southern hemisphere — the latter being precisely what this study intended to remedy. Note also that there have been no critical studies of transformations of local systems to the standard Vilnius system, hence the question marks.

Table 1.6: Comparison of the UBV, *uvby*, and Vilnius Systems.

	UBV	<i>uvby</i>	Vilnius
number of filters	3	4	7
bandwidth of filters	wide	intermediate	intermediate
wavelength range	1600 Å	2000 Å	3100 Å
critical sampling of spectrum	nearly	under-sampled	mixture of under-sampling and nearly critical
intended range of stars	?	normal B-A-F	all normal stars
limiting magnitude	faint	bright	moderately bright
number of stars observed	~ 90000	~ 40000	~ 7000
description of system	poor	good	good
stability of instrumental system	poor	good	good
red leaks	major	none	none
clones/extensions to the system	many	some	one (VilGen)
atmospheric extinction correction procedure	systematic errors, especially in U	small systematic errors in c_1 and $u-b$	good
standard star lists	whole sky distribution, non-homogeneous lists	whole sky distribution, non-homogeneous lists	not in southern hemisphere, homogeneous (?)
standardisation transformation	systematic errors	systematic errors	?
dereddening procedure	poor	good	excellent
parameters measured	Balmer jump, temperature, apparent magnitude	Balmer jump, temperature, metallicity, $\beta \rightarrow$ absolute magnitude	Balmer jump, temperature, metallicity, apparent magnitude
purity/ability to do MK classifications	bad	moderate	good
calibration of physical parameters	poor	good	good
detection of peculiar stars	poor	moderate	good

Chapter 2

Observation and Reduction Techniques.

2.1 The Equipment used.

The observations were made at Mount John University Observatory (MJUO) (see Figure 2.1), located by Lake Tekapo in the South Island of New Zealand and run by University of Canterbury (UoC). The observatory has three main telescopes; an Optical Craftsman (O/C) 61 *cm* Cassegrain, a Boller and Chivens (B&C) 61 *cm* Cassegrain (see Figure 2.2), and the M^cLellan 1 *m* telescope (constructed by UoC). To try to increase the long term stability of the observations, the same instrumental system, as listed in Table 2.1, was used when scheduling permitted. The actual system used for each session is given in Appendix C.

The PMT was used in pulse-counting mode, with the output being amplified and re-shaped to a 'square' shape (suitable for counting) by the amplifier/discriminator circuit. The discriminator part of this circuit rejects any pulses smaller than (an adjustable) threshold, which increases the signal-to-noise ratio (with the noise here being predominately due to the dark counts of the PMT — see section 2.2). The total number of pulses in a given 'integration' period are counted and logged by a computer (initially a PET computer, and then a PC after April 1992).

For bright stars (*V* brighter than 6^{*m*}.0, say), five second integrations (10 *seconds* for the U and S filters) give sufficient accuracy by ensuring the count is larger than 10,000 (see section 2.5). At least three such integrations were done for each filter, allowing the mean ($\bar{x}$) and variance (s^2) of the observation to be calculated. The data logging program uses these to give a real-time

Table 2.1: The preferred instrumental system.

- B&C 61 <i>cm</i> telescope- 9558B PMT (belonging to VUW) operated at 1500 <i>V</i> and cooled to a temperature between -10°C (during summer) and -16°C (during winter)- amplifier/discriminator #3- local Vilnius filter set #1

Figure 2.1: View of the buildings at the top of the Mount John University Observatory, located at longitude $+170^{\circ} 27.9'$ East, latitude $-43^{\circ} 59.2'$, and 1027 m above sea-level.

Figure 2.2: The Boller and Chivens telescope at Mount John University Observatory.

indication of the quality of the observations

$$QF = \frac{s^2}{\bar{x}} \begin{cases} \sim 1 & \Rightarrow \text{'good' observation} \\ > 1 & \Rightarrow \text{'bad' observation} \end{cases} \quad (2.1)$$

assuming the 'noise' follows a Poisson distribution. The reduction program calculates the errors in the reduced observations by propagating the variance of the integrations in the standard manner using

$$s_y^2 = \frac{1}{y^2} \sum_{i=1}^n s_{x_i}^2 \left(\frac{\partial y}{\partial x_i} \right)^2 \quad (2.2)$$

for any function $y = f(x_i)$ with independent variables $x_i, i = 1 \dots n$.

Two filter sets were supplied by the Vilnius Institute of Theoretical Physics and Astronomy. The first set is 15 mm in diameter and up to 12.5 mm thick, and fit in a filter-wheel which can be used on either the B&C or O/C telescopes. The second set are 28 mm diameter, and were designed to fit in the Charge Coupled Device (CCD) photometer for use on the 1 m telescope in addition to PMT photometers on the B&C and O/C telescopes (by using the appropriate filter-wheel). A history of the two filter sets is given below;

Oct 1987 First trial of filter set #1. No Z observations were made as this filter would not fit in the filter-wheel.

June 1988 (Thinner) replacement Z filter used in set #1.

Aug 1992 Filter set #2 arrives. The P filter was found to be cracked and the Y filter was 'cloudy' near one edge.

Nov 1992 Replacement P filter for set #2 arrives.

Dec 1992 Set #2 first used (using the clear region of the Y filter).

June 1993 Replacement Y filter arrives

Sept 1993 Set #2 padded to a common physical thickness ($\approx$ optical depth) using FK5 or BG270 glass and Dow-Corning Q2-3068 'glue'. This ensures the CCD system will have the same focal point through all Vilnius filters (of set #2).

2.2 The Dark Current.

A PMT will produce a (small) signal even in the total absence of any light. In Direct Current (DC) mode, this is called the *dark current* while in Pulse Counting (PC) mode, it is called the *dark count*. The mean dark count can be simply subtracted from a star's signal, however fluctuations in the dark count add to the total noise in the signal. As this dark count noise scales with the mean dark count, it is desirable to reduce the dark count.

The main sources of the dark count are

- cosmic rays

- radioactivity
- after pulses
- electrical leakage
- thermally ejected electrons

Cosmic rays are detected by the Cherenkov radiation they produce on striking the PMT's glass window. The amount of cosmic rays increase with the observatory's height above sea-level, being $\sim 1/\text{minute}/\text{cm}^2$ at sea-level (Young 1974), and depend on the area of the photocathode. The Cherenkov radiation is roughly white and strong in the ultra-violet so it's contribution also depends on the spectral transmittance of the PMT window and the spectral response of the photocathode. The pulse produced is usually larger than a signal pulse so can be removed if the amplifier/discriminator circuit has maximum voltage threshold.

Naturally occurring radioactive isotopes are present in small quantities in all PMT window and envelope materials. The decay of these isotopes can produce spurious signals via Cherenkov radiation or ejecting electrons from the photocathode. Fortunately the count rate is generally low ($\sim 2/\text{minute}$) and slowly reduces with time.

After pulses are extra pulses which may follow any signal (or dark count) pulse. These are due to ionisation by the initial pulse of any residual gas in the PMT. The positively charged ion is then accelerated towards and collides with the photocathode, causing electrons to be ejected and produce the after pulse. The standard vacuum bake out technique can not be used to reduce the amount of residual gas as it would destroy the photocathode. Cooling the PMT reduces the after pulse rate as the 'gas' is more likely to stick to a cold surface.

The connecting pins to the cathode, dynodes and anode all pass through the glass envelope at the back of the PMT, in close proximity to each other. With the large voltages between the cathode, dynodes and anode and the small currents which form the signal, the resistivity of this envelope has to be large to prevent any leakage current between the pins. Cooling the PMT may decrease the resistivity of the envelope and so increase the leakage current.

The major source of dark counts is usually the electrons thermally ejected from the photocathode or the dynodes. Around the region of 0°C , the dark count is an exponential function of absolute temperature, so cooling the PMT will dramatically reduce the dark count. However excessive cooling may cause other problems in addition to the electrical leakage mentioned above. For instance, the conductivity of the photocathode decreases with decreasing temperature and also differential contraction between different materials in the PMT may lead to the vacuum seal being broken. For this reason, the MJUO PMT is permanently cooled to a set temperature, between -10° and -16° .¹ This gives an additional benefit of thermal stability, as, for example, the spectral response of the PMT changes with temperature.

¹The cooling unit is limited by the maximum temperature *difference* it can maintain between the PMT and

The thermal dark count also depends on the work function of the photocathode material and the area of the photocathode. The choice of the photocathode material is determined by the required spectral range, but the star image (via the fabry lens) should cover the entire photocathode area so none of the photocathode contributes to the dark count while not contributing to the signal.

The dark count can be measured by closing a shutter which is mounted between the PMT and the rest of the photometer. These measurements were done at the beginning of each night before starting the observations and again at the end of the night. As this was usually done during twilight, the dome was closed and all interior lights turned off to reduce any light leakage into the PMT. This provided a crude check of the correct operation of the PMT as experience has shown that the dark count (of the PMT used here) is normally ~ 30 Hz.

2.3 Time Corrections.

The time of the beginning of each integration measurement is recorded by the data logging program, using the computer's internal clock. This clock is nominally set to Universal Time (UT) but sometimes has a slow drift away from the true time, on the order of seconds per night. For this reason, a radio tunable to one of the time standard services (WWV — the American service or VNG — the Australian service) is provided in the B&C and O/C domes.

At the beginning of each night, provided the radio reception is suitable, the computer clock is compared with the standard's time pips. Any discrepancy is then either recorded (for later use in the reduction program) or the computer clock is reset to the correct time. This should ensure the recorded time is accurate at the beginning of the night (to approximately one third of a second) and within a few seconds throughout the entire night. As the observing program consists of (nominally non-variable) standard stars, this level of accuracy should be sufficient.

2.4 Dead-time Corrections.

In a pulse counting system, when a photon is detected the system is un-responsive to further photons for a certain time interval, known as the *dead-time*. For instance, this could be due to the finite duration of the output pulse from the amplifier/discriminator circuit or the ability of the frequency counter to resolve two close pulses as two, rather than only one pulse. It is assumed that the photons arriving during a dead-time interval do not contribute their own dead-time to the original interval, i.e. the system is *non-paralyzable*. It is particularly important to correct for these un-detected photons when measuring bright stars.

the ambient temperature. Thus the PMT is usually kept at a higher temperature during summer than during winter.

As photons are Bosons, they obey Bose-Einstein population statistics where they 'bunch' together more than would be expected from a uniform random distribution. The probability density function of two photons being separated by an interval t is

$$p(t) = fe^{-ft} \quad (2.3)$$

where f is the arrival frequency of the photons (Poretti 1992). The number of photons arriving in an interval $\mathcal{T}$ (the dead-time) is

$$n_{\tau} = N \int_0^{\mathcal{T}} p(t) dt = N \int_0^{\mathcal{T}} fe^{-ft} dt \quad (2.4)$$

where N is the number of photons arriving during the total measurement interval. Setting this measurement interval to one second gives $N = f$ and

$$n_{\tau} = N \int_0^{\mathcal{T}} Ne^{-Nt} dt = N[1 - e^{-N\mathcal{T}}].$$

However the number of measured photons is

$$n = N - n_{\tau} = \frac{N}{e^{N\mathcal{T}}} \quad (2.5)$$

on substituting for n_{τ} . This is an exact relation between the measured and actual number of photons, but it can not be analytically solved for N . However, if $N\mathcal{T}$ is small, then a MacLaurin expansion on the exponential term to first order gives

$$\begin{aligned} n &\approx \frac{N}{1 + N\mathcal{T}} \\ \Leftrightarrow N &\approx \frac{n}{1 - n\mathcal{T}} \end{aligned} \quad (2.6)$$

which approximation is used to correct the measured photon count rate for the dead-time.

Poretti (1992) pointed out in a correction to his earlier paper that Bose-Einstein statistics "is not valid since to observe the effects of Bose-Einstein clumping it is necessary to use much faster equipment and much more monochromatic light than we have in ordinary photometry". Instead the arrival of photons should be treated as independent events and described by Poisson statistics (Evans 1955) where the probability of the interval between consecutive photon arrivals being between t and $t + dt$ is

$$dP_t = fe^{-ft} dt.$$

Therefore the number of intervals between $t = 0$ and $t = \mathcal{T}$ (i.e. the number of photons arriving

during the dead-time) is

$$n_{\tau} = N \int_0^{\tau} dP_t = N \int_0^{\tau} f e^{-ft} dt$$

which the same as equation 2.4 and hence the same results follow.

The approximation to the dead-time correction (equation 2.6) is equivalent to assuming the photons arrive at a uniform rate, as will be shown next. During a one second interval, each *measured* photon produces a dead-time τ so the total dead-time is $n\tau$. If the photon arrivals are uniformly distributed throughout the interval, then $Nn\tau$ arrive during the total dead-time. However the number of undetected photons is also $N - n$, hence

$$\begin{aligned} N - n &= Nn\tau \\ \Leftrightarrow N &= \frac{n}{1 - n\tau} \end{aligned}$$

which is the same result as the approximation formula 2.6.

A variety of methods have been developed to measure the dead-time, see for example Hall & Genet (1982), Cooper & Walker (1989), Morris & Naftilan (1994), Sterken & Manfroid (1992a), and Hendon & Kaitchuck (1990). The method used here is given by Wadsworth (1988) and is based on the following;

A stable, diffuse light source is used to illuminate the telescope and measurements through two different sized photometer diaphragms are made giving

$$N_S = \frac{n_S}{1 - n_S\tau} \quad \text{and} \quad N_L = \frac{n_L}{1 - n_L\tau}$$

where the subscripts denote the Small and Large diaphragms respectively. Dividing the smaller diaphragm measurement by the larger gives

$$\begin{aligned} \frac{N_S}{N_L} &= \frac{n_S}{n_L} \frac{1 - n_L\tau}{1 - n_S\tau} \\ \Leftrightarrow \frac{n_L}{n_S} &= \frac{N_L}{N_S} (1 - n_L\tau)(1 - n_S\tau)^{-1} \end{aligned}$$

Provided $n_S\tau$ is small, a binomial expansion may be used

$$\frac{n_L}{n_S} \approx \frac{N_L}{N_S} (1 - n_L\tau)(1 + n_S\tau) = \frac{N_L}{N_S} [1 - (n_L - n_S)\tau] \quad (2.7)$$

to first order. By making a series of measurements with the light source adjusted to different intensities, a straight line may be least squares fitted to (n_L/n_S) vs $(n_L - n_S)$, giving a slope of $-\frac{N_L}{N_S}\tau$ and intercept $\frac{N_L}{N_S}$ and thus $\tau = -\frac{\text{slope}}{\text{intercept}}$.

The light source used at MJUO consists of differently coloured Light Emitting Diodes

(LEDs) arranged in rings behind 'clouded' glass (to diffuse the light) in a 'tophat' and powered by an adjustable, constant current supply run from a rechargeable battery (for stability).

The LED 'tophat' can be mounted in the primary mirror baffle of either the B&C or the O/C telescopes. It is recommended that dead-time measurements be made on a cloudy night with all the dome lights off (to reduce any light leakage into the PMT) and the following sequence used;

1. Choose a suitable combination of LED (colour), filter, small/large diaphragms and LED intensity range so that measurements of at least ten different intensities may be made from $n \sim 10^4 \rightarrow 10^6$ Hz.
2. Set the LED to some intensity and allow time to stabilize (for example five minutes). Measure the dark current while waiting.
3. Make a quick series of measurements alternating between the small and large diaphragms (for example small, large, small, ..., large, small) at uniform time intervals (for example ten second measurements with five seconds between each measurement) so any instrumental drift may be corrected to first order by interpolating the small diaphragm measurements to the time of the large diaphragm measurements.
4. Measure the dark current again.
5. Change the LED intensity and go back to step 2.

The interpolated dark current count rates should be subtracted from each set of measurements to give n_S and n_L .

Table 2.2: Dead-time measurements on the B&C telescope using the VUW PMT at 1500 V.

Date	Ampl #	LED	Filter	τ (ns)	$\langle \tau \rangle$ (ns)
27 Feb 91	1	Green	V	370 ± 50	370 ± 50
14 May 91	3	Red	S	330	
07 Feb 92	3	Green	Z	270	
17 Apr 92	3	Red	S	299	
26 Jun 92	3	Red	S	288	297 ± 25

From the EMI PMT catalog, the rise time (t_r) of the output pulse in response to a detected photon for a 9558B PMT is 10 ns, so $3t_r$ should be a good estimate of the pulse duration and hence the dead-time of the PMT. The same catalog gives the dead-time of

some amplifier/discriminator circuits as being between 10 – 100 ns. As the dead-time of a system is due to the longest dead-time of any component of the system, dead-times (due to the amplifier/discriminator circuit) of the order 10 – 100 ns could be expected. This is also borne out in results reported in the literature, for example Morris & Naftilan (1994), Poretti (1992), and Fernie (1976).

The results of dead-time measurements made at MJUO are shown in Table 2.2, with the average values being used in the data reductions. These are somewhat larger than the expected values, but clearly depend on which amplifier/ discriminator is used.

Fernie (1976) investigated the effect of very bright stars and found that the dead-time (approximate) correction (equation 2.6) fails for stars brighter than $\sim 4^m.0$, using the same sized telescope as those at MJUO (61 cm). The dead-time appeared to increase as the count rate increased ($\tau' = \tau n^b$), leading to a power law correction

$$N = \frac{n}{1 - \tau n^{1+b}} \quad (2.8)$$

with $b = 0.052$. The Vilnius filters have narrower bandwidths and lower peak transmittance than those used by Fernie so at MJUO this effect could be expected to occur from a brighter magnitude, above $\sim 2^m.0$ say. Although only a few (~ 8) stars brighter than this were measured, the MJUO dead-time measurements were also fitted with this correction. This yielded a slightly better fit in some cases, but b was found to be very sensitive to measurement errors and τ was strongly correlated with b , so this power law correction was not used.

2.5 Sky Background Correction.

When measuring the intensity of any star, a background contribution from the night sky is always included and must be subtracted to obtain the star's correct intensity. Listed below are the natural sources of the night sky's background light (Hendon & Kaitchuck 1990);

- integrated light from distant galaxies
- integrated star light from within our own galaxy
- twilight emission lines
- zodiacal light
- Moon light
- airglow
- aurora

Galactic and extra-galactic background light is probably the limiting factor when trying to minimize the 'sky' background contribution. This background light can vary significantly over an angular distance of a few arc-minutes so the correct background subtraction may not be possible. However, the background is 'static' in that it is always the same for the same position (in equatorial or galactic coordinates).

Twilight emission lines are caused by the Sun illuminating certain layers (of Sodium, emitting the Sodium D lines at 5892 Å and Oxygen, emitting red lines at 6300 and 6364 Å) in

the Earth's upper atmosphere. This can only be seen when the Sun is at the correct angle below the horizon, called the solar dispersion angle. This is between 7° and 10° and occurs for approximately one hour (during nautical twilight²), and ends at astronomical twilight.³ Only the Oxygen red lines occur within the Vilnius filters response curves, at the short wavelength 'tail' of the S filter, so the twilight emission lines should make little contribution to the sky background. Inspection of the sky background at dawn twilight on several nights during the observing program show that the largest increase occurs in the Z filter, followed by the Y, X, and P filters. The remaining filters (including the S filter) show approximately the same increase, therefore it is confirmed that the twilight emission lines make a negligible contribution to the sky background.

The zodiacal light is sunlight reflected or scattered off dust in the plane of the solar system, and so is confined to the ecliptic plane. It's intensity increases towards the Sun, but is approximately constant on the scale of arc-minutes. The light is highly polarized and shows a solar spectra.

The intensity of Moon light depends on the phase of the Moon and angular distance from the Moon.

The night airglow is a major contributor to the total sky background. It is due to ionized atoms and molecules recombining (and thus emitting light) following collisions with high energy particles and radiation, which are mainly from the Sun. This mostly occurs in a layer approximately 100 km above the Earth. It's spectra consists of a pseudo-continuum plus some emission lines, the major lines being atomic Oxygen (5577 Å), Sodium (5892 Å), molecular Oxygen (7617, 8645 Å) and hydroxyl (OH^- , in the infrared). The intensity increases towards the horizon but is generally variable, depending on the latitude, season, local time, solar activity and sky conditions.

The aurora is essentially the same as the airglow but occurs when high energy *charged* particles (usually from the solar wind or flares) are trapped by the Earth's magnetic field and forced to spiral in towards the magnetic poles. As the particles are concentrated in an irregular oval around each pole, the aurora can be several hundred times brighter than the airglow. The major emission lines are due to atomic Oxygen (5577, 6300, 6364 Å), Hydrogen (6563 Å) and molecular Nitrogen (red), giving colours ranging from a white-green to deep red. It's intensity varies with latitude, solar cycle and flare activity and season (peaking in March and October). The irregular and highly variable nature of aurora mean that accurate sky measurements are extremely difficult to make and it is recommended that observations not be made during an

²Nautical twilight is defined by the Astronomical Almanac as the interval during which the central point of the Sun's disk is between 6° and 12° below the horizon

³Astronomical twilight is defined by the Astronomical Almanac as the interval during which the central point of the Sun's disk is between 12° and 18° below the horizon

aurora (Hendon & Kaitchuck 1990).

Given that the aim of the observing program was to measure stars rather than the sky, it is worth investigating the optimum (minimum) time to spend measuring the sky. It is usual to observe the star until the shot noise⁴ (assumed to be the dominant error here) achieves the required accuracy level. Denoting the total integrated count as n , the integration time as t and the count rate as $\dot{n}$ ($= n/t$), the shot noise is $n^{\frac{1}{2}}$. Aiming for a 1% accuracy level gives

$$\frac{\text{shot noise}}{\text{signal}} = \frac{n_{star+sky}^{\frac{1}{2}}}{n_{star+sky}} < 0.01 \Rightarrow n_{star+sky} > 10000$$

and an (absolute) error in the count rate of

$$\begin{aligned} \varepsilon_{star+sky} &= \frac{\text{shot noise}}{\text{integ. time}} \\ &= \left(\frac{\dot{n}_{star+sky}}{t_{star+sky}} \right)^{\frac{1}{2}}. \end{aligned}$$

A simple way to minimize the time spent measuring the sky while retaining the required accuracy is to measure the sky until it's error is less than that of the star, i.e.

$$\begin{aligned} \varepsilon_{sky} &< \varepsilon_{star+sky} \\ \Leftrightarrow \left(\frac{\dot{n}_{sky}}{t_{sky}} \right)^{\frac{1}{2}} &< \left(\frac{\dot{n}_{star+sky}}{t_{star+sky}} \right)^{\frac{1}{2}} \\ \Leftrightarrow \frac{t_{sky}}{t_{star+sky}} &> \frac{\dot{n}_{sky}}{\dot{n}_{star+sky}}, \end{aligned}$$

with the total error being

$$\begin{aligned} \varepsilon_{star}^2 &= \varepsilon_{star+sky}^2 + \varepsilon_{sky}^2 \\ &= \frac{\dot{n}_{star+sky}}{t_{star+sky}} + \frac{\dot{n}_{sky}}{t_{sky}} \end{aligned}$$

In the limiting case of a faint star (equal to the sky) and equal errors in the star and sky, then $t_{sky} = t_{star+sky}$ and in general $t_{sky} \leq t_{star+sky}$.

Hendon & Kaitchuck (1990) and Sterken & Manfroid (1992a) both derive the same expression for the optimum fraction of the total integration time to be spent observing the star ($p = t_{star+sky}/t_{total}$) as

$$\frac{1-p}{p} = \left(\frac{\dot{n}_{sky}}{\dot{n}_{star+sky}} \right)^{\frac{1}{2}}$$

This follows from minimizing the total error with respect to p .

⁴Shot noise is also called photon noise.

Given that the peak transmittance of each filter is different and that the count rates for each star will also be different, an optimum sky integration time would need to be calculated for each filter and star combination. It was considered that the time saved by using the optimum time for the sky measurements would be comparable with the time required to do the calculations (in the dome, after observing the star) and reset the integrations times. Therefore it was decided to use the same integration times for both the star and the sky — that way the sky's error contribution should always be less than that of the star.

Another consideration when measuring the sky background level is the diaphragm size. As the sky appears as an extended source (rather than the point source of a star), increasing the size of the diaphragm increases the sky signal and increases the limiting intensity of the faintest star that may be measured. This means the diaphragm size should be the minimum necessary (to satisfy the other conditions on the diaphragm size) when observing faint stars. The most commonly used diaphragm in this program gave, on a Moon-less night, a sky background of ~ 50 Hz. As this includes the ~ 30 Hz contribution from the dark count, using a smaller diaphragm would mean the background level would be set by the dark count rather than the sky background.

The observing sequence between star and sky was adapted to suit each night's conditions and intended program, with some examples listed below;

- In general, the sky was measured before and after the measurement of each star. However, if the star was bright and the sky conditions were stable, the sky was measured only once (after the star measurement, say).
- Choose a location for the sky measurement which appears clear of faint stars and is approximately five diaphragm diameters away from the star. However, if the star has a companion star whose magnitude and proximity are sufficient to contribute significantly to the sky background (yet not close enough that they have to be measured together through the same diaphragm), choose the location of the sky measurement so that it matches the star's background. For instance, choose a location on an arc which is centred on the companion star and runs through the observed star.
- If observing during twilight or Moon rise/set, only bright stars were measured and the sky was measured immediately before and after the star measurement.
- If observing a sequence of 2–4 bright stars which are close together in the sky, then the sky would be measured before and after the sequence rather than with each individual star.
- If re-measuring a previously observed star, use the same location as before for the sky measurement. This is particularly useful for time series or differential photometry (for example

variable, comparison and check stars).

The reduction program was written to allow flexibility in the star/sky sequence used, as the program could be instructed by the user to

- automatically assign all sky measurements to the closest preceding star measurement
- automatically assign all sky measurements to the closest following star measurement
- automatically interpolate the closest sky measurements surrounding the star measurement
- least squares fit a polynomial (order specified by the user) to the sky measurements
- allow the user to over-ride any individual star/sky assignment

while warning the user if any star has not yet had a sky measurement assigned to it.

2.6 The Monochromatic Extinction Correction.

When star light passes through the Earth's atmosphere, some of the photons will be scattered or absorbed. However, as far as the observer is concerned the star appears to be dimmed, hence the term 'extinction' is used for both processes. The main sources of extinction are; Rayleigh scattering by molecules, scattering off aerosols (dust particles and small droplets), and molecular absorption — see Appendix H for more details.

Consider a monochromatic ray of light (wavelength λ , intensity I) passing through a small element of absorbing material with length δh and unit cross-section, at a height h above the observer. The intensity loss δI is

$$\delta I = -I\kappa(\lambda, h)\rho(h)dh \quad (2.9)$$

where $\kappa(\lambda, h)$ is the absorption coefficient per unit mass and $\rho(h)$ is the mass density of the air in the element.

In general, the star is not at the zenith so dh is replaced by $\sec(z)dh$

$$\delta I = -I\kappa(\lambda, h)\rho(h)\sec(z)dh \quad (2.10)$$

where z is the *zenith distance*. Integrating gives

$$I(h_0) = I(h_1)e^{-\int_{h_0}^{h_1} \kappa(\lambda, h)\rho(h)\sec(z)dh} \quad (2.11)$$

where h_0 is the height of the observer and h_1 is the top of the atmosphere.

However, this assumes the ray travels in a straight line through the atmosphere. In fact the angle z varies with height because of the Earth's curvature and refraction of the ray, i.e. $z = z(h)$. Note that z_0 is the *apparent zenith distance* of the star as seen by the observer.

Assuming the absorption coefficient is constant throughout the atmosphere, i.e. $\kappa = \kappa(\lambda)$, then

$$I(h_0) = I(h_1)e^{-\kappa(\lambda) \int_{h_0}^{h_1} \rho(h) \sec(z(h)) dh} \quad (2.12)$$

The integral represents the mass of air in a column along the ray's path. Defining the *air mass* as

$$X = \frac{\int_{h_0}^{h_1} \rho(h) \sec(z(h)) dh}{\int_{h_0}^{h_1} \rho(h) dh}, \quad (2.13)$$

which is the amount of air in the column relative to that at the zenith. Hence

$$\begin{aligned} I(h_0) &= I(h_1)e^{-\kappa(\lambda)X(z(h)) \int_{h_0}^{h_1} \rho(h) dh} \\ &= I(h_1)e^{-\kappa(\lambda)X(z(h))\alpha} \end{aligned} \quad (2.14)$$

with $\alpha (= \int_{h_0}^{h_1} \rho(h) dh)$ being the total mass of air in a vertical column (of unit cross-section) above the observer.

Converting to magnitudes gives Bouguer's Law

$$\begin{aligned} m(h_0) &= m(h_1) + 2.5 \log_{10}(e) \kappa(\lambda) X(z(h)) \alpha \\ &= m(h_1) + k(\lambda) X(z(h)), \end{aligned} \quad (2.15)$$

with the *extinction coefficient* $k(\lambda) = 2.5 \log_{10}(e) \kappa(\lambda) \alpha$.

Bemporad (1904) calculated X as the function of the apparent zenith distance for a standard atmosphere (i.e. at a particular sea level temperature and pressure and having a certain composition and structure). Hardie (1962) shows that $X = \sec(z)$ is a reasonable approximation near the zenith, giving an error of 0.005 *airmasses* at $z = 60^\circ$. Hardie also fitted a polynomial to Bemporad's data

$$X = \sec(z_0) - 0.0018167(\sec(z_0) - 1) - 0.002875(\sec(z_0) - 1)^2 - 0.0008083(\sec(z_0) - 1)^3$$

but this uses the apparent zenith distance (which is difficult to calculate). Young & Irvine

(1967) derive a fit to Bemporad's tables

$$X = \sec(z)(1 - 0.0012(\sec^2(z) - 1)) \quad (2.16)$$

which uses the zenith distance.

Equation 2.16 was used here to calculate the airmass as the zenith distance may be calculated using spherical trigonometry on coordinate transformations,

$$\sec(z) = (\sin(\phi) \sin(\delta) + \cos(\phi) \cos(\delta) \cos(HA))^{-1} \quad (2.17)$$

where ϕ is the observer's latitude, δ is the star's declination and HA is the star's Hour Angle. The hour angle is found from $HA = LST - \alpha$, where LST is the Local Sidereal Time and α is the star's Right Ascension.

The local sidereal time is calculated in turn from the Universal Time as follows; the fractional Julian Century is

$$T_u = \frac{JD - 2451545}{36525}$$

as the Julian Date at the beginning of the century is 2451545 and there are 36525 days in this century. The Julian Date must be calculated from the calendar date, using a BASIC subroutine given by Duffett-Smith (1985) and re-written in FORTRAN.

T_u allows the sidereal time for Greenwich at 0^h UT to be found;

$$GST_0 = 24110.54841 + 8640184.812866T_u + 0.093104T_u^2 - 6.2 \times 10^{-6}T_u^3 \text{ (seconds)}$$

and hence the Greenwich sidereal time at the time of the observation

$$GST = GST_0 + \frac{366.2422}{365.2422} UT \text{ (hours)} \quad (2.18)$$

where 366.2422 is the number of sidereal days in a year while 365.2422 is the number of (mean) solar days in a year. Now the local sidereal time can be found

$$LST = GST + \lambda$$

where λ is the observer's longitude (East of Greenwich, in hours).

Recall that Bouguer's Law was derived assuming the absorption coefficient per unit mass (κ) was constant, i.e. the components making up the atmosphere are well mixed. This is true for the major atmospheric constituents but not for ozone or dust and water droplet aerosols (Sterken & Manfroid 1992a). Ozone is a major component in a layer at ~ 30 km height

Figure 2.3: Bouguer plot to determine monochromatic extinction (for the P filter). Observations were made of the extinction star HD122066 during 22 June 1989, yielding $\langle k_P \rangle = 0.460 \pm 0.006$.

while the aerosols are largely found just above the ground, with a scale height of ~ 1 km. Hence, at some wavelengths where the ozone or aerosol extinction is strong, Bemporad's tables (and equation 2.16) may not give the correct values for the airmass. However, Young (1974) has shown that the ozone and aerosols require corrections in opposite directions (i.e. partially cancel out) and are not significant for $X \lesssim 2.3$.

All that remains is to find the extinction coefficient $k(\lambda)$. Assuming the extinction is uniform across the sky and constant during the night, then observing a star through a range of airmasses gives $k(\lambda)$ by least squares fitting a straight line to the instrumental magnitude ($m(h_1)$) versus the airmass. The slope of the line gives the extinction coefficient while the intercept gives the *extra-terrestrial* instrumental magnitude ($m(h_0)$). As example can be seen in Figure 2.3, and is known as a Bouguer plot.

Measuring the star at larger airmasses should increase the precision of $k(\lambda)$. However, "it is a common experience that the error [of a measurement of the star] is an increasing function of airmass" according to Young (1974). This was investigated for MJUO in Figure 2.4, showing a possible quadratic relationship — but the scarcity of observations at large airmasses mean this relationship can not be definitely confirmed. Assuming however that the accuracy does decrease with increasing airmass, then there will be an optimum airmass (X_{opt}) beyond which the benefits

Figure 2.4: Observational error as a function of airmass at MJUO. The standard deviation of the V filter measurements are plotted against the airmass of the observation.

of increasing X will be offset by the increasing error. Using a power law relationship, Young (1974) finds $X_{opt} \sim 2$ so observations of extinction stars at MJUO were generally restricted to $X \lesssim 2$. Young (1974) also shows that observing the extinction star twice as often at the larger airmasses than at the smaller airmasses gives the correct weighting to the least squares fit — this was usually done at MJUO by observing the star as it rises and again as it sets.

Unfortunately the previous assumption that the extinction remains constant across the sky and throughout the night is seldom true. Figure 2.5 shows a Bouguer plot on a night with an apparently slowly changing extinction — as the star sets it does not re-trace the path it took in the plot while rising.

A standard lamp could be used to measure any change in the zero-point, and hence indicate if an instrumental drift is responsible for the changing ‘extinction’ in Figure 2.5. An ideal standard lamp would be stable for at least the duration of the night, would illuminate the telescope in the same manner as a star and emit light over the spectral range covered by the filter set used.

Unfortunately, such a standard lamp is not yet available at MJUO as the LED Tophat used to measure the dead-time requires too long to install in the primary mirror baffle (of the B&C telescope) to be practical for frequent measurements. Alternatively, the β -light source can be

Figure 2.5: Variable extinction in a Bouguer plot. Observations were made of the extinction star HD114613 during 13 April 1992, giving an incorrect average extinction of $k_P = 0.651 \pm 0.039$ (which is too high). The times of the first, middle and last pair of observations are shown.

mounted in a filter-wheel. This is a radioactive isotope, with an ~ 12 year half-life, which emits β -particles (electrons) that excites a phosphor into glowing. However, it's intensity is strongly temperature dependent (as phonon production is a competing process also excited by the β -particles) and so would need to be thermally regulated, or at least the temperature recorded. Further, it emits light in a narrow spectral range and does not illuminate the filters or telescope mirrors. Finally, as it does not have a shutter, it would be an additional source of background light whose intensity depended on the position of the filter-wheel. This means the cause of the variable extinction in Figure 2.5 must be found from measurements of extinction stars only.

Young (1974) investigated the shapes of Bouguer plots with slowly changing extinction due to different causes — a horizontal extinction gradient, a time-varying extinction coefficient, or an instrumental zero-point drift. Assuming an extinction coefficient which varies linearly with horizontal distance (at some height above the observer), then $m = m_0 + (k_0 + k_1 \tan(z)) \sec(z)$ in a flat-earth approximation, which shows two convex branches meeting in a common tangent at the minimum airmass in a Bouguer plot. Alternately, a linearly time varying extinction coefficient gives $m = m_0 + (k_0 + k_1 t) \sec(z)$, which shows two nearly straight branches meeting at the minimum airmass. Finally, a linearly time varying instrumental zero-point gives $m = m_0 + k_0 \sec(z) + k_1 t$, showing two nearly straight, parallel lines with a rounded end at minimum

airmass. These can be seen in Figure 2.6, which were adjusted by eye to fit the extinction data from 13 April 1992.

The cause of the variable extinction on 13 April 1992 is difficult to decide on the basis of Figure 2.6, as the difference in the shape of the curves is only readily apparent at larger airmasses. However two other stars were also used to measure the extinction during the same night. As these stars are $\sim 3^h$ apart (in RA) from each other, and so are at different airmasses when observed (nearly) simultaneously, a plot of the extinction coefficient versus time should behave in the different manner for each star depending on the source of the extinction variations.

This is shown in Figure 2.7, calculating the extinction coefficient for each observation using $k(t) = (m(t) - m_0)/X$ (the extra-terrestrial magnitude (m_0) for each star was accurately determined using Nikonov's Method — see later). For each possible cause of extinction change, a curve was fitted to HD114613 and the derived coefficients used to draw curves for the other two stars. As the correct source of the extinction change should fit all three stars equally well, the horizontal gradient in extinction can be immediately ruled out. Both the time dependent extinction and zero-point changes appear to match the data well, with the latter being a slightly better fit.

As the changes may not be linear, the extinction coefficients (or zero-point shifts) for all three stars were plotted against time in Figures 2.8 and 2.9 and a polynomial fitted so the required adjustment may be found for the time of any observation. Using these adjustments, the transformation to the standard system was fitted in Figure 2.10. Despite the fact that the standard stars were observed at larger airmasses where the two possible adjustments ($\Delta m = k_1 t X$ or $\Delta m = k_1 t$) should show the greatest difference, no significant difference was found.

As the program stars are usually observed at their minimum airmass, where the adjustments are nearly equal, it was assumed that the changing Bouguer plot was due to a slowly decreasing extinction coefficient. Almost all nights which had a changing extinction showed a slowly decreasing extinction, which was approximately linear with time. According to Young (1974), this is due to a slow fall-out of aerosols in the atmosphere during the night as the convection (stirring up the aerosols) driven by solar heating ceases.

Recall that the calculation of the instantaneous extinction coefficient using $k = (m - m_0)/X$ required an accurate value for m_0 . One method for finding this was devised by Nikonov (1953), and a variation on the technique was used here. Other methods to find m_0 , or otherwise determine better values of the extinction coefficient than from a Bouguer plot, can be found in the literature, for example Hardie (1962), Harris, FitzGerald & Reed (1981), Acker & Jaschek (1986), Sterken & Manfroid (1992a), Straižys (1992), Forbes (1992), and Poretti & Zerbi (1993).

In Nikonov's method, two extinction stars are used; an 'extinction' star and a 'control' star. They are chosen such that when the extinction star culminates (i.e. at its minimum airmass so

time-varying extinction coefficient

horizontal gradient in extinction

time-varying instrumental zero-point

Figure 2.7: Effect on the P filter extinction coefficient of different types of extinction change. During 13 April 1992, three extinction stars were used to find the cause of apparently changing extinction, assuming linearly changing extinction, instrumental zero-point or a horizontal gradient in the extinction.

Figure 2.8: Possible variation of monochromatic extinction during a night. Using the exact magnitudes of HD086629, HD114613 and HD147513, which were determined by Nikonov's Method, the extinction at the time of each observation during 13 April 1992 can be determined.

Figure 2.9: Possible variation of the instrumental zero-point during a night. Using the exact magnitudes of HD086629, HD114613 and HD147513, which were determined by Nikonov's Method, the zero-point at the time of each observation during 13 April 1992 can be determined.

Figure 2.10: Effect of extinction or zero-point changes on transformation to the standard system for 13 April 1992. The symbols in the plots each represent a star; from left to right, the triangle is HD163245, the hollow plus is HD172850, the plus is HD150366, the asterisk is HD150451, the circle is HD157089, the pentagon is HD167768, the square is HD160823, the solid triangle is HD171767, the diamond is HD165462, the x is HD157415, and the solid square is HD175190.

$X \sim 1$), the control star is rising in the East (i.e. starting at a large airmass, $X \sim 2$ say). The control star is only measured twice — once at the beginning of the night (when the extinction star culminates) and again at the end of the night (when the control star culminates and the extinction star sets). Measurements of the extinction star are made (nearly) simultaneously with these observations. Further measurements of the extinction star are made during the night at appropriate intervals, for instance hourly. In the variation of Nikonov's method used here, the control star is measured simultaneously with every extinction star observation rather than only at the beginning and end of the night.

The following criterion, in addition to those above, are used to select the control and extinction stars;

- non-variable
- appropriate (and equal) spectral types
- appropriate (and equal) magnitudes

To try to ensure the stars are non-variable, variable star catalogs (such as the General Catalog of Variable Stars (GCVS)) are checked for their absence. Preference is given to a star that has been observed as part of a standard stars system, for example from the E region Johnson standards. The spectral types should be the same so any heterochromatic extinction correction (see Section 2.7) is the same for both stars. They should also be of the appropriate spectral type for the filter system used so the heterochromatic extinction correction is (nearly) zero, for example use stars in the range F5-G2 V for the Vilnius system. Finally, both stars should be the same magnitude so any non-linearities in the measuring system cancel out. The magnitude should also be suitable for the size of the telescope, for example on the B&C 61 cm telescope, control and extinction stars in the range $m_V \sim 5.0 \rightarrow 7.0$ are acceptable. This range is bright enough to give good signal-to-noise, minimizing the importance of the dark count or sky background, the length of time required to make a measurement and not too bright to make the effect of the dead-time correction important.

The reduction algorithm is;

- Calculate the approximate magnitude of the extinction star ($\tilde{m}_{o,extn}$) from a Bouguer plot.
- Improve the accuracy of the approximate magnitude by taking the average over each photometric night of the observing run, giving $\langle \tilde{m}_{o,extn} \rangle$.
- For each simultaneous pair of control and extinction star observations (subscripted i),

Figure 2.11: Nikonov's Method used to determine the exact (P) magnitude of the extinction star. During 13 April 1992, the extinction star was HD114613, and the control star HD086629, yielding $m_{exact} = m_{approx} + (0.103 \pm 0.017)$.

calculate the approximate magnitude of the control star using

$$\tilde{m}_{o,ctrl_i} = m_{ctrl_i} - (m_{extn_i} - \langle \tilde{m}_{o,extn_i} \rangle) \frac{X_{ctrl_i}}{X_{extn_i}}.$$

- Least squares fit X_{ctrl_i}/X_{extn_i} (as the independent variable) versus $\tilde{m}_{o,ctrl_i}$. The intercept gives the 'exact' mag of the control star ($m_{o,ctrl}$) and the slope gives $\delta_{o,extn}$, which is the difference between the approximate and 'exact' magnitude of the extinction star ($m_{o,extn} = \langle \tilde{m}_{o,extn} \rangle + \delta_{o,extn}$).
- Improve the accuracy of the 'exact' magnitude of the control and extinction stars by averaging.

An example of the least squares fitting is shown in Figure 2.11. The derivation of this method is given in Appendix F, with the key assumptions being that the extinction coefficient is uniform across the sky at any one moment and that the observations of the control and extinction star are made simultaneously. The assumption about the uniform extinction is more likely to hold true than those made for a Bouguer plot.

Figure 2.12: Typical atmospheric extinction across the optical region, assuming the equivalent of 10 mm of water vapour and 3 mm of Ozone. Taken from Table 7 of Straizys (1992). The Vilnius System passbands are included for comparison.

2.7 The Heterochromatic Extinction Correction.

The previous discussion about extinction assumed a monochromatic ray of light passing through the Earth's atmosphere. However each observation is made over a wavelength range defined by the particular filter used (or more strictly, the combined responses of the filter, PMT, any lenses in the photometer and the telescope mirrors). If the extinction coefficient was uniform across this wavelength range, then the same situation as for the monochromatic extinction would be obtained. However, as Figure 2.12 shows, this is seldom the case.

Generally the extinction is larger on the short wavelength side of a filter passband, hence the colour of a star appears reddened, with blue stars being affected more than red stars.

This reddening also increases with larger airmass; for example if the extinction on the short wavelength (blue) side of the filter was twice that of the long wavelength side at some airmass, then doubling the airmass increases the blue extinction by a factor of four over the red. This is equivalent to reducing the bandwidth of the filter, so at larger airmasses any (non-linear) effects of heterochromatic extinction are reduced and the Bouguer plot becomes a straight line — this is known as the Forbes effect, from Forbes (1842). Unless this effect is accounted for, an extrapolation of a straight line fitted from observations at large airmass will give an incorrect extra-terrestrial magnitude.

Thus the measured extinction coefficient depends on the star's spectral class (and luminos-

ity, interstellar reddening etc.) in addition to the wavelength dependence of the atmospheric extinction and airmass of the observation. To obtain the extinction coefficient for another star, the measured coefficient must be 'corrected' for the difference in spectral class and airmass between the stars.

Recall the measured heterochromatic intensity is

$$E_m = \int_{\lambda_1}^{\lambda_2} S(\lambda) R(\lambda) d\lambda$$

where $S(\lambda)$ is the spectral function of the light incident on the receiver system (with response function $R(\lambda)$). A Taylor expansion is made on $S(\lambda)$ about λ_0 , where λ_0 is chosen so that the first moment cancels, i.e. $\lambda_0 = \int_{\lambda_1}^{\lambda_2} \lambda R(\lambda) d\lambda / \int_{\lambda_1}^{\lambda_2} R(\lambda) d\lambda$ and the other moments are denoted by $\mu_n^n (= \int_{\lambda_1}^{\lambda_2} (\lambda - \lambda_0)^n R(\lambda) d\lambda / \int_{\lambda_1}^{\lambda_2} R(\lambda) d\lambda)$;

$$E_m = S(\lambda_0) \int_{\lambda_1}^{\lambda_2} R(\lambda) d\lambda + \frac{1}{2!} \mu_2'' S''(\lambda_0) \int_{\lambda_1}^{\lambda_2} R(\lambda) d\lambda + \frac{1}{3!} \mu_3''' S'''(\lambda_0) \int_{\lambda_1}^{\lambda_2} R(\lambda) d\lambda + \dots$$

where the primes indicate differentiation with respect to λ . Dropping the integral limits λ_1 and λ_2 , the explicit λ dependence and denoting λ_0 by a zero subscript on the function for brevity;

$$E_m = S_0 \int R d\lambda \left\{ 1 + \frac{1}{2!} \mu_2'' \frac{S_0''}{S_0} + \frac{1}{3!} \mu_3''' \frac{S_0'''}{S_0} + \dots \right\}$$

The measured magnitude $m(h_0)$ has $S = E(\lambda)A(\lambda)$, with E being the star's irradiance and A being the Earth's atmospheric transmission function, so

$$\begin{aligned} m(h_0) &= z - 2.5 \log \left[E_0 A_0 \int R d\lambda \left\{ 1 + \frac{1}{2!} \mu_2'' \frac{(E_0 A_0)''}{E_0 A_0} + \frac{1}{3!} \mu_3''' \frac{(E_0 A_0)'''}{E_0 A_0} + \dots \right\} \right] \\ &= z - 2.5 \log \{E_0\} - 2.5 \log \{A_0\} - 2.5 \log \left\{ \int R d\lambda \right\} - \\ &\quad 2.5 \log \left\{ 1 + \frac{1}{2!} \mu_2'' \frac{(E_0 A_0)''}{E_0 A_0} + \frac{1}{3!} \mu_3''' \frac{(E_0 A_0)'''}{E_0 A_0} + \dots \right\}. \end{aligned}$$

Similarly, the extra-terrestrial magnitude $m(h_1)$ has $S(\lambda) = E(\lambda)$, so

$$\begin{aligned} m(h_1) &= z - 2.5 \log \left[E_0 \int R d\lambda \left\{ 1 + \frac{1}{2!} \mu_2'' \frac{E_0''}{E_0} + \frac{1}{3!} \mu_3''' \frac{E_0'''}{E_0} + \dots \right\} \right] \\ &= z - 2.5 \log \{E_0\} - 2.5 \log \left\{ \int R d\lambda \right\} - \\ &\quad 2.5 \log \left\{ 1 + \frac{1}{2!} \mu_2'' \frac{E_0''}{E_0} + \frac{1}{3!} \mu_3''' \frac{E_0'''}{E_0} + \dots \right\}. \end{aligned}$$

The required transformation (which is usually called a 'correction') is

$$\Delta m = m(h_1) - m(h_0)$$

$$\begin{aligned}
&= 2.5 \log\{A_0\} - 2.5 \log \left\{ 1 + \frac{1}{2!} \mu_2^2 \frac{E_0''}{E_0} + \frac{1}{3!} \mu_3^3 \frac{E_0'''}{E_0} + \dots \right\} + \\
&\quad 2.5 \log \left\{ 1 + \frac{1}{2!} \mu_2^2 \frac{(E_0 A_0)''}{E_0 A_0} + \frac{1}{3!} \mu_3^3 \frac{(E_0 A_0)'''}{E_0 A_0} + \dots \right\}. \quad (2.19)
\end{aligned}$$

If the higher order terms in the log functions are small, then the approximation $\ln(1+x) \approx x$ may be used

$$\begin{aligned}
\Delta m \approx & 2.5 \log\{A_0\} - 2.5 \log(e) \left\{ \frac{1}{2!} \mu_2^2 \frac{E_0''}{E_0} + \frac{1}{3!} \mu_3^3 \frac{E_0'''}{E_0} + \dots \right\} + \\
& 2.5 \log(e) \left\{ \frac{1}{2!} \mu_2^2 \frac{(E_0 A_0)''}{E_0 A_0} + \frac{1}{3!} \mu_3^3 \frac{(E_0 A_0)'''}{E_0 A_0} + \dots \right\} \quad (2.20)
\end{aligned}$$

with the $\log(e)$ factors coming from the conversion of base 10 logarithms to natural logarithms.

Now the derivatives of $E_0 A_0$ expand in a binomial series, for example $(E_0 A_0)'' = E_0'' A_0 + 2E_0' A_0' + E_0 A_0''$, which gives

$$\begin{aligned}
\Delta m \approx & 2.5 \log\{A_0\} + 2.5 \log(e) \left\{ \frac{1}{2!} \mu_2^2 \left[2 \frac{E_0'}{E_0} \frac{A_0'}{A_0} + \frac{A_0''}{A_0} \right] + \right. \\
& \left. \frac{1}{3!} \mu_3^3 \left[3 \frac{E_0''}{E_0} \frac{A_0'}{A_0} + 3 \frac{E_0'}{E_0} \frac{A_0''}{A_0} + \frac{A_0'''}{A_0} \right] + \dots \right\} \quad (2.21)
\end{aligned}$$

The 'normalised' derivatives are derivatives of the quantity in magnitudes as $x'/x = \{\ln(x)\}' = \ln(10)\{\log(x)\}'$ and the higher order derivatives can be written in similar terms using the earlier derivatives, for example $x''/x = (x'/x)^2 + (x'/x)'$. Therefore, (assuming the airmass X does not have any wavelength dependence)

$$\begin{aligned}
2.5 \log\{A_0\} &= -k_0 X, \\
\frac{A_0'}{A_0} &= -\frac{\ln(10)}{2.5} k_0' X \quad \text{and} \\
\frac{A_0''}{A_0} &= \left[-\frac{\ln(10)}{2.5} k_0' X \right]^2 - \frac{\ln(10)}{2.5} k_0'' X \quad \text{etc.},
\end{aligned}$$

with the other extinction terms involving further derivatives of the monochromatic extinction at λ_0 and powers of the airmass X . Similar results are also found for the extra-terrestrial monochromatic magnitude terms.

In principle, the extinction at λ_0 and its derivatives can be found by measuring the extinction at several wavelengths closely spaced about λ_0 . To first order, the extinction follows a power law $k(\lambda) = a\lambda^{-n}$, where $n \approx 4$ as Rayleigh scattering is usually the dominant cause of extinction. In particular, this is true for the Vilnius System as the H_2O and O_2 absorption bands do not coincide with the filter passbands, or are very weak if they are included. As the extinction is thus a fairly smooth function, the spacing of the filters is not critical, and the monochromatic extinction values from the filter set in use is adequate to derive the significant

terms.

Unfortunately a star's spectra is not smooth, consisting of absorption or emission lines superimposed on a black body curve. In general, the derivatives of E_0 do not diminish very fast. Young (1988) has shown that the first and second derivatives can be found easily by splitting E into a smooth (parabolic) function E_s and a remainder function E_r . The coefficients of the parabola are found by requiring $\int E_r A R d\lambda = 0$ so the equations above (to second order) hold for the smooth function. A Taylor expansion of this condition about the extinction A_0 gives

$$A_0 \int E_r R d\lambda + A'_0 \int (\lambda - \lambda_0) E_r R d\lambda + A''_0 \int (\lambda - \lambda_0)^2 E_r R d\lambda = 0 \quad (2.22)$$

As A_0 , A'_0 , and A''_0 depend on the airmass through which a star is measured, to ensure the condition is always true requires each integral to vanish. Young (1988) finds this requires the filters to be spaced less than half of the FWHM apart in wavelength to get good results.

This condition is (nearly) satisfied for only the U,P,X and the Z and V filters of the Vilnius System. Hence the expansion can only be carried to the second moment (and also dropping A''_0/A_0)

$$\begin{aligned} \Delta m &\approx 2.5 \log\{A_0\} + 2.5 \log(e) \frac{2}{2!} \mu^2 \frac{E'_0}{E_0} \frac{A'_0}{A_0} \\ &\approx -k_0 X + c k'_0 X \{m(h_1)_0\}' \end{aligned} \quad (2.23)$$

where c absorbs the various constant terms. The derivative of the extra-terrestrial magnitude about λ_0 is found from some colour index, for instance in the Vilnius System X-Y is used. The usual form of this equation is

$$\Delta m \approx -(k' + k'' \text{Colour}) X \quad (2.24)$$

where k' and k'' absorb the various constant factors and are the primary (or monochromatic) and secondary (or heterochromatic or colour) extinction coefficients.

A better approximation can be found by retaining the A''_0/A_0 term. This is done by not expanding $(E_0 A_0)''$ but instead adding the second moment terms (in equation 2.20) together

$$\dots \mu^2 \left[\frac{E''_0}{E_0} + \frac{(E_0 A_0)''}{E_0 A_0} \right] \dots$$

i.e. using the average of the measured and extra-terrestrial colour (Young & Irvine 1967, Young 1974).

As most filter systems are not spaced close enough together in wavelength to correct for heterochromatic extinction more accurately than the second derivatives, according to Sterken

Figure 2.13: Secondary Extinction Coefficient for Y-Z of Vilnius filter set #2, determined from the slope of the heterochromatic extinction coefficients of six stars versus their X-Y colours. The colour X-Y is the extra-terrestrial colour in the instrumental system.

& Manfroid (1992a) it is better that everyone use the same reduction methods (even if they are not strictly correct). Thus everyone will have the same systematic errors, which will at least allow better comparisons between different observers. For this reason, equation 2.24 (with the extra-terrestrial colour) was used here, following the procedures from the originators of the Vilnius System.

The colour extinction coefficient was determined for each filter set by measuring the heterochromatic extinction ($k = k' + k''Colour$) for several extinction stars of different spectral types on a photometric night. To minimize the effect of any errors in measuring the extinction, (for instance, due to variations in k across the sky or during the night) the stars should be close together in the sky and be measured simultaneously. The extinction k is calculated for each star in a Bouguer plot and these then plotted against the extra-terrestrial colour of each star, as shown in Figure 2.13.

The only terms that can vary in the secondary coefficient k'_0 (see equation 2.23) are the derivative of the extinction spectral function (A'_0/A_0) and the second moment of the filter passbands (μ_2^2). Neither of these terms are considered to change very quickly, so estimates for the required measurement frequency of the secondary coefficients vary from monthly to yearly (Young 1974, Hendon & Kaitchuck 1990).

The results for the two filter sets is shown in Table 2.3, with most magnitudes and colours

not having a significant coefficient, i.e. the coefficient was not larger than the measuring errors. The colour term is set to zero for an arbitrary spectral class, being G0 V for the Vilnius System — in the table, this is the $(X-Y)_{\text{offset}}$ in the local (instrumental) system. The coefficients were measured on 21 Feb 1991 for filter set #1 and on 25 May 1993 for set #2.

The theoretical results for the standard Vilnius System are also listed in the table. The Standard System coefficients were

Table 2.3: Vilnius Colour Extinction Coefficients, measured on 21 Feb 1991 (filter set #1) and 25 May 1993 (set #2)

colour	standard	filter set	
		15 mm	28 mm
$(X-Y)_{\text{offset}}$	+0.78	-0.03 ± 0.01	+0.25 ± 0.01
U	—	—	-0.016 ± 0.007
S	—	—	+0.012 ± 0.005
Y-V	—	—	-0.012 ± 0.010
U-P	-0.027	-0.020 ± 0.006	-0.028 ± 0.009
P-X	+0.013	+0.017 ± 0.006	+0.018 ± 0.007
X-Y	-0.011	-0.013 ± 0.006	—
Y-Z	—	—	-0.013 ± 0.006

obtained by convolving the system passbands with a typical extinction spectral curve at different airmasses and for different stars with measured spectra and colours (Straizys 1992, Zdanavičius 1970). The agree-

ment between the different filter sets and the Standard System is reasonably close. The values are also quite small, as the error in measuring the primary extinction coefficient is often a similar size (especially for the nights where the extinction was changing).

2.8 Transformation to the Standard Filter System.

Now the extra-terrestrial magnitude $m(h_1)$, which was measured in the *local* instrumental system (also called the *natural* or *internal* instrumental system or simply the instrumental system), has to be transformed to the equivalent measurement in the standard system (which is defined by the original instrumental system of the photometric system).

In general, the corresponding filters in each system will not have the same effective wavelength. Hence, in a Taylor expansion about λ_0 (choosing λ_0 between the effective wavelengths of each filter, say) the first moments will be non-zero. Denoting the local system by the subscript *A* and the standard system by *B*,

$$\begin{aligned} m(h_1)_A &= z_A - 2.5 \log\{E_0\} - 2.5 \log\left\{\int R_A d\lambda\right\} - \\ &\quad 2.5 \log\left\{1 + \mu_{1,A} \frac{E'_0}{E_0} + \frac{1}{2!} \mu_{2,A}^2 \frac{E''_0}{E_0} + \frac{1}{3!} \mu_{3,A}^3 \frac{E'''_0}{E_0} + \dots\right\}, \\ m(h_1)_B &= z_B - 2.5 \log\{E_0\} - 2.5 \log\left\{\int R_B d\lambda\right\} - \\ &\quad 2.5 \log\left\{1 + \mu_{1,B} \frac{E'_0}{E_0} + \frac{1}{2!} \mu_{2,B}^2 \frac{E''_0}{E_0} + \frac{1}{3!} \mu_{3,B}^3 \frac{E'''_0}{E_0} + \dots\right\}. \end{aligned}$$

Absorbing $\int R_A d\lambda$ into the zero-point z_A etc. and combining the zero-points as z_{AB} , the transformation between systems A and B is

$$\begin{aligned}
 m(h_1)_A - m(h_1)_B &= z_{AB} - 2.5 \log \left\{ 1 + \mu_{1,A} \frac{E'_0}{E_0} + \frac{1}{2!} \mu_{2,A}^2 \frac{E''_0}{E_0} + \frac{1}{3!} \mu_{3,A}^3 \frac{E'''_0}{E_0} + \dots \right\} \\
 &\quad + 2.5 \log \left\{ 1 + \mu_{1,B} \frac{E'_0}{E_0} + \frac{1}{2!} \mu_{2,B}^2 \frac{E''_0}{E_0} + \frac{1}{3!} \mu_{3,B}^3 \frac{E'''_0}{E_0} + \dots \right\} \\
 &= z_{AB} - 2.5 \log \left\{ 1 + \frac{\mu_{1,A}}{\lambda_0} \frac{\lambda_0 E'_0}{E_0} + \frac{1}{2!} \left(\frac{\mu_{2,A}}{\lambda_0} \right)^2 \frac{\lambda_0^2 E''_0}{E_0} + \dots \right\} \\
 &\quad + 2.5 \log \left\{ 1 + \frac{\mu_{1,B}}{\lambda_0} \frac{\lambda_0 E'_0}{E_0} + \frac{1}{2!} \left(\frac{\mu_{2,B}}{\lambda_0} \right)^2 \frac{\lambda_0^2 E''_0}{E_0} + \dots \right\} \quad (2.25)
 \end{aligned}$$

The latter form allows the derivatives of E_0 to be replaced by derivatives of $\ln(E)$ with respect to $\ln(\lambda)$ (at λ_0)

$$\begin{aligned}
 \frac{\lambda E'}{E} &= \frac{\lambda}{E} \frac{dE}{d\lambda} = \frac{d(\ln E)}{d(\ln \lambda)} \\
 \frac{\lambda^2 E''}{E} &= \frac{\lambda^2}{E} \frac{d^2 E}{d\lambda^2} = \frac{d^2(\ln E)}{d(\ln \lambda)^2} + \left[\frac{d(\ln E)}{d(\ln \lambda)} \right]^2 - \frac{d(\ln E)}{d(\ln \lambda)} \quad (2.26)
 \end{aligned}$$

going from the compact prime notation to the explicit dy/dx notation to show the change of variables. As before, a star's spectra can be split into a smooth approximation and a remainder ($E = E_s + E_r$) and E_s chosen such that the above equations hold for E_s instead of E . Hence, the logarithmic derivatives of the smoothed spectra can be estimated by a colour index (for $d(\ln E)/d(\ln \lambda)$) and difference between adjacent colour indices (for $d^2(\ln E)/d(\ln \lambda)^2$). Young (1988) has found that the colours (and differences) give good estimates of the first and second derivatives if the filters (in a system) are spaced less than half of the FWHM apart in wavelength.

It is usually assumed that the higher order terms are all small, so the logarithmic approximation $\ln(1+x) \approx x$ for $x \ll 1$ may be used

$$\begin{aligned}
 m(h_1)_A - m(h_1)_B &\approx z_{AB} - 2.5 \log(e) \left\{ \frac{\mu_{1,A}}{\lambda_0} \frac{\lambda_0 E'_0}{E_0} + \frac{1}{2!} \left(\frac{\mu_{2,A}}{\lambda_0} \right)^2 \frac{\lambda_0^2 E''_0}{E_0} + \dots \right\} \\
 &\quad + 2.5 \log(e) \left\{ \frac{\mu_{1,B}}{\lambda_0} \frac{\lambda_0 E'_0}{E_0} + \frac{1}{2!} \left(\frac{\mu_{2,B}}{\lambda_0} \right)^2 \frac{\lambda_0^2 E''_0}{E_0} + \dots \right\} \\
 &\approx z_{AB} + 2.5 \log(e) \left\{ \frac{\mu_{1,B} - \mu_{1,A}}{\lambda_0} \frac{\lambda_0 E'_0}{E_0} + \right. \\
 &\quad \left. \frac{1}{2!} \frac{\mu_{2,B}^2 - \mu_{2,A}^2}{\lambda_0^2} \frac{\lambda_0^2 E''_0}{E_0} + \dots \right\} \quad (2.27)
 \end{aligned}$$

with the $\log(e)$ factors coming from the conversion of base 10 logarithms to natural logarithms.

Denoting the effective wavelengths of the systems as λ_A and λ_B , then

$$\mu_{1,A} = \frac{\int (\lambda - \lambda_0) R_A d\lambda}{\int R_A d\lambda} = \frac{\int \lambda R_A d\lambda}{\int R_A d\lambda} - \lambda_0 \frac{\int R_A d\lambda}{\int R_A d\lambda} = \lambda_A - \lambda_0$$

and similarly, $\mu_{1,B} = \lambda_B - \lambda_0$. This gives

$$\mu_{1,B} - \mu_{1,A} = \lambda_B - \lambda_A.$$

If the higher order moments of each system are equal, i.e. the filters have (nearly) identical shapes but are shifted in wavelength, then

$$\begin{aligned} m(h_1)_A - m(h_1)_B &\approx z_{AB} - 2.5 \log(e) \left(\frac{\lambda_B - \lambda_A}{\lambda_0} \right) \left[\frac{d(\ln E)}{d(\ln \lambda)} \right]_{\lambda_0} \\ &\approx z_{AB} + \gamma (\text{colour})_{\lambda_0} \end{aligned} \quad (2.28)$$

which is the linear transformation equation commonly used.

The transmittance of the local Vilnius filter sets were measured from $\lambda = 1900 - 8200 \text{ \AA}$ in $20 \text{ \AA}$ steps using a double-beam spectrometer, courtesy of the Chemistry Department, VUW. These are compared with the response curves of the Standard Vilnius system (Straižys 1992) in Figure 2.14. The local filters generally match the standard filters' shapes but are shifted slightly in wavelength, so the equation 2.28 is expected to be a good transformation. However the different shapes of the Z and (interference) S filter, which shows a double peak, may cause some problems.

Convolving the 1990 measurements of filter set #1 and the Standard filter responses with stellar spectra (Gunn & Stryker 1983) to synthesize magnitudes, various transformations between the local and Standard systems were plotted. It was found that using $(Y-V)_0$ as the colour in equation 2.28, single-valued (but often non-linear) transformations were required — the zero subscript now indicates a measurement in the standard system. Using (standard) colours closer in wavelength to the magnitude (or colour) being transformed, for example $V-V_0 = a + b(Z-V)_0$, sometimes gave a multi-valued (and non-linear) transformation. The errors from assuming a linear transformation were $\sim 0.02^m$, which is approximately the same size as the uncertainties in the observations of real (rather than synthesized) standard stars and much less than the scatter in the (real) transformation diagrams (see Figure 2.15).

As the observations could not resolve between linear and non-linear transformations, nor between transformations using $(Y-V)_0$ or a 'closer' colour as an estimate of the derivative of E_s , the following linear transformations were used for all observations;

$$(Y-V)_0 = a_0 + a_1(Y-V)$$

Figure 2.14: Comparison of local and Standard Vilnius filter responses, normalised to 100% transmittance. The local filters are Set #1, measured in 1990, and the standard filters are from Straižys (1992).

3- 7-1993 observed vrs standard magnitudes

Figure 2.15: Transformation from the local to the Standard Vilnius System for 3 July 1993 for the V filter.

$$\begin{aligned} V-V_0 &= b_0 + b_1(Y-V)_0 \\ (U-P) - (U-P)_0 &= c_0 + c_1(Y-V)_0 \\ (P-X) - (P-X)_0 &= d_0 + d_1(Y-V)_0 \\ (X-Y) - (X-Y)_0 &= e_0 + e_1(Y-V)_0 \\ (Y-Z) - (Y-Z)_0 &= f_0 + f_1(Y-V)_0 \\ (Z-V) - (Z-V)_0 &= g_0 + g_1(Y-V)_0 \\ (V-S) - (V-S)_0 &= h_0 + h_1(Y-V)_0 \end{aligned} \tag{2.29}$$

On some nights, insufficient standards were observed to get an accurate transformation. For such nights, the possibility of using an average transformation determined from all the observations of standard stars over the entire observing run was investigated. It was found that the fitted coefficients for average transformations are of similar accuracy to the fitted coefficients for individual nights, i.e. the instrumental system is stable over the entire observing run. This means an average transformation may be used for nights with few standards — this was particularly useful for observations made during summer.

Figure 2.16: The airmass of O Vel at midnight of every night during 1993 at MJUO.

2.9 Planning an Observing Session.

To make optimum use of photometric conditions during an observing run, it is essential to decide on the observing programme beforehand. Some examples of this pre-planning are discussed below.

Program stars are in general best placed for observing at certain times of the year. An example using the O Vel cluster is shown in Figure 2.16 — this shows that O Vel cluster stars can be measured (at small airmass) after midnight during a December observing run, throughout the night from January to April, and before midnight (during the longer winter nights) until the beginning of June.

Similarly, the extinction and control stars need to be chosen to fulfill the conditions discussed in section 2.6 (page 2-19). The declination of the extinction and control stars can be chosen with the aid of Figure 2.17. This shows the relation (for MJUO) between the declination of the control and extinction stars and the Hour Angle (HA) of the control star, fixing the control star at two airmasses while the extinction star is at its minimum airmass (so its HA is zero).

For instance, bright stars such as the extinction and control stars can be observed to approximately halfway between twilight and sunrise (or sunset). In May 1993, this was approximately 13 hours which is also the required difference in HA between the extinction and control stars. This is clearly not practical in this case, so for longer winter nights two control stars would be

Figure 2.17: Choosing the Declination as a function of the control star's HA, when the control star is at two airmasses and the extinction star is at its minimum airmass (i.e. its HA is zero). This allows the stars to be picked to match the duration of the night, for example six hours in summer or two six hours segments in winter.

chosen by dividing the night into two segments. There are now three stars, labeled star_1 , star_2 , and star_3 in order of increasing RA. At the beginning of the night, star_1 is the extinction star and star_2 is the control star. Halfway through the night, star_1 is setting and star_2 is culminating while star_3 is rising so star_2 becomes the extinction star and star_3 the control.

By dividing the night in half, the required difference in HA between the three stars is now 6.5 hours, and $\text{Dec} \sim -25^\circ$. In practice, the extinction and control stars were chosen from the E region standard stars, with $\text{Dec} \sim -45^\circ$ and hence a difference in HA of approximately 8.5 hours — this has the advantages that near the middle of the night all three stars may be observed together (which gives a check on the extinction determinations) and that program stars (i.e. candidates for the Southern Vilnius Standard System) are being used to determine the extinction.

The RA of the extinction star (i.e. star_2 during winter), and hence of the control star(s), may be chosen from diagrams such as Figure 2.18. This shows that the E region standard star E6.047 was chosen as the extinction star for the May 1993 observing run as it has an airmass of ~ 2 at the beginning and end of astronomical twilight and is at its minimum airmass near the middle of the night (in addition to being non-variable etc.).

Finally, star charts need to be checked to ensure there is no possibility of confusion over finding the correct star. If there was another star of similar, or brighter, intensity within $\frac{1}{2}^\circ$

Figure 2.18: The airmass of the extinction star E6.047 at MJUO during 19 May 1993.

say, a finding chart was prepared (using the “starchart” program which reads the Hubble Space Telescope (HST) Guide Star Catalog from Compact Disk Read Only Memory (CDROM)’s). The orientation and scale of the chart should match the view seen through the finder telescope or the pre-diaphragm viewer on the main telescope so the charts are usually printed on transparencies with appropriate scale indications. An example (the finding chart for O Vel) can be seen in Figure 4.7.

2.10 Summary.

The observations for this study were made at Mount John University Observatory, in the South Island of New Zealand. The preferred system was the B&C 61 *cm* Cassegrain telescope using the VUW 9558B PMT in pulse counting mode and the Vilnius filter set #1. A brief background on the observation and reduction procedures for photoelectric photometry is given, together with a detailed description of the methods used in this study. These were all ‘standard’ methods, except for the extinction correction described next.

The (monochromatic) extinction correction used was Nikonov’s Method, which only assumes the extinction is uniform across the sky at the moment of measurement. This allows any changes in extinction during the night to be measured, unlike the more commonly used Bouguer’s

method which required the extinction to be uniform both across the sky and throughout the entire night. During the reductions it was found that apparent extinction variations during a night were common at MJUO— an investigation concluded that this effect is due to either time dependent drifting in the instrument's zero-point or time dependent changes in the extinction. Due to the particular observing program used, there were no detectable differences between the two possible causes of 'extinction' variations on the reduced measurements so the effect was assumed to be from the latter cause.

The final section of the chapter discusses planning for observing sessions, i.e. choosing which extinction, standard and program stars are to be observed depending on the time of year and time of night, together with preparation of finding charts.

Chapter 3

The Southern Vilnius Standard System.

An extensive set of standard stars was established around the North Celestial Pole (Černis et al. 1989), the Kapteyn areas (Černis & Jasevičius 1992), the Cygnus Standard Region (Zdanavičius et al. 1969, Zdanavičius & Cerniene 1985) and Aquila Standard Region (Zdanavičius et al. 1969). As none of these standard regions is south of the celestial equator it became necessary to establish first a set of southern standard stars before any observations in the southern hemisphere could be made. A set of stars that are observable from the southern hemisphere was selected from those previously measured in the Vilnius system (North 1980) to be used as 'primary standards'. The selection was made by accepting only stars brighter than $7^m.00$ and further south than declination $+10^\circ$. Initially any stars in the catalog which had Johnson V magnitudes rather than Vilnius V magnitudes was rejected. Similarly any known or suspected variable stars were also rejected. However these last two criteria had to be relaxed when it was found that they resulted in too few standard stars (especially during summer observations). The final list is given in appendix B.

As the so-called 'primary standards' are not in fact standard stars, the scatter in transformation diagrams (such as Figure 2.15 on page 2-35) was larger than normal and so required more stars to be observed than usual. In addition, as it is likely that measurements made here would be more accurate than the original observations in the northern system (as, in general, more observations per star were made) it was decided to include these stars as part of the Southern Vilnius Standard System.

3.1 Selection of Standard star candidates.

Lists of possible southern standard stars were prepared (see appendix B) which, if measured to sufficient precision and accuracy, will become 'secondary standards' of the Vilnius photometric system. However, the inaccurate transformations inherent in under-sampled filter systems (Young 1988) mean that a new photometric system (the Southern Vilnius System) will actually be established which is *on average* the same as the original system.

The candidate southern standard stars were selected in three groups; a South Polar Sequence (the 'SPS' standards), a group of bright stars spread across the southern sky (the 'all-sky' standards, or sometimes simply the 'secondary standards'), and a group of standard stars from other photometric systems (the 'E region' standards).

The South Polar Sequence (SPS) stars were selected using the Set of Identifications, Measurements and Bibliography for Astronomical Data (SIMBAD) database with the following search criterion; non-variable, $V \leq 7^m.00$, and $\delta \leq -80^\circ$. The advantage of a polar sequence over other standard star regions is that being circumpolar, the same set of stars may be observed at any time of the year, for example allowing long term instrumental (zero-point) drifts to be monitored. Further, polar sequence stars move through a smaller range in airmass, reducing the effects of inexact extinction corrections on transformations to the standard system. If establishing a *completely* new photometric system, such a sequence is essential and should be observed first, before the system can change (due to 'aging' of the filters, long-term drifts in the PMT etc.).

The bright, all-sky group of stars were also selected using SIMBAD with the search criterion being; non-variable, $V \leq 6^m.00$, and $-70^\circ \leq \delta \leq -30^\circ$ (although some stars were observed outside this declination range). Choosing stars spread in an approximately uniform manner across the sky ensures there will always be some standard stars near in the sky to any program star (for example as comparison and check stars of a variable star program). Similarly, there should always be some standard stars suitable as both standard and extinction stars for use in a variety of observing methods (see references given in section 2.6, page 2-19).

The final group of candidate standard stars is taken from a set of standard stars already established for the Johnson photometric system by Menzies et al. (1989). The group consists of nine E regions which contain approximately sixty stars each, ranging from $V = 3^m.0 \rightarrow 12^m.0$, centred near $\delta \approx -45^\circ$ and spaced 2-3 hours apart in RA. The initial program is to observe all bright stars ($V \leq 7$, say) from an E region and then move to progressively fainter stars in the region. In general, the stars denoted as variable, or with optical companions that may not be consistently included (or excluded, following Menzies's notes) in the photometer diaphragm, were not observed. The E region stars are also suitable for a variety of extinction and/or standardisation observing methods, in a complimentary manner to the all-sky group.

3.2 Error analysis.

An error analysis was performed, to check the reliability of the standard deviations (see section 2.1, page 2-1) as an indicator of the uncertainty in the data, and to check for any problems in the instrumental system. A list of all the observed stars is given in appendix C, while

the magnitudes and standard deviations of all the 'good' individual observations are given in appendix D — the definition of 'good' observations is given later on page 3-3.

Some other terms used in the analysis are explained below; The term 'internal errors' refers to the standard deviations of the extinction corrected observations, i.e. the observations are still in the local, or internal, photometric system. Similarly, after transforming to the standard ('external') system, the standard deviations are referred to as the 'external errors'. For the transformed primary standards, a third type of error can be calculated — the 'residual error'. This is the difference between the magnitudes (or colours) from the original (northern) system and the (transformed) local system.

A quick review of the terms 'precision' and 'accuracy' is also appropriate here. Precision refers to the number of significant figures in a measurement and is usually associated with the random error of a measurement, for example a measured V magnitude of $6^m.75$ may be known to a precision of $\pm 0^m.01$. Accuracy refers to how close the measured value is to the true value and is usually associated with systematic errors; in the example above, the accuracy would be $0^m.05$ if the true V magnitude was $6^m.70$. The internal errors are assumed to be predominately random errors, the external errors a mixture of random and systematic and the residuals predominately systematic errors.

First, correlations between the internal V errors and the other filters' errors were investigated. It was found that the other errors show slight to definite correlations with the V errors, hence the V errors could be taken as 'typical' and so further analysis will be described for the V filter only.

Plots of the internal errors against instrumental colour of the star, RA of the star, and the seasonal phase (of the year) of the observation showed no trends, and hence there are no indications of any instrumental problems. However, the errors do show a slight dependence on the airmass through which the observation was made (see Figure 2.4 on page 2-17). There was also a dependence of the errors on the instrumental magnitude of the star (see Figure 3.1). This was plotted from observations made between 1.0 to 1.4 airmasses, where the airmass dependence is small. Hence, the errors increase (as expected) with decreasing brightness and/or increasing airmass of the observations.

A histogram of the internal V errors (s_V) shows the main distribution is between $s_V = 0^m.00 \rightarrow 0^m.05$, followed by a small number of 'outliers' with $s_V > 0^m.05$. All the other filters were also found to have similar distributions with outliers from $0^m.05$, except for U (whose outliers occurred from $s_U > 0^m.09$). These outliers were considered 'bad' observations and rejected from the data set.

The catalogs in Appendix D list the 'good' individual observations of the stars — the individual observations of each star, rather than just the mean values, were included so later

Figure 3.1: Observational error as a function of instrumental magnitude at MJUO. The internal standard deviation of the V filter measurements are plotted against the instrumental magnitude of the observation.

observations may be added to the data set and new mean values calculated, and investigations of possible variability of any star may be made later.

Initially two consecutive observations of each star were made during a night. It was found that the internal errors also indicates the size of the difference between these consecutive observations, so some of the later measurements took advantage of this by making only one observation of each star during a night (except extinction stars, which were measured hourly).

It was hoped that the external errors would correlate with the residual errors of the primary standards, and so indicate how accurately the secondary standards were transformed to the northern Vilnius system. Unfortunately no significant correlation was found but the errors both vary over approximately the same range of values (for example most of the external V errors are found between $0^m.01 \rightarrow 0^m.05$ while the residuals are between $0^m.00 \rightarrow 0^m.06$).

A histogram of the V residuals (of the individual observations) is shown in Figure 3.2, together with a fitted exponential function¹

$$\text{frequency} = N \Delta x \frac{1}{\sigma e^{\bar{x}/\sigma}} e^{-|\frac{x-\bar{x}}{\sigma}|} = a e^{-\frac{|V_{\text{residual}}|}{b}}, \quad (3.1)$$

assuming the mean residual ($\bar{x}$) is zero. To improve the fit, two discrepant data bins were

¹The 'absolute value of the residuals' function was used, rather than the normal function, simply because it gave a better fit to the data.

distribution of residuals of primary Vilnius standards (indiv. obs.)

Figure 3.2: Histogram of residuals from all the 'good' observations of primary standard stars, together with a least squares fitted exponential curve.

rejected ($0.05 \leq |V_{\text{residual}}| < 0.06$, $0.13 \leq |V_{\text{residual}}| < 0.14$), removing 13 observations to leave a total of 471. The fitted terms (a and b) can be interpreted analogously to a normal distribution

$$\text{frequency} = N \Delta x \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2}\left(\frac{x-\bar{x}}{\sigma}\right)^2} \quad (3.2)$$

where N is the number of observations, x is a residual, with $\bar{x}$ and σ being the mean and standard deviation of the residuals. The mean residual was then shifted by the histogram bin width (Δx) to align the data with the fitted curve. The fitted term ($a = 247$) then gives $N = 436$, which agrees reasonably well with the actual number of observations (471). The b factor ($= 0.025$) should be close to the standard deviation of the residuals, which for the full 484 observations is 0.022.

Next the average value for each primary standard star from the individual observations was calculated and the residuals plotted against the number of observations (N) made of each star — see Figure 3.3. The lower curve drawn in the histogram shows the expected $N^{-1/2}$ dependence of the average residual — recall this is 0.025 for a single (average) observation. The upper curve is the expected standard deviation of the residual added to the lower curve. This is calculated assuming a Poisson distribution for observations of a star, with the standard deviation being $\sqrt{0.025} \approx 0.16$. The number in the exponential decay term is $1/\langle N \rangle$ ($= 1/4.7 \approx 0.21$), where $\langle N \rangle$ is the average number of observations per star.

Figure 3.3: Histogram of residuals of the primary standard stars (averaged) observations.

The horizontal line indicates the desired $0^m.01$ accuracy and precision — the lower curve shows six observations of each star are required to reduce the random errors (in the observations and transformations) so that the average residual is $\sim 0^m.01$. The upper curve indicates that up to 18 observations per star might be required to reduce the random (transformation) errors so all 'good' standard stars are measured to better than $0^m.01$ accuracy. Conversely, any star above the upper curve would be a 'bad' standard star; it may not transform correctly with the simple (linear) transformations used here, the value in the standard system may be inaccurate, the star may be variable, or (for $N < 6$, say) not enough observations have been made of the star (in the local system). However, the upper curve should only be used as a guide, especially the 18 observations per star requirement, as very few stars have had a large number of observations made. Note that if the precision and accuracy goal is relaxed to $0^m.02$, the number of observations per star becomes 1.5 and 12 respectively.

The overall precision and accuracy of the observations can be gauged from the standard deviations shown in Table 3.1. The internal errors show that $0^m.01 \leftrightarrow 0^m.02$ precision is being achieved in the local system, and the errors increase by less than a factor of two when being transformed to the standard system. The standard deviations were also calculated separately for the primary standard stars and the three groups of secondary standard stars. However the results for the SPS stars are probably not reliable due to the small number of observations made.

The internal errors of each group of stars generally decrease as the average airmass through

Table 3.1: Standard deviations from all the (N) individual observations, calculated for the internal, external and (primary standard stars) residual errors. The observations are also split into the three secondary standard groups and primary standards discussed in the text.

observations	N	errors	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
SPS standards	33	internal	0.013	0.010	0.011	0.011	0.013	0.012	0.008
		external	0.048	0.030	0.023	0.021	0.018	0.014	0.015
all-sky standards	681	internal	0.023	0.020	0.012	0.012	0.014	0.016	0.012
		external	0.045	0.037	0.027	0.023	0.022	0.022	0.023
E region standards	764	internal	0.017	0.018	0.010	0.009	0.009	0.009	0.011
		external	0.027	0.030	0.017	0.014	0.015	0.013	0.017
primary standards	484	internal	0.020	0.023	0.015	0.013	0.014	0.015	0.012
		external	0.032	0.034	0.023	0.020	0.020	0.019	0.021
		residuals	0.022	0.022	0.015	0.012	0.012	0.011	0.016
all observations	1962	internal	0.020	0.020	0.012	0.011	0.012	0.013	0.012
		external	0.035	0.034	0.022	0.019	0.019	0.018	0.020

which they were observed decreases (in decreasing order; primary standards, all-sky, E region secondary standards). The consistently larger U-P error is probably due to the integration time for the U filter being too short (despite already being twice as long as the other filters) — it is recommended that the U filter integration time be 3-4 times longer than the other filters (i.e. 15-20 *seconds* for bright stars). The V magnitude error is also consistently larger than the colours — this is probably because reducing the data as a colour removes to first order any instrumental drifts and/or any extinction variations having a large ‘grey’ component.

The external errors do not show the same trends between the groups of stars as seen in the internal errors. The airmass dependence is probably responsible for the primary standards’ errors being larger than the E region standards. However the all-sky standards were (unfortunately) almost exclusively observed during the period immediately following the Mount Pinatubo eruption, unlike the other groups of standards (which were observed both before and during the eruption and after it’s effects had started to decrease). This probably accounts for the larger standard deviations of the all-sky standards, and is more clearly seen by plotting the mean internal error of each photometric night against the Julian Date — this shows the mean errors significantly increase after the eruption’s aerosol clouds arrived over MJUO, which is due to the increased variation in the atmospheric extinction (see Appendix G).

The sum (of the squares) of the primary standard stars’ internal and residual errors show a good correlation with the external errors, while slightly under-estimating them. Therefore it was concluded that the external errors give an excellent estimate of the average precision and accuracy of the observations of the Southern Vilnius System.

3.3 Selection of the Standard stars.

Using the 'good' observations discussed earlier, the weighted mean and standard deviation of the mean was calculated for each candidate southern standard star. To select those stars that have been measured to sufficient precision and accuracy to become standards, the following criteria were applied;

- for the (northern) primary 'standards', the star must not be a known or suspected variable (the secondary standards have already been checked for this).
- more than N observations have been made of a star.
- the standard deviation of the mean value for a star must be less than some cut-off value for each filter.
- the star's spectral classification based on its mean Vilnius colours agrees within two sub-classes of the spectral type given in the literature and within one luminosity class.

Setting the required number of observations per star (N) to six (to achieve an average accuracy of $0^m.01$, as shown in Figure 3.3) results in very few stars being accepted as standards. For this reason, it was relaxed to $0^m.02$, which meant two observations of a star should be sufficient — in fact N was set to three so the standard deviation (of the mean) of each star could be calculated.

For the E region stars, the required standard deviation cut-off was set to $0^m.02$ (except for U-P, which was relaxed slightly to $0^m.025$). To achieve a reasonable number of stars acceptable as standards in the remaining groups of stars (primary standards, all-sky and SPS secondary standard candidates), which were generally measured through a larger airmass, the error cut-offs were increased to $0^m.04$ for the V magnitude and $0^m.03$ for the colours. Both the Vilnius 'Q-Search' and 'Q-Spectra' classification methods were used to derive the star's spectral type, with a star being acceptable if successfully matched by both methods. A star was considered marginally acceptable if matched by one method, and nearly matched by the other — this will allow for any shortcomings in the reference lists used by each method. The resulting lists of standard stars for the Southern Vilnius System are given in Appendix E. As the majority of unacceptable stars were rejected due to an insufficient number of observations, these were also included (in separate tables) at the back of the appendix for the benefit of later observers continuing to develop the Southern Vilnius System.

The overall accuracy and precision of the standard stars (rather than that of an individual observation) may be estimated from

$$\varepsilon = \frac{\sigma}{\sqrt{\frac{\sum n_i}{N}}} \quad (3.3)$$

Table 3.2: Error estimates of the Southern Vilnius system standard stars. The observations are also split into the two secondary standard groups and primary standards discussed in the text.

stars	$\sum n_i$	N	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
primary standards	338	49	0.012	0.013	0.009	0.008	0.008	0.007	0.008
all-sky standards	677	31	0.010	0.008	0.006	0.005	0.005	0.005	0.005
E region standards	764	60	0.008	0.008	0.005	0.004	0.004	0.004	0.005
all standard stars	1779	140	0.010	0.010	0.006	0.005	0.005	0.005	0.006

where σ is the standard deviation of a single observation (taken from the external errors in Table 3.1), n_i is the number of observations of the i^{th} star and N is the total number of stars measured. The results are given in Table 3.2, and were also calculated separately for the primary standard stars and two groups of secondary standard stars (none of the SPS stars was accepted as standards, due to small number of observations per star).

3.4 Derivation of the Southern Vilnius System's Passbands.

Following the general method described by Bessell (1990), it was intended to derive the passbands of the Southern Vilnius System (relative to the passbands of the Northern Vilnius system).

First all the stars in the Northern Vilnius Catalog (North 1980) that are also in the Gunn & Stryker (1983) catalog of stellar spectra were collated, giving a data set of 39 stars. As the Vilnius colours are not dereddened but the G-S spectra are (assuming a particular reddening law), the spectra were restored to their original reddened state. Convolution of the spectra ($S(\lambda)$) with the standard passbands of the Northern Vilnius system (Straizys & Zdanavičius 1970) gives synthesized colours

$$\text{Col}_{AB} = \frac{\int_{\lambda_1}^{\lambda_2} S(\lambda) R_A d\lambda}{\int_{\lambda_3}^{\lambda_4} S(\lambda) R_B d\lambda} \quad (3.4)$$

where R_A , R_B are the passbands of the particular Vilnius colour. The G-S spectra have been normalised at the effective wavelength of the Johnson V filter — unfortunately the original intensity at that wavelength was not recorded in the catalog so only colours, but not magnitudes, may be synthesized.

These synthesized colours were then compared with the measured colours. For each colour, all the spectra were multiplied by a polynomial whose coefficients were adjusted until the synthesized colours matched the actual colours. In all cases, a polynomial to first order ($f(\lambda) = a_0 + a_1\lambda$) was sufficient.

Next all G-S stars that have also been measured in the Southern Vilnius system were collated. Using the same polynomial found for the northern system, the adjusted spectra were convolved

with the southern system passbands and the synthesized colours compared with the measured colours. The filter passbands would then be adjusted so that the synthesized colours match the actual colours, using the northern passbands as the initial guess. Unfortunately only 5 stars were found to be common to the G-S catalog and the Southern Vilnius system, which was insufficient to see if there was any difference between the northern and southern passbands.

3.5 Transformations to the Johnson System.

To gauge the accuracy of transforming measurements in the Vilnius system to the Johnson system, Vilnius standard passbands were ‘added’ together in various linear combinations to match each Johnson filter (using the standard passbands given by Straižys (1992)). The best combinations (in the least squares sense) were found to be;

$$\begin{aligned} U_j &= a_1 U_v + a_2 P_v + a_3 X_v \\ B_j &= a_1 P_v + a_2 X_v + a_3 Y_v + a_4 Z_v + a_5 V_v \\ V_j &= a_1 Z_v + a_2 V_v + a_3 S_v \end{aligned} \tag{3.5}$$

with the ‘j’ and ‘v’ subscripts indicating Johnson or Vilnius filters respectively. The actual value of the coefficients a_1 etc. is irrelevant; what is important is how well the best linear combination matches the shape of the corresponding Johnson passband, which can be seen in Figure 3.4.

The Johnson U filter is closely duplicated by the combination of Vilnius filters given above and so accurate transformations (using the same transformation coefficients) should be possible for any star. However the Johnson B and V filters are poorly matched, so separate transformations will be needed for different subsets of stars, for example late type stars have an absorption feature at $\sim 6000\text{\AA}$ which is not measured by the Vilnius combination and hence will not have the same transformation as early type stars (which do not have this feature).

Some actual transformations between the Vilnius and Johnson systems may be found from the E region’s observations,² with the Johnson magnitudes and colours taken from Menzies et al. (1989). Transformations using fluxes (Young 1994) were made in addition to those using magnitudes but gave no improvement in the precision of the least squares fits and so are not presented here. Several transformations to each Johnson colour are included for two reasons; first, the stars may have only been measured using a subset of the Vilnius filter set (for example Banks et al. (1994) CCD photometry), and secondly, if all the transformations give

²E3.087 produced a data point lying a significant ‘distance’ from the relations found in all the following transformations. This is due to it’s companion star being included in Menzies et al. (1989) measurements of the star but not in the Vilnius observations, and so E3.087 was excluded from the transformations.

Figure 3.4: Least squared fitted linear combination of Vilnius filters to match the Johnson filters.

(approximately) the same Johnson colour then the transformations can be considered correct for that particular star.

The first transformation is between the Vilnius and Johnson V magnitudes;³

$$V_j = a_0 + a_1 V_v \quad \left\{ \begin{array}{ll} a_0 = -0.029 \pm 0.028 \\ a_1 = +0.999 \pm 0.004 & R = 0.9994 \\ \sigma = 0.029 & R = 0.9994 \end{array} \right. \quad (3.6)$$

where R are the linear correlation coefficients for each independent variable and σ is the standard deviation of the residuals between the actual and transformed Johnson V magnitudes (the R next to this is the overall correlation coefficient for the fit). This linear transformation is included so transformations may be made in either direction, i.e. from or to the Johnson system. This shows close agreement with the zero-point difference (-0.03 ± 0.02) found by Dzervitis & Paupers (1994).

³All the coefficients (a_0 etc.) are given to *milli-magnitudes* regardless of the size of the associated standard deviation. This is because the large linear correlation coefficients indicate the standard deviations probably over-estimate the actual uncertainties, due to the correlations between the coefficients.

Transformation between Johnson and Vilnius systems for the E Regions

Figure 3.5: Transformations between Vilnius and Johnson V magnitudes, based on E region stars measurements.

The next transformation between the V magnitudes requires the Johnson B-V colour

$$V_v - V_j = a_0 + a_1(B-V)_j \quad \left\{ \begin{array}{ll} a_0 = +0.030 \pm 0.005 \\ a_1 = +0.014 \pm 0.007 & R = 0.228 \\ \sigma = 0.028 & R = 0.228 \end{array} \right. \quad (3.7)$$

and is shown in Figure 3.5. This can be compared with Sviderskienė & Straižys (1970) 'theoretical' transformation ($a_0 \equiv 0, a_1 = 0.01$) which is based on synthesized magnitudes and colours. The difference in zero-points is probably due to the 'standard' passbands used to synthesize the Johnson magnitudes not corresponding exactly to the actual passbands (for instance, see (Bessell 1990) and (Menzies et al. 1991)), and so not reproducing what appears to be a genuine difference (of 0.03) between the Johnson and Vilnius V magnitudes. The colour terms show good agreement (differing by only 0.004) and so the E region measurements confirm the theoretical V transformation.

According to Sviderskienė & Straižys (1970), interstellar extinction (reddening) moves a star's position in the transformation diagram (Figure 3.5) to the right approximately parallel to the data line, except for late-type stars. Most of the other Vilnius-Johnson transformations (see later Figures 3.6 etc.) also have reddening lines nearly parallel to the intrinsic sequence(s). A histogram of the E_{Y-V} colour excesses (calculated from $E_{Y-V} = (Y-V)_0 - Y-V$ and 'looking up' it's intrinsic $(Y-V)_0$ colour from Tables J.7 and J.8, given the star's spectral classification)

shows some of the stars have significant reddening ($E_{Y-V} \sim 0.5 - 1.0$). However there is no strong correlation between the amount of reddening and the star's deviation from the intrinsic sequence, confirming the reddening lines do run nearly parallel to the intrinsic sequences.

An alternative transformation using the Vilnius Y-V colour is

$$V_v - V_j = a_0 + a_1(Y-V)_v \quad \left\{ \begin{array}{ll} a_0 = +0.026 \pm 0.007 \\ a_1 = +0.023 \pm 0.013 & R = 0.224 \\ \sigma = 0.029 & R = 0.224 \end{array} \right. \quad (3.8)$$

The final V transformation is

$$V_j = a_0 + a_1 V_v + a_2 Z_v + a_3 S_v \quad \left\{ \begin{array}{ll} a_0 = -0.002 \pm 0.003 \\ a_1 = +0.436 \pm 0.3 & R = 0.9994 \\ a_2 = +0.369 \pm 0.2 & R = 0.9882 \\ a_3 = +0.192 \pm 0.1 & R = 0.9573 \\ \sigma = 0.028 & R = 0.9995 \end{array} \right. \quad (3.9)$$

Sviderskienė & Straižys (1970) found that relations between Vilnius colours and Johnson U-B were non-linear, with strong luminosity effects and reddening lines non-parallel to the intrinsic sequence, and generally not suitable for transformations. The best relation was between the Vilnius U-Y and Johnson U-B, as can be seen in Figure 3.6 and the following piece-wise equation

$$(U-B)_j = a_0 + a_1(U-Y)_v \quad \left\{ \begin{array}{ll} U-B < 0.5 & \left\{ \begin{array}{ll} a_0 = -1.089 \pm 0.02 \\ a_1 = +0.632 \pm 0.01 & R = 0.998 \\ \sigma = 0.017 & R = 0.998 \end{array} \right. \\ U-B > 0.5 & \left\{ \begin{array}{ll} a_0 = -1.353 \pm 0.05 \\ a_1 = +0.765 \pm 0.02 & R = 0.999 \\ \sigma = 0.011 & R = 0.999 \end{array} \right. \end{array} \right. \quad (3.10)$$

Sviderskienė & Straižys (1970) do not give any equations for the (U-Y) — (U-B) relations but their plotted data agrees well with Figure 3.6.

Figure 3.6: Transformations between Vilnius U-Y and Johnson U-B colours, based on E region stars measurements.

Another relation with the U-B colour was found

$$(U-B)_j = a_0 + a_1(P-X)_v + a_2(X-Y)_v + a_3(Y-Z)_v \quad \begin{cases} a_0 = -1.101 \pm 0.01 \\ a_1 = +1.152 \pm 0.02 \quad R = 0.9469 \\ a_2 = +0.582 \pm 0.04 \quad R = 0.9632 \\ a_3 = +0.188 \pm 0.09 \quad R = 0.9203 \\ \sigma = 0.020 \quad R = 0.9994 \end{cases} \quad (3.11)$$

using the E region measurements.

The following piece-wise transformation was found between the Vilnius X-V and the Johnson B-V colour

$$(B-V)_j = a_0 + a_1(X-V)_v \quad \begin{cases} B-V < 0.8 \quad \begin{cases} a_0 = -0.329 \pm 0.007 \\ a_1 = +0.708 \pm 0.009 \quad R = 0.999 \\ \sigma = 0.011 \quad R = 0.999 \end{cases} \\ B-V > 0.8 \quad \begin{cases} a_0 = +0.05 \pm 0.03 \\ a_1 = +0.48 \pm 0.02 \quad R = 0.999 \\ \sigma = 0.008 \quad R = 0.999 \end{cases} \end{cases} \quad (3.12)$$

and is also plotted in Figure 3.7 for comparison with Sviderskienė & Straižys (1970) graph. Similarly, a nearly linear transformation between Vilnius Y-V and Johnson B-V was compared,

$$(B-V)_j = a_0 + a_1(Y-V)_v \quad \begin{cases} a_0 = -0.312 \pm 0.004 \\ a_1 = +1.708 \pm 0.007 \quad R = 0.9992 \\ \sigma = 0.020 \quad R = 0.9992 \end{cases} \quad (3.13)$$

confirming the theoretical relations. Both these relations have reddening lines nearly parallel to the intrinsic sequences and small luminosity effects (being largest at $B-V \gtrsim 1.0$).

Sviderskienė & Straižys (1970) give $B-V = -0.33 + 0.50[(X-V) + (Y-V)]$ for $B-V \leq 0.80$ as the best relation between the Vilnius system and Johnson $B-V$. The E region measurements confirm this relation;

$$(B-V)_j = a_0 + a_1[(X-V) + (Y-V)]_v \quad \left\{ \begin{array}{ll} B-V < 0.8 & \left\{ \begin{array}{ll} a_0 = -0.322 \pm 0.007 \\ a_1 = +0.498 \pm 0.006 & R = 0.999 \\ \sigma = 0.009 & R = 0.999 \end{array} \right. \\ B-V > 0.8 & \left\{ \begin{array}{ll} a_0 = -0.009 \pm 0.04 \\ a_1 = +0.366 \pm 0.01 & R = 0.999 \\ \sigma = 0.007 & R = 0.999 \end{array} \right. \end{array} \right. \quad (3.14)$$

and extend it piece-wise for $B-V > 0.80$.

Finally, a new transformation to Johnson $B-V$ was found

$$(B-V)_j = a_0 + a_1(X-Y)_v + a_2(Y-Z)_v + a_3(Z-V)_v + a_4(V-S)_v \quad \left\{ \begin{array}{ll} a_0 = -0.314 \pm 0.005 \\ a_1 = +0.304 \pm 0.05 & R = 0.9923 \\ a_2 = +1.410 \pm 0.1 & R = 0.9962 \\ a_3 = +0.342 \pm 0.2 & R = 0.9928 \\ a_4 = +0.252 \pm 0.1 & R = 0.9950 \\ \sigma = 0.015 & R = 0.9996 \end{array} \right. \quad (3.15)$$

Although the Vilnius filters do not cover the same wavelength range as the extended Johnson filter system (R, I, J, K, L, M, M, and Q), Menzies et al. (1989) E region measurements include $V-R$ and $V-I$ colours, which are based on Cousins version of the R and I filters. The Vilnius $V-S$ colour gives good transformations to both $V-R$ and $V-I$, as shown by the following equations and Figures 3.8 and 3.9.

$$(V-R)_j = a_0 + a_1(V-S)_v \quad \left\{ \begin{array}{ll} a_0 = -0.133 \pm 0.003 \\ a_1 = +0.898 \pm 0.06 & R = 0.9987 \\ \sigma = 0.012 & R = 0.9987 \end{array} \right. \quad (3.16)$$

Figure 3.7: Transformations between Vilnius colours and Johnson B-V, based on E region stars measurements.

Transformation between Johnson and Vilnius systems for the E Regions

Figure 3.8: Transformations between Vilnius V-S and Johnson V-R, based on E region stars measurements.

$$(V-I)_j = a_0 + a_1(V-S)_v \quad \left\{ \begin{array}{ll} a_0 = -0.255 \pm 0.007 \\ a_1 = +1.720 \pm 0.01 & R = 0.9978 \\ \sigma = 0.031 & R = 0.9978 \end{array} \right. \quad (3.17)$$

It was found that adding progressively bluer colour terms (i.e. Z-V, then Z-V and Y-Z etc.) to V-S improved the transformations (except for U-P). Only the equations for the most precise transformations (using all the colours P-X to V-S) are given below;

$$(V-R)_j = a_0 + a_1(P-X)_v + a_2(X-Y)_v + a_3(Y-Z)_v + a_4(Z-V)_v + a_5(V-S)_v \quad \left\{ \begin{array}{ll} a_0 = -0.150 \pm 0.005 \\ a_1 = +0.034 \pm 0.1 & R = 0.7625 \\ a_2 = -0.089 \pm 0.02 & R = 0.9855 \\ a_3 = +0.311 \pm 0.07 & R = 0.9940 \\ a_4 = +0.726 \pm 0.1 & R = 0.9937 \\ a_5 = +0.523 \pm 0.06 & R = 0.9987 \\ \sigma = 0.007 & R = 0.9996 \end{array} \right. \quad (3.18)$$

Transformation between Johnson and Vilnius systems for the E Regions

Figure 3.9: Transformations between Vilnius V-S and Johnson V-I, based on E region stars measurements.

$$\begin{aligned}
 (V-I)_j &= a_0 + a_1(P-X)_v + a_2(X-Y)_v \\
 &\quad + a_3(Y-Z)_v + a_4(Z-V)_v \\
 &\quad + a_5(V-S)_v
 \end{aligned}
 \left\{ \begin{array}{ll}
 a_0 = -0.336 \pm 0.02 \\
 a_1 = +0.142 \pm 0.03 & R = 0.7604 \\
 a_2 = -0.438 \pm 0.07 & R = 0.9811 \\
 a_3 = +0.968 \pm 0.2 & R = 0.9938 \\
 a_4 = +1.808 \pm 0.4 & R = 0.9909 \\
 a_5 = +1.018 \pm 0.2 & R = 0.9978 \\
 \sigma = 0.021 & R = 0.9991
 \end{array} \right. \quad (3.19)$$

In all the colour transformation diagrams (Figures 3.6, 3.7, 3.8, and 3.9), a 'gap' in the sequence of data points can be seen (at $U-B \sim 0.5$, $B-V \sim 0.8$, $V-R \sim 0.4$, and $V-I \sim 0.8$). This same gap can be seen in Sviderskienė & Straižys (1970) diagrams as a reduced density of data points and is due to the following selection and luminosity effects. Consider the $(Y-V) - (B-V)$ relation in Figure 3.7 as an example. The early type stars ($B-V < 0.8$) are predominately main-sequence stars, but the late type stars are exclusively brighter luminosity classes (I-III). This is because late type main-sequence stars are intrinsically fainter than early type main-sequence stars (at the effective wavelength of the V filter) and so have not yet been observed from the E region star lists (the selection effect). For early type stars, $B-V$ is approximately independent of luminosity class but for later type stars ($\sim G$ class onwards), $B-V$ increases with

Figure 3.10: Least squared fitted linear combination of Vilnius filters to match the Strömrgren filters.

luminosity for a given spectral class. However $Y-V$ is approximately independent of luminosity for all spectral classes (except M, which wasn't observed here). Hence the selection effect (which meant no main-sequence stars later than G4 were observed) combined with the luminosity effect (which starts at $\sim G$ class) produces the gap in the diagrams.

3.6 Transformations to the Strömrgren System.

Transformations from the Vilnius to the Strömrgren systems were also investigated. As for the Johnson filters, Vilnius standard passbands were added in linear combinations to match each Strömrgren filter. The best combinations were;

$$\begin{aligned}
 u &= a_1 U \\
 v &= a_1 X \\
 b &= a_1 Y + a_2 Z \\
 y &= a_1 Z + a_2 V
 \end{aligned}
 \tag{3.20}$$

with lower-case or upper-case indicating Strömrgren or Vilnius filters respectively — see also Figure 3.10.

The Strömrgren u filter is closely matched by the Vilnius U filter, apart from the short

wavelength tail. However the atmospheric extinction is large at these wavelengths and so the difference between the filters should have negligible effect. The remaining Strömgren filters are reasonably well matched by the Vilnius filter combinations, however in general the fitted filter has a shorter effective wavelength than the standard filter.

The Strömgren y filter has nearly the same effective wavelength as the Vilnius V filter so a simple linear fit between the two magnitudes should give good results;

$$y = a_0 + a_1 V \quad \left\{ \begin{array}{ll} a_0 = -0.061 \pm 0.04 \\ a_1 = +1.001 \pm 0.07 & R = 0.9990 \\ \sigma = 0.034 & R = 0.9990 \end{array} \right. \quad (3.21)$$

A slight colour term remains, which is fit to approximately the same precision by the following colours;

$$V-y = a_0 + a_1(\text{Col}) \quad \left\{ \begin{array}{lllll} \text{Col} & a_0 & a_1 & \sigma & R \\ \text{X-Y} & 0.023 \pm 0.007 & 0.043 \pm 0.009 & 0.027 & 0.608 \\ \text{Y-Z} & 0.017 \pm 0.007 & 0.133 \pm 0.02 & 0.027 & 0.624 \\ \text{Z-V} & 0.024 \pm 0.007 & 0.164 \pm 0.03 & 0.028 & 0.591 \\ \text{V-S} & 0.020 \pm 0.007 & 0.078 \pm 0.02 & 0.027 & 0.611 \\ v-b & 0.028 \pm 0.006 & 0.046 \pm 0.009 & 0.027 & 0.596 \\ b-y & 0.033 \pm 0.005 & 0.073 \pm 0.01 & 0.027 & 0.613 \end{array} \right. \quad (3.22)$$

The best fit is with the Y-Z colour, which is shown in Figure 3.11.

All the 'usual' Vilnius colours give non-linear and multi-valued transformations to the Strömgren $u-b$ colour. However, on the basis of the linear combinations of filters, the U-Y colour is expected to give a good fit. As Figure 3.12 shows, the transformation is linear and single-valued, with the following coefficients;

$$u-b = a_0 + a_1(\text{U-Y}) \quad \left\{ \begin{array}{ll} a_0 = -0.293 \pm 0.007 \\ a_1 = +0.968 \pm 0.004 & R = 0.9997 \\ \sigma = 0.018 & R = 0.9997 \end{array} \right. \quad (3.23)$$

The reddening line for this, and all the following colour transformations, lie nearly parallel to the intrinsic sequence and hence the transformations should be nearly independent of the reddening.

Transformation between Stromgren and Vilnius systems for the E Regions

Figure 3.11: Transformations between the Vilnius and Strömrgren magnitudes, based on E region stars measurements.

Transformation between Stromgren and Vilnius systems for the E Regions

Figure 3.12: Transformations between the Vilnius U-Y and Strömrgren $u-b$ colours, based on E region stars measurements.

As with the y magnitude, a slight improvement is made by the addition of the Z filter;

$$u-b = a_0 + a_1(U-Y) + a_2(Y-Z) \quad \left\{ \begin{array}{ll} a_0 = -0.308 \pm 0.008 \\ a_1 = +0.996 \pm 0.008 & R = 0.9997 \\ a_2 = -0.148 \pm 0.04 & R = 0.9143 \\ \sigma = 0.016 & R = 0.9998 \end{array} \right. \quad (3.24)$$

or the Strömberg $b-y$ colour

$$u-b = a_0 + a_1(U-Y) + a_2(b-y) \quad \left\{ \begin{array}{ll} a_0 = -0.327 \pm 0.01 \\ a_1 = +0.997 \pm 0.009 & R = 0.9997 \\ a_2 = -0.086 \pm 0.02 & R = 0.9216 \\ \sigma = 0.016 & R = 0.9998 \end{array} \right. \quad (3.25)$$

Straižys (1973 a) gives a similar transformation

$$(u-b) - (U-Y) = 0.024(b-y)_0 + cE_{b-y} \quad (3.26)$$

where $c \approx 0.005$ for early stars, increases to $c \approx 0.016$ for F0 I stars and decreases to $c \approx 0.0$ for late type stars. As most of the E region stars have little reddening, only a crude check of Straižys' transformation could be made using $b-y \approx (b-y)_0$

$$(u-b) - (U-Y) = a_0 + a_1(b-y) \quad \left\{ \begin{array}{ll} a_0 = -0.330 \pm 0.003 \\ a_1 = -0.093 \pm 0.008 & R = -0.850 \\ \sigma = 0.016 & R = -0.850 \end{array} \right. \quad (3.27)$$

which shows little agreement.

Again on the basis of the linear combinations of the filters, the Vilnius X-Y colour is expected to give a good transformation to $v-b$. However, according to Straižys (1973 a), this transformation is expected to be non-linear and multi-valued for stars of different luminosity and reddening. This is due to the position of the v and X passbands — for example early type stars have a strong H_δ absorption line near the effective wavelength of the v filter but on the edge of the X filter. Nevertheless, the $(v-b) - (X-Y)$ transformation based on the E region stars is approximately linear, with small 'oscillations' about the line (see Figure 3.13) and the following coefficients

$$v-b = a_0 + a_1(X-Y) \quad \left\{ \begin{array}{ll} a_0 = -0.113 \pm 0.004 \\ a_1 = +0.917 \pm 0.005 & R = 0.9992 \\ \sigma = 0.017 & R = 0.9992 \end{array} \right. \quad (3.28)$$

Transformation between Stromgren and Vilnius systems for the E Regions

Figure 3.13: Transformations between the Vilnius X-Y and Strömgren $v-b$ colours, based on E region stars measurements.

Slight improvements to the precision of the fit are possible using an additional colour;

$$v-b = a_0 + a_1(X-Y) + a_2(Y-Z) \quad \left\{ \begin{array}{ll} a_0 = -0.101 \pm 0.004 \\ a_1 = +1.020 \pm 0.02 & R = 0.9992 \\ a_2 = -0.316 \pm 0.06 & R = 0.9733 \\ \sigma = 0.014 & R = 0.9995 \end{array} \right. \quad (3.29)$$

or

$$v-b = a_0 + a_1(X-Y) + a_2(b-y) \quad \left\{ \begin{array}{ll} a_0 = -0.145 \pm 0.007 \\ a_1 = +1.058 \pm 0.03 & R = 0.9992 \\ a_2 = -0.240 \pm 0.05 & R = 0.9840 \\ \sigma = 0.014 & R = 0.9995 \end{array} \right. \quad (3.30)$$

The final Strömgren colour, $b-y$, is best fitted by the Vilnius Y-V colour, as implied by the linear combination of filters. This is shown in Figure 3.14 and the following equation

$$b-y = a_0 + a_1(Y-V) \quad \left\{ \begin{array}{ll} a_0 = -0.170 \pm 0.002 \\ a_1 = +1.014 \pm 0.004 & R = 0.9995 \\ \sigma = 0.009 & R = 0.9995 \end{array} \right. \quad (3.31)$$

Transformation between Stromgren and Vilnius systems for the E Regions

Figure 3.14: Transformations between the Vilnius Y-V and Strömgren $b-y$ colours, based on E region stars measurements.

A slight improvement may be made by the addition of the Z filter

$$b-y = a_0 + a_1(Y-V) + a_2(Z-V) \quad \left\{ \begin{array}{ll} a_0 = -0.173 \pm 0.003 & \\ a_1 = +1.080 \pm 0.04 & R = 0.9995 \\ a_2 = -0.152 \pm 0.1 & R = 0.9928 \\ \sigma = 0.009 & R = 0.9996 \end{array} \right. \quad (3.32)$$

or the Strömgren $b-y$ colour (with the equation in the form used by Straižys)

$$(b-y) - (Y-V) = a_0 + a_1(b-y) \quad \left\{ \begin{array}{ll} a_0 = -0.168 \pm 0.002 & \\ a_1 = +0.014 \pm 0.005 & R = 0.429 \\ \sigma = 0.009 & R = 0.429 \end{array} \right. \quad (3.33)$$

where Straižys (1973 a) gives $a_0 \equiv 0$ and $a_1 = 0.021$ or later $a_0 = -0.16$ and $a_1 = 0.01$ (Straižys 1992), with the latter agreeing well with the results from the E region measurements.

3.7 Summary.

At the time this study started there were no Vilnius standard star regions observable from MJUO, so one had to be established before any research using the Vilnius system could be

started. As the stars (from the Vilnius catalog) used to tie the new standards back to the original system were not themselves standards, there was a larger than average scatter in the transformation diagrams, so requiring more stars to be observed than usual. Note that due to under-sampling of the wavelength region measured by the Vilnius filters, the southern standards will actually form a new (Southern) Vilnius system, which on average equals the northern system.

The southern standards were divided into three groups; the South Polar Sequence (SPS), the all-sky group and the E Regions. The SPS is a set of bright, circumpolar stars chosen so seasonal effects (for example due to changes in the average temperature between summer and winter) may be eliminated. The all-sky set of stars consists of bright stars evenly scattered around the sky so an observer should always be able to find a standard near any program star or for use as extinction stars. The E regions extend to a fainter magnitude range than the other standard sets, and are spaced in approximately two hour intervals in Right Ascension and centred about -45° in declination. These stars are already used as standard stars in the Johnson and Strömberg systems so are so less likely to include variable stars.

An error analysis was carried out on the observations of the proposed standard stars. A comparison between the different filters revealed that the V errors were typical of the other filters, so further analysis was done only on the V measurements. The only trends found in the internal errors (i.e. before transforming to the standard system) are with the airmass of the observation and brightness of the star (which are to be expected) so there were no signs of instrumental problems. Outliers ($s_v > 0.05$) from main distribution of internal errors were considered 'bad' observations and rejected. Similar thresholds were found for the other filters.

The original intention was to achieve 0.01^m accuracy and precision in the new standard system. However the accuracy and precision achieved was significantly affected by the Mount Pinatubo eruption, which increased the mean value and scatter of the extinction, so it was necessary to relax the precision and accuracy goal slightly to 0.02^m . For instance, based on the residuals (differences between the measurements of stars observed in both the southern and northern systems), it was found that for 50% of the measured stars to meet the original 0.01^m goal requires six observations per star, while eighteen observations per star are needed for 99% of the stars. The revised 0.02^m goal shifts these to 1.5 and 12 observations per star, while the actual average number of observations per star is 4.7.

Another measure of the precision of the observations are the standard deviations of the external (i.e. after transformation to the standard system) measurements. All filters, except V (0.035^m) and U-P (0.034^m), had a standard deviation of approximately 0.020^m . Thus it is recommended that the integration times for U filter be increased to 3-4 times longer than the other filters (it is already twice that of the other filters).

Thus the following thresholds were developed to accept or reject a measured star as a standard; more than three observations must have been made of the star, the standard deviation of the mean value of the star for each filter must be less than some value (for example $0^m.02$ for the E Regions stars, except for U-P which is $0^m.025$), and the star's spectral classification based on mean Vilnius colours agrees within two sub-classes of the spectral type given in the literature and within one luminosity class. An obvious precondition is that the star must not be listed in any of the catalogues of known or suspected variables.

After this selection process, the overall accuracy and precision of the southern Vilnius standard system was estimated (using equation 3.3) as approximately $0^m.005$ in each of the magnitudes and colours (except for V and U-P, which are about $0^m.01$). Note that this is the accuracy and precision achievable by using *all* of the southern standard stars to transform a program star to the Vilnius system.

As the E Region stars are already standard stars in the Johnson and Strömgren systems, the opportunity arose to investigate transformations to/from the Vilnius system. From trying to reproduce the Johnson or Strömgren filter passbands as linear combinations of the Vilnius passbands, it was expected that good transformations should be possible between the U (and *u*) filters but not the others. However it was found several (often piece-wise) transformations to each Johnson or Strömgren filter was possible, to a precision of about $0^m.02$ – $0^m.03$. Some of these transformations had previously been investigated in the literature, with similar results to this study. It should be remembered however that these are only valid for same type of star used to derive the transformation, which here were predominately normal main sequence stars.

Chapter 4

The Omicron Velorum and Kappa Crucis clusters.

4.1 Isochrones in the Vilnius System.

There is a large body of literature available describing stellar models, which, for example, can be used for population synthesis studies, or fitting isochrones to star clusters. These models usually give results in both 'theoretical' units (such as effective surface temperature T_e and solar luminosities $L/L_\odot$) and observational units (such as absolute visual magnitude M_V and Johnson colour B-V). Unfortunately none have yet been published in the colours of the Vilnius system, apart from the limited case of B-type stars given recently by Straizys et al. (1993). However one of the authors of that paper (Kurucz 1995) provided Vilnius magnitudes and colours for a more complete grid of temperatures, gravities and metallicities — see Figure 4.1 for an example.

Kurucz's Vilnius magnitudes and colours are in a natural system and need to be transformed to the standard system (see section 2.8). As they were calculated by convolving model stellar spectra with the passbands of the standard filters, a simple zero-point shift was expected to suffice. However Kurucz's magnitudes are actually the magnitude per unit surface area ($-2.5 \log(I)$), and so need to be integrated over the star's surface first - this is not needed for the colours as the surface area terms cancel. Rearrangement of equation 1.4 leads to a more convenient form

$$-2.5 \log(L) = -2.5 \log(I) - 5 \log(R) \quad (4.1)$$

in terms of magnitudes.

To calibrate the natural magnitudes and colours, the intrinsic colours and absolute magnitudes (M_V) for main sequence stars were taken from Straizys (1992). The effective temperature, gravity and radii for the corresponding spectral types were also taken from Straizys (1992), and Kurucz's magnitudes (after correction for stellar radii) and colours interpolated to these values, assuming solar metallicity ($[M] = 0.0$). This was repeated for giant and super-giant sequences for the V magnitude, and is shown in Figure 4.2.

Figure 4.1: Grid of Vilnius V magnitudes (per unit surface area) from Kurucz's solar metallicity models, not yet converted to the standard system. Other metallicities available range from $[M] = -5.00$ to $+1.00$.

The V calibration curve can be closely fitted by a straight line having a slope of 1.0, i.e. a zero-point shift, with the three luminosity classes all falling on the same line. However Kurucz's late-type Ia stars appear systematically too faint, not overlapping the earlier stars when they loop back in the sequence. This doesn't occur for late-type stars in the other luminosity classes, i.e. in the same range of temperatures and gravities in Kurucz's grid, therefore the 'error' is not due to Kurucz's models and was ignored. The Y-V calibration curve can also be fit by a zero-point shift, but there appear to be some systematic deviations from a straight line with Kurucz's Y-V being too blue for early-type stars.

The required theoretical data to be input to Kurucz's grid was provided by a grid of evolutionary models computed by Schaerer and collaborators (Schaller et al. 1992, Schaerer et al. 1993). These cover an initial mass range of 0.8 to $120 M_{\odot}$, for three metallicities $Z = 0.001$, 0.008 , and 0.020 .¹ A program provided by Dr. Schaerer interpolated between this grid of models to produce an isochrone for a given metallicity and age. To test the results, a Zero Age Main Sequence (ZAMS) was constructed by joining piece-wise segments of various isochrones (with $Z = 0.020$) and comparing to the Vilnius ZAMS in Figure 4.3. Two different calibration

¹Kurucz used solar metallicities $[M]$, which is related to the metallicity used by Schaerer via $[M] = \log(Z/Z_{\odot})$, where $Z_{\odot}$ is the Sun's metallicity (taken here as 0.020).

Figure 4.2: Calibration of Kurucz's models to the standard Vilnius system, for V ($=M_V$) and Y-V. The top diagram includes luminosity classes Ia, III, and V, while the bottom diagram includes only the main sequence, with a straight line corresponding to a zero-point shift drawn through it.

Figure 4.3: Comparison of the ZAMS with the model ZAMS (constructed piece-wise from various age isochrones).

methods (of Kurucz's natural magnitudes and colours) were tested; one using zero-point shifts and the other using Figure 4.2 as calibration curves. The best results were found by taking the average value between the two calibration methods, which is shown in the figure.

This enabled a series of isochrones for three metallicities to be calculated, shown in Figures 4.4 to 4.6. These range from $\log(\text{age}) = 6.5$ to 10.1 in 0.1 increments, with the age in years. As there is essentially a linear transformation between the Johnson B-V colour and the Vilnius Y-V (see section 3.5), the isochrones show the same features as found in the literature for the UBV system (for example, see Meynet et al. (1993)).

4.2 Literature review of the Omicron Velorum cluster.

The first photoelectric study of the open star cluster 'Omicron Velorum'² appears to have been done by Lyngå (1959), hence Lyngå's numbering scheme was adopted here. The cluster is located at RA = $8^{\text{h}}38^{\text{m}}8$, Declination (Dec) = $-52^{\circ}53'$ (1950) or galactic coordinates $l = 270.4^{\circ}$, $b = -6.9^{\circ}$, with an angular diameter of $\sim 45'$.

²So named due to the bright star Omicron Velorum in the middle of the cluster. The O Vel cluster is also known as IC 2391 from the Index Catalogue or C0838-528 using it's International Astronomical Union (IAU) designation.

Figure 4.4: Grid of isochrones for $Z = 0.001$, between $\log(\text{age}) = 6.5$ to 10.1 in 0.1 increments (age in years).

Figure 4.5: Grid of isochrones for $Z = 0.008$, between $\log(\text{age}) = 6.5$ to 10.1 in 0.1 increments (age in years).

Figure 4.6: Grid of isochrones for $Z = 0.020$, between $\log(\text{age}) = 6.5$ to 10.1 in 0.1 increments (age in *years*).

Table 4.1: Review of main characteristics of O Vel.

author	distance (<i>pc</i>)	reddening (E_{B-V})	age (<i>years</i>)
Hogg	153 ± 3 (210, 120, 260)	0.004 ± 0.003	$25 - 53 \times 10^6$ (19×10^6)
Lynga	160	0.017	40×10^6 ($< 20 \times 10^6$)
Buscombe	210 ± 10		
Graham	226 ± 40	0.000	
P&H	148 ± 4 (uvby 158 ± 4)	0.00 ± 0.01	30×10^6 ($> 30 \times 10^6$)
Eggen (UBV)	151	0.02	
Eggen (uvby)	166 ± 22	0.001 ± 0.007	30×10^6
L&W	140 ± 11	0.1 ± 0.1	36×10^6
B&S	167	0.022 ± 0.011	
L&M	150 ± 6	0.02	
K&R			$57 - 80 \times 10^6$
M&C	154 ± 6	0.000	
median	154	0.010	30×10^6

A summary of the cluster's characteristics found by different authors is given in Table 4.1. Hogg (1960) also lists distance determinations from three other authors (shown in parenthesis) and gives ages from the main sequence turn-off (the nuclear age) and the pre-main-sequence turn-on (the gravitational contraction age, shown in parenthesis). Lyngå (1961) fits the nuclear age using two methods; that of Sandage, and von Hoerner (parenthesis). Buscombe (1965) has a note added in proof that the (0.06) discrepancy between his distance (modulus) and Lyngå and Hogg appears to be due to the difference between absolute magnitude calibrations of field stars near A0 V and the ZAMS. Graham (1967) assumes zero reddening and used a preliminary H_β -absolute magnitude calibration, which seems to have the same discrepancy found by Buscombe. Perry & Hill (1969) give distances based separately on their UBV and *uvby* photometry, and the nuclear and contraction (parenthesis) ages. Eggen (1972, 1983) measured the cluster first using the UBV system and then the *uvby* system — here E_{b-y} has been converted to E_{B-V} . Balona & Shobbrook (1984) find the cluster distance assuming the Pleiades is 126 *pc*. Levato & Malaroda (1984) recalculated the cluster's mean reddening using the UBV intrinsic colours based on their spectral classifications and Perry & Hill's (reddened) colours. Koester & Reimers (1985) fit isochrones to a colour-magnitude diagram from previous authors observations. Maitzen & Catalano (1986) conclude the difference in reddening between Perry & Hill and Lyngå & Wramdemark (1984) is due to the zero-point difference (in *b-y*), and the reddening is actually zero. The final row of the table lists the median values³ — note that the actual E_{B-V} may be smaller than the median as negative E_{B-V} 's are not allowed.

Different authors have used a variety of other naming systems for the stars in the cluster, which have been summarized in Table 4.2. The RA and Dec (in hours, minutes, seconds and

³The median was used here to avoid the difficulties in calculating a mean with data (age) involving inequalities.

degrees, minutes respectively) are taken from SIMBAD and are to the Epoch 2000. The third column gives the numbers used by Hogg (1960) while the fourth column is from volume 19 of the Cape Photographic Catalogue (CPC). The next column (23910000+CDS) are those used by Mermilliod in the SIMBAD database. The ninth column (236000+SAO) is from the Smithsonian Astrophysical Observatory (SAO) catalog. The remaining catalogues are sufficiently well known not to need further explanation. Star CPD -52 1579 has a question mark as it appears to be a (much fainter) visual companion to O Vel 3, while a CPD number for O Vel 3 itself could not be found.

A star chart of O Vel suitable for viewing through a finder scope was prepared using Lyngå's numbers and is shown in Figure 4.7. The occasional concentric white ring inside a black circle (for example see O Vel 13) is due to slight discrepancies in the visual magnitude as recorded in the two catalogues (the Yale HR and the SAO) used to prepare the chart.

Table 4.3 gives all the spectral classifications found in the literature for O Vel. These classifications are derived from spectroscopic measurements unless noted otherwise below. The author(s) are listed at the top of each column; Lyngå (1961) - the first column is from the HD catalog, the second from Lyngå's UBV results using the Q method. Feins. = Feinstein (1961), while Busc. = Buscombe (1965), P&H = Perry & Hill (1969), and P&B = Perry & Bond (1969). Craw. = Crawford, Barnes & Golson (1971), with the spectral classes taken from Hoffleit (1964), Lesh (1969) or Hiltner et al. (1969). Eggen = Eggen (1983), with the spectral classes taken from Houk (1978). L&M = Levato & Malaroda (1984), and finally Renson (1988). Most of the stars appear to be on the main sequence, the exceptions being O Vel 1 (B3 III-IV), O Vel 2 (B3 IV-V), O Vel 3 (B5 IV-V), and possibly O Vel 26 (K0-3 III-V), O Vel 27 (F0-2 IV-V), and O Vel 29 (F2 IV-V). The spectral classes generally show good agreement between different authors, apart from the metallic-line or peculiar stars (5, 10, 15, 20, 21, 23, and 25). Maitzen & Catalano (1986) investigated O Vel for chemically peculiar stars, and confirmed that stars 5 and 10 are peculiar while the status of stars 20 and 38 are unclear. They also note that it has become well known the luminosity classification for hot chemically peculiar stars is often wrong (so O Vel 5 and 10 may actually be on the main sequence).

Table 4.4 lists the proper motions found in the literature. The RA proper motion has been converted into *arc-seconds*, via the conversion factor ' $15 \cos(Dec)$ ', from the usual units for RA (time, in *seconds*). As the values often show little agreement, even allowing for the probable errors of $0.005 - 0.010''/yr$, the median was calculated in the final columns. Hogg's (1960) data was copied from the *Cape Annals Vol 19*, so have been supplemented here with further values from the Cape Annals for stars not observed by Hogg. The data given by Lyngå (1961) is the weighted mean of Lyngå's values and the *Cape Annals Vol 19*. As it was not possible to recover Lyngå's own values, it was assumed that where Lyngå's values are identical to the Cape's values

Table 4.2: Synonyms for O Vel's stars.

Lynga	RA	Dec	Hogg	CPC	CDS	HD	HR	SAO	CPD
01	08 40 18	-52 55.3	00	3070	20	74195	3447	164	-52 1583
02	08 42 25	-53 06.9	03	3092	34	74560	3467	205	-52 1607
03	08 39 58	-53 03.3	02	3065	16	74146	3442	157	-52 1579?
04	08 39 22	-53 26.2	12	3062	13	74071	3440	151	-53 1796
05	08 42 19	-53 06.0	04	3090	31	74535	3466	202	-52 1605
06	08 40 18	-53 00.9	01	3071	21	74196	3448	165	-52 1584
07	08 38 45	-53 05.4	13	3055	08	73952	3435	142	-52 1565
08	08 38 25	-53 43.5		3054	06	73904		140	-53 1789
09	08 35 10	-54 12.4		3034	01	73287		100	-53 1760
10	08 40 02	-53 16.3	11	3067	18	74169		160	-52 1581
11	08 40 50	-52 48.2	06	3075	23	74275		177	-52 1587
12	08 40 03	-53 51.1		3069	19	74182		162	-53 1804
13	08 42 13	-52 58.2	08	3086	29	74516		198	-52 1601
14	08 44 50	-53 05.1		3105	41	74955		233	-52 1634
15	08 41 49	-53 04.2	09	3081	27	74438		190	-52 1598
16	08 43 05	-53 04.6	15	3099	39	74678		217	-52 1622
17	08 43 36	-53 31.9		3102	40	74762		223	-53 1842
18	08 42 08	-52 45.2	07	3084	28	74497		196	-52 1599
19	08 37 11	-53 15.6	33	3045	03	73681		125	-52 1552
20	08 42 24	-53 20.7	32	3088	32	74536		201	-52 1603
21	08 42 51	-53 44.8		3098	38	74665		214	-53 1834
22	08 36 24	-53 02.2		3041	02	73503		118	-52 1545
23	08 40 00	-52 42.6		3068	15	74145		161	-52 1580
24	08 42 08	-53 09.6	10	3085	30	74517		197	-52 1600
25	08 42 11	-54 09.5		3089	33	74537			-53 1825
26	08 40 19	-53 26.2		3072	22	74212		168	-53 1808
27	08 37 38	-54 11.0		3049	05	73778		131	-53 1784
28	08 37 30	-52 39.1		3047	04	73722		129	-52 1554
29	08 39 43	-52 57.7	25	3064	14	74117		155	-52 1578
30	08 41 30	-52 59.7	31		26	74387			-52 1597
31	08 39 18	-53 17.1		3061	12	74056		150	-52 1574
32	08 42 18	-53 54.2		3091	35	74561		203	-53 1826
33	08 42 12	-53 06.1	05	3087		74535B			-52 1602
34	08 39 00	-53 01.5	27		72				-52 1568
35	08 39 22	-53 01.5	26		71				-52 1575
36	08 41 09	-52 53.0			24	74340			-52 1592
37	08 39 39	-53 10.4							
38	08 41 25	-53 17.9				74373			
39	08 39 32	-53 19.3							
40	08 38 56	-52 58.2	28		73				-52 1567
41	08 40 59	-52 30.9							
42	08 39 32	-53 19.3							
43	08 39 18	-53 17.1							

Table B.1 continued from previous page												
HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp	
013421	02 11 22	+08 34.3	5.63 N	0.52	0.62	0.75	0.43	0.20	0.50	02	G0 IV	
015130	02 25 57	-12 17.4	4.89 N	0.69	0.78	0.23	0.09	0.06	0.12	03	B9.5 V,N	
015318	02 28 10	+08 27.6	4.28 N	0.57	0.75	0.24	0.08	0.06	0.12	03	B9 III,SB:	
015798	02 32 05	-15 14.6	4.75 N	0.52	0.60	0.59	0.29	0.17	0.42	02	F4 IV	
016060	02 35 04	+07 28.4	6.18 N	0.59	1.00	1.36	0.46	0.33	0.75	03	K0 III	
016160	02 35 59	+06 52.0	5.82 N	0.45	0.98	1.32	0.28	0.43	0.77	03	K3 V	
016399	02 38 00	+07 41.7	6.39 N	0.52	0.62	0.62	0.28	0.17	0.45	02	F6 IV	
016647	02 40 15	+06 06.7	6.25 N	0.49	0.59	0.60	0.27	0.17	0.43	02	F3 V	
016941	02 38 18	-72 51.9	5.43 L	0.78	0.83	1.10	0.45	0.26	0.68	07	F3 V	
017163	02 45 20	+04 42.7	6.03 N	0.61	0.71	0.57	0.21	0.15	0.34	01	F0 V	
018604	02 59 43	+08 54.5	4.70 N	0.40	0.47	0.17	0.08	0.06	0.10	02	B6 III	
018784	03 01 09	-07 39.7	5.78 N	0.60	1.01	1.31	0.47	0.32	0.76	02	K0 II	
020791	03 21 07	+03 40.5	5.69 N	0.59	0.93	1.24	0.44	0.29	0.70	01	G8.5 III	
021364	03 27 10	+09 44.0	3.74 N	0.37	0.59	0.24	0.10	0.04	0.14	02	B9 V,N	
021755	03 30 45	+06 11.3	5.94 N	0.59	0.86	1.18	0.45	0.29	0.69	01	G8 III	
026462	04 11 19	+05 31.4	5.72 N	0.53	0.67	0.56	0.24	0.17	0.39	02	F4 V	
026912	04 15 32	+08 53.5	4.29 N	0.32	0.38	0.20	0.10	0.06	0.17	04	B3 IV	
028749	04 31 53	-00 02.6	4.91 N	0.70	1.21	1.72	0.56	0.41	0.85	02	K3 II-III	
031296	04 54 47	+07 46.8	5.33 N	0.65	1.10	1.58	0.52	0.34	0.84	02	K1 II-III	
032008	04 59 50	-10 15.7	5.38 N	0.52	0.69	1.03	0.39	0.25	0.64	01	G4 V	
032147	05 00 47	-05 44.2	6.22 N	0.46	1.09	1.48	0.28	0.48	0.81	04	K3 V	
033833	05 12 48	-06 03.4	5.91 N	0.56	0.92	1.23	0.46	0.29	0.68	02	G7 III	
034503	05 17 37	-06 50.6	3.60 N	0.38	0.45	0.17	0.09	0.04	0.12	02	B5 III	
034816	05 19 34	-13 10.6	4.29 N	0.05	0.06	0.08	0.02	0.03	0.04	03	B0.5 IV	
035155	05 22 19	-08 40.0	6.77 M	0.90	1.22	2.07	0.92	0.46	1.19	02	S4.1	
036512	05 31 56	-07 18.1	4.62 N	0.02	0.04	0.03	0.03	0.03	0.00	03	B0 V	
037160	05 36 54	+09 17.7	4.09 N	0.58	0.86	1.17	0.44	0.30	0.75	03	K0 IIIB	
040446	05 58 49	+00 33.2	5.22 N	0.62	0.81	0.32	0.12	0.06	0.12	01	A1 V,S	
040536	05 59 04	-09 33.4	5.03 N	0.71	0.82	0.49	0.14	0.11	0.26	01	A6 ,M	
043526	06 16 58	+07 03.2	6.57 N	0.38	0.41	0.22	0.08	0.05	0.13	01	B7 III	
046150	06 31 55	+04 56.6	6.73 N	0.14	0.12	0.25	0.20	0.11	0.29	03	O6 V,E	

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Table B.1 continued from previous page											
HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp
046966	06 36 26	+06 05.0	6.87	N	0.10	0.15	0.13	0.08	0.19	05	O8.5 V
048099	06 41 59	+06 20.8	6.37	N	0.08	0.15	0.13	0.07	0.19	05	O6 E
052382	07 00 39	-09 12.2	6.49	N	0.22	0.30	0.26	0.12	0.35	02	B1 IB
055751	07 14 20	+03 06.7	5.35	N	0.69	1.07	0.54	0.34	0.79	01	K2 II
059881	07 32 06	+01 54.9	5.25	N	0.84	0.84	0.19	0.09	0.13	01	F0 III
063975	07 51 42	+01 46.1	5.14	N	0.40	0.45	0.07	0.06	0.13	02	B8 II
067594	08 08 36	-02 59.0	4.34	N	0.62	1.20	0.46	0.28	0.70	02	G2 IB
077445	09 02 45	+07 17.9	5.85	N	0.62	1.43	0.47	0.33	0.75	02	K0 II-III
090994	10 30 17	-00 38.2	5.09	N	0.26	0.47	0.06	0.03	0.08	03	B6 V
091612	10 34 49	+06 57.2	5.08	N	0.52	1.16	0.43	0.25	0.73	05	G9 III
095345	11 00 34	+03 37.1	4.84		0.64	1.48	0.51	0.35	0.80	01	K1 III
095849	11 03 37	-00 00.1	5.95	N	0.69	1.62	0.47	0.40	0.80	01	K3 III
097585	11 13 46	-00 04.1	5.42	N	0.73	0.79	0.10	0.08	0.13	02	A0 V
097605	11 14 02	+08 03.8	5.79	N	0.62	1.11	0.44	0.37	0.78	03	K3 III
098058	11 16 40	-03 39.1	4.47	N	0.70	0.77	0.18	0.09	0.32	04	A7 IV,N
098366	11 18 55	+01 39.1	5.91	N	0.59	1.02	0.46	0.32	0.78	01	K0 III-IV
098960	11 23 18	+00 07.9	6.05	N	0.76	1.33	0.54	0.49	1.00	02	K3 II-III
099055	11 24 02	+01 24.5	5.39	N	0.59	0.83	0.44	0.28	0.70	04	G8 III
100563	11 34 22	+03 03.7	5.77	N	0.51	0.56	0.26	0.17	0.45	01	F5 V
102124	11 45 16	+08 15.5	4.85	N	0.60	0.78	0.16	0.10	0.25	03	A4 V
102510	11 47 55	+08 14.7	5.32	N	0.59	0.79	0.14	0.04	0.18	02	A2 V
102870	11 50 39	+01 46.1	3.61	N	0.46	0.65	0.33	0.17	0.49	06	F8 V
103484	11 55 03	+08 26.6	5.58	N	0.56	0.88	0.41	0.29	0.69	03	G8 III-IV
104181	11 59 57	+03 39.3	5.37	N	0.63	0.82	0.09	0.07	0.13	03	A1 V
104979	12 05 14	+08 43.9	4.11		0.51	0.83	0.46	0.28	0.70	09	G8 III
105639	12 09 42	+01 54.0	5.95	N	0.63	1.08	0.44	0.37	0.78	02	K3 III
105702	12 10 04	+05 48.4	5.72	N	0.65	0.79	0.25	0.12	0.35	02	A,M
107070	12 18 40	-00 47.3	5.90	N	0.73	0.82	0.17	0.09	0.26	02	A5 V,N
108985	12 31 21	+07 36.2	6.05	N	0.79	1.38	0.56	0.52	1.06	03	K3 II-III
111765	12 51 37	+03 03.4	6.02	N	0.70	1.23	0.51	0.42	0.89	03	K2 III
114960	13 13 58	+01 27.4	6.58		0.76	1.36	0.49	0.52	0.96	01	K5 III

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Table B.1 continued from previous page

HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp
115383	13 16 48	+09 25.3	5.22 N	0.47	0.62	0.77	0.34	0.21	0.52	02	G0 V,S
116160	13 21 42	+02 05.3	5.69 N	0.56	0.83	0.34	0.11	0.06	0.13	01	A2 V
116235	13 22 10	+05 09.3	5.87 N	0.60	0.83	0.43	0.12	0.10	0.16	02	A2,M
120602	13 50 25	+05 29.9	6.01 N	0.59	0.83	1.13	0.44	0.26	0.70	03	G5 III
121607	13 56 28	+01 03.1	5.91 N	0.69	0.79	0.47	0.15	0.10	0.25	02	A8 V
122365	14 01 20	+08 53.7	5.99 N	0.63	0.84	0.40	0.10	0.08	0.16	02	A2 V
122408	14 01 39	+01 32.7	4.26 N	0.77	0.83	0.39	0.18	0.08	0.23	03	A3 V
126053	14 23 15	+01 14.9	6.27 N	0.41	0.60	0.80	0.36	0.22	0.56	02	G1 V
126248	14 24 12	+05 49.2	5.10 N	0.62	0.82	0.41	0.16	0.08	0.20	03	A5 V
127167	14 29 50	+00 49.7	5.94 N	0.67	0.81	0.42	0.14	0.09	0.21	02	A5 IV
127337	14 30 45	+04 46.3	6.02 N	0.74	1.31	1.85	0.56	0.47	0.97	03	K2 II-III
129502	14 43 03	-05 39.2	3.88 N	0.54	0.62	0.61	0.29	0.17	0.45	03	F2 III
129956	14 45 30	+00 43.0	5.69 N	0.62	0.75	0.26	0.08	0.07	0.12	02	B9.5 V
130952	14 51 00	-02 17.8	4.94 N	0.57	0.91	1.22	0.46	0.30	0.73	02	G8 III-IV
130970	14 50 60	-00 15.4	6.18 N	0.77	1.33	1.89	0.52	0.48	0.97	02	K3 III
132345	14 58 54	-11 08.6	5.88 N	0.72	1.30	1.69	0.50	0.42	0.85	01	K3 III,CN2
135482	15 15 11	+04 56.3	5.33 N	0.68	1.00	1.35	0.49	0.36	0.80	05	K0 III
135559	15 15 49	+00 22.4	5.63 N	0.58	0.78	0.47	0.17	0.10	0.25	04	A4 V
136028	15 18 26	-00 27.7	5.89 N	0.78	1.37	2.00	0.59	0.49	1.04	03	K5 III
137898	15 28 39	+01 50.6	5.17 N	0.61	0.75	0.51	0.20	0.12	0.30	05	A8 IV
138716	15 34 10	-10 03.7	4.62 N	0.58	1.06	1.28	0.43	0.33	0.73	03	K1 IV
140573	15 44 15	+06 25.5	2.65 N	0.59	1.17	1.54	0.47	0.30	0.78	06	K2 III,B (CN1)
141795	15 50 48	+04 28.6	3.71 N	0.64	0.86	0.47	0.16	0.05	0.19	02	A2,M
143553	16 00 51	+04 25.6	5.83 N	0.57	0.95	1.24	0.45	0.31	0.74	02	G9 III-IV
145148	16 09 10	+06 23.4	5.97 N	0.52	1.01	1.28	0.40	0.34	0.75	02	K0 IV
147550	16 22 39	-02 04.8	6.22 N	0.73	0.74	0.34	0.17	0.07	0.20	03	B9 V
147869	16 24 11	+06 56.8	5.85 N	0.64	0.82	0.30	0.10	0.07	0.13	02	A2,P(SR):
148287	16 26 50	+02 20.9	6.07 N	0.56	0.87	1.13	0.44	0.27	0.67	02	G8 III
148513	16 28 34	+00 39.9	5.43 N	0.80	1.38	1.98	0.54	0.50	1.00	02	K4 III,P
148760	16 31 22	-26 32.2	6.22 N	0.55	1.15	1.43	0.46	0.32	0.81	01	K1 III
149121	16 32 36	+05 31.3	5.63 N	0.56	0.68	0.22	0.08	0.07	0.11	02	B9.5 III

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Table B.1 continued from previous page											
HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp
150366	16 41 36	-24 28.1	6.07	0.63	0.78	0.49	0.20	0.11	0.29	01	F0 V
150451	16 41 12	-01 00.0	6.22	0.58	0.73	0.54	0.22	0.15	0.36	06	A7 III
150416	16 41 35	-17 44.5	4.96	0.61	0.94	1.30	0.54	0.30	0.78	02	G8 II(CN1,BA)
150557	16 41 42	+01 10.8	5.74	0.61	0.71	0.54	0.25	0.13	0.38	02	F2-4 III-IV
151133	16 45 30	+01 01.2	6.03	0.59	0.70	0.26	0.12	0.06	0.14	02	B9.5 III
151217	16 45 50	+08 34.9	5.18	0.86	1.43	2.08	0.57	0.54	1.06	02	K5 III
152391	16 53 01	-00 00.4	6.64	0.43	0.75	0.98	0.35	0.27	0.61	03	G8 V
153687	17 01 03	-04 13.3	4.82	0.78	1.42	1.98	0.57	0.50	1.01	02	K4 III
154417	17 05 17	+00 42.5	6.01	0.45	0.59	0.77	0.33	0.19	0.53	02	F9 V
156826	17 19 59	-05 54.9	6.32	0.49	0.81	1.05	0.41	0.28	0.67	03	G9 V
157089	17 21 08	+01 26.4	6.96	0.48	0.54	0.72	0.34	0.21	0.52	04	F9 V-MD
157347	17 22 51	-02 23.2	6.29	0.43	0.69	0.88	0.35	0.22	0.58	02	G5 IV
157617	17 23 57	+08 51.2	5.77	0.73	1.16	1.56	0.58	0.37	0.86	03	K1 II-III
158352	17 28 50	+00 19.8	5.44	0.66	0.75	0.49	0.20	0.13	0.28	03	A8 V
159975	17 37 51	-08 07.1	4.62	0.61	0.57	0.28	0.18	0.13	0.24	03	B8 II-III,P(MN)
160346	17 39 18	+03 33.4	6.52	0.43	1.01	1.29	0.31	0.39	0.75	04	K3 V
160781	17 41 32	+06 18.8	5.95	0.69	1.15	1.59	0.60	0.37	0.88	02	G7 III
161573	17 46 07	+05 31.8	6.85	1.28	0.38	0.24	0.14	0.08	0.17	04	B3-4 IV-V
161868	17 47 54	+02 42.5	3.75	0.57	0.83	0.29	0.13	0.07	0.12	03	A0 V,SB:
162917	17 53 15	+06 06.0	5.77	0.49	0.60	0.64	0.28	0.15	0.45	02	F3-5 IV-V
163245	17 55 54	-18 48.1	6.42	0.62	0.83	0.37	0.12	0.08	0.15	02	A4 V
164259	18 00 28	-03 41.4	4.62	0.51	0.62	0.59	0.28	0.14	0.39	03	F2 IV
164353	18 00 38	+02 55.9	3.97	0.35	0.29	0.20	0.18	0.09	0.20	07	B5 IB
165401	18 05 37	+04 39.7	6.79	0.43	0.59	0.77	0.35	0.21	0.57	03	G0 V
165462	18 06 07	-00 26.7	6.34	0.72	0.89	1.23	0.54	0.32	0.81	03	G8 II,P
165438	18 06 14	-04 45.0	5.77	0.52	1.00	1.25	0.42	0.32	0.73	02	K1 IV
166460	18 10 40	+03 19.5	5.51	0.66	1.17	1.56	0.52	0.38	0.84	03	K2 III
167768	18 16 53	-03 00.2	5.96	0.58	0.82	1.07	0.43	0.28	0.68	03	G3 III
168387	18 19 09	+07 15.6	5.39	0.62	1.11	1.42	0.42	0.39	0.78	03	K2 III-IV
169420	18 25 21	-20 32.5	4.81	0.71	0.97	1.43	0.61	0.41	0.94	02	K2 II
170137	18 27 50	+03 44.9	6.07	0.84	1.38	2.04	0.70	0.49	1.10	04	K3 III

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Table B.1 continued from previous page

HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp
171538	18 35 15	+05 59.8	6.47	0.61	0.84	0.39	0.12	0.08	0.21	02	A3 III
171767	18 36 29	+04 57.4	6.74	0.67	1.16	1.47	0.50	0.35	0.79	03	K1 III
171802	18 36 28	+09 07.5	5.39	0.50	0.60	0.58	0.27	0.16	0.40	03	F5 III
171834	18 36 39	+06 40.5	5.45	0.52	0.61	0.56	0.26	0.16	0.40	03	F3 V
172046	18 37 49	+05 53.1	6.67	0.42	0.50	0.23	0.10	0.10	0.18	03	B5 V
172365	18 39 37	+05 15.9	6.38	0.81	0.80	0.94	0.43	0.25	0.66	03	F8 IB-II
173009	18 43 31	-08 16.5	4.90	0.66	0.97	1.36	0.54	0.33	0.81	02	G8 II
173371	18 44 56	-00 22.4	6.88	0.49	0.52	0.20	0.15	0.07	0.15	09	B9 III
173654	18 46 29	-00 57.7	5.90	0.58	0.80	0.46	0.18	0.09	0.21	03	A2 V,M
173764	18 47 10	-04 44.9	4.22	0.66	0.95	1.29	0.54	0.32	0.78	02	G5 II(CN0.5,FE)
175190	18 55 07	-22 40.2	5.05	0.67	1.24	1.78	0.54	0.46	0.85	04	K3-MD(BA)
175679	18 56 26	+02 28.3	6.15	0.57	0.94	1.19	0.48	0.28	0.75	02	G8 III
175775	18 57 44	-21 06.3	3.49	0.66	1.09	1.51	0.52	0.35	0.80	02	K1 III
175869	18 57 17	+02 32.1	5.57	0.64	0.60	0.24	0.14	0.08	0.20	03	B9 III,E,P:(HG)
176704	19 02 28	-24 50.7	5.59	0.68	1.24	1.62	0.47	0.42	0.83	02	K3 III
177178	19 03 32	+01 49.2	5.83	0.61	0.79	0.48	0.17	0.10	0.24	02	A4 V
177756	19 06 15	-04 52.8	3.44	0.50	0.62	0.22	0.07	0.06	0.12	03	B9 V,N
180028	19 14 45	+06 02.9	6.97	0.98	0.82	0.91	0.47	0.28	0.68	03	F6 IB
180482	19 16 31	+04 50.1	5.59	0.81	0.86	0.36	0.13	0.10	0.20	03	A3 IV
180782	19 17 49	+02 01.9	6.19	0.58	0.84	0.32	0.12	0.07	0.16	01	A1 V,N
180928	19 19 00	-15 32.0	6.06	0.78	1.32	1.79	0.54	0.49	0.99	02	K3 III
181053	19 18 50	+00 20.3	6.40	0.58	0.93	1.31	0.48	0.32	0.76	02	K0 IIIA,(BA,CH1
181391	19 20 33	-05 24.9	5.01	0.55	0.88	1.18	0.42	0.30	0.70	02	G8 III-IV,SB
181440	19 20 36	-00 53.5	5.49	0.57	0.65	0.22	0.10	0.07	0.13	03	B9 III
182101	19 22 49	+09 54.7	6.35	0.48	0.56	0.62	0.31	0.16	0.46	04	F6 V
183227	19 28 21	+02 55.8	5.85	0.47	0.49	0.22	0.13	0.09	0.18	03	B6 III
183324	19 29 01	+01 57.0	5.80	0.59	0.82	0.38	0.14	0.08	0.17	03	A0 V
183589	19 30 11	+02 54.2	6.09	0.91	1.37	2.20	0.77	0.59	1.24	02	K5 IB
184492	19 35 07	-10 33.7	5.12	0.65	0.96	1.34	0.52	0.34	0.80	02	G8 IIIA
184930	19 36 43	-01 17.1	4.36	0.41	0.48	0.19	0.10	0.07	0.14	04	B5 III
186442	19 44 02	+09 31.0	6.52	0.69	1.09	1.56	0.60	0.37	0.83	03	G5 IB

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Table B.1 continued from previous page											
HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp
186648	19 46 22	-19 45.6	4.86	N	0.57	0.90	1.21	0.45	0.30	04	K1 III
187003	19 47 34	+01 05.5	6.80	N	0.47	0.62	0.78	0.33	0.21	02	G0 IV
187642	19 50 45	+08 51.8	0.77	N	0.60	0.76	0.47	0.18	0.10	03	A7 IV-V
188350	19 54 44	+00 16.4	5.61	N	0.76	0.79	0.32	0.18	0.08	02	A0 III
189695	20 00 59	+08 33.4	5.91	N	0.84	1.39	2.02	0.57	1.05	02	K5 III
190327	20 04 08	+07 16.6	5.52	N	0.64	0.94	1.34	0.49	0.33	02	G7 II-III
192876	20 17 39	-12 30.5	4.24	N	0.67	0.91	1.25	0.52	0.31	03	G3 IB
194013	20 23 11	+05 20.6	5.31	N	0.56	0.96	1.25	0.46	0.29	03	G8 III-IV
195135	20 29 38	-02 53.1	4.91		0.65	1.18	1.51	0.48	0.38	02	K2 III
195922	20 33 53	+10 03.6	6.56	N	0.68	0.83	0.36	0.15	0.10	02	A2 V, NN
196321	20 36 43	-02 33.0	4.89	N	0.81	1.40	2.10	0.62	0.53	03	K5 II
196426	20 37 19	+00 05.8	6.19		0.41	0.53	0.20	0.09	0.05	05	B8 III, P
196755	20 39 07	+10 05.1	5.05	N	0.49	0.69	0.88	0.36	0.23	05	G5 IV+K2 IV
198070	20 47 48	+03 18.4	6.40	N	0.57	0.76	0.27	0.12	0.07	02	A0 V, N
198743	20 52 40	-08 58.9	4.73	N	0.60	0.72	0.58	0.20	0.13	06	A3, M
199442	20 57 10	+00 27.9	6.06		0.68	1.24	1.62	0.49	0.40	01	K2 III
199960	21 00 34	-04 43.7	6.21	N	0.48	0.67	0.86	0.32	0.23	02	G1 V
200644	21 04 34	+05 30.2	5.61	N	0.80	1.40	2.18	0.65	0.55	02	K5 III
200661	21 04 41	+02 56.5	6.42	N	0.59	1.03	1.31	0.50	0.32	03	K0 III
200663	21 04 45	+02 16.3	6.33	N	0.56	0.88	1.16	0.46	0.30	03	G8 III-IV
200790	21 05 27	+05 57.6	5.94	N	0.50	0.59	0.71	0.31	0.20	02	F8 V
201298	21 08 28	+06 59.4	6.15	N	0.89	1.40	2.13	0.67	0.56	02	K5 III
201507	21 09 58	+02 56.5	6.45	N	0.58	0.69	0.57	0.26	0.16	02	F5 IV
203562	21 22 54	+06 48.7	5.16	N	0.69	0.87	0.32	0.12	0.08	02	A3 V
203926	21 25 17	-03 33.3	5.49		0.79	1.39	1.99	0.53	0.52	01	K4 III
204075	21 26 40	-22 24.7	3.79		0.56	0.87	1.13	0.43	0.27	05	G4 IB
204121	21 26 28	+01 06.3	6.13	N	0.52	0.58	0.66	0.29	0.18	02	F5 V
204867	21 31 34	-05 34.2	2.91	N	0.71	0.80	1.07	0.41	0.25	04	G0 IB
205924	21 38 32	+05 46.3	5.67	N	0.63	0.74	0.50	0.20	0.12	02	A9 IV-V, N
206088	21 40 04	-16 39.8	3.68	N	0.61	0.77	0.59	0.20	0.13	03	F0, P
206301	21 41 33	-14 02.6	5.18	N	0.47	0.65	0.85	0.35	0.24	02	G1 V+G0 V

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Table B.1 continued from previous page												
HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp	
206445	21 42 10	+01 17.1	5.67	N	0.69	1.31	1.92	0.59	0.48	02	K2 III	
206834	21 44 60	-09 05.0	5.10		0.62	1.02	1.39	0.53	0.31	03	G8 II-III	
207203	21 47 14	+02 41.1	5.64	N	0.71	0.82	0.29	0.14	0.07	02	A1 V	
208110	21 53 58	+06 51.9	6.12		0.62	0.66	0.92	0.43	0.26	05	G3 III-MD	
209167	22 01 09	+08 15.5	5.65	N	0.74	1.37	1.95	0.54	0.50	04	K3 II-III	
209625	22 04 47	-00 54.3	5.30	N	0.69	0.78	0.53	0.18	0.12	03	A5, M	
209750	22 05 47	-00 19.2	2.96	N	0.66	0.86	1.21	0.46	0.27	11	G2 IB	
210434	22 10 33	-04 16.0	6.02		0.60	0.97	1.26	0.44	0.31	02	K0 III-IV	
211287	22 15 59	+08 33.0	6.21	N	0.64	0.80	0.30	0.13	0.08	02	A1 V, N	
211391	22 16 50	-07 47.0	4.16	N	0.58	0.95	1.27	0.48	0.29	07	G8 III-IV	
212430	22 24 26	-13 31.8	5.76	N	0.57	0.90	1.23	0.47	0.28	04	G6.5 III	
212943	22 27 52	+04 42.0	4.79	N	0.58	1.04	1.33	0.45	0.37	06	K0 III	
216701	22 54 59	+01 03.9	6.11	N	0.69	0.85	0.46	0.17	0.10	02	A7 III	
216762	22 55 56	-31 55.2	6.41		1.06	1.43	1.86	0.94	0.44	01	S5, 1	
216953	22 57 17	-04 48.6	6.31	N	0.55	0.91	1.19	0.45	0.29	07	G9 III	
217186	22 58 42	+07 20.5	6.33	N	0.59	0.85	0.33	0.13	0.08	02	A1 V	
217459	23 00 43	+03 00.8	5.83	N	0.71	1.28	1.78	0.50	0.48	02	K4 III	
217877	23 03 56	-04 47.7	6.70		0.46	0.59	0.75	0.33	0.20	51	F8 V	
218527	23 08 40	+02 07.6	5.39		0.57	0.83	1.12	0.44	0.28	02	G8 III-IV-MD	
218700	23 10 01	+09 49.3	5.39	N	0.57	0.62	0.18	0.09	0.06	05	B9 III	
219215	23 14 19	-06 02.7	4.22	N	0.88	1.41	2.05	0.60	0.56	05	M2 III	
219449	23 15 52	-09 05.2	4.25		0.64	1.13	1.40	0.48	0.33	03	K0 III	
219615	23 17 07	+03 16.9	3.66		0.60	0.84	1.11	0.46	0.28	02	K0 III:(CN-1, FE	
219983	23 20 15	-03 55.1	6.63		0.50	0.58	0.67	0.32	0.18	03	F7 V	
220009	23 20 21	+05 22.9	5.07		0.70	1.10	1.50	0.52	0.39	03	K2-MDG	
220465	23 24 07	-18 41.3	6.18		0.58	0.99	1.27	0.47	0.29	02	G8 III	
220954	23 27 59	+06 22.7	4.29		0.60	1.06	1.38	0.49	0.33	03	K1 III	
220957	23 28 05	-11 27.0	6.36		0.60	0.84	1.09	0.45	0.27	02	G8 III-MDG	
221148	23 29 31	-04 31.8	6.28		0.62	1.18	1.49	0.42	0.40	02	K3 III	
221356	23 31 31	-04 05.0	6.49		0.46	0.55	0.71	0.32	0.19	02	F8 V-MD	
221409	23 31 58	-01 05.1	6.39		0.65	1.09	1.48	0.53	0.34	02	K1 III	

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Table B.1 continued from previous page

HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp
221950	23 36 23	+02 06.1	5.67	0.47	0.54	0.60	0.30	0.17	0.45	02	F6 V-MD
222377	23 39 55	+09 40.6	5.97	0.61	0.80	0.50	0.17	0.11	0.26	02	A2 ,M
222493	23 41 09	-11 40.9	5.92	0.58	0.98	1.26	0.45	0.31	0.71	02	G9 III
222603	23 42 04	+01 46.9	4.48	0.59	0.78	0.48	0.18	0.10	0.25	02	A7 V
223438	23 49 28	+01 04.6	5.77	0.68	0.85	0.44	0.15	0.10	0.24	02	A5 ,M
223617	23 51 07	+02 14.3	6.96	0.56	1.05	1.46	0.51	0.34	0.77	02	K1 III-MD
224974	00 02 16	-13 24.5	6.92	0.50	0.60	0.73	0.32	0.18	0.50	02	F8 IV
224995	00 02 24	+08 57.4	6.32	0.68	0.86	0.44	0.18	0.10	0.27	02	A6 V
225003	00 02 30	+08 29.2	5.63	0.54	0.67	0.52	0.25	0.14	0.36	02	F0 V

Table B.2: Bright, southern stars selected for use as secondary standards.

HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
000496	00 09 24	-45 44 42	4.91	3.88	K0 III	001581	00 19 51	-64 53 28	4.81	4.20	F9 V
002151	00 25 12	-77 15 32	3.42	2.80	G2 IV	002261	00 26 16	-42 18 03	3.46	2.37	K0 III
002262	00 26 12	-43 40 50	4.11	3.90	A7 V	002834	00 31 24	-48 48 14	4.79	4.77	A0 V
002884	00 31 32	-62 57 27	4.30	4.40	B9 V	002885	00 31 33	-62 57 54	4.69	4.54	A2 V+...
003919	00 41 20	-46 05 06	5.56	4.59	G8 III	004150	00 43 21	-57 27 48	4.36	4.36	A0 IV
006595	01 06 05	-46 43 08	4.21	3.31	G8 IIIvar	007570	01 15 09	-45 32 03	5.54	4.96	F8 V
007788	01 15 42	-68 52 40	4.73	4.25	F6 IV	009362	01 31 14	-49 04 30	4.94	3.95	G9 III
010144	01 37 42	-57 14 11	0.30	0.50	B3 Vpe	011977	01 54 55	-67 38 54	5.64	4.69	G8.5 III
011937	01 55 54	-51 36 47	4.55	3.70	G8 IIIbCN	012055	01 57 09	-47 23 07	5.71	4.83	G8 III
012311	01 58 44	-61 34 13	3.14	2.90	F0 V	014228	02 16 30	-51 30 43	3.44	3.60	B8 IV-V
015008	02 21 45	-68 39 34	4.12	4.10	A3 V	015371	02 26 59	-47 42 14	4.11	4.20	B5 IV
016754	02 39 47	-42 53 29	4.81	4.75	A2 V	016978	02 39 35	-68 16 01	4.05	4.11	B9 V
016815	02 40 39	-39 51 18	5.13	4.11	K0 III	017566	02 45 32	-67 37 03	4.90	4.84	A2 IV-V
017652	02 49 05	-32 24 30	5.45	4.46	G8.5 IIIb	018293	02 50 29	-75 03 60	6.08	4.75	K3 III
018623	02 58 17	-40 18 18	4.4	4.3	A1 V	018866	02 58 48	-64 04 17	5.12	4.98	A4 IIIIm...
018622	02 58 16	-40 18 18	3.54	3.2	A4 III	020794	03 19 42	-43 04 48	4.98	4.27	G8 V
022001	03 29 20	-62 56 34	5.10	4.71	F5 IV-V	022663	03 37 06	-40 16 28	5.62	4.58	K1 III
023227	03 42 15	-31 56 19	4.84	5.00	B5 IV	023319	03 42 50	-37 18 45	5.79	4.59	K2.5 III
023817	03 44 10	-64 48 29	4.98	3.85	K2 III	024512	03 47 14	-74 14 26	4.86	3.24	M2 III
024071	03 48 35	-37 37 13	4.25	4.26	?	024072	03 48 35	-37 37 13	4.85	4.86	B9 V
024160	03 49 27	-36 11 59	5.12	4.17	G9 II-III	025422	03 58 45	-61 24 00	6.18	4.56	M2 III
025728	04 01 18	-61 04 49	6.39	4.97	K4 III	026612	04 10 50	-41 59 40	5.26	4.90	A9 V
026967	04 14 00	-42 17 30	4.96	3.86	K1 III	027256	04 14 25	-62 28 28	4.26	3.35	G8 II-III
027442	04 16 29	-59 17 59	5.52	4.44	K2 IVa	027376	04 17 53	-33 47 54	3.44	3.56	B9 V
028028	04 24 02	-34 01 04	5.45	3.96	K4 III	029291	04 35 33	-30 33 44	4.80	3.82	G8 IIIa
029875	04 40 34	-41 51 46	4.79	4.45	F2 V	032831	05 04 24	-35 28 57	5.75	4.55	K3 III
033262	05 05 31	-57 28 28	5.24	4.72	F7 V	034649	05 13 45	-67 11 09	6.11	4.83	K2.5 IIIa
034642	05 17 29	-34 53 26	5.83	4.83	K0 IV	036597	05 31 13	-35 28 13	5.01	3.87	K1 IIIa
037795	05 39 39	-34 04 26	2.52	2.60	B7 IVe	039014	05 44 47	-65 44 09	4.56	4.35	A7 V
039060	05 47 17	-51 04 04	4.02	3.80	A5 V	039523	05 49 49	-56 09 56	5.61	4.51	K1 III

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Table B.2 continued from previous page

HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
039425	05 50 57	-35 46 26	4.28	3.12	K2 III	040409	05 54 05	-63 05 50	5.70	4.66	K1 III-IV
040176	05 55 30	-37 07 14	6.08	4.97	K1 III	040494	05 57 32	-35 17 01	4.18	4.36	B2.5 IV
040808	05 59 09	-42 48 54	5.10	3.96	K0 III	042167	06 07 32	-37 15 11	4.91	5.00	B9 IV
043785	06 16 33	-35 08 30	5.37	4.37	K0.5 IIIa	044402	06 20 19	-30 03 48	2.83	3.00	B2.5 V
044762	06 22 07	-33 26 09	4.73	3.85	G7 II	045813	06 28 10	-32 34 50	4.31	4.50	B4 V
047306	06 34 59	-52 58 33	4.37	4.40	A0 II	047670	06 37 46	-43 11 45	3.06	3.20	B8 III
047973	06 38 38	-48 13 14	5.79	4.92	G8 III	050241	06 48 12	-61 56 42	3.48	3.30	A7 IV
050310	06 49 56	-50 36 49	4.13	2.93	K1 III	050235	06 50 52	-34 22 02	6.37	4.99	K5 III
051799	06 56 16	-48 43 16	6.64	4.95	M1 III	053811	07 03 54	-49 35 09	5.06	4.94	A4 IV
054893	07 08 51	-39 39 21	4.65	4.80	B2 IV-V	055865	07 08 45	-70 30 02	4.69	3.78	K0 III
056456	07 14 38	-48 16 18	4.66	4.76	B8.5 V	057623	07 16 50	-67 57 26	4.77	4.00	F6 II
056779	07 16 49	-36 35 34	4.86	5.00	B2 IV-V	056855	07 17 09	-37 05 51	4.32	2.70	K3 Ib
059717	07 29 14	-43 18 15	4.77	3.25	K5 III	059890	07 30 43	-30 57 44	5.58	4.60	G3 Ib
061248	07 35 40	-52 32 01	6.34	4.94	K3 III	061330	07 37 22	-34 58 07	4.44	4.53	B8 IV
061831	07 39 27	-38 18 30	4.65	4.80	B2.5 V	063295	07 41 49	-72 36 23	4.99	3.95	K0 III
063032	07 45 15	-37 58 07	5.34	3.61	K2.5 Ib-I	063744	07 48 20	-47 04 36	5.77	4.71	K0 III
063922	07 49 14	-46 22 24	3.93	4.11	B0 III	064440	07 52 13	-40 34 33	4.77	3.73	K1.5 II+...
064740	07 53 04	-49 36 48	4.40	4.60	B1.5 Vp	064760	07 53 18	-48 06 11	4.10	4.20	B0.5 Ib
065456	07 57 40	-30 20 05	4.94	4.79	A2 Vvar	066591	08 00 20	-63 34 04	4.65	4.82	B3 V
066811	08 03 35	-40 00 12	1.99	2.20	O5 Ia...	068520	08 07 56	-68 37 03	4.24	4.40	B6 IV
068456	08 09 02	-61 17 53	5.19	4.76	F5 V	068243	08 09 29	-47 20 44	4.04	4.27	B1 IV
068601	08 11 26	-42 59 14	4.93	4.75	A5 Ib	069142	08 14 03	-40 20 49	5.61	4.44	K1 II-III
070060	08 18 34	-36 39 38	4.67	4.40	A7 III	071243	08 18 30	-76 55 16	4.46	4.07	F5 III
071701	08 20 41	-77 29 06	5.51	4.35	K1 III	070555	08 21 23	-33 03 16	6.28	4.83	K1 III
071129	08 22 31	-59 30 35	3.14	1.86	K3 III+...	070930	08 22 32	-48 29 25	4.67	4.82	B1 V
071878	08 25 45	-66 08 05	4.90	3.77	K1 III	072127	08 29 28	-44 43 30	4.83	4.99	B2 IV
073389	08 35 19	-58 00 34	5.86	4.86	K0 III	073634	08 37 39	-42 59 21	4.25	4.10	A6 II
074439	08 37 09	-76 09 49	5.05	4.04	K2 II	074006	08 40 06	-35 18 29	4.91	3.97	G7 Ib-II
074180	08 40 38	-46 38 56	4.57	3.88	F3 Ia	074272	08 41 13	-47 19 02	4.89	4.77	A5 II
074575	08 43 36	-33 11 11	3.50	3.70	B1.5 III	074772	08 44 24	-42 38 58	4.94	4.07	G5 III
074956	08 44 42	-54 42 26	2.00	1.95	A1 V	075063	08 46 02	-46 02 30	3.91	3.90	A1 III

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Table B.2 continued from previous page

HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
075710	08 49 48	-45 18 29	4.98	4.95	A2 III	076728	08 55 03	-60 38 42	3.74	3.80	B8.5 II
076805	08 56 19	-52 43 25	4.57	4.69	B5 V	077258	09 00 06	-41 15 16	5.10	4.40	K0 III+...
078045	09 02 27	-66 23 41	4.14	4.00	A2.5 IVm	078004	09 04 09	-47 05 51	4.95	3.75	K2 III
078791	09 05 09	-72 36 09	5.09	4.50	F9 II	079447	09 11 17	-62 19 02	3.79	4.00	B3 III
080007	09 13 14	-69 43 07	1.68	1.70	A2 IV	079940	09 15 45	-37 24 47	5.07	4.62	F5 III
079917	09 15 37	-38 34 11	6.05	4.94	K0 III	080230	09 16 12	-57 32 28	5.97	4.34	M1 III
080404	09 17 06	-59 16 31	2.43	2.20	A8 Ib	081101	09 20 57	-62 24 17	5.75	4.81	G6 III
081188	09 22 07	-55 00 39	2.32	2.50	B2 IV-V	082150	09 29 15	-35 57 05	5.95	4.51	K3 IIIa
082434	09 30 43	-40 28 04	3.96	3.60	F3 IV+...	083058	09 34 09	-51 15 20	4.83	5.00	B1.5 IV
083183	09 34 27	-59 13 46	4.09	4.10	B5 II	083446	09 36 50	-49 21 20	4.52	4.40	A5 IV-V
083944	09 39 21	-61 19 42	4.45	4.50	B9 IV-V	085123	09 47 06	-65 04 19	3.23	2.96	A8 Ib
085622	09 51 41	-46 32 52	5.78	4.58	G5 Ib	086440	09 56 52	-54 34 04	3.46	3.50	B5 Ib
088206	10 08 56	-51 48 40	4.74	4.90	B3 IV	089080	10 13 45	-70 02 16	3.24	3.30	B8 IIIe
088955	10 14 45	-42 07 21	3.90	3.80	A2 V	089890	10 21 00	-56 02 04	4.38	4.50	?
090264	10 22 58	-66 54 06	4.86	4.97	B8 V	089998	10 22 20	-41 39 03	5.95	4.83	K1 III
090589	10 24 24	-74 01 52	4.35	4.00	F2 IV	090610	10 27 09	-31 04 04	5.70	4.25	K4 III
090853	10 27 53	-58 44 22	4.13	3.82	F2 II	091375	10 30 19	-71 59 32	4.78	4.74	A1 V
091496	10 31 02	-73 13 18	6.61	4.93	K4.5 III	091324	10 31 24	-53 43 06	5.39	4.89	F6 V
091942	10 35 35	-57 33 27	6.07	4.45	K3.5 II	092305	10 35 29	-78 36 28	5.69	4.11	M0 III
092139	10 37 19	-48 13 32	4.14	3.84	F4 IV+...	092397	10 38 45	-59 10 58	6.51	4.87	K4.5 III:
092449	10 39 18	-55 36 12	5.32	4.28	G2.5 Ib	093030	10 42 58	-64 23 40	2.54	2.78	B0 Vp
092938	10 42 14	-64 27 59	4.68	4.82	B4 V	093070	10 43 32	-60 33 60	6.28	4.57	K4 III
093194	10 44 07	-63 57 40	4.69	4.83	B5 Vn	093845	10 45 48	-80 32 25	4.26	4.40	B2.5 IV
093607	10 46 51	-64 23 00	4.70	4.85	B3 IV	093497	10 46 46	-49 25 09	3.59	2.69	G5 III+...
094510	10 53 29	-58 51 13	4.73	3.78	K1 III	094890	10 56 43	-37 08 10	5.63	4.60	K1 III
095370	11 00 09	-42 13 33	4.50	4.40	A3 IV	096566	11 06 33	-62 25 27	5.64	4.61	G8 III
097534	11 12 36	-60 19 03	5.15	4.60	A6 Iae	098718	11 21 01	-54 29 27	3.74	3.90	B5 Vn
098993	11 23 13	-36 09 54	6.46	5.00	K6 III	100407	11 33 01	-31 51 25	4.48	3.54	G7 III
100673	11 34 46	-54 15 51	4.54	4.62	B9 Ve	100841	11 35 47	-63 01 10	3.09	3.10	B9 III
101431	11 40 13	-34 44 40	4.63	4.70	B9 V	101570	11 40 54	-62 05 23	6.09	4.90	G3 Ib
102249	11 45 37	-66 43 45	3.80	3.64	A7 III	102365	11 46 38	-40 30 21	5.57	4.89	G5 V

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Table B.2 continued from previous page

HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
102350	11 46 31	-61 10 41	5.01	4.10	G5 Ib-II	102839	11 49 57	-70 13 32	6.37	4.97	G6 Ib
102776	11 49 41	-63 47 18	4.17	4.32	B3 Vne	103079	11 51 51	-65 12 21	4.79	4.90	B4 V
102964	11 51 09	-45 10 24	5.76	4.46	K3 III	104174	11 59 38	-78 13 18	4.85	4.91	B9 Vn
104671	12 03 03	-63 18 46	4.60	4.30	Am	105211	12 06 53	-64 36 47	4.49	4.20	F2 III
105382	12 08 05	-50 39 40	4.32	4.50	B6 IIIe	105937	12 11 39	-52 22 06	3.81	4.00	B3 V
106911	12 18 21	-79 18 44	4.14	4.30	B5 Vn	106983	12 18 26	-64 00 10	3.87	4.00	B2.5 V
107079	12 19 00	-55 08 34	6.59	5.00	M1 III	107446	12 21 23	-60 24 08	5.01	3.59	K3.5 III
108249	12 26 37	-63 05 56	2.3	2.09	B1 V	108250	12 26 31	-63 07 19	4.74	4.86	B4 IV
108248	12 26 36	-63 05 55	1.32	1.4	B0.5 IV	108257	12 26 32	-51 27 02	4.68	4.82	B3 Vn
108483	12 28 03	-50 13 49	3.72	3.91	B2 V	108903	12 31 10	-57 06 34	3.22	1.63	M3.5 III
109026	12 32 29	-72 07 58	3.72	3.90	B5 V	109787	12 37 43	-48 32 28	3.91	3.90	A2 V
110073	12 39 53	-39 59 13	4.56	4.64	B8 II-III	110335	12 41 57	-59 41 08	4.89	4.93	B6 IVe
110304	12 41 32	-48 57 34	2.16	2.20	A1 IV	110458	12 42 36	-48 48 45	5.75	4.66	K0 III
110829	12 45 37	-60 58 49	5.74	4.69	K0 III	110879	12 46 17	-68 06 28	2.87	3.00	B2.5 V
110956	12 46 23	-56 29 19	4.49	4.65	B3 V	111597	12 50 41	-33 59 56	4.87	4.91	A0 IV
111915	12 53 07	-48 56 34	5.70	4.33	K3.5 III	111968	12 53 26	-40 10 43	4.48	4.30	A7 III
112092	12 54 36	-57 10 39	3.86	4.03	B2 IV-V	112985	13 02 14	-71 32 54	4.80	3.62	K2 III
113314	13 03 33	-49 31 37	4.87	4.84	A0 V	113791	13 06 55	-49 54 21	4.08	4.27	B1.5 V
113703	13 06 17	-48 27 47	4.57	4.71	B5 V	114613	13 12 05	-37 48 13	5.55	4.85	G3 V
114837	13 14 17	-59 06 03	5.40	4.92	F7 IV	115211	13 17 13	-66 47 00	6.37	4.87	K2 Ib-II
115892	13 20 37	-36 42 40	2.79	2.70	A2 V	116087	13 22 38	-60 59 17	4.40	4.53	B3 V
116243	13 24 00	-64 32 07	5.38	4.50	G6 II	117440	13 31 03	-39 24 26	5.05	3.88	G9 Ib...
119756	13 45 43	-33 02 30	4.61	4.23	F3 IV	119834	13 46 39	-51 25 56	5.61	4.65	G9 III
120307	13 49 30	-41 41 14	3.19	3.40	B2 IV	120709	13 51 50	-32 59 38	4.43	4.56	B5 III
120955	13 53 12	-31 55 39	4.59	4.73	B4 IV	121263	13 55 33	-47 17 15	2.33	2.60	B2.5 IV
121474	13 57 39	-63 41 10	5.82	4.71	K0 III	121790	13 58 41	-44 48 11	3.67	3.90	B2 IV-V
121743	13 58 16	-42 06 01	3.62	3.80	B2 IV	122223	14 01 43	-45 36 11	4.94	4.30	F6 II
123139	14 06 43	-36 21 46	3.07	2.06	K0 IIIb	123569	14 09 56	-53 26 16	5.69	4.75	G8 III
123998	14 18 14	-81 00 24	5.16	4.91	A2m	125238	14 19 24	-46 03 28	3.37	3.55	B2.5 IV
125473	14 20 34	-37 53 06	4.02	4.00	A0 IV	125442	14 20 42	-45 11 10	5.08	4.77	F0 IV
125288	14 20 19	-56 23 11	4.45	4.30	B6 Ib	125628	14 22 37	-58 27 34	5.78	4.92	G8 III+...

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Table B.2 continued from previous page											
HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
126354	14 26 11	-45 22 45	4.78	4.40	A7 :+,...	124882	14 26 58	-83 40 04	5.63	4.32	K2 III
127381	14 32 37	-50 27 24	4.23	4.40	B2 III	128345	14 37 53	-49 25 31	3.90	4.00	B5 V
128621	14 40 01	-60 50 38	2.21	1.33	K1 V	129116	14 41 58	-37 47 35	3.83	4.00	B3 V
128898	14 42 32	-64 58 19	3.43	3.19	Ap...	129456	14 43 40	-35 10 16	5.40	4.05	K5 III
129685	14 44 59	-35 11 30	4.93	4.92	A0 V	129078	14 47 52	-79 02 40	5.26	3.83	K2.5 III
130807	14 51 38	-43 34 30	4.17	4.32	B5 IV	132058	14 58 32	-43 08 00	2.46	2.70	B2 III
132200	14 59 10	-42 06 14	2.93	3.10	B2 IV	133243	15 05 07	-47 03 01	4.68	4.82	B5 IV
133242	15 05 07	-47 03 03	4.58	4.72	B5 V	133955	15 08 51	-45 16 46	3.87	4.05	B3 V
134481	15 11 56	-48 44 13	3.82	3.87	B9.5 Vne	134505	15 12 18	-52 05 53	4.33	3.41	G8 III
134687	15 12 50	-44 30 01	4.65	4.82	B3 IV	135153	15 14 37	-31 31 09	5.28	4.91	F1 II
135379	15 17 31	-58 47 57	4.16	4.07	A3 V	135291	15 17 39	-63 36 38	6.11	4.86	K2.5 III
135734	15 18 32	-47 52 28	4.19	4.27	B8 Ve	135382	15 18 55	-68 40 44	2.89	2.90	A1 V
136422	15 21 49	-36 15 37	5.10	3.56	K5 III	136504	15 22 41	-44 41 21	3.19	3.40	B2 IV-V
136351	15 22 09	-47 55 33	5.50	5.00	F8 V	136664	15 23 09	-36 51 29	4.39	4.54	B4 V
136415	15 23 23	-59 19 12	4.70	4.51	B3-B4 V	136416	15 23 23	-59 19 12	4.70	4.51	F8
137058	15 25 20	-38 44 00	4.60	4.60	A0 IV	138690	15 35 08	-41 09 59	2.58	2.78	B2 IV
138769	15 35 53	-44 57 29	4.36	4.54	B3 IVp	138538	15 36 43	-66 18 59	5.28	4.11	K1.5 III
139127	15 38 04	-42 34 05	5.75	4.33	K4.5 III	139521	15 39 46	-34 24 42	5.66	4.67	G8 III
139664	15 41 12	-44 39 27	5.04	4.64	F5 IV-V	140008	15 42 41	-34 42 36	4.61	4.75	B5 V
141556	15 50 57	-33 37 36	3.91	3.95	B9 IV	141891	15 55 10	-63 25 30	3.14	2.85	F2 III
142629	15 56 54	-33 57 50	4.68	4.58	?	143009	15 59 30	-41 44 39	5.99	4.99	K0 II-III
143118	16 00 07	-38 23 47	3.19	3.41	B2.5 IV	143474	16 03 33	-57 46 27	4.87	4.63	A7 IV
143546	16 03 12	-49 13 47	5.57	4.65	G8 III	143699	16 03 24	-38 36 08	4.75	4.89	B6 IV
144294	16 06 36	-36 48 07	4.06	4.20	B2.5 Vn	144197	16 06 29	-45 10 25	4.95	4.72	Am
145397	16 13 29	-54 37 49	5.98	4.94	G8 III	145544	16 15 26	-63 41 08	4.96	3.80	G2 Ib-II
146143	16 17 01	-50 04 05	5.79	5.00	F9 Ia	146686	16 19 51	-50 09 17	5.10	4.02	G8 III
147971	16 27 11	-47 33 17	4.40	4.47	B4 V	147584	16 28 26	-70 05 09	5.46	4.91	F9 V
148703	16 31 23	-34 42 15	4.07	4.23	B2 III-IV	147675	16 33 29	-78 53 45	4.80	3.89	G9 III
149447	16 36 22	-35 15 20	5.73	4.16	K6 III	149324	16 43 09	-77 30 45	5.30	4.24	K0 III
150798	16 48 40	-69 01 38	3.36	1.92	K2 II-III	151249	16 49 47	-59 02 28	5.33	3.76	K5 III
151680	16 50 12	-34 17 23	3.44	2.29	K2.5 III	151985	16 52 20	-38 01 02	3.36	3.60	B2 IV

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Table B.2 continued from previous page

HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
152334	16 54 35	-42 21 29	4.99	3.62	K4 III	152786	16 58 37	-55 59 23	4.73	3.13	K3 III
152980	16 59 35	-53 09 39	5.51	4.06	K4 III	154090	17 04 49	-34 07 22	5.13	4.87	B1 Iae
155203	17 12 09	-43 14 06	3.74	3.33	F3 III-IV	156277	17 22 00	-67 46 13	5.99	4.78	K2 III
157244	17 25 18	-55 31 46	4.31	2.85	K3 Ib-II	157246	17 25 24	-56 22 39	3.21	3.30	B1 Ib
158408	17 30 46	-37 17 43	2.47	2.70	B2 IV	158427	17 31 51	-49 52 31	2.78	3.00	B2 Vne
158094	17 31 06	-60 40 57	3.52	3.60	B8 Vn	159217	17 35 40	-46 30 18	4.56	4.60	A0 V
159433	17 36 33	-38 37 57	5.38	4.29	K0 IIIb	159532	17 37 19	-42 59 52	2.27	1.90	F1 II
160032	17 40 23	-49 24 47	5.17	4.77	F3 IV	160635	17 45 44	-64 43 23	4.81	3.62	K2 II
161471	17 47 35	-40 07 37	3.54	3.00	F2 Iae	161840	17 49 10	-31 42 11	4.79	4.80	B8 V
161892	17 49 51	-37 02 37	4.38	3.21	K2 III	161912	17 50 11	-40 05 26	5.07	4.81	A2 Ib
163145	17 56 47	-44 20 31	6.07	4.86	K2 III	163376	17 57 48	-41 42 58	6.53	4.88	M0 III
163755	17 59 05	-30 15 12	6.89	4.99	M1 Ib	165135	18 05 49	-30 25 17	3.99	2.99	K0 III
165189	18 06 50	-43 25 24	5.17	4.94	A5 V	165024	18 06 38	-50 05 29	3.58	3.66	B2 Ib
165040	18 08 35	-63 39 57	4.57	4.35	A7 sp...	166063	18 11 14	-45 57 14	5.54	4.53	K0 III
168339	18 23 13	-61 29 38	5.84	4.36	K4 III	169022	18 24 10	-34 22 59	1.82	1.80	B9.5 III
169467	18 26 58	-45 58 04	3.34	3.50	B3 IV	169767	18 28 49	-49 04 03	5.15	4.13	G9 III
170465	18 31 45	-45 54 52	4.85	4.93	B6 IV	169978	18 31 22	-62 16 39	4.53	4.64	B7.5 III
170845	18 33 30	-42 18 44	5.65	4.64	G8 III	171759	18 43 02	-71 25 34	5.15	4.01	K0 III
172910	18 44 19	-35 38 30	4.69	4.87	B2.5 V	172555	18 45 26	-64 52 09	4.99	4.79	A5 IV-V
175510	18 58 28	-52 56 18	4.82	4.87	A0 V	176638	19 03 06	-42 05 40	4.73	4.80	B9.5 V
177474	19 06 25	-37 03 34	4.72	4.20	F7 IV-V	177873	19 08 21	-40 29 47	5.68	4.59	K1 III
178253	19 09 28	-37 54 12	4.15	4.11	A2 V	178345	19 10 02	-39 20 25	5.31	4.11	K0 II
181454	19 22 38	-44 27 32	3.91	4.01	B9 V	181623	19 23 13	-44 47 56	4.63	4.30	F2 III
181869	19 23 53	-40 36 52	3.87	4.00	B8 V	184127	19 35 13	-48 05 56	5.99	4.90	K0 III
188114	19 55 15	-41 52 09	5.21	4.13	K0 II-III	189103	19 59 44	-35 16 34	4.21	4.36	B3 IV
188228	20 00 34	-72 54 32	3.93	4.00	A0 V	189831	20 03 33	-37 56 22	6.18	4.77	K5 III
190056	20 04 19	-32 03 22	6.20	4.99	K1 III	190421	20 07 23	-52 52 52	6.56	4.94	M1 IIIb
190248	20 08 33	-66 09 59	4.32	3.56	G7 IV	193924	20 25 39	-56 44 02	1.74	1.94	B2 IV
195627	20 35 34	-60 34 45	5.04	4.80	F1 III	196171	20 37 34	-47 17 33	4.11	3.11	K0 IIICNv
197051	20 44 58	-66 12 12	3.58	3.42	A7 III	197157	20 44 01	-51 55 13	4.78	4.51	A7 III-IV
198232	20 49 58	-33 46 46	5.90	4.90	G7 III	198048	20 49 29	-46 13 38	6.41	4.89	K5 III

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Table B.2 continued from previous page

HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
198700	20 54 48	-58 27 14	4.90	3.65	K1 II	199951	21 01 17	-32 15 29	5.56	4.67	G4 III
202627	21 17 56	-32 10 20	4.77	4.70	A1 V	202730	21 19 51	-53 26 55	4.58	4.40	A5 V
203608	21 26 26	-65 22 39	4.71	4.22	F6 V	205478	21 41 28	-77 23 13	4.76	3.76	K0 III
206742	21 44 57	-33 01 28	4.29	4.30	A0 V	207971	21 53 55	-37 21 53	2.89	3.01	B8 III
208450	21 57 55	-54 59 34	4.68	4.40	F0 IV	209100	22 02 57	-56 45 03	5.75	4.69	K4.5 V
209688	22 06 07	-39 32 30	5.83	4.46	K3 III	209952	22 08 13	-46 57 33	1.61	1.70	B7 IV
210049	22 08 23	-32 59 18	4.55	4.50	A2 V	210066	22 08 26	-34 02 36	6.47	4.99	M1 III
210302	22 10 07	-32 32 55	5.40	4.92	F6 V	211088	22 15 37	-41 20 50	5.59	4.79	G8 III+,...
211416	22 18 31	-60 15 33	4.25	2.86	K3 III	212581	22 27 19	-64 58 00	4.45	4.50	B9.5 V
213009	22 29 16	-43 29 44	5.00	3.97	G7 III	213398	22 31 30	-32 20 45	4.30	4.29	A0 V
215104	22 43 30	-41 24 48	5.88	4.85	K0 III	215369	22 45 38	-53 30 02	6.03	4.85	K2 IIICNv
214846	22 46 05	-81 22 54	4.35	4.15	A9 IV-V	215643	22 47 16	-39 27 23	4.71	4.20	K0 III
215789	22 48 33	-51 18 58	3.57	3.49	A3 V	216336	22 52 32	-32 52 31	4.42	4.50	A0 III...
216763	22 55 57	-32 32 25	5.18	4.21	G8 III	217364	23 00 53	-52 45 15	5.10	4.12	G9 III
218227	23 06 53	-43 31 13	4.70	4.30	F5 me...	218670	23 10 21	-45 14 47	4.92	3.90	K1 III
219571	23 17 26	-58 14 13	4.39	3.99	F1 III	219784	23 18 49	-32 31 52	5.54	4.41	G8 III
221507	23 32 58	-37 49 08	4.28	4.37	B9.5 IVmn	221760	23 35 04	-42 36 55	4.79	4.71	A2 Vp...
222095	23 37 51	-45 29 32	4.82	4.74	A2 V	224392	23 57 34	-64 17 51	5.06	5.00	A1 V
224686	23 59 55	-65 34 37	4.42	4.50	B9 IV	224889	00 01 37	-77 03 48	6.05	4.78	K3 III

Table B.3: SPS stars selected for use as secondary standards.

HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
000636	00 10 03	-82 13 26	6.33	5.28	G8 III	001032	00 13 19	-84 59 39	7.49	5.77	M0.5 III
001237	00 16 05	-79 51 03	7.2	6.7	G6 V	004229	00 39 32	-85 42 03	8.06	6.80	K3 III
010693	01 37 22	-82 16 51	7.9	7.0	G5 III:+...	011025	01 37 27	-84 46 12	6.63	5.69	G8 III
010800	01 37 52	-82 58 36	6.48	5.87	G2 V	011604	01 47 48	-80 10 33	6.40	6.06	F0 IV
013121	01 55 41	-84 45 05	8.6	7.0	M1 III	025887	03 42 32	-85 15 45	6.40	6.41	B9.5 IV
029245	04 15 57	-84 10 56	8.1	7.0	K0-K1 III	028525	04 17 59	-80 12 54	6.53	5.69	K2.5 III+...
029116	04 20 58	-81 34 54	6.14	5.79	F1 III	029598	04 22 52	-82 53 57	6.96	6.77	A7 IV-V
034172	04 58 51	-82 28 14	6.78	5.85	G9 III	035798	05 12 26	-81 32 33	7.62	6.51	K1 III
039091	05 37 04	-80 29 01	6.25	5.67	G1 V	042556	05 40 01	-85 54 52	7.7	6.8	G8 III
050506	06 40 03	-80 48 51	5.84	5.61	A5 III	058805	06 46 59	-87 01 30	6.89	6.46	F3 V
074566	08 16 19	-86 33 29	6.8	6.7	A1 IV-V	072922	08 24 23	-80 55 02	6.71	5.69	G8 III
079837	08 56 47	-85 39 49	5.73	5.42	A8.5 IV	082554	09 24 12	-80 47 19	5.81	5.36	F4 IV
087971	10 00 45	-82 12 54	5.55	5.52	A0 IV	093845	10 45 48	-80 32 25	4.26	4.40	B2.5 IV
106461	12 18 50	-88 24 54	6.6	6.6	B9 V	111482	12 54 56	-85 07 25	6.48	5.46	K0 III
117374	13 40 60	-85 47 08	5.76	5.57	Am	123998	14 18 14	-81 00 24	5.16	4.91	A2m
124882	14 26 58	-83 40 04	5.63	4.32	K2 III	130650	15 01 50	-83 13 42	6.60	5.65	G9 III
131246	15 04 47	-83 02 17	6.95	5.65	G8 Ib	131596	15 11 08	-84 47 15	5.85	5.88	B9.5 V
137333	15 43 12	-84 27 59	5.68	5.57	A2 V	148527	16 45 53	-83 14 21	8.13	6.76	K4 III
148542	17 00 58	-86 21 51	6.09	6.06	A2 V	148451	17 16 08	-87 33 51	7.48	6.57	G5 III
155454	17 28 44	-82 46 46	6.7	6.6	B2 V	156513	17 31 27	-80 51 31	7.55	5.88	M3 III
159517	18 01 34	-85 12 46	6.89	6.45	F5 IV	162337	18 05 26	-81 29 09	7.85	6.35	K3.5 III
165338	18 28 06	-84 23 13	6.6	6.50	B8-9 V	167714	18 29 20	-80 13 55	7.11	5.95	K2 III
169904	18 42 14	-81 48 28	6.14	6.27	B8 V	164461	18 54 49	-87 36 14	6.56	5.27	K3 IIICN...
172882	18 55 59	-80 43 40	6.5	6.58	A0 V	172226	18 58 09	-83 25 17	6.5	6.4	B9-9.5 V
181466	19 34 59	-81 45 11	7.5	6.6	K0 III	186154	19 56 01	-81 20 60	7.79	6.39	K3.5 III
191220	20 24 54	-83 18 39	6.37	6.16	Am	193721	20 33 17	-80 57 53	6.91	5.77	G7 II
194612	20 38 19	-81 17 19	7.62	5.91	K5 III	194149	20 42 32	-84 24 25	7.1	6.94	A1m...
199509	21 09 15	-82 01 36	7.6	7.0	G3 V	199692	21 17 58	-85 12 04	8.1	7.0	K0 III
203153	21 31 22	-83 02 03	7.1	7.0	A2 V	202418	21 32 02	-84 48 35	7.85	6.45	K3 III
203955	21 33 20	-80 02 21	6.51	6.47	A0 V	203532	21 33 53	-82 40 59	6.51	6.38	B3 IV

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Figure 4.7: Star Chart for O Vel.

(marked with a colon in the table) they are actually the Cape values and were ignored when calculating the median values. The data given by Perry & Bond (1969) is originally from the SAO Catalog, while Eggen's (1983) values are from either the CPC Catalog or Lesh (1972). Again, the table was supplemented from the original catalogues for stars not observed by the authors. Lyngå and Hogg used the FK3 system, while Perry & Bond and Eggen used it's successor, the FK4 system. Comparisons between the different authors revealed that several stars common to Hogg and Eggen differ by exactly $0.006''/yr$ in Dec (marked by a colon under Eggen) — these were assumed to be values copied from the FK3 catalogues and corrected for systematic errors when transformed to the FK4 system and so were ignored when calculating the median values.

Figure 4.8 show histograms of the median values of the proper motions. The RA shows a bimodal distribution, probably due to the separation of field and cluster stars, while the Dec histogram hints at a similar bimodal distribution. As the field star contamination can be expected to increase with the fainter stars, following Lyngå (1961) the data was split into two groups (brighter and fainter than $V = 8.0$, see Table 4.8) and the median found for each. The brighter stars have (median) proper motions of $RA = -0.023 \pm 0.011''/yr$ and $Dec = +0.015 \pm 0.015''/yr$ while the fainter stars have $RA = -0.006 \pm 0.019''/yr$ and $Dec = +0.008 \pm 0.018''/yr$. According to Lyngå (1961), field stars at the distance of the cluster should have parallactic motions of -0.015 and $+0.006''/yr$ respectively and smaller values with increasing distance. Hence the results are consistent with the fainter stars being predominantly field stars.

Table 4.5 gives the available radial velocities (km/s) for O Vel from the literature. The authors are Feinstein (1961), Buscombe (1965), Perry & Bond (1969), Giesecking (1981), Eggen (1983), and Levato et al. (1988). Buscombe's data are the mean of his results plus measurements from the Lick, Cordoba and Stromolo observatories, while Eggen's are taken from Wilson (1953). Comparisons of the radial velocities between the different authors revealed a scatter generally consistent with the individual errors and showing no systematic differences, so the median for each star was calculated in the final column of the table.

A histogram of the (median) radial velocities is given in Figure 4.9, giving an average radial velocity of $13 \pm 9 km/s$ (the uncertainty of the mean is ± 1.5 and the median is $13.5 km/s$) — this compares well with Feinstein's mean (15 ± 1.8), Buscombe's (14 ± 0.7), and Levato (13 ± 1.6 , which is given as a typographical error of -13) while Perry & Bond and Eggen do not have sufficient values to allow useful mean values. This can also be compared with the theoretically expected variation in radial velocity for cluster members of $\sim 0.8 km/s$ (Buscombe 1965).

Several of the stars are listed as a known or suspected Spectroscopic Binary (SB) (usually on the basis of double-lined spectra) or showing variable radial velocities. As the stars were

Table 4.4: Proper motion for O Vel stars from the literature.

#	RA (0.001"/yr)					Dec (0.001"/yr)				
	Hogg	Lynga	P&B	Eggen	median	Hogg	Lynga	P&B	Eggen	median
01	-17	-17 :	-20	-16	-17	+24	+24 :	+19	+20	+20
02	-17	-07	-18	-19.3	-17	+11	+11	+21	+19.8	+15
03	-25	-25 :	-23	-16.9	-23	+03	+03 :	+08	+19.4	+08
04	-21	-25	-33	-25.4	-25	+24	+25	+18	+08.2	+21
05	-17	-17 :	-32		-25	+17	+17 :	+22		+20
06	-21	-21 :	-32	-16	-21	+23	+23 :	+29	+21.2	+23
07	-32	-32 :	-12	-30 :	-22	+18	+18 :	+12	+24 :	+15
08	-21	-21 :	-19	-19 :	-20	+43	+43 :	+40	+49 :	+41
09	-15	-15 :	-23		-19	+05	+05 :	+17		+11
10	-30	-32	-27		-30	+15	+15	+12		+15
11	-25	-34	-22	-22 :	-25	+27	+27	+24	+33 :	+27
12	-16	-16 :	+04		-06	-24	-24 :	-23		-23
13	-29	-30	-46	-27 :	-30	+10	+10	+19	+16 :	+10
14	-05	-05 :	-57	-02 :	-32	+21	+21 :	+04	+27 :	+12
15	-30	-29	-65		-30	+03	+05	+07		+05
16	-44	-41	-35	-42 :	-41	+17	+17	-08	+23 :	+17
17	-01	-01 :	-46		-23	-17	-17 :	-31		-24
18	-27	-24	-24		-24	+24	+20	+21		+21
19	-41	-37	-39	-39 :	-39	+33	+27	+30	+39 :	+30
20	+13	-11	+15		+13	+02	+15	-01		+02
21	-15	-15 :	-24	-13 :	-20	+10	+10 :	+00	+16 :	+05
22	-09	-12	-06		-09	+43	+38	+40		+40
23	-29	-29	-26	-27	-28	+19	+18	+16	+26	+18
24	-17	-23	-14		-17	-05	+20	-08		-05
25	-06	-06 :			-06	+02	+02 :			+02
26	+32	+15	+35		+32	-21	-15	-24		-21
27	-43	-43 :	-42	-40 :	-42	+46	+46 :	+43	+52 :	+44
28	-03	-13	+00		-03	+19	+24	+17		+19
29	-46	-32	-43	-44 :	-43	+18	+18	+15	+24 :	+18
30		+30			+30		+18			+18
31	-03	-06	+00		-03	-27	-16	-30		-27
32	-25	-25 :	-23		-24	+13	+13 :	+10		+11
33	-16	-11			-13	+16	+11			+13
34		-02			-02		+10			+10
35		-11			-11		+08			+08
36		-02			-02		+06			+06
37		+02			+02		-06			-06
38		-06			-06		+17			+17
39		-17			-17		-01			-01
40		+01			+01		+08			+08
41		-34			-34		+37			+37
42		+02			+02		-17			-17
43		+01			+01		-02			-02

Figure 4.8: Proper Motion distribution for the O Vel cluster.

Table 4.5: Radial velocity (*km/s*) for O Vel stars from the literature.

#	Feinstein	Buscombe	P&B	Giesecking	Eggen	Levato	median
01	+15.4	+16	+15		+17.1	+14	+15
02	+19.7 Var	+19 SB			+21.6	+12	+19
03	+12.0 SB	+12 SB				SB +16 SB	+12
04	+15.2	+15			+9 Var	+10	+13
05	+12.7 SB?	+15			+19.8	+13	+14
06	+24.9	+16 SB				SB +05 Var	+16
07	+04.2	+15				+13	+13
08		+21: SB				+09	+15
09		+10				+08 Var	+09
10	+12.0	+06 SB				+19	+12
11	+15 SB?	+15 SB				+12	+15
12		+06					+06
13	+09.0	-02				+13	+09
14		+10 SB				+06	+08
15	+12.5	+21					+17
16		+09 SB				+02 SB	+06
17		-03 SB					-03
18		+15					+15
19	+13.2	+06:				+08	+08
20	+31.6	+23		+8.0 SB?		+16	+20
21		+18 SB				+10 SB	+14
22		+22:				+08	+15
23	+09.3	+16				+15	+15
24		+03 SB					+03
25		+38				+31	+34
26		+03 SB				+50	+26
27		-08:				-09	-08
28		+15	+02			+03	+03
29		+19				+15 Var	+17
30							
31		+16					+16
32		+12				+14	+13
33		+16				+01	+08
34		+52:				+12	+32
35		+29:					+29
36		+13 Var	Var?				+13
37							
38		+06	-15				-04
39							
40							
41							
42							
43

Figure 4.9: Radial Velocity distribution for the O Vel cluster.

not generally observed over a sufficient time to find their centre-of-mass radial velocity, this is also reflected in the larger variation in radial velocities between different authors found for these stars. However, O Vel 3 was observed by Feinstein long enough to derive its orbital elements. Levato later re-observed this star and gave the following orbital elements based on all observations found in the literature (see Table 4.6).

Table 4.7 contains the membership assessments from the literature. Hogg (1960) and Lyngå (1961) based their membership on proper motions, while Feinstein (1961), Perry & Bond (1969), and Lyngå & Wramdemark (1984) used photometric results (colour excesses and distance modulus). Buscombe (1965) used radial velocities and spectroscopic classifications, while Levato

Table 4.6: Orbital elements of Spectroscopic binary O Vel 3.

<i>Period</i>	=	3.192276 ± 0.000008 days
T_o	=	2419729.49 ± 0.05 Julian days
e	=	0.05 ± 0.03
V_o	=	14.5 ± 1.2 km/s
Ω	=	288 ± 31 degrees
K	=	57 ± 1.6 km/s
$a \sin(i)$	=	$(2.4 \pm 0.085) \times 10^6$ km

et al. (1988) used radial velocities, proper motions and spectroscopic classifications. Finally, Stauffer et al. (1989) used proper motions and spectroscopic classifications. The last column gives the median membership value (i.e. majority of the membership assessments). The median values in parenthesis are for those stars with no assessments in the literature and result from fitting normal curves to the proper motion and radial velocity histograms using the median and standard deviations for the cluster, finding the probabilities that a star will have its particular values, multiplying these probabilities together and assigning yes/maybe/no values to the 70 and 40 percentage thresholds. To gauge the 'accuracy' of this simple assessment, these probabilities were calculated for all the stars and compared with the median values, indicating the probability assessment agrees about 50% of the time, and is within one assessment class (for example the median gives yes while the probability indicates maybe) about 70% of the time.

Table 4.8 lists all the visual magnitudes in the literature — these are from the UBV system unless stated otherwise. The earliest observations are from Lyngå (1959) (with a fuller report given later (Lyngå 1961)) and Hogg (1960). Perry & Hill (1969) made measurements in both the UBV and *uvby* systems, as did Eggen (1972, 1983), with the *y* magnitude taken as the visual magnitude. Note the typographical error by Eggen (1972); O Vel 36 (HD74340) should be $V = 9.84$, not 7.84. Rufener (1981) lists measurements of O Vel stars from the Geneva photometric system's catalog, with their M_V corresponding to a visual magnitude. The final authors are Lyngå & Wramdemark (1984). Comparisons between the different authors revealed colour dependent systematic errors in the V magnitude, probably due to incorrect transformations to the standard UBV system. As it was not possible to tell which system is closest to the standard, the median was calculated in the hope that both the systematic and random errors would be reduced.

Several of the brighter stars in the cluster have been investigated for variability. However the results are complicated by the fact that the comparison stars used in several investigations were found to be variable by others, as described next.

O Vel 1 (Omicron Velorum itself) was found to be a radial velocity and photometric variable by Van Hoof (1972) with a change in V of $0^m.03$ – $0^m.04$ and a period just over 3 *hours*, and confirmed by later observations (Van Hoof 1973). However Balona (1977) and Jakate (1979) found it to be constant (within $\pm 0^m.02$) over the order of nights. The Geneva catalog has a larger than usual dispersion and notes that it is listed in the GCVS (Rufener 1981). Later observations by Waelkens & Rufener (1983) in the Geneva system confirm a variability of $\pm 0^m.012$ in V with a period of ~ 2.7 *days*. Finally, Eggen (1983) finds it to vary over $\Delta V \approx 0.1$ and in H_β .

O Vel 2 was found to be variable (± 0.015) with a period of 0.0284 *days*. Note however that stars 1 and 5 were used as comparison stars and found to be stable. Balona (1982) also found

Table 4.8: Visual magnitude V for O Vel stars from the literature.

#	Lynga	Hogg	P&H		Eggen	Rufener	Eggen	L&W	median
			(V)	(uvby)	(UBV)	(Mv)	(uvby)		
01	3.61	3.67	3.64	3.63		3.606	3.60		3.62
02	4.84	4.90	4.89	4.88	4.78	4.804	4.85		4.85
03	5.19	5.27	5.21	5.23		5.176	5.21	5.20	5.21
04	5.48	5.52	5.50	5.50		5.441	5.48		5.49
05	5.52	5.56		5.54	5.47	5.487	5.49	5.52	5.52
06	5.57	5.62	5.60	5.59		5.548	5.58	5.56	5.58
07	6.46	6.48	6.47	6.48		6.429	6.47		6.47
08	7.67					7.647	7.67		7.67
09	7.07								7.07
10	7.23	7.27		7.27	7.27	7.215			7.27
11	7.29	7.31		7.31	7.28	7.275	7.31		7.30
12	7.36		7.40	7.38					7.38
13	7.39	7.41		7.41	7.38	7.362	7.38	7.38	7.38
14	7.58		7.60	7.59	7.55	7.541	7.56		7.57
15	7.59	7.60		7.60	7.54	7.548			7.59
16	7.68	7.69	7.70	7.70	7.66	7.655	7.68	7.68	7.68
17	7.79		7.79	7.77	7.78	7.729			7.78
18	7.81	7.88		7.85				7.83	7.84
19	7.85	7.89		7.86	7.83	7.817	7.86		7.86
20	7.96	7.98		7.96				7.92	7.96
21	8.17		8.17	8.14	8.14	8.113	8.12		8.14
22	8.35								8.35
23	8.55		8.57	8.56	8.52	8.526	8.55	8.53	8.55
24	8.60	8.63		8.63					8.63
25	8.68					8.659			8.67
26	8.68								8.68
27	8.77					8.753	8.78		8.77
28	8.88			8.93	8.91	8.885			8.90
29	9.09	9.12	9.10	9.10	9.09	9.073	9.08	9.11	9.10
30	9.21	9.32							9.25
31	9.38			9.42					9.40
32	9.38					9.357			9.37
33	9.59	9.69			9.59				9.59
34	9.62	9.66				9.606		9.62	9.62
35	9.66	9.74							9.70
36	9.83		9.88	9.87	9.84	9.824	9.86	9.84	9.84
37	9.95								9.95
38	10.15		10.18	10.17					10.17
39	10.16								10.16
40	10.33	10.36				10.288		10.31	10.32
41	10.63								10.63
42	11.48								11.48
43	11.57								11.57

O Vel 2 to be stable but Waelkens & Rufener (1983) find variations of ± 0.015 in V with a period of 1.553 *days* and Eggen (1983) notes it as a possible variable.

O Vel 3 is listed as appearing variable by Van Hoof (1973) but no other authors have noted any variability. Recall however that it was found to be a spectroscopic binary by Feinstein (1961) and Levato et al. (1988). O Vel 4 was used as a comparison star by Balona (1977) and found to be stable but Eggen (1983) states it varies by $\Delta V = 0.02$ with a period of 0.26 *days*.

Thus, it seems that the four brightest stars in the cluster are irregularly variable at the 0.01^m level with various periods ranging from hours to days. A possible explanation for the observations during which the stars appeared constant could be the presence of two, or more, frequencies (perhaps due to intrinsic and orbital variations) whose 'waves' approximately cancel out during certain (short) intervals.

There have been only four investigations using the UBV system, by Lyngå (1959), Hogg (1960), Perry & Hill (1969), and Eggen (1972). The results are shown in Table 4.9, with comparisons between the authors again revealing systematic differences so the median values will be taken as best representing the standard system.

Colour-Magnitude and Colour-Colour diagrams are shown in Figures 4.10 and 4.11. These show all candidate stars for the cluster and probable members (based on Table 4.7). The position of O Vel 1 in the Colour-Magnitude Diagram (CMD) and spectral type (B3 III-V) indicates it is probably just leaving the main sequence, consistent with a cluster age of 30×10^6 *years*. O Vel 24, although given as a probable member in Table 4.7, appears further off the main sequence than could be expected from observational errors and may not be a member. O Vel 40 is the faintest probable member, and is considered by Stauffer et al. (1989) to be a pre-main sequence star, again consistent with a cluster age of 30×10^6 *years*.

There have been only four investigations of O Vel in the *uvby* system; that of Perry & Hill (1969), Crawford et al. (1971), Eggen (1983), and Lyngå & Wramdemark (1984). These are summarized in Tables 4.10 and 4.11 and CMDs plotted in Figure 4.12 using the median values. O Vel 1 and O Vel 40 show the same behaviour seen in the UBV CMD, but the 'blue excess' stars do not (instead they generally lie on the main sequence). O Vel 24 still lies slightly to the left of the main sequence but is within the observational error.

Finally, measurements of the H_β index (using the extension to the *uvby* system) are summarized in Table 4.12. The authors are Graham (1967), Perry & Hill (1969), Crawford et al. (1971), Grønbech & Olsen (1977), Eggen (1983), and Lyngå & Wramdemark (1984). The median values are compared with the H_β -absolute magnitude calibration in Figure 4.13. O Vel 1 is again brighter than the ZAMS, but no conclusion can be drawn for O Vel 40 as it has not yet been observed in the H_β system.

Comparison between the CMDs and the absolute magnitude calibration of all candidate

Table 4.9: U-B and B-V colours for O Vel stars from the literature.

#	U-B					B-V				
	Lynga	Hogg	P&H	Eggen	median	Lynga	Hogg	P&H	Eggen	median
01	-0.67	-0.66	-0.66		-0.66	-0.18	-0.18	-0.18		-0.18
02	-0.67	-0.66	-0.66	-0.67	-0.66	-0.17	-0.18	-0.17	-0.16	-0.17
03	-0.60	-0.57	-0.58		-0.58	-0.14	-0.15	-0.15		-0.15
04	-0.59	-0.55	-0.58		-0.58	-0.15	-0.16	-0.15		-0.15
05	-0.57	-0.54		-0.54	-0.54	-0.15	-0.17		-0.13	-0.15
06	-0.54	-0.50	-0.50		-0.50	-0.13	-0.14	-0.14		-0.14
07	-0.33	-0.37	-0.32		-0.33	-0.09	-0.11	-0.10		-0.10
08	-0.04				-0.04	+0.08				+0.08
09	-0.46				-0.46	-0.11				-0.11
10	-0.17	-0.04		-0.11	-0.11	-0.01	-0.06		-0.05	-0.05
11	-0.11	+0.00		-0.025	-0.03	+0.01	-0.03		-0.00	-0.00
12	-0.03		+0.07		+0.02	+0.29		+0.26		+0.27
13	-0.08	+0.01		+0.025	+0.01	+0.02	-0.02		+0.03	+0.02
14	-0.01		+0.06	+0.08	+0.06	+0.08		+0.08	+0.08	+0.08
15	-0.01	+0.02		+0.08	+0.02	+0.27	+0.22		+0.27	+0.27
16	-0.03	+0.02	+0.05	+0.065	+0.03	+0.10	+0.04	+0.07	+0.09	+0.08
17	+0.02		+0.13	+0.12	+0.12	+0.20		+0.19	+0.19	+0.19
18	+0.20	+0.16			+0.18	+0.66	+0.65			+0.65
19	-0.01	+0.02		+0.06	+0.02	+0.11	+0.05		+0.10	+0.10
20	-0.50	-0.40			-0.45	+0.02	+0.02			+0.02
21	+0.00		+0.11	+0.07	+0.07	+0.21		+0.19	+0.21	+0.21
22	-0.11				-0.11	+0.04				+0.04
23	+0.02		+0.06	+0.06	+0.06	+0.20		+0.24	+0.24	+0.24
24	+0.06	+0.03			+0.04	+0.15	+0.11			+0.13
25	+0.04				+0.04	+0.22				+0.22
26	+0.82				+0.82	+1.06				+1.06
27	-0.07				-0.07	+0.36				+0.36
28	-0.04			-0.06	-0.05	+0.44			+0.43	+0.43
29	-0.07	+0.02	-0.02	-0.055	-0.04	+0.35	+0.37	+0.36	+0.36	+0.36
30	+0.75	+0.76			+0.75	+1.05	+1.05			+1.05
31	+0.03				+0.03	+0.12				+0.12
32	-0.08				-0.08	+0.44				+0.44
33	-0.15	+0.02		-0.08	-0.08	+0.44	+0.42		+0.50	+0.44
34	-0.08	+0.02			-0.03	+0.46	+0.46			+0.46
35	+1.00	+1.14			+1.07	+1.20	+1.21			+1.20
36	-0.06		-0.04	-0.055	-0.05	+0.49		+0.46	+0.45	+0.46
37	+0.12				+0.12	+0.64				+0.64
38	+0.05		+0.14		+0.10	+0.18		+0.15		+0.17
39	+0.03				+0.03	+0.19				+0.19
40	+0.18	+0.17			+0.17	+0.68	+0.68			+0.68
41	-0.36				-0.36	+0.15				+0.15
42						+1.82				+1.82
43	-0.01				-0.01	+0.35				+0.35

Figure 4.10: Colour-Magnitude diagram of O Vel, using the median values from the UBV literature. The line is the ZAMS, taken from Johnson (1963, page 216, Table 4) and assuming a distance modulus of 5.94 ($= 154$ pc). The top diagram is for all stars from Lyngå's list while the bottom diagram are the probable members according to the median column of Table 4.7.

Figure 4.11: Colour-Colour diagram of O Vel, using the median values from the UBV literature. The line is the main sequence, taken from Tables 14 and 15 of Straižys (1992). The top diagram is for all stars from Lyngå's list while the bottom diagram are the probable members according to the median column of Table 4.7.

Table 4.10: $b-y$ colours for O Vel stars from the literature.

#	P&H	Crawford	Eggen	L&W	median
01	-0.075		-0.080		-0.077
02	-0.071	-0.078	-0.075		-0.075
03	-0.073	-0.098	-0.070	-0.061	-0.072
04	-0.070	-0.079	-0.070		-0.070
05	-0.085		-0.078	-0.073	-0.078
06	-0.054	-0.058	-0.060	-0.053	-0.056
07	-0.040		-0.040		-0.040
08			+0.029		+0.029
09					
10	-0.042				-0.042
11	-0.010		-0.011		-0.010
12	+0.163				+0.163
13	-0.005		-0.005	+0.008	-0.005
14	+0.029		+0.031		+0.030
15	+0.134				+0.134
16	+0.028		+0.025	+0.045	+0.028
17	+0.099				+0.099
18	+0.419			+0.428	+0.423
19	+0.024		+0.025		+0.024
20	+0.029			+0.054	+0.026
21	+0.123		+0.110		+0.016
22					
23	+0.140		+0.140	+0.154	+0.140
24	+0.074				+0.074
25					
26					
27			+0.244		+0.244
28	+0.288				+0.288
29	+0.242		+0.240	+0.255	+0.242
30					
31	+0.052				+0.052
32					
33					
34				+0.321	+0.321
35					
36	+0.320		+0.310	+0.327	+0.320
37					
38	+0.106				+0.106
39					
40				+0.435	+0.435
41					
42					
43

Figure 4.12: Colour-Magnitude diagram of O Vel, using the median values from the *uvby* literature. The line segments are the main sequence, taken from Tables 35, 39, 40, 42 and 43 of Straižys (1992) and assuming a distance modulus of 5.94 ($= 154$ pc). The top diagram is for all stars from Lyngå's list while the bottom diagram are the probable members according to the median column of Table 4.7.

Table 4.12: H_{β} colours for O Vel stars from the literature.

#	Gra.	P&H	Craw.	Gron.	Eggen	L&W	median
01	2.66	2.666			2.66V	2.674	2.663
02	2.68	2.688	2.674	2.689	2.695	2.689	2.689
03	2.68	2.713	2.692	2.760	2.710		2.710
04	2.70	2.717	2.693	2.712	2.710		2.710
05	2.73	2.723		2.732	2.730	2.728	2.730
06	2.69	2.710	2.681	2.712	2.710	2.712	2.710
07	2.76	2.778		2.790	2.785		2.782
08					2.879		2.879
09							
10	2.85	2.855					2.852
11	2.85	2.896			2.892		2.892
12		2.788					2.788
13	2.85	2.911			2.916	2.920	2.914
14		2.900			2.894		2.897
15		2.831					2.831
16		2.887			2.899		2.893
17		2.857					2.857
18		2.598				2.586	2.592
19		2.918			2.903		2.910
20		2.705				2.705	2.705
21		2.834			2.830		2.832
22							
23		2.801			2.800	2.801	2.801
24		2.860					2.860
25							
26							
27					2.681		2.681
28		2.663					2.663
29		2.703			2.700	2.699	2.700
30							
31		2.864					2.864
32							
33							
34							
35							
36		2.635			2.637		2.636
37							
38		2.833					2.833
39							
40							
41							
42							
43

Figure 4.13: H_β -Absolute Magnitude diagram of O Vel, using the median values from the *uvby* literature. The lines are the H_β -absolute magnitude calibration for the ZAMS, taken from Tables 39, 40, 42, and 43 of Straižys (1992). The top diagram is for all stars from Lyngå's list while the bottom diagram are the probable members according to the median column of Table 4.7 and assuming a distance modulus of 5.94 ($= 154 \text{ pc}$).

stars and probable members of the O Vel cluster imply the membership assessments given in Table 4.7 are reliable in the sense that few, or none, of the stars are incorrectly assessed as members (i.e. false-positive) — the most likely false-positive star being O Vel 24. Similarly, there appear to be no stars incorrectly assessed as non-members (i.e. false-negative) — as the few non-members which appear near the main sequence in the UBV CMD are not near the *uvby* main sequence and vice versa.

4.3 Vilnius Photometry of the Omicron Velorum cluster.

Recall the purpose of the observations of the O Vel cluster was to compare the analysis from Vilnius photometry alone with those found by other photometric and spectroscopic systems. For this reason, none of the prior knowledge available from the literature was assumed when analyzing the results from the Vilnius observations.

The individual observations are given in Table D.5, while the mean results for each star is given in Table E.8. At the precision level achieved by this study ($0^m.02$ for a single observation), none of the observed stars were found to be variable. As a further check, the standard deviation of the mean for each star was compared with the expected deviation for a star with n observations, using the formula found for primary standards in Figure 3.3 — no stars were indicated as variable using this criteria. To investigate possible variability to higher precision would require dedicated programs of differential photometry, which may be undertaken at a later date. The Vilnius mean V magnitudes compare well with the visual magnitudes found in the literature (see Table 4.8); $\sim 50\%$ agree within $\pm 0^m.01$ of the median value, $\sim 90\%$ within $\pm 0^m.02$ and all but two stars lie within the range covered in the literature.

The next stage in the analysis is to derive the spectral classification of each star, in this case using the Vilnius Q-Search, Q-Spectra and QQ-diagrams methods described in Chapter 1 (sections 1.8, 1.9, and 1.11 respectively), with the results given in Table 4.13. The Q-Search results list the spectral types one standard deviation above and below the mean value, and note in parenthesis any peculiarities of the matching reference stars. The Q-Spectra notes the 'graphical shifting' factor as $1 + a$, with 1.00 meaning no shifting was required to achieve a good match. If the match of the closest reference spectra appeared to be worse than would be expected from the observational errors, then '(p)' follows the spectral type. Recall the QQ-diagrams are calibrated in absolute magnitudes rather than luminosity class, and may also indicate possible spectral peculiarities. Finally, an 'average' spectral type is assigned in the last column. These were compared with the spectral types from the literature (see Table 4.3); $\sim 55\%$ agree within ± 1.0 spectral sub-classes, which is the expected standard deviation of the classification methods (see Chapter 1, sections 1.8 and 1.9), and all agree within ± 3.0 spectral

sub-classes. Three stars have been classified for the first time; O Vel 37 (G2 V), O Vel 40 (G1 V) and O Vel 41 (B6 V).

Given the spectral type of each star (the 'average' column of Table 4.13), the average reddening and distance modulus can be found for the cluster as follows;

1. Using the spectral and luminosity class, look up the intrinsic magnitude V_0 and colour $(Y-V)_0$ from Appendix 1 and Table 73 of Straižys (1992) for each star.⁴
2. Calculate the colour excess for each star from the intrinsic and apparent (reddened) colour using $E_{Y-V} = (Y-V) - (Y-V)_0$.
3. Calculate the distance modulus for each star, using the 'extinction to colour excess' ratio (R) from Table 74 of Straižys (1992) and $m-M = V-V_0 - RE_{Y-V}$.⁴
4. Examine the distribution of distance moduli and calculate the mean ($\langle m-M \rangle$) from the probable members.⁵ Alternatively, use the median value.
5. Re-calculate the intrinsic magnitude for each star using the mean distance modulus ($V_0 = V - \langle m-M \rangle - RE_{Y-V}$).
6. Lookup the intrinsic colour $(Y-V)_0$ using the spectral type and intrinsic magnitude with Table 73.
7. Return to step 2 and repeat until the iterated mean distance modulus converges. Note that the distance moduli and colour excess of the individual stars will only converge for cluster members.

This gives the cluster's distance moduli as 5.94 ± 0.02^6 and a distribution about the mean measured by a standard deviation of 0.03. Similarly, the mean colour excess is 0.00 ± 0.02^7 with a distribution of 0.03 (which is strongly correlated with the distance moduli). Assuming the cluster is spherical, its angular diameter ($\sim 45'$) at the mean distance corresponds to a spread in the distance moduli for individual cluster members of ± 0.03 . Thus it seems reasonable that the entire spread in values is due to the differences in distance moduli of individual cluster stars and that there is no interstellar material causing reddening along the line of sight to the cluster.

Once the cluster's distance modulus and colour excess have been determined, then the distance and excess of individual stars may be used to decide on the star's cluster membership.

⁴See Appendix J for a copy of these tables.

⁵Convert the distance moduli into linear units, for example *parsecs* via $\rho = 10^{(m-M-5)/5}$, before calculating the mean.

⁶This is the standard deviation of the mean.

⁷Although negative colour excesses have no physical meaning, they can arise due to observational and calibration errors in the case of weak, or zero, reddening and should be retained for the purpose of calculating means.

A histogram of the distance moduli (for a fixed, zero colour excess) was examined, with stars outside the cluster's distribution considered non-members and stars in the tails of the distribution considered 'maybe' members. The results are shown in Table 4.14; note that the 'partial' disagreement for O Vel 40 may be due to an incorrect spectral classification from the Vilnius photometry, as it is probably a pre-main sequence star (for which the Vilnius system is not calibrated). Only two stars show complete disagreement; O Vel 37 was assessed from the radial velocity and proper motions studies rather than directly by the authors, while O Vel 17 is considered a cluster member by one (of the three) authors in the literature so a 'maybe' membership assessment could be more accurate - note how the Vilnius assessment is revised to a 'maybe' by examination of the spectral sequence in the CMD (see later).

Figure 4.14 shows the CMD after correcting for the cluster's mean distance modulus and reddening. The error bars in the top diagram indicate more observations need to be made of the fainter stars ($V_0 > 2 \iff V > 8$) before analysis of the (fainter) probable cluster members can be done with confidence. The bottom diagram show the probable members; the various sequences indicate that O Vel 1 appears to be B4 III rather than B4 IV, the stars O Vel 2-7 may have moved off the ZAMS to the main sequence, O Vel 24 again appears too far to the left of the ZAMS to be a member, and that O Vel 37 and 40 are pre-main sequence stars. The

Colour Magnitude diagram: All possible members of O Vel

Colour Magnitude diagram: probable members of O Vel

Figure 4.14: Colour-Magnitude diagrams of O Vel from Vilnius photometry. The top diagram, with all candidate members of the cluster, has error bars indicating the size of the standard deviation of the mean magnitudes and colours for each star, and the ZAMS taken from Straižys (1992) (shown by a dashed line). The bottom diagram shows the probable cluster members (according to median column of Table 4.14) and the ZAMS, main, and giant sequences.

the median age from the literature (30×10^6 years, see Table 4.1).

Figure 4.15: Vilnius isochrones for O Vel. The top diagram compares different metallicities (for an approximate age) to the probable members of O Vel, while the bottom diagram compares different ages for the best fitting metallicity.

Table 4.13: Spectral Classifications of O Vel stars from Vilnius photometry.

#	Q-Search	Q-Spectra		QQ-diagrams			average
1	B3-5 IV-V	B3-4 IV	1.00	B3-5	-1		B4 IV
2	B3-5 IV-V	B5 V (p)	1.00	B4	-0.2	dble?	B4 IV
3	B6 V (SB)	B5 V	1.00	B5	+0.05		B5 V
4	B4-6 V (SB)	B5 V	1.50	B5.3	+0.2		B5 V
5	B5-7 IV-V (SB)	B6 V	1.20	B6	+0.5	dble?	B6 V
6	B5-7 III-V	B5 III	1.00	B6	+0.05		B6 V
7	B9 V	B8 IV-V	1.00	B8.1	+1.05		B8 V
8	A1-5 V	A5 V	1.00	A3	+2.1		A4 V
9	B7-9 III-V	B6 V	1.40	B6.5	+0.5		B6 V
10	A1 IV-V (SB?)	A1 V	0.65	A1	+2	Bp(Si)? or Ap?	A1 V
11	A0-2 V	A1 V	1.00	A1	+2		A1 V
12	A6-F1 III-V	A7 V	1.00	A7	+2.8	Ap?	A7 V
13	A0-2 V	A2 V	1.00	A1	+2.5		A1 V
14	A0-4 V	A3 V (p)	1.00	A3	+2.4		A3 V
15	A4-F1 IV-V (m?)	F0 IV	1.00	A6.5	+3.1		A6 V
16	A0-4 V	A5 V	1.00	A3	+2.6		A4 V
17	A4-8 V (m)	A7 V	1.00	A6	+2.4	Am?	A6 V
18	G4-8 V	G2 V	1.00	G5?	+6.7	sd?	G4 V
20	B3-7 IV-V	B6 V	0.89	B5.3	-0.3	reddened?	B5 V
21	A3-9 V	A3 V	0.85	A6	+2.2		A4 V
23	A3-F0 V (m)	A7 V	1.10	A7	+3.1	Ap?	A7 V
24	A1-7 V	A3 IV	1.00	A4	+2.0		A4 V
25	A3-7 V	A5 V	1.00	A6	+2.7	Am?	A5 V
27	F1-5 IV-V	F2 V	1.00	F4	+3.5		F3 V
28	F6-8 V	F8 V (p)	1.00	F6	+4		F7 V
29	F2-6 III-V	F5 V	1.00	F4	+3.5		F4 V
30	G8-K0 III	K0 IV	1.00	G9-K0	+1.8		K0 IV
32	F5-7 V	F5 V	0.91	F6	+4	Am?	F5 V
33	F6-8 V	F8 V	0.93	F6	+5		F7 V
34	F7-9 V	F8 V (p)	0.90	F2?	+5?		F8 V
35	K2 V	K3 V (p)	1.05	K2	+4.2	sd? or carbon?	K2 V
36	F6-8 V	F8 V (p)	0.88	F5-6	+4.5		F7 V
37	G1-7 V	G2 V (p)	1.00	G5?	+6.7	sd?	G2 V
38	A2-6 IV-V	A2 III	0.83	A4	+1.7		A3 V
40	G0-4 IV-V	G0 V (p)	1.06	G9	+7.8	sd	G1 V
41	B6-8 III-V	B6 V (p)	1.09	B6.7	+0.6	Be? or reddened?	B6 V

Table 4.14: Membership of O Vel stars from Vilnius photometry. The second column is based on the distance modulus and colour excess analysis from the Vilnius photometry. The third column is the revised memberships (showing only the changes from the previous column), based on the spectral classes sequence in the CMD. The fourth column is copied from the median column of Table 4.7 for comparison.

#	member?			#	member?		
	Vilnius m-M	Sp	Literature (median)		Vilnius m-M	Sp	Literature (median)
1	yes		yes	20	no		no
2	yes		yes	21	yes		yes
3	yes		yes	23	yes		yes
4	yes		yes	24	yes		yes
5	yes		yes	25	yes		maybe
6	yes		yes	27	yes		maybe
7	yes		yes	28	yes		maybe
8	yes		yes	29	yes		yes
9	yes	maybe	maybe	30	no		(no)
10	maybe		yes	32	yes		yes
11	yes		yes	33	yes		yes
12	maybe		maybe	34	yes		yes
13	yes		yes	35	no		no
14	maybe		yes	36	yes		yes
15	maybe		maybe	37	yes		(no)
16	yes		yes	38	no		no
17	yes	maybe	no	40	maybe		yes
18	no		no	41	no		(no)

4.4 Literature review of the Kappa Crucis cluster.

The κ Crucis cluster⁸ is located at RA = 12^h53^m, Dec = -60°17' or galactic coordinates $l = 303^\circ$, $b = +2^\circ$, with an angular diameter of $\sim 5.1'$ (Dachs & Kaiser 1984). The numbering scheme of Dachs & Kaiser was adopted, which is based on the first photoelectric study of the cluster by Arp & Van Sant (1958) with the quadrant number becoming the hundred's digit, for example II-06 becomes 206.

A summary of the cluster's characteristics found by different authors is given in Table 4.15. Arp & Van Sant (1958) find the cluster age between that of the $h+\chi$ Persei and Pleiades clusters, with star A assumed to be at the Schonberg-Chandrasekhar limit giving an age of 3×10^6 years. Assuming $E_{B-V} = 0.44$, Hernández (1960) calculated the cluster's distance via an absolute magnitude/spectral type calibration. The other authors used a variety of similar calibrations involving intrinsic colours or reddening-free parameters, for example Graham (1967) used a preliminary H_β /absolute magnitude calibration and a UBV intrinsic colour/spectral type calibration to derive reddening and distance of the cluster. Shobbrook (1984) converted $E_{b-y} = 0.44$ to E_{B-V} using the colour excess ratio $E_{b-y}/E_{B-V} = 0.74$, while the mean reddening $E_{b-y} = 0.278$ found by Balona & Koen (1994) was converted using the colour excess ratio appropriate to B-type stars ($E_{b-y}/E_{B-V} = 0.77$, from Straižys (1992, Table 34)). Dachs & Kaiser (1984) find two overlapping ages for the cluster, based on age calibrations of the intrinsic colours of the bluest stars in a cluster and the bolometric magnitudes of cluster blue supergiants, while Balona & Koen fit isochrones to the CMD.

As the calculated intrinsic magnitude is a function of both the apparent magnitude and colour excess ($V_0 = V - RE_{B-V}$, see section 1.4), it follows that the derived cluster distance and colour excess will be correlated. Hence, to compare results from the different authors, the colour excesses and distance modulus were plotted in Figure 4.16. This shows that all except Arp & Van Sant (1958), Becker (1961, 1963), and Mermilliod & Maeder (1986) fall about the straight line defined by the median value with a slope equal to the ratio of extinction to colour excess (R , taken as 3.0). However the values from Mermilliod & Maeder are "critically evaluated" averages from a literature survey — as their distance modulus is significantly above the main trend, this implies there must be other results (with greater distance moduli) that are not included in Table 4.15.

Different authors have used a variety of other naming systems for the stars in the cluster, which have been summarized in Table 4.16. The RA and Dec (in hours, minutes, seconds and degrees, minutes, seconds respectively) are taken from King (1980) and are to the Epoch 1950. Coordinates marked with an asterisk were calculated by calibrating the CCD (x,y) coordinates

⁸So named due to the bright star κ Crucis (star B using the numbering system adopted here) near the middle of the cluster. The κ Crucis cluster is also known as NGC 4755 or C1250-600 using it's IAU designation.

Table 4.15: Review of main characteristics of Kappa Crucis.

author	distance (<i>pc</i>)	reddening (E_{B-V})	age (<i>years</i>)
Arp & Van Sant (1958)	830 ± 230	0.31 ± 0.03	3×10^6
Wallenquist (1959)	1445 ± 200		
Hernández (1959)	2630		
Hernández (1960)	2100	0.44 (assumed)	
Becker (1961)	1585	0.44	
Becker (1963)	1050	0.31	
Buscombe (1963)	2290	0.40	
Feast (1963)	2355 ± 150	0.48 ± 0.01	
Kennedy (1966)	2400	0.46	
Graham (1967)	2250 ± 1000	0.40	
Schild (1970)	2090	0.42	
Becker & Fenkart (1970)	1035	0.31	
Perry et al. (1976)	2290 ± 210	0.40 ± 0.01	
Kaiser (1980)	2290	0.44	
Mermilliod (1981)	1845	0.35	
Shobbrook (1984)	1900	0.38 ± 0.03	
de Waard et al. (1984)	1780 ± 200	0.36 ± 0.04	
Dachs & Kaiser (1984)	2310 ± 70	0.44 ± 0.04	$8.3 - 11.5 \times 10^6$ $7.8 - 10.4 \times 10^6$
Brown et al. (1986)	1910 ± 330	0.39 ± 0.04	
Mermilliod & Maeder (1986)	3090	0.35	11×10^6
Balona & Koen (1994)	2040 ± 47	0.36 ± 0.05	$(10 \pm 2) \times 10^6$
median	2075	0.40	10×10^6

of Balona & Koen (1994) with King's coordinates, and using the CCD coordinates to fill in the equatorial coordinates missing from King's list. The two coordinates marked with ':' were interpolated from known coordinates of other stars using the finding chart (Figure 4.17). The CD, CPD and CPC numbers are for declination -59° , -59° and zone 20.1 respectively. The question marks indicate there is some disagreement between authors regarding the catalog number, for example CPD $-59^\circ 4553$ is listed as star 103 by several authors but given as star R by the SIMBAD database. Where two numbers are given, the first is from the SIMBAD database while the second is from Perry et al. (1976) and later authors.

A star chart of κ Crucis suitable for viewing through a finder scope was prepared using the numbering scheme of Dachs & Kaiser (1984) and is shown in Figure 4.17.

Table 4.17 gives the spectral classifications found in the literature for κ Crucis, which are all based on spectroscopic observations. The authors are, in left to right order, Bidelman (1954), Arp & Van Sant (1958), Hernández (1960), Feast (1963), Schild (1970), Sowell (1987), and Slettebak (1985). The results of Arp & Van Sant are from the unpublished (1958) observations of Gratton and Hernandez. They also quote Bidelman's spectral classes, but mix up stars A and C according to Hernández (1960). The most complete list is from Feast, with the other

Figure 4.16: Distance modulus and colour excess for Kappa Crucis from the literature. The straight line passes through the median value (see Table 4.15) with a slope R (the ratio of extinction to colour excess, taken as 3.0). The asterisk symbol is the value from this study, after converting from the Vilnius to Johnson systems.

Figure 4.17: Star Chart for Kappa Crucis. The cluster is approximately centered around $RA = 12^h53^m$, $Dec = -60^\circ17'$.

Table 4.16: Synonyms for Kappa Crucis's stars.

D&K	RA	Dec	HD	SAO	HR	CD	CPD	CPC
A	12 50 22	-60 03 25	111904	252069	4887	4455	4529	3732
B	12 50 49	-60 06 17	111973	252077	4890	4460	4555	3740
C	12 51 00	-60 03 51	111990	252080		4461	4566	3743
D	12 50 41	-60 04 41		252073		4459	4547	3736
E	12 50 46	-60 07 55		252074			4552	3737
F	12 50 57	-60 08 41		252078			4564	3741
G	12 50 21	-60 06 59				4454	4528	
H	12 50 33	-60 08 16					4540	
I	12 50 47	-60 02 19					4550	
J	12 50 26	-60 04 31					4537	
K	12 50 23	-60 07 30					4530	
L	*12 50 24	-60 02 19						
M	*12 50 19	-60 02 33						
104	*12 50 42	-60 04 56						
105	12 50 47	-60 06 02					4553?	
106	12 50 38	-60 05 08	111934	252070		4458	4543	3734
107	*12 50 38	-60 05 27						
108	*12 50 36	-60 05 30						
113	12 50 26	-60 05 43					4532	
115	12 50 34	-60 04 43					4541	
117	12 50 24	-60 05 14					4531	
137	*12 50 38	-60 03 10						
138	12 50 27	-60 02 43					4536	
139	*12 50 27	-60 02 43						
201	12 50 52	-60 05 59					4558?	
202	12 50 53	-60 05 14					4562/58?	
203	12 50 49	-60 06 46					4557/66?	
207	*12 50 45	-60 04 51						
215	*12 50 49	-60 04 41						
216	:12 50 48	-60 04 25						
218	:12 51 08	-60 05 47						
223	12 50 47	-60 03 38		252075			4551	3738
224	*12 50 46	-60 03 31						
228	12 51 14	-60 05 31					4571	
305	12 50 51	-60 07 00					4559/57?	
306	12 50 52	-60 07 37					4561/59?	
311	12 50 58	-60 07 06					4565	
405	12 50 38	-60 06 22					4544	
410	*12 50 26	-60 06 09					4533	
414	12 50 26	-60 06 42					4535	
417	12 50 39	-60 07 27					4546	
418	12 50 35	-60 07 30					4542	

authors generally showing good agreement — the major exceptions are stars D, F and G from Arp & Van Sant and star A from Sowell. However Sowell has found that he obtained later-type classifications for O-F type stars when comparing his results with others. Comparison with the apparent V magnitude (see Table 4.20) shows the luminosity classes scale with the magnitude, with stars brighter than $8^m.5$ being luminosity I, fainter than $\sim 9^m.5$ are luminosity V and in-between are luminosity III.

Only one proper motion study of κ Crucis could be found in the literature, that of King (1980) — this paucity is probably due to the difficulty in measuring proper motions due to the cluster's large distance (2075 pc). King's results for the stars observed in this study are given in Table 4.18, while the proper motion histograms for all of King's data is plotted in Figure 4.18. These show approximately normal distributions, but with an excessive tail centred around $RA = -100 \times 0.01''/100yr$. Splitting the data above and below the median value of King's photographic magnitudes ($11^m.3$) shows a greater proportion of the fainter stars have proper motions in this tail region than the brighter stars, suggesting this corresponds to the proper motion of non-members. King also assigned membership probabilities on the basis of the star's proper motion (see Table 4.19) and using a 50% threshold, concluded that 89 stars were likely members and 75 stars were likely non-members.

Table 4.18 also contains the radial velocities found in the literature, in left to right order, from Hernández (1960), Feast (1963), Marraco & Orsatti (1982), and Sowell (1987), with Feast giving the most complete set of radial velocities. As nearly 50% of the stars do not have radial velocity measurements, no further analysis was performed other than to note possible variables.

There are only three studies that explicitly assess cluster membership of the stars; that of King (1980), Dachs & Kaiser (1984), and Shobbrook (1984). Shobbrook lists several stars as possible foreground objects, but none of these were observed here so only the results from King and Dachs & Kaiser are given in Table 4.19. King's are based on proper motions and are given as a percentage. Dachs & Kaiser derive their memberships based on the differences from the mean distance modulus and reddening, using categories 1–4 denoting 'certain', 'probable', 'possible' and 'impossible' membership respectively. To calculate the average membership, the categories were converted to percentages (the thresholds were 75%, 50%, and 25%) and the resulting average re-categorized. This results in only one star being considered a non-member (star 104).

Table 4.20 lists all the visual magnitudes in the literature, from Arp & Van Sant (1958), Graham (1967), Schild (1970), Perry et al. (1976), Grønbech & Olsen (1976), McGregor & Hyland (1984), de Waard et al. (1984), Dachs & Kaiser (1984), Shobbrook (1984), and Balona & Koen (1994). Arp & Van Sant observed stars A to Q photoelectrically, with the remaining stars measured photographically. Graham quotes some UBV results as unpublished by the

Figure 4.18: Proper motions histograms for Kappa Crucis, using all the data from King (1980) rather than just from Table 4.18.

observer (A. R. Hogg), but they had in fact being published by Hogg (1958) according to Marraco & Orsatti (1982). Perry et al. made observations in both the UBV and *uvby* systems, combining the Johnson V and Strömgren *y* to form the visual magnitude. Grønbech & Olsen observed one κ Crucis cluster star (B) as part of their southern bright star *uvby* catalog, while McGregor & Hyland used a red-ward extension of the UBV system (BVHJK) to examine late-type cluster supergiants (measuring star D in κ Crucis). de Waard et al. observed in the Walraven 5 channel system and converted their results to the UBV system. Dachs & Kaiser measured 86 stars photoelectrically, and a total of 533 stars photographically in the UBV system, with only the photoelectric results being given in Table 4.20. Shobbrook and Balona & Koen both observed in the *uvby* system, quoting *y* as a visual magnitude. As only two stars are not B-type, comparisons between the different authors were not expected to allow any colour dependent systematic errors in the V magnitude to be found (and none were seen). One magnitude dependent systematic error was found; Arp & Van Sant consistently measure the faintest stars (below $12^m.0$) as too bright compared to all other authors — however the brighter stars show no systematic deviations. Another possible source of error is due to the crowded nature of the cluster; most stars have faint companion stars, or could be affected by scattered light from the bright cluster stars, either of which being included by differing amounts in the photometry of each author. Therefore a median (rather than a mean, which would be strongly affected by the systematic differences of Arp & Van Sant) was calculated to reduce both the systematic and random errors.

Several authors have conducted investigations which included specific searches for variable stars in the cluster. Their findings are summarized in Table 4.21, with the authors being Jakate (1978), Shobbrook (1984), Dachs & Kaiser (1984), Koen (1993), and Balona & Koen (1994). Jakate searched for β Cephei stars, selecting as candidates stars having B0.5-2 III-V spectral classifications. While Shobbrook did not specifically search for variables, his results confirmed the variability of star F, found an additional variable (star H) but found star 418 to be constant, contradicting the results of Jakate (however Shobbrook considered the possibility that star 418 was multi-periodic and had been observed during a low amplitude phase). However as the other two authors who find star 418 to be constant can easily reach the precision required to detect the apparent variability found by Jakate, and as it is unlikely that the star, if multi-periodic, would be observed all three times during a low amplitude phase, then it is probable that star 418 is actually constant. Dachs & Kaiser conclude star D was variable by comparing their results with Arp & Van Sant (1958) and Schild (1970) — however as star D is the only late-type star in the cluster, it seems more likely the differences are due to discrepancies in the standardisation transformations. They also find star 223 to be variable, contradicting Jakate who found it constant. However Dachs & Kaiser monitored this star over several days (finding

a period of 3.24 days) while Jakate only measured the star for six hours. Koen conducted a further search for β Cephei stars, confirming most of Jakate's results. Finally, Balona & Koen conducted a special CCD search for variable stars, following up with photoelectric photometry to refine the periods and confirming most of the variables found earlier by Jakate or Koen. The apparent contradictions between different authors (for stars 113, 223, 306, and 417) can be easily explained by differences in the precision and time-scale of the measurements as all these stars have low amplitude variations and/or long periods.

There have been seven investigations of κ Crucis in the UBV system, by Arp & Van Sant (1958), Graham (1967), Schild (1970), Perry et al. (1976), McGregor & Hyland (1984), de Waard et al. (1984), and Dachs & Kaiser (1984). These are listed in Table 4.22, with the exception of McGregor & Hyland who observed only one star in common with this study (star D, $B-V = 2.20$). Arp & Van Sant do not have any U-B colours as they used a very early U-type filter (giving a colour index C_u) which could not be transformed to the Johnson system. The other authors have been previously discussed in the visual magnitudes section. Some of the earlier investigations (Arp & Van Sant, Graham, Schild) show systematic differences compared to the later measurements so the median values will be taken as best representing the standard system.

Table 4.23 lists the E_{B-V} reddening found in the literature; the authors are Arp & Van Sant (1958), Graham (1967), Schild (1970), Perry et al. (1976), Shobbrook (1984), de Waard et al. (1984), and Dachs & Kaiser (1984). Arp & Van Sant use two methods; the first based on spectral classes given by Bidelman (1954) or Gratton & Hernández (unpublished), the second method used a colour-colour diagram. Graham used a preliminary β /absolute magnitude calibration, while Schild used a colour-spectral type calibration. Perry et al. used several methods, all based on either intrinsic colours and/or spectral type calibrations. Shobbrook gives the reddening as E_{b-y} , which are converted to E_{B-V} using the colour excess ratio appropriate for B-type stars. de Waard et al. converted their results from the Walraven system, while Dachs & Kaiser did both photoelectric and photographic observations in the UBV system. In addition, Sowell (1987) found star D to have a large infrared excess, suggesting the presence of a thick dust cloud but doesn't give an E_{B-V} value.

The distribution of the median reddening from the literature is plotted in Figure 4.19. This gives a median reddening for the cluster of $E_{B-V} = 0.40$ and a mean of 0.41 ± 0.04 . The small standard deviation implies a constant reddening for the cluster, while the literature gives mixed results. For instance, Arp & Van Sant (1958) implicitly assume constant reddening, Balona & Koen (1994) finds uniform reddening as does Mermilliod (1981) (based on a literature survey) and Shobbrook (1984). Further, Shobbrook concludes all the absorption is in front of the cluster while Feast (1963) finds most of the absorption is not associated with the cluster

Figure 4.19: Colour excesses E_{B-V} for Kappa Crucis stars from the literature (see the median values from Table 4.23).

(i.e. in front). However de Waard et al. (1984), Dachs & Kaiser (1984), and Sagar (1987) find differential reddening across the cluster, with Dachs & Kaiser stating the absorption increases with galactic latitude and angular distance from the Coal Sack but the other authors not finding any systematic variations.

The dereddened colours and magnitudes are plotted in Figures 4.20 and 4.21. The median distance modulus from Table 4.15 and both the median colour excess for the cluster (Table 4.15) and individual stars (Table 4.23) are used to calculate the intrinsic colours and magnitudes.⁹ The possible β Cephei and other variable stars (Table 4.21) are indicated with different symbols; on the CMD most of the variables lie in an instability strip devoid of constant stars. Clearly star 104 is not a cluster member, while star D could be a late-type supergiant member of the cluster and all other stars are probably cluster members (which is consistent with membership assessments found in the literature, see Table 4.19). Except for the faintest stars, the scatter in the CMD seems reduced when using the individual colour excesses (rather than the median for the cluster). This effect is seen more clearly in the colour-colour diagram, and is to be expected as the calculated excess simply absorbs any measurement errors to force each star back onto the appropriate sequence. A solar metallicity isochrone is super-imposed on the CMD, showing the median age (Table 4.15) from the literature agrees well with the data.

⁹Note that as the U-B colour is not available for star 108 and the individual colour excess for star 104 are not available from the literature, these stars are not present in all the diagrams.

Figure 4.20: Colour-Magnitude diagram of Kappa Crucis, using the median values from the UBV literature (see Tables 4.20 and 4.22), assuming a distance modulus of $11.59 (= 2075 \text{ pc})$. The line is a solar metallicity isochrone of $10 \times 10^6 \text{ years}$. The top diagram is dereddened using the median colour excess for the cluster (see table 4.15) while the bottom diagram is dereddened using the median colour excesses for the individual stars (see Table 4.23). The box and plus symbols indicate possible β Cephei and other variable stars respectively (see Table 4.21).

Figure 4.21: Colour-Colour diagram of Kappa Crucis, using the median values from the UBV literature (see Table 4.22). The main and luminosity Ia sequences are shown as solid and dashed lines, taken from Tables 14 and 15 of Straižys (1992). The top diagram is dereddened using the median colour excess for the cluster (see Table 4.15) while the bottom diagram is dereddened using the median colour excesses for the individual stars (see Table 4.23). The box and plus symbols indicate possible β Cephei and other variable stars respectively (see Table 4.21).

4.5 Vilnius Photometry of the Kappa Crucis cluster.

The individual observations of the κ Crucis stars are given in Table D.6, while the mean values are in Table E.9. The precision level achievable by this study ($0^m.02$ for a single observation) is not met by several stars but it should be noted that these are all fainter than $10^m.0$. Further, when the standard deviation of the mean for each star was compared with the expected deviation for a star with n observations, using the formula found for primary standards in Figure 3.3, only two stars were indicated as possible variables (137 and 218). To investigate possible variability to higher precision would require dedicated programs of differential photometry, which may be undertaken at a later date.

The Vilnius mean V magnitudes do not compare well with the visual magnitudes found in the literature (see Table 4.20); $\sim 20\%$ agree within $\pm 0^m.01$ of the median value, $\sim 36\%$ within $\pm 0^m.02$. However as $\sim 70\%$ lie within the range covered in the literature, these results are as much due to the large disagreements in the literature as to errors in the Vilnius photometry.

The next stage in the analysis is to derive the spectral classification of each star, in this case using the Vilnius Q-Search, Q-Spectra and QQ-diagrams methods described in Chapter 1 (sections 1.8, 1.9, and 1.11 respectively), with the results given in Table 4.24. The Q-Search results list the spectral types one standard deviation above and below the mean value, and note in parenthesis any peculiarities of the matching reference stars. The Q-Spectra notes the 'graphical shifting' factor as $1 + a$, with 1.00 meaning no shifting was required to achieve a good match. If the match of the closest reference spectra appeared to be worse than would be expected from the observational errors, then '(p)' follows the spectral type. In some cases, two or three reference spectra which matched equally well are listed. Recall the QQ-diagrams are calibrated in absolute magnitudes rather than luminosity class, and may also indicate possible spectral peculiarities. Note however that the luminosity classes have larger errors than usual due to poor separation in luminosity for early (O and B-type) stars. Finally, an 'average' spectral type is assigned in the last column.

These averages were compared with the spectral types from the literature (see Table 4.17); 24 (out of 30 assigned spectral classes in the literature) lie within the range given by the literature, or within ± 1.0 spectral sub-classes if only one spectral class is given in the literature. The remaining 12 stars have been assigned spectral classes for the first time. Note that star 104 is identified as an R-type star, for which the Vilnius system is not calibrated. Further, this (R-type) classification has since been superseded by a C-type in the classification scheme but the reference catalogues used have not been updated to reflect this.

Given the spectral type of each star, the iterative procedure described in section 4.3 was used to deredden the measurements. The results are given in Table 4.25, with the distance moduli and colour excess distributions plotted in Figure 4.22. The cluster's average distance

modulus and reddening are found to be 12.18 ± 0.05 and 0.31 ± 0.09 . This colour excess was converted to the UBV system using the colour excess ratio appropriate to B-type stars (see Straižys (1992, Table 65)) and plotted in Figure 4.16 — it has the same excess as the median UBV value but gives a slightly larger distance modulus than found by most other authors.

Assuming the cluster is spherical, its angular diameter ($\sim 5.1'$) at the average distance corresponds to a spread in the distance moduli for individual cluster members of $\pm 0^m.003$. Hence the spread in individual moduli is not due to a spread in the distances for individual stars but to observational and calibration errors and so gives an approximately normal distribution. Further, this doesn't allow discrimination between cluster members and field stars at similar distance, and the histogram shows there are no field stars at distances significantly different from that of the cluster.

The colour excess histogram shows a normal distribution about $E_{Y-V} = 0.31$ but also indicates significant variations, due to 'patchy' distribution of clouds either within or in front of the cluster. If these outliers are disregarded, then the standard deviation becomes ~ 0.05 which, after allowing for observational and calibrational uncertainties in the error budget, means there is little variation in the reddening. One extreme outlier (star M) has a negative colour excess — inspection of the mean magnitudes and colours (Table E.9) shows large uncertainties in all of its colours so this anomalous result is due to observational error (this is confirmed by the UBV colour excess for the star which lies in the middle of the E_{B-V} distribution). The spatial distribution of the colour excesses were plotted in Figure 4.23 (not including star M). There are no obvious trends but the spatial distribution indicates a small, denser cloud near star D and a clearer 'window' near star B. However there are large areas within the cluster in which no stars were observed by this study — this needs to be remedied before the contours in Figure 4.23 can be confidently believed. Thus it is concluded that the cluster has a generally uniform reddening of $E_{Y-V} = 0.31$, but some areas have significant variations from this mean so all stars need to be individually dereddened. One possibility is that the patchy reddening is due to small clouds within the cluster while the uniform reddening is due to a large foreground cloud.

The dereddened data is plotted with the three (solar metallicity) isochrones which best fit the data in Figure 4.24, implying the cluster is $(10 \pm 3) \times 10^6$ years old (which agrees with the median age found by other authors, see Table 4.15). As most of the stars lie on the red side of the isochrones, either isochrones with larger Z values are needed (which are not currently available for the models used in this study), or most observations of stars included a faint visual companion, are binaries, or Be stars.¹⁰ Three stars do not fall on the sequence; stars D, M, and 104. Star D is consistent with being a late-type giant member of the cluster, while star M

¹⁰Mermilliod (1981) made an atlas of composite open cluster CMD's and found Be stars are a strong characteristic of open clusters with Kappa Crucis's age, and that Be stars lie red-ward of the main sequence in V,B-V diagrams.

Figure 4.22: Colour excess and distance moduli distributions for Vilnius photometry of Kappa Crucis, from Table 4.25.

Figure 4.23: Spatial distribution (in Galactic coordinates) of Vilnius colour excesses for Kappa Crucis. Stars A to D are indicated by labels just to the right of each star.

Figure 4.24: Vilnius isochrones for Kappa Crucis, using a distance modulus of 12.18 and dereddening from the individual colour excesses (see Table 4.25). The error bars indicate one standard deviation, as from Table E.9 (i.e. without allowing for the errors in the dereddening procedure).

may be a pre-main sequence member but star 104 is definitely a non-member. However star M appears to have a negative colour excess as was discussed earlier — if the observations are reasonably accurate, this anomaly could be due to the fact that main sequence calibrations of the Vilnius system were used (pre-main sequence calibrations are not available). However, assuming the median distance modulus and colour excess for star M gives $((Y-V)_0, V_0) = (-0.04, -1.05)$ which places it back close to the bottom of the observed sequence. In view of the UBV results, the latter case is considered more likely and emphasize the need for more observations per star for the fainter stars.

4.6 Summary.

Two well studied, young, open clusters were observed to compare the astrophysical information that could be derived from the Vilnius system in comparison with other photometric systems. However no stellar models are available yet in the Vilnius system, except for the limited case of B-type stars. To overcome this, Kurucz's grid of (non-standard) magnitudes and colours was calibrated with standard magnitudes from Straižys (1992) and Schaerer's grid of evolutionary models used to produce isochrones. It was found that the Y-V, V isochrones are qualitatively similar to B-V, V isochrones in the Johnson system.

A literature review of the first cluster (Omicron Velorum) found it to be a close (154 pc), young (30×10^6 years) open cluster with little reddening ($E_{B-V} = 0.01$). Individual studies used a wide variety of catalogues to identify the cluster stars, with Lyngå's system being adopted here. Spectral classifications generally show good agreement between different authors, with the cluster (to the limiting magnitude of this study) consisting of B-F type stars. Four proper motion studies have been made, showing a bimodal distribution due to the cluster members and the field stars (which are more common among the fainter stars). Six radial velocity studies were found in the literature, showing the spread about the mean is consistent with the expected variation within the cluster. Several stars are known, or suspected to be, spectroscopic binaries but only O Vel 3 has been measured long enough to determine its orbital elements. Assessments of cluster membership have been made by eight authors, generally showing good agreement with each other, and implying just over half of the stars observed in this study (23 out of 43) are members.

Systematic differences between the V magnitudes in the literature were found. As it is not possible to tell which system is closest to the true standard system, the medium values (for this and all later magnitudes and colours) were used in an attempt to reduce both the systematic and random errors. Differential photometry was used in several studies to investigate variability of individual cluster stars. It appears that the four brightest stars are variable at the $0^m.01 - 0^m.02$ level but the variability may be irregular (or non-existent) as results from different authors often contradict each other.

Only four studies have been made using the Johnson system. Colour-magnitude and colour-colour diagrams of the probable member stars are consistent with the cluster characteristics given earlier, with the brightest star (O Vel 1) just leaving the main sequence and the faintest (O Vel 40) being a pre-main sequence star. The Strömberg system studies show similar results, while the H_β measurements show reasonable agreement with a ZAMS H_β -absolute magnitude calibration.

To compare the Vilnius system with the most commonly used photometric systems (Johnson and Strömberg), no prior knowledge of the cluster (from the literature) was assumed during the analysis (but extensive comparisons made afterwards). At the precision level achieved by this study ($0^m.02$), no stars were found to be variable and 90% of the stars agree with the medium values from the literature. Spectral types and luminosity classes from the Vilnius photometry all agree with the literature values (within the expected accuracy of the classification methods).

Using the 'Vilnius' spectral types, the reddening and distance modulus of the individual stars were found iteratively and closely agree with the medium results of the literature. As the cluster is 'close', a simple error analysis suggests the 'errors' are largely due to differences in the distance of individual stars and that the cluster is unreddened. A histogram of the distance

moduli was used to assign cluster membership for individual stars, agreeing almost completely with the literature.

The CMD indicates that the brightest star (O Vel 1) has moved off the main sequence, the next brighter stars (O Vel 2 – 7) have moved from the ZAMS to the main sequence and that the two faintest stars (O Vel 37 and 40) are pre-main sequence stars. More observations are needed for the fainter stars to reduce the uncertainties in the colours (in particular $Y-V$ which is used in the CMD). The order of the stars along the CMD sequence suggests some minor changes to the Vilnius spectral classification (or downgrading of membership probabilities) are needed for two stars (O Vel 9 and 17). Fitting (by eye) a grid of isochrones to the CMD indicates that cluster has solar metallicity ($Z=0.020$), with an age of $(45 \pm 15) \times 10^6$ years.

A literature review of Kappa Crucis finds it to be 2075 pc away, and reddened ($E_{B-V} = 0.40$) but a quite young (10×10^6 years) cluster. The variation in M_V and E_{B-V} between different authors is reduced when the correlation between those variables is considered. The numbering system used by Dachs & Kaiser was adopted as the other catalogues do not provide complete coverage of the cluster. All spectral classifications are from spectroscopic observations; there is general agreement between different authors with Feast (1963) giving most complete coverage.

Only one proper motion study (by King (1980)) was found in the literature; an excessive tail in the distribution curve appear to be from non-members of the cluster. There have been only four radial velocity studies, with Feast (1963) providing the best coverage. The two studies of membership (for the stars observed here) show only one star considered a non-member (star 104) and one not assessed (star 108).

There have been ten studies of V magnitudes, with Arp & Van Sant (1958)'s fainter stars being consistently too bright compared to all the other authors. Several stars were investigated for variability with somewhat contradictory results between authors, probably due to the low amplitude and long periods of the proposed variability.

Seven investigations using the Johnson system have been made, showing systematic differences between the studies. The same number of reddening (E_{B-V}) studies were done using a variety of methods, but resulting in no agreement on the uniformity of the reddening across the cluster, although the statistics of the medium values suggest the reddening is constant. Colour-magnitude and colour-colour diagrams of the medium values show that most of the variables lie in an instability strip devoid of constant stars, star 104 is not a member and star D could be a late-type supergiant member.

Again, to compare the Vilnius system with the Johnson system, no prior knowledge of the cluster (from the literature) was assumed during the analysis. Several of the faintest stars do not meet the precision level normally achievable by this study. Two stars (137 and 218) are suggested as variable based on the standard deviations about their mean magnitudes, how-

ever a dedicated program of differential photometry would be required to investigate possible variability at the levels found in the literature. Vilnius V magnitudes do not agree well with the medium values of the literature, but the large (and systematic) difference in the literature suggest that the Vilnius photometry is not solely to blame.

Most (24 out of 30) stars' spectral types and luminosities agree with the literature values and 12 stars are classified for the first time. Using the 'Vilnius' spectral types, the reddening and distance modulus of the individual stars were found iteratively – the reddening (after converting to E_{B-V}) agrees with the medium of the literature but the distance modulus is slightly larger. The reddening is generally uniform, but some areas show significant variations so the dereddening needs to be done individually for each star.

The Vilnius colour-magnitude diagram is best fitted by a $(10 \pm 3) \times 10^6$ years isochrone of solar metallicity. Most of the stars are on the red side of the isochrone, implying either isochrones with larger Z (metallicity) values are needed (which are not currently available), most of the stars are binaries, Be stars or the observations included faint companion stars. Three stars do not lie on the sequence; Star D is probably a late-type member of the cluster, star M may be a pre-main sequence star (but is probably a main sequence star whose anomalous results are due to an observational error) while star 104 is definitely a non-member.

Table 4.17: Spectral types for Kappa Crucis stars from the literature.

#	Bidelman	AvS	Hernandez	Feast	Schild	Sowell	Slettebak
A	B9 Ia	B8-9 Ib	B9 Ia-ab	B9 Iab	B9 Ia	A2 Iab	
B	B3 Iab	B5 II or Ib	B3 Iab	B3 Ia	B5 Ia		
C		B3-4 II	B3 Ib	B2 Ib	B2 Ib		
D		K5 giant	M2-3 Iab	M2 Ib	M2 Iab		
E		B5 II-III	B0-5-1	B1 III	B1 III		
F		B6 III:	B0-5-1 II-III	B2 III	B2 III		
G		B6 V:		B0-5 V			
H							
I				B1 V _n			
J				B1 V			
K				B8 V			
L				B8: V			
M				A0: V			
104							
105			B1-2 II-III	B0-5 III(n)	B1 III		
106			B2 Ib:	B1-5 Ib	B1-5 Ib		
107							
108							
113				B1 V			
115				B1 V			
117				B _{nn}			
137							
138							
139							
201				B1 V	B0-5 V		
202				B1 V			
203				B1 V			
207							
215							
216							
218							
223				B0 V?	B0-5 V _n		
224				B0 V			
228							
305			B2::	B0-5 V	B0-5 IV _n		
306				B _{nne}	B2 IV _{ne}		B1 V
311				B2:V			
405				B2 V			
410				B3:V:			
414				B1 V			
417				B _{nne}	B2 IV _{ne}		B1 V
418				B2:V			

Table 4.18: Proper motion ($0.001''/yr$) and radial velocity (km/s) for Kappa Crucis stars from the literature.

star #	RA King	Dec King	Radial Velocity			
			Hernandez	Feast	M&O	Sowell
A	13	35	-20.4	-16(-15)	(-23)	
B	-27	-7	-14.2	-12(-1.3)		
C	9	5	-29.2	-11	(-6)	
D	11	17	-22	-17		(-24)
E	-2	12	-21.2	-23		
F	0	-6	-5,-40,+7,SB?	-22		
G	-8	1	-27	-23		
H	-8	-2				
I	7	-4		-32 var?		
J	14	-2		-34		
K	28	8				
L						
M						
104						
105	-15	14	-26.2	-23		
106	0	-4	-18.5	-20	(-17)	
107						
108						
113	12	0		-19		
115	8	-2		-22		
117	9	-10				
137						
138	-12	-4				
139						
201	-7	-1		-16		
202	0	13		-33 var?		
203	2	9		-22		
207						
215						
216						
218						
223	14	-2	-95,+12,-98,SB?	VAR		
224				-10		
228	-49	-1				
305	-10	0	46,30,-76,-13,SB?	VAR		
306	15	1				
311	13	5		VAR		
405	11	5		-18		
410				-24		
414	4	-9		-19		
417	0	3				
418	3	-3		VAR		

Table 4.19: Membership for Kappa Crucis stars from the literature.

#	King	D&K	average	#	King	D&K	average
A	22	probable	possible	137		possible	possible
B	54	certain	probable	138	88	certain	certain
C	91	probable	probable	139		certain	certain
D	81	certain	certain	201	92	probable	probable
E	90	certain	certain	202	89	certain	certain
F	92	probable	probable	203	91	certain	certain
G	91	certain	certain	207		certain	certain
H	91	certain	certain	215		certain	certain
I	92	certain	certain	216		certain	certain
J	89	certain	certain	218		probable	probable
K	56	probable	probable	223	89	certain	certain
L		certain	certain	224		probable	probable
M		probable	probable	228	1	certain	possible
104		impossible	impossible	305	90	probable	probable
105	78	certain	certain	306	88	certain	certain
106	93	certain	certain	311	89	probable	probable
107		probable	probable	405	90	certain	certain
108				410		probable	probable
113	90	certain	certain	414	91	certain	certain
115	92	certain	certain	417	93	certain	certain
117	90	probable	probable	418	93	certain	certain

Table 4.20: Visual magnitude V for Kappa Crucis stars from the literature.

#	AvS	Gra.	Schild	Perry	G&O	Mc.	Waard	D&K	Shob.	B&K	med.
A	5.75	5.80		5.76			5.75	5.77	5.732	5.728	5.75
B	5.94	6.00		5.94	5.913		5.92	5.98	5.933	5.971	5.94
C	6.80	6.84		6.77			6.76	6.80	6.786		6.79
D	7.58		7.66	7.42		7.7	7.47	7.45		7.500	7.50
E	8.35		8.3	8.32			8.34	8.37	8.360	8.369	8.35
F	9.09		9.07	9.03			9.08	9.10	9.060	9.099	9.08
G	9.79			9.75			9.79	9.83	9.764	9.790	9.78
H	9.93			9.58			9.94	9.90	9.9V		9.93
I	10.01			10.00			10.04	10.02	10.005	9.986	10.01
J	10.58			10.99			11.02	11.01		11.015	11.01
K	11.42			11.42			11.47	11.40	11.436	11.434	11.43
L	11.88			11.99			11.85	12.07 :		12.258	11.99
M	12.40			12.48			12.45	12.70 :		12.658	12.48
104	10.70							11.03		11.110	11.03
105	8.59			8.61			8.70	8.69	8.659	8.690	8.68
106	7.00	6.99		6.86			6.91	6.92	6.891	6.889	6.91
107	11.34			11.18			11.44	11.45		11.437	11.44
108	12.27									12.620	12.45
113	10.23			10.17			10.19	10.17	10.160	10.168	10.17
115	10.39			10.24				10.40		10.377	10.38
117	10.87			10.82			10.76	10.85		10.873	10.85
137	12.48							12.65		12.663	12.65
138	11.18						11.24	11.25		11.222	11.23
139	11.57						11.73	11.68		11.636	11.66
201	9.37			9.41			9.42	9.40		9.438	9.41
202	10.06			10.04			10.08	10.06		10.085	10.06
203	10.22			10.26			10.30	10.29	10.277	10.287	10.28
207	11.91			12.03			12.04	12.13	12.15	12.149	12.08
215	11.49			11.64			11.64	11.72	11.640	11.635	11.64
216	12.22						12.45	12.48			12.45
218	12.07						12.35	12.30			12.30
223	7.93	8.01		7.90			7.97	7.97	7.97 :	8.012	7.97
224	10.18			10.31			10.22	10.30	10.343	10.343	10.31
228	10.97			11.01				11.05	11.040		11.03
305	8.43			8.46			8.39	8.58		8.398	8.43
306	9.98		10.19	9.88			10.09	10.05		10.093	10.07
311	10.78			10.78			10.85	10.78	10.806	10.798	10.79
405	10.27			10.20			10.20	10.22		10.217	10.22
410	10.72			10.71			10.76	10.72		10.734	10.72
414	10.26			10.27			10.27	10.24		10.243	10.26
417	9.76		9.76	9.73			9.77	9.96		9.832	9.76
418	9.86			9.65			9.76	9.83	9.742	9.727	9.75

Table 4.21: Variability of Kappa Crucis stars from the literature.

#	Jakate (Strom. <i>b</i>)	Shobbrook (Strom. <i>y</i>)	D&K (John. V)	Koen (John. B)	B&K (Strom. <i>y</i>)
C	const				
D			var, $\Delta = 0.2$		const?
E	const			const	
F	β Cep, $\Delta = 0.036, P=4.7h$	var, $\Delta = 0.03,$ $P=0.2d$		β Cep, $\Delta = 0.007, f=4.89/d$ $\Delta = 0.006, f=6.16/d$	β Cep, $\Delta = 0.006, f=4.9/d$ $\Delta = 0.005, f=4.5/d$ $\Delta = 0.003, f=3.0/d$
G	var, $\Delta = 0.033, P=6.6h$			β Cep, $\Delta = 0.005, f=6.62/d$ $\Delta = 0.006, f=6.63/d$ $\Delta = 0.003, f=0.21/d$	β Cep, $\Delta = 0.004, f=6.4/d$
H		var, $\Delta > 0.2$			
I				β Cep, $\Delta = 0.007, f=5.59/d$	β Cep, $\Delta = 0.007, f=5.6/d$ $\Delta = 0.005, f=0.2/d$
105	β Cep, $\Delta = 0.01, P=4h$			var?	var, $\Delta = 0.03, P=1.005d$
106	el. var?				const?
107					var, $\Delta = 0.01, P=0.75d$
113				const	β Cep, $\Delta = 0.002, f=4.3/d$
201					β Cep, $\Delta = 0.008, f=5.5/d$
202					binary? $P=6.4d$
223	const		var?, $\Delta = 0.08,$ $P=3.24d$	ell. var?	const?
305	var, $\Delta > 0.06, P > 7h$			binary, $f=0.51/d$	var, $\Delta = 0.12, P=1.96d$
306	const				var, $\Delta = 0.08, P=0.79d$
410					var, $\Delta = 0.07$
417	const				var, $\Delta = 0.03, P=2.21d$
418	β Cep, $\Delta = 0.032, P=3.2h$	const?		const?	const?

Table 4.22: U-B and B-V colours for Kappa Crucis stars from the literature.

#	U-B					B-V						
	Gm.	Sd.	Py.	DK.	mn.	AvS	Gm.	Sd.	Py.	Wd.	DK.	mn.
A	-0.30		-0.34	-0.34	-0.34	0.325	0.39		0.33	0.33	0.32	0.33
B	-0.54		-0.57	-0.58	-0.57	0.224	0.27		0.24	0.23	0.22	0.23
C	-0.54		-0.57	-0.58	-0.57	0.243	0.30		0.24	0.24	0.24	0.24
D		+2.20	+2.38	+2.57	+2.38	(2.07)		2.16	2.19	2.22	2.22	2.19
E		-0.69	-0.69	-0.72	-0.69	0.118		0.13	0.13	0.14	0.14	0.13
F		-0.70	-0.70	-0.70	-0.70	0.153		0.08	0.09	0.09	0.07	0.09
G			-0.67	-0.70	-0.69	0.195			0.13	0.14	0.11	0.13
H			-0.59	-0.67	-0.63	0.194			0.22	0.19	0.18	0.19
I			-0.57	-0.60	-0.59	0.336			0.20	0.22	0.22	0.22
J			-0.52	-0.56	-0.54	0.151			0.18	0.18	0.22	0.18
K			-0.32	-0.32	-0.32	0.321			0.21	0.20	0.26	0.23
L			-0.37	-0.39	-0.38	0.302			0.25	0.29	0.28	0.28
M			-0.02	+0.01	-0.00	0.384			0.30	0.31	0.32	0.31
104				+1.39	+1.39	1.59					1.57	1.58
105			-0.70	-0.71	-0.70	0.21			0.16	0.15	0.15	0.16
106	-0.66		-0.67	-0.67	-0.67	0.18	0.26		0.22	0.21	0.20	0.21
107			-0.32	-0.30	-0.31	0.26			0.25	0.21	0.25	0.25
108						0.33						0.33
113			-0.58	-0.60	-0.59	0.22			0.13	0.14	0.18	0.16
115			-0.58	-0.61	-0.60	0.17			0.14		0.18	0.17
117			-0.56	-0.60	-0.58	0.24			0.18	0.24	0.22	0.24
137				-0.33	-0.33	0.32					0.31	0.31
138				-0.53	-0.53	0.24				0.20	0.20	0.20
139				-0.42	-0.42	0.25				0.22	0.25	0.25
201			-0.63	-0.65	-0.64	0.18			0.13	0.14	0.17	0.16
202			-0.61	-0.62	-0.62	0.19			0.13	0.13	0.18	0.16
203			-0.60	-0.64	-0.62	0.22			0.12	0.12	0.15	0.13
207			-0.31	-0.34	-0.32	0.28			0.22	0.24	0.25	0.24
215			-0.38	-0.41	-0.40	0.27			0.18	0.21	0.16	0.19
216				-0.26	-0.26	0.28				0.21	0.25	0.25
218				-0.37	-0.37	0.32				0.21	0.28	0.28
223	-0.62		-0.66	-0.67	-0.66	0.20	0.24		0.20	0.19	0.20	0.20
224			-0.62	-0.66	-0.64	0.27			0.16	0.18	0.20	0.19
228			-0.49	-0.50	-0.50	0.22			0.18	0.17	0.20	0.19
305			-0.71	-0.72	-0.71	0.18			0.12	0.12	0.11	0.12
306		-0.67	-0.65	-0.67	-0.67	0.36		0.24	0.22	0.24	0.28	0.24
311			-0.43	-0.45	-0.44	0.23			0.15	0.14	0.20	0.17
405			-0.64	-0.66	-0.65	0.24			0.09	0.11	0.11	0.11
410			-0.38	-0.39	-0.38	0.27			0.19	0.18	0.24	0.22
414			-0.57	-0.60	-0.59	0.21			0.13	0.14	0.16	0.15
417		-0.73	-0.72	-0.78	-0.73	0.24		0.26	0.22	0.20	0.16	0.22
418			-0.60	-0.65	-0.62	0.24			0.15	0.14	0.12	0.14

Table 4.23: Colour excesses E_{B-V} for Kappa Crucis stars from the literature.

#	AvS	Graham	Schild	Perry	Shob.	Waard	D&K	median
A	0.30 0.34 0.34	0.38	0.33	0.34	0.40	0.36:	0.32	0.34
B	0.25 0.33 0.26	0.40	0.31	0.38	0.37	0.36:	0.36	0.36
C	0.34 0.38 0.35	0.40	0.41	0.41	0.39	0.37:	0.40	0.39
D			0.42	0.55			0.50	0.50
E	0.28		0.39	0.43	0.40	0.40	0.41	0.40
F	0.29		0.32	0.36	0.33	0.32	0.33	0.32
G	0.34			0.42	0.38	0.37	0.39	0.38
H				0.50	0.42	0.41	0.46	0.44
I				0.48	0.43	0.42	0.49	0.45
J				0.42	0.35	0.36	0.48	0.39
K				0.36	0.33	0.35	0.46	0.36
L				0.43	0.41	0.43	0.49	0.43
M				0.36		0.39	0.40	0.39
104								
105	0.34		0.47	0.38	0.42	0.41	0.44	0.41
106	0.32	0.40		0.46	0.39	0.40:	0.37	0.40
107				0.40		0.39	0.44	0.40
108								
113				0.38	0.36	0.36	0.44	0.37
115				0.40	0.36		0.43	0.40
117				0.45	0.41		0.49	0.45
137							0.52	0.52
138						0.42	0.44	0.43
139						0.40	0.47	0.43
201			0.46	0.39	0.34	0.37	0.44	0.39
202				0.39	0.33	0.36	0.45	0.38
203				0.38	0.38	0.35	0.42	0.38
207				0.41	0.36	0.44	0.45	0.43
215				0.38	0.37	0.35	0.36	0.36
216						0.36	0.43	0.40
218						0.38	0.49	0.45
223	0.32	0.40	0.48	0.50	0.45	0.42	0.47:	0.45
224				0.46	0.41	0.41	0.47	0.43
228				0.40	0.36	0.37	0.44	0.39
305	0.31		0.46	0.41	0.37	0.37	0.39	0.38
306			0.48	0.52	0.48		0.60:	0.50
311				0.38	0.41	0.33	0.42	0.39
405				0.36	0.33	0.36	0.36	0.36
410				0.39	0.35	0.37	0.45	0.38
414				0.39	0.35	0.37	0.41	0.38
417			0.50	0.52	0.47		0.50:	0.50
418				0.41	0.37	0.40	0.38	0.39

Table 4.24: Spectral Classifications of Kappa Crucis stars from Vilnius photometry.

#	Q-Search	Q-Spectra	QQ-diagrams	average
A	B5-8 I-II	B8 I 0.90	B6-5 -6.5 Be?	B7 I
B	O9-B1 III-IV	B5 I 0.92	B3-4 -6.5	B3 I
C	B0 III	B3 I 0.95	B3 -6.3	B3 I
D	K2-6 III	K3 I (p) 0.95	K0 -5.0	K2 I
E	B0-2 III-IV	B3 I 1.00 or B1 III 0.98	B1 -4.5	B1 III
F	B0-2 III-IV	B1 VI 1.03 or B3 I 1.12	B1 -2.5	B1 IV
G	B0 II-IV	B1 VI 0.90 or B3 I 1.00 or B1 V 0.93	B1 -3.0	B1 IV
H	B1-3 III-IV	B2 V 0.75 or B2 III 0.80	B2 -2.0 Be	B2 IV
I	B0-2 III-V	B1 VI 1.05 or B3 I 1.13	B2 -4.7	B2 III
J	B1-5 IV-V	B2 IV 1.12	B2 -3.0	B2 IV
K	B5 IV-V (SB)	B5 VI 1.15 or B5 V 1.13	B4-5 -0.5	B5 V
L	B2-6 III-V	B3 III 1.65	B3-4 -3.2	B3 III
M	F0-6 II-III	F0 III (p) 0.58	F2-3 -1.7	F1 III
104	R0	G8 IV (p) 1.00	R	R
105	B0-2 I-V	B1 III 0.98 or B2 I 1.03	B1 -6.0	B1 I
106	B0-2 II-IV	B3 I 0.98	B2 -7.0	B2 I
107	B4-A2 V (SB)	B5 VI (p) 1.00	B5-6 +1.0 SB	B5 V
108	B5-7 IV-V (P,SB)	B5 V (p) 1.23	B6 +0.0 SB	B5 V
113	B0-4 IV-V	B2 III 1.18	B2 -3.0	B2 IV
115	B2 IV-V	B2 VI 1.00 or B2 III-IV 1.03	B1-2 -2.0	B2 IV
117	B1-5 IV-V	B2 V 1.08	B2-3 -3.0	B2 IV
137	B2-8 II-V	B3 III (p) 1.83	B4 -6.0	B3 II
138	B3 III-IV	B3 III 1.00	B2-5 -3.0	B3 III
139	B2-8 III-V	B5 V (p) 0.95	B5 -2.0 ?	B5 IV
201	O9 V	B0 I 0.98 or B0 V 0.93	B2 -3.5 Be?	B0 IV
202	B2 IV-V	B2 III 1.25	B2 -4.0	B2 III
203	B0-2 III-V	B2 III 1.00	B2 -4.5	B2 III
207	B3 II-V	B3 V 0.83 (p)	B4 -3.5 Be	B3 III
215	B3-5 IV-V	B3 IV 1.13	B4 -0.5	B4 IV
216	B5-9 I-II	B9 I 1.10 or B5 V 1.00	B5-6 -3.0	B5 III
218	B2-6 III-V	B3 V (p) 2.05	B4 -2.0	B3 IV
223	B0-1 II-IV	B3 I 0.95	B1-2 -5.5	B2 II
224	B0-2 III-V	B1 V (p) 0.88	B1 -4.0 Be	B1 III
228	B1-7 IV-V	B2 V 1.28	B2 -3.5	B2 IV
305	B1-3 II-IV	B3 I 1.20	B1-2 -6.0 ?	B2 II
306	O7-B1 I-II	?	B0 -3.0	B0 III
311	B3 III-V	B3 V 0.87 or B3 IV 0.88	B3 -1.5	B3 V
405	B0-2 II-V	B2 IV 0.78	B2 -2.0 Be?	B2 IV
410	B2-7 IV-V	B3 III 1.55	B3 -2.5	B3 IV
414	B1-5 III-V	B2 IV 1.23	B2 -3.5	B2 IV
417	O7-B2 V,E	?	B0 -3 ?	B0 V
418	B0-2 III-V	B1 VI 1.03 or B3 I 1.10	B1-2 -3.5	B2 III

Table 4.25: Dereddening of Kappa Crucis stars from Vilnius photometry. V_0 was calculated using the median of the distance moduli.

#	V	Y-V	E_{Y-V}	$(Y-V)_0$	R	m-M	V_0
A	5.747	0.481	+0.281	0.20	4.48	12.18	-7.69
B	5.965	0.417	+0.267	0.15	4.48	12.22	-7.41
C	6.792	0.420	+0.270	0.15	4.48	12.22	-6.60
D	7.480	1.709	+0.509	1.20	4.54	12.18	-7.01
E	8.324	0.368	+0.308	0.06	4.48	12.27	-5.24
F	9.009	0.338	+0.288	0.05	4.48	12.27	-4.46
G	9.770	0.347	+0.317	0.03	4.48	12.18	-3.83
H	9.874	0.373	+0.303	0.07	4.48	12.27	-3.66
I	9.989	0.416	+0.346	0.07	4.48	12.18	-3.74
J	10.952	0.393	+0.313	0.08	4.48	12.31	-2.63
K	11.391	0.400	+0.300	0.10	4.48	12.18	-2.13
L	11.854	0.495	+0.425	0.07	4.48	12.14	-2.23
M	12.518	0.272	-0.068	0.34	4.48	12.09	+0.64
104	10.989	1.172	+0.517	0.66	4.48	12.16	-3.51
105	8.663	0.375	+0.315	0.06	4.48	12.09	-4.93
106	6.914	0.414	+0.304	0.11	4.48	12.22	-6.63
107	11.304	0.368	+0.268	0.10	4.48	12.18	-2.08
108	11.760	0.402	+0.302	0.10	4.48	12.18	-1.77
113	10.113	0.349	+0.289	0.06	4.48	12.22	-3.36
115	10.235	0.370	+0.310	0.06	4.48	12.22	-3.33
117	10.837	0.373	+0.333	0.04	4.48	12.14	-2.83
137	12.535	0.527	+0.462	0.065	4.48	12.20	-1.71
138	11.057	0.416	+0.341	0.075	4.48	12.18	-2.65
139	11.641	0.370	+0.270	0.10	4.48	12.18	-1.75
201	9.593	0.313	+0.293	0.02	4.48	12.18	-3.90
202	9.906	0.371	+0.311	0.06	4.48	12.14	-3.67
203	10.270	0.321	+0.276	0.045	4.48	12.07	-3.15
207	12.064	0.451	+0.381	0.07	4.48	12.18	-1.82
215	11.613	0.371	+0.281	0.09	4.48	12.18	-1.82
216	12.341	0.424	+0.324	0.10	4.48	12.18	-1.29
218	12.268	0.446	+0.386	0.06	4.48	12.14	-1.64
223	7.969	0.386	+0.281	0.105	4.48	12.20	-5.47
224	10.202	0.419	+0.394	0.025	4.48	12.11	-3.74
228	10.990	0.402	+0.362	0.04	4.48	12.14	-2.81
305	8.231	0.396	+0.291	0.105	4.48	12.20	-5.25
306	10.047	0.405	+0.385	0.02	4.48	12.18	-3.86
311	10.766	0.337	+0.262	0.075	4.48	12.25	-2.59
405	10.093	0.266	+0.216	0.05	4.48	12.18	-3.05
410	10.642	0.426	+0.336	0.09	4.48	12.27	-3.04
414	9.981	0.366	+0.306	0.06	4.48	12.22	-3.57
417	9.790	0.421	+0.391	0.03	4.48	12.31	-4.14
418	9.660	0.357	+0.287	0.07	4.48	12.18	-3.81

Chapter 5

Discussion and Conclusions.

Given that photometry is a practical necessity for most observations (as spectroscopy is limited to the brightest stars using large telescopes), the question arises of which photometric system should be used. Most photometric systems have been designed to investigate a particular astrophysical question, so would be a logical choice for further work in that area. However this must be balanced against the availability of standard stars in that system and the ability to compare your results with those of other observers made in different systems. This has led some observers to consider the idea of one 'perfect all-purpose' photometric system used by everyone, with subsets of the filters chosen to suit any particular investigation. However others do not believe such a system is possible, stating that the differing needs of each investigation would lead to conflicting requirements of the filters.

The Vilnius system was carefully designed to classify all normal stars (regardless of reddening) in the MK system, without recourse to MK spectroscopy. It also turned out to be able to detect many types of peculiar stars, so is also ideally suited for the survey phase necessary before a photometric system designed for that type of peculiar star is used (in many cases the Vilnius system itself will adequately measure the peculiar star). Thus the Vilnius system is arguably the closest any photometric system has come to being the 'perfect all-purpose' system.

Regardless of personal philosophy concerning specialized versus all-purpose systems, the Vilnius system satisfies most of the requirements of a 'good' photometric system. For instance, a full description of the system is given via the transmission passbands of each filter and the system is quite stable, having only one alteration made (to the S filter) since it was established. The choice of glass for the filters (rather than interference filters) means each local filter set itself is stable, and the glasses were picked to ensure there are no red leaks. The reduction procedures (for extinction, standardization and dereddening) are fully described, and have the advantage of measuring the extinction at intervals throughout the night rather than using a single, average value for the entire night. The medium bandwidth of the filters is a compromise between the need for broad bandwidths to measure fainter stars versus the need for narrow bandwidths to measure specific spectral features and reduce the complications in the reduction

procedures arising from non-monochromatic measurements. From the astrophysical point of view, the system has high purity, has several complementary classification methods based on reddening-free Q factors, and is well calibrated in both the MK system and physical parameters such as effective temperature and gravity.

The one major flaw of the Vilnius system (which apparently all photometric systems suffer from) is that it doesn't provide critical sampling of the spectrum at the filters bandwidth resolution, i.e. the filters should be spaced no further apart in wavelength than half their FWHM. The importance of this was not appreciated at the time the system was designed, but insufficient sampling has since been shown to lead to systematic errors in any reduction procedure. As shown in Appendix I, the addition of some extra filters situated between the existing filters should reduce the systematic errors to an acceptable level — however the experimental proof of this has to be left to a future observer.

Note that critical sampling at the medium FWHM of the Vilnius filters (230 Å) over the wavelength range covered (3100 Å) would require ~ 27 filters and would give all information available from a stellar spectrum at that wavelength resolution. Even with the improved filter and detector technology now available this would take too long to measure a star to be practical. However widening the FWHM of filters measuring wavelengths with little astrophysical information (such as the continuum) would significantly reduce the number of filters, suggesting a method to design the 'perfect all-purpose' photometric system.

The use of Nikonov's method to determine the extinction at MJUO has revealed apparent variations throughout the night, which were probably not detected before as the other observing programs at MJUO involve differential photometry using mean extinction values. This has also highlighted the need for a standard lamp at MJUO to check and/or correct for drifts in the instrumental zero-points. It would also be useful for future observations with the Vilnius system to measure the outside air temperature and pressure throughout the night. This may lead to night-time measures of the ozone level and aerosol distribution that would compliment those currently made during the day by other New Zealand researchers (for example the National Institute of Water and Atmospheric Research), in addition to any astrophysical benefits from improved extinction corrections.

The filters supplied by the Vilnius Institute of Theoretical Physics and Astronomy show a close match to the passbands of the standard filters, so should allow transformations to the standard system at least as good as those between local and standard filters of any photometric system (notwithstanding systematic errors due to non-critical sampling). Although the $0^m.01$ precision and accuracy goal was not achieved (reaching $0^m.02$ instead), this was largely due to the effects of the Mount Pinatubo eruption on the atmospheric extinction at MJUO. Further, the largest uncertainties were generally found in the U filter measurements — these appear to

be due to the lower signal because of the larger extinction at the U filter's effective wavelength and its corresponding greater sensitivity to changes in the extinction, and the smaller signal from the star itself after the Balmer jump — and should be easily remedied by making longer measurements through the U filter than the others (at least 4-5 times longer, as they were already observed for 2-3 times longer in this study). Another important factor concerning the 0.02^m results is that the stars used as Vilnius standards for the transformations are not actually standards (an equatorial region of standards only became available after the observational phase of this study was completed). Thus the failure to achieve the original goal should not be taken as a reflection on the quality of the Vilnius system or the MJUO facilities.

At the time this observing program was planned, the difficulty of establishing a standard star system in the New Zealand maritime climate (hindsight has reduced the original estimate of photometric nights from $\sim 30\%$ down to $\sim 10\%$) was balanced against the difficulty (and expense) of obtaining observing time at overseas observatories for such a program. The generous scheduling at MJUO allowed this problem to be overcome by making a large number of observations per star. Having an insufficient number of observations per star accounts for most of the stars that were not accepted as standards, so with relatively little effort a future observer could approximately double the number of standard stars in the southern Vilnius system by completing these measurements.

The possibility of more crowded regions of fainter stars suitable for CCD photometry standards should also be considered. Note that as PMT's are generally used to measure standards (they are still more precise than CCD's), the standards must not be too crowded. Open clusters, the 'outskirts' of globular clusters, and regions near the galactic equator should provide an adequate number of standard stars which can be observed together in one CCD frame (or an acceptably small number of frames) with a wide range in magnitude and colour. It is recommended that the CCD standard regions of other photometric systems be considered, as was done with the E regions.

Two young, open clusters (Omicron Velorum and Kappa Crucis) were observed in this study to demonstrate some of the advantages the Vilnius system has over other photometric systems. As the Vilnius photometry gives the same results (membership, distance modulus, reddening, age and metallicity) as the other photometric systems (without the additional input from spectroscopy and proper motion studies that the other systems need), I believe this has been achieved. However more work needs to be done on isochrones in the Vilnius system, as other CMD's or colour-colour diagrams (than the Y-V, V CMD used here) may have differing sensitivities to reddening, metallicity, age etc. In addition, simultaneous isochrone fitting of different CMD's should increase the precision and accuracy of the results.

As the literature does not agree on the variability (or otherwise) of the brighter members

of each cluster, a dedicated program of differential photometry would be needed to settle this question. More measurements are also needed of the faintest stars observed in this study to decrease their uncertainties in $Y-V$. Among other things, this would suggest eclipsing binary candidates (based on either their variability or position in the CMD relative to the main sequence). Measurements of eclipsing binaries would provide a valuable independent check on the Vilnius system calibrations (of temperature, gravity etc.) and isochrones as light curves of eclipsing binaries, in conjunction with radial velocity curves, yield orbital and astrophysical parameters (for example mass, gravity, luminosity, distance).

Once the brighter cluster members are accurately known, they can be used as a zero-point tie to Vilnius CCD photometry which could rapidly complete observation of all cluster members to a given limiting magnitude (which could be much fainter than that achieved here given a larger telescope, such as the M^cLellan one metre at MJUO). This would also allow a better investigation of reddening variations along the line of sight and within the cluster itself. It would also allow the possibility of detecting a 'pre-main sequence' sequence, which has been hinted at by the results from this study.

In conclusion, the basis of a standard star network for the southern Vilnius photometric system has been established, and the utility of the Vilnius system for astrophysical measurements has been demonstrated. Building on these results, the size of the southern standard star system could be doubled with relatively little extra observations (which time did not permit in this study). Similarly, some further measurements of the cluster stars, plus some CCD observations to complete the coverage of cluster members and extend the limiting magnitude, would yield extra astrophysical information.

Appendix A

Overview of the Appendices.

A brief description of the appendices is given here — note that for the appendices containing tables, a description of the tables are given at the front of the appendix.

Appendix B lists the stars selected as potential standard stars, either for transforming the local system to the northern standard system (the ‘primary’ standards) or as standards of the southern system (the ‘secondary’ standards). These have been included for the benefit of any future observers who wish to continue the development of the southern Vilnius standard system.

Appendix C has two tables; the first is a summarized form of the Observational Log of this study while the second lists all stars observed in this study with relevant information for an observer (for example coordinates, visual magnitude, spectral type).

Appendix D gives the individual observations of the primary and secondary standard stars and the two clusters observed (*K* Crucis and O Velorum). These have been included so future observers may add further observations to each star and recalculate their means, and also investigate possible variability of a star. Appendix E lists the mean values for each star, splitting the tables into those acceptable as standards and those that currently do not qualify.

Appendix F gives the derivation of Nikonov’s method for calculating monochromatic extinction at any time during observations. Appendix G examines the longer term variations in extinction at MJUO, to see if a running average over several nights (or seasonally) can be used for a night for which the extinction was not measured. It was concluded that a running average is only useful for a *photometric* night during which the uncertainty in the measured extinction exceeds 0.03, i.e. the large uncertainty is due to a lack of extinction star observations rather a poor quality night. Further, the variation in the night-to-night extinction was of the same size as the change in the mean extinction during different seasons, so mean values for the extinction should not be used at MJUO. The aerosols and gases ejected into the atmosphere by the June 1991 Mount Pinatubo eruption were found to significantly increase both the mean value and variation in the extinction at MJUO.

Appendix H continues examining extinction, this time using data from the seven Vilnius filters to investigate the various components making up atmospheric extinction over the optical

region (Rayleigh scattering, aerosol scattering and molecular absorption). As four parameters have to be fit, the results had such a large scatter that no trends could be found. However, fixing the Rayleigh parameter reduced the scatter in the remaining parameters sufficiently that trends throughout a night in the aerosol scattering and ozone absorption could be seen. The effect of the Mount Pinatubo eruption on the individual components could also be seen; on average the aerosol extinction was increased by a factor of four while the ozone absorption was halved.

Appendix I looks at the possibility of making Vilnius filters out of Schott glasses. Only three of the Schott glass combinations match the standard filters as well as the local filters provided by the Vilnius Institute of Theoretical Physics and Astronomy, so Schott glasses should not be used to implement a Vilnius filter system. However Schott glasses might be used to construct additional filters centred at wavelengths between that of the Vilnius filters so critical sampling of the wavelength region is achieved. This should result in better transformations to the standard system (compared to using the local Vilnius filters alone), but still awaits experimental confirmation.

Appendix J lists several tables from the literature that were used in this study. They have been included here as most are from a book by Straižys (1992), which may be difficult to obtain.

Appendix K gives a glossary of the acronyms used in this study. The meaning of the acronym is also given the first time it is used in the thesis. Finally, in Appendix L a list of papers relevant to the project published by this author and coworkers is given. There are also other papers planned for publication after the completion of this thesis, which can probably be found in later volumes of *Baltic Astronomy*.

Appendix B

Catalogs of Candidate Primary and Secondary Standard Stars.

The following tables list the stars selected as candidates for primary or secondary standard stars.

The first table are stars selected from the Vilnius catalog (North 1980) to be used to transform the local photometric system to the standard Vilnius system. The first column is the star name, with the next two being the equatorial coordinates (for the Epoch 2000). The following seven columns are the Vilnius V magnitude and colours. An 'N' in the V magnitude column indicates that it is actually a Johnson V magnitude taken from the catalogue of Nicolet (1978). Similarly, an 'M' indicates Johnson V from the catalogues of Mermilliod (1987*a, b*), and 'L' indicates Johnson V from other sources. The second to last column gives the number of measurements made of the star in the standard Vilnius system, and the last column lists the star's spectral type.

The following two tables are stars selected as secondary standards. The first three columns are again the star's name and coordinates. The next two columns are the Johnson B and V magnitudes, followed by the star's spectral type. The E region secondary standard stars are not listed here as they can be found in the literature, for example from Menzies et al. (1989).

Table B.1: Bright, southern Vilnius stars selected for use as primary standards.

HD #	RA	Dec	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#	Sp
000693	00 11 16	-15 27.8	4.88	0.47	0.56	0.65	0.31	0.18	0.47	01	F6 V-MD
000787	00 12 10	-17 56.3	5.29	0.74	1.25	1.95	0.58	0.49	1.04	02	K5 III-MD
001000	00 14 21	-21 11.6	6.91	0.47	0.61	0.68	0.31	0.16	0.49	01	F8 V
001367	00 17 48	+01 41.3	6.17	0.57	0.92	1.20	0.44	0.29	0.70	01	K0 II
001388	00 17 58	-13 27.3	6.48	0.44	0.61	0.78	0.35	0.20	0.54	01	G0 V
001461	00 18 40	-08 03.0	6.39	0.49	0.70	0.90	0.37	0.21	0.55	01	G0 V
001635	00 20 35	+08 11.4	5.37	0.71	1.29	1.78	0.54	0.44	0.90	03	K3 III
001879	00 23 04	-15 56.6	6.47	0.93	1.42	2.02	0.64	0.52	1.16	01	M2 IIIB
002454	00 28 20	+10 11.6	6.04	0.49	0.57	0.60	0.29	0.17	0.44	01	F5 V-MD
003296	00 36 01	-05 34.2	6.73	0.49	0.59	0.64	0.30	0.17	0.44	01	F5 V
003457	00 37 30	+03 08.2	6.43	0.76	1.29	1.76	0.50	0.48	0.94	02	K4 III-MD
004145	00 43 50	-12 00.6	6.03	0.60	1.16	1.43	0.46	0.37	0.78	01	K2 III-IV
004307	00 45 29	-12 52.7	6.16	0.46	0.61	0.76	0.36	0.19	0.55	01	G0 V-MD
004628	00 48 21	+05 17.7	5.75	0.40	0.91	1.21	0.32	0.34	0.73	04	K2 V
004656	00 48 40	+07 35.1	4.43	0.77	1.42	2.02	0.53	0.55	1.02	04	K5 III
004915	00 51 10	-05 02.3	6.97	0.42	0.65	0.83	0.35	0.23	0.56	01	G3 V-MD
004928	00 51 19	+03 23.2	6.37	0.56	0.98	1.37	0.48	0.32	0.74	02	K0 III
005112	00 53 00	-01 08.6	4.77	0.84	1.41	2.10	0.60	0.55	1.00	07	M0 III
005268	00 54 17	-08 44.4	6.16	0.56	0.84	1.10	0.46	0.28	0.70	01	G8 III-MD
005384	00 55 43	-07 20.8	5.84	0.75	1.41	2.06	0.57	0.54	1.01	03	K5 III
005588	00 57 39	+01 47.1	6.98	0.68	1.11	1.51	0.54	0.37	0.84	06	K0 II-III
006186	01 02 57	+07 53.4	4.28	0.56	0.89	1.22	0.45	0.31	0.69	02	K0 III
006386	01 04 52	+05 39.4	6.00	0.80	1.38	2.04	0.55	0.53	1.02	01	K3 II-III
006734	01 07 59	+01 59.9	6.46	0.50	0.78	1.08	0.39	0.30	0.67	04	K0 IV
007446	01 14 42	+06 59.8	6.03	0.63	1.08	1.40	0.47	0.32	0.75	02	K0 III
009138	01 30 10	+06 08.7	4.84	0.74	1.29	1.81	0.51	0.50	0.94	04	K4 III
010380	01 41 26	+05 29.2	4.44	0.71	1.34	1.83	0.54	0.45	0.94	05	K3 III
010700	01 44 10	-15 57.0	3.50	0.43	0.68	0.90	0.33	0.25	0.61	06	G8 V,P
011037	01 48 26	+03 41.1	5.91	0.58	0.91	1.24	0.46	0.30	0.70	01	G9 III
012235	02 00 08	+03 06.0	5.88	0.48	0.67	0.83	0.33	0.21	0.53	02	G2 IV

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Table B.3 continued from previous page

HD #	RA	Dec	B	V	Sp	HD #	RA	Dec	B	V	Sp
206240	21 50 53	-82 43 07	6.04	5.29	G9 III	206053	21 54 23	-85 02 02	7.6	6.7	K0-1 III
211539	22 31 39	-85 58 06	6.79	5.77	K0 III	213615	22 39 58	-83 15 07	6.9	6.6	A9 IV
214846	22 46 05	-81 22 54	4.35	4.15	A9 IV-V	215573	22 50 22	-80 07 26	5.20	5.35	B6 IV
218559	23 12 12	-80 54 46	7.91	6.41	K4 III	219765	23 28 02	-87 28 57	6.76	5.49	K2 III
223647	23 52 08	-82 01 07	6.03	5.11	G7 III	223833	23 53 45	-83 00 28	8.4	6.9	M0 III
224362	23 57 34	-82 10 11	6.78	5.73	K0 III						

Appendix C

The Observational Log.

This appendix contains two tables describing the observations.

The first (Table C.1) summarizes the observations made each night. Column one shows the calendar date (at the start of the night), with an asterisk indicating a note at the end of the table. The second column gives the Julian Date (minus 2440000.5 *days*). The next column lists the observers; RJD = Richard Dodd, MF = Murray Forbes. The instrumental setup is described in the fourth column;

telescopes :

O/C - Optical Craftsman 61 *cm*

B&C - Boller and Chivens 61 *cm*

1m - M^cLellan 1 *m* with either the f13 or f8 secondary mirror

data loggers :

PET - the PET computer

PC - a PC computer

detectors (and settings) :

VUW PMT - Victoria University of Wellington PhotoMultiplier Tube EMI 9558B

CCD - Thomson CSF TH7882 CDA Charge Coupled Device

Ampl # - the **amplifier**/discriminator used with the PMT

filters :

Vil 1 - Vilnius Set 1, 15 *mm* diameter filters

Vil 2 - Vilnius Set 2, 28 *mm* diameter filters

An assessment of the photometric quality of the night is given in the fifth column. The last column summarizes the number of stars (of each type) observed that night;

std - Vilnius primary **standard** stars

SPS - South Polar Sequence Vilnius secondary standard candidate stars

sec std - bright, southern **secondary standard** candidate stars

E? - E region secondary standard candidate stars

- R Arae - differential photometry of the eclipsing binary **R Arae** and a comparison and check star
- drift-scans - attempts to measure the components of an optical double by drifting the stars across the diaphragm
- std lamp - investigation of beta light source
- κ Crucis - stars in the κ **Crucis** open cluster
- O Vel - stars in the **O Vel** open cluster
- M41 - stars in the **M41** open cluster
- NGC1818 - a Large Magellanic Cloud (LMC) "globular cluster" observed for T. Banks
- sec extn - stars used to calibrate the **secondary extinction** coefficients
- dead-time - dead-time calibration measurements (using LEDs)

The second (Table C.2) lists all the stars observed, sorted alphabetically by star name. The first column gives the star name (or cluster name). Any symbols (in parenthesis) following the name denote;

- (v) - variable star, if primary standard then only used if no others are observable at the time
- (v?) - possibly variable star, if primary standard then only used if no others are observable at the time
- (∞) - optical double star (may not be accepted as standard star due to possible errors if both stars not consistently included in later measurements)
- (‡) - nearby star of similar intensity, so not accepted as standard star due to possible errors in identifying correct star

The second column gives the Epoch (*years*) of the star's coordinates, which are given in the next two columns. These are equatorial coordinates Right Ascension (*hours, minutes, seconds*) and Declination (*degrees, minutes*). The next column lists the star's 'type' ;

- PriStd - Vilnius northern **Primary Standard** stars
 - SPS - **South Polar Sequence** Vilnius secondary standard candidate stars
 - SecStd - bright, southern Vilnius **Secondary Standard** candidate stars
 - ESecStd - **E** region Vilnius **Secondary Standard** candidate stars
 - PriExtn - southern secondary standard star used to measure the **Primary Extinction**
 - SecExtn - southern secondary standard star used to measure the **Secondary Extinction**
 - R Arae - an eclipsing binary star
 - Comp - southern secondary standard star used as the **Comparison** star for differential photometry of R Arae
 - Check - southern secondary standard star used as the **Check** star for differential photometry of R Arae
 - Program - all remaining stars (not intended as standards)
- The last two columns give the Johnson *V* magnitude and spectral class, taken from either the Vilnius catalog (for the primary standards) or SIMBAD (all other stars).

Table C.1: A summary of the observations made on each night.

date	julian date	observer(s)	equipment	photometric quality	observations
15 Oct 87*	7083	RJD	O/C scope	no reductions made	
21 Jun 88*	7333	RJD	O/C scope	cloudy	8 SPS
22 Jun 88	7334			100% cloud	
23 Jun 88	7335			100% cloud	
24 Jun 88	7336			photometric	5 std, 8 SPS, R Arae
27 May 89	7673	RJD	O/C scope	clear 3 hours	
04 Jun 89*	7681	RJD	O/C scope	marginal	
05 Jun 89	7682			photometric	3 std, 3 SPS, 8 κ Crucis
06 Jun 89	7683			100% cloud	
07 Jun 89	7684			100% cloud	
08 Jun 89	7685			photometric	9 std, 5 κ Crucis
09 Jun 89	7686			100% cloud	
21 Jun 89	7698			100% cloud	
22 Jun 89	7699			photometric	4 std, 9 SPS
05 Nov 90	8200	RJD	O/C scope, PET logger, Vil #1	clear 3 hours	
06 Nov 90	8201			100% cloud	
07 Nov 90	8202			good	1 std, 3 sec extn
08 Nov 90	8203			100% cloud	
09 Nov 90	8204	RJD		marginal	6 std
10 Nov 90	8205	& MF		100% cloud	
11 Nov 90	8206	MF		100% cloud	
21 Nov 90	8216			100% cloud	
22 Nov 90	8217			clear 3 hours	
23 Nov 90	8218			100% cloud	
24 Nov 90	8219			cloudy	
25 Nov 90	8220			clear 2 hours	4 std
26 Nov 90	8221			100% cloud	
27 Nov 90	8222			100% cloud	
17 Feb 91	8304	MF	B&C scope, PET logger, Ampl #3, Vil #1	100% cloud	
18 Feb 91	8305			100% cloud	
19 Feb 91	8306			cloudy	
20 Feb 91	8307			cloudy	
21 Feb 91	8308			good	7 sec extn, 7 O Vel
22 Feb 91	8309			cloudy	
26 Feb 91	8313			cloudy	
27 Feb 91*	8314			clear 4 hours	5 std, 10 O Vel, dead-time
28 Feb 91	8215			photometric	6 std, 10 O Vel

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Table C.1 continued from previous page					
date	julian date	observer(s)	equipment	photometric quality	observations
11 Apr 91	8357	RJD	O/C scope, PET logger, Ampl #1, Vil #1	cloudy	
12 Apr 91	8358			100% cloud	
13 Apr 91	8359			photometric	1 std, 21 O Vel
14 Apr 91	8360			photometric	6 std, 9 O Vel
11 May 91	8387	MF	B&C scope, PET logger, VUW PMT at 1500 V & $-10^{\circ}C$, Ampl #3, Vil #1	photometric	8 std, 3 κ Crucis, 6 O Vel
12 May 91	8388			cloudy	
13 May 91	8389			clear 3 hours	5 std
14 May 91	8390			clear 5 hours	5 κ Crucis, 7 O Vel, dead-time
15 May 91	8391			100% cloud	
16 May 91	8392			100% cloud	
17 May 91	8393			clear 7 hours	8 std, 10 κ Crucis
18 May 91	8394			cloudy	
19 May 91	8395			cloudy	
20 May 91	8396			cloudy	
21 May 91	8397			marginal	9 std, 11 κ Crucis, 7 O Vel
22 May 91	8398			cloudy	
23 May 91	8399			clear 3 hours	4 std, 6 κ Crucis
29 Nov 91	8589	MF	B&C scope, PET logger, VUW PMT at 1500 V & $-10^{\circ}C$, Ampl #3, Vil #1	100% cloud	
01 Dec 91	8590			100% cloud	
02 Dec 91	8591			100% cloud	
03 Dec 91	8593			good	1 std, 4 sec std, 6 M41
04 Dec 91	8594			good	4 std, 4 sec std, 2 SPS, 6 M41
05 Dec 91	8595	MF	1m scope at f13, CCD, Vil #1	100% cloud	
06 Dec 91	8596			100% cloud	
01 Feb 92	8653	MF	1m scope at f13, CCD, Vil #1	cloudy	3 O Vel
02 Feb 92	8654			cloudy	1 κ Crucis
03 Feb 92	8655			100% cloud	
04 Feb 92	8656			100% cloud	
05 Feb 92	8657			cloudy	NGC1818, R Arae
06 Feb 92	8658		B&C scope, PET logger, VUW PMT at 1500 V & $-12^{\circ}C$, Ampl #3, Vil #1	photometric	8 std, 8 O Vel, 3 M41
07 Feb 92	8659			100% cloud	dead-time
08 Feb 92	8660			good	2 std, 3 κ Crucis, 13 O Vel
09 Feb 92	8661			good	9 std, 13 O Vel
10 Feb 92	8662			good	11 std, 11 O Vel
11 Apr 92	8723	MF	B&C scope, PC logger, VUW PMT at 1500 V & $-16^{\circ}C$, Ampl #3, Vil #1	photometric	6 std, 17 κ Crucis, R Arae drift-scans
12 Apr 92	8724			good	9 std, 6 sec std, 1 E7, 15 κ Crucis
13 Apr 92	8725			good	11 std, 6 sec std, 21 κ Crucis
14 Apr 92	8726			good	9 std, 20 sec std, 13 κ Crucis
15 Apr 92	8727			good	11 std, 30 sec std, 4 SPS
16 Apr 92	8728			cloudy	10 κ Crucis
17 Apr 92	8729			100% cloud	dead-time

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Table C.1 continued from previous page

date	julian date	observer(s)	equipment	photometric quality	observations
18 Apr 92	8730		1m scope at f13, CCD, Vil #1	100% cloud	
19 Apr 92	8731			good	2 std, 6 κ Crucis, R Arae
20 Apr 92	8732			cloudy	
21 Apr 92	8733			good	5 std, 3 κ Crucis, R Arae
23 Jun 92*	8796	MF	O/C scope	cloudy	
24 Jun 92*	8797		B&C scope,	good	12 std, 11 sec std, 1 SPS
25 Jun 92*	8798		PC logger,	good	13 std, 27 sec std, 1 SPS, 1 E7, 1 E8, R Arae
26 Jun 92	8799		VUW PMT at	100% cloud	dead-time
27 Jun 92*	8800		1500 V & -16° C,	marginal	13 std, 34 sec std, 4 SPS, 1 E8, 1 E9, R Arae
28 Jun 92	8801		Ampl #3, Vil #1	good	12 SPS, R Arae eclipse
29 Jun 92	8802			100% cloud	
30 Jun 92	8803			cloudy	9 std, 14 sec extn, 5 sec std
17 Dec 92	8973	MF	1m scope at f13, CCD, Vil #2	100% cloud	
19 Dec 92	8975			100% cloud	
20 Dec 92	8976			cloudy	2 M41
21 Dec 92	8977		B&C scope, PC logger, VUW PMT at 1500 V & -15° C, Ampl #3, Vil #2	100% cloud	
26 Dec 92	8982			100% cloud	
27 Dec 92	8983			photometric	6 std, 4 E2, 9 E3, 4 M41
28 Dec 92	8984			cloudy	
12 Feb 93	9030			cloudy	
13 Feb 93	9031			cloudy	
14 Feb 93*	9032	MF	B&C scope, PC logger, VUW PMT at 1500 V & -16° C, Ampl #3, Vil #2	100% cloud	
15 Feb 93*	9033			100% cloud	
16 Feb 93*	9034			marginal	3 std, 8 E3
17 Feb 93*	9035			photometric	4 std, 5 E3, 16 E4
18 Feb 93*	9036			good	11 std, 2 E3, 16 E4
14 May 93	9121	MF	B&C scope, PC logger, VUW PMT at 1500 V & -12° C, Ampl #3, Vil #2	good	4 std, 12 E4
17 May 93	9124			good	13 std, 15 E4, 9 κ Crucis
18 May 93	9125			100% cloud	
19 May 93	9126			100% cloud	
20 May 93	9127			photometric	16 std, 1 E4, 11 E6, 1 E9, R Arae
21 May 93	9128			clear 7 hours	8 std, 6 sec extn (5 E6, 1 E9), R Arae, std lamp
22 May 93	9129			cloudy	10 std, 1 E4, 5 E6, 10 E8, R Arae
23 May 93	9130			good	11 std, 1 E4, 14 E6, 8 E8, 1 E9, 4 κ Crucis, R Arae
29 Jun 93	9167	MF	B&C scope, PC logger, VUW PMT at 1500 V & -12° C,	clear 9 hours	13 std, 1 E1, 2 E7, 12 E9, R Arae
30 Jun 93	9168			cloudy	
01 Jul 93	9169			good	14 std, 1 E1, 1 E5, 12 E6, 2 E7, 11 E9, R Arae

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Table C.1 continued from previous page					
date	julian date	observer(s)	equipment	photometric quality	observations
02 Jul 93	9170		Ampl #3, Vil #2 + new Y	clear 6 hours	10 std, 1 E5, 11 E6, 2 E7, R Arae
03 Jul 93	9171			good	22 std, 1 E1, 1 E5, 17 E6, 2 E7, 18 E9, R Arae
04 Jul 93	9172			clear 6 hours	5 std, 1 E5, 17 E6, 2 E7
05 Jul 93	9173			100% cloud	
06 Jul 93	9174			good	7 std, 1 E1, 1 E5, 9 E6, 2 E7, 8 E9, R Arae
07 Jul 93	9175			good	18 std, 1 E1, 1 E5, 14 E6, 2 E7, 14 E9, R Arae
08 Jul 93	9176			good	12 std, 1 E5, 2 E7, 7 κ Crucis, R Arae

Notes :

- 15 Oct 87 Z filter missing
- 21 Jun 88 the extinction star (HD122066) differs by $\sim 1.5^m$ from 24 Jun 88, probably observed wrong star (BS5250 is nearby and similar *V* magnitude).
- 04 Jun 89 the extinction star (HD122066) changed by $\sim 1.0^m$ during the night, ditto above note for 21 Jun 88.
- 27 Feb 91 the PET disk drive was not working, data entered from the printout
- 23 Jun 92 dark-counts vary according to scope's position (electrical-noise from tracking motors?)
- 24 Jun 92 moved to the B&C scope due to noise problems found on 23 Jun 92
- 25-27 Jun 92 used wrong check star for R Arae (HD150898 instead of HD150745)
- 14 Feb 93 the dome shutter power socket shorted and destroyed the computer
- 14-18 Feb 93 strange results from the U filter

Table C.2: List of observed stars : coordinates, star type, Johnson V and Spectral class.

Name	Ep	RA	Dec	Type	V	Sp
CPD-80 0962	2000	20 36 22	-80 31.0	SPS		K0
E1_036	2000	01 15 07	-45 32.0	ESecStd	4.97	G0 V
E2_008	2000	03 51 02	-44 22.0	ESecStd	8.01	F2 III
E2_014	2000	03 56 17	-43 37.0	ESecStd	8.13	F5-6 V
E2_015	2000	04 01 08	-44 27.0	ESecStd	8.46	F6 V
E2_052	2000	03 49 49	-42 44.0	ESecStd	7.35	A5-6 V
E3_002	2000	06 37 30	-45 36.0	ESecStd	8.28	B8-9 V
E3_005	2000	06 33 13	-45 23.0	ESecStd	8.05	A1 IV
E3_006	2000	06 38 29	-45 22.0	ESecStd	8.17	A2 III
E3_007	2000	06 38 41	-46 10.0	ESecStd	8.38	A0 V
E3_018	2000	06 34 39	-46 31.0	ESecStd	8.58	F0 V
E3_020	2000	06 38 15	-45 17.0	ESecStd	8.28	F2 V
E3_036(∞)	2000	06 49 57	-45 27.0	ESecStd	6.54	K5-M0 III
E3_037	2000	06 32 19	-45 19.0	ESecStd	7.17	K0 III
E3_041	2000	06 33 27	-45 04.0	ESecStd	8.68	K0 III
E3_045(∞)	2000	06 25 43	-48 11.0	ESecStd	5.76	B9 V
E3_047	2000	06 49 54	-46 37.0	ESecStd	5.14	F5 V
E3_050	2000	06 40 47	-47 37.0	ESecStd	6.65	B3-5 V
E3_051	2000	06 58 00	-46 06.0	ESecStd	6.83	A0 IV
E3_052	2000	06 58 41	-45 46.0	ESecStd	6.22	A0 V
E3_072	2000	06 28 59	-45 22.0	ESecStd	10.75	
E3_087(∞)	2000	06 38 37	-48 13.0	ESecStd	4.94	G8 III
E3_089	2000	06 45 10	-47 13.0	ESecStd	7.22	B2 III
E4_028	2000	09 30 33	-45 34.0	ESecStd	6.63	K2-3 III
E4_029	2000	09 20 15	-45 10.0	ESecStd	6.70	K2 III
E4_030(∞)	2000	09 18 51	-45 00.0	ESecStd	7.20	K0 III
E4_039	2000	09 12 14	-45 50.0	ESecStd	6.66	F3-5 V
E4_040(∞)	2000	09 12 30	-43 37.0	ESecStd	5.56	B8 V(Psi)
E4_041(∞)	2000	09 15 14	-45 33.0	ESecStd	6.25	B8 V
E4_044	2000	09 22 24	-46 03.0	ESecStd	5.74	G6-8 III
E4_045	2000	09 29 22	-43 11.0	ESecStd	6.60	F5 IV
E4_046	2000	09 31 19	-47 57.0	ESecStd	6.53	A9 IV-V
E4_047	2000	09 38 01	-43 11.0	ESecStd	5.50	G8 II
E4_078	2000	09 14 08	-44 09.0	ESecStd	5.85	B5 V
E4_079(∞)	2000	09 14 24	-43 14.0	ESecStd	5.24	B3-5 V
E4_093	2000	09 11 33	-46 35.0	ESecStd	5.78	B2 III-IV
E4_094	2000	09 13 34	-47 20.0	ESecStd	5.91	B9 V
E4_096	2000	09 16 58	-45 01.0	ESecStd	6.74	A0 V
E4_097	2000	09 23 25	-48 17.0	ESecStd	6.27	B3 IV
E4_098	2000	09 23 39	-46 55.0	ESecStd	6.21	B7 III
E5_040	2000	12 03 38	-42 25.9	ESecStd	5.15	F5 V

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Table C.2 continued from previous page

Name	Ep	RA	Dec	Type	V	Sp
E6.012	2000	14 56 14	-44 05.4	ESecStd	7.89	A3 IV
E6.013	2000	14 55 25	-44 20.0	ESecStd	7.99	A4 V
E6.014	2000	14 53 04	-43 43.6	ESecStd	8.15	A5 V
E6.033	2000	14 38 12	-45 52.2	ESecStd	6.83	K2 III
E6.039(∞)	2000	14 30 08	-45 19.2	ESecStd	5.51	B8 V
E6.040	2000	14 36 18	-46 14.7	ESecStd	5.54	K3 III
E6.041	2000	14 39 11	-46 34.8	ESecStd	6.06	F6 V
E6.042(∞)	2000	14 45 57	-44 52.0	ESecStd	6.91	A0 V
E6.043	2000	14 46 28	-47 26.4	ESecStd	5.73	A1 V
E6.044	2000	14 47 31	-43 33.3	ESecStd	6.30	G8 III
E6.045	2000	14 56 24	-44 42.2	ESecStd	6.75	A1 V
E6.046(∞)	2000	14 59 18	-43 28.2	ESecStd	7.04	F2 III
E6.047	2000	14 59 45	-43 48.5	ESecStd	6.58	F7 IV-V
E6.078(v)	2000	14 26 07	-45 13.2	ESecStd	4.6	B2 IV
E6.079(∞)	2000	14 26 10	-45 22.7	ESecStd	4.36	F7
E6.080	2000	14 27 12	-46 07.9	ESecStd	5.82	A1m A5/7-F2
E6.081(∞)	2000	14 28 51	-47 59.4	ESecStd	6.40	ApSi
E6.082	2000	14 35 09	-46 27.6	ESecStd	6.89	B9 V
E6.084	2000	14 35 49	-46 48.9	ESecStd	6.78	G8 III
E6.087	2000	14 37 54	-48 01.3	ESecStd	6.65	B8 V
E6.088(∞)	2000	14 40 18	-45 47.5	ESecStd	6.63	ApSi
E6.090	2000	14 50 58	-42 49.3	ESecStd	6.83	A2 V
E6.091(∞)	2000	14 51 37	-43 34.4	ESecStd	4.32	B5 IV
E6.092(∞)	2000	14 56 31	-47 52.6	ESecStd	5.63	B9 V
E6.095	2000	14 59 26	-43 09.5	ESecStd	6.10	F7 II
E6.100	2000	14 54 00	-43 35.8	ESecStd	8.22	G8 II
E6.101	2000	14 55 47	-44 41.7	ESecStd	7.94	K3 III
E7.048	2000	17 24 43	-45 00.5	ESecStd	6.66	F3 V
E7.061	2000	17 12 09	-43 14.0	ESecStd	3.33	F3 III-IVp
E7.065	2000	17 37 53	-42 33.7	ESecStd	7.17	G2-3 V
E8.026	2000	20 11 16	-43 39.6	ESecStd	6.54	G5-6 III
E8.028	2000	20 02 36	-45 11.7	ESecStd	6.57	K1 III
E8.029	2000	20 10 05	-43 53.5	ESecStd	6.93	K0 III
E8.030	2000	20 05 08	-46 05.7	ESecStd	6.95	K3-4 III
E8.042	2000	20 00 48	-45 06.7	ESecStd	5.79	F0-2 IV
E8.043(∞)	2000	20 01 25	-47 23.7	ESecStd	6.95	F2 IV
E8.044	2000	20 19 17	-47 34.6	ESecStd	6.12	F5 V
E8.045	2000	20 22 27	-42 02.8	ESecStd	5.58	A0 V
E8.069	2000	19 55 15	-41 52.0	ESecStd	4.12	K0 II-III
E8.071(∞)	2000	20 23 53	-42 25.3	ESecStd	5.64	A5 V
E8.072	2000	20 26 04	-46 39.5	ESecStd	6.73	A9 III-IV
E9.024	2000	22 32 11	-43 15.7	ESecStd	6.91	K0 III
E9.025	2000	22 48 30	-43 26.7	ESecStd	7.06	G8 III

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Table C.2 continued from previous page

Name	Ep	RA	Dec	Type	V	Sp
E9_029	2000	22 33 54	-44 41.4	ESecStd	6.79	G8 III
E9_030	2000	22 53 15	-45 08.8	ESecStd	6.85	K0 III
E9_031	2000	22 52 26	-45 59.4	ESecStd	7.25	K4-5 III
E9_040	2000	22 30 43	-44 05.6	ESecStd	6.94	A0-1 V
E9_042	2000	22 36 41	-43 28.2	ESecStd	6.76	F8 V
E9_043	2000	22 42 43	-44 14.9	ESecStd	6.07	K0 III
E9_044	2000	22 45 41	-46 32.8	ESecStd	5.51	K2 III
E9_048	2000	22 30 15	-42 17.4	ESecStd	6.92	B9.5 V
E9_049	2000	22 47 09	-41 41.5	ESecStd	6.83	K2 III
E9_063(∞)	2000	22 42 37	-47 12.3	ESecStd	5.99	G0 V
E9_071	2000	22 15 35	-44 27.1	ESecStd	6.10	G8-K0 III
E9_072	2000	22 23 07	-45 55.6	ESecStd	5.62	F0 V
E9_073	2000	22 23 25	-46 40.1	ESecStd	6.91	A1 V
E9_074	2000	22 29 16	-43 29.7	ESecStd	3.97	G6-8 III
E9_079	2000	22 43 30	-41 24.8	ESecStd	4.84	K0 III
E9_080(∞)	2000	22 46 43	-46 56.4	ESecStd	6.56	A9 IIIIm
HD000496	2000	00 09 24	-45 45.0	SecStd	3.88	K0 III
HD000636	2000	00 10 03	-82 13.0	SPS	5.28	G8 III
HD000693	2000	00 11 16	-15 27.8	PriStd	4.88	F6 V-MD
HD000787	2000	00 12 10	-17 56.3	PriStd	5.29	K5 III-MD
HD001032	2000	00 13 19	-85 00.0	SPS	5.77	M0.5 III
HD001237	2000	00 16 05	-79 51.0	SPS	6.7	G6 V
HD001581	2000	00 19 51	-64 53.0	SecStd	4.20	F9 V
HD001879	2000	00 23 04	-15 56.6	PriStd	6.47	M2 IIIB
HD002151	2000	00 25 12	-77 16.0	SPS	2.80	G2 IV
HD002261	2000	00 26 16	-42 18.0	SecStd	2.37	K0 III
HD002262		00 26 12	-43 41.0	SecStd	3.90	A7 V
HD002834	2000	00 31 24	-48 48.0	SecStd	4.77	A0 V
HD003296	2000	00 36 01	-05 34.2	PriStd	6.73	F5 V
HD004229	2000	00 39 32	-85 42.0	SPS	6.80	K3 III
HD004628	2000	00 48 21	+05 17.7	PriStd	5.75	K2 V
HD005112	2000	00 53 00	-01 08.6	PriStd	4.77	M0 III
HD005268	2000	00 54 17	-08 44.4	PriStd	6.16	G8 III-MD
HD005384	2000	00 55 43	-07 20.8	PriStd	5.84	K5 III
HD006186	2000	01 02 57	+07 53.4	PriStd	4.28	G9 III
HD010800	2000	01 37 53	-82 59.0	SPS	5.87	G2 V
HD011025	2000	01 37 27	-84 46.0	SPS	5.69	G8 III
HD011171		01 49 36	-10 41.0	SecStd	4.77	F3 III
HD011604	2000	01 47 48	-80 11.0	SPS	6.06	F0 IV
HD012311		01 58 44	-61 34.0	SecStd	2.90	F0 V
HD012872(v)	2000	02 06 13	+08 14.9	PriStd	6.31	M4
HD014802	2000	02 22 32	-23 49.0	PriExtn	5.37	G2 V
HD014882		02 23 15	-29 52.0	PriExtn	6.94	G1 V

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Table C.2 continued from previous page						
Name	Ep	RA	Dec	Type	V	Sp
HD015048	2000	02 24 26	-37 22.0	PriExtn	6.98	F5 V
HD015182	2000	02 25 45	-37 45.0	SecStd	9.0	G8 III
HD016399	2000	02 38 00	+07 41.7	PriStd	6.39	F5
HD017081		02 44 07	-13 52.0	SecStd	4.39	B7 IV
HD018331		02 56 37	-03 43.0	SecStd	5.27	A1 Vn
HD018784	2000	03 01 09	-07 39.7	PriStd	5.78	K0 II
HD020630	2000	03 19 21	+03 22.0	SecStd	4.96	G5 Vvar
HD020791	2000	03 21 07	+03 40.5	PriStd	5.69	G8.5 III
HD022049		03 32 59	-09 27.0	SecStd	3.81	K2 V
HD023246	2000	03 44 26	+24 23.7	PriStd	8.17	A8 V
HD023249(v?)	2000	03 43 15	-09 46.5	PriStd	3.54	K0 IV
HD023288	2000	03 44 49	+24 17.4	PriStd	5.46	B7 IV
HD023338	2000	03 45 13	+24 28.1	PriStd	4.30	B6 IV
HD023608	2000	03 47 17	+24 07.7	PriStd	8.69	F3 V
HD023850	2000	03 49 10	+24 03.0	SecStd	3.80	B8 III
HD025422		03 58 45	-61 24.0	SecStd	4.56	M2 III
HD026912	2000	04 15 32	+08 53.5	PriStd	4.29	B3 IV
HD028525		04 21 18	-80 20.0	SPS	5.69	K2.5 III+
HD028556	2000	04 30 37	+13 43.0	PriStd	5.43	F0 V
HD028873		04 30 50	-44 57.0	SecStd	5.16	B2 IV-V
HD029116		04 25 19	-81 42.0	SPS	5.79	F1 III
HD029712		04 36 46	-62 05.0	SecStd		M8 IIIe
HD029875		04 40 34	-41 52.0	PriExtn	4.45	F2 V
HD030652	2000	04 49 49	+06 58.0	SecStd	3.31	F6 V
HD031139(v?)	2000	04 53 23	+02 30.5	PriStd	5.33	M1 III
HD031237(v)	2000	04 54 16	+02 26.4	PriStd	3.72	B3 III+B0 V
HD031283	2000	04 54 47	+11 25.4	PriStd	5.19	A3 V
HD033111		05 07 51	-05 05.0	SecStd	2.92	A3 III
HD033544	2000	05 11 38	+15 38.5	PriStd	5.20	K5 III
HD034484		05 16 24	-32 31.0	PriExtn	7.06	F6-F7 V
HD035299		05 23 42	-00 10.0	SecStd	5.70	B1.5 V
HD036512		05 31 56	-07 18.0	SecStd	4.63	B0 V
HD037224	2000	05 35 27	-33 16.0	PriExtn	6.69	F6 V
HD037495	2000	05 37 45	-28 41.0	PriExtn	5.31	F4 V
HD038558	2000	05 47 26	+17 43.7	PriStd	5.49	F0 III
HD042301		06 08 58	-22 26.0	SecStd	5.46	A0 V
HD045416	2000	06 26 44	+00 18.0	SecStd	5.20	
HD046150	2000	06 31 55	+04 56.6	PriStd	6.73	O6 V,E
HD050082	2000	06 51 54	+06 36.0	PriStd	7.40	G0 (BA)
HD051199	2000	06 55 37	-20 08.0	SecExtn	4.62	F2 IV-V
HD051208	2000	06 54 27	-42 22.0	SecExtn	6.00	C II...
HD052382	2000	07 00 39	-09 12.2	PriStd	6.49	B1 IB
HD052877(‡)	2000	07 01 44	-27 56.0	SecStd	3.46	M0 Iab

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Table C.2 continued from previous page

Name	Ep	RA	Dec	Type	V	Sp
HD053704	2000	07 04 03	-42 20-0	SecExtn	5-26	Am
HD054118	2000	07 04 18	-56 45-0	SecExtn	5-30	A0p...
HD054439	2000	07 08 23	-11 51-0	PriStd	7-68	B2 III,N
HD055751	2000	07 14 20	+03 06-7	PriStd	5-35	K2 II
HD055892	2000	07 12 34	-46 46-0	SecExtn	4-47	F0 IV
HD056855	2000	07 17 09	-37 06-0	SecExtn	2-74	K3 Ib
HD057150	2000	07 18 19	-36 44-0	SecStd	4-68	B2 V+...
HD057623	2000	07 16 50	-67 57-0	SecExtn	4-02	F6 II
HD059881	2000	07 32 06	+01 54-9	PriStd	5-25	F0 III
HD061831	2000	07 39 27	-38 18-0	SecExtn	4-91	B2.5 V
HD062058	2000	07 40 53	-31 40-0	SecExtn	6-64	F8-G0 Ia
HD062345(∞)	2000	07 44 27	+24 24-0	PriStd	3-68	G8 IIIa
HD063032	2000	07 45 15	-37 58-0	SecExtn	3-72	K2.5 Ib-II
HD063077		07 45 36	-34 12-0	PriExtn	5-39	G0 V
HD063975	2000	07 51 42	+01 46-1	PriStd	5-14	B8 II
HD064379	2000	07 52 17	-34 43-0	PriExtn	5-01	F5 V
HD066811		08 03 11	-39 58-0	SecStd	2-20	O5 If
HD067594	2000	08 08 36	-02 59-0	PriStd	4-34	G2 Ib
HD069142	2000	08 14 03	-40 21-0	SecStd	4-44	K1 II-III
HD070569	2000	08 23 22	+18 20-0	PriStd	5-95	A9 V
HD072127(∞)	2000	08 29 28	-44 43-0	SecStd	4-99	B2 IV
HD073389($\ddagger$)	2000	08 35 19	-58 01-0	SecStd	4-86	K0 III
HD073390	2000	08 35 16	-58 13-0	SecStd	5-40	B3 V+...
HD074006	2000	08 40 06	-35 18-0	SecStd	3-97	G7 Ib-II
HD074180	2000	08 40 38	-46 39-0	SecStd	3-88	F3 Ia
HD074272	2000	08 41 13	-47 19-0	SecStd	4-77	A5 II
HD074521(v)	2000	08 44 45	+10 04-9	PriStd	5-66	A1 ,P(EU-CR)
HD075063($\ddagger$)	2000	08 46 02	-46 02-0	SecStd	3-90	A1 III
HD075710	2000	08 49 48	-45 18-0	SecStd	4-95	A2 III
HD076728	2000	08 55 03	-60 39-0	SecStd	3-80	B8.5 II
HD076805	2000	08 56 19	-52 43-0	SecStd	4-69	B5 V
HD077258(∞)	2000	09 00 06	-41 15-0	SecStd	4-40	K0 III+...
HD078004	2000	09 04 10	-47 06-0	SecStd	3-75	K2 III
HD078045	2000	09 02 27	-66 24-0	SecStd	4-00	A2.5 IVm
HD079447	2000	09 11 17	-62 19-0	SecStd	4-00	B3 III
HD079940	2000	09 15 45	-37 25-0	SecStd	4-62	F5 III
HD082434	2000	09 30 43	-40 28-0	SecStd	3-60	F3 IV+...
HD083058	2000	09 34 09	-51 15-0	SecStd	5-00	B1.5 IV
HD083183	2000	09 34 27	-59 14-0	SecStd	4-10	B5 II
HD083446	2000	09 36 50	-49 21-0	SecStd	4-40	A5 IV-V
HD083944	2000	09 39 21	-61 20-0	SecStd	4-50	B9 IV-V
HD085123(∞)	2000	09 47 06	-65 04-0	SecStd	2-96	A8 Ib
HD085622	2000	09 51 41	-46 33-0	SecStd	4-58	G5 Ib

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Table C.2 continued from previous page						
Name	Ep	RA	Dec	Type	V	Sp
HD086440	2000	09 56 52	-54 34.0	SecStd	3.50	B5 Ib
HD086629	2000	09 58 53	-35 53.0	PriExtn	5.23	F1 III-IV
HD087901(v?)	2000	10 08 24	+11 58.0	PriStd	1.35	B7 V
HD088206	2000	10 08 56	-51 49.0	SecStd	4.90	B3 IV
HD088742	2000	10 13 26	-33 02.0	PriExtn	6.37	G1 V
HD088955	2000	10 14 45	-42 07.0	SecStd	3.80	A2 V
HD089080	2000	10 13 45	-70 02.0	SPS	3.30	B8 IIIe
HD090994	2000	10 30 17	-00 38.2	PriStd	5.09	B6 V
HD091316(v)	2000	10 32 49	+09 18.4	PriStd	3.85	B1 IB,SB
HD091612	2000	10 34 49	+06 57.2	PriStd	5.08	G9 III
HD093779(‡)	2000	10 45 17	-80 28.0	SPS	5.48	K0 III
HD093845(‡)	2000	10 45 48	-80 32.0	SPS	4.40	B2.5 IV
HD095345	2000	11 00 34	+03 37.1	PriStd	4.84	K1 III
HD095370	2000	11 00 09	-42 14.0	SecStd	4.40	A3 IV
HD095456	2000	11 00 41	-31 50.0	PriExtn	6.06	F8 V
HD095849	2000	11 03 37	-00 00.1	PriStd	5.95	K3 III
HD096566	2000	11 06 33	-62 25.0	SecStd	4.61	G8 III
HD097585	2000	11 13 46	-00 04.1	PriStd	5.42	A0 V
HD098058	2000	11 16 40	-03 39.1	PriStd	4.47	A7 IV,N
HD098718	2000	11 21 01	-54 29.0	SecStd	3.90	B5 Vn
HD100286		11 32 16	-29 16.0	PriExtn	5.86	F8 V
HD100563	2000	11 34 22	+03 03.7	PriStd	5.77	F5 V
HD100953	2000	11 37 01	-32 59.0	PriExtn	6.28	F6 III-IV
HD101431	2000	11 40 13	-34 45.0	SecStd	4.70	B9 V
HD102124	2000	11 45 16	+08 15.5	PriStd	4.85	A4 V
HD102510	2000	11 47 55	+08 14.7	PriStd	5.32	A2 V
HD102647(v?)	2000	11 49 06	+14 34.4	PriStd	2.14	A3 V
HD102776	2000	11 49 41	-63 47.0	SecStd	4.32	B3 Vne
HD102870	2000	11 50 39	+01 46.1	PriStd	3.61	F8 V
HD102964	2000	11 51 09	-45 10.0	SecStd	4.46	K3 III
HD103026	2000	11 51 42	-30 50.0	PriExtn	5.85	F7 V
HD103484	2000	11 55 03	+08 26.6	PriStd	5.58	G8 III-IV
HD104181	2000	11 59 57	+03 39.3	PriStd	5.37	A1 V
HD104979	2000	12 05 14	+08 43.9	PriStd	4.11	G8 III
HD105211	2000	12 06 53	-64 37.0	SecStd	4.20	F2 III
HD105452	2000	12 08 25	-24 44.0	SecStd	4.02	F0 IV-V
HD105639	2000	12 09 42	+01 54.0	PriStd	5.95	K3 III
HD105937	2000	12 11 39	-52 22.0	SecStd	4.00	B3 V
HD107070	2000	12 18 40	-00 47.3	PriStd	5.90	A5 V,N
HD107079	2000	12 19 00	-55 09.0	SecStd	5.00	M1 III
HD107328(v?)	2000	12 20 23	+03 18.9	PriStd	4.96	K0 III
HD108483	2000	12 28 03	-50 14.0	SecStd	3.91	B2 V
HD110423(v?)	2000	12 41 57	+06 48.4	PriStd	5.59	A2 V

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Name	Ep	RA	Dec	Type	V	Sp
HD111721	2000	12 51 26	-13 29.0	PriStd	7.98	G-MDSGE
HD111765	2000	12 51 37	+03 03.4	PriStd	6.02	K2 III
HD111915	2000	12 53 07	-48 57.0	SecStd	4.33	K3.5 III
HD111968	2000	12 53 26	-40 11.0	SecStd	4.30	A7 III
HD112300(v?)	2000	12 55 38	+03 23.9	PriStd	3.38	M3 III
HD112985	2000	13 02 14	-71 33.0	SPS	3.62	K2 III
HD113703	2000	13 06 17	-48 28.0	SecStd	4.71	B5 V
HD114435	2000	13 11 09	-42 14.0	PriExtn	5.79	F7 IV
HD114613	2000	13 12 05	-37 48.0	PriExtn	4.85	G3 V
HD114837	2000	13 14 17	-59 06.0	SecStd	4.92	F7 IV
HD114960	2000	13 13 58	+01 27.4	PriStd	6.58	K5 III
HD116160	2000	13 21 42	+02 05.3	PriStd	5.69	A2 V
HD116235	2000	13 22 10	+05 09.3	PriStd	5.87	A2 ,M
HD118022(v)	2000	13 34 08	+03 39.5	PriStd	4.94	A1 ,P(SR-CR-EU)
HD119756	2000	13 45 43	-33 03.0	PriExtn	4.23	F3 IV
HD120602	2000	13 50 25	+05 29.9	PriStd	6.01	G5 III
HD120955(∞)	2000	13 53 12	-31 56.0	SecStd	4.73	B4 IV
HD120987	2000	13 53 33	-35 40.0	PriExtn	5.54	F4 V
HD121263	2000	13 55 33	-47 17.0	SecStd	2.60	B2.5 IV
HD121447	2000	13 55 47	-18 15.0	PriStd	7.90	M ,P
HD121607	2000	13 56 28	+01 03.1	PriStd	5.91	A8 V
HD122066	2000	14 00 01	-25 01.0	PriExtn	5.80	F6 V
HD122408	2000	14 01 39	+01 32.7	PriStd	4.26	A3 V
HD123139	2000	14 06 43	-36 22.0	SecStd	2.06	K0 IIb
HD123998	2000	14 18 14	-81 00.0	SPS	4.91	A2 m
HD124639	2000	14 24 23	-82 51.0	SPS	6.37	B8 Ve
HD124780	2000	14 16 18	-33 14.0	PriExtn	6.56	F0 V
HD124850(v?)	2000	14 16 01	-05 59.7	PriStd	4.08	F6 III
HD124882		14 26 58	-83 40.0	SPS	4.32	K2 III
HD126053	2000	14 23 15	+01 14.9	PriStd	6.27	G1 V
HD126248	2000	14 24 12	+05 49.2	PriStd	5.10	A5 V
HD126868(v?)	2000	14 28 12	-02 13.7	PriStd	4.81	G2 IV
HD129116	2000	14 41 58	-37 48.0	SecStd	4.00	B3 V
HD129956	2000	14 45 30	+00 43.0	PriStd	5.69	B9.5 V
HD130650	2000	15 01 50	-83 14.0	SPS	5.65	G9 III
HD131246	2000	15 04 47	-83 02.0	SPS	5.65	G8 Ib
HD132345	2000	14 58 54	-11 08.6	PriStd	5.88	K3 III,CN2
HD133955	2000	15 08 51	-45 17.0	SecStd	4.05	B3 V
HD134169	2000	15 08 18	+03 56.0	PriStd	7.68	F8-SD
HD135559	2000	15 15 49	+00 22.4	PriStd	5.63	A4 V
HD136014	2000	15 19 32	-37 06.0	PriExtn	6.19	G6 III-IV
HD136028	2000	15 18 26	-00 27.7	PriStd	5.89	K5 III
HD136422	2000	15 21 49	-36 16.0	SecStd	3.56	K5 III

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Name	Ep	RA	Dec	Type	V	Sp
HD137058	2000	15 25 20	-38 44.0	SecStd	4.60	A0 IV
HD137613	2000	15 27 48	-25 10.0	PriStd	7.63	R3
HD138716	2000	15 34 10	-10 03.7	PriStd	4.64	K1 IV
HD139409	2000	15 38 42	-17 40.0	PriStd	7.19	K0 (BA)
HD140008	2000	15 42 41	-34 43.0	SecStd	4.75	B5 V
HD140573	2000	15 44 15	+06 25.5	PriStd	2.65	K2 IIIb
HD141556	2000	15 50 57	-33 38.0	SecStd	3.95	B9 IV
HD143118(∞)	2000	16 00 07	-38 24.0	SecStd	3.41	B2.5 IV
HD143474(∞)	2000	16 03 33	-57 46.0	SecStd	4.63	A7 IV
HD143553	2000	16 00 51	+04 25.6	PriStd	5.83	G9 III-IV
HD144470	2000	16 06 49	-20 40.0	SecStd	3.96	B1 V
HD145366		16 20 21	-78 42.0	SPS	4.78	M5 IIIb
HD146836	2000	16 19 32	-30 54.0	PriExtn	5.49	F6 III
HD147196	2000	16 21 19	-23 42.0	PriStd	7.03	B8 V,NN,P
HD147432	2000	16 22 52	-23 07.0	PriStd	7.50	A2 V
HD147513	2000	16 24 01	-39 12.0	PriExtn	5.40	G5 V
HD147550	2000	16 22 39	-02 04.8	PriStd	6.22	B9 V
HD147675		16 33 29	-78 54.0	SPS	3.89	G9 III
HD147977	2000	16 28 15	-58 36.0	Comp	5.78	B9 II-III
HD148513	2000	16 28 34	+00 39.9	PriStd	5.43	K4 III,P
HD148542	2000	17 00 57	-86 22.0	SPS	6.06	A2 V
HD148605	2000	16 30 13	-25 07.0	SecStd	4.78	B3 V
HD148703	2000	16 31 23	-34 42.0	SecStd	4.23	B2 III-IV
HD148760	2000	16 31 22	-26 32.2	PriStd	6.22	K1 III
HD149324		16 43 09	-77 31.0	SPS	4.24	K0 III
HD149447	2000	16 36 22	-35 15.0	SecStd	4.16	K6 III
HD149730	2000	16 39 15	-56 59.0	R Arae		B9 IV-V
HD150366	2000	16 41 36	-24 28.1	PriStd	6.07	F0 V
HD150416	2000	16 41 35	-17 44.5	PriStd	4.96	G8 II(CN1,BA)
HD150451	2000	16 41 12	-01 00.0	PriStd	6.22	A7 III
HD150745	2000	16 46 21	-58 28.0	Check	5.94	B3
HD150898	2000	16 47 20	-58 20.0	SecStd	5.76	B0
HD151046	2000	16 44 59	-00 37.0	PriStd	7.68	K5 III
HD151431(v?)	2000	16 47 10	+02 03.9	PriStd	6.10	A3 V
HD152980	2000	16 59 35	-53 10.0	SecStd	4.06	K4 III
HD153210(v)		16 55 18	+09 27.0	PriStd	3.20	K2 III
HD153687	2000	17 01 03	-04 13.3	PriStd	4.82	K4 III
HD154090	2000	17 04 49	-34 07.0	SecStd	4.87	B1 Iae
HD154417	2000	17 05 17	+00 42.5	PriStd	6.01	F9 V
HD156190		17 22 06	-70 07.0	SPS	5.60	B9 V+...
HD156277	2000	17 21 60	-67 46.0	SecStd	4.78	K2 III
HD156513	2000	17 31 27	-80 52.0	SPS	5.88	M3 III
HD156826	2000	17 19 59	-05 54.9	PriStd	6.32	G9 V

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Table C.2 continued from previous page

Name	Ep	RA	Dec	Type	V	Sp
HD157089	2000	17 21 08	+01 26.4	PriStd	6.96	F9 V-MD
HD157244	2000	17 25 18	-55 32.0	SecStd	2.85	K3 Ib-II
HD157246	2000	17 25 24	-56 23.0	SecStd	3.30	B1 Ib
HD157415	2000	17 23 02	+00 50.0	PriStd	7.78	K0 III-MD
HD158094	2000	17 31 06	-60 41.0	SecStd	3.60	B8 Vn
HD158352	2000	17 28 50	+00 19.8	PriStd	5.44	A8 V
HD158427	2000	17 31 51	-49 52.0	SecStd	3.00	B2 Vne
HD158926	2000	17 33 38	-37 06.0	SecStd	1.63	B1.5 IV
HD159217	2000	17 35 40	-46 30.0	SecStd	4.60	A0 V
HD159433	2000	17 36 33	-38 38.0	SecStd	4.29	K0 IIIb
HD159517	2000	18 01 34	-85 13.0	SPS	6.45	F5 IV
HD159532	2000	17 37 19	-43 00.0	SecStd	1.90	F1 II
HD159975	2000	17 37 51	-08 07.1	PriStd	4.62	B8 II-III,P(MN)
HD160032	2000	17 40 23	-49 25.0	SecStd	4.77	F3 IV
HD160346	2000	17 39 18	+03 33.4	PriStd	6.52	K3 V
HD160635	2000	17 45 44	-64 43.0	SecStd	3.62	K2 II
HD160781	2000	17 41 32	+06 18.8	PriStd	5.95	G7 III
HD160823	2000	17 41 56	+04 22.0	PriStd	7.01	G2 II-MD
HD161868	2000	17 47 54	+02 42.5	PriStd	3.75	A0 V,SB:
HD161912	2000	17 50 11	-40 05.0	SecStd	4.81	A2 Ib
HD162917	2000	17 53 15	+06 06.0	PriStd	5.77	F3-5 IV-V
HD163245	2000	17 55 54	-18 48.1	PriStd	6.42	A4 V
HD163376	2000	17 57 48	-41 43.0	SecExtn	4.88	M0 III
HD164259	2000	18 00 28	-03 41.4	PriStd	4.62	F2 IV
HD164353	2000	18 00 39	+02 56.0	PriStd	3.97	B5 Ib
HD164461	2000	18 54 49	-87 36.0	SPS	5.27	K3 IIICN...
HD165174(v)	2000	18 04 38	+01 55.1	PriStd	6.14	B0 IIIIn
HD165189	2000	18 06 50	-43 25.0	SecExtn	4.94	A5 V
HD165462	2000	18 06 07	-00 26.7	PriStd	6.34	G8 II,P
HD166063	2000	18 11 14	-45 57.0	SecExtn	4.53	K0 III
HD166114	2000	18 11 05	-41 22.0	PriExtn	5.90	F2 V
HD166460	2000	18 10 40	+03 19.5	PriStd	5.51	K2 III
HD167768	2000	18 16 53	-03 00.2	PriStd	5.96	G3 III
HD169111	2000	18 22 36	+12 01.8	PriStd	5.90	A2 V
HD169191	2000	18 22 49	+17 49.5	PriStd	5.25	K3 III
HD169467	2000	18 26 58	-45 58.0	SecStd	3.50	B3 IV
HD169767	2000	18 28 49	-49 04.0	SecStd	4.13	G9 III
HD169904	2000	18 42 14	-81 48.0	SPS	6.27	B8 V
HD170465(‡)	2000	18 31 45	-45 55.0	SecStd	4.93	B6 IV
HD170521	2000	18 31 56	-43 30.0	SecStd	5.71	K2 III
HD170845	2000	18 33 30	-42 19.0	SecExtn	4.64	G8 III
HD171538	2000	18 35 15	+05 59.8	PriStd	6.47	A3 III
HD171767	2000	18 36 29	+04 57.4	PriStd	6.74	K1 III

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Name	Ep	RA	Dec	Type	V	Sp
HD172046	2000	18 37 49	+05 53.1	PriStd	6.67	B5 V
HD172365	2000	18 39 37	+05 15.9	PriStd	6.38	F8 Ib-II
HD172850	2000	18 42 30	-01 18.0	PriStd	7.78	B8 V
HD172910	2000	18 44 19	-35 39.0	SecExtn	4.87	B2.5 V
HD173009	2000	18 43 31	-08 16.5	PriStd	4.90	G8 II
HD173371	2000	18 44 56	-00 22.4	PriStd	6.88	B9 III
HD175190	2000	18 55 07	-22 40.2	PriStd	4.97	K3-MD(BA)
HD175679	2000	18 56 26	+02 28.3	PriStd	6.15	G8 III
HD176638	2000	19 03 06	-42 06.0	SecExtn	4.80	B9.5 V
HD176704	2000	19 02 28	-24 50.7	PriStd	5.59	K3 III
HD176723	2000	19 03 18	-38 15.0	PriExtn	5.73	F2 III-IV
HD177474	2000	19 06 25	-37 04.0	SecExtn	4.20	F7 IV-V
HD177482	2000	21 08 40	-88 57.0	SPS	5.46	F0 III
HD177756	2000	19 06 15	-04 52.8	PriStd	3.44	B9 V,N
HD177873	2000	19 08 21	-40 30.0	SecExtn	4.59	K1 III
HD178125(v)	2000	19 06 58	+11 04.3	PriStd	5.09	B8 III
HD178253	2000	19 09 28	-37 54.0	SecExtn	4.11	A2 V
HD179406(v?)	2000	19 12 41	-07 56.4	PriStd	5.34	B3 V
HD181383	2000	19 19 53	+11 32.1	PriStd	6.02	A2 V
HD181391	2000	19 20 33	-05 24.9	PriStd	5.01	G8 III-IV,SB
HD182101	2000	19 22 49	+09 54.7	PriStd	6.35	F6 V
HD182296	2000	19 23 38	+08 39.6	PriStd	7.07	G3 Ib
HD182640	2000	19 25 29	+03 07.0	SecStd	3.36	F0 IV
HD183324	2000	19 29 01	+01 57.0	PriStd	5.80	A0 V
HD183630(v?)	2000	19 30 40	-02 47.3	PriStd	5.03	M1 III
HD183936	2000	19 31 43	+05 46.1	PriStd	7.20	F2 III
HD184127	2000	19 35 13	-48 06.0	SecStd	4.90	K0 III
HD184313(v)	2000	19 33 46	+05 28.0	PriStd	6.33	M8 V
HD184406(v?)	2000	19 34 05	+07 22.9	PriStd	4.45	K3 III,B
HD184492	2000	19 35 07	-10 33.7	PriStd	5.12	G8 IIIA
HD184915	2000	19 36 53	-07 02.0	SecStd	4.95	B0.5 III
HD184930	2000	19 36 43	-01 17.1	PriStd	4.36	B5 III
HD186154	2000	19 56 01	-81 21.0	SPS	6.39	K3.5 III
HD186648	2000	19 46 22	-19 45.6	PriStd	4.86	K1 III
HD187923(v?)	2000	19 52 05	+11 38.0	PriStd	6.13	G0 V
HD188228		20 00 35	-72 55.0	SPS	4.00	A0 V
HD188350	2000	19 54 44	+00 16.4	PriStd	5.61	A0 III
HD189103	2000	19 59 44	-35 17.0	SecStd	4.36	B3 IV
HD189695	2000	20 00 59	+08 33.4	PriStd	5.91	K5 III
HD190248	2000	20 08 33	-66 10.0	SecStd	3.56	G7 IV
HD190421	2000	20 07 23	-52 53.0	SecStd	4.94	M1 IIb
HD191220	2000	20 24 54	-83 19.0	SPS	6.16	Am
HD192876(‡)	2000	20 17 39	-12 30.5	PriStd	4.24	G3 IB

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Name	Ep	RA	Dec	Type	V	Sp
HD194612	2000	20 38 19	-81 17.0	SPS	5.91	K5 III
HD195135	2000	20 29 38	-02 53.1	PriStd	4.91	K2 III
HD195627	2000	20 35 34	-60 35.0	SecStd	4.80	F1 III
HD195810(v?)	2000	20 33 13	+11 18.0	PriStd	4.03	B6 III
HD196171	2000	20 37 34	-47 18.0	SecStd	3.11	K0 IIICNv
HD196426	2000	20 37 19	+00 05.8	PriStd	6.19	B8 III,P
HD198070	2000	20 47 48	+03 18.4	PriStd	6.40	A0 V,N
HD198743	2000	20 52 40	-08 58.9	PriStd	4.73	A3 ,M
HD199442	2000	20 57 10	+00 27.9	PriStd	6.06	K2 III
HD199951	2000	21 01 17	-32 15.0	SecStd	4.67	G4 III
HD199960	2000	21 00 34	-04 43.7	PriStd	6.21	G1 V
HD200163	2000	21 02 58	-38 37.0	PriExtn	5.35	F3 V
HD200644	2000	21 04 34	+05 30.2	PriStd	5.61	K5 III
HD202418	2000	21 32 02	-84 49.0	SPS	6.45	K3 III
HD202627	2000	21 17 56	-32 10.0	SecStd	4.70	A1 V
HD203532	2000	21 33 54	-82 41.0	SPS	6.38	B3 IV
HD203608	2000	21 26 26	-65 23.0	SecStd	4.22	F6 V
HD203926	2000	21 25 17	-03 33.3	PriStd	5.49	K4 III
HD203955	2000	21 33 20	-80 02.0	SPS	6.47	A0 V
HD204075	2000	21 26 40	-22 24.7	PriStd	3.76	G4 IB
HD204904	2000	21 38 55	-79 27.0	SPS	6.17	F4 IV
HD205478	2000	21 41 28	-77 23.0	SPS	3.76	K0 III
HD205924	2000	21 38 32	+05 46.3	PriStd	5.67	A9 IV-V,N
HD206742	2000	21 44 57	-33 01.0	SecStd	4.30	A0 V
HD206834	2000	21 44 60	-09 05.0	PriStd	5.10	G8 II-III
HD208450	2000	21 57 55	-55 00.0	SecStd	4.40	F0 IV
HD209100	2000	22 02 57	-56 45.0	SecStd	4.69	K4.5 V
HD209750	2000	22 05 47	-00 19.2	PriStd	2.96	G2 Ib
HD210302	2000	22 10 08	-32 33.0	PriExtn	4.92	F6 V
HD210434	2000	22 10 33	-04 16.0	PriStd	6.02	K0 III-IV
HD210967	2000	22 20 01	-80 26.0	SPS	5.10	M5 III
HD211088	2000	22 15 37	-41 21.0	SecStd	4.79	G8 III+...
HD211416	2000	22 18 31	-60 16.0	SecStd	2.86	K3 III
HD212581(∞)	2000	22 27 19	-64 58.0	SecStd	4.50	B9.5 V
HD213009	2000	22 29 16	-43 30.0	SecStd	3.97	G7 III
HD213398	2000	22 31 30	-32 21.0	SecStd	4.29	A0 V
HD214298	2000	22 37 05	+12 34.7	PriStd	6.28	K5
HD214846	2000	22 46 05	-81 23.0	SPS	4.15	A9 IV-V
HD215369	2000	22 45 38	-53 30.0	SecStd	4.85	K2 IIICNv
HD216143	2000	22 50 31	-06 55.0	PriStd	7.85	G8-MDGE
HD216701	2000	22 54 59	+01 03.9	PriStd	6.11	A7 III
HD216762	2000	22 55 56	-31 55.2	PriStd	6.41	S5,1
HD217364	2000	23 00 53	-52 45.0	SecStd	4.12	G9 III

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Name	Ep	RA	Dec	Type	V	Sp
HD217792		23 03 30	-34 45.0	PriExtn	5.13	F0 V+...
HD217877	2000	23 03 56	-04 47.7	PriStd	6.70	F8 V
HD218527	2000	23 08 40	+02 07.6	PriStd	5.39	G8 III-IV-MD
HD218559	2000	23 12 12	-80 55.0	SPS	6.41	K4 III
HD218670	2000	23 10 21	-45 15.0	SecStd	3.90	K1 III
HD219449	2000	23 15 52	-09 05.2	PriStd	4.25	K0 III
HD219571	2000	23 17 26	-58 14.0	SecStd	3.99	F1 III
HD219765	2000	23 28 02	-87 29.0	SPS	5.49	K2 III
HD219784	2000	23 18 49	-32 32.0	SecStd	4.41	G8 III
HD221507	2000	23 32 58	-37 49.0	SecStd	4.37	B9.5 IVmn
HD221760	2000	23 35 04	-42 37.0	SecStd	4.71	A2 Vp...
HD221950	2000	23 36 23	+02 06.1	PriStd	5.68	F6 V-MD
HD222368(v?)	2000	23 39 56	+05 37.9	PriStd	4.13	F7 V
HD222493	2000	23 41 09	-11 40.9	PriStd	5.92	G9 III
HD222603	2000	23 42 04	+01 46.9	PriStd	4.50	A7 V
HD223438	2000	23 49 28	+01 04.6	PriStd	5.77	A5 ,M
HD223647	2000	23 52 08	-82 01.0	SPS	5.11	G7 III
HD223833	2000	23 53 45	-83 00.0	SPS	6.9	M0 III
HD224362	2000	23 57 34	-82 10.0	SPS	5.73	K0 III
HD224392	2000	23 57 34	-64 18.0	SecStd	5.00	A1 V
HD224686	2000	23 59 55	-65 35.0	SecStd	4.50	B9 IV
HD224889	2000	00 01 37	-77 04.0	SPS	4.78	K3 III
HD224935(v)	2000	00 01 58	-06 00.8	PriStd	4.41	M3 III
κ Crucis		12 52 54	-60 17.0	Program		
O Vellorum	2000	08 40 18	-52 55.3	Program		

Appendix D

The Reduced Observations.

The following tables give the reduced magnitudes from the individual observations of the primary standard stars, secondary standard stars, and the clusters κ Crucis and O Vel. They are sorted by star name, and for the same star, further sorted by date and time of observation. These tables have been included so later observers may add further observations to each star and recalculate the mean values, and also investigate possible variability of a star.

The first column in each table is the star's name. The next column is the observation's calendar date. The third column is the time (UT) of the mid-point of the observation, in *hours* and *minutes*. Immediately after this is the index number n of the observation, which indicates this was the n^{th} observation on that night – this is useful for easy reference back to the original data files and observation log books. The remaining seven columns are the reduced V magnitude and colours, with their standard deviations. These values are all given to *milli-magnitudes*.

Table D.1: The individual reduced observations for the primary standard stars.

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
001879	03 Jul 93	18 22	127	6.464 ± 0.040	0.844 ± 0.048	1.406 ± 0.028	2.084 ± 0.023	0.621 ± 0.021	0.527 ± 0.012	1.153 ± 0.021
	07 Jul 93	18 21	120	6.434 ± 0.039	0.879 ± 0.044	1.425 ± 0.026	2.094 ± 0.027	0.641 ± 0.017	0.517 ± 0.017	1.127 ± 0.027
003296	03 Jul 93	18 31	128	6.754 ± 0.030	0.507 ± 0.027	0.575 ± 0.015	0.645 ± 0.019	0.295 ± 0.016	0.171 ± 0.013	0.451 ± 0.019
	07 Jul 93	18 29	121	6.717 ± 0.041	0.485 ± 0.024	0.574 ± 0.014	0.645 ± 0.018	0.289 ± 0.012	0.179 ± 0.012	0.459 ± 0.020
004628	03 Jul 93	18 37	129	5.755 ± 0.034	0.452 ± 0.034	0.893 ± 0.019	1.170 ± 0.022	0.329 ± 0.022	0.364 ± 0.015	0.697 ± 0.020
005112	03 Jul 93	18 44	130	4.797 ± 0.041	0.816 ± 0.045	1.384 ± 0.024	2.084 ± 0.024	0.603 ± 0.024	0.541 ± 0.018	1.050 ± 0.022
	07 Jul 93	18 35	122	4.760 ± 0.046	0.822 ± 0.037	1.372 ± 0.024	2.088 ± 0.027	0.610 ± 0.018	0.523 ± 0.017	1.044 ± 0.027
005268	03 Jul 93	18 50	131	6.199 ± 0.033	0.592 ± 0.031	0.833 ± 0.018	1.104 ± 0.020	0.444 ± 0.016	0.286 ± 0.013	0.712 ± 0.018
	07 Jul 93	18 41	123	6.161 ± 0.040	0.605 ± 0.027	0.833 ± 0.016	1.095 ± 0.021	0.453 ± 0.012	0.283 ± 0.014	0.701 ± 0.021
026912	25 Nov 90	13 45	9	4.290 ± 0.031	0.339 ± 0.033	0.393 ± 0.032	0.202 ± 0.024	0.108 ± 0.031	0.068 ± 0.033	0.150 ± 0.042
	25 Nov 90	13 48	10	4.291 ± 0.032	0.338 ± 0.033	0.409 ± 0.034	0.196 ± 0.029	0.103 ± 0.034	0.072 ± 0.034	0.146 ± 0.039
028556	25 Nov 90	14 24	18	5.439 ± 0.035	0.615 ± 0.044	0.741 ± 0.039	0.536 ± 0.037	0.203 ± 0.040	0.107 ± 0.045	0.319 ± 0.047
	25 Nov 90	14 27	19	5.423 ± 0.033	0.612 ± 0.042	0.747 ± 0.046	0.531 ± 0.039	0.194 ± 0.040	0.134 ± 0.046	0.289 ± 0.048
031237	25 Nov 90	13 32	6	3.724 ± 0.036	0.180 ± 0.036	0.207 ± 0.037	0.135 ± 0.032	0.072 ± 0.039	0.020 ± 0.038	0.086 ± 0.041
	25 Nov 90	13 35	7	3.706 ± 0.032	0.174 ± 0.033	0.221 ± 0.035	0.117 ± 0.030	0.070 ± 0.037	0.040 ± 0.036	0.071 ± 0.038
031283	25 Nov 90	13 58	12	5.197 ± 0.032	0.693 ± 0.037	0.851 ± 0.034	0.408 ± 0.023	0.133 ± 0.028	0.100 ± 0.035	0.193 ± 0.042
	25 Nov 90	14 01	13	5.189 ± 0.031	0.688 ± 0.033	0.832 ± 0.032	0.436 ± 0.023	0.137 ± 0.028	0.099 ± 0.035	0.185 ± 0.041
050082	14 Feb 93	10 00	13	7.407 ± 0.051	0.487 ± 0.054	0.837 ± 0.023	1.285 ± 0.014	0.494 ± 0.021	0.282 ± 0.019	0.707 ± 0.036
	14 Feb 93	10 02	14	7.404 ± 0.052	0.480 ± 0.052	0.846 ± 0.025	1.276 ± 0.015	0.490 ± 0.021	0.295 ± 0.020	0.717 ± 0.026
052382	16 Feb 93	09 39	13	6.420 ± 0.031	0.217 ± 0.055	0.180 ± 0.017	0.285 ± 0.012	0.249 ± 0.012	0.116 ± 0.011	0.333 ± 0.025
	16 Feb 93	09 41	14	6.414 ± 0.031	0.183 ± 0.055	0.178 ± 0.017	0.284 ± 0.012	0.247 ± 0.012	0.123 ± 0.010	0.329 ± 0.025
	18 Feb 93	09 29	10	6.457 ± 0.033	0.222 ± 0.071	0.185 ± 0.017	0.282 ± 0.013	0.255 ± 0.016	0.121 ± 0.013	0.339 ± 0.023
	18 Feb 93	09 31	11	6.468 ± 0.033	0.223 ± 0.070	0.183 ± 0.016	0.294 ± 0.012	0.240 ± 0.015	0.120 ± 0.014	0.331 ± 0.025
055751	27 Feb 91	09 40	11	5.339 ± 0.033	0.659 ± 0.032	1.097 ± 0.022	1.547 ± 0.032	0.529 ± 0.015	0.346 ± 0.015	0.797 ± 0.021
	27 Feb 91	09 43	12	5.337 ± 0.033	0.652 ± 0.032	1.092 ± 0.023	1.547 ± 0.033	0.545 ± 0.015	0.334 ± 0.015	0.804 ± 0.022
	28 Feb 91	09 51	8	5.338 ± 0.019	0.644 ± 0.038	1.102 ± 0.034	1.537 ± 0.029	0.542 ± 0.037	0.332 ± 0.031	0.793 ± 0.033
	28 Feb 91	09 54	9	5.340 ± 0.019	0.638 ± 0.038	1.109 ± 0.033	1.540 ± 0.026	0.554 ± 0.036	0.323 ± 0.031	0.793 ± 0.034
06 Feb 92	11 10	25	25	5.357 ± 0.043	0.651 ± 0.042	1.120 ± 0.037	1.539 ± 0.018	0.547 ± 0.029	0.310 ± 0.066	0.810 ± 0.023
	06 Feb 92	11 12	26	5.364 ± 0.043	0.659 ± 0.032	1.112 ± 0.030	1.545 ± 0.017	0.534 ± 0.027	0.304 ± 0.066	0.818 ± 0.023
	09 Feb 92	10 50	9	5.352 ± 0.038	0.659 ± 0.040	1.125 ± 0.037	1.530 ± 0.024	0.550 ± 0.025	0.308 ± 0.057	0.804 ± 0.026

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
055751	09 Feb 92	10 53	10	5.349 ± 0.040	0.656 ± 0.036	1.107 ± 0.033	1.548 ± 0.029	0.542 ± 0.029	0.300 ± 0.058	0.808 ± 0.024
	10 Feb 92	10 18	19	5.380 ± 0.040	0.666 ± 0.058	1.100 ± 0.044	1.563 ± 0.032	0.535 ± 0.031	0.283 ± 0.064	0.810 ± 0.023
	10 Feb 92	10 20	20	5.376 ± 0.039	0.648 ± 0.055	1.112 ± 0.045	1.533 ± 0.025	0.558 ± 0.026	0.271 ± 0.063	0.817 ± 0.019
	16 Feb 93	10 21	26	5.232 ± 0.034	0.808 ± 0.062	0.846 ± 0.016	0.477 ± 0.013	0.187 ± 0.013	0.105 ± 0.011	0.253 ± 0.025
059881	16 Feb 93	10 23	27	5.217 ± 0.034	0.813 ± 0.062	0.847 ± 0.015	0.472 ± 0.014	0.187 ± 0.015	0.113 ± 0.011	0.256 ± 0.025
	18 Feb 93	10 23	24	5.186 ± 0.038	0.810 ± 0.079	0.832 ± 0.023	0.486 ± 0.018	0.183 ± 0.014	0.120 ± 0.015	0.257 ± 0.025
	18 Feb 93	10 25	25	5.187 ± 0.037	0.821 ± 0.080	0.826 ± 0.019	0.471 ± 0.017	0.194 ± 0.016	0.114 ± 0.013	0.257 ± 0.024
	16 Feb 93	10 27	28	5.131 ± 0.034	0.370 ± 0.062	0.448 ± 0.017	0.168 ± 0.014	0.081 ± 0.015	0.038 ± 0.010	0.089 ± 0.023
063975	16 Feb 93	10 29	29	5.118 ± 0.034	0.420 ± 0.062	0.437 ± 0.019	0.176 ± 0.017	0.082 ± 0.016	0.039 ± 0.012	0.088 ± 0.025
	18 Feb 93	10 29	26	5.088 ± 0.036	0.362 ± 0.078	0.453 ± 0.021	0.172 ± 0.018	0.080 ± 0.018	0.041 ± 0.012	0.085 ± 0.022
	18 Feb 93	10 31	27	5.087 ± 0.036	0.355 ± 0.077	0.444 ± 0.018	0.170 ± 0.015	0.090 ± 0.016	0.033 ± 0.011	0.092 ± 0.021
	27 Feb 91	09 53	14	4.347 ± 0.030	0.662 ± 0.028	0.839 ± 0.020	1.215 ± 0.029	0.467 ± 0.014	0.286 ± 0.014	0.678 ± 0.020
067594	27 Feb 91	09 56	15	4.356 ± 0.030	0.663 ± 0.028	0.839 ± 0.019	1.223 ± 0.029	0.460 ± 0.014	0.277 ± 0.014	0.692 ± 0.019
	28 Feb 91	10 02	11	4.356 ± 0.017	0.656 ± 0.033	0.841 ± 0.029	1.212 ± 0.023	0.468 ± 0.032	0.276 ± 0.028	0.692 ± 0.030
	28 Feb 91	10 05	12	4.355 ± 0.017	0.654 ± 0.033	0.846 ± 0.029	1.211 ± 0.023	0.476 ± 0.032	0.268 ± 0.028	0.694 ± 0.030
	06 Feb 92	13 12	58	4.339 ± 0.040	0.660 ± 0.028	0.849 ± 0.026	1.216 ± 0.014	0.476 ± 0.026	0.271 ± 0.062	0.702 ± 0.020
	06 Feb 92	13 14	59	4.338 ± 0.040	0.644 ± 0.028	0.848 ± 0.027	1.217 ± 0.016	0.472 ± 0.028	0.280 ± 0.063	0.700 ± 0.020
	09 Feb 92	10 59	12	4.349 ± 0.036	0.655 ± 0.032	0.858 ± 0.025	1.220 ± 0.020	0.485 ± 0.026	0.237 ± 0.053	0.698 ± 0.025
	09 Feb 92	11 01	13	4.348 ± 0.035	0.656 ± 0.032	0.870 ± 0.024	1.212 ± 0.019	0.489 ± 0.026	0.232 ± 0.053	0.702 ± 0.019
	10 Feb 92	11 29	38	4.375 ± 0.035	0.670 ± 0.046	0.843 ± 0.038	1.206 ± 0.024	0.480 ± 0.024	0.235 ± 0.058	0.701 ± 0.018
	10 Feb 92	11 31	39	4.364 ± 0.035	0.684 ± 0.047	0.818 ± 0.037	1.231 ± 0.022	0.478 ± 0.024	0.237 ± 0.057	0.697 ± 0.017
	16 Feb 93	11 26	44	4.320 ± 0.038	0.713 ± 0.062	0.844 ± 0.018	1.211 ± 0.015	0.460 ± 0.017	0.288 ± 0.016	0.673 ± 0.033
	16 Feb 93	11 28	45	4.322 ± 0.038	0.704 ± 0.062	0.845 ± 0.019	1.219 ± 0.015	0.457 ± 0.016	0.287 ± 0.015	0.672 ± 0.033
	17 Feb 93	11 29	9	4.316 ± 0.045	0.626 ± 0.047	0.848 ± 0.026	1.204 ± 0.014	0.474 ± 0.017	0.281 ± 0.016	0.680 ± 0.024
	17 Feb 93	11 31	10	4.319 ± 0.043	0.670 ± 0.046	0.841 ± 0.026	1.206 ± 0.015	0.466 ± 0.018	0.276 ± 0.014	0.684 ± 0.022
	18 Feb 93	11 29	44	4.327 ± 0.039	0.614 ± 0.083	0.855 ± 0.020	1.206 ± 0.019	0.465 ± 0.022	0.274 ± 0.014	0.691 ± 0.030
	18 Feb 93	11 31	45	4.321 ± 0.040	0.618 ± 0.084	0.845 ± 0.022	1.216 ± 0.016	0.471 ± 0.019	0.277 ± 0.016	0.688 ± 0.031
074521	27 Feb 91	10 05	17	5.613 ± 0.021	0.496 ± 0.018	0.601 ± 0.013	0.260 ± 0.020	0.021 ± 0.015	0.083 ± 0.012	0.160 ± 0.014
	27 Feb 91	10 08	18	5.612 ± 0.021	0.486 ± 0.018	0.602 ± 0.013	0.257 ± 0.020	0.013 ± 0.015	0.090 ± 0.012	0.147 ± 0.014
	28 Feb 91	10 13	14	5.653 ± 0.018	0.499 ± 0.026	0.612 ± 0.023	0.217 ± 0.020	0.051 ± 0.028	0.061 ± 0.024	0.170 ± 0.023
	28 Feb 91	10 17	15	5.647 ± 0.017	0.499 ± 0.024	0.608 ± 0.024	0.221 ± 0.024	0.060 ± 0.027	0.048 ± 0.022	0.176 ± 0.022

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Table D.1 continued from previous page										
HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
090994	27 Feb 91	13 12	65	5.097 ± 0.019	0.278 ± 0.018	0.460 ± 0.013	0.160 ± 0.019	0.052 ± 0.013	0.050 ± 0.011	0.055 ± 0.013
	27 Feb 91	13 15	66	5.091 ± 0.019	0.280 ± 0.018	0.459 ± 0.013	0.163 ± 0.019	0.062 ± 0.013	0.046 ± 0.011	0.048 ± 0.013
	11 May 91	10 03	14	5.051 ± 0.029	0.290 ± 0.016	0.434 ± 0.020	0.166 ± 0.018	0.071 ± 0.020	0.041 ± 0.019	0.056 ± 0.017
	11 May 91	10 06	15	5.040 ± 0.029	0.287 ± 0.016	0.436 ± 0.019	0.161 ± 0.016	0.062 ± 0.019	0.065 ± 0.019	0.049 ± 0.019
	06 Feb 92	14 19	78	5.062 ± 0.037	0.290 ± 0.021	0.466 ± 0.021	0.163 ± 0.015	0.061 ± 0.024	0.060 ± 0.055	0.087 ± 0.018
	06 Feb 92	14 21	79	5.058 ± 0.036	0.306 ± 0.021	0.455 ± 0.022	0.166 ± 0.015	0.062 ± 0.023	0.060 ± 0.055	0.094 ± 0.017
	09 Feb 92	13 28	57	5.095 ± 0.035	0.308 ± 0.027	0.462 ± 0.021	0.176 ± 0.021	0.087 ± 0.023	0.007 ± 0.050	0.110 ± 0.019
	09 Feb 92	13 31	58	5.101 ± 0.036	0.317 ± 0.025	0.464 ± 0.024	0.179 ± 0.022	0.086 ± 0.022	-0.004 ± 0.051	0.104 ± 0.021
	10 Feb 92	13 21	66	5.076 ± 0.034	0.242 ± 0.034	0.471 ± 0.027	0.140 ± 0.019	0.069 ± 0.022	0.040 ± 0.052	0.093 ± 0.016
	10 Feb 92	13 23	67	5.080 ± 0.035	0.255 ± 0.035	0.473 ± 0.029	0.145 ± 0.023	0.072 ± 0.025	0.037 ± 0.053	0.091 ± 0.019
	16 Feb 93	12 37	64	5.115 ± 0.034	0.276 ± 0.061	0.450 ± 0.018	0.180 ± 0.014	0.078 ± 0.015	0.020 ± 0.012	0.060 ± 0.024
	16 Feb 93	12 40	65	5.115 ± 0.033	0.277 ± 0.061	0.437 ± 0.018	0.183 ± 0.013	0.073 ± 0.014	0.024 ± 0.010	0.068 ± 0.025
	17 Feb 93	12 36	25	5.095 ± 0.038	0.245 ± 0.044	0.470 ± 0.022	0.164 ± 0.017	0.060 ± 0.016	0.030 ± 0.011	0.080 ± 0.018
	17 Feb 93	12 40	26	5.081 ± 0.037	0.270 ± 0.044	0.476 ± 0.021	0.155 ± 0.014	0.060 ± 0.019	0.029 ± 0.015	0.081 ± 0.017
	18 Feb 93	12 36	60	5.081 ± 0.036	0.278 ± 0.075	0.433 ± 0.016	0.182 ± 0.014	0.067 ± 0.016	0.024 ± 0.013	0.068 ± 0.021
	18 Feb 93	12 38	61	5.083 ± 0.035	0.275 ± 0.075	0.444 ± 0.016	0.172 ± 0.013	0.062 ± 0.015	0.032 ± 0.011	0.068 ± 0.021
091316	27 Feb 91	13 23	68	3.899 ± 0.021	0.102 ± 0.022	0.105 ± 0.018	0.091 ± 0.022	0.093 ± 0.019	0.053 ± 0.016	0.101 ± 0.014
	27 Feb 91	13 26	69	3.889 ± 0.021	0.103 ± 0.022	0.107 ± 0.018	0.096 ± 0.022	0.098 ± 0.019	0.055 ± 0.017	0.098 ± 0.015
	14 Apr 91	08 12	1	3.840 ± 0.024	0.125 ± 0.034	0.098 ± 0.028	0.102 ± 0.022	0.113 ± 0.026	0.031 ± 0.029	0.120 ± 0.023
	14 Apr 91	08 17	2	3.825 ± 0.023	0.124 ± 0.036	0.102 ± 0.025	0.112 ± 0.026	0.111 ± 0.028	0.032 ± 0.027	0.111 ± 0.021
	11 May 91	10 16	17	3.835 ± 0.033	0.112 ± 0.021	0.085 ± 0.029	0.094 ± 0.026	0.090 ± 0.027	0.056 ± 0.026	0.111 ± 0.025
11 May 91	10 19	18	3.823 ± 0.032	0.117 ± 0.021	0.080 ± 0.027	0.098 ± 0.027	0.094 ± 0.028	0.059 ± 0.024	0.087 ± 0.021	
091612	14 Apr 91	08 30	4	5.109 ± 0.033	0.488 ± 0.037	0.879 ± 0.028	1.156 ± 0.029	0.434 ± 0.021	0.280 ± 0.026	0.727 ± 0.028
	14 Apr 91	08 34	5	5.109 ± 0.031	0.514 ± 0.038	0.857 ± 0.026	1.185 ± 0.024	0.410 ± 0.018	0.291 ± 0.026	0.713 ± 0.025
	11 May 91	10 28	20	5.013 ± 0.049	0.519 ± 0.028	0.910 ± 0.033	1.175 ± 0.027	0.428 ± 0.025	0.276 ± 0.028	0.683 ± 0.030
	11 May 91	10 31	21	5.022 ± 0.047	0.510 ± 0.027	0.930 ± 0.031	1.170 ± 0.027	0.436 ± 0.026	0.260 ± 0.026	0.696 ± 0.028
	06 Feb 92	14 26	80	5.070 ± 0.044	0.548 ± 0.029	0.878 ± 0.029	1.169 ± 0.019	0.437 ± 0.028	0.289 ± 0.066	0.711 ± 0.022
	06 Feb 92	14 29	81	5.069 ± 0.044	0.561 ± 0.029	0.866 ± 0.027	1.172 ± 0.016	0.433 ± 0.028	0.293 ± 0.067	0.696 ± 0.022
	09 Feb 92	14 22	75	5.080 ± 0.041	0.560 ± 0.044	0.851 ± 0.038	1.173 ± 0.021	0.443 ± 0.025	0.283 ± 0.060	0.711 ± 0.020
	09 Feb 92	14 24	76	5.083 ± 0.041	0.564 ± 0.040	0.874 ± 0.033	1.179 ± 0.033	0.418 ± 0.029	0.291 ± 0.059	0.714 ± 0.021
	10 Feb 92	13 29	68	5.077 ± 0.041	0.561 ± 0.048	0.860 ± 0.039	1.173 ± 0.025	0.439 ± 0.026	0.265 ± 0.065	0.707 ± 0.021
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Table D.1 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
091612	10 Feb 92	13 31	69	5.081 ± 0.040	0.565 ± 0.047	0.852 ± 0.040	1.170 ± 0.028	0.454 ± 0.027	0.256 ± 0.064	0.701 ± 0.018
	18 Feb 93	13 18	72	5.073 ± 0.043	0.600 ± 0.092	0.874 ± 0.020	1.164 ± 0.015	0.439 ± 0.020	0.275 ± 0.016	0.705 ± 0.031
	18 Feb 93	13 20	73	5.089 ± 0.044	0.613 ± 0.092	0.877 ± 0.022	1.160 ± 0.016	0.439 ± 0.020	0.267 ± 0.017	0.704 ± 0.031
095345	06 Feb 92	13 24	61	4.854 ± 0.044	0.632 ± 0.033	1.095 ± 0.032	1.485 ± 0.018	0.501 ± 0.029	0.333 ± 0.067	0.821 ± 0.021
	06 Feb 92	13 26	62	4.834 ± 0.044	0.630 ± 0.033	1.107 ± 0.032	1.469 ± 0.019	0.507 ± 0.029	0.345 ± 0.068	0.801 ± 0.022
	09 Feb 92	14 16	73	4.840 ± 0.040	0.625 ± 0.035	1.093 ± 0.029	1.481 ± 0.022	0.508 ± 0.026	0.355 ± 0.058	0.821 ± 0.026
	09 Feb 92	14 18	74	4.851 ± 0.039	0.603 ± 0.037	1.114 ± 0.034	1.479 ± 0.029	0.492 ± 0.025	0.359 ± 0.057	0.810 ± 0.021
	10 Feb 92	14 18	83	4.855 ± 0.041	0.640 ± 0.053	1.079 ± 0.044	1.477 ± 0.026	0.490 ± 0.027	0.356 ± 0.064	0.819 ± 0.023
	10 Feb 92	14 20	84	4.849 ± 0.039	0.646 ± 0.054	1.067 ± 0.045	1.479 ± 0.030	0.499 ± 0.031	0.352 ± 0.064	0.808 ± 0.018
	11 Apr 92	10 55	51	4.858 ± 0.059	0.614 ± 0.041	1.122 ± 0.049	1.502 ± 0.032	0.515 ± 0.019	0.348 ± 0.022	0.800 ± 0.045
	11 Apr 92	10 56	52	4.856 ± 0.059	0.618 ± 0.041	1.111 ± 0.049	1.490 ± 0.032	0.511 ± 0.019	0.348 ± 0.021	0.803 ± 0.045
	14 Apr 92	10 44	75	4.886 ± 0.075	0.611 ± 0.036	1.126 ± 0.064	1.520 ± 0.054	0.484 ± 0.050	0.357 ± 0.023	0.785 ± 0.038
	14 Apr 92	10 46	76	4.882 ± 0.075	0.608 ± 0.036	1.128 ± 0.064	1.514 ± 0.054	0.471 ± 0.050	0.350 ± 0.026	0.802 ± 0.038
	15 Apr 92	09 42	53	4.848 ± 0.026	0.635 ± 0.047	1.092 ± 0.021	1.511 ± 0.022	0.483 ± 0.029	0.356 ± 0.019	0.807 ± 0.019
	15 Apr 92	09 44	54	4.840 ± 0.028	0.612 ± 0.047	1.111 ± 0.022	1.496 ± 0.021	0.477 ± 0.027	0.364 ± 0.022	0.794 ± 0.023
	15 Feb 93	13 40	43	4.868 ± 0.056	0.579 ± 0.101	1.110 ± 0.049	1.469 ± 0.024	0.487 ± 0.024	0.362 ± 0.017	0.798 ± 0.014
	15 Feb 93	13 42	44	4.849 ± 0.056	0.582 ± 0.101	1.103 ± 0.049	1.473 ± 0.026	0.486 ± 0.025	0.367 ± 0.017	0.804 ± 0.018
	16 Feb 93	13 36	80	4.845 ± 0.041	0.611 ± 0.069	1.085 ± 0.021	1.486 ± 0.014	0.486 ± 0.017	0.358 ± 0.016	0.800 ± 0.035
	16 Feb 93	13 39	81	4.836 ± 0.040	0.604 ± 0.070	1.093 ± 0.022	1.488 ± 0.015	0.497 ± 0.018	0.353 ± 0.015	0.812 ± 0.035
095849	17 Feb 93	13 36	41	4.837 ± 0.048	0.633 ± 0.052	1.089 ± 0.031	1.485 ± 0.018	0.510 ± 0.019	0.344 ± 0.016	0.803 ± 0.024
	17 Feb 93	13 38	42	4.820 ± 0.047	0.620 ± 0.056	1.106 ± 0.030	1.471 ± 0.014	0.511 ± 0.018	0.353 ± 0.012	0.802 ± 0.023
	18 Feb 93	13 24	74	4.831 ± 0.043	0.688 ± 0.092	1.087 ± 0.023	1.480 ± 0.018	0.501 ± 0.021	0.341 ± 0.016	0.810 ± 0.033
	18 Feb 93	13 26	75	4.838 ± 0.043	0.675 ± 0.092	1.092 ± 0.023	1.479 ± 0.015	0.501 ± 0.021	0.345 ± 0.016	0.809 ± 0.033
	23 May 93	07 48	12	5.921 ± 0.026	0.659 ± 0.028	1.207 ± 0.021	1.617 ± 0.013	0.494 ± 0.021	0.384 ± 0.016	0.808 ± 0.015
097585	23 May 93	07 51	13	5.916 ± 0.026	0.665 ± 0.025	1.199 ± 0.017	1.616 ± 0.012	0.492 ± 0.021	0.378 ± 0.016	0.823 ± 0.015
	23 May 93	07 55	14	5.403 ± 0.019	0.684 ± 0.016	0.764 ± 0.013	0.259 ± 0.012	0.107 ± 0.017	0.056 ± 0.014	0.122 ± 0.013
	23 May 93	07 58	15	5.398 ± 0.019	0.682 ± 0.016	0.766 ± 0.013	0.262 ± 0.011	0.103 ± 0.014	0.057 ± 0.011	0.126 ± 0.011
098058	28 Feb 91	14 23	65	4.474 ± 0.015	0.724 ± 0.022	0.803 ± 0.021	0.455 ± 0.018	0.183 ± 0.026	0.110 ± 0.021	0.302 ± 0.021
	28 Feb 91	14 26	66	4.467 ± 0.015	0.721 ± 0.023	0.801 ± 0.021	0.462 ± 0.019	0.182 ± 0.026	0.110 ± 0.021	0.303 ± 0.022
	14 Apr 91	08 47	7	4.467 ± 0.024	0.720 ± 0.027	0.790 ± 0.019	0.461 ± 0.018	0.175 ± 0.018	0.104 ± 0.023	0.281 ± 0.020
	14 Apr 91	08 51	8	4.469 ± 0.024	0.714 ± 0.029	0.803 ± 0.022	0.447 ± 0.019	0.179 ± 0.016	0.106 ± 0.021	0.279 ± 0.020

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
098058	11 May 91	10 39	23	4.440 ± 0.032	0.696 ± 0.015	0.808 ± 0.019	0.447 ± 0.017	0.177 ± 0.018	0.108 ± 0.020	0.271 ± 0.021
	11 May 91	10 42	24	4.442 ± 0.031	0.699 ± 0.017	0.806 ± 0.019	0.443 ± 0.016	0.190 ± 0.018	0.098 ± 0.018	0.268 ± 0.018
	10 Feb 92	14 25	85	4.467 ± 0.033	0.675 ± 0.035	0.804 ± 0.028	0.444 ± 0.019	0.182 ± 0.022	0.127 ± 0.052	0.293 ± 0.016
	10 Feb 92	14 27	86	4.494 ± 0.032	0.679 ± 0.038	0.809 ± 0.032	0.454 ± 0.021	0.186 ± 0.023	0.118 ± 0.051	0.312 ± 0.015
	18 Feb 93	14 08	88	5.793 ± 0.039	0.471 ± 0.082	0.575 ± 0.021	0.669 ± 0.014	0.274 ± 0.016	0.163 ± 0.016	0.443 ± 0.026
102124	18 Feb 93	14 10	89	5.790 ± 0.039	0.429 ± 0.083	0.560 ± 0.022	0.676 ± 0.013	0.274 ± 0.015	0.166 ± 0.013	0.450 ± 0.025
	20 May 93	08 40	21	4.829 ± 0.019	0.599 ± 0.015	0.791 ± 0.011	0.460 ± 0.011	0.169 ± 0.014	0.094 ± 0.012	0.241 ± 0.010
102510	20 May 93	08 43	22	4.834 ± 0.019	0.592 ± 0.014	0.788 ± 0.011	0.462 ± 0.011	0.165 ± 0.014	0.098 ± 0.012	0.241 ± 0.011
	20 May 93	08 47	23	5.305 ± 0.019	0.577 ± 0.015	0.803 ± 0.013	0.339 ± 0.013	0.120 ± 0.013	0.060 ± 0.012	0.146 ± 0.011
102870	20 May 93	08 50	24	5.305 ± 0.019	0.568 ± 0.014	0.810 ± 0.011	0.342 ± 0.010	0.121 ± 0.014	0.059 ± 0.013	0.137 ± 0.011
	28 Feb 91	14 48	72	3.608 ± 0.019	0.496 ± 0.026	0.615 ± 0.024	0.754 ± 0.022	0.310 ± 0.032	0.189 ± 0.028	0.527 ± 0.027
	28 Feb 91	14 51	73	3.595 ± 0.018	0.502 ± 0.027	0.614 ± 0.026	0.759 ± 0.022	0.310 ± 0.032	0.191 ± 0.028	0.514 ± 0.027
	14 Apr 91	09 03	10	3.595 ± 0.029	0.452 ± 0.032	0.614 ± 0.022	0.764 ± 0.022	0.319 ± 0.028	0.175 ± 0.033	0.515 ± 0.025
	14 Apr 91	09 07	11	3.598 ± 0.030	0.429 ± 0.038	0.642 ± 0.024	0.758 ± 0.025	0.333 ± 0.029	0.166 ± 0.034	0.510 ± 0.028
104181	11 May 91	10 50	26	3.564 ± 0.038	0.455 ± 0.021	0.627 ± 0.022	0.745 ± 0.019	0.304 ± 0.022	0.185 ± 0.023	0.508 ± 0.023
	11 May 91	10 54	27	3.569 ± 0.038	0.449 ± 0.020	0.641 ± 0.022	0.744 ± 0.020	0.306 ± 0.023	0.176 ± 0.025	0.509 ± 0.024
	10 Feb 92	15 25	101	3.594 ± 0.036	0.460 ± 0.042	0.606 ± 0.033	0.731 ± 0.022	0.300 ± 0.028	0.223 ± 0.058	0.502 ± 0.018
	10 Feb 92	15 27	102	3.580 ± 0.037	0.452 ± 0.040	0.610 ± 0.033	0.736 ± 0.022	0.307 ± 0.029	0.218 ± 0.059	0.511 ± 0.019
	18 Feb 93	14 14	90	3.633 ± 0.039	0.452 ± 0.082	0.612 ± 0.020	0.753 ± 0.023	0.309 ± 0.024	0.189 ± 0.017	0.509 ± 0.026
104979	18 Feb 93	14 16	91	3.635 ± 0.039	0.414 ± 0.082	0.616 ± 0.022	0.741 ± 0.021	0.316 ± 0.025	0.188 ± 0.019	0.515 ± 0.027
	20 May 93	08 55	25	5.349 ± 0.017	0.623 ± 0.014	0.799 ± 0.011	0.308 ± 0.011	0.114 ± 0.013	0.054 ± 0.011	0.140 ± 0.010
105639	20 May 93	08 58	26	5.352 ± 0.017	0.614 ± 0.014	0.804 ± 0.011	0.307 ± 0.010	0.125 ± 0.013	0.044 ± 0.012	0.138 ± 0.010
	16 Feb 93	14 36	96	4.148 ± 0.042	0.552 ± 0.074	0.836 ± 0.020	1.217 ± 0.017	0.445 ± 0.019	0.289 ± 0.015	0.710 ± 0.033
107070	16 Feb 93	14 38	97	4.145 ± 0.042	0.593 ± 0.074	0.835 ± 0.022	1.215 ± 0.019	0.444 ± 0.020	0.284 ± 0.016	0.715 ± 0.033
	16 Feb 93	15 19	108	5.985 ± 0.041	0.636 ± 0.069	1.102 ± 0.026	1.464 ± 0.018	0.450 ± 0.017	0.371 ± 0.018	0.798 ± 0.036
107070	16 Feb 93	15 21	109	5.970 ± 0.040	0.638 ± 0.068	1.112 ± 0.023	1.464 ± 0.015	0.452 ± 0.018	0.371 ± 0.015	0.792 ± 0.034
	09 Feb 92	15 36	93	5.901 ± 0.035	0.695 ± 0.025	0.848 ± 0.020	0.422 ± 0.019	0.155 ± 0.022	0.115 ± 0.050	0.252 ± 0.019
	09 Feb 92	15 38	94	5.895 ± 0.036	0.696 ± 0.031	0.831 ± 0.020	0.441 ± 0.018	0.153 ± 0.024	0.113 ± 0.052	0.247 ± 0.019
	16 Feb 93	15 25	110	5.967 ± 0.033	0.710 ± 0.060	0.830 ± 0.016	0.434 ± 0.013	0.159 ± 0.013	0.095 ± 0.011	0.228 ± 0.025
	16 Feb 93	15 28	111	5.950 ± 0.034	0.719 ± 0.060	0.828 ± 0.016	0.436 ± 0.013	0.156 ± 0.013	0.104 ± 0.014	0.223 ± 0.026
	18 Feb 93	15 18	110	5.951 ± 0.036	0.597 ± 0.075	0.829 ± 0.017	0.443 ± 0.013	0.161 ± 0.014	0.082 ± 0.014	0.239 ± 0.023

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
107070	18 Feb 93	15 20	111	5.950 ± 0.035	0.579 ± 0.077	0.827 ± 0.021	0.428 ± 0.012	0.165 ± 0.014	0.089 ± 0.011	0.238 ± 0.021
107328	14 Apr 91	12 20	39	5.045 ± 0.044	0.600 ± 0.054	1.155 ± 0.044	1.440 ± 0.032	0.496 ± 0.021	0.327 ± 0.039	0.887 ± 0.040
	14 Apr 91	12 25	40	4.965 ± 0.035	0.605 ± 0.041	1.126 ± 0.028	1.472 ± 0.028	0.466 ± 0.020	0.395 ± 0.026	0.813 ± 0.029
	21 May 91	09 26	43	4.945 ± 0.028	0.688 ± 0.033	1.169 ± 0.030	1.502 ± 0.025	0.488 ± 0.026	0.374 ± 0.022	0.829 ± 0.019
	21 May 91	09 29	44	4.938 ± 0.027	0.659 ± 0.040	1.192 ± 0.039	1.505 ± 0.026	0.499 ± 0.029	0.372 ± 0.026	0.848 ± 0.021
	06 Feb 92	15 42	96	4.943 ± 0.042	0.668 ± 0.035	1.107 ± 0.032	1.473 ± 0.018	0.477 ± 0.027	0.402 ± 0.065	0.832 ± 0.021
	06 Feb 92	15 44	97	4.945 ± 0.043	0.656 ± 0.035	1.124 ± 0.031	1.469 ± 0.018	0.476 ± 0.027	0.405 ± 0.066	0.833 ± 0.023
110423	09 Feb 92	15 42	95	4.938 ± 0.038	0.668 ± 0.041	1.110 ± 0.031	1.472 ± 0.022	0.473 ± 0.026	0.413 ± 0.057	0.832 ± 0.020
	09 Feb 92	15 44	96	4.956 ± 0.040	0.673 ± 0.037	1.107 ± 0.028	1.467 ± 0.024	0.481 ± 0.028	0.394 ± 0.058	0.840 ± 0.025
	10 Feb 92	15 39	105	4.953 ± 0.040	0.689 ± 0.054	1.093 ± 0.047	1.473 ± 0.032	0.470 ± 0.028	0.409 ± 0.064	0.822 ± 0.021
	10 Feb 92	15 41	106	4.949 ± 0.039	0.683 ± 0.052	1.100 ± 0.042	1.475 ± 0.026	0.469 ± 0.026	0.406 ± 0.064	0.834 ± 0.021
	21 May 91	09 37	46	5.544 ± 0.026	0.577 ± 0.019	0.815 ± 0.021	0.293 ± 0.028	0.138 ± 0.031	0.047 ± 0.025	0.127 ± 0.024
	21 May 91	09 39	47	5.569 ± 0.030	0.572 ± 0.022	0.821 ± 0.024	0.301 ± 0.023	0.124 ± 0.025	0.024 ± 0.029	0.144 ± 0.027
111721	06 Feb 92	15 52	99	5.582 ± 0.041	0.566 ± 0.022	0.792 ± 0.022	0.288 ± 0.013	0.087 ± 0.024	0.093 ± 0.061	0.125 ± 0.019
	06 Feb 92	15 54	100	5.572 ± 0.042	0.559 ± 0.026	0.801 ± 0.025	0.293 ± 0.020	0.083 ± 0.027	0.099 ± 0.061	0.111 ± 0.019
	09 Feb 92	15 51	98	5.574 ± 0.041	0.562 ± 0.028	0.806 ± 0.023	0.290 ± 0.021	0.107 ± 0.026	0.060 ± 0.058	0.133 ± 0.020
	09 Feb 92	15 53	99	5.575 ± 0.042	0.557 ± 0.033	0.820 ± 0.026	0.289 ± 0.018	0.102 ± 0.025	0.066 ± 0.059	0.130 ± 0.022
	10 Feb 92	15 45	107	5.571 ± 0.042	0.591 ± 0.053	0.793 ± 0.050	0.270 ± 0.047	0.096 ± 0.028	0.104 ± 0.060	0.126 ± 0.030
	10 Feb 92	15 48	108	5.566 ± 0.039	0.507 ± 0.036	0.809 ± 0.029	0.264 ± 0.022	0.085 ± 0.024	0.103 ± 0.058	0.139 ± 0.028
111765	12 Apr 92	11 52	73	7.953 ± 0.032	0.566 ± 0.033	0.605 ± 0.023	0.892 ± 0.024	0.424 ± 0.021	0.255 ± 0.015	0.671 ± 0.029
	12 Apr 92	11 54	74	7.963 ± 0.033	0.562 ± 0.031	0.586 ± 0.026	0.897 ± 0.020	0.428 ± 0.015	0.253 ± 0.017	0.682 ± 0.024
112300	16 Feb 93	15 34	112	6.037 ± 0.041	0.684 ± 0.072	1.222 ± 0.027	1.697 ± 0.016	0.515 ± 0.017	0.421 ± 0.013	0.866 ± 0.036
	16 Feb 93	15 38	113	6.026 ± 0.041	0.670 ± 0.069	1.234 ± 0.021	1.692 ± 0.015	0.510 ± 0.018	0.424 ± 0.014	0.870 ± 0.036
	18 Feb 93	15 25	112	6.021 ± 0.044	0.625 ± 0.094	1.250 ± 0.024	1.682 ± 0.017	0.512 ± 0.021	0.405 ± 0.017	0.888 ± 0.035
	18 Feb 93	15 28	113	6.013 ± 0.044	0.641 ± 0.097	1.245 ± 0.030	1.683 ± 0.017	0.522 ± 0.021	0.406 ± 0.017	0.883 ± 0.035
	20 May 93	09 31	33	6.015 ± 0.019	0.694 ± 0.027	1.235 ± 0.018	1.688 ± 0.011	0.510 ± 0.016	0.420 ± 0.013	0.873 ± 0.014
	20 May 93	09 34	34	6.013 ± 0.019	0.680 ± 0.023	1.241 ± 0.017	1.691 ± 0.010	0.508 ± 0.016	0.412 ± 0.012	0.883 ± 0.014
114960	14 Apr 91	12 37	42	3.357 ± 0.044	0.853 ± 0.051	1.391 ± 0.037	1.909 ± 0.034	0.682 ± 0.031	0.488 ± 0.041	1.178 ± 0.039
	14 Apr 91	12 42	43	3.321 ± 0.044	0.856 ± 0.050	1.383 ± 0.035	1.916 ± 0.033	0.681 ± 0.029	0.504 ± 0.040	1.146 ± 0.039
	10 Feb 92	16 29	119	6.545 ± 0.040	0.782 ± 0.087	1.360 ± 0.061	1.895 ± 0.034	0.466 ± 0.033	0.573 ± 0.068	0.965 ± 0.026
	11 Apr 92	12 04	69	6.577 ± 0.064	0.719 ± 0.058	1.377 ± 0.059	1.940 ± 0.039	0.478 ± 0.022	0.516 ± 0.024	0.956 ± 0.049

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
114960	11 Apr 92	12 06	70	6.585 ± 0.064	0.741 ± 0.062	1.356 ± 0.058	1.932 ± 0.036	0.488 ± 0.022	0.503 ± 0.026	0.963 ± 0.049
	12 Apr 92	13 04	92	6.550 ± 0.042	0.769 ± 0.046	1.355 ± 0.036	1.923 ± 0.031	0.479 ± 0.021	0.525 ± 0.023	0.952 ± 0.028
	12 Apr 92	13 05	93	6.552 ± 0.041	0.734 ± 0.055	1.363 ± 0.042	1.917 ± 0.033	0.498 ± 0.017	0.506 ± 0.019	0.966 ± 0.027
	15 Apr 92	12 21	112	6.576 ± 0.026	0.711 ± 0.058	1.379 ± 0.037	1.933 ± 0.023	0.472 ± 0.026	0.507 ± 0.013	0.971 ± 0.016
	15 Apr 92	12 24	113	6.577 ± 0.026	0.688 ± 0.059	1.402 ± 0.036	1.933 ± 0.023	0.480 ± 0.026	0.500 ± 0.014	0.969 ± 0.018
	15 Feb 93	16 28	91	6.562 ± 0.058	0.698 ± 0.111	1.391 ± 0.059	1.920 ± 0.028	0.500 ± 0.027	0.517 ± 0.018	0.954 ± 0.017
	15 Feb 93	16 31	92	6.560 ± 0.058	0.708 ± 0.118	1.395 ± 0.059	1.915 ± 0.027	0.504 ± 0.028	0.512 ± 0.021	0.957 ± 0.017
	16 Feb 93	15 43	114	6.551 ± 0.042	0.704 ± 0.074	1.334 ± 0.024	1.939 ± 0.016	0.516 ± 0.019	0.498 ± 0.015	0.964 ± 0.038
	16 Feb 93	15 48	115	6.557 ± 0.042	0.718 ± 0.077	1.337 ± 0.026	1.933 ± 0.016	0.510 ± 0.020	0.498 ± 0.016	0.960 ± 0.038
	20 May 93	09 39	35	6.529 ± 0.019	0.722 ± 0.039	1.362 ± 0.022	1.929 ± 0.010	0.509 ± 0.018	0.501 ± 0.014	0.965 ± 0.014
	01 Jul 93	07 04	10	6.531 ± 0.033	0.731 ± 0.044	1.371 ± 0.023	1.948 ± 0.017	0.512 ± 0.018	0.506 ± 0.012	0.969 ± 0.016
	01 Jul 93	07 10	11	6.521 ± 0.033	0.743 ± 0.041	1.382 ± 0.022	1.951 ± 0.017	0.506 ± 0.019	0.515 ± 0.012	0.970 ± 0.017
	03 Jul 93	07 07	7	6.505 ± 0.038	0.823 ± 0.051	1.391 ± 0.031	1.945 ± 0.025	0.515 ± 0.024	0.510 ± 0.015	0.951 ± 0.021
	01 Jul 93	07 16	12	5.669 ± 0.023	0.597 ± 0.019	0.807 ± 0.010	0.349 ± 0.011	0.115 ± 0.011	0.067 ± 0.009	0.144 ± 0.013
	01 Jul 93	07 19	13	5.664 ± 0.023	0.591 ± 0.019	0.813 ± 0.010	0.348 ± 0.011	0.115 ± 0.011	0.063 ± 0.010	0.135 ± 0.011
116235	02 Jul 93	07 28	10	5.685 ± 0.017	0.577 ± 0.024	0.806 ± 0.012	0.351 ± 0.011	0.133 ± 0.013	0.062 ± 0.011	0.147 ± 0.014
	02 Jul 93	07 31	11	5.680 ± 0.017	0.586 ± 0.024	0.804 ± 0.012	0.354 ± 0.012	0.128 ± 0.014	0.068 ± 0.011	0.136 ± 0.012
	03 Jul 93	07 14	8	5.670 ± 0.029	0.574 ± 0.026	0.813 ± 0.013	0.346 ± 0.015	0.123 ± 0.017	0.055 ± 0.015	0.143 ± 0.019
	01 Jul 93	07 23	14	5.850 ± 0.024	0.610 ± 0.020	0.830 ± 0.012	0.422 ± 0.012	0.135 ± 0.011	0.086 ± 0.009	0.165 ± 0.012
	01 Jul 93	07 26	15	5.855 ± 0.024	0.604 ± 0.019	0.828 ± 0.013	0.429 ± 0.013	0.129 ± 0.011	0.087 ± 0.010	0.174 ± 0.014
118022	17 May 91	11 33	5	4.937 ± 0.021	0.593 ± 0.019	0.777 ± 0.019	0.379 ± 0.020	0.093 ± 0.026	0.069 ± 0.014	0.183 ± 0.017
	17 May 91	11 38	6	4.910 ± 0.021	0.586 ± 0.019	0.782 ± 0.024	0.398 ± 0.026	0.111 ± 0.026	0.045 ± 0.014	0.171 ± 0.015
	21 May 91	09 49	49	4.932 ± 0.024	0.600 ± 0.023	0.780 ± 0.021	0.368 ± 0.021	0.099 ± 0.026	0.072 ± 0.024	0.185 ± 0.018
	21 May 91	09 52	50	4.929 ± 0.027	0.598 ± 0.020	0.794 ± 0.022	0.349 ± 0.023	0.106 ± 0.029	0.081 ± 0.028	0.192 ± 0.020
	09 Feb 92	16 04	100	4.941 ± 0.040	0.559 ± 0.024	0.796 ± 0.019	0.346 ± 0.018	0.084 ± 0.023	0.084 ± 0.056	0.190 ± 0.019
	09 Feb 92	16 06	101	4.951 ± 0.039	0.567 ± 0.026	0.786 ± 0.023	0.356 ± 0.020	0.086 ± 0.023	0.069 ± 0.055	0.197 ± 0.018
120602	01 Jul 93	07 34	17	5.978 ± 0.029	0.592 ± 0.025	0.835 ± 0.014	1.103 ± 0.014	0.428 ± 0.013	0.279 ± 0.010	0.673 ± 0.015
	01 Jul 93	07 37	18	5.979 ± 0.029	0.588 ± 0.024	0.831 ± 0.015	1.110 ± 0.016	0.425 ± 0.013	0.281 ± 0.011	0.681 ± 0.014
	03 Jul 93	07 20	9	5.977 ± 0.035	0.595 ± 0.033	0.845 ± 0.020	1.100 ± 0.022	0.437 ± 0.020	0.269 ± 0.016	0.680 ± 0.020
121607	18 Feb 93	16 17	126	5.970 ± 0.037	0.767 ± 0.077	0.811 ± 0.015	0.470 ± 0.013	0.179 ± 0.015	0.103 ± 0.013	0.259 ± 0.023
	18 Feb 93	16 20	127	5.951 ± 0.037	0.781 ± 0.077	0.800 ± 0.015	0.474 ± 0.011	0.184 ± 0.013	0.093 ± 0.014	0.270 ± 0.024

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
121607	01 Jul 93	07 42	19	5.879 ± 0.023	0.671 ± 0.019	0.795 ± 0.011	0.481 ± 0.012	0.179 ± 0.010	0.110 ± 0.008	0.263 ± 0.017
	01 Jul 93	07 45	20	5.878 ± 0.023	0.669 ± 0.019	0.799 ± 0.010	0.483 ± 0.012	0.175 ± 0.012	0.114 ± 0.010	0.270 ± 0.013
	03 Jul 93	07 26	10	5.894 ± 0.029	0.659 ± 0.026	0.785 ± 0.013	0.494 ± 0.015	0.183 ± 0.017	0.108 ± 0.013	0.270 ± 0.016
	08 Jul 93	07 29	6	5.868 ± 0.037	0.663 ± 0.021	0.811 ± 0.015	0.479 ± 0.017	0.169 ± 0.018	0.117 ± 0.012	0.266 ± 0.018
122408	17 May 91	11 50	8	4.256 ± 0.024	0.775 ± 0.045	0.841 ± 0.020	0.375 ± 0.033	0.155 ± 0.038	0.103 ± 0.022	0.226 ± 0.019
	17 May 91	11 54	9	4.255 ± 0.023	0.751 ± 0.020	0.834 ± 0.020	0.386 ± 0.022	0.157 ± 0.027	0.081 ± 0.018	0.225 ± 0.017
	21 May 91	11 30	75	4.249 ± 0.023	0.718 ± 0.022	0.870 ± 0.019	0.372 ± 0.027	0.174 ± 0.031	0.081 ± 0.022	0.204 ± 0.018
	21 May 91	11 33	76	4.227 ± 0.023	0.747 ± 0.021	0.848 ± 0.020	0.377 ± 0.022	0.177 ± 0.023	0.083 ± 0.020	0.198 ± 0.016
	21 May 91	11 36	77	4.243 ± 0.024	0.740 ± 0.026	0.865 ± 0.027	0.372 ± 0.027	0.158 ± 0.027	0.082 ± 0.022	0.216 ± 0.017
	18 Feb 93	16 24	128	4.298 ± 0.037	0.914 ± 0.077	0.855 ± 0.018	0.366 ± 0.018	0.136 ± 0.019	0.074 ± 0.014	0.197 ± 0.022
	18 Feb 93	16 26	129	4.278 ± 0.036	0.896 ± 0.078	0.869 ± 0.019	0.360 ± 0.018	0.142 ± 0.019	0.078 ± 0.013	0.187 ± 0.021
	20 May 93	10 54	51	4.260 ± 0.017	0.733 ± 0.014	0.831 ± 0.015	0.385 ± 0.017	0.150 ± 0.018	0.090 ± 0.013	0.221 ± 0.011
	20 May 93	10 57	52	4.255 ± 0.018	0.737 ± 0.014	0.833 ± 0.014	0.380 ± 0.017	0.150 ± 0.017	0.087 ± 0.013	0.218 ± 0.011
	23 May 93	10 31	46	4.258 ± 0.020	0.750 ± 0.016	0.857 ± 0.016	0.368 ± 0.018	0.144 ± 0.019	0.086 ± 0.014	0.201 ± 0.012
	23 May 93	10 34	47	4.246 ± 0.020	0.736 ± 0.017	0.852 ± 0.017	0.373 ± 0.018	0.151 ± 0.019	0.083 ± 0.014	0.192 ± 0.012
	01 Jul 93	08 20	29	6.245 ± 0.027	0.454 ± 0.022	0.586 ± 0.011	0.805 ± 0.012	0.338 ± 0.012	0.226 ± 0.012	0.558 ± 0.014
126053	01 Jul 93	08 23	30	6.245 ± 0.027	0.457 ± 0.023	0.590 ± 0.013	0.813 ± 0.013	0.329 ± 0.012	0.226 ± 0.012	0.566 ± 0.015
	02 Jul 93	08 19	24	6.274 ± 0.018	0.467 ± 0.028	0.585 ± 0.014	0.810 ± 0.013	0.341 ± 0.014	0.225 ± 0.011	0.569 ± 0.017
	02 Jul 93	08 21	25	6.267 ± 0.019	0.476 ± 0.028	0.584 ± 0.014	0.806 ± 0.013	0.349 ± 0.015	0.221 ± 0.013	0.570 ± 0.016
	03 Jul 93	08 26	21	6.229 ± 0.031	0.464 ± 0.029	0.599 ± 0.013	0.807 ± 0.016	0.333 ± 0.015	0.219 ± 0.011	0.570 ± 0.023
	04 Jul 93	08 22	14	6.274 ± 0.021	0.444 ± 0.058	0.591 ± 0.026	0.804 ± 0.012	0.331 ± 0.036	0.229 ± 0.024	0.555 ± 0.025
	08 Jul 93	08 20	14	6.259 ± 0.042	0.450 ± 0.025	0.588 ± 0.016	0.809 ± 0.018	0.329 ± 0.019	0.219 ± 0.013	0.565 ± 0.017
	01 Jul 93	08 27	31	5.081 ± 0.025	0.624 ± 0.020	0.821 ± 0.012	0.428 ± 0.013	0.141 ± 0.013	0.087 ± 0.011	0.181 ± 0.013
	01 Jul 93	08 30	32	5.070 ± 0.024	0.607 ± 0.020	0.814 ± 0.011	0.426 ± 0.014	0.150 ± 0.014	0.084 ± 0.009	0.187 ± 0.011
126248	02 Jul 93	08 25	26	5.093 ± 0.018	0.622 ± 0.025	0.807 ± 0.012	0.432 ± 0.013	0.158 ± 0.016	0.084 ± 0.012	0.198 ± 0.013
	02 Jul 93	08 28	27	5.090 ± 0.018	0.617 ± 0.025	0.810 ± 0.013	0.431 ± 0.013	0.157 ± 0.014	0.088 ± 0.011	0.193 ± 0.013
	03 Jul 93	08 32	22	5.053 ± 0.030	0.607 ± 0.027	0.821 ± 0.016	0.431 ± 0.018	0.153 ± 0.018	0.076 ± 0.013	0.196 ± 0.017
	04 Jul 93	08 28	15	5.086 ± 0.021	0.582 ± 0.048	0.813 ± 0.023	0.413 ± 0.014	0.153 ± 0.033	0.094 ± 0.023	0.182 ± 0.021
	08 Jul 93	08 25	15	5.088 ± 0.037	0.611 ± 0.021	0.814 ± 0.016	0.428 ± 0.018	0.142 ± 0.018	0.083 ± 0.012	0.188 ± 0.017
	23 May 93	11 26	57	5.703 ± 0.019	0.619 ± 0.016	0.746 ± 0.013	0.254 ± 0.010	0.108 ± 0.014	0.057 ± 0.012	0.133 ± 0.014
129956	23 May 93	11 28	58	5.693 ± 0.019	0.627 ± 0.015	0.733 ± 0.012	0.257 ± 0.010	0.121 ± 0.016	0.056 ± 0.014	0.127 ± 0.013

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Table D.1 continued from previous page										
HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
129956 132345	08 Jul 93	08 31	16	5.681 ± 0.035	0.590 ± 0.020	0.735 ± 0.014	0.259 ± 0.015	0.102 ± 0.017	0.050 ± 0.011	0.145 ± 0.014
	12 Apr 92	14 31	110	5.873 ± 0.038	0.712 ± 0.036	1.299 ± 0.023	1.685 ± 0.027	0.507 ± 0.021	0.416 ± 0.018	0.828 ± 0.024
	12 Apr 92	14 33	111	5.878 ± 0.037	0.709 ± 0.040	1.289 ± 0.027	1.684 ± 0.024	0.493 ± 0.015	0.422 ± 0.017	0.841 ± 0.022
	15 Apr 92	13 50	135	5.905 ± 0.024	0.687 ± 0.049	1.298 ± 0.026	1.693 ± 0.021	0.497 ± 0.025	0.408 ± 0.013	0.833 ± 0.015
	15 Apr 92	13 53	136	5.895 ± 0.025	0.667 ± 0.049	1.307 ± 0.025	1.689 ± 0.021	0.499 ± 0.027	0.412 ± 0.016	0.833 ± 0.017
	20 May 93	11 50	62	5.878 ± 0.017	0.696 ± 0.020	1.286 ± 0.015	1.679 ± 0.010	0.501 ± 0.014	0.414 ± 0.012	0.844 ± 0.013
135559	20 May 93	11 53	63	5.870 ± 0.018	0.710 ± 0.019	1.271 ± 0.015	1.685 ± 0.011	0.503 ± 0.014	0.413 ± 0.013	0.849 ± 0.013
	20 May 93	11 58	64	5.649 ± 0.018	0.597 ± 0.015	0.771 ± 0.013	0.476 ± 0.009	0.173 ± 0.012	0.096 ± 0.012	0.253 ± 0.013
	20 May 93	12 00	65	5.650 ± 0.017	0.600 ± 0.014	0.768 ± 0.011	0.477 ± 0.009	0.173 ± 0.012	0.094 ± 0.013	0.251 ± 0.011
	01 Jul 93	09 25	46	5.640 ± 0.023	0.605 ± 0.020	0.771 ± 0.011	0.475 ± 0.011	0.164 ± 0.011	0.101 ± 0.009	0.222 ± 0.013
	01 Jul 93	09 28	47	5.621 ± 0.023	0.585 ± 0.019	0.781 ± 0.010	0.463 ± 0.012	0.171 ± 0.012	0.097 ± 0.010	0.222 ± 0.015
	02 Jul 93	09 28	44	5.625 ± 0.017	0.603 ± 0.024	0.780 ± 0.012	0.460 ± 0.012	0.178 ± 0.014	0.092 ± 0.011	0.237 ± 0.013
136028	02 Jul 93	09 31	45	5.616 ± 0.018	0.602 ± 0.024	0.775 ± 0.012	0.469 ± 0.011	0.175 ± 0.013	0.097 ± 0.012	0.226 ± 0.014
	03 Jul 93	09 29	33	5.609 ± 0.028	0.585 ± 0.026	0.787 ± 0.015	0.470 ± 0.016	0.166 ± 0.015	0.097 ± 0.011	0.239 ± 0.017
	17 May 91	13 22	26	5.814 ± 0.028	0.761 ± 0.035	1.397 ± 0.033	2.006 ± 0.035	0.625 ± 0.035	0.471 ± 0.020	1.021 ± 0.022
	21 May 91	12 35	93	5.882 ± 0.028	0.766 ± 0.037	1.405 ± 0.034	2.009 ± 0.032	0.584 ± 0.029	0.481 ± 0.022	1.050 ± 0.025
	21 May 91	12 38	94	5.875 ± 0.029	0.740 ± 0.055	1.420 ± 0.047	2.007 ± 0.029	0.591 ± 0.028	0.483 ± 0.024	1.049 ± 0.022
	14 Apr 92	14 32	124	7.578 ± 0.081	0.478 ± 0.050	0.917 ± 0.076	1.384 ± 0.059	0.631 ± 0.055	0.342 ± 0.025	0.829 ± 0.041
137613	14 Apr 92	14 33	125	7.584 ± 0.082	0.517 ± 0.040	0.921 ± 0.071	1.372 ± 0.063	0.634 ± 0.058	0.335 ± 0.027	0.835 ± 0.043
	15 Apr 92	14 19	144	7.570 ± 0.025	0.505 ± 0.052	0.907 ± 0.024	1.335 ± 0.018	0.664 ± 0.026	0.334 ± 0.013	0.843 ± 0.016
	15 Apr 92	14 23	145	7.567 ± 0.025	0.513 ± 0.058	0.885 ± 0.026	1.352 ± 0.018	0.662 ± 0.026	0.333 ± 0.012	0.854 ± 0.015
	11 Apr 92	14 46	119	4.590 ± 0.056	0.571 ± 0.034	1.019 ± 0.044	1.318 ± 0.029	0.438 ± 0.018	0.325 ± 0.020	0.747 ± 0.042
	11 Apr 92	14 48	120	4.588 ± 0.056	0.579 ± 0.036	1.026 ± 0.045	1.310 ± 0.029	0.442 ± 0.019	0.327 ± 0.021	0.750 ± 0.042
	14 Apr 92	14 39	127	4.648 ± 0.070	0.566 ± 0.032	1.022 ± 0.059	1.322 ± 0.050	0.412 ± 0.046	0.329 ± 0.021	0.738 ± 0.035
138716	14 Apr 92	14 40	128	4.637 ± 0.070	0.560 ± 0.031	1.024 ± 0.059	1.319 ± 0.051	0.413 ± 0.047	0.329 ± 0.020	0.736 ± 0.034
	15 Apr 92	14 33	147	4.641 ± 0.023	0.572 ± 0.043	1.015 ± 0.019	1.297 ± 0.017	0.422 ± 0.024	0.325 ± 0.015	0.760 ± 0.016
	15 Apr 92	14 34	148	4.633 ± 0.022	0.574 ± 0.045	1.011 ± 0.023	1.308 ± 0.017	0.420 ± 0.024	0.325 ± 0.013	0.760 ± 0.015
	21 May 93	12 17	15	4.637 ± 0.019	0.580 ± 0.020	1.009 ± 0.016	1.286 ± 0.014	0.425 ± 0.015	0.333 ± 0.016	0.748 ± 0.014
	21 May 93	12 20	16	4.627 ± 0.019	0.583 ± 0.020	1.016 ± 0.016	1.276 ± 0.013	0.433 ± 0.015	0.324 ± 0.016	0.744 ± 0.015
	07 Jul 93	09 28	25	4.653 ± 0.040	0.586 ± 0.027	1.019 ± 0.016	1.280 ± 0.021	0.445 ± 0.015	0.329 ± 0.015	0.735 ± 0.022
	08 Jul 93	09 19	23	4.627 ± 0.046	0.561 ± 0.029	1.011 ± 0.017	1.289 ± 0.021	0.430 ± 0.022	0.330 ± 0.015	0.739 ± 0.017
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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
139409	11 Apr 92	14 52	121	7.126 ± 0.057	0.555 ± 0.050	0.936 ± 0.053	1.299 ± 0.039	0.486 ± 0.019	0.329 ± 0.021	0.776 ± 0.045
	11 Apr 92	14 54	122	7.133 ± 0.058	0.587 ± 0.043	0.916 ± 0.051	1.293 ± 0.034	0.494 ± 0.021	0.321 ± 0.024	0.775 ± 0.045
	14 Apr 92	14 45	130	7.180 ± 0.073	0.574 ± 0.037	0.935 ± 0.062	1.302 ± 0.053	0.467 ± 0.049	0.331 ± 0.025	0.750 ± 0.039
	14 Apr 92	14 47	131	7.184 ± 0.073	0.563 ± 0.048	0.950 ± 0.067	1.292 ± 0.055	0.469 ± 0.051	0.328 ± 0.022	0.758 ± 0.037
	15 Apr 92	14 40	150	7.192 ± 0.024	0.573 ± 0.046	0.898 ± 0.024	1.282 ± 0.020	0.482 ± 0.025	0.316 ± 0.013	0.791 ± 0.015
	15 Apr 92	14 43	151	7.176 ± 0.024	0.573 ± 0.049	0.905 ± 0.025	1.288 ± 0.025	0.486 ± 0.026	0.325 ± 0.014	0.775 ± 0.017
143553	20 May 93	12 54	75	5.836 ± 0.019	0.577 ± 0.020	0.950 ± 0.011	1.262 ± 0.009	0.441 ± 0.013	0.316 ± 0.012	0.766 ± 0.013
	21 May 93	12 24	17	5.838 ± 0.021	0.588 ± 0.024	0.957 ± 0.020	1.242 ± 0.018	0.448 ± 0.017	0.319 ± 0.018	0.746 ± 0.015
	21 May 93	12 27	18	5.830 ± 0.021	0.587 ± 0.022	0.954 ± 0.017	1.249 ± 0.014	0.450 ± 0.014	0.313 ± 0.017	0.751 ± 0.015
	23 May 93	12 25	70	5.805 ± 0.025	0.571 ± 0.023	0.962 ± 0.018	1.264 ± 0.016	0.435 ± 0.019	0.321 ± 0.016	0.747 ± 0.016
	23 May 93	12 27	71	5.794 ± 0.025	0.580 ± 0.027	0.958 ± 0.021	1.265 ± 0.012	0.440 ± 0.019	0.324 ± 0.015	0.746 ± 0.014
	08 Jul 93	09 25	24	5.792 ± 0.048	0.542 ± 0.031	0.968 ± 0.019	1.267 ± 0.021	0.445 ± 0.022	0.322 ± 0.015	0.739 ± 0.018
147196	12 Apr 92	15 35	126	7.008 ± 0.025	0.583 ± 0.020	0.638 ± 0.016	0.337 ± 0.017	0.201 ± 0.016	0.107 ± 0.013	0.326 ± 0.022
	12 Apr 92	15 36	127	6.994 ± 0.031	0.582 ± 0.022	0.634 ± 0.016	0.334 ± 0.016	0.219 ± 0.015	0.110 ± 0.022	0.318 ± 0.026
	14 Apr 92	15 22	145	6.986 ± 0.056	0.572 ± 0.028	0.643 ± 0.048	0.312 ± 0.041	0.223 ± 0.038	0.113 ± 0.019	0.328 ± 0.033
	14 Apr 92	15 24	146	6.987 ± 0.055	0.578 ± 0.028	0.626 ± 0.049	0.317 ± 0.040	0.223 ± 0.038	0.102 ± 0.019	0.329 ± 0.030
	15 Apr 92	15 22	165	7.024 ± 0.020	0.581 ± 0.034	0.642 ± 0.016	0.337 ± 0.017	0.204 ± 0.020	0.110 ± 0.012	0.332 ± 0.020
	15 Apr 92	15 25	166	7.017 ± 0.019	0.582 ± 0.035	0.648 ± 0.015	0.329 ± 0.013	0.208 ± 0.019	0.114 ± 0.012	0.339 ± 0.017
147432	12 Apr 92	15 41	128	7.495 ± 0.026	0.608 ± 0.022	0.826 ± 0.016	0.506 ± 0.016	0.215 ± 0.012	0.119 ± 0.014	0.318 ± 0.021
	12 Apr 92	15 44	129	7.496 ± 0.026	0.612 ± 0.024	0.822 ± 0.017	0.504 ± 0.015	0.218 ± 0.013	0.115 ± 0.012	0.313 ± 0.018
	14 Apr 92	15 30	148	7.491 ± 0.056	0.607 ± 0.031	0.828 ± 0.049	0.467 ± 0.040	0.230 ± 0.038	0.120 ± 0.019	0.332 ± 0.031
	14 Apr 92	15 32	149	7.495 ± 0.056	0.608 ± 0.031	0.816 ± 0.049	0.476 ± 0.042	0.228 ± 0.038	0.115 ± 0.019	0.335 ± 0.031
147550	11 Apr 92	15 16	130	6.234 ± 0.050	0.733 ± 0.029	0.780 ± 0.038	0.312 ± 0.028	0.153 ± 0.041	0.035 ± 0.046	0.120 ± 0.047
	11 Apr 92	15 18	131	6.297 ± 0.050	0.754 ± 0.038	0.652 ± 0.043	0.316 ± 0.035	0.177 ± 0.033	0.102 ± 0.037	0.265 ± 0.046
	12 Apr 92	15 51	130	6.199 ± 0.029	0.684 ± 0.021	0.758 ± 0.016	0.310 ± 0.018	0.157 ± 0.016	0.081 ± 0.019	0.196 ± 0.024
	12 Apr 92	15 53	131	6.194 ± 0.029	0.676 ± 0.021	0.759 ± 0.017	0.311 ± 0.017	0.154 ± 0.013	0.088 ± 0.018	0.184 ± 0.025
	01 Jul 93	10 25	63	6.250 ± 0.022	0.643 ± 0.019	0.768 ± 0.011	0.296 ± 0.010	0.149 ± 0.011	0.078 ± 0.008	0.179 ± 0.012
	01 Jul 93	10 28	64	6.243 ± 0.022	0.652 ± 0.020	0.768 ± 0.011	0.299 ± 0.011	0.142 ± 0.011	0.084 ± 0.008	0.175 ± 0.012
	02 Jul 93	10 20	60	6.258 ± 0.017	0.673 ± 0.024	0.770 ± 0.012	0.301 ± 0.012	0.155 ± 0.014	0.075 ± 0.012	0.186 ± 0.015
	02 Jul 93	10 23	61	6.235 ± 0.016	0.674 ± 0.024	0.771 ± 0.011	0.298 ± 0.010	0.156 ± 0.013	0.079 ± 0.010	0.185 ± 0.014
	03 Jul 93	10 21	43	6.221 ± 0.027	0.659 ± 0.026	0.769 ± 0.013	0.312 ± 0.016	0.142 ± 0.016	0.082 ± 0.009	0.191 ± 0.017

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
147550 148513	06 Jul 93	09 49	32	6.214 ± 0.037	0.652 ± 0.040	0.768 ± 0.019	0.315 ± 0.018	0.153 ± 0.017	0.086 ± 0.012	0.200 ± 0.019
	15 Apr 92	15 34	168	5.453 ± 0.026	0.716 ± 0.054	1.401 ± 0.030	1.984 ± 0.021	0.524 ± 0.027	0.503 ± 0.015	0.980 ± 0.016
	15 Apr 92	15 37	169	5.445 ± 0.026	0.736 ± 0.052	1.396 ± 0.024	1.993 ± 0.023	0.523 ± 0.028	0.498 ± 0.014	0.987 ± 0.016
	02 Jul 93	10 27	62	5.403 ± 0.021	0.781 ± 0.045	1.364 ± 0.024	1.993 ± 0.017	0.563 ± 0.021	0.508 ± 0.015	0.981 ± 0.021
	02 Jul 93	10 30	63	5.403 ± 0.021	0.785 ± 0.041	1.378 ± 0.023	1.980 ± 0.018	0.564 ± 0.021	0.501 ± 0.016	0.985 ± 0.021
	03 Jul 93	10 26	44	5.361 ± 0.039	0.746 ± 0.046	1.382 ± 0.028	1.992 ± 0.026	0.554 ± 0.026	0.507 ± 0.014	0.971 ± 0.021
150366	04 Jul 93	10 28	32	5.427 ± 0.026	0.763 ± 0.084	1.390 ± 0.039	1.982 ± 0.015	0.544 ± 0.050	0.496 ± 0.033	0.995 ± 0.032
	06 Jul 93	09 55	33	5.395 ± 0.066	0.764 ± 0.073	1.371 ± 0.035	1.995 ± 0.031	0.547 ± 0.027	0.494 ± 0.020	0.983 ± 0.029
	13 Apr 92	15 50	127	6.031 ± 0.018	0.614 ± 0.015	0.775 ± 0.014	0.501 ± 0.012	0.191 ± 0.013	0.113 ± 0.012	0.259 ± 0.017
	13 Apr 92	15 52	128	6.037 ± 0.017	0.620 ± 0.014	0.773 ± 0.013	0.489 ± 0.009	0.194 ± 0.012	0.105 ± 0.011	0.268 ± 0.015
	15 Apr 92	15 45	171	6.054 ± 0.018	0.649 ± 0.036	0.763 ± 0.018	0.509 ± 0.016	0.188 ± 0.021	0.102 ± 0.012	0.283 ± 0.013
	15 Apr 92	15 47	172	6.056 ± 0.020	0.648 ± 0.034	0.768 ± 0.016	0.500 ± 0.017	0.192 ± 0.022	0.103 ± 0.015	0.276 ± 0.017
150416	29 Jun 93	11 02	8	4.941 ± 0.036	0.636 ± 0.023	0.966 ± 0.018	1.278 ± 0.015	0.536 ± 0.017	0.309 ± 0.017	0.801 ± 0.018
	29 Jun 93	11 04	9	4.943 ± 0.036	0.629 ± 0.024	0.963 ± 0.018	1.286 ± 0.014	0.532 ± 0.017	0.306 ± 0.018	0.807 ± 0.019
	07 Jul 93	10 25	35	4.980 ± 0.037	0.651 ± 0.028	0.966 ± 0.017	1.275 ± 0.023	0.531 ± 0.014	0.320 ± 0.014	0.789 ± 0.022
	13 Apr 92	15 58	130	6.233 ± 0.021	0.590 ± 0.022	0.712 ± 0.017	0.542 ± 0.014	0.226 ± 0.013	0.144 ± 0.014	0.345 ± 0.019
	13 Apr 92	15 60	131	6.230 ± 0.021	0.586 ± 0.017	0.701 ± 0.015	0.536 ± 0.014	0.218 ± 0.015	0.142 ± 0.016	0.361 ± 0.018
	21 May 91	13 51	109	6.132 ± 0.022	0.803 ± 0.025	0.866 ± 0.019	0.375 ± 0.021	0.190 ± 0.026	0.041 ± 0.021	0.281 ± 0.020
151431	21 May 91	13 54	110	6.093 ± 0.027	0.784 ± 0.037	0.864 ± 0.028	0.411 ± 0.020	0.168 ± 0.028	0.092 ± 0.030	0.234 ± 0.022
	11 May 91	14 54	81	3.226 ± 0.051	0.567 ± 0.029	1.179 ± 0.031	1.473 ± 0.026	0.491 ± 0.026	0.327 ± 0.027	0.807 ± 0.031
	11 May 91	14 57	82	3.276 ± 0.051	0.602 ± 0.033	1.194 ± 0.029	1.488 ± 0.027	0.471 ± 0.025	0.334 ± 0.028	0.807 ± 0.031
	29 Jun 93	11 09	10	4.817 ± 0.042	0.758 ± 0.030	1.419 ± 0.024	1.997 ± 0.018	0.583 ± 0.021	0.495 ± 0.018	1.008 ± 0.021
	29 Jun 93	11 12	11	4.808 ± 0.042	0.762 ± 0.031	1.407 ± 0.025	2.006 ± 0.017	0.573 ± 0.020	0.504 ± 0.018	1.015 ± 0.021
	08 Jul 93	10 40	34	4.774 ± 0.058	0.792 ± 0.039	1.388 ± 0.024	2.006 ± 0.025	0.576 ± 0.028	0.507 ± 0.018	1.006 ± 0.020
154417	20 May 93	13 49	85	6.032 ± 0.018	0.467 ± 0.015	0.576 ± 0.011	0.767 ± 0.010	0.313 ± 0.011	0.212 ± 0.012	0.535 ± 0.012
	20 May 93	13 52	86	6.025 ± 0.017	0.480 ± 0.013	0.580 ± 0.009	0.760 ± 0.009	0.313 ± 0.012	0.213 ± 0.011	0.535 ± 0.011
	29 Jun 93	11 17	12	5.990 ± 0.032	0.469 ± 0.020	0.590 ± 0.016	0.758 ± 0.013	0.314 ± 0.015	0.214 ± 0.015	0.509 ± 0.020
	29 Jun 93	11 20	13	5.995 ± 0.032	0.471 ± 0.021	0.587 ± 0.020	0.762 ± 0.017	0.318 ± 0.014	0.211 ± 0.015	0.520 ± 0.017
	08 Jul 93	10 45	35	5.985 ± 0.042	0.481 ± 0.024	0.597 ± 0.016	0.765 ± 0.018	0.309 ± 0.019	0.211 ± 0.014	0.534 ± 0.019
	21 May 93	13 53	38	6.332 ± 0.019	0.508 ± 0.019	0.795 ± 0.015	1.037 ± 0.013	0.404 ± 0.014	0.272 ± 0.017	0.675 ± 0.016
156826	21 May 93	13 56	39	6.322 ± 0.020	0.507 ± 0.021	0.794 ± 0.016	1.041 ± 0.013	0.389 ± 0.012	0.283 ± 0.017	0.672 ± 0.016

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
156826	29 Jun 93	11 25	14	6.311 ± 0.033	0.494 ± 0.024	0.796 ± 0.020	1.050 ± 0.017	0.402 ± 0.015	0.274 ± 0.014	0.690 ± 0.016
	29 Jun 93	11 27	15	6.306 ± 0.035	0.504 ± 0.025	0.790 ± 0.021	1.047 ± 0.013	0.406 ± 0.016	0.272 ± 0.019	0.672 ± 0.020
	12 Apr 92	16 17	139	6.956 ± 0.031	0.484 ± 0.022	0.541 ± 0.017	0.718 ± 0.017	0.341 ± 0.014	0.206 ± 0.015	0.538 ± 0.024
157089	12 Apr 92	16 20	140	6.959 ± 0.031	0.483 ± 0.027	0.540 ± 0.022	0.716 ± 0.016	0.337 ± 0.013	0.207 ± 0.016	0.544 ± 0.023
	13 Apr 92	16 21	139	6.969 ± 0.024	0.473 ± 0.023	0.537 ± 0.019	0.720 ± 0.016	0.345 ± 0.016	0.202 ± 0.017	0.541 ± 0.020
	13 Apr 92	16 23	140	6.949 ± 0.022	0.483 ± 0.024	0.546 ± 0.023	0.714 ± 0.015	0.338 ± 0.014	0.216 ± 0.014	0.534 ± 0.017
	13 Apr 92	16 28	142	7.776 ± 0.027	0.609 ± 0.082	1.081 ± 0.062	1.397 ± 0.042	0.593 ± 0.021	0.377 ± 0.017	0.914 ± 0.020
158352	13 Apr 92	16 31	143	7.760 ± 0.026	0.664 ± 0.060	1.065 ± 0.042	1.398 ± 0.033	0.599 ± 0.025	0.384 ± 0.021	0.894 ± 0.018
	29 Jun 93	11 33	16	5.397 ± 0.029	0.651 ± 0.019	0.759 ± 0.015	0.492 ± 0.012	0.196 ± 0.014	0.128 ± 0.014	0.294 ± 0.016
	29 Jun 93	11 36	17	5.392 ± 0.030	0.657 ± 0.020	0.761 ± 0.018	0.493 ± 0.014	0.199 ± 0.016	0.125 ± 0.017	0.291 ± 0.019
159975	06 Jul 93	11 33	51	5.369 ± 0.039	0.683 ± 0.042	0.763 ± 0.021	0.502 ± 0.020	0.197 ± 0.017	0.124 ± 0.013	0.297 ± 0.020
	11 May 91	15 07	84	4.697 ± 0.030	0.573 ± 0.016	0.589 ± 0.017	0.278 ± 0.016	0.198 ± 0.016	0.091 ± 0.017	0.270 ± 0.018
	11 May 91	15 10	85	4.685 ± 0.030	0.569 ± 0.015	0.596 ± 0.017	0.279 ± 0.015	0.187 ± 0.015	0.095 ± 0.017	0.270 ± 0.018
	17 May 91	14 30	38	4.611 ± 0.020	0.586 ± 0.018	0.607 ± 0.018	0.295 ± 0.020	0.205 ± 0.024	0.109 ± 0.014	0.263 ± 0.014
	17 May 91	14 34	39	4.600 ± 0.019	0.588 ± 0.018	0.613 ± 0.018	0.298 ± 0.020	0.210 ± 0.024	0.108 ± 0.014	0.258 ± 0.013
	20 May 93	13 57	87	4.611 ± 0.016	0.612 ± 0.013	0.586 ± 0.012	0.295 ± 0.013	0.193 ± 0.015	0.111 ± 0.012	0.284 ± 0.011
	20 May 93	13 59	88	4.614 ± 0.015	0.609 ± 0.013	0.587 ± 0.012	0.298 ± 0.014	0.193 ± 0.014	0.104 ± 0.011	0.289 ± 0.010
	21 May 93	14 21	45	4.605 ± 0.017	0.624 ± 0.017	0.582 ± 0.015	0.302 ± 0.016	0.195 ± 0.014	0.101 ± 0.015	0.270 ± 0.013
	21 May 93	14 24	46	4.598 ± 0.016	0.603 ± 0.017	0.594 ± 0.016	0.292 ± 0.016	0.190 ± 0.015	0.104 ± 0.014	0.271 ± 0.013
	29 Jun 93	11 40	18	4.579 ± 0.028	0.603 ± 0.019	0.592 ± 0.018	0.296 ± 0.017	0.195 ± 0.018	0.100 ± 0.015	0.269 ± 0.014
160346	29 Jun 93	11 43	19	4.588 ± 0.028	0.593 ± 0.019	0.593 ± 0.018	0.294 ± 0.017	0.187 ± 0.016	0.111 ± 0.014	0.267 ± 0.014
	01 Jul 93	11 27	77	4.643 ± 0.022	0.619 ± 0.019	0.593 ± 0.013	0.289 ± 0.015	0.189 ± 0.014	0.102 ± 0.010	0.270 ± 0.012
	01 Jul 93	11 30	78	4.625 ± 0.022	0.628 ± 0.019	0.593 ± 0.013	0.291 ± 0.015	0.185 ± 0.015	0.110 ± 0.012	0.273 ± 0.012
	02 Jul 93	11 55	85	4.613 ± 0.016	0.627 ± 0.024	0.589 ± 0.014	0.288 ± 0.015	0.195 ± 0.015	0.100 ± 0.011	0.276 ± 0.013
	02 Jul 93	11 57	86	4.606 ± 0.016	0.601 ± 0.024	0.590 ± 0.014	0.296 ± 0.015	0.191 ± 0.016	0.102 ± 0.012	0.274 ± 0.013
	03 Jul 93	11 27	55	4.599 ± 0.027	0.590 ± 0.025	0.591 ± 0.016	0.304 ± 0.019	0.184 ± 0.018	0.104 ± 0.014	0.275 ± 0.016
	04 Jul 93	11 22	42	4.633 ± 0.018	0.612 ± 0.049	0.591 ± 0.023	0.277 ± 0.014	0.201 ± 0.032	0.108 ± 0.021	0.259 ± 0.021
	07 Jul 93	11 26	46	4.620 ± 0.040	0.602 ± 0.022	0.601 ± 0.015	0.294 ± 0.019	0.188 ± 0.014	0.103 ± 0.012	0.294 ± 0.017
	29 Jun 93	11 47	20	6.493 ± 0.035	0.464 ± 0.025	0.982 ± 0.022	1.295 ± 0.019	0.330 ± 0.020	0.376 ± 0.018	0.747 ± 0.023
	29 Jun 93	11 50	21	6.491 ± 0.035	0.460 ± 0.026	0.987 ± 0.020	1.289 ± 0.014	0.336 ± 0.016	0.382 ± 0.016	0.763 ± 0.020
	04 Jul 93	11 28	43	6.521 ± 0.024	0.469 ± 0.066	0.995 ± 0.031	1.284 ± 0.018	0.321 ± 0.040	0.393 ± 0.027	0.760 ± 0.029

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
160781	17 May 91	15 56	54	5.943 ± 0.029	0.690 ± 0.031	1.135 ± 0.031	1.598 ± 0.033	0.620 ± 0.035	0.356 ± 0.020	0.855 ± 0.023
160823	13 Apr 92	16 38	145	6.995 ± 0.025	0.716 ± 0.030	0.765 ± 0.028	1.057 ± 0.016	0.497 ± 0.017	0.307 ± 0.015	0.727 ± 0.017
	13 Apr 92	16 41	146	6.993 ± 0.024	0.697 ± 0.026	0.770 ± 0.022	1.044 ± 0.013	0.491 ± 0.017	0.300 ± 0.015	0.741 ± 0.017
161868	11 May 91	15 19	87	3.834 ± 0.029	0.585 ± 0.015	0.829 ± 0.019	0.315 ± 0.020	0.139 ± 0.022	0.057 ± 0.020	0.141 ± 0.018
	11 May 91	15 22	88	3.792 ± 0.029	0.580 ± 0.018	0.834 ± 0.022	0.336 ± 0.017	0.134 ± 0.020	0.068 ± 0.020	0.144 ± 0.017
162917	21 May 93	14 29	47	5.763 ± 0.019	0.518 ± 0.017	0.573 ± 0.013	0.633 ± 0.012	0.279 ± 0.012	0.166 ± 0.015	0.442 ± 0.013
	21 May 93	14 32	48	5.758 ± 0.022	0.512 ± 0.018	0.571 ± 0.014	0.635 ± 0.012	0.271 ± 0.011	0.177 ± 0.019	0.435 ± 0.019
163245	12 Apr 92	17 15	157	6.456 ± 0.026	0.645 ± 0.020	0.827 ± 0.015	0.372 ± 0.016	0.140 ± 0.014	0.061 ± 0.016	0.160 ± 0.022
	12 Apr 92	17 16	158	6.446 ± 0.026	0.637 ± 0.019	0.830 ± 0.015	0.378 ± 0.016	0.133 ± 0.016	0.069 ± 0.016	0.154 ± 0.022
	13 Apr 92	17 06	154	6.438 ± 0.017	0.613 ± 0.015	0.830 ± 0.014	0.380 ± 0.014	0.128 ± 0.015	0.080 ± 0.011	0.143 ± 0.018
	13 Apr 92	17 07	155	6.443 ± 0.018	0.613 ± 0.016	0.835 ± 0.014	0.370 ± 0.012	0.136 ± 0.012	0.076 ± 0.012	0.144 ± 0.019
	15 Apr 92	16 15	180	6.449 ± 0.018	0.635 ± 0.035	0.834 ± 0.018	0.362 ± 0.013	0.134 ± 0.018	0.083 ± 0.010	0.162 ± 0.013
	15 Apr 92	16 18	181	6.459 ± 0.018	0.649 ± 0.033	0.822 ± 0.015	0.369 ± 0.014	0.138 ± 0.019	0.063 ± 0.012	0.172 ± 0.014
	21 May 93	14 36	49	6.453 ± 0.015	0.615 ± 0.018	0.836 ± 0.015	0.371 ± 0.011	0.136 ± 0.011	0.070 ± 0.012	0.144 ± 0.010
	21 May 93	14 39	50	6.453 ± 0.016	0.603 ± 0.017	0.836 ± 0.014	0.373 ± 0.011	0.134 ± 0.011	0.073 ± 0.013	0.142 ± 0.014
	17 May 91	16 07	56	4.639 ± 0.024	0.528 ± 0.020	0.620 ± 0.019	0.580 ± 0.022	0.274 ± 0.026	0.139 ± 0.018	0.419 ± 0.018
	17 May 91	16 11	57	4.622 ± 0.021	0.534 ± 0.022	0.620 ± 0.020	0.587 ± 0.022	0.280 ± 0.027	0.151 ± 0.016	0.409 ± 0.015
164353	21 May 91	16 28	124	4.654 ± 0.024	0.548 ± 0.021	0.610 ± 0.021	0.592 ± 0.022	0.263 ± 0.025	0.157 ± 0.022	0.420 ± 0.023
	21 May 91	16 31	125	4.654 ± 0.030	0.514 ± 0.029	0.616 ± 0.032	0.604 ± 0.026	0.268 ± 0.023	0.154 ± 0.028	0.426 ± 0.026
	21 May 91	16 34	126	4.641 ± 0.029	0.530 ± 0.021	0.609 ± 0.020	0.602 ± 0.023	0.276 ± 0.026	0.157 ± 0.027	0.398 ± 0.024
	23 May 93	14 32	100	4.626 ± 0.020	0.548 ± 0.016	0.617 ± 0.013	0.589 ± 0.012	0.256 ± 0.016	0.166 ± 0.013	0.387 ± 0.012
	23 May 93	14 35	101	4.621 ± 0.020	0.544 ± 0.015	0.614 ± 0.013	0.591 ± 0.017	0.258 ± 0.019	0.164 ± 0.013	0.383 ± 0.012
	11 May 91	15 44	93	3.984 ± 0.030	0.337 ± 0.018	0.299 ± 0.020	0.198 ± 0.018	0.176 ± 0.021	0.081 ± 0.020	0.232 ± 0.019
	11 May 91	15 47	94	3.987 ± 0.030	0.313 ± 0.019	0.282 ± 0.021	0.187 ± 0.019	0.167 ± 0.022	0.082 ± 0.020	0.211 ± 0.017
165174	23 May 93	14 39	102	3.959 ± 0.020	0.378 ± 0.018	0.301 ± 0.021	0.212 ± 0.023	0.165 ± 0.023	0.090 ± 0.016	0.209 ± 0.013
	23 May 93	14 42	103	3.961 ± 0.020	0.377 ± 0.018	0.299 ± 0.021	0.213 ± 0.023	0.167 ± 0.022	0.090 ± 0.016	0.204 ± 0.012
	08 Jun 89	11 39	28	6.123 ± 0.026	0.136 ± 0.012	0.069 ± 0.014	0.156 ± 0.011	0.174 ± 0.012	0.076 ± 0.010	0.201 ± 0.014
165462	08 Jun 89	11 42	29	6.127 ± 0.026	0.123 ± 0.012	0.068 ± 0.014	0.163 ± 0.010	0.167 ± 0.012	0.077 ± 0.010	0.217 ± 0.014
	13 Apr 92	17 15	157	6.367 ± 0.026	0.703 ± 0.036	0.928 ± 0.031	1.220 ± 0.020	0.520 ± 0.020	0.328 ± 0.015	0.804 ± 0.019
	13 Apr 92	17 16	158	6.360 ± 0.025	0.736 ± 0.031	0.905 ± 0.032	1.240 ± 0.022	0.513 ± 0.023	0.329 ± 0.017	0.807 ± 0.019
	14 Apr 92	17 05	181	6.416 ± 0.073	0.696 ± 0.036	0.943 ± 0.064	1.257 ± 0.054	0.492 ± 0.050	0.329 ± 0.023	0.783 ± 0.036

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X	X-Y	Y-Z	Z-V	V-S
± 0.063	1.252 ± 0.053	0.490 ± 0.048	0.323 ± 0.022	0.792 ± 0.037
± 0.021	1.544 ± 0.013	0.512 ± 0.021	0.383 ± 0.017	0.827 ± 0.017
± 0.022	1.554 ± 0.013	0.506 ± 0.020	0.382 ± 0.015	0.833 ± 0.016
± 0.021	1.078 ± 0.020	0.446 ± 0.015	0.261 ± 0.017	0.682 ± 0.023
± 0.021	1.079 ± 0.021	0.431 ± 0.018	0.280 ± 0.018	0.708 ± 0.023
± 0.018	1.073 ± 0.014	0.454 ± 0.016	0.273 ± 0.014	0.680 ± 0.017
± 0.018	1.072 ± 0.016	0.445 ± 0.018	0.278 ± 0.017	0.691 ± 0.018
± 0.058	1.095 ± 0.050	0.429 ± 0.046	0.272 ± 0.021	0.679 ± 0.035
± 0.058	1.086 ± 0.051	0.435 ± 0.047	0.264 ± 0.020	0.693 ± 0.034
± 0.014	1.072 ± 0.011	0.422 ± 0.018	0.283 ± 0.015	0.682 ± 0.015
± 0.012	1.072 ± 0.011	0.428 ± 0.018	0.276 ± 0.014	0.684 ± 0.015
± 0.016	0.315 ± 0.012	0.138 ± 0.014	0.071 ± 0.013	0.172 ± 0.017
± 0.016	0.309 ± 0.012	0.132 ± 0.014	0.083 ± 0.013	0.167 ± 0.017
± 0.026	1.606 ± 0.023	0.536 ± 0.012	0.389 ± 0.011	0.893 ± 0.013
± 0.026	1.636 ± 0.023	0.532 ± 0.012	0.387 ± 0.011	0.896 ± 0.013
± 0.026	1.471 ± 0.015	0.511 ± 0.016	0.348 ± 0.013	0.781 ± 0.016
± 0.025	1.469 ± 0.017	0.512 ± 0.017	0.349 ± 0.019	0.778 ± 0.021
± 0.011	0.244 ± 0.008	0.120 ± 0.012	0.087 ± 0.012	0.179 ± 0.013
± 0.012	0.252 ± 0.009	0.104 ± 0.012	0.088 ± 0.011	0.186 ± 0.011
± 0.019	0.947 ± 0.016	0.422 ± 0.009	0.249 ± 0.008	0.666 ± 0.011
± 0.019	0.947 ± 0.016	0.421 ± 0.009	0.251 ± 0.008	0.669 ± 0.011
± 0.017	0.948 ± 0.012	0.418 ± 0.013	0.252 ± 0.012	0.665 ± 0.016
± 0.017	0.943 ± 0.012	0.428 ± 0.013	0.248 ± 0.011	0.664 ± 0.016
± 0.019	0.933 ± 0.020	0.404 ± 0.020	0.275 ± 0.018	0.630 ± 0.019
± 0.018	0.937 ± 0.016	0.407 ± 0.018	0.258 ± 0.017	0.629 ± 0.020
± 0.017	0.940 ± 0.017	0.398 ± 0.016	0.273 ± 0.014	0.630 ± 0.018
± 0.014	0.937 ± 0.014	0.401 ± 0.015	0.269 ± 0.013	0.619 ± 0.018
± 0.013	0.236 ± 0.012	0.130 ± 0.012	0.069 ± 0.013	0.157 ± 0.021
± 0.013	0.227 ± 0.012	0.128 ± 0.013	0.083 ± 0.014	0.153 ± 0.021
± 0.016	1.339 ± 0.015	0.534 ± 0.017	0.343 ± 0.015	0.811 ± 0.019
± 0.016	1.341 ± 0.016	0.532 ± 0.018	0.339 ± 0.015	0.814 ± 0.019

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Table D.1 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
173009	06 Jul 93	12 30	61	4.933 ± 0.058	0.694 ± 0.063	0.977 ± 0.029	1.347 ± 0.028	0.525 ± 0.024	0.341 ± 0.018	0.823 ± 0.026
	07 Jul 93	12 26	57	4.917 ± 0.041	0.678 ± 0.029	0.985 ± 0.018	1.327 ± 0.023	0.545 ± 0.014	0.344 ± 0.015	0.802 ± 0.023
175190	13 Apr 92	18 00	172	5.023 ± 0.026	0.689 ± 0.025	1.247 ± 0.023	1.764 ± 0.016	0.554 ± 0.016	0.433 ± 0.014	0.874 ± 0.018
	13 Apr 92	18 02	173	5.014 ± 0.025	0.675 ± 0.028	1.261 ± 0.023	1.760 ± 0.017	0.557 ± 0.016	0.445 ± 0.013	0.863 ± 0.017
	14 Apr 92	17 46	193	4.955 ± 0.084	0.718 ± 0.038	1.113 ± 0.072	1.693 ± 0.060	0.602 ± 0.055	0.428 ± 0.024	0.907 ± 0.041
	14 Apr 92	17 48	194	4.952 ± 0.084	0.698 ± 0.039	1.130 ± 0.072	1.680 ± 0.060	0.605 ± 0.056	0.432 ± 0.024	0.908 ± 0.041
	02 Jul 93	12 46	98	5.053 ± 0.018	0.696 ± 0.036	1.254 ± 0.019	1.785 ± 0.017	0.550 ± 0.018	0.432 ± 0.014	0.880 ± 0.019
	02 Jul 93	12 49	99	5.058 ± 0.018	0.703 ± 0.036	1.242 ± 0.018	1.790 ± 0.017	0.543 ± 0.019	0.440 ± 0.015	0.880 ± 0.019
175679	24 Jun 88	14 24	50	6.143 ± 0.009	0.579 ± 0.026	0.930 ± 0.020	1.198 ± 0.018	0.475 ± 0.009	0.285 ± 0.008	0.732 ± 0.011
	24 Jun 88	14 33	52	6.148 ± 0.009	0.563 ± 0.026	0.918 ± 0.021	1.209 ± 0.018	0.476 ± 0.009	0.284 ± 0.008	0.736 ± 0.011
	08 Jun 89	12 25	37	6.146 ± 0.030	0.587 ± 0.016	0.917 ± 0.018	1.215 ± 0.013	0.467 ± 0.013	0.286 ± 0.011	0.739 ± 0.016
	08 Jun 89	12 30	38	6.149 ± 0.030	0.583 ± 0.016	0.919 ± 0.018	1.210 ± 0.013	0.474 ± 0.013	0.277 ± 0.011	0.734 ± 0.015
	23 May 93	15 26	114	5.636 ± 0.024	0.680 ± 0.023	1.243 ± 0.017	1.619 ± 0.014	0.480 ± 0.020	0.413 ± 0.014	0.816 ± 0.014
	23 May 93	15 30	115	5.635 ± 0.024	0.673 ± 0.024	1.255 ± 0.015	1.611 ± 0.013	0.485 ± 0.021	0.411 ± 0.014	0.818 ± 0.014
176704	03 Jul 93	12 53	71	5.663 ± 0.034	0.661 ± 0.035	1.259 ± 0.020	1.603 ± 0.020	0.485 ± 0.017	0.405 ± 0.010	0.839 ± 0.017
	08 Jul 93	12 47	56	5.700 ± 0.050	0.653 ± 0.033	1.255 ± 0.019	1.591 ± 0.022	0.498 ± 0.024	0.394 ± 0.016	0.831 ± 0.017
177756	08 Jul 93	12 53	57	3.476 ± 0.035	0.517 ± 0.023	0.604 ± 0.033	0.203 ± 0.041	0.079 ± 0.034	0.058 ± 0.021	0.102 ± 0.016
178125	08 Jun 89	12 54	43	5.041 ± 0.030	0.406 ± 0.013	0.525 ± 0.016	0.202 ± 0.013	0.104 ± 0.015	0.053 ± 0.014	0.147 ± 0.016
	08 Jun 89	12 57	44	5.048 ± 0.030	0.404 ± 0.013	0.514 ± 0.016	0.205 ± 0.013	0.111 ± 0.015	0.040 ± 0.014	0.149 ± 0.016
179406	24 Jun 88	14 09	47	5.343 ± 0.008	0.404 ± 0.021	0.404 ± 0.016	0.279 ± 0.014	0.218 ± 0.010	0.089 ± 0.009	0.296 ± 0.009
	24 Jun 88	14 16	49	5.343 ± 0.008	0.403 ± 0.021	0.408 ± 0.016	0.277 ± 0.014	0.214 ± 0.010	0.088 ± 0.009	0.309 ± 0.009
	08 Jun 89	13 05	46	5.341 ± 0.023	0.399 ± 0.010	0.389 ± 0.013	0.285 ± 0.010	0.218 ± 0.012	0.088 ± 0.010	0.294 ± 0.012
	08 Jun 89	13 08	47	5.336 ± 0.023	0.400 ± 0.010	0.393 ± 0.013	0.282 ± 0.010	0.213 ± 0.012	0.103 ± 0.010	0.281 ± 0.012
181391	08 Jul 93	12 59	58	5.026 ± 0.046	0.582 ± 0.028	0.890 ± 0.017	1.150 ± 0.020	0.428 ± 0.022	0.295 ± 0.015	0.712 ± 0.017
182101	08 Jun 89	13 16	49	6.349 ± 0.030	0.479 ± 0.013	0.584 ± 0.016	0.630 ± 0.011	0.292 ± 0.013	0.160 ± 0.012	0.480 ± 0.016
	08 Jun 89	13 19	50	6.339 ± 0.030	0.479 ± 0.013	0.574 ± 0.016	0.636 ± 0.011	0.297 ± 0.013	0.168 ± 0.012	0.474 ± 0.016
182296	08 Jun 89	13 32	52	7.065 ± 0.034	0.770 ± 0.039	1.044 ± 0.023	1.495 ± 0.016	0.648 ± 0.014	0.373 ± 0.012	0.922 ± 0.017
	08 Jun 89	13 37	53	7.054 ± 0.034	0.761 ± 0.039	1.048 ± 0.023	1.490 ± 0.016	0.662 ± 0.014	0.379 ± 0.012	0.903 ± 0.017
183324	08 Jul 93	13 04	59	5.834 ± 0.036	0.609 ± 0.020	0.828 ± 0.014	0.384 ± 0.016	0.132 ± 0.017	0.075 ± 0.012	0.153 ± 0.016
183630	24 Jun 88	14 50	55	5.040 ± 0.011	0.878 ± 0.037	1.554 ± 0.029	2.219 ± 0.026	0.721 ± 0.012	0.580 ± 0.009	1.241 ± 0.016
	24 Jun 88	15 01	57	5.023 ± 0.011	0.881 ± 0.037	1.568 ± 0.029	2.202 ± 0.026	0.724 ± 0.012	0.578 ± 0.009	1.242 ± 0.016

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Table D.1 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
183630	08 Jun 89	14 13	61	5.039 $\pm$ 0.033	0.905 $\pm$ 0.024	1.528 $\pm$ 0.024	2.204 $\pm$ 0.018	0.740 $\pm$ 0.015	0.570 $\pm$ 0.013	1.238 $\pm$ 0.017
	08 Jun 89	14 17	62	5.036 $\pm$ 0.033	0.887 $\pm$ 0.023	1.524 $\pm$ 0.024	2.212 $\pm$ 0.018	0.735 $\pm$ 0.015	0.572 $\pm$ 0.013	1.242 $\pm$ 0.017
184406	17 May 91	16 23	59	4.520 $\pm$ 0.035	0.654 $\pm$ 0.028	1.201 $\pm$ 0.031	1.532 $\pm$ 0.035	0.355 $\pm$ 0.042	0.474 $\pm$ 0.039	0.893 $\pm$ 0.030
	17 May 91	16 27	60	4.460 $\pm$ 0.027	0.639 $\pm$ 0.108	1.272 $\pm$ 0.076	1.583 $\pm$ 0.040	0.474 $\pm$ 0.041	0.411 $\pm$ 0.022	0.819 $\pm$ 0.029
	17 May 91	16 32	61	4.448 $\pm$ 0.028	0.665 $\pm$ 0.069	1.220 $\pm$ 0.061	1.525 $\pm$ 0.059	0.482 $\pm$ 0.062	0.433 $\pm$ 0.030	0.821 $\pm$ 0.022
	21 May 91	16 42	128	4.490 $\pm$ 0.029	0.739 $\pm$ 0.041	1.181 $\pm$ 0.051	1.525 $\pm$ 0.058	0.505 $\pm$ 0.046	0.426 $\pm$ 0.026	0.804 $\pm$ 0.019
	21 May 91	16 49	130	4.440 $\pm$ 0.028	0.658 $\pm$ 0.028	1.199 $\pm$ 0.027	1.567 $\pm$ 0.028	0.458 $\pm$ 0.028	0.416 $\pm$ 0.022	0.843 $\pm$ 0.020
	21 May 91	16 51	131	4.448 $\pm$ 0.029	0.636 $\pm$ 0.031	1.205 $\pm$ 0.030	1.576 $\pm$ 0.026	0.447 $\pm$ 0.026	0.413 $\pm$ 0.024	0.849 $\pm$ 0.021
184492	01 Jul 93	13 41	104	5.158 $\pm$ 0.030	0.651 $\pm$ 0.026	0.966 $\pm$ 0.013	1.317 $\pm$ 0.015	0.521 $\pm$ 0.016	0.347 $\pm$ 0.012	0.790 $\pm$ 0.015
	01 Jul 93	13 44	105	5.153 $\pm$ 0.030	0.657 $\pm$ 0.028	0.960 $\pm$ 0.014	1.321 $\pm$ 0.014	0.512 $\pm$ 0.015	0.347 $\pm$ 0.012	0.802 $\pm$ 0.015
	03 Jul 93	13 30	78	5.150 $\pm$ 0.034	0.681 $\pm$ 0.034	0.978 $\pm$ 0.015	1.313 $\pm$ 0.019	0.516 $\pm$ 0.017	0.342 $\pm$ 0.011	0.803 $\pm$ 0.018
184930	17 May 91	16 43	63	4.376 $\pm$ 0.021	0.415 $\pm$ 0.020	0.460 $\pm$ 0.021	0.173 $\pm$ 0.024	0.097 $\pm$ 0.027	0.093 $\pm$ 0.017	0.137 $\pm$ 0.015
	17 May 91	16 47	64	4.363 $\pm$ 0.020	0.411 $\pm$ 0.019	0.481 $\pm$ 0.019	0.177 $\pm$ 0.023	0.099 $\pm$ 0.026	0.071 $\pm$ 0.015	0.133 $\pm$ 0.014
	17 May 91	16 51	65	4.372 $\pm$ 0.020	0.403 $\pm$ 0.019	0.480 $\pm$ 0.019	0.177 $\pm$ 0.021	0.095 $\pm$ 0.026	0.069 $\pm$ 0.015	0.134 $\pm$ 0.013
	21 May 91	17 22	140	4.360 $\pm$ 0.022	0.396 $\pm$ 0.030	0.478 $\pm$ 0.021	0.186 $\pm$ 0.022	0.122 $\pm$ 0.022	0.059 $\pm$ 0.018	0.143 $\pm$ 0.019
	21 May 91	17 25	141	4.353 $\pm$ 0.022	0.398 $\pm$ 0.021	0.476 $\pm$ 0.022	0.181 $\pm$ 0.025	0.131 $\pm$ 0.025	0.057 $\pm$ 0.019	0.147 $\pm$ 0.018
	21 May 91	17 27	142	4.359 $\pm$ 0.023	0.393 $\pm$ 0.022	0.488 $\pm$ 0.022	0.176 $\pm$ 0.019	0.115 $\pm$ 0.022	0.070 $\pm$ 0.020	0.142 $\pm$ 0.016
188350	20 May 93	16 32	118	5.644 $\pm$ 0.018	0.753 $\pm$ 0.014	0.785 $\pm$ 0.011	0.311 $\pm$ 0.010	0.174 $\pm$ 0.012	0.100 $\pm$ 0.012	0.228 $\pm$ 0.012
	20 May 93	16 35	119	5.631 $\pm$ 0.016	0.745 $\pm$ 0.014	0.792 $\pm$ 0.010	0.309 $\pm$ 0.009	0.168 $\pm$ 0.012	0.107 $\pm$ 0.010	0.224 $\pm$ 0.010
	21 May 93	16 31	75	5.601 $\pm$ 0.017	0.741 $\pm$ 0.018	0.795 $\pm$ 0.015	0.315 $\pm$ 0.011	0.169 $\pm$ 0.011	0.099 $\pm$ 0.013	0.212 $\pm$ 0.015
	21 May 93	16 34	76	5.594 $\pm$ 0.017	0.733 $\pm$ 0.021	0.792 $\pm$ 0.019	0.320 $\pm$ 0.016	0.167 $\pm$ 0.015	0.096 $\pm$ 0.014	0.215 $\pm$ 0.011
189695	21 May 93	16 39	77	5.916 $\pm$ 0.024	0.813 $\pm$ 0.049	1.398 $\pm$ 0.035	2.037 $\pm$ 0.018	0.581 $\pm$ 0.021	0.526 $\pm$ 0.020	1.046 $\pm$ 0.018
	21 May 93	16 41	78	5.912 $\pm$ 0.025	0.827 $\pm$ 0.033	1.398 $\pm$ 0.026	2.031 $\pm$ 0.018	0.590 $\pm$ 0.021	0.525 $\pm$ 0.020	1.045 $\pm$ 0.019
192876	20 May 93	16 42	120	4.257 $\pm$ 0.017	0.694 $\pm$ 0.016	0.905 $\pm$ 0.012	1.268 $\pm$ 0.012	0.500 $\pm$ 0.016	0.321 $\pm$ 0.014	0.759 $\pm$ 0.013
	29 Jun 93	14 25	57	4.281 $\pm$ 0.036	0.689 $\pm$ 0.024	0.925 $\pm$ 0.019	1.266 $\pm$ 0.016	0.511 $\pm$ 0.018	0.320 $\pm$ 0.018	0.754 $\pm$ 0.020
	29 Jun 93	14 28	58	4.277 $\pm$ 0.037	0.685 $\pm$ 0.024	0.929 $\pm$ 0.019	1.262 $\pm$ 0.016	0.511 $\pm$ 0.019	0.323 $\pm$ 0.020	0.755 $\pm$ 0.023
195135	29 Jun 93	14 33	59	4.918 $\pm$ 0.037	0.617 $\pm$ 0.026	1.188 $\pm$ 0.020	1.512 $\pm$ 0.014	0.491 $\pm$ 0.017	0.371 $\pm$ 0.016	0.786 $\pm$ 0.019
	29 Jun 93	14 36	60	4.920 $\pm$ 0.037	0.635 $\pm$ 0.026	1.176 $\pm$ 0.022	1.515 $\pm$ 0.016	0.496 $\pm$ 0.018	0.365 $\pm$ 0.017	0.799 $\pm$ 0.018
	01 Jul 93	14 29	117	4.946 $\pm$ 0.031	0.641 $\pm$ 0.026	1.167 $\pm$ 0.015	1.511 $\pm$ 0.016	0.479 $\pm$ 0.016	0.378 $\pm$ 0.012	0.798 $\pm$ 0.016
	01 Jul 93	14 32	118	4.940 $\pm$ 0.030	0.648 $\pm$ 0.027	1.153 $\pm$ 0.015	1.522 $\pm$ 0.018	0.489 $\pm$ 0.017	0.369 $\pm$ 0.011	0.803 $\pm$ 0.015
	03 Jul 93	14 27	88	4.927 $\pm$ 0.035	0.668 $\pm$ 0.035	1.181 $\pm$ 0.018	1.512 $\pm$ 0.020	0.481 $\pm$ 0.018	0.375 $\pm$ 0.013	0.794 $\pm$ 0.019

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Table D.1 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
195810	08 Jun 89	14 40	67	4.019 ± 0.030	0.401 ± 0.016	0.455 ± 0.020	0.134 ± 0.019	0.102 ± 0.024	0.025 ± 0.022	0.112 ± 0.017
	08 Jun 89	14 43	68	4.019 ± 0.030	0.387 ± 0.015	0.461 ± 0.020	0.147 ± 0.019	0.100 ± 0.024	0.019 ± 0.022	0.120 ± 0.017
198070	06 Jul 93	14 27	82	6.424 ± 0.038	0.607 ± 0.041	0.733 ± 0.021	0.278 ± 0.019	0.123 ± 0.019	0.056 ± 0.014	0.121 ± 0.020
198743	23 May 93	17 27	138	4.759 ± 0.019	0.626 ± 0.015	0.725 ± 0.011	0.575 ± 0.012	0.223 ± 0.016	0.152 ± 0.012	0.324 ± 0.011
	23 May 93	17 29	139	4.754 ± 0.019	0.620 ± 0.015	0.732 ± 0.012	0.570 ± 0.012	0.223 ± 0.016	0.147 ± 0.012	0.330 ± 0.011
199960	20 May 93	17 42	132	6.220 ± 0.017	0.497 ± 0.015	0.684 ± 0.010	0.842 ± 0.009	0.330 ± 0.011	0.228 ± 0.011	0.550 ± 0.012
	20 May 93	17 44	133	6.215 ± 0.016	0.503 ± 0.016	0.682 ± 0.011	0.839 ± 0.009	0.334 ± 0.012	0.226 ± 0.011	0.552 ± 0.011
	06 Jul 93	14 33	83	6.253 ± 0.046	0.503 ± 0.049	0.674 ± 0.023	0.841 ± 0.022	0.331 ± 0.019	0.222 ± 0.014	0.557 ± 0.022
	07 Jul 93	14 27	79	6.228 ± 0.042	0.470 ± 0.024	0.683 ± 0.014	0.828 ± 0.018	0.345 ± 0.012	0.212 ± 0.013	0.547 ± 0.019
200644	20 May 93	17 49	134	5.624 ± 0.022	0.820 ± 0.035	1.411 ± 0.027	2.184 ± 0.014	0.657 ± 0.022	0.547 ± 0.016	1.068 ± 0.016
	20 May 93	17 52	135	5.619 ± 0.022	0.808 ± 0.038	1.404 ± 0.031	2.181 ± 0.014	0.648 ± 0.021	0.562 ± 0.015	1.064 ± 0.016
205924	01 Jul 93	15 27	132	5.693 ± 0.026	0.640 ± 0.020	0.724 ± 0.011	0.518 ± 0.015	0.210 ± 0.015	0.121 ± 0.013	0.313 ± 0.014
	01 Jul 93	15 29	133	5.690 ± 0.026	0.615 ± 0.020	0.734 ± 0.011	0.504 ± 0.012	0.209 ± 0.012	0.122 ± 0.011	0.303 ± 0.016
	06 Jul 93	15 27	93	5.681 ± 0.041	0.627 ± 0.043	0.724 ± 0.020	0.522 ± 0.019	0.215 ± 0.017	0.127 ± 0.013	0.319 ± 0.019
216701	03 Jul 93	16 34	109	6.141 ± 0.029	0.682 ± 0.028	0.838 ± 0.015	0.465 ± 0.016	0.170 ± 0.016	0.110 ± 0.012	0.247 ± 0.020
221950	29 Jun 93	17 45	98	5.757 ± 0.031	0.484 ± 0.020	0.532 ± 0.016	0.598 ± 0.012	0.295 ± 0.014	0.173 ± 0.014	0.462 ± 0.017
	29 Jun 93	17 48	99	5.745 ± 0.031	0.492 ± 0.020	0.531 ± 0.016	0.601 ± 0.013	0.289 ± 0.013	0.180 ± 0.014	0.447 ± 0.015
	01 Jul 93	17 32	160	5.761 ± 0.028	0.499 ± 0.023	0.534 ± 0.019	0.596 ± 0.019	0.306 ± 0.014	0.153 ± 0.015	0.463 ± 0.021
	01 Jul 93	17 35	161	5.734 ± 0.025	0.479 ± 0.021	0.522 ± 0.014	0.603 ± 0.016	0.298 ± 0.012	0.162 ± 0.010	0.472 ± 0.013
	03 Jul 93	17 25	118	5.739 ± 0.032	0.487 ± 0.029	0.524 ± 0.017	0.612 ± 0.017	0.279 ± 0.020	0.168 ± 0.019	0.457 ± 0.021
222493	29 Jun 93	17 52	100	5.945 ± 0.034	0.591 ± 0.024	0.957 ± 0.019	1.234 ± 0.013	0.455 ± 0.015	0.294 ± 0.015	0.707 ± 0.017
	29 Jun 93	17 55	101	5.942 ± 0.035	0.583 ± 0.022	0.965 ± 0.017	1.231 ± 0.013	0.454 ± 0.014	0.297 ± 0.016	0.710 ± 0.018
	03 Jul 93	17 31	119	5.925 ± 0.032	0.605 ± 0.032	0.969 ± 0.016	1.226 ± 0.018	0.448 ± 0.016	0.310 ± 0.012	0.702 ± 0.017
223438	29 Jun 93	17 60	102	5.813 ± 0.029	0.668 ± 0.019	0.831 ± 0.015	0.446 ± 0.011	0.162 ± 0.013	0.107 ± 0.013	0.217 ± 0.014
	29 Jun 93	18 02	103	5.811 ± 0.029	0.670 ± 0.019	0.833 ± 0.015	0.442 ± 0.012	0.159 ± 0.014	0.113 ± 0.013	0.213 ± 0.015
	03 Jul 93	17 37	120	5.797 ± 0.028	0.672 ± 0.027	0.846 ± 0.014	0.431 ± 0.017	0.169 ± 0.018	0.095 ± 0.013	0.229 ± 0.016

Table D.2: The individual reduced observations for the SPS standard stars.

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
002151	24 Jun 92	18 60	68	2.875 ± 0.089	0.479 ± 0.029	0.622 ± 0.046	0.789 ± 0.049	0.326 ± 0.038	0.209 ± 0.038	0.548 ± 0.022
	25 Jun 92	18 45	148	2.947 ± 0.159	0.507 ± 0.096	0.619 ± 0.070	0.808 ± 0.058	0.332 ± 0.050	0.195 ± 0.033	0.569 ± 0.039
	27 Jun 92	18 32	148	3.019 ± 0.188	0.496 ± 0.039	0.600 ± 0.051	0.787 ± 0.073	0.321 ± 0.054	0.200 ± 0.037	0.559 ± 0.045
089080	15 Apr 92	09 11	41	3.272 ± 0.019	0.665 ± 0.036	0.541 ± 0.024	0.180 ± 0.023	0.102 ± 0.030	0.053 ± 0.024	0.206 ± 0.013
	15 Apr 92	09 13	42	3.262 ± 0.019	0.672 ± 0.036	0.538 ± 0.024	0.179 ± 0.023	0.093 ± 0.029	0.069 ± 0.023	0.197 ± 0.014
093845	15 Apr 92	09 52	56	4.437 ± 0.021	0.206 ± 0.034	0.287 ± 0.019	0.094 ± 0.032	0.087 ± 0.037	0.038 ± 0.023	0.078 ± 0.023
	15 Apr 92	09 54	57	4.440 ± 0.022	0.229 ± 0.035	0.282 ± 0.022	0.112 ± 0.022	0.058 ± 0.027	0.028 ± 0.023	0.083 ± 0.022
112985	15 Apr 92	12 05	106	3.669 ± 0.024	0.637 ± 0.046	1.197 ± 0.020	1.564 ± 0.018	0.448 ± 0.027	0.390 ± 0.017	0.838 ± 0.016
	15 Apr 92	12 06	107	3.666 ± 0.024	0.633 ± 0.045	1.195 ± 0.021	1.569 ± 0.020	0.446 ± 0.029	0.392 ± 0.019	0.835 ± 0.018
124882	15 Apr 92	13 33	129	4.384 ± 0.025	0.672 ± 0.049	1.235 ± 0.022	1.719 ± 0.020	0.504 ± 0.026	0.415 ± 0.015	0.909 ± 0.016
	15 Apr 92	13 35	130	4.385 ± 0.025	0.670 ± 0.048	1.234 ± 0.022	1.721 ± 0.020	0.507 ± 0.026	0.412 ± 0.015	0.909 ± 0.017
130650	24 Jun 88	09 29	8	5.641 ± 0.009	0.560 ± 0.026	0.946 ± 0.020	1.221 ± 0.017	0.462 ± 0.009	0.277 ± 0.008	0.730 ± 0.011
131246	24 Jun 88	09 19	6	5.645 ± 0.009	0.674 ± 0.030	1.106 ± 0.023	1.581 ± 0.020	0.615 ± 0.010	0.362 ± 0.008	0.886 ± 0.013
147675	27 Jun 92	10 46	54	3.857 ± 0.206	0.621 ± 0.042	0.892 ± 0.055	1.147 ± 0.079	0.436 ± 0.050	0.286 ± 0.029	0.684 ± 0.048
156513	24 Jun 88	09 42	9	5.870 ± 0.011	0.979 ± 0.036	1.520 ± 0.028	1.949 ± 0.025	0.809 ± 0.012	0.502 ± 0.008	1.246 ± 0.015
	24 Jun 88	09 56	11	5.881 ± 0.011	1.038 ± 0.036	1.542 ± 0.028	1.963 ± 0.025	0.803 ± 0.012	0.507 ± 0.008	1.242 ± 0.015
159517	24 Jun 88	10 33	16	6.487 ± 0.008	0.526 ± 0.022	0.603 ± 0.017	0.634 ± 0.014	0.300 ± 0.008	0.159 ± 0.007	0.485 ± 0.010
	24 Jun 88	10 43	18	6.489 ± 0.008	0.542 ± 0.022	0.606 ± 0.017	0.630 ± 0.014	0.302 ± 0.008	0.138 ± 0.007	0.500 ± 0.009
164461	22 Jun 89	08 35	6	5.309 ± 0.151	0.706 ± 0.021	1.371 ± 0.022	1.719 ± 0.018	0.511 ± 0.013	0.426 ± 0.010	0.928 ± 0.015
	22 Jun 89	08 38	7	5.311 ± 0.152	0.728 ± 0.022	1.358 ± 0.022	1.706 ± 0.018	0.528 ± 0.013	0.422 ± 0.010	0.924 ± 0.015
169904	22 Jun 89	08 45	9	6.148 ± 0.101	0.399 ± 0.014	0.538 ± 0.014	0.186 ± 0.011	0.058 ± 0.010	0.059 ± 0.007	0.097 ± 0.011
	22 Jun 89	08 48	10	6.151 ± 0.102	0.392 ± 0.014	0.540 ± 0.014	0.185 ± 0.011	0.065 ± 0.010	0.056 ± 0.007	0.092 ± 0.011
177482	24 Jun 88	10 51	19	5.461 ± 0.008	0.704 ± 0.021	0.745 ± 0.016	0.517 ± 0.014	0.227 ± 0.009	0.103 ± 0.009	0.366 ± 0.009
	24 Jun 88	10 59	21	5.458 ± 0.008	0.684 ± 0.021	0.760 ± 0.016	0.519 ± 0.014	0.219 ± 0.009	0.115 ± 0.009	0.356 ± 0.009
186154	22 Jun 89	08 58	12	6.430 ± 0.158	0.690 ± 0.031	1.396 ± 0.025	1.829 ± 0.019	0.562 ± 0.013	0.462 ± 0.009	1.012 ± 0.015
	22 Jun 89	09 02	13	6.436 ± 0.158	0.706 ± 0.031	1.400 ± 0.025	1.816 ± 0.019	0.565 ± 0.013	0.452 ± 0.009	1.014 ± 0.015
191220	22 Jun 89	09 10	15	6.074 ± 0.106	0.631 ± 0.014	0.800 ± 0.015	0.490 ± 0.012	0.159 ± 0.011	0.123 ± 0.008	0.271 ± 0.012
	22 Jun 89	09 13	16	6.069 ± 0.106	0.619 ± 0.014	0.807 ± 0.015	0.488 ± 0.012	0.163 ± 0.011	0.125 ± 0.008	0.260 ± 0.012
194612	24 Jun 88	11 17	24	5.939 ± 0.011	0.823 ± 0.036	1.532 ± 0.028	2.186 ± 0.025	0.679 ± 0.011	0.570 ± 0.008	1.202 ± 0.015
	24 Jun 88	11 27	26	5.951 ± 0.011	0.777 ± 0.036	1.515 ± 0.028	2.197 ± 0.025	0.680 ± 0.011	0.558 ± 0.008	1.209 ± 0.015

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Table D.2 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
202418	22 Jun 89	09 23	18	6.473 ± 0.158	0.734 ± 0.033	1.367 ± 0.026	1.813 ± 0.019	0.574 ± 0.013	0.441 ± 0.009	0.999 ± 0.015
	22 Jun 89	09 27	19	6.470 ± 0.158	0.717 ± 0.033	1.372 ± 0.026	1.811 ± 0.019	0.574 ± 0.013	0.440 ± 0.009	1.001 ± 0.015
203532	24 Jun 88	11 34	27	6.381 ± 0.008	0.388 ± 0.021	0.437 ± 0.016	0.293 ± 0.013	0.207 ± 0.008	0.078 ± 0.007	0.278 ± 0.009
	24 Jun 88	11 40	29	6.392 ± 0.008	0.393 ± 0.021	0.431 ± 0.016	0.293 ± 0.013	0.206 ± 0.008	0.079 ± 0.007	0.273 ± 0.009
203955	24 Jun 88	15 39	61	6.483 ± 0.007	0.628 ± 0.020	0.836 ± 0.015	0.325 ± 0.013	0.136 ± 0.008	0.056 ± 0.007	0.156 ± 0.009
	24 Jun 88	15 48	63	6.474 ± 0.007	0.634 ± 0.020	0.837 ± 0.015	0.326 ± 0.013	0.133 ± 0.008	0.060 ± 0.007	0.159 ± 0.009
204904	22 Jun 89	09 52	24	6.123 ± 0.115	0.537 ± 0.015	0.614 ± 0.016	0.626 ± 0.012	0.300 ± 0.011	0.167 ± 0.008	0.490 ± 0.013
	22 Jun 89	09 55	25	6.134 ± 0.115	0.543 ± 0.015	0.600 ± 0.016	0.635 ± 0.012	0.301 ± 0.011	0.163 ± 0.008	0.495 ± 0.013
205478	27 Jun 92	15 45	116	3.908 ± 0.208	0.600 ± 0.042	1.012 ± 0.056	1.276 ± 0.081	0.398 ± 0.051	0.321 ± 0.028	0.745 ± 0.048
210967	22 Jun 89	10 07	27	5.183 ± 0.190	1.183 ± 0.026	1.378 ± 0.025	1.055 ± 0.018	1.002 ± 0.015	0.342 ± 0.012	1.429 ± 0.018
	22 Jun 89	10 12	28	5.182 ± 0.190	1.180 ± 0.026	1.373 ± 0.025	1.055 ± 0.018	1.010 ± 0.015	0.334 ± 0.012	1.424 ± 0.018
214846	22 Jun 89	10 21	30	4.056 ± 0.106	0.627 ± 0.015	0.788 ± 0.017	0.486 ± 0.016	0.188 ± 0.021	0.083 ± 0.019	0.276 ± 0.014
	22 Jun 89	10 23	31	4.052 ± 0.106	0.627 ± 0.015	0.801 ± 0.017	0.475 ± 0.016	0.182 ± 0.021	0.099 ± 0.018	0.271 ± 0.014
219765	22 Jun 89	10 37	33	5.556 ± 0.151	0.672 ± 0.022	1.261 ± 0.022	1.646 ± 0.018	0.548 ± 0.013	0.390 ± 0.010	0.937 ± 0.015
	22 Jun 89	10 41	34	5.547 ± 0.150	0.667 ± 0.022	1.258 ± 0.022	1.649 ± 0.018	0.549 ± 0.013	0.384 ± 0.010	0.939 ± 0.015
224889	27 Jun 92	18 15	144	5.028 ± 0.225	0.685 ± 0.046	1.237 ± 0.061	1.650 ± 0.088	0.435 ± 0.054	0.426 ± 0.029	0.899 ± 0.052

Table D.3: The individual reduced observations for the bright, secondary standard stars.

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
029875	25 Nov 90	13 17	3	4.350 ± 0.031	0.494 ± 0.041	0.670 ± 0.038	0.557 ± 0.024	0.203 ± 0.028	0.147 ± 0.041	0.330 ± 0.047
	25 Nov 90	13 20	4	4.354 ± 0.031	0.486 ± 0.041	0.661 ± 0.037	0.567 ± 0.024	0.200 ± 0.028	0.146 ± 0.041	0.329 ± 0.046
	25 Nov 90	14 11	15	4.346 ± 0.032	0.488 ± 0.040	0.659 ± 0.037	0.559 ± 0.025	0.207 ± 0.029	0.146 ± 0.042	0.328 ± 0.047
	25 Nov 90	14 14	16	4.351 ± 0.031	0.489 ± 0.040	0.664 ± 0.037	0.560 ± 0.025	0.200 ± 0.029	0.149 ± 0.041	0.334 ± 0.046
	25 Nov 90	15 01	27	4.354 ± 0.031	0.490 ± 0.041	0.667 ± 0.038	0.559 ± 0.025	0.203 ± 0.028	0.143 ± 0.041	0.330 ± 0.046
	25 Nov 90	15 04	28	4.350 ± 0.031	0.491 ± 0.041	0.663 ± 0.037	0.564 ± 0.025	0.200 ± 0.028	0.149 ± 0.041	0.328 ± 0.046
035299	25 Nov 90	14 44	23	5.675 ± 0.032	0.105 ± 0.026	0.171 ± 0.025	0.114 ± 0.019	0.044 ± 0.024	0.051 ± 0.026	0.065 ± 0.037
036512	25 Nov 90	15 14	30	4.620 ± 0.034	-0.069 ± 0.046	0.135 ± 0.047	0.078 ± 0.033	0.023 ± 0.029	0.052 ± 0.031	0.056 ± 0.041
	25 Nov 90	15 17	31	4.631 ± 0.032	0.029 ± 0.028	0.035 ± 0.026	0.055 ± 0.022	0.034 ± 0.028	0.029 ± 0.025	0.072 ± 0.037
037495	06 Feb 92	09 23	4	5.299 ± 0.030	0.532 ± 0.022	0.618 ± 0.021	0.671 ± 0.012	0.296 ± 0.020	0.144 ± 0.047	0.477 ± 0.016
	06 Feb 92	09 26	5	5.299 ± 0.030	0.533 ± 0.021	0.620 ± 0.020	0.669 ± 0.010	0.297 ± 0.019	0.143 ± 0.047	0.476 ± 0.016
	06 Feb 92	10 47	19	5.275 ± 0.031	0.529 ± 0.023	0.618 ± 0.022	0.679 ± 0.012	0.287 ± 0.020	0.158 ± 0.048	0.477 ± 0.016
	06 Feb 92	10 49	20	5.283 ± 0.031	0.535 ± 0.023	0.612 ± 0.021	0.668 ± 0.013	0.294 ± 0.021	0.155 ± 0.049	0.475 ± 0.016
	06 Feb 92	11 50	34	5.274 ± 0.035	0.540 ± 0.024	0.607 ± 0.024	0.669 ± 0.017	0.287 ± 0.023	0.164 ± 0.053	0.468 ± 0.018
	06 Feb 92	11 52	35	5.277 ± 0.035	0.531 ± 0.024	0.607 ± 0.022	0.675 ± 0.013	0.280 ± 0.022	0.170 ± 0.053	0.464 ± 0.019
	09 Feb 92	10 30	3	5.331 ± 0.029	0.498 ± 0.029	0.627 ± 0.025	0.677 ± 0.020	0.307 ± 0.023	0.136 ± 0.043	0.487 ± 0.018
	09 Feb 92	10 33	4	5.305 ± 0.029	0.534 ± 0.027	0.610 ± 0.023	0.675 ± 0.019	0.307 ± 0.020	0.130 ± 0.043	0.486 ± 0.017
	09 Feb 92	11 08	15	5.279 ± 0.031	0.531 ± 0.027	0.615 ± 0.021	0.672 ± 0.021	0.308 ± 0.024	0.135 ± 0.045	0.473 ± 0.017
	09 Feb 92	11 10	16	5.289 ± 0.030	0.519 ± 0.025	0.624 ± 0.022	0.671 ± 0.017	0.312 ± 0.021	0.123 ± 0.045	0.482 ± 0.018
	09 Feb 92	12 06	33	5.296 ± 0.035	0.546 ± 0.029	0.620 ± 0.026	0.661 ± 0.020	0.305 ± 0.029	0.131 ± 0.053	0.489 ± 0.024
	09 Feb 92	12 08	34	5.274 ± 0.039	0.510 ± 0.033	0.616 ± 0.029	0.672 ± 0.022	0.288 ± 0.023	0.168 ± 0.053	0.460 ± 0.028
	10 Feb 92	09 23	4	5.329 ± 0.029	0.495 ± 0.037	0.614 ± 0.031	0.660 ± 0.020	0.302 ± 0.022	0.118 ± 0.047	0.492 ± 0.016
	10 Feb 92	09 26	5	5.325 ± 0.028	0.506 ± 0.039	0.609 ± 0.032	0.664 ± 0.020	0.307 ± 0.022	0.115 ± 0.047	0.484 ± 0.016
	10 Feb 92	10 00	13	5.310 ± 0.028	0.516 ± 0.037	0.613 ± 0.030	0.661 ± 0.017	0.297 ± 0.019	0.131 ± 0.046	0.471 ± 0.014
	10 Feb 92	10 03	14	5.309 ± 0.028	0.501 ± 0.037	0.616 ± 0.030	0.663 ± 0.019	0.298 ± 0.019	0.128 ± 0.046	0.478 ± 0.015
	10 Feb 92	11 11	32	5.301 ± 0.030	0.509 ± 0.038	0.619 ± 0.032	0.656 ± 0.022	0.300 ± 0.026	0.139 ± 0.051	0.473 ± 0.015
	10 Feb 92	11 13	33	5.295 ± 0.030	0.510 ± 0.038	0.609 ± 0.030	0.652 ± 0.018	0.292 ± 0.020	0.148 ± 0.049	0.469 ± 0.014
	10 Feb 92	12 00	46	5.293 ± 0.034	0.517 ± 0.039	0.604 ± 0.032	0.658 ± 0.021	0.299 ± 0.022	0.147 ± 0.053	0.466 ± 0.017
	10 Feb 92	12 02	47	5.299 ± 0.033	0.519 ± 0.040	0.609 ± 0.033	0.653 ± 0.022	0.298 ± 0.022	0.149 ± 0.053	0.473 ± 0.016
	14 Feb 93	09 12	2	5.236 ± 0.038	0.503 ± 0.034	0.611 ± 0.015	0.669 ± 0.011	0.301 ± 0.016	0.181 ± 0.015	0.445 ± 0.020

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
037495	14 Feb 93	09 14	3	5.234 ± 0.038	0.508 ± 0.034	0.604 ± 0.014	0.675 ± 0.011	0.299 ± 0.015	0.178 ± 0.014	0.448 ± 0.019
	14 Feb 93	10 14	15	5.235 ± 0.038	0.510 ± 0.035	0.603 ± 0.014	0.677 ± 0.011	0.294 ± 0.016	0.175 ± 0.015	0.456 ± 0.019
	14 Feb 93	10 16	16	5.231 ± 0.038	0.508 ± 0.036	0.604 ± 0.015	0.668 ± 0.011	0.305 ± 0.015	0.174 ± 0.015	0.458 ± 0.020
	14 Feb 93	11 07	27	5.253 ± 0.039	0.518 ± 0.037	0.603 ± 0.015	0.671 ± 0.011	0.295 ± 0.016	0.183 ± 0.015	0.455 ± 0.020
	14 Feb 93	11 09	28	5.245 ± 0.039	0.508 ± 0.037	0.608 ± 0.015	0.672 ± 0.013	0.296 ± 0.016	0.183 ± 0.016	0.449 ± 0.020
	14 Feb 93	12 05	39	5.252 ± 0.040	0.510 ± 0.040	0.613 ± 0.015	0.670 ± 0.013	0.296 ± 0.018	0.178 ± 0.016	0.453 ± 0.020
	14 Feb 93	12 09	40	5.242 ± 0.040	0.508 ± 0.041	0.609 ± 0.016	0.673 ± 0.013	0.298 ± 0.017	0.182 ± 0.017	0.451 ± 0.021
	14 Feb 93	13 12	54	5.256 ± 0.042	0.506 ± 0.049	0.604 ± 0.017	0.671 ± 0.013	0.297 ± 0.020	0.175 ± 0.020	0.454 ± 0.024
	14 Feb 93	13 14	55	5.264 ± 0.043	0.521 ± 0.050	0.610 ± 0.016	0.673 ± 0.014	0.297 ± 0.018	0.170 ± 0.019	0.463 ± 0.026
	15 Feb 93	10 37	2	5.274 ± 0.045	0.484 ± 0.081	0.596 ± 0.040	0.660 ± 0.021	0.286 ± 0.020	0.179 ± 0.013	0.455 ± 0.014
	15 Feb 93	10 39	3	5.265 ± 0.045	0.485 ± 0.082	0.596 ± 0.040	0.660 ± 0.021	0.287 ± 0.019	0.180 ± 0.013	0.453 ± 0.014
	15 Feb 93	11 59	22	5.275 ± 0.049	0.546 ± 0.085	0.596 ± 0.040	0.657 ± 0.022	0.285 ± 0.020	0.178 ± 0.014	0.453 ± 0.013
	15 Feb 93	12 01	23	5.279 ± 0.049	0.532 ± 0.085	0.600 ± 0.040	0.654 ± 0.023	0.283 ± 0.022	0.182 ± 0.015	0.450 ± 0.014
	16 Feb 93	09 04	3	5.249 ± 0.029	0.543 ± 0.048	0.602 ± 0.014	0.668 ± 0.011	0.296 ± 0.011	0.170 ± 0.010	0.432 ± 0.026
	16 Feb 93	09 08	4	5.245 ± 0.030	0.533 ± 0.049	0.601 ± 0.015	0.667 ± 0.012	0.296 ± 0.013	0.174 ± 0.012	0.430 ± 0.026
	16 Feb 93	10 04	21	5.265 ± 0.030	0.469 ± 0.050	0.597 ± 0.014	0.671 ± 0.013	0.295 ± 0.014	0.168 ± 0.012	0.433 ± 0.026
	16 Feb 93	10 06	22	5.262 ± 0.030	0.468 ± 0.050	0.607 ± 0.014	0.666 ± 0.011	0.294 ± 0.012	0.169 ± 0.011	0.438 ± 0.026
	16 Feb 93	11 01	37	5.258 ± 0.032	0.579 ± 0.054	0.599 ± 0.014	0.669 ± 0.012	0.293 ± 0.012	0.175 ± 0.010	0.434 ± 0.026
	16 Feb 93	11 04	38	5.258 ± 0.032	0.601 ± 0.054	0.590 ± 0.014	0.675 ± 0.012	0.290 ± 0.013	0.174 ± 0.011	0.438 ± 0.026
	16 Feb 93	12 10	57	5.264 ± 0.036	0.536 ± 0.063	0.594 ± 0.017	0.666 ± 0.014	0.290 ± 0.015	0.176 ± 0.013	0.431 ± 0.028
	16 Feb 93	12 12	58	5.272 ± 0.036	0.525 ± 0.063	0.599 ± 0.016	0.666 ± 0.013	0.281 ± 0.014	0.177 ± 0.012	0.443 ± 0.027
	17 Feb 93	11 04	2	5.254 ± 0.037	0.490 ± 0.041	0.615 ± 0.021	0.654 ± 0.012	0.289 ± 0.014	0.169 ± 0.009	0.453 ± 0.018
	17 Feb 93	11 07	3	5.241 ± 0.037	0.521 ± 0.041	0.612 ± 0.021	0.656 ± 0.011	0.291 ± 0.013	0.181 ± 0.010	0.433 ± 0.018
	17 Feb 93	12 10	18	5.251 ± 0.042	0.552 ± 0.046	0.609 ± 0.024	0.650 ± 0.016	0.293 ± 0.017	0.175 ± 0.014	0.446 ± 0.023
	17 Feb 93	12 12	19	5.253 ± 0.042	0.532 ± 0.049	0.615 ± 0.027	0.659 ± 0.012	0.287 ± 0.017	0.178 ± 0.016	0.451 ± 0.022
	18 Feb 93	09 00	2	5.224 ± 0.030	0.516 ± 0.064	0.606 ± 0.015	0.670 ± 0.011	0.294 ± 0.014	0.168 ± 0.011	0.442 ± 0.023
	18 Feb 93	09 03	3	5.263 ± 0.031	0.514 ± 0.064	0.608 ± 0.016	0.651 ± 0.012	0.300 ± 0.016	0.147 ± 0.016	0.434 ± 0.025
	18 Feb 93	10 06	19	5.232 ± 0.032	0.548 ± 0.067	0.612 ± 0.016	0.661 ± 0.012	0.303 ± 0.013	0.164 ± 0.012	0.440 ± 0.025
	18 Feb 93	10 08	20	5.231 ± 0.032	0.545 ± 0.067	0.614 ± 0.016	0.658 ± 0.012	0.292 ± 0.014	0.171 ± 0.011	0.436 ± 0.023
	18 Feb 93	11 02	37	5.256 ± 0.034	0.460 ± 0.071	0.603 ± 0.017	0.673 ± 0.013	0.296 ± 0.014	0.162 ± 0.013	0.438 ± 0.025
	18 Feb 93	11 04	38	5.247 ± 0.034	0.459 ± 0.072	0.606 ± 0.016	0.663 ± 0.013	0.298 ± 0.015	0.166 ± 0.013	0.440 ± 0.024

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
037495	18 Feb 93	12 06	53	5.255 ± 0.038	0.526 ± 0.082	0.590 ± 0.017	0.674 ± 0.016	0.294 ± 0.017	0.163 ± 0.013	0.446 ± 0.024
	18 Feb 93	12 08	54	5.249 ± 0.039	0.499 ± 0.082	0.581 ± 0.019	0.680 ± 0.015	0.280 ± 0.015	0.169 ± 0.013	0.447 ± 0.025
045416	16 Feb 93	09 25	9	5.126 ± 0.039	0.639 ± 0.066	1.081 ± 0.020	1.512 ± 0.016	0.536 ± 0.017	0.336 ± 0.014	0.755 ± 0.036
	16 Feb 93	09 27	10	5.119 ± 0.040	0.651 ± 0.068	1.075 ± 0.024	1.505 ± 0.014	0.533 ± 0.016	0.339 ± 0.014	0.758 ± 0.035
	18 Feb 93	09 21	8	5.095 ± 0.042	0.661 ± 0.090	1.085 ± 0.024	1.520 ± 0.016	0.537 ± 0.019	0.334 ± 0.015	0.771 ± 0.034
	18 Feb 93	09 23	9	5.098 ± 0.042	0.660 ± 0.090	1.087 ± 0.022	1.504 ± 0.015	0.545 ± 0.020	0.334 ± 0.016	0.770 ± 0.034
052877	27 Feb 91	08 59	2	3.498 ± 0.043	0.888 ± 0.042	1.326 ± 0.029	2.182 ± 0.042	0.735 ± 0.017	0.525 ± 0.020	1.121 ± 0.029
	27 Feb 91	09 02	3	3.495 ± 0.043	0.888 ± 0.042	1.324 ± 0.029	2.183 ± 0.042	0.731 ± 0.017	0.529 ± 0.020	1.124 ± 0.029
	27 Feb 91	09 26	8	3.489 ± 0.043	0.890 ± 0.042	1.323 ± 0.029	2.185 ± 0.042	0.729 ± 0.017	0.529 ± 0.020	1.122 ± 0.029
	27 Feb 91	09 29	9	3.482 ± 0.043	0.888 ± 0.042	1.324 ± 0.029	2.188 ± 0.042	0.718 ± 0.017	0.539 ± 0.020	1.109 ± 0.029
	27 Feb 91	10 17	20	3.489 ± 0.043	0.878 ± 0.042	1.317 ± 0.029	2.185 ± 0.042	0.721 ± 0.017	0.537 ± 0.020	1.118 ± 0.029
	27 Feb 91	10 19	21	3.503 ± 0.043	0.891 ± 0.042	1.315 ± 0.029	2.183 ± 0.042	0.716 ± 0.017	0.535 ± 0.020	1.121 ± 0.029
	27 Feb 91	11 00	32	3.491 ± 0.043	0.898 ± 0.042	1.317 ± 0.029	2.184 ± 0.042	0.728 ± 0.017	0.531 ± 0.020	1.118 ± 0.029
	27 Feb 91	11 03	33	3.492 ± 0.043	0.895 ± 0.042	1.317 ± 0.029	2.180 ± 0.042	0.729 ± 0.017	0.532 ± 0.020	1.116 ± 0.029
	27 Feb 91	11 45	44	3.496 ± 0.043	0.889 ± 0.042	1.325 ± 0.030	2.184 ± 0.043	0.733 ± 0.018	0.528 ± 0.020	1.123 ± 0.029
	27 Feb 91	11 48	45	3.501 ± 0.043	0.895 ± 0.042	1.319 ± 0.030	2.191 ± 0.043	0.732 ± 0.018	0.524 ± 0.020	1.123 ± 0.029
	27 Feb 91	12 48	59	3.493 ± 0.044	0.898 ± 0.043	1.317 ± 0.031	2.178 ± 0.043	0.738 ± 0.019	0.529 ± 0.021	1.119 ± 0.029
	27 Feb 91	12 51	60	3.499 ± 0.044	0.898 ± 0.043	1.310 ± 0.031	2.187 ± 0.043	0.733 ± 0.019	0.527 ± 0.021	1.127 ± 0.029
	28 Feb 91	09 26	2	3.514 ± 0.020	0.873 ± 0.049	1.348 ± 0.042	2.184 ± 0.031	0.736 ± 0.043	0.519 ± 0.039	1.086 ± 0.044
	28 Feb 91	09 29	3	3.510 ± 0.020	0.879 ± 0.049	1.338 ± 0.042	2.188 ± 0.031	0.733 ± 0.043	0.523 ± 0.039	1.082 ± 0.044
	28 Feb 91	10 27	17	3.500 ± 0.020	0.881 ± 0.049	1.338 ± 0.042	2.200 ± 0.031	0.725 ± 0.044	0.527 ± 0.039	1.081 ± 0.044
	28 Feb 91	10 30	18	3.509 ± 0.020	0.878 ± 0.050	1.339 ± 0.043	2.196 ± 0.032	0.728 ± 0.044	0.523 ± 0.039	1.079 ± 0.044
	28 Feb 91	11 36	35	3.505 ± 0.020	0.883 ± 0.050	1.345 ± 0.043	2.200 ± 0.032	0.735 ± 0.044	0.520 ± 0.039	1.083 ± 0.044
	28 Feb 91	11 39	36	3.498 ± 0.021	0.883 ± 0.049	1.341 ± 0.043	2.201 ± 0.032	0.738 ± 0.044	0.523 ± 0.039	1.073 ± 0.044
	28 Feb 91	12 39	47	3.484 ± 0.022	0.894 ± 0.050	1.333 ± 0.044	2.207 ± 0.033	0.725 ± 0.045	0.534 ± 0.040	1.072 ± 0.045
	28 Feb 91	12 42	48	3.487 ± 0.022	0.901 ± 0.050	1.337 ± 0.043	2.204 ± 0.033	0.724 ± 0.045	0.526 ± 0.040	1.076 ± 0.045
	28 Feb 91	13 43	59	3.498 ± 0.024	0.902 ± 0.051	1.330 ± 0.045	2.210 ± 0.037	0.764 ± 0.048	0.491 ± 0.041	1.086 ± 0.045
	28 Feb 91	13 49	60	3.506 ± 0.026	0.891 ± 0.051	1.332 ± 0.045	2.209 ± 0.037	0.756 ± 0.048	0.497 ± 0.042	1.082 ± 0.046
	28 Feb 91	15 02	76	3.541 ± 0.042	0.912 ± 0.057	1.332 ± 0.057	2.195 ± 0.052	0.776 ± 0.057	0.482 ± 0.055	1.093 ± 0.055
	28 Feb 91	15 05	77	3.531 ± 0.038	0.938 ± 0.057	1.308 ± 0.056	2.180 ± 0.050	0.785 ± 0.056	0.503 ± 0.051	1.093 ± 0.053
064379	06 Feb 92	09 52	7	5.031 ± 0.030	0.463 ± 0.021	0.576 ± 0.021	0.639 ± 0.011	0.283 ± 0.021	0.155 ± 0.048	0.477 ± 0.015

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
064379	06 Feb 92	09 55	8	5.032 ± 0.030	0.459 ± 0.022	0.574 ± 0.021	0.645 ± 0.011	0.286 ± 0.020	0.148 ± 0.047	0.482 ± 0.016
	06 Feb 92	10 56	22	5.033 ± 0.030	0.464 ± 0.022	0.570 ± 0.021	0.638 ± 0.011	0.280 ± 0.020	0.162 ± 0.046	0.482 ± 0.017
	06 Feb 92	10 58	23	5.028 ± 0.030	0.457 ± 0.022	0.574 ± 0.021	0.644 ± 0.012	0.275 ± 0.020	0.166 ± 0.046	0.475 ± 0.016
	06 Feb 92	12 03	37	5.015 ± 0.030	0.463 ± 0.022	0.565 ± 0.021	0.638 ± 0.012	0.278 ± 0.020	0.179 ± 0.046	0.475 ± 0.015
	06 Feb 92	12 05	38	5.008 ± 0.030	0.466 ± 0.024	0.571 ± 0.023	0.632 ± 0.012	0.278 ± 0.020	0.183 ± 0.046	0.466 ± 0.016
	06 Feb 92	12 51	52	4.996 ± 0.030	0.461 ± 0.022	0.571 ± 0.021	0.636 ± 0.011	0.275 ± 0.020	0.188 ± 0.047	0.470 ± 0.017
	06 Feb 92	12 53	53	5.001 ± 0.030	0.462 ± 0.022	0.568 ± 0.022	0.637 ± 0.012	0.276 ± 0.020	0.188 ± 0.047	0.475 ± 0.016
	06 Feb 92	13 59	72	4.994 ± 0.033	0.460 ± 0.023	0.566 ± 0.021	0.637 ± 0.012	0.259 ± 0.021	0.211 ± 0.050	0.462 ± 0.017
	06 Feb 92	14 01	73	4.994 ± 0.033	0.459 ± 0.022	0.569 ± 0.022	0.633 ± 0.013	0.267 ± 0.021	0.203 ± 0.051	0.468 ± 0.018
	06 Feb 92	15 10	88	4.980 ± 0.038	0.449 ± 0.024	0.569 ± 0.024	0.631 ± 0.013	0.262 ± 0.023	0.208 ± 0.057	0.463 ± 0.018
	06 Feb 92	15 12	89	4.986 ± 0.037	0.448 ± 0.024	0.560 ± 0.022	0.642 ± 0.012	0.254 ± 0.023	0.209 ± 0.057	0.468 ± 0.017
	06 Feb 92	16 15	105	5.019 ± 0.046	0.444 ± 0.025	0.562 ± 0.025	0.626 ± 0.019	0.259 ± 0.029	0.207 ± 0.069	0.482 ± 0.024
	06 Feb 92	16 17	106	5.011 ± 0.046	0.444 ± 0.026	0.560 ± 0.024	0.620 ± 0.016	0.264 ± 0.029	0.215 ± 0.069	0.468 ± 0.021
	06 Feb 92	16 19	107	5.013 ± 0.046	0.441 ± 0.026	0.558 ± 0.025	0.626 ± 0.015	0.266 ± 0.029	0.213 ± 0.070	0.471 ± 0.020
	09 Feb 92	10 40	6	5.045 ± 0.028	0.459 ± 0.023	0.571 ± 0.019	0.646 ± 0.014	0.300 ± 0.019	0.127 ± 0.042	0.483 ± 0.019
	09 Feb 92	10 42	7	5.038 ± 0.027	0.460 ± 0.027	0.573 ± 0.021	0.637 ± 0.013	0.308 ± 0.017	0.134 ± 0.040	0.475 ± 0.014
	09 Feb 92	11 16	18	5.042 ± 0.027	0.455 ± 0.024	0.574 ± 0.020	0.646 ± 0.015	0.295 ± 0.018	0.135 ± 0.040	0.493 ± 0.016

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19	09 Feb 92	11 18	19	5.041 ± 0.027	0.462 ± 0.028	0.568 ± 0.020	0.653 ± 0.015	0.287 ± 0.020	0.140 ± 0.041	0.489 ± 0.018
36	09 Feb 92	12 14	36	5.024 ± 0.027	0.453 ± 0.026	0.573 ± 0.019	0.646 ± 0.018	0.287 ± 0.023	0.155 ± 0.041	0.482 ± 0.016
37	09 Feb 92	12 16	37	5.033 ± 0.027	0.455 ± 0.026	0.571 ± 0.021	0.647 ± 0.014	0.292 ± 0.017	0.148 ± 0.040	0.488 ± 0.016
51	09 Feb 92	13 10	51	5.022 ± 0.029	0.457 ± 0.024	0.569 ± 0.019	0.644 ± 0.014	0.289 ± 0.019	0.159 ± 0.042	0.480 ± 0.019
52	09 Feb 92	13 12	52	5.018 ± 0.029	0.449 ± 0.025	0.578 ± 0.019	0.636 ± 0.015	0.286 ± 0.019	0.167 ± 0.042	0.487 ± 0.015
67	09 Feb 92	14 01	67	5.021 ± 0.033	0.459 ± 0.028	0.576 ± 0.022	0.640 ± 0.017	0.282 ± 0.026	0.169 ± 0.049	0.488 ± 0.019
68	09 Feb 92	14 03	68	5.008 ± 0.032	0.443 ± 0.029	0.571 ± 0.020	0.650 ± 0.016	0.275 ± 0.019	0.183 ± 0.046	0.475 ± 0.020
87	09 Feb 92	15 12	87	4.989 ± 0.039	0.454 ± 0.028	0.562 ± 0.022	0.629 ± 0.020	0.287 ± 0.023	0.185 ± 0.054	0.463 ± 0.021
88	09 Feb 92	15 14	88	4.995 ± 0.038	0.455 ± 0.027	0.559 ± 0.024	0.634 ± 0.022	0.277 ± 0.023	0.188 ± 0.054	0.469 ± 0.020
107	09 Feb 92	16 26	107	5.018 ± 0.049	0.437 ± 0.032	0.556 ± 0.026	0.629 ± 0.024	0.268 ± 0.031	0.205 ± 0.071	0.468 ± 0.022
7	10 Feb 92	09 32	7	5.066 ± 0.029	0.437 ± 0.037	0.573 ± 0.029	0.633 ± 0.018	0.298 ± 0.019	0.118 ± 0.047	0.488 ± 0.015
8	10 Feb 92	09 34	8	5.063 ± 0.028	0.448 ± 0.037	0.565 ± 0.030	0.642 ± 0.019	0.294 ± 0.021	0.115 ± 0.047	0.483 ± 0.014
16	10 Feb 92	10 09	16	5.054 ± 0.028	0.445 ± 0.037	0.564 ± 0.030	0.633 ± 0.018	0.291 ± 0.020	0.138 ± 0.046	0.477 ± 0.016
17	10 Feb 92	10 11	17	5.054 ± 0.028	0.441 ± 0.037	0.568 ± 0.029	0.629 ± 0.017	0.288 ± 0.019	0.139 ± 0.046	0.480 ± 0.016

Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
064379	10 Feb 92	11 19	35	5.040 ± 0.027	0.435 ± 0.037	0.567 ± 0.029	0.624 ± 0.017	0.282 ± 0.019	0.155 ± 0.045	0.470 ± 0.013
	10 Feb 92	11 21	36	5.041 ± 0.027	0.445 ± 0.037	0.569 ± 0.030	0.626 ± 0.018	0.283 ± 0.019	0.154 ± 0.045	0.466 ± 0.014
	10 Feb 92	12 08	49	5.034 ± 0.028	0.438 ± 0.037	0.557 ± 0.030	0.631 ± 0.019	0.277 ± 0.019	0.165 ± 0.046	0.473 ± 0.015
	10 Feb 92	12 11	50	5.032 ± 0.028	0.443 ± 0.037	0.565 ± 0.030	0.631 ± 0.019	0.279 ± 0.021	0.159 ± 0.046	0.476 ± 0.015
	10 Feb 92	13 00	60	5.016 ± 0.028	0.434 ± 0.037	0.565 ± 0.030	0.623 ± 0.018	0.270 ± 0.020	0.185 ± 0.047	0.463 ± 0.014
	10 Feb 92	13 03	61	5.019 ± 0.029	0.427 ± 0.038	0.565 ± 0.030	0.626 ± 0.020	0.272 ± 0.022	0.174 ± 0.047	0.474 ± 0.014
	10 Feb 92	14 00	77	5.019 ± 0.031	0.440 ± 0.038	0.566 ± 0.031	0.628 ± 0.020	0.268 ± 0.022	0.197 ± 0.050	0.473 ± 0.017
	10 Feb 92	14 02	78	5.011 ± 0.031	0.428 ± 0.038	0.558 ± 0.031	0.626 ± 0.019	0.269 ± 0.021	0.190 ± 0.050	0.467 ± 0.014
	10 Feb 92	15 03	95	5.008 ± 0.037	0.442 ± 0.040	0.556 ± 0.032	0.614 ± 0.021	0.269 ± 0.025	0.203 ± 0.057	0.474 ± 0.022
	10 Feb 92	15 05	96	5.014 ± 0.036	0.433 ± 0.039	0.558 ± 0.037	0.618 ± 0.028	0.262 ± 0.026	0.200 ± 0.057	0.477 ± 0.017
069142	13 Apr 92	07 32	2	4.432 ± 0.025	0.621 ± 0.020	1.077 ± 0.018	1.460 ± 0.013	0.529 ± 0.016	0.348 ± 0.016	0.813 ± 0.019
	13 Apr 92	07 34	3	4.421 ± 0.025	0.638 ± 0.018	1.075 ± 0.018	1.465 ± 0.013	0.528 ± 0.016	0.348 ± 0.015	0.816 ± 0.017
072127	15 Apr 92	07 45	8	4.971 ± 0.018	0.211 ± 0.033	0.193 ± 0.017	0.097 ± 0.015	0.095 ± 0.018	0.024 ± 0.011	0.100 ± 0.012
	15 Apr 92	07 46	9	4.975 ± 0.018	0.211 ± 0.034	0.193 ± 0.015	0.098 ± 0.014	0.098 ± 0.019	0.022 ± 0.011	0.105 ± 0.012
073389	14 Apr 92	07 48	9	4.875 ± 0.071	0.575 ± 0.032	0.969 ± 0.060	1.273 ± 0.051	0.441 ± 0.048	0.302 ± 0.020	0.716 ± 0.035
	14 Apr 92	07 50	10	4.884 ± 0.070	0.569 ± 0.032	0.973 ± 0.060	1.277 ± 0.051	0.438 ± 0.047	0.298 ± 0.020	0.722 ± 0.035
073390	14 Apr 92	07 53	12	5.160 ± 0.052	0.290 ± 0.024	0.317 ± 0.044	0.111 ± 0.037	0.127 ± 0.035	0.017 ± 0.016	0.122 ± 0.026
	14 Apr 92	07 55	13	5.161 ± 0.052	0.290 ± 0.024	0.313 ± 0.044	0.111 ± 0.037	0.124 ± 0.035	0.021 ± 0.017	0.127 ± 0.027
074006	12 Apr 92	08 08	8	3.958 ± 0.033	0.617 ± 0.023	0.846 ± 0.018	1.180 ± 0.019	0.445 ± 0.017	0.283 ± 0.018	0.673 ± 0.020
	12 Apr 92	08 10	9	3.960 ± 0.034	0.620 ± 0.023	0.845 ± 0.016	1.171 ± 0.017	0.446 ± 0.016	0.279 ± 0.020	0.672 ± 0.021
074180	12 Apr 92	08 18	11	3.801 ± 0.031	1.307 ± 0.022	0.827 ± 0.016	0.680 ± 0.019	0.446 ± 0.019	0.225 ± 0.019	0.626 ± 0.019
	12 Apr 92	08 19	12	3.802 ± 0.031	1.304 ± 0.022	0.828 ± 0.016	0.677 ± 0.017	0.441 ± 0.017	0.237 ± 0.018	0.623 ± 0.020
074272	12 Apr 92	08 25	14	4.725 ± 0.025	1.127 ± 0.018	0.836 ± 0.015	0.352 ± 0.015	0.186 ± 0.013	0.092 ± 0.013	0.270 ± 0.017
	12 Apr 92	08 26	15	4.725 ± 0.026	1.135 ± 0.019	0.824 ± 0.015	0.362 ± 0.014	0.180 ± 0.012	0.093 ± 0.016	0.266 ± 0.019
075063	15 Apr 92	07 54	11	3.862 ± 0.018	1.072 ± 0.034	0.751 ± 0.019	0.230 ± 0.016	0.159 ± 0.023	0.055 ± 0.016	0.208 ± 0.013
	15 Apr 92	07 56	12	3.869 ± 0.018	1.075 ± 0.033	0.739 ± 0.018	0.235 ± 0.017	0.154 ± 0.024	0.056 ± 0.018	0.199 ± 0.015
075710	13 Apr 92	08 00	11	4.906 ± 0.017	0.935 ± 0.013	0.814 ± 0.012	0.283 ± 0.010	0.145 ± 0.012	0.075 ± 0.011	0.194 ± 0.013
	13 Apr 92	08 02	12	4.901 ± 0.017	0.938 ± 0.015	0.821 ± 0.013	0.280 ± 0.010	0.149 ± 0.012	0.075 ± 0.012	0.198 ± 0.014
076728	14 Apr 92	08 02	15	3.747 ± 0.052	0.445 ± 0.026	0.428 ± 0.046	0.132 ± 0.039	0.133 ± 0.038	0.025 ± 0.021	0.155 ± 0.026
	14 Apr 92	08 04	16	3.749 ± 0.052	0.440 ± 0.027	0.428 ± 0.046	0.128 ± 0.039	0.134 ± 0.038	0.025 ± 0.020	0.157 ± 0.027
076805	13 Apr 92	08 10	14	4.629 ± 0.018	0.286 ± 0.015	0.433 ± 0.015	0.178 ± 0.013	0.099 ± 0.015	0.038 ± 0.014	0.094 ± 0.016

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
076805	13 Apr 92	08 11	15	4.637 ± 0.016	0.287 ± 0.015	0.431 ± 0.014	0.171 ± 0.012	0.097 ± 0.013	0.035 ± 0.011	0.094 ± 0.013
077258	14 Apr 92	08 10	18	4.436 ± 0.063	0.601 ± 0.029	0.830 ± 0.053	0.838 ± 0.045	0.341 ± 0.042	0.211 ± 0.020	0.578 ± 0.031
	14 Apr 92	08 11	19	4.440 ± 0.063	0.602 ± 0.028	0.833 ± 0.053	0.837 ± 0.045	0.340 ± 0.042	0.212 ± 0.019	0.582 ± 0.031
	15 Apr 92	08 02	14	4.458 ± 0.020	0.618 ± 0.038	0.822 ± 0.017	0.839 ± 0.015	0.342 ± 0.022	0.209 ± 0.014	0.585 ± 0.014
	15 Apr 92	08 04	15	4.449 ± 0.020	0.607 ± 0.039	0.826 ± 0.017	0.839 ± 0.015	0.341 ± 0.022	0.219 ± 0.012	0.580 ± 0.012
	15 Apr 92	08 09	17	3.781 ± 0.023	0.655 ± 0.046	1.143 ± 0.021	1.553 ± 0.018	0.507 ± 0.027	0.356 ± 0.015	0.808 ± 0.016
078004	15 Apr 92	08 11	18	3.778 ± 0.024	0.657 ± 0.046	1.147 ± 0.020	1.548 ± 0.018	0.512 ± 0.027	0.353 ± 0.017	0.802 ± 0.016
	13 Apr 92	08 18	17	3.973 ± 0.018	0.600 ± 0.016	0.817 ± 0.017	0.463 ± 0.014	0.164 ± 0.017	0.081 ± 0.016	0.201 ± 0.015
078045	13 Apr 92	08 20	18	3.972 ± 0.018	0.608 ± 0.013	0.819 ± 0.015	0.461 ± 0.013	0.162 ± 0.016	0.083 ± 0.016	0.209 ± 0.016
079447	14 Apr 92	08 17	21	3.849 ± 0.051	0.285 ± 0.027	0.270 ± 0.046	0.069 ± 0.039	0.105 ± 0.037	0.018 ± 0.020	0.109 ± 0.026
	14 Apr 92	08 19	22	3.849 ± 0.051	0.285 ± 0.028	0.264 ± 0.046	0.074 ± 0.039	0.108 ± 0.037	0.011 ± 0.019	0.109 ± 0.026
079940	15 Apr 92	08 17	20	4.616 ± 0.019	0.660 ± 0.037	0.651 ± 0.017	0.643 ± 0.016	0.285 ± 0.021	0.170 ± 0.011	0.451 ± 0.016
	15 Apr 92	08 18	21	4.614 ± 0.020	0.655 ± 0.036	0.653 ± 0.017	0.645 ± 0.015	0.286 ± 0.021	0.164 ± 0.014	0.465 ± 0.015
082434	12 Apr 92	08 50	23	3.534 ± 0.027	0.575 ± 0.020	0.637 ± 0.016	0.571 ± 0.017	0.255 ± 0.020	0.148 ± 0.021	0.383 ± 0.019
083058	12 Apr 92	08 52	24	3.537 ± 0.026	0.568 ± 0.020	0.638 ± 0.017	0.570 ± 0.017	0.261 ± 0.020	0.145 ± 0.020	0.379 ± 0.018
	12 Apr 92	08 58	26	4.951 ± 0.024	0.149 ± 0.019	0.138 ± 0.015	0.116 ± 0.014	0.084 ± 0.012	0.021 ± 0.015	0.082 ± 0.019
083183	12 Apr 92	08 59	27	4.955 ± 0.024	0.149 ± 0.018	0.137 ± 0.016	0.123 ± 0.015	0.078 ± 0.013	0.023 ± 0.014	0.086 ± 0.018
	14 Apr 92	08 43	30	4.019 ± 0.053	0.422 ± 0.026	0.320 ± 0.046	0.175 ± 0.039	0.180 ± 0.038	0.066 ± 0.019	0.242 ± 0.027
083446	14 Apr 92	08 45	31	4.025 ± 0.053	0.429 ± 0.026	0.315 ± 0.046	0.178 ± 0.039	0.176 ± 0.037	0.061 ± 0.019	0.245 ± 0.027
	12 Apr 92	09 05	29	4.298 ± 0.024	0.625 ± 0.017	0.802 ± 0.014	0.478 ± 0.015	0.174 ± 0.014	0.090 ± 0.014	0.227 ± 0.017
083944	12 Apr 92	09 07	30	4.315 ± 0.025	0.630 ± 0.020	0.792 ± 0.018	0.476 ± 0.017	0.177 ± 0.014	0.089 ± 0.015	0.227 ± 0.018
	15 Apr 92	08 40	29	4.454 ± 0.018	0.517 ± 0.033	0.647 ± 0.016	0.238 ± 0.015	0.102 ± 0.020	0.052 ± 0.013	0.098 ± 0.012
085123	15 Apr 92	08 42	30	4.462 ± 0.018	0.512 ± 0.033	0.656 ± 0.015	0.227 ± 0.015	0.106 ± 0.020	0.042 ± 0.012	0.111 ± 0.012
	14 Apr 92	08 51	33	2.915 ± 0.057	1.134 ± 0.027	0.787 ± 0.051	0.395 ± 0.045	0.246 ± 0.048	0.125 ± 0.032	0.371 ± 0.030
085622	14 Apr 92	08 52	34	2.911 ± 0.057	1.137 ± 0.027	0.791 ± 0.050	0.397 ± 0.044	0.244 ± 0.048	0.125 ± 0.032	0.373 ± 0.030
	15 Apr 92	08 50	32	2.934 ± 0.021	1.158 ± 0.037	0.791 ± 0.022	0.413 ± 0.023	0.231 ± 0.034	0.137 ± 0.030	0.369 ± 0.017
086440	15 Apr 92	08 51	33	2.941 ± 0.020	1.153 ± 0.036	0.795 ± 0.022	0.412 ± 0.022	0.217 ± 0.034	0.149 ± 0.029	0.363 ± 0.015
	14 Apr 92	08 59	36	4.771 ± 0.083	0.636 ± 0.043	0.991 ± 0.065	1.481 ± 0.057	0.559 ± 0.053	0.271 ± 0.042	0.716 ± 0.070
086440	14 Apr 92	09 06	39	3.463 ± 0.053	0.390 ± 0.030	0.266 ± 0.048	0.117 ± 0.041	0.151 ± 0.040	0.036 ± 0.024	0.186 ± 0.027
	14 Apr 92	09 08	40	3.455 ± 0.052	0.392 ± 0.031	0.269 ± 0.048	0.115 ± 0.041	0.143 ± 0.040	0.049 ± 0.024	0.183 ± 0.027
	15 Apr 92	08 57	35	3.487 ± 0.018	0.398 ± 0.038	0.285 ± 0.024	0.156 ± 0.021	0.100 ± 0.027	0.070 ± 0.020	0.165 ± 0.014

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
086440	15 Apr 92	08 58	36	3.486 ± 0.018	0.398 ± 0.038	0.284 ± 0.024	0.150 ± 0.020	0.116 ± 0.026	0.057 ± 0.020	0.164 ± 0.013
086629	11 Apr 92	08 14	3	5.063 ± 0.047	0.620 ± 0.028	0.714 ± 0.037	0.548 ± 0.024	0.274 ± 0.015	0.136 ± 0.017	0.336 ± 0.035
	11 Apr 92	08 16	4	5.062 ± 0.047	0.620 ± 0.029	0.715 ± 0.037	0.554 ± 0.024	0.265 ± 0.015	0.136 ± 0.017	0.337 ± 0.036
	11 Apr 92	08 46	12	5.073 ± 0.047	0.618 ± 0.028	0.712 ± 0.037	0.546 ± 0.024	0.272 ± 0.015	0.135 ± 0.018	0.339 ± 0.035
	11 Apr 92	08 47	13	5.063 ± 0.046	0.618 ± 0.028	0.716 ± 0.037	0.557 ± 0.024	0.268 ± 0.015	0.134 ± 0.017	0.336 ± 0.035
	11 Apr 92	09 39	28	5.070 ± 0.046	0.626 ± 0.029	0.717 ± 0.037	0.543 ± 0.024	0.274 ± 0.015	0.135 ± 0.017	0.343 ± 0.035
	11 Apr 92	09 41	29	5.062 ± 0.047	0.622 ± 0.029	0.716 ± 0.038	0.552 ± 0.024	0.268 ± 0.015	0.139 ± 0.018	0.341 ± 0.035
	11 Apr 92	10 38	45	5.064 ± 0.047	0.618 ± 0.028	0.719 ± 0.037	0.555 ± 0.024	0.265 ± 0.016	0.133 ± 0.017	0.343 ± 0.035
	11 Apr 92	10 39	46	5.067 ± 0.047	0.619 ± 0.029	0.713 ± 0.037	0.551 ± 0.025	0.277 ± 0.017	0.126 ± 0.018	0.343 ± 0.036
	11 Apr 92	11 46	63	5.062 ± 0.047	0.618 ± 0.030	0.721 ± 0.037	0.548 ± 0.025	0.274 ± 0.016	0.132 ± 0.019	0.347 ± 0.036
	11 Apr 92	11 47	64	5.057 ± 0.047	0.621 ± 0.029	0.717 ± 0.038	0.545 ± 0.026	0.276 ± 0.017	0.136 ± 0.017	0.339 ± 0.036
	11 Apr 92	12 37	77	5.072 ± 0.047	0.631 ± 0.030	0.714 ± 0.038	0.544 ± 0.025	0.269 ± 0.017	0.138 ± 0.018	0.345 ± 0.036
	11 Apr 92	12 39	78	5.070 ± 0.047	0.627 ± 0.029	0.717 ± 0.038	0.543 ± 0.026	0.272 ± 0.017	0.136 ± 0.018	0.346 ± 0.036
	12 Apr 92	07 50	2	5.212 ± 0.028	0.586 ± 0.020	0.684 ± 0.015	0.537 ± 0.015	0.231 ± 0.017	0.121 ± 0.020	0.337 ± 0.021
	12 Apr 92	07 51	3	5.205 ± 0.027	0.593 ± 0.020	0.677 ± 0.015	0.532 ± 0.013	0.229 ± 0.011	0.134 ± 0.015	0.328 ± 0.019
	12 Apr 92	08 32	17	5.199 ± 0.026	0.584 ± 0.018	0.684 ± 0.015	0.540 ± 0.016	0.221 ± 0.012	0.132 ± 0.013	0.334 ± 0.018
	12 Apr 92	08 34	18	5.195 ± 0.026	0.590 ± 0.021	0.678 ± 0.015	0.535 ± 0.016	0.238 ± 0.014	0.124 ± 0.015	0.329 ± 0.019
	12 Apr 92	09 32	39	5.192 ± 0.026	0.581 ± 0.019	0.681 ± 0.014	0.533 ± 0.014	0.234 ± 0.012	0.122 ± 0.013	0.341 ± 0.018
	12 Apr 92	09 33	40	5.186 ± 0.026	0.587 ± 0.018	0.679 ± 0.014	0.529 ± 0.015	0.236 ± 0.012	0.129 ± 0.013	0.346 ± 0.019
	12 Apr 92	10 32	54	5.181 ± 0.028	0.596 ± 0.022	0.678 ± 0.018	0.533 ± 0.016	0.240 ± 0.013	0.122 ± 0.018	0.342 ± 0.020
	12 Apr 92	10 34	55	5.183 ± 0.027	0.600 ± 0.020	0.675 ± 0.017	0.527 ± 0.016	0.239 ± 0.013	0.122 ± 0.016	0.342 ± 0.019
	12 Apr 92	11 34	67	5.190 ± 0.027	0.591 ± 0.019	0.682 ± 0.015	0.533 ± 0.016	0.230 ± 0.015	0.123 ± 0.016	0.342 ± 0.020
	12 Apr 92	11 36	68	5.189 ± 0.027	0.589 ± 0.019	0.682 ± 0.017	0.528 ± 0.016	0.232 ± 0.014	0.129 ± 0.015	0.342 ± 0.019
	12 Apr 92	12 38	83	5.182 ± 0.028	0.599 ± 0.020	0.674 ± 0.016	0.531 ± 0.020	0.224 ± 0.019	0.134 ± 0.015	0.338 ± 0.020
	12 Apr 92	12 40	84	5.192 ± 0.028	0.586 ± 0.019	0.684 ± 0.015	0.524 ± 0.014	0.232 ± 0.016	0.122 ± 0.018	0.343 ± 0.022
	13 Apr 92	07 41	5	5.202 ± 0.019	0.568 ± 0.016	0.682 ± 0.014	0.526 ± 0.013	0.237 ± 0.014	0.130 ± 0.013	0.338 ± 0.015
	13 Apr 92	07 43	6	5.199 ± 0.019	0.571 ± 0.017	0.691 ± 0.014	0.515 ± 0.011	0.238 ± 0.013	0.134 ± 0.012	0.333 ± 0.014
	13 Apr 92	08 26	20	5.200 ± 0.019	0.582 ± 0.013	0.687 ± 0.014	0.516 ± 0.011	0.244 ± 0.013	0.134 ± 0.013	0.336 ± 0.014
	13 Apr 92	08 28	21	5.207 ± 0.020	0.566 ± 0.014	0.689 ± 0.014	0.523 ± 0.013	0.231 ± 0.014	0.132 ± 0.014	0.342 ± 0.018
	13 Apr 92	09 27	41	5.191 ± 0.017	0.571 ± 0.013	0.691 ± 0.015	0.516 ± 0.013	0.237 ± 0.013	0.128 ± 0.011	0.350 ± 0.012
	13 Apr 92	09 28	42	5.182 ± 0.019	0.568 ± 0.017	0.690 ± 0.015	0.520 ± 0.011	0.238 ± 0.014	0.136 ± 0.013	0.333 ± 0.014

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
086629	13 Apr 92	10 30	56	5.180 ± 0.020	0.570 ± 0.014	0.692 ± 0.016	0.517 ± 0.015	0.235 ± 0.014	0.133 ± 0.014	0.345 ± 0.015
	13 Apr 92	10 32	57	5.184 ± 0.018	0.566 ± 0.017	0.697 ± 0.013	0.516 ± 0.011	0.238 ± 0.012	0.124 ± 0.012	0.347 ± 0.015
	13 Apr 92	11 42	71	5.179 ± 0.019	0.577 ± 0.013	0.693 ± 0.014	0.522 ± 0.015	0.230 ± 0.015	0.136 ± 0.012	0.333 ± 0.016
	13 Apr 92	11 43	72	5.186 ± 0.020	0.582 ± 0.014	0.681 ± 0.014	0.524 ± 0.012	0.234 ± 0.013	0.125 ± 0.014	0.348 ± 0.016
	13 Apr 92	12 35	84	5.179 ± 0.019	0.568 ± 0.016	0.694 ± 0.015	0.525 ± 0.014	0.229 ± 0.017	0.150 ± 0.014	0.327 ± 0.017
	13 Apr 92	12 37	85	5.185 ± 0.019	0.574 ± 0.016	0.689 ± 0.016	0.526 ± 0.015	0.229 ± 0.016	0.131 ± 0.011	0.340 ± 0.014
	14 Apr 92	07 27	3	5.190 ± 0.056	0.596 ± 0.025	0.665 ± 0.048	0.509 ± 0.041	0.248 ± 0.038	0.115 ± 0.018	0.361 ± 0.028
	14 Apr 92	07 28	4	5.188 ± 0.056	0.584 ± 0.026	0.672 ± 0.048	0.504 ± 0.041	0.247 ± 0.038	0.121 ± 0.017	0.357 ± 0.028
	14 Apr 92	08 24	24	5.184 ± 0.057	0.589 ± 0.026	0.674 ± 0.048	0.499 ± 0.040	0.248 ± 0.038	0.122 ± 0.019	0.354 ± 0.029
	14 Apr 92	08 25	25	5.192 ± 0.056	0.586 ± 0.025	0.666 ± 0.048	0.503 ± 0.041	0.244 ± 0.038	0.123 ± 0.017	0.351 ± 0.028
	14 Apr 92	09 26	48	5.186 ± 0.057	0.590 ± 0.025	0.671 ± 0.047	0.505 ± 0.040	0.250 ± 0.038	0.116 ± 0.018	0.357 ± 0.029
	14 Apr 92	09 28	49	5.185 ± 0.057	0.587 ± 0.025	0.675 ± 0.048	0.502 ± 0.041	0.248 ± 0.038	0.119 ± 0.018	0.351 ± 0.029
	14 Apr 92	10 29	69	5.184 ± 0.056	0.591 ± 0.025	0.679 ± 0.048	0.505 ± 0.041	0.244 ± 0.038	0.110 ± 0.018	0.368 ± 0.029
	14 Apr 92	10 30	70	5.175 ± 0.057	0.589 ± 0.025	0.674 ± 0.048	0.504 ± 0.041	0.246 ± 0.038	0.122 ± 0.019	0.354 ± 0.030
	14 Apr 92	11 28	84	5.175 ± 0.056	0.589 ± 0.026	0.674 ± 0.048	0.510 ± 0.041	0.242 ± 0.038	0.121 ± 0.018	0.352 ± 0.029
	14 Apr 92	11 29	85	5.176 ± 0.056	0.592 ± 0.026	0.673 ± 0.048	0.505 ± 0.040	0.232 ± 0.038	0.129 ± 0.017	0.360 ± 0.029
	14 Apr 92	12 29	97	5.185 ± 0.056	0.608 ± 0.027	0.676 ± 0.048	0.494 ± 0.040	0.242 ± 0.038	0.128 ± 0.018	0.349 ± 0.029
	14 Apr 92	12 30	98	5.180 ± 0.057	0.594 ± 0.026	0.674 ± 0.048	0.502 ± 0.041	0.244 ± 0.039	0.124 ± 0.018	0.351 ± 0.029
	15 Apr 92	07 25	2	5.216 ± 0.019	0.598 ± 0.035	0.677 ± 0.016	0.522 ± 0.016	0.236 ± 0.021	0.121 ± 0.011	0.349 ± 0.012
	15 Apr 92	07 27	3	5.210 ± 0.021	0.587 ± 0.036	0.686 ± 0.016	0.524 ± 0.016	0.230 ± 0.020	0.123 ± 0.014	0.352 ± 0.016
	15 Apr 92	08 24	23	5.207 ± 0.019	0.599 ± 0.036	0.677 ± 0.016	0.533 ± 0.016	0.224 ± 0.020	0.129 ± 0.011	0.351 ± 0.013
	15 Apr 92	08 26	24	5.207 ± 0.018	0.594 ± 0.037	0.678 ± 0.018	0.529 ± 0.014	0.225 ± 0.021	0.135 ± 0.012	0.349 ± 0.013
	15 Apr 92	09 26	47	5.214 ± 0.019	0.595 ± 0.035	0.678 ± 0.014	0.519 ± 0.015	0.230 ± 0.021	0.121 ± 0.013	0.350 ± 0.014
	15 Apr 92	09 28	48	5.205 ± 0.019	0.593 ± 0.035	0.682 ± 0.015	0.523 ± 0.015	0.225 ± 0.021	0.130 ± 0.013	0.353 ± 0.014
	15 Apr 92	10 27	70	5.204 ± 0.019	0.595 ± 0.035	0.684 ± 0.016	0.523 ± 0.015	0.236 ± 0.020	0.120 ± 0.013	0.353 ± 0.014
	15 Apr 92	10 28	71	5.202 ± 0.019	0.595 ± 0.035	0.679 ± 0.016	0.518 ± 0.014	0.231 ± 0.020	0.130 ± 0.012	0.344 ± 0.013
	15 Apr 92	11 37	97	5.200 ± 0.019	0.597 ± 0.035	0.683 ± 0.015	0.523 ± 0.015	0.223 ± 0.022	0.130 ± 0.013	0.349 ± 0.013
	15 Apr 92	11 38	98	5.190 ± 0.019	0.597 ± 0.035	0.683 ± 0.016	0.521 ± 0.015	0.222 ± 0.020	0.138 ± 0.011	0.348 ± 0.012
	15 Apr 92	12 57	118	5.190 ± 0.021	0.599 ± 0.037	0.681 ± 0.020	0.527 ± 0.017	0.218 ± 0.021	0.137 ± 0.013	0.344 ± 0.014
	15 Apr 92	12 58	119	5.195 ± 0.020	0.602 ± 0.036	0.676 ± 0.016	0.520 ± 0.014	0.229 ± 0.021	0.130 ± 0.014	0.345 ± 0.015
	14 Feb 93	09 24	5	5.241 ± 0.036	0.536 ± 0.038	0.690 ± 0.015	0.537 ± 0.013	0.220 ± 0.016	0.130 ± 0.015	0.332 ± 0.019

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
086629	14 Feb 93	09 26	6	5.238 ± 0.036	0.529 ± 0.038	0.694 ± 0.014	0.530 ± 0.012	0.227 ± 0.019	0.130 ± 0.019	0.323 ± 0.022
	14 Feb 93	10 21	17	5.227 ± 0.035	0.544 ± 0.035	0.700 ± 0.014	0.532 ± 0.011	0.215 ± 0.016	0.141 ± 0.014	0.326 ± 0.019
	14 Feb 93	10 23	18	5.231 ± 0.035	0.552 ± 0.035	0.687 ± 0.014	0.535 ± 0.011	0.220 ± 0.015	0.137 ± 0.013	0.334 ± 0.019
	14 Feb 93	11 14	29	5.256 ± 0.035	0.539 ± 0.033	0.683 ± 0.014	0.535 ± 0.011	0.218 ± 0.015	0.135 ± 0.014	0.335 ± 0.018
	14 Feb 93	11 16	30	5.253 ± 0.034	0.531 ± 0.033	0.692 ± 0.014	0.536 ± 0.011	0.212 ± 0.014	0.141 ± 0.013	0.339 ± 0.017
	14 Feb 93	12 20	41	5.229 ± 0.035	0.519 ± 0.032	0.693 ± 0.014	0.526 ± 0.011	0.222 ± 0.016	0.143 ± 0.015	0.320 ± 0.017
	14 Feb 93	12 22	42	5.228 ± 0.035	0.516 ± 0.032	0.695 ± 0.013	0.525 ± 0.011	0.221 ± 0.015	0.145 ± 0.014	0.326 ± 0.018
	15 Feb 93	10 44	4	5.271 ± 0.043	0.519 ± 0.078	0.684 ± 0.038	0.518 ± 0.020	0.214 ± 0.019	0.128 ± 0.013	0.337 ± 0.010
	15 Feb 93	10 46	5	5.260 ± 0.043	0.491 ± 0.078	0.685 ± 0.039	0.518 ± 0.020	0.220 ± 0.019	0.131 ± 0.013	0.336 ± 0.011
	15 Feb 93	12 13	24	5.269 ± 0.042	0.519 ± 0.076	0.674 ± 0.038	0.527 ± 0.020	0.217 ± 0.019	0.126 ± 0.013	0.338 ± 0.011
	15 Feb 93	12 15	25	5.270 ± 0.041	0.514 ± 0.076	0.682 ± 0.038	0.522 ± 0.020	0.218 ± 0.018	0.125 ± 0.013	0.344 ± 0.010
	15 Feb 93	13 16	38	5.262 ± 0.041	0.457 ± 0.076	0.683 ± 0.038	0.520 ± 0.020	0.218 ± 0.019	0.128 ± 0.013	0.345 ± 0.011
	15 Feb 93	13 18	39	5.264 ± 0.041	0.477 ± 0.076	0.681 ± 0.038	0.524 ± 0.020	0.214 ± 0.018	0.131 ± 0.013	0.337 ± 0.010
	15 Feb 93	14 20	52	5.269 ± 0.042	0.510 ± 0.077	0.681 ± 0.038	0.523 ± 0.020	0.209 ± 0.019	0.135 ± 0.013	0.341 ± 0.013
	15 Feb 93	14 22	53	5.276 ± 0.042	0.520 ± 0.077	0.681 ± 0.038	0.517 ± 0.021	0.207 ± 0.019	0.135 ± 0.013	0.345 ± 0.011
	15 Feb 93	15 03	66	5.284 ± 0.043	0.545 ± 0.078	0.683 ± 0.038	0.519 ± 0.021	0.211 ± 0.020	0.132 ± 0.015	0.344 ± 0.015
	15 Feb 93	15 05	67	5.276 ± 0.043	0.552 ± 0.078	0.679 ± 0.038	0.526 ± 0.020	0.209 ± 0.019	0.138 ± 0.013	0.336 ± 0.011
	15 Feb 93	16 19	88	5.293 ± 0.046	0.535 ± 0.081	0.672 ± 0.038	0.526 ± 0.020	0.207 ± 0.019	0.135 ± 0.014	0.349 ± 0.013
	15 Feb 93	16 21	89	5.297 ± 0.046	0.525 ± 0.081	0.684 ± 0.039	0.520 ± 0.021	0.205 ± 0.020	0.132 ± 0.013	0.353 ± 0.012
	16 Feb 93	09 15	6	5.239 ± 0.033	0.564 ± 0.059	0.689 ± 0.014	0.528 ± 0.012	0.221 ± 0.012	0.124 ± 0.012	0.305 ± 0.026
	16 Feb 93	09 17	7	5.223 ± 0.033	0.566 ± 0.058	0.681 ± 0.015	0.538 ± 0.012	0.223 ± 0.016	0.125 ± 0.014	0.309 ± 0.027
	16 Feb 93	10 11	23	5.239 ± 0.030	0.502 ± 0.053	0.701 ± 0.014	0.525 ± 0.012	0.223 ± 0.012	0.128 ± 0.009	0.311 ± 0.024
	16 Feb 93	10 13	24	5.240 ± 0.030	0.516 ± 0.053	0.693 ± 0.015	0.528 ± 0.011	0.225 ± 0.012	0.121 ± 0.010	0.309 ± 0.024
	16 Feb 93	11 08	39	5.250 ± 0.029	0.614 ± 0.049	0.699 ± 0.014	0.526 ± 0.012	0.223 ± 0.011	0.125 ± 0.009	0.313 ± 0.025
	16 Feb 93	11 10	40	5.252 ± 0.029	0.640 ± 0.048	0.690 ± 0.013	0.534 ± 0.012	0.219 ± 0.013	0.127 ± 0.011	0.322 ± 0.026
	16 Feb 93	12 21	59	5.252 ± 0.028	0.597 ± 0.047	0.687 ± 0.013	0.528 ± 0.012	0.223 ± 0.012	0.128 ± 0.010	0.316 ± 0.025
	16 Feb 93	12 23	60	5.253 ± 0.028	0.588 ± 0.047	0.695 ± 0.013	0.524 ± 0.011	0.220 ± 0.014	0.132 ± 0.012	0.315 ± 0.024
	16 Feb 93	13 21	75	5.243 ± 0.029	0.520 ± 0.047	0.689 ± 0.013	0.536 ± 0.012	0.221 ± 0.013	0.128 ± 0.013	0.314 ± 0.025
	16 Feb 93	13 23	76	5.252 ± 0.028	0.495 ± 0.047	0.689 ± 0.013	0.530 ± 0.011	0.224 ± 0.011	0.122 ± 0.009	0.319 ± 0.024
	16 Feb 93	14 20	91	5.259 ± 0.028	0.539 ± 0.048	0.693 ± 0.013	0.528 ± 0.012	0.218 ± 0.013	0.125 ± 0.010	0.316 ± 0.024
	16 Feb 93	14 22	92	5.252 ± 0.029	0.560 ± 0.048	0.696 ± 0.014	0.528 ± 0.012	0.220 ± 0.012	0.125 ± 0.011	0.321 ± 0.025

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Table D.3 continued from previous page										
HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
086629	16 Feb 93	15 00	103	5.267 ± 0.029	0.589 ± 0.050	0.686 ± 0.014	0.536 ± 0.011	0.215 ± 0.012	0.133 ± 0.011	0.321 ± 0.025
	16 Feb 93	15 02	104	5.275 ± 0.030	0.628 ± 0.050	0.689 ± 0.014	0.531 ± 0.013	0.221 ± 0.013	0.121 ± 0.011	0.322 ± 0.025
	16 Feb 93	15 55	117	5.275 ± 0.032	0.549 ± 0.056	0.683 ± 0.017	0.536 ± 0.012	0.207 ± 0.014	0.132 ± 0.012	0.325 ± 0.028
	16 Feb 93	15 57	118	5.276 ± 0.032	0.550 ± 0.055	0.690 ± 0.014	0.529 ± 0.012	0.209 ± 0.013	0.130 ± 0.011	0.325 ± 0.025
	17 Feb 93	11 11	4	5.247 ± 0.034	0.529 ± 0.036	0.709 ± 0.020	0.509 ± 0.010	0.218 ± 0.014	0.126 ± 0.012	0.330 ± 0.018
	17 Feb 93	11 13	5	5.243 ± 0.033	0.548 ± 0.037	0.710 ± 0.020	0.512 ± 0.010	0.220 ± 0.012	0.131 ± 0.009	0.320 ± 0.017
	17 Feb 93	12 21	20	5.238 ± 0.033	0.548 ± 0.035	0.706 ± 0.020	0.517 ± 0.011	0.210 ± 0.014	0.132 ± 0.010	0.330 ± 0.017
	17 Feb 93	12 23	21	5.246 ± 0.032	0.540 ± 0.035	0.710 ± 0.019	0.514 ± 0.011	0.220 ± 0.013	0.122 ± 0.009	0.331 ± 0.016
	17 Feb 93	13 19	36	5.243 ± 0.033	0.495 ± 0.036	0.715 ± 0.019	0.510 ± 0.011	0.212 ± 0.013	0.128 ± 0.009	0.325 ± 0.017
	17 Feb 93	13 21	37	5.236 ± 0.033	0.492 ± 0.035	0.706 ± 0.019	0.513 ± 0.010	0.219 ± 0.012	0.133 ± 0.010	0.318 ± 0.017
	17 Feb 93	14 18	52	5.240 ± 0.033	0.525 ± 0.036	0.711 ± 0.020	0.510 ± 0.012	0.216 ± 0.013	0.130 ± 0.010	0.323 ± 0.017
	17 Feb 93	14 20	53	5.239 ± 0.034	0.569 ± 0.036	0.707 ± 0.020	0.509 ± 0.012	0.221 ± 0.013	0.128 ± 0.009	0.319 ± 0.017
	18 Feb 93	09 10	5	5.194 ± 0.036	0.536 ± 0.074	0.684 ± 0.015	0.538 ± 0.013	0.226 ± 0.014	0.126 ± 0.014	0.314 ± 0.024
	18 Feb 93	09 12	6	5.196 ± 0.034	0.539 ± 0.074	0.693 ± 0.015	0.532 ± 0.013	0.228 ± 0.017	0.126 ± 0.014	0.311 ± 0.024
	18 Feb 93	10 12	21	5.213 ± 0.031	0.557 ± 0.067	0.695 ± 0.014	0.522 ± 0.011	0.227 ± 0.013	0.127 ± 0.010	0.318 ± 0.022
	18 Feb 93	10 15	22	5.220 ± 0.032	0.496 ± 0.066	0.697 ± 0.015	0.525 ± 0.012	0.223 ± 0.013	0.126 ± 0.012	0.318 ± 0.022
	18 Feb 93	11 09	39	5.242 ± 0.030	0.472 ± 0.063	0.702 ± 0.015	0.518 ± 0.012	0.221 ± 0.016	0.126 ± 0.015	0.320 ± 0.022
	18 Feb 93	11 11	40	5.234 ± 0.030	0.478 ± 0.063	0.695 ± 0.017	0.526 ± 0.014	0.222 ± 0.015	0.130 ± 0.012	0.313 ± 0.021
	18 Feb 93	12 18	55	5.235 ± 0.029	0.561 ± 0.061	0.695 ± 0.015	0.524 ± 0.012	0.226 ± 0.013	0.120 ± 0.010	0.323 ± 0.022
	18 Feb 93	12 20	56	5.239 ± 0.028	0.521 ± 0.061	0.692 ± 0.015	0.531 ± 0.013	0.222 ± 0.013	0.121 ± 0.010	0.331 ± 0.021
	18 Feb 93	13 01	67	5.234 ± 0.029	0.609 ± 0.061	0.693 ± 0.014	0.525 ± 0.011	0.220 ± 0.013	0.128 ± 0.011	0.324 ± 0.022
	18 Feb 93	13 03	68	5.239 ± 0.029	0.623 ± 0.061	0.695 ± 0.015	0.522 ± 0.011	0.221 ± 0.013	0.128 ± 0.011	0.325 ± 0.021
	18 Feb 93	13 50	83	5.253 ± 0.029	0.590 ± 0.061	0.690 ± 0.014	0.530 ± 0.011	0.219 ± 0.013	0.121 ± 0.010	0.324 ± 0.021
	18 Feb 93	13 52	84	5.250 ± 0.029	0.591 ± 0.062	0.696 ± 0.015	0.526 ± 0.012	0.217 ± 0.013	0.124 ± 0.010	0.323 ± 0.021
18 Feb 93	15 01	105	5.248 ± 0.031	0.495 ± 0.065	0.687 ± 0.014	0.531 ± 0.012	0.219 ± 0.014	0.130 ± 0.012	0.324 ± 0.022	
18 Feb 93	15 03	106	5.255 ± 0.031	0.433 ± 0.066	0.701 ± 0.016	0.520 ± 0.013	0.214 ± 0.013	0.129 ± 0.010	0.334 ± 0.021	
18 Feb 93	16 01	121	5.258 ± 0.034	0.577 ± 0.072	0.695 ± 0.016	0.526 ± 0.012	0.217 ± 0.014	0.123 ± 0.012	0.332 ± 0.023	
18 Feb 93	16 03	122	5.257 ± 0.034	0.596 ± 0.072	0.685 ± 0.017	0.526 ± 0.012	0.214 ± 0.014	0.123 ± 0.011	0.328 ± 0.022	
088206	14 Apr 92	09 13	42	4.788 ± 0.052	0.318 ± 0.025	0.234 ± 0.044	0.096 ± 0.038	0.142 ± 0.036	0.029 ± 0.018	0.154 ± 0.027
	14 Apr 92	09 15	43	4.783 ± 0.052	0.326 ± 0.024	0.240 ± 0.044	0.094 ± 0.038	0.138 ± 0.036	0.031 ± 0.017	0.155 ± 0.027
	15 Apr 92	09 04	38	4.805 ± 0.019	0.324 ± 0.034	0.258 ± 0.018	0.129 ± 0.016	0.105 ± 0.021	0.047 ± 0.014	0.132 ± 0.015

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
088206	15 Apr 92	09 05	39	4.806 ± 0.018	0.338 ± 0.033	0.258 ± 0.016	0.130 ± 0.014	0.113 ± 0.019	0.038 ± 0.012	0.140 ± 0.013
	11 May 91	09 42	11	6.342 ± 0.037	0.391 ± 0.018	0.627 ± 0.020	0.766 ± 0.018	0.333 ± 0.016	0.166 ± 0.019	0.542 ± 0.024
	11 May 91	09 46	12	6.341 ± 0.038	0.391 ± 0.019	0.629 ± 0.021	0.762 ± 0.018	0.335 ± 0.015	0.175 ± 0.019	0.536 ± 0.024
	11 May 91	11 14	32	6.326 ± 0.037	0.399 ± 0.020	0.631 ± 0.021	0.772 ± 0.019	0.322 ± 0.017	0.190 ± 0.019	0.532 ± 0.022
	11 May 91	11 17	33	6.337 ± 0.037	0.392 ± 0.020	0.625 ± 0.023	0.779 ± 0.020	0.317 ± 0.016	0.182 ± 0.017	0.533 ± 0.021
	11 May 91	12 13	47	6.351 ± 0.038	0.393 ± 0.020	0.626 ± 0.024	0.768 ± 0.021	0.342 ± 0.019	0.161 ± 0.020	0.544 ± 0.024
	11 May 91	12 16	48	6.351 ± 0.038	0.413 ± 0.022	0.623 ± 0.024	0.759 ± 0.021	0.336 ± 0.022	0.172 ± 0.023	0.540 ± 0.024
	11 May 91	13 15	62	6.340 ± 0.041	0.382 ± 0.032	0.628 ± 0.039	0.768 ± 0.037	0.347 ± 0.031	0.169 ± 0.028	0.536 ± 0.024
	11 May 91	13 18	63	6.349 ± 0.047	0.400 ± 0.026	0.614 ± 0.037	0.795 ± 0.033	0.329 ± 0.028	0.165 ± 0.035	0.546 ± 0.034
	21 May 91	06 57	2	6.376 ± 0.019	0.427 ± 0.019	0.625 ± 0.019	0.778 ± 0.019	0.341 ± 0.020	0.186 ± 0.016	0.552 ± 0.013
	21 May 91	06 59	3	6.377 ± 0.020	0.430 ± 0.020	0.621 ± 0.019	0.788 ± 0.018	0.342 ± 0.018	0.183 ± 0.016	0.558 ± 0.015
	21 May 91	07 57	20	6.377 ± 0.019	0.444 ± 0.022	0.620 ± 0.019	0.783 ± 0.018	0.346 ± 0.019	0.181 ± 0.016	0.558 ± 0.017
	21 May 91	07 60	21	6.377 ± 0.020	0.431 ± 0.020	0.626 ± 0.020	0.781 ± 0.020	0.337 ± 0.020	0.184 ± 0.015	0.554 ± 0.014
	21 May 91	09 04	37	6.369 ± 0.022	0.431 ± 0.022	0.630 ± 0.021	0.774 ± 0.020	0.339 ± 0.019	0.185 ± 0.017	0.553 ± 0.017
	21 May 91	09 07	38	6.360 ± 0.020	0.427 ± 0.022	0.630 ± 0.020	0.783 ± 0.018	0.342 ± 0.020	0.184 ± 0.017	0.552 ± 0.014
	21 May 91	10 09	55	6.356 ± 0.022	0.413 ± 0.028	0.650 ± 0.026	0.767 ± 0.021	0.359 ± 0.022	0.181 ± 0.018	0.543 ± 0.018
088955	21 May 91	10 11	56	6.351 ± 0.027	0.428 ± 0.025	0.633 ± 0.022	0.785 ± 0.024	0.341 ± 0.025	0.183 ± 0.023	0.521 ± 0.028
	14 Apr 92	09 20	45	3.760 ± 0.053	0.632 ± 0.025	0.811 ± 0.046	0.326 ± 0.040	0.165 ± 0.039	0.056 ± 0.022	0.157 ± 0.028
	14 Apr 92	09 22	46	3.764 ± 0.053	0.634 ± 0.025	0.808 ± 0.046	0.327 ± 0.039	0.165 ± 0.038	0.050 ± 0.022	0.165 ± 0.027
	15 Apr 92	09 19	44	3.806 ± 0.018	0.638 ± 0.033	0.825 ± 0.017	0.357 ± 0.017	0.129 ± 0.023	0.070 ± 0.016	0.136 ± 0.012
	15 Apr 92	09 21	45	3.809 ± 0.019	0.637 ± 0.033	0.822 ± 0.018	0.352 ± 0.018	0.125 ± 0.024	0.071 ± 0.018	0.135 ± 0.014
095370	15 Apr 92	10 04	61	4.350 ± 0.018	0.716 ± 0.033	0.856 ± 0.017	0.395 ± 0.016	0.154 ± 0.020	0.077 ± 0.013	0.210 ± 0.013
	15 Apr 92	10 06	62	4.353 ± 0.018	0.729 ± 0.034	0.844 ± 0.015	0.394 ± 0.014	0.155 ± 0.020	0.082 ± 0.012	0.210 ± 0.014
	20 May 93	07 49	10	4.381 ± 0.013	0.683 ± 0.011	0.841 ± 0.013	0.402 ± 0.017	0.157 ± 0.016	0.087 ± 0.012	0.217 ± 0.009
	20 May 93	07 53	11	4.389 ± 0.014	0.684 ± 0.011	0.842 ± 0.013	0.400 ± 0.017	0.146 ± 0.016	0.093 ± 0.011	0.223 ± 0.010
	20 May 93	07 56	12	4.393 ± 0.014	0.685 ± 0.011	0.842 ± 0.013	0.400 ± 0.017	0.151 ± 0.016	0.084 ± 0.012	0.225 ± 0.010
	23 May 93	07 39	10	4.402 ± 0.017	0.677 ± 0.014	0.859 ± 0.014	0.399 ± 0.016	0.152 ± 0.017	0.083 ± 0.013	0.186 ± 0.011
	23 May 93	07 42	11	4.402 ± 0.017	0.676 ± 0.014	0.861 ± 0.014	0.395 ± 0.016	0.147 ± 0.018	0.087 ± 0.013	0.182 ± 0.011
	11 May 91	09 28	8	6.026 ± 0.035	0.440 ± 0.018	0.631 ± 0.019	0.702 ± 0.017	0.314 ± 0.015	0.159 ± 0.017	0.501 ± 0.021
	11 May 91	09 32	9	6.031 ± 0.035	0.445 ± 0.019	0.628 ± 0.020	0.703 ± 0.017	0.315 ± 0.014	0.157 ± 0.015	0.502 ± 0.021
095456	11 May 91	11 03	29	6.040 ± 0.035	0.443 ± 0.017	0.623 ± 0.019	0.705 ± 0.017	0.294 ± 0.015	0.175 ± 0.017	0.497 ± 0.021

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
095456	11 May 91	11 06	30	6.042 ± 0.035	0.444 ± 0.017	0.626 ± 0.021	0.710 ± 0.019	0.301 ± 0.015	0.166 ± 0.016	0.502 ± 0.021
	11 May 91	12 01	44	6.037 ± 0.036	0.447 ± 0.018	0.628 ± 0.021	0.700 ± 0.018	0.300 ± 0.017	0.180 ± 0.018	0.492 ± 0.021
	11 May 91	12 04	45	6.030 ± 0.036	0.451 ± 0.018	0.622 ± 0.021	0.706 ± 0.019	0.312 ± 0.019	0.168 ± 0.019	0.499 ± 0.022
	11 May 91	13 03	59	6.023 ± 0.039	0.443 ± 0.020	0.635 ± 0.026	0.693 ± 0.024	0.331 ± 0.021	0.155 ± 0.021	0.494 ± 0.029
	11 May 91	13 06	60	6.021 ± 0.038	0.445 ± 0.019	0.615 ± 0.024	0.716 ± 0.020	0.329 ± 0.020	0.159 ± 0.021	0.496 ± 0.022
	21 May 91	07 07	5	6.071 ± 0.020	0.480 ± 0.024	0.634 ± 0.021	0.721 ± 0.019	0.323 ± 0.020	0.164 ± 0.016	0.520 ± 0.016
	21 May 91	07 09	6	6.066 ± 0.019	0.472 ± 0.019	0.639 ± 0.018	0.721 ± 0.017	0.327 ± 0.018	0.163 ± 0.015	0.522 ± 0.014
	21 May 91	08 06	23	6.080 ± 0.020	0.485 ± 0.038	0.895 ± 0.038	0.429 ± 0.017	0.319 ± 0.018	0.167 ± 0.016	0.523 ± 0.013
	21 May 91	08 09	24	6.084 ± 0.020	0.475 ± 0.021	0.629 ± 0.020	0.720 ± 0.017	0.315 ± 0.019	0.170 ± 0.017	0.523 ± 0.014
	21 May 91	09 13	40	6.049 ± 0.020	0.472 ± 0.023	0.632 ± 0.022	0.717 ± 0.017	0.325 ± 0.019	0.172 ± 0.017	0.507 ± 0.013
096566	21 May 91	09 16	41	6.069 ± 0.021	0.476 ± 0.019	0.627 ± 0.018	0.717 ± 0.017	0.314 ± 0.022	0.168 ± 0.021	0.520 ± 0.015
	21 May 91	10 18	58	6.079 ± 0.021	0.494 ± 0.025	0.651 ± 0.020	0.722 ± 0.021	0.294 ± 0.027	0.173 ± 0.024	0.503 ± 0.023
	15 Apr 92	10 12	64	4.647 ± 0.022	0.604 ± 0.043	0.952 ± 0.018	1.285 ± 0.017	0.459 ± 0.024	0.300 ± 0.012	0.722 ± 0.014
	15 Apr 92	10 13	65	4.631 ± 0.023	0.607 ± 0.045	0.943 ± 0.020	1.292 ± 0.017	0.457 ± 0.024	0.304 ± 0.013	0.719 ± 0.015
	15 Apr 92	10 20	67	3.843 ± 0.018	0.309 ± 0.036	0.348 ± 0.020	0.134 ± 0.018	0.086 ± 0.023	0.036 ± 0.017	0.085 ± 0.012
	15 Apr 92	10 22	68	3.853 ± 0.018	0.313 ± 0.035	0.350 ± 0.021	0.131 ± 0.019	0.087 ± 0.023	0.028 ± 0.016	0.083 ± 0.012
	27 Feb 91	09 13	5	6.348 ± 0.024	0.522 ± 0.022	0.613 ± 0.015	0.635 ± 0.023	0.281 ± 0.015	0.159 ± 0.013	0.416 ± 0.016
	27 Feb 91	09 16	6	6.372 ± 0.024	0.526 ± 0.021	0.609 ± 0.015	0.635 ± 0.022	0.286 ± 0.015	0.136 ± 0.012	0.434 ± 0.016
	28 Feb 91	09 39	5	6.349 ± 0.018	0.513 ± 0.026	0.622 ± 0.024	0.620 ± 0.021	0.307 ± 0.028	0.115 ± 0.025	0.467 ± 0.034
	28 Feb 91	09 42	6	6.329 ± 0.018	0.507 ± 0.027	0.620 ± 0.025	0.619 ± 0.024	0.301 ± 0.030	0.140 ± 0.026	0.460 ± 0.027
100953	28 Feb 91	10 39	20	6.357 ± 0.016	0.517 ± 0.025	0.621 ± 0.022	0.624 ± 0.018	0.291 ± 0.026	0.146 ± 0.023	0.460 ± 0.024
	28 Feb 91	10 42	21	6.355 ± 0.017	0.518 ± 0.025	0.616 ± 0.023	0.624 ± 0.019	0.297 ± 0.026	0.141 ± 0.024	0.454 ± 0.025
	28 Feb 91	14 07	62	6.334 ± 0.014	0.512 ± 0.025	0.622 ± 0.022	0.630 ± 0.020	0.297 ± 0.025	0.135 ± 0.021	0.458 ± 0.025
	28 Feb 91	14 10	63	6.338 ± 0.014	0.513 ± 0.025	0.622 ± 0.022	0.629 ± 0.018	0.293 ± 0.025	0.141 ± 0.022	0.462 ± 0.023
	28 Feb 91	15 13	79	6.344 ± 0.013	0.516 ± 0.025	0.606 ± 0.022	0.643 ± 0.017	0.266 ± 0.025	0.155 ± 0.022	0.459 ± 0.024
	28 Feb 91	15 16	80	6.342 ± 0.013	0.522 ± 0.025	0.616 ± 0.022	0.634 ± 0.020	0.266 ± 0.026	0.156 ± 0.022	0.452 ± 0.023
	15 Apr 92	10 43	76	4.658 ± 0.017	0.658 ± 0.033	0.636 ± 0.016	0.197 ± 0.014	0.106 ± 0.019	0.057 ± 0.011	0.130 ± 0.012
	15 Apr 92	10 45	77	4.659 ± 0.018	0.651 ± 0.033	0.641 ± 0.015	0.200 ± 0.015	0.108 ± 0.020	0.051 ± 0.013	0.128 ± 0.013
	15 Apr 92	10 51	79	4.260 ± 0.018	0.291 ± 0.034	0.305 ± 0.017	0.126 ± 0.017	0.095 ± 0.021	0.028 ± 0.013	0.141 ± 0.014
	15 Apr 92	10 52	80	4.271 ± 0.018	0.291 ± 0.034	0.309 ± 0.017	0.128 ± 0.017	0.088 ± 0.022	0.026 ± 0.014	0.148 ± 0.012
102964	15 Apr 92	10 58	82	4.514 ± 0.024	0.696 ± 0.048	1.244 ± 0.022	1.714 ± 0.020	0.523 ± 0.026	0.403 ± 0.012	0.873 ± 0.015

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
102964	15 Apr 92	10 60	83	4.512 ± 0.024	0.704 ± 0.048	1.250 ± 0.021	1.705 ± 0.020	0.523 ± 0.027	0.401 ± 0.014	0.868 ± 0.015
103026	06 Feb 92	12 13	40	5.899 ± 0.037	0.484 ± 0.024	0.598 ± 0.024	0.721 ± 0.015	0.314 ± 0.023	0.175 ± 0.056	0.516 ± 0.022
	06 Feb 92	12 15	41	5.884 ± 0.036	0.479 ± 0.025	0.596 ± 0.026	0.722 ± 0.016	0.315 ± 0.023	0.186 ± 0.055	0.512 ± 0.018
	06 Feb 92	13 01	55	5.877 ± 0.033	0.486 ± 0.024	0.596 ± 0.025	0.722 ± 0.017	0.300 ± 0.021	0.200 ± 0.051	0.516 ± 0.019
	06 Feb 92	13 03	56	5.869 ± 0.033	0.486 ± 0.025	0.588 ± 0.022	0.718 ± 0.014	0.306 ± 0.023	0.205 ± 0.051	0.508 ± 0.017
	06 Feb 92	14 08	75	5.869 ± 0.031	0.482 ± 0.024	0.592 ± 0.022	0.719 ± 0.013	0.294 ± 0.020	0.213 ± 0.048	0.519 ± 0.016
	06 Feb 92	14 10	76	5.855 ± 0.031	0.483 ± 0.023	0.589 ± 0.023	0.719 ± 0.014	0.291 ± 0.021	0.224 ± 0.048	0.514 ± 0.016
	06 Feb 92	15 24	91	5.835 ± 0.031	0.479 ± 0.024	0.587 ± 0.022	0.713 ± 0.013	0.283 ± 0.020	0.247 ± 0.047	0.494 ± 0.017
	06 Feb 92	15 27	92	5.833 ± 0.030	0.490 ± 0.025	0.584 ± 0.022	0.713 ± 0.011	0.286 ± 0.020	0.248 ± 0.047	0.494 ± 0.017
	06 Feb 92	16 01	102	5.821 ± 0.031	0.474 ± 0.025	0.590 ± 0.022	0.711 ± 0.013	0.277 ± 0.022	0.256 ± 0.048	0.507 ± 0.017
	06 Feb 92	16 03	103	5.820 ± 0.030	0.476 ± 0.023	0.581 ± 0.022	0.718 ± 0.012	0.286 ± 0.020	0.251 ± 0.047	0.499 ± 0.016
	09 Feb 92	12 23	39	5.895 ± 0.034	0.492 ± 0.026	0.595 ± 0.021	0.724 ± 0.017	0.317 ± 0.022	0.178 ± 0.049	0.517 ± 0.021
	09 Feb 92	12 26	40	5.906 ± 0.032	0.478 ± 0.033	0.597 ± 0.021	0.722 ± 0.015	0.327 ± 0.021	0.162 ± 0.047	0.538 ± 0.023
	09 Feb 92	13 18	54	5.888 ± 0.031	0.477 ± 0.028	0.586 ± 0.025	0.731 ± 0.018	0.309 ± 0.019	0.192 ± 0.044	0.522 ± 0.020
	09 Feb 92	13 20	55	5.886 ± 0.030	0.472 ± 0.027	0.591 ± 0.021	0.729 ± 0.015	0.313 ± 0.019	0.188 ± 0.044	0.524 ± 0.017
	09 Feb 92	14 09	70	5.888 ± 0.030	0.470 ± 0.025	0.590 ± 0.021	0.725 ± 0.016	0.301 ± 0.019	0.202 ± 0.043	0.527 ± 0.021
	09 Feb 92	14 10	71	5.877 ± 0.027	0.475 ± 0.025	0.593 ± 0.020	0.732 ± 0.016	0.310 ± 0.018	0.198 ± 0.041	0.522 ± 0.016
	09 Feb 92	15 26	90	5.855 ± 0.027	0.474 ± 0.027	0.594 ± 0.020	0.718 ± 0.014	0.293 ± 0.017	0.227 ± 0.040	0.510 ± 0.016
	09 Feb 92	15 28	91	5.858 ± 0.028	0.472 ± 0.025	0.585 ± 0.019	0.719 ± 0.014	0.298 ± 0.018	0.220 ± 0.041	0.524 ± 0.018
	09 Feb 92	16 13	103	5.841 ± 0.027	0.468 ± 0.024	0.587 ± 0.019	0.713 ± 0.014	0.304 ± 0.017	0.228 ± 0.041	0.515 ± 0.014
	09 Feb 92	16 15	104	5.842 ± 0.028	0.470 ± 0.026	0.588 ± 0.021	0.715 ± 0.016	0.295 ± 0.019	0.233 ± 0.042	0.511 ± 0.017
	10 Feb 92	12 18	52	5.900 ± 0.032	0.462 ± 0.039	0.583 ± 0.031	0.716 ± 0.020	0.309 ± 0.023	0.172 ± 0.051	0.519 ± 0.016
	10 Feb 92	12 21	53	5.890 ± 0.032	0.459 ± 0.039	0.593 ± 0.033	0.706 ± 0.020	0.314 ± 0.022	0.180 ± 0.052	0.503 ± 0.017
	10 Feb 92	13 09	63	5.897 ± 0.030	0.447 ± 0.044	0.599 ± 0.034	0.706 ± 0.018	0.301 ± 0.021	0.194 ± 0.049	0.516 ± 0.018
	10 Feb 92	13 11	64	5.884 ± 0.032	0.462 ± 0.039	0.580 ± 0.031	0.711 ± 0.020	0.307 ± 0.021	0.191 ± 0.050	0.520 ± 0.021
	10 Feb 92	14 09	80	5.881 ± 0.028	0.463 ± 0.038	0.575 ± 0.031	0.710 ± 0.018	0.297 ± 0.019	0.214 ± 0.047	0.511 ± 0.017
	10 Feb 92	14 11	81	5.883 ± 0.028	0.451 ± 0.039	0.581 ± 0.031	0.709 ± 0.018	0.298 ± 0.020	0.208 ± 0.047	0.515 ± 0.015
	10 Feb 92	15 16	98	5.866 ± 0.028	0.464 ± 0.039	0.578 ± 0.032	0.700 ± 0.018	0.295 ± 0.019	0.232 ± 0.046	0.505 ± 0.014
	10 Feb 92	15 18	99	5.865 ± 0.028	0.450 ± 0.039	0.581 ± 0.032	0.706 ± 0.019	0.287 ± 0.020	0.236 ± 0.046	0.500 ± 0.014
	10 Feb 92	15 55	110	5.838 ± 0.029	0.462 ± 0.040	0.574 ± 0.034	0.702 ± 0.021	0.284 ± 0.020	0.246 ± 0.047	0.502 ± 0.016
	10 Feb 92	15 57	111	5.849 ± 0.029	0.450 ± 0.038	0.585 ± 0.030	0.702 ± 0.017	0.275 ± 0.020	0.242 ± 0.047	0.506 ± 0.017

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
103026	10 Feb 92	16 38	121	5.839 ± 0.030	0.466 ± 0.039	0.563 ± 0.041	0.721 ± 0.032	0.276 ± 0.021	0.261 ± 0.048	0.497 ± 0.017
	10 Feb 92	16 40	122	5.852 ± 0.030	0.453 ± 0.038	0.575 ± 0.032	0.683 ± 0.019	0.287 ± 0.020	0.261 ± 0.049	0.502 ± 0.018
105211	15 Apr 92	11 06	85	4.145 ± 0.020	0.571 ± 0.035	0.648 ± 0.016	0.544 ± 0.015	0.245 ± 0.023	0.143 ± 0.017	0.380 ± 0.015
	15 Apr 92	11 08	86	4.147 ± 0.020	0.578 ± 0.036	0.644 ± 0.017	0.551 ± 0.015	0.243 ± 0.022	0.138 ± 0.015	0.372 ± 0.013
105452	21 May 91	09 59	52	4.053 ± 0.028	0.503 ± 0.017	0.668 ± 0.018	0.524 ± 0.018	0.281 ± 0.021	0.038 ± 0.028	0.377 ± 0.030
	21 May 91	10 02	53	3.991 ± 0.020	0.500 ± 0.022	0.670 ± 0.021	0.548 ± 0.018	0.290 ± 0.023	0.080 ± 0.022	0.379 ± 0.016
105937	15 Apr 92	11 14	88	3.923 ± 0.017	0.287 ± 0.035	0.338 ± 0.020	0.145 ± 0.017	0.072 ± 0.022	0.043 ± 0.015	0.076 ± 0.012
	15 Apr 92	11 15	89	3.921 ± 0.018	0.278 ± 0.035	0.346 ± 0.020	0.132 ± 0.017	0.077 ± 0.022	0.034 ± 0.016	0.076 ± 0.012
107079	15 Apr 92	11 21	91	5.049 ± 0.026	0.829 ± 0.058	1.462 ± 0.026	2.115 ± 0.022	0.569 ± 0.028	0.552 ± 0.013	1.082 ± 0.017
	15 Apr 92	11 23	92	5.056 ± 0.026	0.834 ± 0.058	1.460 ± 0.026	2.122 ± 0.024	0.570 ± 0.028	0.545 ± 0.012	1.090 ± 0.017
108483	15 Apr 92	11 29	94	3.908 ± 0.019	0.207 ± 0.037	0.222 ± 0.021	0.083 ± 0.018	0.065 ± 0.023	0.021 ± 0.018	0.054 ± 0.017
	15 Apr 92	11 31	95	3.926 ± 0.022	0.209 ± 0.039	0.262 ± 0.025	0.083 ± 0.026	0.085 ± 0.029	0.031 ± 0.023	0.074 ± 0.020
111915	15 Apr 92	11 56	103	4.376 ± 0.025	0.687 ± 0.049	1.323 ± 0.023	1.813 ± 0.020	0.514 ± 0.027	0.446 ± 0.015	0.917 ± 0.016
	15 Apr 92	11 58	104	4.379 ± 0.025	0.709 ± 0.049	1.301 ± 0.023	1.820 ± 0.019	0.510 ± 0.026	0.446 ± 0.014	0.923 ± 0.016
	10 Feb 92	16 08	113	4.320 ± 0.031	0.738 ± 0.054	1.266 ± 0.042	1.806 ± 0.024	0.505 ± 0.024	0.489 ± 0.056	0.919 ± 0.017
	10 Feb 92	16 10	114	4.321 ± 0.031	0.741 ± 0.054	1.272 ± 0.043	1.803 ± 0.024	0.501 ± 0.024	0.494 ± 0.056	0.916 ± 0.017
111968	10 Feb 92	16 17	115	4.270 ± 0.027	0.600 ± 0.034	0.815 ± 0.028	0.447 ± 0.017	0.162 ± 0.020	0.161 ± 0.044	0.281 ± 0.016
	10 Feb 92	16 19	116	4.269 ± 0.027	0.606 ± 0.034	0.815 ± 0.028	0.449 ± 0.018	0.153 ± 0.021	0.164 ± 0.044	0.284 ± 0.015
113703	15 Apr 92	12 13	109	4.664 ± 0.017	0.298 ± 0.033	0.374 ± 0.017	0.147 ± 0.015	0.076 ± 0.019	0.047 ± 0.011	0.090 ± 0.012
	15 Apr 92	12 14	110	4.664 ± 0.018	0.299 ± 0.033	0.378 ± 0.016	0.144 ± 0.015	0.091 ± 0.019	0.032 ± 0.013	0.091 ± 0.013
114435	11 Apr 92	08 30	6	5.697 ± 0.050	0.646 ± 0.032	0.687 ± 0.040	0.731 ± 0.027	0.338 ± 0.016	0.181 ± 0.018	0.479 ± 0.039
	11 Apr 92	08 31	7	5.684 ± 0.050	0.653 ± 0.031	0.683 ± 0.040	0.725 ± 0.027	0.341 ± 0.017	0.186 ± 0.018	0.474 ± 0.039
114613	11 Apr 92	08 38	9	4.787 ± 0.052	0.514 ± 0.032	0.734 ± 0.041	0.913 ± 0.027	0.387 ± 0.018	0.228 ± 0.020	0.588 ± 0.040
	11 Apr 92	08 40	10	4.774 ± 0.052	0.522 ± 0.033	0.730 ± 0.042	0.918 ± 0.029	0.389 ± 0.019	0.229 ± 0.020	0.587 ± 0.039
	11 Apr 92	09 48	31	4.771 ± 0.052	0.524 ± 0.032	0.723 ± 0.042	0.926 ± 0.027	0.382 ± 0.018	0.241 ± 0.020	0.579 ± 0.040
	11 Apr 92	09 50	32	4.784 ± 0.052	0.522 ± 0.033	0.726 ± 0.041	0.921 ± 0.027	0.384 ± 0.018	0.227 ± 0.020	0.587 ± 0.039
	11 Apr 92	10 45	48	4.769 ± 0.051	0.524 ± 0.032	0.730 ± 0.042	0.925 ± 0.027	0.387 ± 0.017	0.224 ± 0.018	0.590 ± 0.039
	11 Apr 92	10 47	49	4.768 ± 0.051	0.521 ± 0.032	0.732 ± 0.042	0.913 ± 0.027	0.382 ± 0.017	0.234 ± 0.018	0.585 ± 0.039
	11 Apr 92	11 53	66	4.757 ± 0.051	0.519 ± 0.032	0.734 ± 0.041	0.923 ± 0.026	0.380 ± 0.017	0.236 ± 0.019	0.582 ± 0.039
	11 Apr 92	11 55	67	4.761 ± 0.051	0.517 ± 0.032	0.728 ± 0.041	0.924 ± 0.026	0.375 ± 0.017	0.243 ± 0.019	0.581 ± 0.039
	11 Apr 92	12 44	80	4.754 ± 0.051	0.522 ± 0.033	0.731 ± 0.042	0.925 ± 0.027	0.380 ± 0.017	0.235 ± 0.019	0.583 ± 0.039

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
114613	11 Apr 92	12 45	81	4.758 ± 0.051	0.523 ± 0.032	0.732 ± 0.041	0.921 ± 0.027	0.379 ± 0.017	0.242 ± 0.019	0.577 ± 0.039
	11 Apr 92	13 12	90	4.742 ± 0.051	0.521 ± 0.031	0.729 ± 0.041	0.928 ± 0.027	0.374 ± 0.017	0.244 ± 0.019	0.574 ± 0.039
	11 Apr 92	13 13	91	4.746 ± 0.051	0.518 ± 0.032	0.731 ± 0.042	0.927 ± 0.028	0.378 ± 0.018	0.240 ± 0.018	0.580 ± 0.039
	11 Apr 92	14 12	107	4.763 ± 0.051	0.512 ± 0.031	0.742 ± 0.041	0.913 ± 0.027	0.387 ± 0.016	0.236 ± 0.019	0.589 ± 0.039
	11 Apr 92	14 14	108	4.757 ± 0.051	0.522 ± 0.032	0.736 ± 0.041	0.914 ± 0.027	0.382 ± 0.017	0.237 ± 0.019	0.585 ± 0.039
	11 Apr 92	14 26	113	4.751 ± 0.051	0.521 ± 0.032	0.732 ± 0.041	0.923 ± 0.027	0.379 ± 0.017	0.236 ± 0.018	0.584 ± 0.038
	11 Apr 92	14 28	114	4.755 ± 0.051	0.512 ± 0.033	0.736 ± 0.042	0.915 ± 0.027	0.387 ± 0.018	0.235 ± 0.019	0.586 ± 0.039
	11 Apr 92	15 00	124	4.760 ± 0.051	0.520 ± 0.032	0.732 ± 0.042	0.915 ± 0.028	0.383 ± 0.017	0.234 ± 0.019	0.597 ± 0.039
	11 Apr 92	15 02	125	4.763 ± 0.051	0.527 ± 0.031	0.728 ± 0.041	0.917 ± 0.026	0.379 ± 0.017	0.238 ± 0.019	0.594 ± 0.039
	12 Apr 92	07 58	5	4.864 ± 0.033	0.493 ± 0.024	0.709 ± 0.019	0.900 ± 0.018	0.360 ± 0.018	0.237 ± 0.020	0.587 ± 0.025
	12 Apr 92	07 60	6	4.860 ± 0.033	0.503 ± 0.027	0.695 ± 0.023	0.916 ± 0.022	0.364 ± 0.019	0.227 ± 0.019	0.583 ± 0.025
	12 Apr 92	08 40	20	4.860 ± 0.031	0.504 ± 0.022	0.698 ± 0.018	0.900 ± 0.020	0.361 ± 0.020	0.234 ± 0.018	0.583 ± 0.023
	12 Apr 92	08 42	21	4.857 ± 0.032	0.502 ± 0.025	0.701 ± 0.021	0.896 ± 0.017	0.365 ± 0.014	0.234 ± 0.018	0.583 ± 0.023
	12 Apr 92	09 39	42	4.842 ± 0.031	0.495 ± 0.024	0.717 ± 0.017	0.901 ± 0.018	0.360 ± 0.016	0.232 ± 0.017	0.587 ± 0.021
	12 Apr 92	09 41	43	4.849 ± 0.034	0.498 ± 0.024	0.702 ± 0.017	0.904 ± 0.020	0.362 ± 0.021	0.228 ± 0.024	0.591 ± 0.026
	12 Apr 92	10 40	57	4.854 ± 0.030	0.502 ± 0.021	0.703 ± 0.016	0.909 ± 0.016	0.364 ± 0.014	0.227 ± 0.015	0.576 ± 0.020
	12 Apr 92	10 42	58	4.855 ± 0.031	0.502 ± 0.022	0.707 ± 0.017	0.909 ± 0.017	0.365 ± 0.015	0.229 ± 0.016	0.586 ± 0.020
	12 Apr 92	11 42	70	4.844 ± 0.030	0.502 ± 0.022	0.704 ± 0.016	0.906 ± 0.018	0.356 ± 0.015	0.236 ± 0.014	0.572 ± 0.019
	12 Apr 92	11 44	71	4.840 ± 0.030	0.507 ± 0.021	0.708 ± 0.015	0.900 ± 0.015	0.355 ± 0.014	0.239 ± 0.015	0.581 ± 0.019
	12 Apr 92	12 45	86	4.829 ± 0.030	0.506 ± 0.020	0.711 ± 0.015	0.905 ± 0.016	0.352 ± 0.013	0.232 ± 0.015	0.586 ± 0.021
	12 Apr 92	12 47	87	4.830 ± 0.030	0.507 ± 0.022	0.699 ± 0.017	0.909 ± 0.017	0.361 ± 0.013	0.230 ± 0.015	0.579 ± 0.019
	12 Apr 92	14 12	104	4.831 ± 0.030	0.510 ± 0.023	0.704 ± 0.015	0.905 ± 0.018	0.356 ± 0.015	0.237 ± 0.015	0.587 ± 0.020
	12 Apr 92	14 14	105	4.823 ± 0.031	0.505 ± 0.021	0.708 ± 0.016	0.906 ± 0.018	0.361 ± 0.015	0.232 ± 0.018	0.587 ± 0.025
	12 Apr 92	15 15	120	4.875 ± 0.035	0.519 ± 0.027	0.735 ± 0.020	0.899 ± 0.019	0.376 ± 0.017	0.210 ± 0.025	0.605 ± 0.031
	12 Apr 92	15 16	121	4.874 ± 0.035	0.476 ± 0.032	0.677 ± 0.026	0.908 ± 0.034	0.376 ± 0.039	0.272 ± 0.032	0.501 ± 0.044
	12 Apr 92	15 58	133	4.838 ± 0.031	0.517 ± 0.021	0.711 ± 0.016	0.900 ± 0.017	0.352 ± 0.017	0.231 ± 0.017	0.595 ± 0.022
	12 Apr 92	16 00	134	4.845 ± 0.031	0.522 ± 0.024	0.699 ± 0.021	0.901 ± 0.020	0.358 ± 0.015	0.226 ± 0.016	0.594 ± 0.021
	13 Apr 92	07 49	8	4.834 ± 0.023	0.500 ± 0.026	0.715 ± 0.023	0.904 ± 0.022	0.357 ± 0.021	0.227 ± 0.017	0.587 ± 0.019
	13 Apr 92	07 51	9	4.826 ± 0.023	0.495 ± 0.019	0.720 ± 0.015	0.898 ± 0.015	0.357 ± 0.016	0.240 ± 0.015	0.578 ± 0.019
	13 Apr 92	08 34	23	4.841 ± 0.022	0.501 ± 0.017	0.718 ± 0.018	0.899 ± 0.015	0.364 ± 0.015	0.234 ± 0.014	0.580 ± 0.017
	13 Apr 92	08 36	24	4.841 ± 0.022	0.485 ± 0.027	0.721 ± 0.022	0.893 ± 0.015	0.364 ± 0.020	0.234 ± 0.016	0.573 ± 0.018

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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
114613	14 Apr 92	15 46	155	4.848 ± 0.063	0.496 ± 0.030	0.708 ± 0.054	0.910 ± 0.046	0.355 ± 0.043	0.226 ± 0.020	0.587 ± 0.032
	15 Apr 92	07 34	5	4.848 ± 0.023	0.497 ± 0.039	0.711 ± 0.019	0.893 ± 0.019	0.356 ± 0.024	0.233 ± 0.015	0.580 ± 0.016
	15 Apr 92	07 35	6	4.847 ± 0.024	0.506 ± 0.041	0.707 ± 0.018	0.902 ± 0.018	0.342 ± 0.024	0.235 ± 0.017	0.592 ± 0.019
	15 Apr 92	08 31	26	4.848 ± 0.022	0.506 ± 0.040	0.698 ± 0.019	0.919 ± 0.020	0.340 ± 0.025	0.234 ± 0.014	0.596 ± 0.016
	15 Apr 92	08 32	27	4.857 ± 0.023	0.493 ± 0.041	0.703 ± 0.023	0.911 ± 0.019	0.348 ± 0.024	0.230 ± 0.017	0.591 ± 0.018
	15 Apr 92	09 33	50	4.848 ± 0.023	0.500 ± 0.039	0.712 ± 0.020	0.906 ± 0.019	0.354 ± 0.022	0.228 ± 0.014	0.596 ± 0.016
	15 Apr 92	09 34	51	4.849 ± 0.021	0.498 ± 0.039	0.708 ± 0.018	0.909 ± 0.017	0.351 ± 0.022	0.231 ± 0.012	0.596 ± 0.013
	15 Apr 92	10 33	73	4.868 ± 0.021	0.498 ± 0.039	0.709 ± 0.018	0.903 ± 0.016	0.351 ± 0.022	0.224 ± 0.012	0.596 ± 0.014
	15 Apr 92	10 34	74	4.875 ± 0.021	0.493 ± 0.039	0.714 ± 0.018	0.901 ± 0.015	0.359 ± 0.021	0.216 ± 0.013	0.597 ± 0.015
	15 Apr 92	11 43	100	4.857 ± 0.020	0.498 ± 0.039	0.699 ± 0.017	0.913 ± 0.015	0.348 ± 0.021	0.239 ± 0.011	0.579 ± 0.013
	15 Apr 92	11 45	101	4.864 ± 0.021	0.503 ± 0.039	0.713 ± 0.018	0.899 ± 0.015	0.351 ± 0.023	0.230 ± 0.013	0.590 ± 0.014
	15 Apr 92	13 08	121	4.858 ± 0.020	0.503 ± 0.040	0.708 ± 0.018	0.905 ± 0.016	0.349 ± 0.022	0.232 ± 0.012	0.593 ± 0.013
	15 Apr 92	13 10	122	4.852 ± 0.020	0.503 ± 0.039	0.704 ± 0.018	0.905 ± 0.017	0.349 ± 0.021	0.233 ± 0.012	0.594 ± 0.013
	15 Apr 92	14 01	138	4.838 ± 0.021	0.499 ± 0.038	0.717 ± 0.017	0.903 ± 0.016	0.352 ± 0.022	0.235 ± 0.013	0.592 ± 0.014
	15 Apr 92	14 02	139	4.847 ± 0.022	0.505 ± 0.039	0.712 ± 0.017	0.899 ± 0.018	0.355 ± 0.024	0.227 ± 0.015	0.600 ± 0.016
	15 Apr 92	14 58	156	4.852 ± 0.022	0.507 ± 0.040	0.706 ± 0.018	0.915 ± 0.017	0.351 ± 0.023	0.230 ± 0.015	0.599 ± 0.015
	15 Apr 92	14 60	157	4.852 ± 0.021	0.505 ± 0.039	0.707 ± 0.017	0.906 ± 0.016	0.354 ± 0.022	0.227 ± 0.013	0.598 ± 0.015
	15 Apr 92	15 56	174	4.862 ± 0.022	0.510 ± 0.039	0.712 ± 0.019	0.907 ± 0.017	0.345 ± 0.023	0.236 ± 0.014	0.597 ± 0.017
	15 Apr 92	15 58	175	4.855 ± 0.023	0.507 ± 0.039	0.712 ± 0.018	0.900 ± 0.019	0.354 ± 0.023	0.235 ± 0.014	0.592 ± 0.016
120987	14 Feb 93	12 27	43	5.576 ± 0.040	0.490 ± 0.044	0.573 ± 0.015	0.622 ± 0.013	0.279 ± 0.017	0.165 ± 0.015	0.447 ± 0.023
	14 Feb 93	12 29	44	5.573 ± 0.040	0.503 ± 0.045	0.571 ± 0.017	0.627 ± 0.013	0.282 ± 0.016	0.164 ± 0.016	0.446 ± 0.022
	15 Feb 93	12 22	27	5.581 ± 0.052	0.507 ± 0.087	0.583 ± 0.043	0.601 ± 0.029	0.268 ± 0.023	0.168 ± 0.016	0.453 ± 0.018
	15 Feb 93	13 23	40	5.600 ± 0.047	0.486 ± 0.083	0.567 ± 0.039	0.609 ± 0.021	0.269 ± 0.021	0.168 ± 0.015	0.453 ± 0.013
	15 Feb 93	13 25	41	5.605 ± 0.047	0.477 ± 0.083	0.575 ± 0.039	0.601 ± 0.021	0.277 ± 0.020	0.163 ± 0.014	0.453 ± 0.012
	15 Feb 93	14 26	54	5.603 ± 0.044	0.505 ± 0.081	0.578 ± 0.039	0.605 ± 0.020	0.265 ± 0.019	0.168 ± 0.013	0.460 ± 0.011
	15 Feb 93	14 28	55	5.601 ± 0.044	0.507 ± 0.081	0.568 ± 0.040	0.609 ± 0.020	0.270 ± 0.020	0.169 ± 0.014	0.450 ± 0.015
	15 Feb 93	15 09	68	5.610 ± 0.043	0.513 ± 0.080	0.577 ± 0.039	0.600 ± 0.020	0.267 ± 0.019	0.168 ± 0.013	0.454 ± 0.013
	15 Feb 93	15 11	69	5.606 ± 0.043	0.511 ± 0.080	0.565 ± 0.039	0.612 ± 0.021	0.270 ± 0.019	0.169 ± 0.013	0.447 ± 0.012
	15 Feb 93	16 05	86	5.612 ± 0.043	0.472 ± 0.079	0.571 ± 0.039	0.605 ± 0.020	0.266 ± 0.019	0.167 ± 0.014	0.457 ± 0.013
	15 Feb 93	16 07	87	5.608 ± 0.042	0.443 ± 0.079	0.567 ± 0.040	0.601 ± 0.022	0.268 ± 0.019	0.171 ± 0.013	0.450 ± 0.010
	16 Feb 93	12 27	61	5.573 ± 0.038	0.485 ± 0.066	0.575 ± 0.016	0.616 ± 0.013	0.273 ± 0.015	0.170 ± 0.015	0.420 ± 0.032

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
122066	24 Jun 88	14 40	53	5.768 ± 0.018	0.530 ± 0.027	0.606 ± 0.023	0.672 ± 0.017	0.336 ± 0.015	0.142 ± 0.018	0.498 ± 0.012
	08 Jun 89	08 19	4	5.821 ± 0.021	0.554 ± 0.009	0.616 ± 0.012	0.663 ± 0.009	0.314 ± 0.010	0.153 ± 0.009	0.514 ± 0.011
	08 Jun 89	08 22	5	5.823 ± 0.021	0.555 ± 0.009	0.604 ± 0.012	0.667 ± 0.009	0.325 ± 0.010	0.146 ± 0.009	0.509 ± 0.011
	08 Jun 89	10 37	22	5.828 ± 0.022	0.560 ± 0.009	0.596 ± 0.012	0.678 ± 0.009	0.314 ± 0.010	0.166 ± 0.009	0.498 ± 0.011
	08 Jun 89	10 40	23	5.835 ± 0.021	0.553 ± 0.009	0.608 ± 0.012	0.674 ± 0.009	0.320 ± 0.010	0.151 ± 0.009	0.505 ± 0.011
	08 Jun 89	11 26	25	5.820 ± 0.022	0.567 ± 0.010	0.607 ± 0.012	0.667 ± 0.009	0.322 ± 0.010	0.152 ± 0.009	0.502 ± 0.011
	08 Jun 89	11 28	26	5.817 ± 0.022	0.564 ± 0.010	0.613 ± 0.012	0.659 ± 0.009	0.320 ± 0.010	0.157 ± 0.009	0.493 ± 0.011
	08 Jun 89	12 41	40	5.795 ± 0.024	0.567 ± 0.010	0.618 ± 0.013	0.672 ± 0.009	0.311 ± 0.011	0.155 ± 0.010	0.497 ± 0.013
	08 Jun 89	12 43	41	5.787 ± 0.024	0.567 ± 0.010	0.620 ± 0.013	0.668 ± 0.010	0.313 ± 0.011	0.163 ± 0.010	0.480 ± 0.013
	08 Jun 89	13 48	55	5.795 ± 0.028	0.563 ± 0.012	0.608 ± 0.015	0.675 ± 0.011	0.298 ± 0.013	0.167 ± 0.011	0.488 ± 0.015
	08 Jun 89	13 51	56	5.794 ± 0.029	0.573 ± 0.012	0.606 ± 0.015	0.677 ± 0.011	0.302 ± 0.013	0.167 ± 0.011	0.489 ± 0.015
	08 Jun 89	14 53	70	5.772 ± 0.038	0.556 ± 0.016	0.627 ± 0.019	0.660 ± 0.014	0.307 ± 0.016	0.169 ± 0.015	0.477 ± 0.020
	08 Jun 89	14 56	71	5.768 ± 0.038	0.555 ± 0.016	0.628 ± 0.019	0.661 ± 0.014	0.292 ± 0.017	0.177 ± 0.015	0.475 ± 0.021
124780	11 May 91	08 59	2	6.568 ± 0.031	0.570 ± 0.015	0.723 ± 0.017	0.511 ± 0.016	0.207 ± 0.016	0.128 ± 0.017	0.329 ± 0.020
	11 May 91	09 05	3	6.561 ± 0.031	0.563 ± 0.016	0.727 ± 0.018	0.508 ± 0.017	0.228 ± 0.016	0.109 ± 0.017	0.342 ± 0.021
129116	15 Apr 92	13 41	132	3.951 ± 0.018	0.240 ± 0.036	0.282 ± 0.020	0.113 ± 0.017	0.081 ± 0.022	0.032 ± 0.017	0.084 ± 0.013
	15 Apr 92	13 43	133	3.952 ± 0.018	0.247 ± 0.035	0.277 ± 0.021	0.116 ± 0.019	0.084 ± 0.023	0.026 ± 0.017	0.087 ± 0.014
136014	11 May 91	09 14	5	6.157 ± 0.046	0.538 ± 0.023	0.918 ± 0.025	1.150 ± 0.022	0.458 ± 0.017	0.264 ± 0.021	0.729 ± 0.028
	11 May 91	09 17	6	6.158 ± 0.046	0.537 ± 0.025	0.911 ± 0.026	1.164 ± 0.024	0.445 ± 0.019	0.270 ± 0.022	0.735 ± 0.027
	11 May 91	13 35	65	6.152 ± 0.044	0.532 ± 0.022	0.924 ± 0.023	1.150 ± 0.022	0.445 ± 0.017	0.267 ± 0.019	0.736 ± 0.026
	11 May 91	13 38	66	6.146 ± 0.045	0.522 ± 0.022	0.931 ± 0.025	1.147 ± 0.022	0.447 ± 0.016	0.269 ± 0.019	0.744 ± 0.027
	11 May 91	14 33	78	6.150 ± 0.045	0.534 ± 0.022	0.916 ± 0.023	1.154 ± 0.021	0.450 ± 0.016	0.269 ± 0.019	0.737 ± 0.027
	11 May 91	14 37	79	6.161 ± 0.045	0.544 ± 0.023	0.901 ± 0.024	1.155 ± 0.022	0.456 ± 0.016	0.254 ± 0.020	0.729 ± 0.026
	11 May 91	15 31	90	6.155 ± 0.046	0.535 ± 0.026	0.918 ± 0.026	1.149 ± 0.022	0.450 ± 0.017	0.264 ± 0.021	0.730 ± 0.028
	11 May 91	15 34	91	6.191 ± 0.045	0.526 ± 0.023	0.915 ± 0.024	1.161 ± 0.022	0.453 ± 0.017	0.245 ± 0.020	0.737 ± 0.026
	11 May 91	16 28	104	6.160 ± 0.046	0.546 ± 0.023	0.902 ± 0.025	1.171 ± 0.023	0.450 ± 0.018	0.283 ± 0.020	0.739 ± 0.027
	11 May 91	16 32	105	6.138 ± 0.046	0.542 ± 0.026	0.918 ± 0.027	1.153 ± 0.023	0.453 ± 0.019	0.269 ± 0.022	0.736 ± 0.027
	17 May 91	11 13	2	6.174 ± 0.022	0.570 ± 0.028	0.897 ± 0.028	1.170 ± 0.027	0.480 ± 0.028	0.275 ± 0.016	0.721 ± 0.016
	17 May 91	11 18	3	6.174 ± 0.022	0.590 ± 0.024	0.877 ± 0.026	1.146 ± 0.030	0.493 ± 0.029	0.271 ± 0.015	0.739 ± 0.016
	17 May 91	12 06	11	6.203 ± 0.021	0.585 ± 0.023	0.885 ± 0.023	1.161 ± 0.025	0.455 ± 0.026	0.273 ± 0.015	0.740 ± 0.016
	17 May 91	12 10	12	6.174 ± 0.021	0.584 ± 0.025	0.883 ± 0.025	1.168 ± 0.025	0.468 ± 0.026	0.283 ± 0.015	0.729 ± 0.016

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Table D.3 continued from previous page											
HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	
136014	17 May 91	13 01	22	6.193 ± 0.022	0.585 ± 0.028	0.882 ± 0.024	1.157 ± 0.025	0.465 ± 0.026	0.276 ± 0.016	0.731 ± 0.018	
	17 May 91	13 05	23	6.171 ± 0.022	0.579 ± 0.023	0.880 ± 0.023	1.166 ± 0.025	0.467 ± 0.026	0.288 ± 0.015	0.723 ± 0.016	
	17 May 91	14 13	35	6.182 ± 0.022	0.571 ± 0.023	0.889 ± 0.023	1.150 ± 0.025	0.479 ± 0.027	0.273 ± 0.016	0.731 ± 0.016	
	17 May 91	14 18	36	6.164 ± 0.022	0.592 ± 0.024	0.887 ± 0.025	1.169 ± 0.027	0.488 ± 0.027	0.272 ± 0.015	0.735 ± 0.017	
	17 May 91	15 35	50	6.191 ± 0.023	0.583 ± 0.024	0.882 ± 0.023	1.161 ± 0.026	0.484 ± 0.028	0.269 ± 0.016	0.729 ± 0.017	
	17 May 91	15 40	51	6.174 ± 0.023	0.582 ± 0.024	0.888 ± 0.024	1.160 ± 0.027	0.485 ± 0.028	0.276 ± 0.016	0.732 ± 0.017	
	17 May 91	17 03	67	6.175 ± 0.026	0.595 ± 0.028	0.875 ± 0.025	1.165 ± 0.028	0.472 ± 0.031	0.280 ± 0.017	0.731 ± 0.019	
	17 May 91	17 07	68	6.187 ± 0.026	0.584 ± 0.025	0.880 ± 0.024	1.168 ± 0.027	0.460 ± 0.032	0.279 ± 0.017	0.730 ± 0.018	
	21 May 91	07 21	9	6.196 ± 0.028	0.567 ± 0.026	0.903 ± 0.025	1.190 ± 0.025	0.446 ± 0.025	0.284 ± 0.022	0.752 ± 0.019	
	21 May 91	07 24	10	6.192 ± 0.027	0.585 ± 0.027	0.898 ± 0.026	1.181 ± 0.025	0.454 ± 0.027	0.284 ± 0.023	0.741 ± 0.019	
	21 May 91	10 26	60	6.215 ± 0.024	0.594 ± 0.029	0.897 ± 0.028	1.173 ± 0.022	0.464 ± 0.020	0.271 ± 0.019	0.749 ± 0.018	
	21 May 91	10 28	61	6.201 ± 0.024	0.580 ± 0.032	0.895 ± 0.024	1.189 ± 0.021	0.473 ± 0.022	0.271 ± 0.021	0.751 ± 0.019	
	21 May 91	11 43	79	6.214 ± 0.025	0.572 ± 0.025	0.909 ± 0.023	1.172 ± 0.021	0.478 ± 0.021	0.255 ± 0.022	0.765 ± 0.020	
	21 May 91	11 46	80	6.215 ± 0.021	0.587 ± 0.029	0.899 ± 0.029	1.173 ± 0.021	0.469 ± 0.023	0.270 ± 0.019	0.752 ± 0.016	
	21 May 91	12 27	91	6.227 ± 0.023	0.578 ± 0.025	0.911 ± 0.023	1.169 ± 0.019	0.462 ± 0.021	0.268 ± 0.020	0.753 ± 0.017	
	21 May 91	12 30	92	6.230 ± 0.021	0.575 ± 0.025	0.905 ± 0.023	1.173 ± 0.020	0.471 ± 0.020	0.259 ± 0.017	0.757 ± 0.015	
	21 May 91	13 35	105	6.232 ± 0.028	0.590 ± 0.023	0.897 ± 0.021	1.171 ± 0.019	0.461 ± 0.020	0.254 ± 0.025	0.767 ± 0.026	
	21 May 91	13 38	106	6.196 ± 0.023	0.581 ± 0.028	0.889 ± 0.022	1.192 ± 0.020	0.464 ± 0.022	0.277 ± 0.019	0.746 ± 0.017	
140008	21 May 91	14 22	118	6.204 ± 0.022	0.582 ± 0.029	0.900 ± 0.024	1.173 ± 0.021	0.468 ± 0.021	0.272 ± 0.017	0.752 ± 0.017	
	21 May 91	14 25	119	6.195 ± 0.023	0.558 ± 0.024	0.897 ± 0.022	1.182 ± 0.020	0.465 ± 0.021	0.281 ± 0.018	0.744 ± 0.016	
	21 May 91	16 13	121	6.225 ± 0.029	0.595 ± 0.026	0.893 ± 0.025	1.169 ± 0.024	0.467 ± 0.023	0.269 ± 0.023	0.753 ± 0.021	
	21 May 91	16 16	122	6.227 ± 0.027	0.598 ± 0.027	0.896 ± 0.026	1.215 ± 0.028	0.459 ± 0.028	0.275 ± 0.022	0.754 ± 0.019	
	21 May 91	17 12	137	6.201 ± 0.029	0.572 ± 0.047	0.900 ± 0.043	1.193 ± 0.027	0.442 ± 0.027	0.304 ± 0.022	0.743 ± 0.022	
	21 May 91	17 14	138	6.189 ± 0.031	0.596 ± 0.031	0.875 ± 0.030	1.191 ± 0.029	0.449 ± 0.028	0.322 ± 0.024	0.747 ± 0.021	
	14 Apr 92	14 54	133	4.638 ± 0.052	0.318 ± 0.025	0.367 ± 0.044	0.125 ± 0.037	0.116 ± 0.036	0.024 ± 0.018	0.121 ± 0.027	
	14 Apr 92	14 55	134	4.644 ± 0.052	0.324 ± 0.024	0.365 ± 0.044	0.114 ± 0.038	0.122 ± 0.035	0.027 ± 0.017	0.119 ± 0.026	
	141556	15 Apr 92	14 52	153	3.938 ± 0.018	0.603 ± 0.033	0.702 ± 0.018	0.249 ± 0.019	0.104 ± 0.023	0.054 ± 0.016	0.132 ± 0.012
		15 Apr 92	14 54	154	3.932 ± 0.018	0.603 ± 0.034	0.706 ± 0.019	0.238 ± 0.018	0.113 ± 0.023	0.052 ± 0.015	0.133 ± 0.012
	143118	14 Apr 92	15 15	142	3.339 ± 0.051	0.194 ± 0.040	0.129 ± 0.051	0.033 ± 0.042	0.102 ± 0.041	0.011 ± 0.026	0.092 ± 0.027
		14 Apr 92	15 16	143	3.343 ± 0.051	0.187 ± 0.040	0.129 ± 0.051	0.030 ± 0.042	0.099 ± 0.041	0.013 ± 0.026	0.091 ± 0.027
	143474	15 Apr 92	15 14	162	4.686 ± 0.019	0.617 ± 0.034	0.758 ± 0.016	0.475 ± 0.013	0.206 ± 0.020	0.094 ± 0.013	0.299 ± 0.014

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HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
143474	15 Apr 92	15 15	163	4.675 ± 0.018	0.613 ± 0.034	0.760 ± 0.015	0.481 ± 0.014	0.203 ± 0.021	0.097 ± 0.013	0.298 ± 0.013
144470	21 May 91	14 03	112	3.923 ± 0.019	0.146 ± 0.021	0.197 ± 0.021	0.145 ± 0.019	0.206 ± 0.021	0.005 ± 0.018	0.178 ± 0.015
	21 May 91	14 06	113	3.917 ± 0.019	0.144 ± 0.020	0.192 ± 0.020	0.153 ± 0.020	0.210 ± 0.023	-0.005 ± 0.019	0.186 ± 0.013
146836	11 Apr 92	12 54	83	5.165 ± 0.050	0.561 ± 0.031	0.598 ± 0.039	0.677 ± 0.026	0.329 ± 0.016	0.193 ± 0.019	0.467 ± 0.038
	11 Apr 92	12 57	84	5.416 ± 0.049	0.579 ± 0.030	0.607 ± 0.039	0.663 ± 0.026	0.326 ± 0.016	0.174 ± 0.018	0.457 ± 0.037
	11 Apr 92	12 58	85	5.416 ± 0.050	0.574 ± 0.030	0.616 ± 0.039	0.653 ± 0.026	0.323 ± 0.016	0.178 ± 0.020	0.466 ± 0.038
147513	11 Apr 92	13 04	87	5.291 ± 0.050	0.486 ± 0.031	0.629 ± 0.041	0.851 ± 0.028	0.354 ± 0.018	0.226 ± 0.018	0.555 ± 0.038
	11 Apr 92	13 06	88	5.292 ± 0.051	0.490 ± 0.033	0.628 ± 0.041	0.845 ± 0.028	0.364 ± 0.018	0.218 ± 0.019	0.558 ± 0.038
	11 Apr 92	14 19	110	5.293 ± 0.050	0.484 ± 0.031	0.631 ± 0.040	0.849 ± 0.027	0.358 ± 0.016	0.224 ± 0.018	0.550 ± 0.038
	11 Apr 92	14 21	111	5.297 ± 0.050	0.488 ± 0.031	0.628 ± 0.041	0.841 ± 0.027	0.366 ± 0.017	0.220 ± 0.019	0.549 ± 0.038
	11 Apr 92	15 07	127	5.308 ± 0.050	0.485 ± 0.031	0.631 ± 0.041	0.843 ± 0.027	0.361 ± 0.017	0.215 ± 0.019	0.524 ± 0.048
	12 Apr 92	12 54	89	5.379 ± 0.030	0.469 ± 0.020	0.603 ± 0.016	0.834 ± 0.017	0.331 ± 0.013	0.214 ± 0.015	0.558 ± 0.020
	12 Apr 92	12 55	90	5.373 ± 0.031	0.464 ± 0.024	0.605 ± 0.021	0.835 ± 0.020	0.334 ± 0.015	0.221 ± 0.017	0.550 ± 0.021
	12 Apr 92	14 20	107	5.395 ± 0.029	0.472 ± 0.021	0.594 ± 0.016	0.829 ± 0.017	0.329 ± 0.016	0.217 ± 0.016	0.561 ± 0.020
	12 Apr 92	14 22	108	5.378 ± 0.029	0.469 ± 0.020	0.605 ± 0.015	0.832 ± 0.016	0.337 ± 0.013	0.220 ± 0.015	0.551 ± 0.019
	12 Apr 92	15 23	123	5.393 ± 0.029	0.455 ± 0.020	0.610 ± 0.015	0.827 ± 0.015	0.336 ± 0.013	0.219 ± 0.014	0.556 ± 0.019
	12 Apr 92	15 24	124	5.383 ± 0.028	0.472 ± 0.021	0.607 ± 0.016	0.831 ± 0.015	0.337 ± 0.012	0.210 ± 0.014	0.560 ± 0.018
	12 Apr 92	16 06	136	5.384 ± 0.029	0.465 ± 0.019	0.605 ± 0.016	0.825 ± 0.016	0.341 ± 0.012	0.215 ± 0.014	0.553 ± 0.019
	12 Apr 92	16 08	137	5.376 ± 0.029	0.462 ± 0.021	0.609 ± 0.015	0.828 ± 0.016	0.332 ± 0.013	0.223 ± 0.014	0.549 ± 0.018
	13 Apr 92	12 49	90	5.378 ± 0.020	0.453 ± 0.017	0.616 ± 0.016	0.819 ± 0.012	0.337 ± 0.015	0.230 ± 0.012	0.551 ± 0.015
	13 Apr 92	12 51	91	5.381 ± 0.020	0.454 ± 0.017	0.612 ± 0.017	0.820 ± 0.012	0.343 ± 0.015	0.219 ± 0.013	0.551 ± 0.014
	13 Apr 92	14 20	106	5.378 ± 0.019	0.453 ± 0.019	0.610 ± 0.014	0.825 ± 0.009	0.343 ± 0.012	0.219 ± 0.010	0.552 ± 0.013
	13 Apr 92	14 22	107	5.387 ± 0.020	0.459 ± 0.017	0.613 ± 0.016	0.813 ± 0.010	0.339 ± 0.013	0.219 ± 0.012	0.555 ± 0.014
	13 Apr 92	15 30	121	5.378 ± 0.020	0.465 ± 0.015	0.608 ± 0.014	0.811 ± 0.012	0.351 ± 0.013	0.213 ± 0.011	0.559 ± 0.014
	13 Apr 92	15 31	122	5.375 ± 0.020	0.456 ± 0.014	0.615 ± 0.013	0.816 ± 0.010	0.347 ± 0.014	0.219 ± 0.012	0.547 ± 0.013
	13 Apr 92	16 12	136	5.376 ± 0.021	0.463 ± 0.017	0.611 ± 0.015	0.820 ± 0.010	0.344 ± 0.015	0.211 ± 0.015	0.560 ± 0.016
	13 Apr 92	16 13	137	5.367 ± 0.020	0.460 ± 0.015	0.616 ± 0.014	0.809 ± 0.012	0.340 ± 0.016	0.228 ± 0.014	0.552 ± 0.015
	13 Apr 92	16 57	151	5.366 ± 0.020	0.454 ± 0.017	0.613 ± 0.015	0.817 ± 0.010	0.347 ± 0.014	0.222 ± 0.013	0.552 ± 0.015
	13 Apr 92	16 59	152	5.374 ± 0.019	0.465 ± 0.016	0.606 ± 0.015	0.823 ± 0.012	0.337 ± 0.014	0.222 ± 0.011	0.567 ± 0.014
	13 Apr 92	18 06	175	5.364 ± 0.020	0.459 ± 0.019	0.611 ± 0.015	0.828 ± 0.011	0.334 ± 0.014	0.227 ± 0.011	0.545 ± 0.016
	13 Apr 92	18 08	176	5.365 ± 0.020	0.454 ± 0.017	0.619 ± 0.017	0.810 ± 0.015	0.356 ± 0.016	0.222 ± 0.013	0.551 ± 0.015

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Table D.3 continued from previous page										
HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
147513	14 Apr 92	12 43	103	5.394 ± 0.062	0.453 ± 0.028	0.607 ± 0.053	0.824 ± 0.045	0.336 ± 0.042	0.210 ± 0.019	0.562 ± 0.032
	14 Apr 92	12 44	104	5.387 ± 0.063	0.461 ± 0.029	0.610 ± 0.054	0.826 ± 0.048	0.331 ± 0.044	0.218 ± 0.021	0.560 ± 0.032
	14 Apr 92	14 06	118	5.387 ± 0.062	0.463 ± 0.029	0.605 ± 0.052	0.823 ± 0.045	0.326 ± 0.042	0.223 ± 0.020	0.558 ± 0.031
	14 Apr 92	14 08	119	5.388 ± 0.062	0.462 ± 0.028	0.602 ± 0.052	0.825 ± 0.044	0.339 ± 0.041	0.205 ± 0.018	0.568 ± 0.031
	14 Apr 92	15 06	139	5.384 ± 0.062	0.461 ± 0.028	0.611 ± 0.053	0.816 ± 0.045	0.335 ± 0.042	0.214 ± 0.019	0.558 ± 0.031
	14 Apr 92	15 08	140	5.387 ± 0.063	0.457 ± 0.027	0.608 ± 0.052	0.823 ± 0.044	0.325 ± 0.041	0.222 ± 0.021	0.567 ± 0.032
	14 Apr 92	15 51	157	5.378 ± 0.062	0.460 ± 0.030	0.600 ± 0.053	0.822 ± 0.044	0.338 ± 0.041	0.214 ± 0.019	0.555 ± 0.031
	14 Apr 92	15 52	158	5.383 ± 0.062	0.462 ± 0.028	0.612 ± 0.052	0.815 ± 0.044	0.338 ± 0.041	0.211 ± 0.018	0.563 ± 0.031
	14 Apr 92	16 56	178	5.382 ± 0.062	0.468 ± 0.028	0.604 ± 0.053	0.828 ± 0.044	0.331 ± 0.042	0.218 ± 0.020	0.553 ± 0.030
	14 Apr 92	16 58	179	5.383 ± 0.062	0.450 ± 0.029	0.619 ± 0.053	0.822 ± 0.045	0.344 ± 0.041	0.202 ± 0.018	0.566 ± 0.032
	14 Apr 92	17 53	196	5.390 ± 0.062	0.465 ± 0.028	0.610 ± 0.052	0.815 ± 0.045	0.332 ± 0.041	0.216 ± 0.019	0.557 ± 0.032
	14 Apr 92	17 54	197	5.386 ± 0.063	0.464 ± 0.030	0.603 ± 0.053	0.820 ± 0.045	0.328 ± 0.041	0.221 ± 0.021	0.562 ± 0.032
	15 Apr 92	13 15	124	5.403 ± 0.020	0.460 ± 0.038	0.604 ± 0.017	0.828 ± 0.015	0.326 ± 0.022	0.219 ± 0.013	0.553 ± 0.013
	15 Apr 92	13 17	125	5.406 ± 0.021	0.463 ± 0.038	0.606 ± 0.017	0.823 ± 0.015	0.336 ± 0.020	0.204 ± 0.012	0.566 ± 0.014
	15 Apr 92	14 07	141	5.394 ± 0.020	0.457 ± 0.040	0.604 ± 0.020	0.830 ± 0.016	0.330 ± 0.022	0.212 ± 0.013	0.563 ± 0.013
	15 Apr 92	14 09	142	5.380 ± 0.021	0.460 ± 0.038	0.611 ± 0.018	0.826 ± 0.017	0.332 ± 0.021	0.214 ± 0.012	0.557 ± 0.015
	15 Apr 92	15 05	159	5.396 ± 0.020	0.471 ± 0.038	0.598 ± 0.018	0.823 ± 0.015	0.330 ± 0.021	0.216 ± 0.012	0.564 ± 0.013
	15 Apr 92	15 07	160	5.395 ± 0.020	0.465 ± 0.038	0.606 ± 0.018	0.826 ± 0.016	0.328 ± 0.022	0.218 ± 0.014	0.564 ± 0.013
	15 Apr 92	16 02	177	5.382 ± 0.020	0.473 ± 0.039	0.607 ± 0.016	0.826 ± 0.015	0.314 ± 0.021	0.231 ± 0.011	0.554 ± 0.013
15 Apr 92	16 03	178	5.391 ± 0.021	0.462 ± 0.040	0.607 ± 0.018	0.827 ± 0.017	0.336 ± 0.021	0.210 ± 0.012	0.569 ± 0.016	
15 Apr 92	17 01	195	5.390 ± 0.020	0.466 ± 0.039	0.607 ± 0.017	0.828 ± 0.015	0.329 ± 0.021	0.214 ± 0.012	0.565 ± 0.014	
15 Apr 92	17 03	196	5.382 ± 0.021	0.467 ± 0.039	0.603 ± 0.017	0.823 ± 0.017	0.335 ± 0.022	0.220 ± 0.012	0.556 ± 0.015	
148605	21 May 91	14 14	115	4.777 ± 0.018	0.174 ± 0.018	0.296 ± 0.018	0.131 ± 0.017	0.138 ± 0.019	-0.009 ± 0.016	0.122 ± 0.012
	21 May 91	14 16	116	4.797 ± 0.020	0.181 ± 0.019	0.279 ± 0.032	0.144 ± 0.031	0.134 ± 0.018	0.005 ± 0.017	0.082 ± 0.019
148703	14 Apr 92	15 38	151	4.147 ± 0.051	0.206 ± 0.027	0.165 ± 0.045	0.077 ± 0.038	0.121 ± 0.036	0.023 ± 0.018	0.118 ± 0.026
	14 Apr 92	15 39	152	4.150 ± 0.051	0.200 ± 0.027	0.167 ± 0.045	0.073 ± 0.039	0.127 ± 0.037	0.025 ± 0.018	0.119 ± 0.026
152980	14 Apr 92	16 13	163	4.165 ± 0.082	0.714 ± 0.040	1.412 ± 0.070	1.974 ± 0.058	0.519 ± 0.054	0.474 ± 0.024	0.947 ± 0.040
	14 Apr 92	16 15	164	4.165 ± 0.082	0.720 ± 0.040	1.412 ± 0.071	1.971 ± 0.059	0.523 ± 0.055	0.479 ± 0.024	0.943 ± 0.040
154090	12 Apr 92	16 29	142	4.858 ± 0.027	0.271 ± 0.019	0.178 ± 0.016	0.304 ± 0.016	0.291 ± 0.013	0.142 ± 0.014	0.382 ± 0.017
	12 Apr 92	16 31	143	4.859 ± 0.026	0.267 ± 0.020	0.176 ± 0.015	0.315 ± 0.015	0.283 ± 0.011	0.145 ± 0.013	0.380 ± 0.018
156277	14 Apr 92	16 22	166	4.867 ± 0.075	0.633 ± 0.036	1.185 ± 0.064	1.604 ± 0.054	0.477 ± 0.050	0.374 ± 0.021	0.829 ± 0.037
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Table D.3 continued from previous page

HD #	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
156277	14 Apr 92	16 23	167	4.864 ± 0.075	0.630 ± 0.035	1.196 ± 0.064	1.596 ± 0.054	0.480 ± 0.050	0.377 ± 0.022	0.825 ± 0.037
157244	14 Apr 92	16 30	169	2.942 ± 0.085	0.717 ± 0.038	1.275 ± 0.072	1.890 ± 0.061	0.606 ± 0.061	0.440 ± 0.034	0.884 ± 0.044
	14 Apr 92	16 32	170	2.939 ± 0.085	0.712 ± 0.038	1.275 ± 0.072	1.890 ± 0.061	0.600 ± 0.061	0.447 ± 0.035	0.879 ± 0.044
158094	14 Apr 92	16 38	172	3.536 ± 0.052	0.528 ± 0.028	0.544 ± 0.047	0.147 ± 0.040	0.122 ± 0.040	0.043 ± 0.024	0.129 ± 0.027
	14 Apr 92	16 40	173	3.543 ± 0.052	0.529 ± 0.028	0.540 ± 0.047	0.143 ± 0.040	0.129 ± 0.039	0.033 ± 0.023	0.135 ± 0.026
158427	13 Apr 92	16 50	148	2.829 ± 0.018	0.154 ± 0.048	0.216 ± 0.042	0.131 ± 0.033	0.088 ± 0.039	0.056 ± 0.035	0.337 ± 0.017
	13 Apr 92	16 52	149	2.840 ± 0.018	0.161 ± 0.048	0.208 ± 0.042	0.131 ± 0.032	0.087 ± 0.038	0.053 ± 0.035	0.339 ± 0.016
159217	12 Apr 92	16 54	151	4.701 ± 0.024	0.713 ± 0.021	0.719 ± 0.019	0.228 ± 0.019	0.129 ± 0.018	0.077 ± 0.015	0.179 ± 0.018
	12 Apr 92	16 56	152	4.810 ± 0.024	0.729 ± 0.018	0.629 ± 0.028	0.171 ± 0.035	0.116 ± 0.025	0.062 ± 0.017	0.176 ± 0.017
159433	15 Apr 92	16 27	183	4.375 ± 0.026	0.619 ± 0.053	1.018 ± 0.026	1.357 ± 0.022	0.439 ± 0.031	0.358 ± 0.025	0.778 ± 0.022
	15 Apr 92	16 29	184	4.320 ± 0.022	0.575 ± 0.044	1.007 ± 0.020	1.367 ± 0.017	0.456 ± 0.026	0.341 ± 0.016	0.782 ± 0.014
160032	14 Apr 92	16 49	175	4.755 ± 0.058	0.523 ± 0.027	0.561 ± 0.049	0.572 ± 0.042	0.293 ± 0.039	0.154 ± 0.018	0.440 ± 0.029
	14 Apr 92	16 50	176	4.751 ± 0.058	0.518 ± 0.027	0.571 ± 0.050	0.568 ± 0.042	0.288 ± 0.039	0.163 ± 0.018	0.434 ± 0.029
160635	15 Apr 92	16 43	189	3.667 ± 0.023	0.642 ± 0.045	1.114 ± 0.020	1.539 ± 0.019	0.507 ± 0.027	0.344 ± 0.017	0.797 ± 0.016
	15 Apr 92	16 45	190	3.674 ± 0.023	0.654 ± 0.046	1.108 ± 0.020	1.529 ± 0.018	0.515 ± 0.027	0.336 ± 0.017	0.800 ± 0.015
161912	15 Apr 92	16 55	192	4.810 ± 0.020	1.171 ± 0.037	0.707 ± 0.018	0.373 ± 0.014	0.257 ± 0.020	0.150 ± 0.012	0.375 ± 0.014
	15 Apr 92	16 57	193	4.811 ± 0.019	1.168 ± 0.036	0.721 ± 0.015	0.369 ± 0.014	0.247 ± 0.020	0.151 ± 0.012	0.378 ± 0.013
169467	13 Apr 92	17 40	166	3.458 ± 0.017	0.232 ± 0.027	0.316 ± 0.026	0.114 ± 0.021	0.075 ± 0.025	0.039 ± 0.023	0.062 ± 0.015
	13 Apr 92	17 42	167	3.455 ± 0.017	0.231 ± 0.027	0.318 ± 0.026	0.122 ± 0.022	0.088 ± 0.025	0.038 ± 0.022	0.066 ± 0.014
169767	14 Apr 92	17 38	190	4.171 ± 0.070	0.572 ± 0.032	0.970 ± 0.060	1.295 ± 0.050	0.438 ± 0.048	0.316 ± 0.022	0.745 ± 0.035
	14 Apr 92	17 40	191	4.180 ± 0.070	0.568 ± 0.032	0.979 ± 0.060	1.295 ± 0.051	0.440 ± 0.048	0.314 ± 0.022	0.744 ± 0.035
176723	24 Jun 88	08 42	1	5.712 ± 0.009	0.626 ± 0.022	0.705 ± 0.017	0.552 ± 0.014	0.254 ± 0.009	0.135 ± 0.009	0.393 ± 0.010
	24 Jun 88	08 51	3	5.725 ± 0.009	0.627 ± 0.021	0.704 ± 0.017	0.550 ± 0.014	0.258 ± 0.009	0.117 ± 0.009	0.394 ± 0.009
	24 Jun 88	13 54	45	5.720 ± 0.007	0.626 ± 0.021	0.702 ± 0.016	0.550 ± 0.014	0.256 ± 0.008	0.125 ± 0.007	0.393 ± 0.009
	24 Jun 88	16 01	64	5.724 ± 0.007	0.629 ± 0.021	0.711 ± 0.016	0.550 ± 0.014	0.254 ± 0.008	0.120 ± 0.007	0.393 ± 0.009
	24 Jun 88	16 07	66	5.720 ± 0.007	0.636 ± 0.021	0.706 ± 0.016	0.547 ± 0.014	0.254 ± 0.008	0.121 ± 0.007	0.396 ± 0.009
	08 Jun 89	14 01	58	5.778 ± 0.020	0.640 ± 0.009	0.678 ± 0.011	0.554 ± 0.008	0.259 ± 0.009	0.127 ± 0.008	0.399 ± 0.010
	08 Jun 89	14 04	59	5.787 ± 0.020	0.626 ± 0.009	0.684 ± 0.011	0.556 ± 0.008	0.254 ± 0.009	0.132 ± 0.008	0.395 ± 0.010
182640	11 May 91	15 57	96	3.414 ± 0.033	0.544 ± 0.020	0.674 ± 0.023	0.526 ± 0.020	0.219 ± 0.024	0.147 ± 0.023	0.364 ± 0.023
	11 May 91	16 00	97	3.497 ± 0.033	0.524 ± 0.024	0.674 ± 0.023	0.544 ± 0.020	0.229 ± 0.023	0.123 ± 0.023	0.350 ± 0.026
	11 May 91	16 03	98	3.485 ± 0.035	0.541 ± 0.018	0.655 ± 0.021	0.515 ± 0.020	0.220 ± 0.025	0.161 ± 0.026	0.397 ± 0.023

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Table D.4: The individual reduced observations for the E region standard stars.

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E1_036	29 Jun 93	13 19	42	5.047 ± 0.037	0.464 ± 0.026	0.639 ± 0.023	0.747 ± 0.032	0.305 ± 0.032	0.225 ± 0.017	0.519 ± 0.019
	29 Jun 93	13 22	43	5.042 ± 0.037	0.486 ± 0.025	0.617 ± 0.019	0.752 ± 0.021	0.323 ± 0.025	0.204 ± 0.020	0.515 ± 0.018
	29 Jun 93	14 11	54	5.065 ± 0.034	0.473 ± 0.023	0.618 ± 0.019	0.756 ± 0.016	0.316 ± 0.018	0.203 ± 0.018	0.514 ± 0.017
	29 Jun 93	14 14	55	5.060 ± 0.034	0.467 ± 0.021	0.617 ± 0.018	0.755 ± 0.015	0.322 ± 0.016	0.200 ± 0.017	0.511 ± 0.018
	29 Jun 93	15 24	71	5.069 ± 0.031	0.497 ± 0.020	0.613 ± 0.016	0.756 ± 0.013	0.326 ± 0.014	0.200 ± 0.014	0.510 ± 0.015
	29 Jun 93	15 27	72	5.066 ± 0.031	0.489 ± 0.020	0.619 ± 0.016	0.751 ± 0.012	0.322 ± 0.014	0.203 ± 0.014	0.510 ± 0.015
	29 Jun 93	16 26	82	5.061 ± 0.030	0.472 ± 0.019	0.609 ± 0.015	0.756 ± 0.012	0.326 ± 0.014	0.196 ± 0.014	0.515 ± 0.015
	29 Jun 93	16 29	83	5.061 ± 0.030	0.479 ± 0.019	0.616 ± 0.015	0.754 ± 0.012	0.325 ± 0.014	0.200 ± 0.014	0.499 ± 0.015
	29 Jun 93	17 32	95	5.055 ± 0.029	0.490 ± 0.019	0.613 ± 0.015	0.753 ± 0.012	0.323 ± 0.014	0.199 ± 0.013	0.509 ± 0.016
	29 Jun 93	17 34	96	5.059 ± 0.029	0.494 ± 0.019	0.611 ± 0.015	0.757 ± 0.012	0.322 ± 0.014	0.198 ± 0.014	0.520 ± 0.015
	29 Jun 93	18 10	105	5.039 ± 0.029	0.494 ± 0.019	0.613 ± 0.015	0.756 ± 0.012	0.320 ± 0.013	0.203 ± 0.013	0.515 ± 0.015
	29 Jun 93	18 13	106	5.047 ± 0.029	0.488 ± 0.019	0.615 ± 0.015	0.756 ± 0.013	0.321 ± 0.014	0.199 ± 0.013	0.512 ± 0.015
	29 Jun 93	19 03	112	5.060 ± 0.029	0.481 ± 0.019	0.610 ± 0.015	0.761 ± 0.012	0.320 ± 0.013	0.201 ± 0.013	0.514 ± 0.015
	01 Jul 93	13 08	96	5.027 ± 0.032	0.484 ± 0.027	0.617 ± 0.013	0.755 ± 0.017	0.325 ± 0.019	0.199 ± 0.015	0.500 ± 0.015
	01 Jul 93	13 11	97	5.044 ± 0.033	0.481 ± 0.026	0.610 ± 0.014	0.765 ± 0.016	0.319 ± 0.017	0.194 ± 0.018	0.508 ± 0.019
	01 Jul 93	14 17	114	5.066 ± 0.028	0.496 ± 0.022	0.609 ± 0.012	0.752 ± 0.014	0.318 ± 0.014	0.207 ± 0.014	0.507 ± 0.015
	01 Jul 93	14 20	115	5.066 ± 0.029	0.492 ± 0.023	0.611 ± 0.011	0.758 ± 0.013	0.314 ± 0.013	0.201 ± 0.015	0.515 ± 0.019
	01 Jul 93	15 14	129	5.056 ± 0.025	0.505 ± 0.021	0.601 ± 0.012	0.756 ± 0.013	0.319 ± 0.013	0.201 ± 0.011	0.510 ± 0.014
	01 Jul 93	15 17	130	5.072 ± 0.025	0.497 ± 0.020	0.599 ± 0.010	0.761 ± 0.014	0.317 ± 0.014	0.194 ± 0.011	0.515 ± 0.014
	01 Jul 93	16 30	146	5.061 ± 0.024	0.499 ± 0.019	0.606 ± 0.012	0.759 ± 0.015	0.313 ± 0.014	0.203 ± 0.010	0.508 ± 0.013
	01 Jul 93	16 33	147	5.050 ± 0.024	0.475 ± 0.020	0.608 ± 0.011	0.755 ± 0.013	0.320 ± 0.013	0.199 ± 0.012	0.521 ± 0.013
	01 Jul 93	17 20	157	5.050 ± 0.023	0.508 ± 0.019	0.606 ± 0.010	0.751 ± 0.012	0.317 ± 0.012	0.199 ± 0.010	0.521 ± 0.012
	01 Jul 93	17 23	158	5.053 ± 0.023	0.504 ± 0.019	0.605 ± 0.011	0.755 ± 0.012	0.313 ± 0.012	0.204 ± 0.010	0.515 ± 0.012
	01 Jul 93	18 25	172	5.060 ± 0.023	0.511 ± 0.019	0.611 ± 0.010	0.753 ± 0.012	0.316 ± 0.013	0.199 ± 0.010	0.514 ± 0.011
	01 Jul 93	18 28	173	5.064 ± 0.023	0.503 ± 0.019	0.610 ± 0.011	0.751 ± 0.013	0.314 ± 0.013	0.209 ± 0.009	0.514 ± 0.012
	01 Jul 93	18 53	180	5.066 ± 0.023	0.510 ± 0.019	0.606 ± 0.012	0.758 ± 0.013	0.318 ± 0.013	0.198 ± 0.010	0.519 ± 0.012
	01 Jul 93	18 56	181	5.074 ± 0.023	0.485 ± 0.019	0.605 ± 0.010	0.756 ± 0.012	0.316 ± 0.013	0.204 ± 0.010	0.509 ± 0.011
	03 Jul 93	13 19	76	4.998 ± 0.036	0.498 ± 0.034	0.625 ± 0.021	0.761 ± 0.022	0.312 ± 0.019	0.208 ± 0.016	0.517 ± 0.020
	03 Jul 93	14 15	86	5.043 ± 0.032	0.503 ± 0.030	0.621 ± 0.016	0.756 ± 0.019	0.314 ± 0.017	0.197 ± 0.012	0.513 ± 0.017
	03 Jul 93	15 23	98	5.039 ± 0.030	0.510 ± 0.028	0.617 ± 0.014	0.762 ± 0.016	0.311 ± 0.015	0.200 ± 0.011	0.520 ± 0.018

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Table D.4 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E1_036	03 Jul 93	16 23	107	5.047 ± 0.028	0.484 ± 0.026	0.614 ± 0.014	0.756 ± 0.018	0.318 ± 0.016	0.192 ± 0.011	0.519 ± 0.015
	03 Jul 93	18 10	125	5.049 ± 0.027	0.490 ± 0.026	0.613 ± 0.013	0.755 ± 0.016	0.314 ± 0.014	0.202 ± 0.009	0.513 ± 0.015
	03 Jul 93	19 00	133	5.047 ± 0.027	0.491 ± 0.026	0.615 ± 0.013	0.757 ± 0.016	0.317 ± 0.014	0.195 ± 0.009	0.521 ± 0.014
	06 Jul 93	13 24	71	5.043 ± 0.047	0.526 ± 0.050	0.611 ± 0.024	0.765 ± 0.023	0.318 ± 0.021	0.203 ± 0.016	0.520 ± 0.022
	06 Jul 93	14 16	80	5.073 ± 0.046	0.497 ± 0.048	0.604 ± 0.022	0.764 ± 0.021	0.323 ± 0.020	0.198 ± 0.016	0.521 ± 0.021
	06 Jul 93	15 16	91	5.060 ± 0.045	0.492 ± 0.047	0.602 ± 0.022	0.767 ± 0.022	0.321 ± 0.019	0.198 ± 0.014	0.516 ± 0.021
	07 Jul 93	15 16	88	5.038 ± 0.041	0.493 ± 0.023	0.616 ± 0.014	0.757 ± 0.018	0.321 ± 0.012	0.200 ± 0.013	0.518 ± 0.018
	07 Jul 93	16 14	98	5.012 ± 0.037	0.482 ± 0.023	0.612 ± 0.014	0.753 ± 0.018	0.327 ± 0.012	0.194 ± 0.012	0.514 ± 0.018
	07 Jul 93	17 22	110	5.020 ± 0.034	0.473 ± 0.022	0.609 ± 0.014	0.755 ± 0.019	0.324 ± 0.012	0.197 ± 0.012	0.507 ± 0.018
	07 Jul 93	18 07	118	5.019 ± 0.033	0.497 ± 0.022	0.611 ± 0.013	0.755 ± 0.018	0.318 ± 0.012	0.202 ± 0.012	0.512 ± 0.017
	07 Jul 93	18 51	125	5.007 ± 0.033	0.468 ± 0.022	0.611 ± 0.013	0.756 ± 0.018	0.324 ± 0.012	0.196 ± 0.012	0.516 ± 0.018
	14 Feb 93	10 54	24	8.053 ± 0.032	0.519 ± 0.033	0.827 ± 0.014	0.426 ± 0.010	0.151 ± 0.014	0.090 ± 0.013	0.182 ± 0.020
E3_005	14 Feb 93	10 58	25	8.047 ± 0.035	0.538 ± 0.032	0.825 ± 0.014	0.423 ± 0.011	0.152 ± 0.014	0.096 ± 0.019	0.179 ± 0.025
	14 Feb 93	12 47	48	6.470 ± 0.065	0.707 ± 0.060	1.372 ± 0.036	2.064 ± 0.020	0.577 ± 0.026	0.533 ± 0.023	1.048 ± 0.030
E3_036	15 Feb 93	11 48	19	6.481 ± 0.055	0.833 ± 0.119	1.375 ± 0.062	2.015 ± 0.029	0.549 ± 0.027	0.552 ± 0.018	1.029 ± 0.013
	15 Feb 93	11 51	20	6.488 ± 0.055	0.761 ± 0.111	1.411 ± 0.060	2.026 ± 0.028	0.543 ± 0.027	0.544 ± 0.018	1.041 ± 0.012
E3_037	14 Feb 93	10 47	22	7.123 ± 0.051	0.545 ± 0.046	1.000 ± 0.025	1.346 ± 0.014	0.477 ± 0.019	0.342 ± 0.018	0.765 ± 0.024
	14 Feb 93	10 49	23	7.134 ± 0.051	0.530 ± 0.041	0.999 ± 0.021	1.342 ± 0.014	0.484 ± 0.021	0.336 ± 0.019	0.762 ± 0.024
E3_041	14 Feb 93	11 51	36	8.637 ± 0.053	0.580 ± 0.073	1.115 ± 0.035	1.460 ± 0.018	0.484 ± 0.021	0.360 ± 0.021	0.807 ± 0.028
	14 Feb 93	11 54	37	8.630 ± 0.053	0.632 ± 0.054	1.085 ± 0.036	1.455 ± 0.021	0.487 ± 0.025	0.368 ± 0.020	0.779 ± 0.025
E3_045	15 Feb 93	11 21	11	5.778 ± 0.041	0.579 ± 0.074	0.651 ± 0.037	0.233 ± 0.019	0.097 ± 0.018	0.044 ± 0.013	0.124 ± 0.011
	15 Feb 93	11 23	12	5.779 ± 0.041	0.575 ± 0.074	0.650 ± 0.036	0.234 ± 0.020	0.102 ± 0.019	0.042 ± 0.013	0.118 ± 0.013
	16 Feb 93	09 49	16	5.768 ± 0.026	0.537 ± 0.046	0.682 ± 0.013	0.231 ± 0.010	0.108 ± 0.011	0.034 ± 0.008	0.084 ± 0.022
	16 Feb 93	09 51	17	5.767 ± 0.027	0.500 ± 0.046	0.682 ± 0.013	0.231 ± 0.010	0.102 ± 0.011	0.045 ± 0.009	0.082 ± 0.026
E3_047	14 Feb 93	12 39	46	5.105 ± 0.038	0.462 ± 0.036	0.581 ± 0.015	0.636 ± 0.013	0.291 ± 0.016	0.180 ± 0.015	0.441 ± 0.019
	14 Feb 93	12 41	47	5.112 ± 0.039	0.469 ± 0.036	0.577 ± 0.015	0.637 ± 0.013	0.288 ± 0.016	0.182 ± 0.015	0.449 ± 0.019
	15 Feb 93	11 41	17	5.131 ± 0.043	0.486 ± 0.080	0.569 ± 0.040	0.631 ± 0.021	0.278 ± 0.019	0.182 ± 0.013	0.441 ± 0.010
	15 Feb 93	11 43	18	5.142 ± 0.044	0.485 ± 0.080	0.570 ± 0.039	0.632 ± 0.020	0.277 ± 0.019	0.174 ± 0.014	0.450 ± 0.013
E3_050	15 Feb 93	11 34	15	6.685 ± 0.042	0.230 ± 0.074	0.382 ± 0.036	0.178 ± 0.018	0.079 ± 0.019	0.019 ± 0.017	0.099 ± 0.017
	15 Feb 93	11 36	16	6.679 ± 0.041	0.266 ± 0.074	0.384 ± 0.036	0.174 ± 0.018	0.078 ± 0.018	0.026 ± 0.013	0.086 ± 0.011
E3_051	14 Feb 93	12 52	49	6.819 ± 0.032	0.476 ± 0.035	0.644 ± 0.014	0.226 ± 0.012	0.096 ± 0.015	0.063 ± 0.014	0.114 ± 0.022

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E3.051	14 Feb 93	12 54	50	6.825 ± 0.031	0.475 ± 0.035	0.644 ± 0.014	0.232 ± 0.010	0.089 ± 0.014	0.061 ± 0.012	0.123 ± 0.019
	14 Feb 93	12 56	51	6.208 ± 0.031	0.509 ± 0.034	0.768 ± 0.013	0.300 ± 0.009	0.112 ± 0.013	0.064 ± 0.012	0.122 ± 0.018
	14 Feb 93	12 58	52	6.198 ± 0.031	0.514 ± 0.034	0.761 ± 0.013	0.312 ± 0.010	0.102 ± 0.015	0.075 ± 0.013	0.116 ± 0.018
E3.087	15 Feb 93	11 28	13	5.022 ± 0.048	0.618 ± 0.091	0.948 ± 0.046	1.237 ± 0.025	0.449 ± 0.023	0.306 ± 0.016	0.704 ± 0.012
	15 Feb 93	11 30	14	5.029 ± 0.048	0.603 ± 0.091	0.949 ± 0.046	1.240 ± 0.026	0.446 ± 0.024	0.305 ± 0.015	0.697 ± 0.012
	16 Feb 93	09 57	18	5.008 ± 0.032	0.553 ± 0.051	0.928 ± 0.017	1.260 ± 0.013	0.461 ± 0.013	0.293 ± 0.012	0.688 ± 0.031
	16 Feb 93	09 59	19	5.013 ± 0.032	0.560 ± 0.050	0.932 ± 0.016	1.253 ± 0.013	0.467 ± 0.013	0.287 ± 0.011	0.694 ± 0.031
E4.028	15 Feb 93	12 31	29	6.609 ± 0.049	0.598 ± 0.101	1.174 ± 0.056	1.537 ± 0.025	0.472 ± 0.023	0.400 ± 0.015	0.824 ± 0.015
	15 Feb 93	12 33	30	6.606 ± 0.049	0.567 ± 0.100	1.195 ± 0.054	1.528 ± 0.025	0.471 ± 0.023	0.407 ± 0.016	0.814 ± 0.012
	16 Feb 93	10 35	30	6.593 ± 0.035	0.620 ± 0.064	1.148 ± 0.025	1.556 ± 0.013	0.488 ± 0.014	0.387 ± 0.012	0.818 ± 0.034
	16 Feb 93	10 37	31	6.592 ± 0.035	0.646 ± 0.058	1.152 ± 0.021	1.548 ± 0.014	0.479 ± 0.015	0.394 ± 0.013	0.816 ± 0.034
	17 Feb 93	11 37	11	6.617 ± 0.041	0.656 ± 0.046	1.163 ± 0.029	1.542 ± 0.011	0.490 ± 0.015	0.381 ± 0.009	0.828 ± 0.021
	17 Feb 93	11 42	12	6.618 ± 0.041	0.647 ± 0.046	1.171 ± 0.028	1.534 ± 0.012	0.499 ± 0.016	0.379 ± 0.012	0.836 ± 0.022
	18 Feb 93	09 43	12	6.579 ± 0.037	0.647 ± 0.082	1.148 ± 0.027	1.552 ± 0.021	0.493 ± 0.018	0.374 ± 0.014	0.835 ± 0.033
	18 Feb 93	09 46	13	6.579 ± 0.037	0.681 ± 0.080	1.153 ± 0.026	1.551 ± 0.015	0.494 ± 0.018	0.375 ± 0.015	0.834 ± 0.034
	15 Feb 93	12 38	31	6.682 ± 0.050	0.610 ± 0.101	1.231 ± 0.051	1.600 ± 0.024	0.469 ± 0.023	0.430 ± 0.015	0.837 ± 0.011
	15 Feb 93	12 42	32	6.679 ± 0.050	0.612 ± 0.098	1.231 ± 0.051	1.594 ± 0.025	0.473 ± 0.023	0.431 ± 0.016	0.837 ± 0.012
E4.029	16 Feb 93	10 43	32	6.681 ± 0.035	0.687 ± 0.059	1.203 ± 0.027	1.617 ± 0.015	0.483 ± 0.015	0.412 ± 0.011	0.827 ± 0.034
	16 Feb 93	10 47	33	6.680 ± 0.034	0.660 ± 0.058	1.193 ± 0.025	1.622 ± 0.014	0.483 ± 0.014	0.409 ± 0.011	0.831 ± 0.034
	17 Feb 93	11 47	13	6.685 ± 0.042	0.671 ± 0.050	1.220 ± 0.030	1.607 ± 0.013	0.498 ± 0.015	0.404 ± 0.010	0.841 ± 0.023
	17 Feb 93	11 50	14	6.682 ± 0.042	0.638 ± 0.045	1.208 ± 0.028	1.608 ± 0.012	0.504 ± 0.016	0.403 ± 0.010	0.842 ± 0.021
	18 Feb 93	09 51	14	6.645 ± 0.037	0.718 ± 0.080	1.210 ± 0.024	1.620 ± 0.016	0.487 ± 0.018	0.404 ± 0.014	0.842 ± 0.033
	18 Feb 93	09 54	15	6.658 ± 0.037	0.661 ± 0.079	1.205 ± 0.023	1.622 ± 0.016	0.491 ± 0.020	0.393 ± 0.015	0.849 ± 0.033
	16 Feb 93	14 49	100	7.197 ± 0.035	0.662 ± 0.057	0.998 ± 0.018	1.367 ± 0.013	0.487 ± 0.014	0.334 ± 0.012	0.788 ± 0.034
	16 Feb 93	14 53	101	7.200 ± 0.036	0.677 ± 0.059	1.009 ± 0.026	1.371 ± 0.014	0.488 ± 0.014	0.335 ± 0.013	0.777 ± 0.035
	15 Feb 93	12 47	33	6.681 ± 0.044	0.469 ± 0.079	0.596 ± 0.039	0.585 ± 0.020	0.275 ± 0.019	0.178 ± 0.017	0.440 ± 0.015
	15 Feb 93	12 49	34	6.670 ± 0.043	0.464 ± 0.079	0.588 ± 0.039	0.598 ± 0.020	0.264 ± 0.019	0.185 ± 0.014	0.443 ± 0.013
E4.039	16 Feb 93	10 52	34	6.687 ± 0.029	0.555 ± 0.050	0.603 ± 0.021	0.601 ± 0.010	0.280 ± 0.011	0.161 ± 0.011	0.427 ± 0.027
	16 Feb 93	10 54	35	6.687 ± 0.029	0.558 ± 0.048	0.595 ± 0.014	0.607 ± 0.012	0.283 ± 0.012	0.157 ± 0.011	0.419 ± 0.026
	17 Feb 93	11 54	15	6.669 ± 0.033	0.483 ± 0.036	0.610 ± 0.021	0.591 ± 0.011	0.284 ± 0.012	0.164 ± 0.007	0.435 ± 0.018
	17 Feb 93	11 57	16	6.671 ± 0.033	0.526 ± 0.036	0.614 ± 0.020	0.592 ± 0.010	0.286 ± 0.012	0.157 ± 0.008	0.440 ± 0.016

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Table D.4 continued from previous page										
star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E4_039	18 Feb 93	09 58	16	6.641 ± 0.031	0.512 ± 0.065	0.601 ± 0.018	0.608 ± 0.014	0.291 ± 0.013	0.156 ± 0.011	0.430 ± 0.024
	18 Feb 93	09 60	17	6.643 ± 0.030	0.516 ± 0.065	0.612 ± 0.017	0.602 ± 0.012	0.284 ± 0.013	0.157 ± 0.010	0.427 ± 0.024
	20 May 93	07 04	3	6.674 ± 0.014	0.556 ± 0.012	0.586 ± 0.008	0.601 ± 0.008	0.277 ± 0.010	0.166 ± 0.009	0.475 ± 0.010
	20 May 93	07 07	4	6.673 ± 0.013	0.555 ± 0.013	0.587 ± 0.009	0.592 ± 0.007	0.273 ± 0.010	0.179 ± 0.009	0.471 ± 0.010
	20 May 93	08 06	14	6.653 ± 0.014	0.536 ± 0.014	0.586 ± 0.010	0.605 ± 0.010	0.275 ± 0.009	0.176 ± 0.010	0.463 ± 0.011
	20 May 93	08 09	15	6.661 ± 0.014	0.556 ± 0.011	0.586 ± 0.007	0.600 ± 0.007	0.268 ± 0.011	0.178 ± 0.011	0.471 ± 0.011
	20 May 93	09 07	28	6.656 ± 0.016	0.557 ± 0.015	0.584 ± 0.009	0.601 ± 0.008	0.278 ± 0.012	0.167 ± 0.012	0.470 ± 0.011
	20 May 93	09 10	29	6.662 ± 0.015	0.563 ± 0.012	0.578 ± 0.010	0.602 ± 0.010	0.280 ± 0.013	0.164 ± 0.013	0.467 ± 0.013
	20 May 93	10 13	43	6.663 ± 0.017	0.568 ± 0.015	0.578 ± 0.011	0.606 ± 0.009	0.272 ± 0.013	0.167 ± 0.012	0.463 ± 0.013
	20 May 93	10 16	44	6.666 ± 0.017	0.559 ± 0.013	0.581 ± 0.009	0.606 ± 0.009	0.269 ± 0.012	0.177 ± 0.011	0.457 ± 0.012
	20 May 93	11 06	53	6.659 ± 0.019	0.561 ± 0.017	0.584 ± 0.010	0.601 ± 0.009	0.276 ± 0.012	0.171 ± 0.012	0.467 ± 0.011
	20 May 93	11 09	54	6.662 ± 0.019	0.575 ± 0.015	0.573 ± 0.012	0.608 ± 0.010	0.271 ± 0.014	0.174 ± 0.014	0.470 ± 0.012
	20 May 93	12 11	66	6.676 ± 0.026	0.557 ± 0.022	0.585 ± 0.017	0.608 ± 0.011	0.270 ± 0.014	0.175 ± 0.017	0.470 ± 0.017
	20 May 93	12 13	67	6.683 ± 0.025	0.560 ± 0.022	0.588 ± 0.014	0.605 ± 0.011	0.271 ± 0.016	0.170 ± 0.016	0.467 ± 0.014
	23 May 93	07 12	3	6.671 ± 0.020	0.555 ± 0.016	0.601 ± 0.011	0.599 ± 0.010	0.273 ± 0.015	0.171 ± 0.015	0.436 ± 0.014
	23 May 93	07 15	4	6.677 ± 0.018	0.550 ± 0.016	0.595 ± 0.012	0.601 ± 0.009	0.271 ± 0.014	0.170 ± 0.012	0.437 ± 0.012
	23 May 93	08 02	16	6.663 ± 0.019	0.550 ± 0.017	0.595 ± 0.013	0.601 ± 0.010	0.283 ± 0.014	0.162 ± 0.011	0.442 ± 0.011
	23 May 93	08 05	17	6.667 ± 0.019	0.548 ± 0.017	0.597 ± 0.012	0.598 ± 0.009	0.278 ± 0.014	0.170 ± 0.012	0.435 ± 0.017
	23 May 93	09 17	30	6.660 ± 0.020	0.550 ± 0.015	0.605 ± 0.011	0.597 ± 0.011	0.280 ± 0.016	0.165 ± 0.014	0.440 ± 0.014
	23 May 93	09 20	31	6.667 ± 0.020	0.548 ± 0.017	0.603 ± 0.015	0.597 ± 0.011	0.268 ± 0.014	0.171 ± 0.012	0.450 ± 0.013
	23 May 93	10 17	43	6.657 ± 0.021	0.554 ± 0.017	0.598 ± 0.013	0.601 ± 0.010	0.274 ± 0.015	0.168 ± 0.013	0.439 ± 0.013
	23 May 93	10 20	44	6.664 ± 0.022	0.551 ± 0.021	0.599 ± 0.016	0.599 ± 0.010	0.277 ± 0.015	0.162 ± 0.015	0.458 ± 0.014
	23 May 93	11 12	54	6.646 ± 0.025	0.568 ± 0.018	0.594 ± 0.013	0.602 ± 0.010	0.270 ± 0.015	0.177 ± 0.017	0.430 ± 0.017
	23 May 93	11 14	55	6.652 ± 0.025	0.557 ± 0.017	0.604 ± 0.016	0.592 ± 0.017	0.272 ± 0.020	0.174 ± 0.020	0.438 ± 0.017
	23 May 93	12 10	67	6.651 ± 0.027	0.559 ± 0.028	0.593 ± 0.025	0.603 ± 0.019	0.268 ± 0.022	0.169 ± 0.017	0.450 ± 0.017
	23 May 93	12 12	68	6.647 ± 0.027	0.567 ± 0.024	0.586 ± 0.025	0.599 ± 0.023	0.270 ± 0.026	0.177 ± 0.022	0.429 ± 0.022
E4_040	15 Feb 93	13 48	45	5.600 ± 0.041	0.306 ± 0.074	0.419 ± 0.037	0.183 ± 0.020	0.072 ± 0.018	0.037 ± 0.014	0.119 ± 0.016
	15 Feb 93	13 50	46	5.607 ± 0.041	0.314 ± 0.074	0.419 ± 0.036	0.185 ± 0.019	0.069 ± 0.018	0.035 ± 0.015	0.128 ± 0.013
E4_041	15 Feb 93	13 54	47	6.316 ± 0.041	0.463 ± 0.074	0.561 ± 0.036	0.211 ± 0.020	0.099 ± 0.019	0.035 ± 0.012	0.172 ± 0.013
	15 Feb 93	13 56	48	6.311 ± 0.041	0.472 ± 0.074	0.568 ± 0.036	0.207 ± 0.019	0.095 ± 0.020	0.043 ± 0.014	0.165 ± 0.011
	16 Feb 93	11 33	46	6.275 ± 0.027	0.617 ± 0.046	0.599 ± 0.013	0.204 ± 0.009	0.105 ± 0.012	0.049 ± 0.010	0.116 ± 0.022

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E4.041	16 Feb 93	11 35	47	6.286 ± 0.027	0.619 ± 0.047	0.594 ± 0.015	0.210 ± 0.010	0.107 ± 0.011	0.039 ± 0.010	0.128 ± 0.023
	17 Feb 93	12 44	27	6.257 ± 0.031	0.455 ± 0.035	0.630 ± 0.020	0.180 ± 0.010	0.092 ± 0.013	0.055 ± 0.008	0.128 ± 0.018
	17 Feb 93	12 46	28	6.258 ± 0.031	0.440 ± 0.034	0.622 ± 0.018	0.190 ± 0.009	0.091 ± 0.013	0.051 ± 0.010	0.138 ± 0.017
	18 Feb 93	10 36	28	6.258 ± 0.028	0.418 ± 0.059	0.607 ± 0.015	0.204 ± 0.014	0.104 ± 0.013	0.033 ± 0.010	0.142 ± 0.019
	18 Feb 93	10 38	29	6.254 ± 0.028	0.419 ± 0.060	0.602 ± 0.015	0.201 ± 0.010	0.099 ± 0.012	0.050 ± 0.010	0.123 ± 0.019
	15 Feb 93	14 36	57	5.766 ± 0.047	0.582 ± 0.090	0.893 ± 0.045	1.136 ± 0.022	0.423 ± 0.021	0.282 ± 0.014	0.678 ± 0.016
	15 Feb 93	14 38	58	5.771 ± 0.047	0.560 ± 0.090	0.887 ± 0.045	1.139 ± 0.023	0.425 ± 0.021	0.276 ± 0.014	0.679 ± 0.012
E4.044	16 Feb 93	11 39	48	5.753 ± 0.032	0.649 ± 0.050	0.880 ± 0.015	1.149 ± 0.012	0.441 ± 0.012	0.263 ± 0.012	0.664 ± 0.031
	16 Feb 93	11 41	49	5.752 ± 0.031	0.635 ± 0.050	0.878 ± 0.015	1.150 ± 0.012	0.437 ± 0.013	0.269 ± 0.011	0.661 ± 0.030
	17 Feb 93	12 50	29	5.728 ± 0.038	0.537 ± 0.040	0.896 ± 0.025	1.134 ± 0.012	0.448 ± 0.017	0.263 ± 0.013	0.676 ± 0.020
	17 Feb 93	12 52	30	5.728 ± 0.038	0.527 ± 0.040	0.886 ± 0.024	1.146 ± 0.010	0.445 ± 0.015	0.268 ± 0.010	0.671 ± 0.019
	18 Feb 93	10 42	30	5.723 ± 0.033	0.514 ± 0.071	0.879 ± 0.017	1.157 ± 0.012	0.446 ± 0.015	0.256 ± 0.012	0.668 ± 0.029
	18 Feb 93	10 44	31	5.727 ± 0.033	0.513 ± 0.071	0.901 ± 0.019	1.140 ± 0.012	0.437 ± 0.015	0.263 ± 0.012	0.669 ± 0.028
	15 Feb 93	14 42	59	6.637 ± 0.044	0.549 ± 0.081	0.595 ± 0.041	0.668 ± 0.021	0.281 ± 0.019	0.187 ± 0.014	0.461 ± 0.012
E4.045	15 Feb 93	14 45	60	6.647 ± 0.044	0.541 ± 0.081	0.594 ± 0.040	0.671 ± 0.020	0.281 ± 0.019	0.175 ± 0.013	0.475 ± 0.011
	16 Feb 93	11 44	50	6.620 ± 0.029	0.650 ± 0.049	0.614 ± 0.014	0.661 ± 0.011	0.295 ± 0.011	0.177 ± 0.010	0.448 ± 0.027
	16 Feb 93	11 46	51	6.623 ± 0.028	0.644 ± 0.050	0.621 ± 0.015	0.669 ± 0.011	0.283 ± 0.011	0.177 ± 0.009	0.434 ± 0.027
	17 Feb 93	12 55	31	6.602 ± 0.034	0.501 ± 0.036	0.634 ± 0.020	0.651 ± 0.010	0.296 ± 0.012	0.174 ± 0.010	0.447 ± 0.019
	17 Feb 93	12 58	32	6.608 ± 0.034	0.505 ± 0.037	0.625 ± 0.022	0.658 ± 0.009	0.294 ± 0.013	0.172 ± 0.010	0.454 ± 0.018
	18 Feb 93	10 48	32	6.590 ± 0.030	0.495 ± 0.065	0.624 ± 0.015	0.658 ± 0.011	0.293 ± 0.014	0.173 ± 0.011	0.449 ± 0.025
	18 Feb 93	10 50	33	6.597 ± 0.031	0.495 ± 0.064	0.617 ± 0.016	0.664 ± 0.012	0.291 ± 0.014	0.171 ± 0.014	0.451 ± 0.025
E4.046	15 Feb 93	14 48	61	6.588 ± 0.043	0.529 ± 0.077	0.703 ± 0.037	0.510 ± 0.020	0.200 ± 0.019	0.114 ± 0.014	0.315 ± 0.013
	15 Feb 93	14 50	62	6.581 ± 0.043	0.544 ± 0.077	0.701 ± 0.038	0.502 ± 0.020	0.201 ± 0.019	0.123 ± 0.014	0.308 ± 0.012
	16 Feb 93	11 50	52	6.566 ± 0.027	0.621 ± 0.047	0.717 ± 0.016	0.510 ± 0.010	0.209 ± 0.011	0.117 ± 0.008	0.272 ± 0.023
	16 Feb 93	11 52	53	6.569 ± 0.028	0.585 ± 0.047	0.723 ± 0.013	0.505 ± 0.011	0.207 ± 0.010	0.119 ± 0.009	0.282 ± 0.024
	17 Feb 93	13 42	43	6.542 ± 0.033	0.485 ± 0.036	0.746 ± 0.019	0.490 ± 0.010	0.197 ± 0.012	0.118 ± 0.008	0.309 ± 0.021
	17 Feb 93	13 44	44	6.543 ± 0.033	0.526 ± 0.035	0.738 ± 0.019	0.488 ± 0.009	0.203 ± 0.012	0.122 ± 0.009	0.294 ± 0.022
	18 Feb 93	10 54	34	6.538 ± 0.029	0.471 ± 0.062	0.724 ± 0.017	0.498 ± 0.014	0.210 ± 0.013	0.114 ± 0.009	0.277 ± 0.021
E4.047	18 Feb 93	10 56	35	6.543 ± 0.029	0.463 ± 0.061	0.729 ± 0.015	0.503 ± 0.012	0.205 ± 0.013	0.114 ± 0.010	0.286 ± 0.021
	15 Feb 93	14 54	63	5.533 ± 0.048	0.537 ± 0.091	0.890 ± 0.046	1.242 ± 0.024	0.443 ± 0.022	0.299 ± 0.015	0.688 ± 0.015
	15 Feb 93	14 56	64	5.536 ± 0.048	0.531 ± 0.092	0.892 ± 0.046	1.239 ± 0.023	0.448 ± 0.022	0.298 ± 0.015	0.696 ± 0.012

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E4_047	16 Feb 93	11 55	54	5.509 ± 0.032	0.551 ± 0.051	0.878 ± 0.017	1.254 ± 0.012	0.457 ± 0.012	0.286 ± 0.011	0.685 ± 0.031
	16 Feb 93	11 57	55	5.515 ± 0.032	0.588 ± 0.052	0.868 ± 0.018	1.264 ± 0.012	0.461 ± 0.013	0.281 ± 0.011	0.682 ± 0.031
	17 Feb 93	13 48	45	5.503 ± 0.039	0.507 ± 0.041	0.883 ± 0.025	1.255 ± 0.011	0.464 ± 0.015	0.290 ± 0.010	0.677 ± 0.020
	17 Feb 93	13 50	46	5.509 ± 0.039	0.551 ± 0.042	0.887 ± 0.026	1.243 ± 0.011	0.467 ± 0.015	0.285 ± 0.010	0.695 ± 0.020
	18 Feb 93	11 38	46	5.497 ± 0.034	0.515 ± 0.072	0.890 ± 0.020	1.247 ± 0.013	0.470 ± 0.016	0.274 ± 0.012	0.690 ± 0.030
	18 Feb 93	11 40	47	5.490 ± 0.034	0.499 ± 0.071	0.880 ± 0.019	1.257 ± 0.013	0.471 ± 0.016	0.282 ± 0.012	0.685 ± 0.030
	15 Feb 93	15 19	71	5.927 ± 0.043	0.309 ± 0.076	0.410 ± 0.036	0.181 ± 0.019	0.073 ± 0.019	0.030 ± 0.015	0.116 ± 0.015
E4_078	15 Feb 93	15 22	72	5.928 ± 0.044	0.304 ± 0.076	0.414 ± 0.037	0.175 ± 0.021	0.069 ± 0.021	0.033 ± 0.015	0.124 ± 0.014
	16 Feb 93	12 44	66	5.881 ± 0.027	0.325 ± 0.046	0.443 ± 0.014	0.175 ± 0.011	0.078 ± 0.013	0.037 ± 0.011	0.082 ± 0.022
	16 Feb 93	12 46	67	5.878 ± 0.027	0.277 ± 0.046	0.441 ± 0.013	0.177 ± 0.010	0.086 ± 0.011	0.028 ± 0.009	0.078 ± 0.022
	17 Feb 93	13 53	47	5.867 ± 0.032	0.255 ± 0.036	0.461 ± 0.019	0.162 ± 0.011	0.071 ± 0.013	0.041 ± 0.010	0.082 ± 0.017
	17 Feb 93	13 56	48	5.869 ± 0.034	0.268 ± 0.036	0.458 ± 0.019	0.162 ± 0.009	0.070 ± 0.012	0.039 ± 0.013	0.083 ± 0.018
	18 Feb 93	11 43	48	5.868 ± 0.027	0.234 ± 0.058	0.447 ± 0.014	0.172 ± 0.011	0.085 ± 0.013	0.031 ± 0.009	0.081 ± 0.018
	18 Feb 93	11 46	49	5.870 ± 0.027	0.275 ± 0.058	0.446 ± 0.013	0.172 ± 0.010	0.086 ± 0.012	0.027 ± 0.009	0.081 ± 0.019
E4_079	15 Feb 93	15 26	73	5.325 ± 0.044	0.278 ± 0.076	0.352 ± 0.037	0.164 ± 0.021	0.066 ± 0.021	0.025 ± 0.016	0.118 ± 0.014
	15 Feb 93	15 28	74	5.326 ± 0.044	0.248 ± 0.076	0.351 ± 0.037	0.164 ± 0.022	0.069 ± 0.020	0.029 ± 0.013	0.119 ± 0.014
	16 Feb 93	12 50	68	5.273 ± 0.027	0.288 ± 0.046	0.385 ± 0.015	0.171 ± 0.013	0.079 ± 0.012	0.038 ± 0.011	0.063 ± 0.023
	16 Feb 93	12 52	69	5.279 ± 0.027	0.240 ± 0.046	0.386 ± 0.016	0.156 ± 0.013	0.083 ± 0.013	0.034 ± 0.011	0.073 ± 0.023
	17 Feb 93	14 41	59	5.255 ± 0.033	0.251 ± 0.039	0.408 ± 0.019	0.140 ± 0.012	0.067 ± 0.013	0.038 ± 0.010	0.097 ± 0.017
	17 Feb 93	14 43	60	5.275 ± 0.033	0.247 ± 0.037	0.404 ± 0.021	0.141 ± 0.014	0.063 ± 0.015	0.032 ± 0.011	0.098 ± 0.017
	18 Feb 93	11 50	50	5.253 ± 0.027	0.215 ± 0.058	0.384 ± 0.014	0.160 ± 0.013	0.084 ± 0.014	0.032 ± 0.009	0.079 ± 0.019
E4_093	18 Feb 93	11 52	51	5.242 ± 0.027	0.255 ± 0.058	0.393 ± 0.015	0.157 ± 0.012	0.076 ± 0.014	0.035 ± 0.011	0.072 ± 0.019
	15 Feb 93	15 32	75	5.881 ± 0.044	0.126 ± 0.076	0.157 ± 0.037	0.113 ± 0.019	0.052 ± 0.019	0.001 ± 0.013	0.088 ± 0.014
	15 Feb 93	15 34	76	5.885 ± 0.044	0.113 ± 0.076	0.159 ± 0.036	0.113 ± 0.020	0.048 ± 0.019	-0.001 ± 0.013	0.090 ± 0.015
	16 Feb 93	12 56	70	5.829 ± 0.028	0.082 ± 0.046	0.190 ± 0.013	0.108 ± 0.010	0.061 ± 0.013	0.009 ± 0.015	0.039 ± 0.025
	16 Feb 93	12 58	71	5.824 ± 0.026	0.080 ± 0.046	0.188 ± 0.014	0.108 ± 0.012	0.060 ± 0.012	0.013 ± 0.009	0.041 ± 0.023
	17 Feb 93	14 47	61	5.813 ± 0.033	0.095 ± 0.038	0.201 ± 0.019	0.097 ± 0.013	0.033 ± 0.015	0.029 ± 0.010	0.046 ± 0.020
	17 Feb 93	14 49	62	5.814 ± 0.033	0.116 ± 0.038	0.213 ± 0.019	0.095 ± 0.010	0.034 ± 0.014	0.026 ± 0.010	0.058 ± 0.015
E4_094	18 Feb 93	12 43	62	5.798 ± 0.027	0.116 ± 0.058	0.188 ± 0.014	0.104 ± 0.011	0.059 ± 0.012	0.010 ± 0.010	0.036 ± 0.019
	18 Feb 93	12 45	63	5.799 ± 0.027	0.121 ± 0.058	0.183 ± 0.013	0.111 ± 0.010	0.058 ± 0.012	0.013 ± 0.009	0.050 ± 0.018
	15 Feb 93	15 38	77	6.004 ± 0.044	0.551 ± 0.077	0.707 ± 0.037	0.253 ± 0.020	0.093 ± 0.020	0.042 ± 0.014	0.153 ± 0.014

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E4.094	15 Feb 93	15 40	78	5.998 ± 0.044	0.514 ± 0.077	0.698 ± 0.037	0.256 ± 0.019	0.097 ± 0.019	0.044 ± 0.014	0.156 ± 0.015
	16 Feb 93	13 43	82	5.935 ± 0.028	0.537 ± 0.048	0.737 ± 0.015	0.253 ± 0.011	0.106 ± 0.011	0.047 ± 0.010	0.110 ± 0.024
	16 Feb 93	13 45	83	5.945 ± 0.028	0.535 ± 0.048	0.734 ± 0.015	0.250 ± 0.010	0.101 ± 0.011	0.050 ± 0.011	0.109 ± 0.024
	18 Feb 93	12 49	64	5.932 ± 0.027	0.580 ± 0.058	0.732 ± 0.013	0.254 ± 0.010	0.108 ± 0.012	0.040 ± 0.009	0.118 ± 0.020
	18 Feb 93	12 51	65	5.932 ± 0.027	0.629 ± 0.058	0.736 ± 0.013	0.246 ± 0.010	0.103 ± 0.014	0.043 ± 0.011	0.116 ± 0.019
	15 Feb 93	15 45	79	6.835 ± 0.044	0.541 ± 0.077	0.773 ± 0.037	0.297 ± 0.019	0.108 ± 0.018	0.040 ± 0.013	0.144 ± 0.012
E4.096	15 Feb 93	15 47	80	6.829 ± 0.045	0.538 ± 0.078	0.787 ± 0.038	0.285 ± 0.020	0.108 ± 0.019	0.043 ± 0.014	0.148 ± 0.014
	16 Feb 93	13 49	84	6.783 ± 0.028	0.542 ± 0.047	0.809 ± 0.013	0.286 ± 0.010	0.114 ± 0.010	0.051 ± 0.009	0.100 ± 0.023
	16 Feb 93	13 51	85	6.782 ± 0.028	0.550 ± 0.048	0.803 ± 0.013	0.291 ± 0.011	0.112 ± 0.012	0.050 ± 0.010	0.102 ± 0.023
	18 Feb 93	13 30	76	6.756 ± 0.028	0.640 ± 0.060	0.813 ± 0.014	0.275 ± 0.010	0.116 ± 0.013	0.050 ± 0.011	0.098 ± 0.020
	18 Feb 93	13 32	77	6.765 ± 0.029	0.642 ± 0.060	0.808 ± 0.015	0.284 ± 0.011	0.116 ± 0.013	0.043 ± 0.013	0.107 ± 0.022
	15 Feb 93	15 51	81	6.366 ± 0.044	0.233 ± 0.076	0.315 ± 0.037	0.163 ± 0.020	0.071 ± 0.018	0.025 ± 0.014	0.133 ± 0.016
E4.097	15 Feb 93	15 53	82	6.367 ± 0.044	0.194 ± 0.076	0.325 ± 0.036	0.154 ± 0.019	0.073 ± 0.018	0.021 ± 0.013	0.138 ± 0.015
	16 Feb 93	13 54	86	6.322 ± 0.027	0.243 ± 0.047	0.349 ± 0.013	0.165 ± 0.010	0.081 ± 0.011	0.028 ± 0.009	0.088 ± 0.024
	16 Feb 93	13 57	87	6.326 ± 0.028	0.260 ± 0.047	0.350 ± 0.013	0.160 ± 0.009	0.083 ± 0.011	0.024 ± 0.010	0.087 ± 0.024
	18 Feb 93	13 36	78	6.295 ± 0.028	0.330 ± 0.059	0.356 ± 0.013	0.149 ± 0.010	0.082 ± 0.014	0.033 ± 0.012	0.084 ± 0.019
	18 Feb 93	13 38	79	6.297 ± 0.028	0.332 ± 0.059	0.349 ± 0.013	0.151 ± 0.011	0.082 ± 0.013	0.034 ± 0.009	0.094 ± 0.022
	15 Feb 93	15 56	83	6.308 ± 0.044	0.366 ± 0.077	0.483 ± 0.036	0.192 ± 0.019	0.085 ± 0.019	0.036 ± 0.015	0.153 ± 0.019
E4.098	15 Feb 93	15 59	84	6.305 ± 0.044	0.365 ± 0.077	0.485 ± 0.037	0.195 ± 0.019	0.078 ± 0.020	0.038 ± 0.015	0.143 ± 0.015
	16 Feb 93	14 42	98	6.257 ± 0.028	0.429 ± 0.050	0.504 ± 0.015	0.196 ± 0.011	0.090 ± 0.011	0.034 ± 0.009	0.105 ± 0.025
	16 Feb 93	14 44	99	6.262 ± 0.028	0.486 ± 0.050	0.502 ± 0.013	0.196 ± 0.010	0.091 ± 0.011	0.035 ± 0.009	0.115 ± 0.023
	18 Feb 93	13 42	80	6.252 ± 0.028	0.471 ± 0.060	0.509 ± 0.014	0.181 ± 0.011	0.093 ± 0.013	0.038 ± 0.009	0.110 ± 0.019
	18 Feb 93	13 44	81	6.248 ± 0.028	0.438 ± 0.060	0.510 ± 0.013	0.192 ± 0.010	0.094 ± 0.012	0.033 ± 0.009	0.115 ± 0.019
	01 Jul 93	06 28	3	5.173 ± 0.021	0.528 ± 0.018	0.577 ± 0.010	0.593 ± 0.011	0.268 ± 0.011	0.164 ± 0.008	0.433 ± 0.011
E5.040	01 Jul 93	06 31	4	5.178 ± 0.021	0.527 ± 0.018	0.582 ± 0.010	0.588 ± 0.012	0.272 ± 0.011	0.159 ± 0.009	0.437 ± 0.013
	01 Jul 93	07 53	22	5.148 ± 0.022	0.533 ± 0.018	0.575 ± 0.010	0.598 ± 0.012	0.270 ± 0.012	0.165 ± 0.010	0.431 ± 0.011
	01 Jul 93	07 55	23	5.155 ± 0.022	0.532 ± 0.019	0.578 ± 0.012	0.600 ± 0.013	0.267 ± 0.012	0.166 ± 0.009	0.435 ± 0.012
	01 Jul 93	09 04	41	5.148 ± 0.023	0.529 ± 0.019	0.579 ± 0.010	0.601 ± 0.012	0.269 ± 0.012	0.166 ± 0.009	0.429 ± 0.012
	01 Jul 93	09 07	42	5.148 ± 0.023	0.525 ± 0.018	0.578 ± 0.012	0.603 ± 0.013	0.268 ± 0.012	0.167 ± 0.009	0.435 ± 0.011
	01 Jul 93	10 00	56	5.156 ± 0.024	0.530 ± 0.020	0.575 ± 0.011	0.606 ± 0.013	0.269 ± 0.013	0.168 ± 0.011	0.424 ± 0.016
	01 Jul 93	10 03	57	5.146 ± 0.024	0.528 ± 0.020	0.574 ± 0.010	0.607 ± 0.014	0.264 ± 0.014	0.169 ± 0.010	0.425 ± 0.012

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Table D.4 continued from previous page										
star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E5_040	01 Jul 93	11 04	72	5.151 ± 0.027	0.529 ± 0.022	0.576 ± 0.013	0.604 ± 0.014	0.262 ± 0.013	0.168 ± 0.012	0.443 ± 0.015
	01 Jul 93	11 07	73	5.145 ± 0.027	0.503 ± 0.022	0.581 ± 0.011	0.603 ± 0.013	0.267 ± 0.013	0.169 ± 0.011	0.439 ± 0.014
	01 Jul 93	12 03	86	5.225 ± 0.033	0.516 ± 0.026	0.572 ± 0.015	0.598 ± 0.017	0.283 ± 0.019	0.159 ± 0.020	0.441 ± 0.020
	01 Jul 93	12 06	87	5.231 ± 0.032	0.503 ± 0.025	0.568 ± 0.015	0.600 ± 0.018	0.265 ± 0.016	0.170 ± 0.015	0.428 ± 0.019
	02 Jul 93	06 56	2	5.173 ± 0.014	0.534 ± 0.023	0.579 ± 0.012	0.597 ± 0.012	0.273 ± 0.013	0.163 ± 0.010	0.438 ± 0.014
	02 Jul 93	06 59	3	5.177 ± 0.014	0.533 ± 0.023	0.576 ± 0.012	0.594 ± 0.013	0.281 ± 0.013	0.163 ± 0.010	0.440 ± 0.014
	02 Jul 93	07 57	18	5.191 ± 0.015	0.497 ± 0.024	0.575 ± 0.012	0.597 ± 0.013	0.282 ± 0.014	0.159 ± 0.011	0.430 ± 0.014
	02 Jul 93	07 59	19	5.182 ± 0.015	0.533 ± 0.024	0.574 ± 0.012	0.593 ± 0.012	0.280 ± 0.013	0.159 ± 0.011	0.433 ± 0.015
	02 Jul 93	09 01	36	5.159 ± 0.016	0.535 ± 0.024	0.580 ± 0.012	0.598 ± 0.012	0.280 ± 0.013	0.161 ± 0.011	0.441 ± 0.013
	02 Jul 93	09 04	37	5.164 ± 0.016	0.531 ± 0.024	0.574 ± 0.012	0.601 ± 0.012	0.279 ± 0.013	0.160 ± 0.011	0.442 ± 0.013
	02 Jul 93	10 00	54	5.147 ± 0.017	0.534 ± 0.025	0.578 ± 0.013	0.599 ± 0.013	0.277 ± 0.014	0.166 ± 0.011	0.438 ± 0.014
	02 Jul 93	10 03	55	5.151 ± 0.017	0.530 ± 0.025	0.576 ± 0.012	0.599 ± 0.012	0.278 ± 0.014	0.165 ± 0.012	0.434 ± 0.016
	02 Jul 93	11 05	72	5.197 ± 0.020	0.541 ± 0.027	0.570 ± 0.012	0.600 ± 0.012	0.287 ± 0.014	0.159 ± 0.012	0.433 ± 0.016
	02 Jul 93	11 08	73	5.195 ± 0.020	0.538 ± 0.027	0.576 ± 0.013	0.594 ± 0.013	0.291 ± 0.015	0.155 ± 0.012	0.435 ± 0.014
	02 Jul 93	12 07	88	5.173 ± 0.025	0.505 ± 0.031	0.570 ± 0.016	0.602 ± 0.016	0.261 ± 0.016	0.183 ± 0.013	0.428 ± 0.017
	02 Jul 93	12 10	89	5.170 ± 0.027	0.508 ± 0.032	0.569 ± 0.016	0.611 ± 0.016	0.280 ± 0.020	0.158 ± 0.020	0.432 ± 0.019
	03 Jul 93	06 35	2	5.167 ± 0.026	0.520 ± 0.025	0.581 ± 0.012	0.594 ± 0.015	0.271 ± 0.013	0.159 ± 0.009	0.439 ± 0.016
	03 Jul 93	08 05	17	5.148 ± 0.027	0.520 ± 0.025	0.586 ± 0.012	0.603 ± 0.016	0.274 ± 0.014	0.156 ± 0.009	0.432 ± 0.015
	03 Jul 93	09 03	28	5.135 ± 0.028	0.513 ± 0.026	0.589 ± 0.014	0.603 ± 0.016	0.268 ± 0.014	0.167 ± 0.010	0.431 ± 0.015
	03 Jul 93	09 60	39	5.138 ± 0.031	0.506 ± 0.028	0.586 ± 0.016	0.596 ± 0.017	0.267 ± 0.018	0.164 ± 0.016	0.430 ± 0.019
	03 Jul 93	11 01	50	5.177 ± 0.033	0.514 ± 0.032	0.574 ± 0.021	0.598 ± 0.022	0.288 ± 0.020	0.149 ± 0.011	0.437 ± 0.018
	03 Jul 93	12 08	62	5.175 ± 0.040	0.516 ± 0.034	0.568 ± 0.020	0.609 ± 0.029	0.258 ± 0.029	0.165 ± 0.018	0.438 ± 0.021
	04 Jul 93	07 16	2	5.204 ± 0.019	0.499 ± 0.053	0.581 ± 0.023	0.576 ± 0.010	0.279 ± 0.032	0.164 ± 0.022	0.425 ± 0.023
	04 Jul 93	08 01	10	5.196 ± 0.019	0.506 ± 0.052	0.583 ± 0.023	0.585 ± 0.012	0.273 ± 0.033	0.166 ± 0.022	0.421 ± 0.022
	04 Jul 93	10 02	27	5.206 ± 0.020	0.516 ± 0.053	0.579 ± 0.025	0.579 ± 0.015	0.289 ± 0.035	0.159 ± 0.023	0.432 ± 0.023
	04 Jul 93	11 02	38	5.187 ± 0.024	0.502 ± 0.054	0.577 ± 0.025	0.581 ± 0.012	0.285 ± 0.036	0.163 ± 0.027	0.427 ± 0.025
	04 Jul 93	12 11	50	5.180 ± 0.027	0.507 ± 0.056	0.566 ± 0.029	0.596 ± 0.021	0.272 ± 0.041	0.172 ± 0.029	0.428 ± 0.026
	06 Jul 93	06 44	2	5.159 ± 0.041	0.526 ± 0.044	0.576 ± 0.020	0.607 ± 0.020	0.276 ± 0.017	0.160 ± 0.013	0.445 ± 0.019
	06 Jul 93	09 03	24	5.135 ± 0.042	0.524 ± 0.045	0.574 ± 0.021	0.615 ± 0.020	0.275 ± 0.018	0.167 ± 0.014	0.436 ± 0.020
	06 Jul 93	10 08	35	5.168 ± 0.043	0.539 ± 0.045	0.574 ± 0.021	0.606 ± 0.021	0.278 ± 0.019	0.162 ± 0.015	0.446 ± 0.021
	06 Jul 93	11 08	46	5.142 ± 0.045	0.538 ± 0.047	0.578 ± 0.022	0.608 ± 0.020	0.285 ± 0.020	0.158 ± 0.017	0.448 ± 0.023

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E5.040	06 Jul 93	12 09	57	5.199 ± 0.048	0.527 ± 0.050	0.561 ± 0.026	0.612 ± 0.028	0.262 ± 0.024	0.169 ± 0.017	0.446 ± 0.026
	07 Jul 93	06 48	2	5.196 ± 0.033	0.512 ± 0.021	0.584 ± 0.013	0.590 ± 0.017	0.278 ± 0.012	0.161 ± 0.012	0.447 ± 0.017
	07 Jul 93	08 02	10	5.181 ± 0.036	0.491 ± 0.022	0.587 ± 0.013	0.599 ± 0.017	0.276 ± 0.011	0.169 ± 0.011	0.436 ± 0.017
	07 Jul 93	08 59	20	5.168 ± 0.040	0.521 ± 0.022	0.586 ± 0.013	0.597 ± 0.017	0.276 ± 0.012	0.165 ± 0.012	0.446 ± 0.017
	08 Jul 93	07 04	2	5.173 ± 0.036	0.502 ± 0.022	0.583 ± 0.015	0.593 ± 0.017	0.262 ± 0.018	0.161 ± 0.013	0.435 ± 0.014
	08 Jul 93	08 02	11	5.158 ± 0.037	0.507 ± 0.022	0.584 ± 0.014	0.599 ± 0.016	0.259 ± 0.017	0.165 ± 0.012	0.438 ± 0.014
	08 Jul 93	09 01	20	5.149 ± 0.038	0.506 ± 0.022	0.584 ± 0.014	0.595 ± 0.017	0.262 ± 0.018	0.166 ± 0.013	0.431 ± 0.015
	08 Jul 93	10 18	30	5.160 ± 0.041	0.509 ± 0.023	0.589 ± 0.015	0.597 ± 0.017	0.268 ± 0.018	0.162 ± 0.014	0.447 ± 0.017
E6.012	08 Jul 93	11 23	42	5.148 ± 0.045	0.504 ± 0.024	0.586 ± 0.017	0.605 ± 0.021	0.267 ± 0.020	0.170 ± 0.014	0.450 ± 0.019
	20 May 93	13 29	81	7.915 ± 0.013	0.614 ± 0.015	0.820 ± 0.012	0.460 ± 0.008	0.164 ± 0.012	0.098 ± 0.011	0.236 ± 0.012
	20 May 93	13 32	82	7.911 ± 0.013	0.618 ± 0.015	0.813 ± 0.013	0.456 ± 0.011	0.168 ± 0.010	0.100 ± 0.009	0.216 ± 0.012
	23 May 93	10 41	48	7.929 ± 0.017	0.617 ± 0.015	0.832 ± 0.011	0.438 ± 0.009	0.173 ± 0.014	0.091 ± 0.012	0.194 ± 0.012
E6.013	23 May 93	10 46	49	7.929 ± 0.017	0.603 ± 0.017	0.843 ± 0.009	0.439 ± 0.007	0.165 ± 0.012	0.098 ± 0.010	0.188 ± 0.014
	20 May 93	12 41	73	8.016 ± 0.014	0.673 ± 0.015	0.805 ± 0.009	0.500 ± 0.007	0.181 ± 0.009	0.133 ± 0.010	0.280 ± 0.012
	20 May 93	12 45	74	8.011 ± 0.014	0.662 ± 0.014	0.812 ± 0.011	0.494 ± 0.008	0.196 ± 0.010	0.126 ± 0.011	0.281 ± 0.020
	23 May 93	09 54	39	8.030 ± 0.018	0.661 ± 0.015	0.820 ± 0.011	0.489 ± 0.008	0.191 ± 0.015	0.118 ± 0.014	0.250 ± 0.012
E6.014	23 May 93	09 59	40	8.035 ± 0.017	0.661 ± 0.016	0.827 ± 0.012	0.489 ± 0.008	0.190 ± 0.014	0.114 ± 0.011	0.247 ± 0.015
	20 May 93	14 46	98	8.143 ± 0.018	0.661 ± 0.019	0.801 ± 0.013	0.498 ± 0.008	0.199 ± 0.012	0.126 ± 0.014	0.301 ± 0.020
	20 May 93	14 51	99	8.143 ± 0.015	0.660 ± 0.016	0.809 ± 0.012	0.495 ± 0.008	0.197 ± 0.011	0.131 ± 0.011	0.303 ± 0.015
	23 May 93	12 42	74	8.174 ± 0.017	0.666 ± 0.019	0.823 ± 0.016	0.486 ± 0.007	0.194 ± 0.013	0.122 ± 0.011	0.279 ± 0.012
E6.033	23 May 93	12 47	75	8.170 ± 0.018	0.665 ± 0.015	0.824 ± 0.010	0.483 ± 0.007	0.192 ± 0.014	0.131 ± 0.013	0.272 ± 0.017
	02 Jul 93	07 39	13	6.892 ± 0.018	0.637 ± 0.038	1.172 ± 0.019	1.527 ± 0.016	0.473 ± 0.017	0.389 ± 0.014	0.821 ± 0.019
	02 Jul 93	07 42	14	6.902 ± 0.017	0.624 ± 0.036	1.173 ± 0.018	1.522 ± 0.015	0.481 ± 0.016	0.378 ± 0.013	0.823 ± 0.018
	03 Jul 93	07 37	12	6.865 ± 0.033	0.658 ± 0.039	1.197 ± 0.023	1.520 ± 0.021	0.474 ± 0.017	0.383 ± 0.011	0.818 ± 0.018
E6.039	04 Jul 93	07 45	7	6.940 ± 0.023	0.644 ± 0.073	1.185 ± 0.033	1.518 ± 0.013	0.469 ± 0.043	0.376 ± 0.029	0.822 ± 0.030
	21 May 93	11 51	9	5.487 ± 0.014	0.516 ± 0.014	0.598 ± 0.013	0.211 ± 0.011	0.097 ± 0.010	0.050 ± 0.012	0.111 ± 0.011
	21 May 93	11 54	10	5.480 ± 0.014	0.512 ± 0.015	0.608 ± 0.012	0.212 ± 0.011	0.095 ± 0.011	0.051 ± 0.011	0.112 ± 0.010
	21 May 93	13 37	34	5.478 ± 0.015	0.516 ± 0.015	0.601 ± 0.013	0.213 ± 0.011	0.100 ± 0.011	0.045 ± 0.012	0.114 ± 0.011
	21 May 93	13 39	35	5.480 ± 0.015	0.535 ± 0.016	0.602 ± 0.013	0.215 ± 0.011	0.089 ± 0.011	0.054 ± 0.012	0.115 ± 0.011
	21 May 93	15 45	65	5.475 ± 0.017	0.520 ± 0.018	0.600 ± 0.015	0.217 ± 0.012	0.091 ± 0.012	0.050 ± 0.013	0.123 ± 0.011
	21 May 93	15 48	66	5.470 ± 0.018	0.521 ± 0.019	0.606 ± 0.015	0.206 ± 0.011	0.094 ± 0.012	0.054 ± 0.013	0.123 ± 0.013

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E6.039	21 May 93	17 37	91	5.482 ± 0.026	0.528 ± 0.025	0.600 ± 0.019	0.218 ± 0.014	0.090 ± 0.017	0.049 ± 0.019	0.118 ± 0.017
	21 May 93	17 40	92	5.479 ± 0.025	0.534 ± 0.025	0.577 ± 0.020	0.229 ± 0.016	0.092 ± 0.015	0.053 ± 0.017	0.110 ± 0.015
	01 Jul 93	08 40	34	5.528 ± 0.019	0.547 ± 0.017	0.596 ± 0.011	0.188 ± 0.011	0.101 ± 0.011	0.040 ± 0.007	0.118 ± 0.010
	01 Jul 93	08 43	35	5.531 ± 0.019	0.549 ± 0.017	0.598 ± 0.011	0.187 ± 0.011	0.096 ± 0.011	0.044 ± 0.009	0.114 ± 0.012
	02 Jul 93	07 47	15	5.554 ± 0.014	0.509 ± 0.021	0.586 ± 0.011	0.195 ± 0.011	0.110 ± 0.012	0.037 ± 0.009	0.124 ± 0.013
	02 Jul 93	07 49	16	5.555 ± 0.013	0.536 ± 0.021	0.595 ± 0.012	0.187 ± 0.011	0.111 ± 0.012	0.042 ± 0.009	0.120 ± 0.011
	03 Jul 93	07 43	13	5.537 ± 0.024	0.520 ± 0.023	0.601 ± 0.013	0.196 ± 0.015	0.105 ± 0.015	0.033 ± 0.011	0.126 ± 0.014
	04 Jul 93	07 51	8	5.576 ± 0.016	0.510 ± 0.045	0.588 ± 0.021	0.163 ± 0.011	0.116 ± 0.029	0.050 ± 0.019	0.106 ± 0.019
	07 Jul 93	07 38	6	5.561 ± 0.032	0.509 ± 0.020	0.608 ± 0.013	0.189 ± 0.015	0.104 ± 0.011	0.045 ± 0.010	0.141 ± 0.015
	21 May 93	11 58	11	5.579 ± 0.021	0.773 ± 0.030	1.327 ± 0.022	1.920 ± 0.015	0.593 ± 0.017	0.481 ± 0.018	0.988 ± 0.017
	21 May 93	12 00	12	5.587 ± 0.020	0.737 ± 0.029	1.337 ± 0.020	1.919 ± 0.016	0.589 ± 0.018	0.480 ± 0.019	0.991 ± 0.017
	21 May 93	13 44	36	5.574 ± 0.021	0.755 ± 0.029	1.345 ± 0.026	1.918 ± 0.019	0.596 ± 0.018	0.470 ± 0.019	0.991 ± 0.017
	21 May 93	13 46	37	5.574 ± 0.022	0.767 ± 0.029	1.325 ± 0.024	1.921 ± 0.015	0.583 ± 0.017	0.486 ± 0.019	0.995 ± 0.018
	21 May 93	15 52	67	5.571 ± 0.023	0.750 ± 0.033	1.338 ± 0.026	1.915 ± 0.016	0.592 ± 0.019	0.481 ± 0.019	0.994 ± 0.018
E6.040	21 May 93	15 55	68	5.572 ± 0.023	0.758 ± 0.036	1.323 ± 0.024	1.925 ± 0.017	0.591 ± 0.020	0.481 ± 0.019	0.995 ± 0.018
	21 May 93	17 44	93	5.575 ± 0.030	0.773 ± 0.040	1.326 ± 0.030	1.919 ± 0.019	0.591 ± 0.027	0.493 ± 0.027	0.982 ± 0.022
	21 May 93	17 47	94	5.573 ± 0.029	0.765 ± 0.046	1.324 ± 0.031	1.921 ± 0.019	0.593 ± 0.025	0.497 ± 0.022	0.984 ± 0.020
	01 Jul 93	08 47	36	5.586 ± 0.033	0.747 ± 0.034	1.349 ± 0.021	1.948 ± 0.017	0.587 ± 0.018	0.490 ± 0.012	1.008 ± 0.016
	01 Jul 93	08 50	37	5.586 ± 0.033	0.747 ± 0.031	1.340 ± 0.016	1.952 ± 0.016	0.582 ± 0.017	0.492 ± 0.013	1.008 ± 0.017
	02 Jul 93	08 36	29	5.604 ± 0.020	0.757 ± 0.037	1.339 ± 0.019	1.940 ± 0.018	0.592 ± 0.020	0.490 ± 0.016	1.001 ± 0.021
	02 Jul 93	08 39	30	5.606 ± 0.019	0.736 ± 0.043	1.336 ± 0.020	1.944 ± 0.018	0.592 ± 0.020	0.485 ± 0.015	1.008 ± 0.021
	03 Jul 93	07 49	14	5.566 ± 0.037	0.755 ± 0.037	1.352 ± 0.020	1.942 ± 0.023	0.582 ± 0.019	0.488 ± 0.012	0.998 ± 0.019
	07 Jul 93	07 44	7	5.627 ± 0.035	0.762 ± 0.033	1.347 ± 0.021	1.924 ± 0.026	0.608 ± 0.016	0.480 ± 0.016	0.979 ± 0.026
	01 Jul 93	08 54	38	6.107 ± 0.022	0.523 ± 0.019	0.580 ± 0.011	0.699 ± 0.013	0.298 ± 0.011	0.186 ± 0.009	0.482 ± 0.011
	01 Jul 93	08 57	39	6.091 ± 0.022	0.518 ± 0.019	0.581 ± 0.010	0.698 ± 0.011	0.297 ± 0.011	0.190 ± 0.008	0.485 ± 0.013
	02 Jul 93	08 44	31	6.121 ± 0.015	0.524 ± 0.024	0.584 ± 0.011	0.696 ± 0.011	0.306 ± 0.012	0.183 ± 0.011	0.487 ± 0.015
	02 Jul 93	08 46	32	6.116 ± 0.014	0.499 ± 0.024	0.586 ± 0.011	0.688 ± 0.011	0.306 ± 0.012	0.187 ± 0.010	0.491 ± 0.014
	03 Jul 93	07 55	15	6.084 ± 0.027	0.519 ± 0.026	0.599 ± 0.013	0.691 ± 0.015	0.300 ± 0.014	0.185 ± 0.010	0.487 ± 0.015
E6.042	04 Jul 93	08 39	17	6.141 ± 0.019	0.475 ± 0.054	0.587 ± 0.023	0.676 ± 0.010	0.304 ± 0.033	0.184 ± 0.022	0.476 ± 0.023
	07 Jul 93	07 52	8	6.130 ± 0.033	0.483 ± 0.021	0.595 ± 0.013	0.687 ± 0.017	0.309 ± 0.011	0.185 ± 0.011	0.485 ± 0.017
	23 May 93	12 53	76	6.941 ± 0.018	0.570 ± 0.016	0.793 ± 0.012	0.322 ± 0.009	0.137 ± 0.014	0.073 ± 0.013	0.137 ± 0.014

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E6.042	23 May 93	12 55	77	6.948 ± 0.017	0.572 ± 0.014	0.796 ± 0.010	0.317 ± 0.008	0.134 ± 0.013	0.072 ± 0.010	0.146 ± 0.010
	03 Jul 93	08 53	26	6.941 ± 0.024	0.562 ± 0.024	0.787 ± 0.012	0.326 ± 0.013	0.132 ± 0.012	0.060 ± 0.008	0.178 ± 0.015
	04 Jul 93	08 44	18	6.978 ± 0.016	0.568 ± 0.046	0.780 ± 0.020	0.295 ± 0.010	0.143 ± 0.030	0.072 ± 0.019	0.156 ± 0.021
	07 Jul 93	08 38	16	6.951 ± 0.032	0.533 ± 0.020	0.787 ± 0.013	0.318 ± 0.015	0.134 ± 0.011	0.066 ± 0.010	0.189 ± 0.019
	01 Jul 93	09 36	49	5.750 ± 0.019	0.604 ± 0.016	0.833 ± 0.010	0.364 ± 0.012	0.138 ± 0.013	0.064 ± 0.009	0.149 ± 0.012
	01 Jul 93	09 39	50	5.755 ± 0.019	0.631 ± 0.017	0.831 ± 0.009	0.364 ± 0.010	0.137 ± 0.010	0.065 ± 0.007	0.150 ± 0.011
E6.043	02 Jul 93	08 51	33	5.774 ± 0.014	0.614 ± 0.021	0.832 ± 0.011	0.366 ± 0.011	0.143 ± 0.012	0.069 ± 0.010	0.153 ± 0.014
	02 Jul 93	08 54	34	5.777 ± 0.013	0.614 ± 0.021	0.829 ± 0.011	0.365 ± 0.011	0.143 ± 0.012	0.066 ± 0.009	0.156 ± 0.012
	03 Jul 93	08 42	24	5.754 ± 0.024	0.596 ± 0.023	0.833 ± 0.012	0.375 ± 0.014	0.139 ± 0.012	0.055 ± 0.008	0.165 ± 0.014
	04 Jul 93	08 50	19	5.791 ± 0.016	0.598 ± 0.046	0.826 ± 0.020	0.349 ± 0.010	0.141 ± 0.029	0.081 ± 0.019	0.143 ± 0.020
	07 Jul 93	08 44	17	5.779 ± 0.033	0.596 ± 0.019	0.840 ± 0.012	0.370 ± 0.015	0.137 ± 0.010	0.068 ± 0.010	0.178 ± 0.015
	20 May 93	13 40	83	6.317 ± 0.015	0.640 ± 0.019	0.987 ± 0.014	1.329 ± 0.009	0.484 ± 0.012	0.327 ± 0.011	0.772 ± 0.012
	20 May 93	13 43	84	6.317 ± 0.016	0.607 ± 0.022	0.997 ± 0.015	1.320 ± 0.010	0.489 ± 0.012	0.324 ± 0.011	0.767 ± 0.012
	21 May 93	11 43	7	6.334 ± 0.018	0.643 ± 0.027	0.985 ± 0.020	1.317 ± 0.013	0.487 ± 0.013	0.323 ± 0.016	0.752 ± 0.016
E6.044	21 May 93	11 46	8	6.335 ± 0.018	0.632 ± 0.023	0.998 ± 0.020	1.311 ± 0.014	0.500 ± 0.013	0.312 ± 0.016	0.751 ± 0.015
	21 May 93	13 30	32	6.332 ± 0.019	0.631 ± 0.029	1.001 ± 0.023	1.309 ± 0.013	0.491 ± 0.013	0.324 ± 0.017	0.752 ± 0.015
	21 May 93	13 33	33	6.328 ± 0.018	0.626 ± 0.023	1.002 ± 0.020	1.310 ± 0.013	0.494 ± 0.015	0.321 ± 0.017	0.753 ± 0.015
	21 May 93	15 38	63	6.334 ± 0.021	0.617 ± 0.024	0.994 ± 0.017	1.323 ± 0.014	0.490 ± 0.015	0.328 ± 0.018	0.742 ± 0.017
	21 May 93	15 41	64	6.336 ± 0.020	0.639 ± 0.025	0.989 ± 0.021	1.310 ± 0.014	0.500 ± 0.014	0.317 ± 0.017	0.758 ± 0.015
	21 May 93	17 29	89	6.317 ± 0.031	0.633 ± 0.029	1.002 ± 0.025	1.312 ± 0.021	0.495 ± 0.022	0.329 ± 0.027	0.750 ± 0.025
	21 May 93	17 32	90	6.325 ± 0.029	0.640 ± 0.031	1.010 ± 0.025	1.316 ± 0.016	0.485 ± 0.020	0.327 ± 0.025	0.751 ± 0.022
	01 Jul 93	09 44	51	6.346 ± 0.028	0.630 ± 0.027	1.000 ± 0.013	1.329 ± 0.014	0.496 ± 0.014	0.320 ± 0.011	0.758 ± 0.014
	01 Jul 93	09 47	52	6.339 ± 0.027	0.640 ± 0.025	1.001 ± 0.013	1.327 ± 0.014	0.496 ± 0.014	0.323 ± 0.010	0.766 ± 0.013
	02 Jul 93	09 38	47	6.349 ± 0.017	0.660 ± 0.031	0.997 ± 0.015	1.323 ± 0.015	0.497 ± 0.016	0.323 ± 0.013	0.760 ± 0.020
	02 Jul 93	09 41	48	6.358 ± 0.017	0.658 ± 0.035	0.991 ± 0.019	1.328 ± 0.018	0.500 ± 0.017	0.319 ± 0.013	0.773 ± 0.017
	03 Jul 93	08 47	25	6.333 ± 0.032	0.643 ± 0.032	1.015 ± 0.016	1.319 ± 0.019	0.496 ± 0.016	0.318 ± 0.010	0.761 ± 0.018
	04 Jul 93	09 27	21	6.389 ± 0.022	0.595 ± 0.070	1.012 ± 0.030	1.322 ± 0.012	0.483 ± 0.042	0.319 ± 0.027	0.772 ± 0.028
	07 Jul 93	08 49	18	6.371 ± 0.034	0.617 ± 0.028	1.007 ± 0.017	1.317 ± 0.022	0.514 ± 0.013	0.312 ± 0.015	0.747 ± 0.023
	20 May 93	07 37	7	6.814 ± 0.016	0.620 ± 0.013	0.818 ± 0.011	0.347 ± 0.008	0.128 ± 0.011	0.078 ± 0.010	0.166 ± 0.011
	20 May 93	07 40	8	6.808 ± 0.016	0.623 ± 0.013	0.818 ± 0.009	0.359 ± 0.008	0.119 ± 0.011	0.075 ± 0.010	0.162 ± 0.011
	20 May 93	08 24	18	6.800 ± 0.015	0.624 ± 0.012	0.823 ± 0.008	0.354 ± 0.007	0.123 ± 0.010	0.082 ± 0.010	0.165 ± 0.010

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Table D.4 continued from previous page										
star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E6.045	20 May 93	08 27	19	6.807 ± 0.016	0.625 ± 0.013	0.819 ± 0.010	0.359 ± 0.009	0.116 ± 0.011	0.081 ± 0.011	0.173 ± 0.011
	20 May 93	10 34	47	6.792 ± 0.013	0.624 ± 0.013	0.819 ± 0.008	0.354 ± 0.006	0.132 ± 0.010	0.070 ± 0.009	0.167 ± 0.011
	20 May 93	10 37	48	6.791 ± 0.014	0.624 ± 0.012	0.824 ± 0.008	0.354 ± 0.008	0.124 ± 0.010	0.079 ± 0.011	0.168 ± 0.011
	20 May 93	12 32	71	6.781 ± 0.013	0.625 ± 0.014	0.822 ± 0.009	0.357 ± 0.007	0.122 ± 0.010	0.083 ± 0.010	0.169 ± 0.010
	20 May 93	12 35	72	6.777 ± 0.013	0.629 ± 0.013	0.825 ± 0.008	0.358 ± 0.008	0.121 ± 0.010	0.087 ± 0.010	0.153 ± 0.010
	20 May 93	14 57	100	6.755 ± 0.015	0.609 ± 0.015	0.835 ± 0.010	0.355 ± 0.007	0.134 ± 0.010	0.074 ± 0.009	0.168 ± 0.011
	20 May 93	14 60	101	6.753 ± 0.015	0.609 ± 0.013	0.830 ± 0.010	0.350 ± 0.009	0.142 ± 0.012	0.068 ± 0.010	0.169 ± 0.010
	20 May 93	17 08	125	6.773 ± 0.023	0.629 ± 0.018	0.824 ± 0.014	0.353 ± 0.009	0.128 ± 0.014	0.080 ± 0.017	0.150 ± 0.016
	20 May 93	17 11	126	6.782 ± 0.021	0.617 ± 0.015	0.816 ± 0.017	0.356 ± 0.015	0.121 ± 0.016	0.089 ± 0.016	0.154 ± 0.014
	21 May 93	11 35	5	6.738 ± 0.015	0.612 ± 0.015	0.843 ± 0.012	0.353 ± 0.009	0.134 ± 0.009	0.064 ± 0.012	0.141 ± 0.013
	21 May 93	11 37	6	6.731 ± 0.014	0.619 ± 0.016	0.834 ± 0.013	0.352 ± 0.010	0.136 ± 0.011	0.070 ± 0.012	0.139 ± 0.011
	21 May 93	13 23	30	6.734 ± 0.015	0.627 ± 0.017	0.842 ± 0.014	0.354 ± 0.010	0.129 ± 0.010	0.074 ± 0.012	0.140 ± 0.012
	21 May 93	13 26	31	6.734 ± 0.014	0.614 ± 0.016	0.838 ± 0.013	0.351 ± 0.009	0.136 ± 0.010	0.070 ± 0.012	0.141 ± 0.011
	21 May 93	15 24	61	6.734 ± 0.016	0.608 ± 0.017	0.849 ± 0.012	0.346 ± 0.010	0.131 ± 0.011	0.077 ± 0.013	0.141 ± 0.016
	21 May 93	15 27	62	6.734 ± 0.016	0.607 ± 0.017	0.835 ± 0.013	0.358 ± 0.010	0.138 ± 0.012	0.066 ± 0.013	0.146 ± 0.014
	21 May 93	17 22	87	6.727 ± 0.024	0.629 ± 0.023	0.840 ± 0.019	0.348 ± 0.012	0.137 ± 0.012	0.068 ± 0.017	0.145 ± 0.020
	21 May 93	17 25	88	6.721 ± 0.023	0.624 ± 0.021	0.840 ± 0.017	0.356 ± 0.013	0.136 ± 0.012	0.067 ± 0.017	0.136 ± 0.016
	23 May 93	07 31	8	6.787 ± 0.020	0.609 ± 0.016	0.854 ± 0.013	0.340 ± 0.011	0.123 ± 0.015	0.067 ± 0.015	0.121 ± 0.015
	23 May 93	07 33	9	6.786 ± 0.019	0.616 ± 0.015	0.841 ± 0.011	0.351 ± 0.008	0.128 ± 0.013	0.062 ± 0.013	0.131 ± 0.012
	23 May 93	09 34	35	6.800 ± 0.017	0.601 ± 0.015	0.854 ± 0.011	0.347 ± 0.008	0.134 ± 0.014	0.063 ± 0.012	0.124 ± 0.010
	23 May 93	09 37	36	6.790 ± 0.017	0.615 ± 0.015	0.848 ± 0.011	0.346 ± 0.009	0.127 ± 0.013	0.071 ± 0.011	0.131 ± 0.010
	23 May 93	12 32	72	6.773 ± 0.016	0.617 ± 0.016	0.846 ± 0.011	0.348 ± 0.007	0.131 ± 0.012	0.070 ± 0.010	0.126 ± 0.010
	23 May 93	12 35	73	6.780 ± 0.018	0.613 ± 0.016	0.846 ± 0.013	0.348 ± 0.009	0.130 ± 0.014	0.072 ± 0.013	0.116 ± 0.012
	23 May 93	13 58	93	6.780 ± 0.018	0.619 ± 0.014	0.848 ± 0.011	0.345 ± 0.010	0.130 ± 0.014	0.074 ± 0.012	0.121 ± 0.016
	23 May 93	14 02	94	6.780 ± 0.017	0.615 ± 0.014	0.846 ± 0.010	0.347 ± 0.008	0.133 ± 0.013	0.071 ± 0.011	0.116 ± 0.011
	23 May 93	16 08	122	6.771 ± 0.021	0.627 ± 0.019	0.851 ± 0.015	0.345 ± 0.010	0.135 ± 0.013	0.070 ± 0.014	0.125 ± 0.018
	23 May 93	16 10	123	6.768 ± 0.020	0.625 ± 0.017	0.845 ± 0.013	0.353 ± 0.010	0.130 ± 0.014	0.078 ± 0.013	0.124 ± 0.015
	23 May 93	17 60	146	6.789 ± 0.027	0.641 ± 0.025	0.838 ± 0.025	0.346 ± 0.019	0.127 ± 0.020	0.070 ± 0.017	0.124 ± 0.016
	23 May 93	18 02	147	6.791 ± 0.028	0.631 ± 0.027	0.826 ± 0.023	0.366 ± 0.013	0.122 ± 0.017	0.067 ± 0.018	0.131 ± 0.021
	01 Jul 93	09 51	53	6.776 ± 0.019	0.615 ± 0.016	0.838 ± 0.009	0.344 ± 0.009	0.130 ± 0.012	0.064 ± 0.010	0.152 ± 0.011
	01 Jul 93	09 54	54	6.774 ± 0.020	0.648 ± 0.016	0.832 ± 0.009	0.344 ± 0.009	0.126 ± 0.010	0.068 ± 0.009	0.142 ± 0.012

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E6_045	03 Jul 93	09 40	35	6.760 ± 0.024	0.584 ± 0.023	0.838 ± 0.011	0.350 ± 0.014	0.127 ± 0.013	0.061 ± 0.008	0.159 ± 0.018
	20 May 93	11 32	58	7.072 ± 0.013	0.558 ± 0.012	0.653 ± 0.010	0.576 ± 0.009	0.236 ± 0.009	0.162 ± 0.009	0.390 ± 0.009
	20 May 93	11 35	59	7.079 ± 0.014	0.574 ± 0.012	0.648 ± 0.008	0.579 ± 0.008	0.232 ± 0.010	0.160 ± 0.010	0.400 ± 0.015
	23 May 93	10 54	50	7.085 ± 0.018	0.560 ± 0.016	0.668 ± 0.011	0.573 ± 0.009	0.238 ± 0.014	0.150 ± 0.012	0.363 ± 0.012
	23 May 93	10 57	51	7.085 ± 0.019	0.552 ± 0.015	0.669 ± 0.011	0.572 ± 0.008	0.243 ± 0.013	0.148 ± 0.012	0.365 ± 0.015
E6_047	20 May 93	07 28	5	6.608 ± 0.017	0.499 ± 0.013	0.549 ± 0.010	0.651 ± 0.012	0.294 ± 0.015	0.178 ± 0.012	0.470 ± 0.011
	20 May 93	07 31	6	6.627 ± 0.017	0.496 ± 0.016	0.542 ± 0.010	0.657 ± 0.010	0.280 ± 0.012	0.183 ± 0.011	0.475 ± 0.013
	20 May 93	08 15	16	6.620 ± 0.017	0.492 ± 0.013	0.545 ± 0.009	0.654 ± 0.009	0.288 ± 0.012	0.179 ± 0.012	0.478 ± 0.013
	20 May 93	08 18	17	6.615 ± 0.016	0.491 ± 0.012	0.551 ± 0.009	0.653 ± 0.007	0.277 ± 0.011	0.191 ± 0.011	0.479 ± 0.013
	20 May 93	09 18	30	6.613 ± 0.015	0.492 ± 0.013	0.546 ± 0.010	0.664 ± 0.008	0.284 ± 0.011	0.181 ± 0.011	0.475 ± 0.012
	20 May 93	09 21	31	6.612 ± 0.014	0.497 ± 0.013	0.552 ± 0.010	0.654 ± 0.008	0.287 ± 0.011	0.178 ± 0.010	0.470 ± 0.010
	20 May 93	10 27	45	6.614 ± 0.014	0.489 ± 0.012	0.552 ± 0.009	0.659 ± 0.008	0.280 ± 0.010	0.178 ± 0.010	0.478 ± 0.010
	20 May 93	10 30	46	6.614 ± 0.015	0.498 ± 0.012	0.549 ± 0.010	0.659 ± 0.010	0.284 ± 0.010	0.180 ± 0.011	0.478 ± 0.011
	20 May 93	11 19	55	6.612 ± 0.015	0.495 ± 0.011	0.547 ± 0.008	0.660 ± 0.008	0.284 ± 0.010	0.185 ± 0.012	0.477 ± 0.012
	20 May 93	11 22	56	6.621 ± 0.014	0.494 ± 0.014	0.539 ± 0.011	0.665 ± 0.009	0.288 ± 0.010	0.177 ± 0.009	0.479 ± 0.010
	20 May 93	12 23	68	6.608 ± 0.013	0.491 ± 0.012	0.551 ± 0.009	0.658 ± 0.010	0.287 ± 0.011	0.179 ± 0.009	0.475 ± 0.013
	20 May 93	12 25	69	6.612 ± 0.013	0.509 ± 0.011	0.540 ± 0.008	0.660 ± 0.008	0.285 ± 0.011	0.184 ± 0.011	0.478 ± 0.012
	20 May 93	13 17	78	6.588 ± 0.014	0.500 ± 0.014	0.548 ± 0.010	0.659 ± 0.008	0.292 ± 0.010	0.183 ± 0.009	0.473 ± 0.012
	20 May 93	13 20	79	6.597 ± 0.014	0.503 ± 0.012	0.541 ± 0.009	0.662 ± 0.009	0.292 ± 0.010	0.178 ± 0.010	0.481 ± 0.010
	20 May 93	14 13	91	6.576 ± 0.015	0.498 ± 0.014	0.551 ± 0.010	0.659 ± 0.007	0.293 ± 0.010	0.183 ± 0.011	0.482 ± 0.011
	20 May 93	14 15	92	6.580 ± 0.015	0.480 ± 0.013	0.549 ± 0.009	0.662 ± 0.007	0.291 ± 0.010	0.184 ± 0.010	0.468 ± 0.013
	20 May 93	15 05	102	6.588 ± 0.016	0.497 ± 0.015	0.546 ± 0.009	0.663 ± 0.010	0.294 ± 0.012	0.180 ± 0.011	0.470 ± 0.014
	20 May 93	15 08	103	6.585 ± 0.016	0.504 ± 0.013	0.546 ± 0.010	0.661 ± 0.009	0.291 ± 0.010	0.187 ± 0.010	0.474 ± 0.011
	20 May 93	16 06	113	6.601 ± 0.019	0.489 ± 0.014	0.556 ± 0.013	0.664 ± 0.012	0.289 ± 0.012	0.178 ± 0.013	0.477 ± 0.013
	20 May 93	16 09	114	6.604 ± 0.017	0.502 ± 0.015	0.551 ± 0.012	0.662 ± 0.010	0.285 ± 0.011	0.182 ± 0.011	0.472 ± 0.012
	20 May 93	17 15	127	6.609 ± 0.022	0.500 ± 0.016	0.554 ± 0.011	0.654 ± 0.011	0.294 ± 0.014	0.182 ± 0.015	0.462 ± 0.014
	20 May 93	17 18	128	6.609 ± 0.022	0.498 ± 0.017	0.561 ± 0.011	0.651 ± 0.010	0.288 ± 0.013	0.188 ± 0.013	0.469 ± 0.014
	20 May 93	18 19	140	6.628 ± 0.030	0.491 ± 0.019	0.549 ± 0.017	0.675 ± 0.016	0.287 ± 0.016	0.186 ± 0.019	0.472 ± 0.019
	20 May 93	18 22	141	6.626 ± 0.028	0.485 ± 0.020	0.568 ± 0.015	0.658 ± 0.012	0.273 ± 0.016	0.208 ± 0.016	0.460 ± 0.018
	21 May 93	11 26	3	6.586 ± 0.016	0.506 ± 0.016	0.558 ± 0.013	0.655 ± 0.011	0.289 ± 0.011	0.182 ± 0.014	0.449 ± 0.013
	21 May 93	11 29	4	6.588 ± 0.016	0.491 ± 0.017	0.554 ± 0.012	0.661 ± 0.010	0.295 ± 0.010	0.169 ± 0.013	0.456 ± 0.012

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E6_047	21 May 93	12 04	13	6.598 ± 0.016	0.505 ± 0.015	0.549 ± 0.012	0.666 ± 0.010	0.285 ± 0.010	0.177 ± 0.013	0.455 ± 0.013
	21 May 93	12 07	14	6.592 ± 0.015	0.494 ± 0.015	0.553 ± 0.012	0.661 ± 0.010	0.286 ± 0.010	0.184 ± 0.012	0.456 ± 0.013
	21 May 93	13 13	27	6.580 ± 0.017	0.492 ± 0.016	0.557 ± 0.016	0.653 ± 0.014	0.293 ± 0.010	0.175 ± 0.014	0.453 ± 0.013
	21 May 93	13 16	28	6.582 ± 0.016	0.509 ± 0.015	0.549 ± 0.013	0.659 ± 0.011	0.290 ± 0.010	0.181 ± 0.013	0.452 ± 0.012
	21 May 93	14 09	42	6.567 ± 0.016	0.492 ± 0.016	0.560 ± 0.013	0.647 ± 0.010	0.290 ± 0.010	0.188 ± 0.013	0.451 ± 0.013
	21 May 93	14 12	43	6.579 ± 0.018	0.487 ± 0.017	0.565 ± 0.013	0.650 ± 0.013	0.288 ± 0.014	0.186 ± 0.016	0.453 ± 0.016
	21 May 93	15 14	58	6.575 ± 0.017	0.490 ± 0.019	0.560 ± 0.016	0.657 ± 0.012	0.286 ± 0.011	0.185 ± 0.013	0.450 ± 0.013
	21 May 93	15 17	59	6.577 ± 0.019	0.490 ± 0.016	0.565 ± 0.014	0.650 ± 0.014	0.297 ± 0.013	0.174 ± 0.015	0.448 ± 0.018
	21 May 93	16 02	70	6.572 ± 0.018	0.490 ± 0.020	0.563 ± 0.016	0.655 ± 0.011	0.294 ± 0.011	0.173 ± 0.014	0.450 ± 0.013
	21 May 93	16 05	71	6.573 ± 0.020	0.485 ± 0.017	0.556 ± 0.013	0.657 ± 0.012	0.291 ± 0.011	0.181 ± 0.015	0.463 ± 0.017
	21 May 93	17 16	85	6.579 ± 0.022	0.489 ± 0.022	0.553 ± 0.021	0.660 ± 0.016	0.292 ± 0.013	0.176 ± 0.017	0.463 ± 0.014
	21 May 93	17 18	86	6.576 ± 0.024	0.490 ± 0.019	0.563 ± 0.017	0.658 ± 0.015	0.287 ± 0.013	0.178 ± 0.019	0.456 ± 0.017
	21 May 93	17 54	96	6.592 ± 0.027	0.500 ± 0.030	0.540 ± 0.020	0.669 ± 0.014	0.284 ± 0.014	0.185 ± 0.021	0.448 ± 0.018
	21 May 93	17 56	97	6.586 ± 0.025	0.498 ± 0.027	0.554 ± 0.025	0.659 ± 0.018	0.296 ± 0.014	0.180 ± 0.017	0.457 ± 0.016
	23 May 93	07 21	5	6.612 ± 0.022	0.489 ± 0.016	0.561 ± 0.012	0.655 ± 0.010	0.285 ± 0.015	0.177 ± 0.015	0.463 ± 0.015
	23 May 93	07 23	6	6.614 ± 0.021	0.492 ± 0.017	0.550 ± 0.012	0.663 ± 0.011	0.280 ± 0.015	0.173 ± 0.013	0.454 ± 0.014
	23 May 93	08 10	18	6.627 ± 0.020	0.488 ± 0.016	0.556 ± 0.011	0.661 ± 0.011	0.290 ± 0.016	0.169 ± 0.013	0.444 ± 0.012
	23 May 93	08 12	19	6.609 ± 0.020	0.495 ± 0.017	0.555 ± 0.011	0.658 ± 0.010	0.288 ± 0.014	0.182 ± 0.012	0.446 ± 0.011
	23 May 93	09 25	32	6.619 ± 0.019	0.484 ± 0.017	0.559 ± 0.012	0.669 ± 0.009	0.291 ± 0.014	0.169 ± 0.012	0.444 ± 0.013
	23 May 93	09 27	33	6.622 ± 0.020	0.485 ± 0.016	0.562 ± 0.012	0.655 ± 0.009	0.289 ± 0.014	0.173 ± 0.013	0.448 ± 0.013
	23 May 93	10 04	41	6.622 ± 0.019	0.487 ± 0.016	0.565 ± 0.012	0.655 ± 0.010	0.294 ± 0.016	0.174 ± 0.013	0.446 ± 0.013
	23 May 93	10 06	42	6.626 ± 0.020	0.484 ± 0.016	0.558 ± 0.011	0.654 ± 0.011	0.285 ± 0.015	0.182 ± 0.013	0.440 ± 0.013
	23 May 93	11 01	52	6.617 ± 0.018	0.489 ± 0.017	0.562 ± 0.014	0.658 ± 0.013	0.279 ± 0.015	0.188 ± 0.011	0.447 ± 0.011
	23 May 93	11 04	53	6.617 ± 0.019	0.489 ± 0.016	0.560 ± 0.011	0.659 ± 0.009	0.282 ± 0.014	0.181 ± 0.012	0.452 ± 0.012
	23 May 93	11 58	65	6.607 ± 0.021	0.485 ± 0.017	0.564 ± 0.013	0.663 ± 0.009	0.281 ± 0.014	0.190 ± 0.014	0.443 ± 0.017
	23 May 93	12 01	66	6.619 ± 0.020	0.492 ± 0.015	0.554 ± 0.010	0.662 ± 0.009	0.284 ± 0.015	0.176 ± 0.014	0.449 ± 0.014
	23 May 93	12 59	78	6.613 ± 0.019	0.484 ± 0.016	0.559 ± 0.011	0.661 ± 0.008	0.286 ± 0.014	0.180 ± 0.013	0.439 ± 0.012
	23 May 93	13 02	79	6.612 ± 0.019	0.494 ± 0.015	0.562 ± 0.011	0.660 ± 0.009	0.281 ± 0.014	0.183 ± 0.012	0.445 ± 0.013
	23 May 93	14 06	95	6.603 ± 0.020	0.488 ± 0.015	0.562 ± 0.012	0.667 ± 0.011	0.282 ± 0.015	0.182 ± 0.013	0.451 ± 0.016
	23 May 93	14 08	96	6.597 ± 0.019	0.500 ± 0.019	0.559 ± 0.012	0.658 ± 0.009	0.288 ± 0.014	0.187 ± 0.012	0.436 ± 0.011
	23 May 93	15 04	109	6.591 ± 0.020	0.484 ± 0.016	0.567 ± 0.012	0.657 ± 0.010	0.293 ± 0.016	0.176 ± 0.013	0.445 ± 0.013

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date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
23 May 93	15 06	110	6.597 ± 0.020	0.488 ± 0.016	0.568 ± 0.012	0.660 ± 0.011	0.284 ± 0.015	0.180 ± 0.013	0.452 ± 0.013
23 May 93	16 15	124	6.600 ± 0.023	0.484 ± 0.018	0.565 ± 0.011	0.663 ± 0.009	0.289 ± 0.016	0.178 ± 0.016	0.446 ± 0.015
23 May 93	16 18	125	6.594 ± 0.022	0.487 ± 0.019	0.570 ± 0.015	0.650 ± 0.010	0.285 ± 0.015	0.191 ± 0.014	0.443 ± 0.017
23 May 93	17 03	133	6.601 ± 0.025	0.498 ± 0.019	0.562 ± 0.014	0.656 ± 0.013	0.284 ± 0.017	0.188 ± 0.016	0.438 ± 0.019
23 May 93	17 05	134	6.603 ± 0.024	0.495 ± 0.018	0.567 ± 0.015	0.657 ± 0.014	0.282 ± 0.017	0.193 ± 0.017	0.442 ± 0.019
23 May 93	18 07	148	6.611 ± 0.029	0.502 ± 0.020	0.562 ± 0.016	0.653 ± 0.015	0.294 ± 0.028	0.186 ± 0.028	0.442 ± 0.022
23 May 93	18 10	149	6.607 ± 0.031	0.488 ± 0.024	0.565 ± 0.021	0.668 ± 0.016	0.277 ± 0.020	0.194 ± 0.021	0.441 ± 0.023
01 Jul 93	10 36	66	6.620 ± 0.022	0.507 ± 0.020	0.553 ± 0.012	0.653 ± 0.011	0.289 ± 0.012	0.167 ± 0.010	0.468 ± 0.012
23 May 93	13 46	89	4.591 ± 0.017	0.214 ± 0.017	0.201 ± 0.017	0.127 ± 0.017	0.086 ± 0.018	0.041 ± 0.012	0.086 ± 0.011
23 May 93	13 48	90	4.586 ± 0.017	0.211 ± 0.017	0.206 ± 0.017	0.129 ± 0.017	0.089 ± 0.017	0.037 ± 0.013	0.079 ± 0.011
23 May 93	13 40	87	4.365 ± 0.019	0.729 ± 0.016	0.820 ± 0.012	0.574 ± 0.015	0.265 ± 0.018	0.180 ± 0.014	0.452 ± 0.012
23 May 93	13 42	88	4.363 ± 0.020	0.722 ± 0.016	0.817 ± 0.013	0.573 ± 0.014	0.268 ± 0.018	0.179 ± 0.014	0.449 ± 0.012
01 Jul 93	10 41	67	4.379 ± 0.023	0.736 ± 0.019	0.805 ± 0.012	0.577 ± 0.016	0.268 ± 0.015	0.178 ± 0.011	0.462 ± 0.012
01 Jul 93	10 44	68	4.379 ± 0.023	0.733 ± 0.019	0.807 ± 0.013	0.572 ± 0.016	0.266 ± 0.015	0.175 ± 0.011	0.467 ± 0.012
02 Jul 93	09 44	49	4.395 ± 0.015	0.726 ± 0.024	0.806 ± 0.013	0.572 ± 0.015	0.281 ± 0.017	0.172 ± 0.013	0.476 ± 0.014
02 Jul 93	09 47	50	4.402 ± 0.015	0.732 ± 0.024	0.805 ± 0.013	0.580 ± 0.016	0.278 ± 0.016	0.172 ± 0.012	0.475 ± 0.014
03 Jul 93	09 45	36	4.360 ± 0.027	0.689 ± 0.025	0.816 ± 0.014	0.573 ± 0.018	0.270 ± 0.016	0.169 ± 0.011	0.475 ± 0.015
04 Jul 93	09 33	22	4.398 ± 0.018	0.713 ± 0.053	0.811 ± 0.024	0.562 ± 0.015	0.268 ± 0.034	0.174 ± 0.022	0.458 ± 0.022
07 Jul 93	09 39	27	4.381 ± 0.034	0.689 ± 0.021	0.813 ± 0.015	0.564 ± 0.020	0.275 ± 0.015	0.171 ± 0.013	0.476 ± 0.017
23 May 93	13 52	91	5.840 ± 0.018	0.628 ± 0.016	0.769 ± 0.010	0.580 ± 0.009	0.209 ± 0.014	0.147 ± 0.012	0.298 ± 0.011
23 May 93	13 54	92	5.840 ± 0.018	0.614 ± 0.014	0.765 ± 0.011	0.583 ± 0.009	0.210 ± 0.015	0.145 ± 0.013	0.307 ± 0.011
01 Jul 93	10 49	69	5.842 ± 0.021	0.601 ± 0.018	0.755 ± 0.010	0.581 ± 0.011	0.203 ± 0.010	0.146 ± 0.008	0.322 ± 0.012
01 Jul 93	10 52	70	5.859 ± 0.021	0.632 ± 0.018	0.752 ± 0.011	0.575 ± 0.011	0.204 ± 0.012	0.144 ± 0.010	0.320 ± 0.011
02 Jul 93	09 51	51	5.853 ± 0.014	0.605 ± 0.022	0.753 ± 0.012	0.580 ± 0.012	0.216 ± 0.013	0.138 ± 0.010	0.324 ± 0.013
02 Jul 93	09 53	52	5.853 ± 0.015	0.629 ± 0.023	0.753 ± 0.012	0.582 ± 0.011	0.219 ± 0.012	0.134 ± 0.011	0.342 ± 0.015
03 Jul 93	09 50	37	5.830 ± 0.025	0.584 ± 0.024	0.762 ± 0.012	0.586 ± 0.014	0.211 ± 0.013	0.133 ± 0.008	0.331 ± 0.013
04 Jul 93	09 38	23	5.863 ± 0.018	0.611 ± 0.049	0.757 ± 0.023	0.563 ± 0.012	0.216 ± 0.030	0.140 ± 0.020	0.324 ± 0.023
07 Jul 93	09 45	28	5.850 ± 0.034	0.613 ± 0.021	0.762 ± 0.012	0.581 ± 0.016	0.212 ± 0.011	0.143 ± 0.011	0.342 ± 0.017
01 Jul 93	11 36	79	6.405 ± 0.021	0.448 ± 0.017	0.534 ± 0.010	0.195 ± 0.010	0.079 ± 0.011	0.045 ± 0.009	0.103 ± 0.016
01 Jul 93	11 38	80	6.408 ± 0.020	0.443 ± 0.018	0.530 ± 0.010	0.196 ± 0.010	0.073 ± 0.010	0.053 ± 0.007	0.113 ± 0.017
02 Jul 93	10 37	65	6.412 ± 0.014	0.417 ± 0.022	0.531 ± 0.011	0.192 ± 0.011	0.088 ± 0.012	0.039 ± 0.009	0.110 ± 0.014

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E6_081	02 Jul 93	10 40	66	6.417 ± 0.015	0.436 ± 0.022	0.531 ± 0.011	0.193 ± 0.010	0.087 ± 0.012	0.039 ± 0.012	0.120 ± 0.014
	03 Jul 93	10 37	46	6.406 ± 0.024	0.390 ± 0.024	0.550 ± 0.013	0.190 ± 0.014	0.072 ± 0.014	0.044 ± 0.009	0.108 ± 0.013
	04 Jul 93	09 44	24	6.427 ± 0.017	0.426 ± 0.045	0.538 ± 0.021	0.172 ± 0.011	0.087 ± 0.028	0.057 ± 0.019	0.097 ± 0.021
	06 Jul 93	11 56	55	6.363 ± 0.036	0.441 ± 0.038	0.529 ± 0.019	0.206 ± 0.017	0.083 ± 0.017	0.055 ± 0.013	0.128 ± 0.019
	07 Jul 93	09 51	29	6.424 ± 0.034	0.381 ± 0.020	0.543 ± 0.012	0.197 ± 0.014	0.074 ± 0.011	0.049 ± 0.011	0.137 ± 0.018
	01 Jul 93	11 42	81	6.912 ± 0.021	0.687 ± 0.018	0.676 ± 0.011	0.236 ± 0.011	0.122 ± 0.011	0.062 ± 0.009	0.160 ± 0.014
	01 Jul 93	11 45	82	6.904 ± 0.021	0.688 ± 0.019	0.680 ± 0.012	0.229 ± 0.010	0.121 ± 0.014	0.065 ± 0.012	0.158 ± 0.017
E6_082	02 Jul 93	10 44	67	6.923 ± 0.014	0.680 ± 0.023	0.672 ± 0.011	0.228 ± 0.011	0.135 ± 0.014	0.049 ± 0.011	0.156 ± 0.016
	02 Jul 93	10 47	68	6.918 ± 0.015	0.687 ± 0.022	0.672 ± 0.011	0.230 ± 0.010	0.132 ± 0.011	0.055 ± 0.010	0.164 ± 0.014
	03 Jul 93	10 44	47	6.907 ± 0.027	0.657 ± 0.024	0.680 ± 0.014	0.232 ± 0.015	0.126 ± 0.014	0.052 ± 0.015	0.167 ± 0.024
	04 Jul 93	09 49	25	6.929 ± 0.016	0.657 ± 0.046	0.676 ± 0.021	0.208 ± 0.010	0.134 ± 0.030	0.068 ± 0.020	0.152 ± 0.022
	06 Jul 93	11 51	54	6.862 ± 0.037	0.681 ± 0.039	0.676 ± 0.019	0.237 ± 0.017	0.128 ± 0.017	0.073 ± 0.014	0.174 ± 0.020
	07 Jul 93	10 44	38	6.905 ± 0.036	0.657 ± 0.021	0.680 ± 0.013	0.231 ± 0.015	0.120 ± 0.012	0.065 ± 0.011	0.192 ± 0.018
	01 Jul 93	11 49	83	6.816 ± 0.027	0.622 ± 0.026	0.882 ± 0.014	1.179 ± 0.014	0.455 ± 0.014	0.298 ± 0.010	0.707 ± 0.014
E6_084	01 Jul 93	11 52	84	6.812 ± 0.028	0.618 ± 0.029	0.888 ± 0.014	1.186 ± 0.014	0.456 ± 0.014	0.287 ± 0.012	0.716 ± 0.016
	02 Jul 93	10 51	69	6.823 ± 0.017	0.615 ± 0.029	0.889 ± 0.014	1.177 ± 0.014	0.459 ± 0.015	0.289 ± 0.012	0.710 ± 0.023
	02 Jul 93	10 53	70	6.826 ± 0.017	0.620 ± 0.033	0.891 ± 0.014	1.170 ± 0.014	0.461 ± 0.016	0.288 ± 0.013	0.718 ± 0.017
	03 Jul 93	10 49	48	6.801 ± 0.031	0.616 ± 0.032	0.896 ± 0.019	1.175 ± 0.019	0.451 ± 0.016	0.285 ± 0.011	0.717 ± 0.019
	04 Jul 93	10 39	34	6.842 ± 0.021	0.591 ± 0.067	0.900 ± 0.029	1.170 ± 0.012	0.448 ± 0.040	0.285 ± 0.027	0.708 ± 0.027
	06 Jul 93	11 45	53	6.790 ± 0.053	0.623 ± 0.059	0.883 ± 0.027	1.184 ± 0.025	0.445 ± 0.021	0.290 ± 0.018	0.721 ± 0.024
	07 Jul 93	10 48	39	6.825 ± 0.037	0.579 ± 0.031	0.893 ± 0.015	1.166 ± 0.021	0.472 ± 0.013	0.284 ± 0.013	0.708 ± 0.022
E6_087	03 Jul 93	11 37	57	6.653 ± 0.026	0.506 ± 0.025	0.574 ± 0.013	0.226 ± 0.014	0.123 ± 0.013	0.049 ± 0.010	0.176 ± 0.016
	04 Jul 93	10 45	35	6.686 ± 0.018	0.536 ± 0.046	0.567 ± 0.022	0.197 ± 0.011	0.131 ± 0.029	0.069 ± 0.020	0.155 ± 0.022
	06 Jul 93	10 56	44	6.620 ± 0.036	0.558 ± 0.038	0.573 ± 0.018	0.234 ± 0.017	0.132 ± 0.016	0.066 ± 0.013	0.170 ± 0.022
	07 Jul 93	11 37	48	6.651 ± 0.039	0.527 ± 0.022	0.583 ± 0.013	0.226 ± 0.014	0.125 ± 0.011	0.061 ± 0.011	0.182 ± 0.016
E6_088	03 Jul 93	11 45	58	6.615 ± 0.025	0.413 ± 0.024	0.518 ± 0.013	0.209 ± 0.014	0.031 ± 0.013	0.061 ± 0.008	0.149 ± 0.016
	04 Jul 93	10 50	36	6.673 ± 0.016	0.417 ± 0.045	0.503 ± 0.021	0.185 ± 0.010	0.059 ± 0.029	0.079 ± 0.019	0.134 ± 0.020
	06 Jul 93	10 51	43	6.578 ± 0.035	0.427 ± 0.037	0.503 ± 0.018	0.222 ± 0.016	0.050 ± 0.016	0.068 ± 0.012	0.165 ± 0.021
	03 Jul 93	11 50	59	6.828 ± 0.027	0.655 ± 0.025	0.843 ± 0.014	0.444 ± 0.015	0.143 ± 0.013	0.087 ± 0.011	0.208 ± 0.019
E6_090	04 Jul 93	11 39	45	6.857 ± 0.020	0.667 ± 0.047	0.833 ± 0.022	0.418 ± 0.011	0.154 ± 0.030	0.100 ± 0.022	0.180 ± 0.027
	06 Jul 93	10 45	42	6.801 ± 0.037	0.675 ± 0.039	0.847 ± 0.018	0.439 ± 0.017	0.155 ± 0.016	0.098 ± 0.013	0.203 ± 0.019

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E6_090	07 Jul 93	11 42	49	6.835 ± 0.039	0.644 ± 0.021	0.849 ± 0.013	0.435 ± 0.015	0.149 ± 0.011	0.087 ± 0.012	0.219 ± 0.017
	20 May 93	14 27	94	4.326 ± 0.015	0.286 ± 0.015	0.316 ± 0.019	0.173 ± 0.021	0.070 ± 0.018	0.043 ± 0.012	0.113 ± 0.011
	20 May 93	14 30	95	4.324 ± 0.015	0.271 ± 0.015	0.317 ± 0.019	0.169 ± 0.021	0.073 ± 0.018	0.044 ± 0.012	0.107 ± 0.009
	23 May 93	11 42	61	4.363 ± 0.016	0.276 ± 0.016	0.341 ± 0.019	0.157 ± 0.021	0.062 ± 0.019	0.043 ± 0.013	0.073 ± 0.010
	23 May 93	11 44	62	4.367 ± 0.016	0.292 ± 0.017	0.345 ± 0.020	0.151 ± 0.021	0.065 ± 0.019	0.042 ± 0.013	0.066 ± 0.010
E6_091	03 Jul 93	11 56	60	4.337 ± 0.026	0.253 ± 0.025	0.345 ± 0.020	0.144 ± 0.023	0.073 ± 0.019	0.025 ± 0.012	0.107 ± 0.014
	04 Jul 93	11 45	46	4.364 ± 0.018	0.262 ± 0.046	0.322 ± 0.026	0.126 ± 0.020	0.078 ± 0.032	0.056 ± 0.021	0.086 ± 0.020
	06 Jul 93	10 39	41	4.301 ± 0.035	0.270 ± 0.038	0.331 ± 0.024	0.154 ± 0.025	0.087 ± 0.022	0.043 ± 0.014	0.110 ± 0.016
	07 Jul 93	11 47	50	4.320 ± 0.040	0.273 ± 0.023	0.331 ± 0.020	0.151 ± 0.023	0.065 ± 0.018	0.042 ± 0.013	0.121 ± 0.016
	04 Jul 93	11 50	47	5.669 ± 0.017	0.466 ± 0.046	0.589 ± 0.021	0.208 ± 0.011	0.123 ± 0.029	0.070 ± 0.019	0.125 ± 0.019
E6_092	06 Jul 93	10 34	40	5.607 ± 0.036	0.497 ± 0.038	0.600 ± 0.018	0.242 ± 0.017	0.121 ± 0.016	0.063 ± 0.012	0.155 ± 0.017
	20 May 93	11 38	60	6.138 ± 0.014	0.750 ± 0.013	0.709 ± 0.009	0.782 ± 0.008	0.311 ± 0.011	0.230 ± 0.011	0.551 ± 0.010
	20 May 93	11 41	61	6.137 ± 0.014	0.747 ± 0.013	0.714 ± 0.009	0.782 ± 0.007	0.321 ± 0.011	0.221 ± 0.012	0.552 ± 0.011
	23 May 93	11 34	59	6.134 ± 0.019	0.737 ± 0.017	0.730 ± 0.013	0.779 ± 0.012	0.318 ± 0.016	0.217 ± 0.012	0.526 ± 0.013
	23 May 93	11 37	60	6.133 ± 0.019	0.731 ± 0.018	0.725 ± 0.011	0.786 ± 0.010	0.316 ± 0.015	0.218 ± 0.012	0.518 ± 0.012
E6_100	04 Jul 93	11 55	48	6.171 ± 0.020	0.726 ± 0.057	0.726 ± 0.026	0.758 ± 0.013	0.326 ± 0.036	0.220 ± 0.024	0.529 ± 0.024
	06 Jul 93	10 28	39	6.104 ± 0.045	0.771 ± 0.048	0.724 ± 0.022	0.780 ± 0.021	0.336 ± 0.018	0.213 ± 0.015	0.548 ± 0.021
	20 May 93	14 36	96	8.228 ± 0.017	0.614 ± 0.038	0.895 ± 0.027	1.301 ± 0.010	0.486 ± 0.015	0.301 ± 0.015	0.749 ± 0.014
	20 May 93	14 41	97	8.223 ± 0.016	0.586 ± 0.037	0.896 ± 0.032	1.308 ± 0.012	0.474 ± 0.014	0.313 ± 0.012	0.737 ± 0.013
	23 May 93	11 49	63	8.241 ± 0.023	0.585 ± 0.034	0.932 ± 0.024	1.298 ± 0.012	0.481 ± 0.019	0.311 ± 0.015	0.718 ± 0.015
E6_101	23 May 93	11 54	64	8.243 ± 0.023	0.580 ± 0.044	0.921 ± 0.039	1.308 ± 0.012	0.476 ± 0.018	0.311 ± 0.014	0.731 ± 0.017
	23 May 93	09 43	37	7.956 ± 0.028	0.820 ± 0.078	1.444 ± 0.044	2.082 ± 0.021	0.571 ± 0.025	0.528 ± 0.018	1.070 ± 0.016
	29 Jun 93	10 33	3	6.709 ± 0.027	0.537 ± 0.019	0.610 ± 0.015	0.577 ± 0.011	0.255 ± 0.012	0.157 ± 0.012	0.391 ± 0.016
	29 Jun 93	10 38	4	6.698 ± 0.027	0.530 ± 0.018	0.594 ± 0.015	0.583 ± 0.011	0.269 ± 0.012	0.152 ± 0.012	0.398 ± 0.015
	29 Jun 93	11 59	23	6.670 ± 0.029	0.537 ± 0.019	0.603 ± 0.016	0.580 ± 0.010	0.257 ± 0.015	0.159 ± 0.018	0.404 ± 0.017
E7_048	29 Jun 93	12 02	24	6.678 ± 0.028	0.533 ± 0.019	0.608 ± 0.016	0.574 ± 0.010	0.266 ± 0.013	0.157 ± 0.014	0.402 ± 0.017
	29 Jun 93	13 09	40	6.673 ± 0.028	0.526 ± 0.019	0.605 ± 0.015	0.583 ± 0.012	0.255 ± 0.012	0.166 ± 0.013	0.398 ± 0.020
	29 Jun 93	13 12	41	6.674 ± 0.028	0.538 ± 0.019	0.598 ± 0.014	0.582 ± 0.012	0.257 ± 0.013	0.165 ± 0.012	0.406 ± 0.017
	29 Jun 93	14 03	52	6.657 ± 0.028	0.543 ± 0.019	0.604 ± 0.015	0.585 ± 0.010	0.251 ± 0.015	0.169 ± 0.015	0.402 ± 0.015
	29 Jun 93	14 05	53	6.662 ± 0.028	0.533 ± 0.019	0.596 ± 0.016	0.587 ± 0.012	0.254 ± 0.012	0.163 ± 0.013	0.405 ± 0.018
	29 Jun 93	15 16	69	6.659 ± 0.029	0.518 ± 0.019	0.607 ± 0.016	0.582 ± 0.012	0.252 ± 0.013	0.168 ± 0.013	0.404 ± 0.015

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Table D.4 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E7.048	29 Jun 93	15 18	70	6.670 ± 0.030	0.519 ± 0.021	0.605 ± 0.016	0.584 ± 0.011	0.250 ± 0.014	0.165 ± 0.015	0.414 ± 0.019
	29 Jun 93	16 12	80	6.670 ± 0.031	0.522 ± 0.023	0.606 ± 0.017	0.580 ± 0.013	0.252 ± 0.016	0.166 ± 0.016	0.407 ± 0.016
	29 Jun 93	16 15	81	6.668 ± 0.031	0.532 ± 0.021	0.606 ± 0.016	0.586 ± 0.012	0.247 ± 0.015	0.172 ± 0.015	0.402 ± 0.017
	29 Jun 93	17 17	93	6.684 ± 0.034	0.529 ± 0.022	0.604 ± 0.017	0.591 ± 0.013	0.236 ± 0.021	0.183 ± 0.021	0.399 ± 0.016
	29 Jun 93	17 20	94	6.694 ± 0.035	0.523 ± 0.023	0.599 ± 0.017	0.585 ± 0.015	0.246 ± 0.017	0.176 ± 0.016	0.409 ± 0.017
	01 Jul 93	06 41	5	6.680 ± 0.025	0.545 ± 0.021	0.607 ± 0.011	0.579 ± 0.012	0.264 ± 0.012	0.150 ± 0.010	0.400 ± 0.013
	01 Jul 93	06 44	6	6.675 ± 0.025	0.539 ± 0.022	0.608 ± 0.013	0.577 ± 0.013	0.266 ± 0.011	0.147 ± 0.010	0.396 ± 0.015
	01 Jul 93	08 01	24	6.700 ± 0.023	0.550 ± 0.019	0.600 ± 0.010	0.579 ± 0.011	0.266 ± 0.011	0.143 ± 0.010	0.401 ± 0.014
	01 Jul 93	08 03	25	6.687 ± 0.023	0.543 ± 0.020	0.607 ± 0.010	0.580 ± 0.011	0.266 ± 0.011	0.152 ± 0.009	0.396 ± 0.013
	01 Jul 93	09 13	43	6.700 ± 0.022	0.551 ± 0.020	0.600 ± 0.012	0.577 ± 0.011	0.255 ± 0.011	0.159 ± 0.009	0.402 ± 0.012
	01 Jul 93	09 16	44	6.699 ± 0.022	0.548 ± 0.019	0.605 ± 0.009	0.575 ± 0.010	0.260 ± 0.013	0.152 ± 0.011	0.405 ± 0.014
	01 Jul 93	10 08	58	6.718 ± 0.022	0.553 ± 0.018	0.605 ± 0.010	0.574 ± 0.011	0.256 ± 0.010	0.151 ± 0.009	0.396 ± 0.019
	01 Jul 93	10 10	59	6.721 ± 0.021	0.527 ± 0.018	0.603 ± 0.010	0.571 ± 0.011	0.257 ± 0.010	0.151 ± 0.008	0.409 ± 0.014
	01 Jul 93	11 16	74	6.693 ± 0.021	0.526 ± 0.019	0.605 ± 0.011	0.575 ± 0.012	0.261 ± 0.010	0.151 ± 0.008	0.400 ± 0.014
	01 Jul 93	11 19	75	6.699 ± 0.021	0.560 ± 0.018	0.608 ± 0.012	0.573 ± 0.013	0.259 ± 0.010	0.154 ± 0.008	0.406 ± 0.012
	01 Jul 93	12 13	88	6.698 ± 0.022	0.535 ± 0.018	0.595 ± 0.010	0.586 ± 0.011	0.255 ± 0.013	0.161 ± 0.013	0.388 ± 0.013
	01 Jul 93	12 16	89	6.703 ± 0.021	0.551 ± 0.018	0.603 ± 0.009	0.569 ± 0.012	0.256 ± 0.012	0.164 ± 0.008	0.387 ± 0.015
	01 Jul 93	12 55	93	6.695 ± 0.022	0.551 ± 0.019	0.607 ± 0.011	0.580 ± 0.011	0.255 ± 0.010	0.158 ± 0.009	0.407 ± 0.012
	01 Jul 93	12 58	94	6.698 ± 0.023	0.558 ± 0.018	0.598 ± 0.010	0.584 ± 0.011	0.256 ± 0.010	0.159 ± 0.010	0.400 ± 0.017
	01 Jul 93	14 06	111	6.687 ± 0.022	0.558 ± 0.019	0.597 ± 0.010	0.579 ± 0.011	0.256 ± 0.011	0.157 ± 0.009	0.406 ± 0.017
	01 Jul 93	14 09	112	6.694 ± 0.022	0.553 ± 0.019	0.602 ± 0.009	0.580 ± 0.011	0.253 ± 0.013	0.161 ± 0.012	0.399 ± 0.014
	01 Jul 93	15 03	126	6.691 ± 0.023	0.541 ± 0.020	0.600 ± 0.011	0.577 ± 0.012	0.260 ± 0.012	0.151 ± 0.009	0.399 ± 0.015
	01 Jul 93	15 06	127	6.675 ± 0.024	0.558 ± 0.020	0.601 ± 0.011	0.577 ± 0.013	0.252 ± 0.013	0.161 ± 0.011	0.397 ± 0.027
	01 Jul 93	16 15	143	6.673 ± 0.026	0.556 ± 0.023	0.599 ± 0.010	0.580 ± 0.013	0.254 ± 0.013	0.158 ± 0.011	0.395 ± 0.018
	01 Jul 93	16 17	144	6.677 ± 0.026	0.540 ± 0.021	0.604 ± 0.011	0.580 ± 0.014	0.260 ± 0.014	0.156 ± 0.010	0.403 ± 0.013
	01 Jul 93	17 05	154	6.685 ± 0.029	0.532 ± 0.024	0.599 ± 0.015	0.582 ± 0.017	0.258 ± 0.017	0.158 ± 0.015	0.401 ± 0.014
	01 Jul 93	17 08	155	6.694 ± 0.029	0.546 ± 0.025	0.592 ± 0.016	0.593 ± 0.016	0.253 ± 0.014	0.151 ± 0.011	0.409 ± 0.020
	01 Jul 93	18 10	169	6.739 ± 0.037	0.517 ± 0.034	0.604 ± 0.015	0.578 ± 0.016	0.260 ± 0.014	0.156 ± 0.015	0.422 ± 0.023
	01 Jul 93	18 12	170	6.744 ± 0.036	0.525 ± 0.031	0.586 ± 0.018	0.620 ± 0.017	0.247 ± 0.029	0.147 ± 0.028	0.425 ± 0.026
	02 Jul 93	07 08	5	6.714 ± 0.017	0.543 ± 0.026	0.603 ± 0.013	0.572 ± 0.012	0.272 ± 0.012	0.145 ± 0.010	0.406 ± 0.017
	02 Jul 93	07 10	6	6.699 ± 0.017	0.543 ± 0.025	0.600 ± 0.012	0.581 ± 0.011	0.263 ± 0.013	0.155 ± 0.011	0.406 ± 0.016

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Table D.4 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E7_048	02 Jul 93	08 08	21	6.720 ± 0.016	0.548 ± 0.025	0.600 ± 0.011	0.578 ± 0.011	0.262 ± 0.013	0.159 ± 0.011	0.398 ± 0.014
	02 Jul 93	08 11	22	6.713 ± 0.016	0.551 ± 0.025	0.597 ± 0.012	0.577 ± 0.011	0.269 ± 0.013	0.152 ± 0.012	0.408 ± 0.016
	02 Jul 93	09 11	39	6.720 ± 0.015	0.546 ± 0.024	0.602 ± 0.011	0.571 ± 0.011	0.261 ± 0.013	0.155 ± 0.011	0.402 ± 0.016
	02 Jul 93	09 14	40	6.717 ± 0.015	0.555 ± 0.024	0.598 ± 0.011	0.577 ± 0.011	0.263 ± 0.012	0.152 ± 0.010	0.409 ± 0.018
	02 Jul 93	10 10	57	6.723 ± 0.015	0.531 ± 0.024	0.599 ± 0.012	0.574 ± 0.013	0.266 ± 0.013	0.146 ± 0.010	0.411 ± 0.015
	02 Jul 93	10 13	58	6.719 ± 0.014	0.554 ± 0.024	0.603 ± 0.011	0.573 ± 0.011	0.263 ± 0.012	0.155 ± 0.010	0.408 ± 0.013
	02 Jul 93	11 16	75	6.717 ± 0.015	0.527 ± 0.023	0.603 ± 0.011	0.576 ± 0.011	0.258 ± 0.013	0.156 ± 0.013	0.411 ± 0.016
	02 Jul 93	11 19	76	6.708 ± 0.014	0.552 ± 0.024	0.603 ± 0.011	0.574 ± 0.011	0.269 ± 0.013	0.147 ± 0.010	0.405 ± 0.014
	02 Jul 93	12 17	91	6.712 ± 0.014	0.552 ± 0.023	0.601 ± 0.011	0.573 ± 0.012	0.269 ± 0.012	0.153 ± 0.010	0.401 ± 0.014
	02 Jul 93	12 20	92	6.703 ± 0.014	0.553 ± 0.024	0.596 ± 0.013	0.576 ± 0.012	0.264 ± 0.012	0.152 ± 0.009	0.407 ± 0.014
	02 Jul 93	13 05	103	6.714 ± 0.016	0.550 ± 0.024	0.603 ± 0.012	0.574 ± 0.012	0.268 ± 0.013	0.149 ± 0.012	0.406 ± 0.014
	02 Jul 93	13 07	104	6.710 ± 0.014	0.544 ± 0.023	0.598 ± 0.011	0.578 ± 0.012	0.264 ± 0.014	0.154 ± 0.011	0.413 ± 0.015
	03 Jul 93	06 47	4	6.673 ± 0.030	0.515 ± 0.028	0.612 ± 0.014	0.580 ± 0.016	0.259 ± 0.015	0.149 ± 0.010	0.389 ± 0.021
	03 Jul 93	08 15	19	6.686 ± 0.028	0.506 ± 0.027	0.617 ± 0.015	0.579 ± 0.016	0.260 ± 0.013	0.148 ± 0.011	0.415 ± 0.019
	03 Jul 93	09 13	30	6.699 ± 0.027	0.543 ± 0.026	0.611 ± 0.012	0.577 ± 0.014	0.255 ± 0.013	0.151 ± 0.011	0.413 ± 0.015
	03 Jul 93	10 10	41	6.704 ± 0.026	0.545 ± 0.025	0.610 ± 0.012	0.572 ± 0.014	0.260 ± 0.014	0.145 ± 0.010	0.405 ± 0.014
	03 Jul 93	11 12	52	6.697 ± 0.026	0.519 ± 0.024	0.604 ± 0.013	0.580 ± 0.015	0.259 ± 0.014	0.147 ± 0.011	0.389 ± 0.015
	03 Jul 93	12 18	64	6.695 ± 0.026	0.517 ± 0.026	0.608 ± 0.014	0.575 ± 0.016	0.260 ± 0.014	0.150 ± 0.009	0.399 ± 0.016
	03 Jul 93	13 08	74	6.689 ± 0.027	0.513 ± 0.025	0.611 ± 0.013	0.573 ± 0.016	0.257 ± 0.014	0.151 ± 0.010	0.413 ± 0.017
	03 Jul 93	14 04	84	6.683 ± 0.028	0.520 ± 0.025	0.607 ± 0.012	0.578 ± 0.014	0.257 ± 0.013	0.149 ± 0.011	0.402 ± 0.017
	03 Jul 93	15 12	96	6.679 ± 0.029	0.546 ± 0.027	0.608 ± 0.015	0.580 ± 0.016	0.266 ± 0.014	0.142 ± 0.011	0.414 ± 0.019
	03 Jul 93	16 12	105	6.735 ± 0.032	0.514 ± 0.029	0.608 ± 0.014	0.575 ± 0.017	0.263 ± 0.016	0.151 ± 0.012	0.405 ± 0.019
	03 Jul 93	17 15	116	6.723 ± 0.046	0.514 ± 0.037	0.597 ± 0.035	0.589 ± 0.040	0.246 ± 0.032	0.168 ± 0.033	0.388 ± 0.038
	04 Jul 93	07 27	4	6.741 ± 0.019	0.512 ± 0.052	0.604 ± 0.023	0.566 ± 0.010	0.265 ± 0.033	0.156 ± 0.021	0.397 ± 0.022
	04 Jul 93	08 11	12	6.727 ± 0.018	0.517 ± 0.052	0.607 ± 0.023	0.561 ± 0.012	0.274 ± 0.034	0.150 ± 0.023	0.393 ± 0.021
	04 Jul 93	10 13	29	6.737 ± 0.017	0.509 ± 0.052	0.608 ± 0.022	0.561 ± 0.009	0.254 ± 0.032	0.165 ± 0.021	0.390 ± 0.022
	04 Jul 93	11 12	40	6.747 ± 0.019	0.508 ± 0.052	0.605 ± 0.023	0.560 ± 0.011	0.267 ± 0.033	0.149 ± 0.023	0.395 ± 0.023
	04 Jul 93	12 22	52	6.739 ± 0.018	0.519 ± 0.052	0.611 ± 0.023	0.557 ± 0.010	0.268 ± 0.032	0.155 ± 0.022	0.392 ± 0.023
	06 Jul 93	06 55	4	6.681 ± 0.042	0.555 ± 0.045	0.600 ± 0.020	0.589 ± 0.020	0.270 ± 0.018	0.155 ± 0.014	0.399 ± 0.022
	06 Jul 93	09 14	26	6.700 ± 0.041	0.536 ± 0.044	0.602 ± 0.020	0.584 ± 0.019	0.267 ± 0.016	0.152 ± 0.014	0.416 ± 0.019
	06 Jul 93	10 18	37	6.692 ± 0.041	0.562 ± 0.044	0.599 ± 0.021	0.588 ± 0.019	0.264 ± 0.017	0.154 ± 0.013	0.404 ± 0.019

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Table D.4 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E7_048	06 Jul 93	11 18	48	6.674 ± 0.040	0.538 ± 0.043	0.603 ± 0.021	0.587 ± 0.019	0.272 ± 0.017	0.146 ± 0.013	0.399 ± 0.019
	06 Jul 93	12 19	59	6.686 ± 0.041	0.541 ± 0.044	0.598 ± 0.021	0.589 ± 0.019	0.267 ± 0.018	0.155 ± 0.015	0.406 ± 0.019
	06 Jul 93	13 13	69	6.681 ± 0.041	0.536 ± 0.044	0.596 ± 0.021	0.593 ± 0.020	0.262 ± 0.017	0.162 ± 0.013	0.415 ± 0.019
	06 Jul 93	14 05	78	6.688 ± 0.041	0.550 ± 0.044	0.601 ± 0.020	0.585 ± 0.019	0.269 ± 0.017	0.152 ± 0.013	0.413 ± 0.020
	06 Jul 93	15 05	89	6.687 ± 0.042	0.568 ± 0.045	0.593 ± 0.022	0.592 ± 0.020	0.264 ± 0.017	0.148 ± 0.013	0.411 ± 0.019
	06 Jul 93	16 08	100	6.685 ± 0.043	0.545 ± 0.045	0.600 ± 0.021	0.588 ± 0.020	0.265 ± 0.019	0.158 ± 0.014	0.412 ± 0.021
	07 Jul 93	06 55	3	6.726 ± 0.044	0.532 ± 0.024	0.614 ± 0.016	0.571 ± 0.017	0.264 ± 0.012	0.154 ± 0.013	0.417 ± 0.019
	07 Jul 93	08 08	11	6.722 ± 0.038	0.538 ± 0.023	0.615 ± 0.013	0.570 ± 0.016	0.266 ± 0.010	0.156 ± 0.012	0.415 ± 0.018
	07 Jul 93	09 06	21	6.725 ± 0.035	0.505 ± 0.022	0.615 ± 0.013	0.574 ± 0.016	0.263 ± 0.012	0.152 ± 0.012	0.424 ± 0.017
	07 Jul 93	10 15	33	6.736 ± 0.033	0.507 ± 0.022	0.606 ± 0.013	0.574 ± 0.016	0.263 ± 0.010	0.152 ± 0.011	0.397 ± 0.017
	07 Jul 93	11 11	43	6.704 ± 0.033	0.514 ± 0.022	0.612 ± 0.013	0.575 ± 0.016	0.267 ± 0.011	0.148 ± 0.011	0.411 ± 0.017
	07 Jul 93	12 10	54	6.694 ± 0.033	0.514 ± 0.022	0.608 ± 0.013	0.578 ± 0.016	0.263 ± 0.012	0.153 ± 0.012	0.401 ± 0.018
	07 Jul 93	13 08	65	6.684 ± 0.036	0.533 ± 0.023	0.611 ± 0.013	0.576 ± 0.016	0.264 ± 0.010	0.153 ± 0.012	0.416 ± 0.020
	07 Jul 93	13 58	74	6.660 ± 0.038	0.540 ± 0.022	0.613 ± 0.013	0.577 ± 0.016	0.262 ± 0.010	0.159 ± 0.011	0.415 ± 0.017
	07 Jul 93	15 05	86	6.644 ± 0.044	0.529 ± 0.024	0.612 ± 0.013	0.580 ± 0.017	0.258 ± 0.013	0.160 ± 0.015	0.413 ± 0.020
	08 Jul 93	07 10	3	6.690 ± 0.038	0.529 ± 0.023	0.614 ± 0.014	0.576 ± 0.019	0.248 ± 0.019	0.160 ± 0.012	0.404 ± 0.015
	08 Jul 93	08 09	12	6.717 ± 0.038	0.517 ± 0.022	0.609 ± 0.014	0.569 ± 0.016	0.251 ± 0.017	0.152 ± 0.015	0.403 ± 0.018
	08 Jul 93	09 07	21	6.711 ± 0.036	0.524 ± 0.022	0.612 ± 0.014	0.575 ± 0.016	0.246 ± 0.017	0.157 ± 0.012	0.408 ± 0.017
	08 Jul 93	10 29	32	6.709 ± 0.036	0.519 ± 0.023	0.605 ± 0.015	0.571 ± 0.016	0.244 ± 0.018	0.155 ± 0.014	0.395 ± 0.020
	08 Jul 93	11 33	44	6.712 ± 0.035	0.524 ± 0.022	0.610 ± 0.013	0.569 ± 0.015	0.245 ± 0.017	0.155 ± 0.012	0.399 ± 0.015
	08 Jul 93	12 37	54	6.713 ± 0.036	0.519 ± 0.023	0.607 ± 0.014	0.572 ± 0.015	0.247 ± 0.017	0.157 ± 0.011	0.405 ± 0.014
	08 Jul 93	13 19	62	6.700 ± 0.036	0.523 ± 0.022	0.608 ± 0.013	0.575 ± 0.016	0.248 ± 0.018	0.156 ± 0.013	0.406 ± 0.017
E7_061	12 Apr 92	16 37	145	5.079 ± 0.032	0.573 ± 0.023	0.825 ± 0.018	1.101 ± 0.017	0.429 ± 0.013	0.271 ± 0.014	0.667 ± 0.019
	12 Apr 92	16 38	146	5.094 ± 0.032	0.577 ± 0.023	0.831 ± 0.018	1.092 ± 0.019	0.432 ± 0.013	0.265 ± 0.016	0.666 ± 0.022
E7_065	29 Jun 93	10 47	5	7.212 ± 0.030	0.492 ± 0.019	0.653 ± 0.016	0.815 ± 0.013	0.338 ± 0.015	0.233 ± 0.014	0.550 ± 0.015
	29 Jun 93	10 50	6	7.225 ± 0.030	0.452 ± 0.021	0.659 ± 0.017	0.821 ± 0.012	0.340 ± 0.016	0.228 ± 0.015	0.546 ± 0.017
	29 Jun 93	12 06	25	7.202 ± 0.030	0.469 ± 0.020	0.650 ± 0.017	0.826 ± 0.016	0.358 ± 0.016	0.209 ± 0.014	0.565 ± 0.026
	29 Jun 93	12 08	26	7.202 ± 0.030	0.480 ± 0.021	0.649 ± 0.015	0.828 ± 0.014	0.339 ± 0.015	0.223 ± 0.013	0.561 ± 0.018
	29 Jun 93	13 03	38	7.183 ± 0.030	0.474 ± 0.020	0.646 ± 0.017	0.827 ± 0.016	0.339 ± 0.016	0.219 ± 0.015	0.577 ± 0.017
	29 Jun 93	13 05	39	7.184 ± 0.030	0.469 ± 0.020	0.650 ± 0.016	0.834 ± 0.011	0.325 ± 0.014	0.237 ± 0.015	0.561 ± 0.020
	29 Jun 93	15 06	66	7.178 ± 0.031	0.472 ± 0.021	0.647 ± 0.016	0.838 ± 0.012	0.330 ± 0.014	0.237 ± 0.014	0.558 ± 0.017
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Table D.4 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E7_065	29 Jun 93	15 09	67	7.179 ± 0.032	0.451 ± 0.023	0.665 ± 0.018	0.832 ± 0.013	0.334 ± 0.015	0.226 ± 0.015	0.562 ± 0.017
	29 Jun 93	17 10	91	7.198 ± 0.036	0.449 ± 0.026	0.653 ± 0.020	0.842 ± 0.014	0.317 ± 0.017	0.249 ± 0.019	0.571 ± 0.021
	29 Jun 93	17 13	92	7.200 ± 0.036	0.479 ± 0.024	0.642 ± 0.018	0.841 ± 0.013	0.318 ± 0.016	0.245 ± 0.016	0.569 ± 0.017
	01 Jul 93	06 48	7	7.189 ± 0.030	0.477 ± 0.022	0.648 ± 0.012	0.825 ± 0.013	0.345 ± 0.013	0.217 ± 0.016	0.564 ± 0.019
	01 Jul 93	06 50	8	7.179 ± 0.027	0.486 ± 0.025	0.635 ± 0.012	0.845 ± 0.013	0.344 ± 0.013	0.217 ± 0.010	0.561 ± 0.019
	01 Jul 93	08 08	26	7.210 ± 0.025	0.480 ± 0.021	0.651 ± 0.013	0.823 ± 0.015	0.349 ± 0.013	0.215 ± 0.011	0.558 ± 0.018
	01 Jul 93	08 10	27	7.206 ± 0.025	0.472 ± 0.024	0.652 ± 0.013	0.829 ± 0.015	0.347 ± 0.013	0.215 ± 0.011	0.554 ± 0.015
	01 Jul 93	10 14	60	7.240 ± 0.024	0.490 ± 0.023	0.641 ± 0.015	0.828 ± 0.017	0.342 ± 0.017	0.218 ± 0.012	0.559 ± 0.013
	01 Jul 93	10 17	61	7.227 ± 0.023	0.502 ± 0.023	0.650 ± 0.013	0.821 ± 0.013	0.338 ± 0.012	0.220 ± 0.008	0.558 ± 0.012
	01 Jul 93	12 20	90	7.197 ± 0.024	0.501 ± 0.022	0.644 ± 0.012	0.827 ± 0.012	0.335 ± 0.012	0.229 ± 0.010	0.558 ± 0.018
	01 Jul 93	12 23	91	7.209 ± 0.025	0.468 ± 0.019	0.647 ± 0.010	0.826 ± 0.011	0.334 ± 0.012	0.228 ± 0.012	0.574 ± 0.014
	01 Jul 93	13 59	109	7.210 ± 0.024	0.464 ± 0.021	0.650 ± 0.014	0.833 ± 0.016	0.324 ± 0.012	0.232 ± 0.009	0.563 ± 0.013
	01 Jul 93	14 02	110	7.213 ± 0.024	0.488 ± 0.021	0.639 ± 0.015	0.836 ± 0.016	0.338 ± 0.013	0.221 ± 0.010	0.566 ± 0.012
	01 Jul 93	16 08	141	7.189 ± 0.027	0.486 ± 0.025	0.641 ± 0.016	0.829 ± 0.016	0.332 ± 0.016	0.230 ± 0.012	0.551 ± 0.016
	01 Jul 93	16 10	142	7.192 ± 0.027	0.455 ± 0.024	0.641 ± 0.017	0.834 ± 0.016	0.330 ± 0.013	0.228 ± 0.011	0.554 ± 0.015
	01 Jul 93	18 02	167	7.218 ± 0.040	0.456 ± 0.030	0.641 ± 0.016	0.847 ± 0.017	0.336 ± 0.014	0.240 ± 0.021	0.565 ± 0.029
	01 Jul 93	18 05	168	7.236 ± 0.036	0.479 ± 0.036	0.626 ± 0.022	0.845 ± 0.017	0.334 ± 0.018	0.231 ± 0.018	0.572 ± 0.017
	02 Jul 93	07 15	7	7.219 ± 0.019	0.479 ± 0.032	0.648 ± 0.018	0.825 ± 0.013	0.347 ± 0.014	0.222 ± 0.013	0.552 ± 0.019
	02 Jul 93	07 18	8	7.213 ± 0.019	0.476 ± 0.029	0.653 ± 0.014	0.830 ± 0.016	0.340 ± 0.017	0.223 ± 0.014	0.571 ± 0.017
	02 Jul 93	09 18	41	7.245 ± 0.016	0.500 ± 0.027	0.639 ± 0.013	0.824 ± 0.015	0.346 ± 0.015	0.220 ± 0.011	0.571 ± 0.020
	02 Jul 93	09 20	42	7.233 ± 0.017	0.495 ± 0.027	0.642 ± 0.014	0.827 ± 0.013	0.351 ± 0.015	0.212 ± 0.014	0.565 ± 0.018
	02 Jul 93	11 22	77	7.237 ± 0.015	0.491 ± 0.028	0.652 ± 0.012	0.824 ± 0.012	0.346 ± 0.013	0.213 ± 0.012	0.572 ± 0.018
	02 Jul 93	11 25	78	7.218 ± 0.015	0.507 ± 0.026	0.641 ± 0.012	0.826 ± 0.012	0.340 ± 0.013	0.221 ± 0.011	0.557 ± 0.014
	02 Jul 93	12 57	101	7.232 ± 0.015	0.454 ± 0.026	0.644 ± 0.012	0.839 ± 0.013	0.336 ± 0.013	0.225 ± 0.011	0.567 ± 0.015
	02 Jul 93	13 01	102	7.230 ± 0.015	0.482 ± 0.026	0.650 ± 0.014	0.824 ± 0.014	0.348 ± 0.015	0.220 ± 0.013	0.567 ± 0.018
	03 Jul 93	06 53	5	7.170 ± 0.033	0.491 ± 0.030	0.657 ± 0.016	0.831 ± 0.017	0.350 ± 0.017	0.207 ± 0.016	0.559 ± 0.021
	03 Jul 93	09 19	31	7.210 ± 0.030	0.463 ± 0.027	0.653 ± 0.015	0.824 ± 0.018	0.334 ± 0.014	0.224 ± 0.014	0.564 ± 0.023
	03 Jul 93	11 17	53	7.201 ± 0.028	0.487 ± 0.028	0.660 ± 0.015	0.821 ± 0.018	0.338 ± 0.014	0.220 ± 0.011	0.566 ± 0.021
	03 Jul 93	13 03	73	7.195 ± 0.028	0.451 ± 0.028	0.655 ± 0.014	0.833 ± 0.016	0.334 ± 0.014	0.226 ± 0.011	0.568 ± 0.019
	03 Jul 93	15 07	95	7.175 ± 0.031	0.469 ± 0.029	0.653 ± 0.015	0.829 ± 0.018	0.332 ± 0.016	0.234 ± 0.014	0.581 ± 0.019
	03 Jul 93	17 08	115	7.252 ± 0.041	0.487 ± 0.035	0.653 ± 0.020	0.814 ± 0.025	0.346 ± 0.027	0.212 ± 0.027	0.575 ± 0.028

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E7_065	04 Jul 93	07 32	5	7.240 ± 0.021	0.460 ± 0.058	0.655 ± 0.028	0.819 ± 0.015	0.340 ± 0.037	0.224 ± 0.026	0.564 ± 0.027
	04 Jul 93	10 18	30	7.253 ± 0.019	0.477 ± 0.059	0.656 ± 0.025	0.810 ± 0.013	0.332 ± 0.036	0.228 ± 0.023	0.546 ± 0.024
	04 Jul 93	12 27	53	7.252 ± 0.020	0.474 ± 0.059	0.661 ± 0.025	0.813 ± 0.010	0.340 ± 0.035	0.227 ± 0.023	0.550 ± 0.025
	06 Jul 93	09 20	27	7.222 ± 0.045	0.476 ± 0.049	0.651 ± 0.022	0.830 ± 0.021	0.337 ± 0.018	0.219 ± 0.014	0.571 ± 0.021
	06 Jul 93	11 23	49	7.184 ± 0.045	0.470 ± 0.049	0.649 ± 0.023	0.839 ± 0.022	0.334 ± 0.019	0.225 ± 0.014	0.576 ± 0.021
	06 Jul 93	13 07	68	7.202 ± 0.046	0.511 ± 0.049	0.645 ± 0.023	0.835 ± 0.022	0.335 ± 0.019	0.226 ± 0.016	0.567 ± 0.024
	06 Jul 93	14 60	88	7.201 ± 0.047	0.523 ± 0.050	0.642 ± 0.023	0.833 ± 0.022	0.337 ± 0.020	0.224 ± 0.016	0.559 ± 0.022
	07 Jul 93	09 11	22	7.229 ± 0.035	0.483 ± 0.024	0.659 ± 0.014	0.819 ± 0.018	0.341 ± 0.011	0.224 ± 0.012	0.563 ± 0.019
	07 Jul 93	11 16	44	7.206 ± 0.033	0.474 ± 0.023	0.658 ± 0.016	0.821 ± 0.020	0.345 ± 0.012	0.227 ± 0.013	0.550 ± 0.020
	07 Jul 93	13 02	64	7.201 ± 0.035	0.450 ± 0.024	0.658 ± 0.015	0.822 ± 0.018	0.339 ± 0.013	0.222 ± 0.014	0.567 ± 0.022
	07 Jul 93	14 60	85	7.157 ± 0.043	0.487 ± 0.026	0.646 ± 0.015	0.831 ± 0.018	0.344 ± 0.012	0.220 ± 0.013	0.558 ± 0.021
	08 Jul 93	07 18	4	7.180 ± 0.042	0.470 ± 0.026	0.663 ± 0.016	0.823 ± 0.018	0.322 ± 0.019	0.232 ± 0.015	0.558 ± 0.023
	08 Jul 93	09 12	22	7.223 ± 0.040	0.435 ± 0.025	0.653 ± 0.016	0.825 ± 0.018	0.330 ± 0.019	0.218 ± 0.014	0.559 ± 0.017
	08 Jul 93	11 38	45	7.191 ± 0.039	0.489 ± 0.026	0.653 ± 0.018	0.821 ± 0.020	0.330 ± 0.019	0.223 ± 0.013	0.565 ± 0.015
	08 Jul 93	13 14	61	7.195 ± 0.040	0.489 ± 0.024	0.660 ± 0.015	0.815 ± 0.018	0.330 ± 0.019	0.218 ± 0.013	0.547 ± 0.015
E8_026	23 May 93	15 36	116	6.578 ± 0.022	0.574 ± 0.020	0.843 ± 0.012	1.103 ± 0.010	0.423 ± 0.017	0.272 ± 0.013	0.655 ± 0.014
E8_028	23 May 93	15 39	117	6.572 ± 0.021	0.580 ± 0.019	0.836 ± 0.012	1.100 ± 0.009	0.427 ± 0.017	0.273 ± 0.014	0.655 ± 0.013
	23 May 93	15 43	118	6.595 ± 0.024	0.628 ± 0.030	1.150 ± 0.018	1.569 ± 0.011	0.501 ± 0.020	0.394 ± 0.014	0.835 ± 0.014
E8_029	23 May 93	15 46	119	6.597 ± 0.024	0.641 ± 0.028	1.154 ± 0.018	1.560 ± 0.012	0.504 ± 0.020	0.392 ± 0.015	0.828 ± 0.014
	23 May 93	15 52	120	6.975 ± 0.022	0.594 ± 0.025	0.973 ± 0.018	1.273 ± 0.010	0.457 ± 0.018	0.316 ± 0.013	0.718 ± 0.013
E8_030	23 May 93	15 57	121	6.963 ± 0.022	0.595 ± 0.024	0.976 ± 0.018	1.287 ± 0.012	0.454 ± 0.018	0.317 ± 0.014	0.719 ± 0.013
	23 May 93	16 41	129	6.990 ± 0.027	0.767 ± 0.039	1.385 ± 0.025	2.031 ± 0.016	0.567 ± 0.023	0.515 ± 0.016	1.021 ± 0.016
E8_042	23 May 93	16 46	130	6.989 ± 0.027	0.767 ± 0.043	1.399 ± 0.027	2.037 ± 0.014	0.563 ± 0.023	0.518 ± 0.016	1.021 ± 0.016
	23 May 93	16 51	131	5.835 ± 0.017	0.662 ± 0.015	0.753 ± 0.011	0.529 ± 0.009	0.215 ± 0.013	0.146 ± 0.011	0.314 ± 0.010
E8_045	23 May 93	16 54	132	5.845 ± 0.018	0.649 ± 0.014	0.746 ± 0.010	0.529 ± 0.010	0.217 ± 0.014	0.137 ± 0.012	0.311 ± 0.011
	23 May 93	17 35	140	5.628 ± 0.016	0.555 ± 0.014	0.809 ± 0.010	0.313 ± 0.009	0.124 ± 0.013	0.055 ± 0.010	0.086 ± 0.011
E8_069	23 May 93	17 37	141	5.622 ± 0.016	0.555 ± 0.015	0.813 ± 0.012	0.312 ± 0.009	0.121 ± 0.013	0.061 ± 0.010	0.091 ± 0.010
	23 May 93	17 41	142	4.136 ± 0.024	0.610 ± 0.021	1.005 ± 0.015	1.356 ± 0.014	0.471 ± 0.021	0.347 ± 0.016	0.761 ± 0.014
E8_071	23 May 93	17 44	143	4.146 ± 0.024	0.615 ± 0.021	0.998 ± 0.015	1.353 ± 0.014	0.474 ± 0.021	0.342 ± 0.016	0.763 ± 0.015
	23 May 93	17 48	144	5.685 ± 0.018	0.644 ± 0.014	0.793 ± 0.010	0.460 ± 0.009	0.183 ± 0.014	0.112 ± 0.012	0.235 ± 0.013
	23 May 93	17 50	145	5.683 ± 0.017	0.632 ± 0.015	0.798 ± 0.010	0.460 ± 0.009	0.182 ± 0.013	0.116 ± 0.010	0.236 ± 0.010

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E9.024	29 Jun 93	13 35	45	6.969 ± 0.035	0.587 ± 0.027	0.957 ± 0.020	1.238 ± 0.016	0.461 ± 0.014	0.288 ± 0.016	0.717 ± 0.020
	29 Jun 93	13 38	46	6.984 ± 0.034	0.572 ± 0.027	0.964 ± 0.020	1.214 ± 0.015	0.458 ± 0.016	0.288 ± 0.015	0.717 ± 0.017
	01 Jul 93	14 39	119	7.005 ± 0.027	0.601 ± 0.025	0.945 ± 0.014	1.218 ± 0.015	0.450 ± 0.014	0.294 ± 0.009	0.716 ± 0.014
	01 Jul 93	14 41	120	7.005 ± 0.028	0.586 ± 0.027	0.937 ± 0.016	1.232 ± 0.013	0.444 ± 0.014	0.299 ± 0.014	0.721 ± 0.017
	06 Jul 93	13 47	75	7.000 ± 0.053	0.624 ± 0.058	0.946 ± 0.029	1.233 ± 0.026	0.448 ± 0.021	0.294 ± 0.016	0.717 ± 0.025
	07 Jul 93	13 42	71	6.967 ± 0.037	0.598 ± 0.028	0.953 ± 0.018	1.221 ± 0.022	0.456 ± 0.015	0.306 ± 0.016	0.714 ± 0.022
	03 Jul 93	17 48	122	7.131 ± 0.032	0.581 ± 0.031	0.912 ± 0.017	1.208 ± 0.019	0.456 ± 0.015	0.299 ± 0.011	0.730 ± 0.021
	29 Jun 93	13 51	49	6.872 ± 0.034	0.561 ± 0.026	0.880 ± 0.020	1.155 ± 0.016	0.450 ± 0.018	0.278 ± 0.018	0.704 ± 0.020
	29 Jun 93	13 54	50	6.854 ± 0.033	0.568 ± 0.026	0.887 ± 0.017	1.158 ± 0.013	0.453 ± 0.014	0.277 ± 0.014	0.708 ± 0.017
	01 Jul 93	14 46	121	6.873 ± 0.027	0.585 ± 0.024	0.860 ± 0.012	1.162 ± 0.015	0.450 ± 0.015	0.280 ± 0.011	0.701 ± 0.016
E9.025	01 Jul 93	14 48	122	6.879 ± 0.026	0.586 ± 0.023	0.860 ± 0.013	1.156 ± 0.014	0.439 ± 0.013	0.284 ± 0.010	0.714 ± 0.015
	03 Jul 93	13 41	80	6.847 ± 0.031	0.613 ± 0.032	0.866 ± 0.016	1.158 ± 0.018	0.433 ± 0.016	0.290 ± 0.011	0.717 ± 0.017
	06 Jul 93	13 54	76	6.906 ± 0.052	0.591 ± 0.058	0.867 ± 0.028	1.158 ± 0.026	0.445 ± 0.021	0.279 ± 0.016	0.705 ± 0.023
	07 Jul 93	13 48	72	6.846 ± 0.037	0.560 ± 0.027	0.881 ± 0.017	1.153 ± 0.022	0.451 ± 0.014	0.289 ± 0.014	0.698 ± 0.023
	29 Jun 93	14 47	62	6.937 ± 0.037	0.624 ± 0.025	1.123 ± 0.021	1.414 ± 0.016	0.498 ± 0.018	0.334 ± 0.019	0.771 ± 0.021
	29 Jun 93	14 50	63	6.945 ± 0.036	0.626 ± 0.028	1.106 ± 0.020	1.426 ± 0.015	0.492 ± 0.016	0.329 ± 0.017	0.777 ± 0.021
	01 Jul 93	14 53	123	6.939 ± 0.029	0.624 ± 0.031	1.107 ± 0.016	1.417 ± 0.015	0.483 ± 0.017	0.344 ± 0.015	0.780 ± 0.017
	01 Jul 93	14 55	124	6.943 ± 0.028	0.622 ± 0.027	1.100 ± 0.017	1.424 ± 0.017	0.475 ± 0.015	0.351 ± 0.011	0.789 ± 0.015
	03 Jul 93	13 47	81	6.922 ± 0.034	0.672 ± 0.038	1.108 ± 0.022	1.419 ± 0.020	0.481 ± 0.019	0.347 ± 0.014	0.772 ± 0.020
	06 Jul 93	14 44	85	6.951 ± 0.056	0.640 ± 0.061	1.098 ± 0.029	1.435 ± 0.026	0.477 ± 0.022	0.340 ± 0.017	0.782 ± 0.025
E9.031	07 Jul 93	14 38	81	6.916 ± 0.036	0.628 ± 0.029	1.111 ± 0.018	1.421 ± 0.023	0.495 ± 0.014	0.345 ± 0.015	0.767 ± 0.022
	03 Jul 93	17 56	123	7.298 ± 0.037	0.817 ± 0.053	1.349 ± 0.026	1.929 ± 0.024	0.539 ± 0.020	0.514 ± 0.011	1.013 ± 0.019
	01 Jul 93	15 35	134	7.000 ± 0.020	0.610 ± 0.017	0.838 ± 0.010	0.365 ± 0.010	0.132 ± 0.010	0.065 ± 0.010	0.147 ± 0.013
	01 Jul 93	15 38	135	7.004 ± 0.020	0.613 ± 0.017	0.838 ± 0.010	0.366 ± 0.009	0.135 ± 0.013	0.068 ± 0.012	0.143 ± 0.014
	03 Jul 93	13 53	82	7.007 ± 0.025	0.613 ± 0.025	0.849 ± 0.014	0.376 ± 0.017	0.132 ± 0.015	0.071 ± 0.009	0.146 ± 0.015
	06 Jul 93	14 49	86	7.017 ± 0.036	0.622 ± 0.038	0.831 ± 0.018	0.376 ± 0.017	0.143 ± 0.015	0.071 ± 0.013	0.172 ± 0.023
	07 Jul 93	14 43	82	6.969 ± 0.033	0.616 ± 0.020	0.845 ± 0.012	0.369 ± 0.015	0.137 ± 0.011	0.079 ± 0.010	0.171 ± 0.016
	20 May 93	13 08	76	6.826 ± 0.026	0.511 ± 0.020	0.572 ± 0.017	0.693 ± 0.012	0.315 ± 0.015	0.191 ± 0.015	0.505 ± 0.015
	20 May 93	13 11	77	6.828 ± 0.025	0.525 ± 0.017	0.562 ± 0.012	0.696 ± 0.011	0.315 ± 0.015	0.190 ± 0.014	0.497 ± 0.013
	20 May 93	14 05	89	6.823 ± 0.021	0.522 ± 0.017	0.566 ± 0.015	0.701 ± 0.014	0.317 ± 0.014	0.189 ± 0.015	0.504 ± 0.014
E9.042	20 May 93	14 08	90	6.822 ± 0.020	0.508 ± 0.017	0.574 ± 0.013	0.695 ± 0.011	0.311 ± 0.013	0.197 ± 0.012	0.512 ± 0.012

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E9.042	20 May 93	15 14	104	6.823 ± 0.017	0.522 ± 0.013	0.570 ± 0.009	0.694 ± 0.009	0.314 ± 0.012	0.194 ± 0.010	0.507 ± 0.011
	20 May 93	15 17	105	6.825 ± 0.017	0.525 ± 0.014	0.570 ± 0.011	0.692 ± 0.010	0.318 ± 0.012	0.188 ± 0.011	0.510 ± 0.012
	20 May 93	16 20	115	6.811 ± 0.016	0.522 ± 0.013	0.573 ± 0.009	0.701 ± 0.009	0.305 ± 0.010	0.202 ± 0.012	0.507 ± 0.012
	20 May 93	16 23	116	6.811 ± 0.015	0.519 ± 0.016	0.566 ± 0.011	0.706 ± 0.009	0.300 ± 0.011	0.207 ± 0.011	0.506 ± 0.011
	20 May 93	17 29	129	6.807 ± 0.015	0.522 ± 0.014	0.572 ± 0.011	0.697 ± 0.009	0.294 ± 0.010	0.209 ± 0.010	0.508 ± 0.012
	20 May 93	17 31	130	6.808 ± 0.014	0.525 ± 0.014	0.569 ± 0.013	0.696 ± 0.011	0.300 ± 0.010	0.205 ± 0.010	0.502 ± 0.011
	20 May 93	18 31	142	6.795 ± 0.014	0.512 ± 0.014	0.578 ± 0.010	0.698 ± 0.007	0.299 ± 0.011	0.208 ± 0.011	0.499 ± 0.010
	20 May 93	18 34	143	6.802 ± 0.014	0.509 ± 0.012	0.572 ± 0.009	0.709 ± 0.008	0.292 ± 0.010	0.208 ± 0.010	0.509 ± 0.012
	21 May 93	13 05	25	6.789 ± 0.025	0.523 ± 0.025	0.576 ± 0.019	0.687 ± 0.015	0.303 ± 0.018	0.203 ± 0.021	0.491 ± 0.016
	21 May 93	13 08	26	6.797 ± 0.027	0.527 ± 0.023	0.581 ± 0.016	0.694 ± 0.015	0.318 ± 0.017	0.176 ± 0.023	0.498 ± 0.020
	21 May 93	14 02	40	6.800 ± 0.022	0.513 ± 0.019	0.578 ± 0.014	0.694 ± 0.014	0.318 ± 0.018	0.183 ± 0.020	0.494 ± 0.018
	21 May 93	14 05	41	6.801 ± 0.021	0.513 ± 0.022	0.576 ± 0.018	0.696 ± 0.016	0.316 ± 0.013	0.178 ± 0.016	0.499 ± 0.014
	21 May 93	15 06	56	6.810 ± 0.018	0.535 ± 0.018	0.576 ± 0.014	0.696 ± 0.011	0.312 ± 0.012	0.185 ± 0.016	0.497 ± 0.013
	21 May 93	15 09	57	6.800 ± 0.018	0.519 ± 0.017	0.583 ± 0.014	0.692 ± 0.012	0.307 ± 0.012	0.196 ± 0.014	0.486 ± 0.013
	21 May 93	16 17	72	6.793 ± 0.017	0.511 ± 0.016	0.583 ± 0.013	0.692 ± 0.011	0.309 ± 0.010	0.194 ± 0.014	0.500 ± 0.013
	21 May 93	16 20	73	6.791 ± 0.016	0.516 ± 0.021	0.567 ± 0.016	0.702 ± 0.011	0.309 ± 0.011	0.193 ± 0.013	0.487 ± 0.012
	21 May 93	17 03	83	6.813 ± 0.016	0.514 ± 0.016	0.582 ± 0.014	0.701 ± 0.012	0.309 ± 0.012	0.192 ± 0.015	0.488 ± 0.013
	21 May 93	17 06	84	6.813 ± 0.016	0.519 ± 0.018	0.580 ± 0.016	0.695 ± 0.012	0.311 ± 0.010	0.191 ± 0.013	0.485 ± 0.012
	21 May 93	18 06	98	6.786 ± 0.016	0.536 ± 0.016	0.570 ± 0.013	0.699 ± 0.011	0.314 ± 0.010	0.193 ± 0.014	0.485 ± 0.013
	21 May 93	18 09	99	6.783 ± 0.016	0.530 ± 0.016	0.581 ± 0.014	0.698 ± 0.011	0.310 ± 0.011	0.197 ± 0.013	0.482 ± 0.013
	23 May 93	13 10	80	6.826 ± 0.030	0.509 ± 0.018	0.567 ± 0.015	0.716 ± 0.013	0.301 ± 0.026	0.192 ± 0.030	0.483 ± 0.023
	23 May 93	13 13	81	6.820 ± 0.026	0.522 ± 0.023	0.576 ± 0.021	0.706 ± 0.021	0.319 ± 0.024	0.174 ± 0.018	0.484 ± 0.017
	23 May 93	14 20	97	6.810 ± 0.023	0.524 ± 0.019	0.584 ± 0.014	0.695 ± 0.012	0.304 ± 0.017	0.201 ± 0.015	0.474 ± 0.014
	23 May 93	14 23	98	6.814 ± 0.022	0.508 ± 0.019	0.584 ± 0.014	0.702 ± 0.012	0.310 ± 0.017	0.196 ± 0.014	0.476 ± 0.013
	23 May 93	15 12	111	6.827 ± 0.022	0.516 ± 0.024	0.580 ± 0.017	0.702 ± 0.009	0.311 ± 0.015	0.193 ± 0.014	0.483 ± 0.014
	23 May 93	15 15	112	6.828 ± 0.021	0.511 ± 0.017	0.584 ± 0.013	0.701 ± 0.011	0.310 ± 0.017	0.195 ± 0.014	0.475 ± 0.018
	23 May 93	16 29	126	6.812 ± 0.019	0.508 ± 0.019	0.587 ± 0.013	0.700 ± 0.010	0.304 ± 0.016	0.199 ± 0.013	0.477 ± 0.013
	23 May 93	16 31	127	6.809 ± 0.020	0.509 ± 0.017	0.590 ± 0.012	0.705 ± 0.010	0.310 ± 0.015	0.194 ± 0.014	0.484 ± 0.014
	23 May 93	17 15	135	6.814 ± 0.020	0.508 ± 0.016	0.582 ± 0.011	0.705 ± 0.009	0.305 ± 0.016	0.197 ± 0.015	0.483 ± 0.013
	23 May 93	17 18	136	6.810 ± 0.019	0.513 ± 0.018	0.578 ± 0.015	0.710 ± 0.011	0.299 ± 0.015	0.203 ± 0.012	0.472 ± 0.014
	23 May 93	18 18	150	6.810 ± 0.020	0.513 ± 0.017	0.577 ± 0.012	0.705 ± 0.010	0.309 ± 0.015	0.186 ± 0.013	0.485 ± 0.016

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E9_042	23 May 93	18 21	151	6.802 ± 0.019	0.514 ± 0.017	0.587 ± 0.011	0.701 ± 0.008	0.305 ± 0.015	0.202 ± 0.013	0.474 ± 0.013
	06 Jul 93	15 38	95	6.824 ± 0.043	0.520 ± 0.046	0.567 ± 0.021	0.700 ± 0.020	0.320 ± 0.018	0.180 ± 0.014	0.509 ± 0.021
E9_043	29 Jun 93	14 57	64	6.153 ± 0.034	0.574 ± 0.022	0.913 ± 0.017	1.186 ± 0.013	0.461 ± 0.015	0.285 ± 0.014	0.710 ± 0.017
	29 Jun 93	14 60	65	6.152 ± 0.033	0.561 ± 0.023	0.911 ± 0.017	1.185 ± 0.014	0.460 ± 0.015	0.291 ± 0.014	0.709 ± 0.017
	01 Jul 93	15 43	136	6.157 ± 0.026	0.599 ± 0.022	0.894 ± 0.012	1.187 ± 0.014	0.445 ± 0.014	0.297 ± 0.010	0.718 ± 0.013
	01 Jul 93	15 46	137	6.159 ± 0.027	0.587 ± 0.024	0.900 ± 0.012	1.183 ± 0.013	0.446 ± 0.014	0.302 ± 0.011	0.717 ± 0.014
	03 Jul 93	14 38	90	6.134 ± 0.032	0.582 ± 0.031	0.903 ± 0.015	1.188 ± 0.018	0.447 ± 0.016	0.298 ± 0.013	0.721 ± 0.018
	06 Jul 93	15 44	96	6.155 ± 0.052	0.616 ± 0.057	0.893 ± 0.026	1.197 ± 0.024	0.447 ± 0.021	0.292 ± 0.017	0.715 ± 0.023
	07 Jul 93	14 49	83	6.145 ± 0.035	0.572 ± 0.026	0.897 ± 0.016	1.181 ± 0.020	0.460 ± 0.012	0.294 ± 0.013	0.705 ± 0.021
	29 Jun 93	15 35	73	5.610 ± 0.038	0.686 ± 0.027	1.247 ± 0.021	1.705 ± 0.014	0.554 ± 0.016	0.399 ± 0.016	0.884 ± 0.019
E9_044	29 Jun 93	15 37	74	5.605 ± 0.038	0.666 ± 0.026	1.245 ± 0.021	1.706 ± 0.015	0.561 ± 0.017	0.397 ± 0.016	0.888 ± 0.019
	01 Jul 93	15 50	138	5.611 ± 0.030	0.688 ± 0.029	1.225 ± 0.015	1.718 ± 0.015	0.536 ± 0.016	0.418 ± 0.011	0.893 ± 0.015
	01 Jul 93	15 53	139	5.593 ± 0.031	0.702 ± 0.030	1.219 ± 0.018	1.724 ± 0.015	0.536 ± 0.017	0.423 ± 0.013	0.891 ± 0.016
	03 Jul 93	14 44	91	5.586 ± 0.035	0.698 ± 0.036	1.239 ± 0.018	1.700 ± 0.021	0.538 ± 0.018	0.420 ± 0.012	0.883 ± 0.019
	06 Jul 93	15 49	97	5.608 ± 0.061	0.696 ± 0.067	1.233 ± 0.031	1.725 ± 0.029	0.539 ± 0.025	0.406 ± 0.018	0.888 ± 0.027
	07 Jul 93	15 38	92	5.587 ± 0.035	0.708 ± 0.031	1.238 ± 0.020	1.704 ± 0.025	0.551 ± 0.015	0.411 ± 0.015	0.870 ± 0.023
	29 Jun 93	15 43	75	6.988 ± 0.025	0.568 ± 0.017	0.733 ± 0.013	0.251 ± 0.010	0.106 ± 0.012	0.056 ± 0.011	0.098 ± 0.016
	29 Jun 93	15 46	76	7.001 ± 0.025	0.558 ± 0.017	0.734 ± 0.014	0.250 ± 0.010	0.103 ± 0.013	0.056 ± 0.014	0.096 ± 0.015
E9_048	01 Jul 93	16 44	149	6.990 ± 0.019	0.595 ± 0.017	0.740 ± 0.013	0.242 ± 0.012	0.103 ± 0.010	0.042 ± 0.008	0.109 ± 0.016
	01 Jul 93	16 46	150	6.991 ± 0.019	0.560 ± 0.017	0.739 ± 0.010	0.240 ± 0.009	0.102 ± 0.010	0.040 ± 0.008	0.114 ± 0.010
	03 Jul 93	14 50	92	6.991 ± 0.024	0.567 ± 0.024	0.752 ± 0.013	0.247 ± 0.013	0.105 ± 0.013	0.039 ± 0.009	0.107 ± 0.016
	06 Jul 93	15 55	98	6.956 ± 0.035	0.553 ± 0.037	0.743 ± 0.018	0.260 ± 0.017	0.118 ± 0.017	0.042 ± 0.014	0.108 ± 0.020
	07 Jul 93	15 44	93	6.958 ± 0.033	0.568 ± 0.020	0.751 ± 0.012	0.252 ± 0.015	0.098 ± 0.011	0.049 ± 0.011	0.129 ± 0.017
	29 Jun 93	15 54	77	6.922 ± 0.038	0.651 ± 0.029	1.221 ± 0.024	1.655 ± 0.016	0.539 ± 0.017	0.398 ± 0.017	0.878 ± 0.021
	29 Jun 93	15 57	78	6.930 ± 0.037	0.660 ± 0.031	1.220 ± 0.024	1.654 ± 0.016	0.538 ± 0.018	0.393 ± 0.016	0.883 ± 0.020
	01 Jul 93	16 51	151	6.927 ± 0.030	0.654 ± 0.031	1.217 ± 0.016	1.653 ± 0.016	0.518 ± 0.016	0.419 ± 0.012	0.879 ± 0.016
E9_063	01 Jul 93	16 53	152	6.935 ± 0.030	0.658 ± 0.045	1.210 ± 0.018	1.667 ± 0.017	0.520 ± 0.016	0.412 ± 0.011	0.889 ± 0.015
	03 Jul 93	14 56	93	6.911 ± 0.035	0.712 ± 0.047	1.220 ± 0.023	1.643 ± 0.021	0.519 ± 0.017	0.413 ± 0.011	0.878 ± 0.018
	07 Jul 93	15 50	94	6.901 ± 0.035	0.696 ± 0.035	1.220 ± 0.023	1.651 ± 0.025	0.538 ± 0.015	0.407 ± 0.015	0.869 ± 0.024
	01 Jul 93	17 41	162	6.048 ± 0.023	0.486 ± 0.019	0.585 ± 0.011	0.748 ± 0.012	0.319 ± 0.011	0.201 ± 0.010	0.523 ± 0.013
	01 Jul 93	17 43	163	6.058 ± 0.023	0.505 ± 0.019	0.583 ± 0.014	0.743 ± 0.016	0.327 ± 0.014	0.197 ± 0.010	0.528 ± 0.012

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Table D.4 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
E9_063	03 Jul 93	15 40	100	6.059 ± 0.027	0.485 ± 0.026	0.599 ± 0.012	0.742 ± 0.015	0.320 ± 0.014	0.196 ± 0.010	0.531 ± 0.016
	07 Jul 93	16 35	102	6.028 ± 0.033	0.470 ± 0.022	0.585 ± 0.013	0.744 ± 0.018	0.320 ± 0.011	0.202 ± 0.012	0.526 ± 0.018
	29 Jun 93	16 36	84	6.177 ± 0.034	0.609 ± 0.024	0.953 ± 0.019	1.259 ± 0.013	0.485 ± 0.015	0.288 ± 0.016	0.733 ± 0.018
E9_071	29 Jun 93	16 40	85	6.186 ± 0.034	0.599 ± 0.024	0.957 ± 0.018	1.256 ± 0.014	0.481 ± 0.014	0.291 ± 0.014	0.730 ± 0.017
	01 Jul 93	17 48	164	6.176 ± 0.027	0.642 ± 0.023	0.943 ± 0.012	1.263 ± 0.014	0.465 ± 0.014	0.303 ± 0.010	0.734 ± 0.013
	01 Jul 93	17 50	165	6.182 ± 0.027	0.620 ± 0.024	0.936 ± 0.014	1.272 ± 0.014	0.469 ± 0.014	0.302 ± 0.010	0.730 ± 0.015
	03 Jul 93	15 46	101	6.166 ± 0.031	0.620 ± 0.032	0.952 ± 0.015	1.258 ± 0.018	0.464 ± 0.017	0.305 ± 0.012	0.723 ± 0.017
	07 Jul 93	16 41	103	6.156 ± 0.034	0.642 ± 0.026	0.951 ± 0.017	1.249 ± 0.021	0.486 ± 0.012	0.294 ± 0.013	0.721 ± 0.021
	29 Jun 93	16 53	88	5.696 ± 0.027	0.544 ± 0.018	0.632 ± 0.014	0.571 ± 0.011	0.251 ± 0.012	0.159 ± 0.012	0.393 ± 0.014
E9_072	29 Jun 93	16 56	89	5.681 ± 0.027	0.556 ± 0.018	0.631 ± 0.014	0.572 ± 0.011	0.246 ± 0.012	0.164 ± 0.012	0.398 ± 0.015
	01 Jul 93	18 38	175	5.705 ± 0.022	0.573 ± 0.018	0.623 ± 0.012	0.573 ± 0.013	0.254 ± 0.011	0.150 ± 0.009	0.403 ± 0.012
	01 Jul 93	18 41	176	5.700 ± 0.022	0.548 ± 0.018	0.629 ± 0.010	0.572 ± 0.012	0.261 ± 0.012	0.147 ± 0.009	0.395 ± 0.012
	03 Jul 93	16 00	103	5.684 ± 0.026	0.542 ± 0.025	0.636 ± 0.013	0.572 ± 0.016	0.252 ± 0.015	0.151 ± 0.012	0.394 ± 0.017
	07 Jul 93	16 54	105	5.653 ± 0.033	0.563 ± 0.021	0.631 ± 0.012	0.573 ± 0.016	0.248 ± 0.010	0.158 ± 0.011	0.400 ± 0.017
	29 Jun 93	18 44	107	6.961 ± 0.026	0.642 ± 0.018	0.838 ± 0.014	0.362 ± 0.010	0.131 ± 0.012	0.088 ± 0.013	0.148 ± 0.015
E9_073	29 Jun 93	18 46	108	6.959 ± 0.026	0.656 ± 0.017	0.836 ± 0.013	0.366 ± 0.010	0.127 ± 0.012	0.091 ± 0.011	0.151 ± 0.013
	03 Jul 93	16 45	111	6.977 ± 0.025	0.616 ± 0.023	0.837 ± 0.012	0.362 ± 0.013	0.129 ± 0.013	0.065 ± 0.010	0.165 ± 0.015
	07 Jul 93	17 44	114	6.925 ± 0.034	0.642 ± 0.021	0.838 ± 0.012	0.363 ± 0.015	0.128 ± 0.011	0.074 ± 0.011	0.178 ± 0.022
E9_074	29 Jun 93	13 44	47	4.063 ± 0.035	0.606 ± 0.024	0.955 ± 0.018	1.287 ± 0.016	0.488 ± 0.020	0.299 ± 0.019	0.727 ± 0.018
	29 Jun 93	13 47	48	4.064 ± 0.035	0.600 ± 0.023	0.952 ± 0.019	1.289 ± 0.017	0.491 ± 0.019	0.297 ± 0.018	0.727 ± 0.019
E9_079	29 Jun 93	18 53	109	4.906 ± 0.034	0.538 ± 0.022	0.962 ± 0.018	1.270 ± 0.015	0.467 ± 0.015	0.312 ± 0.015	0.739 ± 0.018
	29 Jun 93	18 55	110	4.911 ± 0.035	0.593 ± 0.022	0.973 ± 0.018	1.264 ± 0.014	0.466 ± 0.015	0.312 ± 0.016	0.740 ± 0.018
	03 Jul 93	16 51	112	4.906 ± 0.031	0.617 ± 0.030	0.967 ± 0.015	1.262 ± 0.018	0.463 ± 0.016	0.308 ± 0.011	0.737 ± 0.017
	07 Jul 93	17 50	115	4.882 ± 0.035	0.612 ± 0.026	0.969 ± 0.016	1.254 ± 0.021	0.476 ± 0.013	0.305 ± 0.014	0.734 ± 0.021
E9_080	03 Jul 93	16 56	113	6.631 ± 0.025	0.624 ± 0.024	0.734 ± 0.011	0.558 ± 0.014	0.204 ± 0.013	0.140 ± 0.009	0.343 ± 0.016
	07 Jul 93	17 57	116	6.591 ± 0.034	0.597 ± 0.020	0.733 ± 0.013	0.555 ± 0.016	0.216 ± 0.011	0.139 ± 0.012	0.343 ± 0.019

Table D.5: The individual reduced observations for the cluster O Vel.

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
001	27 Feb 91	10 29	23	3.652 ± 0.019	0.219 ± 0.023	0.357 ± 0.020	0.126 ± 0.023	0.039 ± 0.019	0.048 ± 0.018	0.055 ± 0.013
	27 Feb 91	10 32	24	3.650 ± 0.019	0.220 ± 0.023	0.360 ± 0.020	0.128 ± 0.023	0.037 ± 0.020	0.046 ± 0.018	0.057 ± 0.013
	11 May 91	11 28	35	3.614 ± 0.030	0.244 ± 0.019	0.334 ± 0.025	0.103 ± 0.023	0.073 ± 0.025	0.019 ± 0.024	0.079 ± 0.020
	11 May 91	11 31	36	3.617 ± 0.030	0.235 ± 0.020	0.336 ± 0.025	0.096 ± 0.023	0.073 ± 0.024	0.029 ± 0.022	0.089 ± 0.017
	21 May 91	07 33	12	3.592 ± 0.019	0.242 ± 0.022	0.372 ± 0.021	0.099 ± 0.020	0.087 ± 0.023	0.025 ± 0.021	0.097 ± 0.015
	21 May 91	07 35	13	3.592 ± 0.020	0.238 ± 0.023	0.369 ± 0.023	0.103 ± 0.022	0.087 ± 0.024	0.029 ± 0.022	0.094 ± 0.016
	21 May 91	07 38	14	3.596 ± 0.019	0.238 ± 0.025	0.371 ± 0.021	0.103 ± 0.021	0.080 ± 0.023	0.026 ± 0.021	0.104 ± 0.014
	06 Feb 92	12 25	43	3.610 ± 0.028	0.252 ± 0.028	0.358 ± 0.027	0.108 ± 0.020	0.065 ± 0.027	0.029 ± 0.047	0.089 ± 0.015
	06 Feb 92	12 27	44	3.616 ± 0.028	0.250 ± 0.028	0.355 ± 0.027	0.112 ± 0.020	0.065 ± 0.026	0.027 ± 0.047	0.087 ± 0.015
	09 Feb 92	11 26	21	3.638 ± 0.027	0.255 ± 0.029	0.357 ± 0.026	0.122 ± 0.024	0.100 ± 0.027	-0.039 ± 0.042	0.105 ± 0.015
002	09 Feb 92	11 28	22	3.642 ± 0.027	0.245 ± 0.030	0.359 ± 0.026	0.131 ± 0.021	0.094 ± 0.025	-0.034 ± 0.042	0.107 ± 0.016
	10 Feb 92	10 28	22	3.637 ± 0.028	0.174 ± 0.038	0.374 ± 0.033	0.090 ± 0.024	0.089 ± 0.027	-0.024 ± 0.047	0.095 ± 0.015
	10 Feb 92	10 30	23	3.636 ± 0.027	0.186 ± 0.038	0.365 ± 0.032	0.094 ± 0.024	0.084 ± 0.026	-0.021 ± 0.046	0.097 ± 0.013
	27 Feb 91	10 40	26	4.863 ± 0.018	0.195 ± 0.018	0.356 ± 0.013	0.132 ± 0.018	0.047 ± 0.011	0.030 ± 0.010	0.047 ± 0.012
	27 Feb 91	10 43	27	4.853 ± 0.018	0.193 ± 0.018	0.356 ± 0.013	0.133 ± 0.018	0.047 ± 0.011	0.036 ± 0.010	0.041 ± 0.012
003	27 Feb 91	11 34	41	5.214 ± 0.018	0.234 ± 0.017	0.414 ± 0.012	0.164 ± 0.018	0.048 ± 0.010	0.055 ± 0.009	0.048 ± 0.012
	27 Feb 91	11 37	42	5.223 ± 0.018	0.233 ± 0.017	0.410 ± 0.012	0.161 ± 0.018	0.050 ± 0.010	0.047 ± 0.009	0.064 ± 0.012
	11 May 91	11 49	41	5.217 ± 0.032	0.246 ± 0.017	0.399 ± 0.021	0.148 ± 0.018	0.079 ± 0.019	0.022 ± 0.021	0.077 ± 0.019
	11 May 91	11 52	42	5.222 ± 0.031	0.247 ± 0.017	0.403 ± 0.023	0.136 ± 0.020	0.096 ± 0.020	0.016 ± 0.020	0.088 ± 0.020
	21 May 91	07 47	17	5.176 ± 0.018	0.255 ± 0.017	0.423 ± 0.016	0.142 ± 0.016	0.101 ± 0.017	0.023 ± 0.014	0.093 ± 0.012
	21 May 91	07 49	18	5.175 ± 0.018	0.250 ± 0.018	0.431 ± 0.016	0.140 ± 0.016	0.096 ± 0.018	0.026 ± 0.015	0.101 ± 0.012
	06 Feb 92	12 42	49	5.176 ± 0.028	0.261 ± 0.020	0.418 ± 0.020	0.163 ± 0.012	0.069 ± 0.018	0.061 ± 0.043	0.102 ± 0.014
	06 Feb 92	12 44	50	5.206 ± 0.028	0.261 ± 0.019	0.413 ± 0.018	0.162 ± 0.010	0.055 ± 0.018	0.056 ± 0.043	0.095 ± 0.014
	09 Feb 92	11 35	25	5.228 ± 0.028	0.269 ± 0.021	0.411 ± 0.017	0.180 ± 0.014	0.083 ± 0.017	-0.006 ± 0.039	0.113 ± 0.017
	09 Feb 92	11 37	26	5.235 ± 0.027	0.267 ± 0.022	0.413 ± 0.020	0.180 ± 0.017	0.086 ± 0.017	-0.012 ± 0.039	0.116 ± 0.019
004	10 Feb 92	10 37	26	5.247 ± 0.027	0.199 ± 0.033	0.430 ± 0.026	0.140 ± 0.018	0.080 ± 0.019	0.002 ± 0.043	0.099 ± 0.015
	27 Feb 91	11 24	38	5.500 ± 0.018	0.248 ± 0.017	0.427 ± 0.012	0.147 ± 0.018	0.047 ± 0.010	0.049 ± 0.009	0.050 ± 0.012
005	27 Feb 91	11 27	39	5.502 ± 0.018	0.247 ± 0.017	0.425 ± 0.012	0.150 ± 0.018	0.043 ± 0.010	0.047 ± 0.009	0.052 ± 0.012
	27 Feb 91	10 49	29	5.546 ± 0.018	0.253 ± 0.017	0.442 ± 0.012	0.169 ± 0.017	0.038 ± 0.010	0.046 ± 0.009	0.067 ± 0.012
	27 Feb 91	10 52	30	5.544 ± 0.018	0.254 ± 0.017	0.442 ± 0.012	0.169 ± 0.017	0.042 ± 0.010	0.044 ± 0.009	0.070 ± 0.012

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Table D.5 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
006	27 Feb 91	11 14	35	5.609 ± 0.018	0.302 ± 0.017	0.465 ± 0.012	0.157 ± 0.018	0.054 ± 0.010	0.048 ± 0.009	0.062 ± 0.012
	27 Feb 91	11 17	36	5.616 ± 0.018	0.304 ± 0.017	0.468 ± 0.012	0.157 ± 0.018	0.053 ± 0.010	0.045 ± 0.009	0.070 ± 0.012
	11 May 91	11 38	38	5.556 ± 0.030	0.326 ± 0.017	0.450 ± 0.022	0.139 ± 0.019	0.094 ± 0.018	0.028 ± 0.018	0.097 ± 0.020
	11 May 91	11 42	39	5.558 ± 0.031	0.327 ± 0.015	0.458 ± 0.024	0.127 ± 0.022	0.089 ± 0.019	0.039 ± 0.019	0.081 ± 0.025
	21 May 91	07 41	15	5.551 ± 0.018	0.319 ± 0.017	0.471 ± 0.016	0.145 ± 0.018	0.110 ± 0.018	0.011 ± 0.014	0.118 ± 0.011
	21 May 91	07 44	16	5.546 ± 0.018	0.320 ± 0.018	0.485 ± 0.016	0.138 ± 0.015	0.109 ± 0.016	0.014 ± 0.014	0.116 ± 0.012
	21 May 91	08 16	26	5.532 ± 0.018	0.321 ± 0.018	0.483 ± 0.015	0.138 ± 0.017	0.117 ± 0.019	-0.004 ± 0.015	0.127 ± 0.012
	21 May 91	08 19	27	5.526 ± 0.020	0.324 ± 0.020	0.480 ± 0.018	0.136 ± 0.018	0.120 ± 0.017	0.000 ± 0.016	0.108 ± 0.016
	06 Feb 92	12 33	46	5.571 ± 0.028	0.332 ± 0.020	0.467 ± 0.019	0.160 ± 0.010	0.067 ± 0.018	0.060 ± 0.043	0.101 ± 0.014
	06 Feb 92	12 36	47	5.574 ± 0.028	0.341 ± 0.019	0.464 ± 0.018	0.160 ± 0.011	0.066 ± 0.019	0.057 ± 0.044	0.105 ± 0.013
	09 Feb 92	11 30	23	5.598 ± 0.026	0.336 ± 0.021	0.465 ± 0.018	0.174 ± 0.015	0.097 ± 0.016	-0.002 ± 0.039	0.112 ± 0.014
	09 Feb 92	11 32	24	5.608 ± 0.027	0.335 ± 0.023	0.469 ± 0.017	0.177 ± 0.014	0.093 ± 0.017	-0.008 ± 0.039	0.123 ± 0.017
	09 Feb 92	12 35	42	5.597 ± 0.027	0.333 ± 0.023	0.468 ± 0.019	0.174 ± 0.014	0.090 ± 0.019	0.004 ± 0.040	0.121 ± 0.016
	09 Feb 92	12 37	43	5.596 ± 0.028	0.330 ± 0.022	0.474 ± 0.019	0.168 ± 0.016	0.088 ± 0.016	0.008 ± 0.040	0.125 ± 0.018
	09 Feb 92	13 38	60	5.590 ± 0.029	0.334 ± 0.022	0.462 ± 0.018	0.178 ± 0.016	0.080 ± 0.020	0.018 ± 0.042	0.119 ± 0.019
	09 Feb 92	13 40	61	5.587 ± 0.028	0.341 ± 0.023	0.466 ± 0.021	0.169 ± 0.016	0.084 ± 0.017	0.020 ± 0.040	0.117 ± 0.014
	09 Feb 92	14 29	78	5.571 ± 0.029	0.327 ± 0.022	0.474 ± 0.016	0.172 ± 0.013	0.072 ± 0.018	0.030 ± 0.042	0.118 ± 0.015
	09 Feb 92	14 31	79	5.573 ± 0.029	0.334 ± 0.021	0.470 ± 0.017	0.162 ± 0.013	0.077 ± 0.019	0.032 ± 0.042	0.111 ± 0.017
	10 Feb 92	10 33	24	5.626 ± 0.027	0.270 ± 0.032	0.483 ± 0.026	0.138 ± 0.017	0.090 ± 0.019	0.008 ± 0.043	0.112 ± 0.014
	10 Feb 92	10 35	25	5.623 ± 0.027	0.281 ± 0.033	0.478 ± 0.026	0.138 ± 0.017	0.086 ± 0.017	0.002 ± 0.042	0.115 ± 0.015
007	10 Feb 92	11 38	41	5.610 ± 0.026	0.279 ± 0.032	0.475 ± 0.026	0.138 ± 0.017	0.076 ± 0.018	0.024 ± 0.042	0.113 ± 0.013
	10 Feb 92	11 40	42	5.595 ± 0.028	0.274 ± 0.032	0.478 ± 0.026	0.142 ± 0.017	0.078 ± 0.018	0.035 ± 0.043	0.106 ± 0.017
	10 Feb 92	12 31	55	5.590 ± 0.027	0.274 ± 0.032	0.479 ± 0.026	0.136 ± 0.018	0.075 ± 0.018	0.033 ± 0.042	0.113 ± 0.015
	10 Feb 92	12 33	56	5.594 ± 0.027	0.274 ± 0.032	0.481 ± 0.026	0.127 ± 0.018	0.081 ± 0.019	0.038 ± 0.043	0.106 ± 0.015
	10 Feb 92	13 38	71	5.576 ± 0.027	0.268 ± 0.031	0.480 ± 0.025	0.134 ± 0.017	0.068 ± 0.019	0.052 ± 0.043	0.114 ± 0.016
	10 Feb 92	13 40	72	5.578 ± 0.027	0.275 ± 0.032	0.472 ± 0.027	0.131 ± 0.018	0.070 ± 0.018	0.058 ± 0.043	0.102 ± 0.014
	10 Feb 92	14 34	88	5.566 ± 0.029	0.273 ± 0.033	0.472 ± 0.026	0.130 ± 0.017	0.058 ± 0.019	0.073 ± 0.045	0.107 ± 0.019
	10 Feb 92	14 36	89	5.568 ± 0.029	0.271 ± 0.032	0.469 ± 0.027	0.131 ± 0.019	0.068 ± 0.018	0.068 ± 0.045	0.097 ± 0.018
	27 Feb 91	11 59	47	6.499 ± 0.018	0.392 ± 0.017	0.598 ± 0.012	0.205 ± 0.017	0.064 ± 0.010	0.051 ± 0.009	0.069 ± 0.012
	27 Feb 91	12 02	48	6.495 ± 0.018	0.386 ± 0.017	0.602 ± 0.012	0.203 ± 0.017	0.066 ± 0.010	0.050 ± 0.009	0.075 ± 0.012
	28 Feb 91	10 52	23	6.478 ± 0.015	0.389 ± 0.020	0.603 ± 0.018	0.183 ± 0.015	0.100 ± 0.021	0.024 ± 0.020	0.137 ± 0.022

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Table D.5 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
007	28 Feb 91	10 55	24	6.478 ± 0.013	0.390 ± 0.020	0.605 ± 0.018	0.177 ± 0.016	0.101 ± 0.021	0.034 ± 0.018	0.132 ± 0.021
	21 May 91	08 54	34	6.415 ± 0.022	0.410 ± 0.020	0.624 ± 0.019	0.177 ± 0.021	0.128 ± 0.021	0.010 ± 0.019	0.117 ± 0.016
	21 May 91	08 57	35	6.418 ± 0.020	0.421 ± 0.021	0.607 ± 0.021	0.190 ± 0.023	0.128 ± 0.027	0.008 ± 0.021	0.115 ± 0.016
008	27 Feb 91	12 10	50	7.689 ± 0.019	0.565 ± 0.017	0.839 ± 0.012	0.385 ± 0.018	0.112 ± 0.010	0.078 ± 0.009	0.145 ± 0.012
	27 Feb 91	12 13	51	7.685 ± 0.019	0.562 ± 0.017	0.853 ± 0.012	0.378 ± 0.018	0.106 ± 0.010	0.086 ± 0.009	0.141 ± 0.012
	28 Feb 91	11 02	26	7.688 ± 0.015	0.562 ± 0.023	0.853 ± 0.021	0.361 ± 0.017	0.145 ± 0.023	0.045 ± 0.021	0.182 ± 0.025
	28 Feb 91	11 05	27	7.676 ± 0.012	0.561 ± 0.021	0.842 ± 0.019	0.368 ± 0.018	0.142 ± 0.023	0.064 ± 0.018	0.181 ± 0.021
009	27 Feb 91	12 20	53	7.103 ± 0.018	0.318 ± 0.017	0.509 ± 0.012	0.174 ± 0.017	0.062 ± 0.010	0.046 ± 0.009	0.071 ± 0.012
	27 Feb 91	12 23	54	7.088 ± 0.018	0.320 ± 0.017	0.506 ± 0.012	0.179 ± 0.018	0.057 ± 0.010	0.059 ± 0.009	0.055 ± 0.012
	28 Feb 91	11 15	29	7.077 ± 0.012	0.312 ± 0.020	0.511 ± 0.018	0.166 ± 0.017	0.084 ± 0.022	0.046 ± 0.018	0.122 ± 0.020
	28 Feb 91	11 18	30	7.081 ± 0.017	0.319 ± 0.020	0.517 ± 0.018	0.158 ± 0.015	0.086 ± 0.021	0.042 ± 0.021	0.133 ± 0.024
	14 Apr 91	11 34	32	7.029 ± 0.023	0.342 ± 0.026	0.510 ± 0.019	0.158 ± 0.017	0.057 ± 0.010	0.057 ± 0.018	0.082 ± 0.021
	14 Apr 91	11 39	33	7.028 ± 0.023	0.335 ± 0.027	0.502 ± 0.018	0.169 ± 0.018	0.045 ± 0.013	0.068 ± 0.017	0.068 ± 0.021
	27 Feb 91	12 31	56	7.272 ± 0.018	0.477 ± 0.017	0.723 ± 0.012	0.298 ± 0.017	0.061 ± 0.010	0.060 ± 0.009	0.133 ± 0.012
010	27 Feb 91	12 34	57	7.272 ± 0.018	0.481 ± 0.017	0.724 ± 0.012	0.297 ± 0.017	0.054 ± 0.010	0.066 ± 0.009	0.125 ± 0.012
	28 Feb 91	11 25	32	7.261 ± 0.012	0.479 ± 0.020	0.735 ± 0.018	0.273 ± 0.016	0.083 ± 0.021	0.049 ± 0.018	0.192 ± 0.019
	28 Feb 91	11 28	33	7.267 ± 0.014	0.474 ± 0.021	0.733 ± 0.018	0.267 ± 0.015	0.093 ± 0.021	0.038 ± 0.019	0.189 ± 0.020
	14 Apr 91	10 28	21	7.208 ± 0.023	0.497 ± 0.028	0.720 ± 0.021	0.273 ± 0.016	0.064 ± 0.010	0.071 ± 0.018	0.135 ± 0.019
	14 Apr 91	10 33	22	7.219 ± 0.024	0.493 ± 0.026	0.725 ± 0.018	0.270 ± 0.015	0.070 ± 0.012	0.063 ± 0.019	0.131 ± 0.019
011	28 Feb 91	11 47	38	7.300 ± 0.013	0.478 ± 0.021	0.794 ± 0.019	0.283 ± 0.016	0.105 ± 0.021	0.057 ± 0.018	0.131 ± 0.020
	28 Feb 91	11 50	39	7.300 ± 0.012	0.483 ± 0.020	0.790 ± 0.020	0.288 ± 0.018	0.095 ± 0.022	0.063 ± 0.018	0.139 ± 0.021
	06 Feb 92	13 43	67	7.288 ± 0.031	0.511 ± 0.026	0.791 ± 0.018	0.289 ± 0.011	0.087 ± 0.018	0.089 ± 0.045	0.112 ± 0.019
	06 Feb 92	13 45	68	7.282 ± 0.029	0.502 ± 0.022	0.794 ± 0.019	0.295 ± 0.013	0.085 ± 0.021	0.093 ± 0.045	0.123 ± 0.018
012	28 Feb 91	11 59	41	7.361 ± 0.013	0.584 ± 0.023	0.738 ± 0.020	0.508 ± 0.016	0.202 ± 0.023	0.123 ± 0.019	0.335 ± 0.021
	28 Feb 91	12 04	42	7.364 ± 0.012	0.583 ± 0.023	0.746 ± 0.021	0.505 ± 0.018	0.202 ± 0.023	0.122 ± 0.019	0.336 ± 0.021
	14 Apr 91	09 25	13	7.320 ± 0.025	0.579 ± 0.029	0.741 ± 0.020	0.489 ± 0.018	0.182 ± 0.012	0.143 ± 0.019	0.294 ± 0.021
	14 Apr 91	09 29	14	7.324 ± 0.024	0.579 ± 0.030	0.737 ± 0.021	0.493 ± 0.017	0.185 ± 0.011	0.140 ± 0.018	0.300 ± 0.020
	14 Apr 91	10 53	25	7.322 ± 0.026	0.577 ± 0.028	0.741 ± 0.019	0.492 ± 0.019	0.185 ± 0.014	0.139 ± 0.021	0.295 ± 0.024
	14 Apr 91	10 57	26	7.323 ± 0.025	0.575 ± 0.028	0.743 ± 0.019	0.492 ± 0.016	0.178 ± 0.010	0.145 ± 0.018	0.292 ± 0.021
	14 Apr 91	12 02	36	7.321 ± 0.025	0.567 ± 0.028	0.744 ± 0.021	0.493 ± 0.019	0.181 ± 0.012	0.139 ± 0.020	0.294 ± 0.029
	14 Apr 91	12 07	37	7.321 ± 0.025	0.583 ± 0.029	0.732 ± 0.020	0.491 ± 0.020	0.180 ± 0.013	0.147 ± 0.020	0.293 ± 0.022

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Table D.5 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
012	14 Apr 91	12 57	45	7.323 ± 0.025	0.585 ± 0.029	0.740 ± 0.023	0.490 ± 0.022	0.187 ± 0.014	0.139 ± 0.019	0.301 ± 0.024
013	28 Feb 91	12 16	44	7.397 ± 0.013	0.511 ± 0.020	0.832 ± 0.018	0.316 ± 0.016	0.104 ± 0.022	0.064 ± 0.019	0.126 ± 0.020
	28 Feb 91	12 21	45	7.406 ± 0.013	0.510 ± 0.021	0.835 ± 0.018	0.316 ± 0.015	0.111 ± 0.021	0.053 ± 0.018	0.140 ± 0.020
014	28 Feb 91	12 53	50	7.556 ± 0.015	0.535 ± 0.022	0.848 ± 0.019	0.367 ± 0.016	0.156 ± 0.022	0.054 ± 0.020	0.185 ± 0.021
	28 Feb 91	12 58	51	7.564 ± 0.013	0.536 ± 0.021	0.855 ± 0.019	0.370 ± 0.016	0.153 ± 0.022	0.050 ± 0.018	0.186 ± 0.021
015	28 Feb 91	13 09	53	7.587 ± 0.016	0.520 ± 0.023	0.767 ± 0.020	0.506 ± 0.017	0.222 ± 0.023	0.080 ± 0.021	0.319 ± 0.027
	28 Feb 91	13 15	54	7.584 ± 0.014	0.528 ± 0.022	0.764 ± 0.020	0.505 ± 0.017	0.214 ± 0.023	0.082 ± 0.020	0.323 ± 0.023
016	10 Feb 92	13 45	73	7.681 ± 0.029	0.515 ± 0.033	0.839 ± 0.026	0.365 ± 0.017	0.108 ± 0.019	0.100 ± 0.045	0.164 ± 0.018
	10 Feb 92	13 47	74	7.684 ± 0.030	0.495 ± 0.034	0.849 ± 0.027	0.363 ± 0.017	0.102 ± 0.018	0.104 ± 0.045	0.162 ± 0.023
017	09 Feb 92	12 43	44	7.788 ± 0.028	0.608 ± 0.023	0.823 ± 0.019	0.493 ± 0.014	0.179 ± 0.018	0.068 ± 0.040	0.273 ± 0.017
	09 Feb 92	12 46	45	7.783 ± 0.027	0.608 ± 0.021	0.824 ± 0.021	0.490 ± 0.018	0.171 ± 0.017	0.080 ± 0.039	0.273 ± 0.014
	10 Feb 92	14 41	90	7.770 ± 0.029	0.553 ± 0.038	0.822 ± 0.034	0.464 ± 0.019	0.148 ± 0.021	0.123 ± 0.046	0.255 ± 0.023
	10 Feb 92	14 43	91	7.748 ± 0.030	0.537 ± 0.034	0.830 ± 0.030	0.466 ± 0.022	0.134 ± 0.019	0.144 ± 0.046	0.236 ± 0.018
018	14 Apr 91	11 52	34	7.811 ± 0.028	0.366 ± 0.033	0.718 ± 0.088	0.803 ± 0.088	0.293 ± 0.013	0.263 ± 0.021	0.568 ± 0.024
	14 Apr 91	11 56	35	7.822 ± 0.029	0.378 ± 0.035	0.650 ± 0.022	0.869 ± 0.022	0.289 ± 0.015	0.255 ± 0.022	0.582 ± 0.027
	06 Feb 92	13 49	69	7.824 ± 0.031	0.443 ± 0.024	0.653 ± 0.024	0.878 ± 0.016	0.313 ± 0.023	0.263 ± 0.049	0.594 ± 0.020
	06 Feb 92	13 51	70	7.820 ± 0.031	0.433 ± 0.034	0.647 ± 0.028	0.882 ± 0.019	0.315 ± 0.026	0.266 ± 0.049	0.584 ± 0.019
020	09 Feb 92	11 56	30	7.951 ± 0.026	0.363 ± 0.022	0.472 ± 0.018	0.242 ± 0.015	0.147 ± 0.017	0.057 ± 0.039	0.191 ± 0.014
	09 Feb 92	11 58	31	7.952 ± 0.028	0.370 ± 0.023	0.473 ± 0.022	0.242 ± 0.018	0.143 ± 0.019	0.059 ± 0.040	0.216 ± 0.016
	10 Feb 92	14 48	92	7.934 ± 0.030	0.305 ± 0.035	0.475 ± 0.028	0.215 ± 0.021	0.106 ± 0.021	0.114 ± 0.046	0.215 ± 0.020
	10 Feb 92	14 50	93	7.929 ± 0.030	0.310 ± 0.034	0.472 ± 0.027	0.198 ± 0.018	0.118 ± 0.018	0.121 ± 0.046	0.192 ± 0.021
021	09 Feb 92	12 49	46	8.163 ± 0.032	0.604 ± 0.029	0.812 ± 0.020	0.481 ± 0.017	0.182 ± 0.021	0.074 ± 0.043	0.298 ± 0.023
	09 Feb 92	12 52	47	8.145 ± 0.034	0.607 ± 0.024	0.812 ± 0.018	0.465 ± 0.015	0.190 ± 0.019	0.090 ± 0.044	0.287 ± 0.025
023	06 Feb 92	14 38	83	8.527 ± 0.031	0.552 ± 0.028	0.738 ± 0.026	0.524 ± 0.022	0.177 ± 0.024	0.146 ± 0.047	0.286 ± 0.019
	06 Feb 92	14 41	84	8.518 ± 0.031	0.538 ± 0.027	0.746 ± 0.026	0.525 ± 0.024	0.171 ± 0.026	0.159 ± 0.048	0.274 ± 0.022
024	09 Feb 92	13 45	62	8.634 ± 0.031	0.624 ± 0.025	0.851 ± 0.020	0.441 ± 0.023	0.156 ± 0.025	0.080 ± 0.043	0.239 ± 0.033
	09 Feb 92	13 47	63	8.617 ± 0.033	0.608 ± 0.033	0.869 ± 0.026	0.444 ± 0.020	0.155 ± 0.018	0.089 ± 0.044	0.216 ± 0.026
	10 Feb 92	13 52	75	8.608 ± 0.029	0.587 ± 0.038	0.847 ± 0.030	0.422 ± 0.018	0.137 ± 0.023	0.110 ± 0.046	0.233 ± 0.019
025	14 Apr 91	11 10	28	8.664 ± 0.025	0.560 ± 0.039	0.786 ± 0.030	0.484 ± 0.028	0.135 ± 0.020	0.116 ± 0.020	0.220 ± 0.022
	14 Apr 91	11 14	29	8.664 ± 0.025	0.535 ± 0.032	0.812 ± 0.024	0.483 ± 0.020	0.138 ± 0.011	0.117 ± 0.019	0.227 ± 0.021
	09 Feb 92	14 37	80	8.666 ± 0.029	0.571 ± 0.027	0.810 ± 0.030	0.488 ± 0.029	0.167 ± 0.020	0.121 ± 0.042	0.231 ± 0.018

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Table D.5 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
025	09 Feb 92	14 40	81	8.682 ± 0.030	0.540 ± 0.025	0.803 ± 0.025	0.510 ± 0.024	0.159 ± 0.022	0.115 ± 0.043	0.256 ± 0.021
	14 Apr 91	11 23	30	8.738 ± 0.027	0.470 ± 0.032	0.611 ± 0.025	0.533 ± 0.022	0.235 ± 0.015	0.163 ± 0.022	0.396 ± 0.028
	14 Apr 91	11 28	31	8.731 ± 0.029	0.498 ± 0.039	0.593 ± 0.024	0.555 ± 0.021	0.222 ± 0.012	0.164 ± 0.023	0.369 ± 0.027
	09 Feb 92	14 47	82	8.767 ± 0.030	0.489 ± 0.024	0.604 ± 0.019	0.560 ± 0.016	0.240 ± 0.021	0.162 ± 0.043	0.401 ± 0.018
	09 Feb 92	14 50	83	8.746 ± 0.043	0.501 ± 0.033	0.605 ± 0.030	0.574 ± 0.028	0.243 ± 0.021	0.164 ± 0.053	0.386 ± 0.037
	09 Feb 92	14 56	84	8.890 ± 0.033	0.459 ± 0.028	0.589 ± 0.027	0.642 ± 0.032	0.260 ± 0.028	0.190 ± 0.046	0.438 ± 0.025
028	09 Feb 92	14 59	85	8.877 ± 0.034	0.467 ± 0.053	0.592 ± 0.036	0.637 ± 0.024	0.246 ± 0.026	0.212 ± 0.046	0.439 ± 0.025
	11 May 91	12 25	50	9.076 ± 0.041	0.415 ± 0.049	0.648 ± 0.038	0.577 ± 0.030	0.275 ± 0.026	0.107 ± 0.028	0.425 ± 0.033
	11 May 91	12 28	51	9.074 ± 0.055	0.490 ± 0.063	0.664 ± 0.051	0.508 ± 0.034	0.296 ± 0.027	0.114 ± 0.045	0.425 ± 0.053
	21 May 91	08 24	28	8.991 ± 0.023	0.478 ± 0.035	0.628 ± 0.025	0.574 ± 0.024	0.248 ± 0.022	0.166 ± 0.019	0.413 ± 0.024
	21 May 91	08 29	29	9.008 ± 0.023	0.466 ± 0.031	0.632 ± 0.019	0.560 ± 0.020	0.256 ± 0.019	0.157 ± 0.019	0.423 ± 0.019
	06 Feb 92	13 34	64	9.082 ± 0.045	0.504 ± 0.026	0.614 ± 0.023	0.606 ± 0.016	0.226 ± 0.021	0.174 ± 0.057	0.378 ± 0.039
	06 Feb 92	13 37	65	9.083 ± 0.035	0.502 ± 0.024	0.595 ± 0.022	0.593 ± 0.012	0.231 ± 0.020	0.177 ± 0.050	0.396 ± 0.036
	10 Feb 92	10 56	29	9.245 ± 0.031	0.606 ± 0.061	0.936 ± 0.050	1.257 ± 0.032	0.465 ± 0.031	0.293 ± 0.055	0.766 ± 0.019
	10 Feb 92	11 00	30	9.240 ± 0.032	0.600 ± 0.067	0.916 ± 0.055	1.256 ± 0.038	0.470 ± 0.029	0.305 ± 0.054	0.770 ± 0.029
032	09 Feb 92	12 56	48	9.395 ± 0.030	0.469 ± 0.034	0.582 ± 0.024	0.628 ± 0.024	0.270 ± 0.024	0.162 ± 0.042	0.430 ± 0.023
	09 Feb 92	13 00	49	9.424 ± 0.035	0.470 ± 0.030	0.580 ± 0.030	0.626 ± 0.028	0.272 ± 0.025	0.127 ± 0.046	0.494 ± 0.028
	09 Feb 92	13 51	64	9.669 ± 0.038	0.415 ± 0.039	0.565 ± 0.029	0.665 ± 0.024	0.261 ± 0.026	0.182 ± 0.050	0.484 ± 0.030
033	09 Feb 92	13 54	65	9.653 ± 0.052	0.477 ± 0.043	0.564 ± 0.038	0.629 ± 0.031	0.286 ± 0.027	0.174 ± 0.061	0.455 ± 0.065
	14 Apr 91	09 48	16	9.591 ± 0.029	0.393 ± 0.058	0.576 ± 0.041	0.647 ± 0.039	0.254 ± 0.029	0.191 ± 0.024	0.421 ± 0.028
	14 Apr 91	09 52	17	9.395 ± 0.298	0.378 ± 0.062	0.581 ± 0.047	0.648 ± 0.046	0.224 ± 0.035	0.406 ± 0.297	0.250 ± 0.298
	21 May 91	08 44	32	9.492 ± 0.020	0.407 ± 0.029	0.576 ± 0.020	0.634 ± 0.022	0.255 ± 0.020	0.211 ± 0.015	0.501 ± 0.015
	21 May 91	08 49	33	9.494 ± 0.029	0.385 ± 0.027	0.581 ± 0.025	0.637 ± 0.020	0.263 ± 0.022	0.206 ± 0.026	0.489 ± 0.025
	11 May 91	12 38	53	9.653 ± 0.079	0.638 ± 0.668	1.368 ± 0.254	1.608 ± 0.168	0.530 ± 0.074	0.308 ± 0.062	0.878 ± 0.065
035	11 May 91	12 41	54	9.630 ± 0.075	0.296 ± 0.417	1.243 ± 0.201	1.642 ± 0.145	0.478 ± 0.072	0.338 ± 0.057	0.881 ± 0.060
	21 May 91	08 35	30	9.539 ± 0.037	0.410 ± 0.064	0.888 ± 0.037	1.337 ± 0.031	0.442 ± 0.030	0.427 ± 0.038	0.823 ± 0.043
	21 May 91	08 39	31	9.541 ± 0.025	0.413 ± 0.068	0.907 ± 0.086	1.346 ± 0.062	0.429 ± 0.028	0.429 ± 0.023	0.843 ± 0.019
	06 Feb 92	14 50	85	9.654 ± 0.037	0.551 ± 0.188	1.277 ± 0.112	1.532 ± 0.048	0.502 ± 0.031	0.417 ± 0.059	0.849 ± 0.032
	06 Feb 92	14 54	86	9.686 ± 0.040	0.533 ± 0.177	1.178 ± 0.068	1.572 ± 0.059	0.486 ± 0.038	0.386 ± 0.059	0.905 ± 0.033
	10 Feb 92	11 45	43	9.879 ± 0.044	0.435 ± 0.043	0.544 ± 0.039	0.651 ± 0.031	0.306 ± 0.026	0.152 ± 0.057	0.498 ± 0.042
036	10 Feb 92	11 49	44	9.896 ± 0.034	0.438 ± 0.044	0.548 ± 0.040	0.633 ± 0.026	0.313 ± 0.021	0.135 ± 0.050	0.489 ± 0.029

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Table D.5 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
037	14 Apr 91	10 42	23	9.928 ± 0.030	0.314 ± 0.086	0.636 ± 0.056	0.834 ± 0.047	0.303 ± 0.019	0.260 ± 0.024	0.569 ± 0.029
	14 Apr 91	10 47	24	10.125 ± 0.054	0.307 ± 0.079	0.558 ± 0.081	0.915 ± 0.089	0.367 ± 0.111	0.267 ± 0.101	0.575 ± 0.062
038	09 Feb 92	11 46	28	10.206 ± 0.045	0.693 ± 0.037	0.842 ± 0.027	0.388 ± 0.039	0.173 ± 0.041	0.041 ± 0.054	0.266 ± 0.062
	09 Feb 92	11 51	29	10.190 ± 0.037	0.692 ± 0.039	0.855 ± 0.028	0.392 ± 0.033	0.176 ± 0.030	0.065 ± 0.048	0.265 ± 0.044
040	14 Apr 91	09 58	18	10.258 ± 0.041	0.450 ± 0.124	0.622 ± 0.076	0.832 ± 0.045	0.331 ± 0.032	0.280 ± 0.042	0.560 ± 0.048
	14 Apr 91	10 02	19	10.268 ± 0.030	0.366 ± 0.143	0.677 ± 0.100	0.901 ± 0.048	0.318 ± 0.028	0.280 ± 0.026	0.568 ± 0.048
041	10 Feb 92	12 45	57	10.629 ± 0.045	0.374 ± 0.044	0.570 ± 0.036	0.327 ± 0.032	0.161 ± 0.030	0.163 ± 0.057	0.198 ± 0.079
	10 Feb 92	12 50	58	10.720 ± 0.075	0.389 ± 0.048	0.551 ± 0.045	0.339 ± 0.046	0.137 ± 0.031	0.097 ± 0.082	0.298 ± 0.093

Table D.6: The individual reduced observations for the cluster Kappa Crucis.

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
A	08 Jun 89	08 33	7	5.841 ± 0.021	0.524 ± 0.009	0.351 ± 0.012	0.395 ± 0.008	0.320 ± 0.010	0.147 ± 0.008	0.482 ± 0.011
	08 Jun 89	08 36	8	5.838 ± 0.021	0.523 ± 0.009	0.354 ± 0.012	0.385 ± 0.008	0.325 ± 0.010	0.150 ± 0.008	0.477 ± 0.011
	11 May 91	13 52	68	5.721 ± 0.038	0.471 ± 0.018	0.398 ± 0.021	0.355 ± 0.019	0.314 ± 0.016	0.140 ± 0.019	0.448 ± 0.024
	11 May 91	13 55	69	5.726 ± 0.038	0.478 ± 0.017	0.390 ± 0.020	0.362 ± 0.020	0.305 ± 0.018	0.142 ± 0.018	0.449 ± 0.021
	17 May 91	12 22	14	5.743 ± 0.020	0.525 ± 0.019	0.385 ± 0.019	0.384 ± 0.021	0.299 ± 0.023	0.177 ± 0.014	0.425 ± 0.015
	17 May 91	12 26	15	5.746 ± 0.020	0.531 ± 0.019	0.381 ± 0.019	0.382 ± 0.021	0.301 ± 0.024	0.167 ± 0.014	0.440 ± 0.014
	21 May 91	10 36	63	5.739 ± 0.019	0.512 ± 0.020	0.410 ± 0.017	0.378 ± 0.018	0.321 ± 0.018	0.138 ± 0.015	0.450 ± 0.015
	21 May 91	10 39	64	5.745 ± 0.019	0.520 ± 0.020	0.410 ± 0.016	0.371 ± 0.017	0.324 ± 0.018	0.136 ± 0.016	0.459 ± 0.014
	21 May 91	11 55	82	5.740 ± 0.021	0.517 ± 0.023	0.405 ± 0.022	0.376 ± 0.019	0.316 ± 0.019	0.150 ± 0.017	0.455 ± 0.015
	21 May 91	11 58	83	5.734 ± 0.020	0.532 ± 0.020	0.403 ± 0.017	0.379 ± 0.019	0.325 ± 0.021	0.145 ± 0.017	0.456 ± 0.016
	21 May 91	12 45	96	5.741 ± 0.021	0.518 ± 0.026	0.404 ± 0.023	0.378 ± 0.018	0.320 ± 0.018	0.143 ± 0.016	0.452 ± 0.018
	21 May 91	12 48	97	5.751 ± 0.021	0.535 ± 0.022	0.395 ± 0.016	0.383 ± 0.017	0.320 ± 0.020	0.137 ± 0.017	0.461 ± 0.017
	11 Apr 92	08 57	15	5.668 ± 0.049	0.575 ± 0.031	0.399 ± 0.040	0.404 ± 0.026	0.332 ± 0.017	0.171 ± 0.018	0.436 ± 0.038
	11 Apr 92	08 59	16	5.665 ± 0.050	0.570 ± 0.030	0.390 ± 0.039	0.410 ± 0.026	0.325 ± 0.016	0.183 ± 0.021	0.428 ± 0.038
	11 Apr 92	09 57	34	5.667 ± 0.049	0.562 ± 0.030	0.406 ± 0.039	0.400 ± 0.026	0.336 ± 0.016	0.178 ± 0.018	0.434 ± 0.037
	11 Apr 92	09 59	35	5.663 ± 0.049	0.571 ± 0.030	0.389 ± 0.040	0.411 ± 0.026	0.336 ± 0.016	0.174 ± 0.018	0.434 ± 0.038
	11 Apr 92	11 03	54	5.661 ± 0.049	0.574 ± 0.030	0.398 ± 0.039	0.403 ± 0.026	0.334 ± 0.016	0.170 ± 0.018	0.441 ± 0.037
	11 Apr 92	11 04	55	5.670 ± 0.049	0.566 ± 0.030	0.396 ± 0.039	0.405 ± 0.026	0.334 ± 0.017	0.166 ± 0.019	0.447 ± 0.038
	11 Apr 92	12 14	72	5.657 ± 0.048	0.574 ± 0.030	0.392 ± 0.039	0.414 ± 0.027	0.321 ± 0.018	0.178 ± 0.018	0.428 ± 0.040
	11 Apr 92	12 17	73	5.666 ± 0.048	0.599 ± 0.053	0.395 ± 0.039	0.406 ± 0.026	0.322 ± 0.016	0.177 ± 0.018	0.440 ± 0.037
	11 Apr 92	13 30	96	5.657 ± 0.048	0.574 ± 0.030	0.397 ± 0.039	0.399 ± 0.026	0.330 ± 0.015	0.176 ± 0.017	0.437 ± 0.036
	11 Apr 92	13 36	97	5.652 ± 0.049	0.570 ± 0.030	0.407 ± 0.039	0.398 ± 0.025	0.330 ± 0.015	0.175 ± 0.018	0.439 ± 0.037
	12 Apr 92	09 15	32	5.766 ± 0.029	0.547 ± 0.022	0.365 ± 0.018	0.388 ± 0.021	0.300 ± 0.016	0.172 ± 0.016	0.435 ± 0.022
	12 Apr 92	09 17	33	5.758 ± 0.031	0.547 ± 0.021	0.368 ± 0.017	0.388 ± 0.018	0.294 ± 0.014	0.178 ± 0.019	0.428 ± 0.023
	12 Apr 92	09 49	45	5.755 ± 0.030	0.550 ± 0.019	0.360 ± 0.015	0.391 ± 0.016	0.296 ± 0.014	0.167 ± 0.019	0.442 ± 0.023
	12 Apr 92	09 51	46	5.755 ± 0.028	0.549 ± 0.020	0.362 ± 0.015	0.389 ± 0.015	0.300 ± 0.015	0.168 ± 0.015	0.436 ± 0.020
	12 Apr 92	10 50	60	5.763 ± 0.030	0.543 ± 0.023	0.369 ± 0.020	0.390 ± 0.021	0.289 ± 0.017	0.174 ± 0.018	0.432 ± 0.023
	12 Apr 92	10 52	61	5.759 ± 0.028	0.547 ± 0.020	0.372 ± 0.015	0.379 ± 0.015	0.295 ± 0.012	0.180 ± 0.014	0.420 ± 0.019
	12 Apr 92	12 02	76	5.744 ± 0.028	0.550 ± 0.020	0.368 ± 0.015	0.383 ± 0.017	0.293 ± 0.014	0.175 ± 0.013	0.434 ± 0.023
	12 Apr 92	12 04	77	5.747 ± 0.028	0.538 ± 0.020	0.369 ± 0.015	0.396 ± 0.014	0.295 ± 0.015	0.169 ± 0.018	0.428 ± 0.019

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
B	17 May 91	12 36	17	5.946 ± 0.019	0.340 ± 0.020	0.271 ± 0.020	0.318 ± 0.021	0.263 ± 0.024	0.143 ± 0.013	0.356 ± 0.013
	21 May 91	12 17	88	5.958 ± 0.020	0.331 ± 0.021	0.290 ± 0.016	0.306 ± 0.016	0.288 ± 0.017	0.118 ± 0.016	0.382 ± 0.018
	21 May 91	12 19	89	5.957 ± 0.021	0.316 ± 0.019	0.289 ± 0.017	0.318 ± 0.019	0.279 ± 0.019	0.122 ± 0.016	0.382 ± 0.015
	11 Apr 92	09 08	19	5.844 ± 0.049	0.392 ± 0.030	0.271 ± 0.039	0.344 ± 0.026	0.303 ± 0.016	0.149 ± 0.021	0.359 ± 0.040
	11 Apr 92	09 10	20	5.843 ± 0.048	0.392 ± 0.030	0.274 ± 0.039	0.344 ± 0.026	0.310 ± 0.018	0.144 ± 0.019	0.360 ± 0.037
	12 Apr 92	09 24	36	5.941 ± 0.028	0.359 ± 0.020	0.245 ± 0.017	0.321 ± 0.016	0.271 ± 0.014	0.139 ± 0.015	0.351 ± 0.020
	12 Apr 92	09 26	37	5.938 ± 0.028	0.349 ± 0.021	0.242 ± 0.017	0.332 ± 0.018	0.265 ± 0.014	0.144 ± 0.016	0.354 ± 0.022
	13 Apr 92	08 51	30	5.948 ± 0.023	0.343 ± 0.020	0.262 ± 0.017	0.309 ± 0.016	0.264 ± 0.015	0.146 ± 0.018	0.358 ± 0.020
	13 Apr 92	08 52	31	5.943 ± 0.019	0.332 ± 0.016	0.254 ± 0.015	0.313 ± 0.013	0.270 ± 0.014	0.144 ± 0.013	0.358 ± 0.020
	14 Apr 92	09 50	58	5.940 ± 0.058	0.355 ± 0.026	0.237 ± 0.049	0.306 ± 0.042	0.276 ± 0.039	0.135 ± 0.018	0.375 ± 0.030
	14 Apr 92	09 52	59	5.935 ± 0.058	0.355 ± 0.028	0.233 ± 0.049	0.312 ± 0.042	0.275 ± 0.040	0.138 ± 0.020	0.367 ± 0.030
	18 Feb 93	14 30	94	6.019 ± 0.031	0.261 ± 0.063	0.263 ± 0.015	0.302 ± 0.012	0.269 ± 0.012	0.128 ± 0.014	0.358 ± 0.024
	18 Feb 93	14 32	95	6.011 ± 0.030	0.259 ± 0.063	0.267 ± 0.015	0.307 ± 0.011	0.259 ± 0.013	0.128 ± 0.010	0.367 ± 0.024
	20 May 93	09 52	38	5.992 ± 0.014	0.375 ± 0.012	0.241 ± 0.008	0.308 ± 0.008	0.252 ± 0.010	0.148 ± 0.010	0.379 ± 0.010
	20 May 93	09 54	39	5.991 ± 0.014	0.375 ± 0.012	0.240 ± 0.008	0.313 ± 0.008	0.255 ± 0.010	0.143 ± 0.010	0.380 ± 0.010
C	08 Jun 89	08 44	10	6.847 ± 0.021	0.312 ± 0.009	0.239 ± 0.012	0.320 ± 0.008	0.290 ± 0.009	0.123 ± 0.008	0.401 ± 0.010
	08 Jun 89	08 46	11	6.847 ± 0.021	0.313 ± 0.009	0.228 ± 0.012	0.332 ± 0.008	0.289 ± 0.009	0.131 ± 0.008	0.397 ± 0.010
	11 May 91	14 04	71	6.775 ± 0.036	0.274 ± 0.018	0.290 ± 0.020	0.286 ± 0.017	0.273 ± 0.016	0.121 ± 0.017	0.362 ± 0.022
	11 May 91	14 07	72	6.770 ± 0.036	0.277 ± 0.019	0.275 ± 0.020	0.300 ± 0.023	0.276 ± 0.022	0.115 ± 0.020	0.363 ± 0.024
	17 May 91	12 46	19	6.787 ± 0.020	0.320 ± 0.019	0.277 ± 0.019	0.314 ± 0.023	0.269 ± 0.025	0.148 ± 0.014	0.363 ± 0.016
	17 May 91	12 50	20	6.773 ± 0.020	0.313 ± 0.019	0.273 ± 0.019	0.320 ± 0.021	0.263 ± 0.023	0.161 ± 0.014	0.352 ± 0.017
	21 May 91	12 11	86	6.789 ± 0.021	0.313 ± 0.021	0.287 ± 0.020	0.311 ± 0.020	0.288 ± 0.018	0.139 ± 0.016	0.380 ± 0.017
	21 May 91	12 14	87	6.805 ± 0.020	0.304 ± 0.019	0.289 ± 0.017	0.318 ± 0.020	0.283 ± 0.021	0.129 ± 0.018	0.388 ± 0.015
	11 Apr 92	09 03	17	6.622 ± 0.048	0.359 ± 0.031	0.274 ± 0.039	0.353 ± 0.028	0.298 ± 0.018	0.162 ± 0.018	0.361 ± 0.038
	11 Apr 92	09 05	18	6.632 ± 0.049	0.359 ± 0.031	0.285 ± 0.039	0.339 ± 0.026	0.306 ± 0.018	0.149 ± 0.019	0.376 ± 0.037
	12 Apr 92	09 19	34	6.745 ± 0.027	0.324 ± 0.020	0.244 ± 0.015	0.336 ± 0.021	0.266 ± 0.022	0.148 ± 0.018	0.371 ± 0.021
	12 Apr 92	09 21	35	6.742 ± 0.028	0.322 ± 0.020	0.247 ± 0.015	0.323 ± 0.018	0.280 ± 0.016	0.141 ± 0.015	0.373 ± 0.021
	13 Apr 92	08 47	28	6.758 ± 0.021	0.313 ± 0.016	0.258 ± 0.014	0.316 ± 0.010	0.268 ± 0.014	0.156 ± 0.016	0.366 ± 0.023
	13 Apr 92	08 48	29	6.762 ± 0.019	0.303 ± 0.021	0.257 ± 0.019	0.318 ± 0.015	0.269 ± 0.015	0.155 ± 0.012	0.366 ± 0.017
	14 Apr 92	09 45	56	6.749 ± 0.059	0.330 ± 0.027	0.243 ± 0.050	0.307 ± 0.044	0.273 ± 0.040	0.144 ± 0.020	0.380 ± 0.032
	14 Apr 92	09 46	57	6.749 ± 0.059	0.327 ± 0.027	0.247 ± 0.049	0.312 ± 0.041	0.275 ± 0.040	0.138 ± 0.022	0.374 ± 0.031

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
C	18 Feb 93	14 35	96	6.854 ± 0.030	0.275 ± 0.063	0.272 ± 0.015	0.295 ± 0.013	0.273 ± 0.014	0.125 ± 0.011	0.366 ± 0.022
	18 Feb 93	14 37	97	6.845 ± 0.030	0.266 ± 0.063	0.269 ± 0.015	0.304 ± 0.012	0.261 ± 0.013	0.141 ± 0.010	0.347 ± 0.024
	20 May 93	09 58	40	6.806 ± 0.014	0.367 ± 0.014	0.249 ± 0.010	0.311 ± 0.008	0.256 ± 0.010	0.149 ± 0.010	0.382 ± 0.015
	20 May 93	10 00	41	6.808 ± 0.014	0.369 ± 0.012	0.245 ± 0.009	0.307 ± 0.008	0.263 ± 0.010	0.144 ± 0.010	0.382 ± 0.011
	17 May 91	13 54	32	7.366 ± 0.037	1.207 ± 0.226	1.547 ± 0.124	2.356 ± 0.052	1.150 ± 0.046	0.603 ± 0.027	1.469 ± 0.029
D	17 May 91	13 58	33	7.363 ± 0.038	1.105 ± 0.270	1.591 ± 0.115	2.324 ± 0.070	1.162 ± 0.045	0.599 ± 0.027	1.471 ± 0.029
	21 May 91	11 10	70	7.488 ± 0.035	0.816 ± 0.064	1.228 ± 0.058	2.205 ± 0.046	1.045 ± 0.035	0.634 ± 0.030	1.492 ± 0.027
	21 May 91	11 14	71	7.478 ± 0.035	0.738 ± 0.096	1.211 ± 0.070	2.226 ± 0.039	1.045 ± 0.033	0.641 ± 0.027	1.493 ± 0.025
	11 Apr 92	10 13	40	7.686 ± 0.089	0.915 ± 0.204	1.602 ± 0.142	2.360 ± 0.057	0.999 ± 0.031	0.661 ± 0.033	1.433 ± 0.067
	11 Apr 92	10 15	41	7.671 ± 0.089	0.772 ± 0.259	1.551 ± 0.113	2.368 ± 0.063	0.999 ± 0.028	0.681 ± 0.030	1.418 ± 0.067
	13 Apr 92	08 56	32	7.501 ± 0.043	1.322 ± 0.533	1.485 ± 0.311	2.334 ± 0.084	1.120 ± 0.030	0.665 ± 0.025	1.424 ± 0.032
	13 Apr 92	08 59	33	7.512 ± 0.038	1.104 ± 0.238	1.542 ± 0.094	2.354 ± 0.047	1.113 ± 0.026	0.641 ± 0.018	1.444 ± 0.026
	14 Apr 92	09 55	60	7.677 ± 0.119	1.032 ± 0.256	1.659 ± 0.176	2.469 ± 0.103	0.977 ± 0.080	0.672 ± 0.034	1.388 ± 0.059
	14 Apr 92	09 58	61	7.671 ± 0.119	1.253 ± 0.183	1.581 ± 0.145	2.472 ± 0.098	0.982 ± 0.080	0.671 ± 0.032	1.382 ± 0.058
	18 Feb 93	14 41	98	7.550 ± 0.052	1.355 ± 0.159	1.561 ± 0.108	2.305 ± 0.030	1.112 ± 0.027	0.574 ± 0.021	1.570 ± 0.055
E	18 Feb 93	14 44	99	7.535 ± 0.052	1.374 ± 0.196	1.478 ± 0.103	2.323 ± 0.036	1.112 ± 0.028	0.592 ± 0.022	1.557 ± 0.056
	17 May 91	15 09	45	8.338 ± 0.022	0.226 ± 0.020	0.216 ± 0.023	0.259 ± 0.027	0.249 ± 0.029	0.117 ± 0.018	0.296 ± 0.021
	17 May 91	15 13	46	8.332 ± 0.026	0.222 ± 0.021	0.227 ± 0.022	0.252 ± 0.024	0.239 ± 0.030	0.132 ± 0.024	0.266 ± 0.020
	21 May 91	12 55	98	8.321 ± 0.022	0.212 ± 0.020	0.249 ± 0.017	0.251 ± 0.019	0.232 ± 0.023	0.114 ± 0.022	0.329 ± 0.024
	21 May 91	12 59	99	8.304 ± 0.026	0.221 ± 0.019	0.241 ± 0.016	0.258 ± 0.017	0.231 ± 0.018	0.129 ± 0.023	0.322 ± 0.023
	11 Apr 92	13 41	98	8.181 ± 0.046	0.288 ± 0.029	0.233 ± 0.038	0.291 ± 0.025	0.260 ± 0.016	0.133 ± 0.017	0.311 ± 0.037
	11 Apr 92	13 43	99	8.178 ± 0.047	0.278 ± 0.030	0.241 ± 0.038	0.288 ± 0.031	0.263 ± 0.024	0.135 ± 0.018	0.278 ± 0.037
	14 Apr 92	10 06	63	8.311 ± 0.057	0.253 ± 0.026	0.182 ± 0.048	0.257 ± 0.041	0.236 ± 0.038	0.110 ± 0.021	0.314 ± 0.034
	14 Apr 92	10 09	64	8.313 ± 0.058	0.242 ± 0.027	0.200 ± 0.049	0.248 ± 0.043	0.240 ± 0.039	0.104 ± 0.025	0.328 ± 0.037
	18 Feb 93	15 52	118	8.390 ± 0.032	0.207 ± 0.062	0.226 ± 0.019	0.240 ± 0.013	0.222 ± 0.014	0.108 ± 0.018	0.295 ± 0.033
F	18 Feb 93	15 54	119	8.398 ± 0.032	0.201 ± 0.062	0.225 ± 0.016	0.258 ± 0.014	0.214 ± 0.015	0.103 ± 0.018	0.302 ± 0.040
	17 May 91	15 19	47	9.074 ± 0.027	0.213 ± 0.022	0.233 ± 0.029	0.242 ± 0.033	0.218 ± 0.030	0.102 ± 0.021	0.247 ± 0.025
	17 May 91	15 24	48	9.036 ± 0.025	0.217 ± 0.026	0.228 ± 0.023	0.242 ± 0.029	0.221 ± 0.032	0.131 ± 0.019	0.213 ± 0.021
	21 May 91	13 05	100	8.997 ± 0.026	0.210 ± 0.021	0.256 ± 0.020	0.241 ± 0.018	0.208 ± 0.024	0.125 ± 0.027	0.281 ± 0.042
	21 May 91	13 09	101	8.995 ± 0.022	0.203 ± 0.021	0.265 ± 0.020	0.242 ± 0.023	0.197 ± 0.023	0.127 ± 0.020	0.292 ± 0.018
	11 Apr 92	13 48	100	8.901 ± 0.050	0.296 ± 0.045	0.247 ± 0.038	0.271 ± 0.028	0.237 ± 0.021	0.116 ± 0.028	0.241 ± 0.043

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
F	11 Apr 92	13 50	101	8.909 ± 0.045	0.278 ± 0.029	0.247 ± 0.038	0.269 ± 0.028	0.230 ± 0.020	0.113 ± 0.018	0.262 ± 0.037
	14 Apr 92	10 12	65	9.031 ± 0.058	0.255 ± 0.026	0.185 ± 0.048	0.240 ± 0.041	0.208 ± 0.037	0.093 ± 0.025	0.271 ± 0.046
	14 Apr 92	10 15	66	9.023 ± 0.064	0.249 ± 0.033	0.193 ± 0.056	0.226 ± 0.047	0.209 ± 0.039	0.106 ± 0.037	0.269 ± 0.052
G	12 Apr 92	12 14	78	9.760 ± 0.031	0.242 ± 0.023	0.211 ± 0.021	0.315 ± 0.024	0.200 ± 0.022	0.119 ± 0.024	0.275 ± 0.029
	12 Apr 92	12 18	79	9.757 ± 0.032	0.227 ± 0.029	0.233 ± 0.020	0.291 ± 0.022	0.219 ± 0.022	0.112 ± 0.025	0.273 ± 0.035
	13 Apr 92	09 57	49	9.769 ± 0.029	0.217 ± 0.035	0.238 ± 0.025	0.266 ± 0.024	0.210 ± 0.023	0.133 ± 0.025	0.272 ± 0.049
	13 Apr 92	10 00	50	9.785 ± 0.019	0.228 ± 0.016	0.225 ± 0.024	0.283 ± 0.032	0.210 ± 0.026	0.105 ± 0.014	0.324 ± 0.019
	14 Apr 92	10 22	67	9.744 ± 0.064	0.246 ± 0.030	0.219 ± 0.052	0.243 ± 0.046	0.243 ± 0.041	0.105 ± 0.036	0.273 ± 0.071
	14 Apr 92	10 58	80	9.736 ± 0.061	0.247 ± 0.033	0.200 ± 0.051	0.257 ± 0.044	0.237 ± 0.038	0.121 ± 0.030	0.273 ± 0.052
H	21 May 91	13 18	102	9.867 ± 0.030	0.271 ± 0.027	0.338 ± 0.033	0.302 ± 0.036	0.179 ± 0.031	0.189 ± 0.027	0.406 ± 0.029
	21 May 91	13 23	103	9.826 ± 0.024	0.254 ± 0.023	0.340 ± 0.018	0.307 ± 0.018	0.180 ± 0.021	0.217 ± 0.022	0.394 ± 0.033
	11 Apr 92	13 54	102	9.904 ± 0.049	0.326 ± 0.033	0.372 ± 0.041	0.291 ± 0.030	0.264 ± 0.028	0.094 ± 0.033	0.401 ± 0.059
	11 Apr 92	13 56	103	9.883 ± 0.062	0.344 ± 0.040	0.352 ± 0.052	0.298 ± 0.045	0.249 ± 0.039	0.130 ± 0.050	0.351 ± 0.060
	14 Apr 92	11 06	81	9.999 ± 0.060	0.290 ± 0.030	0.302 ± 0.049	0.282 ± 0.042	0.229 ± 0.038	0.113 ± 0.029	0.363 ± 0.053
	14 Apr 92	11 13	82	10.009 ± 0.057	0.305 ± 0.027	0.299 ± 0.049	0.277 ± 0.048	0.233 ± 0.044	0.093 ± 0.022	0.383 ± 0.044
I	12 Apr 92	11 16	64	9.982 ± 0.037	0.292 ± 0.025	0.260 ± 0.032	0.326 ± 0.031	0.250 ± 0.025	0.140 ± 0.033	0.304 ± 0.038
	12 Apr 92	11 20	65	10.009 ± 0.044	0.288 ± 0.026	0.295 ± 0.018	0.300 ± 0.034	0.237 ± 0.032	0.132 ± 0.038	0.314 ± 0.049
	14 Apr 92	11 49	92	9.965 ± 0.060	0.290 ± 0.028	0.268 ± 0.051	0.271 ± 0.054	0.264 ± 0.052	0.174 ± 0.023	0.287 ± 0.037
	14 Apr 92	11 56	93	9.991 ± 0.058	0.293 ± 0.032	0.272 ± 0.051	0.270 ± 0.055	0.267 ± 0.053	0.140 ± 0.022	0.332 ± 0.037
	12 Apr 92	13 21	97	10.926 ± 0.050	0.339 ± 0.061	0.306 ± 0.047	0.347 ± 0.042	0.222 ± 0.029	0.148 ± 0.048	0.341 ± 0.103
J	12 Apr 92	13 26	98	10.948 ± 0.097	0.295 ± 0.080	0.364 ± 0.041	0.304 ± 0.070	0.240 ± 0.069	0.123 ± 0.098	0.313 ± 0.136
	14 Apr 92	12 07	94	10.972 ± 0.083	0.287 ± 0.037	0.359 ± 0.056	0.255 ± 0.096	0.252 ± 0.096	0.179 ± 0.062	0.215 ± 0.082
	14 Apr 92	12 15	95	10.987 ± 0.065	0.336 ± 0.031	0.305 ± 0.056	0.273 ± 0.094	0.249 ± 0.093	0.151 ± 0.039	0.299 ± 0.048
	12 Apr 92	12 24	80	11.442 ± 0.097	0.443 ± 0.102	0.476 ± 0.090	0.413 ± 0.082	0.203 ± 0.074	0.091 ± 0.108	0.334 ± 0.120
	12 Apr 92	12 28	81	11.400 ± 0.106	0.460 ± 0.118	0.456 ± 0.105	0.373 ± 0.114	0.230 ± 0.116	0.155 ± 0.116	0.151 ± 0.129
K	13 Apr 92	10 05	51	11.366 ± 0.052	0.378 ± 0.065	0.501 ± 0.060	0.309 ± 0.075	0.287 ± 0.073	0.159 ± 0.052	0.331 ± 0.151
	13 Apr 92	10 10	52	11.395 ± 0.040	0.370 ± 0.067	0.559 ± 0.081	0.325 ± 0.092	0.263 ± 0.079	0.126 ± 0.043	0.308 ± 0.144
	11 Apr 92	11 11	56	11.678 ± 0.089	0.521 ± 0.149	0.470 ± 0.115	0.419 ± 0.099	0.221 ± 0.083	0.256 ± 0.079	0.250 ± 0.137
	11 Apr 92	11 16	57	11.707 ± 0.099	0.498 ± 0.075	0.496 ± 0.056	0.345 ± 0.070	0.292 ± 0.063	0.252 ± 0.086	0.182 ± 0.112
L	12 Apr 92	09 56	47	12.012 ± 0.111	0.387 ± 0.158	0.335 ± 0.093	0.464 ± 0.174	0.214 ± 0.180	0.114 ± 0.126	0.307 ± 0.131
	12 Apr 92	10 01	48	11.983 ± 0.217	0.411 ± 0.167	0.371 ± 0.107	0.406 ± 0.080	0.281 ± 0.060	0.067 ± 0.218	0.499 ± 0.264

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star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
L	14 Apr 92	13 02	108	11.967 ± 0.104	0.417 ± 0.086	0.386 ± 0.154	0.391 ± 0.176	0.257 ± 0.109	0.188 ± 0.090	0.271 ± 0.248
	14 Apr 92	13 11	109	11.966 ± 0.100	0.326 ± 0.115	0.476 ± 0.152	0.292 ± 0.184	0.271 ± 0.126	0.278 ± 0.084	0.277 ± 0.204
	12 Apr 92	10 08	49	12.525 ± 0.076	0.841 ± 0.422	0.582 ± 0.184	0.509 ± 0.122	0.277 ± 0.086	-0.036 ± 0.084	0.462 ± 0.243
M	12 Apr 92	10 12	50	12.480 ± 0.171	0.743 ± 0.366	0.607 ± 0.171	0.428 ± 0.125	0.265 ± 0.102	0.051 ± 0.182	0.515 ± 0.187
	08 Jul 93	08 46	18	10.989 ± 0.067	0.518 ± 0.377	0.788 ± 0.244	1.613 ± 0.127	0.708 ± 0.046	0.456 ± 0.045	1.058 ± 0.084
105	17 May 91	14 48	41	8.634 ± 0.023	0.213 ± 0.025	0.212 ± 0.022	0.249 ± 0.022	0.251 ± 0.027	0.129 ± 0.018	0.279 ± 0.019
	17 May 91	14 52	42	8.622 ± 0.023	0.222 ± 0.027	0.209 ± 0.025	0.256 ± 0.024	0.272 ± 0.028	0.116 ± 0.017	0.306 ± 0.018
	21 May 91	12 02	84	8.620 ± 0.023	0.198 ± 0.022	0.246 ± 0.021	0.264 ± 0.022	0.229 ± 0.022	0.144 ± 0.019	0.305 ± 0.021
	21 May 91	12 07	85	8.628 ± 0.019	0.207 ± 0.022	0.223 ± 0.019	0.272 ± 0.017	0.237 ± 0.018	0.126 ± 0.015	0.327 ± 0.023
	11 Apr 92	10 08	38	8.513 ± 0.047	0.267 ± 0.030	0.227 ± 0.040	0.291 ± 0.032	0.282 ± 0.022	0.129 ± 0.018	0.297 ± 0.044
	11 Apr 92	10 10	39	8.505 ± 0.047	0.264 ± 0.032	0.232 ± 0.038	0.298 ± 0.025	0.269 ± 0.016	0.136 ± 0.019	0.274 ± 0.037
	13 Apr 92	09 04	34	8.652 ± 0.021	0.224 ± 0.028	0.197 ± 0.028	0.253 ± 0.033	0.248 ± 0.034	0.111 ± 0.021	0.298 ± 0.030
	13 Apr 92	09 06	35	8.641 ± 0.026	0.214 ± 0.023	0.208 ± 0.030	0.264 ± 0.029	0.231 ± 0.017	0.132 ± 0.023	0.286 ± 0.034
	14 Apr 92	13 47	112	8.627 ± 0.057	0.240 ± 0.026	0.175 ± 0.048	0.250 ± 0.042	0.243 ± 0.039	0.121 ± 0.020	0.301 ± 0.033
	14 Apr 92	13 51	113	8.602 ± 0.057	0.237 ± 0.026	0.190 ± 0.048	0.237 ± 0.041	0.246 ± 0.038	0.129 ± 0.019	0.294 ± 0.035
	18 Feb 93	14 52	102	8.749 ± 0.031	0.114 ± 0.062	0.227 ± 0.020	0.250 ± 0.018	0.225 ± 0.012	0.108 ± 0.014	0.317 ± 0.033
	18 Feb 93	14 54	103	8.731 ± 0.031	0.133 ± 0.062	0.212 ± 0.017	0.245 ± 0.014	0.237 ± 0.016	0.107 ± 0.017	0.304 ± 0.045
	08 Jul 93	08 38	17	8.701 ± 0.036	0.232 ± 0.022	0.191 ± 0.015	0.253 ± 0.017	0.214 ± 0.018	0.112 ± 0.016	0.281 ± 0.023
	23 May 93	08 29	23	8.717 ± 0.018	0.260 ± 0.022	0.206 ± 0.017	0.245 ± 0.011	0.230 ± 0.015	0.120 ± 0.011	0.287 ± 0.020
	23 May 93	08 32	24	8.721 ± 0.018	0.264 ± 0.019	0.193 ± 0.015	0.256 ± 0.014	0.231 ± 0.021	0.119 ± 0.016	0.292 ± 0.019
106	17 May 91	14 58	43	6.916 ± 0.024	0.253 ± 0.020	0.221 ± 0.019	0.291 ± 0.023	0.277 ± 0.027	0.125 ± 0.017	0.338 ± 0.018
	17 May 91	15 02	44	6.895 ± 0.022	0.260 ± 0.021	0.212 ± 0.019	0.292 ± 0.025	0.290 ± 0.029	0.128 ± 0.016	0.328 ± 0.017
	21 May 91	11 19	72	6.890 ± 0.019	0.248 ± 0.022	0.234 ± 0.019	0.293 ± 0.018	0.273 ± 0.019	0.127 ± 0.016	0.352 ± 0.019
	21 May 91	11 21	73	6.884 ± 0.019	0.243 ± 0.023	0.237 ± 0.018	0.290 ± 0.019	0.282 ± 0.019	0.127 ± 0.016	0.349 ± 0.016
	11 Apr 92	10 02	36	6.759 ± 0.049	0.309 ± 0.029	0.221 ± 0.038	0.320 ± 0.026	0.298 ± 0.016	0.155 ± 0.021	0.329 ± 0.039
	11 Apr 92	10 04	37	6.770 ± 0.048	0.304 ± 0.030	0.232 ± 0.039	0.321 ± 0.027	0.303 ± 0.018	0.132 ± 0.020	0.346 ± 0.037
	13 Apr 92	09 08	36	6.880 ± 0.023	0.250 ± 0.019	0.208 ± 0.018	0.296 ± 0.016	0.262 ± 0.017	0.139 ± 0.020	0.344 ± 0.021
	13 Apr 92	09 10	37	6.874 ± 0.019	0.257 ± 0.018	0.205 ± 0.021	0.291 ± 0.020	0.272 ± 0.017	0.141 ± 0.013	0.349 ± 0.014
	18 Feb 93	14 47	100	6.947 ± 0.029	0.205 ± 0.063	0.216 ± 0.014	0.280 ± 0.014	0.263 ± 0.016	0.120 ± 0.011	0.342 ± 0.027
	18 Feb 93	14 49	101	6.956 ± 0.030	0.156 ± 0.062	0.217 ± 0.014	0.277 ± 0.012	0.261 ± 0.012	0.115 ± 0.010	0.359 ± 0.023
	23 May 93	08 23	21	6.979 ± 0.021	0.303 ± 0.017	0.210 ± 0.012	0.286 ± 0.010	0.259 ± 0.015	0.123 ± 0.015	0.328 ± 0.017

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Table D.6 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
106	23 May 93	08 26	22	6.994 ± 0.018	0.298 ± 0.017	0.206 ± 0.014	0.284 ± 0.010	0.254 ± 0.013	0.133 ± 0.011	0.324 ± 0.011
107	13 Apr 92	11 04	66	11.322 ± 0.040	0.356 ± 0.120	0.512 ± 0.102	0.405 ± 0.071	0.216 ± 0.069	0.135 ± 0.043	0.274 ± 0.116
	13 Apr 92	11 10	67	11.298 ± 0.024	0.346 ± 0.069	0.461 ± 0.043	0.447 ± 0.061	0.245 ± 0.060	0.109 ± 0.023	0.358 ± 0.120
108	13 Apr 92	11 23	68	11.768 ± 0.036	0.486 ± 0.138	0.484 ± 0.072	0.416 ± 0.122	0.231 ± 0.121	0.183 ± 0.043	0.273 ± 0.155
	13 Apr 92	11 31	69	11.743 ± 0.053	0.409 ± 0.144	0.541 ± 0.080	0.485 ± 0.100	0.192 ± 0.094	0.179 ± 0.060	0.320 ± 0.151
113	12 Apr 92	13 57	101	10.110 ± 0.041	0.282 ± 0.027	0.283 ± 0.019	0.309 ± 0.016	0.196 ± 0.015	0.145 ± 0.036	0.243 ± 0.045
	12 Apr 92	14 03	102	10.115 ± 0.036	0.286 ± 0.029	0.298 ± 0.032	0.288 ± 0.031	0.200 ± 0.018	0.146 ± 0.028	0.278 ± 0.058
115	13 Apr 92	09 13	38	10.234 ± 0.038	0.244 ± 0.035	0.345 ± 0.037	0.286 ± 0.039	0.215 ± 0.026	0.122 ± 0.038	0.281 ± 0.047
	13 Apr 92	09 17	39	10.236 ± 0.025	0.264 ± 0.036	0.314 ± 0.032	0.263 ± 0.024	0.244 ± 0.027	0.116 ± 0.025	0.270 ± 0.057
117	12 Apr 92	13 41	99	10.843 ± 0.054	0.333 ± 0.053	0.346 ± 0.045	0.293 ± 0.041	0.218 ± 0.043	0.146 ± 0.055	0.282 ± 0.076
	12 Apr 92	13 48	100	10.832 ± 0.052	0.324 ± 0.046	0.338 ± 0.034	0.309 ± 0.025	0.209 ± 0.020	0.161 ± 0.048	0.278 ± 0.091
137	08 Jun 89	09 51	19	12.595 ± 0.292	0.150 ± 0.374	0.353 ± 0.341	0.410 ± 0.302	0.256 ± 0.236	0.223 ± 0.309	0.361 ± 0.642
	08 Jun 89	10 13	20	12.744 ± 0.428	0.225 ± 0.554	0.411 ± 0.482	0.578 ± 0.380	0.091 ± 0.278	0.116 ± 0.450	0.207 ± 0.882
	12 Apr 92	11 00	62	12.473 ± 0.194	0.553 ± 0.131	0.390 ± 0.149	0.362 ± 0.147	0.277 ± 0.128	0.239 ± 0.199	0.130 ± 0.280
	12 Apr 92	11 08	63	12.526 ± 0.203	0.349 ± 0.141	0.472 ± 0.096	0.178 ± 0.158	0.383 ± 0.154	0.237 ± 0.208	0.301 ± 0.306
138	11 Apr 92	11 32	60	11.053 ± 0.093	0.346 ± 0.043	0.424 ± 0.060	0.292 ± 0.053	0.289 ± 0.037	0.120 ± 0.083	0.377 ± 0.125
	11 Apr 92	11 36	61	11.059 ± 0.078	0.383 ± 0.052	0.372 ± 0.046	0.347 ± 0.071	0.274 ± 0.069	0.129 ± 0.063	0.331 ± 0.082
139	11 Apr 92	11 22	58	11.503 ± 0.137	0.499 ± 0.061	0.419 ± 0.051	0.330 ± 0.106	0.309 ± 0.111	0.130 ± 0.130	0.290 ± 0.154
	11 Apr 92	11 26	59	11.527 ± 0.125	0.424 ± 0.069	0.487 ± 0.075	0.364 ± 0.057	0.274 ± 0.079	0.092 ± 0.131	0.356 ± 0.173
	12 Apr 92	10 19	51	11.671 ± 0.058	0.455 ± 0.117	0.378 ± 0.091	0.368 ± 0.096	0.238 ± 0.073	0.098 ± 0.067	0.298 ± 0.117
	12 Apr 92	10 23	52	11.661 ± 0.060	0.344 ± 0.129	0.368 ± 0.124	0.368 ± 0.125	0.267 ± 0.076	0.088 ± 0.065	0.315 ± 0.096
201	08 Jul 93	10 01	28	9.593 ± 0.039	0.089 ± 0.098	0.208 ± 0.037	0.251 ± 0.019	0.192 ± 0.023	0.118 ± 0.022	0.281 ± 0.057
202	11 Apr 92	10 24	42	9.845 ± 0.051	0.289 ± 0.032	0.307 ± 0.044	0.329 ± 0.042	0.250 ± 0.037	0.148 ± 0.032	0.222 ± 0.044
	11 Apr 92	10 28	43	9.871 ± 0.055	0.303 ± 0.032	0.290 ± 0.043	0.332 ± 0.034	0.239 ± 0.021	0.128 ± 0.034	0.243 ± 0.054
	08 Jul 93	09 50	27	9.963 ± 0.040	0.301 ± 0.025	0.282 ± 0.017	0.298 ± 0.020	0.193 ± 0.024	0.142 ± 0.023	0.301 ± 0.058
203	08 Jul 93	09 41	26	10.270 ± 0.037	0.260 ± 0.028	0.264 ± 0.020	0.250 ± 0.020	0.208 ± 0.022	0.110 ± 0.019	0.261 ± 0.078
207	14 Apr 92	13 31	110	12.047 ± 0.108	0.419 ± 0.105	0.445 ± 0.157	0.324 ± 0.187	0.289 ± 0.127	0.167 ± 0.099	0.427 ± 0.211
	14 Apr 92	13 39	111	12.076 ± 0.093	0.442 ± 0.133	0.459 ± 0.193	0.300 ± 0.193	0.275 ± 0.130	0.152 ± 0.077	0.426 ± 0.209
215	13 Apr 92	12 05	79	11.618 ± 0.041	0.361 ± 0.069	0.440 ± 0.081	0.334 ± 0.108	0.201 ± 0.099	0.131 ± 0.045	0.258 ± 0.088
	13 Apr 92	12 11	80	11.598 ± 0.076	0.337 ± 0.053	0.443 ± 0.054	0.348 ± 0.059	0.235 ± 0.038	0.139 ± 0.076	0.319 ± 0.081
216	13 Apr 92	12 20	81	12.363 ± 0.085	0.515 ± 0.092	0.469 ± 0.098	0.382 ± 0.083	0.280 ± 0.045	0.120 ± 0.091	0.396 ± 0.122

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Table D.6 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
216	13 Apr 92	12 26	82	12.299 ± 0.118	0.543 ± 0.118	0.354 ± 0.132	0.475 ± 0.158	0.215 ± 0.157	0.246 ± 0.145	0.270 ± 0.191
218	13 Apr 92	13 15	95	12.224 ± 0.151	0.366 ± 0.118	0.518 ± 0.099	0.198 ± 0.105	0.286 ± 0.096	0.265 ± 0.153	0.151 ± 0.397
	13 Apr 92	13 21	96	12.366 ± 0.227	0.445 ± 0.100	0.401 ± 0.072	0.450 ± 0.089	0.120 ± 0.079	0.104 ± 0.227	0.181 ± 0.459
223	08 Jun 89	08 57	13	8.047 ± 0.021	0.242 ± 0.009	0.216 ± 0.011	0.295 ± 0.008	0.270 ± 0.009	0.114 ± 0.008	0.367 ± 0.012
	08 Jun 89	09 00	14	8.047 ± 0.021	0.256 ± 0.009	0.203 ± 0.011	0.303 ± 0.008	0.271 ± 0.009	0.105 ± 0.008	0.374 ± 0.012
	17 May 91	13 34	28	7.955 ± 0.021	0.251 ± 0.023	0.224 ± 0.019	0.281 ± 0.023	0.260 ± 0.026	0.140 ± 0.015	0.314 ± 0.016
	17 May 91	13 38	29	7.946 ± 0.025	0.228 ± 0.021	0.224 ± 0.021	0.283 ± 0.022	0.249 ± 0.025	0.135 ± 0.022	0.312 ± 0.021
	21 May 91	10 55	67	7.953 ± 0.019	0.238 ± 0.018	0.261 ± 0.020	0.279 ± 0.021	0.242 ± 0.021	0.136 ± 0.018	0.369 ± 0.018
	21 May 91	10 59	68	7.938 ± 0.019	0.247 ± 0.029	0.264 ± 0.026	0.289 ± 0.018	0.254 ± 0.018	0.130 ± 0.016	0.358 ± 0.022
	11 Apr 92	09 19	23	7.768 ± 0.050	0.326 ± 0.060	0.250 ± 0.038	0.328 ± 0.025	0.282 ± 0.016	0.143 ± 0.023	0.335 ± 0.040
	11 Apr 92	09 21	24	7.775 ± 0.048	0.302 ± 0.030	0.257 ± 0.039	0.298 ± 0.025	0.299 ± 0.015	0.148 ± 0.018	0.316 ± 0.039
	18 Feb 93	15 35	114	7.965 ± 0.030	0.186 ± 0.062	0.240 ± 0.015	0.266 ± 0.013	0.244 ± 0.012	0.121 ± 0.011	0.332 ± 0.026
	18 Feb 93	15 37	115	7.966 ± 0.029	0.198 ± 0.063	0.235 ± 0.015	0.260 ± 0.012	0.253 ± 0.014	0.119 ± 0.011	0.325 ± 0.029
	08 Jul 93	07 41	8	7.968 ± 0.036	0.320 ± 0.022	0.224 ± 0.015	0.285 ± 0.017	0.233 ± 0.019	0.129 ± 0.016	0.357 ± 0.023
	23 May 93	08 35	25	7.977 ± 0.019	0.278 ± 0.017	0.234 ± 0.012	0.280 ± 0.009	0.239 ± 0.014	0.128 ± 0.014	0.325 ± 0.014
	23 May 93	08 38	26	7.966 ± 0.019	0.284 ± 0.017	0.229 ± 0.012	0.280 ± 0.013	0.239 ± 0.017	0.136 ± 0.013	0.314 ± 0.015
224	08 Jun 89	09 17	16	9.995 ± 0.035	0.264 ± 0.026	0.259 ± 0.025	0.324 ± 0.023	0.314 ± 0.019	0.277 ± 0.029	0.539 ± 0.045
	08 Jun 89	09 28	17	10.130 ± 0.037	0.256 ± 0.027	0.246 ± 0.026	0.331 ± 0.024	0.278 ± 0.020	0.244 ± 0.032	0.454 ± 0.053
	17 May 91	13 43	30	10.248 ± 0.026	0.229 ± 0.027	0.289 ± 0.031	0.282 ± 0.032	0.282 ± 0.030	0.118 ± 0.023	0.315 ± 0.047
	17 May 91	13 48	31	9.958 ± 0.037	0.262 ± 0.056	0.346 ± 0.064	0.371 ± 0.136	0.399 ± 0.140	0.081 ± 0.066	0.257 ± 0.136
	21 May 91	10 44	65	9.947 ± 0.054	0.278 ± 0.042	0.305 ± 0.086	0.294 ± 0.083	0.188 ± 0.037	0.228 ± 0.054	0.306 ± 0.053
	21 May 91	10 50	66	10.081 ± 0.043	0.214 ± 0.038	0.325 ± 0.033	0.305 ± 0.020	0.158 ± 0.028	0.261 ± 0.046	0.341 ± 0.062
	11 Apr 92	09 27	25	10.108 ± 0.069	0.267 ± 0.044	0.284 ± 0.050	0.287 ± 0.040	0.266 ± 0.043	0.161 ± 0.058	0.272 ± 0.086
	11 Apr 92	09 31	26	10.123 ± 0.070	0.271 ± 0.040	0.279 ± 0.045	0.313 ± 0.036	0.262 ± 0.040	0.173 ± 0.060	0.271 ± 0.080
	18 Feb 93	15 41	116	10.235 ± 0.058	0.178 ± 0.086	0.258 ± 0.026	0.288 ± 0.030	0.248 ± 0.041	0.085 ± 0.062	0.342 ± 0.119
	18 Feb 93	15 45	117	10.359 ± 0.037	0.157 ± 0.067	0.285 ± 0.031	0.273 ± 0.018	0.218 ± 0.025	0.129 ± 0.033	0.334 ± 0.133
	08 Jul 93	07 48	9	10.120 ± 0.052	0.329 ± 0.031	0.336 ± 0.028	0.291 ± 0.031	0.196 ± 0.030	0.214 ± 0.041	0.451 ± 0.074
	23 May 93	08 43	27	10.295 ± 0.030	0.198 ± 0.060	0.215 ± 0.059	0.269 ± 0.012	0.233 ± 0.017	0.117 ± 0.028	0.289 ± 0.056
	23 May 93	08 48	28	10.357 ± 0.022	0.264 ± 0.027	0.252 ± 0.024	0.276 ± 0.018	0.235 ± 0.024	0.106 ± 0.022	0.335 ± 0.077
228	13 Apr 92	13 30	97	10.968 ± 0.052	0.308 ± 0.027	0.358 ± 0.023	0.294 ± 0.029	0.238 ± 0.031	0.171 ± 0.052	0.222 ± 0.118
	13 Apr 92	13 38	98	11.011 ± 0.050	0.338 ± 0.054	0.322 ± 0.037	0.293 ± 0.031	0.229 ± 0.031	0.147 ± 0.049	0.261 ± 0.112

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Table D.6 continued from previous page

star	date	UT	#	V	U-P	P-X	X-Y	Y-Z	Z-V	V-S
305	11 Apr 92	12 23	74	8.230 ± 0.047	0.262 ± 0.031	0.234 ± 0.037	0.265 ± 0.025	0.265 ± 0.016	0.125 ± 0.020	0.265 ± 0.036
	11 Apr 92	12 27	75	8.232 ± 0.047	0.257 ± 0.028	0.231 ± 0.037	0.274 ± 0.025	0.264 ± 0.017	0.120 ± 0.019	0.264 ± 0.037
306	13 Apr 92	15 05	115	10.049 ± 0.025	0.214 ± 0.018	0.198 ± 0.020	0.317 ± 0.024	0.269 ± 0.025	0.139 ± 0.025	0.712 ± 0.026
	13 Apr 92	15 12	116	10.046 ± 0.022	0.234 ± 0.025	0.204 ± 0.022	0.322 ± 0.018	0.242 ± 0.021	0.153 ± 0.019	0.665 ± 0.027
311	13 Apr 92	14 50	113	10.759 ± 0.046	0.351 ± 0.040	0.399 ± 0.040	0.280 ± 0.035	0.246 ± 0.038	0.103 ± 0.049	0.319 ± 0.087
	13 Apr 92	14 56	114	10.769 ± 0.029	0.321 ± 0.031	0.405 ± 0.031	0.292 ± 0.027	0.233 ± 0.031	0.093 ± 0.032	0.325 ± 0.045
405	13 Apr 92	10 54	64	10.011 ± 0.027	0.231 ± 0.021	0.293 ± 0.020	0.236 ± 0.021	0.171 ± 0.029	0.079 ± 0.031	0.297 ± 0.065
	13 Apr 92	10 58	65	10.133 ± 0.019	0.229 ± 0.028	0.249 ± 0.030	0.214 ± 0.030	0.167 ± 0.021	0.085 ± 0.015	0.259 ± 0.054
410	12 Apr 92	14 49	115	10.642 ± 0.044	0.380 ± 0.039	0.411 ± 0.034	0.351 ± 0.045	0.242 ± 0.046	0.168 ± 0.041	0.207 ± 0.087
	12 Apr 92	14 53	116	10.642 ± 0.043	0.383 ± 0.044	0.402 ± 0.039	0.336 ± 0.027	0.236 ± 0.027	0.194 ± 0.039	0.254 ± 0.064
414	12 Apr 92	15 01	117	9.964 ± 0.027	0.325 ± 0.022	0.279 ± 0.022	0.318 ± 0.028	0.228 ± 0.024	0.102 ± 0.015	0.277 ± 0.027
	12 Apr 92	15 05	118	9.963 ± 0.027	0.301 ± 0.036	0.301 ± 0.026	0.294 ± 0.023	0.232 ± 0.020	0.150 ± 0.018	0.245 ± 0.028
	13 Apr 92	10 16	53	10.026 ± 0.036	0.277 ± 0.032	0.325 ± 0.026	0.307 ± 0.035	0.233 ± 0.040	0.133 ± 0.039	0.269 ± 0.036
	13 Apr 92	10 20	54	9.994 ± 0.031	0.274 ± 0.023	0.325 ± 0.023	0.288 ± 0.022	0.220 ± 0.024	0.125 ± 0.029	0.276 ± 0.046
417	13 Apr 92	13 57	100	9.789 ± 0.021	0.200 ± 0.019	0.192 ± 0.016	0.305 ± 0.026	0.275 ± 0.027	0.130 ± 0.017	0.666 ± 0.036
	13 Apr 92	14 03	101	9.791 ± 0.027	0.197 ± 0.016	0.181 ± 0.019	0.298 ± 0.019	0.276 ± 0.021	0.142 ± 0.027	0.635 ± 0.027
418	11 Apr 92	14 00	104	9.556 ± 0.059	0.286 ± 0.032	0.308 ± 0.053	0.299 ± 0.048	0.235 ± 0.034	0.143 ± 0.044	0.283 ± 0.054
	11 Apr 92	14 03	105	9.567 ± 0.047	0.308 ± 0.031	0.282 ± 0.039	0.304 ± 0.029	0.246 ± 0.021	0.131 ± 0.022	0.290 ± 0.045
	13 Apr 92	14 35	111	9.679 ± 0.030	0.242 ± 0.014	0.254 ± 0.015	0.275 ± 0.015	0.227 ± 0.018	0.109 ± 0.029	0.289 ± 0.029
	13 Apr 92	14 41	112	9.679 ± 0.019	0.245 ± 0.013	0.254 ± 0.013	0.276 ± 0.013	0.218 ± 0.015	0.120 ± 0.015	0.266 ± 0.029

Appendix E

The Mean Reduced Observations.

The following tables give the mean reduced magnitudes from the observations of the primary standard stars, secondary standard stars, the clusters κ Crucis and O Vel.

The first column in each table is the star name, being either an HD number, the E Region number used by Menzies et al. (1989), or the open cluster number (as given by Dachs & Kaiser (1984) for κ Crucis and Lyngå (1959) for O Vel). See the description of Table C.2 for the meaning of any symbols (in parenthesis) following the name. The next eight columns contain Vilnius V magnitude and colours, including the Y-V colour. Each column has the weighted mean (weighted by the standard deviation of the individual observations) and the standard deviation of the mean. The final column is the number of observations made of the star.

The primary standard stars are not in fact standard stars of the (northern) Vilnius system but the stars that were observable from MJUO, and so were considered as candidate secondary standard stars (for the Southern Vilnius system). The secondary standard stars are listed in two tables, the first being bright stars spread across the southern sky and the other is stars from the Harvard E Regions. Four extra tables follows the secondary standard star tables – these list the remaining candidate secondary standard stars that currently do not qualify as standards, usually because insufficient observations have been made of the star.

Not all of the stars listed as observed in Table C.2 are given in these tables as some observations were rejected as bad measurements (usually due to cloud).

Table E.1: The mean reduced observations for the primary standard stars.

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
067594	4.347 ± 0.008	0.744 ± 0.003	0.659 ± 0.009	0.846 ± 0.006	1.213 ± 0.005	0.468 ± 0.005	0.278 ± 0.005	0.693 ± 0.006	16
090994	5.084 ± 0.008	0.103 ± 0.005	0.286 ± 0.006	0.453 ± 0.005	0.168 ± 0.004	0.066 ± 0.004	0.034 ± 0.004	0.074 ± 0.004	16
091612	5.079 ± 0.012	0.708 ± 0.006	0.537 ± 0.011	0.876 ± 0.008	1.169 ± 0.006	0.433 ± 0.007	0.274 ± 0.008	0.706 ± 0.007	12
095345	4.845 ± 0.010	0.849 ± 0.004	0.622 ± 0.010	1.096 ± 0.007	1.483 ± 0.005	0.499 ± 0.005	0.353 ± 0.005	0.806 ± 0.005	20
098058	4.468 ± 0.008	0.289 ± 0.006	0.705 ± 0.008	0.802 ± 0.008	0.451 ± 0.006	0.181 ± 0.007	0.106 ± 0.008	0.290 ± 0.007	8
102870	3.598 ± 0.009	0.498 ± 0.006	0.463 ± 0.010	0.621 ± 0.008	0.748 ± 0.007	0.311 ± 0.008	0.186 ± 0.008	0.511 ± 0.007	10
107070	5.937 ± 0.014	0.257 ± 0.008	0.688 ± 0.017	0.832 ± 0.007	0.434 ± 0.006	0.159 ± 0.006	0.093 ± 0.006	0.240 ± 0.009	6
111765	6.017 ± 0.011	0.929 ± 0.005	0.682 ± 0.016	1.238 ± 0.009	1.689 ± 0.005	0.512 ± 0.007	0.416 ± 0.006	0.878 ± 0.009	6
114960	6.547 ± 0.009	1.002 ± 0.004	0.738 ± 0.015	1.366 ± 0.008	1.934 ± 0.005	0.499 ± 0.006	0.507 ± 0.004	0.963 ± 0.005	15
116160	5.676 ± 0.009	0.184 ± 0.007	0.587 ± 0.010	0.809 ± 0.005	0.350 ± 0.005	0.121 ± 0.006	0.064 ± 0.005	0.140 ± 0.006	5
120602	5.978 ± 0.018	0.699 ± 0.009	0.591 ± 0.015	0.836 ± 0.009	1.105 ± 0.010	0.428 ± 0.008	0.278 ± 0.007	0.678 ± 0.009	3
121607	5.897 ± 0.012	0.285 ± 0.008	0.670 ± 0.010	0.799 ± 0.005	0.479 ± 0.005	0.179 ± 0.005	0.109 ± 0.004	0.267 ± 0.007	6
122408	4.254 ± 0.007	0.240 ± 0.007	0.742 ± 0.006	0.848 ± 0.005	0.374 ± 0.006	0.151 ± 0.006	0.084 ± 0.005	0.209 ± 0.004	11
126053	6.262 ± 0.009	0.560 ± 0.006	0.460 ± 0.010	0.589 ± 0.005	0.807 ± 0.005	0.336 ± 0.006	0.223 ± 0.005	0.565 ± 0.006	7
126248	5.083 ± 0.009	0.235 ± 0.007	0.614 ± 0.009	0.814 ± 0.005	0.427 ± 0.005	0.150 ± 0.006	0.084 ± 0.004	0.190 ± 0.005	7
129956	5.696 ± 0.013	0.166 ± 0.013	0.616 ± 0.010	0.738 ± 0.007	0.256 ± 0.006	0.110 ± 0.009	0.054 ± 0.007	0.135 ± 0.008	3
132345	5.882 ± 0.009	0.916 ± 0.005	0.702 ± 0.012	1.287 ± 0.008	1.684 ± 0.006	0.500 ± 0.007	0.413 ± 0.006	0.840 ± 0.007	6
135559	5.632 ± 0.007	0.266 ± 0.005	0.597 ± 0.007	0.776 ± 0.004	0.471 ± 0.004	0.171 ± 0.005	0.097 ± 0.004	0.237 ± 0.005	7
136028	5.857 ± 0.016	1.077 ± 0.011	0.759 ± 0.023	1.405 ± 0.021	2.007 ± 0.018	0.597 ± 0.017	0.478 ± 0.013	1.039 ± 0.013	3
138716	4.633 ± 0.009	0.756 ± 0.004	0.575 ± 0.009	1.014 ± 0.007	1.292 ± 0.006	0.433 ± 0.006	0.327 ± 0.005	0.748 ± 0.006	10
139409	7.176 ± 0.015	0.805 ± 0.006	0.572 ± 0.018	0.910 ± 0.015	1.288 ± 0.013	0.486 ± 0.011	0.323 ± 0.007	0.779 ± 0.010	6
143553	5.823 ± 0.010	0.762 ± 0.005	0.577 ± 0.010	0.956 ± 0.007	1.259 ± 0.005	0.444 ± 0.007	0.319 ± 0.006	0.751 ± 0.006	6
147550	6.237 ± 0.008	0.232 ± 0.006	0.673 ± 0.008	0.766 ± 0.005	0.303 ± 0.004	0.151 ± 0.005	0.081 ± 0.004	0.184 ± 0.005	10
148513	5.417 ± 0.010	1.034 ± 0.006	0.758 ± 0.020	1.382 ± 0.010	1.987 ± 0.008	0.549 ± 0.010	0.502 ± 0.006	0.982 ± 0.008	7
150416	4.954 ± 0.021	0.844 ± 0.008	0.637 ± 0.014	0.965 ± 0.010	1.281 ± 0.009	0.533 ± 0.009	0.313 ± 0.009	0.800 ± 0.011	3
153687	4.805 ± 0.026	1.072 ± 0.009	0.767 ± 0.019	1.405 ± 0.014	2.003 ± 0.011	0.577 ± 0.013	0.502 ± 0.010	1.010 ± 0.012	3
154417	6.018 ± 0.011	0.526 ± 0.005	0.474 ± 0.008	0.583 ± 0.006	0.762 ± 0.005	0.314 ± 0.006	0.212 ± 0.006	0.530 ± 0.006	5
156826	6.323 ± 0.012	0.676 ± 0.007	0.504 ± 0.011	0.794 ± 0.009	1.043 ± 0.007	0.399 ± 0.007	0.275 ± 0.008	0.678 ± 0.008	4
157089	6.958 ± 0.013	0.546 ± 0.008	0.481 ± 0.012	0.541 ± 0.010	0.717 ± 0.008	0.340 ± 0.007	0.208 ± 0.008	0.539 ± 0.010	4
158352	5.389 ± 0.018	0.317 ± 0.010	0.657 ± 0.013	0.761 ± 0.010	0.494 ± 0.008	0.197 ± 0.009	0.126 ± 0.008	0.294 ± 0.010	3

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Table E.1 continued from previous page

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
159975	4.615 ± 0.005	0.297 ± 0.004	0.601 ± 0.004	0.592 ± 0.004	0.291 ± 0.004	0.192 ± 0.004	0.104 ± 0.003	0.274 ± 0.003	17
160346	6.507 ± 0.017	0.708 ± 0.009	0.463 ± 0.017	0.987 ± 0.013	1.289 ± 0.010	0.333 ± 0.012	0.382 ± 0.011	0.757 ± 0.013	3
163245	6.450 ± 0.006	0.208 ± 0.006	0.621 ± 0.007	0.831 ± 0.005	0.371 ± 0.005	0.135 ± 0.005	0.073 ± 0.004	0.152 ± 0.005	8
164259	4.634 ± 0.009	0.423 ± 0.008	0.538 ± 0.007	0.615 ± 0.007	0.591 ± 0.007	0.265 ± 0.008	0.158 ± 0.007	0.399 ± 0.006	7
164353	3.968 ± 0.012	0.254 ± 0.011	0.352 ± 0.009	0.295 ± 0.010	0.201 ± 0.010	0.169 ± 0.011	0.087 ± 0.009	0.211 ± 0.007	4
173009	4.924 ± 0.012	0.878 ± 0.007	0.667 ± 0.017	0.977 ± 0.009	1.339 ± 0.009	0.537 ± 0.009	0.342 ± 0.008	0.812 ± 0.011	4
175190	5.040 ± 0.010	1.001 ± 0.005	0.693 ± 0.013	1.245 ± 0.010	1.771 ± 0.008	0.554 ± 0.008	0.437 ± 0.006	0.877 ± 0.009	6
175679	6.146 ± 0.006	0.755 ± 0.004	0.581 ± 0.010	0.921 ± 0.010	1.209 ± 0.007	0.474 ± 0.005	0.283 ± 0.005	0.735 ± 0.006	4
176704	5.646 ± 0.015	0.892 ± 0.007	0.670 ± 0.014	1.253 ± 0.009	1.610 ± 0.008	0.486 ± 0.010	0.406 ± 0.006	0.824 ± 0.008	4
184492	5.154 ± 0.018	0.866 ± 0.008	0.660 ± 0.017	0.967 ± 0.008	1.318 ± 0.009	0.516 ± 0.009	0.345 ± 0.007	0.798 ± 0.009	3
184930	4.364 ± 0.009	0.180 ± 0.008	0.404 ± 0.009	0.477 ± 0.008	0.178 ± 0.009	0.111 ± 0.010	0.070 ± 0.007	0.138 ± 0.006	6
188350	5.617 ± 0.008	0.269 ± 0.006	0.745 ± 0.008	0.790 ± 0.006	0.312 ± 0.005	0.170 ± 0.006	0.102 ± 0.006	0.221 ± 0.006	4
192876	4.264 ± 0.014	0.831 ± 0.008	0.691 ± 0.012	0.915 ± 0.009	1.266 ± 0.008	0.507 ± 0.010	0.321 ± 0.010	0.757 ± 0.010	3
195135	4.932 ± 0.015	0.860 ± 0.006	0.639 ± 0.012	1.170 ± 0.008	1.514 ± 0.007	0.487 ± 0.008	0.372 ± 0.006	0.797 ± 0.008	5
199960	6.220 ± 0.011	0.556 ± 0.005	0.495 ± 0.010	0.682 ± 0.006	0.839 ± 0.006	0.335 ± 0.006	0.223 ± 0.006	0.551 ± 0.007	4
205924	5.690 ± 0.017	0.342 ± 0.011	0.627 ± 0.013	0.728 ± 0.007	0.512 ± 0.008	0.211 ± 0.008	0.123 ± 0.007	0.311 ± 0.009	3
221950	5.747 ± 0.013	0.475 ± 0.007	0.488 ± 0.010	0.528 ± 0.007	0.601 ± 0.007	0.295 ± 0.006	0.167 ± 0.006	0.461 ± 0.007	5
222493	5.937 ± 0.019	0.760 ± 0.007	0.590 ± 0.014	0.964 ± 0.010	1.231 ± 0.008	0.453 ± 0.009	0.302 ± 0.008	0.706 ± 0.010	3
223438	5.807 ± 0.017	0.277 ± 0.009	0.670 ± 0.012	0.837 ± 0.008	0.442 ± 0.007	0.162 ± 0.008	0.105 ± 0.008	0.219 ± 0.009	3

Table E.2: The mean reduced observations for the bright, southern secondary standard stars.

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
029875	4.363 ± 0.012	0.371 ± 0.018	0.514 ± 0.010	0.660 ± 0.011	0.553 ± 0.007	0.217 ± 0.010	0.131 ± 0.011	0.376 ± 0.007	10
037495	5.275 ± 0.004	0.460 ± 0.002	0.521 ± 0.005	0.605 ± 0.002	0.664 ± 0.002	0.295 ± 0.002	0.172 ± 0.002	0.461 ± 0.002	66
052877(†)	3.502 ± 0.006	1.257 ± 0.002	0.892 ± 0.009	1.325 ± 0.007	2.193 ± 0.008	0.730 ± 0.005	0.528 ± 0.005	1.108 ± 0.007	25
064379	5.025 ± 0.005	0.446 ± 0.003	0.452 ± 0.004	0.568 ± 0.004	0.636 ± 0.002	0.280 ± 0.003	0.167 ± 0.007	0.475 ± 0.003	44
085123(∞)	2.935 ± 0.014	0.386 ± 0.010	1.143 ± 0.015	0.792 ± 0.014	0.409 ± 0.014	0.231 ± 0.020	0.135 ± 0.015	0.367 ± 0.010	4
086440	3.484 ± 0.012	0.199 ± 0.010	0.394 ± 0.017	0.281 ± 0.015	0.145 ± 0.013	0.120 ± 0.016	0.055 ± 0.011	0.168 ± 0.009	4
086629	5.210 ± 0.003	0.364 ± 0.001	0.578 ± 0.003	0.691 ± 0.002	0.524 ± 0.001	0.229 ± 0.001	0.129 ± 0.001	0.338 ± 0.002	120
088742	6.361 ± 0.007	0.516 ± 0.004	0.410 ± 0.005	0.628 ± 0.005	0.775 ± 0.005	0.335 ± 0.005	0.181 ± 0.005	0.548 ± 0.005	16
088955	3.802 ± 0.012	0.225 ± 0.010	0.635 ± 0.014	0.822 ± 0.012	0.350 ± 0.011	0.137 ± 0.014	0.064 ± 0.009	0.140 ± 0.008	4
095370	4.383 ± 0.006	0.242 ± 0.006	0.684 ± 0.005	0.848 ± 0.005	0.398 ± 0.006	0.152 ± 0.007	0.085 ± 0.005	0.209 ± 0.004	7
095456	6.060 ± 0.006	0.480 ± 0.004	0.456 ± 0.005	0.636 ± 0.005	0.689 ± 0.005	0.313 ± 0.005	0.168 ± 0.004	0.512 ± 0.004	16
100953	6.345 ± 0.005	0.431 ± 0.004	0.517 ± 0.008	0.616 ± 0.006	0.630 ± 0.006	0.287 ± 0.007	0.144 ± 0.006	0.446 ± 0.007	10
103026	5.866 ± 0.005	0.499 ± 0.003	0.474 ± 0.005	0.588 ± 0.004	0.716 ± 0.003	0.298 ± 0.004	0.216 ± 0.008	0.511 ± 0.003	32
111915	4.355 ± 0.014	0.964 ± 0.006	0.717 ± 0.026	1.302 ± 0.014	1.812 ± 0.011	0.507 ± 0.013	0.449 ± 0.010	0.919 ± 0.008	4
114613	4.840 ± 0.003	0.605 ± 0.001	0.502 ± 0.003	0.712 ± 0.002	0.901 ± 0.002	0.365 ± 0.002	0.233 ± 0.002	0.587 ± 0.002	90
120987	5.581 ± 0.005	0.441 ± 0.002	0.514 ± 0.007	0.578 ± 0.003	0.607 ± 0.002	0.278 ± 0.002	0.164 ± 0.002	0.444 ± 0.003	60
122066(†)	5.765 ± 0.003	0.472 ± 0.001	0.559 ± 0.002	0.620 ± 0.003	0.663 ± 0.002	0.308 ± 0.002	0.165 ± 0.002	0.490 ± 0.002	31
129116	3.951 ± 0.013	0.125 ± 0.013	0.239 ± 0.020	0.282 ± 0.014	0.114 ± 0.012	0.086 ± 0.015	0.029 ± 0.011	0.085 ± 0.009	3
136014	6.195 ± 0.003	0.738 ± 0.002	0.572 ± 0.004	0.900 ± 0.004	1.168 ± 0.004	0.463 ± 0.003	0.276 ± 0.003	0.739 ± 0.003	48
140008	4.630 ± 0.035	0.134 ± 0.015	0.324 ± 0.017	0.388 ± 0.028	0.115 ± 0.023	0.121 ± 0.020	0.021 ± 0.011	0.107 ± 0.017	3
141556	3.935 ± 0.013	0.171 ± 0.012	0.597 ± 0.019	0.706 ± 0.013	0.243 ± 0.013	0.110 ± 0.015	0.052 ± 0.010	0.132 ± 0.008	3
148605	4.809 ± 0.008	0.141 ± 0.009	0.177 ± 0.009	0.279 ± 0.010	0.135 ± 0.012	0.100 ± 0.009	0.042 ± 0.008	0.106 ± 0.008	4
148703	4.137 ± 0.035	0.143 ± 0.014	0.206 ± 0.019	0.186 ± 0.028	0.073 ± 0.024	0.120 ± 0.021	0.029 ± 0.010	0.107 ± 0.016	3
154090	4.856 ± 0.019	0.431 ± 0.008	0.270 ± 0.014	0.178 ± 0.011	0.308 ± 0.011	0.287 ± 0.008	0.143 ± 0.008	0.379 ± 0.012	3
158094	3.540 ± 0.036	0.172 ± 0.017	0.522 ± 0.017	0.561 ± 0.027	0.150 ± 0.026	0.115 ± 0.023	0.045 ± 0.014	0.129 ± 0.017	3
166114	5.756 ± 0.031	0.344 ± 0.005	0.619 ± 0.009	0.744 ± 0.012	0.506 ± 0.013	0.213 ± 0.008	0.128 ± 0.005	0.320 ± 0.007	18
169467	3.455 ± 0.012	0.110 ± 0.010	0.236 ± 0.019	0.321 ± 0.018	0.115 ± 0.015	0.074 ± 0.016	0.035 ± 0.013	0.063 ± 0.010	3
176723	5.724 ± 0.003	0.382 ± 0.002	0.635 ± 0.004	0.698 ± 0.004	0.546 ± 0.003	0.251 ± 0.003	0.131 ± 0.002	0.390 ± 0.003	13
182640	3.467 ± 0.021	0.364 ± 0.011	0.534 ± 0.012	0.667 ± 0.013	0.528 ± 0.012	0.222 ± 0.014	0.142 ± 0.014	0.374 ± 0.014	3
184915	4.961 ± 0.007	0.258 ± 0.006	0.140 ± 0.007	0.131 ± 0.007	0.144 ± 0.008	0.173 ± 0.007	0.082 ± 0.006	0.204 ± 0.006	8
210302	4.919 ± 0.027	0.463 ± 0.004	0.499 ± 0.008	0.591 ± 0.011	0.671 ± 0.012	0.279 ± 0.007	0.173 ± 0.005	0.454 ± 0.006	19

Table E.3: The mean reduced observations for the E Region standard stars.

star	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
E1.036	5.053 ± 0.004	0.526 ± 0.002	0.493 ± 0.003	0.609 ± 0.002	0.756 ± 0.002	0.321 ± 0.002	0.200 ± 0.002	0.514 ± 0.002	43
E3.045(∞)	5.775 ± 0.016	0.137 ± 0.006	0.547 ± 0.025	0.682 ± 0.008	0.233 ± 0.007	0.100 ± 0.006	0.039 ± 0.005	0.119 ± 0.007	5
E3.047	5.121 ± 0.020	0.457 ± 0.007	0.467 ± 0.022	0.580 ± 0.010	0.630 ± 0.008	0.288 ± 0.008	0.180 ± 0.007	0.445 ± 0.007	4
E4.028	6.597 ± 0.014	0.874 ± 0.004	0.643 ± 0.022	1.157 ± 0.010	1.539 ± 0.006	0.492 ± 0.006	0.386 ± 0.004	0.822 ± 0.007	8
E4.029	6.673 ± 0.014	0.898 ± 0.004	0.662 ± 0.022	1.208 ± 0.010	1.607 ± 0.006	0.492 ± 0.006	0.409 ± 0.004	0.838 ± 0.007	8
E4.039	6.664 ± 0.004	0.449 ± 0.002	0.555 ± 0.003	0.590 ± 0.002	0.600 ± 0.002	0.276 ± 0.002	0.168 ± 0.002	0.454 ± 0.002	32
E4.041(∞)	6.272 ± 0.011	0.139 ± 0.005	0.487 ± 0.017	0.606 ± 0.006	0.199 ± 0.004	0.098 ± 0.005	0.046 ± 0.004	0.148 ± 0.006	8
E4.044	5.741 ± 0.013	0.706 ± 0.004	0.567 ± 0.019	0.886 ± 0.007	1.140 ± 0.005	0.444 ± 0.005	0.267 ± 0.004	0.674 ± 0.007	8
E4.045	6.612 ± 0.012	0.464 ± 0.005	0.544 ± 0.018	0.621 ± 0.006	0.656 ± 0.004	0.293 ± 0.005	0.175 ± 0.004	0.460 ± 0.006	8
E4.046	6.556 ± 0.011	0.320 ± 0.005	0.527 ± 0.017	0.728 ± 0.006	0.498 ± 0.004	0.205 ± 0.005	0.118 ± 0.003	0.299 ± 0.006	8
E4.047	5.508 ± 0.013	0.746 ± 0.004	0.538 ± 0.020	0.881 ± 0.008	1.246 ± 0.005	0.466 ± 0.005	0.286 ± 0.004	0.690 ± 0.007	8
E4.078	5.880 ± 0.011	0.106 ± 0.006	0.272 ± 0.017	0.448 ± 0.005	0.172 ± 0.004	0.076 ± 0.005	0.033 ± 0.004	0.096 ± 0.006	8
E4.079(∞)	5.270 ± 0.011	0.103 ± 0.006	0.249 ± 0.017	0.391 ± 0.006	0.156 ± 0.005	0.072 ± 0.005	0.034 ± 0.004	0.097 ± 0.006	8
E4.093	5.821 ± 0.011	0.058 ± 0.006	0.099 ± 0.017	0.191 ± 0.005	0.107 ± 0.004	0.049 ± 0.005	0.014 ± 0.004	0.063 ± 0.006	8
E4.094	5.946 ± 0.013	0.142 ± 0.006	0.554 ± 0.023	0.735 ± 0.006	0.253 ± 0.005	0.100 ± 0.005	0.044 ± 0.005	0.135 ± 0.007	6
E4.096	6.782 ± 0.013	0.153 ± 0.006	0.571 ± 0.024	0.809 ± 0.006	0.287 ± 0.005	0.110 ± 0.005	0.047 ± 0.005	0.128 ± 0.007	6
E4.097	6.320 ± 0.013	0.100 ± 0.006	0.266 ± 0.023	0.351 ± 0.006	0.158 ± 0.005	0.077 ± 0.005	0.028 ± 0.004	0.112 ± 0.008	6
E4.098	6.263 ± 0.013	0.120 ± 0.006	0.435 ± 0.024	0.507 ± 0.006	0.194 ± 0.005	0.088 ± 0.005	0.035 ± 0.004	0.127 ± 0.008	6
E5.040	5.170 ± 0.003	0.437 ± 0.002	0.519 ± 0.003	0.578 ± 0.002	0.597 ± 0.002	0.273 ± 0.002	0.163 ± 0.002	0.435 ± 0.002	52
E6.012	7.919 ± 0.007	0.260 ± 0.006	0.615 ± 0.008	0.829 ± 0.005	0.447 ± 0.004	0.168 ± 0.006	0.097 ± 0.005	0.210 ± 0.006	4
E6.013	8.021 ± 0.008	0.313 ± 0.006	0.665 ± 0.007	0.814 ± 0.005	0.493 ± 0.004	0.189 ± 0.006	0.124 ± 0.006	0.263 ± 0.007	4
E6.014	8.157 ± 0.008	0.322 ± 0.007	0.664 ± 0.009	0.814 ± 0.006	0.490 ± 0.004	0.197 ± 0.006	0.127 ± 0.006	0.287 ± 0.008	4
E6.033	6.903 ± 0.010	0.858 ± 0.006	0.640 ± 0.021	1.178 ± 0.011	1.521 ± 0.008	0.477 ± 0.009	0.383 ± 0.007	0.821 ± 0.010	4
E6.039(∞)	5.511 ± 0.004	0.141 ± 0.004	0.525 ± 0.005	0.598 ± 0.003	0.201 ± 0.003	0.099 ± 0.003	0.044 ± 0.003	0.118 ± 0.003	15
E6.040	5.583 ± 0.006	1.077 ± 0.004	0.756 ± 0.009	1.337 ± 0.006	1.929 ± 0.005	0.591 ± 0.005	0.486 ± 0.004	0.995 ± 0.005	14
E6.041	6.113 ± 0.007	0.487 ± 0.005	0.512 ± 0.009	0.585 ± 0.005	0.690 ± 0.005	0.303 ± 0.005	0.186 ± 0.004	0.485 ± 0.005	7
E6.042(∞)	6.951 ± 0.009	0.196 ± 0.009	0.563 ± 0.009	0.791 ± 0.005	0.315 ± 0.005	0.135 ± 0.006	0.066 ± 0.005	0.155 ± 0.006	5
E6.043	5.770 ± 0.006	0.200 ± 0.006	0.612 ± 0.008	0.831 ± 0.004	0.363 ± 0.004	0.140 ± 0.005	0.064 ± 0.003	0.156 ± 0.005	7
E6.044	6.336 ± 0.005	0.819 ± 0.003	0.633 ± 0.006	0.998 ± 0.004	1.320 ± 0.003	0.495 ± 0.004	0.321 ± 0.003	0.759 ± 0.004	17
E6.045	6.771 ± 0.003	0.199 ± 0.002	0.620 ± 0.003	0.833 ± 0.002	0.351 ± 0.002	0.129 ± 0.002	0.072 ± 0.002	0.146 ± 0.002	35

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Table E.3 continued from previous page

star	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
E6.046(∞)	7.079 $\pm$ 0.008	0.395 $\pm$ 0.006	0.564 $\pm$ 0.007	0.656 $\pm$ 0.005	0.575 $\pm$ 0.004	0.237 $\pm$ 0.005	0.156 $\pm$ 0.005	0.381 $\pm$ 0.006	4
E6.047	6.601 $\pm$ 0.002	0.470 $\pm$ 0.002	0.494 $\pm$ 0.002	0.554 $\pm$ 0.001	0.659 $\pm$ 0.001	0.288 $\pm$ 0.002	0.181 $\pm$ 0.002	0.460 $\pm$ 0.002	65
E6.079(∞)	4.383 $\pm$ 0.006	0.446 $\pm$ 0.006	0.723 $\pm$ 0.007	0.810 $\pm$ 0.005	0.572 $\pm$ 0.005	0.272 $\pm$ 0.006	0.174 $\pm$ 0.004	0.464 $\pm$ 0.005	9
E6.080	5.848 $\pm$ 0.006	0.349 $\pm$ 0.005	0.616 $\pm$ 0.007	0.758 $\pm$ 0.004	0.579 $\pm$ 0.004	0.211 $\pm$ 0.004	0.141 $\pm$ 0.003	0.320 $\pm$ 0.004	9
E6.081	6.412 $\pm$ 0.007	0.123 $\pm$ 0.006	0.426 $\pm$ 0.008	0.534 $\pm$ 0.004	0.192 $\pm$ 0.004	0.080 $\pm$ 0.005	0.047 $\pm$ 0.004	0.114 $\pm$ 0.006	8
E6.082	6.915 $\pm$ 0.007	0.184 $\pm$ 0.006	0.679 $\pm$ 0.008	0.675 $\pm$ 0.005	0.227 $\pm$ 0.004	0.127 $\pm$ 0.005	0.060 $\pm$ 0.004	0.164 $\pm$ 0.006	8
E6.084	6.821 $\pm$ 0.008	0.747 $\pm$ 0.005	0.613 $\pm$ 0.012	0.889 $\pm$ 0.006	1.176 $\pm$ 0.005	0.459 $\pm$ 0.006	0.289 $\pm$ 0.005	0.713 $\pm$ 0.007	8
E6.087	6.663 $\pm$ 0.012	0.182 $\pm$ 0.010	0.525 $\pm$ 0.014	0.576 $\pm$ 0.008	0.216 $\pm$ 0.007	0.126 $\pm$ 0.008	0.058 $\pm$ 0.006	0.173 $\pm$ 0.009	4
E6.088(∞)	6.645 $\pm$ 0.013	0.104 $\pm$ 0.013	0.418 $\pm$ 0.018	0.510 $\pm$ 0.010	0.199 $\pm$ 0.007	0.041 $\pm$ 0.010	0.065 $\pm$ 0.006	0.149 $\pm$ 0.011	3
E6.090	6.837 $\pm$ 0.013	0.235 $\pm$ 0.010	0.654 $\pm$ 0.014	0.844 $\pm$ 0.008	0.431 $\pm$ 0.007	0.149 $\pm$ 0.007	0.091 $\pm$ 0.007	0.206 $\pm$ 0.010	4
E6.091(∞)	4.343 $\pm$ 0.007	0.106 $\pm$ 0.008	0.279 $\pm$ 0.007	0.330 $\pm$ 0.007	0.153 $\pm$ 0.008	0.071 $\pm$ 0.007	0.041 $\pm$ 0.005	0.095 $\pm$ 0.004	8
E6.095	6.140 $\pm$ 0.007	0.544 $\pm$ 0.005	0.745 $\pm$ 0.007	0.717 $\pm$ 0.005	0.780 $\pm$ 0.004	0.319 $\pm$ 0.006	0.221 $\pm$ 0.005	0.539 $\pm$ 0.005	6
E6.100	8.231 $\pm$ 0.009	0.791 $\pm$ 0.006	0.593 $\pm$ 0.019	0.912 $\pm$ 0.015	1.303 $\pm$ 0.006	0.479 $\pm$ 0.008	0.310 $\pm$ 0.007	0.735 $\pm$ 0.007	4
E7.048	6.704 $\pm$ 0.002	0.416 $\pm$ 0.002	0.537 $\pm$ 0.002	0.603 $\pm$ 0.001	0.577 $\pm$ 0.001	0.261 $\pm$ 0.001	0.154 $\pm$ 0.001	0.404 $\pm$ 0.002	95
E7.065	7.216 $\pm$ 0.003	0.564 $\pm$ 0.002	0.477 $\pm$ 0.003	0.648 $\pm$ 0.002	0.828 $\pm$ 0.002	0.339 $\pm$ 0.002	0.223 $\pm$ 0.002	0.562 $\pm$ 0.002	55
E8.069	4.142 $\pm$ 0.017	0.805 $\pm$ 0.007	0.617 $\pm$ 0.014	1.000 $\pm$ 0.010	1.354 $\pm$ 0.010	0.471 $\pm$ 0.014	0.339 $\pm$ 0.009	0.763 $\pm$ 0.010	4
E9.024	6.989 $\pm$ 0.013	0.751 $\pm$ 0.005	0.592 $\pm$ 0.012	0.947 $\pm$ 0.008	1.226 $\pm$ 0.007	0.454 $\pm$ 0.006	0.295 $\pm$ 0.005	0.717 $\pm$ 0.007	6
E9.029	6.865 $\pm$ 0.012	0.732 $\pm$ 0.005	0.580 $\pm$ 0.010	0.868 $\pm$ 0.006	1.157 $\pm$ 0.006	0.447 $\pm$ 0.006	0.283 $\pm$ 0.005	0.708 $\pm$ 0.007	7
E9.030	6.935 $\pm$ 0.013	0.831 $\pm$ 0.005	0.632 $\pm$ 0.012	1.106 $\pm$ 0.007	1.421 $\pm$ 0.007	0.488 $\pm$ 0.006	0.344 $\pm$ 0.006	0.778 $\pm$ 0.007	7
E9.040	7.001 $\pm$ 0.011	0.206 $\pm$ 0.008	0.617 $\pm$ 0.009	0.838 $\pm$ 0.005	0.368 $\pm$ 0.005	0.137 $\pm$ 0.006	0.071 $\pm$ 0.005	0.153 $\pm$ 0.007	5
E9.042	6.808 $\pm$ 0.003	0.504 $\pm$ 0.002	0.518 $\pm$ 0.003	0.575 $\pm$ 0.002	0.700 $\pm$ 0.002	0.308 $\pm$ 0.002	0.196 $\pm$ 0.002	0.494 $\pm$ 0.002	37
E9.043	6.152 $\pm$ 0.012	0.752 $\pm$ 0.005	0.582 $\pm$ 0.010	0.899 $\pm$ 0.006	1.186 $\pm$ 0.006	0.454 $\pm$ 0.006	0.295 $\pm$ 0.005	0.714 $\pm$ 0.006	7
E9.044	5.599 $\pm$ 0.013	0.961 $\pm$ 0.005	0.692 $\pm$ 0.012	1.232 $\pm$ 0.008	1.712 $\pm$ 0.007	0.547 $\pm$ 0.007	0.413 $\pm$ 0.005	0.887 $\pm$ 0.007	7
E9.048	6.988 $\pm$ 0.009	0.150 $\pm$ 0.006	0.572 $\pm$ 0.007	0.739 $\pm$ 0.005	0.247 $\pm$ 0.004	0.106 $\pm$ 0.004	0.045 $\pm$ 0.004	0.110 $\pm$ 0.006	7
E9.049	6.922 $\pm$ 0.014	0.941 $\pm$ 0.005	0.670 $\pm$ 0.014	1.215 $\pm$ 0.008	1.655 $\pm$ 0.007	0.530 $\pm$ 0.007	0.410 $\pm$ 0.005	0.881 $\pm$ 0.007	6
E9.063(∞)	6.053 $\pm$ 0.012	0.527 $\pm$ 0.007	0.492 $\pm$ 0.010	0.586 $\pm$ 0.007	0.745 $\pm$ 0.007	0.323 $\pm$ 0.006	0.199 $\pm$ 0.005	0.527 $\pm$ 0.007	4
E9.071	6.176 $\pm$ 0.012	0.779 $\pm$ 0.005	0.625 $\pm$ 0.010	0.945 $\pm$ 0.006	1.261 $\pm$ 0.006	0.477 $\pm$ 0.006	0.299 $\pm$ 0.005	0.730 $\pm$ 0.007	6
E9.072	5.692 $\pm$ 0.010	0.412 $\pm$ 0.005	0.559 $\pm$ 0.008	0.627 $\pm$ 0.005	0.572 $\pm$ 0.005	0.254 $\pm$ 0.005	0.154 $\pm$ 0.004	0.398 $\pm$ 0.006	6
E9.073	6.965 $\pm$ 0.013	0.212 $\pm$ 0.008	0.646 $\pm$ 0.010	0.835 $\pm$ 0.007	0.363 $\pm$ 0.006	0.130 $\pm$ 0.006	0.079 $\pm$ 0.006	0.158 $\pm$ 0.008	4
E9.079	4.908 $\pm$ 0.016	0.782 $\pm$ 0.006	0.608 $\pm$ 0.012	0.966 $\pm$ 0.009	1.264 $\pm$ 0.008	0.469 $\pm$ 0.007	0.309 $\pm$ 0.007	0.738 $\pm$ 0.009	5

Table E.4: The mean reduced observations for the unsuccessful primary standard stars.

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
001879	6.449 ± 0.028	1.156 ± 0.011	0.863 ± 0.032	1.416 ± 0.019	2.088 ± 0.018	0.633 ± 0.013	0.524 ± 0.010	1.143 ± 0.017	2
003296	6.741 ± 0.024	0.474 ± 0.012	0.495 ± 0.018	0.574 ± 0.010	0.645 ± 0.013	0.291 ± 0.010	0.175 ± 0.009	0.455 ± 0.014	2
004628	5.755 ± 0.034	0.704 ± 0.019	0.452 ± 0.034	0.893 ± 0.019	1.170 ± 0.022	0.329 ± 0.022	0.364 ± 0.015	0.697 ± 0.020	1
005112	4.781 ± 0.031	1.138 ± 0.012	0.820 ± 0.029	1.378 ± 0.017	2.086 ± 0.018	0.607 ± 0.014	0.531 ± 0.012	1.048 ± 0.017	2
005268	6.184 ± 0.025	0.739 ± 0.011	0.599 ± 0.020	0.833 ± 0.012	1.100 ± 0.014	0.450 ± 0.010	0.285 ± 0.010	0.707 ± 0.014	2
026912	4.290 ± 0.022	0.178 ± 0.068	0.339 ± 0.023	0.401 ± 0.023	0.200 ± 0.018	0.106 ± 0.023	0.070 ± 0.024	0.148 ± 0.029	2
028556	5.431 ± 0.024	0.310 ± 0.062	0.613 ± 0.030	0.744 ± 0.030	0.534 ± 0.027	0.198 ± 0.028	0.120 ± 0.032	0.304 ± 0.034	2
031237(v)	3.714 ± 0.024	0.111 ± 0.072	0.177 ± 0.024	0.214 ± 0.025	0.125 ± 0.022	0.071 ± 0.027	0.031 ± 0.026	0.078 ± 0.028	2
031283	5.193 ± 0.022	0.233 ± 0.065	0.690 ± 0.025	0.841 ± 0.023	0.422 ± 0.016	0.135 ± 0.020	0.100 ± 0.025	0.189 ± 0.029	2
050082	7.406 ± 0.036	0.780 ± 0.013	0.483 ± 0.037	0.841 ± 0.017	1.281 ± 0.010	0.492 ± 0.015	0.288 ± 0.014	0.714 ± 0.021	2
052382	6.438 ± 0.016	0.371 ± 0.007	0.209 ± 0.031	0.182 ± 0.008	0.286 ± 0.006	0.248 ± 0.007	0.120 ± 0.006	0.333 ± 0.012	4
055751	5.347 ± 0.010	0.872 ± 0.004	0.653 ± 0.012	1.105 ± 0.010	1.542 ± 0.008	0.541 ± 0.007	0.332 ± 0.009	0.807 ± 0.008	10
059881	5.207 ± 0.018	0.297 ± 0.008	0.812 ± 0.035	0.840 ± 0.009	0.476 ± 0.008	0.187 ± 0.007	0.112 ± 0.006	0.256 ± 0.012	4
063975	5.107 ± 0.017	0.121 ± 0.010	0.381 ± 0.034	0.445 ± 0.009	0.171 ± 0.008	0.083 ± 0.008	0.038 ± 0.006	0.089 ± 0.011	4
074521(v)	5.635 ± 0.009	0.105 ± 0.007	0.494 ± 0.010	0.604 ± 0.008	0.240 ± 0.010	0.026 ± 0.009	0.080 ± 0.008	0.159 ± 0.008	4
091316(v)	3.859 ± 0.010	0.148 ± 0.007	0.111 ± 0.010	0.099 ± 0.009	0.098 ± 0.010	0.099 ± 0.010	0.050 ± 0.009	0.103 ± 0.008	6
095849	5.919 ± 0.018	0.877 ± 0.012	0.662 ± 0.019	1.202 ± 0.013	1.616 ± 0.009	0.493 ± 0.015	0.381 ± 0.011	0.816 ± 0.011	2
097585	5.400 ± 0.013	0.166 ± 0.016	0.683 ± 0.011	0.765 ± 0.009	0.261 ± 0.008	0.105 ± 0.011	0.057 ± 0.009	0.124 ± 0.008	2
100563	5.792 ± 0.028	0.441 ± 0.017	0.450 ± 0.058	0.568 ± 0.015	0.673 ± 0.010	0.274 ± 0.011	0.165 ± 0.010	0.447 ± 0.018	2
102124	4.832 ± 0.013	0.268 ± 0.008	0.595 ± 0.010	0.789 ± 0.008	0.461 ± 0.008	0.167 ± 0.010	0.096 ± 0.008	0.241 ± 0.007	2
102510	5.305 ± 0.013	0.184 ± 0.009	0.572 ± 0.010	0.807 ± 0.008	0.341 ± 0.008	0.120 ± 0.010	0.060 ± 0.009	0.141 ± 0.008	2
104181	5.351 ± 0.012	0.171 ± 0.008	0.619 ± 0.010	0.802 ± 0.008	0.307 ± 0.007	0.120 ± 0.009	0.049 ± 0.008	0.139 ± 0.007	2
104979	4.146 ± 0.030	0.731 ± 0.010	0.572 ± 0.052	0.836 ± 0.015	1.216 ± 0.013	0.445 ± 0.014	0.287 ± 0.011	0.712 ± 0.023	2
105639	5.977 ± 0.029	0.822 ± 0.010	0.637 ± 0.048	1.108 ± 0.017	1.464 ± 0.012	0.451 ± 0.012	0.371 ± 0.012	0.795 ± 0.025	2
107328(v?)	4.954 ± 0.011	0.860 ± 0.006	0.661 ± 0.013	1.128 ± 0.011	1.475 ± 0.008	0.479 ± 0.008	0.380 ± 0.012	0.834 ± 0.007	10
110423(v?)	5.565 ± 0.013	0.167 ± 0.009	0.565 ± 0.009	0.808 ± 0.009	0.288 ± 0.007	0.101 ± 0.009	0.056 ± 0.015	0.128 ± 0.008	8
111721	7.958 ± 0.023	0.686 ± 0.013	0.564 ± 0.023	0.597 ± 0.017	0.895 ± 0.015	0.427 ± 0.012	0.254 ± 0.011	0.678 ± 0.018	2
112300(v?)	3.339 ± 0.031	1.177 ± 0.013	0.855 ± 0.036	1.387 ± 0.025	1.913 ± 0.024	0.681 ± 0.021	0.496 ± 0.029	1.162 ± 0.028	2
116235	5.852 ± 0.017	0.213 ± 0.012	0.607 ± 0.014	0.829 ± 0.009	0.425 ± 0.009	0.132 ± 0.008	0.086 ± 0.007	0.169 ± 0.009	2
118022(v)	4.929 ± 0.011	0.165 ± 0.009	0.586 ± 0.009	0.786 ± 0.009	0.363 ± 0.009	0.095 ± 0.010	0.062 ± 0.008	0.185 ± 0.007	6

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Table E.4 continued from previous page

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
137613	7.570 ± 0.017	0.989 ± 0.006	0.504 ± 0.024	0.899 ± 0.017	1.346 ± 0.012	0.658 ± 0.017	0.334 ± 0.008	0.847 ± 0.010	4
147196	7.012 ± 0.011	0.326 ± 0.008	0.580 ± 0.011	0.640 ± 0.008	0.332 ± 0.007	0.210 ± 0.008	0.110 ± 0.006	0.331 ± 0.009	6
147432	7.495 ± 0.017	0.342 ± 0.009	0.609 ± 0.013	0.824 ± 0.011	0.501 ± 0.010	0.218 ± 0.008	0.117 ± 0.008	0.320 ± 0.012	4
150366	6.044 ± 0.009	0.303 ± 0.007	0.622 ± 0.009	0.771 ± 0.007	0.496 ± 0.006	0.192 ± 0.008	0.106 ± 0.006	0.273 ± 0.008	4
150451	6.231 ± 0.015	0.366 ± 0.011	0.587 ± 0.013	0.706 ± 0.011	0.539 ± 0.010	0.223 ± 0.010	0.143 ± 0.011	0.353 ± 0.013	2
151431(v?)	6.116 ± 0.017	0.244 ± 0.015	0.797 ± 0.021	0.865 ± 0.016	0.394 ± 0.014	0.180 ± 0.019	0.058 ± 0.017	0.260 ± 0.015	2
153210(v)	3.251 ± 0.036	0.809 ± 0.012	0.582 ± 0.022	1.187 ± 0.021	1.480 ± 0.019	0.481 ± 0.018	0.330 ± 0.019	0.807 ± 0.022	2
157415	7.768 ± 0.019	0.979 ± 0.012	0.645 ± 0.048	1.070 ± 0.035	1.398 ± 0.026	0.595 ± 0.016	0.380 ± 0.013	0.903 ± 0.013	2
160781	5.943 ± 0.029	0.975 ± 0.021	0.690 ± 0.031	1.135 ± 0.031	1.598 ± 0.033	0.620 ± 0.035	0.356 ± 0.020	0.855 ± 0.023	1
160823	6.994 ± 0.017	0.795 ± 0.010	0.705 ± 0.020	0.768 ± 0.017	1.049 ± 0.010	0.494 ± 0.012	0.304 ± 0.011	0.734 ± 0.012	2
161868	3.813 ± 0.021	0.201 ± 0.013	0.583 ± 0.012	0.831 ± 0.014	0.327 ± 0.013	0.136 ± 0.015	0.063 ± 0.014	0.143 ± 0.012	2
162917	5.761 ± 0.014	0.448 ± 0.011	0.515 ± 0.012	0.572 ± 0.010	0.634 ± 0.008	0.275 ± 0.008	0.170 ± 0.012	0.440 ± 0.011	2
165174(v)	6.125 ± 0.018	0.248 ± 0.006	0.130 ± 0.008	0.069 ± 0.010	0.160 ± 0.007	0.170 ± 0.008	0.076 ± 0.007	0.209 ± 0.010	2
165462	6.369 ± 0.017	0.822 ± 0.008	0.713 ± 0.017	0.921 ± 0.020	1.232 ± 0.014	0.513 ± 0.014	0.328 ± 0.009	0.802 ± 0.012	4
166460	5.486 ± 0.019	0.886 ± 0.012	0.663 ± 0.020	1.160 ± 0.015	1.549 ± 0.009	0.509 ± 0.014	0.382 ± 0.011	0.830 ± 0.012	2
167768	6.014 ± 0.010	0.708 ± 0.006	0.595 ± 0.008	0.818 ± 0.007	1.074 ± 0.006	0.439 ± 0.007	0.274 ± 0.006	0.686 ± 0.007	8
169111	5.970 ± 0.023	0.211 ± 0.006	0.719 ± 0.010	0.830 ± 0.011	0.312 ± 0.008	0.135 ± 0.010	0.077 ± 0.009	0.169 ± 0.012	2
169191	5.252 ± 0.008	0.922 ± 0.008	0.643 ± 0.022	1.247 ± 0.018	1.621 ± 0.016	0.534 ± 0.008	0.388 ± 0.008	0.895 ± 0.009	2
171767	6.749 ± 0.018	0.856 ± 0.011	0.645 ± 0.025	1.155 ± 0.018	1.470 ± 0.011	0.511 ± 0.012	0.348 ± 0.011	0.780 ± 0.013	2
172046	6.674 ± 0.013	0.196 ± 0.008	0.456 ± 0.011	0.492 ± 0.008	0.248 ± 0.006	0.112 ± 0.008	0.088 ± 0.008	0.183 ± 0.008	2
172365	6.378 ± 0.005	0.673 ± 0.003	0.776 ± 0.007	0.811 ± 0.006	0.942 ± 0.005	0.416 ± 0.004	0.255 ± 0.004	0.654 ± 0.005	8
172850	7.763 ± 0.013	0.200 ± 0.010	0.514 ± 0.012	0.613 ± 0.009	0.232 ± 0.008	0.129 ± 0.009	0.075 ± 0.010	0.155 ± 0.015	2
177756	3.476 ± 0.035	0.139 ± 0.033	0.517 ± 0.023	0.604 ± 0.033	0.203 ± 0.041	0.079 ± 0.034	0.058 ± 0.021	0.102 ± 0.016	1
178125(v)	5.045 ± 0.021	0.154 ± 0.007	0.405 ± 0.009	0.520 ± 0.011	0.204 ± 0.009	0.108 ± 0.011	0.046 ± 0.010	0.148 ± 0.011	2
179406(v?)	5.343 ± 0.005	0.308 ± 0.004	0.400 ± 0.006	0.397 ± 0.007	0.282 ± 0.006	0.216 ± 0.005	0.092 ± 0.005	0.297 ± 0.005	4
181391	5.026 ± 0.046	0.726 ± 0.018	0.582 ± 0.028	0.890 ± 0.017	1.150 ± 0.020	0.428 ± 0.022	0.295 ± 0.015	0.712 ± 0.017	1
182101	6.344 ± 0.021	0.459 ± 0.006	0.479 ± 0.009	0.579 ± 0.011	0.633 ± 0.008	0.294 ± 0.009	0.164 ± 0.008	0.477 ± 0.011	2
182296	7.060 ± 0.024	1.031 ± 0.005	0.765 ± 0.028	1.046 ± 0.016	1.493 ± 0.011	0.655 ± 0.010	0.376 ± 0.008	0.913 ± 0.012	2
183324	5.834 ± 0.036	0.210 ± 0.023	0.609 ± 0.020	0.828 ± 0.014	0.384 ± 0.016	0.132 ± 0.017	0.075 ± 0.012	0.153 ± 0.016	1
183630(v?)	5.032 ± 0.007	1.305 ± 0.004	0.891 ± 0.014	1.540 ± 0.013	2.209 ± 0.010	0.728 ± 0.007	0.576 ± 0.005	1.241 ± 0.008	4
184406(v?)	4.464 ± 0.012	0.871 ± 0.011	0.662 ± 0.015	1.204 ± 0.015	1.561 ± 0.014	0.450 ± 0.015	0.422 ± 0.010	0.834 ± 0.009	6

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Table E.4 continued from previous page

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
189695	5.914 ± 0.017	1.103 ± 0.011	0.823 ± 0.027	1.398 ± 0.021	2.034 ± 0.013	0.585 ± 0.015	0.525 ± 0.014	1.046 ± 0.013	2
195810(v?)	4.019 ± 0.021	0.123 ± 0.010	0.394 ± 0.011	0.458 ± 0.014	0.141 ± 0.013	0.101 ± 0.017	0.022 ± 0.016	0.116 ± 0.012	2
198070	6.424 ± 0.038	0.184 ± 0.026	0.607 ± 0.041	0.733 ± 0.021	0.278 ± 0.019	0.123 ± 0.019	0.056 ± 0.014	0.121 ± 0.020	1
198743	4.757 ± 0.013	0.366 ± 0.014	0.623 ± 0.011	0.728 ± 0.008	0.572 ± 0.008	0.223 ± 0.011	0.150 ± 0.008	0.327 ± 0.008	2
200644	5.622 ± 0.016	1.199 ± 0.010	0.814 ± 0.026	1.408 ± 0.020	2.182 ± 0.010	0.652 ± 0.015	0.555 ± 0.011	1.066 ± 0.011	2
216701	6.141 ± 0.029	0.288 ± 0.019	0.682 ± 0.028	0.838 ± 0.015	0.465 ± 0.016	0.170 ± 0.016	0.110 ± 0.012	0.247 ± 0.020	1

Table E.5: The mean reduced observations for the unsuccessful SPS standard stars.

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
002151	2.911 ± 0.072	0.543 ± 0.012	0.486 ± 0.023	0.613 ± 0.031	0.795 ± 0.033	0.326 ± 0.026	0.201 ± 0.021	0.554 ± 0.018	3
089080	3.267 ± 0.013	0.177 ± 0.014	0.669 ± 0.025	0.539 ± 0.017	0.179 ± 0.016	0.097 ± 0.021	0.061 ± 0.017	0.202 ± 0.010	2
093845(†)	4.438 ± 0.015	0.119 ± 0.018	0.217 ± 0.024	0.285 ± 0.014	0.106 ± 0.018	0.068 ± 0.022	0.033 ± 0.016	0.081 ± 0.016	2
112985	3.668 ± 0.017	0.844 ± 0.008	0.635 ± 0.032	1.196 ± 0.014	1.566 ± 0.013	0.447 ± 0.020	0.391 ± 0.013	0.837 ± 0.012	2
124882	4.385 ± 0.018	0.919 ± 0.008	0.671 ± 0.034	1.234 ± 0.016	1.720 ± 0.014	0.506 ± 0.018	0.414 ± 0.011	0.909 ± 0.012	2
130650	5.641 ± 0.009	0.739 ± 0.007	0.560 ± 0.026	0.946 ± 0.020	1.221 ± 0.017	0.462 ± 0.009	0.277 ± 0.008	0.730 ± 0.011	1
131246	5.645 ± 0.009	0.976 ± 0.007	0.674 ± 0.030	1.106 ± 0.023	1.581 ± 0.020	0.615 ± 0.010	0.362 ± 0.008	0.886 ± 0.013	1
147675	3.857 ± 0.206	0.715 ± 0.020	0.621 ± 0.042	0.892 ± 0.055	1.147 ± 0.079	0.436 ± 0.050	0.286 ± 0.029	0.684 ± 0.048	1
156513	5.875 ± 0.008	1.310 ± 0.005	1.008 ± 0.025	1.531 ± 0.020	1.956 ± 0.018	0.806 ± 0.008	0.504 ± 0.006	1.244 ± 0.011	2
159517	6.488 ± 0.006	0.449 ± 0.006	0.534 ± 0.016	0.604 ± 0.012	0.632 ± 0.010	0.301 ± 0.006	0.148 ± 0.005	0.493 ± 0.007	2
164461	5.310 ± 0.107	0.944 ± 0.005	0.716 ± 0.015	1.364 ± 0.016	1.712 ± 0.013	0.520 ± 0.009	0.424 ± 0.007	0.926 ± 0.011	2
169904	6.149 ± 0.072	0.119 ± 0.006	0.395 ± 0.010	0.539 ± 0.010	0.185 ± 0.008	0.061 ± 0.007	0.057 ± 0.005	0.094 ± 0.008	2
177482	5.460 ± 0.006	0.332 ± 0.006	0.694 ± 0.015	0.752 ± 0.011	0.518 ± 0.010	0.223 ± 0.006	0.109 ± 0.006	0.361 ± 0.006	2
186154	6.433 ± 0.112	1.021 ± 0.005	0.698 ± 0.022	1.398 ± 0.018	1.822 ± 0.013	0.563 ± 0.009	0.457 ± 0.006	1.013 ± 0.011	2
191220	6.071 ± 0.075	0.285 ± 0.006	0.625 ± 0.010	0.803 ± 0.011	0.489 ± 0.008	0.161 ± 0.008	0.124 ± 0.006	0.266 ± 0.008	2
194612	5.945 ± 0.008	1.243 ± 0.006	0.800 ± 0.025	1.523 ± 0.020	2.192 ± 0.018	0.679 ± 0.008	0.564 ± 0.006	1.206 ± 0.011	2
202418	6.472 ± 0.112	1.015 ± 0.005	0.725 ± 0.023	1.369 ± 0.018	1.812 ± 0.013	0.574 ± 0.009	0.441 ± 0.006	1.000 ± 0.011	2
203532	6.386 ± 0.006	0.285 ± 0.006	0.390 ± 0.015	0.434 ± 0.011	0.293 ± 0.009	0.206 ± 0.006	0.079 ± 0.005	0.275 ± 0.006	2
203955	6.478 ± 0.005	0.192 ± 0.006	0.631 ± 0.014	0.837 ± 0.011	0.325 ± 0.009	0.134 ± 0.006	0.058 ± 0.005	0.157 ± 0.006	2
204904	6.128 ± 0.081	0.466 ± 0.006	0.540 ± 0.011	0.607 ± 0.011	0.631 ± 0.008	0.301 ± 0.008	0.165 ± 0.006	0.493 ± 0.009	2
205478	3.908 ± 0.208	0.743 ± 0.019	0.600 ± 0.042	1.012 ± 0.056	1.276 ± 0.081	0.398 ± 0.051	0.321 ± 0.028	0.745 ± 0.048	1
210967	5.183 ± 0.134	1.344 ± 0.006	1.181 ± 0.018	1.375 ± 0.018	1.055 ± 0.013	1.006 ± 0.011	0.338 ± 0.008	1.426 ± 0.013	2
214846	4.054 ± 0.075	0.276 ± 0.008	0.627 ± 0.011	0.794 ± 0.012	0.480 ± 0.011	0.185 ± 0.015	0.091 ± 0.013	0.273 ± 0.010	2
219765	5.551 ± 0.106	0.936 ± 0.005	0.669 ± 0.016	1.260 ± 0.016	1.647 ± 0.013	0.549 ± 0.009	0.387 ± 0.007	0.938 ± 0.011	2
224889	5.028 ± 0.225	0.885 ± 0.018	0.685 ± 0.046	1.237 ± 0.061	1.650 ± 0.088	0.435 ± 0.054	0.426 ± 0.029	0.899 ± 0.052	1

Table E.6: The mean reduced observations for the unsuccessful bright, southern secondary standard stars.

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
000496	4.067 ± 0.134	0.763 ± 0.010	0.606 ± 0.039	0.970 ± 0.046	1.304 ± 0.051	0.438 ± 0.034	0.302 ± 0.017	0.746 ± 0.031	2
001581	4.287 ± 0.068	0.519 ± 0.009	0.461 ± 0.022	0.565 ± 0.029	0.746 ± 0.032	0.311 ± 0.019	0.193 ± 0.013	0.530 ± 0.015	3
002261	2.573 ± 0.181	0.812 ± 0.020	0.582 ± 0.111	0.991 ± 0.081	1.374 ± 0.068	0.460 ± 0.061	0.332 ± 0.044	0.796 ± 0.046	1
002262	4.076 ± 0.163	0.274 ± 0.031	0.611 ± 0.033	0.797 ± 0.044	0.467 ± 0.063	0.157 ± 0.041	0.086 ± 0.024	0.254 ± 0.038	1
002834	4.879 ± 0.160	0.198 ± 0.034	0.600 ± 0.032	0.829 ± 0.042	0.333 ± 0.061	0.115 ± 0.039	0.050 ± 0.021	0.146 ± 0.037	1
015048	6.977 ± 0.051	0.390 ± 0.106	0.553 ± 0.039	0.543 ± 0.032	0.527 ± 0.121	0.284 ± 0.040	0.107 ± 0.033	0.496 ± 0.014	4
015182	6.301 ± 0.148	1.027 ± 0.157	0.794 ± 0.142	1.123 ± 0.101	2.135 ± 0.452	0.689 ± 0.147	0.420 ± 0.119	1.101 ± 0.040	1
033111	2.717 ± 0.025	0.209 ± 0.069	0.690 ± 0.025	0.866 ± 0.030	0.427 ± 0.032	0.174 ± 0.048	0.032 ± 0.047	0.201 ± 0.031	2
035299	5.675 ± 0.032	0.107 ± 0.102	0.105 ± 0.026	0.171 ± 0.025	0.114 ± 0.019	0.044 ± 0.024	0.051 ± 0.026	0.065 ± 0.037	1
036512	4.626 ± 0.023	0.083 ± 0.074	0.003 ± 0.024	0.058 ± 0.023	0.062 ± 0.018	0.029 ± 0.020	0.038 ± 0.019	0.065 ± 0.027	2
037224	6.804 ± 0.041	0.378 ± 0.087	0.509 ± 0.031	0.541 ± 0.026	0.529 ± 0.097	0.282 ± 0.032	0.096 ± 0.026	0.498 ± 0.011	6
045416	5.110 ± 0.020	0.871 ± 0.006	0.651 ± 0.038	1.081 ± 0.012	1.509 ± 0.009	0.538 ± 0.008	0.336 ± 0.007	0.764 ± 0.017	4
069142	4.426 ± 0.018	0.899 ± 0.008	0.630 ± 0.013	1.076 ± 0.013	1.462 ± 0.009	0.529 ± 0.011	0.348 ± 0.011	0.815 ± 0.013	2
072127(∞)	4.973 ± 0.013	0.139 ± 0.012	0.211 ± 0.024	0.193 ± 0.011	0.098 ± 0.010	0.096 ± 0.013	0.023 ± 0.008	0.102 ± 0.008	2
073389($\dagger$)	4.880 ± 0.050	0.754 ± 0.010	0.572 ± 0.023	0.971 ± 0.042	1.275 ± 0.036	0.439 ± 0.034	0.300 ± 0.014	0.719 ± 0.025	2
073390	5.160 ± 0.037	0.171 ± 0.018	0.290 ± 0.017	0.315 ± 0.031	0.111 ± 0.026	0.126 ± 0.025	0.019 ± 0.012	0.124 ± 0.019	2
074006	3.959 ± 0.024	0.740 ± 0.010	0.618 ± 0.016	0.845 ± 0.012	1.175 ± 0.013	0.446 ± 0.012	0.281 ± 0.013	0.673 ± 0.014	2
074180	3.802 ± 0.022	0.688 ± 0.010	1.305 ± 0.016	0.827 ± 0.011	0.678 ± 0.013	0.443 ± 0.013	0.231 ± 0.013	0.625 ± 0.014	2
074272	4.725 ± 0.018	0.291 ± 0.011	1.131 ± 0.013	0.830 ± 0.011	0.357 ± 0.010	0.183 ± 0.009	0.092 ± 0.010	0.268 ± 0.013	2
075063($\dagger$)	3.865 ± 0.013	0.231 ± 0.012	1.074 ± 0.024	0.745 ± 0.013	0.232 ± 0.012	0.157 ± 0.017	0.055 ± 0.012	0.204 ± 0.010	2
075710	4.904 ± 0.012	0.242 ± 0.008	0.936 ± 0.010	0.817 ± 0.009	0.281 ± 0.007	0.147 ± 0.008	0.075 ± 0.008	0.196 ± 0.010	2
076728	3.748 ± 0.037	0.186 ± 0.018	0.443 ± 0.019	0.428 ± 0.033	0.130 ± 0.028	0.134 ± 0.027	0.025 ± 0.014	0.156 ± 0.019	2
076805	4.633 ± 0.012	0.153 ± 0.009	0.287 ± 0.011	0.432 ± 0.010	0.174 ± 0.009	0.098 ± 0.010	0.036 ± 0.009	0.094 ± 0.010	2
077258(∞)	4.452 ± 0.013	0.570 ± 0.007	0.605 ± 0.016	0.825 ± 0.011	0.839 ± 0.010	0.341 ± 0.014	0.214 ± 0.008	0.582 ± 0.008	4
078004	3.780 ± 0.017	0.873 ± 0.008	0.656 ± 0.033	1.145 ± 0.014	1.550 ± 0.013	0.510 ± 0.019	0.355 ± 0.011	0.805 ± 0.011	2
078045	3.973 ± 0.013	0.264 ± 0.009	0.605 ± 0.010	0.818 ± 0.011	0.462 ± 0.010	0.163 ± 0.012	0.082 ± 0.011	0.205 ± 0.011	2
079447	3.849 ± 0.036	0.147 ± 0.019	0.285 ± 0.019	0.267 ± 0.033	0.071 ± 0.028	0.106 ± 0.026	0.014 ± 0.014	0.109 ± 0.018	2
079940	4.615 ± 0.014	0.469 ± 0.010	0.657 ± 0.026	0.652 ± 0.012	0.644 ± 0.011	0.286 ± 0.015	0.168 ± 0.009	0.458 ± 0.011	2
082434	3.536 ± 0.019	0.419 ± 0.010	0.572 ± 0.014	0.637 ± 0.012	0.571 ± 0.012	0.258 ± 0.014	0.146 ± 0.014	0.381 ± 0.013	2
083058	4.953 ± 0.017	0.118 ± 0.011	0.149 ± 0.013	0.138 ± 0.011	0.119 ± 0.010	0.081 ± 0.009	0.022 ± 0.010	0.084 ± 0.013	2

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Table E.6 continued from previous page

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
083183	4.022 ± 0.037	0.264 ± 0.016	0.426 ± 0.018	0.317 ± 0.033	0.176 ± 0.028	0.178 ± 0.027	0.064 ± 0.013	0.243 ± 0.019	2
083446	4.306 ± 0.017	0.279 ± 0.011	0.627 ± 0.013	0.798 ± 0.011	0.477 ± 0.011	0.175 ± 0.010	0.090 ± 0.010	0.227 ± 0.012	2
083944	4.458 ± 0.013	0.171 ± 0.012	0.515 ± 0.023	0.652 ± 0.011	0.233 ± 0.011	0.104 ± 0.014	0.047 ± 0.009	0.105 ± 0.008	2
085622	4.768 ± 0.058	0.856 ± 0.026	0.688 ± 0.028	0.989 ± 0.048	1.468 ± 0.044	0.525 ± 0.041	0.329 ± 0.030	0.729 ± 0.049	2
088206	4.803 ± 0.012	0.179 ± 0.010	0.325 ± 0.014	0.255 ± 0.011	0.125 ± 0.010	0.117 ± 0.012	0.038 ± 0.007	0.140 ± 0.009	4
096566	4.639 ± 0.016	0.770 ± 0.008	0.605 ± 0.031	0.948 ± 0.013	1.289 ± 0.012	0.458 ± 0.017	0.302 ± 0.009	0.721 ± 0.010	2
098718	3.848 ± 0.013	0.138 ± 0.013	0.311 ± 0.025	0.349 ± 0.014	0.133 ± 0.013	0.087 ± 0.016	0.032 ± 0.012	0.084 ± 0.008	2
101431	4.658 ± 0.012	0.180 ± 0.012	0.655 ± 0.023	0.639 ± 0.011	0.198 ± 0.010	0.107 ± 0.014	0.054 ± 0.008	0.129 ± 0.009	2
102776	4.266 ± 0.013	0.137 ± 0.013	0.291 ± 0.024	0.307 ± 0.012	0.127 ± 0.012	0.092 ± 0.015	0.027 ± 0.010	0.145 ± 0.009	2
102964	4.513 ± 0.017	0.932 ± 0.008	0.700 ± 0.034	1.247 ± 0.015	1.709 ± 0.014	0.523 ± 0.019	0.402 ± 0.009	0.870 ± 0.011	2
105211	4.146 ± 0.014	0.399 ± 0.011	0.574 ± 0.025	0.646 ± 0.012	0.548 ± 0.011	0.244 ± 0.016	0.140 ± 0.011	0.375 ± 0.010	2
105452	4.012 ± 0.016	0.355 ± 0.013	0.501 ± 0.014	0.667 ± 0.012	0.535 ± 0.013	0.285 ± 0.016	0.063 ± 0.017	0.378 ± 0.014	2
105937	3.922 ± 0.012	0.132 ± 0.013	0.282 ± 0.025	0.342 ± 0.014	0.138 ± 0.012	0.075 ± 0.016	0.039 ± 0.011	0.076 ± 0.008	2
107079	5.053 ± 0.018	1.121 ± 0.008	0.831 ± 0.041	1.461 ± 0.018	2.118 ± 0.016	0.569 ± 0.020	0.548 ± 0.009	1.086 ± 0.012	2
108483	3.916 ± 0.014	0.116 ± 0.016	0.208 ± 0.027	0.239 ± 0.016	0.083 ± 0.015	0.073 ± 0.018	0.025 ± 0.014	0.062 ± 0.013	2
111968	4.269 ± 0.019	0.289 ± 0.013	0.603 ± 0.024	0.815 ± 0.020	0.448 ± 0.012	0.158 ± 0.014	0.162 ± 0.031	0.283 ± 0.011	2
113703	4.664 ± 0.012	0.140 ± 0.012	0.299 ± 0.023	0.376 ± 0.012	0.146 ± 0.011	0.083 ± 0.013	0.041 ± 0.008	0.090 ± 0.009	2
114435	5.690 ± 0.035	0.534 ± 0.010	0.650 ± 0.022	0.685 ± 0.028	0.728 ± 0.019	0.339 ± 0.012	0.184 ± 0.013	0.476 ± 0.028	2
120955	4.569 ± 0.159	0.156 ± 0.036	0.365 ± 0.032	0.415 ± 0.043	0.120 ± 0.061	0.117 ± 0.039	0.055 ± 0.022	0.100 ± 0.037	1
121263	2.347 ± 0.157	0.107 ± 0.044	0.153 ± 0.078	0.177 ± 0.074	0.056 ± 0.075	0.081 ± 0.062	0.042 ± 0.048	0.045 ± 0.039	1
123139	2.095 ± 0.020	0.765 ± 0.018	0.588 ± 0.031	0.978 ± 0.016	1.298 ± 0.019	0.442 ± 0.042	0.319 ± 0.040	0.747 ± 0.022	2
124780	6.567 ± 0.024	0.333 ± 0.012	0.563 ± 0.011	0.725 ± 0.013	0.509 ± 0.012	0.216 ± 0.011	0.118 ± 0.012	0.338 ± 0.015	2
133955	3.750 ± 0.134	0.110 ± 0.022	0.320 ± 0.082	0.363 ± 0.060	0.076 ± 0.049	0.125 ± 0.037	0.028 ± 0.019	0.062 ± 0.031	1
136422	3.619 ± 0.246	1.067 ± 0.022	0.823 ± 0.051	1.404 ± 0.068	1.964 ± 0.098	0.560 ± 0.060	0.524 ± 0.034	1.013 ± 0.058	1
143118(∞)	3.341 ± 0.036	0.126 ± 0.020	0.190 ± 0.028	0.129 ± 0.036	0.032 ± 0.030	0.101 ± 0.029	0.012 ± 0.018	0.091 ± 0.019	2
143474(∞)	4.680 ± 0.013	0.306 ± 0.011	0.615 ± 0.024	0.759 ± 0.011	0.478 ± 0.010	0.205 ± 0.014	0.095 ± 0.009	0.298 ± 0.010	2
144470	3.946 ± 0.007	0.224 ± 0.007	0.140 ± 0.009	0.184 ± 0.009	0.158 ± 0.010	0.154 ± 0.009	0.063 ± 0.009	0.175 ± 0.008	5
146836	5.416 ± 0.035	0.505 ± 0.010	0.576 ± 0.021	0.611 ± 0.028	0.658 ± 0.018	0.324 ± 0.011	0.176 ± 0.013	0.461 ± 0.027	2
147513	5.380 ± 0.004	0.562 ± 0.002	0.462 ± 0.003	0.609 ± 0.003	0.823 ± 0.002	0.340 ± 0.003	0.218 ± 0.002	0.557 ± 0.003	47
149447	4.244 ± 0.160	1.087 ± 0.011	0.855 ± 0.048	1.436 ± 0.055	2.079 ± 0.061	0.551 ± 0.040	0.535 ± 0.019	1.059 ± 0.038	2
150898	5.444 ± 0.041	0.211 ± 0.007	0.153 ± 0.011	0.092 ± 0.013	0.102 ± 0.015	0.161 ± 0.010	0.066 ± 0.005	0.170 ± 0.010	14

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Table E.6 continued from previous page

HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
152980	4.165 ± 0.058	0.992 ± 0.009	0.717 ± 0.028	1.412 ± 0.050	1.973 ± 0.041	0.521 ± 0.039	0.477 ± 0.017	0.945 ± 0.028	2
156277	4.859 ± 0.051	0.859 ± 0.007	0.631 ± 0.025	1.186 ± 0.040	1.594 ± 0.033	0.482 ± 0.029	0.379 ± 0.013	0.824 ± 0.022	3
157244	2.940 ± 0.060	1.040 ± 0.012	0.715 ± 0.027	1.275 ± 0.051	1.890 ± 0.043	0.603 ± 0.043	0.443 ± 0.024	0.882 ± 0.031	2
157246	3.283 ± 0.160	0.182 ± 0.037	0.143 ± 0.046	0.088 ± 0.051	0.080 ± 0.065	0.119 ± 0.046	0.052 ± 0.030	0.129 ± 0.038	1
158926	1.597 ± 0.026	0.107 ± 0.042	0.192 ± 0.112	0.168 ± 0.096	0.119 ± 0.074	-0.001 ± 0.079	0.104 ± 0.072	0.058 ± 0.027	2
158427	2.834 ± 0.013	0.148 ± 0.014	0.164 ± 0.029	0.215 ± 0.026	0.130 ± 0.022	0.090 ± 0.024	0.052 ± 0.021	0.339 ± 0.011	3
159217	4.755 ± 0.017	0.198 ± 0.015	0.722 ± 0.014	0.691 ± 0.016	0.215 ± 0.017	0.125 ± 0.015	0.070 ± 0.011	0.177 ± 0.012	2
159433	4.343 ± 0.017	0.792 ± 0.009	0.593 ± 0.034	1.011 ± 0.016	1.363 ± 0.013	0.449 ± 0.020	0.346 ± 0.013	0.781 ± 0.012	2
159532	1.866 ± 0.021	0.420 ± 0.026	0.880 ± 0.031	0.752 ± 0.030	0.611 ± 0.033	0.229 ± 0.057	0.192 ± 0.054	0.447 ± 0.023	2
160032	4.753 ± 0.041	0.455 ± 0.012	0.520 ± 0.019	0.566 ± 0.035	0.570 ± 0.030	0.290 ± 0.028	0.159 ± 0.013	0.437 ± 0.021	2
160635	3.671 ± 0.016	0.844 ± 0.008	0.648 ± 0.032	1.111 ± 0.014	1.534 ± 0.013	0.511 ± 0.019	0.340 ± 0.012	0.799 ± 0.011	2
161912	4.811 ± 0.014	0.403 ± 0.010	1.169 ± 0.026	0.715 ± 0.012	0.371 ± 0.010	0.252 ± 0.014	0.151 ± 0.008	0.377 ± 0.010	2
169767	4.170 ± 0.048	0.756 ± 0.007	0.570 ± 0.022	0.974 ± 0.037	1.291 ± 0.031	0.440 ± 0.027	0.316 ± 0.012	0.739 ± 0.021	3
170465(†)	4.816 ± 0.103	0.135 ± 0.018	0.436 ± 0.030	0.510 ± 0.035	0.141 ± 0.038	0.102 ± 0.026	0.040 ± 0.013	0.119 ± 0.024	2
184127	4.971 ± 0.137	0.806 ± 0.010	0.650 ± 0.040	1.034 ± 0.047	1.403 ± 0.052	0.467 ± 0.034	0.327 ± 0.016	0.754 ± 0.032	2
189103	4.362 ± 0.158	0.148 ± 0.036	0.259 ± 0.033	0.316 ± 0.043	0.132 ± 0.061	0.084 ± 0.040	0.040 ± 0.022	0.119 ± 0.037	1
190248	3.550 ± 0.162	0.605 ± 0.013	0.484 ± 0.098	0.823 ± 0.072	0.991 ± 0.059	0.342 ± 0.044	0.258 ± 0.023	0.611 ± 0.037	1
190421	5.096 ± 0.219	1.158 ± 0.014	0.747 ± 0.137	1.387 ± 0.100	2.137 ± 0.081	0.605 ± 0.057	0.531 ± 0.024	1.078 ± 0.050	1
195627	4.752 ± 0.110	0.353 ± 0.014	0.604 ± 0.032	0.721 ± 0.037	0.517 ± 0.041	0.211 ± 0.028	0.133 ± 0.015	0.334 ± 0.025	2
196171	3.284 ± 0.204	0.740 ± 0.023	0.609 ± 0.042	0.912 ± 0.058	1.245 ± 0.083	0.414 ± 0.054	0.307 ± 0.033	0.743 ± 0.048	1
199951	4.641 ± 0.077	0.693 ± 0.009	0.580 ± 0.028	0.833 ± 0.041	1.107 ± 0.040	0.413 ± 0.023	0.274 ± 0.016	0.667 ± 0.016	2
202627	4.587 ± 0.066	0.202 ± 0.014	0.583 ± 0.023	0.829 ± 0.032	0.345 ± 0.031	0.120 ± 0.018	0.072 ± 0.013	0.142 ± 0.015	2
203608	4.280 ± 0.117	0.489 ± 0.012	0.471 ± 0.034	0.515 ± 0.039	0.619 ± 0.043	0.302 ± 0.030	0.173 ± 0.015	0.505 ± 0.027	2
206742	4.413 ± 0.159	0.172 ± 0.036	0.546 ± 0.034	0.759 ± 0.043	0.269 ± 0.062	0.083 ± 0.043	0.058 ± 0.026	0.139 ± 0.037	1
208450	4.316 ± 0.078	0.331 ± 0.019	0.645 ± 0.024	0.773 ± 0.039	0.517 ± 0.042	0.189 ± 0.023	0.144 ± 0.022	0.305 ± 0.018	1
209100	4.709 ± 0.087	0.723 ± 0.011	0.466 ± 0.030	1.055 ± 0.050	1.444 ± 0.052	0.280 ± 0.026	0.445 ± 0.025	0.847 ± 0.018	1
211088	4.937 ± 0.125	0.630 ± 0.013	0.594 ± 0.036	0.815 ± 0.042	1.004 ± 0.047	0.371 ± 0.033	0.243 ± 0.019	0.671 ± 0.029	2
211416	3.054 ± 0.151	0.979 ± 0.012	0.710 ± 0.045	1.247 ± 0.052	1.848 ± 0.058	0.499 ± 0.041	0.457 ± 0.024	0.943 ± 0.036	2
212581(∞)	4.651 ± 0.083	0.121 ± 0.044	0.506 ± 0.041	0.707 ± 0.055	0.221 ± 0.053	0.078 ± 0.037	0.044 ± 0.040	0.226 ± 0.045	1
213009	4.150 ± 0.084	0.899 ± 0.008	0.805 ± 0.029	1.090 ± 0.038	1.501 ± 0.041	0.609 ± 0.025	0.335 ± 0.015	1.031 ± 0.018	3
213398	4.371 ± 0.160	0.196 ± 0.034	0.593 ± 0.032	0.830 ± 0.043	0.325 ± 0.062	0.112 ± 0.040	0.052 ± 0.022	0.143 ± 0.037	1

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Table E.6 continued from previous page									
HD #	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
215369	5.041 ± 0.219	0.859 ± 0.017	0.722 ± 0.045	1.058 ± 0.060	1.449 ± 0.086	0.474 ± 0.052	0.363 ± 0.028	0.849 ± 0.051	1
217364	4.178 ± 0.080	0.738 ± 0.009	0.593 ± 0.024	0.911 ± 0.037	1.207 ± 0.044	0.438 ± 0.024	0.292 ± 0.019	0.727 ± 0.017	2
217792	5.171 ± 0.044	0.363 ± 0.023	0.531 ± 0.014	0.659 ± 0.015	0.505 ± 0.010	0.241 ± 0.019	0.116 ± 0.015	0.362 ± 0.008	4
218670	3.997 ± 0.175	0.755 ± 0.011	0.580 ± 0.107	0.977 ± 0.078	1.317 ± 0.064	0.440 ± 0.046	0.298 ± 0.021	0.720 ± 0.040	1
219571	3.997 ± 0.065	0.431 ± 0.010	0.565 ± 0.020	0.620 ± 0.028	0.577 ± 0.031	0.261 ± 0.019	0.159 ± 0.013	0.422 ± 0.015	3
219784	4.574 ± 0.138	0.816 ± 0.009	0.637 ± 0.041	1.081 ± 0.047	1.448 ± 0.052	0.454 ± 0.035	0.338 ± 0.017	0.788 ± 0.032	2
221507	4.464 ± 0.158	0.152 ± 0.036	0.428 ± 0.032	0.565 ± 0.043	0.213 ± 0.061	0.086 ± 0.039	0.031 ± 0.022	0.136 ± 0.037	1
221760	4.812 ± 0.161	0.224 ± 0.033	0.679 ± 0.033	0.847 ± 0.043	0.392 ± 0.062	0.128 ± 0.040	0.063 ± 0.022	0.229 ± 0.037	1
224392	4.980 ± 0.070	0.190 ± 0.019	0.567 ± 0.019	0.839 ± 0.028	0.363 ± 0.034	0.104 ± 0.019	0.068 ± 0.015	0.121 ± 0.015	2
224686	4.465 ± 0.070	0.155 ± 0.020	0.590 ± 0.019	0.609 ± 0.028	0.181 ± 0.033	0.077 ± 0.019	0.055 ± 0.016	0.114 ± 0.015	2

Table E.7: The mean reduced observations for the unsuccessful E Region standard stars.

star	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
E2_008	8.084 ± 0.098	0.320 ± 0.220	0.635 ± 0.073	0.661 ± 0.061	0.433 ± 0.224	0.234 ± 0.073	0.079 ± 0.060	0.422 ± 0.029	1
E2_014	8.295 ± 0.100	0.362 ± 0.215	0.565 ± 0.076	0.542 ± 0.062	0.530 ± 0.235	0.266 ± 0.078	0.094 ± 0.065	0.509 ± 0.034	1
E2_015	8.616 ± 0.103	0.400 ± 0.211	0.505 ± 0.077	0.510 ± 0.063	0.502 ± 0.245	0.278 ± 0.081	0.125 ± 0.069	0.529 ± 0.043	1
E2_052	7.504 ± 0.097	0.174 ± 0.239	0.696 ± 0.065	0.856 ± 0.060	0.260 ± 0.197	0.129 ± 0.064	0.020 ± 0.053	0.281 ± 0.027	1
E3_002	8.456 ± 0.098	0.062 ± 0.254	0.485 ± 0.063	0.667 ± 0.060	-0.022 ± 0.186	0.063 ± 0.061	-0.040 ± 0.051	0.163 ± 0.029	1
E3_005	8.060 ± 0.023	0.233 ± 0.016	0.532 ± 0.020	0.831 ± 0.009	0.424 ± 0.008	0.148 ± 0.009	0.088 ± 0.011	0.193 ± 0.014	3
E3_006	8.306 ± 0.097	0.182 ± 0.238	0.622 ± 0.068	0.849 ± 0.062	0.288 ± 0.198	0.134 ± 0.064	0.024 ± 0.054	0.264 ± 0.031	1
E3_007	8.554 ± 0.098	0.095 ± 0.249	0.574 ± 0.064	0.882 ± 0.060	0.089 ± 0.188	0.087 ± 0.061	-0.027 ± 0.051	0.162 ± 0.040	1
E3_018	8.707 ± 0.098	0.266 ± 0.227	0.655 ± 0.073	0.724 ± 0.065	0.320 ± 0.213	0.208 ± 0.069	0.044 ± 0.059	0.363 ± 0.040	1
E3_020	8.352 ± 0.099	0.345 ± 0.217	0.604 ± 0.075	0.569 ± 0.063	0.427 ± 0.230	0.257 ± 0.075	0.084 ± 0.062	0.452 ± 0.038	1
E3_036(∞)	6.481 ± 0.033	1.097 ± 0.006	0.738 ± 0.047	1.379 ± 0.028	2.035 ± 0.016	0.563 ± 0.014	0.544 ± 0.011	1.037 ± 0.008	3
E3_037	7.128 ± 0.036	0.821 ± 0.011	0.538 ± 0.029	1.000 ± 0.017	1.337 ± 0.011	0.486 ± 0.013	0.339 ± 0.013	0.764 ± 0.017	2
E3_041	8.634 ± 0.037	0.849 ± 0.013	0.615 ± 0.042	1.101 ± 0.025	1.453 ± 0.015	0.489 ± 0.015	0.364 ± 0.014	0.791 ± 0.019	2
E3_050	6.696 ± 0.028	0.092 ± 0.011	0.279 ± 0.040	0.404 ± 0.023	0.173 ± 0.012	0.074 ± 0.013	0.021 ± 0.010	0.094 ± 0.009	3
E3_051	6.822 ± 0.022	0.143 ± 0.016	0.470 ± 0.023	0.648 ± 0.009	0.229 ± 0.008	0.090 ± 0.010	0.062 ± 0.009	0.119 ± 0.014	2
E3_052	6.203 ± 0.022	0.164 ± 0.015	0.505 ± 0.022	0.768 ± 0.009	0.305 ± 0.007	0.105 ± 0.009	0.069 ± 0.009	0.119 ± 0.013	2
E3_072	10.671 ± 0.046	1.002 ± 0.020	0.348 ± 0.362	1.365 ± 0.254	1.712 ± 0.030	0.409 ± 0.027	0.596 ± 0.031	1.028 ± 0.038	2
E3_087(∞)	5.015 ± 0.019	0.754 ± 0.006	0.570 ± 0.031	0.933 ± 0.011	1.245 ± 0.009	0.465 ± 0.008	0.295 ± 0.007	0.699 ± 0.008	4
E3_089	7.437 ± 0.099	0.024 ± 0.259	0.247 ± 0.061	0.342 ± 0.060	-0.104 ± 0.185	0.040 ± 0.060	-0.061 ± 0.050	0.173 ± 0.026	1
E4_030(∞)	7.198 ± 0.025	0.824 ± 0.007	0.671 ± 0.041	1.003 ± 0.015	1.363 ± 0.011	0.493 ± 0.009	0.334 ± 0.009	0.782 ± 0.024	2
E4_040(∞)	5.603 ± 0.029	0.099 ± 0.011	0.303 ± 0.052	0.424 ± 0.025	0.183 ± 0.013	0.069 ± 0.013	0.036 ± 0.010	0.124 ± 0.010	2
E6_078(v)	4.589 ± 0.012	0.123 ± 0.017	0.213 ± 0.012	0.203 ± 0.012	0.128 ± 0.012	0.088 ± 0.012	0.039 ± 0.009	0.083 ± 0.008	2
E6_092(∞)	5.658 ± 0.015	0.182 ± 0.018	0.484 ± 0.030	0.595 ± 0.014	0.218 ± 0.009	0.122 ± 0.014	0.065 ± 0.010	0.142 ± 0.013	2
E6_101	7.965 ± 0.010	1.114 ± 0.006	0.813 ± 0.039	1.430 ± 0.027	2.083 ± 0.011	0.564 ± 0.010	0.538 ± 0.008	1.072 ± 0.008	4
E7_061	3.180 ± 0.148	0.423 ± 0.017	0.678 ± 0.090	0.711 ± 0.066	0.589 ± 0.054	0.282 ± 0.043	0.158 ± 0.025	0.415 ± 0.035	1
E8_026	6.575 ± 0.015	0.698 ± 0.011	0.578 ± 0.014	0.839 ± 0.008	1.101 ± 0.007	0.426 ± 0.012	0.272 ± 0.010	0.655 ± 0.010	2
E8_028	6.596 ± 0.017	0.898 ± 0.010	0.636 ± 0.021	1.151 ± 0.012	1.565 ± 0.008	0.503 ± 0.014	0.393 ± 0.010	0.831 ± 0.010	2
E8_029	6.969 ± 0.016	0.774 ± 0.011	0.597 ± 0.018	0.974 ± 0.013	1.279 ± 0.008	0.457 ± 0.013	0.316 ± 0.010	0.718 ± 0.009	2
E8_030	6.990 ± 0.019	1.084 ± 0.010	0.769 ± 0.030	1.391 ± 0.018	2.034 ± 0.011	0.566 ± 0.016	0.516 ± 0.011	1.021 ± 0.011	2
E8_042	5.840 ± 0.012	0.352 ± 0.013	0.658 ± 0.011	0.748 ± 0.007	0.529 ± 0.007	0.217 ± 0.010	0.142 ± 0.008	0.313 ± 0.007	2

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Table E.7 continued from previous page

star	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
E8_045	5.625 ± 0.011	0.172 ± 0.015	0.558 ± 0.011	0.810 ± 0.008	0.313 ± 0.006	0.124 ± 0.009	0.058 ± 0.007	0.089 ± 0.007	2
E8_071(∞)	5.684 ± 0.012	0.290 ± 0.014	0.640 ± 0.011	0.794 ± 0.007	0.460 ± 0.006	0.184 ± 0.010	0.114 ± 0.008	0.235 ± 0.008	2
E9_025	7.131 ± 0.032	0.763 ± 0.014	0.584 ± 0.031	0.910 ± 0.018	1.208 ± 0.019	0.457 ± 0.015	0.299 ± 0.011	0.730 ± 0.021	1
E9_031	7.298 ± 0.037	1.059 ± 0.014	0.819 ± 0.053	1.348 ± 0.027	1.929 ± 0.024	0.540 ± 0.020	0.514 ± 0.011	1.013 ± 0.019	1
E9_074	4.064 ± 0.025	0.789 ± 0.010	0.604 ± 0.017	0.953 ± 0.014	1.288 ± 0.012	0.491 ± 0.014	0.298 ± 0.013	0.727 ± 0.013	2
E9_080(∞)	6.628 ± 0.018	0.354 ± 0.011	0.613 ± 0.015	0.731 ± 0.009	0.556 ± 0.011	0.213 ± 0.008	0.140 ± 0.007	0.345 ± 0.012	2

Table E.8: The mean reduced observations for the cluster O Vel.

star	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
001	3.621 ± 0.006	0.091 ± 0.005	0.235 ± 0.007	0.359 ± 0.007	0.109 ± 0.006	0.072 ± 0.007	0.027 ± 0.007	0.088 ± 0.004	13
002	4.858 ± 0.013	0.084 ± 0.007	0.194 ± 0.013	0.356 ± 0.009	0.133 ± 0.013	0.047 ± 0.008	0.033 ± 0.007	0.044 ± 0.008	2
003	5.206 ± 0.007	0.106 ± 0.005	0.249 ± 0.006	0.415 ± 0.005	0.158 ± 0.005	0.069 ± 0.005	0.039 ± 0.005	0.087 ± 0.004	11
004	5.501 ± 0.013	0.097 ± 0.007	0.248 ± 0.012	0.426 ± 0.008	0.149 ± 0.013	0.045 ± 0.007	0.048 ± 0.006	0.051 ± 0.008	2
005	5.545 ± 0.013	0.089 ± 0.007	0.254 ± 0.012	0.442 ± 0.008	0.169 ± 0.012	0.040 ± 0.007	0.045 ± 0.006	0.069 ± 0.008	2
006	5.579 ± 0.005	0.109 ± 0.003	0.317 ± 0.004	0.471 ± 0.004	0.153 ± 0.003	0.079 ± 0.003	0.029 ± 0.004	0.107 ± 0.003	28
007	6.470 ± 0.007	0.125 ± 0.006	0.397 ± 0.008	0.604 ± 0.006	0.189 ± 0.007	0.079 ± 0.006	0.041 ± 0.005	0.096 ± 0.006	6
008	7.683 ± 0.008	0.196 ± 0.006	0.563 ± 0.010	0.846 ± 0.007	0.373 ± 0.009	0.114 ± 0.006	0.077 ± 0.006	0.151 ± 0.008	4
009	7.074 ± 0.007	0.118 ± 0.005	0.322 ± 0.008	0.509 ± 0.006	0.167 ± 0.007	0.059 ± 0.005	0.053 ± 0.005	0.077 ± 0.007	6
010	7.258 ± 0.007	0.128 ± 0.005	0.481 ± 0.008	0.726 ± 0.006	0.278 ± 0.007	0.064 ± 0.005	0.061 ± 0.005	0.143 ± 0.006	6
011	7.298 ± 0.008	0.161 ± 0.008	0.491 ± 0.011	0.792 ± 0.009	0.289 ± 0.007	0.092 ± 0.010	0.064 ± 0.012	0.125 ± 0.010	4
012	7.344 ± 0.006	0.326 ± 0.005	0.579 ± 0.009	0.740 ± 0.007	0.495 ± 0.006	0.184 ± 0.004	0.137 ± 0.006	0.306 ± 0.007	9
013	7.402 ± 0.009	0.167 ± 0.010	0.511 ± 0.014	0.834 ± 0.013	0.316 ± 0.011	0.108 ± 0.015	0.058 ± 0.013	0.133 ± 0.014	2
014	7.561 ± 0.010	0.207 ± 0.010	0.536 ± 0.015	0.851 ± 0.013	0.369 ± 0.011	0.154 ± 0.016	0.052 ± 0.013	0.186 ± 0.015	2
015	7.585 ± 0.011	0.300 ± 0.010	0.524 ± 0.016	0.766 ± 0.014	0.506 ± 0.012	0.218 ± 0.016	0.081 ± 0.014	0.321 ± 0.018	2
016	7.682 ± 0.021	0.193 ± 0.015	0.505 ± 0.024	0.844 ± 0.019	0.364 ± 0.012	0.105 ± 0.013	0.102 ± 0.032	0.163 ± 0.014	2
017	7.773 ± 0.014	0.253 ± 0.009	0.591 ± 0.013	0.824 ± 0.012	0.482 ± 0.009	0.160 ± 0.009	0.099 ± 0.021	0.262 ± 0.009	4
018	7.819 ± 0.015	0.556 ± 0.008	0.412 ± 0.015	0.652 ± 0.014	0.876 ± 0.011	0.297 ± 0.009	0.260 ± 0.014	0.583 ± 0.011	4
020	7.943 ± 0.014	0.211 ± 0.010	0.349 ± 0.013	0.473 ± 0.011	0.227 ± 0.009	0.130 ± 0.009	0.083 ± 0.021	0.203 ± 0.009	4
021	8.155 ± 0.023	0.269 ± 0.019	0.606 ± 0.018	0.812 ± 0.013	0.472 ± 0.011	0.186 ± 0.014	0.082 ± 0.031	0.293 ± 0.017	2
023	8.523 ± 0.022	0.309 ± 0.016	0.545 ± 0.019	0.742 ± 0.018	0.524 ± 0.016	0.174 ± 0.018	0.152 ± 0.034	0.281 ± 0.014	2
024	8.619 ± 0.018	0.236 ± 0.014	0.611 ± 0.018	0.855 ± 0.014	0.434 ± 0.012	0.150 ± 0.012	0.092 ± 0.026	0.229 ± 0.014	3
025	8.668 ± 0.013	0.265 ± 0.009	0.551 ± 0.015	0.804 ± 0.013	0.491 ± 0.012	0.145 ± 0.008	0.117 ± 0.013	0.234 ± 0.010	4
027	8.745 ± 0.015	0.394 ± 0.010	0.489 ± 0.015	0.603 ± 0.012	0.555 ± 0.010	0.231 ± 0.008	0.163 ± 0.014	0.392 ± 0.012	4
028	8.884 ± 0.024	0.443 ± 0.020	0.461 ± 0.025	0.590 ± 0.022	0.639 ± 0.019	0.252 ± 0.019	0.201 ± 0.033	0.439 ± 0.018	2
029	9.029 ± 0.013	0.402 ± 0.010	0.486 ± 0.013	0.622 ± 0.010	0.584 ± 0.008	0.251 ± 0.009	0.151 ± 0.011	0.414 ± 0.012	6
030	9.243 ± 0.022	0.771 ± 0.016	0.603 ± 0.045	0.927 ± 0.037	1.257 ± 0.024	0.468 ± 0.021	0.299 ± 0.039	0.767 ± 0.016	2
032	9.407 ± 0.023	0.416 ± 0.020	0.470 ± 0.022	0.581 ± 0.019	0.627 ± 0.018	0.271 ± 0.017	0.146 ± 0.031	0.456 ± 0.018	2
033	9.663 ± 0.031	0.442 ± 0.027	0.443 ± 0.029	0.565 ± 0.023	0.652 ± 0.019	0.273 ± 0.019	0.179 ± 0.039	0.479 ± 0.027	2
034	9.516 ± 0.014	0.463 ± 0.012	0.394 ± 0.018	0.578 ± 0.014	0.638 ± 0.013	0.253 ± 0.012	0.206 ± 0.011	0.484 ± 0.012	4

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Table E.8 continued from previous page

star	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
035	9.592 ± 0.016	0.867 ± 0.012	0.426 ± 0.043	0.982 ± 0.029	1.422 ± 0.022	0.464 ± 0.015	0.408 ± 0.016	0.855 ± 0.013	6
036	9.890 ± 0.027	0.448 ± 0.021	0.436 ± 0.031	0.546 ± 0.028	0.640 ± 0.020	0.310 ± 0.016	0.142 ± 0.038	0.492 ± 0.024	2
037	9.974 ± 0.026	0.568 ± 0.018	0.310 ± 0.058	0.611 ± 0.046	0.852 ± 0.042	0.305 ± 0.019	0.260 ± 0.023	0.570 ± 0.026	2
038	10.196 ± 0.029	0.239 ± 0.030	0.693 ± 0.027	0.848 ± 0.019	0.390 ± 0.025	0.175 ± 0.024	0.054 ± 0.036	0.265 ± 0.036	2
040	10.265 ± 0.024	0.603 ± 0.020	0.414 ± 0.094	0.642 ± 0.061	0.864 ± 0.033	0.324 ± 0.021	0.280 ± 0.022	0.564 ± 0.034	2
041	10.653 ± 0.039	0.292 ± 0.036	0.381 ± 0.032	0.563 ± 0.028	0.331 ± 0.026	0.149 ± 0.022	0.141 ± 0.047	0.240 ± 0.060	2

Table E.9: The mean reduced observations for the cluster Kappa Crucis.

star	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
A	5.747 ± 0.003	0.481 ± 0.002	0.535 ± 0.002	0.378 ± 0.002	0.378 ± 0.002	0.306 ± 0.002	+0.166 ± 0.002	0.443 ± 0.002	58
B	5.965 ± 0.006	0.417 ± 0.004	0.343 ± 0.005	0.254 ± 0.004	0.310 ± 0.003	0.269 ± 0.004	+0.138 ± 0.003	0.368 ± 0.004	19
C	6.792 ± 0.005	0.420 ± 0.003	0.321 ± 0.004	0.256 ± 0.004	0.315 ± 0.003	0.276 ± 0.003	+0.139 ± 0.003	0.380 ± 0.004	20
D	7.480 ± 0.014	1.709 ± 0.006	0.931 ± 0.042	1.410 ± 0.029	2.311 ± 0.014	1.077 ± 0.010	+0.629 ± 0.007	1.467 ± 0.010	12
E	8.324 ± 0.010	0.368 ± 0.007	0.234 ± 0.008	0.231 ± 0.007	0.256 ± 0.006	0.235 ± 0.006	+0.119 ± 0.006	0.301 ± 0.009	10
F	9.009 ± 0.011	0.338 ± 0.008	0.229 ± 0.009	0.244 ± 0.010	0.248 ± 0.010	0.218 ± 0.009	+0.116 ± 0.008	0.258 ± 0.010	8
G	9.770 ± 0.012	0.347 ± 0.012	0.233 ± 0.010	0.225 ± 0.011	0.284 ± 0.012	0.214 ± 0.011	+0.113 ± 0.009	0.298 ± 0.013	6
H	9.874 ± 0.016	0.373 ± 0.011	0.289 ± 0.012	0.338 ± 0.013	0.299 ± 0.012	0.213 ± 0.012	+0.146 ± 0.011	0.391 ± 0.017	6
I	9.989 ± 0.023	0.416 ± 0.018	0.291 ± 0.014	0.284 ± 0.014	0.303 ± 0.020	0.250 ± 0.017	+0.151 ± 0.013	0.309 ± 0.020	4
J	10.952 ± 0.034	0.393 ± 0.034	0.317 ± 0.021	0.336 ± 0.024	0.320 ± 0.032	0.228 ± 0.025	+0.153 ± 0.026	0.288 ± 0.037	4
K	11.391 ± 0.029	0.400 ± 0.046	0.395 ± 0.040	0.504 ± 0.039	0.352 ± 0.044	0.248 ± 0.041	+0.137 ± 0.031	0.278 ± 0.067	4
L	11.854 ± 0.044	0.495 ± 0.046	0.438 ± 0.044	0.442 ± 0.038	0.383 ± 0.042	0.269 ± 0.034	+0.227 ± 0.039	0.260 ± 0.064	6
M	12.518 ± 0.069	0.272 ± 0.084	0.785 ± 0.276	0.595 ± 0.125	0.469 ± 0.087	0.272 ± 0.066	-0.021 ± 0.076	0.495 ± 0.148	2
104	10.989 ± 0.067	1.172 ± 0.038	0.518 ± 0.377	0.788 ± 0.244	1.613 ± 0.127	0.708 ± 0.046	+0.456 ± 0.045	1.058 ± 0.084	1
105	8.663 ± 0.007	0.375 ± 0.005	0.231 ± 0.007	0.209 ± 0.006	0.255 ± 0.005	0.239 ± 0.005	+0.121 ± 0.004	0.296 ± 0.007	15
106	6.914 ± 0.007	0.414 ± 0.005	0.270 ± 0.006	0.216 ± 0.005	0.288 ± 0.004	0.271 ± 0.005	+0.128 ± 0.004	0.338 ± 0.005	12
107	11.304 ± 0.021	0.368 ± 0.045	0.348 ± 0.060	0.469 ± 0.040	0.429 ± 0.046	0.233 ± 0.045	+0.115 ± 0.020	0.315 ± 0.083	2
108	11.760 ± 0.030	0.402 ± 0.074	0.449 ± 0.100	0.510 ± 0.054	0.457 ± 0.077	0.207 ± 0.074	+0.182 ± 0.035	0.297 ± 0.108	2
113	10.113 ± 0.027	0.349 ± 0.022	0.284 ± 0.020	0.287 ± 0.016	0.305 ± 0.014	0.198 ± 0.012	+0.146 ± 0.022	0.256 ± 0.036	2
115	10.235 ± 0.021	0.370 ± 0.022	0.254 ± 0.025	0.327 ± 0.024	0.269 ± 0.020	0.229 ± 0.019	+0.118 ± 0.021	0.277 ± 0.036	2
117	10.837 ± 0.037	0.373 ± 0.035	0.328 ± 0.035	0.341 ± 0.027	0.305 ± 0.021	0.211 ± 0.018	+0.155 ± 0.036	0.280 ± 0.058	2
137	12.535 ± 0.121	0.527 ± 0.135	0.434 ± 0.092	0.442 ± 0.078	0.311 ± 0.098	0.290 ± 0.086	+0.226 ± 0.125	0.222 ± 0.192	4
138	11.057 ± 0.060	0.416 ± 0.051	0.361 ± 0.033	0.391 ± 0.037	0.312 ± 0.042	0.286 ± 0.033	+0.126 ± 0.050	0.345 ± 0.069	2
139	11.641 ± 0.038	0.370 ± 0.046	0.453 ± 0.040	0.424 ± 0.037	0.360 ± 0.042	0.265 ± 0.041	+0.097 ± 0.042	0.311 ± 0.062	4
201	9.593 ± 0.039	0.313 ± 0.026	0.089 ± 0.098	0.208 ± 0.037	0.251 ± 0.019	0.192 ± 0.023	+0.118 ± 0.022	0.281 ± 0.057	1
202	9.906 ± 0.027	0.371 ± 0.017	0.298 ± 0.017	0.286 ± 0.015	0.310 ± 0.016	0.224 ± 0.015	+0.140 ± 0.016	0.249 ± 0.029	3
203	10.270 ± 0.037	0.321 ± 0.026	0.260 ± 0.028	0.264 ± 0.020	0.250 ± 0.020	0.208 ± 0.022	+0.110 ± 0.019	0.261 ± 0.078	1
207	12.064 ± 0.070	0.451 ± 0.086	0.428 ± 0.082	0.451 ± 0.122	0.312 ± 0.134	0.282 ± 0.091	+0.158 ± 0.061	0.426 ± 0.148	2
215	11.613 ± 0.036	0.371 ± 0.061	0.346 ± 0.042	0.442 ± 0.045	0.345 ± 0.052	0.231 ± 0.035	+0.133 ± 0.039	0.291 ± 0.060	2
216	12.341 ± 0.069	0.424 ± 0.074	0.526 ± 0.073	0.428 ± 0.079	0.402 ± 0.073	0.275 ± 0.043	+0.156 ± 0.077	0.359 ± 0.103	2

continued on next page

Table E.9 continued from previous page

star	V	Y-V	U-P	P-X	X-Y	Y-Z	Z-V	V-S	#
218	12.268 ± 0.126	0.446 ± 0.135	0.412 ± 0.076	0.441 ± 0.058	0.345 ± 0.068	0.187 ± 0.061	+0.215 ± 0.127	0.164 ± 0.300	2
223	7.969 ± 0.007	0.386 ± 0.003	0.257 ± 0.005	0.227 ± 0.004	0.287 ± 0.004	0.261 ± 0.004	+0.122 ± 0.004	0.344 ± 0.005	13
224	10.202 ± 0.010	0.419 ± 0.010	0.257 ± 0.010	0.277 ± 0.009	0.288 ± 0.006	0.247 ± 0.007	+0.161 ± 0.010	0.371 ± 0.018	13
228	10.990 ± 0.036	0.402 ± 0.037	0.314 ± 0.024	0.348 ± 0.020	0.294 ± 0.021	0.234 ± 0.022	+0.158 ± 0.036	0.243 ± 0.081	2
305	8.231 ± 0.033	0.396 ± 0.012	0.259 ± 0.021	0.233 ± 0.026	0.269 ± 0.018	0.265 ± 0.012	+0.122 ± 0.014	0.265 ± 0.026	2
306	10.047 ± 0.017	0.405 ± 0.015	0.221 ± 0.015	0.201 ± 0.015	0.320 ± 0.014	0.253 ± 0.016	+0.148 ± 0.015	0.689 ± 0.019	2
311	10.766 ± 0.025	0.337 ± 0.026	0.332 ± 0.025	0.403 ± 0.025	0.288 ± 0.021	0.238 ± 0.024	+0.096 ± 0.027	0.324 ± 0.040	2
405	10.093 ± 0.016	0.266 ± 0.017	0.230 ± 0.017	0.279 ± 0.017	0.229 ± 0.017	0.168 ± 0.017	+0.084 ± 0.014	0.275 ± 0.042	2
410	10.642 ± 0.031	0.426 ± 0.030	0.381 ± 0.029	0.407 ± 0.026	0.340 ± 0.023	0.238 ± 0.023	+0.182 ± 0.028	0.237 ± 0.052	2
414	9.981 ± 0.015	0.366 ± 0.013	0.297 ± 0.013	0.306 ± 0.012	0.299 ± 0.013	0.228 ± 0.012	+0.123 ± 0.010	0.265 ± 0.016	4
417	9.790 ± 0.017	0.421 ± 0.018	0.198 ± 0.012	0.187 ± 0.012	0.300 ± 0.015	0.276 ± 0.017	+0.133 ± 0.014	0.646 ± 0.022	2
418	9.660 ± 0.015	0.357 ± 0.010	0.252 ± 0.009	0.257 ± 0.009	0.279 ± 0.009	0.228 ± 0.010	+0.123 ± 0.011	0.280 ± 0.018	4

Appendix F

Derivation of Nikonov's Method to determine Instantaneous Extinction.

This appendix shows how the method devised by Nikonov (1953) to allow the monochromatic extinction to be measured at any time is derived. The observational technique and reduction algorithm are described in Section 2.6.

Consider an approximate apparent magnitude of the extinction star ($\tilde{m}_{o,extn}$), which can be derived from a least squares fit of the extinction star's magnitudes verses airmasses. This differs from the exact apparent magnitude ($m_{o,extn}$) by a small amount $\delta_{o,extn}$, *ie.*

$$\tilde{m}_{o,extn} = m_{o,extn} - \delta_{o,extn}. \quad (F.1)$$

The extinction star has been chosen so it has no colour dependent term in the extinction correction, *ie.* $m_o = m - k'X$, so an approximate extinction coefficient ($\tilde{k}'$) can be calculated from

$$\tilde{k}' = \frac{m_{extn} - \tilde{m}_{o,extn}}{X_{extn}}. \quad (F.2)$$

After substitution of equation F.1, this becomes

$$\begin{aligned} \tilde{k}' &= \frac{m_{extn} - (m_{o,extn} - \delta_{o,extn})}{X_{extn}} \\ &= \frac{m_{extn} - m_{o,extn}}{X_{extn}} + \frac{\delta_{o,extn}}{X_{extn}} \\ &= k' + \frac{\delta_{o,extn}}{X_{extn}} \end{aligned} \quad (F.3)$$

where k' is the exact extinction coefficient.

Applying the approximate extinction coefficient to a control star measured simultaneously with the extinction star gives

$$\tilde{m}_{o,cntl} = m_{cntl} - \tilde{k}'X_{cntl}. \quad (F.4)$$

Substituting $\tilde{k}'$ from equation F.3 produces

$$\begin{aligned}
 \tilde{m}_{o,cntl} &= m_{cntl} - \left(k' + \frac{\delta_{o,extn}}{X_{extn}} \right) X_{cntl} \\
 &= (m_{cntl} - k' X_{cntl}) - \delta_{o,extn} \frac{X_{cntl}}{X_{extn}} \\
 &= m_{o,cntl} - \delta_{o,extn} \frac{X_{cntl}}{X_{extn}}.
 \end{aligned} \tag{F.5}$$

This requires a minimum of two observations to solve. The first observation is usually made when the extinction star is cumulating, the second when the control star is cumulating. Denoting the observations by the subscripts 1 and 2 ;

$$\begin{aligned}
 \tilde{m}_{o,cntl_1} &= m_{o,cntl} - \delta_{o,extn} \frac{X_{cntl_1}}{X_{extn_1}} \\
 \tilde{m}_{o,cntl_2} &= m_{o,cntl} - \delta_{o,extn} \frac{X_{cntl_2}}{X_{extn_2}}.
 \end{aligned}$$

Subtracting the second observation from the first yields

$$\tilde{m}_{o,cntl_1} - \tilde{m}_{o,cntl_2} = -\delta_{o,extn} \left(\frac{X_{cntl_1}}{X_{extn_1}} - \frac{X_{cntl_2}}{X_{extn_2}} \right). \tag{F.6}$$

Rearranging and substituting for the approximate apparent magnitudes of the control star gives

$$\delta_{o,extn} = \frac{(m_{cntl_1} - \tilde{k}'_1 X_{cntl_1}) - (m_{cntl_2} - \tilde{k}'_2 X_{cntl_2})}{(X_{cntl_1}/X_{extn_1} - X_{cntl_2}/X_{extn_2})}, \tag{F.7}$$

where the approximate extinction coefficients ($\tilde{k}'_1, \tilde{k}'_2$) are calculated from

$$\tilde{k}'_i = \frac{m_{extn_i} - \tilde{m}_{o,extn}}{X_{extn_i}} \quad (i = 1, 2). \tag{F.8}$$

Alternately, if N observations (more than two) of the extinction and control star have been made, a linear least squares fit may be done to calculate $\delta_{o,extn}$. Here the independent and dependent variables (x_i, y_i) are X_{cntl_i}/X_{extn_i} and $\tilde{m}_{o,cntl_i}$, the intercept is $m_{o,cntl}$ and slope is $\delta_{o,extn}$.

Appendix G

Long term changes in extinction and the effect of Mount Pinatubo.

Short term variations of extinction (i.e. on an hourly scale) have already been discussed in Chapter 2. Longer term variations will now be investigated, motivated by the possibility of using averaged extinction coefficients for any nights that have badly determined, or completely unknown, coefficients.

G.1 Correlations between nights.

The following form of auto-correlation was used (Sterken & Manfroid 1992b)

$$\alpha_{\lambda}(\delta n) = \langle |k'_{\lambda}(n + \delta n) - k'_{\lambda}(n)| \rangle \quad (\text{G.1})$$

where $k'_{\lambda}(n)$ is the monochromatic extinction (averaged for each night from the hourly measurements of Nikonov's method) for the Julian Date 'n' and $k'_{\lambda}(n + \delta n)$ is the extinction δn days later. Plots of α versus δn for each filter all have similar shapes, so, in an attempt to reduce the 'noise', α was averaged across all the filters for each δn — see the top diagram in Figure G.1. This shows a monotonically increasing difference in the extinction between observations made δn nights apart, until $\delta n \sim 5$ days. However the apparently good correlations for $\delta n \geq 5$ are not reliable as they are based on a small frequency of observations (that have been made δn days apart), as shown by the lower diagram in Figure G.1. This is also shown in the top diagram by the error bars, which were calculated as $(0.02 + 0.02)/\text{frequency}(\delta n)$, where 0.02 is the standard deviation of the extinction coefficients averaged over all nights.

Therefore, it was concluded that a running average (from $\frac{1}{2}\delta n$ nights before and after the night in question) is only useful if the standard deviation of the extinction coefficient (from that night) exceeds 0.03 and this large uncertainty is due to a lack of suitable extinction star measurements rather than poor photometric quality of the night.

auto-correlation of extinction at Mt. John from 1988–93

auto-correlation of extinction at Mt. John from 1988–93

Figure G.1: Auto-correlation of extinction at MJUO that were measured δn nights apart. The top diagram shows the auto-correlation averaged across the filters while the bottom diagram shows the frequency of observations (that were separated by δn nights).

G.2 The effect of the Mount Pinatubo eruption.

Another possibility is that the mean extinction (averaged over all observations, or perhaps on a seasonal basis) could be used for nights with uncertain extinction. To investigate this, a plot of the extinction coefficient (averaged for each night from the hourly measurements as before) versus the Julian Date was examined for each filter. The extinction from the different filters again closely resembled each other, so k'_V was taken as being typical. As the effective wavelengths of the Vilnius and Johnson V filters are nearly the same, it might be possible to increase the data set by combining the V extinction from other observers using a Johnson system at MJUO.

There were three other such systems in use during the period concerned (late 1987 to early 1994); The first system is a Johnson V filter on either the B&C or the O/C telescopes, with the extinction (Gilmore & Kilmartin 1994) derived from a Bouguer plot using the programs of Hendon & Kaitchuck (1989).

The second system is a Johnson filter set on the M^cLellan one metre telescope using a Thomson CCD with a Photometrics control system (Tobin 1991). The extinction was calculated (Banks 1995) from observations of standard stars over a wide range of airmass, simultaneously fitting the standardisation transformation and extinction coefficients as described by Harris et al. (1981) and implemented in Image Reduction and Analysis Facility (IRAF)(Tody 1986).

The final system is a two channel photomultiplier instrument on the one metre telescope using a Johnson V filter (Sullivan 1989). The extinction data (Sullivan 1994) were derived from custom written software based on a Bouguer plot.

The extinction values found by the different systems were compared for common nights and agree within 0.03 *mags/airmass*. As another check, the average extinction values (before and after the Mount Pinatubo eruption) of each system were calculated and again all found to agree within 0.03 *mags/airmass*. This is sufficiently small compared to the long term variations in extinction that the different systems may be combined with the Vilnius system with reasonable accuracy.

The atmospheric extinction in the various V passbands measured at MJUO from late 1987 to early 1994 is shown in Figure G.2, with the solid line being a running average (smoothed over three data points before and after the current data point). The effect of the 15 June 1991 Mount Pinatubo eruption can clearly be seen, with the dashed lines representing the average extinction before and after the eruption. Both the mean extinction level and the scatter about the mean have increased, and some observers had also noted a 'ripple' pattern of haze was frequently visible during sunset and sunrise (for example this author and Banks (1994) at MJUO). The increase in average V extinction (0.09 *mags/airmass*) is similar to that found at La Silla (0.078 *mags/airmass*), SAAO (0.06 *mags/airmass*) and Kitt Peak

Figure G.2: The effect of the Mount Pinatubo eruption on extinction at MJUO. The V extinction coefficients from various photometric systems at MJUO are combined to increase the data set. The solid line is a running average and the dotted lines are the Pre- and Post-Pinatubo mean extinction levels.

(0.08 mags/airmass)(Grothues & Gochermann 1992) — see Table H.2 for the other mean Vilnius extinction coefficients and changes.

It took approximately 80 days for the aerosol cloud to reach New Zealand (Wadsworth & Cole 1994), with the extinction starting to increase around JD 2448500, and reaching an initial maximum about 1 October 1991 (JD 2448530). As of June 1994, the extinction has not yet returned to pre-eruption levels. Further, the night-to-night variations hide any exponential decay back towards the Mount Pinatubo pre-eruption levels, as also found at La Silla (Grothues & Gochermann 1992).

The data were also investigated for seasonal effects, as there appeared to be an increase in the extinction every July since the eruption. A sinusoid was fitted (Rufener 1986) separately to the Pre-Pinatubo data, the Post-Pinatubo data and the combined data (after adjusting the Post-Pinatubo data to the same mean level as the Pre-Pinatubo data) but none were found to be statistically more significant than a single (mean) extinction value. Hence the night-to-night variations in extinction are greater than any seasonal changes, emphasizing that extinction should be determined for each night rather than using monthly averages.

Appendix H

The Rayleigh, Ozone and Aerosol Extinction Coefficients.

H.1 Introduction.

The total atmospheric extinction is usually considered to be comprised of three different sources of extinction; scattering off molecules (Rayleigh scattering), scattering off particles of dust or droplets of any size (aerosol scattering) and absorption by molecules (van de Hulst 1981, Hayes & Latham 1975). In the optical region, the main molecular absorption bands are weak Ozone bands (the Huggins band from 320–340 nm and the weaker Chappius band centred at 575 nm) (Sterken & Manfroid 1992b) and some water absorption bands at 710, 809, 970 and 1080 nm (Hayes & Latham 1975). The water absorption is highly variable and, at a good observatory site, usually very weak and can be ignored on most nights. This is particularly true for the Vilnius filter set, as can be seen in Figure 2.12. Therefore the total extinction can be written as

$$k_{total} = k_{Rayleigh} + k_{aerosol} + k_{ozone} \quad (H.1)$$

where the prime (indicating primary extinction) has been dropped.

Determining the total extinction coefficients at the seven different wavelengths of the Vilnius system opens the possibility of deriving these individual components and following their evolution on various time scales (hourly if determined by Nikonov's (1953) method or daily if determined by Bouguer's method (Hardie 1962)).

H.2 Rayleigh.

The Rayleigh scattering can, in principle, be calculated at Standard Temperature and Pressure (STP) from the following formula (Hayes & Latham 1975)

$$k_{Rayleigh_{STP}} = 9.4977 \times 10^{-3} e^{-\left(\frac{h}{7.996}\right)} \left[\frac{(n-1)_{\lambda}}{(n-1)_{\lambda=1}} \right]^2 \left(\frac{1}{\lambda} \right)^4 \quad (H.2)$$

with the wavelength λ in μm , which was adapted from Penndorf (1957). The formula has been normalised to $\lambda = 1 \mu m$, with n being the refractive index and the coefficient 9.4977×10^{-3} corresponding to the optical thickness of the atmosphere at $\lambda = 1 \mu m$. This is adjusted for the height h (in km) of the observatory above sea-level with the density scale-height for the lower troposphere assumed to be $7.996 km$.

The normalised index of refraction term is given by

$$\frac{(n-1)_\lambda}{(n-1)_{\lambda=1}} = 0.23465 + \frac{1.076 \times 10^2}{146 - (\frac{1}{\lambda})^2} + \frac{0.93161}{41 - (\frac{1}{\lambda})^2}. \quad (H.3)$$

The Rayleigh scattering can be scaled from STP (Penndorf 1957; King & Byrne 1976) using

$$k_{\text{Rayleigh}} = k_{\text{Rayleigh,STP}} \left(\frac{P_{\text{STP}}}{P} \right) \left(\frac{T}{T_{\text{STP}}} \right) \quad (H.4)$$

where T, P are the actual temperature and pressure during the observations, and T_{STP} and P_{STP} are $273.15 K$ and $760 mm Hg (= 1 atm)$ respectively.

H.3 Ozone.

The Ozone extinction can be calculated from

$$k_{\text{Ozone}} = 1.11 \alpha_{\text{O}_3} R_{\text{O}_3}(\lambda) \quad (H.5)$$

where R_{O_3} is the total ozone content (*atmos*) of the atmosphere in a vertical column of $1 cm^2$ cross section, $\alpha_{\text{O}_3}(\lambda)$ is the ozone absorption coefficient (cm^{-1}), taken from the tables of Gost (1960), and 1.11 corresponds to the optical thickness of ozone at $3200 \text{ \AA}$ (Huges & Latham 1975). Note that the ozone is concentrated between 10 and 35 km and so is independent of a ground based observatory's height.

It has been found that the daily variation in ozone content is approximately the same as the seasonal variation (King & Byrne 1976) so the tables of mean ozone content for season and latitude from Allen (1963) should only be used for seasonal means, not daily values.

H.4 Aerosol.

The aerosol extinction's wavelength dependence is primarily due to the size distribution of aerosol particles (King & Byrne 1976). By modeling the aerosols as homogeneous spheres with radius r and complex refractive index n , it has been shown that Mie theory (van de Hulst

1981, King et al. 1978) gives

$$k_{aerosol} = \int_0^{\infty} \pi r^2 Q_{ext}(r, \lambda, n) N_c(r) dr \quad (H.6)$$

where Q_{ext} is the extinction efficiency factor from Mie theory and N_c is the aerosol number density in a vertical column (cross-section 1 cm^2) in the radius interval $r \rightarrow r + dr$.

Equation H.6 can be inverted to obtain N_c , as was done by King et al. (1978) for observations of fifty-seven days in Tucson. Figure H.1 shows schematically the (log-log) size distributions and corresponding $k_{aerosol}$ 'spectrum' for the three different classes found.

The first class is approximately a linear Junge (1963) size distribution and was found for $\sim 30\%$ of the observations. This can be characterized in a $k_{aerosol}$ diagram by a straight line (occasionally with a slight curvature) with a large negative slope ($\alpha \sim +1.5$, see below).

A Junge size distribution is a power-law

$$N_c(r) = cr^{-(\nu^*-1)} \quad (H.7)$$

for $r = 0 \rightarrow \infty$, giving

$$k_{aerosol} = \beta \lambda^{-\nu^*+2} \quad (H.8)$$

which is the empirical formula found by Ångström (1929)

$$k_{aerosol} = \beta \lambda^{-\alpha} \quad (H.9)$$

with $\alpha = \nu^* - 2$. Assuming the size distribution can be characterized by particles with just one (effective) radius r_e , then the parameter α is related to this radius (Gutiérrez-Moreno et al. 1982); $\alpha \sim 1 \Rightarrow r_e \sim \lambda$, $\alpha \gtrsim 2 \Rightarrow r_e < \lambda$, and $\alpha < 1 \Rightarrow r_e \gg \lambda$. This empirical formula (equation H.9) has been used in many aerosol extinction studies, for example Hayes & Latham (1975), Gutiérrez-Moreno et al. (1982), Rufener (1986), Reimann et al. (1992), and Sterken & Manfroid (1992b). Correction of the unrealistic assumption of infinite spread in radius or slight deviations from the Junge distribution leads to a slight curvature in the $k_{aerosol}$ plot, adding a quadratic term (King & Byrne 1976)

$$\log(k_{aerosol}) = \log(\beta) - \alpha \log(\lambda) + \gamma [\log(\lambda)]^2. \quad (H.10)$$

The second class is an approximately Gaussian size distribution, which was found for $\sim 30\%$ of King's observations. In the $k_{aerosol}$ diagram it is characterized by an line with some curvature and a positive slope, giving a negative α .

The third class is actually a combination of the two previous size distributions and is char-

Figure H.1: The three different aerosol size distributions and their corresponding extinction spectrum.

acterized by a small α . It was the most common distribution, being found for $\sim 50\%$ of the observations. This two component distribution is thought to arise from two aerosol production mechanisms (King et al. 1978), namely

- a) nucleation from a gas phase and later coagulation, predominately with $r \lesssim 0.5 \mu m$
- b) particles created by mechanical or wind stress from the Earth's surface, predominately with $r \gtrsim 1 \mu m$.

Thus even when Ångström's empirical formula (equation H.9) is not an appropriate model for the aerosol size distribution, the sign and magnitude of the parameter α appears to indicate the type of distribution (Junge, Gaussian or combination).

H.5 Fitting procedures.

The Rayleigh extinction coefficients at STP were calculated using equations H.2 and H.3 and convolved with the response functions of the standard Vilnius system (see Table 1.3) to produce the effective extinction coefficients of each filter, given in Table H.1.

Similarly, the absorption coefficients of ozone were taken from Gast (1960) and convolved with the response functions of the standard Vilnius system to produce the effective absorption coefficients (cm^{-1}) of each filter. For comparison with the Rayleigh coefficients, the ozone absorption coefficients were then converted to mean extinction coefficients using

Table H.1: Effective Rayleigh and Ozone extinction coefficients for the standard Vilnius photometric system.

filter	λ_0 (μm)	Rayleigh extinction	Ozone absorption	Ozone extinction
U	0.345	0.661	6.7×10^{-2}	2.0×10^{-2}
P	0.374	0.464	2.5×10^{-4}	7.4×10^{-5}
X	0.405	0.333	5.4×10^{-5}	1.6×10^{-5}
Y	0.466	0.186	3.9×10^{-3}	1.2×10^{-3}
Z	0.516	0.122	1.9×10^{-2}	5.6×10^{-3}
V	0.544	0.099	3.3×10^{-2}	9.8×10^{-3}
S	0.656	0.047	2.7×10^{-2}	8.0×10^{-3}

equation H.5 and the total ozone (averaged over a year) at latitude $40^\circ S$ from Allen (1963).

The aerosol extinction coefficients (equation H.9) were calculated at the effective wavelength (λ_0) of each filter as the wavelength dependence in the optical region was found to be nearly flat — also, it would have been very difficult to calculate the effective extinction as it depends on α , one of the parameters we wish to fit.

On 13 April 1992, the monochromatic extinction was determined approximately hourly using Nikonov's method. The extinction on this night showed a gradual, linear, decrease. Fitting the extinction components may allow Young's (1974) explanation that such decreases in extinction are due to a slow fallout of aerosols (when the solar driven convection which stirs up the aerosols

Figure H.2: Behaviour of the Rayleigh extinction during 13 April 1992.

ceases) to be checked. Hence, the extinction was fitted as a trial using a Levenberg-Marquardt non-linear least squares subroutine (Press et al. 1992) on

$$k_{total} = a_1 k_{Rayleigh_{STP}} + a_2 k_{ozone_{mean}} + a_3 \lambda^{-a_4} \quad (H.11)$$

where a_1 measures the fractional change from STP and a_2 measures the fractional change from the mean ozone content.

H.6 Results.

The total extinction was fitted for each extinction star measurement with all four parameters free. The Rayleigh component (a_1) shows a gradual increase during the night (see Figure H.2) while the other parameters have such large scatter that no trends can be seen. This large scatter is due to strong correlations between the parameters (especially the Rayleigh component which is essentially proportional to λ^{-4} and the aerosol component, which is proportional to $\lambda^{-\alpha}$), which makes the fits very sensitive to measurement errors.

To try to reduce this scatter, a straight line was fitted to the Rayleigh coefficients and a_1 was fixed at the appropriate value from this line for each measurement during the night, while the remaining three parameters were refitted. This succeeded in reducing the scatter sufficiently that trends could be seen in all the coefficients, which will be tentatively interpreted next.

Figure H.3: Behaviour of the ozone extinction during 13 April 1992.

At the beginning of the night, the Rayleigh coefficient was

$$a_1 = \frac{T_{STP}}{T} \frac{P}{P_{STP}} \approx 0.96.$$

Assuming $P = P_{STP}$, this implies the air temperature $T \approx 11^\circ C$, which shows good agreement with the recorded dome temperature of $12^\circ C$. A similar calculation for the end of the night gives $T \approx -10^\circ C$. However the dome (interior) temperature showed no significant change from $12^\circ C$ (i.e. within $\pm 1^\circ$) during the night. The insulating properties of the dome walls and roof together with the heat generated by the electronics and telescope & dome motors would tend to hold the dome interior at a higher temperature than the outside air. Thus it seems more likely that the air temperature did decrease during the night, to $0^\circ C$ say, and the air pressure also increased slightly.

The ozone content shows a decreasing trend until $\sim 8-9^h$ UT, an increase until $\sim 15^h$ UT, when it decreased again (see Figure H.3). As astronomical twilight ended and began at $\sim 7^h$ UT and 17^h UT respectively at sealevel on 13 April 1992 (*The Astronomical Almanac* 1992), and the ozone layer is ~ 21 km above sealevel (Allen 1963), a simple calculation shows that the twilight for the ozone layer ended/began at $\sim 8^h/16^h$ UT. Thus, it seems likely that the decrease in ozone content is due to the Sun's ultraviolet light breaking up the ozone during the day and the increase is the layer reforming during the night.

The negative values for the ozone coefficients around 9^h UT are not realistic. As the ozone

is the weakest component of the total extinction (in the wavelength region measured), slightly too large values in the other components would have a significant effect on the derived ozone content, forcing it too far down.

To reduce this problem, another filter would be needed to measure a wavelength region with stronger ozone absorption. The 6000 Å region is ruled out, as the H₂O absorption band is of approximately equal size to the ozone absorption there. This only leaves a region at ~ 3000 Å. The Rayleigh extinction is also large at that wavelength, but fortunately it can be accurately predicted from measurements of the air temperature and pressure. A blue star (i.e. O or B stars) would probably be needed as the extinction star to get a good signal at these wavelengths.

The aerosol content (a_3 , see Figure H.4) shows an overall decrease during the night, with slight increases at the beginning of the night and between 12–14^h UT. These increases seem to be correlated with a slight breeze present at those times. However the aerosol size distribution parameter (a_4 , see Figure H.5) shows a slight rise until $\sim 11^h$ UT, then a decrease for the rest of the night. The small, positive value of a_4 at the beginning of the night indicates a mixture of Junge and Gaussian particle size distributions. The increasingly negative value after 11^h UT indicates the distribution is becoming more Gaussian as the night progresses, i.e. there are less small sized particles. It is possible that these small particles (which are caused by nucleation from a gas phase) coalesce together, forming larger particles while decreasing the total number of particles (and hence reducing a_3). Hence, the results are consistent with Young's contention that the decrease in extinction is due to a decreasing number of aerosols during the night, but indicates a different mechanism is removing these particles.

The rapid changes in the extinction components (i.e. on a time scale of hours) means fitting the components to the average extinction coefficients for a night would only be valid for nights with constant extinction. However, over a long enough time scale (i.e. months or years), the average extinction might be accurately fitted by the average amount of the components. To test this, the mean extinction coefficients for all photometric nights were fitted — see Figure H.6.

It was necessary to split the data into two sets; before and after the aerosols from the Mount Pinatubo eruption arrived at MJUO — see Table H.2. As the aerosols ejected into the stratosphere may also deplete the ozone layer (Stowe et al. 1992), it was necessary to fit the ozone and aerosol components to both data sets. However, the Rayleigh component was not expected to be changed by the eruption so the value derived in the Pre-Pinatubo fit was used (as a fixed parameter) in the Post-Pinatubo fit. The results are given in Table H.3, where χ^2 is the chi squared goodness-of-fit parameter.

From Allen (1963), the mean temperature (at sea-level) for latitude -45° is $\sim 8^\circ\text{C}$ while

Figure H.4: Behaviour of the aerosol extinction during 13 April 1992.

Figure H.5: Behaviour of the aerosol size distribution parameter during 13 April 1992.

Figure H.6: The mean extinction at MJUO fitted with Rayleigh, Ozone and aerosol components. The extinction has been divided into two groups; before and after the Mount Pinatubo eruption.

Table H.2: The mean Vilnius extinction coefficients at MJUO — before, after, and the changes due to, the Mount Pinatubo eruption. All uncertainties are between 0.02 – 0.03.

date (Pinatubo)	monochromatic extinction coefficients						
	U	P	X	Y	Z	V	S
Pre- (Jun 88 - May 91)	0.65	0.47	0.33	0.19	0.14	0.13	0.07
Post- (Nov 91 - Jul 93)	0.78	0.59	0.45	0.30	0.24	0.22	0.16
Δ Pinatubo	0.13	0.12	0.12	0.11	0.12	0.09	0.09

the mean air pressure at $h = 1$ km is 899 mb (at sea-level, $P_{STP} = 1013$ mb), so

$$a_1 \approx \frac{8 + 273.15}{273.15} \frac{899}{1013} \approx 0.91$$

which agrees (within the uncertainties) with the derived value. The ozone content is approximately halved following the eruption, but in view of the large uncertainties in the coefficients, this decrease may not be real but a result of correlations in the fitting procedure. The aerosol content has increased by a factor of four, with the particle size distribution becoming more Gaussian (from the Pre-Pinatubo Junge and Gaussian mixture). The aerosol extinction spectrum looks nearly flat (i.e. grey — see Δ Pinatubo in Table H.3), as was also found by Gutiérrez-Moreno et al. (1982), Sterken & Manfroid (1992b) and Grothues & Gochermann (1992).

Table H.3: The fitted Rayleigh, Ozone and aerosol coefficients to the mean extinction.

date (Pinatubo)	Rayleigh	Ozone	aerosol		χ^2
	a_1	a_2	a_3	a_4	
Pre-	0.93 ± 0.19	0.76 ± 2.3	0.022 ± 0.087	0.0077 ± 7.4	0.55
Post-	0.93 (fixed)	0.38 ± 1.5	0.086 ± 0.030	0.57 ± 0.39	0.24

H.7 Conclusions.

The extinction data from the Vilnius filter set can be used to derive the contributions from the Rayleigh, ozone and aerosol components. However the major component, Rayleigh scattering, should be predicted (from equation H.2 and measuring the air temperature and pressure) rather than fitted, to reduce the large uncertainties due to the correlations between the parameters. The rapid changes in all three components mean Nikonov’s method (or other similar method) must be used to measure the extinction hourly — only a night with constant extinction may be fitted from the night’s average extinction. The Mount Pinatubo eruption significantly reduced the ozone content and increased the aerosol content (in the stratosphere).

Appendix I

Formulation of the Vilnius Filters using Schott glasses.

Here the possibility of using Schott glasses to make a Vilnius filter set was investigated,¹ as an alternative to those produced by the Vilnius Observatory. The transmittance response curves were taken from the Schott catalog up to $\lambda = 10000 \text{ \AA}$, assuming the detector used does not response to longer wavelengths - this assumption must be checked as many Schott glasses show a second (and larger) red leak for $\lambda > 10000 \text{ \AA}$. Changes in transmittance due to differing thickness for any particular glass are calculated according to

$$R_{d_1}(\lambda) = [R_{d_2}(\lambda)]^{d_1/d_2} \quad (\text{I.1})$$

where R_{d_i} is the transmittance at λ for a glass thickness d_i .

It has been found that the transmittance curves in the catalog are only average values and may not be accurate for any particular sample of a glass (Young 1994). In particular, the long-pass glasses (for example WG, GG, OG, and RG glasses) typically vary by $60 \text{ \AA}$, which corresponds to approximately a factor of four in thickness. Similarly, the band-pass glasses (for example UG and BG) have typical errors corresponding to $\pm 10\%$ thickness variations. This effect can be seen in Figure I.1 where the catalog transmittance curve of BG39 is compared with a sample measured at VUW — the red side differs by $\sim 90 \text{ \AA}$ from the catalog value. This is a significant fraction of the FWHM of the Vilnius System filters (typically $250 \text{ \AA}$), hence orders to manufacturers should be specified by the required transmittance curves rather than the glass thickness and the glass combinations given here should be taken only as a guide.

Many different Schott glass combinations were investigated for each Vilnius filter, and initially compared visually from plots of the transmittance curves. To quantify the closer matches, the following formula was used

$$rating = \frac{|\Delta\lambda_{short} - \Delta\lambda_{long}| |\Delta\lambda_{peak}| (Red Leak\%)}{(R_{peak}\%)} \quad (\text{I.2})$$

¹ A prescription using Schott glasses has already been given by Kučinskas (1990) but four of the filters require glasses which are no longer available and the S filter used the detector as its long-wavelength cutoff.

Figure I.1: Comparison of Measured and Catalog responses of Schott glasses, here BG39 is shown spline fitted.

where $\Delta\lambda_{short}$, $\Delta\lambda_{long}$, and $\Delta\lambda_{peak}$ are the required shifts (in wavelength) of the half-maximum (of the short and long wavelength sides) and the peak transmittance to match the standard filter. The $R_{peak}\%$ is the maximum (peak) transmittance as a percentage and the $Red\ Leak\% = \frac{\text{peak transmittance of the red leak}}{\text{peak transmittance of the Schott filter}}$. Using this crude, but easy to calculate formula, the combination of glasses with the smallest rating gives the best match to the standard filter.

Young (1994) gives a more accurate formula for comparing filters

$$\cos(\phi) = \frac{\int R_A \cdot R_B d\lambda}{|R_A||R_B|} \quad (I.3)$$

where the transmittance of the filters are R_A and R_B , and the magnitude of a filter is

$$|R| = \sqrt{\int R^2 d\lambda}.$$

The angle ϕ measures the difference between the filters, $\phi = 0^\circ$ means the filters are identical (apart from a scaling factor in the transmittance) while $\phi = 90^\circ$ corresponds to completely non-overlapping filters.

This formula is derived by treating each filter as a vector in a multi-dimensional space and

Table I.1: The Vilnius Filter System from Schott glasses.

Filter	Schott glass combination	R_{peak} (%)	Rating	ϕ_{Schott} (degrees)	ϕ_{local} (degrees)
U	WG355(1mm)+UG11(7mm)	45	0.003	5.7	7.3
P	BG23(6mm)+UG1(2mm)	17	0.01	6.5	5.0
X	GG400(1mm)+BG3(9mm)+BG39(1mm)	53	0.9	18.8	2.8
Y	GG455(2mm)+BG3(1mm)+BG39(2mm)	42	0.01	6.6	9.5
Z	GG495(6mm)+BG18(9mm)	38	4.0	35.6	6.0
V	OG530(3mm)+BG39(12mm)	44	2.0	9.7	3.1
S	RG645(2mm)+BG40(2mm)	13	12.0	30.5	30.8

taking the dot product between the vectors. The components of each vector are

$$\tilde{R} = \{R(\lambda_1), R(\lambda_2), \dots, R(\lambda_N)\}$$

where N is the number of transmittance measurements made of the filter. To ensure each vector has measurements at the same wavelengths, the transmittance measurements are interpolated (using a cubic spline) to all the wavelengths measured in both filters.

The results are shown in Table I.1 and Figure I.2. The table also includes the angle between the Standard Vilnius filters (Straižys & Zdanavičius 1970) and the local Vilnius filter set (#1, as measured in 1990) for comparison.

The Schott U filter shows a slightly better agreement with the standard filter (as measured by ϕ) than does the local filter. The most significant difference between the Schott filter and the standard filter is a reduced blue response, which would be more strongly seen for early stars. However the atmospheric extinction is large at these wavelengths so the effect is expected to be small. Both glasses (WG335 and UG11) are sensitive to staining by weak acids (for example from finger-prints or breath) and need either a protective coating (the Schott catalog states a coating is available but gives no further details) or be sandwiched between other glasses with stronger resistance to weak acids and which will not change the transmittance curve, for example WG280. This extra glass can also be used to pad the filters out to a common optical depth, required for imaging detectors (such as CCD's) where all filters should have the same focal point, and optional for non-imaging detectors (such as PMT's) where this is a second order source of error.

The Schott P filter is a slightly worse match to the standard filter (as measured by ϕ) than the local filter. It also has a low peak transmittance, being approximately half that of the local P filter. Like the Schott U filter, it also needs protection against stains, with WG280 again being suitable.

No Schott glass combination could be found to give a good match to the standard X filter. The best combination has too strong a red response and a 'blue' leak. The 'blue' leak (at

Figure I.2: Realization of the Vilnius Photometric System using Schott glasses, with the curves drawn using a cubic spline. The Standard filter responses are in arbitrary units while the Schott glass combinations are a percentage of full transmittance. See following pages for the remaining filters.

Figure I.2 continued.

Figure I.2 continued.

$\sim 3650 \text{ \AA}$) arises from changing the thickness of the GG400 glass from 3 mm (as given in the catalog) to 1 mm, and is probably an artifact of the thickness scaling formula (equation I.1) and measuring uncertainties of the small transmittance in the cut-on of the glass's response. If it is a real leak, then it can be removed by adding 1 mm of GG375 glass. The BG39 glass is used to remove a red leak at $\sim 8000 \text{ \AA}$, and can be increased in thickness if any red leak remains. Both BG3 and BG39 are sensitive to staining and either GG375 or WG280 can be used to protect them.

The Schott Y filter is a better match to the standard filter than the local filter, with a large peak transmittance but a slightly longer effective wavelength. Again, the BG3 and BG39 glasses need protection.

The large difference on the red side between the Schott Z filter and the standard filter occurs as there are no short-pass glasses with a steep enough cut-off at the right wavelength. A more symmetric combination with nearly the right effective wavelength (GG495(1mm) + BG18(9mm)) was found but the blue side of the Schott filter would include an absorption line at $\sim 4850 \text{ \AA}$ (for normal, early stars) so this combination was rejected. The effect of the larger red side of the Schott filter can be estimated as (for normal stars at least) a stellar spectra is approximately straight between 5000–5800 $\text{\AA}$, with a slope proportional to Y–V. The BG18 glass requires protection against staining — use either the Schott protective coating or sandwich the BG18 glass between two GG495 glasses (3 mm thick each). The usual WG280 glass should not be used as the Schott Z filter already has a total thickness of 15 mm.

Figure I.2 continued.

Figure I.2 continued.

Figure I.2 continued.

The shape of the standard V filter is difficult to match with Schott glasses. However, for normal stars, the stellar spectra between 5000–6000 Å is approximately straight (whose slope can be estimated from Y–V), with larger absorption features in late stars. Fortunately the two largest absorption features occur at the blue and red tails of the filters and so are not expected to cause major transformation errors. The BG39 glass should be sandwiched between two OG530 glasses (each 1.5 mm thick) for stain protection — the WG280 glass can not be used as the Schott V filter already has a total thickness of 15 mm. The more stain resistant class of OG530 glass should be used. Either the Z or V filter would define the optical depth to which the other filters should be padded.

As the standard S filter is an interference filter with a narrow passband, it was not possible to duplicate it accurately using glass filters. The Schott filter and local filter show similar angles (ϕ) from the standard filters, however for the local (interference) filter this is due to its passband being shifted to a longer wavelength. Stellar spectra on the red side of the Schott filter imply that late stars will not transform well (using Y–V — another filter centred at 6700–6800 Å should provide the required information).

As only four of the Vilnius filters may be matched by Schott filters to an acceptable accuracy ($\phi < 10^\circ$), it was concluded that the filters provided by the Vilnius Observatory will, in general, give better transformations to the standard system. However, adding extra filters at wavelengths between the standard filters (to give Young's critical sampling at $\frac{1}{2}$ FWHM spacing (Young 1974, Young 1988, Young 1992a, Young 1992b)) may give better transformations in combination with

Figure I.2 continued.

Table I.2: Filters between the wavelengths of the Vilnius Filter System from Schott glasses.

Filter	Schott glass combination	R_{peak} (%)	λ_0 (Å)
U_{short}	WG320(2mm)+UG11(7mm)	49	3420
$U_{long}(=P_{short})$	WG345(2mm)+UG11(5mm)+BG39(1mm)	36	3570
$P_{long}(=X_{short})$	GG375(3mm)+UG1(1mm)+BG39(1mm)	43	3840
$X_{long}(=Y_{short})$	GG400†(1mm)+GG420(1mm)+BG3(3mm)+BG39(2mm)	52	4340
Y_{long}	GG455†(1mm)+GG475(1mm)+BG3(1mm)+BG39(2mm)	24	4760
$Z_{long}(=V_{short})$	OG515(3mm)+BG18(9mm)	31	5370
V_{long}	OG550(3mm)+BG18(4mm)+BG39(4mm)	20	5610
S_{short}	RG610†(1mm)+RG630(1mm)+BG40(2mm)	24	6420

either the Schott filters or the local filters. To investigate this, the ‘intermediate wavelength’ Schott filters were calculated from the Schott catalog response curves, with the results given in Table I.2 and in Figure I.3. The daggers (†) in the table mean the indicated glass was added to the combination to remove the ‘blue’ leak discussed earlier (arising from thinning long-pass glasses). Two filters (Z_{short} , S_{long}) are missing from the table as they could not be made using Schott glasses.

One way of investigating the usefulness of these extra filters is to add the corresponding short and long wavelength filters in a linear combination with the local filter (or the Schott glass version) to see if this improves the match to the standard filter. Using the angle ϕ , the linear combinations were found to be an improvement in approximately half the cases. This is a surprisingly good result, considering the extra filters were chosen to achieve $\frac{1}{2}$ FWHM spacing

Figure I.3: Comparison of intermediate Schott filters with the Vilnius System, normalised and spline fitted.

rather than give better matches to the standard filters via linear combinations.

Another way to evaluate the usefulness of the extra filters is to fit the transformations, in this case using synthesized magnitudes derived by convolving stellar spectra (Gunn & Stryker 1983) with the passbands. Even using transformations to only first order, for example,

$$V-V_0 = a_0 + a_1(V_{\text{short}}-V) + a_2(V-V_{\text{long}})$$

gives results with a precision better (or at least the same) as the usual transformations, for example,

$$V-V_0 = a_0 + a_1(Y-V)_0$$

and should give more accurate transformations for stars with unusual spectra.

The most important test is to make some actual observations of Vilnius standard stars using the existing local filters and the 'intermediate' filters. As up to ten extra filters would be required to achieve $\frac{1}{2}$ FWHM sampling for the Vilnius system, it is recommended that only two extra filters be made for the initial trial, for example, V_{short} and V_{long} . It is expected that a significant improvement could be made using only four extra filters; Y_{short} , Y_{long} , V_{short} and V_{long} , to give more accurate transformations to $(Y-V)_0$, which is then used to transform all the other magnitudes and colours (see equation 2.29).

Appendix J

Tables and Appendices from Straizys book.

Some of the tables from the literature (mainly from Straizys (1992)) have been reproduced in this appendix for the reader's convenience.

Table J.1: Ratio of extinction (in the UBV system for a B0 V star) to colour excess (in the Vilnius system), $R = A_V(B0\ V)/E_{Y-V}$. Taken from Straizys (1992, Table 74).

Sp	R	Sp	R
B0-B5 V-III	4.48	G5-K5 III	4.50
A0-A5 V-III	4.46	M0-M2 III	4.52
F0-G5 V-III	4.48	M3 III	4.54
K0 V	4.50	M4-M5 III	4.55
K3 V	4.48	B0-F5 I	4.48
K5-M0 V	4.44	F8-G0 I	4.50
M2-M4 V	4.48	G2-G8 I	4.52
M5 V	4.50	K2-K3 I	4.54
		M2 I	4.60

Table J.2: Vilnius colour excess ratios for the normal interstellar extinction law. Taken from Straizys (1992, Table 64).

Sp	$\frac{E_{U-Y}}{E_{Y-V}}$	$\frac{E_{P-Y}}{E_{Y-V}}$	$\frac{E_{X-Y}}{E_{Y-V}}$	$\frac{E_{Y-Z}}{E_{Y-V}}$	$\frac{E_{Y-S}}{E_{Y-V}}$
B0 V-III	1.62	1.14	0.76	0.64	1.84
B5 V-III	1.60	1.12	0.75	0.64	1.84
A0 V-III	1.58	1.09	0.73	0.64	1.84
A5 V-III	1.58	1.09	0.73	0.64	1.84
F0 V-III	1.58	1.11	0.74	0.64	1.84
F5 V-III	1.58	1.12	0.74	0.64	1.84
G0 V-III	1.58	1.14	0.73	0.64	1.84
G5 V	1.58	1.14	0.73	0.64	1.84
K0 V	1.58	1.15	0.72	0.64	1.84
K5 V	1.56	1.13	0.69	0.65	1.83
M0 V	1.55	1.12	0.69	0.65	1.83
M2 V	1.54	1.14	0.70	0.66	1.85
M5 V	1.55	1.15	0.72	0.66	1.87
G5 III	1.59	1.15	0.72	0.64	1.85
K0 III	1.57	1.15	0.71	0.64	1.85
K5 III	1.57	1.15	0.69	0.64	1.85
M0 III	1.56	1.15	0.68	0.65	1.85
M2 III	1.55	1.15	0.68	0.65	1.86
M4 III	1.53	1.15	0.71	0.65	1.89
M6 III	1.51	1.15	0.74	0.64	1.90
B0 I	1.62	1.14	0.75	0.64	1.84
B5 I	1.60	1.12	0.75	0.64	1.84
A0 I	1.59	1.11	0.75	0.64	1.84
A5 I	1.57	1.10	0.75	0.64	1.84
F0 I	1.57	1.08	0.74	0.64	1.84
F5 I	1.57	1.10	0.74	0.64	1.84
G0 I	1.57	1.14	0.73	0.64	1.84
G5 I	1.57	1.16	0.72	0.64	1.84
K0 I	1.57	1.17	0.71	0.64	1.85
K3 I	1.56	1.18	0.71	0.64	1.85
M2 I	1.57	1.17	0.71	0.65	1.88

Table J.3: Intrinsic Vilnius colours for the luminosity V and the ZAMS stars. The O6.5–B2 stars are taken from Sūdžius & Bobinas (1994), with the remainder from Straižys (1992, Table 66).

Sp	U-P		P-X		X-Y	Y-Z	Z-V	V-S
	ZAMS	V	ZAMS	V	V	V	V	V
O6.5		0.00		0.00	-0.02	-0.01	0.00	0.00
O7		0.00		0.00	-0.02	-0.01	0.00	0.00
O7.5		0.00		0.00	-0.02	0.00	0.00	0.00
O8		0.00		0.00	-0.02	0.00	0.00	0.00
O8.5		0.00		0.01	-0.01	0.00	0.00	0.00
O9		0.00		0.01	-0.01	0.01	0.00	0.00
O9.5		0.00		0.02	-0.01	0.01	0.00	0.01
B0		0.01		0.05	0.00	0.01	0.00	0.01
B0.5		0.04		0.07	0.02	0.02	0.00	0.01
B1		0.06		0.10	0.04	0.02	0.00	0.02
B1.5		0.09		0.15	0.05	0.03	0.01	0.02
B2		0.13		0.22	0.06	0.03	0.02	0.03
B0		0.01		0.04	0.02	0.00	0.00	0.00
B1	0.07	0.06	0.13	0.13	0.04	0.01	0.01	0.01
B2	0.11	0.15	0.23	0.23	0.06	0.02	0.02	0.03
B3	0.16	0.20	0.31	0.31	0.08	0.04	0.03	0.05
B5	0.24	0.29	0.40	0.40	0.14	0.06	0.04	0.08
B6	0.27	0.34	0.46	0.46	0.15	0.06	0.04	0.09
B7	0.34	0.43	0.54	0.52	0.17	0.06	0.04	0.10
B8	0.43	0.50	0.64	0.58	0.19	0.07	0.05	0.11
B9	0.48	0.57	0.71	0.67	0.23	0.08	0.06	0.12
A0	0.53	0.64	0.76	0.78	0.28	0.10	0.07	0.14
A1	0.55	0.66	0.78	0.82	0.32	0.11	0.08	0.15
A2	0.56	0.68	0.79	0.84	0.36	0.12	0.08	0.17
A3	0.57	0.68	0.79	0.84	0.39	0.14	0.08	0.19
A5	0.57	0.66	0.78	0.82	0.44	0.16	0.10	0.22
A7	0.56	0.62	0.74	0.77	0.48	0.17	0.10	0.27
F0	0.54	0.55	0.65	0.68	0.53	0.21	0.13	0.34
F2	0.52	0.52	0.61	0.62	0.57	0.25	0.15	0.40
F5	0.50	0.49	0.60	0.57	0.64	0.29	0.17	0.45
F8	0.48	0.47	0.62	0.58	0.72	0.32	0.19	0.50
G0	0.47	0.46	0.64	0.60	0.77	0.33	0.20	0.54
G2	0.46	0.46	0.65	0.63	0.82	0.34	0.22	0.56
G5	0.46	0.46	0.69	0.69	0.87	0.34	0.23	0.58
G8	0.46	0.46	0.77	0.75	0.96	0.34	0.27	0.62
K0	0.46	0.45	0.85	0.81	1.06	0.34	0.30	0.65
K1		0.44	0.91	0.87	1.12	0.33	0.32	0.68
K2		0.43	0.96	0.91	1.19	0.32	0.36	0.72
K3		0.42	1.03	0.97	1.30	0.30	0.40	0.77
K4		0.42	1.12	1.05	1.47	0.27	0.47	0.83
K5		0.45		1.10	1.61	0.25	0.53	0.91
K7		0.55		1.12	1.77	0.31	0.61	1.08
M0		0.56		1.12	1.74	0.31	0.61	1.10
M2		0.72		1.06	1.68	0.50	0.62	1.23

Table J.4: Intrinsic Vilnius colours for the luminosity IV stars. Taken from Straižys (1992, Table 67).

Sp	U-P	P-X	X-Y	Y-Z	Z-V	V-S
B0		0.02:	0.00	0.00	0.00	0.00
B1		0.11:	0.03	0.01	0.01	0.03
B2	0.15:	0.20:	0.07	0.02	0.02	0.04
B3	0.21:	0.29:	0.10	0.04	0.02	0.06
B5	0.32	0.41:	0.15	0.06	0.03	0.08
B6	0.37:	0.47:	0.17	0.07	0.04	0.10
B7	0.44:	0.52:	0.19	0.07	0.05	0.11
B8	0.50:	0.58:	0.21	0.08	0.05	0.12
B9	0.59:	0.67:	0.24	0.09	0.06	0.13
A0	0.65:	0.78:	0.27	0.10	0.06	0.14
A1	0.68:	0.82:	0.32	0.11	0.06	0.15
A2	0.68:	0.84:	0.36	0.12	0.07	0.17
A3	0.68:	0.85:	0.39	0.14	0.08	0.20
A5	0.67:	0.82	0.43	0.17	0.09	0.26
A7	0.65:	0.77	0.47	0.19	0.10	0.32
F0	0.62:	0.70	0.54	0.22	0.11	0.35
F2	0.57:	0.65	0.58	0.25	0.15	0.39
F5	0.53:	0.59	0.63	0.29	0.17	0.43
F8	0.50:	0.61	0.72	0.31	0.19	0.48
G0	0.48:	0.67	0.79	0.32	0.21	0.52
G2	0.47	0.71	0.86	0.33	0.22	0.55
G5	0.47	0.75	0.93	0.35	0.24	0.59
G8	0.49	0.81	1.05	0.38	0.27	0.64
K0	0.52	0.88	1.16	0.40	0.30	0.69
K1	0.57	1.10	1.40	0.41	0.36	0.74

Table J.5: Intrinsic Vilnius colours for the luminosity III stars. The O6.5–B2 stars are taken from Sūdžius & Bobinas (1994), with the remainder from Straizys (1992, Table 68).

Sp	U-P	P-X	X-Y	Y-Z	Z-V	V-S
O7	-0.01	+0.00	+0.00	+0.00	+0.00	+0.01
O7.5	+0.00	+0.00	+0.00	+0.00	+0.00	+0.01
O8	+0.00	+0.01	+0.00	+0.00	+0.00	+0.01
O8.5	+0.01	+0.02	+0.00	+0.01	+0.00	+0.01
O9	+0.01	+0.03	+0.01	+0.01	+0.00	+0.01
O9.5	+0.02	+0.04	+0.01	+0.01	+0.00	+0.01
B0	+0.03	+0.05	+0.02	+0.01	+0.00	+0.01
B0.5	+0.04	+0.06	+0.02	+0.02	+0.00	+0.01
B1	+0.07	+0.12	+0.03	+0.03	+0.00	+0.01
B1.5	+0.10	+0.14	+0.04	+0.04	+0.01	+0.02
B2	+0.12	+0.17	+0.06	+0.04	+0.02	+0.03
B0		+0.00	+0.00	+0.00	+0.00	+0.00
B1	+0.07	+0.09	+0.03	+0.01	+0.01	+0.02
B2	+0.15	+0.18	+0.07	+0.02	+0.03	+0.05
B3	+0.21	+0.27	+0.08	+0.03	+0.04	+0.07
B5	+0.35	+0.45	+0.14	+0.05	+0.04	+0.09
B6	+0.40	+0.47	+0.16	+0.06	+0.04	+0.11
B7	+0.44:	+0.50	+0.18	+0.07	+0.05	+0.12
B8	+0.50:	+0.54	+0.20	+0.08	+0.05	+0.13
B9	+0.60:	+0.64	+0.23	+0.09	+0.05	+0.14
A0	+0.67:	+0.75	+0.26	+0.10	+0.06	+0.15
A1	+0.70:	+0.82	+0.30	+0.11	+0.06	+0.16
A2	+0.71:	+0.84	+0.34	+0.12	+0.07	+0.18
A3	+0.71:	+0.85	+0.35	+0.13	+0.08	+0.20
A5	+0.71:	+0.82	+0.43	+0.15	+0.09	+0.22
A7	+0.71:	+0.81	+0.48	+0.19:	+0.10	+0.26
F0	+0.71:	+0.77	+0.54	+0.23:	+0.12	+0.37
F2	+0.70:	+0.73	+0.59	+0.25:	+0.15	+0.41
F5	+0.66:	+0.68	+0.65	+0.28:	+0.17	+0.47
F8	+0.61:	+0.65	+0.73	+0.32	+0.20	+0.53
G0	+0.58	+0.65	+0.86	+0.35	+0.22	+0.58
G2	+0.54	+0.69	+0.95	+0.38	+0.23	+0.61
G5	+0.53	+0.82	+1.08	+0.42	+0.25	+0.66
G8	+0.55	+0.92	+1.19	+0.45	+0.27	+0.69
K0	+0.57	+1.01	+1.30	+0.46	+0.31	+0.73
K1	+0.61	+1.10	+1.40	+0.47	+0.34	+0.77
K2	+0.63	+1.18	+1.53	+0.48	+0.37	+0.81
K3	+0.65	+1.27	+1.70	+0.50	+0.41	+0.87
K4	+0.71	+1.35	+1.90	+0.52	+0.47	+0.95
K5	+0.79	+1.38	+2.05	+0.54	+0.53	+1.00
M0	+0.81:	+1.42	+2.10	+0.57	+0.54	+1.06
M1	+0.84:	+1.43	+2.13	+0.59	+0.54	+1.10
M2	+0.87:	+1.42	+2.08	+0.62	+0.53	+1.14
M3	+0.93:	+1.38	+1.90:	+0.70:	+0.50	+1.20
M4	+1.00:	+1.34	+1.65:	+0.85:	+0.45	+1.27
M5	+1.10:	+1.35	+1.47:	+0.95:	+0.40	+1.36:
M6	+1.30:	+1.39	+0.96:	+1.15:	+0.35	+1.56:

Table J.6: Intrinsic Vilnius colours for the luminosity I stars. The O6.5–B2 stars are taken from Sūdžius & Bobinas (1994), with the remainder from Straižys (1992, Table 69).

Sp	U-P			P-X			X-Y	Y-Z	Z-V	V-S
	Ia	I	Ib	Ia	I	Ib	I	I	I	I
O7.5		+0.00			-0.03		-0.01	+0.02	+0.00	+0.03
O8		+0.01			-0.03		-0.01	+0.02	+0.00	+0.03
O8.5		+0.01			-0.03		+0.00	+0.02	+0.00	+0.03
O9		+0.01			-0.01		+0.01	+0.02	+0.00	+0.03
O9.5		+0.02			+0.01		+0.02	+0.02	+0.00	+0.03
B0		+0.03			+0.02		+0.03	+0.03	+0.00	+0.03
B0.5		+0.05			+0.03		+0.04	+0.04	+0.01	+0.05
B1		+0.08			+0.06		+0.06	+0.05	+0.02	+0.08
B1.5		+0.10			+0.08		+0.08	+0.06	+0.03	+0.09
B2		+0.11			+0.09		+0.09	+0.06	+0.03	+0.09
B0	+0.03:			+0.04:			+0.06	+0.04	+0.02	+0.06
B1	+0.06:			+0.06:			+0.08	+0.06	+0.03	+0.09
B2	+0.10:			+0.10:			+0.10	+0.08	+0.04	+0.11
B3	+0.17:			+0.13:			+0.12	+0.09	+0.05	+0.13
B5	+0.26:			+0.18:			+0.14	+0.10	+0.06	+0.14
B6	+0.31:			+0.22:			+0.16	+0.11	+0.06	+0.16
B7	+0.35:			+0.25:			+0.18	+0.12	+0.06	+0.17
B8	+0.40:			+0.28:			+0.19	+0.13	+0.07	+0.18
B9	+0.47:			+0.32:			+0.20	+0.13	+0.07	+0.19
A0	+0.56:			+0.38:			+0.20	+0.13	+0.07	+0.20
A1	+0.65:			+0.44:			+0.20	+0.14	+0.08	+0.22
A2	+0.75:			+0.50:			+0.22	+0.15	+0.08	+0.23
A3	+1.00:			+0.56:			+0.23	+0.15	+0.09	+0.23
A5	+1.12:			+0.64:			+0.26	+0.16	+0.09	+0.23
A7	+1.14:			+0.69:			+0.31	+0.17	+0.09	+0.25
F0	+1.15:			+0.73:			+0.36	+0.18	+0.10	+0.27
F2			+1.07			+0.80	+0.48	+0.20	+0.13	+0.33
F5			+0.92			+0.74	+0.64	+0.23	+0.16	+0.39
F8			+0.75			+0.74	+0.84	+0.32	+0.19	+0.50
G0			+0.68			+0.77	+1.00	+0.38	+0.22	+0.58
G2			+0.62			+0.82	+1.15	+0.44	+0.25	+0.65
G5			+0.63			+0.95	+1.37	+0.49	+0.29	+0.70
G8			+0.66:			+1.09:	+1.57:	+0.53	+0.33	+0.77
K0			+0.69:			+1.20:	+1.74:	+0.57	+0.39	+0.84
K1			+0.70:			+1.24:	+1.90:	+0.61	+0.43	+0.90
K2			+0.72:			+1.26:	+2.00:	+0.64	+0.47	+0.96
K3			+0.74:			+1.26:	+2.06:	+0.67	+0.50	+1.01
K4			+0.77:			+1.26:	+2.08:	+0.67	+0.50	+1.02
K5			+0.81:			+1.26:	+2.09:	+0.67	+0.51	+1.03
M0			+0.85:			+1.27:	+2.12:	+0.68	+0.51	+1.02
M1			+0.89:			+1.30:	+2.12:	+0.73	+0.50	+1.02
M2			+0.94:			+1.35:	+2.09:	+0.82	+0.48	+1.10
M3							+1.85:	+0.93	+0.44	+1.22
M4							+1.45:	+1.05:	+0.37	+1.35

Table J.7: Intrinsic color indices $(Y-V)_0$ as a function of Sp and M_V , Taken from Straižys (1992, Table 73).

M_V	-7	-6	-5	-4	-3	-2	-1
B1	0.08	0.08	0.06	0.03			
B2	0.105	0.11	0.10	0.08	0.045	0.03	
B3	0.14	0.14	0.13	0.11	0.08	0.07	
B4	0.16	0.16	0.15	0.13	0.105	0.09	0.09
B5	0.16	0.16	0.15	0.14	0.12	0.10	0.10
B6	0.18	0.18	0.17	0.155	0.13	0.11	0.10
B7	0.195	0.19	0.19	0.18	0.17	0.145	0.12
B8	0.20	0.20	0.20	0.195	0.18	0.16	0.13
B9	0.20	0.20	0.20	0.20	0.195	0.18	0.16
A0	0.20	0.20	0.20	0.20	0.20	0.19	0.18
A1	0.22	0.22	0.22	0.21	0.205	0.20	0.195
A2	0.23	0.23	0.23	0.225	0.22	0.215	0.21
A3	0.24	0.24	0.24	0.24	0.24	0.23	0.23
A4	0.245	0.24	0.245	0.245	0.245	0.24	0.24
A5	0.25	0.25	0.25	0.25	0.25	0.25	0.245
A6	0.25	0.25	0.25	0.25	0.25	0.25	0.25
A7	0.26	0.26	0.26	0.26	0.26	0.26	0.26
A8	0.26	0.26	0.26	0.26	0.26	0.26	0.27
A9	0.27	0.27	0.27	0.27	0.27	0.27	0.28
F0	0.28	0.28	0.28	0.28	0.28	0.28	0.295
F1			0.30	0.30	0.30	0.305	0.31
F2			0.33	0.33	0.33	0.335	0.34
F3			0.35	0.35	0.35	0.35	0.36
F4			0.36	0.36	0.36	0.365	0.375
F5			0.38	0.38	0.38	0.38	0.39
F6			0.41	0.41	0.41	0.41	0.41
F7			0.45	0.45	0.45	0.45	0.45
F8			0.485	0.49	0.49	0.49	0.49
F9			0.54	0.54	0.535	0.53	0.52
G0			0.60	0.59	0.585	0.57	0.55
G1			0.65	0.65	0.64	0.62	0.595
G2			0.70	0.69	0.68	0.665	0.64
G3			0.73	0.725	0.71	0.69	0.66
G4			0.76	0.75	0.73	0.71	0.68
G5			0.78	0.77	0.75	0.73	0.71
G6			0.80	0.795	0.78	0.75	0.73
G7			0.82	0.82	0.80	0.775	0.75
G8			0.86	0.85	0.83	0.81	0.78
G9			0.895	0.885	0.86	0.835	0.805
K0			0.96	0.95	0.91	0.875	0.84
K1			1.025	1.01	0.965	0.92	0.885
K2			1.11	1.095	1.04	0.99	0.945
K3			1.14	1.12	1.07	1.02	0.98
K4			1.16	1.15	1.12	1.08	1.04
K5			1.18	1.17	1.15	1.13	1.10

Table J.7 continued from previous page.

M _v	0	+1	+2	+3	+4	+5	+6	+7
B1								
B2								
B3								
B4								
B5								
B6								
B7	0.105							
B8	0.12							
B9	0.14	0.14						
A0	0.16	0.15						
A1	0.19	0.175						
A2	0.20	0.19	0.21					
A3	0.225	0.205	0.225					
A4	0.23	0.22	0.23					
A5	0.24	0.24	0.25					
A6	0.25	0.255	0.26	0.28				
A7	0.26	0.28	0.28	0.28				
A8	0.28	0.29	0.30	0.30				
A9	0.30	0.32	0.33	0.33				
F0	0.315	0.33	0.35	0.365				
F1	0.33	0.35	0.37	0.39 :				
F2	0.35	0.37	0.39	0.42				
F3	0.37	0.39	0.41	0.43				
F4	0.39	0.41	0.43	0.44	0.45			
F5	0.40	0.43	0.45	0.45	0.45			
F6	0.42	0.44	0.46	0.46	0.46			
F7	0.45	0.46	0.475	0.475	0.475			
F8	0.49	0.49	0.49	0.50	0.50			
F9	0.51	0.51	0.51	0.51	0.52	0.52		
G0	0.535	0.52	0.51	0.52	0.53	0.55		
G1	0.57	0.55	0.54	0.54	0.55	0.55		
G2	0.615	0.59	0.585	0.58	0.57	0.56		
G3	0.635	0.62	0.61	0.595	0.58	0.56		
G4	0.66	0.64	0.63	0.61	0.58	0.56		
G5	0.69	0.67	0.66	0.63	0.61	0.575		
G6	0.71	0.69	0.67	0.64	0.615	0.59		
G7	0.73	0.71	0.68	0.65	0.625	0.60		
G8	0.755	0.73	0.70	0.67	0.64	0.61	0.58	
G9	0.775	0.745	0.715	0.685	0.655	0.625	0.595	
K0	0.81	0.775	0.74	0.715	0.68	0.65	0.62	
K1	0.85	0.81	0.775	0.74	0.71	0.68	0.65	
K2	0.895	0.85	0.82	0.78	0.75	0.72	0.68	
K3	0.935	0.895	0.86	0.83	0.80	0.77	0.74	0.70
K4	1.01	0.97	0.93	0.89	0.85	0.815	0.78	0.74
K5	1.08	1.04	1.00	0.96	0.92	0.88	0.84	0.80

Table J.8: Calibration of spectral classes MK in absolute magnitude M_V . Taken from Straižys (1992, Appendix 1), originally from Straižys & Kurilienė (1981).

Sp	ZAMS	V	IV	III	II	Ib	Iab	Ia
O5	-4.6	-5.6	-5.8	-6.0	-6.3	-6.6	-6.9	-7.2
O6	-4.0	-5.4	-5.7	-5.9	-6.3	-6.6	-6.9	-7.2
O7	-3.9	-5.2	-5.5	-5.8	-6.2	-6.5	-6.8	-7.2
O8	-3.7	-4.9	-5.2	-5.6	-6.1	-6.4	-6.7	-7.2
O9	-3.5	-4.5	-4.9	-5.3	-5.9	-6.3	-6.6	-7.2
B0	-3.1	-4.0	-4.4	-4.9	-5.6	-6.1	-6.5	-7.2
B1	-2.3	-3.3	-3.9	-4.5	-5.2	-5.9	-6.4	-7.2
B2	-1.6	-2.5	-3.1	-3.7	-5.0	-5.9	-6.4	-7.2
B3	-1.0	-1.7	-2.3	-3.0	-4.8	-5.9	-6.4	-7.2
B5	-0.1	-0.8	-1.2	-1.7	-4.6	-5.9	-6.4	-7.2
B6	+0.3	-0.5	-0.9	-1.3	-4.4	-5.8	-6.4	-7.2
B7	+0.6	-0.2	-0.6	-1.0	-4.2	-5.8	-6.4	-7.2
B8	+1.0	+0.1	-0.3	-0.7	-3.9	-5.8	-6.4	-7.2
B9	+1.4	+0.5	+0.1	-0.4	-3.6	-5.7	-6.4	-7.2
A0	+1.6	+0.8	+0.4	-0.1	-3.4	-5.5	-6.4	-7.2
A1	+1.7	+1.1	+0.7	+0.2	-3.2	-5.3	-6.4	-7.2
A2	+1.8	+1.3	+0.9	+0.4	-3.1	-5.2	-6.4	-7.3
A3	+1.9	+1.5	+1.0	+0.5	-3.0	-5.1	-6.4	-7.3
A5	+2.3	+1.9	+1.4	+0.8	-2.9	-5.0	-6.5	-7.5
A7	+2.6	+2.3	+1.7	+1.1	-2.8	-5.0	-6.7	-7.7
F0	+3.0	+2.8	+2.2	+1.5	-2.7	-5.0	-6.9	-7.9
F2	+3.2	+3.1	+2.4	+1.8	-2.6	-4.9	-7.0	-8.0
F5	+3.7	+3.6	+2.6	+2.0	-2.6	-4.8	-7.1	-8.0
F8	+4.2	+4.1	+2.8		-2.5	-4.7	-7.2	-8.1
G0	+4.5	+4.4	+2.9		-2.4	-4.6	-7.2	-8.2
G2		+4.7	+3.0	+1.1	-2.4	-4.5	-7.2	-8.2
G5		+5.1	+3.1	+1.0	-2.4	-4.4	-7.2	-8.2
G8		+5.6	+3.2	+0.9	-2.5	-4.3	-7.0	-8.1
K0		+6.0	+3.2	+0.8	-2.5	-4.3	-6.8	-7.9
K1		+6.2	+3.2	+0.8	-2.5	-4.3	-6.7	-7.7
K2		+6.5		+0.7	-2.5	-4.3	-6.6	-7.6
K3		+6.7		+0.6	-2.5	-4.3	-6.5	-7.5
K4		+7.0		+0.5	-2.6	-4.4	-6.4	-7.4
K5		+7.3		+0.3	-2.6	-4.4	-6.2	-7.2
K7		+8.1		+0.0	-2.7	-4.5	-6.0	-7.0
M0		+8.9		-0.6	-2.8	-4.6	-5.8	-6.9
M1		+9.4		-0.8	-2.9	-4.6	-5.8	-6.8
M2		+10.0		-0.9	-3.0	-4.7	-5.8	-6.7
M3		+10.5		-1.0	-3.0	-4.7	-5.8	-6.7
M4		+11.5		-0.6	-3.1	-4.7	-5.8	-6.7
M5		+13.5		-0.1	-3.1	-4.7	-5.8	-6.7

Table J.9: Logarithms of stellar effective temperatures and bolometric corrections. Taken from Straižys (1992, Appendix 3), originally from Straižys & Kurilienė (1981).

Sp	log T _e				BC			
	V	V-III	III	I-II	V	V-III	III	I-II
O5		4.626		4.618		-4.15		-3.80
O6		4.593		4.585		-3.90		-3.55
O7		4.568		4.556		-3.65		-3.30
O8		4.550		4.535		-3.40		-3.15
O9		4.525		4.512		-3.15		-2.95
B0		4.498		4.431		-2.95		-2.50
B1		4.423		4.371		-2.60		-2.15
B2		4.362		4.307		-2.20		-1.75
B3		4.286		4.243		-1.85		-1.40
B5		4.188		4.137		-1.30		-0.90
B6		4.152		4.100		-1.05		-0.75
B7		4.107		4.068		-0.80		-0.60
B8		4.061		4.041		-0.55		-0.45
B9		4.017		4.013		-0.35		-0.35
A0		3.982		3.991		-0.25		-0.25
A1		3.973		3.978		-0.16		-0.16
A2		3.961		3.964		-0.10		-0.10
A3		3.949		3.949		-0.03		-0.03
A5		3.924		3.919		+0.02		+0.05
A7		3.903		3.897		+0.02		+0.09
F0		3.863		3.869		+0.02		+0.13
F2		3.845		3.851		+0.01		+0.11
F5		3.813		3.813		-0.02		+0.08
F8	3.789		3.782	3.778		-0.03		+0.03
G0	3.774		3.763	3.756		-0.05		+0.00
G2	3.763		3.740	3.732		-0.07		-0.05
G5	3.740		3.712	3.699	-0.09		-0.22	-0.13
G8	3.720		3.695	3.663	-0.13		-0.28	-0.22
K0	3.703		3.681	3.643	-0.19		-0.37	-0.29
K1	3.695		3.663	3.633			-0.43	-0.35
K2	3.686		3.648	3.623	-0.30		-0.49	-0.42
K3	3.672		3.628	3.613			-0.66	-0.57
K4	3.663		3.613				-0.86	-0.75
K5	3.643		3.602	3.585	-0.62		-1.15	-1.17
K7	3.602				-0.89			
M0	3.591		3.591	3.568	-1.17		-1.25	-1.25
M1	3.574		3.580	3.556	-1.45		-1.45	-1.40
M2	3.550		3.574	3.544	-1.71		-1.65	-1.60
M3	3.531		3.562	3.518	-1.92		-1.95	-2.0
M4	3.512		3.550	3.491	-2.24		-2.4	-2.6
M5	3.491		3.531	3.470	-2.55		-3.1	-3.3
M6			3.512		-4.4		-4.0	

Table J.10: Logarithms of stellar surface gravities (logg). Taken from Straižys (1992, Appendix 4), originally from Straižys & Kurilienė (1981).

Sp	ZAMS	V	IV	III	II	Ib	Iab	Ia
O5	+4.13	+3.90	+3.86	+3.82	+3.76	+3.74	+3.69	
O6	+4.16	+3.86	+3.80	+3.76	+3.69	+3.64	+3.60	+3.53
O7	+4.18	+3.85	+3.80	+3.74	+3.64	+3.57	+3.52	+3.45
O8	+4.17	+3.87	+3.81	+3.75	+3.62	+3.53	+3.49	+3.39
O9	+4.21	+3.95	+3.82	+3.74	+3.58	+3.50	+3.44	+3.31
B0	+4.22	+4.00	+3.88	+3.74	+3.39	+3.27	+3.19	+3.05
B1	+4.28	+4.00	+3.86	+3.71	+3.31	+3.17	+3.01	+2.87
B2	+4.28	+4.06	+3.88	+3.68	+3.19	+3.00	+2.84	+2.68
B3	+4.31	+4.06	+3.89	+3.71	+3.12	+2.79	+2.68	+2.49
B5	+4.32	+4.10	+3.98	+3.81	+2.90	+2.52	+2.40	+2.22
B6	+4.32	+4.09	+3.96	+3.84	+2.77	+2.42	+2.29	+2.13
B7	+4.35	+4.07	+3.95	+3.82	+2.77	+2.33	+2.21	+2.02
B8	+4.34	+4.07	+3.92	+3.79	+2.79	+2.27	+2.11	+1.97
B9	+4.34	+4.03	+3.94	+3.75	+2.81	+2.20	+2.04	+1.88
A0	+4.32	+4.07	+3.91	+3.75	+2.85	+2.23	+2.01	+1.81
A1	+4.35	+4.10	+3.96	+3.78	+2.88	+2.22	+1.96	+1.76
A2	+4.32	+4.16	+3.98	+3.78	+2.87	+2.23	+1.92	+1.71
A3	+4.34	+4.20	+4.03	+3.83	+2.85	+2.20	+1.86	+1.65
A5	+4.36	+4.22	+4.06	+3.86	+2.81	+2.14	+1.74	+1.53
A7	+4.36	+4.26	+4.10	+3.86	+2.75	+2.08	+1.65	+1.38
F0	+4.32	+4.28	+4.05	+3.83	+2.67	+2.00	+1.51	+1.25
F2	+4.30	+4.26	+4.01	+3.81	+2.63	+1.92	+1.39	+1.15
F5	+4.32	+4.28	+3.93	+3.74	+2.48	+1.81	+1.22	+1.00
F8	+4.39	+4.35	+3.89		+2.38	+1.71	+1.06	+0.83
G0	+4.39	+4.39	+3.84		+2.29	+1.62	+0.95	+0.72
G2	+4.40	+4.40	+3.77	+3.20	+2.20	+1.53	+0.86	+0.61
G5		+4.49	+3.71	+3.07	+2.04	+1.45	+0.71	+0.45
G8		+4.55	+3.64	+2.95	+1.84	+1.30	+0.60	+0.30
K0		+4.57	+3.57	+2.89	+1.74	+1.20	+0.54	+0.25
K1		+4.55	+3.55	+2.78	+1.66	+1.16	+0.54	+0.25
K2		+4.55		+2.63	+1.59	+1.10	+0.48	+0.23
K3		+4.56		+2.36	+1.52	+1.00	+0.46	+0.19
K4		+4.57		+2.16				
K5		+4.57		+1.93	+1.20	+0.77	+0.35	+0.10
K7		+4.62						
M0		+4.61		+1.63	+1.01	+0.61	+0.30	+0.00
M1		+4.67		+1.41	+0.84	+0.51	+0.19	-0.07
M2		+4.69		+1.31	+0.70	+0.39	+0.09	-0.13
M3		+4.71		+1.12	+0.38	+0.10	-0.16	-0.34
M4		+4.77		+0.98				
M5		+5.06		(+0.76)				
M6				(+0.52)				

Table J.11: Logarithms of stellar masses in solar units ($\log \mathcal{M}/\mathcal{M}_\odot$). Taken from Straižys (1992, Appendix 5), originally from Straižys & Kurilienė (1981).

Sp	ZAMS	V	IV	III	II	Ib	Iab	Ia
O5	+1.60	+1.81	+1.85	+1.89	+1.90	+1.92	+1.99	
O6	+1.48	+1.70	+1.76	+1.80	+1.80	+1.87	+1.91	+2.00
O7	+1.40	+1.59	+1.65	+1.68	+1.71	+1.76	+1.83	+1.92
O8	+1.34	+1.48	+1.54	+1.60	+1.65	+1.72	+1.76	+1.90
O9	+1.28	+1.38	+1.45	+1.49	+1.58	+1.66	+1.72	+1.83
B0	+1.20	+1.30	+1.34	+1.40	+1.40	+1.48	+1.56	+1.70
B1	+1.04	+1.11	+1.18	+1.23	+1.28	+1.38	+1.46	+1.64
B2	+0.92	+0.99	+1.04	+1.08	+1.18	+1.30	+1.38	+1.54
B3	+0.78	+0.84	+0.88	+0.94	+1.11	+1.23	+1.32	+1.45
B5	+0.62	+0.68	+0.72	+0.75	+1.00	+1.18	+1.26	+1.40
B6	+0.56	+0.61	+0.64	+0.68	+0.94	+1.15	+1.26	+1.38
B7	+0.49	+0.53	+0.57	+0.60	+0.91	+1.11	+1.23	+1.36
B8	+0.43	+0.48	+0.49	+0.52	+0.88	+1.08	+1.20	+1.34
B9	+0.36	+0.41	+0.45	+0.49	+0.85	+1.04	+1.20	+1.32
A0	+0.32	+0.35	+0.39	+0.43	+0.81	+1.04	+1.18	+1.30
A1	+0.31	+0.34	+0.36	+0.41	+0.78	+1.00	+1.18	+1.30
A2	+0.29	+0.32	+0.34	+0.39	+0.75	+0.98	+1.15	+1.30
A3	+0.27	+0.30	+0.32	+0.36	+0.75	+0.97	+1.11	+1.30
A5	+0.23	+0.26	+0.29	+0.33	+0.74	+0.95	+1.11	+1.30
A7	+0.20	+0.22	+0.26	+0.30	+0.73	+0.94	+1.15	+1.32
F0	+0.16	+0.16	+0.20	+0.23	+0.72	+0.93	+1.20	+1.38
F2	+0.13	+0.13	+0.16	+0.20	+0.72	+0.93	+1.20	+1.40
F5	+0.08	+0.08	+0.13	+0.18	+0.72	+0.93	+1.26	+1.40
F8	+0.04	+0.04	+0.11		+0.72	+0.93	+1.28	+1.41
G0	+0.02	+0.02	+0.10		+0.72	+0.93	+1.30	+1.43
G2	+0.00	+0.00	+0.10	+0.33	+0.72	+0.93	+1.30	+1.45
G5		-0.02	+0.08	+0.39	+0.73	+0.94	+1.32	+1.46
G8		-0.04	+0.08	+0.42	+0.76	+0.94	+1.32	+1.46
K0		-0.07	+0.11	+0.46	+0.78	+0.96	+1.30	+1.45
K1		-0.10	+0.13	+0.46	+0.78	+0.96	+1.30	+1.45
K2		-0.10		+0.45	+0.79	+0.98	+1.28	+1.43
K3		-0.12		+0.38	+0.80	+1.00	+1.30	+1.43
K4		-0.15		+0.36				
K5		-0.19		+0.37	+0.83	+1.08	+1.30	+1.45
K7		-0.22						
M0		-0.26		+0.48	+0.83	+1.15	+1.32	+1.46
M1		-0.30		+0.54	+0.83	+1.18	+1.34	+1.48
M2		-0.35		+0.54	+0.81	+1.18	+1.36	+1.50
M3		-0.40		+0.52	+0.84	+1.20	+1.38	+1.56
M4		-0.52		+0.51				
M5		(-0.82)		(+0.41)				
M6				(+0.40)				

Table J.12: Logarithms of stellar radii in solar units ($\log R/R_{\odot}$). Taken from Straižys (1992, Appendix 6), originally from Straižys & Kurilienė (1981).

Sp	ZAMS	V	IV	III	II	Ib	Iab	Ia
O5	+0.95	+1.17	+1.21	+1.25	+1.28	+1.30	+1.36	
O6	+0.87	+1.13	+1.19	+1.23	+1.27	+1.33	+1.37	+1.45
O7	+0.82	+1.08	+1.14	+1.18	+1.25	+1.31	+1.37	+1.45
O8	+0.80	+1.02	+1.08	+1.14	+1.23	+1.31	+1.35	+1.47
O9	+0.75	+0.93	+1.03	+1.09	+1.22	+1.30	+1.36	+1.48
B0	+0.70	+0.86	+0.94	+1.04	+1.20	+1.32	+1.40	+1.54
B1	+0.59	+0.77	+0.87	+0.97	+1.20	+1.32	+1.44	+1.60
B2	+0.54	+0.68	+0.80	+0.92	+1.21	+1.37	+1.49	+1.65
B3	+0.45	+0.61	+0.71	+0.83	+1.21	+1.43	+1.53	+1.69
B5	+0.36	+0.50	+0.58	+0.68	+1.27	+1.55	+1.65	+1.81
B6	+0.34	+0.48	+0.56	+0.64	+1.30	+1.58	+1.70	+1.84
B7	+0.29	+0.45	+0.53	+0.61	+1.28	+1.60	+1.72	+1.88
B8	+0.26	+0.42	+0.50	+0.58	+1.26	+1.62	+1.76	+1.90
B9	+0.23	+0.41	+0.47	+0.59	+1.23	+1.63	+1.79	+1.93
A0	+0.22	+0.36	+0.46	+0.56	+1.20	+1.62	+1.80	+1.96
A1	+0.19	+0.33	+0.41	+0.53	+1.16	+1.60	+1.82	+1.98
A2	+0.20	+0.30	+0.40	+0.52	+1.15	+1.59	+1.83	+2.01
A3	+0.18	+0.26	+0.36	+0.48	+1.16	+1.60	+1.84	+2.04
A5	+0.15	+0.23	+0.33	+0.45	+1.18	+1.62	+1.90	+2.10
A7	+0.13	+0.19	+0.29	+0.43	+1.21	+1.65	+1.97	+2.19
F0	+0.13	+0.15	+0.29	+0.41	+1.24	+1.68	+2.06	+2.28
F2	+0.13	+0.15	+0.29	+0.41	+1.26	+1.72	+2.12	+2.34
F5	+0.09	+0.11	+0.31	+0.43	+1.30	+1.77	+2.23	+2.41
F8	+0.04	+0.06	+0.33		+1.38	+1.82	+2.32	+2.50
G0	+0.03	+0.03	+0.34		+1.43	+1.87	+2.39	+2.57
G2	+0.01	+0.01	+0.38	+0.78	+1.48	+1.92	+2.44	+2.64
G5		-0.04	+0.41	+0.88	+1.56	+1.96	+2.52	+2.72
G8		-0.08	+0.43	+0.95	+1.67	+2.03	+2.57	+2.79
K0		-0.11	+0.48	+1.00	+1.73	+2.09	+2.59	+2.81
K1		-0.11	+0.50	+1.05	+1.77	+2.11	+2.61	+2.81
K2		-0.11		+1.12	+1.81	+2.15	+2.61	+2.81
K3		-0.12		+1.22	+1.85	+2.21	+2.63	+2.83
K4		-0.15		+1.31				
K5		-0.17		+1.44	+2.03	+2.37	+2.69	+2.89
K7		-0.20						
M0		-0.22		+1.64	+2.12	+2.48	+2.72	+2.92
M1		-0.27		+1.78	+2.21	+2.55	+2.78	+2.99
M2		-0.30		+1.83	+2.27	+2.61	+2.85	+3.03
M3		-0.36		+1.92	+2.44	+2.76	+2.98	+3.16
M4		-0.42		+1.98				
M5		-0.72		(+2.04)				
M6				(+2.16)				

Appendix K

Glossary of Acronyms.

B&C	Boller and Chivens	KPO	Kitt Peak Observatory
BHB	Blue Horizontal Branch	LED	Light Emitting Diode
BS	Bright Star catalog	LMC	Large Magellanic Cloud
CCD	Charge Coupled Device	LST	Local Sidereal Time
CDROM	Compact Disk Read Only Memory	MJUO	Mount John University Observatory
CDS	Centre de Données Astronomiques de Strasbourg	NGC	New General Catalog
CMD	Colour-Magnitude Diagram	NPS	North Polar Sequence
CPC	Cape Photographic Catalogue	O/C	Optical Craftsman
DC	Direct Current	PC	Pulse Counting or Personal Computer
Dec	Declination	PMT	PhotoMultiplier Tube
FRST	Foundation for Research, Science and Technology (NZ)	QF	Quality Factor
FWHM	Full Width at Half Maximum	RA	Right Ascension
GCVS	General Catalog of Variable Stars	SAO	Smithsonian Astrophysical Observatory
HA	Hour Angle	SB	Spectroscopic Binary
HD	Henry Draper catalog	SIMBAD	Set of Identifications, Measurements and Bibliography for Astronomical Data
HJD	Heliocentric Julian Date	SPS	South Polar Sequence
HR	Harvard Revised catalog — synonym for the Bright Star catalog	STP	Standard Temperature and Pressure
HST	Hubble Space Telescope	UoC	University of Canterbury
IAU	International Astronomical Union	UT	Universal Time
IGC	Internal Grants Committee	UV	ultra-violet
IRAF	Image Reduction and Analysis Facility	VUW	Victoria University of Wellington
ITS	Information Technology Services	ZAMS	Zero Age Main Sequence
JD	Julian Date		

Appendix L

List of Publications.

Below is a list of relevant papers published during this project.

- “Vilnius CCD photometry of southern clusters — some preliminary results”
Banks, T., Forbes, M. C., Sullivan, D. J. & Dodd, R. J.
Southern Stars **36**(1 & 2), 69–73, (1994)
- “Vilnius photometry in the southern hemisphere”
Dodd, R. J., Forbes, M. C. & Sullivan, D. J.
‘IAU Colloquium 136 on Stellar Photometry — Current Techniques and Future Developments’, Dublin, August 1992
Cambridge University Press.
- “Determining time-dependant atmospheric extinction”
Forbes, M. C.
Southern Stars **35**(1), 1–11, (1992)
- “Progress report on the establishment of the southern hemisphere Vilnius standard photometric system”
Forbes, M. C.
Southern Stars **35**(3), 69–79, (1993)
- “The southern Vilnius photometric system. I.
Transformation to the standard Vilnius system”
Forbes, M. C., Dodd, R. J. & Sullivan, D. J.
Baltic Astronomy **2**(2), 246–255, (1993)
- “The southern Vilnius photometric system. II.
The bright, southern standard stars”
Forbes, M. C., Dodd, R. J. & Sullivan, D. J.
Baltic Astronomy **3**(3) 227–231, (1994)
- “The Southern Vilnius Photometric System. III.
Observations of E and F Harvard standard regions, 47 Tuc and some metal-deficient stars”
Zdanavičius, K., Dodd, R. J., Forbes, M. C. & Sullivan, D. J.
Baltic Astronomy **4**, 25–38, (1995)
- “The southern Vilnius photometric system. IV.
The E region standard stars”
Forbes, M. C., Dodd, R. J. & Sullivan, D. J.
submitted to *Baltic Astronomy*.

- "Mount Pinatubo and atmospheric extinction at Mount John University Observatory 1987-94"
Forbes, M. C., Banks, T., Sullivan, D. J., Dodd, R. J., Gilmore, A. C. & Kilmartin, P. M.
The Observatory **115**, 29-30, (1995)
- "A Southern Hemisphere Network of the Secondary Standard Stars in the Vilnius Photometric System."
Dodd, R. J., Forbes, M. C., Sullivan, D. J. & Zdanavičius, K.
Baltic Astronomy **5**, 271-275, (1996)
- "A detailed investigation of atmospheric extinction via Vilnius photometry"
Forbes, M. C., Dodd, R. J. & Sullivan, D. J.
Baltic Astronomy **5**, 281-295, (1996)

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