LIGHTCURVE ANALYSIS OF ECLIPSING BINARIES CONTAINING CEPHEIDS

LIGHTCURVE ANALYSIS OF ECLIPSING BINARIES CONTAINING CEPHEIDS

By

DAVID LEPISCHAK, B.Sc.

A Thesis

Submitted to the School of Graduate Studies

in Partial Fulfillment of the Requirements

for the Degree

Master of Science.

McMaster University

MASTER OF SCIENCE (2001)

Department of Physics and Astronomy

McMaster University

Hamilton, Ontario

TITLE: Lightcurve Analysis of Eclipsing Binaries Containing Cepheids

AUTHOR: David Lepischak, B.Sc. (University of Guelph)

SUPERVISOR: Dr. Douglas L. Welch

NUMBER OF PAGES: xi, 198

Abstract

A method for solving the lightcurve of an eclipsing binary system which contains a Cepheid variable as one of its components is presented. We construct a geometric model where the component stars are assumed to be spherical and on circular orbits. The emergent system flux is computed as a function of time, with the intrinsic variations in temperature and radius of the Cepheid treated self-consistently. Fitting the adopted model to photometric observations, incorporating data from multiple bandpasses, yields a single parameter set best describing the system.

This method is then applied to three eclipsing Cepheid systems from the MACHO Project Large Magellenic Cloud database: MACHO ID's 6.6454.5, 78.6338.24 and 81.8997.87. Best-fit values are obtained for each system's orbital period and inclination and for the relative radii, relative surface brightnesses and limb-darkening coefficients of each star. Pulsation periods, radial amplitudes and parameterizations of the intrinsic surface brightness variations of the Cepheids are also obtained.

The system 6.6454.5 is found to contain a 4.97-day Cepheid with an unexpectedly brighter companion. The system 78.6338.24 consists of a 17.7-day, W Vir Class Type II Cepheid with a smaller, dimmer companion. And the system 81.8997.87 contains an intermediate-mass, 2.03-day overtone Cepheid with a dimmer, red giant secondary.

For each star, an LMC distance modulus of 18.5 mag was used to convert mean magnitudes into luminosities, and effective temperature values were found from a T_{eff} - (V-R) calibratation. Comparison with theoretical tracks and isochrones

reveals that these systems, although seemingly well-detached, are inconsistent with standard, single-star evolutionary scenarios.

A complete inventory of observations of all three systems is listed, including data not utilized in this work.

Acknowledgements

Thanks go out to:

Doug, who suggested this project and whose guidance, editing, and occasional prodding helped it towards completion;

The astronomers from all three corners of the globe who supplied the observations that made this work possible;

And the denizens of 253 and surrounding offices who supplied me with advice, anecdotes, books, examples, templates, reassurance, caffeine and the occasional perplexing phonecall.

Contents

List of Figures

List of Tables

*You, who wish to study great and wonderful things, who wonder about the movement of the stars, must read these theorems about triangles. Knowing these ideas will open the door to all of astronomy
and to certain geometric problems.*

-Johann Regiomontanus, De Tringulis Omnimodis

Chapter 1

Overview of Cepheids

1.1 Historical

The stars have been gazed at, charted, catalogued and theorized about for millenia but it has not been until relatively recently that measurements of stellar dimensions have been made with any kind of precision. The magnitude scale, used to measure apparent brightness, dates back to Hipparchus (ca. 150 B.C.) but determination of any star's *intrinsic* properties such as mass, radius, temperature and true brightness (or luminosity) had to wait until the twentieth century.

The first stellar parameter to be accurately measured was not one of those listed above. In 1784 Edward Piggott and John Goodricke discovered that the brightness of the star δ Cephei was not constant but varied with a regular period. Goodricke was able to measure the period of these variations to be 5 days 9 hours 48 minutes, which differs by less than 1% with modern determinations [Goodricke 1784]. This star has since lent its name to the class of variable stars known as Cepheids [Fernie 1985]. Goodricke measured the periods of many other variable systems of various classes including Algol, or β Persei, now known to be an eclipsing binary system. He even correctly theorized that Algol's variability was due to a darker body periodically passing in front of the star.

These two classes of variable stars, Cepheids and eclipsing binaries, have since provided us with most of our opportunities to measure physical stellar properties.

In 1880 E.C. Pickering inferred the relative sizes of the two components of Algol as well as their separation from analysis of the brightness variations of the system [Doig 1950]. By the early twentieth century H.N. Russell had developed techniques for determining the relative temperatures, radii and luminosities of stars in eclipsing systems [Russell and Shapley 1912].

It was Henrietta Leavitt who first noticed a correlation between the periods of Cepheids in the Small Magellanic Cloud (SMC) and their apparent magnitudes: brighter Cepheids tended to have longer periods [Leavitt 1908]. Leavitt was able to calculate the slope of this Period-Luminosity (P-L) relationship since all the stars could be taken to be at the same distance, but, without an accurate value for this distance, could not calculate its zeropoint. Proper calibration of the P-L relation by measuring the luminosity of, or distance to, a single Cepheid would allow determinations of the intrinsic brightnesses of all Cepheids, and therefore the distances to them.

The importance of the calibration of the P-L relation cannot be understated. The first zero point measurement was made by Hertzsprung in 1913 who used statistical parallax to measure the distance to several Galactic Cepheids [Hertzsprung 1913]. Hubble then used the relation to measure the distances to Cepheids in M31, establishing it, for the first time, as a galaxy beyond our own [Hubble 1929]. Even with an inaccurate calibration, the variability of Cepheids could be put to significant use. However, the cause of the variability remained a mystery for some time.

1.2 Pulsation Mechanism of Cepheids

It was Shapley who first demonstrated that the luminosity variations in Cepheids had a different physical origin than those of eclipsing binaries. He further suggested that radial pulsations in the Cepheids themselves were responsible [Shapley 1914]. Figure 1.1 shows the changes in δ Cephei over the course of one period, or pulsation cycle. The easily observed change in luminosity is a result of periodic changes in radius and effective temperature with the temperature change dominating at visual wavelengths. To first order the envelope of the star contracts and heats up, becoming more luminous, and then expands and cools, becoming dimmer. For Classical Cepheids, like δ Cephei, this occurs with an extremely regular period between 0.5-100 days.

Several years later Eddington suggested that the radiant energy produced in the star's core was converted into the mechanical energy of pulsation by means of an envelope ionization mechanism [Eddington 1941]. A layer of an abundant, partially-ionized element, $He^{+} \rightleftharpoons He^{++}$ in the case of Cepheids, acts as a valve modulating the radiant energy flowing through the various layers of the star ([Cox 1985] for a review). The dominant effect is the dependence of the layer's opacity on density and temperature. In most regions of the stellar envelope the opacity, κ, is described by Kramer's Law:

$$\kappa \propto \frac{\rho}{T^{3.5}} \tag{1.1}$$

where ρ is the density and T is the temperature of the gas. Ordinarily, if a layer of gas is compressed both its temperature and density will rise. Because of the stronger dependence on temperature than density, the opacity of the gas will decrease. However, in a partially ionized layer of gas some of the energy will go to further ionizing the gas rather than heating it. A smaller than usual increase in temperature allows the increase in the density term to become dominant and the opacity rises

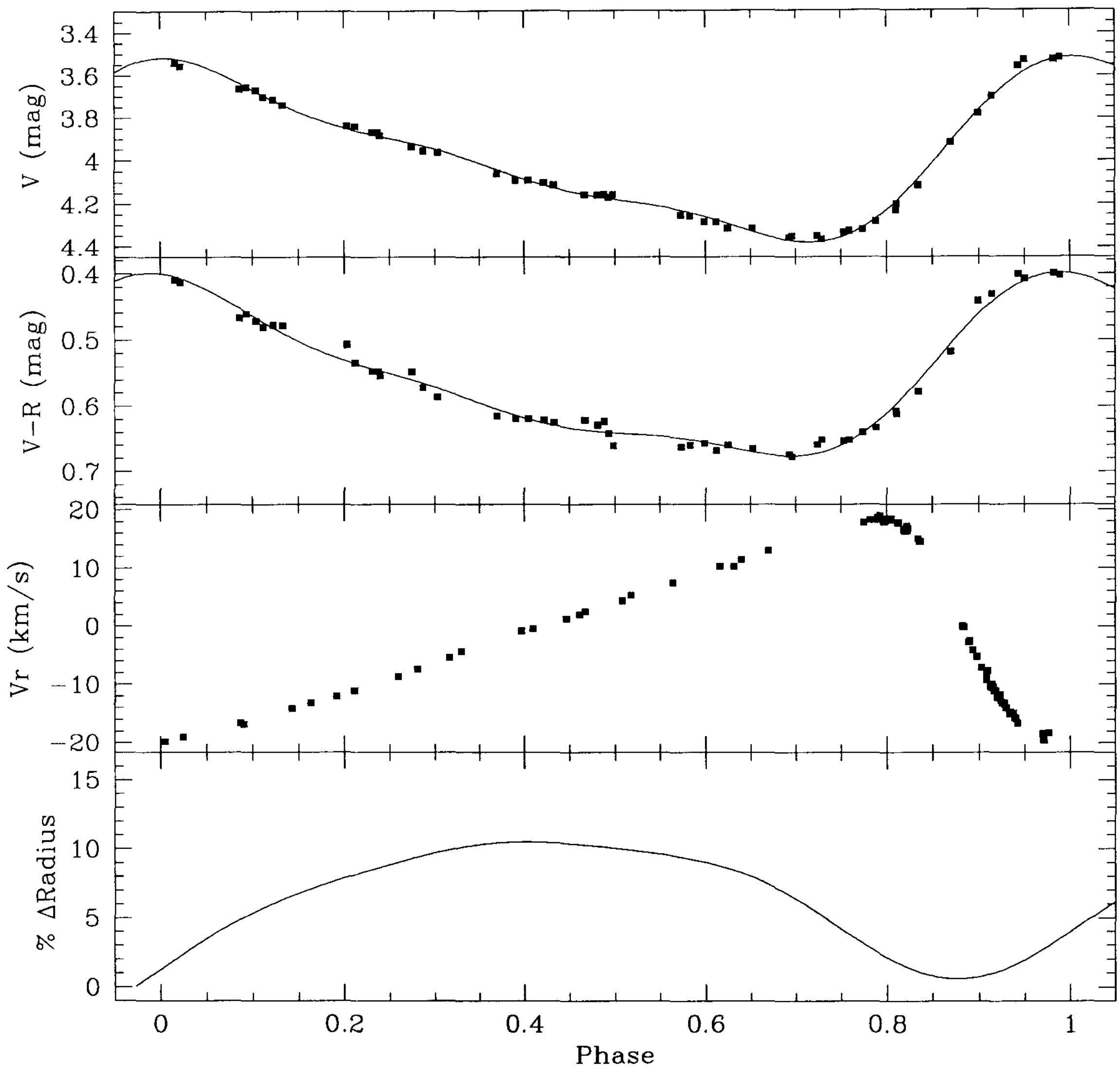

Figure 1.1: Pulsation properties of δ Cephei

Changes in the physical properties of the Classical Cepheid δ Cep over its period. The top panel shows the change in magnitude and below it is the change in colour indicating the change in surface brightness. The solid lines are a third-order Fourier series fit to the data. The third panel displays the change in radial velocity which when integrated and scaled for projection effects gives the change in radius, shown in the bottom panel. The radial change is relative to the minimum radius and is expressed as a percentage. Photometric data is from [Moffett and Barnes 1984], radial velocity data from [Barnes, Moffett, and Slovak 1987].

instead. This increase in opacity traps energy in the layer which will drive the later expansion. As the layer is driven outward, its density and opacity drop, allowing the radiant energy to pass through. With the driving pressure removed the layer will again collapse under the weight of the layers above it.

Partial He^+ ionization zones are believed to be common in evolved stars yet pulsation phenomena are restricted to stars of a very narrow temperature range: $\Delta T_e \sim 600 - 1100$ K [Cox 1980]. This is because the effectiveness of the conversion of heat energy to radial motion of the envelope ionization mechanism is highly sensitive to the location in radius of the ionization region within the star's envelope. In very hot stars the layer is located very close to the surface and there is insufficient mass above it to drive the pulsation. In cooler stars convection in the outer envelope transports energy between the layers.

1.3 Evolution of Cepheids

Stars can be classified by their location in the Hertzsprung-Russell (H-R) diagram, a plot of their absolute magnitude (or luminosity) versus their spectral type (or temperature) (Figure 1.2). The majority of stars cluster in a diagonal band (the Main Sequence) sorting themselves by mass: higher mass stars are hotter and more luminous than less massive stars of the same age. Stars spend 90% of their lifetime on the main sequence but late in their lives, after they have exhausted the supply of hydrogen in their cores, their luminosity increases slightly, their effective temperature decreases and they move to a different location in the H-R diagram. Evolutionary tracks can be calculated for a star of a given initial mass showing the path of a star through the diagram as it ages. Higher mass stars will evolve more quickly than lower mass stars because the higher temperatures within their cores cause them to consume fuel much more rapidly.

The narrow temperature dependence of the envelope ionization mechanism confines Cepheid variability to a small, near-vertical band in the H-R diagram, known as the Cepheid Instability Strip (hereafter CIS) (Figure 1.2). As suggested by the location of the strip, Cepheids are evolved stars that have moved off of the main sequence and are passing through the CIS. Cepheids are divided into two main types which follow different paths to get to the instability strip [Becker 1985].

The classical (or Type I) Cepheids are intermediate mass (2.25 to 10 $M_{\odot}$), relatively young, Population I stars. At the end of their main sequence lifetimes they exhaust the hydrogen in their cores and begin shell hydrogen burning. They move redward (to lower effective temperatures) on the H-R diagram towards the red giant branch (RGB), crossing the instability strip. This crossing takes roughly $10^3 - 10^5$ years, roughly $\frac{1}{100}^{th}$ of the time a star will spend in the CIS on later crossings. After spending some time on the RGB the star can ignite helium in its core and this new energy source moves the star blueward off the RGB. This movement ceases when the star exhausts the helium in its core and returns to the RGB. During this "blue loop" the star can cross the instability strip twice. These crossings will last a few times 10^5 to 10^6 years, much longer than the first crossing, and it is in this evolutionary state that most Cepheids are believed to be found. If the star is massive enough to ignite a helium burning shell (typically $> 7M_{\odot}$ but depends on the model used) an additional blue loop and two further crossings of the instability strip are possible.

The Type II Cepheids are much older stars, many of them Population II objects. To be observed in the instability strip today, they must evolve much more slowly than classical Cepheids and hence must have a much lower initial main sequence mass ($> 0.8M_{\odot}$) [Becker 1985]. There are several different points in these stars' lives when it is possible for them to cross the CIS. After reaching the RGB these stars

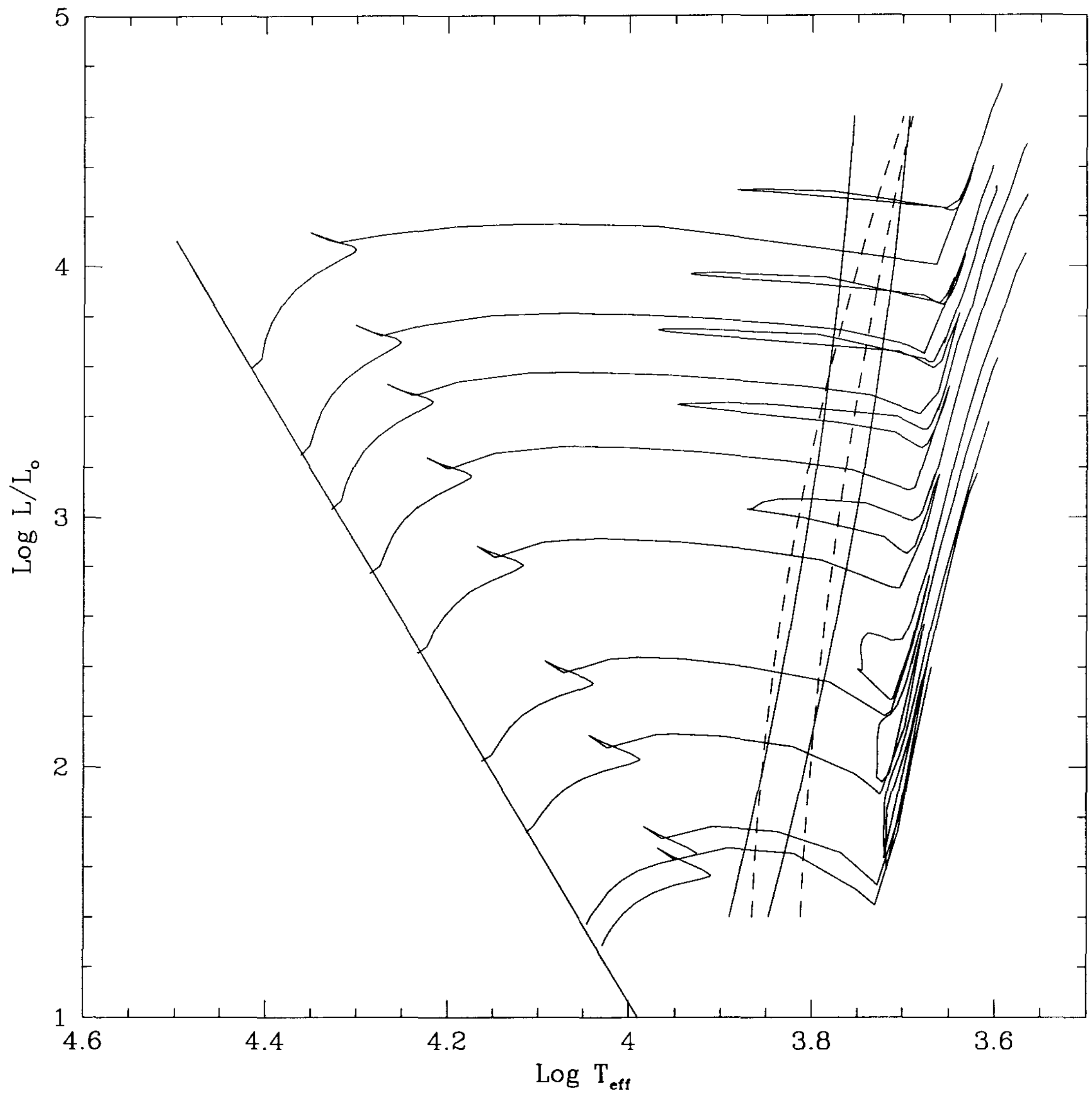

Figure 1.2: Intermediate mass evolution
Post-main sequence evolutionary tracks for intermediate mass stars ($M = 2 - 9M_\odot$) [Fagotto *et al.* 1994b]. The solid, diagonal line beginning in the upper left denotes the zero-age main sequence. Also shown are the theoretical boundaries of the instability strip for pulsation in the fundamental (solid line) and first overtone (dashed line) modes [Chiosi, Wood, and Capitanio 1993].

ignite helium degenerately in their cores, the so-called "helium flash", to begin core helium burning. They then move blueward on the H-R diagram along the horizontal branch. If a star's HB track intersects the instability strip the star will appear as an RR Lyrae variable. When its core helium is exhausted a star will move to higher luminosities on the H-R diagram upon the commencement of He shell burning. After moving off the horizontal branch the star's track may intersect the instability strip, this time as a BL Herculis-type Cepheid, having a period between 1 and 5 days [Wallerstein and Cox 1984]. These stars can spend $\sim 10^6$ years in the instability strip, after which they evolve to the asymptotic giant branch (AGB). After stars reach the AGB they can ignite a hydrogen burning shell in addition to the helium burning shell beginning the "double shell burning" phase. This can result in one or two blue-loop excursions off the AGB possible intersecting the CIS as a W Virginis class Type II Cepheid. W Vir stars have higher luminosities, larger radii and longer periods, typically 12 to 30 days, than other Type II Cepheids [Wallerstein and Cox 1984]. Regardless of the extent of these loops all AGB stars will cross the CIS once more, briefly, after they have exhausted their hydrogen envelopes and cross the H-R diagram on their way to becoming white dwarfs. The evolutionary history needed to produce a BL Her or W Vir type star demands a very limited range of masses on the horizontal branch, on the order of $0.60 \pm 0.05 M_\odot$ [Becker 1985].

1.4 Applications and Unknowns

Historically, the most common use of Cepheids has been as distance indicators. The Period-Luminosity (or Period-Luminosity-Colour) relation converts the period, an easy parameter to measure, into a measure of luminosity which is virtually impossible to measure directly due to the low space density of Cepheids in the solar neighbourhood. Comparing the difference between this true luminosity and the observed brightness allows one to infer the intervening distance. Ground-based observatories can detect Cepheids at distances out to 10 Mpc and the Hubble Space Telescope has extended this out beyond 30 Mpc. These measurements are then used to calibrate secondary distance indicators such as Type Ia supernovae or Tully-Fisher relations ([Jacoby *et al.* 1992] for a complete list) which further extend the distance scale.

As outlined above, pulsation is the result of a specific internal structure of these stars at certain points in their evolution. Thus, accurate observations of Cepheids offer the opportunity to constrain and test models of both the internal structure or state of stars and their evolutionary histories. Of particular interest are the masses of Cepheids. More than any other parameter the mass will determine the evolutionary history and internal physical profile of a star. Direct mass measurements are impossible for non-pulsating stars unless they are a member of a binary system. For Cepheids a variety of *indirect* methods of inferring the mass have been developed ([Cox 1980] for a review):

- Evolutionary mass: matching a star's position in the H-R diagram with the theoretical evolutionary track for a given mass.
- Pulsational mass: the mean density can be related to the period by pulsation theory. The density and an estimate of the radius give a value for the mass.
- Beat mass: for Cepheids that pulsate in more than one radial mode the ratio of the periods is a function of mass for a given metallicity.
- Bump mass: determines the mass from features on the lightcurve, primarily the location of a bump on the descending portion, as well as features on the radial velocity curve. This technique is calibrated by pulsation theory.

These methods have varying degrees of precision with listed uncertainties ranging from 15-54% [Petersen 1990]. More alarming is the fact that, until recently, the different methods yielded mass estimates that differed by as much as a factor of three [Bohm-Vitense 1986]. Recently improved opacities [Iglesias and Rogers 1991] and local distance scales have brought the ranges of most mass estimates into agreement [Evans *et al.* 1997] but the range in, for example, evolutionary masses, can be nearly as large as the original mass discrepancy.

1.5 The Potential of Cepheids in Binaries

Binary star systems bear directly on the mass issue because most measurements of stellar masses come from observations of binary systems [Popper 1980]. Binary star systems are classified based on their system geometry and the nature of the observations that can be made. Most binaries are discovered spectroscopically: orbital motion is inferred from the periodic Doppler shift of absorption lines in a star's spectrum. Single-lined spectroscopic binaries are systems where the spectral line shifts of only one of the stars can be measured. If both stars' lines are visible, the system is classified as double-lined. From such a system's radial velocity curves the mass ratio, q, can be found, as well as the values of $a_1 sin(i)$ and $a_2 sin(i)$, functions for the semi-major axes ($a_{1,2}$) of the orbits of both stars. If the orbital plane of the binary system is nearly aligned with the line-of-sight, the stars will appear to pass in front of one another producing what is called an eclipsing binary system. Analysis of its lightcurve can yield the system's inclination (i) and relative values for the radii and luminosities. Eclipsing binary systems which are also double-lined spectroscopic systems provide the most complete and accurate information about stellar parameters. With i known $a_{1,2}$ can be found and accurate, absolute values for the radii, luminosities and effective temperatures can be determined to higher precision than by any other method. As well, the masses of the two stars can be obtained using q and Kepler's Laws, usually with an uncertainty of only a few percent [Popper 1980]. These measurements do not depend on any intermediate assumptions. Thus a double-lined eclipsing binary system with a Cepheid as one of the components would be the "Rosetta Stone of Cepheid research" [Fernie 1987]. With an accurate mass, constraints can be placed on both evolutionary and pulsation theory and an accurate luminosity allows an improved calibration of the P-L relation and hence the entire distance scale.

Tsvetkov and Petrova illustrated the potential of eclipsing binary systems in variable star research by examining four eclipsing systems containing δ Scuti stars [Tsvetkov and Petrova 1993]. δ Scutis are lower mass objects found in the CIS just above its intersection with the main sequence. For the stars they studied, they were able to deduce orbital and pulsational periods, radii, luminosities, effective temperatures, surface gravities and ages. This wealth of information allowed the mass to be calculated by three routes: from evolutionary considerations, pulsational modeling and dynamically. All methods were found to be consistent.

A number of binary systems containing Cepheids have been observed extensively but none of these systems are eclipsing so none have given a direct, dynamical measurement of a Cepheid's mass. The binaries studied are bright enough that spectroscopic measurements of their radial velocities can be made but since Cepheids are so bright (a few times 1000 $L_\odot$) their flux dominates that of the companion and only one spectrum is visible. If the companion is a main sequence star there will be a considerable temperature difference between the two components: the cool Cepheid will dominate the optical flux but the hotter companion will emit a greater proportion of its flux in the ultraviolet. Spectra for such companions could be obtained with satellite observatories such as the Hubble Space Telescope (HST) or the International Ultraviolet Explorer (or IUE, no longer operational) [Bohm-Vitense 1986]. Lower limits for the masses of the Cepheids could then be derived. Evans *et al.* [1997] used IUE spectra to determine the spectral type of the main sequence companions to known spectroscopic binary Cepheids. A clear relationship exists between mass and spectral type for main sequence stars [Harmanec 1988] (this is why the main sequence appears as a thin band in the HR diagram). The companion mass, inferred from the spectral type, when combined with the mass ratio, from the spectroscopic observations of both stars, yields a value for the mass of such a system's Cepheid. While the mass ratio is dynamical, the Cepheid mass is not. It is also strongly dependent on the calibration of the mass-spectral type relationship rather than on observations of a given system.

The lone candidate for an eclipsing Cepheid system was BM Cas [Thiessen 1956] but Fernie and Evans found upon investigation that the "Cepheid" variability was not periodic [Fernie and Evans 1997].

Chapter 2

Observations

2.1 Detection

The detection of eclipsing, pulsating systems presents a host of difficulties. The first is intrinsic rarity. Variability is a transient stage in a star's evolution, very brief in comparison to a star's main sequence lifetime. A recent survey of $\sim 10^7$ stars yielded roughly 1700 Cepheid variable stars or 0.017% [Alcock *et al.* 1999]. If the ratio of binaries to single stars for Cepheids is the same as that for stars in the solar neighbourhood, then only 50% will be binary members. [Becker 1985] estimates only 27% of Cepheids have companions of comparable mass. The most useful systems for study are those that are well detached so that mass transfer will not have complicated their evolutionary history. This implies a large orbital separation and a long orbital period. Because the size of the stars is small relative to their separation, a high inclination (close to 90°) will be needed to produce eclipses. Consider a binary system consisting of a $5M_\odot$ Cepheid and a $5M_\odot$ main-sequence companion with radii of $48R_\odot$ and $3.7R_\odot$ respectively. At an orbital period of 400 days, implying a semi-major axis of $492R_\odot$, the system will have been well detached throughout its lifetime. The minimum condition for eclipses to occur will be

$$cos(i) = \frac{R_1 + R_2}{a} \tag{2.1}$$

confining eclipses to systems with $i > 84°$. Assuming the inclinations of systems are uniformly distributed this corresponds to 6.7% of binaries. If this example is representative then one star in 325 000 will be both eclipsing and contain a Cepheid.

The second problem is that of actual detection. An extremely long time baseline is needed to observe more than one eclipse and relatively dense coverage is needed to have the chance of capturing an eclipse at all. Assuming a circular orbit and an inclination of 90° for our above example, we find the maximum duration of eclipses for such a system is 26.7 days. Considering both primary and secondary eclipses the system will be in eclipse for roughly 13.4% of its orbital period. If one were observing stars randomly, 2.5 million observations would be required to produce a single detection of an eclipse of an eclipsing pulsating system. Observations of multiple eclipses are needed to confirm the orbital period and many non-eclipse observations are needed to identify the pulsating component.

Thus in order to detect a Cepheid in an eclipsing binary, confirm the detection, and adequately sample the lightcurve of such a system a large number of stars must be observed regularly for a long period of time.

These strict criteria are met by the MACHO (MAssive Compact Halo Object) Project, a large scale survey which searched for the gravitational lensing of distant stars by compact objects in our galaxy's halo. These so-called "microlensing events" would manifest themselves as transient brightenings of the background stars. For over 3000 days, roughly 10 million stars in the Large Magellanic Cloud (LMC), a small companion galaxy to our own, were regularly monitored for such apparent increases in stellar flux. The resulting database affords the long, regular time-baseline and accurate photometry of a large enough sample of candidates to make eclipsing Cepheid detections possible.

The three candidates studied in this work were discovered by visual inspection of approximately 2000 Cepheid lightcurves [Welch 1999].

2.2 Sources of Observations

The majority of the observations of these systems are from the MACHO Project database. The MACHO observations were made with the refurbished 1.27m Great Melbourne telescope at Mount Stromlo, near Canberra, ACT, Australia. It has been equipped with a prime focus reimager-corrector with an integral dichroic beamsplitter to give a 1 degree field in two passbands simultaneously: a 450-590 nm MACHO V filter and a 590-780 nm MACHO R filter. These are each sampled with a 2×2 array of 2048×2048 Loral CCDs which are read out simultaneously via two amplifiers per CCD in about 70 seconds. The resulting images cover 0.5 square degrees with 0.63 arcsec pixels [Cook *et al.* 1995]. Data reduction is performed automatically by Sodophot, a derivative of DoPhot [Schechter, Mateo, and Saha 1993]. MACHO photometry can be transformed into Cousins V and R bands for further interpretation.

Once the observations in the MACHO database had been analysed, it was possible to predict the timing of future eclipses. Thus planned follow-up observations to get more detailed coverage of the eclipses were possible. An eclipse of one of these systems provides a brief window during which especially useful observations can be made. The timing of recent eclipses was less than optimum. The two most recent primary eclipses of 6.6454.5 occurred in March of 1999 and April 2000. The LMC is very low in sky at night during these months making observations more difficult and less continuous than in other years.

Follow-up observations of 6.6454.5 were taken with the MACHO telescope as

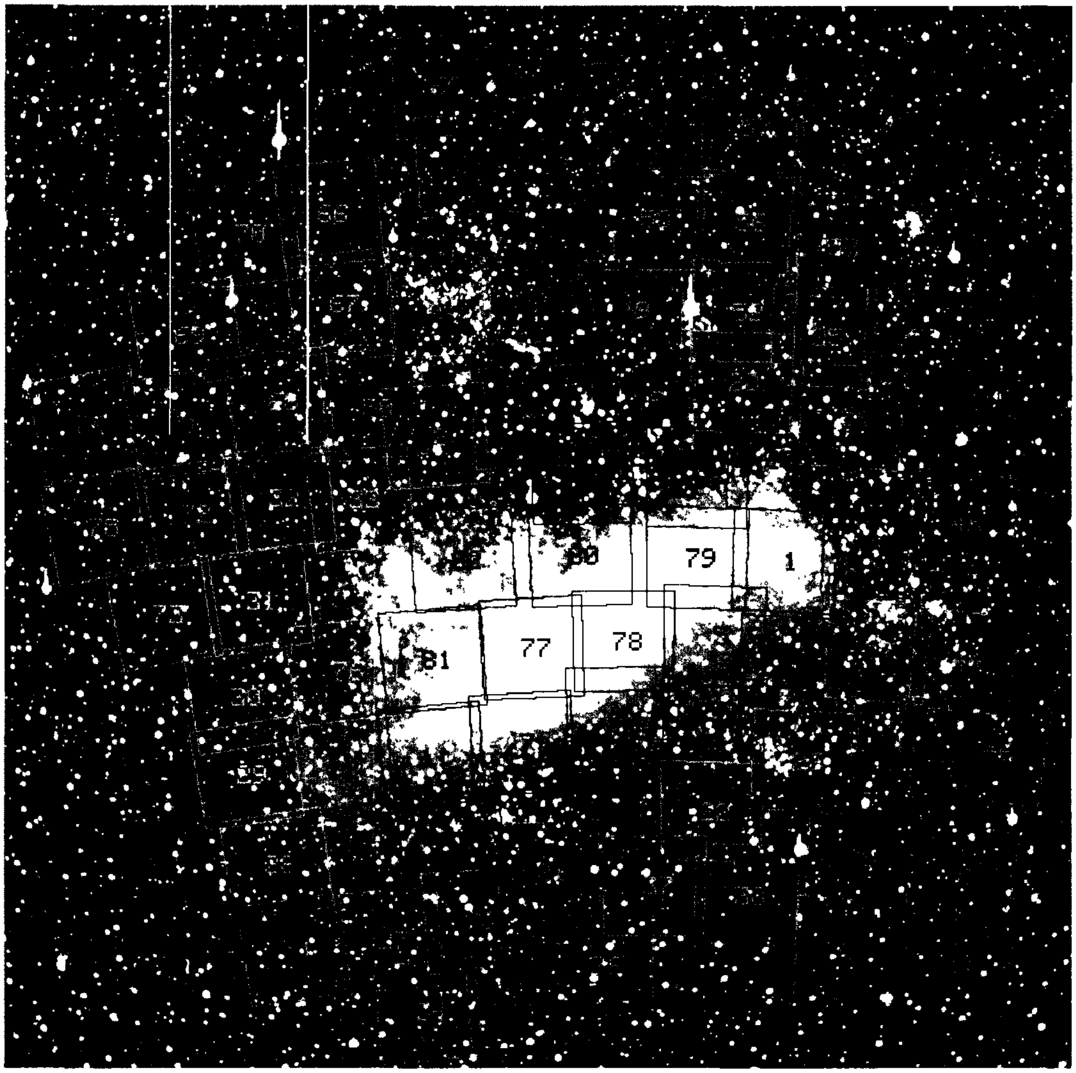

Figure 2.1: The Large Magellanic Cloud (LMC)
LMC R-band image displaying MACHO Project fields. The field is the first number in the MACHO identification codes used to refer to the systems under study. Image by G Bothun. A GIF image of this figure is available from http://wwwmacho.mcmaster.ca.

well as a number of other sites around the southern hemisphere. All data for each system were combined into a single data set prior to analysis. We briefly describe the additional observers, sites and instrumentation below.

2.2.1 CTIO

For the 1999 eclipse, observations were taken by Nick Suntzeff from March 16 to April 21 on the 0.9m telescope at the Cerro Tololo Inter-American Observatory in Chile. The telescope is a 0.9-meter Ritchey-Chretien Cassegrain telescope on an off-axis asymmetrical mounting. It has a dedicated 2048×2048 CCD detector. Observations were in standard BVI and were reduced by DAOPHOT, ALLSTAR and ALLFRAME. [www.ctio.noao.edu]

2.2.2 Hazelwood Observatory

Hazelwood Observatory is located in south-eastern Victoria, Australia and operated by Chris Stockdale. Its instrumentation consists of a Celestron 11-inch telescope with a Meade 416XT CCD camera. Observations were unfiltered, corresponding to the I-band, and covered both the 1999 and 2000 eclipses [Stockdale 2000, private communication].

2.2.3 OGLE

The Optical Gravitational Microlensing Experiment (OGLE) is another gravitational microlensing survey conducting large-scale monitoring of the LMC. Their observations are taken on the 1.3 m Warsaw telescope at Las Campanas Observatory, Chile operated by the Carnegie Institution of Washington. Observations were taken in the standard BVI bands with the majority of the observations in the I-band

[Udalski *et al.* 1999].

OGLE was responsible for the discovery of one of the systems analyzed here: MACHO 81.8997.87 = LMC_SC16 119952 [Udalski *et al.* 1999]. When this work was written, the OGLE database contained V and I observations of only one eclipse. These have been used in this work. In the same paper, they reported observations of the remaining two systems analysed here which had already been detected by MACHO. V and I measurements for 6.6454.5 have also been used here. The OGLE observations of the April 2000 eclipse of this system were graciously provided by Andrzej Udalski in advance of publication.

2.2.4 SAAO

Observations were taken on the 0.75m/1.0m telescope at the South African Astronomical Observatory during the April 2000 eclipse. Measurements were in standard I band and were taken by Gerald Handler, M. Hempel and K. Marcus.

Chapter 3

Analysis

At the heart of eclipsing binary analysis is the lightcurve, a series of pairs (t_k, o_k) where t is some independent, time-related quantity and o is the corresponding observable [Kallrath and Milone 1999]. This observable can be one of many types of observations: light at a given wavelength, radial velocity, polarization, spectral line profile. The quantity t is usually time itself or the orbital phase given by

$$\theta = \frac{t - t_0}{P}, \tag{3.1}$$

where P is the period and t_0 is some time zeropoint. Analysis consists of comparing observed lightcurves with models. At its most general, a model is simply some way of calculating a lightcurve from a given set of parameters believed to describe the system. The *inverse problem* is to determine from an observed lightcurve the set of parameters which best describes it and is, in general, a non-linear, least-squares problem.

3.1 Special Problems

Beyond the difficulties in detection (§2), eclipsing Cepheid systems present numerous difficulties for the modeling of their lightcurves. Due to the short duration of the eclipses, there tend to be relatively few in-eclipse observations. Unfortunately the in-eclipse observations are the most useful for constraining the dimensions of the system. Outside of the eclipses, the contributions of the two components to the lightcurve are indistiguishable: both stars simply contribute their full flux to the total light received.

The variability itself presents additional problems. The observed luminosity variation has two components: a temperature or surface brightness change and a radial change, which is dwarfed by the temperature change at optical wavelengths. Outside of eclipse the effect that changes in these two parameters have on the light curve is degenerate with changes in companion properties. It is only during the eclipse that the radial change becomes unambiguously detectable.

The orbital and Cepheid periods are in no way correlated. The start of each eclipse will occur at a different point in the pulsational period of the Cepheid. A common practice in variable star work is to take observations over multiple periods, then fold them into a single, one-period, very densely sampled lightcurve as there will be a unique system light at each value of the orbital phase. For these eclipsing Cepheid systems the observed flux depends not just on orbital phase but on pulsational phase as well. In order to get densely sampled light curves, the observations must be taken frequently during each eclipse.

Many eclipsing binary lightcurves can be characterized by some simple parameters such as the orbital phase angle at external contact (the beginning of an eclipse where the discs of the two stars first appear to overlap) or the system light at the deepest points of the primary and secondary eclipses. These are constant for normal eclipsing binary systems but in pulsating systems they will vary from one orbital cycle to the next. The contact phase change is due to the variations in radius and the changing depth of eclipses to the variations in the instantaneous luminosity of the Cepheid.

3.2 Model

Models of eclipsing binary systems fall into two general divisions: geometric, where the geometry of the components are fixed *a priori*, and physical models, where the geometry is determined by physical processes within the system [Kallrath and Milone 1999]. The model used here is geometric. There are a variety of computer models for determining the parameters of eclipsing binary systems - some treating exotic phenomenon such as reflection effects (a star's light reflecting off its companion and thence to the observer) or star spots (cooler, darker regions on a star's disk) (see [Milone 1993] for a discussion of recent developments). The model described here encompasses only the minimal properties believed to be needed to adequately model these systems, additional effects were then included as needed.

In our model the stars are assumed to be traveling on circular orbits. This is likely to be a good approximation for these systems and is consistent with their primary and secondary minima being separated by almost exactly one half period for two out of three cases. The stars themselves are treated as circular disks with radius (R) and central surface brightness (J_o). The light received from a non-eclipsed star would then be proportional to

$$L = \pi R^2 J_o \tag{3.2}$$

Absolute dimensions of the stars can not be extracted from the photometric lightcurve alone ([Kallrath and Milone 1999] §1.1.4) so the above parameters are all relative quantities. The radii are measured in units of the orbital separation of the two stars.

The surface brightnesses are normalized such that the mean light received *outside* of eclipse is 1.0.

The intrinsic variability of the Cepheids is handled by taking R and J_o as the minimum radius and the mean surface brightness, respectively. Variability is then added to these values in some functional form. The surface brightness variation is parameterized by a third-order Fourier series:

$$J_{var} = \sum_{k=1}^{3} A_k cos(k\omega t) + B_k sin(k\omega t) \tag{3.3}$$

which can be converted to:

$$J_{var} = \sum_{k=1}^{3} C_k cos(k\omega t - \phi_k) \tag{3.4}$$

As observations have been taken in multiple filters a mean surface brightness and Fourier series is needed for each filter.

The radial variation is modeled by the expression:

$$\Delta R = a \left| sin\left(\frac{1}{2}\omega(t - t_o)\right)\right| \tag{3.5}$$

This produces a curve which, despite being discontinuous at $\Delta R = 0$, reproduces the broad features of the radial variation curve seen in Figure 1.1.

During eclipses, the decrease in the amount of light received from the system is calculated analytically, based on the radii of two overlapping discs and geometrical considerations [Binnendijk 1960]. The general geometry is shown in Figure 3.1. The apparent separation of the centres of the two stars is given by

$$\delta^2 = cos^2 i + sin^2 i \; sin^2 \theta \tag{3.6}$$

Whether the system is in eclipse or not is determined by comparing this distance to the radii of the stars. Within eclipse the area obscured by the eclipsing star is given

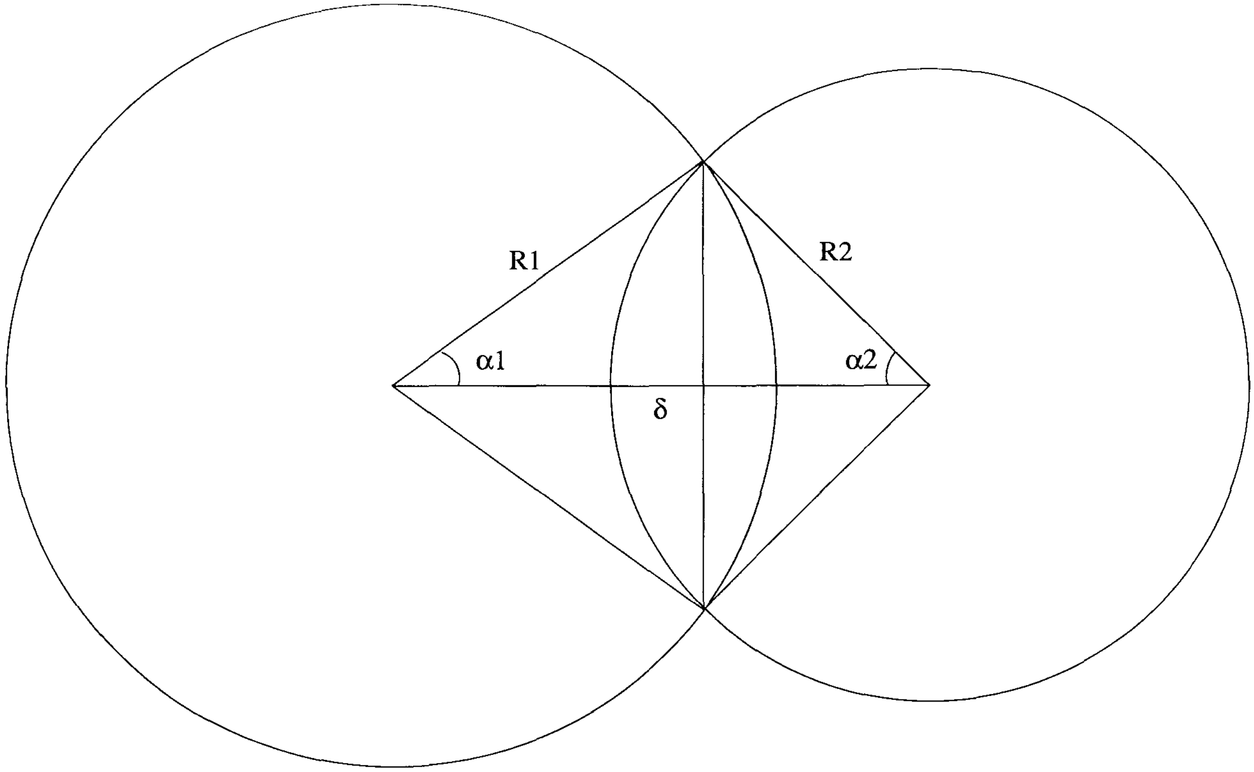

Figure 3.1: Eclipse geometry.

by

$$
\begin{aligned}
Area &= \frac{1}{2}r_1^2\,(2\alpha_1 - sin(2\alpha_1)) + \frac{1}{2}r_2^2\,(2\alpha_2 - sin(2\alpha_2)) && (3.7)\\
cos(\alpha_1) &= \frac{r_1^2 - r_2^2 + \delta^2}{2r_1\delta} && (3.8)\\
cos(\alpha_2) &= \frac{r_2^2 - r_1^2 + \delta^2}{2r_2\delta} && (3.9)
\end{aligned}
$$

Multiplying the area by the surface brightness of the eclipsed star gives the decrease in flux.

Observations of the sun and eclipsing binary systems show that stars appear darker towards their edges (or limbs). Temperature increases with depth in stellar atmospheres. At the limb of the star, the line of sight does not penetrate as deeply into regions of high temperature as the line of sight at the centre of the disk [Kallrath and Milone 1999]. Limb darkening is potentially a significant effect in any eclipsing binary system. In a high inclination system, only the limb of the eclipsed star may be visible at the deepest point of the eclipse and even in only moderately limb-darkened stars the surface brightness at the edge of the disk is half that at the centre.

The effects of limb-darkening have been included here by dividing the stellar disk into 100 concentric rings in the same manner as [Nelson and Davis 1972]. A surface brightness is then assigned to each ring based on a linear limb-darkening law:

$$J = J_o(1 - x_\lambda + x_\lambda cos(\gamma)), \tag{3.10}$$

where x_λ is the limb-darkening coefficient and γ is the angle between the surface normal at that point and the line of sight. The total light received from each star can then be calculated by computing the contribution from each ring and integrating over all of the rings. Outside of eclipse, when the entire disk of the star is visible, an analytic expression for the total light is:

$$L = \pi r^2 J_o \left(1 - \frac{x_\lambda}{3}\right) \tag{3.11}$$

Within eclipses the integration must be performed within suitable limits based on the amount of each stellar surface that is visible. In practice, it is faster to compute the normal fluxes from the above equation and then calculate the amount of flux lost based on the eclipse geometry. This is done by using equations 3.7 - 3.9 repeatedly for eclipsed stars of varying radii. These radii correspond to the rings into which the stellar disk is divided. In this way, the covered area of each ring is found, multiplied by the appropriate brightness given by equation 3.10 and summed to give the amount of flux lost. Integration over the eclipsed region would be more accurate in principle, but poses the practical problem of being difficult to implement. The limits of integration are particularly difficult to express for a star of varying radius. Summation is more straightforward to implement and the loss of accuracy in the final flux value is negligible, roughly one part in 1000, with the number of annuli being used.

3.3 Fitting Procedure

The technique used to fit the model to the data is χ^2 minimization where

$$\chi^2 \equiv \sum_{k=1}^{N} \left(\frac{o_k - o(t_k; a_1 ... a_M)}{\sigma_i} \right)^2 \tag{3.12}$$

The procedure used is a standard Levenberg-Marquandt method from [Press *et al.* 1992]. This procedure alternates between two complementary methods for finding a minimum χ^2: the steepest descent method far from the minimum, switching smoothly to the inverse Hessian method as the minimum is approached. This approach combines the advantages of both methods: rapid progress is made towards a minimum and, once located, accurate determination of the best-fit parameters is achieved. The drawback is the possibility of termination within a local minimum rather than the true minimum. This possibility can be reduced through reasonable selection of the initial values for the fitting process.

These "guess" values come from pre-analysis of the lightcurve. The orbital period can easily be estimated by measuring the average length of time between eclipses. Values for the inclination, radii and relative luminosities were obtained using an algorithm from [Riazi 1992]. First, a coarse removal of the pulsation contribution to the lightcurve is achieved by phasing the data to the orbital period and fitting hyperbolas to both the primary and secondary eclipses. The out-of-eclipse flux is assumed to be 1.0. The result is an averaged lightcurve with clearly defined minima for both eclipses and phase of external contact. From the values for the system light, in two filters, at the eclipse minima, the Riazi algorithm gives the relative luminosities of the two stars as well as the ratio of radii. From these, and the phase angle at external contact, the inclination and relative radii can be computed. These values are then improved by performing a fit to minimize χ^2 relative to a simplified model. Once the boundaries of the eclipses have been defined the parameters controlling the

Cepheid variability can be estimated by examining only the out of eclipse data. The pulsation period is found using a routine `period` from [Press *et al.* 1992] on the out of eclipse data points. This routine uses an algorithm by [Lomb 1976] to compute the power present at various frequencies in unevenly spaced data. Once the pulsation period is known, the data outside of eclipse can be phased to it and a Fourier series fit to the flux variation. The initial radial variation is simply set to be one quarter of the radius of the variable star and the offset is set to be one quarter of a period later than the time zeropoint for the lightcurve. The parameter set resulting from the above procedures will not accurately describe the lightcurve but it is usually sufficient to produce a lightcurve close enough to that observed to allow fitting to proceed and to be in the same valley in parameter χ^2 space as the global minimum.

The data are then subjected to a χ^2 minimization. An array of flags allows each parameter to be fit or held fixed. The data from both filters (or all three filters, when available) are fit simultaneously, allowing parameters such as the inclination and the radii, which correspond to physical dimensions of the system (and so should not vary from filter to filter) to be determined from all of the data.

The limb-darkening coefficients prove to be the parameters most difficult to constrain and we have had to fit them separately. A fit is first performed with all limb-darkening coefficients held fixed at their guess values, usually 0.5, to produce improved values for the other parameters. Another fit is then performed with the limb-darkening coefficients allowed to vary to produce optimum values for all parameters. The x will not vary far from 0.5, typically staying within 0.4 - 0.7, the range expected for x of most main-sequence and giant stars. The relative movement of the x_λ values can then be examined to see if it matches expectations based on the relative temperatures and surface gravities of the two stars.

3.4 Testing

There are two separate aspects of the code which require testing: the fitting process, to see if the algorithms can accurately determine the model parameters that describe a data set, and the model itself, to see if it can accurately describe the properties of these particular types of binary systems.

Preliminary testing of the code was done by using the model to generate synthetic lightcurves of eclipsing, pulsating systems with a variety of parameters. These curves were then fit to see if the code could extract the correct parameter set from the lightcurve.

To test the model, a system was selected from the literature for which both photometry and analysis were available. One of the few well-detached, circular orbit systems fitting this description is FS Monocerotis, a 1.9-day, double-lined, main sequence binary. [Lacy *et al.* 2000] performed both spectroscopic and photometric analysis of the system to determine its absolute parameters. Their differential B and V photometry were fit holding all parameters representing variability to 0. Figure 3.2 shows the B filter fit and Table 3.1 shows a comparison between the Lacy *et al.* photometric orbital elements and ours. Several items are worthy of note. The Lacy *et al.* photometric analysis was done using the Nelson-Davis-Etzel (NDE) model which is similar in many respects to ours [Nelson and Davis 1972]. The radii values may be compared directly. The NDE model normalizes the surface brightness so the $J_p = 1.0$, our code normalizes them so the total light received from the system is $L = 1.0$. It is the ratio of surface brightnesses which must be compared. Limb-darkening coefficients were not fit in either analysis. Lacy *et al.* used coefficients for the primary and secondary of 0.580 and 0.594, respectively, in B and 0.580 and 0.591 in V. The differences between the x_λ values for the primary and secondary components were taken from [Wade and Rucinski 1985] and their magnitude was adjusted to produce minimal residuals. For our fit their limb-darkening coefficients were adopted and held fixed. It can be seen in Figure 3.2 that between the primary and secondary eclipses the lightcurve is not constant, being brighter towards the midpoint and dimming as it approaches either eclipse. This is mostly to due to the oblateness of the stars and the effects of gravity darkening. Neither of these effects are treated in our model but they are in the NDE model. The inability of our model to produce a bent lightcurve between eclipses contributes to the large uncertainties in J_p and the ratio of surface brightnesses. As a test, the magnitude values of the out-of-eclipse points were all set to a mean value. The errors in the J_p parameters decreased. The fact that both models yield very similar results despite this difference gives us confidence that our model has been correctly constructed and our fitting routine is coded correctly.

Table 3.1: Comparison of light curve solutions for FS Mon.

Parameter	Lacy et al.	Our Solution
i $(in\ ^o)$	87.7 ± 0.2	87.7 ± 0.5
r_p	0.2177 ± 0.0012	0.22 ± 0.08
r_s	0.1729	0.18 ± 0.15
$k = \frac{r_s}{r_p}$	0.794± 0.003	0.82
B J_p	1.0	5.2 ± 6.5
J_s	0.877 ± 0.003	4.6
$\frac{J_s}{J_p}$	0.877	0.9 ± 1.1
V J_p	1.0	5.0 ± 6.3
J_s	0.902 ± 0.002	4.7
$\frac{J_s}{J_p}$	0.902	0.9 ± 1.2

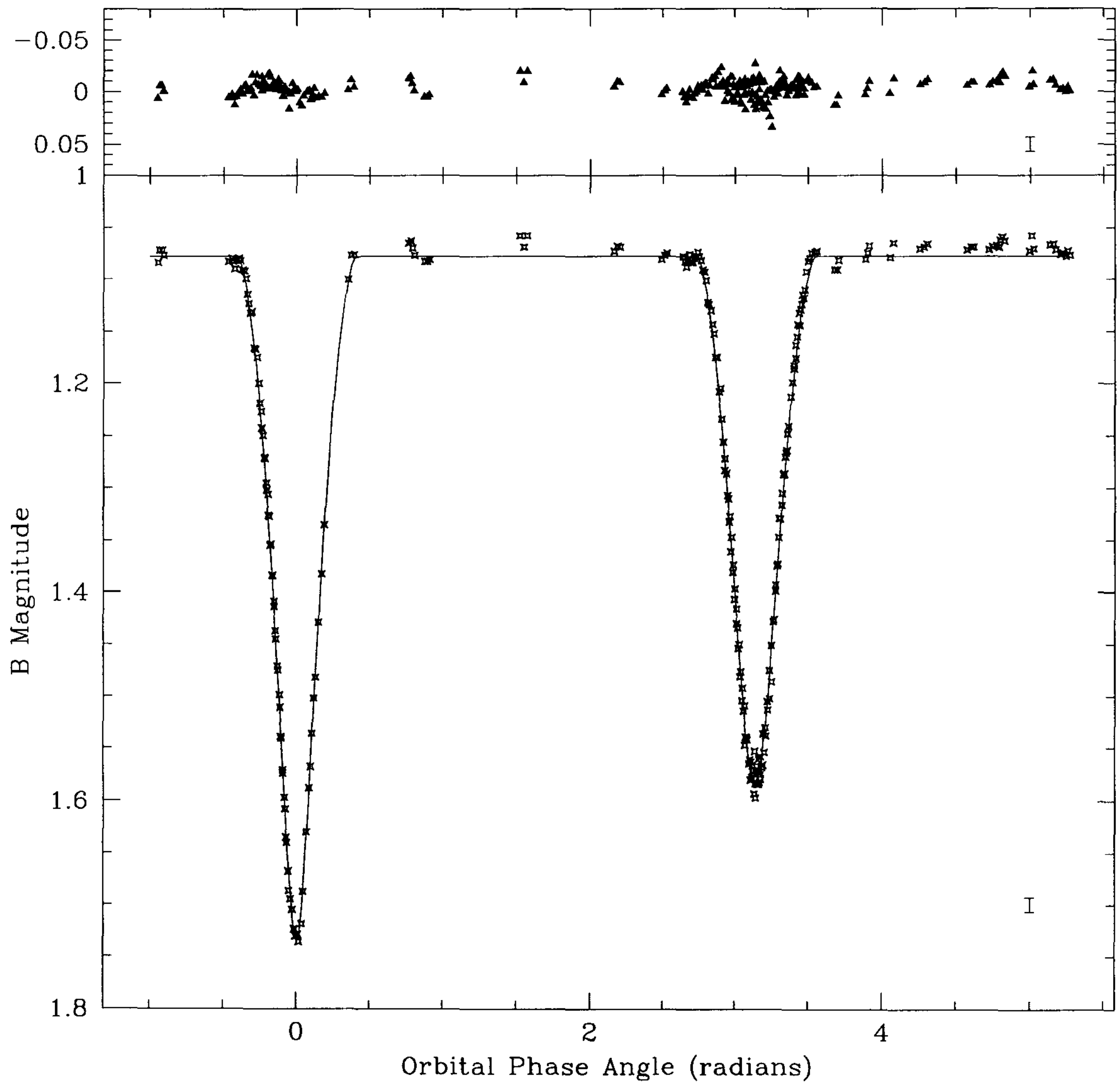

Figure 3.2: Differential light curve of FS Mon in B with curve of best fit. Upper panel shows residuals in magnitudes. A typical error bar is shown in the lower right of each panel.

Chapter 4

Results

4.1 Fit Results

The fitting procedure, described in Chapter 3, was applied to the three eclipsing Cepheid systems for which data was available. We will discuss the results for each system in turn.

4.1.1 6.6454.5

This is the system for which eclipse coverage has been the most dense. It appears to consist of a bright, blue primary with a dimmer Cepheid for a companion. The final χ_v^2 of 2.1 is the best of the three systems studied, reflecting the good quality of the data and probable appropriateness of the model. The final best fit parameters are shown in Table 4.1.

The orbital and pulsational periods are both in days and the inclination is given in degrees. The radii and amplitude of the radial variation, ΔR_{amp}, are relative to the orbital separation of the two stars. ΔR_{shift}, which measures the shift of the radial change relative to the temperature change, has units of days. The mean central

Table 4.1: Best fit parameters for 6.6454.5
Meanings of individual parameters and units are explained in the text.

χ_v^2	2.101		
P_{orb}	397.18 ± 0.01	days	
i	85.9 ± 0.2	degrees	
Companion	(primary)	Variable	(secondary)
R	0.041 ± 0.002	R_{min}	0.070 ± 0.004
J_V	160.0 ± 19.9	J_V	25.2
J_R	146.3 ± 19.7	J_R	29.6
x_V	0.50 ± 0.38	x_V	0.61 ± 0.55
x_R	0.50 ± 0.35	x_R	0.57 ± 0.53
		P_{ceph}	4.97392 ± 0.00003 days
		ΔR_{amp}	0.0152 ± 0.0004
		ΔR_{shift}	-0.25 ± 0.01 days
Variation in J			
	V Band	R Band	
A_1	4.9 ± 1.4	4.7 ± 1.4	
B_1	0.8 ± 0.2	1.1 ± 0.3	
A_2	1.1 ± 0.3	1.2 ± 0.4	
B_2	0.26 ± 0.09	-0.03 ± 0.07	
A_3	0.3 ± 0.1	0.23 ± 0.09	
B_3	0.16 ± 0.06	-0.09 ± 0.06	
C_1	4.9 ± 1.4	4.8 ± 1.4	
ϕ_1	6.12 ± 0.09	6.0 ± 0.1	
C_2	1.2 ± 0.4	1.2 ± 0.4	
ϕ_1	6.1 ± 0.1	0.03 ± 0.07	
C_3	0.4 ± 0.1	0.2 ± 0.1	
ϕ_1	5.8 ± 0.3	0.4 ± 0.4	
R_{21}	0.2 ± 0.1	0.2 ± 0.1	
ϕ_{21}	0.09 ± 0.31	0.5 ± 0.3	
R_{31}	0.07 ± 0.05	0.05 ± 0.04	
ϕ_{31}	6.3 ± 0.6	1.1 ± 0.8	

surface brightnesses, J_λ, is dimensionless, being the result of dividing a normalized flux by an area expressed in terms of our relative radius. It is their size relative to one another, rather than their absolute magnitude, that is meaningful. Only the J values for the primary are fit by the code, the secondary's values are then determined by the normalization condition that total light be equal to one. No error value is quoted for the surface brightness of the secondary. A poorly constrained J_λ for the secondary will produce a larger error in J_λ for the primary. The Fourier parameters A_i and B_i have the same units as the surface brightnesses (see eq. 3.3). Also tabulated are the amplitude (C_i) and phase (ϕ_i) of the combined ith terms and values of R_{i1}, the ratio of the $(i-1)$th harmonic and the base frequency amplitudes (C_i and C_1), and $\phi_{i,1}$, defined by $\phi_{i,1} = \phi_i - i\phi_1$ (see eq. 3.4).

To distinguish between primary-variable and secondary-variable systems, we solved for system parameters using each configuration in turn. The configuration which best fit the data was deemed to be the correct one. The final χ^2_v for the primary-variable configuration was 5.4, over twice that of the secondary-variable configuration. An identical procedure was used for the remaining two systems.

The nature of the Cepheid in this system is unclear. Figure 4.10 shows its mean brightness to be intermediate between the Classical and Type II period-luminosity sequences (although this may be due more to colour effects than to the brightness alone).

The amplitude of the radial variation was found to be 0.0152 ± 0.0004 in units of the orbital separation of the two stars. This corresponds to 0.212 of the minimum radius of the Cepheid. The low value of error indicates the observations of this system have constrained this parameter quite well. A measured radial change of 21.2% is consistent with this variable being a Type II Cepheid. Classical Cepheids typically show radial variations of 10% or less [Armstrong *et al.* 2000] while those of

Type II Cepheids are found to be much greater. [Lebre and Gillet 1992] estimated the relative variation $\frac{\Delta R}{R}$ in W Vir to be between 0.3 and 0.5. 6.6454.5's radial variation seems to place it somewhere between these two classifications.

Trends seen in the limb-darkening coefficients should also be consistent with the interpretation of the nature of the components of the systems. The values of the coefficients x_λ should decline with increasing temperature and increasing surface gravity [Wade and Rucinski 1985]. As the companion is both hotter and has a higher surface gravity, its x_λ should be lower than the corresponding values for the Cepheid. Over the range of wavelengths studied here, we expect a decline in the coefficients as we move from shorter (V band) to longer (R band) wavelengths. However Table 4.1 shows all limb-darkening coefficients are the same within the given uncertainties.

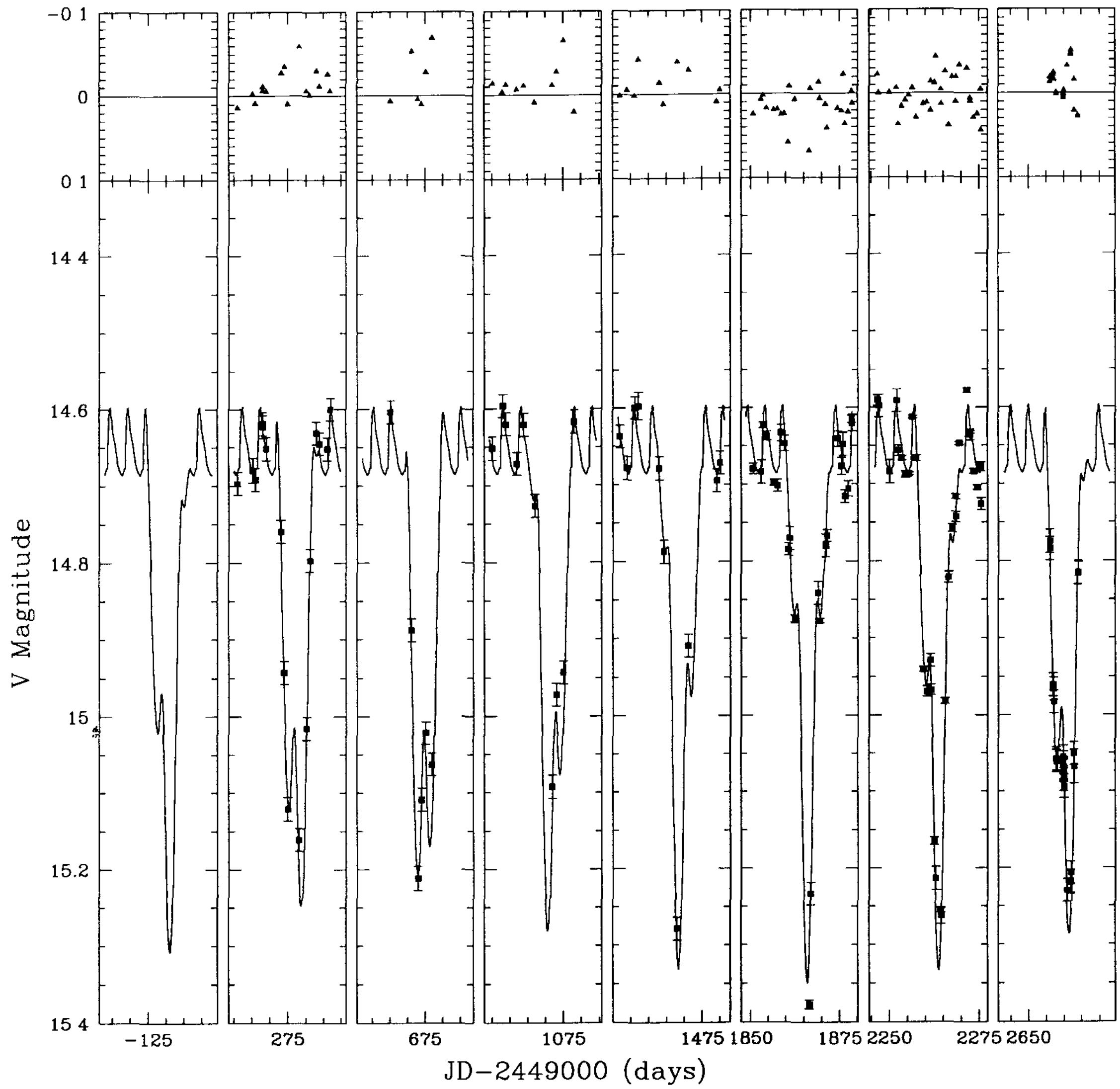

Figure 4.1: Primary eclipses of 6.6454.4 in V with curve of best fit. Upper panels show residuals in magnitudes.

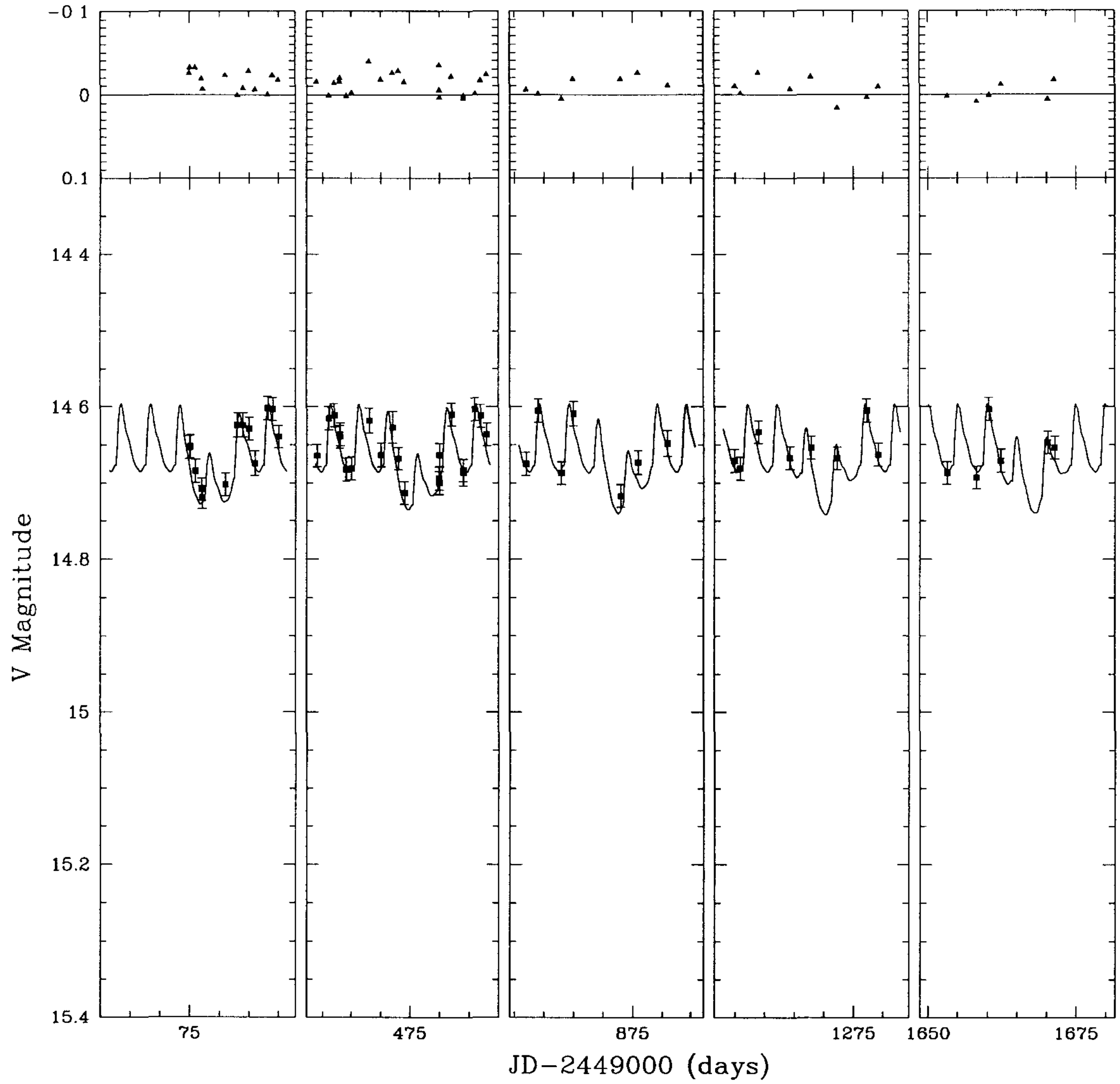

Figure 4.2: Secondary eclipses of 6.6454.4 in V with curve of best fit. Upper panels show residuals in magnitudes.

4.1.2 78.6338.24

The variable in this system appears to be a Type II Cepheid with the primary star a hotter, but somewhat dimmer, star. The variable star in this system exhibits "period drift" resulting in a non-constant pulsational period. In Figure 4.3 it is seen that this is a smooth, slowly-varying effect. Although the period change amounts to less than 1% over the roughly 2500 days of observations it has a significant effect on the fit if not corrected. The correction used was a pulsational angular frequency(ω) that varied with time described by:

$$\omega = \omega_o + A_1 Bt + A_2 (Bt)^2 \tag{4.1}$$

where t is the time of the observation in days, A_i are parameters to be determined by fitting and B is a constant used to insure that the A_i are of a similar order of magnitude as the other fit parameters. B was set at 10^{-6}. The effect of applying this correction can be seen in the lower panel of Figure 4.3.

The best fit to the system (shown in Table 4.2) had a χ^2_v of 11.9. This is still relatively high compared to the other two systems but, by comparison, the best fit without correction for the period change had a χ^2_v of 27.0.

The fitting of this system is complicated by several additional factors. As is to be expected with a longer-period Cepheid, the amplitude of the luminosity change is much greater ($\sim$ 0.3 mags) than in the other, shorter period systems. The eclipses themselves, particularly the secondary eclipses, are less well defined.

There are indications in this analysis of features not taken into account by the model. Figure 4.6 shows the observations of the system in V, as well as the residuals from fitting a third order Fourier series to them. When the observations are phased to the orbital period, we see a systematic change in the minimum system light between eclipses. The system appears brightest at the midpoints between eclipses and dims

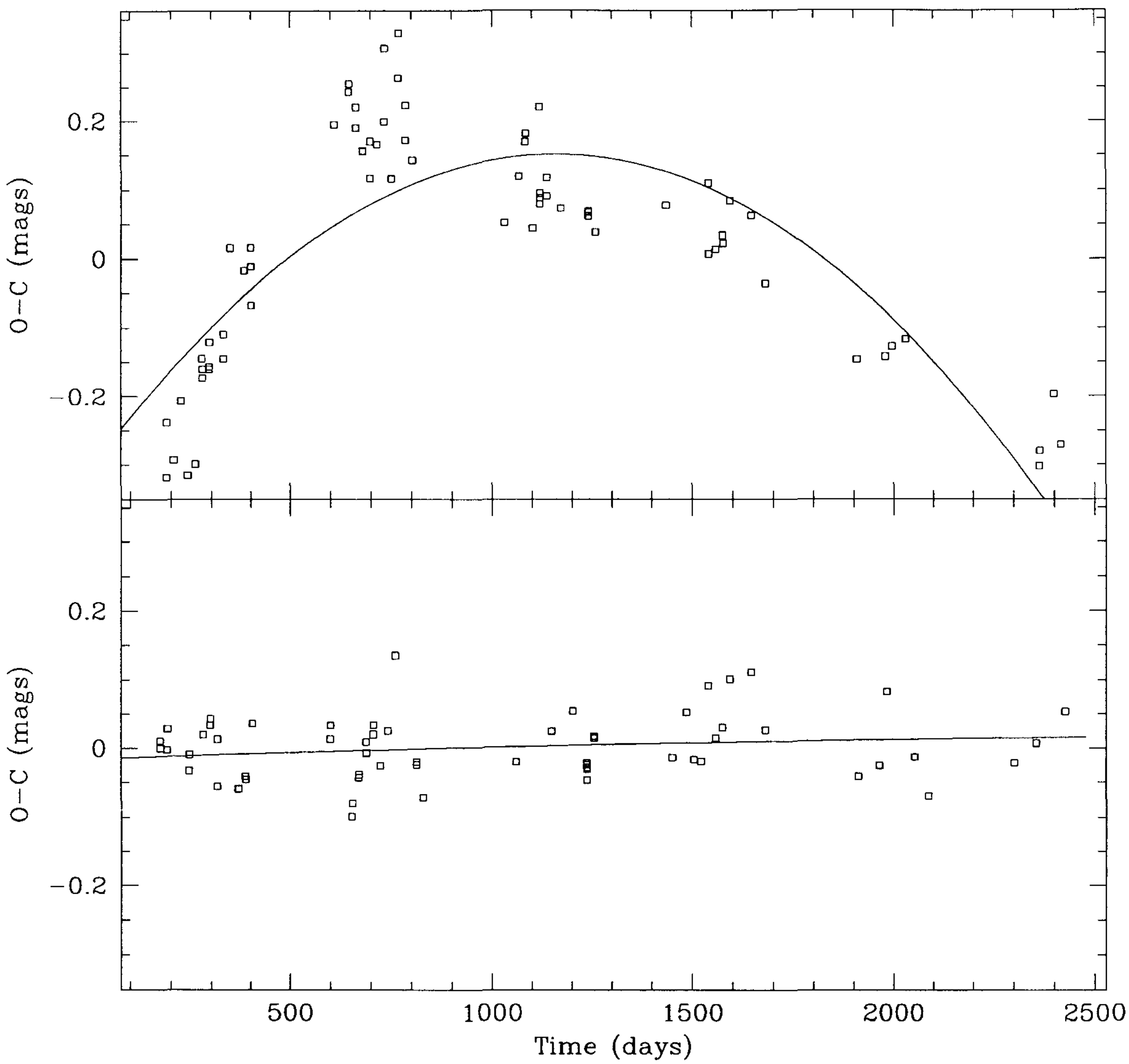

Figure 4.3: Period Adjustment to 78.6338.24
Both panels show residuals from a third-order Fourier series fit (in magnitude space) to the non-eclipse points as function of time (t = 0 is the date of first observation). Only points from the ∼0.5 radian wide portion of the lightcurve where the Cepheid is increasing rapidly in brightness are shown. The solid lines are a quadratic polynomial fit to the points. In the top panel the slow change in pulsational period produces residuals correlated with the time of observation. After applying the correction described by equation 4.1 the residuals are more evenly distributed, as seen in the lower panel.

Table 4.2: Best fit parameters for 78.6338.24
Parameter definitions and units are the same as in Table 4.1 with the exception of A_1 and A_2 which are defined by equation 4.1.

χ^2_v	11.854		
P_{orb}	419.47 ± 0.03	days	
i	85.8 ± 0.2	degrees	
Companion	(primary)	Variable	(secondary)
R	0.040 ± 0.001	R_{min}	0.102 ± 0.002
J_V	83.0 ± 11.3	J_V	23.9
J_R	66.6 ± 9.8	J_R	26.6
x_V	0.59 ± 0.45	x_V	0.47 ± 0.28
x_R	0.61 ± 0.47	x_R	0.49 ± 0.25
		P_{ceph}	17.698 ± 0.001 days
A_1	2.51 ± 0.01	A_2	-514.6 ± 3.6
		ΔR_{amp}	0.01396 ± 0.0004
		ΔR_{shift}	-6.25 ± 0.03 days

Variation in J		
	V Band	R Band
A_1	5.0 ± 0.5	4.6 ± 0.4
B_1	-4.4 ± 0.5	-3.4 ± 0.4
A_2	-2.2 ± 0.2	-2.0 ± 0.2
B_2	-1.32 ± 0.1	-1.0 ± 0.1
A_3	-0.30 ± 0.04	-0.15 ± 0.02
B_3	0.59 ± 0.07	0.38 ± 0.04
C_1	6.7 ± 0.7	5.6 ± 0.5
ϕ_1	0.7 ± 0.1	0.6 ± 0.1
C_2	2.6 ± 0.3	2.2 ± 0.2
ϕ_1	2.6 ± 0.1	2.66 ± 0.08
C_3	0.67 ± 0.08	0.41 ± 0.05
ϕ_1	4.2 ± 0.1	4.33 ± 0.09
R_{21}	0.39 ± 0.09	0.40 ± 0.08
ϕ_{21}	1.2 ± 0.3	1.4 ± 0.3
R_{31}	0.10 ± 0.02	0.07 ± 0.02
ϕ_{31}	2.1 ± 0.4	2.4 ± 0.8

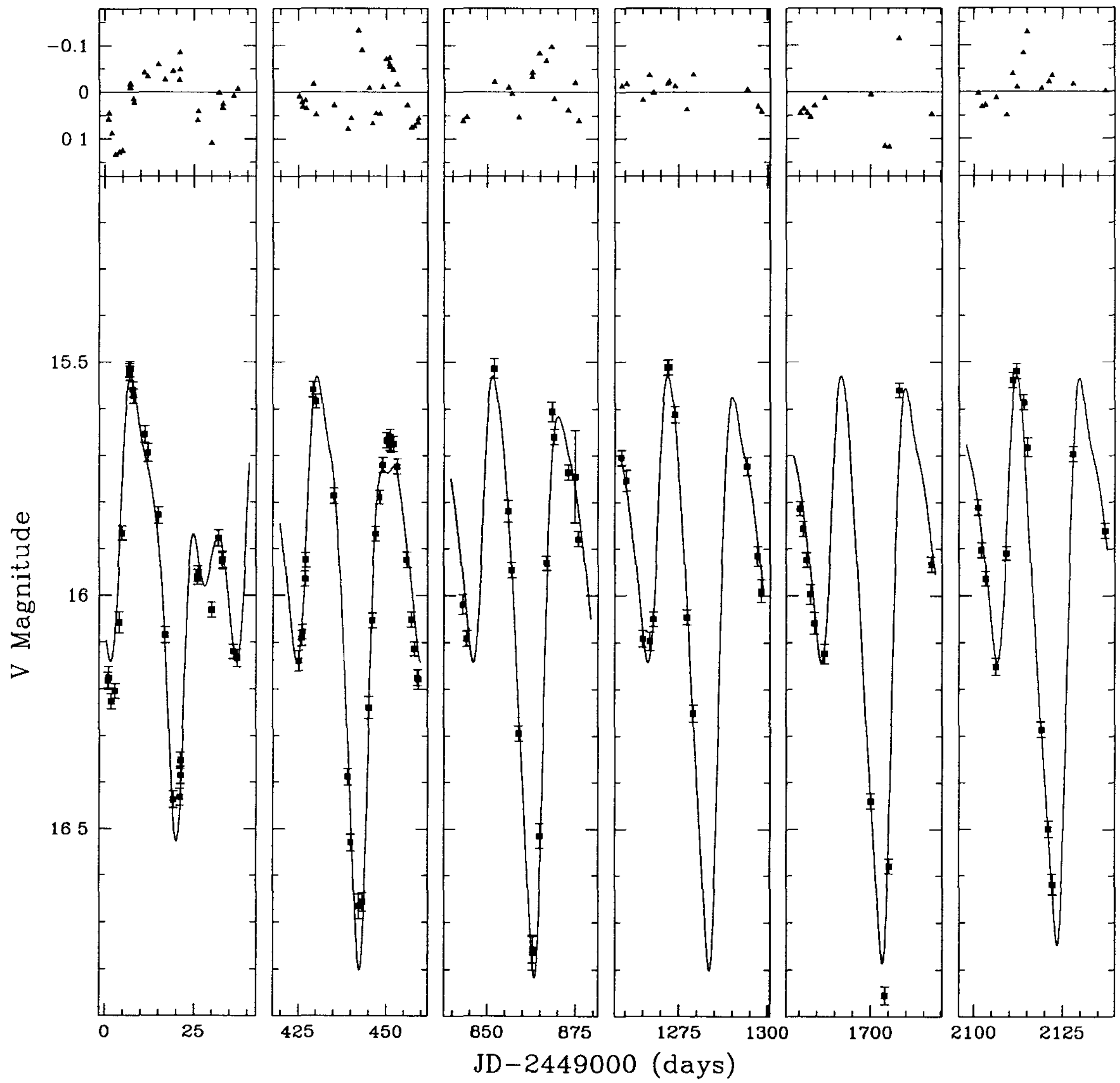

Figure 4.4: Primary eclipses of 78.6338.24 in V with curve of best fit. Upper panels show residuals in magnitudes.

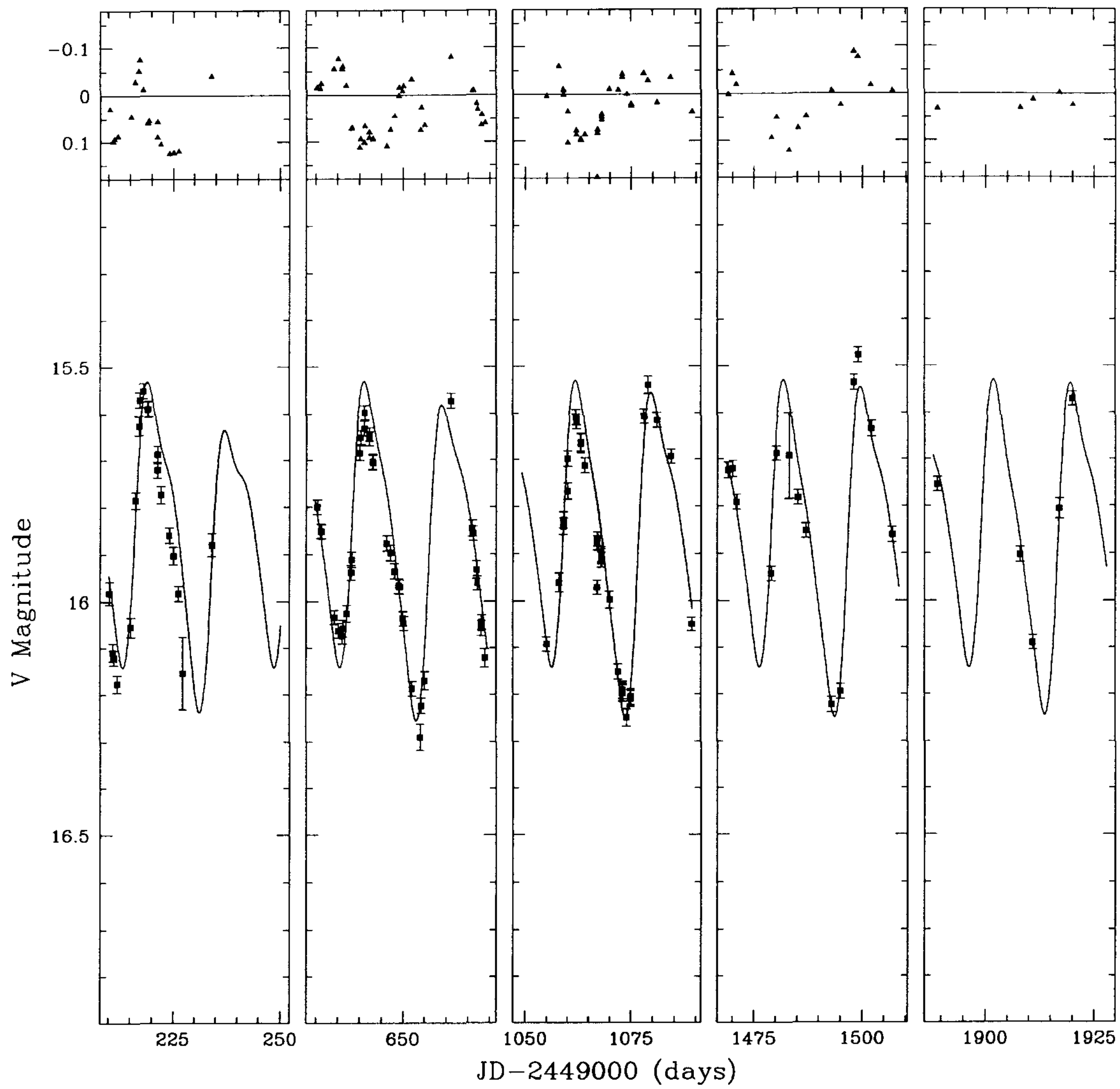

Figure 4.5: Secondary eclipses of 78.6338.24 in V with curve of best fit. Upper panels show residuals in magnitudes.

as it approaches either primary ($\phi = 0$) or secondary ($\phi = \pi$) eclipse. This trend is mirrored in the residuals. This is most likely due to the oblateness of at least one of the stars.

The inferred amplitude of the radial motions is somewhat low for a Type II Cepheid at 14.0% of the Cepheid radius. This is higher than would be expected for a Type I Cepheid. It would not be unexpected for the limb-darkening coefficients to vary in a manner opposite to what is expected from model atmospheres: increasing for the companion rather than the Cepheid and also increasing as we move to longer wavelengths. At a period in excess of 17 days the Cepheid here is likely a W Vir class variable, known to be very large in radius with a very tenuous outer envelope. In such cases the plane-parallel approximation of radiative transfer inherent in most model atmospheres may break down, requiring instead the use of spherical transfer methods [Manduca, Bell, and Gustafsson 1977]. Additionally if one (or both) of the stars are non-spherical, the concentric, circular rings used to simulate the disk of the star will be a poor representation of the actual flux distribution. However, no significant change in limb-darkening coefficients is seen here.

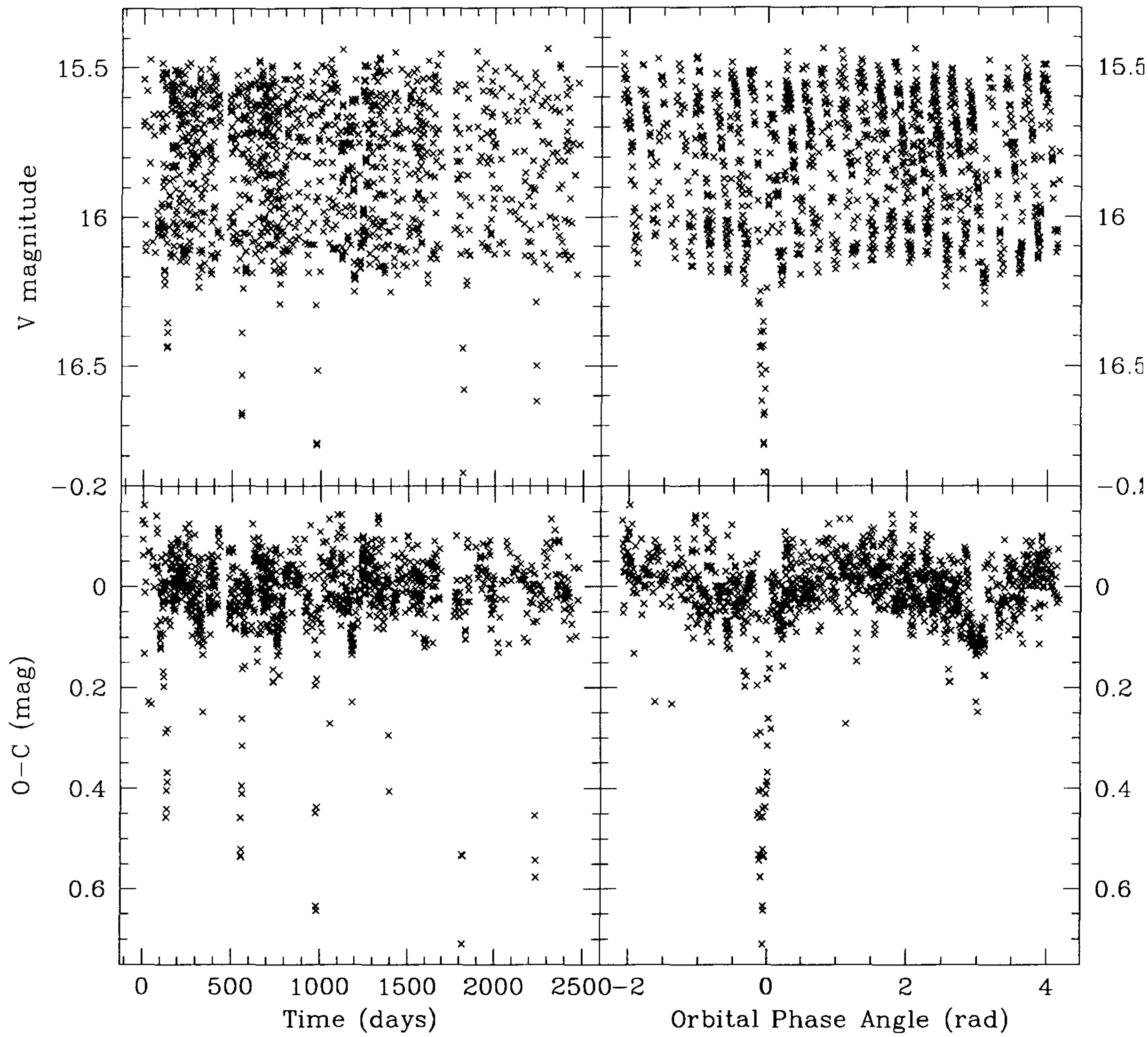

Figure 4.6: V lightcurve and observed minus calculated diagrams for 78.6338.24. V magnitude and O-C both as a function of time and phased to the orbital period. Note the curved shape of the phased O-C diagram between the primary and secondary minima.

4.1.3 81.8997.87

Unlike the other two systems the variable in 81.8997.87 is definitely an intermediate-mass Cepheid, pulsating in the first overtone mode. Also, the Cepheid is the primary in the system and the companion is a cooler and dimmer star. The final, primary-variable configuration is shown in Table 4.3, with a χ_v^2 of 5.4. By comparison the χ_v^2 was 7.8 for the case of the variable as the secondary.

The amplitude of the radial pulsations is only 0.82% of the Cepheid radius. This small value is consistent with the general properties of overtone Cepheids [Gieren 1982]. The errors in the values of J_λ are considerable ($\sim 45\%$). The absence of a significant secondary eclipse makes the surface brightness of the secondary very difficult to constrain. As the surface brightnesses in each band are determined relative to one another, this produces a higher error in J_λ for the primary.

The most distinctive feature of overtone Cepheids is the lightcurve shape, which can be parameterized by R_{21}, the ratio of the amplitudes of the first two Fourier components . Figure 4.9 shows the values of R_{21} for the V band magnitude fits for all MACHO LMC Cepheids with periods between 2.0 and 2.1 days [Welch 2000, private communication]. The plot divides cleanly into two regimes: Cepheids pulsating in the fundamental mode appear at the top of the figure, overtone pulsators appear in the lower region. A higher value of $R_{2,1}$ indicates a more significant second term in the Fourier series and thus a less sinusiodal lightcurve. The black square is the R_{21} for the V band surface brightness variation from the best fit. It falls clearly within the overtone region.

The paucity of observational data on this system in eclipse make it difficult to constrain the parameters. Figure 4.7 shows only three primary eclipses, only two of which have significant observational coverage. The observations of the secondary eclipses (Figure 4.8) show no evidence for any decrease in flux. This is consistent with

Table 4.3: Best-fit parameters for 81.8997.87

Parameter definition are the same as in Table 4.1.

χ_v^2	5.456		
P_{orb}	800.9 $\pm$ 0.1 days		
i	81.0 $\pm$ 1.7 degrees		
Variable	(primary)	Companion	(secondary)
R_{min}	0.017 $\pm$ 0.005	R	0.15 $\pm$ 0.03
J_V	1197.6 $\pm$ 551.2	J_V	0.9
J_R	1180.1 $\pm$ 527.0	J_R	1.2
J_I	1117.8 $\pm$ 490.6	J_I	2.0
x_V	0.5 $\pm$ 1.3	x_V	0.5 $\pm$ 60.5
x_R	0.5 $\pm$ 1.3	x_R	0.5 $\pm$ 35.0
x_I	0.5 $\pm$ 1.3	x_I	0.5 $\pm$ 87.9
P_{ceph}	2.034901 $\pm$ 0.000008	days	
ΔR_{amp}	0.0001 $\pm$ 0.0002		
ΔR_{shift}	0.48 $\pm$ 0.08 days		
Variation in J			
	V Band	R Band	I Band
A_1	-109.2 $\pm$ 57.3	-81.3 $\pm$ 42.1	-56.8 $\pm$ 28.1
B_1	32.8 $\pm$ 19.9	24.9 $\pm$ 16.3	-33.0 $\pm$ 20.3
A_2	-10.1 $\pm$ 5.9	-2.6 $\pm$ 2.9	10.7 $\pm$ 6.0
B_2	-12.6 $\pm$ 6.9	-8.1 $\pm$ 4.4	6.4 $\pm$ 3.7
A_3	0.9 $\pm$ 1.7	0.4 $\pm$ 1.2	1.1 $\pm$ 1.9
B_3	-0.1 $\pm$ 1.8	-2.6 $\pm$ 2.0	8.7 $\pm$ 4.5
C_1	114.0 $\pm$ 60.6	84.9 $\pm$ 45.0	65.7 $\pm$ 34.5
ϕ_1	3.4 $\pm$ 0.3	3.437 $\pm$ 0.328	2.6 $\pm$ 0.5
C_2	16.1 $\pm$ 9.0	8.481 $\pm$ 5.117	12.4 $\pm$ 7.1
ϕ_1	2.2 $\pm$ 0.6	1.887 $\pm$ 0.489	5.7 $\pm$ 0.5
C_3	0.9 $\pm$ 2.0	2.632 $\pm$ 2.157	8.7 $\pm$ 4.7
ϕ_1	0.2 $\pm$ 2.2	1.429 $\pm$ 0.572	4.8 $\pm$ 0.3
R_{21}	0.1 $\pm$ 0.2	0.100 $\pm$ 0.113	0.2 $\pm$ 0.2
ϕ_{21}	1.7 $\pm$ 1.2	1.298 $\pm$ 1.145	0.5 $\pm$ 1.5
R_{31}	0.008 $\pm$ 0.021	0.031 $\pm$ 0.042	0.1 $\pm$ 0.1
ϕ_{31}	2.4 $\pm$ 3.1	3.685 $\pm$ 1.556	3.3 $\pm$ 1.7

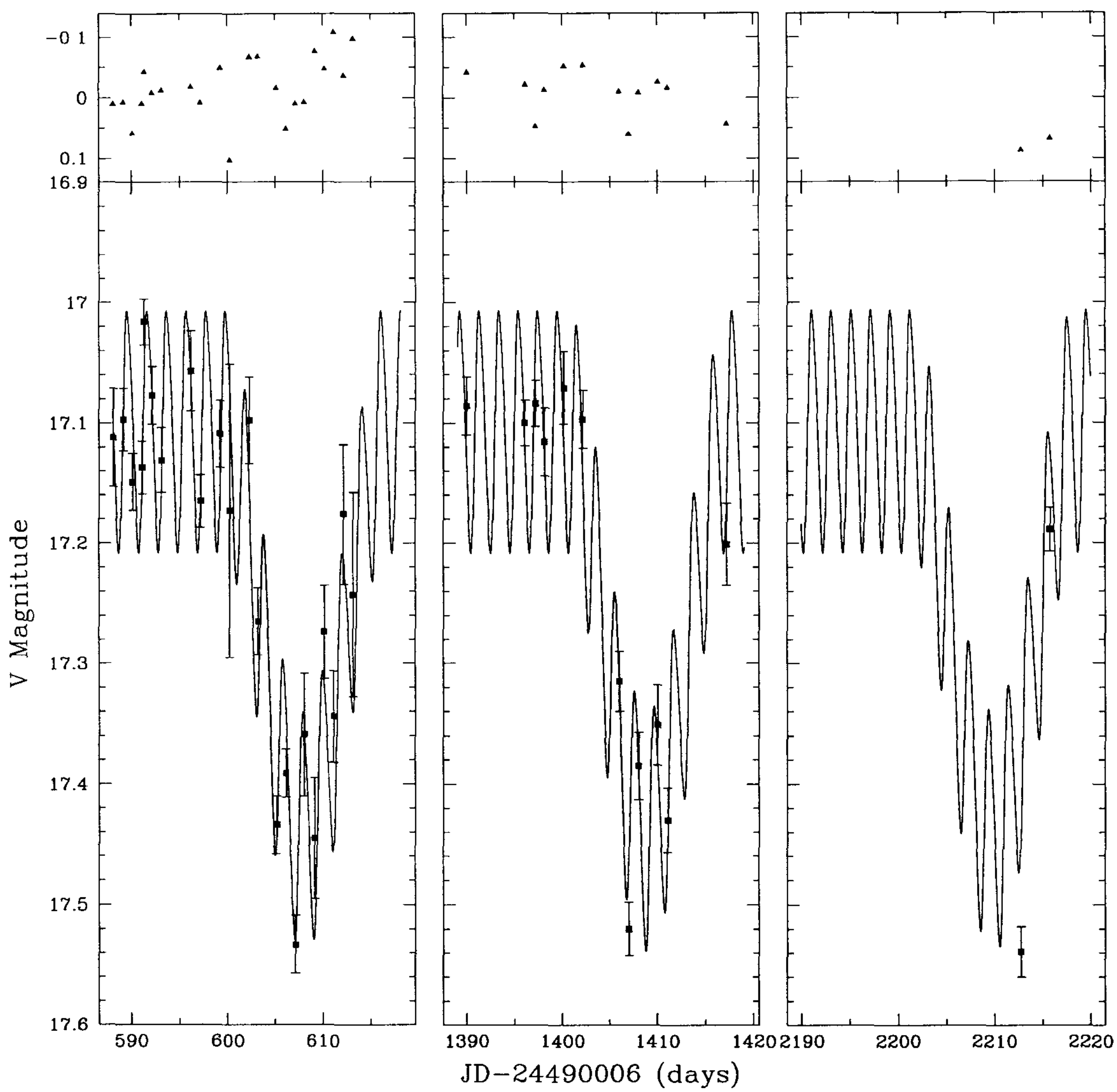

Figure 4.7: Primary eclipses of 81.8997.87 in V with curve of best fit. Upper panels show residuals in magnitudes.

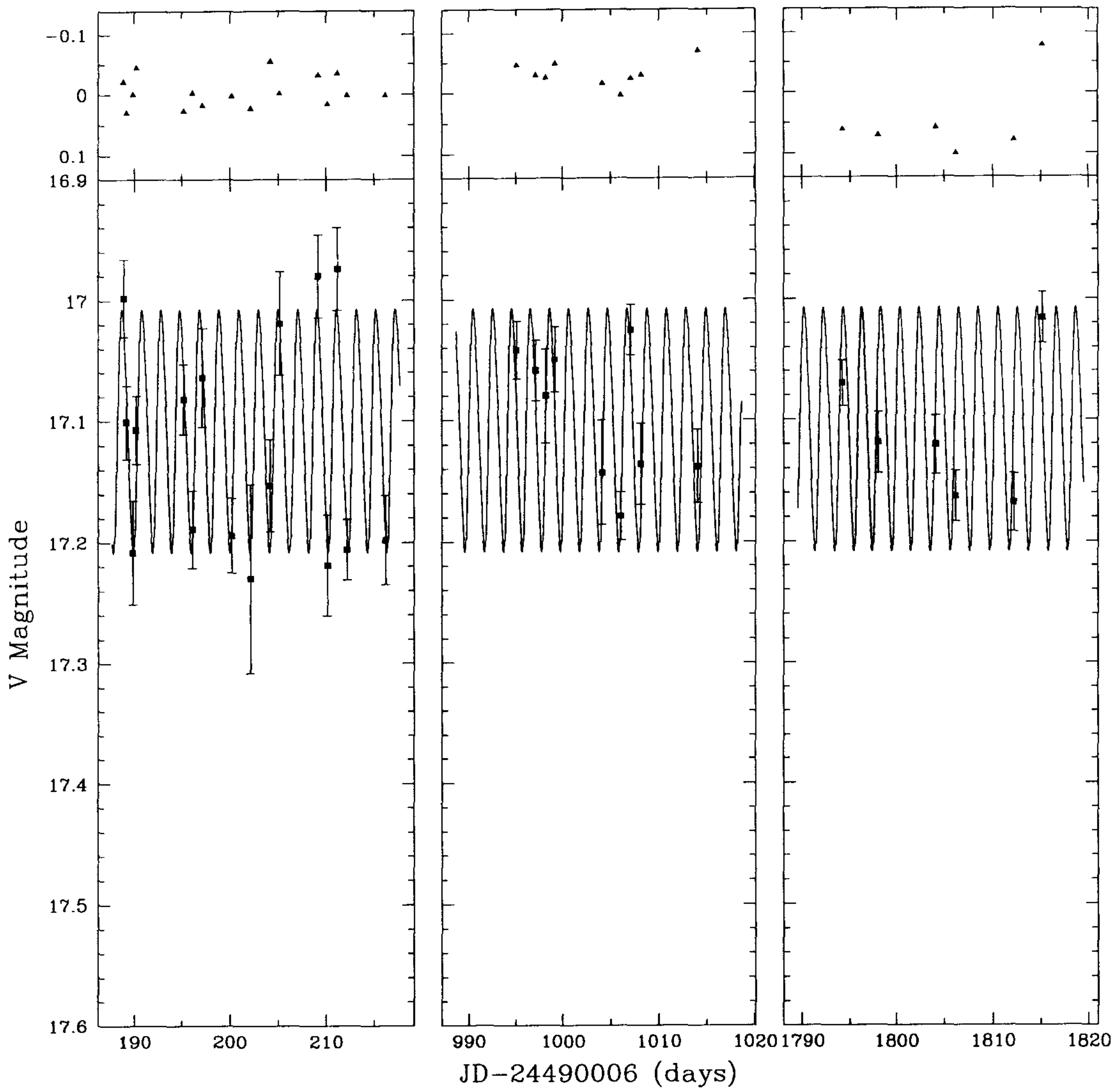

Figure 4.8: Secondary eclipses of 81.8997.87 in V with curve of best fit. Upper panels show residuals in magnitudes.

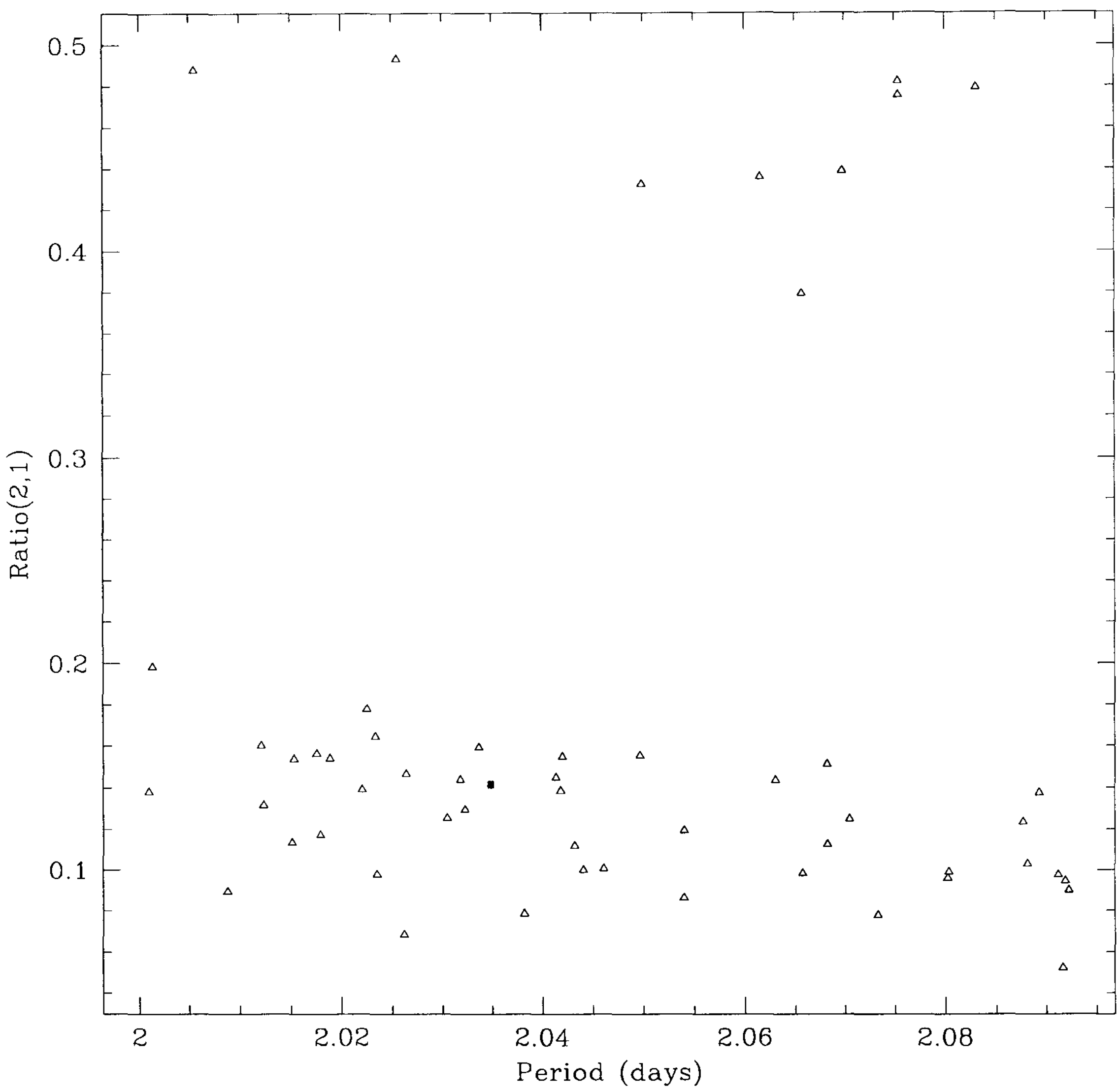

Figure 4.9: R_{21} for LMC Cepheids
Triangles show values of R_{21} for LMC Cepheids form MACHO project database and the filled square is the fit to the variable in 81.8997.87 (with the effect of the companion's flux removed). Overtone pulsators appear in the lower region of the plot and fundamental mode pulsators in the upper region.

the interpretation of a cool, dim secondary. The limb-darkening coefficients remain at their initial values of 0.5 for both stars in both filters.

4.1.4 Comparison of Systems

To compare the results for the three systems we can compute the magnitudes and colours of their constituent stars. A mean magnitude (m_{system}) in each filter was computed for each system by taking a weighted average of all the magnitude observations in each filter. These mean values served as reference magnitudes to convert all magnitude observations into intensities prior to fitting. The amount of light received from the constant companion star (in each filter) is calculated from the best-fit values of R, J_o and x_λ and equation 3.11. For the variable stars, the intensity was calculated at 100 evenly spaced points over a single pulsation period. The average of these values was adopted as the intensity-weighted mean light received from the variable. The apparent magnitude of each star can then be found from

$$m_{star} = m_{system} + 2.5 \cdot log_{10}\left(\frac{L_{system}}{L_{star}}\right) \tag{4.2}$$

where L_{system} has been normalized to 1.0. These results are tabulated in Table 4.4 along with each variable's W_R value. W_R is a quantity that removes most of the effects of reddening and effective temperature differences from a magnitude determination. It is defined by

$$W_R = R - 4.0\,(V - R)\,. \tag{4.3}$$

Values of W_R allow us to compare our results to the properties of other LMC Cepheids prior to reddening correction. However, in calculating W_R we increase the uncertainty in our magnitude values. If the error in V and R are of the same order, the error in W_R will be, roughly, a factor of six larger. The uncertainty ranges in Table 4.4 and all subsequent figures were calculated from the range of allowable system parameters based on the error ranges in each system's best-fit parameter set.

Figure 4.10 shows a period-luminosity diagram for 1766 variable stars in the

Table 4.4: Derived magnitudes for systems and their components. All values are in magnitude units. For the Cepheids the tabulated magnitudes represent intensity-weighted mean magnitudes.

		V	R	I	W(R)
6.6454.5	mean system	14.654	14.558		
	primary	15.057±0.06	15.059±0.06		
	variable	15.66±0.17	15.37±0.12		14.21±0.08
78.6338.24	mean system	15.763	15.347		
	primary	16.945±0.007	16.780±0.009		
	variable	16.027±0.006	15.502±0.006		13.401±0.003
81.8997.87	mean system	17.100	16.410	15.734	
	variable	17.2±1.4	16.5±1.4	15.9±1.4	13.8±1.3
	secondary	20.2±2.8	19.3±2.5	18.0±2.0	

LMC with the Cepheids studied here indicated. 81.8997.87 falls within the overtone band (the brighter sequence at a given period) and 78.6338.24 is among the Type II Cepheids (faint band in the lower right). 6.6454.5 seems to be brighter than a Type II Cepheid would be at that period yet clearly fainter than a fundamental mode classical Cepheid (sequence extending to longer periods).

4.2 Radial Variation

Cepheids are believed to be radial pulsators as outlined in Section 1. However, the change in radius has never been directly observed. Rather it has been inferred from radial velocity measurements. Integration of the radial velocity curve and correction for projection effects gives a radial displacement curve (Figure 1.1).

The difficulty in the present work was outlined in Section 3: with only photometric data the radial variation is only seen through its effect on the total flux and outside of eclipse this is degenerate with the temperature change and/or changes in companion properties. It is possible that the fitting process does not actually capture the radial variation. Another possibility is that the effects of the radial change can

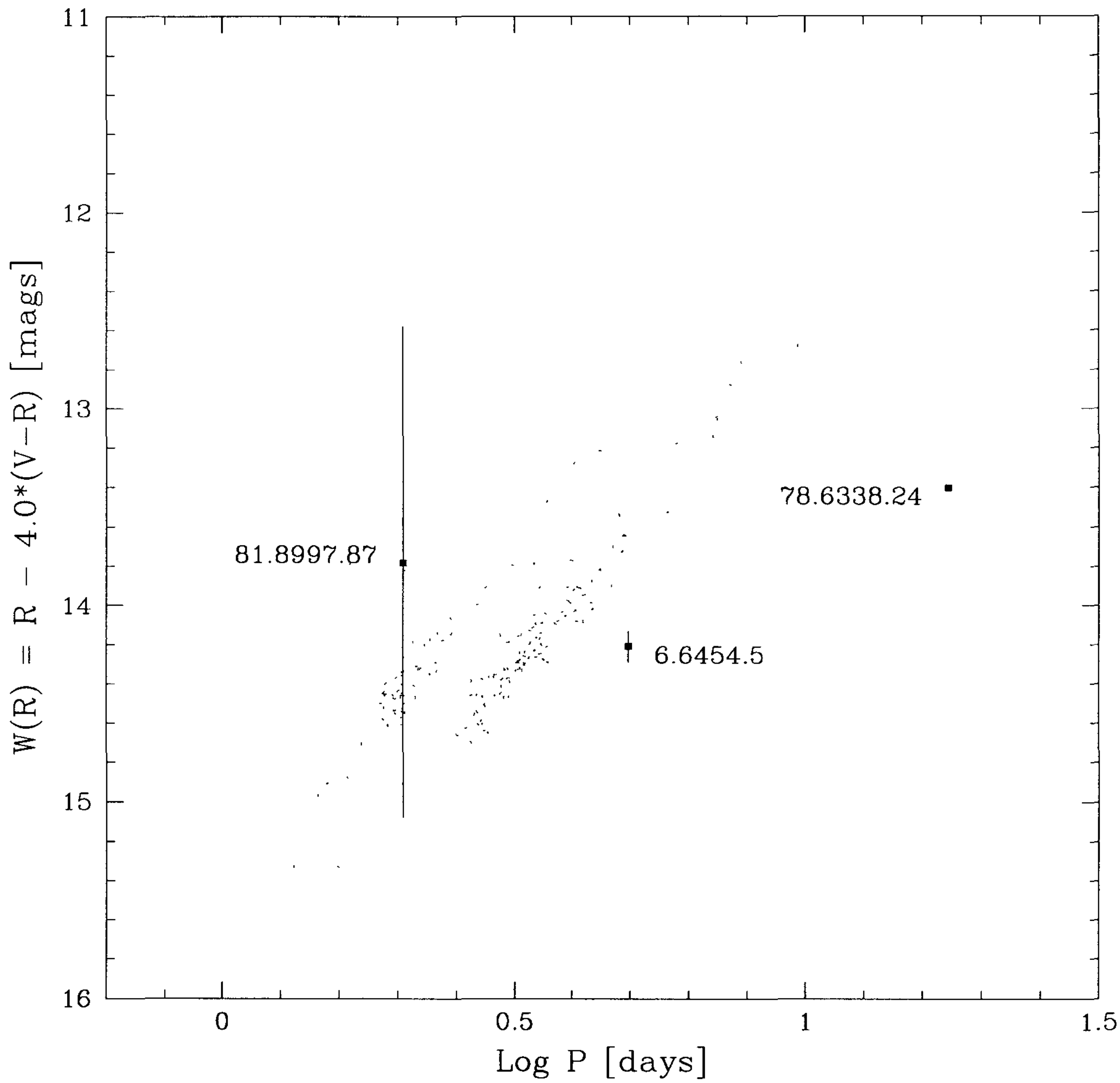

Figure 4.10: Period-Luminosity Relation for LMC Cepheids
W_R vs $log_{10}P$ for 1766 Cepheid variable stars observed by the MACHO project. The brighter sequence at a given period are Cepheids pulsating in the first overtone and the sequence extending to longer periods are fundamental mode pulsators. Stars in the lower right are Type II Cepheids.

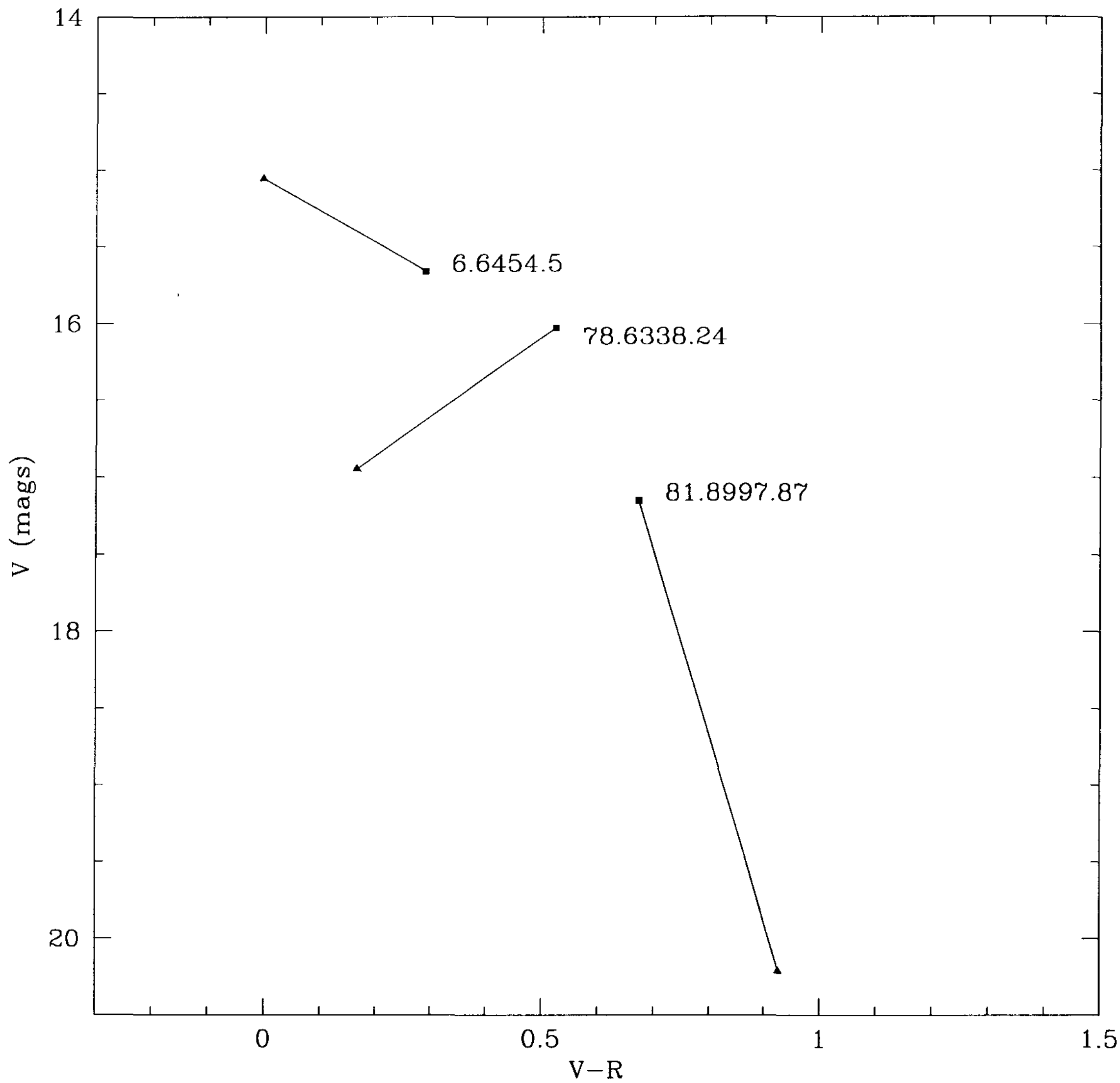

Figure 4.11: Colour-Magnitude Diagram
Filled squares represent the Cepheids, triangles their companions and lines connect members of the same system. Comparison of the relative brightnesses of the Cepheids in this plot and in Figure 4.10 gives an indication of the amount of extinction each system likely suffers.

be modeled equally well by modifying the surface brightness variation.

To evaluate the degree to which the inclusion of radial change improves the fits, all three systems were re-analysed with the amplitude of the radial velocity change held fixed at 0. The result for 6.6454.5 was an increase in the best fit χ_v^2 from 2.5 to 12.3. For 81.8997.87 χ_v^2 increased from 5.5 to 12.5. For 78.6338.24 the effect was much more modest, an increase from 11.9 to 12.1. In each system we see that radial variation can be inferred from the lightcurve alone with varying degrees of success.

The relative difference in the size of the effect is a product of both the properties of the individual systems and the relative quality of the observations. 6.6454.5 was found to have a very large radial amplitude so its significant contribution to the fit is to be expected. The short pulsation period, 4.97 days, relative to the duration of the eclipse, ~12 days, allows several cycles of the flux change due to the Cepheid pulsation to be observed during the eclipse. It is this variation during eclipse that allows accurate determination of the radial parameters. Although the relative radius change in 81.8997.87 is much smaller, its inclusion still has a significant effect on final fit. Again, Figure 4.7 shows several Cepheid periods within one primary eclipse. Radial variation has little effect on the fit for 78.6338.24 and Figure 4.4 shows that the primary eclipses show very little evidence of the Cepheid variation as the pulsation period and duration of the eclipses are both on the order of 20 days. This system also presented significant challenges to modelling: the need to correct for "period drift", and the possible oblateness of the components. It is likely that the contributions of these model inadequacies to the value of χ^2 would dwarf the effects of the radial amplitude.

4.3 Third Light

In eclipsing binary work the generic term "third light" is used to refer to any additional source of flux other than the eclipsing pair. In most cases this is a third star whose separation from the other two stars is large relative to their separation from each other. The three stars may or may not form a gravitationally bound system. The light from this source is generally assumed to be independent of time or phase. In general the effect of a third source of light is to simulate a system of lower inclination. It does this by decreasing the depth of the eclipses; addition of a constant flux reduces the amount of variation relative to the normal emergent flux [Kallrath and Milone 1999].

In our study, the effects can be more varied since one of the stars is intrinsically variable. Thus far we have considered the possibility that the variable star can be either the primary or the secondary component of the system and have seen examples of each. To this we must add the possibility that the variable star is the third light source and the eclipsing pair consists of two constant stars.

A factor arguing strongly for the Cepheid as member of eclipsing system is the detection of its radial variation. As mentioned earlier the effects of radial variation on the resultant light curve of an isolated Cepheid will be degenerate with the change in surface brightness. The fact that the radial change can be observed in all three systems is a strong indicator that the Cepheids are components of the eclipsing systems.

The possibility of an additional, unresolved source of flux is difficult to test. We assume there exists a constant source of flux L_3 in addition to the flux of the two eclipsing components. As the total light received from the system is normalized to 1.0 L_3 can range from 0 to 1.0 with a value approaching 1.0, implying that most of the emergent flux is provided by the third companion. A system such as this is unlikely to have been detected. To obtain only the light of the close binary components we subtract L_3 from each observation of the system light (L). As the code requires that the mean, out-of-eclipse flux be 1.0, we renormalize so that our new system light becomes:

$$L' = \frac{L - L_3}{1.0 - L_3} \tag{4.4}$$

Each system was fit with values of L_3 from 0.0 to 0.8 and resulting χ^2 values compared. The results are tabulated in Table 4.5.

Table 4.5: Third light testing
Resulting values of χ^2_v when various values of third light are assumed. L_3 is expressed as a fraction of the mean system light, which is normalized to 1.0.

L_3	6.6454.5	78.6338.24	81.8997.87
0.0	2.39	11.86	5.44
0.2	2.42	11.85	5.77
0.4	2.46	12.08	5.98
0.6	3.24	12.59	6.76
0.8	3.02	20.68	7.66

For the systems 6.6454.5 and 81.8997.87, an increase in χ^2 is seen if an additional source of flux is assumed. For 78.6338.24 a small decrease is seen but an F-test confirms that this decrease is not statistically significant. From this we can conclude that the systems in question each consist of only two luminous stars.

4.4 Evolutionary Context

Individual magnitude and colour data for both of the stars in each of the systems, combined with the assumption that all are members of the LMC, allow us to infer their evolutionary state. This analysis is facilitated by several constraints that are placed on pulsating binary systems. The current picture of binary star formation is that the two components condensed from the same protostellar cloud, thus forcing them to have the same age. Some binaries may be the result of one star capturing another, in which case their ages may differ. As this is only likely in dense stellar clusters where the rate of stellar interactions is non-negligible, this explanation will not be considered here. Pulsation places a strong constraint on how far the system has evolved as it occurs for a very brief period of the star's life.

Comparisons with published evolutionary tracks and isochrones will be facilitated by converting our results from the $m_V - (V - R)$ plane to the $L - T_{eff}$ plane. The luminosity of a given star is

$$log\left(\frac{L}{L_{\odot}}\right) = -\frac{2}{5}\left(m_V + BC_V - \mu_{LMC} - M^{\odot}\right) \tag{4.5}$$

where m is the apparent magnitude and $M^{\odot}$ the absolute bolometric magnitude of the sun. For the distance modulus to the LMC $\mu_{LMC} = (m - M)$ we will adopt a "canonical" value of 18.5 mag. For each star, the bolometric correction, BC, was taken from the tables in [Lang 1992]. $M^{\odot}$ is taken to be 4.802 mag [Bessell, Castelli, and Plez 1998].

For temperature conversion we adopt the [Rorabeck 1997] transformation of [Chiosi, Wood, and Capitanio 1993] semi-empirical calibration

$$\log T_{eff} = 4.199 - \sqrt{0.08369 + 0.3493(V - R)} \tag{4.6}$$

The three systems probably suffer from differing amounts of extinction and reddening due to obscuration along the line of sight. An indication of this is the changing relative brightness of the three variable stars from Figure 4.11 to Figure 4.10 where W_R corrects (but possibly overcorrects) for some of the effects of extinction. A different correction must be applied to each system.

A correction for 78.6338.24 has already been derived by [Alcock *et al.* 1998] in an analysis of Type II Cepheids and RV Tauri stars in the LMC. A colour excess of $E(B-V) = 0.08$ mag was adopted from a map of foreground colour excess towards the LMC [Schwering and Israel 1991]. The standard value of the ratio of total to selective extinction $R_V = A_V/E(B-V) = 3.1$ [Cousins 1980] and $A_R/A_V = 0.77$, derived from the interstellar extinction law of [Cardelli, Clayton, and Mathis 1989] were used to obtain values for A_V and A_R. This value only takes into account extinction due to the galactic foreground and neglects any effects in the LMC or the systems themselves.

Here we will assume that the variable stars being observed are Cepheids and thus should appear in the instability strip. By inspection, we adopt colour excesses needed to move the Cepheids into the CIS and then apply those corrections to the companions as well. While this process is not definitive, it will suffice to provide an approximate location of the system components in the HR diagram to allow comparisons with theoretical work.

As discussed in Section 1, Type I and Type II Cepheids are believed to originate from different stellar populations and to evolve on different timescales. Accordingly, we should use evolutionary tracks and isochrones of different metallicities and ages for the two regimes. For Population I objects we show Y=0.25 Z=0.008 isochrones from [Bertelli *et al.* 1994] in Figure 4.13 and evolutionary tracks for intermediate mass stars of the same metallicity from [Fagotto *et al.* 1994b] in Figure 4.12. Figure 4.14 shows 0.60 and $0.8M_\odot$ evolutionary tracks for Y = 0.230 Z = 0.0004 objects from [Fagotto *et al.* 1994a] representing Population II evolution up to the horizontal branch. Post-horizontal branch and post-asymptotic giant branch evolution is shown in Figure 4.15 for low metallicity stars with a variety of core masses [Dorman, Rood, and O'Connell 1993]. Each plot shows the locations of the theoretical fundamental and overtone instability strips from [Chiosi, Wood, and Capitanio 1993] for the appropriate metallicity. The results for each system are also shown on appropriate plots. 6.6454.5 appears in all plots because of uncertainty about its classification as Type I or Type II Cepheid.

In order to contain an overtone Cepheid, the system 81.8997.87 must be

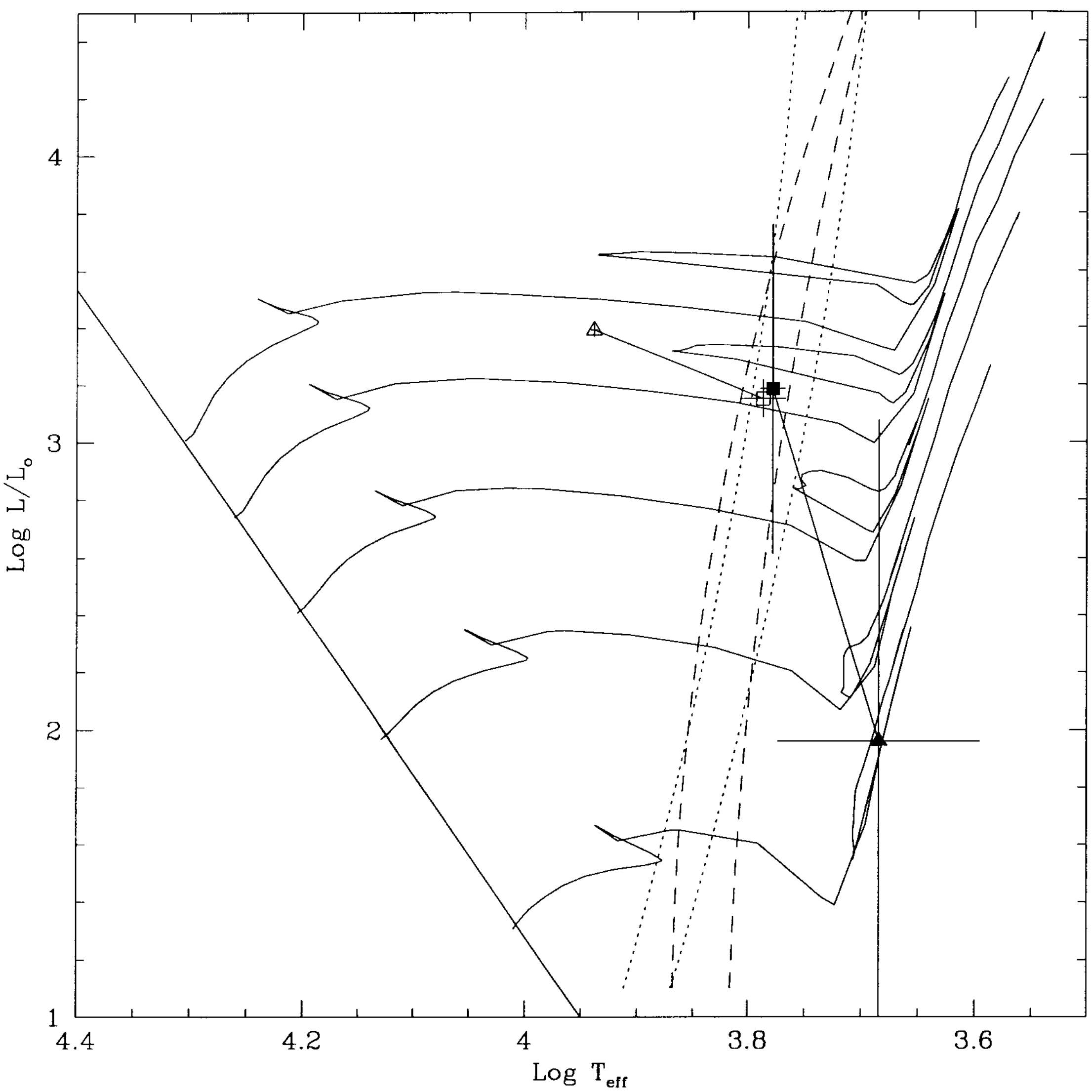

Figure 4.12: Evolutionary tracks for intermediate mass stars 81.8997.87 (filled symbols) and 6.6454.5 (open symbols) components along with evolutionary tracks for 2, 3, 4, 5 and $6M_\odot$ stars with Y = 0.25 Z = 0.008 [Fagotto *et al.* 1994b]. Squares denote Cepheids, triangles their companions. Instability strip is from [Chiosi, Wood, and Capitanio 1993].

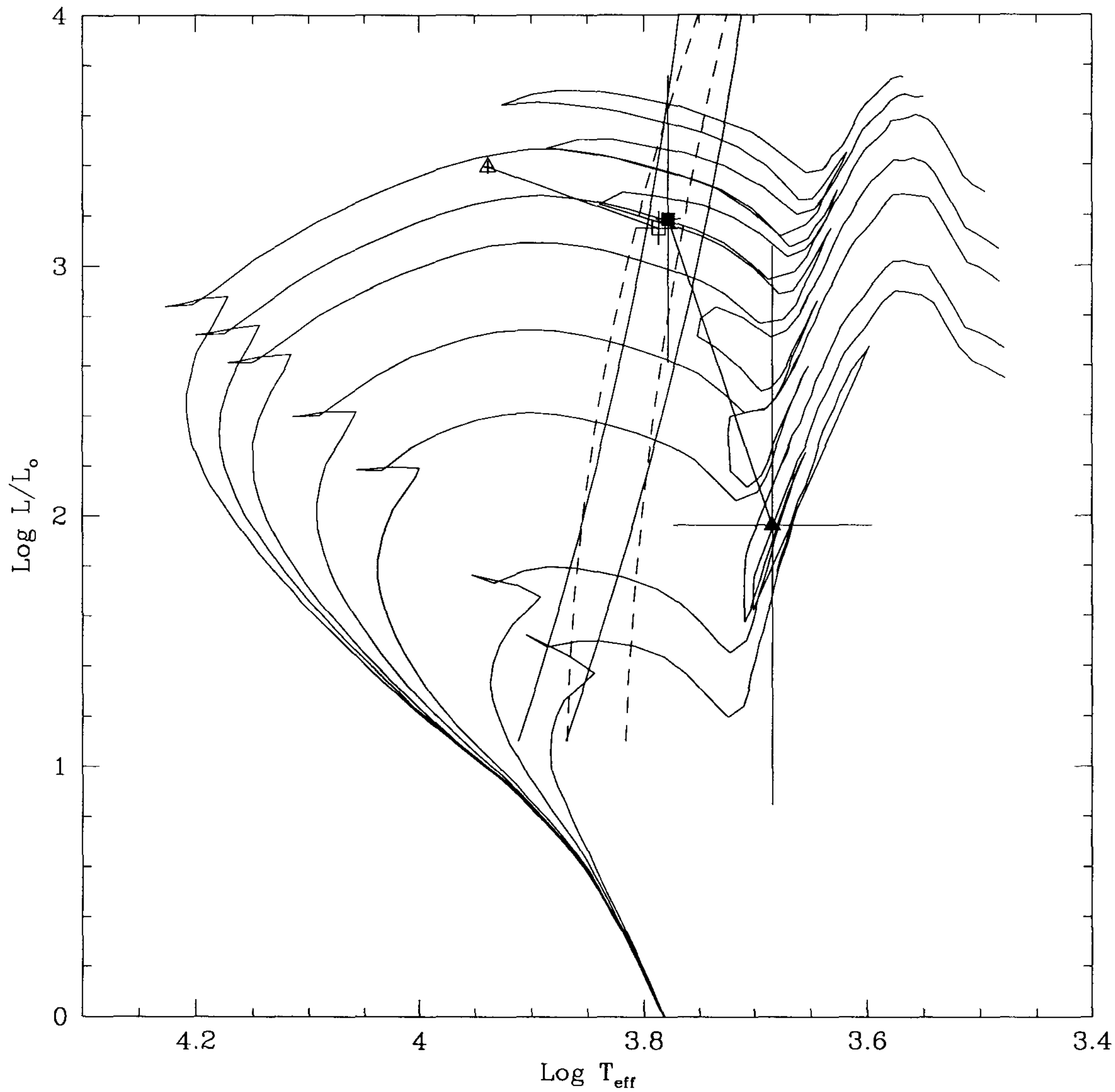

Figure 4.13: Isochrones for young stars
81.8997.87 (filled symbols) and 6.6454.5 (open symbols) components with theoretical isochrones for Y = 0.25 Z = 0.008 stars [Bertelli *et al.* 1994]. Isochrones range from log(age)=9.1 to log(age)=7.9 [years]. Instability strip is from [Chiosi, Wood, and Capitanio 1993].

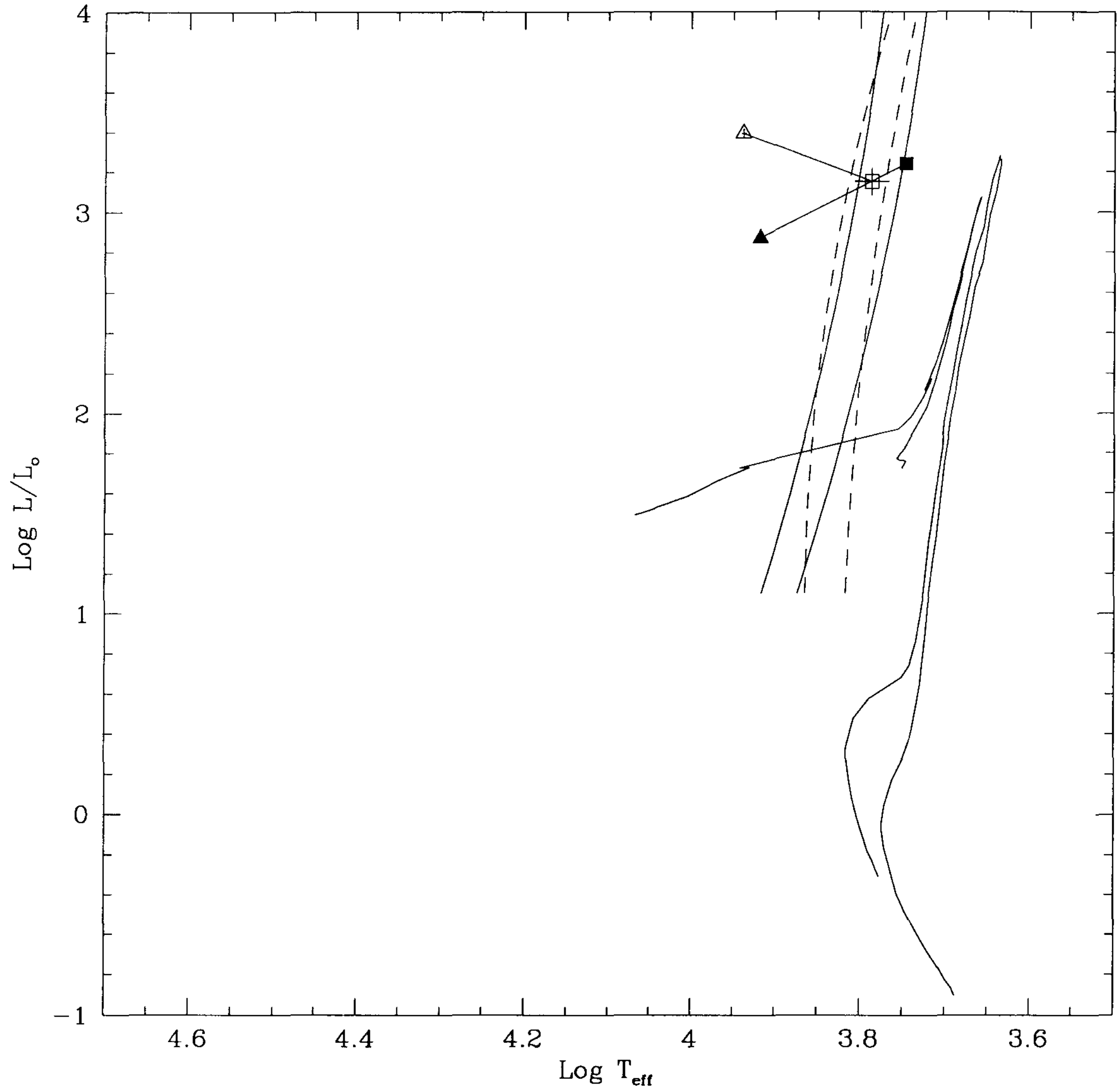

Figure 4.14: Low mass evolutionary tracks
Evolutionary tracks for a $0.6M_\odot$ $0.8M_\odot$ stars with Y=0.230 Z=0.0004 from [Fagotto *et al.* 1994a] with [Chiosi, Wood, and Capitanio 1993] instability strip. 6.6454.5 (open symbols) and 78.6338.24 (filled symbols) components are shown.

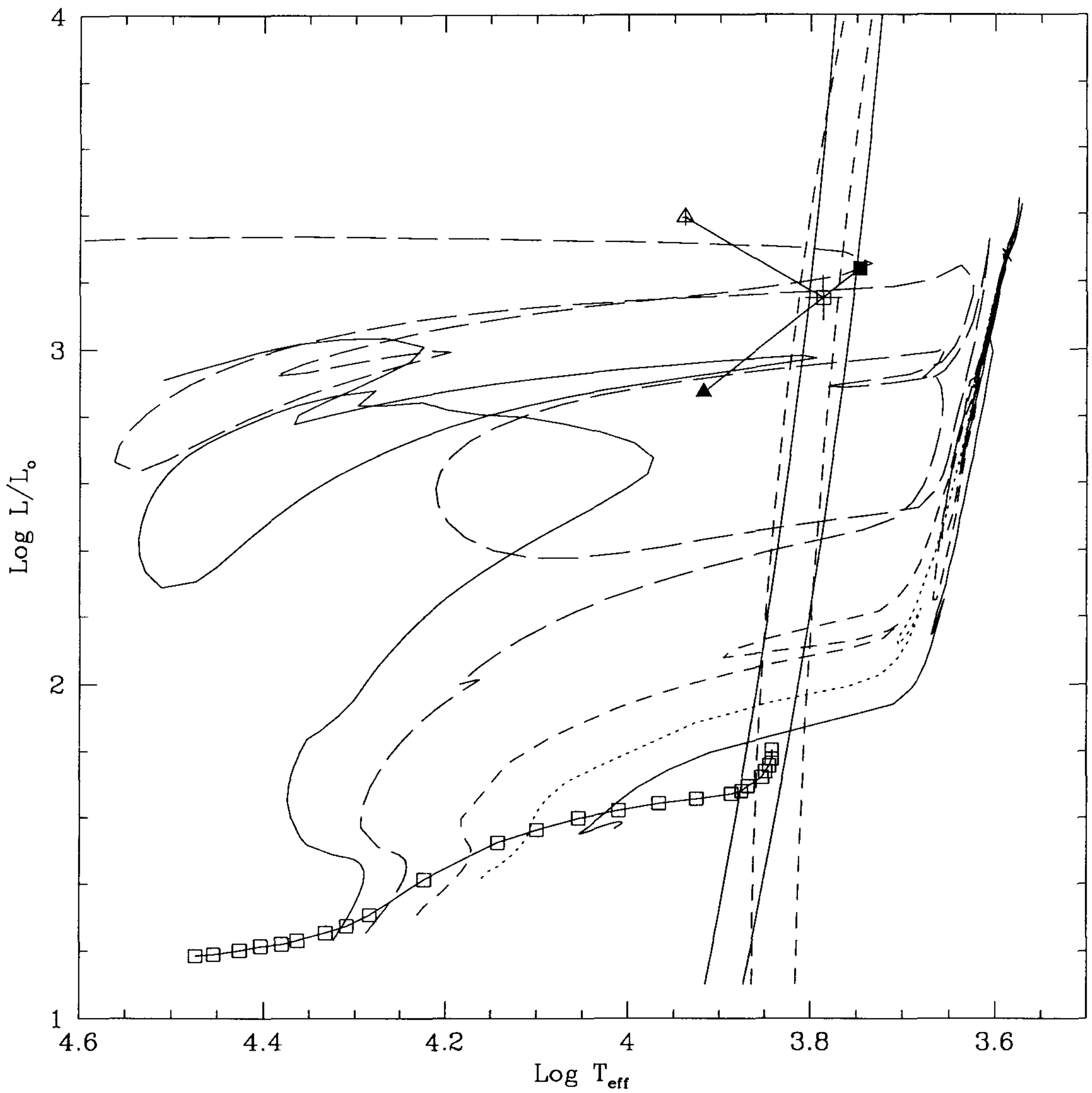

Figure 4.15: Post-Horizontal branch evolution
Post-horizontal branch evolutionary tracks for various core masses and a Y=0.250 Z=0.0006 zero-age horizontal branch (open squares) from [Dorman, Rood, and O'Connell 1993] with [Chiosi, Wood, and Capitanio 1993] instability strip. 6.6454.5 (open symbols) and 78.6338.24 (filled symbols) components are shown.

population I, or relatively young. This Cepheid is reasonably consistent with a $4-5M_{\odot}$ evolutionary track. The companion's location indicates it is most likely a red giant, probably K type, of somewhat lower mass, most likely $< 2M_{\odot}$. However the system is a very poor fit to the isochrones shown in Figure 4.13. The luminosity difference between the two stars is larger that would be expected for a system in this age range. Indeed any system consisting of only these two stars may be evolutionarily inconsistent.

The long period of the Cepheid component of 78.6338.24 indicates that it is a W Vir class (Type II) object. Its location in Figure 4.15 is consistent with this interpretation: it is best fit by tracks making blue loops off of the AGB due to shell helium flash. Its companion is also considerably evolved. It has definitely moved past the HB stage and is either moving toward the AGB or, like the Cepheid, making some sort of blue-loop excursion from the AGB. The lightcurve of this system showed some evidence for asphericity of one of the components and the fit showed non-standard behaviour of the limb-darkening coefficients. Both these features are consistent with a star having a large radius and a tenuous outer envelope. This would also account for the observed "period drift": the trajectory of weakly bound material at the surface of the star can be different from that of more strongly bound layers.

If 6.6454.5's variable is in fact a Type II Cepheid, its period (less than 5 days) suggests it should be BL Her type star, evolving off the HB, towards the AGB, as it begins double shell burning. Its location in Figure 4.15 seems inconsistent with this interpretation. The Cepheid is far too luminous, occupying a region populated with post-AGB stars. The companion would also be over-luminous. Its location suggests it is leaving the AGB for the last time, evolving towards the planetary nebula and white dwarf stages. The excessive brightness of both components raises the possibility that this system is not in the LMC but a foreground object in the Galactic halo. The assumed distance to the system must be reduced to roughly 17.8 kpc to make the Cepheid's calculated luminosity consistent with the post-HB tracks in Figure 4.15.

If the variable is instead an under-luminous classical Cepheid in the LMC we should compare its parameters to the higher metallicity tracks and isochrones of Population I stars. In Figures 4.13 and 4.12 we see that the Cepheid is consistent with the tracks of 4.5 - $5M_{\odot}$ stars in either its first crossing or first blue loop. The more evolved companion is too blue to fit the tracks or isochrones shown.

Comparing the system parameters to the isochrones and tracks presented forces us to draw one general conclusion: none of these systems seem consistent with standard, single-star evolutionary theory. Our initial assumption that no interaction had occurred between the components of these systems might not be correct. 6.6454.5, with a smaller orbital period and two evolved stars, is the most likely candidate for mass transfer between its components.

We must also allow for the possibility that these may be multiple, rather than binary systems. If the additional companions are quite dim they will contribute very little to the observed flux of the system and therefore any testing for third light contamination would be unlikely to detect them. Their only impact on the shape of the lightcurve would be secular changes due to their effects on the orbits of the visible components. Less luminous companions could be dimmed further by circumstellar dust extinction. This is potentially detectable as an infrared excess. Alternatively, the systems could be arranged hierachically with a single star (the Cepheid) in a long period orbit with a short period, close binary companion. Given the evolved nature of the components of such systems, mass transfer between companions could have occurred. This could be the case for 81.8997.87 where the companion itself is a much fainter star.

Chapter 5

Conclusions

We have presented observations and analysis of three eclipsing Cepheids in the LMC. This has allowed us to infer the inclinations, relative radii, and magnitudes of the binary components. We have also determined the brightness and radius change of the pulsating components.

5.1 Future Observations

The search for a normal Classical Cepheid in an eclipsing binary system is ongoing. The discovery and observation of such a system would allow the LMC distance and the Cepheid distance scale to be calibrated with unprecedented accuracy. At present two additional Cepheids in the MACHO database appear to be eclipsing variable systems.

The systems discussed here, while not fundamental mode classical Cepheids, are clearly very important and worthy of additional study.

Additional photometric observations of the eclipses of each system would allow their parameters to be constrained with even greater accuracy. Some of the observations listed in Appendix B, particularly I band observations of 6.6454.5, were

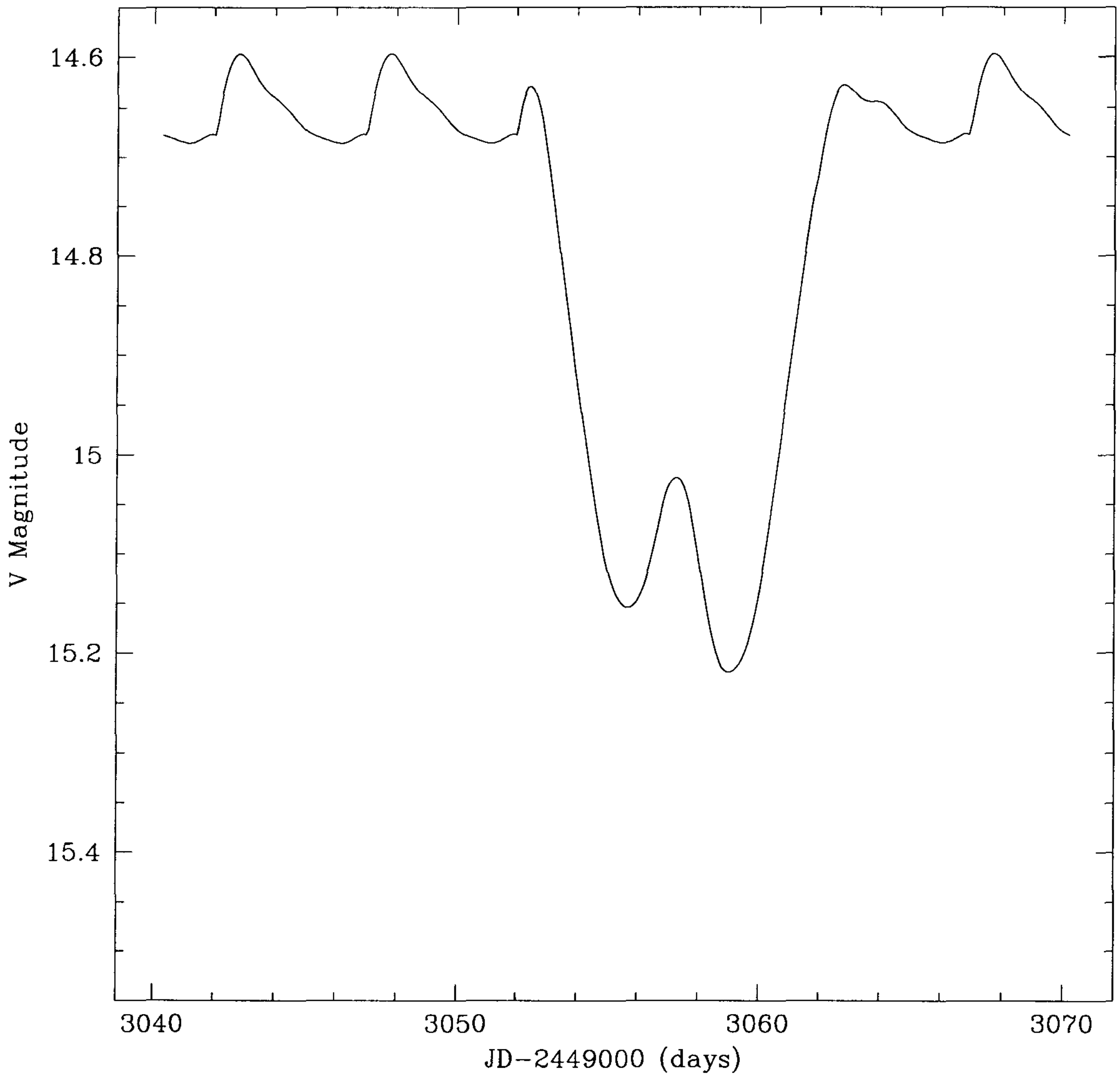

Figure 5.1: Next eclipse of 6.6454.5

Mid-eclipse is at JD = 2452057.6 or 14.6 UT May 27 2001.

not used in the present analysis but should be incorporated into any future work. Given the model and parameters presented here, we can predict the dates of future eclipses. Figures 5.1 - 5.3 show predicted lightcurves for all three systems for their next primary eclipse.

These lightcurves should facilitate future observations by allowing the predic-

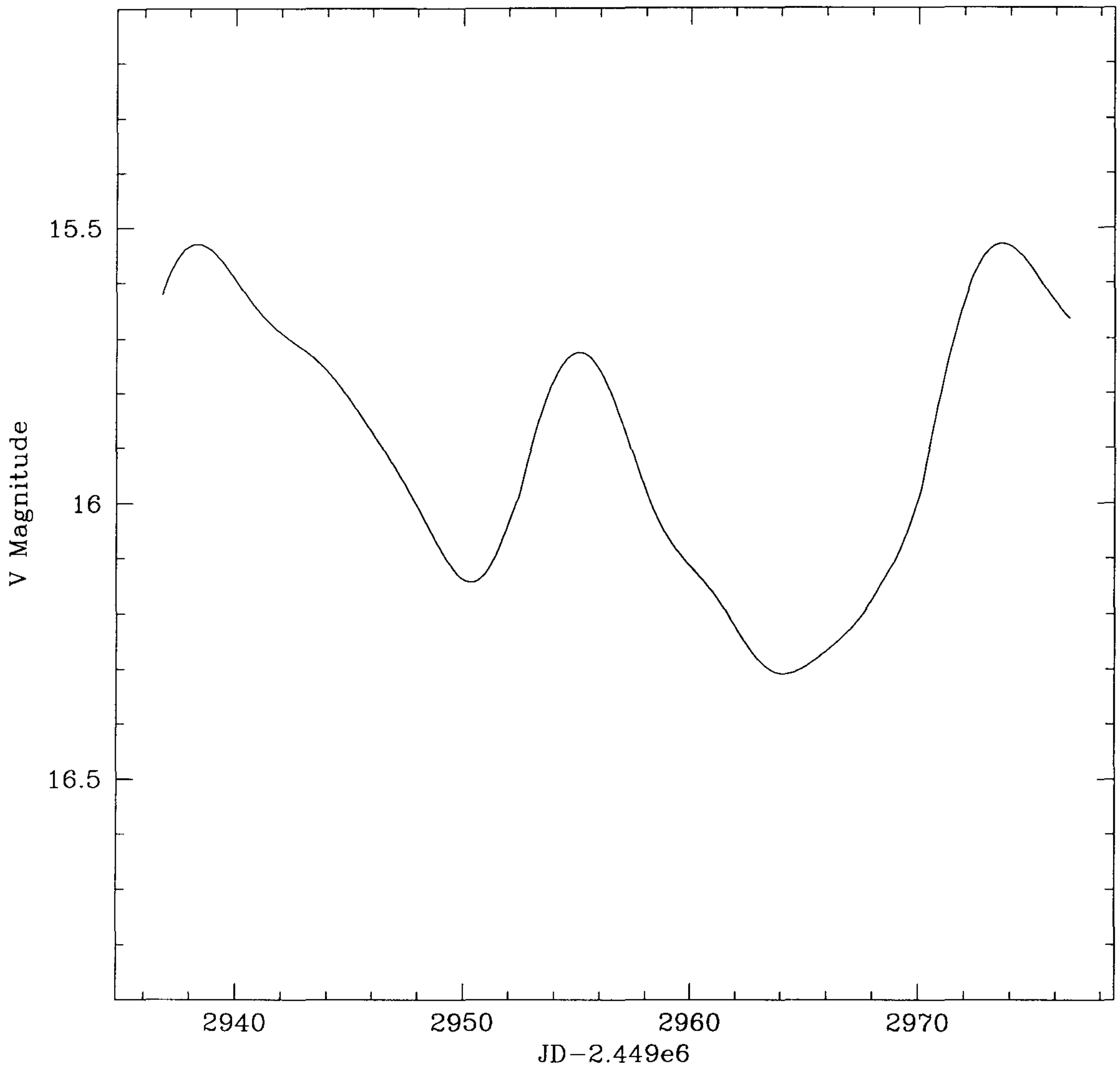

Figure 5.2: Next eclipse of 78.6338.24

Mid-eclipse is at JD = 2451960.3 or Feb 19 2001 6.3 UT. Note that the eclipse minima nearly coincides with a pulsation maxima. This produces a very shallow, unspectacular eclipse.

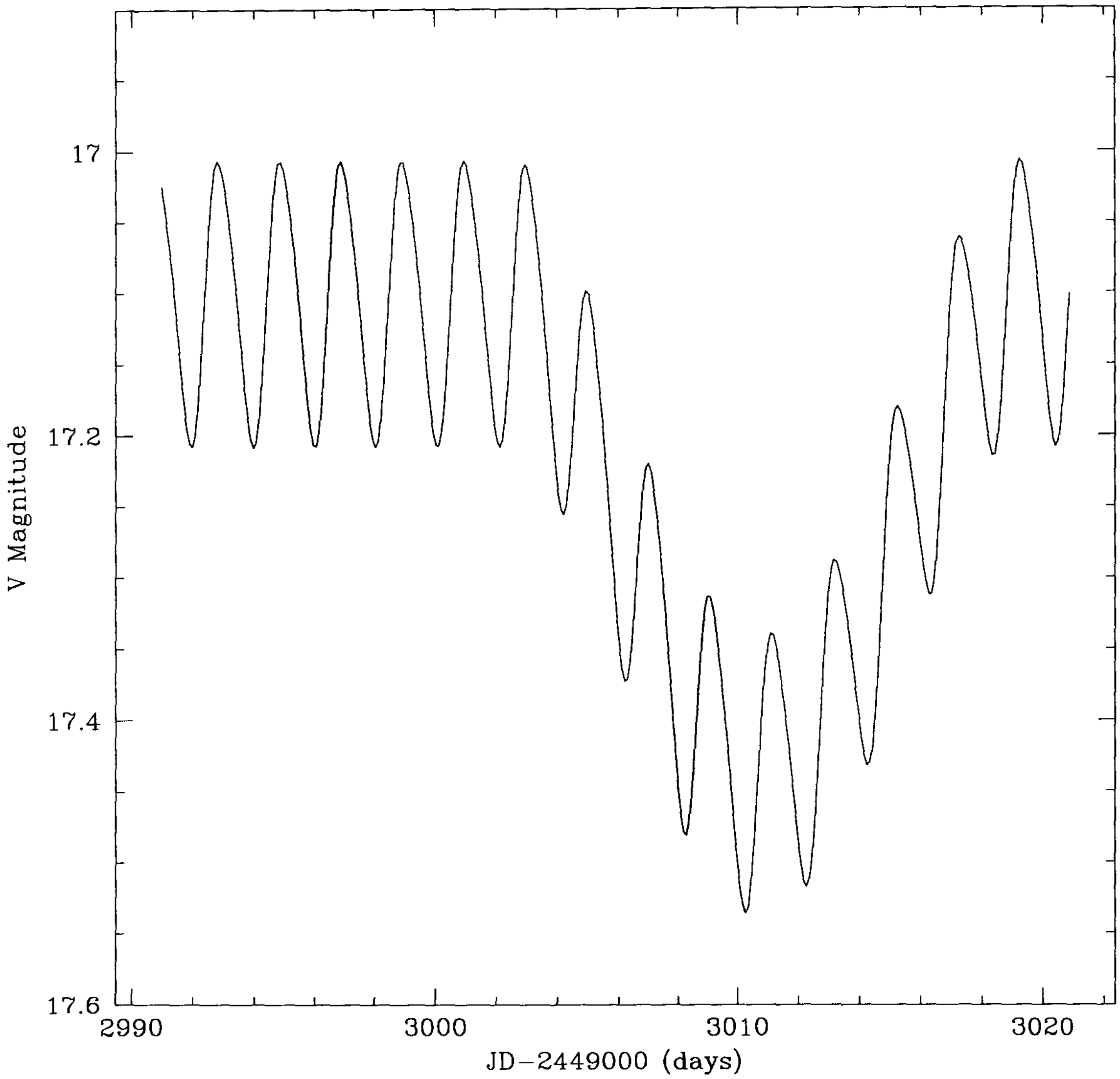

Figure 5.3: Next eclipse of 81.8997.87

Mid-eclipse is at 2452010.8 or Apr 10 2001 4 10 19.4 UT tion of times of specific features within the eclipses so that high-density observations may be obtained. Of particular importance would be observations of the next secondary eclipse of 81.8997.87 at JD = 2452411.2 (May 16 2002). Past secondary eclipses of this system have had poor coverage which has increased the uncertainty in its parameters.

As mentioned in Chapter 1 the systems that can provide the most information are the double-lined eclipsing binaries, where the spectral lines of both stars can be resolved. For the systems, 6.6454.5 and 78.6338.24, spectral observations of sufficient quality would be difficult, if not impossible, to obtain due to the faintness of the components. It may be possible for useful spectroscopic observations to be made of the overtone system 81.8997.87. The cooler, dimmer companion likely has sharp spectral lines. The similarity in temperature between the two components means that spectra of both stars can be obtained simultaneously.

5.2 Program Modifications

The list of physical processes that can be included in a model of an eclipsing binary systems is continually growing. Inclusion of all possible features in modeling every system would be unnecessary and would impair program performance. There are, however, a few basic modifications that should be made to any future version of this code.

Circular orbits are the exception rather than the rule when considering detached binary systems. Any future analysis should allow for eccentricity in the orbit, either in model fitting to the lightcurve or by some form of rectification of the lightcurve prior to fitting. Orbital eccentricity affects the separation and duration of the primary and secondary eclipses and, if significant, can influence the values of the inclination and relative radii.

The stellar disks of the components were assumed by the model to be circular. One of the systems 78.6338.24 showed evidence that this assumption might be violated. Not including this effect results in a weaker constraint on the surface brightnesses of the two stars.

Bibliography

[Alcock *et al.* 1998] Alcock, C. *et al.* 1998, Astron. J., **115**, 1921–1933.

[Alcock *et al.* 1999] Alcock, C. *et al.* 1999, Astron. J., **117**, 920–926.

[Armstrong *et al.* 2000] Armstrong, J. T., Nordgren, T. E., Germain, M. E., Hajian, A. R., Hindsley, R. B., Hummel, C. A., Mozurkewich, D., and Thessin, R. N. 2000, astro-ph/0009398.

[Barnes, Moffett, and Slovak 1987] Barnes, T. G., Moffett, T. J., and Slovak, M. H. 1987, Astrophys. J. Suppl. Ser., **65**, 307–312.

[Becker 1985] Becker, S. 1985. Cepheid Evolution. In *IAU Colloq. 82: Cepheids: Theory and Observation*, pages 104+.

[Bertelli *et al.* 1994] Bertelli, G., Bressan, A., Chiosi, C., Fagotto, F., and Nasi, E. 1994, Astron. Astrophys. Suppl. Ser., **106**, 275–302.

[Bessell, Castelli, and Plez 1998] Bessell, M. S., Castelli, F., and Plez, B. 1998, Astron. and Astrophys., **333**, 231–250.

[Binnendijk 1960] Binnendijk, L. 1960. *Properties of Double Stars.* University of Pennsylvania Press, Philadelphia.

[Bohm-Vitense 1986] Bohm-Vitense, E. 1986, Astrophys. J., **303**, 262–272.

[Cardelli, Clayton, and Mathis 1989] Cardelli, J. A., Clayton, G. C., and Mathis, J. S. 1989, Astrophys. J., **345**, 245–256.

[Carroll and Ostlie 1996] Carroll, B. W. and Ostlie, D. A. 1996. *Modern Astrophysics.* Addison-Wesley, Reading.

[Chiosi, Wood, and Capitanio 1993] Chiosi, C., Wood, P. R., and Capitanio, N. 1993, Astrophys. J. Suppl. Ser., **86**, 541–598.

[Cook *et al.* 1995] Cook, K. H. *et al.* 1995. In *ASP Cenference Series Vol 83, Astrophysical Applications of Stellar Pulsation*, page 221.

[Cousins 1980] Cousins, A. 1980, South Afican Astron. Obs. Circ., **1**, 234.

[Cox 1980] Cox, A. N. 1980, Ann. Rev. Astron. and Astrophys., **18**, 15–41.

[Cox 1980] Cox, J. P. 1980. *Theory of Stellar Pulsation.* Princeton University Press, Princeton.

[Cox 1985] Cox, J. P. 1985. Theory of Cepheid pulsation - Excitation mechanisms. In *IAU Colloq. 82: Cepheids: Theory and Observation*, pages 126–146.

[Doig 1950] Doig, P. 1950. *A Concise History of Astronomy.* Chapman and Hall, London.

[Dorman, Rood, and O'Connell 1993] Dorman, B., Rood, R. T., and O'Connell, R. W. 1993, Astrophys. J., **419**, 596+.

[Eddington 1941] Eddington, A. S. 1941, MNRAS, **101**, 182+.

[Evans *et al.* 1997] Evans, N. R., Bohm-Vitense, E., Carpenter, K., Beck-Winchatz, B., and Robinson, R. 1997, PASP, **109**, 789–795.

[Fagotto *et al.* 1994a] Fagotto, F., Bressan, A., Bertelli, G., and Chiosi, C. 1994a, Astron. Astrophys. Suppl. Ser., **104**, 365–376.

[Fagotto *et al.* 1994b] Fagotto, F., Bressan, A., Bertelli, G., and Chiosi, C. 1994b, Astron. Astrophys. Suppl. Ser., **105**, 29–38.

[Fernie 1985] Fernie, J. 1985. Historical Preface. In *IAU Colloq. 82: Cepheids: Theory and Observation*, pages xi+.

[Fernie 1987] Fernie, J. D. 1987. BM Cas: Rosetta Stone Manqué. In *LNP Vol. 274: Stellar Pulsation*, pages 167+.

[Fernie and Evans 1997] Fernie, J. D. and Evans, N. R. 1997, PASP, **109**, 541–548.

[Gieren 1982] Gieren, W. 1982, PASP, **94**, 960–968.

[Gliese and Jahreiss 1991] Gliese, W. and Jahreiss, H. 1991. Preliminary Version of the third catalogue of nearby stars. In *Nearby Stars, Preliminary 3rd Version (1991)*, pages 0+.

[Goodricke 1784] Goodricke, J. 1784, Philosophical Transactions of the Royal Society of London, **76**, 48.

[Harmanec 1988] Harmanec, P. 1988, Bulletin of the Astronomical Institutes of Czechoslovakia, **39**, 329–345.

[Hertzsprung 1913] Hertzsprung, E. 1913, Astonomische Nachrichten, **196**, 201.

[Hubble 1929] Hubble, E. P. 1929, Astrophys. J., **69**, 103–158.

[Iglesias and Rogers 1991] Iglesias, C. A. and Rogers, F. J. 1991, Astrophys. J., **371**, L73–L75.

[Jacoby *et al.* 1992] Jacoby, G. H. *et al.* 1992, PASP, **104**, 599–662.

[Kallrath and Milone 1999] Kallrath, J. and Milone, E. F. 1999. *Eclipsing Binary Stars.* Springer-Verlag, New York.

[Lacy *et al.* 2000] Lacy, C. H. S., Torres, G., Claret, A., Stefanik, R. P., Latham, D. W., and Sabby, J. A. 2000, Astron. J., **119**, 1389–1397.

[Lang 1992] Lang, K. R. 1992. *Astrophysical Data.* Springer-Verlag, New York.

[Leavitt 1908] Leavitt, H. S. 1908, Harvard Obs. Ann., **60**, 87.

[Lebre and Gillet 1992] Lebre, A. and Gillet, D. 1992, Astron. and Astrophys., **255**, 221–232.

[Lomb 1976] Lomb, N. 1976, Astrophysics and Space Science, **39**, 447–462.

[Manduca, Bell, and Gustafsson 1977] Manduca, A., Bell, R. A., and Gustafsson, B. 1977, Astron. and Astrophys., **61**, 809–813.

[Milone 1993] Milone, E. F. 1993. *Light Curve Modelling of Eclipsing Binary Stars.* Springer-Verlag, New York.

[Moffett and Barnes 1984] Moffett, T. J. and Barnes, T. G. 1984, Astrophys. J. Suppl. Ser., **55**, 389–432.

[Nelson and Davis 1972] Nelson, B. and Davis, W. D. 1972, Astrophys. J., **174**, 617+.

[Petersen 1990] Petersen, J. O. 1990. Mass determination - Methods, accuracies, applications. In *ASP Conf. Ser. 11: Confrontation Between Stellar Pulsation and Evolution*, pages 402–411.

[Popper 1980] Popper, D. M. 1980, Ann. Rev. Astron. and Astrophys., **18**, 115–164.

[Press *et al.* 1992] Press, W. H., Teukolsky, S. A., Vetterlin, W. T., and Flannery, B. P. 1992. *Numerical Recipes in C.* Cambridge University Press, Cambridge.

[Riazi 1992] Riazi, N. 1992, Astron. J., **104**, 228–230.

[Rorabeck 1997] Rorabeck, A. 1997. The Second Overtone Mode of Cepheid Pulsation. Master's thesis, McMaster University.

[Russell and Shapley 1912] Russell, I. H. N. and Shapley, H. 1912, Astrophys. J., **36**, 239+.

[Schechter, Mateo, and Saha 1993] Schechter, P. L., Mateo, M., and Saha, A. 1993, PASP, **105**, 1342–1353.

[Schwering and Israel 1991] Schwering, P. B. W. and Israel, F. P. 1991, Astron. and Astrophys., **246**, 231–242.

[Shapley 1914] Shapley, H. 1914, Astrophys. J., **40**, 448+.

[Stockdale 2000] Stockdale, C. 2000, personal communication.

[Thiessen 1956] Thiessen, G. 1956, Zeitschrift Astrophysics, **39**, 65+.

[Tsvetkov and Petrova 1993] Tsvetkov, T. G. and Petrova, T. C. 1993, Astrophys. and Space Science, **203**, 257–266.

[Udalski *et al.* 1999] Udalski, A., Soszynski, I., Szymanski, M., Kubiak, M., Pietrzynski, G., Wozniak, P., and Zebrun, K. 1999, Acta Astronomica, **49**, 223–317.

[Wade and Rucinski 1985] Wade, R. and Rucinski, S. 1985, Astron. Astrophys. Suppl. Ser., **60**, 471–484.

[Wallerstein 1958] Wallerstein, G. 1958, Astrophys. J., **129**, 356–361.

[Wallerstein and Cox 1984] Wallerstein, G. and Cox, A. 1984, PASP, **96**, 677–691.

[Welch 2000] Welch, D. L. 2000, personal communication.

[Welch and The MACHO Collaboration 1999] Welch, D. L. and The MACHO Collaboration 1999. Cepheid Variables in the LMC and SMC. In *IAU Symp. 190: New Views of the Magellanic Clouds*, volume 190, pages 513+.

[Whitford 1958] Whitford, A. E. 1958, Astron. J., **63**, 201+.

Appendix A

The solve.c and init.c Programs

The C code written to perform fitting of the model to the observations. Code was written by the author except where indicated. The major external source of code was [Press *et al.* 1992].

```
//*****************************************************************
//                 SOLVE.C
/******************************************************************
This program solves for the elements of an eclipsing binary system in
which one of the members is a variable star.  The method used is a
chi-squared minimizaion.

This is the main portion of the program which calls all the
subroutines.
******************************************************************/
#include <stdio.h>
#include <math.h>
#include <strings.h>
#include <stdlib.h>
#include <time.h>

#define PI 3.14159265358979
#define nd 5020 /* maximum no. of data points */
#define np 43 /* maximum no. of parameters in model */

int aflag[np], varstar;
int verfl=0,wtflag=1,iflag=0, crflag = 0;
double t0;
double wgt[nd];
char glname[15];
```

```
#include "solve.h"

//*******************************************************************
// BEGIN MAIN PROGRAM
//*******************************************************************
int main(int argc, char *argv[]){

int i,n,nptsv,nptsr,nptsi,ret,npts,sep,sep2,df;
char inname[15],temp[30];
double gv,gr,gi;
double tv[nd],magv[nd],lv[nd],emagv[nd],elv[nd];
double tr[nd],magr[nd],lr[nd],emagr[nd],elr[nd];
double ti[nd],magi[nd],li[nd],emagi[nd],eli[nd];
double a[np],x[nd],y[nd],sig[nd],err[np];
double chi,red;
FILE *fp;

//*******************************************************************
// INITIALIZE VARIABLES AND SET FLAGS
//*******************************************************************
n = 41;
for (i=0; i<np; i++) {
   aflag[i] = 0; a[i]=0.0;
}
for (i=0;i<nd;i++) wgt[i] = 1.0;
if (argc >= 2) {
   for(i=2; i<argc; i++){
      if (strcmp(argv[i], "verbose")==0) verfl = 1;
      if (strcmp(argv[i], "nwt")==0) wtflag = 0;
      if (strcmp(argv[i], "withi")==0) iflag = 1;
      if (strcmp(argv[i], "nocrash")==0) crflag = 1;
   }
}
//setflags();
//*******************************************************************
// OPEN ".IN" FILE AND READ IN DATA
//*******************************************************************
strcpy(glname,argv[1]);
strcpy(temp,argv[1]);
strcat(temp, ".in");
if (verfl==1) printf("opening - %s\n", temp);

// READ IN GUESS VALUES, ERRORS AND PARAMETER FLAGS

if ((fp = fopen(temp, "r")) == NULL){
   printf("File Error Opening %s\n",temp);
   exit(0);
}
else{
   fscanf(fp, "%s", &inname);
   fscanf(fp, "%lf %lf %lf", &gv, &gr, &gi);
   fscanf(fp, "%d", &varstar);
```

```
   fscanf(fp, "%lf %d %lf", &chi, &df, &red);
   for (i=1;i<=n;i++){
      fscanf(fp, "%lf %lf %d",&a[i],&err[i],&aflag[i]);
   }
}
fclose(fp);
if (verfl==1) printf("%s read\n", temp);
if (gi != 0.0) iflag = 1;

// READ IN PHOTOMETRIC DATA

indata(inname,tv,tr,magv,magr,emagv,emagr,&nptsv,&nptsr);
if(iflag ==1) onedata(inname,ti,magi,emagi,&nptsi);

//*****************************************************************
// CONVERT MAGNITUDES INTO FLUXES
//*****************************************************************
flux(gv,magv,emagv,lv,elv,nptsv);
flux(gr,magr,emagr,lr,elr,nptsr);
if(iflag ==1) flux(gi,magi,emagi,li,eli,nptsi);
//*****************************************************************
// COMBINE MULTIPLE BANDS INTO ONE DATA SET
//*****************************************************************
sep = nptsv;
sep2 = nptsv + nptsr;
npts = nptsv + nptsr;
if(iflag ==1) npts = nptsv + nptsr + nptsi;
for (i=1;i<=nptsv;i++){
     x[i] = tv[i];
     y[i] = lv[i];
     sig[i] = elv[i];
}
for (i=1;i<=nptsr;i++){
     x[i+sep] = tr[i];
     y[i+sep] = lr[i];
     sig[i+sep] = elr[i];
}
if(iflag ==1){
     for (i=1;i<=nptsi;i++){
        x[i+sep2] = ti[i];
        y[i+sep2] = li[i];
        sig[i+sep2] = eli[i];
     }
}
//*****************************************************************
// FIT DATA AND COMPUTE REDUCED CHI-SQUARED
//*****************************************************************
wtflag = 0;  //turn weighting on/off

//call fitting routine
chi = nonlin(x,y,sig,npts,sep,sep2,a,err,n,2);
```

```
df = npts;
for(i=1;i<=n;i++) if(aflag[i] == 1) df--;
red = chi/df;

//*****************************************************************
// OUTPUT RESULTS TO ".OUT" FILE
//*****************************************************************
strcpy(temp, argv[1]);
strcat(temp, ".out");
fp = fopen(temp,"w");
fprintf(fp,"%s\n",inname);
fprintf(fp,"%lf\t%lf\t%lf\n",gv,gr,gi);
fprintf(fp,"%d\n",varstar);
fprintf(fp,"%lf %d %lf\n",chi,df,red);
for(i=1;i<=n;i++) fprintf(fp,"%lf %lf %d\n",a[i],err[i],aflag[i]);
fclose(fp);
if (verfl==1) printf("%s written\n", temp);

// GENERATE OUTPUT OF RESULTS
strcpy(temp,argv[1]);
strcat(temp,".res");
// RECORD SUCCESSFUL COMPLETION
disparam(temp,a,err,chi,gv,gr,gi);
putresult("successful completion", 0);

//*****************************************************************
// END OF PROGRAM
//*****************************************************************
return(0);
}

/*****************************************************************
Assorted utility programs
*****************************************************************/
// OUTPUTS STATE OF FIT TO FILE
void putresult(char line[50], int n){

FILE *fp;
char temp[20];
strcpy(temp,glname);
strcat(temp,".ch");
fp = fopen(temp,"w");
fprintf(fp,"%s  %d\n",line,n);
fclose(fp);
if(verfl==1) printf("%s written\n", temp);
}

// OUTPUTS TWO ARRAYS TO A FILE
void nplot(char name[10], double x[], double y[], int n){

FILE *fplot;
int i;
```

```
fplot = fopen(name, "w");
for (i=1; i <= n; i++) fprintf(fplot, "%lf %lf \n",x[i],y[i]);
if (verfl == 1) printf("%s written\n", name);
fclose(fplot);
}
// GENERATES A PAUSE IN PROGRAM EXECUTION
void pause(void){

char ans[3];
printf("Enter y to continue q to quit: ");
scanf("%s", &ans);
if (strcmp(ans, "q") == 0 ) exit(0);
}


/*******************************************************************
//         NEWCAL.C
/*******************************************************************
These functions compute the system light at any time for eclipsing
binary.  For spherical stars on circular orbits with uniform surface
brightness.
Time and system parameters are sent, intensity is returned.
*******************************************************************/
// FOR V BAND DATA
//*******************************************************************
double lightcal1(double t, double a[]) {

double l1,l2,r1,r2,i,d,ph2,j1,j2,li,fvar,rvar,phase,gamma=0,incr;
int j,n=100;

incr = PI/2/n;
// COMPUTE PHASE
phase = (fmod(t, 2*PI/a[1])*a[1]) - a[2];
if (phase < 0) phase = phase + 2*PI;

i = a[3];   r1 = a[4];   r2 = a[5];   j1 = a[6];
// COMPUTE J2
l1 = PI * r1*r1 * j1*(1-a[10]/3);
l2 = 1 - l1;
j2 = l2 / ( PI*r2*r2*(1-a[11]/3));
a[7] = j2;

// COMPUTE J AND RADIAL VARIATION AND ADD TO J OR R
if (varstar != 0){
   fvar = a[18]*cos(a[14]*t) + a[19]*sin(a[14]*t);
   fvar += a[20]*cos(2*a[14]*t) + a[21]*sin(2*a[14]*t);
   fvar += a[22]*cos(3*a[14]*t) + a[23]*sin(3*a[14]*t);

   rvar = a[15] * fabs(sin(0.5*a[14]*(t-a[16])));
   if(varstar == 1){
      r1 += rvar;  j1 += fvar;
   }
```

```
    else if(varstar == 2){
       r2 += rvar;  j2 += fvar;
    }
}

l1 = PI * r1*r1 * j1*(1-a[10]/3);
l2 = PI * r2*r2 * j2*(1-a[11]/3);

// IF SECONDARY ECLIPSE REDUCE PHASE
if (phase > PI) ph2 = (phase - PI);
else ph2 = phase;

// COMPUTE APPARENT SEPARATION
d = sqrt( 1- pow(sin(i),2) * pow(cos(ph2),2) );

// CHECK FOR ECLIPSE
if (d < (r1+r2)){
  //PRIMARY ECLIPSE
    if ( (phase < PI/2) || (phase > 3*PI/2) ){
       li = (l1 + l2);
       // REMOVE FLUX FROM ECLIPSED REGIONS BY COMPUTING AREA OF A
       // RING COVERED AND MULTIPLYING BY BRIGHTNESS
       for(j=0;j<n;j++){
          gamma += incr;
          li -= (areacalc(r1*sin(gamma),r2,d)-
     areacalc(r1*sin(gamma-incr),r2,d))*j1*(1-a[10]+a[10]*cos(gamma));
       }
    }
    //SECONDARY ECLIPSE
    else {
       li = (l1 + l2);
       for(j=0;j<n;j++){
          gamma += incr;
          li -= (areacalc(r2*sin(gamma),r1,d)-
     areacalc(r2*sin(gamma-incr),r1,d))*j2*(1-a[11]+a[11]*cos(gamma));
       }
    }
}
else li = l1 + l2;

return (li+a[17]);
}
//*****************************************************************
// SAME AS ABOVE FOR R BAND DATA
//*****************************************************************
double lightcal2(double t, double a[]){

double l1,l2,r1,r2,i,d,ph2,j1,j2,li,fvar,rvar,phase,gamma=0,incr;
int j,n=100;

incr = PI/2/n;
phase = (fmod(t, 2*PI/a[1])*a[1]) - a[2];
```

```
if (phase < 0) phase = phase + 2*PI;

i = a[3];  r1 = a[4];  r2 = a[5];  j1 = a[8];
l1 = PI * r1*r1 * j1*(1-a[12]/3) ;
l2 = 1 - l1;
j2 = l2 / ( PI*r2*r2*(1-a[13]/3));
a[9] = j2;

if (varstar != 0){
   fvar = a[25]*cos(a[14]*t) + a[26]*sin(a[14]*t);
   fvar += a[27]*cos(2*a[14]*t) + a[28]*sin(2*a[14]*t);
   fvar += a[29]*cos(3*a[14]*t) + a[30]*sin(3*a[14]*t);

   rvar = a[15] * fabs(sin(0.5*a[14]*(t-a[16])));
   if(varstar == 1){
      r1 += rvar; j1 += fvar;
   }
   else if(varstar == 2){
      r2 += rvar;
      j2 += fvar;
   }
}

l1 = PI * r1*r1 * j1*(1-a[12]/3);
l2 = PI * r2*r2 * j2*(1-a[13]/3);
if (phase > PI) ph2 = (phase - PI);
else ph2 = phase;

d = sqrt( 1- pow(sin(i),2) * pow(cos(ph2),2) );
if (d < (r1+r2)){ //there is an eclipse
   if ( (phase < PI/2) || (phase > 3*PI/2) ){
      li = (l1 + l2);
      for(j=0;j<n;j++){
         gamma += incr;
         li -= (areacalc(r1*sin(gamma),r2,d)-
   areacalc(r1*sin(gamma-incr),r2,d))*j1*(1-a[12]+a[12]*cos(gamma));
       }
   }
   else {
      li = (l1 + l2);
      for(j=0;j<n;j++){
         gamma += incr;
         li -= (areacalc(r2*sin(gamma),r1,d)-
   areacalc(r2*sin(gamma-incr),r1,d))*j2*(1-a[13]+a[13]*cos(gamma));
      }
   }
}
else li = l1 + l2;

return (li+a[24]);
}
//*******************************************************************
```

```
// SAME AS ABOVE FOR I BAND DATA
//*****************************************************************
double lightcal3(double t, double a[]){
double l1,l2,r1,r2,i,d,ph2,j1,j2,li,fvar, rvar, phase,gamma=0,incr;
int j,n=100;

incr = PI/2/n;
phase = (fmod(t, 2*PI/a[1])*a[1]) - a[2];
if (phase < 0) phase = phase + 2*PI;

i = a[3]; r1 = a[4];  r2 = a[5];  j1 = a[31];
l1 = PI * r1*r1 * j1*(1-a[40]/3);
l2 = 1 - l1;
j2 = l2 / ( PI*r2*r2*(1-a[41]/3));
a[32] = j2;

if (varstar != 0){
   fvar = a[34]*cos(a[14]*t) + a[35]*sin(a[14]*t);
   fvar += a[36]*cos(2*a[14]*t) + a[37]*sin(2*a[14]*t);
   fvar += a[38]*cos(3*a[14]*t) + a[39]*sin(3*a[14]*t);

   rvar = a[15] * fabs(sin(0.5*a[14]*(t-a[16])));
   if(varstar == 1){
      r1 += rvar; j1 += fvar;
   }
   else if(varstar == 2){
      r2 += rvar; j2 += fvar;
   }
}

l1 = PI * r1*r1 * j1*(1-a[40]/3);
l2 = PI * r2*r2 * j2*(1-a[41]/3);
if (phase > PI) ph2 = (phase - PI);
else ph2 = phase;

d = sqrt( 1- pow(sin(i),2) * pow(cos(ph2),2) );
if (d < (r1+r2)){
   if ( (phase < PI/2) || (phase > 3*PI/2) ){
      li = (l1 + l2);
      for(j=0;j<n;j++){
         gamma += incr;
         li -= (areacalc(r1*sin(gamma),r2,d)-
   areacalc(r1*sin(gamma-incr),r2,d))*j1*(1-a[40]+a[40]*cos(gamma));
      }
   }
   else {
      li = (l1 + l2);
      for(j=0;j<n;j++){
         gamma += incr;
         li -= (areacalc(r2*sin(gamma),r1,d)-
   areacalc(r2*sin(gamma-incr),r1,d))*j2*(1-a[41]+a[41]*cos(gamma));
      }
```

```
   }
}
else li = l1 + l2;
return (li+a[33]);
}
/******************************************************************
Computes area of covered during eclipse from the two radii
and the apparent separation.
******************************************************************/
double areacalc(double r1, double r2, double d){
// R1 IS STAR BEING ECLIPSED
double arg1,arg2,a1,a2;

// annular/total eclipse
if (d < fabs(r1-r2) ) return(PI*r1*r1);

//partial eclipse
else{
   arg1 = (r1*r1 - r2*r2 + d*d)/(2*r1*d);
   a1 = acos(arg1);
   arg2 = (r2*r2 - r1*r1 + d*d)/(2*r2*d);
   a2 = acos(arg2);
   return(r2*r2/2*(2*a2-sin(2*a2)) + r1*r1/2*(2*a1-sin(2*a1)));
}

}


//******************************************************************
//    NONLIN.C
/******************************************************************
Front end calling routine for non-linear chi-squared fitting.
Accepts data and parameters to be fit and calls mrqmin.
Repeats until chisq value returned decreases and is different from
the old value by a sufficiently small amount.
******************************************************************/

double nonlin(double t[],double ydat[], double sig[], int npts,
int sep,int sep2,double a[], double err[], int na, int level){

double **covar, **alpha;
double chisqr, chiold, alamda,wtsum;
double chi[205];
int i, count = 0,br,br2=1;

// ITERATE UNTIL A VALID PARAMETER SET IS FOUND
do{
  // OUTPUT DETAILS OF CURRENT FIT IF DESIRED
   if(verfl == 1){
      printf("Flags at : ");
      for(i=1;i<=na;i++) printf("%d", aflag[i]);
      printf("\n");
```

```
   printf("varstar = %d\n", varstar);
   printf("guess values: \n ");
   outparam(a);
   plotgen(t,ydat,sep,a);
}
// INITIALIZE VARIABLES USED IN FITTING
count = 0;
covar = dmatrix(1, na, 1, na);
alpha = dmatrix(1, na, 1, na);
alamda = -10;
mrqmin(t,ydat,sig,npts,sep,sep2,a,aflag,na,covar,alpha,&chisqr,
      func1,func2,func3,&alamda);
br2 = 1;
br=0;
// ITERATE UNTIL MINIMUM CHI-SQUARE IS FOUND
do{
   count++;
   chiold = chisqr;

   // ADJUST PARAMETERS, RETURN NEW VALUE OF CHI-SQUARE
   mrqmin(t,ydat,sig,npts,sep,sep2,a,aflag,na,covar,alpha,&chisqr,
         func1,func2,func3,&alamda);

   if (verfl == 1){
      printf("%d chi-sq=%lf ", count, chisqr);
      outparam(a);
      plotgen(t,ydat,sep,a);
   }

   chi[count] = chisqr;

   // CONDITIONS FOR TERMINATION
   if (level==1){
      // CHI-SQUARE DECREASES BY LESS THAN SOME AMOUNT
      if ((chiold > chisqr)&&(chiold-chisqr < 0.001)) br=1;
      // A SPECIFIED NUMBER OF STEPS ARE TAKEN
      if (count == 20) br = 1;
      // CHI-SQUARE HAS CEASED CHANGING
      if (count > 5){
         if (chi[count] == chi[count-5]) br=1;
      }
    }
    else if (level==2){
       if ((chiold>chisqr)&&(chiold-chisqr<0.00001))br=1;
          if (count == 1000) br = 1;
          if (count > 5){
             if (chi[count] == chi[count-5]) br=1;
          }
       }
       else{
          printf("Bad level %d",level);
          exit(0);
```

```
        }
      // CHECK PARAMETERS TO SEE IF THEY ARE VALID
        br2 = check(a);
  }while((br == 0)&&(br2 == 1));
}while(br2 == 0);

if (verfl==1) printf("number of steps: %d\n", count);

// GET ERRORS IN PARAMETERS
alamda = 0.0;
mrqmin(t,ydat,sig,npts,sep,sep2,a,aflag,na,covar,alpha,&chisqr,func1,
func2,func3,&alamda);
for (i=1; i<=na; i++) err[i] = sqrt(covar[i][i]);

//wtsum = 0;
//for (i=1;i<=npts;i++) wtsum += wgt[i];
//printf("wtsum equals: %lf \n",wtsum);

return(chisqr);

}
/*******************************************************************
Displays plot of current fit on screen by calling SM macros
*******************************************************************/
void plotgen(double t[], double y[],int n,double a[]){

int i,nf;
double fx[nd], fy[nd], fph[nd],ph[nd];

nf = nd - 1;
for (i=1;i<=n;i++){
  ph[i] = (fmod(t[i],2*PI/a[1])*a[1]) - a[2];
  if (ph[i] < 0) ph[i] = ph[i] + 2*PI;
}
fx[0] = 0;
for(i=1;i<=nf;i++){
  fx[i] = fx[i-1] + 2000.0/(double)nf;
  fph[i] = (fmod(fx[i],2*PI/a[1])*a[1]) - a[2];
  if (fph[i] < 0) fph[i] = fph[i] + 2*PI;
  fy[i] = lightcal1(fx[i],a);
}

displayfit(ph,y,n,fph,fy,nf);
}

/*******************************************************************
Displays a list of parameters on screen.
*******************************************************************/
void outparam(double a[]){

int i;
printf("\n   ");
```

```
for(i=0;i<=9;i++) if (aflag[i]==1) printf("%lf ",a[i]);
printf("\n   ");
for(i=10;i<=16;i++) if (aflag[i]==1) printf("%lf ",a[i]);
printf("\n   ");
for(i=17;i<=23;i++) if (aflag[i]==1) printf("%lf ",a[i]);
printf("\n   ");
for(i=24;i<=30;i++) if (aflag[i]==1) printf("%lf ",a[i]);
printf("\n   ");
for(i=31;i<np;i++) if (aflag[i]==1) printf("%lf ",a[i]);
printf("\n");
}
/*****************************************************************
These three fuctions call the appropriate routine to calculate the
system light for a given band at a time value.
They also compute the deviatives of the lightcal function to each of
the model parameters.
*****************************************************************/
void func1(double t, double a[], double *y, double dda[], int na){
int i;
double err;

*y = lightcal1(t, a);
for (i=1; i<=na; i++){
   if (aflag[i] != 0){
     // COMPUTE DERIVATIVES
      if(a[i]!=0.0)
         dda[i]=dfridr(lightcal1,t,a,na,i,(0.001*a[i]),&err);
      else dda[i]=dfridr(lightcal1,t,a,na,i,0.01,&err);
   }
   else dda[i] = 0.0;
}
}
void func2(double t, double a[], double *y, double dda[], int na){
int i;
double err;

*y = lightcal2(t, a);
for (i=1; i<=na; i++){
   if (aflag[i] != 0){
     // COMPUTE DERIVATIVES
      if(a[i]!=0.0)
         dda[i]=dfridr(lightcal2,t,a,na,i,(0.001*a[i]),&err);
      else dda[i]=dfridr(lightcal2,t,a,na,i,0.01,&err);
   }
   else dda[i] = 0.0;
}
}

void func3(double t, double a[], double *y, double dda[], int na){
int i;
double err;
```

```
*y = lightcal3(t, a);
for (i=1; i<=na; i++){
   if (aflag[i] != 0){
     // COMPUTE DERIVATIVES
      if(a[i]!=0.0)
         dda[i]=dfridr(lightcal3,t,a,na,i,(0.001*a[i]),&err);
      else dda[i]=dfridr(lightcal3,t,a,na,i,0.01,&err);
   }
   else dda[i] = 0.0;
}
}

/*****************************************************************
Checks to see if parameter set is valid.
If not it fixes parameters and returns br=0 so fitting restats.
*****************************************************************/
int check(double a[]){
int br = 1,i;
/*for (i=3;i<=5;i++){
   if ((aflag[i]==1) && (a[i] < 0.0)){
      a[i] *= -1.0;
      br = 0;
   }
}*/
// ENSURE RADIAL AMPLITUDE IS POSITIVE
if ((aflag[15]==1) && (a[15] < 0.0)){
   if (verfl==1) printf("a[15] negative\n");
      a[15] *= -1.0;
      a[16] -= 0.5 * 2*PI/a[9];
      br = 0;
}

// ENSURE RADIAL SHIFT IS LESS THAN ONE PERIOD
if (aflag[16]==1){
   if(a[16] > 2*PI/a[14]){
      while(a[16] > 2*PI/a[14]) a[16] -= 2*PI/a[14];
      br = 0;
      if (verfl==1) printf("a[16] to high\n");
   }
   if(a[16] < -2*PI/a[14]){
      while (a[16] < -2*PI/a[14]) a[16]+=2*PI/a[14];
      br = 0;
      if (verfl==1) printf("a[16] too low\n");
   }
}
return(br);
}


//*****************************************************************
// MRQMIN.C -- FROM NUMERICAL RECIPES (PRESS ET AL.)
/*****************************************************************
```

```
Levenberq-Marquart method, reduces chi-square of a fit between data
x[],y[] with standard deviations sig[] and a nonlinear function
depending on ma coefficients a[]. ia[] indicates by non-zero elements
components which should be fitted for. Returns improved parameter set
a[] and its chisq value.

Modified to accept three fitting functions and select the appropriate
one.
*****************************************************************/
#define NRANSI
#include "nrutil.h"
void mrqmin(double x[], double y[], double sig[], int ndata, int sep,
int sep2, double a[], int ia[], int ma, double **covar, double **alpha
, double *chisq, void (*funcs1)(double, double [], double *, double []
, int), void (*funcs2)(double, double [], double *, double [], int),
void (*funcs3)(double, double [], double *, double [], int), double
*alamda){

int j,k,l;
static int mfit;
static double ochisq,*atry,*beta,*da,**oneda;

// INITIALIZATION
if (*alamda < 0.0) {
   atry=dvector(1,ma);
   beta=dvector(1,ma);
   da=dvector(1,ma);
   for (mfit=0,j=1;j<=ma;j++) if (ia[j]) mfit++;
   oneda=dmatrix(1,mfit,1,1);
   *alamda=0.001;
   mrqcof(x,y,sig,ndata,sep,sep2,a,ia,ma,alpha,beta,
       chisq,funcs1,funcs2,funcs3);
   ochisq=(*chisq);
   for (j=1;j<=ma;j++) atry[j]=a[j];
}
// ALTER LINEARIZED FITTING MATRIX BY AUGMENTING DIAGONAL ELEMENTS
for (j=1;j<=mfit;j++) {
   for (k=1;k<=mfit;k++) covar[j][k]=alpha[j][k];
   covar[j][j]=alpha[j][j]*(1.0+(*alamda));
   oneda[j][1]=beta[j];
}
// SOLVE MATRIX
gaussj(covar,mfit,oneda,1);

// WHEN CONVERGENCE IS REACHED EVALUATE COVARIANCE MATRIX
for (j=1;j<=mfit;j++) da[j]=oneda[j][1];
if (*alamda == 0.0) {
   covsrt(covar,ma,ia,mfit);
   free_dmatrix(oneda,1,mfit,1,1);
   free_dvector(da,1,ma);
   free_dvector(beta,1,ma);
   free_dvector(atry,1,ma);
```

```
   return;
}
// DID THE TRIAL SUCCEED?
for (j=0,l=1;l<=ma;l++)
   if (ia[l]) {
      atry[l]=a[l]+da[++j];
      //printf("%lf %lf %lf\n",atry[l],a[l],da[j]);
   }
mrqcof(x,y,sig,ndata,sep,sep2,atry,ia,ma,covar,da,chisq,
       funcs1,funcs2,funcs3);
// IF SUCCESSFUL ADOPT NEW SOLUTION
if (*chisq < ochisq) {
   *alamda *= 0.1;
   ochisq=(*chisq);
   for (j=1;j<=mfit;j++) {
      for (k=1;k<=mfit;k++) alpha[j][k]=covar[j][k];
      beta[j]=da[j];
   }
   for (l=1;l<=ma;l++) a[l]=atry[l];
}
// IF NOT INCREASE ALAMBDA AND RETURN
else {
   *alamda *= 10.0;
   *chisq=ochisq;
}

}


//*********************************************************************
//  MRQCOF.C -- FROM NUMERICAL RECIPES (PRESS ET. AL.)
/*********************************************************************
Used by mrqmin to evaluate the linearized fitting matrix alpha and
vector beta and calculate chi-squared.
Modified to use three different functions on different regions of the
data set and to accept alternate weighting.
 ********************************************************************/
#define NRANSI
#include "nrutil.h"
void mrqcof(double x[], double y[], double sig[], int ndata, int sep,
 int sep2,double a[], int ia[], int ma, double **alpha, double beta[],
 double *chisq,void (*funcs1)(double, double [], double *, double [],
 int), void (*funcs2)(double, double [], double *, double [], int),
void (*funcs3)(double, double [], double *, double [], int) ){

int i,j,k,l,m,mfit=0;
double ymod,wt,sig2i,dy,*dyda,ph;

// INITIALIZE SYMMETRIC ALPHA, BETA
dyda=dvector(1,ma);
for (j=1;j<=ma;j++)
   if (ia[j]) mfit++;
```

```
for (j=1;j<=mfit;j++) {
   for (k=1;k<=j;k++) alpha[j][k]=0.0;
   beta[j]=0.0;
}

*chisq=0.0;
// LOOP OVER ALL DATA
for (i=1;i<=ndata;i++) {
   if (i<=sep)(*funcs1)(x[i],a,&ymod,dyda,ma);
   else if(i<=sep2)(*funcs2)(x[i],a,&ymod,dyda,ma);
   else (*funcs3)(x[i],a,&ymod,dyda,ma);

   dy=y[i]-ymod;
   sig2i=1.0/(sig[i]*sig[i]);

   // ADJUST WEIGHTING IF DESIRED
   if (wtflag ==1){
      ph = (fmod(x[i], 2*PI/a[1])*a[1]) - a[2];
      if (ph < 0) ph = ph + 2*PI;
      wgt[i] = 1.0 + 5*pow(cos(ph),6);
      sig2i *= wgt[i];
   }

   for (j=0,l=1;l<=ma;l++) {
      if (ia[l]) {
         wt=dyda[l]*sig2i;
         for (j++,k=0,m=1;m<=l;m++)
            if (ia[m]) alpha[j][++k]+= wt*dyda[m];
         beta[j] += dy*wt;
      }
   }
   // ADD TO CHI-SQUARED
   *chisq += dy*dy*sig2i;
}

for (j=2;j<=mfit;j++)
   for (k=1;k<j;k++) alpha[k][j]=alpha[j][k];
   free_dvector(dyda,1,ma);
}
#undef NRANSI

//*************************************************************
//   COVSRT.C -- FROM NUMERICAL RECIPIES (PRESS ET AL)
/*************************************************************
Expand in storage the covariance matrix covar, so as to take
inot account parameters that are being held fixed. (Returns 0
covariance for the latter)
 *************************************************************/
#define SWAP(a,b) {swap=(a);(a)=(b);(b)=swap;}

void covsrt(double **covar, int ma, int ia[], int mfit){
int i,j,k;
```

```
double swap;

for (i=mfit+1;i<=ma;i++)
   for (j=1;j<=i;j++) covar[i][j]=covar[j][i]=0.0;
   k=mfit;
   for (j=ma;j>=1;j--) {
      if (ia[j]) {
      for (i=1;i<=ma;i++)
         SWAP(covar[i][k],covar[i][j])
      for (i=1;i<=ma;i++)
         SWAP(covar[k][i],covar[j][i])
      k--;
   }
}
}
#undef SWAP


//****************************************************************
//  GAUSSJ.C -- FROM NUMERICAL RECIPES (PRESS ET AL)
/****************************************************************
Linear eqation solution by Gauss-Jordan eliminiation.  a[][] is the
input matrix.  b[][] is input containing the m right-side vectors.
On output, a[][] is replaced by its matrix inverse, and b[] by the
corresponding set of solution vectors.

Here it is only needed to invert a matrix sent to it.

****************************************************************/
#include <math.h>
#define NRANSI
#include "nrutil.h"
#define SWAP(a,b) {temp=(a);(a)=(b);(b)=temp;}

void gaussj(double **a, int n, double **b, int m){

int *indxc,*indxr,*ipiv;
int i,icol,irow,j,k,l,ll;
double big,dum,pivinv,temp;

indxc=ivector(1,n);
indxr=ivector(1,n);
ipiv=ivector(1,n);
for (j=1;j<=n;j++) ipiv[j]=0;

for (i=1;i<=n;i++) {
   big=0.0;
   for (j=1;j<=n;j++)
      if (ipiv[j] != 1)
         for (k=1;k<=n;k++) {
            if (ipiv[k] == 0) {
               if(fabs(a[j][k])> big) {
```

```
                    big=fabs(a[j][k]);
                    irow=j;
                    icol=k;
                  }
                } else if (ipiv[k] > 1)
                   nrerror("gaussj: Singular Matrix-1");
            }

    ++(ipiv[icol]);
    if (irow != icol) {
       for (l=1;l<=n;l++) SWAP(a[irow][l],a[icol][l])
       for (l=1;l<=m;l++) SWAP(b[irow][l],b[icol][l])
    }
    indxr[i]=irow;
    indxc[i]=icol;
    if (a[icol][icol] == 0.0) {
       if (crflag == 1){
          a[icol][icol] = 0.000001;
          printf("diagonal element - %d\n",icol);
       }
    }
    else{
       putresult("diagonal element 0",icol);
       printf("diagonal element 0 - %d\n", icol);
       nrerror("gaussj: Singular Matrix-2");
    }
    pivinv=1.0/a[icol][icol];
    a[icol][icol]=1.0;
    for (l=1;l<=n;l++) a[icol][l] *= pivinv;
    for (l=1;l<=m;l++) b[icol][l] *= pivinv;
    for (ll=1;ll<=n;ll++)
       if (ll != icol) {
          dum=a[ll][icol];
          a[ll][icol]=0.0;
          for (l=1;l<=n;l++) a[ll][l] -= a[icol][l]*dum;
          for (l=1;l<=m;l++) b[ll][l] -= b[icol][l]*dum;
        }
}
for (l=n;l>=1;l--) {
    if (indxr[l] != indxc[l])
       for (k=1;k<=n;k++)
          SWAP(a[k][indxr[l]],a[k][indxc[l]]);
}
free_ivector(ipiv,1,n);
free_ivector(indxr,1,n);
free_ivector(indxc,1,n);
}
#undef SWAP
#undef NRANSI


//*****************************************************************
```

```
//  DFRIDR.C -- FROM NUMERICAL RECIPES
/*******************************************************************
Returns the derivative of a fuction at a point x by Ridders' method
of polynomial extrapolation.  The value h is input as an estimated
initial stepsize; it need not be small, but rather should be an
increment in x over which func changes substantially.  An estimate of
the error in the derivative is returned as err.

Modified so that func will accept both t and an array ao[] as input.
And the derivative is calculated with respect to one of the elements
in the array specified by index.
 *******************************************************************/
#include <math.h>
#define NRANSI
#include "nrutil.h"
#define CON 1.4
#define CON2 (CON*CON)
#define BIG 1.0e30
#define NTAB 10
#define SAFE 2.0

double dfridr(double (*func)(double, double[]), double t, double ao[],
 int na, int index, double h, double *err){
int i,j, k;
double errt,fac,hh,**a,ans;
double ap[np], am[np];

for(k=1; k <=na; ap[k]=ao[k], am[k]=ao[k], k++)

if (h == 0.0) nrerror("h must be nonzero in dfridr.");
a=dmatrix(1,NTAB,1,NTAB);
hh=h;

ap[index] = ao[index]+hh; am[index] = ao[index]-hh;
a[1][1]=((*func)(t, ap)-(*func)(t, am))/(2.0*hh);
for(k=1; k <=na; ap[k]=ao[k], am[k]=ao[k], k++)

*err=BIG;
for (i=2;i<=NTAB;i++) {
   hh /= CON;

   ap[index] = ao[index]+hh; am[index] = ao[index]-hh;
   a[1][i]=((*func)(t, ap)-(*func)(t, am))/(2.0*hh);
   for(k=1; k <=na; ap[k]=ao[k], am[k]=ao[k], k++)

   fac=CON2;
   for (j=2;j<=i;j++) {
      a[j][i]=(a[j-1][i]*fac-a[j-1][i-1])/(fac-1.0);
      fac=CON2*fac;
      errt=FMAX(fabs(a[j][i]-a[j-1][i]),fabs(a[j][i]-a[j-1][i-1]));
      if (errt <= *err) {
         *err=errt;
```

```
         ans=a[j][i];
      }
   }
   if (fabs(a[i][i]-a[i-1][i-1]) >= SAFE*(*err)) break;
}
free_dmatrix(a,1,NTAB,1,NTAB);
return ans;
}
#undef CON
#undef CON2
#undef BIG
#undef NTAB
#undef SAFE
#undef NRANSI


//*****************************************************************
// INDATA.C
/*****************************************************************
Reads data from files placing it in arrays.  Data files must be
named v/r + the name supplied in inname[].

Assumes data is in format:
 Julian Date (days)      V/R(mag)      Error (mag)

*****************************************************************/
void indata(char inname[],double tv[],double tr[],double magv[],
double magr[], double emagv[], double emagr[], int *nptsv, int *nptsr)
{

int num, tran, i;
double d, r, rer, v, ver, ob;
FILE *fp1;
char line[200], newname[15];

// READ IN R BAND DATA
num=0;
strcpy(newname, "r");
strcat(newname, inname);
if(verfl==1)printf("opening - %s\n", newname);
if ((fp1 = fopen(newname, "r")) == NULL){
   printf("File Error\n");
   exit(0);
}
else{
   while ((fgets(line, 200, fp1)) != NULL){
      sscanf(line, "%lf %lf %lf",&d,&r,&rer);
      num++;
      tr[num] = d;
      emagr[num] = rer;
      magr[num] = r;
```

```
   }
}
*nptsr = num;
fclose(fp1);

// READ IN V BAND DATA
num = 0;
strcpy(newname, "v");
strcat(newname, inname);
if(verfl==1)printf("opening - %s\n", newname);
if ((fp1 = fopen(newname, "r")) == NULL){
   printf("File Error\n");
   exit(0);
}
else{
   while ((fgets(line, 200, fp1)) != NULL){
      sscanf(line, "%lf %lf %lf", &d, &v, &ver);
      num++;
      magv[num] = v;
      emagv[num] = ver;
      tv[num] = d;
   }
}
*nptsv = num;
fclose(fp1);

// ADJUST TIMES SO THAT START OF DATA IS T = 0
if (tv[1] < tr[1]) t0 = tv[1];
else t0 = tr[1];
if(verfl==1) printf("Time zero point is %lf\n", t0);
for(i=1;i<=*nptsv;i++) tv[i] -= t0;
for(i=1;i<=*nptsr;i++) tr[i] -= t0;

if(verfl==1)printf("Data read \n");
if(verfl==1)printf("%d visual points\n", *nptsv);
if(verfl==1)printf("%d red points\n", *nptsr);

}


//*****************************************************************
//   ONEDATA.C
/*****************************************************************
Reads in I band data if present.  Works the same as indata.c
*****************************************************************/
void onedata(char inname[],double t[],double mag[],double emag[],
int *npts){

int num, tran, i;
double d, y, yer;
FILE *fp1;
char line[200], newname[15];
```

```
num = 0;
strcpy(newname, "i");
strcat(newname, inname);
if(verfl==1)printf("opening - %s\n", newname);
if ((fp1 = fopen(newname, "r")) == NULL){
   printf("File Error\n");
   exit(0);
}
else{
   while ((fgets(line, 200, fp1)) != NULL){
      sscanf(line, "%lf %lf %lf", &d, &y, &yer);
      num++;
      mag[num] = y;
      emag[num] = yer;
      t[num] = d;
   }
}
*npts = num;
fclose(fp1);
if(verfl==1) printf("Time zero point is %lf\n", t0);
for(i=1;i<=*npts;i++) t[i] -= t0;

if(verfl==1)printf("Data read \n");
if(verfl==1)printf("%d points\n", *npts);

}


//*****************************************************************
// FLUX.C
/******************************************************************
Converts an array of magnitude data into fluxes relative to a
reference magnitude mean.
 *****************************************************************/
void flux(double mean, double mag[], double emag[], double l[],
double el[], int npts){

int i;
for (i=1; i<=npts; i++){
   l[i] = pow( 10, (-0.4*(mag[i]-mean)) );
   el[i] = fabs(l[i] * log(10) * 0.4 * emag[i]);
   if (emag[i] == 0.0) el[i] = 1.0;
}
if (verfl==1)printf("converted to system light\n");

}


//*****************************************************
//   DISPLAY.C
/******************************************************
Displays a plot of x[] vs y[] data to x11 device.  Uses
```

```
SM macros
*******************************************************/
void display(double x[], double y[], int n){

float x2[nd],y2[nd],pt[nd],a;
float minx=1000000.0,maxx=0.0,miny=1000000.0,maxy=0.0;
int i;

// CONVERT DOUBLES TO FLOATS
for(i=1;i<=n;i++){
  x2[i] = (float)x[i];
  y2[i] = (float)y[i];
}

// FIND LIMITS OF DATA SET
for(i=1;i<=n;i++){
  if(x2[i]>maxx) maxx = x2[i];
  if(x2[i]<minx) minx = x2[i];
  if(y2[i]>maxy) maxy = y2[i];
  if(y2[i]<miny) miny = y2[i];
  pt[i] = 41.0;
}

// DRAW PLOT
sm_graphics();
a = sm_device("x11");
sm_ctype_i(0);
sm_expand(1.01);
sm_erase();
sm_limits(minx,maxx,miny,maxy);
sm_box(1,2,0,0);
sm_ptype(pt,n);
sm_points(x2,y2,n);
sm_gflush();
sm_alpha();
//printf("Hit any key to continue.\n");
//sm_redraw(0);
//pause();
}
/*******************************************************
Displays a plot of x[] vs y[] data to x11 device as well
as a line fit to it.  Uses SM macros.
*******************************************************/
void displayfit(double x[],double y[],int n,double fx[],
double fy[],int fn){

float x2[nd],y2[nd],pt[nd],fx2[nd],fy2[nd],fpt[nd],a;
float minx=1000000.0,maxx=0.0,miny=1000000.0,maxy=0.0;
int i;

// CONVERT DOUBLES TO FLOATS
for(i=1;i<=n;i++){
```

```
  x2[i] = (float)x[i];
  y2[i] = (float)y[i];
}
for(i=1;i<=fn;i++){
  fx2[i] = (float)fx[i];
  fy2[i] = (float)fy[i];
}

// FIND LIMITS OF DATA SETS
for(i=1;i<=n;i++){
  if(x2[i]>maxx) maxx = x2[i];
  if(x2[i]<minx) minx = x2[i];
  if(y2[i]>maxy) maxy = y2[i];
  if(y2[i]<miny) miny = y2[i];
  pt[i] = 41.0;
}
for(i=1;i<=fn;i++){
  if(fx2[i]>maxx) maxx = fx2[i];
  if(fx2[i]<minx) minx = fx2[i];
  if(fy2[i]>maxy) maxy = fy2[i];
  if(fy2[i]<miny) miny = fy2[i];
  fpt[i] = 0.0;
}

// GENERATE PLOT
sm_graphics();
a = sm_device("x11");
sm_ctype_i(2);
sm_expand(1.01);
sm_erase();
sm_limits(minx,maxx,miny,maxy);
sm_box(1,2,0,0);
sm_ptype(pt,n);
sm_points(x2,y2,n);
sm_ptype(fpt,fn);
sm_points(fx2,fy2,fn);
sm_gflush();
sm_alpha();
//printf("Hit any key to continue.\n");
//sm_redraw(0);
//pause();
}
```

The following code was used to obtain initial values for the fit parameters.

```
//*******************************************************
//  INIT.C
/*******************************************************
Main program for initial fitting, calls all subroutines.
 *******************************************************/
```

```
#include <stdio.h>
#include <math.h>
#include <strings.h>

#define nd 10002
#define np 40
#define PI 3.14159
int verfl = 1;
int varstar;
int iflag = 0;
int varflag = 1;
double t0;
int aflag2[np];
double pend,sbeg,send,pbeg;

#include "init.h"

int main(){

double tv[nd],magv[nd],emagv[nd],lv[nd],elv[nd],vmag=0.0;
double tr[nd],magr[nd],emagr[nd],lr[nd],elr[nd],rmag=0.0;
double ti[nd],magi[nd],emagi[nd],li[nd],eli[nd],imag=0.0;
double lpv,lsv,lpr,lsr,conv,conr,chi,a[np],phase[nd];
double bper,fx[3001],fy[3001],fph[3000];
int i,nptsv,nptsr,nptsi;
char datfile[15],confile[15],ans[3];
FILE *fp;

for(i=0;i<np;i++) a[i] = 0.0;

printf("Is this a variable system:(y/n)  ");
scanf("%s", &ans);
//strcpy(ans,"y");

if( strcmp(ans,"n")==0 ) varflag = 0;
printf("varflag set at: %d\n", varflag);

printf("Is there I band data:(y/n)  ");
scanf("%s", &ans);
//strcpy(ans,"n");

if( strcmp(ans,"n")==0 ) iflag = 0;
if( strcmp(ans,"y")==0 ) iflag = 1;
printf("iflag set at: %d\n", iflag);

// GET NAME OF DATA FILE
printf("Enter data file name: ");
scanf("%s", &datfile);
//strcpy(datfile,"ceph78.dat");

// READ IN DATA
indata(datfile,tv,tr,magv,magr,emagv,emagr,&nptsv,&nptsr);
```

```
if (iflag == 1) onedata(datfile,ti,magi,emagi,&nptsi);
// GET ORBITAL PERIOD AND PHASE THE DATA
printf("Enter orbital period of the binary system: ");
scanf("%lf",&bper);
//bper = 420.589680;

a[1] = 2*PI/bper;
format(tv,magv,a,nptsv);

// FIND WEIGHTED AVERAGE VALUES OF MAGNITUDE
avemag(magv,emagv,nptsv,&vmag,tv,a);
printf("Average V magnitude: %lf\n",vmag);
avemag(magr,emagr,nptsr,&rmag,tr,a);
printf("Average R magnitude: %lf\n",rmag);
if (iflag == 1){
  avemag(magi,emagi,nptsi,&imag,ti,a);
  printf("Average I magnitude: %lf\n",imag);
}

// CONVERT MAGNITUDES TO FLUXES
flux(vmag,magv,emagv,lv,elv,nptsv);
flux(rmag,magr,emagr,lr,elr,nptsr);
if (iflag == 1) flux(imag,magi,emagi,li,eli,nptsi);

// TAKE A LOOK AT DATA
 for(i=1;i<=nptsv;i++){
   phase[i] = (fmod(tv[i],2*PI/a[1])*a[1]) - a[2];
   if (phase[i]<0) phase[i] += 2*PI;
 }
 display(phase,lv,nptsv);
 for(i=1;i<=nptsr;i++){
   phase[i] = (fmod(tr[i],2*PI/a[1])*a[1]) - a[2];
   if (phase[i]<0) phase[i] += 2*PI;
 }
 display(phase,lr,nptsr);
 if (iflag==1){
   for(i=1;i<=nptsi;i++){
     phase[i] = (fmod(ti[i],2*PI/a[1])*a[1]) - a[2];
     if (phase[i]<0) phase[i] += 2*PI;
   }
 display(phase,li,nptsi);
 }

// GET DEPTHS OF MINIMA, PHASE AT EXTERNAL CONTACT
minima(tv,lv,a,nptsv,&lpv,&lsv,&conv);
minima(tr,lr,a,nptsr,&lpr,&lsr,&conr);
printf("contact angles are %lf %lf\n", conv,conr);

// GET GUESS VALUES AND IMPROVE BY FITTING
guess(lpv,lsv,lpr,lsr,pend,a);
basicfit(tv,lv,elv,nptsv,a);
a[8] = a[6];
```

```
a[9] = a[7];

// GET CEPHEID PERIOD AND VALUES FOR VARIABILITY
if (varflag == 1){
  extract(tv,lv,nptsv,a);
  //a[14] = 0.358328;
  cvar(tv,lv,nptsv,a);
  rvar(tv,lv,nptsv,a);

  for(i=25;i<=30;i++) a[i] = a[i-7];
  if (iflag == 1){
    for(i=34;i<40;i++) a[i] = a[i-9];
    a[31] = a[8];
    a[32] = a[9];
  }
}
else varstar = 0;

// GENERATE FINAL COMPARISON PLOT
for (i=1;i<=nptsv;i++){
  phase[i] = (fmod(tv[i],2*PI/a[1])*a[1]) - a[2];
  if (phase[i] <0) phase[i] += 2*PI;
}
fx[0] = 0;
for(i=1;i<=1000;i++){
  fx[i] = fx[i-1] + 2000/1000;
  fph[i] = (fmod(fx[i],2*PI/a[1])*a[1]) - a[2];
  if (fph[i] < 0) fph[i] += 2*PI;
  fy[i] = lightcal1(fx[i],a);
}

//displayfit(phase,lv,nptsv,fph,fy,1000);


// OUTPUT ".IN" FILE

printf("Enter control file name: ");
scanf("%s", &confile);

fp = fopen(confile,"w");
fprintf(fp,"%s\n",datfile);
fprintf(fp,"%lf\t%lf\t%lf\n",vmag,rmag,imag);
fprintf(fp,"%d\n",varstar);
fprintf(fp,"%lf\n",0.0);
for(i=1;i<=41;i++) fprintf(fp,"%lf %lf %d\n",a[i],0.0,1);
fclose(fp);
printf("%s written\n", confile);

}


/************************************************************
```

```
FORMAT - PUT PRIMARY MINIMUM AT PHASE = 0
**********************************************************/
void format(double t[],double l[],double a[],int npts){

int i;
char ans[3];
double ph[nd],phmin,min;

for(i=1;i<=npts;i++) ph[i] = (fmod(t[i], (2*PI/a[1]))*a[1]);
min = 0;
for(i=1;i<=npts;i++){
   if (l[i]>min){
      min = l[i];
      phmin = ph[i];
   }
}
printf("Primary minimum at %lf\n", phmin);
a[2] = phmin;

for(i=1;i<=npts;i++){
  ph[i] = (fmod(t[i], (2*PI/a[1]))*a[1])-a[2];
  if(ph[i]<0) ph[i] += 2*PI;
}
display(ph,l,npts);
//nplot("plot.tem",ph,l,npts);

// CONFIRM FORMAT
printf("Look good(y/n): ");
/*strcpy(ans,"y");*/
scanf("%s",&ans);

// ENTER IT BY HAND IF YOU WANT
while(strcmp(ans,"y")!=0){
   printf("Enter the phase angle of the primary minimum: ");
   scanf("%lf",&a[2]);
   a[2] = 0.837;
   for(i=1;i<=npts;i++){
ph[i] = (fmod(t[i], (2*PI/a[1]))*a[1])-a[2];
if(ph[i]<0) ph[i] += 2*PI;
   }
   display(ph,l,npts);
   //nplot("plot.tem",ph,l,npts);
   printf("Look good(y/n)");
   scanf("%s",&ans);
}
strcpy(ans,"n");

// FIND BOUNDARIES OF THE ECLIPSES
while(strcmp(ans,"y")!=0){
  printf("Enter the phase angle of contact:  ");
  scanf("%lf", &pend);
  pbeg = 2*PI - pend;
```

```
  send = pend + PI;
  sbeg = pbeg - PI;
  edisplay(ph,1,npts);
  printf("Look good(y/n)");
  scanf("%s",&ans);
}

}
/**************************************************
AVEMAG - FIND AVERAGE VALUE OF MAGNITUDE
**************************************************/
void avemag(double m[],double sig[],int npts, double *mean,
 double t[], double a[]){

int i,count=0;
double ave=0,oldave=0,dif,wt,n,ph[nd],tempy[nd],tempe[nd];

// TAKE ONLY THE ECLIPSE POINTS
printf("Eclipse boundaries: %lf %lf %lf %lf\n",pend,sbeg,send,pbeg);
 for(i=1;i<=npts;i++){
   ph[i] = (fmod(t[i], (2*PI/a[1]))*a[1])-a[2];
   if(ph[i]<0) ph[i] += 2*PI;
   if (((ph[i]>pend)&&(ph[i]<sbeg))||((ph[i]>send)&&(ph[i]<pend))){
     count++;
     tempy[count] = m[i];
     tempe[count] = sig[i];
   }
 }

/*  FIND SIMPLE AVERAGE MAGNITUDE */
for(i=1;i<=count;i++) ave += tempy[i];
ave /= count;
printf("Simple average is %lf\n", ave);

/*  WEIGHT POINTS AND FIND AVERAGE */
do{
   oldave = ave;
   ave = 0;
   n = 0;
   for (i=1;i<=count;i++){
      dif = fabs(tempy[i]-oldave);
      if (tempe[i] != 0) wt = 1.0 / (1 + pow( (dif/(2*tempe[i])),2) );
      else wt = 1.0;
      /*printf("%lf %lf\n", dif, wt);*/
      ave += tempy[i] * wt;
      n += wt;
   }
   ave /= n;
   /* printf("Average is %lf\n", ave); */
}while( fabs(oldave-ave) > 0.000001);

*mean = ave;
```

```
}


//**************************************************
// GETS DEPTH OF MINIMA
//**************************************************
void minima(double t[],double l[],double a[],int npts,
   double *lp,double *ls, double *con){

double ph[nd],tl[nd];
double eclph[nd],ecly[nd],fitx[10000],fity[10000],sig[nd];
int i,count,num,na,fitn;

double **covar, **alpha;
double chisqr,chiold,alamda,b[5],dum[5];
int aflag[5];

aflag[1]=1; aflag[2]=1; aflag[3]=1; aflag[4]=1;

for(i=1;i<=npts;i++){
   ph[i] = (fmod(t[i], (2*PI/a[1]))*a[1])-a[2];
   if(ph[i]<0) ph[i] += 2*PI;
   tl[i] = l[i];
}
sort2(npts,ph,tl);

// GET PRIMARY ECLIPSE POINTS
count = 0;
for (i=1;i<=npts;i++){
   if (ph[i]<pend){
      count++;
      eclph[count] = ph[i];
      ecly[count] = tl[i];
   }
   if (ph[i]>pbeg){
      count++;
      eclph[count] = ph[i]-2*PI;
      ecly[count] = tl[i];
   }
}
sort2(count,eclph,ecly);

// FIT A HYPERBOLA TO THE ECLIPSE
na = 4;
covar = dmatrix(1, na, 1, na);
alpha = dmatrix(1, na, 1, na);
for (i=1;i<=count;i++) sig[i] = 1.0;
alamda = -10;
b[1] = 0.5; b[2] = 0.1; b[3] = 0.001; b[4] = 0.5;
mrqmin(eclph,ecly,sig,count,b,aflag,na,covar,alpha,
       &chisqr,hyper,&alamda);
num = 0;
```

```
do{
   num++;
   chiold = chisqr;
   mrqmin(eclph,ecly,sig,count,b,aflag,na,covar,alpha,&chisqr,
      hyper,&alamda);
}while(((chiold<=chisqr)||(fabs(chiold-chisqr)>0.000000001))
       &&(num<200));

printf("\nFinal chi-sq: %lf, reduced - %lf\n",
       chisqr,chisqr/(count-na));

printf("%lf %lf %lf %lf\n", b[1],b[2],b[3],b[4]);
fitn = 200;

// GENERATE PLOT OF FIT
for (i=1;i<=fitn;i++){
   fitx[i] = eclph[1] + i*(eclph[count]-eclph[1])/fitn;
   hyper(fitx[i],b,&fity[i],dum,5);
}
// GET VALUE AT MINIMA, PHASE AT CONTACT
*lp = b[1] + b[4];
*con = sqrt(b[2]*b[2]/b[1]/b[1] * (1.0-b[4])*(1.0-b[4]))+b[3];
printf("minimum of %lf at %lf\n",*lp,b[3]);
printf("y = 1 at phase of %lf\n", *con);
//plotfit(eclph,ecly,count,fitx,fity,fitn);

// GET SECONDARY ECLIPSE POINTS
count = 0;
for (i=1;i<=npts;i++){
   if ((ph[i]>sbeg)&&(ph[i]<send)){
      count++;
      eclph[count] = ph[i];
      ecly[count] = tl[i];
   }
}
sort2(count,eclph,ecly);

// FIT A HYPERBOLA TO THE ECLIPSE
na = 4;
covar = dmatrix(1, na, 1, na);
alpha = dmatrix(1, na, 1, na);
for (i=1;i<=count;i++) sig[i] = 1.0;
alamda = -10;
b[1] = 0.5; b[2] = 0.1; b[3] = 3.14; b[4] = 0.5;
mrqmin(eclph,ecly,sig,count,b,aflag,na,covar,alpha,
       &chisqr,hyper,&alamda);
num = 0;
do{
   num++;
   chiold = chisqr;
   mrqmin(eclph,ecly,sig,count,b,aflag,na,covar,alpha,&chisqr,
      hyper,&alamda);
```

```
}while(((chiold<=chisqr)||(fabs(chiold-chisqr)>0.000000001))
       &&(num<200));
printf("\nFinal chi-sq: %lf, reduced - %lf\n",
       chisqr,chisqr/(count-na));
printf("%lf %lf %lf %lf\n", b[1],b[2],b[3],b[4]);

fitn = 200;
for (i=1;i<=fitn;i++){
   fitx[i] = eclph[1] + i*(eclph[count]-eclph[1])/fitn;
   hyper(fitx[i],b,&fity[i],dum,5);
}
*ls = b[1] + b[4];
printf("minimum of %lf at %lf\n",*ls,b[3]);
//plotfit(eclph,ecly,count,fitx,fity,fitn);

}

/********************************************************
Equation of a hyperbola, also computes derivatives.  Needed
for fitting
 ********************************************************/
void hyper(double x,double b[],double *y,double dfda[],int n){

*y = sqrt( b[1]*b[1] + b[1]*b[1]/b[2]/b[2]
   * (x-b[3])*(x-b[3]) ) + b[4];
dfda[1] = 1/(*y-b[4]) * (b[1] + b[1]/b[2]/b[2]
   * (x-b[3])*(x-b[3]) );
dfda[2] = 1/(*y-b[4]) * (-b[1]*b[1]/b[2]/b[2]/b[2]
   * (x-b[3])*(x-b[3]) );
dfda[3] = 1/(*y-b[4]) * (-b[1]*b[1]/b[2]/b[2] * (x-b[3]) );
dfda[4] = 1;
}


/*-------------------------------------------------------
Returns guess values for parameters.
Program returns radii and luminosity of the two stars and
inclination of orbit.
Based on Riazi, N. 1992, Astron. J.  104 (1)
-------------------------------------------------------*/
void guess(double li_vp,double li_vs,double li_bp,
   double li_bs,double ph1,double a[]){

int j, m;
double i_guess, phase, delta, temp;
double l1_v, l2_v, l1_b, l2_b, r1_v, r1_b, r2_v, r2_b, k_v, k_b;
double S, xi, zeta, dg, So, S_1, i_o, i_v, i_b, argx, argz;
m = 4; i_guess = 80.0*PI/180;
/*-------------------------------------------------------
evaluate eqns 6-8 to get luminosities and ratio of radii
in both filters
-------------------------------------------------------*/
```

```
l1_v = 1/( fabs(li_bp-li_vp)*(1-li_vs)/fabs(li_vs-li_bs)/
   (1-li_vp) + 1 );
l2_v = 1 - l1_v;
k_v = sqrt((1-li_vp)/(1-li_vs)*l2_v/l1_v);

l1_b = 1/( fabs(li_vp-li_bp)*(1-li_bs)/fabs(li_bs-li_vs)/
   (1-li_bp) + 1 );
l2_b = 1 - l1_b;
k_b = sqrt((1-li_bp)/(1-li_bs)*l2_b/l1_b);

if(verfl==1)printf("visual luminosity and ratio\n");
if(verfl==1)printf("%lf %lf %lf\n", l1_v, l2_v, k_v);
if(verfl==1)printf("blue luminosity and ratio\n");
if(verfl==1)printf("%lf %lf %lf\n", l1_b, l2_b, k_b);

/*-------------------------------------------------------------
for the visual data - begin with guess value of delta
-------------------------------------------------------------*/
dg = cos(i_guess);
i_o = i_guess;
/*printf("\nVisual data\n");
do{
   r1_v = ( sqrt(sin(ph1)*sin(ph1) +
      dg*dg*cos(ph1)*cos(ph1)) )/(1+k_v);
   r2_v = k_v * r1_v;
   if(dg>fabs(r1_v-r2_v)){
      argz = (r1_v*r1_v - r2_v*r2_v + dg*dg) / (2*r1_v*dg);
      argx = (r2_v*r2_v - r1_v*r1_v + dg*dg) / (2*r2_v*dg);
      zeta = acos(argz);
      xi = acos(argx);
      S = r1_v*r1_v/2 * (2*zeta-sin(2*zeta)) +
         r2_v*r2_v/2 * (2*xi-sin(2*xi));
      So = PI * r1_v*r1_v / l1_v * (1-li_vp);
      S_1 = -2*r1_v*r2_v/dg * sin(zeta + xi);
      dg = dg - ((S - So)/S_1);
      i_o = acos(dg);
   }
   else{
      printf("\nTotal eclipsing system in visual\n");
      So = S;
   }
} while( fabs(So-S) > 0.000001);
/*----------------------------------------------------------
for the blue data - begin with guess value of delta
----------------------------------------------------------*/
dg = cos(i_guess);
i_o = i_guess;
/*printf("\nBlue data\n");
do{
   r1_b = ( sqrt(sin(ph1)*sin(ph1) + dg*dg*cos(ph1)*cos(ph1)))
      /(1+k_b);
   r2_b = k_v * r1_b;
```

```
    if (dg>fabs(r1_b-r2_b)){
       argz = (r1_b*r1_b - r2_b*r2_b + dg*dg) / (2*r1_b*dg);
       argx = (r2_b*r2_b - r1_b*r1_b + dg*dg) / (2*r2_b*dg);
       zeta = acos(argz);
       xi = acos(argx);
       S = r1_b*r1_b/2 * (2*zeta-sin(2*zeta)) + r2_b*r2_b/2 *
          (2*xi-sin(2*xi));
       So = PI * r1_b*r1_b / l1_b * (1-li_bp);
       S_1 = -2*r1_b*r2_b/dg * sin(zeta + xi);
       dg = dg - ((S - So)/S_1);
       i_o = acos(dg);
    }
    else{
       printf("\nTotal eclipsing system in blue\n");
       So = S;
    }
 } while( fabs(So-S) > 0.000001);

 a[3] = i_o;

 a[4] = (r1_v+r1_b)/2; a[5] = (r2_v+r2_b)/2;
 a[6] = l1_v/(PI*a[4]*a[4]); a[7] = (1-l1_v)/(PI*a[5]*a[5]);

 printf("\nResults:\n");
 printf("inclination: %lf\n",a[3]);
 printf("radii:  %lf  %lf\n",a[4],a[5]);
 printf("vfluxes: %lf  %lf\n",a[6],a[7]);

 a[8] = l1_b/(PI*a[4]*a[4]); a[9] = (1-l1_b)/(PI*a[5]*a[5]);

 printf("rfluxes: %lf  %lf\n",a[8],a[9]);

 if ((r1_v > r2_v)&&(r1_b > r2_b)){
    varstar = 1;
    if(verfl==1)printf("star 1 is variable\n");
 }
 else if ((r1_v < r2_v)&&(r1_b < r2_b)){
    varstar = 2;
    if(verfl==1)printf("star 2 is variable\n");
 }
 else {
    varstar = 0;
    printf("filters disagree \n");
    exit(0);
 }
 printf("Which star do you want to be the variable(1/2): ");
 scanf("%d", &varstar);
 }


 //************************************************************
 //     BASICFIT.C
```

```
/*********************************************************
Fits a simplified model to a simplified lightcurve.
 *********************************************************/
double areacalc(double r1, double r2, double d);
void basicfit(double tv[],double lv[],double elv[],
int nptsv,double a[]){

double **covar,**alpha;
double chisqr,chiold,alamda,dum[np];
int i,na,num;
char ans[5],ans2[5];
double tempy[nd],tempe[nd],ph[nd],fx[3001],fy[3001],fp[3000];

// REMOVE VARIABILITY BY SETTING
// ALL NON-ECLIPSE POINTS TO l = 1.0
printf("Eclipse boundaries: %lf %lf %lf %lf\n", pend,sbeg,send,pbeg);
for(i=1;i<=nptsv;i++){
   ph[i] = (fmod(tv[i], (2*PI/a[1]))*a[1])-a[2];
   if(ph[i]<0) ph[i] += 2*PI;
   if (ph[i]<pend) tempy[i] = lv[i];
   else if (ph[i]>pbeg) tempy[i] = lv[i];
   else if ((ph[i]>sbeg) && (ph[i]<send)) tempy[i] = lv[i];
   else tempy[i] = 1.0;
   tempe[i] = elv[i];
}
sort3(nptsv,ph,tempy,tempe);

display(ph,tempy,nptsv);
//nplot("plot.tem",ph,tempy,nptsv);
//pause();

for(i=0;i<=np;i++) aflag2[i] = 0;
for(i=3;i<=6;i++) aflag2[i] = 1;
na = np-1;

// FIT LIGHTCURVE TO DATA
covar = dmatrix(1, na, 1, na);
alpha = dmatrix(1, na, 1, na);

// PLOT OF STARTING VALUES
do{
   alamda = -10;
   printf("Starting point: %lf %lf %lf %lf %lf\n",
      a[3],a[4],a[5],a[6],a[7]);
   fx[0] = 0;
   for(i=1;i<=1000;i++){
   fx[i] = fx[i-1] + 2*PI/1000;
   fy[i] = oldcal(fx[i],a);
}
displayfit(ph,tempy,nptsv,fx,fy,1000);

mrqmin(ph,tempy,tempe,nptsv,a,aflag2,na,covar,alpha,
```

```
    &chisqr,light,&alamda);
num = 0;
do{
    num++;
    chiold = chisqr;
    mrqmin(ph,tempy,tempe,nptsv,a,aflag2,na,covar,alpha,
       &chisqr,light,&alamda);
    printf("%d chi-sq = %lf ", num,chisqr);
    for(i=1;i<=np;i++) if(aflag2[i]==1) printf("%lf ",a[i]);
    printf("\n");
}while(((chiold<=chisqr)||(fabs(chiold-chisqr)>0.0001))
    &&(num<300));

printf("\nFinal chi-sq: %lf, reduced - %lf\n",
    chisqr, chisqr/(nptsv-na));
for(i=3;i<=7;i++) printf("%lf ",a[i]);
printf("\n");

// DISPLAY FINAL FIT
fx[0] = 0;
for(i=1;i<=1000;i++){
  fx[i] = fx[i-1] + 2*PI/1000;
  fy[i] = oldcal(fx[i],a);
}
displayfit(ph,tempy,nptsv,fx,fy,1000);
//plotfit(ph,tempy,nptsv,fx,fy,1000);
printf("Is the fit good(y/n): ");
scanf("%s", &ans);

// MANUAL ENTRY OF PARAMETERS IF DESIRED
if(strcmp(ans,"n") == 0){
  do{
    printf("Enter inclination: ");
    scanf("%lf", &a[3]);
    printf("Enter r1: ");
    scanf("%lf", &a[4]);
    printf("Enter r2: ");
    scanf("%lf", &a[5]);
    printf("Enter f1: ");
    scanf("%lf", &a[6]);
    a[7] = (1 - PI*a[4]*a[4]*a[6]) / (PI*a[5]*a[5]);
    printf("f2 is %lf\n", a[7]);

    fx[0] = 0;
    for(i=1;i<=1000;i++){
      fx[i] = fx[i-1] + 2*PI/1000;
      fy[i] = oldcal(fx[i],a);
    }
    displayfit(ph,tempy,nptsv,fx,fy,1000);
    //nplot("plot.tem",fx,fy,1000);
    printf("accept?(y/n): ");
    scanf("%s", &ans2);
```

```
  }while(strcmp(ans2,"n") == 0);
}

}while(strcmp(ans,"n") == 0);

}
//*************************************************************
// CALLS THE LIGHT CALCULATION ROUTINE
void light(double ph, double a[], double *y, double dda[], int na){
   int i;
   double err;
   y = oldcal(ph, a);
   for (i=1; i<=na; i++){
      if (aflag2[i] != 0){
         if (a[i] != 0.0)
            dda[i]=dfridr(oldcal,ph,a,na,i,(0.001*a[i]),&err);
         else dda[i]=dfridr(oldcal,ph,a,na,i,0.01,&err);
      }
      else dda[i] = 0.0;
   }
}
//*************************************************************
// SIMPLIFIED MODEL
/* This function computes the system light at any time for
eclipsing binary system v data only.
For spherical stars on circular orbits with uniform surface
brightness.  Phase data and array of parameters are read in,
system light is returned.*/
//**************************************************************
double oldcal(double phase, double a[])
{
double l1, l2, r1, r2, i, d, ph2,j1,j2;
double li;

i = a[3]; r1 = a[4]; r2 = a[5];
j1 = a[6];
l1 = PI * r1*r1 * j1;
l2 = 1 - l1;
j2 = l2 / ( PI*r2*r2);
a[7] = j2;

l1 = PI * r1*r1 * j1;
l2 = PI * r2*r2 * j2;
if (phase > PI) ph2 = (phase - PI);
else ph2 = phase;

// Apparent separation of two stars
d = sqrt( 1- pow(sin(i),2) * pow(cos(ph2),2) );

if (d < (r1+r2)){ //there is an eclipse

/*primary eclipse*/
```

```
if ( (phase < PI/2) || (phase > 3*PI/2) ){
   // annular eclipse
   if (d < (r1-r2)) li = (l1 + l2) - (PI * r2*r2 * j1);
   // total eclipse
   else if (d < (r2-r1) ) li = l2;
   // partial eclipse
   else li = (l1 + l2)-(areacalc(r1,r2,d)*j1);
}
/*secondary eclipse*/
else {
   // total eclipse
   if (d < (r1-r2)) li = l1;
   // annular eclipse
   else if (d < (r2-r1))li = (l1 + l2) - (PI * r1*r1 *j2);
   // partial eclipse
   else li = (l1 + l2)-(areacalc(r1,r2,d)*j2);
}

}

else li = l1 + l2;

return (li);

}
double areacalc(double r1, double r2, double d){
  double arg1,arg2,a1,a2;
  //Area covered during eclipse
  arg1 = (r1*r1 - r2*r2 + d*d)/(2*r1*d);
  a1 = acos(arg1);
  arg2 = (r2*r2 - r1*r1 + d*d)/(2*r2*d);
  a2 = acos(arg2);
  return(r2*r2/2*(2*a2-sin(2*a2)) + r1*r1/2*(2*a1-sin(2*a1)));
}


/*-----------------------------------------------------------------
extract: examines the data outside of eclipse in order to determine
the period of the Cepheid pulsation
-----------------------------------------------------------------*/

void extract(double t[],double y[],int npts, double a[])
{
double per;
int i, count;
double  ph[nd],newt[nd],newy[nd],newph[nd];
double px[100000], py[100000], prob, ofac, hifac;
double fx[3000],fy[3000],fp[3000];
int n, nout, jmax;

// ELIMINATE ECLIPSE POINTS
for(i=1;i<=npts;i++){
```

```
   ph[i] = (fmod(t[i], (2*PI/a[1]))*a[1])-a[2];
   if(ph[i]<0) ph[i] += 2*PI;
   newy[i] = y[i];
   newt[i] = t[i];
}
sort3(npts,ph,newy,newt);

printf("Eclipse boundaries: %lf %lf %lf %lf\n",pend,sbeg,send,pbeg);
count = 0;
for(i=1;i<=npts;i++){
  if( ((ph[i]>pend)&&(ph[i]<sbeg))||((ph[i]>send)&&(ph[i]<pbeg)) ){
    count++;
    newt[count] = newt[i];
    newy[count] = newy[i];
    newph[count] = ph[i];
  }
}
printf("%d non eclipse points\n",count);
display(newph,newy,count);
//nplot("plot.tem", newph,newy,count);
//pause();
sort2(count,newt,newy);

/*----------------------------------------------------------
use Lomb normalized periodogram to get period
----------------------------------------------------------*/
ofac = 7;
hifac = 8;
n = (int)(ofac * hifac/2*count);
printf("\nFinding period\n");
period(newt,newy,count,ofac,hifac,px,py,n,&nout,&jmax,&prob);
printf("jmax - %d prob - %lf num - %d\n", jmax, prob, n);

per = 1/px[jmax];
printf("period is %lf \n", per);
a[14] = 2*PI/per;

for (i=1; i<=count; i++) ph[i] = fmod(newt[i], per)/per;

display(ph,newy,count);
//nplot("plot.tem", ph,newy,count);
//pause();

}


//*******************************************************************
//   PERIOD.C -- FROM NUMERICAL RECIPES (PRESS ET AL)
/*******************************************************************
Given n data points with abscissas x[] and ordinates y[] and desired
oversampling factor ofac this routine fills array px[] with an
increasing sequence of frequencies up to hifac times the Nyquist
```

```
  swtau=sin(wtau);
  cwtau=cos(wtau);
  sums=sumc=sumsy=sumcy=0.0;
  for (j=1;j<=n;j++) {  //LOOP AGAIN TO GET PERIODOGRAM VALUES
    s=wi[j];
    c=wr[j];
    ss=s*cwtau-c*swtau;
    cc=c*cwtau+s*swtau;
    sums += ss*ss;
    sumc += cc*cc;
    yy=y[j]-ave;
    sumsy += yy*ss;
    sumcy += yy*cc;
            // UPDATE TRIGOMETRIC RECURRENCES
    wr[j]=((wtemp=wr[j])*wpr[j]-wi[j]*wpi[j])+wr[j];
    wi[j]=(wi[j]*wpr[j]+wtemp*wpi[j])+wi[j];
  }
  py[i]=0.5*(sumcy*sumcy/sumc+sumsy*sumsy/sums)/var;
  if (py[i] >= pymax) pymax=py[(*jmax=i)];
  pnow += 1.0/(ofac*xdif);   //NEXT FREQUENCY
}
expy=exp(-pymax);
    //FIND STATISTICAL SIGNIFICANCE OF MAXIMUM
*prob=effm*expy;
if (*prob > 0.01) *prob=1.0-pow(1.0-expy,effm);
free_dvector(wr,1,n);
free_dvector(wpr,1,n);
free_dvector(wpi,1,n);
free_dvector(wi,1,n);
}
#undef TWOPID
#undef NRANSI

/*******************************************************************
Given array data[] returns its mean as ave and its variance as var
*******************************************************************/
void avevar(double data[], unsigned long n, double *ave, double *var)
{
  unsigned long j;
  double s,ep;

  for (*ave=0.0,j=1;j<=n;j++) *ave += data[j];
  *ave /= n;
  *var=ep=0.0;
  for (j=1;j<=n;j++) {
    s=data[j]-(*ave);
    ep += s;
    *var += s*s;
  }
  *var=(*var-ep*ep/n)/(n-1);
}
```

```
//**********************************************************
// FIT FOURIER SERIES TO CEPHEID PULSATION
//**********************************************************

void cvar(double t[],double y[],int npts,double a[]){

double ph[nd],newy[nd],newt[nd],fitx[nd],fity[nd],sig[nd];
double fx[3000],fy[3000],fp[3000],ycalc;
int i,count,na,fitn,num;

double **covar,**alpha;
double chisqr,chiold,alamda,dum[np];
int aflag[7];

for(i=0;i<np;i++) aflag[i] = 0;
for(i=18;i<=23;i++) aflag[i] = 1;
aflag[16] = 1;
na = np-1;


// ELIMINATE ECLIPSE POINTS
 for(i=1;i<=npts;i++){
   ph[i] = (fmod(t[i], (2*PI/a[1]))*a[1])-a[2];
   if(ph[i]<0) ph[i] += 2*PI;
   newy[i] = y[i];
   newt[i] = t[i];
 }
sort3(npts,ph,newy,newt);
printf("Eclipse boundaries: %lf %lf %lf %lf\n",
pend,sbeg,send,pbeg);

count = 0;
 for(i=1;i<=npts;i++){
   if(((ph[i]>pend)&&(ph[i]<sbeg))||((ph[i]>send)&&(ph[i]<pbeg))){
     count++;
     newt[count] = newt[i];
     newy[count] = newy[i];
   }
 }
printf("%d non eclipse points\n",count);

sort2(count,newt,newy);

// FIT FOURIER SERIES TO DATA
covar = dmatrix(1, na, 1, na);
alpha = dmatrix(1, na, 1, na);
for (i=1;i<=count;i++) sig[i] = 1.0;
alamda = -10;
for(i=18;i<=23;i++) a[i] = 0.05;
a[16] = 0.5;
```

```
mrqmin(newt,newy,sig,count,a,aflag,na,covar,alpha,
       &chisqr,fou,&alamda);
num = 0;
 do{
   num++;
   chiold = chisqr;
   mrqmin(newt,newy,sig,count,a,aflag,na,covar,alpha,
  &chisqr,fou,&alamda);
   printf("%d chi-sq = %lf  %lf ", num,chisqr,a[16]);
   for(i=18;i<=23;i++)printf("%lf ",a[i]);
   printf("\n");
 }while(((chiold <= chisqr) || (fabs(chiold-chisqr)>0.000000001))
&&(num<200));

printf("\nFinal chi-sq: %lf, reduced - %lf\n",
       chisqr, chisqr/(count-na));
printf("%lf ",a[16]);
for(i=18;i<=23;i++)printf("%lf ",a[i]);
printf("\n");

// GENERATE PLOT OF FIT
fitn = 2000;
for (i=1;i<=fitn;i++){
  fitx[i] = newt[1] + i*(newt[count]-newt[1])/fitn;
  fou(fitx[i],a,&fity[i],dum,na);
}

// PHASE TO CEPHIED PERIOD
for (i=1; i<=count; i++) ph[i] = fmod(newt[i], (2*PI/a[14])) *a[14];
for (i=1; i<=fitn; i++) fitx[i] = fmod(fitx[i], (2*PI/a[14]))*a[14];
sort2(count,ph,newy);
sort2(fitn,fitx,fity);

displayfit(ph,newy,count,fitx,fity,fitn);
//plotfit(ph,newy,count,fitx,fity,fitn);
//pause();

}

//*************************************************************
// THE FOURIER FUCTION AND DERIVATIVES
//*************************************************************
void fou(double x,double a[],double *y,double dfda[],int n){

*y = a[16] + a[18]*cos(a[14]*x) + a[19]*sin(a[14]*x);
*y += a[20]*cos(2*a[14]*x) + a[21]*sin(2*a[14]*x);
*y += a[22]*cos(3*a[14]*x) + a[23]*sin(3*a[14]*x);
dfda[16] = 1;
dfda[18] = cos(a[14]*x);
dfda[19] = sin(a[14]*x);
dfda[20] = cos(2*a[14]*x);
dfda[21] = sin(2*a[14]*x);
```

```
dfda[22] = cos(3*a[14]*x);
dfda[23] = sin(3*a[14]*x);

}

//****************************************************
// RADIAL GUESS VALUES
//****************************************************
void rvar(double t[],double y[],int npts,double a[]){

double ph[nd];
double max,phmax;
int i;

// PHASE TO CEPHIED PERIOD
for (i=1; i<=npts; i++)
  ph[i] = fmod(t[i], (2*PI/a[14]))/(2*PI/a[14]);

// FIND PHASE AT MAX
max = 0;
for(i=1;i<=npts;i++)
  if(y[i]>max){
    max = y[i];
    phmax = ph[i];
  }
a[16] = phmax * 2*PI/a[14];

if (varstar == 2) a[15] = 0.25*a[5];
if (varstar == 1) a[15] = 0.25*a[4];

printf("Amplitude: %lf\n",a[15]);
printf("offset: %lf\n",a[16]);

}
```

Appendix B

Observation Log

B.1 6.6454.5

```
#-------------------------- MACHO Project --------------------------
# Star 6.6454.5                  05:20:25.132 -70:11:08.38 (J2000.0)
#-------------------------------------------------------------------
# Creation date (JD-2.449e+06): 2379.3765           934 observations
# Calibration: standard
# A tran of 4 indicates that the transformation from MACHO bands made
# use of both r and v values and their errors.
#-------------------------------------------------------------------
# HJD-2.449e+06     r        err_r        v        err_v     obsid  tran
#    (days)       (mag)      (mag)      (mag)      (mag)
#-------------------------------------------------------------------
   -175.8274     14.556     0.016     14.630     0.016       284     4
   -172.8134     14.559     0.015     14.655     0.015       379     4
   -170.8587     14.542     0.016     14.628     0.016       394     4
   -169.8409     14.526     0.015     14.716     0.015       429     4
   -166.8432     14.601     0.015     14.666     0.015       494     4
   -165.7242     14.537     0.015     14.601     0.015       521     4
   -164.8573     14.481     0.015     14.594     0.015       557     4
   -163.7896     14.534     0.015     14.626     0.015       650     4
   -162.8695     14.552     0.015     14.661     0.015       720     4
   -156.8302     14.600     0.016     14.686     0.015       786     4
   -155.8651     14.538     0.015     14.621     0.015       821     4
   -148.8416     14.584     0.015     14.847     0.015       886     4
   -145.7171     14.508     0.016     14.591     0.015       941     4
   -144.7481     14.529     0.015     14.679     0.015       990     4
   -142.6958     14.608     0.015     14.742     0.015      1092     4
   -114.8466     14.613     0.015     14.812     0.015      1111     4
   -113.8786     14.610     0.015     14.929     0.015      1145     4
   -111.8130     14.563     0.015     14.672     0.015      1186     4
   -110.7602     14.560     0.015     14.825     0.015      1208     4
   -106.7229     14.570     0.015     14.722     0.015      1231     4
   -104.7545     14.491     0.015     14.600     0.015      1244     4
   -103.7290     14.594     0.015     14.934     0.015      1277     4
   -102.7275     14.588     0.015     14.745     0.015      1290     4
    -83.8858     14.526     0.015     14.629     0.015      1405     4
```

-82.7866	14.604	0.015	14.691	0.015	1446	4
-81.9636	14.634	0.015	14.915	0.015	1466	4
-80.7618	14.568	0.015	14.901	0.015	1513	4
-79.9612	14.504	0.015	14.649	0.015	1528	4
-78.9735	14.590	0.015	14.891	0.015	1579	4
-72.0126	14.583	0.015	14.754	0.015	1607	4
-69.0327	14.534	0.015	14.691	0.015	1788	4
-68.0179	14.634	0.015	15.020	0.021	1808	4
-67.8449	14.649	0.015	15.055	0.015	1844	4
-63.8747	14.600	0.016	14.960	0.016	1908	4
-60.9948	14.552	0.015	14.829	0.015	1964	4
-59.9781	14.560	0.015	14.909	0.015	2021	4
-57.9172	14.579	0.018	14.676	0.017	2066	4
-49.9811	14.584	0.015	14.990	0.015	2164	4
-34.8311	14.558	0.015	14.875	0.016	2187	4
-14.9918	14.587	0.015	14.922	0.015	2340	4
-14.8266	14.528	0.016	14.634	0.015	2362	4
-13.9717	14.645	0.015	15.111	0.015	2380	4
-11.7871	14.560	0.015	14.656	0.015	2455	4
-10.9927	14.505	0.015	14.599	0.015	2471	4
-10.7986	14.504	0.015	14.600	0.015	2506	4
-9.9742	14.516	0.015	14.632	0.015	2524	4
-2.7877	14.592	0.015	14.683	0.015	2605	4
-0.8141	14.503	0.015	14.597	0.015	2662	4
0.9904	14.558	0.015	14.663	0.015	2688	4
1.1735	14.559	0.015	14.665	0.015	2723	4
1.9784	14.596	0.015	14.683	0.015	2738	4
2.1720	14.596	0.016	14.680	0.015	2775	4
2.9757	14.589	0.015	14.679	0.015	2800	4
4.0723	14.508	0.015	14.602	0.015	2819	4
4.1663	14.509	0.016	14.604	0.016	2834	4
7.1692	14.590	0.015	14.683	0.015	2890	4
7.9943	14.600	0.015	14.682	0.015	2915	4
8.1538	14.575	0.015	14.664	0.015	2939	4
11.1509	14.551	0.018	14.657	0.017	2970	4
11.1958	14.565	0.016	14.657	0.016	2975	4
12.0800	14.613	0.015	14.692	0.015	2986	4
15.1732	14.534	0.016	14.634	0.015	3003	4
17.0123	14.595	0.015	14.691	0.015	3093	4
19.1357	14.510	0.015	14.602	0.015	3174	4
21.0875	14.590	0.015	14.668	0.015	3209	4
22.1237	14.599	0.015	14.683	0.015	3278	4
24.9755	14.510	0.015	14.617	0.015	3318	4
26.0477	14.568	0.015	14.664	0.015	3344	4
29.9795	14.520	0.015	14.626	0.015	3381	4
32.9710	14.567	0.015	14.663	0.015	3409	4
36.1090	14.566	0.015	14.667	0.015	3499	4
37.1826	14.580	0.015	14.678	0.015	3510	4
41.0478	14.560	0.015	14.659	0.015	3602	4
43.9728	14.499	0.015	14.602	0.015	3691	4
44.0745	14.504	0.015	14.603	0.015	3709	4
44.9795	14.524	0.015	14.630	0.015	3756	4

45.1436	14.525	0.016	14.629	0.015	3771	4
45.9594	14.557	0.015	14.664	0.015	3807	4
46.0711	14.573	0.015	14.670	0.015	3826	4
48.9537	14.501	0.015	14.602	0.015	3901	4
49.0568	14.505	0.015	14.608	0.015	3920	4
49.9699	14.525	0.015	14.629	0.015	3969	4
50.1118	14.536	0.015	14.638	0.015	3992	4
51.9497	14.591	0.015	14.680	0.015	4058	4
54.0591	14.512	0.015	14.608	0.015	4071	4
56.1884	14.576	0.016	14.687	0.016	4105	4
59.9872	14.525	0.015	14.630	0.015	4133	4
60.9350	14.577	0.015	14.672	0.015	4170	4
61.9375	14.596	0.015	14.682	0.015	4211	4
62.1182	14.592	0.016	14.696	0.016	4233	4
62.9355	14.564	0.015	14.648	0.015	4257	4
65.0406	14.535	0.015	14.638	0.015	4281	4
65.1696	14.538	0.015	14.641	0.015	4305	4
66.0118	14.580	0.015	14.669	0.015	4338	4
66.1645	14.579	0.015	14.693	0.015	4369	4
67.9634	14.544	0.015	14.632	0.015	4431	4
68.0762	14.519	0.015	14.611	0.015	4452	4
68.9914	14.508	0.015	14.597	0.015	4478	4
69.9748	14.536	0.015	14.632	0.015	4533	4
70.0865	14.533	0.015	14.635	0.015	4555	4
74.9550	14.562	0.015	14.653	0.015	4604	4
75.0647	14.560	0.015	14.652	0.015	4623	4
75.9615	14.603	0.015	14.684	0.015	4644	4
76.9979	14.633	0.015	14.708	0.015	4697	4
77.1120	14.642	0.015	14.719	0.015	4720	4
81.0276	14.621	0.015	14.702	0.015	4839	4
82.9921	14.534	0.016	14.624	0.016	4898	4
83.9408	14.521	0.016	14.624	0.016	4964	4
84.9728	14.525	0.015	14.629	0.015	5007	4
85.9429	14.582	0.016	14.674	0.016	5020	4
88.0674	14.502	0.015	14.602	0.015	5101	4
88.9677	14.506	0.015	14.603	0.015	5116	4
89.9716	14.536	0.015	14.639	0.015	5171	4
93.9066	14.506	0.015	14.599	0.015	5268	4
98.0400	14.509	0.015	14.605	0.015	5601	4
99.0201	14.509	0.015	14.612	0.015	5693	4
99.8996	14.530	0.015	14.637	0.015	5710	4
100.0062	14.533	0.015	14.644	0.015	5733	4
100.8980	14.569	0.015	14.670	0.015	5816	4
101.9123	14.579	0.015	14.674	0.015	5876	4
103.9087	14.499	0.015	14.602	0.015	5903	4
106.9891	14.583	0.015	14.679	0.015	6030	4
107.0857	14.573	0.015	14.677	0.015	6050	4
107.9259	14.511	0.015	14.600	0.015	6069	4
108.0611	14.508	0.015	14.607	0.015	6095	4
108.9107	14.496	0.015	14.610	0.015	6132	4
111.9721	14.593	0.016	14.668	0.016	6299	4
114.9012	14.523	0.015	14.639	0.015	6470	4

114.9278	14.540	0.015	14.640	0.015	6476	4
116.0577	14.577	0.015	14.674	0.015	6547	4
117.9136	14.503	0.015	14.595	0.015	6558	4
118.8858	14.504	0.015	14.605	0.015	6647	4
120.8923	14.577	0.015	14.666	0.015	6708	4
123.8949	14.514	0.015	14.609	0.015	6932	4
124.8917	14.527	0.015	14.639	0.015	7033	4
125.8874	14.569	0.015	14.672	0.015	7137	4
127.8962	14.500	0.015	14.595	0.015	7360	4
130.9308	14.593	0.016	14.678	0.015	7469	4
132.0210	14.584	0.016	14.659	0.016	7517	4
133.0147	14.515	0.016	14.607	0.016	7530	4
133.9606	14.508	0.015	14.612	0.015	7602	4
133.9975	14.518	0.015	14.611	0.015	7606	4
134.8945	14.529	0.015	14.639	0.015	7664	4
135.8758	14.576	0.015	14.677	0.015	7762	4
135.8802	14.561	0.015	14.671	0.015	7763	4
140.8928	14.582	0.016	14.657	0.016	7845	4
141.3045	14.594	0.015	14.687	0.015	7898	4
143.8858	14.497	0.015	14.606	0.015	8039	4
144.2898	14.523	0.015	14.627	0.015	8080	4
144.8799	14.526	0.015	14.642	0.015	8101	4
146.8752	14.582	0.015	14.676	0.015	8255	4
152.8748	14.497	0.015	14.591	0.015	8413	4
153.2870	14.496	0.015	14.597	0.015	8500	4
153.8879	14.503	0.015	14.611	0.015	8521	4
154.8808	14.541	0.016	14.651	0.015	8572	4
155.9100	14.592	0.016	14.683	0.016	8597	4
156.8854	14.586	0.019	14.670	0.018	8637	4
156.9003	14.579	0.016	14.657	0.016	8639	4
162.9228	14.505	0.015	14.594	0.015	8832	4
163.8783	14.507	0.015	14.613	0.015	8925	4
164.8789	14.544	0.015	14.648	0.015	9026	4
165.9289	14.594	0.016	14.693	0.016	9133	4
172.8733	14.506	0.015	14.602	0.015	9370	4
176.8839	14.588	0.016	14.677	0.015	9393	4
179.2709	14.532	0.016	14.626	0.016	9524	4
180.2311	14.568	0.015	14.668	0.015	9551	4
181.1991	14.610	0.015	14.703	0.015	9633	4
182.1804	14.581	0.015	14.674	0.015	9727	4
186.8706	14.589	0.015	14.684	0.015	10000	4
189.1673	14.539	0.015	14.649	0.015	10152	4
195.1895	14.567	0.015	14.671	0.015	10361	4
196.1391	14.609	0.015	14.698	0.015	10437	4
197.1735	14.598	0.016	14.679	0.016	10510	4
200.2054	14.579	0.015	14.675	0.015	10582	4
202.1368	14.584	0.017	14.666	0.017	10645	4
204.1576	14.532	0.015	14.644	0.015	10718	4
205.1565	14.583	0.015	14.683	0.015	10817	4
209.1449	14.531	0.015	14.633	0.015	10941	4
210.1252	14.569	0.015	14.677	0.015	11011	4
211.1422	14.603	0.016	14.693	0.016	11117	4

212.1742	14.551	0.015	14.644	0.015	11188	4
216.1771	14.600	0.015	14.689	0.015	11312	4
217.1032	14.570	0.016	14.660	0.016	11373	4
218.1109	14.506	0.015	14.613	0.015	11475	4
219.1015	14.529	0.015	14.645	0.015	11544	4
221.2174	14.615	0.016	14.702	0.016	11651	4
222.0979	14.557	0.015	14.647	0.015	11717	4
223.0830	14.511	0.015	14.615	0.015	11775	4
224.0859	14.541	0.015	14.650	0.015	11878	4
225.0720	14.585	0.015	14.688	0.015	11942	4
226.2911	14.598	0.015	14.690	0.015	11996	4
234.0644	14.535	0.016	14.645	0.016	12078	4
253.0161	14.518	0.015	14.611	0.015	12121	4
255.1260	14.589	0.015	14.682	0.015	12187	4
256.0324	14.612	0.015	14.697	0.015	12241	4
261.0308	14.608	0.015	14.697	0.015	12510	4
265.2166	14.589	0.016	14.680	0.016	12541	4
266.0063	14.605	0.015	14.692	0.015	12575	4
268.1074	14.522	0.015	14.623	0.015	12649	4
268.1309	14.510	0.015	14.619	0.015	12653	4
269.0506	14.545	0.015	14.652	0.015	12696	4
273.0903	14.647	0.015	14.760	0.015	12845	4
273.9906	14.815	0.015	14.943	0.015	12867	4
275.0145	14.981	0.015	15.121	0.015	12918	4
278.1300	15.001	0.015	15.161	0.015	12949	4
280.2602	14.889	0.015	15.016	0.015	12980	4
281.1789	14.706	0.015	14.797	0.015	12993	4
283.0282	14.529	0.015	14.631	0.015	13020	4
283.9558	14.537	0.015	14.645	0.015	13065	4
286.1735	14.562	0.015	14.652	0.015	13139	4
286.9688	14.511	0.015	14.600	0.015	13168	4
291.9817	14.508	0.015	14.591	0.015	13332	4
303.0874	14.500	0.015	14.610	0.015	13403	4
303.9394	14.538	0.015	14.633	0.015	13436	4
308.0164	14.505	0.015	14.608	0.015	13454	4
312.0288	14.508	0.015	14.601	0.015	13576	4
312.2379	14.505	0.015	14.595	0.015	13614	4
313.0403	14.504	0.015	14.607	0.015	13631	4
313.2327	14.512	0.015	14.614	0.015	13669	4
372.2397	14.508	0.016	14.597	0.016	13901	4
375.1255	14.583	0.015	14.672	0.015	13958	4
375.1395	14.581	0.021	14.662	0.019	13961	4
375.1503	14.593	0.015	14.675	0.015	13963	4
378.9656	14.558	0.015	14.658	0.015	14137	4
381.0818	14.577	0.015	14.667	0.015	14214	4
382.0533	14.490	0.015	14.587	0.015	14258	4
385.2013	14.573	0.015	14.674	0.015	14315	4
386.9902	14.495	0.015	14.595	0.015	14354	4
389.1119	14.575	0.015	14.670	0.015	14408	4
390.9760	14.563	0.015	14.663	0.015	14431	4
393.2487	14.535	0.015	14.642	0.015	14491	4
397.1025	14.504	0.016	14.598	0.015	14506	4

399.9611	14.588	0.015	14.680	0.015	14572	4
400.2681	14.593	0.015	14.684	0.015	14627	4
400.9965	14.577	0.016	14.661	0.015	14638	4
401.1969	14.545	0.015	14.637	0.015	14639	4
405.1628	14.590	0.015	14.680	0.015	14657	4
406.0962	14.547	0.015	14.641	0.015	14693	4
412.2358	14.555	0.023	14.613	0.021	14872	4
412.8276	14.513	0.015	14.623	0.015	14894	4
413.9577	14.561	0.015	14.669	0.015	14938	4
414.2469	14.587	0.015	14.682	0.015	14959	4
414.9859	14.591	0.016	14.680	0.016	14979	4
416.9471	14.502	0.015	14.598	0.015	15056	4
417.9531	14.522	0.015	14.628	0.015	15095	4
423.9592	14.548	0.015	14.638	0.015	15123	4
426.0920	14.528	0.015	14.616	0.015	15247	4
426.9510	14.507	0.015	14.600	0.015	15302	4
428.9437	14.554	0.015	14.655	0.015	15381	4
430.0574	14.596	0.016	14.680	0.016	15464	4
432.9378	14.527	0.015	14.632	0.015	15482	4
434.1658	14.574	0.016	14.667	0.016	15530	4
435.0510	14.592	0.015	14.685	0.015	15574	4
436.1586	14.512	0.015	14.602	0.015	15611	4
437.0041	14.497	0.015	14.587	0.015	15648	4
439.0464	14.585	0.015	14.689	0.015	15732	4
445.1198	14.611	0.015	14.702	0.015	15844	4
447.0238	14.505	0.015	14.609	0.015	15913	4
448.0922	14.553	0.016	14.653	0.016	15972	4
448.1142	14.532	0.015	14.646	0.015	15976	4
448.9796	14.566	0.016	14.661	0.016	16026	4
450.0291	14.592	0.015	14.678	0.015	16114	4
450.9909	14.529	0.015	14.621	0.015	16189	4
451.9962	14.502	0.015	14.605	0.015	16263	4
453.0358	14.528	0.015	14.631	0.015	16333	4
455.9827	14.525	0.015	14.613	0.015	16391	4
457.1170	14.505	0.015	14.608	0.015	16415	4
457.9733	14.523	0.015	14.628	0.015	16459	4
458.9371	14.565	0.015	14.664	0.015	16478	4
460.9642	14.528	0.015	14.615	0.015	16575	4
461.9841	14.516	0.015	14.611	0.015	16648	4
462.9578	14.529	0.015	14.639	0.015	16722	4
462.9990	14.529	0.015	14.636	0.015	16730	4
464.0166	14.580	0.015	14.682	0.015	16748	4
464.9614	14.596	0.015	14.681	0.015	16818	4
468.0119	14.527	0.016	14.618	0.016	16991	4
470.0678	14.567	0.016	14.663	0.016	17113	4
472.0333	14.556	0.025	14.627	0.021	17200	4
473.0209	14.576	0.015	14.668	0.015	17217	4
474.0410	14.629	0.015	14.713	0.015	17295	4
479.9060	14.617	0.015	14.694	0.015	17526	4
479.9388	14.597	0.016	14.663	0.015	17531	4
479.9624	14.616	0.015	14.700	0.015	17533	4
482.0091	14.502	0.015	14.610	0.015	17611	4

483.9824	14.599	0.018	14.686	0.017	17643	4
483.9927	14.590	0.015	14.683	0.015	17645	4
485.9529	14.511	0.015	14.603	0.015	17815	4
486.9447	14.514	0.016	14.612	0.015	17889	4
487.9789	14.530	0.015	14.636	0.015	17981	4
488.9640	14.579	0.015	14.672	0.015	18064	4
489.9277	14.588	0.016	14.676	0.015	18140	4
492.3211	14.530	0.015	14.627	0.015	18213	4
492.9720	14.545	0.015	14.648	0.015	18231	4
494.3156	14.600	0.016	14.698	0.016	18319	4
495.3277	14.597	0.015	14.686	0.015	18353	4
496.9294	14.517	0.016	14.611	0.015	18370	4
498.9565	14.584	0.016	14.680	0.016	18468	4
505.9745	14.509	0.015	14.598	0.015	18734	4
509.9354	14.574	0.015	14.674	0.015	18819	4
511.9475	14.509	0.015	14.612	0.015	18847	4
512.9206	14.539	0.015	14.631	0.015	18932	4
513.2850	14.571	0.016	14.667	0.015	19005	4
513.9270	14.583	0.015	14.683	0.015	19029	4
516.9200	14.512	0.015	14.615	0.015	19177	4
518.2464	14.545	0.016	14.655	0.016	19249	4
519.2805	14.614	0.017	14.696	0.016	19345	4
519.9562	14.581	0.015	14.671	0.015	19374	4
521.2651	14.502	0.016	14.598	0.016	19452	4
526.8926	14.517	0.015	14.613	0.015	19579	4
530.9354	14.505	0.015	14.599	0.015	19648	4
531.2019	14.499	0.016	14.596	0.016	19695	4
532.2543	14.497	0.015	14.603	0.015	19749	4
532.9051	14.547	0.015	14.645	0.015	19777	4
533.9125	14.586	0.015	14.677	0.015	19842	4
536.9107	14.521	0.016	14.642	0.016	20001	4
539.2442	14.588	0.015	14.686	0.015	20226	4
539.9070	14.577	0.015	14.674	0.015	20258	4
541.2294	14.503	0.015	14.607	0.015	20397	4
545.8920	14.515	0.015	14.593	0.015	20609	4
549.1748	14.602	0.017	14.685	0.017	20851	4
549.8827	14.599	0.016	14.687	0.016	20865	4
553.1638	14.566	0.015	14.674	0.015	21102	4
554.1342	14.593	0.016	14.684	0.016	21156	4
555.1491	14.602	0.016	14.684	0.016	21215	4
556.1857	14.515	0.016	14.602	0.016	21283	4
557.1947	14.525	0.015	14.638	0.015	21381	4
558.2682	14.573	0.015	14.671	0.015	21457	4
559.2951	14.610	0.015	14.688	0.015	21548	4
560.1774	14.587	0.016	14.665	0.016	21596	4
567.1493	14.510	0.015	14.625	0.015	21905	4
568.1918	14.556	0.015	14.671	0.015	22003	4
569.2304	14.577	0.015	14.682	0.015	22084	4
570.1915	14.532	0.015	14.649	0.015	22159	4
572.1558	14.513	0.015	14.624	0.015	22250	4
573.1776	14.571	0.016	14.675	0.016	22335	4
574.1533	14.582	0.015	14.679	0.015	22415	4

578.3258	14.581	0.015	14.675	0.015	22652	4
579.1468	14.588	0.016	14.665	0.016	22698	4
579.3248	14.585	0.015	14.672	0.015	22736	4
580.1548	14.563	0.015	14.662	0.015	22786	4
586.1513	14.511	0.015	14.604	0.016	23048	4
587.1463	14.529	0.016	14.625	0.016	23123	4
588.1476	14.565	0.015	14.685	0.016	23189	4
589.1821	14.589	0.015	14.683	0.015	23260	4
590.1175	14.559	0.015	14.660	0.015	23313	4
590.1275	14.553	0.015	14.656	0.015	23315	4
591.1190	14.517	0.015	14.618	0.015	23364	4
592.1428	14.534	0.015	14.641	0.015	23441	4
593.1104	14.564	0.015	14.668	0.015	23511	4
596.1513	14.509	0.015	14.614	0.015	23629	4
598.2092	14.561	0.015	14.666	0.015	23762	4
598.3131	14.574	0.015	14.670	0.015	23777	4
599.1721	14.588	0.015	14.688	0.015	23822	4
602.2514	14.524	0.015	14.630	0.015	23912	4
603.1323	14.560	0.015	14.670	0.015	23967	4
605.1507	14.521	0.015	14.617	0.015	24019	4
607.1428	14.523	0.015	14.634	0.015	24173	4
607.2962	14.532	0.015	14.635	0.015	24199	4
608.0187	14.593	0.022	14.630	0.021	24221	4
608.0354	14.561	0.016	14.664	0.016	24223	4
608.3018	14.589	0.015	14.681	0.015	24264	4
609.2997	14.590	0.015	14.677	0.015	24319	4
610.1699	14.525	0.015	14.611	0.015	24348	4
612.1285	14.529	0.016	14.632	0.016	24498	4
619.1059	14.610	0.015	14.685	0.015	24852	4
621.1397	14.504	0.015	14.605	0.015	25001	4
622.2683	14.535	0.016	14.635	0.015	25033	4
623.1376	14.579	0.016	14.673	0.016	25045	4
624.1369	14.597	0.015	14.680	0.015	25090	4
626.1188	14.518	0.015	14.612	0.015	25182	4
628.1326	14.582	0.015	14.676	0.015	25236	4
629.1782	14.588	0.015	14.681	0.015	25287	4
631.1018	14.508	0.015	14.609	0.015	25373	4
634.0474	14.598	0.015	14.692	0.015	25442	4
635.0368	14.518	0.015	14.619	0.015	25487	4
636.1080	14.512	0.015	14.618	0.015	25556	4
637.0783	14.529	0.015	14.641	0.015	25622	4
638.1591	14.560	0.016	14.638	0.016	25654	4
646.1009	14.497	0.015	14.609	0.015	25928	4
648.2325	14.583	0.015	14.679	0.015	25984	4
649.0178	14.578	0.015	14.680	0.015	26005	4
650.0150	14.523	0.015	14.612	0.015	26068	4
654.1548	14.590	0.015	14.682	0.015	26175	4
665.2181	14.503	0.016	14.604	0.015	26269	4
671.2357	14.759	0.015	14.888	0.015	26471	4
672.9800	15.067	0.016	15.212	0.016	26488	4
674.0880	14.979	0.015	15.109	0.015	26517	4
675.2155	14.902	0.016	15.022	0.015	26556	4

677.0331	14.913	0.016	15.063	0.015	26576	4
688.0734	14.589	0.015	14.686	0.015	26683	4
689.0377	14.577	0.015	14.662	0.015	26714	4
690.0961	14.506	0.015	14.599	0.015	26751	4
696.0765	14.516	0.015	14.625	0.015	26985	4
701.0337	14.516	0.015	14.584	0.015	27216	4
705.0420	14.509	0.015	14.597	0.015	27350	4
707.0894	14.551	0.015	14.651	0.015	27406	4
716.0003	14.530	0.016	14.628	0.015	27437	4
718.1562	14.581	0.015	14.671	0.015	27528	4
724.0317	14.573	0.015	14.666	0.015	27552	4
730.2019	14.491	0.015	14.591	0.015	27679	4
738.2446	14.578	0.016	14.671	0.015	27771	4
742.1207	14.560	0.015	14.652	0.015	27875	4
746.1656	14.527	0.015	14.630	0.015	27961	4
748.1267	14.575	0.015	14.674	0.015	28064	4
749.1373	14.576	0.015	14.660	0.015	28116	4
750.2323	14.498	0.015	14.598	0.015	28177	4
752.0338	14.544	0.015	14.654	0.015	28201	4
753.1625	14.587	0.015	14.679	0.015	28285	4
755.0445	14.506	0.015	14.595	0.015	28317	4
756.1514	14.528	0.015	14.627	0.015	28370	4
756.1845	14.532	0.015	14.635	0.015	28377	4
761.2604	14.541	0.015	14.640	0.015	28477	4
763.0835	14.587	0.015	14.671	0.015	28508	4
765.2190	14.510	0.015	14.613	0.015	28563	4
768.1538	14.598	0.016	14.691	0.016	28628	4
785.0195	14.503	0.015	14.594	0.015	28682	4
785.0240	14.501	0.015	14.593	0.015	28683	4
787.1999	14.581	0.015	14.669	0.015	28734	4
790.9988	14.532	0.015	14.630	0.015	28968	4
795.9980	14.531	0.015	14.623	0.015	29104	4
801.0760	14.530	0.015	14.667	0.015	29372	4
802.0178	14.577	0.015	14.673	0.015	29434	4
804.9912	14.508	0.015	14.602	0.015	29523	4
806.9925	14.562	0.015	14.661	0.015	29630	4
808.1631	14.595	0.015	14.683	0.015	29704	4
808.9902	14.559	0.015	14.646	0.015	29743	4
810.0364	14.505	0.015	14.607	0.015	29822	4
811.0132	14.526	0.015	14.633	0.015	29884	4
820.0027	14.505	0.016	14.597	0.016	30125	4
827.0123	14.576	0.015	14.671	0.015	30327	4
831.9767	14.571	0.015	14.671	0.015	30537	4
836.0387	14.526	0.015	14.636	0.015	30671	4
843.0160	14.596	0.015	14.684	0.015	30768	4
856.9881	14.583	0.015	14.675	0.015	31095	4
858.9759	14.511	0.015	14.605	0.015	31136	4
862.9415	14.598	0.015	14.687	0.015	31248	4
864.9455	14.510	0.016	14.609	0.016	31265	4
872.9551	14.642	0.015	14.717	0.015	31503	4
875.8882	14.591	0.016	14.673	0.016	31608	4
880.9012	14.540	0.017	14.648	0.017	31650	4

887.8910	14.587	0.015	14.676	0.015	31926	4
889.8770	14.504	0.015	14.606	0.015	32098	4
891.8855	14.581	0.015	14.683	0.015	32324	4
902.8881	14.590	0.016	14.671	0.016	32739	4
906.3306	14.556	0.015	14.668	0.015	32855	4
908.3229	14.599	0.015	14.684	0.015	32954	4
913.3297	14.588	0.016	14.675	0.017	32994	4
918.2957	14.576	0.015	14.676	0.015	33161	4
922.2379	14.598	0.015	14.696	0.015	33323	4
930.2431	14.527	0.016	14.640	0.016	33748	4
932.3122	14.597	0.016	14.693	0.016	33853	4
939.1401	14.504	0.015	14.596	0.016	34377	4
940.1675	14.525	0.015	14.636	0.015	34498	4
941.3053	14.582	0.015	14.682	0.015	34602	4
942.1484	14.602	0.015	14.705	0.015	34676	4
943.2211	14.570	0.015	14.658	0.015	34804	4
944.2140	14.512	0.015	14.612	0.015	34916	4
945.2372	14.537	0.015	14.632	0.015	35014	4
946.2489	14.584	0.016	14.678	0.016	35046	4
947.3056	14.608	0.015	14.688	0.015	35140	4
950.1125	14.534	0.015	14.637	0.015	35381	4
952.1327	14.606	0.016	14.694	0.016	35476	4
954.1305	14.506	0.015	14.609	0.015	35622	4
955.2182	14.539	0.015	14.627	0.015	35705	4
958.0826	14.580	0.015	14.672	0.015	35867	4
962.0960	14.616	0.015	14.705	0.015	36022	4
964.2778	14.516	0.015	14.611	0.015	36107	4
966.1415	14.589	0.016	14.675	0.016	36161	4
967.1942	14.617	0.015	14.688	0.015	36220	4
968.1853	14.568	0.015	14.644	0.015	36281	4
971.0520	14.596	0.015	14.685	0.015	36370	4
973.0656	14.578	0.015	14.662	0.015	36479	4
975.2682	14.548	0.015	14.645	0.015	36584	4
981.0932	14.585	0.015	14.674	0.015	36689	4
982.1149	14.614	0.016	14.707	0.016	36726	4
983.0280	14.594	0.015	14.676	0.015	36789	4
987.1024	14.613	0.015	14.697	0.015	36865	4
988.0387	14.568	0.015	14.656	0.015	36934	4
995.0679	14.547	0.015	14.645	0.015	37077	4
995.2740	14.553	0.015	14.643	0.015	37123	4
997.1018	14.611	0.015	14.690	0.015	37180	4
998.1585	14.548	0.015	14.622	0.015	37257	4
999.1821	14.517	0.015	14.610	0.015	37334	4
1004.1168	14.535	0.015	14.623	0.015	37392	4
1006.0971	14.590	0.015	14.668	0.015	37474	4
1007.0832	14.601	0.015	14.681	0.015	37550	4
1008.1652	14.528	0.015	14.607	0.015	37608	4
1014.0503	14.523	0.015	14.616	0.015	37665	4
1020.2099	14.546	0.015	14.642	0.015	37772	4
1022.1521	14.594	0.015	14.680	0.015	37827	4
1030.0280	14.542	0.015	14.638	0.015	37918	4
1032.1309	14.592	0.019	14.678	0.018	37959	4

1037.0296	14.598	0.015	14.706	0.015	38028	4
1039.2311	14.516	0.015	14.619	0.015	38102	4
1046.0889	14.603	0.015	14.684	0.015	38143	4
1047.0741	14.589	0.015	14.671	0.015	38203	4
1048.1493	14.525	0.015	14.604	0.015	38254	4
1049.1677	14.532	0.015	14.622	0.015	38308	4
1055.1880	14.552	0.015	14.652	0.015	38332	4
1058.0545	14.518	0.016	14.596	0.015	38350	4
1059.0655	14.524	0.015	14.620	0.015	38412	4
1062.0641	14.589	0.015	14.672	0.015	38455	4
1064.0345	14.526	0.015	14.621	0.015	38524	4
1067.0677	14.636	0.015	14.727	0.015	38581	4
1072.0040	14.974	0.015	15.093	0.015	38633	4
1073.0664	14.847	0.015	14.972	0.015	38692	4
1075.0385	14.816	0.015	14.943	0.015	38750	4
1078.1073	14.510	0.015	14.617	0.015	38799	4
1087.2253	14.585	0.015	14.670	0.015	38858	4
1090.0440	14.564	0.015	14.713	0.015	38919	4
1092.0763	14.576	0.015	14.668	0.015	38968	4
1096.0701	14.598	0.015	14.694	0.015	39042	4
1100.1835	14.559	0.015	14.659	0.015	39054	4
1102.1236	14.582	0.015	14.667	0.015	39068	4
1106.0800	14.597	0.015	14.688	0.015	39127	4
1108.0850	14.496	0.015	14.591	0.015	39175	4
1109.0811	14.506	0.015	14.615	0.015	39238	4
1124.0324	14.523	0.015	14.623	0.015	39395	4
1125.0723	14.570	0.015	14.662	0.015	39458	4
1127.0654	14.593	0.015	14.666	0.015	39565	4
1128.0675	14.512	0.015	14.601	0.015	39632	4
1129.0778	14.523	0.015	14.619	0.015	39699	4
1132.0512	14.590	0.015	14.671	0.015	39802	4
1132.9982	14.509	0.015	14.594	0.015	39861	4
1134.9650	14.557	0.016	14.652	0.015	39917	4
1136.0468	14.602	0.015	14.685	0.015	39956	4
1139.1220	14.534	0.015	14.637	0.015	40005	4
1141.9916	14.587	0.015	14.668	0.015	40069	4
1146.0159	14.600	0.015	14.684	0.015	40134	4
1152.0077	14.583	0.015	14.665	0.015	40182	4
1154.2180	14.536	0.015	14.643	0.015	40235	4
1156.0624	14.597	0.015	14.685	0.015	40347	4
1158.0211	14.505	0.015	14.599	0.015	40383	4
1160.0483	14.543	0.015	14.656	0.015	40483	4
1162.0760	14.579	0.015	14.663	0.015	40578	4
1164.1900	14.536	0.015	14.644	0.015	40644	4
1169.1463	14.535	0.015	14.638	0.015	40761	4
1173.0410	14.517	0.015	14.613	0.015	40917	4
1174.1069	14.538	0.016	14.628	0.016	41022	4
1175.0031	14.585	0.015	14.680	0.015	41082	4
1178.9692	14.531	0.015	14.631	0.015	41271	4
1181.9991	14.576	0.015	14.659	0.015	41343	4
1185.9529	14.603	0.015	14.676	0.015	41441	4
1187.0523	14.532	0.017	14.602	0.017	41524	4

1188.9485	14.529	0.015	14.632	0.015	41549	4
1192.9273	14.507	0.015	14.604	0.015	41627	4
1194.0316	14.527	0.015	14.622	0.015	41709	4
1196.9934	14.557	0.015	14.646	0.015	41759	4
1198.0414	14.512	0.015	14.608	0.015	41820	4
1199.0743	14.541	0.015	14.640	0.015	41924	4
1199.9542	14.575	0.015	14.678	0.015	42012	4
1200.9527	14.609	0.015	14.696	0.015	42128	4
1201.9636	14.548	0.015	14.637	0.015	42246	4
1206.9322	14.556	0.016	14.627	0.015	42373	4
1212.9164	14.515	0.015	14.617	0.015	42454	4
1214.9408	14.586	0.016	14.671	0.016	42616	4
1216.0524	14.597	0.016	14.692	0.015	42687	4
1218.0444	14.518	0.015	14.615	0.015	42829	4
1218.8825	14.524	0.015	14.632	0.015	42895	4
1219.9192	14.569	0.015	14.670	0.015	42983	4
1220.9777	14.586	0.015	14.678	0.015	43102	4
1223.9748	14.539	0.015	14.642	0.015	43189	4
1224.9182	14.579	0.015	14.678	0.015	43286	4
1227.8860	14.515	0.015	14.609	0.015	43497	4
1228.9850	14.528	0.015	14.634	0.015	43639	4
1234.8956	14.589	0.015	14.685	0.015	44253	4
1236.8983	14.542	0.015	14.628	0.015	44365	4
1238.9724	14.551	0.015	14.634	0.015	44377	4
1241.9473	14.526	0.015	14.611	0.015	44572	4
1243.8854	14.542	0.015	14.642	0.015	44730	4
1245.8776	14.597	0.015	14.686	0.015	44931	4
1247.8911	14.510	0.015	14.613	0.015	45145	4
1254.8807	14.581	0.015	14.671	0.015	45311	4
1255.8749	14.586	0.015	14.681	0.015	45432	4
1258.9196	14.529	0.015	14.633	0.015	45552	4
1264.2900	14.568	0.015	14.667	0.015	45757	4
1267.8860	14.575	0.015	14.654	0.015	45861	4
1272.2676	14.589	0.015	14.668	0.015	46056	4
1277.2697	14.518	0.015	14.605	0.015	46288	4
1279.2145	14.568	0.015	14.663	0.015	46446	4
1289.2957	14.567	0.015	14.665	0.015	46501	4
1294.2641	14.559	0.015	14.658	0.015	46549	4
1297.2704	14.510	0.016	14.591	0.016	46628	4
1298.3184	14.534	0.015	14.627	0.015	46661	4
1301.1690	14.629	0.016	14.689	0.016	46733	4
1302.3240	14.511	0.015	14.595	0.015	46789	4
1303.1774	14.530	0.015	14.624	0.015	46800	4
1304.3283	14.574	0.015	14.667	0.015	46946	4
1305.2232	14.607	0.015	14.688	0.015	47043	4
1307.3072	14.516	0.015	14.606	0.015	47263	4
1308.1582	14.529	0.015	14.639	0.015	47347	4
1311.2794	14.579	0.015	14.662	0.015	47552	4
1312.2349	14.523	0.015	14.610	0.015	47609	4
1314.2762	14.565	0.015	14.661	0.015	47697	4
1316.2068	14.584	0.015	14.669	0.015	47856	4
1319.2453	14.576	0.015	14.669	0.015	47987	4

1320.2967	14.592	0.015	14.678	0.015	48108	4
1323.1394	14.540	0.016	14.636	0.016	48201	4
1328.2598	14.542	0.015	14.637	0.015	48285	4
1330.2749	14.618	0.015	14.690	0.015	48365	4
1334.2074	14.576	0.015	14.665	0.015	48420	4
1336.1916	14.565	0.015	14.636	0.015	48478	4
1342.1938	14.525	0.015	14.615	0.015	48576	4
1349.0420	14.579	0.016	14.669	0.016	48813	4
1350.1604	14.598	0.015	14.684	0.015	48898	4
1351.1228	14.577	0.015	14.649	0.015	48968	4
1353.0820	14.533	0.015	14.626	0.016	49017	4
1354.0176	14.588	0.015	14.667	0.015	49085	4
1360.0919	14.602	0.015	14.684	0.015	49136	4
1361.1189	14.549	0.015	14.630	0.015	49213	4
1367.2110	14.511	0.015	14.601	0.015	49351	4
1369.0505	14.592	0.015	14.678	0.015	49388	4
1370.0718	14.615	0.015	14.737	0.015	49469	4
1371.0556	14.545	0.015	14.628	0.015	49536	4
1372.0418	14.510	0.015	14.607	0.015	49608	4
1375.0560	14.601	0.015	14.688	0.015	49670	4
1377.0364	14.517	0.015	14.613	0.015	49732	4
1380.0820	14.626	0.015	14.769	0.015	49865	4
1381.0369	14.553	0.016	14.630	0.016	49925	4
1385.1122	14.609	0.015	14.684	0.015	49966	4
1386.1605	14.535	0.015	14.619	0.015	50032	4
1390.0089	14.605	0.015	14.692	0.015	50108	4
1396.0898	14.509	0.015	14.602	0.015	50184	4
1397.2004	14.516	0.015	14.614	0.015	50261	4
1398.1511	14.549	0.015	14.645	0.015	50314	4
1400.1627	14.592	0.016	14.678	0.015	50391	4
1402.1489	14.494	0.015	14.604	0.015	50448	4
1406.0161	14.508	0.015	14.600	0.015	50484	4
1407.0154	14.508	0.015	14.608	0.015	50550	4
1408.0505	14.516	0.015	14.636	0.015	50615	4
1410.0202	14.593	0.015	14.677	0.015	50645	4
1411.0968	14.507	0.015	14.601	0.015	50705	4
1412.0986	14.515	0.015	14.627	0.015	50761	4
1413.1579	14.566	0.016	14.650	0.016	50822	4
1417.2060	14.504	0.015	14.609	0.015	50878	4
1420.0168	14.567	0.015	14.675	0.015	50960	4
1421.0631	14.503	0.015	14.606	0.015	51027	4
1423.1755	14.515	0.015	14.641	0.015	51084	4
1425.0214	14.583	0.016	14.667	0.016	51107	4
1426.0045	14.507	0.015	14.616	0.015	51118	4
1426.2144	14.500	0.015	14.593	0.015	51162	4
1427.0600	14.505	0.015	14.636	0.015	51190	4
1429.1366	14.582	0.015	14.681	0.015	51251	4
1432.0426	14.499	0.015	14.597	0.015	51346	4
1433.0711	14.534	0.015	14.635	0.015	51414	4
1434.0834	14.590	0.015	14.678	0.015	51462	4
1438.0447	14.534	0.015	14.641	0.015	51563	4
1439.0856	14.588	0.015	14.678	0.015	51631	4

1440.2219	14.571	0.015	14.666	0.015	51683	4
1449.9970	14.564	0.015	14.666	0.015	51879	4
1451.1826	14.506	0.015	14.598	0.015	51938	4
1452.1156	14.512	0.015	14.637	0.015	51982	4
1454.0969	14.585	0.015	14.678	0.015	52077	4
1456.1762	14.499	0.015	14.599	0.015	52134	4
1457.2238	14.505	0.019	14.597	0.018	52204	4
1463.0263	14.564	0.015	14.679	0.015	52325	4
1464.2133	14.685	0.015	14.787	0.015	52386	4
1468.0475	15.116	0.015	15.279	0.015	52427	4
1471.1354	14.795	0.015	14.909	0.015	52599	4
1479.2221	14.602	0.015	14.695	0.015	52657	4
1480.1576	14.585	0.015	14.672	0.015	52705	4
1485.1019	14.584	0.015	14.665	0.015	52842	4
1493.1433	14.557	0.015	14.649	0.015	52997	4
1495.1809	14.582	0.015	14.674	0.015	53087	4
1498.0729	14.551	0.015	14.661	0.015	53227	4
1503.2250	14.548	0.015	14.662	0.015	53380	4
1510.2324	14.555	0.015	14.643	0.015	53509	4
1520.0389	14.578	0.015	14.664	0.015	53729	4
1522.9738	14.530	0.015	14.652	0.015	53913	4
1528.0284	14.571	0.015	14.662	0.015	54151	4
1531.0792	14.500	0.016	14.577	0.016	54296	4
1534.1639	14.602	0.015	14.702	0.015	54463	4
1539.9865	14.565	0.015	14.647	0.015	54727	4
1543.0003	14.572	0.015	14.657	0.015	54887	4
1548.9815	14.597	0.017	14.669	0.017	55422	4
1553.0735	14.585	0.015	14.670	0.015	55646	4
1557.9703	14.572	0.015	14.672	0.015	55873	4
1565.9750	14.503	0.015	14.608	0.015	56154	4
1570.0138	14.534	0.015	14.623	0.015	56539	4
1577.8949	14.573	0.015	14.669	0.015	56970	4
1593.8870	14.597	0.015	14.689	0.015	57474	4
1600.9037	14.504	0.015	14.612	0.015	57955	4
1606.3150	14.497	0.015	14.611	0.015	58393	4
1610.8928	14.508	0.015	14.603	0.015	58750	4
1615.3215	14.520	0.016	14.595	0.015	59064	4
1619.9093	14.525	0.015	14.626	0.015	59470	4
1632.2448	14.560	0.016	14.661	0.016	59951	4
1640.2319	14.504	0.015	14.605	0.015	60540	4
1643.1834	14.587	0.015	14.696	0.015	60708	4
1649.2237	14.610	0.015	14.686	0.015	61103	4
1653.2379	14.605	0.015	14.687	0.015	61507	4
1658.1646	14.607	0.015	14.693	0.015	61728	4
1660.2835	14.518	0.015	14.603	0.015	61955	4
1662.2976	14.589	0.015	14.671	0.015	62150	4
1670.1736	14.561	0.015	14.647	0.015	62565	4
1671.3265	14.570	0.016	14.654	0.015	62717	4
1680.1279	14.499	0.015	14.599	0.015	63285	4
1681.3174	14.520	0.015	14.617	0.015	63437	4
1683.2633	14.615	0.016	14.690	0.016	63639	4
1689.1018	14.597	0.015	14.685	0.015	63925	4

1700.2688	14.515	0.015	14.606	0.015	64123	4
1704.1751	14.573	0.015	14.655	0.015	64272	4
1708.2469	14.608	0.015	14.686	0.015	64415	4
1717.0864	14.578	0.015	14.662	0.015	64563	4
1719.1170	14.563	0.015	14.649	0.015	64677	4
1720.2479	14.514	0.015	14.600	0.015	64771	4
1722.1483	14.572	0.015	14.691	0.015	64915	4
1725.1187	14.504	0.016	14.596	0.015	65073	4
1726.2006	14.531	0.015	14.620	0.015	65174	4
1733.1527	14.609	0.015	14.692	0.015	65428	4
1734.1905	14.539	0.015	14.623	0.015	65506	4
1736.0274	14.552	0.016	14.645	0.016	65615	4
1742.0773	14.582	0.015	14.673	0.015	65957	4
1744.1835	14.539	0.015	14.654	0.015	66076	4
1785.1581	14.513	0.015	14.620	0.015	66984	4
1798.0333	14.561	0.015	14.654	0.015	67197	4
1804.0961	14.517	0.015	14.604	0.015	67348	4
1806.1376	14.536	0.015	14.655	0.015	67464	4
1812.1991	14.589	0.015	14.678	0.015	67586	4
1815.2039	14.505	0.016	14.602	0.015	67706	4
1833.0797	14.577	0.015	14.665	0.015	67910	4
1841.0097	14.541	0.015	14.643	0.015	68136	4
1843.1716	14.592	0.015	14.677	0.015	68267	4
1846.1397	14.554	0.015	14.646	0.015	68370	4
1853.0573	14.595	0.015	14.684	0.015	68500	4
1861.1024	14.666	0.015	14.770	0.015	68612	4
1866.9769	15.105	0.015	15.234	0.015	68954	4
1869.1338	14.734	0.015	14.841	0.015	69094	4
1871.1768	14.655	0.015	14.780	0.015	69245	4
1876.0481	14.560	0.015	14.648	0.015	69383	4
1882.9874	14.579	0.015	14.661	0.015	69670	4
1885.1742	14.528	0.015	14.635	0.015	69845	4
1908.9955	14.506	0.015	14.601	0.015	70091	4
1922.0426	14.601	0.015	14.686	0.015	70741	4
1941.8531	14.614	0.015	14.692	0.015	71113	4
1973.8694	14.519	0.015	14.613	0.015	72642	4
1981.8838	14.607	0.015	14.685	0.015	73071	4
2171.1817	14.583	0.015	14.661	0.015	79121	4
2176.2027	14.582	0.015	14.662	0.015	79246	4
2181.0823	14.585	0.015	14.673	0.015	79355	4
2183.0937	14.514	0.015	14.617	0.015	79469	4
2185.1923	14.600	0.015	14.682	0.015	79570	4
2194.1249	14.564	0.015	14.697	0.015	79703	4
2196.2501	14.598	0.015	14.681	0.015	79801	4
2208.2185	14.535	0.015	14.642	0.015	79904	4
2224.0844	14.560	0.015	14.649	0.015	80038	4
2227.0528	14.504	0.016	14.583	0.015	80133	4
2232.1349	14.513	0.015	14.597	0.015	80342	4
2232.1794	14.509	0.015	14.601	0.015	80352	4
2241.2220	14.591	0.015	14.679	0.015	80476	4
2247.1012	14.503	0.015	14.598	0.015	80700	4
2250.0954	14.603	0.015	14.684	0.015	80831	4

2252.0444	14.501	0.016	14.591	0.015	81005	4
2262.9031	15.070	0.015	15.214	0.015	81266	4
2286.0031	14.594	0.015	14.680	0.015	82150	4
2287.0093	14.513	0.015	14.605	0.015	82229	4
2289.9171	14.600	0.016	14.672	0.015	82491	4
2292.9149	14.518	0.015	14.625	0.015	82822	4
2299.9345	14.598	0.015	14.690	0.015	83201	4
2301.9850	14.502	0.015	14.605	0.015	83397	4
2304.9664	14.597	0.015	14.679	0.015	83736	4
2307.9566	14.520	0.015	14.633	0.015	83955	4
2312.9529	14.521	0.015	14.631	0.015	84235	4
2315.9050	14.566	0.015	14.652	0.015	84528	4
2320.8963	14.572	0.015	14.657	0.015	85054	4
2330.9446	14.555	0.015	14.640	0.015	85371	4
2364.2535	14.589	0.016	14.671	0.016	87525	4

```
#------------------------- MACHO Project -------------------------
# Star 6.6454.5                 05:20:25.132 -70:11:08.38 (J2000.0)
#-----------------------------------------------------------------
# Creation date (JD-2.449e+06): 2661.0236
# Calibration: standard
#-----------------------------------------------------------------
# HJD-2.449e+06    r       err_r       v        err_v     obsid  tran
#    (days)      (mag)     (mag)     (mag)      (mag)
#-----------------------------------------------------------------
```

2655.9325	14.665	0.015	14.775	0.015	97453	4
2655.9495	14.671	0.015	14.784	0.015	97454	4
2656.9015	14.825	0.015	14.961	0.015	97459	4
2656.9431	14.837	0.015	14.961	0.015	97465	4
2656.9915	14.839	0.015	14.966	0.015	97472	4
2657.0598	14.860	0.015	14.983	0.015	97481	4
2657.8765	14.946	0.015	15.058	0.015	97483	4
2657.9192	14.941	0.015	15.061	0.015	97493	4
2657.9501	14.955	0.015	15.061	0.015	97498	4
2658.0423	14.949	0.015	-99.000	-99.000	97513	3
2659.8649	14.923	0.015	15.055	0.015	97565	4
2659.8876	14.920	0.015	15.063	0.015	97570	4
2659.9099	14.926	0.015	15.070	0.015	97573	4
2659.9178	14.956	0.015	15.074	0.015	97574	4
2659.9258	14.949	0.015	15.074	0.015	97575	4
2659.9337	14.945	0.015	15.072	0.015	97576	4
2659.9787	14.944	0.016	15.084	0.016	97585	4
2660.0424	14.950	0.015	15.094	0.015	97598	4
2660.8848	15.058	0.015	15.230	0.015	97625	4
2661.8755	15.068	0.015	15.218	0.015	97649	4
2661.8883	15.067	0.015	15.219	0.015	97650	4
2661.9501	15.056	0.015	15.207	0.015	97661	4
2662.8742	14.924	0.015	15.051	0.015	97720	4
2662.9509	14.969	0.024	15.068	0.022	97736	4
2663.9943	14.712	0.015	14.815	0.015	97789	4
2664.0022	14.709	0.015	14.816	0.015	97790	4

```
! MACHO object 6.6454.5
#
# 00:00:00.000 +00:00:00.00 (J2000.0)
# photometry in CTIO 0.9m B reduced by DaoPhot
# data in linear units
# ADU = 1.000 * value + 0.000
# magnitude zero-point: 25.000
# reference Julian date: 2448623.5
# 30 observations
#
!         date          value          error         obsid
     2630.0033      3.442e+05          951.1      33605032
     2631.0129      3.360e+05          928.4      33615128
     2631.9998      3.400e+05          939.4      33624998
     2633.0122      3.509e+05          969.5      33635122
     2633.9978      3.402e+05          1567.      33644978
     2635.9974      2.552e+05          1410.      33664973
     2637.0073      2.594e+05          1912.      33675072
     2638.0069      2.583e+05          1428.      33685068
     2639.0210      2.008e+05          739.6      33695210
     2640.0070      1.710e+05          629.8      33705070
     2642.0096      2.467e+05          681.6      33725096
     2642.9903      3.120e+05          862.0      33734902
     2643.9857      3.044e+05          1121.      33744857
     2644.9897      3.324e+05          1225.      33754896
     2648.0573      3.777e+05          695.7      33785572
     2649.0545      3.604e+05          332.0      33795545
     2651.0077      3.400e+05          939.4      33815076
     2652.0104      3.494e+05          643.6      33825104
     2652.9737      3.723e+05          685.7      33834737
     2653.9880      3.474e+05          959.8      33844879
     2654.9769      3.430e+05          947.8      33854769
     2655.9777      3.440e+05          633.6      33864777
     2656.9719      3.523e+05          648.9      33874719
     2657.9669      3.746e+05          2760.      33884668
     2658.9625      3.625e+05          2671.      33894625
     2659.9659      3.555e+05          1637.      33904658
     2660.9704      3.438e+05          949.9      33914704
     2664.9684      3.551e+05          1308.      33954684
     2665.9796      3.445e+05          952.0      33964795
     2666.9642      3.474e+05          639.9      33974641
```

```
! MACHO object 6.6454.5
#
# 00:00:00.000 +00:00:00.00 (J2000.0)
# photometry in CTIO 0.9m V reduced by DaoPhot
# data in linear units
# ADU = 1.000 * value + 0.000
# magnitude zero-point: 25.000
# reference Julian date: 2448623.5
```

54 observations
#

!	date	value	error	obsid
	2230.1232	3.754e+05	1383.	29606232
	2231.1072	3.705e+05	2047.	29616072
	2233.0716	3.502e+05	1290.	29635716
	2239.0932	2.977e+05	1371.	29695931
	2246.0826	2.969e+05	820.4	29765825
	2248.0501	3.287e+05	2422.	29785500
	2255.0120	3.780e+05	1741.	29855119
	2257.0196	3.569e+05	1644.	29875195
	2258.1134	3.453e+05	2226.	29886134
	2261.0328	3.623e+05	1335.	29915327
	2262.0311	3.658e+05	1348.	29925310
	2267.0070	3.590e+05	992.0	29975070
	2272.0170	3.749e+05	2762.	30025170
	2274.0174	3.588e+05	1652.	30045173
	2277.0103	3.557e+05	1310.	30075103
	2281.0577	3.769e+05	1736.	30115577
	2284.0228	3.561e+05	3608.	30145227
	2618.1444	3.843e+05	2478.	33486443
	2619.1015	3.853e+05	2129.	33496014
	2620.1599	3.685e+05	1697.	33506598
	2621.1721	3.711e+05	2392.	33516721
	2622.1424	3.585e+05	1981.	33526424
	2623.1425	3.868e+05	2494.	33536424
	2629.0287	3.638e+05	2346.	33595287
	2630.0150	3.604e+05	995.9	33605150
	2631.0235	3.535e+05	1302.	33615235
	2632.0112	3.537e+05	651.6	33625111
	2633.0241	3.788e+05	697.7	33635240
	2634.0080	3.604e+05	1328.	33645080
	2636.0076	2.801e+05	774.0	33665075
	2637.0194	2.729e+05	1759.	33675193
	2638.0180	2.831e+05	2086.	33685179
	2639.0314	2.278e+05	1049.	33695313
	2641.0005	2.096e+05	579.2	33715005
	2642.0203	2.698e+05	994.0	33725202
	2643.9964	3.315e+05	1527.	33744963
	2645.0007	3.443e+05	951.4	33755007
	2646.0124	3.670e+05	676.1	33765123
	2648.0698	3.913e+05	1081.	33785697
	2649.0675	3.719e+05	685.0	33795674
	2650.0096	3.548e+05	980.5	33805096
	2651.0189	3.480e+05	961.4	33815189
	2652.0209	3.567e+05	1971.	33825209
	2652.9847	3.799e+05	699.8	33834847
	2653.9982	3.702e+05	1705.	33844982
	2654.9874	3.624e+05	1001.	33854873
	2655.9879	3.541e+05	1305.	33864879
	2656.9823	3.597e+05	662.5	33874822
	2657.9772	3.845e+05	6375.	33884772

```
       2659.9761     3.655e+05        1346.       33904760
       2660.9812     3.540e+05        978.1       33914812
       2664.9790     3.696e+05        1362.       33954790
       2665.9915     3.620e+05        1000.       33964914
       2666.9746     3.529e+05        975.1       33974746


! MACHO object 6.6454.5
#
# 00:00:00.000 +00:00:00.00 (J2000.0)
# photometry in CTIO 0.9m I reduced by DaoPhot
# data in linear units
# ADU = 1.000 * value + 0.000
# magnitude zero-point: 25.000
# reference Julian date: 2448623.5
# 55 observations
#
!           date         value        error          obsid
       2222.0557     2.280e+05        1680.       29525557
       2228.1566     2.209e+05        1628.       29586566
       2230.0990     2.293e+05        1267.       29605989
       2230.1999     2.292e+05        844.3       29606998
       2231.0821     2.300e+05        1059.       29615821
       2232.0870     2.411e+05        3109.       29625870
       2233.0492     2.168e+05        599.1       29635491
       2239.0761     1.924e+05        1595.       29695760
       2241.0303     1.616e+05        1191.       29715302
       2243.0951     1.321e+05        486.5       29735951
       2245.0755     1.864e+05        515.0       29755754
       2246.1070     1.921e+05        530.8       29766070
       2247.0914     2.004e+05        1108.       29775914
       2248.0435     2.058e+05        947.8       29785435
       2257.0497     2.264e+05        1043.       29875496
       2258.1452     2.151e+05        990.6       29886451
       2264.0380     2.166e+05        1197.       29945379
       2267.0323     2.300e+05        847.3       29975323
       2268.0500     2.175e+05        801.4       29985500
       2618.1514     2.317e+05        1494.       33486514
       2619.1110     2.336e+05        1076.       33496110
       2620.1670     2.254e+05        1453.       33506670
       2621.1789     2.293e+05        2323.       33516788
       2622.1489     2.188e+05        1814.       33526488
       2623.1494     2.346e+05        1944.       33536493
       2624.1414     2.343e+05        3237.       33546414
       2625.1594     2.402e+05        2212.       33556593
       2630.0223     2.303e+05        848.3       33605223
       2631.0304     2.203e+05        811.5       33615304
       2632.0179     2.147e+05        988.5       33625179
       2633.0307     2.301e+05        1060.       33635306
       2634.0146     2.262e+05        1042.       33645145
       2636.0141     1.764e+05        1462.       33665141
```

2637.0267	1.725e+05	1589.	33675267
2638.0248	1.715e+05	1579.	33685247
2640.0178	1.370e+05	630.7	33705178
2641.0086	1.402e+05	903.8	33715085
2643.0018	1.980e+05	729.5	33735018
2645.0083	2.163e+05	796.9	33755082
2646.0195	2.182e+05	804.0	33765195
2648.0806	2.422e+05	1339.	33785806
2649.0757	2.334e+05	1075.	33795756
2650.0183	2.301e+05	847.8	33805183
2651.0310	2.159e+05	994.5	33815310
2652.0316	2.066e+05	1142.	33825316
2652.9935	2.291e+05	632.9	33834934
2654.0049	2.329e+05	1716.	33845049
2654.9941	2.299e+05	1270.	33854941
2655.9947	2.147e+05	790.9	33864946
2656.9897	2.191e+05	1009.	33874897
2657.9840	2.245e+05	2275.	33884839
2658.9811	2.350e+05	2381.	33894810
2659.9828	2.228e+05	1436.	33904827
2664.9873	2.284e+05	841.5	33954872
2666.9912	2.170e+05	1199.	33974911

```
#-------------------------- OGLE DATA --------------------------
# Star LMC_SC21 40876 = MACHO 6.6454.5
#-------------------------------------------------------------------
#    HJD             v       err_v
#   (days)         (mag)     (mag)
#-------------------------------------------------------------------
  2450833.72329   14.627    0.011
  2450834.75241   14.652    0.010
  2450836.68976   14.706    0.013
  2450840.70630   14.688    0.006
  2450842.72631   14.706    0.010
  2450843.70778   14.647    0.008
  2450845.78953   14.673    0.011
  2450846.74529   14.706    0.008
  2450850.74495   14.680    0.007
  2450857.64824   14.702    0.008
  2450858.72082   14.633    0.011
  2450859.65516   14.647    0.010
  2450860.70693   14.785    0.008
  2450866.59113   15.377    0.006
  2450874.57662   14.641    0.010
  2450875.62917   14.677    0.011
  2450876.56248   14.716    0.008
  2450877.51767   14.706    0.010
  2450878.61290   14.620    0.011
  2450879.59411   14.638    0.007
  2450880.58729   14.673    0.008
```

2450881.52604	14.694	0.011
2450887.52770	14.698	0.007
2450890.51435	14.681	0.010
2450892.61201	14.703	0.008
2450893.66903	14.641	0.008
2450895.64037	14.693	0.013
2450896.64606	14.715	0.011
2450900.61729	14.674	0.008
2450922.53599	14.700	0.008
2451108.85212	14.654	0.007
2451131.78354	14.733	0.008
2451133.84383	14.655	0.011
2451143.82836	14.685	0.013
2451153.73779	14.659	0.011
2451156.76929	14.679	0.007
2451169.84287	14.700	0.007
2451193.67138	14.672	0.010
2451194.79087	14.722	0.007
2451205.78080	14.703	0.008
2451207.75638	14.654	0.010
2451212.71740	14.644	0.011
2451239.65880	14.707	0.010
2451261.55095	14.967	0.007
2451264.55047	15.263	0.011
2451266.57384	14.821	0.007
2451268.55065	14.743	0.007
2451272.55234	14.636	0.007
2451275.57541	14.726	0.008
2451277.56434	14.639	0.013

```
#------------------------- OGLE DATA --------------------------
# Star LMC_SC21 40876  = MACHO 6.6454.5
#------------------------------------------------------------------
```

# HJD (days)	i (mag)	err_i (mag)
2450832.78089	14.452	0.008
2450834.74339	14.360	0.015
2450836.68017	14.431	0.014
2450838.75705	14.380	0.010
2450839.71152	14.369	0.010
2450840.69671	14.389	0.007
2450841.77146	14.444	0.006
2450842.69221	14.447	0.011
2450843.69775	14.380	0.010
2450844.69179	14.349	0.007
2450845.80135	14.385	0.008
2450846.75718	14.438	0.007
2450850.73583	14.389	0.011
2450854.78083	14.348	0.008
2450855.72619	14.393	0.008

2450856.68818	14.416	0.007
2450857.69200	14.460	0.010
2450858.71047	14.391	0.015
2450859.66711	14.353	0.014
2450860.69708	14.441	0.011
2450866.58173	14.979	0.007
2450874.56276	14.353	0.015
2450875.61644	14.358	0.011
2450876.55279	14.443	0.006
2450877.50836	14.422	0.013
2450878.60059	14.341	0.008
2450879.58416	14.351	0.010
2450880.57820	14.382	0.013
2450881.51648	14.423	0.008
2450887.51474	14.431	0.011
2450890.52930	14.394	0.013
2450891.51601	14.460	0.007
2450892.50528	14.469	0.007
2450893.65906	14.383	0.011
2450896.63679	14.444	0.008
2450900.60827	14.385	0.013
2450922.52681	14.441	0.013
2450925.61627	14.399	0.007
2450934.51278	14.346	0.010
2451074.82698	14.403	0.010
2451076.85898	14.478	0.008
2451083.86966	14.376	0.015
2451084.86529	14.399	0.013
2451087.88941	14.375	0.013
2451090.73298	14.441	0.011
2451091.79692	14.467	0.015
2451092.84458	14.360	0.014
2451106.81607	14.458	0.015
2451108.83158	14.373	0.011
2451126.72599	14.464	0.015
2451131.79528	14.459	0.007
2451136.85279	14.437	0.014
2451137.84881	14.346	0.008
2451142.81646	14.352	0.008
2451152.77454	14.353	0.006
2451154.79944	14.415	0.014
2451156.72731	14.449	0.007
2451159.78254	14.399	0.008
2451160.85185	14.462	0.011
2451161.84639	14.419	0.015
2451163.84970	14.371	0.010
2451165.82633	14.447	0.010
2451168.79268	14.378	0.007
2451171.78325	14.404	0.013
2451175.78222	14.458	0.011
2451179.83239	14.415	0.007
2451183.85326	14.372	0.014

2451186.85674	14.374	0.007
2451193.68254	14.389	0.013
2451194.73341	14.431	0.007
2451196.66856	14.416	0.006
2451202.75807	14.361	0.015
2451204.73475	14.443	0.015
2451207.74569	14.354	0.010
2451211.75682	14.379	0.010
2451215.57570	14.445	0.008
2451217.73385	14.355	0.010
2451219.64753	14.427	0.014
2451221.62135	14.427	0.011
2451223.70997	14.383	0.008
2451226.59959	14.388	0.011
2451227.60440	14.377	0.006
2451230.66920	14.433	0.010
2451233.56524	14.373	0.011
2451235.70302	14.437	0.013
2451238.62555	14.374	0.013
2451240.70130	14.454	0.011
2451242.51923	14.361	0.008
2451244.65572	14.432	0.011
2451247.51354	14.372	0.007
2451248.61376	14.371	0.008
2451254.58278	14.430	0.010
2451256.62006	14.399	0.013
2451258.60722	14.517	0.014
2451261.51301	14.666	0.013
2451261.61603	14.674	0.015
2451263.55164	14.924	0.008
2451263.58349	14.921	0.010
2451264.52405	14.907	0.010
2451265.57135	14.709	0.010
2451266.54985	14.514	0.007
2451267.54561	14.492	0.007
2451268.54117	14.450	0.008
2451272.52590	14.357	0.006
2451273.55235	14.384	0.010
2451274.54369	14.442	0.011
2451275.55812	14.429	0.011
2451277.55347	14.345	0.014
2451278.55974	14.403	0.008
2451279.54254	14.434	0.013
2451290.52389	14.435	0.008
2451296.60946	14.336	0.013
2451298.50040	14.376	0.015
2451301.57481	14.335	0.007
2451315.52420	14.447	0.008
2451318.50673	14.390	0.007
2451320.49949	14.433	0.010
2451330.50969	14.433	0.007

```
#-------------------------- OGLE DATA --------------------------
# Star LMC_SC21 = MACHO 6.6454.5
#---------------------------------------------------------------
# HJD-2400000     I   err_I
#   (days)      (mag) (mag)
#---------------------------------------------------------------
51431.85640   14.371 0.007
51433.85135   14.459 0.010
51435.89314   14.364 0.006
51437.88804   14.409 0.008
51439.84310   14.455 0.017
51441.86177   14.355 0.014
51447.81447   14.395 0.007
51471.81228   14.365 0.015
51478.78225   14.472 0.014
51484.77042   14.464 0.008
51487.84127   14.398 0.010
51491.78105   14.406 0.010
51493.72305   14.444 0.014
51496.61992   14.365 0.015
51498.68701   14.452 0.015
51500.82722   14.359 0.010
51503.66254   14.470 0.010
51505.76979   14.347 0.008
51507.72082   14.393 0.011
51508.67353   14.462 0.013
51509.69876   14.452 0.013
51511.69204   14.360 0.011
51512.79677   14.424 0.017
51514.74040   14.463 0.006
51517.70552   14.396 0.013
51519.65909   14.451 0.014
51522.73926   14.404 0.006
51523.68420   14.483 0.010
51525.66066   14.356 0.010
51528.78855   14.444 0.013
51529.83170   14.444 0.011
51531.80988   14.368 0.008
51538.76624   14.451 0.015
51541.80743   14.362 0.011
51544.73268   14.434 0.014
51547.80529   14.420 0.014
51548.81479   14.452 0.013
51549.82472   14.404 0.015
51552.70130   14.423 0.010
51553.77629   14.450 0.015
51554.79157   14.402 0.013
51555.77994   14.365 0.017
51555.83299   14.352 0.014
51562.77766   14.430 0.010
51566.62561   14.359 0.008
51568.64852   14.437 0.011
```

51571.71178	14.360	0.014
51575.67460	14.360	0.008
51577.74164	14.420	0.008
51579.71157	14.384	0.010
51581.65950	14.380	0.010
51584.63563	14.403	0.011
51586.64449	14.367	0.015
51590.59780	14.359	0.008
51595.60828	14.338	0.011
51596.72171	14.363	0.008
51599.71354	14.361	0.006
51600.64136	14.358	0.010
51600.70374	14.347	0.011
51601.71954	14.353	0.010
51602.70094	14.427	0.006
51606.66753	14.386	0.013
51609.68097	14.389	0.008
51610.69856	14.336	0.013
51613.66653	14.432	0.010
51615.67657	14.361	0.011
51616.61352	14.374	0.008
51617.65668	14.420	0.008
51618.49803	14.479	0.010
51620.52156	14.354	0.008
51620.67143	14.330	0.011
51622.66590	14.422	0.008
51624.66394	14.386	0.007
51625.64361	14.355	0.014
51627.66010	14.436	0.007
51629.63505	14.357	0.013
51630.65207	14.352	0.015
51633.48953	14.454	0.014
51634.60885	14.364	0.008
51635.62241	14.362	0.007
51644.54892	14.382	0.013
51653.51590	14.457	0.011
51654.56745	14.354	0.014
51655.50515	14.426	0.013
51655.56960	14.437	0.014
51656.49581	14.579	0.011
51656.58413	14.615	0.017
51657.49350	14.740	0.011
51657.57015	14.754	0.007
51658.51935	14.754	0.015
51658.56081	14.729	0.014
51659.50315	14.708	0.011
51659.55879	14.708	0.011
51660.49735	14.835	0.011
51661.49103	14.894	0.010
51661.58206	14.878	0.010
51662.49671	14.817	0.011
51662.55177	14.817	0.013

```
51663.48448   14.628 0.015
51663.55227   14.611 0.017
51664.51159   14.447 0.013
51664.57497   14.441 0.014
51665.53211   14.436 0.007
51665.57921   14.398 0.006
51667.49221   14.453 0.007
51667.56531   14.412 0.010
51669.50538   14.379 0.007
51669.55358   14.455 0.006
51670.49140   14.348 0.007
51671.49471   14.373 0.011
51671.55687   14.371 0.010
51672.51768   14.424 0.010
51672.55966   14.440 0.008
51684.46619   14.355 0.007
51687.47413   14.433 0.010
51690.47757   14.376 0.006
51691.48123   14.377 0.008
51694.46819   14.342 0.011


#-----------------------------------------------------------------------
# OBSERVATIONS FROM CHRIS STOCKDALE -- HAZELWOOD OBSERVATORY
#
# 1998 - 2000
# Target = 6.6454.5
# All observations are unfiltered.
#-----------------------------------------------------------------------
# Date    Time(UT)   FFld    Target    Ref 2    Ref 3    Ref 4    Ref 5
#-----------------------------------------------------------------------
#Average (Yr 2000)           14.84     14.66    14.99    14.78     No
#R Band                        -       14.65    14.97    14.85    16.18
#-----------------------------------------------------------------------
# Date    Time(UT)   FFld    Target    Ref 2    Ref 3    Ref 4    Ref 5
#-----------------------------------------------------------------------
 980130    12:38      No     14.43     14.64    14.98    14.77    16.02
 980130    12:47      No     14.45     14.65    14.99    14.77    16.28
 980217    11:53      No     14.74     14.61     NA      14.76     NA
 980217    12:22      No     14.54     14.52    15.02    14.59    15.7
 980217    13:02      No     14.77     14.62    14.96    14.71    15.97
 980217    13:54      No     14.69     14.59    14.95    14.68    15.83
 980217    14:43      No     14.75     14.66    14.95    14.8     15.98
 980217    15:17      No     14.71     14.51    14.9     14.68    15.78
 980217    15:52      No     14.62     14.5     14.99    14.73     NA
 980217    17:36      No     14.84     14.69    14.97    14.74    15.95
 980218    12:24      No     14.85     14.7      15      14.8     16.06
 980218    12:45      No     14.81     14.69    14.98    14.83    15.96
 980218    12:57      No     14.81     14.64    14.99    14.79    16.2
 980218    13:18      No     14.74     14.55    14.84    14.64     16
 980218    13:29      No     14.83     14.64    14.9     14.72    15.94
 980218    13:58      No     14.78     14.64    14.91    14.68    15.96
```

980218	15:06	No	14.79	14.63	14.98	14.78	15.96
980218	16:13	No	14.63	14.53	14.89	14.65	15.87
980218	16:21	No	14.75	14.55	14.99	14.7	15.91
980219	12:44	No	14.68	14.51	14.9	14.67	16.05
980219	13:16	No	14.85	14.63	14.89	14.82	15.98
980220	11:14	No	14.88	14.53	14.99	14.64	NA
980220	11:19	No	15.1	14.64	14.94	14.73	NA
980220	11:22	No	15.13	14.63	15.01	14.76	16.07
980220	11:44	No	14.94	14.56	14.87	14.61	15.84
980220	12:23	No	15.08	14.64	14.97	14.73	15.84
980221	11:39	No	15.32	14.67	15.04	14.8	16.1
980221	11:51	No	15.29	14.61	14.91	14.73	15.96
980221	12:45	No	15.32	14.67	15.07	14.89	NA
980221	12:54	No	15.21	14.63	14.98	14.73	15.94
980221	13:24	No	15.25	14.65	14.92	14.83	15.91
980221	13:53	No	15.17	14.66	14.93	14.72	15.96
980222	11:46	No	15.01	14.55	14.94	14.64	
980222	11:57	No	15.14	14.68	14.96	14.83	16.09
980223	10:46	No	15.04	14.77	15.09	14.83	16.13
980223	10:55	No	14.87	14.6	14.87	14.66	15.96
980223	11:25	No	14.94	14.63	14.95	14.85	15.92
980223	12:02	No	14.9	14.59	14.94	14.73	16
980223	12:52	No	14.92	14.61	14.94	14.71	15.94
980223	13:49	No	14.8	14.51	14.86	14.63	15.96
980223	14:00	No	14.91	14.64	14.9	14.72	15.87
980224	10:28	No	14.79	14.6	14.94	14.85	16.09
980224	10:40	No	14.73	14.62	14.88	14.85	16.02
980224	11:30	No	14.68	14.65	14.94	14.78	15.92
980224	11:40	No	14.73	14.69	14.95	14.79	15.97
980224	12:06	No	14.72	14.6	14.95	14.71	15.96
980225	13:32	No	14.59	14.52	15.07	14.63	NA
980225	14:02	No	14.66	14.58	14.83	14.71	15.92
980225	14:30	No	14.78	14.55	14.9	14.66	16.1
980225	14:40	No	14.81	14.64	14.97	14.84	16.02
980227	11:52	No	14.69	14.78	14.9	14.85	NA
980227	12:04	No	14.62	14.65	14.88	14.69	16.13
980227	12:12	No	14.61	14.58	14.99	14.72	NA
980227	12:51	No	14.61	14.65	14.97	14.68	16.12
980227	13:04	No	14.55	14.58			
980227	14:06	No	14.74	14.66	14.93	14.77	16.1
980227	14:23	No	14.68	14.71	14.85	14.75	16.15
980227	14:35	No	14.65	14.62	14.85	14.78	16.04
990320	10:15	Yes	14.46	14.55	14.94	14.64	
990320	10:52	Yes	14.54	14.56	14.84	14.67	
990322	12:45	Yes New	14.88	14.65	15.01	14.78	
990323	09:14	Yes	14.93	14.63	14.89	14.74	
990323	09:36	Yes	14.91	14.65	14.96	14.77	
990323	09:41	Yes New	14.9	14.59	14.85	14.65	
990323	09:58	Yes New	14.78	14.58	14.9	14.66	
990323	11:02	Yes New	14.83	14.61	14.96	14.76	16.06
990323	12:29	Yes New	14.78	14.5	14.48	14.64	15.95
990323	13:01	Yes New	14.93	14.66	14.95	14.74	15.99

990323	13:33	Yes New	14.95	14.62	14.98	14.69	NA
990325	09:14	Yes	15.08	14.64	14.93	14.79	15.99
990325	09:31	Yes	15.1	14.6	14.87	14.72	15.86
990325	09:36	Yes	14.94	14.59	14.81	14.73	16.03
990325	09:45	Yes	15.03	14.52	14.82	14.76	15.95
990326	09:12	Yes	15.05	14.62	14.89	14.75	16
990326	09:44	Yes	15.31	14.66	14.95	14.75	15.88
990326	10:16	Yes	15.26	14.64	14.98	14.67	16.08
990326	10:44	Yes	15.07	14.56	14.91	14.69	16
990326	11:11	Yes	15.17	14.51	14.84	14.64	15.9
990326	11:42	Yes	15.15	14.56	14.87	14.63	15.86
990326	12:02	Yes	15.22	14.64	14.92	14.74	15.97
990326	12:26	Yes	15.17	14.58	14.93	14.71	15.8
990326	12:59	Yes	15.21	14.59	14.87	14.72	15.96
990328	09:21	Yes	14.82	14.6	14.95	14.75	15.88
990328	09:25	Yes	14.8	14.57	14.91	14.77	15.89
990328	12:28	Yes	14.79	14.54	14.88	14.77	NA
990329	09:36	Yes	14.55	14.49	14.94	14.67	NA
990329	09:53	Yes	14.61	14.61	14.9	14.7	15.74
990329	10:10	Yes	14.65	14.71	15.02	14.76	15.86
990329	10:27	Yes	14.61	14.54	14.92	14.64	15.88
990329	10:35	Yes	14.64	14.63	14.87	14.75	15.85
990329	10:52	Yes	14.66	14.6	14.91	14.76	15.91
990329	11:09	Yes	14.68	14.66	15.01	14.77	16.07
990329	11:27	Yes	14.69	14.67	14.99	14.76	16.14
990329	11:51	Yes	14.66	14.62	14.85	14.61	15.85
990329	12:24	Yes	14.64	14.56	14.88	14.69	15.88
990329	12:57	Yes	14.64	14.64	15.06	14.8	NA
990329	13:21	Yes	14.61	14.59	14.86	14.7	16.12
990329	13:57	Yes	14.7	14.77	15.02	14.74	NA
990329	14:28	Yes	14.63	14.53	14.87	14.69	NA
990329	14:37	Yes	14.6	14.6	14.85	14.73	16.04
990329	14:41	Yes	14.72	14.67	14.92	14.79	NA
990331	09:03	Yes New	14.65	14.55	15.04	14.6	NA
990331	09:07	Yes New	14.54	14.61	14.93	14.77	15.84
990331	09:40	Yes New	14.55	14.62	14.89	14.7	15.93
990331	10:21	Yes New	14.63	14.64	14.94	14.75	15.97
990331	10:51	Yes New	14.62	14.6	14.94	14.76	15.95
990331	11:22	Yes New	14.64	14.62	14.96	14.72	15.91
990331	11:53	Yes New	14.59	14.65	14.88	14.75	15.9
990331	12:24	Yes New	14.62	14.69	14.96	14.81	16.05
990331	12:55	Yes New	14.48	14.56	14.81	14.76	15.73
990331	13:07	Yes New	14.61	14.6	14.88	14.7	16.02
990401	11:18	Yes New	14.54	14.5	14.78	14.78	NA
990401	11:31	Yes New	14.54	14.58	14.86	14.71	15.9
990401	11:37	Yes New	14.53	14.55	14.81	14.66	NA
990401	11:48	Yes New	14.41	14.58	14.8	14.62	NA
990411	11:57	Yes New	14.56	14.61	NA	14.68	NA
20000229	12:26	No	14.61	14.66	15.02	14.81	16.34
20000316	10:35						16.8
20000316	10:56	No	14.53	14.66	15.09	14.71	16.31
20000316	11:03	No	14.53	14.61	15.04	14.74	16.52

20000316	11:10	No	14.42	14.68	15.14	14.73	16.52
20000318	11:25	No	14.56	14.59	14.99	14.81	15.98
20000318	11:52	No	14.53	14.62	14.98	14.74	15.94
20000320	10:58	No	14.62	14.55	14.97	14.78	16.06
20000320	11:04	No	14.58	14.61	15.06	14.66	15.97
20000320	11:22	No	14.64	14.67	14.88	14.79	NA
20000320	11:28	No	14.46	14.58	14.85	14.71	NA
20000320	11:44	No	14.69	14.69	14.98	14.79	15.84
20000323	11:16	No*	14.57	14.67	14.94	14.79	16.08
20000324	10:41	No*	14.62	14.64	15.06	14.92	16
20000324	10:55	No*	14.69	14.64	14.93	14.78	15.91
20000324	11:15	No*	14.68	14.7	14.99	14.79	16.11
20000325	10:38	No*	14.76	14.62	14.95	14.76	16.03
20000325	10:40	No*	14.69	14.74	15	14.8	16.09
20000328	10:42	Yes New*	14.54	14.68	14.98	14.79	
20000328	10:50	Yes New*	14.61	14.6	15.07	14.72	
20000328	10:57	Yes New*	14.62	14.64	15.03	14.74	
20000329	10:04	Yes New*	14.65	14.61	14.9	14.73	
20000329	10:08	Yes New*	14.65	14.61	14.9	14.73	
20000329	12:30	Yes New*	14.65	14.69	15.11	14.88	
20000329	12:38	Yes New*	14.68	14.7	14.93	14.8	
20000402	09:40	Yes New*	14.68	14.73	15.04	14.97	
20000402	09:49	Yes New*	14.66	14.66	14.96	14.8	
20000402	10:11	Yes New*	14.69	14.74	14.98	14.97	
20000402	10:45	Yes New*	14.65	14.65	15.01	14.81	
20000406	12:21	Yes New*	14.69	14.67	15.16	14.85	
20000406	12:26	Yes New*	14.54	14.64	15.02	14.73	
20000406	12:36	Yes New*	14.61	14.75	14.99	14.73	
20000406	12:38	Yes New*	14.63	14.63	14.97	14.76	
20000406	12:48	Yes New*	14.55	14.68	14.97	14.79	
20000406	12:55	Yes New*	14.65	14.72	15.02	14.8	
20000406	13:08	Yes New*	14.58	14.68	14.83	14.73	
20000406	12:13	Yes New*	14.55	14.65	14.85	14.71	
20000407	11:08	Yes New*	14.6	14.57	14.89	14.79	
20000407	11:14	Yes New*	14.55	14.58	14.81	14.77	
20000407	11:21	Yes New*	14.62	14.56	14.78	14.81	
20000408	09:58	Yes New*	14.72	14.78	15.07	14.89	
20000408	10:03	Yes New*	14.69	14.62	14.98	14.91	
20000408	10:11	Yes New*	14.68	14.61	14.95	14.73	
20000408	10:23	Yes New*	14.66	14.63	14.96	14.8	
20000416	09:32	Yes New*	14.59	14.65	15.1	14.71	
20000416	09:41	Yes New*	14.56	14.74	14.96	14.76	
20000416	10:23	Yes New*	14.58	14.59	14.89	14.69	
20000416	10:53	Yes New*	14.72	14.56	15.01	14.81	
20000416	10:59	Yes New*	14.63	14.61	14.88	14.79	
20000416	11:24	Yes New*	14.55	14.61	14.87	14.8	
20000416	11:48	Yes New*	14.65	14.72	15.07	14.78	
20000416	12:16	Yes New*	14.64	14.62	14.91	14.75	
20000416	13:12	Yes New*	14.52	14.6	14.89	14.77	
20000416	13:41	Yes New*	14.69	14.73	14.95	14.84	
20000416	13:58	Yes New*	14.46	14.75	15.03	14.84	
20000417	10:32	Yes New*	14.7	14.71	15.07	14.91	

20000417	10:39	Yes	New*	14.6	14.64	15.08	14.78
20000417	11:05	Yes	New*	14.64	14.63	15	14.75
20000417	11:36	Yes	New*	14.58	14.42		14.67
20000417	11:48	Yes	New*	14.72	14.72	15.06	14.83
20000417	12:17	Yes	New*	14.69	14.64	14.96	14.74
20000417	12:45	Yes	New*	14.6	14.58	15	14.79
20000417	12:56	Yes	New*	14.65	14.53	14.78	14.71
20000419	11:11	Yes	New*	14.56	14.6	15.02	14.7
20000419	11:41	Yes	New*	14.65	14.72	14.96	14.8
20000419	12:09	Yes	New*	14.69	14.58	14.98	14.78
20000419	12:53	Yes	New*	14.68	14.59	14.92	14.71
20000420	08:44	Yes	New*	14.41	14.69	15.35	14.79
20000420	08:51	Yes	New*	14.52	14.61	15.02	14.73
20000420	08:58	Yes	New*	14.51	14.59	14.9	14.81
20000420	09:11	Yes	New*	14.6	14.7	15.01	14.96
20000420	09:40	Yes	New*	14.56	14.56	14.96	14.77
20000420	09:48	Yes	New*	14.57	14.65	14.99	14.74
20000420	10:11	Yes	New*	14.63	14.71	15.08	14.79
20000420	10:39	Yes	New*	14.64	14.73	15.14	14.78
20000420	11:07	Yes	New*	14.58	14.69	15.02	14.77
20000420	11:36	Yes	New*	14.65	14.76	14.99	14.79
20000420	12:04	Yes	New*	14.63	14.76	15.11	14.82
20000420	12:32	Yes	New*	14.55	14.64	14.98	14.68
20000420	13:01	Yes	New*	14.56	14.63	14.99	14.74
20000420	13:29	Yes	New*	14.48	14.6	15.05	14.71
20000420	13:58	Yes	New*	14.62	14.78	15	14.82
20000421	11:56	Yes	New*	14.61	14.53	14.91	14.73
20000421	12:04	Yes	New*	14.68	14.55	14.99	14.66
20000421	13:15	Yes	New*	14.84	14.66	14.98	14.8
20000422	09:05	Yes	New*	14.93	14.71	15	14.81
20000422	09:29	Yes	New*	14.98	14.66	14.94	14.81
20000422	09:57	Yes	New*	14.99	14.66	14.94	14.84
20000422	10:26	Yes	New*	15	14.67	14.92	14.75
20000422	10:40	Yes	New*	15.08	14.71	15.08	14.83
20000423	08:23	Yes	New*	14.88	14.46	14.73	14.74
20000423	08:42	Yes	New*	15.04	14.5	14.83	14.68
20000423	08:52	Yes	New*	14.96	14.53	14.94	14.79
20000423	09:03	Yes	New*	15.08	14.67	15.08	14.85
20000423	09:15	Yes	New*	15.06	14.63	15.03	14.77
20000423	09:27	Yes	New*	15.07	14.65	14.99	14.87
20000423	10:02	Yes	New*	15.15	14.76	14.98	14.79
20000423	10:30	Yes	New*	15.06	14.67	14.99	14.88
20000423	10:59	Yes	New*	14.99	14.57	14.98	14.74
20000423	11:27	Yes	New*	15.01	14.61	14.97	14.82
20000423	11:51	Yes	New*	15	14.62	15.12	14.68
20000424	08:32	Yes	New*	15.15	14.66	15.05	14.83
20000424	08:40	Yes	New*	15.08	14.65	14.97	14.8
20000424	08:49	Yes	New*	15.09	14.7	14.98	14.9
20000424	08:57	Yes	New*	15.09	14.68	15.07	14.8
20000424	09:06	Yes	New*	15.22	14.565	14.93	14.94
20000424	09:56	Yes	New*	15.1	14.67	15.08	14.79
20000424	10:13	Yes	New*	14.94	14.77	15.2	14.85

20000424	10:22	Yes New*	15.04	14.66	15.07	14.71
20000424	10:30	Yes New*	15.02	14.66	15.11	14.78
20000424	10:41	Yes New*	15.05	14.69	14.97	14.81
20000424	11:14	Yes New*	15.05	14.57	14.96	14.77
20000424	11:34	Yes New*	15	14.63	15.07	14.74
20000424	12:02	Yes New*	15.06	14.66	15.07	14.8
20000424	12:30	Yes New*	15.04	14.67	15.06	14.73
20000424	12:50	Yes New*	15.06	14.75	15.1	14.71
20000424	13:03	Yes New*	15.05	14.63	15.01	14.77
20000424	13:12	Yes New*	14.95	14.82	15.15	14.91
20000424	13:20	Yes New*	14.89	14.61	15.22	14.73
20000424	13:29	Yes New*	15.09	14.67	14.94	14.67
20000424	13:38	Yes New*	14.9	14.59	15.11	14.84
20000424	13:46	Yes New*	15.09	14.74	15	14.77
20000424	14:03	Yes New*	15.07	14.71	14.95	14.84
20000424	14:12	Yes New*	15.06	14.78	14.98	14.73
20000424	14:20	Yes New*	14.81	14.57	15	14.56
20000425	11:12	Yes New*	15.08	14.68	15.12	14.84
20000425	11:40	Yes New*	15	14.58	14.91	14.68
20000425	11:52	Yes New*	15.04	14.68	15.01	14.75
20000425	12:20	Yes New*	15.12	14.67	15.04	14.79
20000425	12:42	Yes New*	15.02	14.59	14.82	14.67
20000426	08:27	Yes New*	15.25	14.65	14.95	14.83
20000426	08:55	Yes New*	15.07	14.58	14.98	14.79
20000426	09:23	Yes New*	15.25	14.78	15.08	14.93
20000426	09:31	Yes New*	15.23	14.67	14.96	14.81
20000426	10:00	Yes New*	15.25	14.67	15.03	14.82
20000426	10:28	Yes New*	15.25	14.7	14.98	14.78
20000426	10:56	Yes New*	15.25	14.64	15	14.8
20000426	11:11	Yes New*	15.06	14.53	14.95	14.74
20000426	11:39	Yes New*	15.21	14.72	14.93	14.94
20000426	12:08	Yes New*	15.16	14.7	14.98	14.86
20000426	12:31	Yes New*	15.24	14.65	14.93	14.85
20000426	12:57	Yes New*	15.25	14.63	14.94	14.75
20000426	13:22	Yes New*	15.16	14.64	15.11	14.71
20000427	08:51	Yes New*	15.19	14.58	14.95	14.77
20000427	09:21	Yes New*	15.14	14.54	14.92	14.8
20000427	09:50	Yes New*	15.16	14.63	14.99	14.82
20000427	10:18	Yes New*	15.18	14.57	14.96	14.76
20000427	10:52	Yes New*	15.29	14.63	14.9	14.77
20000427	11:21	Yes New*	15.3	14.78	15	14.84
20000427	11:51	Yes New*	15.24	14.74	15.1	14.81
20000427	12:00	Yes New*	15.29	14.68	14.95	14.84
20000427	12:29	Yes New*	15.16			
20000427	13:19	Yes New*	15.26	14.74	14.96	14.73
20000427	13:47	Yes New*	15.21	14.7	14.95	14.78
20000427	14:05	Yes New*	15.22	14.7	14.92	14.72
20000428	08:44	Yes New*	14.98	14.59	15.01	14.66
20000428	08:52	Yes New*	15.03	14.64	14.96	14.79
20000428	09:18	Yes New*	15.11	14.72	15.05	14.86
20000428	09:27	Yes New*	15.06	14.63	14.9	14.83
20000428	09:55	Yes New*	15.11	14.66	14.97	14.8

20000428	10:10	Yes	New*	15.13	14.68	14.95	14.86
20000428	10:38	Yes	New*	15	14.7	14.95	14.73
20000428	10:49	Yes	New*	15.08	14.8	15	14.8
20000428	11:17	Yes	New*	15.13	14.72	14.99	14.79
20000428	11:46	Yes	New*	15.19	14.72	15.02	14.82
20000428	12:14	Yes	New*	15.04	14.65	14.89	14.77
20000428	12:33	Yes	New*	15.03	14.66	14.93	14.84
20000428	13:43	Yes	New*	15.06	14.61	14.87	14.77
20000429	08:40	Yes	New*	14.86	14.68	14.99	14.85
20000429	09:02	Yes	New*	14.83	14.6	15	14.82
20000429	09:14	Yes	New*	14.82	14.7	14.97	14.79
20000429	09:43	Yes	New*	14.86	14.66	14.93	14.69
20000429	10:39	Yes	New*	14.79	14.66	14.94	14.7
20000429	11:07	Yes	New*	14.83	14.63	15	14.8
20000429	11:36	Yes	New*	14.77	14.74	14.96	14.78
20000429	12:04	Yes	New*	14.82	14.76	15.06	14.8
20000429	12:56	Yes	New*	14.65	14.59	14.79	14.64
20000430	08:14	Yes	New*	14.59	14.62	14.97	14.7
20000430	08:23	Yes	New*	14.68	14.68	14.98	14.79
20000430	08:35	Yes	New*	14.58	14.64	14.89	14.72
20000430	08:47	Yes	New*	14.63	14.7	14.98	14.76
20000430	08:59	Yes	New*	14.73	14.71	14.97	14.83
20000430	09:21	Yes	New*	14.61	14.66	14.96	14.79
20000430	09:49	Yes	New*	14.65	14.68	14.95	14.74
20000430	10:18	Yes	New*	14.69	14.57	14.94	14.73
20000430	10:29	Yes	New*	14.59	14.63	14.94	14.69
20000430	10:57	Yes	New*	14.66	14.65	14.95	14.79
20000430	11:26	Yes	New*	14.67	14.62	14.93	14.76
20000501	08:38	Yes	New*	14.55	14.58	15.09	14.64
20000501	08:46	Yes	New*	14.55	14.69	14.95	14.71
20000501	08:58	Yes	New*	14.65	14.63	14.95	14.77
20000501	09:10	Yes	New*	14.71	14.76	15.07	14.84
20000501	09:21	Yes	New*	14.67	14.75	15.02	14.92
20000501	09:35	Yes	New*	14.6	14.67	15.08	14.8
20000501	09:45	Yes	New*	14.61	14.72	14.96	14.83
20000501	10:17	Yes	New*	14.72	14.76	15.09	14.79
20000501	10:45	Yes	New*	14.64	14.72	15.02	14.79
20000501	11:24	Yes	New*	14.6	14.57	14.96	14.73
20000501	12:21	Yes	New*	14.62	14.71	14.98	14.81
20000501	12:50	Yes	New*	14.8	14.72	15.1	14.91
20000502	09:02	Yes	New*	14.7	14.69	15.02	14.82
20000502	09:15	Yes	New*	14.69	14.72	15.03	14.85
20000502	09:43	Yes	New*	14.7	14.67	15.02	14.83
20000502	10:11	Yes	New*	14.68	14.72	15	14.83
20000502	10:44	Yes	New*	14.6	14.68	14.95	14.79
20000502	11:12	Yes	New*	14.7	14.77	15.01	14.8
20000502	11:41	Yes	New*	14.73	14.7	14.92	14.86
20000502	12:09	Yes	New*	14.64	14.73	15.06	14.77
20000502	12:37	Yes	New*	14.67	14.73	14.97	14.87

Obtained by Bob Stobie and Dave Kilkenny

Using SAAO 1.0m telescope at Sutherland and
St Andrews Photometer.
Typical precision of 0.02 mag, the colon means that the V and B-V
have a precision of about 0.05 mag.

observer	HJD (2450000+)	V (mags)	B-V (mags)	U-B (mags)
rss	862.297	14.80	0.20	0.06
rss	863.310	14.86	0.18	0.04
rss	866.323	15.31:	0.27:	0.11
rss	867.334	15.14	0.19	0.06
rss	868.300	14.97	0.17	0.05
dmk	869.287	14.83	0.19	0.05
dmk	871.289	14.72	0.17	0.01

Obtained by Ian Glass - SAAO

H - band (1.65 micron)

JD	H (mag)	err H (mag)
2450863.38	14.00	0.08
2450866.35	14.20	0.10
2450867.39	14.25	0.08
2450868.34	14.39	0.11
2450868.35	14.20	0.07

Obtained by Micheal Feast - SAAO

JD	J (mag)	err J (mag)	H (mag)	err H (mag)	K (mag)	err K (mag)
2450855.3	14.10	0.08	13.86	0.07	13.75	0.15
2450856.3			13.76	0.07		
2450857.3			13.98	0.07		
2450858.5			14.0	0.09		

#---
Obserations from
John Greenhill, Jean-Phillipe Beaulieu and Jadzia Donatowicz
University of Tasmania
#---
magnitudes are relative to 6 standard stars
err are in mags, PLDate is JD - 2450000

```
# seeing is in arcsec, FWHM in pixels(0.436 arcsec)
# Backgr is in ADU = 2.2e
#-----------------------------------------------------------------
```

B Mag	Err	PLDate	Seeing	BackGr	Typ	Epoch	MJD_OBS	ExpTime	Sky	FWHM	AirMass	ErrDop
15.060	0.009	1644.01348	2.840	226.000	11	0.0	51643.51287	300.000	226.000	6.514	0.000	0.007
14.923	0.021	1644.03232	2.598	245.000	11	0.0	51643.53170	300.000	245.000	5.958	0.000	0.013
0.000	0.000	1655.97051	0.200	820.000	0	0.0	51655.46933	300.000	820.000	0.000	0.000	0.000
0.000	0.000	1655.98746	0.200	871.000	0	0.0	51655.48627	300.000	871.000	0.000	0.000	0.000
0.000	0.000	1656.01383	0.200	986.000	0	0.0	51655.51265	300.000	986.000	0.000	0.000	0.000
0.000	0.000	1656.07500	0.200	1152.000	0	0.0	51655.57382	300.000	1152.000	0.000	0.000	0.000
0.000	0.000	1656.09675	0.200	1197.000	0	0.0	51655.59557	300.000	1197.000	0.000	0.000	0.000
15.470	0.011	1659.00413	2.739	2781.000	11	0.0	51658.50280	300.000	2781.000	6.281	0.000	0.006
0.000	0.000	1659.06347	0.200	641.000	0	0.0	51658.56214	300.000	641.000	0.000	0.000	0.000
0.000	0.000	1659.02294	0.200	3867.000	0	0.0	51658.52103	400.000	3867.000	0.000	0.000	0.000
15.469	0.009	1659.08344	2.822	654.000	11	0.0	51658.58211	300.000	654.000	6.472	0.000	0.006
15.461	0.021	1659.04776	2.083	507.000	11	0.0	51658.54642	300.000	507.000	4.777	0.000	0.017
15.505	0.012	1659.86439	2.137	277.000	11	0.0	51659.36302	300.000	277.000	4.901	0.000	0.009
15.529	0.029	1659.91884	1.935	245.000	11	0.0	51659.41746	300.000	245.000	4.439	0.000	0.024
15.516	0.006	1659.88222	2.481	245.000	11	0.0	51659.38084	300.000	245.000	5.690	0.000	0.004
15.542	0.007	1659.90070	2.979	245.000	11	0.0	51659.39933	300.000	245.000	6.832	0.000	0.004
15.529	0.036	1659.93558	1.729	226.000	11	0.0	51659.43420	300.000	226.000	3.966	0.000	0.030
15.562	0.008	1659.97955	2.599	213.000	11	0.0	51659.47817	300.000	213.000	5.960	0.000	0.006
15.562	0.009	1659.99579	2.251	213.000	11	0.0	51659.49441	300.000	213.000	5.162	0.000	0.007
15.558	0.014	1660.01656	2.033	258.000	11	0.0	51659.51518	300.000	258.000	4.662	0.000	0.012
15.604	0.010	1660.03756	2.758	328.000	11	0.0	51659.53618	300.000	328.000	6.326	0.000	0.008
0.000	0.000	1660.06875	0.200	405.000	0	0.0	51659.56737	300.000	405.000	0.000	0.000	0.000
0.000	0.000	1660.90517	0.200	290.000	0	0.0	51660.40375	300.000	290.000	0.000	0.000	0.000
15.716	0.026	1661.02386	2.836	245.000	11	0.0	51660.52243	300.000	245.000	6.505	0.000	0.017
15.709	0.007	1661.89665	2.502	258.000	11	0.0	51661.39517	300.000	258.000	5.738	0.000	0.006
15.748	0.010	1661.92246	2.932	309.000	11	0.0	51661.42098	300.000	309.000	6.725	0.000	0.009
0.000	0.000	1661.94772	0.200	258.000	0	0.0	51661.44625	300.000	258.000	0.000	0.000	0.000
0.000	0.000	1662.00376	0.200	245.000	0	0.0	51661.50228	300.000	245.000	0.000	0.000	0.000
0.000	0.000	1662.03994	0.200	405.000	0	0.0	51661.53672	600.000	405.000	0.000	0.000	0.000
0.000	0.000	1663.96724	0.200	245.000	0	0.0	51663.46567	300.000	245.000	0.000	0.000	0.000
0.000	0.000	1664.01052	0.200	277.000	0	0.0	51663.50895	300.000	277.000	0.000	0.000	0.000

V Mag	Err	PLDate	Seeing	BackGr	Typ	Epoch	MJD_OBS	ExpTime	Sky	FWHM	AirMass	ErrDop
15.668	0.005	1644.00897	2.783	622.000	11	0.0	51643.50836	300.000	622.000	6.383	0.000	0.004
15.666	0.004	1644.02692	2.776	654.000	11	0.0	51643.52631	300.000	654.000	6.368	0.000	0.003
15.648	0.034	1644.05420	1.643	967.000	11	0.0	51643.55359	300.000	967.000	3.769	0.000	0.029
15.793	0.005	1656.04946	3.498	1791.000	11	0.0	51655.54828	300.000	1791.000	8.023	0.000	0.004
15.779	0.004	1655.99153	3.560	1478.000	11	0.0	51655.49035	300.000	1478.000	8.164	0.000	0.003
15.783	0.005	1655.97541	3.477	1446.000	11	0.0	51655.47422	300.000	1446.000	7.975	0.000	0.004
15.810	0.006	1656.02486	3.409	2123.000	11	0.0	51655.52368	300.000	2123.000	7.819	0.000	0.004
15.781	0.009	1656.08165	2.523	1893.000	11	0.0	51655.58046	300.000	1893.000	5.786	0.000	0.008
0.000	0.000	1656.10107	0.200	1976.000	0	0.0	51655.59988	300.000	1976.000	0.000	0.000	0.000
16.020	0.009	1659.00810	2.360	14285.000	11	0.0	51658.50677	300.000	14285.000	5.412	0.000	0.007
16.031	0.009	1659.02790	2.919	19510.000	11	0.0	51658.52600	400.000	19510.000	6.695	0.000	0.007
16.024	0.005	1659.05176	2.652	1152.000	11	0.0	51658.55043	300.000	1152.000	6.083	0.000	0.004
15.990	0.005	1659.07132	4.141	1695.000	11	0.0	51658.56999	300.000	1695.000	9.497	0.000	0.004
16.007	0.015	1659.09216	2.297	1548.000	11	0.0	51658.59082	300.000	1548.000	5.269	0.000	0.013
16.018	0.005	1659.10750	3.133	1810.000	11	0.0	51658.60617	300.000	1810.000	7.185	0.000	0.004
16.046	0.007	1659.86845	2.077	705.000	11	0.0	51659.36708	300.000	705.000	4.763	0.000	0.006
16.049	0.005	1659.88825	2.562	705.000	11	0.0	51659.38687	300.000	705.000	5.876	0.000	0.004
16.065	0.009	1659.98338	2.088	603.000	11	0.0	51659.48200	300.000	603.000	4.788	0.000	0.008
16.077	0.007	1659.93948	3.234	673.000	11	0.0	51659.43810	300.000	673.000	7.418	0.000	0.006
16.056	0.007	1659.90467	2.612	686.000	11	0.0	51659.40330	300.000	686.000	5.990	0.000	0.006
16.079	0.010	1659.92372	2.910	737.000	11	0.0	51659.42235	300.000	737.000	6.674	0.000	0.009
16.069	0.007	1659.99962	2.081	590.000	11	0.0	51659.49824	300.000	590.000	4.773	0.000	0.006
16.075	0.005	1660.02399	2.305	756.000	11	0.0	51659.52262	300.000	756.000	5.286	0.000	0.004
16.066	0.005	1660.04137	4.439	871.000	11	0.0	51659.53999	300.000	871.000	10.181	0.000	0.004
16.213	0.013	1660.90910	2.984	1395.000	11	0.0	51660.40767	300.000	1395.000	6.844	0.000	0.010
16.231	0.009	1661.03328	2.523	1625.000	11	0.0	51660.53012	600.000	1625.000	5.787	0.000	0.007
16.213	0.005	1661.90226	2.704	654.000	11	0.0	51661.40079	300.000	654.000	6.201	0.000	0.004
16.208	0.011	1661.92691	2.170	769.000	11	0.0	51661.42544	300.000	769.000	4.976	0.000	0.010
16.203	0.007	1661.95765	2.491	705.000	11	0.0	51661.45618	300.000	705.000	5.713	0.000	0.006
16.156	0.023	1662.01072	2.745	999.000	11	0.0	51661.50925	300.000	999.000	6.295	0.000	0.017
0.000	0.000	1662.04779	0.200	1363.000	0	0.0	51661.54457	600.000	1363.000	0.000	0.000	0.000
15.810	0.004	1663.97115	3.775	724.000	11	0.0	51663.46957	300.000	724.000	8.658	0.000	0.003
0.000	0.000	1664.02007	0.200	737.000	0	0.0	51663.51849	300.000	737.000	0.000	0.000	0.000
15.810	0.004	1663.97115	3.775	724.000	11	0.0	51663.46957	300.000	724.000	8.658	0.000	0.003
0.000	0.000	1664.02007	0.200	737.000	0	0.0	51663.51849	300.000	737.000	0.000	0.000	0.000

R Mag	Err	PLDate	Seeing	BackGr	Typ	Epoch	MJD_OBS	ExpTime	Sky	FWHM	AirMass	ErrDop
16.064	0.004	1644.02197	2.676	852.000	11	0.00000000	51643.52135	300.000	852.000	6.138	0.000	0.003
16.074	0.004	1644.04057	2.794	903.000	11	0.00000000	51643.53995	300.000	903.000	6.408	0.000	0.003
16.141	0.005	1655.97936	3.205	1663.000	11	0.00000000	51655.47818	300.000	1663.000	7.352	0.000	0.004
16.150	0.004	1655.99566	3.193	1663.000	11	0.00000000	51655.49448	300.000	1663.000	7.323	0.000	0.003
16.160	0.005	1656.02876	3.427	1842.000	11	0.00000000	51655.52758	300.000	1842.000	7.860	0.000	0.004
16.158	0.004	1656.06105	2.946	1906.000	11	0.00000000	51655.55986	300.000	1906.000	6.756	0.000	0.003
16.177	0.005	1656.08560	3.303	2008.000	11	0.00000000	51655.58441	300.000	2008.000	7.576	0.000	0.004
16.377	0.005	1659.07560	2.550	2519.000	11	0.00000000	51658.57427	300.000	2519.000	5.849	0.000	0.004
16.408	0.007	1659.03294	2.958	19082.000	11	0.00000000	51658.53103	400.000	19082.000	6.785	0.000	0.006
16.395	0.007	1659.01210	2.310	13761.000	11	0.00000000	51658.51078	300.000	13761.000	5.299	0.000	0.006
16.386	0.005	1659.05565	2.522	1938.000	11	0.00000000	51658.55432	300.000	1938.000	5.784	0.000	0.004
16.378	0.005	1659.09607	2.469	4365.000	11	0.00000000	51658.59473	300.000	4365.000	5.662	0.000	0.004
16.385	0.005	1659.11130	2.815	2730.000	11	0.00000000	51658.60997	300.000	2730.000	6.457	0.000	0.004
16.393	0.005	1659.87234	2.124	954.000	11	0.00000000	51659.37097	300.000	954.000	4.871	0.000	0.004
16.418	0.008	1660.00851	2.118	884.000	11	0.00000000	51659.50713	300.000	884.000	4.857	0.000	0.007
16.401	0.007	1659.89223	2.410	1018.000	11	0.00000000	51659.39086	300.000	1018.000	5.527	0.000	0.006
16.406	0.007	1659.90863	2.802	999.000	11	0.00000000	51659.40726	300.000	999.000	6.426	0.000	0.006
16.419	0.009	1659.92757	2.992	1050.000	11	0.00000000	51659.42619	300.000	1050.000	6.862	0.000	0.008
16.421	0.006	1659.94325	3.113	986.000	11	0.00000000	51659.44187	300.000	986.000	7.139	0.000	0.006
16.421	0.009	1659.98728	2.346	871.000	11	0.00000000	51659.48590	300.000	871.000	5.381	0.000	0.008
16.426	0.005	1660.02777	2.473	1069.000	11	0.00000000	51659.52639	300.000	1069.000	5.672	0.000	0.004
16.427	0.004	1660.04651	2.738	1184.000	11	0.00000000	51659.54513	300.000	1184.000	6.279	0.000	0.004
16.408	0.018	1659.94831	2.297	935.000	11	0.00000000	51659.44693	300.000	935.000	5.268	0.000	0.016
16.427	0.008	1659.95195	3.273	916.000	11	0.00000000	51659.45058	300.000	916.000	7.508	0.000	0.007
16.437	0.013	1659.95560	3.434	903.000	11	0.00000000	51659.45423	300.000	903.000	7.877	0.000	0.012
16.425	0.013	1659.95923	3.018	903.000	11	0.00000000	51659.45786	300.000	903.000	6.923	0.000	0.012
16.432	0.009	1659.96287	3.730	903.000	11	0.00000000	51659.46149	300.000	903.000	8.555	0.000	0.008
16.531	0.009	1660.91473	2.836	3822.000	11	0.00000000	51660.41157	600.000	3822.000	6.505	0.000	0.008
16.547	0.005	1661.05428	3.279	2021.000	11	0.00000000	51660.55111	600.000	2021.000	7.520	0.000	0.004
16.538	0.004	1661.93452	2.726	1082.000	11	0.00000000	51661.43304	300.000	1082.000	6.253	0.000	0.003
0.000	0.000	1662.05551	0.200	1861.000	0	0.00000000	51661.55229	600.000	1861.000	0.000	0.000	0.000
16.536	0.005	1661.90905	2.627	935.000	11	0.00000000	51661.40758	300.000	935.000	6.025	0.000	0.004
16.541	0.004	1661.96549	2.758	954.000	11	0.00000000	51661.46402	300.000	954.000	6.325	0.000	0.004
0.000	0.000	1662.02065	0.200	2487.000	0	0.00000000	51661.51744	600.000	2487.000	0.000	0.000	0.000
16.197	0.004	1663.97674	3.404	986.000	11	0.00000000	51663.47516	300.000	986.000	7.808	0.000	0.004
0.000	0.000	1664.02413	0.200	1050.000	0	0.00000000	51663.52256	300.000	1050.000	0.000	0.000	0.000

I Mag	Err	PLDate	Seeing	BackGr	Typ	Epoch	MJD_OBS	ExpTime	Sky	FWHM	AirMass	ErrDop
14.484	0.004	1644.01783	2.513	1746.000	11	0.00000000	51643.51721	300.000	1746.000	5.763	0.000	0.004
14.486	0.004	1644.03663	2.909	1727.000	11	0.00000000	51643.53602	300.000	1727.000	6.671	0.000	0.004
14.530	0.005	1655.98336	3.276	2615.000	11	0.00000000	51655.48218	300.000	2615.000	7.513	0.000	0.004
14.551	0.005	1656.03266	3.588	2615.000	11	0.00000000	51655.53148	300.000	2615.000	8.230	0.000	0.004
14.526	0.005	1655.99964	3.007	3279.000	11	0.00000000	51655.49846	300.000	3279.000	6.897	0.000	0.004
14.552	0.005	1656.09005	3.025	2915.000	11	0.00000000	51655.58887	300.000	2915.000	6.938	0.000	0.004
14.791	0.006	1659.01766	2.179	6805.000	11	0.00000000	51658.51575	400.000	6805.000	4.998	0.000	0.006
14.789	0.004	1659.04071	2.763	11155.000	11	0.00000000	51658.53764	600.000	11155.000	6.337	0.000	0.004
14.790	0.005	1659.05966	2.726	2864.000	11	0.00000000	51658.55833	300.000	2864.000	6.252	0.000	0.004
14.775	0.005	1659.07949	2.483	3011.000	11	0.00000000	51658.57816	300.000	3011.000	5.694	0.000	0.004
14.790	0.005	1659.09985	2.507	4148.000	11	0.00000000	51658.59852	300.000	4148.000	5.750	0.000	0.004
14.783	0.004	1659.11543	3.035	3209.000	11	0.00000000	51658.61410	300.000	3209.000	6.960	0.000	0.004
14.788	0.004	1659.87819	2.320	1938.000	11	0.00000000	51659.37682	300.000	1938.000	5.320	0.000	0.004
14.783	0.004	1659.89628	2.615	2040.000	11	0.00000000	51659.39491	300.000	2040.000	5.998	0.000	0.004
14.802	0.013	1659.91390	2.722	2072.000	11	0.00000000	51659.41252	300.000	2072.000	6.244	0.000	0.012
14.795	0.008	1660.01249	2.253	1925.000	11	0.00000000	51659.51111	300.000	1925.000	5.167	0.000	0.007
14.812	0.009	1659.93158	3.199	2072.000	11	0.00000000	51659.43021	300.000	2072.000	7.338	0.000	0.008
14.799	0.009	1659.99126	2.119	1842.000	11	0.00000000	51659.48988	300.000	1842.000	4.861	0.000	0.008
14.809	0.025	1660.03286	1.706	2174.000	11	0.00000000	51659.53148	300.000	2174.000	3.913	0.000	0.023
14.801	0.005	1660.05042	2.588	2436.000	11	0.00000000	51659.54904	300.000	2436.000	5.936	0.000	0.004
14.894	0.009	1660.92604	2.490	6492.000	11	0.00000000	51660.42288	600.000	6492.000	5.711	0.000	0.008
14.907	0.009	1660.93315	2.441	6064.000	11	0.00000000	51660.42999	600.000	6064.000	5.599	0.000	0.008
0.000	0.000	1660.94026	0.200	0.200	0	0.00000000	51660.43710	600.000	0.000	0.000	0.000	0.000
14.903	0.005	1660.94737	2.635	4793.000	11	0.00000000	51660.44421	600.000	4793.000	6.044	0.000	0.004
14.901	0.005	1660.95447	2.616	4416.000	11	0.00000000	51660.45131	600.000	4416.000	6.000	0.000	0.004
14.895	0.005	1660.96744	2.435	4365.000	11	0.00000000	51660.46428	600.000	4365.000	5.586	0.000	0.004
14.895	0.004	1660.97021	2.586	4065.000	11	0.00000000	51660.47139	600.000	4065.000	5.931	0.000	0.004
14.902	0.005	1660.97733	2.473	4263.000	11	0.00000000	51660.47851	600.000	4263.000	5.671	0.000	0.004
14.891	0.004	1660.98443	2.365	3867.000	11	0.00000000	51660.48561	600.000	3867.000	5.424	0.000	0.004
0.000	0.000	1661.06239	0.200	0.200	0	0.00000000	51660.55922	600.000	0.000	0.000	0.000	0.000
0.000	0.000	1661.06951	0.200	4218.000	0	0.00000000	51660.56634	600.000	4218.000	0.000	0.000	0.000
0.000	0.000	1661.09103	0.200	5253.000	0	0.00000000	51660.58786	600.000	5253.000	0.000	0.000	0.000
14.903	0.004	1661.91743	2.546	1989.000	11	0.00000000	51661.41596	300.000	1989.000	5.840	0.000	0.004
14.896	0.004	1661.98113	2.749	1823.000	11	0.00000000	51661.47965	300.000	1823.000	6.304	0.000	0.004
14.892	0.004	1661.94304	2.753	1957.000	11	0.00000000	51661.44156	300.000	1957.000	6.314	0.000	0.004
14.901	0.004	1661.98841	2.836	1823.000	11	0.00000000	51661.48693	300.000	1823.000	6.505	0.000	0.004

```
14.900 0.005 1661.99204 2.537 1938.000 11 0.00000000 51661.49057 300.000 1938.000 5.819 0.000 0.004
14.899 0.004 1661.97020 2.547 1938.000 11 0.00000000 51661.46873 300.000 1938.000 5.841 0.000 0.004
14.903 0.004 1661.99931 2.858 1989.000 11 0.00000000 51661.49784 300.000 1989.000 6.555 0.000 0.004
14.898 0.004 1661.97385 2.635 1906.000 11 0.00000000 51661.47237 300.000 1906.000 6.044 0.000 0.004
14.897 0.004 1661.97748 2.624 1893.000 11 0.00000000 51661.47601 300.000 1893.000 6.019 0.000 0.004
14.899 0.004 1661.98477 2.878 1874.000 11 0.00000000 51661.48330 300.000 1874.000 6.602 0.000 0.004
14.894 0.004 1661.99568 2.989 1989.000 11 0.00000000 51661.49420 300.000 1989.000 6.856 0.000 0.004
 0.000 0.000 1662.02928 0.200 3969.000  0 0.00000000 51661.52606 600.000 3969.000 0.000 0.000 0.000
 0.000 0.000 1662.07000 0.200 3458.000  0 0.00000000 51661.56678 600.000 3458.000 0.000 0.000 0.000
14.620 0.004 1663.98182 3.686 2123.000 11 0.00000000 51663.48024 300.000 2123.000 8.454 0.000 0.004
 0.000 0.000 1663.98545 0.200 2174.000  0 0.00000000 51663.48388 300.000 2174.000 0.000 0.000 0.000
14.610 0.004 1663.98909 3.867 2136.000 11 0.00000000 51663.48751 300.000 2136.000 8.869 0.000 0.004
 0.000 0.000 1663.99273 0.200 2123.000  0 0.00000000 51663.49116 300.000 2123.000 0.000 0.000 0.000
 0.000 0.000 1663.99638 0.200 2155.000  0 0.00000000 51663.49480 300.000 2155.000 0.000 0.000 0.000
 0.000 0.000 1664.02805 0.200 32764.000 0 0.00000000 51663.52647 300.000 32764.000 0.000 0.000 0.000
14.558 0.005 1656.06634 2.824 2768.000 11 0.00000000 51655.56515 300.000 2768.000 6.478 0.000 0.004
14.620 0.004 1663.98182 3.686 2123.000 11 0.00000000 51663.48024 300.000 2123.000 8.454 0.000 0.004
 0.000 0.000 1663.98545 0.200 2174.000  0 0.00000000 51663.48388 300.000 2174.000 0.000 0.000 0.000
14.610 0.004 1663.98909 3.867 2136.000 11 0.00000000 51663.48751 300.000 2136.000 8.869 0.000 0.004
 0.000 0.000 1663.99273 0.200 2123.000  0 0.00000000 51663.49116 300.000 2123.000 0.000 0.000 0.000
 0.000 0.000 1663.99638 0.200 2155.000  0 0.00000000 51663.49480 300.000 2155.000 0.000 0.000 0.000
 0.000 0.000 1664.02805 0.200 32764.000 0 0.00000000 51663.52647 300.000 32764.000 0.000 0.000 0.000
```

B.2 78.6338.24

```
#------------------------- MACHO Project -------------------------
# Star 78.6338.24                 05:19:26.825 -69:51:52.45 (J2000.0)
#-----------------------------------------------------------------
# Creation date (JD-2.449e+06): 2379.3748            1434 observations
# Calibration: standard
# A tran of 4 indicates that the transformation from MACHO bands made
# use of both r and v values and their errors.
#-----------------------------------------------------------------
# HJD-2.449e+06     r       err_r        v       err_v     obsid  tran
#    (days)       (mag)     (mag)      (mag)     (mag)
#-----------------------------------------------------------------
  -113.7452     15.212    0.015     15.539    0.015      1167     4
  -111.8477     15.313    0.017     15.679    0.017      1179     4
  -110.7929     15.314    0.016     15.694    0.016      1201     4
  -106.7626     15.497    0.017     15.876    0.017      1224     4
  -104.7868     15.640    0.018     16.023    0.019      1237     4
  -103.8180     15.730    0.015     16.113    0.016      1259     4
  -102.7591     15.746    0.017     16.087    0.017      1283     4
   -97.7223     15.260    0.015     15.577    0.015      1300     4
   -82.8345     15.506    0.016     15.817    0.016      1437     4
   -80.8048     15.181    0.015     15.472    0.015      1505     4
   -75.7936     15.340    0.015     15.699    0.015      1584     4
   -66.7498     15.750    0.027     16.081    0.024      1869     4
   -59.8500     15.298    0.016     15.657    0.016      2041     4
   -57.8260     15.334    0.016     15.723    0.016      2085     4
   -50.8636     15.766    0.015     16.118    0.016      2139     4
   -34.8635     15.593    0.018     15.977    0.019      2180     4
   -33.8900     15.672    0.017     16.041    0.018      2227     4
   -33.7845     15.675    0.016     16.029    0.016      2239     4
   -32.9101     15.695    0.017     16.057    0.018      2270     4
   -32.7732     15.696    0.019     16.038    0.019      2299     4
   -31.7713     15.686    0.016     16.005    0.016      2309     4
   -24.9835     15.297    0.016     15.652    0.016      2317     4
```

-14.8617	15.706	0.018	16.060	0.018	2355	4
-14.0045	15.706	0.016	16.021	0.016	2373	4
-13.8854	15.681	0.015	16.011	0.016	2398	4
-13.8394	15.609	0.016	15.952	0.016	2405	4
-13.7707	15.628	0.017	15.964	0.016	2411	4
-12.0212	15.399	0.015	15.710	0.015	2414	4
-11.8934	15.387	0.016	15.698	0.016	2439	4
-11.8430	15.376	0.015	15.667	0.015	2445	4
-11.0293	15.244	0.016	15.539	0.016	2464	4
-10.8815	15.245	0.016	15.533	0.016	2493	4
-10.8380	15.221	0.016	15.515	0.016	2498	4
-10.0062	15.170	0.016	15.485	0.016	2517	4
-3.9959	15.428	0.017	15.819	0.018	2547	4
-3.0588	15.473	0.016	15.878	0.016	2552	4
-2.9449	15.494	0.016	15.898	0.016	2576	4
-1.0569	15.630	0.016	16.026	0.016	2613	4
-0.9470	15.647	0.016	16.036	0.016	2636	4
-0.8240	15.653	0.016	16.040	0.017	2659	4
0.9568	15.812	0.017	16.182	0.017	2681	4
1.1363	15.806	0.022	16.177	0.024	2716	4
1.9462	15.863	0.016	16.227	0.016	2731	4
2.9438	15.853	0.016	16.205	0.016	2793	4
3.9823	15.712	0.022	16.058	0.023	2812	4
4.9360	15.521	0.015	15.866	0.015	2841	4
6.9528	15.216	0.015	15.518	0.015	2848	4
7.0520	15.219	0.015	15.524	0.015	2869	4
7.1368	15.227	0.016	15.515	0.016	2883	4
7.9471	15.232	0.017	15.559	0.017	2908	4
8.1145	15.256	0.015	15.573	0.016	2932	4
11.1167	15.303	0.018	15.655	0.018	2963	4
12.1159	15.331	0.019	15.694	0.019	2991	4
15.1215	15.451	0.018	15.828	0.018	2996	4
16.9447	15.664	0.017	16.085	0.017	3086	4
19.2067	16.003	0.017	16.437	0.018	3189	4
21.0328	15.999	0.017	16.432	0.018	3199	4
21.1845	15.939	0.018	16.353	0.017	3229	4
21.2153	15.964	0.019	16.385	0.019	3234	4
25.9727	15.555	0.016	15.961	0.016	3331	4
26.1876	15.537	0.017	15.954	0.017	3364	4
29.9421	15.570	0.016	16.031	0.016	3373	4
31.9632	15.472	0.017	15.877	0.017	3396	4
32.9389	15.517	0.016	15.927	0.017	3402	4
33.0562	15.528	0.018	15.924	0.018	3424	4
36.0668	15.753	0.016	16.120	0.016	3492	4
37.1451	15.804	0.019	16.134	0.019	3502	4
41.1867	15.351	0.019	15.640	0.018	3609	4
42.1279	15.299	0.024	15.603	0.024	3616	4
42.9436	15.242	0.015	15.546	0.016	3620	4
43.9411	15.213	0.015	15.556	0.015	3684	4
44.0426	15.228	0.016	15.559	0.016	3702	4
44.1560	15.229	0.015	15.567	0.015	3723	4
45.1253	15.212	0.019	15.575	0.019	3767	4

45.2133	15.227	0.019	15.584	0.019	3784	4
45.9255	15.240	0.015	15.610	0.015	3800	4
46.0314	15.256	0.016	15.622	0.016	3819	4
46.1591	15.257	0.016	15.607	0.016	3841	4
48.9215	15.363	0.016	15.762	0.016	3894	4
49.0250	15.377	0.016	15.769	0.016	3913	4
49.1552	15.380	0.017	15.759	0.017	3938	4
49.9212	15.436	0.016	15.826	0.016	3961	4
50.0629	15.471	0.016	15.832	0.016	3985	4
50.2065	15.477	0.018	15.869	0.018	4007	4
51.9177	15.616	0.016	16.014	0.017	4051	4
54.0274	15.769	0.017	16.125	0.018	4064	4
54.1509	15.769	0.021	16.096	0.023	4087	4
56.1539	15.722	0.018	16.050	0.019	4098	4
58.9089	15.208	0.015	15.507	0.015	4119	4
59.9190	15.198	0.015	15.509	0.015	4122	4
60.9021	15.225	0.015	15.565	0.015	4163	4
61.1459	15.239	0.016	15.567	0.016	4186	4
61.9047	15.250	0.015	15.603	0.015	4204	4
62.0852	15.261	0.016	15.611	0.016	4226	4
63.0136	15.287	0.016	15.645	0.016	4271	4
65.0019	15.373	0.015	15.758	0.016	4273	4
65.1194	15.369	0.016	15.767	0.016	4296	4
65.9971	15.422	0.015	15.822	0.015	4335	4
66.1224	15.430	0.015	15.828	0.016	4360	4
68.0386	15.508	0.016	15.904	0.017	4444	4
68.9590	15.727	0.015	15.990	0.015	4471	4
69.0610	15.598	0.016	15.975	0.016	4492	4
70.0419	15.654	0.016	16.021	0.016	4547	4
70.1442	15.685	0.016	16.056	0.016	4567	4
73.8834	15.694	0.016	16.033	0.016	4581	4
75.0303	15.481	0.019	15.787	0.018	4616	4
76.1450	15.282	0.019	15.558	0.018	4656	4
76.9350	15.222	0.016	15.510	0.016	4687	4
77.0797	15.220	0.016	15.519	0.016	4713	4
77.9250	15.212	0.015	15.528	0.015	4761	4
78.0590	15.224	0.024	15.561	0.026	4786	4
79.1622	15.249	0.017	15.578	0.017	4791	4
80.9914	15.264	0.016	15.618	0.016	4831	4
81.0094	15.271	0.015	15.625	0.016	4835	4
82.9361	15.281	0.017	15.658	0.018	4888	4
82.9610	15.275	0.019	15.652	0.021	4891	4
84.0043	15.331	0.019	15.702	0.020	4978	4
84.9239	15.400	0.017	15.761	0.017	5000	4
85.9073	15.478	0.016	15.856	0.016	5013	4
86.9147	15.575	0.016	15.934	0.016	5022	4
87.0329	15.581	0.017	15.952	0.017	5045	4
88.0345	15.706	0.016	16.062	0.016	5094	4
88.9278	15.746	0.016	16.096	0.016	5109	4
89.9303	15.799	0.016	16.148	0.016	5162	4
92.9061	15.403	0.016	15.688	0.016	5245	4
93.8743	15.259	0.015	15.551	0.015	5261	4

94.8771	15.208	0.015	15.517	0.015	5288	4
97.8794	15.249	0.015	15.611	0.015	5572	4
98.0069	15.274	0.016	15.628	0.016	5594	4
98.8736	15.275	0.015	15.642	0.015	5663	4
98.9799	15.291	0.015	15.657	0.015	5686	4
99.8671	15.298	0.015	15.677	0.015	5703	4
99.9687	15.314	0.015	15.691	0.015	5725	4
100.9677	15.349	0.015	15.735	0.015	5831	4
101.8799	15.394	0.015	15.790	0.015	5869	4
101.9846	15.409	0.016	15.792	0.016	5891	4
103.8761	15.534	0.016	15.917	0.016	5896	4
103.9773	15.560	0.016	15.946	0.016	5918	4
106.9573	15.784	0.016	16.128	0.017	6023	4
107.0612	15.755	0.018	16.112	0.018	6045	4
107.8938	15.771	0.016	16.100	0.016	6062	4
108.0277	15.786	0.016	16.123	0.017	6088	4
108.8794	15.685	0.016	16.014	0.016	6125	4
111.9402	15.252	0.018	15.551	0.018	6292	4
112.8845	15.213	0.015	15.523	0.015	6376	4
114.8702	15.238	0.016	15.588	0.016	6463	4
116.0307	15.282	0.016	15.653	0.016	6541	4
117.8734	15.299	0.016	15.683	0.016	6551	4
118.8548	15.331	0.019	15.728	0.018	6640	4
120.8539	15.501	0.017	15.884	0.017	6700	4
122.8816	15.654	0.021	16.022	0.022	6854	4
123.8617	15.747	0.016	16.108	0.016	6925	4
124.8607	15.809	0.016	16.149	0.016	7026	4
125.8560	15.796	0.016	16.125	0.016	7130	4
126.8566	15.651	0.016	15.974	0.016	7246	4
127.8653	15.440	0.016	15.744	0.016	7353	4
127.9006	15.443	0.015	15.743	0.015	7361	4
128.3191	15.332	0.016	15.628	0.016	7458	4
130.8995	15.197	0.018	15.496	0.017	7462	4
131.9980	15.232	0.019	15.568	0.019	7512	4
132.9831	15.240	0.019	15.590	0.019	7523	4
133.9189	15.274	0.015	15.649	0.016	7595	4
134.8559	15.296	0.015	15.682	0.015	7655	4
135.3150	15.328	0.015	15.721	0.016	7750	4
135.8448	15.348	0.015	15.744	0.015	7755	4
138.9086	15.551	0.018	15.942	0.019	7820	4
140.8460	15.692	0.031	16.040	0.030	7835	4
141.2654	15.748	0.024	16.109	0.024	7890	4
142.2740	15.754	0.022	16.097	0.024	7952	4
143.2578	15.747	0.030	16.080	0.033	8010	4
143.8548	15.694	0.017	16.023	0.017	8032	4
144.2587	15.643	0.021	15.980	0.022	8073	4
144.8487	15.534	0.016	15.845	0.016	8094	4
145.2765	15.465	0.019	15.777	0.019	8175	4
146.8442	15.206	0.017	15.485	0.017	8248	4
152.8438	15.370	0.016	15.756	0.016	8406	4
153.2560	15.391	0.016	15.790	0.017	8493	4
153.8515	15.399	0.016	15.787	0.016	8513	4

154.8451	15.439	0.022	15.831	0.019	8564	4
154.8584	15.424	0.021	15.817	0.023	8567	4
155.8684	15.488	0.027	15.883	0.029	8589	4
156.8496	15.529	0.016	15.954	0.017	8629	4
157.8503	15.657	0.022	16.020	0.021	8704	4
162.2598	15.672	0.022	15.992	0.021	8805	4
162.8850	15.572	0.016	15.886	0.016	8825	4
163.2329	15.501	0.019	15.821	0.018	8894	4
163.8472	15.409	0.016	15.698	0.016	8918	4
164.2539	15.348	0.016	15.644	0.016	8999	4
164.8455	15.278	0.016	15.577	0.016	9019	4
165.2406	15.285	0.017	15.593	0.017	9102	4
165.8966	15.273	0.017	15.585	0.017	9126	4
166.2181	15.289	0.018	15.624	0.018	9195	4
166.9177	15.306	0.041	15.575	0.045	9221	4
168.3354	15.297	0.017	15.653	0.017	9275	4
169.3107	15.313	0.019	15.705	0.019	9279	4
169.8450	15.330	0.017	15.716	0.018	9281	4
172.2370	15.381	0.021	15.781	0.023	9338	4
172.8424	15.424	0.016	15.806	0.017	9363	4
176.8564	15.681	0.018	16.035	0.018	9387	4
179.1789	15.695	0.025	15.988	0.026	9515	4
180.2002	15.604	0.018	15.903	0.018	9544	4
180.8492	15.498	0.017	15.794	0.017	9558	4
181.1675	15.449	0.016	15.749	0.016	9626	4
181.8635	15.357	0.017	15.671	0.017	9664	4
182.3140	15.310	0.015	15.626	0.015	9739	4
184.1469	15.249	0.023	15.570	0.021	9805	4
184.8595	15.280	0.016	15.614	0.016	9839	4
186.8470	15.365	0.016	15.742	0.016	9995	4
189.1360	15.401	0.017	15.793	0.018	10145	4
189.8508	15.428	0.021	15.802	0.021	10189	4
190.1445	15.432	0.016	15.821	0.016	10234	4
195.1583	15.836	0.018	16.200	0.019	10354	4
195.3269	15.857	0.018	16.200	0.017	10390	4
196.1081	15.876	0.017	16.235	0.018	10430	4
197.1425	15.816	0.021	16.164	0.021	10503	4
197.3347	15.758	0.017	16.113	0.018	10543	4
200.1697	15.228	0.017	15.542	0.017	10574	4
201.3362	15.186	0.029	15.532	0.029	10623	4
202.1055	15.208	0.020	15.563	0.023	10638	4
202.3348	15.185	0.017	15.506	0.016	10669	4
204.1267	15.271	0.016	15.653	0.017	10711	4
204.3254	15.259	0.016	15.619	0.016	10752	4
205.1253	15.300	0.016	15.702	0.017	10810	4
209.1140	15.526	0.021	15.919	0.021	10934	4
209.3201	15.541	0.016	15.935	0.016	10967	4
210.0926	15.618	0.021	16.011	0.021	11004	4
210.3180	15.628	0.024	15.982	0.024	11050	4
211.1039	15.731	0.019	16.109	0.019	11109	4
211.3211	15.747	0.016	16.121	0.016	11153	4
212.1426	15.820	0.019	16.177	0.019	11181	4

215.2439	15.720	0.022	16.055	0.021	11251	4
216.3031	15.486	0.018	15.785	0.018	11335	4
217.0699	15.328	0.022	15.625	0.021	11366	4
217.3018	15.285	0.016	15.569	0.016	11411	4
218.0800	15.243	0.016	15.551	0.016	11468	4
219.0698	15.264	0.016	15.590	0.016	11537	4
219.3089	15.276	0.016	15.588	0.017	11575	4
221.2872	15.345	0.017	15.720	0.017	11666	4
221.3054	15.350	0.019	15.687	0.019	11668	4
222.0668	15.396	0.018	15.773	0.019	11710	4
224.0539	15.476	0.016	15.860	0.016	11871	4
225.0321	15.517	0.017	15.903	0.018	11935	4
226.2528	15.584	0.016	15.983	0.016	11989	4
227.2854	15.755	0.062	16.154	0.078	12015	4
234.0266	15.566	0.022	15.880	0.024	12071	4
253.0205	15.281	0.016	15.577	0.016	12122	4
253.9631	15.240	0.016	15.560	0.016	12164	4
255.2903	15.187	0.015	15.505	0.016	12210	4
256.2712	15.226	0.016	15.562	0.016	12287	4
257.0131	15.269	0.015	15.633	0.016	12315	4
257.2652	15.271	0.015	15.628	0.015	12362	4
258.0086	15.286	0.015	15.679	0.016	12390	4
258.2629	15.302	0.015	15.677	0.015	12433	4
258.9537	15.339	0.016	15.769	0.017	12450	4
259.2722	15.351	0.019	15.759	0.020	12471	4
260.0174	15.387	0.018	15.795	0.019	12476	4
260.1697	15.378	0.015	15.779	0.016	12481	4
260.9841	15.444	0.016	15.846	0.017	12503	4
265.1823	15.765	0.020	16.127	0.021	12535	4
265.9678	15.839	0.017	16.191	0.017	12568	4
266.2627	15.844	0.017	16.178	0.017	12588	4
268.0602	15.773	0.018	16.091	0.017	12641	4
268.2629	15.700	0.018	16.016	0.018	12673	4
269.2552	15.512	0.016	15.821	0.016	12734	4
270.0636	15.385	0.018	15.676	0.018	12741	4
271.2683	15.190	0.017	15.471	0.017	12827	4
273.0566	15.213	0.015	15.531	0.015	12838	4
273.9405	15.230	0.016	15.577	0.016	12860	4
274.2516	15.242	0.015	15.575	0.015	12904	4
274.9330	15.245	0.015	15.604	0.015	12911	4
278.0981	15.354	0.016	15.747	0.016	12942	4
280.1883	15.511	0.016	15.899	0.017	12967	4
280.9236	15.578	0.028	15.999	0.031	12983	4
281.1384	15.599	0.018	15.970	0.019	12984	4
283.9156	15.788	0.016	16.138	0.017	13057	4
284.2397	15.783	0.016	16.130	0.016	13122	4
286.1183	15.656	0.017	15.961	0.017	13132	4
286.9331	15.498	0.017	15.803	0.017	13161	4
287.2466	15.404	0.018	15.696	0.019	13199	4
288.0120	15.285	0.015	15.568	0.015	13213	4
288.2464	15.257	0.015	15.526	0.015	13249	4
290.0164	15.220	0.016	15.536	0.016	13259	4

290.2369	15.234	0.016	15.550	0.016	13300	4
291.1766	15.247	0.017	15.636	0.018	13307	4
292.2217	15.261	0.016	15.623	0.016	13373	4
301.9377	15.780	0.017	16.121	0.017	13383	4
303.0485	15.728	0.016	16.052	0.016	13396	4
303.2176	15.730	0.016	16.043	0.016	13422	4
307.9837	15.253	0.015	15.591	0.015	13447	4
309.9393	15.246	0.015	15.599	0.015	13504	4
311.9962	15.260	0.016	15.619	0.016	13569	4
312.2061	15.283	0.016	15.650	0.016	13607	4
313.0012	15.287	0.016	15.670	0.016	13624	4
313.2016	15.310	0.016	15.684	0.016	13662	4
319.2155	15.743	0.019	16.067	0.019	13884	4
372.9496	15.690	0.015	16.033	0.016	13903	4
373.2107	15.672	0.017	15.999	0.017	13936	4
375.0687	15.438	0.017	15.739	0.017	13949	4
375.9581	15.344	0.016	15.649	0.016	13974	4
376.2434	15.326	0.016	15.621	0.016	14029	4
377.2225	15.300	0.016	15.599	0.016	14080	4
378.2252	15.303	0.017	15.619	0.017	14123	4
379.2252	15.304	0.018	15.639	0.019	14179	4
379.2301	15.300	0.017	15.646	0.018	14180	4
379.9493	15.316	0.019	15.699	0.021	14188	4
380.9365	15.335	0.016	15.737	0.016	14199	4
381.2501	15.343	0.016	15.728	0.018	14247	4
383.2367	15.377	0.017	15.785	0.018	14283	4
385.1636	15.481	0.016	15.872	0.016	14308	4
387.2566	15.632	0.018	16.020	0.019	14393	4
388.2630	15.715	0.033	16.013	0.037	14396	4
389.0718	15.732	0.016	16.064	0.017	14399	4
390.2023	15.764	0.016	16.088	0.016	14419	4
391.2396	15.663	0.019	15.982	0.018	14476	4
393.2311	15.326	0.017	15.593	0.017	14487	4
398.9256	15.347	0.015	15.742	0.015	14509	4
399.9302	15.373	0.016	15.763	0.016	14565	4
400.2318	15.388	0.017	15.766	0.017	14620	4
405.0032	15.696	0.016	16.070	0.016	14642	4
405.9826	15.787	0.017	16.179	0.017	14678	4
409.1094	15.751	0.018	16.054	0.021	14780	4
412.1531	15.237	0.020	15.526	0.020	14864	4
412.9700	15.271	0.016	15.569	0.016	14920	4
414.2287	15.276	0.018	15.580	0.018	14955	4
414.9180	15.270	0.017	15.589	0.017	14969	4
414.9764	15.294	0.015	15.630	0.016	14977	4
415.9143	15.327	0.015	15.723	0.015	14991	4
416.2297	15.335	0.019	15.673	0.020	15036	4
425.2162	15.811	0.023	16.140	0.022	15216	4
425.9955	15.768	0.017	16.091	0.017	15238	4
426.1947	15.740	0.016	16.078	0.016	15268	4
426.9095	15.635	0.016	15.965	0.016	15294	4
427.1810	15.613	0.016	15.925	0.016	15343	4
429.1734	15.280	0.017	15.559	0.017	15411	4

429.9338	15.262	0.015	15.584	0.015	15448	4
435.1616	15.401	0.017	15.786	0.017	15586	4
439.0047	15.905	0.016	16.388	0.018	15723	4
439.9004	16.009	0.016	16.530	0.018	15742	4
442.1149	16.180	0.021	16.667	0.026	15771	4
443.0994	16.202	0.018	16.657	0.020	15811	4
445.0621	15.833	0.023	16.240	0.024	15837	4
446.0338	15.696	0.017	16.054	0.016	15862	4
446.9911	15.536	0.016	15.868	0.016	15906	4
448.0511	15.427	0.015	15.789	0.015	15965	4
448.8830	15.361	0.016	15.720	0.016	16011	4
449.9663	15.308	0.016	15.667	0.016	16105	4
450.8888	15.293	0.015	15.674	0.015	16173	4
450.9599	15.280	0.016	15.660	0.016	16184	4
451.1465	15.302	0.016	15.676	0.016	16218	4
451.9547	15.296	0.016	15.675	0.016	16255	4
452.9999	15.338	0.016	15.723	0.016	16326	4
455.8771	15.522	0.017	15.924	0.017	16381	4
457.0789	15.668	0.016	16.052	0.016	16408	4
457.9372	15.722	0.015	16.114	0.015	16452	4
458.8993	15.807	0.017	16.176	0.017	16471	4
459.1149	15.822	0.019	16.179	0.021	16501	4
460.0990	15.854	0.028	16.187	0.028	16531	4
460.9328	15.833	0.016	16.177	0.016	16569	4
461.1190	15.835	0.018	16.168	0.019	16608	4
461.9462	15.749	0.016	16.116	0.016	16641	4
462.9202	15.561	0.016	15.873	0.016	16715	4
463.9204	15.338	0.015	15.626	0.016	16740	4
464.1067	15.327	0.016	15.609	0.016	16766	4
464.9254	15.237	0.015	15.511	0.015	16810	4
465.9232	15.249	0.015	15.566	0.016	16839	4
466.1033	15.259	0.016	15.577	0.016	16867	4
466.9287	15.259	0.015	15.596	0.015	16913	4
467.9745	15.279	0.016	15.625	0.017	16984	4
470.0364	15.352	0.019	15.718	0.020	17106	4
471.0300	15.397	0.018	15.774	0.018	17160	4
471.9210	15.423	0.015	15.812	0.015	17191	4
472.9899	15.486	0.016	15.883	0.016	17210	4
474.0088	15.563	0.016	15.940	0.016	17288	4
478.9269	15.717	0.015	16.055	0.015	17443	4
479.8659	15.608	0.016	15.934	0.016	17519	4
481.9780	15.275	0.016	15.554	0.016	17604	4
483.9461	15.234	0.016	15.559	0.016	17636	4
484.8555	15.278	0.019	15.616	0.019	17720	4
485.3142	15.286	0.016	15.648	0.016	17798	4
485.9119	15.313	0.016	15.671	0.016	17808	4
486.3207	15.328	0.018	15.708	0.018	17880	4
486.9078	15.319	0.017	15.690	0.018	17882	4
487.3120	15.337	0.021	15.717	0.021	17963	4
487.9377	15.350	0.017	15.741	0.017	17974	4
488.9249	15.411	0.016	15.799	0.016	18057	4
489.3001	15.424	0.022	15.817	0.021	18125	4

489.8864	15.453	0.016	15.833	0.017	18132	4
492.9342	15.666	0.021	16.023	0.021	18224	4
495.2860	15.825	0.020	16.187	0.021	18345	4
496.8927	15.759	0.022	16.084	0.023	18363	4
498.9101	15.418	0.019	15.718	0.019	18461	4
501.3074	15.233	0.016	15.554	0.016	18569	4
505.9179	15.248	0.016	15.625	0.016	18727	4
509.8945	15.483	0.016	15.874	0.016	18812	4
512.8893	15.745	0.020	16.080	0.019	18925	4
513.2496	15.744	0.022	16.080	0.021	18998	4
513.8788	15.785	0.016	16.123	0.016	19022	4
516.8793	15.337	0.018	15.642	0.018	19170	4
519.8424	15.211	0.017	15.544	0.018	19359	4
522.3068	15.267	0.021	15.623	0.021	19469	4
523.8933	15.315	0.028	15.711	0.031	19511	4
525.8827	15.412	0.016	15.816	0.017	19525	4
526.2628	15.435	0.018	15.830	0.019	19556	4
526.8480	15.479	0.017	15.858	0.017	19572	4
530.8699	15.758	0.017	16.111	0.017	19636	4
532.2176	15.752	0.016	16.091	0.017	19742	4
532.8403	15.669	0.016	16.002	0.016	19764	4
533.8457	15.479	0.026	15.766	0.024	19828	4
534.8470	15.267	0.021	15.563	0.020	19893	4
535.8450	15.177	0.018	15.475	0.019	19967	4
536.8471	15.177	0.016	15.482	0.016	19988	4
537.8468	15.182	0.020	15.532	0.019	20053	4
538.8605	15.242	0.017	15.568	0.017	20154	4
539.8494	15.267	0.018	15.624	0.017	20247	4
540.8957	15.325	0.017	15.681	0.018	20340	4
541.8939	15.350	0.015	15.730	0.016	20422	4
542.8947	15.404	0.016	15.797	0.016	20485	4
543.3186	15.420	0.021	15.838	0.022	20560	4
543.3339	15.402	0.021	15.817	0.021	20562	4
546.1669	15.692	0.019	16.062	0.019	20645	4
547.3033	15.788	0.017	16.147	0.018	20734	4
549.8737	15.724	0.020	16.048	0.021	20863	4
550.2996	15.637	0.019	15.949	0.018	20946	4
550.8707	15.538	0.016	15.853	0.016	20956	4
551.2942	15.430	0.016	15.717	0.016	21024	4
552.8615	15.232	0.017	15.512	0.017	21045	4
553.3197	15.221	0.015	15.525	0.015	21128	4
554.1241	15.228	0.018	15.555	0.019	21154	4
554.8582	15.242	0.024	15.536	0.026	21191	4
555.3134	15.225	0.016	15.554	0.016	21243	4
555.8563	15.239	0.018	15.560	0.019	21248	4
556.3029	15.267	0.017	15.611	0.018	21309	4
556.8511	15.279	0.017	15.640	0.017	21318	4
557.3043	15.299	0.016	15.661	0.017	21402	4
558.2494	15.331	0.018	15.723	0.018	21454	4
560.1304	15.397	0.016	15.807	0.017	21589	4
560.3122	15.402	0.015	15.793	0.016	21619	4
562.1741	15.552	0.019	15.901	0.019	21763	4

563.1910	15.618	0.016	15.998	0.016	21824	4
563.3347	15.633	0.016	16.009	0.016	21847	4
565.3319	15.744	0.017	16.107	0.017	21849	4
567.1123	15.721	0.021	16.033	0.021	21898	4
567.3038	15.674	0.016	16.001	0.016	21936	4
568.1444	15.557	0.016	15.866	0.016	21995	4
568.3098	15.530	0.016	15.841	0.016	22025	4
569.3076	15.374	0.018	15.659	0.018	22099	4
570.1473	15.295	0.016	15.585	0.016	22152	4
570.3088	15.288	0.015	15.586	0.016	22183	4
571.3270	15.259	0.017	15.558	0.016	22200	4
572.1169	15.275	0.016	15.596	0.016	22243	4
572.3120	15.259	0.017	15.586	0.017	22277	4
573.1250	15.303	0.020	15.633	0.019	22326	4
573.3071	15.278	0.016	15.625	0.016	22361	4
574.1147	15.315	0.016	15.680	0.016	22408	4
575.1174	15.325	0.015	15.700	0.016	22493	4
575.3047	15.318	0.015	15.708	0.015	22526	4
576.3276	15.336	0.016	15.727	0.017	22532	4
577.1360	15.357	0.020	15.729	0.021	22568	4
578.2921	15.400	0.018	15.790	0.018	22645	4
579.2915	15.459	0.015	15.857	0.016	22729	4
580.1184	15.530	0.016	15.914	0.016	22779	4
580.2875	15.546	0.015	15.935	0.015	22816	4
581.0714	15.629	0.016	16.047	0.016	22854	4
581.2808	15.636	0.016	16.020	0.016	22895	4
583.1669	15.739	0.017	16.089	0.018	22970	4
584.3127	15.721	0.017	16.046	0.017	22998	4
585.3201	15.616	0.016	15.937	0.016	23000	4
586.1325	15.511	0.018	15.819	0.019	23044	4
586.2962	15.469	0.020	15.758	0.021	23071	4
587.1088	15.380	0.020	15.677	0.021	23116	4
587.2869	15.326	0.018	15.605	0.019	23149	4
588.1222	15.262	0.016	15.566	0.018	23184	4
589.1441	15.249	0.016	15.563	0.016	23253	4
589.2916	15.251	0.016	15.568	0.016	23278	4
590.0748	15.266	0.015	15.614	0.016	23305	4
591.0827	15.306	0.015	15.664	0.016	23357	4
591.2661	15.303	0.015	15.657	0.015	23383	4
592.2876	15.343	0.016	15.714	0.016	23465	4
593.0728	15.379	0.016	15.756	0.016	23504	4
596.1336	15.471	0.017	15.852	0.017	23625	4
596.2860	15.485	0.018	15.856	0.018	23645	4
597.1052	15.515	0.016	15.910	0.016	23684	4
597.2817	15.529	0.015	15.919	0.015	23711	4
598.1715	15.584	0.015	15.976	0.016	23755	4
598.2721	15.595	0.015	15.975	0.015	23770	4
599.1353	15.658	0.016	16.037	0.016	23815	4
599.2702	15.673	0.018	16.019	0.018	23838	4
600.1372	15.729	0.016	16.091	0.017	23880	4
602.2127	15.693	0.020	16.037	0.021	23905	4
603.0896	15.622	0.016	15.949	0.016	23960	4

605.1118	15.265	0.015	15.560	0.015	24012	4
605.2762	15.247	0.015	15.531	0.015	24042	4
606.0931	15.202	0.015	15.494	0.015	24087	4
606.2743	15.213	0.015	15.504	0.015	24119	4
607.1034	15.229	0.015	15.546	0.015	24166	4
607.2562	15.236	0.015	15.549	0.015	24192	4
607.9787	15.283	0.017	15.630	0.018	24214	4
608.2652	15.274	0.017	15.611	0.017	24257	4
609.2638	15.300	0.016	15.648	0.016	24312	4
610.2665	15.324	0.019	15.683	0.019	24367	4
611.0907	15.356	0.018	15.724	0.019	24412	4
611.2660	15.345	0.016	15.725	0.016	24447	4
612.0917	15.369	0.021	15.733	0.022	24491	4
614.2656	15.471	0.017	15.857	0.018	24580	4
619.0698	15.842	0.017	16.178	0.018	24845	4
619.2660	15.821	0.017	16.146	0.018	24882	4
620.2620	15.748	0.020	16.095	0.021	24957	4
621.0935	15.648	0.018	15.963	0.018	24993	4
621.2624	15.610	0.016	15.934	0.016	25019	4
622.1910	15.393	0.019	15.690	0.019	25026	4
623.1027	15.267	0.017	15.552	0.017	25038	4
624.1009	15.277	0.016	15.592	0.016	25083	4
626.0807	15.330	0.016	15.673	0.016	25175	4
628.0832	15.364	0.016	15.743	0.016	25229	4
629.1383	15.394	0.016	15.778	0.016	25280	4
629.2816	15.392	0.016	15.758	0.017	25302	4
630.2530	15.426	0.016	15.800	0.016	25333	4
631.0653	15.466	0.015	15.851	0.015	25366	4
631.2522	15.475	0.015	15.852	0.015	25405	4
634.2558	15.676	0.016	16.034	0.016	25475	4
635.2386	15.721	0.016	16.063	0.016	25519	4
636.0693	15.735	0.017	16.074	0.017	25549	4
636.2529	15.725	0.018	16.058	0.018	25585	4
637.0410	15.703	0.018	16.026	0.018	25615	4
638.1229	15.613	0.016	15.939	0.016	25647	4
638.2442	15.608	0.016	15.912	0.016	25665	4
640.0450	15.385	0.016	15.684	0.016	25727	4
640.2560	15.359	0.015	15.651	0.015	25765	4
641.0796	15.326	0.016	15.632	0.016	25791	4
641.2341	15.294	0.015	15.597	0.015	25820	4
642.1907	15.321	0.015	15.653	0.015	25852	4
642.2402	15.320	0.015	15.644	0.015	25860	4
642.9884	15.363	0.016	15.703	0.016	25876	4
643.0511	15.361	0.016	15.705	0.016	25888	4
646.2505	15.494	0.016	15.877	0.016	25947	4
647.1255	15.506	0.016	15.897	0.017	25962	4
648.0370	15.542	0.016	15.936	0.016	25975	4
648.9803	15.588	0.016	15.967	0.016	25998	4
649.2255	15.593	0.015	15.969	0.015	26047	4
649.9756	15.654	0.016	16.037	0.016	26061	4
650.2247	15.680	0.015	16.047	0.015	26111	4
652.1004	15.824	0.016	16.187	0.016	26141	4

654.0408	15.941	0.026	16.291	0.028	26168	4
654.2435	15.888	0.016	16.224	0.016	26191	4
655.0071	15.845	0.019	16.170	0.019	26208	4
661.1256	15.220	0.016	15.572	0.016	26238	4
666.0135	15.458	0.016	15.846	0.017	26282	4
666.2062	15.475	0.015	15.857	0.015	26311	4
666.9756	15.547	0.017	15.933	0.018	26325	4
667.2009	15.567	0.015	15.961	0.015	26369	4
668.1048	15.659	0.016	16.058	0.016	26380	4
668.2246	15.652	0.016	16.045	0.016	26403	4
668.9865	15.731	0.018	16.122	0.020	26410	4
670.9939	15.814	0.018	16.183	0.019	26422	4
671.2047	15.806	0.018	16.160	0.019	26464	4
671.9372	15.771	0.019	16.109	0.019	26474	4
672.9230	15.653	0.016	16.001	0.017	26481	4
673.9500	15.424	0.027	15.760	0.029	26502	4
675.1776	15.252	0.016	15.538	0.017	26549	4
676.9826	15.275	0.016	15.629	0.016	26569	4
681.9809	15.429	0.015	15.824	0.015	26608	4
682.1914	15.450	0.015	15.835	0.016	26650	4
682.9800	15.485	0.015	15.882	0.015	26660	4
687.9841	15.759	0.016	16.114	0.017	26675	4
688.9834	15.762	0.016	16.103	0.016	26706	4
690.0612	15.656	0.016	15.986	0.016	26744	4
692.0326	15.329	0.015	15.631	0.015	26849	4
692.0459	15.319	0.015	15.617	0.015	26852	4
693.0588	15.245	0.015	15.538	0.015	26911	4
696.0231	15.276	0.016	15.623	0.016	26976	4
697.0354	15.291	0.015	15.655	0.015	27027	4
698.0555	15.334	0.015	15.706	0.015	27090	4
699.0042	15.347	0.018	15.721	0.018	27131	4
699.1407	15.346	0.017	15.731	0.017	27133	4
700.9971	15.419	0.018	15.797	0.019	27209	4
703.0104	15.553	0.015	15.927	0.016	27256	4
704.0827	15.650	0.016	16.019	0.016	27311	4
705.0052	15.725	0.017	16.078	0.018	27343	4
706.0325	15.767	0.016	16.114	0.016	27398	4
715.9637	15.282	0.018	15.651	0.017	27430	4
718.1227	15.398	0.015	15.777	0.015	27521	4
723.9738	15.744	0.016	16.093	0.016	27545	4
727.9692	15.264	0.015	15.609	0.016	27579	4
730.1649	15.219	0.015	15.541	0.015	27672	4
731.0150	15.241	0.015	15.575	0.015	27694	4
733.1977	15.319	0.015	15.699	0.015	27742	4
738.1969	15.593	0.019	15.970	0.023	27763	4
739.1275	15.669	0.017	16.033	0.018	27779	4
742.0898	15.735	0.016	16.073	0.016	27868	4
745.1662	15.191	0.021	15.495	0.021	27949	4
746.1336	15.204	0.016	15.492	0.016	27954	4
748.0932	15.255	0.015	15.590	0.015	28057	4
749.0244	15.293	0.016	15.640	0.016	28109	4
750.2004	15.315	0.016	15.669	0.016	28170	4

751.9971	15.348	0.015	15.732	0.015	28194	4
753.1221	15.406	0.015	15.793	0.015	28277	4
755.0075	15.538	0.016	15.915	0.016	28310	4
756.1160	15.654	0.016	16.012	0.016	28363	4
757.1615	15.722	0.017	16.065	0.017	28393	4
760.0492	15.647	0.016	15.964	0.016	28409	4
761.2278	15.451	0.016	15.748	0.016	28470	4
763.0423	15.245	0.015	15.534	0.016	28500	4
765.1694	15.231	0.016	15.560	0.016	28556	4
768.0748	15.312	0.016	15.691	0.017	28621	4
769.2715	15.344	0.017	15.731	0.018	28667	4
784.9876	15.273	0.015	15.636	0.015	28675	4
787.1658	15.363	0.017	15.746	0.018	28727	4
790.9676	15.624	0.016	15.986	0.016	28961	4
792.1651	15.706	0.018	16.084	0.021	29017	4
795.9667	15.515	0.016	15.795	0.016	29097	4
799.9530	15.259	0.015	15.599	0.015	29265	4
803.1298	15.358	0.016	15.742	0.016	29486	4
804.9482	15.407	0.016	15.797	0.016	29515	4
806.1577	15.498	0.016	15.887	0.016	29590	4
806.9558	15.544	0.015	15.931	0.015	29623	4
808.1401	15.663	0.016	16.043	0.017	29699	4
808.9515	15.717	0.016	16.091	0.016	29736	4
809.9824	15.779	0.016	16.127	0.016	29813	4
810.9739	15.839	0.016	16.186	0.016	29877	4
818.0670	15.255	0.018	15.595	0.018	30018	4
819.1328	15.299	0.016	15.662	0.017	30075	4
819.9610	15.320	0.016	15.687	0.016	30118	4
826.9755	15.736	0.016	16.092	0.016	30320	4
831.9365	15.315	0.016	15.599	0.016	30530	4
833.0825	15.262	0.016	15.546	0.016	30592	4
833.9609	15.267	0.015	15.583	0.015	30641	4
835.9496	15.311	0.015	15.658	0.015	30664	4
842.9780	15.640	0.021	16.019	0.021	30761	4
844.0689	15.738	0.017	16.092	0.017	30853	4
851.9968	15.205	0.019	15.514	0.021	30911	4
856.0340	15.382	0.021	15.819	0.024	31033	4
856.9646	15.511	0.016	15.946	0.016	31091	4
858.9356	15.796	0.016	16.295	0.016	31129	4
862.8560	16.263	0.029	16.764	0.037	31240	4
862.9012	16.238	0.024	16.758	0.028	31241	4
864.9101	16.087	0.028	16.515	0.027	31258	4
866.8485	15.573	0.015	15.931	0.015	31363	4
868.3262	15.294	0.016	15.606	0.021	31397	4
868.9529	15.312	0.016	15.660	0.016	31405	4
872.9116	15.358	0.016	15.735	0.016	31496	4
874.8728	15.322	0.079	15.745	0.099	31594	4
875.8475	15.487	0.016	15.879	0.017	31601	4
880.8411	15.851	0.021	16.183	0.024	31641	4
884.3192	15.339	0.016	15.649	0.016	31752	4
885.8576	15.202	0.018	15.493	0.017	31801	4
887.8509	15.297	0.016	15.637	0.016	31919	4

889.8427	15.352	0.017	15.711	0.017	32091	4
890.8587	15.391	0.016	15.778	0.016	32203	4
891.8517	15.427	0.016	15.816	0.016	32317	4
895.8354	15.688	0.017	16.048	0.017	32480	4
900.3351	15.650	0.016	15.982	0.016	32597	4
902.3225	15.281	0.016	15.588	0.016	32727	4
902.8490	15.270	0.016	15.553	0.016	32732	4
903.8964	15.211	0.042	15.498	0.050	32785	4
906.2903	15.268	0.016	15.619	0.016	32848	4
908.2824	15.308	0.017	15.693	0.017	32947	4
913.8607	15.651	0.019	16.021	0.019	32997	4
917.3129	15.707	0.018	16.006	0.018	33071	4
926.1606	15.312	0.018	15.692	0.019	33540	4
926.2099	15.549	0.026	15.741	0.019	33543	4
930.2122	15.573	0.021	15.938	0.022	33741	4
932.2812	15.732	0.018	16.087	0.019	33846	4
937.2233	15.271	0.016	15.565	0.016	34180	4
938.2382	15.369	0.022	15.525	0.020	34285	4
939.1092	15.165	0.017	15.473	0.018	34370	4
940.1360	15.172	0.016	15.502	0.016	34491	4
941.2742	15.218	0.016	15.573	0.016	34595	4
942.1172	15.249	0.015	15.616	0.016	34669	4
943.1890	16.106	0.016	15.968	0.015	34797	4
945.2040	15.637	0.017	15.817	0.016	35007	4
947.2747	15.481	0.017	15.864	0.017	35133	4
949.2244	15.665	0.020	16.039	0.021	35311	4
950.0812	15.736	0.022	16.109	0.023	35374	4
952.1017	15.757	0.020	16.104	0.021	35469	4
953.1814	15.620	0.016	15.946	0.016	35554	4
954.0979	15.521	0.016	15.754	0.016	35615	4
955.1826	15.260	0.017	15.558	0.017	35698	4
956.2735	15.206	0.017	15.521	0.017	35778	4
958.0516	15.214	0.015	15.553	0.015	35860	4
959.3027	15.214	0.018	15.573	0.018	35956	4
962.0651	15.298	0.016	15.692	0.016	36015	4
967.1626	15.663	0.016	16.027	0.016	36213	4
968.0582	15.746	0.016	16.103	0.017	36274	4
970.0189	15.756	0.020	16.108	0.026	36326	4
971.0211	15.624	0.017	15.959	0.018	36363	4
972.2681	15.356	0.015	15.661	0.015	36437	4
973.0344	15.261	0.015	15.566	0.015	36472	4
975.0677	15.248	0.016	15.583	0.016	36574	4
977.0201	15.266	0.015	15.668	0.016	36635	4
981.0248	15.327	0.023	15.723	0.025	36680	4
987.0226	15.655	0.017	15.983	0.017	36854	4
988.0077	15.602	0.015	15.911	0.016	36927	4
995.0364	15.339	0.016	15.714	0.016	37070	4
996.0237	15.363	0.021	15.753	0.023	37126	4
997.0348	15.398	0.017	15.781	0.018	37165	4
997.0437	15.393	0.017	15.765	0.018	37167	4
997.0525	15.395	0.017	15.778	0.018	37169	4
1004.0491	15.795	0.120	16.142	0.121	37377	4

1004.0579	15.771	0.021	16.122	0.019	37379	4
1004.0668	15.773	0.023	16.101	0.021	37381	4
1005.2631	15.645	0.124	16.132	0.160	37428	4
1006.0034	15.567	0.016	15.879	0.016	37453	4
1006.0130	15.557	0.015	15.869	0.015	37455	4
1006.0219	15.557	0.015	15.883	0.016	37457	4
1007.0257	15.322	0.018	15.624	0.018	37537	4
1007.0346	15.329	0.018	15.631	0.018	37539	4
1008.1341	15.164	0.016	15.440	0.016	37601	4
1013.9826	15.370	0.016	15.753	0.016	37650	4
1013.9926	15.372	0.016	15.778	0.016	37652	4
1014.0015	15.346	0.016	15.751	0.016	37654	4
1014.2638	15.381	0.016	15.776	0.017	37711	4
1015.9875	15.449	0.020	15.858	0.021	37735	4
1020.1238	15.758	0.018	16.118	0.018	37764	4
1022.9953	15.665	0.026	15.997	0.027	37837	4
1023.0119	15.635	0.018	15.968	0.019	37840	4
1023.9639	15.457	0.021	15.755	0.020	37879	4
1029.9608	15.307	0.016	15.716	0.016	37903	4
1029.9704	15.314	0.016	15.709	0.016	37905	4
1029.9792	15.299	0.016	15.667	0.016	37907	4
1032.0157	15.374	0.019	15.755	0.019	37946	4
1033.9618	15.451	0.016	15.837	0.016	37991	4
1033.9706	15.458	0.016	15.848	0.016	37993	4
1033.9795	15.463	0.016	15.846	0.016	37995	4
1035.1508	15.549	0.016	15.926	0.017	38006	4
1036.9732	15.695	0.015	16.064	0.015	38016	4
1036.9851	15.700	0.015	16.076	0.015	38018	4
1036.9940	15.693	0.015	16.067	0.015	38020	4
1046.9806	15.330	0.016	15.694	0.016	38182	4
1046.9901	15.327	0.016	15.698	0.016	38184	4
1046.9990	15.315	0.017	15.692	0.017	38186	4
1047.9833	15.351	0.020	15.717	0.021	38232	4
1048.1226	15.325	0.019	15.718	0.019	38248	4
1048.9827	15.368	0.015	15.750	0.015	38273	4
1048.9929	15.371	0.015	15.758	0.016	38275	4
1049.0021	15.355	0.015	15.754	0.015	38277	4
1054.9975	15.722	0.015	16.093	0.016	38324	4
1058.0148	15.658	0.020	15.961	0.020	38343	4
1058.9960	15.521	0.017	15.843	0.017	38397	4
1059.0063	15.518	0.017	15.829	0.017	38399	4
1059.0155	15.528	0.017	15.830	0.017	38401	4
1059.9945	15.408	0.016	15.767	0.017	38425	4
1060.0089	15.395	0.017	15.698	0.017	38428	4
1061.9973	15.293	0.016	15.608	0.016	38440	4
1062.0064	15.299	0.016	15.609	0.016	38442	4
1062.0152	15.294	0.016	15.618	0.016	38444	4
1063.0166	15.349	0.021	15.663	0.019	38501	4
1063.0257	15.335	0.020	15.666	0.020	38503	4
1064.0013	15.358	0.016	15.712	0.016	38517	4
1067.0008	15.507	0.015	15.971	0.015	38566	4
1067.0097	15.488	0.015	15.877	0.015	38568	4

1067.0185	15.485	0.015	15.870	0.015	38570	4
1067.9985	15.514	0.016	15.906	0.016	38598	4
1068.0073	15.518	0.016	15.913	0.016	38600	4
1068.0162	15.519	0.016	15.902	0.016	38602	4
1070.0006	15.620	0.018	15.997	0.018	38619	4
1071.9729	15.783	0.016	16.152	0.016	38626	4
1072.9979	15.842	0.019	16.196	0.019	38677	4
1073.0070	15.836	0.018	16.191	0.019	38679	4
1073.0158	15.843	0.018	16.198	0.018	38681	4
1074.0181	15.899	0.018	16.250	0.018	38725	4
1074.9567	15.879	0.017	16.208	0.017	38735	4
1074.9655	15.878	0.017	16.210	0.017	38737	4
1074.9755	15.875	0.017	16.205	0.017	38739	4
1078.0191	15.296	0.015	15.607	0.015	38783	4
1079.0032	15.237	0.019	15.540	0.018	38802	4
1080.9839	15.268	0.016	15.615	0.016	38837	4
1084.1739	15.319	0.015	15.693	0.015	38843	4
1089.0187	15.670	0.015	16.050	0.015	38861	4
1092.0437	15.767	0.016	16.159	0.016	38961	4
1094.2001	15.414	0.015	15.723	0.015	39015	4
1100.1507	15.376	0.016	15.752	0.016	39047	4
1103.0375	15.462	0.022	15.856	0.023	39090	4
1108.0123	15.815	0.015	16.155	0.015	39159	4
1108.0308	15.810	0.015	16.146	0.015	39163	4
1108.9939	15.837	0.016	16.170	0.016	39219	4
1109.0028	15.840	0.016	16.173	0.016	39221	4
1109.0117	15.834	0.016	16.172	0.016	39223	4
1109.9896	15.765	0.016	16.086	0.016	39278	4
1109.9987	15.773	0.016	16.101	0.016	39280	4
1110.0075	15.765	0.016	16.097	0.016	39282	4
1123.9654	15.598	0.016	15.969	0.016	39387	4
1124.2749	15.667	0.021	15.991	0.023	39440	4
1124.9754	15.686	0.016	16.043	0.016	39442	4
1125.0049	15.680	0.016	16.030	0.016	39447	4
1125.0314	15.681	0.015	16.050	0.015	39451	4
1126.0089	15.746	0.016	16.074	0.017	39490	4
1126.0180	15.757	0.016	16.085	0.016	39492	4
1126.0269	15.757	0.016	16.087	0.016	39494	4
1126.0589	15.754	0.016	16.086	0.016	39501	4
1126.9905	15.763	0.016	16.072	0.016	39549	4
1126.9993	15.757	0.016	16.069	0.016	39551	4
1127.9336	15.688	0.017	15.991	0.017	39602	4
1127.9427	15.684	0.016	15.990	0.016	39604	4
1127.9813	15.666	0.016	15.983	0.016	39613	4
1127.9902	15.661	0.016	15.976	0.016	39615	4
1129.9884	15.296	0.015	15.577	0.015	39732	4
1129.9983	15.297	0.015	15.580	0.015	39734	4
1130.0072	15.295	0.015	15.575	0.015	39736	4
1130.0715	15.291	0.015	15.583	0.015	39745	4
1130.9520	15.245	0.015	15.541	0.015	39764	4
1130.9608	15.243	0.015	15.545	0.015	39766	4
1130.9697	15.244	0.015	15.544	0.015	39768	4

1132.0291	15.178	0.015	15.491	0.015	39797	4
1132.9463	15.194	0.016	15.496	0.016	39854	4
1133.9985	15.211	0.015	15.543	0.016	39892	4
1134.9237	15.235	0.016	15.595	0.016	39908	4
1134.9425	15.245	0.016	15.610	0.016	39912	4
1135.9301	15.302	0.016	15.687	0.017	39940	4
1138.2574	15.406	0.019	15.800	0.021	39975	4
1138.9834	15.416	0.015	15.811	0.015	39988	4
1138.9932	15.425	0.015	15.815	0.015	39990	4
1139.0021	15.413	0.015	15.806	0.016	39992	4
1139.9960	15.498	0.015	15.889	0.015	40020	4
1140.0053	15.499	0.015	15.889	0.015	40022	4
1140.0141	15.509	0.015	15.893	0.015	40024	4
1141.9408	15.673	0.016	16.044	0.017	40058	4
1141.9597	15.694	0.016	16.048	0.016	40062	4
1145.9845	15.594	0.017	15.878	0.017	40127	4
1148.2062	15.216	0.016	15.497	0.018	40146	4
1151.9623	15.234	0.016	15.596	0.016	40175	4
1152.9702	15.263	0.017	15.614	0.018	40199	4
1154.1902	15.323	0.017	15.706	0.017	40229	4
1154.9279	15.311	0.015	15.702	0.015	40251	4
1155.9842	15.374	0.015	15.751	0.015	40332	4
1155.9942	15.374	0.015	15.766	0.015	40334	4
1156.0039	15.383	0.015	15.762	0.015	40336	4
1157.9363	15.524	0.016	15.895	0.016	40376	4
1159.9919	15.719	0.019	16.062	0.019	40471	4
1161.1464	15.812	0.016	16.158	0.016	40531	4
1162.0104	15.793	0.016	16.122	0.016	40569	4
1163.0798	15.690	0.024	16.001	0.023	40628	4
1166.9577	15.264	0.016	15.581	0.016	40655	4
1167.9561	15.249	0.018	15.592	0.018	40702	4
1169.1145	15.278	0.016	15.626	0.017	40754	4
1170.0011	15.279	0.015	15.642	0.015	40817	4
1170.9359	15.299	0.016	15.674	0.016	40834	4
1172.0325	15.352	0.028	15.689	0.032	40903	4
1172.9923	15.341	0.016	15.720	0.016	40910	4
1173.9775	15.397	0.015	15.786	0.016	40995	4
1174.9640	15.449	0.016	15.829	0.017	41075	4
1176.9398	15.619	0.024	15.973	0.028	41202	4
1178.9379	15.718	0.017	16.056	0.017	41264	4
1179.9631	15.700	0.016	16.020	0.016	41279	4
1181.0460	15.586	0.020	15.883	0.019	41297	4
1181.9573	15.426	0.016	15.722	0.016	41336	4
1183.9567	15.192	0.038	15.530	0.042	41412	4
1185.9219	15.283	0.015	15.619	0.015	41434	4
1186.8837	15.276	0.016	15.626	0.016	41495	4
1188.8905	15.315	0.016	15.689	0.016	41540	4
1192.8942	15.556	0.016	15.936	0.016	41620	4
1193.8867	15.651	0.016	16.025	0.016	41678	4
1196.9035	15.837	0.085	16.139	0.084	41750	4
1196.9214	15.743	0.034	16.102	0.033	41753	4
1197.8804	15.688	0.017	16.005	0.017	41786	4

1198.9293	15.534	0.017	15.830	0.017	41891	4
1199.9232	15.322	0.016	15.595	0.016	42005	4
1200.8884	15.197	0.017	15.489	0.016	42114	4
1201.9192	15.198	0.015	15.511	0.015	42236	4
1202.8690	15.219	0.016	15.546	0.016	42343	4
1203.8629	15.272	0.015	15.626	0.016	42353	4
1206.9008	15.367	0.016	15.763	0.017	42366	4
1210.0142	15.522	0.019	15.918	0.020	42385	4
1210.9649	15.633	0.021	16.034	0.020	42432	4
1212.8836	15.792	0.016	16.166	0.016	42447	4
1213.9337	15.804	0.018	16.167	0.018	42535	4
1214.9091	15.729	0.018	16.066	0.018	42609	4
1216.8952	15.366	0.016	15.658	0.016	42717	4
1217.9433	15.195	0.016	15.473	0.016	42808	4
1218.0019	15.189	0.015	15.471	0.015	42821	4
1218.8510	15.169	0.015	15.466	0.015	42888	4
1219.8536	15.201	0.018	15.518	0.018	42974	4
1219.8858	15.184	0.015	15.511	0.015	42976	4
1220.8593	15.228	0.016	15.586	0.016	43079	4
1221.8545	15.278	0.016	15.642	0.016	43142	4
1223.9438	15.338	0.016	15.732	0.017	43182	4
1224.8550	15.359	0.015	15.763	0.015	43273	4
1226.8652	15.473	0.016	15.871	0.016	43436	4
1227.8550	15.534	0.016	15.924	0.016	43490	4
1228.8639	15.639	0.015	16.030	0.016	43612	4
1229.8768	15.733	0.016	16.099	0.016	43738	4
1230.9100	15.801	0.017	16.164	0.017	43861	4
1232.8536	15.677	0.016	16.014	0.016	44018	4
1233.8612	15.492	0.019	15.801	0.018	44132	4
1234.8642	15.318	0.016	15.607	0.016	44246	4
1236.8503	15.228	0.016	15.524	0.016	44357	4
1239.3040	15.277	0.017	15.633	0.018	44452	4
1239.8485	15.304	0.015	15.682	0.016	44461	4
1241.9122	15.345	0.017	15.736	0.017	44565	4
1243.8543	15.440	0.016	15.832	0.016	44723	4
1244.8574	15.517	0.016	15.925	0.016	44816	4
1245.8466	15.629	0.016	16.014	0.016	44924	4
1246.8546	15.721	0.016	16.107	0.016	45024	4
1247.8520	15.813	0.016	16.188	0.018	45136	4
1247.8685	15.810	0.016	16.176	0.016	45140	4
1249.2751	15.811	0.035	16.162	0.038	45189	4
1254.8491	15.257	0.015	15.590	0.015	45304	4
1255.8437	15.272	0.015	15.620	0.015	45425	4
1258.8729	15.317	0.016	15.704	0.016	45541	4
1260.2819	15.375	0.023	15.753	0.022	45660	4
1264.8866	15.738	0.017	16.092	0.018	45765	4
1266.8453	15.755	0.019	16.097	0.020	45776	4
1267.8542	15.711	0.016	16.050	0.016	45854	4
1271.8738	15.191	0.016	15.512	0.016	45978	4
1272.2353	15.189	0.016	15.511	0.016	46049	4
1273.8837	15.274	0.017	15.612	0.017	46145	4
1277.2388	15.574	0.016	16.046	0.016	46281	4

1279.1835	15.754	0.017	16.252	0.018	46439	4
1294.2220	15.347	0.019	15.722	0.019	46542	4
1297.2394	15.513	0.019	15.915	0.021	46621	4
1298.2133	15.616	0.025	15.990	0.024	46636	4
1300.3201	15.789	0.018	16.137	0.018	46666	4
1302.2521	15.819	0.021	16.164	0.021	46776	4
1304.1875	15.526	0.017	15.848	0.017	46915	4
1305.1916	15.302	0.016	15.585	0.016	47036	4
1306.1988	15.167	0.015	15.449	0.015	47156	4
1308.1171	15.253	0.017	15.590	0.017	47340	4
1309.3205	15.285	0.018	15.643	0.018	47480	4
1311.1463	15.348	0.017	15.721	0.017	47523	4
1312.1329	15.373	0.018	15.760	0.018	47600	4
1313.1563	15.420	0.016	15.815	0.016	47659	4
1314.2442	15.493	0.018	15.876	0.018	47690	4
1316.1735	15.659	0.015	16.031	0.016	47849	4
1319.1558	15.838	0.018	16.194	0.019	47964	4
1320.1651	15.773	0.015	16.099	0.016	48079	4
1321.1546	15.642	0.016	15.946	0.016	48151	4
1323.0794	15.319	0.019	15.610	0.020	48192	4
1328.2285	15.299	0.016	15.679	0.017	48278	4
1329.1861	15.315	0.016	15.698	0.016	48304	4
1330.2320	15.324	0.017	15.717	0.017	48358	4
1331.2735	15.389	0.016	15.768	0.016	48387	4
1334.1102	15.621	0.022	15.999	0.021	48405	4
1336.1606	15.764	0.017	16.108	0.017	48471	4
1337.1210	15.772	0.016	16.111	0.016	48528	4
1341.2542	15.212	0.016	15.506	0.016	48548	4
1349.0095	15.382	0.021	15.772	0.022	48806	4
1351.0022	15.544	0.017	15.937	0.018	48942	4
1353.0508	15.723	0.021	16.106	0.024	49010	4
1353.9871	15.792	0.016	16.159	0.018	49078	4
1364.9790	15.324	0.016	15.705	0.016	49234	4
1367.0793	15.437	0.016	15.823	0.016	49333	4
1371.0043	15.768	0.016	16.118	0.016	49529	4
1372.2485	15.808	0.016	16.167	0.016	49653	4
1375.2627	15.343	0.016	15.642	0.016	49715	4
1377.2466	15.217	0.016	15.525	0.016	49777	4
1378.2465	15.224	0.015	15.554	0.015	49847	4
1385.9914	15.473	0.016	15.856	0.016	49997	4
1388.2445	15.675	0.016	16.031	0.016	50057	4
1389.0057	15.716	0.015	16.065	0.016	50070	4
1390.2306	15.711	0.015	16.048	0.015	50154	4
1395.2216	15.270	0.016	15.594	0.016	50161	4
1396.0599	15.272	0.015	15.604	0.015	50178	4
1397.0752	15.275	0.016	15.619	0.016	50233	4
1399.9656	15.324	0.016	15.713	0.016	50351	4
1407.2179	15.707	0.015	16.041	0.015	50594	4
1408.0171	15.683	0.016	16.005	0.016	50608	4
1411.0168	15.279	0.015	15.576	0.015	50688	4
1411.2353	15.258	0.016	15.577	0.016	50735	4
1412.0662	15.212	0.015	15.517	0.015	50754	4

1413.0293	15.223	0.016	15.579	0.016	50797	4
1418.0293	15.365	0.015	15.755	0.015	50903	4
1419.9797	15.473	0.018	15.851	0.018	50953	4
1421.0322	15.550	0.016	15.938	0.016	51020	4
1421.9864	15.640	0.016	16.010	0.016	51049	4
1422.9896	16.004	0.018	16.155	0.016	51077	4
1424.9905	15.790	0.017	16.111	0.017	51100	4
1425.9912	15.820	0.016	16.037	0.015	51115	4
1427.0291	15.457	0.015	15.767	0.015	51183	4
1428.9972	15.214	0.015	15.506	0.015	51221	4
1430.0639	15.229	0.015	15.547	0.015	51297	4
1432.0107	15.276	0.015	15.616	0.016	51339	4
1433.0402	15.309	0.016	15.663	0.016	51407	4
1434.1164	15.322	0.018	15.709	0.018	51469	4
1436.0595	15.401	0.016	15.785	0.016	51499	4
1437.0915	15.472	0.018	15.842	0.019	51517	4
1437.9956	15.541	0.015	15.916	0.016	51552	4
1438.2273	15.548	0.015	15.923	0.015	51604	4
1439.0528	15.823	0.018	16.037	0.017	51624	4
1440.1150	15.681	0.018	16.043	0.019	51661	4
1441.0014	15.714	0.020	16.059	0.022	51690	4
1443.9506	15.576	0.033	15.874	0.034	51741	4
1445.0519	15.395	0.016	15.679	0.016	51766	4
1446.0127	15.315	0.015	15.604	0.015	51812	4
1448.1222	15.302	0.015	15.623	0.016	51864	4
1449.0282	15.317	0.015	15.652	0.016	51867	4
1449.9791	15.335	0.015	15.697	0.015	51875	4
1451.0305	15.367	0.015	15.734	0.015	51929	4
1451.9503	15.387	0.016	15.767	0.016	51953	4
1453.0330	15.416	0.015	15.804	0.016	52007	4
1454.0616	15.453	0.016	15.828	0.016	52069	4
1456.0011	15.565	0.016	15.942	0.016	52095	4
1457.0431	15.656	0.015	16.019	0.015	52165	4
1458.0193	15.740	0.016	16.090	0.016	52215	4
1460.1893	15.739	0.018	16.083	0.019	52234	4
1461.0057	15.647	0.016	15.970	0.016	52245	4
1461.9923	15.499	0.015	15.799	0.015	52254	4
1462.2270	15.457	0.016	15.763	0.016	52307	4
1462.9942	15.326	0.016	15.615	0.016	52318	4
1464.1650	15.243	0.015	15.539	0.016	52377	4
1465.9911	15.240	0.015	15.579	0.016	52400	4
1466.9491	15.282	0.015	15.628	0.016	52409	4
1468.0159	15.301	0.016	15.680	0.016	52420	4
1468.2424	15.320	0.015	15.704	0.015	52471	4
1469.0370	15.373	0.021	15.723	0.017	52490	4
1470.0994	15.295	0.016	15.720	0.017	52539	4
1470.9992	15.406	0.016	15.791	0.016	52570	4
1479.0255	15.626	0.015	15.943	0.015	52614	4
1480.2368	15.389	0.015	15.688	0.015	52720	4
1483.1490	15.346	0.081	15.692	0.092	52774	4
1485.2206	15.421	0.016	15.782	0.016	52863	4
1487.0400	15.476	0.016	15.853	0.016	52904	4

1492.9950	15.873	0.016	16.223	0.016	52973	4
1495.0680	15.865	0.016	16.195	0.016	53064	4
1498.1793	15.261	0.016	15.536	0.016	53245	4
1499.1076	15.190	0.015	15.478	0.016	53296	4
1502.0912	15.273	0.016	15.635	0.017	53351	4
1506.9263	15.477	0.015	15.861	0.016	53415	4
1510.2459	15.794	0.020	16.140	0.020	53512	4
1518.9623	15.233	0.015	15.574	0.015	53644	4
1521.9792	15.314	0.016	15.701	0.016	53831	4
1523.0806	15.359	0.015	15.753	0.016	53937	4
1523.9752	15.394	0.015	15.788	0.016	53984	4
1526.0088	15.553	0.016	15.927	0.016	54016	4
1528.1050	15.766	0.016	16.126	0.017	54168	4
1529.9921	15.794	0.017	16.114	0.017	54227	4
1531.9751	15.563	0.016	15.865	0.017	54375	4
1533.9403	15.251	0.015	15.555	0.016	54418	4
1535.0545	15.214	0.016	15.526	0.016	54540	4
1535.9703	15.212	0.015	15.535	0.015	54614	4
1537.9852	15.298	0.026	15.656	0.029	54669	4
1540.9487	15.347	0.015	15.723	0.015	54785	4
1542.1464	15.438	0.018	15.811	0.017	54835	4
1544.0097	15.616	0.016	15.987	0.016	54972	4
1545.9503	15.787	0.017	16.141	0.017	55126	4
1547.9193	15.763	0.016	16.093	0.016	55309	4
1550.9317	15.214	0.016	15.494	0.016	55440	4
1552.9610	15.229	0.016	15.547	0.016	55624	4
1554.0217	15.251	0.016	15.581	0.016	55677	4
1556.9566	15.333	0.016	15.707	0.016	55853	4
1565.0060	15.764	0.017	16.105	0.017	56048	4
1566.9368	15.472	0.016	15.784	0.016	56261	4
1568.9515	15.173	0.016	15.454	0.016	56419	4
1576.8697	15.441	0.019	15.832	0.020	56854	4
1653.1864	15.709	0.016	16.043	0.016	61496	4
1657.1800	15.265	0.017	15.580	0.017	61643	4
1659.1866	15.314	0.016	15.664	0.016	61832	4
1660.2879	15.330	0.016	15.702	0.016	61956	4
1662.1591	15.384	0.021	15.774	0.023	62120	4
1663.1930	15.426	0.016	15.814	0.016	62231	4
1664.3211	15.490	0.016	15.872	0.016	62362	4
1669.2708	15.690	0.020	16.037	0.019	62470	4
1671.2256	15.554	0.018	15.873	0.018	62696	4
1674.1881	15.258	0.016	15.558	0.016	62855	4
1678.1895	15.360	0.019	15.722	0.020	63107	4
1680.1686	15.438	0.016	15.813	0.016	63294	4
1681.1553	15.474	0.016	15.857	0.016	63404	4
1682.1106	15.530	0.015	15.924	0.016	63503	4
1683.0970	15.627	0.019	15.997	0.021	63602	4
1684.2630	15.712	0.023	16.059	0.023	63682	4
1687.1799	15.792	0.021	16.124	0.021	63784	4
1700.1251	15.938	0.016	16.439	0.017	64089	4
1704.0695	16.618	0.019	16.855	0.019	64251	4
1705.2734	16.130	0.016	16.579	0.016	64360	4

1708.1708	15.270	0.016	15.560	0.016	64411	4
1717.2026	15.542	0.016	15.933	0.016	64587	4
1721.0013	15.879	0.017	16.229	0.017	64796	4
1722.0068	15.881	0.016	16.213	0.016	64883	4
1723.0000	15.783	0.016	16.115	0.016	64956	4
1724.0116	15.542	0.024	15.861	0.024	65024	4
1730.2342	15.235	0.016	15.602	0.016	65249	4
1733.0797	15.315	0.018	15.703	0.018	65412	4
1734.0395	15.384	0.016	15.767	0.017	65474	4
1736.9762	15.647	0.024	16.042	0.028	65671	4
1737.9891	15.764	0.018	16.129	0.020	65750	4
1739.0822	15.783	0.017	16.127	0.017	65825	4
1740.9827	15.644	0.016	15.959	0.016	65886	4
1779.2029	15.153	0.016	15.446	0.016	66910	4
1784.2211	15.314	0.016	15.698	0.016	66941	4
1794.0027	15.509	0.017	15.814	0.017	67065	4
1797.1135	15.190	0.015	15.505	0.015	67155	4
1798.1666	15.207	0.015	15.538	0.015	67225	4
1802.9994	15.346	0.016	15.737	0.016	67292	4
1804.2307	15.404	0.016	15.795	0.017	67376	4
1805.9830	15.531	0.015	15.934	0.015	67432	4
1808.9412	15.744	0.016	16.087	0.016	67483	4
1813.1827	15.286	0.015	15.578	0.015	67630	4
1819.1337	15.275	0.015	15.646	0.015	67719	4
1825.2326	15.733	0.017	16.100	0.017	67754	4
1831.0752	15.192	0.016	15.484	0.016	67848	4
1835.0117	15.280	0.015	15.636	0.015	67924	4
1837.1123	15.334	0.016	15.721	0.016	68043	4
1839.1082	15.412	0.021	15.820	0.020	68076	4
1842.0806	15.671	0.015	16.035	0.015	68200	4
1843.1145	15.763	0.016	16.111	0.016	68261	4
1845.0314	15.768	0.015	16.098	0.016	68294	4
1846.2375	15.609	0.019	15.800	0.018	68390	4
1851.0849	15.234	0.016	15.578	0.016	68459	4
1857.1613	15.428	0.016	15.810	0.016	68520	4
1861.0648	15.705	0.017	16.053	0.017	68605	4
1862.0526	15.742	0.016	16.060	0.016	68660	4
1863.0670	15.688	0.016	16.008	0.016	68734	4
1864.0016	15.557	0.016	15.858	0.016	68789	4
1865.1123	15.379	0.016	15.664	0.015	68859	4
1866.0519	15.268	0.015	15.547	0.015	68912	4
1867.0300	15.283	0.018	15.583	0.018	68965	4
1868.0165	15.325	0.016	15.651	0.016	69014	4
1869.0936	15.351	0.015	15.714	0.015	69087	4
1870.0481	15.356	0.015	15.718	0.016	69147	4
1871.1149	15.369	0.016	15.743	0.016	69231	4
1874.9825	15.516	0.015	15.902	0.016	69298	4
1876.1324	15.612	0.016	15.970	0.016	69399	4
1879.0063	15.773	0.017	16.125	0.017	69451	4
1881.1324	15.624	0.017	15.937	0.017	69545	4
1882.1201	15.476	0.016	15.765	0.016	69617	4
1883.0937	15.309	0.016	15.595	0.016	69694	4

1884.0223	15.223	0.016	15.513	0.016	69763	4
1889.0628	15.375	0.016	15.754	0.016	69963	4
1907.9909	15.518	0.016	15.903	0.016	70057	4
1910.9348	15.706	0.016	16.090	0.016	70278	4
1916.9931	15.524	0.021	15.806	0.022	70440	4
1920.0995	15.227	0.015	15.570	0.015	70688	4
1930.0371	15.712	0.018	16.084	0.019	70807	4
1939.9789	15.280	0.017	15.658	0.018	71046	4
1945.8613	15.527	0.016	15.940	0.016	71334	4
1949.8874	15.776	0.023	16.122	0.024	71367	4
1955.9708	15.181	0.019	15.501	0.019	71781	4
1959.8612	15.291	0.015	15.680	0.015	71957	4
1968.8667	15.656	0.016	15.981	0.016	72321	4
1974.8816	15.234	0.016	15.597	0.017	72738	4
1980.8646	15.563	0.016	15.940	0.016	72947	4
1990.2482	15.195	0.016	15.522	0.016	73379	4
1995.8891	15.383	0.016	15.783	0.017	73690	4
1999.2239	15.603	0.016	15.983	0.016	73965	4
2010.3231	15.267	0.015	15.647	0.016	74642	4
2011.2994	15.288	0.015	15.678	0.015	74715	4
2017.2869	15.630	0.016	16.007	0.016	74826	4
2025.2963	15.219	0.016	15.538	0.016	74973	4
2034.0893	15.603	0.021	15.959	0.026	75229	4
2040.3075	15.320	0.016	15.616	0.016	75494	4
2048.1397	15.397	0.016	15.779	0.016	75538	4
2050.1780	15.500	0.016	15.880	0.016	75727	4
2052.1879	15.667	0.016	16.023	0.017	75812	4
2054.1882	15.779	0.015	16.131	0.015	75971	4
2057.0812	15.533	0.016	15.851	0.017	76163	4
2058.2542	15.296	0.016	15.566	0.016	76287	4
2062.0708	15.297	0.017	15.646	0.019	76370	4
2073.0468	15.752	0.017	16.082	0.017	76637	4
2074.2155	15.617	0.016	15.931	0.016	76741	4
2085.1863	15.503	0.017	15.900	0.018	77001	4
2087.0266	15.660	0.016	16.043	0.016	77103	4
2088.0610	15.722	0.028	16.086	0.029	77187	4
2089.9894	15.857	0.024	16.130	0.026	77252	4
2097.1627	15.250	0.015	15.608	0.015	77331	4
2101.1311	15.419	0.017	15.811	0.017	77508	4
2102.1898	15.508	0.015	15.903	0.016	77576	4
2103.1999	15.565	0.016	15.964	0.016	77644	4
2106.1987	15.809	0.018	16.152	0.018	77673	4
2109.1682	15.576	0.015	15.910	0.015	77812	4
2110.9815	15.321	0.016	15.539	0.016	77886	4
2112.0623	15.208	0.015	15.520	0.016	77960	4
2113.9811	15.249	0.016	15.586	0.016	78025	4
2115.0542	15.317	0.019	15.682	0.020	78120	4
2119.0037	15.780	0.016	16.286	0.017	78158	4
2121.0896	15.985	0.016	16.499	0.018	78290	4
2122.1551	16.105	0.019	16.619	0.022	78343	4
2127.9348	15.372	0.016	15.696	0.016	78360	4
2137.1004	15.481	0.015	15.861	0.016	78502	4

2143.1450	15.695	0.017	16.025	0.018	78635	4
2147.0219	15.257	0.015	15.560	0.015	78673	4
2149.0965	15.288	0.015	15.629	0.015	78764	4
2151.0739	15.347	0.017	15.747	0.018	78795	4
2154.0268	15.440	0.016	15.839	0.016	78849	4
2160.2018	15.778	0.016	16.122	0.017	79004	4
2168.1179	15.236	0.016	15.614	0.016	79034	4
2172.0609	15.425	0.015	15.817	0.015	79152	4
2176.1106	15.820	0.024	16.163	0.024	79229	4
2182.0824	15.088	0.015	15.438	0.015	79405	4
2185.0666	15.230	0.016	15.604	0.016	79550	4
2187.9855	15.385	0.015	15.756	0.016	79582	4
2194.0477	15.811	0.016	16.177	0.016	79689	4
2196.1877	15.675	0.016	15.999	0.016	79787	4
2203.9615	15.263	0.015	15.636	0.015	79806	4
2208.2420	15.410	0.016	15.787	0.018	79909	4
2222.0783	15.212	0.015	15.645	0.015	80011	4
2228.0364	15.640	0.016	16.006	0.016	80153	4
2229.1603	15.677	0.016	16.035	0.016	80248	4
2232.0542	15.480	0.016	15.786	0.016	80325	4
2236.1566	15.259	0.016	15.602	0.016	80377	4
2241.1682	15.379	0.015	15.812	0.016	80465	4
2243.0674	15.508	0.017	15.905	0.018	80585	4
2246.1618	15.756	0.016	16.129	0.017	80636	4
2248.1155	15.705	0.016	16.063	0.017	80786	4
2249.9540	15.302	0.015	15.651	0.015	80803	4
2251.0849	15.207	0.016	15.492	0.016	80921	4
2251.9310	15.215	0.016	15.504	0.016	80980	4
2260.0465	15.489	0.021	15.893	0.023	81176	4
2263.1160	15.731	0.019	16.085	0.019	81306	4
2275.9277	15.427	0.015	15.815	0.015	81461	4
2278.9931	15.628	0.017	16.008	0.017	81615	4
2280.0554	15.740	0.015	16.117	0.016	81745	4
2281.9877	15.772	0.019	16.129	0.019	81914	4
2284.9975	15.453	0.015	15.760	0.016	82061	4
2287.9137	15.237	0.016	15.540	0.016	82293	4
2289.0111	15.234	0.016	15.592	0.017	82437	4
2291.0393	15.327	0.018	15.714	0.018	82632	4
2292.0307	15.365	0.016	15.743	0.016	82737	4
2293.0427	15.392	0.016	15.780	0.016	82849	4
2298.9378	15.775	0.016	16.145	0.016	83103	4
2301.0000	15.684	0.016	16.014	0.017	83284	4
2302.8617	15.350	0.016	15.636	0.016	83505	4
2304.0018	15.258	0.020	15.567	0.020	83667	4
2305.8726	15.230	0.015	15.568	0.015	83829	4
2307.8759	15.306	0.015	15.683	0.015	83937	4
2309.8693	15.375	0.015	15.775	0.015	84051	4
2312.8645	15.543	0.016	15.937	0.016	84216	4
2314.9333	15.748	0.015	16.133	0.015	84425	4
2318.8763	15.688	0.016	16.020	0.016	84888	4
2325.8817	15.400	0.019	15.753	0.020	85155	4
2336.8744	15.520	0.015	15.859	0.015	85569	4

2350.8526	15.820	0.016	16.194	0.017	86410	4
2357.3375	15.229	0.016	15.553	0.016	86922	4
2363.8520	15.365	0.016	15.759	0.016	87400	4

B.3 81.8997.87

```
#-------------------------- MACHO Project ---------------------------
# Star 81.8997.87                 05:36:04.630 -70:01:55.51 (J2000.0)
#--------------------------------------------------------------------
# Creation date (JD-2.449e+06): 2422.0827            886 observations
# Calibration: standard
# A tran of 4 indicates that the transformation from MACHO bands made
# use of both r and v values and their errors.
#--------------------------------------------------------------------
# HJD-2.449e+06    r       err_r        v       err_v     obsid  tran
#    (days)      (mag)     (mag)      (mag)     (mag)
#--------------------------------------------------------------------
```

-81.7688	-99.000	-99.000	16.993	0.021	1498	4
-80.7574	16.442	0.017	17.153	0.022	1514	4
-79.9524	16.347	0.018	17.030	0.023	1530	4
-78.9592	16.471	0.017	17.188	0.022	1582	4
-75.7433	16.345	0.018	16.993	0.023	1595	4
-72.0036	16.304	0.019	16.970	0.027	1609	4
-70.9700	16.460	0.017	17.196	0.020	1674	4
-70.0226	16.320	0.018	16.983	0.024	1725	4
-69.0238	16.439	0.021	17.167	0.036	1790	4
-68.0090	16.339	0.018	17.006	0.024	1810	4
-67.8356	16.317	0.018	16.977	0.024	1846	4
-65.8658	16.296	0.017	16.956	0.022	1886	4
-63.8654	16.314	0.024	16.994	0.042	1910	4
-61.8102	16.310	0.021	16.986	0.030	1939	4
-60.9855	16.425	0.019	17.134	0.028	1966	4
-59.9685	16.344	0.018	17.011	0.024	2023	4
-57.9077	16.340	0.029	17.051	0.050	2068	4
-51.8598	16.331	0.021	17.028	0.034	2107	4
-50.8070	16.435	0.017	17.129	0.022	2145	4
-49.9717	16.398	0.018	17.099	0.027	2166	4
-34.8221	16.408	0.022	17.102	0.036	2189	4
-33.9741	16.466	0.021	17.181	0.035	2210	4
-32.9830	16.365	0.019	17.044	0.028	2256	4
-14.9778	16.298	0.019	16.951	0.025	2343	4
-13.9577	16.455	0.017	-99.000	-99.000	2383	4
-11.9671	16.459	0.029	17.129	0.046	2425	4
-11.7779	16.481	0.017	-99.000	-99.000	2457	4
-10.9826	16.309	0.017	16.972	0.022	2473	4
-10.7890	16.310	0.018	16.998	0.026	2508	4
-9.9651	16.456	0.018	17.153	0.026	2526	4
-3.0169	16.380	0.017	17.068	0.021	2561	4
-2.7734	16.301	0.018	16.974	0.027	2608	4
-1.0152	16.370	0.018	17.042	0.022	2622	4

-0.7903	16.323	0.018	17.005	0.027	2664	4
0.9997	16.369	0.019	17.029	0.028	2690	4
1.1829	16.331	0.018	16.997	0.027	2725	4
1.9876	16.433	0.018	17.131	0.024	2740	4
2.1812	16.453	0.019	17.178	0.030	2777	4
2.9850	16.394	0.017	17.064	0.021	2802	4
4.2383	16.438	0.078	17.181	0.143	2837	4
6.9949	16.407	0.017	17.100	0.019	2857	4
7.1796	16.328	0.019	16.998	0.027	2892	4
8.0034	16.401	0.019	17.096	0.027	2917	4
8.1629	16.425	0.018	17.143	0.024	2941	4
11.0958	16.422	0.016	17.092	0.019	2961	4
11.1701	16.399	0.017	17.073	0.021	2972	4
12.0846	16.405	0.021	-99.000	-99.000	2987	3
15.1829	16.377	0.022	17.050	0.035	3005	4
17.0216	-99.000	-99.000	17.140	0.027	3095	4
19.0170	16.491	0.016	17.212	0.018	3153	4
22.0590	-99.000	-99.000	17.057	0.021	3267	4
24.9848	16.475	0.024	17.124	0.040	3320	4
30.0306	16.337	0.018	16.993	0.024	3392	4
32.9801	16.479	0.019	17.184	0.028	3411	4
37.1922	16.471	0.020	17.195	0.033	3512	4
41.0095	16.473	0.017	17.163	0.023	3598	4
43.2379	16.463	0.020	17.180	0.030	3675	4
44.0050	16.332	0.017	16.980	0.020	3698	4
44.0836	16.318	0.018	16.978	0.025	3711	4
45.0051	16.469	0.019	17.156	0.028	3760	4
45.1529	16.467	0.025	17.215	0.043	3773	4
46.0014	16.326	0.017	16.979	0.021	3816	4
46.0803	16.324	0.017	16.980	0.022	3828	4
47.1391	16.478	0.032	-99.000	-99.000	3876	4
48.9898	16.459	0.019	17.148	0.028	3909	4
49.0801	16.453	0.019	17.153	0.028	3924	4
50.0176	16.324	0.019	17.000	0.028	3975	4
50.1469	16.310	0.019	16.959	0.027	3996	4
54.0686	16.342	0.019	16.994	0.028	4073	4
56.1975	16.296	0.021	16.951	0.042	4107	4
59.9964	16.361	0.017	17.034	0.022	4135	4
60.9500	16.410	0.018	17.086	0.024	4173	4
61.9512	16.437	0.017	17.101	0.020	4214	4
62.1701	16.346	0.019	16.993	0.030	4235	4
62.9494	16.414	0.018	17.094	0.024	4260	4
65.0498	16.415	0.018	17.106	0.024	4283	4
66.0209	16.408	0.017	17.095	0.021	4340	4
67.9680	16.424	0.018	17.120	0.027	4432	4
68.0854	16.406	0.019	17.078	0.026	4454	4
69.0071	16.393	0.017	17.094	0.022	4480	4
69.9839	16.420	0.018	17.114	0.024	4535	4
70.0983	16.413	0.016	17.083	0.021	4557	4
74.9646	16.366	0.019	17.050	0.026	4606	4
75.0739	16.375	0.021	17.093	0.033	4625	4
75.9957	16.454	0.019	17.148	0.028	4646	4

77.1212	16.361	0.020	17.066	0.032	4722	4
77.9666	16.496	0.018	17.201	0.024	4770	4
81.0368	16.361	0.017	17.016	0.024	4841	4
83.0013	16.328	0.025	16.963	0.050	4900	4
83.0483	16.319	0.033	-99.000	-99.000	4909	3
83.9498	16.502	0.030	17.196	0.067	4966	4
84.9834	16.334	0.019	16.974	0.028	5009	4
86.9601	16.340	0.019	17.004	0.026	5031	4
88.9769	16.328	0.017	17.006	0.021	5118	4
89.9828	16.498	0.018	17.237	0.024	5173	4
93.0255	16.298	0.018	16.984	0.027	5254	4
93.9159	16.454	0.017	17.165	0.024	5270	4
94.9203	16.300	0.017	16.946	0.022	5297	4
97.9217	16.463	0.017	17.175	0.022	5581	4
98.0493	16.489	0.017	17.190	0.024	5603	4
98.9195	16.325	0.016	16.970	0.021	5673	4
99.0292	16.326	0.017	16.983	0.022	5695	4
99.9088	16.450	0.019	17.162	0.028	5712	4
100.0151	16.468	0.018	17.170	0.025	5735	4
100.9077	16.357	0.019	16.988	0.024	5818	4
101.9212	16.460	0.017	17.156	0.024	5878	4
103.9180	16.457	0.018	17.162	0.026	5905	4
106.9983	16.325	0.018	17.000	0.025	6032	4
107.0903	16.310	0.018	16.981	0.027	6051	4
107.9348	16.428	0.018	17.124	0.028	6071	4
107.9657	16.448	0.018	17.152	0.028	6078	4
108.0700	16.471	0.018	17.168	0.026	6097	4
108.9202	16.366	0.017	17.037	0.022	6134	4
111.9836	16.437	0.031	17.066	0.067	6301	4
112.9269	16.382	0.017	17.062	0.024	6385	4
114.9102	16.391	0.018	17.065	0.026	6472	4
117.9247	16.390	0.019	17.090	0.028	6560	4
118.8947	16.383	0.018	17.062	0.026	6649	4
120.9012	16.436	0.017	17.138	0.024	6710	4
123.9046	16.375	0.018	17.057	0.025	6934	4
124.9006	16.430	0.019	17.143	0.029	7035	4
125.9007	16.354	0.017	-99.000	-99.000	7140	4
126.9150	16.447	0.016	17.132	0.021	7257	4
127.9098	16.381	0.017	17.058	0.023	7363	4
130.9947	16.426	0.022	17.151	0.035	7475	4
132.0260	16.386	0.024	17.101	0.043	7518	4
133.0192	16.425	0.024	17.138	0.040	7531	4
133.9695	16.367	0.018	17.052	0.026	7604	4
134.9034	16.475	0.018	17.177	0.024	7666	4
135.8896	16.350	0.017	17.019	0.024	7765	4
140.8982	16.434	0.031	16.961	0.056	7846	4
141.3136	16.396	0.021	17.102	0.032	7900	4
142.3138	16.418	0.023	17.089	0.037	7961	4
143.2977	16.436	0.034	17.185	0.069	8019	4
143.8947	16.338	0.019	16.989	0.029	8041	4
144.2986	16.392	0.023	17.069	0.038	8082	4
144.8888	16.475	0.017	17.190	0.024	8103	4

145.3165	16.447	0.022	17.158	0.037	8184	4
146.3029	16.408	0.036	-99.000	-99.000	8238	4
146.8840	16.471	0.021	17.153	0.034	8257	4
152.8836	16.461	0.018	17.164	0.026	8415	4
153.2958	16.482	0.019	17.196	0.029	8502	4
153.9056	16.328	0.016	16.962	0.020	8525	4
154.8896	16.462	0.026	17.176	0.043	8574	4
156.2515	16.363	0.031	17.022	0.050	8616	4
156.2550	16.347	0.026	17.024	0.040	8617	4
156.9105	16.459	0.028	17.156	0.052	8641	4
162.2996	16.327	0.020	-99.000	-99.000	8814	3
162.9279	16.444	0.026	17.122	0.045	8833	4
163.2729	16.482	0.028	17.175	0.046	8903	4
163.8873	16.350	0.018	17.006	0.024	8927	4
164.8883	16.420	0.019	17.142	0.031	9028	4
165.9337	16.348	0.021	16.997	0.035	9134	4
170.3290	16.323	0.019	16.971	0.025	9333	4
172.8823	16.403	0.019	17.110	0.033	9372	4
176.8883	16.362	0.031	17.108	0.058	9394	4
179.2816	16.497	0.018	17.194	0.026	9526	4
180.8856	16.372	0.019	17.045	0.029	9566	4
181.2078	16.445	0.019	17.137	0.027	9635	4
182.1895	16.350	0.023	16.983	0.033	9729	4
183.2936	16.457	0.021	17.174	0.035	9755	4
184.8857	16.367	0.018	17.043	0.026	9844	4
186.8752	16.341	0.019	16.991	0.028	10001	4
188.8768	16.335	0.021	16.998	0.032	10095	4
189.1760	16.404	0.020	17.101	0.030	10154	4
189.8645	16.477	0.024	17.208	0.043	10192	4
190.1844	16.428	0.019	17.107	0.028	10243	4
195.1982	16.385	0.020	17.082	0.029	10363	4
196.1478	16.461	0.020	17.189	0.032	10439	4
197.1822	16.401	0.025	17.064	0.041	10512	4
200.2147	16.479	0.019	17.194	0.031	10584	4
202.1455	16.497	0.034	17.230	0.078	10647	4
204.1664	16.459	0.021	17.153	0.038	10720	4
205.1652	16.333	0.024	17.019	0.043	10819	4
209.1536	16.334	0.021	16.980	0.034	10943	4
210.1341	16.493	0.024	17.219	0.042	11013	4
211.1510	16.311	0.022	16.974	0.034	11119	4
212.1829	16.495	0.018	17.206	0.025	11190	4
216.1869	16.474	0.023	17.198	0.037	11314	4
217.1129	16.304	0.028	-99.000	-99.000	11375	4
218.1324	16.523	0.017	17.220	0.021	11478	4
219.1105	16.335	0.018	16.984	0.023	11546	4
221.2265	16.322	0.022	16.964	0.032	11653	4
222.1069	16.488	0.027	17.209	0.048	11719	4
224.0948	16.483	0.020	17.190	0.033	11880	4
225.0900	16.342	0.018	16.976	0.024	11944	4
226.2999	16.513	0.025	17.224	0.044	11998	4
234.0731	16.443	0.027	17.123	0.053	12080	4
253.0381	16.473	0.018	17.174	0.024	12126	4

255.1369	16.482	0.018	17.181	0.023	12189	4
256.0411	16.359	0.019	-99.000	-99.000	12243	3
257.0655	16.503	0.017	17.221	0.023	12325	4
258.0868	16.385	0.017	17.075	0.020	12400	4
259.2410	16.473	0.017	-99.000	-99.000	12468	3
261.0399	16.492	0.020	-99.000	-99.000	12512	3
265.2259	16.460	0.027	17.197	0.050	12543	4
266.0150	16.343	0.018	17.013	0.023	12577	4
267.0850	16.508	0.018	17.229	0.024	12615	4
268.1210	16.339	0.019	16.999	0.024	12651	4
269.0596	16.485	0.021	17.197	0.032	12698	4
271.0827	16.458	0.023	17.142	0.035	12793	4
273.0992	16.493	0.018	17.199	0.022	12847	4
273.9999	16.327	0.017	16.975	0.021	12869	4
275.0287	16.495	0.018	17.198	0.026	12920	4
277.2598	16.517	0.017	17.208	0.021	12938	4
278.1387	16.314	0.030	16.994	0.050	12951	4
278.1602	16.327	0.017	16.994	0.021	12953	4
281.1881	16.478	0.020	17.188	0.032	12995	4
283.0400	16.463	0.017	17.184	0.022	13022	4
283.9653	16.369	0.018	17.046	0.025	13067	4
286.1915	16.342	0.022	16.963	0.030	13141	4
286.9791	16.421	0.021	17.146	0.037	13170	4
288.0589	16.387	0.019	17.053	0.031	13222	4
290.0585	16.377	0.019	17.030	0.028	13268	4
291.9913	16.406	0.019	17.077	0.029	13334	4
303.0979	16.406	0.018	17.089	0.023	13405	4
308.0256	16.505	0.017	17.196	0.020	13456	4
309.9886	16.505	0.017	17.207	0.019	13514	4
312.0381	16.464	0.019	17.148	0.028	13578	4
313.0495	16.379	0.017	17.033	0.022	13633	4
372.9955	16.490	0.017	17.200	0.024	13912	4
375.1682	16.456	0.019	17.161	0.028	13967	4
375.9996	16.333	0.017	16.995	0.023	13983	4
377.0228	16.507	0.017	17.203	0.022	14043	4
378.9745	16.525	0.020	17.219	0.034	14139	4
381.0939	16.467	0.019	17.200	0.035	14216	4
382.0632	16.348	0.019	16.976	0.028	14260	4
385.2260	16.489	0.019	17.223	0.029	14317	4
386.9992	16.481	0.019	17.203	0.030	14356	4
389.1209	16.460	0.019	17.186	0.030	14410	4
390.9894	16.446	0.018	17.149	0.028	14434	4
393.2577	16.475	0.021	17.181	0.035	14493	4
398.9724	16.460	0.016	17.173	0.019	14518	4
399.9701	16.351	0.019	17.019	0.027	14574	4
405.1721	16.438	0.018	17.152	0.025	14659	4
406.1180	16.349	0.017	17.001	0.025	14695	4
407.1649	16.438	0.019	17.148	0.032	14743	4
410.0897	16.364	0.018	17.020	0.028	14819	4
412.7450	16.396	0.018	17.071	0.026	14881	4
413.0047	16.424	0.021	17.087	0.036	14925	4
413.9667	16.442	0.017	17.116	0.022	14940	4

414.2534	16.317	0.019	16.991	0.035	14961	4
414.9911	16.429	0.035	17.063	0.063	14980	4
415.9662	16.488	0.016	17.174	0.019	15001	4
416.2512	16.327	0.022	16.999	0.035	15040	4
416.9564	16.379	0.017	17.064	0.022	15058	4
423.9637	16.446	0.021	17.171	0.036	15124	4
424.9549	16.336	0.018	17.003	0.024	15165	4
426.1012	16.450	0.017	17.143	0.023	15249	4
426.9556	16.333	0.017	16.998	0.023	15303	4
428.9484	16.314	0.019	16.980	0.027	15382	4
432.9427	16.323	0.017	16.982	0.023	15483	4
433.9400	16.478	0.019	17.167	0.028	15520	4
434.9451	16.334	0.017	16.981	0.022	15561	4
435.9434	16.461	0.021	17.167	0.038	15602	4
436.9383	16.312	0.017	16.980	0.024	15637	4
439.0557	16.325	0.018	17.016	0.029	15734	4
445.1320	16.325	0.026	-99.000	-99.000	15846	4
446.1463	16.470	0.018	17.177	0.026	15871	4
447.0526	16.321	0.017	16.980	0.018	15915	4
448.1035	16.482	0.017	17.183	0.021	15974	4
448.1096	16.489	0.017	17.178	0.021	15975	4
448.9066	16.354	0.021	16.999	0.031	16016	4
450.0383	16.414	0.020	17.122	0.032	16116	4
451.0104	16.297	0.017	16.965	0.023	16192	4
452.0065	16.426	0.018	17.146	0.028	16265	4
453.0450	16.306	0.020	16.974	0.028	16335	4
456.0170	16.417	0.019	17.128	0.030	16394	4
457.1217	16.316	0.019	16.993	0.029	16416	4
457.9823	16.430	0.016	17.108	0.022	16461	4
459.0025	16.346	0.018	17.017	0.024	16487	4
459.0213	16.350	0.016	17.001	0.021	16490	4
460.9731	16.357	0.018	17.033	0.024	16577	4
461.9932	16.408	0.017	-99.000	-99.000	16650	3
462.9668	16.376	0.017	17.053	0.024	16724	4
464.0256	16.428	0.017	-99.000	-99.000	16750	4
464.9703	16.378	0.019	17.020	0.031	16820	4
465.9806	16.397	0.016	17.066	0.023	16849	4
466.9832	16.443	0.017	17.130	0.024	16924	4
468.0208	16.411	0.021	17.121	0.040	16993	4
469.1093	16.390	0.019	17.054	0.031	17053	4
470.0768	16.383	0.022	17.061	0.040	17115	4
471.0968	16.378	0.042	-99.000	-99.000	17167	4
473.0299	16.418	0.018	17.094	0.028	17219	4
474.0501	16.376	0.017	17.042	0.025	17297	4
478.9727	16.494	0.016	17.193	0.021	17452	4
479.9150	16.337	0.017	17.001	0.023	17528	4
482.0180	16.354	0.017	17.018	0.023	17613	4
483.9972	16.336	0.018	17.024	0.026	17646	4
484.9388	16.494	0.107	17.430	0.278	17734	4
485.9618	16.328	0.018	16.996	0.026	17817	4
486.9540	16.473	0.024	17.224	0.041	17891	4
487.9879	16.335	0.017	16.992	0.023	17983	4

488.9729	16.449	0.021	17.140	0.033	18066	4
489.9367	16.287	0.021	16.936	0.031	18142	4
492.3302	16.363	0.029	17.060	0.047	18215	4
492.9813	16.418	0.027	17.171	0.057	18233	4
496.9528	16.449	0.026	17.209	0.055	18372	4
498.9756	16.386	0.039	17.154	0.090	18470	4
500.9298	16.413	0.029	-99.000	-99.000	18515	4
505.9834	16.320	0.017	16.966	0.024	18736	4
509.9444	16.357	0.017	16.990	0.021	18821	4
511.9642	16.310	0.022	16.989	0.035	18849	4
512.3006	16.298	0.023	16.986	0.034	18911	4
512.9295	16.401	0.019	17.115	0.030	18934	4
516.9433	16.357	0.031	-99.000	-99.000	19182	3
518.2555	16.210	0.068	16.927	0.147	19251	4
518.2869	16.312	0.022	16.998	0.034	19254	4
519.9606	16.374	0.019	17.047	0.029	19375	4
521.2741	16.465	0.025	17.150	0.042	19454	4
523.3070	16.442	0.021	17.129	0.029	19498	4
526.3119	16.343	0.021	16.997	0.030	19565	4
526.9062	16.415	0.030	17.119	0.065	19581	4
527.9411	16.380	0.047	17.122	0.118	19612	4
531.2067	16.409	0.023	17.109	0.041	19696	4
532.2866	16.366	0.018	17.022	0.024	19752	4
532.9099	16.338	0.017	16.989	0.024	19778	4
533.3378	16.482	0.016	17.186	0.019	19826	4
533.9178	16.493	0.018	17.171	0.025	19843	4
535.2124	16.417	0.028	17.054	0.046	19941	4
536.9154	16.313	0.025	16.980	0.041	20002	4
539.2489	16.391	0.020	17.096	0.030	20227	4
539.9125	16.447	0.021	17.168	0.035	20259	4
540.9088	16.290	0.021	16.978	0.035	20342	4
542.3091	16.429	0.017	17.112	0.020	20469	4
543.1745	16.362	0.019	17.025	0.028	20541	4
546.3221	16.402	0.019	17.090	0.028	20652	4
547.8881	16.428	0.025	17.146	0.047	20750	4
549.2859	16.354	0.024	17.031	0.039	20854	4
550.1576	16.438	0.027	17.187	0.049	20915	4
551.2161	16.347	0.022	17.006	0.034	21010	4
551.3339	16.369	0.018	17.039	0.022	21033	4
553.1771	16.341	0.018	17.004	0.025	21104	4
554.1430	16.439	0.026	17.117	0.047	21158	4
555.1579	16.314	0.028	17.006	0.050	21217	4
556.1989	16.415	0.027	17.062	0.048	21286	4
557.2048	16.303	0.028	16.997	0.056	21383	4
557.2501	16.329	0.019	16.990	0.028	21392	4
558.2770	16.419	0.025	17.085	0.047	21459	4
559.3083	16.324	0.020	16.986	0.031	21551	4
560.1861	16.486	0.020	17.211	0.032	21598	4
562.3304	16.457	0.020	17.166	0.031	21773	4
562.8501	16.331	0.018	16.993	0.026	21775	4
563.2667	16.336	0.020	16.980	0.028	21833	4
567.1596	16.320	0.019	16.986	0.028	21907	4

568.2048	16.474	0.018	17.188	0.024	22005	4
569.2401	16.290	0.019	16.956	0.028	22086	4
570.2013	16.474	0.019	17.185	0.028	22161	4
572.1659	16.443	0.024	17.126	0.037	22252	4
572.3074	16.467	0.021	17.168	0.032	22276	4
573.1920	16.310	0.022	16.960	0.031	22337	4
574.1634	16.439	0.020	17.125	0.029	22417	4
575.1631	16.361	0.016	17.023	0.019	22502	4
578.1431	16.382	0.024	17.111	0.041	22614	4
579.1555	16.327	0.021	16.994	0.030	22700	4
580.1635	16.448	0.017	17.132	0.022	22788	4
581.1247	16.394	0.017	17.064	0.020	22863	4
582.1692	16.426	0.023	-99.000	-99.000	22926	3
582.2788	-99.000	-99.000	17.154	0.027	22948	3
586.1669	16.401	0.022	17.070	0.042	23051	4
587.1573	16.327	0.028	16.994	0.056	23125	4
588.1568	16.412	0.019	17.112	0.041	23191	4
589.1954	16.411	0.018	17.097	0.026	23262	4
590.1377	16.448	0.017	17.149	0.024	23317	4
591.1278	16.436	0.017	17.137	0.022	23366	4
591.3146	16.364	0.016	17.016	0.019	23392	4
592.1520	16.390	0.018	17.077	0.024	23443	4
593.1191	16.434	0.019	17.131	0.027	23513	4
596.1731	16.388	0.021	17.057	0.033	23631	4
597.1498	16.461	0.017	17.165	0.022	23693	4
599.1815	16.419	0.019	17.109	0.028	23824	4
600.2045	16.457	0.059	17.173	0.122	23890	4
602.2615	16.435	0.022	17.098	0.036	23914	4
603.1433	16.539	0.019	17.265	0.028	23969	4
605.1604	16.723	0.018	17.434	0.024	24021	4
606.1558	16.707	0.017	17.391	0.020	24096	4
607.1517	16.818	0.018	17.533	0.024	24175	4
608.0560	16.682	0.029	17.359	0.051	24226	4
609.1611	16.748	0.028	17.445	0.050	24291	4
610.1786	16.612	0.024	17.274	0.039	24350	4
611.1404	16.651	0.024	17.344	0.038	24421	4
612.1372	16.484	0.030	17.176	0.058	24500	4
613.1344	16.529	0.037	17.243	0.085	24572	4
619.1146	16.483	0.024	17.171	0.041	24854	4
621.1594	16.522	0.018	17.223	0.023	25003	4
622.2820	16.310	0.019	16.971	0.028	25035	4
623.2273	16.468	0.018	-99.000	-99.000	25047	3
624.1459	16.299	0.023	16.936	0.035	25092	4
626.1353	16.331	0.017	16.966	0.019	25184	4
628.1444	16.315	0.018	16.956	0.024	25238	4
629.1876	16.449	0.018	17.138	0.027	25289	4
630.1882	16.317	0.018	16.956	0.024	25320	4
631.1112	16.445	0.018	17.130	0.024	25375	4
634.0561	16.352	0.018	17.011	0.025	25444	4
635.0457	16.433	0.017	17.151	0.022	25489	4
636.1221	16.341	0.022	16.961	0.033	25559	4
637.0939	16.405	0.019	17.090	0.028	25625	4

639.1505	16.433	0.018	17.134	0.023	25697	4
640.1023	16.401	0.016	17.092	0.019	25737	4
641.1349	16.456	0.016	17.168	0.019	25802	4
643.0600	16.427	0.018	17.121	0.025	25889	4
646.1096	16.403	0.021	17.090	0.035	25930	4
648.2421	16.397	0.017	17.049	0.022	25986	4
650.0331	16.453	0.018	17.143	0.024	26072	4
652.1586	16.473	0.019	17.136	0.025	26152	4
654.1654	16.429	0.019	17.117	0.028	26177	4
655.1060	16.351	0.022	17.025	0.034	26217	4
661.1714	16.367	0.019	17.033	0.027	26247	4
665.2292	16.338	0.021	16.994	0.031	26271	4
666.0849	16.489	0.018	17.188	0.024	26293	4
667.0240	16.352	0.017	17.010	0.020	26334	4
667.2427	16.371	0.018	-99.000	-99.000	26378	3
668.1497	16.470	0.018	17.187	0.025	26389	4
671.0412	16.304	0.020	16.975	0.031	26431	4
672.9888	16.332	0.024	16.956	0.035	26490	4
674.0973	16.496	0.019	17.205	0.028	26519	4
674.2150	16.493	0.019	17.232	0.025	26541	4
675.2243	16.324	0.020	16.982	0.030	26558	4
677.0439	16.326	0.027	17.033	0.043	26578	4
682.0265	16.448	0.018	17.147	0.024	26617	4
688.0826	16.423	0.018	17.138	0.028	26685	4
689.0470	16.346	0.019	16.998	0.026	26716	4
690.1050	16.430	0.018	17.116	0.024	26753	4
691.0330	16.391	0.016	17.057	0.018	26791	4
692.0786	16.442	0.016	17.158	0.019	26859	4
693.1028	16.393	0.016	17.067	0.018	26920	4
694.0509	16.446	0.017	17.154	0.021	26964	4
696.0855	16.390	0.019	17.086	0.028	26987	4
697.0756	16.388	0.017	17.054	0.022	27036	4
698.0960	16.445	0.016	17.166	0.018	27099	4
700.2136	16.428	0.028	-99.000	-99.000	27199	4
701.0433	16.407	0.021	17.117	0.035	27218	4
703.0560	16.448	0.017	17.132	0.022	27265	4
704.1467	16.412	0.018	17.085	0.024	27320	4
705.0515	16.410	0.021	17.122	0.033	27352	4
707.1002	16.442	0.019	17.127	0.028	27408	4
716.0329	16.357	0.023	17.054	0.037	27439	4
718.1658	16.369	0.017	17.046	0.021	27530	4
724.0419	16.329	0.017	16.992	0.021	27554	4
728.9739	16.508	0.016	17.219	0.019	27589	4
730.2121	16.336	0.016	16.989	0.020	27681	4
731.0659	16.488	0.017	17.209	0.024	27703	4
739.1418	16.430	0.021	-99.000	-99.000	27781	3
742.1301	16.322	0.018	-99.000	-99.000	27877	3
746.1746	16.316	0.018	-99.000	-99.000	27963	3
748.1360	16.317	0.018	-99.000	-99.000	28066	3
749.1464	16.428	0.018	-99.000	-99.000	28118	3
750.2418	16.333	0.017	-99.000	-99.000	28179	3
752.0430	16.388	0.017	17.047	0.019	28203	4

753.1715	16.444	0.017	17.140	0.022	28287	4
755.0535	16.410	0.019	17.128	0.026	28319	4
756.1606	16.367	0.017	17.030	0.021	28372	4
763.0969	16.397	0.017	17.095	0.024	28511	4
765.2297	16.419	0.018	17.111	0.030	28565	4
768.1646	16.389	0.023	17.071	0.040	28630	4
785.0329	16.313	0.018	16.967	0.024	28685	4
787.2095	16.314	0.019	16.977	0.028	28736	4
790.2284	16.458	0.020	17.176	0.032	28935	4
791.0078	16.313	0.019	16.950	0.028	28970	4
796.0116	16.451	0.018	17.162	0.026	29107	4
798.0320	16.470	0.017	17.159	0.023	29193	4
799.9961	16.459	0.018	17.199	0.028	29274	4
801.0850	16.336	0.018	17.006	0.026	29374	4
802.0267	16.426	0.018	17.135	0.026	29436	4
803.1666	16.310	0.018	16.966	0.025	29494	4
805.0027	16.343	0.019	16.990	0.027	29525	4
806.1832	16.450	0.018	17.128	0.024	29593	4
807.0101	16.369	0.017	17.036	0.021	29632	4
808.9995	16.382	0.017	17.057	0.021	29745	4
810.0512	16.392	0.018	17.100	0.025	29824	4
811.0236	16.392	0.017	17.054	0.020	29886	4
819.1473	16.349	0.021	17.020	0.035	30078	4
820.0242	16.440	0.022	17.067	0.035	30128	4
827.0223	16.451	0.019	17.144	0.028	30329	4
829.0764	16.483	0.016	17.170	0.019	30431	4
831.9865	16.310	0.019	16.986	0.028	30539	4
833.1105	16.460	0.019	17.145	0.028	30598	4
834.0858	16.339	0.019	16.977	0.028	30649	4
834.0907	16.343	0.019	16.990	0.028	30650	4
836.0637	-99.000	-99.000	17.000	0.019	30673	3
843.0274	-99.000	-99.000	17.186	0.035	30770	3
852.9468	16.440	0.018	17.137	0.028	30970	4
857.0012	16.415	0.078	17.070	0.128	31097	4
858.9859	16.433	0.019	17.130	0.027	31138	4
866.9071	16.437	0.016	17.091	0.018	31372	4
869.9003	17.151	0.303	-99.000	-99.000	31423	4
872.9655	16.372	0.018	17.051	0.024	31505	4
875.8980	16.442	0.032	17.141	0.057	31610	4
880.9124	16.329	0.036	-99.000	-99.000	31652	4
887.9017	16.449	0.019	17.146	0.030	31928	4
889.8858	16.463	0.019	17.178	0.029	32100	4
891.8947	16.490	0.018	17.198	0.024	32326	4
895.9066	16.455	0.021	17.169	0.033	32493	4
902.8972	16.308	0.025	16.942	0.040	32741	4
906.8413	16.310	0.019	16.966	0.030	32858	4
913.8892	16.406	0.022	17.119	0.036	33002	4
918.3063	16.472	0.018	17.190	0.028	33163	4
922.2587	16.431	0.019	17.129	0.027	33325	4
930.2519	16.433	0.023	17.127	0.038	33750	4
932.3213	16.424	0.023	17.102	0.037	33855	4
937.2629	16.361	0.018	17.010	0.025	34189	4

938.2779	16.433	0.024	17.092	0.037	34294	4
939.1489	16.457	0.033	-99.000	-99.000	34379	3
940.1762	16.399	0.018	17.069	0.027	34500	4
941.3142	16.370	0.019	17.029	0.028	34604	4
942.1574	16.371	0.021	17.058	0.036	34678	4
943.2299	16.438	0.016	17.119	0.019	34806	4
944.2227	16.383	0.023	17.066	0.040	34918	4
945.2464	16.398	0.019	17.047	0.028	35016	4
946.2576	16.351	0.024	17.000	0.038	35048	4
947.3144	16.401	0.020	17.100	0.030	35142	4
949.2662	16.382	0.028	-99.000	-99.000	35320	4
950.1227	16.327	0.021	16.984	0.030	35383	4
952.1419	16.336	0.024	16.976	0.036	35478	4
953.2221	16.449	0.017	17.148	0.022	35563	4
954.1395	16.325	0.018	16.995	0.024	35624	4
955.2279	16.447	0.022	17.153	0.036	35707	4
956.3148	16.368	0.021	17.015	0.032	35787	4
958.0913	16.341	0.017	16.973	0.019	35869	4
962.1047	16.333	0.018	16.971	0.024	36024	4
964.2868	16.317	0.021	16.930	0.031	36109	4
966.1502	16.281	0.025	16.913	0.041	36163	4
967.2029	16.490	0.018	17.191	0.026	36222	4
968.1940	16.338	0.018	16.973	0.024	36283	4
971.0608	16.452	0.022	17.193	0.045	36372	4
973.0743	-99.000	-99.000	17.188	0.056	36481	4
973.1758	16.488	0.017	17.171	0.021	36494	4
975.2775	16.497	0.017	17.185	0.022	36586	4
981.1019	16.396	0.020	17.075	0.030	36691	4
982.1237	16.337	0.021	16.968	0.030	36728	4
983.0367	16.437	0.019	17.134	0.026	36791	4
987.1316	16.413	0.019	17.076	0.028	36868	4
988.0474	16.426	0.017	17.102	0.021	36936	4
995.0766	16.373	0.017	17.042	0.024	37079	4
997.1162	16.384	0.018	17.059	0.025	37183	4
998.1673	16.384	0.021	17.080	0.039	37259	4
999.1909	16.392	0.018	17.050	0.027	37336	4
1004.1255	16.423	0.026	17.143	0.043	37394	4
1006.1059	16.489	0.017	17.179	0.020	37476	4
1007.0919	16.357	0.017	17.025	0.021	37552	4
1008.1739	16.435	0.021	17.136	0.033	37610	4
1014.0590	16.445	0.020	17.138	0.030	37667	4
1020.2316	16.454	0.018	17.138	0.025	37774	4
1022.1609	16.458	0.019	17.161	0.028	37829	4
1023.1937	16.321	0.021	16.973	0.033	37870	4
1030.0367	16.403	0.025	17.100	0.045	37920	4
1032.1441	16.588	0.327	-99.000	-99.000	37962	3
1037.0384	16.362	0.017	17.013	0.022	38030	4
1039.1128	16.361	0.016	17.011	0.018	38078	4
1039.2399	16.347	0.016	16.992	0.019	38104	4
1047.0829	16.373	0.018	17.049	0.024	38205	4
1048.1581	16.382	0.024	17.097	0.042	38256	4
1049.1765	16.374	0.017	17.027	0.021	38310	4

1055.1968	16.430	0.018	17.096	0.023	38334	4
1058.0634	16.354	0.021	17.028	0.034	38352	4
1059.0744	16.481	0.021	17.185	0.034	38414	4
1062.0729	16.360	0.019	17.009	0.027	38457	4
1064.0433	16.334	0.019	16.972	0.028	38526	4
1067.0765	16.478	0.018	17.170	0.024	38583	4
1072.0128	16.335	0.016	16.983	0.019	38635	4
1073.0753	16.458	0.019	17.151	0.028	38694	4
1075.0501	16.463	0.021	17.142	0.031	38752	4
1079.0177	16.448	0.023	17.154	0.039	38805	4
1087.1604	16.465	0.018	17.159	0.027	38854	4
1089.0590	16.480	0.016	17.186	0.018	38870	4
1090.0529	16.358	0.017	17.011	0.020	38921	4
1092.0852	16.353	0.016	16.984	0.019	38970	4
1096.0792	16.353	0.018	16.995	0.024	39044	4
1100.1924	16.404	0.022	17.065	0.032	39056	4
1102.1326	16.378	0.016	17.037	0.017	39070	4
1106.0895	16.386	0.018	-99.000	-99.000	39129	4
1108.0940	16.424	0.016	17.097	0.021	39177	4
1109.0918	16.387	0.016	17.061	0.021	39240	4
1110.1007	16.421	0.017	17.103	0.021	39301	4
1119.0405	16.344	0.018	-99.000	-99.000	39355	3
1124.0423	16.451	0.018	17.161	0.026	39397	4
1125.0868	16.318	0.018	16.987	0.026	39460	4
1127.0753	16.334	0.017	16.983	0.022	39567	4
1128.0765	16.473	0.018	17.191	0.023	39634	4
1129.0995	16.320	0.017	16.974	0.021	39701	4
1132.0602	16.480	0.017	17.156	0.022	39804	4
1133.0076	16.347	0.018	17.015	0.023	39863	4
1134.9753	16.318	0.018	16.970	0.025	39919	4
1136.1073	16.477	0.020	-99.000	-99.000	39962	4
1138.2716	16.433	0.066	17.217	0.174	39978	4
1142.0013	16.450	0.017	17.157	0.023	40071	4
1146.0249	16.449	0.019	17.138	0.034	40136	4
1152.0196	16.419	0.018	17.112	0.026	40184	4
1154.2246	16.425	0.020	17.124	0.035	40236	4
1156.0728	16.409	0.017	17.087	0.022	40349	4
1158.0312	16.737	0.186	17.337	0.298	40385	4
1158.0548	16.394	0.019	17.095	0.028	40390	4
1160.0584	16.452	0.032	17.177	0.040	40485	4
1162.0859	16.391	0.018	17.084	0.024	40580	4
1164.1949	16.397	0.021	17.082	0.032	40645	4
1169.1553	16.791	0.149	17.438	0.308	40763	4
1173.0505	16.451	0.019	17.166	0.033	40919	4
1174.1162	16.343	0.023	17.006	0.039	41024	4
1175.0124	16.538	0.035	17.315	0.079	41084	4
1178.9782	16.501	0.018	17.188	0.025	41273	4
1182.0102	16.302	0.018	16.984	0.025	41345	4
1185.9619	16.294	0.019	16.979	0.027	41443	4
1188.9590	16.472	0.022	17.195	0.035	41551	4
1192.9362	16.438	0.018	17.158	0.024	41629	4
1194.0405	16.312	0.017	16.974	0.022	41711	4

1197.0024	16.439	0.018	17.135	0.024	41761	4
1198.0508	16.307	0.020	16.966	0.030	41822	4
1199.0834	16.456	0.024	17.162	0.040	41926	4
1199.9631	16.322	0.018	16.995	0.028	42014	4
1200.9616	16.407	0.020	17.099	0.032	42130	4
1201.9725	16.344	0.018	17.006	0.024	42248	4
1206.9413	16.418	0.021	17.151	0.033	42375	4
1212.9262	16.379	0.019	17.061	0.026	42456	4
1214.9497	16.381	0.028	17.115	0.048	42618	4
1216.0574	16.384	0.023	17.046	0.035	42688	4
1218.0498	16.384	0.017	17.048	0.023	42830	4
1218.8914	16.343	0.017	17.008	0.023	42897	4
1219.9281	16.431	0.018	17.123	0.026	42985	4
1220.9999	16.368	0.019	17.058	0.028	43104	4
1223.9837	16.428	0.019	17.133	0.030	43191	4
1224.9900	16.363	0.017	17.034	0.021	43300	4
1227.8948	16.473	0.018	17.185	0.027	43499	4
1228.9939	16.342	0.018	17.011	0.025	43641	4
1232.8936	16.345	0.016	16.994	0.019	44027	4
1234.9057	16.296	0.018	17.007	0.028	44255	4
1236.9077	16.315	0.018	16.991	0.027	44367	4
1238.9772	16.301	0.022	16.961	0.038	44378	4
1241.9574	16.475	0.026	17.130	0.042	44574	4
1243.8942	16.456	0.018	17.174	0.025	44732	4
1245.8868	16.424	0.018	17.131	0.024	44933	4
1247.9000	16.446	0.018	17.157	0.024	45147	4
1254.8896	16.333	0.018	17.022	0.026	45313	4
1255.8837	16.429	0.017	17.113	0.021	45434	4
1258.9240	16.354	0.021	17.023	0.033	45553	4
1264.2989	-99.000	-99.000	17.151	0.034	45759	4
1264.9018	16.409	0.019	17.077	0.030	45768	4
1267.8949	16.417	0.016	17.085	0.019	45863	4
1272.2764	16.409	0.020	17.115	0.032	46058	4
1277.2785	16.352	0.017	17.001	0.022	46290	4
1279.2233	16.372	0.019	17.037	0.028	46448	4
1289.3044	16.387	0.019	17.074	0.027	46503	4
1294.2728	16.380	0.019	17.055	0.029	46551	4
1297.2791	16.451	0.025	17.166	0.052	46630	4
1298.3272	16.370	0.020	17.060	0.033	46663	4
1301.1777	16.461	0.024	17.145	0.039	46735	4
1303.1861	16.458	0.021	17.186	0.033	46802	4
1305.2319	16.455	0.019	17.153	0.027	47045	4
1307.3160	16.451	0.018	17.157	0.026	47265	4
1308.1669	16.315	0.018	16.996	0.026	47349	4
1309.2452	16.451	0.021	17.155	0.035	47463	4
1312.2437	16.299	0.024	16.933	0.036	47611	4
1314.2849	16.321	0.022	16.955	0.032	47699	4
1316.3089	16.340	0.017	16.993	0.021	47879	4
1319.2541	16.467	0.019	17.170	0.027	47989	4
1320.3054	16.309	0.017	16.968	0.023	48110	4
1323.1484	16.434	0.029	17.121	0.058	48203	4
1328.2685	16.315	0.023	16.961	0.035	48287	4

1330.2881	16.347	0.018	17.013	0.024	48367	4
1334.1818	16.361	0.019	17.017	0.026	48416	4
1336.2003	16.380	0.018	17.047	0.026	48480	4
1342.2484	16.379	0.019	17.057	0.029	48581	4
1349.0507	16.331	0.025	16.994	0.042	48815	4
1350.1691	16.475	0.017	17.158	0.024	48900	4
1351.1359	-99.000	-99.000	17.010	0.037	48970	3
1353.0907	16.354	0.025	-99.000	-99.000	49019	3
1354.0263	16.464	0.021	17.178	0.038	49087	4
1360.1006	16.486	0.017	17.180	0.021	49138	4
1361.1276	16.359	0.022	17.012	0.033	49215	4
1365.0186	16.312	0.019	16.964	0.028	49243	4
1367.2213	16.307	0.020	16.967	0.029	49353	4
1369.0593	16.305	0.018	16.961	0.024	49390	4
1370.0805	16.508	0.016	17.228	0.018	49471	4
1371.0654	16.342	0.016	16.998	0.018	49538	4
1372.0513	16.480	0.016	17.182	0.019	49610	4
1375.0648	16.347	0.017	17.006	0.021	49672	4
1377.0460	16.335	0.018	17.005	0.023	49734	4
1378.0733	16.485	0.016	17.193	0.018	49809	4
1380.0908	-99.000	-99.000	17.189	0.022	49867	4
1381.0456	16.351	0.023	17.038	0.039	49927	4
1385.1262	16.368	0.021	17.021	0.028	49968	4
1386.1699	16.428	0.019	17.099	0.027	50034	4
1390.0177	16.401	0.018	17.086	0.024	50110	4
1396.0985	16.422	0.016	17.100	0.019	50186	4
1397.2091	16.418	0.016	17.084	0.019	50263	4
1398.1599	16.409	0.019	17.116	0.028	50316	4
1400.1724	16.399	0.021	17.071	0.030	50393	4
1402.1577	16.416	0.018	17.097	0.024	50450	4
1406.0249	16.626	0.018	17.315	0.025	50486	4
1407.0242	16.815	0.017	17.520	0.022	50552	4
1408.0593	16.694	0.018	17.385	0.028	50617	4
1410.0290	16.663	0.020	17.351	0.033	50647	4
1411.1056	16.734	0.019	17.430	0.027	50707	4
1412.1086	-99.000	-99.000	17.192	0.025	50763	4
1417.2148	16.498	0.021	17.201	0.034	50880	4
1420.0270	16.315	0.017	16.971	0.023	50962	4
1421.0719	16.520	0.016	17.228	0.019	51029	4
1423.1843	16.504	0.017	17.198	0.022	51086	4
1426.0134	16.355	0.016	16.997	0.019	51120	4
1427.0689	16.509	0.016	17.216	0.018	51192	4
1429.1454	16.483	0.018	17.193	0.026	51253	4
1432.0514	16.341	0.017	17.012	0.019	51348	4
1433.0800	16.448	0.017	17.155	0.024	51416	4
1434.0922	16.333	0.019	16.998	0.027	51464	4
1436.1883	16.338	0.017	16.990	0.021	51508	4
1438.0536	16.371	0.019	17.024	0.026	51565	4
1439.0949	16.441	0.019	17.115	0.028	51633	4
1440.2308	16.313	0.019	16.992	0.028	51685	4
1441.2182	16.464	0.022	17.177	0.033	51735	4
1446.0983	16.392	0.017	17.060	0.022	51831	4

1450.0059	16.474	0.016	17.162	0.019	51881	4
1451.1915	16.437	0.016	17.125	0.021	51940	4
1452.1245	16.431	0.017	17.102	0.020	51984	4
1453.0835	16.409	0.016	17.080	0.020	52017	4
1454.1058	16.420	0.019	17.091	0.028	52079	4
1456.1851	16.410	0.017	17.087	0.023	52136	4
1457.2328	16.453	0.026	17.142	0.041	52206	4
1462.0323	16.515	0.016	17.209	0.019	52263	4
1463.0352	16.356	0.017	17.029	0.023	52327	4
1464.2222	16.464	0.017	17.159	0.023	52388	4
1468.0564	16.497	0.018	17.215	0.027	52429	4
1469.0772	16.389	0.025	17.034	0.030	52499	4
1471.1444	16.383	0.018	17.056	0.025	52601	4
1479.2310	16.355	0.017	17.003	0.023	52659	4
1480.1666	16.525	0.016	17.240	0.019	52707	4
1485.0763	16.344	0.016	16.993	0.018	52837	4
1493.1037	16.347	0.016	17.006	0.020	52988	4
1495.1351	16.323	0.017	17.001	0.024	53077	4
1498.0111	16.449	0.017	17.134	0.021	53213	4
1499.2785	16.339	0.020	17.005	0.028	53331	4
1508.2008	16.432	0.018	17.121	0.026	53483	4
1519.0725	16.482	0.017	17.166	0.021	53669	4
1522.0501	16.360	0.018	17.040	0.024	53847	4
1526.0797	16.352	0.018	17.026	0.024	54032	4
1530.0730	16.352	0.017	17.023	0.025	54243	4
1533.0152	16.494	0.019	17.227	0.032	54406	4
1535.1513	16.610	0.113	18.134	0.742	54561	4
1540.1301	16.339	0.016	16.977	0.020	54756	4
1543.0525	16.464	0.019	17.194	0.030	54898	4
1546.0600	16.312	0.024	16.983	0.036	55147	4
1548.9551	16.442	0.018	17.118	0.024	55416	4
1553.0378	16.429	0.018	17.144	0.026	55638	4
1555.0786	16.426	0.019	17.128	0.032	55746	4
1563.9337	16.445	0.017	17.127	0.023	56003	4
1566.9679	16.375	0.017	-99.000	-99.000	56268	4
1577.0433	16.354	0.024	16.995	0.037	56893	4
1580.0245	16.474	0.019	17.164	0.031	57116	4
1582.8936	16.346	0.018	17.000	0.023	57372	4
1593.9875	16.465	0.022	17.209	0.041	57495	4
1599.9935	16.449	0.019	17.196	0.033	57874	4
1603.9208	16.444	0.017	17.131	0.022	58202	4
1608.9521	16.388	0.017	17.047	0.021	58630	4
1614.8986	16.414	0.021	17.086	0.034	58954	4
1617.9163	16.376	0.021	17.091	0.037	59283	4
1623.2610	16.384	0.018	17.054	0.026	59667	4
1632.2860	16.425	0.021	17.101	0.032	59960	4
1640.2409	16.374	0.019	17.040	0.026	60542	4
1643.1937	16.484	0.025	17.186	0.045	60710	4
1652.1681	16.339	0.023	16.993	0.042	61378	4
1657.3099	16.462	0.020	17.173	0.030	61671	4
1660.1997	16.341	0.017	16.997	0.021	61938	4
1663.1265	16.482	0.018	17.197	0.025	62216	4

1671.1480	16.431	0.028	17.127	0.047	62680	4
1675.2441	16.463	0.018	17.169	0.026	62919	4
1679.1627	16.420	0.023	17.141	0.048	63202	4
1681.1729	16.430	0.018	17.105	0.025	63408	4
1683.2142	16.420	0.022	17.115	0.037	63628	4
1687.2887	16.428	0.019	17.116	0.028	63806	4
1700.2422	16.458	0.021	17.176	0.035	64117	4
1704.1298	16.506	0.017	17.206	0.021	64264	4
1708.2525	16.497	0.018	17.209	0.024	64416	4
1717.0919	16.346	0.016	16.984	0.021	64564	4
1720.2522	16.480	0.018	17.190	0.024	64772	4
1722.1526	16.503	0.016	17.233	0.017	64916	4
1725.1318	16.320	0.021	16.972	0.032	65076	4
1727.0094	16.372	0.018	17.039	0.023	65198	4
1732.0083	16.415	0.019	17.097	0.028	65324	4
1733.1808	16.362	0.019	17.014	0.027	65434	4
1734.2524	16.457	0.018	17.169	0.023	65520	4
1736.1392	16.436	0.028	17.154	0.063	65629	4
1737.2347	16.371	0.020	17.056	0.033	65728	4
1739.1638	16.379	0.021	17.021	0.033	65841	4
1742.1415	16.391	0.019	17.096	0.028	65971	4
1744.2409	16.461	0.016	17.148	0.017	66089	4
1765.2057	16.516	0.018	17.226	0.027	66440	4
1769.2345	16.496	0.019	17.194	0.028	66540	4
1772.0409	16.351	0.018	17.010	0.024	66646	4
1776.0781	16.302	0.020	16.958	0.024	66769	4
1778.1564	16.340	0.017	16.984	0.021	66890	4
1785.2156	16.463	0.017	17.156	0.022	66997	4
1794.1799	16.421	0.016	17.070	0.019	67105	4
1798.0456	16.445	0.018	17.119	0.025	67199	4
1804.1049	16.444	0.018	17.121	0.024	67350	4
1806.1420	16.471	0.017	17.163	0.021	67465	4
1812.1750	16.451	0.018	17.168	0.024	67582	4
1815.1685	16.359	0.017	17.016	0.021	67699	4
1826.2091	16.503	0.017	17.231	0.025	67813	4
1833.0665	16.321	0.017	16.984	0.021	67907	4
1840.9992	16.361	0.017	17.041	0.024	68134	4
1843.1422	16.341	0.018	16.995	0.025	68265	4
1846.1252	16.441	0.016	17.137	0.021	68367	4
1860.0651	16.368	0.019	-99.000	-99.000	68585	4
1862.2327	16.414	0.017	17.096	0.022	68696	4
1864.1936	16.398	0.026	17.107	0.047	68816	4
1866.1733	16.364	0.021	17.059	0.030	68937	4
1868.1803	16.370	0.018	-99.000	-99.000	69046	4
1871.0503	16.485	0.018	17.188	0.025	69219	4
1875.9878	16.332	0.018	16.991	0.024	69371	4
1880.0099	16.332	0.019	16.997	0.026	69495	4
1881.2105	16.474	0.020	17.184	0.032	69562	4
1883.0894	16.497	0.019	17.203	0.031	69693	4
1887.0207	16.462	0.018	17.186	0.031	69889	4
1911.0807	-99.000	-99.000	17.104	0.027	70310	3
1931.9762	-99.000	-99.000	17.170	0.026	70887	3

1942.8587	-99.000	-99.000	17.019	0.029	71215	3
1952.9003	-99.000	-99.000	17.078	0.024	71547	3
1961.8609	-99.000	-99.000	17.101	0.030	72131	3
1973.8915	-99.000	-99.000	17.038	0.024	72647	3
1981.8572	-99.000	-99.000	16.994	0.021	73065	3
1991.8513	-99.000	-99.000	17.014	0.024	73458	3
1996.3063	16.363	0.019	17.028	0.027	73778	4
2005.2245	16.501	0.023	17.216	0.042	74298	4
2018.2419	16.260	0.048	-99.000	-99.000	74856	3
2029.2707	16.424	0.019	17.120	0.028	75219	4
2035.1553	16.434	0.018	17.116	0.025	75355	4
2050.1867	16.486	0.018	17.197	0.025	75729	4
2055.2360	16.369	0.019	17.049	0.026	76069	4
2058.1578	16.487	0.023	17.197	0.039	76272	4
2063.1295	16.357	0.019	17.024	0.029	76468	4
2073.2777	16.327	0.018	16.981	0.023	76683	4
2083.1708	16.429	0.017	17.114	0.019	76880	4
2085.2618	16.373	0.018	17.035	0.024	77018	4
2087.1637	16.398	0.020	17.070	0.029	77131	4
2090.1274	16.390	0.024	17.068	0.046	77282	4
2101.2089	16.489	0.018	17.195	0.027	77521	4
2103.2260	16.510	0.020	17.198	0.029	77649	4
2107.2355	16.516	0.018	17.201	0.023	77746	4
2110.2480	16.365	0.020	17.011	0.028	77871	4
2110.2619	16.364	0.020	17.044	0.033	77874	4
2113.2039	16.452	0.027	17.184	0.047	78011	4
2115.2179	16.534	0.018	17.253	0.023	78139	4
2120.1264	16.375	0.017	17.032	0.021	78250	4
2128.0595	16.409	0.017	17.058	0.019	78383	4
2137.0296	16.460	0.017	17.147	0.020	78486	4
2141.1228	-99.000	-99.000	17.132	0.022	78593	4
2147.1941	16.422	0.017	17.097	0.022	78705	4
2153.0567	16.387	0.025	17.076	0.041	78836	4
2159.1446	16.380	0.017	17.032	0.021	78981	4
2171.1596	-99.000	-99.000	17.006	0.021	79116	3
2176.1891	-99.000	-99.000	17.231	0.025	79243	3
2181.0779	-99.000	-99.000	17.026	0.024	79354	3
2183.0741	-99.000	-99.000	17.033	0.026	79466	3
2185.1791	-99.000	-99.000	16.991	0.021	79567	3
2190.2400	-99.000	-99.000	17.187	0.026	79677	3
2196.1700	-99.000	-99.000	17.167	0.021	79783	3
2208.1952	-99.000	-99.000	17.451	0.032	79899	3
2222.0840	-99.000	-99.000	17.009	0.020	80012	3
2226.0452	-99.000	-99.000	16.988	0.023	80107	3
2229.0861	-99.000	-99.000	17.191	0.024	80236	3
2241.0593	-99.000	-99.000	17.171	0.025	80444	3
2243.1237	-99.000	-99.000	17.133	0.046	80597	3
2248.0445	-99.000	-99.000	17.098	0.026	80772	3
2250.9985	-99.000	-99.000	17.092	0.023	80903	3
2260.9056	-99.000	-99.000	17.047	0.021	81193	3
2266.0280	-99.000	-99.000	17.198	0.038	81388	3
2278.9181	16.358	0.016	17.014	0.018	81598	4

2282.9528	16.346	0.018	17.013	0.023	81975	4
2287.9994	16.433	0.023	17.168	0.038	82311	4
2288.0469	16.466	0.021	17.173	0.034	82318	4
2290.9392	16.376	0.019	17.051	0.027	82613	4
2294.9067	16.392	0.017	17.068	0.023	82968	4
2302.9485	16.421	0.017	17.092	0.021	83523	4
2305.0333	16.388	0.018	17.082	0.024	83749	4
2307.9699	16.405	0.017	17.102	0.021	83958	4
2312.9303	16.462	0.019	17.163	0.026	84230	4
2315.8826	16.377	0.016	17.052	0.019	84523	4
2319.9488	16.379	0.017	17.040	0.021	84950	4
2329.9846	16.343	0.022	17.002	0.037	85293	4
2341.8852	16.450	0.122	16.994	0.171	85898	4
2352.8838	16.446	0.018	17.124	0.026	86650	4
2363.2960	16.480	0.018	17.195	0.025	87385	4
2383.2310	16.391	0.018	17.070	0.025	88269	4
2396.2025	16.492	0.019	17.248	0.032	89366	4
2405.2468	16.321	0.019	17.000	0.028	89822	4
2408.2726	16.489	0.018	17.212	0.027	90130	4
2412.1519	16.463	0.023	17.189	0.040	90449	4
2415.2145	16.362	0.018	17.025	0.023	90757	4

```
#------------------------- OGLE DATA --------------------------
# Star LMC_SC16 119952 = MACHO 81.8997.87
#-------------------------------------------------------------------
# HJD-2.4e6      v        err_v
# (days)        (mag)     (mag)
#-------------------------------------------------------------------
50822.69785   17.192    0.014
50825.84796   17.297    0.018
50844.79814   17.444    0.017
50875.68722   17.142    0.018
50900.67399   17.161    0.014
51130.83885   17.283    0.015
51143.80521   17.496    0.022
51152.82764   17.159    0.017
51155.72357   17.534    0.024
51156.83019   17.269    0.017
51159.83737   17.482    0.018
51160.78100   17.131    0.014
51169.81810   17.457    0.017
51212.72661   17.539    0.021
51215.73149   17.189    0.018
51232.70314   17.221    0.010
51239.66803   17.324    0.021
51258.53119   17.111    0.010
```

```
#------------------------- OGLE DATA --------------------------
# Star LMC_SC16 119952 = MACHO 81.8997.87
#-------------------------------------------------------------------
```

# HJD-2.4e6	i	err_i
# (days)	(mag)	(mag)
50739.86067	15.672	0.010
50744.76901	15.784	0.013
50745.85362	15.668	0.013
50746.83950	15.795	0.018
50747.73495	15.658	0.013
50750.79988	15.802	0.013
50751.80069	15.661	0.020
50752.85852	15.783	0.011
50755.78274	15.653	0.010
50759.70861	15.668	0.015
50761.78982	15.686	0.013
50766.83954	15.749	0.015
50773.79513	15.705	0.014
50776.82033	15.741	0.014
50778.85342	15.710	0.010
50780.78070	15.713	0.014
50782.80933	15.703	0.013
50788.83681	15.703	0.011
50792.74686	15.665	0.011
50795.83221	15.783	0.014
50798.75651	15.674	0.014
50819.83152	15.766	0.011
50824.70222	15.705	0.015
50827.69168	15.721	0.015
50828.75132	15.696	0.015
50829.69892	15.724	0.014
50830.75705	15.718	0.014
50832.76392	15.728	0.020
50833.58351	15.682	0.014
50834.70279	15.738	0.021
50837.66715	15.672	0.015
50841.75463	15.706	0.010
50842.74454	15.779	0.010
50846.77142	15.764	0.013
50854.78715	15.780	0.011
50855.70919	15.642	0.013
50856.67121	15.791	0.014
50857.72988	15.651	0.011
50858.69302	15.787	0.020
50859.75977	15.692	0.013
50860.65273	15.794	0.013
50867.62514	15.786	0.010
50874.68884	15.766	0.015
50876.60490	15.754	0.010
50876.70738	15.765	0.014
50878.69492	15.780	0.013
50880.62923	15.755	0.018
50887.67349	15.764	0.014
50892.54387	15.635	0.018

50893.71012	15.767	0.010
50896.51184	15.664	0.015
50900.56532	15.689	0.015
50919.56721	15.757	0.014
50925.52026	15.737	0.013
50934.52702	15.743	0.013
50947.54182	15.715	0.013
50950.52019	15.789	0.017
51072.90278	15.736	0.013
51079.81114	15.690	0.013
51080.81477	15.797	0.011
51084.82073	15.772	0.021
51086.84876	15.791	0.018
51090.77641	15.768	0.015
51091.88421	15.679	0.018
51092.82682	15.784	0.017
51093.83888	15.644	0.014
51106.76779	15.768	0.020
51108.78880	15.758	0.014
51114.79823	15.790	0.020
51120.74606	15.716	0.017
51126.76588	15.680	0.011
51129.83018	15.855	0.010
51131.83610	15.876	0.011
51132.82571	15.712	0.011
51137.80791	15.800	0.013
51138.84921	15.690	0.017
51142.77589	15.680	0.014
51154.74909	15.668	0.014
51155.70534	15.782	0.015
51157.75922	15.812	0.013
51159.76494	15.766	0.013
51161.82897	15.767	0.021
51163.83087	15.789	0.011
51164.84578	15.676	0.020
51166.76325	15.689	0.014
51168.77213	15.705	0.013
51171.74101	15.748	0.017
51175.73843	15.735	0.014
51179.78782	15.746	0.014
51181.75134	15.711	0.020
51183.83627	15.738	0.018
51185.83362	15.733	0.015
51187.78894	15.714	0.011
51189.72540	15.698	0.018
51191.76411	15.690	0.017
51192.82290	15.791	0.018
51193.81484	15.695	0.014
51201.77899	15.725	0.008
51202.78820	15.843	0.017
51204.69476	15.936	0.010
51206.79492	16.074	0.014

51207.70516	16.015	0.013
51211.76308	15.904	0.015
51214.67721	15.816	0.014
51215.58201	15.714	0.014
51216.65842	15.767	0.018
51217.74013	15.672	0.014
51219.65383	15.704	0.013
51220.76182	15.804	0.008
51221.62767	15.740	0.014
51223.71628	15.670	0.008
51226.60589	15.757	0.013
51227.61070	15.733	0.010
51233.57155	15.796	0.010
51235.70934	15.770	0.011
51238.63185	15.684	0.010
51240.70759	15.717	0.017
51242.52553	15.714	0.014
51244.66205	15.679	0.015
51247.51984	15.797	0.013
51248.62007	15.671	0.008
51251.57456	15.782	0.010
51254.58908	15.676	0.010
51255.62231	15.768	0.017
51256.62634	15.685	0.015
51258.61352	15.669	0.015
51261.51932	15.775	0.015
51264.53033	15.695	0.011
51267.55190	15.734	0.011
51272.53218	15.700	0.008
51274.54998	15.708	0.013
51276.56248	15.708	0.011
51278.56604	15.718	0.014
51279.54881	15.793	0.010
51290.53014	15.784	0.017
51298.50667	15.853	0.017
51301.58107	15.693	0.010
51306.49802	15.816	0.018
51315.53040	15.696	0.015
51318.51295	15.777	0.011
51320.50567	15.754	0.014
51330.51586	15.774	0.014
51335.50900	15.731	0.013