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CCD MINIMA OF SELECTED ECLIPSING BINARIES IN 1999

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Thirty-two new times of minima for selected eclipsing binaries have been determined using a CCD camera at the Prince George Astronomical Observatory in 1999.

All observations were made using an unfiltered SBIG ST6 CCD camera (chip: TI TC-241, 375 × 241 pixels each 23 × 27 μm, with an anti-blooming gate – not the author's choice) cooled to -40° C and mounted at the Cassegrain focus of a 61-cm telescope. The camera was equipped with a telecompressor lens that reduced the focal ratio from $f/12$ to $f/7$. Field of view was then $5'.35 \times 7'.00$; each pixel covered $1''.11 \times 1''.30$. Images were taken, in most cases, every two or three minutes throughout the eclipse for a time span of 2 to 4 hours. Finder charts were made using the program Guide 7; the data bases therein proved invaluable.

All data reduction was performed with MIRA AP version 5.04 (and later version 6.01) by Axiom Research Inc. Between exposures, frames were flat-fielded in batch mode and aperture photometry (using a single comparison star) performed. The aperture sizes (pinhole for the star and annular region for the sky background) were adjusted to gather counts from the star in the most efficient manner, and to avoid contamination from other stars in the annular region. For each eclipse, a comparison magnitude, close to the best available value, was adopted and used throughout the eclipse.

Times were adjusted to the mid-point of the exposure in each case. For all of the data sets (depending on the stars' brightnesses, exposure times and other factors), signal to noise values for the variable or comparison varied from 81 to 1355.

In order to determine the time of minimum, several methods were used. First of all, unless the minimum was clearly flat-bottomed, a parabola was fitted by the method of least squares to that part of the central part of the minimum that appeared to fit a parabola well. To estimate the error, the time of minimum was adjusted until an obvious bad fit was seen; the difference in times of minimum was taken as the error by this method.

In the majority of cases, there were significant descending and ascending portions of the curve. The tracing paper method (where the ascending and descending portions of the curve are made to overlap – but now done on a spreadsheet) was used to determine the time of minimum approximately and to determine the symmetric regions of the descending and ascending branches. The bisector of chords method, and the method of Kwee & van Woerden (1956) were then applied to these regions.

Table 1

Date (UT)	Star	Comparison	Minimum (HJD – 2400000)	Est. err. (days)	Type*	Notes
1999-10-14	RT And	GSC 3998-2312	51465.764	0.001	I	
1999-12-01	WZ And	GSC 2799-0902	51513.7810	0.0001	I	
1999-10-05	OO Aql	GSC 1058-0409	51456.7720	0.0002	I	
1999-12-28	CV Boo	GSC 2570-0423	51540.9172	0.00004	I	1
1999-10-19	Y Cam	GSC 4527-0438	51470.8049	0.00014	I	
1999-09-14	XX Cep	GSC 4288-0150	51435.7132	0.0001	I	
1999-09-28	XX Cep	GSC 4288-0150	51449.7371	0.0001	I	
1999-09-21	EG Cep	GSC 4585-0165	51442.86571	0.00007	I	
1999-10-19	ZZ Cyg	GSC 3576-0964	51470.67204	0.00008	I	
1999-05-11	BR Cyg	GSC 3556-3310	51309.8253	0.0002	I	2
1999-09-12	BR Cyg	GSC 3556-3310	51443.75421	0.00007	I	2
1999-09-21	CG Cyg	GSC 2696-2622	51442.71870	0.00008	I	
1999-12-08	Z Dra	GSC 4396-1221	51520.81684	0.00001	I	
1999-10-23	UZ Dra	GSC 4444-0836	51474.86051	0.00016	I	
1999-10-04	SW Lac	GSC 3215-0906	51455.7416	0.0003	I	
1999-12-03	SW Lac	GSC 3215-1586	51515.8613	0.0001	I	
1999-10-27	VX Lac	GSC 3214-1065	51478.7423	0.0001	I	
1999-08-14	FL Lyr	GSC 3542-1400	51404.833	0.002	II	3
1999-09-19	FL Lyr	GSC 3542-1400	51440.770	0.002	I	3
1999-11-29	RW Mon	GSC 0733-0826	51511.92103	0.00005	I	
1999-11-21	RV Per	GSC 2366-1081	51503.8915	0.0002	I	
1999-11-27	ST Per	GSC 2847-1270	51509.8531	0.0001	I	
1999-10-18	XZ Per	GSC 3328-2029	51469.82784	0.00003	I	
1999-11-27	RW Tau	GSC 1826-0015	51509.68687	0.00003	I	
1999-10-11	V Tri	GSC 2293-1382	51462.8213	0.0002	I	
1999-12-31	X Tri	GSC 1763-2015	51543.790	0.001	I	
1999-10-26	RV Tri	GSC 2321-1715	51477.7786	0.0001	I	
1999-12-07	VV UMa	GSC 3810-0988	51519.84743	0.00006	I	
1999-04-28	AW UMa	GSC 1984-0145	51296.829	0.003	II	4
1999-04-13	AG Vir	GSC 0871-0330	51281.8693	0.0006	I	5
1999-05-09	AG Vir	GSC 0871-0330	51307.8597	0.0005	II	5
1999-11-01	BU Vul	GSC 2182-0483	51483.71885	0.00005	I	

Notes:

* I = primary, II = secondary.

1 Ephemeris for identifying type of minimum is from Busch (1985).

2 Comparison star GSC 3556-3310 was later discovered to be NSV 12304. However, light curves of comparison versus check star (GSC 3556-3166) revealed no significant variation over the 0.1 magnitude level that could not be attributed (based on other data) to varying extinction from clouds.

3 Ephemeris for identifying type of minimum is from Keskin & Pohl (1989).

4 Ephemeris for identifying type of minimum is from Pribulla et al. (1999).

5 Ephemeris for identifying type of minimum is from Bell et al. (1990).

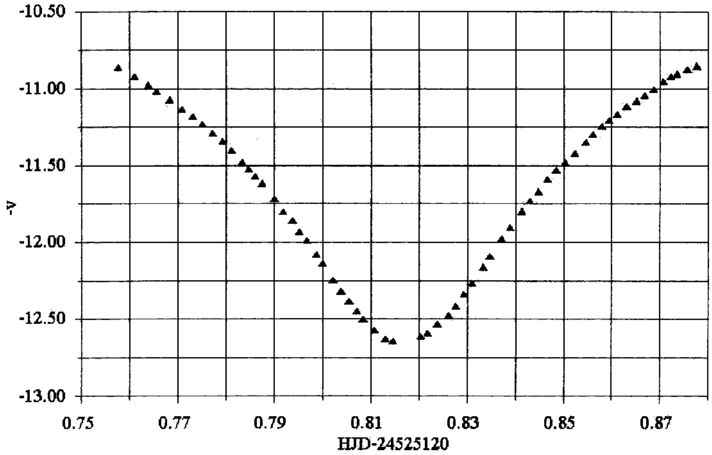

Figure 1. Primary minimum of the 1.36-day semidetached Algol-type binary Z Draconis.

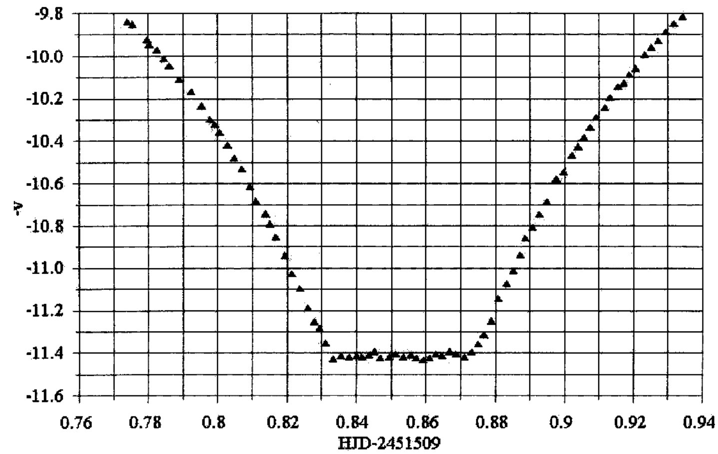

Figure 2. Primary minimum of the 2.65-day semidetached Algol-type binary ST Persei.

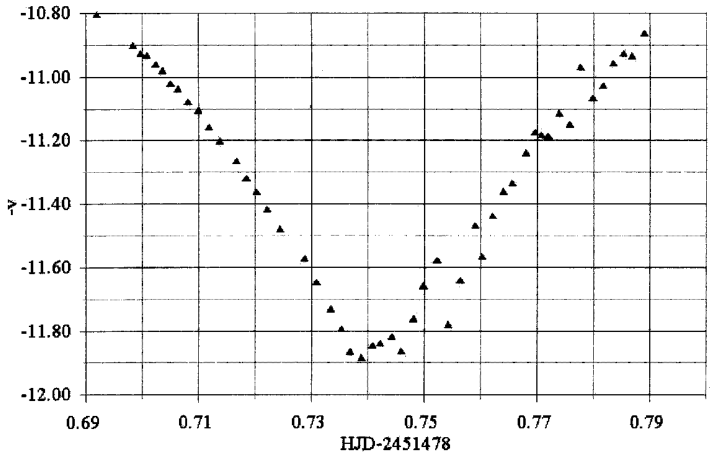

Figure 3. Primary minimum of the 1.07-day Beta Lyrae-type binary VX Lacertae.

The selection of comparison stars generally followed the recommendations of Henden & Kaitchuck (1982). The main consideration was that the difference in brightness between variable and comparison be less than 2 magnitudes; the matching of spectral types (where known) was a secondary consideration.

The quoted error for each time of minimum is the standard deviation of times obtained by the various methods. The greatest source of error by far is spatial variations in thin cloud that act differentially on variable and comparison in a random way (see comments below). Other effects are imperfect flat-fielding (and the drifting of stars on the image), non-linearity from the anti-blooming gate, limitations in the length of observing run (by dawn or dusk, clouds or other problems), and miscellaneous noise in data reduction. Unless otherwise noted, the identification of the type of minimum was from Samolyk (1999).

The light curve for Z Dra is shown in Figure 1. Over the last nine data points, the absorption by thin clouds increased to 0.25 magnitudes.

The light curve for ST Per is shown in Figure 2. Absorption by thin clouds was less than (or constant to) 0.06 magnitudes.

The light curve for VX Lac is shown in Figure 3. Here the sky was photometric up to JD 0.72; the absorption by clouds increased by 2 magnitudes in the interval from JD 0.72 to about 0.74; it remained constant (with fluctuations) thereafter. In solving for the time of minimum, one of the methods was to fit the reflected (smooth) descending portion of the curve to the noisy ascending part by least squares; the JD of the reflection axis agreed with mean of times of minimum obtained by other methods to 0.0001 days.

This combination of a 61-cm telescope and a moderately priced unfiltered CCD camera has yielded some good to excellent light curves around times of minima, some taken in marginal conditions. With less than photometric skies, the method is clearly superior to single-channel photometry (see Nelson, 1998) where no results would be possible at all. In the case of photometric skies, very accurate times of minimum (to a precision of a few seconds) can and have been determined.

It is a pleasure to acknowledge the assistance of the AAVSO Eclipsing Binary Ephemeris, (prepared each year by Gerald Samolyk) which greatly helped the author plan observing sessions. Thanks are also due to Dr. Michael Newberry who has developed a fine CCD data reduction and analysis tool in MIRA and has responded promptly to problems and suggestions for improvement. The author is also a Guest User, Canadian Astronomy Data Centre, which is operated by the Dominion Astrophysical Observatory for the National Research Council of Canada's Herzberg Institute of Astrophysics.

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ERRATUM FOR IBVS 4840

In IBVS 4840, the correct time of minimum for AG Vir should be 51281.8282 ± 0.0006 (the original value reported was out by one hour).

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