Times of Minima for Several Eclipsing Binaries and New Ephemerides for V569 Lyrae, V571 Lyrae, and V572 Lyrae

A. Marchini
University of Siena Astronomical Observatory, Siena, Italy; and Sezione Stelle Variabili UAI-GRAV; stellevariabili@uai.it

M. Banfi
Nova Milanese Astronomical Observatory, via Cesare Battisti 26, Nova Milanese, Milano 20054, Italy; and Sezione Stelle Variabili UAI-GRAV

M. Cena
Torgnon Astronomical Observatory, Valle d'Aosta, Italy; and Sezione Stelle Variabili UAI-GRAV

G, Corfini
Corfini Astronomical Observatory, Lucca, Italy; and Sezione Stelle Variabili UAI-GRAV

S. Mandelli
Seveso Astronomical Observatory, Seveso, Italy; and Sezione Stelle Variabili UAI-GRAV

G. Marino
Skylive and Gruppo Astrofili Catanesi, Catania, Italy; and Sezione Stelle Variabili UAI-GRAV

R. Papini
San Casciano Astronomical Observatory, San Casciano, Italy; and Sezione Stelle Variabili UAI-GRAV

D. Premoli
Seveso Astronomical Observatory, Seveso, Italy; and Sezione Stelle Variabili UAI-GRAV

S. Santini
Santini Astronomical Observatory, Prato, Italy; and Sezione Stelle Variabili UAI-GRAV

S. Valentini
Marana Astronomical Observatory, Marana di Crespadoro, Italy; and Sezione Stelle Variabili UAI-GRAV

M. Vincenzi
Poggio Ameno Astronomical Observatory, Roma, Italy; and Sezione Stelle Variabili UAI-GRAV

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Abstract We present several CCD minima observations of eclipsing binaries. New ephemerides are given for V569 Lyrae, V571 Lyrae, and V572 Lyrae.

1. Introduction

The accompanying table (Table 2) contains times of minima for fourteen eclipsing binary stars calculated from CCD observations made by participants in the Sezione Stelle Variabili-Unione Astrofili Italiani-GRAV (SSV-UAI-GRAV) Eclipsing Binaries Program. The whole set of data was acquired between July 2005 and July 2010. All the observatories are located in Italy; one is managed by the Physics Department of the University of Siena, while the others are privately operated. The observations were reduced following standard procedures (see next section) and the light curves were analyzed using the Kwee-van Woerden algorithm (Kwee and van Woerden 1956) to determine the times of minimum. This algorithm also provides an error estimate. All the times of minima listed in this paper are heliocentric.

2. Instruments and data reduction

Table 1 shows, for each observer contributing to this study, the instrument and detector used. Frame calibration (dark subtraction and flat field correction) and photometric analysis (differential photometry on each image) were mainly performed using MAXIM-DL and AIP4WIN software packages; in a few cases IRIS and ASTROART were used.

3. Minimum determination

The times of minima, expressed as heliocentric Julian days (Table 2), were computed adopting the KW method (Kwee and van Woerden 1956) mainly using AVE (Barberá 1996) software; PERANSO (Vanmunster 2007) and KWEE, a DOS program available from the AAVSO (2000), were also used on some occasions.

The types of minimum quoted in Table 2 for V569 Lyr and V571 Lyr were deduced according to our updated elements (see below). For the other stars, the type of minimum was deduced by adopting the ephemerides provided by Kreiner (2004).

4. Individual cases: V569 Lyr, V571 Lyr, and V572 Lyr

4.1. V569 Lyr

For V569 Lyr, which is not included in Kreiner's database, only three times of minimum were found in the literature, reported by Diethelm (2001) and Nelson (2002). Diethelm (2001) did not specify the types of his two ROTSE1 minima, while Nelson (2002) assumed his minimum to be primary. These three times of minimum are consistent with a period of 0.62 day or 1.24 days. Our minima, however, lead us to discard the 0.62-day period.

In order to derive the ephemeris of this star, the linear best fit of the O–C vs. the epoch for the available times of minimum was computed, leaving the initial epoch and period free to vary. Assuming that the primary is the deeper minimum, we obtain the following new ephemeris:

$$T_{min}\ (\mathrm{HJD}) = 2451274.5520\ (\pm\ 0.0045) + 1.2397626\mathrm{d}\ (\pm\ 0.0000018)\ E \qquad (1)$$

With this ephemeris, the minimum given by Nelson (2002) has to be considered as secondary. Figure 1 shows the O–C diagram obtained by adopting our ephemeris.

Note that O–C of our minima and that of Nelson minima are nearly zero (within the errors), as can be seen in Figure 1. For the ROTSE1 minimum times, the O–C are instead much larger than their errors. At this stage, the data available do not allow us to establish whether the large O–C residuals are due to period variations or whether they are the result of the data quality.

4.2. V571 Lyr

V571 Lyr is not included in Kreiner's database. To study the behavior of the O–C, our data were analyzed together with the only two times of minimum present in the literature (Diethelm 2001).

Our minima are consistent with the period of $\simeq$ 1.25 days given by Diethelm (2001), and they turn out to be primary, in accordance with the types of Diethelm's minima. This period is about double that originally reported in the ROTSE1 catalog (Akerlof *et al.* 2000). However, using p = 0.62d, it is not possible to justify the secondary type given by Diethelm to one of his two minima.

The linear best-fit of the O–C allows us to greatly improve Diethelm's ephemeris, obtaining:

$$T_{min}\ (\mathrm{HJD}) = 2451303.2009\ (\pm\ 0.0037) + 1.2525883\mathrm{d}\ (\pm\ 0.0000022)\ E \qquad (2)$$

The O–C diagram obtained with the new ephemeris is shown in Figure 2. Note that the errors given by the KW method are internal formal errors, which are typically underestimated with respect to actual uncertainties (Nelson 2009). This explains why the data scatter is larger than three times the 1-σ error bar, at least for the last points.

4.3. V572 Lyr

Figure 3 shows the O–C diagram for V572 Lyr computed using Kreiner's updated elements, including the two minima retrieved from the literature. The linear fit (dashed line in Figure 3) of our data and the previously published data leads to the following updated ephemeris:

$$T_{min}\ (\mathrm{HJD}) = 2452500.8459 + 0.9933045\ E \qquad (3)$$
$$\pm\ 0.0011 \pm\ 0.0000007$$

which is in agreement with the ephemeris reported in Kreiner's database within the errors.

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Table 1. Instruments and detectors.

Observer	*Instrument*	*Detector*
Banfi	Meade LX200 20cm F = 126cm	SBIG ST7E
Cena	Apochromatic William Optics 8cm F = 54cm	FLI Kaf 0402 Me
Corfini	Newton 11cm F = 90cm	CCD UAI-Sony ICX429ALL based
Mandelli	Meade LX200 20–25cm F = 200–250cm	SBIG ST8–ST9
Marchini	Meade LX200 25cm F = 160cm	Starlight Xpress SX-L8
Marino	Apochromatic Takahashi 9cm F = 51cm	SBIG ST8
Papini	Meade LX200 20–25cm F = 200–250cm	SBIG ST8-ST9
Premoli	Meade LX200 20–25cm F = 200–250cm	SBIG ST8-ST9
Santini	Celestron Celestar 20cm F = 200cm	Hisis22
Valentini	Celestron 23cm F = 235cm	FLI-CM9
Vincenzi	Meade LX200 20–25cm F = 200–250cm	SBIG ST8-ST9

Table 2. Times of minima of selected eclipsing binary stars.

Star name	*Time of min. HJD 2400000+*	*Error*	*Type*	*Filter*	*Observer*
TW And	53693.351	0.002	I	V	PRI
OO Aql	53962.3642	0.0004	I	—	MST
	54034.327	0.002	I	V	VST
	54300.392	0.003	I	—	MST
	54656.4111	0.0002	II	V	MST
	54689.3531	0.0002	II	V	MST
	55028.3984	0.0002	II	—	MST
	55031.4389	0.0001	II	V	PDA
GU Cas	53579.459	0.0011	I	V	BMA
	53644.420	0.001	I	V	PRI
	53644.422	0.0031	I	V	BMA
	53706.289	0.002	I	V	BMA
	53706.290	0.003	I	—	MST
	53712.482	0.002	I	V	BMA
	53944.479	0.002	I	V	BMA
	53947.569	0.003	I	—	MST
	53975.4083	0.0004	I	V	PRI
	54278.553	0.004	I	—	BMA
	54306.3941	0.0006	I	—	VST
	54309.4852	0.0003	I	V	BMA
	54405.383	0.001	I	V	VST
	54340.419	0.002	I	V	VST
DO Cyg	53933.430	0.0011	I	—	SSI
YY Del	55118.4198	0.0002	I	—	CGI
IK Her	53983.349	0.004	I	V	VST
V400 Lyr	55021.4022	0.0008	I	—	CGI
	55021.5293	0.0008	II	—	CGI
V569 Lyr	54288.4147	0.0009	I	V	BMA
	55372.588	0.001	II	g	MAR
	55374.448	0.001	I	g	MAR
	55379.4064	0.0004	I	V	MXI
	55382.5059	0.0002	II	V	MXI
V571 Lyr	53932.389	0.002	I	V	BMA
	53937.3933	0.0002	I	—	MST

Table continued on next page

Table 2. Times of minima of selected eclipsing binary stars, cont.

Star name	*Time of min. HJD 2400000+*	*Error*	*Type*	*Filter*	*Observer*
	54299.3881	0.0006	I	—	SSI
V572 Lyr	53894.449	0.004	I	V	BMA
	53897.431	0.001	I	V	BMA
	53899.4171	0.0004	I	—	MST
	53900.4056	0.0007	I	—	SSI
	53901.3978	0.002	I	V	PRI
	53902.4000	0.0004	I	V	PRI
	53955.5439	0.0004	II	—	MXI
	53969.4439	0.0004	II	—	MST
	53970.442	0.002	II	V	PRI
	53971.4324	0.0006	II	—	MST
	53971.4339	0.0003	II	V	MXI
	53971.4339	0.0005	II	V	PRI
	53974.4148	0.0003	II	V	MXI
	53979.3810	0.0007	II	V	PRI
	53980.3745	0.0002	II	V	MXI
	53980.375	0.001	II	V	PRI
	53982.3599	0.0007	II	V	PRI
	53983.3553	0.0002	II	V	PRI
	53984.3481	0.0004	II	V	PRI
	54062.3204	0.0006	I	V	MXI
	54062.3208	0.0006	I	V	VST
	54069.2764	0.0006	I	V	MXI
	54275.3850	0.0007	II	—	MST
	54277.3716	0.0006	II	—	MST
	54338.4596	0.0002	I	V	CEM
	54346.4052	0.0006	I	V	MST
	54354.3518	0.0002	I	V	MXI
	54355.3452	0.0007	I	V	MXI
	54359.3130	0.0004	I	—	MST
	54646.3857	0.0004	I	V	MST
	54648.3733	0.0004	I	V	MST
	54719.3923	0.0003	II	R	MST
	54720.3843	0.0004	II	B	MST
V576 Lyr	53913.4250	0.0003	I	—	MST
	54294.399	0.003	I	—	MST

Table continued on next page

Table 2. Times of minima of selected eclipsing binary stars, cont.

Star name	*Time of min. HJD 2400000+*	*Error*	*Type*	*Filter*	*Observer*
FZ Ori	54093.461	0.002	II	—	MST
	54094.4599	0.0004	I	—	MST
	54116.4557	0.0007	I	V	VST
	54128.459	0.001	I	R	VST
	54135.460	0.002	II	R	VST
	54527.4442	0.0005	II	V	MST
BO Peg	55070.3930	0.0002	I	—	VMA
	55077.3651	0.0001	I	—	VMA
GQ Tau	54438.3654	0.0001	I	V	VST

Observers: BMA = M. Banfi; CEM = M. Cena; CGI = G. Corfini; MAR = G. Marino; MST = S. Mandelli; MXI = A. Marchini; PRI = R. Papini; PDA = D. Premoli; SSI = S. Santini; VST = S. Valentini; VMA = M. Vincenzi.

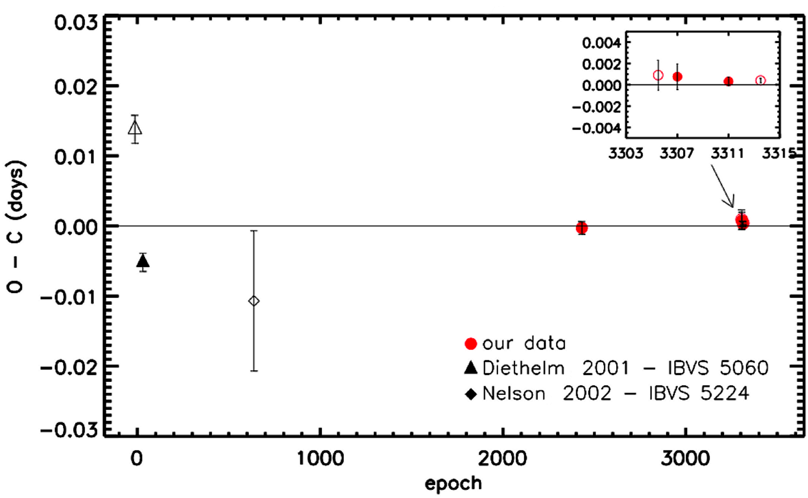

Figure 1. O–C diagram for V569 Lyr. Open symbols for secondary minima.

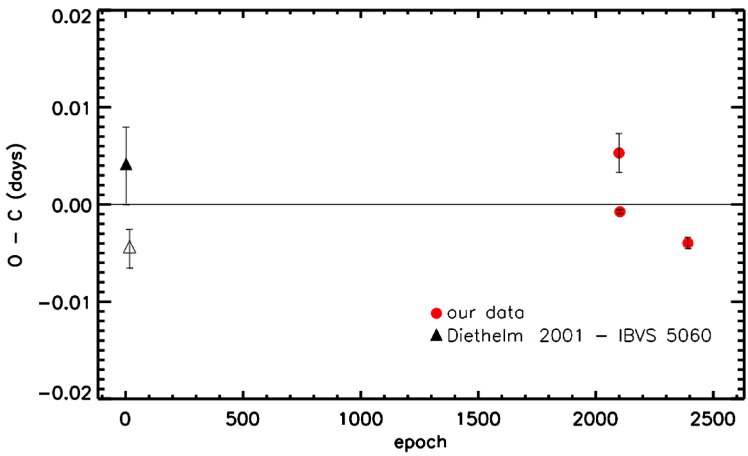

Figure 2. O–C diagram for V571 Lyr. Open symbols for secondary minima.

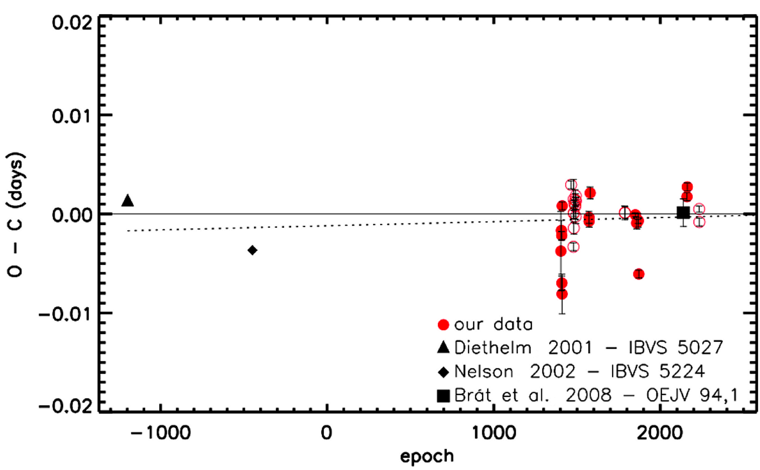

Figure 3. O–C diagram for V572 Lyr. Open symbols for secondary minima.