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First analysis of eight Algol-type binaries: EI Aur, XY Dra, BP Dra, DD Her, VX Lac, WX Lib, RZ Lyn, and TY Tri

P. Zasche*

Astronomical Institute, Faculty of Mathematics and Physics, Charles University in Prague, V Holešovičkách 2, Praha 8 CZ-180 00 Czech Republic

HIGHLIGHTS

- SWASP photometric data were used for a LC analysis of systems never studied yet.
- The second-order effects, like the third light, are also detectable in these data.
- EI Aur and BP Dra contain a large amount of the third light in the LC solution.
- The LC templates were used for deriving the sufficiently precise times of minima.
- XY Dra and VX Lac are probably triples with the periods of 18 and 49 years.

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ABSTRACT

The available photometry from the online databases were used for the first light curve analysis of eight eclipsing binary systems EI Aur, XY Dra, BP Dra, DD Her, VX Lac, WX Lib, RZ Lyn, and TY Tri. All these stars are of Algol-type, having the detached components and the orbital periods from 0.92 to 6.8 days. For the systems EI Aur and BP Dra the large amount of the third light was detected during the light curve solution. Moreover, 468 new times of minima for these binaries were derived, trying to identify the period variations. For the systems XY Dra and VX Lac the third bodies were detected with the periods 17.7, and 49.3 years, respectively.

1. Introduction

The role of eclipsing binaries in nowadays astrophysics is undisputable. We use the eclipsing binary systems (hereafter EB) for the most accurate determination of the stellar masses, radii, as distance indicators, or as classical celestial mechanics laboratories. We can test the stellar structure models even outside of our Galaxy, see e.g. Ribas (2004). In addition, also the hidden components can be studied via the dedicated observations of particular binaries as well as the dynamical effects in such multiple systems (Rappaport et al., 2013). Due to all of these reasons the photometric monitoring and analysis of the light curves of selected eclipsing binaries still presents a fruitful contribution to the stellar astrophysics.

On the other hand, the available photometry for many interesting eclipsing binaries exists, but some of these EBs were still not analysed yet. Hence, we decided to use mainly the Super WASP photometry (Pollacco, 2006) for a light curve analysis and derivation of new minima times for such systems, which were not studied before and their light curve solution is missing.

2. Analysis

The selection criteria for the binaries included in our study were the following. Only such binaries with known orbital periods were chosen, having no light curve solution published up to date, have enough data points for the analysis and also have several published times of minima. The last point was checked via an online archive of minima times observations, a so-called *O–C* gateway[1] (Paschke and Brát, 2006). Due to the very good time coverage provided by the Super WASP survey we used this database for the whole analysis of the light curve. The other databases such as NSVS (Woźniak et al., 2004), ASAS (Pojmanski, 2002), CRTS (Drake et al., 2009), or OMC (Mas-Hesse et al., 2004) were used only for deriving the times of minima for a subsequent period analysis. All of the studied systems are the northern-hemisphere stars of moderate brightness (10 mag $< V < 15$ mag) and with the orbital periods ranging from 0.9 to 6.8 days.

* Corresponding author. Fax.: +420221912577.
E-mail address: zasche@sirrah.troja.mff.cuni.cz

[1] http://var.astro.cz/ocgate/ .

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1384-1076/

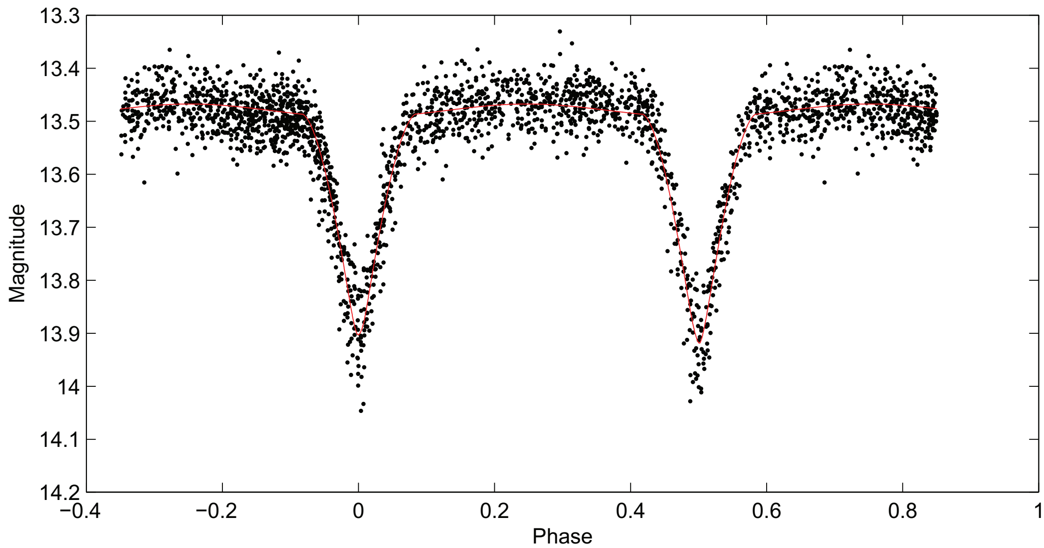

Fig. 1. Light curve analysis of EI Aur, based on the Super WASP photometry.

Table 1
The light-curve parameters as derived from our analysis.

Parameter	EI Aur	XY Dra	BP Dra	DD Her
JD_0 – 2,400,000	54050.6460 ± 0.0019	54597.5551 ± 0.0160	54659.5430 ± 0.0013	53165.3571 ± 0.0152
P [d]	1.2266930 ± 0.0000013	2.3152311 ± 0.0000342	0.9868093 ± 0.0000003	5.6433970 ± 0.0000061
i [deg]	87.67 ± 0.59	89.76 ± 0.40	86.97 ± 0.52	79.61 ± 0.35
T_1 [K]	6000 (fixed)	6500 (fixed)	6000 (fixed)	8800 (fixed)
T_2 [K]	6044 ± 38	4343 ± 34	5429 ± 41	4985 ± 50
Ω_1	4.847 ± 0.059	5.942 ± 0.039	5.312 ± 0.052	5.354 ± 0.022
Ω_2	5.181 ± 0.072	4.619 ± 0.020	6.216 ± 0.063	10.671 ± 0.021
L_1 [%]	38.3 ± 0.5	83.7 ± 0.8	45.3 ± 0.9	93.7 ± 0.8
L_2 [%]	32.9 ± 0.7	16.3 ± 0.5	18.5 ± 0.8	6.3 ± 0.6
L_3 [%]	28.8 ± 0.7	0.0 ± 0.0	36.2 ± 0.4	0.0 ± 0.0

For analysing the light curves we used the PHOEBE program (Prša and Zwitter, 2005), which is based on the algorithm by Wilson and Devinney (1971). Having sometimes rather limited information about the stars, some of the parameters have to be fixed for the light curve (hereafter LC) solution. At first, the “Detached binary” mode (in Wilson and Devinney mode 2) was assumed for computing. The value of the mass ratio q was set to 1. The limb-darkening coefficients were interpolated from van Hamme’s tables (see van Hamme (1993)), and the linear cosine law was used. The values of the gravity brightening and bolometric albedo coefficients were set at their suggested values for convective or radiative atmospheres (see Lucy (1968)). Therefore, the quantities which could be directly calculated from the LC are the following: the relative luminosities L_i, the temperature of the secondary T_2, the inclination i, and the Kopal’s modified potentials Ω_1 and Ω_2. The synchronicity parameters F_1 and F_2 were also fixed at values of 1. The value of the third light L_3 was also computed if a non-negligible value resulted from the fitting process. And finally, the linear ephemerides were calculated using the available minima times for a particular system.

With the final LC analysis, we also derived many times of minima for a particular system, using a method as presented by Zasche et al. (2014). The template of the LC was used to fit the photometric data from the Super WASP as well as from other surveys. This set of minima times was then combined with the already published minima mostly taken from the O–C gateway (Paschke and Brát, 2006).

3. The individual systems

3.1. EI Aur

The system EI Aur (also GSC 02392–00102) was discovered by Hoffmeister (1936), who also classified the star as an Algol-type. Its orbital period is of about 1.2 days, but there was no light curve or any spectroscopic analysis performed. We can only roughly estimate its type from the color indices, hence we fixed the primary temperature at a value of 6000 K for the whole fitting process.

The Super WASP photometry revealed that it is a detached system, having both minima of roughly equal depths. Therefore, the PHOEBE code was used to these data and the LC fit is presented in Fig. 1, while the LC parameters are given in Table 1. As one can see, the secondary component has almost the same temperature as the primary, hence there is still a doubt which of the minima is the primary one. Another interesting finding is the fact that relatively large contribution of the third light was detected in the LC solution. This would naturally explain why both the minima have only so shallow depths.

One can ask whether the third body detected in the LC solution is somehow gravitationally bounded with the eclipsing pair or is it just a coincidence as a so-called optical binary. We also derived the times of minima from the Super WASP photometry and plotted them together with the already published ones in Fig. 2. As one can see, there is no obvious variation in the times of minima. The data