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RW LACERTAE: A NEW PHOTOMETRIC TRIPLE STAR

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The detached eclipsing binary RW Lacertae (GSC 3629.0740 = AN 34.1910 = FL 3421; $\alpha_{2000} = 22^{\rm h}44^{\rm m}57\overset{\rm s}{.}1$, $\delta_{2000} = +49^\circ39'28''$, Sp. G5V + G7V, $V_{\rm max} = 10.6$ mag) is a relatively well-known binary with a slightly eccentric orbit ($e \simeq 0.01$) and a rather longer orbital period about 10.4 days. This system was selected as a possible candidate for the study of the apsidal motion (Giménez 1994) and thus it was also included to our long-term observational project of monitoring of eclipsing binaries with eccentric orbits (f.e. Wolf et al. 1998).

RW Lac was discovered to be a variable star photographically by Gaposchkin (1932). Later Martinoff (1938) derived the correct period of 10.36922 days and recognized the eccentric orbit. See also history of work on this binary in Lacy et al. (2005). Due to the relatively long orbital period and slow magnitude changes this variable was not often observed visually. Recently, Lacy et al. (2005, hereafter LTCV) in their comprehensive spectroscopic and photometric study derived the absolute dimensions of the components with high precision. They obtained $M_1 = 0.928 \pm 0.006\ M_\odot$ and $M_2 = 0.870 \pm 0.004\ M_\odot$ for masses and $R_1 = 1.186 \pm 0.004\ R_\odot$ and $R_2 = 0.964 \pm 0.004\ R_\odot$ for radii of primary and secondary component, respectively. They also derived the following linear light elements:

$$\text{Pri. Min.} = \text{HJD } 24\ 52253.66551(37) + 10\overset{\rm d}{.}3692046(17) \times \text{E}.$$

Our new CCD photometry of RW Lac was carried out during three nights between November 2003 and October 2005 at the Ondřejov and Brno observatories and the private observatory of L.B. in Pec pod Sněžkou, Czech Republic. A 65-cm reflecting telescope with a CCD camera Apogee AP7, 25-cm reflector with a CCD camera SBIG ST7 and 20-cm Cassegrain with a camera SBIG ST8 were used in Ondřejov, Brno and Pec, respectively. The measurements were done using the standard R filter with 35 or 60 s exposure time. The nearby stars GSC 3629.0796 ($V = 11.2$ mag) on the same frame as RW Lac served as a primary comparison star. See also `http://nyx.asu.cas.cz/~lenka/dbvar/` for more information. The new times of primary minimum and their errors were determined using the least squares fit of the data, by the bisecting chord method or by the

Table 1: New times of primary minimum of RW Lac.

JD Hel.- 24 00000	Epoch	Error (days)	N	Telescope, camera, filter
52948.40127	67.0	0.00015	250	65-cm, AP7, R
53259.47934	97.0	0.00030	40	25-cm, ST7, R
53653.5130	135.0	0.0015	145	20-cm, ST8, R
53653.5147	135.0	0.0002	200	25-cm, ST7, R

Kwee-van Woerden algorithm. These times of minimum are presented in Table 1. In this table, N stands for the number of observations used in the calculation of the minimum time. The epochs were calculated according to the light elements of LTCV. Figure 1 shows the differential R magnitudes during the primary minimum observed at JD 24 52948.

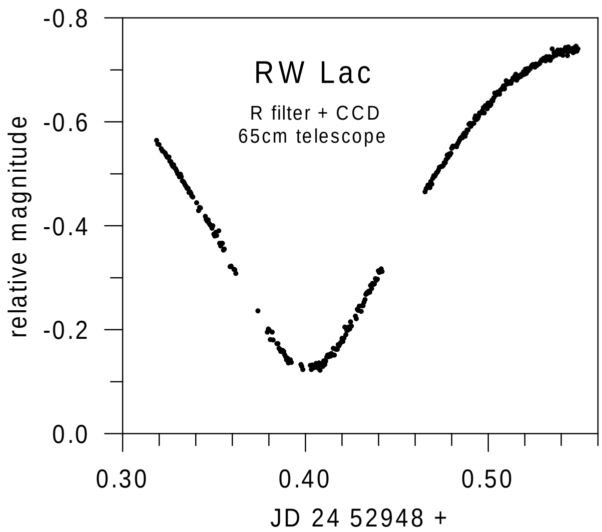

Figure 1. A plot of differential R magnitudes obtained during primary eclipse of RW Lac on November 4, 2003 at Ondřejov.

The change of period and possible apsidal motion of RW Lac were studied by means of an $O-C$ diagram analysis. We can confirm the result of LTCV, that the apsidal motion is not clearly detectable in this eccentric system. We adopted only the relativistic contribution $\dot{\omega}_{rel} = 0.000\ 17$ deg/cycle according to the eccentricity and masses of both components (Giménez 1985). Our reduction procedure was following:

1. For the orbital period P, zero epoch T_0 and the corresponding position of periastron ω_0 of the eclipsing pair we took in consideration all visual and photographic times of minima found in the literature (see Kreiner et al. 2001) as well as new times given in LTCV and our results (see also current $O-C$ diagram on Fig. 1 in LTCV). We found

$$
\begin{aligned}
T_0 &= \text{HJD } 24\ 52253.6332(8) \\
P &= 10.369209(3) \text{ days} \\
\omega_0 &= 161.3\ (2.5) \\
e &= 0.0118\ (2)
\end{aligned}
$$

2. Subtracting the influence of the eccentric orbit and very slow apsidal motion, sinusoidal deviations of the $O-C$ values are well remarkable and could be caused by a light-time effect. For its solution we used only the new photoelectric or CCD timings obtained after JD 24 51000 given originally in Lacy et al. (1999), Lacy et al. (2001) and Lacy (2002) - recalculated in LCTV - and our own CCD times given in Table 1. A preliminary analysis of the third body circular orbit gives the following parameters:

P_3 (period)	$= 2670 \pm 240$ days
	$= 7.2 \pm 0.7$ years
T_3 (time of conjunction)	$=$ J.D. 2450925 ± 40
A (semi amplitude)	$= 0.0052 \pm 0.0006$ day
e_3 (eccentricity)	$= 0$ (fixed)

These values were obtained by the least squares method. The $O-C_2$ diagram is plotted in Fig. 2. Only the primary minimum at HJD 24 52253.66687 - given first in Lacy (2002) and recalculated in LTCV - has a relatively large $O-C$ deviation of about $-$ 0.0029 days, i.e. approx. 15 times of the given error.

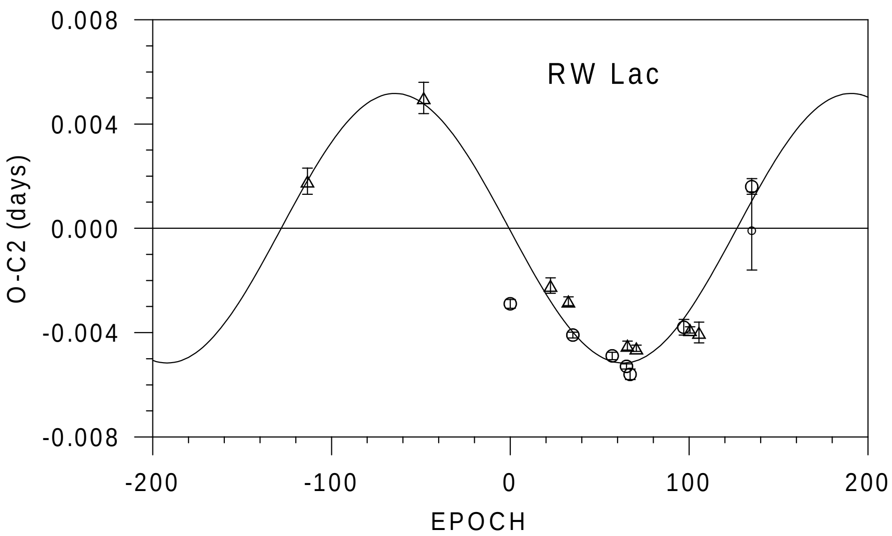

Figure 2. $O-C2$ diagram for RW Lac after removing the influence of the eccentric orbit. The individual times of primary and secondary minimum are denoted by circles and triangles, resp. For very precise timings the error bars are inside the circles. The curve corresponds to the third body orbit.

Assuming a coplanar orbit ($i_3 = 90°$) and a total mass of the eclipsing pair with G5 primary and G7 secondary, $M_1 + M_2 = 1.798\ M_\odot$ (LTCV), we can obtain a lower limit for the mass of the third component $M_{3,\rm min}$. The present explanation is supported by the quite reasonable value of the mass function $f(M) = 0.0137\ M_\odot$, from which the minimum mass of the third body follows as 0.41 $M_\odot$. A possible third component of spectral type M1 with the bolometric magnitude of $m_3 = 8.3$ mag (Harmanec 1988) produces the third light of $L_3 = 1.8\%$. Moreover, this value is in good agreement with the third light contribution of about 2% resulting from the light-curve analysis of LTCV.

Our result indicates, that RW Lac is probably next member of an interesting group of triple eccentric eclipsing binaries (f.e. RU Mon, U Oph, YY Sgr and DR Vul) deserving a regular monitoring. Only a relatively small part of the third body orbit is well-covered by the precise observations. Therefore, new high-accuracy timings of this eclipsing system are necessary in order to confirm the light-time effect and its parameters given above.

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