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V407 Peg AND LU Vir: TWO CONTACT BINARIES WITH DISPLACED SECONDARY MINIMA

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The role of eccentric eclipsing binaries in modern stellar astrophysics is undisputed. There are a few binaries, however, which are not eccentric, but show displaced secondary minima nevertheless. If one has no information about their light curve, one can consider the eccentricity only on the basis of the $O-C$ diagram of all available minima of a particular system. Due to the increasing number of CCD observations of minima, some systems were discovered with short period but displaced secondary minima.

The process of circularization is rather rapid in those binaries, which are close. Eccentric orbits are common in well-detached binaries with longer periods, or in systems which are very young. When the system is semi-detached or even contact, the nonzero eccentricity is extremely improbable. Therefore any discovery of a short period binary with displaced secondary minima (i.e. $\phi_2 \neq 0.5$ with respect to the primary) has to be considered very carefully.

The system **V407 Peg** (= GSC 01720-00658, V = 9.28 mag, sp F1) is a typical W UMa-type eclipsing binary. It was discovered by Maciejewski et al. (2002), showing two minima of almost equal depths. However even in the discovery paper it was noted that the secondary minimum is located in phase 0.52. The secondary minima occurred about 0.015 days later than phase 0.5. This is rather unusual for a W UMa type binary.

A detailed analysis was done by Maciejewski et al. (2003) and Rucinski et al. (2008). These complete analyses show that the inclination is about 73 deg and the masses are 1.53 and 0.39 for the primary and secondary, respectively. The observed asymmetry of the LC was explained by a photospheric hot spot. This spot also distorts both minima and also the maxima of the LC (O'Connell effect).

We collected all available (published) times of minima of V407 Peg. For a prospective analysis we need as many minima times as possible. Therefore, we also used the data for this target obtained by the automatic photometric monitoring system ASAS (Pojmanski, 2002). The star was also observed by the Pi of the Sky (Burd et al., 2005). Thanks to these observations, many new minima times were derived. A collection of all available times of minima is given in Table 1. These minima follow a linear ephemeris with the orbital period of 0.636883915 day.

Thanks to these minima one is able to study a potential long-term variation of the LC. The changing position of the spot on the surface is able to modulate the shape of the minima, and therefore also the position of primaries versus secondaries in the

$O - C$ diagram (plotted in Fig. 1). As one can see, the difference between primary and secondary minima is still visible and is not changing significantly. Some of the points have rather large errors, but still one can speculate about some year-to-year differences. For example the first data point from 2003 and the following ones from 2004 show a non-negligible difference. For a detailed evolution of the spot or other processes in the system a more detailed year-by year LC analysis would be desirable.

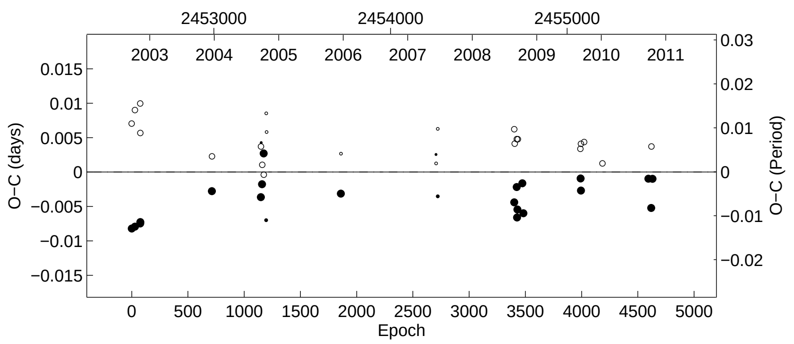

Figure 1. $O - C$ diagram of V407 Peg dots stand for primary and open circles for the secondary minima.

The shape of the LC taken from ASAS data is plotted in Fig. 2. As one can see, both minima are distorted and asymmetric. The bottom parts of minima (probably total eclipses) are not flat either, but rather inclined. As a result it is complicated to derive a precise time of minimum from the observed data. Most of the often used methods for minima computation are based on symmetric minima (e.g. Kwee-van Woerden, bisector chord method or polynomial fitting). Thus, using the data points with different slope of ascending and descending branch makes the application of these methods rather questionable and affects the result.

Table 1: Collected times of minima. The full table is available electronically. Sources: Brát et al. (2008, 2011); Nagai, K. (2003, 2004, 2005, 2008, 2009, 2011); Yilmaz et al. (2009), Perryman et al. (1997).

Star	HJD-2400000	Error	Type	Filter	Source
V407 Peg	52534.2999	0.0014	II	V	IBVS 5343
V407 Peg	52534.6031	0.0008	I	V	IBVS 5343
V407 Peg	52552.7715	0.0013	II	V	IBVS 5343
...					
LU Vir	48085.9734	0.0023	I	Hp	Hipparcos
LU Vir	48085.7456	0.0021	II	Hp	Hipparcos
LU Vir	48727.8604	0.0025	I	Hp	Hipparcos
...					

The second system is **LU Vir** (= HD 116914 = HIP 65590, V = 7.78 mag, sp A0). It is also a W UMa or β Lyrae star, but lacking a detailed analysis. Unlike the case of V407 Peg neither the LC nor the radial velocity curve were studied and a period analysis is missing too. The orbital period of the system is 0.492240615 day.

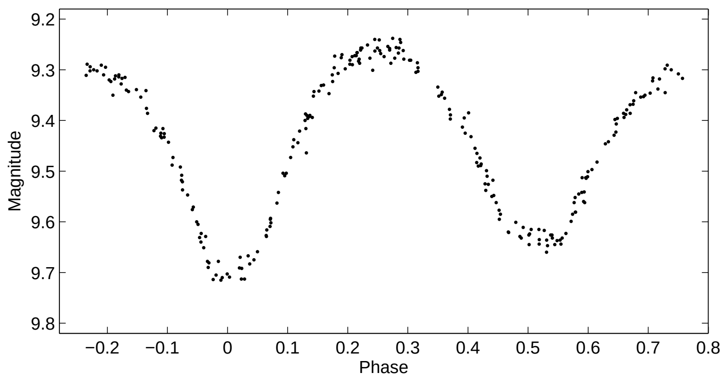

Figure 2. V light curve of V407 Peg from ASAS.

We collected all available published times of minima, these are given in Table 1. Some of the published minima are not included because we used the original data and recalculated the minima (these apply for the Hipparcos and "Pi of the Sky" data). The $O-C$ diagram of these minima is plotted in Fig. 3, where one can clearly see the difference between primary and secondary minima over a time span of almost two decades. The precision of individual observations is questionable, therefore a possible variation of displacement of secondary minima with time is still problematic to detect. New and more precise observations are needed to confirm some possible variation of the LC.

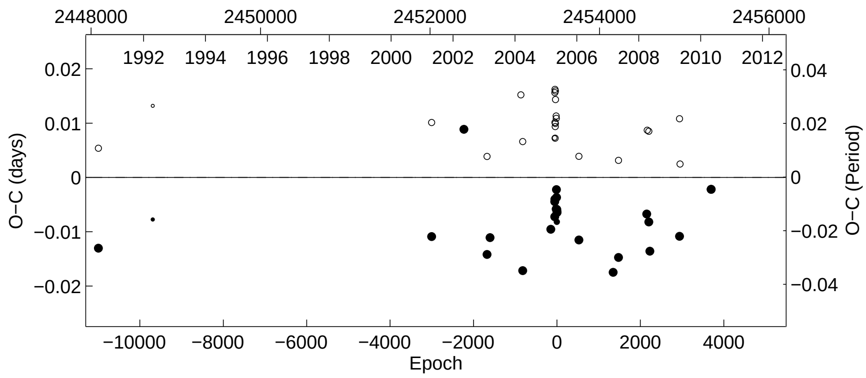

Figure 3. $O-C$ diagram of LU Vir.

The light curve of LU Vir is asymmetric in the same way as that of V407 Peg. We can see the curve in Fig. 4, where the primary minimum with its total eclipse is clearly distorted and the flat part is inclined. Thus the derivation of minima times is affected by asymmetry and the use of standard routines for minimum computation is problematic.

To conclude, in both systems the displaced secondary minima are very probably caused by asymmetry of the light curve, which is not changing significantly over a time span of more than a decade. It could be produced by an accreting hot spot from a stream of material flowing from one component to another, which is a rather common phenomenon in such semidetached or contact binaries.

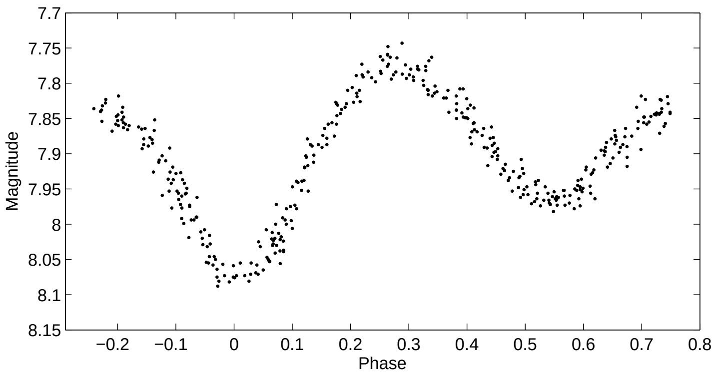

Figure 4. *V* light curve of LU Vir from ASAS.

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