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# A CONTACT BINARY SYSTEMATICALLY CHANGING ITS BRIGHTNESS

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The OGLE–II project has led to discovery of over 200,000 variable stars in the region of the Galactic Bulge (Wozniak et al. 2002). Most of this material remains to be analysed. In the course of a casual survey of the results by the second of us, a W UMa-type binary systematically changing its brightness has been noted. The star, BUL_SC27_506 (OGLE–II Bulge Scan 27, Star 506) is located at J2000: $17^{\rm h}48^{\rm m}02^{\rm s}.67$, $-35^\circ 28' 20''.8$. The photometric data in the $I$–band are available from the OGLE Internet site:
`ftp://bulge.princeton.edu/ogle/ogle2/bulge_dia_variables/plain_text/`
`/BUL_SC27/bul_sc27_506.dat.gz`.

Figure 1 shows the $I$-band magnitudes of the star over the three year span of the OGLE–II project. One can note the 0.1 – 0.12 magnitude wide band of the eclipsing-star variability superimposed on a climbing trend over the duration of the project. The observations were obtained typically once per night and were rather evenly distributed over time within each of the visibility seasons of 1997, 1998 and 1999. The photometric data have been analysed for the periodic content, giving the orbital period of $P = 0^{\rm d}.403586 \pm 0^{\rm d}.000007$. The same data, but expressed in flux units for an easier inter-comparison of the brightness variations between the seasons, are shown in a phase plot in Figure 2; the magnitude $I_0 = 15^{\rm m}.43$ has been assumed as the reference level. The initial epoch was set at $T_0 = 2,450,551.861 \pm 0.008$. This epoch is very preliminary as the moments of the apparent light minima are obviously affected by the evolving stellar spots. At this moment, there is no information on the colour index of the star and on the amount of reddening, so that we cannot evaluate $M_V$ for the system nor its distance. Judging by the orbital period and using the period – colour relation, any value within $0^{\rm m}.35 < (V-I)_0 < 1^{\rm m}.2$ appears to be possible, giving the likely distance within $1.5 < d < 4$ kpc (or less, if the reddening is large).

The three light curves shown in Figure 2 correspond to the three observing seasons 1997 – 1999. Each of the seasonal light curves has been Fourier decomposed into a 5-term cosine series with one sine term (to capture the light curve asymmetry), $l(\phi) = \sum_{i=0}^{4} a_i \cos(i2\pi\phi) + b_1 \sin(2\pi\phi)$. The coefficients are given in Table 1. The second line for each season gives the standard mean errors of the coefficients estimated using the "bootstrap" method. Only $a_2$, $b_1$, and $a_1$ for the first season significantly differed from zero, indicating the well-known low information content of light curves of partially-eclipsing

**Table 1. Fourier coefficients and their errors of the light curve decomposition.**

| Year | $a_0$ | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $b_1$ |
|---|---|---|---|---|---|---|
| 1997 | 0.8992 | −0.0051 | −0.0338 | −0.0005 | 0.0000 | −0.0225 |
| | 0.0011 | 0.0014 | 0.0012 | 0.0014 | 0.0016 | 0.0014 |
| 1998 | 0.9309 | 0.0022 | −0.0329 | −0.0014 | −0.0015 | 0.0016 |
| | 0.0021 | 0.0025 | 0.0022 | 0.0033 | 0.0026 | 0.0034 |
| 1999 | 0.9553 | 0.0017 | −0.0347 | 0.0000 | −0.0024 | −0.0059 |
| | 0.0016 | 0.0021 | 0.0021 | 0.0023 | 0.0024 | 0.0022 |

W UMa systems. The light curve evolved over time during each of the seasons, so that part of the scatter in the seasonal light curves and the low accuracy of the Fourier coefficients was obviously due to the stellar spot evolution. As one can directly see in Figure 2, but also through a comparison of the first cosine and sine terms, the light curve changed from an asymmetric one with a well defined primary deeper eclipse in 1997 into somewhat similar light curves with equally deep minima, but with different mean light levels. The largest changes took place at the first minimum, apparently in relation to a slow disappearance of a large spot or of a group of spots. The overall changes caused by the spots were comparable those due to the eclipsing effects and amounted to about 10%. This has an important implication for the $M_V = M_V(\log P, CI)$ calibrations for the W UMa-type systems (where $CI$ is for a colour index, such as $B-V$ or $V-I$; Rucinski 1994, Rucinski & Duerbeck 1997) and directly illustrates the inherent limitations of these calibrations.

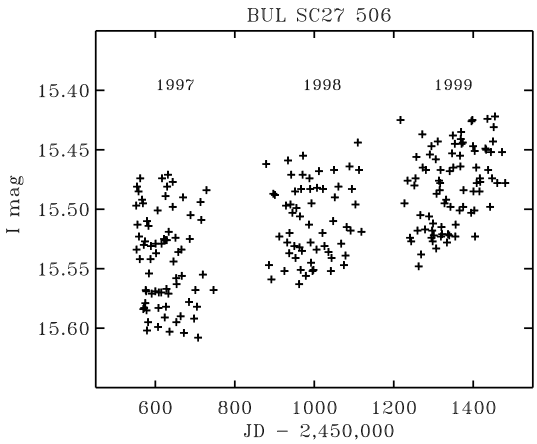


**Figure 1.** The $I$-magnitude OGLE–II observations of BUL_SC27_506 in three seasons 1997 – 1999.

Large changes of the *shape* of the light curves of W UMa-type systems have been noticed before. They have been normally explained by changes in the surface distribution of dark stellar spots. The particularly large light curve shape changes, with quasi-periodic mutual eclipse interchanges within only 3.5 years, were observed for TZ Boo (Hoffmann 1980). However, the case described here is – we believe – the first one where the changes *in the shape and in the light level* are very clearly visible in a continually monitored contact binary. This is due to the extended nature and high photometric stability of the OGLE–II program. Clearly, the more distorted light curve of 1997 was associated with a lower level of brightness. As the spots receded over 1998 – 1999, the brightness level increased and the light curves became more symmetric.

The time scales of the spot activity build-up and decay in W UMa-type binaries are currently unknown, but are of great interest because the solar-type component stars rotate typically 80 – 120 times faster then the Sun. Yet, the time scale of the spot re-organisation does not seem to be very dissimilar from the solar cycle of 11/22 years. The micro-lensing projects, such as OGLE, or similar project aimed at studying stellar-variability for very large numbers of stars, appear to be ideal in resolving several questions related to activity in very close binary stars with components spun up to very high rotation rates by tidal forces. Not only that such systematic surveys can answer the questions on the duration of activity cycles, but also the basic question of the overall statistics can be addressed: How prevalent are the spots? What percentage of the binaries suffer from them at a given time? How large are the typical systematic brightness changes? How do these activity-cycle variations relate to the binary star physical parameters?

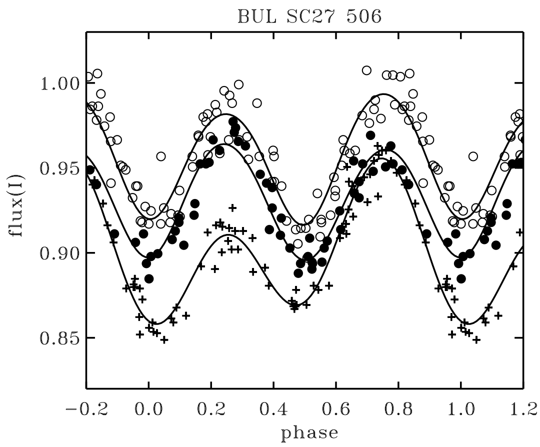


**Figure 2.** The phased observations of BUL_SC27_506 with the period and the initial epoch as in the text. The brightness is expressed in flux units with the reference level $I_0 = 15.43$. The seasonal curves are for 1997 (crosses), 1998 (filled circles) and 1999 (open circles). The continuous lines give the Fourier fits, with the coefficients given in Table 1.

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