TYC 1031 01262 1: the first known Galactic eclipsing binary with a Type II Cepheid component

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ABSTRACT

We present the discovery and CCD observations of the first eclipsing binary with a Type II Cepheid component in our Galaxy. The pulsation and orbital periods are found to be 4.1523 and 51.38 d, respectively, i.e. this variable is the system with the shortest orbital period among known Cepheid binaries. Pulsations dominate the brightness variations. The eclipses are assumed to be partial. The EB-subtype eclipsing light curve leads us to believe that the binary components are non-spherical.

Key words: binaries: close – binaries: eclipsing – Cepheids.

1 INTRODUCTION

At present, we know of three Type II Cepheids that are components of short-period binary systems. They are TX Del (with an orbital period of 133 d), IX Cas (110 d) (Harris & Welch 1989) and AU Peg (53.3 d) (Vinkó, Szabados & Szatmáry 1993). The binary separations in these systems are near the possible minimum for the size of a Type II Cepheid. Tidal forces influence the pulsating components of such systems, and it is even possible that their pulsations are excited by tidal effects (Harris, Olszewski & Wallerstein 1984). The orbital inclinations of these binary systems relative to the terrestrial observer do not make them eclipsing.

Three long-period eclipsing binary systems with Type I or II Cepheid components have been discovered in the Large Magellanic Cloud by the OGLE and MACHO microlensing photometry programmes (Udalski et al. 1999; Alcock et al. 2002; Lepischak, Welch & Kooten 2004). The importance of the search for Cepheid members of eclipsing binaries is considerable. If an eclipsing binary is a double-line system, then the mass, radius and luminosity of the components can be directly determined from the analysis of the light and radial velocity curves. This gives us an opportunity to investigate the structure and evolution of Cepheids, to test the theories of pulsation and to calibrate independently the scale of distances and the Hubble constant (Guinan et al. 2005; Guinan & Engle 2006).

In the past, BM Cas was considered a candidate eclipsing binary with a Cepheid component in the Galaxy, but a detailed investigation by Fernie & Evans (1997) revealed that the out-of-eclipse light variations were non-periodic, inconsistent with the Cepheid classification.

In this Letter, we announce the discovery and present our CCD photometry of the first eclipsing Type II Cepheid in the Galaxy – a component of the binary with the shortest orbital period among similar systems.

2 OBSERVATIONS AND ANALYSIS

The variability of TYC 1031 01262 1 = ASAS 182611+1212.6 (\(\alpha = 18^\text{h} 26^\text{m} 11^\text{s} . 50, \delta = +12^\circ 12^\prime 34^\prime\prime. 8, J2000.0\)) was discovered several years ago in the All-Sky Automated Survey (ASAS-3) (Pojmański, Piłecki & Szczygiel 2005). The variability was independently discovered by the authors on Moscow archive plates taken with the 40-cm astrograph in the Crimea. The photographic phased light curve based on 120 eye estimates is given in Fig. 1. Moreover, observations of TYC 1031 01262 1 are contained in the Northern Sky Variability Survey (NSVS) data base (Woźniak et al. 2004). In all three cases, the data permit us to consider the new variable as a Cepheid with some peculiarity that is rather similar to multiperiodicity of unknown nature. However, the available data do not allow us to explain the observed light variations completely. For this reason, we started observations of the star in 2004 with the 50-cm Maksutov telescope of the Crimean Laboratory (Sternberg Astronomical Institute) equipped with a Pictor 416XTE CCD camera and Johnson V filter.

The observations continued for three years: 729 images on 17 nights in 2004 (July 4–29, JD 245 3191–216), 560 images on 13 nights in 2005 (July 1–19, JD 245 3553–571), and an additional 367 images on 24 nights in 2006 (July 4–August 2, JD 245 3921–950) were obtained. The images were dark-subtracted, flat-fielded and analysed with the aperture photometry software WINPITS developed by V. P. Goranskij. The comparison stars are marked in Fig. 2. To improve the accuracy of our photometry and to evaluate uncertainties, we used two comparison stars and averaged the obtained differential magnitudes, bearing in mind that \(V_{\text{comp1}} - V_{\text{comp2}} = 0.123\) mag. The accuracy of our photometry is about 0.017 mag. The data are available upon request. Combination of our results with the ASAS-3

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The data permits us to propose a suitable explanation of the variations observed for TYC 1031 01262 1. Note that we (1) used the ASAS-3 observations taken from the official web site of the project before the 2006 RAID problem, (2) made use of the third of the five columns of ASAS-3 data which corresponds to an aperture 4 pixels in diameter, and (3) assumed $V_{\text{comp}} = 13.12$ mag to make our $V$-band observations agree with the ASAS-3 ones.

Fig. 3 shows the suggested solution of the observed variability of TYC 1031 01262 1. Cepheid oscillations with the elements $\text{Max} = \text{HJD 245 3196.529 + 4.1523 d } \times E$

dominate in the light curve. Then the data were whitened for pulsations, and we found that the residuals could be well described by an eclipsing (EB-subtype) curve with the following light elements: $\text{Min} = \text{HJD 245 3571.36 + 51.38 d } \times E$.

The photographic and NSVS observations do not contradict the proposed interpretation. However, in these cases, the eclipsing light curves, after whitening the data for pulsations, are rather noisy.

3 DISCUSSION AND CONCLUSIONS

TYC 1031 01262 1 is definitely a Type II Cepheid. Using the $K$-band period–luminosity relations for Galactic classical Cepheids by Berdnikov, Voznyakova & Dambis (1996),

$M_K = -5.462 - 3.517 \times (\log P - 1)$,

$K_s = 9.525$ [from the Two-Micron All-Sky Survey (2MASS) catalogue] and the Galactic latitude $b = 11^\circ$, considering that the extinction in the $K$ band is not significant (less than 0.05 mag for the variable), we can estimate the distance from the Galactic plane as $Z \gtrsim 1$ kpc, in contradiction with the DCEP classification. Note...
that, even in the case of the extinction actually being large, the last
conclusion will not change.
For now, we have the following multicolour photometry of the
system: $B_T = 12.034 \pm 0.124$ and $V_T = 11.431 \pm 0.109$ from the
Tycho-2 catalogue (Høg et al. 2000); average $V = 11.353 \pm 0.016$
and $I = 10.530 \pm 0.012$ from The Amateur Sky Survey (TASS)
observations (Droege et al. 2006); $(V) = 11.376 \pm 0.010$ from
ASAS-3 data; $J = 9.998 \pm 0.020$, $H = 9.630 \pm 0.026$ and $K_S =
9.525 \pm 0.020$ taken on JD 245 1613.0243 (from 2MASS, Cutri
et al. 2003). The colours do not differ noticeably from those of a
single Type II Cepheid. Direct spectroscopy is required to determine
the spectral types of the components.
Our detection of eclipses and observations solely in the $V$
filter are only the first step in the investigation of this unique system. It
is necessary to continue observations of the variable star, and to
carry out multicolour photometry and spectroscopy to confirm the
derived orbital period in radial velocity variations and to determine
parameters of the binary system. The most similar non-eclipsing
binary system with a Cepheid component, AU Peg, shows a con-
siderably larger amplitude of the orbital radial velocity variation
than that for the pulsations, $\kappa = 44.7 \text{ km s}^{-1}$ versus the pulsational
semi-amplitude of about 13 km s$^{-1}$ (Samus, Rastorguev & Gorynja
1997). We can expect a similar situation in the case of TYC 1031
01262 1.
Judging from their small amplitude, the eclipses are partial, and
therefore the eclipse depth must depend on the radius of the Cepheid,
i.e. on the phase of the pulsation period. This effect is slightly no-
ticeable in our observations, but it must be confirmed and studied in
detail by subsequent photometry. Moreover, we would like to turn
the reader’s attention to the fact that the eclipsing light curve, being
of $\beta$ Lyrae type, gives us reasons to believe that the components are
ellipsoidal. It is interesting to study how non-spherical Cepheids
pulsate. TYC 1031 01262 1 provides a rare opportunity to learn this.

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