Photometric search of orbital periods in symbiotic stars

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Abstract. We present UBVRI photometry of three symbiotic stars ZZ CMi, TX CVn and AG Peg carried out from 1997 to 2008 in Piwnice Observatory near Toruń. To search orbital periods of these stars Fourier analysis was used. For two of them, TX CVn and AG Peg, we have confirmed the earlier known periods. For ZZ CMi we found a relatively short period 218.59 days. Assuming, that the orbital period is twice longer (P=437.18 days), the double sine wave in the light curve can be interpreted by ellipsoidal effect.

Photometric data

We used a 60cm Cassegrain telescope equipped with an EMI 9558B photomultiplier (1991 – 1999), a RCA C31034 photomultiplier (2001 – 2004) and CCD camera (2005 - 2008), to obtain the UBVRI photometry of the selected symbiotic stars (for details see Ga\l\an et al. 2008). For TX CVn and AG Peg we used additional data from the Slovak long-term monitoring programme of photometric observations of selected symbiotic stars (Hric & Skopal 1989, Skopal et al. 2007, and references therein).

ZZ Canis Minoris

All multicolour photometric measurements of ZZ CMi are presented in Figure 1 (left panel). The Fast Fourier Transform (FFT) of the data gives a 218.59 days period for BVRI filters and 835.12 days – for U (Figure 1 middle panel). On the right panel of Figure 1 the BVRI light curves phased with the double period (437.18 days) are demonstrated.

We have used Wilson – Devinney’s code (Wilson & Devinney 1971) to verify the assumption, that the double sine wave could be interpret as an ellipsoidal effect connected with the tidal distortion of the giant surface. A circular orbit (e = 0) with inclination \(i = 90^\circ\) was adopted. We have determined the ephemeris \(JD_{\nu_0} = 2450326.24 + 437.18 \times E\), and used it to phase the data. The temperature of the cool component was assumed to be \(T = 3400 \text{ K}\) according to M5III classification of Taranova (1986). Many solutions for the components mass, in the range 1 – 3 \(M_\odot\) for the giant and 0.5 – 1.4 \(M_\odot\) for the white dwarf, were tested.
Figure 1. Left panel: Multicolour light curves of ZZ CMi. Black squares are mean values of brightness to normalize three photometric systems for Fourier analysis, Middle panel: Power spectrum for $UBVRI$ filters data of ZZ CMi, Right panel: The residual $BVRI$ and $U$ light curves of ZZ CMi phased with $437.18$ and $835.12$ days respectively. Residual magnitudes were obtained by substraction of a mean value from observational data (see Figure 1 left panel) for each of the photometric systems.

The possible solutions, in which the hot star is less massive than $1.4 \, M_\odot$ and the giant doesn’t overflow Roche lobe, are restricted to the filled area in Figure 2 (left panel). It is clearly seen that the cool component has to be less massive than $\sim 2 \, M_\odot$ and the mass ratio ($q$) is greater than $\sim 0.6$. All synthetic light curves obtained for combination of masses from the filled region in Figure 2 (left panel) give practically the same solutions, similar to that shown in Figure 2 (right panel).

Figure 2. Left panel: the relationship between $q = M_h/M_c$ and $M_c$ is presented. The filled area shows the possible mass solutions for which the cool giant does not overfill the Roche surface and the mass of the white dwarf is smaller than $1.4 \, M_\odot$. Right panel: The $BVRI$ light curves phased with double of $218.59$ days period. Solid lines represent the synthetic curves computed for $M_c = 1.0 \, M_\odot$, $M_h = 1.0 \, M_\odot$. 
TX Canum Venaticorum

TX CVn is a symbiotic star, which spectrum is combined by a late B and an early M star spectra \cite{Kenyon1986} and with an orbital period \(199 \pm 3\) days \cite{GarciaKenyon1988}. Spectrophotometric observations show that the hot component is not a normal late B-type star, because the He I features are produced in an expanding with a velocity of \(\sim 300 km s^{-1}\) photosphere.

We used photometric data to confirm the spectroscopic period of this system. To subtract the long term trends we fitted lines to our data (Figure 3 left panel), and then the FFT was calculated separately for the \(UBVRI\) data. The power spectra are shown in the middle panel of Figure 3. The periodograms show a peak at frequency \(f \sim 0.0050 d^{-1}\), which corresponds to the known period of \(\sim 199\) days. The phased light curves are shown in Figure 3 (right panel).

AG Pegasi

AG Peg is a symbiotic binary consisting of a white dwarf and a red giant. The stars orbiting their mass center with a period of \(812.3 \pm 6.3\) days \cite{Kenyonetal1993}. Murset et al. \cite{1995} found the evidence for colliding stellar winds in this system: a fast wind \((V \sim 900 km s^{-1})\) from the hot component and a slow wind \((V \sim 60 km s^{-1})\) from the giant. The colliding winds form the gaseous nebula surrounding the system.

Our \(UBVRI\) photometric measurements of this star are presented in Figure 4 (left panel). The periodograms of multicolour photometry are shown in

Figure 3. Left panel: Multicolour light curves of TX CVn with the lines fitted to subtract the trends. Middle panel: The power spectrum for \(UBVRI\) filters data of TX CVn. Right panel: The \(UBVRI\) light curves of TX CVn – the residual data after the trend subtraction phased with the 199.75 days period. The \(I_c\) light curve shows evidence for an elliptical effects. The triangles mark the Slovak data, the circles - our data.
Figure 4 (middle panel). We adopted a mean value of 806.31 days for the period in all filters obtained from the FFT analysis. This value is within the error box of the period published by Kenyon et al. (1993). The data were phased with our period, using $T_0 = 2442710.1$ from Fernie (1985). The phased light curves are shown in Figure 4 (right panel).

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References

Fernie, J.D, Publications of The Astronomical Society of The Pacific, 1985 March 4
Galan, C., Mikołajewski, M., Tomov, T., et al., 2008, The Observatory, in press
Garcia, M.R., Kenyon, S.J., 1988. In the Symbiotic Phenomenon , IAU Colloquium No.103,p.27.
Hric L., Skopal A., 1989, IBVS No. 3364
Kenyon S.J., 1986, The Symbiotic Stars. Cambridge University Press, Cambridge, p. 179
Kenyon S.J., Mikołajewska J., Mikołajewski M., Polidan R.S., Slovak M.H., 1993 AJ, 106,1573
Murset U., Jordan S., Walder R., 1995, A&A, 297, 87
Skopal A., et al, Astron. Nachr. 999, No. 88, 2007
Taranova O.G., 1986, Astromicheskii Tsirkulyar, No.1467
Wilson R. E., Devinney E. J., 1971, ApJ, 166, 605