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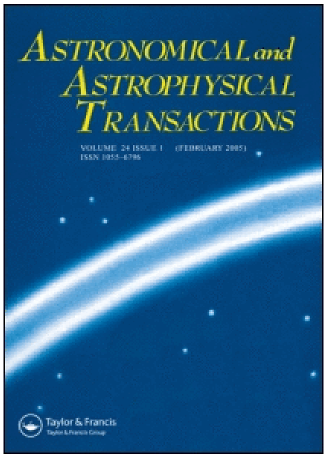

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Photographic brightness variations of the symbiotic stars UV AUR, TX CVN, V1016 CYG and V1329 CYG

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PHOTOGRAPHIC BRIGHTNESS VARIATIONS OF THE SYMBIOTIC STARS UV AUR, TX CVN, V1016 CYG AND V1329 CYG

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Multiharmonic analysis of the photographic observations (based on Moscow and Odessa plate collections) showed best fit photometric period $P = 399.0 \pm 1.7^d$ in UV Aur (number of harmonics $j = 4$). For TX CVn there are three "candidate values" 282.9 ± 2.9^d ($j = 2$), 352.2 ± 3.0^d ($j = 3$) and 426.5 ± 4.2^d. The light curve of V1329 Cyg shows significant cycle-to-cycle variations and a large asymmetry $f = 0.54$ which is typical of stars with the periods close to the observed one 1030 days. Cycle length variations are present in the variations of these 3 stars. V 1016 Cyg showed an outburst followed by no (quasi) periodic variations.

1 INTRODUCTION

International program of observations of symbiotic variables using photometric and spectral methods was initiated by Hric & Skopal (1989) at the Astronomical Institute of the Slovak Academy of Sciences in Tatranska Lomnica. They also published, in a preprint, finding charts of the objects investigated and some comparison stars for photoelectric observations. Reviews on the structure and evolution of these objects one can find e.g. in Boyarchuk (1983) and Kenyon (1986). Tables of individual observations were published by Hric *et al.* (1994) as a part of a large international campaign. Here we present detailed results of analysis of these data obtained in the photographic system close to B.

For a more precise determination of the period we used a computer code written by I. L. Andronov. The light curve for each trial period was approximated by a trigonometrical polynomial

$$m(\varphi) = a_0 + \sum_{k=1}^{j}[a_k \cos(2\pi k\varphi) + b_k \sin(2\pi k\varphi)],$$

where $m(\varphi)$ is a smoothed value of the brightness m at a phase φ, and coefficients a_k ($k = 0 \ldots j$) and b_k ($k = 1 \ldots j$) are determined using the least squares method.

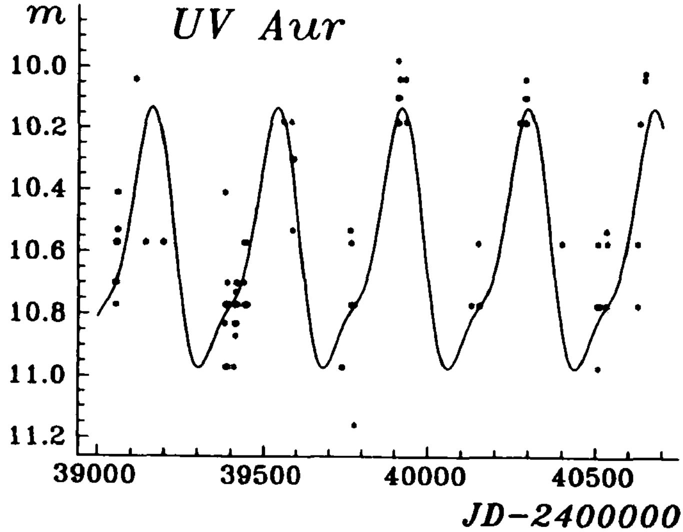

Figure 1 Part of the light curve of UV Aurigae (asteriscs). Solid line represents a two-harmonic ($j = 2$) fit for $P = 377.9^d$.

The semi-amplitude of variations is equal to $r_k = (a_k^2 + b_k^2)^{1/2}$.
As a test function, we have used

$$S(P) = \frac{\sigma^2_{0-C}(P)}{\sigma_0^2}$$

where σ_0^2 and $\sigma^2_{0-C}(P)$ are the variances of the original signal and of the deviations "observed-calculated". For each j, an optimal value of the period was computed precisely by using the method of "differential corrections". The value of j was determined as such corresponding to a minimum of the square of the "unit weight error"

$$\sigma_*^2 = \frac{1}{n-2j-1}\sum_{i=1}^{n}(m_i - m(\varphi_i))^2 = \frac{n\sigma^2_{0-C}}{n-2j-1}$$

where m_i ($i = 1 \dots n$) are the observed values.

2 UV AURIGAE

Photographic brightness estimates were obtained on 156 negatives of the Sternberg State Astronomical Institute (SAI) in Moscow covering the interval JD 2439052–40649. Comparison stars were published by Kurochkin (1951). In this system, one of the stars is pulsating. Our observations allowed to obtain moments of brightening near maxima at JD 2439115, 39573, 39909, 40293 and 40649 (Figure 1). These

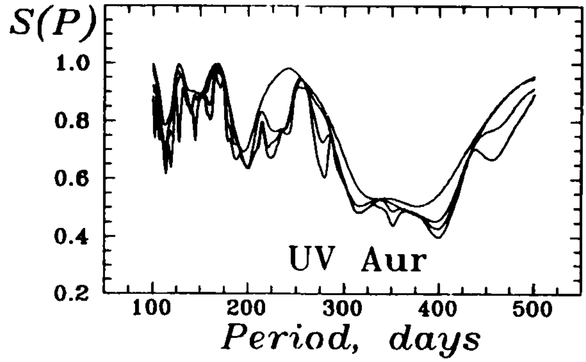

Figure 2 Periodogram $S(f) = \sigma^2_{0-C}/\sigma^2_0$ for UV Aur. With increasing number of harmonics j, the curves become lower, thus the upper one corresponds to $j = 1$.

values corresponding to a mean period of 383.5^d. Brightness varies in a range from $10^m.0$ to $10^m.8$. Such small amplitude is in agreement with a photoelectric value $0^m.5$ in B (Luthardt, 1992) Periodograms for various numbers of harmonics j are shown in Figure 2. For $j = 1$ the corresponding period is equal to $P = 377.9 \pm 5.6^d$. For a "best fit" value $j = 4$ one obtains $P = 399.0 \pm 1.7^d$ coinciding with the value 396^d (Luthardt, 1992) within errors. From 650 observations from the AFOEV database (Chinarova *et al.*, 1993) the following best fit values were derived for $j = 1$: $P = 389.23 \pm 0.47^d$, $T_{max} = 2446551.4 \pm 1.8$, $r_1 = 0.92 \pm 0.026^m$ and $a_0 = 9.23 \pm 0.02^m$.

3 TX CANUM VENACORUM

Photometric behavior of this relatively bright object BD+37^{0}2318 in 1890–1952 was studied by Mumford (1966) who published 9 comparison stars. Our observations on 42 compact distributed in time SAI plates obtained from JD 2445850 to 2447680 show brightness variations from $9^m.9$ to $10^m.2$ with a small brightening up to $9^m.7$ near JD 2447204 (Figure 3). The periodogram has a complicated structure (Figure 4). Three peaks with nearly equal significance levels correspond to the periods 282.9 ± 2.9^d ($j = 2$), 352.2 ± 3.0^d ($j = 3$) and 426.5 ± 4.2^d ($j = 4$). These 3 peaks are present also for $j = 1$. Skopal *et al.* (1992) suspected a 9-yr cycle of the brightness variations. Our data cover the time interval studied by Skopal *et al.* (1992), but show smaller amplitude $\approx 0^m.2$ (pg) as compared with $\approx 0^m.4$ (vis). Our analysis of 1340 visual observations from the AFOEV database (Chinarova *et al.*, 1993) implied a 2-frequency model with $a_0 = 9.68 \pm 0.05^m$ and semi-amplitudes $r_1 = 0.215 \pm 0.007^m$ ($P_1 = 3768 \pm 74^d$, $T_{max\,1} = 2446988 \pm 21^d$) and $r_2 = 0.056 \pm 0.007^m$ ($P_2 = 475.3 \pm 3.9^d$, $T_{max\,2} = 2446887 \pm 10^d$). The first period corresponds to that mentioned by Skopal *et al.* (1992), whereas the second one differs significantly from our three "candidates", possibly suggesting a period change.

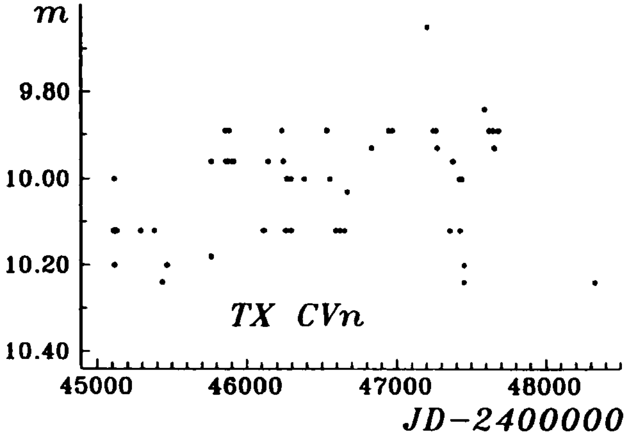

Figure 3 The light curve of TX CVn. The best fit line is not shown because of three possible "best fit" periods.

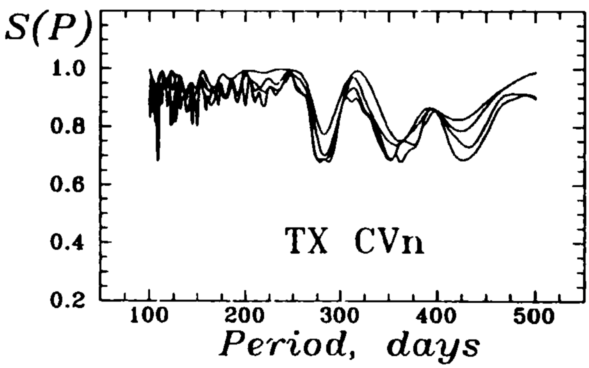

Figure 4 Periodogram $S(f) = \sigma^2_{0-C}/\sigma^2_0$ for TX CVn. One may note that for $j > 1$ three period values may formally be "best fit" ones.

4 V 1016 CYGNI

Besides the SAI plate collection ($n = 153$), we made estimates on 141 negatives of the 7-camera astrograph of the Astronomical Observatory of the Odessa University. Brightness of the comparison stars was determined by Miller (1967), who designated it as VV 180. The object is surrounded by a relatively bright nebula (extended envelope) which hardly affects the accuracy of the observations. Brightness increased from $14^m.0$ near JD 2436500 to a "maximum state" 11–12^m near JD 2440000 (Figure 5). After JD 2444500, a brightness depression by $\approx 0^m.5$ occurred with a corresponding increase of the observational scatter which is possibly linked with a physical variability. Similar result with the same amplitude was obtained from visual observations by Skopal *et al.* (1992).

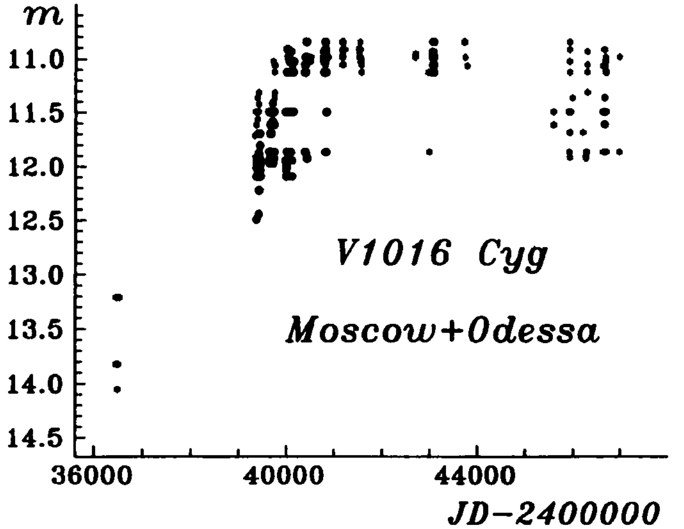

Figure 5 The light curve of V 1016 Cyg based on observations on the Odessa (asteriscs) and Moscow (filled circles) plate collections.

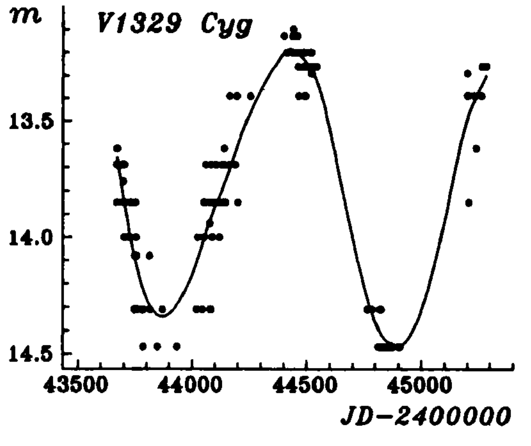

Figure 6 Part of the light curve of V 1329 Cygni (asteriscs). Solid line represents a "running parabolae" fit with $\Delta t = 400^d$.

5 V 1329 CYGNI

Brightness estimates were obtained on 165 SAI plates. Comparison stars were published by Arkhipova (1977). In Figure 6, a part of the light curve within an interval JD 2443669–45284 (n = 145) is shown. A smoothing curve was obtained by using the method of "running parabolae" (Andronov, 1990) with a filter half-width $\Delta t = 400^d$. Two brightness minima were detected near JD 2443871 ($14^m\!.34$)

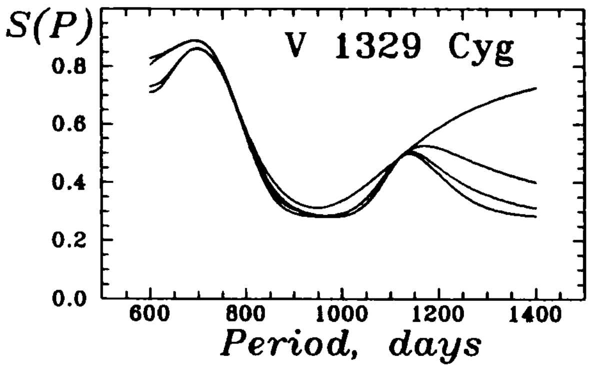

Figure 7 The periodogram $S(f) = \sigma^2_{0-C}/\sigma^2_0$ for V1329 Cyg. A decrease for $j > 1$ and $P > 1150^d$ corresponds to fitting of the main period by a second harmonic.

and 2444900 ($14^m_.47$) corresponding to a period $P \approx 1030^d$. A maximum between them occurred near JD 2444427 ($13^m_.29$) corresponding to an asymmetry $f = 0.54$. This value is typical of Mira-type stars with long periods. Significant difference of the brightness in the minima caused apparent deviation (4σ) of the "best fit" value $P = 966 \pm 15^d$ corresponding to a multiharmonic analysis (Figure 7) with $j = 2$. Our data fill the gap in the visual observations of Skopal *et al.* (1982) which showed, on other dates, significant variability of the amplitude and the cycle length (700–1150^d). From one-harmonic analysis of the 1617 visual observations from the AFOEV datafiles, Chinarova *et al.*, (1993) derived $a_0 = 13.26 \pm 0.07^m$, semi-amplitude $r = 0.49 \pm 0.10^m$, initial epoch for the Maximum 2445345 ± 3^d and a mean period $P = 958.7 \pm 1.2^d$.

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