CCD OBSERVATIONS OF THE INTERMEDIATE POLAR MU CAM AND GSC 04370-00206

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ABSTRACT. Results of CCD observations of MU Cam and GSC 04370-00206 obtained at the 60 cm telescope of the RSI "Astronomical Observatory" of the Odessa National University.

Key words: Variable stars: intermediate polars, eclipsing.

Cataclysmic variable stars are excellent natural laboratories to study various astrophysical processes (cf. Warner 1995). Among them, there is a very interesting class of intermediate polars with rapidly rotationg magnetic white dwarf (see Patterson 1994 for a review). The spin period variations have been discovered for many of these objects, showing either increase, or decrease. This depends on arbitrary dimensions of the corotation radius and radius of the magnetosphere. Andronov (2005) proposed a model, according to which, the variations may be explained by a precession of the white dwarf, even if the accretion rate does not undergo significant changes.

To study rotational evolution of the white dwarf, a regular monitoring is needed. Thus intermediate polars are included in the part "Polar" of the international campaign "Inter-Longitude Astronomy" (see Andronov et al. 2010 for recent highlights). One of the objects is a newly discovered intermediate polar 1RXS J062518.2+733433 (Araujo-Betancor et al. 2003, Staude et al. 2003). Results of our previous study of this object (now known as MU Cam) were published by Kim et al. (2005).

In this paper, we report on first CCD observations of cataclysmic variable stars obtained in Odessa (Mayaki). Totally, 1817 unfiltered data were obtained during 12.6 hours during the nights on December 15 and 20, 2006 with time resolution of 16 seconds.

To study the instrumental system, we have used secondary photometric standards for 7 comparison stars published by Kim et al. (2005). The instrumental magnitude m was determined using the "artificial comparison star" method (Andronov and Baklanov, 2004; Kim et al. 2005) using the V calibration of the comparison star C2 ($V = 13.^{m}842$, $B-V = 0.^{m}920$) by Henden (2002). The color transformation equations are

$$m - V = 0.026(30) - 0.844(160)\cdot(B - V - 0.774),$$
$$m - V = 0.026(30) - 1.390(264)\cdot(V - Rc - 0.547)$$

with the unit weight error of $\sigma_0 = 0.^{m}080$. Here "(numbers)" are error estimates in units of the last decimal digit. Excluding two outstanding points at the diagram, we recomputed the coefficients, so

$$m - V = 0.111(8) - 0.942(120)\cdot(V - Rc - 0.422)$$

with much smaller $\sigma_0 = 0.^{m}018$. In other words, the unfiltered instrumental system is close to the standard Rc within statistical error estimates. Thus finally we have used for calibration the extrapolated value of brightness of C2 in the Cousins' Rc system of $Rc = 12.^{m}936$. The r.m.s. accuracy of the "artificial comparison star" is $0.^{m}0095$, i.e. by a factor of 1.4 better than an accuracy of the "most stable" comparison star C2. The accuracy estimate is $\sigma = 0.^{m}019$ for $R = 13.^{m}5$ and $\sigma = 0.^{m}066$ for $R = 15.^{m}0$ for exposures of 15 seconds.

The first step is to determine nightly "mean timings". For this purpose, we have used a two-period approximation

$$m_C(t) = m_0 - r_1\cos(\tfrac{2\pi(t-T_1)}{P_1}) + r_2\cos(\tfrac{2\pi(t-T_2)}{P_2}),$$

where we have adopted $P_1 = P_{spin} = 0.^{d}01374116815$ and $P_2 = P_{orb} = 0.^{d}19661$ are the spin and the orbital periods, respectively (Kim et al. 2005). For the two nightly runs, we determined initial epochs for the spin maximum $T_1 = HJD2454085.50661(12)$, 2454090.52210(9); semi-amplitudes of the spin pulse $r_1 = 0.^{m}055(3)$, $0.^{m}084(4)$; initial epochs for the orbital minimum $T_2 = 2454085.45826(81)$, 2454090.57783(263), semi-amplitudes of the orbital variations $r_2 = 0.^{m}114(3)$ and $0.^{m}045(4)$ and mean brightness $m = 14.^{m}739(2)$ and $14.^{m}766(3)$. As the parameters vary from night to night, we have used the second step - the "running sine" fit

$$m_C(t) = m_0 - r_1\cos(2\pi((t - T_{01})/P_1 - \phi)),$$

where the "initial epoch" for maximum is $T_{01} = 2452893.78477$ (Kim et al. 2005) and ϕ is the phase of maximum. For such a "running approximation", we have used a filter half-width of $\Delta t = 0.5P_1$.

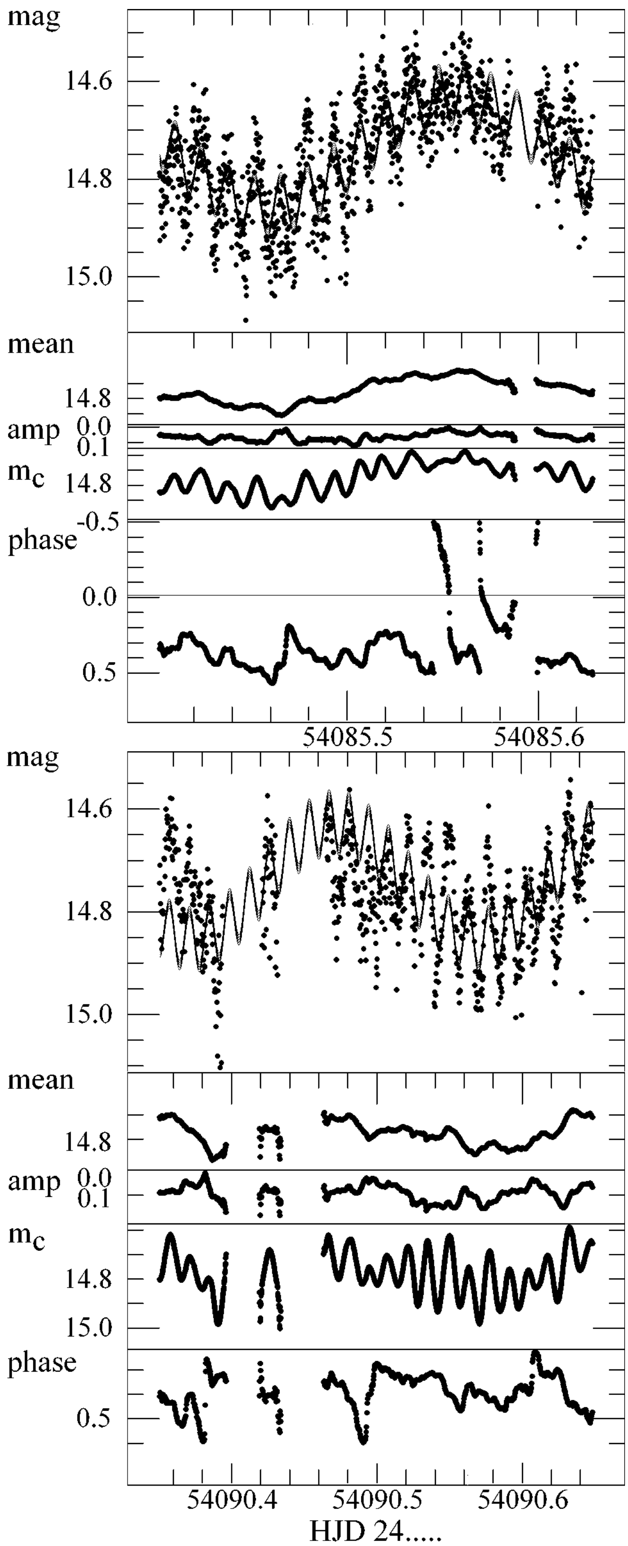

Figure 1: Light curves of MU Cam and their approximations: (up) two-periodic fit (spin+orbital) and (bottom) parameters of approximation using the "running sine" (Andronov 1997): "mean" m_0, semi-amplitude r_1 ("amp") and ϕ ("phase") of the spin maximum according to the ephemeris by Kim et al. (2005). Contrary to the two-period fit, where the mean, amplitude and phase are suggested to be constant, the "running sine" shows significant variability of all three parameters.

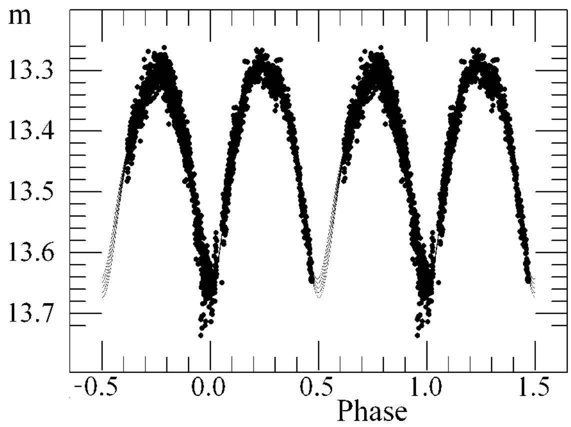

Figure 2: Phase light curve of GSC 04370-00206 and 6-th order trigonometric polynomial fit with $\pm 1\sigma$ and $\pm 2\sigma$ error corridors.

All the parameters of the running approximations significantly vary with time, indicating cycle-to-cycle instability of the shape. The phase is significantly shifted from zero, indicating that the photometric ephemeris needs an improvement. Moreover, period variations may be suggested.

During our first study of MU Cam, we have discovered a new EW-type variable GSC 04370-00206. It is studied in more detail separately in this volume by Breus et al. (2010). The phase light curve according to an improved ephemeris $Min.HJD = 2454805.7548 + 0.4426448 \cdot E$ by Breus et al. (2010) is shown in Fig. 2 along with the 6-th order polynomial fit and "1σ and "2σ corridors (Andronov 1994). There is no statistically significant shift of the primary minimum. To determine individual minima (only primary ones were covered), we have used the "asymptotic parabola fit" (Marsakova and Andronov, 1996). The timings are 2454085.57243(53) and 2454090.43569(126). The magnitude estimates 13.652(7) and 13.669(10) are the same within error estimates. The deviations from the phase zero are 0.0016(12) and –0.0116(28) are negligible.

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