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LARGE-AMPLITUDE MODULATIONS OF THE CATACLYSMIC STAR ER UMa IN 2008

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Abstract. We present our BR observations of the cataclysmic star ER UMa covering three consecutive light cycles at quiescence. Their light curves are asymmetric with steeper decreasing branch. While the large light amplitudes of the first two cycles may be expected for the quiescent state, the 0.9^m amplitude of the third cycle is unusual big. The period of the observed light modulations in 2008 is shorter than the orbital one. Thus our observations leaded to a discovery of large-amplitude negative superhumps at quiescent state of ER UMa.

1. INTRODUCTION

ER UMa (PG 0943+521) is reported by Ringwald (1993) as an UX UMa nova-like variable with a spectroscopic period of 0.1997 d. The dwarf-nova nature of this object was first noticed by Hurst and Poyner (1992). Iida (1994) registered outbursts resembling SU UMa stars. The discovery of superhumps after superoutbursts of ER UMa with a period P_{sh}=0.0656 d and amplitudes of 0.15^m confirmed its SU UMa-type (Kato and Kunjaya 1995, Misselt and Shafter 1995).

The 43 d supercycle of ER UMa begins with slow smooth decay of 0.8^m from 13.2^m over 13 days. It is followed by an interval containing nearly 7 oscillations with an amplitude 2^m (normal outbursts from 13.7^m to 15.7^m) and a period of 4.4 d (Robertson et al. 1995, Kato and Kunjaya 1995).

ER UMa is considered as a prototype of small group of three SU UMa-type dwarf novae (RZ LMi, V1159 ORi) which are characterized by extremely short (19-50 d) supercycle between successive superoutbursts, short (3-4 d) outburst interval of normal outbursts, and small (around 3^m) outburst amplitude (Robertson et al. 1995).

Kato et al. (1996) reported on the existence of large-amplitude 0.35^m superhumps during the earliest stage of a superoutburst (during the rise to the maximum light) which amplitudes quickly decay (to less 0.1^m) with a time scale of few days and usual superhumps appearing in the later stage of the superoutburst. Gao et al. (1999) found negative superhumps with a period P_{sh}=0.0589 d and rising amplitude from 0.04^m to 0.13^m a day before supermaximum that became positive superhumps with a period of P_{sh}=0.0654 d and amplitude of 0.25^m at the supermaximum. Due to the detection of superhumps with different amplitudes (0.12-0.22^m) in the normal outbursts Gao et al. (1999) concluded that superhumps occasionally exist at essentially all phases of the eruption cycle of ER UMa.

Kato et al. (2003) observed phase reversal of the superhump maxima 5 days after the superoutburst maximum. They interpreted the superhumps following this switch as late superhumps. Zhao et al. (2006) found superhumps during normal outbursts with variable amplitudes reaching 0.48^m at the light minimum (V=15.7^m) that faded out before the next outburst maximum.

Thorstensen and Taylor (1997) obtained UX UMa-like spectrum of ER UMa with a little radial-velocity variation (K=48 km/s) and determined P_{orb}=0.0636 d. Zhao et al. (2006) confirmed this period but found phase shift of 0.22 of the Balmer lines. Almost the same value (0.0635 d) was determined earlier by Kato et al. (1995) on the basis of the observed semi-periodic photometric oscillations of ER UMa during quiescence and was assumed as the orbital period. But the lack of eclipses and the small-amplitude radial velocity curve (probably due to a low inclination of the sytem) makes the determination of the orbital period of ER UMa quite difficult task.

The behavior of the SU UMa stars can be explained by an accretion disk which expands during superoutbursts to the point that its outer regions are subject to an eccentric instability. Superhumps are due to a tidal deformation of the accretion disk in a binary with a high mass ratio, a precession of the deformed disk in a non-axisymmetric gravity field, and a varying tidal dissipation resulting from a periodic modulation of viscous heating for a varying aspect of the secondary star against the disk (Osaki 1989, 1995 a, b).

The investigation of the light variability of ER UMa is an important task to verify its classification and our study is focused on this problem.

2. OBSERVATIONS

We carried out CCD photometry of ER UMa with the 60-cm telescope at the Mt. Suhora Observatory. The observations in B and R filters were with exposures 60 s and 30 s and covered 3 consecutive light cycles of the star (Fig. 1). The data were reduced in a standard way using the comparison star [HH95] UMa1-4 with magnitudes B=14.83^m and V=14.21^m.

According to the supercycle ephemeris of ER UMa 2449398.45+42.95*E (Robertson et al. 1995) the phase of our observations is 0.0025. This means that ER UMa should have brightness in V around 13.25^m while our data showed that its light was around V=15^m, i.e. the star was at quiescence during our observational run.

3. ANALYSIS OF THE OBSERVATIONAL DATA

The analysis of the presented photometric data (Fig. 1) leaded us to several conclusions.

(1) The light variations in B and R color have similar course. The observed three consecutive light cycles are asymmetric with steeper decreasing branch. Such a shape is opposite to those of the observed superhumps which increasing branch is steeper than the decreasing one (Gao et al. 1999, Kato et al. 1996, 2003).

(2) The light amplitudes of the first two cycles are 0.53^m in R color and 0.47^m in B color. The bigger R amplitude implies that these light variations originate from

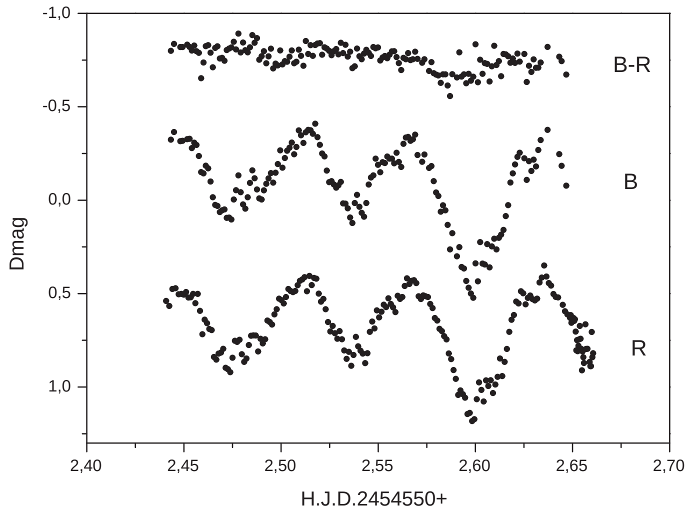

Figure 1: The three consecutive B and V light curves of ER UMa from March 16 2008

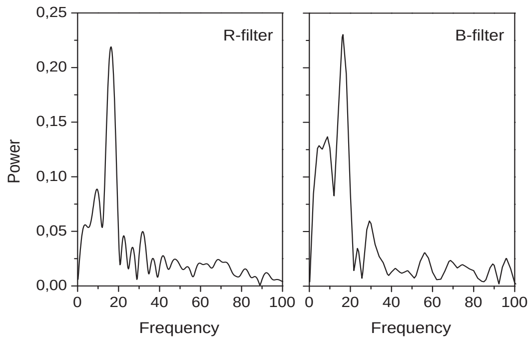

Figure 2: Fourier spectra of out data

the cooler component. Besides ours, the only so large-amplitude oscillations were observed by Zhao et al. (2006) at the light minimum of ER UMa.

(3) The light amplitude of the third cycle (Fig. 1) is almost 2 times bigger (0.9^m in B color and 0.8^m in R color) than these of the first two cycles. It should be noted that it is the third amplitude of variability of ER UMa after the superoutburst amplitude (around 3^m) and normal outburst amplitude (around 2^m). Consequently, the star revealed the largest-amplitude light variations at quiescence during our observations in 2008. Taking into account that the light maxima of the three consecutive cycles are almost the same (Fig. 1) we may consider the third unusual variation as a dip (light depression).

(4) There are some features on the increasing branch of the light curves (Fig. 1). They are more pronounced in B color and can be noted also in previous observations (Kato and Kunjaya 1995, Kato et al. 1996, etc.).

(5) The B-R color index gradually changes during the three consecutive cycles (Fig. 1) and has extremal values during the third light depression.

The Fourier spectra of all our photometric data (3 cycles) showed one big peak (Fig. 2) corresponding to a period P_3=0.0607 d. On the other hand the Fourier spectra of the first two light cycles (excluding the unique third cycle) of our data lead to a period P_2=0.0592 d that is very close to the value P_{sh}=0.0589 d determined by Gao et al. (1999) for the negative superhumps of the star.

It is interesting to determine the type of the light modulations of ER UMa in 2008 in the framework of the known five kinds of superhumps of SU UMa stars (O'Donoghue 2000). We consider that the observed light variations cannot be neither "normal" positive superhumps, nor "orbital" superhumps visible during the last stage of the superoutburst, nor "late" superhumps, nor "permanent" superhumps, because their period P_3 (or P_2) is shorter than the spectroscopic orbital period (Thorstensen and Taylor 1997). Due to the same reason we conclude that the light modulations in 2008 can be only "negative" superhumps. Such oscillations have been observed earlier in short-period nova-like variables (O'Donoghue 2000). Then let's remember the first classification of ER UMa as an UX UMa-type variable (Ringwald 1993) as well as the similarity of ER UMa spectrum with those of UX UMa-type stars!

It should be noted that the theory of negative superhumps meets big difficulties. The recent alternative explanations of the negative superhumps are retrograde precession of a tilted accretion disk and transit of the bright spot across the face of the disk that is titled out of the orbital plane (Wood and Burke 2007).

We hope that our observations leading to a discovery of large-amplitude negative superhumps at quiescent state of the cataclysmic star ER UMa throw additional light on the phenomenon "negative superhumps".

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