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ER UMa: a dwarf nova that continues to amaze

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Abstract. ER UMa is a well known SU UMa-type dwarf nova with a number of outstanding properties. It is the prototype of a small group of dwarf novae with a high frequency of superoutbursts and a short orbital period. Our multicolor $BVRcIc$ investigation of ER UMa carried out at the Crimean astrophysical observatory in 2020 showed that in some occasions ER UMa may be a "bridge" between the subclasses of ER UMa-type stars and nova-like ones.

Key words: dwarf novae – superhumps – photometry

1. Introduction

ER UMa was identified as a cataclysmic variable in 1986 (Green et al., 1986). In 1992 this object was classified as a dwarf nova by Kato & Kunjaya (1995). For the first time, ER UMa was found to have superhumps with a period of 0.06549-0.06573 days (Kato et al., 2003), which is an attribute of SU UMa-type dwarf novae. Soon this object became a prototype of a special small group of ER UMa dwarf novae with a short interval between neighboring super-outbursts (supercycle) of 19-50 days and a short (3-4 days) interval between neighboring normal outbursts (cycle) (Kato & Kunjaya, 1995). From a theoretical point of view, Osaki (1995) suggested that such a short cycle requires an unusually high mass transfer rate within the disk instability theory, which is not described by the theory of standard evolution of compact binaries. Thorstensen & Taylor (1997) found the orbital period of ER UMa equal to 0.06366 days and concluded that the orbital inclination is low. Gao et al. (1999) and Kjurkchieva & Marchev (2010) were first to observe negative superhumps during rise of an superoutburst and during a quiescence, respectively. Ohshima et al. (2012) were first to detect negative superhumps during the 2011 superoutburst, which had not been previously observed not only in ER UMa but also in SU UMa-type dwarf novae in general. Next, Ohshima et al. (2012), Zemko et al. (2013, 2014) found a correlation between the frequency of normal outbursts and the appearance and disappearance of negative superhumps, thereby confirming the theoretical

prediction (Osaki & Kato, 2013) that the appearance of negative superhumps, triggered by the tilt of the accretion disk, should entail a decrease in the frequency of normal outbursts, since in this case it will take more time for enough matter to accumulate in the disk to trigger thermal instability.

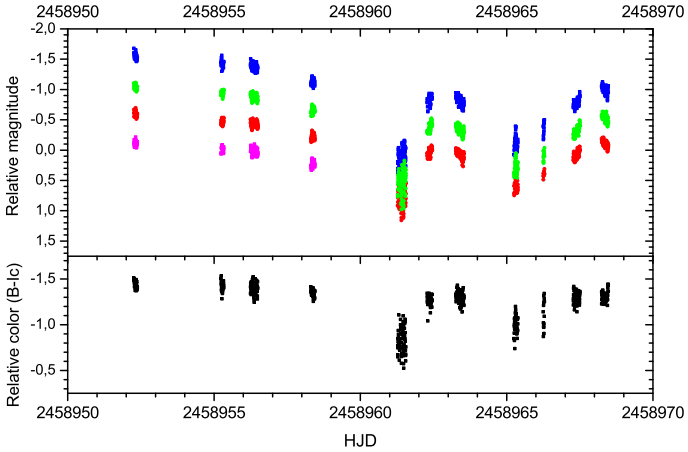


Figure 1. Top: Long-term light curve of ER UMa. The data is shown in blue (B), green (V), red (Rc) and magenta (Ic). Bottom: Color-indice $B - Ic$.

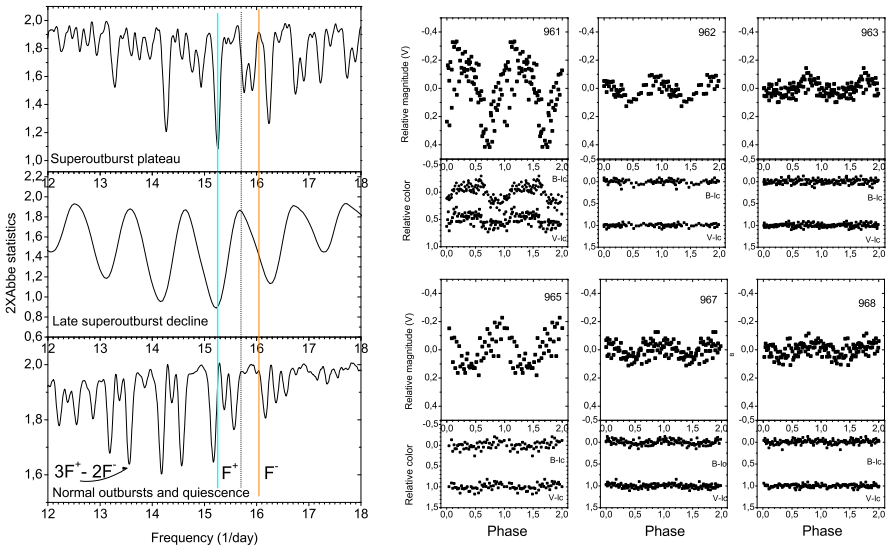
2. Observations and Result

We have undertaken a $BVRcIc$ study of ER UMa to determine the behavioral features of the object in one of the 2020 supercycles. Our observations have been carried out at the 1.25-m telescope of the Crimean astrophysical observatory with CCD ProLine PL23042 during 11 nights. Observations covered part of the superoutburst, two normal outbursts and quiescence in between (see Fig 1). The object became bluer in the outbursts and redder in the minimum. ER UMa displayed a short-term light variations both during the superoutburst, normal outbursts and quiescence in between. We calculated periodograms for three nights of the superoutburst plateau, two nights of the late superoutburst decline and quiescence + normal outbursts using method of Stellingwerf (1978), Pel'T (1980). The result is shown in the Fig 2a.

One could see that there are no clear evidences both of orbital and negative superhump period. However the positive superhumps with period of 0.0656 d (F=15.26), 0.0657 d (F=15.23) and P=0.0659 d (F=15.17) and their one-day aliases were registered along all stages of superoutburst and in quiescence including normal outbursts. A combination of frequencies that practically coincides with the frequency $3F(+) - 2F(-)$, where $F(+)$ and F(-) are frequences of positive and negative superhumps respectively and their daily aliases are also present at the stage "quiescence + normal outbursts".

The selected data of quiescence and normal outbursts folded on the period 0.0659 d is presented in the Fig 2b. A strange detail draws attention: a strong increase in the amplitude of brightness variations at the end of superoutburst (JD ...961) up to $0^m.4$. The possible explanation could be the appearance of another temporary source of variatons – "impulsive" or "faded" negative superhumps, which can affect the positive superhumps, increasing or decreasing the amplitude.

There are also no prominent variations of color-indices $B-Ic$ and $V-Ic$ for all curves with exception for JD . . . 961, . . . 965 and . . . 967. The object is bluest close to maximum light. Note that similar color indices of positive superhumps (blue at the phase of the superhump maximum on some nights and constant at all phases on others) were also recorded for RZ LMi by Shugarov et al. (2018).



a) b)

Figure 2. a) Periodograms for different states of ER UMa. The position of the frequencies of the positive ($F+$) and negative (F-) superhumps taken from (Kato et al., 2003) and (Ohshima et al., 2012) respectively is marked with a blue and orange line respectively, and those of the orbital period is shown by a black dotted line.
b) Examples of phased light curves folded with 0.0659d period and their color-indices for the data in normal outbursts and quiescence. For each curve the last three digits of the Julian date are given.

3. Discussion

The presence of positive superhumps in the quiescent state and normal outbursts was an unexpected effect. This means that the accretion disk in the ER UMa

continued to be in a state of thermal and tidal instability after the end of the superoutburst, similar to some nova-like stars. Kato et al. (2016) found that another ER UMa-type dwarf nova with an anomalously short supercycle, RZ LMi, can behave as a nova-like in some seasons, i.e., exhibit positive superhumps throughout the supercycle. Since this behavior was transient, Kato named the star "RZ Leonis Minoris Bridging between ER Ursae Majoris-Type Dwarf Nova and Novalike System". It is worth recalling that in the early stages of studying RZ LMi, the possible belonging of this system to the UX UMa-type nova-likes was suggested by Ringwald (1993), and to the VY Scl-type nova-likes by Pikalova & Shugarov (1995).

4. Conclusion

According to our observations, ER UMa in one of the 2020 supercycle showed positive superhumps during superoutburst and complex signal at "quiescence + normal outbursts" state. This signal consists of a dominant one - positive superhumps and possibly temporary one - negative superhumps. The evidence of positive superhumps of ER UMa found during all phases of one of the 2020 supercycle gives reason to suspect that this dwarf nova, like RZ LMi, in some occasions may be a bridge between the subclasses of ER UMa-type stars and nova-like ones.

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References

Gao, W., Li, Z., Wu, X., Zhang, Z., & Li, Y., Superhumps in a Peculiar SU Ursae Majoris-Type Dwarf Nova, ER Ursae Majoris. 1999, *Astrophysical Journal, Letters*, **527**, L55, DOI:10.1086/312398

Green, R. F., Schmidt, M., & Liebert, J., The Palomar-Green Catalog of Ultraviolet-Excess Stellar Objects. 1986, *Astrophysical Journal, Supplement*, **61**, 305, DOI:10.1086/191115

Kato, T., Ishioka, R., Isogai, K., et al., RZ Leonis Minoris bridging between ER Ursae Majoris-type dwarf nova and nova-like system. 2016, *Publications of the ASJ*, **68**, 107, DOI:10.1093/pasj/psw101

Kato, T. & Kunjaya, C., Discovery of a Peculiar SU UMa-Type Dwarf Nova ER Ursae Majoris. 1995, *Publications of the ASJ*, **47**, 163

Kato, T., Nogami, D., & Masuda, S., Unusual Phase Reversal of Superhumps in ER Ursae Majoris. 2003, *Publications of the ASJ*, **55**, L7, DOI:10.1093/pasj/55.2.L7

Kjurkchieva, D. & Marchev, D., Large-Amplitude Modulations of the Cataclysmic Star ER UMa. 2010, *Publications de l'Observatoire Astronomique de Beograd*, **90**, 147

Ohshima, T., Kato, T., Pavlenko, E. P., et al., Discovery of Negative Superhumps during a Superoutburst of 2011 January in ER Ursae Majoris. 2012, *Publications of the ASJ*, **64**, L3, DOI:10.1093/pasj/64.4.L3

Osaki, Y., A Model for a Peculiar SU Ursae Majoris-Type Dwarf Nova ER Ursae Majoris. 1995, *Publications of the ASJ*, **47**, L11

Osaki, Y. & Kato, T., The Cause of the Superoutburst in SU UMa Stars is Finally Revealed by Kepler Light Curve of V1504 Cygni. 2013, *Publications of the ASJ*, **65**, 50, DOI:10.1093/pasj/65.3.50

Pel'T, Y. 1980, *Frequency analysis of astronomical time series.*

Pikalova, O. D. & Shugarov, S. Y., The Photometric Investigation of RZ LMi. 1995, in Astrophysics and Space Science Library, Vol. **205**, *Cataclysmic Variables*, ed. A. Bianchini, M. della Valle, & M. Orio, 173–173

Ringwald, F. A., The Cataclysmic Variables from the Palomar-Green Survey. 1993, *Publications of the ASP*, **105**, 805, DOI:10.1086/133235

Shugarov, S. Y., Katysheva, N. A., Chochol, D., Krushevska, V. N., & Vozyakova, O. V., Superhump and outburst activity of the cataclysmic variable RZ LMi in the U- and optical passbands. 2018, *Astrophysics and Space Science*, **363**, 100, DOI:10.1007/s10509-018-3299-9

Stellingwerf, R. F., Period determination using phase dispersion minimization. 1978, *Astrophysical Journal*, **224**, 953, DOI:10.1086/156444

Thorstensen, J. R. & Taylor, C. J., Orbital Periods for the Interesting Old Novae V446 HER and V533 HER. 1997, in American Astronomical Society Meeting Abstracts, Vol. **191**, *American Astronomical Society Meeting Abstracts*, 109.04

Zemko, P., Kato, T., & Shugarov, S. Y., Detection of Change in Supercycles in ER Ursae Majoris. 2013, *Publications of the ASJ*, **65**, 54, DOI:10.1093/pasj/65.3.54

Zemko, P., Shugarov, S., Kato, T., & Katysheva, N., Study of a long and short—term variability of ER Ursae Majoris. 2014, *Contributions of the Astronomical Observatory Skalnate Pleso*, **43**, 319