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ACCRETION MECHANISMS AND SUPERHUMPS OF THE NOVA-LIKE SYSTEM V592 CAS

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Abstract. Accretion discs are complex energetic systems ruled by various dynamical physical processes. We consider different mechanisms that are responsible for the accretion dynamics in Nova-like stars. In this work, we focus our study onto their relation with the superhumps activity of Cataclysmic variable binaries, particularly in the Nova-like system V592 Cas. Based on the observational data obtained from both the National Astronomical Observatory (NAO) Rozhen and the American Association of Variable Star Observers (AAVSO), an appearance of superhumps in this object are detected. They are mostly visible in U band, with amplitude variations of $\approx 0.2 - 0.3$ mag. The possible active mass-transfer mechanisms between the binary's components are suggested and discussed.

1. INTRODUCTION

Cataclysmic variable stars (CVs) are binary systems with a white dwarf primary star, accreting matter from a main-sequence secondary via Roche lobe overflow (Warner 1995). Nova-like (NL) stars are subclass of Cataclysmic variable binaries that do not produce outbursts. They have high-mass accretion rate and the emission in UV band in these systems is coming from the disc (from Godon 2017, la Dous 1991).

One interesting Nova like (NL) system is V592 Cas, discovered by Greenstein et al. (1970). The orbital period of the system is ≈ 2.76 h (Taylor et al. 1998, Witherick et al. 2003). The distance to the object is measured in the range: from 360 pc (see Taylor) to 466 ± 4 pc (GAIA). The estimated accretion rate of V592 Cas is varied from $9 \times 10^{-9} \mathrm{M}_{\odot} y^{-1}$ to $1 \times 10^{-8} \mathrm{M}_{\odot} y^{-1}$ (Taylor et al. 1998, Hoard et al. 2009). Its blue color and spectral characteristics identified it as a disk-accreting Nova-like cataclysmic variable (CV). The presence of a wind is also detected by its spectrum (Witherick et al. 2003, Prinja et al. 2004). V592 Cas shows a behavior of an orbital modulation in the velocity extended UV lines profiles, typical for some cataclysmic variables. Observational effects that appeared as short-period, low-magnitude brightness variations are usually recognized as humps and/or superhumps (Isogai et al. 2016, Kato et al. 2000). They are typical for the Cataclysmic variable stars (CVs). The past observational data of V592 Cas show evidences that the star exhibits superhumps with all necessary conditions (Patterson 1998). The humps are observed with a periodicity Ph similar to the binary orbital period, usually in the quiescence low state. Superhumps' periodicity Psh is a few percent longer than the binary period and they can be observed during the high state of the objects (Warner 1995).

In this work, we present observational data that show superhumps activity of V592 Cas. We discuss on the currently active mass-transfer mechanisms between the binary components. This could be relevant to the type of accretion, wind or disc is dominant for the studied object.

2. OBSERVATIONAL RESULTS

We use observational data both from AAVSO and 2m telescope of the National Astronomical Observatory (NAO) Rozhen, Bulgaria. Data from AAVSO are for the observational period of time: 20060921 to 20081119, in V band. During this time, an activity with several superhumps is clearly detected (Figure 1). We select a better distinguished superhump among them and it is on the night of JD 2454750.40 – 2454750.50 (20081010 – 20081011 UTC date). The maximum amplitude of the brightness variation is $\approx 0.12 - 0.14$ mag in a frame of 3 hours. The magnitude is in the range 12.5612.42, in the V band.

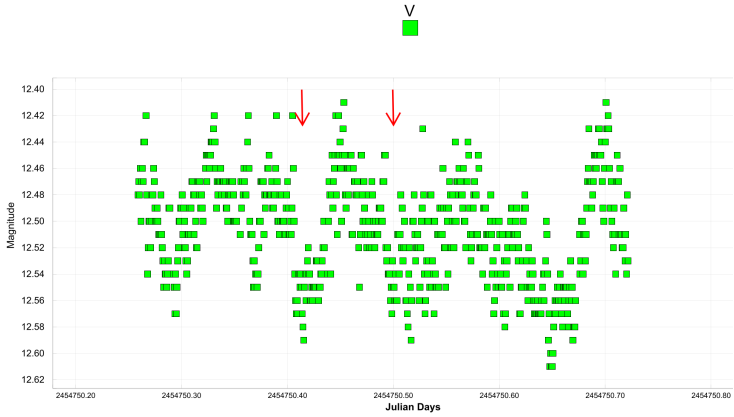

Figure 1: Light curve of V592 Cas in V band. Observational time: 20081010 – 20081011. Superhump is seen during this period (marked with red arrows). AAVSO data.

The 2m telescope with two channel focal reductor FoReRo2 and two identical CCD cameras Andor iKON-L was used for observations in B and U bands. The obtained data are for two different dates. On the night of JD 2459615 (20220204 UTC date) the brightness of the object decreases with 0.5 magnitudes in a time-frame of one orbital period. Quasi-periodic oscillations are also observed within this time, with average amplitude variations in brightness ≈ 0.3 mag. They have very short periodicity, in a range of $5 - 10$ minutes (Figure 2a).

On the night of JD 2459852 (20220929 UTC date), observations in the U band are in a frame of one orbital period of the star. A trend of a rising and decreasing brightness with an average amplitude of 0.3 mag during this time is seen. We measure its period and it is $\approx 3.2 \pm 0.002$ hours, which is slightly longer than the orbital period. This brightness variation is identified more like superhump (Figure 2b). Within this superhump period, we deciphered short-period quasi-periodic variations in brightness again, with amplitudes of $0.15 - 0.3$ mag. We suppose they look much more like

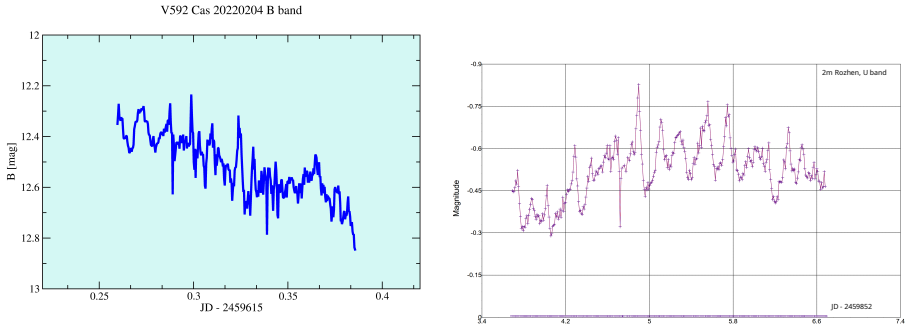

Figure 2: Light curve of V592 Cas in B band (2a-left) and U band (2b-right). Observational data are for different periods, obtained with the 2m telescope, NAO Rozhen. The magnitude in the U band is presented as amplitude variations.

flickering activity.

3. ACTIVE MASS-TRANSFER MECHANISMS AND EFFICIENCY

Further, to give a characteristic of an active mass-transfer mechanism, it is important to know an accretion efficiency values. It gives the measurement of how efficiently the mass energy of the accreted material is converted into radiation. We calculate average accretion efficiency values for V592 Cas, by using the expression of (Kolb 2010). Our results (current work and (Boneva & Yankova 2023)) confirm that V592 Cas is dominantly active in a disc than in a spherical accretion. The values both of the disc accretion rate ($\dot{M}_{\rm d}$) and the disc accretion efficiency η, are higher than those in the case with a spherical-like accretion, ($\dot{M}_{\rm sph}$) and efficiency ξ (see Table 1).

Table 1: Mean values of the accretion efficiency and accretion rate, calculated for the two modes' types.

Object/Mode	$\xi \times 10^{-4}$	$\eta \times 10^{-4}$	$\dot{M}_{\rm d} {\rm M}_{\odot} y^{-1}$	$\dot{M}_{\rm sph} {\rm M}_{\odot} y^{-1}$
V592 Cas	0.50 ± 0.02	2.05 ± 0.11	1.3×10^{-8}[1]	5×10^{-10}[2]

[1]Kafka et al. 2009 [2]Ringwald & Naylor 1998

We see that the observed precessing accretion disc around the primary component (Long 2003) could also affect on the values of the disc's accretion efficiency. The efficiency of V592 Cas is relatively low, but it increases through the modes, at higher accretion activity, during the time of a decreasing distance between the accretor and the accretion disc. In this binary, the stream from the secondary is most possibly transferring through the Lagrange point L1. A pseudo-spherical inflow is also possible to contact the outer parts of the accretion disc. Both type of inflows into the disc are affected by the two components' approach, which could cause a reaction in the spot or hot line contact area. Then, this reaction can be seen as a source of the superhumps.

4. SUMMARY

We presented observational results of NL star V592 Cas from both sources: AAVSO for the period of time ≈ 2 years in the V band; our own, obtained from the 2m telescope of the NAO Rozhen, Bulgaria, for two nights in the U and B bands. We have detected a manifestation of superhumps in the U and V bands in different nights. We found indications of flickering during one night in B, and also in the U band that was appeared within one superhump's period. Flickering indicates the presence of activity in the disc. This activity generates an energy excess that contributes to the appearance of the hot accretion zone, which on the other hand could be responsible for the humps and superhumps appearance. The calculated dereddened colors of the star present it rather as a bluer object ($B-V=-0.18; U-B=-0.99$ (Taylor 1998)), but mostly expressed its activity in the U band. The roughly estimated negative value of the color index ($U-B<0$) during our observations is an indication of a hotter radiation zone in the accretion disc. These heating parts of the disc could be one reason for the humps and superhumps productions. We give our estimations of the accretion efficiency of V592 Cas and discussed on the possible dominated accretion mode around the primary component of the object.

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