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NEGATIVE SUPERHUMPS IN CATACLYSMIC VARIABLES

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Abstract. We calculated relations between the known periods of positive and negative superhumps and the orbital periods (Stolz–Schoembs relation) for nova-like variables. Using the linear approximations we obtained slopes around 1.31 and 0.93 for (P_{sh+} - P_{orb}) and (P_{sh-} - P_{orb}) respectively.

In the typical for NLs range of orbital periods 0.1- 0.2 days the corresponding coefficients are 1.07 and 0.91.

1. INTRODUCTION

A common feature in different types of cataclysmic variables (CVs) such as Dwarf Novae (DN), AM CVn, Old Novae, Nova-likes (NLs), is the existence of superhumps (SHs) - periodic changes in brightness with periods close to the orbital period (P_{orb}). If this period is few percents longer than the P_{orb}, then we have positive superhumps (P+), while if variations are with period few percents shorter than the orbital period Porb, we have negative superhumps (P-).

There are many reviews and studies on this phenomena – for example the works of Patterson et al. (2005; 2002), Kato (2022), Montgomery (2009), Bruch (2022), etc. A major difficulty in such studies is the obtaining of long light curves of the objects during several consequent nights. The new space telescopes and missions, like TESS (Transiting Exoplanet Survey Satellite) can help by providing such data for superhumps detections and studies.

Many works show evolution of SHs in DN - during superoutbursts and during normal outbursts, the SH amplitudes and periods are changing. In NLs SHs are stable for months and even years and they are called "permanent" superhums. But in this type of systems, a disappearing of the SHs is observed, a switching from states with positive to negative SHs or even simultaneous existing of these two periods.

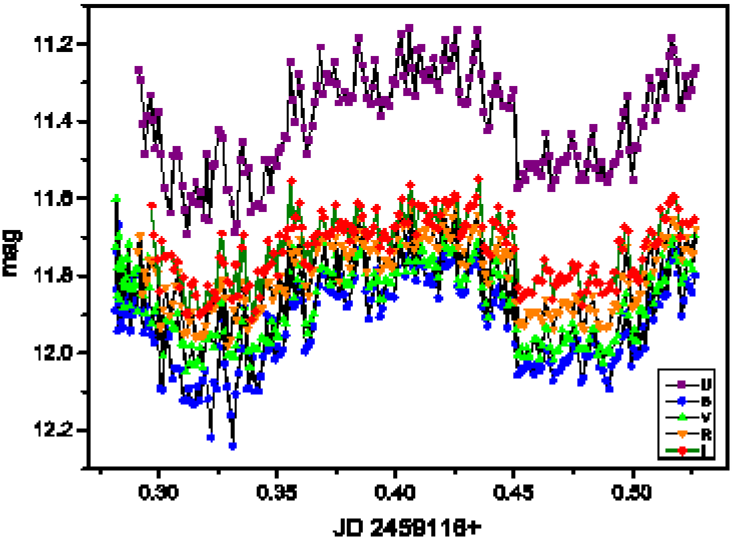

Figure 1: Light curve of BG Tri on September 23rd, 2020. Clearly is visible an existence of negative superhump with period 5 % shorter than the orbital one.

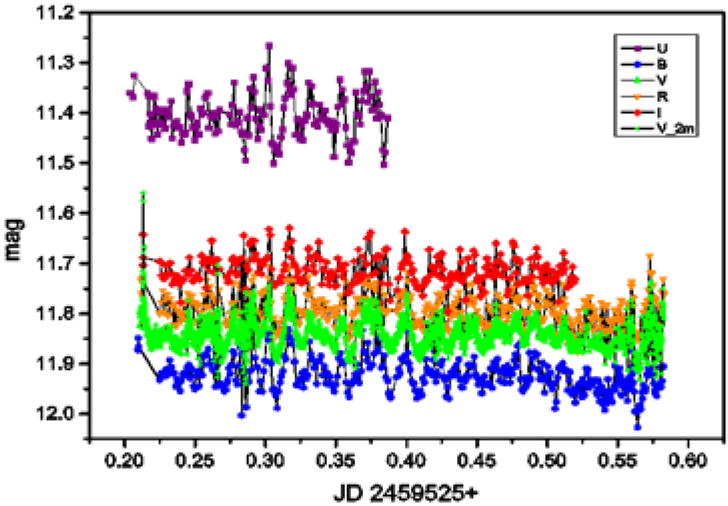

Figure 2: Light curve of BG Tri on November 06th, 2021 – the negative superhump is missing.

Fig.1 and Fig. 2 are example for above mentioned occurrence – the detected in 2020 negative SH in nova-like BG Tri is missing in the light curve from 2021 (Stefanov et al., 2022).

The theory interprets the positive SHs as prograde apsidal precession of an eccentric accretion disk caused by the tidal instability driven by a 3:1 resonance. The most accepted explanation of the nature of negative SHs is nodal retrograde precession of a tilted disk with respect to the orbital plane.

Stolz and Schoembs (1984) proposed a linear relation between P_{sh} and P_{orb}. This relation can be used for determination of P_{orb} using P_{sh} or for an estimation of mass ratio q ($q=M_2/M_1$) of the systems using period excess. Fuentes Morales et al. (2018) published actual linear fit for positive superhumps for several types of CVs. In this work we calculate linear fits for the positive and the negative SHs of NLs.

2. DATA

In the last years, the amount of detected SHs in NLs increased. In 2018 Fuentes Morales et al. have used for the calculation of their (P_{sh}-P_{orb}) linear fit 17 NL systems. In the literature we found 22 NLs with P+ and 26 with P- (Ritter & Kolb, 2005; Wood et al., 2009; Pavlenko et al., 2020; Castro Segura et al., 2021; Iłkiewicz et al., 2021; Bruch, 2022; Stefanov et al., 2022; Stefanov, 2022; Kato, 2022, etc.). Our sample for positive SHs contains all these 17 systems except BK Lyn (probably very old nova) and 6 additional ones. The average excess of the positive superhump period is ~ 9 % and the deficit for negative superhumps is ~ 4%.

10 of the included stars have both types of superhumps: BH Lyn, TT Ari, MV Lyr, PX And, TV Col, AQ Men, LS Cam, BG Tri, V 1193 Ori, V 795 Her. It is not clear why and when they switch the regime of the humps.

There are observations that show slight changes of the periods of the “permanent” SHs, their shapes, amplitudes and colors, but it does not significantly change the relations. Probably they are caused by long-term variations in the accretion disc or some of its structures. Part of NL systems belong to the sub-class VY Scl which sometimes show low photometric states. The decrease of mass-transfer rate leads to disappearance of SHs.

3. RESULTS AND DISSCUSION

We preferred to use Stolz–Schoembs relation from Gänsicke et al. (2009) and Fuentes Morales et al. (2018) in the reversed form

$$P_{sh} = a + b^* P_{orb}.$$

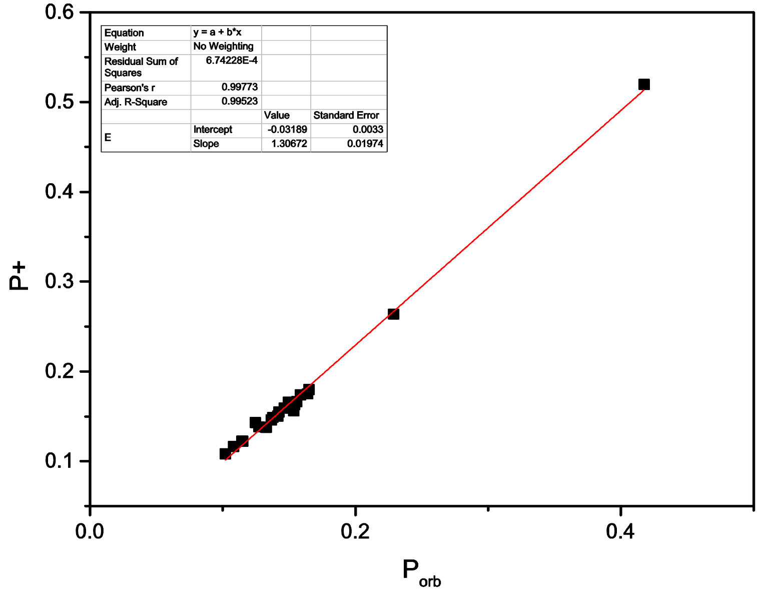

Figure 3: P+ as a function of Porb. Linear fit for 22 NLs.

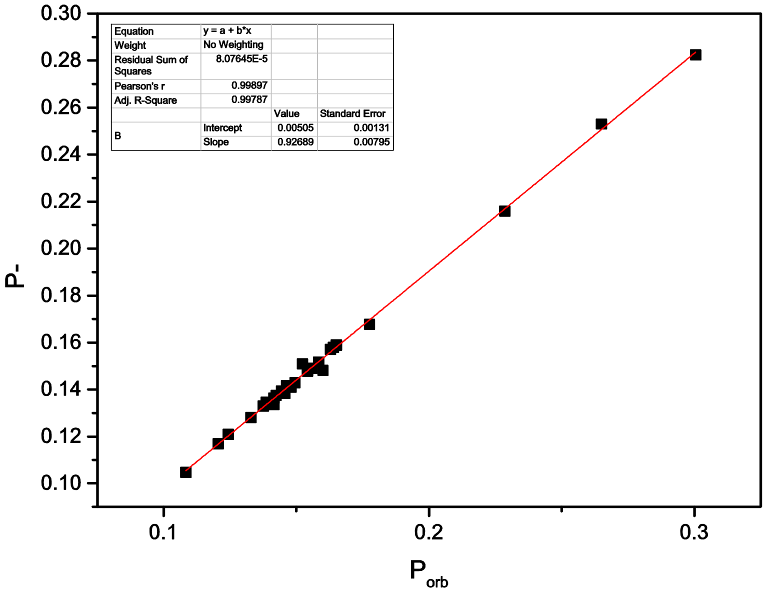

Figure 4: P- as a function of Porb. Linear fit for 26 NLs.

This equation form is more appropriate because we calculated not only the relation for the positive superhumps but also for the negative ones. The corresponding coefficients can easily be converted into one another. In that way we obtained the dependence of the period of the superhump as a function of the orbital period.

We obtained the coefficients of the linear fit as per below:

$$P+ = -0.032\ (\pm\ 0.003) + 1.306\ (\pm\ 0.020) * P_{orb}$$
$$P- = 0.005\ (\pm\ 0.001) + 0.927\ (\pm\ 0.007) * P_{orb},$$

where the periods are given in days (Fig. 3 and Fig.4). Both Pearson correlation coefficients are 0.998 and 0.999, respectively.

If we use the standard form of the equation, then the calculated coefficient of the slope for P+ is 0.76. Gänsicke et al. (2009) in their work used various types of CVs with positive SHs, but Fuentes Morales et al. (2018) determined separately for nova-like variables the slope 0.84 and 0.90 for dwarf novae - nova-like stars have smaller slopes. Our result is slightly less than this value. If we use only systems with typical for NLs orbital periods in the range of 0.1 – 0.2 days, the obtained slope is 0.90 (in reversed relation – 1.07). It seems, the outliers – TV Col and RZ Gru, have changed the coefficient of this relation. Although the dependence gives a good linear fit over a wide interval of periods, probably there exists some difference in all sections. It seems the (P_{sh+} - P_{orb}) relation is more flat for systems with longer orbital periods.

For negative superhumps the slope is 0.93. A recalculation using stars with orbital periods in the interval 0.1 – 0.2 days, obtained value is 0.91 and it is in the standard error interval of the slope. Therefore negative superhumps are more often detected in NLs and probably the linear dependence between their periods and the orbital ones is valid at more wide range.

The relation between P+ and P- for all 10 systems with both types of superhumps gives 1.35 ± 0.04.

4. CONCLUSIONS

We calculated linear fits for Stolz–Schoembs relation for period of SH (P_{sh}) as function of the orbital period (P_{orb}).

The obtained value of the slope for the positive superhumps is 1.31. For systems in the range of orbital periods 0.1- 0.2 days respectively this value is 1.07. It is possible that the relation is more flat for systems with longer orbital periods.

For positive superhumps the slope of the linear fit is 0.93 and it changes slight (0.91) for systems with orbital periods 0.1 – 0.2 days.

The periods of positive superhumps are approximately 35 % longer than the periods of negative ones for systems which have both types.

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