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Superoutbursts of WZ Sge-type dwarf novae as seen by Swift

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1 Introduction

WZ Sge-type stars are an extreme subgroup of the dwarf nova (DN) class of cataclysmic variables. In contrast to ordinary SU UMa-type DNe, the WZ Sge-type stars exhibit only very rare (∼ once a decade) and long superoutbursts (a few weeks) with amplitudes exceeding 6 mag, and no normal outbursts. A unique property of superoutbursts is the appearance of superhumps, low-amplitude modulations with a period of a few percent longer than the orbital one.

Though X-ray properties of different DNe are not always consistent, on the whole, they can be characterized by suppression of the X-ray flux during an outburst, accompanied by the softening of the X-ray spectrum. In contrast, the WZ Sge-type objects show an increase of their X-ray luminosity during an outburst. Unfortunately, not too many WZ Sge-type DNe have been observed in X-rays. However, thanks to *Swift*, a few such objects have complete coverage of an X-ray light curve throughout their superoutburst. Here we present the results of X-ray observations of these objects with Swift/XRT through their superoutbursts and the following decline, and compare the X-ray light curves with optical observations.

2 Objects

SSS J122221.7−311525 (hereafter **V0754 Hya**) was discovered in outburst on 2013 January 1 at V = 12.3, and was subsequently found to have been in outburst by 2012 December 16. The superoutburst with the total amplitude of ∼7 mag had a double structure and a long duration (Fig. 1). The two segments of the superoutburst were separated by an ∼5 mag and ∼10 d dip. The second segment of the superoutburst had a duration of 33 d and it displayed an extended post-outburst decline lasting ∼500 d. The *Swift* X-ray satellite started observing V0754 Hya on 2013 January 6, 5.8 days after the discovery announcement. Observations were obtained every 1–3 days until 2013 July 1. A total of 60 observations were taken during this period. A few follow-up observations were performed in 2014, 2015, 2016, 2017. The total exposure time of our observations is 86.6 ks. UV–optical–NIR and X-ray observations of V0754 Hya were presented by Neustroev et al. (2017,2018).

GW Lib is a WZ Sge-type DN with an orbital period of 77 min. Its most recent superoutburst in 2007 lasted ∼26 d and its optical amplitude exceeded 8 mag. The optical light curve showed a usual pattern of superoutburst with no sign of a dip during the plateau stage (Fig 2). Observations of the outburst in the optical, ultraviolet and X-ray wavelengths started before the system reached the maximum light, and the outburst was followed in great detail (Byckling et al. 2009, Vican et al. 2011; Neustroev et al. 2018). A few follow-up X-ray observations were obtained in quiescence.

ASASSN-15po is a WZ Sge-type DN with an orbital period of 73 min. Its main superoutburst in 2015 lasted for about 28 days, and, after a few days, the rebrightening phase began and continued for at least 24 days (Namekata et al. 2017). This object appeared much fainter in X-rays than the two previous ones. Even though *Swift* observed it 23 times during the outburst, most have given only upper limits on an X-ray count-rate (Fig. 3).

A few other WZ Sge objects were observed only occasionally through their outbursts.

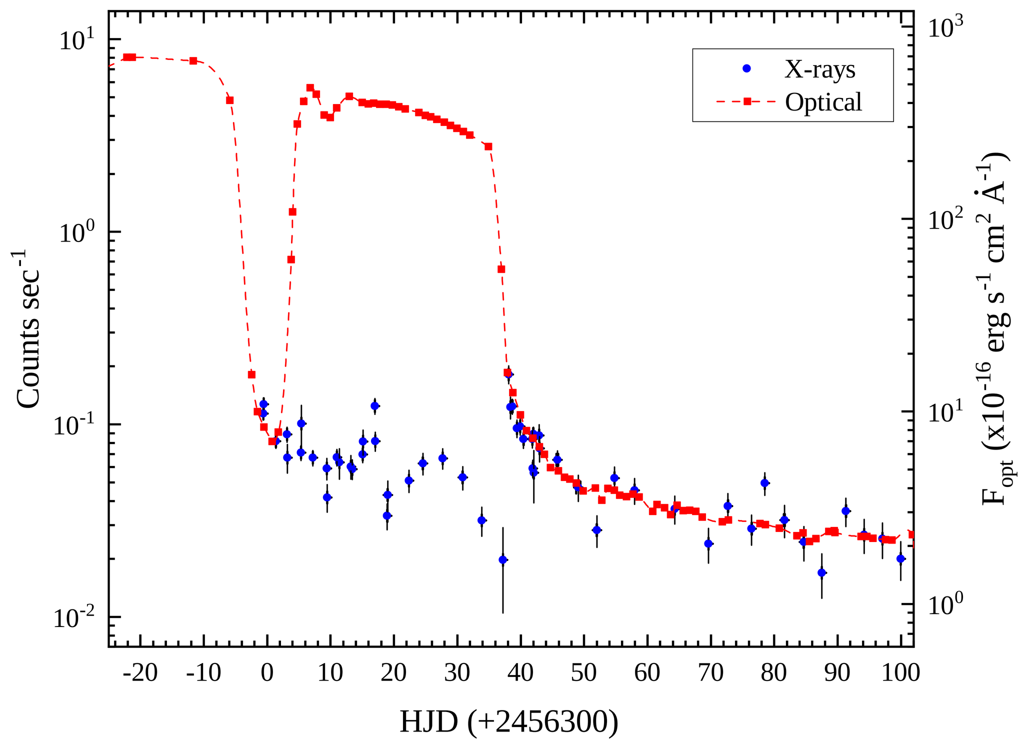

Figure 1: X-ray light curve of V0754 Hya (the first 100 days of observations) in the energy range 0.3–10 keV shown together with the optical V-band light curve.

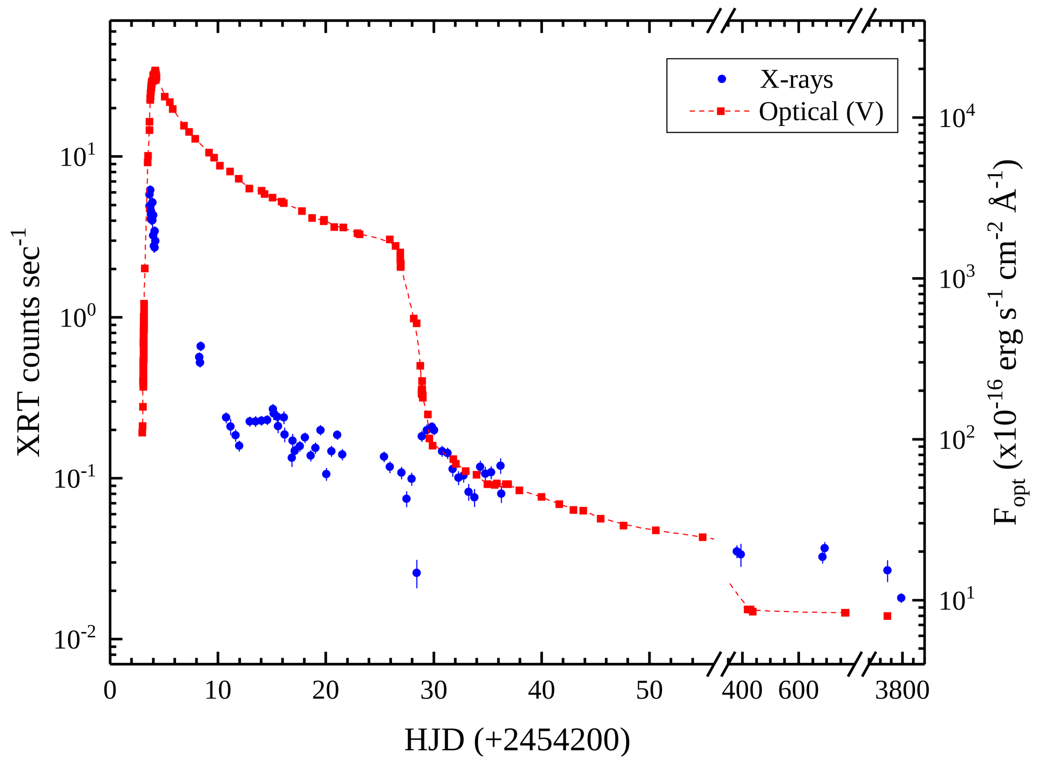

Figure 2: X-ray and optical light curve of GW Lib.

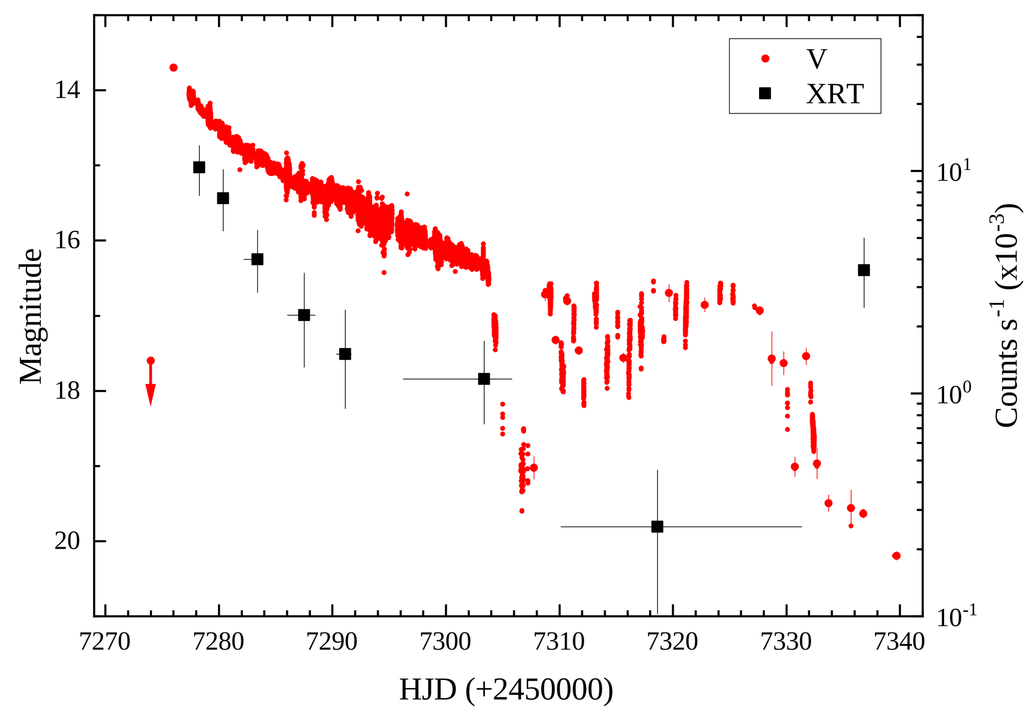

Figure 3: X-ray and optical light curve of ASASSN-15po.

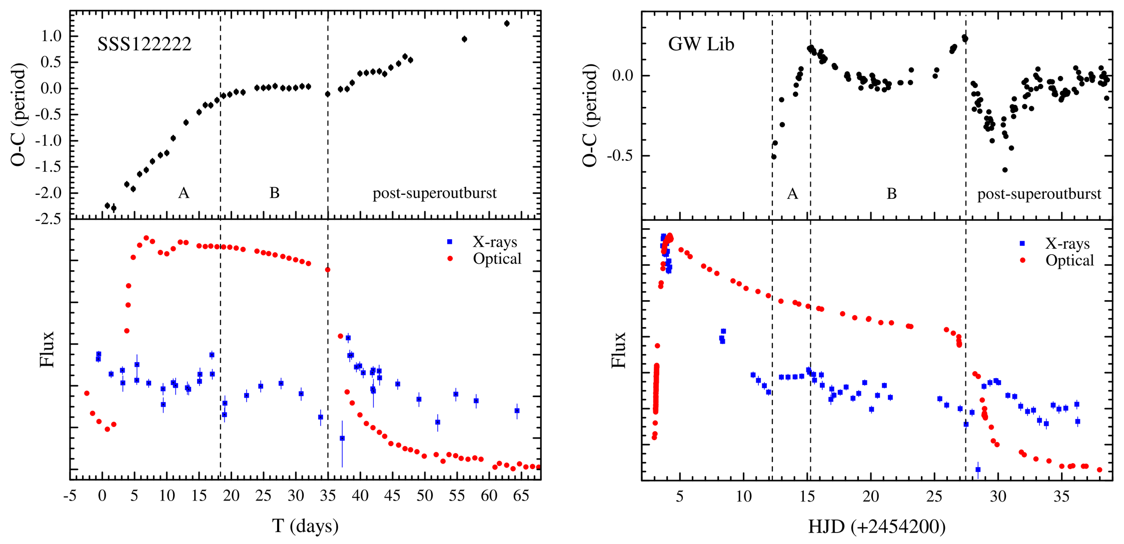

Figure 4: O–C diagrams (upper panels) and optical and X-ray light curves (bottom panels, arbitrary scaling to emphasise the change in flux) of SSS J122222 and GW Lib (see Neustroev et al. 2018 for detail).

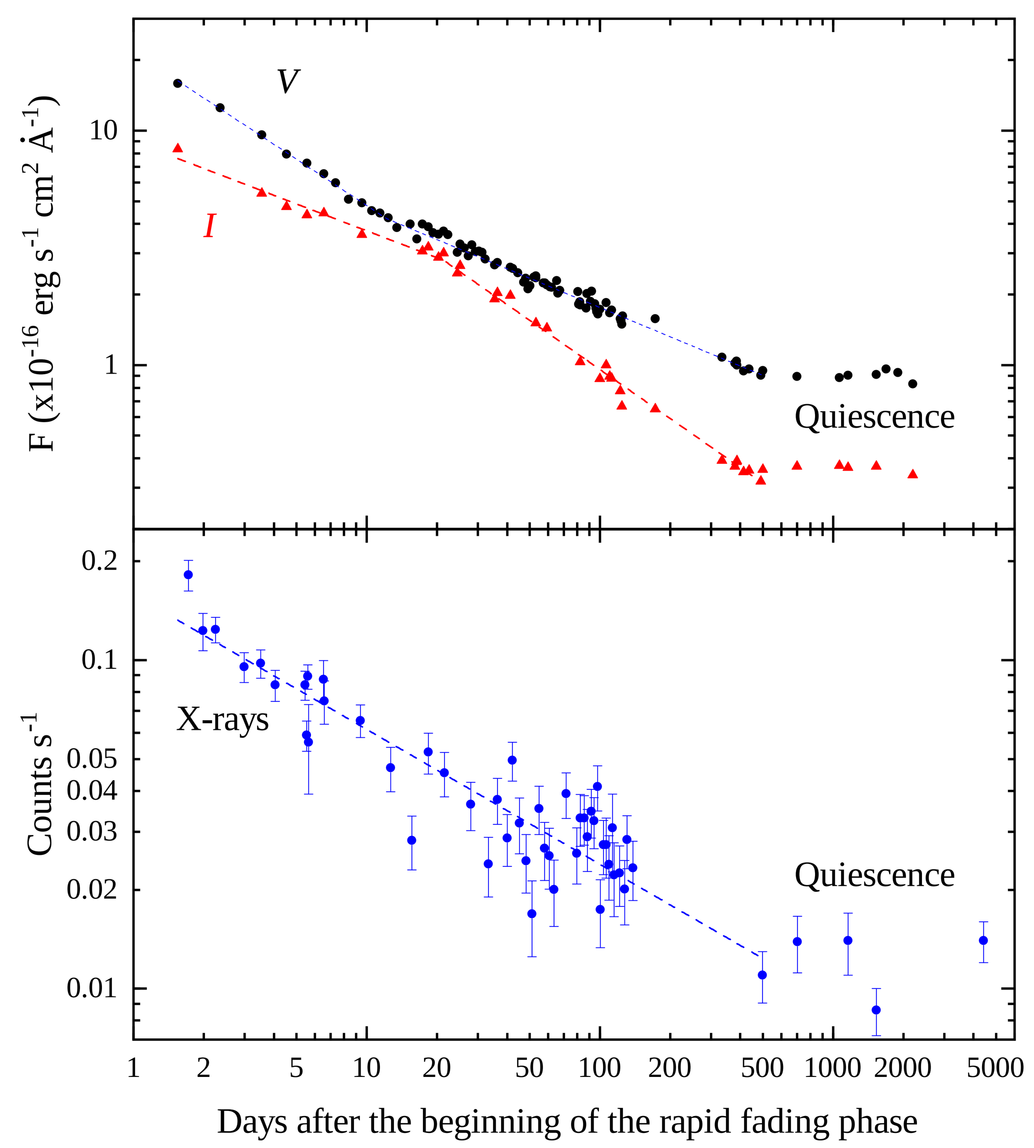

Figure 5: Optical (top panel) and X-rays (bottom) light curves of the decline stage of the superoutburst of V0754 Hya plotted with a logarithmic time scale. The days are counted from the beginning of the rapid optical fading stage at at HJD 2456336.4.

3 Results

We investigated the relation between the optical and X-ray fluxes during superoutbursts of WZ Sge-type DNe. We found the following:

1. All the observed objects showed a higher X-ray luminosity during their superoutbursts than during subsequent quiescence.
2. The X-ray flux of GW Lib reached the maximum before the optical light. All the observed objects were much brighter in X-rays at the very beginning of the outbursts and then declined.
3. The rapid decline of the X-ray flux of GW Lib, which was observed during the first 10 days after the initial rise at the beginning of the superoutburst, ended exactly at the time of the first appearance of superhumps (Fig. 4). This stage of the superoutburst of V0754 Hya was missed, but a similar behaviour was detected in ASASSN-15po.
4. The post-outburst decline of both the X-ray and optical fluxes of V0754 Hya (the only target frequently monitored after the outburst) lasted for ∼500 d (Fig. 5). Also, observations of GW Lib in 2017 showed a decrease of X-ray flux in comparison to that observed after the optical outburst eight and nine years before. However, 10 years after the superoutburst, the X-ray flux was still about five times larger than was measured before the superoutburst.
5. We detected a sudden X-ray flux change in the middle of the superoutburst of V0754 Hya coincident with a change in superhump behaviour. A similar X-ray behaviour was also detected in GW Lib (Fig. 4).
6. We also detected, in most objects, a sudden X-ray flux increase at the very end of the rapid decline phase, after which the X-ray flux declined slowly.

4 Conclusion

- We have shown for the first time that the X-ray flux from **WZ Sge-type** systems is linked to their simultaneous superhump behaviour, thus linking the inner disc properties to those of the outer (possible whole) disc. Indeed, superhumps are caused by the disc precession, and their appearance, evolution and stage transitions reflect geometrical and/or dynamical transformations of the asymmetrical disc. This result suggests that models for accretion discs in high mass ratio accreting binaries are currently incomplete.
- The very long decline to X-ray quiescence is also in strong contrast to the expectation of low viscosity in the disc after outburst.
- We propose that the disc precession is a cause of an enhanced viscosity and an increased temperature of the inner disc, stimulating thus a matter drift through the disc during the decline stage of superoutbursts.

These unexpected findings can have important implications beyond CVs, for example to LMXBs, in which a precessing accretion disc can be formed during outbursts.

5 References

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