Flickering returns as RS Oph reestablishes quiescent conditions following its 2021 nova outburst

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ABSTRACT

RS Oph has persistently displayed flickering at optical wavelengths when observed away from its repeating nova outbursts. During the 2006 eruption the flickering disappeared, and this repeated during the recent 2021 event. We have been monitoring RS Oph looking for the reappearance of flickering at $B$-band following the 2021 outburst. The flickering was still absent ($\sigma(B)<0.002$ mag) on day +210 (counted from nova optical maximum), appeared at $\sigma(B)=0.008$ mag on day +224, and raised to $\sigma(B)=0.029$ mag on day +250. On following dates the amplitude remained large, although fluctuating. The recovery of $B$-band quiescence brightness by RS Oph begun around day +225 and was completed by day +260. The parallel patterns followed by the rise in system brightness and the reappearance of flickering confirm the central role played in RS Oph by the return to pre-outburst conditions of the accretion disk and the refilling by the RG wind of the immediate circumstellar space.

Keywords: Recurrent Novae (1366) — Symbiotic stars (1674) — Stellar accretion disks (1579) — Time series analysis (1916)

1. INTRODUCTION

RS Oph is one of the most studied symbiotic stars and recurrent novae, following its repeated outbursts in 1898, 1933, 1958, 1967, 1985, 2006, and 2021, with possibly two more in 1907 and 1945 (Schaefer 2010). Away from the fast evolving nova eruptions, in quiescence RS Oph is powered by accretion onto its massive white dwarf (WD) of material lost the red-giant companion (RG), on a 456-days orbit. RS Oph has been a popular target in searches for accretion-induced, rapid light-variability (flickering) during its quiescence periods, with all observing campaigns that have invariably detected its presence (Walker 1977; Bruch 1992; Dobrzycka et al. 1996; Sokoloski et al. 2001; Gromadzki et al. 2006; Zamanov 2011; Zamanov et al. 2015, 2018; Georgiev et al. 2019, 2020a,b, 2021).

Flickering is not expected from RS Oph during outbursts, because of the overwhelming glare of the eruption, and the disturbing and disrupting effect that the impacting ejecta have on the accretion disk. In fact, early searches for flickering during the 2006 and 2021 outbursts detected none (Zamanov et al. 2006, 2021; Marchev et al. 2022). After dispersal of the ejecta into the circumbinary space and the ending of nuclear burning on the surface of the WD, the end of each outburst leaves RS Oph significantly fainter than quiescence. This also repeated for the 2021 outburst, as the $B$-band light-curve in Figure 1 clearly illustrates: the drop below quiescence results from the combined effect of the cavity emptied by the expanding ejecta which has not yet been (fully) replenished by the wind of the RG, and of the accretion disk that has not yet returned to its pre-outburst conditions.

As the accretion gradually resumes and the disk consequently grows in brightness, it is expected that flickering progressively returns. We report here about our intensive monitoring of RS Oph in search of the return of flickering, following the exit from Solar conjunction of the star on Jan 13, 2022 (day +156, Munari et al. (2022); all dates in this paper are counted from nova optical maximum on 2021 Aug 09.58). Some preliminar results on the reappearance of flickering in RS Oph have been presented by Romanov (2022) and Zamanov et al. (2022).

2. OBSERVATIONS

To monitor RS Oph for flickering we have used the 67/92cm Schmidt telescope operated in Asiago by INAF National Institute of Astrophysics (Italy). The telescope observes robotically from Mt. Ekar (elevation 1400m), has an excellent optical quality and frequently enjoys 1 arcsec seeing conditions. The 4k×4k CCD camera covers 1 squared-degree on the sky at 0.88 arcsec/pix scale.
Figure 1. Upper panels: flickering of RS Oph and the five check stars for two of the observing dates. The ordinate scale is the same in all panels. The values for $B$, $B-V$, and $\sigma$ are in magnitudes. Lower-left panel: ANS Collaboration $B$-band light-curve of RS Oph during the 2021 nova outburst. Two levels of $B$-band brightness in quiescence are indicated (median values from the ANS Collaboration long-term monitoring): $B=12.24$ mag characterizing the first 10 years following the 2006 eruption, and $B=11.94$ mag for the last 5 years preceding the 2021 outburst. Lower-right panel: summary of the results of our observations in search for flickering in RS Oph following its emergence from Solar conjunction.

The observing procedure we have adopted for RS Oph is identical to that followed by Munari et al. (2021) in their characterization of 33 new symbiotic stars. In essence, the observations has been conducted as sequences of 10 exposures of 30-sec each in the $B$-filter preceded and followed by a single 20-sec exposure with the $V$-filter, repeating the cycle for up to 70 minutes. Each $B$-band exposure is paired with the closest-in-time $V$-band frame, and the transformation color equations to the Landolt (2009) standard system are solved for such a pair against a set of 72 reference stars imaged together with RS Oph. These reference stars have been selected from APASS DR8 (Henden & Munari 2014), are non-variable, span an interval of a couple of magnitudes centered on the quiescence value of RS Oph, and are well distributed in color over the range $B-V=+0.671$ to $+2.048$, thus well bracketing the color of RS Oph. Around RS Oph we have also selected a set of five field stars (not part of the reference stars) of $B$-band brightness and $B-V$ color similar to RS Oph, and equally well clear of interfering nearby stars. These check stars are measured along RS Oph with identical aperture parameters.

An example of the collected measurements is presented in Figure 1 (upper panels). The dispersion $\sigma$ for the five check stars (4.2 millimag on average) represents the overall noise in the measurements (combining all sources, from shot-noise to transformation to the standard Landolt system). A larger dispersion of the measurements for RS Oph ($\sigma_{RSOph}$) is...
taken as indicative of the presence of flickering, with its effective amplitude computed as $\sigma_{fl} = \sqrt{\sigma_{RSOph}^2 - \sigma_{CS}^2}$, where $\sigma_{CS}$ is the quadratic mean of $\sigma$ for the five comparison stars.

3. RESULTS

The results of our monitoring are listed at the lower-right of Figure 1, with 2022 March 09 being the latest of our observing dates in which RS Oph did not yet present detectable flickering. The reappearance of flickering coincides with the upturn of the $B$-band lightcurve around day +225. From day +250 the recorded amplitude of the flickering seems to depend more on the actual observing date rather than on the $B$-band brightness of RS Oph.

By day +260 RS Oph has resumed the same $B$-band brightness that has characterized the initial 10 years of the quiescence following the 2006 outburst, indicating that the the immediate circumstellar space in RS Oph has been refilled by the RG wind and the accretion disk has returned to its pre-outburst conditions. Such disk is probably less massive and extended than it has been for the last five years preceding the 2021 eruption, when the quiescence brightness of RS Oph raised by $\Delta B = 0.3$ mag. This fact suggests that, similarly to what is observed in T CrB (Munari et al. 2016; Luna et al. 2020), also in RS Oph the accretion onto the WD is not smooth and constant between outbursts, but is instead of a more episodic nature.

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