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PHOTOMETRY OF RS Oph AFTER THE 2006 OUTBURST†

ZAMANOV, R.[1]; BOËR, M.[2]; LE COROLLER, H.[2]; PANOV, K.[1]

[1] Institute of Astronomy, Bulgarian Academy of Sciences, 72 Tsarighradsko Shousse Blvd, 1784 Sofia, Bulgaria

[2] Observatoire de Haute-Provence (CNRS), 04870 Saint Michel l'Observatoire, France

In February 2006, the recurrent nova RS Oph has undergone its first outburst for this century. On February 14th, 2006 it reached $4\overset{m}{.}4$ (Narumi et al., 2006) and began to decline. In late May, the brightness of the star had already returned to its pre-outburst level of $V = 10\overset{m}{.}5$–$11\overset{m}{.}5$ (see O'Brien et al., 2006, and AAVSO light curves for more details).

CCD photometry of this recurrent nova has been secured with the 120-cm telescope at OHP. With an 1024 × 1024 CCD, the field of view is $11\overset{'}{.}8 \times 11\overset{'}{.}8$. Our aim was to investigate the variability on time scales from minutes to days after the 2006 recurrent nova outburst.

Our B, V, R (Johnson–Cousins) measurements are summarized in Table 1. As comparison stars we have used SAO 141899 (HD 162215, $V = 9.307, B = 10.513, R = 8.601$) and GSC 0509400061 (USNO 0825-11335145, $V = 11.494, B = 12.199, R = 11.040$). The reduction was done in a way similar to Chevalier & Ilovaisky (1991) using average extinction from June 2006. In order to search for rapid variability, we performed time-resolved differential CCD photometry in B band. This procedure involved the repeated measurement of RS Oph relative to our main comparison stars SAO 141899 and set of stars in the field. Each observational run consisted of a series of exposures in B band, with exposure time $\sim$ 40 sec. In Table 2 we give the start of the run, its duration, number of the points obtained, the minimal and maximal value of B magnitude, the mean B magnitude, and the standard deviation ($\sigma_B = \sqrt{\frac{1}{(N-1)}\sum_i (B_i - \overline{B})^2}$) calculated from all points in the run. In Fig. 1 we plot time-resolved B magnitudes. The behaviour of σ_B for the stars in the field is illustrated in Fig. 2.

Table 1. BVR magnitudes of RS Oph. Typical error of our measurement is ±0.015 mag

Date of obs. yyyy/dd/mm	UT	JD 24...	B	V	R
2006/06/06	22.92	53893.454	12.702	—	10.241
2006/06/09	0.53	53895.522	12.732	11.373	10.224
2006/06/09	2.02	53895.584	12.734	11.404	10.222
2006/06/09	23.99	53896.499	12.734	11.396	10.221
2006/06/10	23.44	53897.477	12.722	11.405	10.232
2006/06/11	1.73	53897.571	12.734	11.394	10.230

†Based on observations obtained with the 120-cm telescope at the Observatoire de Haute-Provence.

Table 2. Time-resolved B band photometry

Date of obs. yyyy/mm/dd	UT-start h	length [h]	N_{pts}	B min/max	B mean	σ_B [mag]
2006/06/06	21.258	5.16	136	12.680/12.738	12.708	0.014
2006/06/08	20.704	5.28	144	12.680/12.730	12.706	0.011
2006/06/09	20.558	4.28	100	12.702/12.747	12.727	0.012
2006/06/10	23.515	2.47	66	12.710/12.745	12.730	0.008

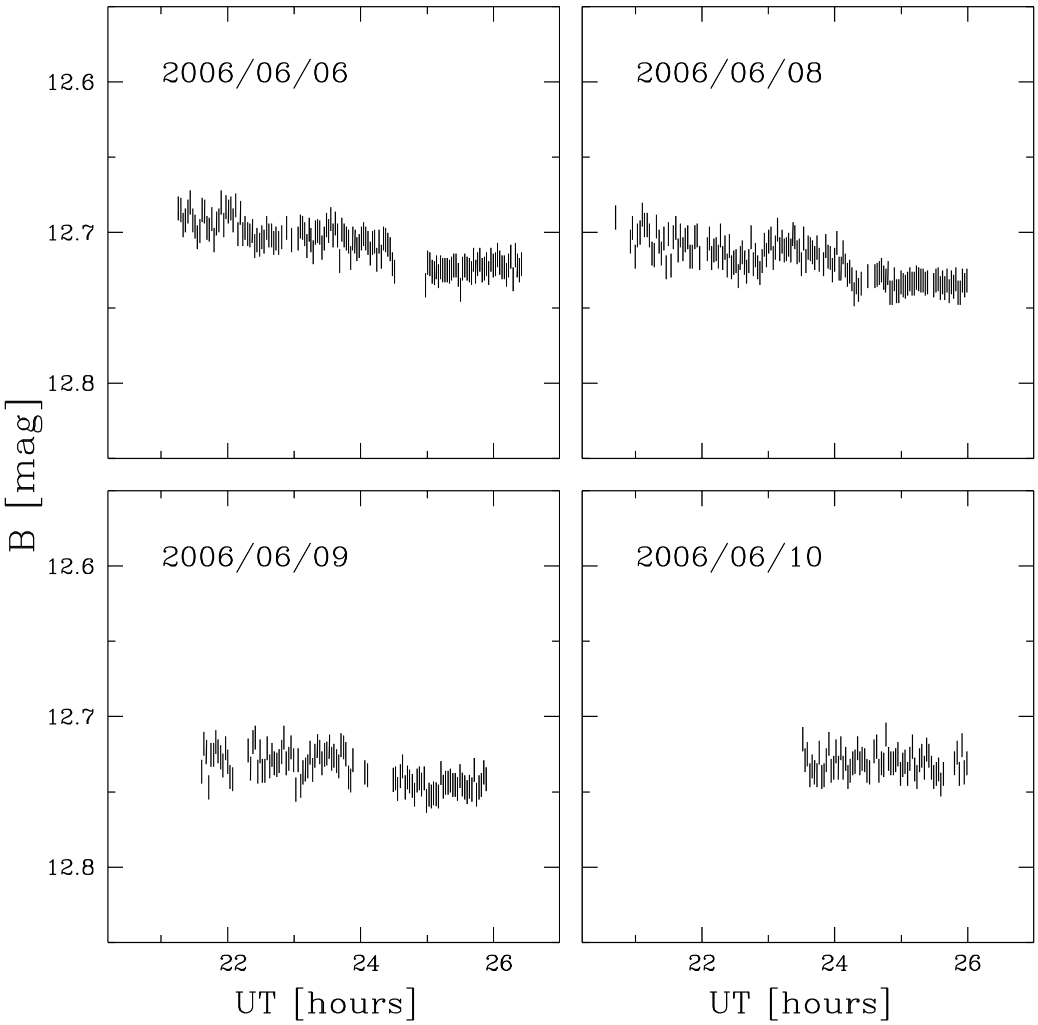

Figure 1. Time resolved CCD photometry of RS Oph obtained in June 2006 with the 120-cm telescope of OHP in B band. The date when the observation started is displayed in YYYY/MM/DD format. No short term variability (flickering) with total amplitude $\Delta B > 0\overset{m}{.}06$ has been detected on minute-to-hour time scale. The behaviour of the check star is plotted in Fig. 3

From Table 2 and Fig. 1, we derive upper limits of the variability: $\Delta B \leq 0\overset{m}{.}06$, and according to Table 1: $\Delta V \leq 0\overset{m}{.}035$, and $\Delta R \leq 0\overset{m}{.}02$. To the best of our knowledge, these are the first observations when the minute-to-day photometric variability of RS Oph in the optical is so low.

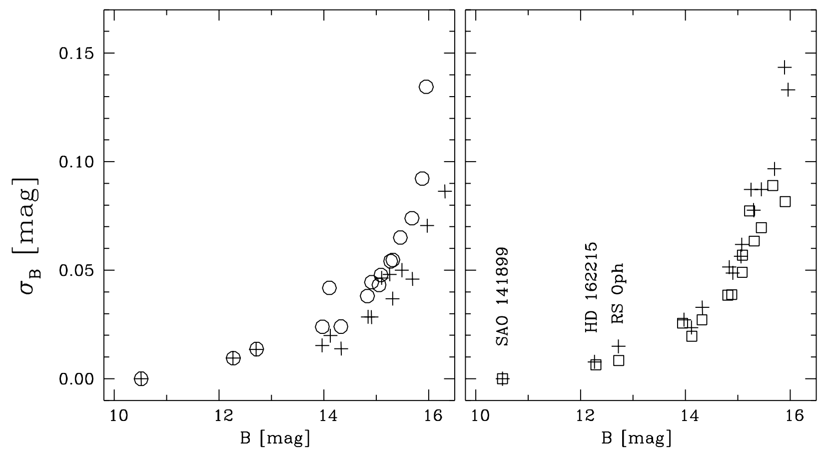

Figure 2. The standard deviation for the stars in the CCD field. Left panel: 2006/06/06 — crosses, 2006/06/08 — circles. Right panel: 2006/06/09 — crosses, 2006/06/10 — squares. The three brightest objects including RS Oph, are indicated on the right panel only. There is no clear departure of RS Oph from the behaviour expected for a star of constant brightness. SAO 141899 has been used as comparison star and its $\sigma_B \equiv 0$

Our B band light curves (see Fig. 1) are considerably different from those obtained with similar setup between the 1985 and 2006 outbursts (examples of the flickering of RS Oph can be seen in Dobrzycka et al., 1996, and Sokoloski et al., 2001). The flickering of RS Oph is known since a long time. However, no systematic investigations of its properties have been made to date. The previous observations in B band (see Table 3), revealed strong variability on the minute-to-hour time scale.

Table 3. Observations of RS Oph in B band on minute-to-hour time scale. In the table are given the date of observations, the amplitude of the B band variability, σ_B, and the reference.

Date of obs. yyyy/mm/dd	ΔB [mag]	σ_B [mag]	Reference
1983/07/14	0.32	0.07	Bruch, 1992
1983/07/18	0.38	0.06	Bruch, 1992
1983/08/14	0.34	0.07	Bruch, 1992
1993/06/06	0.19	0.07	Dobrzycka et al., 1996
1993/06/07	0.28	0.06	Dobrzycka et al., 1996
1993/06/09	0.24	0.05	Dobrzycka et al., 1996
1997/09/02	0.36		Sokoloski et al., 2001
2002/16/06	0.330	0.057	Gromadzki et al., 2006
2002/08/27	0.275	0.047	Gromadzki et al., 2006
2006/June	<0.05	<0.020	this paper

Usually, the variability of RS Oph on flickering time scale has an amplitude of $\Delta B \sim 0\overset{\rm m}{.}20$–$0\overset{\rm m}{.}35$ and typical $\sigma_B \sim 0\overset{\rm m}{.}05$–$0\overset{\rm m}{.}07$. During our June 2006 observations, we did not detect such a variability. On the panels for 2006/06/06 and 2006/06/08 in Fig. 1, one can see fading of RS Oph with $0\overset{\rm m}{.}05$ during both nights. Our experiments have shown that this trend is probably real, although part of it can be due to the extinction. Is this fading real or not does not change our main result that the flickering of RS Oph is absent.

The disappearance of the flickering of RS Oph indicates that the accretion disk around the white dwarf has been demolished by the 2006 outburst. We can compute the approximate time to rebuild it, as the time needed the matter to cross the accretion disk (viscous time scale). An estimation of this time is $\Delta t = 2(R/H)^2 R^{3/2}/3\alpha\sqrt{GM}$, where R is the outer radius of the accretion disk, and M is the white dwarf mass. For a typical Shakura–Sunyaev accretion disk, we can use $\alpha \approx 0.1$–0.2, $(R/H) \approx 10$. Using parameters appropriate for RS Oph, $R \approx 10$–$20\ R_\odot$, $M \approx 1.4\ M_\odot$, we derive $\Delta t \sim 160$–800 days.

It will be very interesting: (1) to follow the re-appearance of flickering; (2) to detect whether it will appear first on minutes or on hour time scale; (3) to compare the behaviour of the accretion disk after a nova explosion (RS Oph) and after a jet-ejection as observed in CH Cyg (Sokoloski & Kenyon, 2003).

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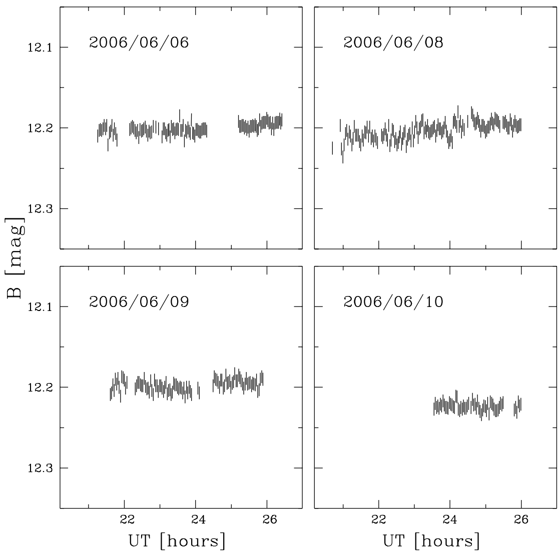

Figure 3. To illustrate the quality of our data, we plot the behaviour of the check star HD 162215 obtained in the same way as RS Oph's data in Fig. 1

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