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DETECTION OF A LARGE FLARE IN THE RS CVn STAR WY Cnc

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As a part of our ongoing study of RS CVn stars, we obtained new optical photometry of WY Cnc in 2005 and 2006. Here we report on a flare detected on WY Cnc in February 2006. We calculated the flare characteristics and analyzed the WY Cnc spot activity before and during the flare. WY Cnc (G5V+M2V, $P = 0.83$ d) is a short-period eclipsing RS CVn system (N 82 in the catalogue of Strassmeier et al., 1993). WY Cnc has been studied since 1965 (Chambliss, 1965). It shows starspot activity with the hotter primary star being the active one. Recently Heckert et al. (1998), Heckert (2001), and Kjurkchieva et al. (2004) noted secular luminosity increases of nearly 0.1 mag in 1988, 1997 and 2001.

We observed WY Cnc at three observatories. We obtained Johnson–Cousins $BVRI$ photometry with the 61-cm telescope at San Diego State University's Mount Laguna Observatory in May 2005 and January 2006, Johnson $UBVRI$ photometry with the 1.25-m telescope and Piirola photometer at Crimean Astrophysical Observatory in February 2006 and at Ural State University's Kourovka Observatory in January 2005 and February 2006. The Mount Laguna and Crimean data were transformed to the standard system using data reduction methods described by Heckert et al. (1998) and by Alekseev & Gershberg (1996). At Kourovka Observatory we used a three-channel photometer attached to the 70-cm telescope. The program and comparison stars and the sky were observed simultaneously. The data were collected with 4-s sampling times. Because the angular separation between the program and comparison stars is only $17'$, the differential magnitudes are only corrected for the first order atmospheric extinction. The second order atmospheric extinction is small in the V and R bands but can play a role in the B band. However, we compared our data obtained during several consecutive nights and made sure that the points of the individual lightcurves with the same orbital phases and different air masses are in range ±0.01 mag. Thus, the second order atmospheric extinction during our observations in the B band was small too. Moreover, its influence is cancelled out to some extent when data from different nights are averaged.

Simultaneous measurements of the program and comparison stars are advantageous because they provide more confidence in the reality of the observed brightness variations. However, such observations are difficult to transform to the standard system because we do not know the program and comparison star magnitudes corrected for atmospheric extinction separately. Therefore at Kourovka observatory we used standard Johnson filters, but the data were not transformed. Nonetheless, we compared the Kourovka data to the data obtained at the Mount Laguna and Crimean observatories during the overlapping time intervals in January and February 2006 and found that the Kourovka data are brighter than the Mt. Laguna data only by 0.01 mag. Also the Crimean data are brighter than the Mt. Laguna data by 0.02–0.03 mag (in different bands). Therefore we shifted the Kourovka and Crimean data towards the Mount Laguna data to diminish these deviations. We used HD 77173 as a comparison star at Mt. Laguna and CrAO, and BD+26°1883 at Kourovka. The data points have a statistical accuracy of 0.01 mag or better. Phases were calculated from the ephemeris of Hall & Kreiner (1980): HJD = $2426352.3895 + 0.82937112 \times E$. Figures 1a, 1b, 1c show WY Cnc V band lightcurves.

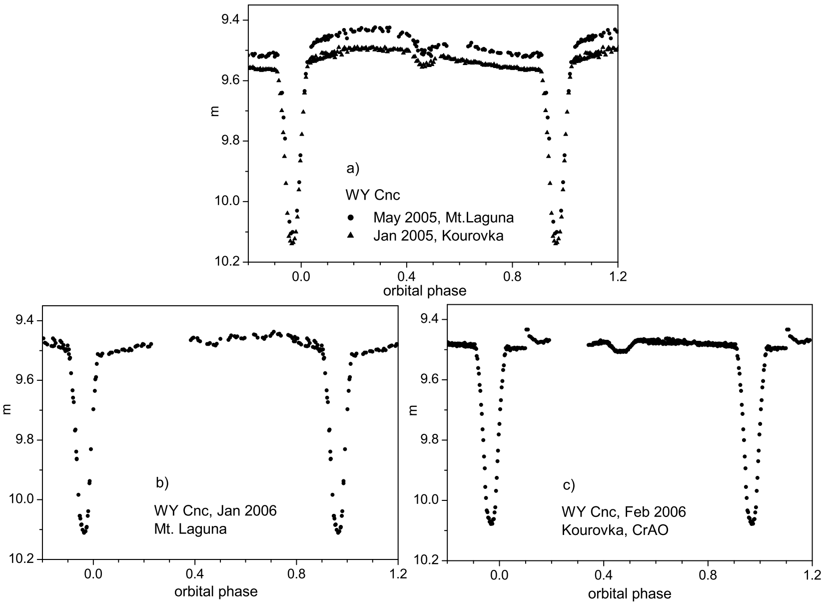

Figure 1. WY Cnc lightcurves in the V band, 2005–2006

Each point of the Kourovka Observatory lightcurves is an average of 31 individual 4-s integrations. The lightcurves show the out-eclipse distortion wave caused by starspots.

The flare was detected on 19.02.2006 during BVR observations at Kourovka observatory (see Fig. 1c). The flare occurred at phase 0.10 near the minimum of the distortion wave. After the initial rapid flaring, the brightness decayed slowly. The star remained 0.025 mag brighter for at least an hour after the flare began.

Figure 2 shows small portions of BVR lightcurves near phase 0.10 with both individual 4-s integrations and averages plotted. Since each color was observed sequentially, some points of the flare may be seen in different colors. The flare peaked at 21:50 UT and had a maximum amplitude of 0.134 mag in the B band. The time required for the flare to peak (impulse phase) is about 3 min. The flare duration is 64 min.

The intensity of the flare was calculated as $I_f/I_0 = (I_{0+f}/I_0) - 1$, where I_0 is the mean intensity of the quiescent star level in one of the B, V, R bands. By numerical integration of the flare intensity over the flare duration, the relative energy of the flare was defined by $RE = \int I_f(t)/I_0 \, dt$. We estimated the absolute energy output E_f of the flare using the relation: $E_f = RE \times E_q^X$, where E_q^X is the quiescent star luminosity in X band, which we calculated using: $V = 9.467$, $B - V = 0.73$, $V - R = 0.63$ and a distance of 85 pc to the system. We used the Hipparcos parallax (11.76 mas) of WY Cnc as the most accurate

Table 1: Flare properties

Band	Amplitude, mag	Flare flux/system flux, %	Integrated energy, erg
B	0.134	5	10.24×10^{34}
V	0.062	3	5.63×10^{34}
R	0.045	2.6	0.96×10^{34}

Table 2: WY Cnc spot parameters

Obs. period	$V_{\max}$	ΔV	φ_0	$\Delta\varphi$	$f_{\min}$	S_1	S_2	Observatory
2005 Jan	9.496	0.069	0	8.3	0.51	6.3	4.5	Kourovka
2005 May	9.430	0.087	0	6.7	0.20	4.7	2.3	Mt. Laguna
2006 Jan	9.456	0.056	0	6.5	0.45	4.8	3.3	Mt. Laguna
2006 Feb	9.461	0.026	0	5.1	0.67	4.1	3.4	Kourovka + CrAO

(http://simbad.u-strasbg.fr/sim-fid.pl). We also used the luminosity of the star with an absolute magnitude of 0 mag from Johnson's calibration (Johnson, 1966).

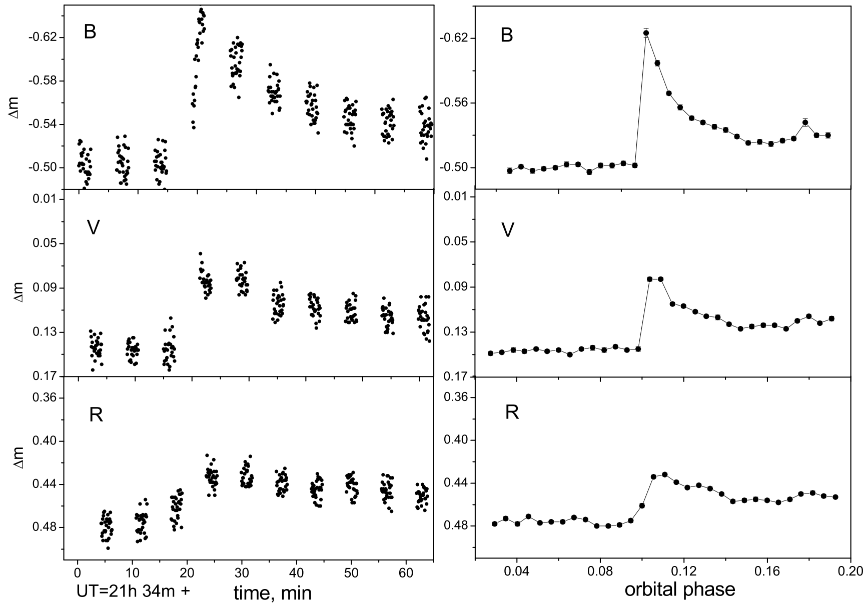

Figure 2. The flare of WY Cnc: lightcurves in B, V, R bands with individual 4-s integrations (left) and averages of 31 points (right) plotted

To study the spot activity before and during the flare, we analyzed all our lightcurves using the Zonal Spottedness Model, developed by Alekseev & Gershberg (1996). Results are given in Table 2. $V_{\max}$ is the maximal star brightness and ΔV is the amplitude of the distortion wave. According to the Zonal Model, two spotted belts located symmetrically about the equator can represent spotted regions on cool stars. These belts occupy regions with the latitudes (in degrees) from $\pm\varphi_0$ to $\pm(\varphi_0 + \Delta\varphi)$ and have a spot coverage that varies linearly with the longitude from 1 at the minimum brightness phase to some value $f_{\min}$ at the maximum brightness phase. S_1 and S_2 are the spotted areas of the dark and bright hemispheres of the stellar surface that are symmetric to the phase of the brightness minimum, in percents. The analysis of our observations allows us to make the following conclusions.

1. Both before and during the flare minima of the distortion waves were at phases of 0.87–0.03. This means, that the “face side” hemisphere of the primary star (the side facing the secondary component) was more spotted than the “back side” hemisphere (we took into account that WY Cnc is a tidally locked system).

2. In May 2005 the brightness of WY Cnc increased by 0.07 mag compared to January 2005 (see Fig. 1a). Note that this brightness difference is larger than the differences found between the light curves from the two different observatories as discussed earlier in this paper. Hence the difference is real rather than a calibration error. This secular increase is similar to those observed in 1988 and 1997 by Heckert et al. (1998) in that the brightness increases outside of the primary eclipse but remains approximately the same during the primary eclipse. The fact that the primary eclipse portions of the light curves match well is also evidence that this is a real luminosity increase rather than a calibration error resulting from different observatories and instruments. While the luminosity increased, the total spotted area became less with the more asymmetric spots concentrated on the hemisphere facing the secondary: $S_1/S_2 = 2.0$. So we may suppose, that this luminosity jump might be caused by several new bright active regions (analogous to solar plages) with some small-sized spots (spot coverage $f_{\min} = 0.20$) which appeared at the back side hemisphere.

3. In January 2006 and in February 2006 the brightness of the system and the amplitude of the distortion wave began to decrease, and spots began to fill the bright hemisphere in a more homogeneous way ($f_{\min} = 0.67$). The flare occurred at the time when the amplitude of the distortion wave was minimal (0.026 mag) and the spotted areas of face and back sides hemispheres became almost equal ($S_1/S_2 = 1.2$), i.e. during the flare, the spots filled both hemispheres in an almost homogeneous way.

A flare in WY Cnc was detected for the first time. A similar flare has been reported by Zeilik et al. (1983) for another RS CVn system XY UMa. However, its energy was one order of magnitude smaller than that of the flare reported here. Another similar system SV Cam was reported to show flares too (Patkós, 1981). The strongest of these flares had a duration of 43 minutes and an amplitude of 0.12 mag in U band. In the very active RS CVn star II Peg optical flares had energy from 10^{33} to 2×10^{35} erg (Mathioudakis, 1992). So, compared to other flares on RS CVn stars, we conclude that the flare we detected is a large one. All of these other flares occurred on the spotted hemisphere, just as in our observations.

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