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OBSERVATION OF ERUPTIONS IN ECLIPSING BINARY NSVS 01031772

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Abstract: We report on eruption activity of NSVS 01031772. This eclipsing binary was discovered only recently and no eruption has been reported in literature so far. We observed five eruptions between 2013 and 2015. Based on these observations the rate of eruptions seems to be randomly distributed in time and no periodicity is detected. Based on simple assumptions we give a very rough estimation of the energy released during the strongest eruption from March 2015.

1 Introduction

NSVS 01031772 (=UCAC4-847-011196=UNA 1650-01666928, V =13.36 mag, $B-V$ = 1.60 mag, J2000 α =13^{h}45^{m}34.416^{s}, δ =+79°23'48.98", Camelopardalis) is an eclipsing binary discovered in Northern Sky Variability Survey (Woźniak et al., 2004) by McIntyre & Shaw (2005). The binary composed of two dMe type red-dwarf stars (M_1 = 0.5428(27) $M_\odot$, R_1 = 0.5260(28) $R_\odot$, M_2 = 0.4988(25) $M_\odot$, R_2 = 0.5088(30) $R_\odot$, Lopez-Morales et al., 2006) is about 60.3(1) pc far away. According to *O-C* analysis performed by (Wolf et al., 2012) third body can be present in NSVS 01031772.

The aim of our efforts was, except for minima timings determination, find out if eruption are present in this system because the presence of high stellar activity of solar type could be expected in this type of stars due to the presence of large convective layers. Except for NSVS 01031772 we monitor several other similar targets to confirm/discover their activity.

The evolution of eruption can be divided into four phases – activating, impulsive, gradual and late (Dyčková, 2013). During eruption emission in various electromagnetic wavelengths are produced - from soft X-ray (1-10 keV) to radio wave interval (1-10 GHz), which can explain observation of NSVS 01031772 by ROSAT satellite (Zickgraf et al., 2003).

2 Observation

The star was observed at Observatory Valašské Meziříčí (hereafter OVM) and at Trhové Sviny Observatory (hereafter TSO), both Czech Republic. Telescopes and instruments that we used are in Tab. 1. Altogether we obtained more than 13000 images with total length of 271 hours at OVM during 51 observation nights (July 2013 – May 2015). At TSO 2450 images of total length of observations 60 hours (11 nights, February–March 2015) were gathered. The star was observed in C and Johnson-Cousins $VR_\mathrm{c}I_\mathrm{c}$ filters. Nevertheless, we usually observed only in one filter to gain a better time resolution.

Table 1: Telescopes, instruments and filters used.

Telescope	Instrument	Filters	Exposures [s]	FOV
	OVM			
Schmidt-Cassegrain 355/2450mm	MII G2-1600	VRI	60	25'x25'
	TSO			
Newtonian 200/860 mm	Atik 314L	C	90	36'x27'

Differential aperture photometry, as well as dark frame and flat field corrections were performed using C-MuniPack package (Motl, 2009) which is based on DAOPHOT (Stetson, 1987). Characteristics of comparison stars are in Tab. 2, FOV are shown in Fig. 1. Although one star with similar colour index is located in the FOV, we decided to use different stars as a comparisons because of significantly lower scatter of the light curve. In addition, choosing comparison with the same colour is not very important for us since the aim of our observations is to determine minima times and confirm/discover eruptions.

Table 2: Comparison stars. Coordinates are in J2000.

Star	ID	RA [h:m:s]	DEC [° ' "]	B [mag]	V [mag]
			OVM		
Comp	UCAC4-847-011208	13:46:58.263	+79:22:04.33	13.48	12.93
Check	UCAC4-847-011211	13:47:30.174	+79:23:37.66	11.45	10.68
			TSO		
Comp	UCAC4-847-011195	13:45:19.668	+79:18:02.04	13.18	12.54
Check	UCAC4-847-011189	13:44:02.114	+79:23:49.28	14.51	13.67

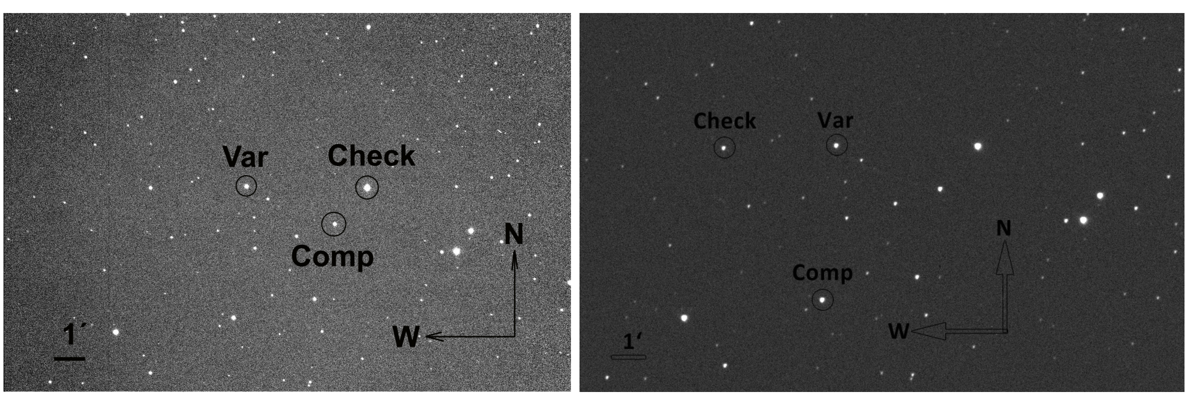

Figure 1: FOV of OVM (the left panel) and TSO (the right panel) with identification of stars.

During our observations we caught 41 primary minima (32 OVM, 9 TSO), 30 secondary minima (22 OVM, 8 TSO)[1], and 5 brightenings which we consider to be eruptions (4 OVM, 2 TSO).

3 Stellar eruptions

From obvious reasons we were unable to observe first two eruption phases – pre-eruption activity and changes in active region. The impulse phase in NSVS 01031772 is very fast - it takes only 4–7 minutes, gradual and late phase were in very broad ranges between 13 and 103 minutes. These values were estimated visually. The same applies for all time durations and amplitude estimations.

The first observed eruption was observed on March 29, 2014. It was not an eruption in usual meaning because it was only a gradual brightening with total length of 77 minutes and amplitude of about 0.1 mag (Fig. 2). Because the evolution of eruption is very fast and integration time is about 1 minute, time of maximum brightness is estimated from the highest observed point. The lowest limit for uncertainty estimation is therefore 1 minute (0.0007 d) for all given times.

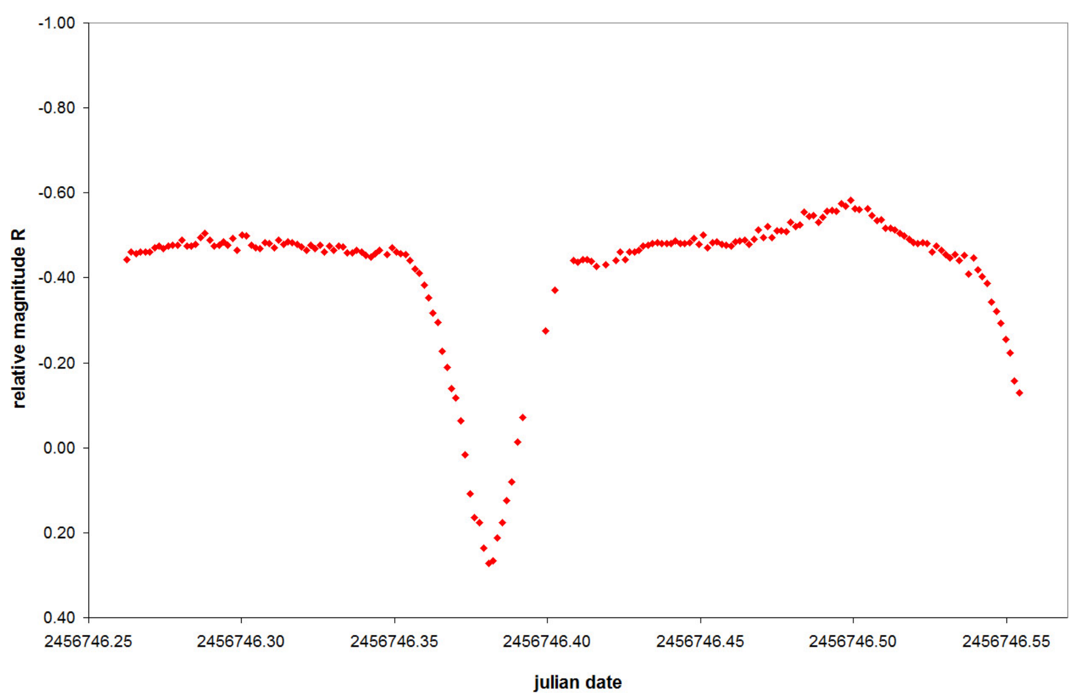

Figure 2: Brightening from March 29, 2014. Beginning of the event was at geocentric Julian date (GJD) 2456746.4674, maximum at 2456746.4990, the end at 2456746.5211.

[1]Minima times will be published in forthcoming B.R.N.O. contribution list no. 40.

The second eruption was observed on February 15, 2015 in $R_c I_c$ with maximum brightness at 2457069.4646. The evolution of the eruption was typical with fast progression to maximum (during one minute) and slow decrease lasting about 22 minutes. Amplitude in R_c filter was about 0.29 mag (Fig. 3). It is nicely seen that the amplitude in R_c is significantly larger than in I_c, which corresponds well with the assumption that the maximum of released energy is in energetic part of the spectrum.

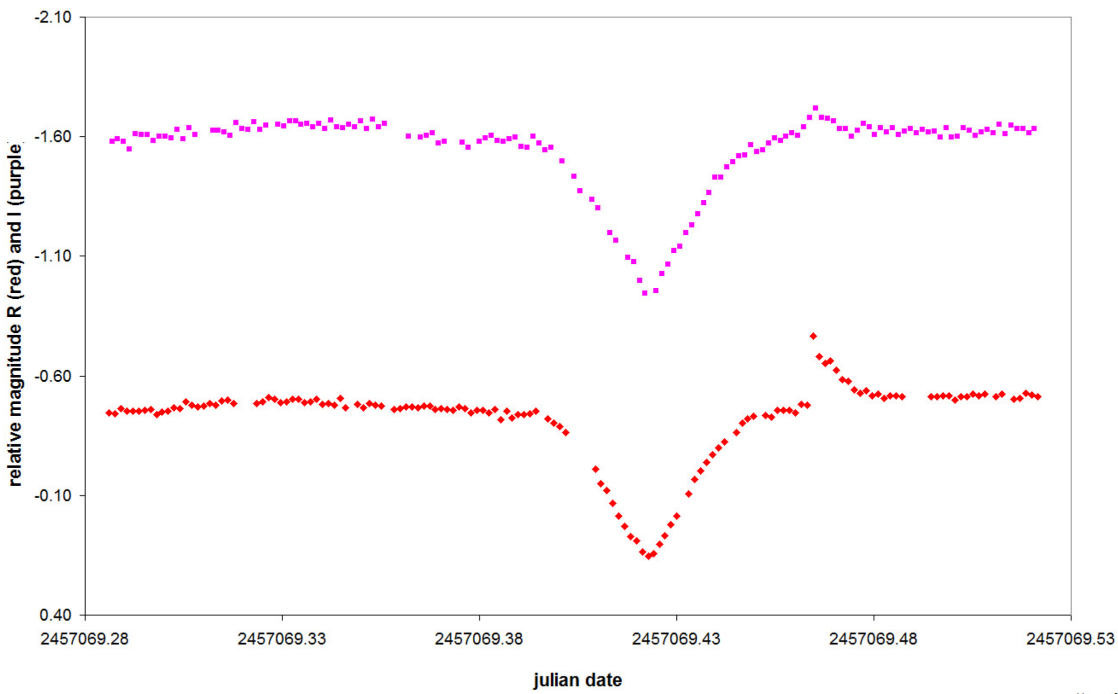

Figure 3: Eruption from 2015/02/15 (maximum at GJD 2457069.4646) in R_c and I_c.

On March 7, 2015 another event with maximum at GJD 2457089.2700 was observed (Fig. 4). The increase of brightness lasted about 7 minutes, then a slow decrease was observed. This eruption was special because it took place during secondary minimum which was about 0.25 mag brighter than usually is. Fading eruption is still apparent at the end of the secondary minimum. The amplitude of brightening was about 0.35 mag and the entire eruption lasted 103 minutes. This eruption was observed from both observational stations. From observations at TSO it is apparent that subsequent secondary minimum was normal (Fig. 4).

Another two eruptions took place on March 17 (Fig. 5), 2015 and March 23, 2015 (Fig. 6). The first maximum occurred at GJD 2457099.3943, the eruption had amplitude 0.12 mag (R_c) and length 19 minutes. The second eruption had maximum at GJD 2457105.3964, lasted approximately 7 minutes and amplitude was only about 0.07 mag in C.

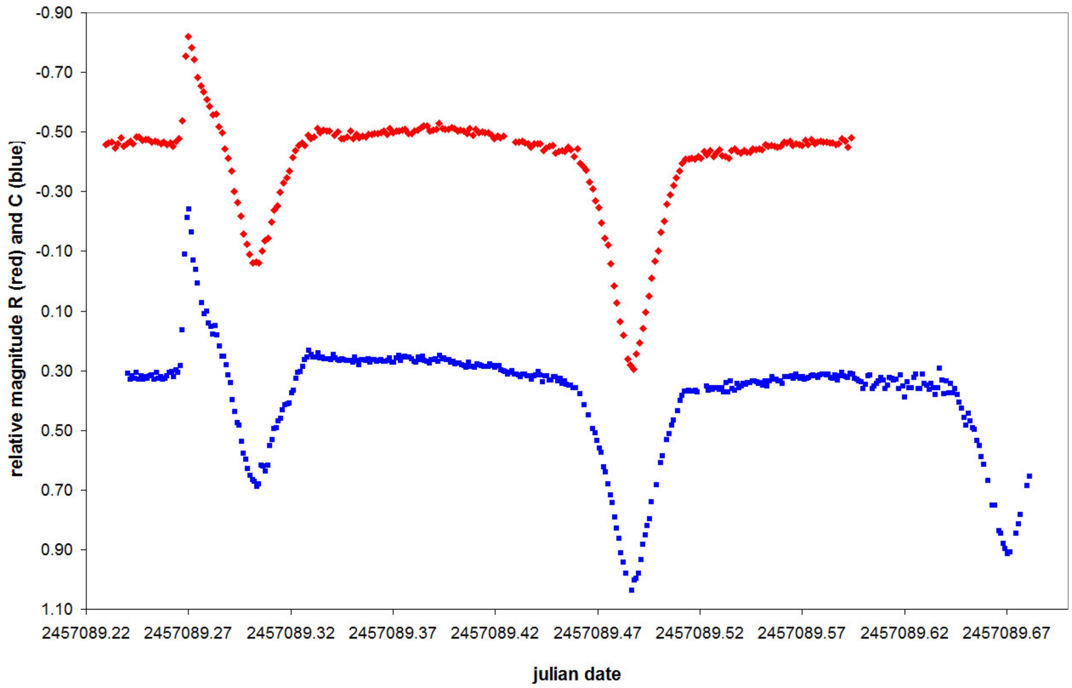

Figure 4: Eruption from March 07, 2015 (maximum at GJD 2457089.27032, amplitude at maximum 0.55 mag) observed in C at TSO and in R_c at OVM. Note the lower amplitude of the first secondary maxima observed.

From the distribution of observed events we cannot give reliable analysis of the time distribution of eruptions. It seems that the majority of brightenings took place during February and March 2015, but this is probably only observation bias because during this period the majority of observations were performed.

4 Estimation of energy release during eruption

Because we know the luminosity and temperature of both components ($T_{\rm prim}$ =3615 K, $L_{\rm prim} = 0.0425\,{\rm L}_\odot = 1.63\times10^{25}$ W, $T_{\rm sec}$ =3513 K, $L_{\rm sec} = 0.0356\,{\rm L}_\odot = 1.36\times10^{25}$ W, Lopez-Morales et al., 2006) and we observed the whole eruption on March 7, 2015 (Fig. 4), we can roughly estimate the amount of energy released during this eruption using Planck law. Fig. 7 shows the energy distribution for a black body (blue line) with temperature 3513 K (surface temperature of the secondary component for simplicity[2]). The red line shows the interval where the R_c filter is transparent. This area is about 8.7 % of the total energy of the secondary component. For filter C and used chip (Sony ICX 285AL) this fraction is about 21.0 % (Fig. 8). Total luminosity in R is $L_R = 0.087 L_{\rm prim+sec} = 2.6\times10^{24}$ W, in clear filter it is $L_C = 0.21 L_{\rm prim+sec} = 6.28\times10^{24}$ W.

[2]Both components have almost the same temperatures.

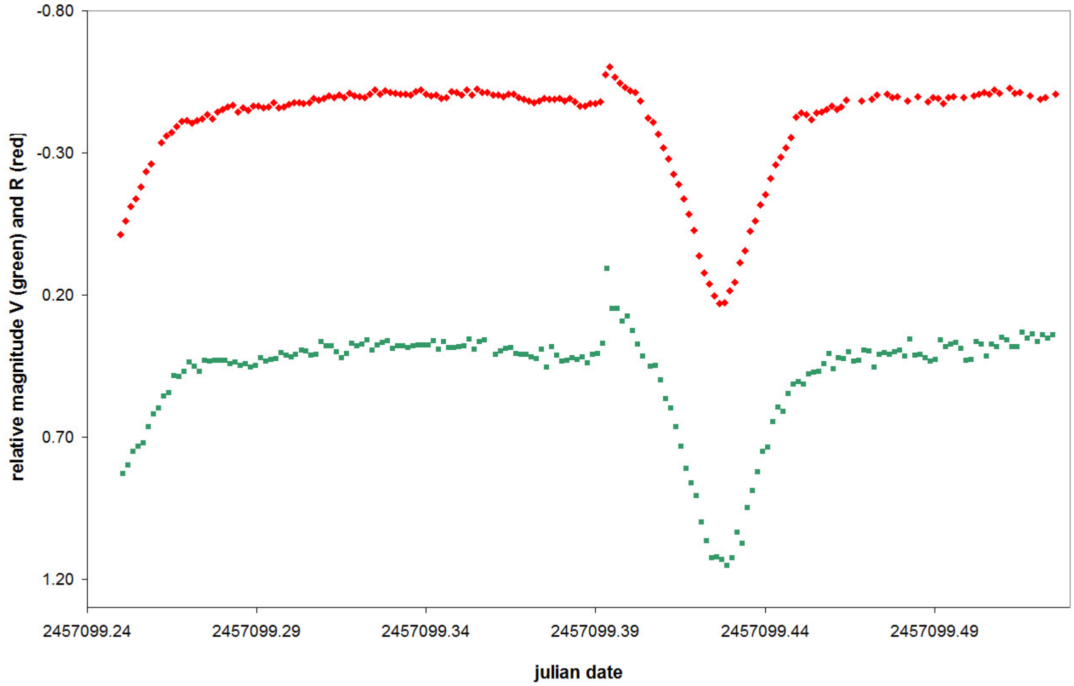

Figure 5: Eruption from March 17, 2015 with maximum at GJD 2457099.3943.

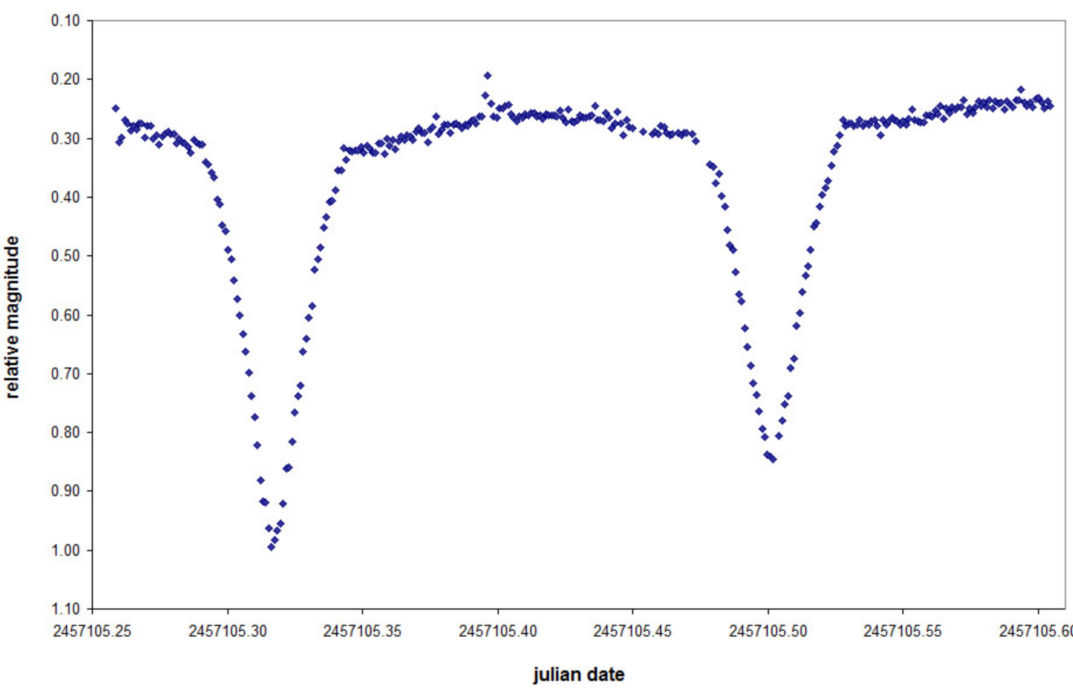

Figure 6: Eruption from March 23, 2015 with maximum at GJD 2457105.3964.

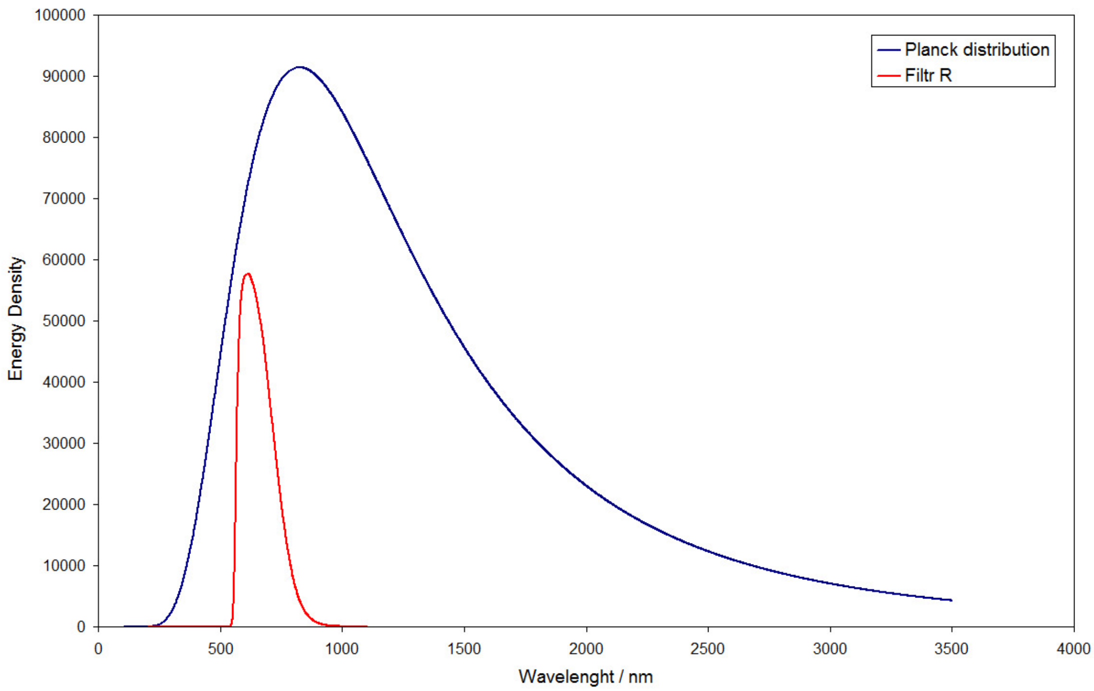

Figure 7: Energy distribution of a black body with temperature of 3513 K (the full blue line). The red line shows the area transparent for R_c filter used at OVM.

The energy released during the eruption can be calculated from the amplitude of the eruption Δm (estimated visually) using Pogson's equation in a form of

$$L_\mathrm{max} = 10^{-0.4\Delta m} L_\mathrm{prim+sec}. \qquad (1)$$

Corresponding total luminosity during eruption was then $L_{R\mathrm{max}} = 3.6^{24}$ W and $L_{C\mathrm{max}} = 10.4 \times 10^{24}$ W in R_c and C filter, respectively. The difference between stable state and eruption is the difference between $L_\mathrm{prim+sec}$ and maximal luminosity in particular filters, $\Delta L_R = 0.44 \times 10^{24}$, $\Delta L_C = 1.47 \times 10^{24}$ W.

At this point, when the luminosity of eruption is known, we can visually estimate duration of the eruption as $t \sim 6180$ s. Assuming triangle shape of the eruption we can calculate the total energy released during the event as

$$E = \Delta L \times t/2. \qquad (2)$$

Following this relation the total released energy is $E_{R_\mathrm{c}} = 3.0 \times 10^{27}$ J in R_c and $E_C = 1.3 \times 10^{28}$ J in C, respectively. Although our calculation is based only on visual estimates of Δm and total duration of the eruption the values are very similar to energies released during super-eruptions in cool stars (e.g. Candelaresi et al., 2014).

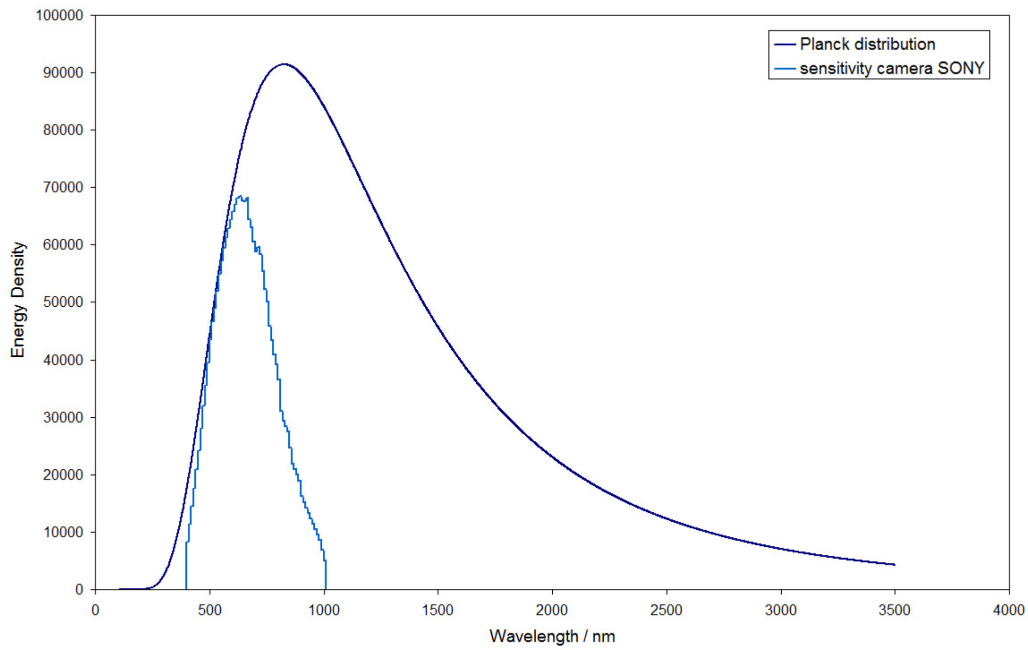

Figure 8: Energy distribution of a black body with temperature of 3513 K (the full blue line). The light blue line shows the area transparent for Sony camera with C filter used at TSO.

5 Conclusions

We observed NSVS 01031772 between July 2013 and May 2015 in a scope of eruptive binary stars survey. During this interval we detected five eruptions. As a by-product of this observations 41 primary and 30 secondary minima, which will be published soon, were observed.

Although majority of eruptions were observed in February and March 2015, we assign this behaviour to a happy coincidence than to intrinsic behaviour. We roughly estimated the total energy released during eruption at the secondary component. It was found that the value well corresponds to the values for super-eruptions in cool stars.

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