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OPTICAL OBSERVATIONS OF BQ Cam USING ROTSE3D OBSERVATIONS

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BQ Cam is the optical counterpart of the transient X-ray source V0332+53. This system which consists of a Be star and a 4.4 s X-ray pulsator has an orbital period of 34.25 days, eccentricity of 0.31 and semi-major axis of 48 light seconds (Stella et al., 1985). The mass function of 0.1 $M_\odot$ indicates an inclination angle smaller than 11° for the Be star of mass between 16-20 $M_\odot$ and a neutron star mass of 1.4 $M_\odot$.

Two optical brightenings of BQ Cam were detected: one is in 1983 and the other is in 1989 (Goranskij, 2001). Both optical brightenings which were related to the ejection of circumstellar shells were accompanied by X-ray outbursts. Bernacca et al. (1984) indicated that the H_α line showed a P-Cygni profile on their spectra which was obtained in about 20 days after the maximum brightness of BQ Cam was reached. However, Kodaira et al. (1985) did not confirm this identification and found that H_α emission line is the most prominent feature in their spectra. Iye and Kodaira (1985) and Corbet et al. (1986) reported the decline of the equivalent width of the H_α emission line in their spectrum which was related to evolving circumstellar envelope that surrounds Be star.

At the beginning of the year 2004, Goranskij and Barsukova (2004) informed that BQ Cam reached to its brightness maximum predicting a new X-ray outburst within 1-2 years. About 300 days later, Swank et al. (2004) reported the first All Sky Monitor detection of the November 2004 X-ray outburst.

Optical observations of BQ Cam were obtained between JD 2453235 (August 2004) and JD 2453384 (January 2005) using ROTSE3d robotic telescope located at Bakırlıtepe, Turkey. It operates without filters and has a wide passband which peaks at 550 nm (Akerlof et al., 2003). ROTSE magnitudes were calculated by comparing all the field stars to USNO 2.0 R-band catalog. About 1600 CCD frames were analyzed following the procedure described in Kızıloğlu et al. (2005), Smith et al. (2002) and Smith et al. (2003).

All frames are dark-and-flat-field corrected automatically as soon as they are exposed. A pipeline procedure feeds corrected frames to SExtractor package (Bertin and Arnouts, 1996). 5 pixel (17 arcsec) diameter aperture is used to determine all source candidates within the FOV. Gaussian centers and the instrumental magnitudes of the identified objects are compared against USNO A2.0 catalog with a triangle-matching technique. An approximate R-band magnitude zero point offset of each frame is calculated using a

relative photometry algorithm which results in a calibrated list of R-band magnitudes of the objects. Unfortunately ROTSE has no color information. Approximate V-band values can be obtained by applying a constant correction factor from the observations of the reference stars (Goranskij, 2001). We applied differential photometry in order to eliminate the atmospheric and other systematic effects over hundred days of observations. These include seeing variations in a specific night and between observation days, and also pointing variations of the order of $\sim 0\overset{\circ}{.}3$ in large FOV ($1\overset{\circ}{.}8$). Table 1 lists the reference stars used for the light curve. m_{ROTSE} is the mean measured ROTSE magnitude and σ is the estimated error of the mean for all the frames.

Table 1. Coordinates and photometric magnitudes of BQ Cam and the reference stars.

Star	$\alpha(J2000)$	$\delta(J2000)$	USNO.A2.0 R	m_{ROTSE}	σ
BQ Cam	$03^h34^m59\overset{s}{.}92$	$+53^\circ10'23\overset{''}{.}3$	14.2		
1	$03^h34^m52\overset{s}{.}90$	$+53^\circ11'53\overset{''}{.}6$	13.8	13.919	0.106
2	$03^h35^m11\overset{s}{.}46$	$+53^\circ08'56\overset{''}{.}3$	13.3	13.255	0.103
3	$03^h35^m03\overset{s}{.}73$	$+53^\circ12'09\overset{''}{.}1$	13.2	13.147	0.102

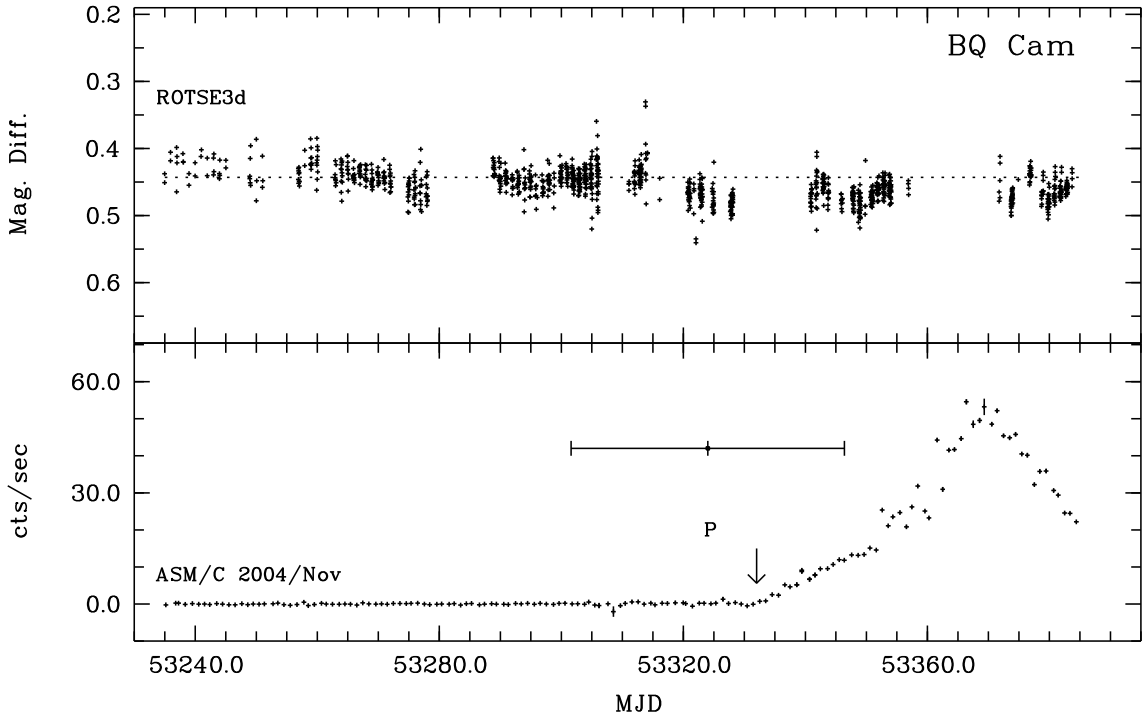

Figure 1. ROTSE3d light curve of BQ Cam (upper panel) and X-ray light curve (lower panel) of V0332+53 taken with RXTE/ASM (daily average of 5.0-15.0 KeV band light curve). Error bars on ROTSE3d data points are not shown for clarity however estimated errors are of the order $\sim 0\overset{m}{.}02$. Dotted line shows mean differential magnitude calculated for the data before the periastron passage time. Arrow points the first ASM detection of November 2004 outburst (MJD = JD − 2400000.5). The region of periastron passage is also indicated with its uncertainty in time.

In Figure 1 the difference in the ROTSE magnitudes of BQ Cam and the mean of the reference stars were plotted together with the X-Ray observations. RXTE-ASM/C-band daily averaged data of V0332+53 shows the Nov 23, 2004 X-ray outburst in counts/s. On the same figure the periastron passage time is also shown with its uncertainty in time. The X-ray outburst occurs close to the time of periastron passage.

The light curve of BQ Cam which is in Be star phase remained almost the same during the observation time interval of about 150 days, however $\sim 0\overset{m}{.}04$ decrease in brightness before the X-ray outburst is notable. Observed rapid low-amplitude variability on time scales of few days is typical to BQ Cam (Goranskij, 2001). Figure 2a is an example of low-amplitude irregular variability with an amplitude of about $\sim 0\overset{m}{.}02$. Figure 2b shows a near sinusoidal variation of duration $\sim$ 11 days. The fading of the source can be expected after the X-ray outburst was completed if the cessation of X-ray outburst was

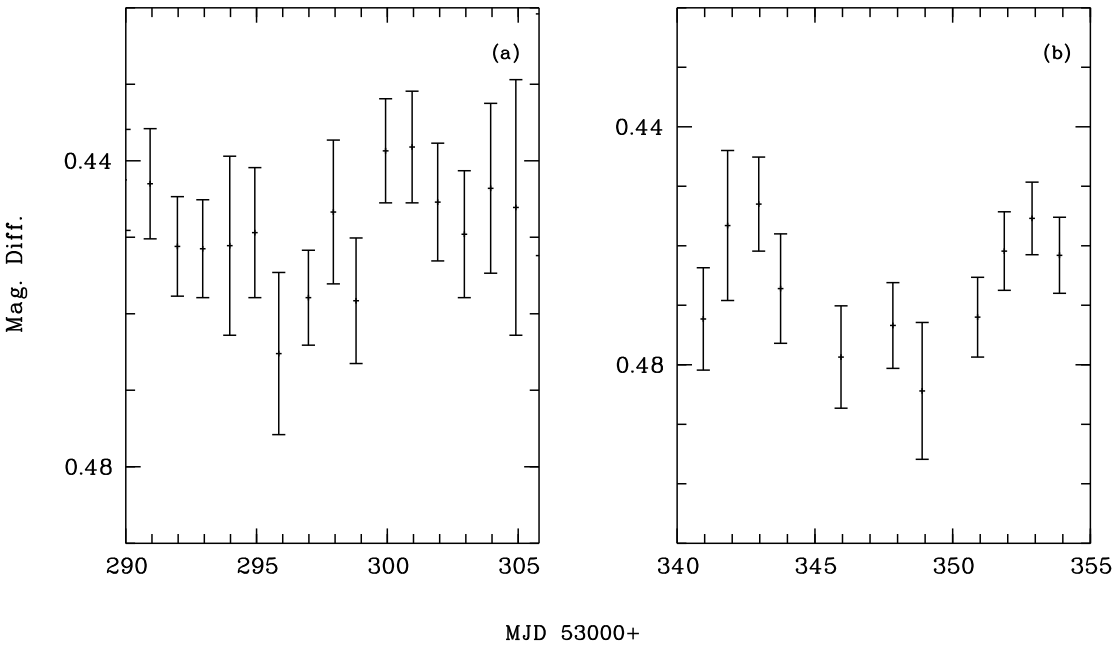

Figure 2. Examples of the daily averaged variations of ROTSE3d light curve of BQ Cam before and after November 2004 outburst (MJD = JD − 2400000.5). Error bars are the variance of variations within each night of observations.

Further ROTSE3d observations are being performed to see the long term variations.

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