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DETECTION OF INCREASE IN THE OPTICAL LIGHT OF Be/X-RAY BINARY SYSTEM GRO J2058+42

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The Be/X-ray binary GRO J2058+42 (CXOU J205847.5+414637) has an orbital period of 55.03 days (Corbet et al., 1997; Wilson et al., 2005). The optical counterpart of GRO J2058+42 was discovered by Reig et al. (2004). Its spectral type is O9.5-B0 IV-V (Wilson et al., 2005) with V=14.9 mag and R=14.2 mag. The spectra obtained by Reig et al. and Wilson et al. have shown a double peak Hα emission line which was a signature of a Be star. They have calculated a mean equivalent width (EW) of 4.5 Å. The Be star has a disk in its equatorial plane which can give rise to X-ray outburst of its companion, the neutron star. When material from the disk of the Be star accretes to the neutron star X-rays are produced. This system is in X-ray quiescent state since 2002 according to the X-ray observations of RXTE/ASM[1].

The results of our optical observations of this system between JD 2453500 and 2454000 were published in Kızıloğlu et al. (2007). A non-radial pulsation with a frequency of 2.404 d^{-1} has been found in our light curve from period analysis of the Be star. No long term variability has been observed. Therefore we expected a nearly stable disk around the Be star. We have calculated the EW of the Hα emission line as 2.31 Å.

In this study further optical photometric and spectroscopic observations of this Be/X-ray system are presented. The photometric observations were obtained by using 45 cm robotic reflecting telescope (ROTSE IIId, located at Bakırlıtepe, Turkey[2]) which operates without filters (Akerlof et al., 2003). The telescope was equipped with a 2048×2048 pixel CCD with pixel size of 3$''$.3. Data reduction procedures are the same as in Baykal et al. (2005) and Kızıloğlu et al. (2007). The optical spectroscopic observations were obtained using medium resolution spectrometer TFOSC (TUBİTAK Faint Object Spectrometer and Camera; installed on the RTT150, 1.5 m Russian-Turkish telescope located at Bakırlıtepe). The camera is equipped with 2048×2048, 15 micron pixel CCD. Grism G8 (5800-8300 Å) with average dispersion of 1.1 Å per pixel was used.

Figure 1 shows the differential light curve of the optical counterpart to GRO J2058+42. We adopted three nearby stars as the reference stars (Table 1) and we used their mean magnitudes in obtaining the differential magnitudes (Kızıloğlu et al., 2007). The X-ray light curve in the energy band 5-12 keV is also plotted in the same figure to see if there is any correlation with the optical light curve. However, no correlation was observed

[1] http://xte.mit.edu

[2] http://www.tug.tubitak.gov.tr

between the optical and X-ray light curves after an increase of the optical brightness. The system is in X-ray quiescent phase in spite of the presence of the Be disk. Type I X-ray outbursts which are expected to occur at every periastron passage of neutron star were not observed after 2002. If the Be disk is truncated at a resonance radius which is smaller than the Roche Lobe radius, then Type I outbursts are not seen since there is no mass transfer to the neutron star from the disk of the Be star (Okazaki and Negueruela, 2001).

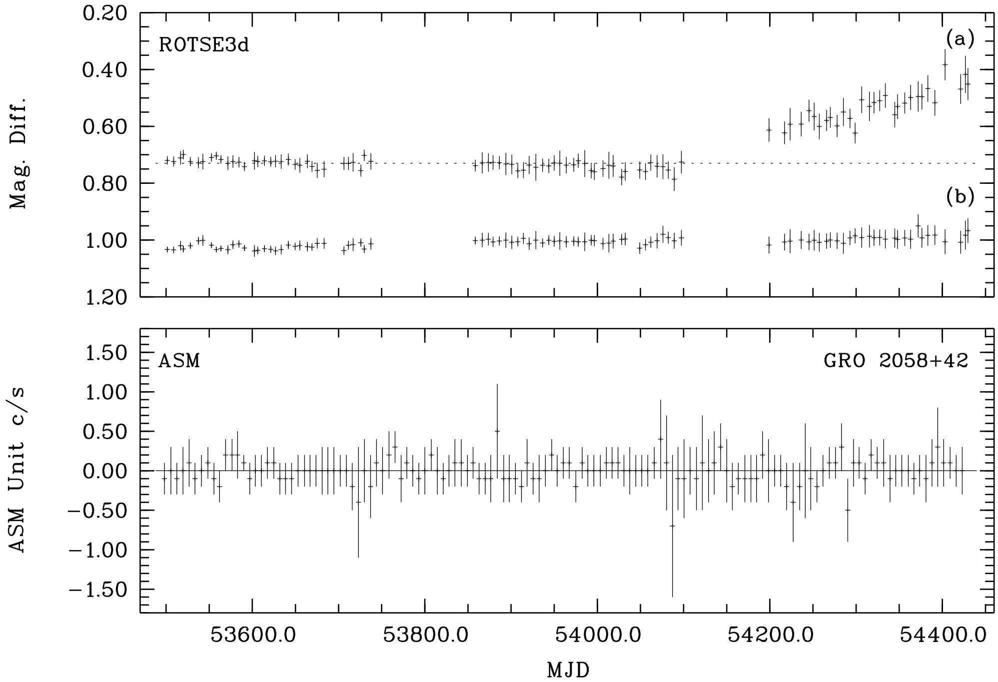

Figure 1. ROTSEIIId weekly averaged differential light curve of the Be/X-ray system GRO J2058+42 (CXOU J205847.5+414637) (top panel, a) and weekly averaged mean light curve of reference stars properly offsetted (top panel, b) for the period 2005-2007. X-ray light curve of the system obtained from RXTE/ASM observations (weekly average of 5.0-15.0 keV band light curve) is given in the lower panel. MJD = JD - 2400000.5.

No long-term variability is seen in the optical light curve up to JD 2454100. After JD 2454100 there is an increase in the light output of the system. The change is about 0.3 magnitude. Such an increase is also reflected in the EW of Hα profile, obtained on 2007, June 14. The EW is found to be as 5.4 Å. This value is greater than the previous value of 2.3 Å. We suppose an increase in the disk density after JD 2454100, since Hα EW is related with the disk density of the Be star rather than with its size (Wilson et al., 2005; Negueruela et al., 2001). There is a structural change in the disk of the Be star. The double peaked Hα line profile is shown in Figure 2. The depth of the self absorption is not as deep as in the previously obtained Hα line profiles (Kızıloğlu et al., 2007).

Table 1. CXOU J205847.5+414637 and the reference stars.

Star	$\alpha(J2000)$	$\delta(J2000)$	USNO.A2.0
J205847.5+414637	$20^h58^m47.^s54$	$+41°46'37.''3$	14.1
Star 1	$20^h58^m53.^s53$	$+41°46'28.''0$	13.9
Star 2	$20^h58^m45.^s85$	$+41°45'06.''0$	13.9
Star 3	$20^h59^m05.^s50$	$+41°44'20.''1$	14.1

After JD 2454100, there are less observational data since we intended to follow only long-term variations. Nevertheless, we performed period analysis for the increasing part of the light curve, but we did not detect any periodic behavior. Folding the same data with the known pulsation periods of 0.4162 and 0.4218 d did not reveal strong indications for the presence of the pulsations.

An increase in the disk density may enhance the optical brightness of the system. A change of 0.3 mag corresponds to a disk luminosity of about 10^{36} erg/s with T_{disk}=10000 K and R_{disk}= $4R_{star}$ assuming a cylindrical disk with a vertical height of 0.1 R_{star} for the Hα emitting region (Hanuschik et al., 1993). Rivinius et al. (2003) pointed out that enhancement in brightness is associated with mass loss from a Be star which is induced by non-radial pulsations. Such a mass loss will increase the disk density. We also know from our previous study that GRO J2058+42 has at least one non-radial pulsation mode.

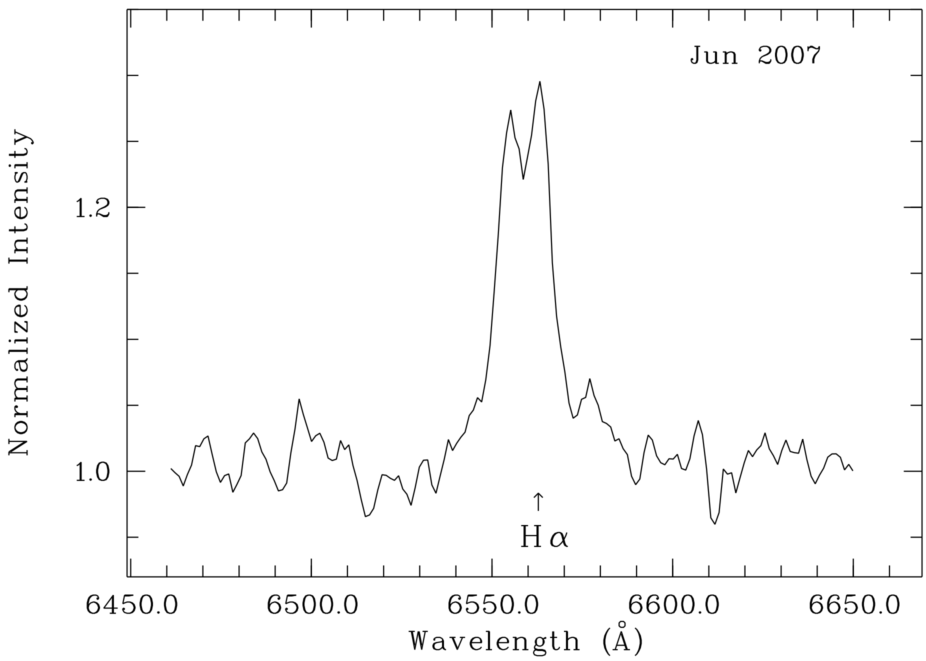

Figure 2. Hα profile observed on 2007 June 14 (JD 2454266.498).

It is also possible that the disk begins its precession with a sudden change in the structure of the Be disk. As the revealed part of the disk gets larger due to precession we get more light from the system and the Hα EW will also be larger than our previous value (Kızıloğlu et al. 2007).

Further ROTSEIIId observations are needed to explain the long term variations. Collaborations are welcomed.

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