PHOTOMETRIC EVIDENCE OF BULLETS IN SS433 JETS

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We report the photometric evidence of bullet like features in SS433 in X-rays, Infra-red and Radio bands through a multi-wavelength campaign.

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1. Introduction

The enigmatic micro-quasar SS433 showed evidence of bullet-like ejection in optical band (e.g., Vermeulen, 1993). Chakrabarti et al (2002) presented a mechanism to produce quasi-regular bullets. These bullets would be ejected from X-ray emitting region and propagate through optical, infra-red (∼ 10^{13−14} cm) and finally to radio emitting region at ∼ 10^{15} cm (roughly the distance covered in a day with v ∼ v_{jet}) or so. Thus if the object is in a low or quiescence state, each individual bullet flaring and dying away in a few minutes time scale, should be observable not only in optical wavelengths (Margon, 1984) but also in all the wavelengths, including X-ray, IR and radio emitting regions. Here, we report the results of a multiwavelength campaign in X-ray, infra-red (IR) and radio observations of September, 2002. Our main results indicate that there are considerable variations in the timescale of minutes in all the wavelengths. Detailed results are in Chakrabarti et al. (2003).

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2. Observation and Data Reduction

Radio observation was carried out with Giant Meter Radio Telescope (GMRT) at 1280MHz (bandwidth 16 MHz). The data is binned at every 16 seconds. AIPS package was used to reduce the data. Infrared observation was made using Physical Research Laboratory (PRL) 1.2m Mt. Abu infrared telescope equipped with Near-Infrared Camera and Spectrograph (NICMOS). The filters used were standard J, H and K’ bands. X-ray observation was carried out using Proportional Counter Array (PCA) on board RXTE satellite. The data reduction and analysis was performed using software (LHEASOFT) FTOOLS 5.1 and XSPEC 11.1. We extract light curves from the XTE/PCA Science Data of GoodXenon mode. We also extracted energy spectra from PCA Standard2 data in the energy range 3-25keV.

3. Results on short time-scale variabilities

The observational result of September 27th, 2002 is shown in Fig. 1 with UT (Day) along the X-axis. The upper and middle panels show the radio and IR fluxes (uncorrected for reddening) in Jansky and the lower panel shows X-ray counts per second. These observations correspond to an average flux of $10^{-14}$ ergs/cm$^2$/s, $5 \times 10^{-10}$ ergs/cm$^2$/s and $10^{-10}$ ergs/cm$^2$/s respectively. Observations in radio and IR were carried out during 25-30th September, 2002 and no signature of any persistent ‘flare’ was observed. The radio data clearly showed a tendency to go down from 1.0Jy to 0.7Jy reaching at about 0.3Jy on 28th/29th, while the X-ray data showed a tendency to rise towards the end of the observation of the 27th. The IR data in
Fig. 2: Differential photometry of SS433 with respect to two brightest standard stars (std1 and std2) in the same frame of the object are plotted. X-axis of the graph is the relative time of measurements in seconds.

each band remained virtually constant. The H-band result was found to be higher compared to the J and K' band results during 25th-29th September, 2002.

Light curves around ‘local mean’ (Fig. 2 of Chakrabarti et al. 2003) clearly indicate significant variability in the time-scale of $T_{var} \sim 2 - 8$ minutes. In Fig. 2 the differential flux density variation of IR observations in the J and H bands during 27th September 2002 using differential photometry is shown. Here we compare the differential flux variation between SS433 and two brightest standard stars (std1 and std2) for the whole light curve. This clearly indicates that the variation in the IR light curves of SS433 is intrinsic. The analysis shows above 2σ level variability in both the bands.

Could these variations be due to individual bullets? In order to be specific, we present in Fig. 3a, one ‘micro-flare’-like event in radio from the data on 29th of Sept., 2002, when radio intensity was further down $\sim 0.3$Jy so that the micro-flares could be prominently seen. We observe brightening of the source from 0.35Jy to 0.8Jy in $\sim 75$s. The source faded away in another $\sim 75$s. Similarly in Fig. 3b, where we presented a ‘micro-flare’ from the 2nd (central) ‘spell’ of X-ray data of 27th Sept. 2002 (Fig. 1), we also observe significant brightening and fading in $\sim 100$s. The count rate went up more than 15% or so in about a minute. We calculated the energy contained in the individual radio and X-ray micro-flare are $1.1 \times 10^{33}$ergs and $2.7 \times 10^{35}$ergs. Since the radio luminosity is very small, even when integrated over 0.1GHz to 10GHz radio band (with a spectral index of $\sim -0.5$) (Vermeulen et
we find that almost all the injected energy at X-ray band is lost on the way during its passage of $\sim 1-2d$. We also analysed the X-ray spectrum and found that the thermal bremsstrahlung model with two Fe line features are best fitted. We didn’t find any signature of Keplerian disk in the system.

Fig. 3: Individual flares in very short time scales are caught. (a) A radio flare lasting 2.5 minutes (observed on 29th Sept. 2002) and (b) an X-ray flare (observed on 27th of Sept. 2002) lasting for about 3.5 minutes. Each bin-size is 16s

4. Discussion and conclusions

Our multi-wavelength observations of X-ray, IR and Radio suggest that we may be observing the individual bullet like events in different wave bands. Analysis of the subsequent X-ray observations during inferior and superior conjunctions on Oct. 2nd, 2003 and March 13th, 2004 respectively confirmed the presence of fast variabilities, X-flares, and the fact that the base of the jet is the major source of X-ray emission (Nandi et al. 2004). We also verified that the Doppler shifts of X-ray lines generally follow the ‘kinematic model’.

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