

Results of Recent Multi-wavelength Campaign of SS433

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Abstract We conducted multi-wavelength campaign on SS433 in Sept. 2002 using X-ray, B, Infra-Red and radio telescopes. We observed variabilities on a time-scale of a few minutes in all the wavelengths. We interpret them to be due to bullet-like features from the accretion disk. We also present X-ray properties as obtained by RXTE.

Key words: Black hole physics – accretion: accretion disks – magnetic fields – radio continuum: stars–stars: individual (SS433)

1 INTRODUCTION

SS433 is a well known object which is ejecting matter in the form of two jets in symmetrically opposite directions at a speed of $v_{\text{jet}} \sim 0.26c$. Margon (1984) and Pal and Chakrabarti (2003) reviewed different theoretical and observational aspects of the source. Grandi (1981) suggested that jets are not continuous and they are ejected from the compact object, like successive and discrete bullet-like entities, at least in the optical wavelength. Since the bullets of energy $\sim 10^{35}$ erg do not change their speed for a considerable time ($\sim 1 - 2$ days), Chakrabarti et al. (2002) postulated that they must be ejected from accretion disk itself. They presented a mechanism to produce quasi-regular bullets. Using results of numerical simulations, they concluded that in the normal circumstances, a time interval of 50–1000s is expected in between successive bullet ejections. These bullets are ejected from the X-ray emitting region and propagate through the optical, IR and radio emitting regions. Thus, if the object is in a quiescence state, each individual bullet would be flaring and dying away in a few minutes timescale. This should be observable not only in optical wave length but also in all other wave lengths. So far, no such observations of individual bullets have been reported and it is necessary to make multi-wavelength observation at relatively quieter states. In this paper, we present some results of our multi-wavelength studies.

2 OBSERVATIONS

Radio observation was made using Giant Meter Radio Telescope (GMRT) at 1.28 GHz (bandwidth 16 MHz). GMRT has 30 antennas, each of 45 meter diameter in nearly ‘Y’ shaped array.

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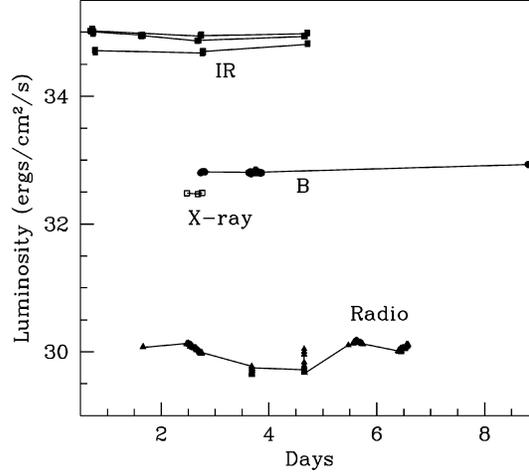


Fig. 1 Multi-wavelength observation of SS433 from 25th Sept. 2002 to 1st Oct. 2002. Time is plotted in units of day (0 indicates 0:00 hour, 25th sept. 2002 UT). The observations were made at Giant Meter Radio Telescope, Pune at 1.28 GHz (Radio), State Observatory at Nainital (B band), 1.2 m Mt. Abu Infra Red Telescope at J , H and K' bands and RXTE satellite (2–20 keV) respectively. No correction due to extinction has been made.

Here we present results of 26th, 27th, 29th Sept. and 1 Oct. 2002. 3C286 and 3C48 were used as flux calibrators and 2011-067, 1925+211 and 1822-096 were used as phase calibrators. The data of the source is band-passed, self-calibrated and background subtracted.

X-ray observation was made using the Proportional Counter Array (PCA) aboard RXTE satellite. We extracted the light curve from the XTE/PCA Science Data of Good Xenon mode. We also extracted energy spectra from PCA **standard 2** data in the energy range 2–20.0 keV. For the spectrum, we subtracted the background data.

IR observation was carried out using 1.2 m Mt. Abu Infra Red Telescope equipped with Near - Infrared Camera and Spectrograph (NICMOS) having 256×256 HgCdTe detector array cooled at 77 K. We have used standard J ($\lambda=1.25 \mu\text{m}$, $\Delta\lambda=0.30 \mu\text{m}$), H ($\lambda=1.65 \mu\text{m}$, $\Delta\lambda=0.29 \mu\text{m}$) and K' ($\lambda=2.12 \mu\text{m}$, $\Delta\lambda=0.36 \mu\text{m}$) bands. Observation took place on 25th, 26th, 27th and 29th Sept. 2002 UT. J and H bands were binned at every 10 second and K' band were binned in every 20 second. The data reduction were carried out using the IRAF package. All the object frames were de-binned, sky subtracted and flat fielded using normalized dome flats. GL748 was used as the standard star.

Observation in B-band was carried out using Nainital state observatory 104 cm diameter telescope. We have observed on 27 and 28th Sept. 2002 UT using standard B band filter. The data was binned for every 20 minutes, thus short time-scale variability could not be observed.

3 RESULTS

The observational results of multi-wavelength campaign from 25th Sept. 2002 to 1st Oct. 2002 are shown in Fig. 1. Here, zero signifies 0:00 hour of 25th Sept. 2002, UT. The results show a considerable variation in all the wavelengths. In Fig. 2, we have shown observational results of 27th Sept., 2002. The first and second panels show the radio and IR fluxes in Jansky, the third panel shows B band flux in mag and the lower panel shows X-ray counts per second in

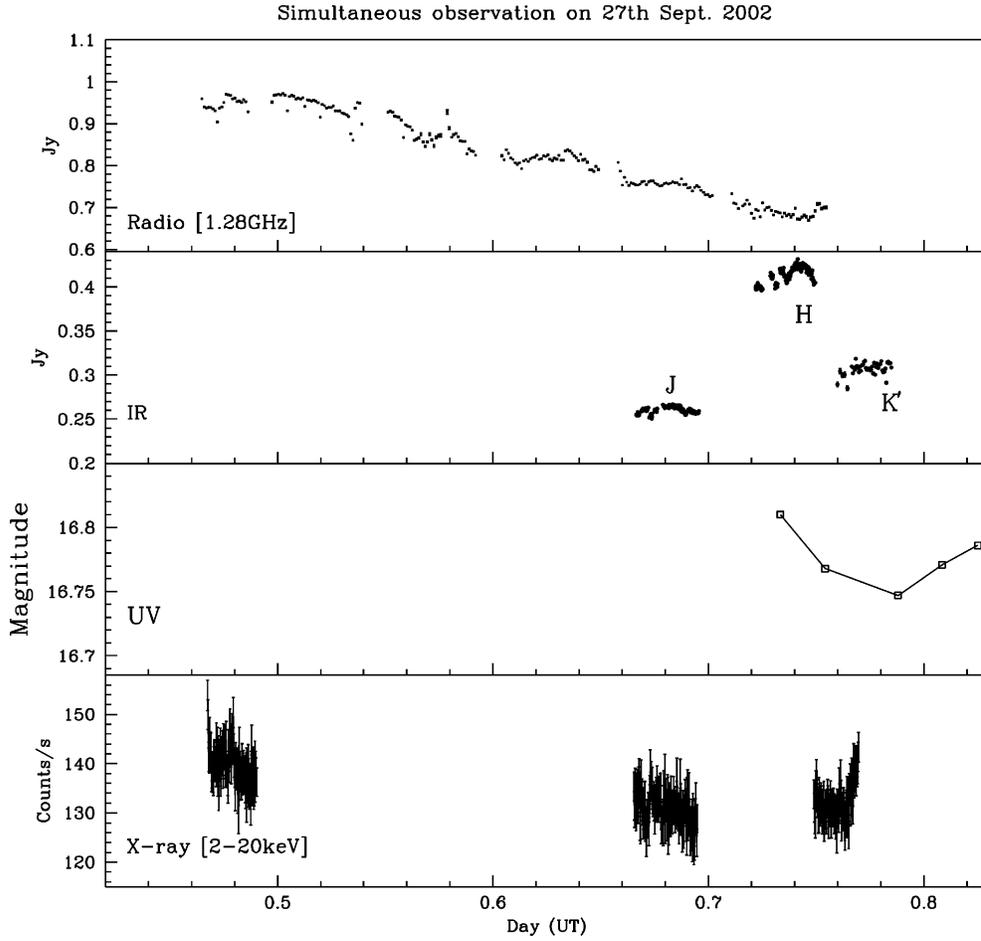


Fig. 2 Multi-wavelength observation of short time variability in SS433 by Radio (upper panel), Infra Red (second panel), B (third panel) and X-ray (lower panel) on 27th September, 2002. The observations were made at Giant Meter Radio Telescope, Pune at 1.28 GHz (radio), 1.2 m Mt. Abu Infra Red Telescope at J H and K' bands, Nainital State Observatory at B band and RXTE satellite (2–20 keV) respectively.

2–20 keV. Assuming isotropic emission, at a distance of 3 kpc for the source, the average radio, IR, X-ray and B luminosities are 1.1×10^{30} erg s^{-1} , 5.5×10^{34} erg s^{-1} , 5×10^{32} erg s^{-1} and 10^{34} erg s^{-1} respectively. Observations of radio, IR and B were carried out during 25th Sept. to 3rd October, 2002 and no signature of any persistent flare was observed. The radio data showed a tendency to go down from 1.0 Jy to 0.7 Jy reaching at about 0.3 Jy on 29th Sept., while the X-ray data showed a tendency to rise toward the end of the observation of the 27th. The IR data in each band remained virtually constant. The flux in H band was found to be higher than the flux in the J and K' bands during 25–29th Sept. 2002. This could be possibly due to free-free emission in optically thin limit as discussed by Fuchs (2002).

From Fig. 2, we have seen that there are significant variation in time-scale of $T_{\text{var}} \sim 2\text{--}8$ minutes in all the wavelengths. In order to check if these are due to individual bullets, we present in Fig. 3a, one ‘micro-flare’ like event from X-ray data of 27th Sept. 2002. It shows significant brightening and falling in ~ 100 s. The count rate goes up more than 15% or so in

about a minute. Similarly, in Fig. 3b, one micro-flare like event in radio is shown from 29th Sept. 2002 data. Here the initial radio intensity (before the flare) was ~ 0.3 Jy, so that the micro-flare could be seen prominently. We observed brightening the source from 0.35 Jy to 0.80 Jy in ~ 75 s which faded away in another ~ 75 s. That is, the intensity became more than double in one minute! The energy contained in the radio micro-flare integrated over there lifetime is about $I\nu\tau 4\pi D^2 10^{-23} = 1.1 \times 10^{33}$ erg (Here, $I \sim 0.8$ is the intensity in Jy, $\nu = 1280$ MHz is the frequency of observation, $\tau \sim 100$ s is the rise time of the bullet, $D = 9 \times 10^{21}$ cm is the distance of SS433). Similarly, the energy contained in the X-ray micro-flare is about $\frac{1}{2}\tau(N_{\gamma,\max} - \bar{N}_{\gamma})E_{\gamma}4\pi D^2/A_{\text{PCA}} = 2.7 \times 10^{35}$ erg (Here, $\tau \sim 100$ s is the rise time of the flare, $N_{\gamma,\max}$ is the maximum photon count rate, \bar{N}_{γ} is the average photon number s^{-1} , E_{γ} is the average photon energy, A_{PCA} is the area of the PCA detectors). The spectroscopic study yields an average flux of 2.41×10^{-10} $\text{erg cm}^{-2} \text{s}^{-1}$. With an estimated duration of 100 s, about 15% energy is going to the micro-flare (Fig. 3a). The energy of this micro-flare is about 4.1×10^{35} erg. Since the radio luminosity is very small, even when integrated over 0.1 to 10 GHz radio band (with a spectral index of ~ -0.5), we find that almost all the injected energy at X-ray band is lost on the way during its passage of $\sim 1 - 2$ d.

In Fig. 4, left panel, we present the available RXTE/ASM light curve of SS433. We superpose on it (dashed) the lightcurve folded around 365 days. Note that flares are strongly periodic in nature with a periodicity of 368 days (Nandi et al. 2005). In the right panel, we present the X-ray spectrum of SS433 on 27th Sept. 2002 UT in which two iron lines were fitted. We took the Power Density Spectrum (PDS) of the variation in all the wavelengths in order to search for periodicities. We did not find any, but the PDS does show a significant power in the frequency range of $\sim 0.002 - 0.008$ Hz. Deviation of the PDS from a power law background $\propto \nu^{-\alpha}$ in all three bands gives an estimate of excess power at low frequencies. The best fit values of α are 1.6, 1.8 and 1.9 for radio, X-ray and IR, respectively. Radio PDS shows excess at ~ 0.0023 Hz ($> 3.2\sigma$), i.e. at $T_{\text{var},r} \sim 7.2$ min and at ~ 0.003 Hz ($> 1.6\sigma$), i.e. at $T_{\text{var},r} \sim 5.5$ min. X-ray power shows excess at ~ 0.003 Hz ($> 2.7\sigma$), i.e. at $T_{\text{var},x} \sim 5.5$ min and at 0.0077 Hz ($> 1.4\sigma$), i.e. at $T_{\text{var},x} \sim 2.1$ min. IR power shows excess at 0.0022 Hz ($> 4\sigma$), i.e. at $T_{\text{var},ir} \sim 7.7$ min. These excesses (residuals) in PDS are shown in Fig. 5.

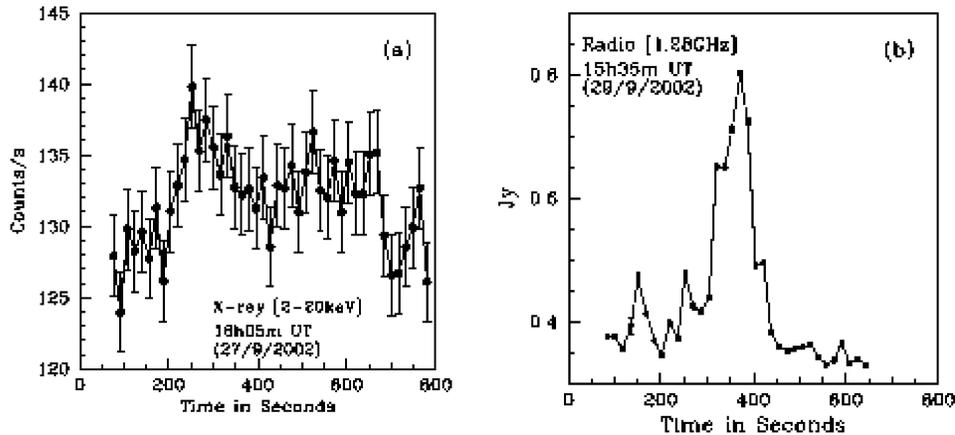


Fig. 3 Individual flares in very short time-scale are caught. (a) An X-ray flare lasting 3.5 minutes (observed on 27th Sept. 2002) and (b) a radio flare lasting 2.5 minutes (observed on 29th Sept. 2002). Each bin size is 16 seconds (from Chakrabarti et al. 2003).

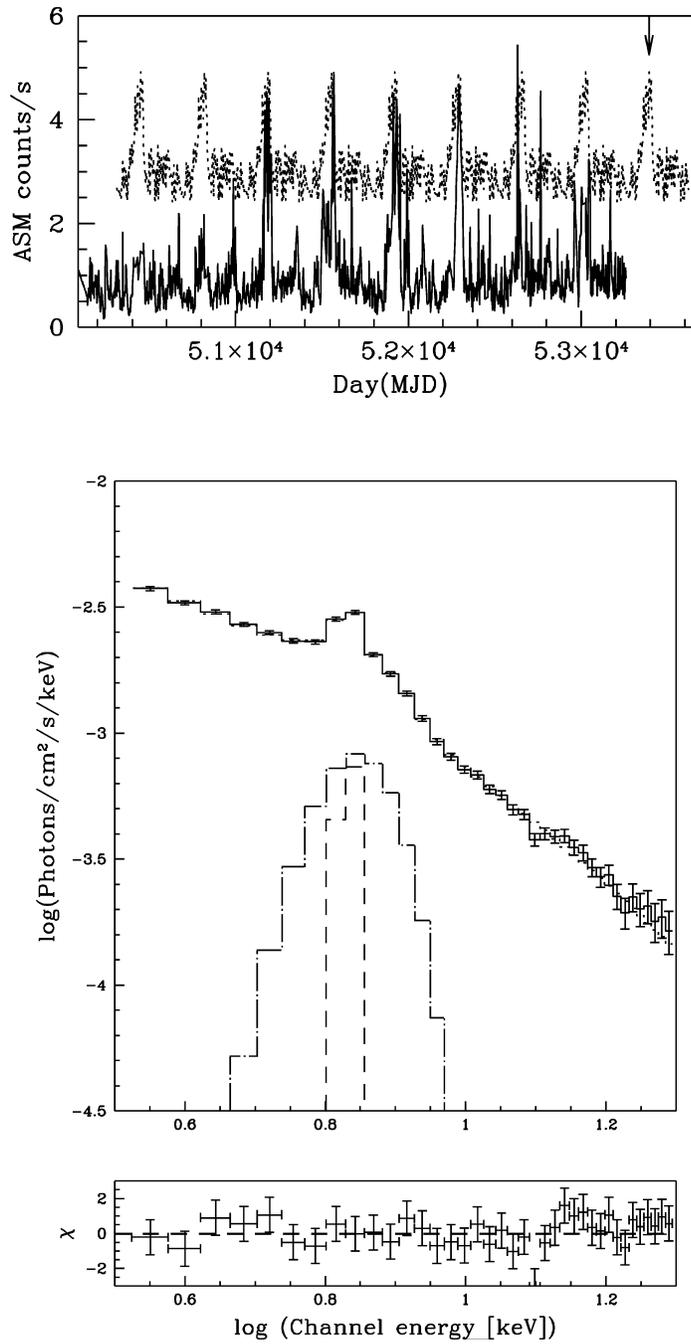


Fig. 4 Available RXTE/ASM lightcurve of SS433 (top) and X-ray spectrum of SS433 on 27th September 2002 (middle). The ASM is superposed by the folded lightcurve around 365d to show periodic nature. Next predicted flare (peaking on Jan 22nd, 2005) is shown in arrow. In the bottom panel, the residuals are plotted (from Nandi et al. 2005).

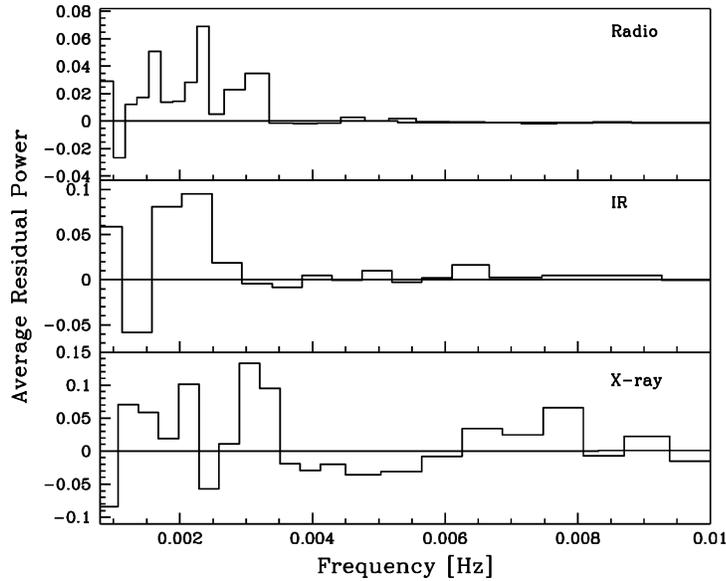


Fig. 5 Residuals of the data obtained by subtracting the suitable background noise from the Power Density Spectrum (PDS). Residuals of radio, IR and X-ray are shown in upper, middle and lower panels respectively.

4 CONCLUSION

In this paper, we presented results of recent multi-wavelength observation in X-ray, radio, B and IR wavelengths. We conclude that we may be observing ejection events of bullet-like features from the accretion disk in time-scales of 2–10 mins. Identification of small micro-flare events with those of bullet ejection is derived from the time-scale of variabilities, which are roughly the same in all the wavelengths. We find their presence in X-ray ($< 10^{11} - 10^{12}$ cm), IR ($< 10^{13} - 10^{14}$ cm) and radio ($< 10^{15}$ cm) emission regions. We also find a periodicity in X-ray flaring behaviour which is probably due to alignment of SS433 with the Sun once in every year.

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