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GMRT Observations of Microquasar V4641 Sgr

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Abstract We report the GMRT observations of V4641 Sgr during the May 2002 outburst at radio frequencies of 610 and 244 MHz. This is the lowest frequency radio detection of this source. The present low frequency radio observations clearly showed spectral evolution from the optically thick to thin state. This behavior is broadly consistent with the expanding bubble model. However, the flux densities observed at lower frequencies are much higher than predicted by this model. In the conical jet model, this discrepancy could be reconciled.

Key words: stars: individual: V4641 Sgr — radio continuum: stars — X-rays: binaries

1 INTRODUCTION

The microquasar V4641 Sgr (SAX J1819.3−2525) was discovered by `BeppoSax` and `RXTE` in 1999. Optical spectroscopy and photometry of the source showed that V4641 Sgr is a black hole candidate in a binary system with a high mass companion (Orosz et al. 2001). The object also showed flares in the optical (Uemura et al. 2002) and radio (Hjellming et al. 2000). The radio flare lasted only a few days. The radio morphology of this source suggests that it is a relativistic jet source, similar to GRS1915+105 and GROJ 1655−40 (Hjellming et al. 2000). In this paper, we present low frequency radio observations of V4641 Sgr with GMRT at 610 and 244 MHz during its radio outburst in May 2002.

2 OBSERVATION AND RESULTS

The present observations at 610 and 244 MHz were carried out with Giant Metrewave Radio Telescope (GMRT; Swarup et al. 1991) during the radio flare in May 2002. GMRT consists of 30 antennas, each of 45 metre diameter spread over about 25 km south of Mumbai, India. It is the world's largest radio telescope at metrewavelengths. Some of the useful parameters of GMRT are given in Table 1, more details about the telescope can be found in `www.ncra.tifr.res.in`. GMRT currently has a facility to observe simultaneously at 610 and 244 MHz, which was not operational during these observations. However, whenever possible, the observations at 610 and 244 MHz were taken nearly simultaneously. The observational details are given in Table 2. The flux density scale is set by observing the primary calibrator 3C286 or 3C48. A phase calibrator was observed before and after a 30 min scan on V4641 Sgr for phase calibration. The integration time was 16 s. The data recorded from GMRT have been converted to FITS and were analysed

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Table 1 Some Useful Parameters of GMRT

Frequency (MHz)	151	235	325	610	1000 − 1450
Primary Beam (°)	3.8	2.5	1.8	0.9	0.56–0.4
Resolution (″)	20	13	9	5	2–3
RMS (mJy)/hour	??	2	1	0.5	0.1

Table 2 Observation Log and Fluxes

Date 2002 May-(UT)	Frequency (MHz)	Duration (min)	Flux(mJy) (V4641)	Flux (mJy) (Bg. Source)
24.03	610	32	101.8 ±5.25	65.2 ±3.39
25.02	610	25	102.5 ±5.33	66.3 ±3.44
25.92	610	75	47.8 ±2.97	71.0 ±3.66
26.92	610	80	14.4 ±1.75	71.3 ±3.68
28.01	610	45	7.6 ± 1.38	67.9 ±3.51
29.76	610	28	1.4 ± 1.28	61.2 ±3.20
23.99	241	28	57.8 ±7.70	102.9 ± 6.3
24.89	241	45	81.8 ±5.04	105.0 ± 8.2
27.85	241	30	< 19.9†	105.8 ± 10.1
28.90	241	30	< 20.3†	107.5 ± 13.6

†Limits are 5 σ upper limits

using Astronomical Image Processing System (AIPS). A few iterations of phase self calibration have been performed to reduce the phase errors and improve the image quality. The flux density at 610 and 244 MHz has been corrected for increased background noise in the direction of V4641 Sgr.

3 DISCUSSION

This is the first positive detection of V4641 Sgr at low frequency of 244 MHz. Images of the field at 610 and 244 MHz are presented in Figure 1. At this frequency, the peak of the radio flare is expected at a later time as compared to higher frequencies. The radiative lifetime of the electrons is also longer at these frequencies, making them visible for longer duration as compared to higher frequencies. Below we discuss the radio light curve and the plasma expansion model to understand the observed spectral change.

3.1 The radio light curve

The radio light curve of V4641 Sgr from the present observation is shown in Figure 2. For comparison, the flux density of a control source in the background is also given in the Table 2. At 610 MHz, the flux density of V4641 Sgr was constant on May 24 and 25, 2002, while the 244 MHz flux density increased from 58 to 82 mJy during the same period. This suggests that the source was optically thick on May 24 and became partially optically thin on May 25. The flux density decayed at both frequencies subsequently. The overall profile of the flux density decay is similar to the September 1999 radio outburst (Hjellming at al. 2000).

3.2 Plasma expansion and the Spectral evolution

The plot of spectral index with time clearly shows the spectral evolution from optically thick to thin state. The spectral index α on May 24, 2002 is 0.60 ($S_\nu \propto \nu^\alpha$) which changed to 0.24 next

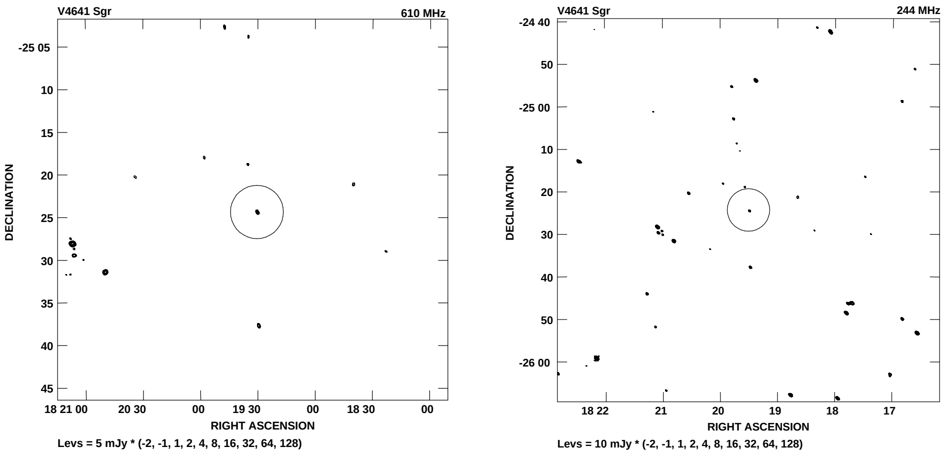

Fig. 1 Field of V4641 Sgr at 610 (left) and 244 MHz (right). The circle drawn at the central region is only to help to locate the V4641 Sgr, which is at the center of this circle.

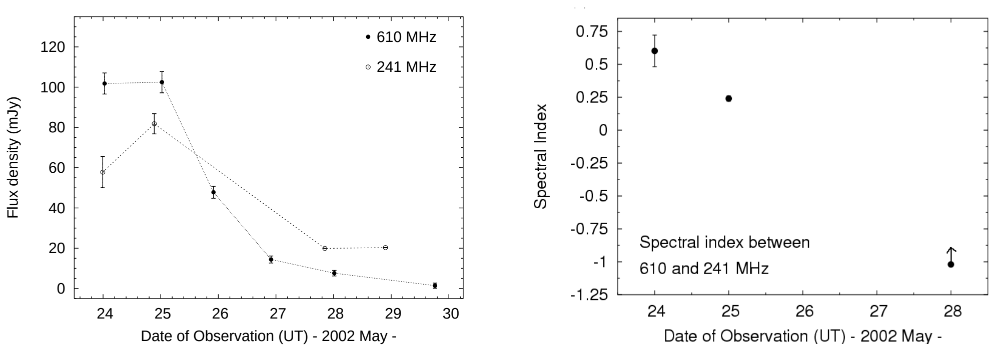

Fig. 2 Light curve of V4641 Sgr at 610 and 244 MHz (left) and the plot of spectral index for each day with nearly simultaneous observation at these frequencies (right).

day. This can be qualitatively understood in terms of plasma expansion in the bubble model. In this model, a blob of plasma is ejected from the accretion disk, which is initially optically thick and the low frequency radio emission self is absorbed. As the plasma expands with time and becomes optically thin, the flux density at lower frequencies rises and reaches its peak emission. Application of the synchrotron bubble with the parameters used by Hjellming et al. (2000) predicts the 610 MHz emission to peak ~ 37 hours after the ejection. From the ASM lightcurve (Figure 3), it appears that the X-ray flare occurred on May 21, 2002. If this is taken as the time of ejection, the 610 MHz emission should have peaked between May 22 and 23, 2002. This is confirmed by the peak observed by Molonglo Synthesis Telescope (MOST) at 843 MHz near this time (Champbell-Wilson,private communication). However, the naive application of the synchrotron bubble model predicts the flux density at lower frequencies to be much less than that at higher frequencies, which is inconsistent with the observations. This inconsistency may be reconciled in the conical jet model (Hjellming and Johnston, 1988).

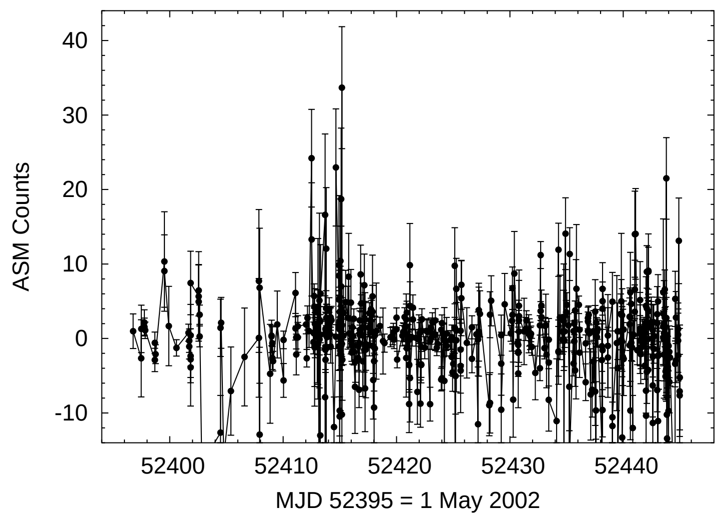

Fig. 3 RXTE/ASM Lightcurve for V4641 Sgr during May - June 2002.

4 CONCLUDING REMARKS

We have shown for the first time that the microquasar V4641 Sgr exhibits strong radio emission at metrewavelengths. Although the time-delays estimated by assuming the expanding bubble model agrees reasonably with the observations,the flux density measurements at low frequencies are significantly higher than predicted by this model. This may be in better agreement with the conical jet model. This observational result demonstrates the importance of the low frequency radio observations for constraining the models of radio emission from microquasars.

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