RevMexAA (Serie de Conferencias), **27**, 222–224 (2007)

RADIO AND X-RAY MONITORING OF SS433

Z. Paragi,[1] S. Chakrabarti,[2] S. Pal,[3] K. Borkowski,[4] P. Cassaro,[5] T. Foley,[6] G. Hrynek,[4] X. Huang,[7] A. Kraus,[8] M. Lindqvist,[9] A. Orlati,[10] L. Xiang,[11] and A. Nandi[12]

RESUMEN

SS433 es la fuente binaria de rayos X persistente en radio más potente en la galaxia. Sus chorros en radio se forman probablemente en forma parecida a los que ocurren en otras binarias, pero su enorme potencia se debe posiblemente a una tasa de acreción super-Eddington y a la interacción con un viento denso. La meta de nuestra campaña de observación era el establecer una relación entre los rayos X y la emisión en radio para diferentes geometrías del disco y el chorro. Aquí reportamos resultados iniciales, basados principalmente en observaciones con el VLBI.

ABSTRACT

SS433 is the most powerful permanent radio-jet X-ray binary (XRB) in the Galaxy. Its unique radio jets are probably formed similar to other XRBs, but their superior radio power is thought to be a result of super-Eddington accretion rate and interaction with a dense disk wind. The goal of our monitoring campaign was to establish the relation between the X-ray and radio properties of the system at different accretion disk/jet geometries. Here we report on early results, mainly from the VLBI observations.

Key Words: **ISM: JETS AND OUTFLOWS — STARS: INDIVIDUAL (SS433) — RADIO CONTINUUM: STARS — TECHNIQUES: INTERFEROMETRY**

1. INTRODUCTION

SS433 is the first radio-jet X-ray binary in the Galaxy, discovered more than 25 years ago. The mechanism by which its unique radio beams are formed is still not known. A good review on recent observational and theoretical works is given by Fabrika (2004). A possible solution to address this problem can be multifrequency monitoring campaigns such as the pioneering work done by Vermeulen et al. (1993), and more recently by Chakrabarti et al. (2005) and Revnivtsev et al. (2004).

We carried out joint EVN/GMRT/RXTE monitoring of the source to see how changes in the accretion environment and jet geometry are related to the structural changes in the jet. Here we summarise mainly the radio results, focusing on the total flux density changes and the VLBI structure. A detailed analysis of all the data and interpretation will be given by Chakrabarti et al. (in prep.).

2. THE OBSERVING CAMPAIGN

RXTE observations of SS433 took place in August 2004, as a continuation of an earlier multifrequency campaign (Chakrabarti et al. 2005). In parallel, radio observations were carried out at 1280 MHz with the GMRT, Pune, India, and at 4990 MHz with a sub-array of the European VLBI Network (EVN), outside the EVN observing sessions. The GMRT observations took place on 23, 24, 25 and 28 August 2004 using 16 MHz bandwidth. Except on the last date when the full array was operational, 29 telescopes observed. The EVN observed for four hours on 23, 25 and 27 August with the disk-based MkV recording system. The recording rate was 256 Mbps, which resulted in 4×8 MHz channels in both left and right circular polarization. The data were correlated at the EVN Data Processor at JIVE. The core of the ad-hoc VLBI array was Effelsberg, Torun, Noto and Westerbork, available at all epochs. Medicina, Onsala, Shanghai and Urumqi also joined at one or two epochs, making the total number of telescopes six at any time. Some data were transferred through the Internet and processed with the NICT (formerly CRL, Japan) software correlator to monitor network performance (ftp fringe tests; see http://www.evlbi.org/tog/ftp_fringes/ftp.html). We

[1]JIVE, Dwingeloo, The Netherlands.
[2]S.N. Bose Nat. Center for Basic Sciences, Kolkata, India.
[3]Centre for Space Physics, Kolkata, India.
[4]Nicolaus Copernicus University, Torun, Poland.
[5]Istituto di Radioastronomia, Noto, Italy.
[6]Astron, Dwingeloo, The Netherlands.
[7]Shanghai Astronomical Obs., Shanghai, P.R. China.
[8]Max-Planck Institut für Radioastronomie, Bonn, Germany.
[9]Onsala Space Observatory, Onsala, Sweden.
[10]Istituto di Radioastronomia, Medicina, Italy.
[11]Urumqi Astronomical Observatory, Urumqi, P.R. China.
[12]Centre for Space Physics, Kolkata, India.

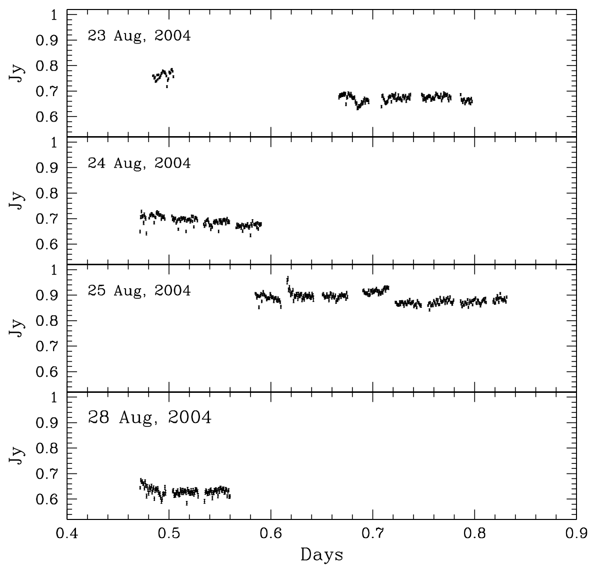

Fig. 1. GMRT lightcurves at 1280 MHz. The source flux density varied between 600 and 900 mJy during our observing campaign. Chakrabarti et al. (in preparation).

quickly realised that there were no fringes to Noto, but the problem could not be fixed in the short time available, making the total number of telescopes five for each epoch.

The VLBI data were processed in AIPS (Diamond 1995) using the EVN Data Calibration Pipeline (Reynolds, Garrett, & Paragi 2002). Self-calibration and imaging was done manually, using Difmap (Shepherd 1997). The rms noise levels achieved were 50-100 microJy/beam, about what was expected with our limited array and short observing time available.

3. COMPARISON OF THE GMRT, EVN AND RXTE RESULTS

The radio lightcurves at 1280 MHz are shown in Fig 1, while the high-resolution images at 4990 MHz can be seen in Figure 2. SS433 was in a quiet state, but showed significant variations. The total flux density increased by about 200 mJy between 24 and 25 August, and then dropped by 300 mJy by 27 August. Intriguingly, the high resolution images do not show this brightening at 4990 MHz. Instead, the correlated flux density on the shortest EVN baseline Effelsberg-Westerbork ($\sim 3\mathrm{M}\lambda$) decreased by at least 40 mJy (at the visibility maximum, measured at the same hour angle at all three epochs), while the radio core brightness remained roughly constant, it decreased only slightly. The corresponding spectral indices (strictly speaking, lower limits) on these

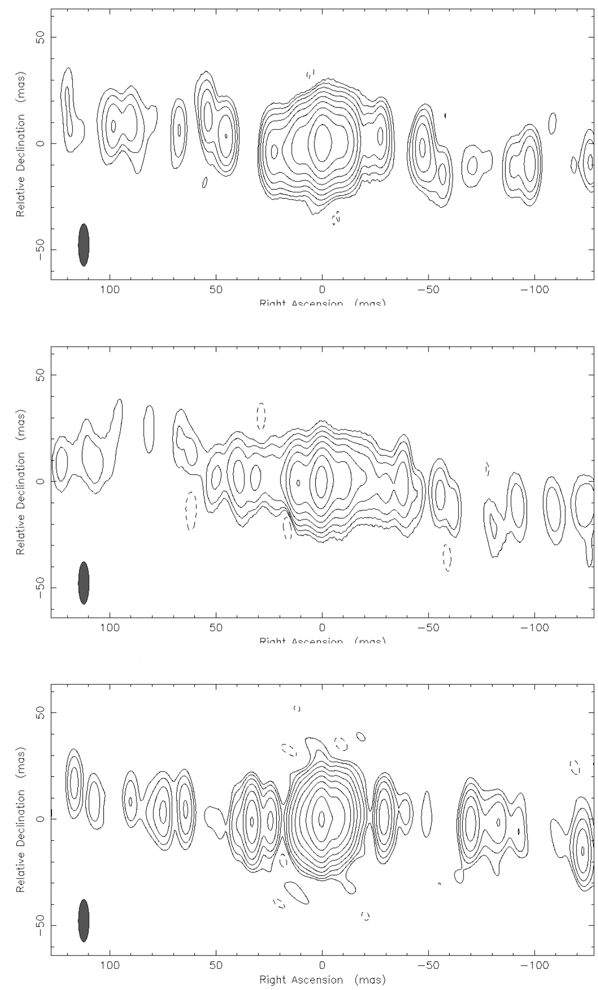

Fig. 2. High-resolution EVN images at 4990 MHz on 23 (top), 25 (middle) and 27 August (below). Peak brightnesses were 87, 75, and 112 mJy/beam, in the same order. All the images were restored with 20×5 mas N-S beam. The contour levels increase with a factor of two, the lowest being 0.4 mJy/beam for 25 August, and 0.2 mJy/beam at the other two epochs.

dates were $\alpha \sim -0.6$, $\alpha \sim -0.9$ and $\alpha \sim -0.5$ ($S \propto \nu^{\alpha}$). These are consistent with RATAN measurements (http://cats.sao.ru/cgi-bin/ss433.cgi) in early August 2004, and with the general spectral properties of the source (e.g. Trushkin, Bursov & Nizhelskij 2003). The steep spectral index on 25 August indicates an increase in jet dominance. Because the maximum proper motion of SS433 jet components is 9 mas/day, these daily flux variations must originate in a region with a size of this order: individual blobs within 100 mas from the core, or the core-jets themselves. Since the core-jets have a flat spectral index due to partial self-absorption and additional free-free

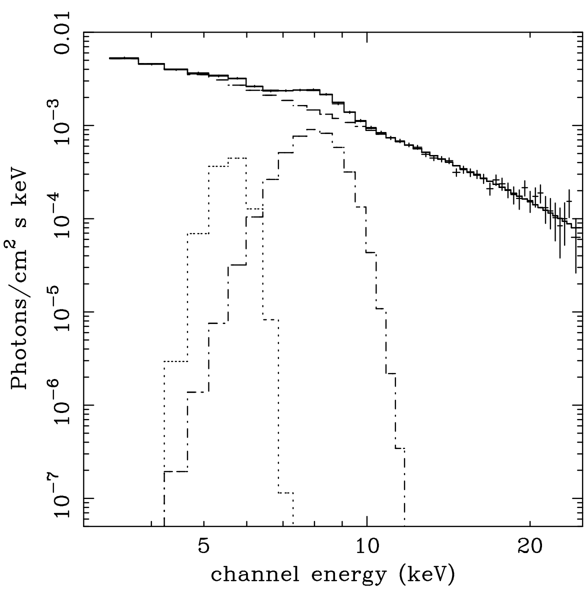

Fig. 3. X-ray spectrum of SS433 on 23 August 2005. Two iron lines and a bremsstrahlung component was fitted to the data. Chakrabarti et al. (in preparation).

absorption (Paragi et al. 1999), the observed increase in low-frequency flux is unlikely to originate from the inner parts of the radio jets. A possible candidate region is the brightening zone 40-50 milliarcsecond from the core (Vermeulen et al. 1993). Although some moving jet features can be identified on the VLBI images, there is no obvious brightening observed in the brightening zone, neither in the source as a whole at this frequency.

The *RXTE* spectrum on the 23 August is shown in Figure 3. Observational data taken at other epochs are being analysed. The spectrum is fitted with two iron lines (related to the approaching and the receding jet) and a bremsstrahlung component. There is no sign of a Keplerian disk from these data. The overall X-ray flux of the source decreased between 23 and 24 August. This was due to a geomtric effect: at this epoch the companion blocked emission from the base of the X-ray jets. A more thorough description of the radio and X-ray data analysis and results will be given by Chakrabarti et al. (in preparation).

The European VLBI Network is a joint facility of European, Chinese, South African and other radio astronomy institutes funded by their national research councils.

REFERENCES

Chakrabarti, S. K., Anandarao, B. G., Pal, S., et al. 2005, MNRAS, 362, 957

Fabrika, S. 2004, Astrophys. Space Phys. Rev., 12, 1

Diamond, P. J. 1995, in ASP Conf. Ser. 82, Very Long Baseline Interferometry and the VLBA, ed. J. A. Zensus, P. J. Diamond, & P. J. Napier (San Francisco: ASP), 227

Paragi, Z., Vermeulen, R. C., Fejes, I., Schilizzi, R. T., Spencer, R. E., & Stirling, A. M. 1999, A&A, 348, 910

Revnivtsev, M., Burenin, R., Fabrika, S., Postnov, K., Bikmaev, I. Pavlinsky, M. et al. 2004, A&A, 424, L5

Reynolds, C., Paragi, Z., & Garrett, M. 2002, in Proc. of the XXVIIth General Assembly of the International Union of Radio Science (URSI: (Gent: URSI), Paper 924, Session J8.P4

Shepherd, M. C. 1997, in ASP Conf. Ser. 125, Astronomical Data Analysis Software and Systems VI, ed. G. Hunt & H. E. Payne (San Francisco: ASP), 77

Trushkin, S. A., Bursov, N. N., & Nizhelskij, N. A. 2003, Bull. Spec. Astrophys. Obs., 56, 57

Vermeulen, R. C., Schilizzi, R. T., Spencer, R. E., Romney, J. D., & Fejes, I. 1993, A&A, 270, 177

Zsolt Paragi: Joint Institute for VLBI in Europe, Postbus 2, 7990 AA Dwingeloo, The Netherlands (zparagi@jive.nl).