Low Frequency Observations of Peculiar Radio Galaxies

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Radio galaxies strikingly produce collimated jets from kiloparsec to megaparsec scale. These jets are powered by relativistic particles and magnetic field emanating from the core of active galactic nuclei. With new highly resolved deep sky surveys, radio galaxies with rare morphologies are increasingly discovered such as S-, X- and Z-shaped sources. Galaxies with such twisted jets underlie a complex and dynamic mechanism taking place at their cores. With many leading theories explaining the formation of these peculiar structures, there is a lack of sufficient evidence in support of either of them. We intend to probe the distorted jet/lobe morphology in order to understand the physical conditions at the central supermassive black hole of such host galaxies. Here we present new 608 MHz data of an S-shaped source from dedicated low frequency uGMRT observations.

1 Introduction

Energetic jets of radio galaxies (RGs) are dominantly hosted by giant ellipticals containing supermassive black hole (SMBH) at their centre. These RGs display diverse set of morphologies that include the standard Fanaroff-Riley I and II type (Fanaroff & Riley 1974) which are based on their total radio power and the surface brightness distribution, head-tail, narrow/wide-angle tail (Wilber et al. 2018; Sakelliou & Merrifield 2000) and X-, S- and Z-shaped radio sources (Capetti et al. 2002; Florido et al. 1990; Leahy & Parma 1992) which seem to posses more dynamic and complicated nature of the central active region. For understanding the peculiar morphology of S-shaped galaxies, a range of possible models have been proposed explaining these changes in the direction of the propagation of the jets, including reorientation of the jets due to the presence of another SMBH companion (Begelman et al. 1980; Merritt & Ekers 2002) and/or due to a surrounding tilted accretion disk (Lu 1990).

The study of such sources is crucial for an in depth analysis of galaxy evolution including growth via galaxy mergers and nuclear activity. In both cases, the central active galactic nucleus (AGN) is bound to undergo disturbances and perturbations, and jets act as excellent tracers of the central SMBH behaviour. Depending on the central SMBH spin, mass and the amount of gas in the surrounding accretion disk, AGN can transfer magnetic field, mass and energy from the nucleus to the large-scale environment via outflows (kpc or even Mpc in scale). Analysing such distorted and peculiar jets will lead to further understanding of SMBHs growth and AGNs evolution.

2 Observations

We observed a sample of five promising candidates revealing S-shape radio morphology with the upgraded Giant Metrewave Radio Telescope (uGMRT, Gupta et al.

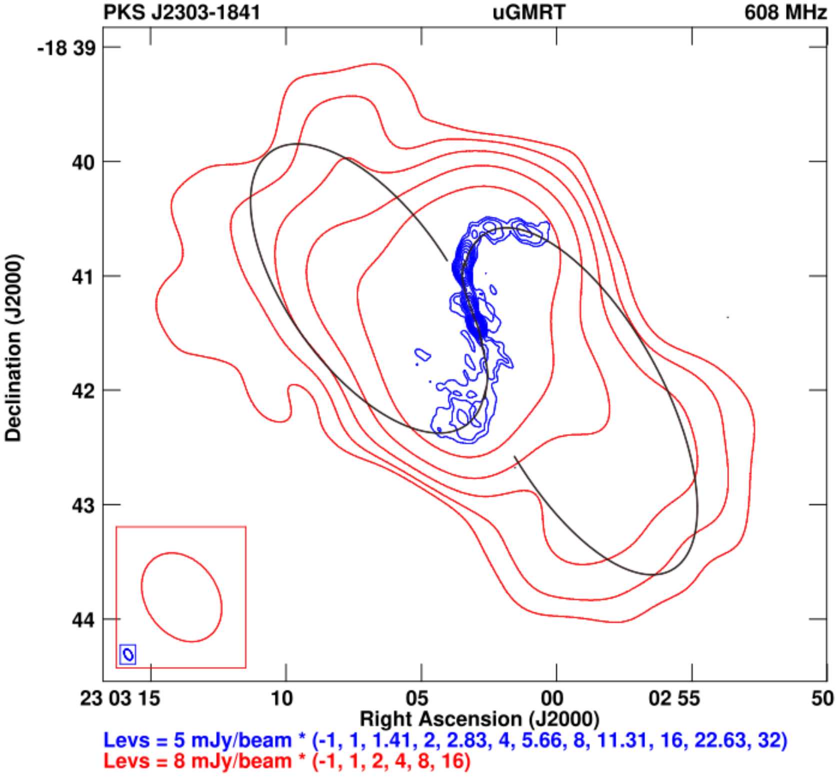

Fig. 1: 608 MHz uGMRT map of PKS J2303−1841. Blue: original map with the resolution of 6.01″ x 3.71″, contour values selected to visualize well the inner compact emission. Red: tapered (3.5 x 3.5 kλ) map with the resolution of 49.91″ x 37.88″, contour values selected to visualize well the extended diffuse emission of the protrusions. Shape of the beams are marked in the lower left corner. The solid line represents the plasma distribution predicted by the precessing jet model (Hunstead et al. 1978).

2017) at 608 MHz. The radio map of one of those sources is given in Fig 1. This source J2303−1841, is labeled as one of the clearest examples of precessing jets observed in Quasi Stellar Object hosts (Hunstead et al. 1984). It was first identified by Bolton & Ekers (1966) having peculiar, concave radio spectrum: steep at low frequencies and flat at shorter wavelengths (Hunstead et al. 1978), which is typically observed for a compact flat-spectrum core surrounded by steep spectrum extended emission.

The band 4 (608 MHz) overlay map in Fig. 1 shows the inner compact structure of the S-shaped jets stretched along the north-south direction and also reveals diffuse emission towards north-east and south-west direction extended up to $\sim 5'$ in the sky plane. The spectral index α ($S_\nu \propto \nu^{-\alpha}$) of the diffuse emission between 608 MHz and 1400 MHz NVSS (NRAO VLA Sky Survey, Condon et al. 1998) maps is ~ 1.3, this steep spectrum indicates an old electron population from a previous episode of jet activity. Hence the compact jets surrounded by the large scale steep and diffuse emission, in an S-shaped morphology, imply at an underlying jet precession of the radio source.

All the remaining four candidate sources demonstrate newly observed extended and diffuse emission compared to their higher frequency 1400 MHz maps, constraining the extent of the plasma flow; they also show an inversion symmetric S-shape morphology. The low frequency observations here are crucial for analysing the live-long morphology of these radio galaxies as they help trace the movement of the jets from their earliest to the current orientation.

3 Summary

Since these unique sources are rarely studied in detail, our multifrequency data will be used to build the radio spectra in many different locations of the sources. This will allow us to collect quintessential information like the spectral age, which would give clues about their evolution. With the spectral age of the sources and by modelling of the jets, we would study the motion of these jets in the inter galactic medium and the behaviour of their central SMBH.

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