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, more radio galaxies are discovered with interesting morphologies such as S-, X- and Z-shaped sources. Radio galaxies with such twisted jets underlie a complex and dynamic mechanism taking place at their cores. With many theories explaining the cause behind these peculiar structures, there is less 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. We present here new 610 MHz data of a sample of S-shaped sources from dedicated low frequency GMRT observations.

INTRODUCTION

- Radio galaxy jets mostly conform to the standard FRI or FRII morphology (Fanaroff & Riley 1974), having straight jets axis direction from radio core to the edges of the lobe (example fig 1 and 2).
- However some galaxies show peculiar morphology of jets such as X-, S- and Z- shaped sources.
- Observing such galaxies hint at a more dynamic nature of the central AGN and pose questions about the phenomenological changes responsible for their deviation.
- A range of possible models for this reorientation or precession connected to the changing direction of the spin axis have been proposed including :
  - reorientation of the jets due to the presence of another supermassive black hole in the same nucleus (e.g. Begelman et al. 1980)
  - surrounding tilted accretion disk (e.g. Lu 1990)

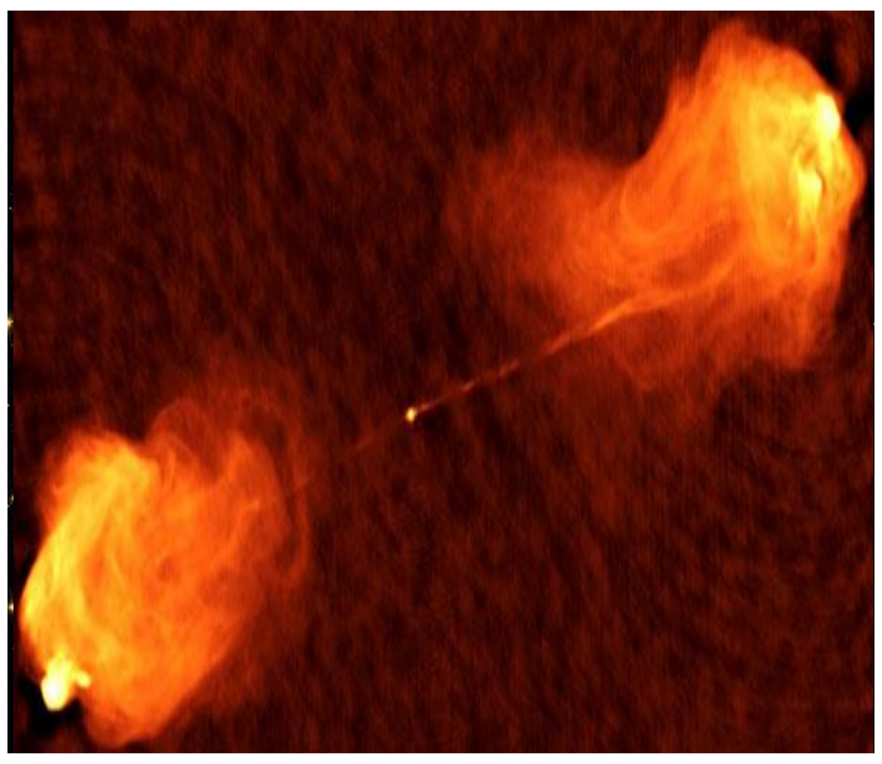

Fig 1. FR II type radio galaxy Cygnus A
Image Credit : NRAO, AUI

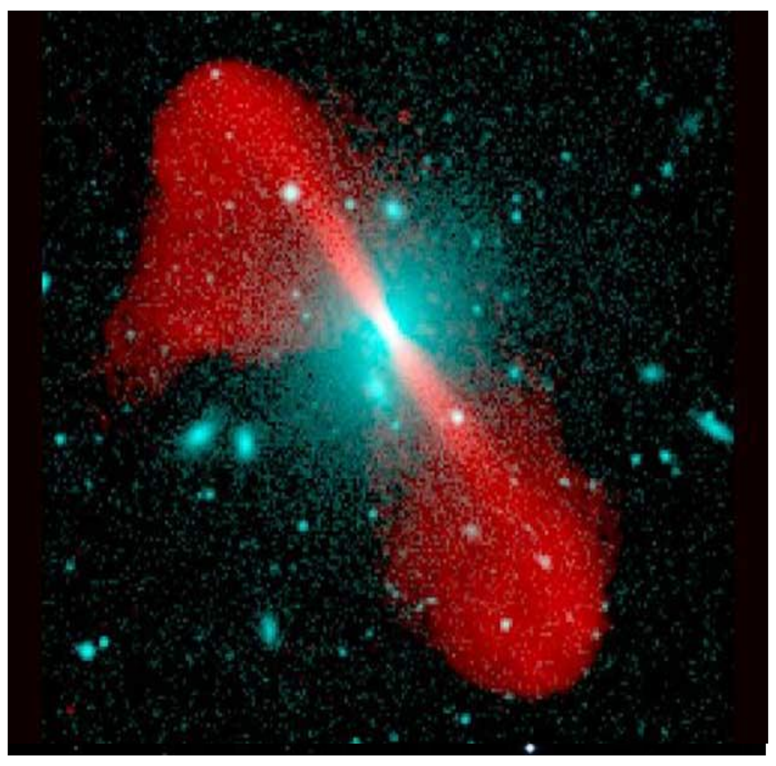

Fig 2. FR I type radio galaxy 3C296
Radio (red) overlaid on optical (blue)
Image Credit : AUI, NRAO

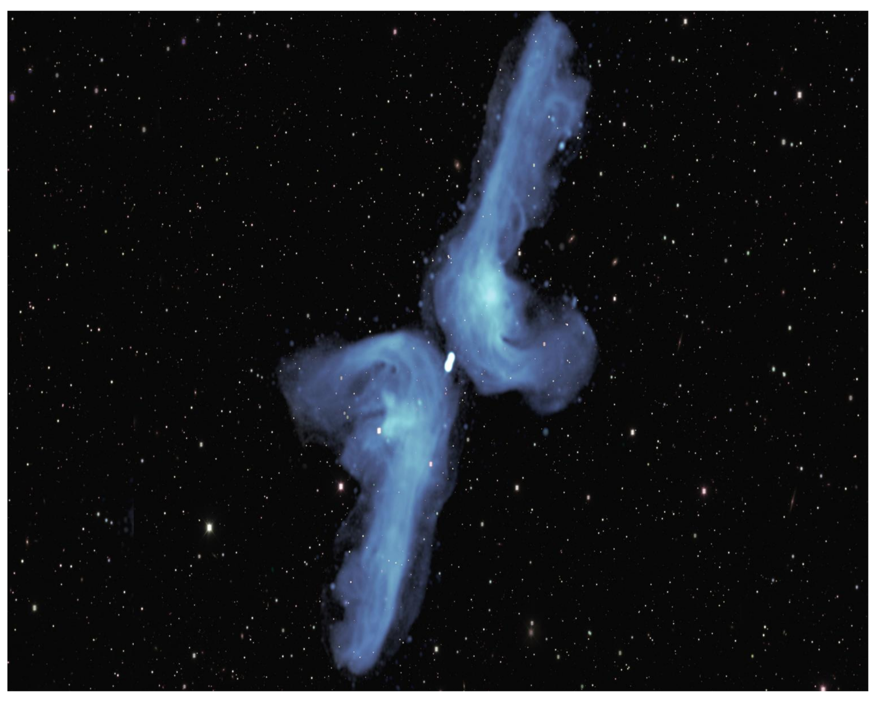

Fig 3. X-shaped radio galaxy
Radio (blue) overlaid on optical background
Image Credit : NRAO/AUI/NSF; SARAO; DES

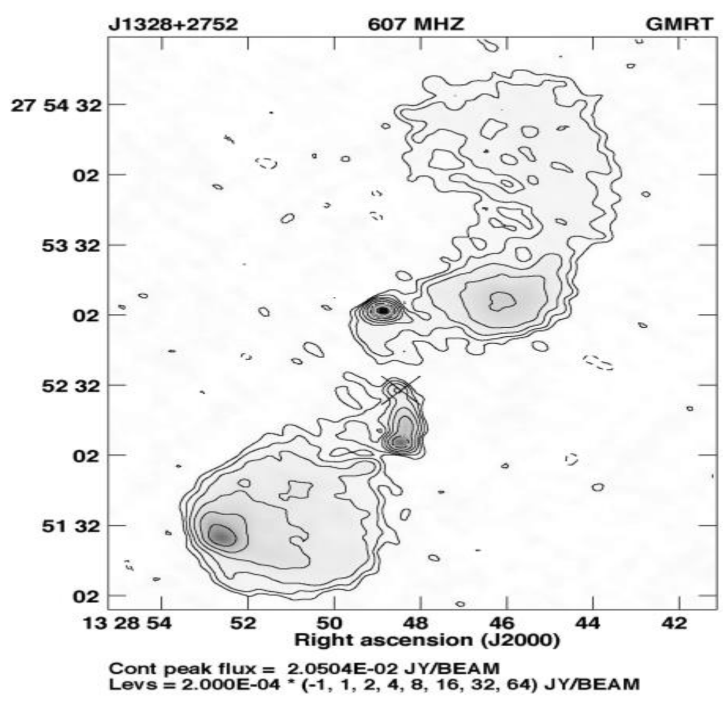

Fig 4. S-shaped radio galaxy
607 MHz radio image of J1328+2752
Image Credit : Nandi et. al

LITERATURE MODEL

- Among several S-shaped sources discovered so far, J2303−1841 is one of the clearest examples of precessing jets observed in QSO hosts (Hunstead et al. 1984).
- It has peculiar, concave radio spectrum, steep at low frequencies and flat at shorter wavelengths (Hunstead et al. 1978),
- This is typically observed for a compact flat-spectrum core surrounded by steep spectrum extended emission.
- 1.5 GHz Very Large Array images of J2303−1841 clearly reveal diffuse emission towards the north-east and south-west direction extended up to ~2′ in the sky plane.
- High resolution observations provide a direct proof for a nodal structured jet's precession.

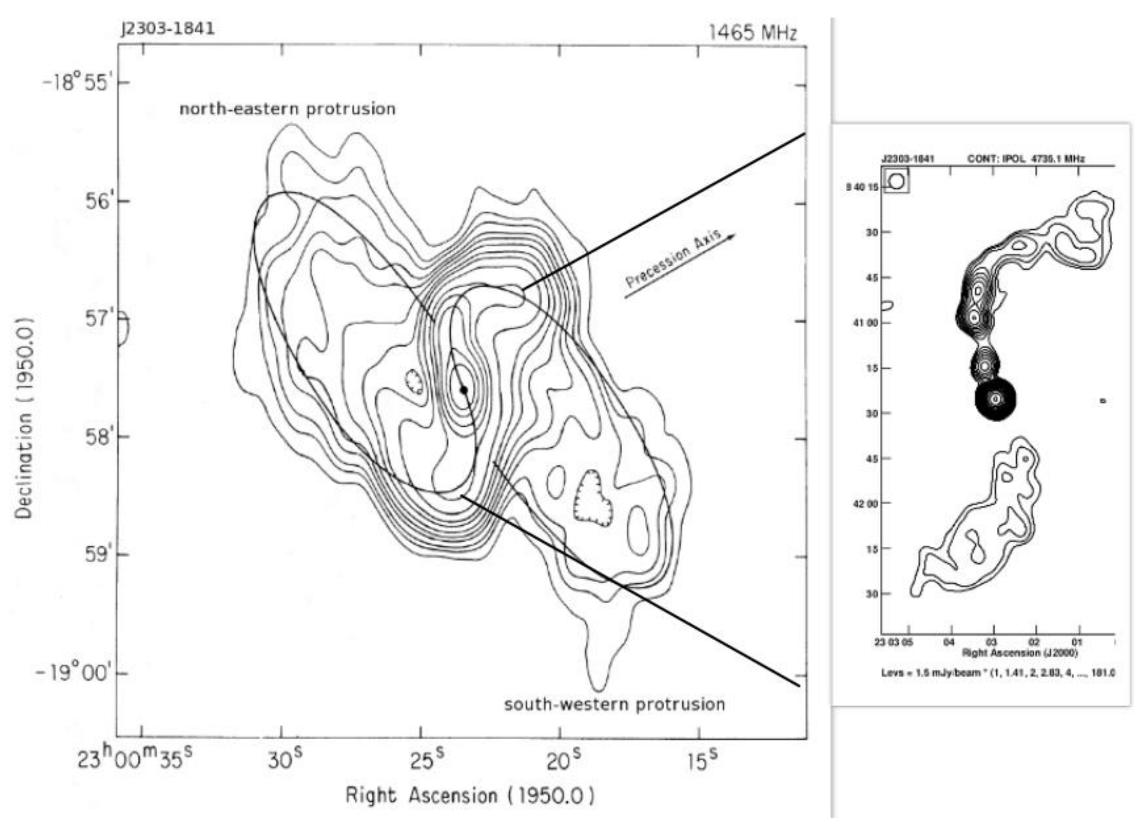

Fig. 5 1.4 GHz contour map of J2303−1841 on the left panel from Hunstead et al. (1984). The solid line represents the plasma distribution predicted by the precessing jet model. 5 GHz map (right panel) reveals the innermost structure of the radio source with a bright core and twisted jets.

LOW FREQUENCY RADIO OBSERVATIONS

- A sample of five promising candidates showing similar S-shape radio morphology were observed with upgraded Giant Metrewave Radio Telescope (uGMRT) at 610 MHz.
- The selection of these sources were based on the clear morphological precision denoting an S-shape from archival radio maps.
- Shown below are two of the sample sources observed with uGMRT at 610 MHz.
- The diffuse emissions are well mapped at the low radio frequency along with the current direction of jets.
- The jets show an S- shaped morphology, tracing old and new direction of plasma flow indicating jet precession.
- In Fig 6, the south east protrusions indicate jets being dragged from their previous position creating the twisted pattern of jets. The core and clear hotspots in the north-south direction indicate the current orientation and fresh activity of the source.
- In Fig 7, the north-west and south-east protrusion showcasing the extended emission, traces an horizontal S-shape. The core and the hotspots indicate the recent direction of jets.

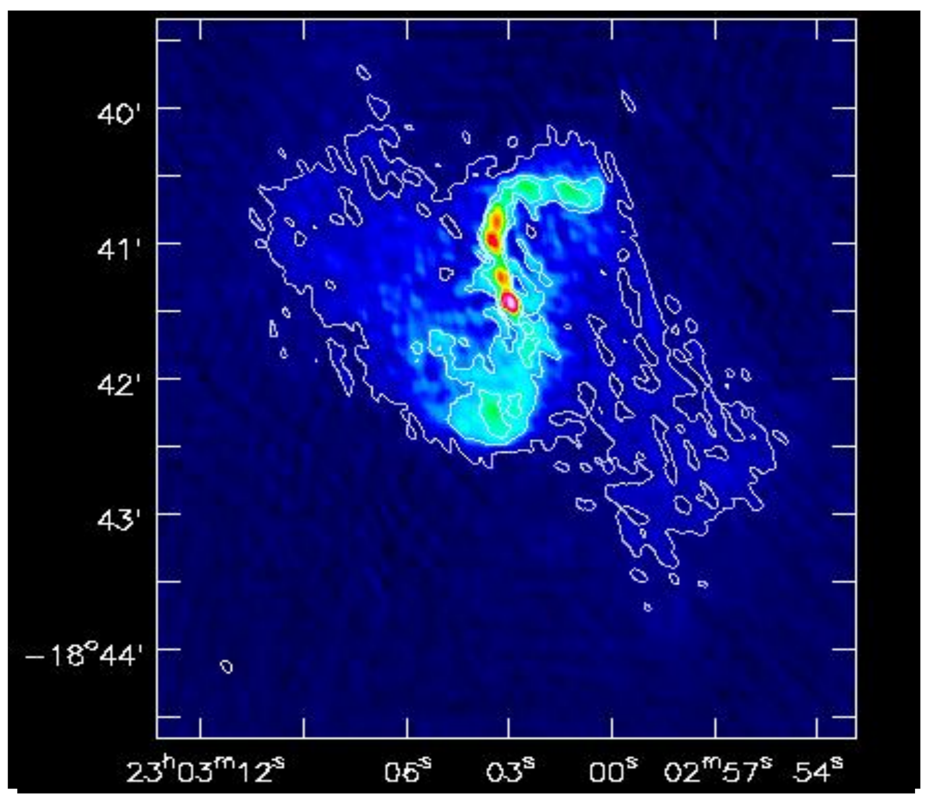

Fig 6. 610 MHz map of J2303−1841

- The source J2303−1841, with associated redshift z = 0.128 has angular size of 4'.
- The total flux of the source at 610 MHz is 2.26 Jy.
- The total flux of the diffuse emission surrounding the core is 0.5 Jy.
- The spectral index of the diffuse emission between 610 MHz and 1400 MHz is **1.3,** indicating an extremely steep spectrum.

- The source J1319+2938, with associated redshift z = 0.0728 has angular size of 3'.
- The total flux of the source at 610 MHz is 2.05 Jy.
- The total flux of the diffuse emission surrounding the core is 0.6 Jy.
- The spectral index of the diffuse emission between 610 MHz and 1400 MHz is **1.1,** indicating an extremely steep spectrum.

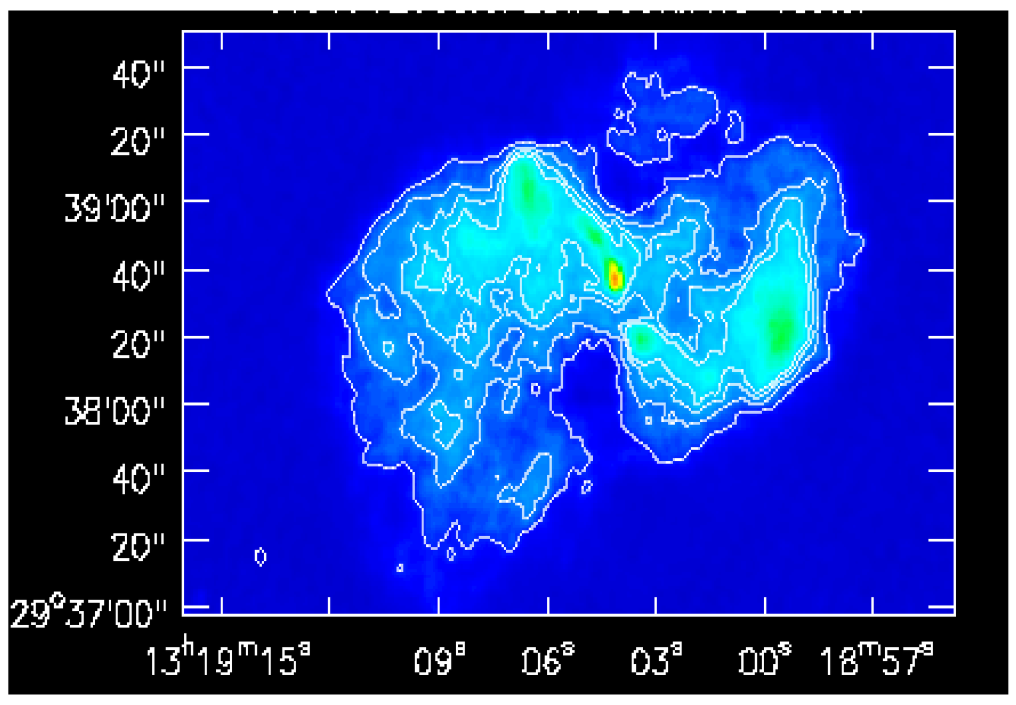

Fig 7. 610 MHz map of J1319+2938

CONCLUSION

- There are many theoretical models describing S-shaped sources, but they lack sufficient observational evidences that come from a large sample study of homogeneous radio data.
- At high radio frequencies the "fresh" energetic particles and the recent jet orientation are well traced. However, for the complete motion of the plasma, from the past up to present time, multifrequency and particularly low-frequency radio observations are highly desirable.
- This would be beneficial for observing steep spectrum "old" low energy particles present in the diffuse lobes to study precession.
- Our project is an attempt towards understanding the cause behind the morphology of some of the peculiar sources with the help of low frequency observations.
- The study of such sources with distorted morphology is crucial for an in depth analysis of galaxy evolution including growth via galaxy mergers and nuclear activity.
- In both cases, the central AGN is bound to undergo disturbances and perturbations, and jets act as excellent tracers of the central SMBH behaviour.
- Future work will involve multifrequency observations of the target sources with spectral ageing analysis on independent sections of the jets.

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