A dying, giant radio galaxy in the distant Universe

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Outline

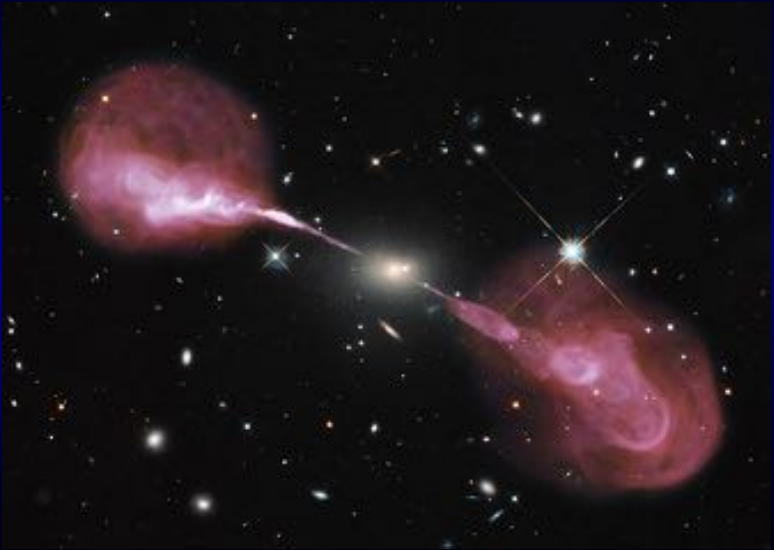
Collaborators

This work was done as a part of an Indo-French project titled **Distant, obscured galaxies with GMRT and Herschel**

- **Prathamesh Tamhane, IISER, Pune**
- Aritra Basu, MPifR, Germany
- **Veeresh Singh, PRL, Ahmedabad**
- Alexandre Beelen, IAS, France
- **C.H. Ishwara-Chandra, NCRA-TIFR, Pune**
- Sandeep Sirothia, NCRA-TIFR and SKA-SA

This work already published in **Tamhane et al. 2015, MNRAS, 453, 2438**

Giant radio galaxies



Studies of Giant radio galaxies help us to

- understand the evolution of radio sources in dense environments
- constrain orientation-dependent unified schemes
- probe the properties of the intergalactic medium at different redshifts

In the complete sample of 3CR radio sources (Laing, Riley & Longair (1983)), about 6 per cent of the radio sources are giants. Number density in the local Universe is $\sim 7 \times 10^{-7}$ Mpc^{-3} based on MWA data (Hurley-Walker et al. 2015). We need large samples at different redshifts for statistical studies.

Common GRG characteristics and why low freq. telescopes are best to study them

- lobes have a steep radio spectrum $\Rightarrow$ low frequency surveys can detect them even at high redshift.
- they typically have low surface brightness $\Rightarrow$ low frequency interferometers with short spacing baselines can detect them well.
- the poorer resolution of low frequency radio telescopes is not much of a problem since the radio lobes are very large and resolved relatively easily .

Low frequency telescopes - LOFAR, MWA, GMRT play an important role in the identification and study of radio galaxies.

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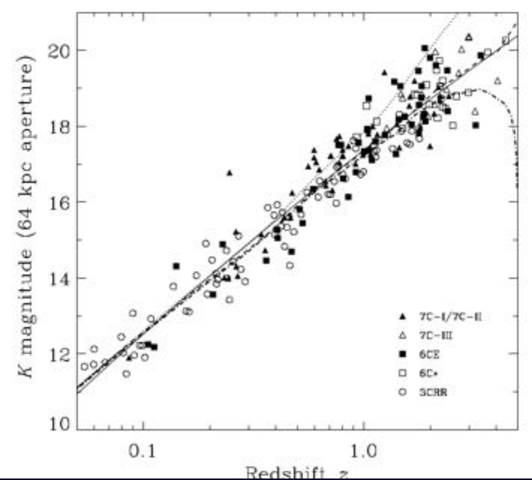
The $K - z$ relation



Willott et al. (2003)

Scientific Motivation for our 325 MHz survey

- radio counterparts of Herschel HerMES survey sources (and stacked blank sky!) , radio-FIR correlation, identify optical counterparts (and hence redshifts!), study obscured AGN and star-forming galaxies out to cosmological distances.

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- characterise and study the zoo of objects with steep radio spectra e.g. high z radio galaxies.
- most other studies currently being pursued at higher radio frequencies can also be done with these data. e.g. studies of the impact of radio mode AGN feedback on galaxy evolution.

GMRT data of XMMLSS field

- 40 hours of continuum imaging at 325 MHz with 16 overlapping pointings in snapshot mode (Proposal 20_006 - PI (Wadadekar))
- reaches nearly uniform rms of $\sim 150\mu$Jy over a ~ 12 deg^2 area. Deepest multi-pointing survey with GMRT in P-band.
- data processing was done by Sandeep Sirothia.
- **2 more fields still to be analysed (18 sq. deg in Lockman Hole and 9 sq. deg in ELAIS N1)**

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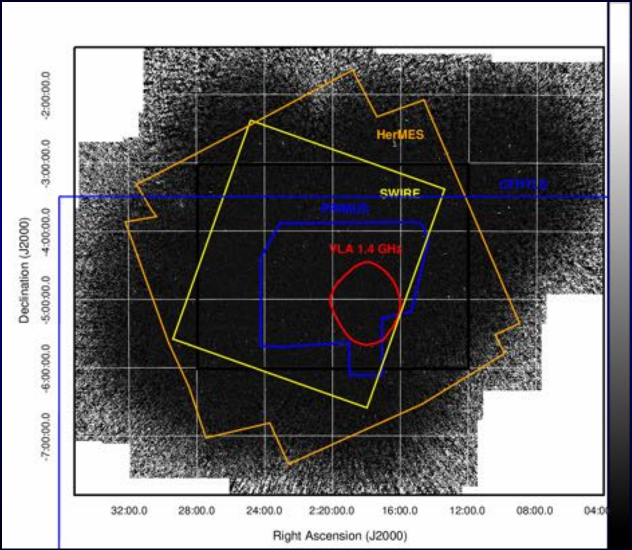
The coverage map



Basu et al. (2015)

Auxillary Data in the UDS field

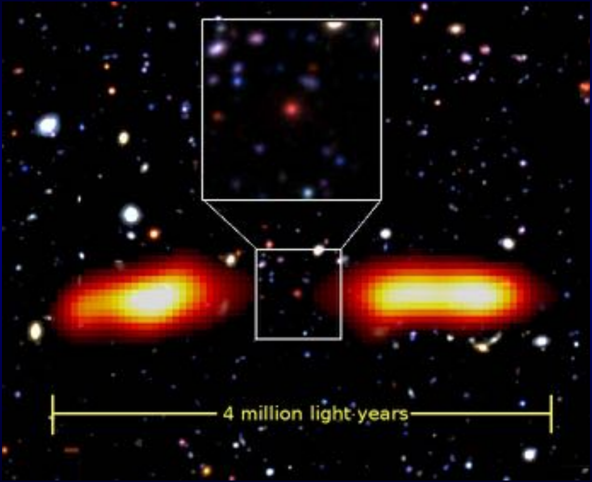
- X-ray data from XMM-Newton (EPIC PN and EPIC MOS, $\sim$ 30 ks)
- Subaru imaging in the optical (5 bands)
- Near-IR imaging with UKIDSS-UDS (0.8 deg^2, K=23, 5σ)
- mid-IR imaging from SpUDS (4 IRAC + 24μm MIPS bands)
- 1.4 GHz imaging from VLA (20 μJy beam^{-1} rms)
- 610 MHz imaging from GMRT (0.5 mJy beam^{-1})
- more than 10^5 spectra in the XMMLSS field from many campaigns - VVDS, VIPERS, PRIMUS etc.

A really special area of sky!

Other Projects completed and in progress

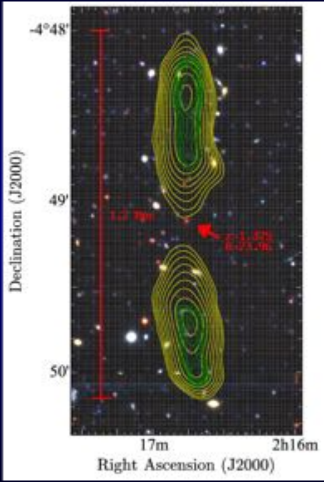
- identification and study of a sample of high redshift radio galaxies (Singh et al. 2014; Veeresh spoke about this at SPARCS 2015)
- the radio-FIR correlation in blue-cloud normal galaxies with $0 < z < 1.2$ (Basu et al. 2015; I spoke about this at SPARCS 2015)
- identification and study of infrared faint radio sources (Singh et al. 2017; Veeresh spoke about this at this meeting)

A giant radio galaxy



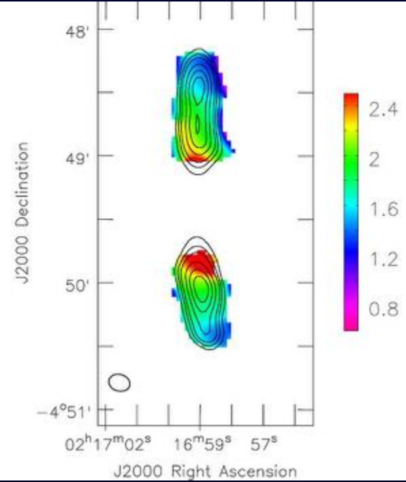
Tamhane et al (2016)

Giant radio galaxy at $z = 1.325$



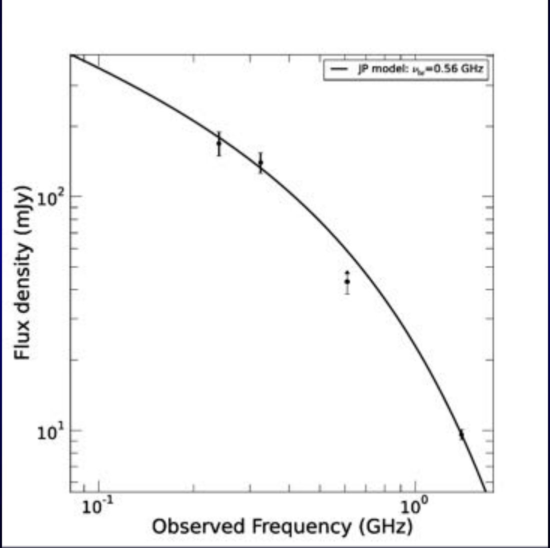
Tamhane et al. (2015)

Spectral Index map



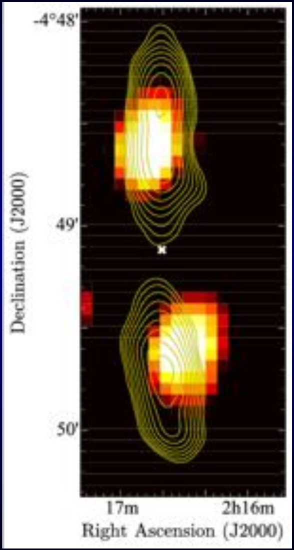
Tamhane et al. (2015)

Jaffe and Perola Model fit to radio observations



Tamhane et al. (2015), age of relic is $\sim 8 \times 10^6$ yr old

Diffuse X-ray emission from the lobes



Tamhane et al. (2015)

Summary

- The radio lobes are best detected at low radio frequencies observed using the GMRT at 0.325 GHz. The total angular extent at 0.325 GHz is $2'.4$, and corresponds to a projected linear size of $\sim$ 1.2 Mpc.
- The host galaxy is identified in deep optical (Subaru), near-IR (UKIDSS) and mid-IR (SpUDS). It is a red (R $-$ z$'$ = 2.0) galaxy that brightens in mid-IR bands.
- The relic nature of the radio galaxy is evident as the AGN core, jets and/or hot-spots remain undetected and the lobes exhibits a very steep radio spectral index, $\alpha_{0.325\ \mathrm{GHz}}^{1.4\ \mathrm{GHz}}$ $\sim$ 1.4 — 2.5. The 0.24—1.4 GHz radio spectrum of the lobe emission is convex and steepens sharply above 0.325 GHz due to radiative losses.

- The comparison of radio and X-ray spectral and morphological properties suggests that X-ray emission is likely due to inverse Comptonization of CMB photons by low energy electrons compared to electrons radiating at 0.325 — 1.4 GHz frequencies.
- Using the ICCMB X-ray emission, we estimate the lower limit for the total energy in relativistic electrons to be $\sim 4.0 \times 10^{59}$ erg s^{-1} (for $\gamma_e \sim 10^3$) $\Rightarrow$ significant feedback from GRG into the surrounding inter galactic medium.
- The magnetic field strength estimated using X-ray and radio emission and by energy equipartition yield consistent field strengths of $\sim 3.5\ \mu$G.

Finding radio galaxies in the distant Universe

- find double lobed structures in radio surveys (easy, few per sq deg. at 1 mJy level, 100 per sq. deg at 10 μJy)
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- check for ICCMB X-ray emission (sensitive large area X-ray survey needed here)

Strategy for the near future

Since optical, near-IR imaging and spectroscopy at the required depths is very expensive to obtain, the only workable strategy is to focus on deep fields where such data are already available or will be available soon.
This may mean that the record for the most distant radio galaxy may not be broken anytime soon.