PROBING NON-THERMAL EMISSION IN MERGING GALAXY CLUSTERS THROUGH SPECTRAL ANALYSIS

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Introduction

Merging in galaxy clusters drives hierarchical growth, releasing up to ergs over Gyr timescales. As this energy traverses the intracluster medium, it accelerates electrons to relativistic speeds, emitting synchrotron radiation within magnetic fields (Ricker & Sarazin, 2001). By deriving the spectral properties of these sources, we can link magnetic fields to hot gas, allowing us to map energy flow and explore plasma physics on a cosmic scale.

Aim

This study aims to combine multi-frequency data to map the spectral index of diffuse emission in SZ-selected merging clusters. By integrating MeerKAT L-band and uGMRT Band 3 data, we can derive the spectral properties of these sources to better understand their energy distribution.

Data

- uGMRT Band 4 data observation.
- Central frequency of 700 MHz
- Calibration performed using Source Peeling Atmospheric Modeling (SPAM)
- Semi automatic pipeline that performs 1gc - 3gc calibration.

- A sub-sample of the MERGHERS catalog of SZ-selected clusters.
- MeerKAT L-Band data observation.
- Central frequency of 1.28 GHz
- Calibration performed using the CARACAl pipeline for MeerKAT data.

Diffuse emission recovery

Recovering diffuse emission at low frequencies is difficult because RFI, low signal-to-noise ratios, and faint surface brightness often drown out the signal. The process is further complicated by nearby compact sources that can affect the target region. To recover the extent of the diffuse emission, we follow (Knowles et al. 2016).

1. **Full-Resolution** Imaging: Use WSClean on all visibilities to create a base image that captures both compact and extended sources.
2. **High-Resolution** (Long-Baseline) Imaging: Apply a UV restriction to isolate the longer baselines and generate a high-resolution image.
3. **Source Subtraction**: Perform a UV-subtraction of the compact sources from the dataset.
4. **Subtraction evaluation**: Image the resulting data using the original full-resolution parameters to evaluate how effectively the point sources were removed.
5. **Diffuse Emission Recovery**: Apply a UV restriction to select only the shorter baselines, allowing for the imaging of the emission's full spatial extent.

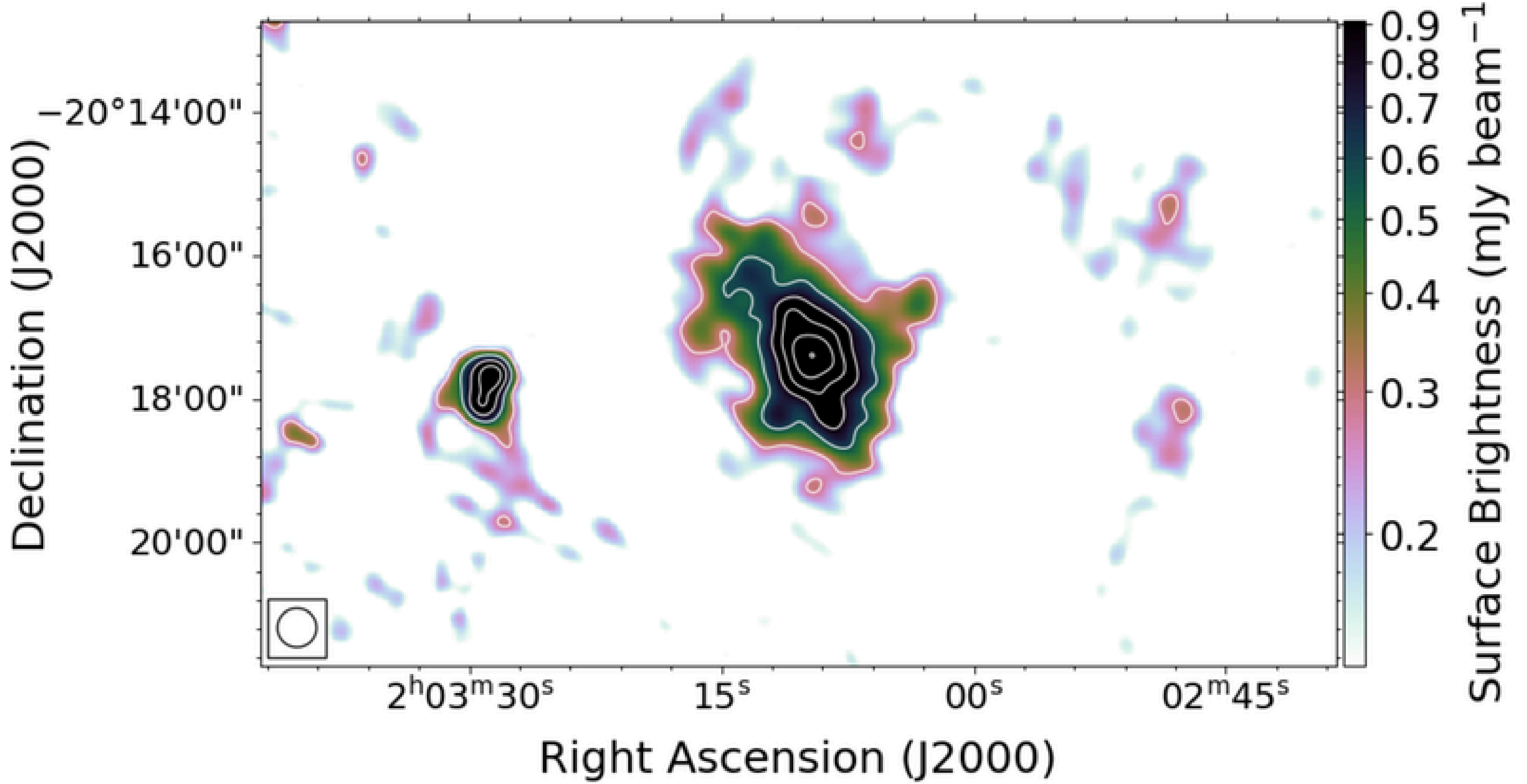

Figure 1: uGMRT 700 MHz point source subtracted, low resolution image of J0203.1-2017 cluster with a beam size of 33" and overlaid contours at [3,6,9,12, 15]* 90 μJy/beam^{-1}

Results

J0203.1-2017 is a galaxy cluster hosting a central halo, originally detected using MeerKAT L-band observations. At it's cluster redshift, the halo's integrated flux density is 11.4 mJy, with a largest angular size (LAS) of 238″, equivalent to a physical diameter of 1.35 Mpc.

Spectral analysis

Determining the in-band spectral index with uGMRT is challenging due to the low signal-to-noise ratio of the diffuse emission. To overcome this, we then calculate the spectral index by comparing flux densities across two frequency bands using the formula:

$$S_\nu \propto \nu^\alpha$$

This results in:

$$\alpha = \frac{\log(S_1/S_2)}{\log(\nu_1/\nu_2)}$$

And a spectral index of -1.82

Conclusion

- Restricting visibilities to shorter baselines was critical in capturing the full angular extent (238″) of the emission, which is otherwise lost in high resolution only images.
- Our target is a merging cluster, hosting a radio halo at its central region with an integrated flux density of 11.4 mJy.
- In-band spectral index for uGMRT measurements were limited by low S/N, instead, a spectral index was derived using two separate frequency bands resulting in α = -1.82 making it a steep -spectrum radio halo.

- Ricker, P. M., & Sarazin, C. L. 2001, ApJ, 561, 621
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- Offringa., et al. 2014, MNRAS, 444, 606