Project title: Characterising radio emission high-redshift ($z > 4$) AGN with MIGHTEE-MOONS
Academic level: Honour's
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Project Description

New populations of faint active galactic nuclei (AGN) at redshifts of $z > 4$ have been identified and studied in great detail over the last several years. The identification of these faint high-redshift AGN has largely been made possible by the James Webb Space Telescope (JWST) which has been a great for identifying galaxies in the early Universe. Statistical samples of near-infrared detected AGN have been identified through JWST/*NIRSpec* and *NIRCam* observations and using techniques such as SED-fitting, detailed studies of physical properties such as stellar mass, black-hole mass, bolometric luminosities, and Eddington ratios are possible (Harikane et al. 2023; Scholtz et al. 2024; Maiolino et al. 2024; Napolitano et al. 2025; Treiber et al. 2024). While the optical, and infrared components of these sources are well studied, an investigation of the radio emission from these infrared-faint AGN is still required for many of the known samples. Since radio emission originates from processes involving the acceleration of relativistic particles (synchrotron radiation) by radio jets and thermal free-free emission from HII regions, studying the radio component of AGN is key to determining whether an AGN is jetted (or jet dominant) or non-jetted (star-formation dominant).

Aims and Objectives

The main aim of the project is to identify and measure radio emission from faint and distant infrared-selected AGN. The starting point for a study of radio emission in infrared-faint AGN is the identification of radio components in these targets. This is possible when wide-field radio continuum survey detections are carefully cross-correlated with deep infrared and optical photometric and spectroscopic observations over the same field. On the extended Chandra Deep Field South (E-CDFS) field, we now have MIGHTEE (MeerKAT International Gigahertz Extragalactic Exploration; Jarvis et al. 2016; Heywood et al. 2022; Hale et al. 2025) and uGMRT (upgraded Giant Metrewave Radio Telescope) (Lal et al. 2025, in prep.) forming the superMIGHTEE observations which are available to depths of 2μJy in MIGHTEE L-band (1.3 GHz) at varying completeness levels across the uGMRT bands. The photometric redshift limit of the radio-detected sample on E-CDFS is $z \approx 6$. A survey of the GOODS-S (which overlaps sufficiently with E-CDFS) field with JWST was conducted for the JADES (JWST Advanced Deep Extragalactic Survey) large program of which the *NIRSpec* and *NIRCam* detections are publicly available. Additionally, MOONS will provide spectroscopy for targets in the E-CDFS (GOODS-S) field. By cross-correlating the radio continuum with the deep infrared and optical detections, an identification of radio components in high-z AGN is possible.
In this project, the student will be required to:

- Collate the E-CDFS multiwavelength catalogues from detections with MIGHTEE, uGMRT, *Subaru*/HSC, *VISTA*/VIDEO, and *JADES*.

- Apply an appropriate photometric redshift cut to filter high-z ($z > 4$) sources in their data and cross-correlate their multiwavelength detections.
- Refine their cross-correlations by applying deblending techniques and visual inspections.
- Compile a catalogue of faint AGN with deep radio, optical and infrared detections
- Select a small sample of faint AGN and determine the line-widths of emission lines detected. Show redshift distributions from spectroscopic (MOONS) and photometric (VIDEO) for comparison.
- Where [OIII] and/or Hα is present in *NIRSpec* spectra, calculate bolometric luminosities $L_{\rm bol}$ and black-holes masses using known empirical relations. Determine how $L_{\rm bol}$ scales with $L_{\rm radio}$ for faint AGN identified.

Requirements

The student should be able to write their code in Python/MATLAB for numerical and computational analysis. They should know or be willing to quickly adapt to writing up reports in LaTeX. They should have a basic knowledge of concepts that are integral to galaxy population studies.

References

• Hale, C. L., Heywood, I., Jarvis, M. J., et al. 2025, MNRAS, 536, 2187 • Harikane, Y., Zhang, Y., Nakajima, K., et al. 2023, ApJ, 959, 39 • Heywood, I., Jarvis, M. J., Hale, C. L., et al. 2022, MNRAS, 509, 2150 • Jarvis, M., Taylor, R., Agudo, I., et al. 2016, in MeerKAT Science: On the Pathway to the SKA, 6 • Maiolino, R., Scholtz, J., Witstok, J., et al. 2024, Nature, 627, 59 • Napolitano, L., Castellano, M., Pentericci, L., et al. 2025, A&A, 693, A50 • Scholtz, J., Witten, C., Laporte, N., et al. 2024, A&A, 687, A283 • Treiber, H., Greene, J., Weaver, J. R., et al. 2024, arXiv e-prints, arXiv:2409.12232