Uncovering the faintest peaked radio sources

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Level

MSc or PhD project (see below)

Description

At the heart of almost every galaxy lies a supermassive black hole (SMBH), but only a fraction of them are massive enough to cause the core of the galaxy to become active, which we know as Active Galactic Nuclei (AGN). Of these, only about ten per cent are radio loud, enabling them to be detected with radio telescopes. Amongst these, we observe many radio galaxies, which reaccelerate the material accreted onto the SMBH and eject it into highly collimated jets. Amongst the most luminous are the Fanaroff-Riley Type II (FR-II) galaxies, whose higher powered jets collide with the surrounding medium, causing a bright hotspot, which then flows backwards into a diffuse lobe of emission. These symmetric, edge-brightened FR-IIs differ to the less luminous and less powerful FR-Is, which have jet-brightened morphologies, consisting of an asymmetric jet and plume.

At their youngest stage, when radio galaxies have only recently become active, their jets have only just begun to launch, and can only be observed at very high spatial resolution, often with Very Long Baseline Interferometry (VLBI). These highly opaque jets, which dominate the radio emission over its core, cause a peaked radio spectrum, with a characteristic turnover frequency that correlates with its linear size. Those peaking around the GHz range are known as GHz-Peaked Spectrum (GPS) sources, while those that peak below this are known as Compact Steep Spectrum (CSS) or MHz-Peaked Spectrum (MPS). As they evolve, these are thought to turn into the large scale FR-I/II galaxies. However, the over-abundance of the most compact radio galaxies has led to alternative theories, including that they're frustrated galaxies within a dense medium, that they prematurely die, or that they're recurrent or restarted radio galaxies, each of which includes observed examples. While the evolutionary scenario is likely a function of the availability of material accreting onto the SMBH, and that each of these is likely at play within the entire population, the prevalence of each scenario is not well known.

Furthermore, at the lowest luminosities, these objects are largely unknown (Sadler, 2016), and it has also been proposed that the low-luminosity population includes the missing precursors to

FR-I galaxies (Tingay & Edwards, 2015; Kunert-Bajraszewska, 2016). However, very few examples are known, due to the lack of high-resolution observations within deep radio surveys that include low-frequency coverage. Since the number of peaked radio sources increases with decreasing peak frequency, selecting from low-frequency samples increases your sample size. Using deep, high-resolution observations that include low frequencies would enable the low-luminosity population to be uncovered, and increase the number of known peaked radio sources manyfold. This would also include compact MPS sources, which are known to include high-redshift radio galaxies (HzRGs; Coppejans 2015, 2016), whose low frequency turnover suggests they are large in size, but whose compact size suggests they are highly redshifted GPS sources. Selecting such sources from the upgraded Giant Metrewave Radio Telescope (uGMRT), with a peak at ~400 MHz, traces GPS sources peaking from 1.2-1.6 GHz between redshifts $2 < z < 3$.

In this project, the student will compile a sample of peaked radio sources from amongst the deepest radio fields observed with the uGMRT, and other radio telescopes such as the VLA, LOFAR and MeerKAT, by fitting radio spectra to the sources and selecting those with the characteristic GPS/CSS/MPS spectrum. Depending on the graduate student level (i.e. Masters or PhD), this will include data from either or both the ELAIS-N1 and SuperMIGHTEE fields. The student will characterise the properties of the sample, using the myriad of multi-wavelength data available within these fields, determining their redshifts, luminosities, star formation rates, and much more. The student will focus primarily on the low-luminosity sample, and how their properties compare to the well-known brighter samples, using evolutionary tracers such as their spectral ages, linear size and turnover frequency to understand whether their sample represents a continuous population of young and evolving radio galaxies, and the prevalence of other evolutionary scenarios within their sample. Depending on the graduate student level, this may lead to the submission of a proposal for VLBI, led by the student, to follow-up of a sub-sample of the most interesting objects, including candidate FR-I precursors, and HzRGs selected from MPS source. These VLBI observations would enable the linear size of the most compact objects to be determined, and may also enable monitoring of jet growth to determine dynamical ages.

Further Reading

http://cssgps2020.umk.pl
https://www.youtube.com/playlist?list=PLFIpuyhGfJZvqXB5-kvkdn1IF7tgxJhRD