On the selection and exploration of radio powerful Active Galactic Nuclei

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Models of Galaxy Formation

One of the fundamental questions in astronomy is how galaxies form and evolve through cosmic time. For the past few decades, various teams have been trying to answer this question through the construction of computational models for simulated galaxies.

A key factor, both in the models and in galaxy evolution, is the existence of an actively accreting supermassive black hole (SMBH), revealing itself as an active galactic nucleus (AGN). It is believed that most galaxies host an SMBH at their centres, and that both grow somehow in tandem. Therefore, studying the formation, growth, and feedback of SMBHs is fundamental in understanding the growth of galaxies throughout the Universe's history.

With the next generation of telescopes currently developing survey strategies with a strong emphasis in exploring the early Universe (e.g., Athena in the X-ray, and SKA in the radio regime), it is of the utmost importance to explore the predictions from state-of-the-art galaxy formation and evolution models, in particular at the Epoch of Reionization (EoR).

Recent works (Amarantidis et al., 2019) have showed that current models for SMBH and galaxy evolution (e.g., EAGLE, GALFORM, Millennium) compare well to the observational data, and are able to extrapolate into the high-redshift Universe ($z > 6$) and provide predictions to the number of AGN to be detected by Athena and SKA. These predictions are, however, still limited, as the models are still unable to reproduce the most extreme SMBH masses already known to exist at very high redshifts. It is thus necessary to improve upon the physical prescriptions in the models.

This project will look to implement improved recipes for radio emission, taking into account the most recent advances in our understanding of black hole accretion physics. One of the outputs of this activity will be the improvement of methodologies for the selection of very high redshift AGN, to be tested in current surveys and used to optimize SKA observing strategies for the detection of the earliest examples of AGN activity.

Known Powerful Radio AGN

Studying the radio properties of known powerful AGN will allow us to:
- build a picture of how such sources would appear if placed at different distances throughout the Universe's history;
- test and improve the model predictions, which will also highlight potential improvements of galaxy formation and evolution models;
- define a set of objective criteria that can be used to more effectively assemble AGN candidates from radio observations, out to very high redshifts.

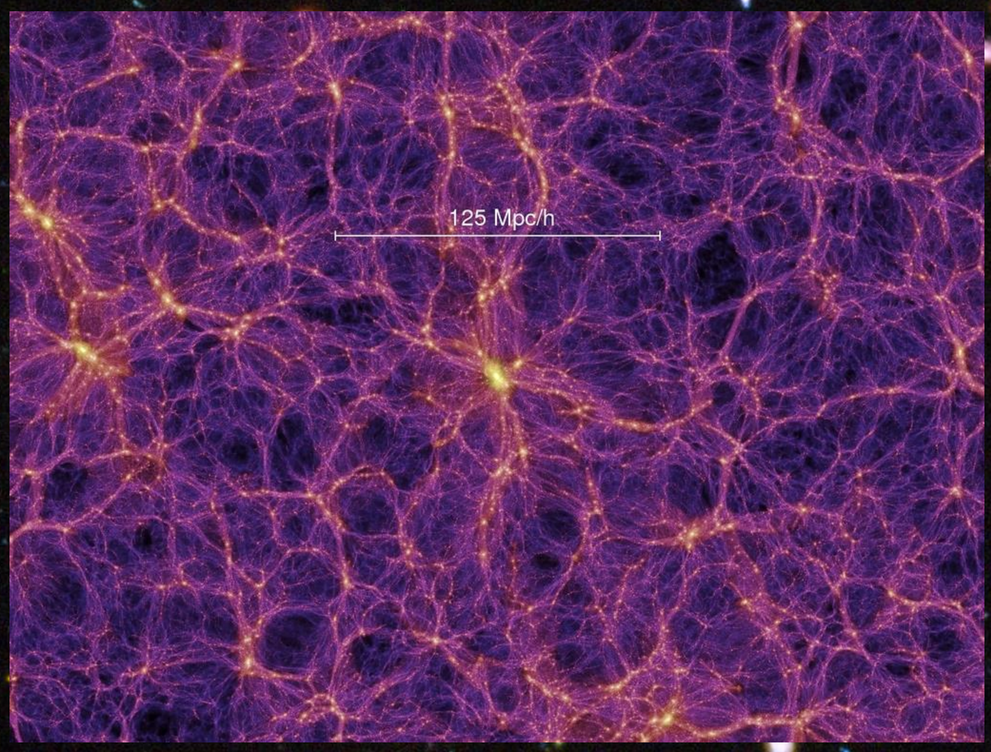

Figure 1: The Millennium Simulation Project

Variability of Radio AGN

In parallel, this project will implement a monitoring campaign of nearby AGN, using the Santa Maria radio telescope, part of the RAEGE network. This will complement the above approach, by setting the framework to further explore the physical mechanisms behind AGN radio emission, as revealed by AGN variability. Here, the project will aim to:
- perform a census of AGN monitoring efforts being made worldwide, leading to the identification of the best, more impactful, strategy for this program;
- identify the impact of variability studies in the AGN accretion physics and evaluate how this can lead to improved recipes for radio emission;
- initiate the monitoring program and analyse the first results.

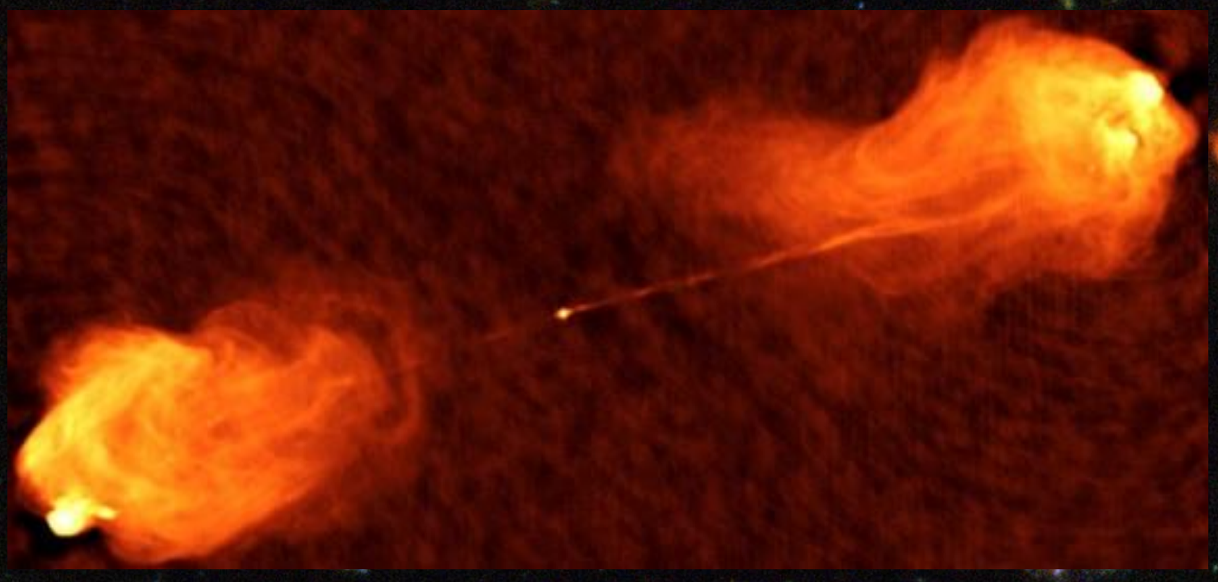

Figure 2: Cygnus A, a powerful radio galaxy ($z = 0.06$) (McKean et al., 2016)

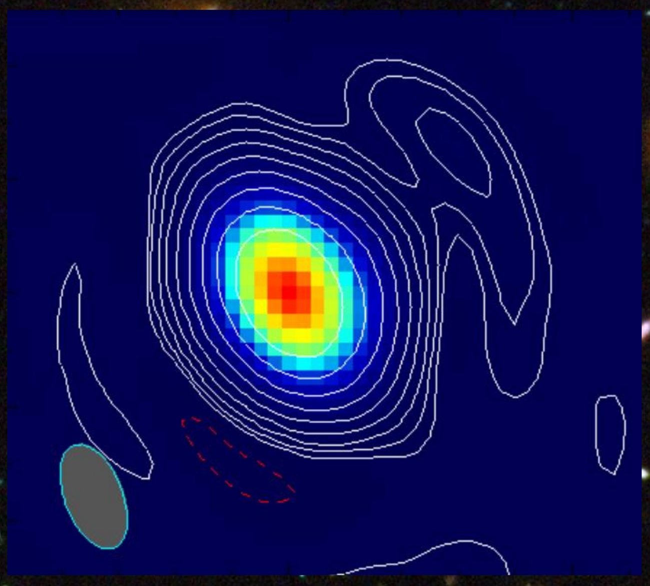

Figure 3: J2102+6015, radio-loud AGN ($z = 4.58$) (Frey et al., 2023)

Figure 4: The RAEGE-Az radio telescope

Improved Selection Criteria

With the implementation of the aforementioned approaches, we will:
- define new, more efficient criteria for the selection of AGN from radio observations, out to very high redshifts;
- identify and analyse robust candidates for high redshift radio AGN in very sensitive surveys currently being performed (e.g., SKA Pathfinder and MeerKAT);
- optimize the design of the upcoming generation of whole-sky radio surveys, currently being developed for the future Square Kilometre Array telescope.

Figure 5: The South African MeerKAT telescope

Figure 6: The upcoming Square Kilometre Array telescope

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