# INAF2

# INAF-IRA  Projects available

| Project code | Main supervisor | Title of the project |
|---|---|---|
| Bondi1 | Bondi | HPC enhanced LOFAR VLBI Observations of the Euclid Deep Field North |
| Prandoni1 | Prandoni | MeerKAT and Euclid Team up: Exploring the galaxy-halo connection at cosmic noon. |

**Title: HPC enhanced LOFAR VLBI Observations of the Euclid Deep Field North**

**Supervisors INAF-IRA: Dr. Marco Bondi, Dr. Claudio Gheller**

**Supervisor UniBO: Prof. Annalisa Bonafede**

**Summary:**

The PhD project addresses the effective exploitation of the next generation of LOFAR observations to produce large VLBI images at a resolution of about 0.3 arcsec at 144 MHz in the Euclid Deep Field North (EDFN). The EDFN is part of the LoTSS Deep Field project, and it was observed with LOFAR at 144 MHz for around 400 hours. An image obtained from the first 72 hours with an angular resolution of 6 arcsec centered on the EDFN has been recently published (Bondi et al 2024), and the analysis of the remaining observations will provide an image with a rms sensitivity of around 10 microJy/beam at 6 arcsec resolution.

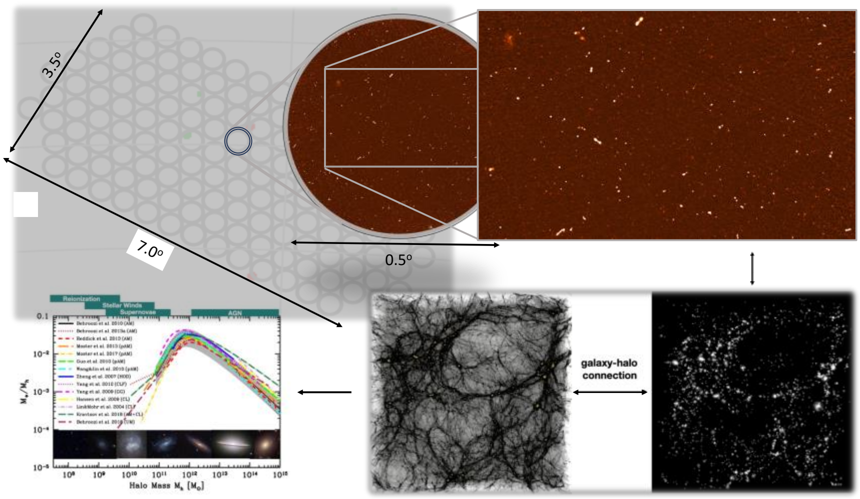
The scientific objective of the project is to obtain deep LOFAR images with sub-arcsecond angular resolutions (0.3-1.0 arcsec, the so-called widefield LOFAR-VLBI) using the data from the LOFAR International Stations on a subset of the available observations and reaching a sensitivity of around 20 microJy/beam at 144 MHz to fully exploit the synergy with the Euclid mission. The images and catalogs of radio sources that will be obtained will be cross-matched with the data from the Euclid mission and the optical/near-infrared ancillary observations. The final scientific goal is to investigate the linear radio size cosmic evolution of radio selected AGNs and star-forming galaxies, comparing them with the optical/near-infrared sizes that will be measured by the Euclid mission, both for the radio-selected sample and for a mass-selected control sample.

The VLBI data have large size and high complexity, requiring the adoption of highly computational demanding algorithms for their processing and the analysis, as well as the usage of High-Performance Computing (HPC) resources. In modern HPC systems, performance is achieved through many-core and accelerated computing (based, for instance, on GPUs), combined to the exploitation of sophisticated high-speed interconnects, for data exchange, and storage subsystems, for effective and efficient I/O. Data reduction and imaging software tools must be adapted, if not completely re-designed, to exploit such systems. The Ph.D. candidate will also contribute to the development of the RICK (Radio Imaging Code Kernels) library, focusing on the enabling and optimization on GPUs of selected algorithms, necessary to accelerate the generation of VLBI images and on the optimization of the I/O, exploiting advanced parallel or in-memory I/O solutions to minimize the impact of data read/write processes. During the PhD work, the candidate will have the opportunity to extensively work on the most advanced supercomputing systems available at INAF and at CINECA (the Italian National Supercomputing Centre).

**TITLE: MeerKAT and Euclid Team up: Exploring the galaxy-halo connection at cosmic noon**

**Supervisor:** I. Prandoni (INAF-IRA) - prandoni@ira.inaf.it
**Collaborators:** M. Brienza (INAF-IRA), F. Pozzi (UniBO), G. Rodighiero (UniPD), M. Talia (UniBO), C. Vignali (UniBO), on behalf of a larger international team

**Scientific Framework:** Galaxies are thought to emerge at the centre of dark matter (DM) halos (Silk & Mamon 2012) forming st ars in a way connected to the growth of such halos (so-called galaxy–halo connection; see figure, bottom right). On the micro scale, supermassive black holes (SMBH) accrete gas and grow tightly connected to properties of the host galaxies (Kormendy & Ho 2013). Feedback processes within galaxies may impact their surroundings, influencing future gas accretion and star formation (SF). Feedback from radio-loud AGN, in particular, is often invoked to explain the observed properties of massive galaxies in the local Universe (see figure, bottom left). Shedding light on the interplay between SMBHs, galaxies and DM halos at the peak epoch of cosmic assembly ($1<z<3$; the 'cosmic noon'), requires observations over large cosmological volumes to probe all environments and include the rarest galaxy/AGN populations, while also being gas/dust-insensitive to unveil the dominant contribution of obscured AGN and SF activity (Dunlop+2017; Vito+2018). Deep radio–continuum surveys provide a unique tool to reach an unbiased census of SFG and radio AGN (Prandoni & Seymour 2015). Euclid (www.euclid.org), on the other hand, will provide an unprecedented view of the large-scale structure up to cosmic noon and beyond, as well as a direct estimate of the DM halo mass and distribution around galaxies.




**Project description:** Euclid Deep Fields will represent the premiere extra-galactic deep fields for the next decade and beyond. We have started an observational campaign with MeerKAT (MK) to obtain deep radio coverage of the Euclid Deep Field South (EDFS). Joint MeerKAT/Euclid analysis of the EDFS will shed light on the complex interplay between SMBHs, galaxies and DM halos at cosmic noon, by enabling statistically robust, multi-variate studies of the various galaxy/AGN populations. As a first step we asked and obtained 118h to produce a 23 $deg^2$ uniform sensitivity (rms ~6 μJy/b) mosaic of the entire EDFS at 1.4 GHz (see figure, top). A first set of Euclid data will become available around late 2024. The PhD student will become part of the EDFS team and will exploit the MK and Euclid data to work on one or more of the following scientific topics, based on his/her skills and interests:

• Assessing the role of environment in driving jet-induced feedback - We will explore the debated issue of the role of environment in triggering radio AGN activity. Comparing radio AGN properties with the ones of the underlying galaxy population traced by Euclid, over a wide range of environments, will enable us to explore the connection between DM halo, galaxy mass, morphology and occurrence of radio-AGN activity, and how it has evolved since cosmic noon (Magliocchetti 2022).

• Cosmic SFR history from a radio perspective - We will infer the role of dust-enshrouded SF in galaxy assembly and evolution, by quantifying the (currently poorly constrained) contribution of dusty star-forming galaxies to the star formation rate (SFR) density and to the massive end of the stellar mass function at $z>2-3$ (Davidzon+17; Talia+21; Enia+22).

• Assessing the role of HI in galaxy evolution - We will include HI diagnostics in radio-based galaxy/evolution studies. The large area covered by the EDFS will enable direct studies of scaling relations between e.g. stellar mass, SFR and HI content in galaxies in different environments (filaments, clusters, voids, etc.; see Sinigaglia+24 for preliminary results).

On a longer term the student will have the possibility to expand his/her studies by exploiting both Euclid and MK deeper observations, that are planned for the coming years.