PhD project in ASTROPHYSICS

STILES: Strengthening the Italian Leadership in ELT and SKA – STILES

Missione 4, Componente 2, Investimento 3.1 Codice Progetto MUR: IR0000034 – CUP: C33C22000640006

PhD Thesis on "Science with ELT, SKA and their pathfinders"

One PhD fellowship at INAF-IRA will be funded. Potential candidates can choose one of the two following projects, based on his/her interests:

STILES-IRA1

Title: Unveiling the spectral properties of radio halos in the galaxy clusters of the LOFAR survey
PROPONENTS INAF-IRA: R.Cassano, A. Botteon, G. Brunetti, on behalf of the LOFAR Survey Key Project
Supervisor UniBO: A. Bonafede
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Abstract:
Radio halos in galaxy clusters are generated by relativistic electrons interacting with magnetic fields in the intra-cluster-medium (ICM). In the last decade we have demonstrated a connection between radio halos and the dynamics of galaxy clusters, suggesting that these radio sources form in the turbulent ICM when clusters merge with each other in the process of large scale structure formation. However this scenario has key predictions on the spectral properties of radio halos that have not been tested so far because of the lack of low frequency sensitive radio observations.
Thanks to the combination of the LOw-Frequency ARray (LOFAR; observing at 144 MHz) and the uGMRT (observing at 330 MHz), this thesis project will overcome this issue. We already have LOFAR data of a large sample of Planck clusters. We ask and obtained uGMRT data at higher frequency (330 MHz, more than 100 hrs already available) of clusters with radio halos detected with LOFAR. The aim of the Thesis is: 1) to analyse LOFAR and uGMRT data of these radio halos; 2) to derive the unbiased spectral properties of the population of radio halos in the LOFAR sample and 3) to test the most important prediction of current models for the formation of radio halos, i.e. that about half of these radio halos should have steep synchrotron spectra. Finally, these results will be interpreted in the framework of the latest theoretical models and expectations for future radio surveys with SKA1- LOW and SKA1-MID will be also derived.

STILES-IRA2

TITLE: MeerKAT and Euclid Team up: A unique window on galaxy/AGN co-evolution.
PROPONENTS: I. Prandoni (INAF-IRA), F. Pozzi (UniBO), G. Rodighiero (UniPD), M. Talia (UniBO), C. Vignali (UniBO), on behalf of a larger national/international team. The team includes members with coordination roles in either Euclid or MIGHTEE collaborations.
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ABSTRACT:
Radio-continuum (RC) observations are essential to measure dust-unbiased star formation rates (SFR) across cosmic time, and assess the role of jet-induced AGN feedback in galaxy evolution. Thanks to their sensitivity, new-generation RC surveys offer a uniquely valuable tool to provide an unbiased view of SF and nuclear activity up to early epochs (z>6), and investigate their interplay. The spatial resolution capabilities of radio interferometers allow us to beat natural confusion, and enable resolved studies of the high-z Universe. In addition, SKA precursors represent the first opportunity to push atomic hydrogen (HI) studies beyond the local Universe, and investigate the role of HI in galaxy formation and evolution, before the advent of the SKA. Euclid, while primarily designed for cosmology, will play a unique role in galaxy evolution studies, particularly in the assessment of the role of environment on galaxy assembly and evolution: Euclid spectroscopy will enable unprecedented reconstruction of the large scale structure (LSS) at cosmic noon, while Euclid near-HST imaging quality will provide a unique information on dark halo parameters through weak lensing.
This project builds on state-of-the-art radio surveys to provide new insights on galaxy/AGN co-evolution, based on synergic use of RC and HI data, both provided by MeerKAT. Specifically, we intend to exploit the deep radio coverage obtained as part of the MIGHTEE legacy survey for well-known fields (COSMOS, ECDFS, XMM-LSS and ELAIS-S1), combined with available extensive multi-band ancillary data, essential for prompt scientific exploitation of the radio data.
One of the longer-term goals of this project is to put our team in the position to fully exploit the scientific synergies between radio and Euclid Deep Fields (EDF). The EDFs will become the premier multi-degree-scale extra-galactic fields, and will remain so for at least the next decade. One of the MIGHTEE fields (ECDFS) overlaps with the EDF Fornax (EDFF). In addition, our team is planning to use MeerKAT and MeerKAT+ to observe the EDF South (EDFS).
This team include members of the Euclid collaboration, and Euclid data of the EDFS and the EDFF from the first two years of the mission should become available within the timescale of the proposed PhD (2023-2026). The PhD student will become part of the collaboration and will have the opportunity to work on one or more of the following scientific topics, based on his/her skills and interests:
Cosmic SFR history from a radio perspective - We will infer the role of dust enshrouded star formation in galaxy assembly and evolution, by quantifying the contribution of dark/dusty star-forming galaxies to the star formation rate density (SFRD) and to the massive end of the mass function at high redshifts (z>2-3; Davidzon+2017; Talia+21; Enia+22). Large radio samples are needed to put firm statistical constraints: over the MIGHTEE fields we expect of the order of ~1000 dark galaxies, with ~200 at z>4.5, that can be identified as dropouts thanks to the existing (and forthcoming through Euclid/LSST) deep opt/NIR multi-band imaging.

Assessing the role of HI in galaxy evolution - We will include HI diagnostics in radio-based galaxy/evolution studies. MIGHTEE deep fields enable direct studies of scaling relations between e.g. stellar mass, SFR and HI content in galaxies beyond the local

Universe (to z~0.5; see Sinigaglia+22 for preliminary results in the COSMOS field). Analysis of larger areas are essential to put firmer constraints on such relations, and explore their dependence on environment (filaments, clusters, voids, satellite/central galaxies) and/or other parameters.

The role of jet-induced feedback in galaxy evolution - We will explore the debated issue of the role of environment (mergers vs. secular processes) in driving the growth of galaxies and SMBH. Tracing radio AGN over a wide range of environments will enable us to explore the connection between large-scale structures (LSS), galaxy mass, morphology and occurrence of radio-AGN activity, and how it has evolved since cosmic noon (Magliocchetti+2018,2020). Particularly interesting is the possibility to study jet-induced feedback in proto-clusters, using high-z radio galaxies as signposts (e.g. Gilli+19). We also intend to exploit MIGHTEE full spectral resolution (5 km/s) datasets for HI absorption studies against radio AGN cores for investigations of AGN fueling/ feedback processes to z~0.5 (e.g. Maccagni+2016,2020,2021), as a function of environment, host galaxy and AGN properties.