Title of the Project: ***From Micro to Macro physics of FR0 radio galaxies***

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Scientific Background

A key goal of modern astrophysics is to understand the formation and evolution of galaxies through the Universe. Accreting black holes (BHs) at the hearts of massive galaxies, i.e. Active Galactic Nuclei (AGN), are widely believed to be able to impact galaxy evolution by facilitating a global shut down or regulation of star formation (SF) (e.g. Fabian 2012; Heckman & Best 2014). Galaxy formation models require the injection of energy or momentum into the surrounding gas (via jet-mode or quasar-mode feedback), in order to reproduce key observables of galaxy populations (e.g. BH-bulge scaling relationships, luminosity function; e.g., Silk & Rees 1998; Hopkins+2006). In the local Universe, at $z< 2$, after the quasar activity peak, adult early-type galaxies are kept mostly quiescent through the continuous ejection of energy by AGN which accrete at low rates. In fact, the vast majority of such AGN channels their accretion power into compact jets expanding in the galaxy-scale interstellar medium (ISM). Such a population of low-luminosity AGN has been recently revealed with characteristics distinct from classical radio-loud jetted AGN (RLAGN). About 80% of local RLAGN ($z<0.05$), in fact, emanate pc-scale jets, termed FR0s, differing from classical extended FRI/FRII radio galaxies (Baldi 2023). This discovery reshapes our understanding of radio-loud AGN phenomenology, previously focused on large-scale jets (>100 kpc). FR0s outnumber FRIs by a factor of five, indicating they are the most common local RLAGN and provide a snapshot of the ordinary accretion-ejection process in local AGN. FR0s are linked to long-lived AGN activity and are fundamental to galaxy-BH co-evolution. Recent simulations suggest FR0s impact their host galaxies through jet-ISM interactions, altering SF efficiency and regulating gas cooling over long timescales ($>10^7$ yr). Deciphering their nature and their characteristics allow to better understand how AGN at low regimes are able to affect the the galaxy evolution.

Project Goals

In order to explore the FR0 origin and their role in the galaxy evolution, the PhD project will focus on different aspects of the AGN-galaxy symbiotic relation by analyzing data in radio, X-ray, optical and millimeter bands for a sample of FR0s in comparison with large-scale radio galaxies. The PhD project will involve the statistical analysis of a large sample of compact RLAGN (104 compact sources, $z<0.05$, Baldi+2018) to investigate the connection among accretion, ejection, large-scale environment and feedback in understanding the role of the FR0 phase into the evolution of RL AGN and ellipticals in the local Universe:

1. **Accretion:** Using eROSITA X-ray data to study accretion properties of FR0s and compare jet kinetic and bolometric luminosity with other classes of RLAGN;
2. **Environment:** Assessing how large-scale environments (cluster richness, dark-matter halo mass) derived from eROSITA data, influence AGN activity. FR0s are expected to be found in lower-density environments than FRIs, which may extend their active phase.
3. **Ejection:** Investigating jet launching mechanisms via LOFAR, VLA, and VLBI radio data. The role of BH spin and jet collimation will be explored.
4. **Feedback:** Probing FR0 jet-ISM interactions using archival ALMA and optical NTT data to study molecular and ionized gas kinematics and assess AGN-driven turbulence in host galaxies.
5. **High-redshift**: selecting and studying FR0s at high redshifts to explore the evolution of the RL AGN population from the quasar activity peak $z\sim2$ to the local Universe.

The PhD student will also be involved in international working groups, and travels to visit collaborators and conferences in Italy/Europe are planned.