Shedding light on the accretion/ejection properties of Active Galactic Nuclei in the multi-messenger era

Tutors: Prof. C. Vignali (DIFA); Dr.ssa P. Grandi (INAF, OAS)

Abstract

Jetted Active Galactic Nuclei (JAGN), with a supermassive black hole (SMBH) at their center, can convert gravitational power into thermal radiation, jets, and winds. The large amount of energy released in the environment plays an important role in galaxy evolution and in heating the surrounding medium. Although many steps forward in the study of JAGN have been taken in the last years, thanks to X-ray/γ-ray observations and detailed cm/mm radio maps, many questions remain unanswered.
This project aims at exploring the properties of JAGN through an original approach based on electromagnetic and multi-messenger studies.

The candidate will take advantage of public data from several archives and, if necessary, will submit follow-up proposals to ground- and space-based observatories. He/she will have the possibility to collaborate with a large international team, bringing together experts on observations, simulations, modeling, and interpretation.

Project Description

Jetted AGN, i.e., blazars and Misaligned AGN (MAGN), convert gravitational energy into thermal radiation, jets, and winds. Being the most energetic phenomena among AGN, they are extraordinarily relevant to studying matter accretion and particle acceleration in the proximity of SMBHs.
MAGN are particularly interesting sources. Unlike blazars, they do not have the jet pointing directly to the observer and suffer less extreme relativistic and projection effects. This favorable geometry allows for a better characterization of the accretion regime and of the jet on different spatial scales; more in general, it provides a complete view of the impact of the accretion-ejection (i.e., feedback) process on the surrounding environment.

Despite the results achieved over the years, crucial questions are not fully understood. In particular:

1) The relation among the jet kinetic power, accretion gas mode, black hole spin, and magnetic field threading its horizon;

2) The accretion-jet-wind system evolution in time and the role played by AGN feedback on small scales (via jet/wind production) and large scales (via interaction with the interstellar and intergalactic medium);

3) The lepton and/or hadronic jet content. An answer to this question has become particularly urgent after the association of the blazar TXS0506+056 with extragalactic neutrinos detected by IceCube (Aartsen et al 2018).

This project aims at addressing the open issues reported above by adopting a multi-scale (from sub-parsec to kpc and beyond), multi-wavelength (from radio to TeV), and multimessenger (neutrino events) approach. It will exploit archival (VLA, VLBI, ALMA, MUSE,

Chandra, XMM-Newton, Swift, NuSTAR, Fermi, Magic, HESS, Ice-Cube, etc.) data, complemented by submission of follow-up proposals to ground- and space-based facilities.

Activity Plan

First-year: **Feedback via accretion/ejection**

- Investigation of the link among jet power, accretion mode, black hole spin, and magnetic field studying the radio, optical and X-ray properties of large samples of jetted sources with well-defined optical and radio classifications. Jetted AGN are classified in the radio band as FRI and FRII based on their radio morphology. In the optical band, they are divided into Low Excitation Radio Galaxies (LERG) and High Excitation Radio Galaxy (HERG), depending on the relative strength of the narrow emission lines.

- Study of the interaction between the AGN and the large-scale environment through high-resolution X-ray/optical/radio/(sub)-millimeter imaging and spectroscopy;

- Submission of at least one publication in a peer-reviewed journal, and presentation of the results at international conferences.

Second Year: **Jet composition, acceleration processes, and neutrino sources**

- Use of different techniques (based on cross-correlation between Fermi and radio catalogs) to reveal new Fermi misaligned AGN and enlarge the sample of γ-ray MAGN;

- Production of MAGN Spectral Energy Distributions (from radio to TeV) and application of the state-of-the-art leptonic/hadronic models to explore other possible neutrino sources in addition to blazars;

- Search for neutrino sources among (all) jetted AGN exploring temporal coincidence between electromagnetic flares and IceCube neutrino events;

- Submission of at least one publication in a peer-reviewed journal, and presentation of the results at international conferences.