Università di Genova

PHD IN PHYSICS AND NANOSCIENCE – XXXIX CYCLE – SECOND YEAR REPORT

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Research activity

In the second year of my PhD, I focused on the study of blazars, a class of jetted active galactic nuclei (AGN) with their jets oriented close to our line of sight (LoS). They are classified into two families: BL Lacertae objects (BL Lacs), less powerful blazars characterized by weak (or absent) emission lines, and flat-spectrum radio quasars (FSRQs), with luminous accretion disc and strong emission lines.

My research has expanded to investigate different accretion regimes in the context of blazars, in particular: (i) the low-power accretion regimes of BL Lacs, where the luminosity and morphology of the host galaxy provide crucial constraints; (ii) the transitional regime between radiatively inefficient accretion flows (RIAFs) and Shakura–Sunyaev standard discs, which is key to understanding the evolution of blazars; and (iii) the highly accreting super-massive black holes (SMBHs) in narrow-line Seyfert 1 galaxies (NLSy1s), which represent a case of super-Eddington accretion. This work aims to advance our understanding of blazars in a broader context.

1. BL Lacs host galaxy characterisation

Building on the activities initiated during my first year, I focus on developing a method to characterise the host galaxies of BL Lacs through optical-to-near infrared spectroscopy.

Host galaxies of AGN give crucial information on the interaction between the SMBHs and their surroundings, and on their common evolution. Their study in the case of BL Lacs is complicated by the non-thermal jet component, whose emission dominates over the whole electromagnetic spectrum, and the lack of broad emission lines, typically used to derive the black hole mass (that is instead estimated by analysing the luminosity of the host galaxy). BL Lac host galaxies have thus been sparsely studied, and their elliptical nature is currently a hypothesis supported by few observations.

For this reason, I developed a method based on optical-NIR spectroscopic analysis to systematically distinguish whether the host galaxy is elliptical or spiral. To implement and test the algorithm I created a sample of realistic synthetic spectra by combining different host galaxy templates and analytic BL Lac spectral energy distributions (SEDs), varying luminosity and redshift. Each spectrum was then analysed twice using the adapted version of QSFit that I developed last year: once with an elliptical template as host galaxy, once with a spiral one. QSFit provides a fit statistic for each analysis, I used it to understand capabilities and limitations in the host galaxy classification. Recently, I selected a sample of SDSS spectra on which to test the reliability of the method for real data.

2. Blazars intermediate accretion regime

I have been co-supervising a master's thesis project (by Gabriele Valente, UNIGE) about the characterization of blazars SMBHs accretion regimes, employing optical spectroscopy techniques. Because of their privileged orientation, blazars allow a direct view of the emission coming from their nuclear regions, in particular from the Broad Line Region (BLR). The broad emission lines are key traces of the accretion radiation. Due to their intense emission lines, FSRQs are thus expected to accrete through a radiatively efficient accretion disk, while BL Lacs are likely powered by a radiatively inefficient accretion flow. How the transition between the two regimes happens is an open question of AGN physics. Across the powerful AGN population, broad emission lines show a similar behaviour, suggesting a common accretion regime and common features. For less powerful sources, this may not be true, in fact the fraction of the accretion disk radiation that ionizes the BLR depends on the geometry of the disk and its radiation efficiency. We focused on exploring the accretion characteristics of potentially intermediate blazars, with spectroscopic features that lie between FSRQs and BL Lacs.

In addition, the few extragalactic neutrino tentative associations to blazars refer to these possibly intermediate objects. Therefore, Gabriele and I are using QSFit to measure the broad emission lines intensities, and thus the

BLR luminosity, in different samples: I focus on a set of optical spectra from sources associated with neutrino emission, while Gabriele analyses a sample of blazars from the ZBLLAC catalogue.

3. NLSy1: Super Eddington accretion regime

I started a new project on the Super-Eddington accretion regime in NLSy1 galaxies. NLSy1s are a class of AGN, whose peculiar multi wavelength features have always sparked debate on their nature and accretion regime. Low black hole masses, high luminosities, broad emission lines with FWHM<2000 km/s, combined with steep X-ray spectra and rapid variability, suggest accretion rates exceeding the Eddington limit.

In particular, I focus on gamma-ray NLSy1s, hosting jets most likely oriented along our LoS and thus providing a privileged point of view on their central engine. I'm studing their optical spectra with specific focus on emission line intensity and relative fluxes, finding significant deviations with respect to the average Type 1 AGN behaviour.

Whether these emission line ratios are due to outflows induced by super-critical regimes, or instead they trace an ionising spectrum not consistent with standard accretion, they are key to understand NLSy1 intrinsic nature. To understand which is the case, I am employing two independent approaches: direct modelling of the accretion emission through SEDs, and constraining the ionising potential via indirect tracers. In the first approach, I compare spectroscopic observations with analytical models to reconstruct the accretion disc profile across different accretion phases. In the second, I measure the broad emission lines luminosity and compare it with disc luminosity required to ionize the corresponding elements.

Attended courses:

1. *Neutrino Physics: theory and experiments*: PhD course by S. Zavatarelli and C. Biggio
2. *Astrophysical Experimental Methods*: PhD course by F. M. Zerbi
3. PhD school - *Scientific Communication in Astronomy*: October 12 – 17, 2025 at CEUB Bertinoro.

Publications:

1. G. Delucchi et al, "BL Lac host galaxies: how to systematically characterise them in optical-NIR spectroscopy", paper accepted by ApJ and under revision.

Conferences:

1. Talk at *XVth Italian meeting on Active Galactic Nuclei* – "The ever elusive blazar host galaxies: a guide to their characterization", 23 – 27 September 2024, Padova.
2. Talk at the conference *Jets on the rocks: on the trails of radio activity in and around galaxies* - "The ever elusive blazar host galaxies: a guide to their characterization", 14 – 18 July 2025, Sexten.
3. Abstract accepted for talk at the ESO conference *Highly Accreting Supermassive Black Holes Across all Cosmic Times* – "NLS1 accretion: using emission lines in new ways", 1 – 5 December 2025, Santiago (Chile).
4. Attendance at the seminar series "*Quando la violenza di genere non esiste*": 7/2/25, 7/3/25, 10/4/25, 4/6/25, Osservatorio astronomico di Brera.

Other activities:

1. Tutor for "Fisica Generale 1" class at the Physics bachelor (Freshmen Project), Sep. 2024 – May 2025
2. Involved in the organisation of the conference *VASTO Accretion Meeting* as part of the LOC and outreach activities, 30 June – 4 July 2025, Vasto.
3. Involved in the organisation of the *XLV National Congress of the Italian Society for the History of Physics and Astronomy* as part of the LOC, 9 – 12 September 2025, Genoa.