1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title:

Constraining blazar variability via spectral energy distribution modelling

1.1. Project goals

- To establish the physical mechanisms governing the variability of blazars, with focus on the high-energy regime.
- To perform comprehensive spectral energy modelling of a big sample of blazars.
- To understand the connections between spectral and variability properties in order to critically assess which physical scenarios are crucial in describing and explaining the observed patterns.

1.2. Outline

Blazars are active galactic nuclei that point their relativistic jets toward the observer. They are highly variable in all wavebands. This variability is phenomenologically described with various stochastic models. From a physical perspective, the emission stems from one- or multi-zone leptonic, hadronic, or lepto-hadronic interactions within the jet. Some blazars conform well to one model, whereas other better fit into other descriptions. Establishing the global picture of how physical mechanisms lead to the observed variability patterns has become a viable goal with the advent of space-borne, uninterrupted long-term monitoring of a sizeable blazar sample.

1.3. Work plan

The PhD candidate will start by performing statistical analyses of light curves of Fermi-LAT blazars, utilizing data in other wavebands whenever applicable and feasible. They will explore existing codes for performing physical modelling of spectral energy distributions (SEDs) within the leptonic, hadronic, and lepto-hadronic scenarios. One particular goal will be to characterise the differences in emission processes during flares and quiescent phases. Interpretation of the results regarding the population of blazars in light of prevailing theories (α-disk model, accretion disk and jet perturbations, relativistic trajectories of plasma around a Kerr black hole, etc.) will be the culmination of this PhD project.

1.4. Literature (*max. 10 listed, as a suggestion for a PhD candidate*)

- Böttcher, Reimer, Sweeney, Prakash, *ApJ*, **768**, p. 54 (2013)
- Lyubarskii, *MNRAS*, **292**, p. 679 (1997)
- Rana, Mangalam, *Galaxies*, **8**, p. 67 (2020)
- Tarnopolski, M., Żywucka, N., Marchenko, V., Pascual-Granado, J., *ApJS*, **250**:1 (2020)
- Thiersen, H., Zacharias, M., Böttcher, M., *ApJ*, **925**:177 (2022)
- Urry, Padovani, *PASP*, **107**, p. 803 (1995)
- Zacharias, Böttcher, Jankowsky, Lenain, Wagner, Wierzcholska, *ApJ*, **871**:19 (2019)
- Żywucka, N., Tarnopolski, M., Böttcher, M., Stawarz, Ł., Marchenko, V., *ApJ*, **888**:107 (2020)

1.5. Required initial knowledge and skills of the PhD candidate

- Knowledge about high-energy emission processes of blazars (synchrotron, synchrotron-self Compton, external Compton, etc.);
- experience with statistical analyses (time series, hypothesis testing, distributional and regression fitting, etc.);
- programming skills, especially in PYTHON, but flexible to utilize other languages (R, MATLAB, etc.) when needed;
- analytical thinking, theoretical inclinations, eagerness to learn.

1.6. Expected development of the PhD candidate's knowledge and skills

With the rising amount of data provided by space-borne instruments, and in the prospect of forthcoming exciting results provided by JWST, SKA, etc., there is a unique opportunity to examine the blazar population as a whole in order to constrain the universal physical mechanisms that govern their variability and evolution. The PhD candidate will

- deepen their knowledge about the physical processes governing the high-energy and multiwavelength emission of blazars,
- gain experience in modelling the emission within leptonic, hadronic, and mixed models,
- develop the methodology and framework to performing end-to-end analysis and inference of blazar variability.

The obtained knowledge and skill set will be a strong foundation for the candidate to investigate other accreting sources in their future scientific endeavours, e.g. other types of active galactic nuclei, ultraluminous X-ray sources, etc., hence will obtain expertise to do research on a variety of astronomical topics.