Characterizing multi-wavelength blazar variability

SUMMARY.
Blazars are a type of jetted active galactic nucleus (AGN) with a relativistic jet closely aligned with the observer's line of sight. Their emission, dominated by jet processes, spans the entire electromagnetic spectrum from radio to gamma rays and exhibits strong variability. Studying blazar variability provides insights into the number, size, and geometry of emitting regions, as well as the mechanisms driving particle acceleration and radiation in jets. With the increasing availability of long-term, multi-wavelength light curves from monitoring programs and open-access data repositories, a wealth of observational data is accessible to the scientific community. This project aims to: (i) develop an understanding of blazar physics, with a focus on variability; (ii) learn how to retrieve and analyze multi-wavelength observational data; and (iii) characterize variability patterns, such as periodicity, to investigate underlying physical processes.

OBJECTIVES

- **Knowledge:** Blazar physics and main radiation mechanisms (synchrotron and Inverse Compton); variability mechanisms (e.g. jet precession); multi-wavelength data availability and main characteristics.
- **Skills:** Retrieve and process multi-wavelength data; analyze time-series data for variability patterns; use Python-based tools for data analysis; interpret results and present scientific findings.

INSTITUTE

- University of Padova, Physics and Astronomy Department
- Institute URL
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THEORY

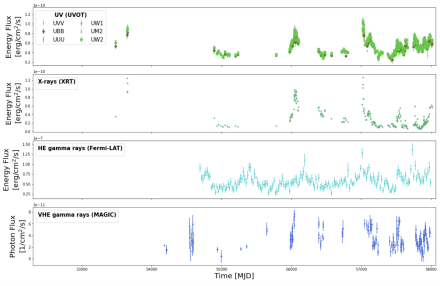
by Elisa Prandini

The theoretical component of this module covers the physics of blazars, focusing on their jet emission and variability across the electromagnetic spectrum. Blazar variability spans a wide range of timescales (1), from rapid sub-day flares to long-term multi-year trends, reflecting diverse physical processes at work, including shock acceleration, magnetic reconnection, and geometric effects (2). Recent studies have revealed periodicity in the gamma-ray emission of some blazars, suggesting potential underlying mechanisms such as binary supermassive black holes or jet precession (3).

APPLICATIONS

by Elisa Prandini

The practical work will focus on retrieving and analyzing multi-wavelength blazar data. The first activity will involve selecting the sample to analyze. Then, the student will access public astronomical databases to collect long-term light curves, primarily in the optical, X-ray, and gamma-ray bands. She/He will learn to use Python-based tools for time-series analysis, identifying variability patterns, including potential periodicity. Data visualization techniques will be applied to interpret trends. The work will be carried out in a friendly and collaborative environment within the High-Energy Astroparticle (HEAP) group of the Physics and Astronomy Department. The candidate will have the opportunity to actively participate in our weekly group meetings and other research activities.



Example of multi-waveleght lightcurve from a blazar, adapted from (2).

MAIN PROGRESSION STEPS

- `Tier 1`: course on experimental high-energy astrophysics and exercices
- `Tier 2`: project
- `Tier 3`: project

EVALUATION

- `Theory grade [20%]`
  - Oral exam (50%): theoretical questions, simple physics problems based on lectures
  - Presentation of an article (50%): critical spirit
- `Practice grade [50%]`
  - Exercices (30%): thought-process and results from a case-study
  - Project (70%): initiative, progress, analysis
- `Defense grade [40%]`
  - Oral and slides quality
  - Context
  - Project / Personal work
  - Answers to questions

BIBLIOGRAPHY & RESOURCES

(1) *Rieger F. M., 2019*
(2) *MAGIC Collaboration, et al., 2024*
(3) *Peñil P., et al., 2020*

CONTACT

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