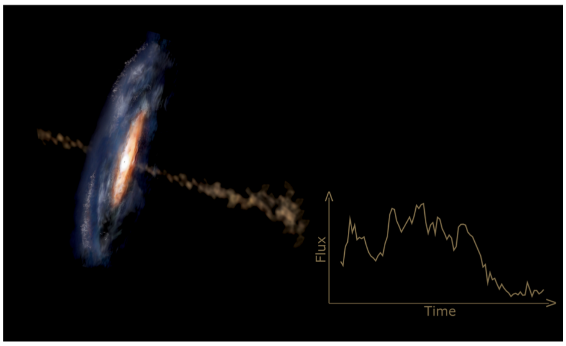
Particle re-acceleration in AGN jets



SUMMARY.
Active galactic nuclei (AGN) hosting relativistic jets are among the most powerful persistent sources of electromagnetic radiation in the universe. AGN jets are characterized by pronounced flux variability, often observed as flares. These are typically attributed to episodes of relativistic particle injection into a localized region of the jet, known as the radiation zone. Particles escaping this zone may experience further acceleration as they interact with, for example, turbulent plasma regions downstream. The goal of this METEOR project is twofold: (i) to introduce the student(s) to the non-thermal radiative processes governing jet emission, and (ii) to investigate the effects of particle re-acceleration on the escaping population and its observational signatures. (Image credit: NASA/H.E.S.S.)

OBJECTIVES

- *What will students learn? (**Knowledge:** non-thermal radiation processes, mathematical methods)*
- *What will students learn to do? (**Skills:** analytical, numerical solvers of PDEs)*

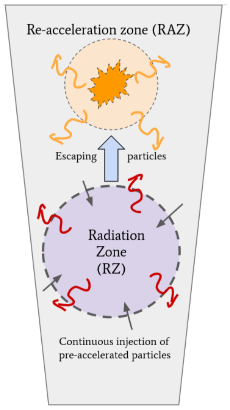
INSTITUTE

- Department of Physics, National and Kapodistrian University
- Institute URL
- University Campus GR-157 84 Zografou, Athens

THEORY

by Maria Petropoulou

The radiation zone (RZ) in AGN jets is a localized region where pre-accelerated particles are injected and produce the bulk of the observed non-thermal emission through synchrotron radiation and inverse Compton scattering (for a review, see [1]). Particles escaping from this region may undergo further re-acceleration in another zone farther downstream, as shown in the Figure. Depending on the properties of the re-acceleration zone (RAZ) and the distribution of the escaping particles, the resulting photon emission can differ significantly from that produced in the original radiation zone. This aspect has not yet been systematically explored, and the proposed project aims to fill this gap.



Model schematic.

APPLICATIONS

by Maria Petropoulou

The student will investigate how the re-acceleration of escaping particles from the RZ would impact their distribution function and the emitted radiation spectrum. The particle evolution in RAZ is described by the following PDE:

$$\frac{\partial N}{\partial t} + \frac{\partial}{\partial \gamma}\left(-a_B \gamma^2 N + a_{\rm acc}\gamma N\right) + \frac{N}{t_{\rm esc}} = Q_{\rm RZ} \qquad (1)$$

Starting from the Green's function of Eq. (1) [2] the student will derive the distribution function of particles in RAZ for different source functions ($Q_{\rm RZ}$) that represent the spectrum of escaping particles from the RZ (e.g., power law or broken power law). Depending on the student's interests, they will either focus on more analytical work or on developing their own PDE solver that can be added to the open-source numerical code `LeHaMoC`[1] [3].

MAIN PROGRESSION STEPS

- `Tier 1`: High-Energy Astrophysics course and exercises
- `Tier 2`: Project

EVALUATION

- `Theory grade [20%]`
  - Exercises (50%): theoretical questions, simple physics problems based on lectures
  - Presentation of an article (50%): critical thinking
- `Practice grade [40%]`
  - Project (100%): initiative, analysis, understanding, presentation skills
- `Defense grade [40%]`
  - Oral and slides quality
  - Context
  - Project / Personal work
  - Answers to questions

BIBLIOGRAPHY & RESOURCES

- [1] Cerruti, M., Galaxies 2020, 8, 72.
- [2] Mastichiadis A., Kirk J. G., 1995, A&A, 295, 613
- [3] Stathopoulos S. I. et al., A&A, 2024, 683, A225.

CONTACT

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[1] https://github.com/mariapetro/LeHaMoC