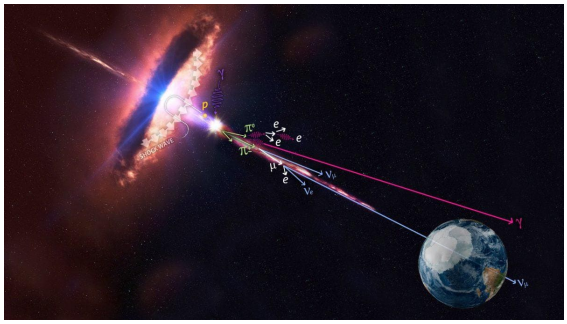
Modeling of blazars associated with neutrinos



SUMMARY.
Blazars are a subclass of active galaxies hosting jets of plasma moving at relativistic speeds that are viewed at small observer's angles ($\theta \lesssim 10$ deg). Blazars are the most powerful persistent sources of electromagnetic radiation. Their spectral energy distribution (SED) spans many orders of magnitude, from radio wavelengths to GeV and TeV gamma-ray energies. Recently, blazars have been associated with high-energy neutrinos detected by the IceCube Neutrino Telescope on the South Pole. These observations consist a breakthrough in the nascent field of multi-messenger astronomy. The goal of this METEOR project is to (i) introduce the student(s) to the physical processes relevant to neutrino production and to the various multi-messenger models of blazars, and (ii) to infer the physical conditions in blazars associated with neutrinos by applying numerical models to blazar SEDs. (Image credit: IceCube Collaboration/WIPAC)

OBJECTIVES

- *What will students learn? (**Knowledge:** non-thermal radiation processes, progresses in neutrino astronomy)*
- *What will students learn to do? (**Skills:** run numerical simulations, SED fitting)*

INSTITUTE

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THEORY

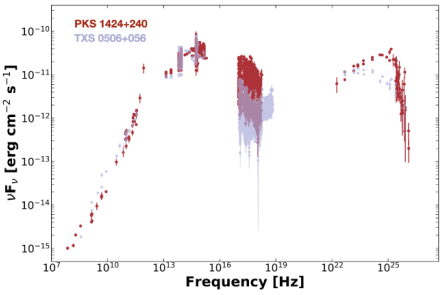
by Maria Petropoulou

Leptonic scenarios have been widely used to explain the high-energy emission of blazars by means of inverse Compton scattering of low-energy photons by relativistic electrons. Blazars are one of the few astrophysical environments that can confine the highest energy ($\sim 10^6 - 10^8$ TeV) protons and heavier ions that we detect on Earth as ultra-high-energy cosmic rays. This motivated the so-called *hadronic* scenarios that attribute the high-energy blazar emission to radiative processes involving relativistic protons, such as photomeson production and photopair production processes (for a review, see Ref. [1]). Neutrinos, unlike photons, can only be produced through interactions of relativistic protons with matter and radiation, making them the smoking gun of hadronic accelerators in the Universe!

APPLICATIONS

by Maria Petropoulou

The student will model one blazar that has been associated with high-energy neutrinos using the public numerical code `LeHaMoC`[1] (Ref. [3]). Using the results of the SED modeling he/she will infer the physical conditions in the jet and compare with those of blazar TXS 0506+056, the first non-stellar source to be associated with neutrinos. Relation of expected results to existing missions: IceCube and NASA satellites *Fermi, Swift*.



Spectral Energy Distribution (SED) of blazars associated with high-energy neutrinos. Adopted from [2].

MAIN PROGRESSION STEPS

- `Tier 1`: High-Energy Astrophysics course and exercises
- `Tier 2`: project
- `Tier 3`: 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

- [3] Cerruti, M., Galaxies 2020, 8, 72.
- [2] Padovani P., et al., MNRAS, 2022, 511, 4697.
- [3] Stathopoulos S. I. et al., A&A, 2024, 683, A225.

CONTACT

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