

PhD third year report

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1 Research activity

During my PhD I am working with INAF Brera-OA Merate and the MAGIC Collaboration on blazar physics.

Active Galactic Nuclei (AGN) outshine the host galaxy thanks to the bright emission of their central supermassive black holes. About 10% of the AGN are radio-loud, i.e. presents two-sided relativistic jets. *Blazars* are radio-loud AGN with a relativistic jet pointing towards the Earth. Blazar variability is generally extreme, moreover their spectral energy distribution (SED) ranges from radio to gamma rays and it is dominated by the non-thermal emission of the jet. For this reason the SED of blazars displays two broad humps, attributed respectively to synchrotron and inverse Compton mechanisms and amplified by the relativistic beaming.

Blazars can be classified using the position of the first peak, which ranges from the infrared to the x-ray band. Blazars whose first peak is in the x-ray band are called *Extreme Highly Peaked BL Lacs* (EHBL). There is a subclass of EHBL, called extreme TeV BL Lacs, which presents peculiar characteristics: i) the second SED peak beyond 1 TeV; ii) a hard sub-TeV intrinsic spectrum; iii) in most cases, the TeV emission is stable over years.

Recent 3D MHD simulations of recollimated jets show that if the magnetization is low, the downstream of the recollimation shock becomes turbulent. Therefore we elaborated a hybrid model where the non-thermal electrons are firstly accelerated through diffusive shock acceleration and then they are further energized by the turbulence through stochastic acceleration.

We calculated the electron and turbulence spectra solving a system of two non-linear Fokker-Planck equations and then we compute the emission spectrum using again the Synchrotron Self Compton model. The resulting SED is in good agreement with the data of 1ES0229+200 and the model parameters are in line with the theoretical expectations. The model was improved adding lower order effects (e.g. Inverse Compton cooling for electrons) and new numerical algorithms were tested (e.g. Implicit-Explicit Runge Kutta). Moreover we tested the model with additional extreme TeV BL Lac objects using Markov Chain Montecarlo sampling: the results confirm the theoretical predictions.

Currently we are working directly on MHD simulations of recollimated jets. Our goal is to calculate the emission directly from the simulations, using a technique called Lagrangian particle approach.

2 Attended courses and exams

- **Particle Physics and Multimessenger Astroparticles:** Exam attended and passed
- **Introduction to High Energy Astrophysics:** Exam attended and passed
- **Observational Astronomy:** Exam attended and passed
- **Artificial Intelligence for Astrophysical Problems:** Master course of Università degli studi dell'Insubria, exam attended and passed

- **International School of Physics “Enrico Fermi” - Course 208, Foundations of Cosmic Ray Astrophysics:** attended in place of a PhD course

3 Main publications

- [1] Fabrizio Tavecchio, Agnese Costa, and Alberto Sciaccaluga. **Extreme blazars: the result of unstable recollimated jets?** In: MNRAS (July 2022).
- [2] Alberto Sciaccaluga and Fabrizio Tavecchio. **Extreme TeV BL Lacs: a self-consistent stochastic acceleration model.** In: MNRAS (Oct. 2022).
- [3] Alberto Sciaccaluga and Fabrizio Tavecchio. **Extreme TeV BL Lacs: a self-consistent stochastic acceleration mode.** In: *Probing the Universe with Multimessenger Astronomy* (May 2023).
- [4] Alberto Sciaccaluga et al. **Stochastic acceleration in extreme TeV BL Lacs through MCMC.** In: A&A (July 2024).

4 Conference presentations

- Speaker at “Hands On the Extreme Universe with High Energy Gamma Ray data”, **Extreme TeV blazars: a phenomenological model**, Sesto Pusteria (Italy), 18-22 July 2022
- Speaker at “PASTO - Particle Acceleration in Astrophysical Object”, **Extreme TeV blazars: a stochastic acceleration model**, Roma (Italy), 5-7 September 2022
- Speaker at “PUMA - Probing the Universe with Multimessenger Astrophysics”, **Extreme TeV blazars: a stochastic model**, Sestri Levante (Italy), 26-30 September 2022
- Poster at “HEPRO - High Energy Phenomena in Relativistic Outflows”, **Modelling and fitting of Extreme TeV BL Lacs**, Paris (France), 23-26 October 2023
- Speaker at “European Astronomical Society (EAS) Annual Meeting”, **Understanding HSP BL Lacs polarization through MHD-PIC simulations**, Padova (Italy), 1-5 July 2024
- Speaker at “Committee on Space Research (COSPAR) Scientific Assembly”, **Understanding HSP BL Lacs polarization through MHD-PIC simulations**, Busan (South Korea), 13-21 July 2024
- Speaker at “8th Heidelberg International Symposium on High-Energy Gamma-Ray Astronomy”, **Stochastic acceleration in Extreme TeV BL Lacs**, Milano (Italy), 2-6 September 2024

5 PhD Schools

- **International School of Physics “Enrico Fermi” - Course 208, Foundations of Cosmic Ray Astrophysics**, Varenna (Italy), 23-29 June 2022
- **The Transient Universe 2023**, Cargèse (France), 30 May-9 June 2023