

PhD first year report

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1 Research activity

During my first PhD year I worked with INAF Brera-OA Merate and the MAGIC Collaboration. *Extreme TeV Bl Lacs* are the main topic of my research activity. In most cases the emission of a galaxy is dominated by the emission of its stars. *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 (for the latter one there is no general consensus yet) 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.

The standard phenomenological models based on a single shock acceleration are not able to reproduce these features, therefore many alternative models have been proposed, for example based on multiple shocks. The phenomenological models that leaves the acceleration mechanism unspecified show that extreme TeV Bl Lacs present an extremely low magnetization. Recent 3D MHD simulations show that if the magnetization is low, the turbulence prevails after the first shock, preventing the formation of multiple shocks. Therefore we decided to elaborate 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.

A first attempt was made supposing a constant turbulence spectrum and using the Synchrotron Self Compton (SSC) leptonic model, in which the photons emitted by synchrotron emission by the non-thermal electrons are then upscattered by the same electrons. Since the resulting SED was harder than the data of the prototypical extreme TeV Bl Lac object 1ES0229+200 and the magnetic energy density was much more lower than the electrons energy density, we deduce that the damping of the turbulence due to the non-thermal electrons was not negligible. Therefore we elaborated a more refined model which includes the interaction between electrons and turbulence. We calculated the electron and turbulence spectra solving a system of two non-linear Fokker-Planck equations and then we compute the emission spec-

trum using again the SSC 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 next steps of my research activity are the improvement of the model, e.g. the implementation of more precise algorithm, and the comparison of the model with the data of other extreme TeV BL Lacs, which will also require the participation to the observational and the analysis activities of the MAGIC Collaboration.

2 Attended courses and exams

- **Particle Physics and Multimessenger Astroparticles:** Exam not given yet
- **Introduction to High Energy Astrophysics:** Exam not given yet
- **Observational Astronomy:** Exam not given yet
- **International School of Physics “Enrico Fermi” - Course 208, Foundations of Cosmic Ray Astrophysics:** attended in place of a PhD course, I have not been evaluated yet

3 Publications

- [1] Fabrizio Tavecchio, Agnese Costa, and Alberto Sciacaluga. **Extreme blazars: the result of unstable recollimated jets?** In: MNRAS (July 2022).
- [2] Alberto Sciacaluga and Fabrizio Tavecchio. **Extreme TeV BL Lacs: a self-consistent stochastic acceleration model.** In: *arXiv e-prints* (Aug. 2022).

4 Conference presentations

- Speaker at “Hands On the Extreme Universe with High Energy Gamma Ray data”, **Extreme TeV blazars: a phenomenological model**, 18-22 July 2022
- Speaker at “PASTO - Particle Acceleration in Astrophysical Object”, **Extreme TeV blazars: a stochastic acceleration model**, 5-7 September 2022