Relativistic jets in Blazars and Gamma-Ray Bursts

Both *Blazars* and *Gamma-Ray Bursts* are astrophysical sources related to the formation of relativistic jets expelled from a central compact object. While Blazars are *persistent* sources, continuously powered by accretion on a supermassive black hole, Gamma-Ray Bursts are *transient* sources, where the outflow is ejected for a limited amount of time (seconds) and is powered by accretion on a stellar mass black hole.

Blazars

About 10% of Active Galactic nuclei, beside accreting matter, have two anti-parallel jets in which the matter flows relativistically, reaching bulk Lorentz factors $\Gamma \sim 10$-15. When the jet points in our direction the source is called *blazar*. The fast motion makes the emission beamed, in such a way that the flux we receive from blazars is strongly enhanced, and for this reason well visible at high redshifts: blazars are therefore excellent probes of the far Universe and, possibly, of fundamental processes beyond the standard model.

The emission produced by blazars ranges from the radio to the high-energy γ-rays, reaching the TeV band. The mechanisms through which radiating particles acquire their extreme energy are still unclear. Hydrodynamical/MHD instabilities or shocks, leading to dissipation of the jet power, likely play an important role.

Our group investigates these topics by a mix of observations (especially at high and very-high energy and, more recently, in the new X-ray polarimetric window), theory and numerical computations.

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Gamma-Ray Bursts

At the end of their life, the heaviest stars may eject an outflow travelling at a huge speed (Γ~100-1000) in the form of two opposite, highly-collimated jets. Similarly, ultra-relativistic jets can be launched also following the merger of compact object binaries (hosting at least a neutron star). In the latter case, gravitational waves are emitted as well.

In the first phase of their propagation, the jets undergo processes that lead to the production of impulsive episodes of emission of gamma-ray radiation (hence the name gamma-ray bursts, GRBs), lasting typically a few tens of seconds (or less than two seconds in case of mergers of compact objects). Once they reach larger distances, a second phase of the emission begins, with the production of slowly fading radiation in radio, optical X-ray and gamma-rays, up to TeV energies.

Even though the general scenario for the interpretation of GRBs is robust, there are controversial issues that are still very puzzling. The most serious one concerns the origin of the gamma-ray radiation we see in the first 10-50 seconds (the so-called “prompt” emission). Is it produced by energetic electrons? How is the jet energy dissipated and transferred to those electrons? Do the accelerated electrons produce the observed photons via synchrotron mechanism? This ignorance severely limits our ability to infer the physics of the source from what we observe (how electrons are accelerated, at what distances from the central engine, what is the magnetic field strength). The recent discovery that GRB radiates also in the TeV domain are helping us to constrain different models.

The properties of the jet of GRBs are still unknown. Recent discoveries support the theoretical expectation that material along the jet axis carries more energy and is faster with respect to that moving at larger angular distances with respect to the jet axis. The jet structure should leave signatures in the emission components, which we aim to search and study. Key questions are: what is the structure of jets? Is it universal across GRB populations? What is the origin of the structure?

The study of GRBs as high energy transients and multimessenger sources benefits from the continuous advancement of the instruments dedicated to transient and multi-messenger astronomy The observations and modelling of these sources provide the tools to develop the science cases and improve the instrumental design of planned future space and ground based facilities.

Our team investigates the jet dynamics and the origin of the radiated emission by means of population studies, radiation models and numerical studies, complemented by data analysis from the major facilities detecting GRBs.

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