

“Particle Acceleration by Magnetic Reconnection in Relativistic Jets: Testing the Extreme Energies with Relativistic MHD simulations and Test Particles”

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Relativistic Jets from active galaxies are among the most extreme particle accelerators and very high energy (VHE) emitters. These jets are born magnetically dominated and as such can accelerate particles efficiently by magnetic reconnection in their inner regions close to the source. This process has helped to explain, for instance, the origin of VHE flares in blazar jets and GRBs. In this seminar, I will discuss this mechanism and show, by means of three-dimensional relativistic magnetohydrodynamical (3D-RMHD) simulations, that low energy test protons can be accelerated predominantly by Fermi process in turbulent reconnection up to ultra-high energies (UHEs) in these jets. In our simulated models, turbulent fast magnetic reconnection is naturally driven by current-driven-kink instability (CDKI) in the helical magnetic fields of the jet. Average reconnection rates of the order of $0.05 v_A$ are obtained. Test protons injected in the nearly stationary turbulent jet, experience an exponential acceleration in time, predominantly of its parallel momentum component to the local field, up to a maximum energy. For a jet with initial magnetic field $B \sim 0.1$ G ($B \sim 10$ G), this energy is $E_p \sim 10^7 m_p c^2 \simeq 10^{16}$ eV ($\sim 10^{18}$ eV). The giro-radius of the particles attaining this energy corresponds to the size of the acceleration region, given by the diameter of the perturbed jet. This regime of particle acceleration lasts for several hundred hours until the saturation energy. The simulations reveal a clear association of the accelerated particles with the regions of fast reconnection and largest current density, indicating its dominant role on the acceleration process. Beyond the saturation energy, the particles suffer further acceleration at a slower rate, due to drift in the non-reconnected fields (mostly of the perpendicular component of their momentum) up to energies 100 times larger. This contributes to extend the CR particle spectrum to UHEs up to 10^{20} eV, directly demonstrating that the magnetically dominated regions of relativistic jets can produce UHECRs by turbulence-driven magnetic reconnection acceleration. The acceleration time due to magnetic reconnection has a weak dependence on the particles energy, $t_{\text{acc}} \propto E^{0.1}$ (characteristic of nearly exponential acceleration in time). The energy spectrum of the accelerated particles develops a power-law tail with spectral index $p \sim -1.2$, but this hardness of the spectrum should decrease if particle losses and feedback into the background plasma were included. Finally, I will also show very recent results of PIC-MHD simulations which are comparable to the ones described above. Our results may explain observed variable emission at very high energies as well as the neutrino emission in blazar jets.