

## 3D PIC Simulations for Relativistic Jets with a Toroidal Magnetic Field

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The properties of relativistic jets, their interaction with the ambient environment, and particle acceleration due to kinetic instabilities are studied self-consistently with Particle-in-Cell simulations. An important key issue is how a toroidal magnetic field affects the evolution of a pair and an electron - proton jet, how kinetic instabilities such as the Weibel instability (WI), the mushroom instability (MI) and the kinetic Kelvin-Helmholtz instability (kKHI) are excited, and how such instabilities contribute to particle acceleration. In this work we use a new jet injection scheme where an electric current is self-consistently generated at the jet orifice by the jet particles. We perform four different simulation runs. We inject pair and electron - proton unmagnetized and magnetized jets into unmagnetized ambient plasmas with same species, the latter with a toroidal magnetic field (with a top-hat jet density profile), and for a sufficiently long time in order to examine the non-linear effects of the jet evolution. We show that WI, MI and kKHI excited at the linear stage, generate a quasi-steady x-component of electric field which accelerates and decelerates electrons. Despite the weakness of the initial magnetic field, we observe significant differences in the structure of the strong electromagnetic fields that are driven by the kinetic instabilities. We find that the two different jet compositions (pair and electron - proton) showcase different instability modes respectively. Moreover, the magnetic field in the non-linear stage generated by different instabilities becomes dissipated and re-organized into a new topology. The 3 dimensional magnetic field topology indicates possible reconnection sites as the particles are significantly accelerated in the non-linear stage by the dissipation of the magnetic field or probably reconnection.

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