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Structure of a collisionless pair jet in a magnetized electron–proton plasma: flow-aligned magnetic field

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Accreting black holes can eject jets that are composed of electrons, positrons and ions. Electromagnetic emissions by such jets reveal the presence of strong coherent magnetic fields, of hot plasma and relativistic leptons. Several mechanisms contribute to the magnetic field of the jet: magnetic field transport by the jet, the amplification of the ambient magnetic field by shocks and collisionless plasma instabilities. The latter two have been studied with particle-in-cell simulations. Collisionless shocks, which develop between plasma clouds with the same particle composition that collide at a relativistic speed, are mediated by magnetic fields that are driven by the filamentation (beam-Weibel) instability.

We present results from a particle-in-cell simulation that models the interaction between a spatially localized pair cloud and a magnetized electron-proton plasma. The pair cloud has the temperature 400 keV and mean speed 0.9c. Its mean velocity vector is aligned with the background magnetic field that permeates the electron-proton plasma. A jet forms in time. Its outer cocoon consists of jet-accelerated ambient plasma and is separated by an electromagnetic piston from the jet material. This piston is the counterpart of a hydrodynamic contact discontinuity in collisionless plasma. Its coherent magnetic field enwraps the pair jet and its thickness is comparable to the thermal gyroradius of the relativistic jet particles. This piston constitutes a novel plasma structure that could contribute to the radio emissions of jets. A beam of electrons and positrons moves along

the jet spine at its initial speed. Its electrons are slowed down and some positrons are accelerated as they cross the jet's head. The latter escape upstream along the magnetic field, which yields an excess of MeV positrons ahead of the jet. Some of the protons, which were located behind the electromagnetic piston at the time it formed, are accelerated to MeV energies.

Primary authors: DIECKMANN, Mark Eric (Linkoping University); Dr FOLINI, Doris (CRAL, Ecole Nationale Superieure, Lyon); Prof. HOTZ, Ingrid (Linkoping University); Dr NORDMAN, Aida (Linkoping University); Dr DELL'ACQUA, Pierangelo (Linkoping University); Prof. YNNERMAN, Anders (Linkoping University); Prof. WALDER, Rolf (CRAL, Ecole Nationale Superieure, Lyon)

Presenter: DIECKMANN, Mark Eric (Linkoping University)

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