Numerical simulations modelling the interaction of ultra-relativistic neutral fireball beams with magnetised plasmas

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Energetic astrophysical objects, such as gamma-ray bursts, neutron stars and active galactic nuclei are powered by relativistic electron-positron jets. These jets interact with the surrounding medium and may cause a variety of phenomena including magnetic field amplification, particle acceleration and radiation emission [1].

In this work, we explore the microphysics of the interaction between a neutral ultra-relativistic electron-positron beam and a magnetised plasma. By using Particle-In-Cell simulations [2], we investigate how a pre-existing magnetic field in the direction parallel to the beam propagation modifies the growth and saturation of kinetic instabilities. While in the absence of a magnetic field, the dominating instability is the current filamentation instability (CFI) which causes modes perpendicular to the direction of the beam [3], by increasing the strength of the magnetic field, we observe the transition towards progressively more oblique modes. The growth rate of these modes is smaller than the growth rate of the CFI. In all cases, these instabilities generate a magnetic field in the direction perpendicular to both the beam velocity and the wavenumber. Our simulations indicate that the instability-driven field reaches higher values at saturation in the presence of higher degrees of magnetisation. Finally, with the aim of probing the physics underpinning the interaction in the laboratory, we examine the impact of beam length and density on the development of the oblique instability.

References

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