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Simulating Astrophysical Flows in Laboratory Experiments[1]

PAUL BELLAN, Caltech

A laboratory plasma configuration which simulates astrophysical jets has been developed. The experimental geometry is arranged so that the jet is unaffected by walls and the experimental time scale is such that ideal magnetohydrodynamics is reasonably approximated. The jet evolves through a reproducible sequence consisting of formation, collimation, kink instability, and at sufficiently drive high currents, detachment. Diagnostics include high speed imaging, magnetic probing, spectroscopy, and interferometry. The collimated nature of the jet and of a related experiment simulating solar corona loops suggest that collimation is a ubiquitous feature of flux tubes having axial electric currents. This observation has motivated a model for the collimation mechanism. According to this model, pile-up of convected, frozen-in toroidal magnetic flux near the jet tip increases the toroidal magnetic flux density near the tip. This flux accumulation corresponds to an increase of the toroidal field near the tip so that the pinch force is increased, thereby collimating the jet. The model shows that plasma-filled coronal loops can be considered as resulting from two counter-propagating jets colliding head-on. Color-coded images of two colliding jets confirm this. The experiments have also motivated development of a dusty-plasma dynamo mechanism suitable for driving an actual astrophysical jet. This mechanism involves dust grains having a charge to mass ratio so small that their cyclotron frequency becomes comparable to the Kepler frequency. The resulting collisionless orbits spiral across magnetic field lines towards the central object and the accumulation of charged dust grains creates a radial electromotive force appropriate for driving an astrophysical jet. The spiral orbits are not described by magnetohydrodynamics but instead result from detailed considerations of canonical angular momentum in an axisymmetric Hamiltonian system.

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