

Laboratory simulations of astrophysical jets and solar coronal loops: new results

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Experiments at Caltech produce plasmas with complex, dynamically changing morphology determined by self-organization. A surprising result has been that self-collimating MHD-driven plasma jets are ubiquitous and play a fundamental role in the self-organization. The jets can be considered as lab-scale simulations of astrophysical jets and are also intimately related to solar coronal loops. The jets are driven by the axial component of the $\mathbf{J} \times \mathbf{B}$ force in combination with the axial pressure gradient resulting from the non-uniform pinch force associated with the flared poloidal current density. Behavior is consistent with a model showing that collimation results from axial non-uniformity of the jet velocity: flow stagnation in the jet frame compresses frozen-in toroidal magnetic flux, squeezes together toroidal magnetic field lines, thereby amplifying the embedded toroidal magnetic field, enhancing the pinch force, and hence causing collimation of the jet.

Recent research highlights include:

1. Direct time-of-flight laser interferometer measurements [1] showing that the jet velocity is proportional to the azimuthal magnetic field and inversely proportional to the square root of the mass density.
2. Direct measurements [2] of ‘color-coded’ plasmas in a simulated solar coronal loop experiment showing that the arched magnetic flux tube contains two oppositely directed MHD-driven jets that collide head-on.
3. A Hamiltonian-based model [3] showing how astrophysical jets could be driven by the electromotive force provided by a dusty-plasma, gravitationally powered dynamo.

References

- [1]. D. Kumar and P. M. Bellan, Phys. Rev. Lett. 105, Art. No. 105003 (2009)
- [2]. E. V. Stenson and P. M. Bellan, IEEE Trans. Plasma Sci. 36, 1206 (2008)
- [3.] P. M. Bellan, ApJ 687, 311 (2008)