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Simulation of astrophysical jets in a laboratory experiment[1]

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Astrophysical jets are routinely simulated in a reproducible, well-diagnosed laboratory experiment. The experimental sequence starts by imposing a vacuum poloidal magnetic field linking a disk electrode to a co-planar annular electrode. Neutral gas (H, Ne, N, or Ar) is then injected via 8 nozzles located on the disk and 8 nozzles on the annulus. A 120 μF capacitor bank power supply charged to 4-7 kV is applied via ignitron switches across the electrodes, breaking down the injected gas to form plasma. The low impedance ($<$10 mΩ) of the highly conducting plasma causes the power supply to behave as a current source, rather than a voltage source. The discharging capacitor bank drives a $\sim$100 kA poloidal electric current through the plasma; this current initially flows in eight distinct 'spider legs' (see photo in April meeting poster) that span from the disk to the annulus. The spider legs quickly merge via mutual attraction of their currents to form the simulated astrophysical jet. The axial gradient of the toroidal magnetic field energy density provides the force that accelerates the jet. The mass flux boundary condition at the electrodes is tightly coupled to the jet behavior. The jet is 'fueled' by plasma ingested from the nozzles and the accumulation (pile-up) of the ingested plasma collimates the jet because of the associated pile-up of frozen-in toroidal magnetic flux convected with the plasma. The jet undergoes a kink instability when it becomes long enough to satisfy the Kruskal-Shafranov q =1 condition.

[1] In collaboration with Setthivoine You and Gunsu Yun, Caltech.