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Dynamic and Stagnating Plasma Flow Leading to Magnetic-Flux-Tube Collimation[1]

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This talk presents experimental observations, first reported by You, Yun, Bellan in PRL (art. 045002, 2005), strongly supporting the "MHD pump-collimation" model proposed by Bellan in Phys. Plasmas (vol. 10, p.1999, 2003). Collimated, plasma-filled, magnetic flux tubes are observed over a tremendous range of scales. In laboratory plasmas, on the surface of the Sun, or jetting out of galactic cores, these flux tubes are extremely collimated, with cross-sections that do not vary much along the length of the tube even in the absence of external magnetic fields or any significant ambient medium pressure. Furthermore, these flux tubes are not in static equilibrium but exhibit strong plasma flows on a rapid time-scale compared to their overall motion within their surroundings. The Caltech experiment simulates magnetically-driven astrophysical jets at the laboratory scale by imposing boundary conditions analogous to astrophysical jet boundary conditions and with plasma dimensionless numbers comparable to numerical MHD simulations. Observations show a distinct sequence of events. The initial flux tubes flare out into the large vacuum, because the magnetic field weakens away from the source. As electrical current flows, the flux tubes become denser and more collimated while sucking plasma from gas sources at the system boundary, effectively acting like a magnetohydrodynamic pump. These flux tubes then merge together into a single column which jets out into the vacuum. The jet continues the same pumping process, to become even denser and more collimated, until either the electrical current or the supply of particles stop. The strong plasma flow convects frozen-in magnetic flux to regions of weaker magnetic field at the end of the tube, and as the flow stagnates there, magnetic flux piles up, pinching the tube into a collimated filament.

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