The dynamics of arched, plasma-filled magnetic flux tubes

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Abstract

The solar corona is home to a vast array of arched plasma structures (e.g., solar coronal loops and prominences) that are magnetically linked to a conducting boundary. These structures can exhibit rapid dynamic evolutions. Laboratory plasma experiments at Caltech provide a means to study the basic physics of these events, while offering the benefits of reproducibility, diagnostic accessibility, and parameter tuning.

The experiments show that the evolution of an individual arched, plasma-filled magnetic flux tube is governed by two complementary MHD-driven processes. The first process is the hoop force, which transforms a small, semi-circular tube of plasma into a much larger "loop"; the length of the arched flux tube typically increases five- to seven-fold. The second process is the acceleration of bulk flows along the flux tube axis. The flows originate from both footpoints, carry plasma toward the apex of the plasma loop, and maintain both the density and the collimation of the flux tube during its dramatic lengthening.

Both processes scale in proportion to an "azimuthal Alfven speed" $B_\phi/(\mu_o\rho)^{1/2}$, where B_ϕ is the magnetic field due to the electrical current flowing along the flux tube. This has been demonstrated in laboratory experiments by such means as varying the plasma mass density with the use of different ion species (sometimes within the same

loop), and increasing or decreasing the azimuthal magnetic field. Because MHD has no intrinsic length scale, it is expected that the same physics occur in magnetic flux tubes in the solar corona.