Experimental Exploration of Dynamic, Astrophysically-relevant MHD Plasmas

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Dynamics relevant to solar and astrophysical plasmas is being investigated using lab experiments governed by the same physics, having the same topology, but much smaller space scales and much faster time scales. Plasma dynamics is tracked using high speed imaging that resolves sub-Alfven time scales. These movies reveal unexpected, new phenomena. In contrast to the often-used zero-beta approximation where flows and pressure gradients are neglected, the movies clearly show that highly collimated MHD-driven plasma flows are a critical feature of the dynamics. These collimated flows can be considered to be a lab version of an astrophysical jet. Since the jet has both axial and azimuthal magnetic fields, it can also be considered to be a flux rope, i.e., a plasma-confining flux tube with embedded helical magnetic field. The jet velocity scales with axial electric current and is in good agreement with an MHD acceleration model [1]. Axial stagnation of the jet compresses embedded azimuthal magnetic flux resulting in jet self-collimation. Depending on how the flux rope radius varies with axial position, plasma jets flow into the flux rope from just one end or from both ends where the latter corresponds to an expanding solar coronal loop [2]. Jets kink when they breach the Kruskal-Shafranov stability limit [3]. The lateral acceleration of a sufficiently strong kink provides a substantial effective gravity. This 'gravity' provides the environment for a spontaneously developing fine-scale, extremely fast Rayleigh-Taylor instability involving 'heavy' plasma interchanging places with 'light' plasma in a series of ripples. These ripples erode the width of the current channel and can choke the current channel to be smaller than the ion skin depth [4]. This cascade from the ideal MHD scale of the kink to the current-choking, non-MHD ion skin-depth scale can result in a fast magnetic reconnection whereby the jet breaks off from its source electrode [4].

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[1] D. Kumar and P. M. Bellan, Phys. Rev. Letters **103**, Article Number 105003 (2009)
[2] E. V. Stenson and P. M. Bellan, Phys. Rev. Letter **109**, Article Number 075001 (2012)
[3] S. C. Hsu and P. M. Bellan, Phys. Plasmas **12**, art. 032103 (2005)
[4] A. L. Moser and P. M. Bellan, Nature **482**, p. 379-381 (2012)