DPP13-2013-000055

Abstract for an Invited Paper
for the DPP13 Meeting of
the American Physical Society

Laboratory Experiments on the Generation of Perpendicular, Magnetized Collisionless Shocks by a Laser-Ablated Piston[1]

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Collisionless shocks occur ubiquitously in space plasmas and have been extensively studied *in situ* by spacecraft, though they are inherently limited in their flexibility. We present laboratory experiments utilizing a highly flexible laser geometry at UCLA to study the generation of magnetized, perpendicular collisionless shocks by a super-Alfvénic laser-ablated piston. Experiments were carried out on the LArge Plasma Device (LAPD), which can create a highly reproducible 20 m long by Ø1 m H or He magnetized ($\leq$ 2 kG) ambient plasma. The 100 J Raptor laser was used to ablate perpendicular to the background magnetic field a carbon target embedded in the LAPD plasma. Emission spectroscopy revealed a significant spread between laser debris charge states, consistent with 2D hybrid simulations that show fast-moving, highly ionized debris slipping through the ambient plasma, while slower, lower charge states drive a diamagnetic cavity. The cavity grew to several ion gyroradii and lasted around one gyroperiod, large and long enough to act like a piston by allowing laminar fields at the cavity edge to transfer energy from the debris to the background plasma. This is confirmed by spectroscopy, which shows a reduction in debris velocities relative to a non-magnetic case, and Thomson scattering, which shows an increase in electron densities and temperatures in the ambient plasma. An increase in the intensity of the ambient plasma seen by gated imaging also indicates an energetic population of electrons coincident with the cavity edge, while Stark-broadened ambient lines may indicate strong local electric fields. Magnetic flux probes reveal that the cavity launches whistler waves parallel to the background field, as well as a super-Alfvénic magnetosonic wave along the blowoff axis that has a magnetic field compression comparable to the Alfvenic Mach number, consistent with simulations that suggest a weak collisionless shock was formed.

[1]Supported by DOE and DTRA.