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Collisionless Coupling between Explosive Debris Plasma and Magnetized Ambient Plasma

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The explosive expansion of a dense debris plasma cloud into relatively tenuous, magnetized, ambient plasma characterizes a wide variety of astrophysical and space phenomena, including supernova remnants, interplanetary coronal mass ejections, and ionospheric explosions. In these rarified environments, collective electromagnetic processes rather than Coulomb collisions typically mediate the transfer of momentum and energy from the debris plasma to the ambient plasma. In an effort to better understand the detailed physics of collisionless coupling mechanisms in a reproducible laboratory setting, the present research jointly utilizes the Large Plasma Device (LAPD) and the Phoenix laser facility at UCLA to study the super-Alfvénic, quasi-perpendicular expansion of laser-produced carbon (C) and hydrogen (H) debris plasma through preformed, magnetized helium (He) ambient plasma via a variety of diagnostics, including emission spectroscopy, wavelength-filtered imaging, and magnetic field induction probes. Large Doppler shifts detected in a He II ion spectral line directly indicate initial ambient ion acceleration transverse to both the debris plasma flow and the background magnetic field, indicative of a fundamental process known as Larmor coupling. Characterization of the laser-produced debris plasma via a radiation-hydrodynamics code permits an explicit calculation of the laminar electric field in the framework of a "hybrid" model (kinetic ions, charge-neutralizing massless fluid electrons), thus allowing for a simulation of the initial response of a distribution of He II test ions. A synthetic Doppler-shifted spectrum constructed from the simulated velocity distribution of the accelerated test ions excellently reproduces the spectroscopic measurements, confirming the role of Larmor coupling in the debris-ambient interaction.