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Laser-Driven Magnetized Collisionless Shocks

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Collisionless shocks – supersonic plasma flows in which the interaction length scale is much shorter than the collisional mean free path – are common phenomena in space and astrophysical systems, including the solar wind, coronal mass ejections, supernovae remnants, and the jets of active galactic nuclei. These systems have been studied for decades, and in many the shocks are believed to efficiently accelerate particles to some of the highest observed energies. Only recently, however, have laser and diagnostic capabilities evolved sufficiently to allow the detailed study in the laboratory of the microphysics of collisionless shocks over a large parameter regime. We present experiments that demonstrate the formation of collisionless shocks utilizing the Phoenix laser laboratory and the LArge Plasma Device (LAPD) at UCLA. We also show recent observations of magnetized collisionless shocks on the Omega EP laser facility that extend the LAPD results to higher laser energy, background magnetic field, and ambient plasma density, and that may be relevant to recent experiments on strongly driven magnetic reconnection. Lastly, we discuss a new experimental regime for shocks with results from high-repetition (1 Hz), volumetric laser-driven measurements on the LAPD. These large parameter scales allow us to probe the formation physics of collisionless shocks over several Alfvénic Mach numbers (M_A), from shock precursors (magnetosonic solitons with $M_A < 1$) to subcritical ($M_A < 3$) and supercritical ($M_A > 3$) shocks. The results show that collisionless shocks can be generated using a laser-driven magnetic piston, and agree well with both 2D and 3D hybrid and PIC simulations. Additionally, using radiation-hydrodynamic modeling and measurements from multiple diagnostics, the different shock regimes are characterized with dimensionless formation parameters, allowing us to place disparate experiments in a common and predictive framework.