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First direct experimental observation of Weibel-mediated collisionless shock formation and the resulting nonthermal electron acceleration in laboratory experiments[1]

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Collisionless shocks are ubiquitous in astrophysics and are thought to be a source of magnetic field generation and particle acceleration in the universe. They can occur in supernova remnants, cataclysmic variables, protostellar jets, active galactic nuclei, and colliding galaxies. Laboratory experiments with high-Mach number plasma flows can provide critical information to help understand the shock formation mechanisms in these systems. High velocity, low density, interpenetrating plasma flows were studied on the Omega laser. These interpenetrating flows exhibited strong filamentation via the ion-Weibel instability, which in turn generated microscale magnetic fields that were observed with proton radiography and optical Thomson scattering [2, 3]. No evidence for collisionless shock generation was observed in these Omega experiments. On the National Ignition Facility (NIF), the interpenetrating plasmas extended over much larger time intervals and interaction volumes. Under these conditions on NIF, we observed the first unambiguous experimental evidence of Weibel-mediated collisionless shock formation, as demonstrated by an abrupt 3x increase in density, with significant increase in temperature. Detailed plasma characterization using optical Thomson scattering was carried out, and the first experimental observation of particle acceleration from these high velocity collisionless shocks on NIF was obtained[4, 5]. The role of the Weibel instability in creating seed magnetic fields, initiating plasma flow stagnation, and generating collisionless shocks in laboratory experiments on Omega and NIF will be discussed.

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[3]G.F. Swadling et al., **Phys. Rev. Lett.**, submitted (2019)
[4]J. S. Ross et al., **Phys. Rev. Lett.**, 118, 185003 (2017)
[5]F. Fiuza et al., **In Preparation** (2019)