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Preface to Special Topic: High-Energy Density Laboratory Astrophysics

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In the 1990s, when the large inertial confinement fusion facilities in the United States became accessible for discovery-class research, physicists soon realized that the combination of these energetic drivers with precision plasmas diagnostics would allow the unprecedented experimental study of astrophysical problems. These facilities routinely produce states of matter in the high-energy density physics regime,[1] i.e., pressures above a million atmospheres, 10^{11} J m^3, and employ a suite of temporally and spatially resolving imaging[2] and scattering[3] measurements that were originally developed to understand the behavior of inertial confinement fusion plasmas.[4] These capabilities bring to the field of astrophysics critical experimental tests of simulations in relevant regimes that are far from the conditions that can otherwise be routinely produced on earth.[5] These astrophysical motivated studies are now finding their way into the laboratory plasma community. Further, laboratory astrophysics helped to motivate the development of new precision experimental capabilities; the latest AQ2 being the world-class LCLS x-ray laser at the Matter in Extreme Conditions instrument[6] at Stanford that is dedicated to fundamental research.

On May 16–20, 2016, the 11th International Conference on High Energy Density Laboratory Astrophysics was held at the SLAC National Accelerator Laboratory in Menlo Park, California, continuing the 20 years-long history of the conference series. The conference was co-organized by SLAC National Accelerator Laboratory, Stanford University, Lawrence Livermore National Laboratory, and the University of California, Berkeley. The meeting drew a record number of attendees from North America, Asia, and Europe discussing research in many areas, such as compressible hydrodynamic mixing, shock phenomena, magnetic reconnection, turbulence, jets, dynamos, heat conduction, radiative transport, complex opacities, equations of state, warm dense matter, relativistic plasmas, and pair plasmas.

This variety of topics can be grouped into five areas. The first main topic is the study of Dense Plasmas and Warm Dense Matter as they relate to planetary interiors or dwarf objects. Of particular interest is the thermodynamics of mixing to the atomic level. It determines atmospheric boundary conditions and affects our interpretation of how planets are formed. Models for the equation of state of mixtures and new theories of the conductivity of matter in these extreme states were discussed in depth. Research on this topic is timely in light of the Juno and Cassini missions and the recent discovery of a large number of exo-planets that have sparked the public interest. In "Properties of hydrogen, helium, and silicon dioxide mixtures in giant planet interiors," Soubiran *et al.*[7] performed simulations to study the diffusion and viscosity effects of heavier species in the hydrogen-helium envelope. These results affect planetary interior models and the time scale for core erosion.

The second group, Fluid and Collisional Plasmas, has focused on the physics of jets and the role of plasma instabilities and turbulence. Simulations and laboratory studies were specifically motivated by observations from active galactic nuclei (AGN), the crab nebula, or the Perseus galaxy cluster. In "Numerical modeling of laser-driven experiments aiming to demonstrate magnetic field amplification via turbulent dynamo," Tzeferacos *et al.*[8] proposes new experiments that have been designed through radiation magneto-hydrodynamics simulations. These studies are aimed at explaining the vast range of magnetic field strengths in the universe by experimentally inducing turbulence and amplification of Biermann battery generated fields as plasma jets pass rods or grids. Koenig *et al.*[9] used a similar geometry in their paper titled "Interaction of a highly radiative shock with a solid obstacle" to pursue experiments aimed at observing the effect of radiation on shock structures. In "Formation of high-speed electron jets as the evidence for magnetic reconnection in laser-produced plasmas," Huang *et al.*[10] studies the formation of jets in two colliding plasma bubbles to simulate magnetic field reconnection. In "Using collisions of AGN outflows with intra cluster medium (ICM) shocks as dynamical probes," Jones *et al.*[11] developed a set of relationships to describe the dynamics of fast plasma jets to the Intra Cluster Medium (ICM).

On the Transport and Atomic Processes topic several challenging experiments have been presented that described opacity and conductivity measurements with high precision. These studies show significant discrepancies with current models. In particular, an independent and accurate measurement of the plasma conditions has proven to be very challenging warranting further theoretical and experimental studies, for example, with improved diagnostic tools. In "Contribution of satellite lines to temperature diagnostics with He-like triplet lines in photoionized plasma," Wang *et al.*[12] perform collision-radiative calculations to develop accurate spectroscopic methods for temperature measurements that can be applied to astrophysical or laboratory plasmas (Fig. 1). AQ3

"Collisionless Plasmas and Particle Acceleration" has received significant attention. Particle injection in shocks is an important open question that laboratory experiments can help solve. Such studies have far reaching consequences for our understanding of the formation of cosmic rays and may be important for applications. In "On the generation of

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FIG. 1. The group photo shows the attendees of the 2016 High Energy Density Laboratory Astrophysics Conference held at SLAC National Accelerator Laboratory, Menlo Park, CA, May 16–20, 2016.

magnetized collisionless shocks in the Large Plasma Device," Schaeffer *et al.*[13] used a laser-driven magnetic piston at UCLA's Large Plasma Device to drive a sub-critical collisionless shock. These studies motivate future experiments to drive a super-critical collisionless shock at higher velocity where ion reflection at the shock front becomes important. In "Laboratory experiments investigating magnetic field production via the Weibel instability in interpenetrating plasma flows," Huntington *et al.*[14] produced counter-streaming plasmas at the Omega laser and applied Thomson scattering and proton probes to determine the conditions that approach a collisionless regime. Experiments are now being conducted on the NIF to observe the formation of collisionless shocks mediated by the Weibel instability. In "A self-consistent analytical model for the upstream magnetic field and ion-beam properties in Weibel-mediated collisionless shocks," Ruyer *et al.*[15] shows that the field and plasma evolution fulfill the Rankine-Hugoniot relations in the regime upstream of a collisionless shock. In "Particle acceleration in laser-driven magnetic reconnection," Totorica *et al.*[16] investigates Omega laser conditions with 3D PIC simulations to show non-thermal particle acceleration from magnetic reconnection. The results indicated that acceleration at x-points is dominant and leads to high-energy tails with $\sim 50\times$ the thermal electron energy.

In New Frontiers, researchers discussed simulations and experiments in the QED regime, recent experiments with high intensity lasers on the production of pair plasmas, and nuclear astrophysics. In the final paper "Development of an inertial confinement fusion platform to study charged-particle-producing nuclear reactions relevant to nuclear astrophysics," Gatu Johnson *et al.*[17] presents proof of principle experiments on the OMEGA and NIF laser facilities that demonstrate the charge particle energy and yield from nuclear reactions. This research is aimed to explore thermonuclear reaction rate in stellar plasmas.

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