From Ultracold Plasmas to White Dwarf Stars

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Some of the most extreme environments in the universe can be described as strongly coupled plasmas, which are characterized by an average Coulomb interaction energy between neighboring particles that exceeds the thermal kinetic energy. This is the case in dense laboratory and astrophysical plasmas, such as in inertial-confinement-fusion experiments, white dwarf stars, and gas-giant-planet interiors. Strong interactions limit our ability to model and understand these systems because they violate fundamental assumptions underlying the standard theoretical description of collision rates and transport coefficients. They also lead to spatial correlations and surprising equilibration dynamics. I will describe how we can study the physics of strongly coupled plasmas in a system created by photoionizing laser-cooled atoms [1]. This creates the coldest neutral plasmas in existence, with temperatures barely one degree above absolute zero. Strong coupling is obtained at relatively low density, which slows the dynamics and makes short-timescale processes (compared to the inverse collision rate) experimentally accessible. This combination of atomic and plasma physics opens a new direction in the study of "dense" plasmas, which has traditionally been the playground of astrophysics and large national facilities. In particular, I will describe recent experiments studying the breakdown of standard kinetic theory and the measurement of self-diffusion [2,3].

This work is supported by the National Science Foundation, Department of Energy, and the Air Force Office of Scientific Research.

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[3] "Experimental measurement of non-Markovian dynamics and self-diffusion in a strongly coupled plasma," T. S. Strickler, T. K. Langin, P. McQuillen, J. Daligault, and T. C. Killian, arXiv.org/1512.02288 (2015).