X-ray measurements of the equation of state of White Dwarf conditions

Siegfried H. Glenzer[1,†]

[1] *SLAC National Accelerator Laboratory*

[†] glenzer@slac.stanford.edu

Over 97% of the stars in the Milky Way, including the Sun, will become White Dwarfs (DWs) at the end of their nuclear burning phases of evolution. The Milky Way already hosts a large population of WDs. Consisting almost entirely of carbon and oxygen, WDs are the most compact form of normal matter known, with densities exceeding $10^6 g/cm^3$. In the interior of WDs, matter is a fully-ionized plasma and the pressure is provided largely by electron degeneracy with an Equation of State (EOS) that, while untested, is thought to be understood as the Thomas-Fermi limit for degenerate matter. However, near the surface of WDs, knowledge of the degree of ionization is critical for accurate modeling, particularly in the thin convective region of the star, yet it is less constrained by robust theory. These lower density states – still extreme by laboratory standards – are now directly accessible on the National Ignition Facility. Some classes of WDs are variable stars, where the excited modes of oscillation of the star depend on the EOS and opacity of the partially ionized matter. These stars are particularly sensitive to the EOS in the Gbar-heV regime.
In this talk, we present the first X-ray measurements of the EOS at Gbar pressures using time resolved X-ray radiography. These experiments have accessed a regime in carbon where significant discrepancies between EOS models exists and where our data clearly favor modeling that includes the atomic shell structure. Recently, these studies have been expanded to the EOS of oxygen to constrain, verify, or discriminate between theoretical EOS predictions in regimes important for our understanding of WDs stars. Finally, I will provide an outlook for future X-ray scattering studies that can provide complementary information on the ionization state of WD matter.

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