OBSERVATION OF FINITE-WAVELENGTH SCREENING IN SHOCK-COMPRESSED PLASTIC USING X-RAY THOMSON SCATTERING

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The familiar concept of charge screening is an essential part of the description of a diverse range of charged-particle systems, including warm dense matter (WDM), laboratory and astrophysical plasmas, electrolytes, nuclear matter, solid state systems and charged biochemical macromolecules. The most well-known descriptions of screening applied to such systems are the Debye-Hückel and Thomas-Fermi models [1], where the long-range Coulomb potential is exponentially reduced due to polarisation of the background medium.

Whilst such simple descriptions often yield reasonable estimates of the thermodynamics of many states of interest, they are restricted to weak coupling, and static screening in the long-wavelength limit. The latter is fulfilled only for processes involving small momentum transfer, e.g. small-angle electron-ion scattering. In contrast, large momentum transfer processes are important for describing, e.g., transport and relaxation in dense matter.

In this work [2], we build upon recent experimental investigations of ionization potential depression and the electronic response of WDM [3] using spectrally-resolved x-ray Thomson scattering (XRTS) of laser-driven shock-compressed CH shells at the Omega laser. Applying large-angle XRTS accesses the noncollective response of the plasma, enabling the plasma conditions to be accurately determined from the inelastic scattering profile. Moreover, probing at large k ensures that the static structures of the ions and bound electrons are well understood. Our experiment enables direct investigation of the screening cloud in a regime where deviations from the long-wavelength limit, i.e. finite-wavelength screening, are expected to be crucial for correctly describing the elastic scattering.

Detailed statistical analysis of the inelastic scattering contribution shows that a WDM state is achieved, characterised by electron densities and temperatures close to nₑ = 10²⁴ cm⁻³ and Tₑ = 10 eV, respectively, with helium-like carbon ions (Zₑ = 4). The latter is supported by previous analysis and self-consistent ionization equilibrium calculations based on simulations of the imploding shells. Under such conditions, we find that the Debye-like screening cloud over-estimates the observed elastic scattering signal. In contrast, finite-wavelength screening gives generally good agreement. Moreover, considering modification of the electron-ion interaction due to carbon K-shell electrons leads to significantly underestimated elastic scattering, further ruling out Debye-like screening behaviour.