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Probing the complex ionic structure of warm dense carbon

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The carbon phase diagram at extreme pressure conditions has received broad interest for modeling planetary interiors and high energy density laboratory experiments. Numerous theoretical models and simulations have recently been performed but critical experimental data at the phase boundaries and of the microscopic physical properties remain very scarce. In this work, we present novel experimental observations of the complex ion structure in warm dense carbon at pressures from 20 to 220 GPa and temperatures of several thousand Kelvins. Our experiments employ powerful x-ray sources at kilo-joule class laser facilities and at the Linac Coherent Light Source to perform spectrally and angularly resolved x-ray scattering from shock-compressed graphite samples; the absolute static ion structure factor is directly measured by resolving the ratio of elastically and inelastically scattered radiation. Using different types of graphite and varying drive laser intensity, we were able to probe conditions below and above the melting line, resolving the shock-induced graphite-to-diamond and graphite-to-liquid transitions on nanosecond time scale. Our results confirm a complex ionic structure predicted by QMD simulations and demonstrate the importance of chemical bonds at extreme conditions similar to those found in the interiors of giant planets. The evidence presented here thus provides a firmer ground for modeling the evolution and current structure of carbon-bearing icy giants like Neptune, Uranus, and a number of extra-solar planets.