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Systematic measurements of opacity dependence on temperature, density, and atomic number at stellar interior conditions[1]

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Opacity calculations for hot dense plasma are challenging due to environment effects on the atoms. In fact, modeled iron opacities are notably different from measurements performed at matter conditions similar to the boundary between the solar radiation and convection zones [J.E. Bailey et al., Nature 517, 56 (2015)]. The calculated iron opacities have narrower spectral lines, weaker quasi-continuum at short wavelength, and deeper opacity windows than the measurements. If correct, these measurements help resolve a decade old problem in solar physics. A key question is therefore: What is responsible for the model-data discrepancy? The answer is complex because the experiments are challenging and opacity theories depend on multiple entangled physical processes such as the influence of completeness and accuracy of atomic states, line broadening, and contributions from myriad transitions from excited states. To help determine the cause of this discrepancy, a systematic study of opacity variation with temperature, density, and atomic number is underway. Measurements of chromium, iron, and nickel opacities have been performed at two different temperatures and densities. The collection of measured opacities provides constraints on hypotheses to explain the discrepancy [T. Nagayama et al., Phys. Rev. Lett. 122, 235001 (2019)]. We will discuss implications of measured opacities, experimental errors, and possible opacity model refinements.

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