Two decades of stellar interior opacity research at Z.

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Nearly a century ago, Eddington [1] recognized that the attenuation of radiation by stellar matter controls the internal temperature and density profiles within stars like the Sun. Opacity calculations for high energy density (HED) matter are challenging because accurate and complete descriptions of the energy level structure, equation of state, and plasma effects such as continuum lowering and spectral line broadening are needed for partially ionized atoms. This requires approximations. Opacity calculations, however, have never been benchmarked against laboratory measurements at stellar interior conditions until now. The measurements are challenged by creating and diagnosing sufficiently large and uniform samples at stellar interior conditions. Over the last two decades, we developed an experimental platform on the Z facility and measured [2] spectrally-resolved opacity at electron temperatures T_e = 150-200 eV and densities $n_e = 0.6 – 5.0 \times 10^{22}$ cm^{-3} - conditions very similar to the solar radiation/convection boundary zone. Models agree with iron data at the lower temperature and densities, but notable model-data discrepancies arise at higher temperatures and densities. The comparisons raise questions about how well we understand atoms embedded in high energy density plasma. These measurements may also help resolve two-decade-old discrepancies between solar model predictions and helioseismic observations. So far, however, there is no reconciliation of the model-data discrepancy and both theory and experiment scrutiny must continue. The experiments have now been expanded to include opacity data for chromium, nickel [3], and oxygen. The wavelength range has also been expanded to cover 5-20 Angstroms, a span that is unprecedented in opacity research. This presentation will describe experiment design considerations for benchmark quality results. It will provide an overview of the results, investigations of possible errors, and ongoing experiments.

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