Laboratory Measurment of Opacity for Stellar Envelopes

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Using the world's most energetic pulsed power accelerators, we create stellar plasma conditions in the laboratory and perform measurements of importance for stellar modeling and astrophysics. We have recently completed a series of experiments to critically test the accuracy of opacity models used in calculations of the structure and pulsation properties of Cepheid Variable stars. Understanding of these stars is important since they serve as a standard candle for extragalactic distances up to 60 million light-years. Astronomical observations of double-mode Cepheid's indicated a lack of understanding for these stars, attributed to inaccuracies in earlier opacity models. The measurements provide the first direct validation of the OPAL opacity models in regimes of interest for stellar envelopes, and resolve long-standing puzzles in stellar pulsation and evolution.

Cepheid pulsation depends critically on the absorption properties of mid-Z elements, mostly iron, at temperatures of order 20 eV, and densities of order 10^{-4} g/cc, where the contribution of the M-shell $\Delta n = 0$ transitions to the Rosseland mean opacity is maximal. Calculations of the opacity at this low density are particularly difficult because they depend sensitively on the treatment of millions of individual lines, and the merging of these lines into quasi-continua. Using the 500 kJ Saturn pulsed power facility at Sandia National Laboratory, we created and measured the opacity of Fe and Ni plasmas at stellar envelope conditions. In particular, the absorption properties of the M-shell $\Delta n = 0$ transition arrays were studied at high spectral resolution and compared to predictions used in Cepheid Variable modeling. Experimental requirements include: high spectral resolution, large homogenous plasma sources, and Planckian radiation fields lasting tens of nanoseconds.

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