arise from the constrained geometry of the photoinitiated reaction of the $HBr.I_2$ van der Waals molecule (see Fig. 1*c*). The very high angular momentum ($L_m \approx 250h/2\pi$) of complexes formed in the cross-beam reaction may also exert a strong influence on the lifetime. Indeed, much progress[7,8] has been achieved in recent years in identifying the structure and dynamics of persistent complexes, and characterizing the transition states for their dissociation to reaction products in reactive scattering experiments.

Zewail and co-workers now hold out the prospect of gaining higher collision energies by photodissociating the $CH_3Br.I_2$ van der Waals molecule and observing the BrII complex directly, thereby gaining sufficient resolution to identify the time evolution of individual vibration–rotation states of the complex. With these and parallel theoretical advances on quantized transition states[9], we may truly be within sight of a spectroscopy of reaction transition states and collision complexes. □

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ASTROPHYSICS

Stellar opacities in a flash

D. B. Guenther

THE opacity of matter has been measured for the first time at the temperatures and densities that occur in the interiors of stars. Da Silva, of the University of California at Berkeley, and his collaborators at the Lawrence Livermore National Laboratory[1] used an X-ray laser to heat a thin sample of iron to about 2.5×10^5 K, while X-rays from another laser were used to determine the photo-absorption properties of the heated sample. The entire measurement lasted less than a nanosecond because of the speed of cooling.

Because the densities and temperatures of matter in stellar interiors are inaccessible to experiment (the Sun's central density is greater than 100 g cm^{-3} and its central temperature is greater than 1.5×10^7 K), the photo-absorption properties of stellar matter must be calculated theoretically. For more than two decades, tables of opacities calculated at Los Alamos National Laboratory[2,3] (LANL) have been used to construct stellar models, which depend enormously on how photons generated in the core find their way out through the highly ionized medium.

At the time that the LANL opacity programs were being developed, computers were not sufficiently powerful to carry out a full and detailed solution to the problem, and several approximations to the atomic physics were made. But armed with the latest supercomputers, Rogers and Iglesias, at the Lawrence Livermore Laboratory, have now calculated a new set of opacity tables (OPAL), that are based on better atomic physics and that take into account the Coulomb interactions among all the electrons and the nuclei of the mixture of elements found in stars[4].

To the surprise and delight of many astrophysicists, the OPAL opacities are larger than the LANL opacities (up to three times larger at temperatures near 3×10^5 K). The astrophysicists were surprised because they had believed the LANL opacities to be accurate to within 25 per cent; they were delighted because the increased opacity was just what they needed to resolve several difficulties in stellar-evolution theory.

The list of puzzles that have been resolved is quickly growing, with the most dramatic improvements being found in solar and stellar pulsation theory. One of the first published success stories for the OPAL opacities concerned classical Cepheid and RR Lyrae stars — stars whose brightness pulsates every few days. (Their opaque atmospheres physically inflate as they are heated by radiation from below, until they become transparent enough to let the radiation escape, subsequently deflating, and so on.) Before the OPAL opacities were available, the mass of the stars could be adjusted in astrophysical models to give the correct mean luminosity or to give the correct pulsation period, but not both. With the OPAL opacities, the mass discrepancy disappears[5]. Other success stories include bringing the theoretically predicted non-radial acoustic oscillation spectrum of the Sun into closer agreement with that observed[6], and removing the need to invoke large amounts of convective-core overshoot in explaining the observed mass–luminosity relationship in massive stars[7].

An important new feature of the OPAL opacity calculation is the inclusion of so-called $\Delta n=0$ transitions. These transitions (in which an atom's principal quantum number n remains unchanged, while its angular momentum does change) add a dense forest of lines to the spectrum, especially from iron, which increases the opacity inside the Sun's convective envelope at temperatures near 3×10^5 K. This increase is responsible for most of the improvements in stellar pulsation theory. The critical test for the new OPAL opacities was Da Silva and colleagues' experiment, because it measures the opacity of iron near these temperatures.

To do the experiments required the Nova laser facility at Lawrence Livermore, one of the most powerful lasers in the world. The 20-nanometre layer of iron (sandwiched in polypropylene supports) was heated by X-rays from a gold film irradiated by a 1-nanosecond, 3.3-kilojoule pulse of laser radiation. Its temperature raised to 2.5×10^5 K, the film's opacity was probed by a second pulse of X-rays, made in the same way, which passed through the plasma and were analysed with a spectrometer.

The agreement between the measured opacity and that predicted is remarkable, and confirms astrophysicists' faith in the OPAL calculations. □

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Star turn: Nova, one of the world's most powerful lasers, used by Da Silva and colleagues in their iron-plasma experiments, is seen here imploding a hydrogen pellet in an inertial fusion experiment.

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1. Da Silva, L. B. *et al. Phys. Rev. Lett.* **69**, 438–441 (1992).
2. Cox, A. N. & Steward, J. *Astrophys. J. Suppl.* **31**, 243–259 (1970).
3. Heubner, W. F., Merts, A. L., Magee, N. H. & Argo, M. F. *Los Alamos Scientific Report* LA–6760-M (1977).
4. Rogers, F. J. & Iglesias, C. A. *Astrophys. J. Suppl.* **79**, 507–568 (1992).
5. Cox, A. N. *Astrophys. J.* **381**, L71–L74 (1991).
6. Guenther, D. B., Demarque, P., Kim, Y.-C. & Pinsonneault, M. H. *Astrophys. J.* **387**, 372–393 (1992).
7. Stothers, R. B. & Chin, C.-W. *Astrophys. J.* **381**, L67–L70 (1991).