The Iron Project and NLTE stellar modeling

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Non-LTE models of stellar atmospheres require large amount of atomic parameters for collisional and radiative processes specific to many excited atomic levels. The collisional process is primarily electron impact excitation (EIE) of ions, while the radiative processes are: photoionization, electron-ion recombination, and bound-bound transitions. I will describe the latest developments in theoretical computations under the international collaboration the Iron Project (IP), and further extensions, following the Opacity Project (OP). The aims of these projects are to obtain accurate radiative and collisional data for EIE collision strengths, photoionization cross sections, and oscillator strengths of most astrophysically abundant ions for applications to astrophysical opacities and modeling of a variety of objects such as nebulae, AGN, and stellar plasmas.

As an extension of the OP and the IP, a self-consistent and unified theoretical treatment of photoionization and recombination has been developed. Both the radiative and the dielectronic recombination processes are considered in an unified manner, and the photoionization and recombination cross sections are computed using identical wavefunction expansions, thus ensuring self-consistency in an ab initio manner. All calculations for the various atomic parameters are carried out using the accurate and powerful R-matrix method in the close-coupling approximation. Another recent development is the inclusion of relativistic fine structure effects in Breit-Pauli approximation, especially for highly charged and for heavy ions. Atomic data for many ions have been recalculated to higher precision using larger waverfunction expansions. At the prevailing densities and temperatures in stellar atmospheres, the role of metastable states and low-lying fine structure levels in photoionization and recombination of ions bears special emphasis. I will present recent results from the Ohio State atomic-astrophysics group, highlighting the recent benchmarking of the computed photoionization and recombination cross sections with new laboratory experiments using accelerator based light sources for photoionization, and from heavy ion storage rings for electron-ion recombination.

I will also describe the efforts for an electronic web-interactive database, TIPTOPBASE, to enable the Opacity and the Iron Project data to be accessed. TIPTOPBASE will also include electron-ion recombination data and new fine structure transition probabilities. Of particular importance for stellar applications is the recent devlopment of efficient opacity codes by M.J. Seaton. Seaton's codes will enable, for the first time, on-line computations of 'customized opacities', with user-specified mixture of elements. In addition, radiative accelerations may also be obtained to compute radiative forces on elements (particularly iron) to study processes such as 'levitation' in stellar envelopes and environments.