Balancing Detail and Completeness in Collisional-Radiative Atomic Models

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In hot plasmas, collisional and radiative excitation and ionization open up a dizzying array of electronic configurations in multi-electron atoms and ions. These electronic states are closely coupled to the plasma radiation field, thus informing both observables (like x-ray spectra, which are useful for plasma diagnostics) and thermodynamic properties (like internal energies and charge state distributions, which are critical for radiation-hydrodynamic simulations). But due to the explosive combinatorics of high-n and multiply excited electronic states, it is difficult for computationally tractable models to include both the detailed states needed for useful spectroscopy and the complete state space needed for reliable thermodynamic properties. This talk will describe a hybrid-structure approach to balancing detail and completeness [1] that was developed in collaboration with Claire Bauche-Arnoult and Jacques Bauche. The hybrid model uses a combination of fine-structure states, relativistic configurations, and superconfigurations to describe the electronic structure of multi-electron ions. A key aspect of the model is its use of effective temperatures [2,3], a concept pioneered by Bauche, Bauche-Arnoult, and Michel Busquet, within superconfigurations, which provide a highly compact description of complex electronic structure [4,5]. Using effective temperatures to describe the internal partition functions of superconfigurations enables efficient modeling of complex ions that is reliable across a wide range of plasma conditions, from the low-density coronal limit to full local thermodynamic equilibrium (LTE).

This work is dedicated to the memory of Jacques Bauche. SH was supported by SNL's LDRD program, project number 218456. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

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