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Kinetic And Spectral Descriptions for Atomic Processes in Astrophysical and Laboratory Plasmas

An investigation has been in progress on the influence of autoionizing resonances on atomic processes in high-temperature plasmas, particularly those encountered in magnetic- and laser-fusion research. In the kinetic-theory description, account is taken of the indirect contributions of autoionizing resonances to the effective rates for excitation, de-excitation, ionization, and recombination. A microscopic many-body kinetic-theory foundation is employed for the systematic reduction to the macroscopic radiation-hydrodynamics description. From the spectral perspective, particular emphasis has been directed at radiative emission processes from autoionizing resonances. These processes can give rise to resolvable dielectronic-recombination satellite features, which have been analyzed to determine plasma temperatures, densities, electric and magnetic field distributions, and charge-state distributions. We also investigate radiative absorption processes, which play important roles in the denser plasmas encountered in laser-matter interactions. Particular emphasis is directed at radiative excitation processes involving autoionizing resonances, which can provide significant contributions to the non-equilibrium ionization structures and to the radiative absorption and emission spectra in the presence of intense electromagnetic fields. A reduced-density-matrix formulation has been under development for the microscopic many-body description of the electromagnetic interactions of atomic systems in the presence of environmental collisional and radiative decoherence and relaxation processes. A central objective is to develop a fundamental quantum-statistical formulation, in which bound-state and autoionization-resonance phenomena can be treated on an equal footing. An ultimate goal is to provide a comprehensive framework for a systematic and self-consistent treatment of non-equilibrium (possibly coherent) atomic-state kinetics and high-resolution (possibly overlapping) spectral-line shapes. This framework would facilitate the fundamental investigation of a broad class of atomic processes in laboratory and astrophysical plasmas covering extensive density and field regimes.

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