Radiative Recombination and Cascade in Ultracold Rydberg Plasmas

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Advances in cooling and trapping of neutral gases have made possible a new branch of plasma physics namely interactions, dynamics and collisions in ultracold systems. When atoms, initially prepared in the ground state at sub-millikelvin temperatures, are laser excited to highly excited Rydberg levels a gas of slowly moving Rydberg atoms is produced. The sufficiently dense sample of highly excited atoms then ionizes spontaneously with very high efficiency producing extremely cold plasma containing Rydberg atoms, electrons and ions. The ionization is caused by collision with the small number of Rydberg atoms at cold temperature or by absorbing background radiation. Most of the electrons are trapped by the ions and collide, de-excite and ionize the Rydberg gas creating an electron avalanche. The fact that the plasma can be sustained is evidence of the importance of `super-elastic” (de-excitation) collisions. The plasma state can also revert back to Rydberg atoms via three-body recombination between electrons, ions and neutral gas atoms. We are interested here in the dynamics/interplay between the gas and the plasma, a hybrid which we shall refer, for brevity, as a cold Rydberg plasma.

In this paper, we shall summarize the various ongoing radiative and collisional processes and shall provide, in particular, interesting classical and quantal treatments of radiative recombination into highly excited levels and the subsequent radiative cascade [1] down to the lower levels. Slow collisions of heavily charged ions with the radiating excited atom at large impact parameters lead to angular-momentum changing transitions (Stark mixing) within the degenerate states of a given energy shell n. At ultralow energies, it will become important to incorporate the radiative decay effect into the theory [2] of Stark mixing. Collisonal Stark mixing coupled with radiative decay, can be termed Radiative-Stark mixing. We shall also present the theory of Radiative-Stark mixing. Finally, various classical-quantal correspondences for processes involving highly excited states will be highlighted.

* Research supported by AFOSR Grant FA 9550-06-1-0212 and NSF Grant 04-00438.

Reference