Numerical Simulation of Ultracold Plasmas

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One approach to the production of antihydrogen relies on three-body recombination in ultracold plasmas [1]. Such recombination has been studied in recent experiments where ultracold neutral plasmas were produced by abruptly photoionizing small clouds of laser-cooled atoms [2]. Indeed there has been speculation that the traditional theory of three-body recombination fails at the ultralow temperature of these plasmas. This talk will present the results of novel molecular dynamic simulations for the early time evolution (~ 350 plasma periods) of the plasmas. The simulations are challenging because it is necessary to follow three-body recombination into weakly bound (high n quasi-classical) Rydberg states, and the time scale for such states is short compared to that for the plasma dynamics. This kind of problem was faced earlier in computational astrophysics when studying binary star formation in globular clusters. The binary stars are the analogue of the high-n Rydberg atoms and the cluster of the plasma cloud. Thus, we adapted a code by Aarseth [3] that was developed originally for studies of binary star formation. In three-body recombination, the binding energy is carried off by a second electron and enters the plasma as heat. This heating raises the plasma temperature and dramatically reduces the predicted recombination rate. In the simulations, the observed rate is in reasonable agreement with theory [4], $R = 3.9 \times 10^{-9}\text{sec}^{-1}[n\ (\text{cm}^{-3})]^2[T_e(^\circ K)]^{-9/2}$, but care must be taken to use the correct temporally evolving temperature, T_e.

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References

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