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Understanding Plasmas with a High Degree of Correlation Through Modeling: From Rydberg and Fermionic Plasmas to Penning Plasmas[1]

ANDREW CHRISTLIEB, Michigan State University

Ultra cold neutral plasmas have gained attention over the past 15 years as being a unique environment for studying moderately to strongly coupled neutral systems. The first ultra cold neutral plasmas were generated by ionizing a Bose Einstein condensate, generating a plasma with .1K ions and 2-4K electrons. These neutral plasmas have the unique property that the ratio of their potential energy to their kinetic energy, ($\Gamma = PE/KE$), can greatly exceed 1, leading to a strongly correlated system. The high degree of correlation means that everything from wave propagation through collision dynamics behaves quite differently from their counterpart in traditional neutral plasmas. Currently, a range of gases and different methods for cooling have been used to generate these plasmas from supersonic expansion, through penning trap configurations (reference Tom, Jake and Ed). These systems have time scales form picoseconds to milliseconds have a particle numbers from 10^5 to 10^9. These systems present a unique environment for studying the physics of correlation due to their low particle number and small size. We start by reviewing ultra cold plasmas and the current sate of the art in generating these correlated systems. Then we introduce the methods we will use for exploring these systems through direct simulation of Molecular Dynamics models; Momentum Dependent Potentials, Treecodes and Particle-Particle Particle-Mesh methods. We use these tools to look at two key areas of ultra cold plasmas; development of methods to generate a plasma with a $\Gamma \gg 1$ and the impact of correlation of collisional relaxation. Our eventual goal is to use what we learn to develop models that can simulate correlation in large plasma systems that are outside of the scope of Molecular Dynamics models.

In collaboration with Gautham Dharmuman, Mayur Jain, Michael Murillo and John Verboncoeur.

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