Three-body physics of ultracold gases: theory of weakly bound quantum states in strongly interacting systems

Summary for the general public

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1. Motivation

Ultracold atoms are a rapidly developing field of physics providing unparallel opportunities for studying molecular dynamics. The advances in laser cooling and trapping in the last decades have made it possible to investigate the ultracold matter. The experimental development of optical lattices has allowed for quantum simulations, which helped researchers model complex quantum processes and opened possibilities of creating novel materials. Complex questions in many-body physics can now be investigated and are often modeled using two-body interactions. In some cases, however, the true nature of atom-atom interactions emerges only after including three or more particles in the theoretical model. The relevance of few-body physics is paramount in determining the stability of ultracold gases, characterized by temperatures below 1 mK

2. Research project goal

During our project, we will study the processes involving the formation of three-body molecules. Our goal is to predict the formation paths of various species of atoms (including ionized atoms), which give valuable insight into the nature of chemical reactions and collisions. We will describe the energy levels and interactions between electrons in a given molecule. Using this knowledge, we will model the interaction between whole atoms and investigate the pathways of their collisions. We will describe the dependence of the physical properties on the external magnetic and electric fields, which will give the prospect of controlling the collisions in the system. We will use a range of mathematical and numerical methods to solve differential equations describing the motion of involved particles (including the Shrödinger equation).

3. Work plan

During the project, we will collaborate with world-leading research centers in atomic, molecular, and optical (AMO) physics. We will focus on working with theoretical groups at JILA at the University of Colorado and experimental groups at the University of Amsterdam, the University of Freiburg, and the University of Warsaw in order to model atom-ion and atom-atom collisions, scattering properties of ultracold gases, and their chemical interactions.