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Novel states of matter with ultracold magnetic lanthanides[1]

SVETLANA KOTOCHIGOVA, Temple University and NIST

Ultracold atomic physics is now poised to enter a new regime, where far-more complex atomic species can be cooled and studied. Magnetic lanthanide atoms with their large magnetic moment and large orbital momentum are extreme examples of such species. In fact, ultracold gases of magnetic lanthanides provide the opportunity to examine strongly correlated matter, creating a platform to explore exotic many-body phases such as quantum ferrofluids, quantum liquid crystals, and supersolids. Experimental advances in trapping and cooling magnetic Dy and Er atoms are paving the way towards these goals. Over the last few years we have developed a framework for understanding the complex anisotropic interactions between magnetic lanthanide atoms. Our theoretical model uses novel tools and advanced numerical treatments to describe the underlying mechanism that generates correlations and chaos in dipolar scattering and bridges the enormous conceptual gap between simple atoms and complex molecules. This allows us to explain the origin of the dense spectra and statistics of the observed Er and Dy collisional resonances due to the anisotropy of the short- and long-range interactions between the atoms. We also study the distribution of the values of the molecular wave functions to isolate Anderson-type localized states within chaotic structures and confirm the existence of an intermediate chaotic regime. In addition, our model for the three-body recombination via the formation of a resonant trimer has identified the origin of the temperature-sensitive resonance density observed in both Er and Dy collisions as due to d-wave entrance channel collisions.

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