SYCM 1: Hot topics in cold molecules: From laser cooling to quantum resonances

Time: Friday 11:00–13:00 Location: e415

Invited Talk SYCM 1.1 Fri 11:00 e415

Trapped Laser-cooled Molecules for Quantum Simulation, Particle Physics, and Collisions — •John Doyle — Harvard University, Cambridge, USA

Due to the controllable complexity of cold polar molecules - in particular the body frame fixed electric dipole of polar molecules - they are a potentially powerful platform for quantum simulation. This has led to significant efforts to control molecules at the quantum level. We report on laser cooling and trapping of molecules and the creation of optical tweezer arrays of ultracold CaF molecules in a single quantum state. We have also conducted collision studies using optical tweezers, demonstrating the potential for exploring state-selective ultra-cold quantum chemistry on a molecule by molecule basis. These methods can be extended beyond diatomic molecules to polyatomic molecules, which have additional features that are advantageous for quantum computation and particle physics. For example, we have advanced a scheme for quantum computation using symmetric top molecules in optical tweezers. We will also discuss progress toward laser cooling of polyatomic molecules such as CaOH, YbOH, CaSH, and $YbOCH_3$, and their potential use in experiments, including precision searches for new particles (beyond the standard model) and quantum information.

Invited Talk SYCM 1.2 Fri 11:30 e415

Cold polyatomic molecules — •Gerhard Rempe — Max-Planck Institute of Quantum Optics, Hans-Kopfermann Straße 1, 85748 Garching, Germany

Cold polyatomic molecules provide fascinating research possibilities in physics and chemistry, especially when the density is high enough for collisions to take place. Reaching the cold collision regime, however, is a challenge, as polyatomic molecules require radically new control techniques. Thanks to electrostatic skimming, guiding and trapping as well as opto-electric Sisyphus and cryogenic buffer-gas cooling combined with mechanical centrifuge deceleration it is now possible to produce high-density trapped ensembles of, e.g., cold fluoromethane and formaldehyde molecules. This allows for long-range dipolar-collision studies, narrow-linewidth magic-transition spectroscopy, and the exploration of coherence-preserving internal dynamics. The talk introduces the basic techniques and discusses recent achievements.

Invited Talk SYCM 1.3 Fri 12:00 e415

Collisions between laser-cooled molecules and atoms — •Michael Tarbutt — Centre for Cold Matter, Blackett Laboratory, Imperial College London, London SW7 2AZ, UK

Ultracold molecules can be used to test fundamental physics, simulate many-body quantum systems, process quantum information, and study ultracold chemistry. We capture CaF molecules in a magneto-optical trap (MOT) [1, 2], cool them to a few microkelvin [3], trap them magnetically [4], and coherently control their rotational state [5, 6]. To increase the phase-space density, we aim to sympathetically cool the molecules using ultracold atoms. For this purpose, we have developed a dual-species MOT for CaF and Rb. I will present our first studies of collisions between these two species in the MOT and in a magnetic trap.

[1] S. Truppe et al., Nature Physics 13, 1173 (2017)
[2] H. J. Williams et al., New J. Phys. 19, 113035 (2017)
[3] L. Caldwell et al., Phys. Rev. Lett. 123, 033202 (2019)
[4] H. J. Williams et al., Phys. Rev. Lett. 120, 163201 (2018)
[5] J. A. Blackmore et al., Quantum Sci. Technol. 4, 014010 (2019)
[6] L. Caldwell et al., arXiv:1908.11839 (2019)

Invited Talk SYCM 1.4 Fri 12:30 e415

Collisions between cold molecules in a superconducting magnetic trap — •Edvardas Narevicius — Weizmann Institute of Science

Collisions between cold molecules are essential for studying fundamental aspects of quantum chemistry, and may enable formation of quantum degenerate molecular matter by evaporative cooling. However, collisions between trapped, naturally occurring molecules have so far eluded direct observation due to the low collision rates of dilute samples. We report the first directly observed collisions between cold, trapped molecules, achieved without the need of laser cooling. We magnetically capture molecular oxygen in a 0.8K x kB deep superconducting trap, and set bounds on the ratio between the elastic and inelastic scattering rates, the key parameter determining the feasibility of evaporative cooling. We further co-trap and identify collisions between atoms and molecules, paving the way to studies of cold interspecies collisions in a magnetic trap.