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1. Polyatomic molecules in an ultracold gas

Polyatomic molecules in an ultracold gas are of interest for application in quantum information devices, in investigations into nonequilibrium dynamics, and as supersensitive sensors. However, some difficulties arise on the way to obtaining such molecules. For example, the use of Feshbach resonance [1] allowed creating weakly bound triatomic NaK_2 molecules at a temperature of 100 nK, but for larger molecules collisional losses destroy resonance. X-Y Chen (Max Planck Institute of Quantum Optics and Munich Center for Quantum Science and Technology, Germany) et al. have demonstrated a new method for obtaining tetratomic $(NaK)_2$ molecules in an ultracold gas through electro-association of smaller polar $(NaK)_2$ molecules [2]. Microwave-induced scattering resonance was used to bind NaK pairs. The bond between the components in $(NaK)_2$ is much weaker than ordinary chemical bonds, but it acts over distances hundreds of times greater. About 10^3 molecules of $(NaK)_2$ were obtained at a temperature of 134 nK, which is 3000 times lower than the temperature at which tetratomic molecules were obtained previously. And the lifetime of the molecules was ≈ 8 ms both in the free state and in the optical trap, which demonstrated their resistance to collisions. The measurements performed during dissociation of molecules showed anisotropy of their wave function, coincident with the expected anisotropy for the p-wave structure of molecules.

2. Second sound in a Fermi gas

While in ordinary substances heat is transported by diffusion, in a superfluid liquid heat can propagate as waves in the form of a 'second sound' generated by an out-of-phase motion of the normal and superfluid components. Although second sound has already been recorded in experiments, its wavelike motion has not been directly observed. Z Yan and his co-authors (Massachusetts Institute of Technology, USA) have demonstrated a new method of local temperature measurement in a Fermi gas and observed for the first time second sound propagation in space [3]. The method is based on temperature sensitivity of the spectral response of molecules. Depending on the temperature of degenerate gas, the spectral maximum in the radio frequency range has different positions corresponding to different ratios of the number of fermion pairs to unpaired atoms. This effect allowed measuring the local temperature and directly observing the wavelike heat propagation typical of second sound. For second sound in superfluid helium, see [4].

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3. Magnetic reconnection and plasmoids

Reconnection of magnetic field lines is an important factor in cosmic plasma and in laboratory experiments. Under reconnection, the field changes its topology and releases magnetic energy. In the contemporary theoretical description of this phenomenon, the classical Sweet-Parker model is supplemented with the formation of magnetic islands, called plasmoids. This causes enhancement of the rate of reconnection and energy release. J A Pearcy (Massachusetts Institute of Technology, USA) and his co-authors have performed an experiment [5] to observe for the first time plasmoids in laser-driven plasma with a large thermal-to-magnetic pressure ratio $\beta \sim 10$. A plastic foil was exposed to laser pulses, and when it evaporated, two intersecting plasma bubbles appeared. In the bubbles, a magnetic field was generated by the Biermann battery mechanism (due to shifted temperature and density gradients). In this magnetic field, magnetic reconnection occurred and was observed using proton radiography. Plasmoids predicted by the theoretical model were seen in the plasma structure. For magnetic reconnection, see [6, 7].

4. Primordial black holes as dark matter

Thirteen microlensing events in the direction of the Large Magellanic Cloud — a satellite of our Galaxy — have already been detected by the MACHO and EROS (EROS-2) collaborations. Microlensing is a gravitational focusing and star light amplification by objects on the line of sight. One hypothesis suggests that the discovered objects are primordial black holes (PBHs), whose possible birth in the early Universe was substantiated by Ya B Zel'dovich and I D Novikov [8] in 1966. However, calculations based on a flat curve of galactic rotation showed that the observed microlensing objects can amount to no more than $\sim 10\%$ of the total dark matter (DM) mass. Recently, observations of millions of stars with the Gaia telescope have led to obtaining new data [9] that will possibly entail revision of the previous notions of the Galactic structure. According to these data, the total DM halo mass is several times less than previously thought, and the rotation curve is not flat but bends downward at distances of more than 20 kpc from the center of the Galaxy. Based on the data obtained, J Garcia-Bellido (Autonomous University of Madrid, Spain) and M Hawkins (University of Edinburg, United Kingdom) have constructed a 4-component model of the Galaxy, including a bulge, a stellar disc, a gaseous halo, and a dark halo, and reconsidered the previous constraints on PBHs [10]. The constraints in the new Galaxy model turn out to be significantly weakened, and the PBH, if responsible for microlensing, can even constitute all the DM in the Galaxy. An exception is the region of their masses near $\sim 0.01 M_{\odot}$, where the PBH may be no more than $\sim 20\%$ or $\sim 12\%$ according to MACHO or EROS-2, respectively. If this conclusion is correct, then the status of PBHs as a possible candidate for the role of DM is significantly strengthened.

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