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1. Bose–Einstein condensate in space

D C Aveline (Jet Propulsion Laboratory — JPL, USA) and co-authors have obtained Bose–Einstein condensate for the first time under microgravity aboard the International Space Station [1]. Bose–Einstein condensate is the name of atoms-bosons with zero energy accumulated at low temperatures. In ground-based experiments, the studies of condensate are hampered by the gravitational force. To compensate, experiments have been conducted in falling setups, as well as on airplanes and suborbital rockets. But optimal conditions exist in Earth's orbit. In the compact device brought to the ISS in 2018, ^{87}Rb atoms undergo evaporative cooling in an atomic trap and are transferred to the required initial state. After cooling, the trap potential is off and light absorption on an expanding atomic cloud is registered. These observations showed that thrice as many atoms were transferred to the condensate state than in the same ground-based device, and the free-expansion time of the cloud reached a record value of ~ 1 s. The main obstacle on Earth was the gravitational field, whereas in space the residual forces acting on the condensate are due to the quadratic Zeeman effect. Bose–Einstein condensate is planned to be used in studies of fundamental effects in in-orbit studies of quantum mechanics and General Relativity. For Bose–Einstein condensates (see [2–5]) and for experiments in conditions of microgravity (see [6]).

2. Molecular motor

O Groning (Swiss Federal Laboratories for Materials Science and Technology and Federal Polytechnic School of Lausanne, Switzerland) and colleagues have demonstrated in their experiment [7] a continuous molecule rotation under the action of the quantum tunneling effect. In the 'molecular motor' devised by them, the rotating rotor was a solitary C_2H_2 molecule and the immobile starter was a cluster of three Pd atoms on the surface of a PdGa crystal with a broken rotational symmetry. The motor was less than 1 nm in size and consisted of only 16 atoms. Through the needle in a scanning tunneling microscope, the electrons were tunneled to a molecule, thus causing a constant-velocity molecule rotation in one direction. The motion in the opposite direction was blocked by the crystal atoms, similar to the action of a ratchet gear. The unidirectionality of rotation exceeded 97%, which is a record value for molecular motors designed hitherto. Rotation was observed even at temperatures below 17 K, where classical rotation is impossible, which implied the quantum character of the effect. In the future, fine effects of energy dissipation in processes with quantum tunneling will be investigated in such an experiment. For molecular motors and control over nanoparticle motion (see [8–10]).

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3. Pauli crystal

M Holten (Heidelberg University, Germany) and his colleagues have observed for the first time [11] a Pauli crystal in which an ordered arrangement of atoms was due to their fermion nature, even without the participation of actual interaction forces. An ultracold ^{6}Li gas was placed in a quasi-two-dimensional optical trap with harmonic potential along the radius. In the transverse direction, the atoms could move freely, interacting with one another like fermions. The other residual interactions were compensated by Feshbach resonance. The observation of atoms was carried out using their fluorescent radiation at the stage of free expansion after the trap potential was off. Such measurements were performed thousands of times, and ordered structures were found in the momentum distribution of the atoms. They corresponded to Pauli crystals consisting of several atoms at three levels of harmonic oscillators. Also observed was Pauli crystal 'melting' owing to the additional energy transferred to it during trap potential perturbations.

4. Quantum information erasure

In 1982, M O Scully and K Druhl suggested the idea of a 'quantum eraser'. It consisted of the fact that, if in a quantum interference experiment the information on the particle trajectory is not used ('erased'), the lost interference pattern can be recovered. This scheme has already been realized in experiments with optical and microwave photons. A Bienfait (University of Chicago, USA) and co-authors have become the first to carry out the 'quantum eraser' experiment [12] with surface acoustic phonons (vibrational motion quanta). A Fabry–Pérot interferometer was used that consisted of a phonon channel on a piezoelectric surface with two superconducting qubits at the ends. The electromagnetic signals could be converted into phonons and vice versa and could be registered by qubits. The phonon paths were determined using the second phonon of a quantum entangled pair. When the path was determined, the interference was absent, but the absorption of the second phonon led to quantum information erasing and to recovering the interference pattern. The low phonon velocity allowed these measurements to be performed in accordance with the scheme of the experiment with Wheeler's delayed choice, when the decision of erasing is made only after the interference. For the key points of quantum mechanics (see [13, 14]).

5. Census of 'lost baryons' using fast radio bursts

The properties of relic radiation and the theory of primordial nucleosynthesis imply that most ordinary baryon matter in the Universe does not emit light and is therefore invisible. J-P Macquart (International Center for Radio Astronomy Research, Australia) and colleagues have developed [15] a new method of recording so-called 'lost baryons' through the observation of fast radio bursts with a good localization in the sky. The localization allows the host galaxies of the bursts to be identified and their red shifts to be thus determined. Since the dispersion measure of fast radio burst depends on the number of electrons along the line of sight, the total amount of ionized gas can be found from the dispersion measure and the red shift of the source. Using the data on several fast radio bursts, the authors determined the cosmological baryon density parameter $\Omega_{\mathrm{b}} \simeq 0.051^{+0.021}_{-0.025}$. Thus, the new independent method confirmed that the greater part of 'lost baryons' are actually contained in ionized hydrogen clouds in intergalactic space. For fast radio bursts (see [16]), and on the observation of gas in the Universe (see [17]).

References

1. Aveline D C et al. *Nature* **582** 193 (2020); https://doi.org/10.1038/s41586-020-2346-1
2. Kadomtsev B B, Kadomtsev M B *Phys. Usp.* **40** 623 (1997); Kadomtsev B B, Kadomtsev M B *Usp. Fiz. Nauk* **167** 649 (1997)
3. Pitaevskii L P *Phys. Usp.* **49** 333 (2006); Pitaevskii L P *Usp. Fiz. Nauk* **176** 345 (2006)
4. Kagan M Yu, Turlapov A V *Phys. Usp.* **62** 215 (2019); Kagan M Yu, Turlapov A V *Usp. Fiz. Nauk* **189** 225 (2019)
5. Isaev T A *Phys. Usp.* **63** 289 (2020); Isaev T A *Usp. Fiz. Nauk* **190** 313 (2020)
6. Fortov V E et al. *Phys. Usp.* **47** 447 (2004); Fortov V E et al. *Usp. Fiz. Nauk* **174** 495 (2004)
7. Stolza S et al. *PNAS*, online publication 15 June 2020; https://doi.org/10.1073/pnas.1918654117
8. Romanovsky Yu M, Tikhonov A N *Phys. Usp.* **53** 893 (2010); Romanovsky Yu M, Tikhonov A N *Usp. Fiz. Nauk* **180** 931 (2010)
9. Rozenbaum V M, Shapochkina I V, Trakhtenberg L I *Phys. Usp.* **62** 496 (2019); Rozenbaum V M, Shapochkina I V, Trakhtenberg L I *Usp. Fiz. Nauk* **189** 529 (2019)
10. Gulyaev Yu V et al. *Phys. Usp.* **63** 311 (2020); Gulyaev Yu V et al. *Usp. Fiz. Nauk* **190** 337 (2020)
11. Holten M et al., https://arxiv.org/abs/2005.03929
12. Bienfait A et al. *Phys. Rev.* X **10** 021055 (2020); https://doi.org/10.1103/PhysRevX.10.021055
13. Kadomtsev B B *Phys. Usp.* **37** 425 (1994); Kadomtsev B B *Usp. Fiz. Nauk* **164** 449 (1994)
14. Zheltikov A M, Scully M O *Phys. Usp.* **63** 698 (2020); Zheltikov A M, Skully M O *Usp. Fiz. Nauk* **190** 749 (2020)
15. Macquart J-P et al. *Nature* **581** 391 (2020); https://arxiv.org/abs/2005.13161
16. Popov S B, Postnov K A, Pshirkov M S *Phys. Usp.* **61** 965 (2018); Popov S B Postnov K A, Pshirkov M S *Usp. Fiz. Nauk* **188** 1063 (2018)
17. Shchekinov Yu A et al. *Phys. Usp.* **60** 961 (2017); *Usp. Fiz. Nauk* **187** 1033 (2017)