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1. Search for relic neutrinos in KATRIN experiment

Our Universe is filled with neutrino ν gas that remains from early cosmological epochs. It has been impossible to register this relic ν because of its low energy and concentration. Nevertheless, the search for new detection methods and a design of next-generation neutrino telescopes to register these neutrinos is under way. Currently available detectors would be able to register relic ν if near our Galaxy their density and their number increased for a not yet clear reason by many orders of magnitude compared to the average cosmological concentration. Such an increase, although no more than $\eta = 1.2-20$ times, must actually take place due to gravitation. The new search for relic ν was undertaken using the KATRIN detector aimed mainly at measuring the ν mass [1]. The KATRIN experiment, with the participation of Russian researchers from the Institute for Nuclear Research, is a larger-scale version of the Troitsk nu-mass experiment, which was performed under the guidance of academician V M Lobashev [2]. In KATRIN, the spectrum of electrons from the beta-decay of tritium nuclei $^3H \to {}^3H^+ + e^- + \bar{\nu}_e$ is measured using a silicon detector and electrostatic filtration, and the ν mass is determined from spectrum specific features near the maximum energy determined by the decay kinematics [3]. To date, the constraint $m_\nu < 0.8$ eV has been obtained. Relic ν must with some probability be captured by tritium nuclei, excite them, and thus affect the beta-decay spectrum. In the 2019 KATRIN observations, such an effect was not revealed with the currently available precision, suggesting the conclusion that $\eta < 9.7 \times 10^{10}$. This constraint is several times better than those obtained earlier in the Los Alamos and Troitsk experiments.

2. Relativistic particles in the Bohm interpretation of quantum mechanics

The concepts of a pilot wave and real particle trajectories are introduced in the nonlocal Bohm interpretation of quantum mechanics (in the de Broglie–Bohm theory) [4]. The predictions of probabilistic the Copenhagen and deterministic Bohm interpretations are consistent for nonrelativistic particles. However, the Bohm interpretation could not earlier be extended to the relativistic case. A conclusion was drawn about the impossibility of introducing in that case the concept of the photon as a particle. J Foo (University of Queensland, Australia) and his co-authors have developed a new approach, considering relativistic particles with the help of weak quantum measurements [5]. The authors managed to construct a Bohm velocity field having a relativistic form of dispersion and the velocity addition rule. It is also of importance that the developed theory has a usual nonrelativistic limit for low particle velocities.

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3. Rotation of deuterium molecules in helium nanodroplets

J Qiang (East China Normal University) and their co-authors have investigated the rotation of D_2 molecules inside superfluid helium nanodroplets [6]. Nanodroplets consisting of ~ 2000 atoms were formed through helium ejection from a nozzle and were doped with ^{4}He molecules. Rotational degrees of freedom of D_2 molecules were excited by laser pulses, and after some time they were ionized and dissociated. The momentum distribution of the D_2 ions produced was measured at the output. The obtained spectrum has shown that HeD^+ were in the superposition of rotational quantum states. The D_2 molecules made over 500 revolutions inside the nanodroplets. That is, the lifetime of a rotational level with $J = 2$ exceeds 100 ps — almost as it is for free molecules in a gaseous medium. Thus, a rotating molecule experiences almost no resistance, similarly to macroscopic bodies in a superfluid liquid.

4. Vortices in an electron liquid

In some systems, electrons can interact with one another more strongly than with a crystal lattice and behave as a viscous liquid. However, it is only the laminar motion of electron liquid (in graphene and WTe_2) that was earlier directly observed. A Aharon-Steinberg (Weizmann Institute, Israel) et al. have become the first to directly observe turbulent vortices in a hydrodynamic electron flow [7]. The research tool was a superconducting contact (SQID) assembled on a needle at a distance of 50 nm from the examined sample surface. This device measured the magnetic field generated by an electron flow. Vortices were observed in an ultrapure Weyl semimetal WTe_2 in the form of a current-conducting strip between two semicircles. A whirl-like electron motion occurred for a small isthmus size. The pulse diffusion length measured by the vortex stability diagram turned out to be 30 times smaller that given theoretically.

5. First observations with the James Webb Space Telescope

The James Webb Space Telescope working in the IR range was launched on December 25, 2021 and was located at the Lagrange point L_2 at a distance of 1.5 mln km from Earth. The telescope has a segmented mirror 6.5 m in diameter, a shield, and a low detector temperature of 7 K (low intrinsic noise). The James Webb Space Telescope excels all IR telescopes in the effective combination of light sensitivity and resolution. Among its scientific tasks is the investigation of exoplanets in our Galaxy and early galaxies in the late epoch of the 'Dark Ages'. The optical radiation of these galaxies is shifted towards the IR range owing to the cosmological redshift. The first full-value (not test) scientific data were obtained on July 12, 2022 after calibration and tuning of the telescope [8]. Images of galaxies that had undergone gravitational lensing on massive galactic clusters were obtained. Among them is a galaxy with low metallicity and a small dust content, which was observed only 286 mln years after the Big Bang ($z \simeq 14.3$). An unexpected result was the fact that, at redshifts $z = 3-6$, disc galaxies made up half of all the galaxies [9]. This is larger by an order of magnitude than follows from previous estimates and may indicate that a coalescence of galaxies played a smaller role in their evolution than was considered before. An image of the compact group of interacting galaxies — Stephan's Quintet — was obtained. A photo of the Carina Nebula with young stars was taken. Of interest is also the image of a planetary nebula 0.5 light years in diameter and consisting of several shells. The spectrum of the star with the exoplanet WASP-96 b was measured. Its atmosphere contains water gas and clouds. Further observations with the James Webb Space Telescope may give valuable information on the Universe's evolution and even change some conventional views.

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