PHYSICS NEWS

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1. Interaction of solar neutrinos with ^{13}C

A flux of boric neutrinos ν_e from the Sun has already been registered in experiments in the channel of neutral currents and also by elastic scattering. Interactions of solar boric ν_e with ^{13}C nuclei have been recorded for the first time by the underground SNO+ detector (Sudbury, Canada) in the charged current channel [1]. The detector contains 800 tons of liquid scintillator viewed by 9000 photomultipliers. Electrons and positrons from successive $^{13}C + \nu_e \rightarrow$ $^{13}N + e^-$ and $^{13}N \rightarrow ^{13}C + e^+ + \nu_e$ reactions were singled out by the coincidence method. The registration is significant up to 4.2σ, and the measured cross section of the ν_e interaction with ^{13}C with the formation of ^{13}N at the ground energy level corresponds to theoretical calculations. The obtained results are completely consistent with the standard model of the Sun with allowance for neutrino oscillations. The interaction between Earth-origin ν_e and ^{13}C has already been analyzed in the KARMEN experiment (Karlsruhe, Germany) but for much higher energies and totally for all the levels of the ^{13}N nucleus.

2. Einstein–Bohr experiment with movable slit

In the 1927 debates between Albert Einstein and Niels Bohr, an idea was born to supplement the interferential double-slit experiment with an additional movable slit. Then, the scattered photon momentum might be measured by movable slit recoil momentum. Such a thought scheme could not be reproduced earlier. Y.-C. Zhang (University of Science and Technology of China) and his co-authors have become the first to conduct an experiment fully realizing the Einstein–Bohr idea [2]. The role of a movable photon-scattering slit was played by a single ^{87}Rb atom trapped by optical tweezers. The atom was cooled by the Raman scattering method in a lateral band, and the uncertainty of its momentum in the ground state was comparable to the single photon momentum, which is inadmissible for macroscopic objects. Upon weakening of the atom fixation force in the trap, the single photon behavior changes from wave to corpuscular. This confirmed Bohr's explanation: when measuring momentum,

the information on slit position is lost, and the interference pattern smears out. According to the authors of paper [2], in future experiments of this kind, an increase in the mass of an object which is a mobile slit will make it possible to analyze the interrelation between decoherence and quantum entanglement.

3. Superion Fe–C alloy at high pressures

Y. Huang (Sichuan University, China) et al. have examined an iron-carbon alloy under conditions close to those in Earth's inner core [3]. Upon collision at a velocity of $7\ \text{km s}^{-1}$ of a shell onto an iron-carbon sample, a pressure of 140 GPa and a temperature of 2600 K were reached. The measurements showed that the hexagonal closely packed Fe–C (carbon mass fraction of $\sim 1.5\%$) alloy appearing under these conditions has a superion (intermediate between liquid and a solid crystal) character, where carbon atoms can flow relative to the iron, the shear wave velocity V_s is lower by 23% than in pure iron, and the Poisson ratio has a high value $\mu \sim 0.43$. A superion Fe–C alloy with such characteristics was theoretically proposed earlier to explain the data of seismic observations of Earth's inner core. Thus, the experiment [3] yields a weighty confirmation of the superion model. Earth's core mainly consists of an iron-nickel alloy with an impurity of C, O, and H. The diffusion of light elements through iron in a superion alloy is important for understanding the state and dynamics of Earth's core, in particular, the moving mechanisms of geodynamo — the magnetic field generation.

4. Realization of Letokhov–Chebotaev spectroscopic method

One of the main problems in the spectroscopy of atoms and molecules is the Doppler frequency shift due to particle motion [4]. To solve this problem, for example, two-photon transitions in the field of colliding laser beams are applied. The method for weakening the influence of the Doppler effect through capture of molecules has been applied. In their papers [5, 6], Letokhov and Chebotaev have developed a method for weakening the influence of the Doppler effect through capture of molecules in an electromagnetic standing-wave field in a cavity. The particle must either have a low absolute velocity or move at a very small angle to the wave front. This method was demonstrated by W. Ubachs (Free University Amsterdam, Netherlands) and their co-authors for H_2 molecules in the cavity [7]. Optical heterodyne spectroscopy was used to examine a weak quadrupole overtone transition S(0)(2-0) in H_2. The measured transition width was four orders of magnitude less than the Doppler broadening, which shows a successful realization of the

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Letokhov–Chebotaev method. The demonstrated effect of 1D trapping of molecules may become a part of the instruments of precision molecular spectroscopy.

5. New cosmological observations

A refined value of the Hubble constant $H_0 = 73.7 \pm 0.06 \,(\text{stat.}) \pm 1.1 \,(\text{syst.}) \,\text{km s}^{-1} \,\text{Mpc}^{-1}$ has been obtained using the DESI (Dark Energy Spectroscopic Instrument) spectrograph on the 4-meter telescope of the Kitt Peak National Observatory (USA) [8]. This value was found from observations of peculiar galactic velocity with the use of the Tully–Fisher relation and the so-called fundamental galactic plane together with redshift measurements. Measurements of distances to galaxies makes it possible to distinguish between the contribution of peculiar velocities and the cosmological Universe expansion. Although the normalization is performed using Ia supernovae, the measurement results are largely independent of other methods of determining H_0. Another independent method is observation of strong gravitational lensing with time lag measurements. The TDCOSMO-2025 collaboration investigated eight lensed quasars using stellar velocity dispersion data in lens galaxies, allowing the density profile to be reconstructed [9]. The obtained value $H_0 = 71.6^{+3.9}_{-3.3} \,\text{km s}^{-1} \,\text{Mpc}^{-1}$ is consistent with other H_0 measurements at the error level. The gravitational lensing method may reach an accuracy of 1% in the future, which will help clarify a number of fundamental effects in cosmology, such as the 'Hubble tension' (the discrepancy among H_0 measurements for processes in the early and modern Universe).

6. Sunyaev–Zeldovich effect and hot gas in galaxy protocluster

In their theoretical papers [10–12], R.A. Sunyaev and Ya.B. Zeldovich predicted the effect of a change in the intensity of relic radiation upon its scattering by electrons of the hot cosmic medium, with a soft photon transfer to the high frequency range. As a result, in the direction of the cluster of galaxies containing a hot gas, the relic radiation brightness must lower. This effect is reliably confirmed in observations and, moreover, the examination of the hot gas of clusters by the Sunyaev–Zeldovich effect become comparable in precision to the best X-ray measurements of the characteristics of this gas [13]. With the help of the world's largest submillimeter and millimeter telescope-interferometer ALMA (Atacama Large Millimeter/submillimeter Array), D. Zhou (University of British Columbia, Canada) et al. have performed a new observation of relic radiation, which passed through the young galactic cluster SPT2349-56 at redshift $z = 4.3$ [14]. Such a far cluster is accessible for examination because the 'shadow' spectra in the background of relic radiation in the direction to objects with a hot gas do not depend on the redshift, as was shown in the fundamental work of R.A. Sunyaev and Ya.B. Zeldovich. The ALMA telescope includes 66 fully steerable antennas with cryogen bolometers located at an altitude of 5000 km in the Chilean Atacama Desert. The forming cluster (protocluster) SPT2349-56 contains 33 galaxies, including three with active nuclei. The total thermal gas energy in the cluster, measured by the Sunyaev–Zeldovich effect, turned out to be about an order of magnitude higher than might be the energy of gravitational compression heating and thus occurring shock waves. The authors of paper [13] suppose that the gas was additionally heated by radiation of active galactic nuclei, although this issue has not yet been completely clarified. As has been shown by the recent discovery of an excess of early galaxies by the James Webb Space Telescope, the formation of the Universe's structure possibly proceeds not as was thought before. The described result, obtained from observations of the thermal Sunyaev–Zeldovich effect, may be of importance to solve this and other enigmas of the early Universe.

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