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1. Neutrino mass

Observation of neutrino oscillations shows that the neutrino ν has a mass m_ν. Although the differences among the mass squared of different ν mass states are measured with increasing accuracy [1], the absolute scale of m_ν is still unknown. Cosmology and experiments searching for neutrinoless double β decay only give an indirect limit on the sum of ν masses. A direct way of measuring m_ν is an analysis of β decay near the kinematic endpoint of the energy spectrum using a high-resolution spectrometer [2, 3]. Such measurements have been carried out at the Institute for Nuclear Research RAS (INR RAS) under the guidance of V M Lobashev and in an experiment in Mainz (Germany) and were continued in the international KATRIN experiment (Germany) with the participation of researchers from INR RAS. The KATRIN collaboration presented the results of recording 36 million electrons from the decays $T_2 \to {}^3\mathrm{He}\,T^+ + e^- + \bar{\nu}_e$ [4]. The limit on the mass of the electron $\bar{\nu}$ was a factor of two better than the previous result and is now $m_\nu < 0.45$ eV. Measuring m_ν is important for clarifying fundamental issues in elementary particle physics. The neutrino is approximately six orders of magnitude lighter than other fermions, which may point to a new mass generation mechanism including sterile ν.

2. Solar neutrino detection in experiments searching for dark matter (DM) particles

Several underground laboratories are currently searching for DM (hidden Universe mass) particles by the effect of their possible scattering by atomic nuclei. However, in the same experiments, ν, born in the Sun and in other sources, must experience an elastic coherent scattering by the nuclei [5]. These ν create a background, called a 'neutrino fog,' which has not been detected earlier. Z Bo (Shanghai Jiao Tong University, China) et al. have reported that they managed to register for the first time the 'neutrino fog' in the PandaX-4T experiment performed in the China Jinping underground laboratory [6]. The PandaX-4T detector contains 3.7 tonnes of liquid xenon and is designed for searching for DM particles. The measured flux of ν that experienced an elastic coherent scattering by Xe nuclei is consistent with the 2.6σ significance with the expected flux of solar ν born in reactions with ^{8}B nuclei in the pp-cycle. A similar result with a statistical significance of 2.7σ was also obtained in the XENONnT experiment at the Gran Sasso National Laboratory (Italy). Although DM detectors were not initially intended for ν detection, the possibility of such recording opens new useful channels for investigation.

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3. Cluster structure of $GaTa_4Se_8$

The lacunar spinel $GaTa_4Se_8$ is interesting in that it has properties of a Mott insulator at room temperature and becomes a superconductor at 5.8 K, its superconductivity being perhaps of an exotic topological character. M Magnaterra (University of Cologne, Germany) and his co-authors used the method of resonant inelastic X-ray scattering at a thallium boundary to prove that $GaTa_4Se_8$ has a cluster quasi-molecular structure [7]. The electrons in it are delocalized over the Ta_4 tetrahedron, forming quasi-molecular spin-orbital $J_{\mathrm{tet}} = 3/2$ moments. The intracluster interactions mix the electron orbitals, reducing the effective constant of spin-orbital coupling by one third. Owing to mixing, the cluster wave function is sensitive to structural changes caused, for instance, by external pressure or chemical substitution. This property of $GaTa_4Se_8$ and other compounds of this family may find useful technical applications.

4. Quantum Mpemba effect

The Mpemba effect, observed in several experiments, is a situation when an initially hotter system cools faster than a cold system. Colloidal systems have also shown an inverse Mpemba effect, with faster heating from a colder initial state. Quantum analogs of the Mpemba effect, which are due to quantum entanglement and fluctuations, were considered theoretically. A group of researchers from the Weizmann Institute (Israel) has demonstrated for the first time the inverse quantum Mpemba effect for a single qubit on the basis of an $^{88}Sr^+$ ion in a thermal photon bath [8]. The ion with a higher degree of coherence underwent decoherence (heated up) and restored balance with the surroundings faster than the one with a lower initial coherence. Moreover, a cold qubit could heat up exponentially faster than a warm qubit, thus demonstrating a strong version of the Mpemba effect. The direct quantum Mpemba effect was also discovered in a chain of 12 ions in another experiment [9] examining the time of symmetry restoration under a more or less strong initial deviation from the symmetric state.

5. Cygnus X-3

The X-ray source Cygnus X-3 has attracted great attention for nearly 50 years already owing to its unusual properties, in particular, powerful bursts in the radio range and gamma-ray

emission [10]. The source is presumably a binary system consisting of a Wolf–Rayet star and a compact object (a black hole or a neutron star) at a distance of $\simeq 9.7$ kpc from Earth. In IXPE (Imaging X-ray Polarimetry Explorer) observations, a polarization of X-rays from Cygnus X-3 has been revealed for the first time [11] and the radiation mechanism has been clarified. During an active X-ray phase within the range of 2–8 keV, the degree of linear polarization reaches $20.6 \pm 0.3\%$, it is orthogonal to the direction of radio emission, and, at 3.5–6 keV, it is almost energy-independent. These properties are indicative of the X-ray flux collimation with a half-angle of $\leqslant 15^\circ$, determined, probably, by a funnel in an optically thick medium. In the polarization signal, the part of the accretion disc radiation reflected from the funnel internal region is dominant. Collimation testifies, in turn, to gas accretion in the supercritical regime, when the radiation flux exceeds the Eddington limit. With allowance for the value of the opening angle, the object luminosity in the range of 2–8 keV makes up $\geqslant 5.5 \times 10^{39}$ rg s^{-1} and, thus, Cygnus X-3 may be attributed to the class of ultraluminous X-ray sources.

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