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1. Search for neutrinoless double-beta decay

Some atomic nuclei undergo double-beta decay when two neutrons in the nucleus simultaneously decay into two protons, two electrons, and two antineutrinos. However, also discussed is the hypothetic possibility of double-beta decay without the emission of neutrinos. The presence of such a decay would mean nonconservation of the lepton number, which is forbidden in the Standard Model, but is predicted in its extensions. The neutrino must then be a Majorana fermion, i.e., its own antiparticle. Neutrinoless double-beta decay is being sought, in particular, in the CUORE experiment at the National Gran Sasso Laboratory (Italy), where an array of low-temperature TeO_2 crystals is used. Thermal bursts due to $^{130}Te \to {}^{130}Xe$ decays are being sought. Neutrinoless double-beta decay has not been revealed at the current level of precision, and a lower bound has been obtained on the decay half-life: $T_{1/2} > 1.5 \times 10^{25}$ years. This limit is comparable to the limit $T_{1/2} > 5.3 \times 10^{25}$ years obtained earlier for ^{76}Ge nuclei in the GERDA low-background experiment performed at Gran Sasso with the participation of Russian scientists.

Source: https://arXiv.org/abs/1710.07988

2. Electronic topological Lifshits transition in $YbAl_3$

Using angle-resolved photoemission spectroscopy, S Chatterjee (Cornell University, USA) and his colleagues have discovered that valence-bond structure fluctuations [transitions between two valence configurations $Yb^{2+}(4f^{14})$ and $Yb^{3+}(4f^{13})$] due to the interaction between localized and itinerant electrons appear in a thin $YbAl_3$ film upon temperature or pressure variations. The results of measurements were compared with calculations by the density functional method with allowance for relativistic effects and spin–orbit interaction. The fluctuations were found to lead to variation of the Fermi surface topology, which corresponds to phase transition of the order of $2\frac{1}{2}$ ('Lifshits transition'), which was considered theoretically by I M Lifshits in 1960. For the Fermi surface geometry, see the paper by M I Kaganov and I M Lifshits in *Physics–Uspekhi* **22** 904 (1979) [*Usp. Fiz. Nauk* **129** 487 (1979)].

Source: *Nature Communications* **8** 852 (2017)
https://doi.org/10.1038/s41467-017-00946-1

3. Fraction of atoms in Bose–Einstein condensate

R Lopes (University of Cambridge, Great Britain) and his colleagues have become the first to confirm experimentally what was theoretically predicted by N N Bogolubov in 1947 [N Bogolubov *Journal of Physics* Vol. XI, No. 1, p. 23 (1947) (see https://ufn.ru/dates/pdf/j_phys_ussr/j_phys_usser_1947_11_1/3_bogolubov_j_phys_ussr_1947_11_1_23.pdf); *Usp. Fiz. Nauk* **93** 564 (1967)] about the fraction of interacting Bose atoms that go over to the composition of Bose–Einstein condensate. The momentum distribution of ^{39}K atoms and their fraction in the condensate were measured via two-photon Bragg scattering after the atomic trap potential was switched off. Measurements were performed for different magnitudes of the pair interaction of atoms, regulated with the aid of Feshbach resonance. The results were well consistent with the Bogoliubov theory.

Source: *Phys. Rev. Lett.* **119** 190404 (2017)
https://arXiv.org/abs/1706.01867

4. Dzyaloshinskii–Moriya interaction in dielectrics

The Dzyaloshinskii–Moriya interaction in the form of a vector product of atomic spins occurs when symmetry under reflection is locally violated in a crystal. The capability to control this interaction is of importance for future applications in spintronics. This kind of control as applied to metal alloys has already been demonstrated. G Beutier (Grenoble Alpes University, France) and colleagues have observed the Dzyaloshinskii–Moriya interaction in $MnCO_3$, $FeBO_3$, $CoCO_3$, and $NiCO_3$ ferromagnets, which are dielectrics. The Dzyaloshinskii–Moriya interaction occurs in them due to oxygen layer structure twisting. Phase-sensitive X-ray magnetic diffraction was employed in the study, which gave a good quantitative correlation with 'first principles' calculations, reproducing both the sign and magnitude of the Dzyaloshinskii–Moriya interaction. Russian scientists from MSU, UrFU (Ekaterinburg), and the A V Shubnikov Institute of Crystallography affiliated with FSRC Crystallography and Photonics RAS (Moscow) took part in the research.

Source: *Phys. Rev. Lett.* **119** 167201 (2017)
https://doi.org/10.1103/PhysRevLett.119.167201

5. Muon radiography

K Morishima (Nagoya University, Japan) and his colleagues have used the muon radiography method to discover a 30-m long chamber in the Great Pyramid of Khufu (Cheops). The muons produced in the atmosphere by cosmic rays are able to pass through a thick layer of matter, and hence the registration of muons makes it possible to reveal inner inhomogeneities (similar to X-ray photos), which is important for distant investigation of mines, volcanoes, and other objects. The pyramid was studied using nuclear photoemulsion films exposed in chambers inside the pyramid for several months. The density distribution in the pyramid was retrieved and a new void found based on the muon track positions in the films. These results were then confirmed by scintillation and gas detectors. The idea of employing cosmic rays in

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geological survey was first put forward by P P Lazarev (the founder and the first Editor-in-Chief of our journal) in 1926 and was widely developed in practice in the USSR and abroad. At the present time, this method is being revived using nuclear photoemulsions in Russia by researchers from FIAN and SINP MSU (see the article on page 1277 in the present issue of *Physics–Uspekhi*).

Source: *Nature*, online publication of November 2, 2017
https://arXiv.org/abs/1711.01576

6. Gamma-ray halo around pulsars

The PAMELA cosmic detector has recently discovered an excess of positrons e^+ with energies > 10 GeV. As a possible explanation, along with dark matter particle annihilation, the emission of e^+ by nearby pulsars was considered. A U Abeysekara (University of Utah, USA) and colleagues have investigated the extended halos of gamma-ray emission with an energy of 8–40 TeV around pulsars Geminga and PSR B0656 + 14 using the HAWC Cherenkov telescope and considered the hypothesis that these halos are produced by the same e^+ flows as those that give the e^+ excess observed on Earth. The gamma-ray emission might have been generated by the emitted e^- and e^+ particles during their inverse Compton scattering by background photons. However, the observed gamma-ray emission spectrum turned out to be incompatible with this model, for many more e^+ are registered than might reach Earth, and the shape of the calculated energy spectrum of e^+ (a peak) differs from the observed power-law spectrum. Thus, the excess positrons cannot have been emitted by the indicated pulsars and must be of another origin.

Source: *Science* **358** 911 (2017)
https://arXiv.org/abs/1711.06223

Compiled by *Yu N Eroshenko*
(e-mail: erosh@ufn.ru)