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1. Coherent neutrino–nucleus scattering

The international collaboration COHERENT, also including Russian researchers from ITEP, MEPhI, and MIPT, has performed an experiment in the Oak Ridge National Laboratory (USA) wherein coherent neutrino–nucleus scattering was registered for the first time. Under the coherent scattering theoretically predicted by D Z Freedman in 1974, low-energy neutrinos interact simultaneously with all nucleons in the nucleus, because the interaction-carrying Z boson has the de Broglie wavelength exceeding the nucleus size. Although the coherent scattering cross section proportional to the square of the number of neutrons in the nucleus is large compared to the scattering cross section by individual nucleons, the coherent scattering could not be registered earlier because of low-energy recoil nuclei. The detector used in the COHERENT experiment only contained 14.6 kg of the low-background scintillator CsI[Na] (sodium-doped cesium iodide). The detector was placed in a deep cellar with a low background from both neutrons and cosmic rays, and was exposed to neutrinos produced in the interaction between proton pulses from the accelerator and a mercury target. Coherent scattering was registered at a confidence level of 6.7σ. Owing to the compactness of the detector, the method applied to register coherent neutrino–nucleus scattering can find practical application in nuclear reactor monitoring.

Source: *Science* **357** 1123 (2017)
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2. Mechanism of structureless phase transition in $(TMTTF)_2PF_6$

S Kitou (Nagoya University, Japan) and his colleagues have applied the synchrotron X-ray diffraction method to clarify for the first time the mechanism of phase transition in an organic molecular conductor $(TMTTF)_2PF_6$ near the temperature of 67 K, when the crystal moves from the state of Mott isolator to the charge-ordered state and then to the Peierls spin phase. Since no changes in the crystal structure were observed earlier under these conditions, this transition was called structureless. In spite of 40 years of research, the mechanism of this transition remained unknown. In the new experiment, a synchrotron X-ray source was used for the structural analysis. The intrinsic electron coupling of atoms in molecules and the coupling with surrounding molecules were characterized by the inverse Fourier analysis. The study gave evidence that the phase transition links to the formation of a two-dimensional Wigner crystal, to a change in the bond length, and to a $0.20e$ charge transfer between two neighboring TMTTF molecules in a dimer.

Source: *Phys. Rev. Lett.* **119** 065701 (2017)
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Translated by M V Tsaplina

3. Magnesium rechargeable batteries with a nanostructured cathode

The first prototype of magnesium-based rechargeable batteries was demonstrated by D Aurbach and his colleagues in 2000. These batteries are safer than and not as expensive as lithium ones, but are lower than them in capacity. H D Yoo (University of Houston, USA) and his colleagues modified the magnesium rechargeable battery by using another electrolyte and an improved nanostructured cathode. This time, instead of the former Mg^{2+}, the role of charge carriers was played by $MgCl^-$ ions. For the battery to function, no Mg–Cl bond breaking is needed, unlike what was earlier necessary for Mg^{2+} release, which resulted in the energy barrier lowering in chemical reactions from 3 eV to 0.8 eV. The new cathode was coated with titanium disulfide (TiS_2) and the distance between TiS_2 layers was increased from 5.69 to 10.86 Å through implantation (intercalation) of organic molecules. This made the penetration of $MgCl^-$ ions in the cathode much easier and speeded up their diffusion. As a result, the capacity of the magnesium battery was raised fourfold to 400 mA h g^{-1}. The capacity increase is also accompanied by a good productivity upon recharging.

Source: *Nature Commun.* **8** 339 (2017)
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4. Interatomic Coulomb decay

In some high-energy processes, so-called 'hole atoms' appear in which electrons find themselves on highly excited external orbitals, the low-lying energy levels being unoccupied. It is known that in interactions with surrounding matter hole atoms are able to transfer to the ground state within several femtoseconds, but the mechanism of fast energy effluence by the electrons remained unclear. R A Wilhelm (Institute of Applied Physics, Austria and the Institute of Ion Beam Physics and Materials Research, Germany) and colleagues have revealed that this mechanism reduces to the 'interatomic Coulomb decay' during which the electrons of a hole atom interact simultaneously with several neighboring atoms. The experiment was performed with multiply charged Ar^{16+} and Xe^{30+} ions flying through a graphene layer. At a distance of several Å from the graphene surface, the ions entrap electrons from it and are partially neutralized. The entrapped electrons have high energies, and therefore they find themselves predominantly at the high-lying levels. The flight of the 'hole atoms' thus produced through a graphene layer takes ~ 1 fs, but within this time the electrons manage to move to the inner orbitals. The outlet electrons were registered by an electrostatic analyzer. A comparison of the results of the present study with *ab initio* calculations showed that the interatomic Coulomb decay is responsible for the energy effluence effect in this case, whereas other mechanisms make a negligible contribution. Interatomic Coulomb decay can also take place in biological tissues upon atomic deexcitation induced by ionizing radiation.

Source: *Phys. Rev. Lett.* **119** 103401 (2017)
https://doi.org/10.1103/PhysRevLett.119.103401

5. Magnetic field in a distant galaxy

S A Mao (Max Planck Institute for Radio Astronomy) and his colleagues have measured the magnetic field in a galaxy as distant as 4.6 billion light years. The galaxy emission was observed in the frequency band of 1–8 GHz by VLA radio telescopes in New Mexico. It comprises a strong gravitational lens producing two images of a distant quasar. A model of electron density distribution in the galaxy was developed and the difference between Faraday rotations of polarization planes in the two images was measured. The measurement of the difference helped rule out the influence of background fields on the line of sight. Using these data, the magnitude of the large-scale magnetic field in the galaxy was found to be on the order of several μG. In its magnitude and configuration, the field in the distant galaxy is similar to the field in our Galaxy and in other nearby galaxies. This is indicative of the fact that strong magnetic fields appeared in galaxies earlier than previously believed. The mechanism of magnetic field origination in the early Universe has not yet been definitely clarified, but a magnetic dynamo in moving plasma offers a universal mechanism of their strengthening to high values. The observed magnetic field characteristics in the investigated galaxy are quite consistent with the dynamo theory.

Source: *Nature Astronomy* **1** 621 (2017)
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