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1. Spiral spin-liquid

S Gao (Paul Scherrer Institute and University of Geneva, Switzerland) and colleagues have applied the diffuse neutron scattering and neutron diffraction methods to unambiguously demonstrate for the first time the presence of a new type of spiral state, the spiral spin-liquid, in an $MnSc_2S_4$ crystal, i.e., a vortex-like distribution of neighboring atomic spins. The existence of such structures was theoretically predicted in 2007 by L Balents (University of California at Santa Barbara, USA) and colleagues. The neutron scattering by $MnSc_2S_4$ crystals revealed correlations typical of a spiral spin-liquid in spin distribution in the form of a spiral surface. These experimental data are well reproduced in the model with a $J_1 - J_2$ Hamiltonian. Some evidence of the existence of spiral spin-liquids had been obtained before but at a lower confidence level than in the new work by S Gao et al.

Source: *Nature Physics*, online-publication of 24.10.2016
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2. Photoionization on attosecond scale

M Ossiander (Max Planck Institute of Quantum Optics, Germany) and his colleagues have become the first to observe helium atom photoionization with a time resolution of less than an attosecond (1 as $= 10^{-18}$ s) exposed to laser pulses in the extreme UV range. After leaving the atoms, the electrons were scattered by subsequent laser pulses and were registered by an electron spectrometer. The electron ionization dynamics were retrieved by their spectrum with a resolution up to 0.85 as. Either a single electron participates in the ionization process, or two electrons at the intermediate stage move to the excited state. Important at the latter case are many-electron interaction effects, i.e., electron correlations. The propagation of the wave packet of the escaping electron in the field of the atomic nucleus was reconstructed from the experimental data. The measured ionization characteristics are in good agreement with the results of the solution of the Schrödinger equation for the helium atom. The electron was found to escape 4 to 6 as before passage of the laser pulse maximum. Thus, the exact time reading of the atomic ionization process is established.

Source: *Nature Physics*, online publication of 07.11.2016
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3. Ultrafast Fano resonance

Fano resonance (the interference of two wave processes) was predicted theoretically to emerge in helium atom ionization owing to the presence of two channels of ionization. Either one electron immediately leaves the helium atom, or two electrons first move to 2s2p, a correlated two-electron excited state, and then one of the electrons transfers the energy to the second electron (owing to the Coulomb interaction) and leaves the atom (the process is called autoionization). These two cases are indistinguishable in their final result, and therefore they undergo quantum interference, a so-called Fano resonance. A Kaldun (Max Planck Institute for Nuclear Physics, Germany) and colleagues observed this resonance with the aid of absorption spectroscopy — the absorption of laser radiation by helium atoms. At first, the helium atoms were exposed to laser pulses in the extreme UV range and were excited, and then after a short time lag the atoms were irradiated by a strong ($\sim 10^{13}$ W cm^{-2}) IR pulse. When the time lag was sufficiently long, the Fano resonance was clearly pronounced because of interference with the direct (one-electron) ionization channel, which showed up in the characteristic asymmetric Fano line shape in the UV radiation absorption. On the contrary, if the time lag was short, the second pulse immediately caused atomic ionization, which resulted in Fano resonance breakage. The dependence of the line shape on the time lag characterized the buildup of the Fano resonance in time. Thus, this was the first successful attempt to control the Fano resonance on a time scale on the order of femtoseconds.

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4. Tracks of superheavy nuclei in meteorites

The aim of OLIMPIYA, the experiment initiated by V L Ginzburg and started by the Vernadsky Institute of Geochemistry and Analytical Chemistry in collaboration with the Lebedev Physical Institute (FIAN), is the search for and identification of the tracks of heavy and superheavy atomic nuclei in olivine crystals from stone-iron meteorite pallasites employed as natural track detectors. Heavy nuclei could have been synthesized in supernova outbursts, and if long-lived (if they belong to the so-called 'stability island' in the case of superheavy nuclei) they could have flown into the Solar System in the composition of galactic cosmic rays to leave tracks in meteorites. The nucleus transfers energy to the atoms producing defects in the meteorite crystal lattice in the shape of an extended track. After chemical etching, these tracks become visible with an optical microscope. The time of exposition for meteorites — millions of years — is incomparably longer than for ordinary detectors on satellites or aerostats. It was G N Flerov who proposed that meteorites be used as natural cosmic ray detectors, and the first studies of this kind were carried out at JINR (Dubna). As distinct from previous studies, in the OLIMPIYA experiments it is not only the track length L that is measured but also the etching velocity V_{etch} along the tracks without the preliminary thermal annealing that typically results in unpredictable L variations. With the help of a series of exposures to fast ions at the Darmstadt heavy-ion accelerator and the IMP accelerator

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(China), the dependence of the nuclear charge Z on L and V_{etch} was calibrated. Marjalahti and Eagle Station meteorites were explored. In layer-by-layer scanning, the tracks of nuclei were found with the help of the PAVICOM automated measuring facility designed at FIAN under the guidance of N G Polukhina. As a result, the charge spectrum of nuclei with $Z > 40$ in the cosmic ray composition was measured on the basis of 11,647 processed tracks. 384 nuclei with charges $Z > 75$, including ten nuclei-actinoids with $90 < Z < 103$, were identified. Three nuclei with charges $Z = 119^{+10}_{-6}$ were also identified. These nuclei might belong to the stability island. Such superheavy nuclei cannot now be technologically obtained in ground-based accelerators. Researchers from MISiS, MEPhI, the Kurchatov Institute, and JINR and their colleagues from China and Germany took part in the OLIMPIA experiment. (See also *Usp. Fiz. Nauk* **180** 839 (2010) [*Phys. Usp.* **53** 805 (2010)].)

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