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1. Pear-shaped atomic nuclei

L P Gaffney (University of Liverpool, UK) and his colleagues have reliably demonstrated for the first time that radon and radium nuclei in response to perturbations may take the shape of a pear, which corresponds to the octupole distribution of nucleons inside the nucleus. Nonspherical nuclei have been studied comprehensively in many experiments, but in most cases these were elongated ellipsoids or oblate ellipsoids of revolution, i.e., they showed quadrupole distribution of nucleons; only weak ambiguous indications were obtained in the past concerning lop-sided pear-shaped nuclei. In this new experiment, ^{220}Rn and ^{224}Ra nuclei were born in collisions of a beam of protons with a uranium carbide target at the REX-ISOLDE facility at CERN. After further acceleration, these nuclei flew through layers of nickel, cadmium, or tin. In the course of Coulomb interactions with nuclei in these layers, some of the ^{220}Rn and ^{224}Ra nuclei would undergo excitation. Reverse transitions would cause emission of gamma photons in such a way that pear-shaped nuclei revealed additional transitions between rotational levels of unequal parity. It was this characteristic spectrum of gamma emission that provided the evidence that the excited nuclei had an octupole distribution of nucleons. The octupole nuclear deformation occurred either statically for a long time (in the case of ^{224}Ra), or the oscillating nuclei would periodically become pear-shaped (^{220}Rn). The study of pear-shaped nuclei is important not only for the verification of theoretical models of the atomic nucleus, but also for searching for effects outside the Standard Model of elementary particles, since in the case of octupole distribution of nucleons the electric dipole moment of nuclei might be enhanced by two-to-three orders of magnitude. The nuclear electric dipole moment has not been detected so far, but the very fact of its absence at the achieved level of accuracy has already imposed constraints on possible extensions of the Standard Model.

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2. Quantum Hong–Ou–Mandel effect for microwave photons

The quantum Hong–Ou–Mandel effect consists in the following: when nearly indistinguishable photons from two sources pass simultaneously through a light splitter, these photons are detected in pairs on one side of the optical splitter much more frequently than severally. This effect is implied by the Bose statistics of photons and cannot be explained in terms of classical (nonquantum) physics. In the past, the Hong–Ou–Mandel effect was only observed in experiments with laser photons in the optical range. A Wallraff (ETH in Zurich, Switzerland) and his colleagues are the first to detect the Hong–Ou–Mandel effect for photons of microwave radiation. In their experiment, photons in single-photon Fock states were emitted by two generators built around transmon qubits. By smoothly varying the phase difference between the generators, it was possible to make the states of the photons more or less similar and to identify the instant of time when the Hong–Ou–Mandel effect set in. The splitter was made of intersecting microwave waveguides, while the photons were detected by measuring the correlation functions of the electromagnetic field at the outputs of the two waveguides after splitting. Owing to the possibility of controling the microwave generators, the Hong–Ou–Mandel effect was examined in better detail than in optical experiments. The quantum properties of microwave photons may find application in quantum communication devices.

Source: *Nature Physics*, online publication of May 5, 2013
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3. Uniform Bose–Einstein condensate

Typically, the Bose–Einstein condensate of atoms is created in a trap with harmonic potential, in which the density of the condensate increases towards the center. However, it would be preferable in a number of applications to work with a uniform condensate. In the past, a condensate that is uniform in one direction only was created only in quasi-one-dimensional linear or toroidal traps. A group of researchers at the Cavendish Laboratory, Cambridge University (UK) were able for the first time to produce a uniform condensate of rubidium atoms in a three-dimensional trap. The trap was prepared by three laser beams: a hollow cylindrical beam and two flat beams intersecting the cylindrical one. After initial evaporative cooling, the potential inside the trap was made flat and the gravitational field was compensated for by applying a constant-gradient magnetic field. As a result, a uniform Bose–Einstein condensate was created in the trap. The observation of the condensate was run both in real time, by the absorption method, and at the stage of free expansion of the atomic cloud once the trap potential was turned off. In contrast to the case of a harmonic potential, the transition to the condensate state was not accompanied by spatial separation of the components and sharp visible changes. At the same time, the momentum distribution of atoms, measured at the expansion stage, exhibited a bimodal anisotropic shape which corresponded to the flat potential lacking spherical symmetry.

Source: *Phys. Rev. Lett.* **110** 200406 (2013)
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4. Gamma horizon

Alberto Dominguez (University of California, Riverside, USA) and his colleagues recorded for the first time and with high statistical significance the attenuation effect of gamma-ray emission from blazars (active galaxies with jets directed at

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Earth) owing to the creation of e^+e^- pairs in the interaction between γ photons and extragalactic background light (EBL). It had not been possible until recently to achieve reliable recording of the gamma horizon in view of the low statistics of blazar observations and uncertainties in spectra. The new work is largely free of these factors, because of the method applied. Dominguez and his co-workers observed simultaneously 15 blazars in a wide spectral range from radio waves to gamma rays. The data on gamma radiation were obtained from the Fermi Gamma-ray Space Telescope and the low-threshold atmospheric Cherenkov detectors. The universal model of synchrotron Compton radiation with self-absorption that was used to simulate the initial spectrum predicted the evolution of the spectrum with sufficient reliability, thanks to normalization at different frequencies. It was therefore possible for the first time to identify the cosmic gamma ray horizon in the observational data at redshifts $z \leqslant 1$. For instance, it was found to be $E_0 \sim 10-30$ TeV at low $z \sim 0.01$, and then to decrease by approximately two orders of magnitude at $z \approx 1$.

Source: http://arXiv.org/abs/1305.2162

5. MASTER-II network of robotic optical telescopes

This report presents the observational results obtained by the Russian network of robotic optical telescopes, MASTER-II (mobile astronomical network of robotic optical telescopes) built by V M Lipunov (Sternberg State Astronomical Institute, MSU) and his colleagues. The Russian segment of the network was installed and began regular operations at the end of 2010. The network is composed of nine optical telescopes that cover the skies from the European part of Russia to the Far East. The most important result of the MASTER-II network was the discovery of hundreds of optical transients (315 by May 2013). Among them the astronomers found optical afterglow of cosmic gamma-ray bursts, nova and supernova stars, flashes in quasars and in lacertids (emission in relativistic plasmas in the vicinity of supermassive black holes), and other optical objects with short lifetimes. Searching for optical afterglow from gamma bursts is the main task of the MASTER-II networks. Telescopes are capable of rapid automatic focusing on sky areas defined with known coordinates sent from space gamma telescopes. Photometric measurements of light curves from optical binaries of gamma bursts were carried out, sometimes for two polarizations at the same time. At the moment, MASTER-II is completing a record-high number of first recordings of afterglow events among robotic networks. Two types of bursts were distinguished in observations by the MASTER-II networks: with synchronous and with independent variations of signals in the soft and hard parts of the spectrum. MASTER-II observed 387 cosmological supernovas, with 111 of them being examined for the first time. Network expansion and its employment in searching for smallish asteroids and warning about their dangerous approaches to Earth have also been contemplated.

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