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1. High-energy neutrinos

The IceCube Collaboration reported on the registration of two neutrino-induced events with a record-high estimated deposited energy in the IceCube neutrino detector of about 1 PeV $= 10^{15}$ eV at a 2.8σ confidence level. IceCube is composed of 5160 Cherenkov detectors in a volume of about 1 km^3 deep in the Antarctic ice at a depth of about 1450–2450 m. These detected events, which created cascades of particles in the ice, can be explained in terms of both the interaction of neutrinos $\nu_{e,\mu,\tau}$ (or antineutrinos) with nuclei via weak neutral currents and by the interaction between ν_e ($\bar{\nu}_e$) via charged currents. The task of recording high-energy neutrinos is facilitated by the fact that cosmic rays create very few background events in the atmosphere at energies $\geqslant 1$ PeV. In addition, muon events from the upper hemisphere were excluded and only events caused by neutrinos that have passed through Earth were taken into account. In fact, therefore, the probability of having two or more background events in the data obtained was only 2.9×10^{-3}. If the two recorded events were actually caused by neutrinos of astrophysical origin, their sources could, for example, be cosmic gamma-ray bursts or processes in active galactic nuclei.

Source: *Phys. Rev. Lett.* **111** 021103 (2013)
http://arXiv.org/abs/1304.5356

2. Van der Waals forces between Rydberg atoms

L Béguin (Charles Fabry Laboratory of Institut d'Optique, France) and his four co-workers have become the first to measure the van der Waals interaction between two atoms occupying highly excited Rydberg states. Dipole–dipole interactions between Rydberg atoms (via van der Waals forces) are much stronger than in atoms residing in the ground state. In the past, van der Waals forces were measured by indirect methods in a large variety of experiments. For example, the attraction of macroscopic bodies and the frequency shift of the atomic vibrations in diatomic molecules with a van der Waals bond were measured, and the interaction of Rydberg atoms with the surface of a conductor were worked on. In the new experiment, two atoms of rubidium were captured into traps created by focused laser beams at a controlled distance (from 3 to 20 μm). A focusing aspherical lens collected at the same time photons emitted by the atoms. Atomic exposure to resonant laser pulses caused oscillations between the ground and Rydberg states of the two-atom quantum system, and the Rabi frequency Ω of these oscillations was perturbed by interactions between atoms. The experiment was carried out in a partial Rydberg blockade mode, where the energy of the van der Waals interaction was comparable to the energy of oscillations: $U_{\mathrm{vdW}} \sim \hbar\Omega$. The probability of finding the atoms in the ground and Rydberg states depending on the distance between atoms and the laser pulse length was measured by recording the photons emitted by the atoms. The curve $U_{\mathrm{vdW}}(r) \propto r^{-6}$ obtained from this data fits quite well the theoretical *ab initio* calculations. The experiment is also of interest due to the fact that it proved possible to sustain the coherence of a pair of Rydberg atoms. This holds promise for the creation of quantum logic gates based on such pairs in the future.

Source: *Phys. Rev. Lett.* **110** 263201 (2013)
http://arXiv.org/abs/1302.4262

3. Structure of the energy gap in $CeCoIn_5$

J C Davis (Brookhaven National Laboratory and Cornell University, USA) and his colleagues have investigated the structure of the energy gap in the heavy fermion superconductor $CeCoIn_5$. It is assumed that the mechanism of Cooper pairing in these compounds is dictated by spin fluctuations, although further research is needed to fully clarify the mechanism of superconductivity. The gap structure $\Delta(\mathbf{k})$ in momentum space was studied in the experiment in terms of the interference of quasiparticles (i.e., of Bogoliubov quasiparticle interference imaging). The electrons of the split Cooper pairs went through the interference on the impurities; the standing electron waves arising from this were recorded using a scanning tunneling microscope. This technique made it possible to identify very small variations of gap energy as a function of direction. It was found that the gap is oriented in the crystal direction along the Ce–Ce bonds and possesses $d_{x^2-y^2}$ symmetry. The shape of the Fermi surface and the structure of the energy levels were also measured, including the region of splitting of the level with low effective mass to the hybridized levels of heavy fermions.

Source: *Nature Physics* **9** 468 (2013)
http://dx.doi.org/10.1038/nphys2671

4. Photocatalyst TiO_2

We know that rutile and anatase, the polymorphic crystalline modifications of titanium dioxide (TiO_2), are the most widely used oxides for photocatalysts — when illuminated, they efficiently split water molecules (i.e., perform photolysis) on their surface. In 1972, it was discovered that specimens with a mixture of two modifications possess significantly better catalyst properties than pure rutile and pure anatase severally. It was assumed that this behavior is caused by the relative shift of the valence bands in rutile and anatase, even though there was no unequivocal experimental confirmation. D O Scanion (University College, Kathleen Lonsdale Materials Chemistry, United Kingdom) and his colleagues performed a new experiment and carried out computer

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modeling of the structure of TiO_2, which confirmed quite reliably the differences in energy levels. The heterostructure composed of rutile and anatase layers was studied with the aid of an X-ray photoemission technique. It turned out that the anatase valence band is resided 0.4 eV lower than the rutile valence band. These observations point to an electron flux from rutile to anatase under photoexcitation. It may be that this arrangement of valence bands results in a considerable improvement in the photocatalytic properties of the mixed crystal.

Source: *Nature Materials* **12** 798 (2013)
http://dx.doi.org/10.1038/nmat3697

5. Extragalactic radio bursts

D Thornton et al., astronomers at the 64-meter Parkes Radio Telescope (Australia), have discovered in a recent survey for pulsars and fast transients a new population of cosmological radio emission bursts lasting ~ 1 ms and reaching a spectral flux density of 0.4–1.3 Jy. A similar powerful burst had already been recorded in 2007 (the Kerry Lorimer burst), whose origin remains unknown. Four more bursts from the directions $\geqslant 40^\circ$ over the galactic disk were then recorded. The strong dispersion of the signals could only develop if they arrived from the distances of 1.7–3.2 Gpc (from sources at $z = 0.45$–0.96) as a result of interaction between radio waves and cosmic plasma, since dispersion in the rarefied plasma of the Galaxy at high galactic latitudes is insufficient for the formation of the observed spectra. In connection with this, a conclusion of the cosmological origin of bursts is made. The number of such radio bursts per day from all directions is predicted as $\sim 10^4$ if the result is extrapolated to the entire celestial sphere. No repeated or overlapping events have been found yet in other wavebands. Although the origin of these radio bursts remains unclear, high-energy processes close to black holes or neutron stars have been suggested as possible sources.

Source: *Science* **341** 53 (2013)
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