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1. Superconductivity of H_2S at a temperature of 203 K under pressure

M I Eremets (Max Planck Institute of Chemistry, Germany) and colleagues have reported the discovery of conventional superconductivity [described by the Bardeen–Cooper–Schrieffer (BCS) theory] of hydrogen sulfide (H_2S) at a record superconducting transition temperature $T_c = 203$ K and a pressure of 150 GPa. A previous record temperature $T_c = 164$ K had been observed for cuprates under high pressure, while for conventional superconductors (MgB_2) T_c had not exceeded 39 K. The BCS theory does not limit T_c and suggests how to increase it: a higher phonon oscillation frequency, a strong electron–phonon coupling, and a high density of electron states are needed. These factors must be best of all pronounced in metallic hydrogen or hydrogen compounds. In this experiment, an H_2S sample was first examined for $P > 100$ GPa. It was compressed in a diamond anvil, where the pressure was controlled by the Raman spectrum. Superconductivity was registered both by the electric resistance drop and on the basis of the Meissner effect in a magnetic field. The observed effect of an isotopic T_c shift in D_2S is indicative of the BCS mechanism of superconductivity. The authors of the experiment believe that H_2S decomposes under pressure and is partially transformed into H_3S, which is the carrier of superconductivity. The temperature $T_c = 203$ K ($-70\,^{\circ}$C) already exceeds the natural temperatures observed on Earth, and there is hope to discover room-temperature superconductivity in the future (for more details, see V L Ginzburg in *UFN* **170** 619 (2000), **175** 187 (2005); *Phys. Usp.* **43** 573 (2000), **48** 173 (2005)).

Source: *Nature* **525** 73 (2015);
http://arXiv.org/abs/1506.08190

2. Zero quantum fluctuations of a mechanical resonator

An experiment conducted under the guidance of K C Schwab (California Institute of Technology, USA) has demonstrated the method of 'squeezing' zero quantum fluctuations of a mechanical system, when the magnitude of fluctuations of one variable $\hat{X}_1$ describing the system is lowered at the expense of increasing fluctuations of the second conjugate variable $\hat{X}_2$ (in the Wigner diagram, this looks like squeezing a circle into an ellipse). The root-mean-square fluctuations of two noncommuting variables cannot be diminished simultaneously because of the quantum-mechanical uncertainty principle. A micrometer-sized aluminum plate had a resonance frequency $\nu_m = 3.6$ MHz of mechanical oscillations and constituted one of the capacitor plates of the oscillatory circuit with resonance frequency $\nu_c = 6.23$ GHz, which allowed triggering the parametric resonance. Quantum variables were the coefficients in the plate coordinate decomposition $\hat{x} = \hat{X}_1 \cos(\omega_m t) + \hat{X}_2 \sin(\omega_m t)$. Quantum fluctuations were squeezed by the action of an additional electromagnetic field on the plate at frequencies $\nu_c \pm \nu_m$, the action being stronger at the lower frequency. The amplitude-frequency characteristic of the circuit near the resonance was analyzed. The measurements showed that the fluctuations were squeezed by about 9%. This technique may appear to be useful in the design of ultrasensitive sensors for gravitational wave detectors for which quantum restrictions following from the uncertainty principle are of paramount importance.

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3. Quantum squeezing under resonance fluorescence

A squeezed quantum state of light is most often achieved in nonlinear crystals under highly intense laser irradiation. However, as far back as 1981, D F Walls and P Zoller proposed another way of obtaining a squeezed state by making use of resonance scattering of photons from a two-level system. This method cannot yet be realized on the levels in real atoms due to the low value of fluorescence yield. M Atature (Cambridge University, Great Britain) and colleagues have become the first to demonstrate this method of squeezing making use not of real but of 'artificial' atoms represented by the energy levels of electrons in a semiconductor quantum dot. Owing to the high intensity of dipole transitions, the photon detection rate was increased by two orders of magnitude over that in real atoms. The quantum dot was illuminated by a laser beam, and the fluorescent light was gathered by a lens and transmitted through splitters and an interferometer, which assisted in the separation of the photons from the original and fluorescent radiation. As a result, the correlation function of photons that had passed through the interferometer arms was measured and the squeeze of quantum fluctuations was recorded: one of the conjugate variables describing the electromagnetic field of a reemitted wave had a $3.1 \pm 1\%$ lower dispersion than the quantum noise level at the expense of the larger uncertainty of the other variable.

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4. Radon and thoron as predecessors of earthquakes

A rise in the concentration of radon isotope ^{222}Rn in the air is sometimes associated with approaching earthquakes, but this correlation is not rigorous: radon ejections and earthquakes occur most often independently, and therefore it is not usually possible to forecast earthquakes based on ^{222}Rn. Researchers from Seoul National University (Republic of Korea), Y H Oh and G Kim, have shown that a clearer dependence can be established by simultaneously measuring ^{222}Rn and thoron ^{220}Rn concentrations. ^{220}Rn and ^{222}Rn were monitored in a cave in South Korea for 13 months with the help of silicon detectors of α particles. In February of 2011, a strong simultaneous ejection of ^{220}Rn and ^{222}Rn was detected, which cannot be explained by ordinary weather or seasonal variations. This ejection preceded the 9.0-magnitude earthquake in Japan on 11 March, 2011 at a distance of 1200 km from the detector — such a large distance can be explained by an overall shift of the tectonic plate. Strong ejections of ^{222}Rn, but without ^{220}Rn, were also detected in the summer of 2010; however, no earthquake then followed. In the course of diffusion through rock microcracks, ^{222}Rn, whose half-life $T_{1/2} = 3.82$ days, can emerge on the surface. On the contrary, because of the small half-life $T_{1/2} = 55.6$ s, ^{220}Rn does not have enough time to reach the detector through diffusion, but is rather transported by advection air flows. In the researchers' opinion, this is the reason for the lower sensitivity of ^{220}Rn concentration to meteorological conditions, and a higher sensitivity to earthquake-preceding geological events. Thus, detection of a pair of radon–thoron isotopes may provide a good tool for earthquake prognosis provided a corresponding network of underground detectors is set up.

Source: *Scientific Reports* **5** 13084 (2015)
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5. A bright supernova and an ultralong gamma-ray burst

A class of bursts lasting longer than 10^4 s is distinguished among cosmic gamma-ray bursts. It was assumed that some of them may be due to supernova explosions, but such supernovae had not been observed before. J Greiner (Max Planck Institute for Extraterrestrial Physics and Technical University of Münich, Germany) and colleagues have first revealed a rather convincing linkage between supernova 2011kl and the ultralong burst GRB 111209A which occurred at the red shift $z = 0.677$. After the GRB 111209A burst, a high-power afterglow related to supernova 2011kl was observed for approximately 43 days. Its luminosity could not be due to ^{56}Ni decay, because too large a mass of ejected ^{56}Ni would be needed. This can be explained by the model in which extra energy is transferred by the magneto-rotational mechanism from a strongly magnetized neutron star — a magnetar — produced in an explosion. Magnetar models had already been discussed earlier, but the most comprehensive and self-consistent picture was obtained in surveying the case of GRB 111209A and 2011kl.

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