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Physics news on the Internet (based on electronic preprints)

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1. Two-proton decay

Researchers at the Universita di Catania and Istituto Nazionale di Fisica Nucleare (Italy) obtained for the first time unambiguous data proving the existence of two-proton decay. They studied collisions of a beam of ^{20}Ne nuclei with a beryllium foil. Some of these excited ^{20}Ne nuclei lost two neutrons in collisions and transformed into ^{18}Ne nuclei, which then fragmented upon collision with a lead target. This decay happened with a 31% probability through the diproton resonance, when a nucleus ejected a bound pair of protons which can be regarded as a short-lived ^{2}He isotope that rapidly decays into two individual protons. The formation of ^{2}He was established unambiguously by analyzing the kinematics of the processes, the energies of nuclear fragments, and the correlations between the trajectories of ejected protons. Earlier experiments had already established the simultaneous ejection of two protons but there was no exact evidence of these two first forming a bound state.

Sources: *Phys. Rev. Lett.* **100** 192503 (2008)
http://dx.doi.org/10.1103/PhysRevLett.100.192503

2. Quasiparticles with a charge of $e/4$

M Dolev, V Umansky, and their colleagues at the Weizmann Institute of Science in Israel observed for the first time quasiparticles (collective electronic excitations) with a charge that is a simple fraction with an even denominator, namely, 1/4 in units of electron charge e. Only quasiparticles with charges of 1/3, 1/5, etc. had been observed earlier. The object of study was highly purified gallium arsenide sample placed in a magnetic field at a temperature of about 1 K. Electrons in the semiconductor moved in two-dimensional layers and their collective excitations effectively behaved as quasiparticles with a fractional charge of 1/4. There were five electrons per magnetic flux quantum $h/2e$. The quasiparticle charge was measured from the characteristics of fluctuations of electric current. As followed from theoretical predictions, quasiparticles with even denominators in the fractional charge possess properties different from those of quasiparticles with odd denominators. In particular, quasiparticles with one quarter the charge of an electron can be used to create a 'topographical quantum computer' that might be powerful, yet highly stable.

Source: http://arXiv.org/abs/0802.09309

3. Bose glass

One usually assumes that the Bose – Einstein condensate of quasiparticles and the superfluidity of matter corresponding to it occur at the same temperature. However, K Shirahama and his coworkers at Keio University in Tokyo (Japan) discovered that these phenomena may arise on the nanometer scale at different temperatures. They studied nanosized helium-4 confined in a nano-structure composed of porous material with a pore diameter of about 2.5 nm. The transition to the Bose – Einstein condensate state was detected by monitoring the heat capacity of helium-4, while superfluidity manifested itself by a drop in the moment of inertia and hence by a change in the period of torsional vibrations of the sample. The temperature dependence of heat capacity is adequately described by a model in which phonons and rotons are excited in helium-4. It was discovered that the temperature of transition to the Bose – Einstein condensate is considerably higher than the superfluid transition temperature. It is possible that this experiment examined for the first time the state of the so-called 'Bose glass' whose properties have been predicted in theoretical papers and stem from the disordered nature of the small-scale structure of the sample. Hypotheses have been advanced that a state of a similar type may exist in high-temperature superconductors. This discovery may also find practical applications for the creation of quantum interference devices.

Source: http://arXiv.org/abs/0711.3969

4. Anderson localization in the Bose – Einstein condensate

Electrons possessing certain momenta can move freely in the periodic potential of a crystalline lattice (Bloch waves). About 50 years ago, Philip Anderson predicted theoretically that if the periodicity of this potential is disrupted, electrons will be trapped (i.e., wave functions will be localized) in the vicinity of some groups of atoms. This effect, known as Anderson localization, was observed in experiments with light and sound waves, but until recently it was impossible to observe it with massive particles. Two independent groups of researchers observed Anderson localization for the first time in Bose – Einstein condensates made from ultracold atomic gases. Alain Aspect and his colleagues at the University of Paris-Sud and CNRS's Institut d'Optique in France studied the condensate of rubidium atoms flying freely apart from the center of a magnetic trap after the magnetic field is turned off. However, atoms stayed in the trap if laser beams created an irregular potential inside the trap. The irregularity was achieved by reflecting laser light from a rough surface. The researchers concluded that retention of atoms was caused by the Anderson localization. The second group of researchers led by Massimo Inguscio at the University of Florence in Italy studied the Bose – Einstein condensate of potassium atoms in a one-dimensional periodic potential (a 1D optical lattice) created by laser beams. Atoms were able to move in the course of diffusion. Irregularity was introduced by a second laser beam which interfered with the first. The intensity of the second beam was varied and when it reached a certain level,

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atomic diffusion stopped, which again was explained in terms of Anderson localization. Both groups of researchers intend to improve and extend their experimental techniques for observing Anderson localization in two- and three-dimensional systems and in the case of interacting atoms.

Sources: *Nature* **453** 891 (2008), *Nature* **453** 895 (2008)
http://dx.doi.org/10.1038/nature07000,
http://dx.doi.org/10.1038/nature07071

5. Supernova SN 2008D

Scheduled observations in January 2008 by the NASA Swift space observatory accidentally recorded an X-ray burst which proved to be the initial phase of the explosion of a supernova in the spiral galaxy NGC 2770 (redshift $z = 0.007$). Optical observations which made it possible to identify the X-ray source as a supernova were made 1.77 days after the X-ray burst. The powerful burst was probably produced during the shockwave front breaking. It is the first time that a type-Ib supernova has been observed at a very early stage of its explosion. The shape of the spectrum, the luminosity curve (evolution of luminosity with time), and spectral lines were measured in detail; this will help to better understand the physical mechanisms active during the explosion and to evaluate the statistics of such events.

Sources: *Nature* **453** 469 (2008)
http://dx.doi.org/10.1038/nature06997

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