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1. Quantization in a gravitational field

V V Nesvizhevskiĭ, of the B P Konstantinov Institute of Nuclear Physics in St. Petersburg and the Laue – Langevin Institute in Grenoble, and colleagues have performed an experiment which revealed discrete quantum states of particles in a potential well created by the gravitational field. In quantum theory the classically finite motion of a particle is quantized: an example are electron energy levels in the field of the atomic nucleus. Because under laboratory conditions gravitational interactions are far weaker than other interactions, the observation of the discrete levels required a unique technique capable of eliminating external influences. A beam of ultracold neutrons (at a velocity of 8 m s^{-1}) was directed at a shallow angle onto the plane of a horizontal mirror. The neutrons were provided by an atomic reactor. Parallel to the mirror, a neutron absorber was placed. The neutrons traversing the gap between the mirror and the absorber were recorded by a detector. The mirror together with the gravitational field created a potential well in which the vertical component of neutron motion should be quantized. In exactly the way predicted by theory, as the distance d between the mirror and absorber increased, the observed neutron flux increased in jumps rather than continuously. The first flux jump was observed at $d = 15$ μm, corresponding to the minimal energy of a neutron in the well of 1.4×10^{-12} eV. Evidence was also found for the existence of further jumps. If provided with a more powerful neutron beam, this facility could be used to test the equivalence principle — the equality of the neutron's gravitational and inertial masses, in this context.

Source: *Nature* **415** 297 (2002); www.nature.com

2. Testing special relativity

The special theory of relativity states that the speed of light c is independent of that of the observer. The independence of c of the direction of motion has been tested to high accuracy by Michelson – Morley type experiments. The independence of c of the magnitude of the observer's speed v, however, has been established with lower precision. The way it has been studied is by using the experiment H P Kennedy and E M Thorndike devised in 1932. The idea is to observe a standing electromagnetic wave in a resonator and to compare its frequency with a standard one. Now German physicists from the University of Konstanz have collaborated with their colleagues at the University of Düsseldorf to perform the most accurate experiment yet of this type. The physicists studied a standing laser wave in a sapphire cavity cooled to 4.3 K. Under such conditions, the sapphire's coefficient of thermal expansion is low. The frequency standard used was electronic transitions in iodine molecules. The observations were conducted over half a year. In this time, the velocity of the Earth changed by 60 km s^{-1} relative to an adopted preferred reference frame — for example, that of the cosmic background radiation. The experiment revealed no departure from the predictions of the special theory of relativity. For the coefficient A in the expansion $c(v)/c_0 = 1 + Av^2/c_0^2 + \ldots$ the researchers obtained a value of $A = (1.9 \pm 2.1) \times 10^{-5}$, a factor of 3 improvement over previous limits. The researchers hope to improve their accuracy by yet another order of magnitude in the near future.

Source: *Phys. Rev. Lett.* **88** 010401 (2002);
http://prl.aps.org

Uspekhi Fizicheskikh Nauk **172** (2) 220 (2002)
Translated by E G Strel'chenko

3. Phase transitions in atomic nuclei

A heavy atomic nucleus may be considered approximately as a drop of liquid, the motion of its protons and neutrons corresponding to a certain effective temperature ($\sim 10^{11}$ K) and pressure of nuclear matter. A collision with a high-energy particle heats the nucleus, with the result that some of its nucleons fly out: the nucleus evaporates, in a sense. Experiments at Brookhaven National Laboratory have allowed physicists for the first time to determine a 'liquid – gas' phase diagram for nuclear matter similar to that for ordinary substances. The experiment involved colliding a beam of 8-GeV pions with gold nuclei and measuring the number and size of the debris of the destroyed (evaporating) nuclei using a specially designed detector. Interestingly, the equation of state of the nucleus in the 'gaseous' phase is similar to that of an ideal gas. The phase diagram of nuclear matter may prove useful for studying nucleosynthesis in supernova explosions, during which the 'condensation' of nuclei occurs.

Source: *Physics News Update*, Number 572
http://www.aip.org/physnews/update/

4. Quantum computing

An IBM-Princeton collaboration have created a quantum logic device, a prototype of a quantum computer, which proved capable of factorizing the number 15 to the prime numbers 3 and 5 using Shor's algorithm. This is the most complicated quantum computation performed to date. The device consists of seven quantum bits which are represented by the radio-wave- and magnetic-field-controlled interacting spins of atomic nuclei.

Source: *Nature 414* 883 (2001)
http://xxx.lanl.gov/abs/quant-ph/0112176

5. X-ray sources at the center of the Galaxy

High-resolution observations of the central region of our Galaxy using the space-based X-ray Chandra telescope have revealed about 1000 X-ray sources, of which only 20 were known previously. The sources may be divided into two classes, diffuse and point-like. The former are presumed to be gas clouds heated by supernova explosions and stellar winds. Of the latter, about half may arise from distant galaxies and be their active cores projected onto the center of our Galaxy. The remaining point sources are compact objects (neutron stars, white dwarfs, or black holes) existing as components of binary star systems. The X-ray radiation is due to the matter flow from an ordinary star to the compact object.

Source: *Nature* **415** 148 (2002)
http://xxx.lanl.gov/abs/astro-ph/0201070

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