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1. Testing mass-energy equivalence directly

Einstein's best known formula $E = mc^2$ that relates the mass of a body to the energy it contains has been given a new direct test at the Laue – Langevin Institute in Grenoble, France. The test involved the study of reactions in which Si and S nuclei capture neutrons to form the respective ^{29}Si and ^{33}S isotopes. The isotope masses before and after the nuclear reaction were measured from the cyclotron frequencies of ions of the initial and final isotopes confined over a period of weeks in a Penning trap. The ion mass ratios were measured with a precision two to three orders of magnitude better than in previous experiments. After capturing neutrons, the nuclei passed to their ground states with emission of γ-rays whose frequency v and energy hv were determined by measuring the photon diffraction angles by a crystal reflection. The series of experiments performed yielded the combined result of $1 - \Delta mc^2/E = (-1.4 \pm 4.4) \times 10^{-7}$, which is 55 times the precision of similar results obtained five years ago from the annihilation of electron – positron pairs.

Source: *Nature* **438** 1096 (2005);
www.nature.com

2. Electron bubbles in superfluid helium

An electron embedded in a superfluid helium environment repels the neighboring helium atoms, making a spherical cavity around itself. The size of this 'electron bubble' is such as to minimize the total energy of the bubble, i.e., the sum of the quantized kinetic energy of the electron, the surface tension energy, and the work of the pressure forces acting in the liquid. In a number of previous experiments, bubble radii of 19 Å have been observed. Now A Ghosh and H Maris of Brown University in the USA have discovered a new, larger type of an electron bubble in liquid helium. In their experiments, electron emission from a β-radioactive source or a metal tip was directed into a cell filled with liquid helium in which a controlled-amplitude ultrasonic wave was also generated and focused onto the center. The ultrasound caused the electron bubbles to rapidly grow in size and then collapse, leading to cavitation effects which were detected by laser light scattering. The threshold ultrasound amplitude for the onset of cavitation determined the pressure in the wave and hence the size of the bubbles. In the diagram of temperature vs. critical pressure, three regions corresponding to different types of electron bubbles were observed. The first objects are the ordinary electron bubbles — those that have been observed before. The second, newly-discovered region in the diagram is interpreted in terms of electron bubbles attached to vortex filaments in the superfluid helium. The properties of bubbles near vortices have been the subject of theoretical studies, and it is known that they can grow to larger sizes due to the fact that the pressure near vortices is less than average because of the Bernoulli effect. The third unidentified electron object forms at low temperatures and has the largest threshold pressure. Its nature is not yet clear. It is hypothesized that these bubbles interact simultaneously with two vortices or, alternatively, with a single vortex line that has a circulation around it of $2h$.

Source: *Phys. Rev. Lett.* **95** 265301 (2005);
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3. Direct observation of sub-Poissonian atom number statistics in a degenerate Bose gas

Until recently, the quantum statistics of degenerate Fermi and Bose gases have only been examined by studying the macroscopic properties of the gases, but now an experiment by C S Chuu and his colleagues at the University of Texas at Astin, USA has for the first time revealed the deviation from the classical statistics by counting atoms directly. The team measured fluctuations in the number of Bose-condensed ^{87}Rb atoms held in a trap. The system under study was in the Thomas – Fermi limit, meaning that the number of atoms and the trap potential depth are related by $N \propto U_0^{5/2}$. The counting techniques used relied on either laser light absorption by atoms or the fluorescence of excited atoms, depending on whether the number of atoms exceeded or was less than a thousand, respectively. The marked instrument noise reduction the team achieved compared with previous experiments provided a sufficient counting accuracy to directly observe deviations from the Poisson fluctuation law for the number of atoms, namely $\Delta N \propto N^{1/2}$. Deviations were observed for $N < 500$. As expected theoretically, the magnitude of the fluctuations exceeds $N^{1/2}$ in correspondence with Bose – Einstein statistics.

Source: *Phys. Rev. Lett.* **95** 260403 (2005);
prl.aps.org

4. A new source of coherent radiation

A new type of coherent electromagnetic radiation source, involving a mechanism fundamentally different from that of traditional lasers and free-electron lasers, can be possibly created according to theoretical calculations and numerical simulations performed at the Lawrence Livermore National Lab and MIT. It was established that as a mechanical shock wave propagates through a dielectric crystal, its front makes the atoms at the crystal sites vibrate in phase, leading to the radiation of coherent light waves in the frequency range from one to a hundred terahertz (1 terahertz = 10^{12} Hz). Radiation generated in this way may have properties which cannot be obtained using conventional lasers. The experimental realization of this theoretical prediction is an important and interesting problem to be solved in the near future.

Source: *Phys. Rev. Lett.* **96** 013904 (2006);
prl.aps.org

5. A giant gas cloud above the Galaxy's disk plane

A giant cloud of gas appearing to be about 10,000 light-years above the plane of Milky Way and nearly 23,000 light-years from Earth has been discovered by Yu Pidopryhora [National Radio Astronomy Observatory (NRAO) and Ohio University], J Lockman (NRAO), and J Shields (Ohio University) using the NSF GBT telescope. The cloud is a million times as massive as the Sun, and the energy powering its outflow from the disk is about a hundred times as energetic as a supernova explosion. This giant gas bubble is by far the largest among other known gas clouds. Whereas the upper layers of the cloud are primarily comprised of neutral hydrogen, which is seen at a wavelength of 21 cm, its interior is likely to be filled with ionized hydrogen. The hydrogen is strongly disturbed in that there are many smaller outflows closer to the plane of the disk. The astronomers believe that the gas was initially in a cluster of young stars in one of our Galaxy's spiral arms and that it was blown from there either by supernova explosions or by intense stellar winds. In the latter case, the age of the cloud should be between 10 and 30 million years. Such gas outflows may be crucial for the evolution of galaxies because they transfer heavy chemical elements and control star formation rate, among other things.

Source: http://www.nrao.edu/pr/2006/plume/

Compiled by *Yu N Eroshenko*