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1. Charge radius of the proton

R Pohl (Max Planck Institute of Quantum Optics, Garching, Germany) and coworkers established a better value for the charge radius (the root-mean-square radius of charge distribution) of the proton using pulsed laser spectroscopy to measure the Lamb shift (energy difference between the states $2S^{F=1}_{1/2}$ and $2P^{F=2}_{3/2}$, which is dominated by purely radiative corrections) in muonic hydrogen atoms μp in which the electron of the ordinary hydrogen atom is replaced with a negative muon. The advantage of utilizing μp over ordinary atomic hydrogen lies in the fact that the muon is, on the average, 200 times heavier and correspondingly closer to the nucleus than the electron, and therefore the finite size of the nucleus has a greater effect on the wave function of the muon in the S state. As a result, it was possible to improve the accuracy of measuring the charge radius of the proton approximately tenfold. In the given experiment, the μp atoms formed in collisions of a beam of muons with a hydrogen target; in some of these collisions muons replaced electrons, forming highly excited μp atoms. Pulsed laser radiation at wavelengths around 6.01 μm induced 2S→2P transitions, and the spectrum of X-ray radiation of 2P→1S transitions was recorded using an array of 20 large-area avalanche photodiodes; the Lamb shift was calculated with high accuracy from the measured centroid position of the resonance peak in the spectrum. The charge radius was obtained by combining experimental data and quantum electrodynamics computations. Therefore, the correctness of theoretical calculations significantly affects the result. The new value of the charge radius $r_p = 0.84184 \pm 67$ fm was found to be 4% less than previously accepted. The discrepancy with previous results, which were mostly obtained using ordinary atomic hydrogen, comes to about five standard deviations. The cause of the discrepancy has not been understood so far, but it could tentatively be an unknown systematic error in measurements or an insufficient accuracy of theoretical computations.

Source: *Nature* **466** 213 (2010)
http://dx.doi.org/10.1038/nature09250

2. Photoemission delay in neon atoms

M Schultze (Ludwig-Maximilians-Universität, Garching, Germany) and his colleagues measured the delay time between acts of ejection of electrons from 2p and 2s electron orbitals in a neon atom caused by ultrashort light pulses. The measured interval amounted to $(21 \pm 5) \times 10^{-18}$ s — the shortest time observed in nature to date. The experiment was carried out by illuminating neon atoms with synchronized IR (lasting less than 4 fs) and UV (lasting less than 200 as) laser pulses causing photoemission of electrons, and measuring the time offset of electron spectrograms relative to the initial pulses. It is usually assumed that photon absorption and electron ejection in photoemission occur simultaneously. A more accurate approach requires taking account of the finite time necessary to transform the wave function of the electron in the atom into the wave function of the ejected electron, taking into account the complicated sequence of interactions with other neighboring electrons. The durations of formation of a wave packet of the ejecting electron are different for various atomic orbitals. Theoretical calculations of many-electron interactions have not been able thus far to offer an accurate prediction of time delay in the photoemission of atoms heavier than helium — the calculated values are much shorter than the measured delay. In contrast, the photoemission cross sections in the helium atom, for which reliable calculations are possible, prove to be very small, which has made experimental verification of the time delay effect in helium atoms so far infeasible. Investigation of delays in the photoemission is important for establishing the 'time-zero' reference point in experiments studying the structure of atoms and molecules using the photoelectric effect.

Source: *Science* **328** 1658 (2010)
http://dx.doi.org/10.1126/science.1189401

3. Bose–Einstein condensate under microgravity conditions

T van Zoest (the University of Hanover) and his colleagues from Germany, France, and the UK carried out an experiment in which the Bose–Einstein condensate of rubidium atoms was created during the time of free fall of an experimental setup. A capsule with the setup was pulled up in the 146-m-high drop tower at the Center of Applied Space Technology and Microgravity of the University of Bremen. The capsule had all the necessary equipment for cooling the gas and remotely monitoring its properties. In this experiment, the residual gravitational field was less than $10^{-5}g$. During its free fall for more than a second, the gas on the atom chip formed the Bose–Einstein condensate. Then, the potential of a mirror magneto-optical trap was switched off, and the gas cloud expanded freely. The characteristics of the way the cloud spread were indicative of the physical characteristics of the degenerate gas and of the external fields affecting it. Such experiments with the Bose–Einstein condensate may prove useful for ultraprecise measurements, for instance, to test the equivalence principle. Plans for the future include adding an atom interferometer to the capsule in free fall, and in the more distant future — to conduct the experiment under conditions of weightlessness in space.

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4. Paramagnons in palladium

R Doubble (H.H. Wills Physics Laboratory, University of Bristol) and his colleagues in the UK and the US investigated spin fluctuations in palladium — a nearly ferromagnetic metal — using the inelastic neutron scattering method. Nearly ferromagnetic materials possessing no stable ferromagnetism are of interest because spin fluctuations significantly modify their bulk electronic properties. The experiment was carried out on the MARI neutron spectrometer at the Rutherford Appleton Laboratory. Dispersive overdamped collective magnetic excitations — paramagnons — were observed in palladium crystals over a wide range of energies from 25 to 128 meV. The contribution of paramagnons to the specific heat was studied and found to comprise about 30–40%, which is consistent with the observed spectrum of paramagnons.

Source: *Phys. Rev. Lett.* **105** 027207 (2010)
http://arXiv.org/abs/1005.4402

5. The asymmetry of type Ia supernova explosions

Type Ia supernovas are used as 'standard candles' in evaluating cosmological distances owing to a well-defined relationship between their maximum luminosity and decline rate in their light curve. However, there is a certain diversity in spectral properties of supernovae with respect to this function, namely, a distribution is observed in expansion velocity gradient $\dot{v}_{\mathrm{Si}}$. K Maeda (University of Tokyo, Japan) and his colleagues compared the gradient $\dot{v}_{\mathrm{Si}}$ with the expansion velocity of matter v_{neb} along the line of sight, determined from the Doppler effect, for 20 type Ia supernovae. The researchers came to the conclusion that the observed diversity is caused by the nonspherical character of thermonuclear explosions of white dwarfs. In this case, the appearance of the spectrum depends on the direction from which the explosion is viewed. A possible reason for the nonsphericity of the front of thermonuclear spark is an offset of its initial point from the center of the white dwarf because of the convective motion of matter before the explosion. An alternative scenario to an asymmetrical explosion is a collision of white dwarfs in a binary system [see *Usp. Fiz. Nauk* **180** 264 (2010) (*Phys. Usp.* **53** 325 (2010))].

Source: *Nature* **466** 82 (2010)
http://arXiv.org/abs/1006.5888

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