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Physics news on the Internet (based on electronic preprints)

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1. Direct measurement of the proton magnetic moment

A Mooser and his colleagues (University of Mainz, Germany) have measured the magnetic moment μ_p of a proton to a record precision. Before this, the most precise measurements of μ_p had been taken by an indirect method, i.e., by analyzing the hydrogen maser spectra in a magnetic field. In the new experiment, a double Penning trap was used. The spin state of the proton was measured in a region with magnetic inhomogeneity, and then the proton was moved to the part of the trap with a homogeneous magnetic field, where the cyclotron frequency of proton revolution round the trap axis and the Larmor frequency of precession under the effect of the radio-frequency field were measured. The ratio of these frequencies contains information about μ_p. A similar method has already been used earlier in measuring the magnetic moments of electrons and positrons. The measured μ_p value was found to be $\mu_p = 2.792847350(9)\mu_N$, where $\mu_N = e\hbar/(2m_p)$ is a nuclear magneton. The accuracy of this result is 760 times higher than that of earlier direct measurements in double Penning traps, and thrice as high as that using the indirect method. When such high-precision measurements are performed with antiprotons, it will become possible to check the *CPT* theorem another time, which implies equality of the magnetic moments of particles and their antiparticles.

Source: *Nature* **509** 596 (2014)
http://dx.doi.org/10.1038/nature13388

2. Verification of the equivalence principle using an atomic interferometer

D Schlippert (Wilhelm Leibniz University, Germany) and his colleagues have become the first to compare the free-fall time of atoms of two different elements, ^{39}K and ^{87}Rb, in an atomic interferometer and to confirm the equivalence principle (universality of the acceleration of gravity) to an accuracy of $\approx 10^{-7}$. Earlier, such measurements were only taken for different isotopes of one element, but the distinction in the composition of nuclei is of paramount importance for verification of the Einstein equivalence principle. In the new experiment, beams of ^{39}K and ^{87}Rb atoms began simultaneously falling in a magneto-optical trap. Upon laser light scattering, each of the beams split into two interfering beams. From the interference pattern observed through fluorescence radiation of atoms, a gravitational phase shift was obtained which depends on the gravitational accelerations g_K and g_{Rb} of ^{39}K and ^{87}Rb atoms, respectively. The Étvés parameter $\eta = 2(g_{Rb} - g_K)/(g_{Rb} + g_K)$ is restricted to the level of $\eta = (0.3 \pm 5.4) \times 10^{-7}$. The measurement data serve to verify some theories which predict violation of Einstein's equivalence principle. In atomic interferometers, quantum effects are examined and, hence, in spite of a lower accuracy, such experiments are an important supplement to the classical measurements built around torsion pendulums.

Source: *Phys. Rev. Lett.* **112** 203002 (2014)
http://dx.doi.org/10.1103/PhysRevLett.112.203002

3. Superradiation in Bose-Einstein condensate

P Engels (Washington State University, USA) and his colleagues have demonstrated in an experiment with Bose–Einstein condensate an analogue of the superradiation effect predicted by R Dicke in 1954. In the original form, this effect consists in the fact that an ensemble of atoms having two active energy levels and interacting with each other by means of the radiation field can undergo collective spontaneous transitions and radiate coherently (see the review in *Sov. Phys. Usp.* **23** 493 (1980). The superradiation effect has recently been observed in an experiment with Bose–Einstein condensate in an optical cavity. C Zhang predicted theoretically that a similar superradiation effect shows itself in the case of spin–orbit interaction in an external potential. P Engels and colleagues realized this version in the Bose–Einstein condensate of ^{87}Rb atoms. In their experiment, the linkage between the two spin states and the states of atomic motion in a trap was established with the help of Raman lasers by the 'Raman dressing' method. A cloud of atoms was observed by its light absorption at the stage of free expansion after magnetic spin separation (as in the Stern–Gerlach experiment). By measuring different cloud characteristics, including quadrupole oscillations, it was confirmed that upon a change in the magnitude of Raman coupling the condensate actually experienced phase transition to the state of superradiation, in accordance with the Dicke theory. The behavior of the atomic cloud is described by the Gross–Pitaevskii equation, and a comparison of the experimental data with calculated results showed excellent agreement.

Source: *Nature Communications* **5** 4023 (2014)
http://arXiv.org/abs/1405.2132

4. Plasmon controling in graphene

P Alonso-Gonzalez (Joint Center for Research in Nanoscience, Spain) and his co-workers have demonstrated a new method of directed plasmon generation and control in graphene utilizing dipole resonance antennas nearly 3 μm long. Plasmons in graphene (surface plasmon-polaritons) comprise bound states of photons and charges. The antennas, which were made of gold and had contact with the graphene, absorbed photons of polarized light and generated a near optical field under the effect of which plasmons were born in graphene with a wavelength a fraction the size of the antenna. The employment of such antennas for plasmon excitation is much simpler than the near-field microscope exploited earlier for the same purpose. Refraction of plasmons upon their passage through a conduction inhomo-

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geneity was investigated. This effect holds out the possibility, in principle, to control plasmons. In future optoelectronics, plasmons may become a connecting link between optical and electron signals. For optical nanoantennas, see review in *Phys. Usp.* **56** 539 (2013).

Source: *Science* **344** 1369 (2014)
http://dx.doi.org/10.1126/science.1253202

5. Magnetic field near supermassive black holes

On the basis of systematic radio emission survey of 76 galaxies by the VLBA radio telescope, researchers from the Berkeley National Laboratory (USA) and the Max Planck Institute for Astronomy (Heidelberg, Germany) have confirmed the fact that the magnetic fields near supermassive black holes in galactic nuclei are so strong that the magnetic field force acting on plasma is comparable to the gravitational attraction of black holes. Thus, the magnetic field can be an important or even decisive factor of accreting plasma dynamics in galactic nuclei. To all appearances, the magnetic fields are responsible for the formation of relativistic jets emanating from the centers of active galaxies and, therefore, magnetic field studies can proceed from the character of jet radio emission. In the work described, the calculations of the magnetic field strength were based on the data about the position of features in the map of jet radio emission at different frequencies. The results obtained agree well with the numerical accretion models worked out by A Tchekhovskoy (Berkeley Lab) and his colleagues.

Source: Berkeley Lab News Center
http://newscenter.lbl.gov/2014/06/04/black-holes/

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