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1. Two-loop QED corrections

The first measurement of two-loop corrections to the Lamb shift has been made at the Lawrence Livermore National Laboratory. The Lamb shift, i.e., the shift of electronic energy levels in an atom, is due to the interaction of electrons with virtual electron – positron pairs and photons that are produced from a vacuum. To accurately evaluate this shift requires that interactions between various types of virtual particles be taken into account which, in terms of the Feynman diagram technique, means adding higher-order (in comparison with single-loop processes) loop contributions to the probability of the processes. In the hydrogen atom, the relative two-loop correction to the Lamb shift is as small as 10^{-6}, which is beyond current measurement abilities. In the multiply ionized atoms of heavy elements, however, the strong electric field of the nucleus increases these corrections considerably. The Livermore team studied the Lamb shift in lithiumlike uranium ions that have been stripped of all but three electrons. In these ions, the corresponding corrections are already as large as about one-third of one percent of the overall effect. The measurements were made by accumulating ions in a trap and detecting the photons emitted in electronic transitions. The two-loop corrections were measured with an accuracy of about 10%, according to the Livermore physicists.

Source: *Physics News Update*, Number 756 (2005)
http://www.aip.org/pnu/2005/split/756-2.html

2. Josephson junction capacitance

Two independent teams of researchers have measured the electrical capacitance of a Josephson junction for the first time. A Josephson junction consists of two superconducting layers separated by a thin insulating layer through which Cooper pairs can tunnel without losing their superconducting properties. It has been theoretically predicted that when in electrical circuits, Josephson junctions have quantum capacitance in addition to the ordinary geometric capacitance. In both experiments, the quantum capacitance was measured in much the same way, by detecting the phase shift of a radio frequency signal in a resonant circuit containing a Josephson junction (or junctions) cooled down to several mK temperatures. The single-junction (a Cooper-pair box) experiment by P Hakonen and colleagues at Helsinki University of Technology and the Landau Institute of Theoretical Physics (Yu G Makhlin), and the two-junction (a Cooper-pair transistor containing two Josephson junctions in series) experiment by P Delsing and colleagues at Chalmers University of Technology in Sweden produced results that are in good agreement with the theoretical predictions. The Josephson junction is a promising device for storing quantum bits of information (known as qubits). The fact that quantum capacitance was measured without destroying the quantum state of the junctions makes the technique potentially useful for future quantum computer technologies.

Sources: http://prl.aps.org
Phys. Rev. Lett. **95** 206806 (2005);
Phys. Rev. Lett. **95** 206807 (2005)

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3. Pseudogap in a ferromagnet

According to the Bardeen – Cooper – Schrieffer theory of low-temperature superconductivity, the energy gap in a superconducting material is associated with the binding energy of the electron Cooper pairs. However, a similar peculiarity, known as a pseudogap, is also observed in high-temperature superconductors above the transition temperature. Zhi-Xun Shen of Stanford University and colleagues in the US, Canada, Japan and the Netherlands first found the pseudogap in the energy spectrum of the $La_{1.2}Sr_{1.8}Mn_2O_7$ manganite, a material which is not a high-temperature superconductor. The interesting point about $La_{1.2}Sr_{1.8}Mn_2O_7$ is that close to the Curie temperature it makes an abrupt transition from the ferromagnetic-metallic ground state to the paramagnetic-insulating phase. The spectrum of $La_{1.2}Sr_{1.8}Mn_2O_7$ in its ferromagnetic phase was examined at the Lawrence Berkeley National Lab using the technique known as angle-resolved photoemission spectroscopy (ARPES). Along with the pseudogap, the team observed an anisotropy in the material's spectrum in momentum space, which is another characteristic feature of a high-temperature superconductor. The observational results imply that the pseudogap is inherent not only in high-temperature superconductors but it is in fact a more general phenomenon yet to be explained theoretically.

Source: *Nature* **438** 474 (2005)
http://physicsweb.org/articles/news/9/11/14/1

4. Positronium molecules

Positronium constitutes a hydrogenlike system consisting of an electron and a positron bound together without a nucleus. A P Mills and colleagues from the University of California at Riverside may have discovered bound molecular states of positronium atoms. In their experiment, positrons traveling in a beam through porous silicon dioxide caught silicon atomic electrons to form positronium atoms which remained trapped within the pores for some time before positron – electron annihilation took place. The photons emitted in the annihilation process were registered by a detector. Under the conditions of high-density positronium gas as obtained in the experiment, frequent positronium – positronium collisions led to frequent transitions from the angular-momentum-one state to short-lived angular-momentum-zero state, thus increasing the annihilation rate. It was found that at a high density of positrons in the original beam, the annihilation rate was four times higher than predicted by theoretical consideration. One possible explanation for this is the presence of defects in the porous material in use. It is also hypothesized that when at high concentrations, positronium atoms start to interact with one another to form a short-lived bound system — a positronium molecule. Because experiments cannot as yet establish for certain which theory is correct, further investigations are needed. In the future, plans are to experiment on the creation of a Bose – Einstein condensate of positronium atoms and, possibly, to develop an electron – positron annihilation laser.

Source: *Phys. Rev. Lett.* **95** 195006 (2005); prl.aps.org

5. Laser nuclear fusion

A new test experiment for a fusion technology based on the use of powerful ultraviolet laser beams has been performed at the Lawrence Livermore National Laboratory in California on the National Ignition Facility (NIF). In this experiment, light from four existing NIF laser beams (from 192 laser beams planned for full operation in 2009) was passed through a hole into a sphere whose inner surface was covered with gold. The resulting heating caused the gold to emit powerful X-ray radiation which was focused to the center of the sphere. For the present, the researchers have only been concerned with the device's X-ray production capability and focusing properties. Future plans are to obtain a 100-fold increase in laser power and to place a deuterium – tritium capsule at the center of the sphere. The heating and evaporation of the capsule's shell will produce a large pressure rise in its core, causing fusion reactions to occur. It is believed that the Livermore machine can potentially be the basis for future fusion electric power plants.

Source: *Physics News Update*, Number 755 (2005) http://www.aip.org/pnu/2005/split/755-2.html

6. Galaxy cluster lensing

A new Hubble Space Telescope/Advanced Camera for Surveys (ACS) study has been made of the galaxy cluster MS 1054-0321 observed at a redshift $z = 0.83$ (corresponding to the time when the Universe was about half its current age). Using data on the weak gravitational lensing of line-of-sight galaxies provided unprecedented accuracy in determining the mass distribution in the cluster as compared to previous observations. In particular, in addition to the three main mass clumps of dark matter (or hidden mass), a few smaller clumps were seen as satellites around the cluster. Comparison with the Chandra X-ray images of the same cluster showed that only two of the three larger clumps are X-ray luminous and that the X-ray maxima are off the centers of the dark matter clumps, presumably due to the gas-pressure-driven motions of the hot matter. The new findings are important for understanding the structure and formation of galaxy clusters.

Source: http://arXiv.org/abs/astro-ph/0508044

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