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1. Antiprotonic helium

The term antiprotonic helium refers to a helium atom in which one of the electrons is replaced by an antiproton. This is achieved in an experiment by passing an accelerator-produced beam of antiprotons through a helium medium. Antiprotonic helium was first discovered in 1991, although its existence had been predicted theoretically by Kondo as early as 1964. This exotic atom is interesting in that it has an unusual energy level diagram. The antiprotonic helium exhibits fine and hyperfine level splittings, due to the interaction between the magnetic moments of the antiproton and the electron. In 1998, D Bakalov (Bulgaria) and V I Korobov (JINR, Dubna) showed theoretically that each of the two energy levels of the hyperfine doublet must in turn split into two close sublevels. This results from the interaction of the antiproton and electron spin magnetic moments with the antiproton orbital magnetic moment. This splitting has now been discovered for the first time by a group of European and Japanese researchers headed by E Widmann. To obtain atoms of antiprotonic helium, a CERN accelerator was used. The presence of the two sublevels was registered by quantum transitions between them. Using a laser, excess population of the upper sublevel was achieved, and then quantum transitions to the lower sublevel occurred under the action of microwave radiation. The frequency of the microwave radiation was chosen such as to initiate allowed transitions between the sublevels involved. The resulting population of the levels was controlled by a second laser which caused transitions from the metastable levels to short-living ones, thus leading to a rapid annihilation of the antiproton and producing a burst. By varying the frequency of the laser pulses it was possible to determine the shape of the transition lines and to measure the energies of the states involved. The experiment has confirmed with a high degree of accuracy the predictions made by D Bakalov and V I Korobov.

Source: http://prl.aps.org;
Phys.Rev.Lett. **89** 243402 (2002)

2. A new superconductor

Researchers from the Los Alamos National Laboratory (US), the University of Florida (US) and the Institute for Transuranium Elements in Karlsruhe (Germany) have discovered that the plutonium – cobalt – gallium alloy $PuCoGa_5$ becomes a superconductor when cooled to a temperature below $T_c = 18.5$ K. This temperature is about an order of magnitude higher than the superconducting transition temperature in so-called 'heavy-fermion systems', compounds based on uranium and cerium. The plutonium-based alloy may therefore belong to a new class of superconducting materials. It was also found that the critical current and critical magnetic field that destroy superconductivity have relatively large values. The superconductivity of the $PuCoGa_5$ alloy is due to the complex electronic structure of the plutonium atom, according to the authors of the experiment.

Source: http://www.nature.com;
Nature **420** 297 (2002)

3. The Belyaev effect

N Katz and colleagues in Israel have examined collisions between elementary excitations (quasi-particles) and atoms in a Bose – Einstein condensate in the previously unexplored regime of the continuous energy spectrum of quasi-particles. It was observed that the collision rate decreased with decreasing energy. This effect was theoretically predicted by S T Belyaev in 1958. The decrease in the collision rate is explained by a quasi-particle decaying into two or more lower-energy quasi-particles and may occur at almost zero temperature. At higher temperatures, Landau damping usually predominates. The experimental facility used was a quadrupole-type magnetic trap in which 10^5 atoms of ^{87}Rb were confined in the Bose – Einstein condensate state. Quasi-particles were generated by laser radiation modulated with sound frequency. The scattering of the quasi-particles was registered by atoms that flew out of the condensate after undergoing a recoil in a scattering event. The study of the Belyaev effect is important for understanding quantum correlations between quasi-particles and for creating 'atom lasers'.

Source: http://prl.aps.org;
Phys. Rev. Lett. **89** 220401 (2002)

4. Magnetic cooling

The underlying mechanism of the well-known magnetic cooling technique (adiabatic demagnetization) is one in which the internal energy of the paramagnetic material goes to disordering the magnetic moments of the particles as the magnetic field is decreased. Now O Waldmann and his colleagues at Erlangen-Nürnberg University in Germany have for the first time encountered the opposite situation, in which the material is cooled when the magnetic field is increased. The team studied crystals whose molecules, $NaFe_6$, consist of a ring of six iron atoms and a sodium atom at the center. Such ring structures attract the attention of researchers because they open the possibility of coherent quantum tunneling and because they hold the promise of quantum computer applications. As a result of the interaction between the spin magnetic moments of the iron atoms and the magnetic field, the $NaFe_6$ molecules have two energy levels which cross when the external magnetic field is $B_c = 12$ T. As the magnetic field is varied around B_c, the crystal exhibits hysteresis. If the rise of the magnetic field starts from values below B_c, the crystal cools.

Source: http://prl.aps.org;
Phys. Rev. Lett. **89** 246401 (2002)

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Translated by E G Strel'chenko

5. A galaxy with two active nuclei

Astronomers using the ACIS spectrometer aboard the Chandra X-ray Observatory have made detailed observations of the nuclei of galaxy NGC 6240 which has great brightness in the infrared and X-ray regions of the spectrum. The presence of two nuclei about 3000 light years apart was established earlier using optical telescopes. It was also known that at least one of the nuclei is active. New Chandra observations have now shown that indeed both nuclei are active. The nuclei have an X-ray spectrum characteristic of single active galactic nuclei and which may result from the accretion of matter onto supermassive black holes. Given its irregular shape, galaxy NGC 6240 is the result of the coalescence of two lower-mass galaxies. Additional evidence for this is the high rate of star formation, which could have been initiated by tidal forces. The scientists estimate that in a few hundred million years two supermassive black holes in galaxy NGC 6240 will coalesce into one black hole. The observation of galaxy NGC 6240 is important in constructing models for the formation of galaxies and black holes. It is not yet clear which process dominates the growth of the black holes: their coalescences following the coalescence of galaxies or the mass increase due to the accretion of matter. If coalescences of black holes are frequent enough, the gravitational waves they produce can be registered by gravitational wave detectors within the next few years (see *Usp. Fiz. Nauk* **170** 743 (2000) [*Phys. Usp.* **43** 691 (2000)] and *Usp. Fiz. Nauk* **173** 89 (2003) [*Phys. Usp.* **46** 81 (2003)]).

Source: http://arxiv.org/abs/astro-ph/0212099

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