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Physics news on the Internet (based on electronic preprints)

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1. Rydberg atom forming a molecule

V Bendkowsky and her coworkers at the Universitat Stuttgart in Germany and the University of Oklahoma in the US prepared and then investigated unique Rb_2 molecules in which one of the rubidium atoms is in a Rydberg state with the outer electron in the s-state and having principal quantum number in the range $n = 30 - 40$, while the second atom remains in the ground state. The bonding between these atoms is caused by the scattering of the Rydberg electron on the electrons of the second atom. As Enrico Fermi established in 1934, the interaction potential in this sort of scattering of low-energy electrons may be attractive (negative scattering length). Since the electron frequency in the Rydberg atom is much higher than the characteristic frequency of interaction $E/\hbar$, the Rydberg electron wave function is practically undistorted by scattering. The molecules obtained possess a lifetime before decay of about 18 μs and are about 100 nm in size, which is 1900 times the Bohr radius and makes them much farther apart than the atoms in most other molecules. The molecules were created by laser excitation of rubidium atoms in a Ioffe–Pritchard magnetic trap at a temperature of 3.5 μK. The vibration spectra of the molecules were measured in the ground and first excited states. The results obtained are in good agreement with the results of theoretical calculations. The researchers expressed hope that similar molecules may soon be created with the Rydberg electron in the p-state, as well as a three-atom molecule and a molecule belonging to a class of what is known as trylobite molecules, in which the Rydberg electron has a high angular momentum.

Source: *Nature* **458** 1005 (2009)
http://dx.doi.org/10.1038/nature07945

2. Superconductivity of europium

Atoms of bivalent rare-earth element europium at normal atmospheric pressure possess high magnetic moments; this is an obstacle to europium's transition to a superconducting state. However, researchers of Washington University in St. Louis, J S Schilling and M Debessai, established that europium becomes a weak Van Vleck paramagnet under a pressure of 80 GPa and exhibits superconducting properties. Its superconducting transition temperature is $T_c = 1.8$ K, and T_c grows linearly with increasing pressure, reaching $T_c = 2.75$ K at 142 GPa. To generate such high pressures on a sample, Eu specimens were placed in a diamond anvil cell. The superconducting transition was identified by measuring electrical resistivity and ac electrical susceptibility. The electron levels of europium get distorted under high pressure, so it is transformed from a bivalent to a trivalent element. A similar effect has already been observed in americium metal, which also becomes Van Vleck paramagnetic and superconducting under pressure ($T_c = 0.79$ K). Europium thus becomes the 53rd known element which has manifested superconducting properties in the elemental state, and the 23rd element in which superconductivity arises only on application of high pressure.

Sources: *Phys. Rev. Lett.* **102** 197002 (2009)
http://dx.doi.org/10.1103/PhysRevLett.102.197002
http://arXiv.org/abs/0903.1808

3. 'Incandescent lamp' made of a nanotube

B C Regan and colleagues at the University of California Department of Physics and Astronomy and California NanoSystems Institute at UCLA (Los Angeles) studied the glow produced by a single current-heated carbon nanotube. This experiment allowed them to test Planck's law of blackbody radiation almost to the limit of applicability of thermodynamics. Two gold contacts were lithographically attached to the ends of a nanotube placed over a hole in a silicon substrate in a vacuum. The multilayer carbon nanotube was about 100 atoms thick. When electric current was passed through such a filament, it heated up and began to glow. The emission wavelength was on the order of the nanotube length and much larger than the tube thickness. The radiation spectrum of nanotube emission was studied at different temperatures (different currents) by using an optical microscope and a set of color filters. The classical thermodynamics used together with Max Planck's quantum hypothesis to derive the spectrum of blackbody radiation are applicable only to macroscopic systems consisting of a very large number of particles. The spectrum of thermal emission of a nanotube was nevertheless found after corrections for geometric factors to be in good agreement with the Planck formula. A nanotube has microscopic dimensions but is still large enough for a statistical description. At the same time, the quantum properties of a microscopic system already manifest themselves sufficiently well. This experiment therefore dealt with properties at the borderline between the thermodynamic and quantum regimes.

Source: *Phys. Rev. Lett.* **102** 187402 (2009)
http://dx.doi.org/10.1103/PhysRevLett.102.187402

4. Topological Hall effect in MnSi

A number of small-angle neutron scattering experiments have provided indirect evidence that the distribution of electron spins in the compound MnSi exhibits a nontrivial topological structure composed of quasiparticles known as skyrmions. Skyrmions are described by chiral soliton models suggested by Tony Skyrme in 1961. It is assumed that topological excitations we call skyrmions arise in MnSi due to the spin–orbit interaction and form a lattice composed of three helices, i.e., the lattice of topologically stable knots in the spin

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structure. Two independent groups of experimenters carried out new experiments that confirm this picture. M Lee and his colleagues in the USA and Japan studied the Hall effect in a specimen of MnSi under a pressure of 6 – 12 kbar. They found an additional contribution to conductivity detected at the magnetic field induction in the interval 0.1 – 0.45 T, which is not typical of the conventional Hall effect. In the model with skyrmions, this contribution is known as the topological Hall effect. In another experiment, A Neubauer and his colleagues in Germany also studied the Hall effect in MnSi, but in a different segment of the phase diagram of this compound. Similar features of the Hall effect were discovered and could be explained in terms of skyrmion distribution.

Source: *Phys. Rev. Lett.* **102** 186601 (2009)
http://dx.doi.org/10.1103/PhysRevLett.102.186601

5. Refined Hubble constant

Two hundred forty Cepheid variables and several type Ia supernova explosions in remote galaxies have been observed using the NASA's Hubble Space Telescope (HST), making it possible to improve the accuracy of the universe's expansion rate, called the Hubble constant, by a factor of more than two, reaching the level of approximately 5%. Some of the observed Cepheids (variable stars with a known period vs. luminosity curve) were located in the same galaxies as six type Ia supernovas; this made it possible to carry out direct joint calibration of various distance markers. The team also recorded Cepheids in the galaxy NGC 4258 which contains cosmic masers. Using the geometry of the maser emission, the distance to the galaxy was measured with sufficient accuracy. Furthermore, the Hubble telescope measured the parallax of ten Cepheids in our Galaxy. This led to further refinement of the accuracy of calibration of distance measurements. The importance of calibration is illustrated by the fact that the relative accuracy of the Hubble diagram for type Ia supernovas is better than 1% but the presence of systematic errors does not yet permit reaching the same accuracy in measuring the absolute value of the Hubble constant. Likewise the observation of baryonic oscillations in the spectrum of microwave background radiation has not yet reached better accuracy without the assumption that the Universe is flat plus the hypothesis that the parameter of the equation of state of dark energy is $w = p/(\rho c^2) = -1$ (the cosmological constant). According to the new HST data, the refined value of the Hubble constant is $H_0 = 74.2 \pm 3.6$ km s^{-1} Mpc^{-1}. Together with the WMAP data over the last five years, this gives $w = -1.12 \pm 0.12$ independent of high-redshift SNe Ia or baryon acoustic oscillations.

Source: http://arXiv.org/abs/0905.0695vl

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