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Physics news on the Internet (based on electronic preprints)

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1. Polarized degenerate Fermi gas

G B Partridge and his colleagues at Rice University and Utrecht University in the US and the Netherlands have studied the properties of a cloud of polarized degenerate fermionic ^{6}Li atoms in a magneto-optical trap. Using microwave radiation to control the degree of polarization (i.e., the relative excess of spin-up and spin-down atoms), the team looked at the shape and phase state which different regions of the cloud assumed at various polarizations and temperatures. As some portion of the atoms were converted into the paired state using the Feshbach resonance, the resulting pairs of atoms, now bosons, formed an unpolarized core of Bose – Einstein condensate at the center of a partially polarized gas halo (the highly elongated spheroidal shape of the halo being consistent with the geometry of the combined optical and magnetic trapping potential). At a sufficiently low temperature, the core was observed to have a sharp boundary and a close-to-spherical shape due to surface tension acting at the boundary. Increasing temperature strongly deformed the core and gave rise to a transition layer of partially polarized gas between it and the halo. The experiment confirms the existence in the phase diagram of a tricritical point where the superfluid-to-normal transition changes its order from second to first as the temperature is lowered.

Sources: *Phys. Rev. Lett.* **97** 190407 (2006); prl.aps.org

2. 'Purifying' entangled quantum states

There has been much recent activity in the study of entangled quantum states (see *Usp. Fiz. Nauk* **171** 625 (2001) [*Phys. Usp.* **44** 597 (2001)]). The focus of experimental interest in this area is decoherence, i.e., the perturbation-induced destruction of quantum correlations in the system. C H Bennett and his colleagues in 1996 proposed an entanglement 'purification' protocol that first checks whether there is correlation in the system and then distills the correlated pairs of particles. The basic idea underlying the protocol is to make copies of a quantum state (i.e., additional pairs of particles correlated with the original one) and then to use classical communication channels to compare their quantum state with that of the first pair. Until recently, this protocol has only been implemented in experiments with photons, but with low efficiency and in a destructive way — that is, with the entangled state being destroyed in the measurement process. Now R Reichle and his colleagues at the National Institute of Standards and Technology in Boulder, Colorado, USA, have developed a new technique which they used in an experiment on spin-entangled pairs of ^{9}Be$^+$ ions. After first entangling two such ions in an ion trap by using laser pulses, the researchers then entangled each ion of the first pair with the ions of the second. Measuring the quantum correlation of one of the ion pairs revealed whether the ions of the second one were or were not successfully entangled, thus weeding out the failures. The entanglement 'purification' level achieved was 35%, the important point being that the entangled state of the second ion pair remained undestroyed and could be used in further studies. This new protocol can, in principle, be repeated several times, leading to higher-fidelity entanglement.

Sources: *Nature* **443** 838 (2006); www.nature.com

3. Superconductivity in boron-doped silicon

Superconducting silicon has previously only been observed in its β-Sn and the hexagonal metallic phases under extreme pressures of about 10 GPa. Now E Bustarret and his colleagues from France and Slovakia have for the first time observed boron-doped silicon becoming superconducting in the cubic phase at ambient pressure. The team used a method known as gas immersion laser doping (GILD), in which boron atoms were made to penetrate a thin silicon film by repeatedly melting and solidifying the film with ultraviolet laser pulses. In this way, silicon films with a very high (several percent) boron content were created. The superconducting transition temperature of the film was 0.35 K, and the (critical) magnetic field necessary to suppress superconductivity was 0.4 T. The superconducting transition was detected by electrical resistance and magnetic susceptibility measurements. Doped silicon turned out to be a type II superconductor. The superconductivity of the films is due to a phonon mechanism, as theoretical calculations predict and Raman spectroscopy confirms.

Sources: *Nature* **444** 465 (2006); www.nature.com

4. A gamma-ray source at the center of the Galaxy

In 2004, a TeV gamma-ray source was detected at the center of our Galaxy, whose nature is not yet known. Suggested as possible candidates for emitting radiation have been the shell of a newly exploded supernova, matter near the central supermassive black hole or dark matter particles annihilating at the center of the Galaxy. Theoretical models predict (see, for example, *Usp. Fiz. Nauk* **165** 723 (1995) [*Phys. Usp.* **38** 687 (1995)]) and galaxy formation simulations confirm that radiation due to annihilation appears as a nearly pointlike gamma-ray source if dark matter increases in density toward the center of the Galaxy. Now astronomers have used the high-energy spectroscopic system (HESS) telescope, an array of four Cherenkov detectors, to further study the source by detecting the particle showers in the atmosphere, produced by high-energy photons. It is found that the gamma-ray source is less than $1.2'$ in angular size and that it possesses an approximately power-law energy spectrum with no fall-off at high energies. Given the current restrictions on the parameters of neutralinos, the annihilation

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of these particles cannot explain this spectrum. The cutoff scale for the spectrum produced by a neutralino model should be the energy equivalent of the particle mass, so that neutralino annihilation does not contribute more than about 10% to the source's gamma-ray radiation, and the bulk of the radiation flux should be of a different origin. Besides, the HESS J1745-290 observations did not reveal any variabilities or spectral lines in the radiation emitted by the source.

Sources: http://arxiv.org/abs/astro-ph/0610509

5. Dark energy at $z \approx 1$

It is an established fact (see *Usp. Fiz. Nauk* **174** 764 (2004) [*Phys. Usp.* **47** 747 (2004)]) that about 70% of the total density of the Universe falls at dark energy. To determine the nature of dark energy, it is essential to know precisely how its density evolved in time. Astronomers using the Hubble Space Telescope (HST) have now carried out a new search for distant type Ia supernovae (SNe Ia) — thermonuclear explosions of white dwarf stars — that serve as standard candles for estimating cosmological distances and the cosmological expansion rate. In addition to the two previously found $z \gtrsim 1$ supernovae, HST has detected 21 more supernovae, thus tracing the history of cosmic expansion from 8 to 10 billion years ago. The analysis of the observations suggests that even at the far back time dark energy contributed noticeably to the total cosmological density, and the expansion of the Universe was gradually changing from decelerating to accelerating. Unfortunately, with the precise dark energy equation of state still unknown from observations, quintessence models remain a possibility along with the cosmological constant.

Sources: http://arxiv.org/abs/astro-ph/0611572

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