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1. The limiting magnetic field

In analyzing stability of the vacuum with respect to the so-called 'positronium collapse,' A E Shabad (P N Lebedev Physics Institute, RAS, Russia) and V Usov (Weizmann Institute of Science, Rehovot, Israel) established theoretically that the maximum possible magnetic field allowed in our Universe is 10^{42} G, i.e., 10^{9} times lower than previously thought. Shabad and Usov performed standard QED calculations by employing the Bethe – Salpeter equation for a positronium atom — an electron – positron pair — in a strong magnetic field and found that as magnetic field increases, the attraction between the particles grows and ultimately causes them to fall onto one another and annihilate, thus eliminating the energy barrier for pair production from the vacuum. The magnetic field cannot be higher than 10^{42} G because when approaching this threshold it gets screened by the electron – positron pairs produced from the vacuum. This finding places stringent constraints on the theories describing superconductive cosmic strings and magnetic monopoles. For example, according to existing estimates, a magnetic field near a string can be as large as $10^{47} - 10^{48}$ G — a value which the new theoretical finding now rules out.

Source: *Phys. Rev. Lett.* **96** 189401 (2006); prl.aps.org

2. Vortices found to form in a phase transition

T Kibble and W Zurek in the 1980s developed a theory that relates the cooling rate of a material to the number of topological defects that form as a phase transition occurs. The general predictions of this theory apply both to laboratory processes and the extreme states of matter cooling rapidly at the early stages in the evolution of the Universe. Now, a multinational team of experimenters led by R Monaco of the University of Salerno in Italy have successfully tested the Kibble – Zurek theory for the first time by studying how inhomogeneities in the quantum-mechanical phase in superconducting samples shape themselves as a sample is cooled at different rates. The samples studied consisted of two niobium rings separated by a thin insulating layer and thus forming a Josephson junction. The cooling time was varied from several milliseconds to dozens of seconds and, all in all, more than 100,000 cooling cycles were run. The phase distribution in the material was detected based on electric potential and current measurements. Theoretically predicted topological vortex-type defects were observed at different places around the rings, and the probability of vortex formation was found to be proportional to the square root of the cooling rate — as the Kibble – Zurek theory predicts it should.

Source: *Phys. Rev. Lett.* **96** 205301 (2006); prl.aps.org

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3. Bosons and fermions in a 3D trap

Two independent research teams have developed a technique that enables ultracold degenerate gases of bosons and fermions to be trapped together in a 3D optical trap. Experiments showed that such a mixture of gases has interesting properties — in particular, that boson atoms interact differently in the presence of fermions. The 3D trap is a 'light crystal' formed by many interfering laser beams. S Ospelkaus and colleagues at the Institute of Laser Physics in Hamburg, Germany placed bosonic ^{87}Rb and fermionic ^{40}K atoms into this trap at a temperature of several hundred nanokelvins and studied the behavior of the mixture as the optical trap was abruptly switched off. It was found that unlike a pure gas of ^{87}Rb atoms, in this case the presence of fermions led the ^{87}Rb atoms to attract rather than repel one another. In a similar experiment, T Esslinger and colleagues at the ETH Zurich in Switzerland have performed a very similar experiment in which they looked at the effect of ^{40}K atoms on the superfluid properties of the Bose – Einstein condensate of ^{87}Rb atoms and found that the presence of the fermions diminished the condensate's phase coherence.

Sources: *Phys. Rev. Lett.* **96** 180402 (2006);
Phys. Rev. Lett. **96** 180403 (2006); prl.aps.org

4. Laser goes acoustic

The acoustic analogue of an optical laser — a device capable of amplifying and generating superhigh-frequency acoustic waves — has been developed by a British – Ukrainian collaboration (the University of Nottingham – the Lashkarev Institute of Semiconductor Physics) using a stack (or a superlattice) of thin semiconductor layers. The lattice was designed to give rise to the stimulated emission of sound quanta (phonons) in the frequency range 0.1 – 1 THz, which formed a coherent sound wave. Layer separations on the lattice faces were chosen such that the sound wave reflected from the faces similar to the way in which light reflects from mirrors in a conventional laser. As a result, a narrowly directed, superhigh frequency, high intensity sound beam emerged from the device. The acoustic 'laser' (or saser) can be used for a wide variety of technical applications including, for example, optical modulators in optoelectronic devices.

Source: *Physics News Update*, Number 779
http://www.aip.org/pnu/2006/split/779-1.html

5. Properties of matter under combined high pressure and ion irradiation conditions

A study of the combined effect of high pressure and intense ion irradiation has revealed structural changes in the material that neither of these factors could produce alone. Researchers at the GSI laboratory in Darmstadt, Germany placed samples of graphite or zirconium in a 'diamond anvil cell' under a pressure of about 14 GPa and irradiated them with a beam of uranium or gold ions at an energy of 70 GeV for several seconds. Electron microscope observations showed that the graphite transformed from a crystalline to an amorphous state as a result of carbon – carbon bond transformations — in contrast to atmospheric pressure experiments, in which ions just leave tracks behind them without changing the structure of the crystal. For zirconium samples irradiated with uranium ions, Raman spectroscopy revealed the formation of nanoscale microcrystals and a phase transition which occurs only at a pressure of 20 GPa in the absence of ion irradiation. The study may help to better understand the properties of some deep-earth minerals subject to the combined action of high pressure and radioactive decay products. Another potential application of this technique is to produce new metastable phases of matter.

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Compiled by *Yu N Eroshenko*