Physics Update

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Physics Update

All-optical trapping of a degenerate Fermi gas has been demonstrated. First created in a magnetic trap (see Physics Today, October 1999, page 17), a degenerate Fermi gas consists of fermionic atoms--those with an odd total number of protons, neutrons, and electrons--sufficiently dense and cold that only the lowest trap energy levels are occupied. An all-optical trap has previously been used to confine a Bose-Einstein condensate (see Physics Today, July 2001, page 20 and September 2001, page 79). Now, using a stable, high-power CO_2 laser, physicists at Duke University have created a kind of "optical bowl" for lithium-6 atoms: Slowly lowering the bowl's rim permitted the hottest atoms to evaporate. The researchers then adiabatically recompressed the trap to its full depth, which tightly confined the remaining degenerate gas. In this way, an equal mixture of lithium atoms in spin-up and spin-down states was captured, a feat not possible in magnetic traps. According to the Duke researchers, such equal two-state mixtures are potentially ideal for forming neutrally charged, quasibound pairs of atoms in Fermi gases--something the researchers hope to observe soon. Several groups are pursuing such an atomic-gas analog of superconductivity in different ways. (S. R. Granade et al., *Phys. Rev. Lett.* **88**, 120405, 2002.) --bps

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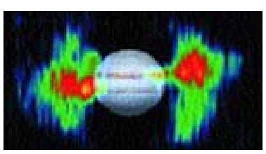

Jupiter's magnetosphere has been simultaneously sampled by two spacecraft, Galileo (already on patrol in the Jupiter system) and Cassini-Huygens (headed toward Saturn). Just as Cassini was approaching Jupiter in January 2001, other Earthbound observatories, including radio telescopes and the Hubble (optical) and Chandra (x-ray) satellites, were turned to the giant planet. The Sun also cooperated: Three interplanetary shock waves in the solar wind swept by. The two spacecraft caught Jupiter's magnetosphere in the act of being compressed. That compression produced strong electric fields and therefore particle accelerations, which brightened Jupiter's auroras. Internal magnetospheric dynamics caused other observed auroral brightenings and a wind of neutral atoms--formed from ions spewed by Io's volcanic eruptions--sent outward against the incoming solar wind. Such energetic neutral atoms had not been directly observed before. The flyby also provided the first opportunity to observe electrons above 50 MeV trapped in Jupiter's radiation belts. Shown here is the synchrotron radiation from those electrons, with a superimposed Hubble image of Jupiter. (Seven articles in *Nature* **415**, 985 ff, 2002.) --pfs

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Microtesla nuclear magnetic resonance (NMR) has been demonstrated. In conventional NMR, a several-tesla magnetic field is used to orient atomic nuclei in the sample. The polarized nuclei can resonantly absorb a burst of radio waves, and precess around the imposed field. The spectral "chemical shift" information from reemitted radio waves is then used to identify molecules. NMR also lies at the heart of magnetic resonance imaging (MRI). Now, a team of scientists led by John Clarke and Alexander Pines (Lawrence Berkeley National Laboratory and the University of

California, Berkeley) have exploited an often overlooked fact: For a homogeneous field, the NMR linewidth scales linearly with the field strength. Thus, a 1000-fold reduction in field strength produces a line both narrower and taller by that same factor. The researchers placed a small liquid sample of methanol and phosphoric acid in a polarizing field of only 1 mT and a much weaker orthogonal measuring field of 5 mT (Earth's field is roughly 50 mT). The group then turned off the polarizing field and used a SQUID to detect not chemical shift but "J-coupling," which can measure an atom's chemical environment as well as its identity. In that way, they not only identified protons and phosphorous-31, but saw the signature--a doublet split by 10.4 Hz--of the covalent bonds in trimethyl phosphate. These techniques open the possibility for "pure J" spectroscopy and perhaps could form the basis of inexpensive MRI machines. (R. McDermott et al., *Science* **295**, 2247, 2002.) --pfs

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Electrical biosensors for individual living cells were described at the March meeting of the American Physical Society. Cells are complex networks of interacting molecules, and are usually studied with optical techniques. Electrical measurements, however, can provide complementary information. Toward that end, Lydia Sohn of Princeton University described several new biosensors. With one, she measured the amount of DNA in a single living cell passed through a small fluid chamber between two metal electrodes. The cell changed the system's capacitance in a way that reflected the amount of the cell's negatively charged DNA but not its other ions. Sohn reported that the technique can identify the stage of a cell's development (since cells can contain different amounts of DNA at different stages) and can potentially distinguish cancerous cells from healthy ones. Sohn also described a biosensor that can detect small amounts of a specific protein in live *E. coli* cells. The eventual goal of Sohn's lab is to take inventory of a living cell's protein contents--something that cannot be done with current protein assay techniques, which require the destruction of cells. (http://www.aps.org/meet/MAR02/baps/vpr/layf7-003.html.) --bps