physics update

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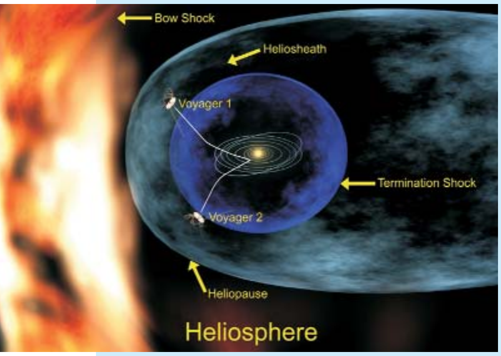
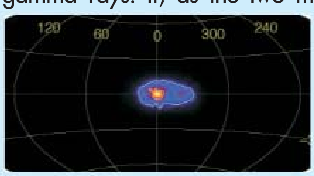
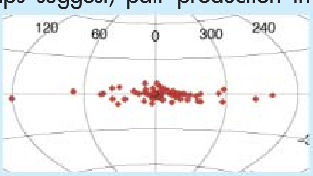
***Voyager 2* reaches the heliosheath.** Like its sister craft *Voyager 1* several years before it, *Voyager 2* has now flown far enough out into the solar system to cross the termination shock, where the supersonic wind of solar particles—the wind that blows a bubble in space around our solar system—is abruptly slowed by pressure from the interstellar medium. Beyond that thin shock, the heliosheath extends to the farthest reaches of the Sun's magnetic influence, which ultimately ends at the yet-unseen heliopause (see the schematic). As of 1 September 2007, *Voyager 1* was 104 astronomical units from the Sun (1 AU is the mean distance between the Sun and Earth), traveling at 3.6 AU per year, while *Voyager 2* was 84 AU away and moving at a more sedate 3.3 AU per year. Although *Voyager 1* reached the termination shock first, its plasma-measuring instrument stopped working before it arrived there. *Voyager 2*'s working instrument found the temperature beyond the shock surprisingly lower than predicted, which could indicate that energy is being transferred to so-called pickup ions and shock-accelerated cosmic rays. In addition, the data from the spacecrafts' two different locations confirm that the termination shock is not spherical. (Results reported by several researchers at the December 2007 meeting of the American Geophysical Union in San Francisco.) —PFS



Mapping galactic positrons. Thirty years ago, Marvin Leventhal, Crawford MacCallum, and Paul Stang detected 511-keV photons emanating from the center of our galaxy. Evidently, positrons are meeting electrons there and annihilating each other. But what produces the positrons? In the near vacuum of interstellar space, a positron typically travels for 100 000 years before annihilation. The corresponding distance depends on local magnetic fields, but it's small enough that a map of the galaxy's 511-keV emission should reveal the locations of positron production and, indirectly, the production mechanism itself. Now, after four years of photon gathering, the *Integral* spacecraft has produced the best-ever map of the central region of the galaxy. The map (below left) confirms earlier findings that the emission is strongly peaked at the galactic center itself. It also shows for the first time a distinct and significant asymmetry that coincides with the distribution (below right) of "hard" low-mass x-ray binaries that emit at energies above 20 keV. In hard LMXBs, a low-mass star donates material via an accretion disk to a compact companion star—either a black hole or a neutron star. Theorists think that the inner disk gets so hot that electron–positron pairs are spontaneously produced by ambient gamma rays. If, as the two maps suggest, pair production in

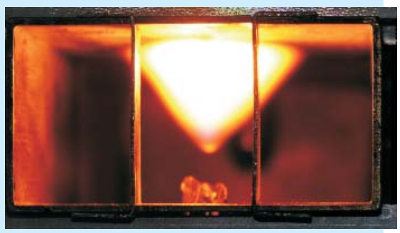




LMXBs accounts for the 511-keV emission, then other exotic explanations, such as the decay of dark-matter particles, are no longer needed. (G. Weidenspointner et al., *Nature* **451**, 159, 2008.) —CD

Pairs of trapped atoms undergo superexchange. Manganese oxide is an archetypal antiferromagnet: Below a critical temperature, the unpaired electrons on the Mn atoms arrange themselves between the O atoms in an alternating spin-up/spin-down configuration. Direct spin–spin interaction is not responsible for the correlation. Rather, a virtual process called superexchange prevails. By hopping to virtual states on the O atoms, the electrons can correlate their spins and lower their energy. Superexchange has now been observed in pairs of optically trapped atoms. Immanuel Bloch of the University of Mainz, Germany, and his collaborators loaded rubidium-87 atoms into an array of double-well potentials formed by interfering laser beams. Bloch's team could ensure that each double well started out with a spin-up atom in one well and a spin-down atom in the other. Superexchange occurred when one atom virtually hopped to join its neighbor. By adjusting the barrier between the wells, the Mainz researchers could make tunneling between the wells—and therefore superexchange—more or less likely. The observable consequence was an oscillation in time of the net spin polarization about perfect antialignment. To detect the oscillation, the researchers raised the left wells to dump their contents into the right wells. The energy acquired by the transferred atoms depended on their spin. When the trap was turned off, the atoms fell through a Stern–Gerlach filter. Where the atoms ended up revealed their spin and whether they originated from a left or right well. Repeating the procedure for different release times traced the oscillation, which matched textbook theory. (S. Trotzky et al., *Science* **319**, 295, 2008.) —CD

Nanoparticles in ball lightning. For centuries, scientists have been perplexed by reported sightings of unusual and rarely observed luminous orbs that show up during electrical storms and can range up to a meter in diameter. Such "fireballs" shift and float and don't stay still long enough to be properly imaged and probed.



Scientists have been synthesizing fireballs in their laboratories for the past few decades in attempts to study their composition (see PHYSICS TODAY, February 2007, page 22). The Abrahamson– Dinniss theory, which guides present-day experimentalists, suggests that ball lightning is simply a cloud of slowly burning silicon nanoparticles ejected from the soil after a lightning strike. Recently a French and Israeli research team gathered at the European Synchrotron Radiation Facility in France to make fireballs in a microwave cavity and probe them with 12.5-keV x rays at atmospheric pressure. The researchers created a hotspot by concentrating microwaves with a copper electrode, then touching that electrode to a borosilicate glass substrate. Upon retracting the electrode, a molten drop detached and vaporized into a buoyant fireball (see image). Small-angle x-ray scattering revealed that the particles contained in the fireball are approximately 50 nm in diameter. The researchers believe that those hot (on the order of 10^3 K) nanoparticles emit electrons and form a dusty plasma. (J. B. A. Mitchell et al., *Phys. Rev. Lett.*, in press.) —JNAM ■