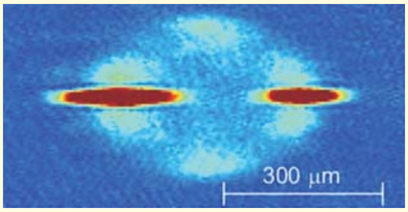
Physics Update

Map of the nuclear world. A new experiment at the Laboratory for Heavy Ion Research (GSI) in Darmstadt, Germany, has created and analyzed the largest number of elements (from nitrogen through uranium) and the largest number of isotopes (1385) ever seen in a single nuclear research effort. The only ingredients were a beam of uranium-238 nuclei and a liquid-hydrogen target. Fragment nuclei of all sizes, flying away from the collision point, were accurately identified by GSI's high-resolution fragment separator with its time-of-flight and energy-loss detectors. The meticulous and comprehensive nuclear experiment produced a set of cross sections, each a measure of the likelihood for creating a particular nuclide in the spallation reaction. The data also revealed a clear separation between the heavy evaporation products and the lighter fission fragments. Altogether, the information is valuable for planning a future accelerator of rare isotopes, for studying how to break down nuclear waste in subcritical reactors, and for studying fundamental aspects of nuclear fission and nuclear viscosity. (P. Armbruster et al., *Phys. Rev. Lett.* **93**, 212701, 2004.) —PFS

Partial-wave interference in quantum scattering. Two research groups, one in New Zealand, the other in the Netherlands, have banged quantum gases together at velocities of up to 20 cm/s. Both groups cooled clouds of rubidium-87 atoms to the nanokelvin regime. Each group then manipulated magnetic fields to create a double-well potential with roughly half of the original cloud on each side. The physicists then quickly changed the potential back to a single well; the two clouds then accelerated to the potential minimum whereupon their constituent atoms scattered off each other. Absorption images revealed the resulting halo distributions of atoms. At collision energies less than about 100 μK, the distribution was spherically symmetric, due to pure *s*-wave scattering. At energies above about 300 μK, the distribution was dumbbell-shaped, from pure *d*-wave scattering. At intermediate energies, quantum interference effects were apparent as shown here in an absorption image taken at a collision energy of 192 μK by the New Zealand physicists. The Dutch group took similar images and also used their data to directly determine the scattering length for the cold bosonic gas: 102 Bohr radii, which agrees with the accepted value of 99 a_0. (N. R. Thomas et al., *Phys. Rev. Lett.* **93**, 173201, 2004; C. Buggle et al., *Phys. Rev. Lett.* **93**, 173202, 2004.) —PFS



Cooper pairs unpaired. In a low-temperature superconductor, electrons don't travel singly but in weakly tethered pairs called Cooper pairs. When an electron is sent from a normal metal into such a superconductor, a process called Andreev reflection occurs: A hole of opposite spin is retroreflected at the interface back into the metal and a Cooper pair appears in the superconductor. In a new experiment at the Karlsruhe Research Center in Germany, physicists attached tiny iron wires to a superconducting aluminum bar. The wires were magnetized to pick out pairs with the characteristic opposite-spin orientation of Cooper pairs. If the wires were spaced more closely than the coherence length of the Cooper pairs themselves, the physicists found that the Andreev reflection was "crossed"—the electron went in one wire but the hole was reflected into another. Looked at differently, the Cooper pair split up into the two wires. Although the partners are in different wires, they are quantum-entangled, which might prove useful in quantum information processing. (D. Beckmann et al., *Phys. Rev. Lett.* **93**, 197003, 2004.) —PFS

Our sense of balance is as good as it gets. All vertebrates, from mice to whales, have a set of three mutually perpendicular fluid-filled tubes—the vestibular semicircular canals (SCCs)—housed in each inner ear. The SCCs mechanically sense rotation, a function that is imperative not only for maintaining balance but also for vision: The SCCs' neural output causes a reflexive, compensating motion of the eyes, which allows a fixed gaze to be maintained even while the head is moving. Knowing how the canals work is also important for understanding various forms of dizziness. Roughly, an SCC is donut-shaped, with a major radius of a few millimeters and minor radius of a few tenths of a millimeter. Each torus is interrupted by a membrane called a cupula that is impregnated with tiny hairs for sensing the sloshing of the fluid through the canal. Those hairs trigger the neural signal. Incredibly, although vertebrates span nearly three orders of magnitude in length, the size of SCCs varies by only about a factor of five across vertebrate species. Todd Squires, a physicist at Caltech, has now investigated the question of why the SCCs should have a roughly universal size, and suggested that evolutionary pressures had converged on an optimal solution. Squires derived expressions for the SCCs' structure, mechanical operation, and signal transduction. He then optimized the system's sensitivity by varying four size parameters—major radius, minor radius, cupula thickness, and cupula height—while enforcing physical and physiological constraints. The greatest canal sensitivity occurred for those parameter values manifested in actual vertebrates. (T. M. Squires, *Phys. Rev. Lett.* **93**, 198106, 2004.) —PFS