ASTROPHYSICS

INTRODUCTION

Review Focus

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in this compendium. Readers can get a much wider view of the year’s top physics research by

Update

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electronic news service FYI produced by the Media and Government Relations Division of the

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Angular Scale Interferometer (DASI) telescope. The small

An image of the intensity and polarization of the cosmic microwave background has been measured.

POLARIZATION IN THE COSMIC MICROWAVE BACKGROUND has been measured. The most fundamental properties of the CMB—which can reveal conditions in the universe when it was only about 400,000 years old—are its frequency spectrum and its angular power spectra of both temperature and polarization fluctuations. According to the modern theory of cosmology, the CMB microwaves received an orientation (polarization) just before the seething plasma that pervaded the cosmos in that early era finally became a neutral, transparent gas. Until now, the low level of polarization had allowed that quantity to escape detection. Using the Degree Angular Scale Interferometer detector situated at the South Pole, a group from the University of Chicago and the University of Toronto has acquired and analyzed enough high-quality data to actually see the CMB polarization. The observed value is consistent with predictions and thus strongly validates the underlying theory. (J. Kovac et al., preprint available at http://arXiv.org/abs/astro-ph/0209478.)

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 through the two spacecraft, causing Jupiter’s magnetosphere to act as a cosmic shock absorber. That compression produced strong electric fields and therefore particle accelerations, which brightened Jupiter’s auroras. Internal magnetohydrodynamic dynamics caused other observed auroral brightenings and a wind of neutral atoms—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 eV 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, 2002.)

A YOUNG EVOLVING PLANETARY SYSTEM has been seen. A star much like our Sun when it was only 3 million years old has been winking at astronomers from a distance of about 2400 light years for the past five years. Every 48.36 days, the star suddenly dims to a small percentage of its normal brightness for about 18 days. The duration and depth of these periodic occultations, discovered by William Herbst and his colleagues in 1998, suggest a nearby ’young Jupiter’. In Connecticut, had not been seen before. Eighteen days is much too long for occultation by a lone planet in a 48-day orbit. The observations’ most likely explanation, put forth by Herbst at a meeting at the Carnegie Institution of Washington in June 2002, is that a collection of dust grains, rocks, and perhaps asteroids is swirling out in a clumpy arc of an orbiting circumstellar disk, with a larger object like a protoplanet shepherding the material. Now, with a worldwide collaboration watching the star continually, the Wesleyan group has found evidence that the orbital period is, in fact, 96.72 days: The star is being occulted by two separate clumpy regions on opposite sides of the disk. Theoretical models indicate that a single shepherding object could account for both clumps. The 97-day period indicates that the ringlike disk is about far away from the star as Mercury is from the Sun. The conclusion also changes the system changing slightly on a scale of months and years, thus tantalizing astronomers with the prospect of viewing planetary evolution in real time. (W. Herbst et al., http://www.armo.wesleyan.edu/h15d/)

SPIRAL ARMS, COSMIC RAYS, AND ICE AGES. Most cosmic rays (CRs) are thought to originate in supernovae, and most supernovae occur in the wake of galactic density waves. Alf Shaviv of the University of Toronto and Jerusalem’s Hebrew University has developed a new CR diffusion model that includes the presence of arms. Not surprisingly, he found that the CR flux at Earth would vary with time and be correlated with our Solar System’s passage through galactic spiral arms as we circumnavigate the Milky Way. He then looked at a historical record of CR flux, in 9 million years, against the iron content in the stars that comprise CRs to be determined. He found a periodicity of 143 million years in the CR flux, which he attributes to passages through spiral arms. On the assumption that CRs originate in Earth’s lower atmosphere and can thus influence climate, Shaviv next looked at the geologic record for ice ages and found “a compelling correlation” of both period and phase between CR flux and glaciation epochs during the past billion years. Between 1 and 2 billion years ago, there is no evidence for any ice age, consistent with a slowed star-formation rate during that period of our galaxy’s history. Shaviv says that the weakest link in his analysis is the uncertainties in the glaciologic record. (N. J. Shaviv, Phys. Rev. Lett. 89, 051102, 2002.)

NEW COSMOLOGICAL UPPER LIMIT ON NEUTRINO MASS. Recent neutrino results imply that one or more of the three neutrino flavors (electron, muon, and tau neutrinos) have some mass (see Physics Today, July 2002, page 13). Considering the number of neutrinos loose in the universe, even a small mass means they will have significantly influenced the development of galaxies. Various physics experiments have established an upper limit of 3 eV on the electron neutrino mass. Now, a worldwide collaboration of astronomers has located at the distribution of 250,000 galaxies in the 2 Degree Field Galaxy Redshift Survey and measured large-scale structure statistics in the form of a power spectrum. They compared the data with calculated power spectra using a model that included baryons, cold dark matter, massive neutrinos (hot dark matter), and a cosmological constant. The model had a few reasonable assumptions—for example, that all three types of neutrinos drop out of thermal equilibrium at the same temperature and that the spectrum of primordial fluctuations from which galaxies evolved is scale-independent—and an appropriate treatment of previously measured cosmological parameters. The group then arrived at two big conclusions: Neutrinos can account for no more than 13% of the matter in the universe, and the sum of all three neutrino masses is no more than 2.2 eV. Group members Gabeig and Orfe Labab say that this is the best upper limit for neutrino mass derived with relatively conservative assumptions on cosmological parameters, (Elgaroy et al., Phys. Rev. Lett. 88, 061301, 2002.)

QUAOAR is the provisional name for a large, newly discovered planet-like object inhabitant of our solar system. First spotted on 4 June 2002, Quaoar (pronounced KWAH-o-war) lives in the Kuiper Belt debris zone beyond Neptune’s orbit. Its diameter of 1250 km is about half that of Pluto, and its distance of 42 astronomical units from Earth is far beyond Pluto’s current distance of about 30 AU. (One AU is the mean distance of Earth from the Sun, about 150 million kilometers.) Caltech scientists announced the finding in October at the meeting of the division for planetary sciences of the American Astronomical Society, held in Birmingham, Alabama. (Abstract 9.04, Bull. A.A.S. 34(1), 2002. Also see http://www.gps.caltech.edu/~chad/quaoar/)

ATOMIC, MOLECULAR, AND OPTICAL PHYSICS

STORAGE RING FOR NEUTRAL ATOMS. Generally, a storage ring not only stores atoms but also changes their energy and trajectory; particles with the wrong
A DENDRIMER LASER has been demonstrated. A conventional dye laser uses fluorescing dye molecules as the active medium. When excited with an external laser, the molecules emit light at a range of wavelengths that are then tuned by the dye-laser cavity. In most dye lasers, the dye concentration is low—typically on the order of one million molecules per liter without quenching the fluorescence. Now, scientists at the California Institute of Technology in Pasadena, California, and PRESTO Japan Science and Technology Corp have achieved lasing with a dye concentration of 9 mmol/l by encapsulating the dye dye molecules in a spherical cavity of hyperstructured, tree-shaped polymers called dendrimers. As the dye concentration increased within the new dendritic high-gain medium, the laser output also increased while the lasing threshold decreased. Furthermore, the researchers have shown that the laser line can only be 0.2 nm. The researchers are now working to incorporate their dendrimers into solid-state waveguides, optical fibers, and photonic crystals. (S. Yokoyama, A. O'Domo, S. Mathiho, Appl. Phys. Lett. 80, 7, 2002)

A large dendrimer polymer molecule (green) with a dye molecule lodged at its center. (Courtesy S. Yokoyama et al.)

LIGHT SLOWED AND STORED IN A SOLID. The group velocity of light—the speed at which wave packets propagate—can be considerably lowered, even to zero, in a medium having an index of refraction that changes dramatically with wavelength. The energy and information in the original light pulse can be stored, without any heating, in the form of coherent spin excitations in the atoms of the medium. Last year, two different experiments showed that this phenomenon is possible. In March 2001, page 17), the first had been carried out in a 3-mm-thick crystal—yttrium silicate doped with atoms of the rare-earth praseodymium—already in common use for high-density optical data storage. The experiment was carried out at MIT and at the Air Force Research Laboratory in Hanscom, Massachusetts, by a team led by Michael D. Hill. The researchers used the rare earth because it has a low-threshold electron laser, which can be pumped for many applications in areas such as quantum computing, ultrafast microscopy, and acousto-optics. (A. V. Turukhin et al., Phys. Rev. Lett. 88, 023602, 2001)

NONLINEAR LASER WITH ULTRALOW THRESHOLD. Physicists at Caltech coupled a 70-micron silica sphere to an optical fiber, which enabled light to race around near the surface of the sphere in a "whispering gallery" mode. Whispering modes have been produced before, but the Caltech team uses practical applications seemed remote. The light builds up in these modes is characterized by a Q, referred to as the quality factor; for the microsphere, Q exceeded 100. The light can build up to such an extent that nonlinear interactions take place and engender coherent light emission. The result is a Raman laser, which is akin to what carbon-70 molecules at a temperature of 900 K, are themselves in an excited state (undergoing 3 rotational and 204 vibrational modes of internal motion), it should be possible to study the way in which an atom moves slowly enough, its dipole is strong enough and its charge for magnets to act on, but they can energy simply fly away from their magnetically induced state. Such a laser was recently proposed by E. A. Swanson, Phys. Rev. A 63, 023801, 2001)

A MATTER-WAVE INTERFEROMETER FOR LARGE MOLECULES. A matter-wave interferometer for large molecules has been devised and demonstrated for the first time. For many years scientists have studied the proposition that things we normally think of as particles, such as electrons, should also have wave properties. Indeed studies of beams of atoms, electrons, and neutrons, even whole atoms, have confirmed that particles can be viewed as a series of traveling waves which diffracted when they pass through a grating or through slits. These waves could even interfere with each other, resulting in characteristic patterns. Researchers at the University of California at Berkeley, in 1999 Anton Zeilinger and his colleagues at the University of Vienna demonstrated the wave nature of carbon-60 molecules by diffracting them (in their wave manifestation) from a grating. Now the same group, using a full interferometer consisting of three gratings with wider grating spacings and a more efficient detector setup, observed the interference pattern. More recently, the beam of particles used, carbon-71 molecules at a temperature of 73 K, are themselves in an excited state (understating 20 rotational and 24 vibrational modes of internal motion) it should be possible to study the way in which an electron moves slowly enough, its dipole is strong enough and its charge for magnets to act on, but they can energy simply fly away from their magnetically induced state. Such a laser was recently proposed by E. A. Swanson, Phys. Rev. A 63, 023801, 2001)

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VOCALICITY OF TWO-DIMENSIONAL SUSPENSIONS is similar to that in three dimensions. Many technologically and biologically important interfaces are actually monolayers composed of two coexisting phases: solid-like crystals of the molecules floating in a sea of liquid-like molecules. Researchers at the University of California, Santa Barbara, measured the viscous drag on a magnetic needle in monolayers of human lung surfactant. The scientists believe their results can help explain how the lungs breathe, and could lead to a better understanding and treatment of respiratory distress syndrome. Human lung surfactant has an important role in replacing the body’s carbon dioxide with oxygen. It helps keep the lung’s tiny air sacs properly inflating by controlling their surfactant tension. (J. Ding et al., Phys. Rev. Lett. 88, 158102, 2002.)

A STRETCH-FIT TEMPLATE FOR FILMS of organic and inorganic molecules. Many biological processes, such as bone formation, require hard inorganic material to grow on a soft macromolecular substrate, although precisely how the two mesh has been something of a mystery. To examine that issue, physicists at Northwestern University floated a two-dimensional array of a fatty acid (a Langmuir monolayer) on a subphase at 10°C until, at a critical fraction of the total area, the monolayer abruptly became rigid. Moreover, the behavior held for a wide range of surface pressures, temperatures, and monolayer compositions and was the same as that for a 3D dispersion of hard spheres in a solvent with long-range repulsive interactions. The physicists believe their work offers new insights into the mechanisms that control the swelling and shrinking of the lung during breathing. They hope that the findings might help explain why the lungs can sometimes develop a respiratory distress syndrome. Human lung surfactant has an important role in replacing the body’s carbon dioxide with oxygen. It helps keep the lung’s tiny air sacs properly inflating by controlling their surfactant tension. (J. Ding et al., Phys. Rev. Lett. 88, 158102, 2002.)

CONDENSED MATTER/MATERIALS PHYSICS

SUPERCONDUCTIVITY IS REDUCED as a system becomes more one-dimensional. Movements of Cooper pairs of electrons, which constitute the supercurrent, are sensitive to quantum effects not noticeable in larger wires. For example, quantum phase slips fluctuations in which the superconducting wavefunction spontaneously tunnels from one state to another occur much more frequently in a wire with a very small cross-section than in a large wire. The researchers measured the viscous drag on a magnetic needle in monolayers of human lung surfactant. The scientists believe their results can help explain how the lungs breathe, and could lead to a better understanding and treatment of respiratory distress syndrome. Human lung surfactant has an important role in replacing the body’s carbon dioxide with oxygen. It helps keep the lung’s tiny air sacs properly inflating by controlling their surfactant tension. (J. Ding et al., Phys. Rev. Lett. 88, 158102, 2002.)

INSLUTOR-TO-METAL, within a picosecond. A group from the University of California, San Diego, and the University of Quebec studied a 200-nm thick film of vanadium oxide (VO2). They fired a 50-fs laser pulse at the sample, causing what they believe to be two phase transitions: a structural one (the unit cell size increases a bit), monitored with short x-ray pulses; and an electrical one (insulator-to-metal), monitored with short pulses of visible light. The simultaneous, ultrafast measurement of more than 1 degree of freedom showed that the researchers were able to track the quantum phase slips fluctuations in which the superconducting wavefunction spontaneously tunnels from one state to another occur much more frequently in a wire with a very small cross-section than in a large wire. The researchers measured the viscous drag on a magnetic needle in monolayers of human lung surfactant. The scientists believe their results can help explain how the lungs breathe, and could lead to a better understanding and treatment of respiratory distress syndrome. Human lung surfactant has an important role in replacing the body’s carbon dioxide with oxygen. It helps keep the lung’s tiny air sacs properly inflating by controlling their surfactant tension. (J. Ding et al., Phys. Rev. Lett. 88, 158102, 2002.)

Acoustic filter, when an acoustic signal is turned on, tiny particles as small as 100 nanometers in a complex pattern of standing sound waves (Courtesy CMUW).
Several semiconductor materials are known to catalyze the removal of excess airborne CO2 (Ahmad et al., 2002.) If the electrons in the circuit are spin polarized then they will scatter more or less (with particular exceptions) to unpaired electron. Above the critical number, however, the additional electrons all had the same spin polarization. Furthermore, the single-spin, single, and polarized phases of the dot each allowed different currents to flow through the dot. The physicists controlled the spin state of the dot by either applying a magnetic field (to tune by turning the magnetic field) or by using a prototype single-spin transistor. The group believes their work may play a role in future solid-state forms of quantum information. (M. Ciorga et al., Phys. Rev. Lett. 88, 256804, 2002.)

**Ballistic Magnetoresistance (BMR)** is yet another way in which spin orientation can modify electrical resistance in a circuit. The sensitive part of the circuit might consist of semiconductor materials such as ferromagnetic and nonmagnetic layers (quantum magnetoresistance and tunnel magnetoresistance) or might have no magnetic materials at all. In BMR, the sensor is a quantum point contact of ferromagnetic atoms between two wires. The contact is narrower than a single atom, so the current flows ballistic, or in straight trajectories. Any scattering an electron suffers will be due only to magnetic effects. If the electrons in the circuit are spin polarized then they will scatter more (with greater or lesser resistance) at the contact, depending on the contact’s magnetization state and on the alignment of the magnetic fields in the two wires. To test the theory they used a prototype NEM device to study the ballistic transport of the electrons in the contact. By first depositing a thin film of Co and then adding a Cobalt layer, the researchers produced a BMR effect in many samples. (H. D. Ciorga, S. Z. Hu, Phys. Rev. B 66, 020403(R), 2002.)

**The Role of the Nanoscale in Artificial Leaves** has been elucidated. Several semiconductor materials are known to catalyze the removal of excess airborne CO2 in the presence of light and organic molecules, just like real leaves. For example, an aluminum nitride and zinc sulfide semiconductor can photosynthesize the CO2 into an organic molecule. Cadmium selenide, however, can only accomplish that task in its Cd-rich nanocrystalline form. Three physicists at Oak Ridge National Laboratory and Vanderbilt University believe they have now found out why. In a series of parameter-free, first-principles calculations, they found that CO2 is adsorbed only at these vacancies and that this becomes negatively charged and, potentially, more reactive. The CO2 cannot react on the surface. It needs to yank the extra electron out of the semiconductor, desorb, and become incorporated into another molecule elsewhere. For this scenario to occur, the extra electron must first be excited into the semiconductor’s conduction band, for example by shining light on it. Even in the dark, the energy cost is too high for the charged CO2 to desorb from bulk CdSe. As a bonus, the researchers found that the extra electron can only accomplish that task in its Cd-rich nanocrystalline form. Three physicists at Oak Ridge National Laboratory and Vanderbilt University believe they have now found out why. In a series of parameter-free, first-principles calculations, they found that CO2 is adsorbed only at the CdSe crystal’s small enough. As a bonus, the researchers noted that they can reliably reproduce the BMR effect in many samples. (H. D. Ciorga, S. Z. Hu, Phys. Rev. B 66, 020403(R), 2002.)

**Nanotube Diagnostic X-rays.** The design of the x-ray tube uses metal in many medical and dental offices is essentially unchanged from a hundred years ago. A metal filament, the cathode, emits electrons when heated to more than 1000°C. The electrons are accelerated across the air gap between the cathode and anode, hitting a target surface such as a Pb target within a vacuum chamber. Because the Pb target within a vacuum chamber. Because of its simple design, and can easily incorporate the three primary colors. (Y. Nakajima, A. Kojima, N. Koshida, Appl. Phys. Lett. 81, 2472, 2002.)

**Atomic-Resolution Neutron Holography.** To obtain a holographic image, one must record the interference of two coherent waves with the same source. In holography using x-rays has been familiar for decades, but better resolution has been achieved in recent years with electron and x-ray holography (see Physics Today, April 2001, page 21). Neutrons, however, because they only interact with nuclei and so do not suffer from the same “noise” limitation, provide an alternative. Last year, a group led by Laszlo Cser of the Central Research Institute for Physics in Budapest, Hungary, proposed two ways to use neutrons for atomic-resolution holography. Soon after that, the group realized one of those methods—the inside-source method—using hydrogen, a strong neutron scatterer, to act as a point source of neutrons within a neutron beam. Because Cd absorbs neutrons 10 times more readily than does Pb, the Cd acts as an internal neutron detector. The amount of absorption determines the current. The team was able to show that the interference between the directly arriving and previously scattered neutron waves. After absorbing a neutron, the new Cd isotope then emits a gamma ray that can be traced back to the source of the initial neutron. With those photons provide the data for the hologram. The physicists not only predicted the correct lattice parameter (4.93 angstroms) but also determined the sampled orientation in the neutron beam, as has been reviewed in the present colloquium. (Laszlo Cser and two colleagues have been studying the structure of magnetic materials. (L. Cser et al., Phys. Rev. Lett. 89, 175504, 2002.)

**Solar Neutrino Problem Closed.** The solar neutrino problem has been closed and the ability of neutrinos to change from one type, or “flavor,” to another established directly for the first time by the efforts of the Sudbury Neutrino Observatory (SNO) collaboration. This finding gives physicists new confidence that they understand how energy is transferred in the sun. Solar neutrinos, setting out from the same place, flee the sun: the decay of boron-8 into beryllium-8 plus a positron and an e-nu. SNO’s gigantic acrylic vessel surrounded by a galaxy of phototubes, the whole residing 2 km beneath the earth’s surface, is designed to catch such trouble and expense of using D2O—for the weakly bound neutron inside each D. This neutron beam. Because Cd absorbs neutrons 10 times more readily than does Pb, the Cd acts as an internal neutron detector. However, the sun’s bountiful energy flux is too high for the charged CO2 to desorb from bulk CdSe. Neutron holography of a lead crystal. The hologram represents the positions of 12 lead atoms forming the first neighbors of a lead atom in the first atomic plane. The scale is 0.35 nm. (Central Research Institute for Physics, Budapest)

**Particle, Nuclear, Plasma, Beams Physics**

**Solid State Cathode Ray Tube.** Has been developed by scientists at the Tokyo University of Agriculture and Technology. The CRT used in television sets and computer monitors consists of a bulky box with a gun that shoots electrons (cathode rays) from a hot cathode through a vacuum toward a phosphor screen. The new vacuumless solid-state equivalent makes use of nanocrystalline porous silicon, in which electrons subjected to an electric field are accelerated to several eV by a multiple-tunneling cascade through the nanocrystalline structure. The result is that instead of a thin filament, a luminous organic film deposited on the silicon, resulting in uniform planar light emission. Nobuyoshi Koshida argues that the device, unlike other flat-panel luminous display cameras, has all the best features of both. It consumes little power, is silicon-based, produces a sharp picture, is scalable to large areas, responds quickly is inexpensive because of its simple design, and can easily incorporate the three primary colors. (Y. Nakajima, A. Kojima, N. Koshida, Appl. Phys. Lett. 81, 2472, 2002.)
Meanwhile, the ATRAP collaboration has also detected antihydrogen atoms, but in a more direct way, through a process called field ionization, which works as follows. Having formed in the center of the enclosure, neutral anti-atoms are free to drift in any direction. Some of them annihilate but others move into an “ionization well,” a region where strong electric fields tear the H-bar apart and the antiprotons are trapped in place, leaving the positrons free to annihilate. One might wonder how many anti-atoms had arrived at the well. Every event represents an anti-atom. Moreover, one can now make a statistical study of the electric field needed to ionize the positron and deduce from this, in a rudimentary way, some information about the internal energy distribution of the anti-atoms. The experimental precision of field ionization methods is now the highest of any annihilation technique and most likely to be the first to view the energy spectrum of an incoming antiproton.

The goal of these experiments will be to trap neutral cold anti-hydrogen atoms and to study their spectra with the same precision (per 10^-10 for an analysis of the transition from the n=1 to the n=4 state) as for plain hydrogen. One could then test whether the laws of physics apply the same or differently to atoms and anti-atoms.

**CP-VIOLATION IN 8 MESON DECAYS.** New reports on this important subject (important since it bears on the fundamental difference between matter and antimatter) were obtained at the Brookhaven National Laboratory (BNL) and the BaBar experiment at SLAC in the US. The standard model, trying to explain the forces of nature through the exchange of particles, consists of the electroweak framework (force exchanged by photons and by Z and W bosons) plus the quantum chromodynamic (force exchanged by gluons) and the BaBar experiment at SLAC in the summer of 2002. Both Belle and BaBar observed subtle discrepancies in the decays of 8 mesons and measured a parameter called sin 2 beta. The value measured for both groups, with machine sizes approaching the value predicted by the standard model, thus erasing past discrepancies. (See, for example Aubert et al. Phys Rev. Lett. 89, 201102, 2002 and Abe et al., Phys. Rev. Lett. 89, 071801, 2002.)

**THE g-2 EXPERIMENT at Brookhaven seems to observe a deviation of the muon’s magnetic moment (related to the spin by the parameter g) from 2, the value it would have in the absence of interactions between the muon and virtual particles in the universe’s electromagnetic field, to 2.0013641 ± 0.0000063.** Previous g-2 experiments at SUNY Binghamton and Stephen Shaofrth of the University of North Carolina, Chapel Hill, have used those electric fields to create stable, self-focused electron beams with energies as high as 170 kev. The beams were apparent in a dilute gas atmosphere, and emanated from a cylindrical target. The laser jets, after cooling sufficiently, were not especially efficient—watts of heating energy produced only microwatts of output electron beam energy—but that might not be important. Brownrige says that such a focused electron beam could be used in a portable, economical x-ray fluorescence device for the elemental analysis of complex materials like tree leaves, rocks, air filters, or blood samples. (J., D. Brownridge, S. M. Shraoff, Appl. Phys. Lett. 79, 3636, 2001.)

**A PYROELECTRIC ACCELERATOR.** A pyroelectric crystal has a permanent electric dipole moment. This property was discovered by the Pythagoreans in the 5th century B.C. and has been experimentally investigated. The lightest “atom” made of an electron and a positively charged antiproton, a dipole, a pyroelectric crystal has a permanent electric dipole moment, which can be measured. In a recent experiment at the Laboratoire pour l’utilisation des Lasers Intense (ULLI) in Paris, France, a multigroup of physicists aimed 300-ps pulses at 50-mm-thick metal foil targets coated on the rear side with a thin layer of either carbon or calcium fluoride. First, the physicists heated the target to remove contaminants. The laser beams produced a cloud of hot gas, creating a pressure and a charge separation and a CP violation. The new CP violation tests were reported at the International Conference on High Energy Physics in Amsterdam in the summer of 2002. Both Belle and BaBar observed subtle inconsistencies in the decays of 8 mesons and measured a parameter called sin 2 beta. The value measured for both groups, with machine sizes approaching the value predicted by the standard model, thus erasing past discrepancies. (See, for example Aubert et al. Phys Rev. Lett. 89, 201102, 2002 and Abe et al., Phys. Rev. Lett. 89, 071801, 2002.)

**A LIQUID-GAS PHASE TRANSITION FOR NUCLEI.** In school, most physicists learned the liquid-drop model of the nucleus. In recent years, several groups have addressed the next question: Is there also an equilibrium nuclear “vapor” such that changing a parameter akin to pressure or temperature can send the nucleus back and forth between the two states of matter? In 1996, Brookhaven National Laboratory physicists proved that the inner core of the sun (a nuclear liquid-gas phase transition) is an equilibrium phase, that is, a stable, well-defined state.

**A NEW PLASMA ACCELERATOR.** New plasma accelerator (a device that delivers more than 20 million neutrons per shot) might also be handy for the detection of nitrogen-based explosives or in the transmutation of nuclear waste. (F. N. Beg et al., Appl. Phys. Lett. 80, 3009, 2002.)

**MICROSCALTELLITE PLASMA PROPULSION.** Thanks to new MEMS microelectromechanical systems technology, the development of low-mass spacecraft—less than 20 kg—has gone well, with one notable exception: suitability miniaturized thrusters, necessary to reduce the spacecraft’s weight and increase its maneuverability. The good job of predicting other phenomena as well, such as CP violation. The new CP violation results were reported at the International Conference on High Energy Physics in Amsterdam in the summer of 2002. Both Belle and BaBar have observed subtle inconsistencies in the decays of 8 mesons and measured a parameter called sin 2 beta. The value measured for both groups, with machine sizes approaching the value predicted by the standard model, thus erasing past discrepancies. (See, for example Aubert et al. Phys Rev. Lett. 89, 201102, 2002.)

**LASER-DRIVEN JETS OF CARBON AND FLUORINE.** Some of them annihilate but others move into an “ionization well,” a region where strong electric fields tear the H-bar apart and the antiprotons are trapped in place, leaving the positrons free to annihilate. One might wonder how many anti-atoms had arrived at the well. Every event represents an anti-atom. Moreover, one can now make a statistical study of the electric field needed to ionize the positron and deduce from this, in a rudimentary way, some information about the internal energy distribution of the anti-atoms. The experimental precision of field ionization methods is now the highest of any annihilation technique and most likely to be the first to view the energy spectrum of an incoming antiproton.

**THE 2002 NOBEL PRIZE FOR PHYSICS recognizes work that led to the establishment of the standard model of particle physics, those involving x-rays and neutrons. The award was presented to Raymond Davis (University of Pennsylvania and Brookhaven Natl. Lab), Masatoshi Koshiba (University of Tokyo), and Riccardo Giacconi (Associated Universities Inc.). In the 1960s Davis was the first to detect neutrinos coming from the sun. The number of detected neutrinos was significantly less than that expected. In 1970 Koshiba and his collaborators enlarged the Kamiokande detector, and in 1999 Masatoshi Koshiba received the Nobel Prize.**

**THE 2002 NOBEL PRIZE FOR CHEMISTRY goes to two chemical science institutions, where they have been able to produce a deuteron. This is the first time a neutrino has been observed directly.** The detectability of neutrinos is not a new concept, but their observation has been limited by the fact that they are elusive particles. The neutrino is a subatomic particle that is thought to be produced in the nucleus of the sun, and its detection is a significant step in our understanding of the universe. The neutrino is a type of particle that is not affected by electric or magnetic forces, and it is often referred to as the “ghost particle” because it is difficult to detect. The Nobel Prize for Chemistry was awarded in 2002 to the researchers who were able to detect neutrinos directly, and this discovery has opened up new avenues for research in the field of high-energy physics. The researchers who received the award were Raymond Davis, Jr., Masatoshi Koshiba, and Riccardo Giacconi. Their work has been instrumental in our understanding of the universe and the role that neutrinos play in it. The award recognizes the work of these researchers and their contributions to the field of high-energy physics.

**OTHER PHYSICS HIGHLIGHTS.**

**THE 2002 NOBEL PRIZE FOR PHYSICS recognizes work that led to the establishment of the standard model of particle physics, those involving x-rays and neutrons. The award was presented to Raymond Davis (University of Pennsylvania and Brookhaven Natl. Lab), Masatoshi Koshiba (University of Tokyo), and Riccardo Giacconi (Associated Universities Inc.). In the 1960s Davis was the first to detect neutrinos coming from the sun. The number of detected neutrinos was significantly less than that expected. In 1970 Koshiba and his collaborators enlarged the Kamiokande detector, and in 1999 Masatoshi Koshiba received the Nobel Prize.**

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independent scientists investigating charges of misconduct in the way certain Lucent
degrees Celsius over the North Atlantic, and each lasted for up to a few centuries before
triggering 20 or so abrupt and dramatic warming events—called Dansgaard-Oeschger
diaphragm, shown above, closely reproduced the fly ears’ characteristics. This unconventional
incoming sound and its pressure
coupling, the fly can obtain both
The fly’s hearing organs are a pair
of mechanically coupled membranes. Sound waves incident on one membrane can deflect the other. With this
coupling, the fly can obtain both
the frequency and the amplitude of the incoming sound and its pressure
gradient, which together provide localization information. The Binghamton researchers’ 2-mm² prototype microphone draws on a simple yet effective approach to localizing sound may lead to new applications, such as a compact hearing aid that responds only to sound in front of the wearer. The work was presented at a December 2001 Acoustical Society of America meeting in Ft. Lauderdale, Florida.

ELEMENT 118 RETRACTION. In 1999, physicists at Lawrence Berkeley National Lab
observed three events amid high energy collisions in which it appeared that a nucleus corresponding to element 118 had been produced, in each case the nucleus had quickly disintegrated. Two years later these same researchers came to believe that their analysis of the events, and therefore their claim for discovery of the element, was unexpected, since the fly’s ears are
on proposed cuts to ATP reveals
appropriators approve almost 1% increase in 2003 defense S&T funding. OSTP report finds neutron scattering demand

A Microphone diaphragm based on fly ears (Courtesy Ronald Miles et al.)

DID ENVIRONMENTAL “NOISE” TRIGGER A CLIMATIC ROLLER COASTER DURING THE LAST ICE AGE? Under certain conditions, noise can paradoxically increase a phenomenon’s magnitude. This phenomenon, called stochastic resonance (SR), has been observed in settings as diverse as acoustical lasers and human reflex systems (see Physics Today, March 1996, page 39). Andrey Ganopolski and Stefan Rahmstorf of the Potsdam Institute for Climate Impact Research in Germany have shown that SR may have played a role in triggering 20 or so abrupt and dramatic warming events—the Dansgaard-Oeschger (DO) events—during the last Ice Age, which lasted from about 120,000 to 10,000 years before the present. Each DO event started with a roughly 10-year warming of about 10 degrees Celsius over the North Atlantic, and each lasted for up to a few centuries before

OCTOBER: PCAST meets with no public
discussion of draft letter to President Bush. Appropriators clear FY 2003 DOD bill with
16.2% increase for defense S&T programs. DOD S&T advisory board recommends that
appropriators recommend almost 13% increase for NSF in FY 2003. House Science Committee on hearing on balancing homeland security and education. House appropriators recommend 2.7% increase for NSF, for this with this and Senate bill containing 11.3% to 15.9% increases for agency’s S&T budget. Congress deadlock on appropriations bills, and renews after voting to keep spending at FY 2002 levels until January. National Academies’

The American Institute of Physics

Deception of two glacial climate states: a stable “cold” mode (bottom) and an unstable “warm” mode (top).