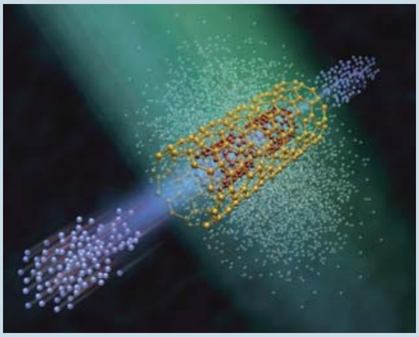
physics update

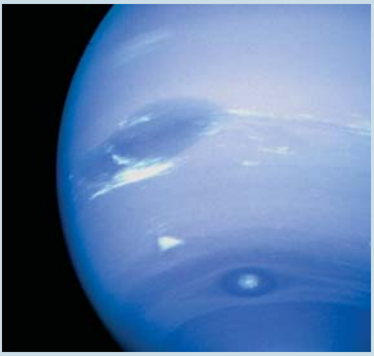
These items, with supplementary material, first appeared at http://www.physicstoday.org.

What kept the Moon's dynamo alive? The Moon's magnetic field used to have both the strength and the dipolar structure of a vigorous, dynamo-generated field like Earth's. Now, however, the lunar field is weak and patchy. Accounting for the field's enfeeblement might seem straightforward. As it aged, the Moon's molten core cooled and shrank to the point at which it could no longer sustain a dynamo. The trouble is, whereas an analysis of Moon rocks published last year put that transformation at 3.7 billion years ago, models of thermal convection in the Moon's core put it at 4.1 billion years ago. What kept the dynamo alive for the intervening 400 million years? To find out, MIT's Clément Suavet and his collaborators recently subjected two Moon rocks, both 3.56 billion years old, to magnetic, thermal, and other tests. (The photo shows a 5-g sample of one of the rocks next to a 1-cm^3 cube.) The researchers deduced that the rocks had been magnetized by a surface field of at least 13 μT, which is consistent with a strong dynamo. Although the age difference is just 4% between the rocks in the 2012 study and the younger rocks in the new study, one explanation for the prolonged life of the dipolar field beyond its expected span can be ruled out: an off-center hit by an asteroid that set the Moon rocking back and forth in its tidally locked orbit. No impacts big enough occurred that late. Another proposed mechanism remains in play: The chemically stratified layers that formed when the mantle crystallized could have become dynamically unstable and triggered a second round of convection. (C. Suavet et al., *Proc. Natl. Acad. Sci. USA*, in press, doi:10.1073/pnas.1300341110.) —CD

Proton beams from a nanotube accelerator. Carbon nanotubes (CNTs) are hardy and versatile, with remarkable material and electronic properties. And they could be useful in some extreme conditions as well. Two physicists in Japan, Masakatsu Murakami of Osaka University and Motohiko Tanaka of Chubu University, propose using a CNT as a shotgun barrel to shoot a beam of protons. Their scheme nests two small hydrogen-rich fragments—which could be water ice, paraffin, or some other low-Z material but were modeled as hydrogen nanotubes—within a larger CNT that has gold atoms chemically adsorbed in its wall. The assembled structure is then zapped from the side with an ultraintense femtosecond laser pulse (green in the schematic). As shown in three-dimensional simulations, the laser partially ionizes the gold and fully ionizes the hydrogen and carbon in the assemblage; after a few swings of the laser's electric field, significant numbers of electrons (white) are blown off and form a cloud around the CNT. The now highly ionized coaxial structure generates a Coulomb potential in which the protons (blue) from the low-Z shotgun shells are squeezed toward the axis and accelerated out both ends of the CNT. The simulations indicate that even a non-optimized setup can produce highly collimated beams of nearly monoenergetic protons—1.5 MeV for the parameters used. Such beams are of great interest in fields as diverse as medicine, fusion energy, and materials engineering. (M. Murakami, M. Tanaka, *Appl. Phys. Lett.* **102**, 163101, 2013.) —SGB



Demystifying the ice giants' puzzling poles. Like our own planet, Jupiter and Saturn have magnetic and geographic poles that are closely, but not perfectly, aligned; each planet's magnetic dipole is angled just a few degrees off its rotational axis. But the magnetic fields of Uranus and Neptune, the so-called ice giants, are dramatically tilted—by 59° and 46°, respectively. New experiments by Eric King (University of California, Berkeley) and Jonathan Aurnou (UCLA) may help to explain why. Planetary magnetic fields are thought to be generated by dynamos—turbulent, convective flows of electrically conducting fluid in the planet's interior (see the article by Daniel Lathrop and Cary Forest in PHYSICS TODAY, July 2011, page 40). Coriolis forces due to planetary rotation can influence those convective flows and thereby orient the dynamo's field. To probe that effect in the lab, King and Aurnou did what's known as a rotating Rayleigh–Bénard experiment: They heated a 20-cm-wide spinning drum of liquid gallium from below while simultaneously cooling it from above. Using conditions that, through appropriate scaling, mimic those of planetary interiors, the researchers found that the rotation–convection coupling is especially pronounced in fluids with high thermal conductivity. Therein may lie the secret of the ice giants' skewed poles: Based on trends seen in the experimental data, the researchers estimate that Earth, Jupiter, and Saturn, whose dynamos comprise high-conductivity molten metal, fall within the strongly coupled regime, whereas Uranus and Neptune, whose dynamos comprise moderate-conductivity aqueous solution, do not. (E. M. King, J. M. Aurnou, *Proc. Natl. Acad. Sci. USA* **110**, 6688, 2013.) —AGS


NASA

Hot fire, cool soil. Wildfires around the planet burn an average of 3.7 million km^2 of vegetation annually and can leave landscapes scorched, barren, and vulnerable to erosion and flooding. According to the literature, the more vegetative fuel, the more intense the fire, the hotter the soil, and the more severe the damage to fragile roots, seeds, and microbes.

But that understanding is based on laboratory studies and prescribed burns in small fields. An experiment led by Cornell University's Cathelijne Stoof, who at the time was working at Wageningen University in the Netherlands, now provides evidence that in more heterogeneous conditions the opposite may occur—the hotter the fire, the cooler the soil. To study the effects of landscape and fire dynamics on soil temperature, the group mapped a 0.1-km^2 shrub-covered watershed in Portugal, installed 52 thermocouples throughout the region, and then set it ablaze. Although the most thickly vegetated areas burned at temperatures as high as 800 °C, topsoil in those areas remained below 100 °C. The soil temperature remained low, the researchers argue, because large air-temperature gradients increased the upward transport of heat and dense vegetation contained the most moisture. Dry, sparsely vegetated areas that burned less intensely, in contrast, suffered the greatest damage; their soil reached more than 300 °C in places. Managers of fire-prone ecosystems could use the results to decide how, where, and when to set off controlled burns. (C. R. Stoof et al., *Geophys. Res. Lett.*, in press, doi:10.1002/grl.50299.) —RMW

First results from the *Planck* microwave telescope. The European Space Agency's *Planck* satellite, launched in 2009, surveys the entire sky at microwave and submillimeter wavelengths with much better sensitivity, angular resolution, and spectral coverage than was available to earlier generations of microwave orbiters. *Planck*'s main objective is to measure the parts-per-million spatial temperature fluctuation of the cosmic microwave background—the light from the first moments of cosmic transparency, 3.7×10^5 years after the Big Bang. Precision measurements of its tiny, random departures from thermal isotropy on all angular scales inform and constrain cosmological models. Now the *Planck* collaboration has presented the results of its first 16 months of observation in 28 simultaneously released papers; the team's overview paper is cited below. The principal finding is that cosmology's widely accepted concordance model is alive and healthier than ever. Some of its fundamental parameters have suffered interesting tweaks, but none that clearly require new physics or additional parameters in the model's scenario of cosmic birth, inflation, and structure formation. For example, the cosmic inventory of matter and dark energy has shifted by a few percent toward more matter, with a consequent slight reduction of the expansion rate and a mere hundred million years added to the previous best estimate (13.7×10^9 years) of the age of the universe. (P. A. R. Ade et al., *Planck* collaboration, *Astron. Astrophys.*, in press, http://arxiv.org/abs/1303.5062.) —BMS

Ideal point source for modeling room acoustics. When analyzing the characteristics of sound—be it in a concert hall, a doctor's office, or a city street—acousticians can't always have unfettered access to the soundscape. So they build scale models and adjust the sounds' frequencies and amplitudes accordingly. A broadband, omnidirectional source of sound is very useful to modelers, and electrical sparks have been used to that end for many years. But the waveforms that emanate from electrodes are not only directional but vary from spark to spark in unpredictable ways. In addition, the electrodes' presence can complicate the sound propagation. So a group of acousticians at Aalto University and Helsinki University, both in Finland, came up with a solution that has been effective for studying shock wave propagation: They used a laser-induced pressure pulse (LIPP). When a point in space is heated to thousands of degrees by a focused laser, a local dielectric breakdown in air gives rise to an electrodeless spark that sends out a pressure wave—the LIPP. In their version, the acousticians focus a pulsed laser and send it into the scale model through an acoustically opaque glass window. Projected into the enclosed space, the LIPP has all the hallmarks of an ideal acoustical point source: It produces a lot of sound while being small, massless, omnidirectional, and broadband. (J. G. Bolaños et al., *J. Acoust. Soc. Am.* **133**, EL221, 2013.) —SGB

The crystal structure of a lower-mantle mineral. Just above Earth's liquid outer core lies a 200-km-thick region, dubbed D″, whose properties differ from those of the rest of the mantle. Long a mystery, the origin of D″ became clear in 2004 when the most common mineral in Earth's mantle, magnesium silicate ($MgSiO_3$), was found to change its crystal structure at conditions that prevail in D″—that is, at pressures above 120 gigapascals and temperatures above 2500 kelvin. A new study by Ho-Kwang Mao of the Carnegie Institution of Washington and his collaborators sheds further light on the transition. Like their predecessors, Mao and his team used a diamond anvil cell to apply pressure, a laser to apply heat, and x-ray crystallography to determine structure. As the transition neared, a hundred or so randomly oriented crystallites of the high-pressure phase nucleated within the micron-scale sample. To gather enough structural information about the ensemble, Mao and team rotated the sample through 51° in 0.2-degree steps, yielding 256 sets of overlapping diffraction patterns (see figure for an example). A computer algorithm sorted through thousands of discrete spots to determine the crystallites' orientations and structures. Besides confirming previous results, Mao's study reveals that replacing 10% of the magnesium with iron barely alters the structure. An admixture of iron is expected in the lower mantle. Its lack of structural influence is encouraging, because it suggests that inhomogeneities in seismic data could be mapped to inhomogeneities in temperature and pressure, such as plumes and hot spots. (L. Zhang et al., *Proc. Natl. Acad. Sci. USA* **110**, 6292, 2013.) —CD ■