Whether either dissipation mechanism occurs is hard to say, but the CoMP data contain a clue. As figure 2 shows, Tomczyk and McIntosh could identify whether waves travel out from the photosphere (prograde) or back down toward it (retrograde). The retrograde signal is one-third to one-half as strong as the prograde signal. Dissipation that occurred before the waves made their return trip could account for the deficit.

Nanoflares remain the leading candidate for heating the corona, even though no one has definitively observed them. They are thought to originate in the myriad thin flux tubes that together make up the thick coronal loops in figure 1. Stirring the photosphere's velocity field causes the roots of the loops and tubes alike to jostle violently and randomly, twisting the magnetic field lines. Eventually, when the twist becomes too great, the loops and tubes snap into a new configuration of lower curvature and energy.

At its most extreme, such reconnection hurls vast amounts of plasma back onto the Sun or out into space, knocking out satellites and power grids. When thin tubes reconnect, the result is a nanoflare, which impulsively heats the local plasma. Instabilities can also yield nanoflares. A constant, ubiquitous barrage of reconnection or instabilities could in principle heat the corona.

Unfortunately, evidence for nanoflares is even harder to obtain than it was for Alfvén waves. Not only are the events small in scale, they are also fleeting. At the temperatures and densities that prevail in the corona, thermal conduction is extremely efficient. When an individual nanoflare pops off, the local plasma temperature shoots up to 1 MK, then drops rapidly. Meanwhile, the density, and with it the observable intensity, also drops as the plasma sinks rapidly. Trying to see an individual nanoflare is like trying to hear an individual cicada.

The best prospect for observing nanoflares lies in the x-ray band, where the hot corona emits most of its photons. Space-based instruments can deploy filters as fine as CoMP's and can observe with the spatial and temporal resolution needed. The challenge used to be squeezing copious data into limited telemetry. Now, it's a matter of getting the right instrument into space.

If the nanoflare hypothesis is vindicated, Alfvén waves will remain important. Observing them provides crucial information about the strength and evolution of the coronal magnetic field. And regardless of what heating mechanisms they favor, solar physicists all want to observe the Sun with higher spectral, temporal, and spatial resolution.

Charles Day

References

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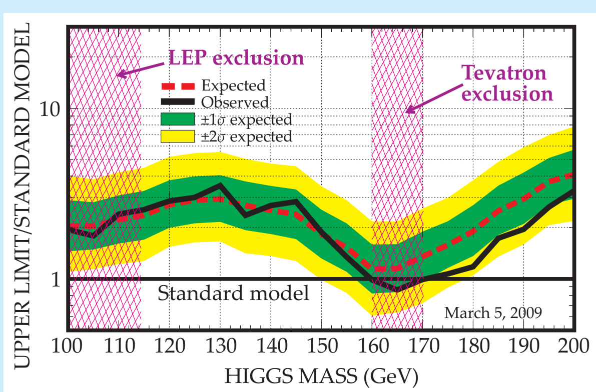
physics update

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

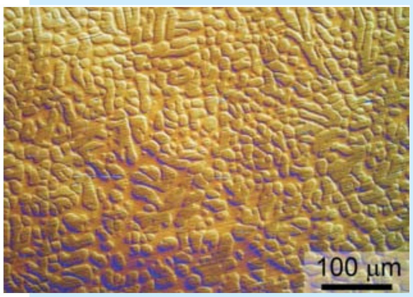
Constraining the Higgs mass. In the standard model of particle physics, the predicted and much-sought Higgs boson (H) remains the principal missing link. The theory attributes the nonzero masses of the quarks, leptons, and weak vector bosons to their interaction with the H's quantum field. Searches at CERN's Large Electron–Positron collider have put a lower limit of 114 GeV (about 120 proton masses) on the H mass, and theoretical analysis of a variety of well-measured particle-physics parameters suggests an upper mass limit of about 185 GeV. Now a significant bite has been taken out of the interval 114–185 GeV by a new analysis of Higgs-search data accumulated in nine years of running at Fermilab's 2-TeV Tevatron proton–antiproton collider. The analysis, a combined undertaking of the large CDF and D0 detector collaborations at the collider, concluded with a confidence limit of 95% that the H mass does not lie between 160 and 170 GeV—presuming that its production and decay properties are those predicted by the standard model (see the figure). The combined data set comes from 10^{15} proton–antiproton collisions, but the teams had to limit their searches to events that produced a W or Z weak vector boson. Only a few percent of H-producing collisions are expected also to produce a W or Z. But the decays of those very heavy particles are spectacular enough to provide a discernable signal under the haystack of routine events that would otherwise hopelessly obscure the tiny fraction of events that create an H. The two collaborations expect to accumulate a lot more data before CERN's new 14-TeV Large Hadron Collider joins the Higgs search early next year. (CDF and D0 collaborations, http://arxiv.org/abs/0903.4001v1.) —BMS



An asteroid's composition has been determined by sky and ground observations. How an asteroid reflects sunlight as a function of wavelength reveals something about the asteroid's make-up. Based on reflectance spectra, astronomers have developed a classification scheme for asteroids and noted that those of a given type tend to be formed in the same region of the asteroid belt. The composition of meteorites, most of which come from asteroids, can be determined in detail. Until recently, however, no meteorite could be unambiguously associated with a specific asteroid or even a spectral class. But now scientists have obtained reflectance and composition data for the same asteroid—2008 TC_3, which blew up over Sudan's Nubian Desert shortly before dawn on 7 October 2008. Its story was told recently by an international team led by the SETI Institute's Peter Jenniskens. The asteroid, also called Almahata Sitta, had been sighted 20 hours before it disintegrated—early enough for scientists to take reflectance measurements. And some of Almahata Sitta survived the explosion high above Earth and rained down to the surface. Students

from the University of Khartoum, led by professor Muawia Shaddad, gathered 47 of the meteorites, one of which was studied in detail. That remnant's high porosity and dark carbon-rich material are peculiar. Those anomalies may, in time, help physicists understand the processes that took place in the solar nebula in the region where Almahata Sitta and its spectral classmates formed. (P. Jenniskens et al., *Nature* **458** 485, 2009. Photo courtesy of NASA/Peter Jenniskens.) —SKB

Confining cracks in metallic glass. Lightness, strength, and moldability are among the most desired material properties for aircraft, sporting equipment, and many structural applications. Those sometimes opposing properties converge in bulk metallic glasses—supercooled amorphous metal alloys that can be cast into complex shapes and are resilient under large elastic strains. However, their toughness is suspect: Under repeated stress, BMGs fatigue and develop fatal cracks much more quickly than crystalline metal alloys do. To control crack propagation, Caltech's William Johnson, Lawrence Berkeley National Laboratory's Robert Ritchie, and their collaborators focused on controlling the microstructure of a particularly tough BMG composite made of zirconium, titanium, and other metals. Its finger-like crystalline dendrites (67% by volume) are surrounded by an amorphous matrix, as seen in this optical micrograph. By heating the precursor alloys between their melting points then rapidly quenching the solution, the researchers were able to control dendrite size and the spacing between the glassy and crystalline phases. The width of the glassy region between the much-tougher dendrite fingers was tailored to be short enough to serve as a "microstructural arrest barrier" for just-formed cracks. Compared with existing dendrite-containing BMGs, the new material holds up under three times more stress cycles and is comparable in toughness to high-strength steel or aluminum. (M. E. Launey et al., *Proc. Natl. Acad. Sci. USA* **106**, 4986, 2009.) —JNAM



Making a splash. In his "Milkdrop Coronet," strobe-photography pioneer Harold Edgerton famously captured the splash produced by a milk droplet falling into a saucer. But our understanding of the underlying physics remains poor. It's known that before a liquid droplet splashes upward from a surface, a thin sheet of liquid spreads out from the impact point. Four years ago experiments by Sidney Nagel and colleagues at the University of Chicago showed, surprisingly, that splashing on a dry surface can be suppressed by reducing the ambient air pressure. The researchers concluded that compressible effects in the air are responsible for the splashing (L. Xu, W. W. Zhang, S. R. Nagel, *Phys. Rev. Lett.* **94**, 184505, 2005). Now Michael Brenner and coworkers at Harvard University have further looked into the air's role in how droplets splash on a dry surface. Taking into account the compressibility and viscosity of the gas and the surface tension of the liquid, they modeled the behavior of the approaching droplet as it reaches the surface. They find that instead of spreading out over the surface, the liquid spreads over a very thin film of air. When the droplet nears the surface, pressure builds beneath it and the bottom of the droplet deforms by flattening and then becoming dimpled. The droplet's bottom perimeter develops a kink that, still over a layer of air, moves out and creates capillary waves. The calculations don't, however, show any indications of splashing; the researchers suggest that other parameters, such as the droplet viscosity and thermal transfer, must become important after the initial spreading phase. (S. Mandre, M. Mani, M. P. Brenner, *Phys. Rev. Lett.* **102**, 134502, 2009.) —RJF

Engineering a faster battery. Today's laptop computers, cell phones, hybrid vehicles, and other technologies rely on rechargeable batteries. As discussed in PHYSICS TODAY, December 2008, page 43, batteries—in particular, the popular lithium-ion batteries—typically have a high energy density but a low power density: They can't deliver their stored energy particularly quickly. Often the limiting step in Li^+ batteries is not getting the ions through the electrolyte and electrode structure but getting them into the active electrode material itself. Using nanoscale materials in the electrodes and doping the materials are among present techniques to improve battery rates. Now Byoungwoo Kang and Gerbrand Ceder of MIT have shown that using particles of a common electrode material, lithium iron phosphate ($LiFePO_4$), covered with a glassy coating of iron-doped lithium phosphate can significantly increase the charging and discharging rates. Moreover, the particles and coating can be formed together in a single step. In test experiments, the researchers obtained discharge rates 100 times as fast as today's commercial Li^+ batteries. The researchers suggest that the amorphous coating may improve Li^+ transport across the surface of the electrode particles; uncoated $LiFePO_4$, in contrast, conducts ions poorly except in a narrow range of directions. Additionally, they say that the coating may modify the surface potential and provide adsorption sites for a range of ion energies. (B. Kang, G. Ceder, *Nature* **458**, 190, 2009.) —RJF

Plasma waves and cosmic rays. With energies exceeding 10^{20} eV, the highest-energy cosmic-ray protons are as energetic as well-hit tennis balls. How does a proton become so energetic? Recent cosmic-ray data disfavor the notion that these ultra-energetic protons have exotic origins such as the decay of very massive particles as yet unidentified. So one must seek the proton acceleration mechanism in familiar astrophysical environments. The conventional suggestions—acceleration by relativistic shocks, spinning black holes, or flares on hypermagnetized neutron stars—each have problems accounting for the highest observed energies. Shock acceleration, for example, becomes increasingly inefficient at high energy because the inevitable trajectory bending causes severe synchrotron energy loss. Now theorist Pisin Chen (SLAC and National Taiwan University) and coworkers have demonstrated analytically and by computer simulation that so-called magnetowaves—electromagnetic waves with unusually strong magnetic components in magnetized plasmas—can drive plasma waves in their wake much as laser pulses in the laboratory drive plasma wakefields in experimental plasma-based accelerators (see PHYSICS TODAY, March 2009, page 44). The mechanism avoids synchrotron loss, and it provides strong accelerating gradients even at very high energy. Chen and company show that a proton surfing a stochastic succession of such plasma wakes can, with luck, be accelerated to 10^{21} eV. Magnetowaves are believed to be produced in the relativistic jets emanating from active galactic nuclei. And the "luck" required for the proton to catch just the right sequence of plasma waves in an AGN jet accords with the observation that ultra-energetic cosmic rays are extremely rare. That's why the detector arrays that study them cover thousands of square kilometers. (F.-Y. Chang et al., *Phys. Rev. Lett.* **102**, 111101, 2009.) —BMS