for the experiment, since above that pressure xenon forms a solid clathrate with water—xenon is 70% as dense as water, whereas an ideal gas with xenon's mass would be just 36% as dense as water.

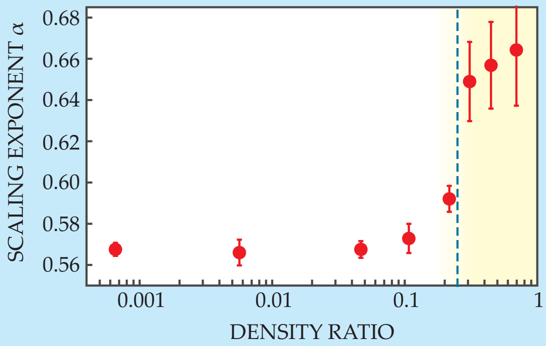

Figure 2. The scaling exponent *α* describes the pinch-off neck width *w* as a function of time *t*: *w* is proportional to t^{α}. In the experiments on xenon bubbles in water, when the xenon-to-water density ratio was less than about 0.25, $\alpha = 0.57$, the same as for air bubbles in water. At higher density ratios, $\alpha = 2/3$, the same as for water droplets in air. The error bars are much larger in the droplet-like regime because the xenon bubble sometimes obscures the narrowest point of the pinch-off region. Even subject to that limitation, the sharp boundary between bubble-like and droplet-like scaling is evident. (Adapted from ref. 3.)

Housing the bubbles

Burton and Taborek built their own high-pressure xenon source from which they could bubble the gas into a stainless steel cell filled with water. But taking highly magnified pictures of the xenon formations under such large pressures was a challenge. The camera needed to sit within 2 cm of the bubbles and yet remain outside the cell. So the researchers fitted their cell with two parallel sapphire windows—one for illuminating the bubbles and the other for imaging them—which could withstand the pressure but were less than a centimeter thick.

The available range of densities from $D \approx 0$ to $D = 0.7$ allowed the researchers to observe both bubble-like and droplet-like pinch-off behavior, as shown in figure 1. "We were initially hoping to see evidence of the instabilities that were predicted in the numerical simulations," says Burton. But the droplet profiles they observed, as far as they could tell, were perfectly smooth. The researchers speculate that perhaps the instabilities were damped out by viscous effects on the small but nonzero viscous length scales of xenon and water.

The shapes of the pinch-off regions appeared to vary continuously from the symmetric profile of the bubble-like regime to the tapered filament of the droplet-like regime. But the scaling exponent that describes the neck width as a function of time was another story, as shown in figure 2. "You might expect to see a smooth, linear transition from 0.57 to ⅔," explains Burton. "But that's not the case." To the researchers' surprise, what they saw instead was a nearly constant value of 0.57 for low values of *D*, a nearly constant value of 0.66 for high values of *D*, and an abrupt transition near $D = 0.25$.

Theoretical understanding of Burton and Taborek's results—why the transition is so sharp and why it occurs at $D = 0.25$—has yet to come. Burton and Taborek themselves are now working on numerical simulations to help them understand what they've seen. But they're also looking experimentally at droplet and bubble formation in electrically charged fluids and non-Newtonian fluids—further exploring the zoo of pinch-off possibilities.

Johanna Miller

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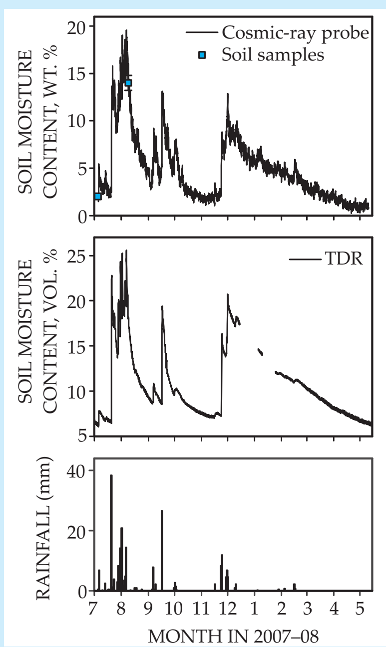
physics update

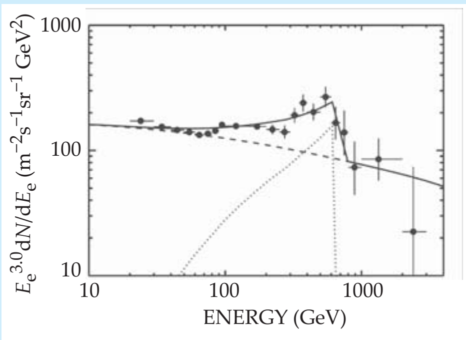
These items, with supplementary material, first appeared at http://www.physicstoday.org.

Measuring soil moisture with cosmic-ray neutrons. Through its influence on evaporation rates, humidity levels, and other factors, the moisture content of soil has a significant impact on weather. Accurate measurements of that content, though important for meteorological, hydrological, and ecological forecasting, are difficult to make. Extrapolating point measurements to larger areas is inaccurate, and satellite-based remote-sensing methods are hindered by ground cover, surface roughness, and other limitations. A team from the University of Arizona and the Southwest Watershed Research Center in Tucson has shown that just above the ground surface, so-called fast neutrons with energies on the order of an MeV are quantifiably correlated with soil moisture and thus provide a noninvasive means for measuring the average moisture levels over regions several hundred meters wide and tens of centimeters deep. The neutrons are generated by cosmic rays. Upon collision with atmospheric nuclei, cosmic rays create showers of high-energy secondary particles, and those that reach Earth's surface can penetrate it, collide with nuclei there, and produce among their debris fast neutrons, some of which escape back into the atmosphere. Marek Zreda and colleagues discovered that hydrogen, mostly found in water, dominates soil's ability to moderate fast neutrons and that a strong inverse correlation, independent of soil chemistry, exists between moisture content and the intensity of the fast neutrons that escape out of the ground. The team demonstrated that with an independent measurement of the moisture



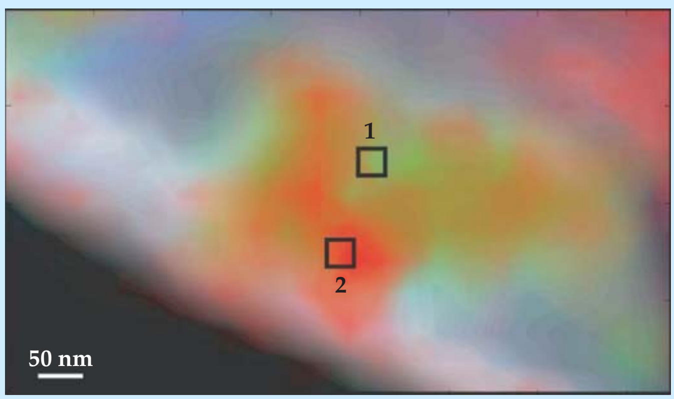
content for calibration, a neutron detector a few meters above the ground can give precise measurements of soil moisture on the time scale of minutes to a few hours. As the figure shows, the hourly soil moisture determined by a cosmic-ray neutron detector (top) agrees with that determined by time-domain reflectometry probes (middle) and with the monitored daily precipitation (bottom). (M. Zreda et al., *Geophys. Res. Lett.* **35**, L21402, 2008, doi:10.1029/2008GL035655.) —RJF

Signs of dark matter? Two groups of cosmic-ray observers have reported unexpectedly large fluxes of high-energy electrons and positrons. Those excesses suggest either that there are undiscovered astrophysical sources such as radio-quiet pulsars surprisingly nearby or that the positrons and electrons are annihilation products of WIMPs—weakly interacting dark-matter particles hundreds of times more massive than the proton. Standard cosmology predicts that dark nonbaryonic matter dominates the material content of the cosmos. But its constituent particles have yet to be identified. The ATIC balloon collaboration, led by John Wefel of Louisiana State University, reports a significant enhancement in the spectrum of cosmic-ray electrons, peaking near 600 GeV (see the figure). The peak suggests that 600-GeV WIMPs of the kind predicted by extradimensional extensions of standard particle theory might be annihilating with each other to create e^+e^- pairs in very dense concentrations of dark matter not far from our solar system. The ATIC detector cannot distinguish positrons from the much more abundant cosmic-ray electrons. But the magnetic spectrometer aboard the orbiting PAMELA satellite can. Positrons are routinely produced in collisions between cosmic rays and ordinary interstellar matter. The ratio of such positrons to cosmic-ray electrons was expected to fall steeply with increasing energy. Instead, the PAMELA collaboration, led by Piergiorgio Picozza of the University of Rome "Tor Vergata," reports that the positron fraction grows steadily with energy from 10 GeV to 100 GeV. So it appears that there must be some additional source of high-energy positrons. The collaboration will continue taking data for at least another year, hoping to find spectral structure suggestive of WIMPs or anisotropy pointing to a nearby astrophysical source. Both WIMP annihilations and pulsars are expected to produce high-energy gamma rays. So for the moment, all eyes are on the recently launched Fermi Gamma-ray Space Telescope (originally called GLAST), which is designed to pinpoint gamma-ray sources and spectral features but can also confirm the ATIC electron result with higher statistics. (J. Chang et al., ATIC collaboration, *Nature* **456**, 362, 2008; O. Adriani et al., PAMELA collaboration, http://arxiv.org/ abs/0810.4995.) —BMS



Ultrasound's role in wire bonding. In almost all integrated circuit chips, the wires that connect the internal circuitry to the external packaging are attached by a process called wire bonding. In that technique, ultrasound is used in combination with heat and pressure to weld the tip of the wire, usually gold, to the surfaces to be connected. It's been known for 40 years that ultrasound can make metals easier to work, an effect called acoustic softening. But the process of working the metal can have its own impact on the metal's hardness. Thus it's been difficult until now to get a clear picture of what's going on, and wire bonding has remained a largely empirical process. By placing gold microballs under different levels of applied force and ultrasound and measuring their resulting deformation, a team of researchers from the University of Waterloo in Canada and Tsinghua University in Beijing has succeeded in separating the softening contributions of the ultrasound from the effects of the mechanical force. The researchers were also able to quantify the residual effects of ultrasound on gold, and they found residual softening that increased with greater ultrasound amplitude above a certain threshold. They attribute the residual effects to the net balance between ultrasound's dynamic annealing and its potential opposing effect on activating and multiplying dislocations. (I. Lum et al., *J. Appl. Phys.*, in press.) —RJF

A catalyst caught in the act. Catalysts are ubiquitous in today's chemical industry, but there remains much to be learned about the specific mechanisms by which many of them work. Though such knowledge could lead to improved or new catalysts, obtaining atomic-scale information about in situ chemical changes in a hot environment at atmospheric pressure has presented a difficult challenge. A Dutch team led by Frank de Groot and Bert Weckhuysen of Utrecht University has recently demonstrated the potential of a new approach to imaging catalysts at work: scanning transmission x-ray microscopy. As a catalyst and reactants interact, the valence states and chemical bonding of the participating atoms evolve. STXM detects those changes by looking at the absorption of x rays by the atoms' inner electron shells. The researchers demonstrated the technique by looking at the iron-based catalyst for the Fischer–Tropsch process, in which hydrogen and carbon monoxide are converted to hydrocarbon chains. Soft x rays used in STXM are strongly attenuated in matter, so the research team used a nanoreactor of thickness 50 μm; the reactor was connected to gas lines and mounted on an adapter that was scanned in 35-nm steps through the focus of a monochromatic x-ray beam. In that way, two-dimensional absorption maps at various x-ray energies could be recorded.



The researchers paid particular attention to energies near the absorption edges of carbon, oxygen, and iron. Analyzing the maps they obtained, the researchers could extract the carbon hybridization states and determine the extent to which the iron atoms, which started off in iron oxide, had been reduced, formed other oxides, or reacted with the silicon dioxide substrate or with carbon. The figure maps the distribution of the inferred iron compounds, each represented by a different color. With better optics and detection techniques, the team hopes to