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A vortex knot caught on camera

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physics update

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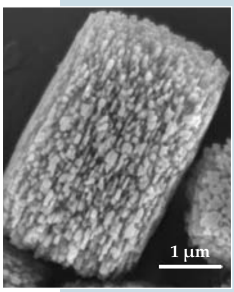
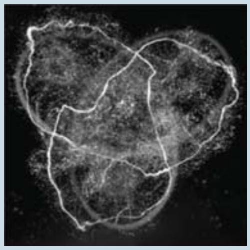
A seismometer in orbit. Earth's interior, oceans, and atmosphere are all mechanically coupled. So when a huge megathrust earthquake struck Japan two years ago and released the energy equivalent of a 100-megaton bomb, it excited seismic waves beneath Earth's surface, unleashed a devastating tsunami, and sent acoustic waves skyward (see the article by Thorne Lay and Hiroo Kanamori in PHYSICS TODAY, December 2011, page 33). A new study by Raphaël Garcia (Paul Sabatier University) and colleagues reveals that the European Space Agency's *GOCE* satellite detected those acoustic waves—the first orbiting satellite to directly do so from an earthquake. Since it was launched in 2009, *GOCE* has been mapping Earth's gravity field with a precision of 10^{-12} m/s^2 from an orbit of 270 km. Low-frequency infrasound waves reach that height, which is low enough that Earth's atmosphere exerts significant drag on the satellite. Onboard accelerometers adjust the satellite's engines to offset the drag and maintain the orbit. As *GOCE* circled Earth on 11 March 2011, it crossed the infrasound wavefront in two places—first over the Pacific Ocean and then over Europe. Each time, the accelerometers picked up telltale 11% variations in air density and 10^{-7} m/s^2 variations in the satellite's vertical acceleration. The researchers also modeled the amplitude, timing, and waveform of the atmospheric waves and found that the numerical results compared well to those recorded by *GOCE*. (R. F. Garcia et al., *Geophys. Res. Lett.*, in press, doi:10.1002/grl.50205.) —RMW

Mesoporous crystals. Solar cells and many other optoelectronic applications can benefit from semiconductor or ceramic materials that have a large surface area and also high charge mobility. Although nanoparticles have the large surface area, producing electrodes from them typically involves sintering them together, which introduces numerous interfaces that reduce the mobility. Attempts to fabricate mesoscopic, pore-filled materials often yield a porous assembly of nanocrystals with similar interface problems. Now Henry Snaith and colleagues at the University of Oxford have demonstrated a straightforward, inexpensive, versatile method for creating mesoporous single crystals of semiconducting titanium dioxide. The team started with a template, a close-packed array of silica beads of diameter 20–250 nm. In an insightful advance, Snaith and company "seeded" the template by bathing it in titanium tetrachloride; nanocrystals or other residues served as nucleation sites for growing TiO_2 crystals within the template's voids. The result was a near-perfect yield of mesoscopic single crystals; the silica could then be etched in such a way as to leave high-surface-area pores. A prototype solar cell the team made by filling the mesoporous crystal with a photosensitive dye had 7.3% efficiency—a record for dye-filled cells produced at temperatures below 150 °C. Moreover, the material, seed density, reaction temperature, reaction time, and bead diameter can all be adjusted to tweak numerous crystal properties for different applications. (E. J. W. Crossland et al., *Nature* **495**, 215, 2013.) —RJF



A vortex knot caught on camera. Vortex rings pop up often in nature—perhaps most famously as smoke rings emanating from a smoker's expert exhale, but also in the exhalations of fire eaters and underwater dolphins. More complex vortex topologies, such as interconnected rings and knots, are thought to figure prominently in turbulent flows, but they've proved notoriously difficult to create and study in the lab. Now, Dustin Kleckner and William Irvine of the University of Chicago have come up with a clever way to generate the elusive, self-entangled flow structures. The trick was to use a 3D printer to fashion hydrofoils whose topologies correspond to those desired of the vortices. One such hydrofoil, when placed in a water tank and given a swift tug, shed the trefoil vortex knot pictured here. (A video is available online.) Light-scattering microbubbles, which tend to get trapped along the vortex lines, provided a convenient way to visualize the flow; with high-speed laser tomography, the researchers could track the knot's evolution at 76 000 frames per second. In an ideal, inviscid fluid, a trefoil knot would never come undone, but in water it unravels via a bit of fluid-mechanical sleight of hand: In a sequence of vortex-line reconnections that takes just a few hundred milliseconds, the knot morphs into two unconnected rings, which then drift apart. (D. Kleckner, W. T. M. Irvine, *Nat. Phys.* **9**, 253, 2013.) —AGS



When dust slams into spacecraft. Low Earth orbit abounds in dust particles whose masses are less than 1 microgram and whose speeds lie in the range of 10–100 km/s. Although the particles' momenta are typically too low to imperil spacecraft, the dust poses a potentially more dangerous threat. When high-speed particles slam into a spacecraft, the impacts kick up clouds of plasma. As the clouds expand, they oscillate and emit radio waves that could conceivably disrupt or even knock out the spacecraft's electrical equipment. To evaluate the threat, a team from Stanford University in California and Stuttgart University in Germany used a Van de Graaff accelerator to shoot a total of 6000 iron particles of various masses and impact speeds at representative spacecraft materials. To emit radio waves at significant levels, the plasma must be cool enough—and, therefore, its expansion slow enough—that it lingers in the oscillatory regime before it disperses. Those conditions did indeed prevail in the experiment. Another finding: Targets made of glass, which is used in solar panels, emitted radio waves at low impact speeds more readily than metal targets did. Whether dust-induced radio emission is a real threat is difficult to tell, but at least one spacecraft, *ADEOS 2*, depicted here, shut down in the dusty conditions of a meteor shower. (N. Lee et al., *Phys. Plasmas* **20**, 032901, 2013.) —CD