and the fluids don't always flow homogeneously, even when subjected to homogeneous stress.

But simple YSFs have no reason not to flow homogeneously. So Manneville and colleagues didn't expect to see any shear banding. When they set out to study their material's flow under shear stress, they were hoping to get some insight into how a YSF yields, or turns from solid to liquid. More specifically, they wanted to see whether the smoothness or roughness of the container walls had any effect.

The material they studied was carbopol gel, a main ingredient in hair gel and many pharmaceutical gels. Synthesized from carbopol powder and water, the gel itself is an assembly of soft, swollen polymer blobs. The researchers used a rheometer equipped with a Couette cell, shown in figure 1a: A layer of gel filled the 1.1-mm gap between two concentric cylinders, and the inner cylinder was rotated at a constant rate.

To measure the gel's velocity profile, the researchers used ultrasonic speckle velocimetry, a technique Manneville had developed for cheaply studying optically opaque fluids.[3] They seeded the gel with micron-sized glass spheres, which scatter acoustic waves, and aimed an ultrasonic transducer at the sample at an angle to the direction of flow. Every millisecond or so, they shot an ultrasound pulse through the gel and recorded its reflection. From correlations between consecutive shots, they deduced the gel's velocity as a function of position and time.

Not so simple

Figure 1b shows some results from a typical run, during which the inner cylinder rotated once every three minutes. At first the gel flowed only near the moving wall, but with time the flowing band gradually widened and then suddenly gave way to homogeneous flow. That so-called fluidization time was surprisingly long: more than half an hour for the experiment shown.

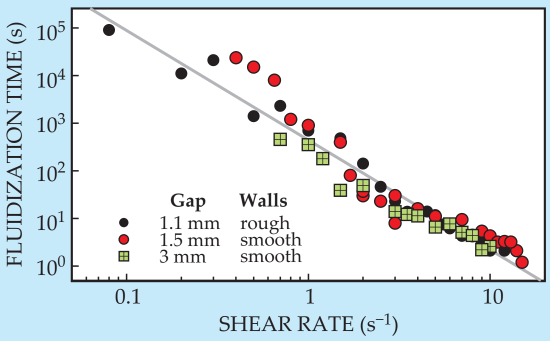

Figure 2. Power-law dependence of the fluidization time (the duration of the transient shear banding) on the shear rate. Symbols represent different gap widths and different boundary conditions, as indicated by the legend. The gray line is a power-law fit with slope −2.3. (Adapted from ref. 2.)

Manneville and colleagues repeated the experiment, rotating the cylinder at different speeds. Not surprisingly, fluidization happened faster when the cylinder was spun faster. But quantitatively, the dependence took an unexpected form: The fluidization time was inversely proportional to the cylinder's speed raised to the 2.3 power. When the researchers looked at thicker layers of gel, they found a power-law dependence on the shear rate (the inner wall's linear speed divided by the gap width), as shown in figure 2. And it mattered little whether the inner and outer walls were bare plexiglass or whether they were coated with sandpaper to make them rough.

Where the exponent 2.3 comes from is unclear. The researchers think it's a material property, since using carbopol gel from a different batch—which may have had different-sized polymer blobs—was enough to change the exponent from 2.3 to about 3. They're now looking at gels prepared with different concentrations of carbopol powder to better understand the material dependence. Extending the study to different simple YSFs, such as foams, would be more difficult: The high acoustic contrast between a foam's gas and liquid phases makes the ultrasound probe unsuitable.

The observation of transient shear banding shows that nonthixotropic YSFs are not as simple as they've been assumed to be; they don't yield uniformly, even under uniform stress. (The researchers briefly looked at other flow geometries to make sure that the shear banding was not an artifact of the slight stress heterogeneity induced by the circular geometry.) That the power-law relationship is independent of the layer thickness means that the fluid boundary doesn't simply diffuse across the gel. And the long fluidization times point to the importance of distinguishing between steady-state and transient regimes in future YSF models and experiments. **Johanna Miller**

References

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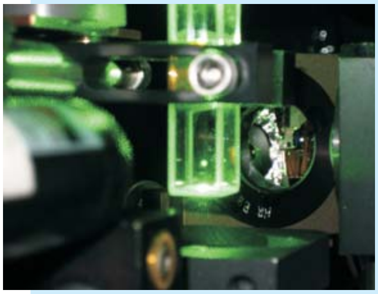
physics update

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

A thermometer for modern and extinct vertebrates. Robert Eagle of Caltech and his collaborators have shown that they can determine the body temperature of living and long-dead vertebrates by measuring the abundance of a molecule made of isotopes—an isotopologue—in bones, scales, and teeth. The isotopologue is a heavy version of the carbonate ion CO_3^{2-}. In a typical piece of bone or other biomineral, all but 1.8% of the CO_3^{2-} ions are made of the lightest carbon and oxygen isotopes, ^{12}C and ^{16}O. At around 45 ppm, $^{13}C^{18}O^{16}O_2^{2-}$ is barely present, but its scarcity is made up for by a useful property: The isotopologue's precise abundance depends on the ambient temperature when the biomineral first crystallized. The temperature dependence arises because lower temperatures boost the propensity of a heavy isotope to form a bond with another heavy isotope rather than with a light isotope. Five years ago, Prosenjit Ghosh, who is now at the Indian Institute of Science, and his colleagues extracted CO_2 gas from carbonate crystals they'd made in the lab. From their measurements they derived a robust formula relating the abundance of $^{13}C^{18}O$ carbonate to its formation temperature. By applying the formula to tooth samples, Eagle could accurately predict the body temperature of five vertebrates, including the white rhino (37 °C) and the sand tiger shark (23 °C). From fossilized samples he could also predict the body temperature of the woolly mammoth (38 °C). Applying the paleothermometer to samples of other extinct vertebrates could reveal when vertebrates first became warm-blooded. (R. A. Eagle et al., *Proc. Natl. Acad. Sci. USA* **107**, 10377, 2010.) —CD

An optical speed trap for Brownian motion. One hallmark of Albert Einstein's genius is his 1905 theory that the kinetic energy of pollen grains, dust, and other similarly sized objects in thermal equilibrium depends solely on temperature—the classic definition of Brownian motion. Einstein then concluded that the instantaneous velocity of such particles would be impossible to physically measure, and for more than a century, it seemed that he was right. But now, Mark Raizen and his colleagues at the University of Texas at Austin have used optical tweezers in a vacuum chamber to trap a 3-μm-diameter silica bead, observe its ballistic (inertial) motion at short time scales, and determine its instantaneous velocity. The bead is held at the focal point of two noninterfering laser beams, similar to the setup in the image. When the bead makes a random move, it deflects the beams, which allows its position to be traced and the instantaneous velocity to be measured. From those measurements, the researchers calculated root mean square velocities. Even when obtained at varying air pressures, the results agreed with each other and with the theoretically predicted value, proving that in the ballistic regime, the bead's mean velocity is solely dependent on temperature and not on pressure or the inertial effects of the surrounding air molecules. Raizen says they will next attempt to cool the particle's motion to the quantum ground state and confirm that the kinetic energy will be nonzero even at 0 K. (T. Li et al., *Science*, in press, doi:10.1126/science.1189403.) —JNAM



Casimir force, antennas, and salt water. As famously predicted by Hendrik Casimir in 1948, parallel conductors in a vacuum will attract each other because the conductors impose boundary conditions that affect the vacuum energy of the electromagnetic field (see the article by Steve Lamoreaux in PHYSICS TODAY, February 2007, page 40). In general, the Casimir force depends on the shape of the conductors and its value is notoriously difficult to calculate, but research groups worldwide have been developing increasingly applicable computational techniques. Now a team at MIT has shown how tabletop measurements might provide the key information needed for the general calculation. The Casimir force may be expressed as an integral over frequency (ω) of correlation functions that involve electric and magnetic fields. In principle, those frequency-dependent correlations can be obtained in a suitably scaled tabletop experiment from measurements of how an antenna at one point responds to a current generated at a distant point. In practice, such measurements won't work because the integrand oscillates wildly with ω. The integrand becomes well behaved—it decays and doesn't oscillate—if the integration is performed in the complex plane, but real antennas respond to real frequencies. The key observation made by the MIT team is that their mathematical expressions always involve ω in the combination $\varepsilon\omega^2$, where ε is the permittivity. Thus, the researchers predict, a force integral with real vacuum permittivity and complex contour can be calculated from a tractable number of antenna measurements made at real ω in a medium of complex permittivity—for example, salt water. (A. W. Rodriguez et al., *Proc. Natl. Acad. Sci. USA* **107**, 9531, 2010.) —SKB

Quantum teleportation through open air. A central tenet of quantum information processing asserts that an unknown qubit cannot be cloned (see PHYSICS TODAY, February 2009, page 76). But the unknown state of one qubit can be transferred to another qubit in a process termed quantum teleportation. The first experimental demonstrations succeeded in teleporting a qubit state a meter or so (see PHYSICS TODAY, February 1998, page 18). Subsequent experiments with photons, whose polarizations form a convenient basis for quantum information, have used fiber optics to achieve teleportation over hundreds of meters. But practical quantum communication will require teleportation over much greater distances. Jian-Wei Pan, Cheng-Zhi Peng, and coworkers at the University of Science and Technology of China and Tsinghua University have now transferred a qubit state through free space over a distance of 16 km, from "Alice" in the Beijing suburb of Badaling, across towns and roads, to "Bob" in Huailai, on the other side of Guanting Reservoir. The experiment employed a standard teleportation protocol: Alice and Bob each receive one of a pair of entangled photons; Alice measures hers in combination with an unknown qubit and sends the result, by classical means, to Bob; armed with that result, Bob projects his photon onto the state of the unknown qubit. The new work, though, adds many refinements, including novel telescope designs for open-air transmission, active feedback control for increased stability, and synchronized real-time information transfer. The resulting teleportation fidelity was nearly 90%. Such high-fidelity transmission, say the researchers, could help enable quantum teleportation to orbiting satellites. (X.-M. Jin et al., *Nat. Photon.* **4**, 376, 2010.) — RJF

Using noise to map Earth's deforming crust. Earth is awash in vibrations—literally. Interference between ocean waves near a coastline excites faint ambient noise throughout the planet. Thanks to a recent innovation in seismic imaging, long time sequences of the ambient noise can be used to reveal details about Earth's interior hundreds of miles inland. The technique, ambient noise tomography, involves looking for correlations between the diffuse seismic surface waves recorded at pairs of closely spaced seismometers and then extracting the group and phase velocities from the correlated signals. By tapping high-frequency wave components, which are typically lost to scattering and attenuation in signals from distant earthquakes but strong in ambient noise, seismologists can probe the roughly 30-km-thick continental crust, whose rheology differs from that of the deeper mantle. Using the technique, Michael Ritzwoller and his colleagues at the University of Colorado, Boulder, have now found evidence for widespread crustal deformation in the western US, a region long thought to have suffered strain from extension ever since the Cenozoic era began 65 million years ago. Ritzwoller's team processed waveforms captured between 2004 and 2007 by the USArray Transportable Array, which comprises some 400 broadband seismometers on a 70-km² grid, and extracted the radial anisotropy—the differences in speed of vertically and horizontally polarized surface waves, plotted here. The anisotropy, a proxy for strain in crustal rock, is consistent with the lattice orientation of minerals found in surface outcrops and constrains models of how continents are built. (M. P. Moschetti et al., *Nature* **464**, 885, 2010.) —RMW