physics update

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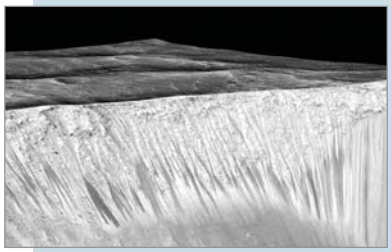
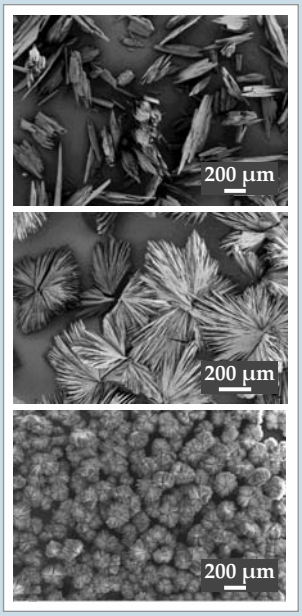
A new probe for a changing constant. Water in distant galaxies is difficult to detect from Earth because the molecule lacks favorably placed spectral transitions. Astronomers seeking a proxy turn instead to water's protonated form, hydronium (H_3O^+), whose lowest vibrational transitions lie in the millimeter band. Now Vladimir Špirko of Charles University in Prague and his collaborators have identified another use for hydronium: as a probe to determine whether the proton-to-electron mass ratio, μ, varies. Given that gluons, not quarks, make up most of the proton's mass, variations in μ could arise if the strong nuclear force changes through cosmic time, as some theorists have speculated. The energy of a vibrational state depends on the molecular mass and therefore on the proton mass and μ. When those vibrational states lie close to inversion and rotational states, the μ dependence strengthens. To determine how sensitive those combined states are to variations in μ, Špirko and his collaborators calculated hydronium's potential energy and dipole moment as functions of the positions of its constituent atoms. They then fed those functions into a nuclear motion code to calculate the transition energies. It turned out that some of the transitions could indeed serve as probes. The difference between two of them—from the ground state to the third excited state—was about four times more sensitive to μ than the methanol transitions used earlier this year to constrain the value of $\Delta\mu/\mu$ during the past 7 billion years to be no more than 10^{-7}. (A. Owens et al., *Mon. Not. R. Astron. Soc.* **454**, 2292, 2015; see also the article by David DeMille on page 34.) —CD

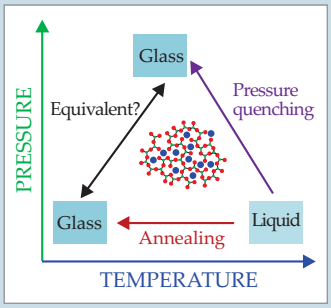
Liquid water inferred on present-day Mars. Morphological evidence abounds for the flow of liquid water on ancient Mars; see, for example, the article by Bruce Jakosky and Michael Mellon, PHYSICS TODAY, April 2004, page 71. However, little definitive evidence for it exists on today's surface. What surface water Mars holds has long been thought to reside as ice at its poles. In 2010 the *Mars Reconnaissance Orbiter* (*MRO*) spotted features known as recurring slope lineae that are consistent with transient flow: The dark, narrow streaks—the ones in the figure are hundreds of meters long—elongate on warm slopes in the spring and summer when their temperatures exceed about 250 K, fade and vanish in colder seasons, and reappear annually. Georgia Institute of Technology doctoral student Lujendra Ojha and his colleagues have now analyzed absorption spectra taken by *MRO* of four separate regions containing the streaks. They found signatures of a family of hydrated salts known as metal perchlorates at all of the sites during the warm seasons when the streaks are most extensive. Perchlorates can depress the freezing point of water by up to 70 K, and even in Mars's scant relative humidity, they may be able to adsorb moisture from the atmosphere (or from seeps underground) and dissolve; the hydrated salts whose *MRO* spectra the researchers analyzed are thought to be the dried precipitates. Ojha and colleagues conclude that the spectra support the hypothesis that the seasonal streaks form as a result of the activity of liquid, albeit very briny, water on contemporary Mars. Even so, the proof is indirect; the spectral lines are too narrow to come from liquid water itself. (L. Ojha et al., *Nat. Geosci.* **8**, 829, 2015; image courtesy of NASA/JPL/University of Arizona.) —RMW



Custom shapes for organic crystals. As the feature sizes of electronic devices become smaller, the mass production of nanometer- and micron-scale hierarchical structures is a major challenge. (See the article by Matthias Imboden and David Bishop, PHYSICS TODAY, December 2014, page 45.) One possible approach is to coax crystals to grow into a desired structure by exploiting chemical interactions between crystal faces and dissolved molecules. Though much used for inorganic systems, that technique has been less explored for organic materials—even though organic molecules offer a far richer range of chemical properties. Now Helmut Cölfen (University of Konstanz, Germany) and colleagues have used a diblock copolymer (see the article by Frank Bates and Glenn Fredrickson, PHYSICS TODAY, February 1999, page 32) to control the morphology of a material called PTCAPS, one of an important class of organic semiconductors. The polymer consists of a block of polyethylene glycol, which is highly soluble in water, bound to a block of polyethyleneimine, which has a strong electrostatic affinity to the (001) face of the nascent PTCAPS crystals. For PTCAPS in a water–polymer solution, therefore, crystal growth on the (001) face is stifled, so the crystals grow in micron-thick plates. The polymer concentration determines whether the plates cluster into irregular aggregates (top panel in the figure), star-shaped structures (middle panel), or round flower-like particles of uniform size (bottom panel). Adjusting the solution's pH—which affects the polyethyleneimine's electric charge and thus the strength of the polymer–PTCAPS interaction—also influences the crystals' final morphology. (M. Huang, M. Antonietti, H. Cölfen, *APL Mater.* **4**, 015705, 2015.) —JLM

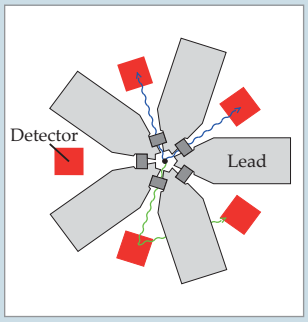


History matters for glass hardness. Two objects of the same material—wooden blocks, say, or windowpanes—are commonly thought to be identical. Microscopically, of course, things are not always so straightforward. Researchers from Denmark, Poland, and the US now show that the route a glass takes to reach its final state can profoundly affect its macroscopic properties. Morten Smedskjaer of Aalborg University in Denmark and his colleagues used both experiments and simulations in a comparative study of aluminosilicate glasses that had identical composition but were brought to the same density via two routes: thermal annealing and high-pressure quenching in a nitrogen-gas chamber. The effects of annealing are well known, but the role of pressure history is less studied. When the researchers compared glasses of the same density and chemical makeup, those that had been annealed were significantly harder—as measured by indentation tests—than the pressure-quenched ones. The simulations reveal that both methods result in the same interatomic

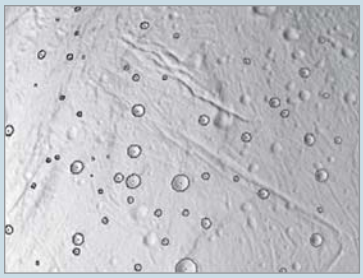


distances between nearest neighbors, but in the annealed glass the bond angles have a narrower distribution, which leads to greater short-range order. On the other hand, pressure quenching has a stronger influence on the medium-range order—the repetition distances for typical atomic arrangements—which has much less influence on the material's hardness. Thus, as shown schematically here, thermal annealing and pressure-quenching treatments can be thought of as independent degrees of freedom, comparable to composition, in designing new industrial glasses. (M. M. Smedskjaer et al., *J. Chem. Phys.* **143**, 164505, 2015.) —SGB

A two-in-a-million double-photon nuclear decay. In her 1930 dissertation, Maria Goeppert Mayer used perturbation theory to derive the probability for an atom to change its electronic state by absorbing or emitting two photons of appropriate combined energy. Such two-photon processes are today being routinely used in spectroscopy and other applications. Although atomic nuclei can undergo similar transitions involving two gamma-ray photons, they are usually overwhelmed by single-gamma transitions. Two-gamma decays have been observed only for three isotopes in which quantum mechanics forbids single-gamma decay. Now a team at the Darmstadt University of Technology in Germany reports the first clear observation of two-photon emission from excited nuclei for which the single-photon decay *is* allowed—and 5×10^5 more likely—a situation the researchers call competitive double-gamma decay. As sketched here, the researchers deployed five detectors (red) to record pairs of gammas (blue) emitted in the two-photon decay of excited barium-137 nuclei. However, a lone gamma (green) from the copious single-photon decays might deposit only part of its energy in a detector; so to prevent it from caroming into a second detector and mimicking a double-gamma decay, the experimenters placed lead shields (gray) between the detectors. Moreover, the detectors' subnanosecond time resolution captured the additional flight time of the scattered gamma. Careful statistical analysis took account of the other significant background source: two nearly simultaneous yet independent single-gamma decays. The result: distinct two-gamma decay signatures. What is more, the researchers could determine the dominant perturbation-theory contributions, which depend on details of nuclear structure. (C. Walz et al., *Nature* **526**, 406, 2015.) —RJF



Enceladus's subsurface ocean wraps the moon. A decade ago the *Cassini* orbiter spotted gas and ice spewing from the south polar region of Saturn's moon Enceladus. Subsequent investigations revealed that the ice is salty, a result indicating that the ice originated from a liquid ocean between Enceladus's frozen surface and its silicate core. Now Peter Thomas (Cornell University) and his colleagues have analyzed more than seven years of *Cassini* surface observations and shown that the ocean is not localized at the polar region of Enceladus; rather, it is global. The figure shows some of the several hundred surface features tracked by the researchers. To first approximation, Enceladus, like our Moon, presents one face to its planet. But because Enceladus is a bit out of round, Saturn torques the satellite and induces a so-called libration, a wobble in the Enceladean hemisphere visible from Saturn. For a localized ocean, the icy surface of Enceladus and its core would be physically connected; the entire mass of the moon would respond to the torque and the libration would be small. A global ocean, on the other hand, would act like a lubricant, so the surface and core slide past each other; only the surface would respond to Saturn's torquing and the wobble could be relatively big. Thomas and colleagues' analysis yielded the large libration consistent with a global ocean. Tidal heating can provide the energy to liquefy subsurface ice on Enceladus. But just how tidal heating can maintain the moon's global ocean remains an unanswered question. (P. C. Thomas et al., *Icarus* **264**, 37, 2016.) —SKB



A study in contrasts for inhibiting surface frost. Whether on airplane wings or old refrigerators, frost forms when water droplets nucleate on a surface, grow, coalesce, and finally freeze. Although the interactions between water and surfaces can seem simple, they are remarkably complex (see, for instance, "The first wetting layer on a solid" by Peter Feibelman, PHYSICS TODAY, February 2010, page 34, and the Quick Study by Laurent Courbin and Howard Stone, PHYSICS TODAY, February 2007, page 84). To slow down freezing and decrease freezing temperatures, scientists have explored nanopatterned or superhydrophobic surfaces that delay nucleation, for example, or increase droplet mobility. Now Amy Betz and colleagues at Kansas State University show that so-called biphilic surfaces that combine hydrophilic and hydrophobic regions can lower freezing temperatures even further, to as much as −6 °C. The team's biphilic samples resemble slices of Swiss cheese on crackers: A hydrophilic substrate shows through regularly spaced holes (200 μm for some samples, 25 μm for others) in a self-assembled monolayer of a hydrophobic polymer. Placed inside a chamber kept at atmospheric pressure, 295 K, and 30%, 60%, or 75% relative humidity (RH), each sample was cooled in 0.5-K steps, with up to 3 hours between steps, until all the visible water droplets on it froze, like those seen here. Freezing was most inhibited at 60% RH. On all the surfaces, the initial droplets were about 5 μm across. But the researchers found significant differences in the surfaces' average frozen-droplet size and density and in the time it took them to freeze; those differences must be due to how the droplets grow and merge. The researchers explain that the behavior is consistent with the energetics of coalescence. (A. S. Van Dyke et al., *Appl. Phys. Lett.* **107**, 141602, 2015.) —RJF