undoubtedly significant He component in both clouds is not seen at optical frequencies because all its excitations remain in the UV even at these high redshifts.

"It's quite possible that the first generation of stars produced nothing heavier than oxygen," says Santa Cruz theorist Stan Woosley. "So I'm particularly impressed by the lack of carbon and oxygen."

Fumagalli and coworkers place an upper limit of $10^{-4.2}$ $Z_\odot$ on the metallicity of cloud A. The other apparently metal-free cloud, found by the team in a different LLS, has only about 15% of cloud A's column density. So its upper metallicity limit, $10^{-3.8}$ $Z_\odot$, is somewhat weaker.

Though each cloud, perhaps 100 light-years thick, was several orders of magnitude denser than the cosmic mean of 10^{-5} H atoms per cm^3 in that epoch, neither is thought to have been dense enough to form late first-generation stars. "But they may well be our first sighting of the so-called cool flows predicted by computer simulations of that epoch," says Prochaska. Those would be filamentary intergalactic streams of moderately dense, low-metallicity gas that flow into galactic halos and replenish the gas that sustains star formation.[2]

The primordial isotope ratio

The primordial D/H abundance ratio is particularly important to cosmologists because its predicted value depends sensitively on the cosmic mean baryon density. That density, usually given as Ω_b, the fraction of all mass and energy attributed to ordinary baryonic matter, is determined from cosmic-microwave-background (CMB) measurements to be $(4.5 \pm 0.1)\%$. (See PHYSICS TODAY, April 2003, page 21.) That predicts a D/H ratio of $10^{-4.6}$.

Stars can destroy D. So a long-standing question had been whether direct measurements of D/H in high-z clouds with small but nonzero metallicity reliably represent the primordial ratio. Figure 2 compares the CMB prediction with a variety of measurements at different metallicities, including the new measurement in LLS1134. They are all seen to be consistent, with no trend attributable to stellar destruction.

"So we can now conclude," says Fumagalli, "that deuterium abundances from quasar absorption-line systems are solid anchor points for models of galactic chemical evolution."

Bertram Schwarzschild

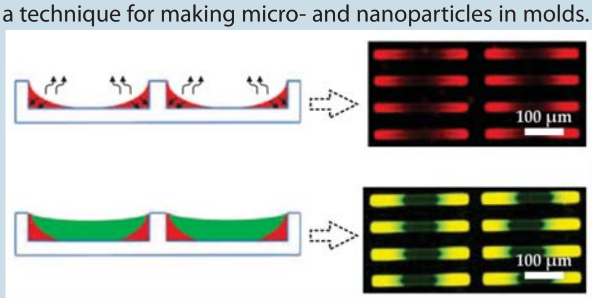
References

1. M. Fumagalli, J. M. O'Meara, J. X. Prochaska, *Science* **334**, 1245 (2011).
2. A. Dekel et al., *Nature* **457**, 451 (2009).

physics update

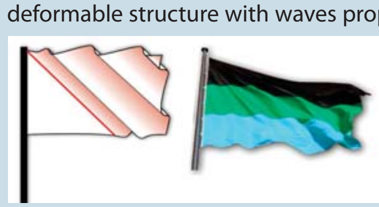
These items, with supplementary material, first appeared at http://www.physicstoday.org.

Molding many-faced particles. Scalable production of micron- and nanometer-sized particles with controlled sizes, shapes, and compositions is of interest for a host of applications. Toward that end, in 2005 Joseph DeSimone and colleagues (University of North Carolina, Chapel Hill) introduced PRINT—particle replication in nonwetting templates—a technique for making micro- and nanoparticles in molds.



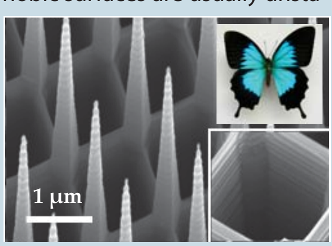
The researchers fill an array of molds with an organic monomer liquid, use UV light to cure the liquid into a polymeric solid, extract the polymer particles using an adhesive film, and free them by dissolving the adhesive. In addition to pursuing various biomedical applications, DeSimone and colleagues have used PRINT to produce Janus particles: Hydrophobic on one side and hydrophilic on the other, the particles are interesting for the self-assembled structures they form (see the Quick Study by Steve Granick, Shan Jiang, and Qian Chen in PHYSICS TODAY, July 2009, page 68). The researchers fill the molds with a dilute solution of a hydrophilic monomer, evaporate off the solvent, and top off the molds with a hydrophobic monomer. Now, they've exploited capillary forces in rod-shaped molds to produce a wider range of multiphase particles. As shown in the figure, when the molds are filled with a hydrophilic solution and the solvent evaporated, the remaining liquid is drawn to the molds' ends; topping off with a hydrophobic monomer gives symmetric triblock particles. The researchers also created asymmetric triblock and diblock rods by spinning the partially filled molds in a centrifuge to drive some or all of the hydrophilic liquid to one end. (J.-Y. Wang et al., *J. Am. Chem. Soc.*, in press, doi:10.1021/ja2066187.) —JLM

Wrinkled roaches and flapping flags. For fluid dynamicists who seek a greater understanding of fluid–solid interactions, a flapping flag is a simple realization of a deformable structure with waves propagating in the direction of fluid flow. From models of such systems, researchers have determined, for example, that stiffer flags stretch nearly flat as they fly, as do those subjected to high fluid drag, whereas heavier flags form more and larger-amplitude wrinkles. Now, Jérôme Hœpffner at the Pierre and Marie Curie University in Paris and Yoshitsugu Naka at the University of Lille in France explain why the flag's wrinkles are oblique and how those oblique waves counterbalance gravitational forces. The researchers divide a flapping flag into two parts, as seen in the schematic and image: the pinned portion, represented by a right triangle, and the unpinned portion, which they call the roach, a term used for extra material on a sail. As the roach begins to collapse under its weight, it forms oblique waves, an observation that had not been explained by prior models. The researchers find that the flag's lift comes primarily from those waves. Aerodynamic forces act orthogonal to the wave-crests and impart the periodic rolling and snapping of the upper unpinned corner, which has been shown in old flags to suffer the greatest wear. (J. Hœpffner, Y. Naka, *Phys. Rev. Lett.* **107**, 194502, 2011.) —JNAM



Measuring morphological change. Objects alter their form in the course of such physical and biological processes as sedimentation and species differentiation. One approach to understanding those processes is to quantify the degree of morphological change. Suppose, for example, you were presented with a collection of molars, one each from a number of related species. Establishing which teeth were most similar might provide insights into evolutionary dynamics. To facilitate the comparison, you could identify a limited number of cusps or other landmarks on the molar, as in the figure. Once each molar is reduced to some tens of landmarks, straightforward algorithms allow you to determine a scientifically useful, quantitative "distance" measure to express the similarity of any two molar surfaces. But placing the landmarks requires a practiced eye and possibly controversial judgments. To circumvent those difficulties, an international, interdisciplinary team led by Ingrid Daubechies has devised two new methods for defining a morphological distance between a pair of two-dimensional surfaces. Their algorithms consider the entirety of the surfaces—no special markers needed—and, importantly, can be speedily implemented on a computer. As one of several checks on the utility of their methods, the research team calculated the distances between each pair in a sample of 116 molars that had previously been analyzed with a conventional landmark-based technique. With impressive fidelity, both methods devised by Daubechies and colleagues reproduced the earlier results. (D. M. Boyer et al., *Proc. Natl. Acad. Sci. USA* **108**, 18221, 2011.) —SKB

Silicon meets the butterfly wing. Inspired by the nanostructures in the wing of a male *Papilio ulysses*, researchers have made a silicon wafer that both repels water and strongly absorbs light. Also known as the blue mountain swallowtail, the butterfly (shown in the inset) has multilayered structures in its wing that create multiple traps for both air and light. Air trapped on a rough surface is known to significantly reduce the frictional drag on a flowing liquid—a property known as superhydrophobicity (see PHYSICS TODAY, October 2009, page 16). But artificial superhydrophobic surfaces are usually unstable to capillary flows and other external perturbations and easily lose their trapped air. A multinational group led by Sang-Ho Yun (Royal Institute of Technology, Kista, Sweden) has now used standard microfabrication techniques to drill micron-deep pores in a silicon wafer and build nanocones on the pores' edges as shown in the image. The production process took 10 minutes for a 10-cm wafer. Together with etched grooves and bumps on the walls, the arrays of cones and pores form a hierarchy of air traps that proved to be stable for a full year. Water drops bounce off the surface, and a fine mist bunches up into spherical drops that roll off. In addition, light at wavelengths longer than 750 nm is nearly perfectly absorbed. Together, those properties make the textured surface promising for integrated electro-optical devices, such as solar cells, IR-imaging detectors, cell culture devices, and chemical sensors. (S.-H. Yun et al., *Appl. Phys. Lett.*, in press.) —SGB



A marriage of microscopy and image compression. Instead of looking at a surface pixel by pixel, a new microscope takes a more global view to achieve improved resolution. The detailed chemical structure of a surface can reveal a wealth of information about such processes as catalysis, corrosion, and wetting. One technique for getting at that surface structure is sum frequency generation (SFG), in which a pair of photons simultaneously strike a spot on the surface, interact with the material there, and convert to a single photon. Conventional SFG microscopes use a raster-scan; that is, they image the surface one pixel at a time. That approach has an inherent limitation: As the microscope samples smaller pixels to improve resolution, the intensity associated with each pixel drops, eventually becoming too small to measure. Now Steven Baldelli of the University of Houston, Kevin Kelly of Rice University, and colleagues have combined the mathematics of image compression with SFG to create a microscope that acquires less data than its conventional counterpart but generates an image with improved resolution. In the key step, the light emitted from the entire sample is focused onto a collection of tiny mirrors arranged in a random-looking pattern such as in the figure. Crucially, the light emanating from a particular pixel on the surface strikes a corresponding element of the mirror arrangement. The total intensity of the light reflected from the mirrors is then measured; it represents a type of dot product between the sample and the mirror state. It turns out that a relatively small number of such dot products suffices for faithful reproduction of the sample. Baldelli and colleagues used their proof-of-principle microscope to image 100-μm-wide gold stripes deposited onto silicon with a resolution of about 10 μm, significantly better than would be obtained in raster-scan mode. (X. Cai et al., *J. Chem. Phys.* **135**, 194202, 2011.) —SKB

Monitoring surface diffusion, one molecule at a time. The symmetry of a surface can influence the preferred direction in which adsorbed molecules may diffuse—their motion constrained either to particular sites or to one dimension, for instance, because of surface anisotropy. But the converse is also true: An adsorbed molecule's symmetry can also influence its diffusion—sometimes dramatically. A University of Regensburg group led by Jascha Repp has now studied that converse situation using a scanning tunneling microscope to image copper tetraaza phthalocyanine adsorbed on an ultrathin film of sodium chloride. The organometallic molecule, pictured here, forms four distinct isomers that differ only in the position of the nitrogen atoms (blue) localized on each arm of the molecule's carbon framework. The STM resolved the orbital configuration, and thus the symmetry, of each isomer and its position on the NaCl surface. Crucially, the STM also was used to trigger an isomer's movement by injecting enough current for it to overcome the diffusion barrier. The microscope's tip was positioned atop a molecule at constant voltage until a drop in current occurred, signaling lateral motion. By performing that experiment repeatedly for distinct isomers, the Regensburg team found specific patterns of movement, which allowed them to determine the different symmetry-specific diffusion behavior. (T. Sonnleitner et al., *Phys. Rev. Lett.* **107**, 186103, 2011.) —RMW ■