

mean flux in each spectral channel.

Space-based radio emissions, on the other hand, show up as horizontal stripes, localized in position and weakly dependent on frequency. To remove them, the researchers used a matrix-algebra technique, called a principal component analysis, to decompose their data into a sum of components, each the product of a function of

frequency times a function of position. The strongest components, they figured, probably represented the unwanted synchrotron sources. They removed those and retained only the weaker components that contained most of the hydrogen signal. The result is shown in figure 2b.

That done, the researchers calculated the cross-correlation of their data

and the DEEP2 galaxy density. The two were correlated up to length scales of 40 Mly—quantitatively similar to the DEEP2 data's autocorrelation. That means that the extracted signal measures much the same thing as the galaxy survey: The teasing out of the hydrogen contribution was a success.

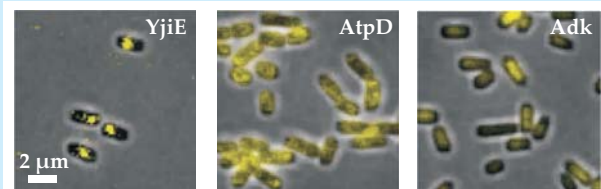
There's a long way to go, though, before intensity mapping can provide any

physics update

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

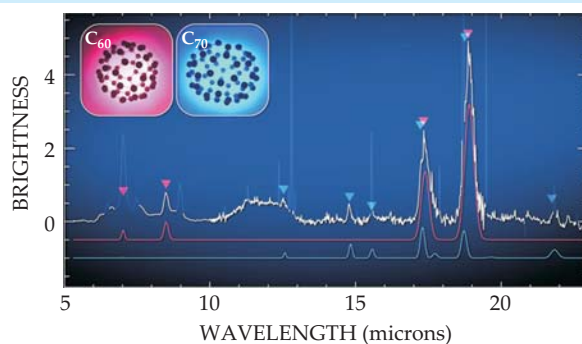
Muonic Lamb shift. Willis Lamb's 1947 measurement of the tiny splitting between the $2s$ and $2p$ states of atomic hydrogen gave a crucial impetus to the development of quantum electrodynamics (QED). That "Lamb shift" from the Dirac hydrogen spectrum is a 4- μeV increase in the $2s$ energy level due primarily to vacuum fluctuations of the electromagnetic field. Now Randolph Pohl (Max Planck Institute for Quantum Optics, Garching, Germany) and coworkers at the Paul Scherrer Institute (PSI) in Switzerland have finally measured the analogue of the Lamb shift in the muonic H atom—a proton orbited by a μ^- instead of an e^- . Muons live only microseconds, but they are 200 times heavier than electrons, and their atomic orbits are correspondingly tighter. The muonic Lamb shift is about 200 meV, and its precise value is particularly sensitive to the proton's finite size. The PSI experiment was accomplished with precision laser excitation of μ^- p atoms created by an intense μ^- beam stopping in a small volume of H_2 gas at very low pressure. The team measured the muonic Lamb shift to a part in 10^5 and compared it with elaborate QED calculations that parameterize the proton's finite size with an effective charge radius R_p . They find an R_p about 4% smaller than that measured, with less precision, by conventional H spectroscopy and e^- -p scattering experiments. The discrepancy is 5 standard deviations. Either the proton really is smaller than previously thought, argue Pohl and company, or there's something wrong with the QED calculations or their input constants. But the proton is a quark composite whose size and shape are quantum-chromodynamic manifestations beyond the purview of QED. Several QCD theorists suggest that at the extraordinary precision achieved by the PSI experiment, it may not be possible to describe proton-size effects adequately with a single length parameter. (R. Pohl et al., *Nature* **466**, 213, 2010.) —BMS

The noisy expression of genes into proteins. Genetic information is transcribed from DNA to RNA and translated from RNA to make proteins. Because each step entails a modest number of molecules, gene expression, as the DNA-to-protein conversion is termed, is inevitably noisy: Identical genes in identical cells don't yield identical numbers of proteins. But how noisy? Sunney Xie of Harvard University and his collaborators have used single-molecule fluorescence microscopy and microfluidics to find out.



They started by modifying the DNA of *Escherichia coli* to create 1018 different strains of the single-celled bacterium. In each strain, the code for a yellow fluorescent protein (YFP) was inserted after the gene for a different protein. To see the rate at which one gene is expressed in one cell of one strain, you'd illuminate the cell with a laser and measure the YFP emission through a microscope. To gather gene-expression statistics for a sample of cells from all 1018 strains, the Harvard team sent streams of cells through channels cut in a microfluidic chip and imaged them. The figure shows sample images for three proteins, YjiE, AtpD, and Adk. Ninety-six strains could be processed at once at a total throughput of 160 cells per second. The team found that the least abundant proteins appear at 10^{-1} molecules per cell; the most abundant, at 10^4 per cell. Gene expression is indeed noisy, but with a twist. As you'd expect, the least abundant proteins have the largest cell-to-cell fluctuations. But for proteins whose mean abundance is 10 per cell or higher, the expression noise saturates, presumably because the various molecules that mediate gene expression inside a cell are in limited supply. (Y. Taniguchi et al., *Science* **329**, 533, 2010.) —CD

Space buckyballs. The field of nanotechnology is in part rooted in the 1985 Nobel Prize-winning laboratory synthesis of buckyballs—the soccer-ball-shaped carbon molecule C_{60} —by Rice University chemists Richard Smalley and Robert Curl and their collaborator, University of Sussex chemist Harold Kroto. The synthesis was guided by Kroto's hypothesis that complex carbon chains could naturally form in the interstellar medium of aging carbon-rich, hydrogen-poor giant branch stars. Now, 25 years later, Jan Cami at the University of Western Ontario and his colleagues have reported the clearest evidence yet of such complex carbon structures in space. The research team analyzed IR spectroscopic data—collected by the *Spitzer Space Telescope*—of the circumstellar region of a planetary nebula known as Tc 1. As the image shows, the spectrum contains several prominent peaks of C_{60} (red arrows) and peaks of the rugby-ball-shaped C_{70} (blue arrows); both molecules were uncharged and in the solid phase. Previous spectra of other carbon-rich planetary nebulae indicated strong emission peaks of volatile polycyclic hydrocarbons, which were completely absent in the monitored region of Tc 1.



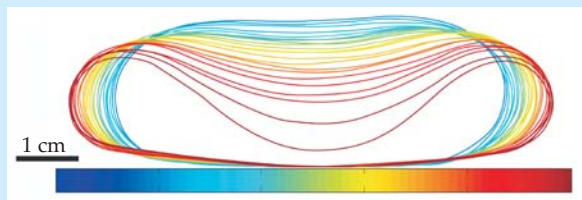
cosmologically significant conclusions. The radio data's autocorrelation—the quantity that should eventually reveal the BAO peak at 480 Mly—was so noisy that it wasn't statistically different from zero. But Chang notes, “The situation has improved since late 2009, since digital TVs no longer occupy the 700-MHz frequency range.” With 300 more observing hours at the GBT, she and her

colleagues are now mapping a larger area of sky—about 50 square degrees—which they'll use as a test for even larger surveys aimed at BAO measurement. And they hope to get funding to build a dedicated intensity-mapping telescope that's as big as the GBT. Peterson, Bandura, and others have already built a prototype.

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Cami and his colleagues suggest that the planetary nebula may have ejected its hydrogen envelope a few thousand years ago and that a recent thermal pulse prompted the ejection of the pure carbon dust they're now observing. (J. Cami et al., *Science*, in press, doi:10.1126/science.1192035.) —JNAM

Rolling ribbons get the bends. For thousands of years, children have delighted in hoop rolling. Certainly, most of them have not considered that the rings are subject to gravitational and inertial forces; in any case, the hoops are stiff enough that they maintain their circular form despite those forces. But what happens to a rolling hoop that's not so stiff? John Bush of the MIT mathematics department, along with visiting student Pascal Raux and colleagues, has answered that question in a recent study of more general systems—rolling bands that may be wider than they are high. Bush and company's work was both experimental and theoretical. In their experimental investigations they took pictures of a vinyl polysiloxane loop placed on the inner surface of a rotating drum. The figure shows how the form of a representative loop changes as the drum speed is increased; blue corresponds to low speeds; red, high. In their theoretical work, the investigators confirmed the intuitive idea that the rolling band deforms as the inertial or gravitational force overwhelms the internal stiffness force. Indeed, if either gravity or inertial effects



are strong enough, the top of the band can make contact with the bottom; new forces then come into play and the team's analysis is no longer valid. Rolling droplets, tumbling blood cells, and carbon nanotubes deformed by van der Waals forces, the authors note, all display similar shapes to the rolling ribbons; the dynamics of those varied systems may be elucidated by the relatively simple ribbon study. (P. S. Raux et al., *Phys. Rev. Lett.* **105**, 044301, 2010.) —SKB

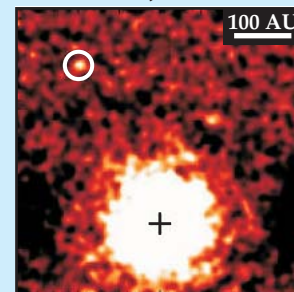
Bali's beating gong. At the heart of the Balinese percussive orchestra known as a gamelan is the large gong called the *gong ageng wadon*. It features a large, protruding dome or boss in the middle; when the boss is struck with a padded mallet, the gong produces a pronounced acoustic beating or *ombak* (meaning “wave”), as can be heard in the online version of this item. Using acoustical and vibrometric analyses, David Krueger and his colleagues at Brigham Young University have studied the sources of the ombak. Although some beating was found to come from asymmetric vibration modes with closely spaced frequencies, those appear to contribute mostly to the gong's timbre. The

more significant contribution arises from the gong's nonlinear structural response. Its two dominant vibration modes, both axially symmetric, have nearly a 2:1 frequency ratio. That relationship gives the gong its perceived pitch, but the ratio isn't exact. So when the gong is struck, causing displacements large enough to produce overtones, the fundamental generates harmonics and interacts with the second axisymmetric mode to yield sum and difference frequencies. The resulting sound spectrum features strong peaks of similar amplitudes that are spaced only a few hertz apart and give rise to the distinctive sound of ombak. (D. W. Krueger, K. L. Gee, J. Grimshaw, *J. Acoust. Soc. Am.* **128**, EL8, 2010.) —RJF



Directly imaged exoplanet challenges formation models.

Two years ago, astronomers in Canada directly imaged what seemed to be a gas giant planet in a very distant orbit—more than 300 times the Earth–Sun distance of one astronomical unit (AU)—around a star much like our Sun. (For comparison, Jupiter's orbit is 5.2 AU, Neptune's is 30 AU.) Such a scenario poses difficulties for all the major planet-formation models in current use: core accretion, gravitational instability, and fragmentation of a pre-stellar core. The main difficulty is that either much larger objects, like another star, or much smaller ones are expected at such a great distance. Now, with further observations in hand from the Gemini North telescope and its adaptive optics, University of Toronto astronomers Ray Jayawardhana, Marten van Kerkwijk, and David Lafrenière (now at the University of Montreal) have confirmed the puzzle: The planet, with about eight times the mass of Jupiter, is moving through space gravitationally bound to the parent star, known by its nickname 1RXS 1609. Besides astrometric observations, the direct imaging (shown here) along with spectroscopic and photometric data allowed the researchers to further characterize the planet and confirm that no other large planets are farther out in the system. A mere toddler at only 5 million years old, 1RXS 1609 is about 500 light-years away. Hundreds of other exoplanets have been discovered in recent years, but this one is expected to keep theorists busy for some time. (D. Lafrenière, R. Jayawardhana, M. H. van Kerkwijk, *Astrophys. J.* **719**, 497, 2010.) —SGB



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