

the source on the plane of the sky.

Clowe and coworkers deduced the projection of the bullet cluster's overall mass density on the celestial sphere from the so-called gravitational shear field of nonrandom orientations of apparently elliptical background galaxies. Because the two-dimensional mass density thus derived integrates over any lensing foreground or background masses along the line of sight, one might worry that one (or both) of the cluster's two apparent mass peaks could be an artifact due to unrelated galaxies or gas along the sight line. The paper raises the issue but concludes that such artifacts are extremely unlikely. Furthermore, the group's follow-up strong-lensing analysis of selected background galaxies, which is somewhat less sensitive to interlopers along the line of sight, supports the conclusions of the weak-lensing paper.⁴

A circular argument?

Clowe and company call the lensing result "a direct empirical proof of the existence of dark matter." But if the purpose is to present evidence against nonstandard gravity as a plausible alternative to dark matter, the argument might seem circular. Isn't the group basing its conclusions on lensing analyses that presume the correctness of general relativity?

"In fact, our conclusion that the baryon peaks are offset from the total-matter peaks relies only on very general assumptions about gravity that are obeyed by MOND and other plausible alternatives," says Clowe. "Any non-standard gravitational force that points

back to its source and scales with mass can't reproduce our lensing results without invoking preponderant concentrations of unseen matter. Our demonstration of dark matter doesn't preclude nonstandard theories of gravity, but it does remove their primary motivation."

But some cosmologists argue that invoking dark energy—even more mysterious than the putative dark matter—to explain the observed acceleration of cosmic expansion is an even stronger motivation for seeking a new theory of gravity. Does Bekenstein's modification of general relativity generate anisotropic lensing effects that could explain away the bullet-cluster offset without dark matter? "We won't know until someone does the full calculation for this very asymmetric system," says Bekenstein. "The closest anyone has come is a new approximation by Garry Angus,⁵ which fails to reproduce the offset without dark matter." But Angus argues that the dark matter could conceivably be nothing more mysterious than moderately heavy neutrinos. Princeton University theorist Jeremiah Ostriker concludes that "the bullet-cluster observations really do make a strong case against nonstandard gravity."

How collisionless

In the concordance model, dark matter that is cold (nonrelativistic) and essentially collisionless is essential for explaining the evolution from the almost perfectly homogeneous cosmos evinced by the microwave background to today's profusion of galaxy clusters. A useful measure of collisionality is

σ/m , a system's collision cross section per unit mass. For hydrogen gas, it's of order 10^8 cm²/g (a square angstrom per atom). For the weakly interacting dark-matter particles most often proposed by particle theorists, it would be much less than 1 cm²/g.

Computer models of galaxy formation with collisionless cold dark matter have been complicated by two problems—perhaps minor, but persistent. They predict intragalactic mass distributions that are too peaked at the centers, and they predict too many small satellites surrounding large galaxies. Princeton theorists David Spergel and Paul Steinhardt argued in 1999 that both problems go away if dark-matter particles have σ/m anywhere from 0.5 to 500 cm²/g. Now Clowe and company have excluded most of that range. From the bullet-cluster observations, they were able to set an upper limit of 1 cm²/g. That means a typical dark-matter particle in the inner precincts of a galaxy would suffer at most one or two collisions every ten billion years.

Bertram Schwarzschild

References

1. J. D. Bekenstein, *Phys. Rev. D* **70**, 083509 (2004).
2. D. Clowe, M. Bradac, A. Gonzalez, M. Markevitch, S.W. Randall, C. Jones, D. Zaritsky, *Astrophys. J. Lett.* **648**, L109 (2006).
3. D. Clowe, A. Gonzalez, M. Markevitch, *Astrophys. J.* **604**, 596 (2004).
4. M. Bradac et al., *Astrophys. J.* (in press); available at <http://arxiv.org/abs/astro-ph/0608408>.
5. G. W. Angus, H. Shan, H. Zhao, B. Famaey, available at <http://arxiv.org/abs/astro-ph/0609125>.

physics update

Supplementary material related to these items can be found at www.physicstoday.org.

Acoustic nanocavities. Phonons pulsed at around 100 GHz, with wavelengths of a few nanometers, have been confined in the same kind of resonant cavity used in photonics. A collaboration of physicists in France and Argentina used a superlattice made of carefully grown alternating layers of gallium arsenide and aluminum arsenide, materials with different acoustic impedances—the acoustic analog of refractive index for light. Two sets of multilayers in the superlattice act as Bragg mirrors for phonons, while a single nanometer-thick layer of GaAs in the center serves as the cavity. A femtosecond laser focused on the bottom of the stack generates the high-frequency sound, which is reflected multiple times through the nanocavity. After some delay, narrow phonon wavepackets at certain allowable sharp frequencies are detected by a laser probing the top of the device. Bernard Jusserand (CNRS and University of Paris VI and VII) says that he and his colleagues hope to reach the terahertz acoustic range. The

researchers think that a new field of nanophononics has been inaugurated and that the acoustical properties of semiconductor nanodevices will play important roles. One envisaged use is high-frequency modulation of the flow of charges or light in small spaces. Another is for novel forms of tomography that could image the interior of opaque solids. (A. Huynh et al., *Phys. Rev. Lett.* **97**, 115502, 2006.) —PFS

Repairing a cell's cancer defenses looks possible now that scientists have determined how mutations prevent a tumor-suppressing protein from doing its job. In healthy cells, the protein p53 monitors the transcription of genetic information from DNA to RNA. When p53 detects DNA damage or incipient cancer, it blocks DNA replication and kills the cancer cells. Mutated p53, which turns up in half of all human cancers, is powerless to prevent errors from propagating and resulting tumor cells from proliferating. Now, Andreas Joerger, Hwee Ching Ang, and Alan Fersht of Cambridge University in England have used x-ray crystallography to identify structural changes caused by the mutations. Overall, a substantial fraction of the mutations don't prevent p53 from folding or from binding to DNA. Rather, the

mutations make the protein so floppy that it melts at body temperature and flubs its tumor-suppressing role. The finding gives the researchers hope that drugs could bind and buttress p53's structure to restore its stability and health-preserving function. (A. C. Joerger, H. C. Ang, A. R. Fersht, *Proc. Natl. Acad. Sci. USA* **103**, 15056, 2006.) —CD

A tiny electrically pumped laser has been created by bonding a wafer of III-V compounds on a silicon substrate. Because the minimum of silicon's conduction band doesn't line up with the maximum of its valence band, holes and electrons can't recombine efficiently to make photons. As a result, silicon is a poor photonic material. But if its photonic shortcomings could be circumvented, silicon-based computers could tap directly into the torrents of data that flow through fiber-optic cables. To reach that goal, a silicon laser is essential. Ideally, the laser should work at room temperature, be electrically pumped, and be manufactured using lithography, epitaxy, and other techniques from the industrial repertoire. Mario Paniccia and his collaborators at Intel Corp's research labs in Santa Clara, California, have now built a prototype that meets those requirements. Working with John Bowers of the University of California, Santa Barbara, the Intel researchers have assembled an optically active AlGaInAs heterostructure on top of an etched silicon waveguide. Ordinarily, bonding III-V compounds to silicon creates performance-sapping defects. To avoid that outcome, Bowers devised a novel low-temperature (300 °C) wafer-bonding technique. At 13%, the prototype's efficiency is modest, but Paniccia foresees improvements. As the figure shows, the researchers can already make more than 30 lasers on a single 8-mm-wide chip. (A. W. Fang et al., *Opt. Express* **14**, 9203, 2006.) —CD



Room-temperature spin Hall effect. In the regular Hall effect, electrons that move longitudinally under the force of an applied electric field through a sample will, if exposed to a vertically oriented magnetic field, be deflected slightly to one side. Two years ago, physicists showed that a kind of Hall effect in a vertical electric field could produce a net pileup of spins at the edge of the sample, even though no pileup of electric charges would occur (see *PHYSICS TODAY*, February 2005, page 17). Physicists at the University of California, Santa Barbara, with collaborators from the Pennsylvania State University, now have used a sample of zinc selenide—a nonmagnetic II-VI semiconductor—to demonstrate both electrically induced spin polarization and the segregation of electrons based on spin. Using a diagnostic technique called Kerr rotation spectroscopy, the researchers showed that spins of opposite sign congregated on opposite sides of the sample, that the effect persists all the way up to room temperature, and that no internal magnetic fields arose in the process. All this despite the fact that ZnSe should not be efficient at electrically polarizing spins. Group leader David Awschalom says that the evidence for a strong spin Hall effect in ZnSe will add to the interesting controversy swirling around interpretations of the spin Hall effect. In another recent experiment, Awschalom and colleagues showed that spins needn't just pile up in a semiconductor; they can be led off as a polarized current into a wire made of the same material. (V. Sih et al., *Phys. Rev. Lett.* **97**, 096605, 2006; N. P. Stern et al., *Phys. Rev. Lett.* **97**, 126603, 2006.) —PFS

Ellipsoidal universe. A new theoretical assessment of data taken by the *Wilkinson Microwave Anisotropy Probe* suggests that the observable universe is not spherically symmetric, but more like an ellipsoid. The WMAP data have helped nail down some cosmological parameters such as the age of the universe since the Big Bang (13.7 billion years), the time when the first atoms formed (380 000 years after the Big Bang), and the fractions of all available energy vested in the form of ordinary matter, dark matter, and dark energy (roughly 5%, 25%, and 70%, respectively). One remaining oddity about the WMAP results, however, involves the way in which different portions of the sky contribute to the overall map of cosmic microwaves: Samples of the sky smaller than tens of degrees across seem to be contributing radiation at expected levels; only the largest possible scale, on the order of the entire sky, seems to be underrepresented. That largest scale is measured in the radiation's quadrupole moment. Now Leonardo Campanelli of the University of Ferrara and his colleagues Paolo Cea and Luigi Tedesco at the University of Bari (all in Italy) have taken a closer look at the so-called quadrupole anomaly. They found that if the surface of last scattering—the shell from which the cosmic microwaves come toward Earth—is slightly ellipsoidal rather than spherical, then the WMAP quadrupole is just what it should be. The cosmologists say that a nanogauss magnetic field pervading the cosmos could bring about the required 0.01 eccentricity. An ellipsoidal universe would nicely parallel Johannes Kepler's discovery that the planetary orbits are ellipses and not circles. (L. Campanelli, P. Cea, L. Tedesco, *Phys. Rev. Lett.* **97**, 131302, 2006.) —PFS

Artificial-muscle diffraction grating. Manuel Aschwenden and Andreas Stemmer of ETH Zürich in Switzerland molded a soft, electroactive polymer into a shape resembling a microscopic pleated window shade and bonded it onto a prestretched elastic polymer. The result is an artificial muscle that contracts when a voltage is applied. With no voltage, the grating's lines are spaced 1 μm apart. But when a voltage is applied to the ETH device, the line spacing can change by up to a whopping 32%—compared with less than 1% for tunable gratings made of hard materials. When white light strikes a diffraction grating, different wavelengths fan out at different angles; a small



aperture placed within the fan can isolate any of the colors. Changed line spacing means changed angles, and a different color sweeps across the aperture. With different voltages, the test device isolated different wavelengths over a range of 139 nm starting at 446 nm, as shown in the figure. The researchers envision replacing the fixed red, green, and blue light-emitting elements in each pixel of a display screen with two or more tunable diffraction gratings, which would make available the full range of colors that the human eye can perceive. Tunable diffraction gratings are routinely used in fiber-optic telecommunications and video projectors. The new technology could exploit newly developed white LED lights. (M. Aschwenden, A. Stemmer, *Opt. Lett.* **31**, 2610, 2006.) —DC ■