a similar mission planned by NASA, see reference 5.

Known unknowns

Despite its wildly different climate, Venus is sometimes known as Earth's twin. The two are similar in size, mass, bulk composition, and proximity to the Sun. And although radar maps have revealed Venus to be covered in volcanic and tectonic features, no one knows whether volcanism and tectonic activity continue today. Establishing the current geological state would help scientists address a fundamental question about Venus that they are still struggling to answer about Mars—whether the planet ever had a habitable environment with liquid-water oceans. (See the article by Ashwin Vasavada on page 34 of this issue.)

Unlike Mars's surface, whose study has benefited enormously from a succession of rovers crawling around the planet for the past decade, the surface of Venus remains almost completely unexplored. If roving on Venus's rugged terrain turns out to be too challenging or otherwise impractical, the high atmospheric density near its surface—50 times that on Earth—enables another possible way to get around: using metal Chinese-lantern-like balloons whose bellows can expand or contract to control buoyancy.[6]

The concept of planetary ballooning is less outlandish than one might think. Back in 1985 the Soviet Union successfully deployed two balloons in the clouds of Venus, 55 km above the surface. Too high up to image the ground, the balloons and their payloads were carried more than 10 000 km by fast winds and enjoyed balmy temperatures around 20 °C. Today's research into robust SiC circuitry could lead to high-temperature balloon missions that travel far closer to the ground—even touching down in spots—so that instruments can photograph passing terrain or sample its broiling soil and rock.

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PHYSICS UPDATE

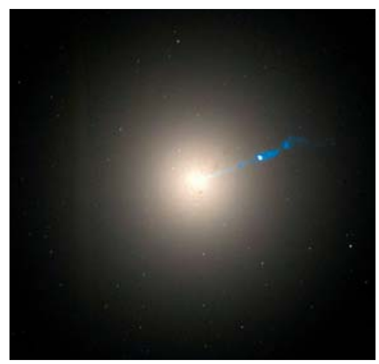
These items, with supplementary material, first appeared at www.physicstoday.org.

TESTING THEORIES OF MODIFIED GRAVITY

The accelerated expansion of the universe is usually attributed to a mysterious dark energy, but there's another conceivable explanation: modified gravity. Unmodified gravity—that is, Einstein's general relativity—satisfactorily accounts for the dynamics of the solar system, where precision measurements can be made without the confounding influence of dark matter. Nor have any violations been detected in one of general relativity's principal ingredients, the strong equivalence principle, which posits that inertial mass and gravitational mass are identical.

But those observational constraints are not ineluctable. In particular, a class of gravitational theories called Galileon models can also pass them. In 2012 Lam Hui and Alberto Nicolis of Columbia University devised a cosmic test that could refute or confirm the models. Their test hinges on the models' central feature: an additional scalar field that couples to mass. The coupling can be characterized by a charge-like parameter, Q. For most cosmic objects, Q has the same value as the inertial mass. But for a black hole, whose mass arises entirely from its gravitational binding energy, Q is zero; the strong equivalence principle is violated.

Galaxies fall through space away from low concentrations of mass and toward high concentrations. The supermassive black holes at the centers of some galaxies are carried along with the flow. But if gravity has a Galileon component, the black hole feels less of a tug than do the galaxy's stars, interstellar medium, and dark-matter particles. The upshot, Hui and Nicolis realized, is that the black hole will lag the rest of the galaxy and slip away from its center. The displacement is arrested when the black hole reaches the point where the lag is offset by the presence of more of the galaxy's gravitational mass on one side of the black hole than on the other. Given the right circumstances, the displacement can be measured.



Hui and Nicolis's proposal has now itself been put to the test. Asha Asvathaman and Jeremy Heyl of the University of British Columbia, together with Hui, have applied it to two galaxies: M32, which is being pulled toward its larger neighbor, the Andromeda galaxy, and M87 (shown here), which is being pulled through the Virgo cluster of galaxies. Both M32 and M87 are elliptical galaxies. Because of their simple shapes, their centroids can be determined from optical observations. The locations of their respective black holes can be determined from radio observations. Although the limit on Galileon gravity that Asvathaman, Heyl, and Hui derived was too loose to refute or confirm the theory, they nevertheless validated the test itself. More precise astrometric observations could make it decisive. (A. Asvathaman, J. S. Heyl, L. Hui, *Mon. Not. R. Astron. Soc.* **465**, 3261, 2017.)

—CD

WATCHING PEROVSKITE PHOTOEXCITATIONS, ATOM BY ATOM

Certain members of the class of crystalline materials known as perovskites have recently shown great promise for optoelectronic applications. Perovskites have the chemical formula ABX_3, where A and B are cations and X is an anion, arranged as shown on page 22. Crystals that combine an organic cation, lead as the

BATS' EARS MAY SOLVE AN EVOLUTIONARY PUZZLE

Despite the common saying, bats aren't actually blind—but about 85% of bat species can hunt in the dark by tracking the echoes of their own voices, an ability called laryngeal echolocation. (See the article by Whit Au and Jim Simmons, PHYSICS TODAY, September 2007, page 40.) The remaining 15%, a group called the Old World fruit bats (for example, the lesser short-nosed fruit bat shown here), rely on plain old eyesight. This finding has led to a fierce debate among evolutionary biologists: Did bats descend from a single ancestor capable of laryngeal echolocation, with fruit bats losing the ability somewhere along the way? Or did laryngeal echolocation evolve independently in different branches of the bat family tree?

A team of researchers led by Shuyi Zhang at Shenyang Agricultural University may have uncovered new clues to this evolutionary mystery by studying the fetal

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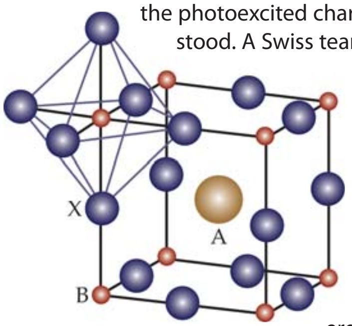
development of bats' ears. Many animals exhibit vestigial structures inherited from distant ancestors during early stages of development. Human embryos, for example, begin with a tail.

Zhang's team, along with Emma Teeling at University College Dublin, analyzed the development of the cochlea, a spiral-shaped bone in the inner ear. Species that use laryngeal echolocation have extremely large cochleae relative to their skull size; that trait enables greater sensitivity to the vibrations generated by their echoing voices.

The researchers tracked relative cochlear size at different stages of fetal development for seven species of bat and for five other mammals. They found that at early stages of fetal development, the relative cochlear size of the Old World fruit bats was similar to that of bat species capable of laryngeal echolocation. Whereas more-developed fruit bat fetuses had smaller cochleae than their laryngeal-echolocating relatives, they still had relatively large cochleae compared with other non-echolocating species such as mice and hedgehogs. The presence of large fetal cochleae suggests that Old World fruit bats did indeed descend from an ancestor capable of laryngeal echolocation. (Z. Wang et al., *Nat. Ecol. Evol.* **1**, 0021, 2017.) —MB

second cation, and a halogen anion make for solar cells of remarkably high efficiency despite rather modest charge-carrier mobilities (see PHYSICS TODAY, May 2014, page 13). Yet the nature and fate of the photoexcited charge carriers remain little understood. A Swiss team led by Majed Chergui of the Swiss Federal Institute of Technology in Lausanne has now peeled back some of that mystery. With time-resolved x-ray absorption spectroscopy, the researchers studied two inorganic perovskites—$CsPbBr_3$ and $CsPb(Cl_xBr_{1-x})_3$— at the Swiss Light Source. By tuning the energy of the pulsed x rays, they could interrogate each element independently with a resolution of 80 ps. For both materials, the team found that the excited electrons are delocalized in the conduction band, whereas the holes left behind in the valence band are localized at the Br sites. The Br signal consisted of one component that decayed quickly and one that decayed slowly; the photoluminescence kinetics of organic–inorganic perovskite solar cells show a similar biexponential decay. Meanwhile, the Cs^+ cations showed no evidence of being involved in the charge transport, which suggests that organic cations would likewise be uninvolved. (F. G. Santomauro et al., *Struct. Dyn.* **4**, 044002, 2017.) —RJF



A FAST RADIO BURST'S EXTRAGALACTIC HOME

Discovered in 2007, fast radio bursts (FRBs) emit luminous pulses of radio light that last mere milliseconds. To date, astronomers have reported about 20 FRBs but don't know what causes them. One, identified in 2014 by Laura Spitler and colleagues, stands apart because it has been observed to burst repeatedly (see PHYSICS TODAY, April 2016, page 22). The source was first detected on 2 November 2012, hence its designation FRB121102. An international team took advantage of FRB121102's ongoing intermittent activity to run a series of follow-up observations with several radio telescopes in the US and Europe and has located FRB121102 with unprecedented precision. The radio observations didn't just refine the location of FRB121102, they also spotted a persistent source coincident with the FRB, to within experimental uncertainty. It is possible that the persistent source is related to the FRB; it could be, for example, a highly energetic neutron star in a young supernova remnant or an unusual active galactic nucleus.

The researchers also observed the neighborhood of FRB121102 with the Gemini North optical telescope. They determined that the location of the FRB coincides with that of a dwarf galaxy some 3 billion light-years distant from Earth. Although astronomers had expected FRBs to lie beyond the Milky Way, some models allowed for sources in our galaxy; the new work provides the first direct confirmation of the earlier consensus. Dwarf galaxies are more likely than regular galaxies to host two other classes of high-energy transients: superluminous supernovae and long-duration gamma-ray bursts. The observation of an FRB in a dwarf galaxy creates the tantalizing prospect that all three types of high-energy events may be generated by massive progenitors. (S. Chatterjee et al., *Nature* **541**, 58, 2017; S. P. Tendulkar et al., *Astrophys. J. Lett.* **834**, L7, 2017; B. Marcote et al., *Astrophys. J. Lett.* **834**, L8, 2017.) —SKB PT

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