thought, by how much energy they've expended on their trip. In a key experiment, Mandyam Srinivasan and Shaowu Zhang, neurobiologists at Australian National University in Canberra, Jürgen Tautz of the University of Würzburg in Germany, and their colleagues tested this idea by training bees to fly down tunnels with different patterns painted inside. They found that the bee danced longer than it should have after flying through a semicheckered tunnel that gave the bee the sense of moving past many, many objects. If the tunnel was lined with horizontal stripes, which had no vertical boundaries to signify an object being passed, the bee's dance was too short. These experiments, coupled with earlier work by Esch, strongly indicated that the bees use the passing landscape to click off the meters.

In this new work, Srinivasan, Zhang, and Tautz teamed up with Esch to see whether a bee actually communicated its misperceptions to other bees. "It's another in a series of very cleverly designed experiments," comments Mark Frye, a neurobiologist at the University of California, Berkeley. The researchers first set up a tunnel lined with a complex pattern, then trained bees leaving the hive to fly through the tunnel to get to a feeder on the other side. They videotaped the bee's dance when it returned and calculated the distance communicated. The bee danced as if it had traveled 72 meters instead of 11, the true distance. "The bees felt like they had gone a greater distance," says Frye.

The researchers then stationed themselves 35, 70, and 140 meters away from the hive for 2.5 hours and counted how often bees from the hive flew up to them in search of food. About three-quarters of the 220 bees approached the 70-meter spot looking for nectar—the distance communicated in the dance. Based on these results, says Frye, "there is now no question that the way honeybees communicate distance depends on what they see." –ELIZABETH PENNISI

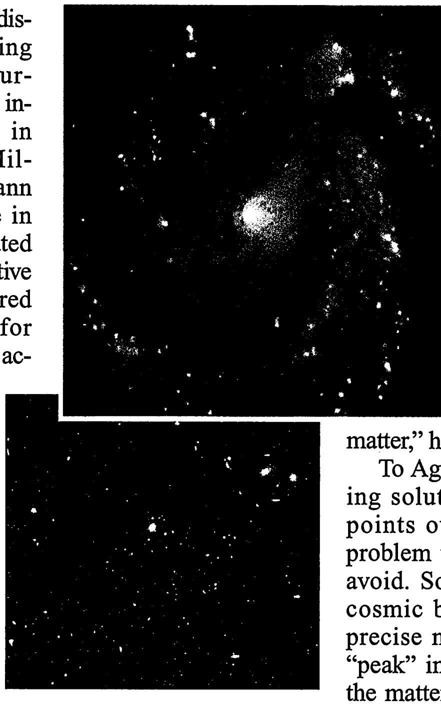
ASTROPHYSICS

Radical Gravity Theory Hits Large-Scale Snag

La fin du MOND c'est arrivé—perhaps. For nearly 2 decades, modified Newtonian dynamics (MOND), a heretical theory that alters some properties of gravity to eliminate the need for dark matter, has survived one astronomical observation after another—and even gained strength in the process. But now, physicists at the Institute for Advanced Study in Princeton, New Jersey, have shown that the theory is deeply at odds with observations of galaxy clusters, suggesting that MOND is in trouble.

"I take it very seriously," says Stacy McGaugh, an astrophysicist at the University of Maryland, College Park, who has supported the theory. "It's a real problem for MOND."

On one level, MOND is an attractive idea. Astronomers have long been troubled by the motion of matter within galaxies; peripheral stars and clouds orbit the galactic center faster than Newtonian (and Einsteinian) laws of gravity dictate. Most scientists explain the discrepancy by assuming that galaxies are surrounded by a halo of invisible matter, but in 1983 Mordechai Milgrom of the Weizmann Institute of Science in Rehovot, Israel, created MOND as an alternative explanation. He altered the standard rule for gravity so that slowly accelerating objects feel a slightly stronger gravitational pull than Newton's laws dictate. That gives the outer edges of galaxies an extra little tug, causing them to move faster. The tweak reproduced the motion of the galaxies with high precision, without the need for dark matter.



A matter of scale. Although MOND succeeds in individual galaxies such as M100, it fails in galaxy groups like the Virgo cluster.

CREDITS: (TOP TO BOTTOM) NASA; DIGITIZED SKY SURVEY/PALOMAR OBSERVATORY/STSCI

"It's a simple and clear prediction that matched the observations well," says Anthony Aguirre of the Institute for Advanced Study. "It does seem to succeed miraculously well." On another level, however, MOND is a very unappealing theory, because mathematicians haven't been able to meld it with the framework of general relativity.

It should come as no surprise that scientists have been taking potshots at MOND for years; however, the theory has survived them surprisingly well (*Science*, 28 January 2000, p. 572). Indeed, a missing "peak" in microwave-background data (*Science*, 28 April 2000, p. 595) was briefly seen as a surprising source of support for MOND, although the peak has since been found (*Science*, 4 May, p. 823). But the tide might now be turning.

Aguirre and his colleagues have analyzed x-ray data from the ROSAT, ASCA, and BeppoSAX satellites to determine the temperature of matter in galaxy clusters. Much of that matter takes the form of x-ray-emitting gas, whose temperature depends on its density, pressure, and acceleration. Those factors, in turn, reveal information about what governs the clouds' motion—dark matter or modified gravity. It turns out that MOND fails the test: The observed temperatures look nothing like what would be expected in a MOND-controlled cluster. The data "disagree very strongly with MOND's prediction," says Aguirre. "MOND is not a viable alternative to dark matter in clusters."

"There is a conundrum," Milgrom admits, although he notes that he has known about problems with galaxy clusters for some time. Additional unseen matter, like the once-unknown x-ray-emitting gas throughout the cluster, might account for the discrepancy, he says. "There is always room for yet-undetected matter," he says.

To Aguirre, this is an unsatisfying solution. Unseen matter, he points out, smacks of the very problem MOND was designed to avoid. Soon, observations of the cosmic background radiation—precise measurements of a third "peak" in the data—may well put the matter to rest once and for all. "Oh, I hope so," says McGaugh. "I really do hope so." In the meantime Milgrom holds fast to MOND, although he admits the possibility that his theory will one day be falsified. "As its inventor, I would like it to be a revolution, but I look at it coolly," he says. "I will be very sad, but not shocked, if [the answer] turns out to be dark matter."

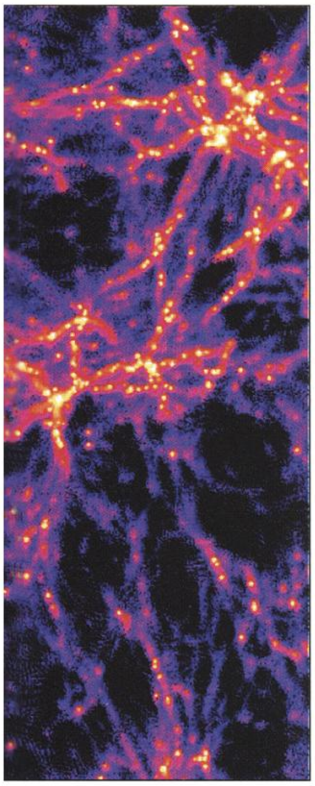
–CHARLES SEIFE

ASTRONOMY

Deep-Space 'Filament' Shows Cosmic Fabric

Astronomers peering back to the early days of the universe have detected the primordial building blocks of galaxies. These cosmological Lego blocks—older and smaller than any detected before—are arranged in an elongated filament. The observations support a popular theory of cosmic evolution in which matter first collected into a network of thin filaments and later coalesced into clusters and superclusters.

The so-called cold dark matter theory was proposed some 20 years ago to explain the structure of the universe. It holds that in the earliest days after the big bang, exotic



Filaments of matter. Simulation of the early universe is supported by new observation.

dark matter, with just a sprinkling of normal matter, clumped into blobs along narrow filaments. Later, these galactic building blocks streamed along filaments into connecting nodes, where clusters and superclusters of galaxies formed. According to astronomer Palle Møller of the European Southern Observatory (ESO) in Garching, Germany, the new observations "lend further strong support" to this picture.

Møller and his team found the primordial filament by making precise measurements of remote blobs of glowing hydrogen gas, using ESO's Very Large Telescope in Chile. The hydrogen clouds are named Lyman-α Emitting Galaxy-Building Objects, or LEGOs, not only for the children's building blocks but also for the radiation the objects emit. Lyman-α radiation is redshifted at very great distances; the redshift is caused by the expansion of the universe and is a measure of distance and look-back time. The newly observed filament has a redshift of just above 3, corresponding to 85% of the current age of the universe. Møller says this is the first convincing observation of a cosmic filament in the very early universe. His team will publish its results later this year in *Astronomy & Astrophysics*.

The objects that make up the filament are less massive and more representative of the primordial matter in the universe than the larger hydrogen clouds that have been observed previously, says Simon White of the Max Planck Institute for Astrophysics in Garching, a theorist who studies structure formation in the early universe. And because these smaller clouds are much more common, they can be used to trace the large-scale structure of the early universe. "This filament is a first example," White says. "The network predicted by our simulations may at last be visible." **–GOVERT SCHILLING**

Govert Schilling is an astronomy writer in Utrecht, the Netherlands.

ASTRONOMY

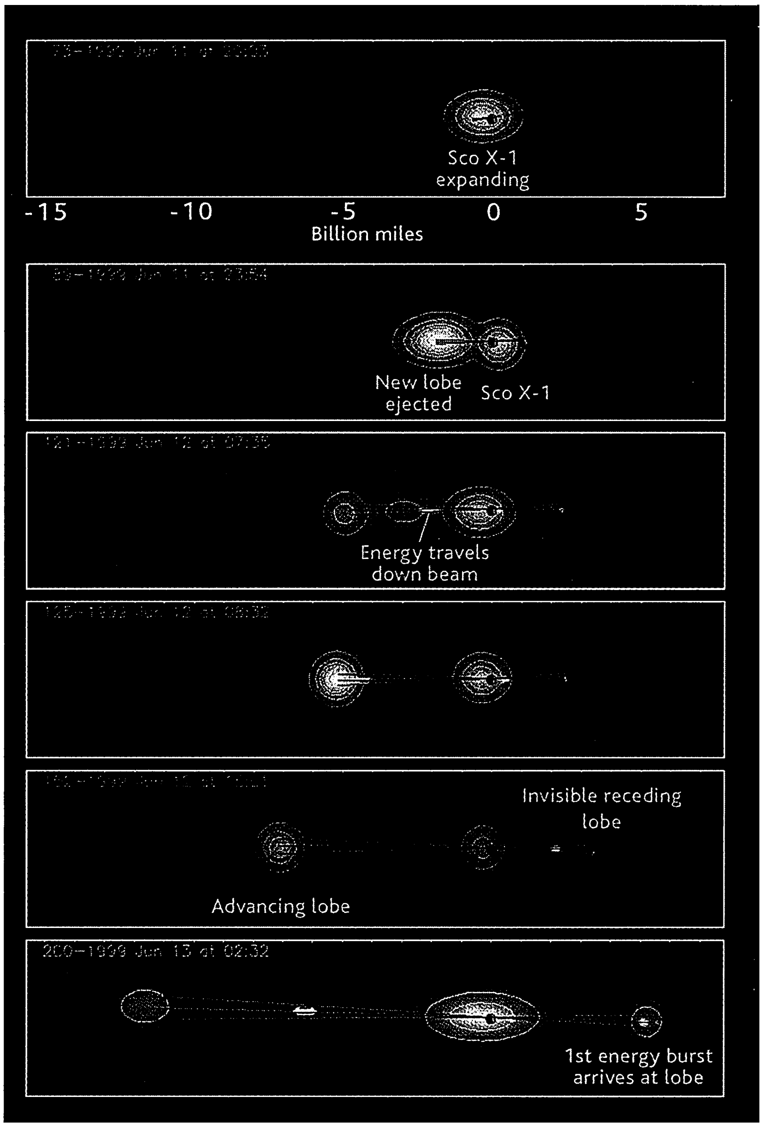
The Most Powerful Action Flick Ever

A neutron star has the lead role in a first-of-its-kind movie. An international team this week released unique footage of Scorpius X-1 gobbling gas from a companion star and then spitting out blobs like so many watermelon seeds. The new flick should help astronomers understand the narrow jets formed by neutron stars and black holes in our galaxy and beyond.

The jets have turned up everywhere in the past decade, from nearby neutron stars to black holes in distant galaxies. Seen up close, the seemingly smooth jets break up into a series of blobs that race down the length of the jet at nearly the speed of light. Astronomers believe that the star or black hole launches the blobs when it vents accumulated hot gas. If they are right, a burst of x-rays from near the star should precede each new blob in the same way a flash of light from a gun barrel signals the approach of a bullet.

But testing the idea is difficult. Blobs cool rapidly and become invisible to x-ray telescopes; it takes many optical and radio telescopes working together around the globe to follow them down the jet. Coordinating such an operation is a logistical and political nightmare that had prevented any team from watching the birth and evolution of a single blob—until now.

For 56 hours in June 1999, Scorpius X-1 was continuously observed by a worldwide network of radio telescopes, called the Very Long Baseline Array (VLBA), and by additional radio telescopes in Australia, China, Japan, and South Africa. Two optical observatories and the orbiting Rossi X-ray Timing Explorer also provided continuous monitoring.



The stellar movie (below)—described in a paper published in the 20 May issue of *Astrophysical Journal Letters* and viewable at www.aoc.nrao.edu/pr/scox1/scox1.movie.html—reveals the predicted x-ray flash, followed by two pairs of blobs exploding in opposite directions at 95% of the speed of light. After a few hours, the blobs catch up with cooler material left over from previous eruptions. Soon another blob takes off. "This is the first time anyone has ever watched the whole cycle," says lead author Ed Fomalont, an astronomer at the National Radio Astronomy Observatory in Socorro, New Mexico.

"This is what the VLBA was set up to do, and by combining it with x-ray and optical observations they have pushed it to the max," says astrophysicist Roger Blandford of the California Institute of Technology in Pasadena. The next step is to figure out what causes the explosions.

–MARK SINCELL

Mark Sincell is a science writer in Houston.

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