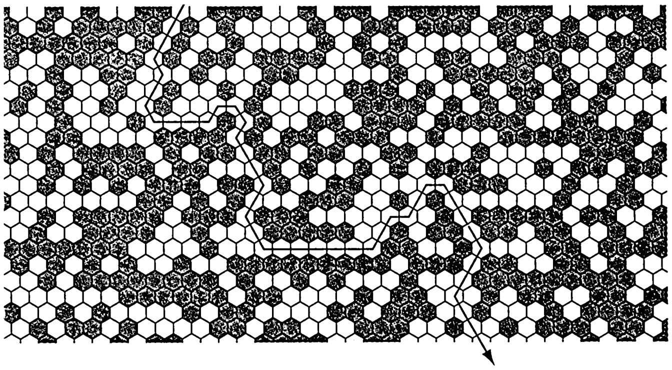


Leaking through. Percolation across a filter made of random barriers (gray) may be linked to Brownian motion.

nents for two-dimensional Brownian motion. Their proof is now available on the Web (xxx.lanl.gov/abs/math.PR/0010165) as a series of preprints totaling over 100 pages, the first of which has been accepted by the journal *Acta Mathematica*.

The exponents settle a variety of related problems about Brownian motion. They show, for example, that the outer edge or "frontier" of a Brownian motion is a fractal with dimension 4/3. In other words, just as the circumference of a circle is proportional to its diameter, the size of a Brownian path's frontier is proportional to the 4/3 power of its diameter (the longest distance across the frontier). When Benoit Mandelbrot proposed that neat relationship in his 1982 book, *The Fractal Geometry of Nature*, mathematical colleagues shrugged it off as speculation, Lawler recalls. But 18 years later, Mandelbrot has been vindicated.

Most tantalizingly for physicists, the SLE process may describe a number of other random phenomena. The best candidate appears to be "critical percolation," a way of describing how water and other liquids flow through a porous barrier. To model it in two dimensions, physicists start with a blank filter ruled like a honeycomb with hexagonal cells, then randomly assign each cell to be either permeable or impermeable. By flowing through clusters of permeable cells, water can percolate across the honeycomb. If the cells of the honeycomb are made vanishingly small, Schramm believes, the boundaries of those clusters become random curves identical with the ones the SLE process produces.

"It's fantastic that the process that is conjectured to be important for percolation is rigorously proved to be connected to Brownian motion," Peres says. As Rick Durrett, a probability theorist at Cornell University, explains, "Physicists like to think various models are in the same universality class. This may be one of the first examples where you can prove one model is equivalent to a second."

–DANA MACKENZIE

Dana Mackenzie is a writer in Santa Cruz, California.

MEETING AAS HIGH-ENERGY ASTROPHYSICS DIVISION

X-rays Hit the Spot for Astrophysicists

HONOLULU—About 500 astronomers flocked to Waikiki Beach from 6 to 10 November for a meeting of the American Astronomical Society's High-Energy Astrophysics Division. Looking splendid in their complimentary aloha shirts, speakers told tales of intense radiation from deep space, including x-rays from quasars and baby stars.

Hot Times for Baby Stars

A dark nest of dust seems like a cool place for a baby star to fledge. However, astronomers have learned that long before some new stars ignite their nuclear furnaces, they unleash powerful flares of x-rays that reach temperatures of 100 million degrees Celsius. Now, two reports at the meeting indicate that that surprising process is common in the infancies of all types of stars.

Stars hatch within dense clouds of gas and dust, some of which forms whirling protoplanetary disks, or "proplyds." The Orion Nebula, the closest major stellar nursery, contains many such knots. Thick dust prevents optical light from escaping, but astronomers can use x-rays to detect the protostars within. Previous low-resolution studies of emerging stars with x-ray observatories, including the German ROSAT satellite and the Japanese ASCA, suggested that a few nearby stars could emit hot x-rays at a tender age. However, resolving x-rays from scores of stars in Orion became possible only last year, when the Chandra X-ray Observatory was launched.

Two new Chandra studies show that cracklingly hot stellar childhoods are common. First, astronomer Norbert Schulz of the Massachusetts Institute of Technology and his colleagues probed Orion's heart, a close-packed cluster of stars and protostars called the Trapezium. Energetic x-rays streamed from all of the Trapezium's stars, regardless of their masses. High-mass stars raged at up to 80 million degrees, three times hotter than previously measured. That rules out a scenario that some researchers have used to explain x-rays from infant stars: strong stellar winds that plow into the surrounding gas, creating fierce shocks. "We cannot explain the highest temperatures we see with shocks," Schulz says.

Blazing babies. Newborn stars in the Orion Nebula emit surprisingly hot bursts of x-rays (blue, with white contours).

Even low-mass proplyds got into the act, emitting x-rays that pointed to steady temperatures of 60 million to 80 million degrees —far beyond the occasional hot bursts seen in earlier observations. "These are stars like our sun that are only about 300,000 years old, so they haven't even started burning yet," Schulz notes.

Deepening the mystery, a Japanese team of astronomers led by Katsuji Koyama of Kyoto University and Yohko Tsuboi of Pennsylvania State University examined low-mass objects in a different part of Orion and in another dense cloud, called ρ Ophiuchi. Those protostars were even younger, merely 10,000 to 100,000 years old. Still, Chandra perceived torrents of x-rays from flares that sometimes approached 100 million degrees. Koyama contrasts this with gas and dust temperatures of a few tens of degrees at the cores of the clouds. "No one expected that stars could produce such x-ray activity at such an early stage," Koyama says.

CREDITS: (TOP TO BOTTOM) ODED SCHRAMM/MICROSOFT RESEARCH; (CHANDRA OVERLAY) NORBERT SCHULZ/MIT; (HUBBLE TELESCOPE IMAGE) J. BALLY

The two teams can think of just one explanation: intensely twisted coils of magnetic field that lace through the rapidly rotating protostars and their disks. Such tangled fields should short-circuit and snap, says Penn State astronomer Eric Feigelson, flash-heating the surrounding gas to tens of millions of degrees. The resulting flares might unleash hundreds of thousands of times more energy than flares on our sun today.

Tsuboi's detection of x-rays from the youngest protostars ever observed is especially noteworthy, Feigelson believes. "The greatest implication will be to help us learn how early the x-rays turn on and whether they affect the star-formation process," he says. "It's possible, but controversial, that x-rays will sufficiently ionize the gas in the proplyd and surrounding environment to lock it to the magnetic field. If that were true, we might have to alter our entire picture of early star and planet formation." Current theories focus on the self-gravitation of the collapsing cloud and the hydrodynamics of neutral molecules, he notes, rather than magnetic interactions among charged molecules.

The genesis of strong magnetic fields within proplyds is "very puzzling," says astronomer Andrea Dupree of the Harvard-Smithsonian Center for Astrophysics. "There are a lot of options on the table," including fields generated at the roiling interfaces between the growing stars and the disks of gas around them. "The geometry of the field is not known," Feigelson agrees. "It's an open question."

Quixotic Quasar May Yield Cosmic Yardstick

Flickering x-rays from a mirage in the depths of space may refine estimates of how quickly the universe is expanding. The x-rays stream from a quasar, whose light splinters along several paths as it passes another galaxy along the line of sight to Earth. Slight variations in the time it takes for x-rays to navigate each path promise to reveal the distance to the intervening galaxy, according to research presented at the meeting. That, in turn, could give astronomers their longest yardstick yet for gauging the growth rate of space itself.

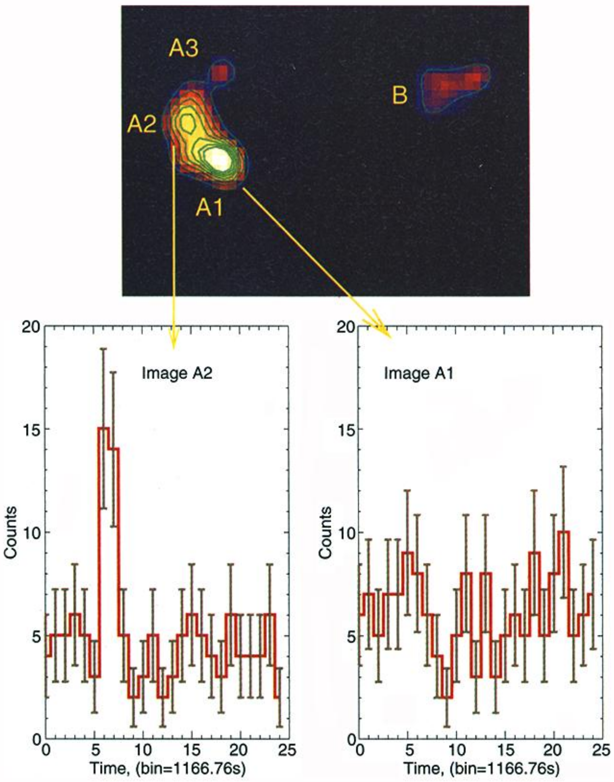
The quasar, a beacon called RXJ 0911.4+0551, shines near the fringes of the observable universe. It probably draws its power from matter swirling into a huge black hole at the core of a young galaxy. Gravity from a galaxy between Earth and the quasar shears the quasar's light into four closely spaced beams. This optical fracturing makes the quasar appear in a telescope as four spots, an illusion called a gravitational lens.

Cosmologists admire more than the eerie beauty of such lenses. For example, lenses probe the curvature of the universe, thanks to precise predictions of the light paths from Einstein's general theory of relativity. In 1991, astrophysicist Ramesh Narayan of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, also showed that one could derive an exact distance to a lensing galaxy by observing the difference in light's travel times along each path, a quantity called "time delay." The delay is evident when one of the quasar's images flares up, followed some time later by similar flares in the other spots.

A firm distance, combined with the known speed at which the lensing galaxy is receding from Earth, leads directly to a measure of the Hubble constant—the rate at which the universe is growing. "The beauty of this technique is that it's a one-shot direct measurement of distance," Narayan says. "We don't have anything else like it." Other methods of gauging distance require astronomers to build a "distance ladder" from nearby objects out to remote ones, he notes—a process rife with uncertainty.

Astronomers have seen time delays in lensed quasars by monitoring peaks and valleys in their radio or optical emissions. However, it takes months or years for quasars to vary at those wavelengths, and the changes are subtle. Now, astronomers George Chartas of Pennsylvania State University, University Park, and Marshall Bautz of the Massachusetts Institute of Technology have overcome both of those hurdles by finding x-ray emissions from RXJ 0911.4+0551 that fluctuate dramatically in a few hours.

The team used the Chandra X-ray Observatory on 2 November 1999 to document a sharp, 40-minute flare in one of the quasar's four spots. Calculations suggest that if Chandra had focused on the quasar continuously for a half-day before that, the same flare would have brightened at least one of the other three spots. Chartas believes that longer observations of RXJ 0911.4+0551 and a dozen other tightly spaced quasar lenses will nail down their time delays to an accuracy of 1%. The team has won further time on Chandra and the European XMM-Newton x-ray satellite to pursue their flickering quarries.



X-ray specs. A satellite witnessed a flare in the second-brightest of four gravitational-lens images from quasar RXJ 0911.4+0551.

CREDIT: GEORGE CHARTAS *ET AL.*/PENNSYLVANIA STATE UNIVERSITY/CHANDRA X-RAY OBSERVATORY

Even if they can nail down the time delays to that accuracy, calculating the distance to the lensing galaxy would still involve a lot of uncertainty. Einstein's equations require a model for how mass is distributed in the intervening galaxy. That's a tough chore, says astronomer Wendy Freedman of the Carnegie Observatories in Pasadena, California. "Astrophysical lenses are messy," she observes, as clusters of galaxies and hidden clumps of dark matter can alter the light paths.

Indeed, Narayan notes that the extreme closeness of the lensed images in RXJ 0911.4+0551 suggests that some distortion in the lensing galaxy—or even a small satellite galaxy—induces the mirage. That departure from a smooth blob of mass "would seriously compromise the measurements, and you wouldn't even realize it," he says.

Still, both Narayan and Freedman welcome the technique as a check on estimates of the Hubble constant. Freedman leads a team that will soon publish a slightly revised value of 72 kilometers per second per megaparsec (which roughly translates to an age of 13 billion years for the universe). That figure, based on a distance-ladder approach with the Hubble Space Telescope, has a 10% margin of error, Freedman says. Chartas and his colleagues, she believes, will have to scrutinize x-ray flares from many quasar lenses to reach the same plateau. **–ROBERT IRION**