flies are spreading the disease, there's a chance they may also infect humans; in fact, that may already have happened, says NCSU's Breitschwerdt. Because a few foxhound cases occurred in the 1980s, "we probably uncovered a smoldering epidemic that has been in this country for 20 years or more," he says. Doctors could have easily missed a few scattered human cases of visceral leishmaniasis, whose symptoms include fever, malaise, and weight loss. But there is no reason to panic, says Killick-Kendrick. The *Leishmania infantum* strain isolated from the Millbrook dogs is the same one found throughout the Mediterranean; there, about 20% of all dogs are infected, yet human cases are rare, and an effective treatment exists. Most at risk are people with a weakened immune system. "From what I know from about the Mediterranean, the risk is very low indeed," says Killick-Kendrick. "I would be very upset if a scare erupted about this."

The route of transmission will also determine whether the disease can ever be wiped off the continent. If *Leishmania* is transmitted directly among foxhounds, it might be eradicated by simply culling all infected dogs. In fact, some hunt clubs have already started putting down their sick animals. But if sandflies are involved, they have likely already infected other dogs, foxes, or coyotes, making it impossible to stamp out *Leishmania*. "That's the fear," says Breitschwerdt. "If the disease has become endemic in the United States, then we can't eliminate it, and we'll have to live with it."

–MARTIN ENSERINK

MATHEMATICS

Taking the Measure of the Wildest Dance on Earth

By exploiting the symmetry of randomness, three mathematicians have revealed the geometric underpinnings of Brownian motion

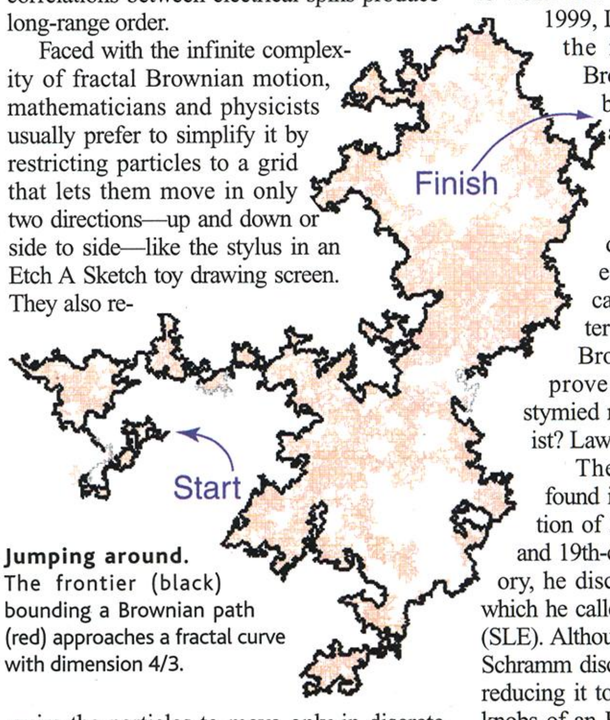
If you could watch an individual air molecule, you would see a dance that puts the wildest mosh pit to shame. Slamming into its neighbors, rebounding, ricocheting without letup, each humble particle traces out a path so jittery that nothing can tame it. The slowest slow-motion camera, the most powerful zoom lens, would only bring quicker and smaller lurches into view.

Now, a trio of American and French mathematicians has proved that the frenetic random dance called Brownian motion has geometric properties that can be calculated as exactly as the circumference of a circle. The methods they used to prove that counterintuitive notion seem likely to apply to other random processes, some as familiar as the flow of water through a filter. The proof, presented at the recent Current Developments in Mathematics 2000 conference* sponsored by Harvard University and the Massachusetts Institute of Technology, is drawing rave reviews. Says Yuval Peres, a mathematician at the University of California, Berkeley, "I feel their work is one of the finest achievements in probability theory in the last 20 years."

The proof by Gregory Lawler of Duke University, Oded Schramm of Microsoft Research, and Wendelin Werner of the Université de Paris–Sud describes the probability that two or more neighboring air molecules, trapped in a plane, will escape to a large distance apart without crossing one another's tracks. In theory, the molecules could travel in straight lines, avoiding collisions with other particles; in practice, however, it is infinitely more likely that they will get jostled into tangled fractal paths.

Whether those paths cross has little physical significance: "Particles in the real world aren't worrying about where they've been," Lawler notes, and they usually are not confined to a plane. But the numerical parameters that describe the likelihood of crossing, called intersection exponents, interest physicists intensely, as they model a variety of systems near a phase transition. In the study of magnetic materials, for example, similar "critical exponents" describe how short-range correlations between electrical spins produce long-range order.

Faced with the infinite complexity of fractal Brownian motion, mathematicians and physicists usually prefer to simplify it by restricting particles to a grid that lets them move in only two directions—up and down or side to side—like the stylus in an Etch A Sketch toy drawing screen. They also require the particles to move only in discrete steps. The finer the grid is, the more closely the Etch A Sketch squiggle resembles true Brownian motion.



Jumping around. The frontier (black) bounding a Brownian path (red) approaches a fractal curve with dimension 4/3.

Unfortunately, such simplified "finite-lattice models" have not led to a rigorous derivation of the long-sought intersection exponents. "[Brownian motion] problems have been studied to death on the lattice using combinatorial methods, and no exact solution is in sight," says John Cardy, a theoretical physicist at Oxford University. Lattice models also lack some crucial characteristics of true Brownian motion. For example, in the lattice version, a strong enough magnifying glass would reveal the underlying graininess of the motion. Real Brownian motion when magnified still looks like Brownian motion—even if the magnification varies from point to point, as in a funhouse mirror.

That extremely strong symmetry property, called "conformal invariance," may actually make the fractal Brownian paths easier to work with than their lattice imitations. In 1999, Lawler and Werner showed that the intersection exponents for Brownian motion are determined by its symmetry properties alone, regardless of what physical process produces the motion. Any other random, conformally invariant process that doesn't get distorted by edge effects (a condition called "locality") would have the same intersection exponents. Such a non-Brownian random process might prove a mathematical godsend to stymied researchers. But did it even exist? Lawler and Werner had no idea.

Then, independently, Schramm found it. Using an ingenious combination of 20th-century probability theory and 19th-century conformal mapping theory, he discovered a wholly new process, which he called stochastic Loewner evolution (SLE). Although SLE looks two-dimensional, Schramm discovered a mathematical trick for reducing it to one dimension—as if the two knobs of an Etch A Sketch toy were secretly controlled by a single master dial. That made the intersection exponents for SLE much simpler to compute. Werner, Lawler, and Schramm then showed that SLE was also conformally invariant and local, thus confirming that its exponents were the same as the expo-

* 17–18 November, Cambridge, Massachusetts.

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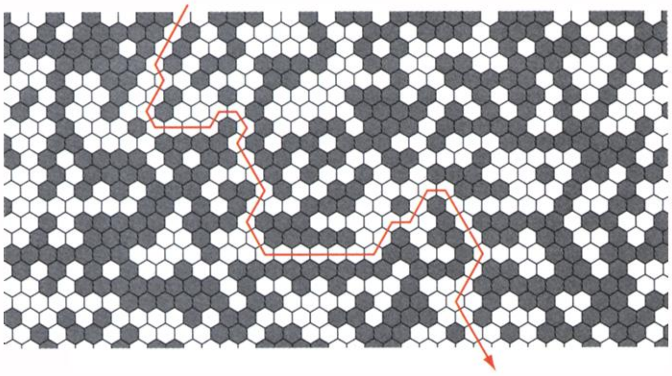

Leaking through. Percolation across a filter made of random barriers (gray) may be linked to Brownian motion.

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

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MEETING AAS HIGH-ENERGY ASTROPHYSICS DIVISION

X-rays Hit the Spot for Astrophysicists

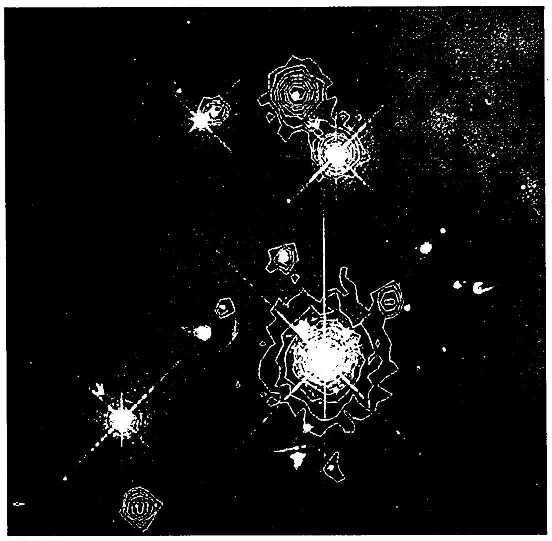
HONOLULU—About 500 astronomers flocked to Waikiki Beach from 6 to 10 November for a meeting of the American Astronomical Society's High-Energy Astrophysics Division. Looking splendid in their complimentary aloha shirts, speakers told tales of intense radiation from deep space, including x-rays from quasars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

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