turtles insisted on heading south. Lohmann was shocked by the turtles' "large shift in direction for only 3 degrees inclination angle." But then he realized that 60 degrees corresponded to the fork in the Gulf Stream off Portugal—an ideal site for natural selection of a magnetic inclination sense. "It is pretty easy to see how those mutants who tended to head south when they encountered a 60-degree inclination angle were much more likely to survive than those who

K. LOHMANN

Loggerhead on a leash. The apparatus helped researchers track turtles' behavior in magnetic fields.

didn't and ended up cold-shocked on the coast of Great Britain," says Lohmann.

According to Lohmann, the loggerhead migration picture now looks like this: Hatchlings emerge from their beachfront nests at night and head toward the bright light coming off the ocean, setting their magnetic compasses. Once in the water, they swim directly into the waves. Swimming into the waves keeps the youngsters heading away from the coast. When they hit the Gulf Stream, they ride the current, relying on their magnetic inclination compasses to tell them when to turn and head south for the Sargasso Sea. Then, in late adolescence, they find the magnetic inclination angle of the Florida beaches and ride it home.

Many marine biologists, such as Michael Salmon of Florida Atlantic University in Boca Raton, say Lohmann's scenario makes a persuasive case. But David Owens of Texas A&M University says the North Carolina scientist may have left out a major factor: smell. "I think [Lohmann's research] is great. These contraptions he has developed are elegantly simple, but I still happen to think that olfaction is important," says Owens. He suggests the two senses may work in tandem and that sniffing out location clues may allow the turtles to fill in details on their large-scale magnetic maps.

Further experiments may reveal whether smell indeed fits into this navigational scheme. When that work is done, says Lohmann, scientists may be able to trick turtles into nesting on specific beaches designated as protected sites, helping the endangered animals to survive. And that, he continues, would produce yet another sense—one of satisfaction.

–Lisa Seachrist

VOLCANOLOGY

Throttling Back the Great Lava Floods?

Floods in any form wreak havoc, but the kind of floods that struck 16 million years ago near the Columbia River were the stuff of nightmares. Great cracks opened in the Earth and erupted repeatedly, each time gushing a thousand cubic kilometers of lava or more, along with noxious gases that could have spread destruction over a broader area. The closest comparison in historical times, the 1783 Laki eruption in Iceland, unleashed a piddling 12 cubic kilometers over 5 months—but the exhalations of even that eruption were enough to devastate the island and throw a chilling pall over Europe.

Given the magnitude of the ancient lava floods, some scientists have suggested that these eruptions and even larger ones like those that produced the Deccan Traps of India 65 million years ago might have triggered, or at least contributed to, major extinctions, including the disappearance of the dinosaurs. But if volcanologist Stephen Self of the University of Hawaii is right, these eruptions now look a shade less catastrophic.

Specialists in flood basalts, the remnants of these flows, had assumed that each eruption, which formed a layer of lava tens of meters thick and hundreds of kilometers long, took place in a matter of days. But Self and his colleagues see signs that flood basalts "erupted more slowly," he says. Rather than days, "it has to be longer than a few weeks"—more likely a year, even several years. A slower pace would have prolonged the environmental insult from noxious gases, but also given natural cleanup processes such as rainfall a better chance to limit the damage.

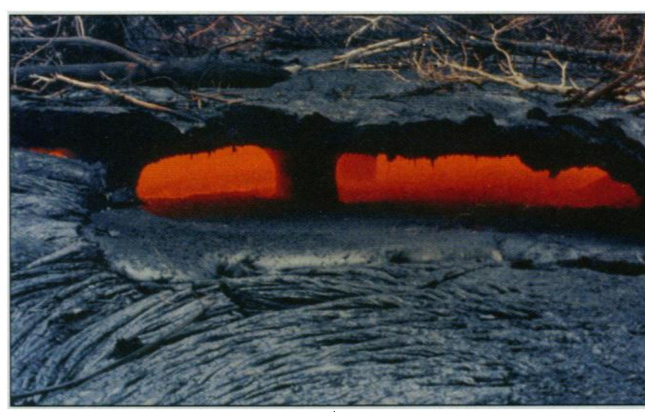
Volcanologists had settled on a sudden torrent of lava because they could see no way for that lava to remain hot and liquid for long enough to flow slowly across hundreds of kilometers. Some slow-moving lavas from present-day volcanoes do manage to stay hot over relatively great distances; in the lavas known as pahoehoe, for example, the outer skin of a flow solidifies, forming an insulating tube that pipes hot, fluid lava great distances. But geologists could find few signs of lava tubes in the Columbia River basalts, leaving them to assume that the eruptions gushed lava so fast it tumbled hundreds of kilometers before freezing.

But Self and his students think they have found clues that mark the Columbia River flood basalts as slow-moving pahoehoe after all. Among them are "spiracles"—partially filled vertical tubes. Other researchers had explained spiracles as the result of steam blasting up through the lava as it flowed over swampy ground. But recent observations on Kilauea suggest that similar structures might form in pahoehoe.

The process that might be responsible was recently documented by Ken Hon of the U.S. Geological Survey (USGS) in Denver and his colleagues. An advancing sheet of lava a few tens of centimeters thick stalls as its crust thickens, but magma continues to push under the crust, lifting it and inflating the flow to a thickness of from 1 to 5 meters. George Walker of the University of Hawaii went on to suggest that when two abutting lobes of pahoehoe lava inflate, fingers of lava are injected into the growing suture between the lobes, forming spiracle-like columns.

Self and his colleagues think the same suturing process operated in the Columbia River flows—along with the tube formation that allows pahoehoe to flow long distances. The tubes, they say, are hard to see because on the gentle slope of the plateau the broad, thin tubes probably never drained, so that little was left to mark their presence.

Spacecraft imagery may lend support to this idea, as planetary scientists Jeffrey Taylor and Barbara Bruno of the University of Hawaii, along with Self, reported last month at the Lunar and Planetary Science Conference in Houston. This group had already shown that the margins of pahoehoe flows are more convoluted than those of faster moving flows. That test can't be applied to terrestrial flood basalts, because erosion and vegetation have erased their edges. So Taylor, Bruno, and Self looked at 15 flows of equivalent size on Venus, Mars, and the moon. All but two of the huge lava flows, they reported, bear the telltale wiggly mar-



K. HON

Flow inflation. When this Hawaiian lava forms a crust, underlying fluid lava can inflate a flow to many times its original thickness.

gins, suggesting they too flowed slowly.

Stephen Reidel of the Westinghouse Corp. in Richland, Washington, isn't buying Self's geologic arguments by analogy. "I've looked at [the Columbia] flows for 20 years. They're nothing like what we see in Hawaii." He agrees that the older estimates of a few days may be too short to get that much lava out of the ground. "Months seem fine to me," he says, "but a year is probably pushing it." But Donald Swanson of the USGS at the University of Washington, who coauthored the original estimate of days rather than months, isn't ruling out Self's pahoehoe scenario—or any other, for that matter. "I'm [now] at a loss to explain how the flows were emplaced," he confesses.

If Self turns out to be right, flood basalt eruptions would look less promising as a trigger for extinctions, according to climate modeler Starley Thompson of the National Center for Atmospheric Research in Boulder, Colorado. Volcanic debris would be more likely to get washed out by rain before it built up to a high concentration. And without the intense heat of a rapid eruption, says Thompson, sulfuric acid aerosols would be less likely to reach the stratosphere, where they can spread globally and linger for years, blocking sunlight and cooling the climate. Self still sees plenty of destructive potential in these ancient floods, but to know just how devastating they might have been, volcanologists will have to decide how fast is fast.

–Richard A. Kerr

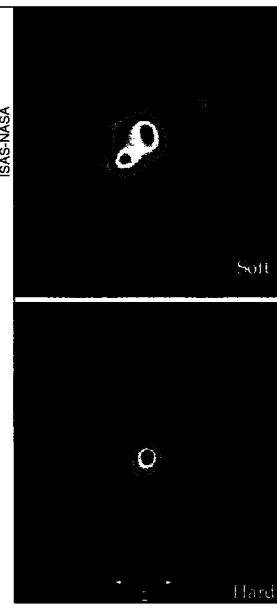
ASTRONOMY

X-rays Make a Smooth Move

The night sky, seemingly serene, is abuzz with signals from our cosmic neighborhood: light, radio waves, and other radiation from stars and gas within our galaxy. This cosmic buzz tends to drown out whispers from the wider universe, but two messages do make it through. One, the cosmic microwave background, is well understood as the afterglow of the Big Bang. The other, a uniform haze of x-rays visible only from space, has been a mystery since its discovery 30 years ago. Pervasive hot gas, supernovae, quasars, and other exotic objects have all been fingered as possible sources, but a new x-ray satellite is now hinting at a more mundane but nonetheless startling candidate: countless galaxies much like our own.

The new candidate made its debut last week in Crystal City, Virginia. There, at the joint meeting of the American Physical Society and the American Association of Physics Teachers, investigators from the joint Japanese-U.S. x-ray satellite ASCA, launched in February of last year, unveiled some early results. ASCA's unprecedented combination of high resolution and sensitivity has enabled researchers to search for graininess in the x-ray background—a hint of the number and brightness of the x-ray sources that compose it. What they've found is an unexpectedly smooth texture. And if ASCA investigator Hajime Inoue of the Institute of Space and Astronautical Science in Japan is correct (not everyone thinks he is), the smoothness implies that the background includes a multitude of weak sources, which might take the form of garden-variety galaxies much like the Milky Way.

The smoothness ASCA has discovered might have come as no surprise a few years ago, when many astronomers thought the x-ray background emanated from a uniform fog of hot gas that was thought to pervade the universe. But that idea was dropped in the early 1990s, when precise measurements of that other universal presence, the cosmic background radiation, showed no signs that the radiation had interacted with any pervasive gas. After the fog vanished, many investigators embraced a new x-ray source: active galaxies and quasars—bright radiation sources that may be powered by massive black holes. To the blurry eyes of most x-ray telescopes, hordes of these sources scattered around the sky would look like a uniform glow.



ISAS-NASA

The normal heart? In the galaxy M106, hard (high-energy) x-rays reveal a central source.

As x-ray eyes get sharper, however, these point sources should start to pop out; indeed, some already have. ASCA, for example, was able to pick out enough active galaxies to account for about a third of the background. In search of clues to the nature of the remaining sources, Inoue's group compared the brightness of small patches of background. If each patch were made up of a few bright sources just below the detection limit, chance variations in the number of sources per patch should lead to large brightness differences; larger numbers of weaker sources should yield smaller differences.

In fact, the observed differences were minuscule, says Inoue, implying that the x-ray background is composed of swarms of very weak sources—at least 10 of them per square arc minute of sky. Those faint sources aren't likely to be active galaxies, because there simply aren't enough of them in the universe, says ASCA investigator Robert Petre of NASA's Goddard Space Flight Center. "You need far more sources than there are active galaxies. You fall at least an order of magnitude shy," he notes. Inoue and his colleagues think ordinary galaxies in the distant universe—far more common than their powerful active cousins—could do the job.

It will take more than sheer numbers, however, for ordinary galaxies to fit into this picture. To account for the background, they would also need to act as x-ray beacons, like active galaxies in miniature—and ASCA has produced some of the first evidence that they can. Turning its x-ray eyes on a handful of nearby galaxies, the satellite found that their centers glowed brightly, emitting a spectrum of x-rays resembling that of the background.

Astronomers can only speculate about what's powering this emission. One possibility, says Inoue, is that many ordinary galaxies have a black-hole engine like those of active galaxies—but it's somehow throttled back. If so, says Peter Serlemitsos of Goddard, who directed the galaxy observations, "the contribution [of these galaxies] to the background can't be insignificant."

But some advocates of active galaxies are standing their ground. Goddard's Elihu Boldt is impressed with the observations of normal galaxies, but he's not convinced that they are a major component of the background. He and his colleagues Takamitsu Miyaji of the University of Maryland, Ofer Lahav of the Institute for Astronomy in Cambridge, England, and Keith Jahoda of Goddard recently analyzed data from an earlier x-ray satellite to tease out a measure of the x-ray emissions from nearby objects. They compared that result with the emissions expected from nearby active galaxies and found a rough match, Boldt says. That implies, he says, that based on the nearby universe, "there's no glaring need for an additional population of sources." But he notes that if the ASCA result on the smoothness of the background does hold up, some other kind of fine-grained sources might be lurking in the far reaches of the universe.

Serlemitsos cautions that the evidence of smoothness "should be considered preliminary" because the ASCA researchers have not ruled out the possibility that it is some kind of artifact. But if the background keeps on looking this smooth, the buzz in the astronomy community may soon be about the extraordinary features of ordinary galaxies.

–Tim Appenzeller