cuttings; the mud inevitably carries bacteria. Lasers and other high-temperature methods automatically sterilize the walls of the holes they make; small exploratory side passages could then be made to pick up biological samples, says microbiologist Thomas Phelps of Oak Ridge National Laboratory in Tennessee.

New digging methods such as a semi-robotic thermal spallation device may also allow deeper mines with less risk to people—although working conditions won't be pleasant. The deepest mine in the world is the 3777-meter Western Deeps gold mine outside Johannesburg, South Africa, where the rock reaches 60°C; the only thing keeping the miners from cooking is cold air pumped from the surface. The veins may continue to 7 kilometers, but to keep expanding downward, companies must deal with daily earthquakes and high-pressure outbursts of rock. "We feel we can get further," says Ray Durrheim, head of deep-mining programs at the South African Council for Scientific and Industrial Research in Johannesburg. "Rock is rock. Further down is more of the same, just hotter and hotter." **–KEVIN KRAJICK**

New York journalist Kevin Krajick is writing a book about diamond prospectors.

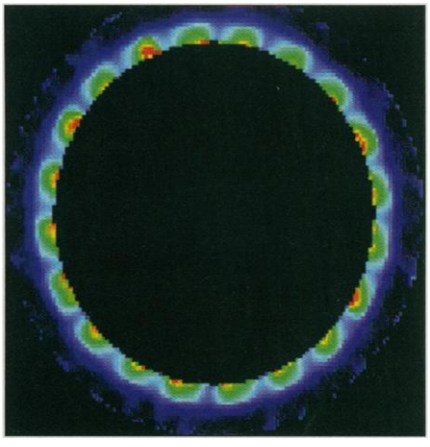
ASTRONOMY

Pulsar Weather Map Shows Storms on a Strange World

Flickers in the radio beam from a spinning neutron star may reveal a procession of compact, energetic storms marching around its polar cap

Two radio astronomers, peering at the polar cap of a dead star 3000 light-years away, have put to shame the weather report graphics that show cold fronts and low-pressure zones rambling across the earthly continents. The spinning, collapsed star, called a pulsar, could easily fit within the city limits of Chicago, and the astronomers may have mapped as many as 20 individual "microstorms"—each probably an explosive hail of gamma rays and subatomic particles—circulating around a region of the cap that is no more than 400 meters across. The storms appear as transient, drifting flashes within the beam of radio waves that emanates from the pulsar's cap.

Astronomers had puzzled over the flashes before. Now, by observing a pulsar with an especially regular sequence of them, Joanna Rankin of the University of Vermont, Burlington, and Avinash A. Deshpande of the Raman Research Institute in Bangalore, India, may have traced them back to features near the stellar surface—like keen listeners deducing the pattern of holes on a player-piano roll from the tune it plays. "This is the first time that any analysis of [the subpulses] has been possible to such remarkable accuracy," says Raman Institute astronomer V. Radhakrishnan. And some astronomers think the work, presented at an American Astronomical Society meeting in Austin, Texas, last month, holds a clue to precisely how and where pulsars generate their intense radio beams in the first place.



CREDITS: JOANNA RANKIN AND AVINASH A. DESHPANDE

Maelstrom. In this computer model, hot spots of radio emission form a ring that may be less than 400 meters across around the polar cap of a pulsar.

The spinning object at the heart of a pulsar is believed to be a neutron star, a superdense ball of matter left behind after an ordinary star explodes as a supernova. As gravitational forces crush the neutron star to roughly 20 kilometers across, its magnetic field gets compressed and amplified as well, becoming more than a trillion times as intense as Earth's.

The fields sprout like cowlicks from each cap, and as they are whipped around by the rapid spin, they act like the whirling dynamos in a terrestrial power station, creating electric fields that accelerate electrons, positrons, and other charged particles. Accelerated charges radiate, and somehow they act in concert to generate "lighthouse beams" of radiation. Because the caps are offset from the spin axis, the beams rotate through space like a lighthouse warning distant ships of a reef, and astronomers pick up blips of radio waves if a beam's orientation allows it to sweep past Earth.

That much seems clear, but not much more. "Pulsars have been around for a long time," says Jonathan Arons, a theorist at the University of California, Berkeley, "so people assume the problem must be solved." But theorists have struggled to explain the great intensity of the beams and debated whether they originate close to the surface or thousands of kilometers up, where the magnetic fields are whipping around at nearly the speed of light. And they have had even less success in explaining the subpulses that dance, drift, and disappear within the clocklike blips of the main radio emission.

Fitful signal. Intensity spikes in the pulses (rows) hold clues to the structure of the radio-emitting region.

One problem was the fickle nature of the subpulses, says Rankin. But she and Deshpande focused on a pulsar in the constellation Leo whose subpulse behavior, while complicated, was regular and reproducible. It was as if a dancer was going through the steps of a complicated waltz, then repeating them over and over. The team mapped this choreography in vivid detail with the 305-meter-diameter radio dish in Arecibo, Puerto Rico, then analyzed the results.

Rankin and Deshpande found that the data pointed to a train of radio-emitting hot spots, which were marching around the outside of the polar cap. The pulsar they chose, which spins on its axis once every 1.1 seconds, was ideal for analyzing such behavior, says Rankin, because its lighthouse beam just grazes Earth. Thus, each time the beam sweeps past, Arecibo observes a different slice through the slowly circulating train, allowing the full pattern to be mapped.

The map showed that a sequence of 20 hot spots, circulating about once every 37 seconds, remains stable for minutes at a time, then jumps to a pattern with just two spots (see www.uvm.edu/~jmrankin). "They've seen a pattern that they can follow all the way around," says Alice Harding, a theorist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Rankin and Deshpande think they are seeing an effect first predicted by Malvin Ruderman of Columbia University and Peter Sutherland of McMaster University. In their theory, the electric fields generated by a pulsar's spin

are strong enough to cause "sparks" near the surface, like breakdowns above an ordinary electrode. Charged particles generated in these electrical storms could stream up the magnetic field lines and eventually act as a kind of antenna to send out the radio waves that are observed as the subpulses. Meanwhile, according to some well-known physics of charged particles in electric and magnetic fields, the microstorms—each about 100 meters high—would drift around the polar cap.

That picture has implications for the source of the main beam, says Harding: It suggests that the underlying physics could be similar and, she says, "argues for radio emission near the surface of the star." Ruderman, however, isn't convinced that the new work says anything about the main beam. "I personally don't see how it reflects directly on the mechanism for radio emission," he says. And among other criticisms, Arons argues that even the source of the radio hot spots may not lurk right at the stellar surface. The action could be taking place anywhere along the line of sight, he says.

Rankin replies that Ruderman and Sutherland's picture of electrical storms near the surface is the only reasonably complete explanation for the hot spots at the moment. "It would be absurd not to map these emission centers back onto the surface," she says. But she concedes that the real test will come in studies of the "weather maps" on other pulsars. Astronomers will be watching as closely as picnickers glued to their TV sets during a bad-weather weekend. —JAMES GLANZ

GERMANY

New Minister on a Mission to Modernize

Three months into her new job, Germany's research and education minister is stirring up the system, while promising not to go too Green

BONN—When Germany's new Social Democrat–led government swept into power last fall, after 16 years of rule by the conservative Christian Democrats, the nation's scientists greeted the change with mixed emotions. The new government, elected on a tide of high expectations, formed a coalition with the eco-friendly Green Party, and some scientists fretted that the Greens would be put in charge of the research and education ministry. After a few weeks of nail biting, however, they breathed a sigh of relief when the job went to Edelgard Bulmahn, the Social Democrat's parliamentary "shadow minister" for science and education. But that doesn't mean that the research community is in for a smooth ride.

In a wide-ranging interview with *Science* last week, Bulmahn made it clear that she intends to shake up the research system, with a long list of goals that include loosening bureaucratic restraints on German research institutes, modernizing the university system, bolstering programs to promote women and independent young scientists, and more closely linking research efforts at universities and independent research institutes. "We now have a research system that is supported by separate columns: Max Planck Society basic research institutes, applied research institutes, university research, and national research centers," Bulmahn says. "We must significantly strengthen the connections among these different research organizations."

Bulmahn has also inherited some thorny political problems from her predecessor, Jürgen Rüttgers, and some controversial policies of her new government are creating still more. The Social Democrats and their Green coalition partners have pledged to phase out nuclear power in Germany, prompting fierce debate over the future of the nuclear industry and nuclear research. A recent revival of militant animal-rights activism in Germany has led to demands for stricter laws in that area, while activists have threatened some prominent researchers. And federal and state officials continue to struggle over how to restructure the nation's troubled system of higher education and how to improve research.

"The number of women in leading scientific positions in Germany is too low."

—Edelgard Bulmahn

Bulmahn, who studied political science at the University of Hannover and then rose through Germany's political landscape, has so far drawn qualified praise from the research community. Although many scientists are wary of some positions being taken by the new government, she is given credit by research and university leaders for moving quickly to tackle some difficult problems. "She has the courage to try to modernize an old-fashioned system," says Klaus Landfried, president of the HRK, the conference of university rectors and presidents.

One reason for nervousness in Germany's laboratories is concern over how far the government will lean toward Green Party policies. Bulmahn has sought to reassure the scientific community that the Greens' presence will not lead to a sea change in research policy in fields such as biotechnology and nuclear fusion. "I don't foresee any fundamental change" in policy on gene technology, she says. "This government believes that biotechnology is a key technology for Germany." However, Bulmahn says the government feels that more research is needed into "the long-term impact of genetically modified plants and microorganisms on the environment." On the animal-rights issue, Bulmahn notes that "we already have strict laws about the treatment of animals in research," and says she does not support an effort by activists to amend the German constitution to guarantee animal rights.

The new government's stance on nuclear power is also causing jitters. Although the research ministry no longer has jurisdiction over applied research in nuclear energy and other energy sources, it remains responsible for federal policy on research reactors, including the controversial FRM-II neutron source in Munich (see sidebar), and for those facilities—mainly national research centers and Max Planck institutes—that carry out fusion research. Bulmahn says that, at present, she does not foresee any major change in Germany's support for the fusion research programs, in part because it is largely coordinated and partly funded by the European Union's Euratom program. "The budget for the new European research program already has been decided," she says.

That's reassuring to researchers such as Klaus Pinkau, director of the Max Planck Institute for Plasma Physics, who helps coordinate Germany's fusion research program.

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