SPACE PHYSICS

Finally Getting the Big Picture Of Earth's Magnetosphere?

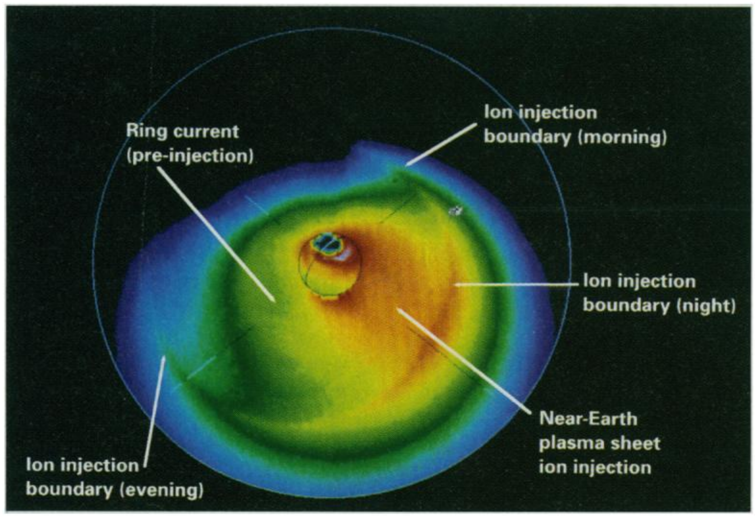
Imagine trying to understand the atmosphere and predict weather without a network of weather stations, radars, and satellites—nothing, in fact, but three or four airplanes, cruising the globe and recording whatever weather they happened to fly through. That's roughly the plight of space physicists, who must make sense of Earth's vast, teardrop-shaped magnetosphere from point measurements made by three or four satellites at best. No wonder their efforts to figure out the overall workings of this region of charged particles trapped by Earth's magnetic field and predict its "weather" have fallen short. At last month's meeting of the American Geophysical Union in Baltimore, however, several researchers held out hopes of finally getting the big picture.

These space physicists are planning the equivalent of high-flying weather satellites that could take in much of the magnetosphere in a single image. "What we have in prospect," says Thomas Armstrong of the University of Kansas, "is something that will let us have a picture for the nightly weather report." By detecting hitherto unrecorded signals—radiation or atoms from deep within the magnetosphere—instruments aboard these probes should be able to record the overall structure of the magnetosphere near Earth and how it reacts as it is buffeted by the wind of charged particles streaming from the sun. Such images could, in turn, lead to better predictions not only of magnetospheric weather but also of its disruptive effects on radio communications, electrical power networks, and satellites.

The challenge facing all these schemes is that most magnetospheric particles give off no signals for a distant sensor to detect. One approach presented at the meeting, energetic neutral atom (ENA) imaging, gets around that problem by relying not on electromagnetic waves but on particles: protons and heavier singly-charged ions neutralized when they pick up electrons from hydrogen atoms escaping from the top of the atmosphere. In the mid-1980s, Edmond Roelof of the Applied Physics Laboratory in Laurel, Maryland, realized that these newly neutralized particles would shoot off into space. Capture this atomic "glow" with an ENA "camera," and much of the inner magnetosphere becomes visible—as Roelof showed a decade ago using serendipitous ENA detections made by the ISEE spacecraft.

But that initial demonstration didn't mean ENA imaging was ready to go. The method had to clear a couple of hurdles, one of which was demonstrating its practicality. The other hurdle was finding a way to infer the three-dimensional structure of the magnetosphere from a two-dimensional image—a problem Roelof thinks he can solve by comparing images with 3D simulations and varying the simulations until they match.

Roelof is still working to convince some of his colleagues, he says, but he has inspired enough confidence that one group—Rickart Lundin and his colleagues at the Swedish Institute of Space Physics—is piggybacking an ENA detector on a low-orbiting Russian satellite. The satellite, to be launched by early next year, should be able to image parts of the magnetosphere from below. A fuller test, however, may come on a mission that is now under study, the Magnetospheric Imager spacecraft.



Picture this. A simulated image of the inner magnetosphere illustrates the features that might be revealed by neutral atoms striking a spacecraft imager.

A working group headed by Armstrong (and including Roelof) is recommending that this high-flying craft, which could be launched by 2000, carry both high- and low-energy ENA instruments. From its high orbit, it should be able to monitor the response of several parts of the inner magnetosphere to powerful solar wind disturbances. Such disturbances tend to pump particles into the so-called ring current, made up of high-energy particles that encircle Earth and feed into both the aurora and ground-level magnetic disturbances. Early in the next century the ENA imaging concept will get a third test when the planned Cassini spacecraft arrives at Saturn, carrying an ENA detector to image that planet's large, complex magnetosphere.

As promising as ENA imaging may be, it leaves much of the inner magnetosphere out of the picture. For example, the ions that escape from Earth's upper atmosphere into the plasmasphere (the relatively low-energy region of plasma that rotates along with Earth between the ring current and the upper atmosphere) are usually not energetic enough to produce detectable ENAs. So as a complement to ENA imaging, the Magnetospheric Imager working group proposes capturing the extreme-ultraviolet glow given off by singly-charged helium ions in the plasmasphere as they absorb and re-emit sunlight. Such an instrument aboard the Magnetospheric Imager should reveal how the plasmasphere swells with charged particles during a magnetospheric disturbance.

But even that complement of instruments won't provide a complete view of the magnetosphere, which extends into space for a distance of tens of Earth radii and has a long, comet-like tail flapping in the solar wind. To get a broader view and to sharpen the ENA images, Patricia Reiff of Rice University in Houston and her colleagues explained at the meeting, an imaging technique would have to light up the magnetosphere artificially, with radio waves. Reiff's group proposed an imaging experiment that would broadcast radio waves into the magnetosphere; by picking up radio echoes, the instrument could discern the magnetosphere's large-scale internal boundaries and outer skin. This technique—a form of radar—has already been used to probe the ionized part of the upper atmosphere from the ground and from low orbit, but studying the more tenuous magnetosphere requires lower radio frequencies, and their echoes are harder to analyze. Newly available signal processing techniques, Reiff thinks, should bring this grand-scale radar within reach, although so far no plans have been laid to test it.

When all these sensors do fly, space physicists may finally be able to compete with their colleagues who probe Earth's atmosphere. There would still be no alternative to riding out heavy magnetospheric weather, but at least the physicists could warn when it's on its way.

–Richard A. Kerr