SPACE PHYSICS

Getting in Touch With the Edge of the Solar System

Where does the solar system end? A planetary geologist might draw the line at the farthest point of Pluto's orbit, 50 times Earth's distance from the sun, or 50 astronomical units (AU). But a space physicist would go farther out, much farther, to where the vanishingly thin ionized gas blown off the sun—the solar wind—runs head-on into another wind, the similarly tenuous interstellar gases through which the solar system is traveling. Exactly where these winds collide has long been debated, with guesses ranging as far out as 1000 AU. Now a pair of spacecraft, venturing out of the solar system after exploring the outer planets, has picked up a hint.

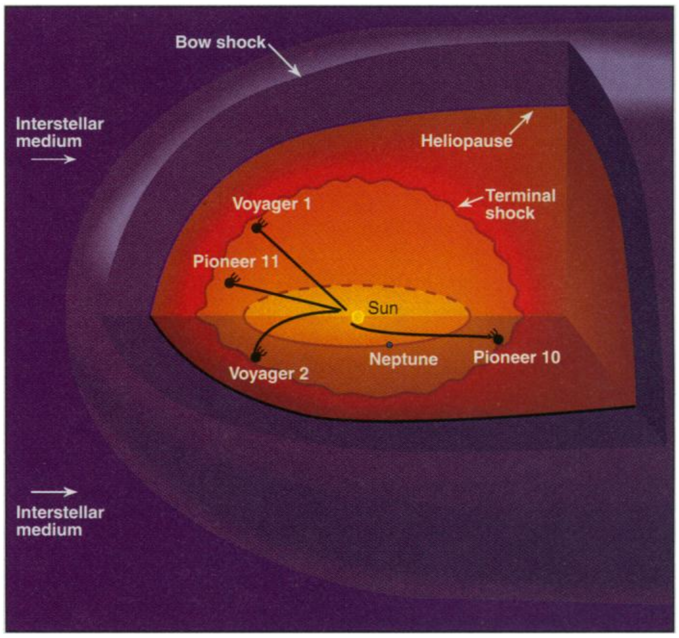
What the two Voyager spacecraft, now more than 50 AU out from the sun, have heard is the sound of that distant collision: a powerful radio signal apparently unleashed when a "gust" in the solar wind slammed into the boundary. The timing of the signal—about a year after the gust left the sun—points toward a solar system boundary somewhere around 120 AU, according to reports at the spring meeting of the American Geophysical Union (AGU) held in Baltimore late last month. If either of the Voyagers or the two Pioneer spacecraft also bound for interstellar space should survive for several decades more, they just might pass through the boundary, known as the heliopause, and for the first time directly probe the material between the stars.

The first hints of news from the edge of the solar system started turning up in data from the Voyagers last July: a very-low-frequency hiss—down in the 2- to 3-kilohertz range that falls below even the low frequencies used on Earth for submarine communications. The radio signal vanished below a sharp cutoff at 1.8 kilohertz, and its upper reaches rose in pitch with time. The intensity of the hiss peaked in December and is now slowly declining.

At first, some Voyager team members thought the hiss might be coming from Jupiter, a powerful natural radio beacon. But space physicist and Voyager team member Donald Gurnett of the University of Iowa and his colleagues now argue that there is no way Jupiter's emissions could be as strong as this signal, given the distance from Jupiter to the spacecraft. And because the two Voyagers, though widely separated, detected the signal at roughly the same strength, Gurnett calculated that the source had to be generating more than 10 trillion watts, dwarfing Jupiter's emissions of 6 billion watts.

Examining earlier data on the behavior of the solar wind, Gurnett and his colleagues realized that there was another possibility. The radio noise might be coming from the leading edge of the heliopause—the side where it bears the brunt of the oncoming interstellar medium, which piles up like snow in front of a plow. The researchers noted that in late May and early June of 1991, solar physicists had detected a sudden burst of activity at the sun, which launched a high-speed stream of electrons, protons, and other charged particles—in effect, a gust in the solar wind. By September the surge of ionized gas, or plasma, and its accompanying shock wave had swept past the Voyagers at speeds of 600 to 800 kilometers per second on the way toward the heliopause. Three months later and 1.1 years after the original solar activity, the Voyagers began hearing a din from the direction of the heliopause.

The noise, Gurnett argues, bears all the hallmarks of a run-in between a shock wave in the solar wind and the heliopause. Crashing into the cold interstellar material piled up at the leading edge, says Gurnett, the shock wave would set electrons just beyond the heliopause oscillating, as they do in a radio antenna, generating radio waves with the sharp lower cutoff and rising pitch seen in the spacecraft data.



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An uncertain goal. A decade or more will pass before a spacecraft reaches the end of the sun's sphere of influence, the heliopause.

When Gurnett returned to his office after the AGU meeting, he and his Iowa colleague James Van Allen dug up additional support for the scenario. They found that a major burst of solar activity had preceded the only other significant radio emission the craft had detected, in 1983 and 1984. Space physicist Ralph McNutt of John Hopkins University's Applied Physics Laboratory in Laurel, Maryland, had suggested in 1988 that solar activity had triggered the radio signal. Gurnett thinks the heliopause must have been the link: In this earlier case, too, the lag between the solar activity and the onset of the radio emission was just over a year.

Assuming that gusts of solar wind do trigger these radio signals and that the heliopause is their source, researchers can calculate the distance of that boundary. It's something like hurling a rock at a distant wall and waiting for the sound of the impact. If you know the average speed of the rock (the high-speed solar plasma, in this case), the speed of sound (the radio signal), and the elapsed time, you can calculate the distance to the wall (the heliopause).

Using this time-of-flight approach, Gurnett estimates that the heliopause lies no more than 126 to 169 AU from the sun. That range is an upper limit, he notes, because the outward-bound solar wind slows well before the heliopause as it starts to encounter back pressure. McNutt prefers a slower solar wind speed overall, which implies a closer heliopause—80 to 130 AU, in his estimate.

Exactly where the heliopause lies may determine whether any working spacecraft will ever penetrate it and sail free into the interstellar wind. All four spacecraft leaving the solar system were launched during the 1970s, and they are slowly dying as their radioactivity-driven electrical generators wind down. Pioneer 11 will fade away within the next couple of years, and Pioneer 10 will follow by the end of the decade. The Voyagers are better off. Barring mechanical failures, says mission director Dick Rudd of the Jet Propulsion Laboratory, they should last until 2015 or 2020. Now at 52 AU, Voyager 1 would be at 148 AU by 2020. Voyager 2 would make it to 123 AU. "If the heliopause is inside 150 AU," as Gurnett and McNutt believe, says Rudd, "we stand a pretty good chance of getting there with Voyager 1."

–Richard A. Kerr