A Place for the Sun

Exploring the solar neighborhood

By RON COWEN

If a director were making a movie about the sun's neighborhood, the first scene might be a close-up of the outer solar system. Here, the wind of charged particles blowing out from the sun runs head-on into the gas left over from the formation of nearby stars.

A longer shot would reveal that the solar system and its environs resides inside a cloud of warm gas nicknamed the Local Fluff.

An extreme wide-angle shot would show that the Local Fluff lies within a network of overlapping bubbles. One of these, the barrel-shaped Local Bubble, extends up to about 300 light-years from the sun and supplies the interstellar ions that flow toward it.

The whole kit and caboodle—sun, Local Fluff, and Local Bubble—nestles between two of the Milky Way's star-forming spiral arms in a low-density, relatively inactive part of the galaxy.

By mapping the distribution of interstellar material in and around the Local Bubble, investigators are shedding light on each of these scenes of the solar neighborhood. One team of astronomers has found new evidence of a wall of hydrogen surrounding the solar system. These researchers have also mapped the distribution of gas within the Local Fluff. Another group has measured the extent and temperature distribution of the low-density gas that fills the Local Bubble.

Ultimately, astronomers may have the tools to document how interstellar gas and dust feed into the solar system and affect Earth's climate, says the University of Chicago's Priscilla C. Frisch, who has studied the solar system's environs for more than 20 years. Exploring the sun's surroundings, she adds, may also give researchers some idea of what to expect as they accelerate the search for planets in the neighborhood of nearby stars.

The first scene of the imaginary movie might focus on the hydrogen wall, a region about 100 astronomical units from the sun (100 times the distance between the sun and Earth), where the solar wind peters out and the interstellar gas begins. Jeffrey L. Linsky and Brian A. Wood of the University of Colorado at Boulder and their colleagues accidentally encountered this wall in 1994 while using the Hubble Space Telescope to observe Alpha Centauri, one of the stars nearest the sun. By measuring the absorption of ultraviolet light emitted by the star, the researchers hoped to deduce the density and temperature of the hydrogen gas between it and Earth.

Linsky and Wood found evidence that two components of the interstellar medium, rather than just one, were absorbing the light. Moreover, one was moving considerably faster toward Earth than the other.

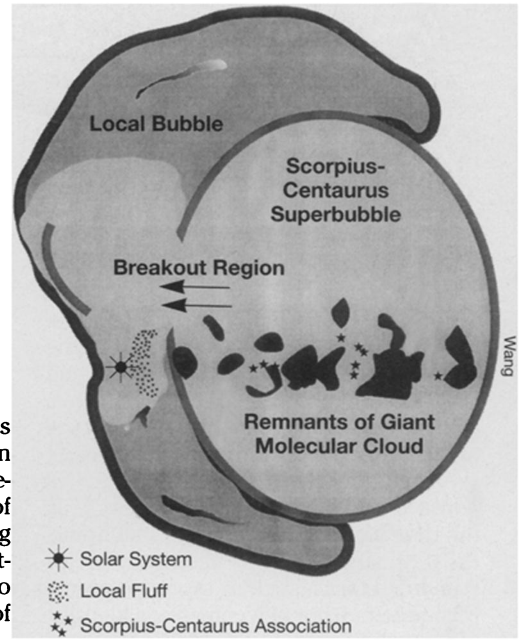
Linsky presented this perplexing finding at a meeting last summer. At the meeting, Frisch and Gary Zank of the Bartol Research Institute in Newark, Del., pointed out a likely explanation. The absorption recorded by Hubble had revealed the presence not only of swiftly moving interstellar hydrogen gas near the star but also of slower-moving hydrogen gas at the edge of the solar system.

Compressed and heated by the solar wind, protons and other charged particles in the interstellar medium slow down as they enter the heliopause, the horseshoe-shaped region that marks the boundary between the solar system and the rest of the universe. Neutral hydrogen should pass by without delay. However, protons from the interstellar gas capture the lone electrons from many of the hydrogen atoms. The addition of an electron to a slow-moving proton creates a slow-moving hydrogen atom. These atoms are detected by Hubble.

Intriguingly, notes Frisch, the hydrogen atoms observed at the heliopause, along with other atoms, molecules, and ions—all refugees from interstellar space—invade the solar system and dominate much of interplanetary space. The solar wind, which blows more strongly near Earth than at the heliopause, keeps most of these intruders from impinging on Earth's atmosphere.

Linsky and Wood presented a complete analysis of their findings in January at a meeting of the American Astronomical Society in San Antonio. They also detail the work in an article scheduled for the May 20 Astrophysical Journal.

Researchers had previously inferred the presence of a hydrogen wall around the sun. Now, "the Alpha Centauri data confirm [its] existence," says Wood.



The solar system lies at the edge of a cloud called the Local Fluff. The entire region resides within a huge cavity of gas known as the Local Bubble. Some astronomers believe that hot gas from an adjacent cavity, the Scorpius-Centaurus superbubble, broke out into the Local Bubble a few million years ago and raised the temperature of the sun's neighborhood. Winds and supernova explosions generated by the Scorpius-Centaurus Association of stars created the Scorpius-Centaurus superbubble.

Beyond that wall lies the Local Fluff, the setting for the next cinematic scene.

More than a decade ago, researchers deduced that the solar system lies inside this moving cloud of warm gas, which extends in most directions for about 10 light-years.

Two years ago, Frisch reported evidence that the sun entered the Local Fluff a few thousand years ago and lies just inside that cloud (SN: 9/3/94, p. 148).

Recently, Linsky, Wood, and Nikolai Piskounov of the University of Colorado combined ultraviolet observations taken by Hubble and the Extreme Ultraviolet Explorer spacecraft to construct a new, three-dimensional map of the Local Fluff. By analyzing the amount of atomic hydrogen gas along the lines of sight between Earth and each of 18 stars, they also explored the region tens of light-years beyond the cloud.

Linsky and his colleagues found evidence that the Local Fluff is elongated along the plane of our galaxy and that our solar system lies close to the edge of the cloud. The absorption spectra of the starlight suggest that a network of clouds lies just beyond the Local Fluff, within 35 light-years of the solar system.

Using the wide-angle lens, the movie's third scene reveals the landscape of the Local Bubble, the giant cavity that encloses the solar system and its surroundings. A new study may help elucidate the origin of a high-temperature region nested within it. To examine this region, Q. Daniel Wang of Northwestern University in Evanston, Ill., analyzed X-ray emissions recorded by the ROSAT satellite.

Fierce stellar winds from a rash of massive newborn stars, combined with the blast from supernova explosions, may have created a smaller cavity that abuts the Local Bubble. Gas from this cavity, known as a superbubble, could have heated the solar neighborhood. Frisch has proposed that violent outbursts from a group of stars called the Scorpius-Centaurus Association, which lies about 600 light-years from the sun, generated the superbubble.

Just as an inflating balloon expands more easily into a region of lower density, the superbubble pushed deep into the region around the sun, already swept clear of material by the much older and larger Local Bubble. Inside the Local Bubble were tiny remnants of the giant cloud that gave birth to the Scorpius-Centaurus Association. Subsequent generations of supernova explosions eroded the surface of these remnants, causing their gas to evaporate and blow toward the solar region. Some of this gas, speculates Frisch, may have formed the Local Fluff.

Wang notes that his findings, presented at the American Astronomical Society meeting in January, argue against the proposal that a single, relatively close supernova called Geminga created the Local Bubble (SN: 1/2/93, p. 4). Some researchers now believe that Geminga resides in the wrong place to have carved out a hole in space near the solar system.

In his ROSAT study, Wang measured the absorption of X rays by two gas clouds that appear in adjacent patches of sky in the constellation Reticum. One of the clouds lies about 200 light-years from Earth, the other about twice as far. ROSAT detected X-ray emissions in front of both clouds, although the signal in front of the nearer cloud was only 40 percent as strong as that in front of the more distant cloud.

The signals indicate that, rather than concentrating behind a particular cloud, hot, X-ray-emitting gas pervades the region, he says. Wang interprets the data as suggesting that a bubble of hot gas bathes the area surrounding both clouds and, by inference, much of the rest of the region surrounding the sun.

Wang also found that the cloud nearer the sun has a higher temperature than the more distant one. That finding, he says, suggests that the superbubble recently blew out a stream of hot gas that flooded the solar neighborhood.

"The X-ray evidence appears to support the view that the hot gas represents a breakout from the [Scorpius-Centaurus] superbubble," says Frisch.

The coming attractions in the movie theater might be based on another type of direct observation that looms on the horizon. Scientists calculate that by 2010, the venerable Voyager 1 and Voyager 2 craft, now more distant than Pluto and speeding rapidly toward the edge of the solar system, will cross the heliopause. Equipped with ultraviolet spectrometers and radio-wave detectors, these craft may help pinpoint the exact location of the hydrogen wall and detect interstellar gas as it enters the solar system.

Such observations may have more than academic interest. Fifty thousand to 100,000 years from now, says Frisch, when the sun is expected to emerge from the passing Local Fluff, it may encounter a far denser cloud. Atoms and ions from such a cloud would penetrate deep into the solar system, overwhelming the solar wind near Earth and bombarding its atmosphere.

Frisch and her colleagues haven't yet calculated the effect of this bombardment, but it could make a world of difference to Earth's climate. □

Materials Science

Richard Lipkin reports from San Francisco at a meeting of the Materials Research Society

Sound signals surf on waves of light

As a means of carrying signals from one place to another, nothing beats light. Fast and frictionless, photons trounce electrons as the ideal carriers of information.

As computers get ever speedier, scientists are finding that microprocessors are pushing the physical limits of electric conduction. So researchers have been looking for ways to use pulses of light to ferry digital information within a computer.

Now, Jurgen Michel and Lionel C. Kimerling, materials scientists at the Massachusetts Institute of Technology, have used light to transmit messages—specifically, the sound of a voice. They've fabricated an integrated circuit, a single chip made entirely of silicon, that combines conventional semiconducting logic with optical data transfer.

Their circuit consists of three components—an erbium-silicon light-emitting diode, a device to guide the light waves, and a detector to pick up the processed signal at the other end. Although others have used light to carry signals, he adds, this is the first success with a single silicon chip, which would fit inside a computer.

Although the long-term goal isn't to transmit chatter, says Michel, the circuit proves that one can use light to move information "from one place to another on a chip or between chips." The technique could obviate the need for metallic interconnections, which limit signal-processing speed on chips. Computers would still use conventional semiconductors and microelectronics to perform calculations.

"With the metal interconnects in use today, it's hard to push microprocessors faster than 1 gigahertz," Michel says. This speed represents 1 billion operations per second. Using silicon-based optical electronics, it's possible to double or even quadruple that rate, he believes.

Bite-sized vacuum tubes

Paying homage to the early days of broadcasting, when oak-paneled radios blared out swing tunes, physicists Griff L. Bilbro and Christopher W. Hatfield of North Carolina State University in Raleigh and their colleagues are fashioning tiny vacuum tubes out of diamonds.

"We're revisiting vacuum tubes from the 1940s," says Bilbro. "But now we're taking advantage of new materials and computer design tools to predict their performance at very high frequencies, for use in radar and cellular phones."

Vacuum tubes offer some advantages over semiconductors and computer chips, Bilbro says. They're more durable than other microelectronics materials, outperforming semiconductors at high temperatures, voltages, and radiation levels.

The researchers made arrays of vacuum tubes by encasing electrodes in diamond, then evacuating the air from the interiors. These arrays resemble "furrowed fields, with rows of ridges and troughs," Bilbro says. "Each array looks like a glass bead, about the size of a match head."

A big difference between the new diamond vacuum tubes and the large glass bulbs of 50 years ago is heat. The old tubes had to glow red-hot to emit streams of electrons. The new tubes produce current at room temperature.

"There's an interesting irony here," says Hatfield. "Vacuum tubes paved the way for solid-state transistors. Now we're seeing that, for certain applications, the new vacuum tubes offer advantages over solid-state components."