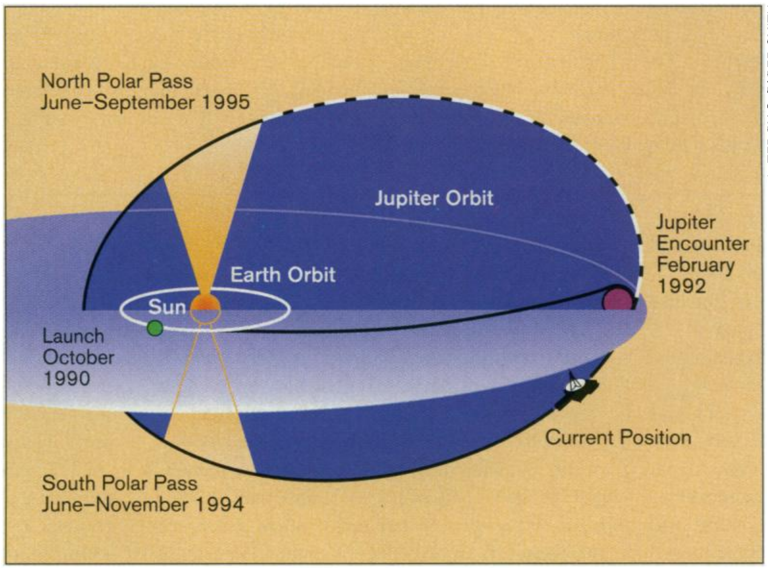
Leaving Jupiter, Ulysses Heads For the Sun's South Pole

As the Ulysses spacecraft swept past Jupiter last February, like its wily Greek namesake speeding past Scylla and Charybdis, it sent back a crop of findings. Included in the harvest: evidence that the planet's magnetic cocoon, or magnetosphere, had swollen to twice the size observed by earlier probes, signs of an unexpected region of turbulence near the planet, and confirmation that volcanoes on the Jovian moon Io fill the magnetosphere with particles. But for Ulysses investigators, those findings and others, which are reported in the 13 papers of this special issue of *Science* (see p. 1503), are valuable windfalls, gathered fortuitously as Ulysses heads toward its main business—an exploration of the poles of the sun.

There, starting in June 1994, Ulysses will peer toward the sun to gain new insight into what drives its hot, thin "wind" of charged particles, what triggers the flares that periodically erupt near its equator, and what generates the magnetic fields that shape every solar "breeze." Besides searching for clues to the workings of our own star—and by extension other stars—Ulysses will also turn its attention outward, seeking what may be the first pristine sample of cosmic rays from elsewhere in the galaxy. A common thread in these studies, says U.S. project scientist Edward Smith of the Jet Propulsion Laboratory, is the hope that the poles of the sun will be a region of simplicity—an escape from the turbulent winds and twisted magnetic fields that complicate space physicists' lives in the plane of the solar system.



SOURCE: NASA/JPL ADAPTED BY C. FABER SMITH

Going south. Ulysses heads out of the ecliptic. The mission is scheduled to end after it passes over the sun's north pole, but team members would like to swing around for another look *(dashed line).*

That hope has been strong enough to carry the project through some bureaucratic and technical travails that, Smith likes to say, would have tried even cunning Odysseus. Space scientists started dreaming of such a mission as early as 1959. But no rocket then—or even now—was powerful enough to boost a spacecraft directly out of the plane of the solar system, known to astronomers as the ecliptic. The problem, Smith explains, is that in launching a probe out into interplanetary space "you're shooting off this very rapidly moving launch platform"—Earth itself, which is zipping around the sun at 30 kilometers a second. To leave the ecliptic, a space probe has to lose much of that velocity. It wasn't until the early 1970s that space engineers realized that they could do it by launching the spacecraft toward Jupiter and letting that planet's powerful gravity shear away the craft's momentum. Choreographed just right, the encounter would fling the craft out of the ecliptic on a tilted orbit that would take it over the poles of the sun.

That elegant solution would ultimately be of great help in space, but it didn't smooth the mission's earthly course. Originally conceived as two probes—a U.S. craft laden with x-ray cameras and other imaging equipment and a European "particles and fields" craft—which would orbit the sun in opposite directions, the mission was halved in 1981, when NASA budget cuts forced cancellation of the U.S. probe. Mission scientists soldiered on, aiming for an early 1986 launch of the $750 million the European Space Agency probe from the ill-fated space shuttle Challenger. That year's Challenger explosion, one flight before Ulysses' scheduled launch, forced a further delay. Not until October 1990 did Ulysses finally sally forth from the cargo bay of the space shuttle Discovery, bound for Jupiter, the south pole of the sun, and in the summer of 1995, the north pole.

One goal of this odyssey is the chance to study something that is well known much closer to home: the solar wind. The thin wind of protons and electrons that gusts past Earth and sometimes disrupts communications and satellites (*Science*, 21 February, p. 922) is easy enough to observe from the plane of the solar system. So why go to extremes to study it? The reason, says Aaron Barnes of the NASA Ames Research Center at Moffett Field, California, an investigator on Ulysses' solar wind plasma experiment, is that "the polar regions look in all respects a lot simpler" than the regions in the solar system's plane that can be studied from Earth.

The sun's equator, explains Jack Gosling of Los Alamos National Laboratory, a member of the same experiment, "is a region of very strong magnetic fields that bottle up most of the corona [the envelope of hot gases that emits the solar wind]," alternating with patches where the wind blows freely. And the sun's rotation—it spins every 27 days—further complicates matters. As the streams of fast wind sweep around like water from a whirling sprinkler, they collide with slower wind, heating and compressing it. As a result, says Gosling, "we get a garbled signal."

At the sun's poles, in contrast, the sun's magnetic field may have a simpler structure, and rotation shrinks to a minor factor. Predicts Sam Bame of Los Alamos, principal investigator of the solar wind experiment: "It will be a much less disturbed solar wind." And that should make it possible to "trace it back into the corona to get a better handle on why it's blowing out."

The same factors that should make the poles of the sun a good laboratory for solar wind studies may also make them a prime vantage for studying cosmic rays—high-speed particles that, because they are charged, tend to follow magnetic field lines. The complex magnetic structures at the sun's equator can screen out cosmic rays, and even when the equatorial field lines are at their simplest, they are bent into a giant spiral by the sun's rotation. As a result, any cosmic rays reaching Earth from elsewhere in the galaxy have to follow a winding course inward from interstellar space—a journey that can filter out as much as 90% of their low-energy component, according to Bruce McKibben of the University of Chicago, an investigator on the Ulysses cosmic ray experiment.

But at the poles, the field lines may stretch north and south into space. And that configuration should allow galactic cosmic rays an easier entrance. Says Smith, "There may be what amounts to a funnel for cosmic rays over the polar regions." If so, the poles should give investigators their first look at low-energy cosmic rays in their pristine state.

Their composition and energies, says McKibben, should provide clues about how they're generated in such tumultuous environments as supernovas and "how much time they've spent knocking around in the interstellar medium."

McKibben's hopes rest on the assumption that the magnetic field of the sun really will be simpler at the poles—and among Ulysses' nine other experiments is one that will test that assumption directly, by measuring the field's structure. Other instruments, sensitive to x-rays, will exploit the polar vantage to take a sideways look at solar flares, in an effort to learn the anatomy of these powerful eruptions. Still others will study radio waves from the sun, dust and gas particles from outside the solar system, and the mysterious cosmic explosions called gamma-ray bursts.

The scientists running all those experiments back on Earth are a disparate lot, but there's one thing uniting them: the hope that Ulysses won't be shut down as currently scheduled, in September 1995, after it finishes its pass over the sun's north pole. "We're very keen to extend the mission," says Smith. He and his colleagues are appealing to NASA headquarters for another 6 years—enough for Ulysses' long orbit to carry it baxck over the poles. By then the sun, at the peak of its 11-year activity cycle, will be a very different star from the quiescent one Ulysses will see on its first pass. And the year will be 2001—a fitting time, Ulysses investigators think, to continue their space odyssey.

–Tim Appenzeller

MEETING BRIEFS

User-Friendly Chemistry Takes Center Stage at ACS Meeting

These days it seems that what chemistry needs more than anything else is a good p.r. agent. If you ask John or Joan Q. Public about the accomplishments of the chemical industry, chances are they'll mention Love Canal, CFCs destroying the ozone layer, or carcinogens in food. On the public confidence list, chemists probably rank somewhere above lawyers and politicians–but that's not saying much. However, if the national meeting of the American Chemical Society in Washington, D.C., 2 weeks ago is any indication, chemists are working hard to fix the image problem. Nearly all of the two dozen press conferences held during the meeting focused on food, health topics, environment-friendly technology, or some other subject close to consumers' hearts. And the scientific talks themselves reflected the same interests, with sessions such as "Environmental Successes in the Chemical Industry" and "Food Phytochemicals for Cancer Prevention" (*Science*, 4 September, p. 1349) taking their place alongside "Chemistry of Electrophilic Metal Complexes" and "New Advances in Polyolefin Polymers."

Zapping Acid Rain With Microwaves

Chang Yul Cha of the University of Wyoming in Laramie is an example of the new, environmentally sensitive chemist. Cha has found a cleaner, greener way to remove sulfur dioxide and nitrogen oxides from coal-fired smokestacks—and so reduce acid rain. Current schemes for cleaning smokestack emissions, such as limestone scrubbers, are expensive and create other wastes, such as sludge, which must themselves be treated. Cha's process, which relies on microwaves and char, a charcoal-like substance created by anaerobically heating coal, produces only nitrogen, sulfur, and carbon dioxide.

The first step is to pass the sulfur dioxide and nitrogen oxides through a bed of activated char, where the gases are absorbed into the char's tiny pores. Cha then zaps the char with microwaves, heating it and stimulating a reaction between the gases and the carbon atoms in the char. The resulting nitrogen and carbon dioxide are released into the atmosphere; the sulfur is cooled in a spray chamber and collected for sale.

Even the char becomes a product in this thrifty scheme. Cha adds powdered coal to the char-gas mixture, and the heat in the reaction chamber turns the coal into more char. This char is used again and again, becoming more activated (more porous) with each cycle, until after about 40 cycles it can be removed and sold for use in filtration, such as in waste-water treatment plants.

Cha says his scheme decomposes about 98% of the sulfur dioxide and 90% of the nitrogen oxides that pass through it—more than conventional scrubbers. Even better, he says, it will be cheaper than existing methods once the income from selling the activated char is taken into account. Soung Kim, a Department of Energy project manager who funded Cha's work, agrees, saying the technique is "technically and economically feasible and has the potential to be highly efficient and cost effective." Since the 1990 Clean Air Act requires industry to reduce sulfur dioxide emissions by 10 million tons a year by 2000, Kim says that Cha's technique is likely to get a close look and could be in use somewhere in the United States by next year.

Wooden You Love Biodegradable Plastics?

Paul Gatenholm of Chalmers University of Technology in Götenborg, Sweden, has targeted another of society's unwanted byproducts: solid waste. His point of attack is plastics, which make up only a small percentage of the materials going into landfills but pose a disproportionate problem because they are mostly not biodegradable. One exception is polyhydroxybutyrate-hydroxyvalerate, or PHB-V, which is produced commercially in vats of bacteria and is broken down in the environment by naturally occurring microbes (*Science*, 15 September 1989, p. 1187). The problem is that PHB-V is too expensive to replace conventional petroleum-derived plastics except for special uses.

By combining PHB-V with wood fibers, a natural biodegradable material, Gatenholm has come up with a lower cost alternative he calls a "compostable composite." And as reported at the meeting by another chemist, John Meister of the University of Detroit Mercy in Detroit, the same hybrid strategy can be used to improve other properties of plastics as well, to make them into more useful as well as more environment-friendly materials.

Getting the cellulose of wood to mix with plastic wasn't easy, Gatenholm and Meister say, because cellulose is hydrophilic (it mixes well with water) and plastic is hydrophobic (it repels water). Gatenholm, however, discovered a processing technique that does blend the cellulose and PHB-V—although he still hasn't figured out what happens at the molecular level to make them compatible. The resulting composite will decompose completely in a composting system, Gatenholm says. He pictures it being used in such products as diapers and food containers, which can't always be recycled because of contamination.

Meister took a different path to a similar end. In creating his wood-plastic composites, which he calls "fiberwood" by analogy with "fiberglass," Meister was searching not so much for a biodegradable material (although he says his fiberwood can be made to decompose in the environment) as for a cheap way to strengthen ordinary plastics. The wood fibers, he thought, would act like the glass fibers in fiberglass, adding strength and tear resistance to the original substance.