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OF THE WEEK

RESEARCH NOTES

ARTICLES

COVER: Midnight view of fountain and cracks in the lava lake of central crater during an eruption of Kilauea volcano on Hawaii. Kilauea's accessibility and frequent but relatively mild eruptions make it an ideal laboratory for study of volcanoes. See p. 170. (Photo: U.S. Geological Survey)

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SCIENCE NEWS OF THE WEEK

Pioneer 11's Saturn

For centuries, Saturn represented the limit of the known solar system. Even after the telescope enabled Galileo to observe the "cup handles"—his description in 1610 of the planet's rings — it would be more than 170 years before the discovery of Uranus would lengthen the list of worlds perceived to be circling the sun. In the compressed time-scale of the Space Age, Saturn has continued to be an imposing goal: More than three dozen spacecraft have been launched toward Mercury, Venus, Mars and Jupiter since 1962, yet it was not until last week that a tiny probe called Pioneer 11 was able to flash past in the first close look at the huge but distant planet.

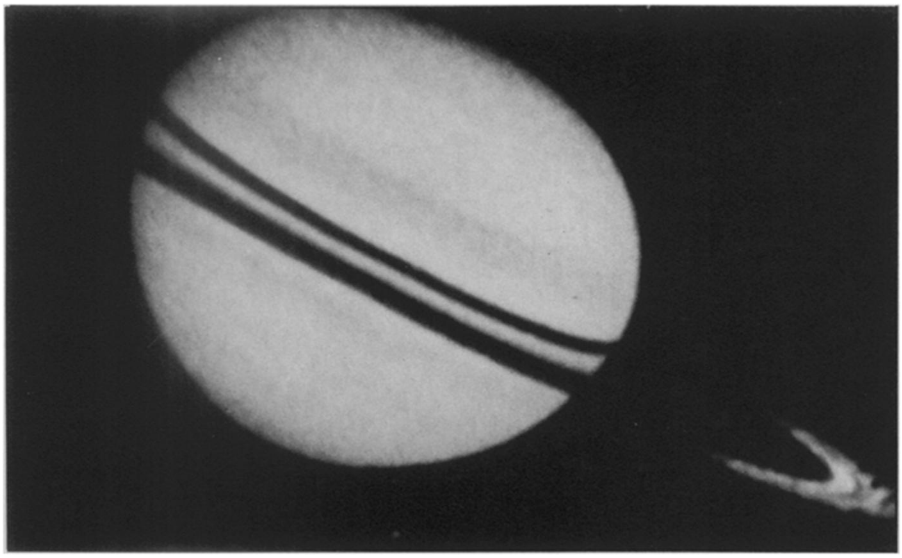
Though Saturn's ring system has been known for about three and a half centuries longer than that of Jupiter, the two gas-giant planets have in large measure been considered as a set — great concentrations of hydrogen, shaped and decorated by the laws of fluid mechanics rather than of hard-rock geophysics. But that view is changing, and as Pioneer 11 has both confirmed and newly shown, the differences range from skin-deep to the very heart of the planet, and back to the outermost sphere of Saturn's influence.

By comparison with Jupiter, Saturn is a bland-faced world, in part because its lower temperatures (it is twice Jupiter's distance from the sun) allow the formation of high-altitude hazes such as ammonia that may wash out a possibly more dramatic, Jupiter-style color scheme underneath. Early looks at Pioneer 11's images showed subtle tinges of blue-green and brownish hues in the pale, yellow-orange disc, but no signs of the abrupt color differences that characterized the cloud tops of the larger planet.

Specific features proved similarly difficult to identify. In contrast with Jupiter's numerous spots, streaks, plumes and other details, Saturn has shown only about nine discrete features to earth-based observers, says the University of Arizona's Bradford Smith, imaging team leader of the Voyager spacecraft that will offer additional close-ups of the planet in 1980 and 1981. The Pioneer 11 views added little to the list, revealing signs of some horizontal banding but only a few of the isolated circular forms (some in the slightly sub-polar regions) seen in profusion on Jupiter. Possible "whorls and scallops" may have been seen along the interfaces between some of the more northerly bands, and U.A.'s Tom Gehrels, principal investigator for Pioneer 11's imaging photopolarimeter, tentatively pointed out a possible high-altitude jet-stream at about 70°N. More could emerge with computer processing, and Voyager's cameras promise greatly improved resolution, but neither step will make Saturn look like simply a smaller Jupiter. Not even the five-micron infrared "hotspots," representing viewports into the deeper atmosphere, exist on Saturn as they do on Jupiter, says Garry Hunt of University College London, although infrared measurements from the spacecraft are enabling the "thermal mapping" of the planet, in part indicating the relative altitudes of its pale belts and zones of cloud.

Saturn's most conspicuous visible difference from Jupiter, however, is its rings, a difference that has changed only a little with the discovery by Voyager 1 and 2 that the larger world also has a thin ring system of sorts. For Saturn's rings are a true spectacular of the solar system — and Pioneer 11 saw them as no human eyes have ever done: from "behind," on the side away from the sun. The difference in their appearance is striking — and not always obvious. In regions where the ring particles are closely spaced, appearing bright by reflected sunlight on the side visible from earth, the reverse view is basically dark. Thinner concentrations of particles, however, can look dark from some angles (if they block the sunlight) and bright from others (if they redirect the light toward the viewer). There are even angles from which adjacent thickly and thinly populated regions can both appear dark — one because it blocks the light and the other because it contains too few particles to scatter the light in the viewer's direction.

The classically recognized rings have been three in number, known, from the outside in as A, B and C. Earth-based measurements, however, have in recent years provided faint indications of two more — a D ring, possibly reaching from the inside of "C" all the way in to the cloud tops, and an "E" ring, extending from the outside of "A" out to a distance estimated from some data to be as great as 50 times the radius of Saturn, or more than 20 times the radius of the A ring. Pioneer 11's path would take it through the plane of the rings twice, and the decision was made to go through the E-ring region, in part because the D ring appeared from the limited data to be more dense, but also because Voyager 2 must also pierce the E-ring region if it goes on to Uranus after its August 1981 encounter with Saturn. Pioneer 11, living up to its name, would go first to survey the route.



Saturn shows faint banding, with rings lit from behind by sun. Spot below planet is satellite Tethys.

Pioneer 11/NASA

It pierced the ring plane twice — down, in beneath the main ring structure, back out and up again — and although most of the project's scientists expressed optimism about the probe's chances, the crossings were dramatic. "We've just won another planet," said one Voyager scientist after Pioneer 11 had survived the second crossing. "On to Uranus!" If it survives the trip, Voyager 2 will yield the first close-ups of that world (about twice Saturn's distance from the earth) in January of 1986.

Although neither the D nor E rings appeared in early analyses to have been detected by Pioneer 11's instruments, the probe did reveal significant details about the ring system's structure. Most striking was what appeared to be the discovery of a previously unknown ring, labeled the "F" ring and described initially as being about 500 kilometers wide and centered about 3,500 km outside the A ring. The gap between the faint, new ring and the much more prominent A ring inside it was informally christened the "Pioneer Division," in honor of the spacecraft. Data on the yet more tenuous E ring are so limited that scientists are uncertain about even its inward extent, including whether it reaches all the way to the A ring with the F ring being merely a more concentrated part of it. In fact, according to one of the project's scientists, it would probably not be unreasonable to think of the whole ring system as one continuous sheet, with all the supposed individual rings and gaps simply representing different particle concentrations. Meanwhile, however, Pioneer 11 confirmed the existence of a gap (or sparse-particle region) between the B and C rings, previously identified in earth-based observations by French astronomers but never confirmed. Gehrels termed it "the French Division."

The complex nomenclature of the ring system, as updated by Pioneer 11, now reads as follows, with the out-of-sequence lettering reflecting the various rings' order of discovery: the D ring (innermost, inferred only from earth-based data), the Guerin Division (visible from earth and spacecraft alike), the C ring, the French Division, the dense B ring, the well-known Cassini Division (in which Pioneer 11's data do show some stray reflected light, supportive of the continuous-sheet idea), the A ring (which also contains a thinning-out known as the Encke Division), the Pioneer Division (unless the E ring is taken to mean everything beyond A's outer edge), the newly discovered F ring, and whatever else exists of the E ring.

Besides their sheer, awesome presence, the rings have another dramatic effect on the space around their planet. Where the rings intercept the lines of Saturn's magnetic field — only about a twentieth as strong as Jupiter's but perhaps a thousand times as strong as earth's — they absorb the charged particles traveling back and forth on the field lines, radically reducing the intensity of the planet's radiation belts until they are more like an earthly phenomenon than one on a huge, Jovian scale. As Pioneer 11 swooped under the edge of the rings, its detectors showed the particles existing farther out to be cut off as if by a guillotine. "Almost all the magnetospheric particles are totally wiped out by the A, B and C rings," says James Van Allen of the University of Iowa. "We've also examined Cassini's Division, and nothing gets through there either." The spacecraft sustained some radiation damage when it passed close to Jupiter in December of 1974, but at Saturn, says Van Allen, "there is no radiation hazard whatever for electronic apparatus" (for humans, though, the dose — about 400 rads per hour by one estimate — would still be lethal).

Also sweeping out the charged particles may be several of Saturn's numerous satellites. Early looks at the data suggested that as many as five of them — Janus, Mimas, Enceladus, Tethys and Dione — could be having an effect, leaving "negative rings" of reduced numbers of particles as they orbit the planet. In the days following the flyby, scientists were working to match the "dips" in their particle counts with the satellites' orbital positions. The particle detectors, in fact, serve in a sense as mapping devices for the Saturnian system, and dips in their data early this week were prompting researchers to examine the possibility that otherwise unseen rings or satellites could be making their presence felt.

But in addition to trapping charged particles that show the sweeping effects of moons and rings, Saturn's magnetic field is striking in its own right. Perhaps its most surprising characteristic — and one of Pioneer 11's major findings — is that its axis appears to be aligned with the planet's axis of rotation. Other planets known to have magnetic fields tend to have their magnetic axes tilted on the order of 10° (give or take a few) to their rotation axes, says Edward J. Smith of Jet Propulsion Laboratory, and some researchers have felt that this difference in tilt has been a key factor in a "precession dynamo" that keeps the field going. Yet Saturn seems to have virtually none. And it may pose yet another quandary: The sun, Mercury, Earth and Mars all have fields whose strength correlates at least approximately with their angular momentum; indeed, this correlation has been cited by some as one of magnetic-field theory's few rules of thumb. But Saturn, said the University of Chicago's John Simpson during the initial looks at Pioneer 11's data, appears to have a somewhat weaker magnetic moment than its angular momentum would suggest. More work for the theorists — and for the Voyagers.

One of the most intriguing parts of the Saturnian system is the planet's huge satellite Titan, bigger than Mercury and made more provocative by speculations that organic molecules possibly generated in its methane-rich atmosphere could be providing ingredients relevant to life. Pioneer 11 got no closer to Titan than about 350,000 km, and the resulting images were tiny and indistinct. There were some data, such as observed variations in the object's red/blue brightness ratio, suggesting that there may be features for Voyager 1 to photograph during its much closer pass next year, and the promise of pinning down the satellite's mass to within 0.3 percent. Unfortunately, the most potentially interesting of Pioneer 11's Titan measurements — infrared indications of the day-night temperature difference, relevant to whether the atmosphere is thin and Mars-like or, as has been speculated by some, several times thicker than earth's — were lost. Unanticipated interference from an earth-orbiting Soviet satellite transmitting on the same frequency drowned out the little probe's far weaker signal at the critical time, though the Voyagers will almost certainly make up for the loss. (The whole encounter, in fact, was plagued with data-loss problems, due in large part to the swamping effect of intense flare- and solar-wind activity from the sun, and in lesser measure to occasionally bad weather over the tracking stations on earth, which were hard-pressed to pick up the probe's weak, 10^{-20} watt signal.) One important finding relevant to Titan, however, was that when Saturn's magnetosphere is highly compressed — as it was by the intense solar-wind activity that accompanied most of the encounter — Titan is just about on the edge of the field, sometimes just inside it, other times outside. One consequence of this, scientists suggested, is that Titan's atmosphere is probably only a limited source of particles to the plasma trapped in Saturn's magnetic field, whereas Jupiter's satellite Io, much closer in to its own host world, contributes voluminously (though more from volcanically erupted gases than from a dense atmosphere) to the Jovian environment.

There were even hopes (unresolved by press time) that Pioneer 11 might have discovered a new moon of Saturn, which would make it the first spacecraft to be credited with such a find. Early on, however, it was difficult to tell whether the object — detected dimly in at least one photo — was merely Janus, or "S 11" (a tentatively identified satellite for which no orbit has been worked out, making it difficult to match its location with the Pioneer image) or, in fact, a previously unknown object.

Days, weeks and months of work will answer some of Pioneer 11's questions, and raise new ones, and the Voyagers will do the same. But the little probe, designed more than a decade ago and surviving a six-and-a-half-year journey for which it was never originally intended, has made a more familiar object out of the most distant member of the solar system that for centuries was all that earthlings knew. ☐

Lower SATs: Fallout from the fifties?

When the average Scholastic Aptitude Test scores of college aspirants dropped drastically in 1975, a number of explanations were offered — many of them having to do with changing sociological and educational factors, such as school busing, economic patterns and other environmental influences (SN: 11/8/75, p. 294; 9/3/77, p. 148). But University of Pittsburgh radiation physicist Ernest Sternglass envisions far different causes.

"I saw that report in a 1975 New York Times article, and it got me to thinking: What happened 18 years before?" Sternglass recalls. What happened, he says, was the largest single series of atomic bomb tests in U.S. history — 303 kilotons were detonated in Nevada in 1957. Sternglass, author of several controversial studies linking radiation exposure to cancer and other long-term physical problems, now has a new hypothesis: The sharp decline in SAT scores was due primarily not to school system or integration problems but to radioactivity that infiltrated the bodies of many youngsters when they were in the fetal stage during 1957.

"Iodine-131 seeks out the thyroid, leading to a slowing down ... of the [development of] the baby in the mother's womb," Sternglass says. In addition, strontium-90, another by-product of nuclear testing, "goes for the pituitary" and is "stored in the bones of the mother of the child." It is this developmental slowdown, "even ever so slight," that the physicist says can have long-term effects on intellect, as measured by aptitude scores.

Sternglass's hypothesis, however, has met with severe opposition from other researchers familiar with the effects of radiation and atomic testing.

Sternglass tested his hypothesis by reviewing the mean SAT scores, provided by the Educational Testing Service, in various states and regions around the United States. Although the study covered about 20 years, it concentrated on the period from 1972-73 through 1976-77 — meaning that most of the test takers were born between 1955 and 1959.

The results, presented last week in New York at the annual meeting of the American Psychological Association, "are indeed very startling, to say the least," says Sternglass. He found that after a number of years of slow decline, SAT scores plummeted sharply from 1973-74 through 1975-76 among students born between 1956 and 1958.

Moreover, the sharpest drop in the mean verbal score for that period — 26 points — occurred in Utah, a state adjacent to the Nevada test areas. And California, another adjacent state, showed a decline of 20 points during that period. Verbal scores were lower in most regions of the United States during those years, but the drop was most marked in the western states.

Statistically, what impresses Sternglass and his followers most about the data is that after the sudden, sharp drops, SAT scores — particularly the verbal ones — just as suddenly leveled off. "We got a base line, then a drop, then a return to a plateau," says Steven Bell of the Department of Education and Psychology at Berry College in Mount Berry, Ga. If the primary causes were sociological, educational or economic in nature, Bell says, the scores probably would have dropped more gradually. "But they leveled in the absence of radiation [18 years earlier]," he says. In Utah, verbal SAT scores "bounced back up" by 9 points in 1976-77.

Sternglass also notes that Utah, a Mormon stronghold in the United States, has one of the lowest smoking and alcoholism rates and highest socioeconomic levels in the country. "And they in fact had the greatest drop in scores — this cannot be accounted for by any other variables [outside of nuclear testing]," he says.

During the same period, 1973-74 through 1975-76, scores declined least in the midwestern states. Ohio, for example, showed only a 2 point drop on verbal SAT scores. Sternglass suggests that weather patterns, as well as proximity to testing sites, are reflected in these data. From June of 1957 to June of 1958 — when the highest radiation levels were recorded in Utah and Nevada — low rainfall in the midwest may have allowed much of the fallout to pass over to the East Coast, where "heavy rainouts" are often triggered by eastern mountain ranges. New York State, for instance, showed a 17 point decline in verbal SAT scores in the affected period, he notes. But Sternglass acknowledges that he has not yet studied weather patterns during the nuclear testing periods of the 1950s — something he says should be done in future research.

The implications of the figures are frightening, Sternglass says. "The fallout in Utah from mid-1957 to mid-1958 was comparable to Hiroshima," he says. Published measurements around Salt Lake City during that period showed 249 picocuries of iodine per liter of milk, according to the physicist. Aside from the fallout's possible long-term physical effects, the lowered SAT scores could have kept many high school seniors out of college careers that they would otherwise have achieved.

"People who take SAT's are aspiring to be leaders in engineering, the sciences and other fields," he says. "If you cut down the number of people who will score over 700 on the SAT, you're cutting down on professionals in those fields. You get people dropping out of the educational system, which has implications in our unemployment, delinquency and teenage parent rates." Though such effects may be somewhat speculative, says Bell, "there is a latency effect of 18 years of a toxic insult to the fetus. What we know now is that less than optimal development is occurring."

Despite the apparently high correlation between the two events, other researchers familiar with Sternglass's work were cautious at best about accepting the hypothesis. (Sternglass was severely criticized in the late 1960s for his methods in a study that purported to show a relation between fallout and infant mortality.) Researchers at the Center for Disease Control in Atlanta and at the National Institutes of Health, who asked not to be identified, criticized Sternglass's "broad-brush stroke" treatment of data. Said one: "You can link anything to atomic testing. You could also link [the testing to] crime in the streets and the divorce rate."

Other factors — including socioeconomic ones — would have to be ruled out before accepting fallout as the culprit for the declining scores, they said. Particularly lacking, noted a researcher at