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Saturn's Atmosphere

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Cover: False color processing can reveal features of a planet's atmosphere that would be muted or invisible to the human eye. Here, combined ultraviolet, violet and green images from Voyager 2 bring out bands, waves and spots that are hard to discern in Saturn's bland, true colors. Using false color images, scientists can model details of the atmosphere composition and structure.

PHOTO: JPL/NASA

Voyager: A Sting From Outer Space

by Art Buchwald

I know it doesn't sound important when you measure it against other budget cuts, but NASA is now considering abandoning the Voyager 2 spacecraft which, at this very moment, is on its way to Uranus and Neptune.

The estimated arrival time to Uranus was 1986, and if all went well it was supposed to make a pass at Neptune in 1989.

I happen to be a big fan of Voyager 2 and I know it would break the spacecraft's heart if they cut off all its controls after its magnificent performance to date. To me, it would be a human tragedy. How do you break the news to this magnificent satellite, which is now billions of miles from home?

"Hello, Voyager, this is NASA Control. We are aborting your mission. Do you read us? We are aborting your mission."

"Are you crazy, NASA Control? Everything is going smoothly."

"You are being rifled for budgetary reasons. Over."

"But my understanding was, when I took this mission, I would get to photograph all the planets. If I don't get to Uranus or Neptune we'll never know what makes them tick."

"We're sorry, Voyager, it's out of our hands. We've decided you're expendable."

"Now you tell me. I'm up here in nowhere barreling away from Saturn and you're going to leave me in the dark."

"Believe us, Voyager, it hurts us more than it hurts you. But David Stockman is adamant. You go out with the school lunches."

"I know what the problem is. You didn't like my pictures of Saturn. But it wasn't my fault. I developed a glitch in one of the movable instrument panels. It could have happened to anybody."

"The pictures you sent back were just great, Voyager. Believe us, we're all very proud of you. But the money isn't there to let you continue on your way."

"I'll go to Uranus and Neptune as a free-lance photographer and it won't cost you a dime."

"It isn't just you that's being rifled. The whole program has to be aborted. We can't afford the ground support to get you to Uranus."

"But where am I going to go? What am I going to do?"

"I guess you're going to have to keep tumbling along. But you can no longer count on any help from us."

"What are we talking about, moneywise?"

"Stockman figures we can save \$220 million by canceling your trip."

"That's chicken feed compared to what you people can get out of it. *Playboy* spends more than that to photograph a centerfold."

"Please, Voyager, don't make it harder on us than it is already. If we could have saved the mission we would. A lot of us on Earth are being rifled too."

"Yeah, but you have families to go home to, and you can probably find jobs in military space probes. I'm up here all alone with no one to talk to. If you would just let me get to Uranus, maybe I could get the money from Traveler's Aid to get me back."

"Sorry, Voyager, orders are orders. In 10 seconds we're cutting off all power. You're on your own. Is there anything you want before I press the abort button?"

"Yeah. I want to talk to a priest."

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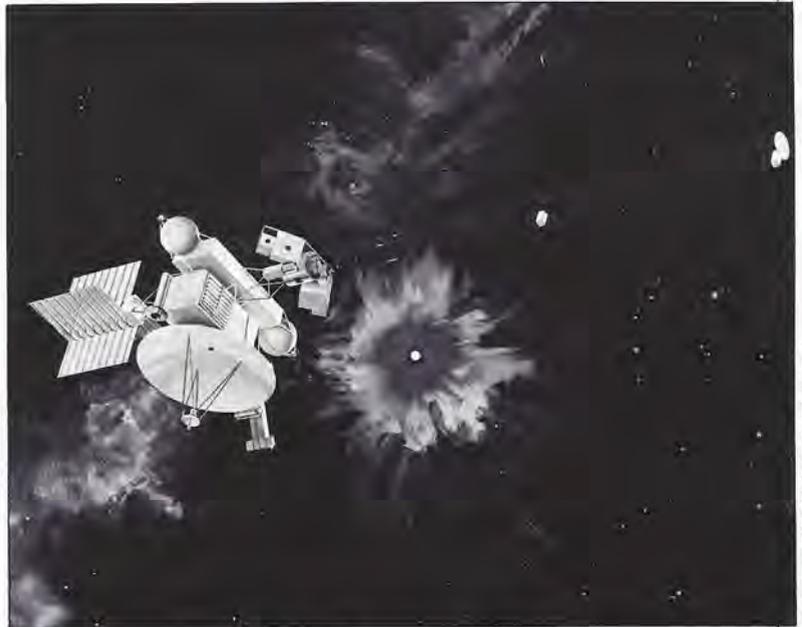
At present, space science is one of the most vital and productive fields in the United States. There is a brisk flow of fresh data into research laboratories throughout the nation, and our current journals of geophysics, solar physics, planetary science, and astronomy are bulging with reports of discoveries and new insights gained by space techniques. Simultaneously, the high technology of the space industry is being used in a rich variety of utilitarian applications of global scope. The most important of these is rapid worldwide radio communication by satellite relay stations, now flourishing as a commercial enterprise. Others, still primarily in the form of government services, are weather observation and forecasting, military reconnaissance and surveillance, navigation, geodesy, and the survey of earth resources on land and at sea. All of these applications are of pervasive civil and military importance, and many evolutionary improvements in the technology are under development.

Despite all of this, a deep distress is spreading through the community of scientists and engineers who are engaged in space work. This distress is not alone a matter of narrow special interest. Rather it portends a grave slippage in our international stature in yet another area of science and technology. The most immediate concern is with the paucity of opportunities for new initiatives. During 1980, the United States placed only 13 satellites into earth orbit and launched no spacecraft into deep space. Of the 13 satellites, 8 were primarily for military purposes, 4 were primarily for civil applications, and only 1 was for scientific purposes (the Solar Maximum Mission for refined study of the sun). The corresponding figures for the Soviet Union were 83, 18, and 2, respectively, plus 6 manned flights, for a total of 109. By contrast, in 1966 the United States made 96 launches, including 18 scientific flights and 5 manned missions. As of 1981, it is almost impossible to obtain a go-ahead for a new scientific mission or for an advanced application mission in space. Even previously authorized missions are being terminated or, what may be worse, placed in a status of indefinite postponement on a starvation budget.

It is easy to blame this bleak outlook on shortsighted policy of the Reagan Administration, as many of my colleagues are inclined to do. But I find it difficult to argue that an annual federal expenditure of \$6 billion for the National Aeronautics and Space Administration plus an estimated \$3 billion for space activities of the Department of Defense is not adequate for a vigorous program of new achievements by the immensely capable cadre of space scientists and engineers using the superb instrumentation and technology that exist in the United States. It is time to recognize that the dominant element of our predicament is the massive national commitment of the past decade to development of the space shuttle and the continuation of manned flight. This commitment has diverse bases but arises largely

U.S. Space Science and Technology

by James A. Van Allen



The United States' part of the International Solar Polar Mission, seen here in an artist's conception, has been cancelled. ISPM would have been a joint mission of the European Space Agency and NASA.

from a (possibly false) analogy with the history of aeronautics and from vaguely perceived future benefits of vast enterprises, such as manufacturing in space, solar power satellites, human colonies in space, and mining of the moon and asteroids. It may well turn out that the space shuttle is a technical success but a financial monstrosity, as on a smaller scale has proved to be the case with the Concorde supersonic transport. Stated otherwise, the shuttle may be ahead of its time, by perhaps 20 to 50 years. Meanwhile, clearly realizable and important objectives in space are languishing.

I consider that our national policy in space is in desperate need of critical and dispassionate reappraisal. A refreshing start has been made by the Corson committee of the National Research Council in its report on *Electric Power from Orbit: A Critique of a Satellite Power System*.

James Van Allen, discoverer of the Van Allen radiation belts, is a member of The Planetary Society Board of Advisors.

Weather on Saturn— The Second Voyager Look

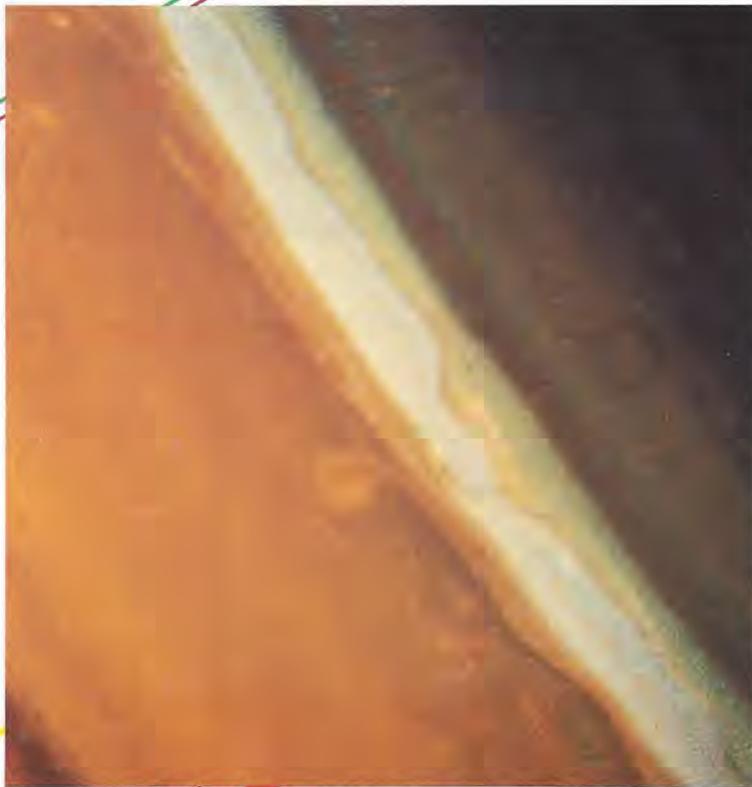
by Garry E. Hunt

The second *Voyager* encounter with Saturn in August, 1981, provided an excellent opportunity to study the weather systems of this distant planet. A wealth of new detail is seen in the images, showing Saturn's cloud structures to be more like Jupiter's than we thought they were on the basis of *Voyager 1* data. Long-lived oval spots, small-scale convection, and alternating easterly and westerly wind streams are some of the major similarities.

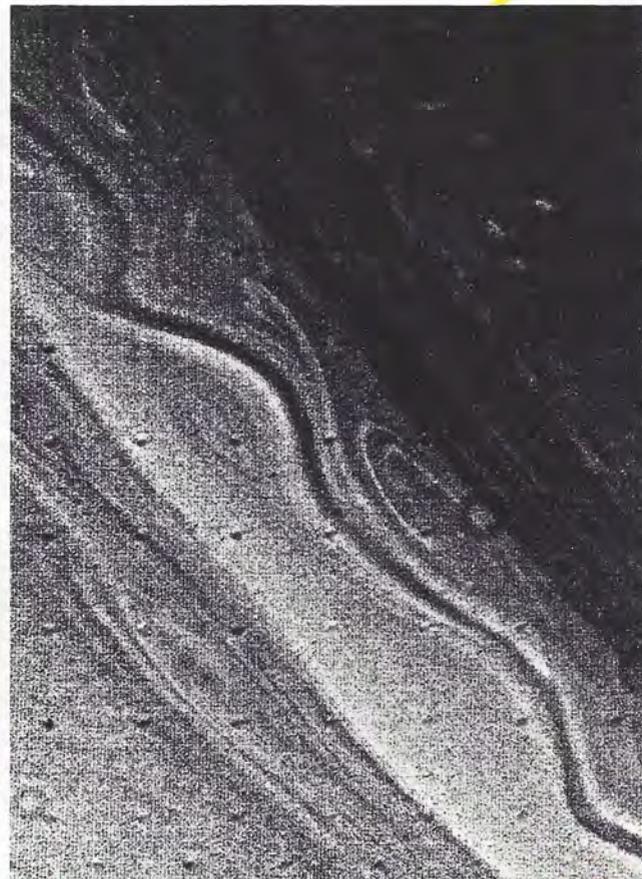
Easterly and westerly wind streams

in the Saturn atmosphere are symmetrical about the equator in spite of the planet's axial tilt. As a consequence of the long radiative relaxation time of the huge planetary atmosphere, the ring shadow has no major effect on the planet's local weather systems. Saturn's zonal wind profile does have important differences from the structure found in the cloud tops of Jupiter. On Saturn, there are only three easterly jets in each hemisphere, and the east-west flow seems to extend

poleward to approximately 75 degrees latitude. This is in contrast with Jupiter, where the predominately zonal motion terminated at about 50 degrees in each hemisphere. Does this difference in the wind structure relate to any difference in the depth of the active weather systems of these atmospheres? Although the interpretation is controversial, it is certainly possible that the zonal winds on Saturn are related to motions of the atmosphere at a greater depth than on Jupiter.



4
What appears to be the numeral 6 (center of photo) is actually a white cloud revolving within Saturn's northern mid-latitudes. *Voyager 2* monitored the cloud for seven rotations around Saturn, and it appeared to be forming a closed loop—perhaps evolving into a more familiar atmospheric spot, like that in the bottom right of this photo.



Some *Voyager* scientists have suggested that this sinuous feature running through Saturn's atmosphere is a large-scale atmospheric wave, lying within a rapidly-moving eastward jet stream.

All the easterly jets on Saturn (and Jupiter, too) are unstable flows. The region between 20 and 40 degrees north showed the greatest changes in visible appearance in the nine months between the *Voyager* encounters. Unstable convection clouds observed by *Voyager 1* in the easterly flow at 39 degrees north were seen to originate from several discrete sources in this latitude band. The flow now resembles that of vortices shed by a solid vertical cylinder in a classical fluid flow. This type of intermittent convection propagating from the depths of the planet's atmosphere must be important in Saturn's meteorology, as it transports heat and momentum up into the layers that we observe.

Spots of several kinds have been seen in Saturn's atmosphere. Stable, symmetric ovals of various colors exist, ranging from white to brown and red. "Big Bertha," at 75 degrees north, is 1000 x 6000 kilometers in size and situated in a weak westerly flow of four

meters per second. Three "brown spots" have been seen at 42 degrees north latitude. They are approximately 7000 x 5000 kilometers in size and appear to rotate anticyclonically in a westerly flow of about 100 meters per second. The spot at 27 degrees north is prominent in ultraviolet wavelengths and may therefore be higher than its surroundings.

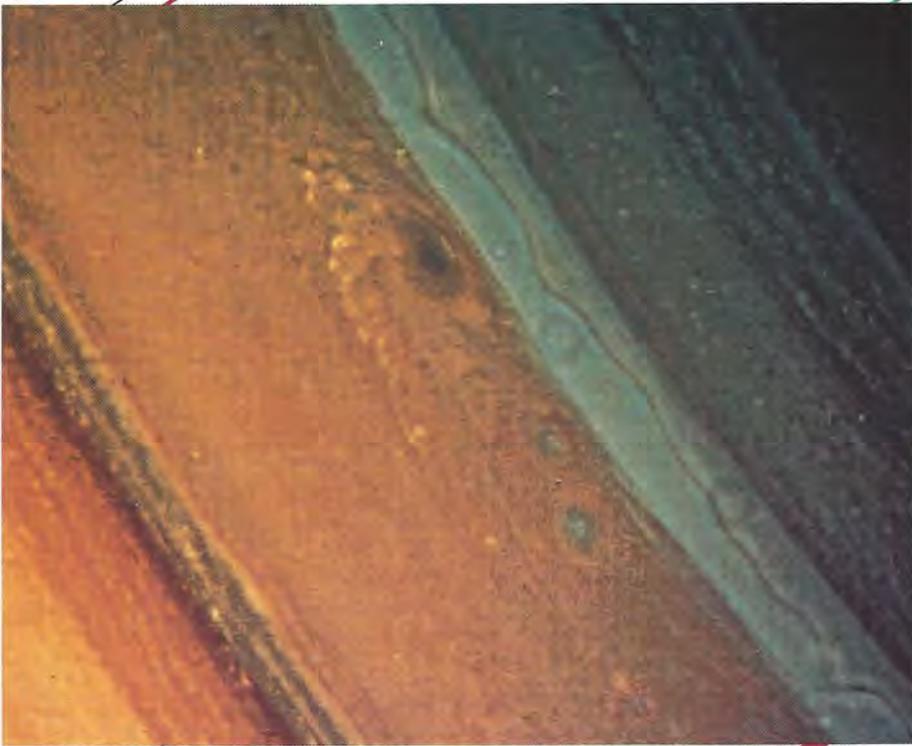
In the southern hemisphere a red spot about 5000 x 3000 kilometers in size has been observed by the *Voyager* cameras since early August, 1980. Some of the larger Saturn cloud systems have thus persisted for more than a year.

Two ribbon-like cloud features are apparent in the northern hemisphere of Saturn. The "jet stream" structure at 46 degrees latitude marks a westerly wind of about 150 meters per second. Nestled in troughs in its northern edge are cyclonic vortices (counterclockwise swirls). In the southern hemisphere, the corresponding features are anticyclonic, spinning clockwise.

In the polar regions are two hurricane-like cloud features 250 kilometers across with 60-kilometer dark centers. These structures are similar to those found on the Earth, except that if it is raining on Saturn, the precipitant will be ammonia!

Our new look at the weather on Saturn has presented new problems for meteorologists. In particular, the seasonal differences in the appearance of Saturn's northern and southern hemispheres are in contrast with the symmetry of the zonal wind profile, suggesting that the zonal winds are deeply seated. Putting all of the *Voyager* observations together into a self-consistent model of Saturn's atmosphere is a fascinating task for the future.

Garry Hunt, of the Laboratory for Planetary Atmospheres, University College, London, England, is a member of the Voyager Imaging Science Team.



The east- and west-flowing ribbons that encircle Saturn are seen in this false color image from *Voyager 2*. The convective features below the large, blue oval are moving westward at 20 meters per second; the wavelike feature dividing the ribbon north of the oval is moving eastward at 150 meters per second.



PHOTOS: JPL/NASA



Some Saturn features changed between the visits of *Voyager 1* on Nov. 1, 1980 (top photo) and *Voyager 2* on Aug. 21, 1981 (bottom photo) while others were relatively unchanged. The large oval (lower right, both photos) seems to be long-lived, like its counterparts on Jupiter.

News & Reviews

by Clark R. Chapman

In the last few weeks, the national media have been reporting that budget-cutters in Washington are threatening to further dismantle NASA's already weakened programs of civilian research and development in space science and applications. The most stunning and successful of these programs—the planetary exploration program, which costs only three per cent of NASA's budget—was threatened last October with outright extinction. Apparently, a temporary reprieve has been won, but the threat could return with a vengeance when the President announces his Fiscal Year 1983 budget in January, 1982.

Military Shift

In its November 16, 1981, issue, *Aviation Week and Space Technology* reports on shifts in NASA's long-term goals being considered at high levels in the space agency. The Space Act of 1958 mandated NASA to be devoted to the peaceful exploration of the atmosphere and outer space, and relegated matters of national defense to the Defense Department, with appropriate liaison. But NASA's second-in-command, Dr. Hans Mark, author of the long-range planning document quoted in *Aviation Week*, emphasizes the military utility of NASA's aeronautics and applications programs, while stating that planetary exploration must be "de-emphasized somewhat."

How can this once proud endeavor be further de-emphasized, with only the *Galileo* mission resting in the nearly empty cupboard, as the Soviets alone continue to explore Venus and NASA sits out the long-heralded return of Halley's Comet? How long can the highly motivated and talented planetary engineers and scientists be expected to wait for renewed opportunities to do what they do best? Mark's answer is: "Until we have a space station that can serve as a base for the launching of a new generation of planetary exploration spacecraft."

Mark suggests that a manned space station should be NASA's new big goal; NASA Administrator James Beggs said as much himself in an interview in the December, 1981, issue of *Omni*. A few weeks before the *Aviation Week* article appeared, I met *Omni* Editorial Director Ben Bova at a cocktail party during his whirlwind promotional tour for his new book, *The High Road* (Houghton-Mifflin, 1981). Bova told me that NASA's salvation rests in everyone's rallying around the space station. At the time, I told him I more-or-less agreed. Now I am not so sure.

Will the Reagan administration permit NASA to pursue a balanced program involving Earth-resources exploration, space-borne observatories, Mars landings and comet-*rendezvous* missions? Or will these scientific projects be squeezed to non-existence by one monster technological endeavor? Will a space station become a military fortress in the sky after millions of space enthusiasts have supported its development for more lofty goals? The shuttle is the test. Will we reap the shuttle bonanza promised a decade ago? Let's hope the shuttle becomes more than a truck to be filled with military cargo.

Failure to address questions such as these is the chief flaw in Bova's new book. In *The High Road*, he asks us to rally around the goal of building a prototype solar power satellite (SPS) by the year 2000. Whether Bova has recently lowered his sights to the space station, or simply regards it as a way-station to the SPS, is not clear. But either way, I think his agenda for the 1980's is somewhat lacking in practical perspective. A quarter-century into the space age, NASA should be busy reaping the rewards from its already-developed launch vehicles, while pursuing the future in parallel. But Bova's agenda lacks science, applications, and even commercial exploitation. He focuses instead on more technology and hardware: a heavy launch vehicle, a space operations center, a space tug, operations technologies and a geosynchronous space station.

Is Space Our Salvation?

In other respects, *The High Road* is a good read and a substantial argument for an active space program. Perhaps Bova is a bit apocalyptic about imminent world catastrophe and a bit glib about how space will solve all the world's problems. He actually writes: "A vigorous space program that expands our economic horizons is the best chance for advancement that the poor have." The *best*? Well, at least he makes a case that it is a good chance. Bova establishes a dialectic between the "Prometheans" (he counts himself as one) and the "Luddites" (mainly limits-to-growth environmentalists), but then he goes to great effort to woo environmentalists to the side of space. Despite the uncomplimentary name-calling, Bova shows himself throughout the book to be sensitive to environmentalists' concerns and saves his scorn only for what he describes as the small, know-nothing faction of the environmental movement.

The High Road may not be great literature, but Bova writes crisply and well. The book is filled with useful facts, anecdotes, comparisons and arguments. I only wish he were a little more specific and practical about how we get from here to there. He asserts, for example, that the asteroids are a "miner's bonanza." That is, indeed, a good hypothesis, as I know from my own ground-based research. But before anyone invests billions of dollars in a space mining operation, it would be a good idea to look closely at an asteroid and see whether this hypothesis is any better than many other good hypotheses that have bitten the dust in the face of close-up examination by planetary spacecraft. NASA needs to be bold in dreaming about, and planning for, a future with human settlements in space. But it also needs to fulfill its earlier promises and do its homework before corporate investors, or society itself, will have confidence in Bova's vision of our salvation.

A few reading notes: the October, 1981, issue of *Technology Review* deals almost entirely with the shuttle and with our possible technological futures in space. The November, 1981, issues of both *Sky & Telescope* and *Astronomy* highlight discoveries made by *Voyager 2* about Saturn, its rings and its moons. On a more erudite level, the November, 1981, *Scientific American* contains a lengthy article on the rings of Saturn, Jupiter and Uranus, written by planetary scientists James Pollack and Jeffrey Cuzzi. Finally, a new book of planetary paintings, with accompanying prose, has just been published by Workman Press—*The Grand Tour: A Traveler's Guide to the Solar System*, painted and written by Ron Miller and William K. Hartmann.

Clark R. Chapman, of SAI's Planetary Science Institute in Tucson, Arizona, is Vice Chairman of the Division of Planetary Sciences of the American Astronomical Society. He is also a member of the Galileo Imaging Team.

PROBING SATURN'S RINGS

by Arthur L. Lane, Richard B. Pomphrey and Larry W. Esposito

On August 25, 1981, three and three-quarters hours from *Voyager 2*'s closest approach to Saturn, one instrument began an unusual observation. The on-board computer targeted the scan platform toward a specific location in space, near the dark limb of the planet. The photopolarimeter subsystem (PPS) locked onto a star that was about to rise from behind Saturn's nightside limb. For the next two and one-quarter hours, it would track this star while the cameras—those workhorses of so many *Voyager* discoveries—remained idle. Why were the *Voyager* scientists willing to sacrifice the most detailed possible pictures of Saturn, its rings and some of its satellites?

From both *Pioneer 11*, in September, 1979, and *Voyager 1* in November, 1980, we had learned that the rings of Saturn were far more mysterious and complex than anyone could have imagined. After a preliminary analysis of the data from *Voyager 1*'s Saturn encounter, the scientific team had decided to attempt an in-depth study of the rings with *Voyager 2*. We had several important questions about the fine structure of the rings: How many rings does Saturn have? Five hundred? One thousand? Or several thousand? Although *Voyager 1* had revealed ringlets within the rings, the images from its cameras rarely surpassed a resolution of five kilometers. What would the rings look like at one, or one-quarter, kilometer resolution? Only the photopolarimeter could see the rings in such fine detail.

Because of a unique geometry on the spacecraft's approach to Saturn, the bright ultraviolet star Delta Scorpii was occulted by the shadowed portion of the rings (**Figure 1**, next page). As the star appeared to move away from the planet (along the red arrow in **Figure 1**) through the C, B, A and F-rings, the PPS saw the starlight flicker as it passed through the rings and was attenuated by varying densities of ring material. Sampling this starlight one hundred times per second, the photopolarimeter obtained an ultimate resolution of one hundred meters (about a city block) across the 74,000 kilometer

radius of the rings. We can now study the rings at resolutions ten times higher than any other *Voyager* data, and with twenty to fifty times the detail of images provided by the spacecraft's cameras.

The photopolarimeter subsystem recorded about 800,000 separate measurements as it passed over Saturn's ring system. The sheer volume of data is overwhelming, and we cannot simultaneously display both the expanse of data and its high resolution. To appreciate how the PPS data complements the standard *Voyager* camera images, one can examine small regions where the high spatial resolution of the PPS provides unique information (see next page).

Consider the thin F-ring lying outside the A-ring. Scientists have determined from *Voyager* images that the entire F-ring is about 700 kilometers across. *Voyager 2*'s telephoto camera recorded this ring shortly before the spacecraft's closest approach to Saturn (**Figure 2**). The image shows one bright, relatively dense strand, along with several tenuous filaments of ring material.

Compare this image with the PPS data for the same region of space (physical data in **Figure 3a**, synthesized PPS image in **Figure 3b**). The PPS revealed at least ten distinct ringlets within the sixty-kilometer-wide region that appears as a single bright strand in the *Voyager 2* image. Upon closer examination of the very dense outer ringlet, we found it was split into two dense and narrow ringlets only one-half kilometer apart (data in **Figure 4a**, synthesized image in **Figure 4b**). Down to the limit of even the PPS resolution, narrow ringlets contain smaller ringlets. And these ringlets contain even narrower features.

One must keep in mind that the photopolarimeter data come from a single, narrow radial cut through the ring plane, and provide no azimuthal information—data along the plane of the rings. Thus, the PPS could not have detected the "braids" in the F-ring discovered by the *Voyager* imaging system. However, using a mini-computer and a computer graphics system, we can take a single radius and from it

synthesize a two-dimensional ring that is symmetrical around the ring plane.

We convert the amount of starlight passing through the rings, as measured by the PPS, into a density—less transmitted light indicates a higher density of material. Next, this density is converted into a brightness of reflected sunlight—more material reflects more sunlight. Finally, we choose a point in space from which to observe a specific portion of the rings. Given this information, the computer system generates pictures (as in **Figures 3b** and **4b**) from physical data. The brightest, or most dense, regions of the rings appear yellow-white, while the thinnest portions are a deep red.

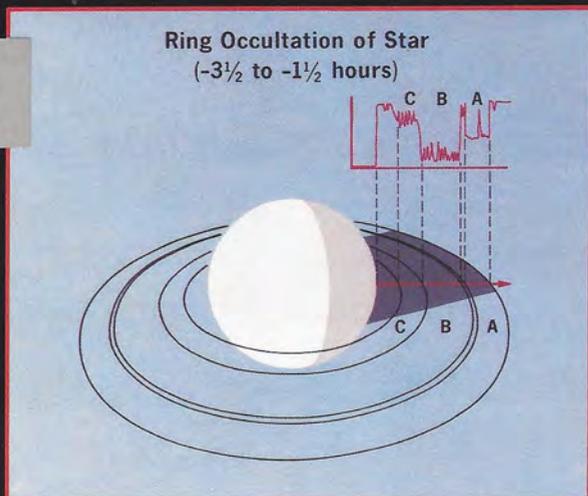
Although we have studied only a small portion of the rings in detail, we have observed many interesting phenomena. The B-ring, considered the thickest ring, did not completely block all the starlight throughout its expanse. The photopolarimeter detected undulations in brightness in several large regions. The computer-generated image (**Figure 5**) reveals many high- and low-density ringlets. Our analysis of these data indicate that "waves" undulate across this part of the B-ring. These spiral waves are similar to those some researchers have proposed to explain spiral structures in galaxies.

The photopolarimeter revealed incredibly fine structure in the F-ring and a myriad of waves across parts of the B-ring. Yet we are still unable to answer many of the questions posed before the *Voyager 2* encounter with Saturn. How many rings are there? Until we know how long the strange ring structures last and how frequently they form, there can be no answer. On August 25, 1981, Saturn was surrounded by several thousand ringlets. Today, it may have more or less. The answers must wait until we return to the Saturn system.

A.L. Lane is the Principal Investigator for the Voyager photopolarimeter, R.B. Pomphrey is the PPS experiment representative at JPL, and L.W. Esposito is a PPS co-investigator at the Laboratory of Atmospheric and Space Physics at Boulder, Colorado.

TURN THE PAGE FOR DISPLAY OF FIGURES MENTIONED IN THIS ARTICLE

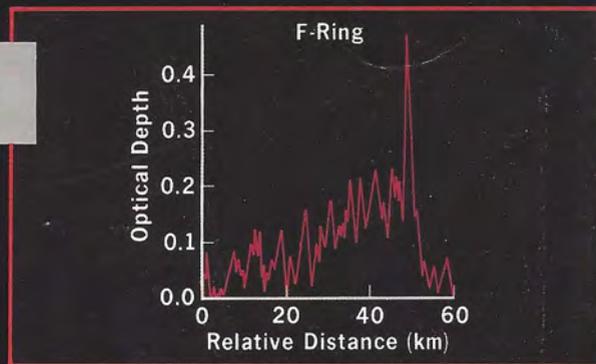
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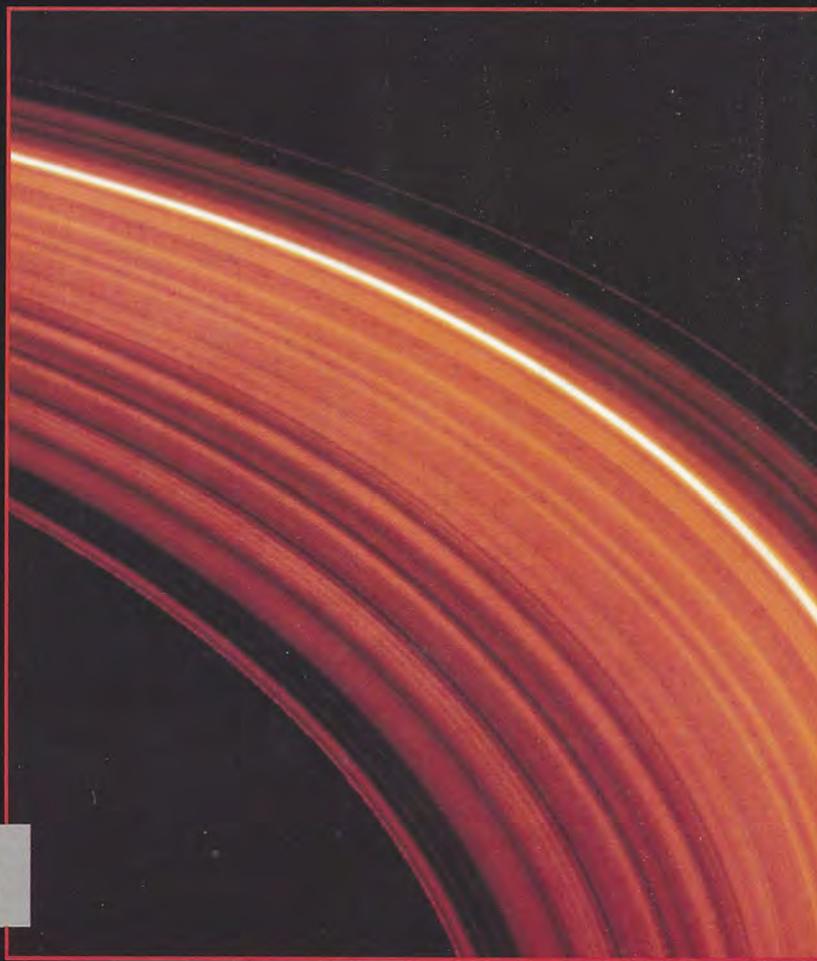
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3a



3b

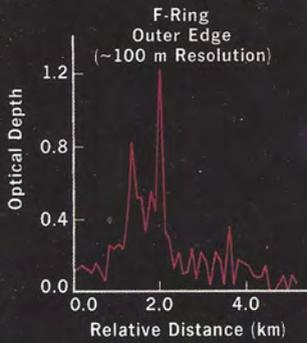


1 This diagram shows the apparent path of Delta Scorpii behind Saturn's rings, as viewed from the Voyager 2 spacecraft just before its closest approach to Saturn. The star emerged from behind the dark limb of the planet, then "moved" radially across the C, B, A, and F-rings. The red line graph shows an artist's conception of the observed intensity of starlight as the various rings attenuated the transmitted light by differing amounts.

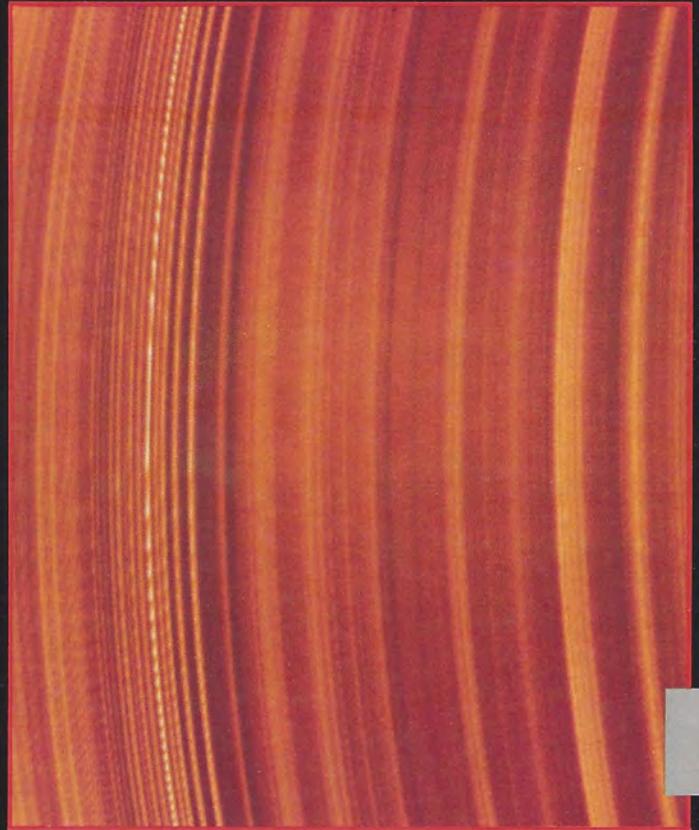
2 This Voyager 2 image of the F-ring was taken near the time of the photopolarimeter starlight occultation experiment. The PPS data for the F-ring discussed in this report cover only the region of the single bright ringlet. The full four or five ringlets seen in this image measure about seven hundred kilometers across.

3a The PPS measurement of the optical thickness, or amount of material, in the single bright strand seen in figure 2. Individual one-hundred-meter samples were averaged together to form an effective spatial resolution of one kilometer. The peaks in the graph indicate areas of dense material—or ringlets within ringlets.

3b A pseudo-image of the bright F-ring strand seen in figure 2. Computer processing of the PPS data in figure 3a created this "picture" of the F-ring strand; the bright yellow-white color indicates denser material and the red color represents the thinner regions of the ring.



4a



PHOTOS: JPL/NASA

5

4b

4a

A high-resolution examination of the single, dense three-kilometer-wide ringlet in 3a. This data trace, at the highest PPS resolution, decomposes the dense ringlet (the spike in 3a) into two smaller ringlets less than one-half kilometer in width. Scientists still do not understand the forces that produce such fine structure.

5

A pseudo-image of five hundred kilometers of the thick B-ring. The radial undulations in brightness indicate wave-like concentrations of material within the ring. Such phenomena may be caused by the gravitational effects of Saturn's satellites on individual ring particles.

4b

A computer converted the high-resolution data in 4a into a pseudo-image to show the remarkable detail in the brightest F-ring strand.

WASHINGTON WATCH

by Louis D. Friedman

Last October, proposed cuts to the federal budget seemed to be threatening the very existence of the planetary science program. The reaction against such cuts was vigorous. President Reagan and Edwin Meese III (who was responsible for the budget review) received thousands of letters in support of continued exploration. Newspapers and magazines throughout the country published editorials lauding past achievements in planetary science and decrying loss of the resolve that has carried us so far in our exploration of the solar system.

At one point, rumors spread that NASA was going to shut down the *Voyager* spacecraft, close the deep space tracking network, and would not even

tune in as *Voyager 2* passes Uranus in 1986. Although we hardly believed that *Voyager* was really in danger of being abandoned, the threat to future planetary exploration was very real and remains so.

The President's budget proposal for Fiscal Year 1983 will be presented to Congress following his State of the Union address on January 20, 1982. The administration's commitment to planetary exploration will be shown by the support they provide for the Galileo mission. There will be no new starts for missions, but support for the 1985 Galileo mission to Jupiter is absolutely necessary to maintain a minimum effort in U.S. solar system exploration while the NASA program is re-defined

and restructured.

The President's budget will first be reviewed by the Senate and House Budget Committees. They will then recommend a figure for the next NASA budget, based on information supplied by the Authorization and Appropriation Committees in both Houses. Following Budget Committee action, the House and Senate Authorization Committees will hold hearings on the NASA budget. These hearings will probably begin in February and continue through March, as the Congressional committees take testimony from both NASA and public witnesses about the state of the space program and plans for its future. Policy, as well as budget issues, will be discussed, especially regarding the future of the space shuttle and its domination of the NASA budget.

The Appropriation Committees in both the House and Senate will also hold hearings about the NASA program, probably in April, and will pass their final recommendations for Congressional action. For a particular program or project to be approved, it has to receive the approval of all six of the Congressional committees involved with the NASA budget. Debate on the budget can also occur on the floor of either the Senate or the House, although most issues are settled in committee hearings and conferences among the committees.

In the next issue of *The Planetary Report* we will provide a detailed look at the course of the budget through Congress.

Louis Friedman is Executive Director of The Planetary Society.

Soviet SETI Conference

The Soviet Union held an international conference on the search for extraterrestrial intelligence (SETI) in December, 1981. The meeting was in Estonia, USSR, and many scientists from the United States were invited.

Because of federal budget cuts, it appeared that many American scientists would not be able to attend this meeting. Consequently, The Planetary Society arranged for private funding. In addition to supporting two scientists directly, we arranged for the Alfred P. Sloan Foundation to provide \$10,000.

Scientists from the U.S. who were invited to attend included The Planetary Society's President, Carl Sagan, and Vice President, Bruce Murray, as well as Society Advisor Bernard M. Oliver, of Hewlett-Packard Corp., and Harvard physicist Paul Horowitz, whose SETI research recently received support from the Society. Also invited were Samuel Gulkis of the Jet Propulsion Laboratory and Jill C. Tarter of the University of California at Berkeley.

—Thomas R. McDonough

Planetary Society and DPS Join Forces

At the recent meeting of the Division for Planetary Sciences (DPS) of the American Astronomical Society, officers of The Planetary Society and the DPS made plans to work closely together to focus national attention on planetary exploration. Immediately, the letter reprinted on page 11 was sent to Edwin Meese III, special counselor to President Reagan, signed by representatives of both organizations.

The letter was promptly answered by Mr. Meese, who reiterated administration support for space exploration. Mr. Meese also said that he would share our concerns with the President.

In another effort, the DPS agreed to supply speakers for various Planetary Society events around the country. This will help the Society realize its goal of sharing the results of deep space exploration with its members, and will bring the general public closer to the scientists actually involved in the planetary program.

**THE FOLLOWING LETTER WAS SENT TO THE WHITE HOUSE BY
THE PLANETARY SOCIETY AND THE DIVISION FOR PLANETARY
SCIENCES OF THE AMERICAN ASTRONOMICAL SOCIETY**

Mr. Edwin Meese
Special Counselor to the President
The White House
Washington, DC 20500

Dear Mr. Meese:

We are writing out of deep concern for the future of this nation's commitment to the exploration of the solar system—an extraordinary technological triumph in which American spacecraft have visited, for the first time in human history, forty new worlds. Our two organizations represent a part of the professional and public constituency of planetary exploration: approximately one thousand scientists engaged in planetary research, and one hundred thousand other citizens who have joined The Planetary Society during the past year because of their commitment to planetary exploration. The Planetary Society is, in fact, the fastest growing membership organization of any sort in America over the past decade.

We recognize the efforts being made to reduce unnecessary federal spending. But we also recognize that there are some activities that can only be supported by the federal government, and that are critical to our national and global future. Much of basic scientific research represents just such a critical area. Planetary exploration is on the leading edge of our efforts to advance high technology and to increase our understanding of the Earth and its place in the universe. In two decades, we have developed a unique capability to send sophisticated robot vehicles to the farthest reaches of the solar system. The pioneering accomplishments of the Vikings and Voyagers and their predecessors have captured the interest and imagination, not only of millions of Americans, but of multitudes around the world. Even those dubious about the policies of the United States have acknowledged the benign influence and technical leadership represented by this endeavor. It is hard to think of another federal program that has been so successful in accomplishing its goals, or so generally recognized as positive in its effects. It is an example of what we do best.

If we back off from the enterprise of the planets, we will be losing on many levels simultaneously. By examining other worlds—their weather, their climate, their geology, their organic chemistry, the possibility of life—we calibrate our own world. We learn better how to understand and improve the Earth. Planetary exploration is an activity involving high technology which has many important applications to the national and global economy—robotics and computer systems being two of many examples. It uses aerospace technology in an enterprise which is a credit to our nation, our species and our epoch. And planetary exploration is an adventure of historic proportions. A thousand years from now our age will be remembered because this was the moment when we first set sail for the planets.

In the decades of the 1960's and 1970's, dozens of American missions were launched to the Moon and the planets. For the decade of the 1980's at most one such launch has been approved, and even it is in jeopardy. We write to ask your support to ensure the survival of planetary exploration in the United States. Survival truly is at stake, because once the engineering teams are dispersed, the scientists demoralized, and the facilities closed or redirected to other functions, it would take many years and a great deal of money to return us to our present capabilities. The minimum level of effort essential for such survival is to complete the Galileo orbiter and probe for launch to Jupiter in 1985, to approve at least one other new planetary mission for launch in this decade, and to maintain the base support for science and engineering necessary to revitalize the program when a stronger economy can support it.

We and millions of Americans will appreciate any help you give to the enterprise of the planets.

Sincerely,



CARL SAGAN, President, The Planetary Society



DAVID MORRISON, Chairman, American Astronomical Society, Division for Planetary Sciences

A Report from the Division for Planetary Sciences

by Jon Lomberg

From October 13 to 16, 1981, the Division for Planetary Sciences of the American Astronomical Society held its annual meeting in Pittsburgh, Pennsylvania. Several hundred planetary scientists gathered to hear papers and discuss results from spacecraft and ground-based observations of solar system objects and phenomena.

Radar Echoes From Asteroids

Three astronomers using the Arecibo observatory in Puerto Rico have been bouncing radar signals off the asteroids Iris, Psyche, Klotho, Apollo and Quetzalcoatl. Steven J. Ostro of Cornell University, Irwin Shapiro of the Massachusetts Institute of Technology, and Don Campbell, director of the planetary radar facility at Arecibo, have used the radar echoes to deduce the sizes, shapes, compositions, rotations and orbits of these tiny planets.

The observations revealed that the asteroids have extremely rough surfaces, more rugged than closely-studied areas of the Moon, Mars or Venus. Quetzalcoatl is a hunk of rock about the size of the Empire State Building, while Iris and Psyche are closer in size to New Jersey. The radar reflectivity of these objects suggests they are a mixture of rocky and metallic material, rather than pure nickel-iron like many meteorites that fall to Earth. These meteorites cannot have come from asteroids like these, so their origin remains a mystery.

Traveling at light speed, the radar echoes took almost one-half hour to make the round trip to Psyche, the most distant of the observed asteroids. Only 55 and 90 seconds were needed to make the round trips to Apollo and Quetzalcoatl, respectively. These two asteroids, and hundreds of others, pass so close to Earth that there is a good probability of a collision between our planet and an asteroid sometime within the next hundred million years. Luis Alvarez and his colleagues have hypothesized that such a collision may have caused the extinction of the dinosaurs and many other species 65 million years ago. Clearly, precise measurement and calculation of these orbits is very important. Asteroid radar astronomy is of more than academic interest.

Lava Flows on Io

The discovery of active sulfur volcanoes on Io, the innermost large moon of Jupiter, was one of the high points of the *Voyager 1* mission. *Voyager 2*'s "volcano watch" revealed several other active volcanoes on Io's surface and evidence of many dormant ones. Giant plumes were seen shooting ejecta hundreds of kilometers above the moon. Surface features changed in the four months between the two spacecrafts' encounters. The active sulfur vulcanism was changing the face of Io right before our eyes.

Early analyses indicated that the ejecta from the plumes were modifying the map of Io. Now David Pieri, of the Jet Propulsion Laboratory, is suggesting that sulfur lava flows, rather than ejecta, play the dominant role in surface modification. Pieri has investigated liquid sulfur lava flows and found that they behave in a manner that seems to counter common sense. On Earth, molten silicate lava gets thicker and more viscous as it cools. Sulfur lava does the reverse—it is thickest and more viscous when very hot and gets thinner as it cools. Falling just one-half degree below 161 degrees Centigrade, the liquid sulfur transforms, in Pieri's words, "from the consistency of cold molasses to the consistency of hot 3-in-1 Oil." The sluggish, cooling lava will suddenly run fast and free, burying and eradicating existing land forms. By mathematically modeling the rate at which sulfur cools and flows, Pieri has determined that flowing sulfur lava plays the dominant role in modifying the face of Io.

More Ring Mysteries

Before spacecraft visited Saturn, astronomers had thought the planet was surrounded by four or five broad, flat rings. Then, in 1979, *Pioneer 11* discovered the slender F-ring outside the main ring system. Just over a year later, *Voyager 1* revealed that the Saturnian rings consisted of hundreds, perhaps thousands, of individual ringlets, which looked like the grooves on a phonograph record.

Explaining this structure has been difficult. Many scientists hypothesized that moonlets, embedded in the rings, could sweep out clear lanes and con-

fine ring material to narrow bands between the moonlets. *Voyager 1* had discovered two small "shepherding" satellites, one on either side of the F-ring, and some scientists took this as a model to explain other rings and gaps.

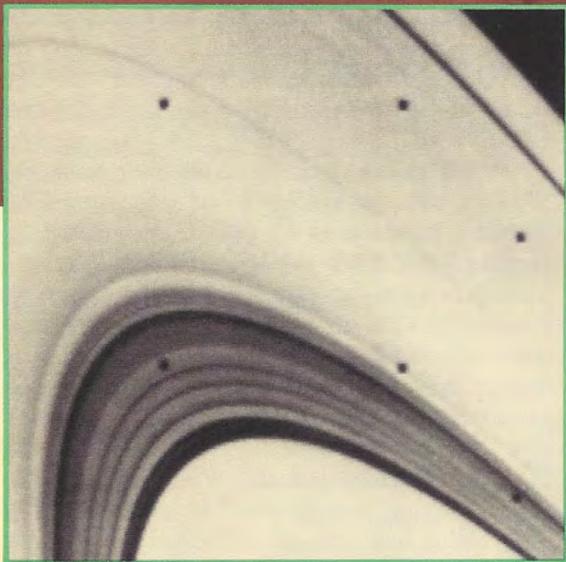
Voyager 2 undertook a careful search for small moonlets within the rings, reports Jeffrey Cuzzi, a member of the *Voyager* Imaging Team from Ames Research Center. *Voyager 1* had discovered a number of ringlets within the Cassini Division, a relatively "empty" gap between the A- and B-rings. Photographs of a section of the Cassini Division were taken at selected time intervals, then lined up vertically, like the rungs on a ladder. Any moonlet within the Division would have to be orbiting at a speed that could be calculated by the known laws of orbital mechanics. Scientists calculated how far any moonlet should have moved along its orbit from photo to photo. The photos were then offset from each other by this calculated distance, so any moonlet would appear in the same position in each photo, forming a vertical line of dots that would be easy to spot.

No moonlets were detected. Cuzzi has concluded that there are no moonlets ten kilometers in diameter or larger in the Cassini Division. The slender ringlets must be confined by some other means, still unknown at this time.

The Clouds of Titan

In the early 1950s, Harold Urey and Stanley Miller simulated planetary atmospheres in laboratory jars, added energy from shock waves, light or electrical discharges, and watched what was produced. They found that complex organic molecules, including protein-building amino acids, can easily be made in this way. Since then, many researchers have elaborated on these experiments. Carl Sagan and Bishun Khare, of the Laboratory for Planetary Studies at Cornell University, have synthesized a whole class of substances that Sagan has dubbed "tholins," from the Greek for "star tars." Some reddish-brown tholins may be related to the material that gives Jupiter's Great Red Spot its color.

Now Sagan and Khare have made some new tholins. Using data from *Voyager 1*, they mixed nitrogen and



The surface of Io, Jupiter's innermost Galilean satellite, is continually re-formed by active sulfur volcanoes (above). From their early analyses, scientists believed that material ejected by volcanic plumes was changing the face of the moon. Now, David Pieri of JPL suggests that sulfur lava flowing from volcanoes (top of photo) is the dominant surface sculptor.

Before Voyager 1 visited Saturn, astronomers believed the Cassini Division was a large, empty gap between the A and B-Rings. But scientists discovered a number of slender ringlets in images returned by the spacecraft (left). Thus, Voyager 2 was programmed to search out small moonlets that might be confining the ring material into ringlets, but none were detected.

methane in the same proportions found in the Titan atmosphere, and sparked the mixture with electrical discharges for several months. A thin red film formed on the walls of the Titan Jar. Analysis of this tholin material shows that it is a very close match in particle size and spectral reflectivity to the material observed in the clouds of Titan.

Voyager scientists suspect that organic material might be produced in Titan's atmosphere—and the spacecraft did detect certain hydrocarbons.

Sagan and Khare's tholins may duplicate organic material found on Titan. Although detailed analysis is not yet complete, Sagan does say that their tholins are probably "polynitriles," a class of organic molecules that have nitrogen bonded with carbon and hydrogen, permitting very complex molecular structures. Since Titan is, by turns, bombarded by the solar wind and shielded by Saturn's magnetosphere, varying kinds of charged particles hit its atmosphere, providing an energy source analogous to the elec-

trodes in the Earth-based Titan jars.

Within the solar system, Titan's atmosphere is most like the Earth's in composition and pressure, and scientists have speculated that biologically interesting molecules could be found on this Saturnian moon. Since a sample return mission to Titan is highly unlikely in the near future, Sagan and Khare's work is the next best thing to being there. In Sagan's words, "We may have bottled the clouds of Titan."

Jon Lomberg is a freelance journalist and artist working in Toronto, Ontario.

Society Notes

by Louis D. Friedman

The Planetary Society has just passed two milestones: we have completed our first full fiscal year, and our membership has topped 100,000. We are now the fastest growing membership organization in the country. Individual membership dues and donations provide most of our income and we plow nearly all of that back into continuing membership drives and publication of *The Planetary Report*. These individual contributions will always be the financial base of The Planetary Society. In our first year and a half, our business costs have increased approximately 15 percent, but we hope to keep our dues at their current low level. To fund special projects, expand information services, and continue to meet expenses, we will have to rely on additional donations.

We were surprised, but pleased, that during our first year we could produce a program such as Planetfest '81, begin a lecture series, sponsor conferences, offer pictures and books to members, and, best of all, begin to fund important research and development activities such as SETI.

The Halley-SETI Appeal

Last June we sent a special appeal to members for funds to encourage a U.S. mission to Halley's Comet and to

finance a project in the search for extraterrestrial intelligence (SETI). Planetary Society members showed their interest and support with contributions of over \$70,000. We immediately turned the Halley's Comet money into an all-out effort to generate publicity about the mission, and to attract the attention of Washington policy makers. Society members sent more than 10,000 letters to the White House. According to NASA, 99 percent of the mail received about space last summer was in favor of the Halley mission. Yet the pleas fell on deaf ears, arriving as the administration was proposing the newest round of budget cuts to the space program. The letters were ignored by the White House staff, boxed up and shipped to NASA—and they have not yet been answered.

Work on the U.S. mission to Halley's Comet was stopped. And while we did not see the mission initiated, our effort did catch the attention of the budget makers and may have contributed to the successful efforts to save the planetary program from further cuts, perhaps even from cancellation.

In the last issue we reported the beginnings of our SETI projects. News media around the country picked up the story of Planetary Society funding for new equipment to speed up the search. We are continuing our SETI activities by arranging for private funds for American participation in an international SETI conference (see page 10).

Louis Friedman is Executive Director of The Planetary Society.

This summarizes The Planetary Society's finances for the Fiscal Year Ending September 30, 1981

INCOME STATEMENT/Fiscal Year Ending September 30, 1981

DEPARTMENT	INCOME	EXPENSES
Office	\$ 13,690	\$ 113,282
Membership	806,868	919,450
<i>The Planetary Report</i>	426	145,818
Events & Lectures	49,014	26,080
Special Projects	86,026	19,476
Planetfest '81	183,475	184,562
Sales	52,843	38,141
TOTALS	\$1,192,343	\$1,446,812

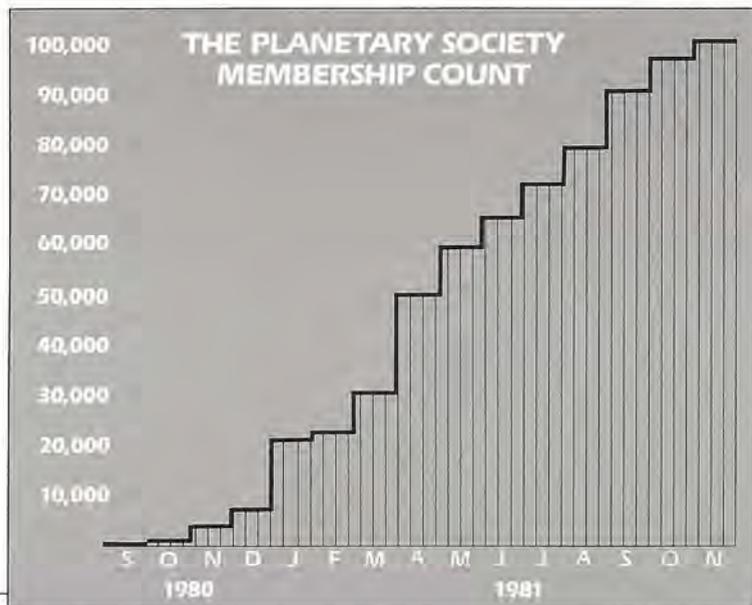
BALANCE SHEET/Fiscal Year Ending September 30, 1981

ASSETS	
Cash (Checking & Savings)	\$ 108,536
Receivables	105,000
Prepaid expenses	2,725
Inventory	6,682
Office equipment (net)	3,425
TOTAL ASSETS	\$226,368

LIABILITIES & CAPITAL

Accounts payable	\$ 174,852
Notes payable	7,500
Deferred revenue	320,106
Total Liabilities	\$ 502,458
Retained earnings	\$ 21,621
Excess of expenses over income	254,469
Total Capital	\$ 276,090
TOTAL LIABILITIES & CAPITAL	\$226,368

The excess of expenses over income arises by accounting our dues as deferred revenue (income spread out over the year). Membership income in 1981 was \$806,868 plus \$320,106 of deferred revenue.



THE SOLAR SYSTEM IN PICTURES AND BOOKS

Available from The Planetary Society

● FULL COLOR PHOTOGRAPHIC REPRODUCTIONS (8½" x 11")

	PRICE	QUAN.	TOTAL
The Rings of Saturn (set of 5 <u>Voyager 1</u> prints)	\$ 9.50		
Satellites of Saturn (set of 5 <u>Voyager 1</u> prints)	\$ 9.50		
Approach to Saturn (set of 5 <u>Voyager 1</u> prints)	\$ 9.50		
All Three Sets (15 <u>Voyager 1</u> prints)	\$23.00		
Voyager 2 Saturn Encounter (set of 10 prints)	\$14.00		
Photo-Montage of The Saturn System	\$ 2.00		

● 35MM SLIDE SETS

Voyager 1 Saturn Encounter (20 slides with analysis report)	\$15.00		
Voyager 2 Saturn Encounter (20 slides with analysis report)	\$15.00		
Voyager 2 Saturn Encounter (40 slides with sound cassette)	\$18.50		
Viking 1 & 2 at Mars (40 slides with sound cassette)	\$18.50		
Voyager 1 & 2 at Jupiter (40 slides with sound cassette)	\$18.50		

● VOYAGER COLOR POSTERS

Voyager at Jupiter (Six 23" x 35" posters)	\$16.00		
Voyager 1 at Saturn (Two 11" x 17" mini-posters)	\$ 6.50		
Voyager 1 at Saturn (Five 23" x 25" posters)	\$16.00		
Planetfest '81 (Two 23" x 25") (Saturn and the F-ring)	\$ 8.00		

● BOOKS

	PRICE	QUAN.	TOTAL
Voyage to Jupiter , by David Morrison and Jane Samz – Description of the <u>Voyager</u> encounters with Jupiter, illustrated with color photographs.	\$ 9.00		
Pioneer: First to Jupiter/Saturn and Beyond , by Richard O. Fimmel, James Van Allen and Eric Burgess – Complete description of two Pioneer missions, illustrated.	\$14.50		
Beyond the Atmosphere , by Homer E. Newell – History of the United States space program.	\$12.00		
Voyager 1 Encounters Jupiter – A colorfully illustrated booklet describing the <u>Voyager</u> mission to Jupiter.	\$ 4.50		
Voyager 1 Encounters Saturn – An illustrated booklet with many of the best pictures from the Saturn encounter.	\$ 4.50		
Mars and the Mind of Man – Illustrated results of the Mariner 9 mission, with commentary by Ray Bradbury, Arthur C. Clarke, Bruce Murray, Carl Sagan and Walter Sullivan.	\$10.00		
The Planets: A Cosmic Pastoral , by Diane Ackerman, A collection of poems about the planets.	\$ 4.00		

● PLANETFEST '81 SOUVENIRS

T-shirts (Adult sizes – S, M, L, XL)	\$ 7.00		
Buttons	\$ 1.00		

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BAJADA CHUBASCO—This could be a scene on another planet—or the Earth sometime in the future—if our planet were to capture a wandering asteroid to companion the Moon. Artist Kim Poor named his landscape after the Bajada, a desert terrain of eroded mountains surrounded by sloping aprons of sediment, and the Chubasco, a brief, powerful thunderstorm that occurs frequently over the Sonoran desert.

Kim Poor is a freelance artist from Tucson, Arizona. His work has appeared in Discover, Science Digest and the L-5 News.

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