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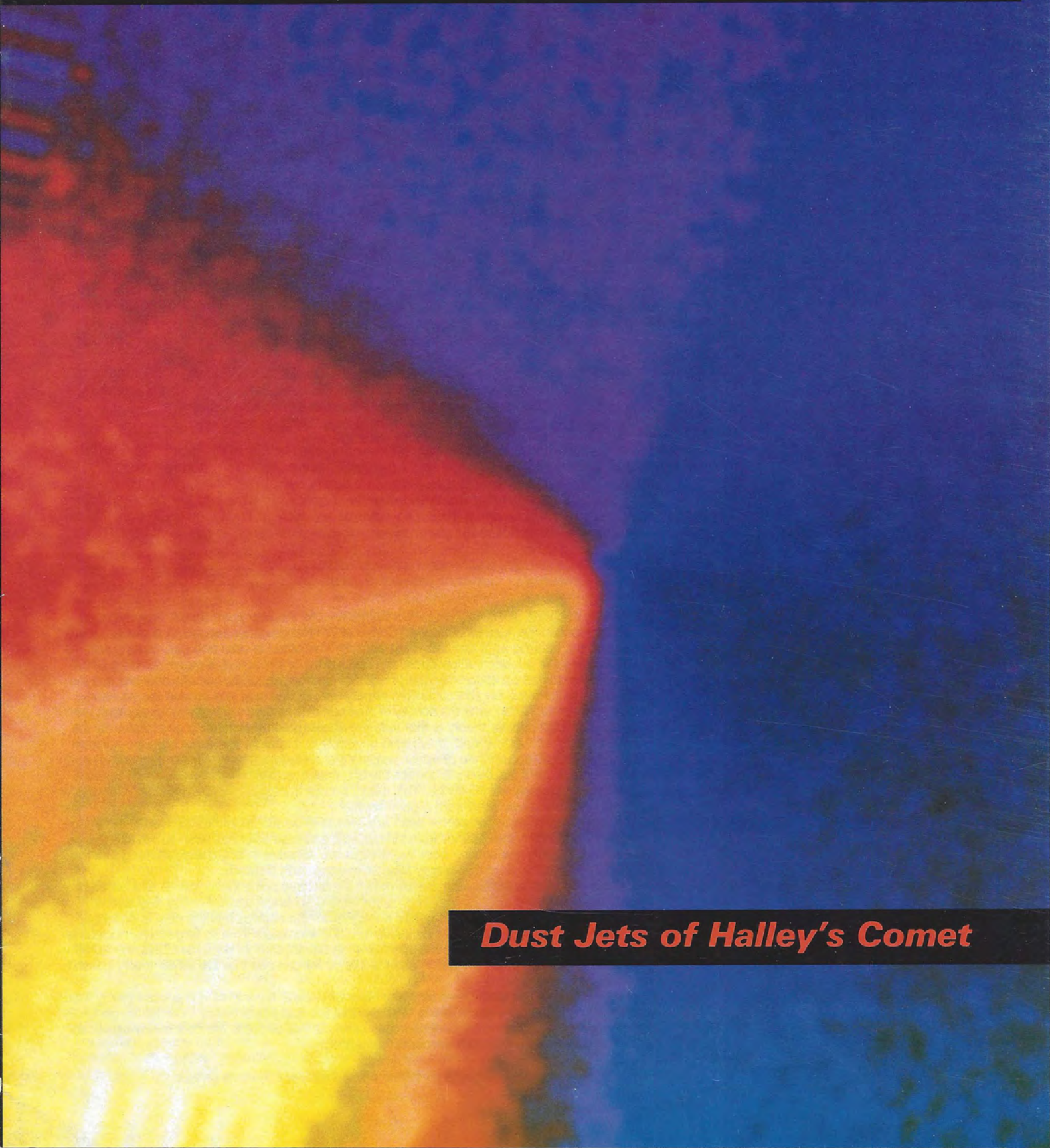

Dust Jets of Halley's Comet

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We encourage our members to write to us on topics related to the goals of The Planetary Society: Continuing planetary exploration and the search for extraterrestrial life. Address them to: Letters to the Editor, 65 N. Catalina Avenue, Pasadena, CA 91106.

1987 National Merit Scholar Announced

MARY R. CHRISTY of Poplar Bluff Senior High School in Poplar Bluff, Missouri has been selected as The Planetary Society's National Merit Scholar for 1987. Each year the Society presents one of these prestigious scholarships to an outstanding high school student who plans to major in one of the disciplines that make up the planetary sciences. Mary is planning to attend Washington University in St. Louis, Missouri. She is not only interested in science, but also plays flute and piano and has participated in many extracurricular activities.

Merit Scholarships are awarded for four years. The Planetary Society is continuing to provide support for our previous Merit Scholars, Sylvanie Wallington, who is attending Princeton University, and Douglas O'Neal, who is at Penn State University.

We would like to share Ms. Christy's thank you with our members:

I wish to thank The Planetary Society for awarding me The Planetary Society Merit Scholarship. I am very honored. I hope that I can fulfill your expectations and my own at Washington University in St. Louis. Since I am a member of The Planetary Society myself, the scholarship means that much more to me. I believe in what you are doing and hope that some day I will be doing research worthy of an article in The Planetary Report. *Thank you again for the scholarship and for your show of confidence in me. — MARY CHRISTY*

COVER: THE DUST JETS OF HALLEY'S COMET — As the European Space Agency probe *Giotto* approached the nucleus of Halley's Comet at 68 kilometers per second, dust and gas were pouring off the nucleus at .9 kilometers per second. This cloud of dust and gas, moving with 10 times the speed of a hurricane, produces the famous tail of the comet. Images taken by *Giotto* and the Soviet *Vegas* will allow scientists to test their theories about the comet's dust jets and the processes that form the tail and coma (the atmosphere of dust and gas around the nucleus).

One dust jet theory concerns the density of dust particles as they are propelled away from the nucleus. The most popular theory is that they are accelerated by expanding gas heated by the Sun. Once they are up to speed, they move uniformly in a straight line away from the nucleus. This motion should occur in the area surrounding the nucleus where the force of solar radiation pressure is minimal. If this theory is correct, the brightness caused by light scattering off the dust should fall off inversely with distance. This theory comes from geometrical arguments about how particles uniformly move away from a point source.

This image of Halley's Comet has been adjusted to show the fall-off. Each point in the image has been multiplied by the distance from the nucleus, and false color has been added to enhance the contrast. Radial lines coming from the nucleus are constant in brightness, showing that the brightness — and therefore the dust — falls off inversely with distance.

The theory holds, assuming the dust comes from a single point, that it travels at a constant velocity away from the nucleus and that the particles don't break apart. For the dust density theory, these assumptions should hold far enough from the nucleus that the dust is no longer accelerating. This image was taken by *Giotto* 150,000 kilometers from its target. The nucleus is small, about 15 by 6 kilometers, so it is approximately a point source. Because of this, the fall-off theory holds for most of the image. In other displays, we can see that the fall-off theory doesn't hold close to the nucleus.

Now, what does this fall-off inversely with distance mean? It confirms a proposed theory that was based on reasonable assumptions. It shows that the dust jets of Halley's Comet are generally well behaved. There are no mysterious forces or winds that disperse the dust in any significant way. The observed dust distribution confirms the theory.

Image processing and caption by Andy Williams, Ball Aerospace Systems Division

Questions & Answers

Why was the* Voyager 1 *spacecraft expended after its encounter with Saturn? Wasn't it possible to put the* Voyager *in an orbit around Saturn to make it an orbiter instead of a flyby mission?
— Maziar Shirakh, Sacramento, CA

It was not possible to insert *Voyager 1* into a captured orbit at Saturn. The spacecraft approached this planet with a substantial speed and such a capture would have required a velocity change of about five kilometers per second. On the other hand, the spacecraft's propulsion system was only capable of delivering a velocity increment of, at most, 100 meters per second, which is 50 times too small. However, this shortfall should not be viewed as a performance deficiency, as *Voyager 1* was never intended to orbit Saturn.

The scientific investigations of the *Voyager 1* spacecraft did not cease with its flyby of the saturnian system in November 1980. Although that was the last planetary flyby for this spacecraft, it continues to travel to the outer reaches of the solar system, returning useful data all the while.

Of the four spacecraft escaping the solar system, that is, the two *Voyagers*, *Pioneer 10* and *11*, *Voyager 1* is the one most likely to cross the heliopause while still in operation and communicating with controllers on Earth. The heliopause is the boundary between the space of the solar system, which is dominated by the magnetic field of our Sun, and the true interstellar space of our galaxy. Scientists are very interested in crossing this boundary with an operating spacecraft, as it would give them the first-ever direct sensing of the environment of interstellar space.

As an additional note, barring catastrophic failure of some essential onboard equipment, *Voyager 1* should be able to maintain communications until around the year 2013 at which time it will be about 120 Astronomical Units from the Sun (an Astronomical Unit is about 150 million kilometers or the average distance between Earth and the Sun).

— ROBERT J. CESARONE,
Jet Propulsion Laboratory

Why are the inner planets pockmarked with many craters, while Earth's craters are few and relatively small in size?
— Stan Kellogg, San Diego, CA

Craters on Earth today are few because Earth is an active planet, with ancient craters being erased by crustal movements and weathering. The same is true, for example, in the northern hemisphere of Mars, while that planet's southern highlands, less disturbed by volcanism and erosion, do preserve the ancient bombardment record. An extreme example of resurfacing is seen on Io, where very few, if any, impact craters have survived that moon's continuing overlay of sulfurous volcanic deposits.

— JAMES D. BURKE, *Jet Propulsion Laboratory*

If you have a question you'd like answered, send it to: *The Planetary Report*, Q&A, 65 N. Catalina Avenue, Pasadena, CA 91106. Please keep the questions short and limit their subjects to planetary exploration and the search for extraterrestrial life.

The* Voyager *spacecraft sent radio signals through Saturn's rings to measure the size of particles in the rings. Assuming all the planets orbit in the ecliptic plane, how are the signals sent to avoid the asteroid belt? Or does the computing analysis consider the debris in the asteroid belt to get meaningful data?
— Chip Coward, Moorestown, NJ

In principle we could perform the same type of radio experiment on the asteroid belt, determining particle sizes and their number density. Solar system objects, however, do not orbit in *precisely* the same plane; and the abundance of asteroids is actually quite low. Many thousands have been cataloged — and there are undoubtedly millions more too small to be seen — but they are spread over a volume that makes them very sparse. Serendipitous detection of asteroids by these radio methods would be very unlikely. The abundance of material in Saturn's rings is much higher. During our 15 minutes of Saturn observation we are confident that the vast majority of occultation signatures are from Saturn and not from objects along the remainder of the path.

There is always the possibility that a large asteroid — or a swarm of small ones — might have wandered into our radio beam during the Saturn experiment. The beam, when it passed through the asteroid belt, had a diameter on the order of 100 kilometers, however. Only an object or swarm of comparable size would have seriously interfered. We have no evidence that such an event took place (100 kilometer asteroids are easily seen from Earth) and we have seen no similar events during those times when the spacecraft was clear of the ring system.

— G. LEONARD TYLER *and* RICHARD A. SIMPSON, *Center for Radar Astronomy, Stanford University*

I have read about "Earth-crossing" asteroids. In this day of computers, hasn't somebody figured out when one might strike Earth? **— Morgan C. Larkin, Palatine, Illinois**

Yes, but only in a statistical sense; it is a certainty that we will be hit by a small object (after all, meteorites continue to fall through our atmosphere). An object forming a one-kilometer crater seems to hit about every 25,000 to 150,000 years; Meteor Crater in Arizona, for instance, is 50,000 years old.

No known asteroid has an orbit that would make it strike Earth within the next few years, but the continuing discovery rate proves that we haven't found all the Earth-crossers. Also, orbits evolve over time, due, for example, to small perturbations from other planets, so the calculations become more inexact as we go farther into the future.

— JAMES D. BURKE, *Jet Propulsion Laboratory*

ILLUSTRATION: S. A. SMITH

Half an Hour

Co

by Roald Z. Sagdeev and Leonid V. Ksanfomality

HALLEY'S COMET HAS COME AND gone, but the lessons it taught us have not been forgotten. Not only did the world learn much more about this periodic celestial visitor, but a group of scientists from many nations learned that people of differing political persuasions can work together toward a common goal. Three space agencies sent five spacecraft to study Halley's Comet: Intercosmos, a consortium of nations led by the Soviet Union, sent Vegas 1 *and 2; the European Space Agency sent* Giotto*; and the Japanese Institute of Space and Astronautical Science sent* Suisei *and* Sakigake. *(See the March/April 1987* Planetary Report.*)*

This unprecedented scientific effort was launched by more than memories of the spectacular 1910 apparition of Halley's Comet. Comets may hold clues to our origins, and so are prime targets for those studying the origin and evolution of our solar system. Most scientists believe that comets are hunks of matter that formed during the birth of our solar system. The heart of a comet is its nucleus, a conglomeration of ice and dust that has remained frozen for most of 4.6 billion years. But when a comet swings by the Sun, heat, sunlight pressure and the solar wind act on its icy heart, melting the ices, releasing the dust and blowing them out into the magnificent tails that make these periodic visitors such long-remembered celestial events.

When we observe a comet from Earth, we almost never see the nucleus. It is wrapped in an atmosphere of gas and dust called the coma. This usually appears as a glowing ball and is the brightest part of the comet. But when most people think of a comet, they think of the tail that can stretch across the night sky. Comets actually have two tails: a dust tail that curves back from the coma with the pressure of sunlight, and a straight plasma or ion tail, blown out by the solar wind. The Vegas *and* Giotto *were after a much more elusive quarry: the nucleus. And each spacecraft returned spectacular images and important data that researchers will be analyzing for the next several years.*

All the missions involved scientists from around the world, but the premier example of international cooperation was the Vega *project. During a time when there were no formal arrangements for cooperative space science between the Soviet Union and the United States, the comet researchers managed to find a way to include an American experiment aboard a Soviet spacecraft. This article tells their story.*
— CHARLENE M. ANDERSON

In March 1986, two *Vega* spacecraft transmitted to Earth the image of the nucleus of Halley's Comet. It was the first time humanity saw the nucleus close up. The results of the numerous other scientific researches performed by the *Vegas*, the European Space Agency's *Giotto* and the Japanese *Sakigake* are flowing out in popular and scientific articles and professional conferences.

Soon it will be the 30th anniversary of the first spacecraft, *Mechta* (dream) also called *Luna 1*, ever launched toward another celestial body. Nowadays spacecraft are able to perform much more complicated multipurpose programs. *Vega* was precisely this sort of mission.

The abbreviation *Vega* for Venus-Halley (*Ve*nera is Russian for Venus, *Ga*lley is the transliteration of Halley) reflected the sequence of goals: the exploration of Venus, then the passage to Halley's Comet and the encounter with its nucleus. (See the January/February 1986 *Planetary Report* for the results of the Venus mission; the March/April 1986 issue for Comet Halley results.)

Before the spacecraft reached the comet, information about the nucleus had to be gathered indirectly; it was obtained from Earth-based observations of the extensive coma (atmosphere of gas and dust) surrounding the nucleus. Many factors would make our exploration difficult: unknown physical phenomena that the spacecraft would find, the fantastic relative speeds of the spacecraft and the comet, bombardment by dust particles, and uncertainty in the comet's trajectory. Extremely complicated celestial-mechanics calculations were required to prove that an encounter with a comet was feasible. And we had to solve unprecedented technical problems.

The preparation for exploring Halley's Comet drew mass media attention. After interviewing an engineer or a scientist, correspondents presented the material to their readers in their own ways, depending on the extent of their understanding. For instance, after interviewing Professor A. Galeev, one of them reported about a new "Galeev comet" — confusing Galeev with Galley. When the idea arose to find an elderly scientist with a sound memory who could well remember the comet's appearance in 1910, it turned out that one of the aspirants was born in 1912.

There were many funny situations, but the development and creation of the two *Vega* spacecraft were time-consuming and laborious processes. Finally all the trials came to an end, the days of launch arrived, then the approaches to Venus and, at last, the encounters with Halley's Comet. *Vega 1* reached the comet on March 6, 1986. For the first time, we peered at the heart of a comet.

Early in the morning of March 9, there was a "comet session" with *Vega 2* at the Space Research Institute of the USSR Academy of Sciences in Moscow. The spacecraft was plunging through the coma, rapidly approaching the mysterious nucleus. *Vega 2's* radio signals were reaching Earth from 160 million kilometers away. Its route through the coma was over 100,000 kilometers long, but its speed of approach was so great (75 kilometers per second) that it took only half an hour to pass through the coma.

Everyone sitting in the brightly lit room full of monitors and keyboards, pointers and plotters, was united by expectation. The businesslike atmosphere was supplemented with a festive elation shared by the experimenters and the "outsiders." Although not numerous, unauthorized visitors were not to be let in. But several journalists managed to get through the blockade. Now they were rather high-handedly driven away from the tables piled with calibration charts and diagrams, and illuminated by colored flashes of characters and figures on the displays.

But even the experimenters themselves were eager to know what was going on at their neighbors' tables. Only by comparing all the data could one understand the

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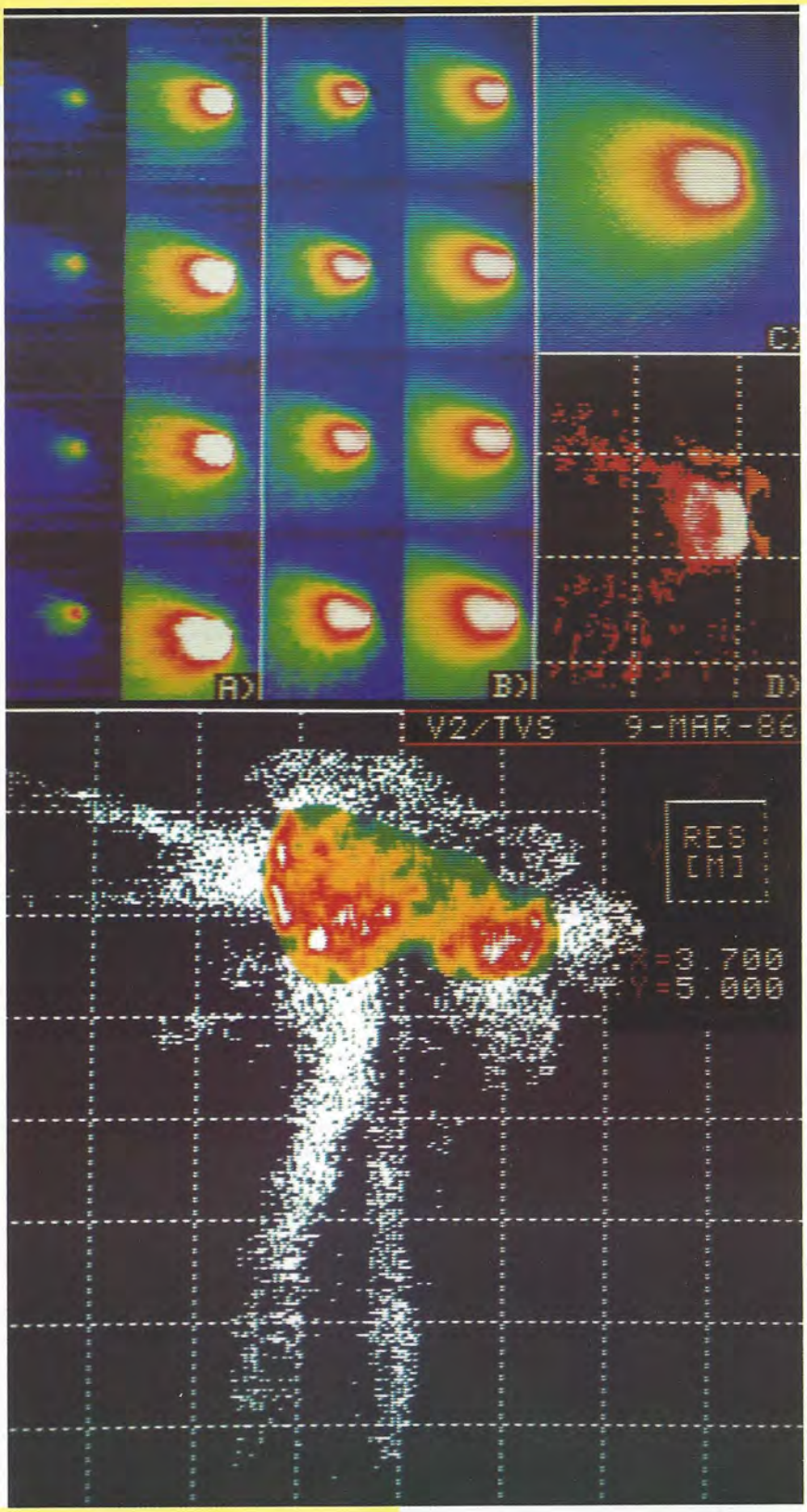
complicated phenomena occurring near the comet's nucleus but not yet seen by anybody.

The nucleus is a giant block of muddy ice; before the encounters we believed it was two to five kilometers across. But processing of the television survey images indicated that it was much larger. The nucleus was an irregularly shaped body looking like an old shoe worn down at the heel. The longest axis of this celestial iceberg was about 16 kilometers.

Once every 76 years Halley's Comet passes by the Sun and then retreats for a long time somewhere beyond the orbit of Neptune. When it approaches the Sun, its surface is heated and evaporation increases drastically. The flows of evaporating gases — first and foremost water vapor — carry away the finest solid particles. Near the Sun, the amount of the ejected matter reaches tens of tons per second.

After thousands of passes, the comet's nucleus may be nearly destroyed. Most of its mass will be ejected in gas jets; dust makes up about one-fifth of the matter ejected. The materials evaporated into

(continued on page 16)



***TOP:** On March 9, 1986, the* **Vega 2** *spacecraft made its closest approach to Halley's Comet. This series of images was compiled from its television data; the colors represent differences in brightness. After extensive computer processing, the shape of the nucleus can be discerned, as seen in the bottom right section (D) here.*

***BOTTOM:** As sunlight heats the icy nucleus, jets of gas and dust erupt from its surface. In this* **Vega 2** *image, the nucleus appears in false color to distinguish it from the white dust jets.*

***Images:** Institute for Space Research, Soviet Academy of Sciences, Moscow*

ABOVE: Academician (and Planetary Society advisor) Roald Z. Sagdeev (center left) chaired the final meeting of the International Scientific Committee on the Vega project.

the vacuum accelerate quickly, up to about one kilometer per second. Ultraviolet solar radiation destroys the molecules of the primary gases released (these molecules may be primordial, formed at the birth of our solar system). The density of the gas diminishes quickly as it leaves the nucleus. At least four factors affect the gas flows: gravity, sunlight pressure, the solar wind plasma and, for charged particles, electromagnetic fields. These factors determine the formation of the coma, the dust tail and the plasma tail. (See the July/August 1985 *Planetary Report*.) Theories predicted some interesting peculiarities for the dust particles' motion. Their trajectories were to look like parabolas, depending on the mass of the particle. The final answers were to be given by the *Vegas*.

Aboard each spacecraft were several instruments specially designed to investigate dust flows: to define the masses, numbers, composition and trajectories of particles. Scientists from many countries prepared these experiments. Here we'll tell about the experiment called DUCMA, which was to register dust particles as small as half of one-thousandth of a millimeter across.

The DUCMA experiment was performed within the framework of scientific cooperation between the Space Research Institute in Moscow and the Enrico Fermi Institute of the University of Chicago. Professor John A. Simpson, the experiment's supervisor from Chicago, described the instrument's sensitivity in this way: The finest dust particles recorded are 10 times as small as those of cigarette smoke. The instrument grades them by mass. The experiment enabled us to define how the particles were distributed with distance from the nucleus.

That morning of March 9, Professor Simpson and his American and Soviet colleagues watched the instrument readings with emotion. Although the spacecraft was closing in on the comet, the instrument still recorded few particle collisions. However, the scientists were ready for that; three days earlier, on March 6, *Vega 1* recorded two main events only 10 minutes before closest approach. Since, for the time being, there were few dust particles, we had time to review how it had all started:

In late 1983, when preparations for *Vega* were in full swing and the engineering model of the spacecraft was ready, Professor Simpson had applied to the Space Research Institute (through West German participants in the project) with a proposal to supplement the completed payload with a new instrument to measure dust particles ejected by the nucleus. His name was widely known for his work on cosmic rays and anti-protons, and about 30 space experiments had been carried out under his guidance.

The idea for the new instrument, developed by Professor Simpson with the help of his colleague Anthony Tuzzolino, was to use an extremely thin film of a polarized polymer, polyvinylidene fluoride, as a detector. Once it is applied, this material can preserve a strong electric field. Materials of this type are called electrets. They are similar to magnets, but they possess a static electric field, not a magnetic one.

The new material proved to be very sensitive, both to mechanical effects and to heat (pyroeffect). Dust projectiles cut into the film and burned out a microscopic volume from it. The film reacts with a voltage inrush on its conductive coating. Researchers in various technological fields have already found many applications for this new material.

All was well with the experiment's physics, but Professor Simpson had to work hard to get official permission from the US government to mount his new instrument on the Soviet spacecraft. Then, in February 1984, a scientific meeting was held in Budapest to specify the experiment's goals and the technical measures needed to "catch up with the train" — to keep up with the spacecraft development program. It was interesting to watch how, an hour after the meeting had started, the ice of formality and distrust started melting among the participants who had met for the first time. We may note that American scientists and engineers always got every kind of assistance, and they were treated with favor and friendliness by their Soviet colleagues during their further work in Moscow through 1984.

At the Budapest meeting, the efforts of scientists and engineers from both countries were joined to prepare the experiment. Engineers from Hungary and the Federal Republic of Germany gave invaluable help. The experiment preparation required another kind of help, as well. The acronym DUCMA stands for dust particle counter and mass-analyzer. However, it could become an actual analyzer only after calibration on a special dust-particle accelerator; the best is located in Heidelberg, FRG. The scientists and engineers of the Heidelberg Institute helped out, and the DUCMA instruments were calibrated for each *Vega*.

But first, the "general's question" had to be settled. After weighing the pros and cons, *Vega*'s scientific management officially decided to include DUCMA in the payload, within a framework of cooperation between the Soviet Academy of Sciences and the University of Chicago. So the Chicagoans joined the scientists from

LEFT: John A. Simpson (right), builder of the dust-counter experiment on the Vega spacecraft, discusses the mission with Fred Whipple (left), developer of the dirty-snowball model of cometary nuclei.

ABOVE: Gordon Lentz of the University of Chicago and the author, Leonid Ksanfomalitiy of the Institute for Space Research, monitor the radio contact with Vega 2.

LEFT: Gordon Lentz and Anthony Tuzzolino of the University of Chicago discuss the data gathered by Vega 2.

IMAGES: Institute for Space Research, Soviet Academy of Sciences, Moscow

nine participating countries.

Preparing DUCMA was not easy. This instrument had to be developed in a very short time, and that could be done only by real enthusiasts, like our guests A. Tuzzolino, M. Perkins and G. Lentz. For example, the number of electrical connectors on the spacecraft, commands and telemetry channels were strictly calculated and fixed, and so could not be changed. Also, there was no free space on board. Nevertheless, we managed to build the instrument into the scientific payload package. Sometimes there were blank spaces — windows — in the telemetry data flow. DUCMA intercepted part of the flow, searched for windows, and filled them with its own data. Other *Vega* experimenters and technical managers rendered great assistance.

By the end of 1984, all preparations were over, and in December the *Vegas* were launched. While passing Venus, the planetary probes were released to their target, and the DUCMA detectors were exposed to space. They started recording sparse interplanetary dust particles, about 10 per month. Their numbers changed only slightly until the spacecraft met the comet.

Thus, on March 9, 1986 the University of Chicago researchers were standing by the display in Moscow, exchanging comments on the rapidly growing particle flow. Professor Simpson recorded the most interesting comments on a portable tape recorder.

Now, five minutes before closest approach, the instruments were registering several projectiles per second, then 20, 30, 50 and more. The instruments showed a peak, then the particle flow went down smoothly. That was very unlike *Vega 1* data, from March 6th, when after the approach the number of particles jumped by 30 times, reaching 1,000 per second. Evidently, *Vega 1* encountered a jet of dust ejected from the nucleus.

Before *Vega 1*'s closest approach, the particle flow had begun to pulsate. Periodically the spacecraft was passing through regions of increased dust density, some 300 to 500 kilometers apart. It was assumed that the pulsations were connected with the jet. Now, with *Vega 2*, there were no pulsations. What had happened? During the three days between encounters, the nucleus had made almost a revolution and a half. It seemed to have an active side and a passive side, and now it had turned its passive side to *Vega* and to the Sun. This was also its position when it was approached by *Giotto* on March 14th.

But the structure of the dust flows was not the only scientific prey of DUCMA. Despite the theoretical predictions, the finest particles found far from the nucleus were the most numerous ones. But some theoretical predictions were immediately confirmed by the experiment.

After encountering Halley's Comet, the DUCMA instruments and the spacecraft were still alive. During the first days of 1987, both spacecraft passed through the comet's tail very far from the nucleus. Again dust particles were recorded, but they then totaled fewer than 10.

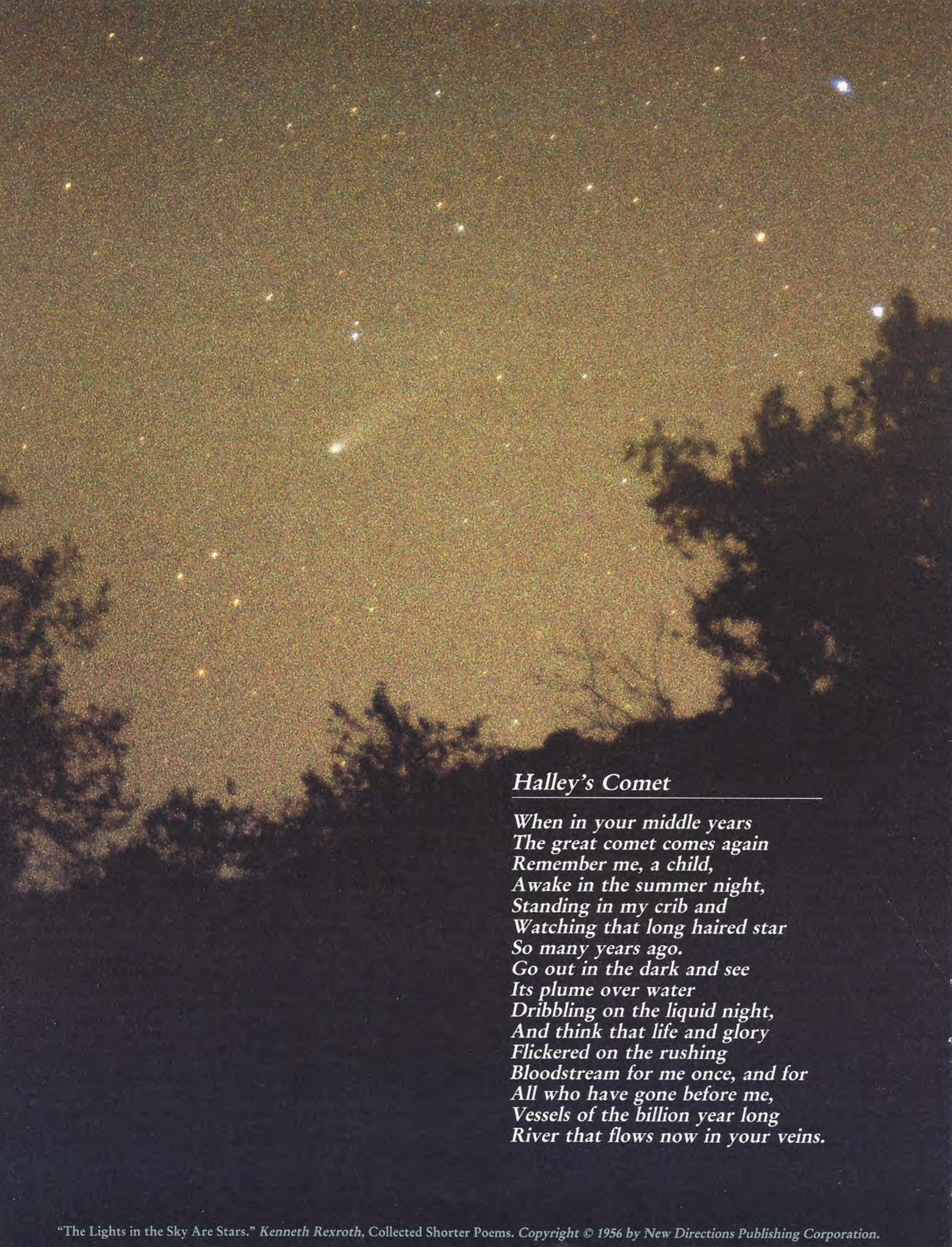
Now, over a year after the encounter, scientists well understand the processes occurring in the comet's nucleus. The results of different experiments promoted better understanding not only when they agreed, but when they contradicted each other as well. For example, as we mentioned, DUCMA noted a very intense jet with a sharp front, but other dust experiments showed much slower growth in the particle count rate. The most probable reason for this discrepancy is in the physics of the comet and the high time resolution of DUCMA.

It turned out that the cometary dust particles have a friable structure similar to that of a snowflake. In such a structure, the separate crystals and needles of the solid matter are weakly fixed to each other, and they occupy only a small part of a particle's volume. Such a particle's density is only 0.1 to 0.4 grams per cubic centimeter (compared to one gram per cubic centimeter for liquid water). Its components may be fixed to each other by hoarfrost.

Under the action of the Sun, the particles soon disintegrate. But the disintegrated microparticles, even if far from the nucleus, still move in a tight group. This was discovered by DUCMA. Many times the recorded impacts were not those of separate particles, but a cluster of 6 to 8, and sometimes 30 particles, with only tens of centimeters between them.

Over 10 articles have been published on the DUCMA results, and many more on other experiments. We now know that the average density of Halley's Comet is less than that of water; its mass is close to 200 billion tons. At its closest approach to the Sun, it loses up to 45 tons every second, 6 to 10 tons of this being dust of a special kind. But the comet can afford such expenditures coming only once in 76 years. It has at least 50,000 years left.

Planetary Society Advisor Roald Z. Sagdeev is Director of the Institute for Space Research, Academy of Sciences of the USSR. Leonid V. Ksanfomality, a Division Leader at the Institute, was chief contributor to DUCMA on the Soviet side.



Halley's Comet

When in your middle years
The great comet comes again
Remember me, a child,
Awake in the summer night,
Standing in my crib and
Watching that long haired star
So many years ago.
Go out in the dark and see
Its plume over water
Dribbling on the liquid night,
And think that life and glory
Flickered on the rushing
Bloodstream for me once, and for
All who have gone before me,
Vessels of the billion year long
River that flows now in your veins.

World Watch

by Louis D. Friedman

BOULDER, COLORADO — On July 18, 1987, The Planetary Society held an extraordinary meeting of Soviet and American scientists and engineers to discuss the possibilities of exploring Mars together. Twenty-four Americans and twenty-four Soviets joined together in a four-hour, satellite-connected "Spacebridge." The participants were divided into three panels — on policy, Mars exploration and mission design. Their discussions covered many topics, including piloted and robotic missions, scientific goals, design of roving vehicles, interplanetary trajectories, long-duration life-support for a crew, adaptation to weightlessness or artificial gravity and the benefits of exploring with robots and humans.

This Planetary Society meeting will be the basis of a PBS television special, "Together to Mars?" which is being produced by Erna Akuginow for Geoff Haines-Stiles Productions and is scheduled to air October 7. Check your local listings for the time. The program is funded, in part, by the Polaroid Corporation and the William and Mary Greve Foundation.

No one had ever held such a meeting with so many participants from both countries. Four major Soviet space institutions were represented. Three Soviet cosmonauts were on the policy panel: Nikolai Rukavishnikov, Svetlana Savitskaya, the first woman to "walk" in space, and Valeriy Kubasov, a veteran of the *Apollo/Soyuz* mission. On the American side, the policy panel included Society President Carl Sagan, Director Thomas Paine, space policy expert John Logsdon and two astronauts: Buzz Aldrin of *Apollo 11* and Joe Kerwin of *Skylab 2*.

Among the meeting's surprises was the Soviets' emphasis on searching for life on Mars. They are planning a series of ambitious missions in the 1990s, and stated unequivocally that they regard the quest for Martian life as a principal goal of those missions. They plan to test the hypothesis that life can exist beneath the surface, protected from high ultraviolet radiation and the oxidizing surface layer. Some American scientists, familiar with the negative (although not definitive) results of *Viking*'s biology experiments, were skeptical of the Soviets' hypothesis. The US emphasis is on the search for extinct life — fossils of forms that may have flourished when Mars was warmer and wetter.

During the mission-design discussions, the Soviets proposed that the two nations work on a joint engineering model of the martian surface that could be used to design landers for future missions. This would, in effect, create an international data bank about Mars. They also suggested that navigational aids, such as radio beacons, be placed on Mars for future landers and rovers.

The policy panel discussed the reasons for exploring Mars and dealt with the sometimes touchy subject of cooperation between the two nations. The participants did not always agree: Arkadiy Strugatskiy, a noted Soviet science fiction writer, dismissed the idea that humans should be sent to explore Mars. But most of the scientists, cosmonauts and astronauts supported human exploration. Many noted that it would be economically and technologically advantageous for both nations to conduct the missions cooperatively. National policy inhibitions and technology-transfer concerns would have to be worked out in any cooperative program. But by almost all standards discussed, the advantages would heavily outweigh the disadvantages.

WASHINGTON, DC — Despite enormous congressional support generated by Planetary Society members, NASA has officially delayed the *Mars Observer* mission until 1992. In mid-April, the space agency ordered the Jet Propulsion Laboratory to stop payment on its contract with RCA for the spacecraft. NASA took this action while Congress was in recess, and when Congress returned to session, it was too late for any intervention to keep the mission on schedule. The House Committee on Science and Technology, under Congressmen William Nelson (D-FL) and Robert Roe (D-NJ), had already put funds for a 1990 *Mars Observer* launch into their budget, but the other relevant congressional committees had not.

However, as a result of the widespread interest in this project, Congress has supported improvements in the mission, including the building of a second *Observer* spacecraft which, if the 1992 launch to Mars goes well, could be used for other missions. Planetary Society officers and some NASA officials feel that public interest in the *Mars Observer* bodes well for future proposals to Congress for Mars exploration.

Although the delay ended any possibility of coordinating with the Soviet 1988 *Phobos* mission to Mars, cooperation with their 1992 Mars mission is now being discussed. The 1992 mission will include an orbiter, with instrument-carrying balloons and perhaps surface penetrators and rovers.

WASHINGTON, DC — On August 17, NASA released a report on new initiatives, developed by a study group led by Dr. Sally Ride. The report proposes four major directions – not necessarily mutually exclusive – for NASA's activities: an intensified and unified study of the planet Earth, exploration of the solar system with major missions to Mars and the outer planets, establishment of a base on the Moon with human crews and a human mission to Mars.

Dr. Ride's group recommended to NASA Administrator James Fletcher that the agency pursue the technological developments that will enable it to carry out the missions, beginning in the early 1990s. Dr. Fletcher indicated that one initiative need not be singled out unless the political leadership wants the agency to embark on a single bold project.

In her statements presenting the report, Dr. Ride emphasized her belief that a lunar base should be the major new thrust in NASA's program. She feels that it would produce important developments in both robotic and human spaceflight that will be necessary for the eventual human exploration of Mars.

BOULDER, COLORADO — In his keynote address to the Case for Mars III conference, NASA Administrator James Fletcher acknowledged the interest in and importance of the goal of the human exploration of Mars, but failed to endorse it as a major national goal. Immediately afterward, *Apollo 11* astronauts Buzz Aldrin and Michael Collins presented Dr. Fletcher with a patch that they had carried to the Moon. They asked that it be given to the first explorers of Mars.

In a stirring speech following Dr. Fletcher's address, Dr. Aldrin stressed the importance of setting difficult goals and endorsed The Planetary Society's "Declaration for Mars," now in preparation. The conference chairman, Thomas Paine (himself a former NASA Administrator), then presented The Planetary Society with his "Mars flag" — an award for those doing the most to advance the cause of martian exploration. (The flag is now on display at our headquarters.)

The Case for Mars III was sponsored by The Planetary Society, the American Astronautical Society, NASA and several other organizations. The technical conference drew hundreds of scientists, engineers and others from around the world who are actively working toward Mars. A special public session featuring Society President Carl Sagan drew a standing-room-only crowd of over 1,500 to the Glenn Miller Ballroom of the University of Colorado at Boulder. The enthusiastic audience gave Dr. Sagan a standing ovation when he declared that the superpowers owe it to the world to devote their tremendous energies to something constructive and explore Mars together on behalf of the human species.

Louis Friedman is the Executive Director of The Planetary Society.

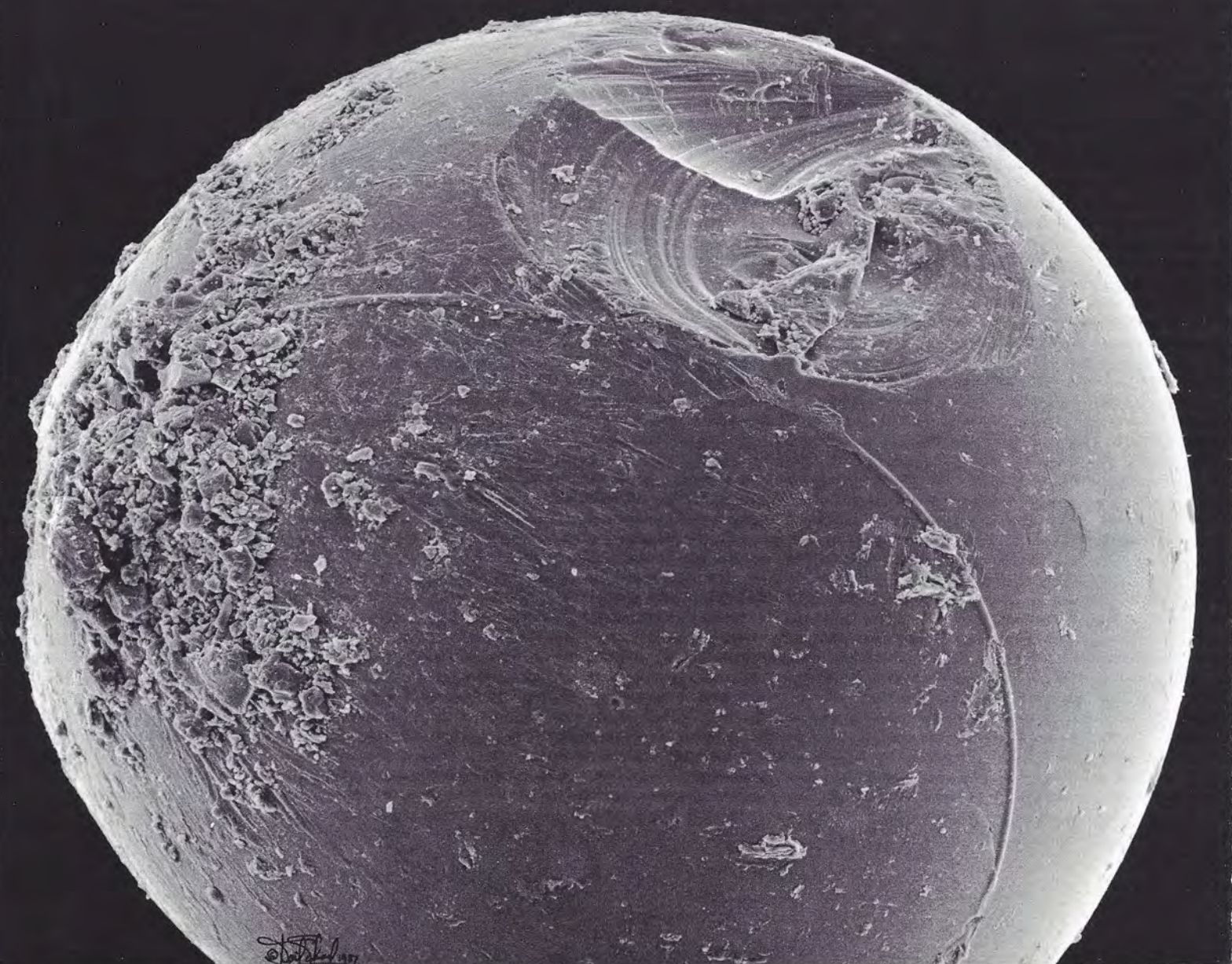
PHOTOGRAPH OF HALLEY'S COMET: LUBOMIR GIZEK

Exploring the Infinitesimal: Photography with a Scanning Electron Microscope

Through the pages of *The Planetary Report*, our readers are used to traveling to giant planets and massive moons — sizeable companions to our Earth in the solar system. When an image of a spherical body appears on our pages, chances are that it's a planet, rendered by a spacecraft or telescopic camera. A landscape is usually safely interpreted as a planetary surface. But the readers who view these pages in such a way will find themselves fooled.

Here we travel to worlds that are alien, not just because of their otherworldly origins, but because they are exceedingly small. Our exploratory vehicle is a scanning electron microscope, handled by the world-renowned photographer David Scharf. The objects visited are bits of moondust and a chip off the Murchison meteorite.

With the help of The Planetary Society, Mr. Scharf obtained his samples from Dr. Samuel Epstein of the California Institute of Technology. As thanks, Mr. Scharf has given these images to *The Planetary Report* for their first publication anywhere. They will soon be part of an exhibition of his work at the Los Angeles County Museum of Natural History, opening in September, 1987.



ABOVE: This alien landscape is actually the surface of a minute glassy sphere found in the moondust collected by the *Apollo 15* astronauts. The origin of such pieces of glass is uncertain, but they may have been formed when parts of the Moon's surface were melted by impacts with meteorites or comets. It is magnified 1,960 times.

LEFT TOP: The 4.52-billion-year-old Murchison meteorite is a carbonaceous chondrite, a jumble of materials left over from the formation of our solar system. It's made up of fragments of different types of rocks — some formed at high temperatures, some at low temperatures — and nonbiological organic matter. This is a minuscule grain embedded within the meteorite, magnified 2,580 times.

LEFT CENTER: The Moon's surface is covered with famous impact craters, such as Tycho and Copernicus, that are easily seen from Earth. It is also covered by craters invisible from Earth, unless they are seen on returned samples with a scanning electron microscope. This impact crater, surrounded by scattered debris and splash marks, mars a tiny grain of dust. The crater is magnified 990 times.

LEFT BOTTOM: Along a fresh fracture surface, strange filaments appear under the scanning electron microscope. What are they? No one knows — yet. They might be splashes of melted material or polymers of organic matter. Here they are magnified 1,100 times.

OPPOSITE PAGE: To an imaginative eye, this might be a planet, but it is really a glass sphere from an *Apollo 15* dust sample. The "mountains" are debris probably stuck to the surface while the sphere was cooling. A splash of molten material could have formed the long, stringy feature. The "crater" is a scar where material cracked off. The sphere is magnified 381 times.

TOGETHER TO MARS? A Pla

The mission design panel on the American side.

Carl Sagan, Joseph Kerwin and Buzz Aldrin of the policy panel.

ON JULY 18, 1987, THE PLANETARY SOCIETY hosted an extraordinary meeting of American and Soviet scientists and engineers, who discussed future Mars exploration over a "Spacebridge" satellite link. This unprecedented event will be the topic of a PBS television special to be broadcast October 7 at 10:00 pm. (Individual PBS stations may vary this schedule; consult your local listings for the week of October 4.)

Here we present some of the scenes and statements from the Spacebridge. This is just a brief peek at four hours of discussion, to give our members a feeling for the event. A complete transcript will be available later this year.

Carl Sagan: People are here with us who explore space, who design spacecraft, who try to understand images of exotic worlds sent back to us by spacecraft; cosmonauts, astronauts and high officials of both space programs. We are linked together today by the same sort of satellite technology that launched the space age. Some members of these panels are still young enough that they might hope, themselves, to voyage one day to Mars. We want to ask: Why are we so interested in Mars? What do we know about it? How can we go about learning more about Mars? Should we send human beings or only robots? Can we *afford* to send human beings? Can we afford *not* to send human beings? And, in particular, what is the obligation of the United States and the Soviet Union, together with other nations, on behalf of the human species in this historically unprecedented concept of human exploration of Mars?

Gary Rogovskiy: I think it is high time to join our efforts by creating an engineering model of Mars. We'd have to have characteristics of the soil, we'd use photometric data and models and so on. If we summarize the problems and our knowledge on Mars, and use the information that will be obtained on further flights, then we will create a model of Mars. In other words, we will have an international data bank on Mars.

Mikhail Ivanov: The question of finding life forms in Mars, in my opinion, is one of the top priority issues of the Mars program, so therefore it seems to me there is no point in waiting to send man to Mars. We ought rather to be thinking about new programs for the quest for life on Mars by sending robots. One main target should be the subsurface horizons of the soil, various types of solutions in rocks that might be a suitable environment in which to look for life. These ecosystems on Earth are inhabited quite densely and quite constantly. The question of the existence of possible oases on Mars should not be ruled out.

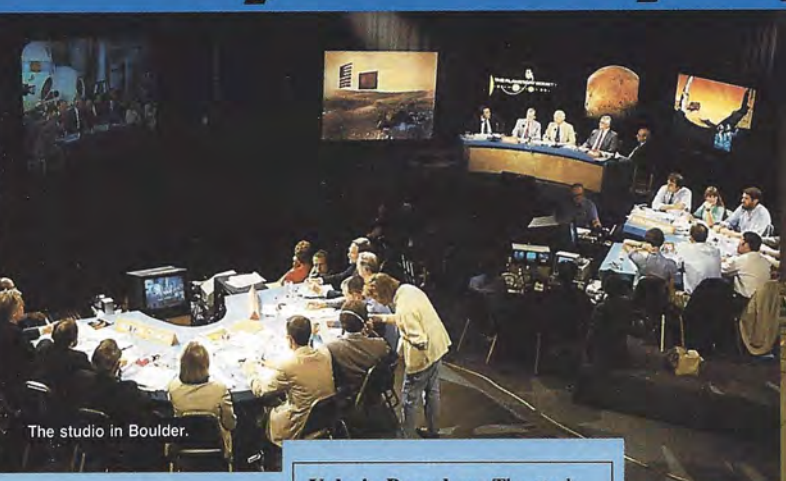
Penny Boston: It is clear that two of the really important issues are whether life even originated on Mars and if not, why not? Twin tracked with this is the history of water and climate on Mars, because as we learn more and more from studies of Earth, we see that the biology, climate, geology and even hydrology of the planet have all evolved together, and each component of the system has had significant effects upon the others. Mars is the perfect opportunity to join these two broad areas.

Thomas Paine: Mars is the great adventure of mankind for the coming decades. If, indeed, the 21st century will become the extraterrestrial century, we can see that there will be a human outpost on the Moon. There will be a human outpost on Mars. There will be Soviet cosmonauts and American astronauts visiting and working together on these distant worlds. They will be joined by men and women from other nations. We are at the very outset, and it is an excellent opportunity today for us to begin to tackle some of the problems that lie before us.

Michael Malin, Andrew Ingersoll and Steven Squyres of the science panel.

Equipment for the Spacebridge satellite link.

netary Society Spacebridge



The studio in Boulder.

The control room for the Spacebridge.

James French: One thing that has afflicted our program here in the United States — I don't know if it has affected the Soviet program or not — is the idea that if we wait just a little bit longer, then there will be a breakthrough that will make it a lot easier. I make the analogy that if Columbus had followed that philosophy, he would still be sitting on the beach waiting for someone to develop the *Queen Elizabeth II* so he could go exploring in style and comfort.

Arcadiy Strugatskiy: I am a resolute opponent of the development of any kind of long-term program, joint or separate, for the purpose of sending men into space.

Valeriy Barsukov: The study of the Moon, Venus and particularly Mars has led us to the conclusion that Mars occupies a key position in our understanding the development of all these bodies similar to Earth. And this fact, and the possibility that we may find some sort of biological activity there, is giving rise to an enormous interest in Mars. We cannot fail to be concerned by the question of the evolution of the atmosphere and climate on Mars. We know that formerly there were rivers on Mars, that now there is nothing but permafrost. We know the temperature situation very poorly and on that depends the possibility for discovering life on the planet.

This range of questions is important for our agenda in the study of Mars. But I think that the study should be done first by robots, by machines. Man is too valuable a creature for us now, when we know practically nothing about Mars. Doubtless men will be on Mars somewhere beyond the year 2000, when we will have sufficient knowledge of the basic data regarding the planet Mars.

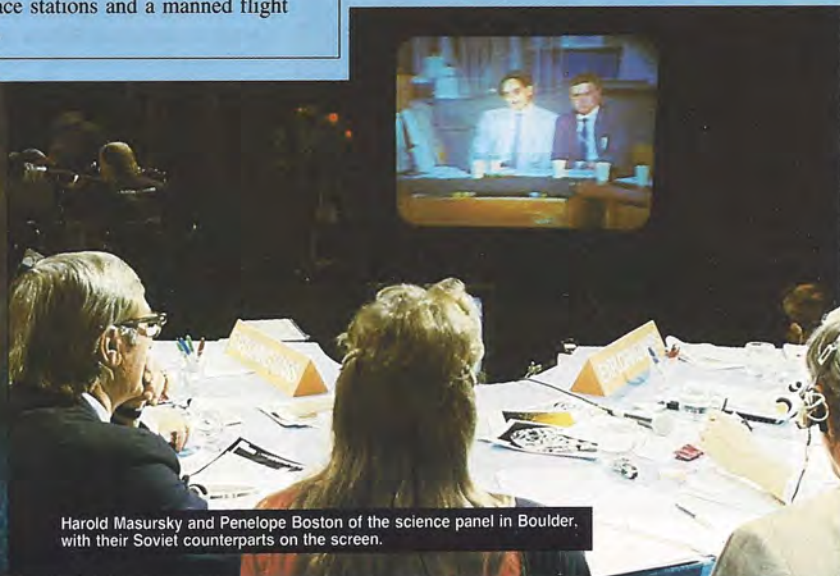
Harold Masursky: We would like to go to look at the polar layered terrain, to look at the history of climate changes. I think that is the best way to look at the very youngest history of Mars. In other areas we can see places where lava has flowed and channels have covered that, and then lava flowed again and covered the channels. If we look at those horizons, we look at the soils. Those are the best places to look for ancient life. In Earth geology, we always look at the fossils that tell us what the conditions were like; I don't think it will be different on Mars.

Svetlana Savitskaya: The title of our program, "Together to Mars?" has various aspects to it — political, scientific and human. It seems to me that, as a result of the extensive discussion we have had, we have come to the conclusion that this project should be carried out, and that in addition to robots, man himself must take part because the very course of the history and the development of space science requires it. We need to start here and now. We should not be put off by some 10, 15 or 30 years because there are too many questions, and we need to start solving them — together. The sooner we start, the sooner we will have space stations and a manned flight to Mars.

Sergei Kapitsa: In the last analysis, we are flying to Mars to better understand the history and future of our own planet. This is a search for fundamental knowledge and understanding of what is going on. It is knowledge that belongs to all of mankind, and the results of the Mars expedition should belong to everyone. There are no secrets here except for the secrets of nature itself, and to discover those we are setting off for Mars.

I should like to end by removing that question mark which popped up at the end of the title of your broadcast, "Together to Mars?"

Sergei Kapitsa, the moderator in Moscow.



Harold Masursky and Penelope Boston of the science panel in Boulder, with their Soviet counterparts on the screen.

News & Reviews

by Clark R. Chapman

The planets attract a diversity of scientists from many nations and from many disciplines. The great public interest in space also brings planetary scientists and laypeople together more closely than in most other technical fields. I was reminded of these traits of planetary science yet again this past July in Newcastle-upon-Tyne, England, as I attended the fiftieth annual meeting of the world's largest organization of planetary scientists, the Meteoritical Society.

Meteorites, of course, are those fragments mainly of broken-up asteroids that occasionally strike Earth and wind up in museum exhibits. These literally un-Earthly objects, arriving as they often do with blinding flashes and sonic booms, have intrigued people for millennia. The metallic irons are especially exotic in appearance; some meteorites have even become objects of religious reverence. It was fewer than 200 years ago, after the first asteroids had been discovered, that the conservative scientific establishment finally accepted the evidence that stones literally fall from space.

Meteorites were studied by 19th-century geologists who dissected their minerals, measured chemical compositions and displayed them alongside gems, crystals and other rocks. They also intrigued astronomers, who speculated on their association with the less spectacular but more frequent phenomena of "shooting stars."

Other people turned to meteorite collection as a hobby, or even a business. For instance, the Barringer family entrepreneurs attempted to prove that their Arizona crater was of meteoritic origin long before most scientists would agree. Harvey Nininger, who died last year at the age of 99, interested many people in meteorites, persuading them to comb the plains of the American west and mid-west for extraterrestrial rocks. So when the Meteoritical Society was formed in the 1930s, the early members included astronomers and geologists, both amateur and professional. The developing field received a boost in the late 1960s as scientists prepared to study the first extraterrestrial samples hand carried back to Earth — the moonrocks.

Nowadays, most meteoriticists are geologists and chemists. While their research addresses a range of general planetary topics, there is little dialogue between meteoriticists and specialists in planetary astronomy, geophysics, atmospheric sciences, stellar astrophysics and other related fields. Meteoritical Society meetings treat craters on Earth, but not craters on the Moon or Mars. In Newcastle, papers were given about geological effects on the atmosphere of the young Earth, but few atmospheric chemists were in the audience. The one or two astrophysicists familiar with stellar evolution, supernovae and collapsing molecular clouds who regularly attend Society meetings can hardly represent the views of astrophysicists generally.

Nevertheless, the tenuous interdisciplinary connections achieved in Meteoritical Society meetings have more potential than the even more parochial get-togethers of other planetary science specialists. Internationalism, which was just beginning to be recognized last autumn in Paris at the meeting of the Division for Planetary Sciences of the American Astronomical Society, has long been a hallmark of the Meteoritical Society. Planetary Society members interested in meteorites should note that among the nearly 1,000 members of the Meteoritical Society there remains a small but enthusiastic group of amateurs who just love these rocks from the sky and enjoy Society meetings without getting bogged down in technical details.

Diamonds from the Stars

Amid prosaic reports about how some newly found meteorites differ subtly from others, some exciting papers were given at Newcastle. Imagine a whole session on "interstellar diamonds!" Believe it or not, there is evidence that some meteorites (in particular the famous "Rosetta Stone" of meteorites that fell in Allende, Mexico two decades ago) contain microscopic diamonds formed, perhaps, in the outer envelopes of red supergiant stars.

Whatever the precise origin of these very fine-grained diamonds, they carry traces of xenon, krypton, nitrogen and other gases that have signatures different from anything else known in our solar system. Apparently the diamonds truly have an interstellar, pre-solar-system origin. They prove, yet again, that solar system formation processes failed to vaporize and homogenize everything, so clues still remain from epochs before the birth of our system 4.6 billion years ago.

Interplanetary (if not interstellar) diamonds have long been known in a rare type of meteorite called ureilites. Many new ureilites have been discovered during the last few years on the icefields of Antarctica. Measurements show that they are closely associated with a common type of carbonaceous chondritic meteorite, a type that includes the Allende meteorite. Where could these peculiar meteorites be coming from? How are they related to the Allende-type rocks? What processes have made them different?

In one talk, Ann Spitz argued that a complex, four-stage process created ureilites, involving partial melting of Allende-like material, remelting of a fraction of the residue, and crystallization of a tiny fraction of that melt. Altogether, she feels that less than one-part-in-a-million of the original parent-body could have been refined in this special way. Why then does so much of it fall to Earth?

Alan Hildebrand suggested that ureilites might come from the very largest asteroid of all, Ceres. A millionth of Ceres is still a lot of stuff, but why don't we get any pieces of all the residual material? Meteoriticists will continue to wrestle with such problems until we ultimately can fly spacecraft out to study asteroids in detail.

Cretaceous-Tertiary Extinctions Revisited

Another topic discussed yet again at the Meteoritical Society meeting was the demise of dinosaurs (and other flora and fauna) due to the impact of a 10-kilometer asteroid or comet. The arguments at Newcastle related to whether the impact occurred on a continent, on a continental margin or the ocean floor. Questions raised in other quarters about whether the impact happened at all are moot among meteoriticists, who have long appreciated the inevitability of occasional catastrophic impacts.

The original proponent of the idea, Nobel-Prize winner Luis Alvarez, takes on his nonmeteoriticist critics in a popular-level article in the July issue of *Physics Today*. I recommend it as an up-to-date summary of the impressive array of evidence amassed in favor of the impact idea. However, Alvarez's witty, personal writing style does not rescue him from seeming arrogant and closed minded. ("My geologist friends are sharply split on the significance of the danidine spherules as temperature indicators, so I will simply say that for me they rule out volcanic theories....") We are reminded that great scientific ideas cannot always be separated from the personalities of the great minds who propose them.

Clark R. Chapman is a senior research scientist at the Planetary Institute (Tucson, Arizona), a division of Science Applications International Corporation.

SOCIETY Notes

MARS WATCH '88

Astronomy alert! The Red Planet is moving closer and in 1988 it will be nearer to Earth than it has been in 17 years. The Planetary Society has decided to take advantage of Mars' brightness and visibility during this period of Earth-Mars opposition, when Mars reaches perihelion (its closest approach to the Sun) while it and Earth are on the same side of the Sun.

We are launching a campaign to increase public awareness and scientific knowledge of our neighboring planet, with the purpose of increasing interest in Mars exploration. "Mars Watch '88" was kicked off in July at "Universe '87," a conference of astronomy organizations held at Pomona College in California. The program will be coordinated by Stephen Edberg of the Jet Propulsion Laboratory.

Mars Watch '88 will link The Planetary Society with amateur astronomy organizations to provide telescopic viewing opportunities for the public at Mars Watch parties throughout the United States. We will also produce educational materials and publish a Mars Watch bulletin of observational information.

Major funding for this program is being provided by the Norris Foundation of California.

KEEPING AN EYE ON MARS

Joining Steve Edberg at Universe '87 were Baerbel Lucchitta from the United States Geological Survey (USGS) and Christopher McKay from NASA's Ames Research Center, who is also coordinator of The Planetary Society's Mars Institute. Dr. Lucchitta showed stunning slides of Earth and Mars simultaneously to compare and contrast surface features and geologic processes. Dr. McKay discussed Mars exploration, concentrating on the need to coordinate ground-based observations with other scientific data.

SPACE EDUCATION DAY IN HAWAII

The Hawaii Legislature made a request of The Planetary Society: Provide a Space Education Day for science teachers and students from every high school in the state, in conjunction with the Pacific International Space Year Conference and the Society's own program there. Our response, "Preparing for the 21st Century," was kicked off on August 22 by US Senator Spark Matsunaga (D-HI), Hawaii's governor, John Waihee, and Society President Carl Sagan. Astronaut Kathryn Sullivan gave the keynote address. Charles Kohlhase, *Voyager* Mission Planning Office Manager, discussed the accomplishments of the *Voyager* mission, commemorating its tenth anniversary.

The *Voyagers* are each carrying a gold-coated copper phonograph record, filled with the sounds and sights of planet Earth for their interstellar missions. Some of its creators, Ann Druyan, Carl Sagan and Jon Lomberg, remembered the record at a luncheon gathering. The Planetary Society presented Ms. Druyan with an award for her work on the record, and her crucial help in many of the Society's scientific and popular projects.

Over 200 Hawaiian teachers and students attended these events. The teachers were treated to workshops while there were special presentations for the students. About 100 Planetary Society members and others also attended the events.

MARS CONTEST WINNERS ANNOUNCED

The Planetary Society has a continuing commitment to encourage outstanding students. One of our programs is the Mars Institute Student Contest, open to all high school and college students, and designed to stimulate them in planning the future exploration of Mars. This year's contest was divided into two categories, one technical and one socioeconomic. Winners in each received $750 and an all-expenses-paid trip to Boulder, Colorado for the Case for Mars III conference.

For the first time since the contest began in 1984, a high school student won the technical contest: Mark Stanley of Penn High School in Osceola, Indiana. His paper was called "Mission to Mars: Design of a Mission Using the Capabilities of the Various Spacefaring Nations." In the social science category, the award went to three students from the California State Polytechnic University, San Luis Obispo: Kent McCammon, Mitchell DeShields and Steven Muther. Their paper was called "Feasibility of US Participation in an Internationally Sponsored Manned Mission to Mars."

KUDOS TO SPACEBRIDGE BUILDERS

Several members felt that the Society's "Together to Mars?" Spacebridge (see page 12) was so significant to the future of space exploration that they made substantial contributions to ensure its success. New Millennium Committee member Sam Karayusuf made a $12,000 challenge grant, contingent on full funding of the project. Other contributors include Polly Brooks, another New Millennium Committee member, Claire and John Radway, and Richard Gunther.

MARS UNDERGROUND NEWS TAKES OFF

Subscriptions to the "Mars Underground News" are pouring in, keeping our computer department busy entering them into new files. Over 4,000 people have signed up for this newsletter chronicling the growing movement among space scientists and enthusiasts to declare Mars the next target for human explorers. The upcoming issue will cover the recent "Case for Mars III" (see page 12). At the conference top scientists, astronauts, engineers and others met to share new developments and debate plans for Mars exploration.

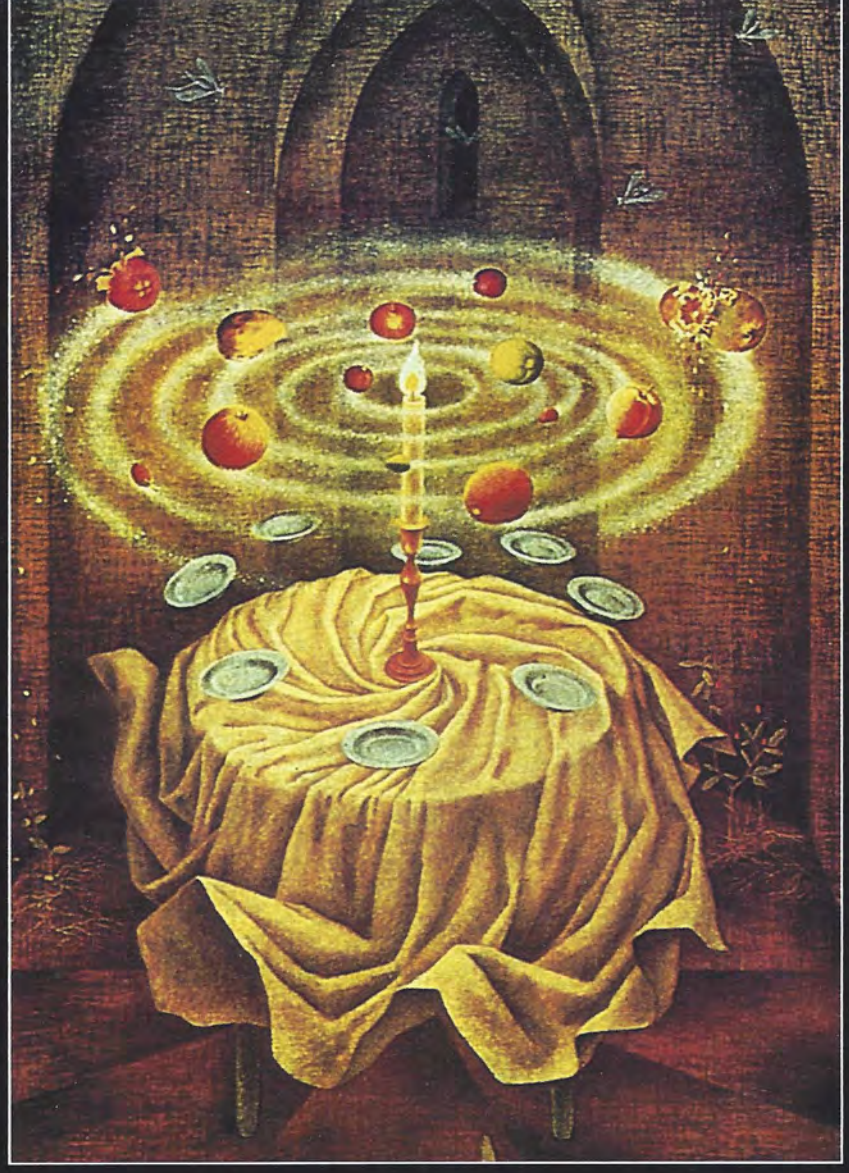
The "Mars Underground News" is published by The Planetary Society as a service to those actively involved in Mars research. Subscriptions are also open to Society members, whose dues and contributions support some of this research. All money raised by subscriptions goes to produce and distribute the newsletter; anything left over is deposited into the Society's Mars Fund, dedicated to support further steps to Mars.

If you would like to receive this quarterly newsletter and keep up with the latest activities of those working toward Mars, send a check for $10.00 to: "Mars Underground News," The Planetary Society, 65 N. Catalina Avenue, Pasadena, CA 91106.

COMPUTER DONATION MOBILIZES SOCIETY

The Planetary Society thanks Edker Pope of San Diego for his recent donation of a PC/AT compatible computer and a PC/XT laptop model. Mr. Pope gave the computers for the Society's Mars Balloon Study Project. The laptop is to be flown on an experimental balloon, where it will record data from a small prototype camera developed by Society Advisor Jacques Blamont (see the March/April 1987 *Planetary Report*.) The PC/AT will be used to produce images from the data. (The Matrox Corporation of Montreal has also donated a "frame-grabber" for processing the images.)

However, the always-resourceful Society staff immediately pounced on this windfall and found many more ways to use the computers. The PC/AT is now the "Planetary Society Computer Communications Center" and, through the hard work of summer intern Emily Pelton, we are now plugged into several computer networks around the world. Your editor seized the laptop and carried it off to the "Case for Mars III," where it was used to telex congratulations to the Soviet participants of the Spacebridge.



"STILL LIFE REVIVING" was the last work finished by Remedios Varo, who spent her life producing complex paintings that were both surreal and scientific.

Born in Spain in 1908, she fled Europe's political turmoil in 1941 for Mexico City, where she remained until she died in 1963. There her work has always been very popular, although she is still nearly unknown in the United States and Europe.

One of many ways to look at "Still Life Reviving" is as a solar system where the swirling fruits symbolize planets orbiting the Sun.

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