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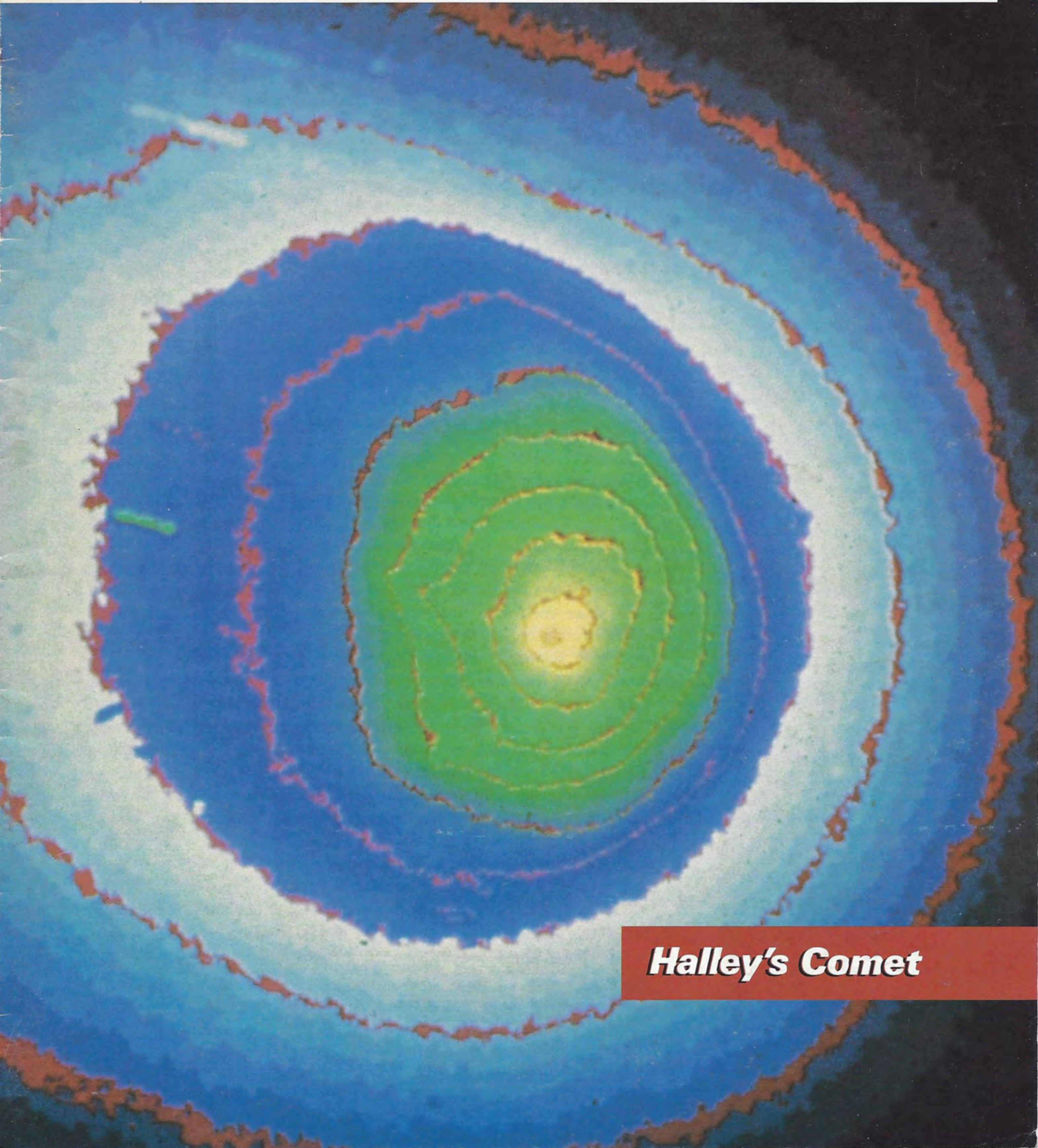

Halley's Comet

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COVER: Modern techniques of image enhancement have enabled scientists to bring out photographic details that are barely visible in the negative and disappear when printed. This image of Halley's Comet, enhanced from photographs taken May 25, 1910 at Helwan, Egypt, shows a jet (center) shooting out behind the comet.
Image: Daniel A. Klinglesmith III

HALLEY'S COMET

A Preface to This Special Issue

Comets are thought to be pristine remnants of our origins, preserved in cold storage from the time, 4.5 billion years ago, when such little worlds collided, grew and helped to form our solar system. Earth, the other planets, their satellites, and many of the asteroids are different; they have been processed, reworked, physically and chemically modified since those early days. Comets may provide a window to our origins.

But because comets are small icy objects — generally a few kilometers across, or smaller — and because they tend to envelop themselves in a coma and tail of gas and dust as they approach Earth, no one has ever had a good close-up look at the nucleus of a comet. Early next year, Halley's Comet will make another of its periodic forays into the inner solar system, as it has probably done for 10,000 years or more (since it was gravitationally perturbed into its present orbit by a close approach to Jupiter).

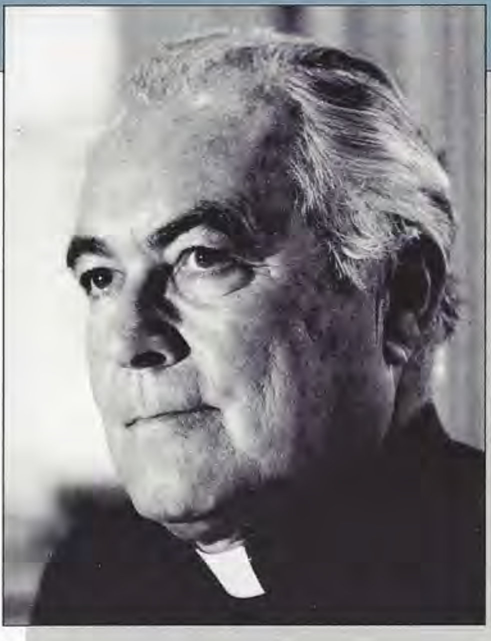
In the interim, we humans have gone from painting caves to launching spacecraft, not really as big a change as it sounds. In March 1986, we will at last be ready to meet a comet as it hurtles by Earth. Five spacecraft, from a total of 20 nations, will approach Halley's Comet, and one of them may even crash into it at high speed.

This issue of *The Planetary Report* is devoted to Halley's Comet and this major step forward in the history of exploration. — CARL SAGAN

Carl Sagan, President of The Planetary Society, and Ann Druyan have written COMET, a richly illustrated book to be published by Random House this fall.

THEODORE HESBURGH JOINS BOARD OF ADVISORS

THE PLANETARY SOCIETY is delighted to welcome Father Theodore Hesburgh, President of the University of Notre Dame, to its Board of Advisors. He has been very active in the Society's area of interest: Hesburgh was a leading member of the National Science Board, when many of the major American optical and radio observatories were first being organized by the National Science Foundation. He also helped to organize the International Atomic Energy Agency, whose role is to restrict, partly through on-site inspection, the proliferation of weapons-grade nuclear material throughout the world — an example of international cooperation in which the United States and the Soviet Union have a common interest. Hesburgh was also the first civilian to fly in the SR-71, the US Air Force's extremely high altitude reconnaissance aircraft. He has a long-standing interest in several different facets of the Search for Extraterrestrial Intelligence (SETI). We are proud to welcome him to our Board of Advisors. — *Carl Sagan*



Carl Sagan has asked me to write a few words about why I accepted membership on the Board of Advisors of The Planetary Society. The most fundamental reason is that I am a very curious person and a space buff who graduated from previously being an aviation buff. Had I been born earlier in human history, I would have liked to sail the then largely unknown regions of the Pacific and Antarctic with Captain Cook. Earlier yet, it would have been crossing the Atlantic with the Vikings or Columbus, or exploring Mexico and Peru with Cortés or Pizarro. Later, it would have been seeing Africa for the first time with Stanley and Livingstone.

One speaks of climbing mountains because they are there. One explores unknown, distant places because they are there. Today, space is the last frontier, a vast unknown region, for exploration by curious people. There was not much to see when Roald Amundsen stood on the South Pole for the first time in December of 1911. How much greater the thrill to see the moons of Jupiter or the rings of Saturn up close.

On a higher level of anticipation, imagine the first conversation, albeit a long distance one, between intelligent beings of different species in our universe. As I said years ago in a preface to NASA's SETI report:

"I was discussing the subject of extraterrestrial intelligence with a Russian lawyer who regarded me with some surprise and asked: 'Surely you must abandon your theology when you consider these possibilities?' 'Indeed, I don't,' I replied. 'It is precisely because I believe theologically that there is a being called God, and that He is infinite in intelligence, freedom, and power, that I cannot take it upon myself to limit what He might have done.' Once He created the Big Bang — and there had to be something, call it energy, hydrogen, or whatever, to go bang — He could have envisioned it going in billions of directions as it evolved, including billions of life forms and billions of kinds of intelligent beings. I will go even further. There conceivably can be billions of universes created with other Big Bangs or different arrangements. Why limit Infinite Power or Energy which is a name of God? We should get some hint from the almost, but not quite, infinite profusion of the Universe we still know only in part. Only one consideration is important here regarding creation. Since God is intelligent, however He creates — 'Let there be light', Bang, or otherwise — whatever He creates is a cosmos and not a chaos since all His creation has to reflect Him. What reflects Him most is intelligence and freedom, not matter. 'We are made in His image,' why suppose that He did not create the most of what reflects Him the best. He certainly made a lot of matter. Why not more intelligence, more free beings, who alone can seek and know Him?"

All this really whets my appetite for new and creative exploration on a level surpassing all past searchings limited to our small planet. As a member of the Explorers Club, I read their magazine of earthly explorations. Sadly, I am reminded in reading the various articles, how slim the exploratory pickings have become on Earth. But beyond, in space, the opportunities are practically limitless, although currently limited by the speed of light. Even that limitation I hope to transcend after death, for a spirit unlimited by a body can travel anywhere in this universe, or in other possible universes, simply by thinking of a destination and being there immediately. We are now where our body is. Untrammeled by the body, spirit is where it operates. Maybe the Advisory Board is getting more than it bargained for in this traveler.

(REV.) THEODORE M. HESBURGH, C.S.C.
President, University of Notre Dame

THROUGH HISTORY with

***I** came in with Halley's Comet in 1835. It is coming again next year, and I expect to go out with it. It will be the greatest disappointment of my life if I don't go out with Halley's Comet. The Almighty has said, no doubt, "Now here are these two unaccountable freaks; they came in together, they must go out together." Oh! I am looking forward to that.*

Mark Twain — 1909

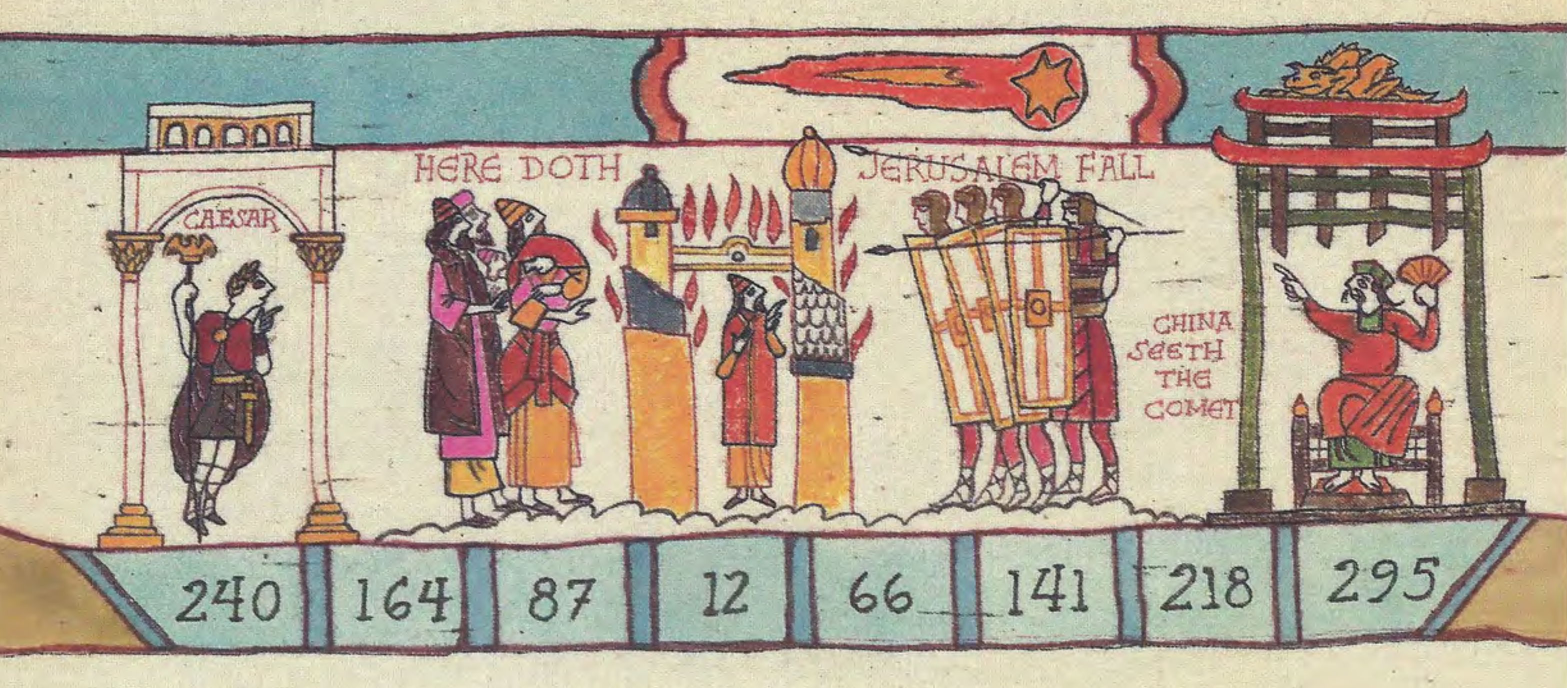
This oft-quoted remark by the American humorist, Mark Twain, would not be remembered today except that Twain did indeed go out with Halley's Comet in 1910. Successful predictions are not only well remembered, but they provide the test by which scientific theories must be judged — and accepted or forgotten.

One hundred years before Halley's Comet's first positively recorded return to Earth's neighborhood in 240 B.C., the Greek philosopher, Aristotle, taught that a successful theory should follow from the observed facts. Unfortunately, he got some of his facts wrong. Aristotle divided space into an imperfect, changeable region below the Moon and a perfect, eternal celestial world beyond. In the heavenly sphere, the changeless Sun, stars and planets moved about Earth timelessly in perfect circles.

Because of their peculiar, changing appearance and behavior, comets were doomed to the region of Earth in the imperfect sublunar space. Comets were thought to be warm, earthy exhalations that rose up into the upper atmosphere and were there ignited by the fiery upper regions. The size, shape and duration of a particular comet depended upon the nature of the exhalation or fuel.

Foreshadowing Disasters

From the circumstances surrounding the apparitions of past comets, Aristotle claimed that comets, when frequent, foreshadow winds and droughts. Partly initiated by Aristotle's enormous influence, the superstition developed that comets presaged extreme weather conditions, pestilence, wars, changes of rule and, particularly, the deaths of sovereigns or people of noble birth. The scientific concept of prediction being used to test theories was overshadowed by the astrological use of cometary apparitions to presage malefic events.



Halley's Comet was first recorded in 240 BC, but the medieval Bayeux Tapestry contains the most famous illustration of Halley's Comet. Here, based on the tapestry, we illustrate some of the comet's apparitions. In 87 BC, the young Julius Caesar saw the comet. Its AD 66 appearance allegedly presaged the fall of Jerusalem in AD 69. Chinese astronomers recorded an impressive cometary display in AD 141.

HALLEY'S COMET

by Donald K. Yeomans

The Jewish historian, Josephus, described a comet that "hung like a sword" and allegedly foretold the destruction of Jerusalem in the first century A.D. This comet may well have been Halley's Comet during its close approach to Earth in March of A.D. 66. After misgovernment by several Roman procurators, the people of Judea rebelled and the Roman legate, Vespasian, was sent with three legions to suppress the revolt. Vespasian took Josephus prisoner and laid siege to Jerusalem in A.D. 69. The city fell the next year. Josephus' description of the comet foretelling Jerusalem's destruction was written later, so there was really no prediction involved — just a connection after the fact.

One thousand years later, Halley's Comet was again accused of foretelling a major conflict — the Battle of Hastings. The 1066 return of the comet has been immortalized in a panel of the Bayeux Tapestry. The tapestry (actually an embroidery) is 20 inches wide by 231 feet long and was made for the cathedral in the French town of Bayeux. It is sectioned into 72 scenes that pictorially document the Norman conquest of England.

"Isti Mirant Stella"

The scenes begin with the Saxon King Harold (falsely) pledging allegiance to Duke William of Normandy. The final scenes depict the Saxon defeat at the Battle of Hastings. One of the 72 panels shows Harold's justified fear of invasion. Harold and his subjects are frightened by a bright comet with a forked tail. The comet is seen with a latin inscription "Isti Mirant Stella," which loosely translates into "They wondered at the star."

Toward the end of April 1066, when William and his army were in the south of France, Halley's Comet would have appeared to them as an impressive object in the western evening sky. Perhaps the apparent position of the comet over England acted as an impetus to William and his men. In the autumn of 1066, the armies of William and Harold met at Hastings, the first and most decisive victory in the Norman conquest of England.

Whether or not the comet was actually taken as a sign of destiny by William and a portent of coming defeat by Harold is open to question. History is written by the victors, and the Bayeux Tapestry was created for William long after the battles were over.

While all of Halley's Comet's medieval apparitions were obvious celestial displays, the ninth century return was the most spectacular in its history. This celestial extravaganza began on March 22, 837 when the comet, with a 10-degree-long tail, was first recorded by Chinese astronomers. (The Moon is half a degree across.)

By April 9, the Chinese recorded that the tail was 66 degrees long and was branched into two sections. The next night the comet passed within 5 million kilometers of Earth — its closest approach yet. After moving an incredible

Attila the Hun was defeated in 451. In 530 a plague spread across Europe, and was blamed on the comet. The famous Italian volcano, Vesuvius, erupted in 684.

45 degrees across the sky on April 10, 837, and glowing nearly as brightly as Venus at its brightest, the comet appeared the next day with a tail 76 degrees long.

During this apparition, the Chinese noted that a comet's tail is always directed away from the Sun. Western astronomers would rediscover this in 1538, seven centuries after the Chinese casually made reference to it in 837.

While the Chinese duly noted the circumstances of Halley's Comet's extraordinary apparition in 837, and while it must have been the most impressive celestial display of that century, western chronicles hardly mention it at all. Why would the majority of the western world ignore a comet that would have astonished anyone who looked up in the evening sky during April 837?

Back to Aristotle

In a sense, medieval Europe did not look up, nor did they look ahead — they looked back to Aristotle. During this period, there was very little scientific progress made as a result of observational evidence, and there was certainly no testing of existing theories. It was an age of faith, and medieval authorities relied upon the teachings of Aristotle for their knowledge.

It would be difficult to overestimate the impact of Aristotle upon the history of western science. Although the scientific method became widespread in the sixteenth century, the influence of Aristotle could still be felt. Even Johannes Kepler, whose fame rests upon his abandoning circular planetary motion in favor of elliptical motion, ran amok when his Aristotelian logic was applied to comets.

In a classic irony, Kepler used his observations of Halley's Comet in 1607 to demonstrate that cometary motion could be represented by a straight line. Although recognizing that his theory did not fit the comet's motion well, he felt the extra work required to improve it was unwarranted because he assumed that comets do not return.

Kepler represents a transitional figure between the science of Aristotle and that of Isaac Newton and Edmond Halley. It was largely through the efforts of his friend, Halley, that Newton was persuaded to set down his ideas on gravitational theory in his scientific classic, the *Principia*.

Applying Genius

While Newton was busy developing his ideas, the great comet of 1680 was seen throughout the world as a morning object in November and early December of 1680, and as an evening object later in December and in early January of 1681. Halley pleaded with Newton to apply his genius to the motion of comets as he had to the Moon and planets. Newton obliged and began by assuming that the comet seen in the morning in November was different from that seen later in December and January — and that the motion of both comets could be represented with a straight line. Aristotle strikes again!

Through a correspondence with the first Astronomer Royal, John Flamsteed, Newton gradually changed his mind, and by 1684 he was convinced that comets do indeed travel about the Sun in highly elliptical paths, and that the comets seen in November and late December 1680 were one and the same object.

Newton then set out to find a method whereby a comet's orbit could be determined and accurately predicted. Newton described the problem as one of great difficulty and spent the next two-and-one-half years on it, finishing just before the publication of the *Principia* in 1687. Using three observations of the comet on the sky, Newton's method allowed the computation of a parabolic orbit — a good approximation to a very elongated ellipse.

Armed with the method outlined in Newton's *Principia*, Halley began what he termed "a prodigious deal of calculation" and computed parabolic orbits for two dozen well-observed comets. As early as 1695, Halley wrote to Newton stating his suspicion that the comets seen in 1531, 1607 and the one both Newton and he had seen in 1682, had very similar orbital paths, and they might well be the same object. Still, he was troubled by the unequal periods between successive returns and he asked Newton to think about the perturbative effects of Jupiter and Saturn on a comet's period of revolution.

Halley was then occupied with his duties as Deputy Comptroller of the English Mint, with two voyages across the Atlantic Ocean to map geomagnetic variations (in hopes that these maps could be used to determine a ship's position at sea), as well as with two trips to Europe to offer advice on the fortification of seaports.

The Bayeux Tapestry celebrated King Harold's 1066 defeat by William the Conqueror, an event supposedly foretold by the appearance of the comet. In 1456, East battled West in the Crusades.

Predicting the Comet

By the time Halley had pulled together his cometary research it was 1705. He finally predicted that the comet that would one day bear his name would return in 1758. Halley later took account of the effects of Jupiter and Saturn on the comet's motion and revised his prediction to late 1758 or early 1759.

There, it was done. Finally a theory of cometary motion resulted in a prediction that could be shown true (thus confirming the theory on which it was based) or it could be shown false (thus relegating the theory to the scientific scrap heap).

The recovery of Halley's Comet on Christmas evening 1758 by Johann Palitzsch, a German amateur astronomer, immortalized Halley, verified Newton's theory and showed that this comet, and by inference others as well, revolved about the Sun in an elongated ellipse. Encouraged by Halley's success (which, unfortunately, he missed, dying in 1742), other scientists sought and found additional periodic comets.

Cometary Problems

By the early nineteenth century, modified versions of Newton's cometary theory had been used to successfully predict the returns of several comets. However, with cometary motions there were still some problems that were not evident when the same theories were applied to the motions of planets and asteroids. Despite the efforts of astronomers before Halley's Comet's expected returns in 1835 and 1910, the best predictions for the comet's closest solar passage were early by about four days. Clearly some force affecting the comet's motion was not being taken into account in the predictions.

During his own observations of Halley's Comet in 1835, the German astronomer F.W. Bessel noticed jet-like fountains near the center, or nucleus, of the comet. He reasoned that, if material were being ejected from the comet's nucleus, there might be a jet-like thrust acting upon it and this could cause the comet's motion to deviate slightly from that expected due to purely gravitational forces of the Sun and planets.

It was these "nongravitational" forces that Fred Whipple wished to explain, in 1950, when he introduced his dirty snowball model for a comet's nucleus. (See pages 12-14.) According to Whipple, when a "dirty snowball" comet approaches the Sun, the ices vaporize preferentially on the sunward side of the nucleus, and if the comet is rotating, a jet-like thrust pushes it either in the direction it is moving, or against it, depending on the direction of its spin.

Beginning with the work of Brian S. Marsden, Whipple's model has successfully been used to represent the nongravitational forces affecting the motion of comets. Whipple's model also predicted the presence of water ice in comets. Abundant amounts of hydrogen (H) and the hydroxyl radical (OH) have been identified in the spectra of comets, and water ice (H_2O) seems the obvious source.

For Halley's Comet, the Whipple model explained the nongravitational effects accounting for a four-day change in its period of revolution about the Sun. Hence it was possible to accurately predict its position as it moved toward Earth, allowing David Jewitt and G. Edward Danielson to recover the comet with the Mount Palomar 200-inch telescope on October 16, 1982.

Backward in Time

Whipple's model and Newton's theory also allowed researchers to track Halley's Comet backward in time, and to recently identify observations of the comet made in 87 and 164 B.C., and recorded on clay tablets now preserved in the British Museum. The 164 B.C. apparition was the only one between 240 B.C. and now that was not observed by Chinese astronomers.

Now confident in our theory, we can predict the future motion of Halley's Comet. It will next return to the Sun on July 28, 2061 and, one period later, on March 27, 2134. During this latter apparition, the comet will pass within 14 million kilometers of Earth on May 7, 2134 and briefly appear brighter than the brightest stars.

You may wish to urge your grandchildren to tell their grandchildren about this coming celestial attraction. As Mark Twain would have said, "Oh! I am looking forward to that."

Donald Yeomans is an astronomer at NASA's Jet Propulsion Laboratory who has provided predictions of the comet's motion at each return from 1404 B.C. to A.D. 2134.

Kepler applied Aristotelian logic to his 1607 observations of the comet. In 1682, Halley applied Kepler's and Newton's laws to predict that the comet would return in 1758. Mark Twain came in with the 1835 apparition; he went out with it in 1910. Humankind will get its first close-up look at the comet in 1986. It will return again in 2061 and 2134. Painting: S.A. Smith

LOOKING INTO

As Halley's Comet, in its 76-year orbit, falls ever faster inward toward the Sun, a fleet of spacecraft is coursing toward the points in space where the comet will be on certain days in March, 1986. Meanwhile, back on the blue and white planet from which the spacecraft came, a worldwide community of observers has begun a watch on the comet.

It is already brightening as it comes closer, and even the weak sunlight out beyond the orbit of Mars has begun to warm it and boil off gases from its frozen surface. As it swings through the inner solar system early next year, the comet's tiny nucleus will be enveloped in an enormous cloud of gas and dust, streaming away in long tails.

Some of the spacecraft will fly into the cloud; others will watch from a distance, and all will be coordinated with ground observations in an unparalleled display of international scientific action.

First off were the two Soviet *Vega* craft, launched on December 15 and 21, 1984 on a long course to Halley's Comet via Venus. (The "Ve" in *Vega* is for "Venera," the Russian word for Venus; the "ga" is for "Halley," which begins with "G" in the Russian language.) The spacecraft carry investigations designed by scientists in the USSR, Hungary, Bulgaria, Czechoslovakia, the German Democratic Republic, Austria, the USA and Poland. France and the Federal Republic of Germany are also participating in the mission, with cooperation from the European Space Agency (ESA) and the US's National Aeronautics and Space Administration (NASA).

Next off was MS-T5 (now called *Sakigake* or *Pioneer*), a test precursor for the Japanese comet encounter spacecraft, *Planet-A*. MS-T5 entered heliocentric orbit on January 7, 1985. This is Japan's first interplanetary mission, built by its Institute

ASTRO-1

On March 6, 1986, Astro-1, an impressive payload of three ultraviolet (UV) telescopes and two wide-field cameras, will be launched into Earth orbit onboard a space shuttle. Their purpose? To observe Halley's Comet free of interference from Earth's atmosphere.

The ultraviolet instruments are:

***The Johns Hopkins Ultraviolet Telescope* (HUT), which will see into the far-ultraviolet spectrum through a much shorter wavelength than the other instruments. It will search for chemical elements not yet detected in comets, such as helium, neon, argon and nitrogen.**

***The University of Wisconsin Ultraviolet Photopolarimeter Experiment* (WUPPE), which will be the first instrument to observe and measure the polarization of light in the ultra-violet, as well as its spectral distribution. These measurements will provide information on the size and shape of cometary particles.**

***The Ultraviolet Imaging Telescope* (UIT), built by Goddard Space Flight Center, which will take pictures in the deep ultraviolet with a large field of view. It is also capable of observing objects too faint to be detected by Mount Palomar's 200-inch telescope. The UIT will map plasma and dust distributions.**

Although the UV instruments differ in their functions, they will complement each other and work together.

***The Wide-Field Dust and Plasma Cameras* will observe Halley's Comet's plasma and dust tails at visible wavelengths. This wide-field coverage will allow scientists to study the tails' motions and changes in shape or form, as well as the comet's interaction with the solar wind. While each camera is designed for a particular tail type, both will record both types as insurance against equipment failures.**

Astro-1 is scheduled to study the comet from March 9-14, then return to Earth with the shuttle. The mission will coincide with the *Vega 2* and *Giotto* encounters. ☐

HALLEY'S COMET

by Julian Loewe and the staff of The Planetary Report

FAR LEFT:
A telescope array, mounted in a space shuttle's cargo bay, gazes steadily at a comet from orbit about Earth.
Painting: William K. Hartmann

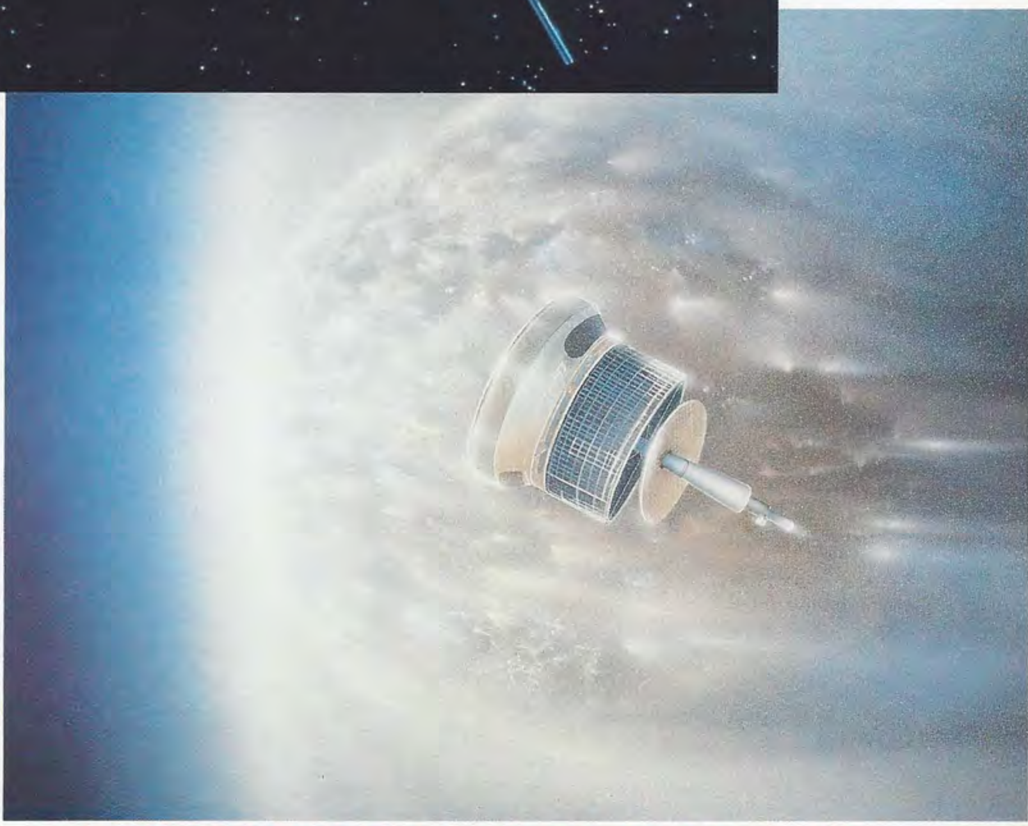
LEFT:
Japan's *Planet-A*, that nation's first interplanetary spacecraft, will view Halley's Comet from 100,000 kilometers away.
Painting: Kazuaki Iwasaki, courtesy of Space Art International

of Space and Astronautical Science. *Planet-A* is to be launched in August, 1985.

Meanwhile, an *Ariane* vehicle sent *Giotto* on its way July 2, 1985. *Giotto* is a mission of ESA, whose members include Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom.

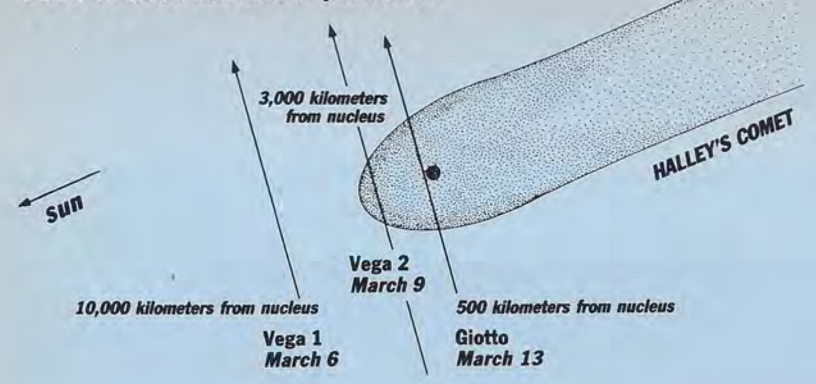
The *Vegas*, *Giotto* and *Planet-A* will all intercept Halley's Comet early in March, 1986, when the comet is outbound from perihelion, its closest point to the Sun. (See the April/May 1981 *Planetary Report*.) Because the comet's motion is almost opposite to that of the planets and the spacecraft around the Sun, the relative speeds at encounter will be very high, between 70 and 80 kilometers per second (or 157,000 to 179,000 miles per hour). This has three consequences: First, the encounter observations will last only a few hours and the closest, critical measurements only minutes. Second, instruments collecting cometary material for analysis will gather it at such high speed that the comet's molecules will be broken up as they strike the detectors. Third, the *Vegas* — and

(continued on next page)



ABOVE: *Giotto*, the European Space Agency's probe, will fly as close as possible to the comet, risking destruction by dust streaming out from the nucleus.
Painting: Mark Paternostro

Paths of close encounter spacecraft



especially *Giotto,* aimed the closest of all — may be damaged or even destroyed by the impact of cometary particles.

Experiments and Instruments

A main objective of sending spacecraft to Halley's Comet, apart from the historic meaning of the event, is to make observations that cannot be done from Earth because the comet is surrounded by an interfering atmosphere extending out millions of miles.

As sunlight warms the comet's tiny nucleus (it is thought to be only a few kilometers across), its long-frozen ices will evaporate and stream away, carrying a mixture of gases and whatever dust particles were embedded in the ice. Once the gases are flowing rapidly outward, forming the coma, the huge hydrogen cloud, and the dust and plasma tails, complicated physical and chemical processes begin. The energy and pressure of sunlight and the solar wind act upon the comet's transient atmosphere, dissociating (breaking up) and then ionizing its molecules.

What we see from Earth is the end result of these complex processes. To get closer to their beginnings we must get close to the comet, with instruments that can find the signatures of the so-called parent molecules that were once part of the comet's primordial ices.

Why is it important to do this? The reason is found in the solar system's early history. After the Sun formed out of a swirling nebula, the planets, capturing nebular material (gas, dust and planetesimals), grew toward their present sizes. Short-lived radioactivity, gravity and heat from the Sun destroyed the volatiles in the small, close-in planets. In the far outer reaches of the nebula, the forming comets escaped these heat sources and maintained their volatiles.

Now astronomers are finding, in cold

Comet Missions Scorecard

Key Data on Missions

AGENCY	PROJECT	LAUNCH	FLY-BY DATE	FLY-BY DISTANCE
European Space Agency	*Giotto*	July, 1985	March 13, 1986	500 kilometers (km)
Intercosmos	*Vega 1* *Vega 2*	December, 1984 December, 1984	March 6, 1986 March 9, 1986	10,000 km 3,000 – 10,000 km
Institute of Space and Astronautical Science (Japan)	MS-T5 *Planet-A*	January, 1985 August, 1985	March, 1986 March 8, 1986	1.5 million km 100,000 km
National Aeronautics and Space Administration (USA)	ICE	December, 1983	March 28, 1986	3 million km

Experiments		*GIOTTO*	*VEGAS 1 & 2*	MS-T5	PLANET-A	ICE
Remote Sensing	Wide-angle camera		X			
	Narrow-angle camera	X	X			
	Ultraviolet camera (Observes hydrogen cloud)				X	
	Infrared sounder (Detects coma radiation)		X			
	Photopolarimeter (Measures scattered light from dust)	X				
	Three-channel spectrometer (Detects chemical species)		X			
Gas/Dust Measurements	Neutral mass spectrometer (Measures molecular composition of gas)	X	X			
	Dust mass spectrometer (Measures composition of dust)	X	X			
	Ion mass spectrometer (Measures compositon of ionized gases)	X	X			
	Dust impact detector (Determines number and mass of particles)	X	X			
Plasma Measurements	Solar-wind ions (Measures compositon and energy)	X	X	X	X	
	Solar-wind electrons (Determines energy spectrum)	X	X		X	X
	Plasma waves (Detects interaction of solar wind and comet)		X	X		X
	Energetic particles (Measures cosmic ray environment)	X	X			X
	Magnetometer (Determines magnetic field around comet)	X	X	X		X
Radio waves						X

PLANET-A
Japan's First Interplanetary Mission
by K. Hirao

In its first interplanetary effort, Japan is sending two spacecraft, *Planet-A* and MS-T5, to investigate Halley's Comet on its next passage through the inner solar system. The *Planet-A* mission will complement the near-nucleus investigations of *Giotto* and *Vega* with measurements of the solar wind and images of the hydrogen-hydroxyl cloud surrounding the nucleus.

MS-T5, a test vehicle to prove the capability of a new satellite launcher, was successfully sent on its way on January 8, 1985. *Planet-A* is scheduled for launch in August. Neither spacecraft, operated by the Institute of Space and Astronautical Science (ISAS), will come as close as the European and Soviet spacecraft, but the data they will return will be important to understanding the behavior of the comet in its approach to the Sun.

Somewhere around the orbit of Mars, volatile materials start to evaporate off the comet's surface. Water (H_2O) is the main volatile, and as it is blown off the surface, sunlight will break the molecules up into their component parts. The hydrogen forms a gigantic cloud, millions of kilometers in diameter, around the head of the comet. *Planet-A* carries an imaging system that will watch in extreme ultraviolet light, viewing the emissions in the hydrogen Lyman-alpha spectral line.

These Lyman-alpha pictures will begin several weeks before perihelion (closest approach to the Sun) and will give us information on the growth and decay of the hydrogen cloud. The velocity of the hydrogen atoms depends on the mechanism that formed them. Thus these spectral observations will tell us how the hydrogen cloud is formed.

The long, straight ion tails streaming out behind the comet's head are formed primarily by the solar wind blowing across the comet's nucleus. Solar flares cause "gusts" in this wind, propagating shock fronts through interplanetary space. These fronts may cause turbulence in both the ion tail and coma. Therefore, it is important to measure the solar wind simultaneously with several spacecraft in the vicinity of the comet.

***Planet-A* will investigate the behavior of particles within the solar wind. MS-T5 will study the structure of the solar wind, measuring plasma waves, solar-wind particles and magnetic fields. Scientists will coordinate the experiments on these two spacecraft that will be flying between the Sun and the comet, ensuring that solar-wind conditions affecting the comet can be more completely understood.**

Dr. Kunio Hirao is the former Director of the Planetary Science Research Division of the Institute of Space and Astronautical Science in Japan.

interstellar clouds like the one from which the solar system may have formed, the radio and infrared signatures of a rich variety of molecules: carbon monoxide, water, methane, hydrocyanic acid, ethyl alcohol, formic acid and many others, including even the amino acids that are the very stuff of life.

Did these fragile substances, after cold storage in the outer solar nebula, rain down on the cooling planets, bringing atmospheres, oceans and the possibility of life? Well, some of them are found even in certain meteorites that fall today, and also in the tiny meteoroids that trail along the orbits of comets and make brief, annual meteor displays when intercepted by Earth. Thus in examining the primal stuff of comets we may be advancing the quest for our own origins.

Four main classes of techniques are available for investigating cometary materials and processes. The first is remote sensing: measuring properties of radiations emitted or reflected from the comet's atmosphere, or coma. This class is typified by the ultraviolet spectrometry of *Planet-A*, which will, from its flyby distance of 100,000 kilometers, define the extent and nature of the vast hydrogen cloud surrounding the comet.

Other remote-sensing instruments are the infrared spectrometers on the *Vegas* and *Giotto*, which will record the signatures of various gases in the coma and can also detect some properties of the comet's dust.

The second technique is direct spacecraft imaging, to show the size and nature of the nucleus and the morphology of the coma and tails. Several cameras are aboard the *Vegas* and *Giotto*. On its kamikaze plunge into the comet, *Giotto* may have a best resolution (ability to resolve detail) as fine as 30 meters. The *Vegas'* best resolution is expected to be near 150 meters.

While *Giotto's* resolution will be finer, the *Vegas'* imaging system will benefit from innovative design. "The cameras are on a scan platform, with an onboard computer to keep them focused on the comet," according to Bradford Smith of the University of Arizona, a member of the *Vega* imaging team. (Smith is also leader of the *Voyager* imaging team; that spacecraft will encounter Uranus in January, 1986, a few months before the *Vegas* reach Halley's Comet.) The onboard computer eliminates the need to control the scan platform from Earth, saving communication time — very important because of the high speed and brief duration of the encounter.

The third class of investigations involves the direct capture of cometary material for analysis onboard the spacecraft. The high encounter speed makes this difficult, be

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Balloons on Venus

On June 11 and 15, 1985, *Vegas 1* and *2* interrupted their cruise to Halley's Comet to drop two balloon probes into the atmosphere of Venus and two landers to the planet's surface. A French/Soviet project, the balloons hovered 54 kilometers (about 36 miles) above the planet's surface, enabling them to take the first steady, long-term measurements of the dense atmosphere. Previous experiments on the US *Pioneer* Venus probe and Soviet *Venera* spacecraft had been limited to readings of 50 seconds or less, at each altitude.

The balloons carried instruments that measured the motion of the wind, and an optical device detected cloud particles. A barometer and thermometer took pressure and temperature readings, and a small photo-electric instrument counted lightning discharges. The information was transmitted to Earth through a one-way communications system.

The *Vegas* dropped the helium-filled balloons on Venus' night side, where they encountered a pressure of about one-half Earth's atmosphere (as measured at sea level). They recorded temperatures ranging from 20 to 70 degrees Celsius in being carried by the wind from the night side to the day side of Venus. The balloons stopped transmitting after 46 hours when their batteries were exhausted.

Two separate but coordinated networks tracked the balloons on their flights — a Soviet network and a French network, which includes the United States, the German Democratic Republic, Canada, Brazil, South Africa, the Federal Republic of Germany, and one Soviet station. Although the Soviet and French networks exchanged no information during the actual transmissions, scientists from all involved nations will meet to discuss their findings this August in Toulouse, France.

The* Vega *balloon experiment is the brainchild of Professor Jacques Blamont of the French Centre National d'Etudes Spatiales, and advisor to The Planetary Society. He explains: "I had been working very long hours and, finally, exhaustion forced me to sleep. In a dream I saw Venus with a probe in its atmosphere . . . and that was it, the idea for the mission."

"That was 17 years ago, and it has been one of my projects ever since." The amiable scientist joked, "When I started it, I had no gray hair."

A Talk with **Fred Whipple**

Fred Whipple is one of the "greats" of solar system astronomy. His recent interests have focused on comets, and his "dirty snowball" hypothesis of the cometary nucleus has attracted enormous attention. It will not be too long, I hope, before the Halley's Comet spacecraft bring us new evidence to confirm his hypothesis.

In the late 1940's, Fred and I were members of the Upper Atmosphere Rocket Research Panel trying to foster the use of rockets to carry instruments on a vertical trajectory above the sensible atmosphere. At that time, Fred was interested in meteor studies, particularly photography of meteor trails. His photographic techniques led to Baker-Nunn cameras which are still used to track satellites. Under his direction, the Smithsonian Astrophysical Observatory at Cambridge, Massachusetts, established a network of optical tracking stations to observe artificial satellites.

Fred received his Ph.D. from the University of California at Berkeley in 1931. He has spent most of his professional life at Harvard University, where he was chairman of the Astronomy Department from 1949 to 1956. He was named Director of the Smithsonian Astrophysical Observatory in 1955, and was elected to the National Academy of Sciences in 1959.

W. H. PICKERING, *Former Director, Jet Propulsion Laboratory*

Kelly Beatty: *How would you describe a comet?*

Fred Whipple: When we see comets, they appear as fuzzy and hazy on the sky, as distinguished from a star that appears sharp. We usually see the head as a fuzzy region, sometimes with a sharp nucleus inside. When they're first observed at great distances from the Sun, at two or three astronomical units, for example, [one astronomical unit equals the average distance from the Sun to Earth, about 150 million kilometers] comets do not have tails. But as they come in, they develop them.

The tails divide into two classes. The long, straight, graceful ones that we see in picture books are the great ion tails. They can stretch out for up to about 300 million kilometers. The stubby, curved tails are the dust tails, and sometimes they can be very conspicuous. Dust tails are much more stable over time, whereas ion tails tend to change rapidly, with clumps moving out from the head at very high speeds.

KB: *At what point do the tails form?*

FW: We rarely see the conspicuous tails until the comet comes within one astronomical unit of the Sun. As a comet comes in, the coma, or head of the comet, grows until it comes within 1.8 or so astronomical units. Then the tails develop as the coma shrinks.

KB: *Do these comets come in from great distances?*

FW: We somewhat arbitrarily separate comets into two categories, based on their orbits. The short-period comets go around the Sun in less than 200 years. Anything with a period longer than that is a long-period comet. Many of those travel in nearly parabolic orbits.

Back in 1931 or '32, Ernst Öpik showed that a system of comets out to about 100,000 astronomical units would remain in orbits stable against perturbations by the Sun for the lifetime of the solar system. But the gravitational effect of passing stars would knock out a lot of comets, very much like shooting a bullet through a swarm of gnats. The bullet would kill a lot of gnats, but the swarm would still be left. Then in 1950, Jan Oort in Holland showed that passing stars could cause comets to come into the inner solar system. They would travel in orbits with periods of a million years or so.

About a hundred years ago, H.A. Newton at Yale, who was not a relative of the bachelor Sir Isaac Newton, showed that if a long-period comet came in with just the right orbit, there was a very small but finite chance that Jupiter might turn it into a short-period orbit. In recent years, Edgar Everhart in Denver has shown how, in many passes through the solar system, comets can be perturbed by the planets into short-period orbits. But of these comets, about half will be knocked out.

KB: *Do you mean actually ejected from the solar system?*

FW: The planets will kick them out so they never come back again. It's a very wasteful process. But apparently there are enough comets to keep up the supply of short-period comets.

KB: *All these comets come in from some great distance. Do estimates exist of how many comets reside in the outer solar system?*

FW: Oort estimated about a hundred billion were needed out there to keep the supply of new comets coming. This is the Öpik-Oort cloud, extending out to some 50,000 astronomical units or more. It is the storehouse of comets from which the passing stars appear to send in a few new comets each year.

KB: *What are comets made of?*

FW: In the 1860's, H.A. Newton and G. Schiaparelli, and others, established that some meteor showers come from debris left in the paths of comets — the Perseid and Leonid showers, for example. That gave us a picture of a comet as a big mass of unconsolidated material — dust, gravel or whatever — moving in orbit around the Sun. The picture of comets as flying sand banks dominated the scene for almost a century. But since the 1860's gas had been

observed in the tails of comets. It was attributed to dust particles, having absorbed gas, releasing it when exposed to sunlight.

All light from a comet arises from sunlight. We see sunlight reflected from the dust. In both the ion tails and the gas around the head of the comet, we see fluorescence of gases. Sunlight excites the atoms, giving them energy. Then they radiate away that energy in visual wavelengths, and we see it.

This was well known by the early 1900's. About that time, Karl Schwartzschild calculated how much gas was coming out of these comets. In the 1930's and 40's, Wurm continued the calculations. They found so much gas coming out that it would be very difficult for the dust to hold enough gas to provide the fluorescent illumination of comets.

That bothered me in the 1940's. The question arose: Was there any way a comet might pick up gas while traveling through space? It was a nice thought. With a graduate student, I calculated the number of electrons in the zodiacal light. [Sometimes called the false dawn, the zodiacal light is caused by sunlight reflecting off interplanetary particles.] It was a very low number and there was just no way comets could pick up enough gas to account for the tails.

So there had to be a deep freeze storage of gas in a comet. Ice was the obvious answer, and that led me to the dirty snowball model. If you put dust into a deep freeze of ice, particularly water and possibly carbon dioxide or ammonia, then you have a supply that could last for a huge period of time.

That seemed pretty obvious to me. The idea that comets were made of ice had actually been suggested by Laplace long before. But he thought that the vapor recondensed at great distances from the Sun, which is physically impossible in terms of modern knowledge of the Sun and physics. So his concept was forgotten. A lot of other people were very close to the idea, but never published it specifically.

Then I remembered the peculiar motion of Encke's Comet. This comet has the shortest-known period, three and one-third years, and was discovered in 1786. Around 1819, Encke calculated its orbit and discovered it was shortening by about two and one-half hours every orbit.

This concept of the snowball being activated by sunlight gave a physical mechanism for the changing period of the comet. When the Sun shines on an icy mass in space — in a vacuum — the gas comes off at about half a kilometer per second. That's a lot of force acting on the nucleus. Now if the nucleus is spinning, and everything seems to be spinning in the universe (it's very hard to keep anything still), then the gas goes off at an angle to the Sun. Depending on which way the comet is spinning, it can increase the period, or reduce it.

When I calculated the numbers, they came out very reasonable if Encke's Comet was a dirty snowball, two or three kilometers in diameter.

KB: *How did comets come to be?*

FW: There's a lot of evidence that the inner, earthy planets — Mercury, Venus, Earth and Mars — collected from rocky planetesimals, growing larger and larger into planet-sized bodies. But within the inner solar nebula, from which the Sun and planets formed, (see the September/October 1984 *Planetary Report*) the temperature was just too hot for much ice to form. However, out beyond Saturn's orbit, it would have been cold enough that ice could freeze. Planetesimals could there form out of ices, plus earthy stuff.

In fact, the compositions of Uranus and Neptune are what we would expect if they were made of ice and dust frozen out of the original solar mix of gas. Collect enough of this stuff, say 14 or 15 times Earth's mass, and we'd have very nearly the gross physical properties of Uranus and Neptune. The comets may have formed out in this region, so the ones we see could be leftover building blocks of Uranus and Neptune.

After the planets became large, their gravity was great enough to kick the comets out into very long orbits. Many of them got kicked into infinity, and were lost forever. Many got kicked into the Sun, and were lost there. Many were lost, as comets are today, by coming into the inner solar system where the Sun's radiation destroyed them.

KB: *If, in its early history, a large number of comets passed through the inner solar system, could this bombardment of comets have had some major effect on Earth? For example, is there some component of cometary material in Earth's atmosphere?*

FW: I looked into that. If you assume that the original number of comets was very high, so that billions of them passed through the inner solar system over a hundred million years or so, even then the number that would strike Earth is trivial. So it's very unlikely, from my calculations at least, that comets contributed much to Earth's atmosphere.

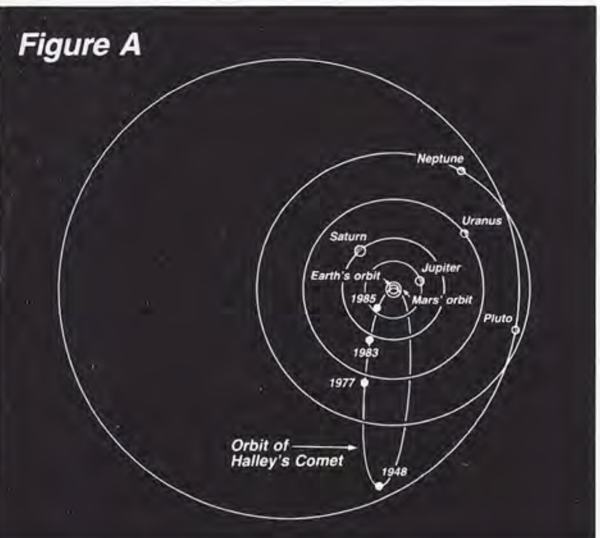
Possibly, however, we had a cometary nebula form in the inner solar system. It could have contributed a considerable mass to the inner planets.

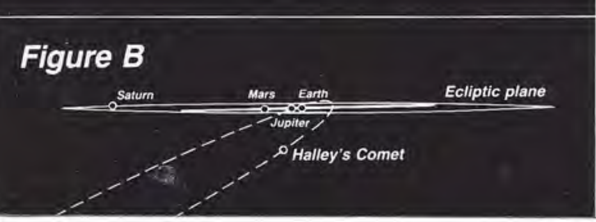
KB: *You mentioned that a comet, in a short-period orbit, becomes exhausted and eventually dies. Is there any firm link* →

***Upper left:** A big, bright, reliable comet, Halley's Comet returns to our neighborhood every 76 years. Here artist Ron Miller imagines how it might look in 2062, seen from the Moon during a solar eclipse.* Painting: Ron Miller ***Left:** No one has yet seen the nucleus of a comet close-up. According to Fred Whipple's "dirty snowball" hypothesis, it is primarily ice, mixed with particles of dust. Here is artist James Hervat's rendering of the surface of a comet nucleus.* Painting: © J. Hervat 1985

In its 1986 apparition, Halley's Comet will not be as spectacular as in 1910, when this photo was taken. Photo: Harvard University

Above: Here is scientist-artist William K. Hartmann's version of a comet nucleus. Snowfields of long-frozen water erode away as sunlight heats the comet. Rocks protect underlying ice, forming short pedestals that erode to slim spires when the rocks fall off. Propelled by gas jets, ice and dust particles stream away from the comet. Painting: William K. Hartmann ***Below: If viewed from above the plane of the solar system (the ecliptic), Halley's Comet would appear to cross the orbits of all the planets except Pluto (Figure A). The comet's positions at given dates are here indicated on its orbital path. But if viewed from a point (Figure B) looking along the ecliptic, the comet would appear to come from below, crossing the ecliptic and rising above it at perihelion (its closest approach to the Sun).*** Drawings: S.A. Smith





between comets and asteroids? Are some asteroids defunct comets?

FW: There may well be some link. I've been troubled by this question ever since I first thought of the dirty snowball model, and wondered about Encke's Comet, which I proved has been around for thousands of revolutions. But the question has never been answered very clearly; I've always been on the fence.

There are two aspects of this problem. If you start out with a large comet, and if there's meteoritic material — large hunks of rock — on it, some of them would be too big to be blown off by the gas. They would fall back and eventually cover the comet's surface, so the comet would become inactive.

Then, R.P. Stefanik and I made some calculations in the 1960's on effects of radioactivity in the middle of a large comet. If the comet is big enough — 30 to 50 or more kilometers in diameter — its radio activity could warm it up. This could transfer the ice (as gas) outward and leave a meteoritic core. After many passes around the Sun, the outer ice would have been removed, leaving a stony core.

This may well have happened. For many years there's been the question of Hidalgo, an asteroid traveling in a comet-like orbit that carries it outside of Jupiter's orbit. There are two or three other such asteroids in unusual orbits. Then there is 1983TB, the first asteroid found moving in the orbit of a meteor stream, the source of the Geminid meteor shower. This looks very suspiciously like an old comet that deteriorated and left a meteor stream.

Quite a few people are in favor of the Earth-crossing asteroids, the Apollos, being defunct comet nuclei that look like asteroids.

KB: *A fair number of well-known comets have been watched for generations. What is special about Halley's Comet, that all these spacecraft are converging on it?*

FW: The special thing about Halley's Comet is that it is the only large, very active comet whose return is predictable. As a consequence, we can plan ahead. Now, if you compare Halley's Comet to almost all other short-period comets, it's much more active, with a long tail and a big coma.

We cannot, at this stage of the game, plan our space missions and execute them rapidly enough to take advantage of an unexpected new comet, which might be more active than Halley's. Kohoutek was a good example of a case where a great deal of activity was mobilized for a comet — very successfully, as far as science is concerned. We had enough time to do quite a bit of scientific preparation. But the press overemphasized its possible brightness and got everybody excited, and then disappointed.

In the case of Halley's Comet, we have had many years to prepare. Big projects were aimed at it with the certainty that Halley's will be an interesting and active comet.

KB: *Astronomers have very powerful telescopic techniques for observing comets. What is to be gained from actually visiting the comet?*

FW: Take the example of IRAS-Araki-Alcock, the closest comet in a hundred years. We had very little time to prepare for it. And although it came very close, we still cannot say what the diameter of its nucleus is.

That's why we want to get some good spacecraft images of Halley's Comet. It's possible that the dust may make it difficult, if not impossible, to see the nucleus. That's a gamble. But we hope we can get a picture of the nucleus and see what it looks like.

The space missions will also pick up material immediately after it comes off the comet. One of the results of the studies of IRAS-Araki-Alcock was the identification of the S_2 molecule, diatomic sulfur, which is almost impossible to make in the laboratory. If you heat up and cool down sulfur to make a compound, you get something more like S_8, instead of the diatomic form. P. Feldman and M. A'Hearn show, I think convincingly, that the only way to make diatomic sulfur is at extremely low temperatures. This is almost conclusive evidence that comets were formed at extremely low temperatures, and have never been heated up until their surfaces are exposed to sunlight.

Now that evidence came from this unexpected comet for which we had very little

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THE INTERNATIONAL HALLEY WATCH

An Experiment in Cooperation

by Jurgen Rahe and Ray L. Newburn, Jr.

People knew Halley's Comet was coming in 1910, and they waited anxiously for its appearance in the sky. Scientists hoped to learn as much as they could about this famous celestial visitor. But while they focused their telescopes, calibrated their spectrographs, and otherwise prepared to use their observational skills, many scientists neglected some of their most important techniques: cooperation, coordination and collaboration. Much valuable information was lost because scientists around the world did not work as a team.

While preparing for the 1986 apparition of Halley's Comet, Louis D. Friedman of NASA's Jet Propulsion Laboratory (now Executive Director of The Planetary Society) recognized how the scientists of 1910 had missed a great opportunity. With several missions to the comet being planned, he felt it was especially important to coordinate space and ground observations. In the fall of 1979, Friedman proposed a worldwide organization of professional and amateur astronomers to coordinate observations of the comet during this apparition. He called it the International Halley Watch (IHW).

Following its strong endorsement by international science groups and funding by NASA, two IHW Lead Centers were established, the western hemisphere office in Pasadena, California, and the eastern hemisphere office in Bamberg, Federal Republic of Germany.

Internationally selected scientists have organized worldwide networks of observers from different technical disciplines. They will set up observations, solve special problems and, ultimately, submit data collected to a comprehensive Halley's Comet archive that will include all properly documented data obtained from both ground and space. The data will be published in 1989.

Over 900 professional astronomers from 47 countries are now collaborating in the IHW, with many amateur astronomers also involved. (As a service to the IHW and NASA, The Planetary Society publishes an Amateur Observers' Bulletin for over 3,000 participants.)

Why do we need so many observers? One reason is that scientists would like continuous observations to look for such things as flares or other sporadic activity from the comet. But continuous observations require complete longitudinal coverage from around Earth. Consider the remote continental areas and the vast expanse of the oceans, and you'll see the difficulty.

In addition, we have so few opportunities to prepare observations of big, bright comets that we must make the most of this one, which means coordinating and comparing, as much as possible, complementary observations taken at the same time. Comets change so rapidly that comparing observations taken even a day apart may be like comparing apples and oranges.

These observations will include those of the five spacecraft that will encounter Halley's Comet in 1986. (See pages 8-11.) One of the most exciting roles of the IHW is to supply information about the comet's position in space. European and Soviet mission controllers will use this information to precisely target their spacecraft.

While other countries are flying spacecraft by Halley's Comet, the United States will conduct space-shuttle-based experiments to make longer-term but much more distant observations of the comet in wavelengths blocked by our atmosphere, and so not observable from Earth's surface. Equipment in airplanes, balloons and sounding rockets will augment these studies.

The IHW will help put together the short-duration, close-up spacecraft data with the long-duration, faraway Earth-orbital and ground-based observations.

Both the professional and the amateur astronomers will contribute to the ground-based effort. The professionals are organized into eight technical disciplines:

- ☐ Astrometry will provide data for orbital position and velocity computations, and will model the shape, motion and behavior of the comet's nucleus to help explain its motion. These data will be given to all observers, including the spacecraft navigational teams.
- ☐ Large-Scale Phenomena Studies will use wide-angle photography to study the comet's gas and dust tails with high temporal and spatial resolution.
- ☐ Near-Nucleus Studies, using photographic and electronic imaging of structures in the coma, will yield data on the nucleus, such as rotation rate, active regions and surface structure, and also data on the general activity of the comet.
- ☐ Infrared Spectroscopy and Radiometry will provide detailed information on the energy balance and temperature of the dust particles released by the comet, as well as on their size and composition. Some data may also be obtained on gaseous components of the coma.
- ☐ Photometry and Polarimetry will determine the abundances and distribution of volatile (easily evaporated) and non-volatile components of the coma, and the physical mechanisms acting on them.
- ☐ Radio Sciences will provide further data on the physical processes and composition of the comet through the study of cometary chemical species observable at radio wavelengths.
- ☐ Spectroscopy and Spectrophotometry will yield data on the composition and physical state of the nucleus, coma and tail.
- ☐ Meteor observations of the Aquarid meteor shower in early May and the Orionid meteor shower in late October may provide information on their source, believed to be dust left behind in the trail of Halley's Comet.

Amateur astronomers will play an important role by supplementing the observations of professionals. The visual and photographic techniques available to amateurs today are very similar to those used by professionals in 1910. In many cases, work by amateurs will fill in gaps in professional coverage, which is limited by telescope time allotments and the geographical positions of observatories. A few amateurs can also provide spectroscopic and photoelectric data to supplement those taken at major observatories.

All these data will be collected and archived by the International Halley Watch, and will serve as the most complete data set ever compiled on a single comet. Generations of scientists will sift through it and, in the process, increase our understanding not only of comets, but of the origin of the solar system, Earth, and the life on it.

Jurgen Rahe of Remeis Observatory in Bamberg, Federal Republic of Germany, heads the International Halley Watch Eastern Lead Center; Ray Newburn runs the Western Lead Center from Jet Propulsion Laboratory, Pasadena, California.

COMET-

A Short Guide to Seeing Halley's Comet

AS THE LONG-AWAITED APPARITION APPROACHES, people are preparing to watch Halley's Comet. For some of us, this will be the only chance of our lifetimes. But, unfortunately, many are going to be disappointed. There will be no bright, glowing light spread across the sky. At its 1986 best, Halley's Comet will be a faint smudge apparent only to those who know how to look for it. This coming apparition of the comet may be the worst in 2000 years, and it won't be any better in 2061.

The Planetary Society wants to help its members make the most of this visit by the comet. Many members have already called or written with questions about how best to see the comet, and we would like to share those questions, and the answers, with you.

When will Halley's Comet become visible?
Scientists with high-powered telescopes have been watching the comet since October 16, 1982, when Dave Jewitt and Ed Danielson photographed it with the 200-inch instrument on Mount Palomar. But for those with smaller telescopes, the comet will become visible sometime in August, 1985.

In northern skies, by December, 1985, people with binoculars should be able to find it in the southwest sky about half-way between the horizon and zenith about one and one-half hours after sunset.

In early January, 1986, Halley's Comet will be visible in the west to the naked eye. As the month goes on, it will sink lower in the sky, eventually becoming lost in the Sun's glare. It will then be moving behind the Sun for its closest approach to the Sun — perihelion on February 9. The comet will then be at its most active, with its longest, brightest tail, but we won't be able to see it from Earth.

Halley's Comet will reappear in March in the southeastern sky. Unfortunately, it will be very close to the horizon in the northern hemisphere, probably not visible from north of a line drawn, roughly, through Chicago, Madrid and Vladivostok.

In southern skies, by December, the comet can be seen with binoculars low on the northwest horizon about one and one-half hours after sunset. In early January, it will be visible to the naked eye. Then it moves behind the Sun and disappears for over a month.

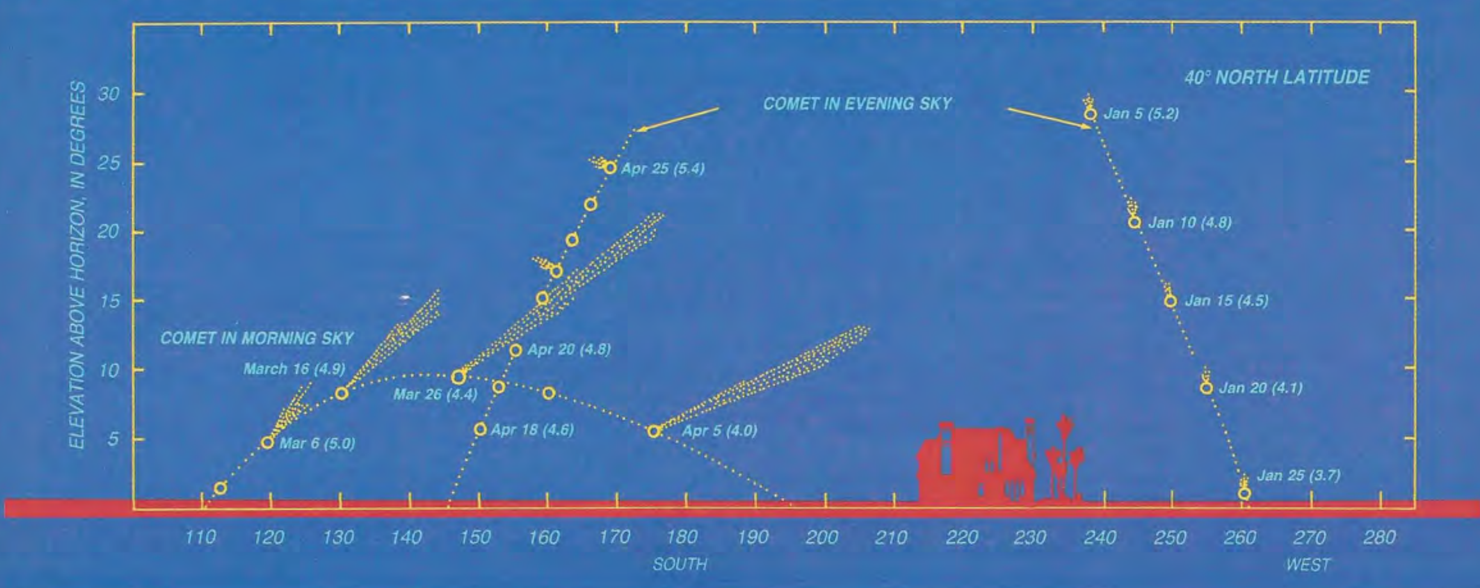
Toward the end of February the comet will reappear in the morning sky, low on the southeast horizon. Each day it will climb higher in the sky, moving from southeast to southwest. The tail will grow and the comet will brighten, reaching its best between the last week of March and the first week in April. By the end of April, it will no longer be visible to the naked eye. People with telescopes or binoculars will be able to watch it fade for a few more months.

Where should I go to get my best view of the comet?
Get as far away as possible from city lights and pollution. These human-made interferences could be the greatest obstacles to seeing the comet. Find the darkest skies you can, probably in the mountains or desert.

During March and April, go as far south as possible. Many travel agents, astronomy clubs and other organizations, including The Planetary Society, are planning tours to the southern hemisphere especially to see the comet.

Wherever you go, pick a time during the dark of the Moon. Bright moonlight can interfere with comet-viewing as much as city lights and pollution.

Will it be worth the trip?
This is a difficult question for another person to answer for you. A good question to ask yourself is: Have you always wanted to see South America, southern Africa, Australia or New Zealand? If so, then Halley's Comet is a good excuse to go.



WATCHING

What equipment should I buy?
A good pair of binoculars is probably your best investment. Those marked 7 x 35 are good, with 7 x 50 as the best bets. Because the comet will be a dim band of light stretching across the sky, the light-gathering power of the binoculars, rather than the magnification, will be the most important thing to consider.

A telescope with a wide field of view will enable you to see the comet long before and long after it is visible with binoculars. With it, you may see details of the comet's coma and tail. STAY AWAY FROM LONG, NARROW, SPYGLASS-TYPE TELESCOPES! These instruments may claim extraordinary magnifying power, but they have extremely narrow fields of view — much too narrow for watching comets. Find instead an instrument with a large aperture — the larger the aperture, the brighter the image.

Remember, good telescopes are expensive and require some skill to use. Before you sink hundreds, or even thousands, of dollars into an instrument, carefully consider how you will use it after Halley's Comet has faded from the sky.

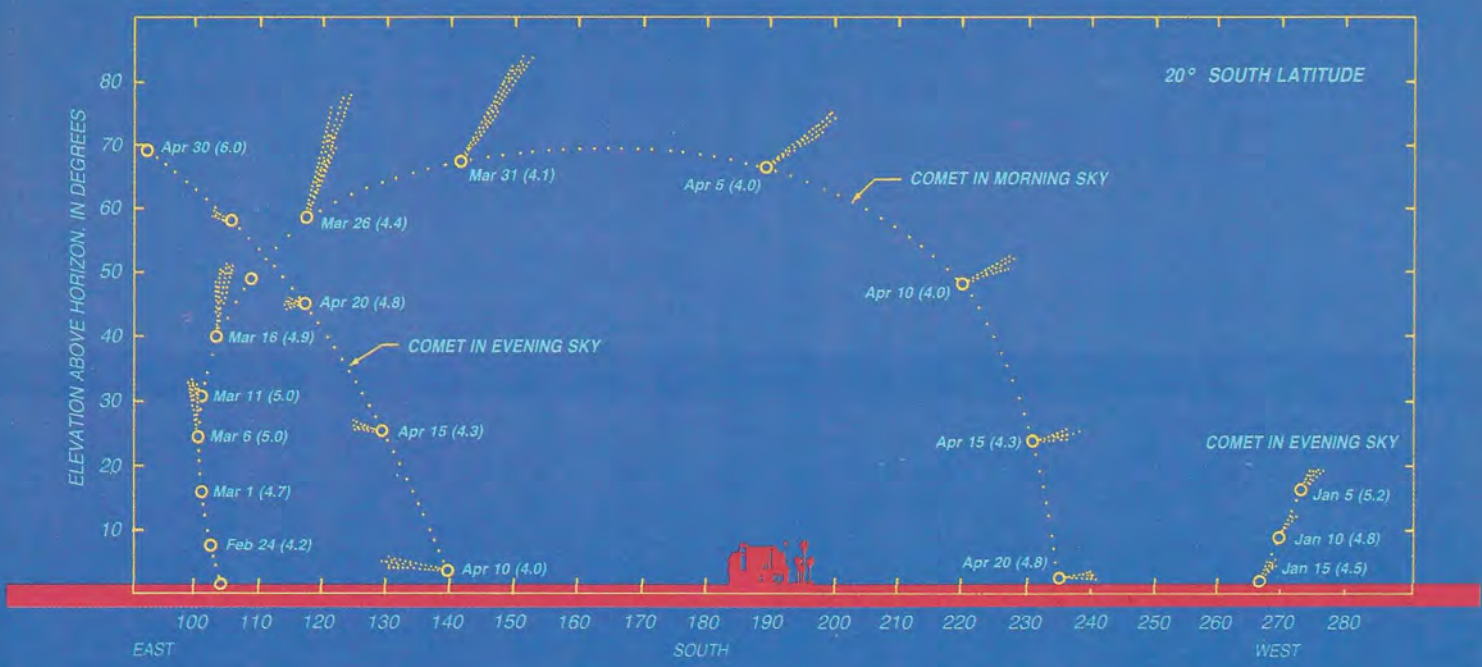
How can I photograph the comet?
Use any camera that can take time exposures (most of these have a "B" setting for the shutter speed). You should also use a tripod and a cable release. A standard, 50 mm lens will have a field of view wide enough to take in the entire comet. It may also be able to record more of the comet than you can see with your naked eyes.

Load your camera with ISO (ASA) 1000 daylight slide or print film. Focus on infinity, and open the lens as wide as possible (the lower the f-stop, the wider the aperture). Using your cable release, take a series of exposures from five seconds to several minutes long.

You should begin and end each roll of film with a non-astronomical photograph. For example, you could take a flash photo of your binocular-bedecked friends or family huddled together for warmth in the midst of a very dark desert. By taking such pictures you'll give the photo-processing technician references for cutting your film into frames. Most technicians are not familiar with astronomical photographs; they may see your prize shot of Halley's Comet as a bit of fogged-up film. Instruct the processor to print all negatives and mount all slides.

You should now be almost ready for Halley's Comet. If you would like more information, there are many books and pamphlets about the comet available from your local bookshops, planetarium, other magazines and The Planetary Society (see page 23). *Mr. Halley's Comet*, a booklet prepared by the editors of *Sky & Telescope* magazine, is available to Society members for $1.00, $2.00 for non-members. Send your money (to cover handling and postage) to: *Mr. Halley's Comet*, The Planetary Society, 110 S. Euclid Avenue, Pasadena, CA 91101.

Happy comet-watching! □



These charts summarize the observing conditions for Halley's Comet in 1986. The comet's positions are given for the beginning of morning twilight and the end of evening twilight. The visual magnitude (apparent brightness) is given in parentheses. The lower the number the brighter the comet; a sixth-magnitude star is about the dimmest that can be seen with the naked eye. As a reference for the sky positions, five degrees is about the width of a hand held at arm's length. ***Charts: S.A. Smith***

News & Reviews

by Clark R. Chapman

What colors are planets? People have long thought of Mars as the Red Planet. In song and verse, the Moon is "silvery." Recently we have marvelled at *Voyager*'s pictures of Jupiter's larger inner moon, Io, which make it seem like a pizza smothered in orange tomato sauce.

Now along comes Andrew Young, a planetary astronomer writing in the May *Sky & Telescope*, who wants us to believe that Mars is a "dark yellowish brown," that the Moon is a dark "brownish gray," and that Io is pale yellow with hints of green! These startling assertions will be difficult for many people to accept; but Young makes a persuasive case that the pizza-like version of Io is the creation of darkroom photographers and magazine printers rather than of Nature itself.

It is not that there is any dispute about what fraction of sunlight, at every wavelength, is reflected by the various planetary surfaces. The question is how can those telescopic and spacecraft measurements be used to fabricate a "hard-copy" picture that the human eye will perceive as having the same color as the planet. For example, how could we mix a paint having the same color as the sands of Mars, and then how could we photograph and print a picture of that paint so that our eye/brain responds as it would to the "true" color of Mars?

In his *Sky &Telescope* article, Young explains how one might try to do this and then — provocatively — presents some examples for us to see for ourselves. His logic sounds good to me, but I don't predict you'll see many of Young's pale yellow versions of Io in future issues of *The Planetary Report*, or even in *Sky & Telescope* again. I think this particular "truth" will be too difficult for people to accept.

Other Worlds

The June issue of *Science 85* features four articles on the theme of whether or not planets and life abound elsewhere in the universe. Mitchell Waldrop's article on the search for other planets features a five-part scenario of current beliefs about how our solar system was formed.

Many scientists feel that such processes should have operated in countless other stellar systems. But, despite recent discoveries of interesting companions and disks near some other stars, we are still awaiting the first definitive proof for the existence of an Earth- or Jupiter-like planet near any other star.

A thought-provoking article by George Greenstein proposes that we should fear making contact with extraterrestrials, a common attitude some decades ago, but now out of style. And there is an historical overview by Alan Lightman on the religious implications of other worlds.

History is also the topic of Donald Osterbrock's article in the March/April *Mercury* about James Keeler's famous measurement, ninety years ago, of the rings of Saturn. Using the principles of Doppler spectroscopy, Keeler provided the first observational proof of Maxwell's earlier theoretical proof that the rings are composed of a myriad of particles rather than being solid and rigid.

Planetary discoveries were big news then as now, and Keeler found his results sensationalized in the national press, to his considerable consternation. Donald McCarthy ran into similar problems just last year when a National Science Foundation press release heralded his discovery of a 2,000 degree Fahrenheit brown dwarf companion of a faint, nearby star as the first extra-solar-system "planet" (see Waldrop's *Science 85* article).

Hype, Seriously Reconsidered

I have complained in recent columns of fads in science, which are sometimes inaccurately hyped in popular magazines and newspapers. Sometimes the scientists themselves get overexcited and lose perspective. Some sober reconsiderations of Nemesis — the supposed companion star to the Sun responsible for comet showers and periodic extinctions — were voiced at a recent meeting on our galaxy and solar system. As described by Richard Kerr in the March 22nd issue of *Science*, much of the support for periodic extinctions, for periodic cratering of Earth, and for Nemesis itself has eroded away under serious scientific scrutiny. The giant-impact model for the origin of the Moon has generated some enthusiastic but inaccurate reports, as well. The sober scientific facts are recounted in a brief but somewhat technical article by Jeffrey Taylor (*Geotimes*, April 1985).

Some hype I can appreciate. Steve Erickson's prose waxes flowery and extravagant as he tells the story of the *Galileo* project in the January 1985 issue of the PSA airlines flight magazine. This spacecraft mission, more than a decade in the planning and due for launch next year, deserves Erickson's enthusiasm. I can even accept as poetic license a picturesque inaccuracy in Ray Bradbury's accompanying poem, which anticipates *Galileo*'s probe diving into the heart of Jupiter's Red Spot. The men and women who have struggled to bring this project to fruition will be gathering at Cape Canaveral just a year from now to watch a space shuttle carry the product of their work into orbit and send it on its way to the giant planet.

In Erickson's tale, the greatest threat to *Galileo* was in the form of "a vast slithering form of alien life. . .oozing inertia and indecision" called the US Congress. As I write this column, that same entity is once again thrashing about, trying to enact a budget freeze that *could* freeze out many planetary missions and other NASA endeavors for years to come. Should that happen, *Galileo* might become the last planetary mission of the century. We need more Steve Ericksons to kindle enthusiasm for the potential of deep space exploration in US decision-makers.

Clark R. Chapman will be among the thousands at Cape Canaveral next year to watch the beginning of Galileo*'s journey.*

SOCIETY NOTES

HALLEY'S COMET TELEVISION SPECIAL

The Corporation for Public Broadcasting and the Public Broadcasting Service (PBS) have now committed to the Planetary Society television special on Halley's Comet.

The television show is scheduled to air nationwide on November 26, 1985. M&M/Mars, makers of Mars and Milky Way bars, have joined us as the corporate underwriter for this important television event.

John L. Wilhelm, WETA-TV of Washington, DC and the Asahi Broadcasting Company of Japan are co-producing the show. Wilhelm, a former national science correspondent for *Time* magazine and former managing editor for *Science 80*, is serving as Executive Producer and co-writer and Lawrence K. Pomeroy is Senior Producer and co-writer. The Planetary Society is providing scientific advice under the direction of Professor Joseph Veverka of Cornell University.

With the support of our members, we intend this to be the most exciting and complete Halley's Comet TV presentation anywhere. The show will present historical and scientific information about Halley's Comet, while focusing on the Soviet, Japanese and European spacecraft encounters.

This can be the beginning of an important new project for The Planetary Society, enabling us to reach millions of people through the medium of television. Members who wish to help make this happen may contribute to the Halley's Comet Television Fund. Tax-deductible donations should be mailed to P.O. Box 2530, Pasadena, CA 91102, or use the mailing form you should have received during our special appeal in May.

COMET QUEST AT THE SMITHSONIAN

The Planetary Society and the Smithsonian Institution's National Air and Space Museum are co-sponsoring an international comet symposium, "Comet Quest," on December 6 and 7, 1985 in the museum. On Friday evening, December 6, Dr. Carl Sagan, President of The Planetary Society, will give a public lecture on Halley's Comet and its scientific importance.

Symposium participants will discuss other topics, including: "Comets and the Mind of Man," "What is a Comet?," "In Search of Edmond Halley," "The International Halley Watch," "Comet Giacobini-Zinner," and "The Space Missions to the Comet."

M&M/Mars is the corporate sponsor of the symposium, as well as the underwriter of The Planetary Society's television special on Halley's Comet.

Admission to the symposium is free.

HAWKING HALLEY'S COMET

Many books, pamphlets, pictures, souvenirs, paraphernalia and gimmicks are being marketed in connection with the 1986 apparition of Halley's Comet, as also happened in the previous (1910) apparition. The Planetary Society will make available, at discounts for members, as much worthwhile material as we possibly can. Our September/October issue will include a special sales section on Halley's Comet. If you would like to get a jump on the comet, we now have available:

- *Mr. Halley's Comet: Everyone's Complete Guide to Seeing the Celestial Event* by the editors of *Sky & Telescope*. Available to members for $1.00, $2.00 for non-members.
- Observer's guides to the northern and southern hemispheres, published by the International Halley Watch. Available for $1.00 each.
- *The Comet Book: A Guide for the Return of Halley's Comet* by Robert D. Chapman and John C. Brandt. Available for $14.00.

To order, use the form in the back of this magazine, or write to The Planetary Society, 110 S. Euclid Avenue, Pasadena, CA 91101.

UPCOMING EVENTS

September 29, 1985 — Initiation of the META (Megachannel Extraterrestrial Assay) project in Harvard, Massachusetts. Project leader Paul Horowitz, Carl Sagan and others will discuss the significance of this new 8.4-million channel receiver for the Search for Extraterrestrial Intelligence (SETI).

October 30, 1985 — Public policy discussion at the annual meeting of the Division for Planetary Sciences of the American Astronomical Society in Baltimore, Maryland. In the ballroom of the Baltimore Plaza Hotel, leading planetary scientists will discuss the future of space exploration.

November 26, 1985 — Broadcast of the Planetary Society television special on Halley's Comet.

December 6, 1985 — International comet symposium at the Smithsonian Institution's National Air and Space Museum. Dr. Carl Sagan will speak in the evening of December 6 in the Samuel P. Langley Theater.

January 24, 1986 — "Uranus — The Voyage Continues," symposium to celebrate *Voyager 2*'s encounter with Uranus. Live images from the spacecraft will be transmitted to the symposium site at Beckman Auditorium at the California Institute of Technology in Pasadena, CA.

March 29-April 12, 1986 — Halley's Comet cruise from Rio de Janeiro to Fort Lauderdale on the Cunard Line ship *Vistafjord*. The Planetary Society will present a lecture program on the comet. Discounts are available for Society members.

COMPARING THE PLANETS

Did an asteroid destroy the dinosaurs? Could humans turn Earth into a deep-freeze like Mars or a furnace like Venus? What do the other planets still have to teach us about Earth? Leading planetary scientists Eugene Shoemaker, James Pollack and Harold Masursky addressed these questions at a Planetary Society event, "Dinosaurs, Greenhouses and Ice Ages — The View from Space," held June 8 at Beckman Auditorium at the California Institute of Technology. The talks formed a public session to the scientific conference, "Terrestrial Planets: Comparative Planetology," held the preceding week and cosponsored by the Society, Caltech's Division of Geological and Planetary Sciences and several other science organizations.

1984 AUDIT COMPLETED

The Price Waterhouse audit of our complete 1984 financial statement resulted in an opinion with no qualifications, finding our statements in conformity with generally accepted accounting principles. A one-page summary is available upon request.

World Watch

by Louis D. Friedman

When one realizes that *Voyager* was approved in 1973 and *Galileo* in 1976, it is evident that the pace of the United States' deep space exploration has slowed down. At the same time, other spacefaring nations have been quickening their paces.

The Soviet program, in particular, is impressive not only in the number of missions they now contemplate, but in the innovation and creativity they employ in designing them. They will soon be sending single missions to several different targets, with spacecraft carrying innovative experiments that could make important discoveries at each target.

The Soviets are also showing a welcome openness in discussing their future missions. Academician Roald Sagdeev, Director of the Institute for Cosmic Research, and Academician Valeriy Barsukov, Director of the Vernadsky Institute for Geochemistry and Analytical Chemistry, both visited the United States earlier this year. Sagdeev, at The Planetary Society in January, and Barsukov, at the Houston Lunar and Planetary Conference in March, were very informative about the Soviet program to explore the solar system.

The corresponding US program is the Solar System Exploration Committee (SSEC) Report. The SSEC recommended a three part strategy: the core program, consisting of two parts, *Observers* and *Mariner Mark II*; and the augmented program, focusing primarily on the surface exploration of Mars.

The *Observers* are designed as low-cost spacecraft, adapted from Earth-orbital satellites, to be used for special-purpose planetary missions. The first *Observer* will be the Mars Geoscience/Climatology Observer (MGCO), approved last year and scheduled for launch in 1990. Other possible *Observers* are a lunar orbiter and a rendezvous with a near-Earth asteroid.

The *Mariner Mark II* is a new multi-purpose spacecraft that will follow in the tradition of earlier *Mariners* and will include new technology wherever possible to reduce costs and simplify design. Engineers at NASA's Jet Propulsion Laboratory are designing common modular subsystems for the *Mariner Mark II*, to share and save costs among the individual spacecraft that will be sent on different missions.

The first *Mariner Mark II* mission planned is the Comet Rendezvous Asteroid Flyby (CRAF), to be launched in 1991, probably to Comet Wild II. (Because of the frequency of short-period comets, the launch date and target can be varied, depending on schedule and budget considerations.) Comet rendezvous differ from flybys (like the missions to Halley's Comet) in that spacecraft can fly very near a comet during a large portion of its course around the solar system. Measurements can be taken over months through the whole gamut of comet activity, rather than in a few minutes, as in the fast flybys.

After CRAF, the most studied candidate for *Mariner Mark II* is a Titan lander-Saturn orbiter project, the *Cassini* mission now being studied jointly by NASA and the European Space Agency. This mission would be launched in the mid-1990's and would reach Saturn about the turn of the century.

The core program of *Observers* and *Mariner Mark II* missions was considered an irreducible minimum by the SSEC and other science advisory groups to NASA. Above the minimum, they recommended an augmented program of sample returns from and rovers on Mars. These automated missions would pave the way for human exploration of that planet in the next century.

But even the core program is in jeopardy from current budget constraints and other program priorities in NASA. Although President Reagan proposed a five percent increase in the fiscal year 1986 budget for NASA, it contained no new planetary missions. Thus far Congress, in its consideration of the FY'86 budget, has concentrated on reducing the federal deficit by freezing, wherever possible, budgets at their FY'85 level.

For NASA this means a significant cut from the President's proposal and further difficulties for new starts in space science and exploration missions. Although not officially confirmed, the budget cut would probably kill the new start for the CRAF mission in FY'87. This would be a serious loss, not only because of the importance of a rendezvous mission for comet studies, but because of the damage it would do to the entire SSEC program.

Another casualty of the budget cuts is space science research — the analysis of data from past planetary missions. Although, in response to congressional pressure, NASA officials promised to restore the research budget to its 1981 level (it has been cut every year since then), it is not possible to maintain that level within existing budget constraints. The issue is very serious. If present trends continue, many planetary scientists will be forced to leave the field.

As these budget deliberations continue and NASA reacts to constraints imposed by national priorities, it will be necessary to rethink NASA's own priorities and whether it wishes to continue the historic American program of planetary exploration. The Planetary Society encourages discussion on this subject. Members who wish to make their views known may write us or the congressional committees most involved in defining the priorities for space exploration (see box).

Louis Friedman is Executive Director of The Planetary Society.

Following the reorganization of the US congressional committees as a result of the November, 1984 elections, the chairmen and ranking minority members of the six key committees involved with the NASA budget are:

Senate Committee on Commerce, Science and Transportation
Subcommittee on Science, Technology and Space
Chairman: Slade Gorton, *Washington*
Ranking Minority Member: Donald W. Riegle, Jr., *Michigan*

Senate Appropriations Committee
Subcommittee on HUD and Independent Agencies
Chairman: Jake Garn, *Utah*
Ranking Minority Member: Patrick J. Leahy, *Vermont*

Senate Committee on the Budget
Chairman: Pete V. Domenici, *New Mexico*
Ranking Minority Member: Lawton Chiles, *Florida*

House Committee on Science and Technology
Subcommittee on Space Science and Applications
Chairman: Bill Nelson, *Florida*
Ranking Minority Member: Robert S. Walker, *Pennsylvania*

House Committee on Appropriations
Subcommittee on HUD and Independent Agencies
Chairman: Edward Boland, *Massachusetts*
Ranking Minority Member: Bill Green, *New York*

House Committee on the Budget
Chairman: William H. Gray III, *Pennsylvania*
Ranking Minority Member: Delbert L. Latta, *Ohio*

The address for the House of Representatives is Washington, DC 20515; for the Senate, it's Washington, DC 20510.

A TALK WITH FRED WHIPPLE
(continued from page 14)

time to prepare. With probes going right into the comet nucleus, we can measure those molecules and atoms in close.

KB: *So in exploring comets, we're really trying to examine material that's unchanged since its formation, and presumably since the formation of the solar system.*
FW: Exactly, that's why it's of great interest. We suspected this all the time, and talked about it. But the S_2 evidence of A'Hearn and Feldman is a very strong substantiation of that concept.

KB: *You were born in 1906; do you remember Halley's Comet?*
FW: No. I was living on a farm then and my parents didn't go out to see it themselves, even when it was most conspicuous. And I would have only been about 3 and one-half at the time, so it's unlikely I would have remembered it anyhow. But I asked them specifically, and they said they didn't take me out to see it.

KB: *Are you looking forward to this passage?*
FW: Oh yes, naturally. Not so much for seeing it as for finding out what the missions will divulge about the nature of the comet.

KB: *Are you bothered or pleased by all the attention that's being given to this passage of Halley's Comet?*
FW: I've had the unhappy experience of the press overselling Kohoutek, and the public being disillusioned. It should be said that there's very little chance that Halley's Comet will be as bright as Kohoutek at its best.

KB: *You've been fortunate enough to see the entire drama of space exploration unfold. During the 1950's you did some speculative articles on the future of humans in space. With all that experience under your belt, can you wax speculative again, and suggest what might happen in the next 20 years?*
FW: With Wernher von Braun and others I contributed to a series of articles in *Collier's* magazine. The question of man (by this I mean mankind) in space I've always considered as separate problem from the scientific investigation of space. There was a confusion in people's minds, and there still is, between these two projects. Generally speaking, we can deal with science by remote control at about 10 percent of the cost for the same results achieved by sending men. On the other hand, man in space is a highly commendable goal, and I think we should push for it. We should try to conquer space as we've conquered all parts of Earth — Mount Everest, the Antarctic, and so forth.

KB: *Sort of a manifest destiny?*
FW: Yes. And, of course, if you are highly pessimistic, it would be an awfully good idea to have a viable colony or two on Mars or the Moon in case somebody triggers off a nuclear holocaust on Earth. But I don't like to use that as an argument for it.

The ideal nature of space colonies has been distorted in recent times, because of ignoring or underestimating the effects of cosmic rays on people. You put people into small colonies with only a few inches of steel or aluminum between them and outer space, and the secondary cosmic rays will be much more dangerous than the original rays. (See the March/April 1985 *Planetary Report.*) The only safe places to have viable colonies are in very large spacecraft, far beyond what anyone was thinking of building in the early days, or inside the Moon or Mars.

For the serious propagation of the human race, I'm much happier with the concept of lunar, martian or asteroidal colonies than I am with space colonies.

KB: *So you encourage or endorse the recent movement to rethink the idea of lunar bases?*
FW: Yes, I think we should have somebody up there. We could also go to Mars or an asteroid. There would be valuable minerals that might be mined on an asteroid more easily than on Earth.

J. Kelly Beatty is Senior Editor of Sky & Telescope *magazine.*

LOOKING INTO HALLEY'S COMET
(continued from page 11)
cause the results are very dependent on what happens when the dust and gases smash into the detectors inside the instrument.

A dust particle will be vaporized by impact; mass spectrometry of the resulting cloud gives an idea of the particle's composition, while determining its impact energy and speed gives a measure of its mass.

These investigations will be important in the search for parent molecules. "We will not see actual parent molecules. These are broken up by their impacts [with the instruments]," explained *Giotto* Project Scientist Ruediger Reinhard of ESA. "We'll look for atoms such as carbon, nitrogen and oxygen and do a number of clever calculations to try to determine the nature of the parent molecules."

The fourth and last technique is the investigation of interplanetary particles and fields around the comet, including its interactions with the solar wind. (The solar wind is a stream of ionized particles blown outward by the Sun.) All of the involved deep-space craft, including the Japanese MS-T5 millions of kilometers from the comet and the International Cometary Explorer (see the May/June 1985 *Planetary Report*), will carry magnetometers, charged-particle detectors, or other instruments for this type of investigation.

A key element in the 1986 Halley's Comet campaign is the simultaneous use of a wide variety of techniques, invented by scientists throughout the world, to permit cross-checks and correlations of measurements based on many different principles. Not only does this vastly improve the missions' scientific yield; also it brings together investigators from many countries, even including those with opposed political systems.

Two Planetary Society Advisors are prominent members of this scientific community. Roald Sagdeev is Director of the USSR's Institute for Cosmic Research, the agency responsible for the *Vega* mission. Jacques Blamont of the French Centre National d'Etudes Spatiales is a principal scientist on the *Vegas'* Venus balloon experiment (see box on page 11).

In addition to Bradford Smith on the imaging team, the Soviets have invited several other American scientists to participate in the *Vega* mission. John Simpson, a physicist at the University of Chicago, has a comet dust analyzer on each of the spacecraft. Ke Chiang Hsieh, a colleague of Smith's at the University of Arizona, designed a neutral mass spectrometer for the mission. Dr. Andrew Nagy of the University of Michigan, a veteran of the US *Pioneer* Venus mission, is a member of the *Vega* plasma physics science team.

This encounter with Halley's Comet will be an unprecedented, worldwide scientific event. The spacecraft missions are fully cooperative and their data will be combined with the ground-based observations of the International Halley Watch (see page 15) and the Earth-orbital observations of Astro-1 onboard a US space shuttle (see box on page 8).

Thus the human race, despite its bickerings and miseries on Earth, has risen at last with modern science to meet a mysterious celestial visitor whose regular passages through our neighborhood in the solar system have been marked by our forebears for over two thousand years. □

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March	29	Rio de Janeiro
	30	At sea — Comet viewing — Meet the faculty and introduction of program
	31	At sea — Comet viewing — seminar and workshop
April	1	Recife, charming tropical city of canals evoking classical Italy, watched over by the well known landmark Sugar Mountain
	2	At sea — Comet seminar and workshop
	3	At sea — Comet seminar and workshop
	4	Belem, a thriving metropolis which is chief port of the world's most powerful river, the Amazon
	5	At sea — Comet seminar and workshop
	6	At sea — Comet seminar and workshop
	7	Barbados — enjoy a bit of Britain amid swaying palms and sandy beaches
	8	St. Lucia — explore the inside of a volcano, tour a picturesque fishing village, or enjoy relaxing on the beach
	9	St. Thomas, the shopper's paradise of the Carribean
	10	At sea — Comet seminar and workshop
	11	At sea — Comet seminar and workshop
	12	Ft. Lauderdale and your return flight home

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(30 minutes)

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This outstanding videotape provides an opportunity to share in some of the most intriguing discoveries of the solar system. It includes exceptional images of Saturn's rings and the amazing moons of the giant planets.

(28 minutes)

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Journey through the universe from our solar system to the edge of known space with this information-packed videotape, narrated by William Shatner. Planets and pulsars, the lives and deaths of stars, and the origin of the universe are just a few of the topics covered. (30 minutes)

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008	**The Surface of Mars** by Michael Carr. 232 pages.	$15.00
009	**Voyages to Saturn** by David Morrison. 227 pages.	$14.00
010	**The New Solar System** edited by J. Kelly Beatty, Brian O'Leary, and Andrew Chaikin. **2nd edition**	$12.50
012	**The Moon** by Patrick Moore. 96 pages.	$12.00
015	**The Grand Tour: A Traveler's Guide to the Solar System** by Ron Miller and William K. Hartmann. 192 pages.	$ 9.00
016	**Planets of Rock and Ice** by Clark R. Chapman. 222 pages.	$12.50
018h 019s	**The Planets** edited by Bruce Murray. 129 pages. **Hard cover** **Soft cover**	$15.00 $ 9.50
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052	**The Solar System Close-Up, Part One** (50 slides with booklet)	$36.00
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Space artist (and new father) Michael Carroll lives in San Diego and works at the Reuben H. Fleet Space Theater and Science Center.

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