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Planet or Star?

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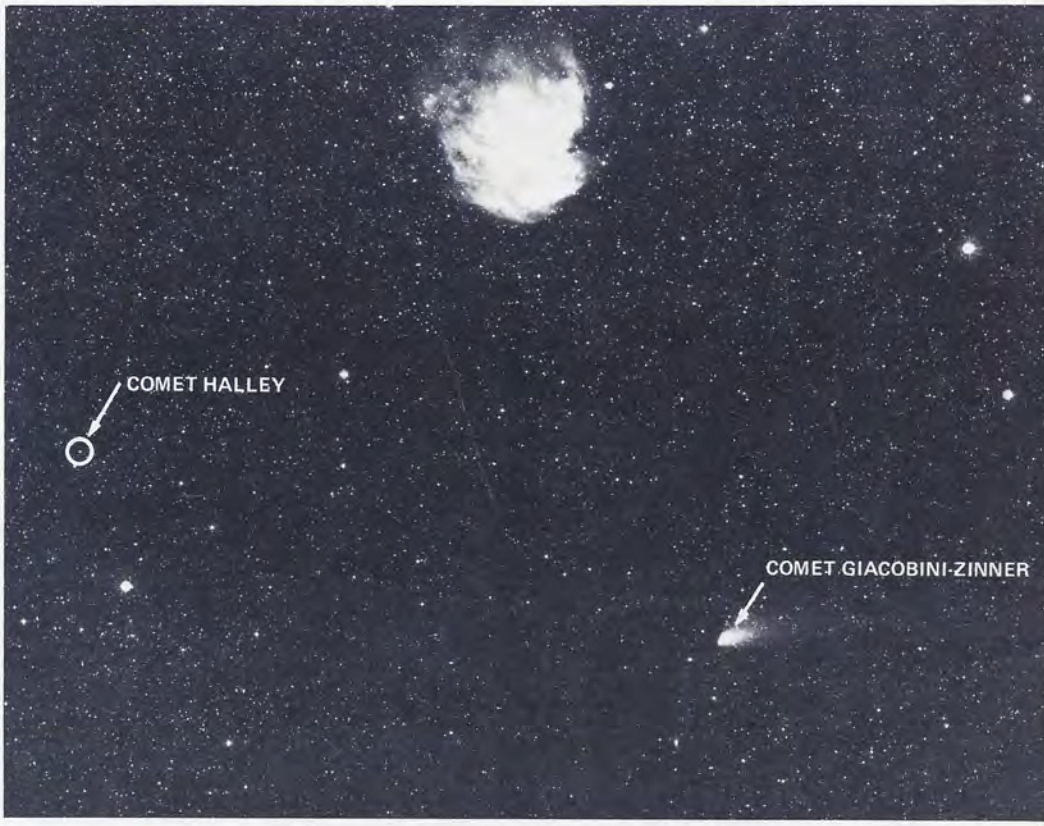
COVER: Almost a star, giant Jupiter is the lord of the planets. It radiates four times as much energy as it receives from the distant Sun — energy from the slow contraction of its huge mass, 318 times that of Earth. But even Jupiter is not large enough to sustain a thermonuclear fire, so it represents a class of bodies intermediate between tiny, rocky planets and the huge, gaseous objects that collapse into stars. ***Image: JPL/NASA***



Comets Halley and Giacobini-Zinner Photographed

Like two ships that passed in the night, Comets Halley and Giacobini-Zinner were photographed by JPL planetary scientist Eleanor Helin and her team in mid-September using the 48-inch Schmidt telescope on Mount Palomar. This image was taken September 14, 1985, three days after the International Cometary Explorer (ICE) spacecraft encountered Giacobini-Zinner. At that time, Halley was heading in toward its perihelion (closest approach to the Sun), while Giacobini-Zinner was heading back to the outer reaches of our solar system. Although in this image the comets appear to be passing close by one another, they are nearly 299 million kilometers (194 million miles) apart. (The nebula in the background, NGC 2174, is far outside our solar system.)

Eleanor Helin is the principal investigator of the Asteroid Project supported by The Planetary Society, NASA and the World Space Foundation. Working with an international team of astronomers, she recently discovered another near-Earth asteroid, 1985 PA, while observing from the Centre d'Etudes et de Recherches Geodynamiques et Astronomiques (CERGA) observatory at Caussols, France. This was the 22nd asteroid discovered by the JPL project.

HALLEY'S COMET

I

A nomad roaming
the starlit halls
of evening,

in a cold sweat
from some early tantrum
of light,

it bolts toward
the glow of a dashing
blue planet,

ancient, glacial,
always in a lather,

to blaze its loop
through the pastures
of the Sun.

A rumor at first
on a thousand
glass lips,

it passes
like Winter
from land to land,

stretching a long arm
around the shivers
of the night,

waving its white
plume:
cascading lilies,

signing the blue
petition of each day
with its haste.

II

Dropped out of nothing,
it will return
to nothing,

but, in between,
toast the miracle waters
of Earth:

the long sermon
of her deserts,

the green wings
of her jungles,

the pink moths
of her cities

trembling
along the hilltops,

the thick fungus
of her buildings,

the worn brown corduroy
of her farms,

the walking symphonies
of dappled cells,

themselves wonder enough
to startle the eons.

III

A waltzing iceberg
large as life,

it arrives with a shout
and will go
with a whisper,

vanish from the fragment
isolation
of our skies,

tugged away
by a grip beyond plea,
beyond mourning,

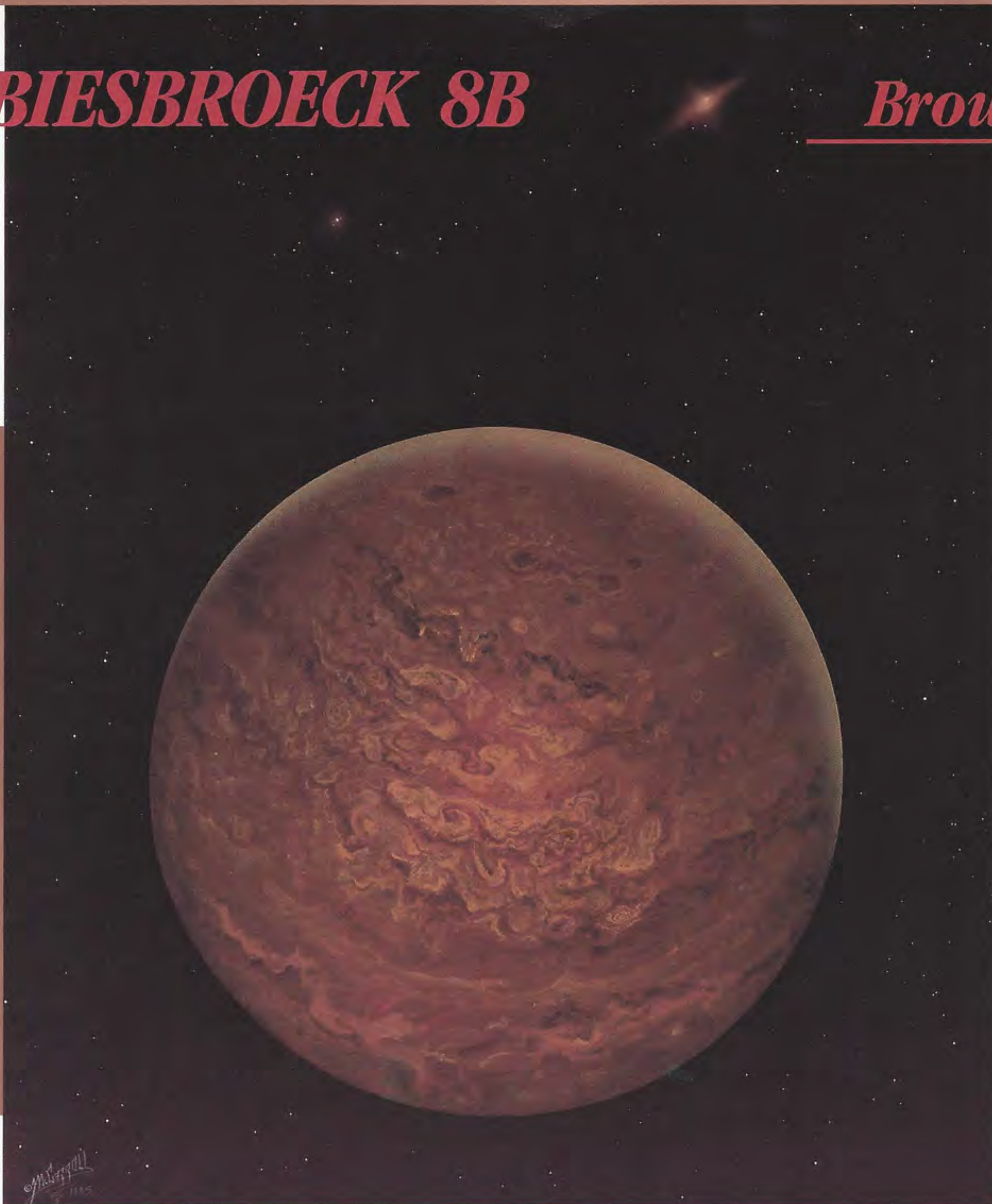
as if it heard news
from a far country.
It will leave with its cold

gemlike pith,
a moment's gorgeous visitor
fading.

— Diane Ackerman

Poet and author Diane Ackerman is the director of the Writers' Program at Washington University in St. Louis, Missouri. She is working on a revised edition of *The Planets: A Cosmic Pastoral.*

VAN BIESBROECK 8B Brown



Almost a star, the giant "brown dwarf" Van Biesbroeck 8B is imagined in this painting by Michael Carroll. Glowing red-hot on its night side, with violent convective motions in its atmosphere, this object is about 40 times as massive as Jupiter but only a little larger. Its heat is due to its gravitational contraction, not thermonuclear reactions, as in stars. When instrumental techniques are refined in coming years we may be able to tell how accurate is the painter's portrayal of VB 8B.

Painting: Michael Carroll

In December 1984, the University of Arizona and the National Science Foundation announced the discovery of the first planet outside our solar system. The detection of Van Biesbroeck 8B, a companion to the nearby star Van Biesbroeck 8, and the resulting debate over "What to call it — planet or star?", have emphasized that astronomers lack a cosmic perspective of planets.

The only known planetary system is our own solar system, with its nine individually unique planets. Thus, astronomers still cannot define "planet" or "planetary system" with the same confidence as "stars" and "galaxies," which can be examined and compared throughout the universe. Without this cosmic perspective, we can't know if our system is unique, and we can only hypothesize the physical processes that created it.

The detection of infrared light from VB 8B is a dramatic development in the search for other planetary systems. Until now, the search has depended on astrometric techniques — looking at minute perturbations of stars rather than measuring the energy emitted by their companions. Now that we can record this energy, we can deduce directly the characteristics of extrasolar planets, including their brightnesses, temperatures, sizes, orbital motions and compositions.

Emissions from Cool Dwarfs

In the September/October 1984 issue of *The Planetary Report*, I discussed a technique for detecting heat from low-mass companions to bright stars. This method, infrared speckle interferometry, uses a series of short exposures, taken with large telescopes, to obtain the greatest possible detail in infrared images of small objects. By using micro-

Dwarf and Extraordinary Planet

by Donald W. McCarthy, Jr.

computers to process these infrared images, we can alleviate the blurring caused by atmospheric turbulence.

Detecting "brown dwarf" companions to stars is difficult. These objects, including Jupiter and Saturn, aren't massive enough to ignite the thermonuclear reactions that sustain stars, such as small, hot white dwarfs or small, cool red dwarfs. (To ignite, an object would have to be 85 times as massive as Jupiter; Jupiter has 1/1000th the mass of the Sun.) Instead, brown dwarfs shine with heat left over from their births and with heat generated internally by radioactivity and by slow gravitational contraction. They may also briefly burn deuterium (heavy hydrogen) as they form.

Lacking high internal temperatures, brown dwarfs are compressed into Jupiter-sized objects, and are cooler, redder and much fainter than typical stars. Brown dwarfs in planetary systems might also derive energy from a central star or from other interactions, much as Jupiter's moon Io is heated by tidal processes.

With ground-based telescopes, we expect to find brown dwarfs around red dwarf stars most easily at those infrared wavelengths that penetrate Earth's atmoshpere. Two such red dwarfs are Van Biesbroeck 8 (21 light-years away) and Van Biesbroeck 10 (19 light-years distant). Discovered between 1944 and 1961 by the Belgian-born American astronomer Georges Van Biesbroeck, these objects are among the intrinsically faintest stars known. They are especially faint in visible light, with apparent magnitudes around 17, but in the infrared, they're about 1600 times brighter, near 9th magnitude. (The brighter a star, the smaller its magnitude number; a bright star such as Sirius A has a magnitude of −1.5, while the dimmer Tau Ceti has a magnitude of 3.5.)

VB 8 was discovered through its membership in a small star cluster which includes the brighter objects Wolf 629 and Wolf 630. Each of these, in turn, is composed of two or more red dwarf stars. These objects are illustrated in the accompanying painting by the brighter points of light in the background.

Searching for brown dwarf companions to VB 8 and VB 10 was a natural extension of my systematic survey for low-mass companions to stars as distant as 100 light-years. Although no brown dwarfs had ever been seen, their existence was inferred indirectly by minute wobbling motions of red dwarf stars. Measurements by Robert Harrington and collaborators at the United States Naval Observatory indicated that there might be companions around VB 8 and VB 10. However, these measurements could not distinguish between very small companions or ones nearly as massive as the stars themselves. In the case of VB 10, the wobbles indicated an object with an orbital period of about five years. However, during the ten years of measurements no period could be established for VB 8.

Discovering Van Biesbroeck 8B

The first infrared speckle measurements were taken on May 9, 1984, the first of five nights on the Mayall four-meter reflector atop Kitt Peak in Arizona. Every three minutes for about two hours, the telescope was moved alternately between VB 8 and a known point-like star. I took 10,000 exposures for each object. This large number of observations helped to average out low changes in atmospheric blurring.

The final results indicated that VB 8 had a companion about 16 times fainter, separated from it by about one arcsecond. (One arcsecond is the apparent size of a dime two miles away.) Identical measurements of VB 10 didn't reveal the companion suggested by the wobbling data. Perhaps this companion is too faint to be detected with present infrared equipment, or it's too close to the star to be resolved.

I immediately realized that VB 8's companion, now dubbed VB 8B, was probably a brown dwarf. Its intrinsic brightness, calculated from the measured brightness and distance, is more than 25 times fainter than the least massive star known, Ross 614B (86 Jupiters in mass). The measured separation, combined with the observed wobbling of the star, now VB 8A, indicated a possible mass of less than 10 Jupiters. However, more measurements at different infrared wavelengths would help confirm the brown dwarf interpretation. Only then could we estimate the temperature, diameter and total energy output of VB 8B.

Unusually bad weather limited our observing at the four-meter telescope to only two nights. However, the Steward Observatory 2.3-meter telescope, adjacent to the Mayall telescope on Kitt Peak, was available for follow-up measurements. Together with Kitt Peak astronomer Ron Probst, I used the same instrument on June 7 to 10 and again on July 6 to 12. Although the summer rains hampered our observing, we were able to verify the earlier results and to take measurements at a shorter infrared wavelength, allowing us to make a direct estimate of VB 8B's temperature.

This discovery of VB 8B could legitimately be called the first direct detection of a brown dwarf and an extrasolar planet. Our excitement was tempered by the need to be certain of the measurements and interpretation. We compared the results with theoretical models of brown dwarfs, and we adopted the accepted nomenclature. Although my previous article for *The Planetary Report* was written at this time, it was then premature to discuss VB 8B.

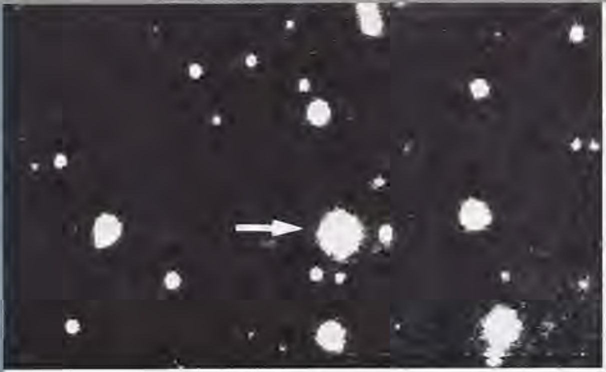
Characteristics of VB 8B

As measured on the plane of the sky, VB 8B lies about 6.5 Astronomical Units (an Astronomical Unit is the average distance from Earth to the Sun, about 150 million kilometers) from VB 8A, nearly the same distance as that between Jupiter and the Sun. The actual separation could be larger, since the orbit may be inclined to our view from Earth. More recent infrared observations, in May 1985, revealed an orbital period of at least 30 years. Continued measurements over the next decade will determine the orbit of VB 8B relative to the star.

Just as Neptune and Pluto were discovered from irregularities in the motion of Uranus, peculiarities in the orbit of VB 8B may reveal other companions in the VB 8 system. In the near future, improved infrared detectors may sense these objects directly.

VB 8B is much cooler (2000 degrees Fahrenheit, 1390 degrees Kelvin) and ten times less luminous than any known star. Because of its cool temperature, VB 8B is brightest in the infrared; the predicted brightness in visible light is 6 million times fainter. It will be quite a challenge for astronomers to see it in visible light, even from the Hubble Space Telescope (scheduled for launch August 8, 1986).

We can now only estimate the mass of VB 8B. Although the wobbling motion of the primary star and the measured separation between the two objects should permit an exact determination, we don't accurately know the wobbling motion for an entire orbital period. The best orbit available,



VB 8 (indicated by an arrow) appears in this electronic CCD (charge-coupled device) image taken in 1980. Its companion, VB 8B, is too faint and too close to VB 8 to be seen.
Image: US Naval Observatory

computed recently by Harrington, yields a mass range of 10 to 70 Jupiters.

A comparison of the temperature and brightness with theoretical predictions yields masses of 30 to 80 Jupiters for an age of 5 billion years. Unfortunately, these theories differ somewhat in their treatments of the internal physics, and some effects have not yet been included in the calculations. At the moment, our best value for VB 8B's mass is about 40 Jupiters.

From the infrared brightness and temperature, we can derive the diameter of VB 8B, assuming it to be an efficient radiator of energy — a so-called black body. This diameter nearly equals that of Jupiter, a result expected theoretically. How can 40 Jupiter masses exist in the same volume as Jupiter? The answer is that hydrogen, the primary constituent of stars and the giant planets, is a compressible material. For more massive objects, the central density increases. In brown dwarfs, pressure between electrons offsets the pull of gravity, in a condition called quantum degeneracy. At a mass of about 85 Jupiters, the central density and temperature are high enough to trigger self-sustaining thermonuclear reactions. The central density of the Sun is 160 grams per cubic centimeter; for Jupiter, 4 grams per cubic centimeter. The diameters of VB 8A, VB 8B and Jupiter are nearly identical, but their masses and internal properties are significantly different.

What to Call It?

According to both conventional astronomical nomenclature and modern observational and theoretical investigations, VB 8B is not a star. Its characteristics match those expected for brown dwarfs, a term proposed in 1975 by Jill Tarter to describe presumed Jupiter-like objects in the mass range of 1 to 85 Jupiters, including Jupiter itself. Today this term is frequently used, though such objects have been called "dark Lilliputian stars" and "Brobdignagian planets" (Harlow Shapely, 1958), "black dwarfs" (Shiv Kumar, 1972), "infrared dwarfs" (Kris Davidson, 1975) and "massive planets" (George Gatewood, 1976).

VB 8B is a substellar object orbiting a normal star and displaying planet-like properties. In 1984, a NASA scientific workshop led by David Black defined "planet-like" " . . . to mean any object whose intrinsic properties match those generally associated with planets in the solar system." VB 8B resembles Jupiter. Although more massive, it is similar in diameter and almost certainly is composed of identical materials — primarily hydrogen and helium. It also appears to follow a circular orbit of planetary dimension, in contrast to double stars whose orbits are generally more eccentric.

VB 8B is unquestionably hotter than Jupiter. However, its measured temperature may be an overestimate since, as for Jupiter, infrared measurements can penetrate to low, warm levels in the atmosphere. Indeed, Jupiter in its youth was probably as hot as VB 8B is now.

Despite its temperature, if VB 8B replaced Jupiter in our solar system, our eyes would see it by light it reflected from the Sun. It would appear as bright as Jupiter in visual light and, historically, would have been called a planet. Possibly, VB 8B is the most massive member of an actual planetary system around VB 8A.

Scientists have not established a general definition of a planet. Some require planets to be Earth-like, capable of supporting human life. They regard Jupiter, Saturn, Uranus and Neptune as more star-like. Yet these objects dominate the dynamics of our solar system. Others consider planets to shine only by reflected sunlight, even though Earth itself is heated internally — by radioactive decay. Still others believe that theoretical interior properties ought to establish the dividing line between stars and planets.

Without a cosmic perspective, astronomers can't improve on the original definition of planet: from the Greek for "wanderer." The Greeks applied this definition to lights that appeared to wander across the sky; VB 8B is too far away to have the same motion. But VB 8B may be a more typical planet than Earth. We'll have to find and study more planets outside our solar system before we can settle on a better definition.

Brown dwarfs may also be found as freely floating objects in space. Indeed, this possibility is one explanation for the so-called "missing mass" of the universe. However, no isolated brown dwarfs have yet been detected, even by the Infrared Astronomical Satellite (IRAS), which conducted an extensive sky survey from Earth orbit in 1983. It's more likely that brown dwarfs occur most frequently in multiple systems as companions to stars. My own infrared measurements of nearby stars support this idea.

Many children have written to suggest names for the "new planet." Some ideas are: Starbit, Hercules, Arizon, Massunone (mass unknown) Far-Heat and Mongo. Until we determine the mass of VB 8B more accurately and measure the frequency of such objects, it seems premature to adopt a name.

Future Investigations

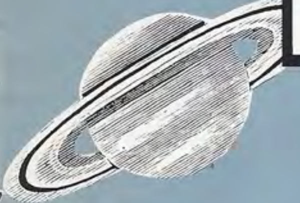
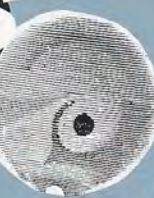
To obtain a cosmic perspective of our solar system, we must discover other planetary systems and examine them in fine detail. The detection of VB 8B is a step in this direction, but ultimately we want to image planets less massive than Jupiter around brighter stars like our Sun. A breakthrough is now occurring: Many new techniques are being applied and each one can address a different and important piece of the puzzle. No single technique will be enough to reach our goal.

In the infrared, significant advances in detector technology will soon be applied both on the ground and in space. The Hubble Space Telescope, though initially equipped with instruments operating only in the visible and ultraviolet, may be fitted in the 1990's with an infrared camera. This combination will directly image companions as small as 10 Jupiters around Sun-type stars more than 35 light-years from the Sun; it could detect VB 8B in an exposure of 1/100th of a second. This camera is our best opportunity for direct detection in the near future.

Later in the decade, the Space Infrared Telescope Facility (SIRTF) will be launched. About 1,000 times more sensitive than IRAS, SIRTF will be capable of imaging Jupiter-sized planets around the nearest stars. The next decade or two should reveal the general properties of planets and planetary systems and tell us how typical our own solar system really is.

A new field is emerging: Interstellar comparative planetology, the study of interrelationships among extrasolar planets and planetary systems, is fast becoming a reality. VB 8B is one of many early discoveries in this new discipline.

Donald McCarthy is an associate astronomer at Steward Observatory in Tucson, Arizona. His professional interests are infrared astronomy and high-resolution imaging techniques for telescopes.


What is a Planet?


by Jonathan Eberhart

What is a planet? It sounds like an easy enough question, although as Donald McCarthy's article about Van Biesbroeck 8B suggests, it may not be so simple. Eugene Levy, director of the University of Arizona's Lunar and Planetary Laboratory in Tucson, says, "I don't think there's a useful answer to that question. It really doesn't address any significant issue."

The point made by Levy and other researchers isn't just a preference for more substantive aspects of science. A few years ago, Clark Chapman of the Planetary Science Institute, also in Tucson, served on an International Astronomical Union commission charged with naming surface features on Mercury. "I decided," he says, "that more scientists waste more time on matters of nomenclature that are actually meaningless or counter-productive." But more than that, he adds, "I don't like the whole question of nomenclature because it tends to constrain ideas."

In announcing his discovery of VB 8B, McCarthy initially described it as "the first detection of an extrasolar planet." After all, he said, "If you have a 'substar' revolving around a star, you have a planet."

However, "There's a psychological side," says Brian Marsden of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. "You mention 'planets,' and that stirs people up, and they think, 'Aha, life!' and all that." Yet while "brown dwarf" could be seen as a less controversial term, it comes from a vocabulary that also includes such established stellar types as red dwarfs and white dwarfs, making it a term that is biased, in a sense, in the other direction. "The word 'dwarf,' even with 'brown' in front of it," says Marsden, "certainly gets one thinking about stars."

For Levy and other scientists, the real intellectual question is one of understanding what makes a planetary system, not of finding words for its components.

"We've got a set of objects going around a star," Levy begins, "and they don't go around the star in a random way — they're a highly ordered assemblage. First, all of the orbits are very closely circular, as opposed to being highly elliptical. All of the orbits are concentric (because they're centered on a single star). All of the orbits are confined very closely to a single plane. The planets' spin axes are aligned, and they're aligned with the orbits, to a degree too high to be anything like random chance. The whole planetary system is aligned with the spin of the Sun."

There's nothing new in that description, and there are even exceptions to Levy's generalized view — Uranus spins on an axis lying almost in the plane of the ecliptic. But the existence of this elaborately detailed system, he says, is the crux of the matter and the key distinction that separates a planetary system from those of multiple stars.

"It tells us that this whole system was formed from a single precursory object." The randomness of the original object "all settled out with friction — viscosity. It was a highly 'dissipative' evolution."

The issue, he says, arises because "most people think of a multiple star system and a planetary system as being sort of end-members of the same type of general processes. And to Levy, "given what we presently know, the evidence doesn't support this."

Multiple star systems, he says, typically have elliptical orbits, which preserve a "memory" of the infall velocity of the precursory cloud's collapse. In the highly circularized orbits of a planetary system, however, says Levy, "that memory is gone — the inward motion had already ceased by the time the planets had begun to form. The result is that "the dominant objects in the solar system all move perpendicular to their distance from the Sun. There are none that fall toward the Sun in substantial parts of their orbits."

Still, Levy says, "although we can speculate about this stark difference between star systems and planetary systems, we can only speculate so far based on the observation of only one planetary system. Ultimately, as in all questions of science, the question about whether the difference is really 'stark' will have to be resolved observationally. It may be then that we'll discover things that don't fit into our present understanding — in which case, we'll have to alter our ideas."

In the semantic debate about planets-versus-stars, however, a distinction can at least be drawn in the matter of whether a given object is warmed by the fires of its own thermonuclear fusion. VB 8B then appears to fall fairly securely into the category of non-stars.

The question of "what is a planet" has been a part of astronomy for more than two centuries. In 1781, when William Herschel discovered Uranus, he thought it was a comet. When Giuseppe Piazzi discovered the first asteroid, Ceres, in 1801, says Marsden, there was at first some thought that it might be a comet, a comet presumably being "the only thing that would be found by accident." Ceres gained (minor) planethood because it lacked a comet's fuzzy appearance and because its distance from the Sun was that expected for a planet between Mars and Jupiter — where most of the minor planets in what is now called the main asteroid belt were later found.

Our present knowledge leaves room for a vast array of objects that may be hard to classify. "Taxonomy has its place," says Chapman. "It's useful to put some kinds of things in one group and some kinds of things in another group, but I consider the attachment of the name a subsidiary aspect of trying to discover what the diversity of objects truly is."

Already the Infrared Astronomical Satellite (IRAS) has observed cool matter orbiting stars, and sensitive ground-based observations have detected VB 8B and a cloud around Beta Pictoris. Soon it may be possible to measure temperatures, compositions and even the sizes of circumstellar objects; then we can consider what to call them. Looking for extrasolar planetary systems, says Levy, is "the most exciting scientific project that one could think of doing from a space station." A new era is about to begin.

Jonathan Eberhart is Space Sciences Editor of Science News.

APPROACHING URANUS:

Voyager 2 took this image of Uranus on July 15, 1985, when the spacecraft was 247 million kilometers (153 million miles) from the planet. Here we see Uranus nearly pole-on, since it is tipped "on its side" in relation to the plane of the ecliptic. Methane in its atmosphere gives this planet its bluish color, although like the other giant planets — Jupiter, Saturn and Neptune — its atmosphere is primarily hydrogen. Image: JPL/NASA

We have marveled at the huge and fascinating variety of detail revealed by *Voyagers 1* and *2* as they passed by Jupiter and Saturn. Although both planets had been studied for years through telescopes, and had been visited by *Pioneer* spacecraft, the *Voyagers* had much to teach us about these distant worlds.

Now we are looking forward to the thrill of an encounter with a relatively unknown planet. On January 24, 1986, *Voyager 2* will pass within 107,000 kilometers (60,000 miles) of the center of Uranus. This distance seems large, but if we could ride along with the spacecraft, at our closest approach we would see the planet as a great sphere spanning 27.5 degrees of our field of view. By comparison, our Moon seen from Earth spans only about one-half of a degree.

Voyager will fly almost directly toward the south pole of Uranus. Five small satellites will be arrayed in a plane extending outward from the equator; the outermost, Oberon, will be about 586,000 kilometers from the planet. Nine thin rings also circle Uranus, but they reflect light so poorly that they will not dominate the scene as Saturn's rings do. Details on the planet and its moons will appear with very low contrast, so we will need to enhance the images electronically on our viewing screens.

For several months already, *Voyager 2* has been acquiring images of Uranus with its high-resolution camera. The planet's image has grown steadily in diameter as the spacecraft approaches; in early November, it spans one-twelfth of the field of view. At closest approach, the high-resolution camera will image only a small portion of the cloud deck covering the entire planet and will be able to discern features as small as four kilometers (2.5 miles) — about the width of Manhattan Island.

The third week in January — encounter week — will be packed with activity. The spacecraft's approach will be so rapid that all of our high-resolution observations must be jammed into a short span of time. After we zoom past the satellites, we will turn and look back toward the planet's rings and the thin rim of atmosphere visible during the short interval when the planet's shadow will protect our instruments from the damaging glare of the distant Sun.

Voyager 2 is a remotely-controlled spacecraft, capable of receiving updated operating instructions from Earth. The spacecraft's 10 instruments and its returning radio signal will probe this planetary system. Using its capabilities, *Voyager* science team members, working at the Jet Propulsion Laboratory, will collect data giving us our first closeup view of Uranus, its known satellites, its system of thin, dark rings and its magnetic field. Our experiences at Jupiter and Saturn suggest the exciting possibility that we will discover more satellites and perhaps features of the uranian system that we can't even imagine now.

Observing Uranus from Earth

On March 13, 1781, William Herschel, a musician in Bath, England, discovered the first new planet since ancient times. Being so distant from the Sun, and therefore dim, Uranus had escaped detection until the future court astronomer to George III turned his powerful telescope toward it. Because of their remoteness, Uranus and its satellites and rings remain largely unexplored territory. The planet's average distance from the Sun — some 2,870 million kilometers — is about 19.2 times that of Earth. Although Uranus' diameter is four times Earth's, its apparent size, as seen from Earth, covers only 4 seconds of arc — equal to the size of a quarter seen from 1.2 kilometers (0.73 miles). Uranus' largest satellites are less than one-half the size of our Moon. They can be distinguished from background stars only by their orbital motions around the planet, with periods ranging from 1.5 to 13.5 days.

A medium-sized telescope collects enough light from Uranus to form a small, bright image of the planet. The telescope's eyepiece magnifies the image, but this does not help the astronomer to distinguish small details. He or she is hampered by distortions produced by turbulent "cells" or "bubbles" along a line of sight through Earth's atmosphere. This effect is easily noticed on hot summer days: Our atmosphere becomes so turbulent from irregular heating and mixing that "shimmering heat" distorts our view of

Priority Observations During Voyager's Closest Approach

Instrument abbreviations:

- IRIS — Infrared Interferometer Spectrometer
- PPS — Photopolarimeter
- PWS — Plasma Wave
- UVS — Ultraviolet Spectrometer
- PLS — Plasma Detector

All times are Pacific Standard Time.

Symbol abbreviations:

- ■ Observation
- ● Instrument
- ▲ Objective

	Jan. 23	2 p.m.	4 p.m.	9 p.m.	Jan. 24 12:48 a.m.	1:08 a.m.	1:40 a.m.
	(approx. – 1 day from closest approach)	*(– 20 hours)*	*(– 18 hours)*	*(– 13 hours)*	*(– 9.2 hours)*	*(– 8.9 hours)*	*(– 8.3 hours)*
■	Magnetopause and bowshock crossing	Rings	Umbriel	Rings	Oberon	Titania	Sunlit auroral zone
●	Fields and particles instruments	Cameras	Cameras	PPS	Cameras	Cameras	UVS
▲	Search for and characterize edge of magnetic field.	Series of photos for mosaicking.	Color photography.	Four-hour study of ring characteristics while occulting star (Nunki/ Sigma Sagittarii).	Highest resolution photos.	Color photos.	Highest resolution mosaic of sunside auroral zone.

Voyager 2 Prepares to Encounter the Seventh Planet

by Reta Beebe and Jay Bergstralh

objects near the ground.

No matter what magnification is used, an astronomer is unable to distinguish details smaller than the distortions produced by turbulence in our atmosphere. At the remote distance of Uranus, the smallest feature distinguishable under typical conditions is about the diameter of Earth.

Seasons and Clouds

The orientation of Uranus and its satellites with respect to incoming sunlight is unique in our solar system. Uranus rotates about its spin axis with its north pole always pointed toward the constellation of Taurus and its south pole always pointed toward the constellation of Ophiuchus. This means its spin axis lies nearly in the plane of its orbit around the Sun — the planet lies on its side. As it revolves around the Sun once every 84 years, Uranus alternately presents one pole and then the other — 42 years later — toward the Sun. (Coincidentally, Uranus' south pole will be pointing almost directly toward the Sun when *Voyager 2* flies by.) The Figure below illustrates the geometry of Uranus' extreme seasons, each lasting about 21 years. The satellites, revolving in the planet's equatorial plane, experience similar seasons. The fact that both Uranus and its satellites rotate about an axis nearly perpendicular to that of the rest of the solar system must tell us something about how planets formed from the swirling solar nebula, but the true sequence of events still eludes us.

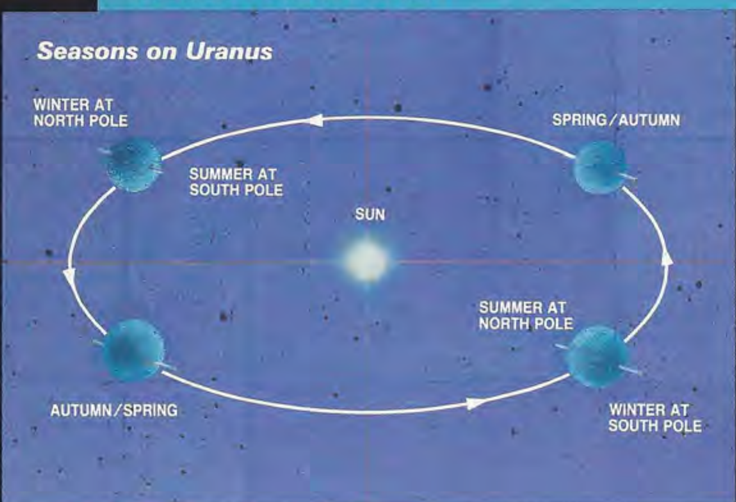
As a result of this strange geometry, one of Uranus' poles is warmed by sunlight continuously for 42 years while the other is in darkness, continuously losing heat to space. Conditions are only a little less extreme at intermediate latitudes, so we might expect large seasonal temperature differences between Uranus' summer (sunlit) and winter (dark) hemispheres.

Surprisingly, we've seen very little temperature difference between the hemispheres. Temperatures are moderated by the capacity of the planet's atmosphere to store heat, just as Earth's climate is moderated by heat stored in the oceans. At its great distance from the Sun, Uranus receives about 370 times less sunlight per unit area than does Earth. The planet's atmosphere absorbs and stores this energy without its temperature rising very much. Remote measurements show temperatures about −210 degrees Celsius (−350 degrees Fahrenheit) in the visible part of Uranus' atmosphere.

The rate at which a body loses energy to space depends strongly on its temperature, with the rate of loss decreasing steeply as temperature decreases. At its already cold temperature, Uranus' atmosphere can't lose the heat it stores in summer fast enough in winter to lower its temperature appreciably — even though winter lasts for 42 years at the pole.

The temperature of the planet's central core and the rate at which heat from the core is transported to the surface can greatly affect Uranus' visible atmosphere. If this rate is large enough to produce active vertical motions, rising bubbles of warmer air will cause distinct clouds to condense. A similar process operates on Earth. In our atmosphere, water vapor carried along by rising air condenses to form visible cloud

Uranus points first one pole and then the other toward the Sun in its 84-year orbit, creating extreme seasons at the poles. Did a giant impact upset the planet's spin axis into its present orientation, almost in the plane of the orbit? Illustration: S.A. Smith

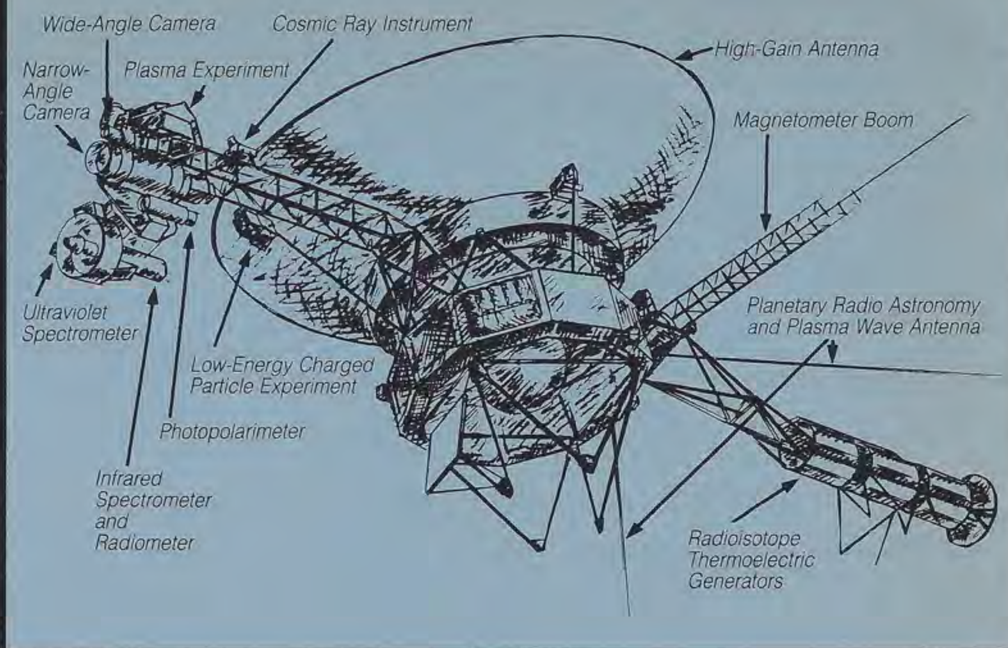


This first clear image of Uranus and its rings was taken with a camera and CCD (charge-coupled device) and computer processed to bring out the dark rings. (The vertical lines are artifacts of the camera.) Image: Richard J. Terrile, JPL and Bradford A. Smith, University of Arizona

3:04 a.m.	3:45 a.m.	4:26 a.m.	6:16 a.m.	6:36 a.m.	7:01 a.m.	7:14 a.m.	8:09 a.m.	8:37 a.m.
(−6.9 hours)	(−6.3 hours)	(−5.6 hours)	(−3.7 hours)	(−3.4 hours)	(−3 hours)	(−2.8 hours)	(−1.9 hours)	(−1.4 hours)
■ Uranus	■ Umbriel	■ Uranus	■ Titania	■ Ariel	■ Miranda	■ Uranus	■ Ariel	■ Miranda
● PPS	● Cameras	● IRIS	● Cameras	● Cameras	● Cameras	● PPS	● Cameras	● Cameras
▲ Measure solar energy absorbed by Uranus.	▲ Photos at closest approach — 365,000 kilometers (226,000 miles.)	▲ Atmospheric chemical composition at location of radio science occultation point of Earth.	▲ Highest resolution images.	▲ Color photos.	▲ Color photos.	▲ Measure solar energy absorbed by Uranus.	▲ Highest resolution photos.	▲ Highest resolution photos.

particles; cloud particles carried along by sinking air melt and evaporate. Thus water functions as a dye marker, tracing motions in the atmosphere.

Uranus' atmosphere is so cold that we don't expect water to evaporate and re-freeze at any level we can see. However, the atmosphere does hold large quantities of methane (CH_4, or marsh gas). Methane's freezing point lies within the range of temperatures expected in the visible parts of Uranus' atmosphere, so individual clouds of frozen methane might mark atmospheric motions. If this is the case, we will be able to determine wind velocities as the clouds are swept along, and deduce information on heat transport in this distinctive atmosphere. *Voyager 2* will search for these cloud features.



The Uranian Satellites

Our understanding of Uranus' satellites is derived from careful mapping of their orbits about the planet and from measuring their brightnesses and the way they reflect the spectrum of sunlight. We can estimate their masses in terms of the planet's mass from the orbital information, using Kepler's laws. From the spectra, we can estimate the fraction of sunlight they reflect. Then, knowing their measured brightnesses and distances from the Sun, we can estimate their diameters.

Best estimates of the diameters of the five known satellites — Miranda, Ariel, Umbriel, Titania and Oberon — are, respectively, 500, 1300, 1100, 1600 and 1600 kilometers. By comparison, our Moon's diameter is 3,476 kilometers. Assuming they are spherical, we can compute the satellites' volumes and, using the masses estimated from Kepler's laws, we can compute an average density for each satellite. The average densities then tell us whether the satellites are made mostly of ice, or mostly of rock, or a combination.

Our current understanding of the uranian satellites rests on a chain of approximations and inferences applied to a small amount of data. Our best estimates of their average densities are so uncertain that we can't decide whether these bodies are mainly rocky or mainly icy. The way they reflect the solar spectrum indicates that both water ice and dark (rocky or organic) material lie on their surfaces, but we can't deduce the proportion of rock or organics to ice. Even if we could estimate these proportions for the surface material, they would not necessarily represent the bulk proportions of the satellites' interiors.

On January 24, between 3 pm and 5 pm Greenwich Mean Time, *Voyager 2* will visit Titania, Oberon, Ariel and Miranda. As the spacecraft flies almost perpendicularly through the plane of the satellites' orbits, it will pass close enough for the high-resolution camera to distinguish features as small as 6-9 kilometers on Titania and Oberon, 0.5 kilometers on Miranda and 2.5 kilometers on Ariel. After it crosses their orbital plane, at about 9 pm, it will view Umbriel, recording features as small as 6 kilometers. We will then have direct, precise measurements of the satellites' diameters, and our understanding of their bulk compositions will improve enormously.

Investigators interested in the satellites will be handicapped by low light levels owing to Uranus' remoteness from the Sun and by the low rate at which *Voyager 2* can transmit data back to Earth from that great distance. Their handicap will be compounded by the high speed of the spacecraft flying past the satellites. Although just one close-up image of each satellite will enormously improve our understanding of these bodies, you can imagine the determination and vigor of the satellite investigators arguing against other investigators who wanted a portion of the spacecraft's limited resources to observe the planet, or its rings, or to measure its magnetic fields!

The Uranian Ring System

In 1977, in an organized effort to determine the planet's size and shape, several groups of astronomers observed Uranus as it passed in front of a distant star. By measuring the time it obscured the star, and knowing its relative velocity, they planned to calculate the distance across Uranus. Unexpectedly, they saw the starlight dim and brighten again several times before and after the planet itself occulted the star. The astronomers quickly deduced that a system of narrow rings — quite unlike Saturn's familiar wide rings — caused these fluctuations. Between 1977 and 1984, they observed thirteen stellar occultations by Uranus and mapped a system of nine distinct rings revolving about the planet.

Efforts to photograph Uranus' rings were hampered by their narrowness and dimness; they are very difficult to see against the glare of the nearby planet. Their particles are not densely enough packed to make the rings opaque, so most of the sunlight that strikes the rings passes right through them. Furthermore, the particles are very dark, scattering only two percent of the sunlight and absorbing the rest. Nevertheless, by carefully masking the planet, and by choosing a "color" (infrared) that minimizes brightness differences, astronomers have produced the accompanying ground-based images of Uranus' ring system.

Voyager 2 will investigate this system as it flies by. Most of the detailed ring observations are scheduled soon after the spacecraft passes through the plane of the ring system, where we expect to observe sunlight glancing off the small ring particles.

In 1979, we were surprised when *Voyager 1* photographed a single, narrow ring encircling Jupiter. Our perceptions of planetary

8:54 a.m.	9:08 a.m.	9:15 a.m.		9:18 a.m.	9:38 a.m.	JAN. 24, 1986 10 A.M. PST:	10:14 a.m.	10:26 a.m.
(−1.1 hours)	*(−0.9 hours)*	*(−0.7 hours)*	*also:*	*(−0.7 hours)*	*(−0.4 hours)*	URANUS CLOSEST APPROACH	*(+0.2 hours after closest approach)*	*(+0.4 hours)*
■ Miranda ● Radio ▲ Determine Miranda's mass.	■ Rings ● Cameras ▲ Search for moons embedded in rings at ring-plane crossing.	■ Rings ● PWS ▲ Ring crossing: search for ring particles near Miranda's orbit.	■ Magnetic equatorial plane crossing ● Fields and particles instruments ▲ Observe expected maximum in magnetic field, plasma torus, and trapped radiation.	■ Uranus ● UVS ▲ Study composition of sunlit polar atmosphere while focusing on star Algenib (Gamma Pegasi.)	■ Uranus ● PPS ▲ Measure solar energy absorbed by Uranus.	*107,000 kilometers (66,000 miles)*	■ Uranus ● UVS ▲ Study composition of dark polar atmosphere while occulting star Algenib (Gamma Pegasi).	■ Rings ● PPS ▲ Study of ring characteristics while occulting Algol (Beta Persei).

Voyager Scientific Experiments at Uranus

Imaging Science: *Visible light images of Uranus' cloud layers, possibly giving information on atmospheric energy transport, physical and chemical processes, and winds. Images of Uranus' satellites with resolutions down to a few kilometers.*

Infrared Interferometer Spectrometer (IRIS): *Atmospheric composition, temperature and energy balance. Composition of satellite surfaces.*

Ultraviolet Spectrometer (UVS): Hydrogen/helium ratio in upper atmosphere; atmospheric structure and energy transport.

Photopolarimeter (PPS): *Atmospheric molecules, composition and dimensions of ring particles, composition and physical state of satellite surfaces.*

Cosmic Ray Investigation: *Nature and energy of high-energy particles in the interplanetary medium and in the magnetosphere of Uranus.*

Low-Energy Charged Particles Investigation: *Nature and energy of interplanetary and magnetospheric charged particles.*

Plasma Investigation (PLS): *Interstellar hydrogen, interplanetary ions and electrons, magnetospheric properties.*

Plasma Wave Investigation (PWS): *Magnetospheric dynamics; "sounds" due to particle-wave interactions; satellite perturbations.*

Magnetometers: *Interplanetary field; magnetic field of Uranus, which may trap charged particles and lead to auroras in the planet's atmosphere.*

Planetary Radio Astronomy: Magnetospheric emissions, plasma oscillations, disturbances due to planet, rings and satellites.

Radio Science: *Atmosphere, ionosphere properties; masses densities and gravitational shapes of planet and satellites; ring properties.*

rings changed dramatically. The ring systems we have investigated display a bewildering variety of properties that have opened up new avenues of scientific inquiry. What processes produce and maintain planetary ring systems? What accounts for the similarities and differences among ring systems of different planets? These are hot topics of research. Finding answers is proving difficult.

What about Neptune? Since the discovery of Uranus' rings, astronomers have attempted to find neptunian rings by observing every passage of the planet in front of a suitably bright background star. The results are tantalizing: All but two of the events showed no evidence of rings. On the two exceptions, starlight dimmed momentarily as if interrupted by a narrow ring, but it dimmed on only one side of the planet. Evidently, the dimming was caused by either a previously undiscovered moon or a bizarre partial ring which doesn't encircle the planet completely. (A banana-shaped collection of orbiting particles is dynamically possible.) When *Voyager 2* encounters Neptune in August, 1989, one of its top-priority assignments will be to search for a ring system.

The Magnetic Field

As schoolchildren, we learned that Earth is a big magnet. A familiar consequence of this is that a compass needle points north-south. Another consequence, familiar to residents of high latitudes, is the aurora, caused by electrically charged atomic particles that stream from the Sun and are trapped by Earth's magnetic field. The magnetic field funnels them into our atmosphere at high latitudes, where they cause atmospheric gases to glow.

Other planets also have magnetic fields. Mercury's is weak but measureable. If Venus and Mars have fields, they are too weak to be measured. Jupiter has a very strong field that was discovered more than 25 years ago by radio observations from Earth. Saturn's field is also strong, but it was not positively identified and measured until the *Pioneer* and *Voyager* encounters.

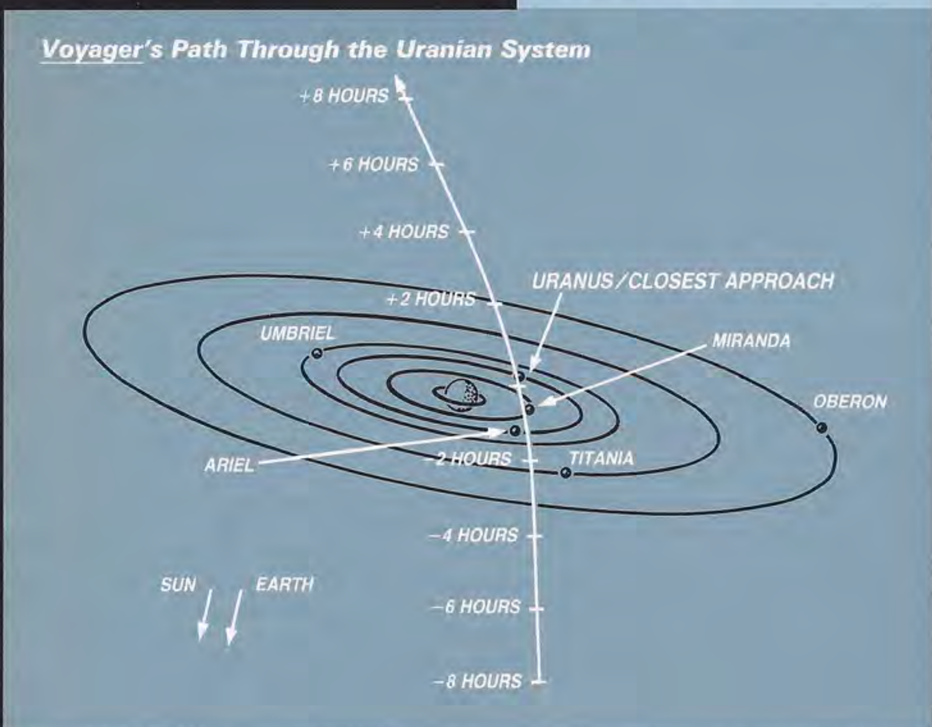
There is indirect evidence that Uranus also has a magnetic field: Using an astronomical satellite to observe the planet, some astronomers have detected an ultraviolet glow that appears to be an aurora. *Voyager 2* will carefully investigate Uranus' magnetic field and any charged particles trapped in it.

We are now sitting in a ringside seat, receiving information telemetered to us by our aging but well-tended spacecraft. Its signals require more than two and one-half hours to travel, at the speed of light, across the intervening space. When we consider that light from the nearest star takes more than four years to reach us, we realize that we are pioneers taking our first tentative steps to explore our own tiny corner of the universe.

As *Pioneers 1* and *2* and *Voyager 1* slowly make their way outward into interstellar space, *Voyager 2* has one more task to do for us: In 1989 it will encounter Neptune. After that, these four human artifacts, the surviving product of our brief, modern golden age of planetary exploration, will become a part of the cosmos, gradually passing beyond our most sensitive reach.

Reta Beebe, a professor of astronomy at New Mexico State University, is a member of the Voyager *imaging team. Jay Bergstralh works in the atmospheric and cometary science section of JPL. They both specialize in the study of giant planetary atmospheres.*

Voyager 2's path through the Uranian system on January 24, 1985. Positions are given at two hour intervals before and after the spacecraft's closest approach to the planet.
Illustration: S.A. Smith



							Jan. 25	
11:22 a.m.	11:44 a.m.	12:06 p.m.	12:36 p.m.	2:35 p.m.	7:42 p.m.	9:27 p.m.	3:55 a.m.	6:00 a.m.
(+1.4 hours)	*(+1.7 hours)*	*(+2.1 hours)*	*(+2.6 hours)*	*(+4.6 hours)*	*(+9.7 hours)*	*(+11.5 hours)*	*(+17.9 hours)*	*(+20 hours)*
■ Rings	■ Rings	■ Uranus	■ Uranus	■ Rings	■ Auroral zone on dark side of planet.	■ Uranus	■ Uranus	■ Rings
● PPS	● Radio	● UVS	● Radio	● Radio	● UVS	● PPS	● PPS	● Cameras
▲ Ring occultation of Beta Persei.	▲ Occultation of radio signal by rings.	▲ Atmospheric studies while occulting Sun.	▲ Atmospheric studies; occultation of radio signal by planet.	▲ Occultation of radio signal by rings.	▲ Highest resolution mosaic of darkside auroral zone.	▲ Measure solar energy absorbed by Uranus.	▲ Measure solar energy absorbed by Uranus.	▲ Series of photos for mosaicking.

News & Reviews

by Clark R. Chapman

"Star Wars." The film's name is now popular shorthand for President Reagan's "Strategic Defense Initiative," or SDI. His goal is to remove civilization from the moral dilemma — and sheer horror — of Mutual Assured Destruction (MAD). He would replace the nuclear balance of terror with the security of a purely defensive "shield" against attack. The President regards it as so important that he intends to spend more on SDI next year than on all the research sponsored by the National Science Foundation.

While many scientists and engineers now work on SDI research, others are signing pledges never to accept SDI dollars. Why raise these profound issues and heated debates in the pages of *The Planetary Report*? Of course, the issues affect all of humankind, including Planetary Society members. But they strike even closer to home, as evidenced by articles and letters to the editor that have appeared in recent *Planetary Reports*.

The September issue of *Discover* magazine is devoted to SDI. Psychedelic photos of laser laboratories and futuristic paintings of SDI space weapons are seductively enthralling for any lover of technology. Artists' conceptions of manned martian landings rarely seem so appealing. Star Wars could become the avenue to inhabiting space. Although sophisticated, computer-controlled SDI devices would seem to leave little room for manned space activities, never fear that the Pentagon's dreams of defending America from space would omit the human element. So maybe President Reagan has offered us a 1980's alternative to old-fashioned dreams of comet sample returns, martian expeditions and L5 colonies in space. The enticement of SDI as an alternative framework for the use of space is enough reason for Planetary Society members to sit up and take notice.

There are other reasons. As SDI grows ever larger than the National Science Foundation, or the civilian space program, many of our best and brightest minds will be turned from unfettered research on the mysteries of the universe to the goal-directed activities of SDI. SDI's gravy-train of funding will distort the balance of scientific research; with the constrained federal budget, non-SDI research will suffer. Who would deny that making our skies impregnable to enemy attack is worth giving up the civilian space program? Whether or not SDI truly makes our skies impregnable, America may not be willing to pay for SDI *plus* a civil space program *plus* research in other promising scientific arenas.

Discover presents the pros and cons of SDI as a "debate" between Edward Teller and Carl Sagan. Neither was given an opportunity to read the remarks of the other. They fail to address each other's points, and they are worlds apart. But I recommend the contrasting viewpoints as fine food for thought.

The key question, it seems to me, is one that permeates our modern society: Are we optimistic or pessimistic about trusting science and technology to solve society's problems? Sagan decries the confident hope that gadgets in space could ever provide the necessary security against nuclear holocaust. Should SDI work imperfectly, or could it be outwitted, the attempt to implement it would be terribly destabilizing: Civilization would be more threatened than ever.

Teller, however, seems confident that creative minds can devise a defensive system that the "other side's" creative minds could not outwit. He writes with fascination about the technological possibilities; it never seems to occur to him that SDI scientists might spend much of our national treasure before realizing they misestimated. It's one thing to goof in calculating whether a Three-Mile-Island disaster is possible (the pre-TMI figures said "no"); it's quite another to say "oops" after we've spent a trillion dollars on a pig in a poke or, worse, after civilization has been scorched off the face of our planet. It all comes down to whether you're a pessimist or an optimist about the chances of an "oops" conclusion to this giant technological endeavor. Civilization could possibly be scorched *without* SDI if we fail to find an alternative to MAD, so something needs to be done.

Planetary Climates

In the October issue of *Science 85*, Owen B. Toon and Steve Olson offer a readable account of how Earth's climate got to be the way it is. The complex interactions of air and sea, plankton and volcanism, plants and rocks, have yielded the temperature climate in which we now thrive. But also, in times past there have been periodic ice ages and the torrid climate of the dinosaur era.

Earth's carbon cycle is the central player: Carbon's gaseous form, carbon dioxide, triggers the greenhouse effect which controls Earth's water budget, and how much water is in clouds or ice sheets. The authors remind us of recent discoveries that our planet's climate can change surprisingly rapidly, and that civilization is now raising carbon dioxide to levels never witnessed since the age of the dinosaurs.

Toon and Olson present two sidebars on why the climates of Mars and Venus are so different from each other, and from Earth's climate. Mars has an abundance of carbon dioxide and would have a wonderful climate if its water could be liberated from the frozen ground; the authors blame lack of plate tectonic action on the Red Planet for inhibiting the carbon and water cycles. (They haven't always been inhibited, though, as the dry riverbeds attest, and the planet may well be renewed in the future.) As for Venus, it was just enough hotter than Earth that the greenhouse effect "ran away," boiling its primitive oceans, and trapping our sister planet in the perpetual heat of a self-cleaning oven.

Halley Hype

The fat, 144-page October issue of *Astronomy* just arrived on my doorstep, packed with ads for comet T-shirts, comet caps, comet coins, comet software and comet tours (including one that offers to let you "touch" it). A letter to the editor, entitled "Beyond the Hype," suggests that Halley's Comet's faint apparition in the far-southern skies may be the best chance ever to promote amateur astronomy — and *Astronomy* jumps on the bandwagon with this "Collector's Edition."

I like skywatching, and so do tens of thousands of amateur observers around the world, but I harbor some doubts that this comet will create a Great Leap Forward for this fine hobby. Still, if you are eager to look at Halley's Comet, and curious about what it looked like in 1910 and in earlier apparitions back to 239 BC, this issue of *Astronomy* is for you.

Clark R. Chapman, who is not going on a cruise, will be looking at Halley's Comet from the darkest possible site near his home in Tucson, Arizona.

World Watch

by Louis D. Friedman

WASHINGTON — On July 16, 1984, the United States Congress mandated the creation of a National Commission on Space to help the US develop a plan which:

1) Defines the long-range needs of the US that may be fulfilled through the peaceful uses of outer space;

2) Maintains US "preeminence" in space science, technology and applications;

3) Promotes the peaceful exploration and utilization of the space environment; and

4) Articulates goals and develops options for the future direction of the US civilian space program.

President Reagan announced the appointment of 15 members to the commission:

Thomas O. Paine, former administrator of NASA (Chairperson);

Laurel L. Wilkening, University of Arizona (Vice Chairperson);

Luis W. Alvarez, Nobel laureate physicist, Lawrence Berkeley Laboratory;

Neil Armstrong, former astronaut, now with Computer Technology Aviation;

Paul J. Coleman, geophysicist, University of California at Los Angeles;

George B. Field, astrophysicist, Smithsonian Astrophysical Observatory;

Lt. General William H. Fitch, US Marine Corps, retired;

Charles M. Herzfeld, vice president and director of research and technology, ITT Corporation;

Jack L. Kerrebrock, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology;

Jeane J. Kirkpatrick, former US ambassador to the United Nations;

Gerard K. O'Neill, president, Geostar Corporation;

Kathryn D. Sullivan, astronaut;

David C. Webb, space development consultant;

Brig. General Charles E. Yeager, US Air Force, retired;

General Bernard A. Schriever, US Air Force, retired.

Joining the 15 voting members are four congressional advisors: Representatives Don Fuqua (D-FL) and Manuel Lujan, Jr. (R-NM); Senators Slade Gorton (R-WA) and John Glenn, Jr. (D-OH). Dr. Marcia S. Smith heads the commission's staff.

The commission will submit a report to President Reagan and Congress on March 1, 1986, identifying long-range goals, opportunities and policy options for the US civilian space activity to the year 2035.

In carrying out its duties to achieve a consensus on the US space agenda for the 21st century, the commission is holding a series of hearings in various cities, and actively soliciting written testimony from a broad cross section of the American pubic. Upcoming meetings include: San Francisco, November 19-20, 1985; Washington, DC, December 17-18, 1985; Pasadena, California, January 22-23, 1986; and Washington, DC, February 12-13, March 12-13 and April 9-10, 1986.

Society members interested in writing the commission or in attending meetings may contact the commission at: 490 L'Enfant Plaza East, SW, Suite 3212, Washington, DC 20024. Dr. Sagan will make a presentation on behalf of the Society to the commission about future exploration of the solar system and the search for extraterrestrial life at their San Francisco meeting on Nov. 19.

PASADENA — On June 10, 1985, we witnessed a remarkable scene at the Jet Propulsion Laboratory. A group of scientists and engineers, their families and invited guests crowded into the JPL auditorium to watch and listen by audiovisual link as the Soviet *Vega* probe to Venus entered the planet's atmosphere. A cheer went up as a signal appeared on the video monitor, indicating that the balloon probe had successfully deployed and was transmitting data.

It looked like a typical spacecraft encounter scene at JPL — just like *Mariner, Viking* or *Voyager* — but it was a Soviet spacecraft, with Russian and French voices on the audio link, along with American voices from the Deep Space Network. They were part of an international effort to measure the winds of Venus. The cheer knew no national origin, but represented joy for a successful spacecraft exploring another world.

We've had too few experiences like this recently, and it was nice to share the excitement, no matter what country launched or paid for the space mission.

WASHINGTON — The US Office of Technology Assessment (OTA) recently issued a technical memorandum entitled "US-Soviet Cooperation in Space." The report summarizes past and present US-Soviet cooperation and possible areas for future joint efforts. The Planetary Society's initiative in this area is mentioned, as is the 1984 meeting we hosted between US and Soviet scientists in Graz, Austria.

The report thoroughly describes the issues of US-Soviet cooperation and cites specific areas where such cooperation can benefit the scientific programs and foreign policy of both countries. A special section also examines French-Soviet space cooperation, particularly in planetary exploration. The recent *Vega* balloon mission in Venus' atmosphere is the result of such cooperation.

The conclusions of an OTA workshop on US-Soviet space science cooperation are also summarized. The report concludes: "From a scientific and practical point of view, past experience has shown that cooperation in space can lead to substantive gains in some areas of space research and applications and can provide insight into the Soviet space program and Soviet society as a whole." Scientists at the OTA workshop determined that the scientific return from US space exploration could be expanded significantly through cooperation with the Soviet Union.

The OTA memorandum, number OTA-TM-STI-27, is for sale by the Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

Louis Friedman is Executive Director of The Planetary Society.

VOYAGER ENCOUNTERS URANUS

It's time for another encounter! *Voyager 2* has already visited Jupiter and Saturn and sent to Earth invaluable images and data on these worlds of the outer solar system. Early next year it's Uranus' turn to be the focus of Earth's attention. *Voyager 2* will fly by Uranus and its moons on January 24, 1986, giving us our first close look at those distant bodies.

To celebrate the occasion, The Planetary Society will host a "*Voyager* Watch" at the California Institute of Technology in Pasadena, California. As images of the planet, its rings and moons are received by the Jet Propulsion Laboratory, they will be transmitted to large screens set up for public viewing in Beckman Auditorium at Caltech. "Uranus — The Voyage Continues," a symposium on the encounter and its significance will be held from 4 to 6 pm on Friday, January 24, in Beckman Auditorium. Panelists will include Carl Sagan, President of The Planetary Society and Edward Stone, Project Scientist for *Voyager*.

A dinner honoring Society Vice President Bruce Murray, who was Director of JPL when the *Voyager* mission left Earth, will be given Wednesday, January 22 to kick off our encounter schedule. Carl Sagan is honorary chairperson of the dinner and will be a featured speaker.

This gala will be held at the Beverly Wilshire Hotel in Beverly Hills. For details, contact Lyn McAfee at the Society's offices, 818/793-5100.

SCHOLARSHIP WINNERS ANNOUNCED

The New Millennium Committee of The Planetary Society is proud to announce its scholarship winners for 1985. Dawn Smith of Bethany, West Virginia, and Wade Roush of Charlotte, Michigan were each awarded scholarships of $1000. Receiving $500 awards were: Karl Dishaw of Port Jefferson Station, New York; Gregory Wirth of Midland, Michigan; Robert Palandech of Homewood, Illinois; Stephan Vernier of Berkley, Michigan; and Morgan Burke of Vancouver, British Columbia.

We congratulate these young people for their achievements. Fifty outstanding applications were received from the United States and several other countries, making the choice of winners difficult. Selection was based on SAT or ACT scores, scholastic achievement, letters of recommendation and a written essay. Applicants were required to be members of The Planetary Society or the nominees of members, and seniors in high school planning a career in space science.

The applicants' essays showed remarkable insight and maturity of thought. Wade Roush, who is planning a career in astronomy, wrote: "I do not remember a time before manned space flight, before interplanetary probes, or before men walked on the Moon. My generation has grown up with these wonders; they are a part of our world. They are as real and exciting to us as through-the-air flight must have been to those who lived in the early years of the century. I am glad to have been born into a world where I can make a tangible contribution."

Dawn Smith, whose goal is to be an astronaut, wrote: "The importance of space exploration is often underplayed in the arena of national affairs. In reality, it cannot be overemphasized. Leaving the cradle — leaving Earth for the first time — is mankind's first step toward developing an adult view of the universe."

In addition to the scholarships, an international award of special recognition was given to Paul Bracken of Dublin, Ireland for "interest and enthusiasm in promoting space science and exploration."

The New Millennium Committee, chaired by David Brown of Houston, Texas, is composed of individuals who share an interest in supporting educational and scientific projects that will extend into the 21st century — the beginning of the next millennium.

CORPORATE GIFTS

Almost five years ago, as The Planetary Society was getting its start, the Board of Directors set a policy of not accepting donations from aerospace corporations. They were establishing the Society as a public membership organization and making it clear that we were not a lobbying arm for the aerospace industry. Then, as now, our real and perceived independence of judgment and action were much more important than money.

In the years since, independence of The Planetary Society has become widely recognized. On occasion, we take stands that may make things a little more difficult for some corporations (as our concern about the Raytheon Corporation's radio interference with the Society's Sentinel/META project. See the Sept./Oct. 1985 *Planetary Report*). Our members, in their letters, have asked why we have not solicited money from corporations, and encouraged us to accept donations from them. Accordingly, last year, the Board of Directors modified their earlier policy and we can now accept corporate donations if they are earmarked for programs unrelated to the business interests of those corporations. We would like to thank the Aerospace Corporation for a contribution to our Education Program, and the Atlantic-Richfield Corporation, for matching gifts from its employees.

Planetary Society members can help solicit donations from their employers. Many companies provide matching gifts to charities and nonprofit organizations of their employees' choice. Ask your employers about matching gifts. All donations, made in the United States, are tax deductible.

1986 MARS CONTEST ANNOUNCED

The Planetary Society's Mars Institute has announced its third annual student contest, open to students in any high school or college. The topic this year is: Design a system of transportation for the scientific exploration of Mars from a Mars research base. The winner will receive $1,000 plus an all-expense-paid trip to an upcoming conference on Mars exploration in Washington, DC.

If you would like more information on the contest, please write: Mars Institute Student Contest, The Planetary Society, 65 N. Catalina Avenue, Pasadena, CA 91106.

The Solar System in Pictures and Books

● Books

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104	**Comet! The Story Behind Halley's Comet** by Greg Walz-Chojnacki. 64 pages.		$ 9.50
105	**The Case for Mars** edited by Penelope J. Boston. 314 pages	Soft Cover	$18.00
106	**Mission to Mars** by James Oberg.	Soft Cover	$11.00
107	**Out of the Cradle: Exploring the Frontiers Beyond Earth** by William K. Hartmann, Ron Miller and Pamela Lee. 190 pages.	Soft Cover	$11.00
108	**The Case for Mars II** edited by Christopher P. McKay. 700 pages	Soft Cover	$27.00
109	**The Surface of Mars** by Michael Carr. 232 pages.		$15.00
110	**Imaging Saturn** by Henry S.F. Cooper, Jr. 210 pages.		$13.00
111	**Voyages to Saturn** by David Morrison. 227 pages.		$14.00
113	**The New Solar System** edited by J. Kelly Beatty, Brian O'Leary, and Andrew Chaikin.	2nd Edition	$12.50
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121	**The Planets** edited by Bruce Murray. 129 pages.	Soft Cover	$ 9.50
123	**Murmurs of Earth** by Carl Sagan, Frank Drake, Ann Druyan, Timothy Ferris, Jon Lomberg, Linda Salzman Sagan. 273 pages.		$ 7.00
127	**Out of the Darkness** by Clyde W. Tombaugh and Patrick Moore. 221 pages.		$13.00
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133	**Pioneer Venus** by Richard O. Fimmel, Lawrence Colin and Eric Burgess. 253 pages.		$12.50
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135	**Atlas of the Solar System** by Patrick Moore and Garry Hunt. 464 pages.	Soft Cover	$20.00
137	**Worlds Beyond: The Art of Chesley Bonestell** by Ron Miller and Frederick C. Durant III. 133 pages.		$13.00
138	**The Comet and You** by E.C. Krupp, Illustrated by Robin Rector Krupp. 48 pages.		$11.50
139	**The Return of the Comet** by Dennis Schatz, Design and Illustration by Yasu Osawa. 42 pages.		$11.50
140	**Comet** by Carl Sagan and Ann Druyan		$21.00
141	**The Comet Book** by Robert Chapman and John Brandt. 168 pages.		$14.00
143	**Comet Halley – Once in a Lifetime** by Mark Littmann and Donald K. Yeomans. 175 pages.		$12.00
144	**Voyager: The Story of a Space Mission** by Margaret Poynter and Arthur C. Lane. 152 pages.		$ 8.50
145	**Cosmic Quest: Searching for Intelligent Life Among the Stars** by Margaret Poynter and Michael J. Klein. 124 pages.		$ 9.00
221	**Mr. Halley's Comet** by editors of *Sky & Telescope*. 30 pages.		$ 1.00

For a written description of each item, see back issues of THE PLANETARY REPORT or write to The Planetary Society.

● Other Items

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213	**Planetary Report Binders** – blue with gold lettering. (2 for $16.00)	$ 9.00
215	**Mars Model** by Don Dixon and Rick Sternbach	$65.00
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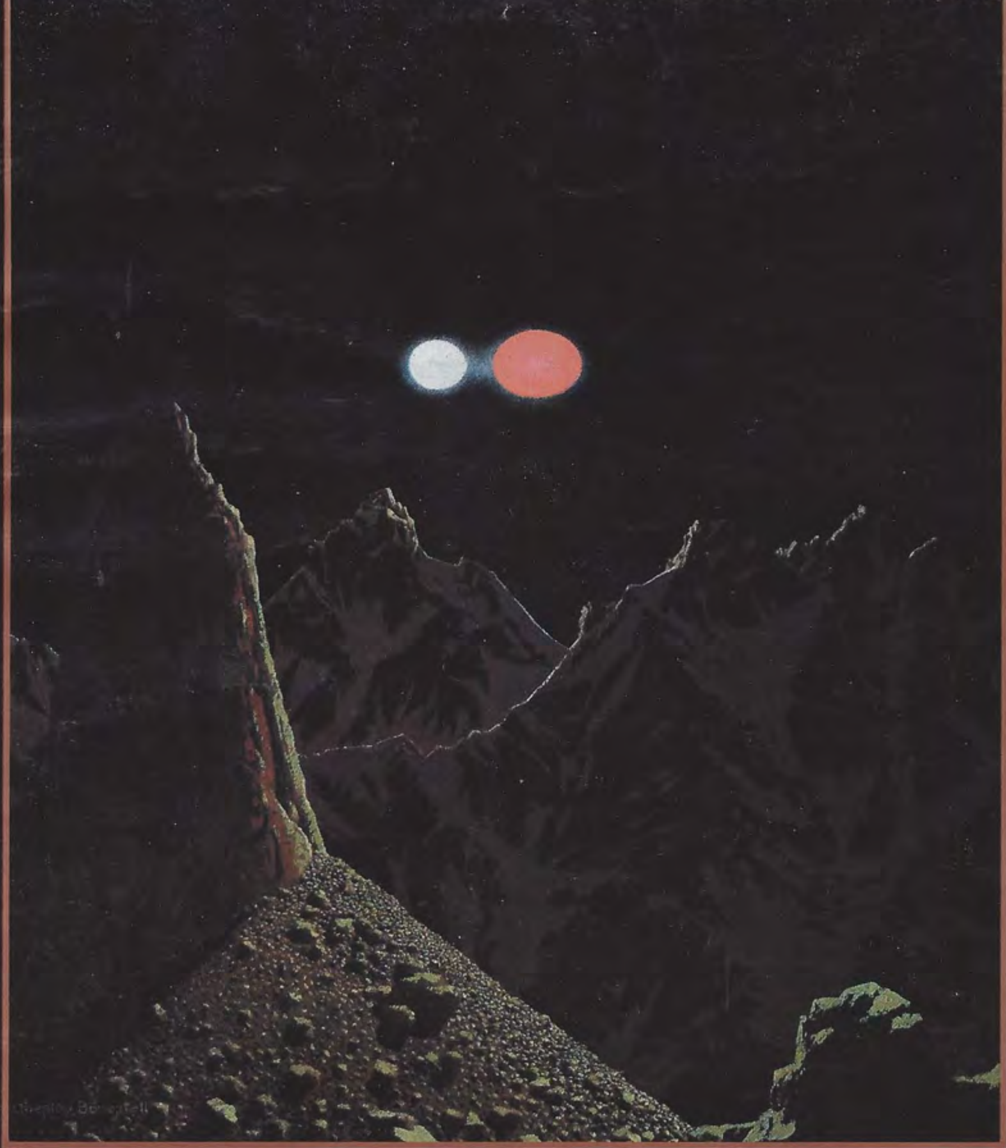

U SAGITTAE —
In this painting of a star system in the constellation Sagitta, an imaginary planet orbits a double star of the kind known as a "contact binary." The hot white star and the cooler red one exchange material as each goes through its own thermonuclear evolution; planets orbiting the stars' common center of gravity would experience strange alternations of color and shadow every few days.

Considered the dean of astronomical art, Chesley Bonestell will be 98 on January 1st. He is still painting.

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