Pioneering way to Jupiter

by Everly Driscoll

Jupiter has been called by various astronomers the "dominating planet," a "potted star" and the "Rosetta stone of the solar system." Theories about its origin range from that of a planet that is still "falling together" to that of a "would-be binary star" of the sun (SN: 10/16/71, p. 261). It is the largest planet in the solar system and, in fact, accounts for more than three-fourths of the planetary mass in the solar system.

The first journey of a spacecraft to Jupiter will begin in less than five months with the launch of the 550-pound unmanned Pioneer F. Beyond the orbit of Mars, the terrestrial planet farthest from the sun, lies untraveled territory. Pioneer F will chart this region: through the 240 million-kilometer-wide asteroid belt that circles the sun, to within 139,040 kilometers (86,900 miles) of Jupiter, to beyond the orbit of Pluto (about 5.8 billion kilometers from the sun) and to the edges or out of the solar system into interstellar space.

The trip will take from six to ten years (600 to 900 days just to get to Jupiter)—a formidable task for one of the less sophisticated spacecraft in the National Aeronautics and Space Administration's arsenal. But the Pioneers have a successful record.

The most hazardous leg of the trip will be the 175 days or so through the asteroid belt. "Our knowledge of this region is pretty bad," says Maurice Dubin of NASA headquarters. Scientists have catalogued 1,776 asteroids with diameters between 2 kilometers and the 752 kilometers of Ceres, the largest. They estimate that there may be as many as 50,000 asteroids in this size range. There are 34 with enough gravitational force to influence the spacecraft trajectory, but they are not along the flight path.

There are estimated to be countless smaller particles from the size of a pea down to 10^{-12} grams and smaller. This microgram-sized matter causes the zodiacal light—the glow of scattered sunlight in space. But since this material is always in motion (affected by the solar wind and radiation pressure) it is impossible to estimate the number and density.

"We want to find out whether this matter is gradually forming into a planet, or whether it is the debris from some cataclysmic collision of planets," says Robert Kraemer, director of planetary programs at NASA headquarters.

Two spacecraft instruments will focus on the asteroid belt: a meteoroid detector and an asteroid/meteoroid detector called "Sisyphus." The first instrument consists of pressurized cells mounted on the spacecraft. Penetrations of the cells by small bits of matter (10^{-9} grams) will be detected and counted by a cold cathode gauge. Scientists will be able to determine the mass and energy of the particles penetrating the cells by the rate at which pressure is lost. They will also determine the spatial density of the small meteoroids.

Sisyphus will make an optical survey of fragments of matter about 0.006 centimeters in diameter and heavier than 10^{-6} grams. It will detect meteoroids and asteroids by the solar light they reflect: Their ranges and velocities will be calculated by timing their entries and departures on four telescopic subsystems that will provide four overlapping fields of view.

About Pioneer's chances of survival through the asteroid belt, Charles F. Hall of NASA's Ames Research Center says, "A typical model of the belt indicates a 90 percent chance of non-penetration."

"I have nightmares about that 10 percent chance of getting clobbered," says Guido Münch of the California Institute of Technology.

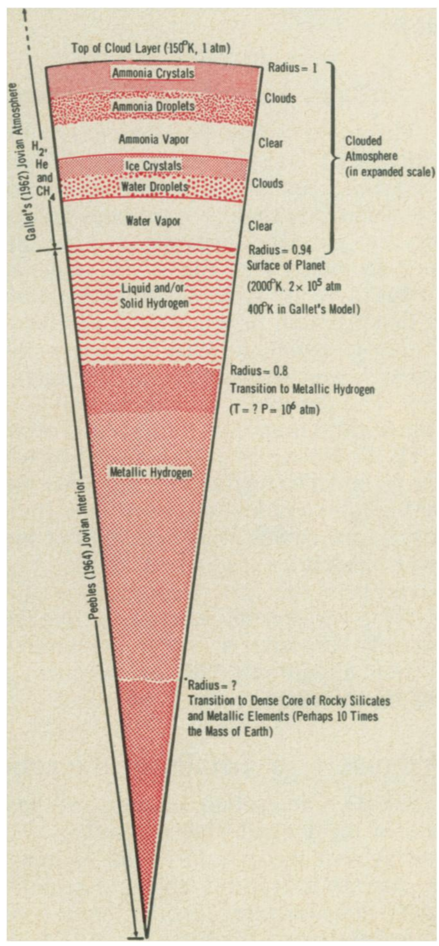
On the other side of the asteroid belt lies the prime target of Pioneer F's mission—Jupiter. Jupiter's diameter is more than 11 times earth's, it's volume, more than 1,000 times, and it's mass, more than 300 times. When the Pioneer is 560,000 kilometers from Jupiter —more than the distance from earth to moon—the 11 instruments on board the craft will scan the entire sun-side disk of the planet. At the closest approach to Jupiter, 139,040 kilometers, Jupiter would fill 60 percent of a man's field of view, but the instruments, with their more limited fields of view, will be able to observe only 25 percent of the sun-side disk.

As Pioneer approaches Jupiter, an imaging photopolarimeter will make 10 to 12 pictures of the planet (each picture taking from 25 to 50 minutes to make). The instrument will obtain two-color images with a resolution of 200 kilometers in both the red and blue spectral bands. These images will enhance colors masked by atmospheric effects.

Major questions about Jupiter cannot be solved from earth-based observations. Scientists know that Jupiter emits decameter, centimeter and decimeter radio radiation. Although they understand something about the behavior of the decameter radiation, they do not know what generates and alters it.

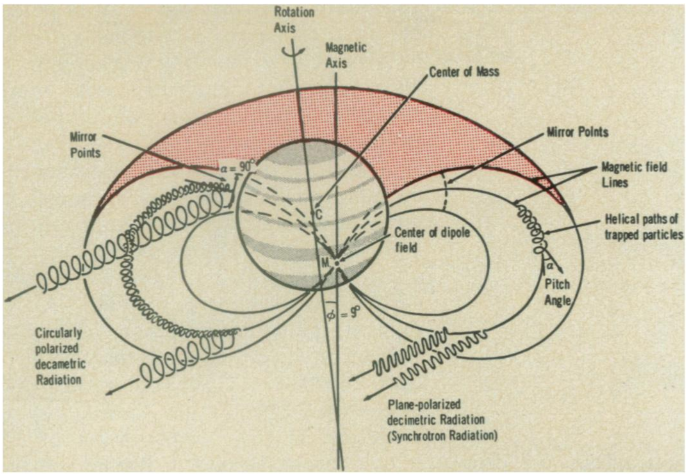
James A. Van Allen's Geiger-Mueller tubes on the craft will look for the radiation belts and survey the intensities, energy spectra, and angular distribution of electrons and protons along the trail Pioneer will make through the planet's magnetosphere. Scientists would also like to understand the origin of Jupiter's magnetic field, the interaction of this field with interplanetary magnetic fields and the relationship of the fields to the decameter radiation. The magnetometer on board will measure magnetic fields along the way to Jupiter and beyond and how they affect and alter the course of the solar plasma as the spacecraft moves away from the sun.

One of the more important unanswered questions about Jupiter is the ratio of hydrogen to helium in the atmosphere, as well as the exact abundances of other gases such as ammonia, methane, deuterium, neon and water vapor. Estimates of the amount of hydrogen and helium vary from 60 percent hydrogen and 36 percent helium to 97 percent hydrogen and 2 percent he-



R. Gallet and P. J. E. Peebles

Jovian atmosphere and interior model.



Observations of Jovian belts and zones have revealed a number of more or less permanent "surface currents" within and alongside the belts.

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lium. Many scientists believe the abundances may be the same as existed in the original solar nebula at Jupiter's distance from the sun, since even the lightest molecules would be captured in Jupiter's strong gravitational field.

A University of Texas team wanted to obtain the exact ratio of hydrogen to helium during the occultation of the star Beta Scorpii by Jupiter (SN: 10/16/71, p. 261). To do this, however, they needed an accurate temperature profile of Jupiter's atmosphere above the troposphere, which, as it turned out, they didn't have. While they didn't get the ratio they wanted, however, their observations did support the theory that hydrogen was abundant.

Whether or not Jupiter really does emit more energy than it receives from the sun could be answered by data from the infrared radiometer. If so "We don't know where the energy is coming from," explains Münch. "Some stars radiate energy from contraction, but Jupiter should have contracted already." Another explanation, he says, could be from energy resulting from changes in the state of matter, temperature and pressure.

The instrument will also map the temperature distribution, which may help to explain Jupiter's red spot. The red spot is more than three times the diameter of the earth—40,000 kilometers in length by 13,000 kilometers in width. It has circled the planet three times in the last 200 years, relative to other features on the rotating body. Its color and visibility wax and wane, and sometimes the color disappears. One theory of the red spot is that it might be the upper end of a Taylor column, a stagnant column of fluid caused by a two-dimensional atmospheric flow that is unable to surmount a topographical feature. This theory, however, assumes a solid surface for Jupiter, and many scientists believe that Jupiter's surface is fluid.

Another theory says that the red spot is organic material: that lightning discharges have created complex organic compounds from hydrogen, helium, methane and ammonia in the atmosphere.

"These conditions [on Jupiter] are not conducive to the existence of any form of life, yet the school of thought that eliminates Jupiter as a possible abode of life without giving it any more consideration is missing the point," says Cyril Ponnamperuma of the University of Maryland. "Life on the earth is believed to have evolved initially in an atmosphere of methane and ammonia which could be rapidly fatal to a man, and which is closely similar to that existing on Jupiter at the present day," he says.

On the theory that life evolves to fit itself to existing conditions, Ponnamperuma has simulated in the laboratory the atmosphere of Jupiter (although he didn't know exact hydrogen to helium ratio) and put it through various tests. Using anhydrous methane-ammonia mixtures, Ponnamperuma's group simulated electrical discharges in the atmosphere and the result was the formation of organic compounds as simple aliphatic nitriles, amino-nitriles, and their oligomers. A red tar adhered to the side of the flask.

As an alternate approach, the group tested the survival ability of common terrestrial microorganisms in aqueous media at 100 atmospheres pressure and at 0 to 20 degrees C. in a simulated Jovian atmosphere. The organisms tolerated these conditions for 24 hours with few deaths.

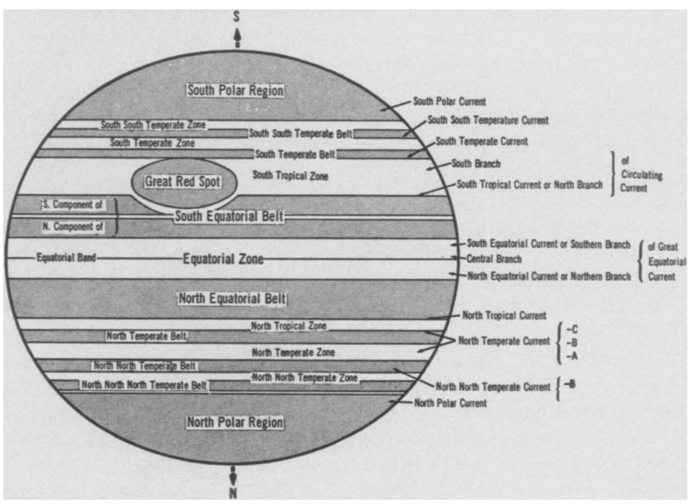
"The ability of terrestrial organisms to survive Jovian atmospheric conditions, taken together with the likelihood of advanced prebiotic synthesis," says Ponnamperuma, "suggests that life may have evolved on Jupiter in parallel with life on earth."

The red spot is immersed in the gray, brown, blue, pink and yellow bands that circle the planet. The clouds seen through telescopes from earth are believed to be ammonia ice indicated in the model proposed by Roger M. Gallet and P. J. E. Peebles. Periodic disturbances have been observed in these clouds, but says Münch, "We have not yet started to understand the complicated meteorology of Jupiter."

Jupiter's rotation period of 10 hours also poses a mystery. Scientists are puzzled why a planet 11 times as large as earth rotates more than twice as fast.

Since Pioneer will pass inside the orbits of all of Jupiter's 12 moons, some of the instruments will be focused on them, looking for atmospheres, magnetic fields and surface features.

After swinging by Jupiter, Pioneer F will continue out past the orbit of Pluto, but the radio transmitter aboard will probably be too weak to be heard on earth at beyond 2 billion kilometers past Jupiter. Until then, the instruments will be transmitting data on solar plasma, the interplanetary medium and cosmic rays. J. H. Wolfe of NASA's Ames Research Center will reduce the data from the plasma analyzer. As Pioneer F moves farther and farther from the sun, the analyzer will be used to search for signs of the solar-galactic boundary—the line between plasma bound to the interplanetary magnetic field and plasma bound to the galactic field. □



A model of the Jovian magnetosphere drawn from observations made by V. Radhakrishnan and J. A. Roberts.

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