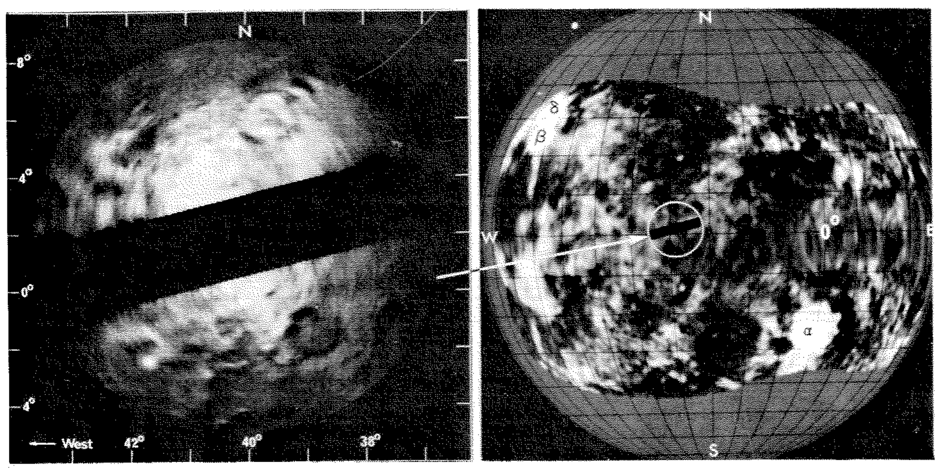
Research Notes

Craters on Venus

At least three planets in the solar system —Earth, Mars, and the Moon—are known to be scarred by craters resulting from some sort of cataclysmic collisions over the past several million years. Now it appears that a fourth—cloud-shrouded Venus—is marked by this kind of cratering too. The surprising discovery was made by radar astronomers at Caltech's Jet Propulsion Laboratory, who pierced the 13-mile-thick Venusian cloud layer with high-intensity radar beams sent from the Goldstone Deep Space Station in the Mojave Desert. A dramatic map assembled from these radar measurements reveals a 910-mile swath (about the size of Alaska) pitted with a dozen huge shallow craters. The largest is about 100 miles in diameter; others are between 20 and 65 miles across. All of them are relatively shallow—less than 1,200 feet deep. In fact, the whole area seems to vary by no more than 3,300 feet in altitude, and the presence of any craters at all is surprising.

It has usually been assumed that the surface of Venus would have to be relatively smooth because it is shielded by an atmosphere 100 times more dense than Earth's. With this protective mantle, meteors on a collision course with Venus normally should have burned up before hitting the surface as meteorites. Nevertheless, the size and shallow nature of the craters defined by the JPL radar measurements suggest that they were created by impact and have somehow survived the erosion processes on the super-heated planet.



A close-up of JPL's radar map (left) reveals an area near the equatorial region of Venus that is almost as cratered as the Moon. The black bar through the center of the area is a section that could not be scanned by radio telescopes at the Goldstone Deep Space Station. The photograph on the right shows the location of the cratered area in relation to bright sections mapped in previous JPL radar scans, marked α, β, and δ.

The JPL team is headed by Richard M. Goldstein, who has been radar-mapping Venus for a decade ("Mapping a Mystery" —*E&S,* November 1971). Manager of JPL's communications systems research section, he is also a research associate in planetary science at Caltech. The scientists used signal-processing equipment designed by Senior Research Engineer Richard R. Green (BS '64, MS '65, PhD '69) and George A. Morris, a group supervisor. The cratered map of Venus was assembled with the aid of computer techniques devised by Senior Research Engineer Howard C. Rumsey Jr. (BS '57, MS '58, PhD '61).

For the first time, Goldstein and his co-workers were able to scan the planet with two huge dish antennas—one 210 feet wide and the other 85 feet across—located 14 miles apart near Goldstone. The stereoscopic view that resulted made it possible to determine elevation differences on Venus to within 600 feet and distances on the surface to within six miles. These results are five times better than those of the last Venus radar experiment in 1970, which used only one of the Goldstone antennas.

The project scientists hope to get a closer look at Venus when JPL's Mariner 10 flies by the planet in February 1974 on its way to Mercury. They are now studying the results of the six radar scans of the last decade to help decide just where to point the Mariner 10 cameras, and they have also planned further radar probes in conjunction with the Mariner flight. Even though the spacecraft's television cameras may not be lucky enough to find holes in the Venus cloud curtain, the radar beams should be helpful in interpreting the close-up spacecraft data.

A New Telescope for Big Bear

Caltech's Big Bear Solar Observatory got a new three-barreled, four-ton, million-dollar telescope this summer. It can make five observations of the sun simultaneously, and it replaces a much less versatile system. Workers are still sorting out the miles of wires necessary to connect the electronic controls, but the system should be in full operation by next month, when one of its jobs will be to aid the astronauts on Skylab 3 in monitoring solar activity that is not visible from the earth's surface. A telephonic "hot line" will be maintained between the Johnson Space Center in Houston and the Big Bear Solar Observatory. When Big Bear observers spot impending interesting activity on the sun, they will notify Houston. There, the information will be relayed quickly by radio to Skylab or will be used in planning the following day's solar observations aboard the spacecraft.

Planets and Planetesimals

Scientists have a general idea of how the solar system developed, though a lot of details still haven't been completely worked out. But at least there seems to be general agreement that, in the very beginning stages of the evolution of the solar system, debris the size of dust—or even of small particles of gravel—condensed out of the slowly cooling gases in the nebula around the newly formed sun. It also seems fairly certain that, quite a bit further along in the evolutionary process, planet-sized bodies formed as the products of a series of collisions of smaller, asteroid-like objects called planetesimals. The gravitational fields of these objects would have caused them to stick together once they collided, creating a new and larger body. And this process must have continued until planets came into being.

This theory explains everything except what happened between that first evolutionary step and the end product. How did fragments no bigger than dust or gravel, and with no apparent gravitational attraction for one another, "grow" into planetesimals? Peter Goldreich, professor of planetary science and astronomy, and research fellow William Ward, have worked out a possible explanation of how the transition was made:

As gas in the solar nebula began to cool billions of years ago, the tiny solid particles that condensed out of it formed a thin, plate-like disk of debris that orbited around the sun. Although the gravitational pull of any one of these countless miniscule fragments was virtually negligible, their combined mutual attraction was enough to break the newly formed disk into separate clusters. Each cluster was composed of bits of debris—all attracting one another sufficiently to cause the space between the particles to shrink. Eventually, portions of each cluster collapsed on each other to form larger objects.

In just a few years—an incredibly fast time scale as cosmic time is measured—planetesimal bodies about half a mile thick were formed. In clusters of about 10,000 they continued to rotate around themselves in a delicately balanced equilibrium, prevented from contracting further by the strength of their rotational patterns.

Over a period of a few thousand years, however, the planetesimals interacted with the hydrogen gas that formed most of the remaining solar nebula, and the gas produced a drag that drained away the energy of the clusters. This caused them to continue to contract upon themselves until they formed still larger planetesimals about five miles in diameter.

This is about as large as these objects could have gotten by this process, but by this time they would have started colliding with each other, and their gravitational fields would have been strong enough to cause them to stick together. Eventually, they would have become planet-sized bodies.

If the process Goldreich and Ward describe is accurate, it has taken place many times—in fact, around every sun in the universe that has a solar system. And the formation of planets is very likely a natural consequence of the formation of stars.

Another Apollo

Caltech planetary scientist Eleanor Helin celebrated the Fourth of July this year in spectacular style. She discovered a five-mile-wide asteroid that whipped across the sky faster than anything but a meteor, and came to within 7 million miles of Earth. Moving at 60,000 miles an hour, if it had hit this planet—as objects of this kind occasionally do—it would have gouged out a crater 50 to 60 miles in diameter.

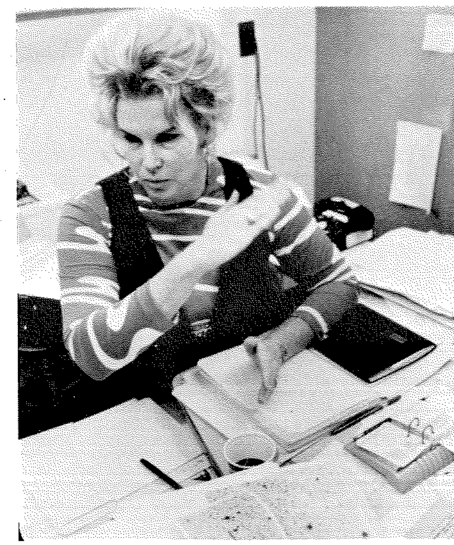
This is the 17th asteroid of its type discovered since 1932, when the first one was observed and named Apollo—a name that has since been applied to the whole group. It is the first discovered in a six-month search program now being conducted by Mrs. Helin and Eugene Shoemaker, professor of geology. The aim of the search is not only to locate Apollo objects but to find out more about them and their relationship to the processes by which the solar system was formed.

The new object was located within the constellation of Scorpius on discovery, and it showed up as a streak of light on a 20-minute exposure on a photographic plate taken by Mrs. Helin. She used the 18-inch Schmidt telescope at Palomar Mountain and was assisted by undergraduate John Smith, '74.

The asteroid travels in an elongated ellipse around the sun, coming as close as 80 million miles and swinging out as far as 290 million miles. Mrs. Helin and Shoemaker will have the honor of naming it when it returns to the neighborhood of Earth in late 1975 or early 1976.

Apollo group objects may be the residue of comets from which gases, dust, and small particles have been stripped away by close approaches to the sun. Like comets they follow up-and-down paths that crisscross diagonally through the plane of the orbits of the planets—in contrast to main-belt asteroids whose orbital inclinations are similar to those of the planets.

The most unusual thing about this particular object—and what makes it so spectacular to planetary scientists—is the extreme angle of its orbit to the plane of the earth's



Eleanor Helin

orbit: 67 degrees (an orbital inclination greater by far than any other known asteroid) as compared to the 10- to 15-degree inclinations of most other Apollo group objects. One 40-degree-inclination Apollo object was discovered last December and another earlier this year; together with the new discovery, the three appear to represent a whole new group of planetary objects.

Astronomers estimate that there are as many as 10,000 of these objects scattered throughout the space above and below the orbital plane of the planets of the solar system—space previously supposed to be empty except for the comets that travel through it. While some comets take as long as 100 million years to complete their orbits, there are also short-period comets that appear and disappear every few years. Mrs. Helin's discovery is the first solid evidence that there may be a link between the Apollo group objects and the short-period comets.

P.S. On August 27 another object was discovered by Mrs. Helin, who made seven observations, followed by observations by Richard Green, a graduate student, and Charles Kowal, research assistant in astrophysics. Preliminary orbital computations suggest that this is another Apollo group object. □