CHAPTER 6

THE OUTER SOLAR SYSTEM: REALM OF THE GIANTS

* CLASS COPY *

Jupiter's rapid spin, are frequently stretched out into great parallel bands that completely encircle the planet, giving it a striped face.

331 Chemically speaking, Jupiter is a lot more like the Sun than the Earth. While Jupiter has an iron core as does the Earth, about 85 percent of the giant planet is made up of hydrogen with most of the other 15 percent consisting of helium. Less than 1 percent is made up of all the other elements. Jupiter's strong gravitational field allowed it to retain all the elements in the original cloud out of which the solar system formed. Earth, with its much weaker gravitational field, lost most of its light elements (hydrogen and helium) into space long ago.

332 Jupiter's clouds are a riot of color. Unlike Earth's clouds, which are all simply white, Jupiter's clouds also contain brilliant splashes of color: shades of yellow, orange, red, and brown. The colors are believed to be due, in part, to the presence of complex molecules, including ethane and phosphine. The colored clouds lie between brighter white clouds. These bright bands, called *zones,* are places where gas is rising in the Jovian atmosphere. The alternate dark bands are referred to as *belts* and are places where gas is descending to lower depths. The belts in general are a bit lower in the atmosphere than the zones, so they are also slightly warmer. Jet streams cut back and forth across Jupiter's face between the zones and the belts, sometimes racing past each other at hundreds of miles per hour.

333 Days go by faster on Jupiter than on any other planet in the solar system. Although Jupiter is the largest planet, its size doesn't keep it from spinning the fastest of all. A day on Jupiter is less than ten Earth hours long. But just how long a day lasts depends on where you are. Like the Sun, Jupiter is not solid, so different latitudes on the planet rotate at different speeds. Near the equator, a Jovian day lasts about 9 hours and 50 minutes, but a Jovian day near the poles is about 9 hours and 56 minutes long. So on Jupiter, unlike Earth, a point that's due south of you today won't be due south of you tomorrow. If you want to go on vacation to a different latitude on Jupiter, just wait until it's passing by at your longitude. You'll save on airfare.

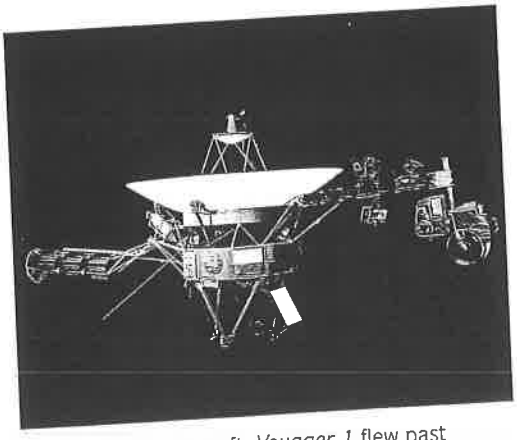
334 The top of Jupiter's atmosphere is a seething caldron of storms. Within Jupiter's multicolored clouds, telescopes and spacecraft have revealed enormous swirling systems of clouds that pack incomprehensible amounts of energy. As jet streams rush past each other, they create ribbons of turbulent gas tens of thousands of miles long and propel hurricanes the size of Earth's continents. In addition to the striped belts and zones, Jupiter also has *spots.* The largest, known as the Great Red Spot (GRS), is an oval-shaped maelstrom of clouds more than twice the size of Earth that has been raging unabated on Jupiter for over 350 years.

338 **Because it is still collapsing, Jupiter has infernolike central temperatures.** All of the planets in the solar system collapsed out of a giant cloud of gas and dust about 4.6 billion years ago. While some of Jupiter's internal heat is due to energy released by radioactive decay, there must be another source of heat at work to produce such high temperatures. Scientists suggest that the extra heat may be due to the fact that Jupiter's interior is probably still collapsing.

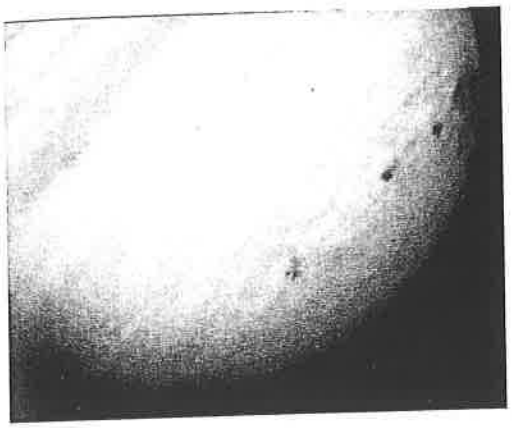
339 **It doesn't take much collapse to generate a great deal of heat.** A "settling down" of only a few inches per year in Jupiter's massive core would generate enough additional energy to create Jupiter's incredible central temperatures. As a result, Jupiter actually radiates two and a half times as much heat as it receives from the Sun.

340 **Will Jupiter someday ignite as a star or did it somehow just miss becoming a star?** In both cases, the answer is a simple and very definite no. The more mass an object has as it forms, the higher its central temperature will rise. In order for Jupiter to have become a star, it would have to have formed with almost 100 times more mass than it has. An object needs a central temperature of over 1 million°F to qualify as a star and generate its own energy by converting hydrogen into helium through nuclear reactions. Jupiter's mass isn't going to increase and neither will its central temperature, which is in the range of tens of thousands of degrees and thus far less than the 1 million°F readings you need to ignite thermonuclear fusion. Thus, Jupiter failed to become a star by a wide margin and will never be able to become one.

341 **Jupiter has a thin dusty ring.** Scientists didn't really expect the giant planet to have a ring, but the *Voyager 1* spacecraft was programmed to look for one nonetheless. Not to disappoint, *Voyager* found a small faint ring around Jupiter's equator about 35,000 miles above the cloud tops. The ring looks much brighter when seen from the nightside of Jupiter (looking back toward the Sun) than from the dayside (as seen from Earth). (Just like a dusty windshield appears much more brightly lit if you're in the car driving into the Sun than



The *Voyager* spacecraft. *Voyager 1* flew past Jupiter and Saturn. *Voyager 2* made flybys of Jupiter, Saturn, Uranus, and Neptune between 1979 and 1986. On the right arm of the spacecraft are the two cameras. The images and other data were transmitted to Earth by radio signals sent from *Voyager*'s large antenna. On the central part of the spacecraft can be seen a cover over a record that contains sounds and pictures from Earth. (NASA/JPL)

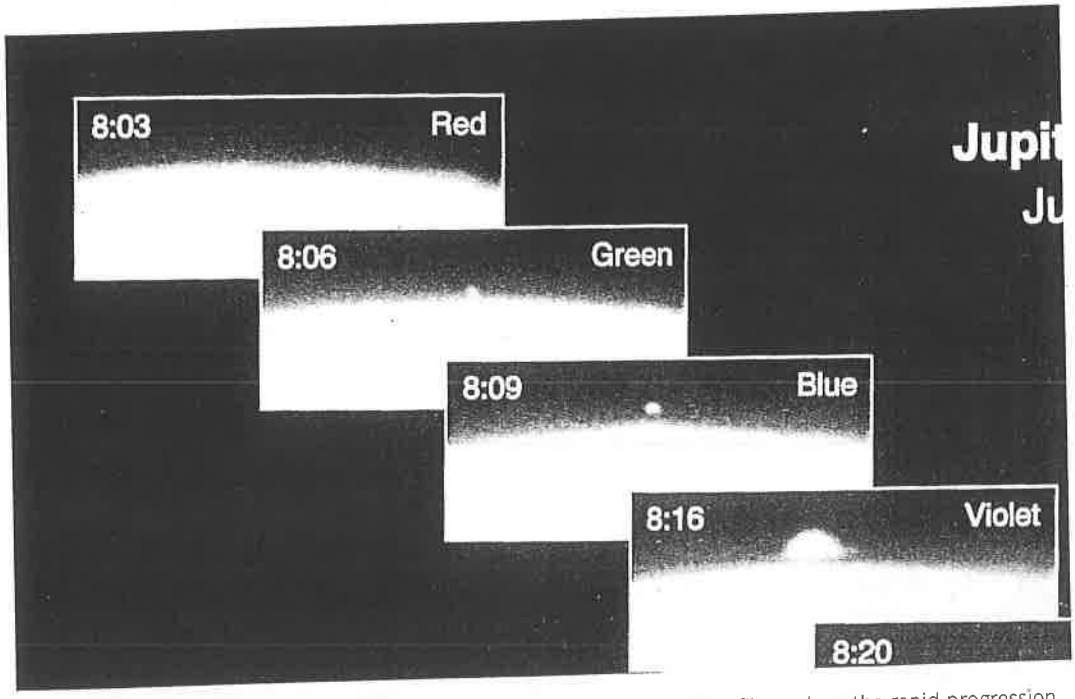


A series of SL-9 impacts leave a succession of scars on Jupiter's battered face. The discolorations lasted for more than a year. (NASA/STScI)

watch the unprecedented event. The nearly two dozen impacts occurred over a five-day period and detonated in Jupiter's upper cloud decks, releasing the energy of millions of tons of TNT. The explosions created shock waves the size of Earth and dredged up huge dark clouds of material from the lower clouds that persisted for over a year.

---

344 **In late 1995, a new chapter in the exploration of Jupiter began.** On December 7, 1995, after a six-year trip, the *Galileo* spacecraft reached Jupiter. But unlike *Pioneer* and *Voyager* spacecraft that just flew past the planet back in the 1970s, *Galileo* was designed to go into orbit and send back at least two years' worth of data. First on the agenda was the release of a 746-pound probe that became the first man-



A series of images from the Hubble Space Telescope taken through various filters show the rapid progression of events as a mushroom cloud from SL-9's W fragment impact rises over Jupiter's limb. (NASA/STScI)

paints a complete picture or even perhaps a typical one.

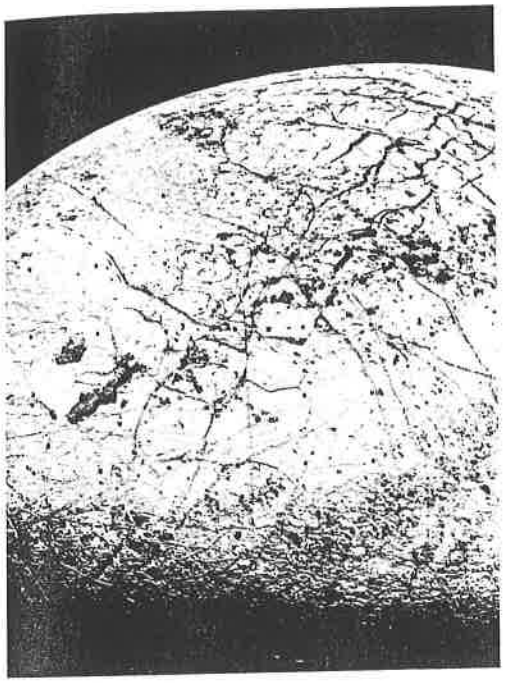
347 **Jupiter's four largest satellites were discovered by Galileo back in 1610.** When Galileo first looked at Jupiter through a telescope, he discovered four little starlike objects arranged in a straight line on either side of the planet. Watching them from night to night, he saw that they changed position but always followed Jupiter. He correctly surmised that they were satellites of Jupiter—the first satellites to be found in orbit around another planet. Knowing where his bread was buttered, Galileo initially named the moons in honor of his patrons, the wealthy Medici family. Since Galileo's time, however, these four worlds have been referred to as the *Galilean satellites.*

348 **The Galilean satellites of Jupiter are actually bright enough to be seen with the naked eye.** These moons are so large that they are actually brighter than the faintest stars that can be seen with the naked eye. They remained undiscovered until the invention of the telescope, however, because the glare from Jupiter blinds us to their fainter light in the same way that it would be impossible to see a firefly crawling on the rim of a searchlight shining directly into our eyes.

349 **The Galilean satellites take their names from Greek mythology.** In Greek mythology, Zeus (the king of the gods) was the equivalent of Jupiter (the father of the sky). And so, in time, Jupiter's four largest satellites, always hovering about it, were appropriately named after several of Zeus' many mistresses and consorts: Callisto, Ganymede, Europa, and Io.

350 **Jupiter has a large and colorful entourage.** In the years since Galileo first looked to the sky, astronomers have discovered twelve additional satellites orbiting Jupiter. Indeed, there are so many that the planet and its moons look a bit like a miniature solar system. Twelve moons travel around Jupiter in one direction, while the outermost four (probably captured asteroids) orbit in the opposite direction. The moons vary in size from little more than oversized rocks to worlds larger than Mercury and Pluto. Several of the moons have been explored at close range by spacecraft. The amazing images sent back by the spacecraft show that these satellites vary as much as the planets do.

351 **Callisto is a big "dirty ball of ice."** The outermost of the four Galilean satellites is Callisto. About 3,000 miles in diameter, it is considerably larger than the Earth's Moon. But whereas the Earth's only satellite is made of rock, Callisto is mostly frozen water with a smattering of metals and silicates. The surface of Callisto is peppered with thousands of bright ice craters that were caused by the impact of smaller objects from space. Callisto's largest and



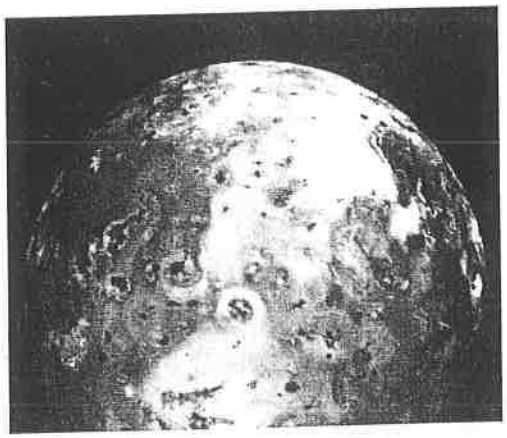
Jupiter's Europa, smooth as a billiard ball, is covered with features that look like cracks. The surface is likely a thin layer of ice that encases a worldwide ocean. (NASA/JPL)

tions for hundreds of miles. When scientists saw similar features on Earth in sea ice that had partially melted and refrozen several times, it led some to speculate that Europa's icy surface crust may be quite thin and encase a worldwide ocean. Temperatures above the freezing point would be maintained in this alien ocean by heat delivered through *tidal friction* from Jupiter.

355 **Europa is also a colorful place with exciting possibilities.** Europa's orange coloration has also led scientists to speculate that this moon might contain the same kinds of complex organic molecules that were the precursors to the development of life on Earth. Someday, a spacecraft may chip off a piece of Europa's ice and return it to Earth. A future spacecraft/submarine may send back some fascinating data and pictures from this very intriguing moon as it explores the exotic depths of this alien ocean.

356 **Io looks like a pizza.** The most bizarre and exotic satellite in all the solar system has to be Io. As the *Voyager* spacecraft approached this moon, scientists looked down on a landscape like none they had seen before. Not a single crater could be found. Instead, Io's blotchy surface was a cosmic palette of color—reds, yellows, oranges, black, and white—that made it look not unlike a pepperoni pizza with anchovies.

357 **Io's strange appearance is caused by an extraordinary phenomenon.** Why does Io look so strange? In a *Voyager* image of Io's dark side that was purposely overexposed (to show the stars and make sure *Voy-*



Io, which looks like a pizza, is the most volcanically active world in the solar system. (NASA/JPL)

that were attributable to Io having an iron core about 1,000 miles across—nearly half the diameter of the satellite itself. Io thus becomes the first satellite known to have a magnetic field of its own.

361 **Io is a bit of a litterbug.** As Io travels around Jupiter spewing its sulfurous fumes, it "pollutes" its orbit by leaving a cloud of sulfur atoms in its wake. Over time, this has formed a complete doughnut-shaped cloud around Jupiter that traces Io's entire orbit.

362 **Jupiter's tidal forces create a significant pattern of differences among its largest satellites.** The densities of the four largest satellites of Jupiter increase as we get closer to Jupiter and the temperatures of their interiors also rise. Callisto and Ganymede are little more than "dirty balls of ice," while Europa probably is an ocean world under a thin crust of ice. And Io is almost completely made of molten sulfur and iron with no craters and virtually no water or ice at all. Similarly, the surface of Callisto is probably quite ancient and shows no evidence of internal activity. By contrast, Ganymede's wrinkle ridges demonstrate that some geological activity has gone on there. Europa's crisscrossed ice pattern may indicate repeated meltings and refreezings, perhaps even to the present, and its thin or slushy ice crust has obliterated most signs of cratering in the past. Finally Io, through its erupting volcanoes, is having its surface continuously "repaved." Indeed, Io has the "youngest face" in the solar system.

363 **Jupiter itself is the reason for the primary differences between its major satellites.** Simply put, the closer a satellite is to Jupiter, the stronger its tidal forces and the greater its tidal heating. Thus, the far-out worlds (such as Callisto and Ganymede) are frozen solid and have been for a long time, while worlds closer in are warmer. This, in turn, accounts for whether a moon is solid or liquid or molten and determines whether the original water the satellite may have had remains frozen in place or has evaporated into space long ago, leaving heavier substances behind to give that moon a higher density.

Saturn

364 **Saturn is the lord of the rings.** Twenty years ago, astronomers wondered why, of all the giant planets, only Saturn had rings. Today, we know that all four giants (Jupiter, Saturn, Uranus, and Neptune) have rings of some sort, but none can compare to the magnificent rings of Saturn. Shining brilliantly, Saturn's rings span over 200,000 miles (nearly the distance from the Earth to the Moon) and can be seen in even a small amateur telescope.

---

365 **Saturn's rings were first seen by Galileo, who couldn't figure out what he was looking at.** When Galileo first looked at Saturn through a telescope, he noticed that something about this planet was unusual. He reported that "the sixth planet is three" (that

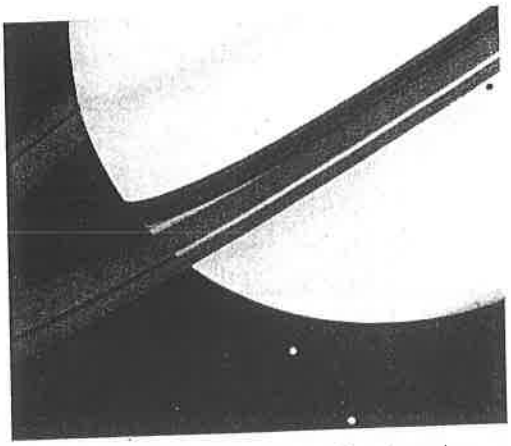
Seen from Earth, Saturn appears to have three rings. They are simply called the A-ring (outer), the B-ring (middle), and the C-ring (inner). The B-ring, the broadest, is separated from the A-ring by a gap named the *Cassini Division* (for the astronomer who discovered it). It's wide enough to drop our Moon through and can be seen in medium-sized amateur telescopes. The C-ring is also referred to as the *Crepe ring* because of its gauzelike or semitransparent appearance.

368 **When it comes to the rings of Saturn, there's a lot more than meets the eye.** As the *Voyager* spacecraft approached Saturn in 1980 and 1981, finer structure in the rings began to be revealed. What appeared to be only three rings from Earth turned out to be first hundreds, then thousands of "ringlets." From close up, Saturn's rings began to look like a phonograph record. In addition, the *Voyager* spacecraft discovered rings never seen from Earth, including one that mysteriously braids and unbraids like a girl's hair.

369 **While they may look like a racetrack or CD, Saturn's rings are not solid.** It has long been known that the rings and ringlets are not solid disks but instead are made up of millions of pieces of "dirty ice." They range in size from particles the size of grains of sand to icebergs the size of a small house. Each object in this blizzard behaves like a tiny moon in its own separate orbit. Like the planets orbiting the Sun, the closer a ring particle or boulder is to Saturn, the faster it travels. Some race around at speeds of up to 50,000 miles per hour. To our eyes, all these minisatellites blur, like the blades of a fan, into the beautiful adornment we call the rings.

370 **Saturn's B-ring has *spokes*.** Flying high over Saturn's broad middle ring, *Voyager 1* discovered what appeared to be dark spokelike streaks. Scientists believe the spokes may be electrostatically charged dust suspended just above the ring that is trapped in Saturn's magnetic field and forced to orbit the planet as it spins.

371 **Gaps between the rings are the result of tugs-of-war between some of Saturn's satellites.** In addition to the 3,000-mile-wide gap known as the Cassini Division, other gaps are also visible within the rings. In time, astronomers realized that these separations were not only semipermanent features

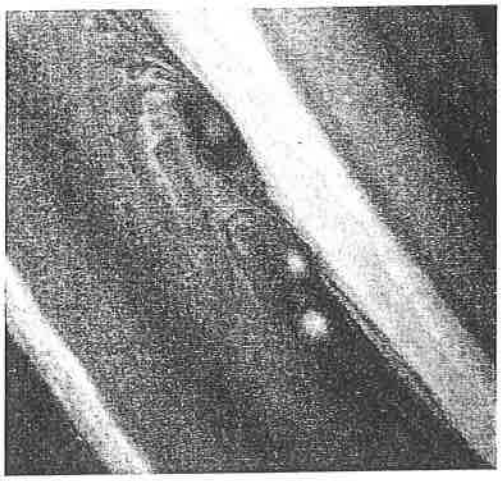


Saturn's thin rings can be seen casting a shadow on the cloud tops far below. The clouds can be seen shining through a major gap in the rings known as the Cassini Division while Tethys and Dione orbit nearby. (NASA/JPL)

375 **Saturn is made of such lightweight stuff that if you could find a bathtub big enough to hold it, Saturn would float.** Like Jupiter, Saturn is a giant cloud-covered planet with an atmosphere that descends for thousands of miles. And, like Jupiter, Saturn is made up mostly of the two lightest elements in nature: hydrogen and helium. Saturn also contains a smattering of heavier and more complex chemicals, but its overall density is actually less than that of water. This means that, given a large enough bathtub, Saturn would literally bob around like a marshmallow in a cup of hot cocoa.

376 **While Jupiter is a riot of color, Saturn looks more like a big lump of pale butterscotch pudding.** From its Great Red Spot to its belts of orange and brown, Jupiter's atmosphere displays dramatic swirls and splashes of color. Saturn, by comparison, is far more subdued. Its pastel yellowish brown cloud bands are interspersed with white. The reason seems to be a combination of two factors. First, there is a high haze layer in Saturn's atmosphere that makes it seem as though we are looking at the planet through frosted glass. Second, Saturn has a more thorough mixing of weather systems, which makes large single-colored cloud features quite rare.

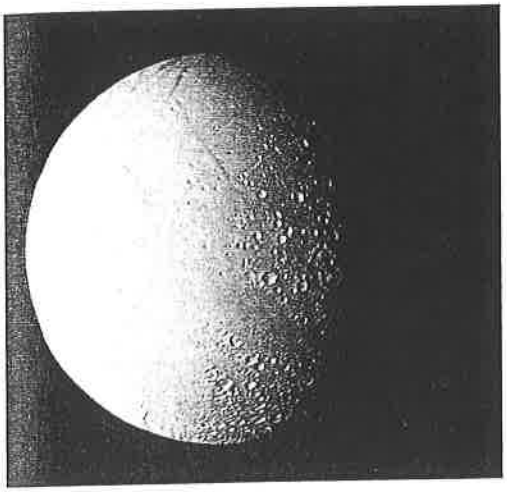
377 ***Voyager*** **found strange hurricanes on Saturn.** *Voyager*'s cameras spied pinwheel-shaped swirls of clouds, where it rains ammonia, that are likely hurricanes the size of Asia. Such meteorological phenomena are nothing, however, compared to a mind-boggling event that may occur like clockwork on Saturn every 30 years.



Storms on Saturn. (NASA/JPL)

378 **Saturn may have the biggest blizzards in the solar system.** Each time Saturn is closest to the Sun, the additional warming it receives triggers a huge upwelling of clouds from deep within the planet. As copious amounts of ammonia vapor rocket upward into the Saturnian stratosphere, they are turned into trillions of snowflakes. Caught by jet streams that blow at over 1,000 miles per hour, the storm quickly explodes into a giant ammonia blizzard that encompasses an area several times the size of Earth. Seen as an enormous white cloud that covers millions of square miles, the blizzard rages for weeks before slowly subsiding.

379 **Like Jupiter's Callisto and Ganymede, many of Saturn's moons are made of**



Saturn's icy moon Enceladus is a little over 300 miles across. Just below center a broad area of the satellite has been wiped clean—the likely result of liquid water gushing in torrents across Enceladus's surface at some time in the past and obliterating everything in its path. (NASA/JPL)

and licked it clean, obliterating all detail. The border of this area is even marked by craters that are partly intact and partly wiped away. Oversized extraterrestrials with a liking for cosmic-sized snow cones not being a likely hypothesis, scientists think this is where the moon's ice melted at least once in the past and gushed in torrents across the landscape. The heating source? Tidal tuggings from giant Saturn.

---

385 **Iapetus is a two-faced world.** Iapetus is one of the strangest worlds in the solar system. About 900 miles across, it has one hemisphere coated with ice as bright as newly fallen snow, while portions of the opposite hemisphere are darker than asphalt. Astronomers speculate that the dark material may be some sort of rich organic material (not unlike tar) that has somehow welled up from deep inside the moon because of tidal heating between Iapetus and Saturn.

386 **On Hyperion, no two days are alike.** Hyperion is about 160 miles across and looks like a cross between a hamburger and a hockey puck. Its far-from-spherical shape is probably due to a collision in the ancient past that knocked off one or more large chunks and blasted what was left into an egg-shaped orbit. Its odd shape and strange orbit give the moon such a chaotic rate of spin that the length of a day on Hyperion varies from one day to the next. If the long days always occurred on Saturdays and Sundays, it wouldn't be such a bad place to live.

387 **Titan is a world shrouded in natural gas.** Titan, Saturn's largest satellite, is the second-biggest satellite in the solar system (after Jupiter's Ganymede). With a diameter of 3,200 miles, Titan is larger than the planets Mercury and Pluto. It is not only a planet-sized world, it also has another feature typically characteristic of a planet: an atmosphere. In fact, Titan's atmosphere is two and a half times as dense as that of Earth. When the *Voyager* spacecraft flew past Titan, scientists hoped to see its potentially exotic surface, but instead all they saw was a globe enshrouded in a featureless orange haze. Rich in methane (commonly known as natural gas), Titan's atmosphere is acted on by the Sun's light to produce a natural hydrocarbon smog. Some scientists have suggested that over the

distant ancestors may just find a new home in orbit around Saturn when our old one is no longer fit for life.

---

391 **Astronomers have known for years that Saturn has the largest number of moons in the solar system, but the family may be even larger than suspected.** Astronomers recently took advantage of a special event to go looking for more satellites around Saturn. For 15 to 17 years at a time, the Earth is positioned in such a way that we are able to see either the top side or the under side of Saturn's rings. Then, for the next decade and a half, we see the opposite side of the rings. But in between, for periods of a few weeks, the rings are seen virtually edge-on. At such times, the rings virtually disappear because they are so thin. With the rings' visibility greatly diminished, so is the glare of sunlight reflecting off of them. This, in turn, allows astronomers to search for tiny satellites that may have gone undetected. During the summer of 1995, astronomers took advantage of a *ring plane crossing* and used the newly sharpened eyes of the Hubble Space Telescope to ferret out what may prove to be even more family members. Future observations will be needed to tell for sure.

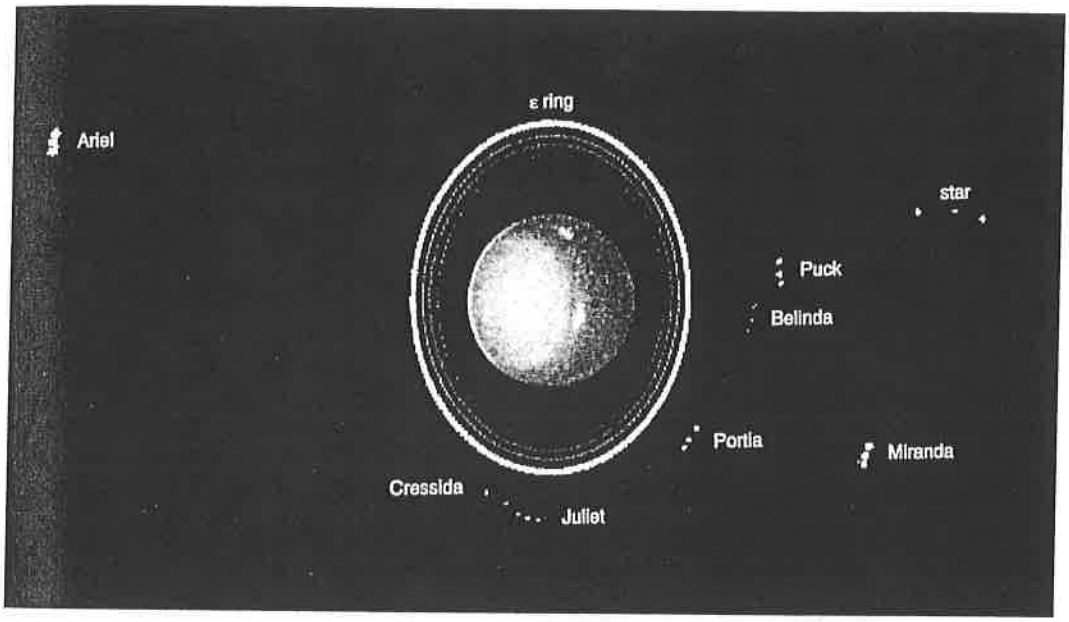
Uranus

392 **Uranus was the first planet to be discovered with a telescope.** In 1781, astronomer William Herschel (who wasn't a half-bad musician, by the way) spotted Uranus in his telescope. Unlike a star, Uranus had a small disk and Herschel at first thought his discovery might be a comet. Carefully noting its change in position over time, however, he was able to plot Uranus's orbit and found that it didn't follow the long looping path of a comet but the nearly circular path of a planet—in this case, a planet beyond Saturn.

393 **Under the right circumstances, you can see Uranus with the naked eye.** At maximum brightness, Uranus is actually bright enough to be glimpsed with the naked eye on a clear, dark, moonless night. Undoubtedly, over the centuries lots of folks did, but they failed to take note of the planet's slow telltale motion amid the stars from night to night and so didn't realize it was a planet.

---

394 **If Herschel had gotten his way, the seventh planet wouldn't have a name that makes junior high school students snicker no matter how you pronounce it.** Herschel, the first human being to officially discover a planet, felt he ought to have the right to name it. If Herschel had gotten his way, the planets (in order from the Sun) would have been: Mercury, Venus, Earth, Mars, Jupiter, Saturn, and . . . George. Although born in Germany, Herschel was living in England at the time of his discovery and, being a loyal subject of the crown, thought it



A composite of exposures by the Hubble Space Telescope show Uranus, its rings, and several of its moons. Multiple exposures to record the faint rings have resulted in multiple images of the satellites. Two rare cloud features on Uranus are 1,800 and 2,700 miles across. (NASA/STScI)

tops in both seasons rarely warm to more than –300°F.

399 **Uranus gets its blue color from methane gas in its atmosphere.** Like Jupiter and Saturn, Uranus is another giant cloudy world consisting mostly of hydrogen and helium. Its atmosphere also has trace amounts of methane gas, however. The methane absorbs the reds, oranges, and yellows in the Sun's light and scatters back the blue into our eyes, thus making the planet appear that color.

400 **In 1977, rings were discovered around Uranus without anyone actually seeing them.** In 1977, astronomers were observing Uranus, waiting for it to pass in front of a star. From the way the star's light dimmed as it went behind the planet, the scientists would be able to deduce things about the structure of Uranus's upper atmosphere. Before the planet ever got in line with the star, however, the star's light blinked off and on several times. The astronomers correctly deduced that it had done so because a system of thin dark rings surrounding the planet had eclipsed the star's light. The process, as expected, repeated after the star passed behind the planet. From the number of blinks and their duration, astronomers estimated that Uranus was surrounded by nine very thin rings.

401 **In 1986, we actually got to see the rings of Uranus for the first time.** *Voyager 2* got close enough to Uranus to map its

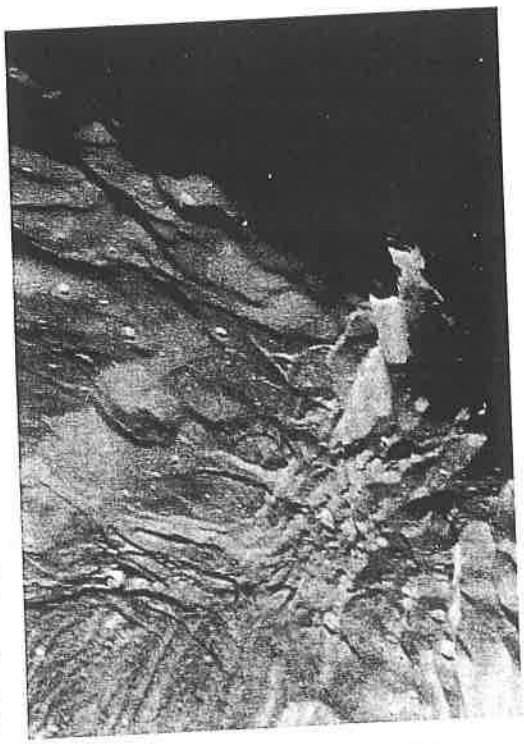
A close-up of some of the truly chaotic terrain found on Uranus's "patchwork quilt" moon, Miranda. Scientists believe that Miranda was broken apart by a powerful collision and then reassembled by gravity in a haphazard way.
(NASA/JPL)

more ranging in size from about 70 to less than 20 miles across.

---

405 **Miranda is a "patchwork quilt" of geological wonders.** Of all the moons in the solar system, Uranus's Miranda is the greatest geological treasure trove. While Miranda is only about 300 miles in diameter, within the confines of this tiny world lie cliffs, canyons, and terrain that can only be described as a chaotic jumbled mess. Scientists believe that earlier in its life, Miranda was struck at least once by an object massive enough to break it into pieces. Pulled back by the force of their mutual gravity, the pieces reassembled, but not in their original arrangement, thus creating a moon that resembles a giant three-dimensional jigsaw puzzle where the pieces don't quite fit.

406 **The ice cliffs of Miranda are not only a great geological wonder, they'll also make a great theme park ride someday.** Few geological features rival the vertical ice cliffs of Miranda, the tallest of which, Verona Rupes, towers 9 miles high and represents the greatest sheer drop in the solar system. If you stood at the top and stepped off into space, you would find the gravity of this tiny world so slight that it would take you nearly half an hour to reach the canyon floor below.



A close-up of the 9-mile-high ice cliffs of Miranda—one of the true wonders of the solar system.
(NASA/JPL)

Neptune as it appeared to *Voyager 2* in 1989. Visible are the Great Dark Spot; the Wizard's Eye, and the Scooter. High methane ice crystal clouds show up as brilliant white just under the Great Dark Spot and in the center of the Wizard's Eye. (NASA/JPL)

411 **Neptune has blizzards of frozen natural gas.** *Voyager* also took pictures of long streaks of white that cast shadows on the blue cloud tops far below. They turned out to be enormous clouds made of methane ice crystals (frozen natural gas) that would stretch from New York to Paris.

412 **The fastest winds in the solar system are found on Neptune.** While jet streams on Jupiter have been clocked at over 300 miles per hour and some on Saturn exceed 1,000 miles per hour, Neptune's jets can rip along at an astounding 1,400 miles per hour—the fastest winds in the solar system. If Earth had jet streams that strong, storms would be propelled clear across the United States in barely two hours and commercial jets could fly coast to coast in even less time.

413 **The Hubble Space Telescope recently recorded remarkable changes in Neptune's weather systems.** In 1994, the refurbished Hubble Space Telescope provided the first close-up views of Neptune since *Voyager 2* flew past in 1989. The images revealed dramatic changes, including the complete disappearance of the Great Dark Spot in Neptune's northern hemisphere and the emergence of a comparably colossal dark storm in its southern hemisphere! Gone too were both the Wizard's Eye and the Scooter. More recent images taken with the Hubble Space Telescope suggested that Neptune can somehow undergo such tremendous changes in as little time as a few weeks.

414 **Even more recent images reveal a quieter, gentler Neptune.** HST images from 1995 and 1996 reveal the disappearance of all of the dark spots, great or otherwise, from Neptune's atmosphere with only high bright clouds remaining.

415 **Could there be a link between Neptune's weather and the sunspot cycle?** When *Voyager* reached Neptune in 1989 and found a very active atmosphere with several dark storms, the Sun was near the maximum in its sunspot cycle. By the

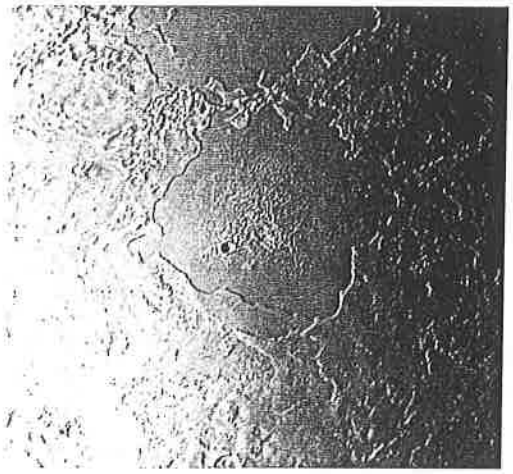
as seen by
nage is the
antaloupe
that reveal
ark parallel
nt geysers.

ratered terrain
was seen to be
tern that looks
. Its origin con-

oil field" out of
opposite hemi-
of dark streaks
ng. The strange
ers until move-
: of the streaks.
large number of
g Sun-darkened
ore into the sky.
, then paints the
ıks.

419 **Triton, the coldest spot in the solar system, is also one of the brightest.** With a temperature of around –400°F, Triton's surface is the coldest place found so far in the solar system. This icy surface also reflects more than 90 percent of the weak sunlight that falls on it, making Triton one of the brightest spots in the solar system.

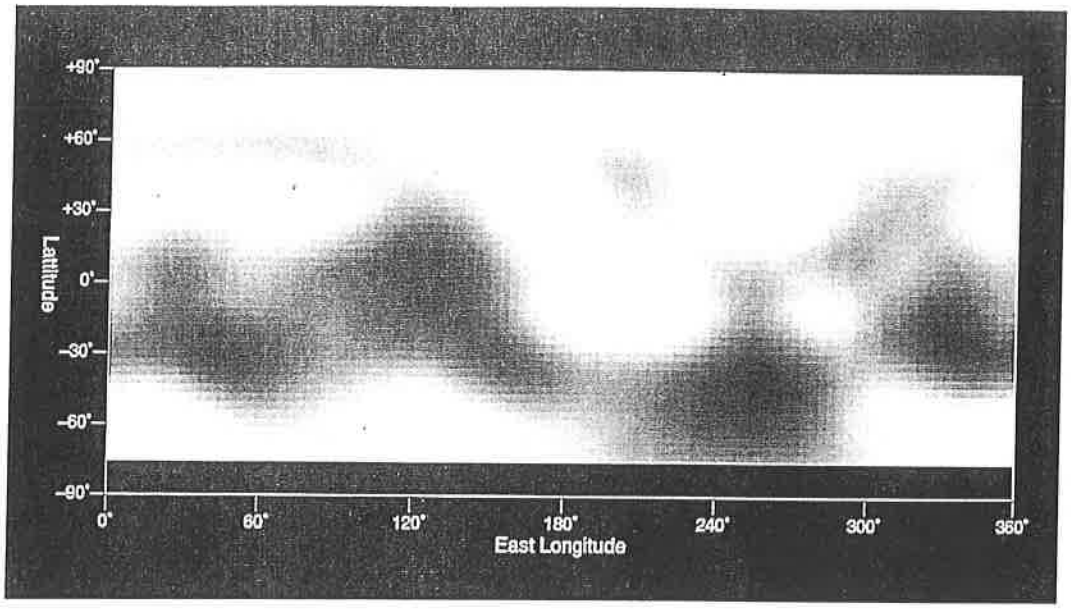
420 **Scientists had to retrain the *Voyager 2* spacecraft to get the images they wanted from Neptune and Triton.** When *Voyager 2* was originally launched from Earth in 1977, its primary targets were Jupiter and Saturn. Scientists knew they could take advantage of a rare planetary configuration to send *Voyager* on to Uranus and Neptune, but they didn't really expect the spacecraft, built in the early 1970s with late-1960s technology, to still be working by the time it got to these outer planets. However, by 1986, as it approached Neptune, *Voyager* was still alive and well. There was a problem to be solved, however, before *Voyager* could send back any useful pictures from Neptune: Light levels at Neptune are only .0025 what they are on Earth because of the great distance of the Sun. To get good pictures, long time exposures had to be taken and cameras turned to track the planet as the spacecraft sped past.



The surface of a large frozen lake on Triton. Similar in appearance to the lunar maria, it marks a place where a basin was flooded with a mixture of water, ammonia, and methane, which then froze in the frigid temperatures. (NASA/JPL)

421 **Fancy shooting was responsible for getting *Voyager 2* to Neptune.** When *Voyager* 2 left Earth, it barely had enough fuel for its extended mission. But scientists took advantage of a rare configuration of the giant planets that wouldn't be repeated for over 170 years and utilized a technique known as *gravitational assists.* Gravitational assists work by bringing a spacecraft past a planet at just the right distance and at just the right angle and letting that planet's gravity redirect and boost the spacecraft on to the next planet.

Voyager was given just the right trajectory as it rounded Jupiter to allow the giant planet's gravity to redirect it so that when *Voyager* crossed the orbit of Saturn, Saturn was there to meet it. Saturn, in turn, performed the same trick to propel *Voyager* on to an encounter—five years and several billion miles later—with Uranus. Uranus did the same, getting *Voyager* to Neptune. All of



A map of light and dark areas on Pluto. Determining the exact nature of these "features" will likely have to wait for a spacecraft to visit Pluto sometime in the twenty-first century. (NASA/STScI)

ture will have to wait for a spacecraft to visit Pluto someday.

425 **While spacecraft have yet to visit Pluto, scientists think that Triton may have given them a sneak preview.** As statistics on Triton began to come in from *Voyager* in 1989, scientists couldn't help but notice some basic similarities between Triton and Pluto. Triton is about 1,700 miles in diameter, while Pluto is a little over 1,400 miles across. The densities of Triton and Pluto are similar (about twice that of water). Furthermore, both worlds average about the same distance from the Sun over significant portions of their orbits. All of this has led some to suggest that if we send a spacecraft to Pluto someday, we might find a world not too different from Triton. Ironically, until *Voyager*'s Triton encounter, scientists had more or less written off Pluto as a pretty dull place. But now that Triton has proven to have such a fascinating and varied landscape with both active geology and weather, Pluto is seen by many as a potentially more interesting place. Several plans to send a small spacecraft to Pluto are on the drawing boards. By the second decade of the twenty-first century, we may get our first close-up glimpse of this distant world.

426 **Naming the planets in order from the Sun sometimes requires you to change your tune.** If you asked most folks who went to school before the 1970s to name the planets in order from the Sun, they would probably answer: "Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and

430 **Nevertheless, some scientists believe that there may be many small icy objects beyond Pluto.** Such objects may be at least tens if not hundreds of miles in diameter and may resemble worlds like Pluto and Charon. Whether you would call these objects *minor planets* (a name now reserved for the asteroids), "icy midgets," or something else may be more a matter of semantics than science. If they exist, Pluto may someday be seen as simply the largest and closest of this different breed of solar system nomad. In 1996, one such object dubbed 1996TL66 was found. It had a diameter of about 300 miles. The discovery of many more will likely follow.