

OUR SOLAR SYSTEM

By Nathan C. Long

The solar system consists of the Sun; the nine planets, more than 130 satellites of the planets, a large number of small bodies (the comets and asteroids), and the interplanetary medium. (There are probably also many more planetary satellites that have not yet been discovered.) The inner solar system contains the Sun, Mercury, Venus, Earth and Mars. The main asteroid belt lies between the orbits of Mars and Jupiter. The planets of the outer solar system are Jupiter, Saturn, Uranus, Neptune and Pluto: The first thing to notice is that the solar system is mostly empty space. The planets are very small compared to the space between them.

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SUN

The Sun is by far the largest object in the solar system. It contains more than 99.8% of the total mass of the Solar System (Jupiter contains most of the rest). It is often said that the Sun is an "ordinary" star. But there are many more smaller stars than larger ones; the Sun is in the top 10% by mass. The median size of stars in our galaxy is probably less than half the mass of the Sun. The Sun is personified in many mythologies: the Greeks called it Helios and the Romans called it Sol. The Sun is, at present, about 70% hydrogen and 28% helium by mass everything else ("metals") amounts to less than 2%. This changes slowly

over time as the Sun converts hydrogen to helium in its core. The differential rotation extends considerably down into the interior of the Sun but the core of the Sun rotates as a solid body. Conditions at the Sun's core (approximately the inner 25% of its radius) are extreme. The temperature is 15.6 million Kelvin and the pressure is 250 billion atmospheres. At the center of the core the Sun's density is more than 150 times that of tap water.

MERCURY

Mercury is the closest planet to the Sun and the eighth largest. Mercury is slightly smaller in diameter than the moons Ganymede and Titan but more than twice as massive. In Search of Planet Vulcan An

account of the non-discovery of a planet interior to Mercury. A much more interesting tale than you might imagine. In Roman mythology Mercury is the god of commerce, travel and thievery, the Roman counterpart of the Greek god Hermes, the messenger of the Gods. The planet probably received this name because it moves so quickly across the sky.

Mercury has been known since at least the time of the Sumerians (3rd millennium BC). It was given two names by the Greeks: Apollo for its apparition as a morning star and Hermes as an evening star.

knew, however, that the two names referred to the same body. Heraclitus even believed that Mercury and Venus orbit the Sun, not the Earth. Since it is closer to the Sun than the Earth, the illumination of Mercury's disk varies when viewed with a telescope from our perspective. Galileo's telescope was too small to see Mercury's phases but he did see the phases of Venus.

Mercury has been visited by only one spacecraft, Mariner 10. It flew by three times in 1974 and 1975. Only 45% of the surface was mapped (and, unfortunately, it is too close to the Sun to be safely imaged by HST). A new discovery-class mission to Mercury, MESSENGER was launched by NASA in 2004 and will orbit Mercury starting in 2011 after several flybys.

VENUS

Venus (Greek: Aphrodite; Babylonian: Ishtar) is the goddess of love and beauty. The planet is so named probably because it is the brightest of the planets known to the ancients. (With a few exceptions, the surface features on Venus are named for female figures.) Venus has been known since prehistoric times. It is the brightest object in the sky except for the Sun and the Moon. Like Mercury, it was popularly thought to be two separate bodies: Eosphorus as the morning star and Hesperus as the evening star, but the Greek astronomers knew better. (Venus's apparition as the morning star is also sometimes called Lucifer.)

Since Venus is an inferior planet, it shows phases when viewed with a telescope from the perspective of Earth. Galileo's observation of this phenomenon was important evidence in favor of Copernicus's heliocentric theory of the solar system.

Venus in visible light from Galileo The pressure of Venus' atmosphere at the surface is 90 atmospheres (about the same as the pressure at a depth of 1 km in Earth's oceans). It is composed mostly of carbon dioxide. There are several layers of clouds many kilometers thick composed of sulfuric acid. These clouds completely obscure our view of the surface. This dense atmosphere produces a run-away greenhouse effect that raises Venus' surface temperature by about 400 degrees to over 740 K (hot enough to melt lead). Venus' surface is actually hotter than Mercury's despite being nearly twice as far from the Sun.



EARTH

Earth is the third planet from the Sun and the fifth largest: Earth is the only planet whose English name does not derive from Greek/Roman mythology. The name derives from Old English and Germanic.

There are, of course, hundreds of other names for the planet in other languages. In Roman Mythology, the goddess of the Earth was Tellus - the fertile soil (Greek: Gaia, terra mater - Mother Earth). It was not until the time of Copernicus (the sixteenth century) that it was understood that the Earth is just another planet. Mir space station and Earth's limb Earth, of course, can be studied without the aid of spacecraft. Nevertheless it was not until the twentieth century that we had maps of the entire planet. Pictures of the planet taken from space are of considerable importance; for example, they are an enormous help

in weather prediction and especially in tracking and predicting hurricanes. And they are extraordinarily beautiful. The Earth is divided into several layers which have distinct chemical and seismic properties.

Unlike the other terrestrial planets, Earth's crust is divided into several separate solid plates which float around independently on top of the hot mantle below. The theory that describes this is known as plate tectonics. It is characterized by two major processes: spreading and subduction. Spreading occurs when two plates move away from each other and new crust is created by upwelling magma from below. Subduction occurs when two plates collide and the edge of one dives beneath the other and ends up being destroyed in the mantle. There is also transverse motion at some plate boundaries (i.e. the San Andreas Fault in California) and collisions between continental plates (i.e. India/Eurasia). There are (at present) eight major plates:

MARS

Mars (Greek: Ares) is the god of War. The planet probably got this name due to its red color; Mars is sometimes referred to as the Red Planet. (An interesting side note: the Roman god Mars was a god of agriculture before becoming associated with the Greek Ares; those in favor of colonizing and terraforming Mars may prefer this symbolism.) The name of the month March derives from Mars.

Mars has been known since prehistoric times. Of course, it has been extensively studied with ground-based observatories. But even very large telescopes find Mars a difficult target, it's just too

small. It is still a favorite of science fiction writers as the most favorable place in the Solar System for human habitation. But the famous "canals" "seen" by Lowell and others were, unfortunately, just as imaginary as Barsoomian princesses.

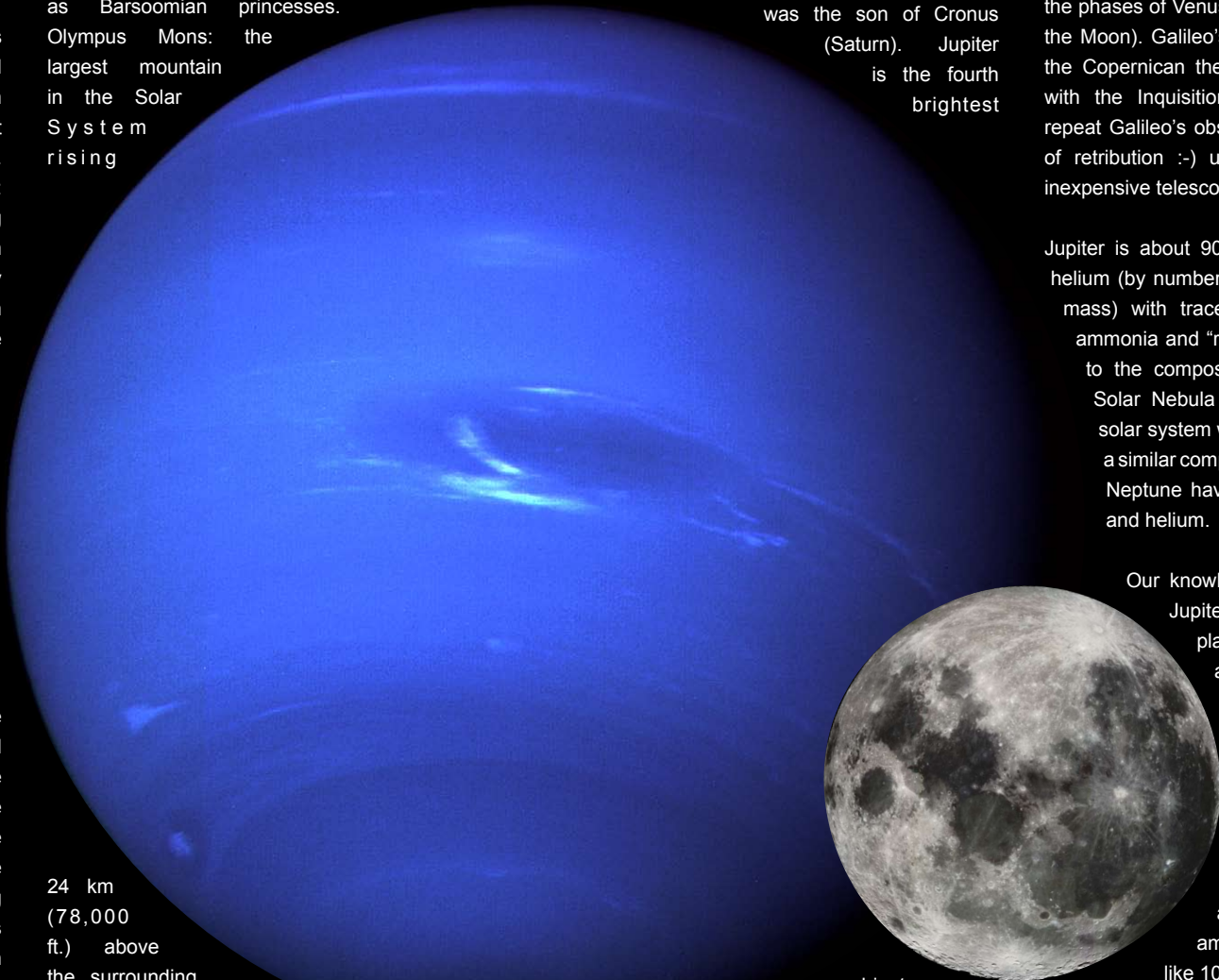
Olympus Mons: the largest mountain in the Solar System rising

24 km (78,000 ft.) above the surrounding plain. Its base is more than 500 km in diameter and is rimmed by a cliff 6 km high.

Tharsis: a huge bulge on the Martian surface that is about 4000 km across and 10 km high. Much of the Martian surface is very old and cratered, but there are also much younger rift valleys, ridges, hills, plains, cayons, and mountains.

JUPITER

Jupiter (a.k.a. Jove; Greek Zeus) was the King of the Gods, the ruler of Olympus and the patron of the Roman state. Zeus was the son of Cronus (Saturn). Jupiter is the fourth brightest



object in the sky (after the Sun, the Moon and Venus). It has been known since

prehistoric times as a bright "wandering star". But in 1610 when Galileo first pointed a telescope at the sky he discovered Jupiter's four large moons Io, Europa, Ganymede and Callisto (now known as the Galilean moons) and recorded their motions back and forth around Jupiter. This was the first discovery

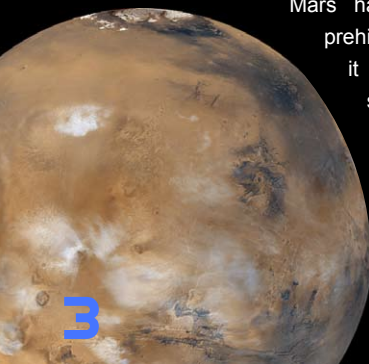
of a center of motion not apparently centered on the Earth. It was a major point in favor of Copernicus's heliocentric theory of the motions of the planets (along with other new evidence from his telescope: the phases of Venus and the mountains on the Moon). Galileo's outspoken support of the Copernican theory got him in trouble with the Inquisition. Today anyone can repeat Galileo's observations (without fear of retribution :-)) using binoculars or an inexpensive telescope.

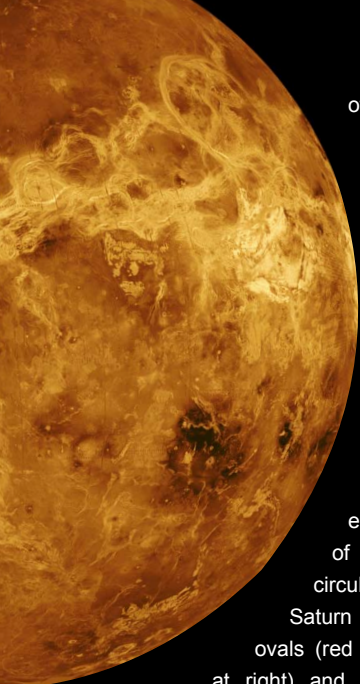
Jupiter is about 90% hydrogen and 10% helium (by numbers of atoms, 75/25% by mass) with traces of methane, water, ammonia and "rock". This is very close to the composition of the primordial Solar Nebula from which the entire solar system was formed. Saturn has a similar composition, but Uranus and Neptune have much less hydrogen and helium.

Our knowledge of the interior of Jupiter (and the other gas planets) is highly indirect and likely to remain so for some time. (The data from Galileo's atmospheric probe goes down only about 150 km below the cloud tops.) Jupiter probably has a core of rocky material amounting to something like 10 to 15 Earth-masses.

SATURN

Saturn is the sixth planet from the Sun and the second largest. Summarizes what we have learned from interplanetary explorations in the last 25 years. In Roman mythology, Saturn is the god of agriculture. The associated Greek god, Cronus, was the son of Uranus and Gaia and the father





of Zeus (Jupiter). Saturn is the root of the English word "Saturday"

The bands that are so prominent on Jupiter are much fainter on Saturn. They are also much wider near the equator. Details in the cloud tops are invisible from Earth so it was not until the Voyager encounters that any detail of Saturn's atmospheric circulation could be studied.

Saturn also exhibits long-lived ovals (red spot at center of image at right) and other features common on Jupiter. In 1990, HST observed an enormous white cloud near Saturn's equator which was not present during the Voyager encounters; in 1994 another, smaller storm was observed (left).

Early observations of Saturn were complicated by the fact that the Earth passes through the plane of Saturn's rings every few years as Saturn moves in its orbit. A low resolution image of Saturn therefore changes drastically. Saturn has been known since prehistoric times. Galileo was the first to observe it with a telescope in 1610; he noted its odd appearance but was confused by it. It was not until 1659 that Christiaan Huygens correctly inferred the geometry of the rings. Saturn's rings remained unique in the known solar system until 1977 when very faint rings were discovered around Uranus (and shortly thereafter around Jupiter and Neptune).

URANUS

Uranus is the seventh planet from the Sun and the third largest (by diameter). Uranus is larger in diameter but smaller in mass than Neptune. Uranus is the ancient Greek

deity of the Heavens, the earliest supreme god. Uranus was the son and mate of Gaia the father of Cronus (Saturn) and of the Cyclopes and Titans (predecessors of the Olympian gods). Uranus, the first planet discovered in modern times, was discovered by William Herschel while systematically searching the sky with his telescope on March 13, 1781.

Herschel named it "the Georgium Sidus" (the Georgian Planet) in honor of his patron, the infamous (to Americans) King George III of England; others called it "Herschel". The name "Uranus" was first proposed by Bode in conformity with the other planetary names from classical mythology but didn't come into common use until 1850. Most of the planets spin on an axis nearly perpendicular to the plane of the ecliptic but Uranus' axis is almost parallel to the ecliptic. At the time of Voyager 2's passage, Uranus' south pole was pointed almost directly at the Sun. This results in the odd fact that Uranus' polar regions receive more energy input from the Sun than do its equatorial regions. Uranus is nevertheless hotter at its equator than at its poles. The mechanism underlying this is unknown.

NEPTUNE

Neptune is the eighth planet from the Sun and the fourth largest. Neptune is smaller in diameter but larger in mass than Uranus. This road map of the solar system contains lots of maps and data as well as photos. In Roman mythology Neptune was the god of the Sea. Neptune's composition is probably similar to Uranus': various "ices" and rock with about 15% hydrogen and a little helium. Like Uranus, but unlike Jupiter and Saturn, it may not have a distinct internal layering but rather to be more or less uniform in composition. But there is most likely a small core of rocky material. Its atmosphere is mostly hydrogen and helium with a small amount of methane.

PLUTO

Pluto is the farthest planet from the Sun (usually) and by far the smallest. Pluto is smaller than seven of the solar system's moons (the Moon, Io, Europa, Ganymede, Callisto, Titan and Triton). In Roman mythology, Pluto (Greek: Hades) is the god of the underworld. The planet received this name (after many other suggestions) perhaps because it's so far from the Sun that it is in perpetual darkness and perhaps because "PL" are the initials of Percival Lowell.

Pluto was discovered in 1930 by a fortunate accident. Calculations which later turned out to be in error had predicted a planet beyond Neptune, based on the motions of Uranus and Neptune. Not knowing of the error, Clyde W. Tombaugh at Lowell Observatory in Arizona did a very careful sky survey which turned up a small planet known as Pluto anyway.

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COMETS

Unlike the other small bodies in the solar system, comets have been known since antiquity. There are Chinese records of Comet Halley going back to at least 240 BC. The famous Bayeux Tapestry, which commemorates the Norman Conquest of England in 1066, depicts an apparition of Comet Halley.

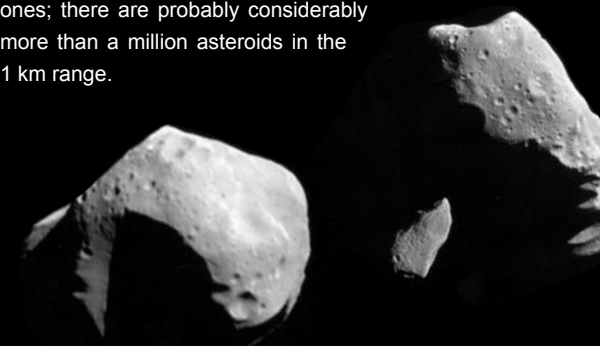
As of 1995, 878 comets have been cataloged and their orbits at least roughly calculated. Of these 184 are periodic comets (orbital periods less than 200 years); some of the remainder are no doubt periodic as well, but their orbits have not been determined with sufficient accuracy to tell for sure.

Comets are sometimes called dirty snowballs or "icy mudballs". They are a mixture of ices and dust that for some reason didn't get incorporated into planets when the solar system was formed. This makes them very interesting as samples of the early history of the solar system.

ASTEROIDS

On the first day of January 1801, Giuseppe Piazzi discovered an object which he first thought was a new comet. But after its orbit was better determined it was clear that it was not a comet but more like a small planet. Piazzi named it Ceres, after the Sicilian goddess of grain. Three other small bodies were discovered in the next few years. By the end of the 19th century there were several hundred. Several hundred thousand asteroids have been discovered and given provisional designations so far. Thousands more are discovered each year. There are undoubtedly hundreds of thousands more

that are too small to be seen from the Earth. There are 26 known asteroids larger than 200 km in diameter. Our census of the largest ones is now fairly complete: we probably know 99% of the asteroids larger than 100 km in diameter. Of those in the 10 to 100 km range we have cataloged about half. But we know very few of the smaller ones; there are probably considerably more than a million asteroids in the 1 km range.



Sources:

<http://www.nineplanets.org>

<http://solarsystem.nasa.gov/planets>