Astronomy

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Small 239

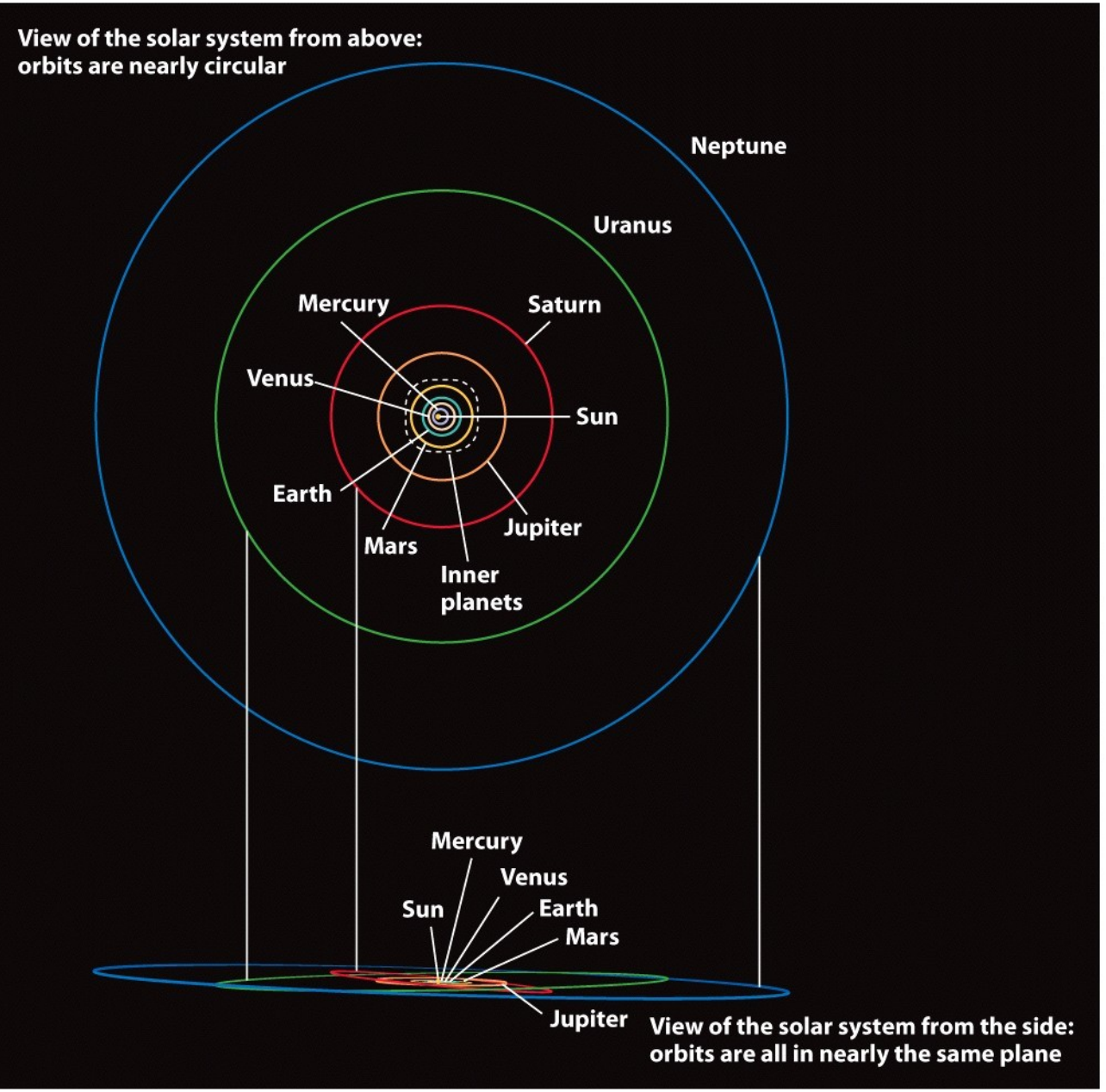
Office hours:
MTWR 10-11am

Planetology I

- Terrestrial and Jovian planets
- Similarities/differences between planetary satellites
- Surface and atmosphere compositions
- Why planets have atmospheres
- Small bodies that orbit the Sun
- Craters reveal the age of a surface
- Magnetic fields and fluid interiors
- Diversity of the solar system

http:// physics.wm.edu/~hancock/171/

Two Types of Planets



The planets that orbit the Sun can be divided into two groups. The inner (or terrestrial) planets orbit close to the sun (< 2 AU). The outer (or Jovian) planets orbit the Sun from 5 AU out to 30 AU

The orbits are all nearly circular (e = .206 for Mercury) and are nearly in the same plane

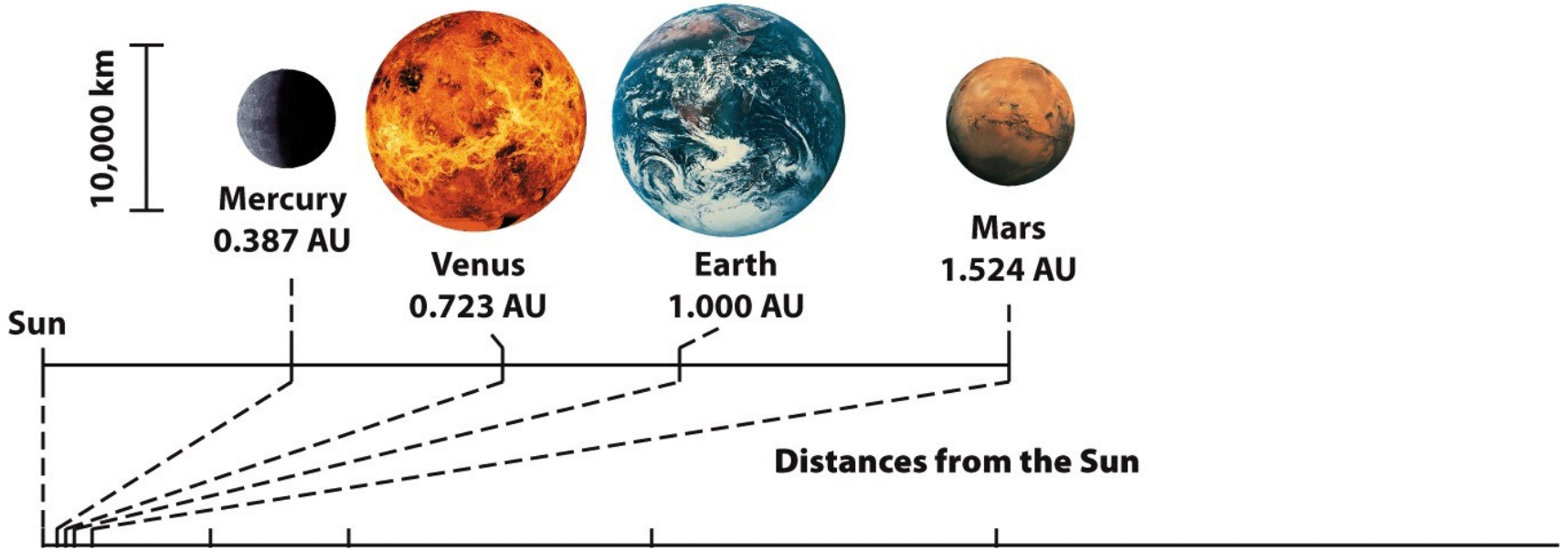
Figure 7-1
Universe, Tenth Edition

The Terrestrial Planets

TABLE 7-1 Characteristics of the Planets

	The Inner (Terrestrial) Planets			
	Mercury	**Venus**	**Earth**	**Mars**
Average distance from the Sun (10^6 km)	57.9	108.2	149.6	227.9
Average distance from the Sun (AU)	0.387	0.723	1.000	1.524
Orbital period (years)	0.241	0.615	1.000	1.88
Orbital eccentricity	0.206	0.007	0.017	0.093
Inclination of orbit to the ecliptic	7.00°	3.39°	0.00°	1.85°
Equatorial diameter (km)	4880	12,104	12,756	6794
Equatorial diameter (Earth = 1)	0.383	0.949	1.000	0.533
Mass (kg)	3.302×10^{23}	4.868×10^{24}	5.974×10^{24}	6.418×10^{23}
Mass (Earth = 1)	0.0553	0.8150	1.0000	0.1074
Average density (kg/m3)	5430	5243	5515	3934

Table 7-1 pa
Universe, Ten



The Jovian Planets

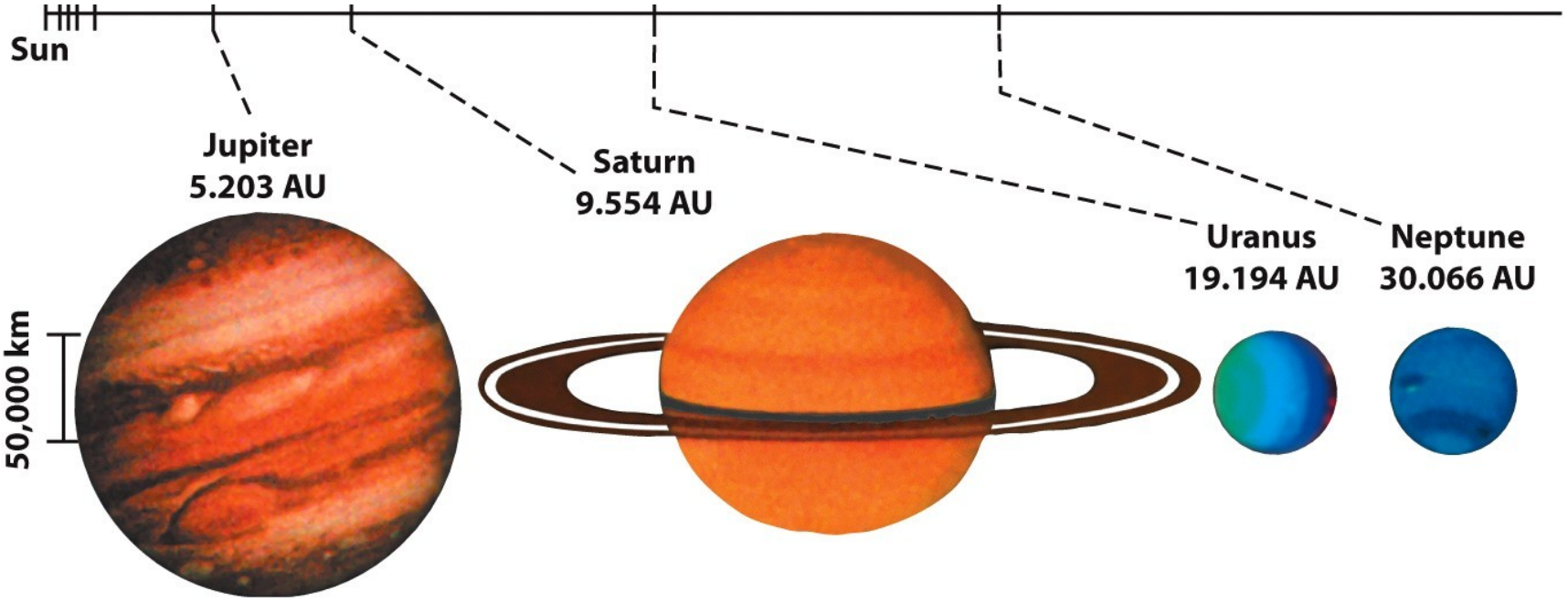
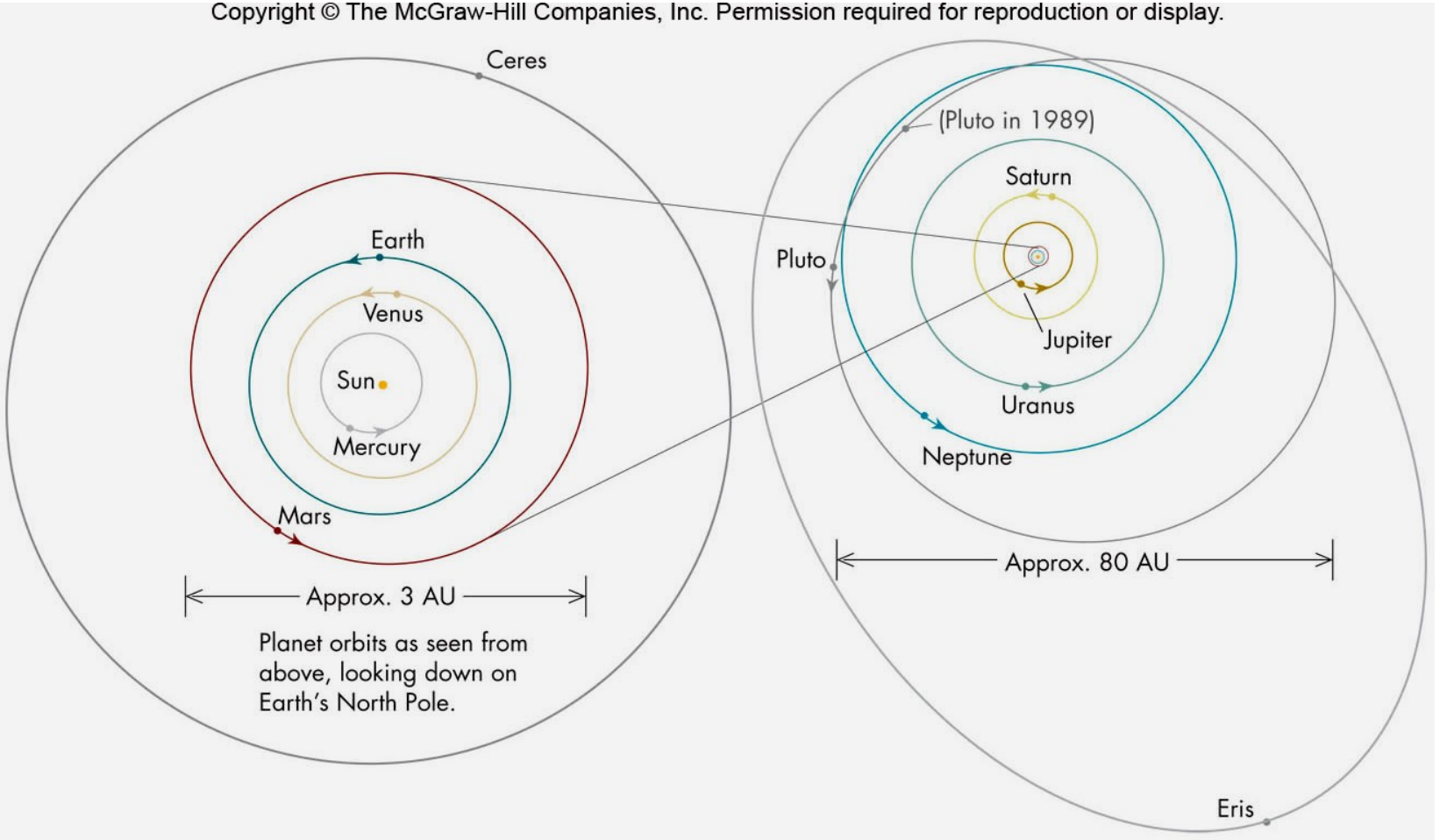


Table 7-1 figure

TABLE 7-1 Characteristics of the Planets

	The Outer (Jovian) Planets			
	Jupiter	**Saturn**	**Uranus**	**Neptune**
Average distance from the Sun (10^6 km)	778.3	1429	2871	4498
Average distance from the Sun (AU)	5.203	9.554	19.194	30.066
Orbital period (years)	11.86	29.46	84.10	164.86
Orbital eccentricity	0.048	0.053	0.043	0.010
Inclination of orbit to the ecliptic	1.30°	2.48°	0.77°	1.77°
Equatorial diameter (km)	142,984	120,536	51,118	49,528
Equatorial diameter (Earth = 1)	11.209	9.449	4.007	3.883
Mass (kg)	1.899×10^{27}	5.685×10^{26}	8.682×10^{25}	1.024×10^{26}
Mass (Earth = 1)	317.8	95.16	14.53	17.15
Average density (kg/m^3)	1326	687	1318	1638

The Direction of Planet orbits



- All of the planets travel counterclockwise around the Sun (looking down from above the Earth's north pole)

Physical Characteristic of the Planets

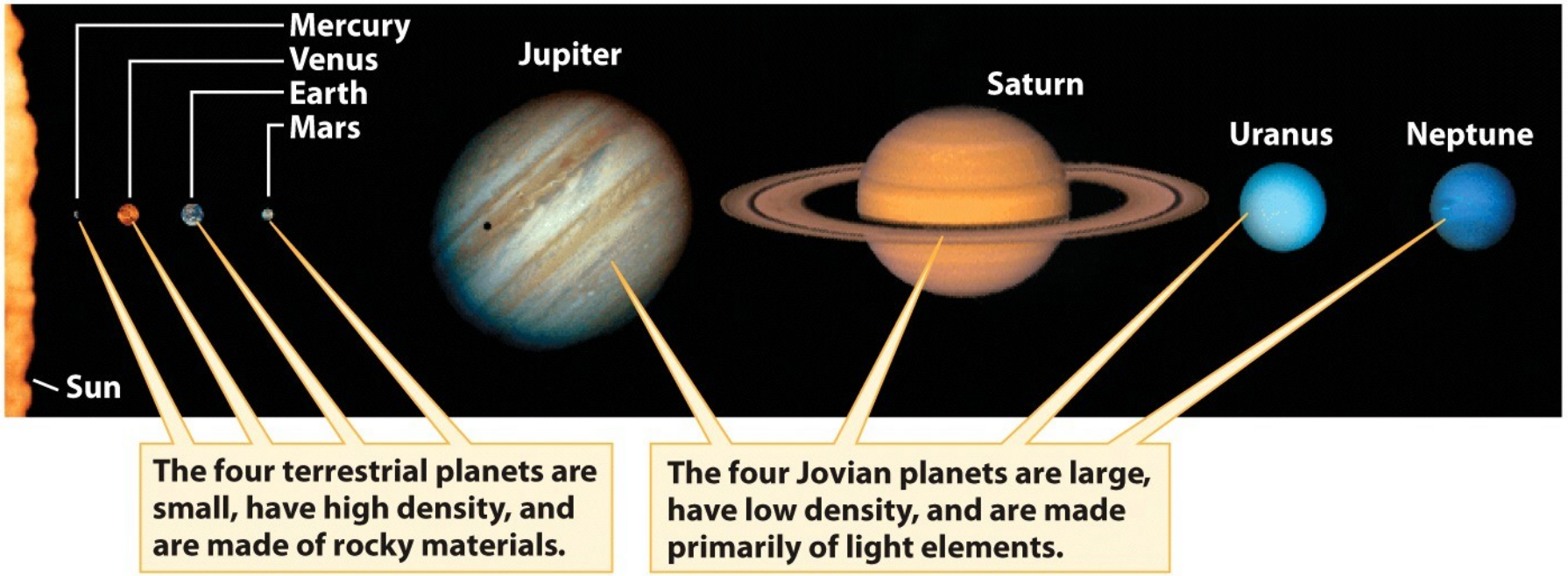


Figure 7-2
Universe, Tenth Edition
Calvin J. Hamilton and NASA/JPL

The terrestrial planets are small, rocky and have a high density. Their surfaces are cratered. Mostly heavy elements like iron, silicon, oxygen etc.

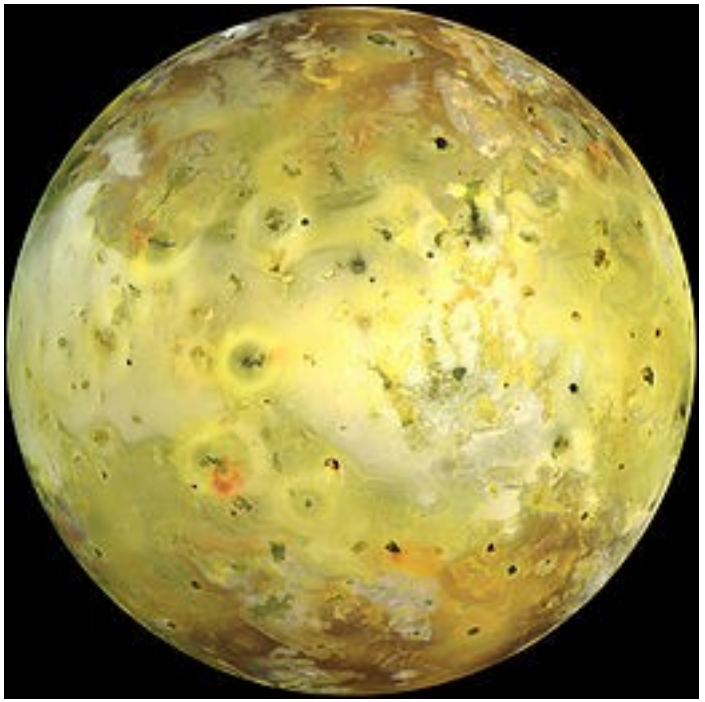
The Jovian planets are large and have a low density. They contain primarily light elements (hydrogen and helium). They have no 'surface'

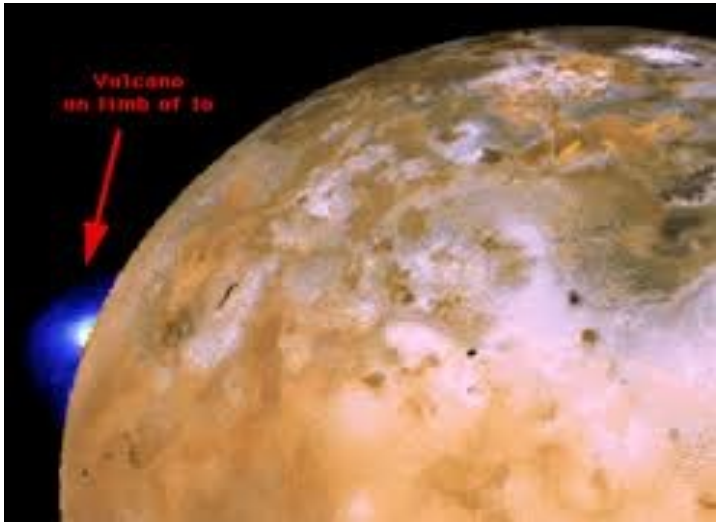
Large Satellites (Moons) of the Planets

Table 7-2 figure
Universe, Tenth Edition
NASA/JPL/Space Science Institute

There are at least 179 moons of the planets. Mercury and Venus have no moons. The Earth has one especially large moon for a terrestrial planet. Mars has two small moons. Jupiter has four large moons (Io, Europa, Ganymede and Callisto). Saturn has one large moon (Titan) and Neptune has one large moon (Triton). The various large moons have solid surfaces and vary greatly in the composition and activity.

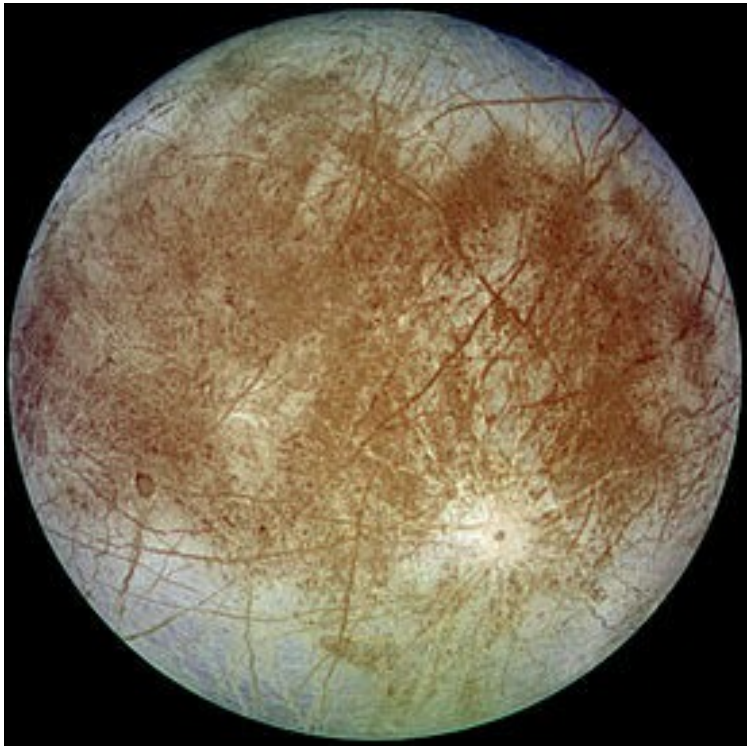
Different Big Moons - Io





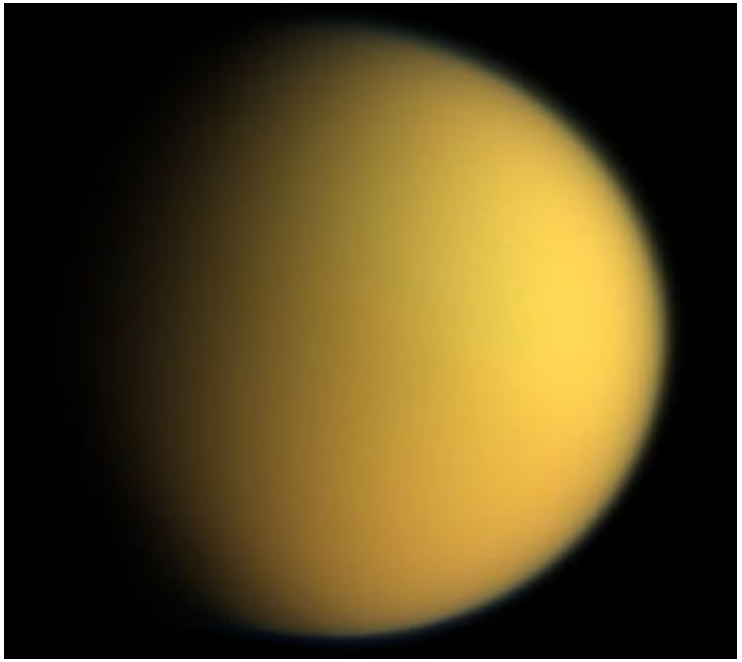
Io is a moon of Jupiter
It is the innermost moon to Jupiter. It surface is coated with sulfur and sulfur compounds. There are active sulfur volcanoes on Io driven by tidal forces.

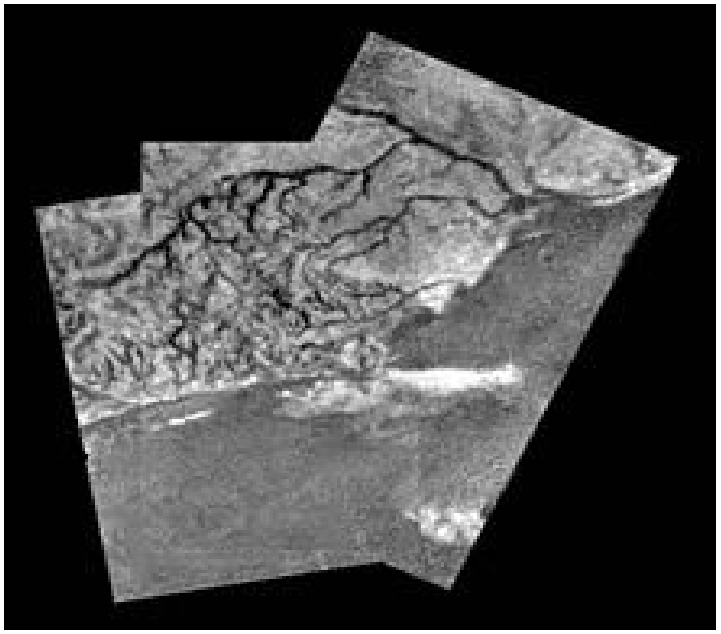
Different Big Moons - Europa



Europa is the smallest of the Galilean moons of Jupiter. Its surface is mainly ice and some rock. There are large networks of cracks running over its surface. Europa has almost no atmosphere.

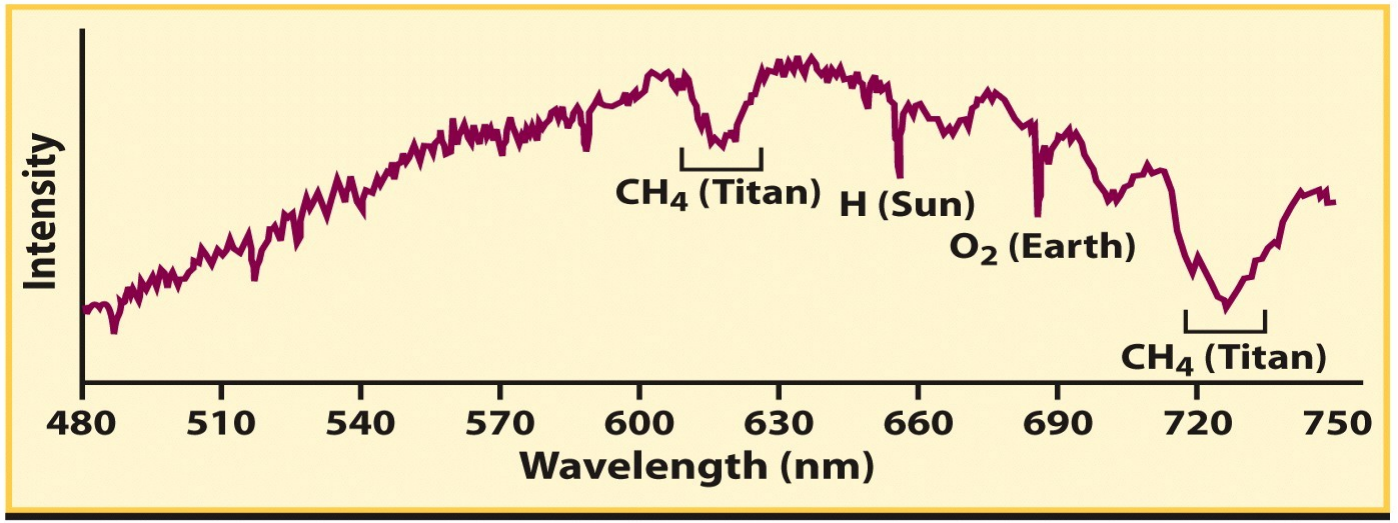
Different Big Moons - Titan



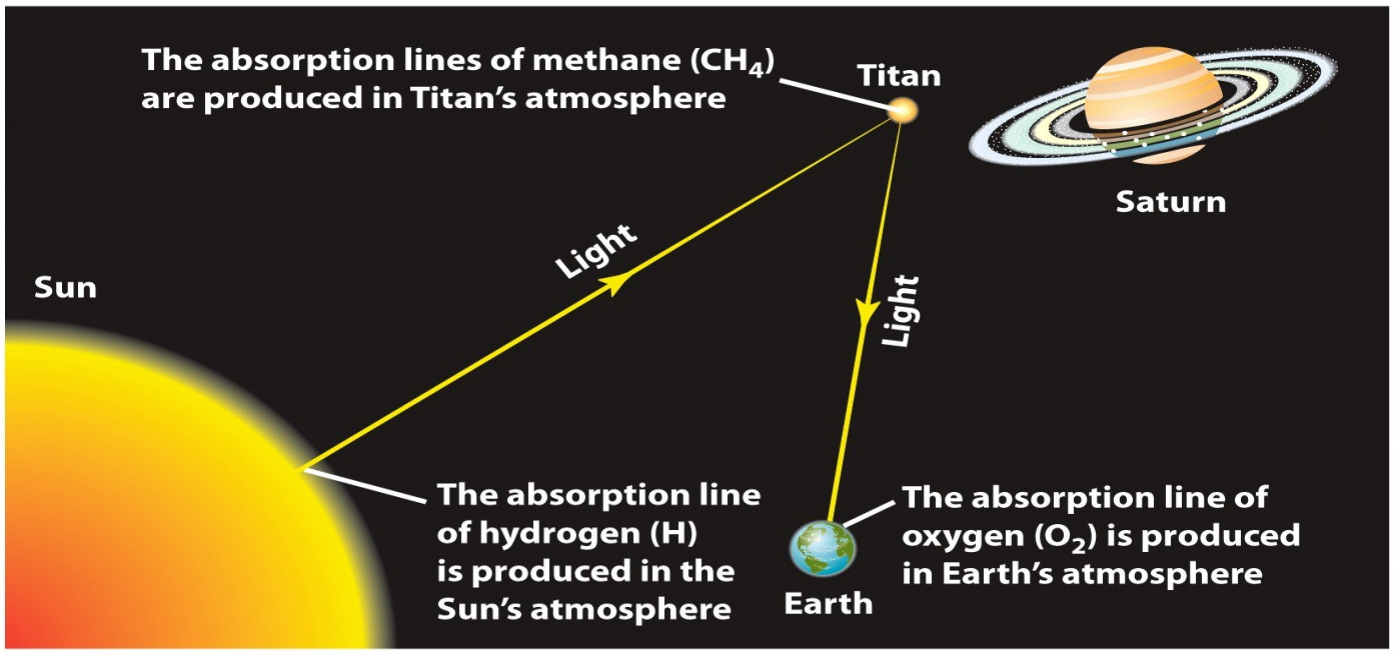


Titan is the largest largest moon of Saturn. Its atmosphere is mainly nitrogen and methane. The Huygens lander send back pictures of rivers and lakes of what is probably liquid methane.

Spectroscopy of Planets and Moon



The spectrum of sunlight reflected from Titan



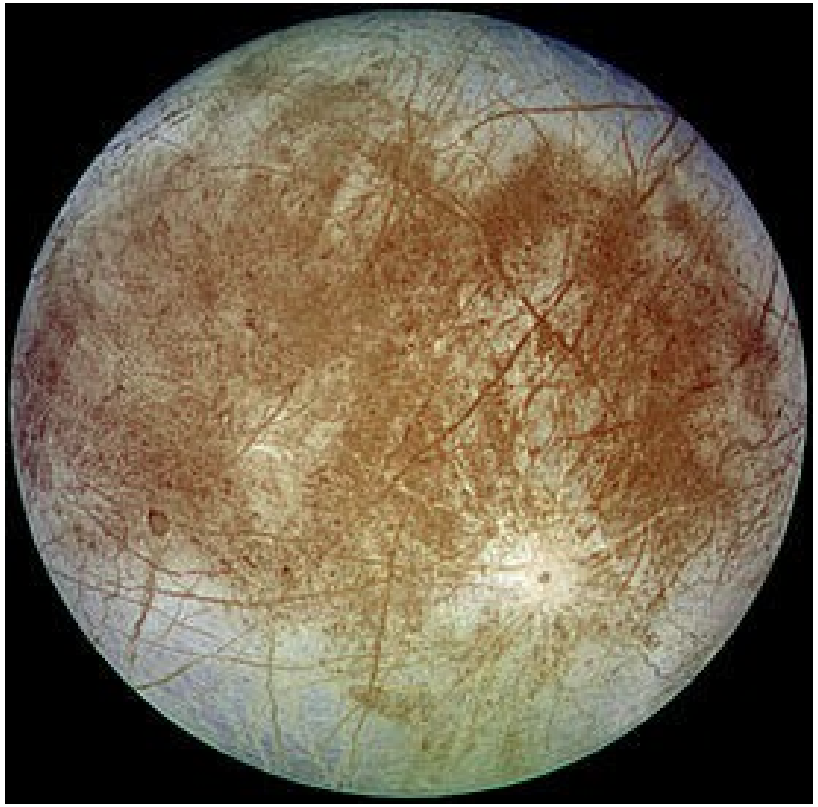
Interpreting Titan's spectrum

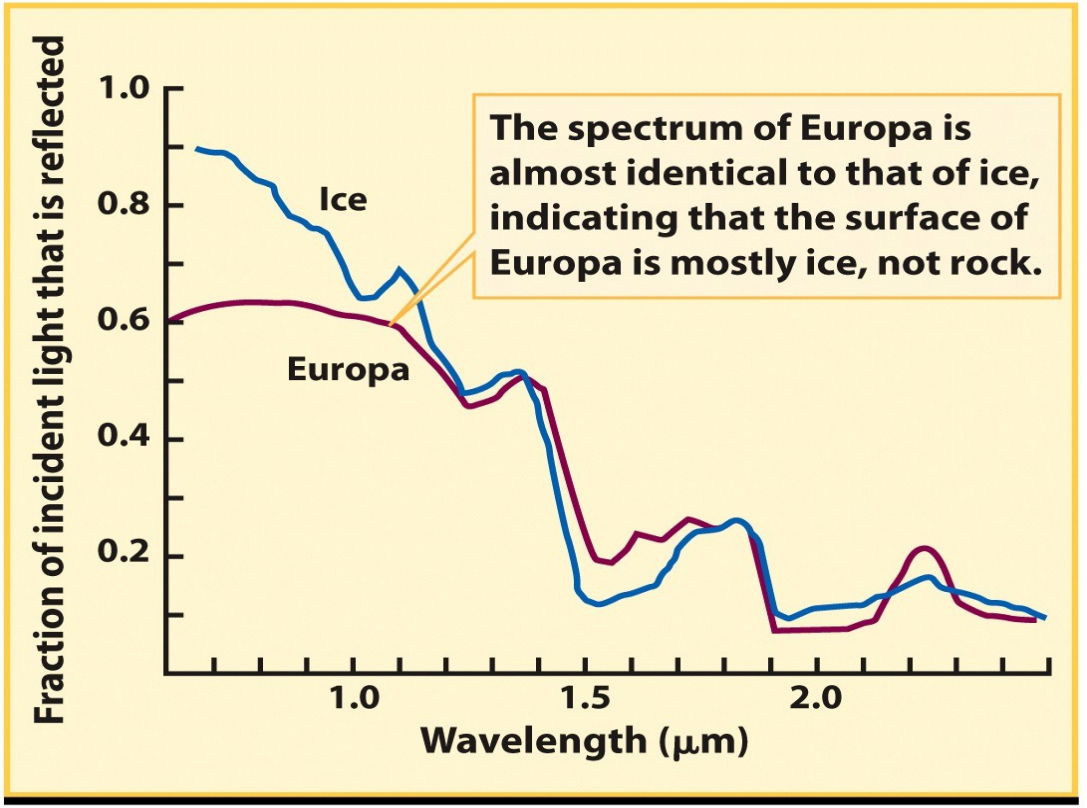
Figure 7-3c
Universe, Tenth Edition

Absorption spectra using reflected sunlight show the composition of the atmosphere or surface of a moon or planet.

The O_2 absorption line is the Earth's atomosphere.

Spectroscopy of Planets and Moon



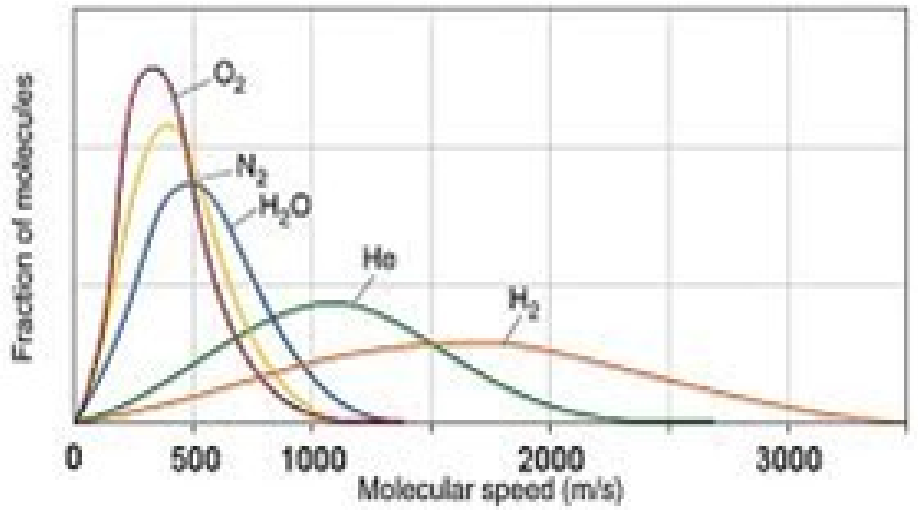


The spectum of light reflected from Europa

Figure 7-4b
Universe, Tenth Edition

Europa's cracked surface is mainly ice

Why Planets and Moon have Atmospheres



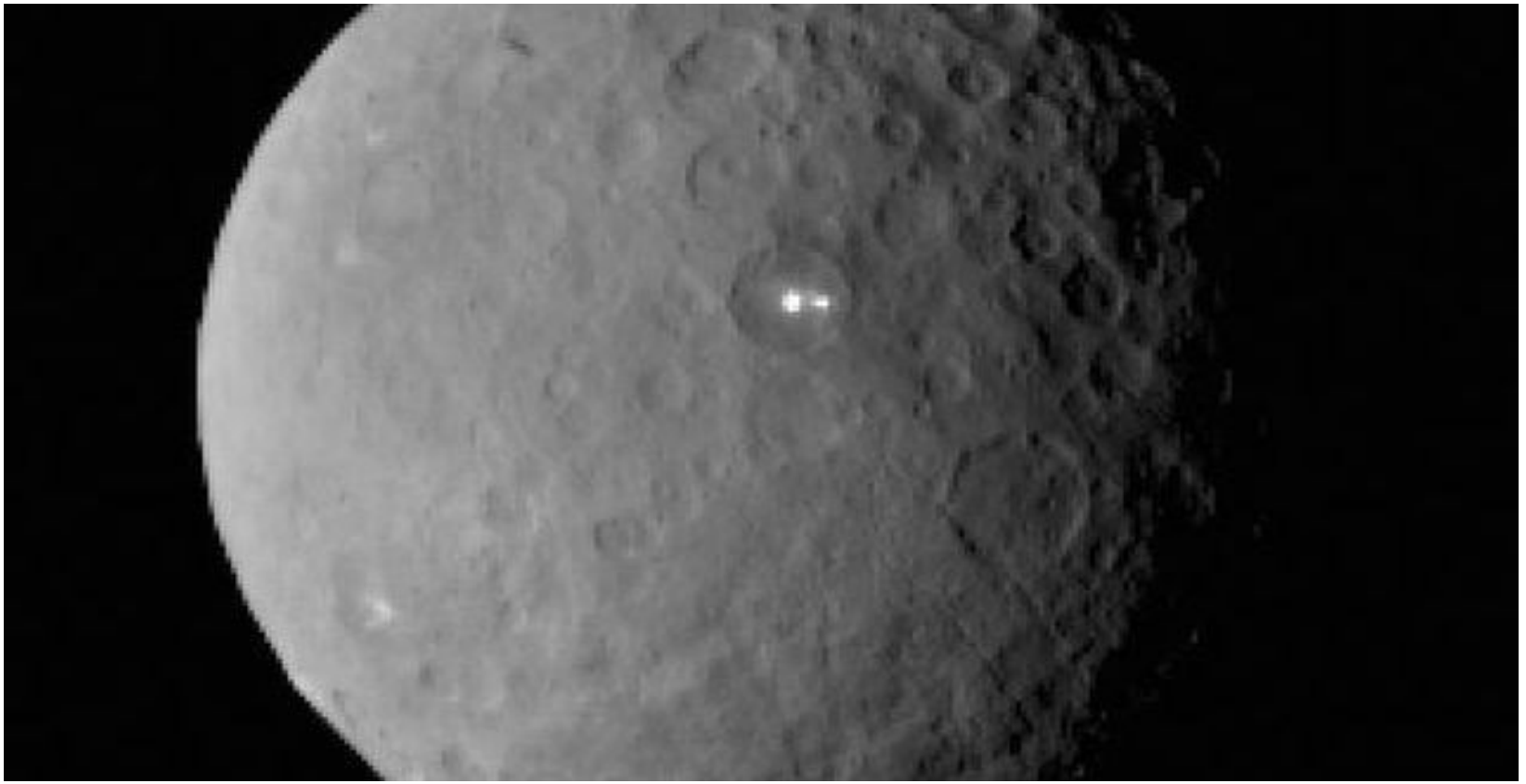
Planets have atmospheres because of the type and temperature of the gases and the escape velocity from the planet or moon. The velocity of a gas molecule depends on its mass according to the Maxwell-Boltzmann distribution. The distribution has a a very long tail. Heavier molecules like O_2, H_2O, N_2 have less of a tail than He and H_2. On Earth the H_2 and He in the tail of the speed distribution can reach escape velocity of 11.2 km/s. Over time these elements leak out of the atmosphere. On the Jovian planets the escape velocity is too high for the H_2 or He to escape. For example, escape velocity of Jupiter is 59.5 km/s

Asteroids

Figure 7-7
Universe, Tenth Edition
NEAR Project, NLR, JHUAPL, Goddard SVS, NASA

Asteroids are objects that orbit inside the orbit of Jupiter. They range in side from pebble size to the largest which is Ceres with a diameter of 900 km. There are estimated to be hundreds of thousand asteroids. Most asteroids orbit between Mars and Jupiter in the asteroid belt. This images is of Eros which is about 33 km x 13 km

Asteroids



The large asteroid Ceres (or minor planet) orbits between Mars and Jupiter. The Dawn spacecraft has been in orbit around Ceres since March of 2015. Note the heavily cratered surface. The bright spots are not currently understood. It contains ~1/3 of the mass of the entire asteroid belt

Trans-Neptunian Objects

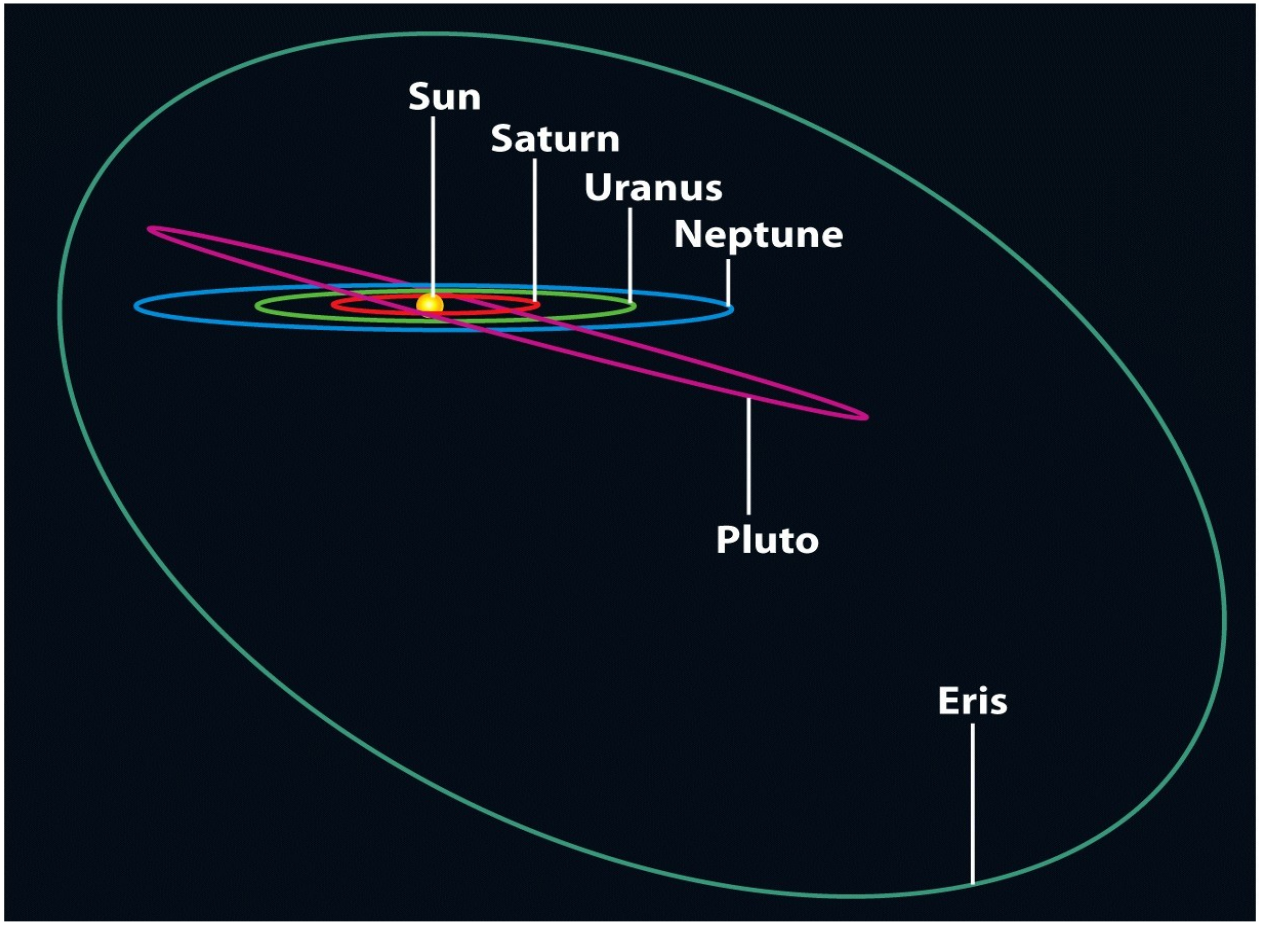


Figure 7-8
Universe, Tenth Edition

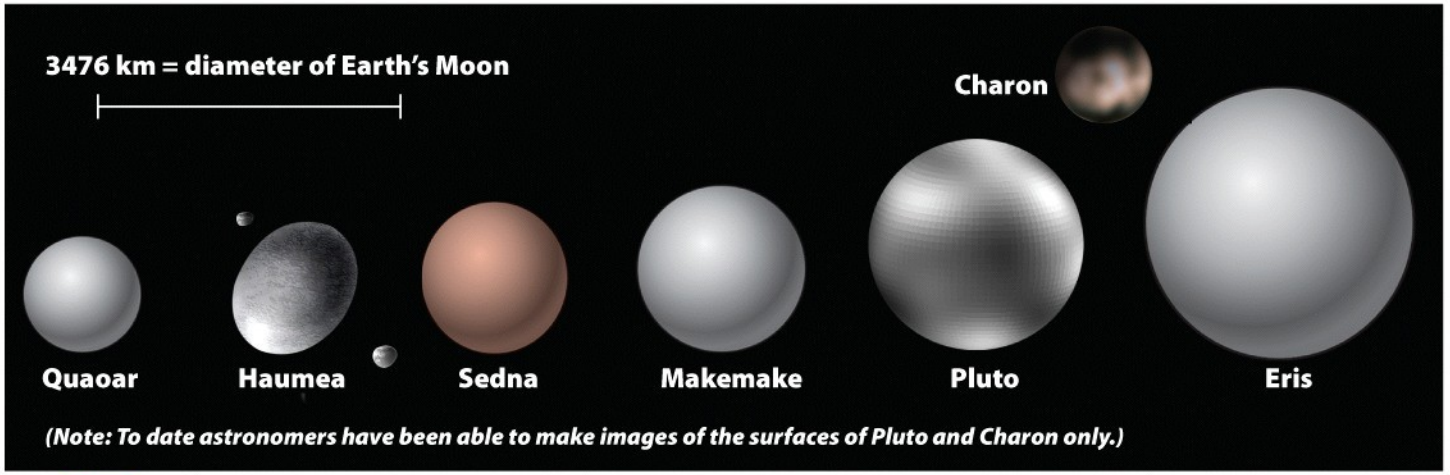
Trans-Neptunian objects orbit outside the orbit of Neptune. The orbits are typically steeply inclined with respect to the ecliptic plane and have large eccentricities. The are made of ice and rock.

Most trans-neptunian objects orbit in a region outside the orbit of Neptune known as the Kuiper belt.

Large Trans-Neptunian Objects

TABLE 7-4 Seven Large Trans-Neptunian Objects

	Quaoar	Haumea	Sedna	Makemake	Pluto	Charon (satellite of Pluto)	Eris
Average distance from the Sun (AU)	43.54	43.34	489	45.71	39.54	39.54	67.67
Orbital period (years)	287	285	10,800	309	248.6	248.6	557
Orbital eccentricity	0.035	0.189	0.844	0.155	0.250	0.250	0.442
Inclination of orbit to the ecliptic	8.0°	28.2°	11.9°	29.0°	17.15°	17.15°	44.2°
Approximate diameter (km)	1250	1500	1600	1800	2274	1190	2900



R I V U X G

(Haumea: A. Field [STScI]/NASA; Charon: Lanthanum-138; all others: Alan Stern [Southwest Research Institute]/Marc Buie [Lowell Observatory]/ NASA/ESA)

Table 7-4
Universe, Tenth Edition

Comets

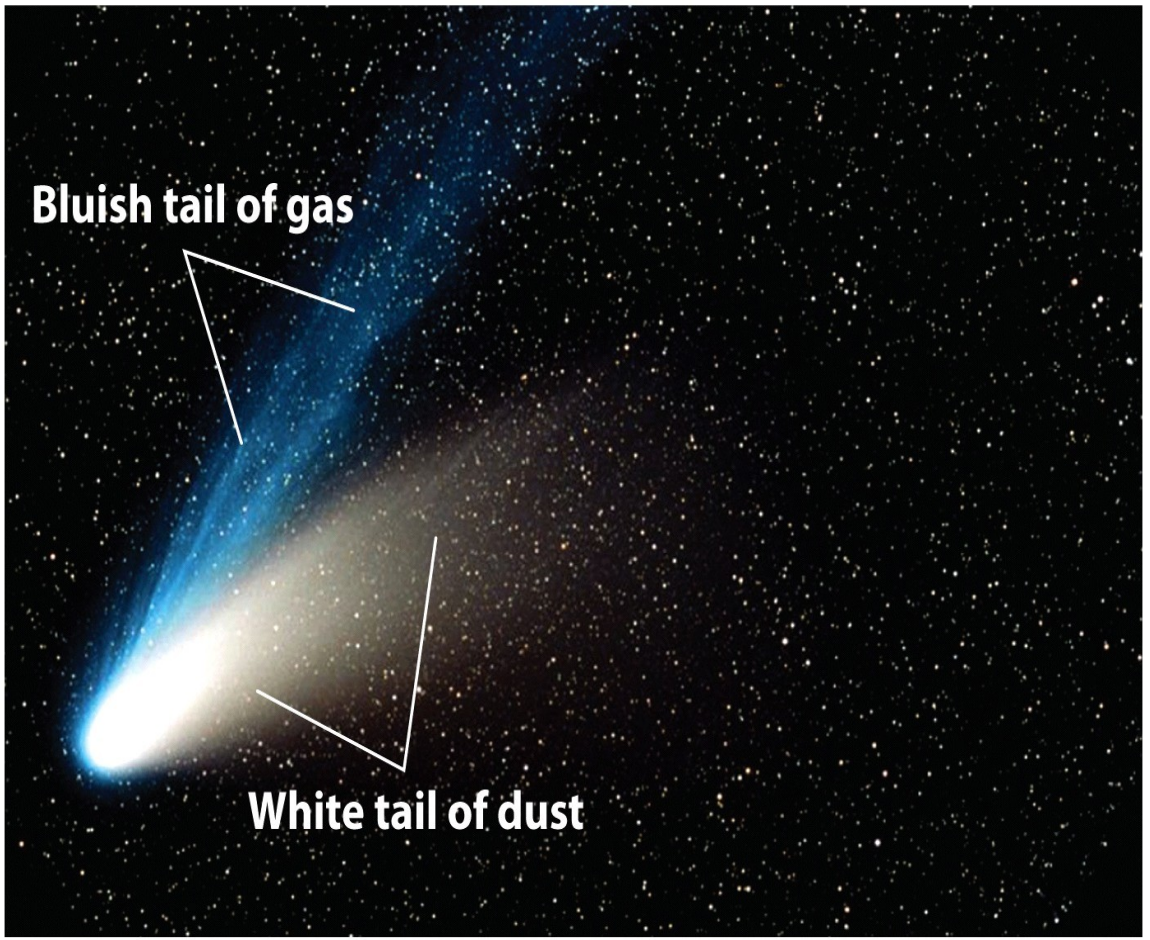
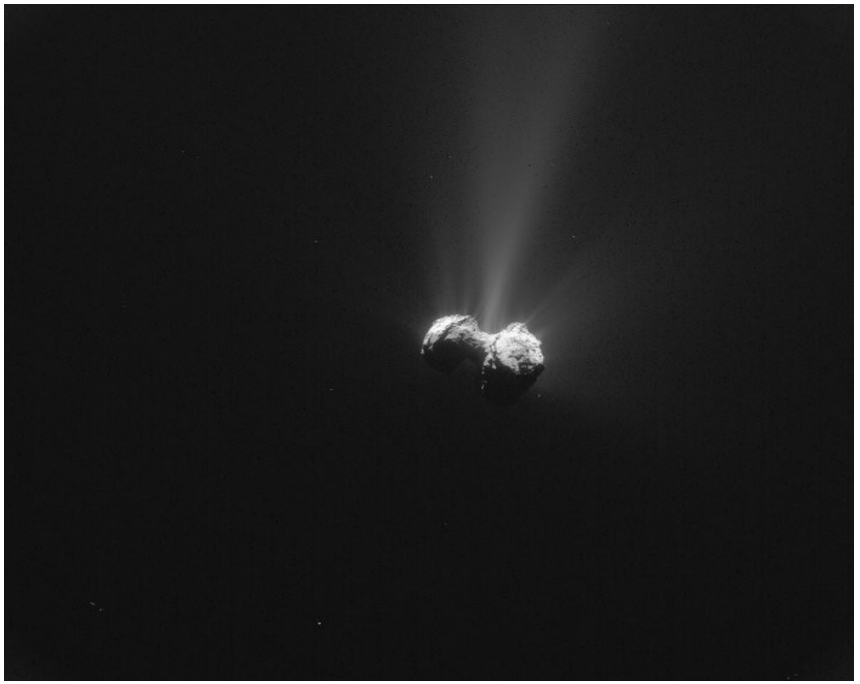


Figure 7-9
Universe, Tenth Edition
Agencia el Universal/AP Images

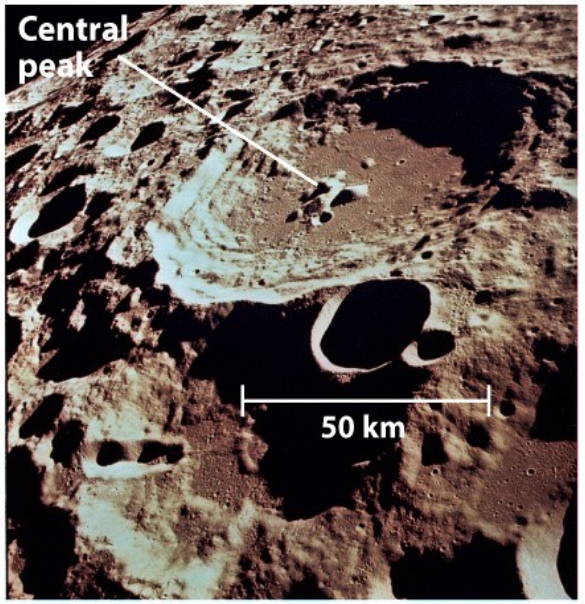
When two Kuiper belt objects collide or gravitationally interact, a small ice and rock object can be knocked into a highly elliptical orbit that brings it near the Sun. The result is a comet. As it heats up from the Sun's radiation, the gases vaporize some of the comet's ice. The solar wind pushes the ionized gas (blue) away from the comet and away from the sun. The dust (white) leaves a trail behind the comet's path. Many comets inhabit a a region outside of the Kuiper belt know as the Oort cloud.

Comets

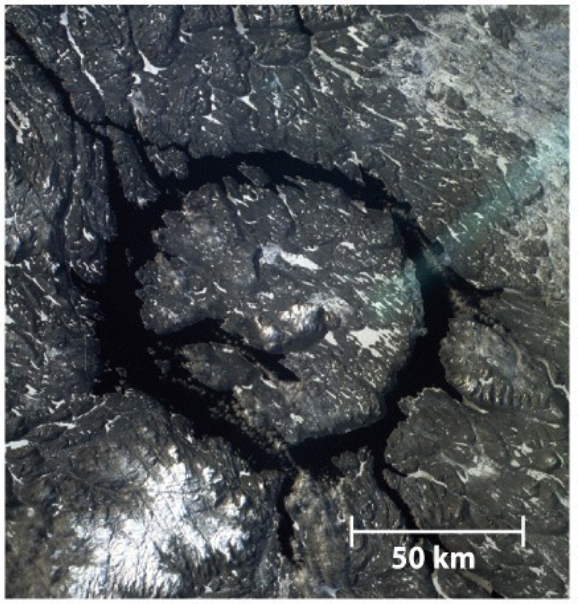


The ESA Rosetta mission visited the comet 67P/C–G in 2014. The top image shows the comet's 'peanut' shape. Recent information suggest the comet is actually two comets that collided and stuck together. The lower image was taken on September 25, 2015

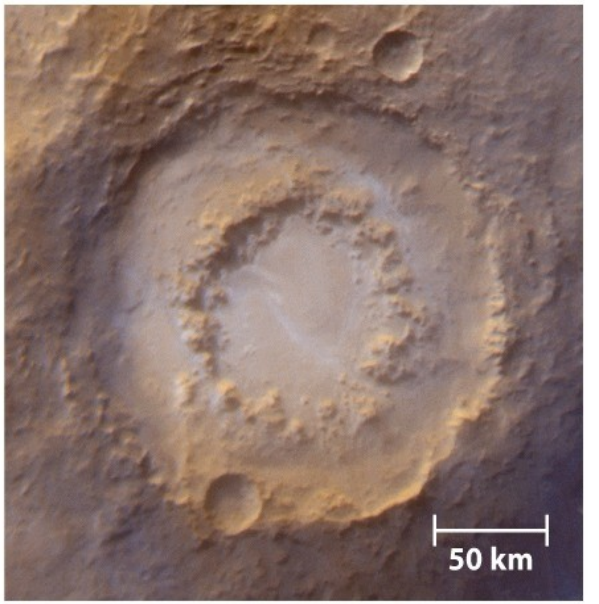
Craters on Planets and Moons



(a) A crater on the Moon



(b) A crater on Earth

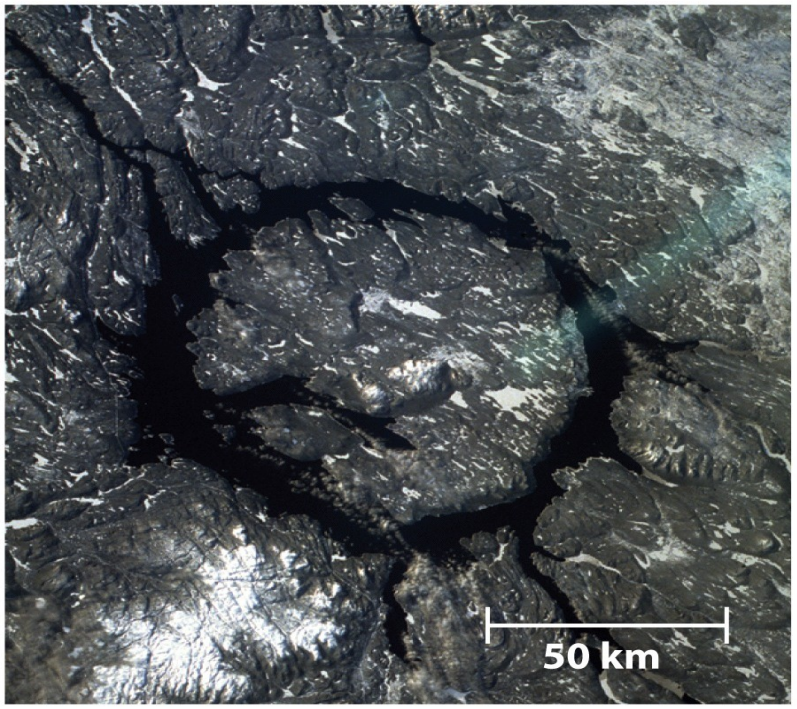


(c) A crater on Mars

Figure 7-10
Universe, Tenth Edition
a: NASA; b: JSC/NASA; c: NASA/JPL/MSSS

When asteroids or comets hit a the solid surface of a terrestrial planet or satellite, they leave a large impact crater. Most impact craters have a central peak. Smaller pieces of space debris from collision of asteroids or comets are called meteoroids and leave small craters when they impact a sold surface.

Craters on Planets and Moons



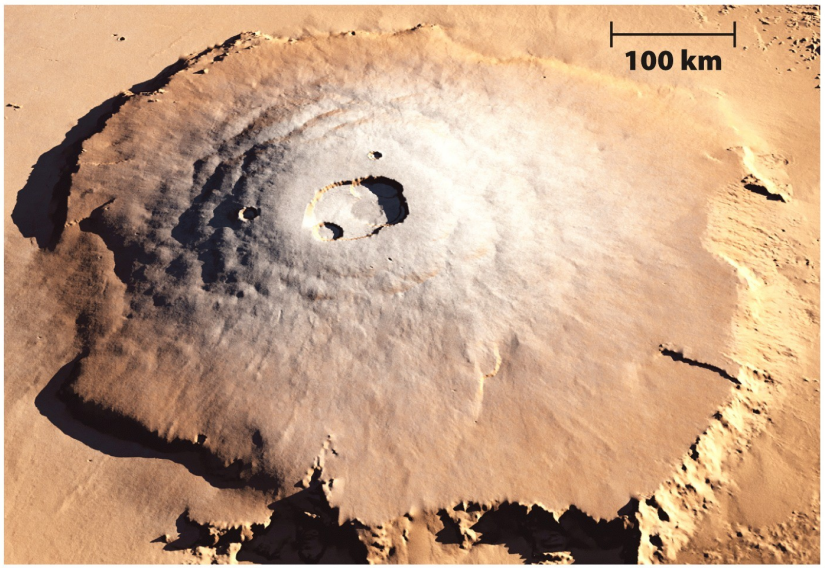


Figure 7-12
Universe, Tenth Edition
Kees Veenenbos/Science Source

Why don't we see more craters on the Earth? The Moon is geologically inactive while the Earth is very geologically active. Plate tectonics (the motion of the Earth's rocky plates over the molten inner core) recycles the surface of the Earth over geological times. Weathering also removes signs of cratering.

On Mars, the planet is not thought now be geologically active but was earlier in it's history as the giant volcano 'Olympus Mons' shows.

Why are Planets Cratered Differently

Planet #1

Planet #2

Figure 7-11
Universe, Tenth Edition

Larger planets cool off more slowly than smaller objects. Larger objects have a smaller ratio of surface area to volume than a smaller object. The heat (left over from the original collisions that formed the planet and from internal radioactivity) results in larger planets having a molten core which leads to the geological activity and fewer craters.

Magnetic Fields of Planets

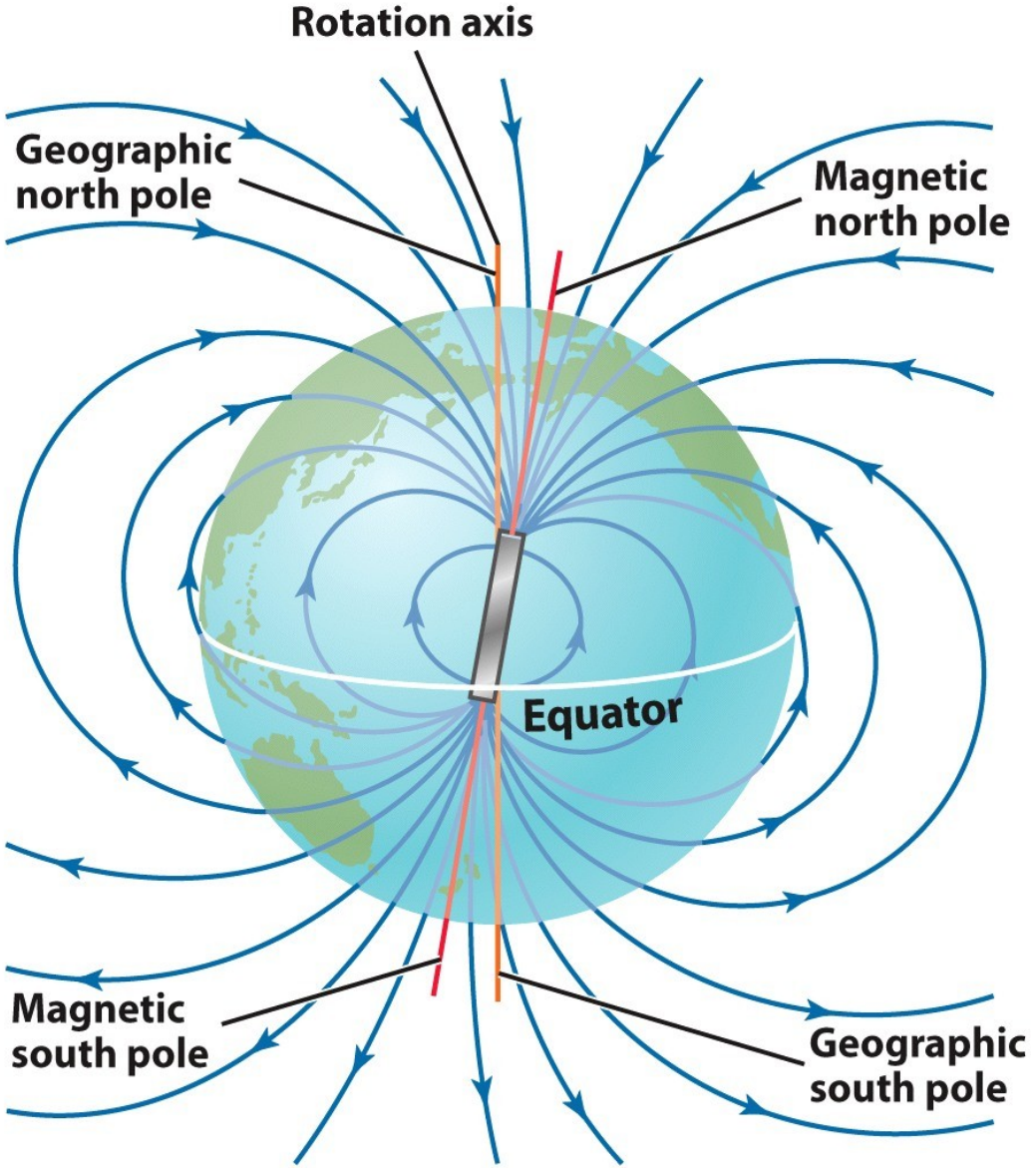


Figure 7-13b
Universe, Tenth Edition

Magnetic fields around a planet indicate the planet (or moon) has a moving molten core that conduces electricity. This is usually a metal like iron or nickel. Electrical currents in the core caused by the dynamo effect produce the magnetic field. Most space probes carry magnetometers to measure the magnetic field around planets.

Magnetic Fields of Planets

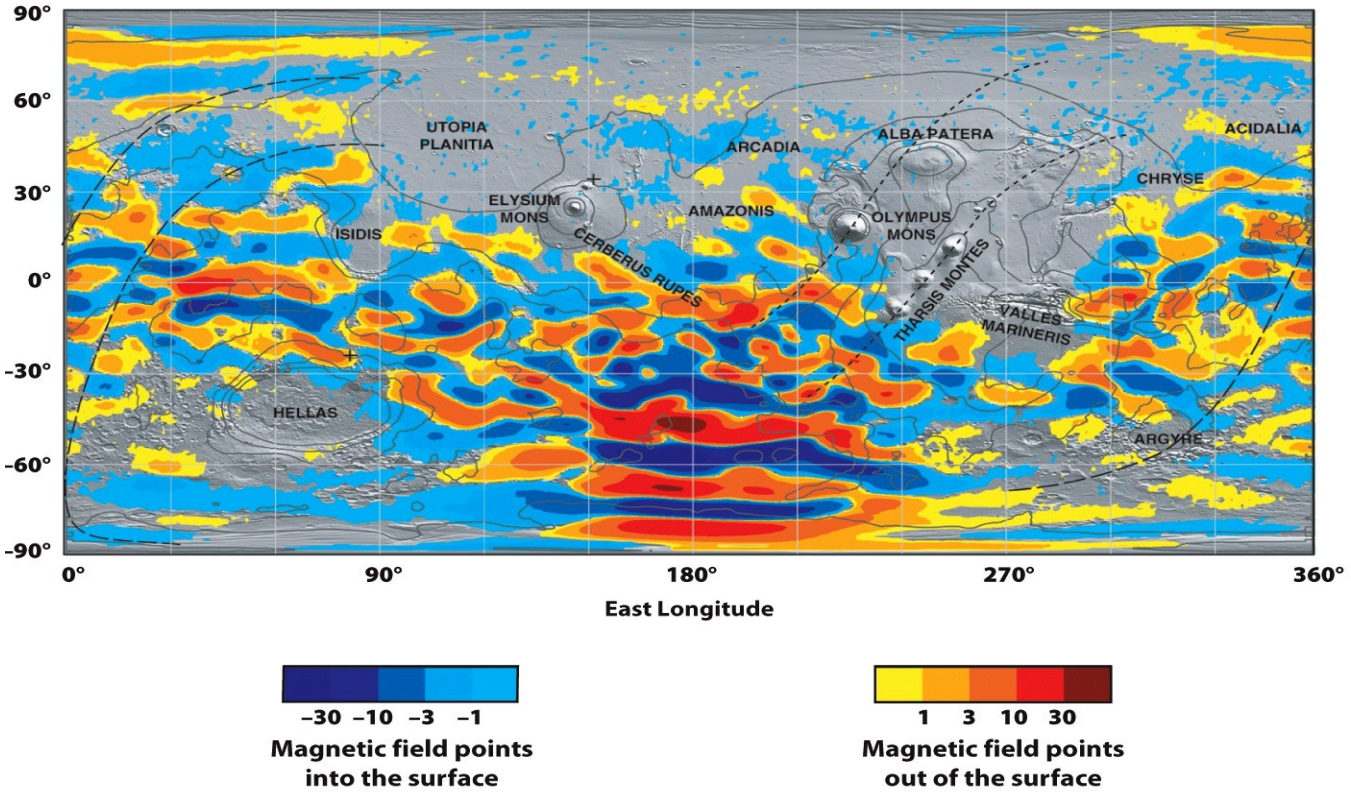


Figure 7-15
Universe, Tenth Edition
NASA

Mars no longer has a molten core and so does not have a magnetic field like the Earth.
The surface is magnetized. The magnetic field is 'frozen' into the surface from ancient times when Mars had a molten core. Moon rocks returned by the Apollo astronauts show this effect. Jupiter has a magnetic field which is though to be due to a liquid core of metallic hydrogen which only exist at extreme pressure.