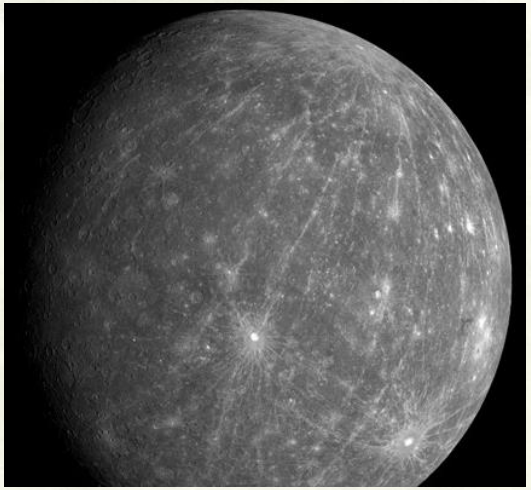
Planets

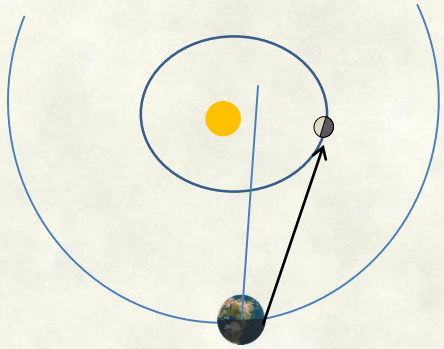
ASTR 101

11/16/2016

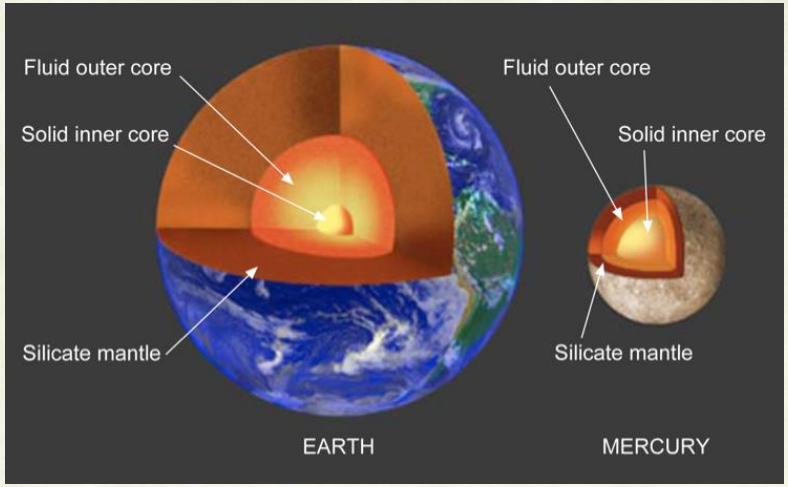
Mercury

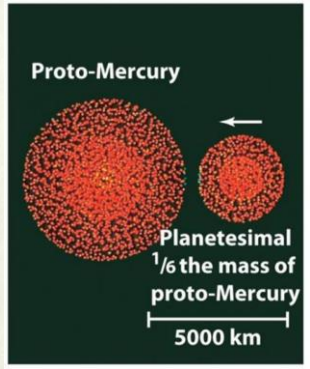


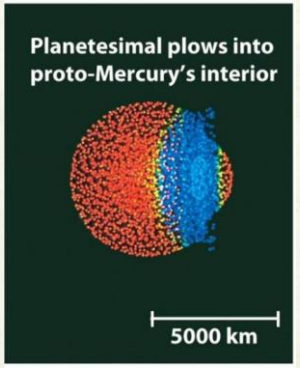
- Mean distance from the sun 5.8×10^7km (0.39 AU)
  - maximum and minimum 0.3AU-0.47AU
  - Eccentricity of the orbit 0.207
- Orbital period 88 days
- Rotation period 58.7 days
- Diameter 4880 km
- Mass 5.8×10^7kg (1/18 earth)
- Escape velocity 4.3 km/s
- Surface temperature day 623K (350C°)
  night 103K (-170C°)

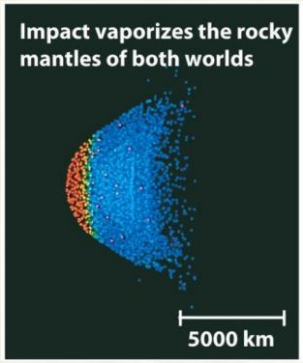


- Closest planet to the sun. It is the smallest planet.
- Mercury is always located very close to the Sun in the sky.
  - It is never more than 28 degrees from the Sun in the sky, so very difficult to study from the Earth even at the greatest elongation.
- It has no atmosphere, long day/night time result in harsh surface conditions with extreme temperature fluctuations.

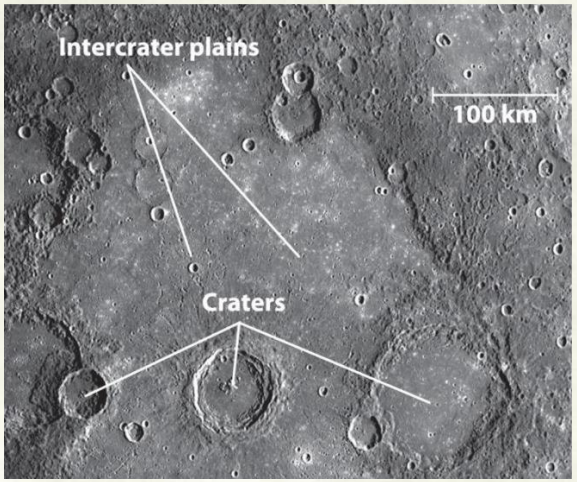


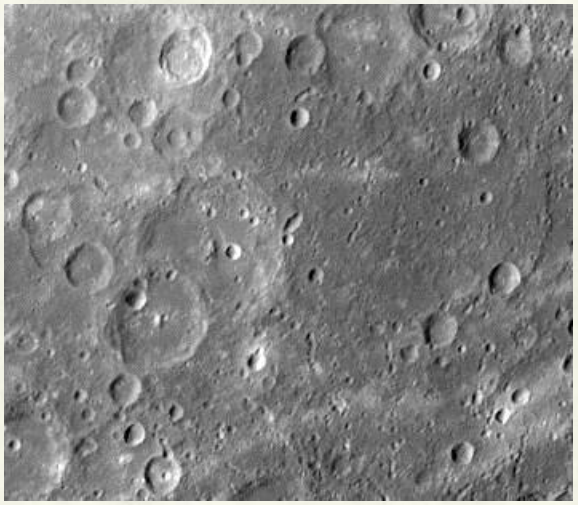




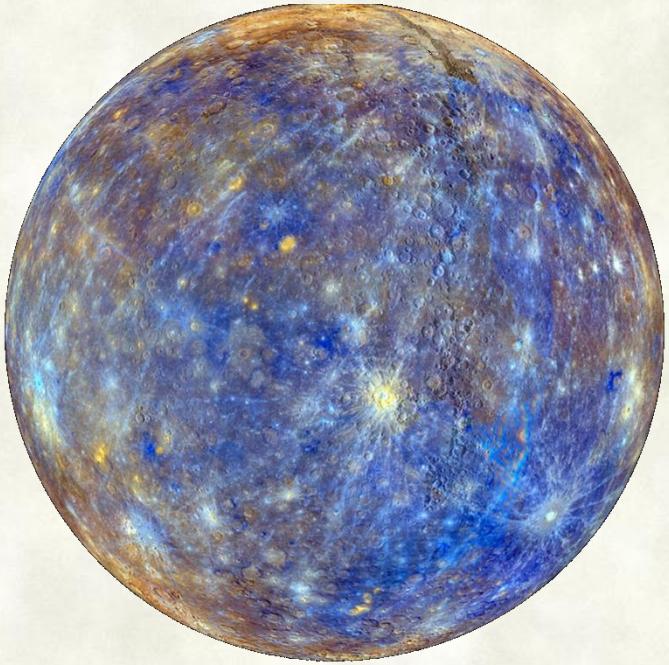


- Mercury has a weak magnetic field, which suggests a large iron core.
- It is estimated to be about 50% of the interior by volume.
  (In the case of the Earth the metallic core occupies about 16% of the interior by volume and in the case of the Moon the core occupies about 4% by volume).
- This large interior core could have been the result of a collision with another planetesimal in the early stages of its formation, which had ejected the lighter rocky material from it.
- Its mental is too thin to cause tectonic plate movements, so like Moon mercury is not geologically active





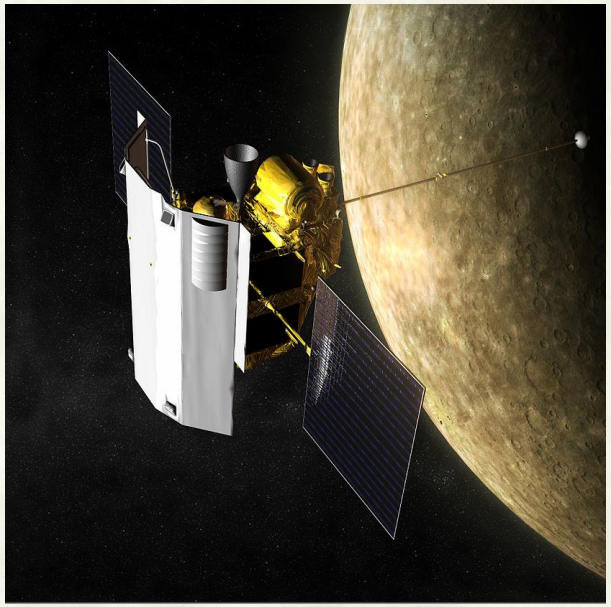
Mercury image from the Mariner missions (1970s)



An image from the MESSENGER (2009)

- Lack of geological activity and atmosphere has left its impact craters intact.

MESSENGER Spacecraft (2004-2015)

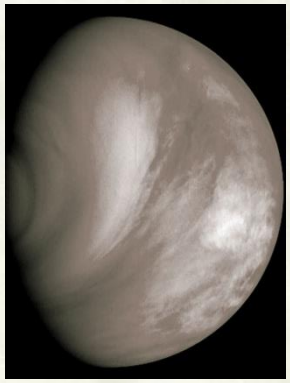


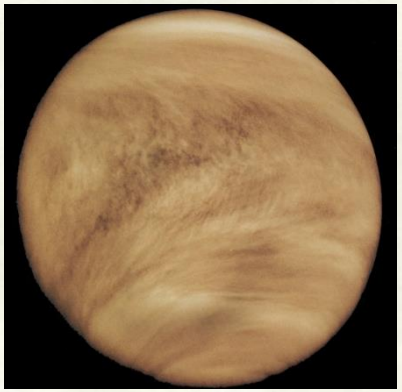
Venus

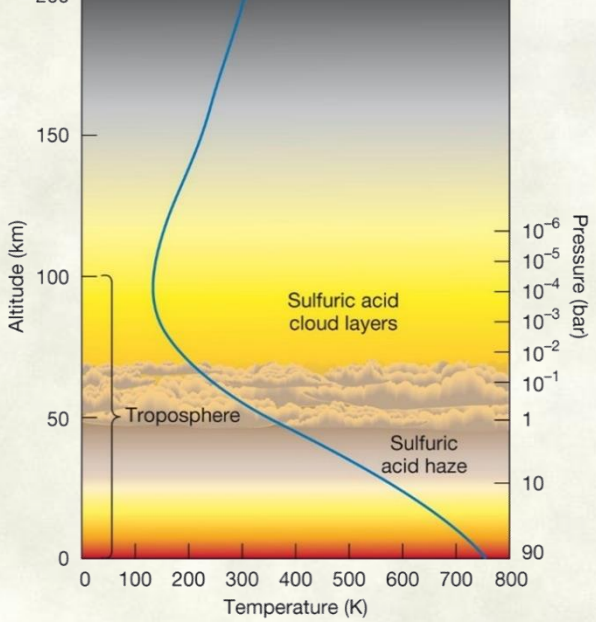
- Distance to Sun: 1.08 x 10^8 km (0.72 AU)
- Diameter : 12100 km (0.95 Earths)
- Mass: 4.9 x 10^{24} kg (0.82 Earths)
- Density: 5200 kg/m^3
- Orbital period : 224.7 days
- Rotation period: 243 earth days (retrograde)

- Brightest object in the sky, after Sun and Moon, morning/evening star.
- In the past Venus was often considered a "twin planet" to Earth,
  - but now we know that almost nothing on Venus is like that on the Earth.
- Venus is always covered by a thick layer of clouds that make it impossible to see its surface with telescopes.
  - Radio waves can penetrate clouds somewhat. Most ground studies are based on radar imaging.
  - Even space probes flying near Venus, using ultraviolet or infrared, can see only a little deeper into the clouds
- Unlike other planets, Venus rotate retrograde (ie. clockwise as seen from north pole).

Atmosphere



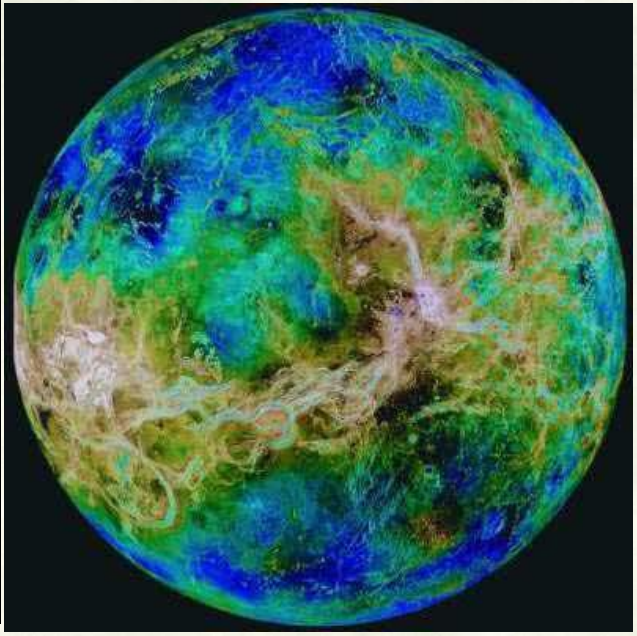


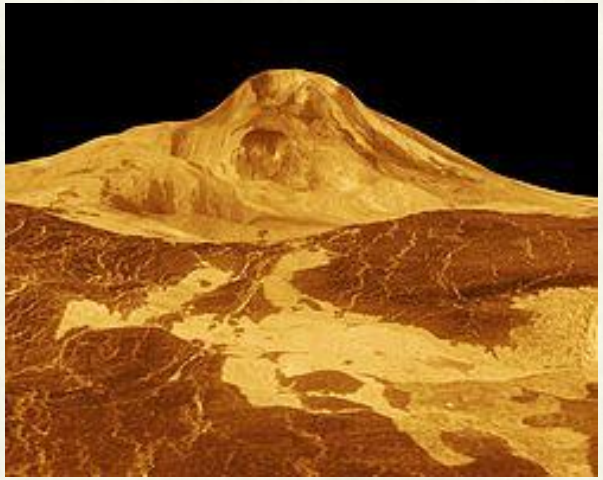


- Venus' thick and atmosphere is made up mostly of carbon dioxide (96%) and nitrogen (N_2), with clouds of sulfuric acid (H_2SO_4) droplets and no water.
- The pressure at the planet's surface is about 92 times that at Earth's surface, (equal to 1km under water on Earth)

- Surface temperatures on Venus are around 730K (460^{o}C),
  - exceeding that of Mercury,
  - It is a consequence of the 'runaway' greenhouse effect from carbon dioxide in the atmosphere, along with thick clouds of sulfur dioxide.
  - Increasing temperatures evaporate liquids in ground and sublimate minerals (rocks) releasing more greenhouse gases into the atmosphere, which further increase the atmospheric temperatures...

Surface and Interior





Maat Mons, a massive volcano on Venus (diameter 395 km, height 8km)

Radar images of Venus taken by a Magellan Spacecraft, (false color)

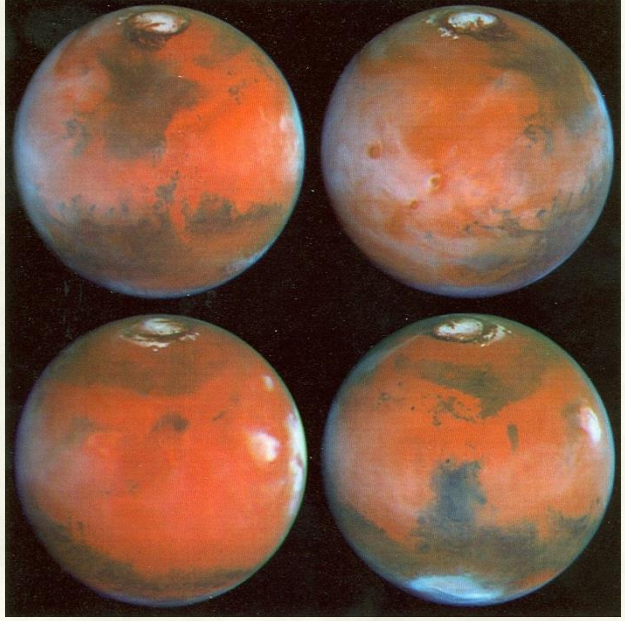
- Very weak magnetic field, probably because rotation is so slow.
- Many lava domes and shield volcanoes, large craters, Mountains, large lava flows
- Magellan mission in 1990s found that 85 percent of the surface is covered with volcanic flows and showed evidence of tectonic movement.
- Despite the high surface temperatures (475°C) and high atmospheric pressures (92 atmospheres), lack of water makes erosion an extremely slow process.
  - As a result, surface features can persist for hundreds of millions of years.

An image of Venus surface from Venera 13 lander (1982)

Venera 14 lander (1982)

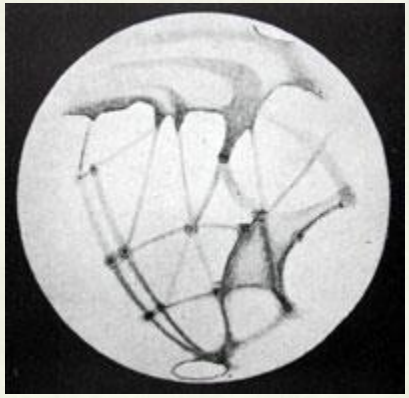
- Soviet Venera missions in (1961 -1984) landed on Venus and sent images and other information.
- Spacecrafts survived less than an hour due to extreme conditions of high temperature and pressure .

Mars



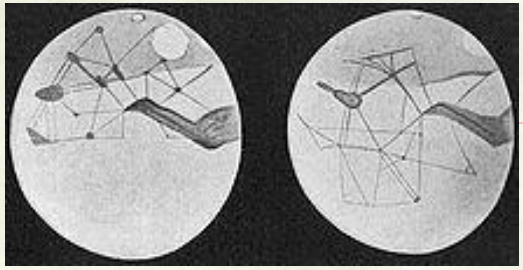
- Average distance fro Sun: 2.28×10^8km (1.52 AU)
- Mass 6.41×10^{23}kg (0.11 earth)
- Diameter 6780km (0.53 earth)
- Density 3934 kg/m^3
- Rotation period 24h 37h
- Orbital period 687 days

- Mars has fascinated people since the antiquity.
  - they called it the 'red planet' because of its red appearance.
- It captured human imagination even more after telescopic observations
  - In 1877 Giovanni Schiaparelli, an Italian astronomer reported observing channels on mars using a telescope.
  - Perhaps a mistranslation this word as "canals" led the imagination of an American businessman Percival Lowell, with an interest in astronomy.
  - He founded an observatory (1894) in northern Arizona, where his observations of the Red Planet convinced him that that canals were dug by intelligent beings

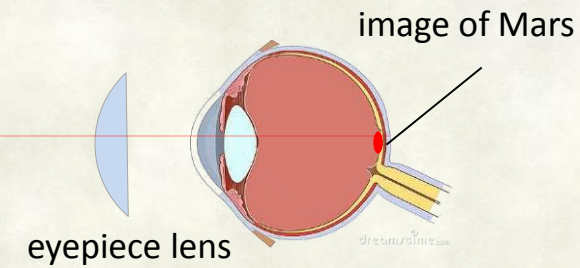


Schiaperelli's sketch of 'canals'

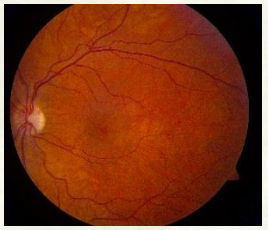
Lowell Observatory



Martian canals depicted by Percival Lowell, An idea that he energetically promoted.

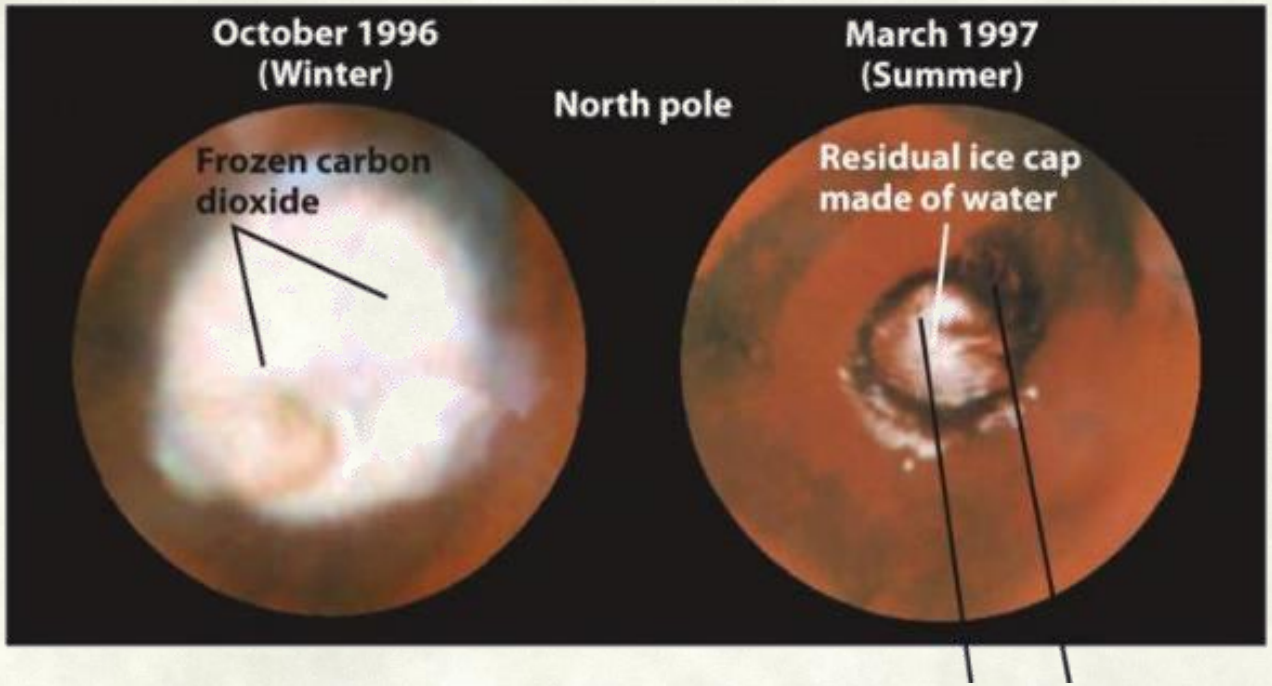


Retina of eye



- Canals Schiaparelli and Lowell reported were more likely an illusion,
  - probably they were seen the reflection of their retina illuminated by Mars, on the back surface of the eyepiece.
- We now know the red color is due to iron oxide rich dust and rocks on the surface of the planet.
  - Changing color that were once thought to be vegetation, is changing color due to blowing sand, not vegetation.
- Surface temperature 293-133K (20Cº to -140Cº)
- Thin atmosphere (0.7% of the density of Earth's)
  - 95% carbon dioxide
  - 3% nitrogen
  - Traces of oxygen and water

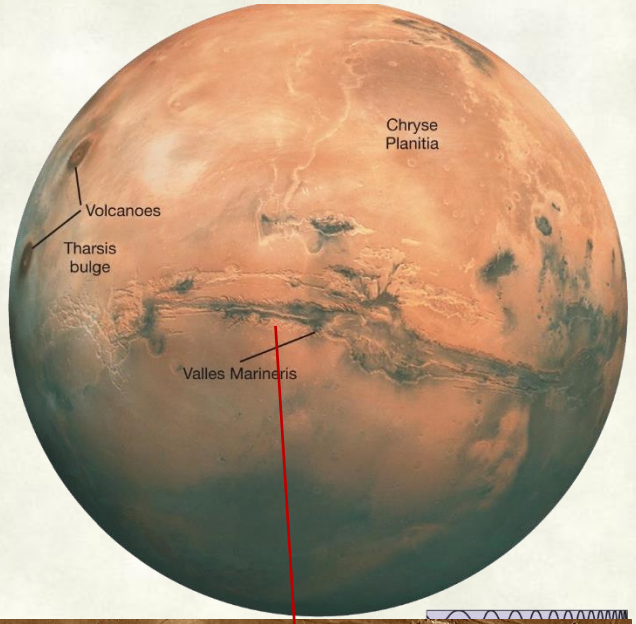
Ice caps

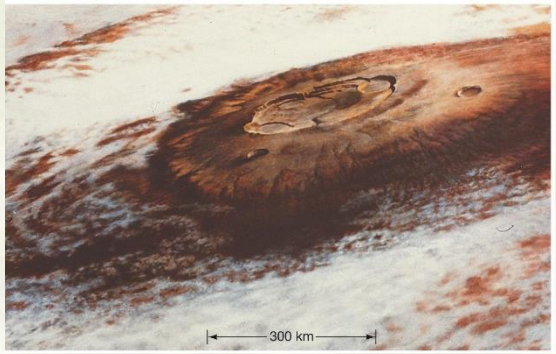


- During the Martian winter, the temperature drops and carbon dioxide freezes out of the Martian atmosphere to make a large polar ice cap of carbon dioxide.
- During summer, the carbon dioxide returns to the atmosphere, revealing a residual ice cap made of water, which is permanently frozen

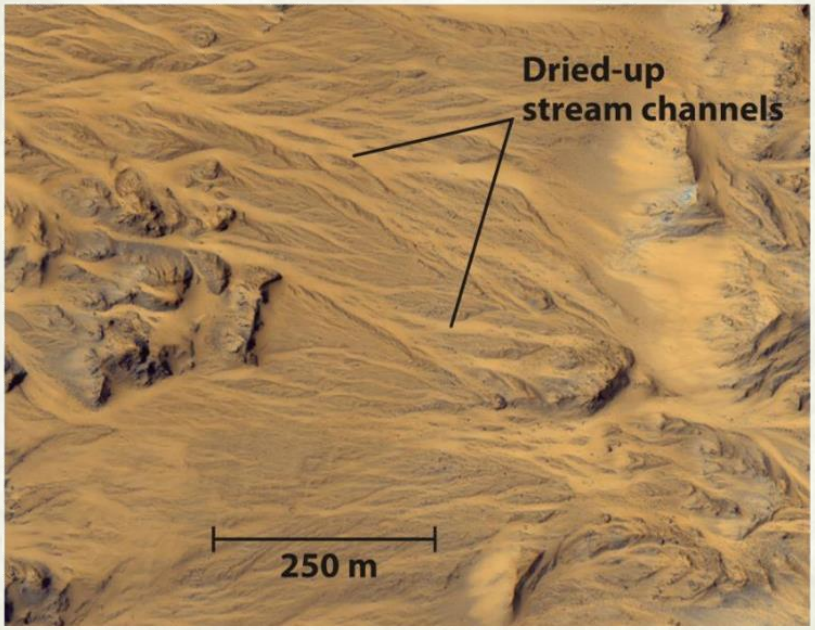
The Martian interior and Surface

- There is no evidence for plate tectonics.
- No magnetic field, so Martian core is probably not metallic or liquid.
- Major feature: Tharsis bulge:
  - vast volcanic plateau centered near the equator,
  - size of North America and 10 km above surroundings
- Valles Marineris: A huge canyon
- Mars has largest volcano in solar system: Olympus Mons
  - 700 km diameter at base 25 km high

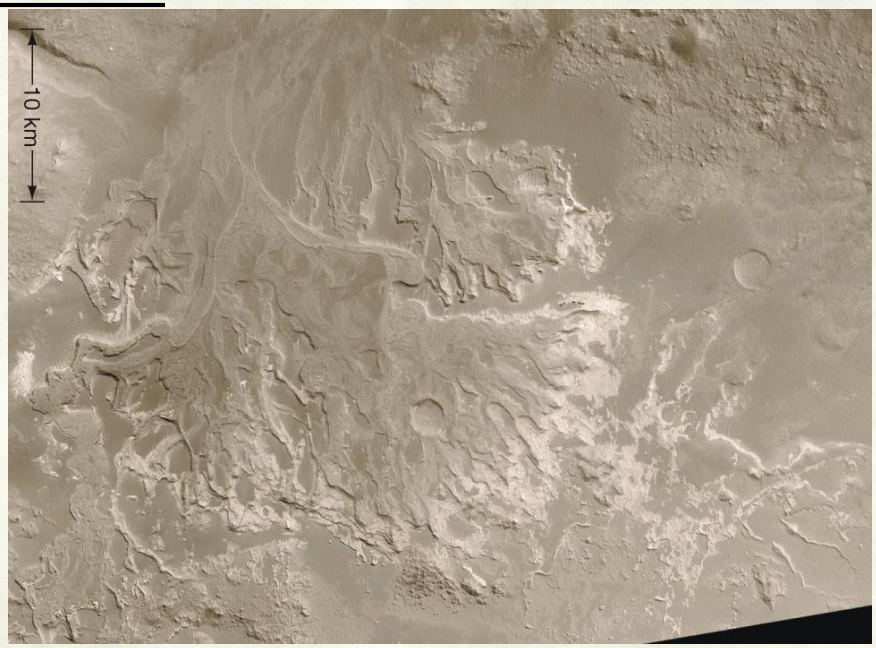




Water on Mars



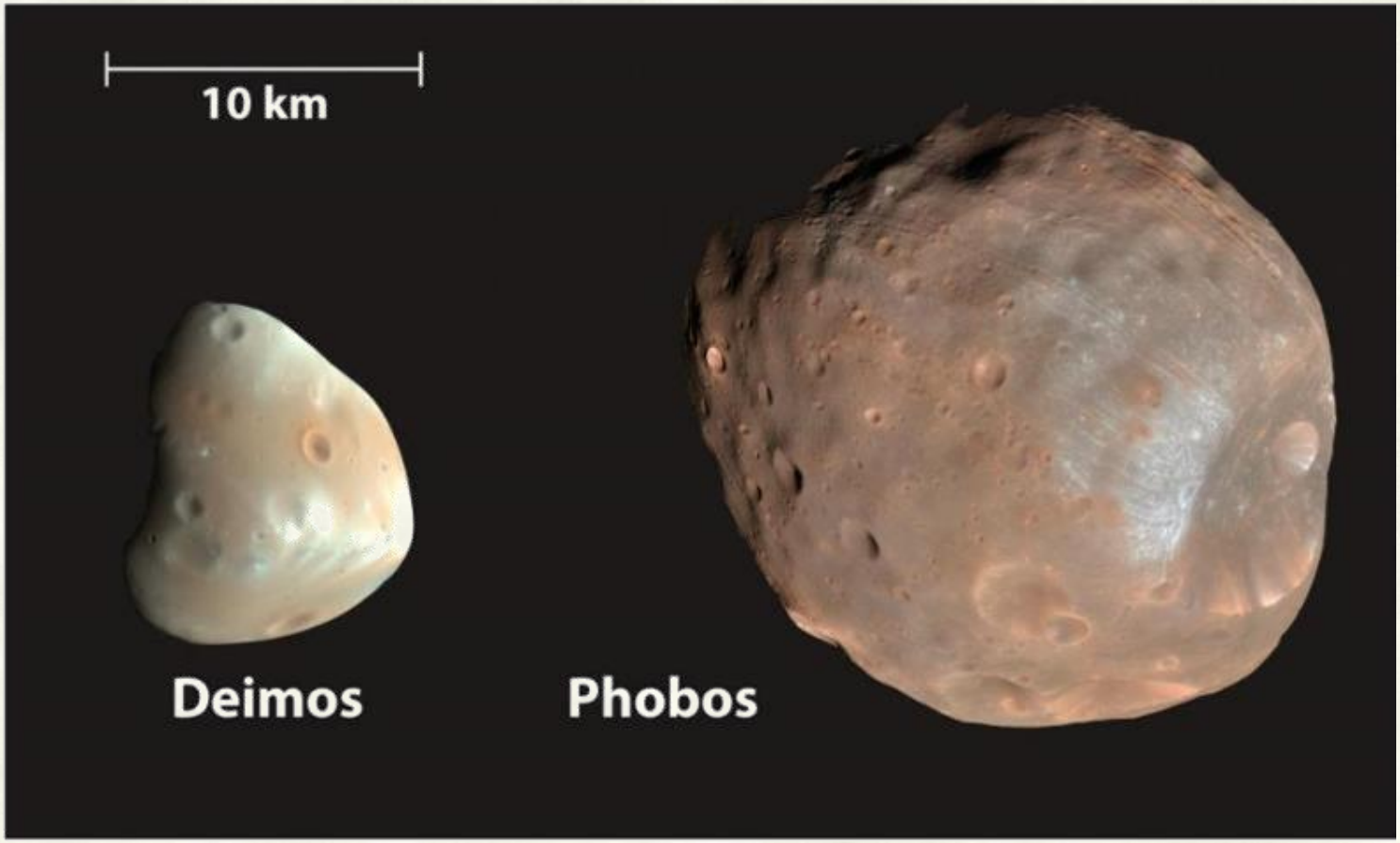
Mars Reconnaissance Orbiter images



Valles Marineris canyon (4,000 km long 200 km wide) likely formed by flowing water few billion years ago.

- Liquid water cannot exist on present-day Mars because the atmosphere is too thin and cold.
- There are evidence that liquid water existed on Mars in its early history, when the atmosphere was thicker.
- Many surface features resembling dry riverbeds, flood plains, gullies, and canyons carved out by flowing water.
- There is evidence for frozen water at polar ice caps and beneath the surface soil layer.

Moons of Mars



- Mars has two tiny moons:
- Phobos (left, 28 km x 20 km); Deimos (right, 16 km x 10 km)
- They are probably captured asteroids, too small to become spherical under their gravity.

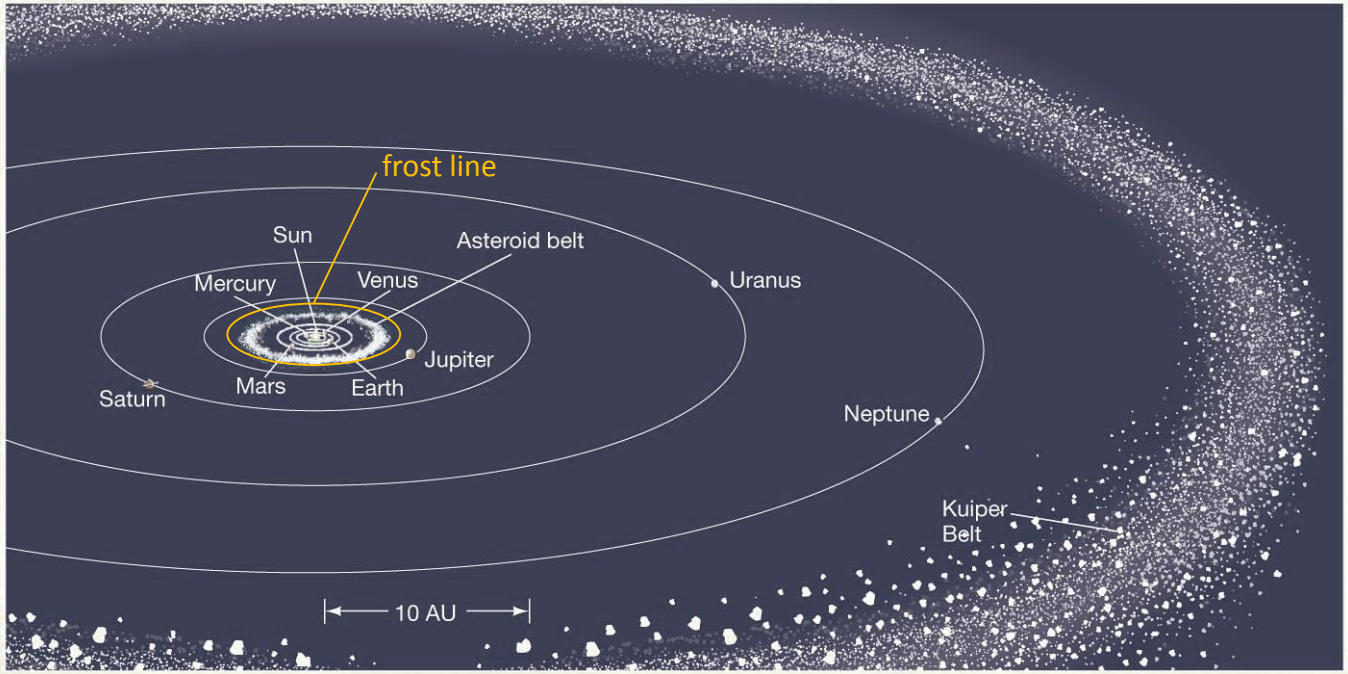
Space probes to Mars

Martian landscape image rom the Curiosity

- Mars has been the target for many space missions, with flyby, orbiter, lander and rover missions visiting the planet
- Over 20 successful mission since Mariner 4 in 1964

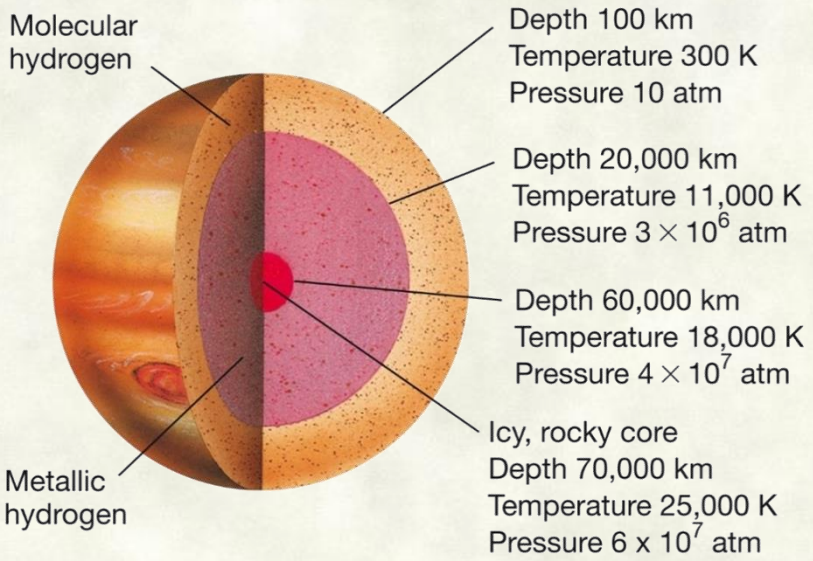
Curiosity –Mars rover operational since November 2012

Jovian planets (outer planets, gas giants)



- Formed beyond the frost line (3.5 AU) from the Sun,
  - in addition to rocky and metallic dust ice particles made of hydrogen compounds (water, methane, ammonia) were available to clump and form planetesimals which further accrete to form Jovin planets
  - Composition of the solar nebula 98% hydrogen and helium, 0.6% rock and metal dust, 1.4% ices. So significantly more material were available than for terrestrial planets, they grew larger.
  - Larger size resulted in a stronger gravitational field, which pulled and retained H, He gas around it and grew even larger, becoming gas giants.

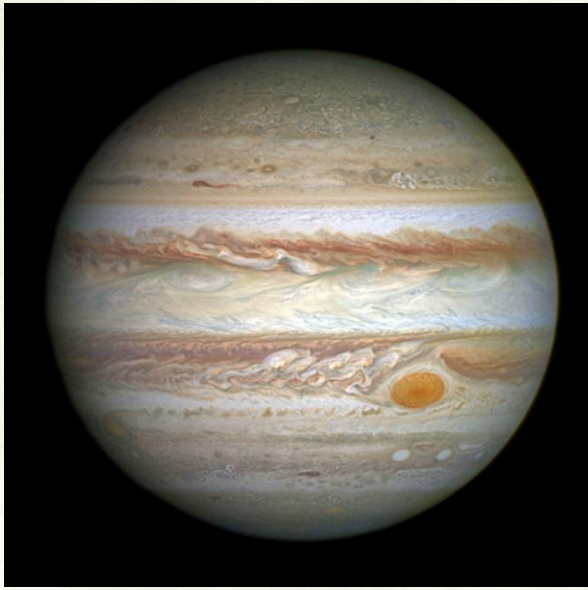
Jupiter



- Mass: 1.9×10^{27} kg (318 Earth)
- diameter: 143,000 km (11.2 Earth)
- Density: 1300 kg/m^3

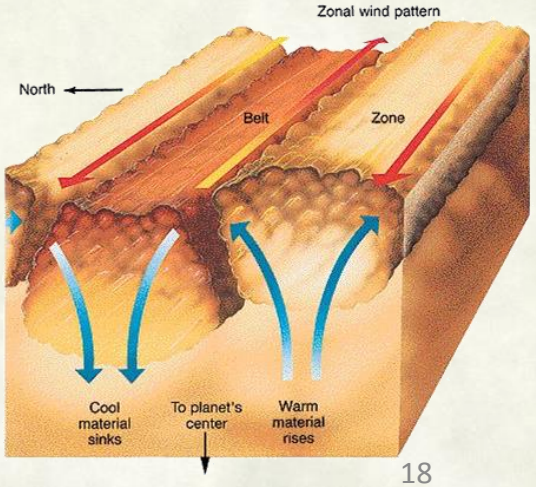
- Composed mostly of gases (hydrogen (90%) and helium(10%)) with a rocky core.
  - comparable in size to terrestrial planets and perhaps with a similar composition (but we have no direct evidence of this).
  - Deeper down, at extreme pressures hydrogen changes to a electrically conducting liquid metallic hydrogen, which compose 75% of the planet's mass .
  - Its rapidly spinning metallic hydrogen interior results in a strong magnetic field, 20,000 times stronger than that of Earth.
- Jupiter radiates more energy (60% more) than it receives from the Sun.
  - Likely its core is still cooling off from the original heating during the collapse of the primordial nebula.

Jupiter



- Because Jupiter surface is not solid, it does not rotate at exactly the same velocity everywhere, and varies with latitude.
  - From magnetic field, rotation period (core) is 9 hr, 55 min
- Because of its rapid rotation, the planet's is bulged around the equator (6%) and has oblate spheroid shape

- All that we see is the top of the atmosphere.
  - has bright zones and dark belts
  - Zones are cooler, and are higher than belts
  - Thus the belts appear to be regions of descending gas and the zones are regions of rising gas.



- Each hemisphere has around 6 bands
  - winds blowing in zones and bands at very high velocities in opposite directions.
  - extensive shear and turbulence at the boundaries between these regions, with hundreds of vortices

Cloud movement
in 24 Jovian days
(~10 Earth days)

http://www.nasa.gov/centers/goddard/multimedia/largest/eduindex.html

The Great Red Spot

taken by Voyager 1 (left) and Voyager 2 (right) flew by Jupiter in 1979,

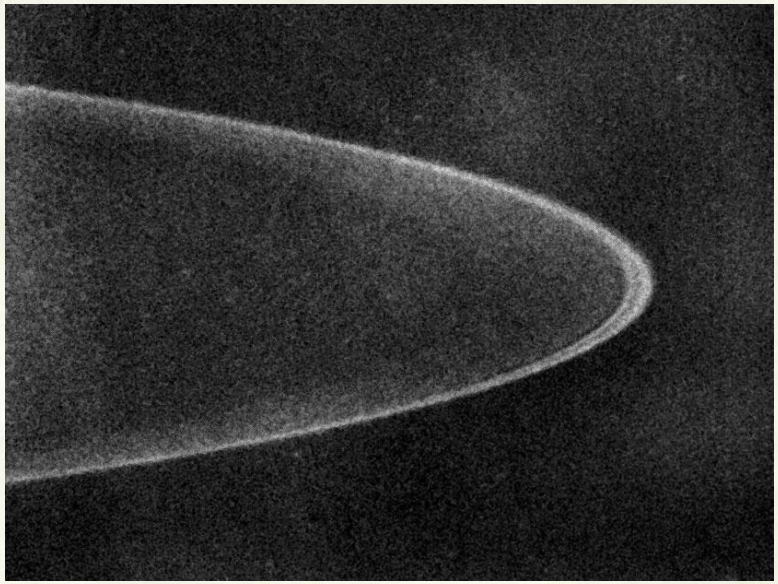
- A prominent feature is the "Great Red Spot, a giant storm system which has existed since first observed in 1664, over 350 years ago.
- Located 22° south of the equator, it spans an area 40,000 km×14,000 km (3 earth sizes)
- It rotates counterclockwise with a period of about seven days, corresponding to wind speeds at its periphery of 400 km/h
- Presumably its persistence is due to the fact that it never comes over land and that is driven by Jupiter's internal heat.

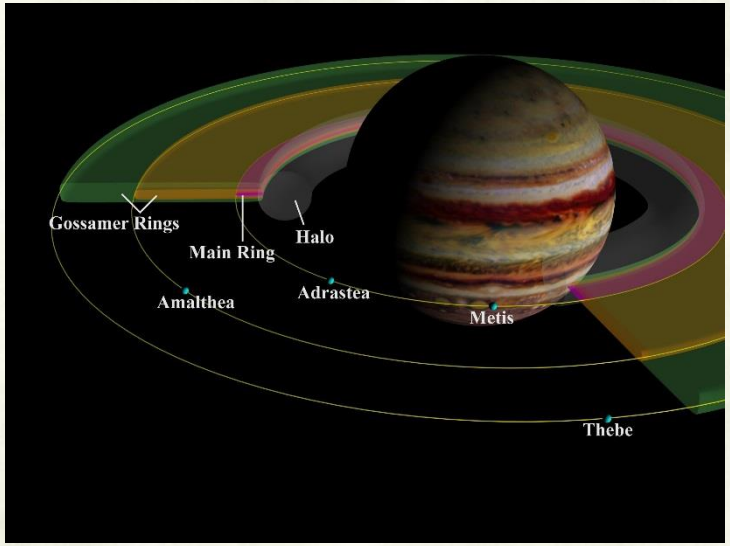
Moons of Jupiter

Io Europa Ganymede Calisto

- 63 moons have now been found orbiting Jupiter, but most are very small less than 250km in size.
- Largest moons: Io, Europa, Ganymede, Calisto were discovered by Galileo, have similarities to terrestrial planets in terms of structure and composition.
- Ganymede, the largest moon in the solar system—is larger than Mercury (diameter 5262 km).

Rings



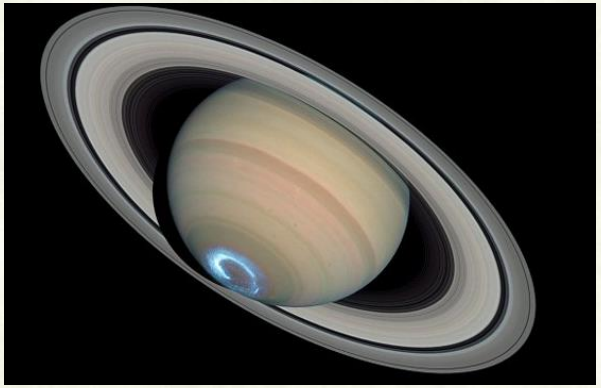


- In 1979 Voyager 1 spacecraft discovered faint rings around Jupiter.
- Unlikely Saturn’s icy rings full of large icy and rock chunks, they are composed of small dust particles.
- They are believed to be are formed from dust particles hurled up by small meteor impacts on Jupiter's small inner moons and captured into orbit.

Saturn

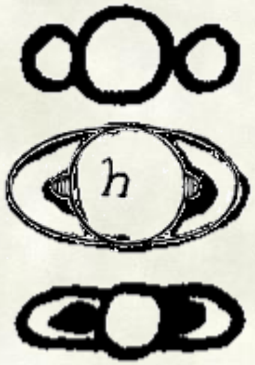
- average distance to Sun: 1.43×10^9 km (9.6 AU)
- mass: 5.7×10^{26} kg (95 times Earth)
- diameter: 120536 km (9.4 times Earth)
- density: 700 kg/m^3 less than water
- Orbital period: 29.45 years
- Sidereal rotation period 10.57 hours

- Saturn is noticeably flattened (10%) due to its high rotation rate.
- Saturn's atmosphere also shows zone and band structure and wind patterns, but less coloration.
- Its atmosphere is similar to Jupiter's, mostly hydrogen(96%), helium (3%), methane, and ammonia.
- Interior structure is similar to Jupiter's, smaller metallic hydrogen core, strong (but only 5% of Jupiter's) magnetic field
- Like Jupiter, it radiates more energy than it receives from the Sun.

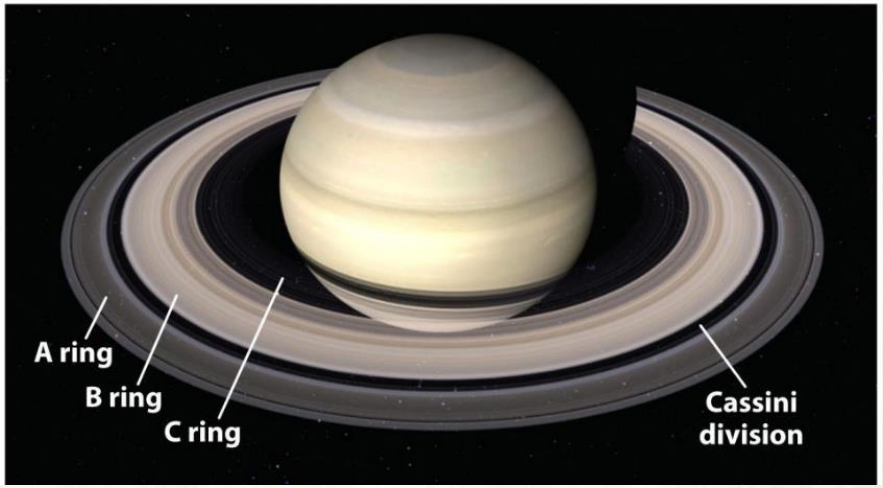


Saturn's Aurora (mostly in UV)

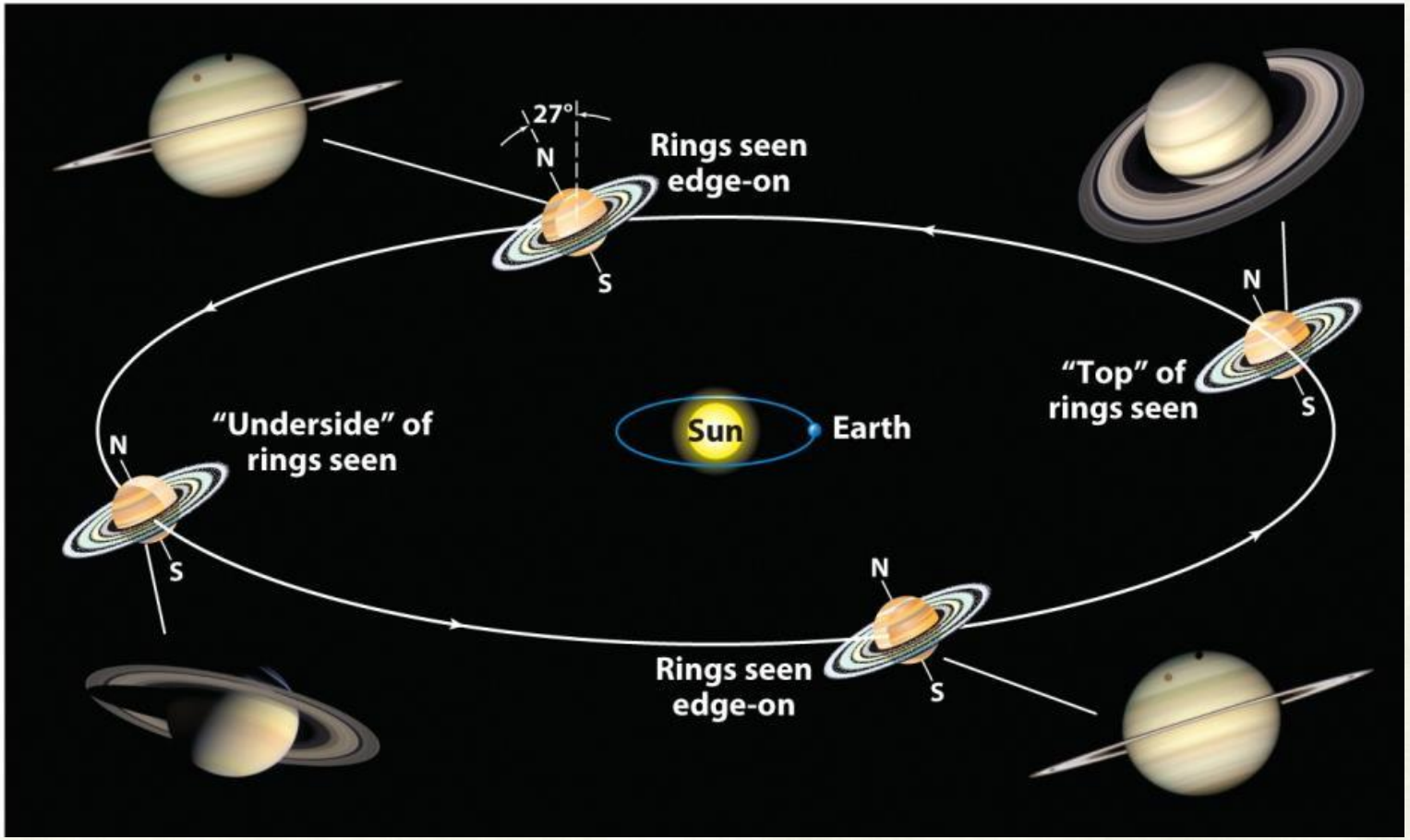
Rings of Saturn



Galileo's sketches of Saturn



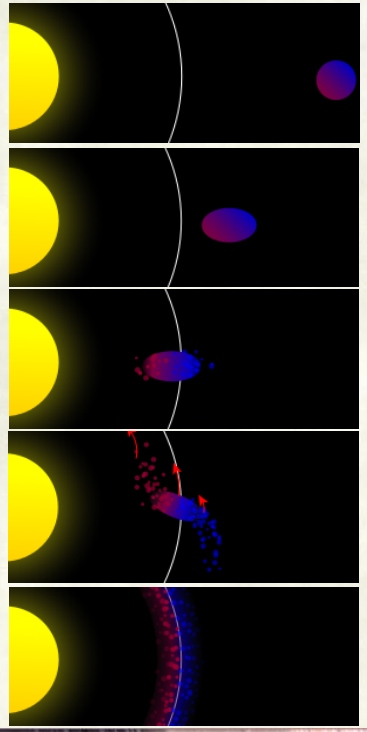
- Most distinctive feature of Saturn is its rings.
- Galileo first observed some unusual elongation and 'ears' like structures surrounding Saturn which puzzled him, but he did not realize they were rings.
- Christian Huygens in 1659, gave the explanation that "Saturn is surrounded by a thin flat ring that nowhere touch it".
- In 1675, Giovanni Cassini discovered a gap in the rings, dividing it into two, now known as the Cassini Division.
- Saturn has three major, broad rings (A, B, and C) that can be seen from Earth. Numerous Other, fainter rings were found by the Voyager 1 spacecraft when it flew by in 1980.



- Saturn's' rings are tilted away from the plane of its' orbit, which causes the rings to be seen at various angles from Earth over the course of a Saturn year.

Roche limit

- When an object come too close to a massive object (planet, star), tidal forces become stronger than the gravitational forces holding it together.
  - Objects breaks apart, or prevent from coalescing under self-gravity.
- The smallest distance this will not happen is called the **Roche limit**.



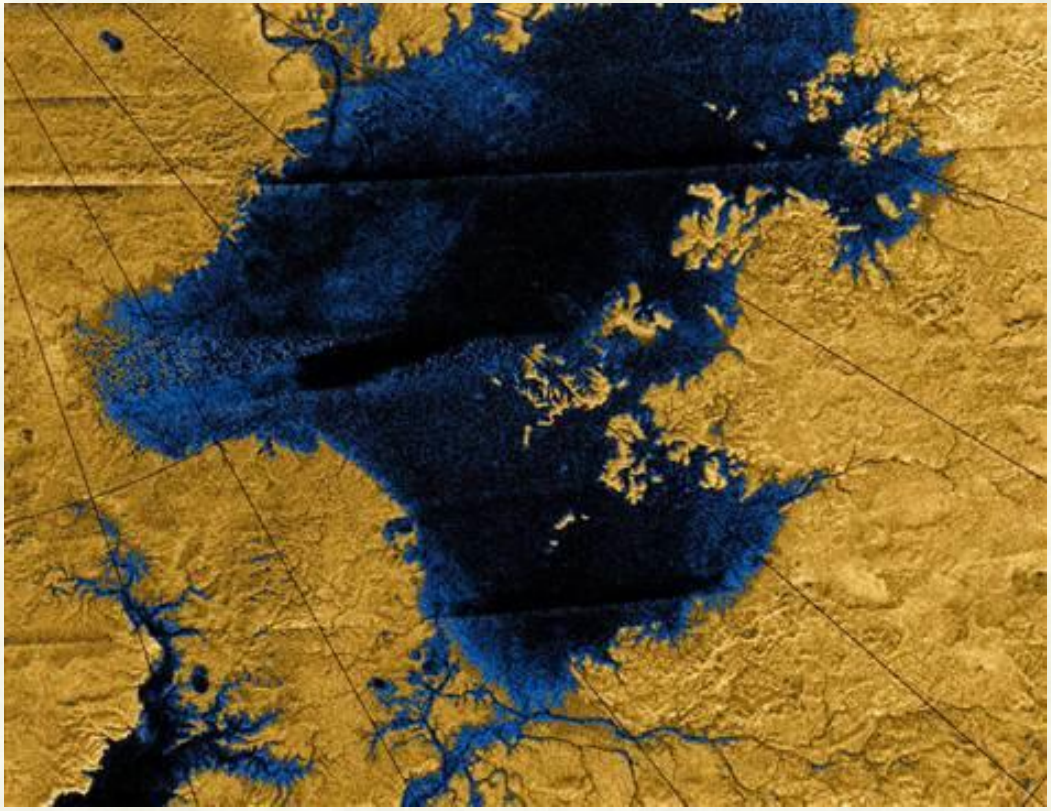
- Inside the Roche limit, orbiting material will tend to disperse and form rings, while outside the limit, material will tend to coalesce and form larger objects.

- Each of Saturn's major rings is composed of a great many narrow 'ringlets'. They are composed of numerous particles of ice and ice-coated rock ranging in size from a few micrometers to about 10 m.
- Most of the rings exist inside the Roche limit of Saturn

Moons of Saturn

Voyager image of Titan, looking back showing the atmosphere illuminated by sunlight

- There are 62 confirmed satellites orbiting around it, most are small 'moonlets', only 13 larger than 50km.
- Largest Saturn moon Titan, 5,150 km diameter is the second largest moon in the solar system.
- Titan is the only moon in the Solar system known to have a dense atmosphere.
  - A thick nitrogen-rich atmosphere composed of 95% nitrogen with traces of methane extends nearly 600 km into space (which hides its surface features)



Radar images of a Titan lake and rivers taken by the Cassini spacecraft.

- Titan is the only solar system object other than Earth for which clear evidence of stable bodies of surface liquid has been found.
- Titan seems to be covered with lakes or oceans filled with liquefied methane (-180^{o}C).

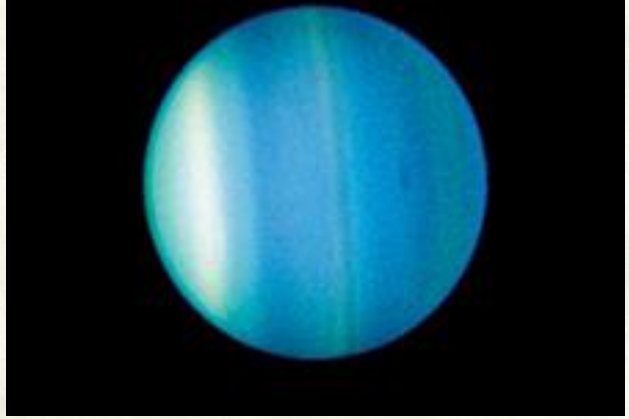
Uranus

A replica of the 7 inch reflector telescope used by Herschel to discover Uranus

- First planet to be discovered since antiquity, visible to naked eye as a faint star (magnitude ~6).
- Uranus was discovered in 1781 by William Herschel, a professional musician and an amateur astronomer and telescope-maker.
  - On March 13, 1781 while he was looking for double stars with his telescope, he saw a star appeared like a fuzzy disk like rather than a point in the constellation Gemini.
  - Over the following few night it appeared to be moving against the stars. object, He initially thought it was a comet,
  - but subsequent observation by him and others indicated that it was a planet, lying beyond Saturn not known until then.
  - Later on Hershel became one of the prominent astronomer of the time, built larger telescopes, and made many discoveries.

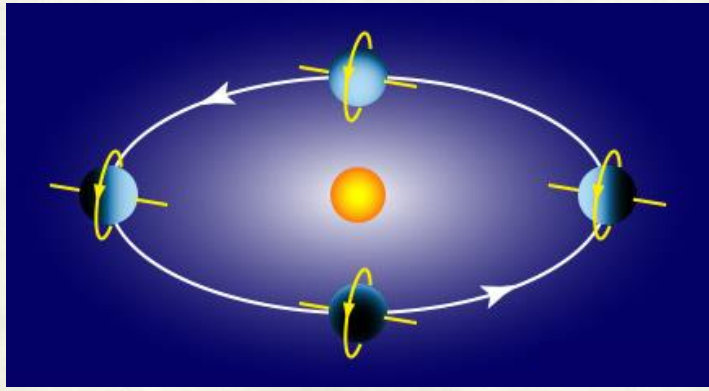
Uranus

- Distance to Sun: 2.9x10^{9}km (19.2 AU)
- Orbital period: 84.1 years
- Rotational period: 17.24 hours
- Mass: 8.68x1025 kg, (14.5 times Earth's)
- Diameter: 51100 (4 times Earth's)
- Temperature: 55K (-218^{o}C)



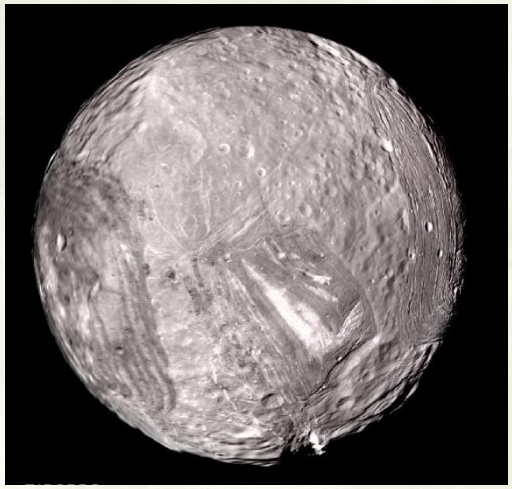
Hubble space telescope / Keck combined image of Uranus

- Little detail can be seen from Earth; In 1977, the first nine rings of Uranus were discovered.
- The atmosphere of Uranus is composed of 83% hydrogen, 15% helium, 2% methane and trace amounts of water and ammonia.
- Methane in the upper atmosphere absorbs red light, giving Uranus its blue-green color.



- Uranus rotates on an axis almost parallel to the orbital plane (tilt 98º) resulting extreme seasons roughly 20 years long.
- This unusual tilt could be a result of a collision with another large object billons years ago.

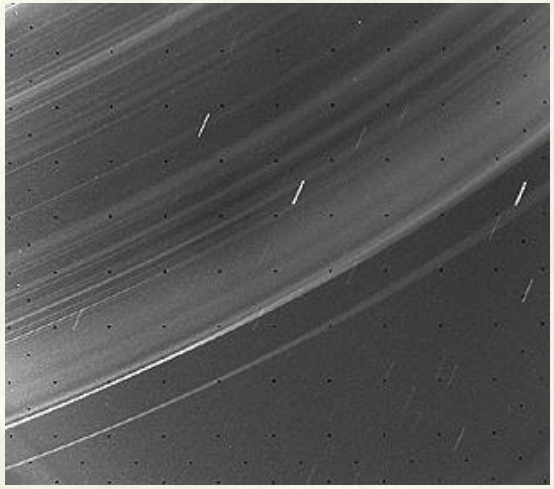
Three of the moons of Uranus



Miranda image taken by Voyager 2

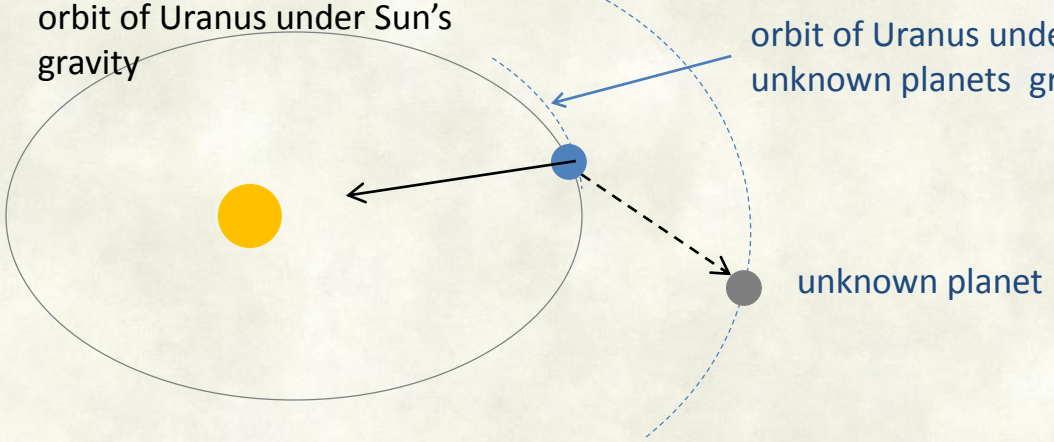
An illustration of Uranus' rings

- Uranus has 27 moons, five of which are medium sized.
  - Miranda (490 km) , Ariel, Umbriel, Titania, and Oberon
- Voyager 2 flew passed within 81,500 km of the surface of Uranus, only space mission done so far.
- Uranus has a system of faint rings. They were discovered in 1977 by ground based observations.



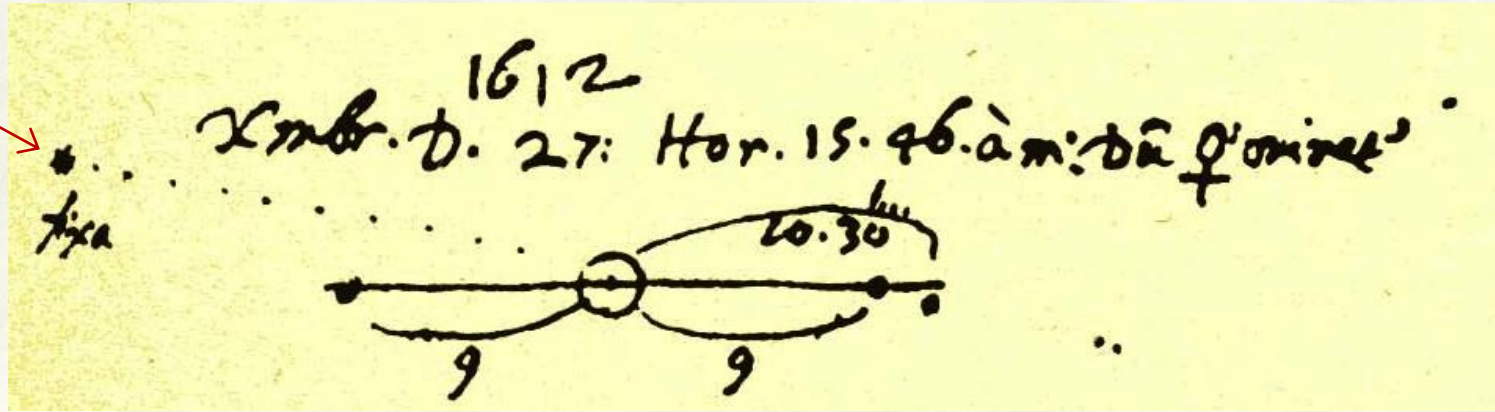
A Voyager 2 image of Uranus' rings

Neptune



- After the discovery of Uranus, it was noticed that its orbit was not as it should be in accordance with Newton's laws.
  - It was deviating about 1 arc second per year from the predicted orbit
  - Could be something wrong with Newton's laws of motion and gravitation
  - Or could be some unknown massive object pulling it away from the orbit around Sun.

- Two mathematicians, British John Adams and French Urbain Le Verrier thought it was due to the gravitational pull of hitherto unknown plant causing the deviation of Uranus orbit.
- They independently predicted the position of such an object that would account for the deviations observed.
- Neptune was first observed by Johan Galle and Heinrich d'Arrest on 1846 Sept 23 very near to the locations predicted from theoretical calculations based on the observed positions of Jupiter, Saturn, and Uranus and Newtonian mechanics.
- It was a big triumph of Newton's laws of motion and gravitation.



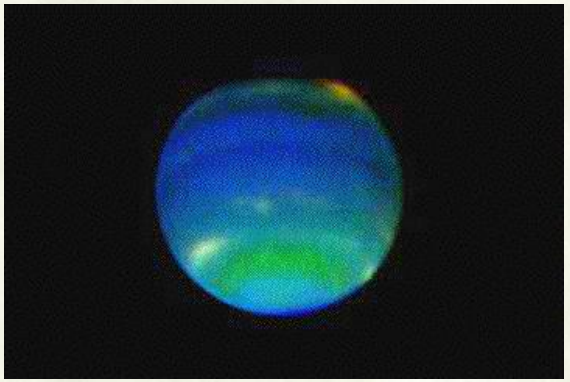
- Galileo's astronomical drawings show that he had seen Neptune while observing Jupiter.
- The ”fixed star” Galileo noted to left of Jupiter in his December 28, 1612 sketch was actually Neptune. (and again on January 27, 1613)
- On both occasions Galileo had mistaken Neptune for a fixed star!

Neptune

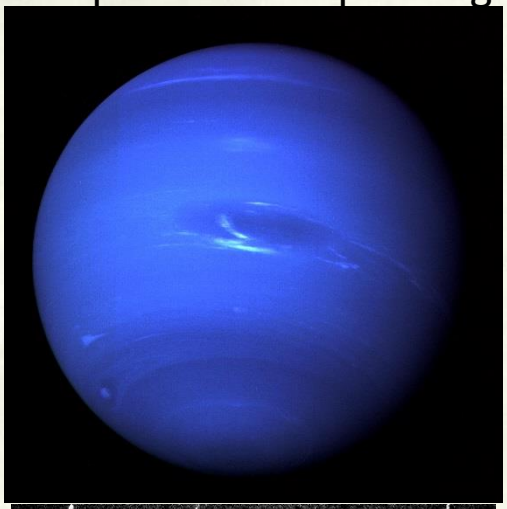
- Distance to Sun: 4.5×10^9 km (30.1 AU)
- Orbital period: 164.86 years
- Rotational period: 15.97 hours
- Diameter: 49528 km (3.88 times Earth's)
- Mass: 1.02×10^{26}kg (17.2 earth Masses)
- Temperature: 55K (-218^{o}C)

- Atmosphere: Hydrogen79%, Helium 18%, Methane 3%
- Many properties similar to Uranus.
- It has 14 known Moons,
  - only two can be seen from Earth: Triton(2705 km) and Nereid (340km) which have retrograde (moving clockwise) orbit.
  - Probably because they are captured objects.
- Neptune has a faint ring system, discovered in 1984.

- Voyager 2 flew by Neptune in 1989.



Hubble Space Telescope images



A Voyager 2 images of Neptune

Review Questions

- What is the primary difference between the inner planets and outer planets?
- Which planet has virtually no atmosphere?
- Why is the temperature of Venus higher than that of Mercury even though Mercury is closer to the Sun?
- What are the evidence that at one time water flowed on Mars? Which planet is closest in size to the earth?
- Which planet has the hottest temperatures?
- Why can't we see any surface details of Venus through a telescope?
- What makes Mars look red?
- What are the evidence that liquid water existed on Mars long time ago?
- What is the largest planet in the Solar System?
- What is the Great Red Spot and Jupiter?
- What are the band like features visible on Jupiter?
- Which planet was the first planet located through mathematical predictions rather than through regular observations of the sky?
- Why do Jupiter and Saturn radiate more energy than they receive from the Sun?
- What is unique about Saturn's moon Titan?
- What makes Uranus and Neptune blue in color?