IX. ASTRONOMY: THE GAS GIANTS

A. We begin with a brief summary of the properties of the giant planets.

1. Consider Jupiter, Saturn, Uranus, and Neptune in this order.

a. Their orbits have semimajor axes of 5.2, 9.5, 19.2, and 30.1 A.U.

b. Their orbital periods are 11.9, 29.5, 84.1, and 165 years.

c. Their radii are 11.2, 9.4, 4.0, and 3.9 times that of the Earth.

d. Their masses are 318, 95.2, 14.5, and 17.2 times that of Earth.

e. Their average densities are 1.3, 0.7, 1.3, and 1.6 g/cm^3.

f. Their rotation periods are 0.41, 0.45, 0.72, and 0.67 days.

g. Their rotation axes are tilted by 3.1^0, 26.7^0, 97.9^0, and 29.6^0.

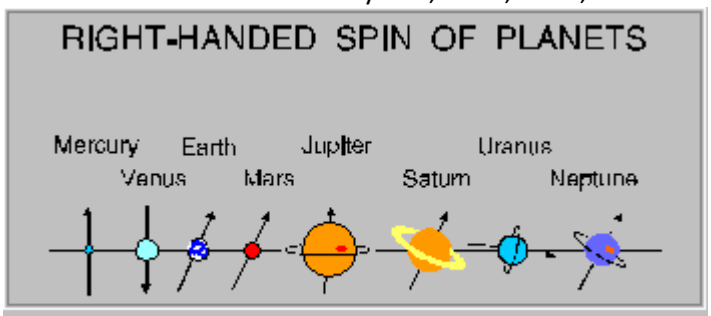


Figure 4 Spin and Orientation of the Planets

h. They have 16, 19, 17, and 8 recognized moons, (increases regularly).

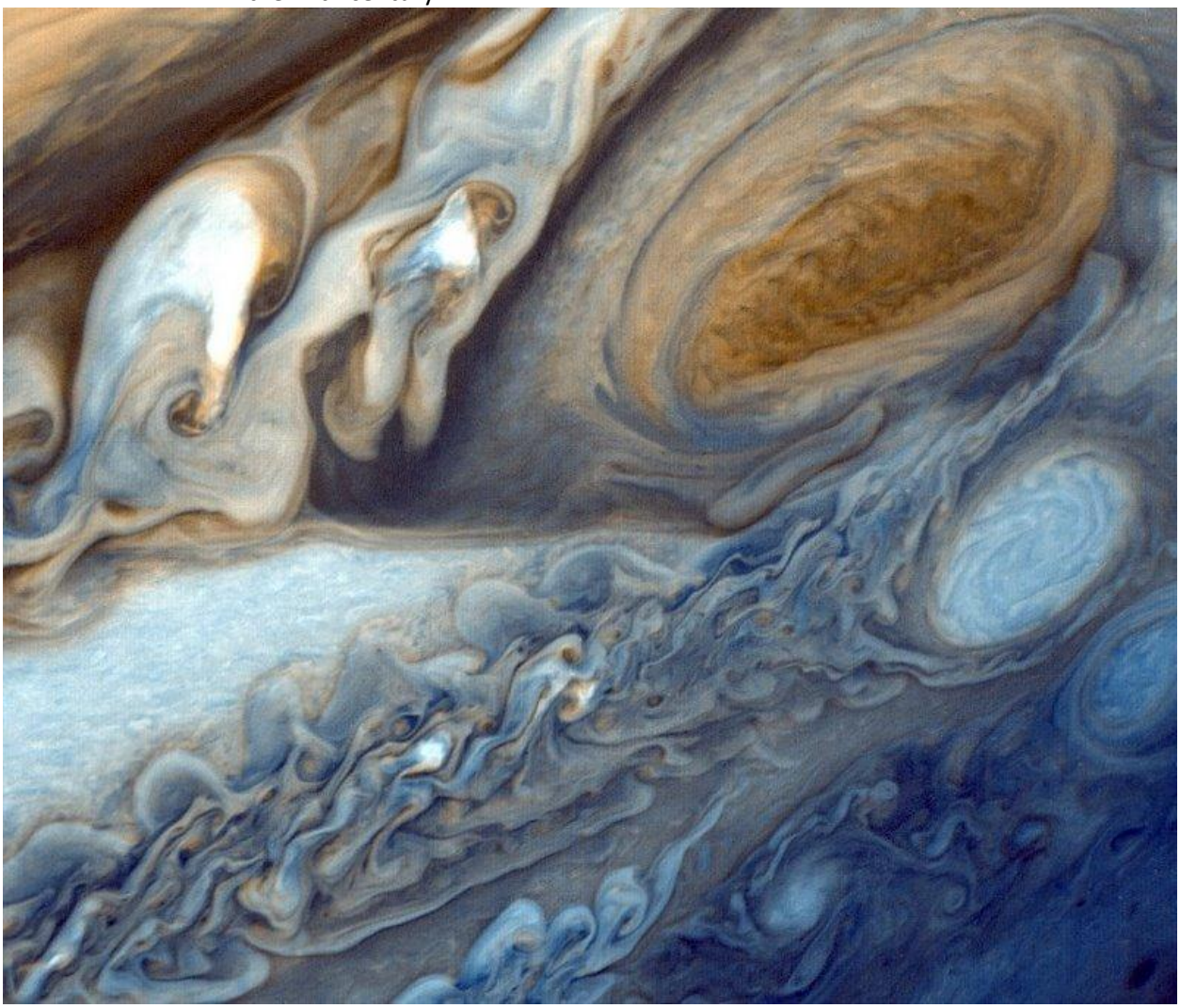
2. In words, the giant planets are far from the Sun, large, massive, low in density, rotate rapidly, and have many moons. It is believed that they are largely liquid, with gaseous atmospheres and small rocky/iron cores.

B. Jupiter is the fifth planet from the Sun. It is named after Jove, the King of the gods

1. It is more massive (by a factor of 2.5) than all the other planets combined.

a. It's radius and mass are 10% and 0.1% of the Sun's respectively.
b. Like the Sun, it consists primarily of hydrogen and helium.
c. In it's interior, hydrogen becomes molecular and liquefies. At great depths, the hydrogen has metallic properties: it conducts heat and electricity.
d. It probably has an Earth-like core of iron and silicates (rocks).
e. Jupiter appears oblate (squashed) because it spins so rapidly (1 rotation [day] = 10 hours).
f. It has a very strong magnetic field.

2. Jupiter's apparent ' surface" is simply the region of the atmosphere beyond which the gases become opaque.
   a. It exhibits many colorful bands that are parallel to the equator. The colors are due to various gases (methane, ammonia, etc.) with different temperatures and densities.
   b. There are also numerous spots and swirls that resemble storms.
   c. The famous "Great Red Spot" appears to tbe a giant high-pressure storm within which 2-3 Earths could fit. It is over 300 years old, having been seen in the 17th century.



d. In 1979, the Voyager 1 and 2 missions provided spectacular detailed views of

the surface features.

e. In 1995 - 1998, the Galileo spacecraft transmitted additional close-up images.

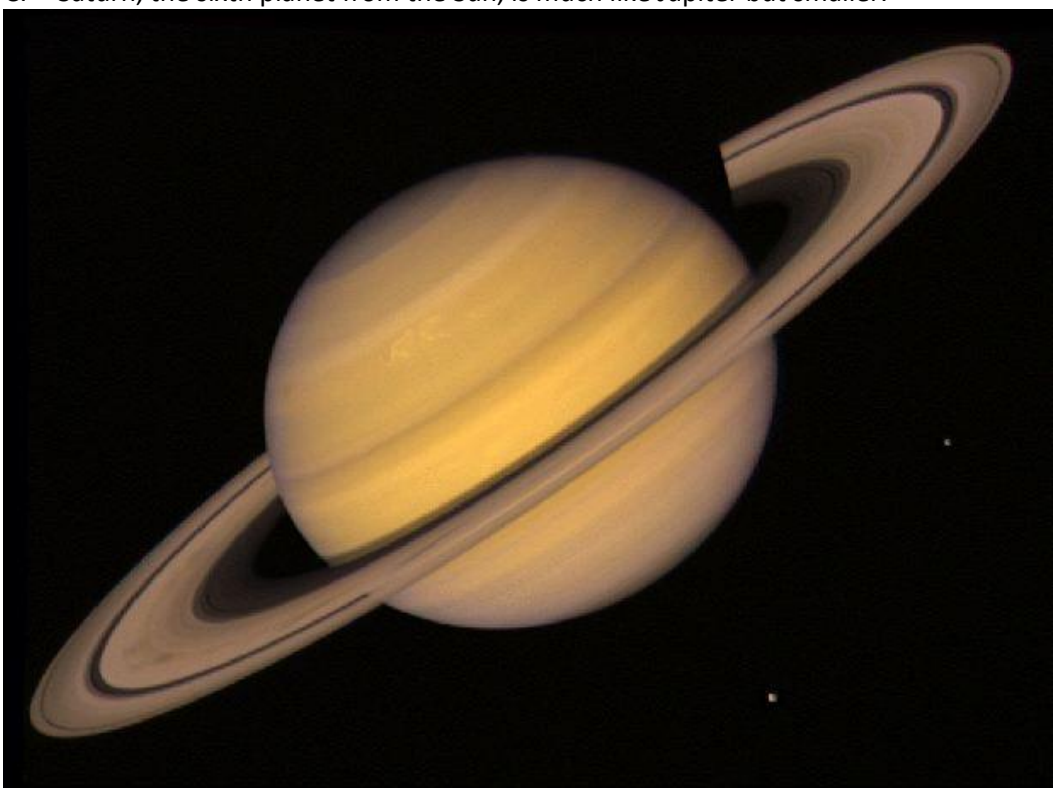
f. The Galileo probe sampled some of the gases below the surface and found an unexpected shortage of water, but this was probably on of the driest parts of Jupiter.

3. The great complexity of Jupiter's atmosphere is probably powered in part by gravitational contraction of interior gases.

a. Indeed, Jupiter radiates (mostly at infrared wavelengths) about 1.6 times as much energy as it receives from the Sun.

b. The gravitational release of energy leads to convection, storms , etc.

C. Saturn, the sixth planet from the Sun, is much like Jupiter but smaller.



1. It consists mostly of hydrogen and helium, with and Earth-like core.

a. It's average density is only 0.7 g/cm^3, less than that of water.

b. It has bands and spots, but less obvious than those on Jupiter.

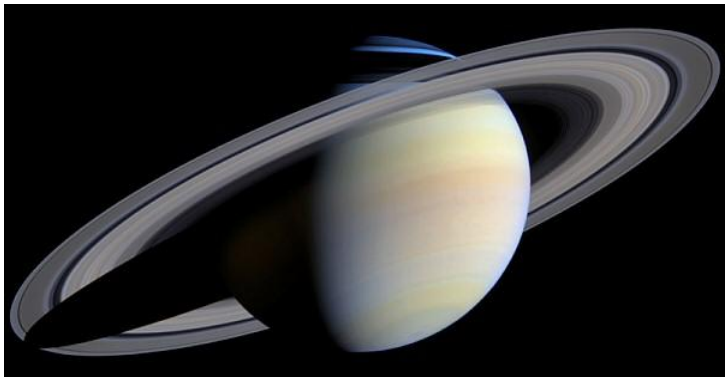
c. Since the release of gravitational energy is comparable in Saturn and Jupiter, perhaps Saturn looks different due to the smaller amount of solar heating.

d. Occasionally, large storms appear in Saturn's atmosphere. A few of these have been monitored with the Hubble Space Telescope. Among other things, we hope to gain a better understanding of storms on Earth from studies of Saturn.

2. Saturn boasts a magnificent set of rings.

a. These consist of ice chunks and icy rocks, mostly cm to meters in size.

b. Only about 20 m thick, they are thinner than a phonographic record (relative to their diameter).



c. The material probably failed to form a moon because of the tidal forces of Saturn, or it might be from a disrupted moon.

d. The rings are inside the "Roche limit", within which particles cannot gravitationally coalesce or accrete to form a moon.

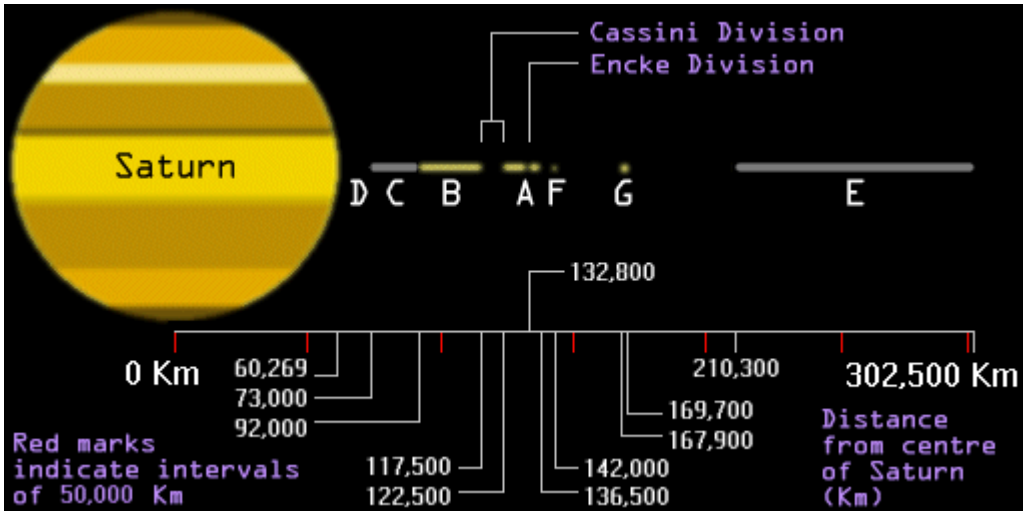
e. One mystery is how the rings manage to remain intact; perhaps small moonlets get torn up and gradually replenish the supply of material.

f. The rings are in Saturn's equatorial plane, which is inclined by 27^0 to it's orbital plane. Thus, they appear "edge on" twice per Saturn's 29 year orbital period.
   i) This last occurred in 1995.
   ii) The rings are difficult to detect when they are edge-on.

h. As seen from Earth under excellent viewing conditions, the rings consist of 4-5 parts. The two main parts are separated by a dark gap called Cassini's division.

i. In 1980, the Voyager spacecraft revealed that the rings actually consist of over 100,000 narrow ringlets; they can be distinguished from each other in specially enhanced photographs.

j. It is thought that gravitational interactions between small moons and particles in the rings might produce many, but perhaps not all, of the fine graduations. Interactions with Mimas (a moon), for example, are at least partly responsible for Cassini's division.



k. The changing tilt of Saturn's rings, as viewed from Earth's perspective, has led to beautiful views in 2003 and 2004.

3. Although Voyager 1 was directed out of the Solar System after passing Saturn, "gravity" assist" was used to help propel Voyager 2 toward Uranus.

4. The Cassini mission to Saturn in 2004 provided much new information about this beautiful planet and it's moons.

D. Uranus is the seventh planet from the Sun. It's correct pronunciation is YOUR-uh-nus.

1. It was not known to the ancients. W. Herschel discovered it in 1781.
2. Like the other giant planets, Uranus consists mostly of hydrogen and helium.
   a. However, unlike Jupiter and Saturn, the pressure deep inside is not sufficiently high to produce metallic hydrogen.
   b. It has an Earth-like core of heavy elements.
   c. Methane in it's outer atmosphere give it a greenish-blue hue.
   d. The outer atmosphere is cold: only about 60 K.
3. Uranus's axis of rotation is tipped by 98^0, nearly in it's orbital plane.
   a. Hence, Uranus rotates in a direction opposite that of most planets.
   b. It has extreme seasons in terms of Sun visibility over it's 84 year orbit.
   c. The atmosphere is remarkably featureless; apparently the uneven heating by the Sun is somehow smoothed out.
   d. Jupiter's atmosphere is far more dynamic; Jupiter receives more heat from the Sun, a larger reservoir of heat is stored inside, and it may even still be contracting a little.
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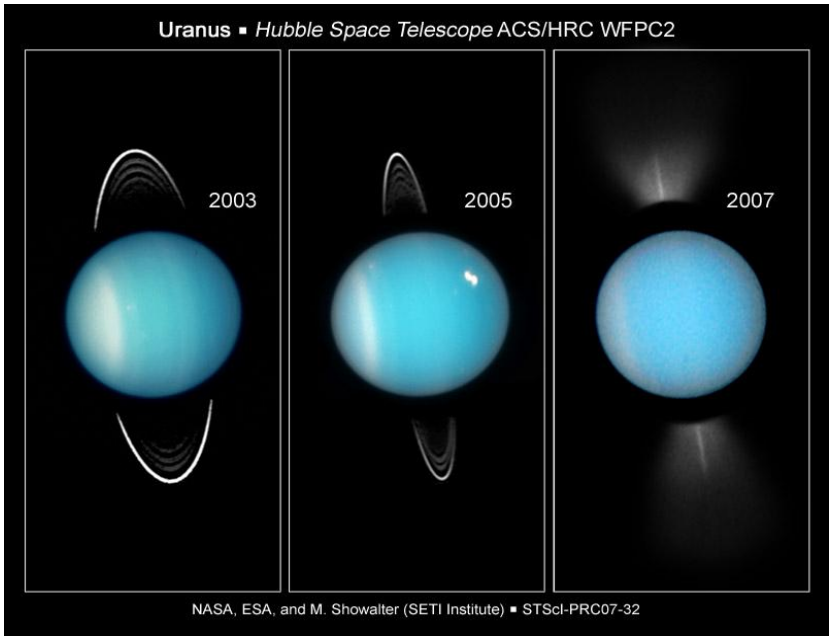
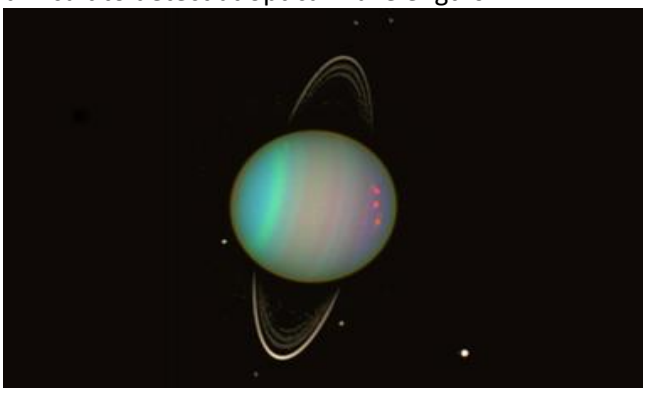
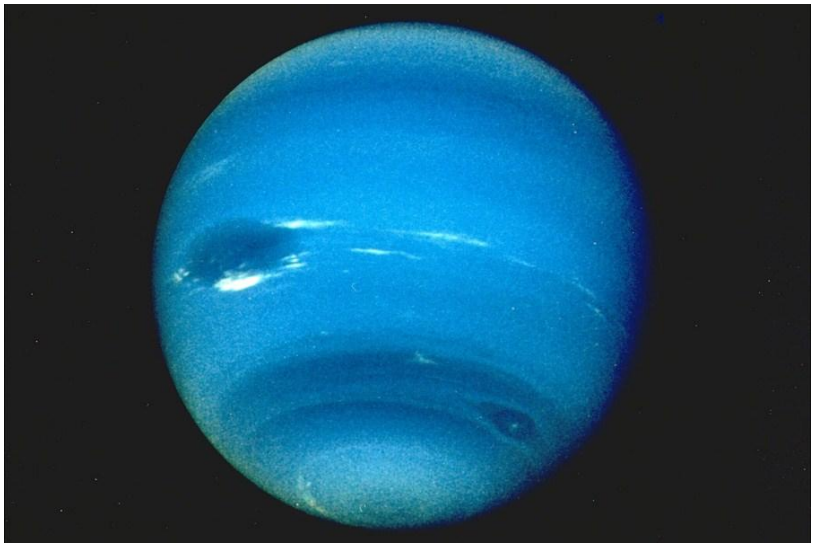


4. About 10 very narrow rings were discovered in 1977.
   a. Uranus passed in front of a bright star.
   b. The star blinked out many times, due to occultation by the rings.
   c. The short duration of the occultations indicated that some rings are ≤ 10 km wide.
   d. To explain this narrowness, it was proposed that each ring has two "shepherd moons" that keep it from spreading.
5. The Voyager 2 flyby in 1986 provided our first detailed views or Uranus.
   a. The presence of shepherd moons was confirmed for at least one of the rings.
   b. Uranus's magnetic field is tilted by about 60^0 relative to the rotation axis, and offset substantially from the planet's center. Some have speculated that these peculiarities and the 98^0 tilt of the rotation axis were caused by a giant collision.
   c. Good views were obtained of several moons.
   d. The jubilation over Voyager's success was dampened by the terrible Space Shuttle *Challenger* disaster a few days later.
   e. Striking new infrared images of Uranus, taken with one of the 8 m units of the Very Large Telescope (VLT) in Chile, nicely show the ring system, which is very difficult to detect at optical wavelengths.



E. Neptune is the eighth planet form the Sun.



1. It's discovery is one of the triumphs of celestial mechanics.
   a. The predicted and observed positions of Uranus disagreed in detail.
   b. U. Leverrier and J. Adams independently concluded that another planet must perturb Neptune, and calculated it's expected location.
   c. J. Galle searched around the predicted position and found Neptune in 1846.
   d. Galileo apparently saw Neptune in 1613, when it was nearly at the same position as Jupiter, but he didn't recognize it as a new planet.
2. Neptune is about the same size as Uranus and has similar structure.
   a. Methane in it's outer atmosphere makes it appear greenish-blue.
   b. Temperatures are very cold; about 40 K.
   c. Narrow arc-like structures (perhaps parts of rings) were detected by the method used to discover the rings of Uranus.
   d. The axis of rotation has a tilt of 30^0, typical of planets.
3. The Voyager 2 flyby in August 1989 provided a wealth of information.
   a. A complete set of narrow, clumpy rings was seen.
   b. The atmosphere was found to be far more dynamic than that of Uranus; winds up to 1100 km/hr, many spots, etc. This difference is not yet understood.
   c. The largest spot, known as the Great Dark Spot, was roughly mid-1990s with the Hubble Space Telescope showed no evidence for this feature.
   d. Wispy, high-altitude clouds of methane skirt around the spots.

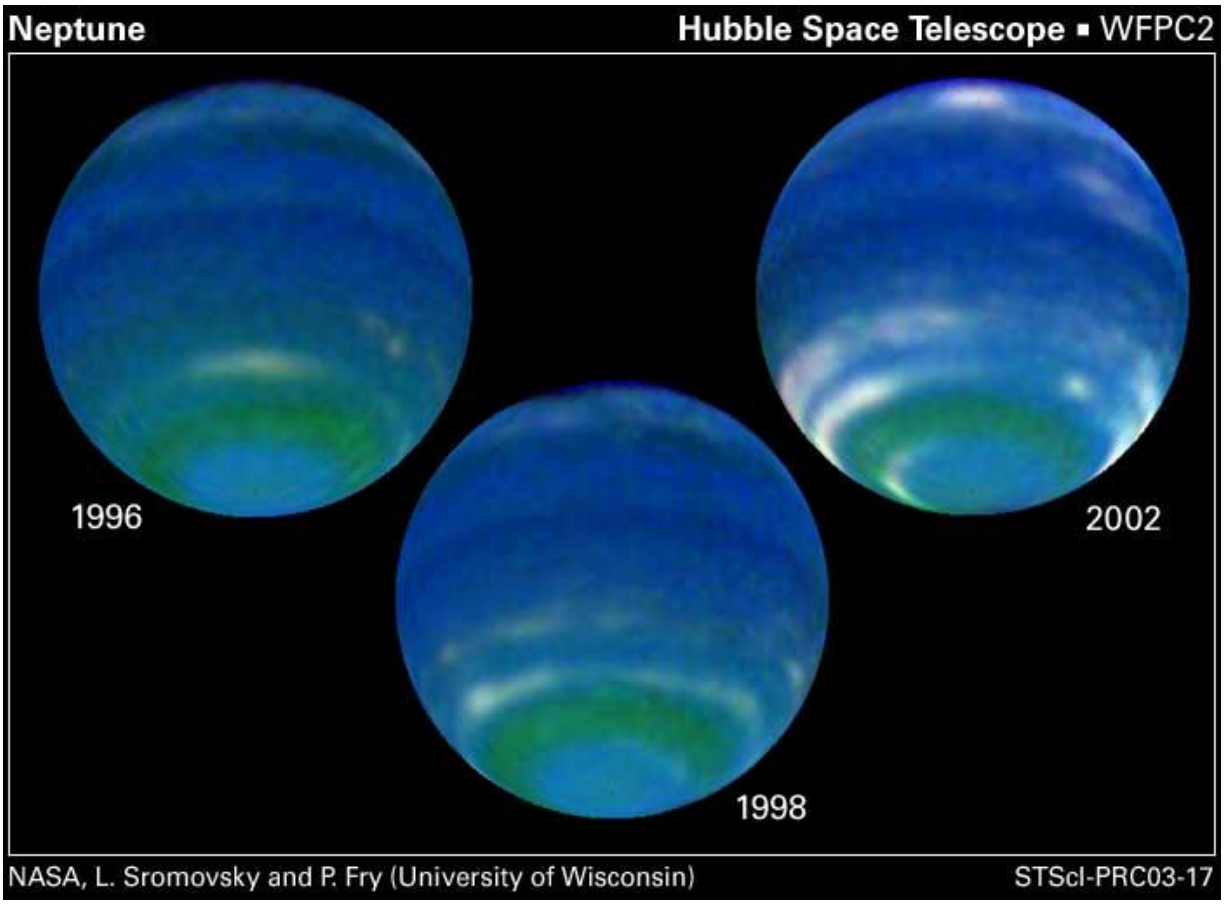
   e. Neptune's magnetic field, like that of Uranus, is tilted (by 50^0) and offset from

from the planet's center. Since Neptune's rotation axis is normal, this suggests that a giant collision was *not* responsible for the peculiarities of Uranus's magnetic field.

f. Neptune's large moon Triton is especially fascinating. Neptune and Triton were a great way to end the 12-year odyssey of Voyager 2.

g. Using adaptive optics on the Hubble telescope, astronomers have obtained detailed images of Neptune, showing the changing cloud patterns.

i) There is evidence that Neptune's southern hemisphere has gradually been warming up and forming more clouds; we are seeing seasonal changes.



F. Questions:

1. Summarize the properties of the four giant (jovian) planets, and compare them them with those of the four terrestrial planets.

2. Describe the visual appearance of Jupiter.

3. Describe the appearance, origin, and nature of Saturn's rings.

4. Explain why the rings essentially disappear from view twice during each 29-year orbit of Saturn.
5. Why are the chemical compositions of Jupiter and Saturn so close to that of

The Sun, but those of the terrestrial planets are not?

6. Summarize the main characteristics of Uranus and Neptune.

7. Describe how the existence and location of Neptune were predicted.

8. List some of the discoveries made when Voyager 2 visited Uranus and Neptune.