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ASTRONOMY

Chapter 11 THE GIANT PLANETS

PowerPoint Image Slideshow

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11.1 EXPLORING THE OUTER PLANETS

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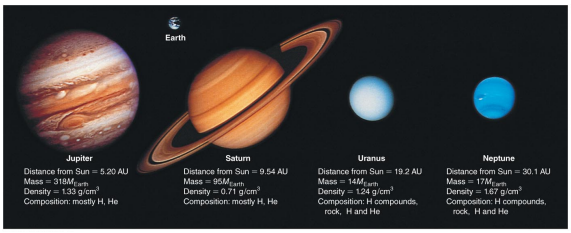

- **Giant Planets.** The four giant planets in our solar system all have hydrogen atmospheres, but the warm gas giants, Jupiter and Saturn, have tan, beige, red, and white clouds that are thought to be composed of ammonia ice particles with various colorants called "chromophores." The blue-tinted ice giants, Uranus and Neptune, are much colder and covered in methane ice clouds.

Basic Properties of the Jovian Planets

Planet	Distance (AU)	Period (years)	Diameter (km)	Mass (Earth = 1)	Density (g/cm^3)	Rotation (hours)
Jupiter	5.2	11.9	142,800	318	1.3	9.9
Saturn	9.5	29.5	120,540	95	0.7	10.7
Uranus	19.2	84.1	51,200	14	1.3	17.2
Neptune	30.0	164.8	49,500	17	1.6	16.1

Table 11.3

Exploration

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- **Galileo Probe Falling into Jupiter (Fig 11.3 artist's depiction).**
- Jupiter (60+ moons)
  - 1970's Pioneer 10&11 and Voyager 1&2
  - 1990's Ulysses & Galileo
  - 2000's Cassini & New Horizons
- Saturn (60+ moons)
  - 1979 Pioneer 11
  - 1981 and 1982 Voyager 1 & 2
  - 2004 Cassini
- Uranus (30- moons)
  - 1986 Voyager 2
- Neptune (15+ moons)
  - 1989 Voyager 2

Figure 11.2

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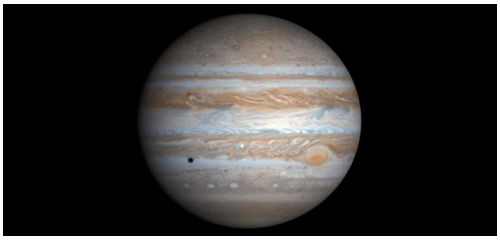
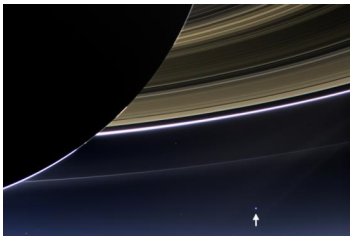


- **Jupiter.** The Cassini spacecraft imaged Jupiter on its way to Saturn in 2012. The giant storm system called the Great Red Spot is visible to the lower right. The dark spot to the lower left is the shadow of Jupiter's moon Europa. (credit: modification of work by NASA/JPL)

Figure 11.4



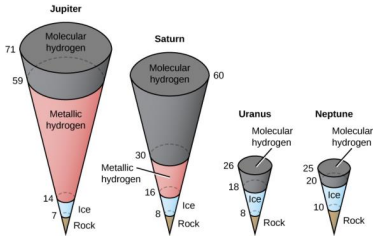
- **Earth as Seen from Saturn.** This popular Cassini image shows Earth as a tiny dot (marked with an arrow) seen below Saturn's rings. It was taken in July 2013, when Saturn was 1.4 billion kilometers from Earth. (credit: modification of work by NASA/JPL-Caltech/Space Science Institute)

11.2 THE GIANT PLANETS

- The jovian cores are very similar:
  ~ mass of 10 Earths
- The jovian planets differ in the amount of H/He gas accumulated.

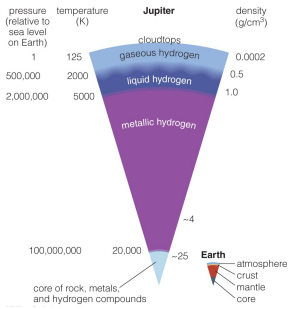
Why did that amount differ?

Figure 11.7



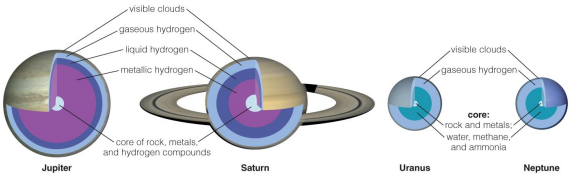
- **Internal Structures of the Jovian Planets.** Jupiter and Saturn are composed primarily of hydrogen and helium (but hydrogen dominates), but Uranus and Neptune consist in large part of compounds of carbon, nitrogen, and oxygen. (The diagrams are drawn to scale; numbers show radii in thousands of kilometers.)

Inside Jupiter



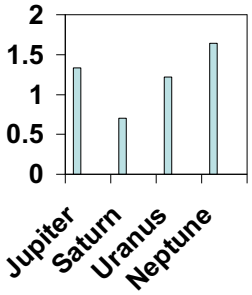
- High pressure inside of Jupiter causes the phase of hydrogen to change with depth.
- Hydrogen acts like a metal at great depths because its electrons move freely.
- The core is thought to be made of rock, metals, and hydrogen compounds.
- The core is about the same size as Earth but 10 times as massive.

Comparing Jovian Interiors



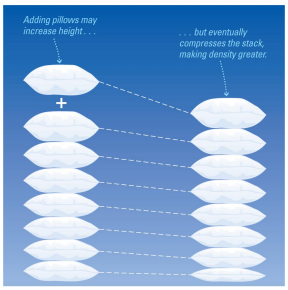
- Models suggest that cores of jovian planets have similar composition.
- Lower pressures inside Uranus and Neptune mean no metallic hydrogen.

Density Differences



- Uranus and Neptune are denser than Saturn because they have less H/He, proportionately.
- But that explanation doesn't work for Jupiter.

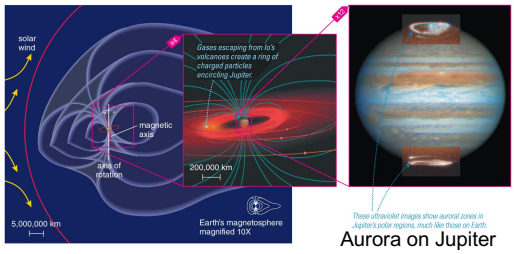
Sizes of Jovian Planets



a Adding pillows to a stack may increase its height at first but eventually compresses the stack, making its density greater.

- Adding mass to a jovian planet compresses the underlying gas layers.

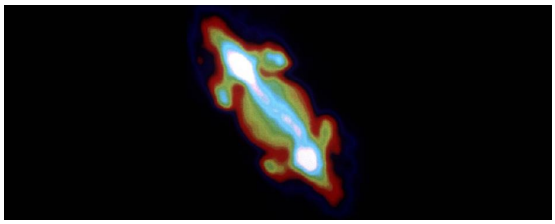
Jupiter's Magnetosphere



Aurora on Jupiter

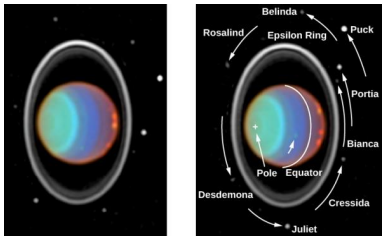
- Jupiter's strong magnetic field gives it an enormous magnetosphere.
- Gases escaping Io feed the donut-shaped Io torus.

Fig 11.8



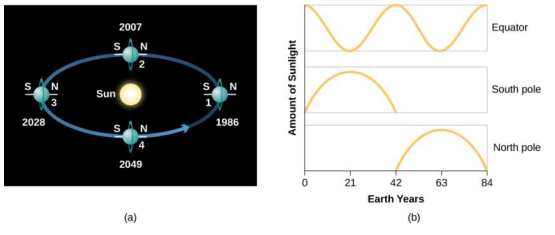
- **Jupiter in Radio Waves (Fig 11.8).** This false-color image of Jupiter was made with the Very Large Array (of radio telescopes) in New Mexico. We see part of the magnetosphere, brightest in the middle because the largest number of charged particles are in the equatorial zone of Jupiter. The planet itself is slightly smaller than the green oval in the center. Different colors are used to indicate different intensities of synchrotron radiation.

Figure 11.5



- **Infrared Image of Uranus.** The infrared camera on the Hubble Space Telescope took these false-color images of the planet Uranus, its ring system, and moons in 1997. The south pole of the planet (marked with a "+" on the right image) faces the Sun; its green color shows a strong local haze. The two images were taken 90 minutes apart, and during that time the five reddish clouds can be seen to rotate around the parallel to the equator. The rings (which are very faint in the visible light, but prominent in infrared) and eight moons can be seen around the equator. This was the "bull's eye" arrangement that Voyager saw as it approached Uranus in 1986. (credit: modification of work by Erich Karkoschka (University of Arizona), and NASA/ESA)

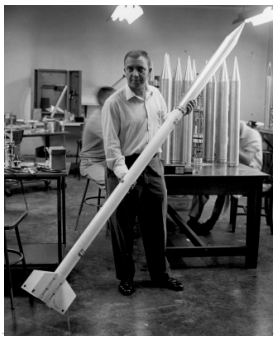
Figure 11.6



- **Strange Seasons on Uranus.**
  - (a) This diagram shows the orbit of Uranus as seen from above. At the time Voyager 2 arrived (position 1), the South Pole was facing the Sun. As we move counterclockwise in the diagram, we see the planet 21 years later at each step.
  - (b) This graph compares the amount of sunlight seen at the poles and the equator of Uranus over the course of its 84-year revolution around the Sun.

Figure 11.9

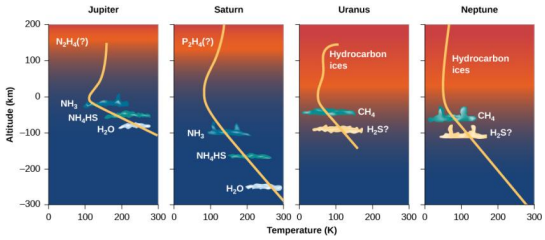
- **James Van Allen (1914–2006).** In this 1950s photograph, Van Allen holds a "rockoon." (credit: modification of work by Frederick W. Kent Collection, University of Iowa Archives)



11.3 ATMOSPHERES OF THE GIANT PLANETS

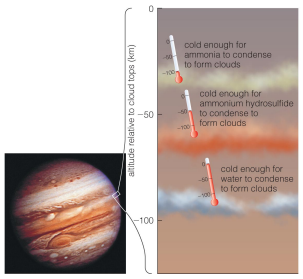
- **Jupiter's Colorful Clouds (Fig 11.10).** The vibrant colors of the clouds on Jupiter present a puzzle to astronomers: given the cool temperatures and the composition of nearly 90% hydrogen, the atmosphere should be colorless. One hypothesis suggests that perhaps colorful hydrogen compounds rise from warm areas.

Figure 11.12



- **Atmospheric Structure of the Jovian Planets.** In each diagram, the yellow line shows how the temperature (see the scale on the bottom) changes with altitude (see the scale at the left). The location of the main layers on each planet is also shown.

Jupiter's Atmosphere

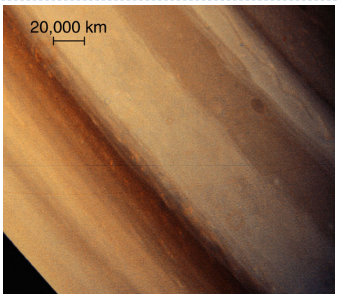


- Hydrogen compounds in Jupiter form clouds.
- Different cloud layers correspond to freezing points of different hydrogen compounds.
- Other jovian planets have similar cloud layers.

Jupiter's Colors

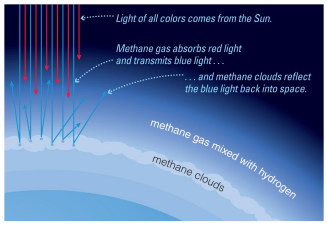
- Ammonium sulfide clouds (NH_4SH) reflect red/brown.
- Ammonia, the highest, coldest layer, reflects white.

Saturn's Colors



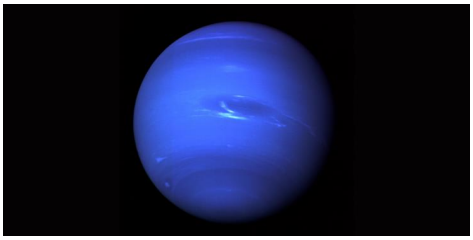
- Saturn's layers are similar but are deeper in and farther from the Sun—more subdued.

Methane on Uranus and Neptune



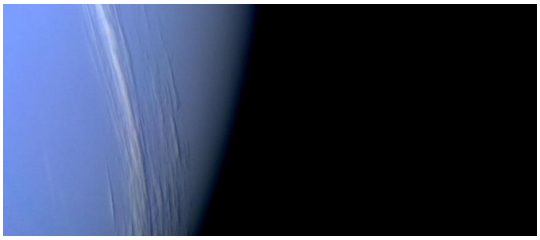
- Methane gas on Neptune and Uranus absorbs red light but transmits blue light.
- Blue light reflects off methane clouds, making those planets look blue.

Figure 11.15



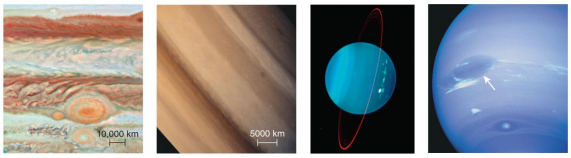
- **Neptune.** The planet Neptune is seen here as photographed by Voyager in 1989. The blue color, exaggerated with computer processing, is caused by the scattering of sunlight in the planet's upper atmosphere. (credit: modification of work by NASA)

Figure 11.16



- **High Clouds in the Atmosphere of Neptune.** These bright, narrow cirrus clouds are made of methane ice crystals. From the shadows they cast on the thicker cloud layer below, we can measure that they are about 75 kilometers higher than the main clouds. (credit: modification of work by NASA/JPL)

Weather on Jovian Planets



a This Hubble Space Telescope image shows Jupiter's southern hemisphere with the Great Red Spot, "Baby Red" (to its left), and "Red Jr." (below). Baby Red was torn apart by the Great Red Spot a few days later.

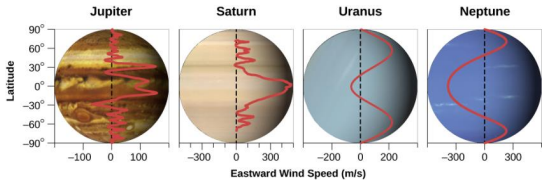
b Saturn's atmosphere, photographed by *Voyager 1*. Its banded appearance is very similar to that of Jupiter, but it has even faster winds.

c This infrared image of Uranus from the Keck Telescope shows several storms (the bright blotches) and Uranus's thin rings (red).

d Neptune's atmosphere, viewed from *Voyager 2*, shows bands and occasional strong storms. The large storm (white arrow) was called the Great Dark Spot.

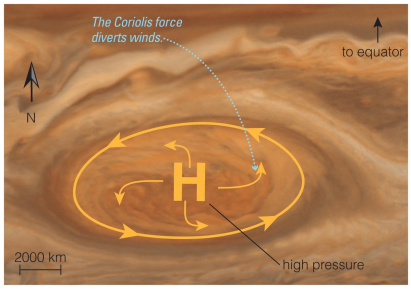
- All the jovian planets have strong winds and storms.

Figure 11.17



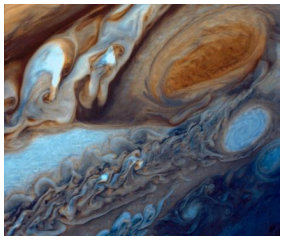
- **Winds on the Giant Planets.** This image compares the winds of the giant planets, illustrating that wind speed (shown on the horizontal axis) and wind direction vary with latitude (shown on the vertical axis). Winds are measured relative to a planet's internal rotation speed. A positive velocity means that the winds are blowing in the same direction as, but faster than, the planet's internal rotation. A negative velocity means that the winds are blowing more slowly than the planet's internal rotation. Note that Saturn's winds move faster than those of the other planets.

Jupiter's Great Red Spot



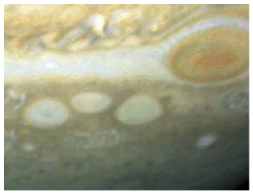
- A storm twice as wide as Earth
- Has existed for at least 3 centuries

Figure 11.19

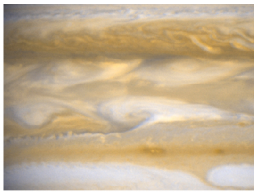


- **Jupiter's Great Red Spot.** This is the largest storm system on Jupiter, as seen during the Voyager spacecraft flyby. Below and to the right of the Red Spot is one of the white ovals, which are similar but smaller high-pressure features. The white oval is roughly the size of planet Earth, to give you a sense of the huge scale of the weather patterns we are seeing. The colors on the Jupiter image have been somewhat exaggerated here so astronomers (and astronomy students) can study their differences more effectively.

Figure 11.18



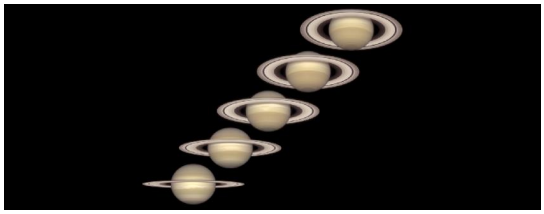
(a)



(b)

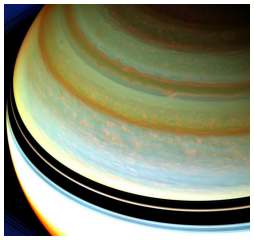
- **Storms on Jupiter.** Two examples of storms on Jupiter illustrate the use of enhanced color and contrast to bring out faint features.
- (a) The three oval-shaped white storms below and to the left of Jupiter's Great Red Spot are highly active, and moved closer together over the course of seven months between 1994 and 1995.
- (b) The clouds of Jupiter are turbulent and ever-changing, as shown in this Hubble Space Telescope image from 2007.

Figure 11.11



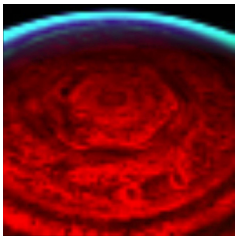
- **Saturn over Five Years.** These beautiful images of Saturn were recorded by the Hubble Space Telescope between 1996 and 2000. Since Saturn is tilted by 27°, we see the orientation of Saturn's rings around its equator change as the planet moves along its orbit. Note the horizontal bands in the atmosphere. (credit: modification of work by NASA and The Hubble Heritage Team (STScI/AURA))

Figure 11.13



- **Cloud Structure on Saturn.** In this Cassini image, colors have been intensified, so we can see the bands and zones and storms in the atmosphere. The dark band is the shadow of the rings on the planet. (credit: NASA/JPL-Caltech/Space Science Institute)

Figure 11.14



- **Hexagon Pattern on Saturn's North Pole.** In this infrared nighttime image from the Cassini mission, the path of Saturn's hexagonal jet stream is visible as the planet's north pole emerges from the darkness of winter.
- Winds are also extremely high on Saturn, with speeds of up to 1800 kilometers per hour measured near the equator.

Links

- VIDEO: Cassini 3 min
- VIDEO: Jupiter 8 min

Reading

- 11.1 optional
- 11.2
- 11.3