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ASTRONOMY

Chapter 12 RINGS, MOONS, AND PLUTO
PowerPoint Image Slideshow

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12.1 RING AND MOON SYSTEMS INTRODUCED

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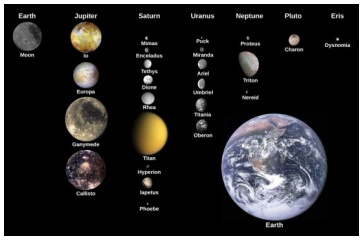
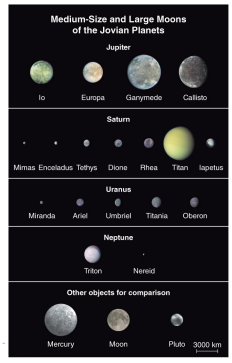


- **Moons of the Solar System.** This image shows some selected moons of our solar system and their comparison to the size of Earth's Moon and Earth itself. (credit: modification of work by NASA)

Sizes of Moons

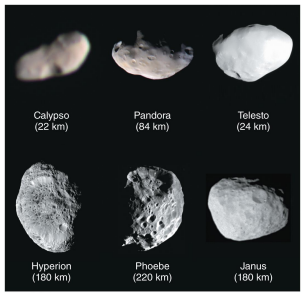
- Small moons (< 300 km)
  - No geological activity
- Medium-sized moons (300–1500 km)
  - Geological activity in past
- Large moons (> 1500 km)
  - Ongoing geological activity

Medium and Large Moons



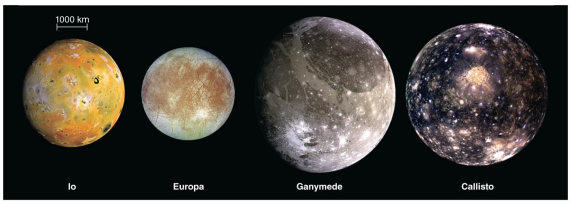
- Enough self-gravity to be spherical
- Have substantial amounts of ice
- Formed in orbit around jovian planets
- Circular orbits in same direction as planet rotation

Small Moons

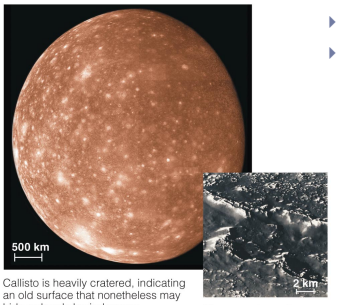


- Far more numerous than the medium and large moons
- Not enough gravity to be spherical: "potato-shaped"

12.2 THE GALILEAN MOONS OF JUPITER



Callisto



Callisto is heavily cratered, indicating an old surface that nonetheless may hide a deeply buried ocean.

Close-up photo shows a dark powder overlaying the low areas of the surface.

- "Classic" cratered iceball
- Has a magnetic field!?
  - Not do to tidal heating

Figure 12.3

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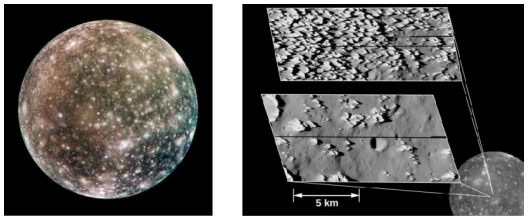


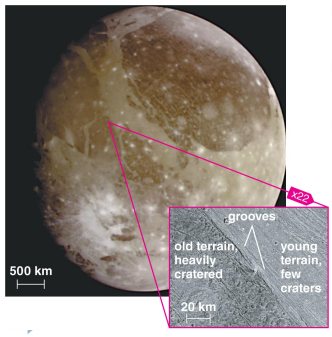
(a) (b)

Callisto(Fig 12.3).

(a) Jupiter's outermost large moon shows a heavily cratered surface. Astronomers believe that the bright areas are mostly ice, while the darker areas are more eroded, ice-poor material.

(b) These high-resolution images, taken by NASA's Galileo spacecraft in May 2001, show the icy spires (top) on Callisto's surface, with darker dust that has slid down as the ice erodes, collecting in the low-lying areas. The spires are about 80 to 100 meters tall. As the surface erodes even further, the icy spires eventually disappear, leaving impact craters exposed, as shown in the lower image.

Ganymede



- Largest moon in the solar system
- Clear evidence of geological activity
- Tidal heating plus heat from radio-active decay?

Figure 12.4

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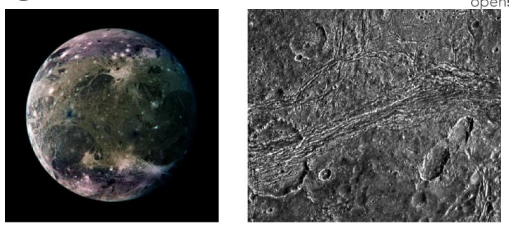


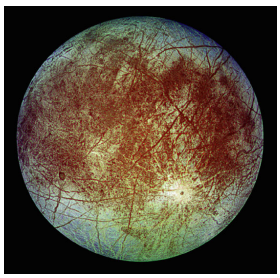
(a) (b)

Ganymede.

(a) This global view of Ganymede, the largest moon in the solar system, was taken by Voyager 2. The colors are enhanced to make spotting differences easier. Darker places are older, more heavily cratered regions; the lighter areas are younger (the reverse of our Moon). The brightest spots are sites of geologically recent impacts.

(b) This close-up of Nicholson Regio on Ganymede shows an old impact crater (on the lower left-hand side) that has been split and pulled apart by tectonic forces. Against Ganymede's dark terrain, a line of grooves and ridges appears to cut through the crater, deforming its circular shape.

Europa



- Waterworld
- Ice on the surface
- Liquid ocean under the surface
- Tidal heating.

Tidal stresses crack Europa's surface ice

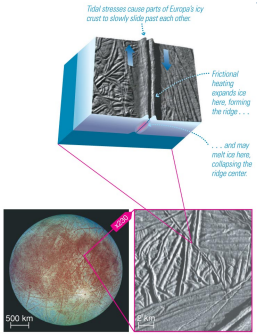


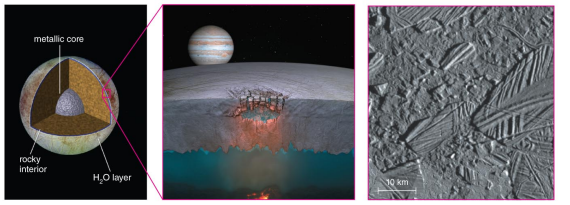
Figure 12.5

- **Evidence for an Ocean on Europa.**

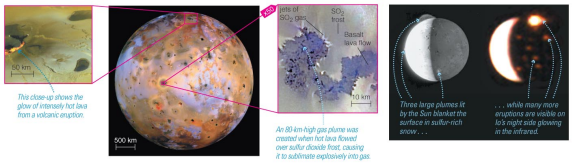
(a) A close-up of an area called Conamara Chaos is shown here with enhanced color. This view is 70 kilometers wide in its long dimension. It appears that Conamara is a region where Europa's icy crust is (or recently was) relatively thin and there is easier access to the possible liquid or slushy ocean beneath. In fact, the formations seen here look similar to views of floating sea-ice and icebergs in Earth's Arctic Ocean.

(b) In this high-resolution view, the ice is *wrinkled* and crisscrossed by long ridges. Where these ridges intersect, we can see which ones are older and which younger; the younger ones cross over the older ones. The ridges are a natural result of the flexing of the moon.]

Europa's interior



Io's

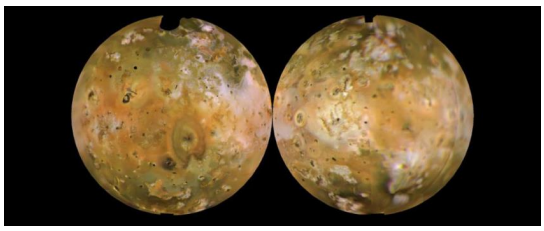


a Most of the black, brown, and red spots on Io's surface are recently active volcanic features. White and yellow areas are sulfur dioxide (SO_2) and sulfur deposits, respectively, from volcanic gases. (Photographs from the *Galileo* spacecraft; some colors slightly enhanced or altered.)

b Two views of Io's volcanoes taken by *New Horizons* on its way to Pluto.

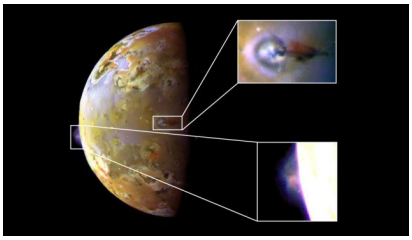
- Io is the most volcanically active body in the solar system, but why?

Figure 12.7



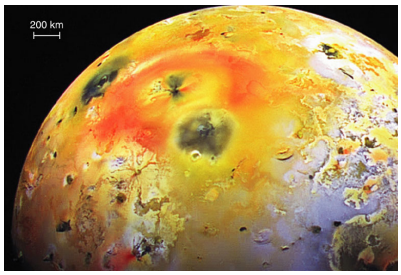
- **Two Sides of Io.** This composite image shows both sides of the volcanically active moon Io. The orange deposits are sulfur snow; the white is sulfur dioxide. (Carl Sagan once quipped that Io looks as if it desperately needs a shot of penicillin.) (credit: modification of work by NASA/JPL/USGS)

Figure 12.8



- **Volcanic Eruptions on Io.** This composite image from NASA's Galileo spacecraft shows close-ups (the two inset photos) of two separate volcanic eruptions on Jupiter's volcanic moon, Io. In the upper inset image, you can see a close up of a bluish plume rising about 140 kilometers above the surface of the volcano. In the lower inset image is the Prometheus plume, rising about 75 kilometers from Io's surface. The Prometheus plume is named for the Greek god of fire. (credit: modification of work by NASA/JPL)

Io's Volcanoes

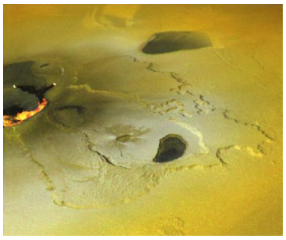


- Volcanic eruptions continue to change Io's surface.

Figure 12.9

- **Volcanic Changes on Io.** These three images were taken of the same 1700-kilometer-square region of Io in April 1997, September 1997, and July 1999. The dark volcanic center called Pillan Patera experienced a huge eruption, producing a dark deposit some 400 kilometers across (seen as the grey area in the upper center of the middle image). In the right image, however, some of the new dark deposit is already being covered by reddish material from the volcano Pele. Also, a small unnamed volcano to the right of Pillan has erupted since 1997, and some of its dark deposit and a yellow ring around it are visible on the right image (to the right of the grey spot). The color range is exaggerated in these images.

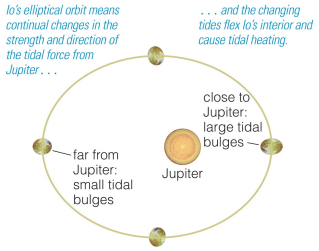
Figure 12.10



- **Lava Fountains on Io.** Galileo captured a number of eruptions along the chain of huge volcanic calderas (or pits) on Io called Tvashtar Catena in this false-color image combining infrared and visible light. The bright orange-yellow areas at left are places where fresh, hot lava is erupting from below ground. (credit: modification of work by NASA/JPL)

Tidal Heating

Io is squished and stretched as it orbits Jupiter.

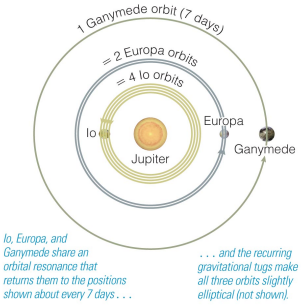


a Tidal heating arises because Io's elliptical orbit (exaggerated in this diagram) causes varying tides.

But why is its orbit so elliptical?

Orbital Resonances

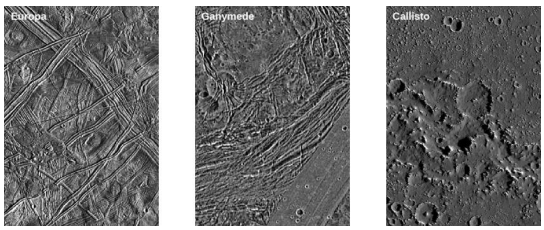
The tugs add up over time, making all three orbits elliptical.



Every seven days, these three moons line up.

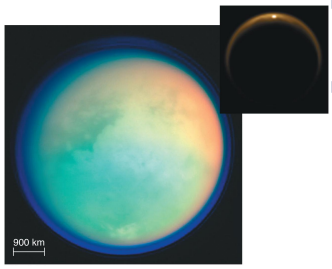
b Io's orbit is elliptical because of the orbital resonance Io shares with Europa and Ganymede.

Figure 12.11



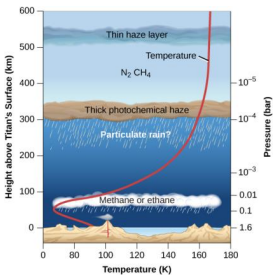
- **Three Icy Moons.** These Galileo images compare the surfaces of Europa, Ganymede, and Callisto at the same resolution. Note that the number of craters (and thus the age of the surface we see) increases as we go from Europa to Ganymede to Callisto. The Europa image is one of those where the system of cracks and ridges resembles a freeway system. (credit: modification of work by NASA/JPL/DLR)

Titan



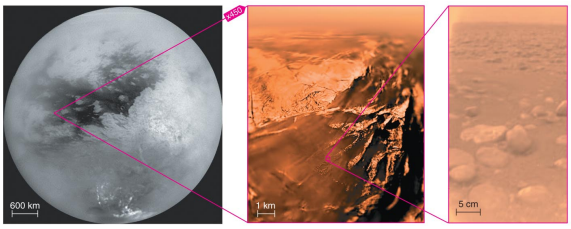
- Saturn's Moon
- Titan is the only moon in the solar system that has a thick atmosphere.
- It consists mostly of nitrogen with some argon, methane, and ethane.

Figure 12.12



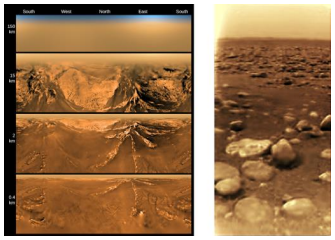
- **Structure of Titan's Atmosphere.** Some characteristics of Titan's atmosphere resemble those of Earth's atmosphere, although it is much colder than our planet. The red line indicates the temperature of Titan's atmosphere at different altitudes.

Titan's Surface



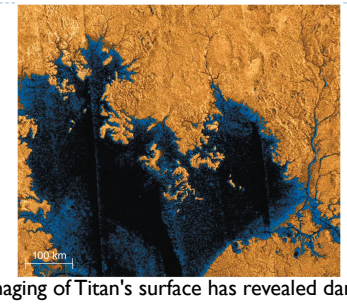
- The *Huygens* probe provided a first look at Titan's surface in early 2005.
- It had liquid methane, "rocks" made of ice.

Figure 12.13



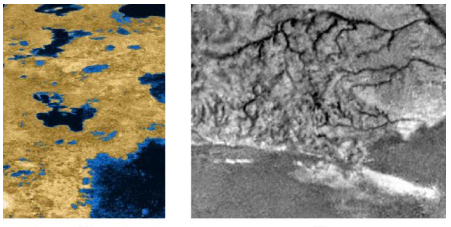
- **Views of the Surface of Titan.**
- The left image shows the views of Titan from the descent camera, in a flattened projection, at different altitudes.
- The right image, taken after landing, shows a boulder-strewn surface illuminated by faint reddish sunlight. The boulders are composed of water ice.

Titan's "Lakes"



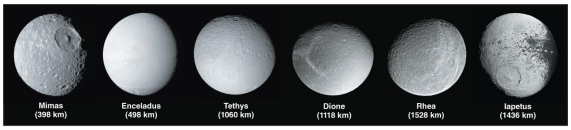
- Radar imaging of Titan's surface has revealed dark, smooth regions that may be lakes of liquid methane.

Figure 12.14



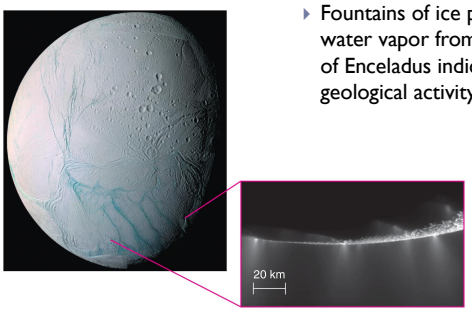
- **Titan's Lakes.**
- (a) This Cassini image from a September 2006 flyby shows the liquid lakes on Titan. Their composition is most likely a combination of methane and ethane. (Since this is a radar image, the colors are artificially added. The dark blue areas are the smooth surfaces of the liquid lakes, and yellow is the rougher solid terrain around them.)
- (b) This mosaic of Titan's surface from the Cassini-Huygens mission shows in detail a high ridge area and many narrow, sinuous erosion channels that appear to be part of a widespread network of "rivers" carved by flowing hydrocarbons.

Medium Moons of Saturn



- Almost all show evidence of past volcanism and/or tectonics.

Ongoing Activity on Enceladus



- Fountains of ice particles and water vapor from the surface of Enceladus indicate that geological activity is ongoing.

Figure 12.29

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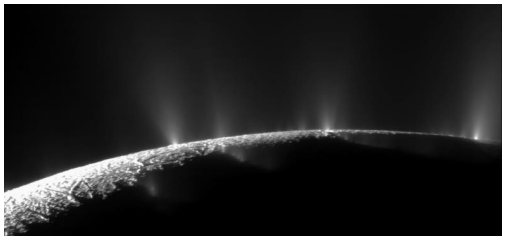
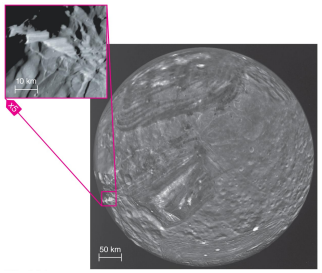


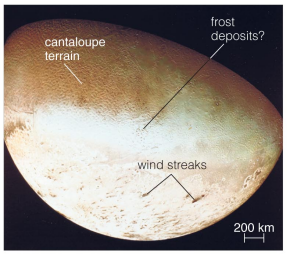
- **Geysers on Enceladus.** This Cassini image shows a number of water geysers on Saturn's small moon Enceladus, apparently salty water from a subsurface source escaping through cracks in the surface. You can see curved lines of geysers along the four "tiger stripes" on the surface. (credit: modification of work by NASA/JPL/Space Science Institute)

Medium Moons of Uranus



- Varying amounts of geological activity occur.
- Moon Miranda has large tectonic features and few craters (episode of tidal heating in past?).

Neptune's Moon Triton



Triton's southern hemisphere as seen by *Voyager 2*.

This close-up shows lava-filled impact basins similar to the lunar maria, but the lava was water or slush rather than molten rock.

- Similar to Pluto, but larger
- Evidence for past geological activity

Figure 12.15

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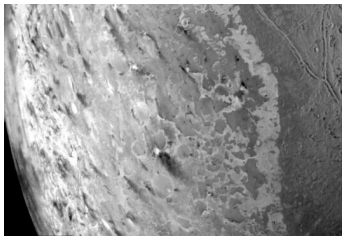
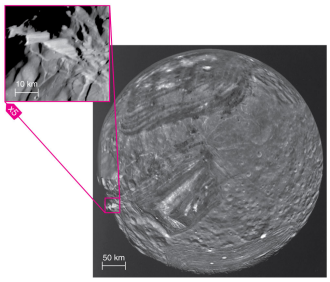
- **Neptune's Moon Triton.** This mosaic of Voyager 2 images of Triton shows a wide range of surface features. The pinkish area at the bottom is Triton's large southern polar cap. The south pole of Triton faces the Sun here, and the slight heating effect is driving some of the material northward, where it is colder. (credit: modification of work by NASA/JPL/USGS)

Figure 12.16

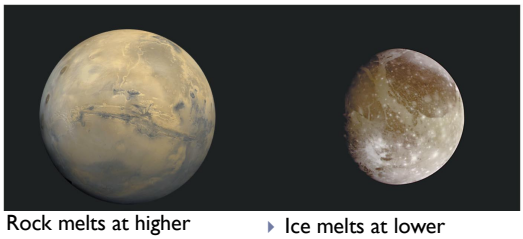


- **Triton's Geysers.** This close-up view shows some of the geysers on Neptune's moon Triton, with the long trains of dust pointing to the lower right in this picture.

Why are jovian planet moons more geologically active than small rocky planets?

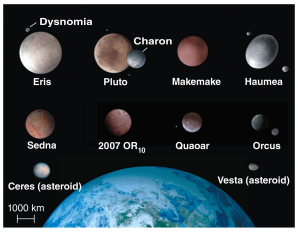


Why are jovian planet moons more geologically active than small rocky planets?



- Rock melts at higher temperatures.
- Only large rocky planets have enough heat for activity.
- Ice melts at lower temperatures.
- Tidal heating can melt internal ice, driving activity.

12.4 PLUTO AND CHARON

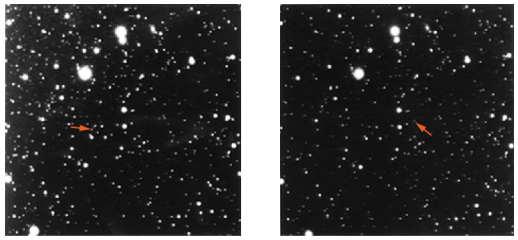


- There are many icy objects like Pluto on elliptical, inclined orbits beyond Neptune.
- The largest ones are comparable in size to Earth's Moon.

Figure 12.18

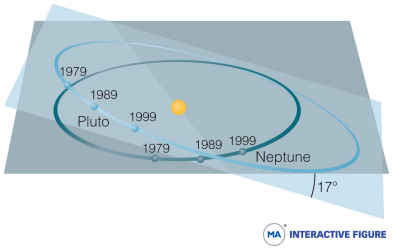
- **Comparison of the Sizes of Pluto and Its Moon Charon with Earth.** This graphic vividly shows how tiny Pluto is relative to a terrestrial planet like Earth. That is the primary justification for putting Pluto in the class of dwarf planets rather than terrestrial planets. (credit: modification of work by NASA)

Figure 12.17



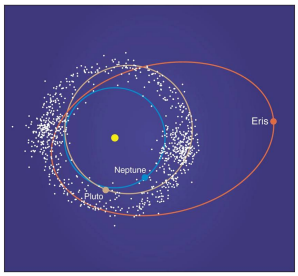
- **Pluto's Motion.** Portions of the two photographs by which Clyde Tombaugh discovered Pluto in 1930. The left one was taken on January 23 and the right on January 29. Note that Pluto, indicated by an arrow, has moved among the stars during those six nights. If we hadn't put an arrow next to it, though, you probably would never have spotted the dot that moved. (credit: modification of work by the Lowell Observatory Archives)

Pluto's Orbit



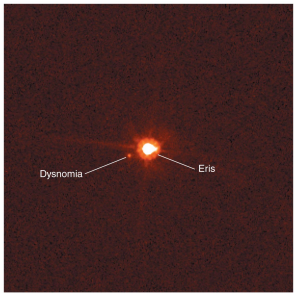
- Pluto's orbit is tilted and significantly elliptical.
- Neptune orbits three times during the time Pluto orbits twice—resonance prevents a collision.

Kuiper Belt Objects



- These large, icy objects have orbits similar to the smaller objects in the Kuiper Belt that become short period comets.
- So are they very large comets or very small planets?

Discovering Large Iceballs



- In summer 2005, astronomers discovered Eris, an iceball even larger than Pluto.
- Eris even has a moon: Dysnomia.

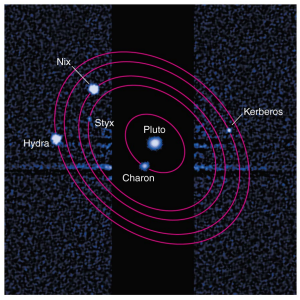
Is Pluto a planet?

- In 2006, the International Astronomical Union decided to call Pluto and objects like it "dwarf planets."

What is Pluto like?

- Its largest moon, Charon, is nearly as large as Pluto itself (probably made by a major impact).
- Pluto is very cold (40 K).
- Pluto has a thin nitrogen atmosphere that refreezes onto the surface as Pluto's orbit takes it farther from the Sun.

HST's View of Pluto and Its Moons



a This Hubble Space Telescope photo shows Pluto and its five known moons, along with orbital paths for the moons. Horizontal stripes are scattered light from Charon and Pluto in the long exposure.

Figure 12.20

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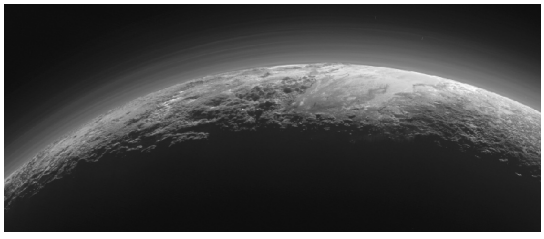


- **Haze Layers in the Atmosphere of Pluto.** This is one of the highest-resolution photos of Pluto, taken by the New Horizons spacecraft 15 minutes after its closest approach. It shows 12 layers of haze. Note also the range of mountains with heights up to 3500 meters. (credit: modification of work by NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute)

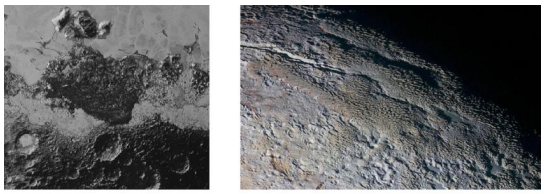
Figure 12.21

- **Global Color Image of Pluto.** This New Horizons image clearly shows the variety of terrains on Pluto. The dark area in the lower left is covered with impact craters, while the large light area in the center and lower right is a flat basin devoid of craters. The colors you see are somewhat enhanced to bring out subtle differences. (credit: modification of work by NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute)

Figure 12.22

- **Diversity of Terrain on Pluto.** This enhanced color view of a strip of Pluto's surface about 80 kilometers long shows a variety of different surface features. From left to right, we first cross a region of "badlands" with some craters showing, and then move across a wide range of mountains made of water ice and coated with the redder material we saw in the previous image. Then, at right, we arrive at the "shoreline" of the great sea of frozen nitrogen that the mission scientists have nicknamed the "Sputnik Plains." This nitrogen sea is divided into mysterious cells or segments that are many kilometers across.

Figure 12.23



(a) (b)

- **Diversity of Terrains on Pluto.**

(a) In this photo, about 250 kilometers across, we can see many different kinds of terrain. At the bottom are older, cratered highlands; a V-shaped region of hills without cratering points toward the bottom of the image. Surrounding the V-shaped dark region is the smooth, brighter frozen nitrogen plain, acting as glaciers on Earth do. Some isolated mountains, made of frozen water ice, are floating in the nitrogen near the top of the picture.

(b) This scene is about 390 kilometers across. The rounded mountains, quite different from those we know on Earth, are named Tartarus Dorsa. The patterns, made of repeating ridges with the more reddish terrain between them, are not yet understood.

Figure 12.24

(a) (b)

- **Pluto's Large Moon Charon.**

(a) In this New Horizons image, the color has been enhanced to bring out the color of the moon's strange red polar cap. Charon has a diameter of 1214 kilometers, and the resolution of this image is 3 kilometers.

(b) Here we see the moon from a slightly different angle, in true color. The inset shows an area about 390 kilometers from top to bottom. Near the top left is an intriguing feature—what appears to be a mountain in the middle of a depression or moat.

12.5 PLANETARY RINGS

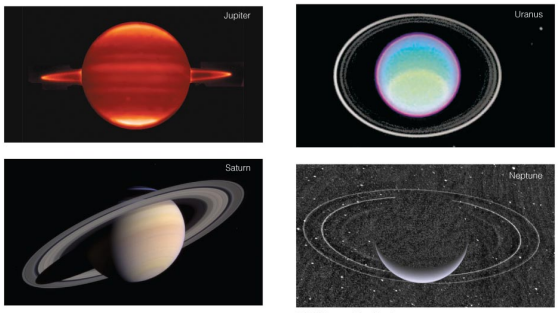
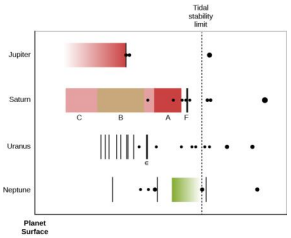
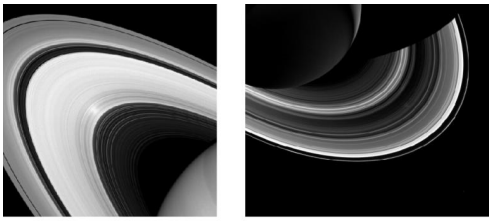


Figure 12.25



- **Four Ring Systems.** This diagram shows the locations of the ring systems of the four giant planets. The left axis represents the planet's surface. The dotted vertical line is the limit inside which gravitational forces can break up moons (each planet's system is drawn to a different scale, so that this stability limit lines up for all four of them). The black dots are the inner moons of each planet on the same scale as its rings. Notice that only really small moons survive inside the stability limit.

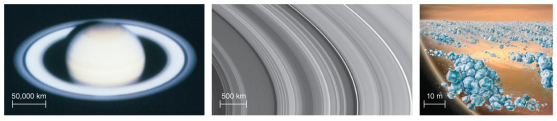
Figure 12.26



(a) (b)

- **Saturn's Rings as Seen from Above and Below.**
  - (a) The view from above is illuminated by direct sunlight.
  - (b) The illumination seen from below is sunlight that has diffused through gaps in the rings.

What are Saturn's rings like?

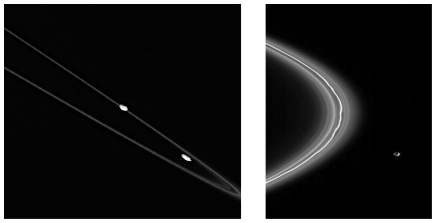


a This Earth-based telescopic view of Saturn makes the rings look like large, concentric sheets. The dark gap within the rings is called the *Cassini division*.

b This image of Saturn's rings from the *Cassini* spacecraft reveals many individual rings separated by narrow gaps.

c Artist's conception of particles in a ring system. Particles clump together because of gravity, but small random velocities cause collisions that break them up.

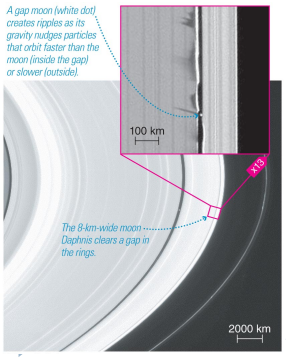
Figure 12.32



(a) (b)

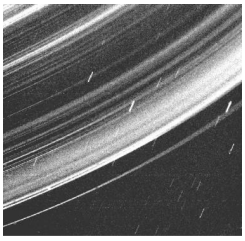
- **Saturn's F Ring and Its Shepherd Moons.**
  - (a) This Cassini image shows the narrow, complex F Ring of Saturn, with its two small shepherd moons Pandora (left) and Prometheus (right).
  - (b) In this closer view, the shepherd moon Pandora (84 kilometers across) is seen next to the F ring, in which the moon is perturbing the main (brightest) strand of ring particles as it passes. You can see the dark side of Pandora on this image because it is being illuminated by the light reflected from Saturn.

Gap Moons



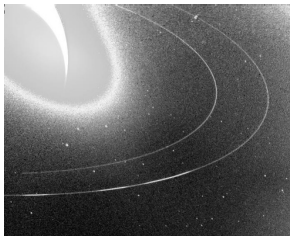
- Some small moons create gaps within rings.

Figure 12.30



- **Rings of Uranus.** The Voyager team had to expose this image for a long time to get a glimpse of Uranus' narrow dark rings. You can see the grainy structure of "noise" in the electronics of the camera in the picture background. (credit: modification of work by NASA/JPL)

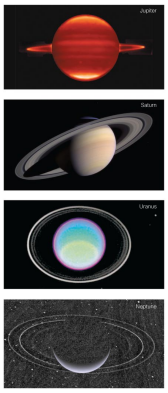
Figure 12.31



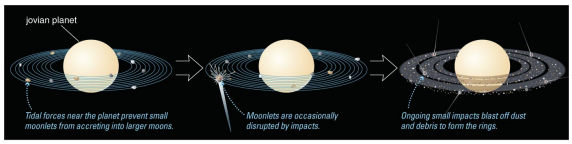
- **Rings of Neptune.** This long exposure of Neptune's rings was photographed by Voyager 2. Note the two denser regions of the outer ring. (credit: modification of work by NASA/JPL)

Jovian Ring Systems

- All four jovian planets have ring systems.
- Others have ring particles that are smaller and darker than Saturn's.



Ring Formation



- Jovian planets all have rings because they possess many small moons close-in.
- Impacts on these moons are random.
- Saturn's incredible rings may be an "accident" of our time.

Links

- VIDEO: Moons 4 min
- VIDEO Enceladus 3 min

Reading

- 12.1
- 12.2
- 12.3
- 12.4
- 12.5