Brooks Observatory sessions this week

Monday through Thursday 8:30 PM, or after class

Tonight’s session may be cancelled because of clouds. As of 6 PM, things looked marginal.  

Not cancelled yet!

Bring your *blue* ticket.

A short, journal-type report on your experience will be due in class Wednesday, October 31.

If you attended a September session at Brooks and turned in a report, you have already satisfied this requirement and do not need to attend any more sessions.
Tips for observing sessions

• Don’t expect the view through the telescope to look like the pictures in the textbook.

• Don’t allow yourself to be rushed when at the eyepiece.

• Ask as many questions as you like.
Homework 5 is due today.

Today’s Topics

Titan, a satellite of Saturn
Saturn’s rings
Meteorites
Asteroids
Comets

Quiz 5: October 31

• October 22: Venus (chapter 7), Jupiter, jovian planets, Galilean satellites of Jupiter (chapter 8)
• Today’s topics, above
• Monday, October 29: The Sun
Saturn's satellite **Titan**

Second largest satellite in solar system, after Ganymede; Saturn's only large satellite

Bulk density is 1.9 grams per cubic centimeter; suggests ice & rock bulk composition
Atmosphere

- Opaque in visible light because of haze & clouds
- Composition mostly nitrogen (N₂)
- Methane (CH₄) can exist as solid, liquid, or gas (similar to water on Earth)
- Other substances: various hydrocarbons
- A recent discovery: propane (C₃H₈) in upper atmosphere
How it got that way

• Water is frozen beneath surface

• Sunlight broke up ammonia (NH₃) molecules, hydrogen escaped

• Hydrocarbons like ethane (C₂H₆) formed

In conditions thought to exist at surface, ethane can rain out and form lakes

Seeing through the atmosphere to the surface with Cassini

• Short-wavelength infrared, just beyond visible: specific wavelengths

• Radar
Cassini findings. Here, “ice” means mixture of frozen volatiles: water, methane, ammonia

- Bright, icy hills, possibly volcanic (icy lava)
- Dry river beds emptying into large plains - radar image
- Liquid not directly visible
- Radar shows areas of low reflectivity (smooth); possibly bodies of liquid
**Huygens lander findings**

- During descent, photographed river valleys
- Soft, mushy surface
- Ice boulders, smoothed by erosion
Saturn’s rings

From Earth, appear as thin, continuous sheets

But close examination shows many thin ringlets.

Ringlets in turn are made of small bodies, each in individual orbit around Saturn.

Rings give a strong echo of radar transmission, similar to echoes from icebergs.

Ring particles are probably ice-rich, house sized and smaller.
Gaps in rings (for example, Cassini division) are caused by repeated gravitational tug from satellite Mimas.

- Orbital period in gap is half the period of Mimas
- Repeated tugs eject ring particles from that location, gap is left
Jovian planets’ rings

Jupiter, Uranus, and Neptune also have rings, but they are thin, the ring particles are mostly dark (low reflectivity) and the rings are difficult to see.

Origin of rings

- Temporary: ring particles are being ground down to dust by collisions/impacts
- Satellites large and small are being pulverized as well; they are the source of new ring particles
- Number of particles in rings probably varies over time; brightness, visibility of rings may change.
Small bodies of the solar system: debris from planet building

Meteorites
Asteroids
Kuiper Belt Objects
Comets
Meteorites

Terminology

- **Meteors**
  - Short-lived trails of light — “shooting stars”
  - Produced when small interplanetary particles enter the Earth’s atmosphere and vaporize because of frictional heating
  - Called “meteor showers” when they come in bunches
  - The Leonids are a famous shower that occurs in November.
Showers are named after the constellation from which the meteors appear to come; owing to a perspective effect, they *radiate* away from a point.
- Meteoroids: chunks of rock in space, which may or may not strike a planet

- Meteorites: chunks of rock that have struck a planet
Meteorites: two main types

- Processed meteorites: stones, stony irons, irons
  - Iron meteorites easily identified.

Example:

After following this link, click on "Iron meteorites" in the left sidebar
– Solidified from liquid, similar to planetary rocks
– Broken fragments of a planet-sized, differentiated parent body: stones from mantle/crust, irons from core

● Primitive meteorites. Example:

After following this link, click on "Stony meteorites" in the left sidebar
– Made of tiny grains stuck together
– Appear to have formed by condensation directly from gas phase; never liquid
– Compared to planetary rock, rich in substances that are easily driven out by heating
– Rich in water of hydration
– Some are rich in carbon-bearing compounds, even including amino acids (non-biological origin)
– Never have been subjected to heating or processing of any kind; were never part of a larger parent body
– Preserve record of conditions at their formation
Radioisotope ages

- All primitive meteorites: $4.56 \pm 0.01$ billion years
- Evidence for solar-system-wide condensation event, supports nebular theory
- Interpreted as age of solar system, meaning date of first formation of solid material in primordial cloud surrounding infant Sun
- Processed meteorites are slightly but definitely (up to 0.1 billion years) younger. They came from parent bodies that underwent subsequent evolution. Implies rapid formation of planets.
Where meteorites come from

When a meteorite is seen to fall, its path can often be traced backwards, and its prior orbit around the Sun can be calculated.

In all such cases, the far end of the ellipse is in the asteroid belt, between the orbits of Mars and Jupiter.

Implication: meteorites originally were chunks of asteroids that were broken off in collisions.

There is also other evidence that meteorites are chunks of asteroids.
Meteorites from Mars
During formation of an impact crater, a small portion of the ejected material can reach escape speed from the planet and go into orbit around the Sun. Eventually, a few fragments may reach Earth.

About 20 meteorites are thought to have come from Mars in this way.

Evidence:
- Mineral makeup suggests formerly belonged to a planet’s crust
- Trapped gases exactly correspond to composition of Mars’s atmosphere.
Asteroids

Location

• Most are in *main belt* between orbits of Mars & Jupiter
• A few are in orbits that cross that of Earth or Mars; collisions theoretically possible

Characteristics

• Largest asteroid: Ceres, diameter about 600 miles
• Most are much smaller; likely collision fragments
• The largest ones are spherical, while smaller ones have *irregular shapes*
– Gravity pulls large, massive objects into a spherical shape.

– For small objects, gravity is too weak to overcome native strength of rock.

– Transition from spherical to irregular shapes at diameters between 300 & 600 miles.
Comets

Visible appearance

- Tail
- Head

Comet West, 1976
Model: “dirty snowball” or “icy dirtball”

• Nucleus up to about 10 miles across made of ices, rock powder (dust), possibly chunks of rock

• When comet approaches Sun, ices vaporize, dust particles released from ice, atmosphere develops, hides nucleus
Nature of tail

- Always points away from Sun
- Dust pushed by sunlight, forms *dust tail*
- Gas pushed by solar wind, forms *ion tail*
- These forces produce two tails.
Nucleus hidden by atmosphere or *coma*; size estimated indirectly, typically a few miles
Nucleus of Comet Halley: image from *Giotto* spacecraft

- Surprisingly dark
- Spacecraft particle sensors found carbon-rich material
- General remark: dark, carbon-rich material is abundant in outer asteroid belt and beyond.

Originate in two “comet reservoirs”
**An erupting comet**

Comet Holmes, a short-period comet with a period of about 7 years, elliptical orbit

Currently near opposition, about 1.6 AU from Earth, in the constellation Perseus, approaching Sun and Earth

Normally very faint, difficult to see, but last weekend it brightened several hundred thousand times, is now naked eye visible in good sky conditions.

The eruption is probably a sudden release of a lot of ice.

It should be a good sight—yellow fuzz ball—in binoculars, small telescopes. I’ll post a link to a [sky map](#) after class.
Kuiper Belt

- More than 800 objects now known
- Extends from Pluto’s orbit (40 AU) to 50 AU
- Pluto is 2nd largest object known in Kuiper Belt; largest is called Eris
- Circular or somewhat elliptical orbits
- Occasionally, the gravitational pull from Neptune deflects a comet into a highly elliptical orbit that plunges into inner solar system
- Origin of most comets with periods less than about 200 years
Oort Cloud

- Spherical cloud containing billions of comets
- About 50,000 to 100,000 AU from Sun, essentially at rest there
- Occasionally, gravitational pull from a passing star nudges a comet toward the Sun (or ejects it from solar system)
- Comets enter inner solar system on orbits that have shapes of extremely long, narrow ellipses
Short-period comets: after many passages close to the Sun, the comet’s ices eventually vaporize.

Only a cloud of rock powder and chunks remains, continuing to orbit the Sun and gradually spreading out along the orbit.

When the Earth passes through such a cloud of debris, we experience a meteor shower.
Brown, P. G. et al. 2000, Science, 290, 320
“The Fall, Recovery, Orbit, and Composition of the Tagish Lake Meteorite: A New Type of Carbonaceous Chondrite”