8. Welcome to the Solar System

"How vast those Orbs must be, and how inconsiderable this Earth, the Theater upon which all our mighty Designs, all our Navigations, and all our Wars are transacted, is when compared to them. A very fit consideration, and matter of Reflection, for those Kings and Princes who sacrifice the lives of so many People, only to flatter their Ambition in being Masters of some pitiful corner of this small Spot."

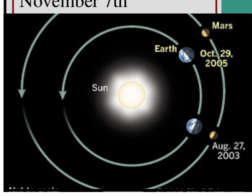
Christiaan Huygens (1629 -- 1695)
Dutch Astronomer and Scholar

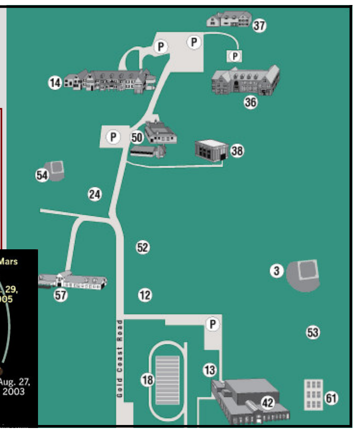
Agenda

- Announce:
  - Thursday:
    - Review for test next Tuesday on Ch. 5-8, various labs (Constellations, Thin Lenses, Diffraction) and lab procedures ("Aspects of Observing," "Telescopes & Light," "Lab and Labwork")…all multiple choice (no T/F)?
    - Debate: Should this country at this time spend its limited space exploration budget on both manned and unmanned flights or restrict itself to automated robotic missions?
  - Diffraction Results?
  - Observations: Wednesdays at 6:30pm Location: to be discussed
- Constellation of the day
- Chapter 8—Intro to the Solar System

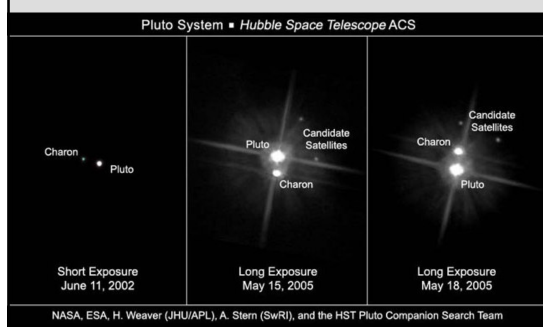
Where Shall We Observe?

BTW: Mars is passing very close to Earth these few weeks…only 43 million miles…is at **opposition** on November 7th

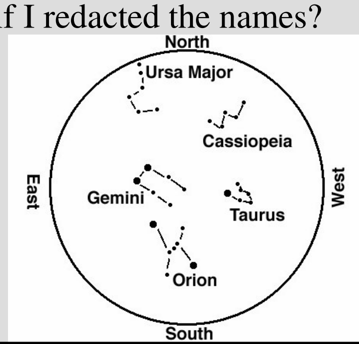




Pluto…now w/ 3 moons



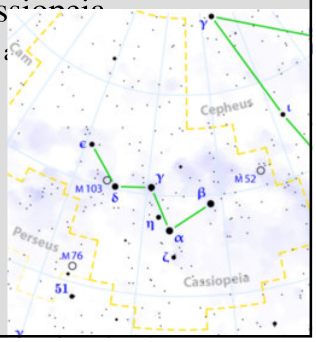
Could you identify constellations if I redacted the names?



What about on here?

Constellation of the Day: Cassiopeia

- 5 bright stars making a
- Near NCP



8.1 Comparative Planetology

Our goals for learning:

- What can we learn by comparing the planets to each other?

Comparative Planetology

- Studying the similarities among and differences between the *planets*
  - this includes moons, asteroids, & comets
- This approach is useful for learning about:
  - the physical processes which shape the planets
  - the origin and history of our Solar System
  - the nature of planetary systems around other stars

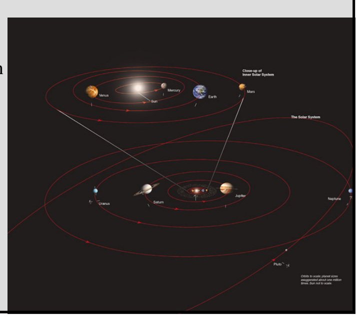
8.2 The Layout of the Solar System

Our goals for learning:

- What are the major patterns of motion in our solar system?
- What are the two major types of planet?
- Where do we find asteroids and comets in the solar system?
- Describe a few important exceptions to the general rules.

The Layout of the Solar System

- Large bodies in the Solar System have orderly motions
  - planets orbit counterclockwise in same plane
  - orbits are almost circular
  - the Sun and most planets rotate counterclockwise
  - most moons orbit counterclockwise



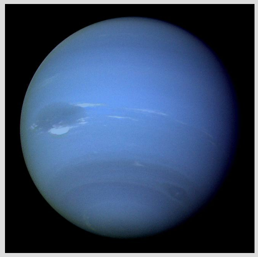
The Layout of the Solar System

- Planets fall into two main categories
  - Terrestrial (i.e. Earth-like)—
    Mercury, Venus, Earth, Mars
  - Jovian (i.e. Jupiter-like or gaseous)—
    Jupiter, Saturn, Uranus, and Neptune
- What about the misfit Pluto? Is it a planet?

Terrestrial Planets	Jovian Planets
Smaller size and mass	Larger size and mass
Higher density (rocks, metals)	Lower density (light gases, hydrogen compounds)
Solid surface	No solid surface
Closer to the Sun (and closer together)	Farther from the Sun (and farther apart)
Warmer	Cooler
Few (if any) moons and no rings	Rings and many moons

Mars

Terrestrial



Neptune

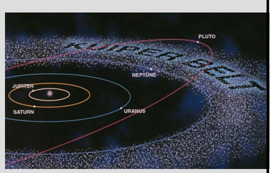
Jovian

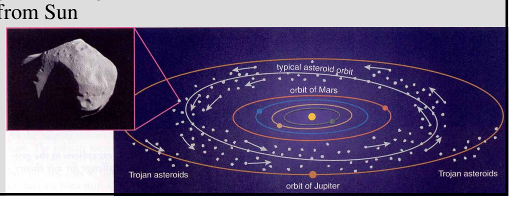
Photo	Planet	Average Distance from Sun (AU)	Temperature†	Relative Size	Average Equatorial Radius (km)	Average Density (g/cm³)	Composition	Known Moons	Rings?
	Mercury	0.387	700 K	·	2,440	5.43	Rocks, metals	0	No
	Venus	0.723	740 K	•	6,051	5.24	Rocks, metals	0	No
	Earth	1.00	290 K	•	6,378	5.52	Rocks, metals	1	No
	Mars	1.52	240 K	·	3,397	3.93	Rocks, metals	2 (tiny)	No
	Most asteroids	2–3	170 K	·	≤500	1.5–3	Rocks, metals	?	No
	Jupiter	5.20	125 K	●	71,492	1.33	H, He, hydrogen compounds‡	28	Yes
	Saturn	9.53	95 K	●	60,268	0.70	H, He, hydrogen compounds‡	30	Yes
	Uranus	19.2	60 K	●	25,559	1.32	H, He, hydrogen compounds‡	21	Yes
	Neptune	30.1	60 K	●	24,764	1.64	H, He, hydrogen compounds‡	8	Yes
	Pluto	39.5	40 K	·	1,160	2.0	Ices, rock	1	No
	Most comets	10–50,000	A few K§	·	A few km?	<1?	Ices, dust	?	No

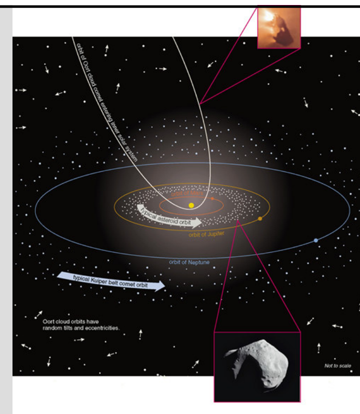
*Appendix C gives a more complete list of planetary properties.
†Surface temperatures for all objects except Jupiter, Saturn, Uranus, and Neptune, for which cloud-top temperatures are listed.
‡Includes water (H_2O), methane (CH_4), and ammonia (NH_3).
§Comets passing close to the Sun warm considerably, especially their outer layers.

Layout of Solar System

- Asteroid belt—between Mars and Jupiter orbits
- Kuiper belt—comets orbit in same plane and direction as planets, from Neptune's orbit out
- Oort cloud—comets in random orbits—not planar—at great distance from Sun







A Few Exceptions to the Rules…

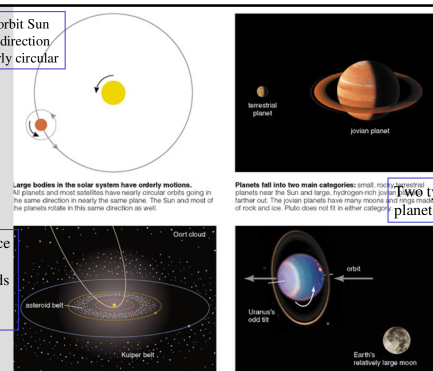
- Both Uranus & Pluto are tilted on their sides.
- Venus rotates "backwards" (i.e. clockwise).
- Triton orbits Neptune "backwards."
- Earth is the only terrestrial planet with a relatively large moon.

Planets orbit Sun in same direction and nearly circular

Two types of planets

Existence of Asteroids & Comets

Certain Exceptions



Large bodies in the solar system have orderly motions. All planets and most satellites have nearly circular orbits going in the same direction in nearly the same plane. The Sun and most of the planets rotate in this same direction as well.

Planets fall into two main categories: small, rocky terrestrial planets near the Sun and large, hydrogen-rich jovian planets farther out. The jovian planets have many moons and rings made of rock and ice. Pluto does not fit in either category.

Swarms of asteroids and comets populate the solar system. Asteroids are concentrated in the asteroid belt, and comets populate the regions known as the Kuiper belt and the Oort cloud.

Several notable exceptions to these general trends stand out, such as planets with unusual axis tilts or surprisingly large moons, and moons with unusual orbits.

8.3 A Brief Tour of the Solar System

Our goals for learning:

- How does the Sun influence the planets?
- Describe an interesting feature of each planet.

The Sun – King of the Solar System

- How does the Sun influence the planets?
  - Its gravity regulates the orbits of the planets.
  - Its heat is the primary factor which determines the temperature of the planets.
  - It provides practically all of the visible light in the Solar System.
  - High-energy particles streaming out from the Sun influence planetary atmospheres and magnetic fields.

The Sun's Energy Output

- Each second, transforms 600 million tons H into 596 millions tons of He
- Converts 4 million tons of mass into energy each second
- Been doing so for 5 billion years and the tank is only half empty (so-to-speak)

What is density?

density = mass/volume

typical units: [g/cm^3]

Density of water is *defined* as 1 g/cm^3.

Mercury

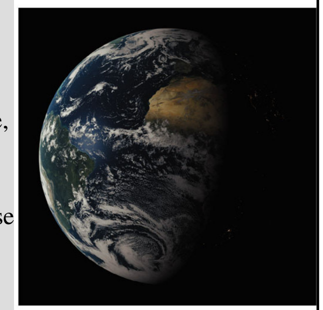
- 2^{nd} smallest planet (Pluto)
- No volcanoes, earthquakes, wind, rain, life, atmosphere
- Craters almost everywhere, tall cliffs
- Mostly iron, most metal-rich planet
- NASA's *Messenger (2007)* and ESA's *Bepi-Colombo* (2011) scheduled to visit

Venus

- Nearly identical in size to Earth
- Dense clouds hide surface except for radar
- Huge greenhouse effect makes surface hot
- Thick atmosphere causes high pressure
- Mountains, valleys, craters…volcanic

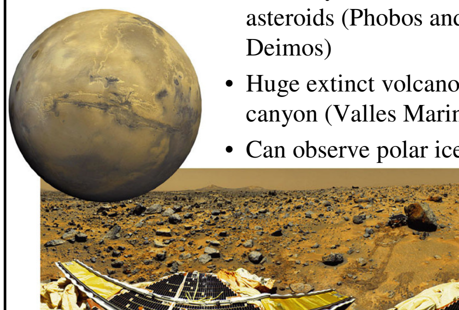
Earth

- Only known planet with life (supposedly intelligent)
- Only planet with conditions for humans (water, oxygen, temperature, etc)
- Mysterious large moon made of cheese



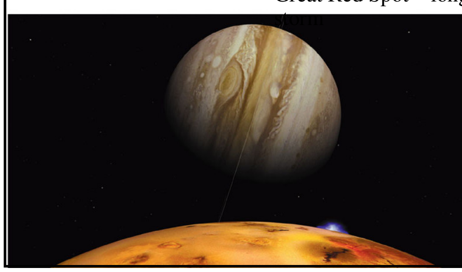
Mars

- About half Earth's diameter
- Two tiny moons that look like asteroids (Phobos and Deimos)
- Huge extinct volcanoes, great canyon (Valles Marineris)
- Can observe polar ice caps



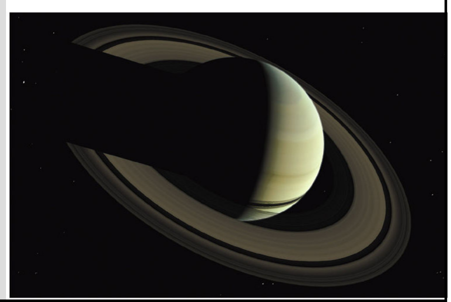
Jupiter

- Double distance to Mars to get there
- Huge (1000 Earth volumes)
- 60 moons (many very interesting) and also rings
- Great Red Spot—long lived storm



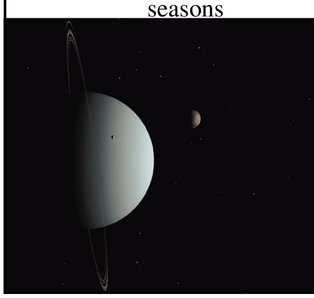
Saturn

- 2nd Largest
- 30 moons (Titan bigger than Mercury…studied by NASA's *Cassini*)



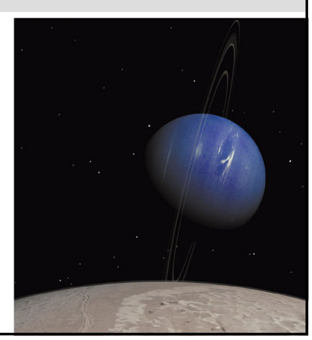
Uranus

- Methane makes blue-green
- 21 moons and rings
- Rotation axis and moon/ring orbits tilted w/r/t rest of planets…makes for extreme seasons



Neptune

- Nearly twin of Uranus
- Rings an eight moons
- Large moon, Triton w/ nitrogen geysers and only large moon to orbit planet backward



Pluto

- Orbit is way out there
- "Misfit"…neither Jovian nor Terrestrial
- Smallest, mostly ice, quite elliptical, and inclined orbit
- NASA's New Horizons launches 1/06 to arrive in 2014

Hayden's Policy on Pluto

For the exhibit on planets in our "Hall of the Universe," rather than use the word planet as a classifier, we essentially abandon the ill-defined concept and simply group together families of like-objects. In other words, instead of counting planets or declaring what is a planet and what is not, we organize the objects of the solar system into five broad families: the terrestrial planets, the Asteroid Belt, the Jovian planets, the Kuiper Belt and the Oort Cloud. With this approach, numbers do not matter and memorized facts about planets do not matter. What matters is an understanding of the structure and layout of the solar system. On other panels, in an exercise in comparative planetology, we highlight rings, storms, the greenhouse effect, surface features and orbits with discussions that draw from all members of the solar system where interesting and relevant.

8.4 Exploring the Solar System

Our goals for learning:

- What are four major categories of spacecraft mission?
- Describe a few important missions to the planets.

Major Categories of Spacecraft Mission

1. Flyby – spacecraft "flies by" a world just once
2. Orbiter – spacecraft orbits the world it studies
   – longer-term study is allowed
3. Lander/Probe – spacecraft lands on the surface of the world or plunges through its atmosphere
4. Sample Return – spacecraft returns to Earth with a sample of the world it has studied

These types of mission are listed in order of increasing cost.

Missions to Other Worlds

Table 8.3 Selected Robotic Missions to Other Worlds

Name	Type	Destination	Lead Space Agency	Arrival Year	Mission Highlights
Stardust	Flyby and sample return	Comet Wild 2	NASA	2004	Collect dust from comet and return it to Earth in 2006.
Deep Impact	Flyby and "lander"	Comet Tempel 1	NASA	2005†	"Lander" to hit at 10 km/sec, flyby spacecraft to study the impact
Cassini	Orbiter	Saturn	NASA	2004†	Includes lander (called *Huygens*) for Titan
Mars Exploration Rovers	Lander	Mars	NASA	2004†	Twin rovers to study the surface in two locations
Mars Express	Orbiter and lander	Mars	ESA*	2004†	Climate and surface studies of Mars
Nozomi	Orbiter	Mars	Japan	2004†	Japanese-led mission to study Martian atmosphere
Mars Odyssey 2001	Orbiter	Mars	NASA	2001	Detailed study of Martian surface features and composition
Near Earth Asteroid Rendezvous (NEAR)	Orbiter	Eros (asteroid)	NASA	2000	First spacecraft dedicated to in-depth study of an asteroid
Mars Global Surveyor	Orbiter	Mars	NASA	1997	Detailed imaging of surface from orbit

*European Space Agency.
†Scheduled arrival year.

Table 8.3 Selected Robotic Missions to Other Worlds

Name	Type	Destination	Lead Space Agency	Arrival Year	Mission Highlights
Mars Pathfinder	Lander	Mars	NASA	1997	Carried *Sojourner*, the first robotic rover on Mars
Galileo	Orbiter	Jupiter	NASA	1995	Dropped probe into Jupiter; close-up study of moons
Magellan	Orbiter	Venus	NASA	1990	Detailed radar mapping of surface of Venus
Voyager 1	Flyby	Jupiter, Saturn	NASA	1979, 1980	Unprecedented views of Jupiter and Saturn; continuing out of solar system
Voyager 2	Flyby	Jupiter, Saturn, Uranus, Neptune	NASA	1979, 1981, 1986, 1989	Only mission to Uranus and Neptune; continuing out of solar system
Vikings 1 and 2	Orbiter and lander	Mars	NASA	1976	First landers on Mars

*European Space Agency.
†Scheduled arrival year.

What have we learned?

- What can we learn by comparing the planets to each other?
  - We gain new insights into the physical processes that shape Earth and other planets, we learn about the origin and history of the solar system as a whole, and we learn to apply ideas from our solar system to other planetary systems.
- What are the two major types of planet?
  - The small, rocky terrestrial planets and the large, hydrogen-rich Jovian planets.

What have we learned?

- What are the major patterns of motion in our solar system?
  - All planets orbit the Sun in the same direction and with nearly circular orbits in nearly the same plane. The Sun and most planets rotate in the same direction that they orbit. Most large moons orbit their planets in the same direction as well.
- Where do we find asteroids and comets in the solar system?
  - Most asteroids reside in the asteroid belt between Mars and Jupiter. Comets are found in two main regions: the Kuiper belt and the Oort cloud.

What have we learned?

- Describe a few important exceptions to the general rules.
  - The sideways tilt of Uranus and Pluto, the "backward" rotation of Venus, the "backward" orbit of Triton, and Earth's relatively large Moon.
- How does the Sun influence the planets?
  - Its gravity governs planetary orbits, its heat is the primary influence on planetary temperatures, it is the source of virtually all the visible light in our solar system, and high-energy particles from the Sun influence planetary atmospheres and magnetic fields.

What have we learned?

- Describe an interesting feature of each planet.
  - Mercury's extreme days and nights, tall steep cliffs, and large iron content
  - Venus's extreme greenhouse effect
  - Earth as an oasis of life
  - Evidence on Mars for a past, wet era
  - Jupiter's hydrogen and helium atmosphere and its many moons
  - Saturn's rings and its moon Titan, which is larger than Mercury
  - Uranus and its moons: a system tipped on its side compared to the other planets
  - Neptune's largest moon, Triton, with nitrogen "geysers" and a "backward orbit"
  - Pluto as a "misfit" among the planets

What have we learned?

- What are four major categories of spacecraft mission?
  - flyby, orbiter, lander or probe, sample return mission
- Describe a few important missions to the planets.
  - Voyager 1 and 2 multi-planet flybys, missions to Mars, Galileo mission to Jupiter, Cassini mission to Saturn

In the National Mall scale model of the solar system, where does the asteroid belt lie (see page 207)?

1. Between Mars and Jupiter, around the National Air and Space Museum.
2. Between Uranus and Neptune, around the Hirshorn Museum.
3. Between Neptune and Pluto, around the Art and Industries Building.
4. From Neptune outwards, but still within the Mall.
5. Well beyond the orbits of the planets, and off the scale completely (i.e. in a different state).

In the National Mall scale model of the solar system, where does the asteroid belt lie (see page 207)?

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In the National Mall scale model of the solar system, where does the Kuiper belt lie (see page 207)?

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In the National Mall scale model of the solar system, where does the Oort cloud lie (see page 207)?

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How often do the giant planets line up in a similar pattern that allows for a gravitational slingshot "grand tour" as Voyager 2 did in 1979-1989 (see Figure 8.17)?

1. Every Earth year.
2. Every Jupiter year (about 12 Earth years).
3. Every Saturn year (about 29 Earth years).
4. Every Uranus year (about 84 Earth years).
5. None of the above (it would take much longer).

How often do the giant planets line up in a similar pattern that allows for a gravitational slingshot "grand tour" as Voyager 2 did in 1979-1989 (see Figure 8.17)?

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4. Every Uranus year (about 84 Earth years).
5. **None of the above (it would take much longer).**

The mass of the Sun compared to the mass of all the planets combined is like

1. the mass of a dog compared to the mass of a cat.
2. the mass of a human compared to the mass of a cat.
3. the mass of an elephant compared to the mass of a cat.
4. the mass of the Earth compared to the mass of the Moon.
5. the mass of Jupiter compared to the mass of the Earth.

The mass of the Sun compared to the mass of all the planets combined is like

1. the mass of a dog compared to the mass of a cat.
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