7. 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

7.1 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

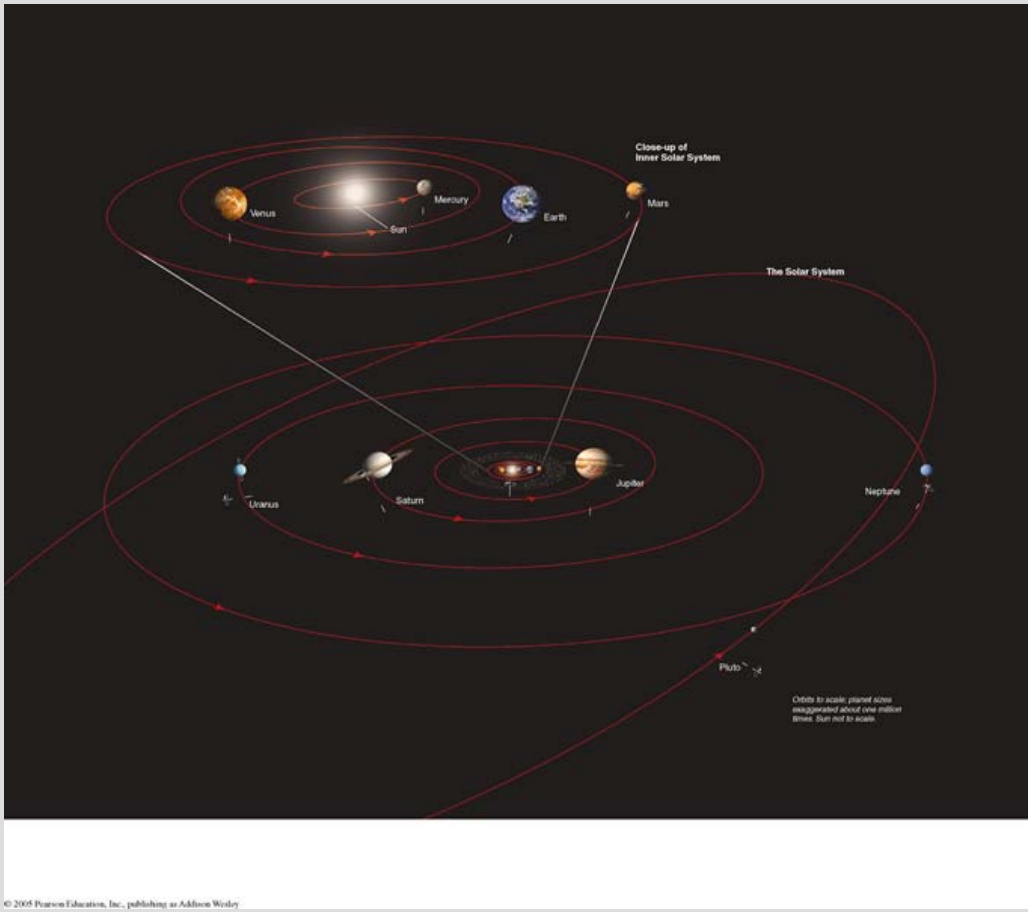
7.2 The Layout of the Solar System

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



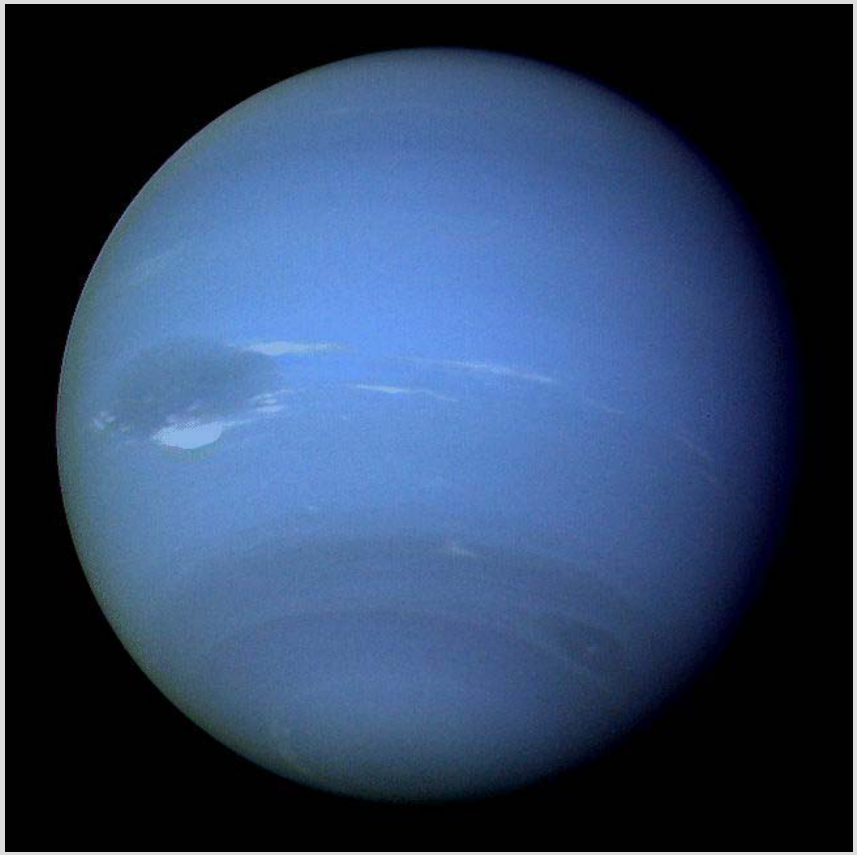
The Layout of the Solar System

- Planets fall into two main categories
  - Terrestrial (i.e. Earth-like)
  - Jovian (i.e. Jupiter-like or gaseous)

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

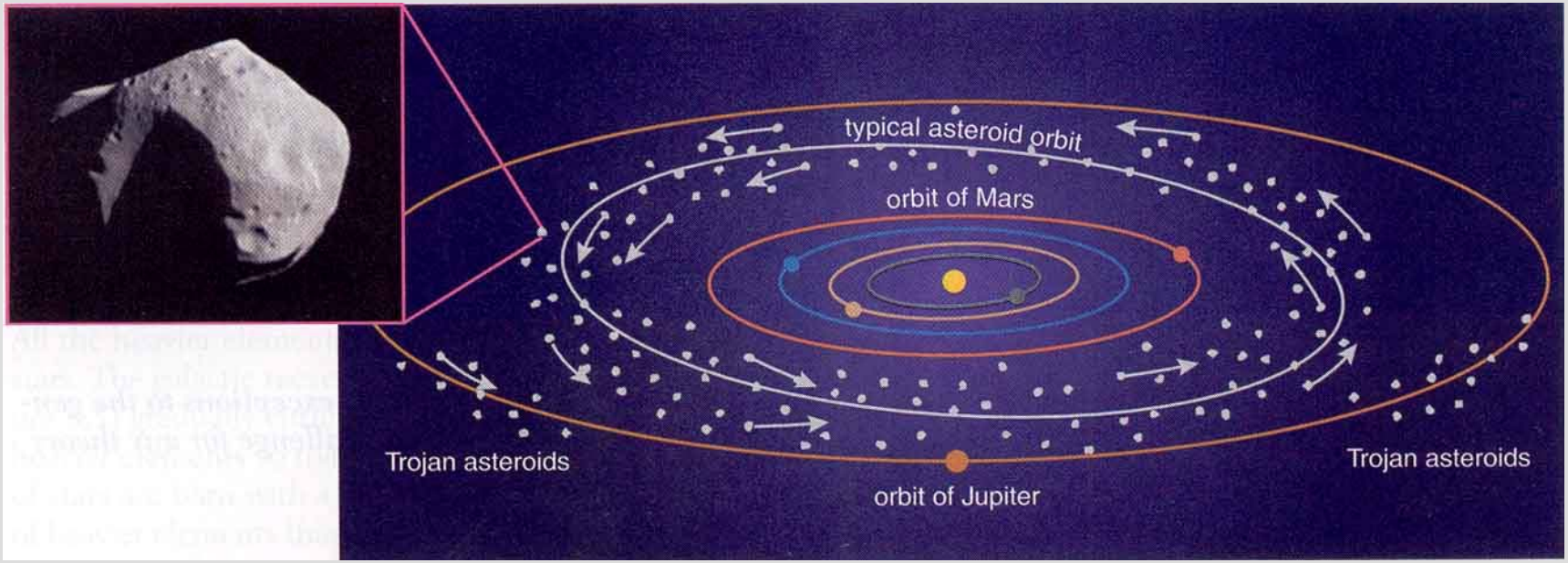
Jovian

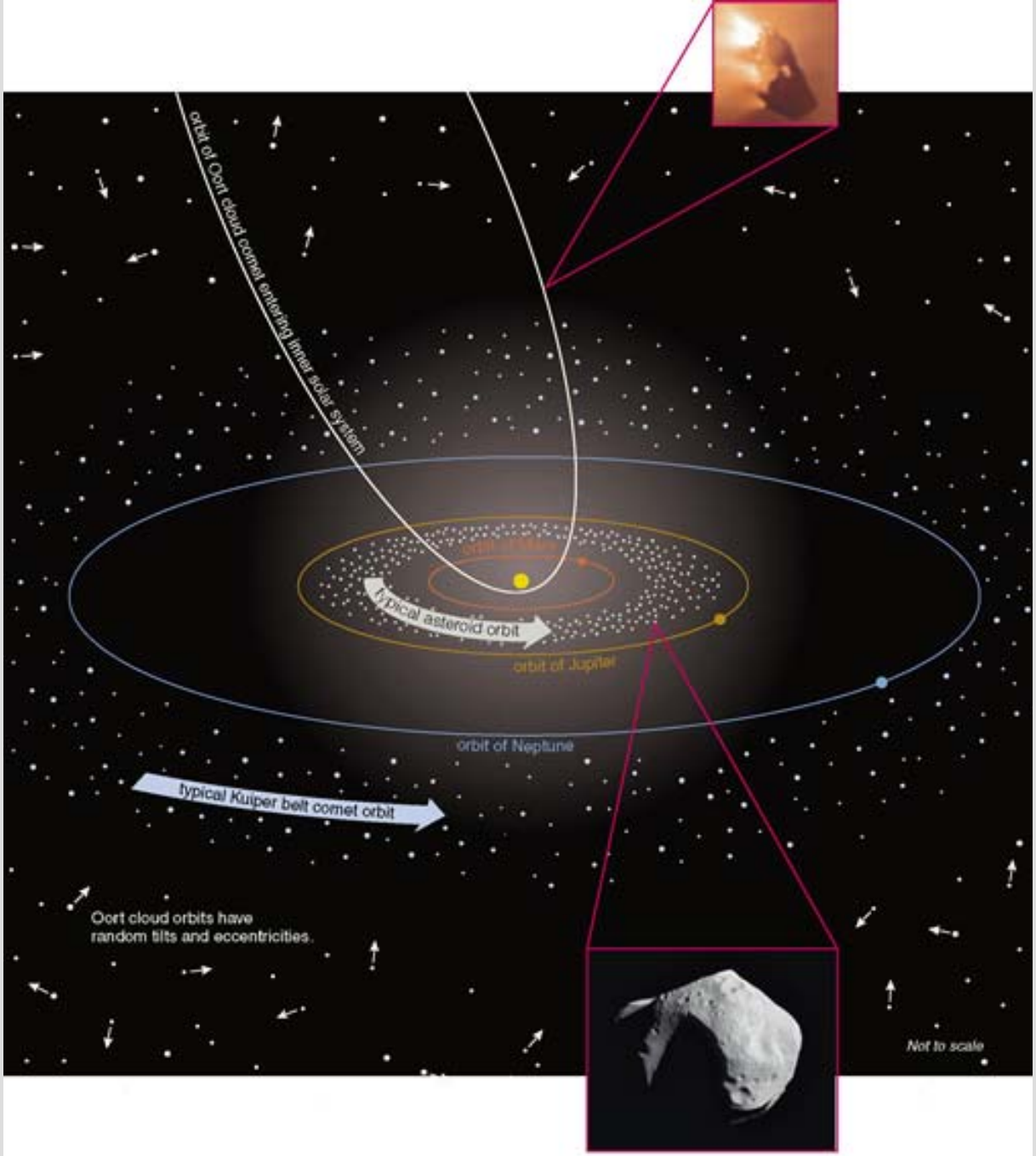
Photo	Planet	Average Distance from Sun (AU)	Temperature†	Relative Size	Average Equatorial Radius (km)	Average Density (g/cm^3)	Composition	Known Moons	Rings?
	Mercury	0.387	700 K	·	2,440	5.43	Rocks, metals	0	No
	Venus	0.723	740 K	•	6,051	5.24	Rocks, metals	0	No
	Earth	1.00	290 K	•	6,378	5.52	Rocks, metals	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.

The Layout of the Solar System

- Swarms of asteroids and comets populate the Solar System





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.

7.3 A Brief Tour of the Solar System

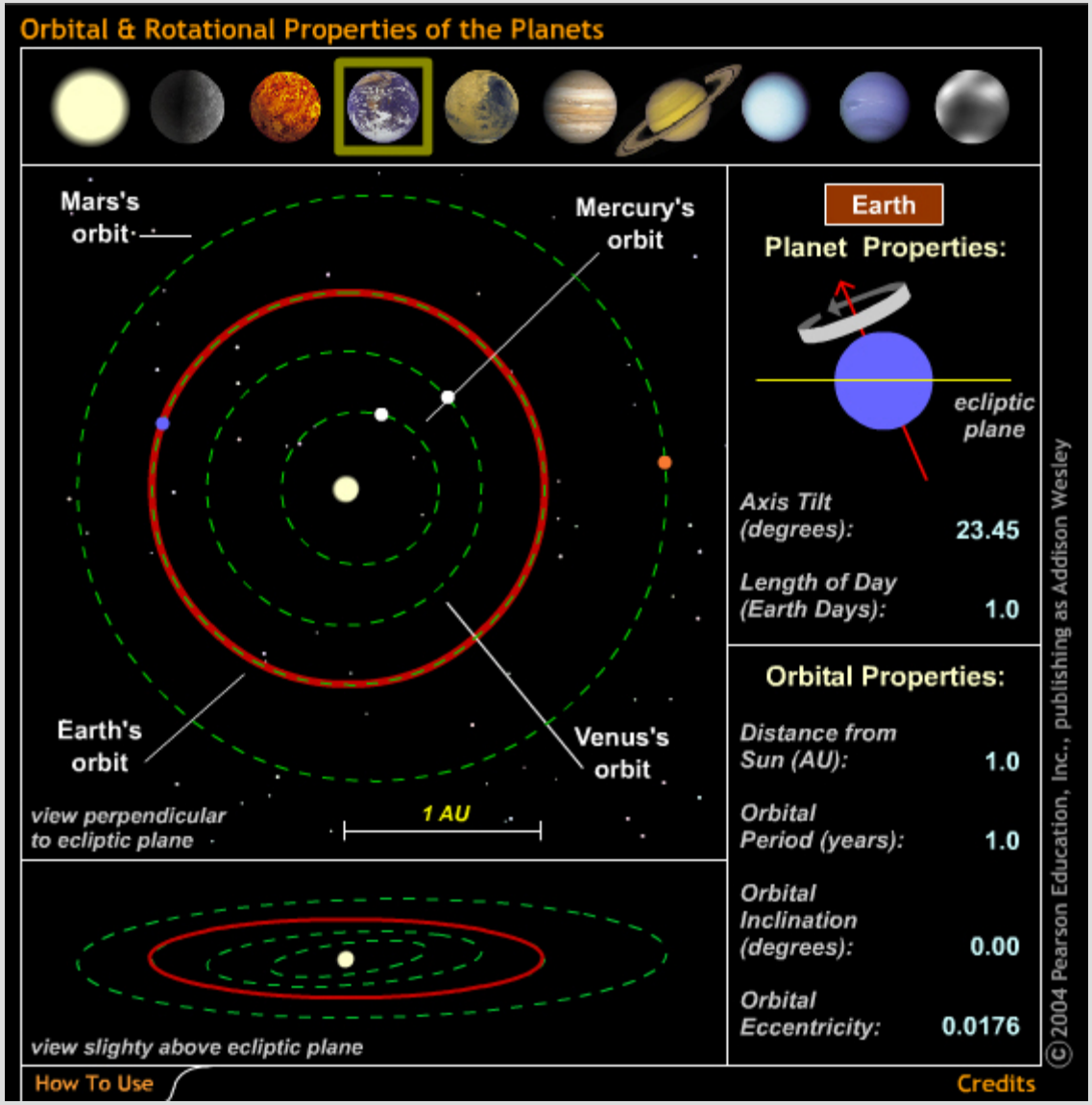
Our goals for learning:

- 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.

A Brief Tour of the Solar System -- Motions



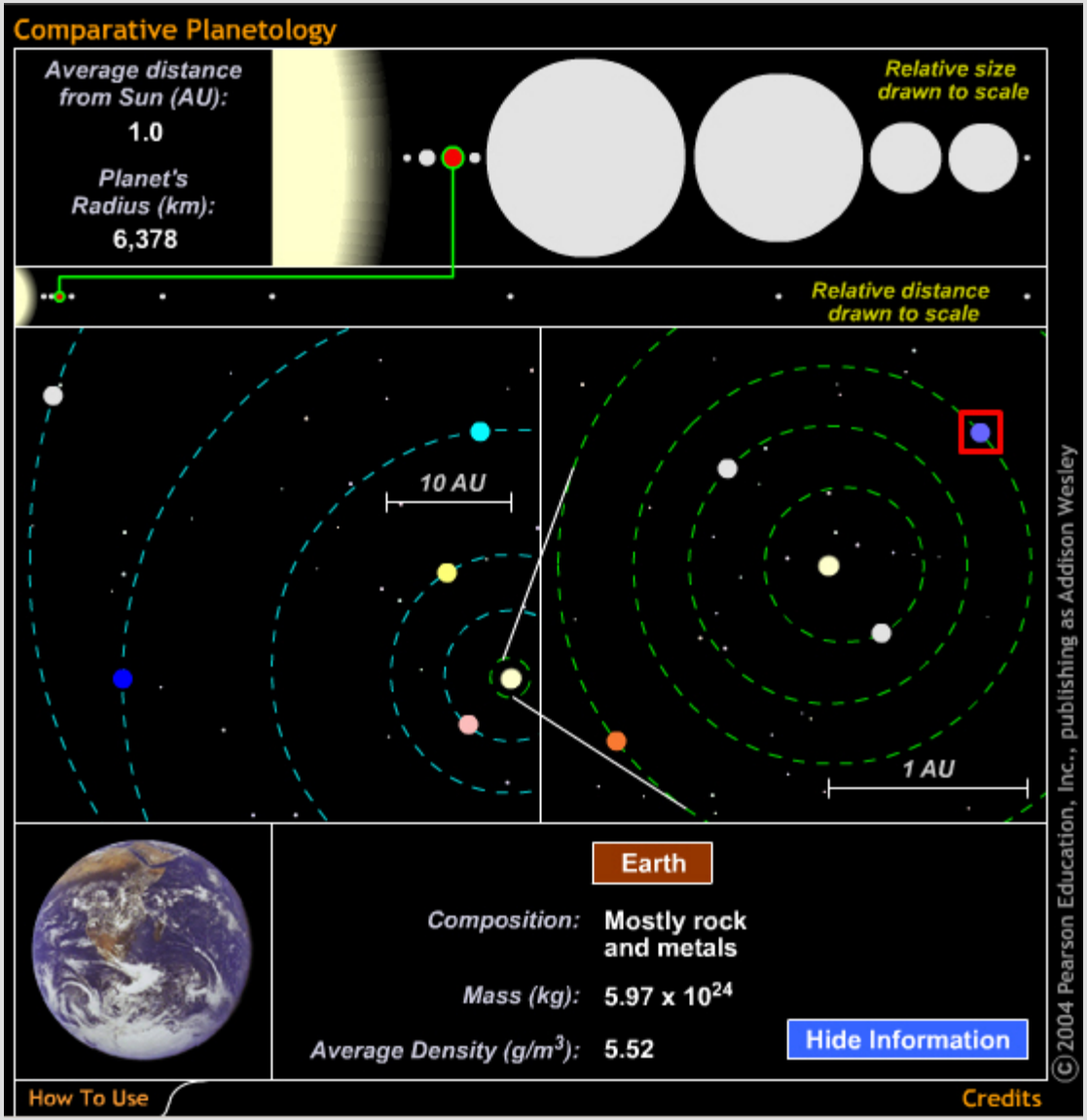
What is density?

density = mass/volume

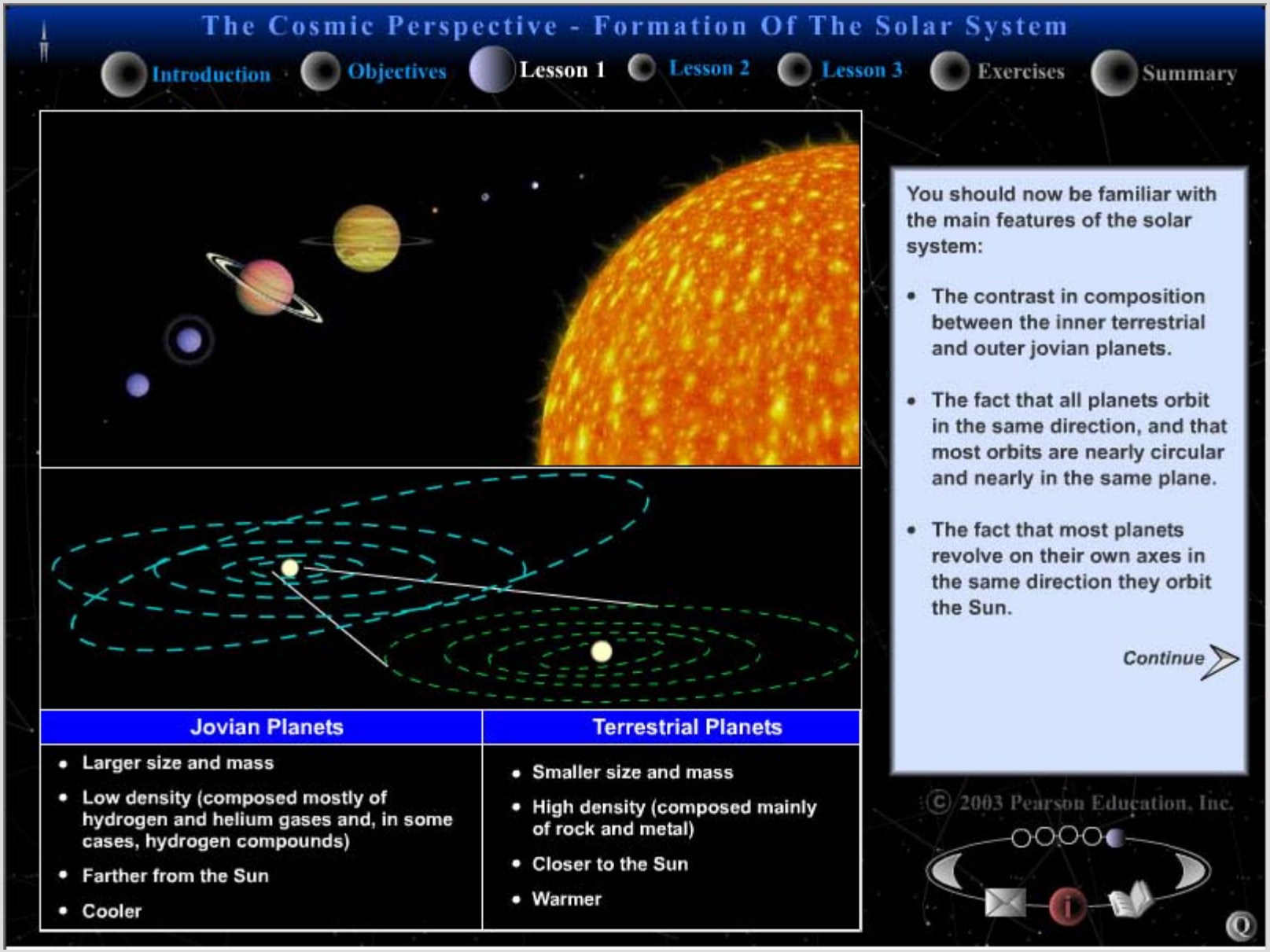
typical units: [g/cm^3]

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

A Brief Tour of the Solar System – Composition



A Brief Tour of the Solar System – Summary



7.4 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.

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.

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