

Chapter 6

Other Worlds: An Introduction to the Solar System



6.1 Overview of Our Planetary System

We've learned more about the solar system than any other branch in astronomy in the past 40 years because of space probes

- Mercury: Mariner 10
- Venus: Magellan
- Mars: Global Surveyor, Pathfinder, Spirit, Opportunity, Phoenix, etc.
- Jupiter: Voyager 1 and 2, Galileo, et al
- Saturn: Voyager 1 and 2, Cassini
- Uranus: Voyager 2
- Neptune: Voyager 2
- (Pluto: no missions...yet...New Horizons enroute)

6.1.1 An Inventory

Sun

- Just an ordinary star
- 1,400,000 km (864,000 mi) in diameter
- Interior temp = millions of degrees
- Surface temp = ~11,000°F
- Contains most of the mass in the solar system



6.1.1 An Inventory

Planets

- Five known to the ancients
 - Mercury
 - Venus
 - Mars
 - Jupiter
 - Saturn
- Three discovered since invention of telescope
 - Uranus
 - Neptune
 - Pluto ... poor Pluto ☹️



6.1.1 An Inventory

Planets

- Common traits
 - Each rotates on an axis
 - In most cases, direction of rotation is the same as the direction of revolution
 - Exceptions: Venus, Uranus, Pluto
 - Elliptical orbits
 - Varying degrees of eccentricity

6.1.1 An Inventory

Table 6.1

Object	% total mass
Sun	99.80
Jupiter	0.10
Comets	0.05
All other planets	0.04
Satellites and rings	0.00005
Asteroids	0.000002
Cosmic dust	0.0000001

6.1.1 An Inventory

Three "families" of planets

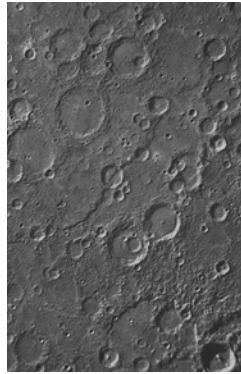
- **Terrestrial**
 - Mercury, Venus, Earth, Mars
 - Also our Moon
- **Jovian**
 - Jupiter, Saturn, Uranus, Neptune
- **Dwarf**
 - Pluto, Eris, Ceres



6.1.1 An Inventory

Terrestrial planets

- Relatively small
- Mostly rock and metal
- Solid surfaces
- Craters, mountains, volcanoes (past or present)
- Thin atmospheres, if any
- Few, if any, moons
 - Mercury = 0
 - Venus = 0
 - Earth = 1
 - Mars = 2



6.1.1 An Inventory

Jovian planets ("Jupiter-like")

- Much larger
- Composed mainly of lighter gases, liquids, ices
- Solid surfaces?
- Very thick atmospheres
- Many moons
 - > 100 total
 - Count changing all the time



6.1.1 An Inventory

Table 6.2

Name	Distance from Sun (AU)	Revolution period (years)	Diameter (km)	Mass (10^{23} kg)	Density (g/cm^3)
Mercury	0.39	0.25	4,878	3.3	5.4
Venus	0.72	0.62	12,102	48.7	5.3
Earth	1.00	1.00	12,756	59.8	5.5
Mars	1.52	1.88	6,787	6.4	3.9
Jupiter	5.20	11.86	142,984	18,991	1.3
Saturn	9.54	29.46	120,536	5,686	0.7
Uranus	19.18	84.07	51,118	866	1.3
Neptune	30.06	164.82	49,660	1,030	1.6
Pluto	39.44	248.60	2,200	0.01	2.1

6.1.1 An Inventory

Dwarf Planets:

- orbit the Sun
- spherical shape
- have not cleared the area around their orbit
- not a satellite

Largest dwarf planets:

- Eris: largest
- Pluto
- Ceres



6.1.1 An Inventory

Satellites

- Mercury = 0
- Venus = 0
- Earth = 1
- Mars = 2
- Jupiter = 63
- Saturn = 61 confirmed (as of 2009), probably many more
- Uranus = 27
- Neptune = 13



6.1.1 An Inventory

Asteroids

- Small, rocky objects
- Most found between orbits of Mars and Jupiter
- Made of ancient, remnant material



6.1.1 An Inventory

Comets

- Small bodies of frozen gases
 - Water ice
 - Carbon dioxide
 - Carbon monoxide
 - Methyl alcohol
- Follow highly elliptical orbits
 - Most lie far beyond orbit of Pluto
 - Only become visible when close to Sun



6.1.1 An Inventory

Meteors

- “Shooting stars”
- Broken rock (cosmic dust)
 - Most no larger than a grain of sand
 - Some can be quite large
- Meteor: atmospheric event
- Meteoroid: beyond earth’s atmosphere
- Meteorite: after impact

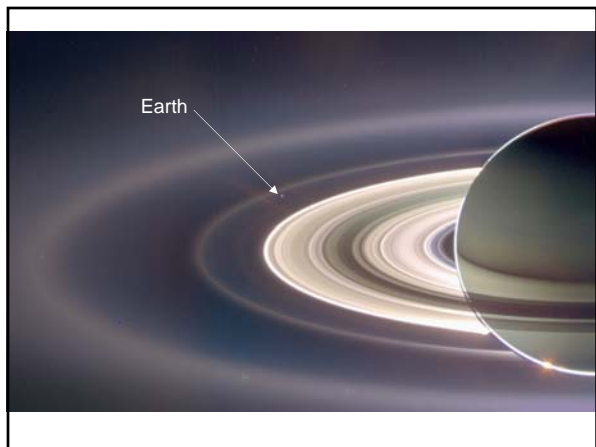


6.2 Composition and Structure of Planets

The Giant Planets

- Jupiter and Saturn
 - Impenetrable clouds of hydrogen and helium
 - “Gas giants?” No!
 - Mostly liquid
 - The few heavier elements sink to center due to gravity
 - Solid cores of rock, metal, and ice
 - Never been seen directly



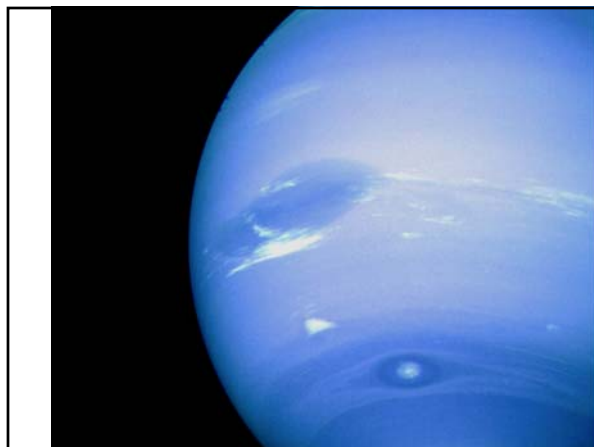


6.2 Composition and Structure of Planets

The Giant Planets

- Uranus and Neptune
 - Also hydrogen and helium
 - Smaller mass
 - Cores about the same mass as Jupiter and Saturn, however (~10x mass of Earth)





6.2 Composition and Structure of Planets

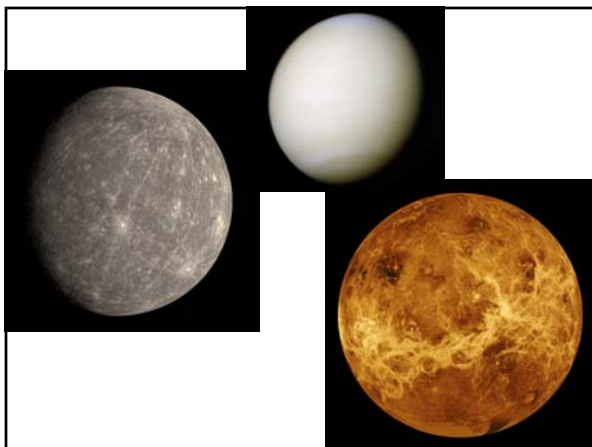
The Giant Planets

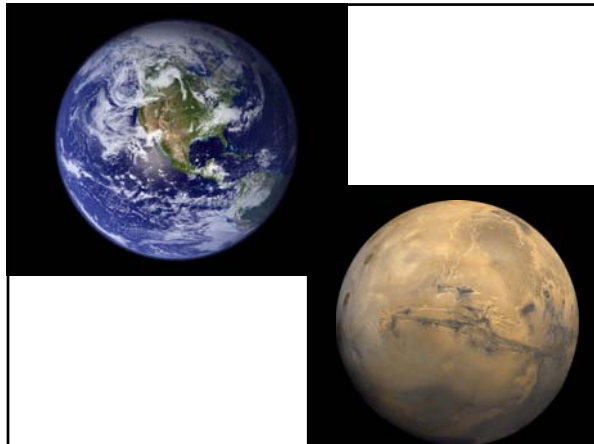
- Very little free oxygen: most is combined with hydrogen to form water
- Chemists call such hydrogen-dominated composition *reduced*

6.2 Composition and Structure of Planets

The Terrestrial Planets

- Much smaller than giant planets
- Higher density
 - Metals and rocks
 - Iron
 - Silicates
- Very little free hydrogen
 - Planets display a wide variety of oxygen compounds; said to be *oxygenated*.

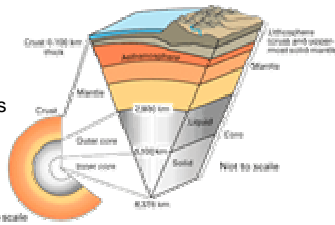




6.2 Composition and Structure of Planets

The Terrestrial Planets

- Planets are **differentiated**
 - Densest materials in cores (iron, etc.)
 - Lighter materials near surfaces (silicates)
 - This led scientists to conclude that these planets were once molten



6.2 Composition and Structure of Planets

Moons, Asteroids, and Comets

- Our Moon is like the terrestrial planets in terms of structure
- Outer moons are completely different
 - Mostly frozen gases and ice
 - Pluto, Eris probably very similar
- Asteroids and comets
 - Never heated to the melting point, so never differentiated
 - “Fossil” objects from primordial solar system

6.2 Composition and Structure of Planets

Temperatures

- In general, closer to Sun is hotter.
 - Mercury: 500 K (230° C)
 - Pluto: 50 K (-220° C)
 - Colder than liquid air
 - Earth is only planet where water can exist as a liquid
 - All others are too hot or too cold

6.3 Dating Planetary Surfaces

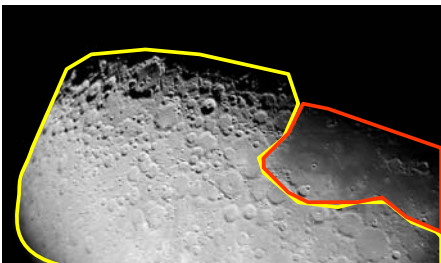
Counting craters

- Assuming little erosion, estimate age by counting # of craters
- # craters proportional to time that surface has been exposed
- Can only tell time since last major change took place
- Calibrate crater counts with evidence from lunar samples to estimate ages of Mercury and Mars

6.3 Dating Planetary Surfaces

Counting craters

- Where are the oldest areas in the photograph?
- The youngest?

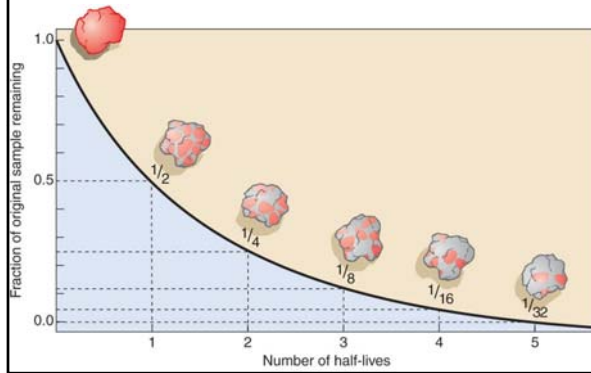


6.3 Dating Planetary Surfaces

Radioactive rocks

- Radioactivity:
 - natural process by which some atomic elements split, giving off energy (radioactive decay)
- Half-life
 - Length of time when radioactive decay equal one-half of original amount
 - Material decays into a second, nonradioactive material (“daughter product”)
 - Never quite hits zero

6.3 Dating Planetary Surfaces



6.3 Dating Planetary Surfaces

Radioactive rocks

- By comparing how much of a radioactive element we have in a sample (parent) to how much we have of the element that it decays into (daughter), we can tell how long the decay process has been going on, and hence, the age of the sample.

6.4 Origin of the Solar System

Evidence

- All planets revolve around the Sun in the same direction
- All lie nearly on the same flat plane
- Sun spins in the same direction as planets revolve
- Ecliptic on same plane as Sun's equator

All this points to the solar system being formed 4.5 billion years ago from a swirling cloud called the **solar nebula**.

6.4 Origin of the Solar System

Heat from the Sun evaporated all of the lighter materials from the inner solar system, which is why we see mostly heavier elements in the terrestrial planets

- Less heat farther out allowed those elements to remain
- Planetessimals
 - Millions of them (100 km diameter or less)
 - Violent collisions
 - All planets heated above their melting points: differentiated
 - Could also explain some oddities
 - Venus retrograde rotation
 - Uranus spinning on its side

6.4 Origin of the Solar System



6.4 Origin of the Solar System

- We also see protoplanetary disks around other stars

