

Comparative Planetology I: Our Solar System

Chapter Seven



Introduction To Modern Astronomy I: Solar System

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-15)

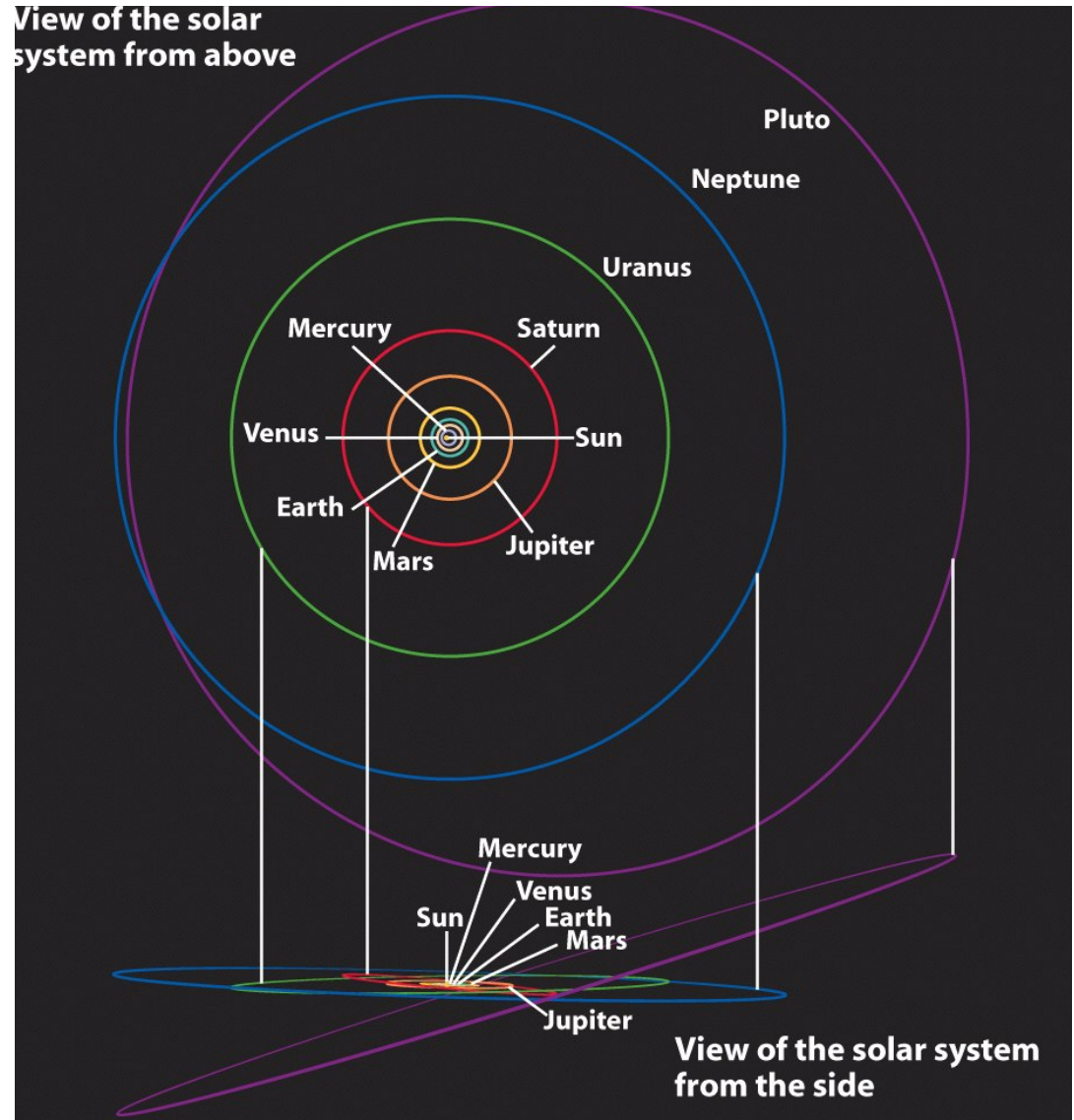
Chap. 16:
Chap. 28:

Ch7: Comparative Planetology I
Ch8: Comparative Planetology II

Ch9: The Living Earth
Ch10: Our Barren Moon
Ch11: Earthlike Planets
Ch12: Jupiter and Saturn
Ch13: Satellites of Jupiter & Saturn
Ch14: Uranus, Neptune and Beyond
Ch15: Vagabonds of Solar System

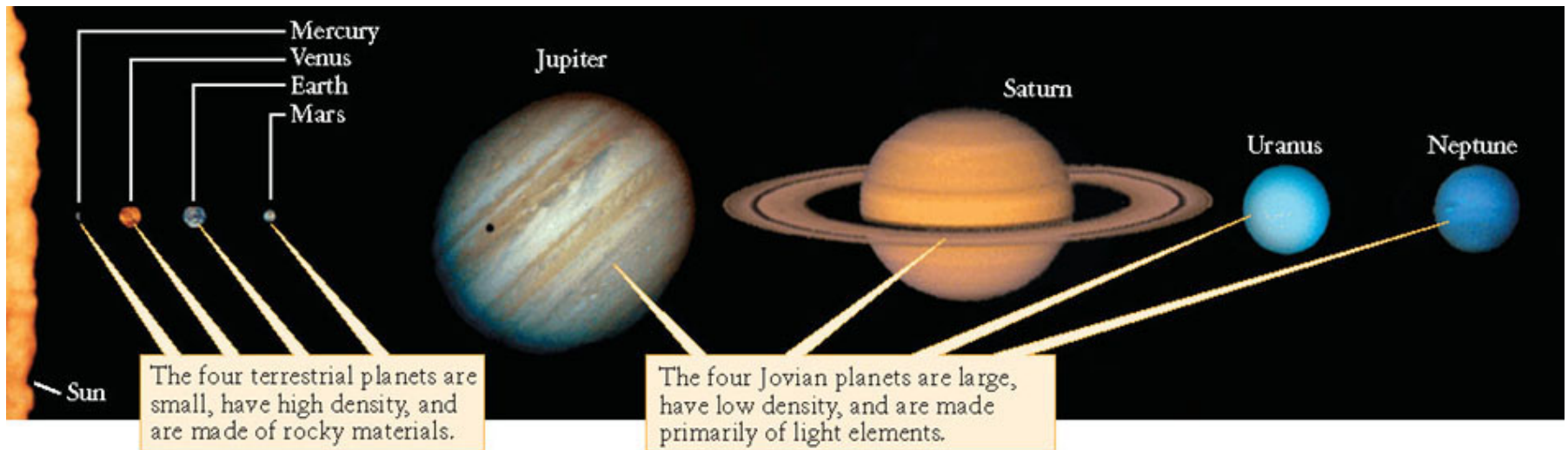
The Solar System

- There are 8 planets in the solar system
 - In 2006, Pluto was disqualified as a normal planet
- They are common in:
 - Orbiting the Sun in the same direction: CCW
 - Orbits in almost the same plane
 - Nearly circular orbits



Two Categories of Planets

1. **Terrestrial planets:** the four inner planets resembling the Earth
 2. **Jovian planets:** the four outer planets resembling the Jupiter
- Differ in Physical properties
 - **Diameter:** small versus large
 - **Mass:** small versus large
 - **Density:** high versus low
 - **State:** solid versus gaseous



Terrestrial Planets

- Small in size (Diameter $\sim 10,000$ km; $\leq 1 D_E$)
- Small in mass ($\sim 10^{24}$ kg; $\leq 1 M_E$)
- high density (~ 5000 kg/m³)
- Composed of heavy elements: Fe, Ni, Si
- Solid

table 7-1

Characteristics of the Planets

The Inner Planets				
	Mercury	Venus	Earth	Mars
Average distance from Sun (10^6 km)	57.9	108.2	149.6	227.9
Average distance from Sun (AU)	0.387	0.723	1.000	1.524
Orbital period (years)	0.241	0.615	1.000	1.88
Orbital eccentricity	0.206	0.007	0.017	0.093
Inclination of orbit to the ecliptic	7.00°	3.39°	0.00°	1.85°
Equatorial diameter (km)	4880	12,104	12,756	6794
Equatorial diameter (Earth = 1)	0.383	0.949	1.000	0.533
Mass (kg)	3.302×10^{23}	4.868×10^{24}	5.974×10^{24}	6.418×10^{23}
Mass (Earth = 1)	0.0553	0.8150	1.0000	0.1074
Average density (kg/m ³)	5430	5243	5515	3934

Jovian Planets

- Large in size (Diameter $\sim 100,000$ km; $\sim 10 D_E$)
- Large in mass ($\sim 10^{26}$ kg; $\sim 100 M_E$)
- Low density (~ 1000 kg/m³)
- Composed of light elements: H, He
- Gaseous


The Outer Planets

	Jupiter	Saturn	Uranus	Neptune	Pluto
Average distance from Sun (10^6 km)	778.3	1429	2871	4498	5915
Average distance from Sun (AU)	5.203	9.554	19.194	30.066	39.537
Orbital period (years)	11.86	29.46	84.10	164.86	248.60
Orbital eccentricity	0.048	0.053	0.043	0.010	0.250
Inclination of orbit to the ecliptic	1.30°	2.48°	0.77°	1.77°	17.15°
Equatorial diameter (km)	142,984	120,536	51,118	49,528	2300
Equatorial diameter (Earth = 1)	11.209	9.449	4.007	3.883	0.180
Mass (kg)	1.899×10^{27}	5.685×10^{26}	8.682×10^{25}	1.024×10^{26}	1.3×10^{22}
Mass (Earth = 1)	317.8	95.16	14.53	17.15	0.0021
Average density (kg/m ³)	1326	687	1318	1638	2000

Satellites

- >140 satellites are known
- Earth:1 ; Mars: 2; Mercury and Venus: none
- Jupiter: 62; Saturn 63; Uranus: 24; Neptune: 13
- Seven largest satellites, > 2000 km

table 7-2	The Seven Giant Satellites						
	Moon	Io	Europa	Ganymede	Callisto	Titan	Triton
Parent planet	Earth	Jupiter	Jupiter	Jupiter	Jupiter	Saturn	Neptune
Diameter (km)	3476	3642	3130	5268	4806	5150	2706
Mass (kg)	7.35×10^{22}	8.93×10^{22}	4.80×10^{22}	1.48×10^{23}	1.08×10^{23}	1.34×10^{23}	2.15×10^{22}
Average density (kg/m ³)	3340	3530	2970	1940	1850	1880	2050
Substantial atmosphere?	No	No	No	No	No	Yes	No

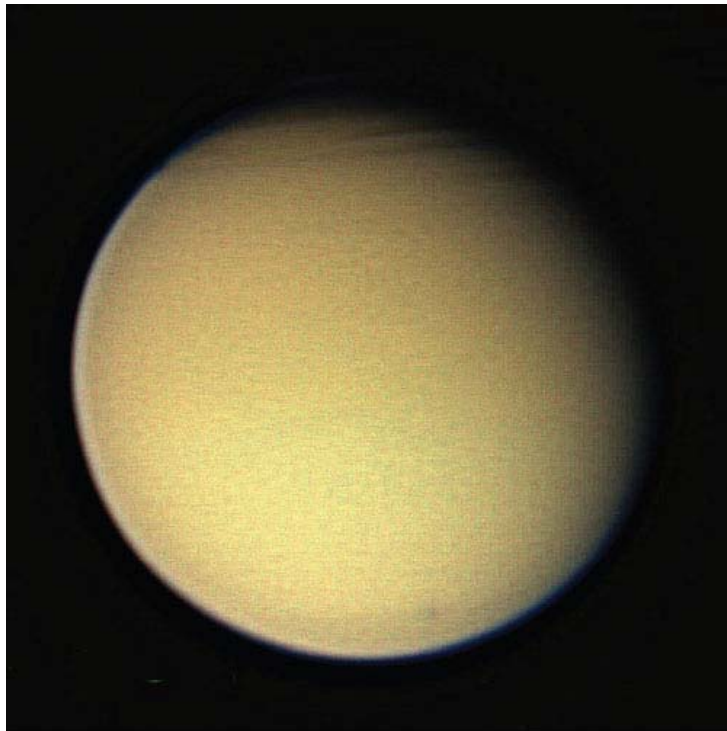


Moon
Io
Europa
Ganymede
Callisto
Titan
Triton

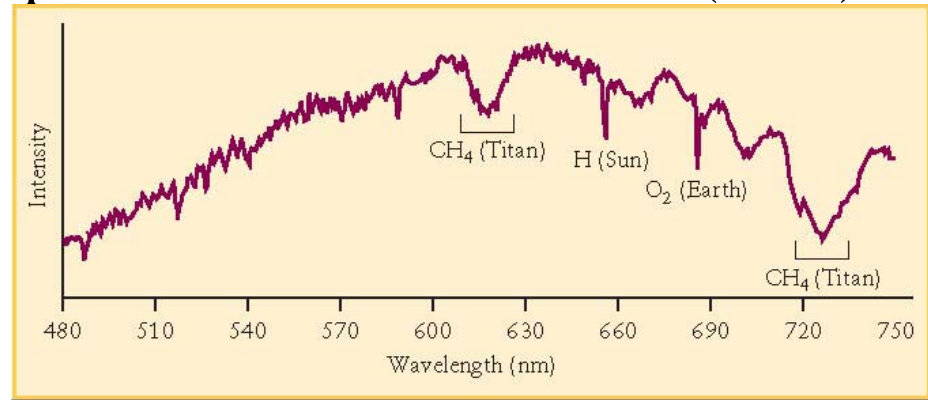
(JPL/NASA) R I **V** U X G

Chemical Composition

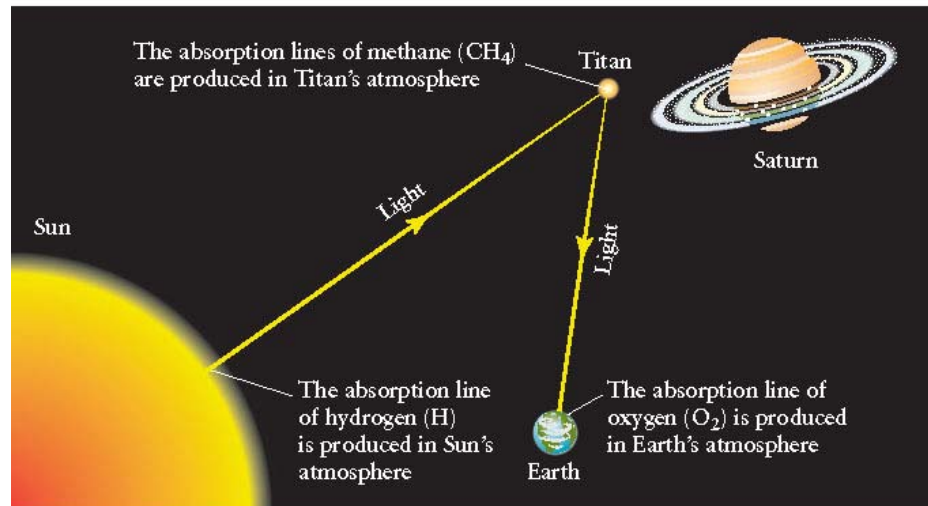
- Spectroscopes are used to study the spectra and spectral lines
- For example: Titan's atmosphere is made of methane (CH_4)



(a) Saturn's satellite Titan



(b) The spectrum of sunlight reflected from Titan



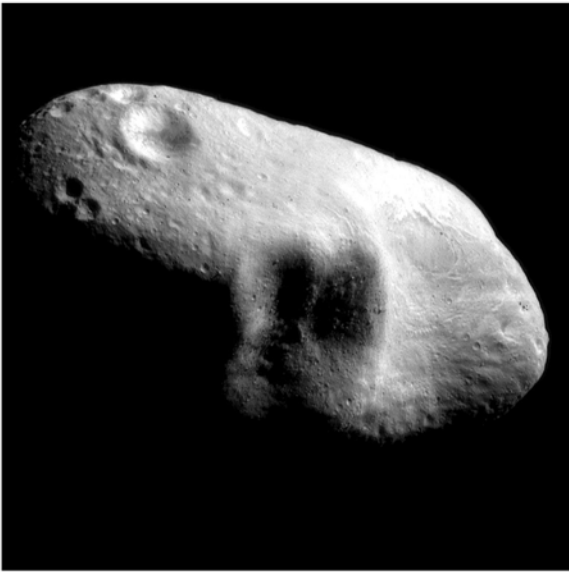
(c) Interpreting Titan's spectrum

Chemical Composition

- **Temperatures**, determined by the distance from the Sun, explains chemical differences between terrestrial and Jovian planets
- **Terrestrial planets** are made mostly of heavy elements, such as iron, oxygen, silicon, magnesium, nickel and sulfur.
- Light elements (H and He) escape from the terrestrial planets, because of their high speed at high temperature (>250 K, or $> -23^{\circ}\text{C}$)
- **Jovian planets** are composed mainly of light elements: hydrogen and helium
- Light elements (H and He) are trapped by Jovian planets because of their slow speed at low temperature (< 120 K, or $< -153^{\circ}\text{C}$)
- The stronger gravity of Jovian planets also help trap light elements.
- **Ice particles**: substance such as water (H_2O), carbon dioxide (CO_2), methane (CH_4) and ammonia (NH_3) solidify at low temperature (100 K to 300 K) and form ice

Asteroids

- **Asteroids** are small and rocky objects orbiting the Sun, also called minor planets
- **Asteroids belt:** most asteroids orbit the Sun at distance between 2 to 3.5 AU (between Mars and Jupiter)
- There are thousands of kilometer-sized asteroids and millions of meter-sized asteroids
- The largest asteroid, Ceres, is about 900 km
- They are debris in the inner solar system



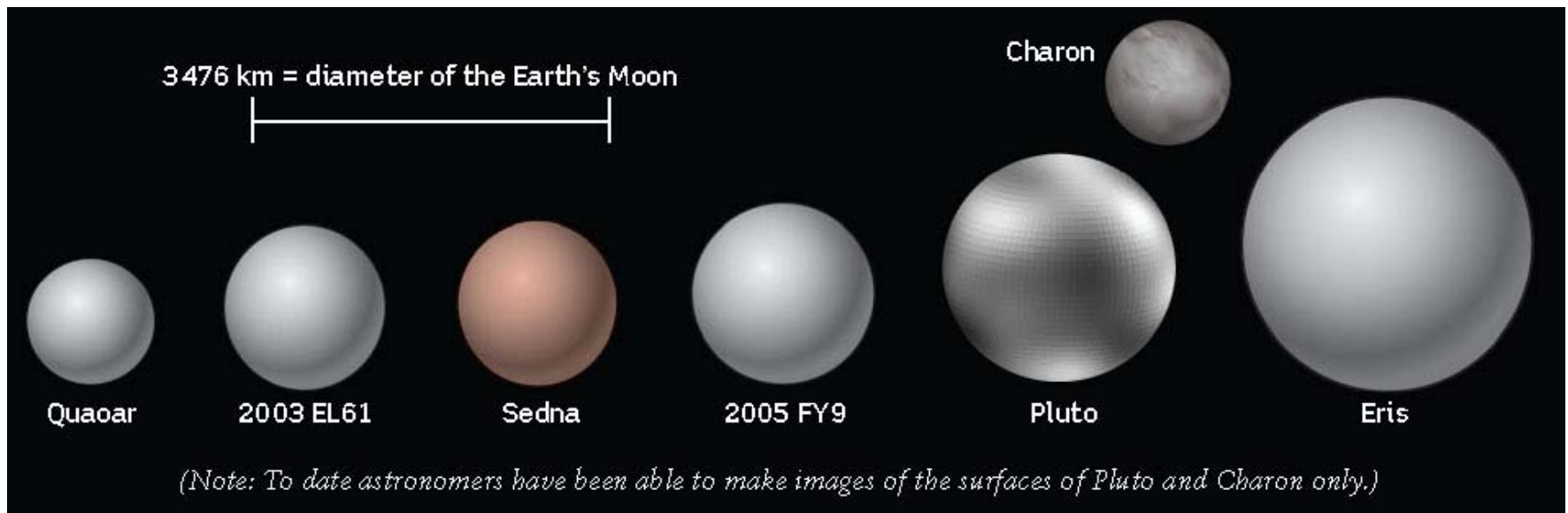
Eros

33 km long and 13 km wide

NEAR Shoemaker spacecraft
landed on it in March 2000

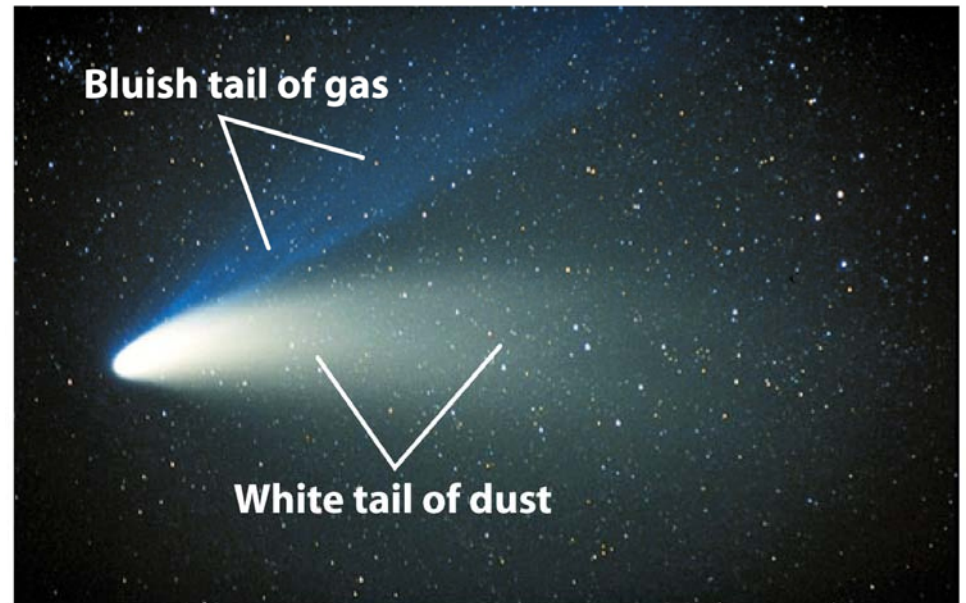
Trans-Neptune Objects

- **Trans-Neptunian objects:** small and icy objects orbiting the Sun beyond the orbit of Neptune
- **Kuiper belt:** most trans-Neptunian objects orbit within a band that extends from 30 AU to 50 AU.
- >900 such objects have been found.
- **Pluto is one of this category.**
- They are debris in the outer solar system



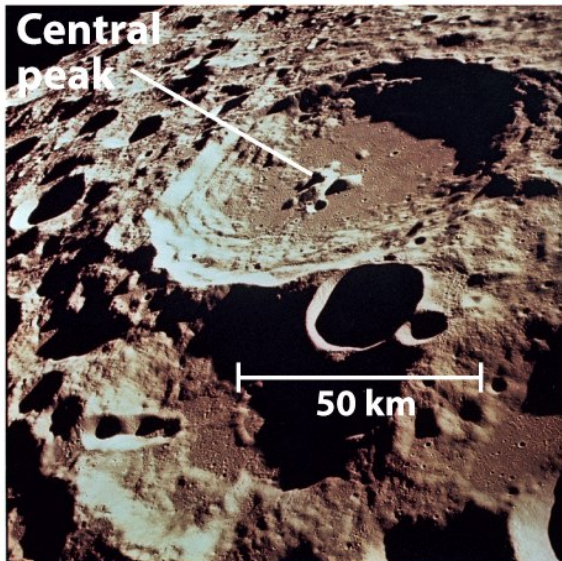
Comets

- **Comets** are chunks of dirty ice.
- Oort cloud: a swarm of comets forming a spherical “halo” extending to 50,000 AU
- They have highly elongated orbit.
- When close to the Sun, solar radiation vaporizes some of the ice material, forming a bluish tail of gas and a white tail of dust; both tails can extend for tens of million of kilometers

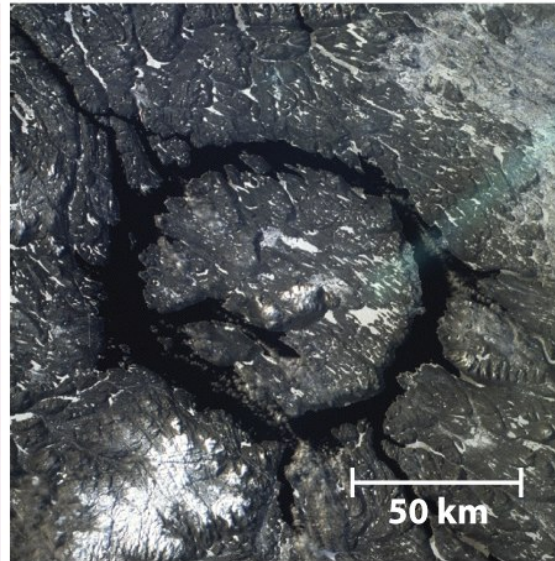


Craters

- **Impact Craters:** the result when **meteoroids** collide with the surface of a terrestrial planet or satellite
- **Meteoroid:** small object in space ranging from a few centimeters to a few hundred meters.
- Moon is heavily cratered, ~ 30,000 craters larger than 1 km
- Earth has few impact craters.



Moon



Earth



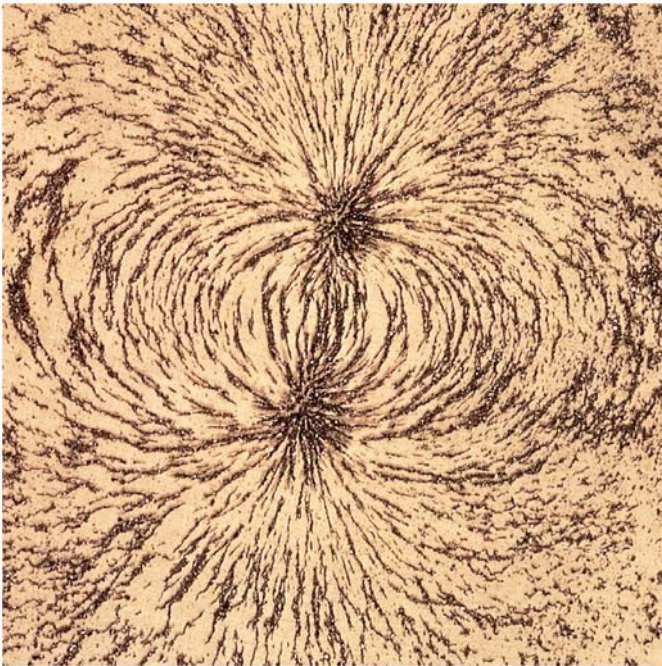
Mars

Craters

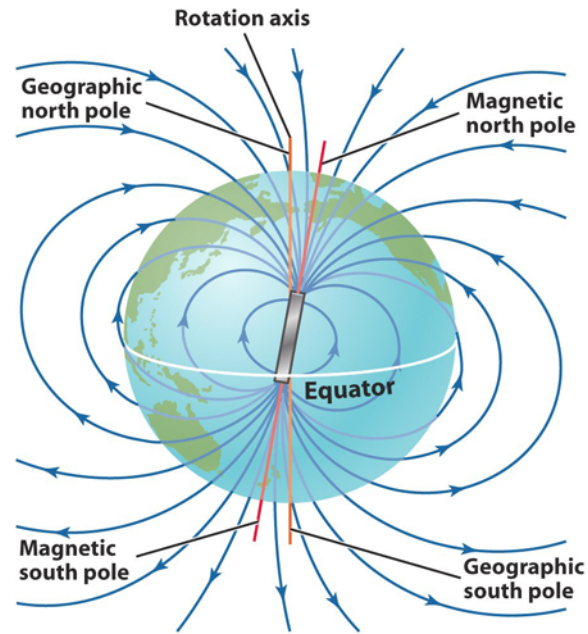
- Moon is geologically inactive
- Earth is geologically active. Craters are erased with time
 - Plate movement
 - Volcanoes
 - Erosion from Water and Wind
- **Geologic activity** is powered by **internal heat**, which keeps the interior partially molten
 - The cooling rate of a planet is determined by the ratio of surface area and its volume; the larger the size, the smaller the ratio, thus the smaller the cooling rate
 - The smaller the terrestrial world, the less internal heat it has retained, and thus, the less geological activity it will display on its surface. The less geologically active the world, the older and hence more heavily cratered its surface

Planet Interior

- A planet or satellite with a global magnetic field has liquid metallic material in its interior that conducts electricity.
 - The liquid material, e.g. molten iron.
 - It is in motion, generating magnetic field through a process similar to electric dynamo.



Bar Magnet



Earth's Magnetic Field

Final Notes on Chap. 7

- There are in total 8 sections. Section 7-1 to 7-7 are studied.

Advanced Question

Chap. 7, Q22 in P181

Mars has two small satellites, Phobos and Deimos.

Phobos circles Mars once every 0.31891 day at an average altitude of 5890 km above the planet's surface. The diameter of Mars is 6794 km. Using this information, calculate the mass and average density of Mars.