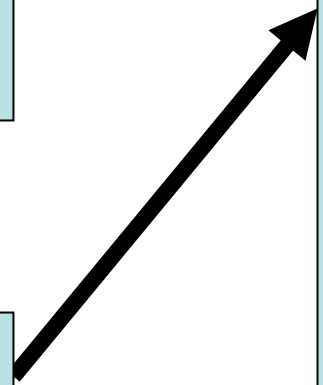
Comparative Planetology I: Our Solar System

Chapter Seven

Introduction To Modern Astronomy I

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-17)



Ch7: Comparative Planetology I

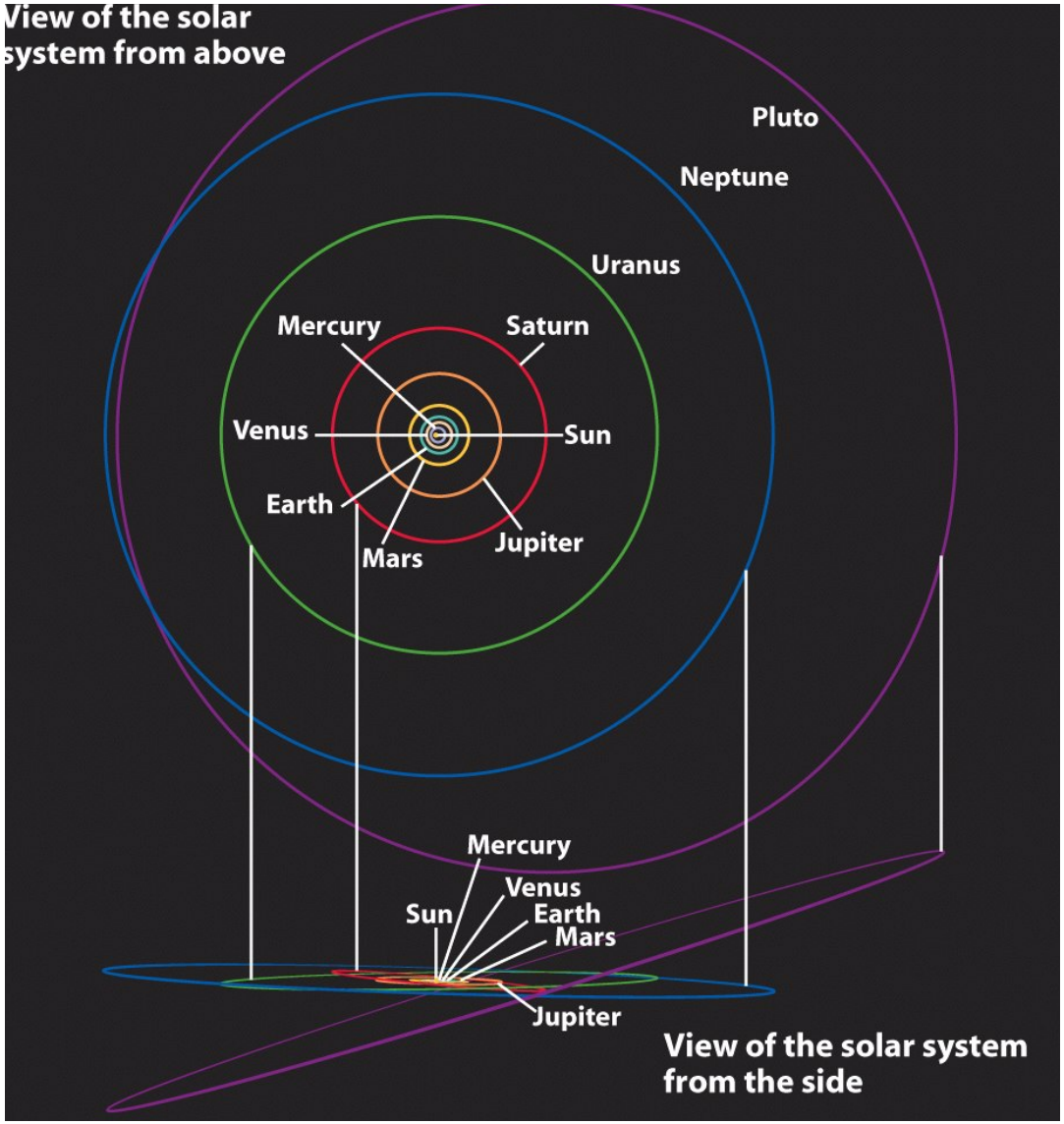
Ch8: Comparative Planetology II
Ch9: The Living Earth
Ch10: Our Barren Moon
Ch11: Sun-Scorched Mercury
Ch12: Cloud-covered Venus
Ch13: Red Planet Mars
Ch14: Jupiter and Saturn
Ch15: Satellites of Jup. & Saturn
Ch16: Outer World
Ch17: Vagabonds of Solar System

Guiding Questions

1. Are all the other planets similar to Earth, or are they very different?
2. Do other planets have moons like Earth's Moon?
3. How do astronomers know what the other planets are made of?
4. Are all the planets made of basically the same material?
5. What is the difference between an asteroid and a comet?
6. Why are craters common on the Moon but rare on the Earth?
7. Why do interplanetary spacecraft carry devices for measuring magnetic fields?
8. Do all the planets have a common origin?

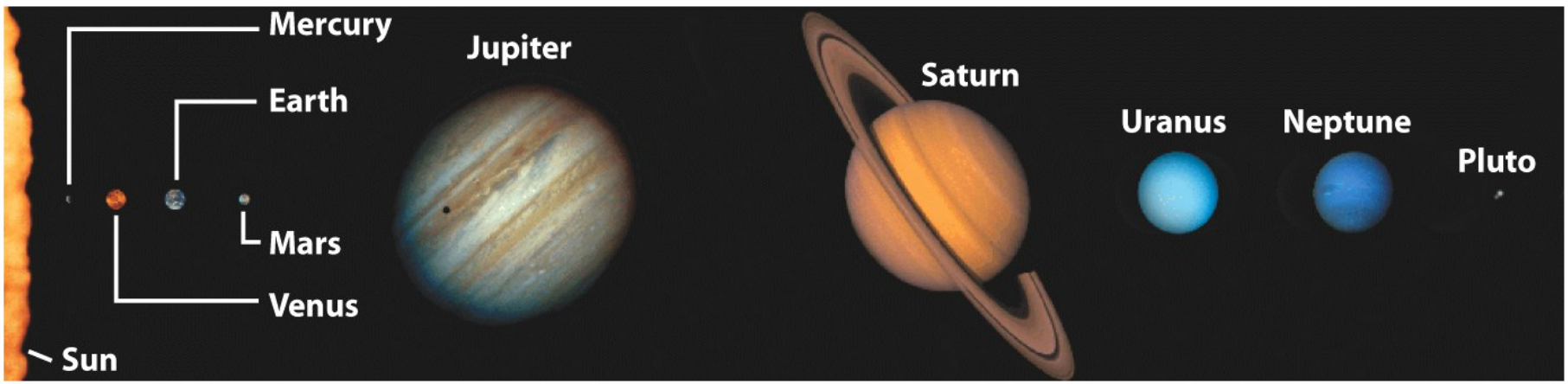
Solar System

- There are 8 planets in the solar system
- In 2006, Pluto is disqualified as a regular planet
- All of the planets orbit the Sun in the same direction and in almost the same plane
- Planets have elliptical orbits, but nearly circular.



Planets

- Physical properties of planets:
  - **Diameter**
  - **Mass**
  - **Average Density**
  - **Chemical Composition**
- Planets are divided into two broad categories
  - **Terrestrial planets**: the four inner planets resembling the Earth
  - **Jovian planets:** the four outer planets resembling the Jupiter



Terrestrial Planets

- Terrestrial planets
  - Relatively small in size (with diameters of 5000 to 13,000 km)
  - Relatively small in mass (10^{24} kg)
  - Relatively high average densities (4000 to 5500 kg/m^3)
  - Composed primarily of rocky materials

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

- Jovian planets
  - Large diameters (50,000 to 143,000 km)
  - Large in mass (10^{26} kg)
  - Low average densities (700 to 1700 kg/m^3)
  - Composed primarily of hydrogen and helium; gas objects

	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

Pluto: why not a planet?

- Pluto is a special case
  - An outer planet, but smaller than any of the terrestrial planets
  - Intermediate average density of about 1900 kg/m^3
  - Density suggests it is composed of a mixture of ice and rock
  - Its orbit has large eccentricity and inclination angle
  - It is now called a “dwarf planet”, possibly a member in the family called in Kuiper Belt Objects

Seven large satellites

- Comparable in size to the planet Mercury
- The remaining satellites of the solar system are much smaller

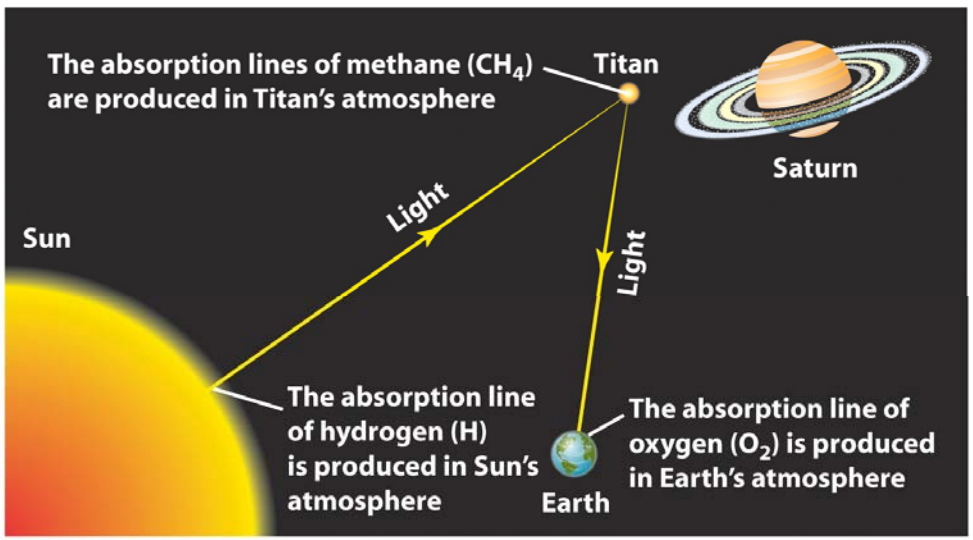
table 7-2 The Seven Giant Satellites

	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

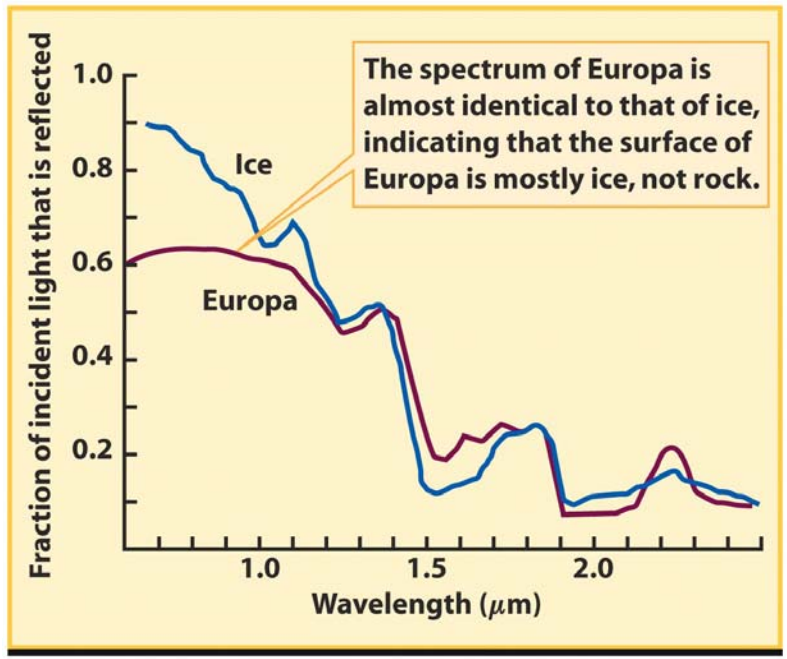
(JPL/NASA) R I V U X G

Planets: Chemical composition

- Spectroscopy observations reveal the chemical composition of a planet or satellite
- If there is no atmosphere, the spectrum indicates the composition of the surface.
- For example: Titan's atmosphere is made of methane (CH4)
- For example: Europa's surface is made of ice, not rock



(b) Interpreting Titan's spectrum



Planets: Chemical composition

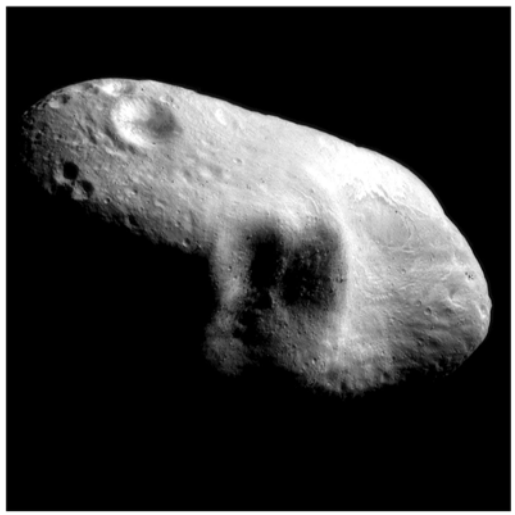
- Terrestrial planets are made mostly of heavy elements, such as iron, oxygen, silicon, magnesium, nickel and sulfur.
- Terrestrial planets are solid or rocky, because these elements remain solid except at very high temperature (>1000 K)

- Jovian planets are composed mainly of light elements, hydrogen and helium
- Jovian planets are gaseous (in the outer layers) or liquid (in the interior) , because hydrogen and helium are gaseous except at extremely low temperature and extraordinary high pressure

- **Ice in the solar system**: 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)

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 the orbits between Mars and Jupiter
- They are thousands of kilometer-sized asteroids and millions of meter-sized asteroids
- The largest asteroid, Ceres, is about 900 km



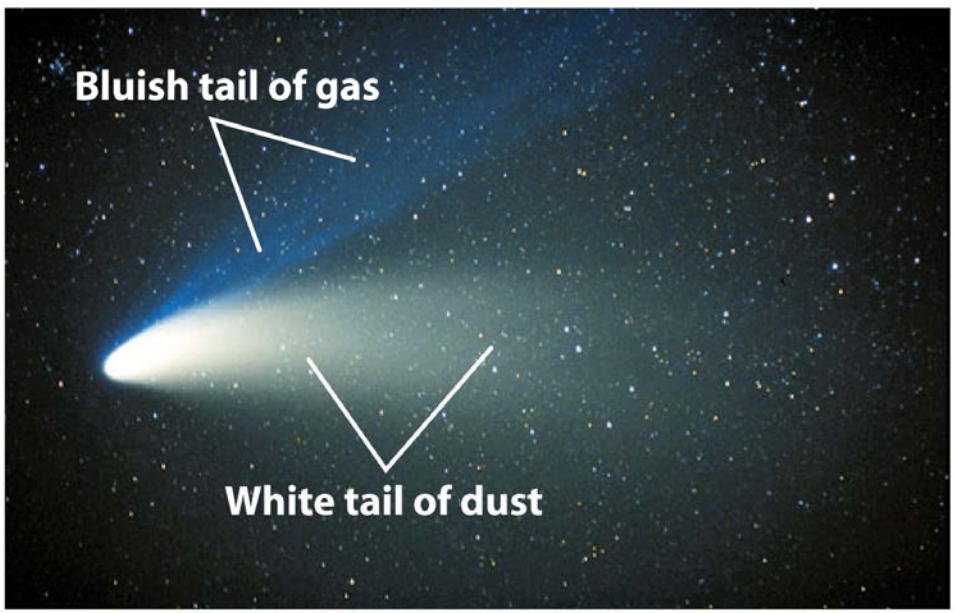
Eros

33 km long and 13 km wide

NEAR Shoemaker spacecraft landed on it in March 2000

Comets

- **Comets** are chunks of dirty ice.
- They have highly elongated orbit, thus occasionally bring them close to the Sun
- 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

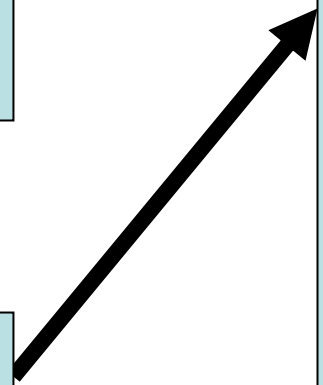


- Comets are thought to come from the **Kuiper Belt**, a region of the solar system extends from around the orbit of Neptune to about 500 AU from the Sun

Introduction To Modern Astronomy I

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-17)

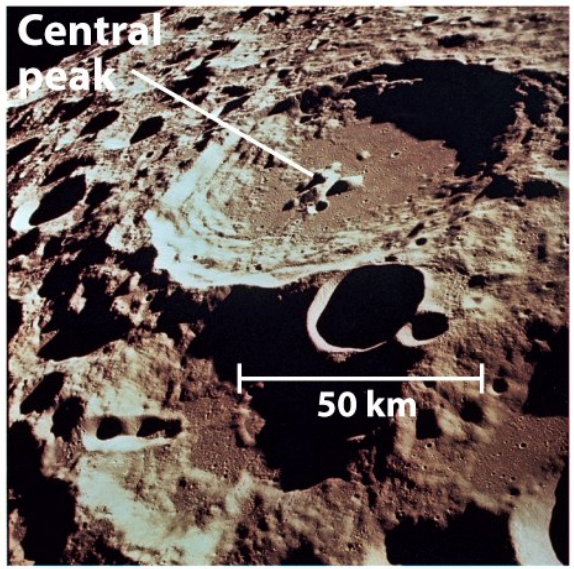


Ch7: Comparative Planetology I

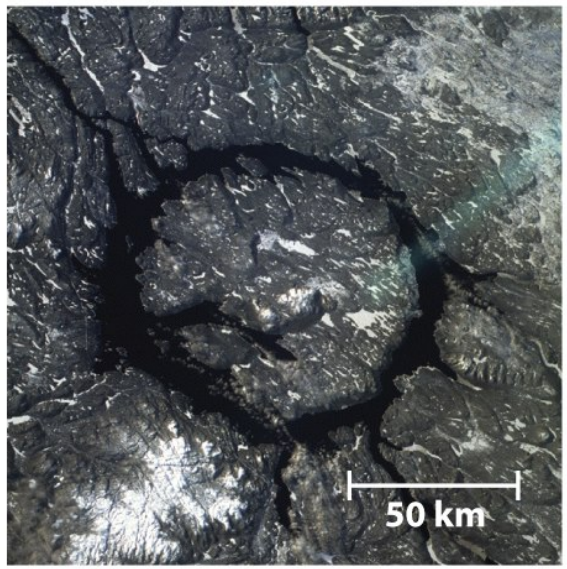
Ch8: Comparative Planetology II
Ch9: The Living Earth
Ch10: Our Barren Moon
Ch11: Sun-Scorched Mercury
Ch12: Cloud-covered Venus
Ch13: Red Planet Mars
Ch14: Jupiter and Saturn
Ch15: Satellites of Jup. & Saturn
Ch16: Outer World
Ch17: Vagabonds of Solar System

Craters

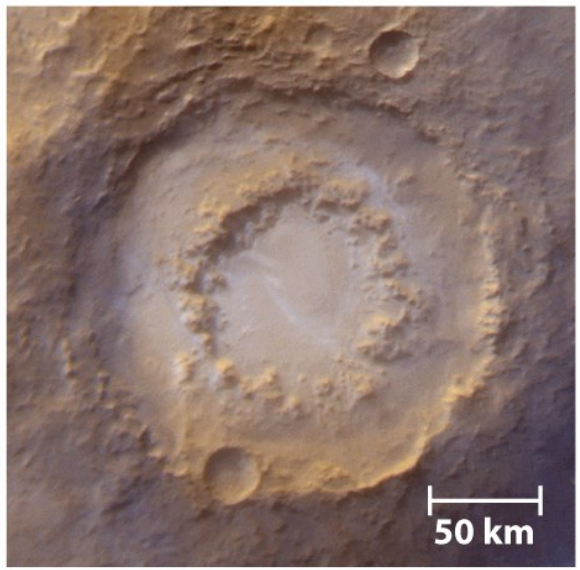
- **Impact craters**: the result when **meteoroid** collides with the surface of a terrestrial planet or satellite
- **Meteoroids**: small objects in space ranging from a few centimeters to a few hundred meters. They are mainly the result of collisions between asteroids.



Moon



Earth



Mars

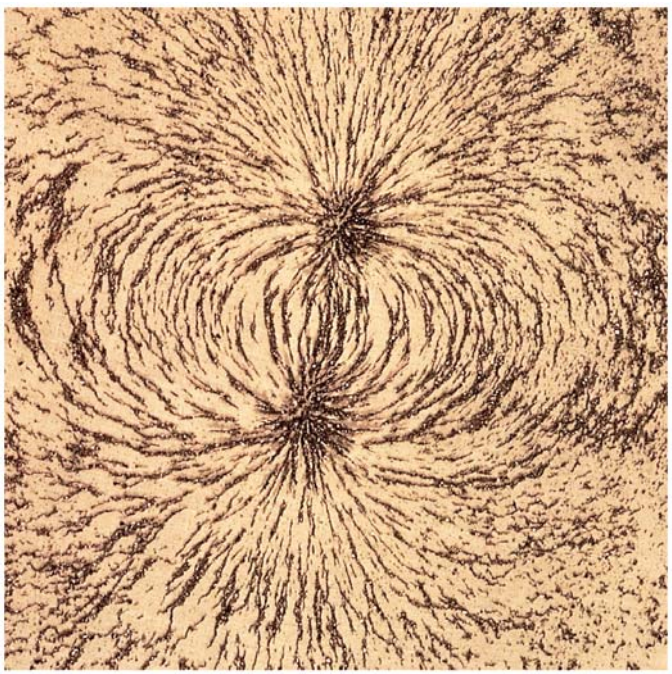
Craters

- Why is the Moon heavily cratered?
  - Answer: Moon is geologically inactive
- Why is the Earth rarely cratered?
  - Earth is geologically active. Craters are erased with time
    - Plate movement
    - Volcano
    - Water and Wind

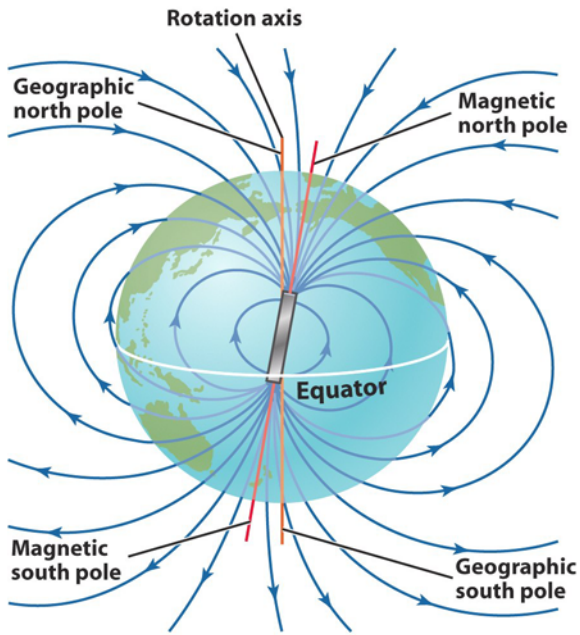
- **Geologic activity** is powered by **internal heat**, which keeps the interior is at least partially molten
  - The smaller the object, the easier it loses heat, the less internal heat it is likely to have retained. For instance, the Moon
  - The larger, the more difficult it loses heat, the more internal heat it is likely to have retained. For instance, the Earth

Magnetic field of Planets

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



Bar Magnet



Earth's Magnetic Field

Diversity of the Solar System

- Sun, Planets, satellites, comets, asteroids and meteoroids
- The diversity is a result of its origin and evolution

table 7-3 **Comparing Terrestrial and Jovian Planets**

	Terrestrial Planets	Jovian Planets
Distance from the Sun	Less than 2 AU	More than 5 AU
Size	Small	Large
Composition	Mostly rocky materials containing iron, oxygen, silicon, magnesium, nickel, and sulfur	Mostly hydrogen and helium
Density	High	Low

Final Notes on Chap. 7

- 8 sections, all studied.

- Section 7-1 to 7-5 covered in lect 07 on Oct. 16, 2006
- Section 7-6 to 7-8 covered in lect 08 on Oct. 23, 2006