1 Lecture: Solar System Inventory

- Read chapter 6
- Exercises: Do all "Review and Discussion" and all "Conceptual Self-Test")

1.1 Discovering and learning about the solar system's content

- Greeks and ancients aware of 5 planets: Mercury, Venus, Mars, Jupiter, and Saturn
- ancients also aware of comets and meteors – transient phenomena – not well understood until much later
- knowledge of the solar system remained unchanged for most of human history
- early 17th century – optical telescopes
- new planets discovered: Uranus (1781), Neptune (1846)
- minor planets, and asteroids 19th century
- 20th century – Kuiper Belt Objects (beyond Neptune)
- satellite observations, rovers, and probes – high level of detail
- current knowledge: 1 star (the sun), 8 planets, 165 moons (and counting), 8 asteroids and Kuiper Belt objects larger than 300km across, tens of thousands of smaller asteroids and comets, countless smaller objects less than 100m across
- comparative planetology: help understand origin of the solar system, help understand earth's history and geology better, help understand planetary evolution and formation

1.2 Measuring planets and the solar system layout

- see table 6.1 – basic properties
- distance to each planet known – Kepler's and Newton's Law, radar ranging
- sidereal orbital period of each planet known – earth's motion well understood
- the sizes of the all planets are known – angular size
- masses of all the planets known – the ones with observable moons, can use Newton's Laws – use perturbations used for Mercury and Venus (modern methods use satellites)
- immense size of the solar system – Kuiper Belt 50 AU from the sun
- planets relatively close to sun – nearest star 4 light years away (Neptune is a few light hours)

- planet orbits are ellipses, but are nearly circular (Mercury most eccentric)
- planets not evenly space – get farther apart as we move out
- all planets orbit counterclockwise as seen from above the Earth's North Pole
- all planets orbit in nearly the same plane as the earth's orbit – flat solar system
- rocky planets (terrestrial planets) orbit close to the sun, gas giants (Jovians) orbit further away
- Kuiper Belts on the edge of the solar system – icy bodies
- Oort cloud – domain of the comets, out to almost a light year from the sun!

1.3 Terrestrial and Jovians: two different worlds

- inner planets – Mercury, Venus, Earth, Mars – small (compared to the Jovians), dense, rocky bodies
- physical and chemical properties of similar to the earth – hence names terrestrial
- all 4 terrestrials have an atmosphere, but very different from one another
- Earth, only one with liquid water and oxygen in atmosphere
- surfaces rocky but again very different – heavily cratered Mercury to ocean covered Earth
- few moons – Earth has a large moon compared to its size, Mars has two small "potato" shaped moons while Mercury and Venus have none
- Earth and Mars have almost the same length of day – Mercury and Venus take months just to rotate once
- Earth and Mercury have significant magnetic fields, Venus and Mars do not
- the *uncompressed density* of the terrestrial planets diminish as we proceed outward from the sun
- many differences, but broad similarities compared to the Jovians
- Jovians – more distant from the sun, widely spaced throughout the solar system
- Jovians are large and gaseous, low density (Saturn would float in water) – very different from the terrestrial worlds
- Jovians have no solid surface
- Jovians have strong magnetic fields

- each Jovian has a dense ”terrestrial inner core that makes up more and more of each Jovian planet as we move outward from the sun
- Jovians have many moons all very different from our moon
- all Jovians have a ring system

1.4 Interplanetary matter

- vast space between the planets – countless chunks of rocks and ice
- cosmic debris, as large as asteroids to as small as a grain of dust
- interplanetary space extremely good vacuum by laboratory standards, but not by interstellar standards or inter-galatic standards
- asteroids and meteoroids – rocky in composition (less than 100 m across meteoroid, larger asteroid)
- total mass less then the our moon – play no important role in the dynamics of the present solar system
- crucial information about that history and origin of the solar system
- outer asteroid belt – Kuiper belt, range from a few tens of metres to more than 1000km (Pluto is an example)
- information from the Kuiper belt will help us understand more about the history of our solar system

1.5 Spacecraft exploration

- started in the 1960s (first artificial satellite Sputnik 1957)
- many missions – flybys (satellite did not orbit, just went on by)
- Stand out examples:
  - Mission to Mercury
    - Mariner 10 launched 1973 (stopped returning data 1975)
    - orbit passed by Mercury every six months
    - 4000 photographs mapping 45% of the surface
    - new missions underway – Messenger mission
  - Venus
    - most visited – 20 spacecrafts

    * Soviet Venera program (late 60s through early 80s) landed probes on the surface (only lander on Venus)
    * 1978 US Pioneer mission – radar mapping of the planet's surface
    * Magellan mission (1990-1994) high resolution radar mapping (120m scale), 98% of the surface
    * Venus Express, current mission by ESA
  - Mars
    * exploration started in 1960s (US and USSR)
    * Mariner 4 – first flyby July 1965
    * Mariner program included an orbiter (Mariner 9), early 1970s
    * entire surface mapped – evidence of liquid water
    * Viking mission mid-1970s, included orbiter and landers
    * landers sampled surface chemistry – transmitted data for several years
    * since Viking, Mars Global Surveyor, Mars Pathfinder (Sojourner minirover), Mars Odyssey, Mars Express (ESA), Mars Exploration Rover (Spirit and Opportunity)
    * ongoing missions, Mars Reconnaissance Orbiter (climate, geology)
    * http://marsrovers.nasa.gov/gallery/video/animation.html for more info
  - Missions to the outer planets
    * two pairs of US spacecraft lion's share of the work – Pioneer 10, Pioneer 11 (72, 73), and Voyager 1, Voyager 2 (77)
    * Pioneer mission – Jupiter, scientific mission, and scout for Voyager mission
    * Voyager 2 – Grand Tour (Jupiter, Saturn, Uranus, and Neptune)
    * Galileo – 1989, latest mission to Jupiter, atmospheric entry probe
    * New Horizon Mission – probe sent to Pluto and the Kuiper Belt (2015)

1.6 Prelude: how did the solar system form?

- observations, satellites, and probes over the 20th century provide a foundation for understanding the history of the solar system
- Nebular contraction theory
  - old idea – 17th century Rene Descartes
  - suggests that cloud of gas begins to contract from a perturbation, heats up, sun ignites, planets form in cooler regions
  - Pierre Simon de Laplace – mathematical physicist, used mathematics (Newton's Laws), showed that collapsing gas flattens into a pancake, solar nebula
- Planetary Condensation

  - variant of nebular theory
  - favoured by most astronomers
  - planets condense out, like snowflakes condensing in a snowstorm
  - sun forms in the center – temperature gradient across nebula
  - hot near sun – only rocky and metallic material can condense (terrestrial planets)
  - cooler regions further out allow gas giants to form
- more details to come when we get to chapter 15