ASTR 371, Fall 2016

Review III

9. Jovian Planets and Rings (Lecture Notes 9; Chap 12, 14)

9.1-2 Introduction, Motion
   a. Carefully study the data for the Jovian planets. Must know the general properties of the Jovian planets: orbit, rotation, size, mass, density, composition, atmosphere, and magnetic fields, in comparison with the terrestrial planets.
   b. Must know what is a differential rotation, and what it tells us about the interior of a planet.
   c. Know the history of discoveries of the Jovian planets.

9.3-4 Atmosphere & Internal Structure
   a. Must know the atmosphere circulation patterns on the Jovian planets and how they form, in comparison with the terrestrial planets.
   b. Must know cloud patterns on Jupiter and Saturn: zones, belts, spots (e.g. Great Red Spot), ovals, and what kind of motions is found in these features.
   c. Must know how Jupiter’s surface appears in visible and infrared observations, and what’s the meaning of these observations.
   d. Must know the source of energy that drives the atmosphere activities on the Jovian planets. Understand why some atmospheres are more dynamic than others.
   e. Must know the composition, structure, and temperature profiles of the Jovian atmospheres, in comparison with atmospheres of the terrestrial planets.
   f. Know the internal structure of the Jovian planets, in comparison with the terrestrial planets.
   g. Must know methods to deduce the interior structure of a planet.

9.5 Magnetic fields
   a. Must know mechanisms to generate global magnetic fields in the terrestrial and the Jovian planets: what is common, what is different.
   b. Must know what are plasmas and how plasmas behave in magnetic fields.
   c. Must know how the magnetosphere of a planet is observed. Must know what causes auroras on planets, where they are observed, and why.
   d. Must understand why Jupiter has strong magnetic fields and magnetosphere.
   e. Know properties of Uranus and Neptune’s magnetic fields.

9.6 Rings
   a. Know general properties of the Jovian planets’ (esp. Saturn’s) rings: ring systems, divisions (gaps), ring particles, brightness, colors, and arrangement.
   b. Must know how rings formed around the Jovian planets.
   c. Must know what is tidal force, and what effects tidal forces have on planets and satellites. Must know what is the Roche limit. Must understand why rings of the Jovian planets are within the Roche limit.
General: must understand the critical role of gravity in many important properties of the Jovian planets (see the summary in Lecture 9).

10. Satellites
   a. Know the names of the seven largest satellites in the solar system and their general properties: their parent planets, motions, relative sizes, surface features, atmospheres, and magnetic fields.
   b. Must know the effects of tidal forces on satellites and planets (see Lecture 6 Ex.1 for summary).
   c. Must know general properties of Galilean satellites: their names, orbits, motions, surface features, geological activities (and energy source), interiors, compositions, magnetic fields, and mechanisms to generate magnetic fields.
   d. Must know what is Io torus.
   e. Must know general properties (composition and evolution) of Titan’s atmosphere in comparison with the Earth’s atmosphere. Know of Titan’s surface features and possible evidence for wetlands on Titan.
   f. Know of special features of Triton.

11. Vagabonds of the Solar System
11.1 Introduction
   Must know the similarities and differences between asteroids and comets in terms of their origin, orbits, motions, and compositions.
11.2 Asteroids
   a. Must know what is the asteroid belt and the general properties of asteroids: their discovery, size, composition, orbit, and the names of the largest asteroids.
   b. Must know how the asteroid belt formed: must know the effects of Jupiter’s gravity on asteroids and the asteroid belt; must know what are Kirkwood gaps and Trojan asteroids, and how they formed.
   c. Know of asteroids’ encounter with the Earth and its possible relation to extinction of dinosaurs.

11.3 Meteoroids, Meteors, and Meteorites
   a. Must know what are meteoroids, meteors, and meteorites.
   b. Know of the composition and internal structure of meteorites.
   c. Know how meteorites may tell us about the history of the solar system.

11.4 Comets
   a. Must know general properties of comets: orbits, composition, structure, and appearance. Must know the concepts of nucleus, coma, tail, and hydrogen envelop.
   b. Must know formation of comet’s tails when a comet is approaching the Sun. Must know why a comet often has two tails. Must know the composition, color, and direction of the two tails, and be able to explain why so. (Review what are plasmas and how they behave in magnetic fields.)
c. Know the two reservoirs of comets: the Kuiper belt and Oorts cloud. Know the rough distance ranges of the Kuiper belt and Oorts cloud. Know what populations of comets originate from the Kuiper belt and Oorts cloud.
d. Know how comets may break up. Know why observers on Earth can observe some meteor showers from fragments of burned out comets around the same time every year.
e. Must know how Pluto is different from the planets and why it is demoted to a Kuiper Belt object.

12. The Origin of the Solar System
12.1 Diversity: must know general properties of planets and other solar system objects.
   (review previous lectures).
12.2 The Abundances of Chemical Elements
   a. Must know which elements are most abundant in the universe and in what cosmic process they are produced. Must know how heavy elements are produced.
   b. Must be able to estimate relative masses of the terrestrial and Jovian planets from their compositions and abundances of chemical elements in the Milky Way (see Examples in the Lecture).
   c. Know the age of the solar system and how it is determined.

12.3 Formation of the Solar System
   a. Must know the basic idea of the nebular hypothesis. Know the following concepts: solar nebula, protoplanetary disk, protosun, thermonuclear reaction, planetesimal, accretion.
   b. Must know how the nebular hypothesis explains formation and evolution of the solar system.
   c. Must know how general properties of the planets in the solar system are explained by the nebular hypothesis.
      ■ properties of planet’s orbits and rotations
      ■ differences (in size, mass, density, composition) between the terrestrial planets and the Jovian planets.
   d. Must know why gravity, abundances of chemical elements in the universe, the distances of planets to the Sun are key factors to determine the diversity of the solar system
   e. Must understand and be able to summarize the role of gravity in forming and shaping the solar system (review previous Lectures and summary in this Lecture).

12.4 Extrasolar planets and extraterrestrial life: (review your group presentations)
   a. Know how extrasolar planet candidate can be found with astrometric method, spectroscopic method, and by transit observations.
   b. Know of latest discoveries of possible candidates of exoplanets.
   c. Know of critical elements and important conditions for life.
   d. Know of possible candidates in the solar system that may host life.
13. Gravity in the Solar System (Chapter 4 and lecture notes)

b. Know of major contributions by Copernicus, Tycho, Kepler, Galileo, and
Newton to our current understanding of the solar system, and the basic idea of
heliocentric model.

c. Must know Kepler’s three laws of the motions of the planets. Must be able to
use Kepler’s laws to calculate parameters of the orbital motion (sidereal
period, semi-major axis of the orbit, perihelion or aphelion distance etc.) of a
planet. Must know the units of the terms in the equation of Kepler’s third law:
\[ P^2 = a^3. \]

d. Newton’s law of universal gravitation:

- Must understand Newton’s law of universal gravitation.

\[
F = G \frac{m_1 m_2}{r^2}
\]

- Must know what force maintains the orbital motions of the planets
around the Sun and satellites around the planets.

- Must understand Newton’s form of Kepler’s third law. Must be able to
calculate orbital motions and determine masses in a binary system (see
Examples in the Lectures and relevant homework
problems).

\[
a^3 = \left( \frac{G (m_1 + m_2)}{4 \pi^2} \right) P^2
\]

- Must be able to calculate parameters (e.g., orbital velocity) in a
circular orbit.

\[
F = m \omega^2 r = \frac{mv^2}{r}
\]

- Must be able to use Newton’s law and \textit{scaling relationship} to
compare parameters of different orbital systems: go over and must be
able to solve all the example questions in this lecture as well as HW problems.

e. Must understand and be able to explain the role of gravity in the solar system in many examples (see examples in this lecture, some previous lectures, and your homework problems).

   a. Must know what is the energy source of the Sun (and stars). Understand the key physical property that decides whether a celestial body can become a star.
   b. Must know the meaning of the mass-energy equation \( E = mc^2 \).
   c. Must know the structure of the solar interior, and the major physical process in each layer. Must know major observational studies of the solar interior.
   d. Understand how the standard solar model is built. Understand how force balance (hydrostatic equilibrium) and energy balance are maintained. Understand the means of energy transfer from the interior outward.
   e. Know the pattern of the differential rotation of the Sun.

15-17. The Sun’s Dynamic Atmosphere, Magnetism, Dynamo, and Eruptions (Lecture Notes and Chapter 16).
   a. Must know the structure of the Sun’s atmosphere. Must know the relative temperature and density variations in different layers of the atmosphere. Must know at what wavelengths these different layers are best observed.
   b. Must know major observational signatures in each layer of the atmosphere and physical properties of the Sun’s atmosphere reflected in these signatures.
   c. Understand the importance of magnetic field in governing the dynamics of the Sun’s atmosphere.
   d. Must know what is the solar cycle in terms of sun spot number and latitude distribution, and solar radiation. Must know what is the butterfly diagram. Must know what is the solar maximum and what is the solar minimum.
   e. Must know what governs, or what is the nature of, the solar cycle.
   f. Must know the basic idea of solar magnetic dynamo model: what are poloidal and toroidal magnetic fields, how and what motions in the Sun recycle the poloidal and toroidal fields to generate the cyclic pattern of sunspots from the solar minimum to the solar maximum and to the solar minimum again.
   g. Must know what are solar active regions. Must know what is the Zeeman effect, and how magnetic field in the photosphere is measured.
   h. Must know what are plasmas and how plasmas behave in magnetic field.
   i. Must know how to compare magnetic pressure and gas pressure, and know which pressure dominates in different layers of the Sun’s atmosphere (e.g. the photosphere and corona; see HW11-12).
**Gas pressure**: \( P_g = nkT \)

- \( P_g \): gas pressure in N/m\(^2\)
- \( n \): particle number density in m\(^{-3}\)
- \( k \): Boltzmann constant = \( 1.38 \times 10^{-23} \) J/K
- \( T \): temperature in K degree

**Magnetic pressure**: \( P_m = \frac{B^2}{2\mu_0} \)

- \( P_m \): magnetic pressure in N/m\(^2\)
- \( B \): magnetic field in Tesla
- \( \mu_0 \): permeability of vacuum = \( 4\pi \times 10^{-7} \) N A\(^{-2}\)

j. Must know what kind of magnetic fields provide energy for solar activities.

k. Must know what are solar flares and coronal mass ejections (CMEs), what is the relation between flares, CMEs, and magnetic fields, and what is the mechanism of flare energy release.

l. Know of the standard flare model. Know of how flares look like in different atmosphere layers and in different wavelengths such as optical, UV, EUV, and X-rays. Know of emission mechanisms at these wavelengths.

m. Must understand the relation between space weather and energetic solar events like flares and CMEs.