Astronomy 110G **Review Sheet for Exam #2**

The following summarizes the topics covered in the second third of this semester. Just the main topics are listed, or those I think most important. Since the exam will be comprehensive, review earlier materials as well. As a start, be sure you understand all of the words that appear below.

Electromagnetic Radiation (Light): (continued)

- Importance in Astronomy: Analysis of light emitted, absorbed, or reflected from objects can give position, motion, rotation, temperature, pressure, composition, etc., information about those objects.
- Basic Characteristics: Linear (straight-line) propagation of light, constancy of speed of light.
- Basic particle (photon) and wavelike (diffraction & interference) behavior.
- Frequency and wavelength. The electromagnetic spectrum (X-rays, γ-rays, ultraviolet, visible, infrared, radio waves, *etc.*) The relationship $\lambda f = c$ (true for any wave).
- The Inverse-Square Law for apparent brightness: $F = L/4\pi r^2$. What are F, L, and r? Why is this useful?
- Doppler effect: $\Delta\lambda/\lambda = v_{radial}/c$. What are these quantities and how do we use this relation?
  (What is $\Delta\lambda$? What is a radial velocity? A tangential velocity? See also "proper motion" below.)
- Optical Phenomena: Interference & diffraction, reflection, refraction, dispersion; scattering, absorption.
- Light and Matter: Emission and absorption by solids, liquids, gases. What are the spectral differences?
- Spectral lines as a "fingerprint" for responsible atoms or molecules. "Chemical analysis" of starlight.
- Luminosity and color *vs*. temperature and surface area for emitting objects. (Wien's and Stefan's Laws).

The Solar System:

- Basic Constituents: The Sun, 9 planets (names?) & their satellites, "trans-Neptunian objects", asteroids (→ sporadic meteors), comets(→ shower meteors), interplanetary dust (→ zodiacal light) and gas (the "solar wind").
- Sun has 99.8% of the total mass of the Solar system .
  (Angular momentum or "spin" is mostly in Jupiter's orbital motion, though!)
- Basic Orbital Characteristics: Orbit sizes, shapes, and orientations. (Know how these are determined).
- General behavior; differences and similarities in orbital motions, etc. Comets as exceptions?
- Other Planetary Motions: Rotation (also differential rotation) and inclination. Observational ways of determining planetary rotation periods. Oddities (*e.g.* Venus' retrograde rotation).
- Physical Properties: (Know how these are determined)
  Techniques for determining planetary masses (Kepler III), sizes, and shapes.
  Mean density (Mass/Volume) as a composition clue.
  Albedo. (=Reflectivity) Solid surfaces *versus* cloudy atmospheres.
- General differences between Jovian and Terrestrial planets. (Physical and orbital properties)
  *Outer (Jovian) planets are larger, more massive, rotate faster, have lower mean densities, and are more oblate. Basically they are gaseous bodies composed mostly of lighter elements.
  *Terrestrial planets are rocky bodies (some with a low-mass atmospheres). Heavier elements.
  *Satellites can be rocky or icy bodies. Asteroids are rocky whereas comets and KBOs are icy.
- General Solar System Characteristics:
  Orbits: Almost circular, coplanar. All in same (direct) direction. (Same is true for satellites, asteroids, *etc.*)
  Comets: How are long- and short-period comet orbits different from those of the planets?
  Other Motions: Mostly same axial (spin) directions. Exceptions: Venus, Uranus and Pluto.
- Ages: Radioactive age-dating technique (understand!): Age is elapsed time since "last melt."
- Earth, Moon, Mars, and asteroids (meteorites) are about 4.5 billion years old. (Sun has the same age.)

Origins

- Origin of the Solar System: Theory is required to explain above physical and orbital characteristics, common age, plus details and exceptions (*e.g.*, unusual orbits or rotations) . A good theory makes testable predictions. You should understand the basics (and faults) of the various ideas considered:
- Random Capture Hypothesis: Are there loose "planets" out there? Makes wrong orbital predictions. Doesn't explain common ages, Jovian/Terrestrial differences, rotations, ...
- Encounter Hypothesis: Gives reasonable orbital predictions, but any "pulled-out" material would be too hot and would evaporate, not condense into planets. (The latter is also a problem with the hypothesis based on an (unexplained) increase in the Sun's rotation leading to ejection of hot gas by centrifugal forces.) Doesn't explain how deuterium can present in planets; it would have been destroyed in the early Sun beforehand.

• Protoplanetary Hypothesis (a variant of the Nebular Hypothesis):
The basic idea is that the planets (and other solar system bodies) form in conjunction with formation of Sun from a contracting gas/dust cloud. Common age is a consequence. Evidence, for this picture, including that based upon observation of other star systems, strongly supports this hypothesis. It works!

• Basic scenario is cold collapsing dust/gas cloud which flattens (due to rotation) and heats (due to compression) as collapse proceeds. Most material in center (Sun), most spin in disk (planets). Only heat-resistant (refractory) solids can form in inner region - to give low mass rocky "terrestrial" bodies. Ices can form from volatile materials and merge in cooler regions- giving massive but low density (jovian) bodies.
• Subsequent evolution: Heating/melting/vaporization by collisions gives differentiation in terrestrial bodies. Atmospheric loss and replenishment by volcanic and biological activity in the latter.
• Meteoritic impacts, geological activity, meteorological activity (and erosion) are responsible for most surface characteristics. Comets may have provided terrestrial water - and produced extinctions!
• Comets ("orbital exception") are formed early in the process; their orbits reflect the rather random non-circular motions prevalent before significant flattening occurred. Outliers; those we see are the rare ones driven inward by interactions which alter their orbits. Are comets our source of water?
• Venus' retrograde rotation results from tidal coupling to the Earth (as does the Moon's). Uranus' tilt is still a puzzle, as is Pluto's. Maybe the result of a long-ago collision?
• Synchronous satellite rotations (common) and 3:2 rotation of Mercury also explained *via* tidal coupling.
• Subsequent Earth history: The atmosphere as a consequence of plant life. Impacts and the extinctions.
• Origin of the Moon resulting from a terrestrial impact of a Mars-sized body about 4.4 Gyr ago.

Basic Properties of Stars:

• Distances: Trigonometric Parallax (triangulation). The parsec.
Spectroscopic Parallax (inverse-square law for light).
Moving Group Parallax (for clusters; a perspective effect).
Dynamic Parallaxes (some binary stars).
Statistical parallaxes (Uses Sun's space motion to provide a baseline for triangulation).
• Motions: Radial velocity (via the Doppler effect)
Tangential velocity (from proper motion and parallax-distance).
(Again, you should understand the differences between radial and tangential motion.)
The Solar Motion.
• Distribution of Stars in Space. Typical separations (about 1 parsec) and motions (a few 10's of km/sec).
• Basic Physical Properties of Stars: Mass, Radius, Luminosity, (Surface) Temperature.
• Stellar Brightness: Apparent brightness versus luminosity. (*i.e.*, the inverse-square law.)
The range of stellar luminosities and the relative numbers of each luminosity.
• Stellar Colors & Spectra: Spectral classification. Color *vs*. temperature, spectrum & spectral types.
Classification of stars and the *****Hertzsprung-Russell Diagram*****.
• Luminosity - Temperature-Radius relationships: giants, supergiants, white dwarves, *etc*.
• The relative numbers of different kinds of stars. Rarity of supergiants and giants, *etc*.
• Binary Stars: Types and classifications. Importance of binaries for our knowledge of stellar masses and sizes. (Visual doubles and visual binaries, astrometric binaries, single- and double-lined spectroscopic binaries, spectrum binaries, eclipsing binaries) . Star masses from binaries via Newton's version of Kepler 's Third Law: $a^3/P^2 = M+m$. Mass ratios from center-of-mass (barycentric) motions.
• Stellar sizes: Radii from eclipsing systems. Interferometric sizes. Photometric sizes: $L=4\pi R^2\sigma T^4$
• Summary of Stellar Properties: L and T; M, R and composition. Ranges. The stellar mass function.
Useful fact: Outer parts of stars are composed mostly of hydrogen and helium (about 75% and 24% by mass, respectively). The deep interiors, where hydrogen has been converted to helium, will be somewhat different but still poor in heavier elements (<1%) Only white dwarf stars really contain much of anything else (mainly carbon). The only objects that seem to be dominated by the heavier elements are things like the terrestrial planets and related stuff like the asteroids and some planetary satellites.

What Makes Stars Shine?

• Basic information. Estimates of relative star lifetimes. Abundances of the elements. Temperatures.
• Possible processes; arguments pro and con for residual heat, gravitational contraction, accretion, chemical reactions, nuclear fission, and nuclear fusion.
• Fusion processes: Nuclear reactions and the conversion of hydrogen to helium. Required conditions of high density and, particularly, temperature (a few million degrees Kelvin). Why?
• The lifetime of the Sun. (About 10 billion years; its present age is about 4.6 billion years.)