Astrophysics. Exam I Review

Chapter 1

• Ancient civilizations and their understanding
• Ancient Greek astronomers
• Stellar parallax
• Precession (what is it, period, consequences)
• Celestial Sphere
• Coordinates systems
• Planetary configurations (opposition, etc)
• Synodic and sidereal periods; $1/S = 1/P_{in} - 1/P_{out}$
• Proper motion ($\mu = v_\theta/r$), radial motion ($v_r$)

Chapter 2

• Ptolemaic system (epicycle, deferent, etc)
• Heliocentric system
• Copernicus, Tycho, Kepler, Galileo, Newton
• Ellipses ($r = \frac{a(e^2-1)}{1+e \cos \theta}$)
• Kepler’s Laws
• Newton’s Laws
• Law of Universal Gravitation
• Shell theorems
• Coordinate conventions for 2-body problem. (Relative orbit or C.O.M, absolute coords)
• Reduced mass: $\mu = \frac{m_1 m_2}{m_1 + m_2}$
• Center of mass (COM) coords: \( \vec{r}_1 = -\frac{\mu}{m_1}\vec{r} \); and \( \vec{r}_2 = \frac{\mu}{m_2}\vec{r} \)

• Center of mass (COM) coords: \( \vec{r} = \vec{r}_2 - \vec{r}_1 \)

• Total energy in terms of reduced mass:

\[
E_{tot} = \frac{1}{2}\mu v^2 - GM\frac{\mu}{r}
\]

• Total orbital angular momentum

\[
\vec{L}_{tot} = \mu \vec{r} \times \vec{v}
\]

• Results from the derivation of Kepler’s 2nd law

1. \( \frac{d\vec{r}}{dt} = 0 \) (angular momentum is constant in 2-body problem)
2. \( \frac{dA}{dt} = \frac{L}{2\mu} \)
3. \( L = \mu \sqrt{GMa(1 - e^2)} \)

• The total energy of a 2-body system is 1/2 of the time-average potential energy:

\[
E_{tot} = \frac{1}{2}\langle U \rangle
\]

• Escape velocity: \( v_{esc} = \sqrt{2Gm/r} \)

• Kepler’s 3rd law (modified)

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

• Virial Theorem: for a multi-body system in equilibrium, the time-averaged kinetic energy and potential energy are related by:

\[-2\langle K \rangle = \langle U \rangle\]

• Also, for both multi-body systems and 2-body systems, total energy is:

\[
\langle E \rangle = \frac{1}{2}\langle U \rangle
\]

Chapter 3

• Parallax and distance. \( d(pc) = \frac{1}{\rho^2} \) (for baseline = 1 AU)
- Parallax (more general): \( d = \frac{B}{2\tan p} \)
- Flux, \( F = \frac{L}{4\pi r^2} \) in \( Wm^{-2} \)
- Luminosity: total energy leaving an object in all directions over all wavelengths
- Monochromatic luminosity: \( L_\lambda d\lambda \) = a luminosity only within the wavelength range \( \lambda \) to \( \lambda + d\lambda \).
- Luminosity (blackbody) = \( L = A\sigma T^4 \).
- Luminosity (not quite perfect blackbody) = \( L = \epsilon A\sigma T^4 \).
- Magnitude System
  - 5 magnitudes difference corresponds to a flux ratio of 100X.
  - smaller numbers means brighter
  - apparent magnitude: \( m = 2.5\log_{10} \frac{F}{F_{\text{ref}}} \)
  - absolute magnitude, \( M \): the apparent magnitude of a star at the standard reference distance (10 pc = 32.6 ly).
  - absolute magnitude, \( M = 2.5\log_{10} \frac{L}{L_{\text{ref}}} \) (\( L_{\text{ref}} \) is about \( 80 \times L_\odot \)).
  - absolute magnitude is a measure of luminosity, apparent is a measure of brightness.
  - Example: \( M_\odot = 4.76 \), \( m_\odot = -26.7 \), \( L_\odot = 3.826 \times 10^{26} W \)
  - Distance modulus, (m-M),: \( (m - M) = 5\log_{10} \frac{d}{10pc} \)
  - Distance modulus: an alternative measure of distance that directly tells you how the brightness of the object differs from its brightness at 10 pc.
- Wave nature of light
  - Light has wave properties: interference pattern formed by double-slit
  - \( c = \lambda \nu \)
  - Time-averaged Poynting Vector: a measure of monochromatic flux
  - Time-averaged Poynting Vector: \( \langle S \rangle = \frac{1}{2\mu_0}E_0B_0 \) (mks) or \( \frac{\epsilon_0}{8\pi}E_0B_0 \) (cgs)
  - Radiation pressure is greater when light is completely reflected than when light is absorbed - transfer of momentum.
  - Radiatio pressure, absorption: \( F_{rad} = \frac{SA}{c} \cos \theta \)
  - Radiatio pressure, reflection: \( F_{rad} = \frac{2SA}{c} \cos^2 \theta \)
• Blackbody radiation
  – Blackbody: an ideal emitter and absorber.
  – Blackbody absorption: 100%
  – Wien’s Law: $\lambda_{\text{max}} T = 0.0029 mK = 2.9 \times 10^7 \text{ÅK} = (5000 \text{Å})(5800K)$
  – Stefan-Boltzmann law: $F_{\text{surf}} = \sigma T^4$
  – Planck’s Law: $B_\lambda(T) = \frac{2hc^2/\lambda^5}{e^{hc/\lambda kT} - 1}$
  – Color indices: $B - V = m_B - m_V = -2.5 \log \left( \int \frac{F_\lambda S_B d\lambda}{\int F_\lambda S_V d\lambda} \right) + C_{B-V}$

Chapter 4

• Special relativity: the physics of high speeds
  • $z = \Delta \lambda / \lambda$
  • $z = \frac{v_r}{c}$ for low $v_r$
  • $z = \sqrt{1 + \frac{v_r}{c}} - 1$ for high $v_r$

Chapter 5

• History of spectroscopy
• Kirchoff’s Laws: how absorption, emission and continuous spectra are formed.
  • Space motion of a star: $v = \sqrt{v_r^2 + v_\theta^2}$
  • $E_{\text{photon}} = h\nu = hc/\lambda = pc$
  • Photoelectric Effect: $K_{\text{max}} = h\nu - \phi$
  • Compton Scattering: $\lambda_f - \lambda_i = \frac{h}{m_e c}(1 - \cos \theta)$
  • Bohr model of hydrogen atom - required $L = n\hbar$
    – Energy levels are labeled $n=1$ (ground), 2, 3, 4, etc.
    – $r_n = a_0 n^2$
    – $E_n = -13.6eV n^{-2}$
    – An upward transition means atom has absorbed energy
    – A downward transition means the atom emits a photon