AST713: Mid-Term Review

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- There will be 10 multiple choice questions (1 pt each) and 4 problems (5 pt each) in the mid-term exam.
- Thirty points altogether.
- Physical constants will be provided.
- Simple calculations are needed. Please bring a calculator with you.
- Some simple derivations are required.

You are supposed to know the following.

- Basic concepts of I_ν, j_ν, α_ν, S_ν, τ_ν, and mean free path l_ν.
- The radiative transfer equation $dI_\nu/ds = -\alpha_\nu I_\nu + j_\nu$, its physical meaning, and solution.
- Blackbody spectrum:
$$I_\nu = B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{\exp(h\nu/kT)-1}.$$
Rayleigh-Jeans law and Wien law.
- Blackbody energy density $u = aT^4$ ($a = 7.56 \times 10^{-15}$ erg cm^{-3} K^{-4}), blackbody flux $F = \sigma T^4$ ($\sigma = 5.67 \times 10^{-5}$ erg cm^{-2} s^{-1} K^{-4}).
- Brightness temperature T_b, color temperature T_c, and effective temperature T_{eff}.
- Stellar luminosity $L = 4\pi r_*^2 \sigma T^4$.
- Stellar classification: spectral types: O(0-9), B(0-9), A(0-9), F(0-9), G(0-9), K(0-9), M(0-9); luminosity types: I (super giant), II (bright giant), III (giant), IV (sub-giant), V (main sequence or dwarf), VI (sub-dwarf), VII (white dwarf).
- H-R diagram and physical meaning, post main sequence evolutionary track in the H-R diagram.
- Gas pressure ($P = nkT$), radiation pressure ($P = (1/3)aT^4$), degeneracy pressure ($P(\mathrm{non-relativistic}) = b_1\rho_e^{5/3}$, $P(\mathrm{relativistic}) = b_2\rho_e^{4/3}$).
- Three destinies of stars with different initial masses, rough separations of the initial masses and rough separations of the compact star masses.
- Typical sizes of a white dwarf, neutron star, and a black hole [in unit of its mass: $r_s = (2GM/c^2) = 3$ km$(M/M_\odot)$].
- Definitions and physical natures of Type Ia, Ib, Ic, II supernovae.
- Pulsar period P, period derivative $\dot{P}$, estimate the magnetic field $B = 2.02 \times 10^{12}$ G$\sqrt{P\dot{P}_{-15}}$ and the age $\tau \sim P/2\dot{P}$.
- Energy release efficiency of accretion power $\eta = (r_s/4r_{in})$.
- Two conditions of star formation: Jeans instability and cooling.

- Dust (solid grains, extinction/reddening, re-emission, sites of molecular formation).
- Origins of the elements (H, He, Li: Big Bang; other elements lighter than Fe: inside massive stars; elements heavier than Fe: SN explosions).
- Milky Way structure
- Galaxy types (ellipticals, spirals and irregulars) and relations to star formation (ellipticals little SF), spirals and irregulars (high SFR).
- Scales of galaxies, clusters, super-clusters, and the visible universe.
- Gravitational lensing: deflection angle $2r_s/b$; Einstein radius
$$\theta_E = \left(\frac{2r_s D_{ls}}{D_{ol} D_{os}}\right)^{1/2}.$$
- Olbers paradox: assumptions and solution
- Distance ladder: name some standard candles and standard rulers.
- Hubble's law $v = H_0 r$, the value of H_0.
- Redshift definition: $\frac{\Delta t_o}{\Delta t_e} = \frac{R(t_o)}{R(t_e)} \equiv (1 + z)$.
- Radiation dominant $\rho \propto R^{-4}$, matter dominant $\rho \propto R^{-3}$.
- Three distances: proper distance $D_p = R(t_o) f(r)$; angular separation distance $D_A = D_p/(1+z)[r/f(r)]$; luminosity distance $D_L = D_p(1+z)[r/f(r)]$.
- CMB temperature $T_{cmb} = 2.725 \pm 0.002$ K, $T_{rec} \sim 3000$ K, $z_{rec} \sim 1100$.
- Pie chart of the cosmic composition. Age of the universe.
- Nucleosynthesis, light element abundances: [H]=3/4. [He]=1/4.

You are supposed to derive the following:

- Virial theorem;
- White dwarf mass-radius relation; Chandrasekhar mass limit;
- Multi-color spectrum of an accretion disk;
- Eddington luminosity;
- Jeans mass, radius, density;
- Strömgren radius;
- Two estimates of the AGN black hole mass (from luminosity and from variability);
- From the Schwarzschild metric derive gravitational time dilation and gravitational redshift;
- Remember the FRW metric and the physical meanings of $R(t)$ and r;
- Use the Friedmann equations to derive $R(t)$, D_p, D_A, D_L, and the age of the universe t_0 for different cosmologies (at least for the simplest cosmology with $\Omega_k = 0$ and $\Omega_\Lambda = 0$).