PhD Qualifying Exam (2009) --- Stellar Astrophysics

Choose 5 questions out of the following 8. Each question carries an equal weight of 20%.

1. For a star cluster of *N* stars with the initial mass function characterized by the Salpeter function, if the minimum mass is 0.1 $M_\odot$ (solar mass) and the maximum mass is 30 $M_\odot$, please estimate the fraction of stars which will eventually turn into white dwarfs. Approximately, how much mass will be returned to the interstellar space? Please describe in detail the different major stages from star formation to the end phase of white dwarf formation. Please do the same for the high mass stars. Describe one observational method to estimate the initial mass function of a stellar system.

2. In a stellar atmosphere, measurements of the line broadening effect of the spectral lines of hydrogen atoms and iron atoms yield $\triangle\lambda_D/\lambda = 6.68\text{x}10^{-5}$ for the iron atoms and $\triangle\lambda_D/\lambda = 7.33\text{x}10^{-5}$ for the hydrogen atoms. Please explain the difference. Explain the different line broadening mechanisms.

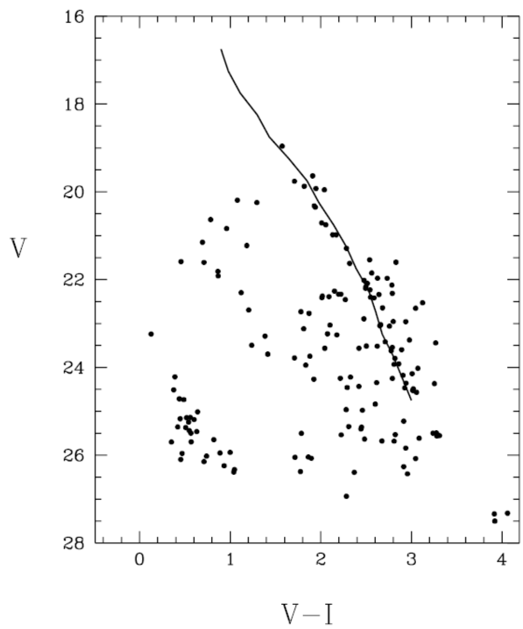
3. Please use the linear approximation of the source function $S_\lambda(\tau_\lambda)$ as a function of the optical depth (τ_λ) to derive the limb darkening effect. Furthermore, please explain what is the definition of the effective temperature of a stellar atmosphere (T_{eff}) and why $T_{eff} = T(\tau = 2/3)$ if its atmosphere is a gray atmosphere. What is a gray atmosphere anyway?

4. Please use the radiative transfer equation to explain why the H-alpha line in 656.3 nm in the solar atmosphere appears in absorption while it is in emission in planetary nebulae. Along the same line, please sketch the temperature profile of the solar atmosphere from the photosphere to the coronal region to explain why the solar ultraviolet and X-ray radiation should be found in line emission?

5. The spectral energy distribution (SED) of the standard star Vega, with an effective temperature of 10,000 K, displays a bite-out at 365.7 nm. Can you please describe the temperature dependence of the continuous absorption coefficients of a hydrogen atmosphere to explain this effect? Vega has been found to exhibit infrared excess in its SED. What is its origin?

6. Below is the V－I color-magnitude diagram in the center of the Galactic cluster NGC 188, observed by the *Hubble Space Telescope* (Andreuzzi et al., 2002, A & A, **390**, 961). The solid line between V~19 to 25 mag is the synthesized lower main sequence at the distance of this cluster. (a) Write down the equation set that determine the structure of main sequence

stars. These equations describe respectively how the energy is generated and transported in a star, and how the star is balanced by different forces, and the properties of the gas. Carefully explain every physical quantity in your equations. (b) Explain why such a sequence exists in a color-magnitude diagram for which both axes are observables, i.e., from the "appearance" of a star whereas the equations govern the interior properties. (c) Note another "sequence" to the bottom left of the diagram (V~24 to 27 mag), also diagonal from the upper-left to the lower-right. These are white dwarfs. Explain what a white dwarf is. (d) Why should there be a sequence for white dwarfs in the diagram? Will this sequence different for a different star cluster? Explain your reasoning.



7. The UV photons from a luminous star ionize the surrounding hydrogen atoms, forming a spherical H II region called the Strömgren sphere. Explain why an H II region usually appears reddish in a color image. Assuming the star radiates like a blackbody, estimate the size of the Strömgren sphere given stellar parameters. Show that the transition zone from the H II region to the H I cloud is very sharp. Once created, the ionization region expands, sometimes influencing the star formation activity in nearby molecular clouds. Explain why the region should expand and estimate roughly its expanding speed.

8. A spherical Galactic H I cloud at a distance of D=1 kpc has an angular diameter of θ=1.2 arcmin and an isothermal temperature of T=85 K. This cloud is known to have a λ21 cm line width due to thermal motion only. The flux density of the cloud at the peak of the line is f_{max}=0.1 Jy. Find the line width FWHM, Δv (km/s), the H I mass, $M_{H2}(M_\odot)$, the diameter, d(pc), volume, V(cm^{-3}), and the number density, n(cm^{-3}) of the cloud. Will the cloud collapse under its own gravity? Estimate the brightness temperature, T_B (K) and optical depth, τ, at the line peak.