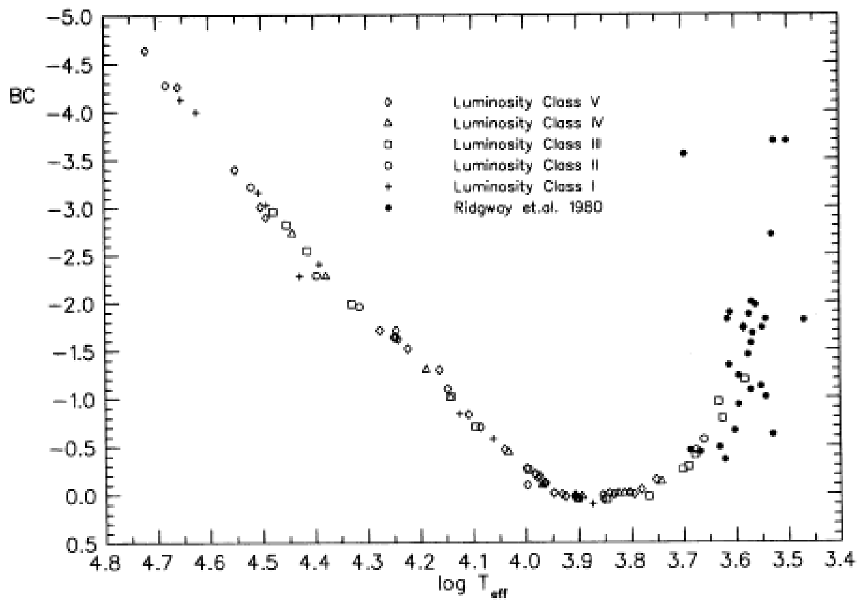
Institute of Astronomy, National Central University

PHD QUALIFYING EXAMINATION 2021 — STELLAR ASTROPHYSICS

1. [**TOTAL: 20%**] **Stellar Temperature and Magnitude:**
Assume a star exhibits the strongest Balmer absoprtion lines in its spectrum when compared to the spectra taken from other stars, and this star has a measured radius of $2R_{\odot}$.



(a) What are Balmer lines? [**2%**]

(b) What is the corresponding effective temperature for this star? [**3%**]

(c) Taking the surface temperature of the Sun as $T_{\odot} = 6000K$, then what is the luminosity of this star in Solar unit $L_{\odot}$? [**3%**]

(d) The bolometric magnitude for the Sun is $M_{\odot,\mathrm{bol}} = 4.74$, then what is the absolute bolometric magnitude of this star? [**3%**]

(e) Using the provided Figure, estimate the absolute V-band magnitude of this star. [**3%**]

(f) If the observed V-band magnitude and color excess of this star is $m_V = 8.0$ mag and $E(B-V) = 0.2$, then what is the distance to this star? [**3%**]

(g) Assume that there is a nearby faint star around this star such that our small telescope cannot re-solved both stars. From observations with our small telescope we measured the V-band magnitude of this star is $m_V = 7.8$ mag, then what is the V-band magnitude of the faint (and unresolved) star? [**3%**]

2. **[TOTAL: 20%] Massive Stars vs Low-Mass Stars:**
List out 5 differences between a $50M_\odot$ star and a $1M_\odot$ star, from their internal structure to their evolution (each 4%). No "extra" points will be given if there are more than 5 differences being listed.

3. **[TOTAL: 10%] Binary Stars:**
Binary stars are important for measuring the physical quantities of stars. Explain how to use eclipsing binaries to measure the mass (M_1 and M_2) and radius (R_1 and R_2) for both stars, such as the equations involved, what observational data are needed, and etc. 5% each for the mass and radius.

Constants

Speed of light	$c = 3.00 \times 10^8\,\mathrm{m\,s^{-1}}$
Gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$
Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
Electron volt	$1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\,\mathrm{J\,m^{-2}\,s^{-1}\,K^{-4}}$
Radiation constant	$a = 7.56 \times 10^{-16}\,\mathrm{J\,m^{-3}\,K^{-4}}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Atomic mass unit	$m_H = 1.66 \times 10^{-27}\,\mathrm{kg}$
electron mass	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
proton mass	$m_p = 1.6726 \times 10^{-27}\,\mathrm{kg}$
neutron mass	$m_n = 1.6749 \times 10^{-27}\,\mathrm{kg}$
helium-4 nucleus mass	$m_{He4} = 6.643 \times 10^{-27}\,\mathrm{kg}$
hydrogen atom mass	$1.674 \times 10^{-27}\,\mathrm{kg}$
helium-3 atom mass	$5.009 \times 10^{-27}\,\mathrm{kg}$
helium-4 atom mass	$6.648 \times 10^{-27}\,\mathrm{kg}$
ideal gas constant	$\mathcal{R} = 8.31 \times 10^3\,\mathrm{J\,kg^{-1}\,K^{-1}}$
Solar mass	$M_\odot = 1.99 \times 10^{30}\,\mathrm{kg}$
Solar radius	$R_\odot = 6.96 \times 10^8\,\mathrm{m}$
Solar luminosity	$L_\odot = 3.85 \times 10^{26}\,\mathrm{J\,s^{-1}}$
Earth mass	$M_\oplus = 5.98 \times 10^{24}\,\mathrm{kg}$
Earth radius	$R_\oplus = 6.38 \times 10^6\,\mathrm{m}$
Astronomical unit	$1\,\mathrm{AU} = 1.50 \times 10^{11}\,\mathrm{m}$
π	$\pi = 3.14$
cal and J	$1\,\mathrm{cal} = 4.2\,\mathrm{J}$

4 (20%) (a) What is the approximate temperature at the core of the Sun? Provide two pieces of observational evidence to support this. (b) A hypothetical star has a density profile varying linearly from the core, ρ_0 at radius $r = 0$, to the surface, $\rho \to 0$, at $r = R$. Estimate the total mass, central pressure, and central temperature of the star.

5 (10%) (a) What is the typical Fermi temperature of a white dwarf?
(b) Derive qualitatively the mass-radius relation for white dwarfs.

6 (20%) Explain each of the following terms succinctly:
(1) Chandrasekhar-Schönberg limit; (2) Roche limit;
(3) Diffraction limit; (4) Eddington limit; (5) Kramers opacity;
(6) Gaunt factor; (7) Color excess; (8) Infrared excess; (9) Jeans mass;
(10) Gray atmosphere