PHD QUALIFY EXAMINATION — STELLAR ASTROPHYSICS

2nd March, 1998

(1) (25 points)

An A type star has $M = 2M_\odot$, $L = 12L_\odot$, and $T_{\rm eff} = 8000$ K.

(a) Estimate its radius.

(b) Estimate how long it can live on the main sequence on its nuclear energy source.

[For the Sun $M_\odot = 2 \times 10^{33}$ g , $T_{\rm eff} = 5800$ K, $R_\odot = 7 \times 10^{10}$ cm, $L_\odot = 3.9 \times 10^{33}$ erg/s.]

(2) (25 points)

(a) What are the basic stellar structure equations?

(b) For homologous stars in radiative equilibrium, derive the luminosity–$T_{\rm eff}$ relations for (i) the lower and (ii) the upper main sequence stars. Assume the Kramers' opacity law.

(3) (25 points)

(a) Do you believe that star formation is an ongoing process in our Galaxy? Give two reasons at least to support your argument.

(b) On an H-R diagram, sketch the evolution of a high mass star ($M \approx 10M_\odot$) and a low mass star ($M \approx M_\odot$) (i) towards and (ii) away from the main sequence.

(c) Describe the similarities and differences between the evolutionary tracks. Give detail physical argument.

(d) Discuss the four possible end states of stellar evolutions.

(4) (25 points)

A dense, cool isothermal gas sphere with mass M, temperature T, and radius R, is embedded in a uniform medium with pressure $P_{\rm ext}$. (You may assume that the uniform medium has a much higher temperature and a much lower density than the gas sphere.)

(a) Assume hydrostatic equilibrium, derive the virial theorem for the dense cool sphere.

(b) Express $P_{\rm ext}$ in terms of M, R and T. (You may assume some approximate expressions for the total internal energy and gravitational potential energy of the gas sphere.)

(c) Sketch $P_{\rm ext}$ against R. Argue that the sphere is unstable if its radius is smaller than some value $R_{\rm J}$. Derive the Jeans' radius $R_{\rm J}$ in terms of T and the mean density of the sphere.

(d) The model above can be used to describe star formation in molecular clouds. When the gas sphere (i.e., the dense core) is compressed beyond the Jeans' radius, $R < R_{\rm J}$, it collapses freely (free-fall) initially. What is the reason for the free-fall? When and why will the free-fall collapse stop?