PHD QUALIFY EXAMINATION — STELLAR ASTROPHYSICS

10th July, 1996

(1) (20 points)

(a) Show that the outward pressure required to support a normal star of mass M and radius R is approximately M^2G/R^4.

In general the outward pressure is the combination of gas pressure and radiation pressure:

$$P = \frac{\rho kT}{\mu m_{\rm H}} + \frac{1}{3}aT^4$$

(b) Assuming a star of 1 $M_\odot$ is mostly Hydrogen and is almost completely ionized, calculate the central temperature for (a) pure gas pressure support, and (b) pure radiation pressure support. Which case requires higher temperature? How massive is a star that its radiation pressure becomes more important than gas pressure in support of the star?

(c) The flux of momentum carried by the radiation past a unit area a distance r from the star's center is $L/4\pi r^2c$. The cross section fro electron-photon scattering is roughly $\sigma_{\rm T} = (8\pi/3)(e^2/m_{\rm e}c^2)^2$. Using these information, calculate the Eddington luminosity in terms of $(M/M_\odot)$.

(2) (20 points)

Please write down the major kinds of opacity (about 4 – 5 kinds) in the interior of a normal star. Describe their physical mechanisms, and point out the dominant factors in each opacity.

(3) (20 points)

Draw an H-R diagram, on which please draw the evolutionary track of a 5 $M_\odot$ star (starting from its ZAMS), and describe the major physical change along the track. Explain in particular why when a star approaches the end of its main-sequence life time, its core contracts while its envelope expands.

(4) (20 points)

Express $\tau_{\rm n}$ (nuclear timescale), $\tau_{\rm hydro}$ (hydrostatic timescale), and τ_{KH} (Kelvin-Helmholtz timescale) in terms of G, M, R, L. Calculate $\tau_{\rm n}$, $\tau_{\rm hydro}$, and τ_{KH} for the Sun. Compare their orders of magnitude, and discuss the physical meaning of the order.

(5) (20 points)

Estimate roughly ρ and κ inside the Sun. Calculate the number of steps (absorption and then re-emission) needed for a photon to reach solar surface. Compare this timescale with the time for neutrinos generated in the core to reach the surface. How can this comparison be related to the observed deficiency of neutrinos from inside the Sun?