Assignment #12: due Tuesday, Jan. 22

Theoretical Astrophysics

Winter 2007/2008

lecturer: Ralf Klessen, ZAH/ITA, Albert-Ueberle-Str. 2, 69120 Heidelberg

1. Thermal radiation — 30 pt

A spherical gas cloud of radius R and temperature T emits thermal radiation at a rate $P(\nu)$ (power per unit volume and frequency range). Its distance from the Earth is d ($d \gg R$).

(a) First assume the cloud is optically *thin*. What is the brightness of the cloud measured on Earth? Assume the cloud is viewed along a parallel ray which has a distance b from the cloud centre.

(b) What is the effective temperature of the cloud?

(c) What is the flux F_ν measured at the Earth coming from the entire cloud?

(d) How does the measured brightness temperatures compare with the cloud's temperature? The brightness temperature T_b is defined by the equation

$$I_\nu = B_\nu(T_b) \tag{1}$$

where B_ν is the black body spectrum.

(e) What are the above answers for an optically *thick* cloud?

2. Eddington limit — 20 pt

(a) Derive the conditions under which a star with luminosity L_* can disperse its surrounding, optically thin, gas with mass M (result: $M/L < \kappa/(4\pi\, G\, c)$, where κ is the frequency independent mass absorption coefficient).

(b) Calculate the terminal velocity of the gas in this case.

(c) Calculate the Eddingtion luminosity, i.e the critical luminosity at which a central source starts to disperse its environment. Use the minimum value of κ which can be estimated from Thomson scattering of free electrons off fully ionised hydrogen. Express your result as a function of the solar mass $M_\odot$.

3. Strömgren radius — 10 pt

The Strömgren sphere is defined as the sphere of fully ionised gas around a (massive) star.

(a) Derive the expression for the radius $R_{\rm S}$ of the Strömgren sphere in hydrogen gas, given that the number of recombinations per unit volume per second can be written as $\alpha\, n_e\, n_p$, where $\alpha = 3.1 \times 10^{-13}\,{\rm cm}^3\ {\rm sec}^{-1}$ and n_e and n_p are the electron and proton number density, respectively. Inside $R_{\rm S}$ the number of recombinations is equal to the number of ionising photons from the star.

(b) Calculate the Strömgren radius for an O5 star ($T_{\rm eff} = 54.000\,K$, $L = 2 \times 10^5\,L_\odot$) embedded in a homogeneous cloud of atomic hydrogen with number density $n_{\rm H} = 10^4\,{\rm cm}^{-3}$. To calculate the number of ionising photons from the star use Wien's law and assume for simplicity that all photons are emitted at the peak frequency of the spectrum.