AST6245: Radiative Processes and Stellar atmospheres
Fall 2023 - Prof. Rana Ezzeddine

Assignment 2 (due: October 6th, 11:59pm)

1. Imagine you would want to detect the presence of an exoplanet around a Sun-like star at 10 pc away from Earth via the perturbation of the star's emission spectrum at $\lambda_{max}^{\rm planet}$. How accurate would your measurement need to be (i.e. in other words, what is the relative perturbation on the stellar flux from the planet?). Assume that the star and planet are perfect blackbodies with temperatures 5500 K and 273 K, respectively, and that the radius of the star and planet are equal to those of the Sun and Earth, respectively.

Hint: Assume that the flux density of each body can be estimated by:

$$f_\lambda = B_\lambda \Omega \tag{1}$$

where $\Omega = \pi(R/d)^2$ is the solid angle, R is the radius and d is the distance (from Earth).

2. Estimate how far you could see through the atmosphere of the Earth if it had the opacity of the solar photosphere at 500 nm of $\kappa_{500} = 0.264\,{\rm g}^{-1}\,{\rm cm}^2$.

3. A supernova remnant has an angular diameter $\theta = 4.3$ arc minutes and a flux at 100 MHz of $F_{100} = 1.6 \times 10^{-19}$ erg cm^{-2} s^{-1} Hz^{-1}. Assume that the emission is in thermal equilibrium.

a. What is the total intensity I_ν (i.e., brightness) of the supernova remnant?

b. Calculate the brightness (effective) temperature of the remnant in the $h\nu \ll kT$ regime. What blackbody energy regime does this correspond to?

c. The emitting region is actually more compact than indicated by the observed angular diameter. What effect does that have on the brightness temperature?

d. What kind of telescope do you need to observe the maximum brightness (radiation) emitted by this supernova remnant?

4. Consider a spherical cloud with particles emitting blackbody radiation. These particles all have the same temperature $T = 4 \times 10^3$ K. The cloud has a diameter of 0.1 pc. At frequency $\nu_0 = 1.3 \times 10^{15}$ Hz the particles have an absorption coefficient $\alpha_\nu = 5.51 \times 10^{-20}\,{\rm cm}^{-1}$ and a scattering coefficient $\sigma_\nu = 9.51 \times 10^{-18}\,{\rm cm}^{-1}$. What is the total emission at frequency ν_0 emitted by this cloud in all directions together?