PEU438-Fall2024
Compact Objects and High Energy Astrophysics

Lecturer: Karim Hammam **Due Date:** October 12, 2024, 11:30 PM
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Problem 1 Evaluate the energy of the blackbody photons inside your eye. Compare this with the visible energy inside your eye while looking at a 100 -W light bulb that is 1 m away. You can assume that the light bulb is 100% efficient, although in reality it converts only a few percent of its 100 watts into visible photons. Take your eye to be a hollow sphere of radius 1.5 cm at a temperature of 37°C. The area of the eye's pupil is about 0.1 cm^2. Why is it dark when you close your eyes?

Problem 2 Consider a horizontal plane-parallel slab of gas of thickness L that is maintained at a constant temperature T. Assume that the gas has optical depth $\tau_{\lambda,0}$, with $\tau_\lambda = 0$ at the top surface of the slab. Assume further that no radiation enters the gas from outside. Use the general solution of the transfer equation to show that when looking at the slab from above, you see blackbody radiation if $\tau_{\lambda,0} \gg 1$ and emission lines (where j_λ is large) if $\tau_{\lambda,0} \ll 1$. You may assume that the source function, S_λ, does not vary with position inside the gas. You may also assume thermodynamic equilibrium when $\tau_{\lambda,0} \gg 1$.

Problem 3 Consider a horizontal plane-parallel slab of gas of thickness L that is maintained at a constant temperature T. Assume that the gas has optical depth $\tau_{\lambda,0}$, with $\tau_\lambda = 0$ at the top surface of the slab. Assume further that incident radiation of intensity $I_{\lambda,0}$ enters the bottom of the slab from outside. Use the general solution of the transfer equation to show that when looking at the slab from above, you see blackbody radiation if $\tau_{\lambda,0} \gg 1$. If $\tau_{\lambda,0} \ll 1$, show that you see absorption lines superimposed on the spectrum of the incident radiation if $I_{\lambda,0} > S_\lambda$ and emission lines superimposed on the spectrum of the incident radiation if $I_{\lambda,0} < S_\lambda$. You may assume that the source function, S_λ, does not vary with position inside the gas. You may also assume thermodynamic equilibrium when $\tau_{\lambda,0} \gg 1$.

Problem 4 A supernova remnant has an angular diameter $\theta = 4.3$ arc minutes and a flux at 100MHz of $F_{100} = 1.6 \times 10^{-19} \mathrm{erg cm^{-2}\ s^{-1}\ Hz^{-1}}$. Assume that the emission is thermal.

- a. What is the brightness temperature T_b ? What energy regime of the blackbody curve does this correspond to?
- b. The emitting region is actually more compact than indicated by the observed angular diameter. What effect does this have on the value of T_b ?
- c. At what frequency will this object's radiation be maximum, if the emission is blackbody?

Problem 5 A certain gas emits thermally at the rate $P(\nu)$ (power per unit volume and frequency range). A spherical cloud of this gas has radius R, temperature T and is a distance d from earth ($d \gg R$).

- a. Assume that the cloud is optically thin. What is the brightness of the cloud as measured on earth? Give your answer as a function of the distance b away from the cloud center, assuming the cloud may be viewed along parallel rays as shown in Figure.
- b. What is the effective temperature of the cloud?
- c. What is the flux F_ν measured at earth coming from the entire cloud?
- d. How do the measured brightness temperatures compare with the cloud's temperature?
- e. Answer parts (a)-(d) for an optically thick cloud.