ASTR240: Radio Astronomy

HW#1

Due Feb 6, 2013

Problem 1

(Adapted from Kraus Ch 8)
A radio source has flux densities of $S_1 = 12.1\,\mathrm{Jy}$ and $S_2 = 8.3\,\mathrm{Jy}$ at frequencies of $\nu_1 = 600\,\mathrm{MHz}$ and $\nu_2 = 1415\,\mathrm{MHz}$, respectively.

A) Show that its spectral index $\alpha = [\log(S_1/S_2)]/[\log(\nu_2/\nu_1)]$

B) Calculate its spectral index.

C) Is the spectrum thermal or nonthermal?

Problem 2

(Rybicki & Lightman Problem 1.5)
A supernova remnant has an angular diameter θ=4.3 arc minutes and a flux at 100 MHz 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?

D) What can you say about the temperature of the material from the above results?

Problem 3

(Rybicki & Lightman 1.9)
A spherical, opaque object emits as a blackbody at temperature T_c. Surrounding this central object is a spherical shell of material, thermally emitting at a temperature $T_s(T_s < T_c)$. This shell absorbs in a narrow spectral line; that is, its absorption coefficient becomes large at the frequency ν_0 and is negligibly small at other frequencies, such as ν_1: $\alpha_{\nu 0} >> \alpha_{\nu 1}$ (see Fig. 1.16). The object is observed at frequencies ν_0 and ν_1 and along two rays A and B shown above. Assume that the Planck function does not vary appreciably from ν_0 to ν_1.

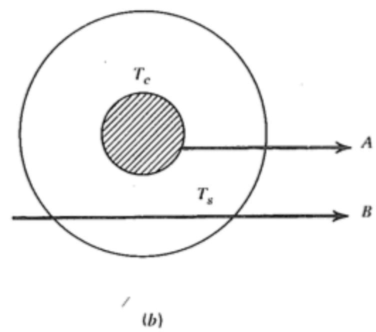


Figure 1.16a Blackbody emitter at temperature T_c surrounded by an absorbing shell at temperature T_s, viewed along rays A and B.

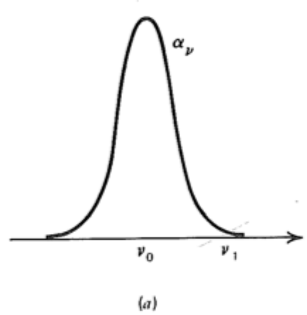


Figure 1.16b Absorption coefficient of the material in the shell.

A) At which frequency will the observed brightness be larger when observed along ray A? Along ray B?

B) Answer the preceding questions if $T_s > T_c$.

Problem 4

(Courtesy J. Moran)
Calculate the quietest (i.e., darkest) place in the radio spectrum. Neglect noise from the earth's atmosphere. At low frequencies the sky noise is dominated by synchrotron emission from relativistic electrons rattling

around all over the galaxy. Away from the galaxy plane, the brightness temperature is

$$T_B \simeq 180\text{K} \left(\frac{\nu}{180\text{MHz}} \right)^{-2.6}$$

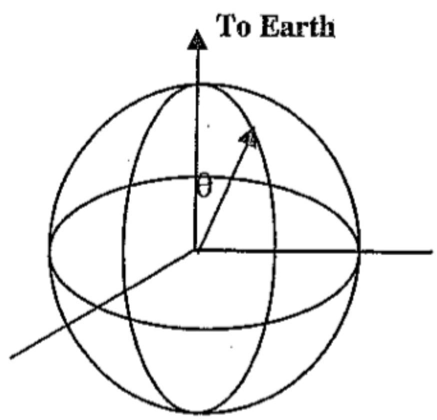
which is more or less independent of direction. At high frequencies, the CMB dominates with $T_B \sim 2.7\,\text{K}$ in all directions

A) What is the frequency of minimum background brightness temperature? Of minimum background flux density?

B) What is the incident power on the earth from $10\,\text{MHz} \rightarrow 1\,\text{THz}$ ($10^6 - 10^{12}\,\text{Hz}$)? If we intercept this power could we reduce our reliance on fossil fuels?

Problem 5

(Courtesy J. Moran)
The full moon at millimeter wavelengths has a brightness temperature distribution that might be approximated as (see figure): $T_B(\theta) = T_0 + T_1 \cos\theta$.



The Moon (with Great Circles Painted on)

A) What is the flux density at the earth? Hint: First calculate the brightness temperature as a function of polar angle in the earth coordinate system.

B) What is the mean brightness temperature, i.e., "disk temperature"?