AST 300B – Spring 2019

In-class/take-home Problems Due: Jan. 30

2 pages (see back)

9. Compute the column density and optical depth for the following cases and indicate if the medium is optically thin or optically thick:

   (a) UV photons (< 13.6 eV) elastically scattering off electrons (Thompson scattering) with $n_e \sim 10^{-2}$ cm^{-3} in an HII region with a diameter of 10 pc. Comment on how easy it is for these UV photons to propagate through the HII region.

   (b) 13.6 eV photons capable of ionizing hydrogen atoms impinging on CNM HI clouds of density $n_H \sim 1$ cm^{-3} and thickness 1 pc. Comment on how easy it is for these photons to propagate through a CNM HI cloud.

Table 5.1. Sample photon interaction cross-sections[a]

Type	Description	Wavelength or energy	Cross-section (cm^2)
σ_{T^b}	Thomson scattering	$\ll 0.51$ MeV	6.65×10^{-25}
σ_{K-N^c}	Compton scattering	0.51 MeV	2.86×10^{-25}
		5.1 MeV	8.16×10^{-26}
σ_{R^d}	Rayleigh scattering (N_2)	532 nm	5.10×10^{-27}
	(CO)	532 nm	6.19×10^{-27}
	(CO_2)	532 nm	12.4×10^{-27}
	(CH_4)	532 nm	12.47×10^{-27}
σ_{b-b^e}	Ly α (natural)[f]	121.567 nm	7.1×10^{-11}
	Ly α (10^4 K)[g]	121.567 nm	5.0×10^{-14}
$\sigma_{HI \rightarrow HII^h}$	H ionization	13.6 eV	6.3×10^{-18}
σ_{f-f^i}	free-free absorption	21 cm	2.8×10^{-27}

See Irwin for full table footnotes.

10. A spherical optically thick object emits ***thermally*** at temperature T_c and is surrounded by an optically thin shell. This shell absorbs/emits ***thermally*** with temperature T_s, but only in a narrow spectral line with absorption coefficient plotted below as a function of frequency ν (NOTE: that α_ν goes to ZERO on each side of the spectral line centered at frequency ν_0 which means that τ_ν goes to ZERO at those frequencies – i.e. the shell is completely transparent at ν away from the spectral line.). You may assume that this spectral line is narrow enough in frequency such that any Planck function is essentially constant in frequency across the line. The total optical depth through the shell at frequency ν_0 is τ_A along ray A and is τ_B along ray B. Assume there is no background radiation field outside the central object and shell.

(a) Sketch the spectra (Monochromatic Specific Intensity vs. Frequency) for this spectral line for rays A and B assuming that $T_s < T_c$. On the x-axis, label ν_0 and ν_1. On the y-axis, label the continuum level (the intensity level outside the frequency range of the spectral line) and label how high the spectral line peak is above or below the continuum level. **HINT:** Write down a formula for ΔI_ν at ν_0 where ΔI_ν is the intensity difference between the peak of the spectral line and the continuum level.

(b) Sketch the spectra for this spectral line for rays A and B assuming that $T_s > T_c$. Same Hint/axis labelling comments apply.