

RADIATION IN THERMODYNAMIC EQUILIBRIUM:

RAD. FIELD IS γ -ENSEMBLE

- DETERMINES SOURCE f_n, S_ν :

"STRICT" THERMODYNAMIC Eq. (TE) :

- REQUIRES PERFECT HOMOGEITY,

ISOTROPY & STASIS :

$$f(\vec{r}, \vec{l}, t) = f$$

- TE A GOOD APPROXIMATION IN STELLAR INTERIOR:

$$- dp/dr < 0$$

→ p LARGE

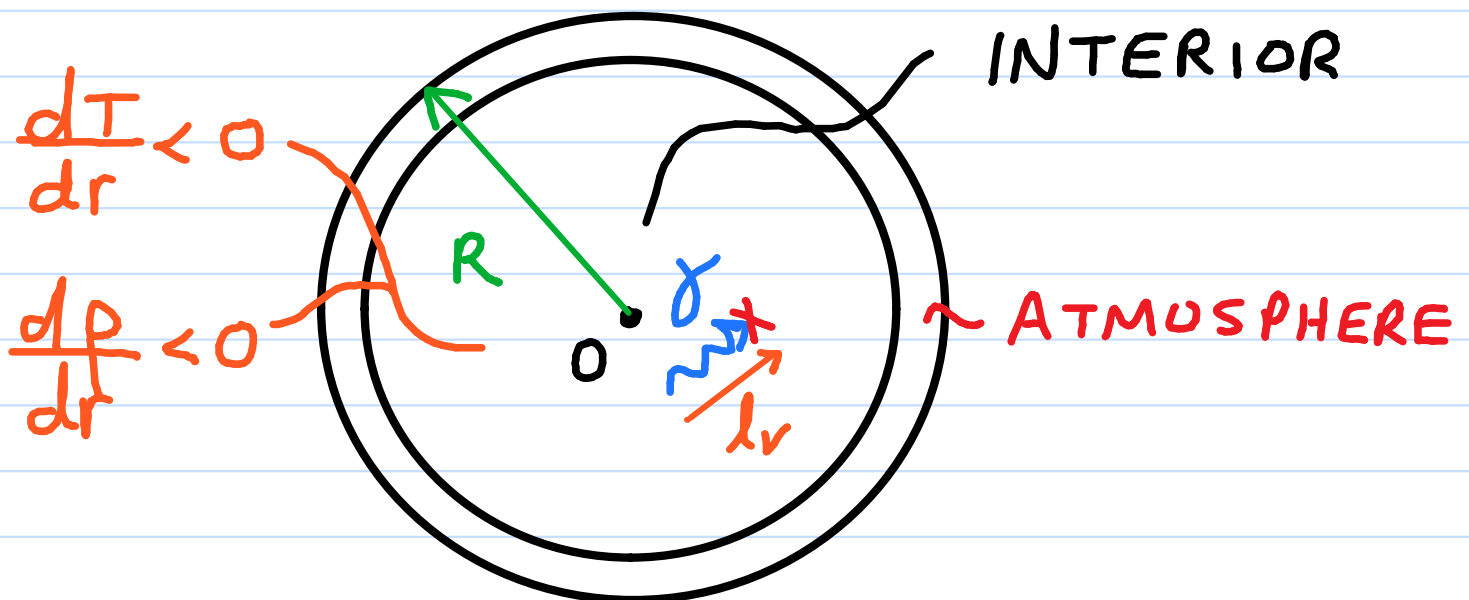
→ α_ν = p K_ν LARGE

→ l_ν $\approx 1/\alpha_\nu \lll R$

→ FOR MEAN PHOTON (γ) FLIGHT:

$$\frac{\Delta T}{T} \approx \frac{l_\nu}{T} \frac{dT}{dr} \lll 1$$

\therefore TE IS LOWER BOUNDARY CONDITION OF ATMOSPHERE



IN TE:

$$\underline{I}_\nu(\underline{T}_\nu, \mu) = B_\nu(\nu, \underline{T}_{\text{KIN}}(\underline{T}_\nu)) = \underline{B}_\nu(\underline{T}_\nu)$$

- $B_\nu(\nu, T_{\text{RAD}})$ = PLANCK f_n

- BLACKBODY (BB) SPECTRUM

- T_{RAD} = RADIATION TEMPERATURE (K)

- IN TE: $T_{\text{RAD}}(\underline{T}_\nu) = \underline{T}_{\text{KIN}}(\underline{T}_\nu)$

ISOTROPY IN TE:

$$\underline{I}_\nu(\underline{T}_\nu, \mu) = \underline{J}_\nu(\underline{T}_\nu) = B_\nu(\underline{T}_\nu)$$

AND:

$$\underline{S}_\nu(\underline{T}_\nu) = B_\nu(\underline{T}_\nu)$$

$$\therefore \underline{I}_\nu(\underline{T}_\nu, \mu) = \underline{S}_\nu(\underline{T}_\nu), \text{ ALL } \mu$$

BUT \underline{S}_ν NOT NEEDED! ($\underline{I}_\nu(\underline{T}_\nu, \mu) = B_\nu(\underline{T}_\nu)$)

LOWER BOUNDARY CONDITION:

$$\underline{T_v \rightarrow \infty} :$$

$$I_v(T_v, \mu) \rightarrow J_v(T_v)$$

$$J_v(T_v) \rightarrow B_v(T_v)$$

$$(S_v(T_v) \rightarrow B_v(T_v))$$

PLANCK fn:

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$$B_{\nu}(\nu, T_{\text{RAD}}) = \frac{2h\nu^3}{c^2} \frac{1}{e^{h\nu/kT_{\text{RAD}}} - 1}$$

(erg/s/cm²/STER/Hz)

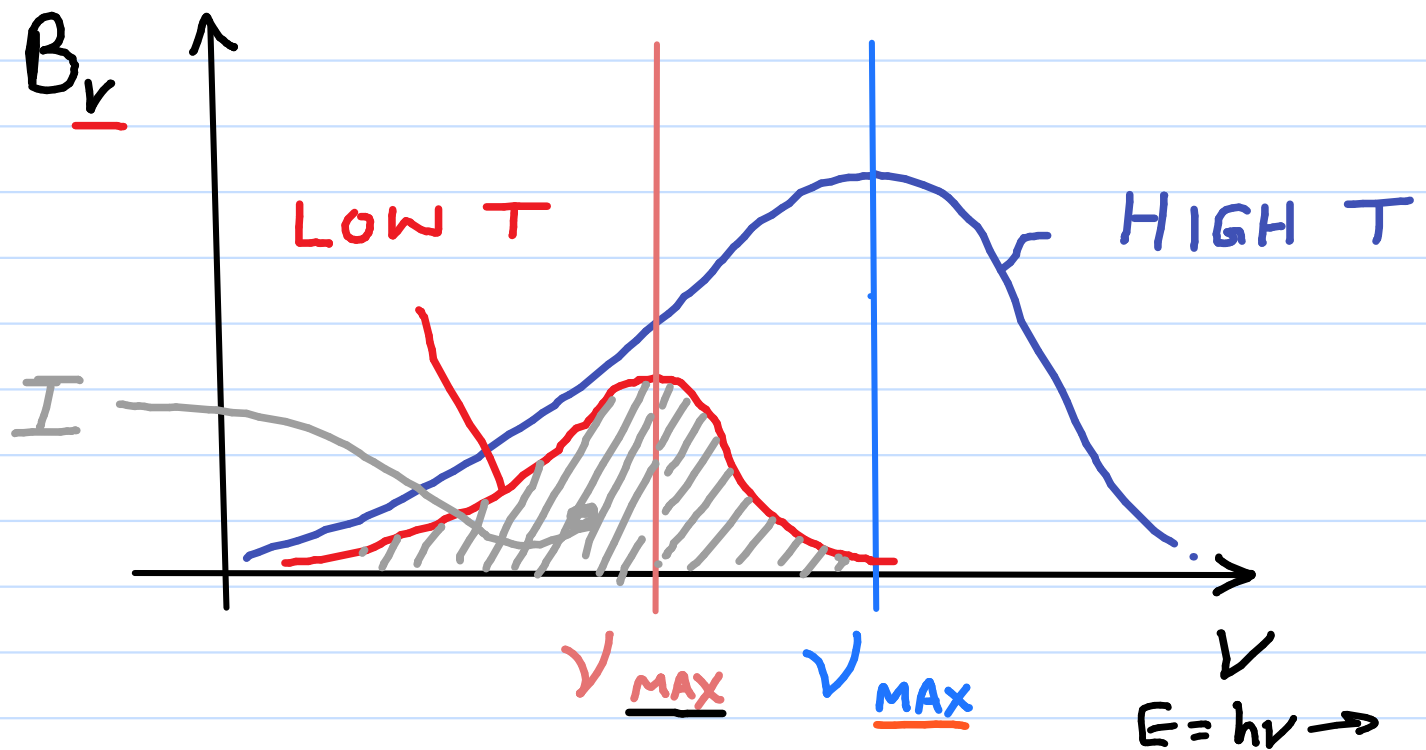
- RECALL: IN TE: $T_{\text{RAD}}(\vec{r}) = T_{\text{KIN}}(\vec{r})$

• BOLTZMANN FACTOR: $e^{-h\nu/kT}$

→ $h\nu = \gamma$ -ENERGY

$kT_{\text{KIN}} = \text{THERMAL } E$

$$B_{\nu}(\nu, T_{\text{RAD}}) = \frac{2h\nu^3}{c^2} \frac{1}{e^{h\nu/kT_{\text{RAD}}} - 1} :$$



IN TE:

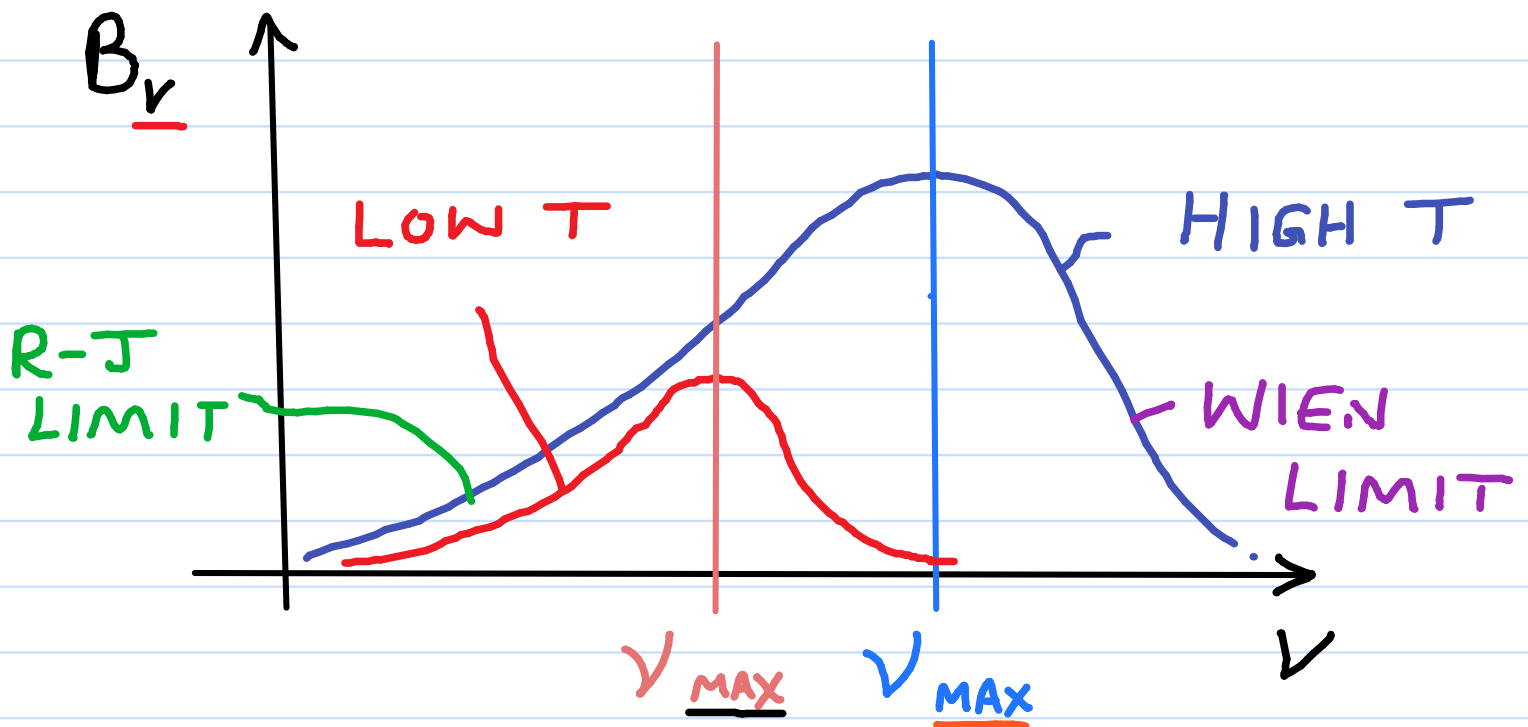
$$I = J = \int_{\nu=0}^{\infty} B_{\nu} d\nu = \frac{\sigma}{\pi} T_{\text{RAD}}^4$$

- STEFAN - BOLTZMANN LAW

WIEN LAW FOR B_{ν} :

$$\lambda_{\text{MAX}} = \frac{c}{\nu_{\text{MAX}}} = \frac{0.50995 \text{ cm} \cdot \text{K}}{T_{\text{RAD}}}$$

$$B_{\nu}(\nu, T_{\text{RAD}}) = \frac{2h\nu^3}{c^2} \frac{1}{e^{h\nu/kT_{\text{RAD}}} - 1} :$$



RAYLEIGH-JEANS (R-J) LIMIT: $h\nu/kT \ll 1$:

$$B_{\nu} \approx \frac{2kT\nu^2}{c^2}$$

WIEN LIMIT: $h\nu/kT \gg 1$:

$$B_{\nu} \approx \frac{2h\nu^3}{c^2} e^{-h\nu/kT}$$

PLANCK fn, B_{λ}
 (erg/s/cm²/STER/nm)

$$B_{\lambda}(\nu, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}$$

WIEN LAW FOR B_{λ} :

$$\lambda_{\text{MAX}} = \frac{0.28978 \text{ cm} \cdot \text{K}}{T_{\text{RAD}}}$$

Σg. SUN:

ADOPT $T_{\text{RAD}} = T_{\text{eff}} \approx 5800 \text{ K}$

$$B_{\lambda} \lambda_{\text{MAX}} = 550 \text{ nm}$$

$$B_{\nu} \lambda_{\text{MAX}} = 880 \text{ nm} \quad (\text{IR})$$

LOCAL THERMODYNAMIC EQUILIBRIUM

(LTE):

- BETTER APPROXIMATION IN ATMOSPHERE:

$$- dp/dr < 0$$

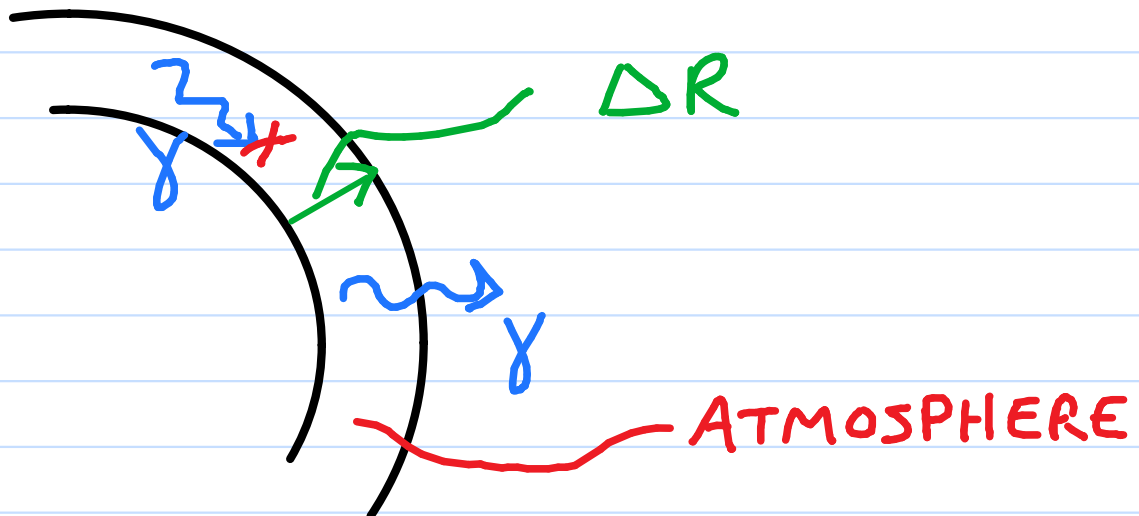
→ p SMALL

→ α_ν = p K_ν SMALL

→ l_ν $\approx 1/\alpha_\nu \approx \Delta R$

→ FOR MEAN PHOTON (γ) FLIGHT:

$$\frac{\Delta T}{T} \approx \frac{l_\nu}{T} \frac{dT}{dr} \approx \mathcal{O}(1)$$



IN LTE:

$$I_\nu(\tau_\nu, \mu) \neq B_\nu(\nu, T_{\text{KIN}}(\tau_\nu))$$

BUT, ASSUME:

$$\underline{S_\nu(\tau_\nu)} = B_\nu(\underline{T_{\text{KIN}}(\tau_\nu)}) = "B_\nu(\tau_\nu)"$$

- ONLY EXACT AT $\tau_\nu \rightarrow \infty$

\therefore NEED RAD. TRANS. Eq. TO FIND I_ν

eg. IN LTE:

$$J_\nu(\tau_\nu) = \Lambda_\nu[S_\nu(\tau_\nu)] = \Lambda_\nu[\underline{B_\nu(\tau_\nu)}]$$

TEMPERATURE OUT OF T.E.:

$$I_\nu(\tau_\nu, \mu) \neq B_\nu(T_{\text{KIN}}(\tau_\nu))$$

BUT, ALWAYS:

$$I_\nu(\tau_\nu, \mu, \nu) \equiv B_\nu(\nu, T_{\text{RAD}}(\tau_\nu, \nu))$$

- FOR SOME T_{RAD} VALUE

$$\text{GENERALLY: } T_{\text{RAD}}(\tau_\nu, \nu) \neq T_{\text{KIN}}(\tau_\nu)$$

DEPARTURE FROM T.E., ΔT :

$$\Delta T(\tau_\nu, \nu) = T_{\text{RAD}}(\tau_\nu, \nu) - T_{\text{KIN}}(\tau_\nu)$$

