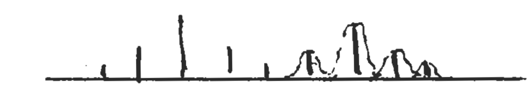
- WHY ARE PLANTS GREEN? LEAF PLANTS AND SINGLE-CELL PLANTS (ALGAE) BOTH LOOK GREEN

(AARON SAYS THEY REFLECT GREEN AND ABSORB RED & BLUE LIGHT)

- WHY ARE RUBYS RED?

- WHY ARE STOP LIGHTS RED?



BROADENING

(i) NATURAL

(ii) COLLISION

(iii) DOPPLER

* LINES BECOME MORE NARROW AS A MATERIAL COOLS

WE TAKE ADVANTAGE OF THE FACT THAT

$$N = n + i\kappa \approx 1 \quad \therefore \text{ CAN USE LORENTZ MODEL}$$

$\hookrightarrow K_\eta$ "ABSORPTION COEFFICIENT"

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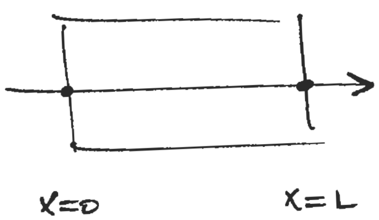
$$\frac{dI_\eta}{dx} = -K_\eta I_\eta \quad \Rightarrow \quad \tau_\eta = e^{-K_\eta x}$$

EX: BOX WITH A GAS

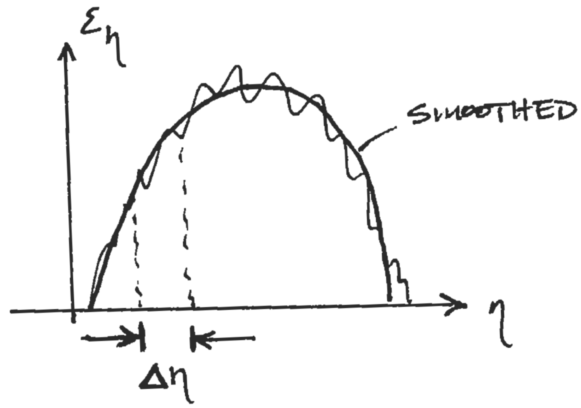


$$\varepsilon_\eta = 1 - \tau_\eta$$

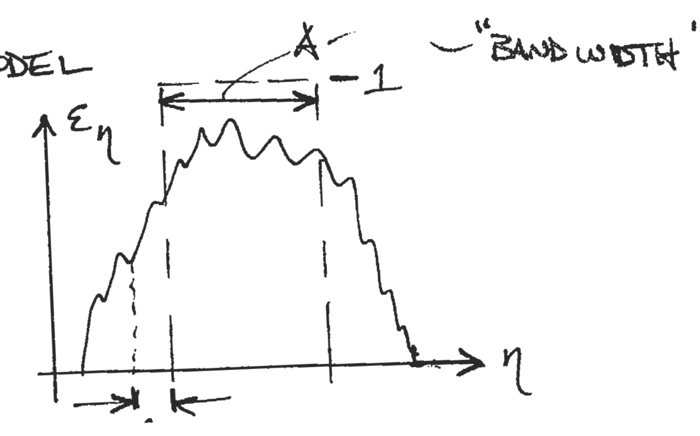
* * WE CAN MODEL THE SPACING AND SHAPE OF EACH LINE

.... TO GET ε_η ?

(1) $\overline{\varepsilon_\eta}$ (AVG) FROM NARROW-BAND MODELS $\left\{ \begin{array}{l} \text{ELSASSER} \\ \text{GOODY} \end{array} \right.$

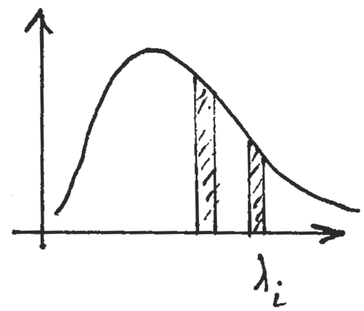


(2) WIDE-BAND MODEL



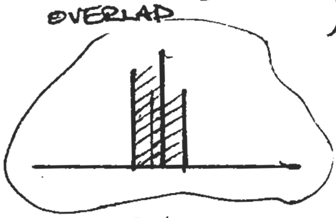
TOTAL EMISSIVITY

BLK. BODY SOLAR



$$\varepsilon = \frac{\int_0^\infty \varepsilon_\eta I_{b\eta}\, d\eta}{\int_0^\infty I_{b\eta}\, d\eta} = \sum_{i=1}^{N} \left(\frac{\pi I_{b\eta_i}}{\sigma T^4} \right) A_i$$

BANDS COULD OVERLAP



$$\tau_{a+b} = \frac{1}{\Delta\eta} \int_{\Delta\eta} e^{-\kappa_{\eta a} x} e^{-\kappa_{\eta b} x}\, dx \approx \underbrace{\overline{\tau}_a}_{(1-\varepsilon_a)} \overline{\tau}_b$$

$$\varepsilon_{a+b} = 1 - \tau_{a+b} = \varepsilon_a + \varepsilon_b - \varepsilon_a \varepsilon_b$$

PLANK MEAN ABSORPTION COEFFICIENT

$$\kappa_p \equiv \frac{\int_0^\infty \kappa_\eta I_{b\eta}\, d\eta}{\int_0^\infty I_{b\eta}\, d\eta}$$

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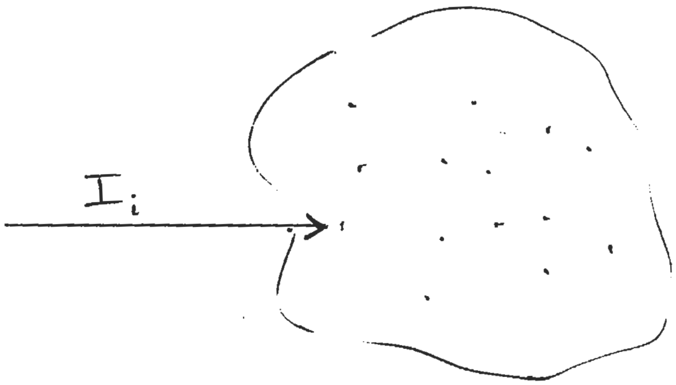
EQUATION OF RADIATIVE TRANSFER

BODY OF PARTICLES (e.g., e, PHOTONS, AIR MOLECULES, NEUTRONS etc ....)

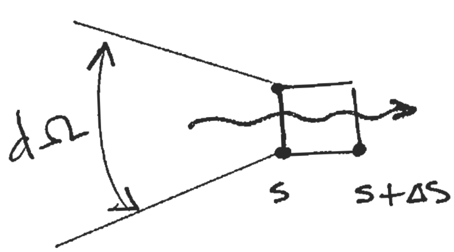


SCATTERING : CHANGES DIRECTION OF ENERGY FLOW

ABSORPTION : REDUCES ENERGY TRAVELING IN INCIDENT DIRECTION

EMISSION : CAN OCCUR IN ALL DIRECTIONS AT THE PARTICLES TEMPERATURE ; AND THUS A PORTION ~~SO~~ OF EMISSION CONTRIBUTES TO ~~INCOMING~~ INCIDENT DIRECTION

TAKE A CONTROL VOLUME



POWER IN = POWER OUT + POWER ABSORBED

$$I(s)\,d\Omega\,d\eta = I(s+\Delta s)\,d\Omega\,d\eta + K_\eta I_\eta\,d\Omega\,d\eta\,ds$$

$$\left(K_\eta = \frac{4\pi\chi}{\lambda}\right) \quad N = n + i\chi$$

$$\frac{dI_\eta}{ds} = -K_\eta I_\eta \qquad \text{(ABSORPTION ONLY)}$$

... ADD EMISSION (ONLY RELATED TO OBJECTS TEMP. AND UNIFORM IN ALL DIRECTIONS)

LOCAL EMISSIVITY –

$$\varepsilon(x) = 1 - e^{-K_\eta \Delta s} \approx K_\eta \Delta s$$

Δs OR x — SINCE $K_\eta \Delta s$ IS SMALL w.r.t. 1

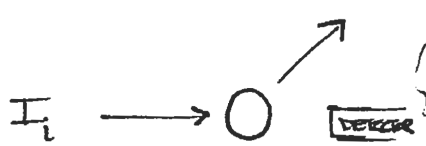
TOTAL ABS. + EMISS. –

$$\frac{dI_\eta}{ds} = \underbrace{-K_\eta I_\eta}_{\text{ABSORPTION}} + \underbrace{K_\eta I_{b\eta}(T)}_{\text{EMISSION}}$$

ABSORPTION: ENERGY LOSS TO SURROUNDING MEDIA

EMISSION: ENERGY GAIN FROM SURROUNDING MEDIA

- OUT SCATTERING (SINGLE PARTICLE)



C_s, C_a, C_e

- GROUP OF PARTICLES

$$K_s = NC_s \left[\frac{1}{m}\right]$$

$$K_a = NC_a$$

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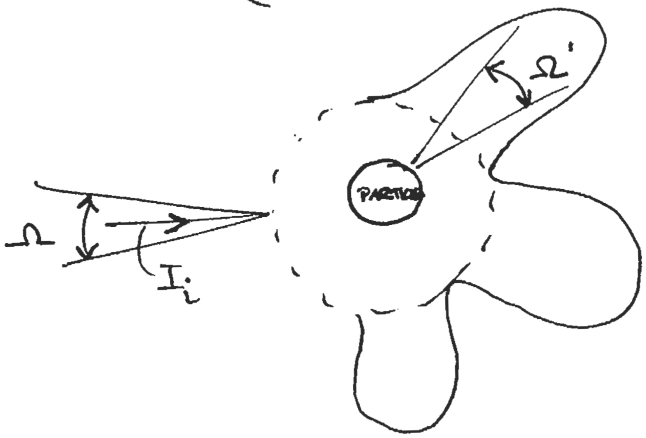
RECALL PHASE FUNCTION (Φ) ACTUAL VS. ~~ACTUAL~~ TOTAL DISTRIBUTION OF SCATTERING

$$\Phi = \frac{\text{AMOUNT IN PARTICULAR DIR.}}{\text{TOTAL AMOUNT}}$$



* RELATED TO ~~OUT~~ INCOMING SCATTERING

NOW OUTGOING SCATTERING REDUCES THE INTENSITY ∴

IS ~~NOT~~ ONLY RELATED TO A SPECIFIC DIRECTION

OUR EQN. BECOMES

$$\frac{dI_\eta(\Omega)}{ds} = \underbrace{-K_{a\eta} I_\eta}_{\text{abs}} \underbrace{- K_{s\eta} I_\eta}_{\text{outgoing scattering}} + \underbrace{K_{a\eta} I_{b\eta}(T)}_{\text{emission}} + \text{in scattering}$$

NOW, ADD THE INCOMING SCATTERING

PHASE FUNCTION

$$\boxed{\frac{dI_\eta(\Omega)}{ds} = -K_{a\eta} I_\eta - K_{s\eta} I_\eta + K_{a\eta} I_{b\eta}(T) + \frac{K_{s\eta}}{4\pi}\int_{4\pi} I_\eta'(\Omega')\,\Phi(\Omega' \rightarrow \Omega)\,d\Omega'}$$

EQUATION OF RADIATIVE TRANSFER

** COULD ADD TRANSIENT HERE $\frac{1}{c}\frac{dI}{\partial t} +$; SINCE C IS SO LARGE, ~~BUT~~ FOR MOST ENGINEERING APPLICATIONS WE IGNORE THIS TERM

WE OBSERVE $I_\eta(\Omega, \vec{s})$

$\vec{s} = \vec{s}(x, y, z)$

$\Omega = \Omega(\theta, \phi)$

$\Downarrow$

$c \times \theta$ i, $\phi \Longrightarrow v_x, v_y, v_z$

$\Longrightarrow$ PHASE SPACE

$$f(\vec{v}, \vec{r}, t)$$