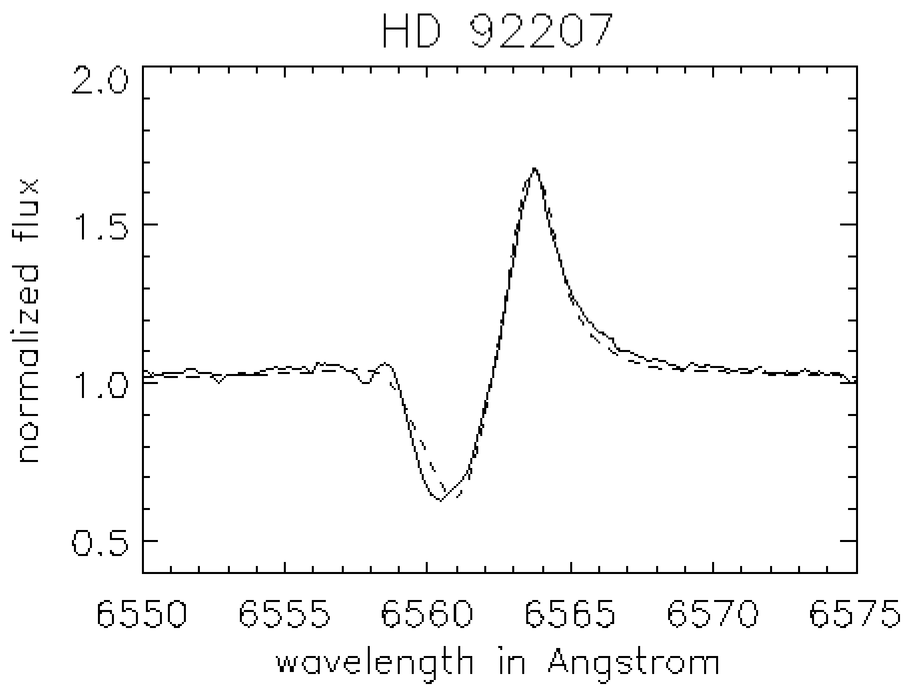
Lecture 15

Stellar Atmospheres
prof. Marcos Diaz

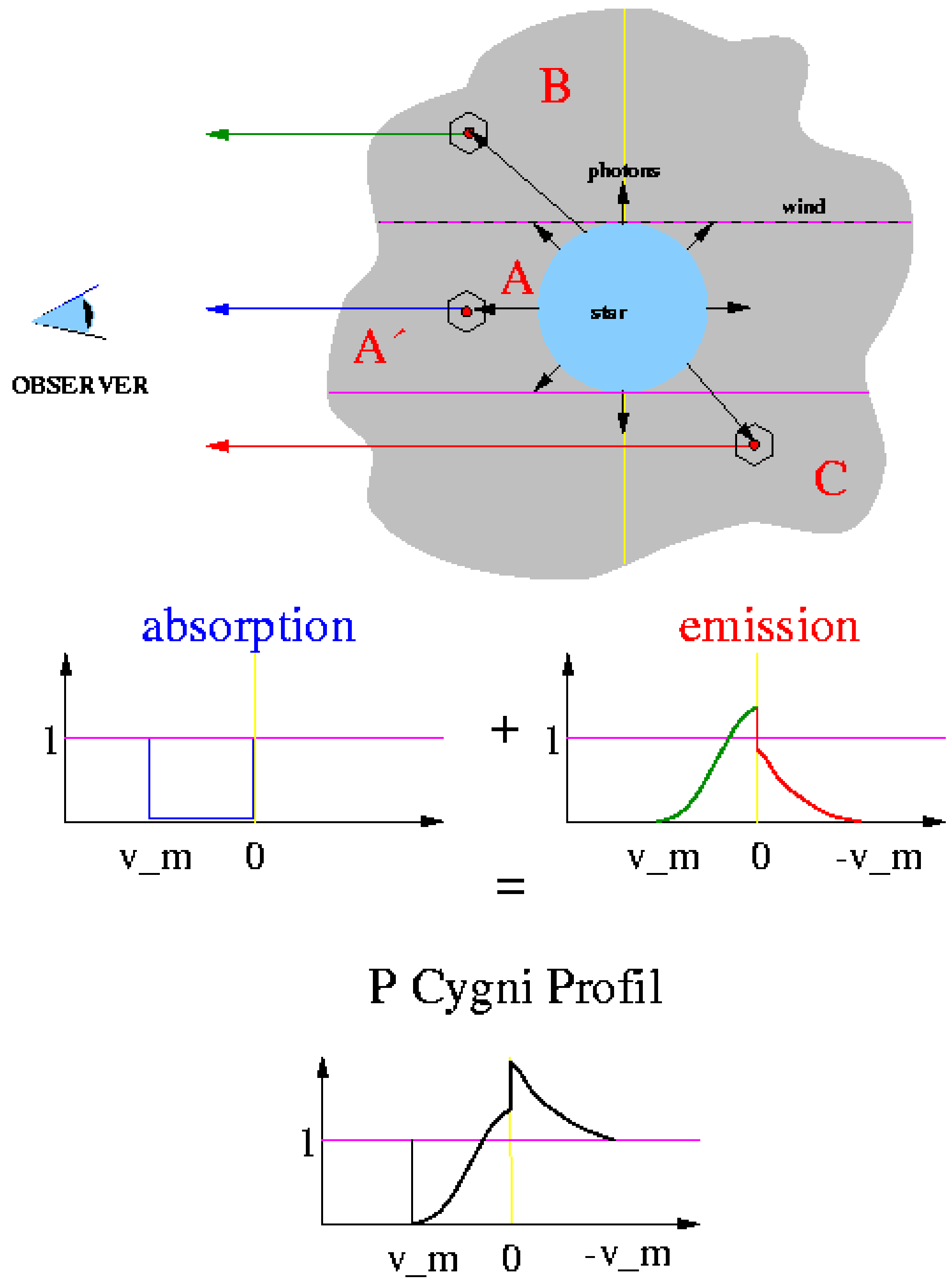


(from Kudritzki 1997)

treasure map:

H&M: pg 743
Mihalas, 1978
Lamers et al. 1987, ApJ, 314, 726
(1) Kudritzki & Hummer, ARAA, 1990
(2) Kudritzki & Puls, ARAA, 2000

P Cygni profile formation



(from Kudritzki 2000)

Basic line transfer in accelerated medium

formal r.t. equation solution for an expanding shell:

$$I(\tau_{1,}\mu) = I(\tau_2)e^{\frac{\tau_1-\tau_2}{\mu}} + \frac{1}{\mu}\int_{\tau_1}^{\tau_2} S(\tau')e^{\frac{\tau_2-\tau'}{\mu}}d\tau'$$

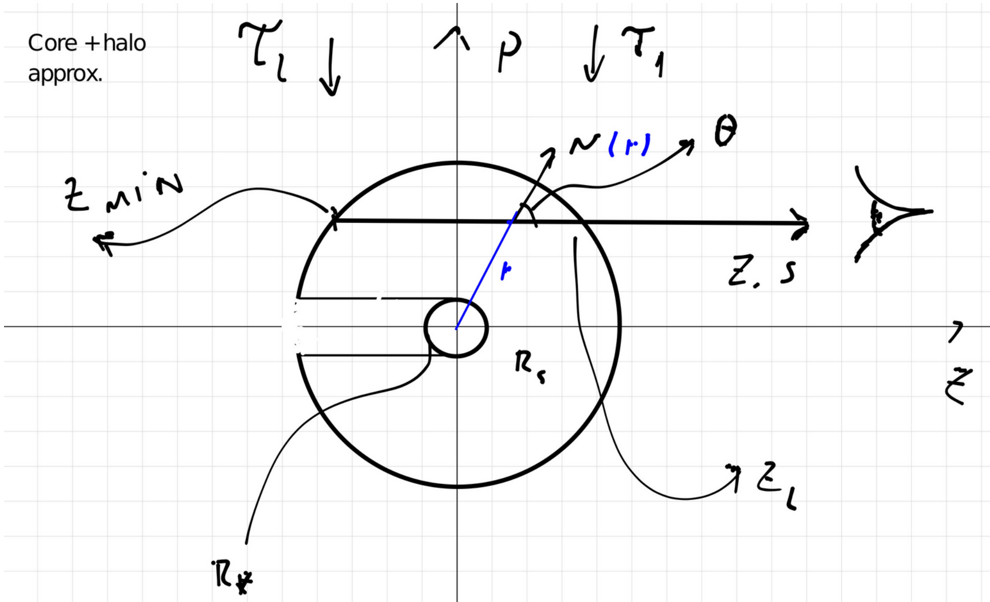
$$I(\tau_2)=0; \qquad for \ |P|>R_*$$

$$I(\tau_2)=I_*; \qquad for \ |P|\leq R_*$$

$$\mu = cos(\theta); \qquad v_z = \mu v(r)$$

R_* = *stellar radius*

R_s = *shell radius*



with pure thermal broadening:

$$\phi(\Delta\nu_D) \propto e^{-\left(\frac{\Delta\nu_D}{\Delta\nu_{th}}\right)^2}$$

$$x = \frac{V_z}{V_{th}} = \frac{\Delta\nu_D}{\Delta\nu_{th}}; \qquad v = \frac{V(r)}{V_{th}};$$

$$\phi(x) = \frac{1}{\pi} e^{-(x-\mu v)^2} \qquad \int_{-\infty}^{\infty} \phi(x)\,dx = 1$$

and opacities (thin scattering continuum, thick lines):

$$k_\nu^L = k(r)\rho(r)\phi(x-uv); \qquad k_{cont} = n_e \sigma_{Thom};$$

$\Delta s \equiv$ size of interaction region

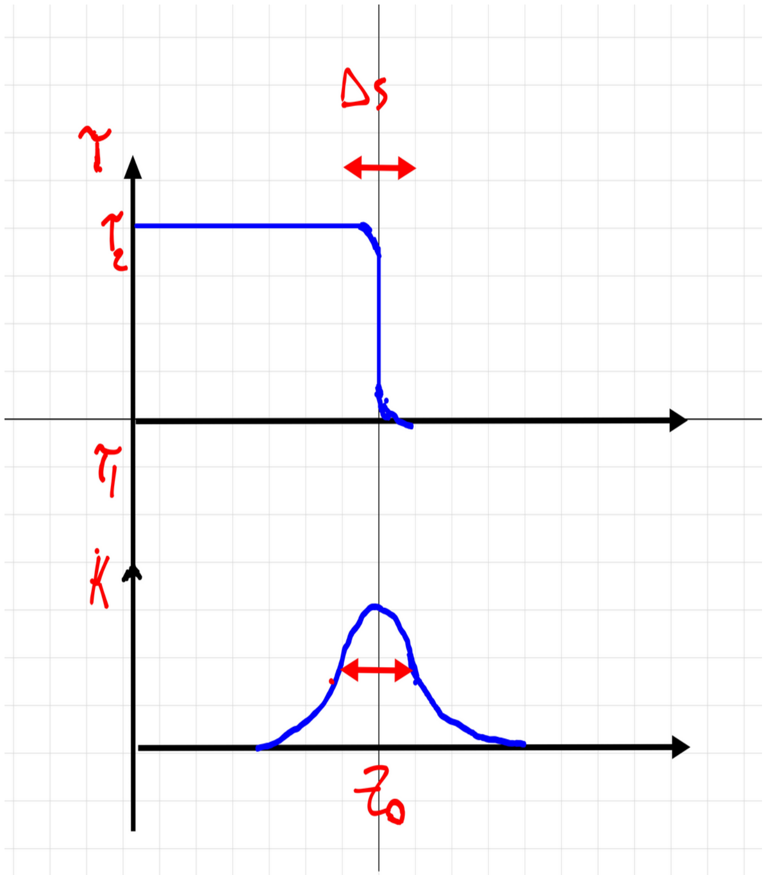
$$k_\nu^L(s+\Delta s)=k_\nu^L(s)\,e^{-1} \quad \rightarrow \quad |\Delta(\mu v)|=1 \qquad \left|\frac{d(\mu v)}{dz}\Delta s\right|=1$$

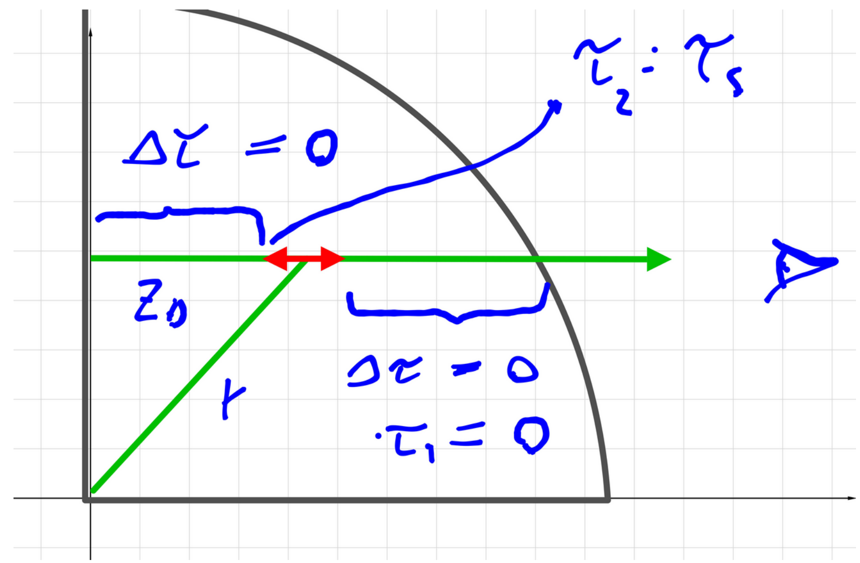
single slab shell:

$$\left|\frac{(V_\infty - V_{th})/V_{th}}{R_s}\Delta s\right|=1 \qquad V_\infty \gg V_{th} \qquad \left|\frac{V_\infty}{V_{th}}\right|=\frac{R_s}{\Delta s}$$

$\Delta s << R_S$ Sobolev approximation

fast accelerated high-β winds





$$\tau\left(r\left(P,z\right)\right)=\tau_2\Phi \qquad \Phi=0;\ \ z>\left(z_0+\Delta s/2\right)$$

$$\Phi=1;\ \ z\leq\left(z_0-\Delta s/2\right)$$

$\tau_1 = 0$
$\tau_2 = \tau_S$

a) $|P| < R_*$
with $R_S >> R_*$ $\rightarrow$ $(\theta \sim 0; \quad \mu \sim 1)$

$$I(\tau_1) = I_* e^{-\tau_s} + \int_0^{\tau_s} S(\tau') e^{-\tau'} d\tau'$$

$k^L >> k_{cont}$; $S_{cont} \sim 0$; $S(\tau) \sim S_L(z_0) = \text{constant}$

$$I_\nu(0) = I_* e^{-\tau_s} + S_L(z_0)\left(1 - e^{-\tau_s}\right)$$

$$I(x, P, \tau_s) = I_* e^{-\tau_s} + S_x^L(r(P, Z_0))(1 - e^{-\tau_s})$$

b) $|P| > R_*$
with $R_S >> R_*$ $(\theta > 0; \ \mu < 1)$

$$I(x, P, \tau_s, \mu) = \frac{1}{\mu} S_x^L(r(P, Z_0))(1 - e^{-\frac{\tau_s}{\mu}})$$

c) detailed integration of source function – Sobolev with Exact Integration (SEI)

Deriving the source function from escape probabilities

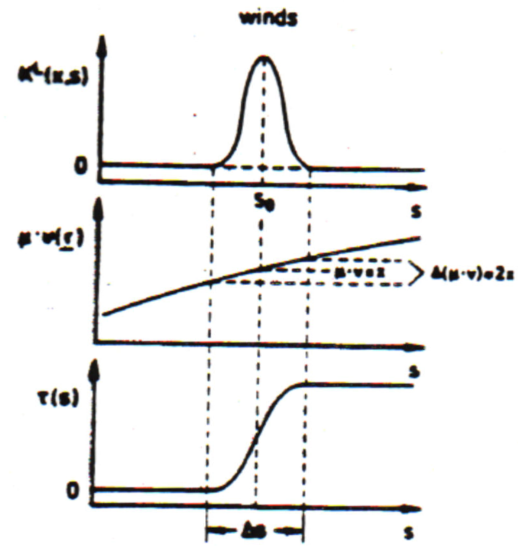


Fig. VI,1: The dependence of line absorption coefficient $\kappa^L(x,s)$, line optical depth $\tau(s)$ and projected velocity μ v for a beam with fixed frequency x along its path s in the static case and in the presence of stellar winds.

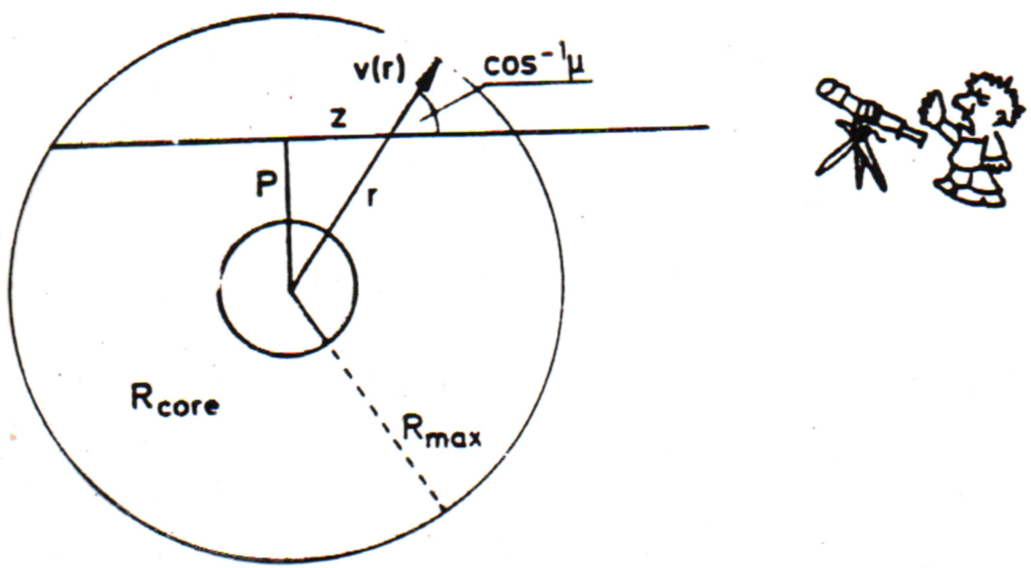


Fig. VI,2: The (p,z)-geometry for spherical winds.

(from Kudritzki 1987)