Spectral Modeling *of* X-Rays *from* Hot Star Winds

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Hot Stars

Massive Stars

Early-type Stars

- Short-lived (~ 1-10 million yrs)
- Found near birth-place (nebulae)
- Responsible for metal production
- Produce supernovae (neutron stars, black holes)

HD 93129 A

(O3)

$M = 94.8\ M_{\odot}$

$L = 1.5e6\ L_{\odot}$

$T = 7.4\ T_{\odot}$

$R = 22.5\ R_{\odot}$

Stellar *Winds*

- Net momentum transfer from starlight to material at the star's surface

- More luminosity → stronger wind

- Hot star mass-loss rates ~ 1-10 $M_\odot$ / 10^6 yr

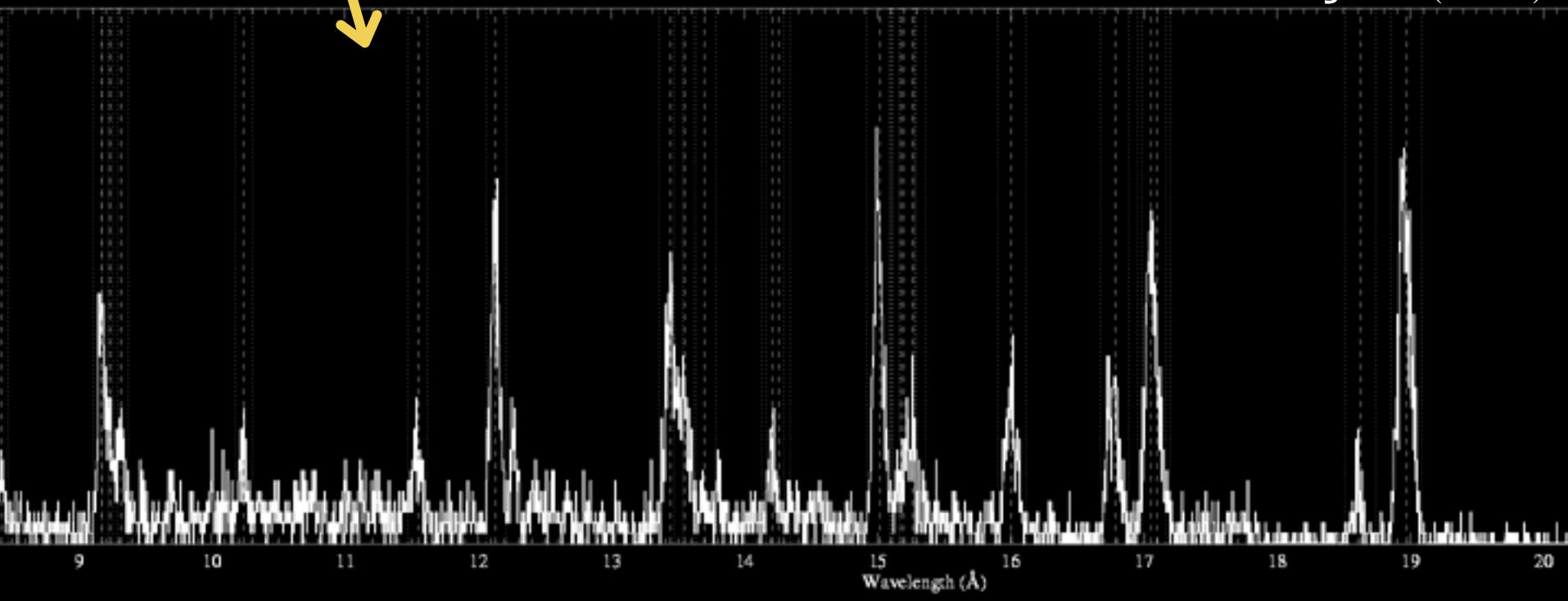
- Mass-loss rate determines the fate of the star

X-ray Production

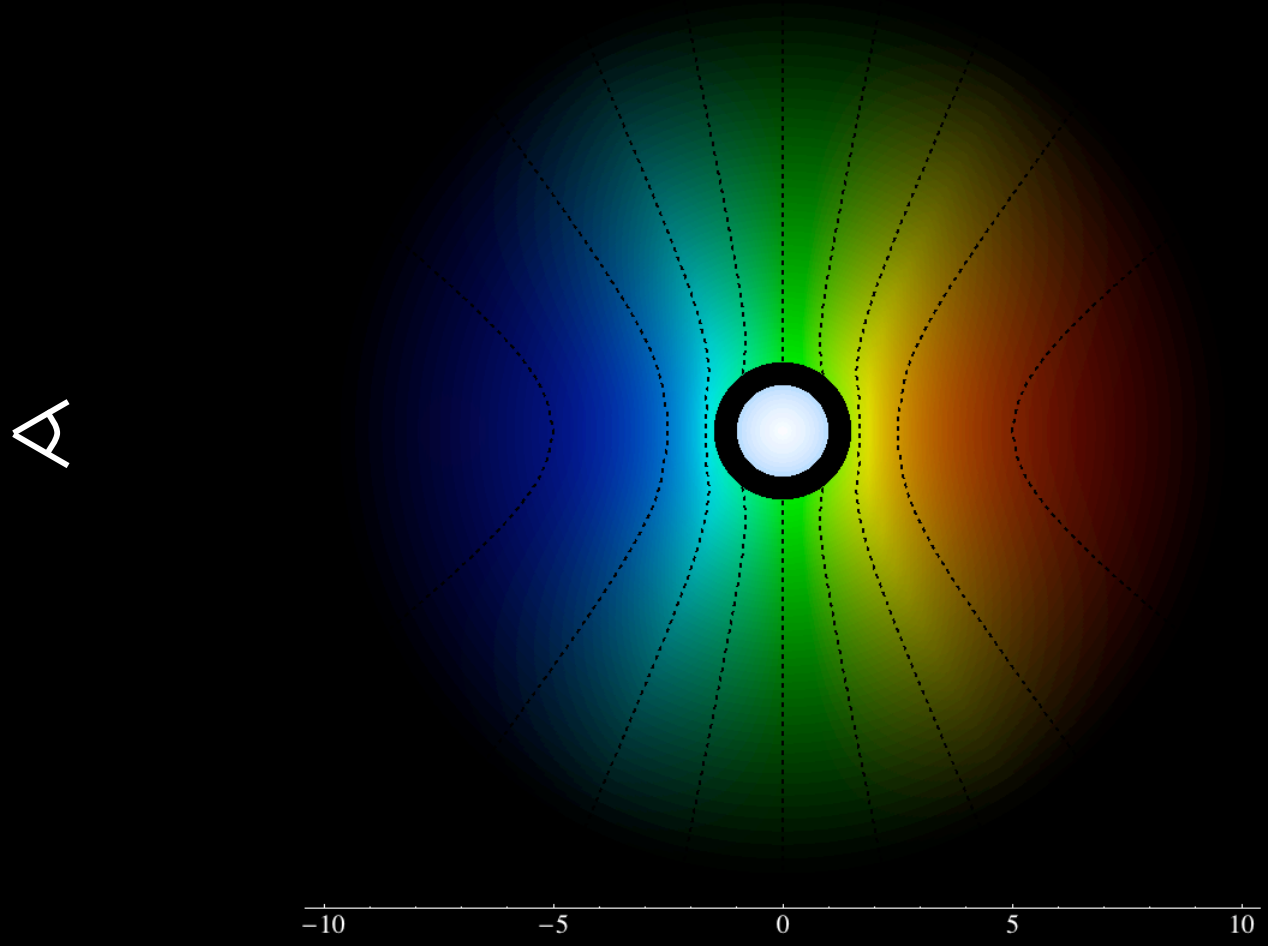
- Winds are unstable.

- High temperature plasma in a small fraction of the wind emits x-rays.

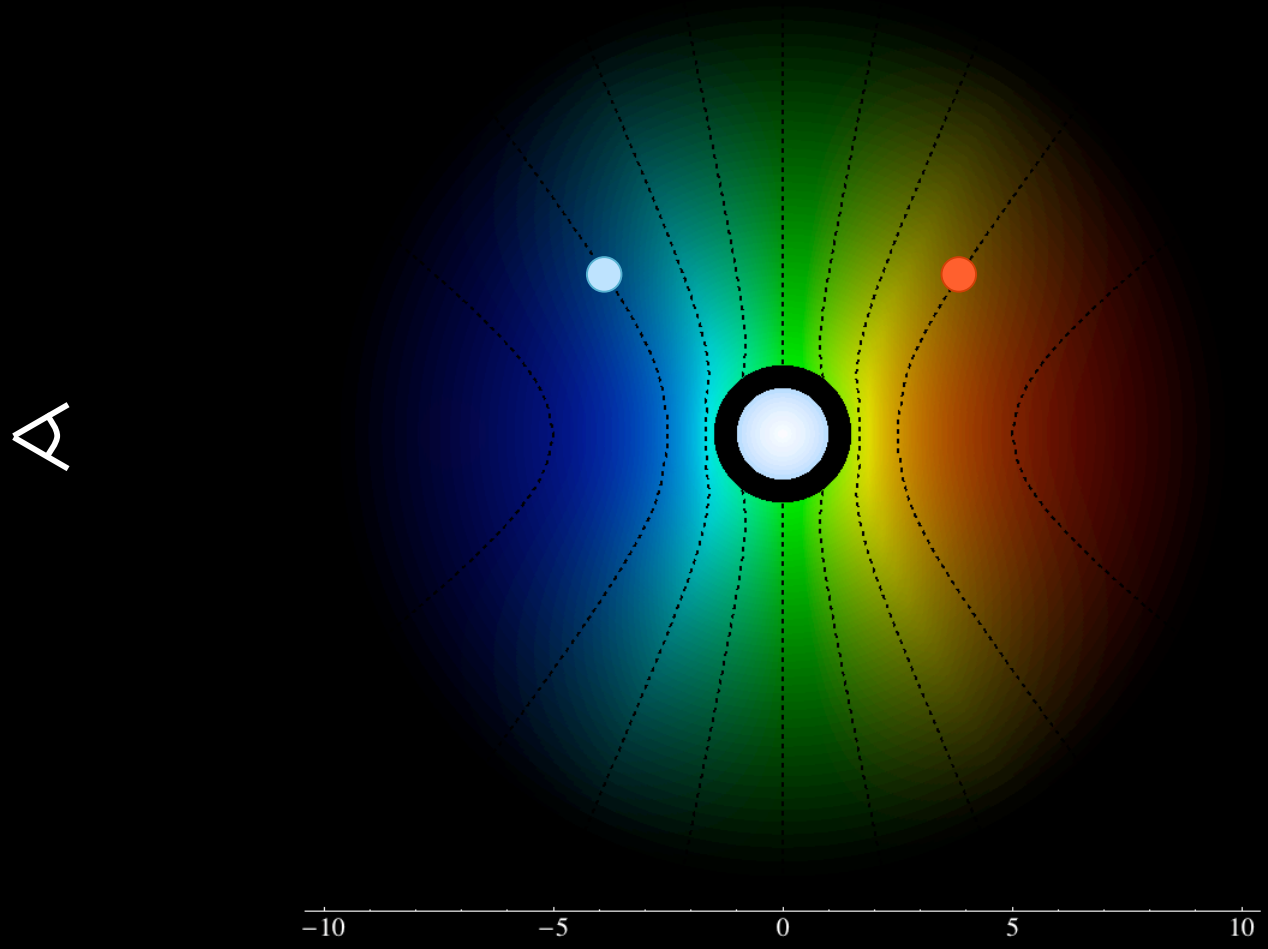
ζ Ori (O9.7)



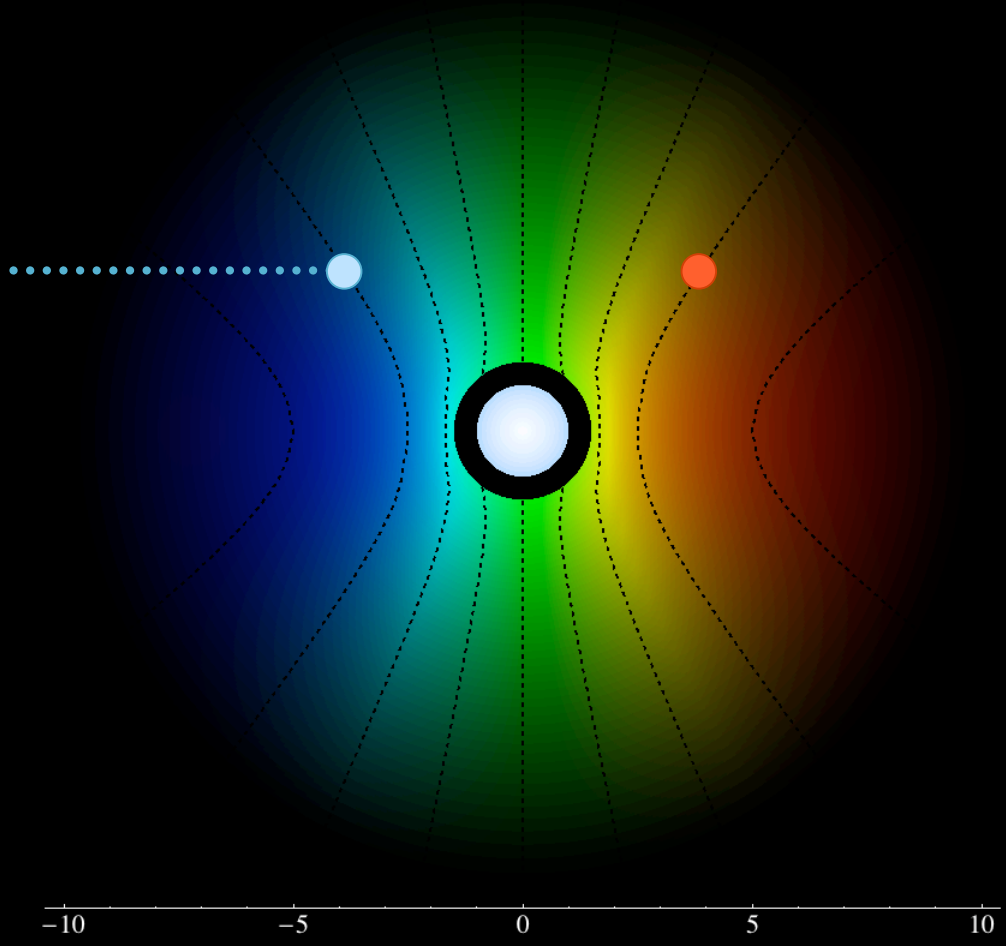
Wind Profile Model



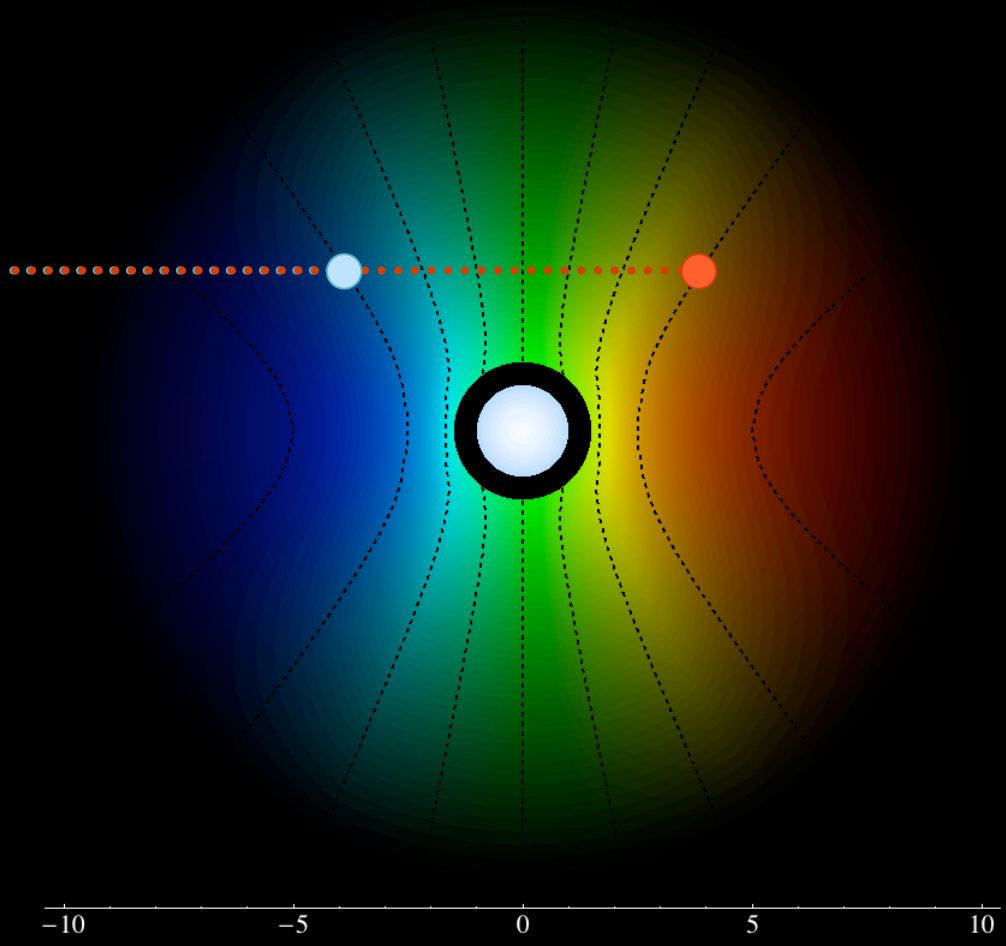
Wind Profile Model



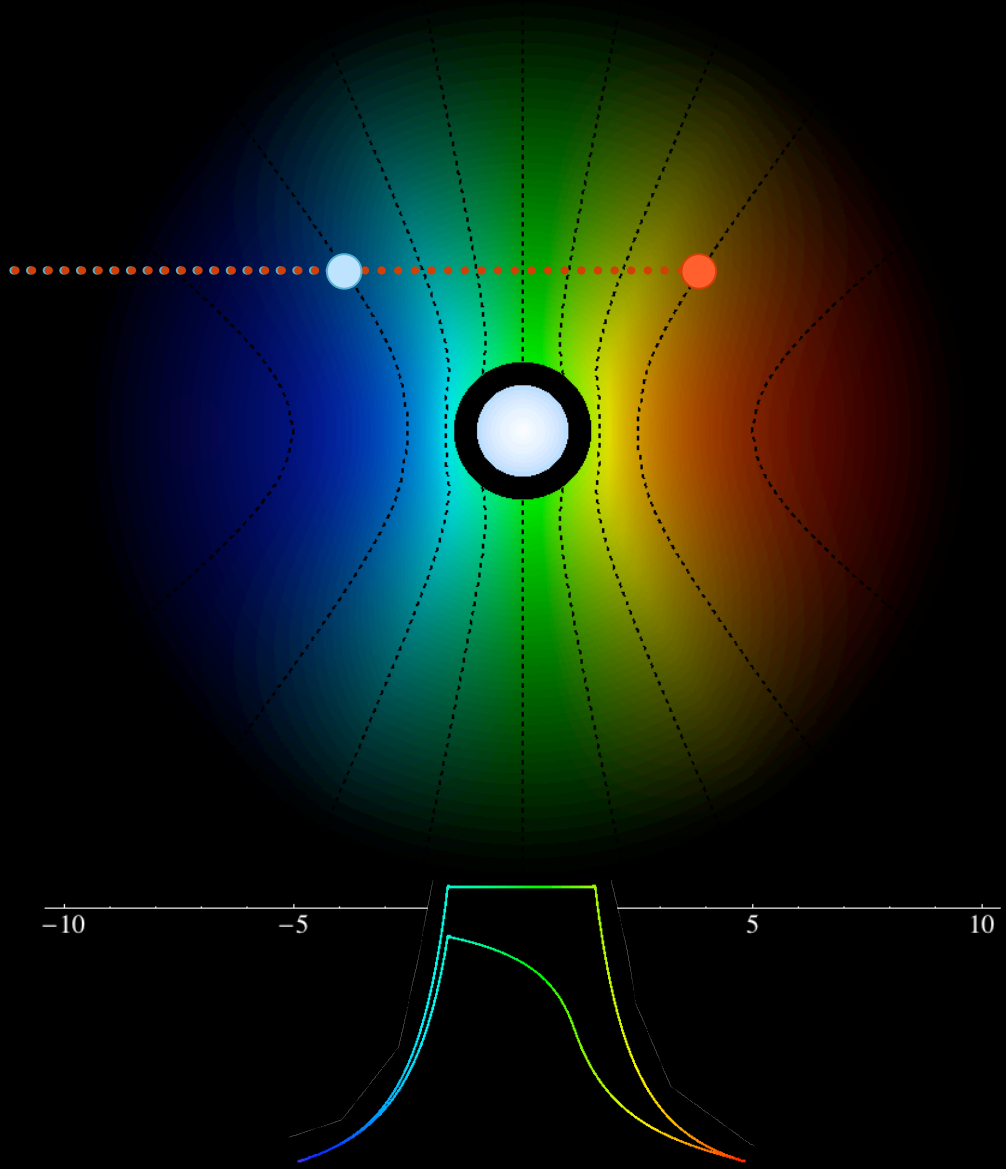
Wind Profile Model



Wind Profile Model

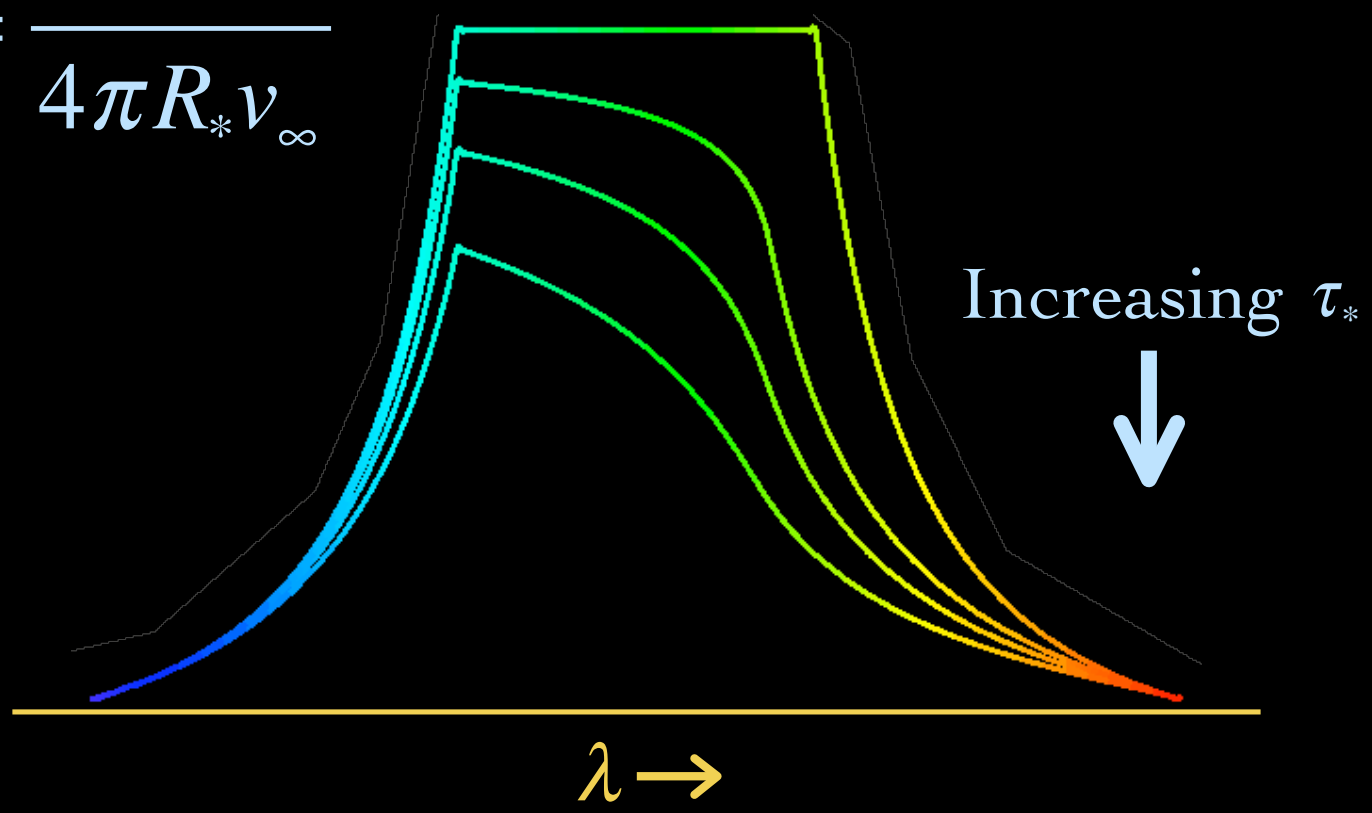


Wind Profile Model

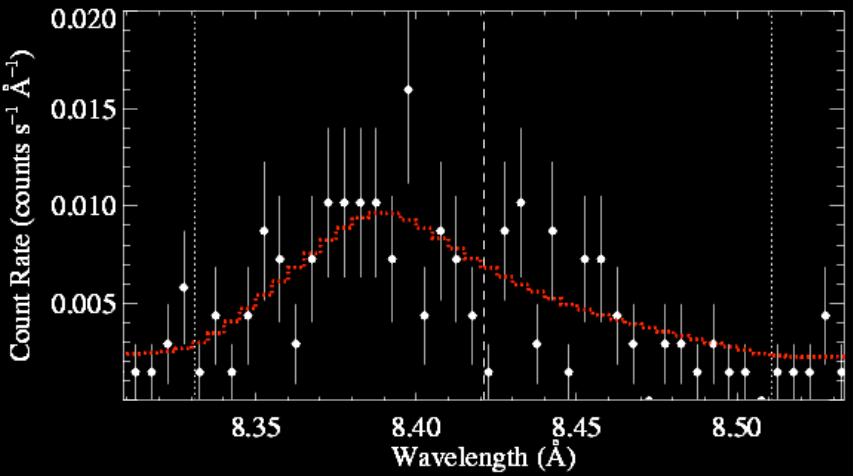


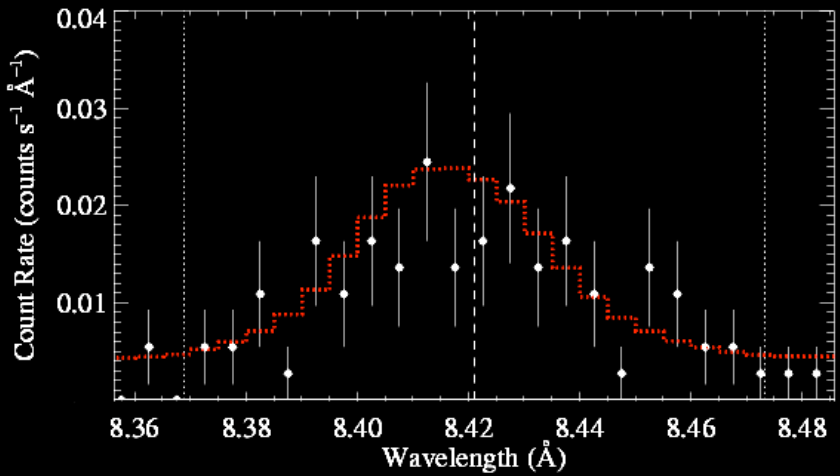
Wind Profile Model

$$\tau_* = \frac{\kappa \dot{M}}{4\pi R_* v_\infty}$$



Model Fitting





HD 93129 (O3)

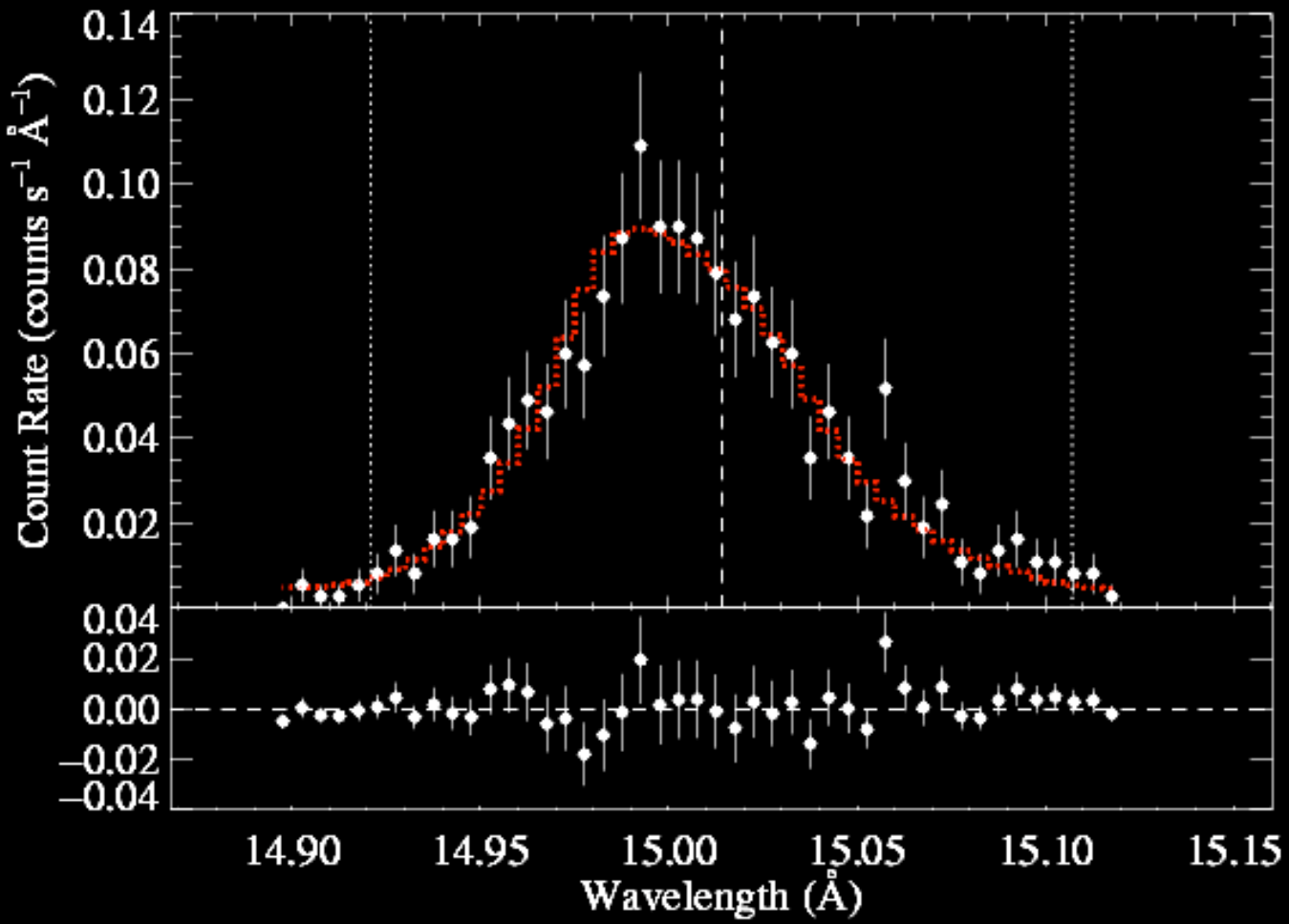
$\tau_* = 2.44 \pm^{1.44}_{1.30}$

ζ Ori (O9.7)

$\tau_* = 0.08 \pm^{0.24}_{0.08}$

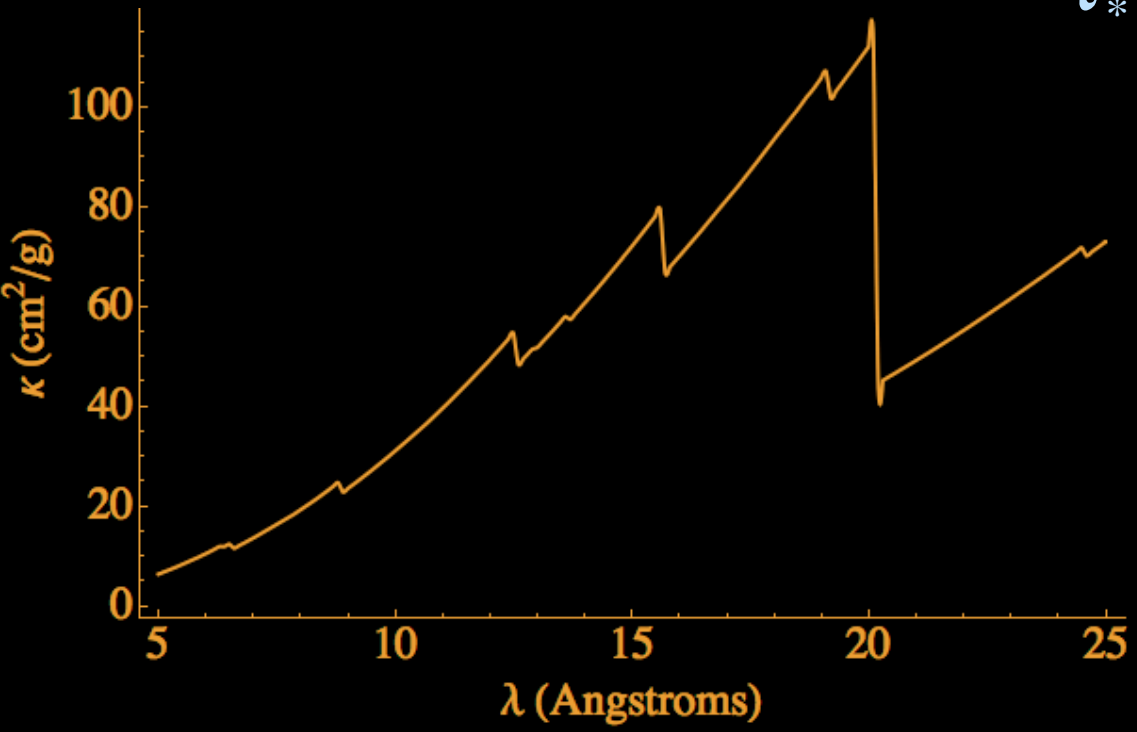
Mg XII @ 8.421 angstroms

Model Fitting



ζ Ori $\quad \tau_* = 0.38 \pm^{0.13}_{0.11}$

Wavelength Dependence

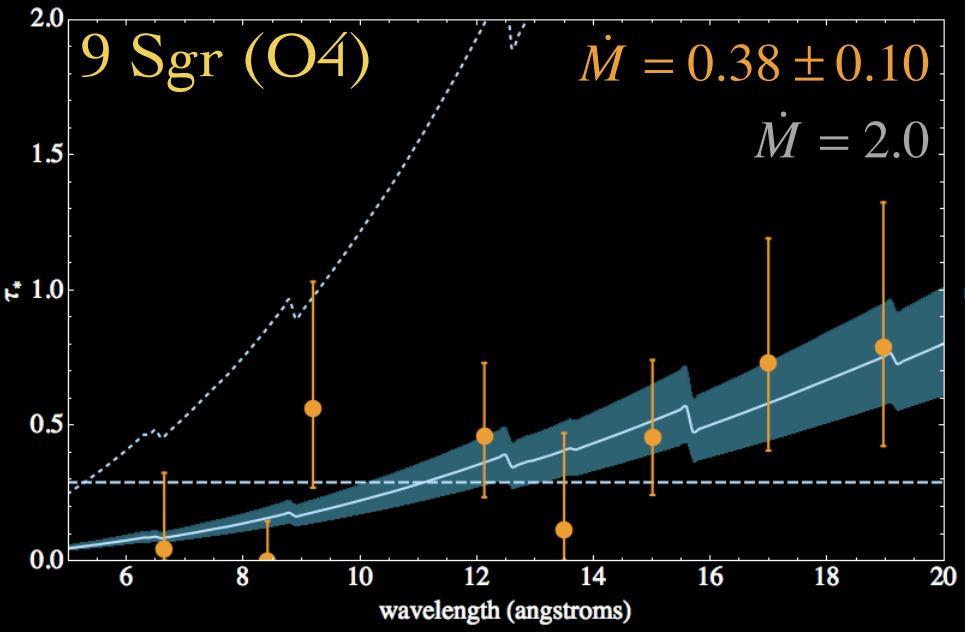


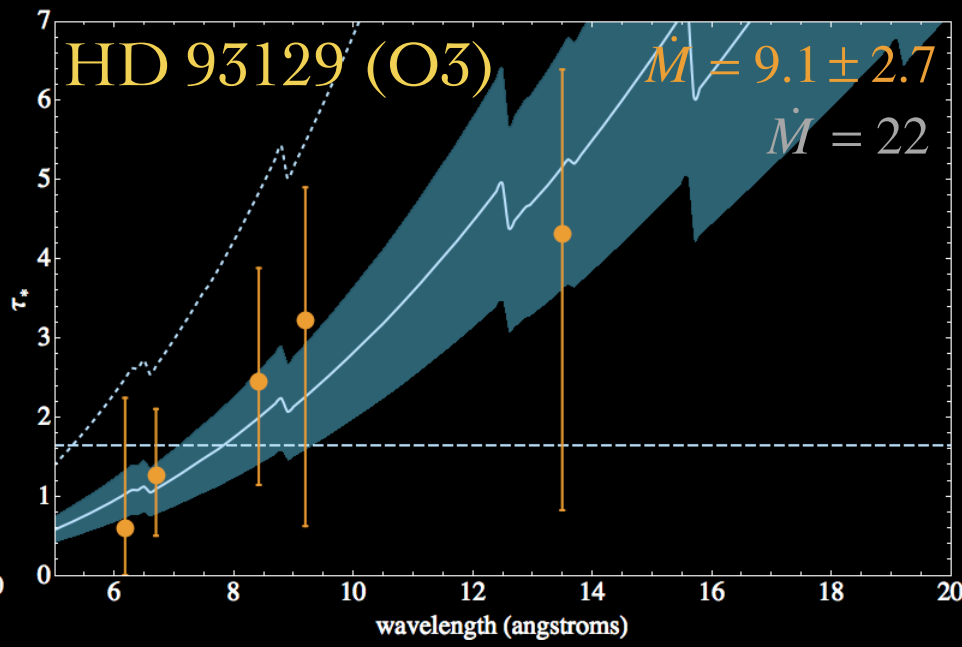
$$\tau_* = \frac{\kappa \dot{M}}{4\pi R_* v_\infty}$$

Results

(Mass-loss rates in units of 10^{-6} solar masses / year)

(Literature values of the mass-loss rate in gray)





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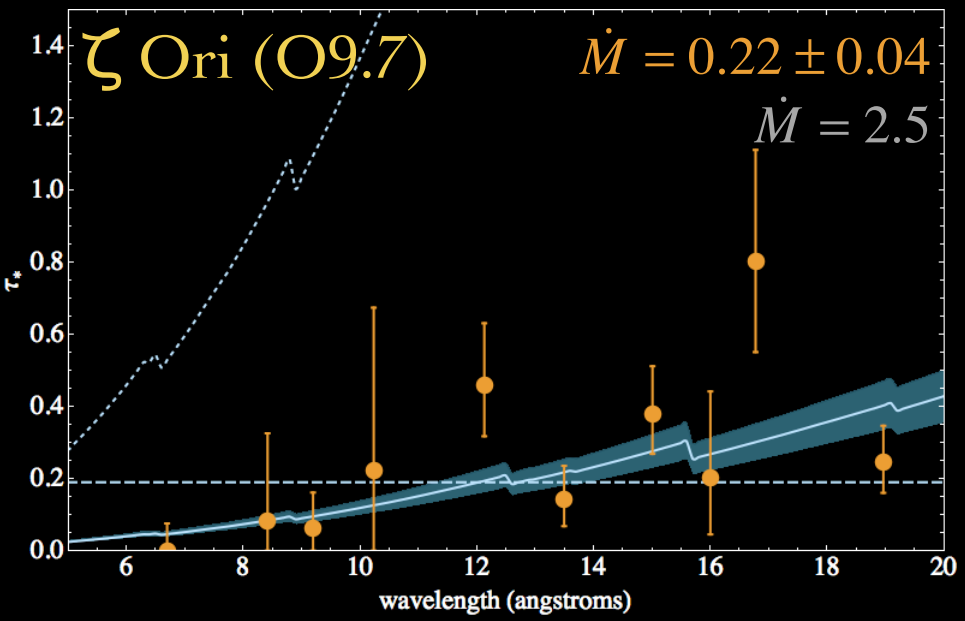
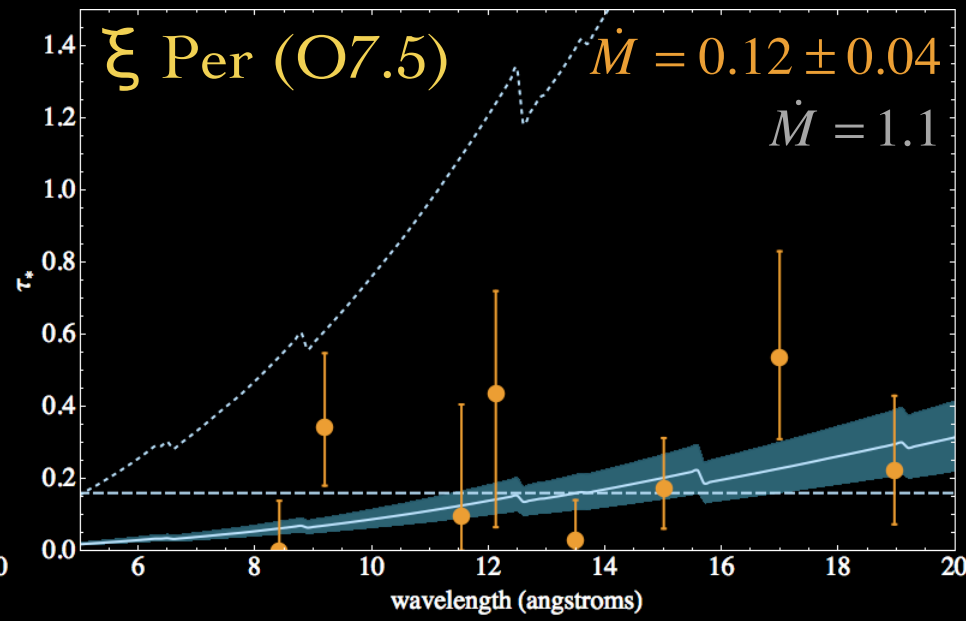
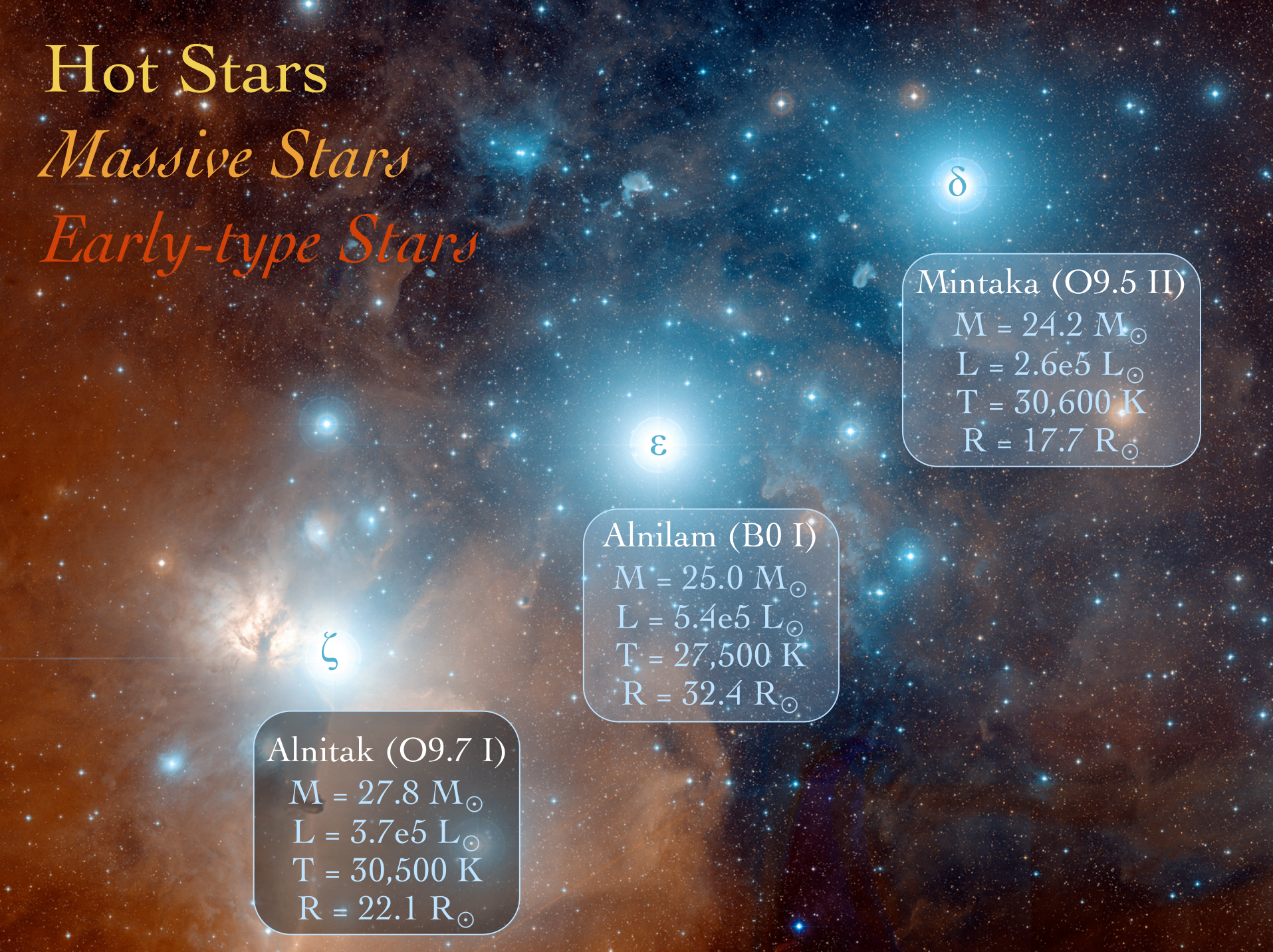




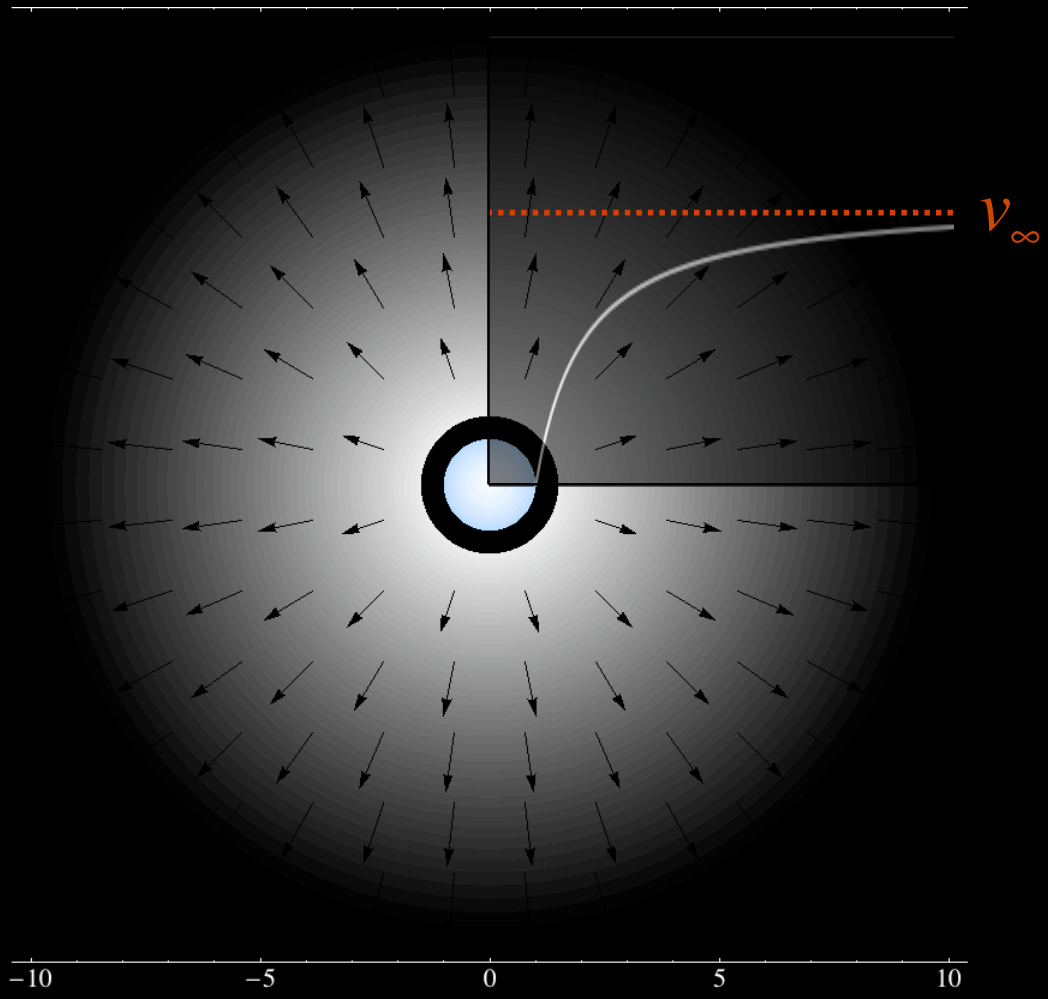
Conclusions

- The x-ray line profile model produces statistically good fits to the data.
- Spectral modeling of the x-rays suggests that current mass-loss rates should be revised downwards.
- τ_* values are more consistent with a wavelength-dependent model than with a constant value.


Hot Stars
Massive Stars
Early-type Stars
δ
Mintaka (O9.5 II)
M = 24.2 M⊙
L = 2.6e5 L⊙
T = 30,600 K
R = 17.7 R⊙
ε
Alnilam (B0 I)
M = 25.0 M⊙
L = 5.4e5 L⊙
T = 27,500 K
R = 32.4 R⊙
ζ
Alnitak (O9.7 I)
M = 27.8 M⊙
L = 3.7e5 L⊙
T = 30,500 K
R = 22.1 R⊙

Wind Profile Model

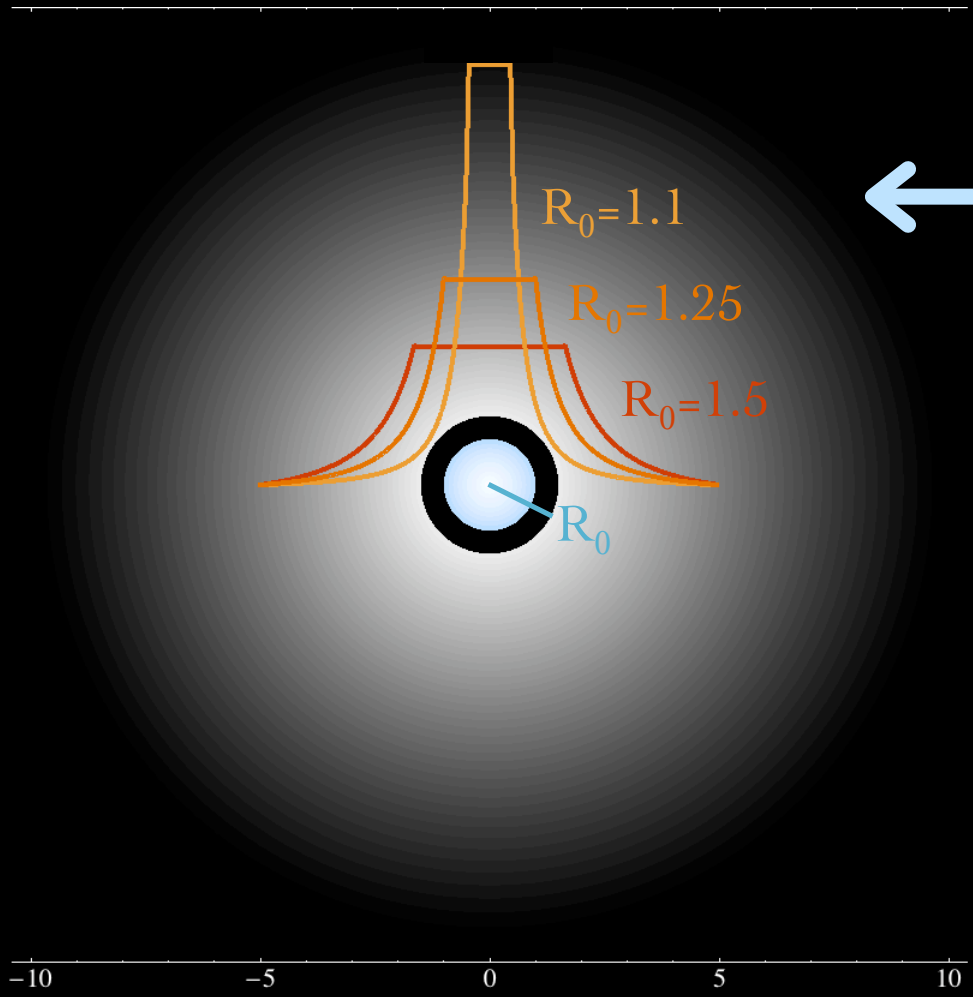
Velocity Field



$$v(r) = v_\infty (1 - R_* / r)^\beta$$

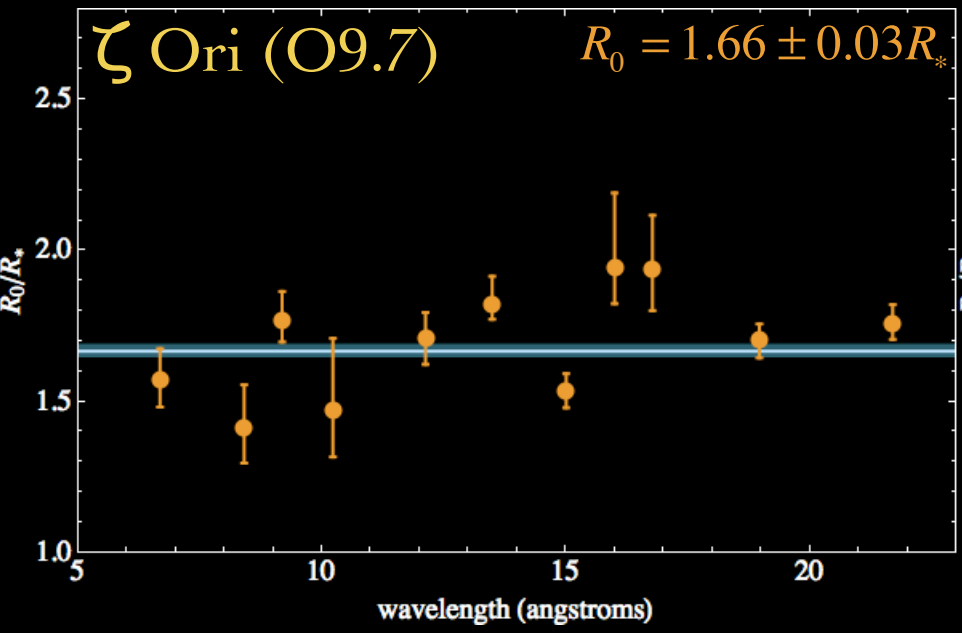
For most stars,
$\beta \sim 1$ and
$v_\infty \sim 2000$ km/s

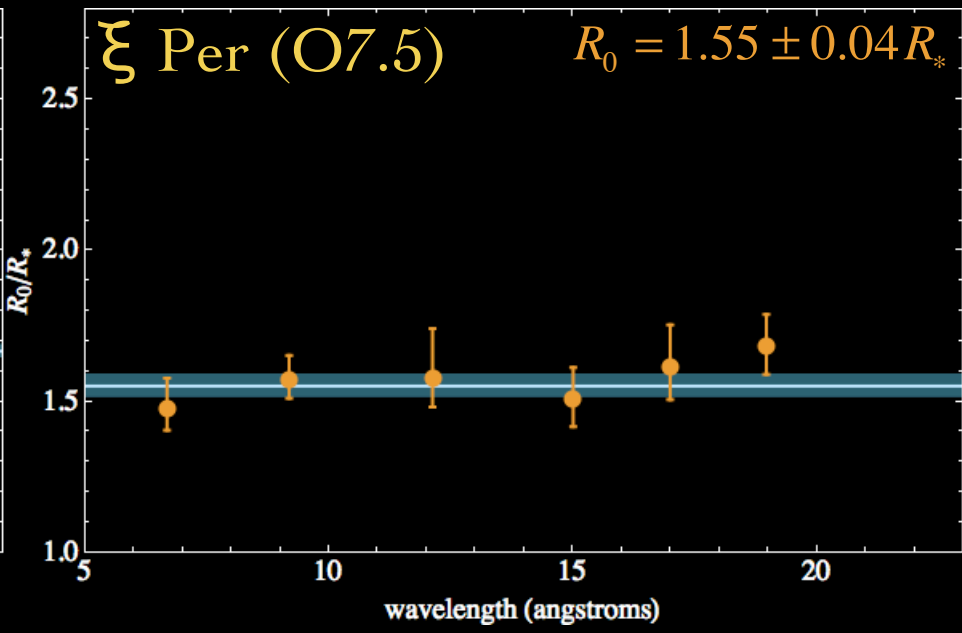
Wind Profile Model

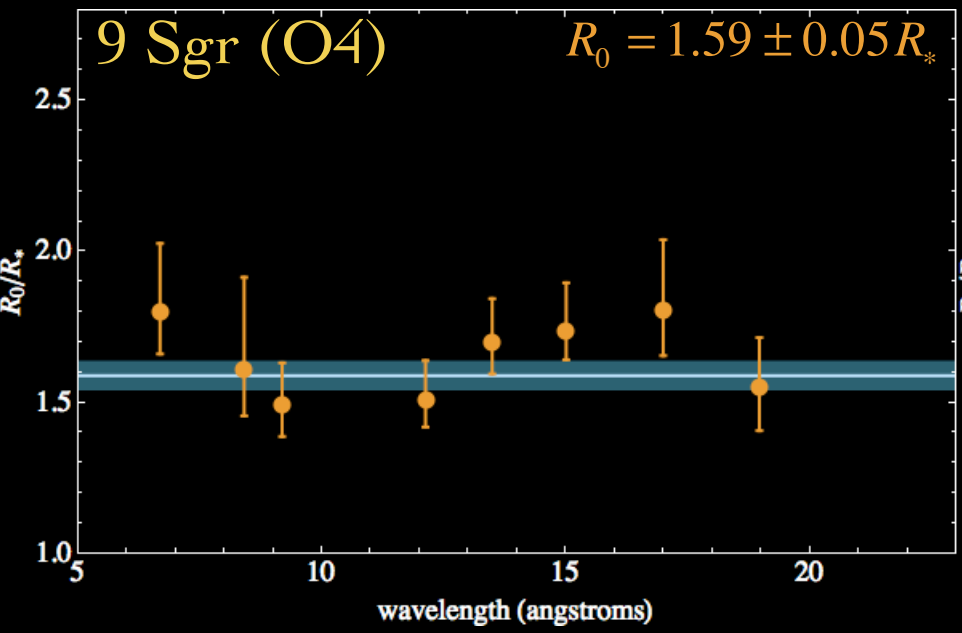


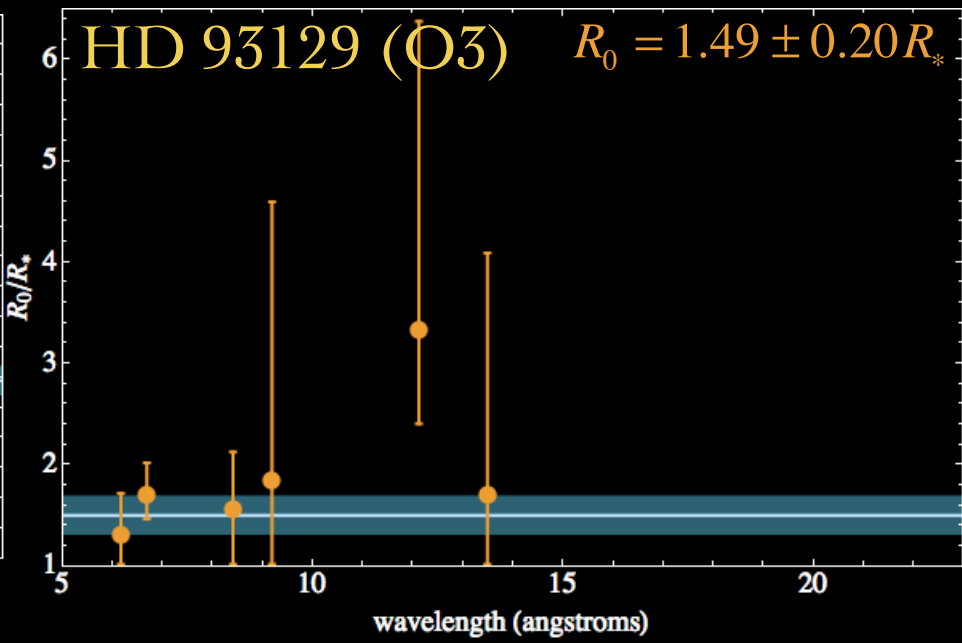
Emission lines without absorption

Results


ζ Ori (O9.7)
$R_0 = 1.66 \pm 0.03 R_*$
R_0/R_*
wavelength (angstroms)


ξ Per (O7.5)
$R_0 = 1.55 \pm 0.04 R_*$
R_0/R_*
wavelength (angstroms)


9 Sgr (O4)
$R_0 = 1.59 \pm 0.05 R_*$
R_0/R_*
wavelength (angstroms)


HD 93129 (O3)
$R_0 = 1.49 \pm 0.20 R_*$
R_0/R_*
wavelength (angstroms)