Near Star Radiative Feedback and the Stellar Upper Mass Limit

Nathaniel Dylan Kee

University of Tübingen

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Rolf Kuiper (University of Tübingen)
Stan Owocki (University of Delaware)
Jon Sundqvist (KU Leuven)

Emmy Noether-Programm

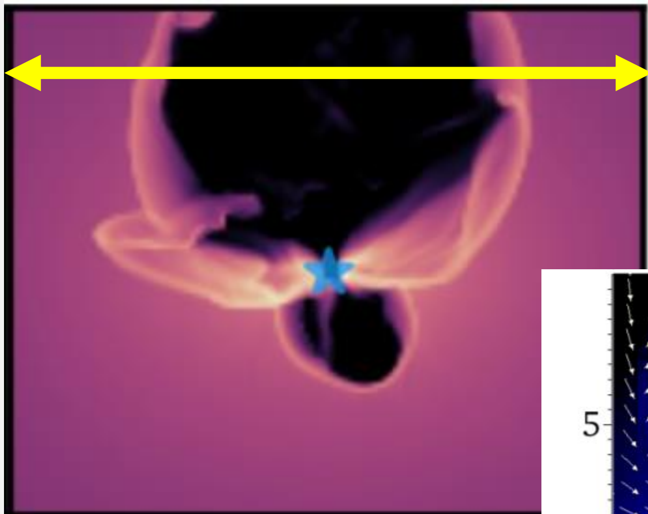
Deutsche Forschungsgemeinschaft DFG

Tracing the Flow, Lake Windermere 2018

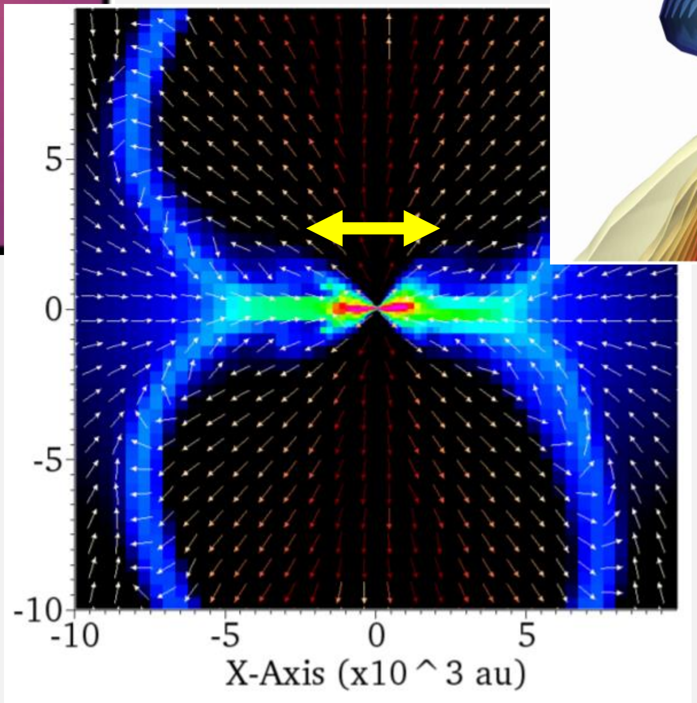
Many types of feedback

- Direct Radiation Pressure
- Indirect Radiation Pressure
- Ionization
- Outflows
- Etc…

Generally feedback studies focus on ~ au to pc scales



Rosen et al. (2016), MNRAS



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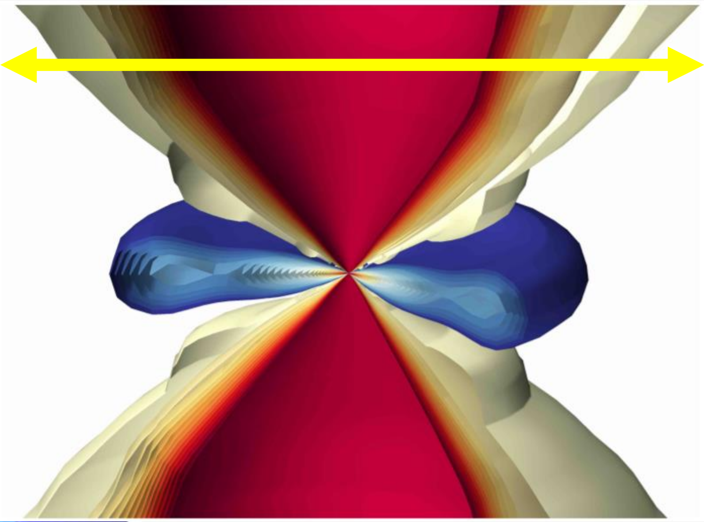
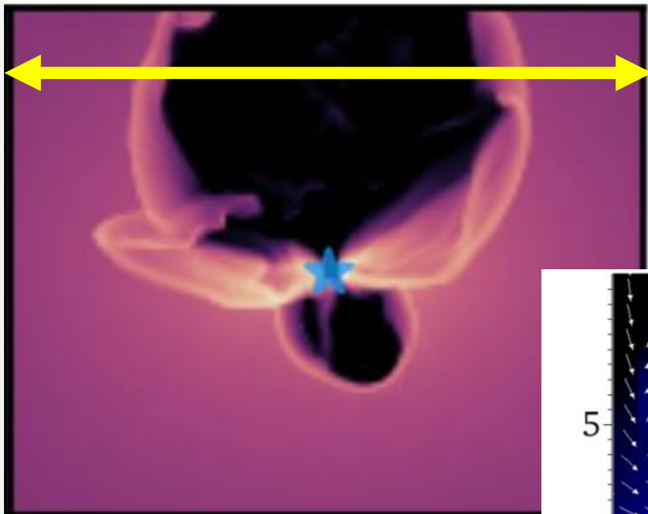


Kuiper & Hosokawa (2018), A&A

Arrows span 5000 au

“Near star” is tiny ($R_* \sim 1$ au)



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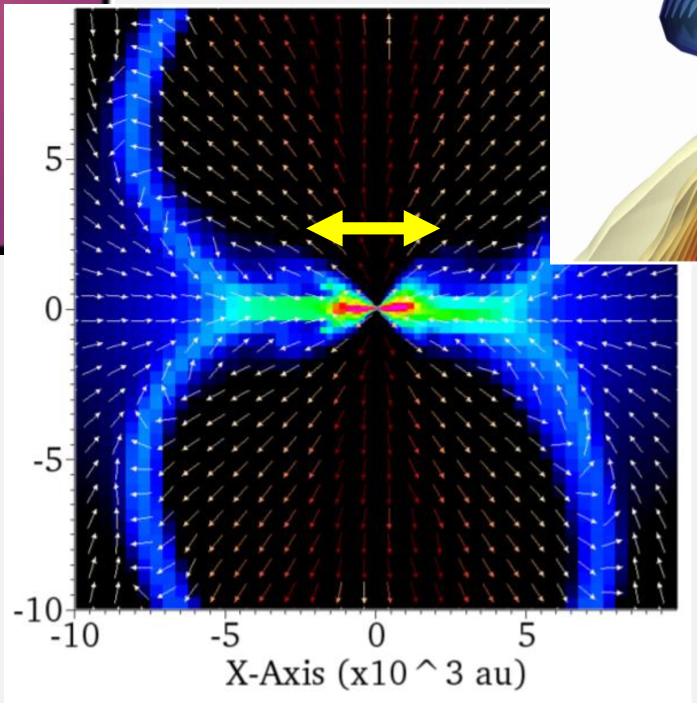

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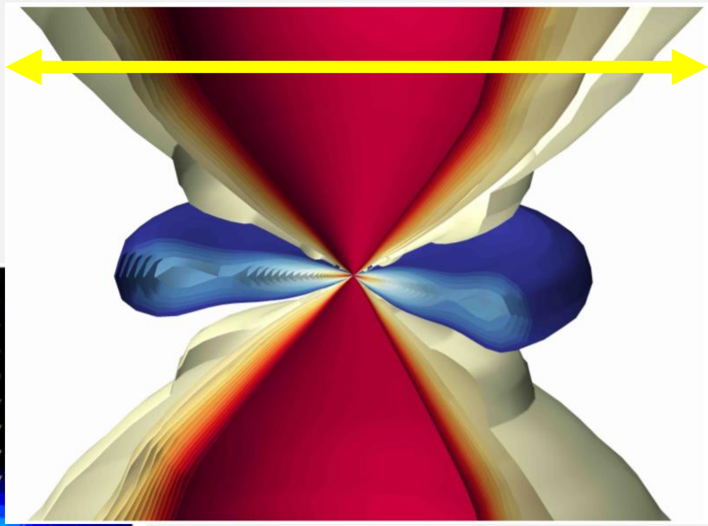

Kuiper & Hosokawa (2018), A&A

Arrows span
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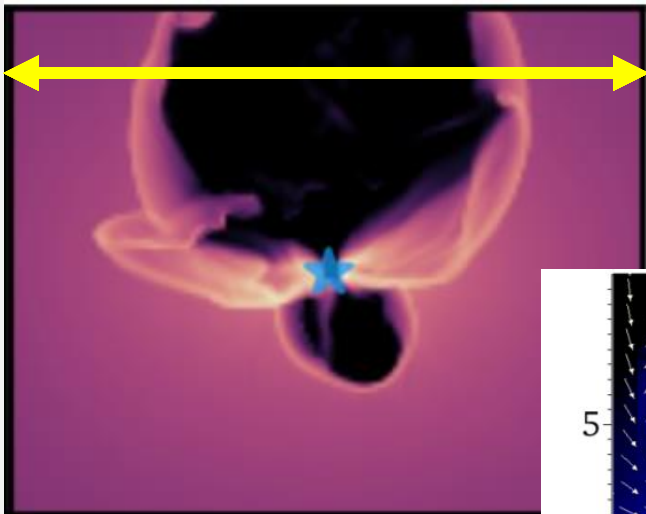
UV line-driven outflows are launched at these small radii



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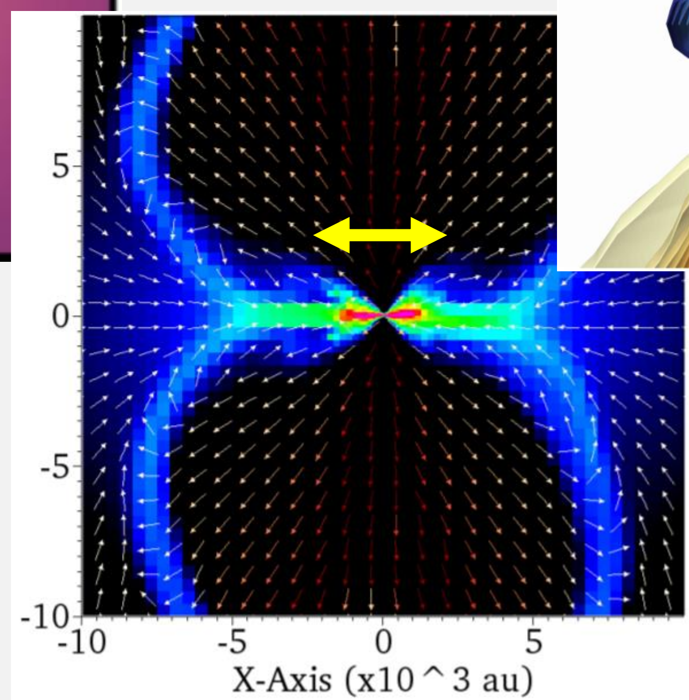

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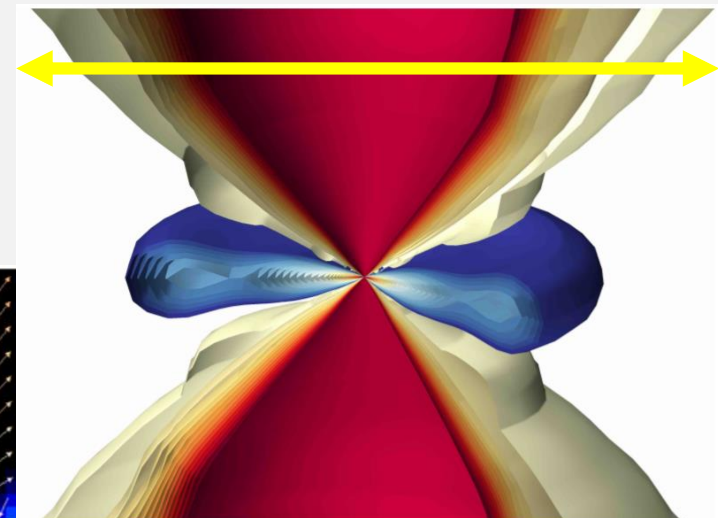

Kuiper & Hosokawa (2018), A&A

Arrows span ~5000 au

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What do these forces do to disk material?

UV line acceleration in a nutshell

- $\kappa_{\text{line}} \sim 1000 \times \kappa_e$
- Confined to a very narrow spectral range
- Doppler shifting the line changes this spectral range into a spatial range
- Allows for local calculations

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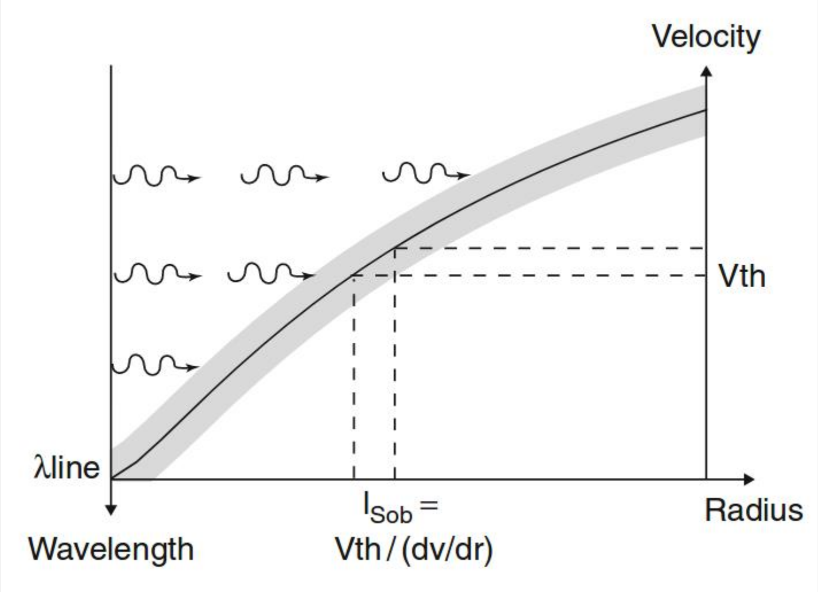

Owocki (2013), Springer

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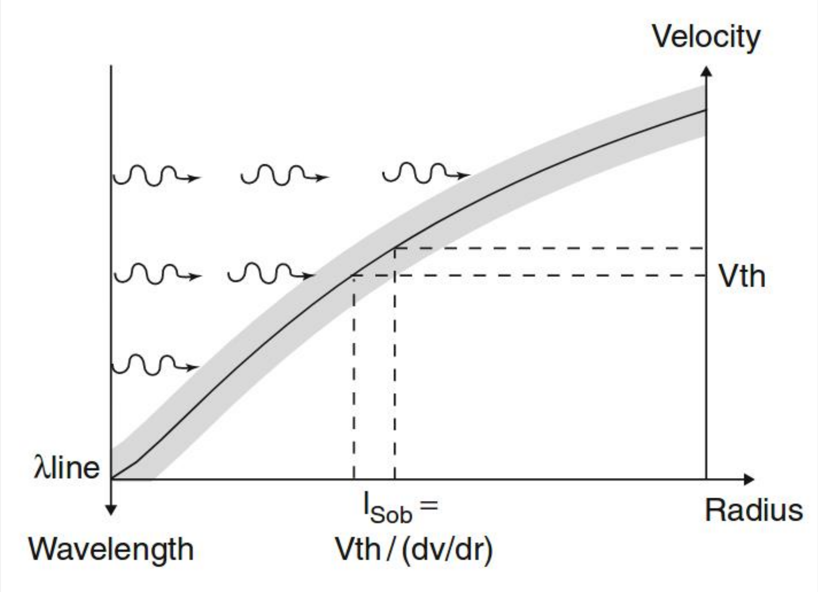

Owocki (2013), Springer

$$g_{\rm lines} \propto \frac{dv_n/dn}{\rho}$$

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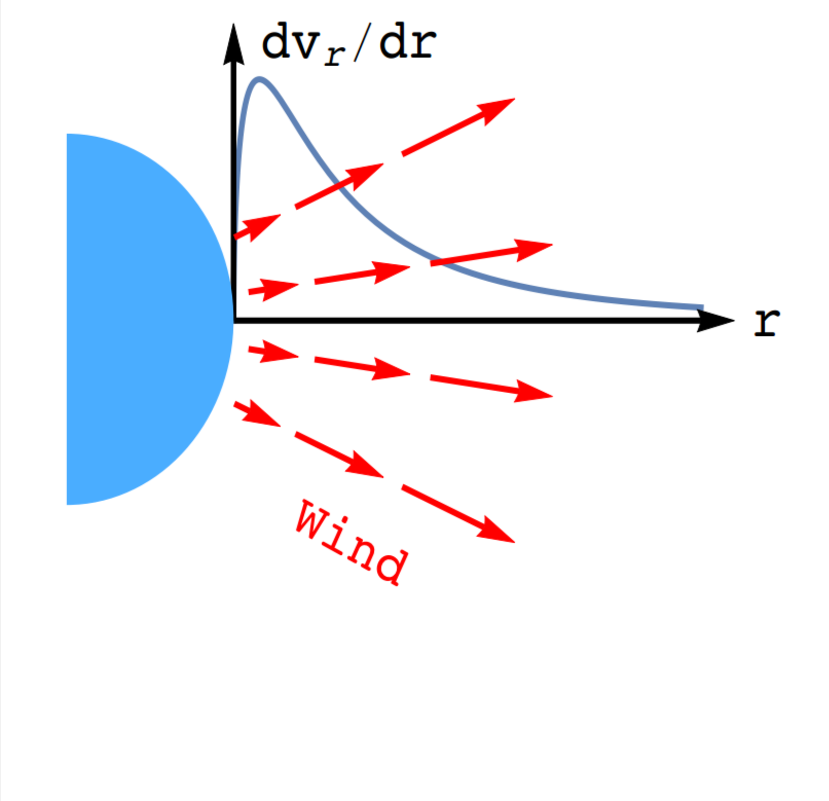
From stellar winds to disk outflows

Non-wind circumstellar material (e.g. disk material) can be accelerated by UV line opacity too, it just needs a velocity gradient

From stellar winds to disk outflows



Kee et al. (2016), MNRAS

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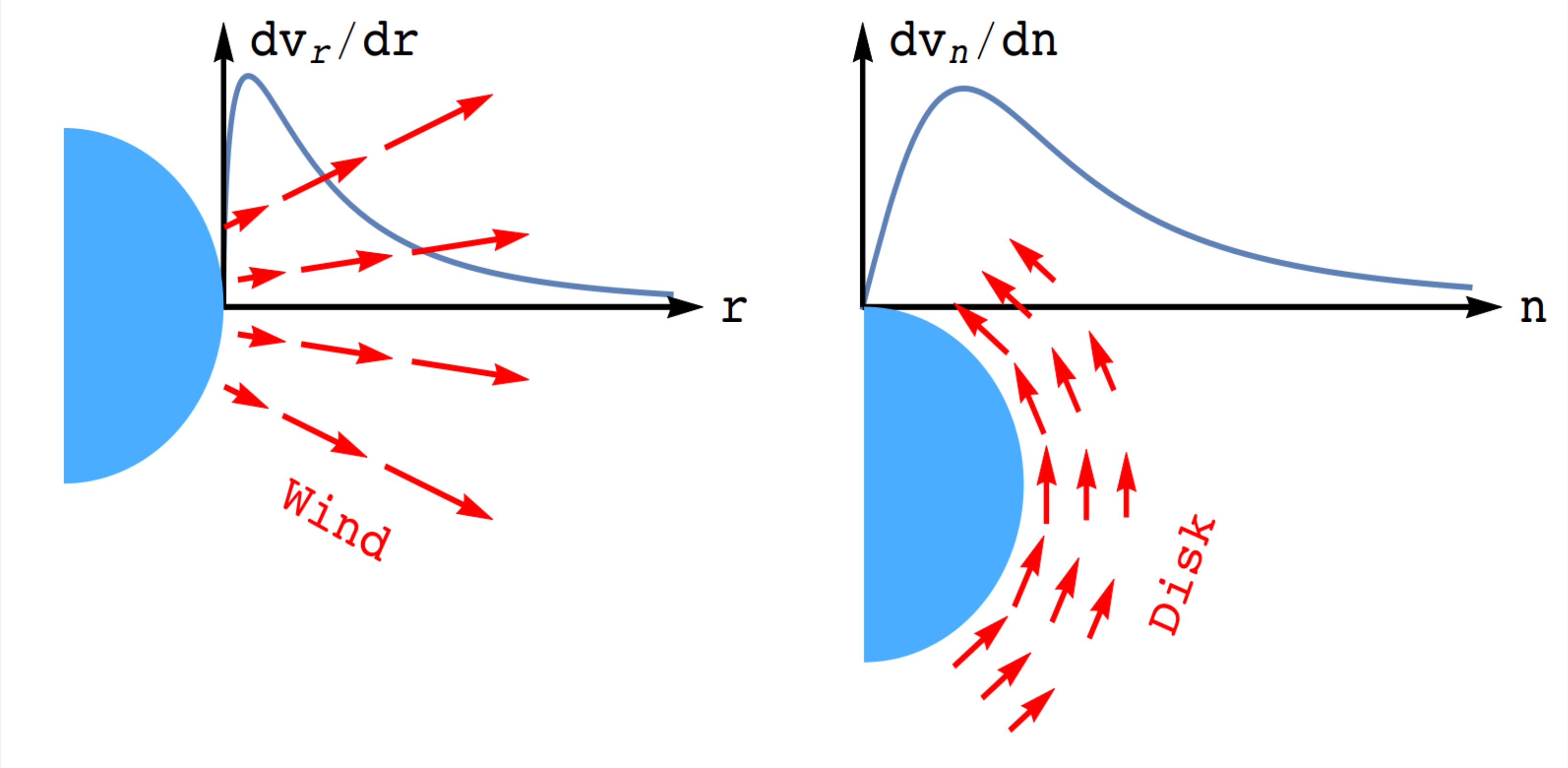

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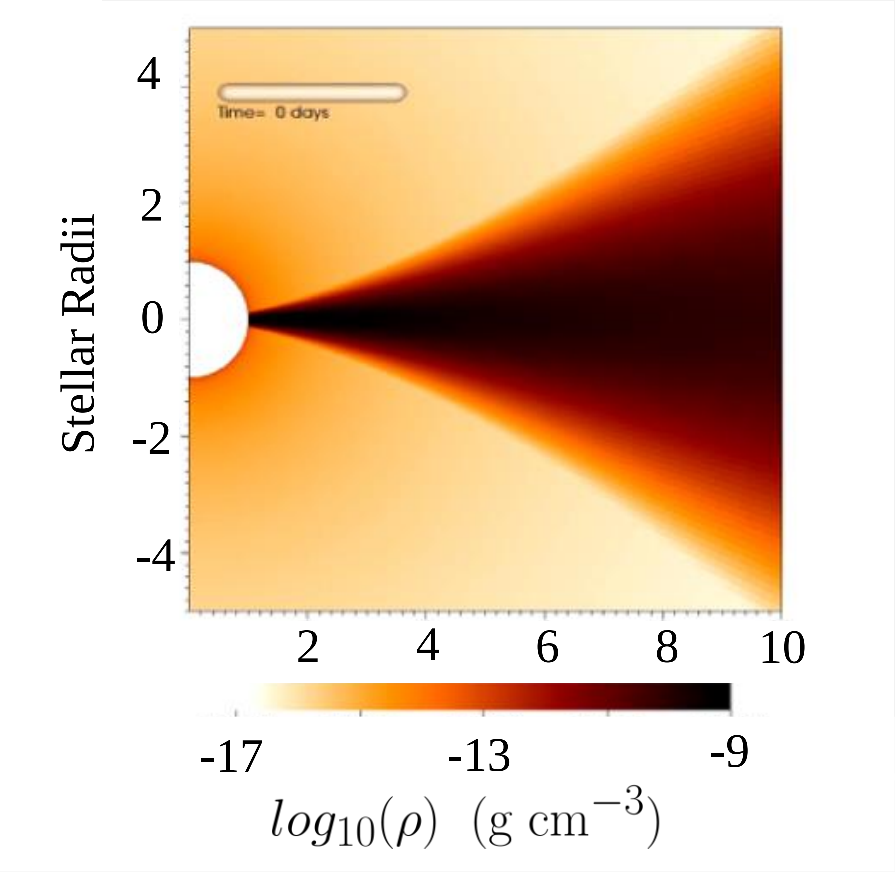
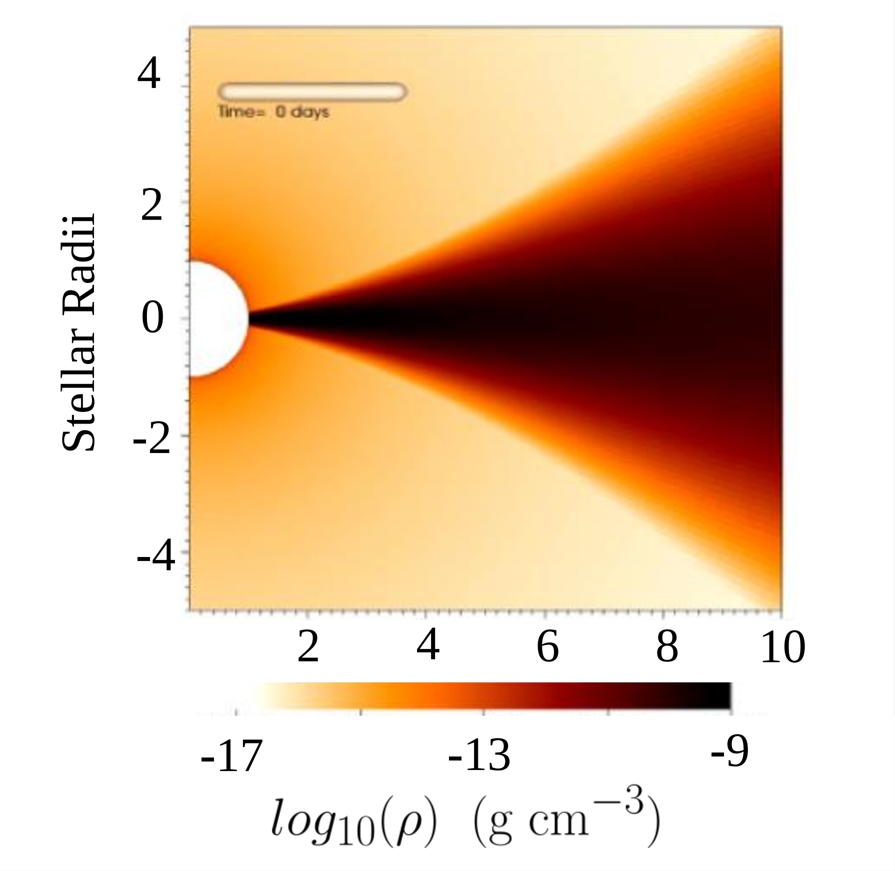


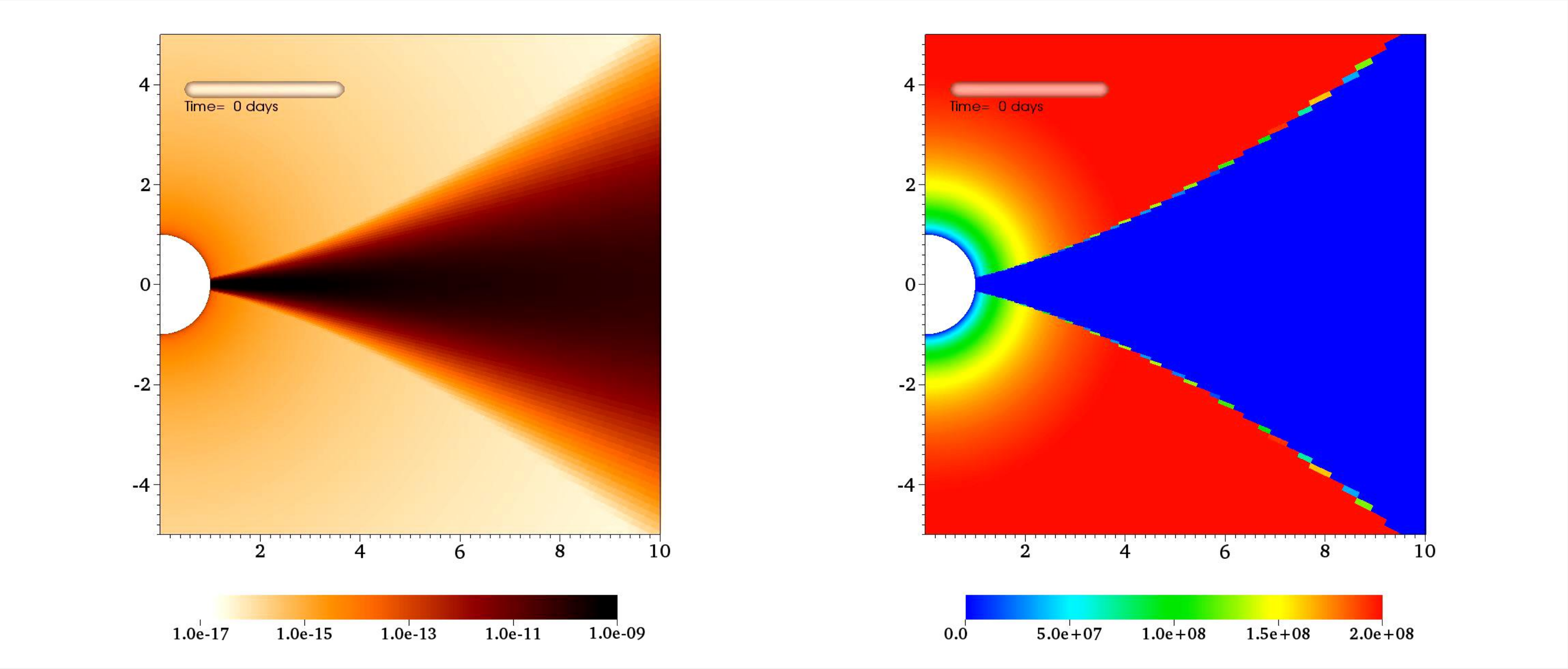
Extrapolation of a disk with $M_{\rm disk} = 9\,M_\odot$ in 500 au down to the stellar surface

From stellar winds to **disk ablation**



Extrapolation of a disk with $M_{\rm disk} = 9\,M_\odot$ in 500 au down to the stellar surface

Sample simulation of disk ablation



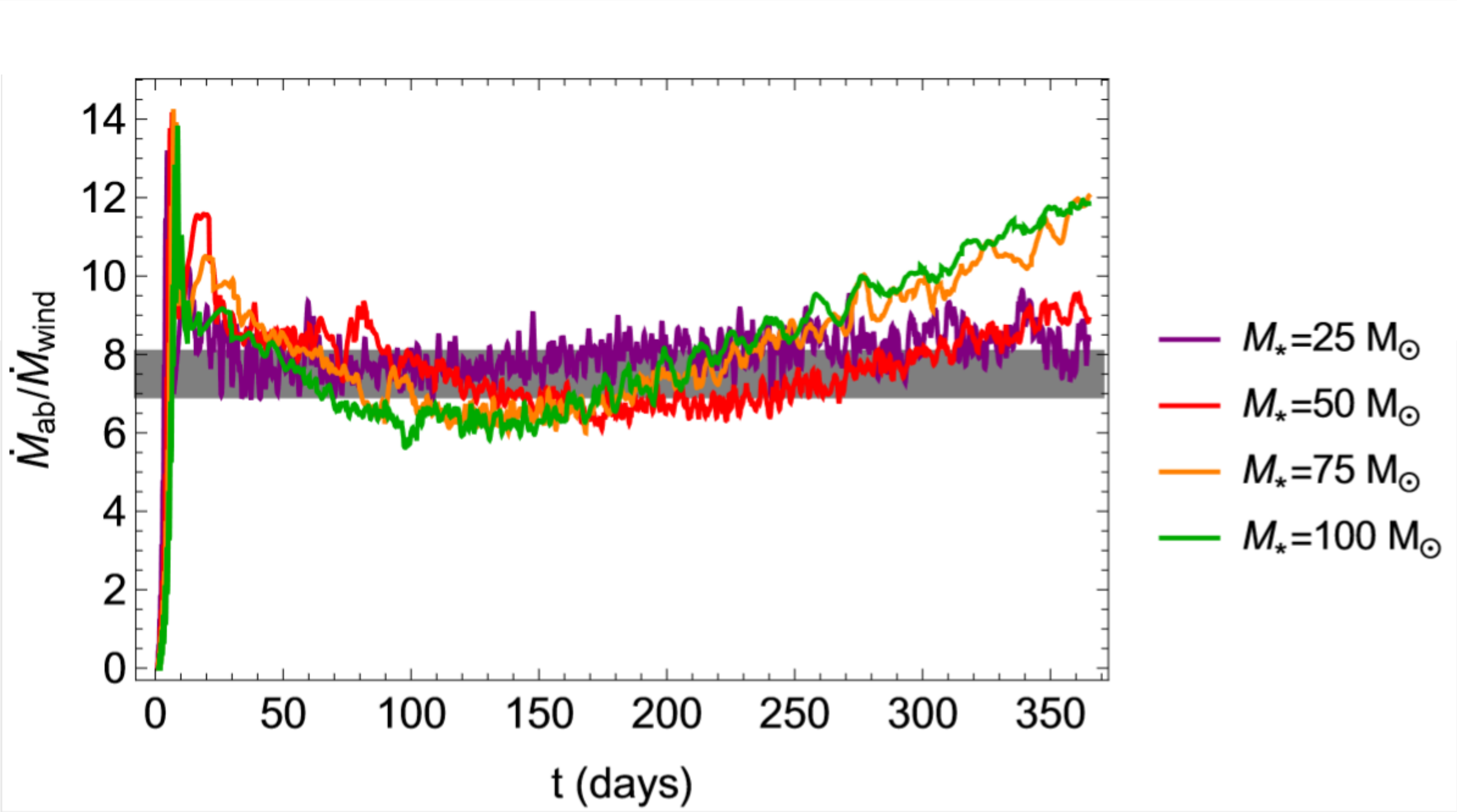
$M_* = 25\ M_\odot$

$L_* = 7.34 \times 10^4\ L_\odot$

$\dot{M}_{\rm wind} = 5.5 \times 10^{-8}\ M_\odot/{\rm yr}$

$M_{\rm disk} = 9\ M_\odot$ in $500\,{\rm au}$

Ablation rate as a function of stellar mass



This uniformity of behavior makes ablation analytic

$$\dot{M}_{\mathrm{wind}} \approx 1.26 \times 10^{-11} \frac{L_*}{L_\odot} \left(\frac{\Gamma_e}{1 - \Gamma_e} \right)^{0.75} \; M_\odot/\mathrm{yr}$$

$$\Gamma_e = \frac{\kappa_e L_*}{4\pi G M_* c}$$

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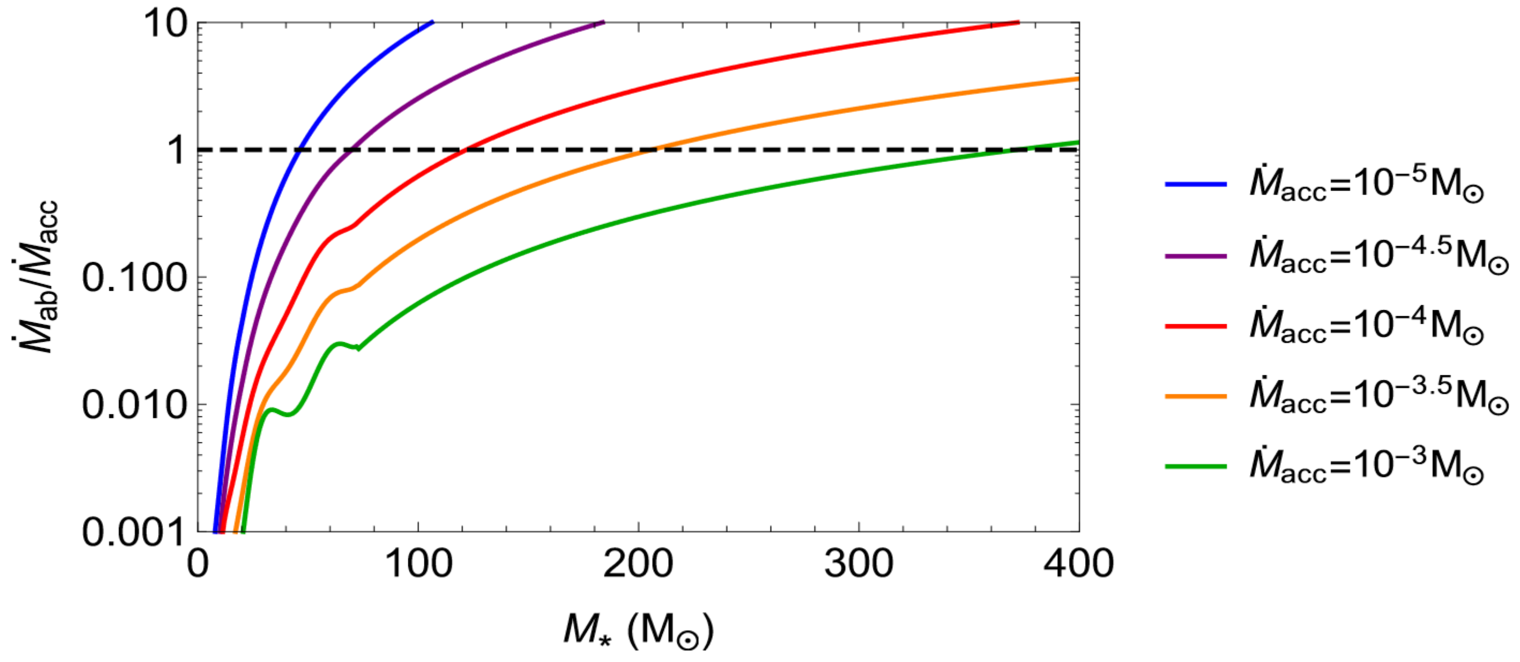
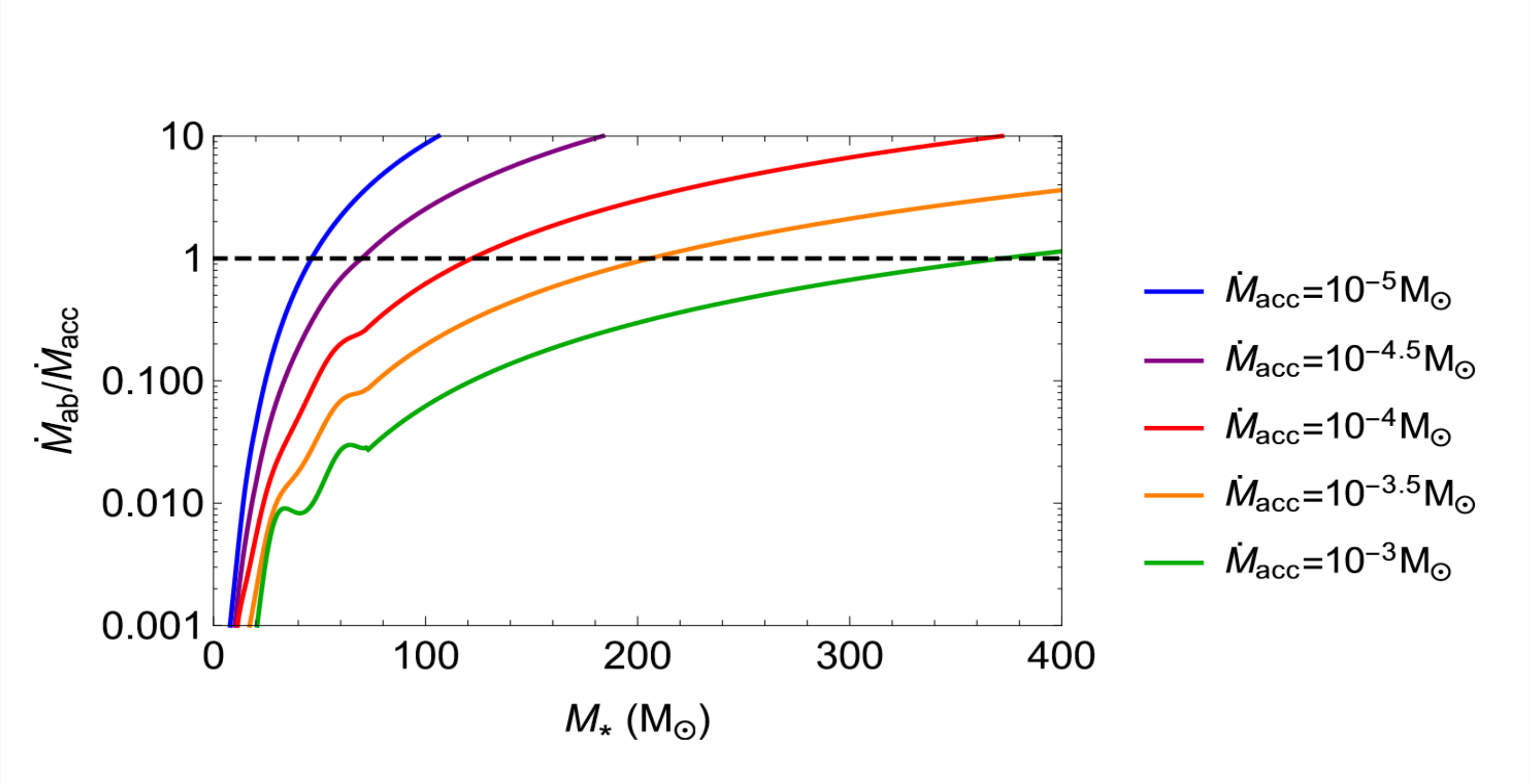
$$f \sim 7 - 8$$

Ablation efficiency



Mass-luminosity relations extrapolated from
Hosokawa & Omukai (2009), ApJ

An accretion rate dependent stellar upper mass limit



Mass-luminosity relations extrapolated from Hosokawa & Omukai (2009), ApJ

Thank you for your attention

Summary

- UV acceleration ablates material off of circumstellar disks
- The enhancement of this ablation rate over wind mass loss rate is fairly insensitive to stellar mass (~7-8x)
- Ablation alone is sufficient to shut off accretion
- When combined with feedback at larger radii, ablation plays an important role in setting the stellar upper mass limit