



Winds and dynamical friction... surprise

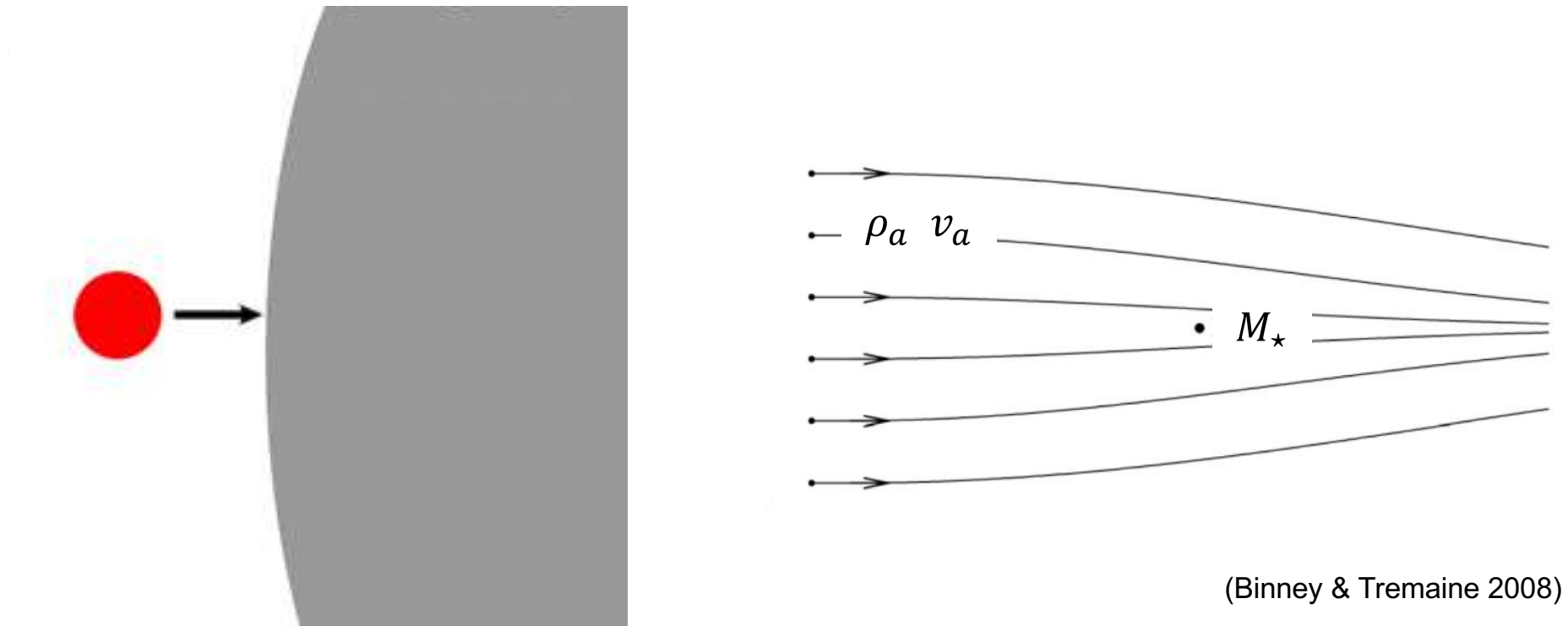
Diego López-Cámara (ICN-UNAM)

+ Jesús Carrillo-Santamaría, Enrique Moreno Méndez,
Fabio De Colle, Javier Sánchez Salcedo

(Carrillo-Santamaría et al. 2025)

Dynamical friction (basics)...

Dynamical friction is the gravitational drag on a massive body moving through a background of lighter particles. (Binney & Tremaine 2008)



Dynamical friction (in astronomy)...

Satellite galaxy orbital decay when merging vs a galaxy (Binney & Tremaine 2008)

Inspiral of massive BHs during galaxy mergers (Begelman, Blandford & Rees 1980)

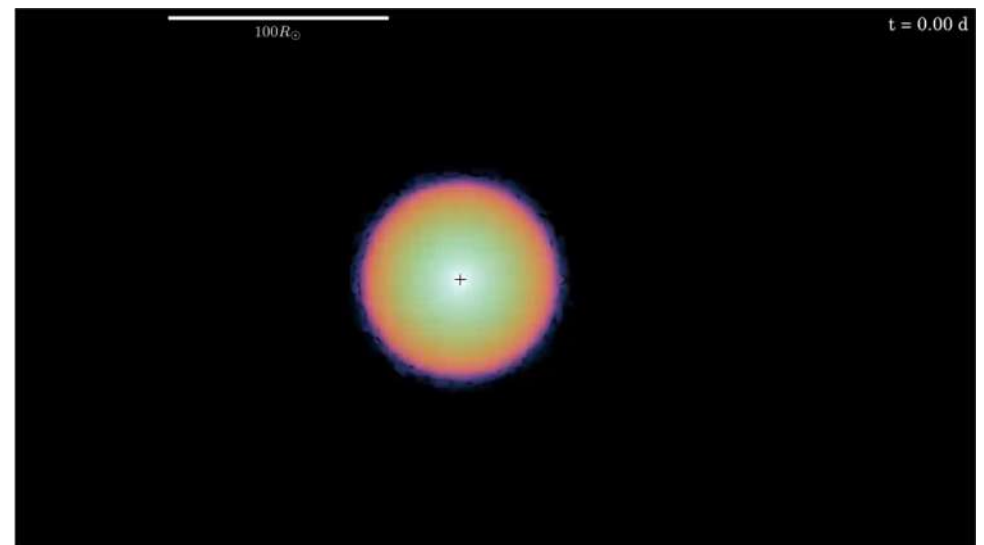
Migration of star clusters toward galactic centers (Tremaine, Ostriker & Spitzer 1975)

Contact binaries (Kopal 1959)

W Ursae Majoris (Worden & Whelan 1973)

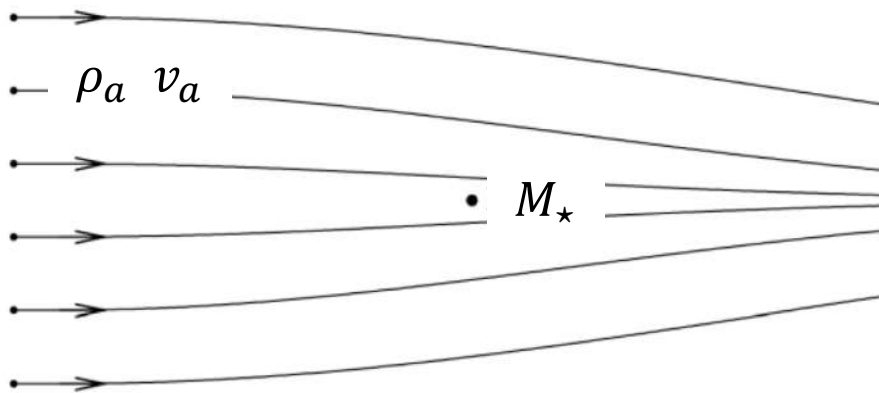
$$\begin{array}{c} 1 M_{\odot} + 1 R_{\odot} \\ \text{vs} \\ 0.5 M_{\odot} + 0.8 R_{\odot} \end{array}$$

CE?

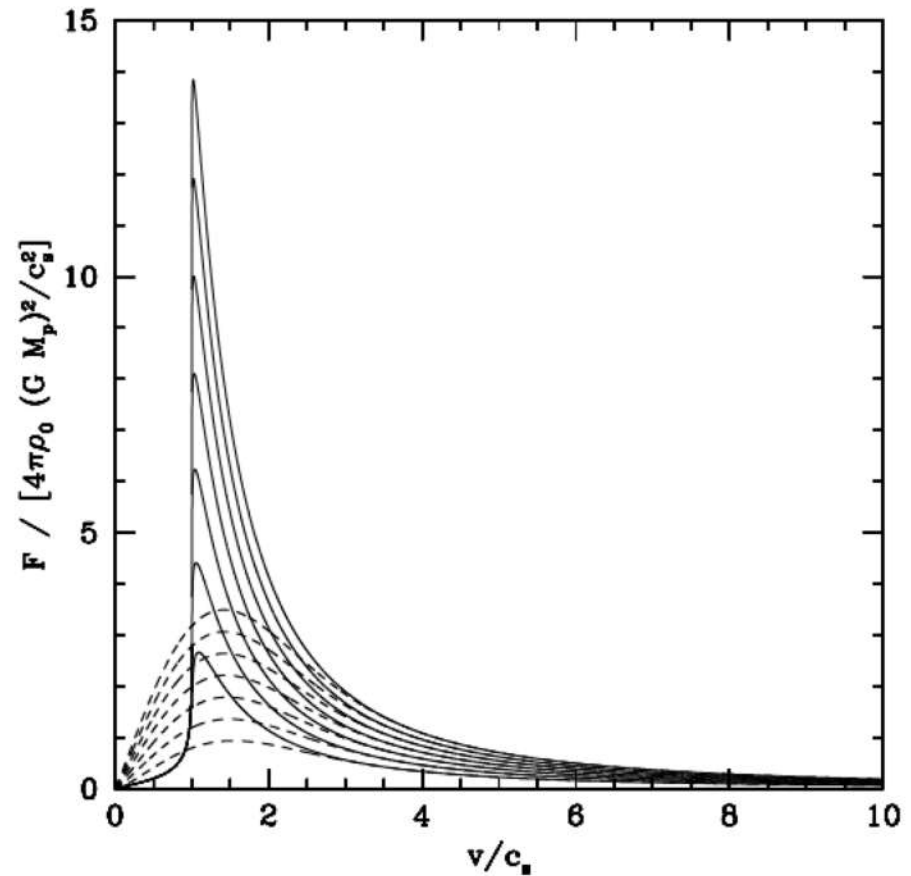


(Ohlmann et al. 2016)

Dynamical friction (Ostriker 1999)...

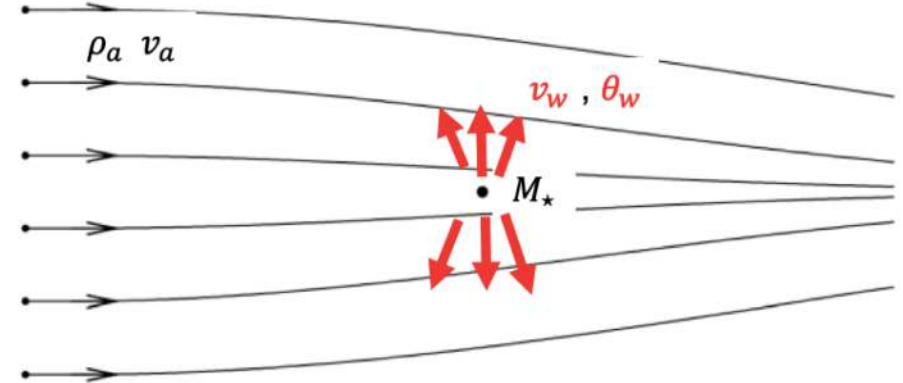
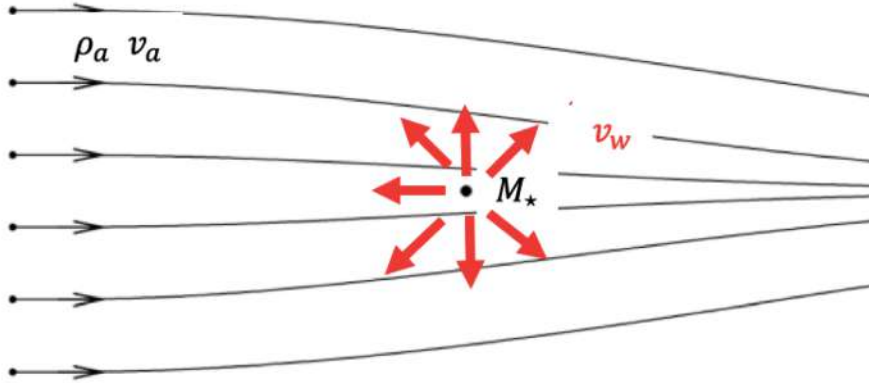


$$F_D^{Os} = \frac{4\pi G^2 M_\star^2 \rho_a}{v_a^2}$$



(Ostriker, 1999)

Dynamical friction (winds)...



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The role of wind asphericity in dynamical friction

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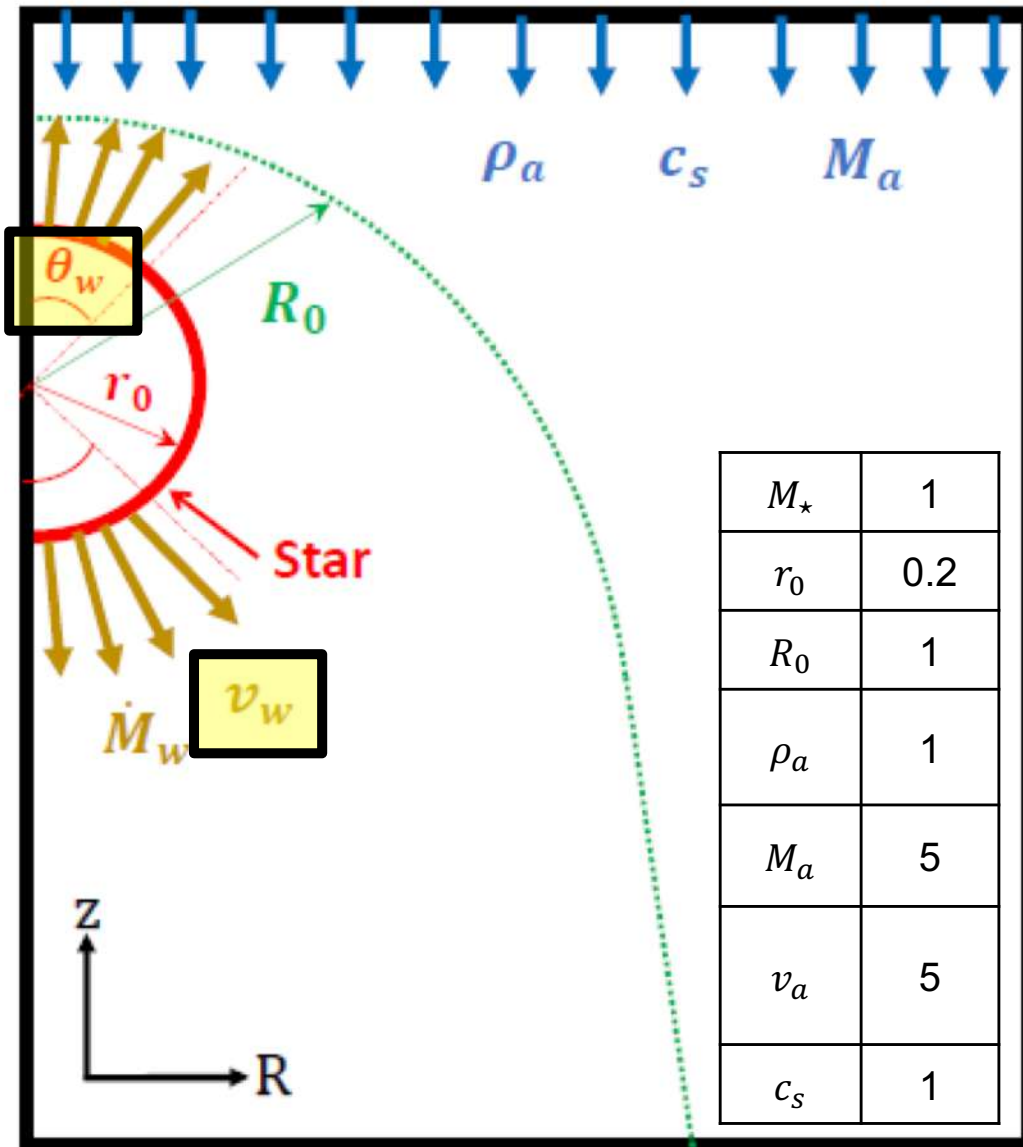
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Setup...

2DHD with Mezcal code (De Colle et al. 2012)

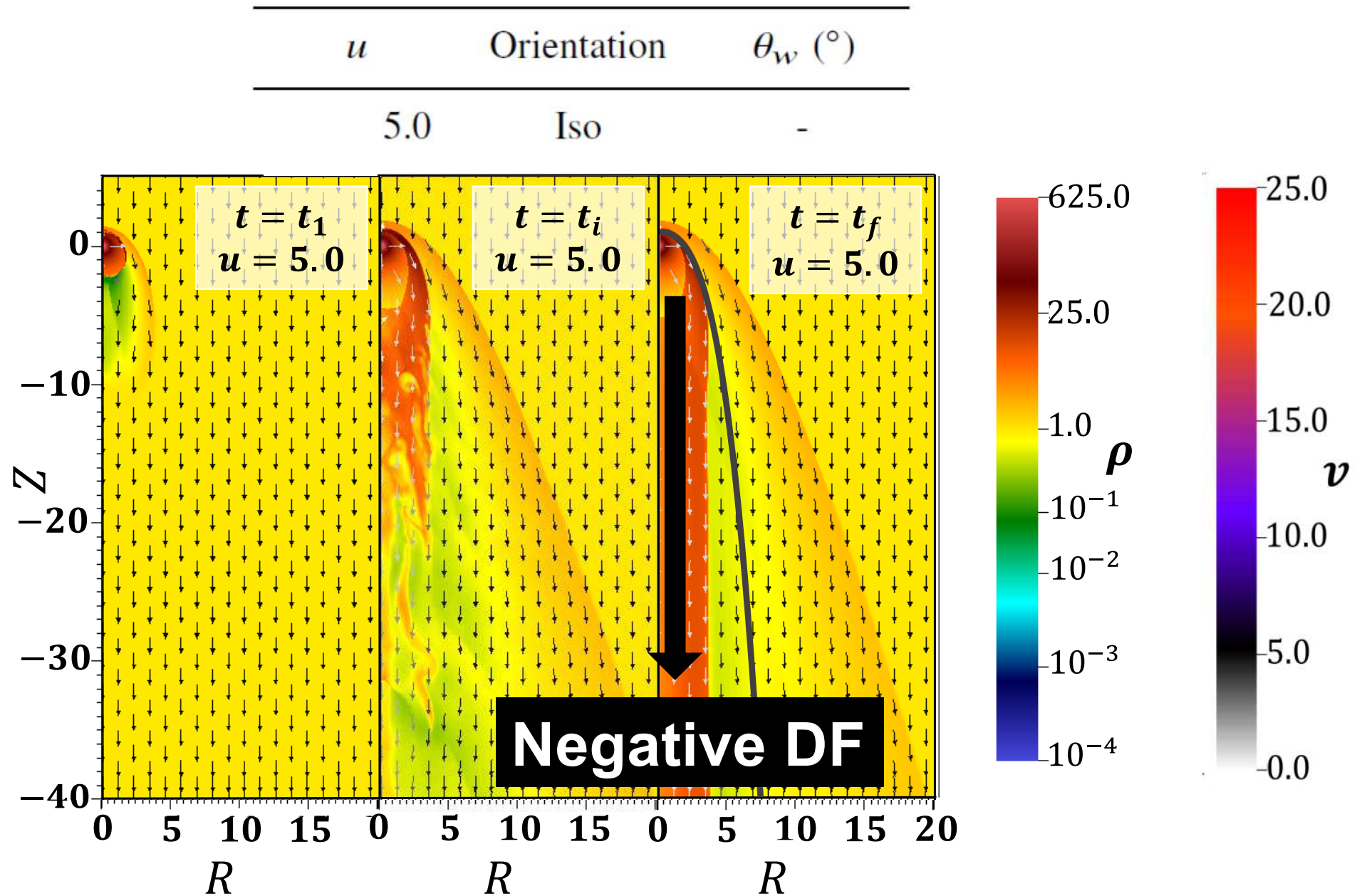
Wind-tunnel configuration: star fixed + incoming medium



$$u = \frac{v_a}{v_w}$$

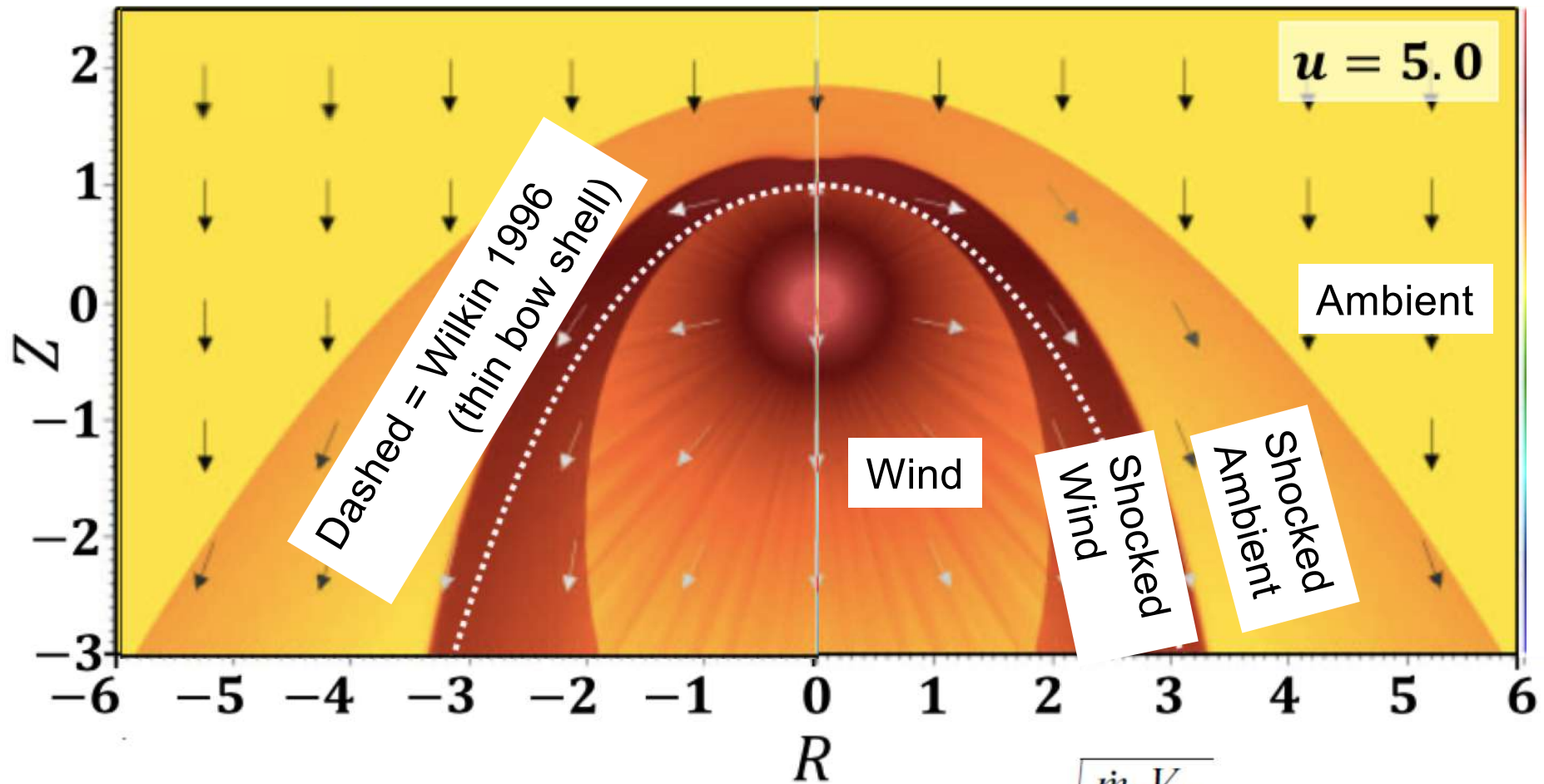
u	Orientation	θ_w (°)
0.07 - 5.0	Iso	-
0.2	P, E	30, 45, 60
0.6	P	45, 60
2.0	P	45, 60
2.6	P, E	45, 60
5.0	P, E	30, 45, 60

Negative DF ($v_w \ll v_a + \text{Isotropic wind}$)...



Ram pressure equilibrium...

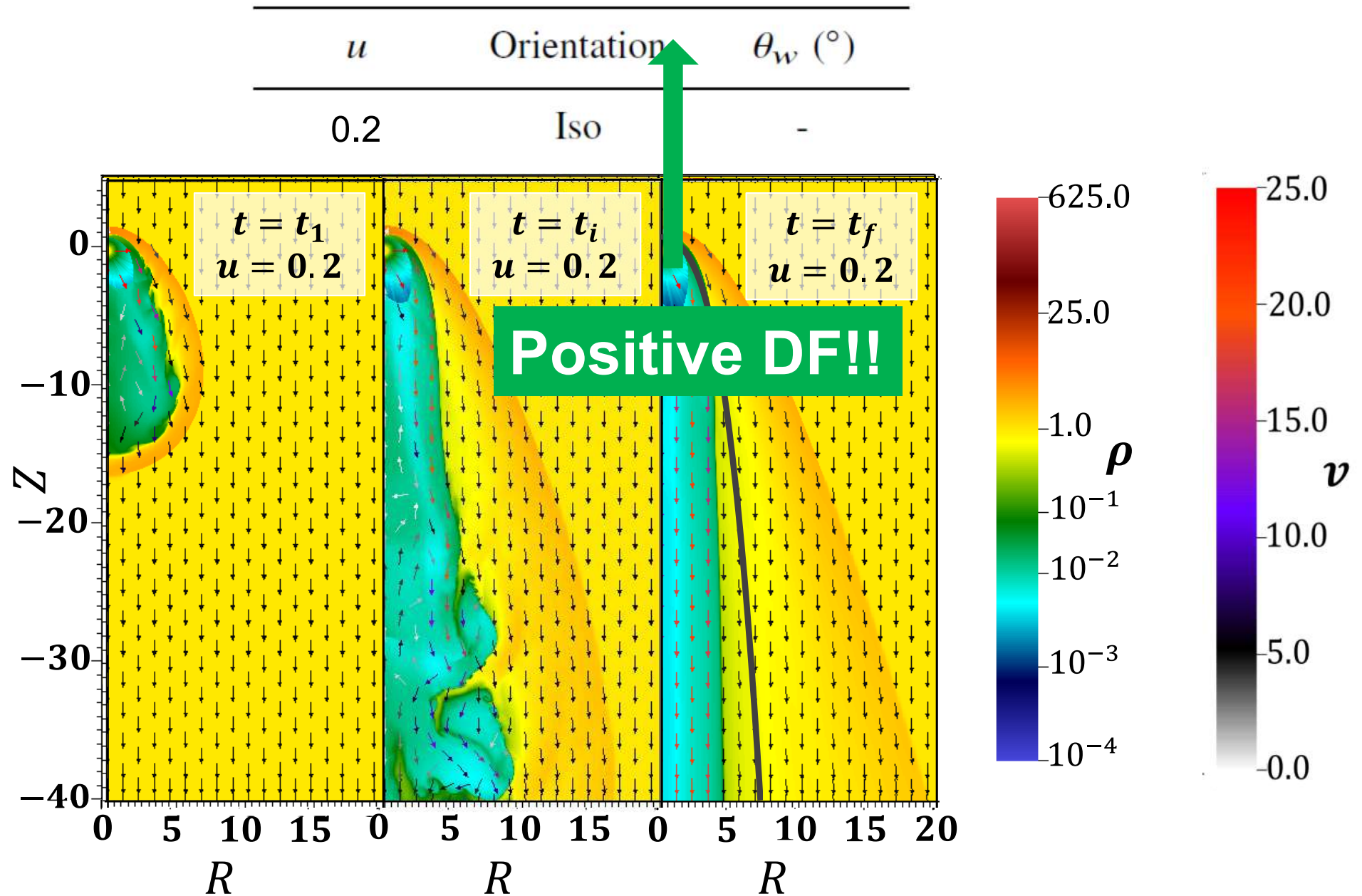
u	Orientation	θ_w (°)
5.0	Iso	-



$$R(\theta) = R_0 \csc \theta \sqrt{3(1 - \theta \cot \theta)}$$

$$R_0 = \sqrt{\frac{\dot{m}_w V_w}{4\pi \rho_a V_*^2}}$$

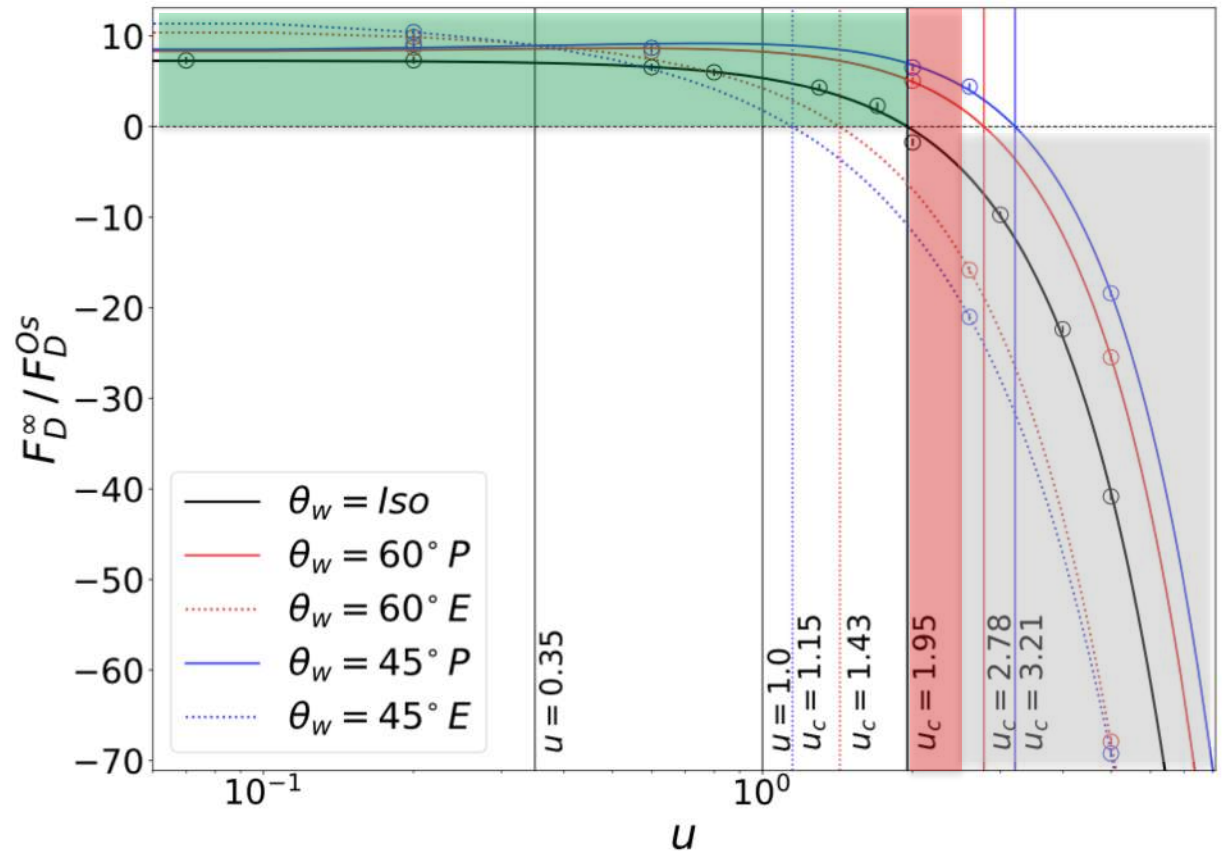
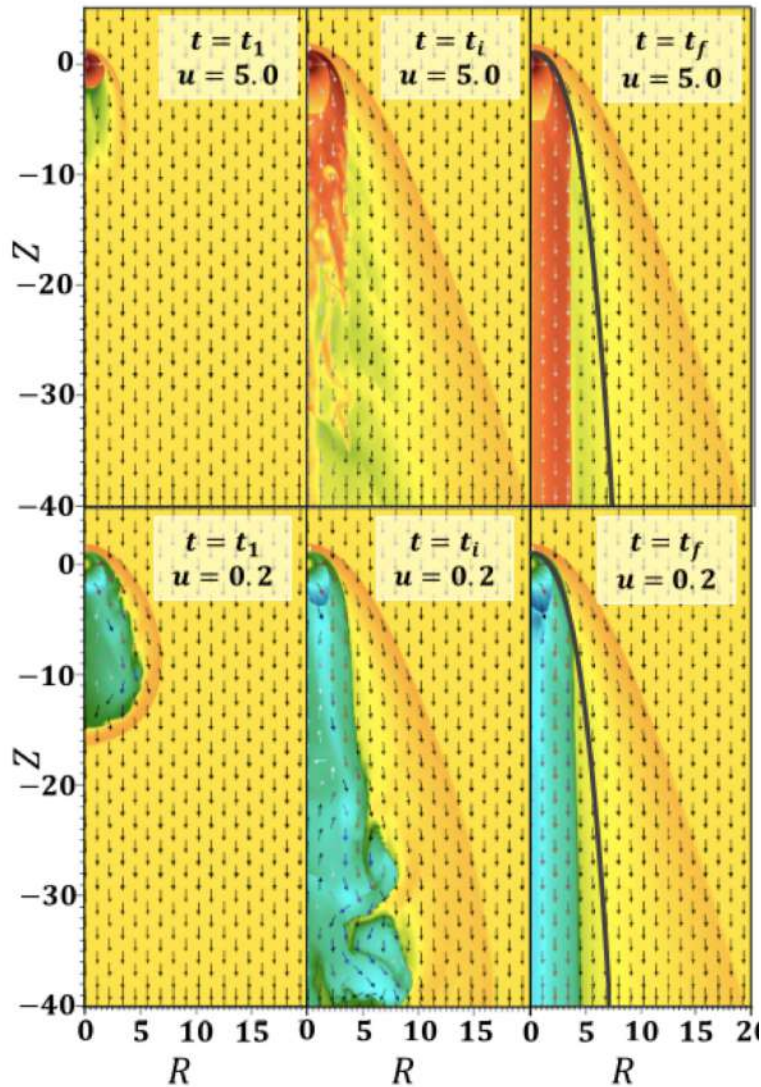
Surprise ($v_w \gg v_a$ + Isotropic wind)...



Negative/Positive DF (all models)...

Critical $u = 1.95$

Gruzinov (2020) $u_c = 1.71$ (thin shell)



$$F_D^{Os} = \frac{4\pi G^2 M_\star^2 \rho_a}{v_a^2}$$

$$u = \frac{v_a}{v_w}$$

Astronomy cases...

Important implications for CE evolution.

Object + wind	Medium	Critical time
CO	AGN disk	~ Myr
CO	CE	Days - years
Solar type star	Interstellar medium	> Gyr
Solar type star	AGN disk	~ Myr
Wolf-Rayet	Interstellar medium	~ Gyr
Wolf-Rayet	AGN disk	~ Myr

$$t_c = 1.07 \times 10^6 \left(\frac{n_a}{\text{cm}^{-3}} \right)^{-\frac{1}{2}} \left(\frac{\dot{M}_w}{10^{-14} \text{M}_\odot \text{yr}^{-1}} \right)^{-\frac{1}{2}} \\ \times \left(\frac{v_w}{100 \text{ km s}^{-1}} \right)^{\frac{1}{2}} \left(\frac{v_a}{100 \text{ km s}^{-1}} \right) \text{ Gyr} ,$$

Conclusions...

Dynamical friction is important in many astrophysical phenomena.

Winds may produce a positive dynamical friction.

Effects may be important in common envelopes.



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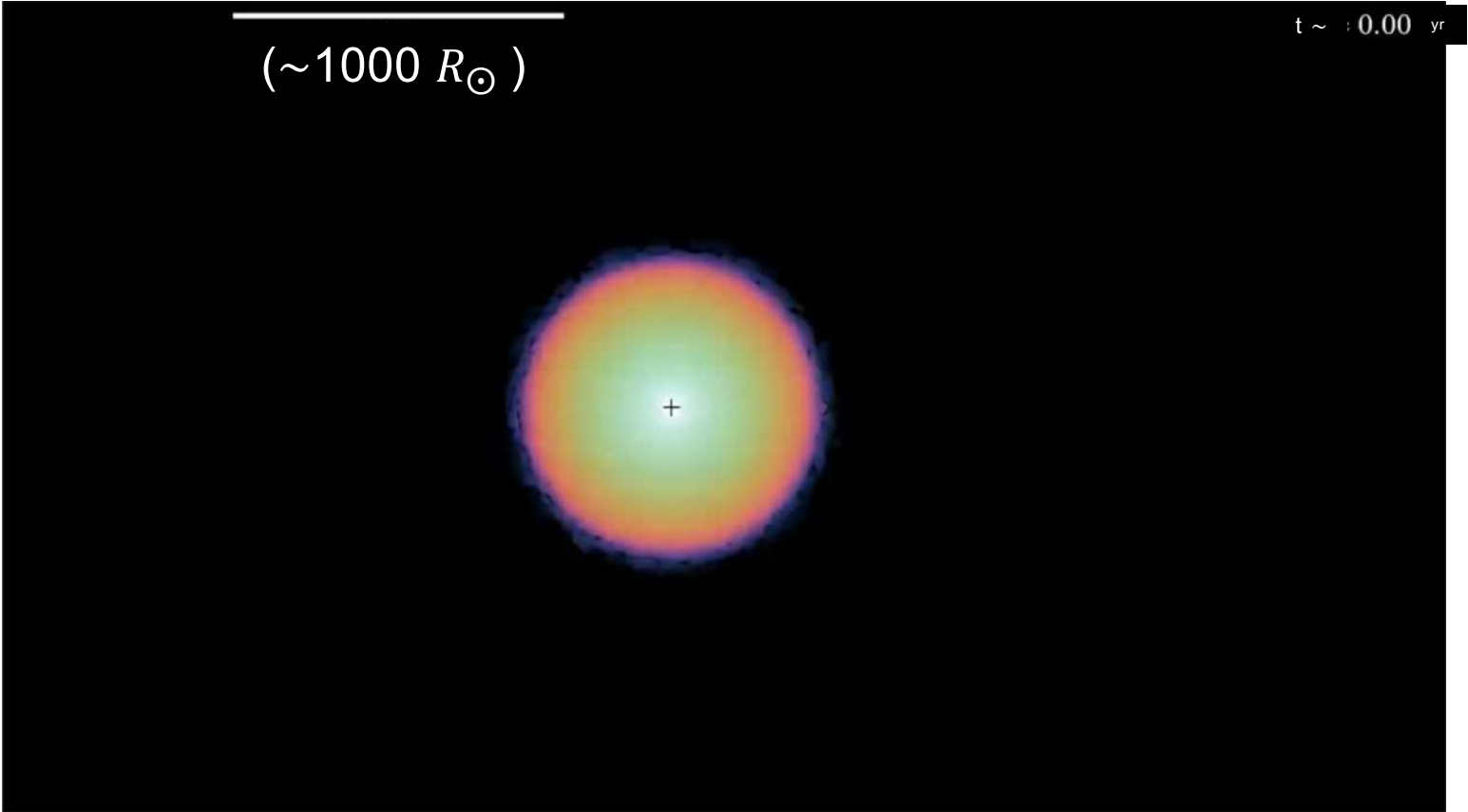
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New study ()....

Object $\pm$ wind	Medium	Critical time
CO ($5 M_{\odot}$)	CE (RG $23 M_{\odot}$)	Years



New study (CO + CE = Negative DF)...



Object (no wind)	Medium	Critical time
CO ($5 M_{\odot}$)	CE (RG 23 $M_{\odot}$)	-

$$\left. \begin{aligned}
 J &= M(\leq a) M_{\text{acc}} \sqrt{\frac{Ga}{M}} \\
 \dot{J} &= 0 \\
 \dot{M}_{\text{tot}} &= 0 \\
 M_{\text{don}} &> M_{\text{acc}} \\
 \dot{M}_{\text{don}} &< 0
 \end{aligned} \right\} \frac{\dot{a}}{a} = - \frac{2 \dot{M}_{\text{don}}}{M_{\text{don}}} \left(1 - \frac{M_{\text{don}}}{M_{\text{acc}}} \right) < 1$$

Negative DF
 (Ostriker)

New study (CO + CE + wind = Positive DF)...

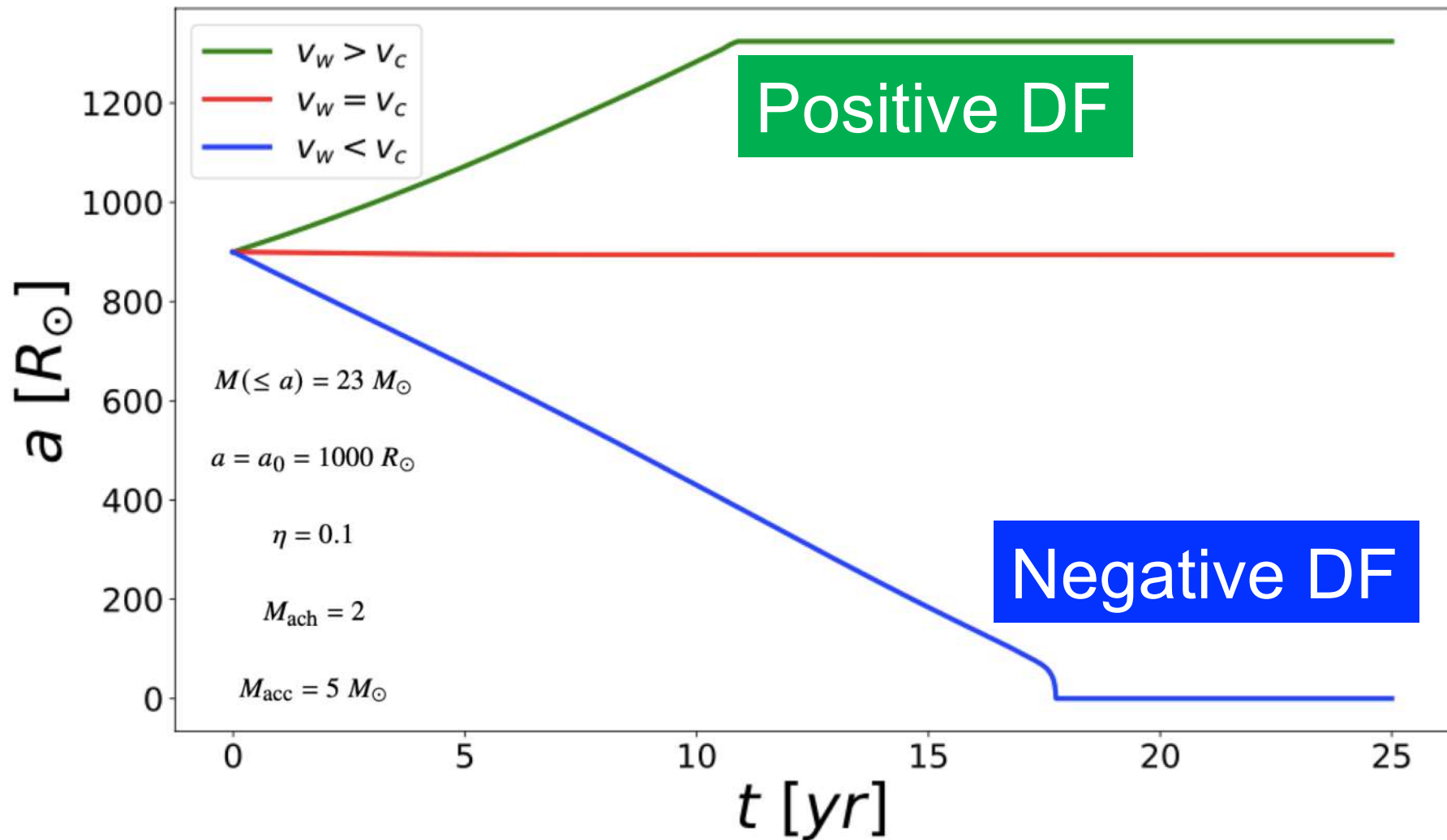


Object + wind	Medium	Critical time
CO ($5 M_{\odot}$)	CE (RG 23 $M_{\odot}$)	Years

$$\left. \begin{aligned}
 J &= M(\leq a) M_{\text{acc}} \sqrt{\frac{Ga}{M}} \\
 \dot{J} &\neq 0 \\
 \dot{M}(r < a) &\neq 0 \\
 \dot{M}_{\text{acc}} &\sim \dot{M}_{\text{BHL}} \\
 \dot{M}_{\text{wind}} &\sim \dot{M}_{\text{acc}}
 \end{aligned} \right\} \begin{aligned}
 \frac{\dot{a}}{a} &= \left[1 + \left(\frac{2}{M(\leq a)} - \frac{1}{M} \right) \frac{\partial M(\leq a)}{\partial a} a \right]^{-1} \times \\
 &\left[2 \frac{\dot{J}}{J} + \left[\frac{2\lambda(1-\eta)}{M(\leq a)} + \frac{2(\eta-\beta)}{M_{\text{acc}}} + \frac{(\beta+\lambda\eta-\lambda-\eta)}{M} \right] \dot{M}_{\text{BHL}} \right]
 \end{aligned}$$

Positive DF

New study results I...



New study results II...

