# *Mass loss as critical ingredient to massive BH seed formation*

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collaborators:
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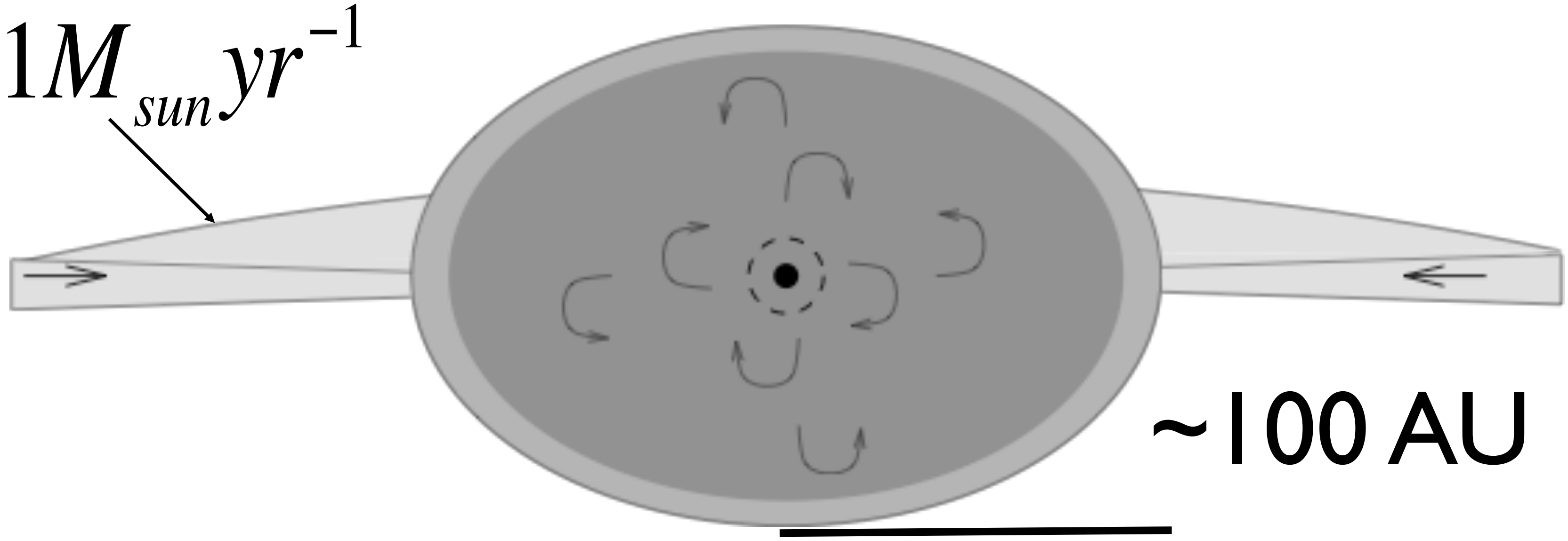
# *After core-collapse*

*following halo formation (Begelman) or major merger (Mayer)*

3 main questions:

$$\frac{dM_*}{dt} \approx 1 M_{sun} yr^{-1}$$



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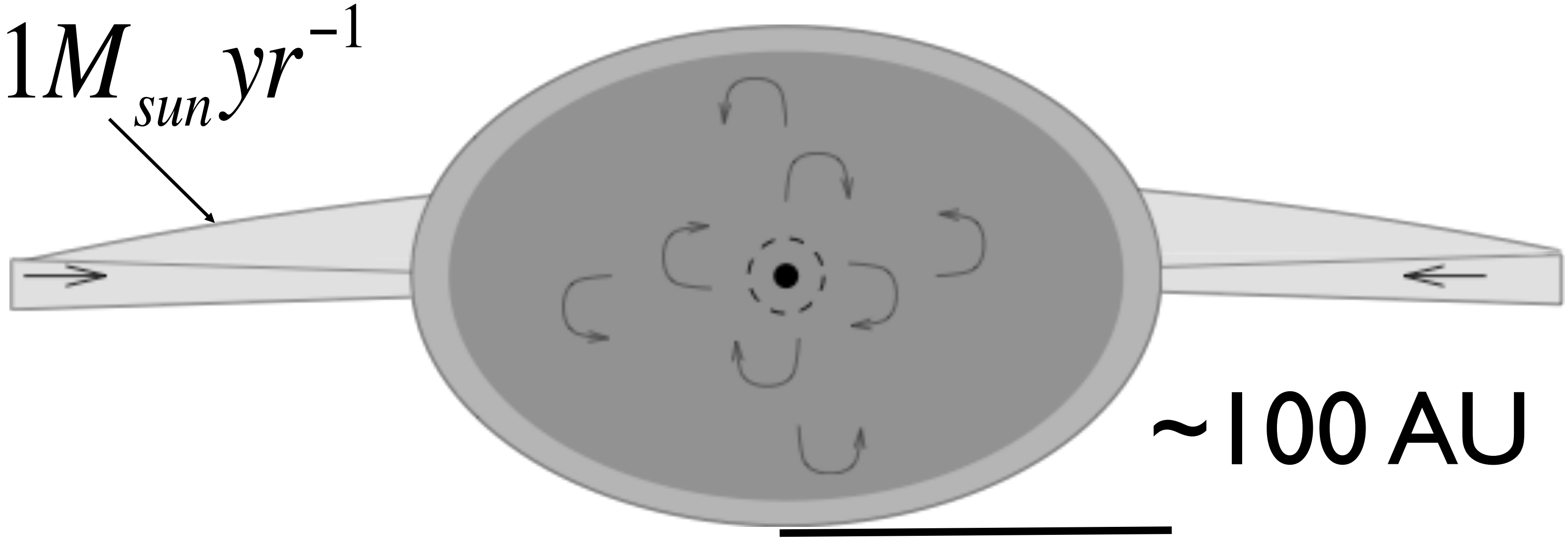

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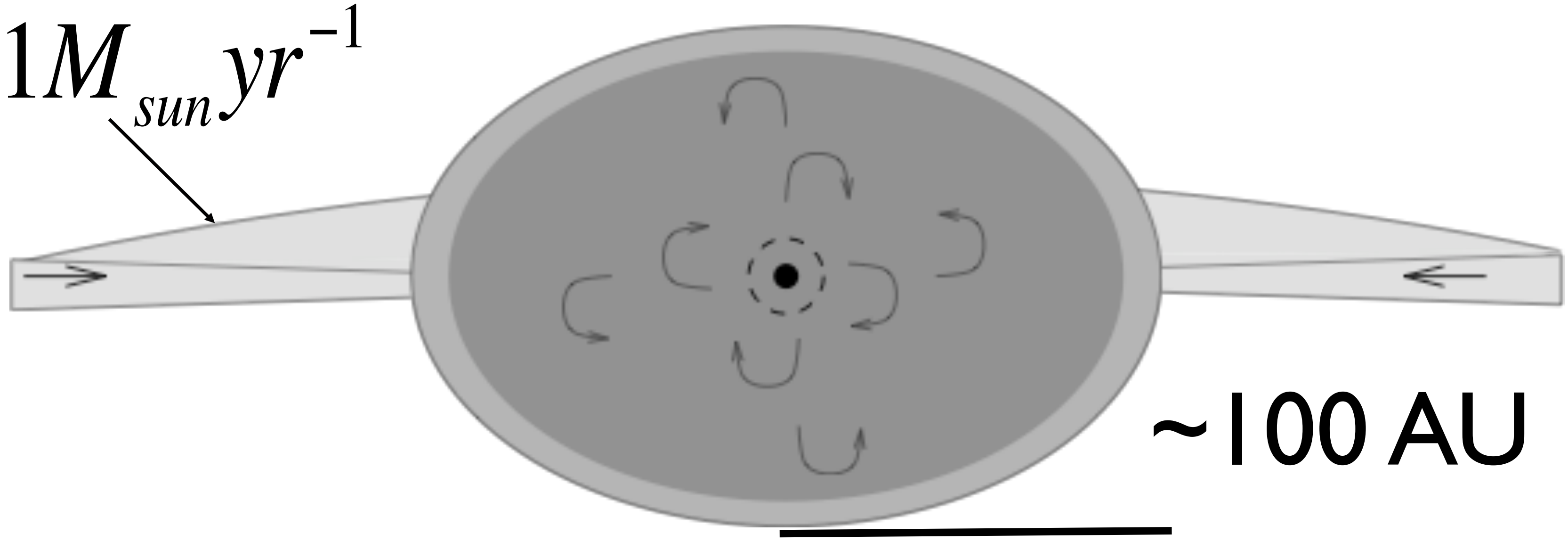

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3. What happens at the surface of super-Eddington flow

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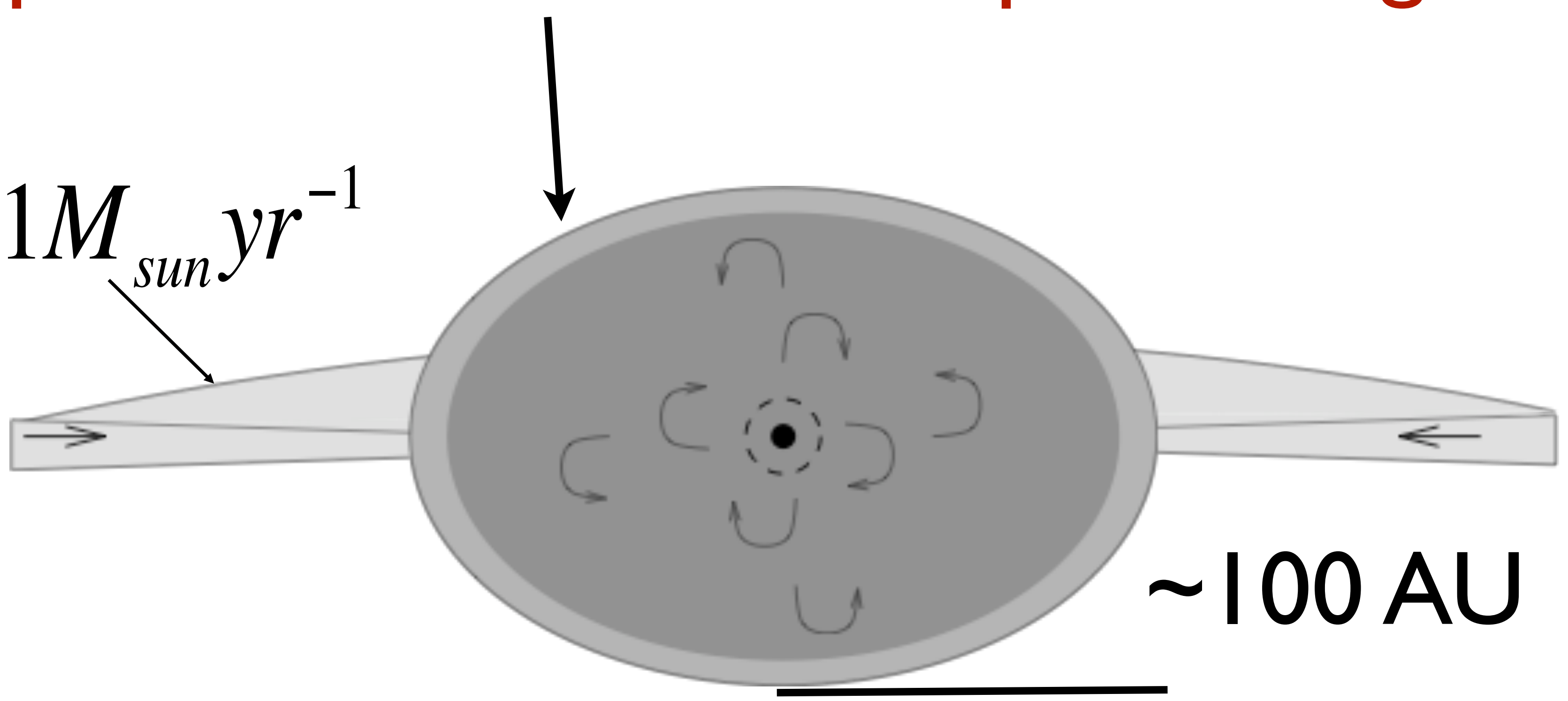

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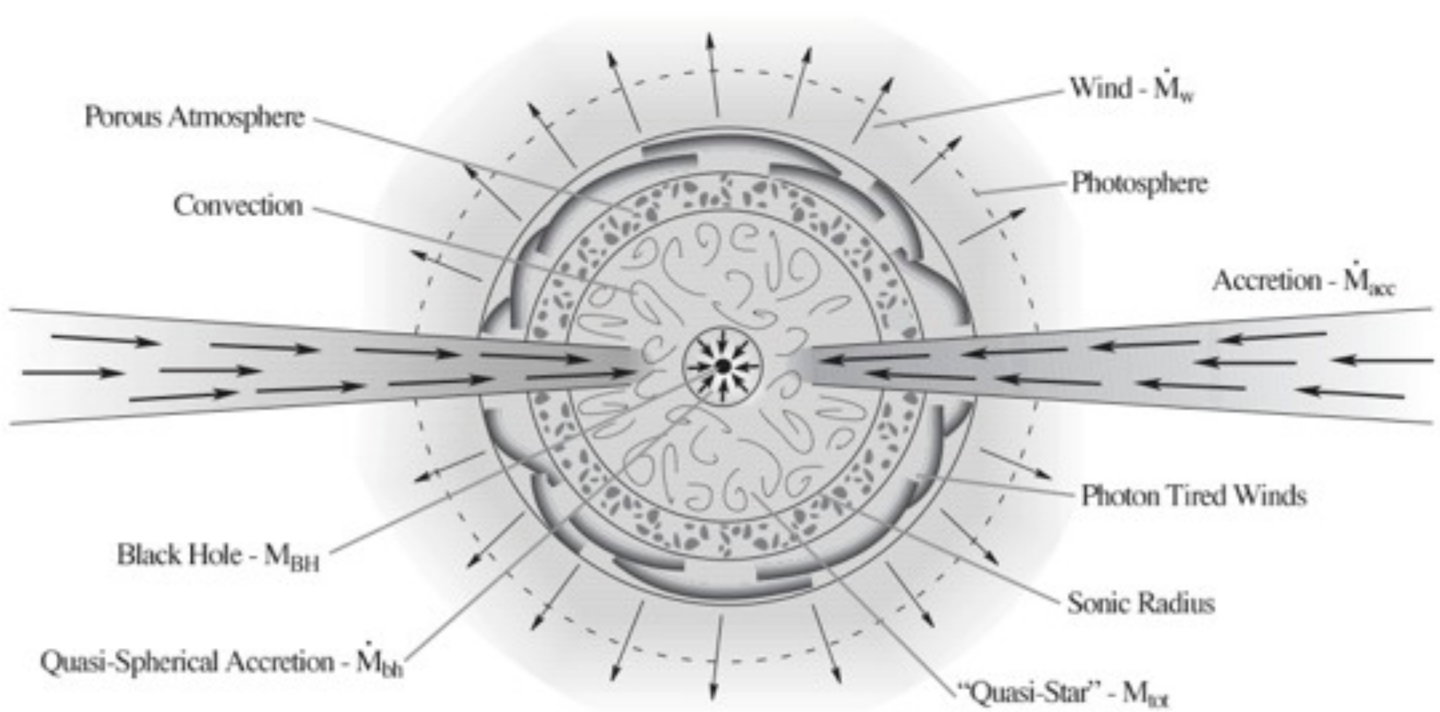

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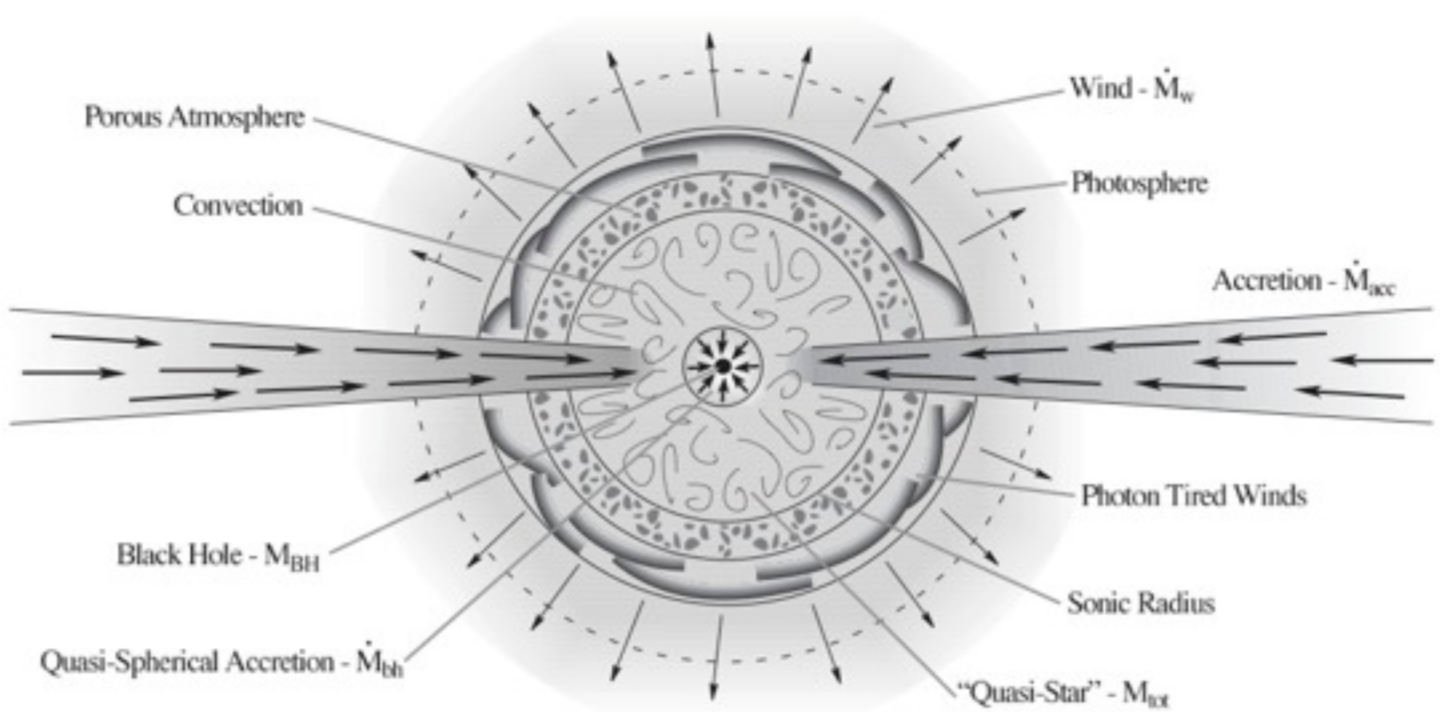

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- Mass loss are present and are important
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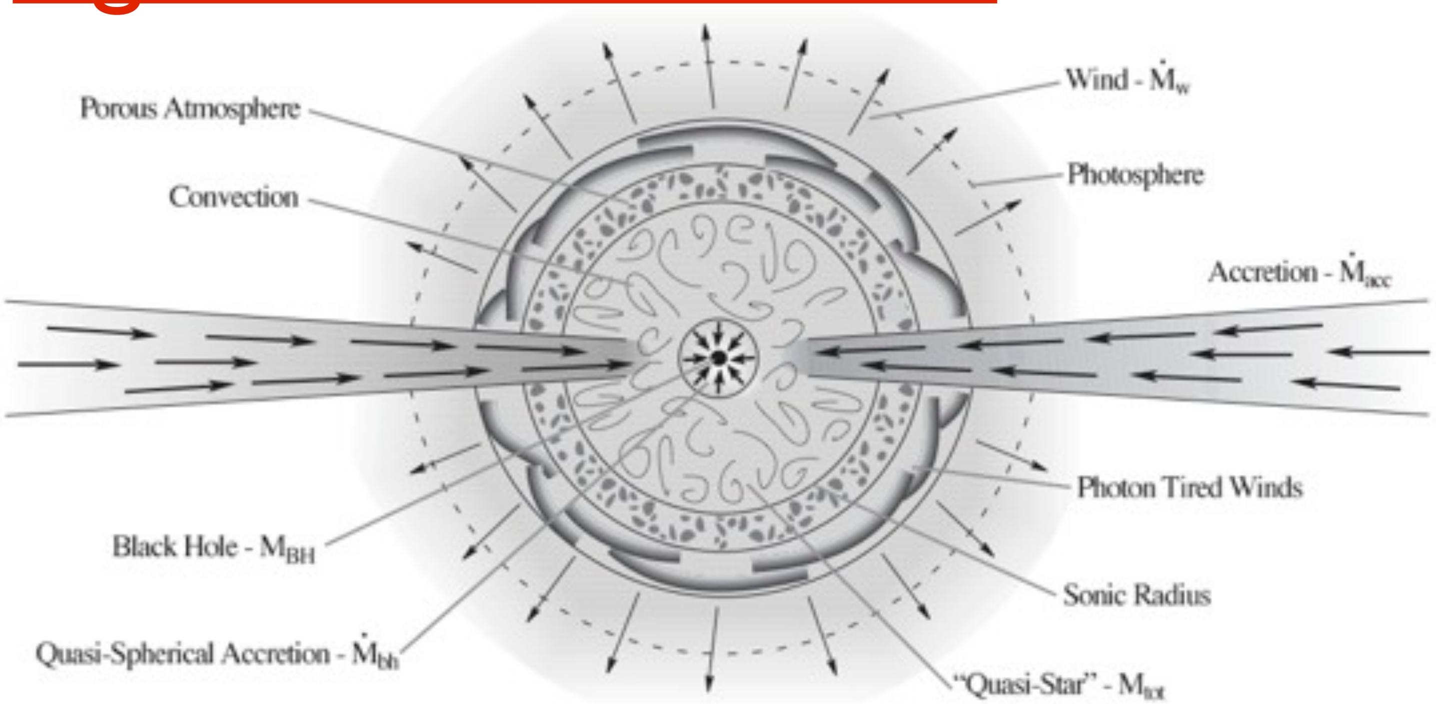
    - Mass loss *greatly* affect BH seed mass: lowers the BH mass, requires higher minimum mass for host halo



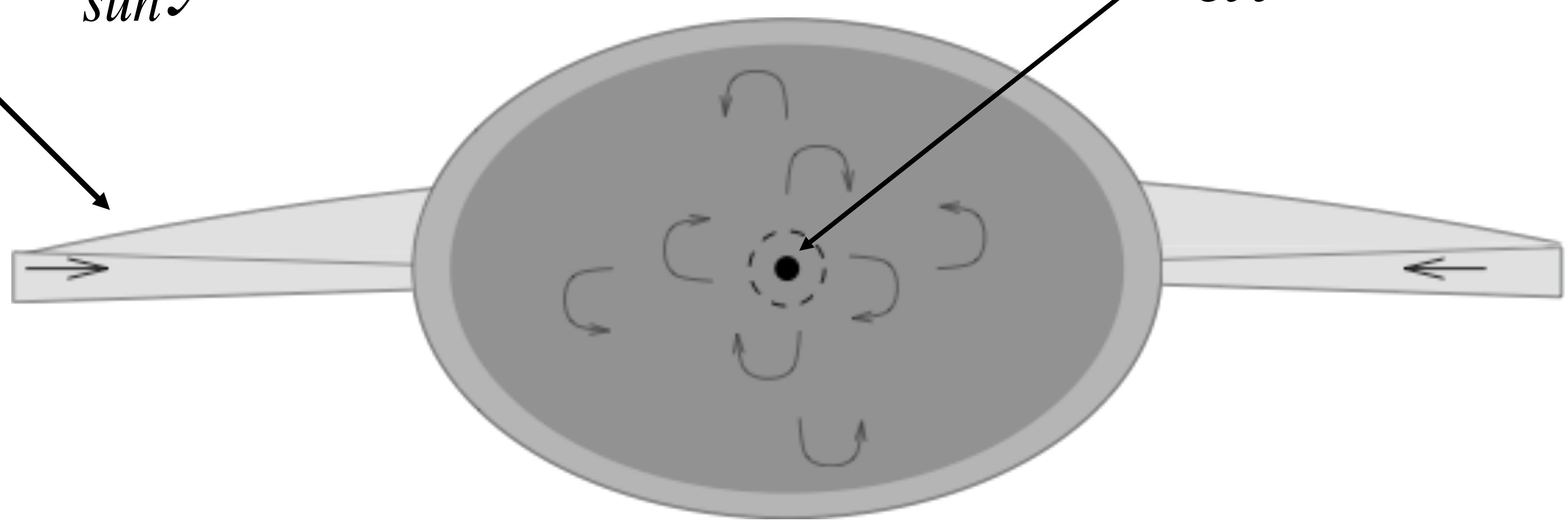
# *Structure & accretion rate*

Hydrostatic equilibrium solutions have

- BH accretes at Eddington for the whole mass: i.e. super-Edd.
- Most of mass in convective envelope (Joss, Salpeter, Ostriker 1973)
- Radiative layer with 0.1 Radius and 0.01 Mass

$$\frac{dM_*}{dt} \approx 1 M_{sun} yr^{-1}$$

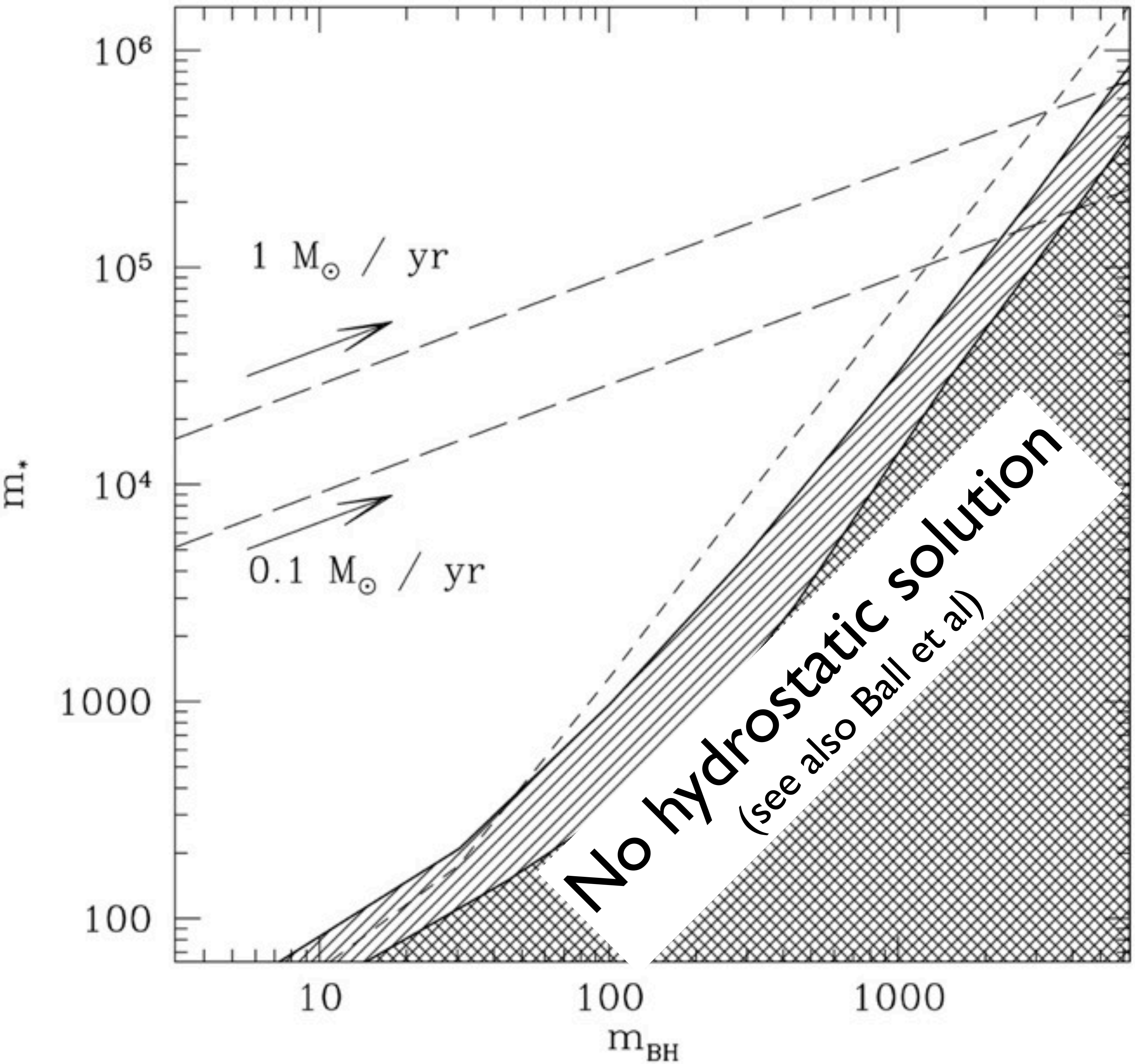
$$\frac{dM_{BH}}{dt} = \frac{L_{edd}(M_*)}{\varepsilon c^2}$$



Begelman, ERM, Armitage 08, Ball et al. 12

# *No solution line & BH seed mass*

Begelman, EMR, Armitage 08



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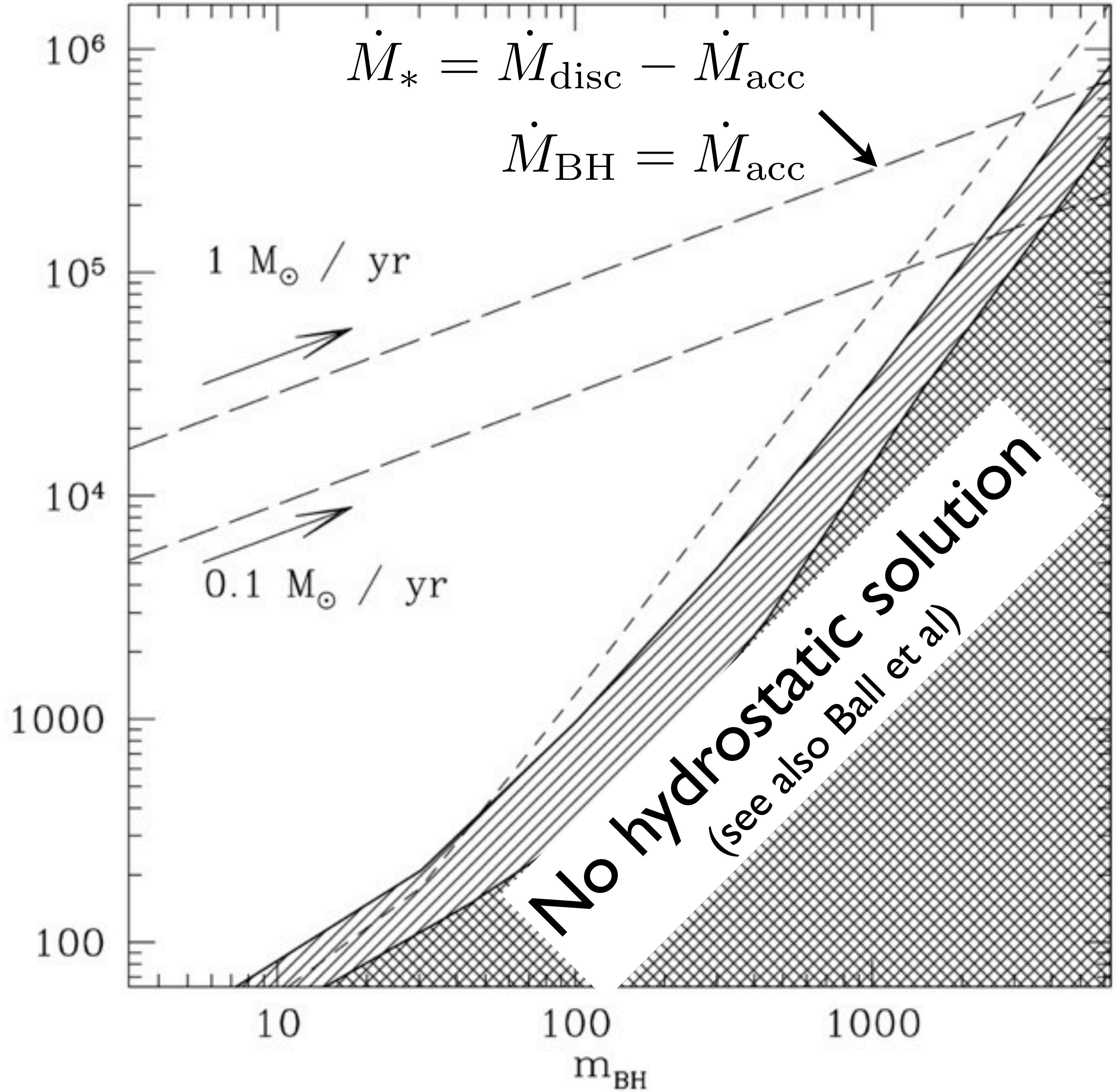


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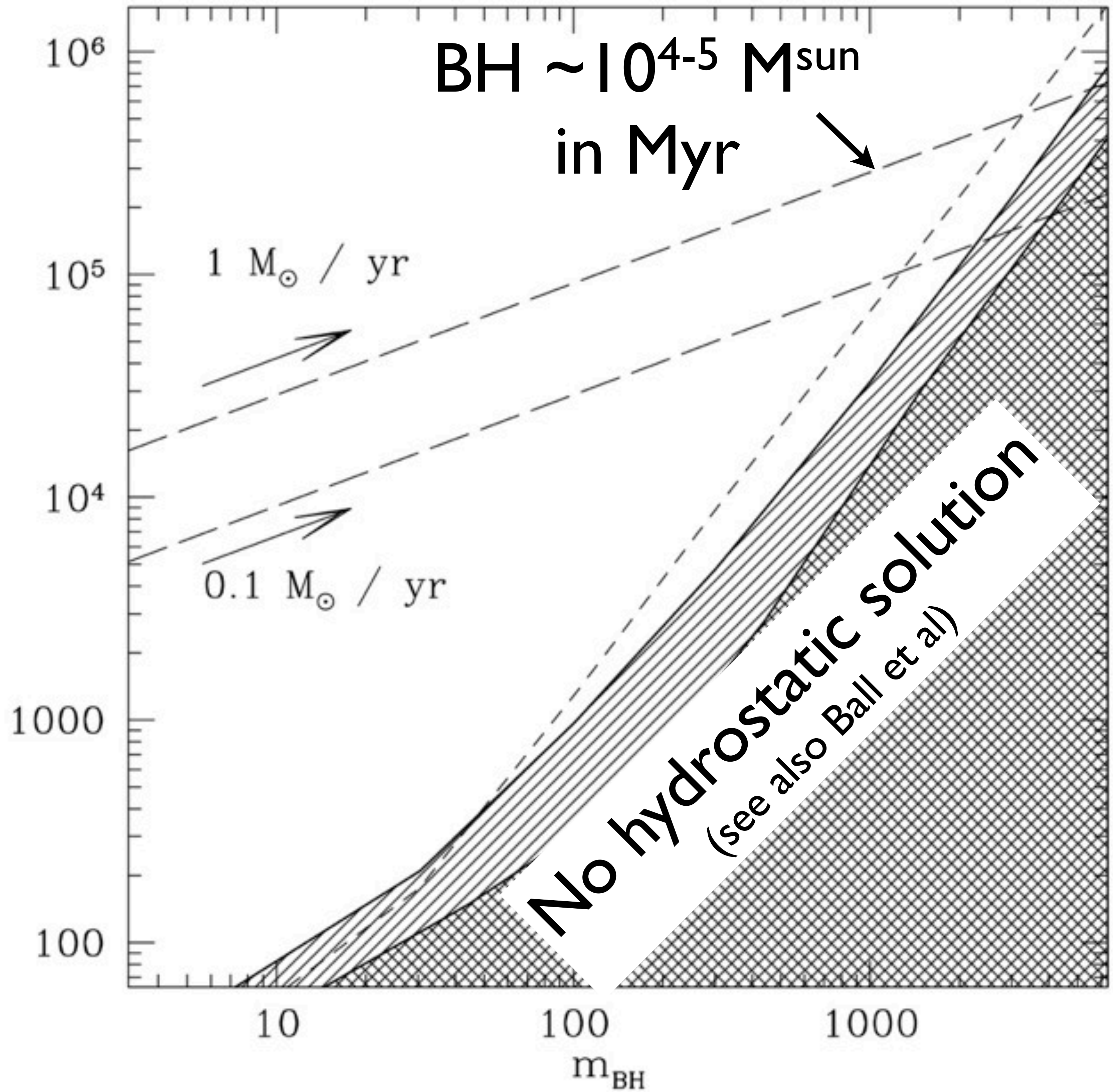

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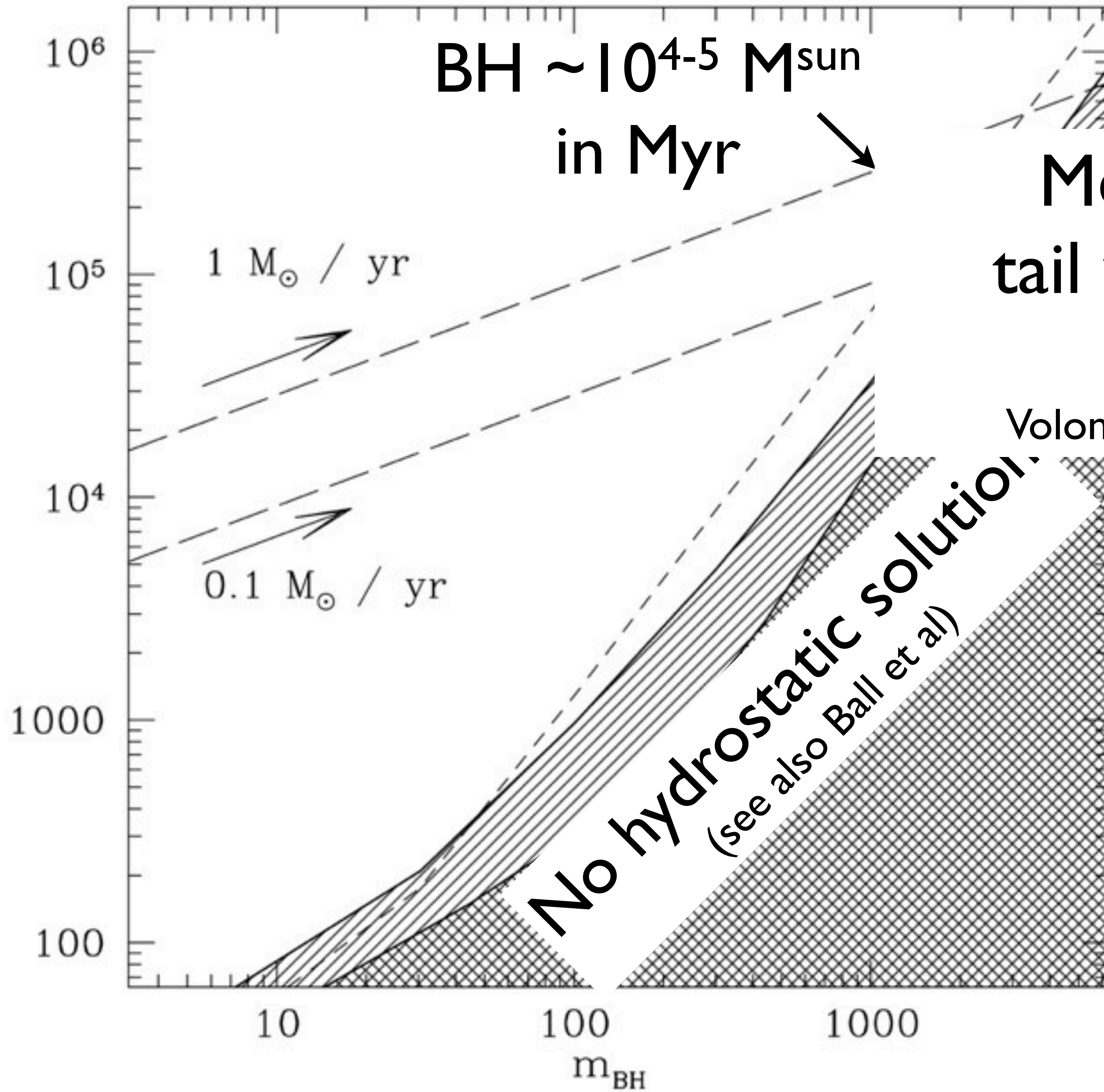


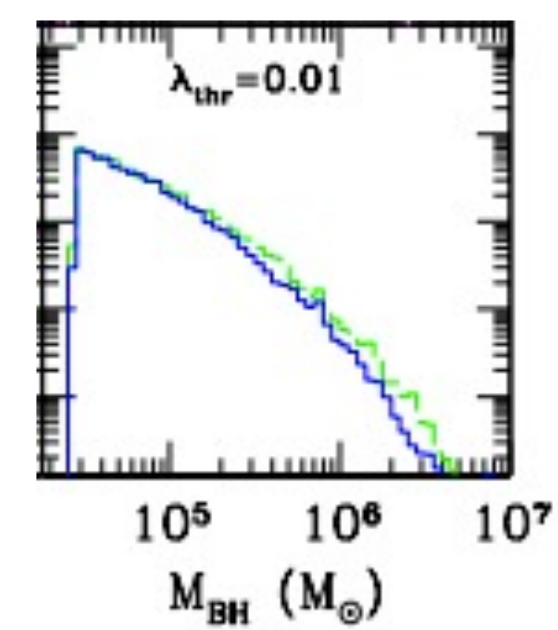

BH ~$10^{4-5}$ $M^{sun}$ in Myr ↘

No hydrostatic solution

(see also Ball et al)

Merger tree: tail with masses $10^{5-6}$ $M_{sun}$

Volonteri & Begelman 10



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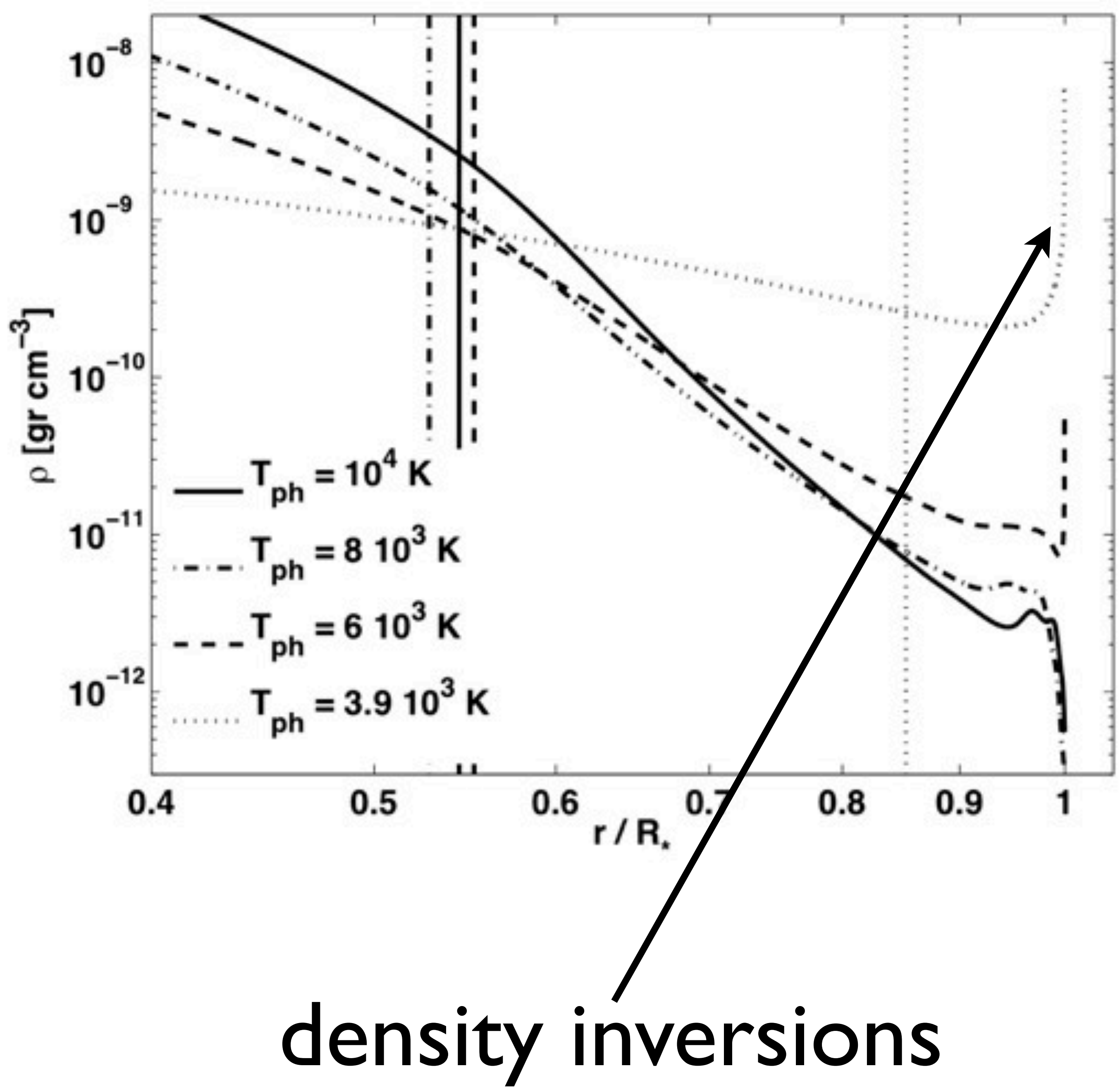

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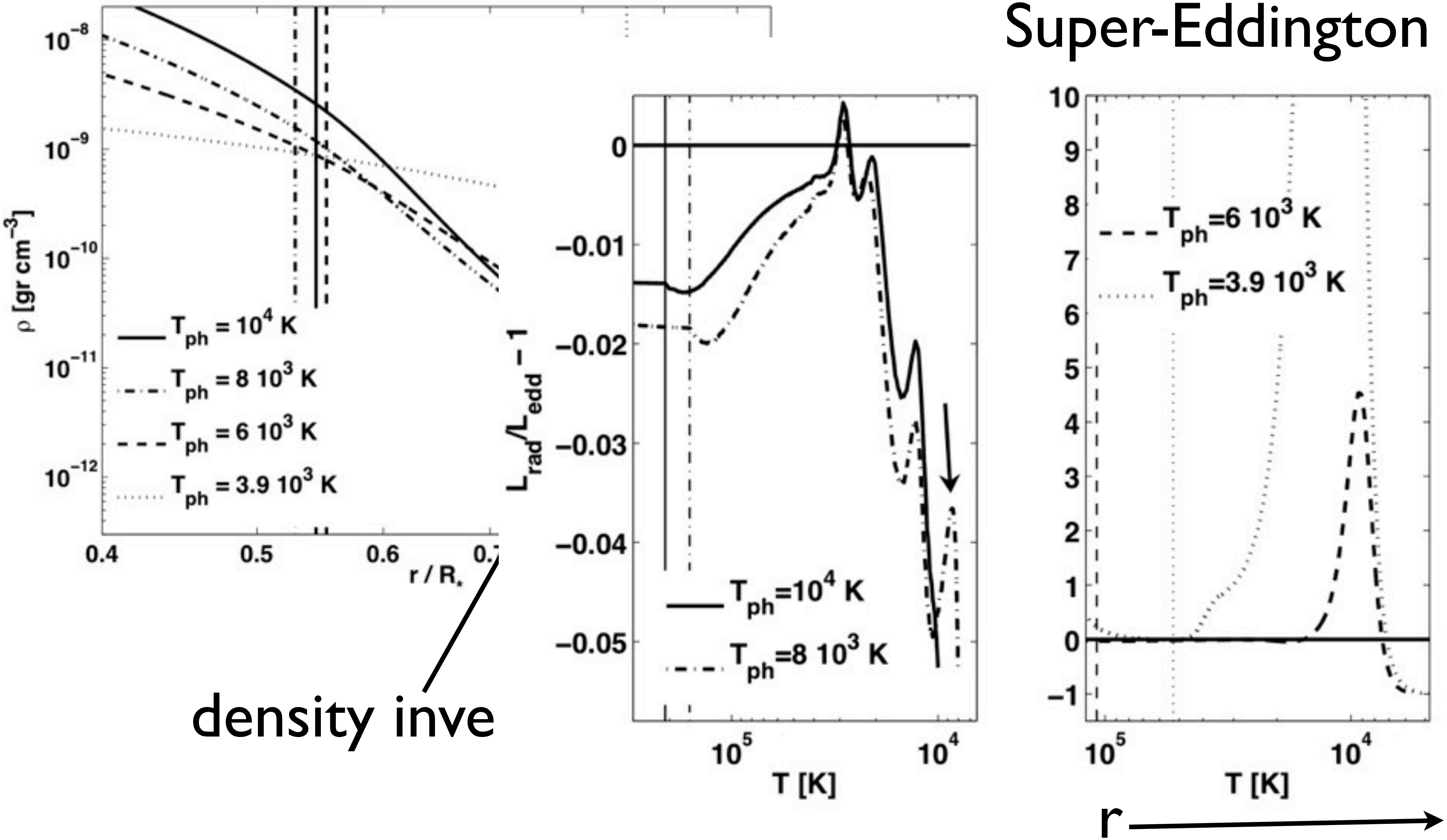
Super-Eddington



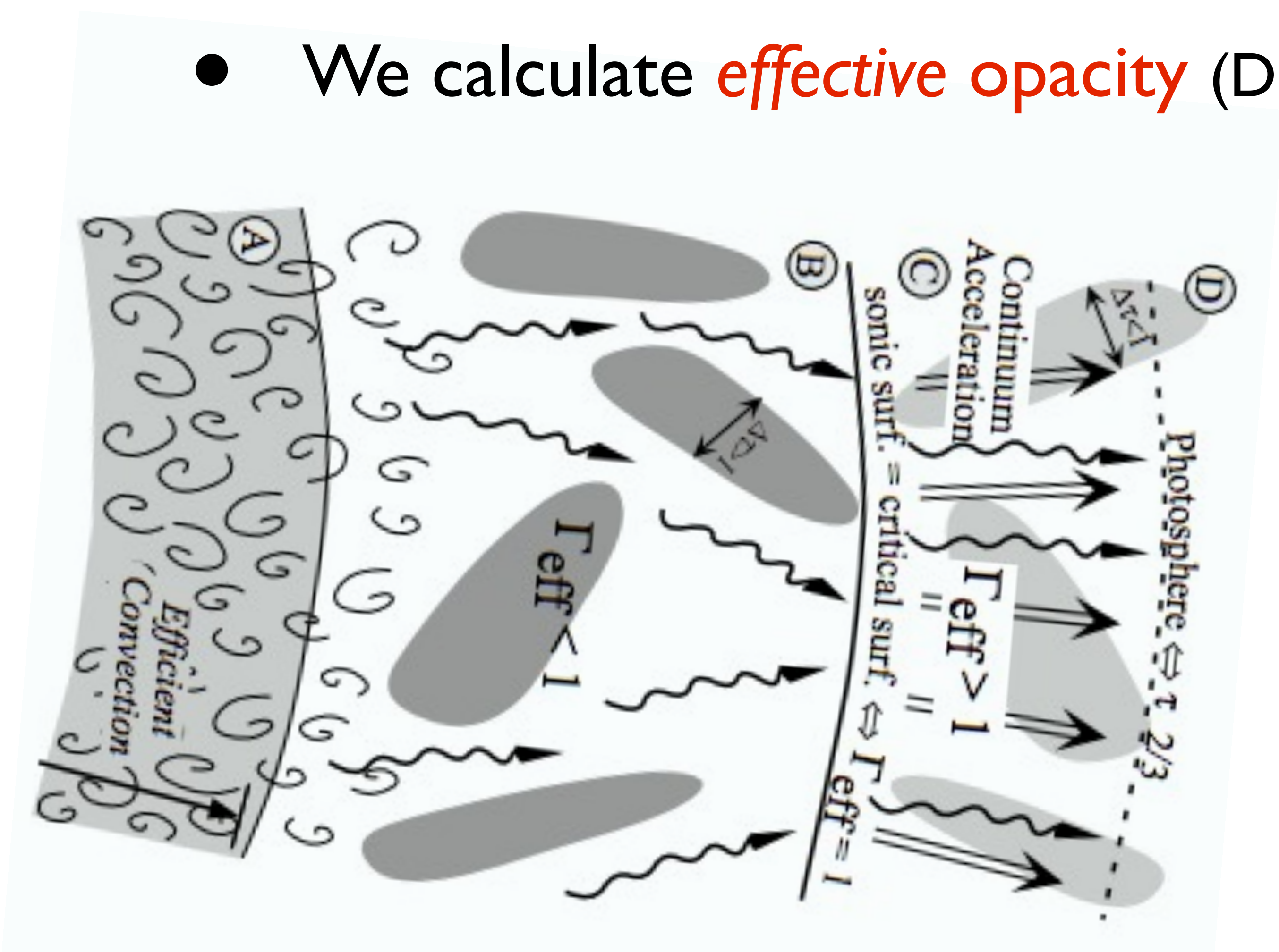
# *Super-Eddington atmosphere*

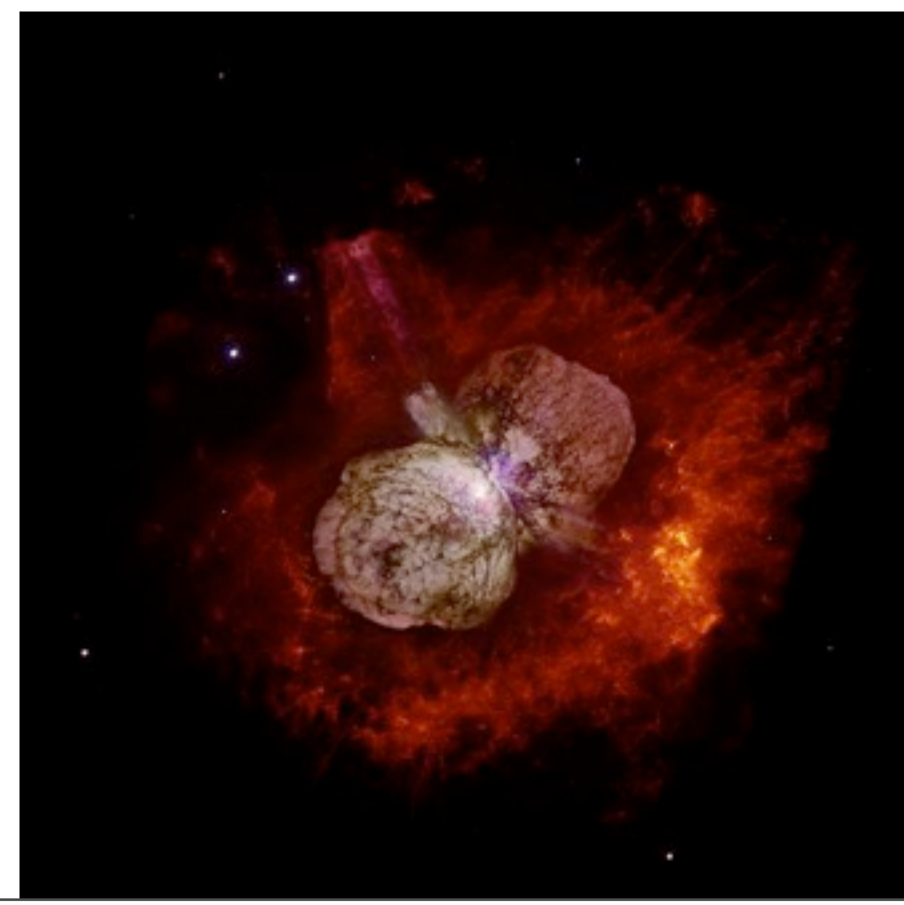
- Observationally, there are persistent super-Eddington atmosphere (classical novae, Luminous blue variables)

- Theoretically, atmosphere becomes unstable and porous as the approach Eddington (e.g., Arons 1992; Gammie 1998; Blaes & Socrates 2001; Begelman 2002, Glatzel 1994; Papaloizou et al. 1997, Shaviv 2001).

- Porosity allow super-Eddinton luminosity reduces the opacity

- We calculate *effective opacity* (Dotan & Shaviv 11)



η Carinae with Hubble

# Mass loss rate in wind

$$\dot{M}_{\rm w} = 4\pi r_{\rm s}^2 \rho_{\rm s} c_{\rm s} = {\rm const.}$$

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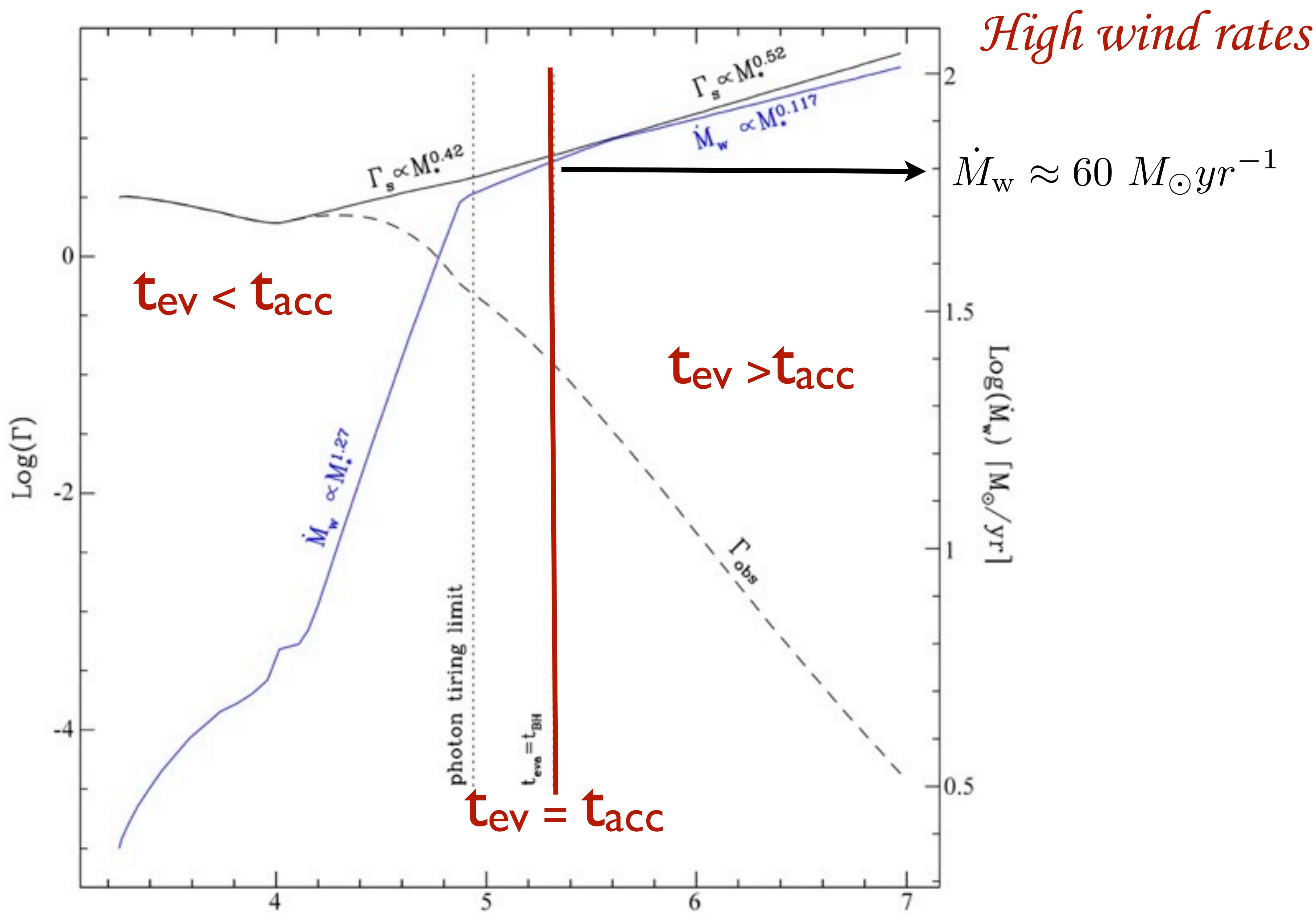
2) The photosphere and left over luminosity

# *Mass loss vs Mass of envelope*




Dotan, ERM, Shaviv 11

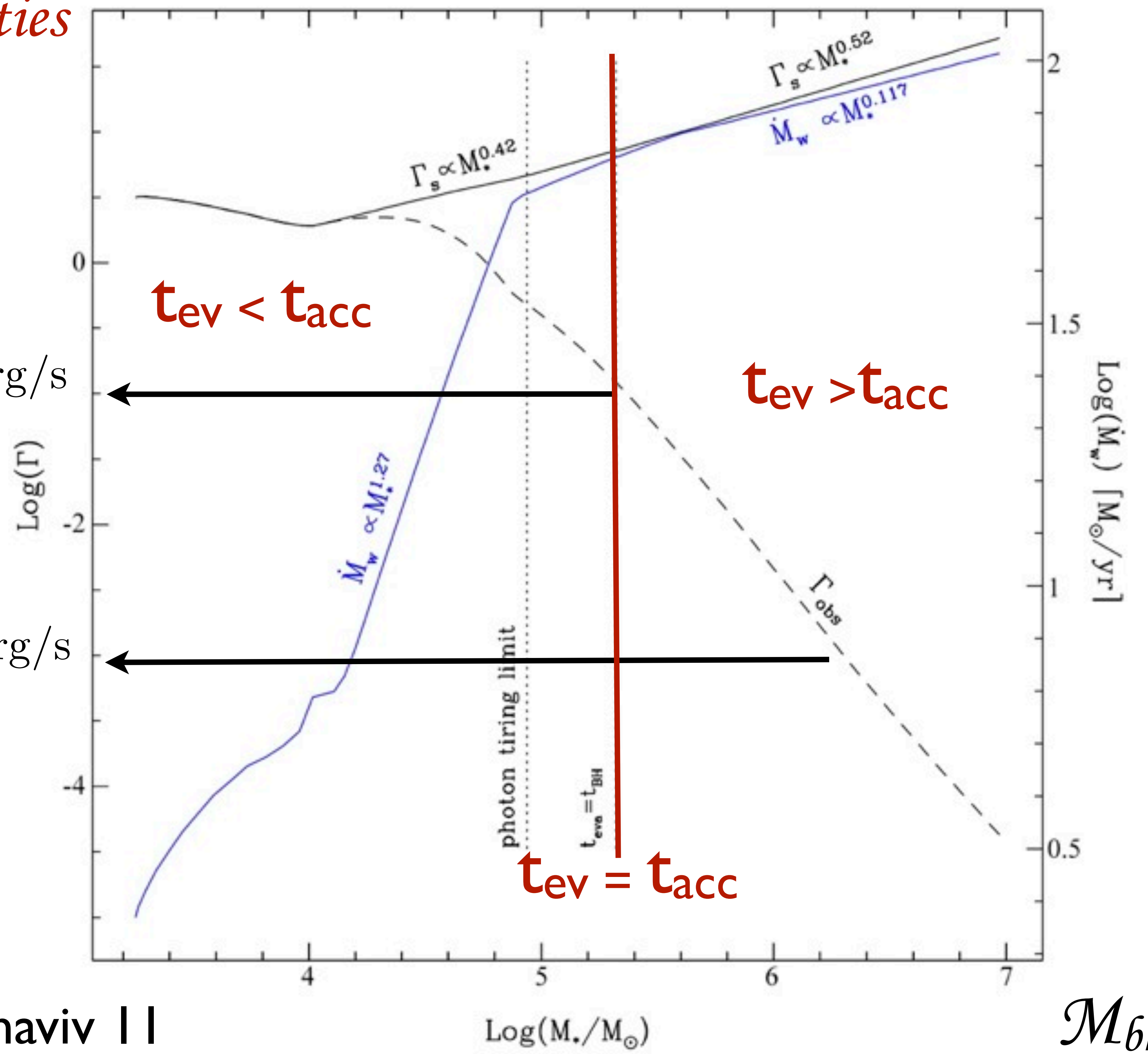
$\mathcal{M}_{bh}$=100 $\mathcal{M}_{sun}$

# *Luminosity vs Mass of envelope*

*Low Luminosities*

$L_{\rm obs} \approx 6 \times 10^{42}$ erg/s

$L_{\rm obs} \approx 6 \times 10^{41}$ erg/s

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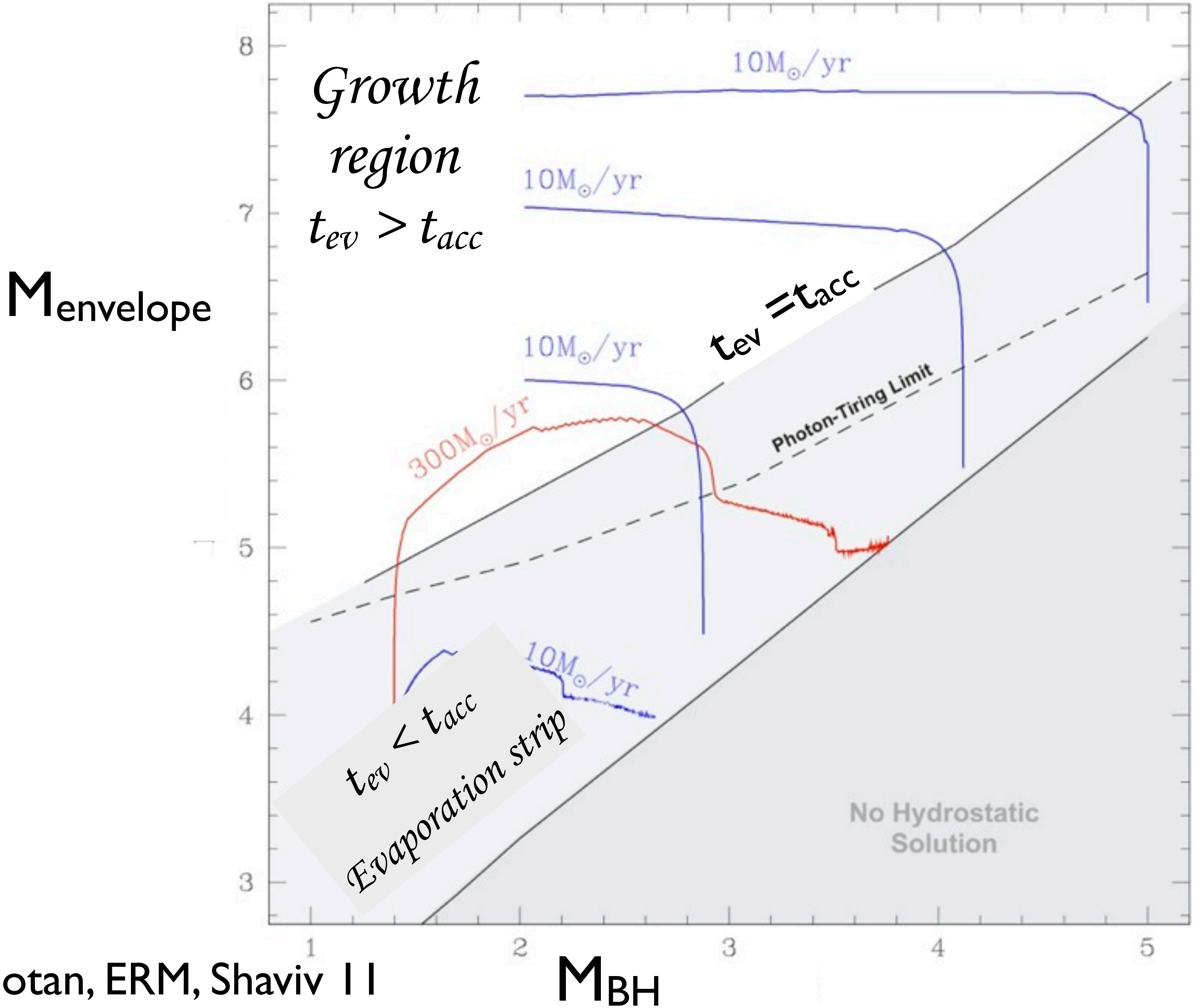
# *BH seed mass*

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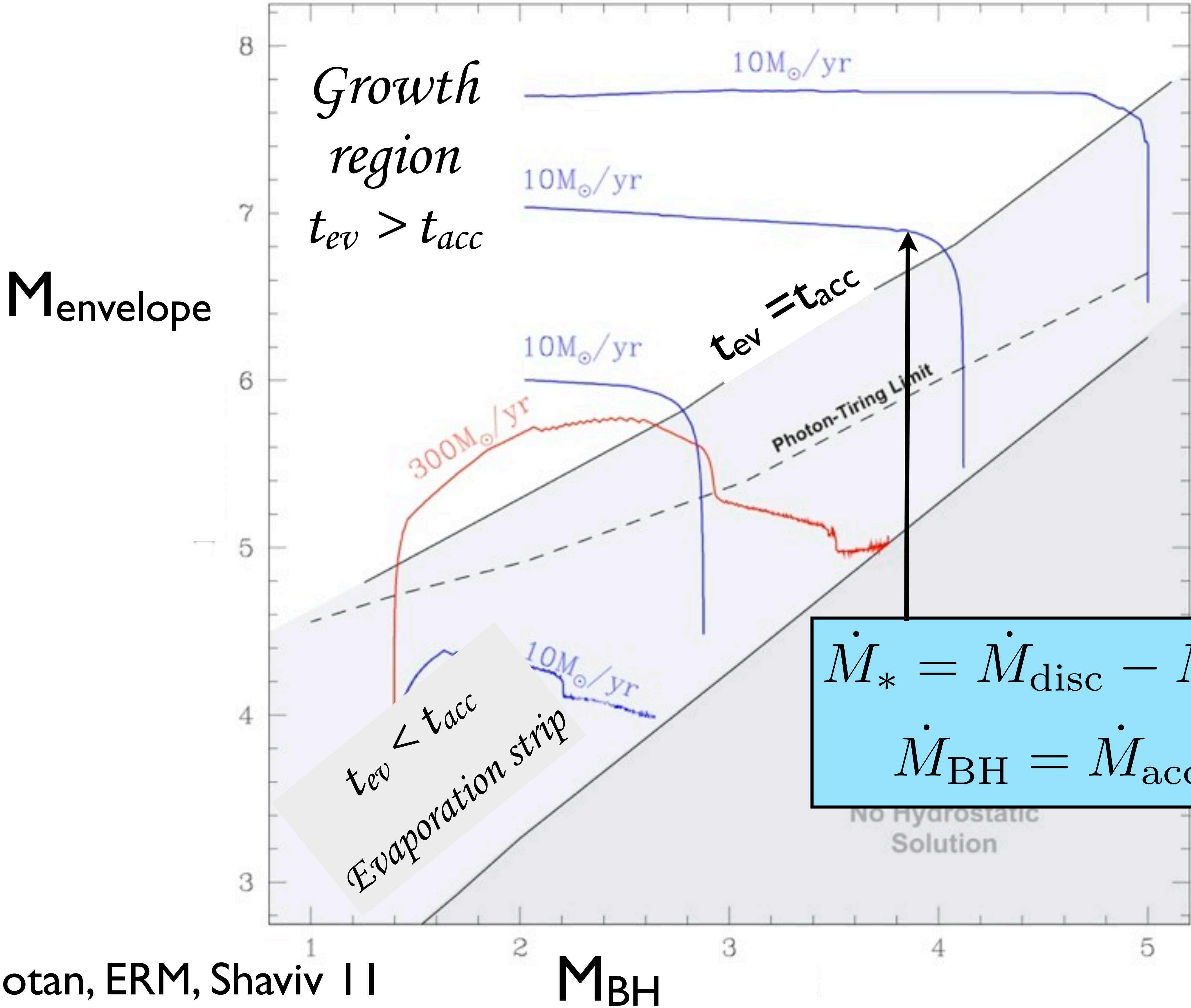


$$\dot{M}_* = \dot{M}_{\rm disc} - \dot{M}_{\rm acc} - \dot{M}_{\rm w}$$

$$\dot{M}_{\rm BH} = \dot{M}_{\rm acc} = \Gamma M_{\rm Edd}$$

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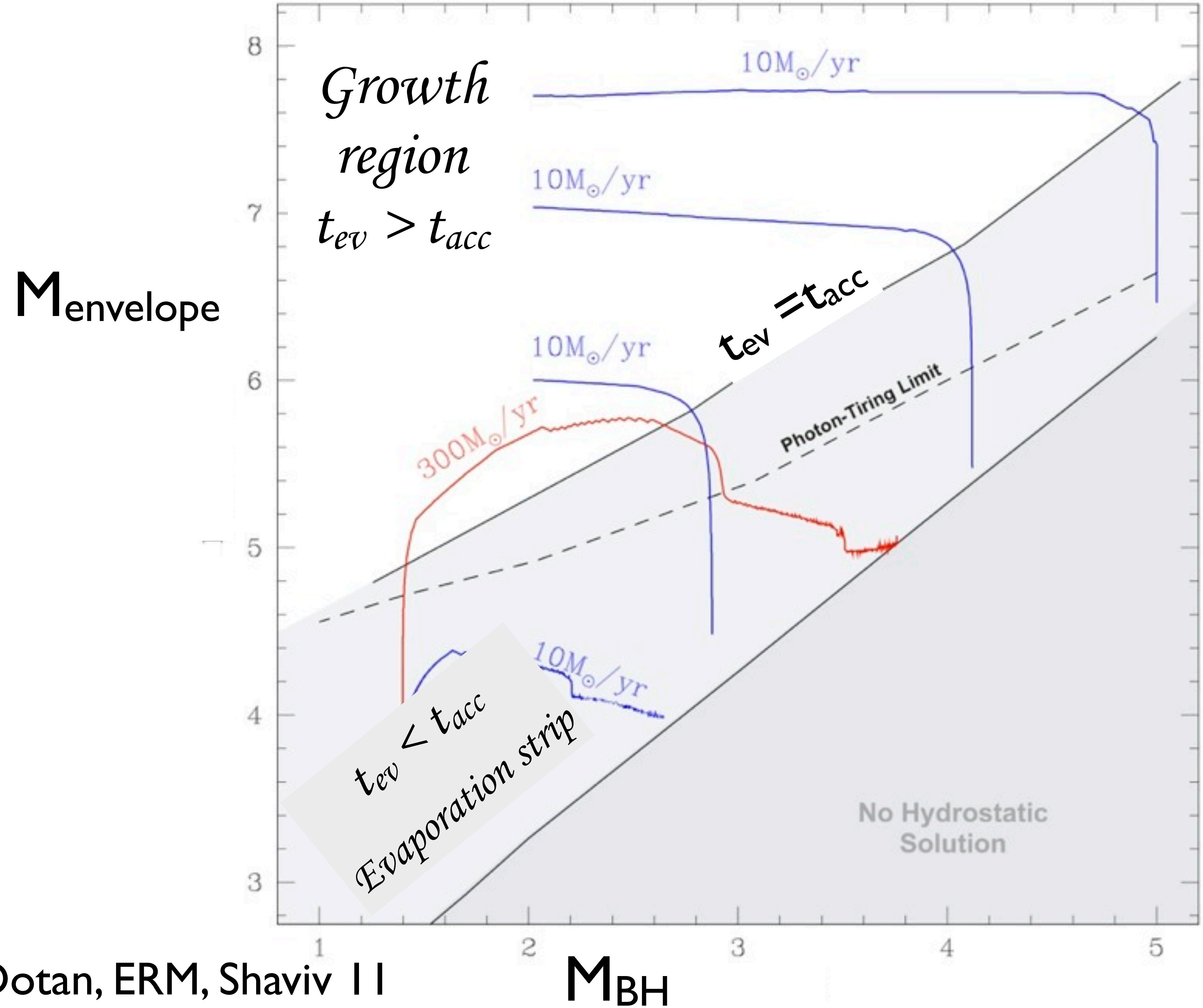


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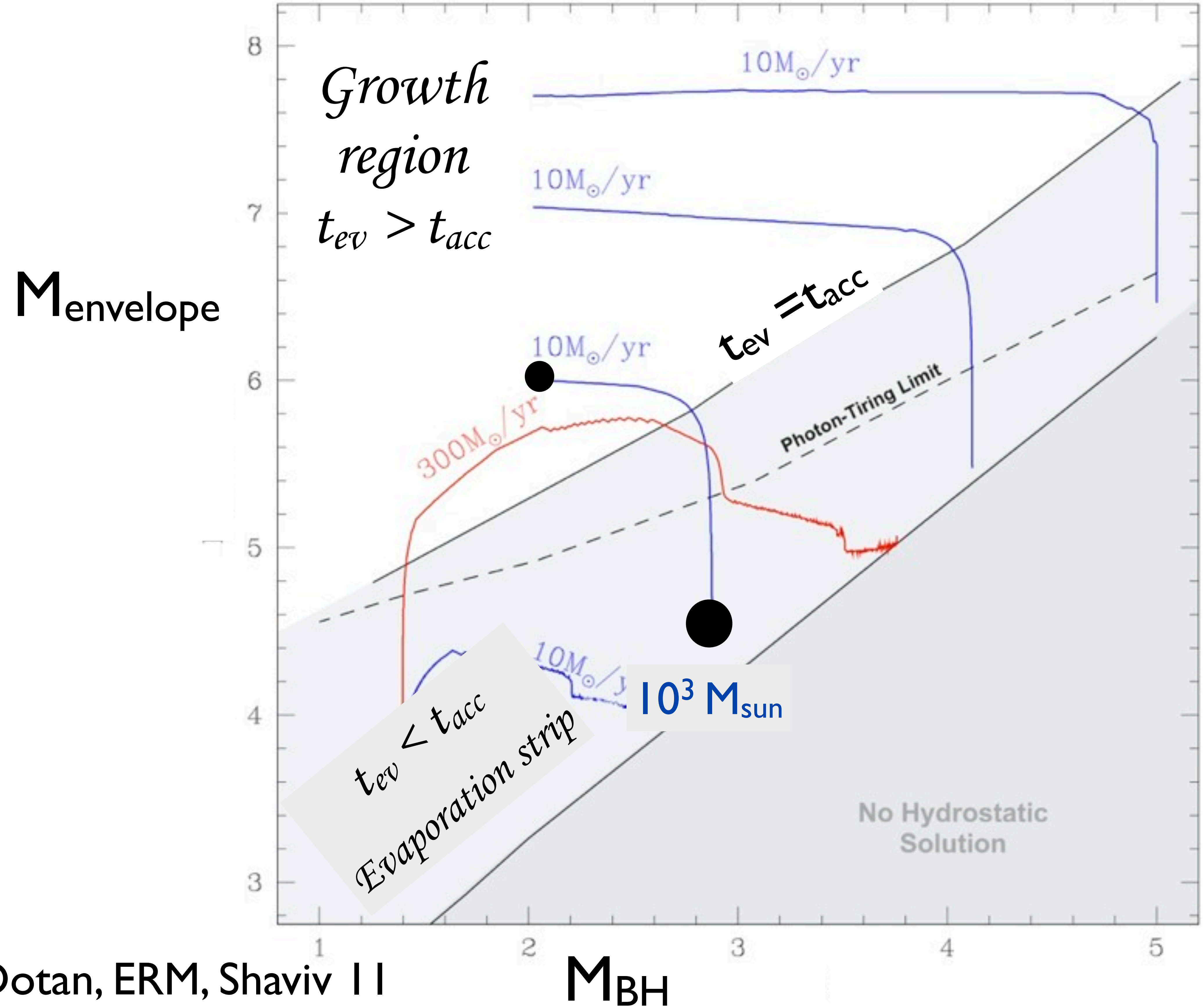


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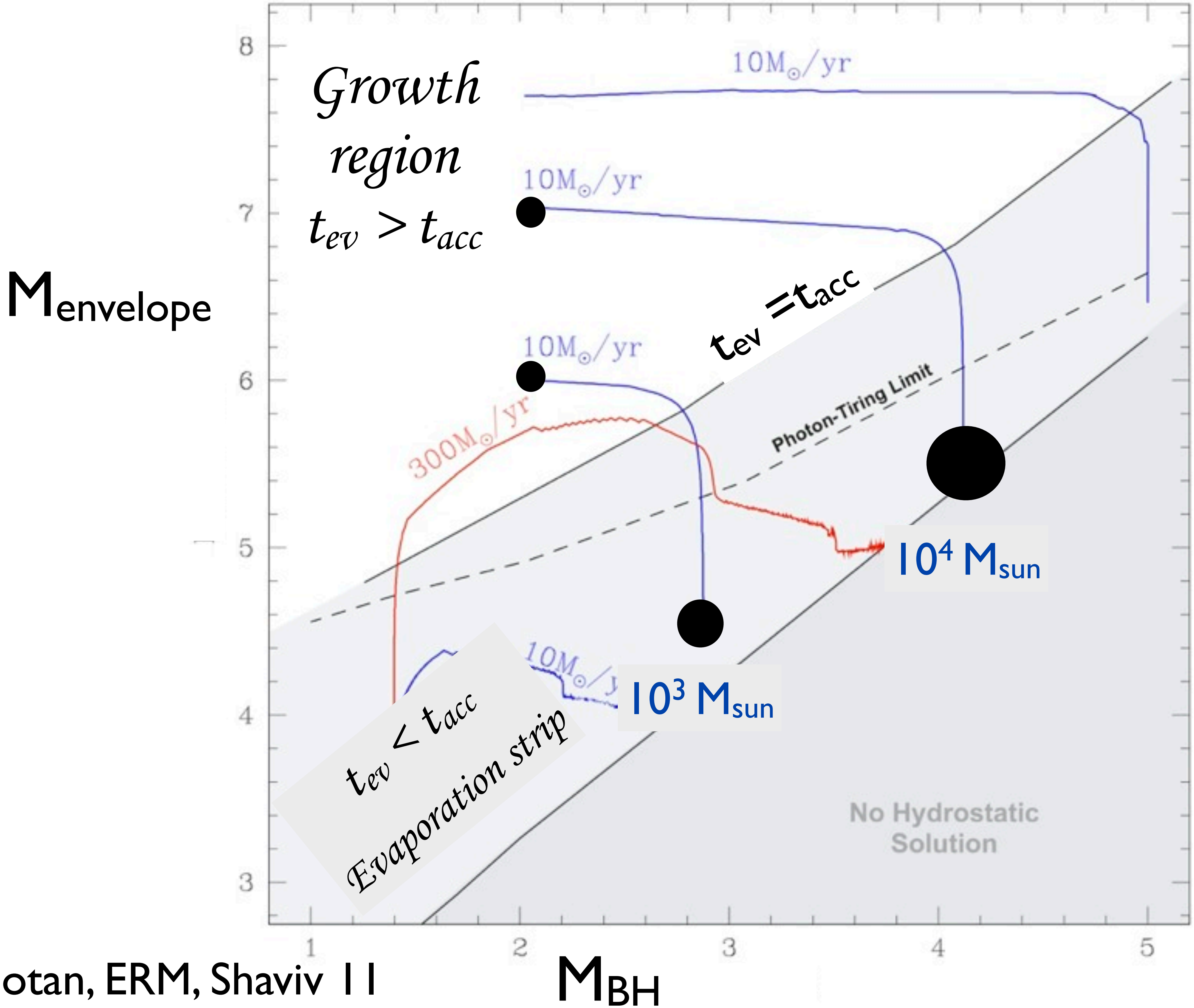


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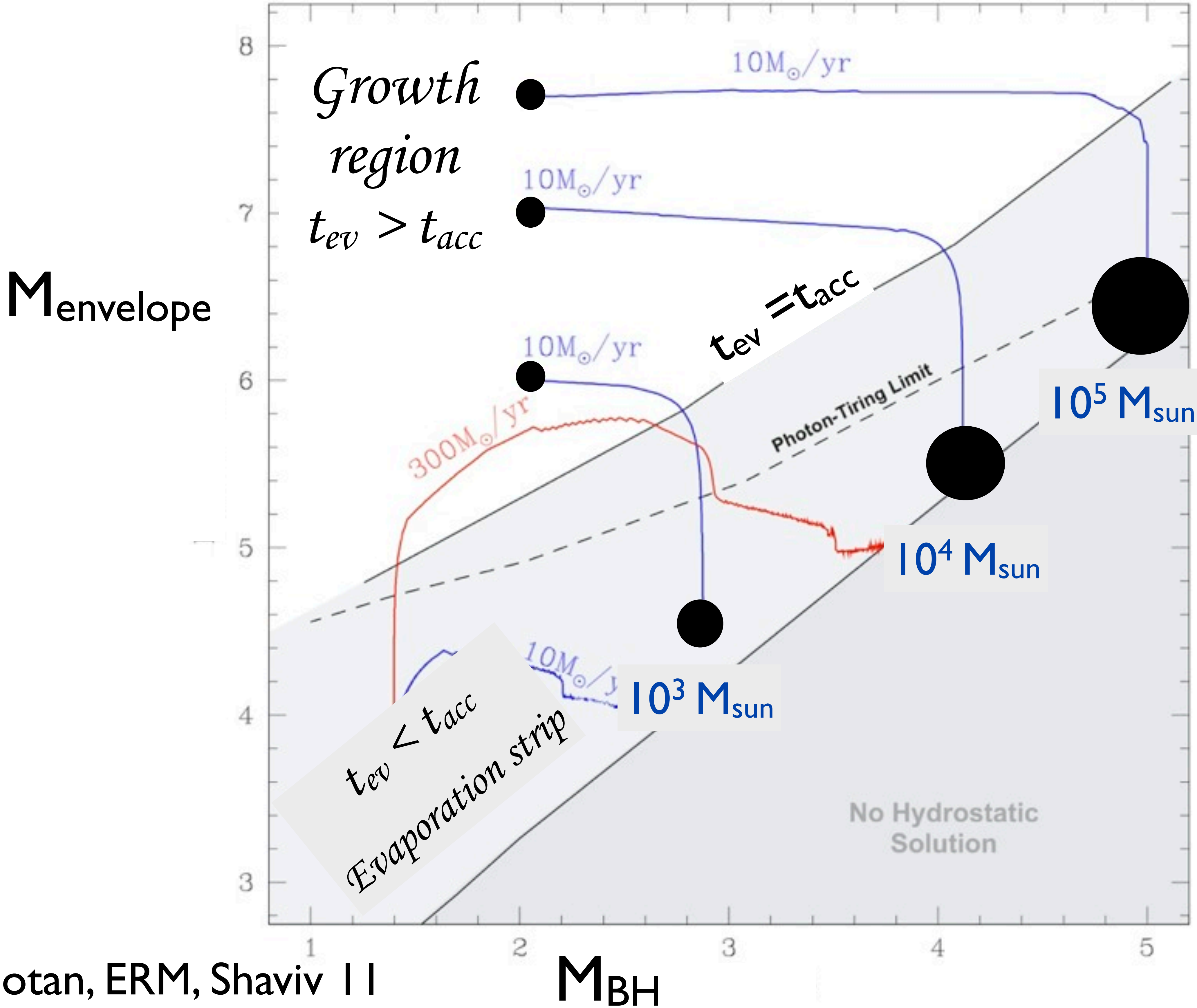


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# *Lower limit on halo mass for massive seeds*

$$\frac{M_{\rm h}}{M_\odot} \approx \max\left[\frac{7\times10^8}{(1+z)_{10}^{2.2}}\left(\frac{M_*}{10^6 M_\odot}\right)^{0.9}, 6\times10^8\frac{M_*}{10^6 M_\odot}\right]$$

Fakhouri et al. 10

Neistein et al. 10

- $M_{bh} \sim 10^5$ $M_{sun}$ in $M_{halo} > 10^{10}$ $M_{sun}$ @z~10
- $M_{bh} > 10^5$ $M_{sun}$, $M_* \geq 10^8$ $M_{sun}$ *but* envelopes unstable to pulsations (Fowler 66)
- *if* $M_* = 10^8$ $M_{sun}$ is a hard upper limit, *NO* black hole seeds with $10^6$ $M_{sun}$