Accretion of Dissipative Dark Matter onto Active Galactic Nuclei

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Preparing people to lead extraordinary lives

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Can dissipative dark matter affect the growth of supermassive black holes?

Can dissipative dark matter

affect the growth of supermassive black holes?

Motivated by small-structure

5% DDM → $m_{e'}, m_{p'}, \alpha'$ Fan, Katz, Randall & Reece '13

95% CDM $n_{e'} \approx n_{p'} \gg n_{\bar{e}'}, n_{\bar{p}'}$

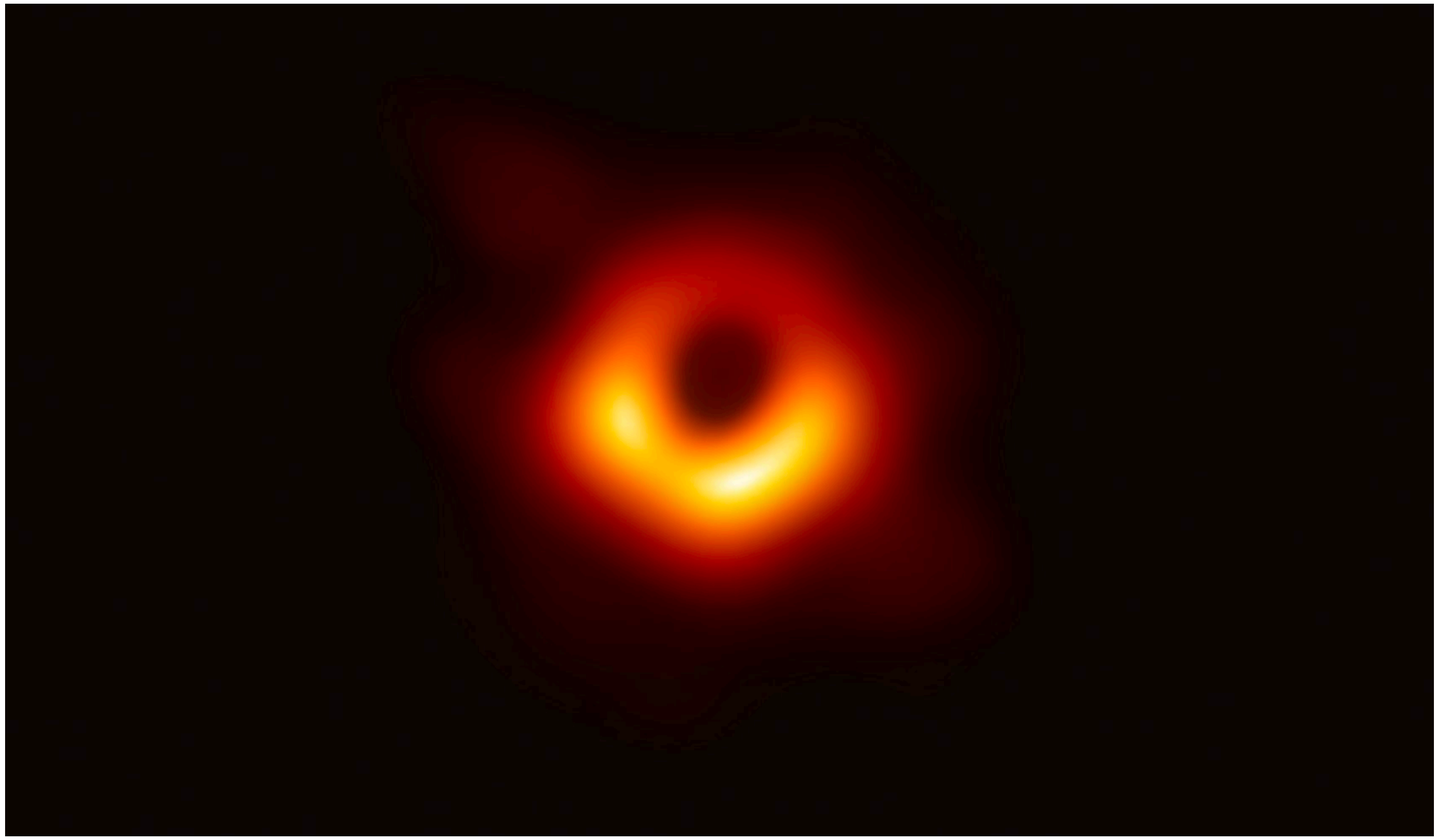
Can dissipative dark matter

affect the growth of supermassive black holes?

Active galactic nuclei (AGN)

Accretion dynamics

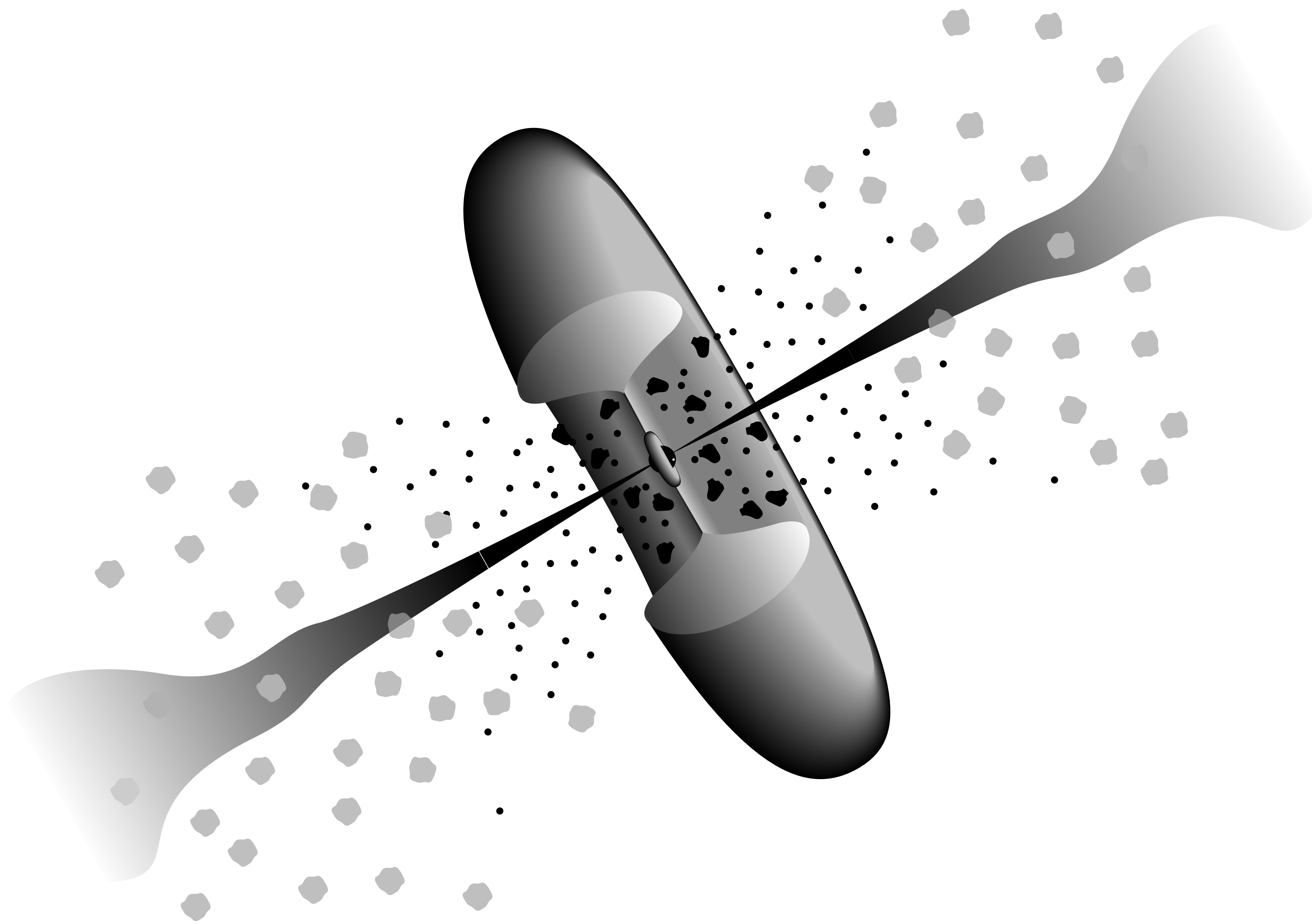
Observations



Event Horizon Telescope Collaboration

Active Galactic Nuclei

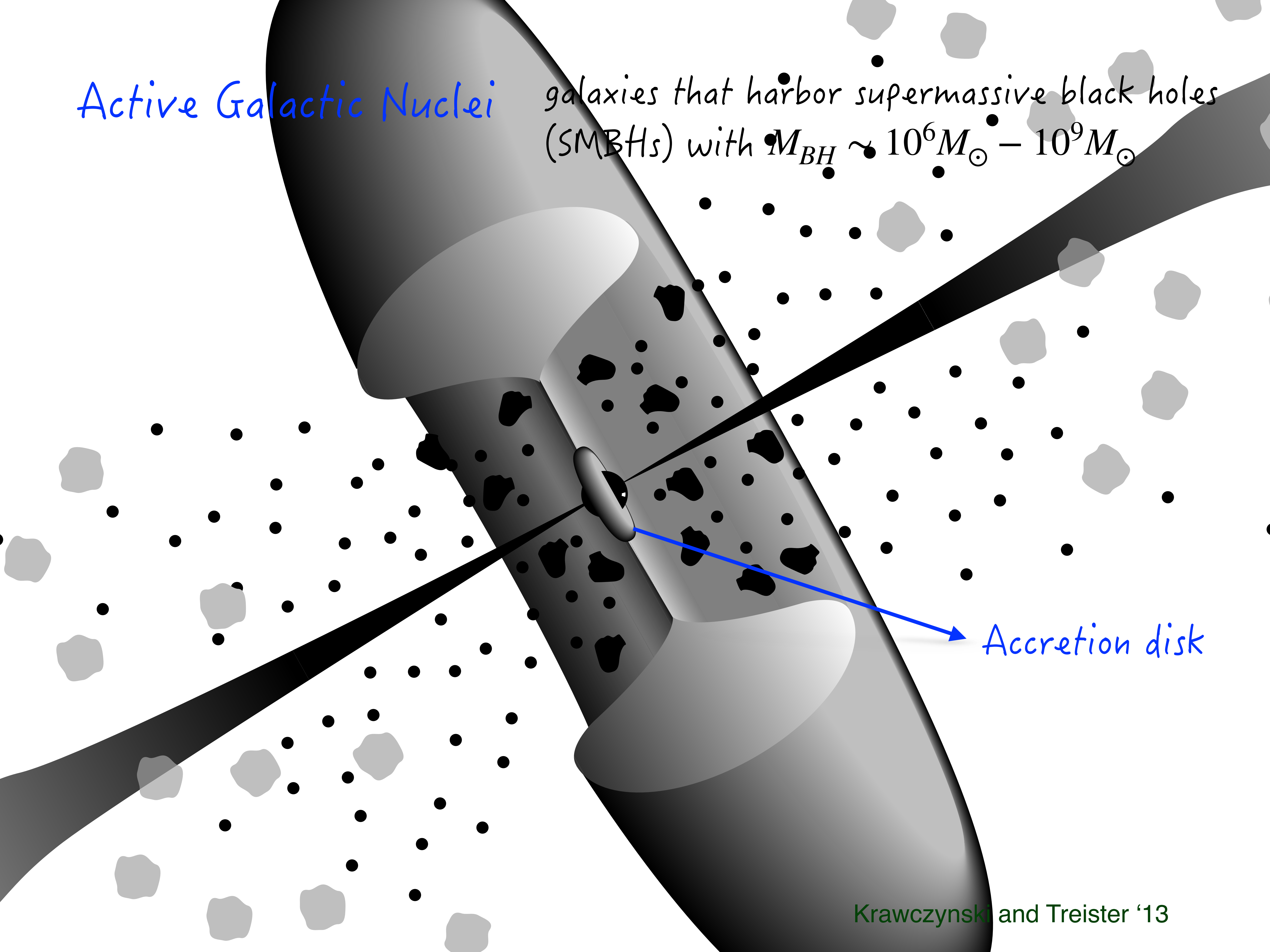
galaxies that harbor supermassive black holes (SMBHs) with $M_{BH} \sim 10^6 M_\odot - 10^{10} M_\odot$



Krawczynski and Treister '13

Active Galactic Nuclei

galaxies that harbor supermassive black holes (SMBHs) with $M_{BH} \sim 10^6 M_\odot - 10^9 M_\odot$



Krawczynski and Treister '13

Accretion

An element δM from the disk falls into the black hole and releases energy δE in form of radiation.

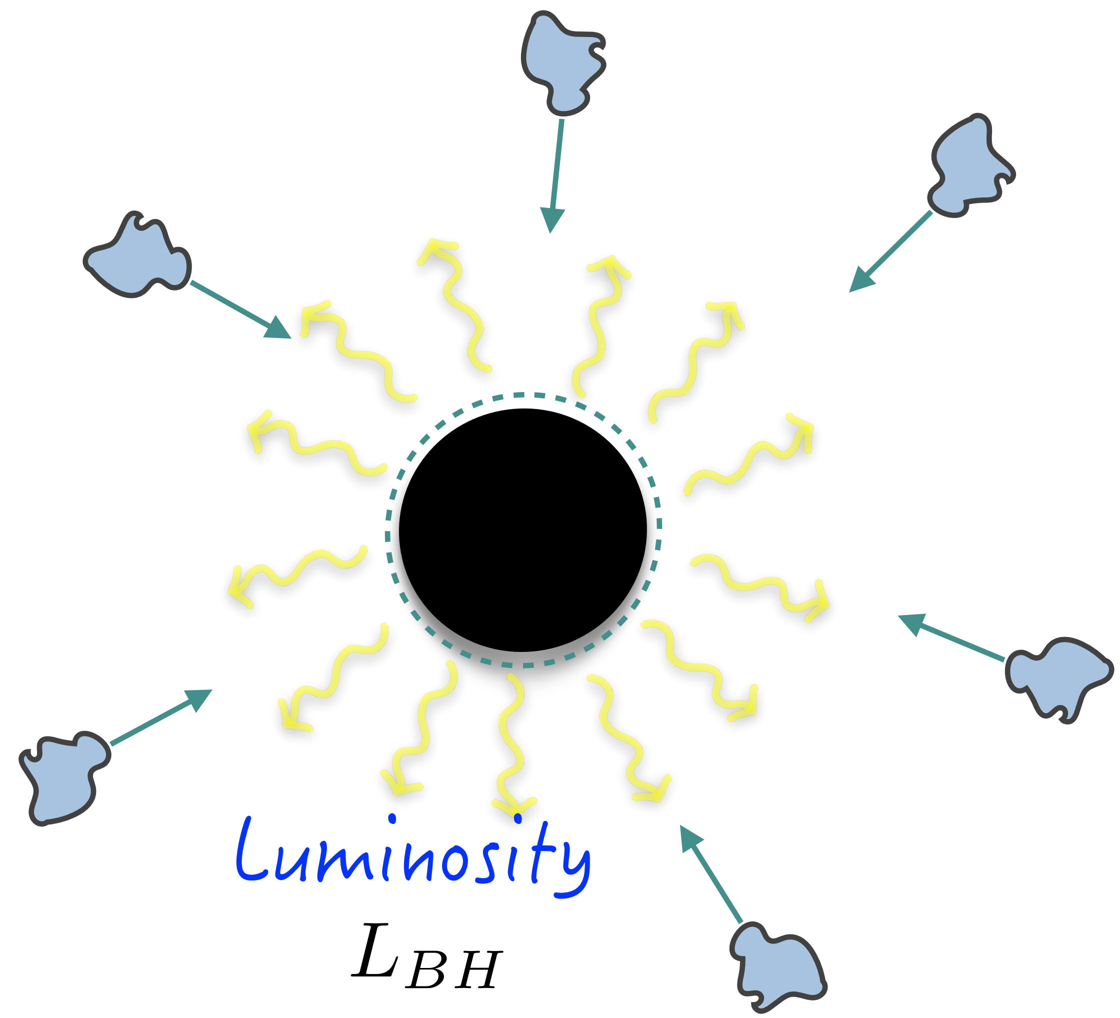
$$\delta E = \eta\, \delta M$$

The rest of the energy is absorbed by the black hole

$$\dot{M}_{BH} = \frac{1-\eta}{\eta} L_{BH}$$

But the accretion is not continuous.

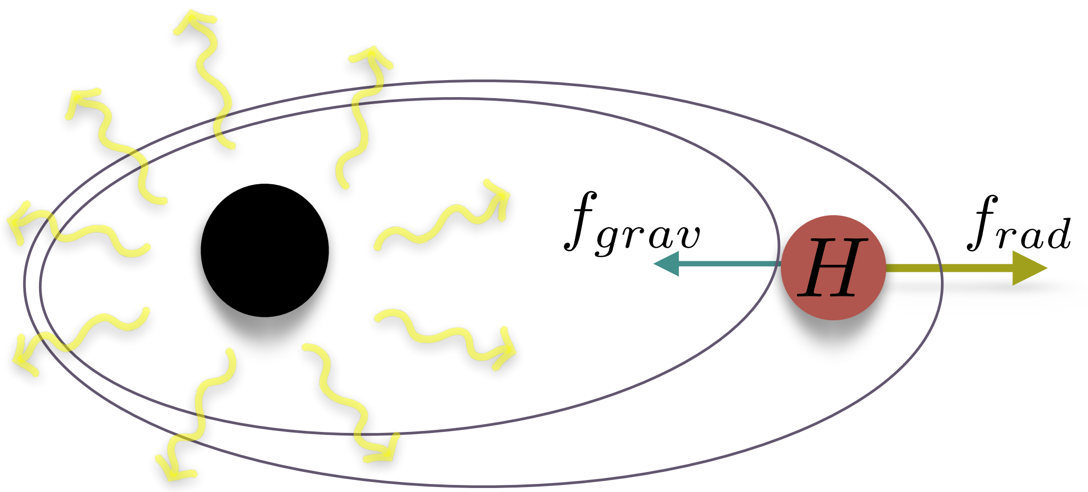
$$\langle \dot{M}_{BH} \rangle = D \times \frac{1-\eta}{\eta} L_{BH}$$



Duty cycle: $D \in [0, 1]$

Accretion

What's the maximum luminosity?



$$\left(\frac{L_{BH}\sigma_T}{4\pi r^2} - \frac{GM_{BH}m_p}{r^2}\right) = 0$$

$$L_{Edd} \equiv \frac{4\pi G m_p}{\sigma_T} M_{BH} \equiv \frac{M_{BH}}{\tau_{Sal}}$$

Salpeter time: $\tau_{Sal} \sim 4.5\mathrm{Gyr}$

$$\langle \dot{M}_{BH} \rangle = D \times \frac{1-\eta}{\eta} L_{BH} \longrightarrow \langle \dot{M}_{BH} \rangle = D \times \frac{1-\eta}{\eta} \frac{L_{BH}}{L_{\mathrm{Edd}}} \frac{M_{BH}}{\tau_{Sal}}$$

Observations

A sample of 40 AGN

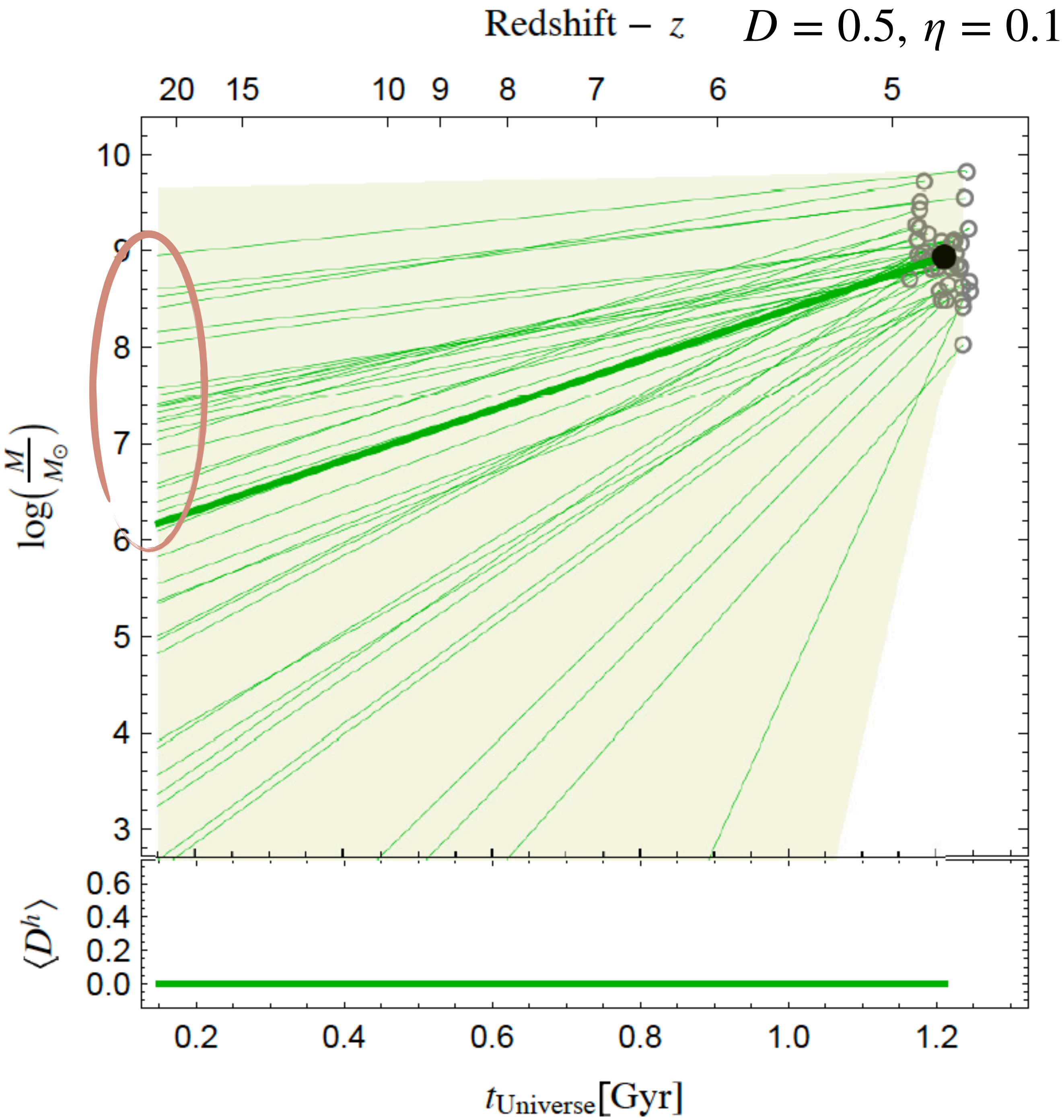
$\langle z_{BH} \rangle \sim 4.8$

$\langle M_{BH} \rangle \sim 10^9 M_\odot$

$\langle L_{BH}/L_{Edd} \rangle \sim 0.8$

$$t_{\rm grow} = \frac{\tau_{\rm Sal}}{D}\frac{\eta}{1-\eta}\left(\frac{L}{L_{\rm Edd}}\right)^{-1}\ln\left(\frac{M_{\rm BH}}{M_{\rm seed}}\right)$$

Trakhtenbrot, Netzer, Lira, Shemmer
arXiv: 1012.1871



$z_{formation} \sim 20 \qquad M_{seed} \sim 10^{2-6} M_\odot$

Black hole formation:

remnants of population III stars

$M_{\rm seed} \sim 10 M_\odot - 10^2 M_\odot$

mergers of dense stellar clusters

$M_{\rm seed} \sim 10^3 M_\odot$

collapse of primordial gas clouds

$M_{\rm seed} \sim 10^6 M_\odot$

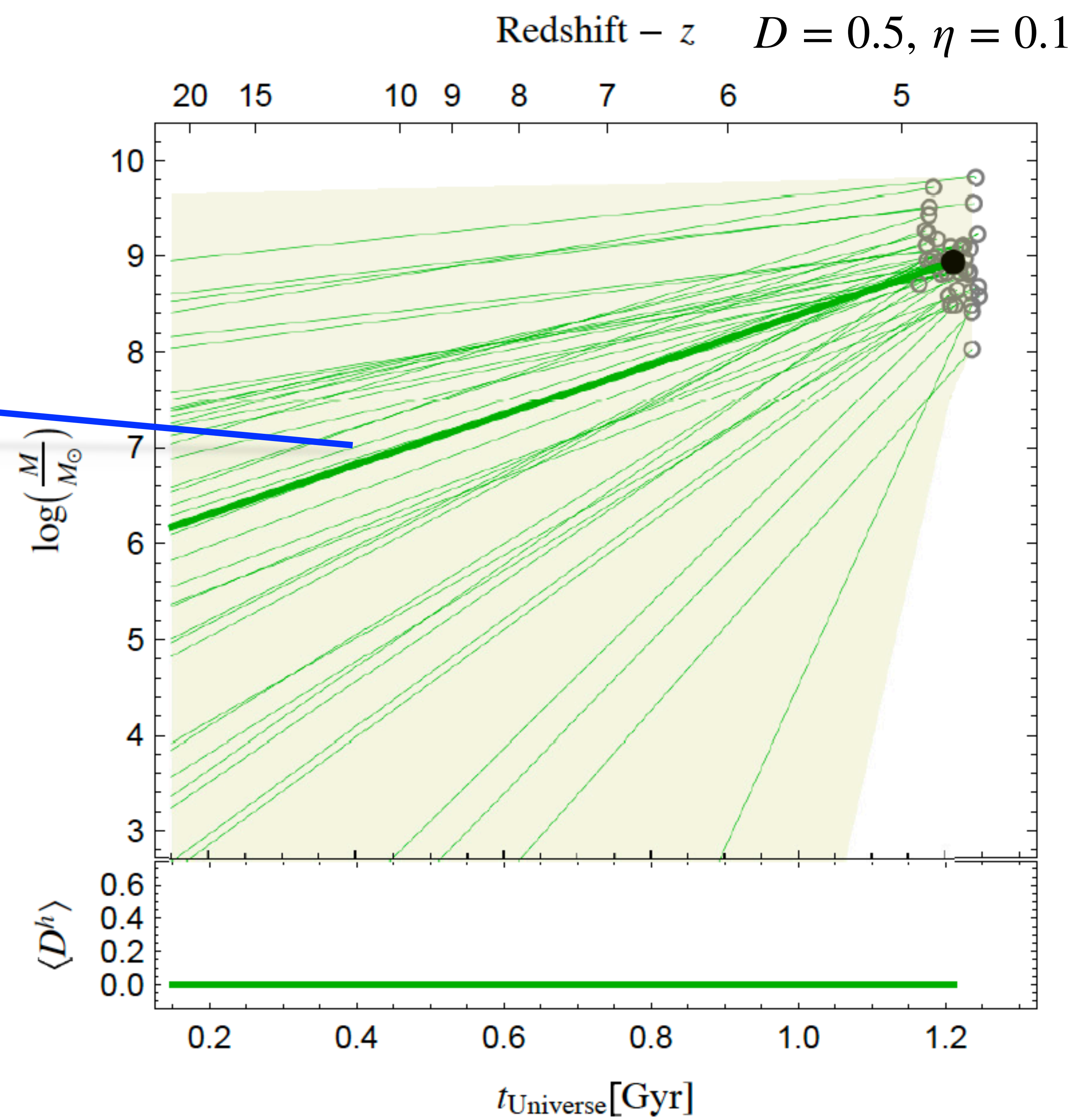
Solutions?

Change this:

Super-Eddington accretion

Dissipative DM

Outmezguine, Slone, Tangarife and Volansky, '18



Black hole formation:

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collapse of primordial gas clouds

$M_{\text{seed}} \sim 10^6 M_\odot$

Change this:

Collapse of SIDM into a BH

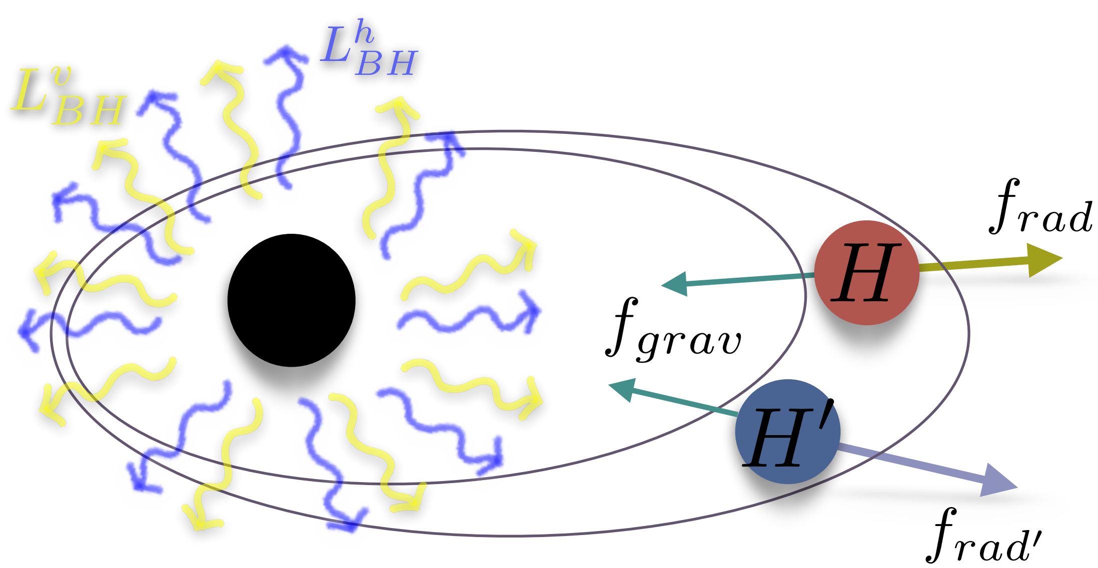
Pollack, Spergel, and Steinhardt '15

Accretion of Dissipative Dark Matter

Assume: 5% DDM $\longrightarrow$ $m_{e'},\, m_{p'},\, \alpha'$ Fan, Katz, Randall & Reece '13

95% CDM $\quad n_{e'} \approx n_{p'} \gg n_{\bar{e}'},\, n_{\bar{p}'}$

Dissipative DM cools down by bremsstrahlung and Compton scattering of dark CMB radiation.

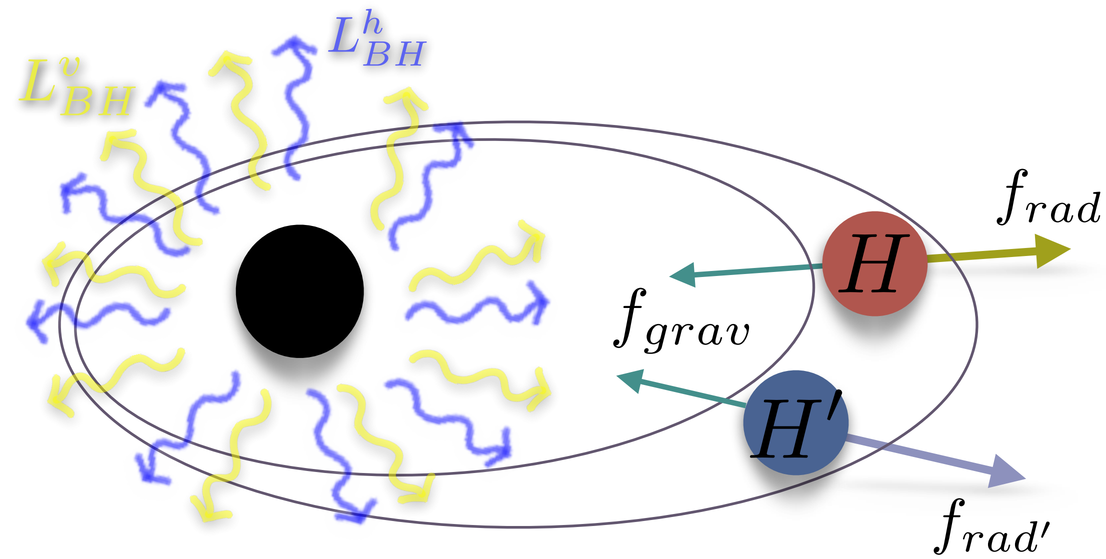


Accretion of Dissipative Dark Matter

We need to satisfy:

Efficient accretion

Formation of a
bound substructure



Large duty cycles

Accretion of Dissipative Dark Matter

We need to satisfy:

Efficient accretion

$$\langle \dot{M}_{\rm BH} \rangle = \frac{1-\eta}{\eta}\left(D^v \frac{L^v}{L^v_{\rm Edd}} + \zeta D^h \frac{L^h}{L^h_{\rm Edd}} \right) \frac{M_{BH}}{\tau_{\rm Sal}}$$

$$\zeta \equiv \frac{L^h_{\rm Edd}}{L^v_{\rm Edd}} = \frac{\sigma_T/m_p}{\sigma'_T/m_{p'}}$$

$\longrightarrow$ $$\frac{\sigma'_T}{m_{p'}} \lesssim 0.9 \ \frac{\rm cm^2}{\rm g}$$

Formation of a bound substructure

$$\tau_{\rm cool} \simeq \frac{2}{\Gamma_{\rm Comp} + u_0^{-1}\Gamma_{\rm brem}}$$

$\longrightarrow$ $$\tau_{eq} < \tau_{cool} < \tau_{universe}$$

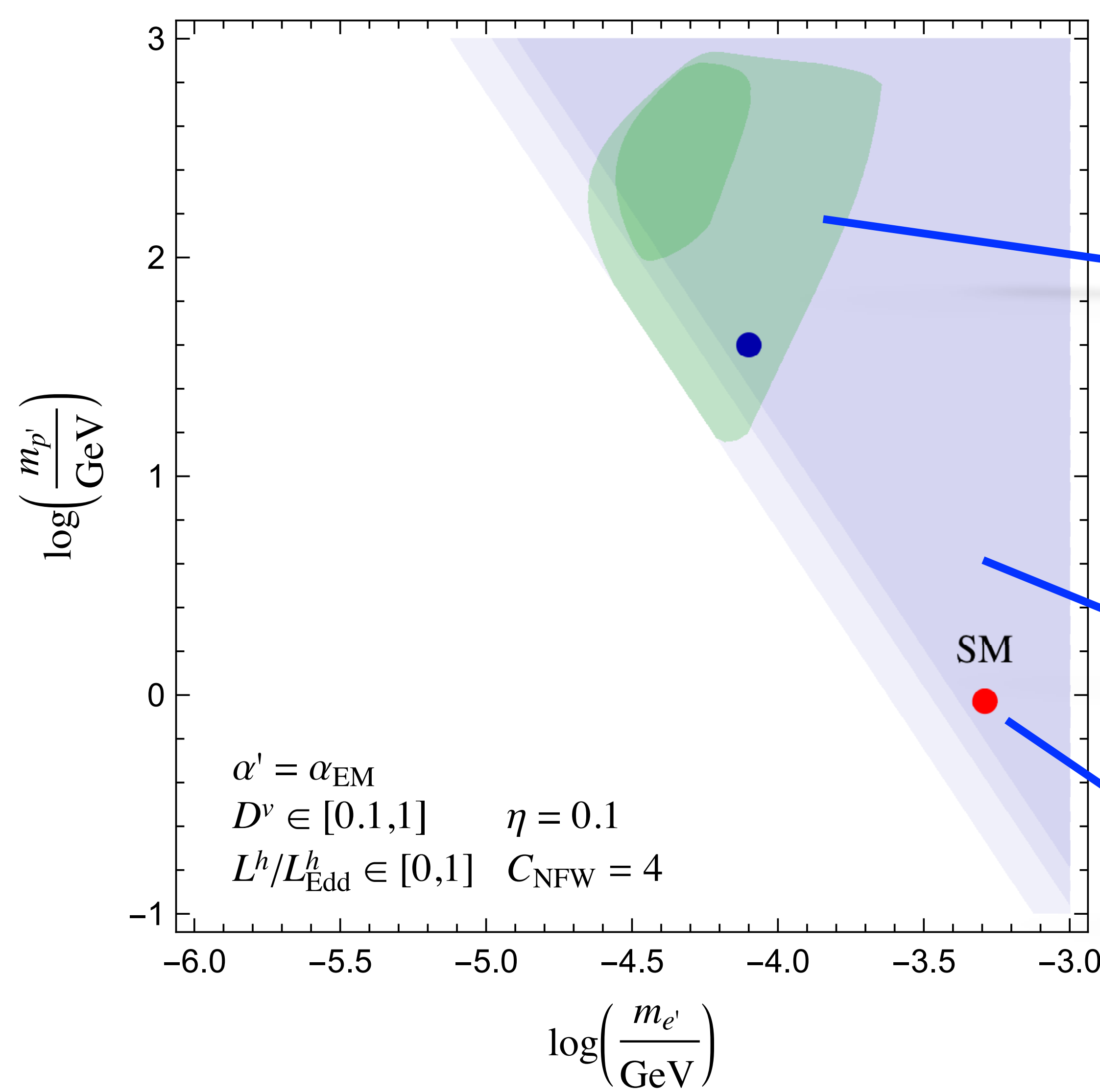
Large duty cycles

When $\tau_{acc} < \tau_{cool}$, continuous accretion is impossible

Dark duty cycle: $$D^h = \Theta(\tau_{cool} - \tau_{eq})\Theta(\tau_{universe} - \tau_{cool}) \min\left[1, \frac{\tau_{acc}}{\tau_{cool}}\right]$$

Results

What region of the parameter space may allow for dark accretion and could help the baryonic accretion to account for the growth of our 40 SMBHs from seed masses ~$10^2 - 10^6\ M_\odot$?



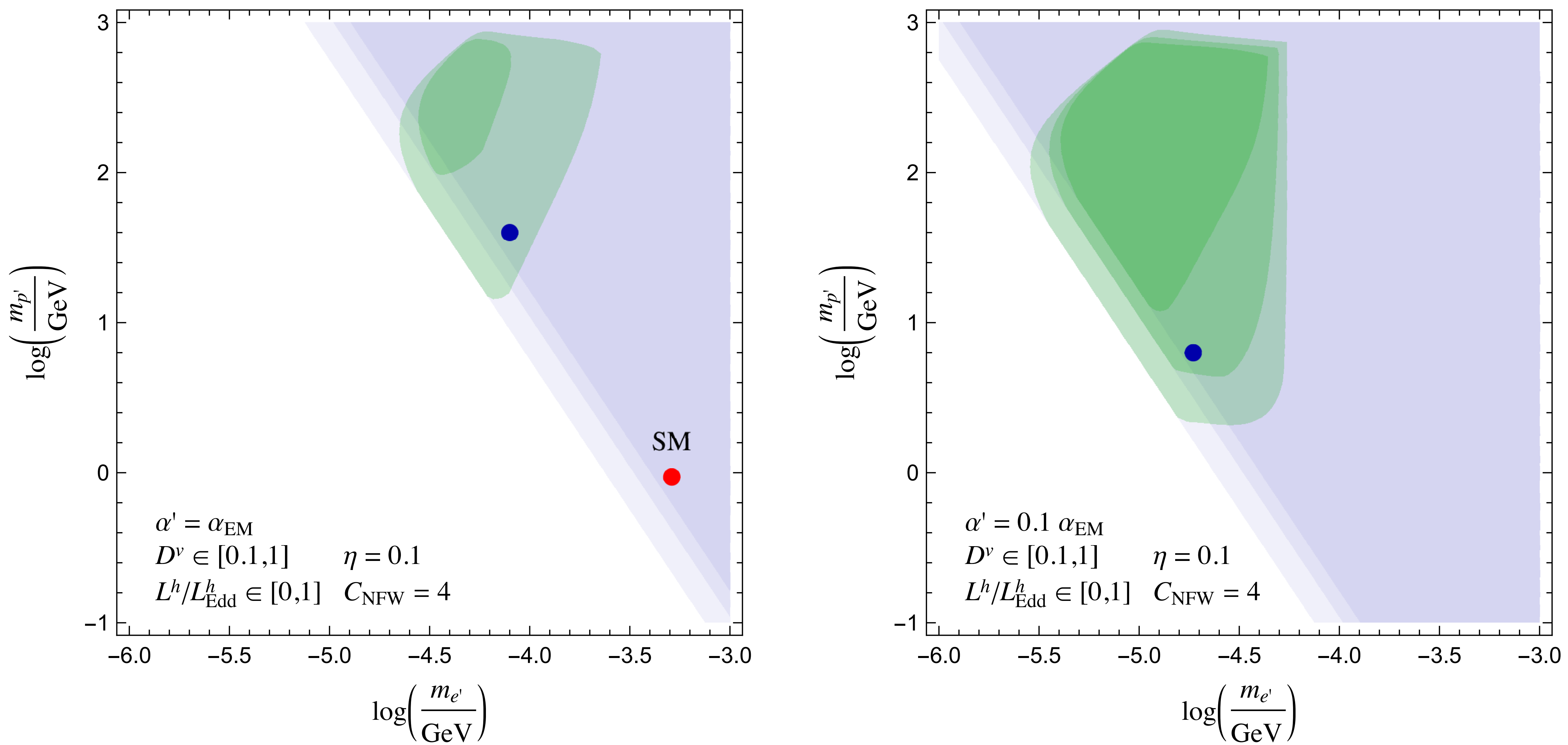
$\tau_{eq} < \tau_{cool} < \tau_{universe}$

$\frac{\sigma'_T}{m_{p'}} \lesssim 0.9\ \frac{\mathrm{cm}^2}{\mathrm{g}}$

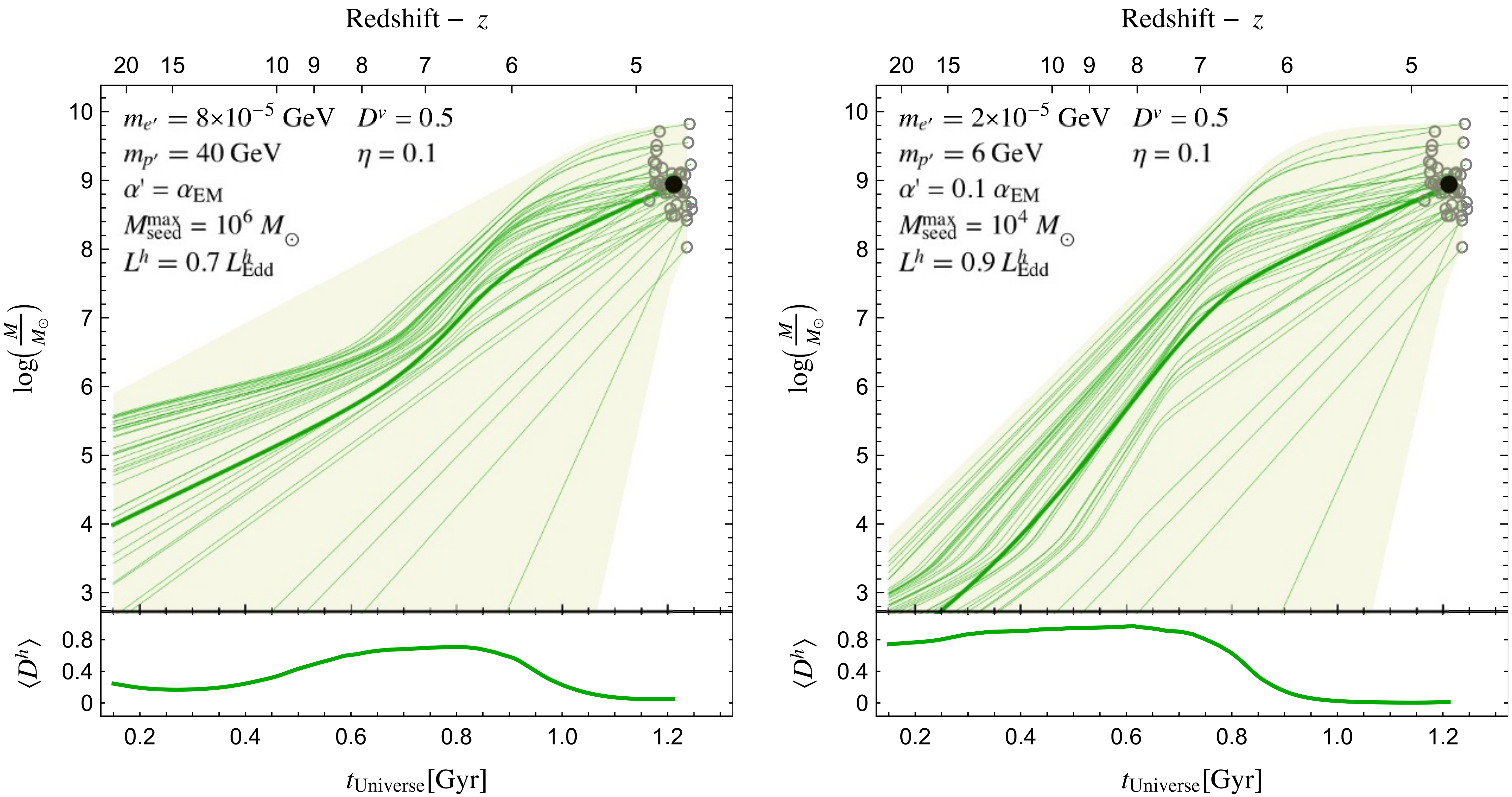
Why?

Results

What region of the parameter space may allow for dark accretion and could help the baryonic accretion to account for the growth of our 40 SMBHs from seed masses ~$10^2 - 10^6\ M_\odot$?



Results



Early fast accretion! Netzer et al. '15

Conclusions

Can dissipative dark matter affect the growth of supermassive black holes?

Yes! Or maybe! And it may help SMBHs grow from standard (low) seed masses.

We find that for some regions in the parameter space, the accretion history for our SMBHs is consistent with the observation of early fast accretion that slows down at later times

What needs to be done?

A lot!
Numerical simulations, turbulences, magnetohydrodynamics, ⋯

Thank you!