Constraints on PBH: the importance of accretion

de Luca, Franciolini, Pani and Riotto

2003.12589 (and also a bit of 2003.02778)

Main message

- Accretion changes mass function with redshift;
- Taking accretion into account reduces CMB constraints at a few solar masses scale

PBHs review

PBHs review

Poisson:

$$\Delta_\delta^2(k) = \left(\frac{4k^2}{9a^2H^2}\right)^2 \Delta_{\mathcal{R}}^2(k)$$

Matter variance at horizon entry:

$$\sigma_\delta^2(R_H) = \int_0^\infty d\ln k\, W^2(k, R_H)\Delta_\delta^2(k)$$

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PBH fraction at formation:

$$\beta(M) = \int_{\delta_c}^\infty \frac{d\delta}{\sqrt{2\pi}\sigma_\delta} e^{\delta^2/2\sigma_\delta^2}$$

PBH fraction nowadays:

$$f_{\mathrm{PBH}}(M) \equiv \frac{1}{\rho_{\mathrm{DM}}}\frac{d\rho_{\mathrm{PBH}}}{d\ln M} \approx \left(\frac{\beta}{6.6\cdot 10^{-9}}\right)\left(\frac{\gamma}{0.2}\right)^{\frac{1}{2}}\left(\frac{106.75}{g_*}\right)^{\frac{1}{4}}\left(\frac{M_\odot}{M}\right)^{\frac{1}{2}}$$

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Press-Schechter

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PBHs are exponentially sensitive to scalar fluctuations !!!

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PBH constraints (2002.12778)

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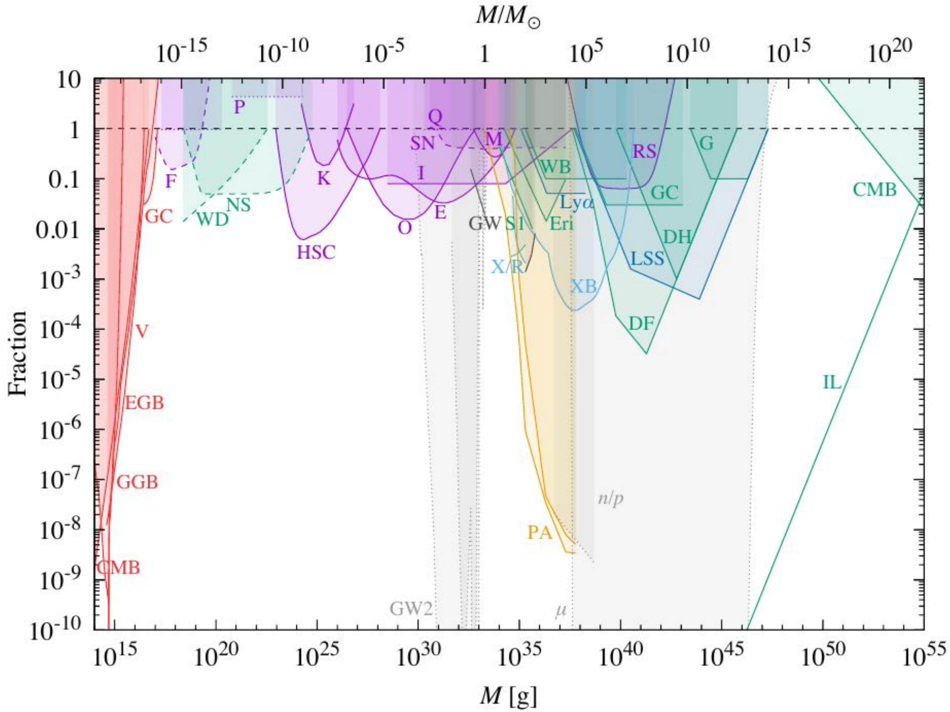


Evaporation

Lensing

Dynamical

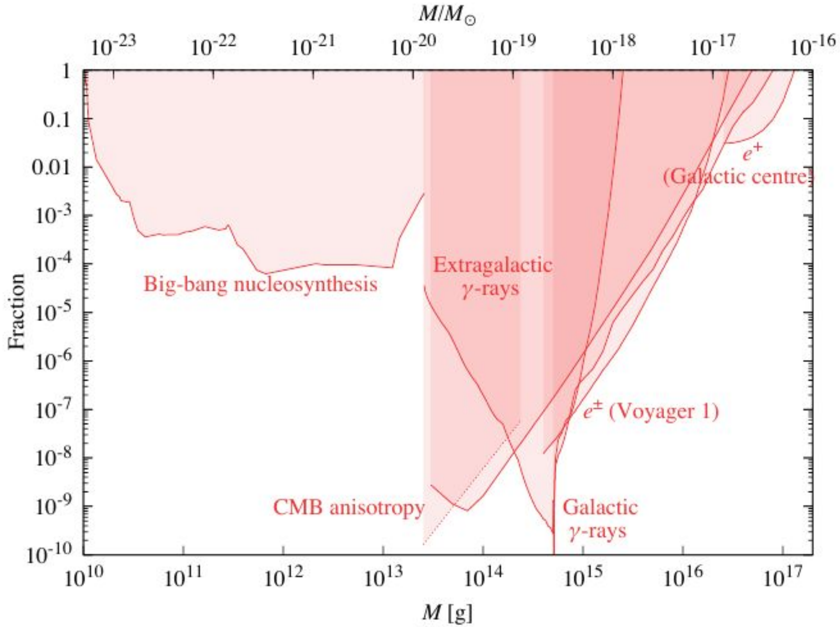
Large Scale Structure

CMB by PBH accretion

PBH constraints (2002.12778)

Evaporation

Small masses



PBH constraints (2002.12778)

Lensing

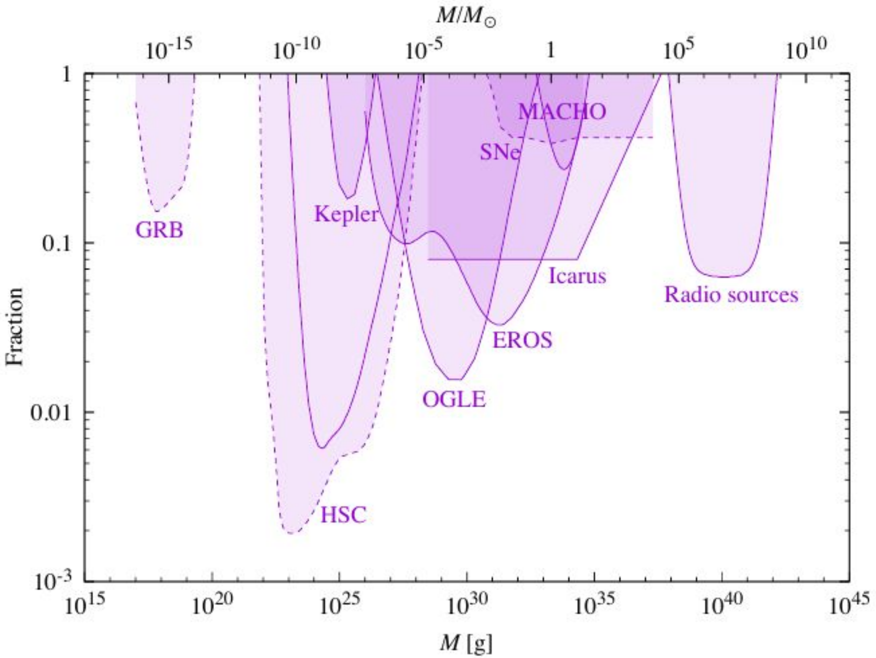
from multiple scales

and objects

(Femto, picolensing,

microlensing of stars/

supernovae/quasar/pulsar)



Broad mass range

PBH constraints (2002.12778)

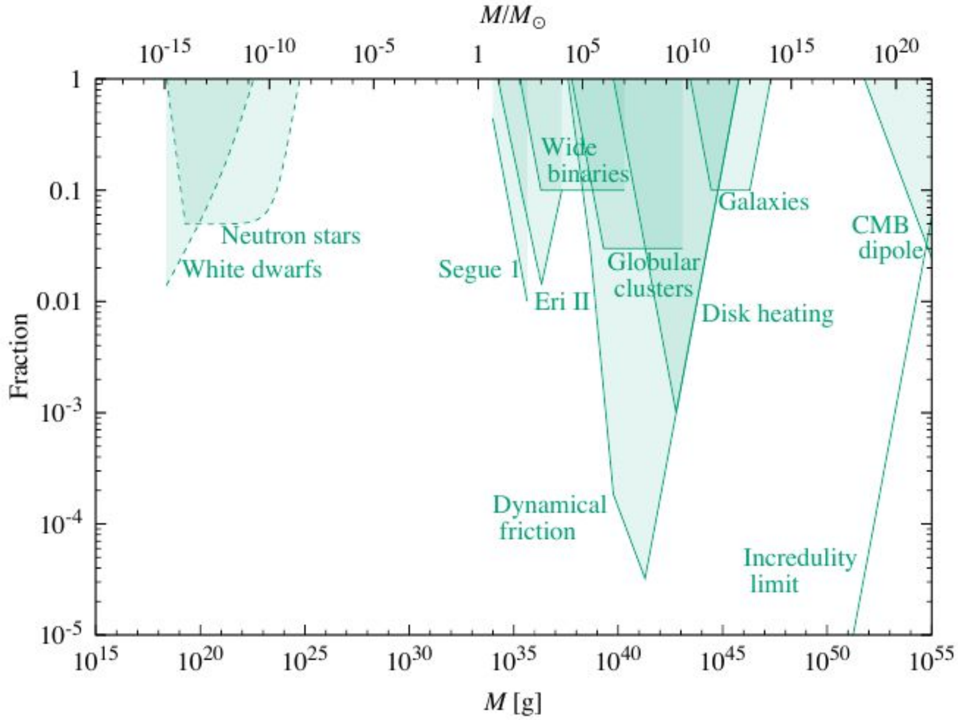
Dynamical

Collision with astro objects,

PBH swallowed by white

dwarfs and neutron stars,

trigger explosions



Broad mass range

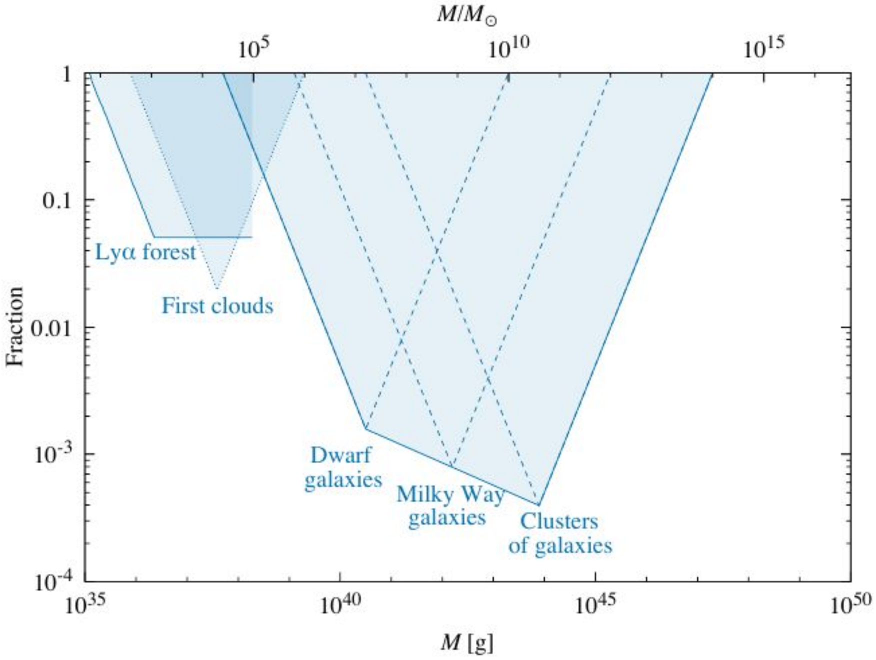
PBH constraints (2002.12778)

LSS

PBH cannot provide DM, but

may play a role in structure

formation (1801.00672)



Large masses

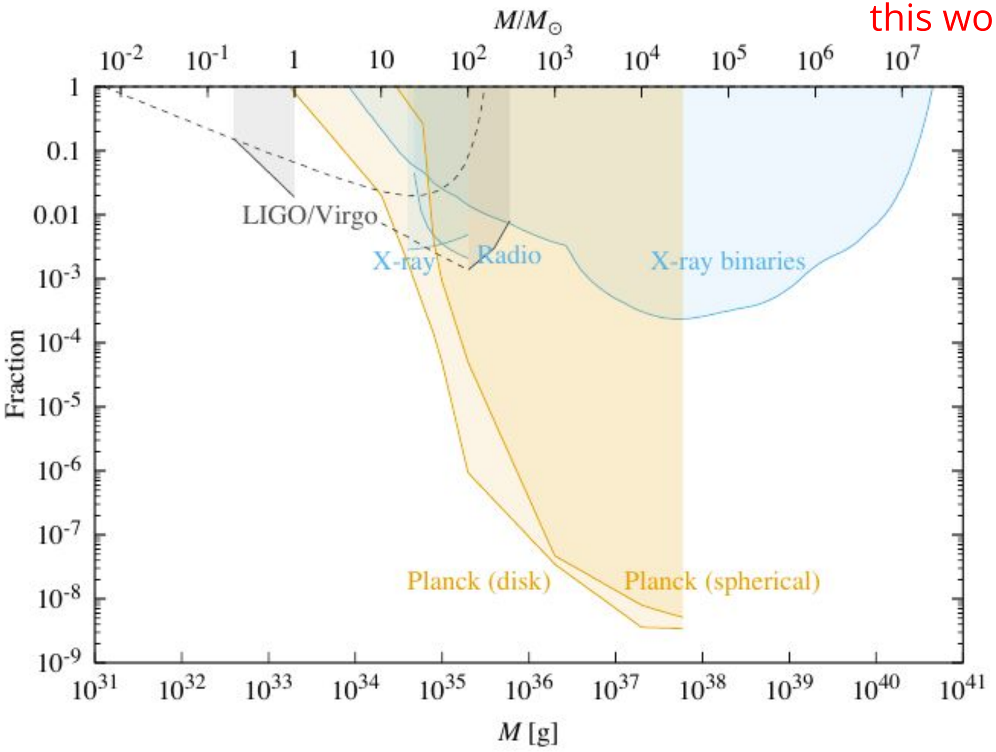
PBH constraints (2002.12778)

The main object of this work!

CMB by PBH accretion

PBH accretion at MR equality

heats up the gas and emit radiation.



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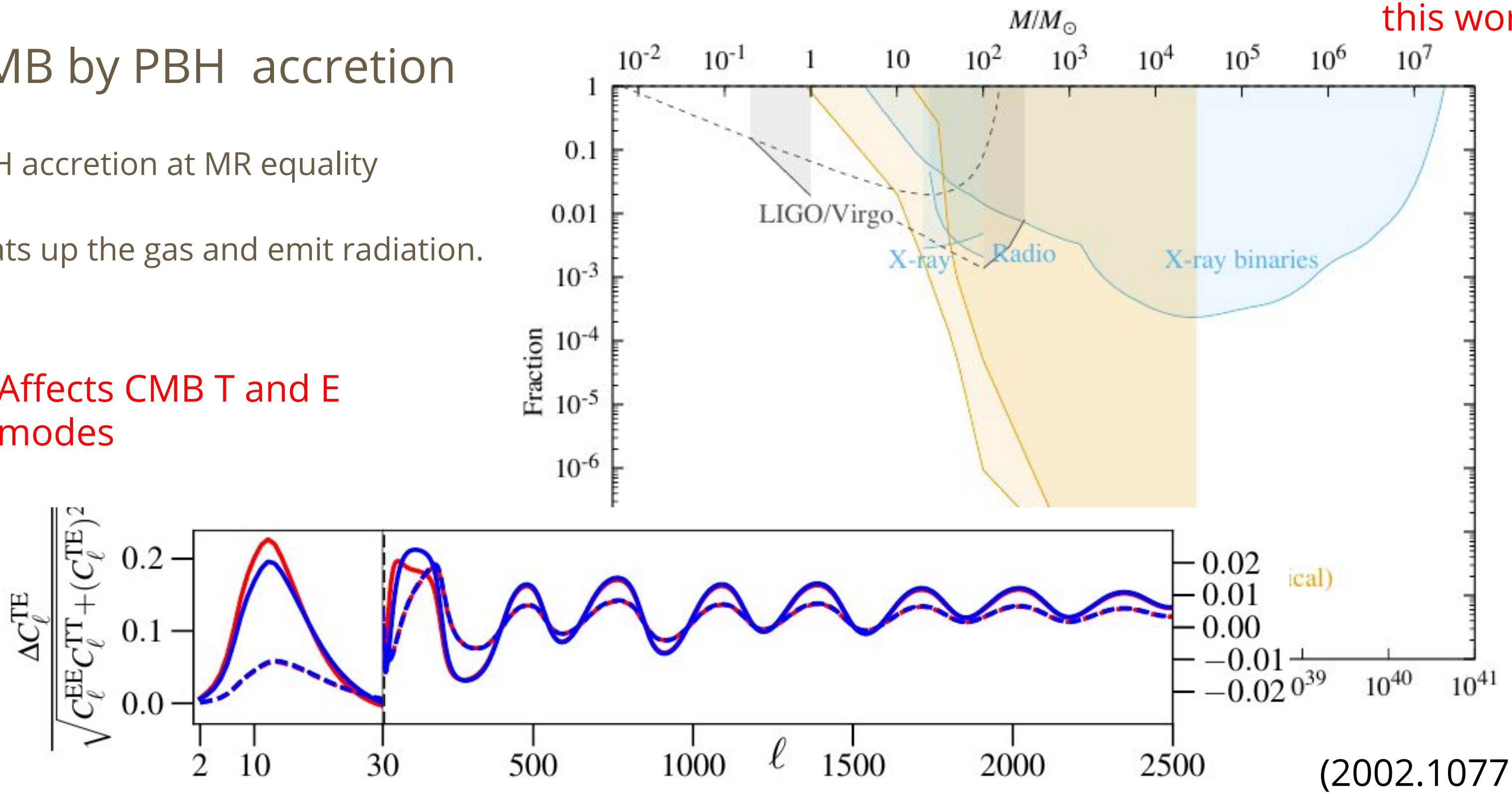
Affects CMB T and E modes



(2002.10771)

Physics of accretion

Physics of accretion

Bondy-Hoyle rate

$$\dot{M}_{\mathrm{B}} = 4\pi\lambda m_H n_{\mathrm{gas}} v_{\mathrm{eff}} r_{\mathrm{B}}^2$$

For isolated PBH

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* Warning: If PBH are not the unique DM component, it is important to consider PMH embedded in a halo cluster with mass

$$M_h(z) = 3M\left(\frac{1+z}{1000}\right)^{-1}$$

Halo acts as a catalyzer, but doesn't accrete DM (0709.0524)

Physics of accretion

$$\boxed{\dot{M} \sim 0.002\,\dot{m}(M)\left(\frac{M}{10^6\,M_\odot}\right) M_\odot\,\mathrm{yr}^{-1}}$$

$$\dot{m} = \frac{\dot{M}_{\mathrm{B}}}{\dot{M}_{\mathrm{Edd}}} \quad \text{with} \quad \dot{M}_{\mathrm{Edd}} = 1.44 \times 10^{17}\left(\frac{M}{M_\odot}\right) \mathrm{g\,s^{-1}}$$

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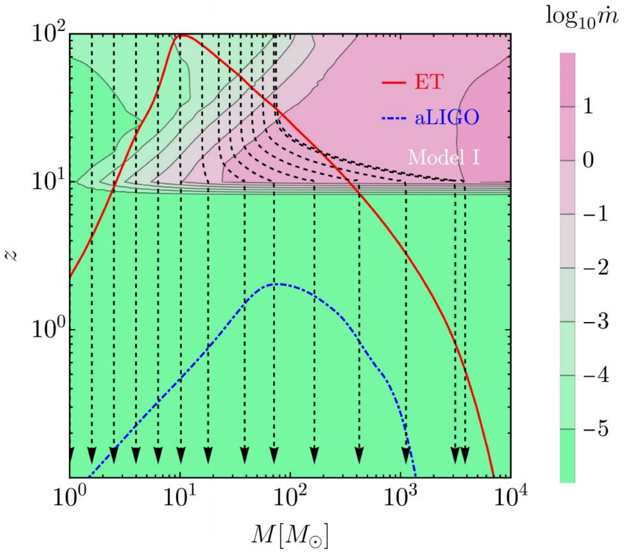
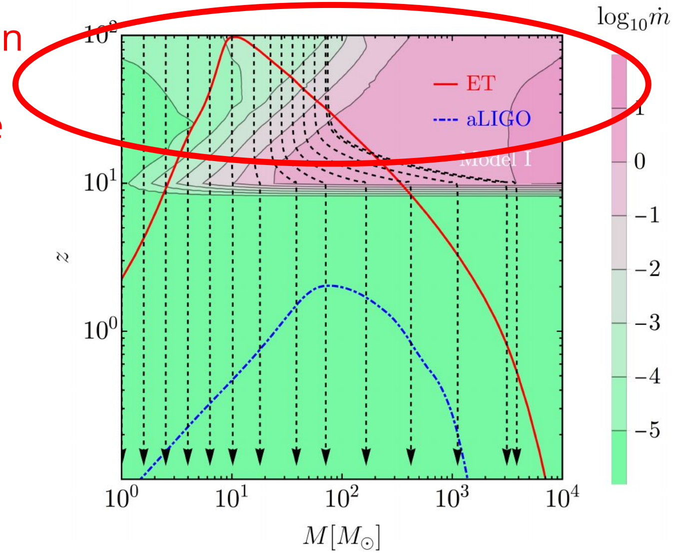


Physics of accretion

High z: accretion time is much longer than the age of the universe



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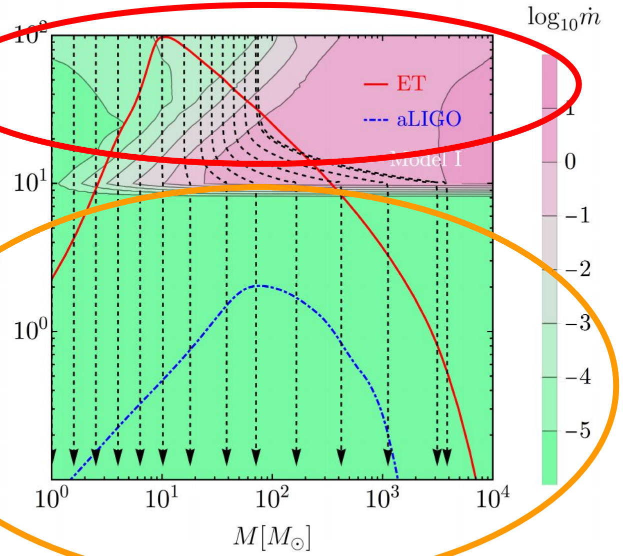

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Low z: accretion rate decrease (increase of velocities, reionization, feedback).
HARD TO MODEL!

$$\boxed{z_{\text{cut-off}} \simeq 10,\ 7 \text{ and } 3}$$

Physics of accretion

How the final mass depends on the initial mass

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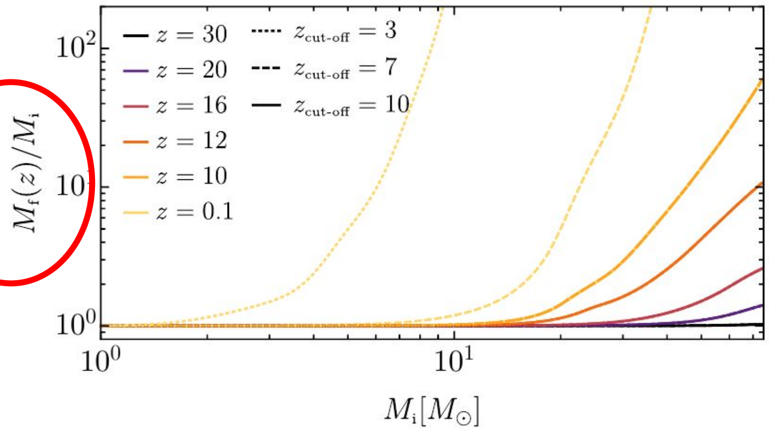

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Physics of accretion

How the mass function and PBH fraction evolve?

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$$\psi(M_\mathrm{f}(M,z),z)\mathrm{d}M_\mathrm{f} = \psi(M,z_\mathrm{i})\mathrm{d}M$$

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$$= \frac{\langle M(z)\rangle}{\langle M(z_\mathrm{i})\rangle(f_\mathrm{PBH}^{-1}(z_\mathrm{i})-1)+\langle M(z)\rangle},$$

Assuming matter domination

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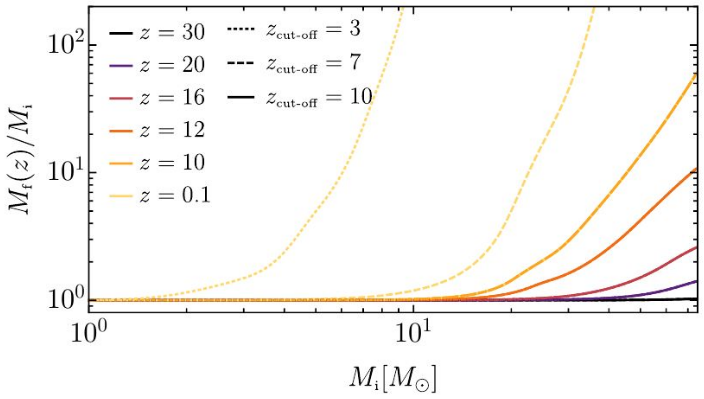

Physics of accretion

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Consider initially a log-normal distribution

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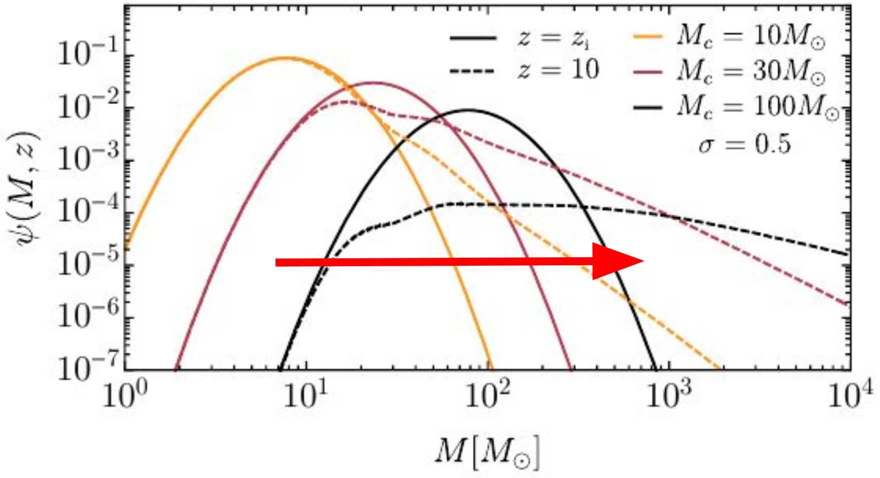

Initial distribution (continuous) gets a tail (dashed) after evolving

Physics of accretion

How the mass function and PBH fraction evolve?

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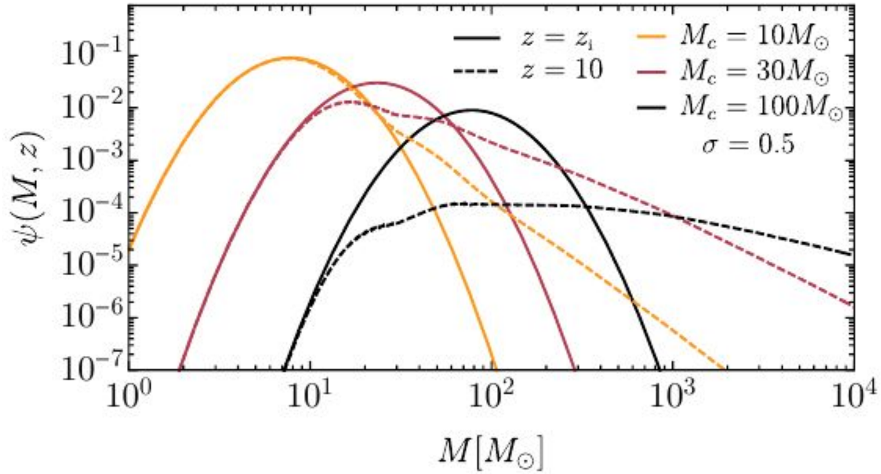
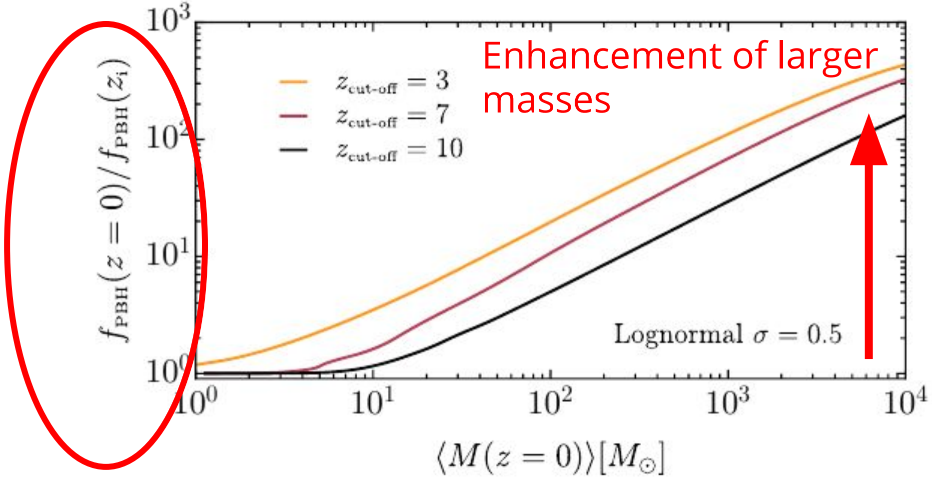


Final/Initial ratio



How it affects PBH constraints

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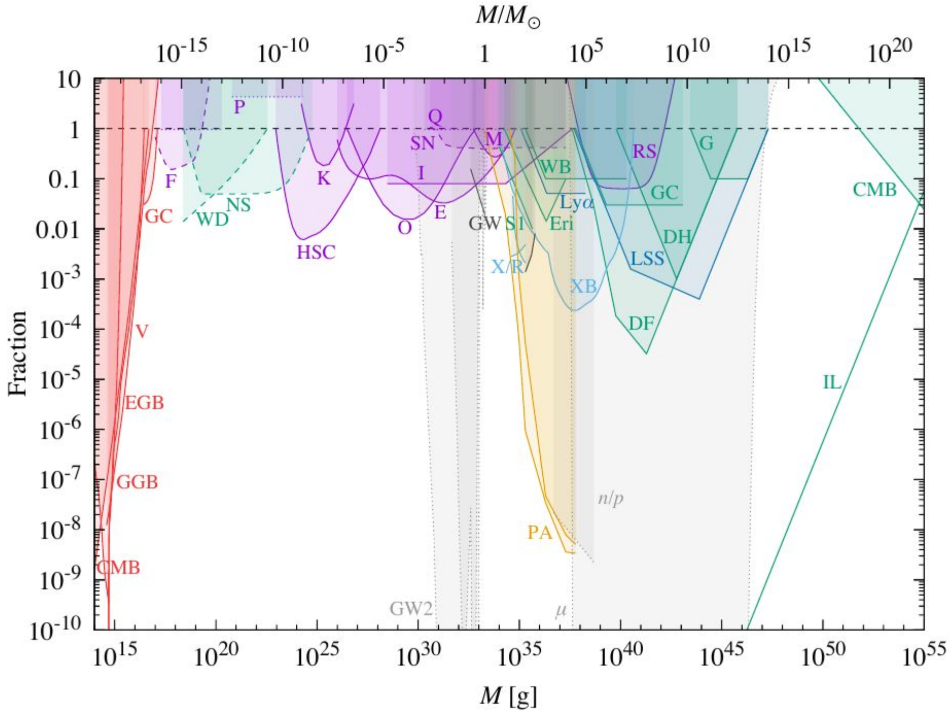


Evaporation

Lensing

Dynamical

Large Scale Structure

CMB by PBH accretion

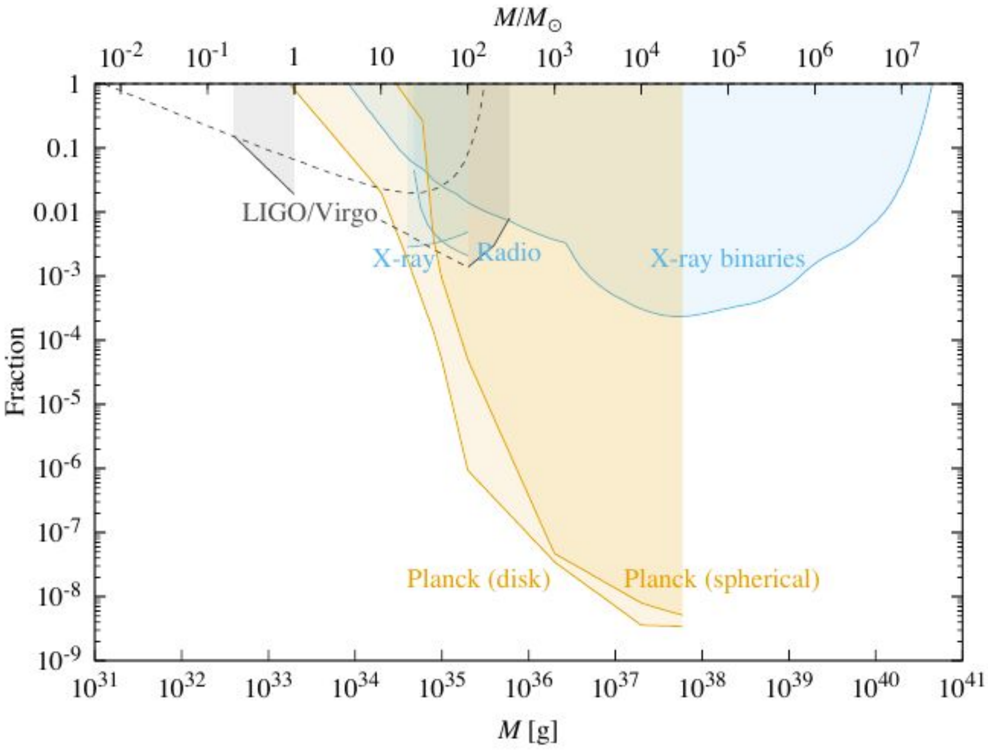
How it affects PBH constraints

CMB by PBH accretion

PBH accretion at z >>~ MR equality

heats up the gas and emit radiation.

We need to translate the initial PBH mass to today's mass to impose the constraint in PBH mass today



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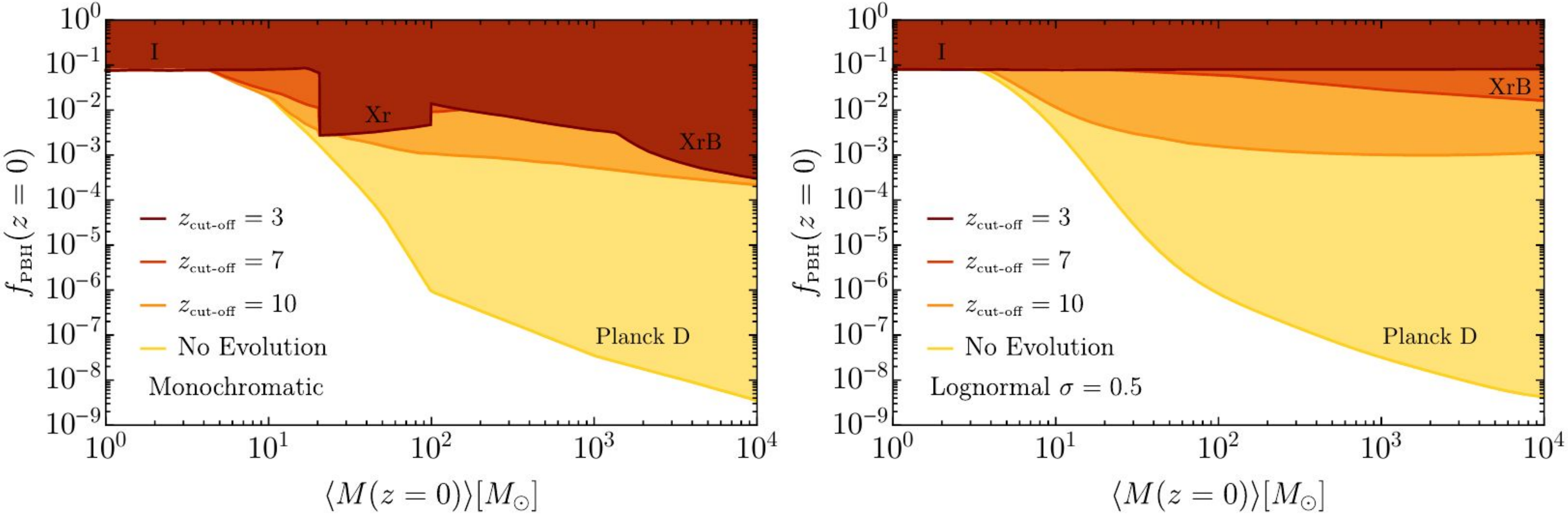

Conclusions and prospects

- Soft constraints at a few solar masses are specially important to address the question of the origin of BH in LIGO/VIRGO observations

future prospects:

- Impact of LSS, reionization and baryon feedbacks onto accretion;
- Effects of accretion at f_PBH~1 (w/o consider DM halo)