Amherst Center for Fundamental Interactions
Physics at the interface: Energy, Intensity, and Cosmic frontiers
University of Massachusetts Amherst

Limits on the burst rate of exploding PBHs

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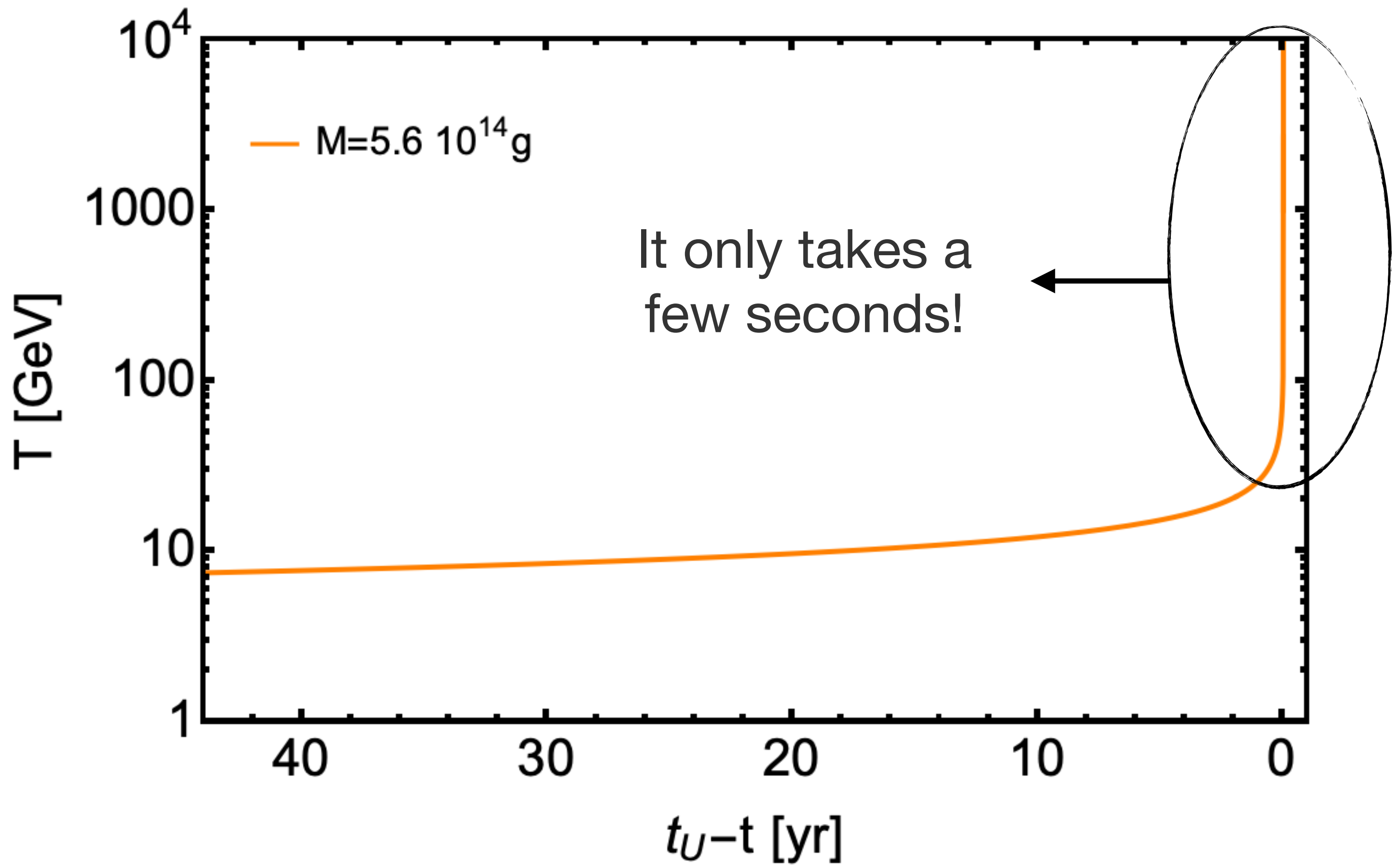
Exploding PBHs

Black hole explosions?
S.W. Hawking. *Nature* 248, 30-31 (1974)



Current HAWC limit is $\dot{n} < 3400\ \mathrm{pc}^{-3}\ \mathrm{yr}^{-1}$

HAWC Collaboration. *JCAP* 04 (2020) 026

Unprecedented observation!

Experimental evidence for **Hawking radiation**

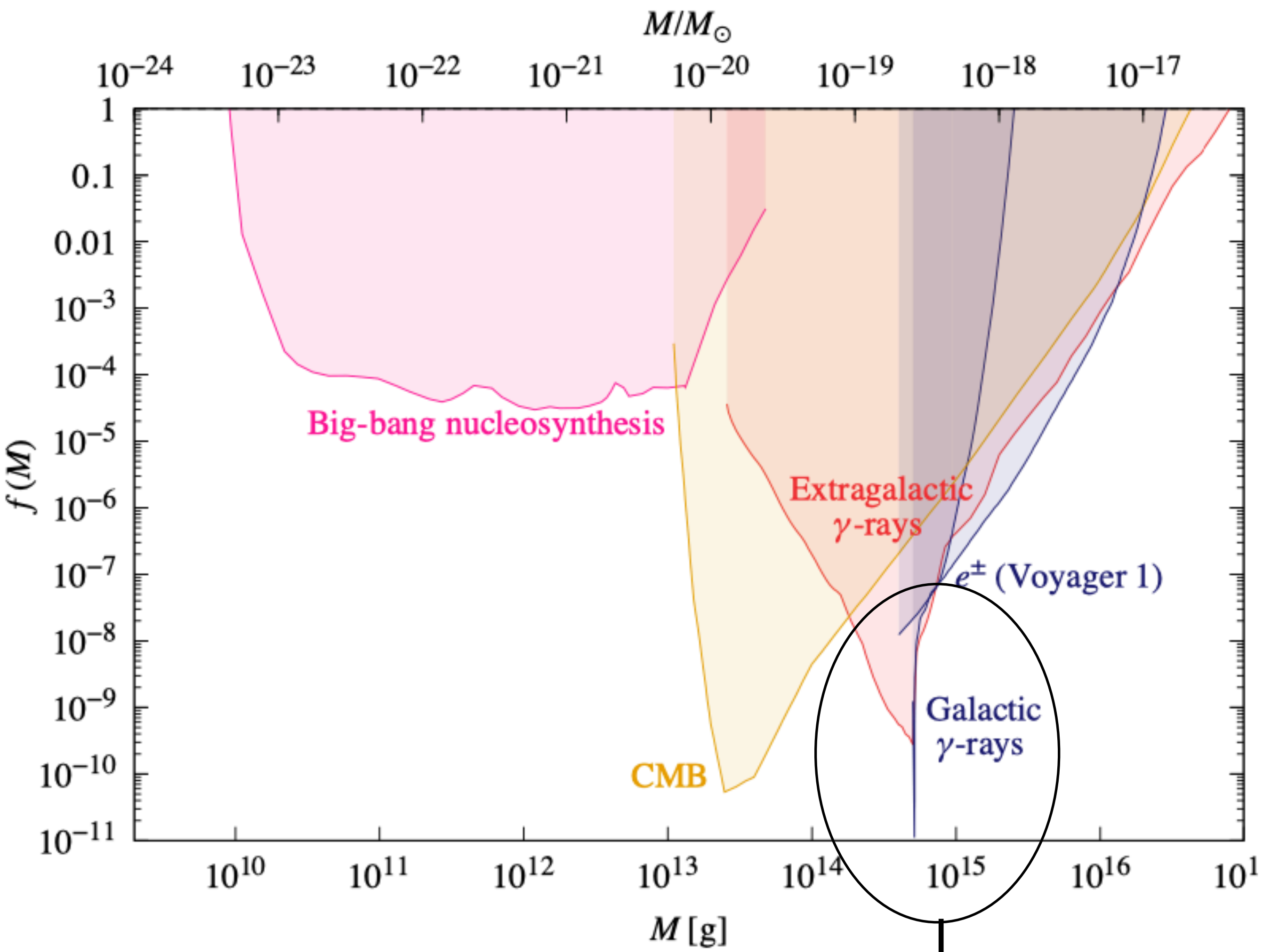
BSM physics
(dark sector secluded from visible sector?)

T.N Ukwatta et al. *Astropart.Phys.* 80 (2016) 90-114
M.J. Baker et al. *SciPost Phys.* 12 (2022) 150
M.J. Baker et al. *JHEP* 01 (2023) 063

Quantum gravity
(physics close to Planck scale)

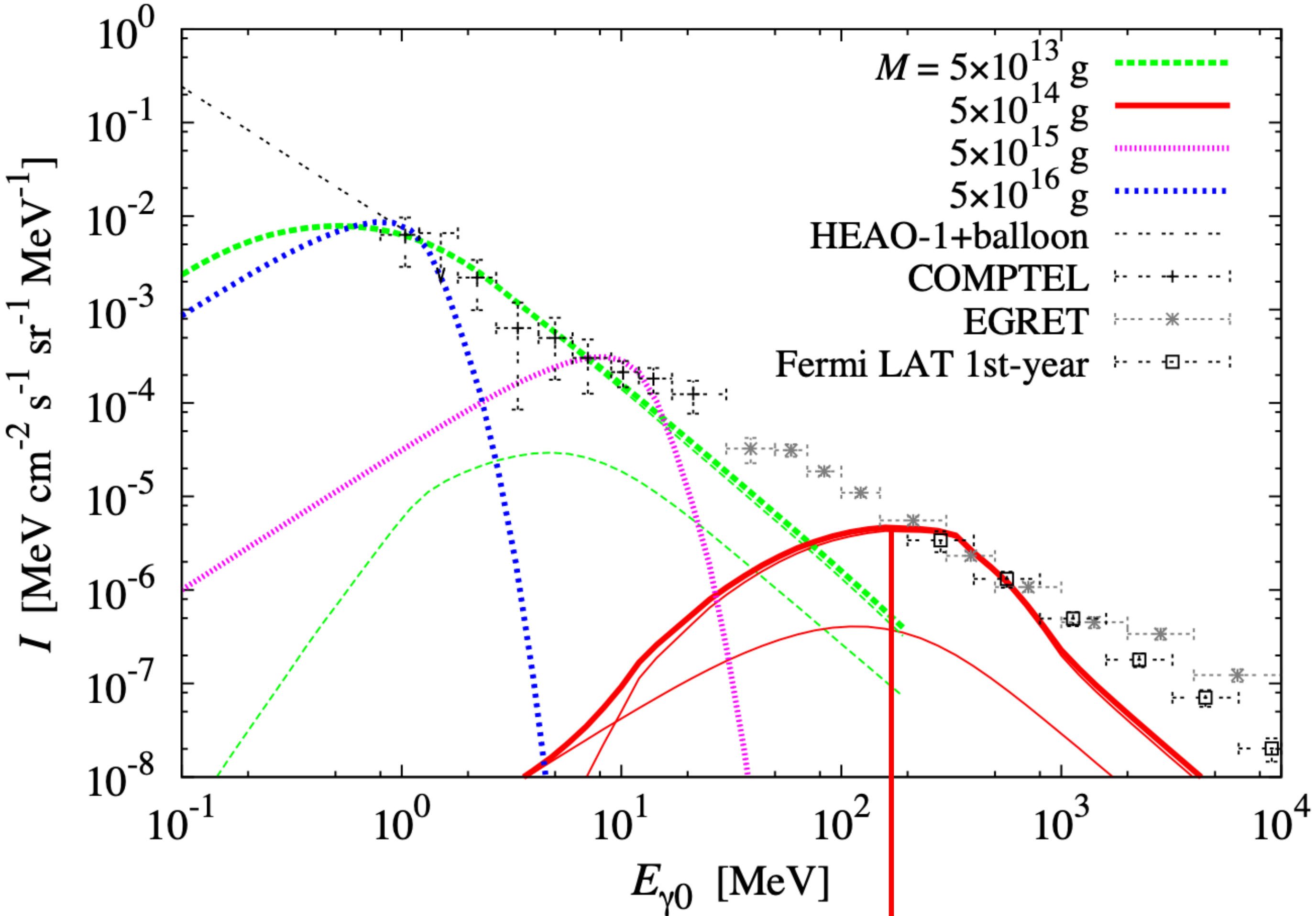
B. Lehmann et al. *JCAP* 10 (2019) 046

Exploding PBHs



Very constrained!

B.J. Carr et al. *PRD* 81 (2010) 104019



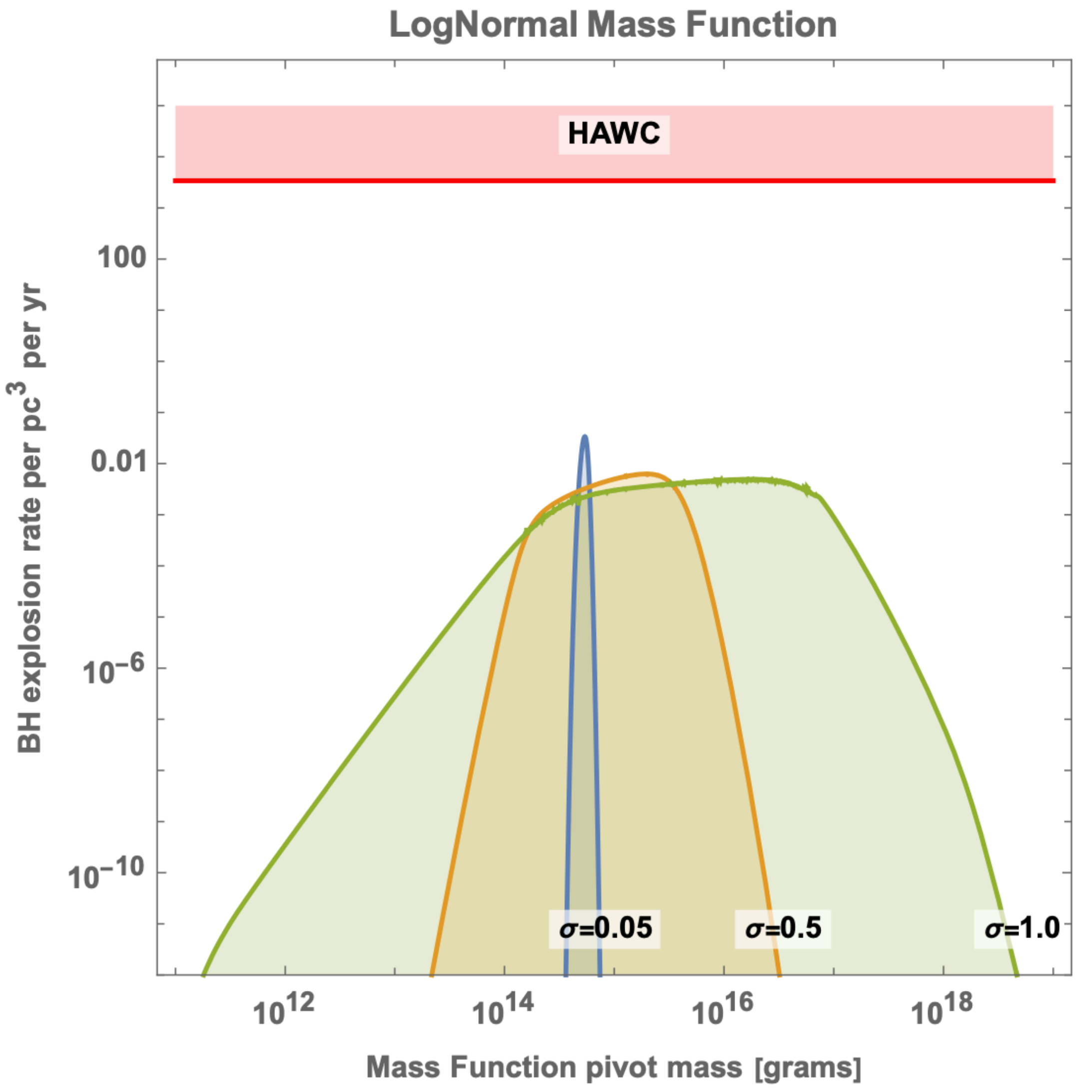
$f_{PBH} \sim 10^{-9}$

We want to maximize burst rate $\dot{n}_{\rm PBH} = \rho_{\rm DM} \dfrac{\psi_i(M_U)}{3t_U}$

How to enhance the burst rate?

Mass function? Most favorable scenario is a monochromatic mass function…

X. Boluna et al. *JCAP* 04 (2024) 024



Interestingly, for log-normal:

$$\psi(M, M_*, \sigma) = \frac{\exp\left(-\frac{\log(M/M_*)^2}{2\sigma^2}\right)}{\sqrt{2\pi}\sigma M}$$

$$\dot{n}_{\rm PBH} \simeq \frac{1.2 \times 10^{-3}\ {\rm pc}^{-3}{\rm yr}^{-1}}{\sigma}$$

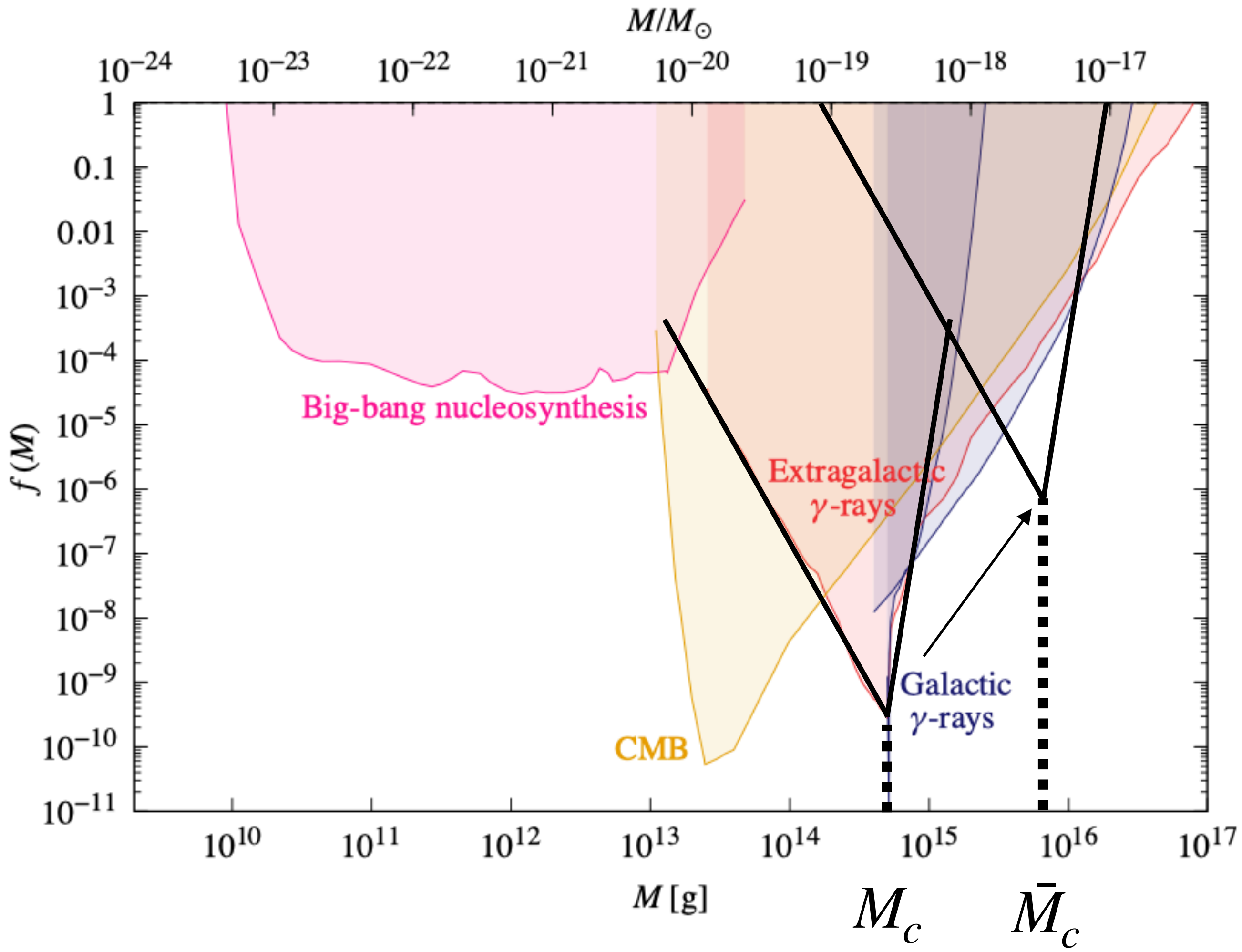
$$\Downarrow$$

‘for sufficiently small σ the HAWC constraints are the strongest constraints on f_{PBH}’

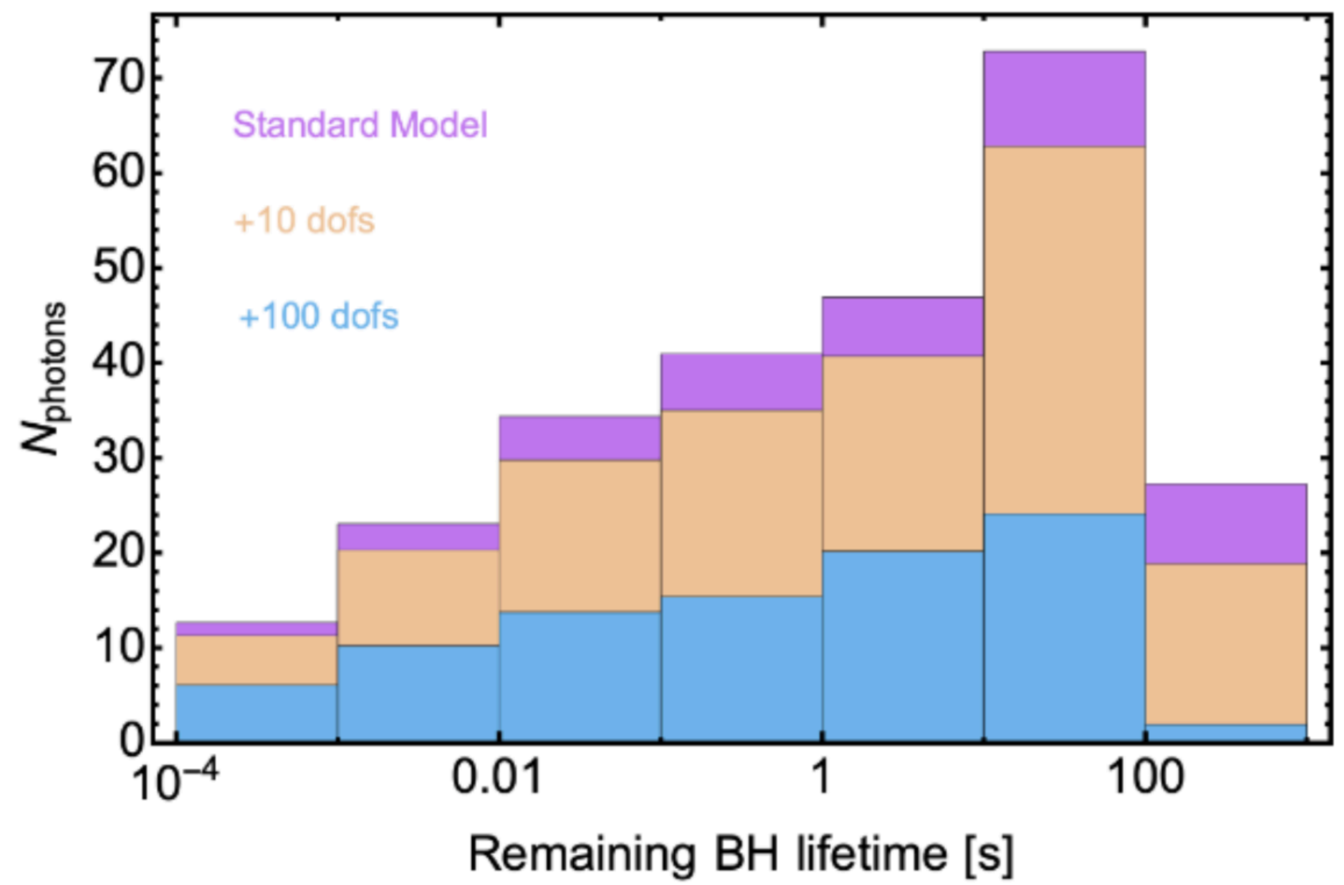
X. Boluna et al. *JCAP* 04 (2024) 024

How to enhance the burst rate?

New dark light dofs? It shifts $M_c \to \bar{M}_c = t(\#dofs) \times M_c \implies \dot{n}_{\bar{M}_c} \simeq t^{2.3} \dot{n}_{M_c}$



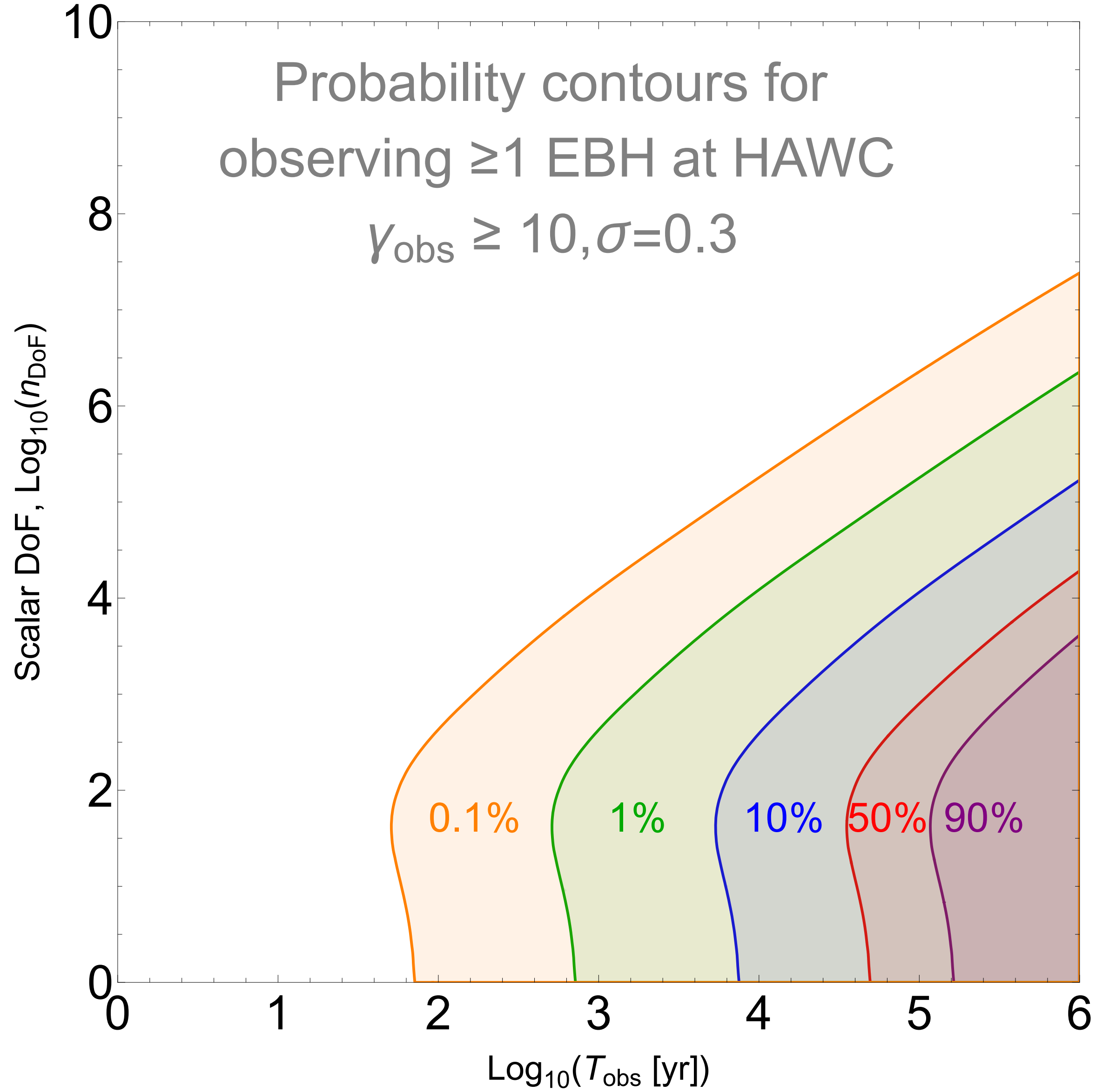
$E_\gamma \geq 10^3$GeV For a PBH at 0.01pc from Earth



But at the same time, the addition of new DoFs also suppresses direct observations!

New degrees of freedom

HAWC observation probability contours within first zenith band.



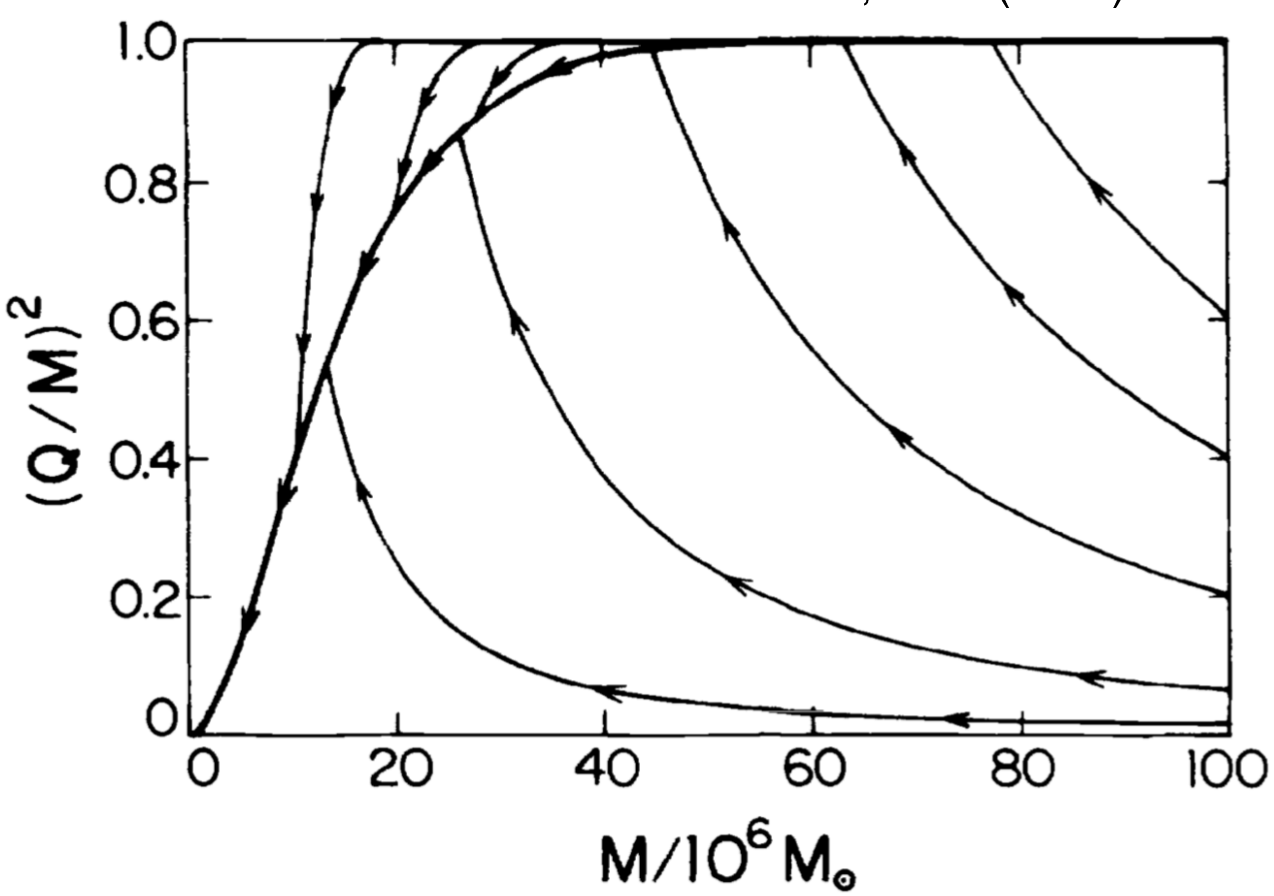
Log-normal mass distribution

$$\psi(M, M_*, \sigma) = \frac{\exp\left(-\frac{\log(M/M_*)^2}{2\sigma^2}\right)}{\sqrt{2\pi}\sigma M}$$

How else to enhance the burst rate?

Beyond SM and Schwarzschild black holes:

W. A. Hiscock et al. *PRD* 41, 1142 (1990)



Discharge due to Schwinger effect.

$$\frac{d\Gamma}{dV} = \frac{e^2}{4\pi^3}\frac{Q^2}{r^4}\sum_{n=1}^{\infty}\frac{1}{n^2}\exp\left(\frac{-\pi n m^2 r^2}{eQ}\right)$$

$$T_{RN}(Q^* = Q/M \to 1) \ll T_{Sch}$$

- ✔ γ emission suppressed, so weakens contribution to indirect bounds
- ✘ Accretion will neutralize BH in astrophysical setup
- ✘ PBHs are too massive (no explosions)
- ✘ Timescales are too long!

Beyond SM and Schwarzschild black holes

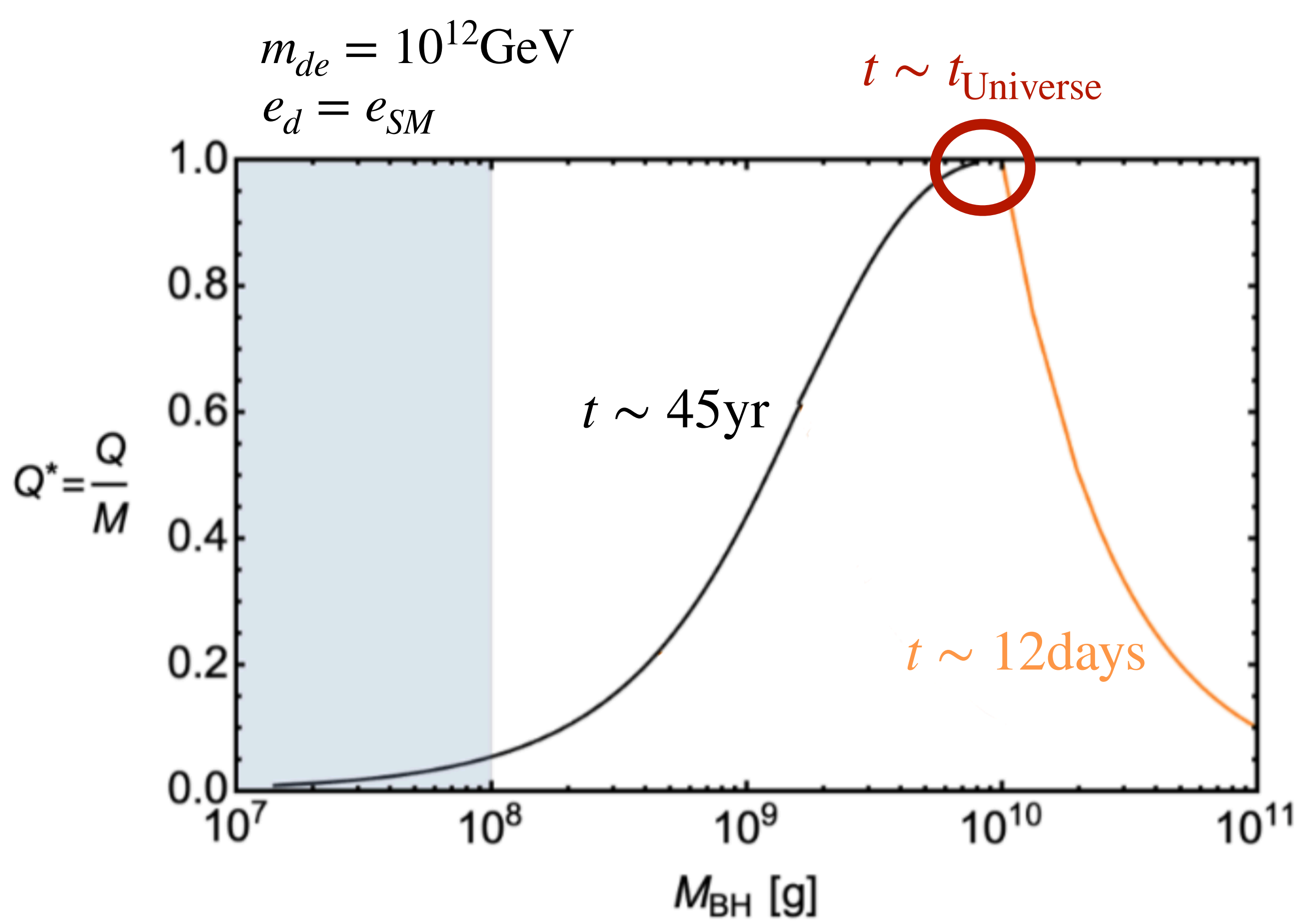
Y. Bai et al. *PRD* 101 (2020) 5, 055006

Introduce massive dark electron.

Viable PeBH formation mechanism.

$\Longrightarrow$

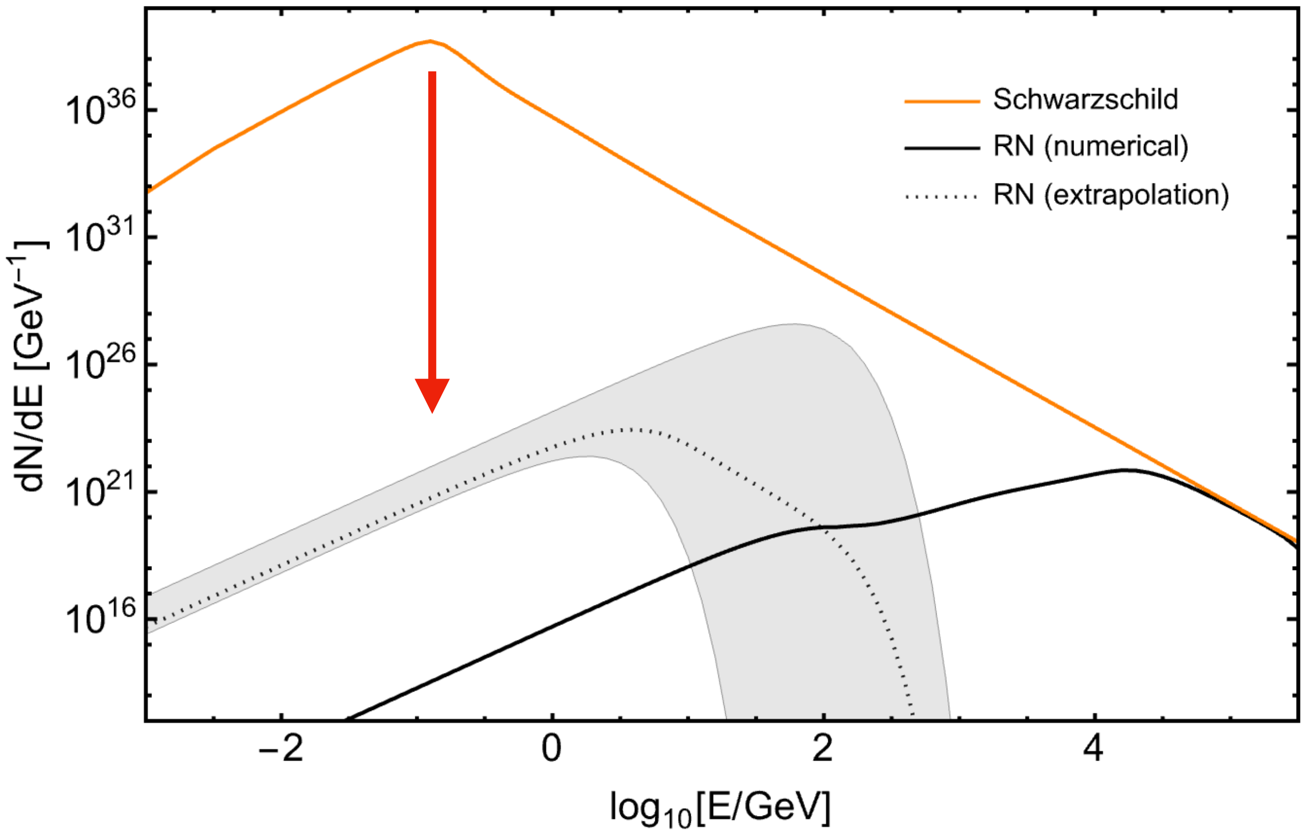
- Schwinger effect (fast)
- Light PBHs
- PBH spends most of its time being extremal

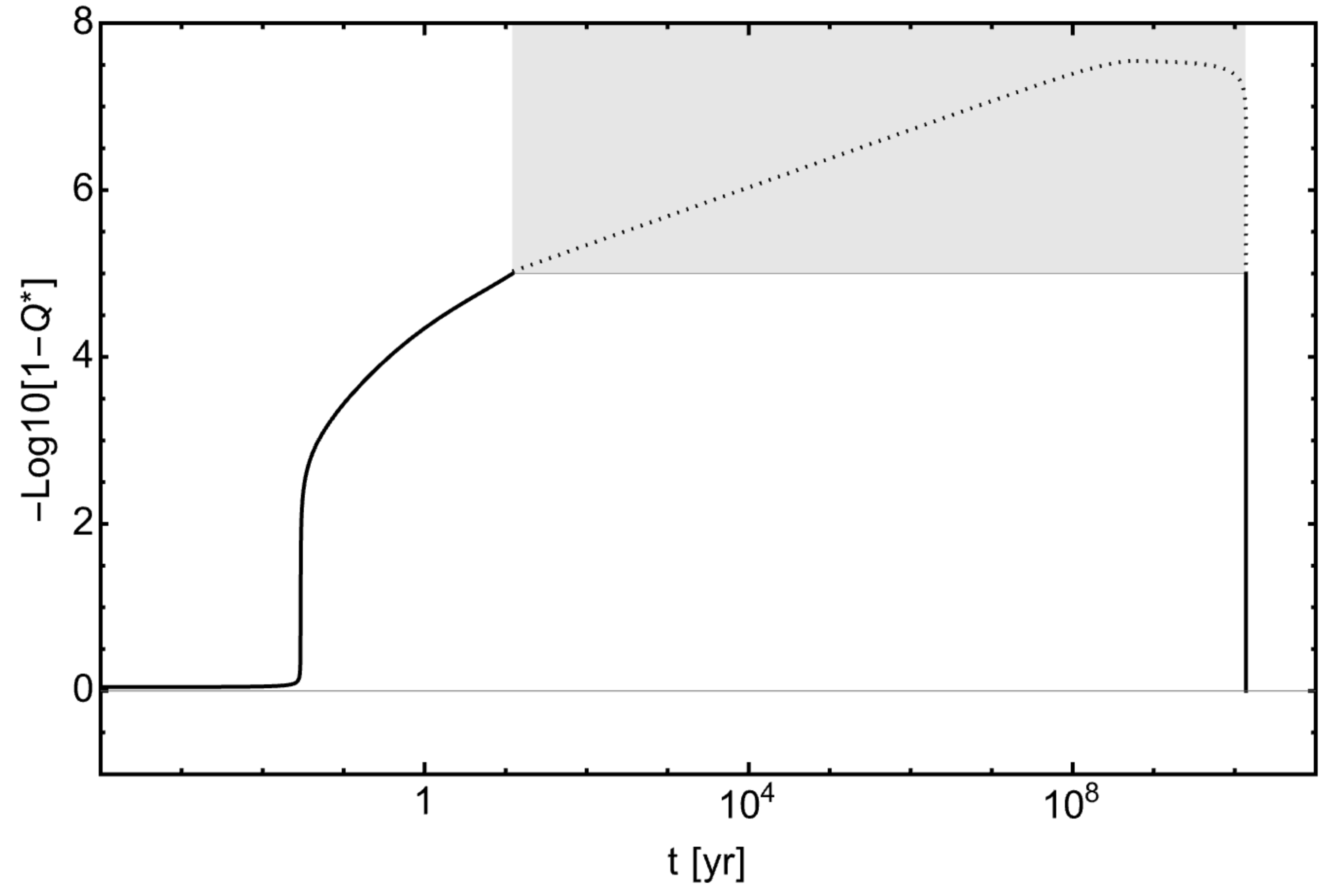


Can be realized in large portion of parameter space for the dark model.

Beyond SM and Schwarzschild black holes

The photon flux at energies around 100 MeV will be largely suppressed.





This (hopefully) allows for an enhanced **number density** consistent with indirect bounds.

$\Longrightarrow$ Larger burst rates are allowed! $\Longrightarrow$ We may soon observe an EBH!

Conclusions

The observation of an exploding black hole would be an unprecedented event and would offer insights on fundamental physics topics.

We have the technological capacity (e.g. HAWC) to observe such event. However, there are very stringent constraints on the population of exploding black holes.

EXTRA DOFS

Extra dofs provide a slight enhancement of the burst rate.

For realistic mass distributions the required time of observation is too long.

A window of opportunity opens when considering extremal black holes.

Larger burst rates are expected, but further analysis is required!

EXTREMAL BHs