Novel Applications of Primordial Black Holes

Michael J. Baker

19th Rencontres du Vietnam – TMEX 2023
07 January 2023

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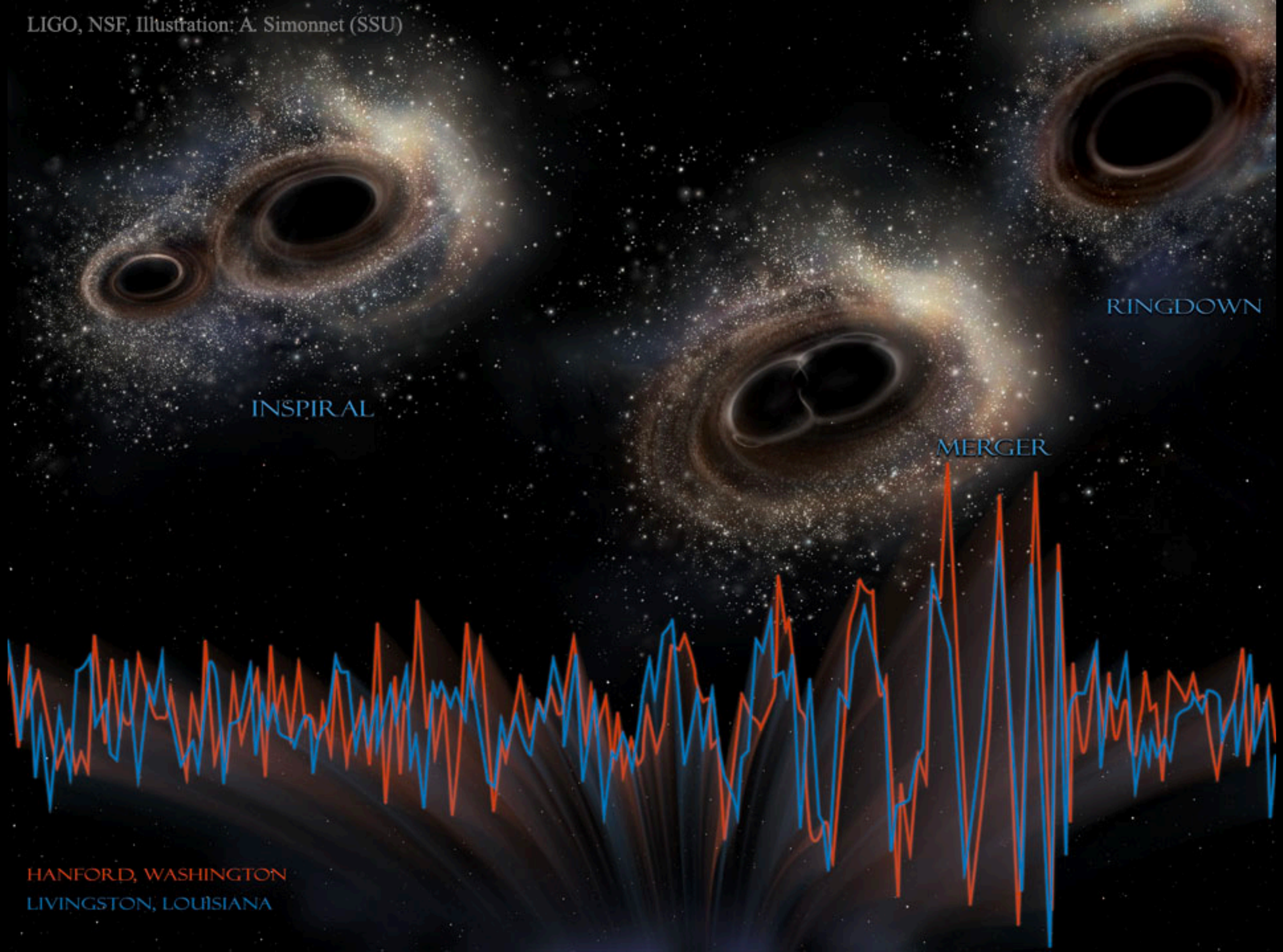
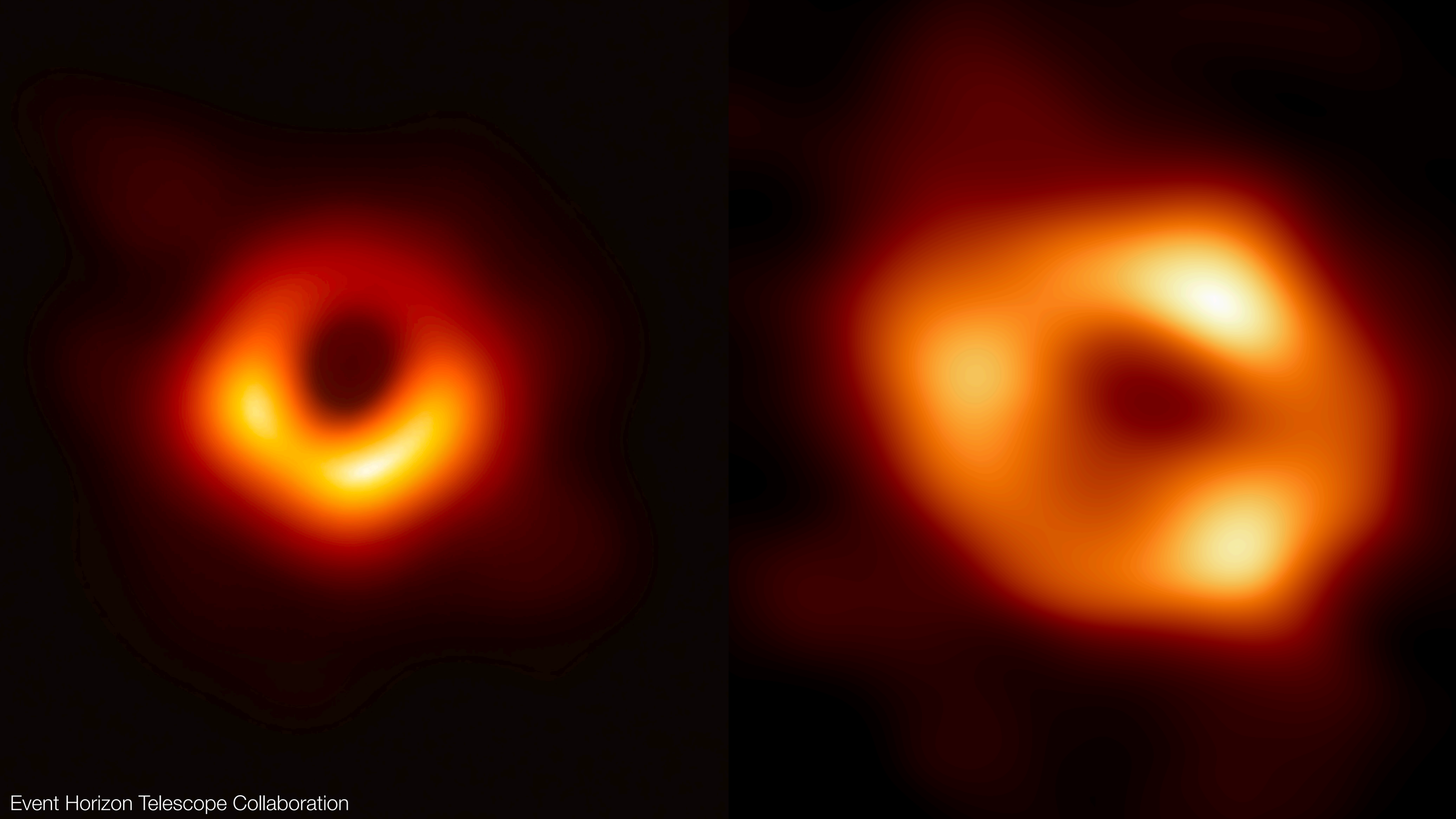

LIGO, NSF, Illustration: A. Simonnet (SSU)
INSPIRAL
MERGER
RINGDOWN
HANFORD, WASHINGTON
LIVINGSTON, LOUISIANA

Event Horizon Telescope Collaboration



Event Horizon Telescope Collaboration

Hawking Radiation

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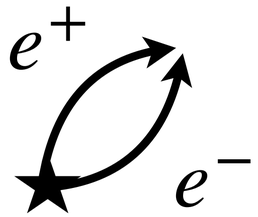

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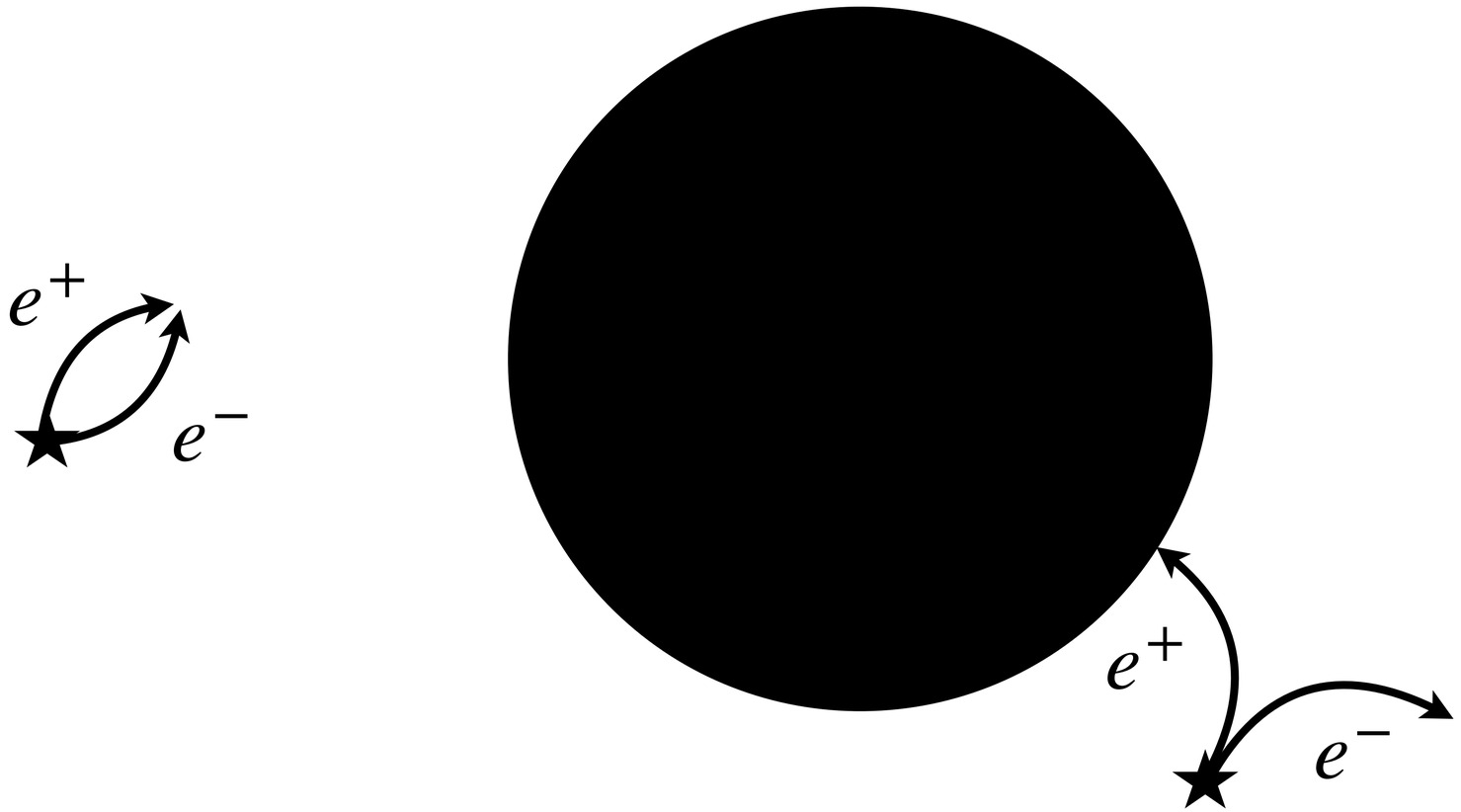

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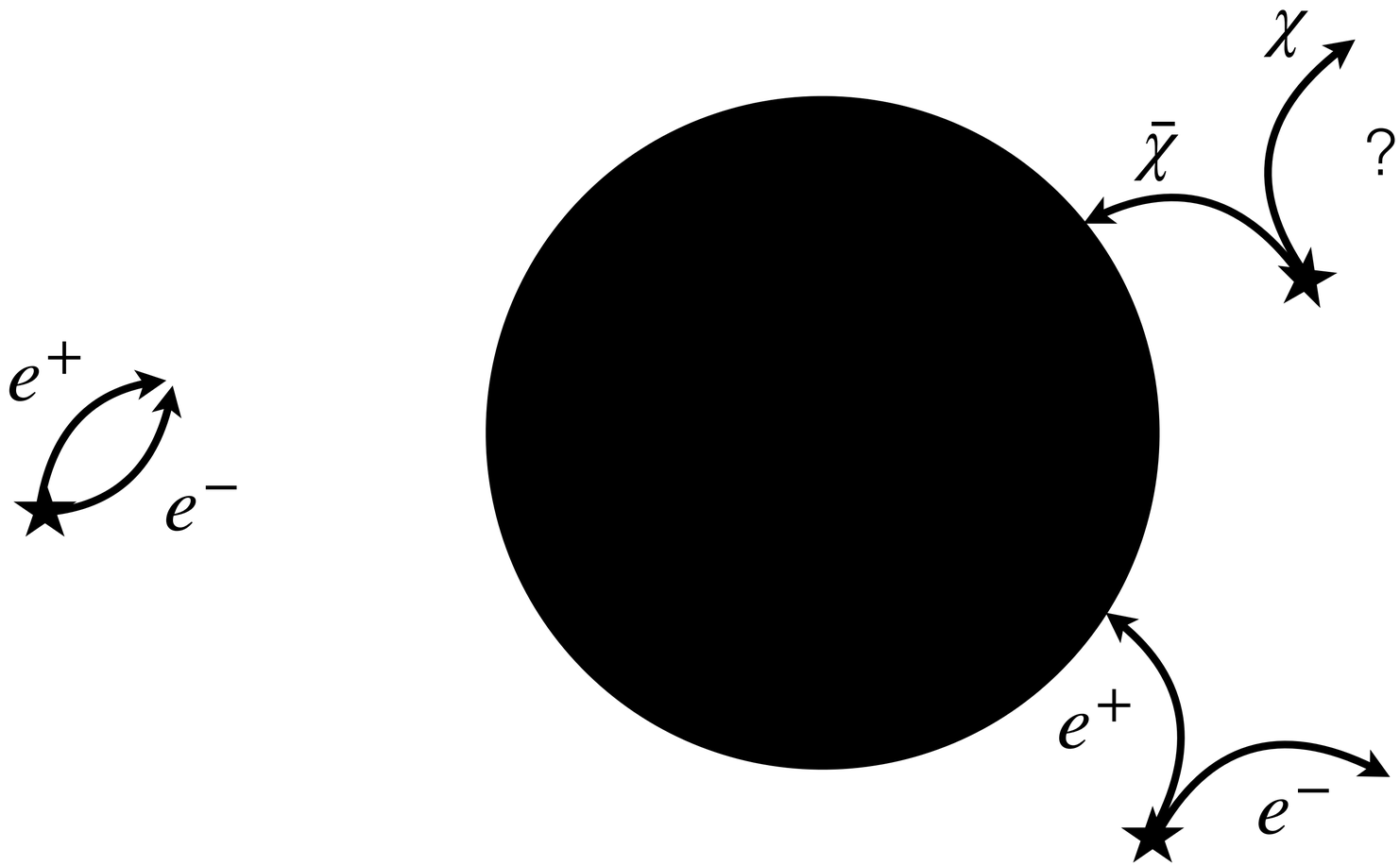

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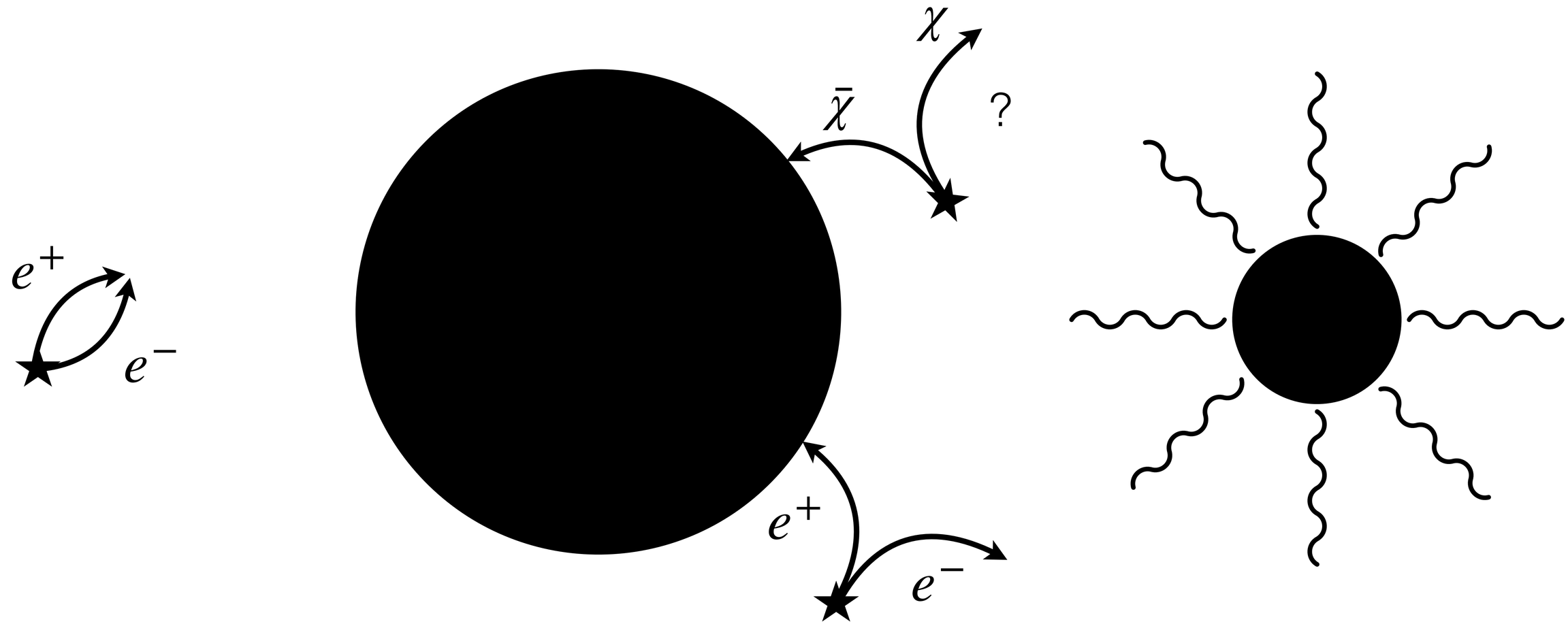
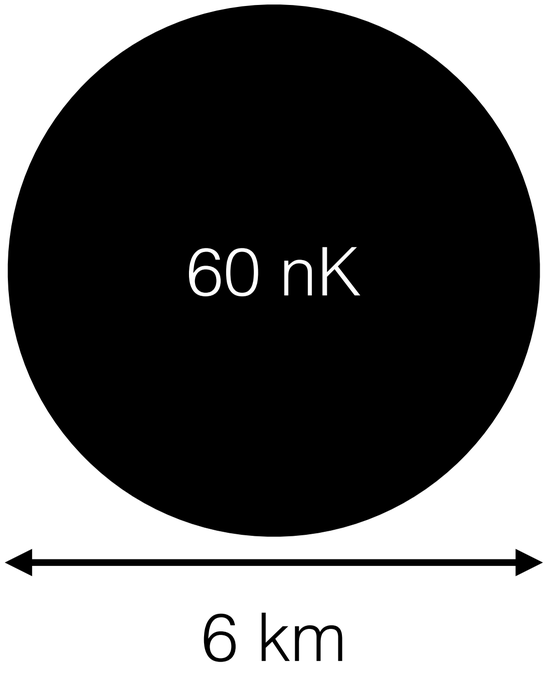


Hawking Radiation

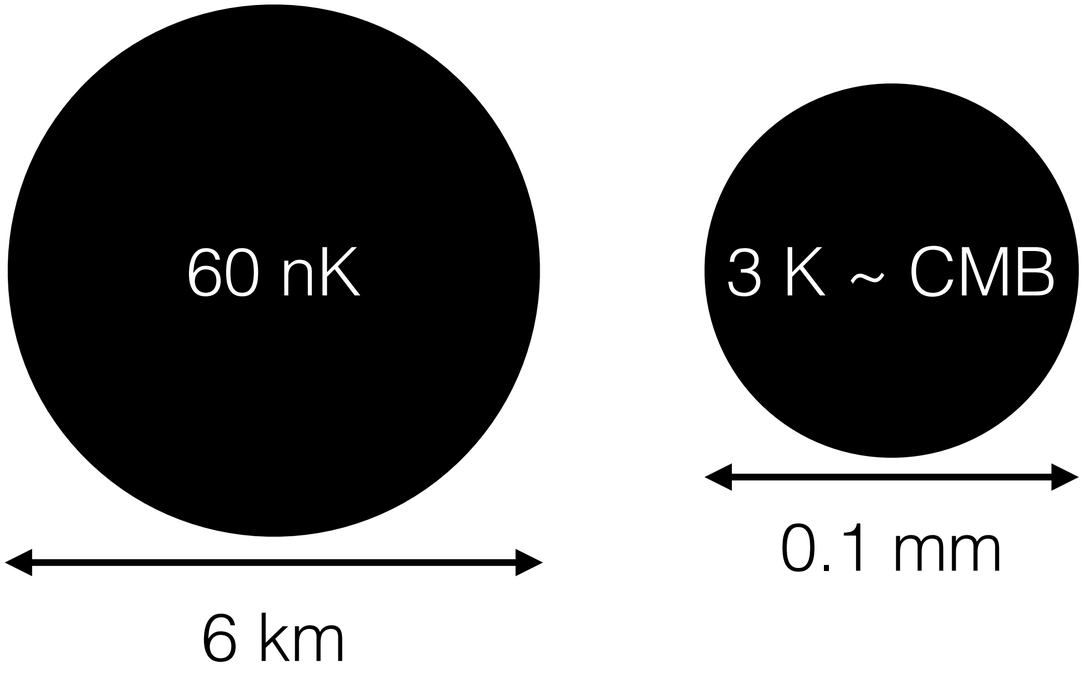
Mass: Sun



Lifetime: 10^{67} years

Hawking Radiation

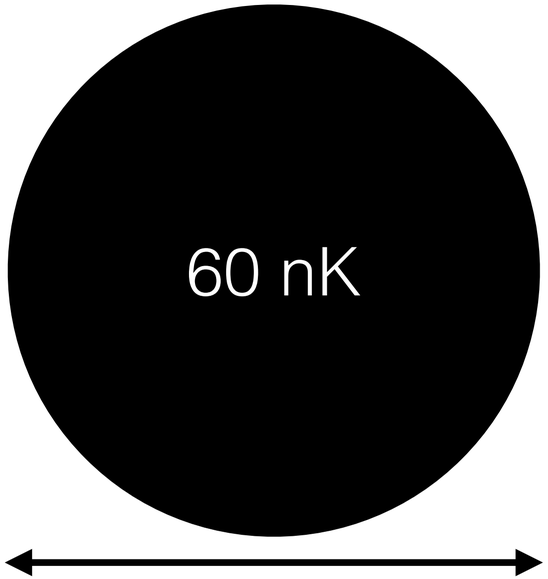
Mass: Sun Moon

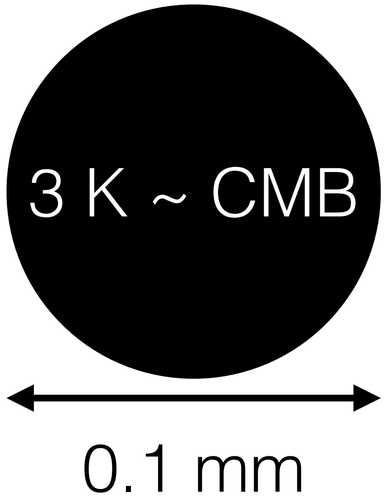


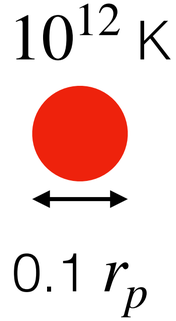
Lifetime: 10^{67} years 10^{44} years

Hawking Radiation

Mass: Sun Moon 10 x







Lifetime: 10^{67} years 10^{44} years 13.8 Gyr

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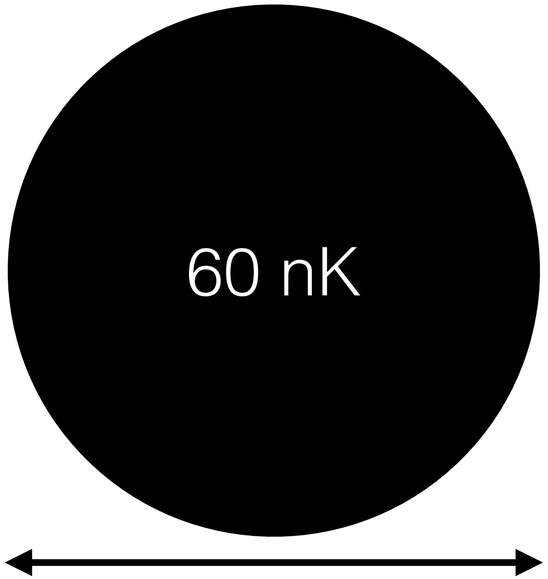

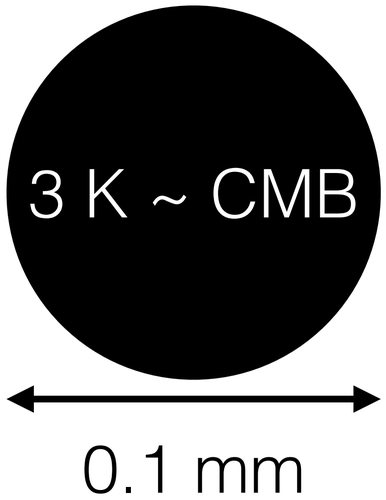

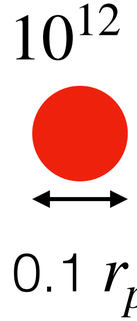

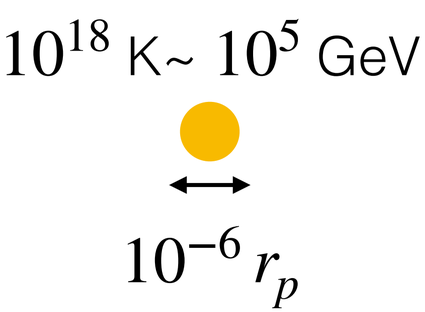

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Primordial Black Holes

Primordial Black Holes

- Motivations
  - Remove unwanted monopoles or domain walls
  - Seeds for SMBHs or LSS
  - Dark matter?

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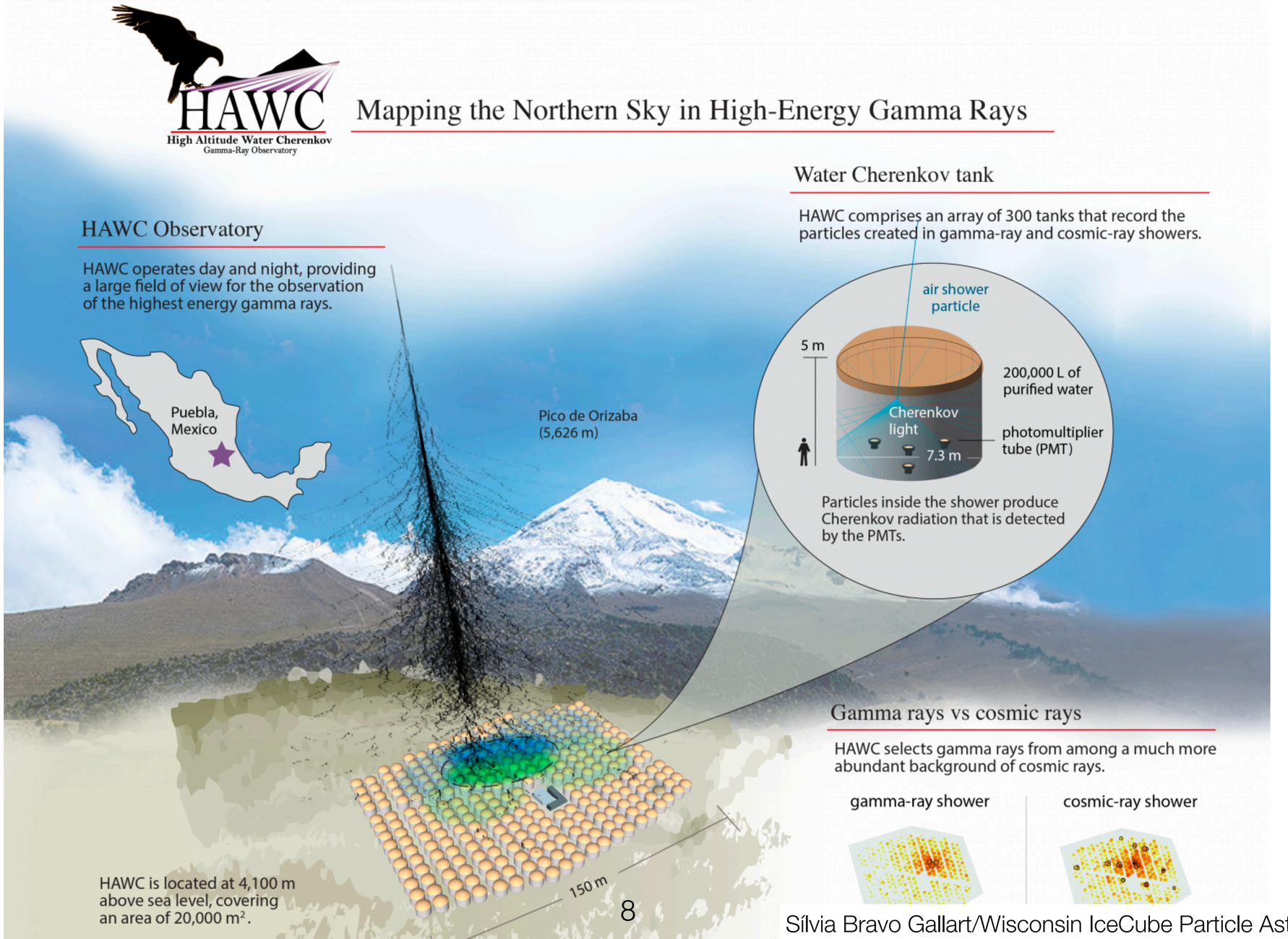
- Motivations
  - Remove unwanted monopoles or domain walls
  - Seeds for SMBHs or LSS
  - Dark matter?
- Production mechanisms
  - Density perturbations generated during inflation
  - Topological defects
  - Scalar condensates
  - First order cosmological phase transition

HAWC Observatory



Sílvia Bravo Gallart/Wisconsin IceCube Particle Astrophysics Center (WIPAC)

Overview

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- We ask the question:
  - What could we learn about BSM physics if an evaporating black hole were observed today?

Outline

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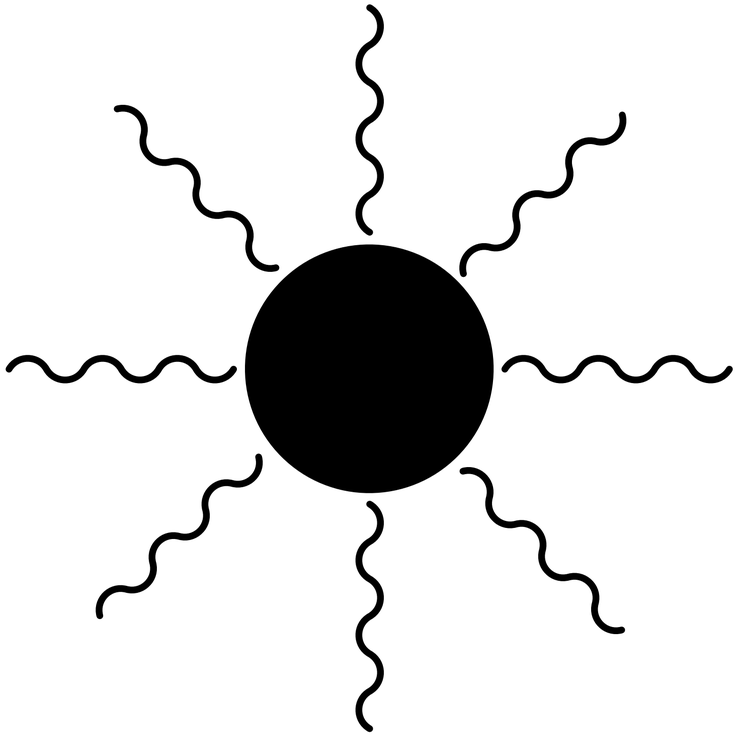
- Black Hole Evaporation
  - Standard Model
  - Beyond the Standard Model
- Conclusions

Primary Particles and Mass Evolution



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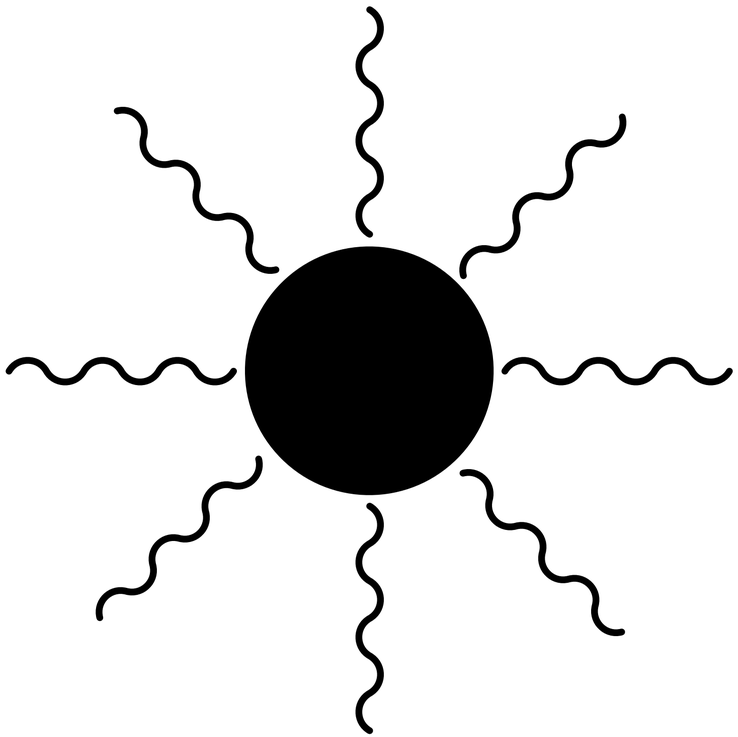

$$\frac{d^2 N_{\mathrm{p}}^i}{dt dE} = \frac{n_{\mathrm{dof}}^i \Gamma^i(M, E)}{2\pi(e^{E/T} \pm 1)}$$

$$T = \frac{1}{8\pi GM}$$

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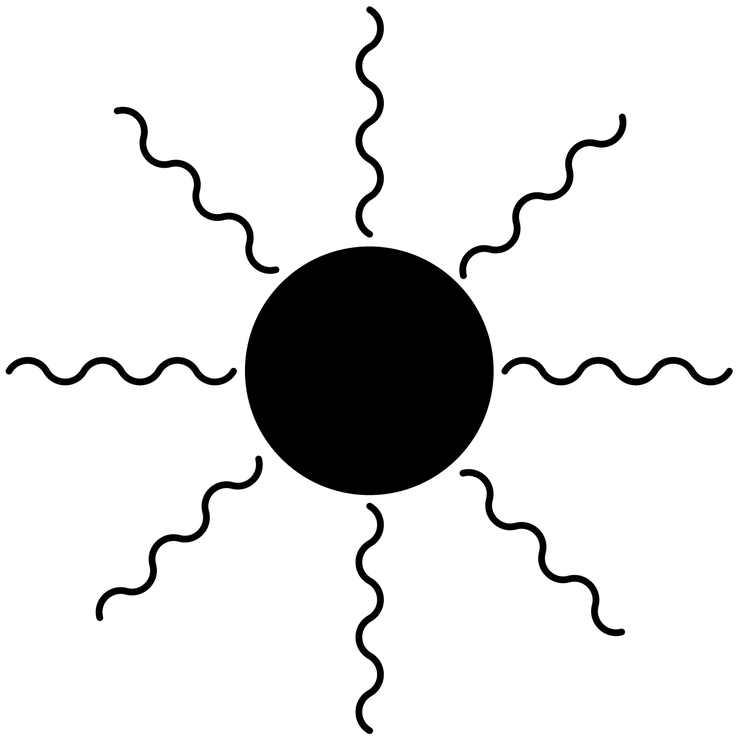

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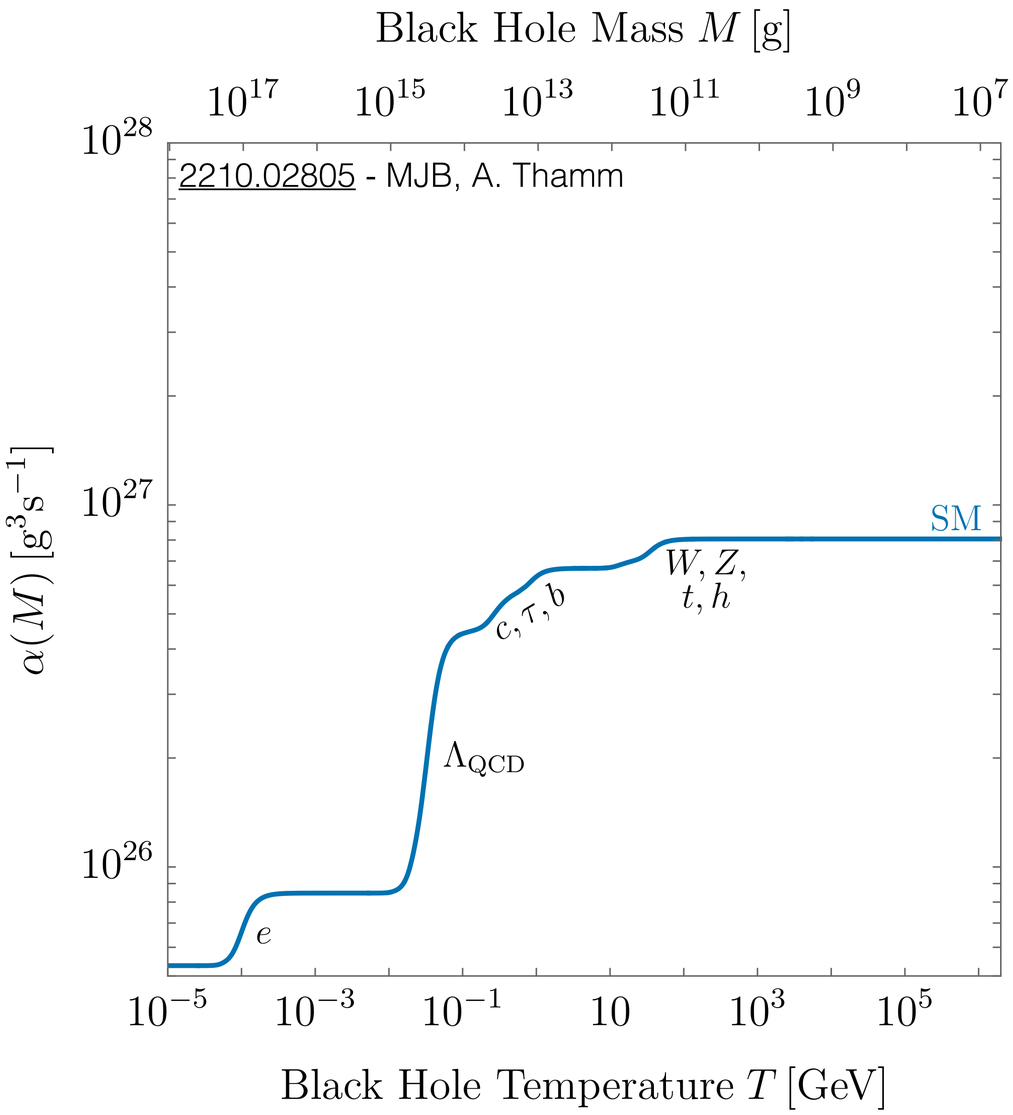

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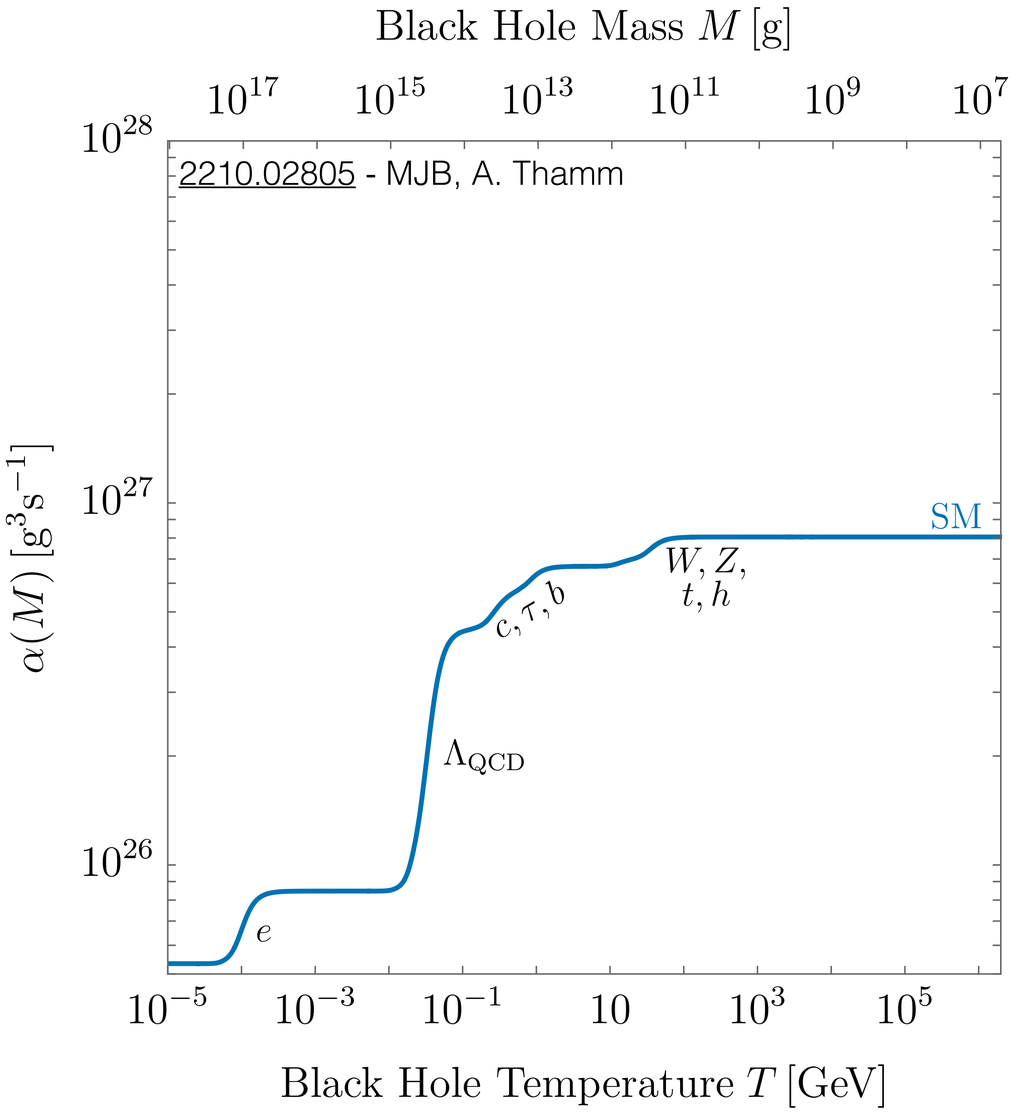
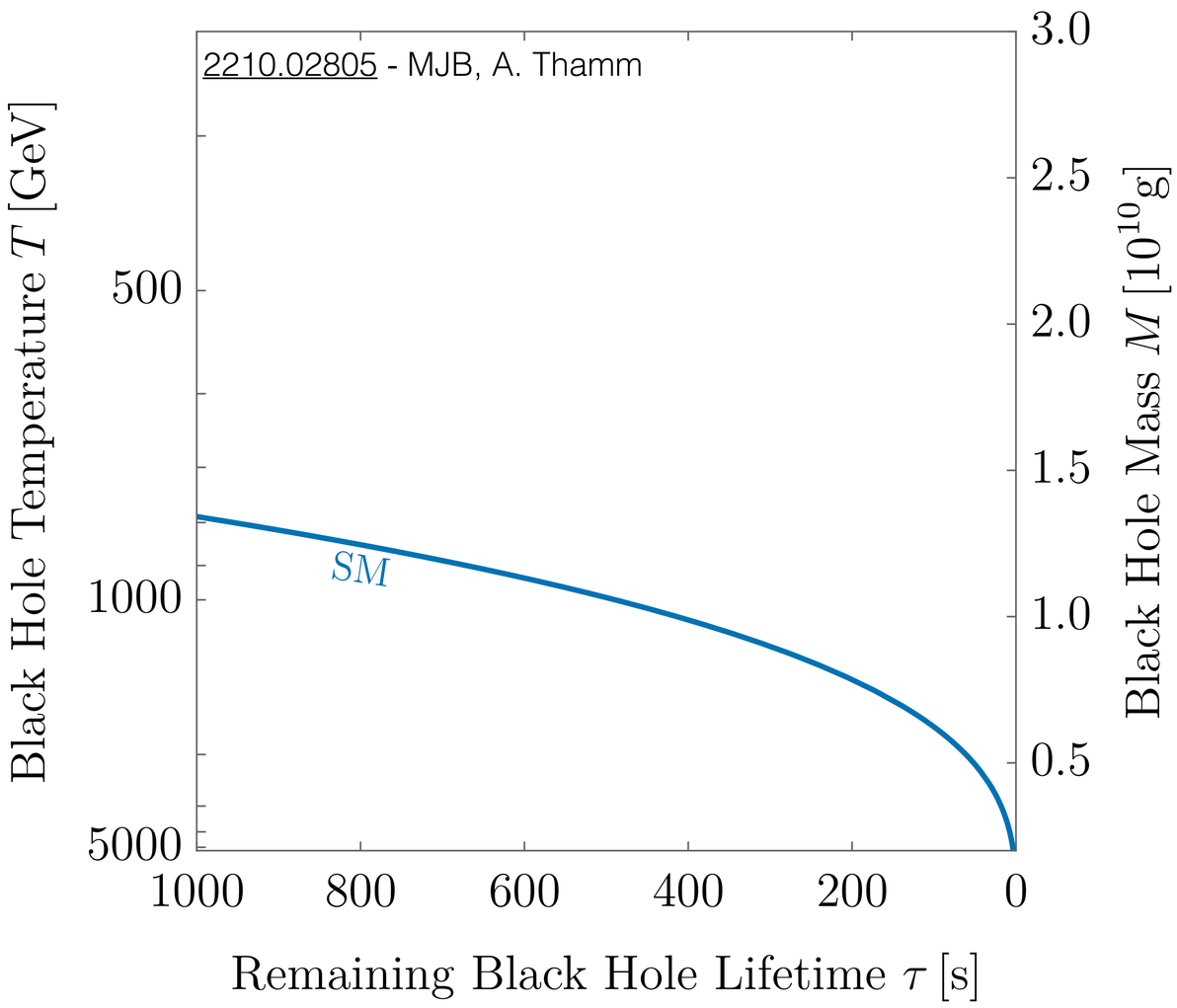
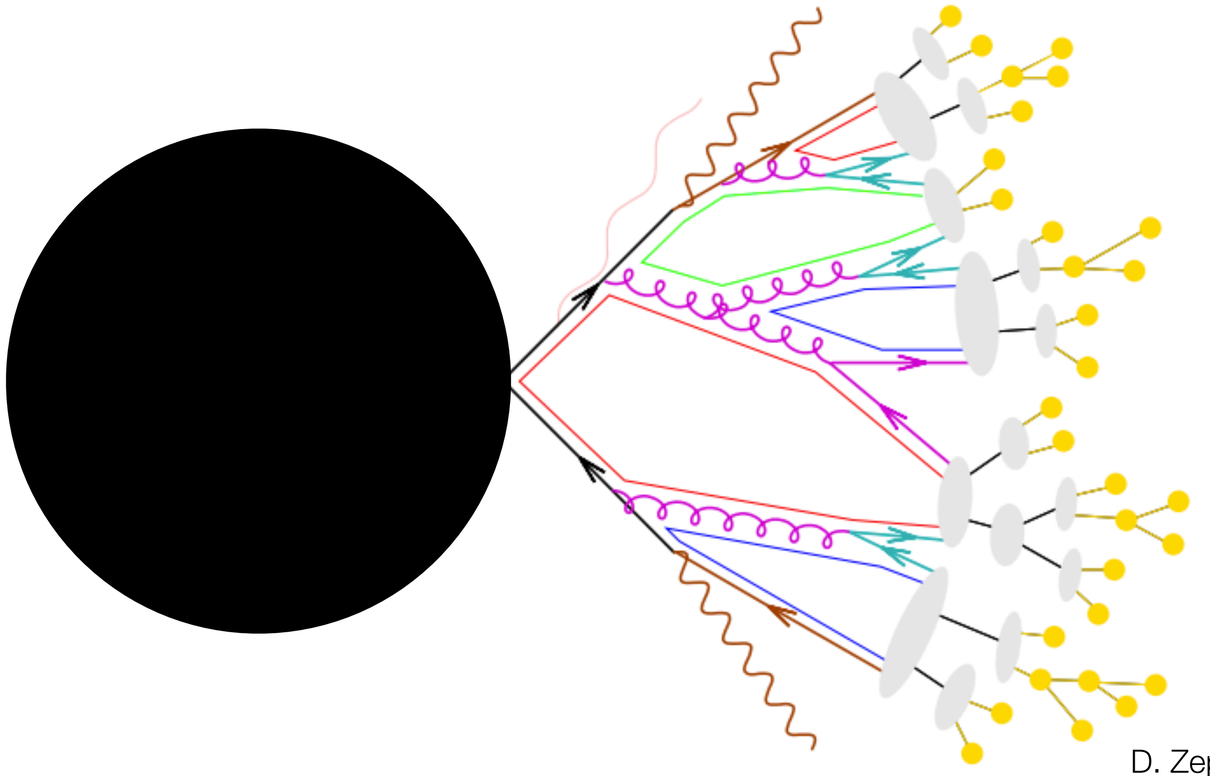




Secondary Photons



D. Zeppenfeld

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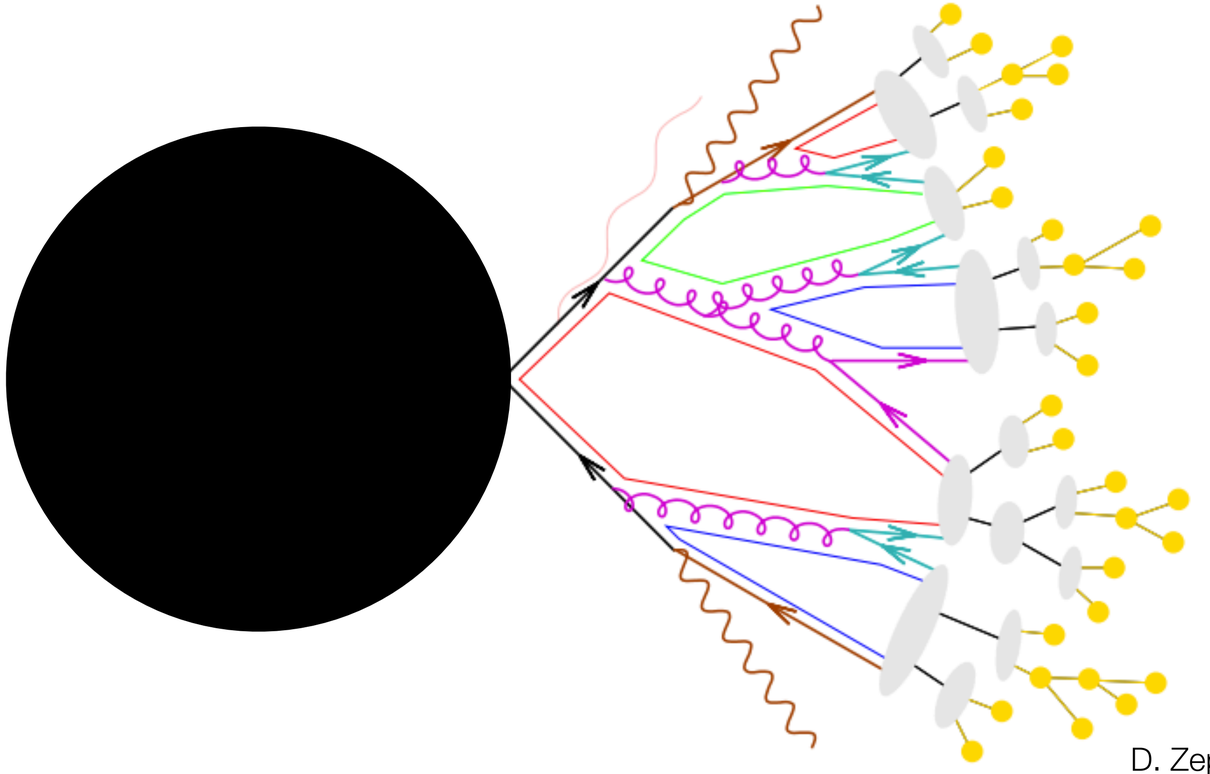

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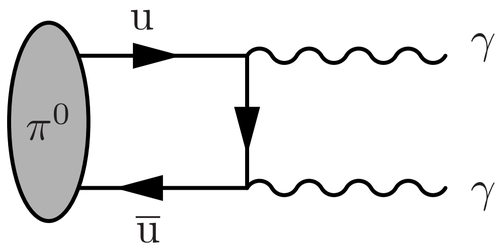

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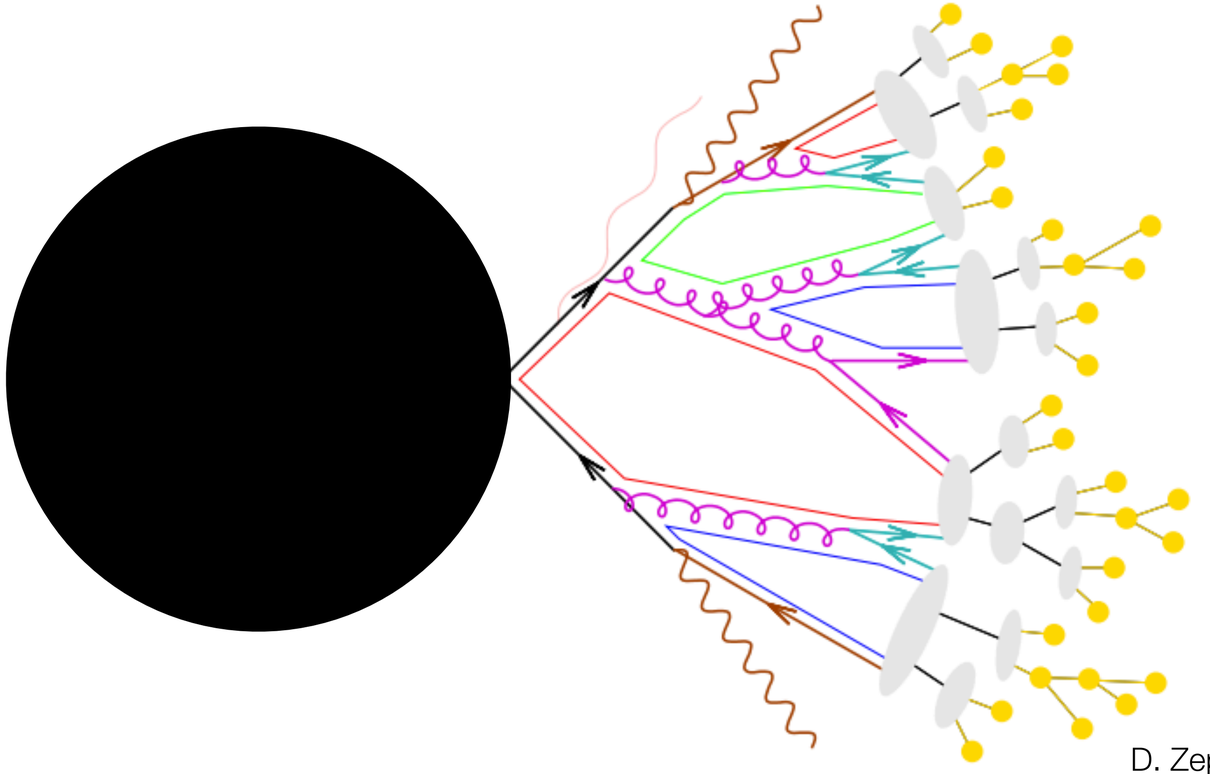

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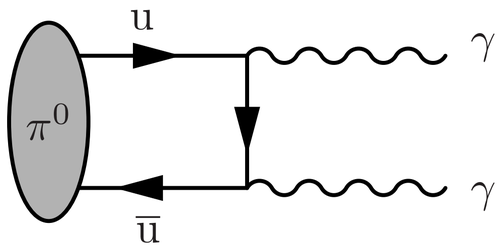
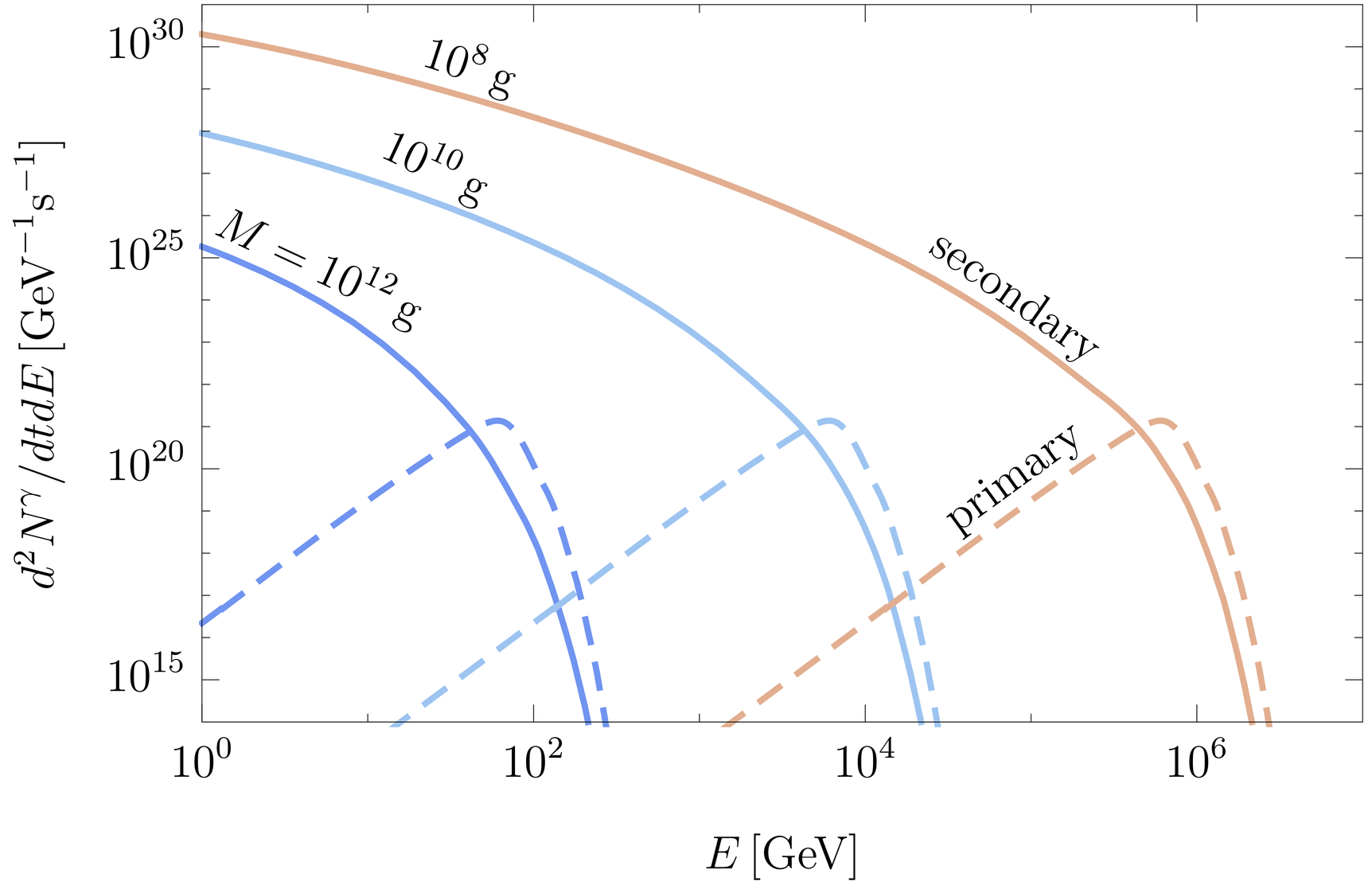
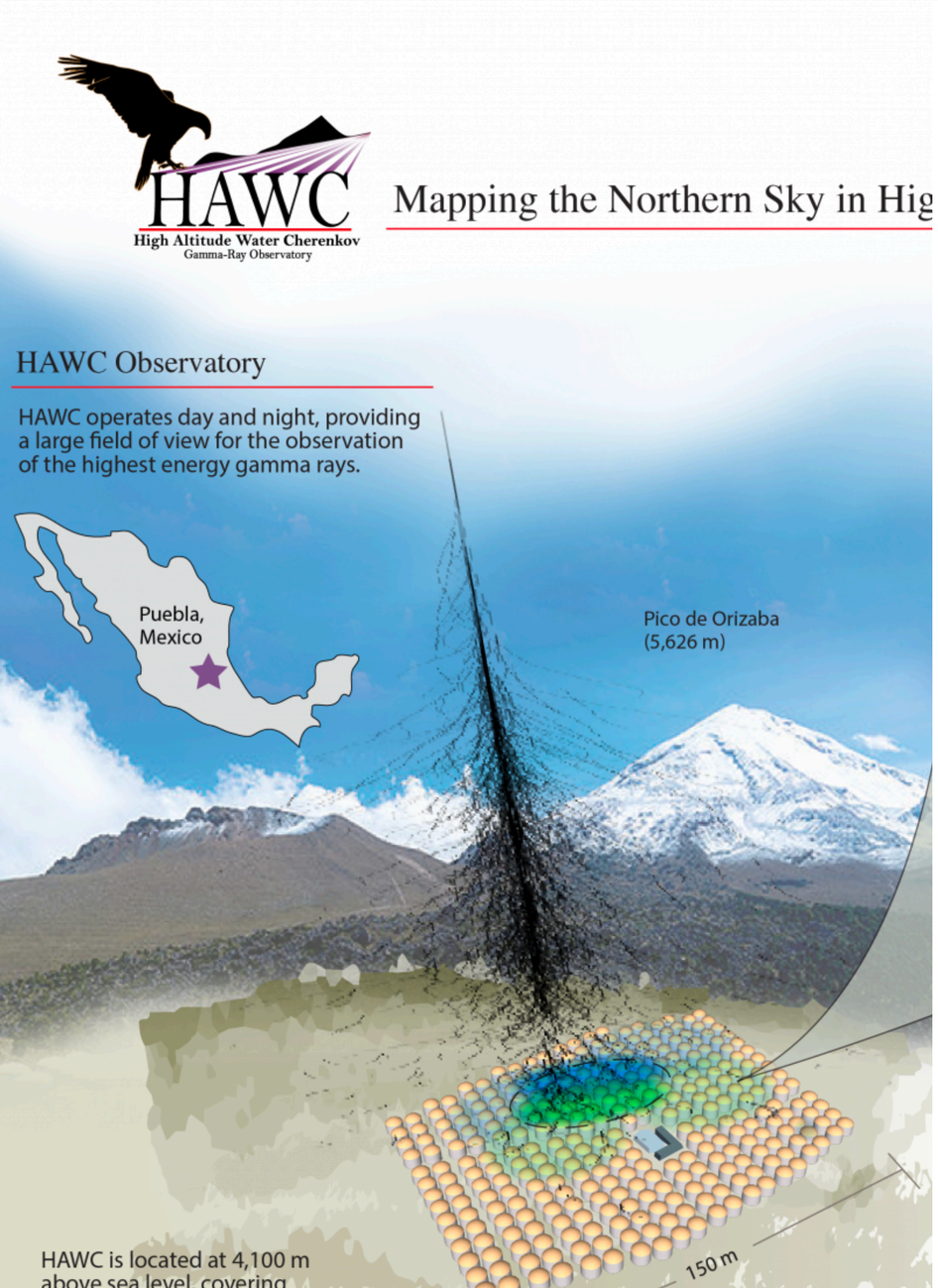


$$\frac{d^2 N_{\mathrm{s}}^{\gamma}}{dt dE} = \sum_i \int_0^{\infty} \frac{d^2 N_{\mathrm{p}}^{i}}{dt dE_{\mathrm{p}}}(M, E_{\mathrm{p}}) \frac{dN^{i\to\gamma}}{dE}(E_{\mathrm{p}}, E) dE_{\mathrm{p}}$$

Primary and Secondary Photon Spectra



Photon Spectra at HAWC



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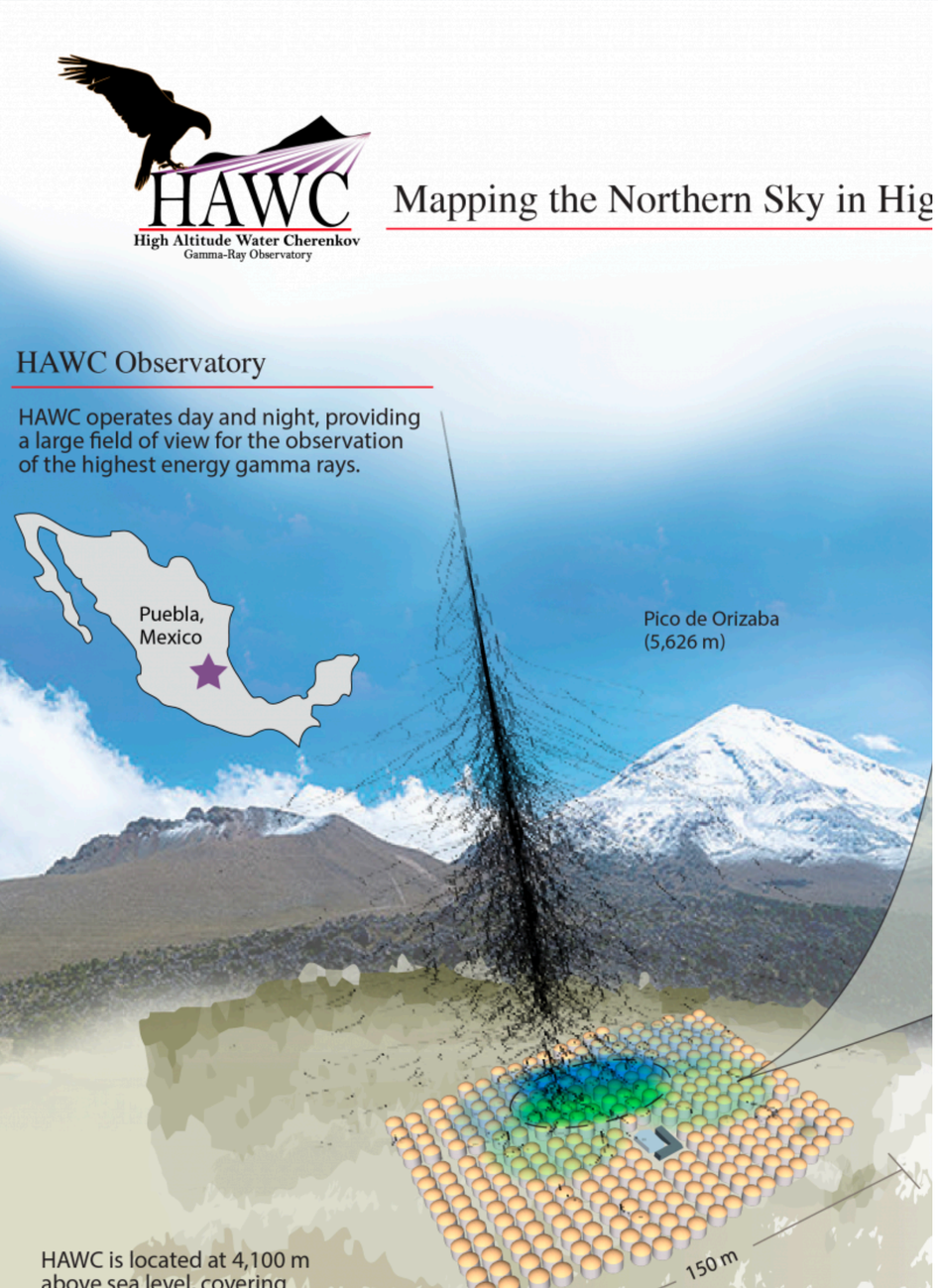

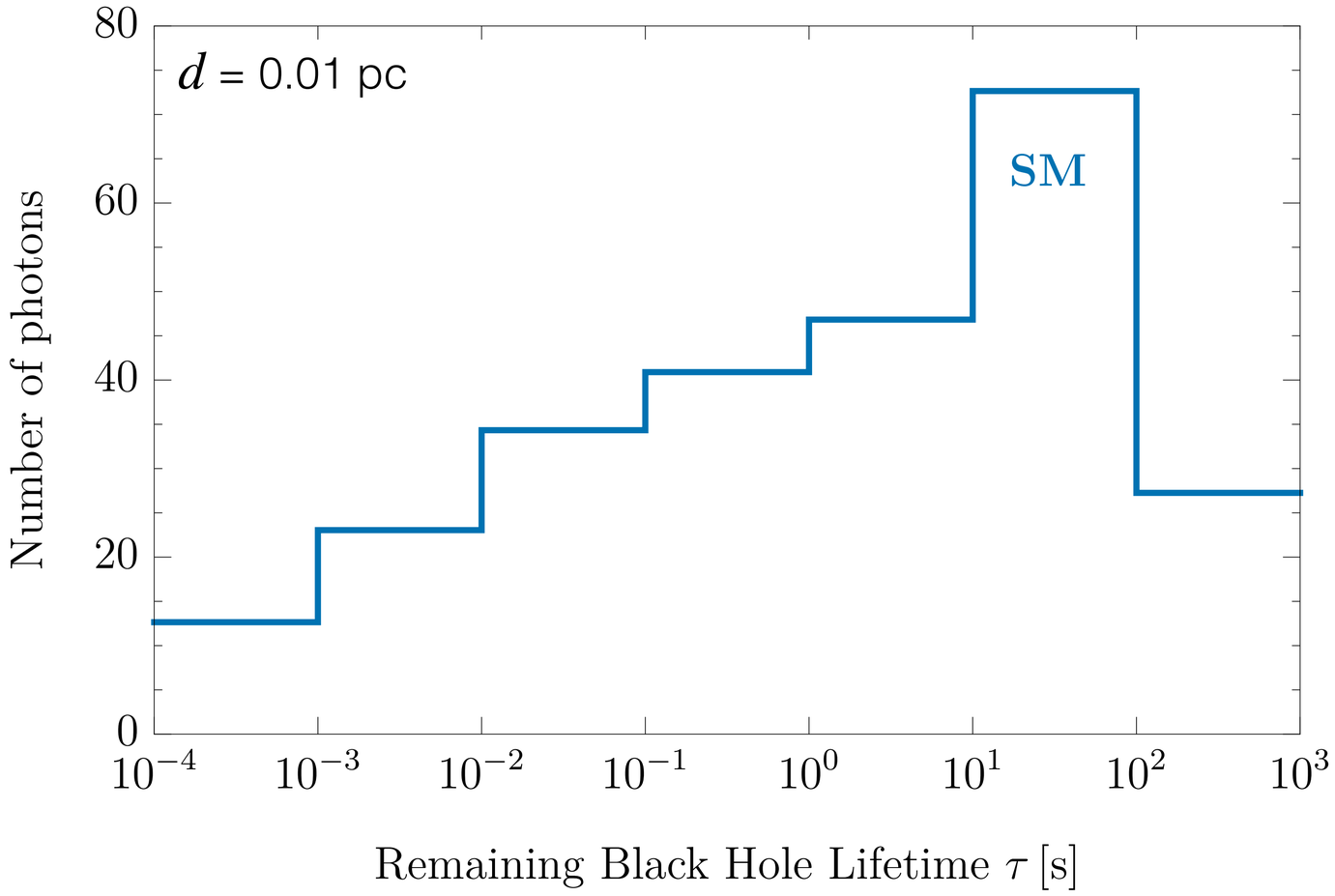

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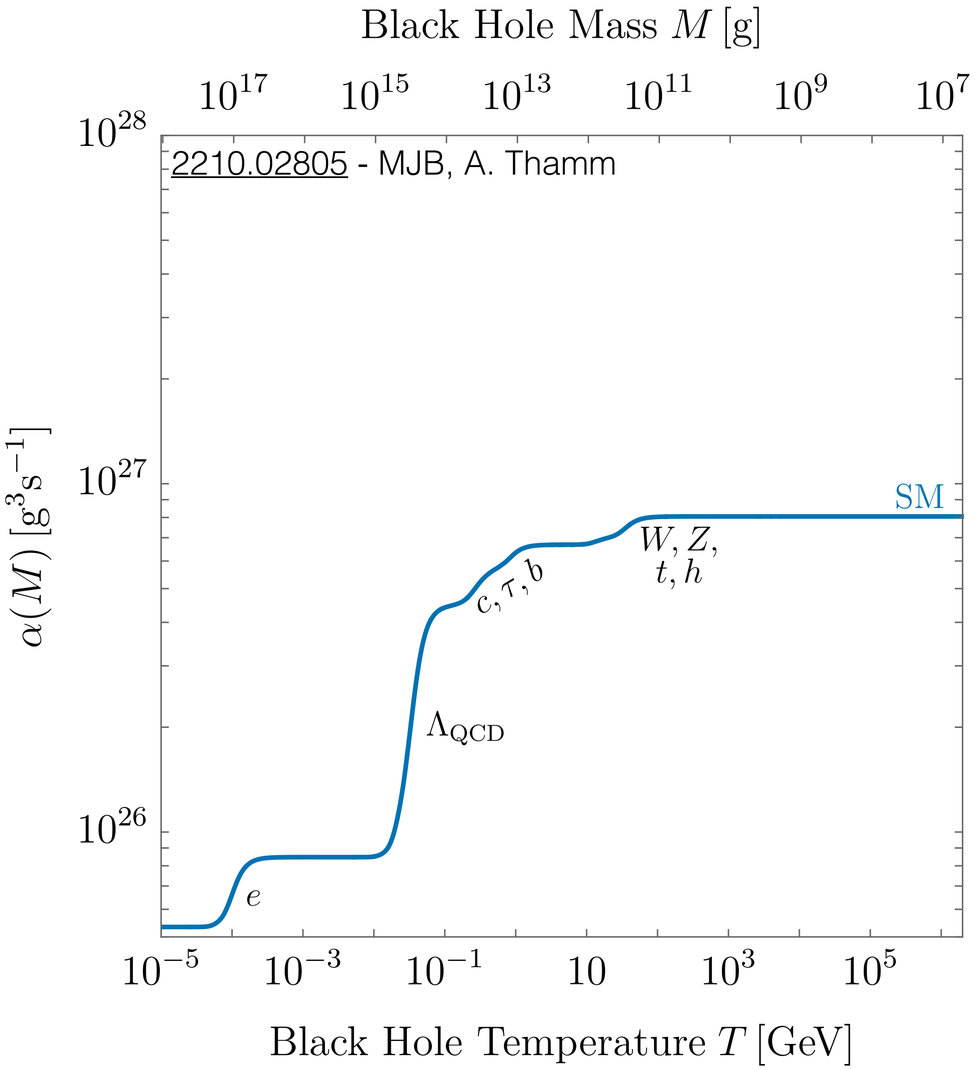

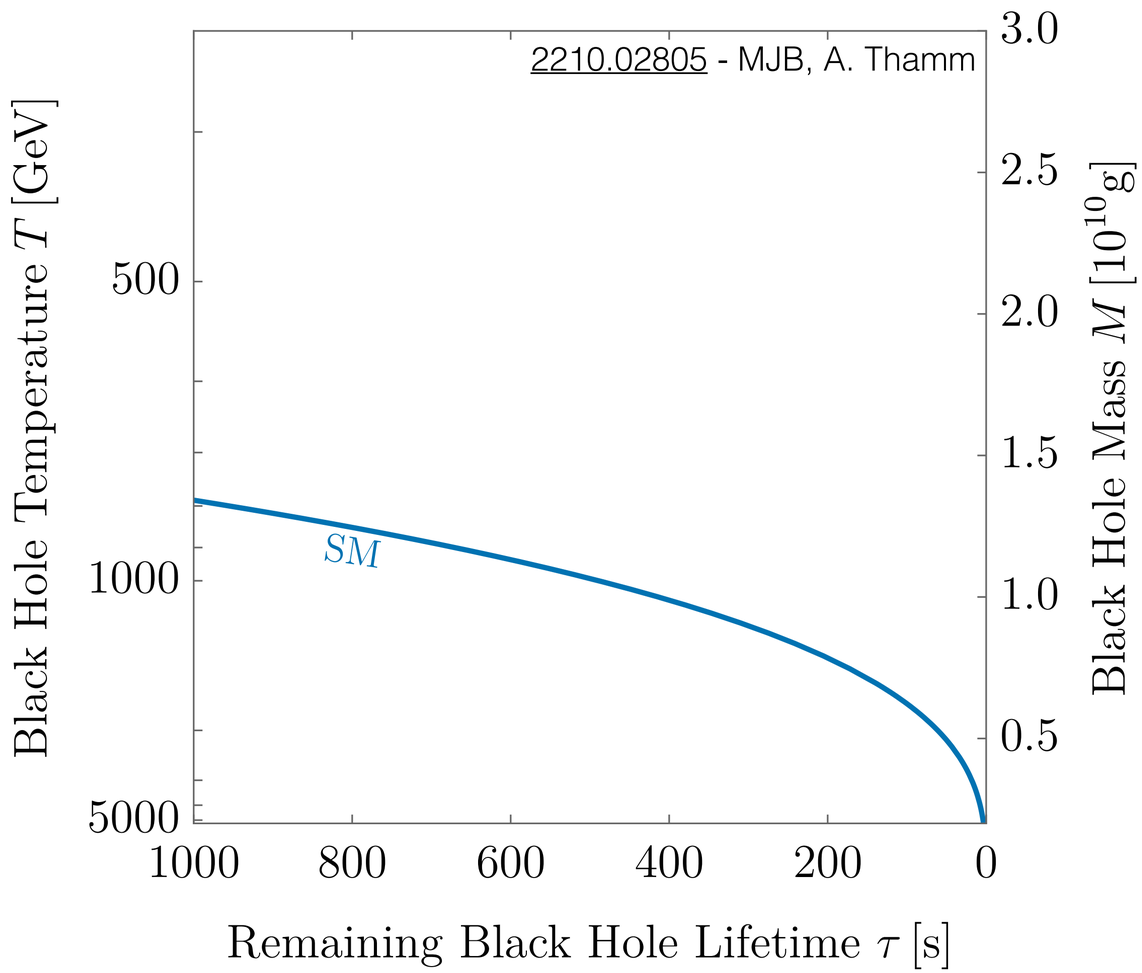

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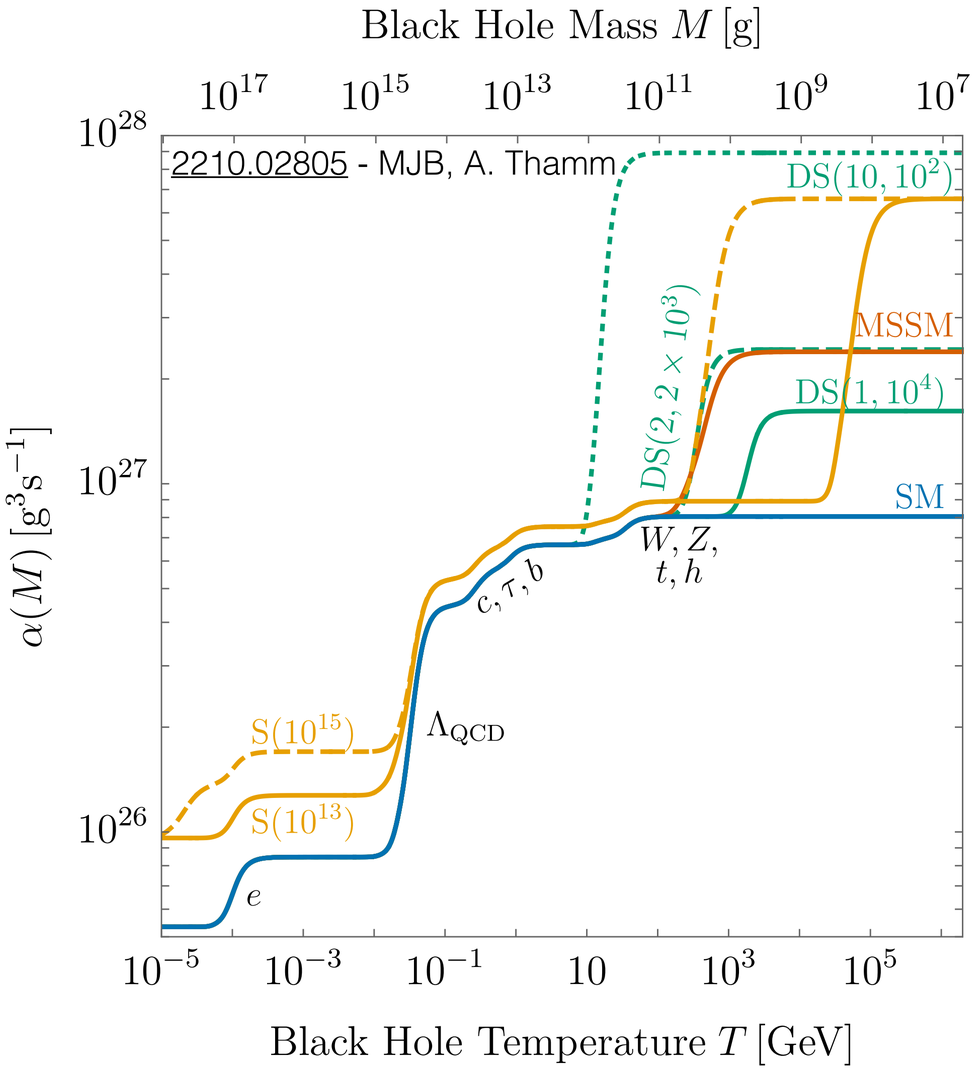

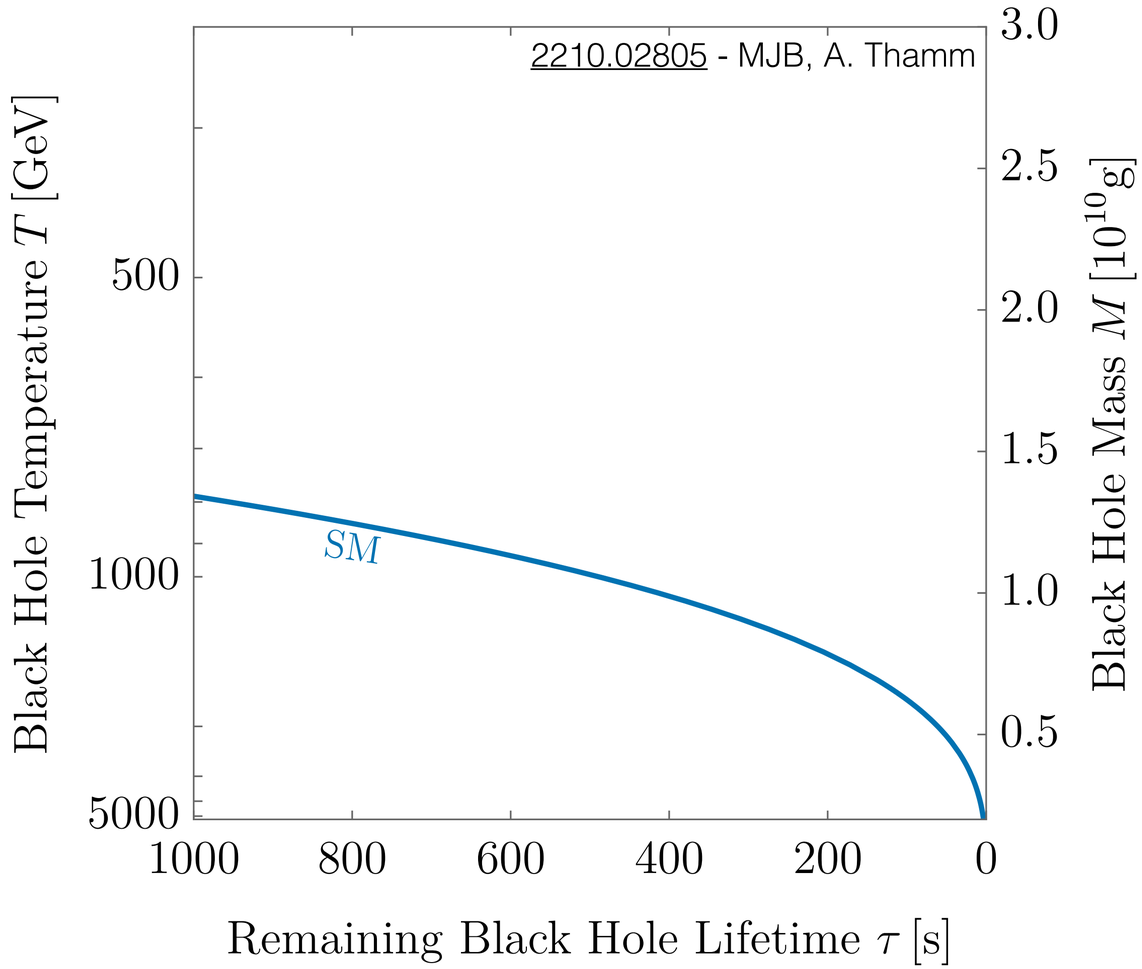

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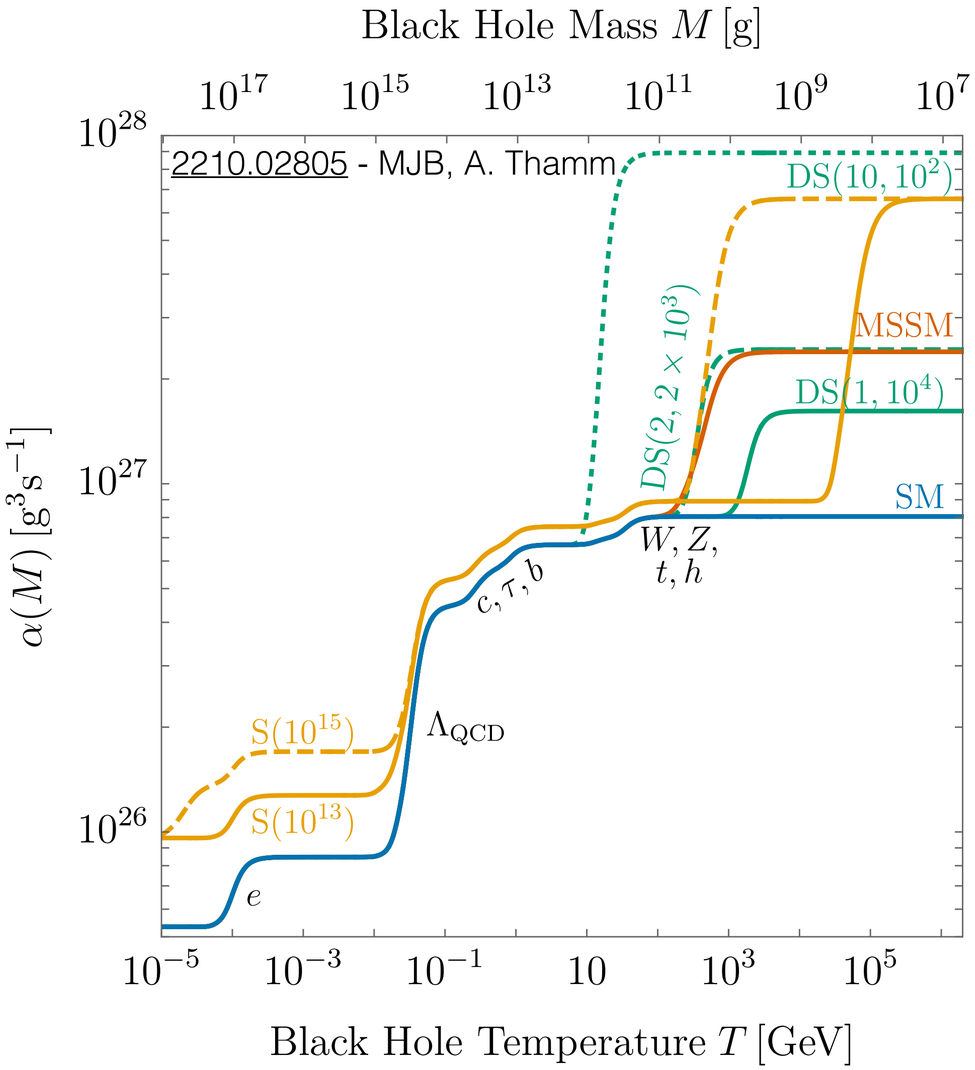

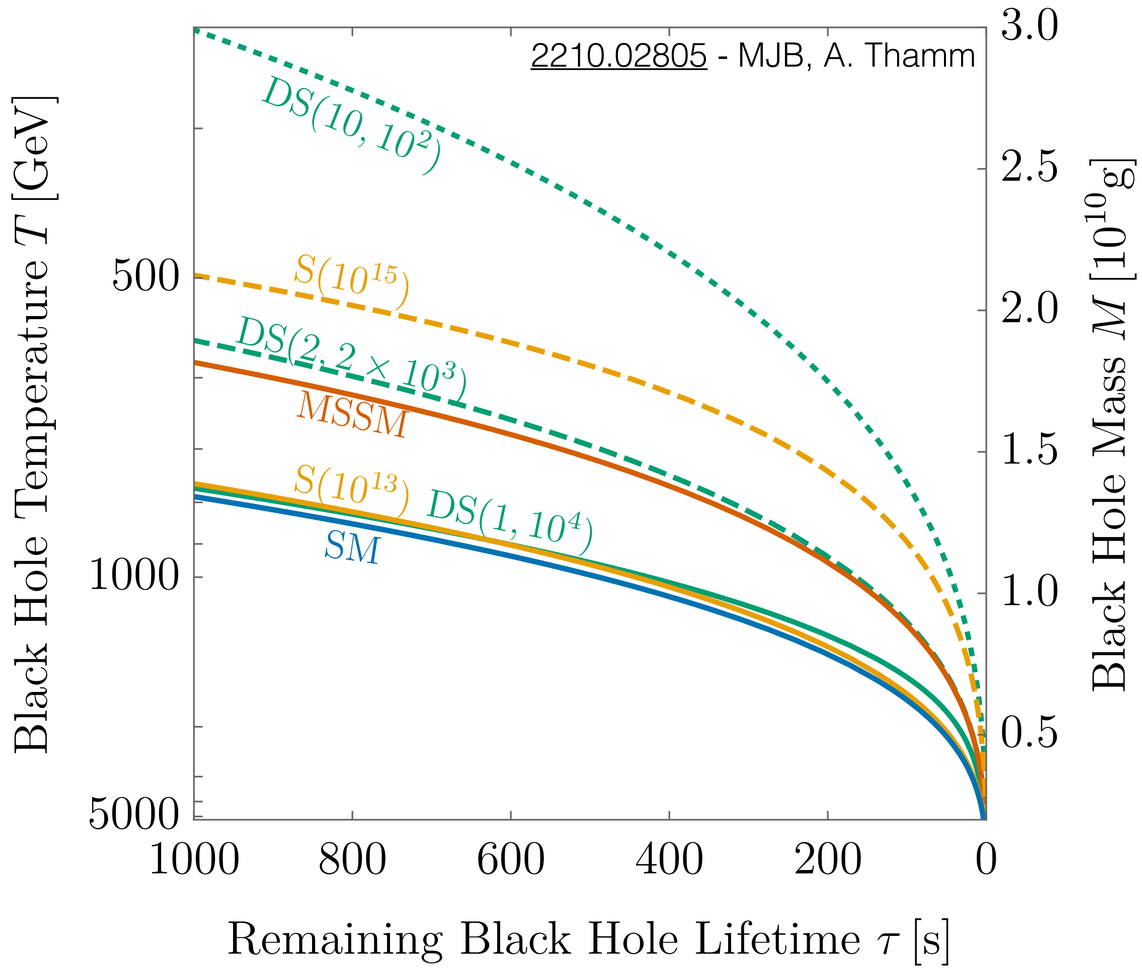

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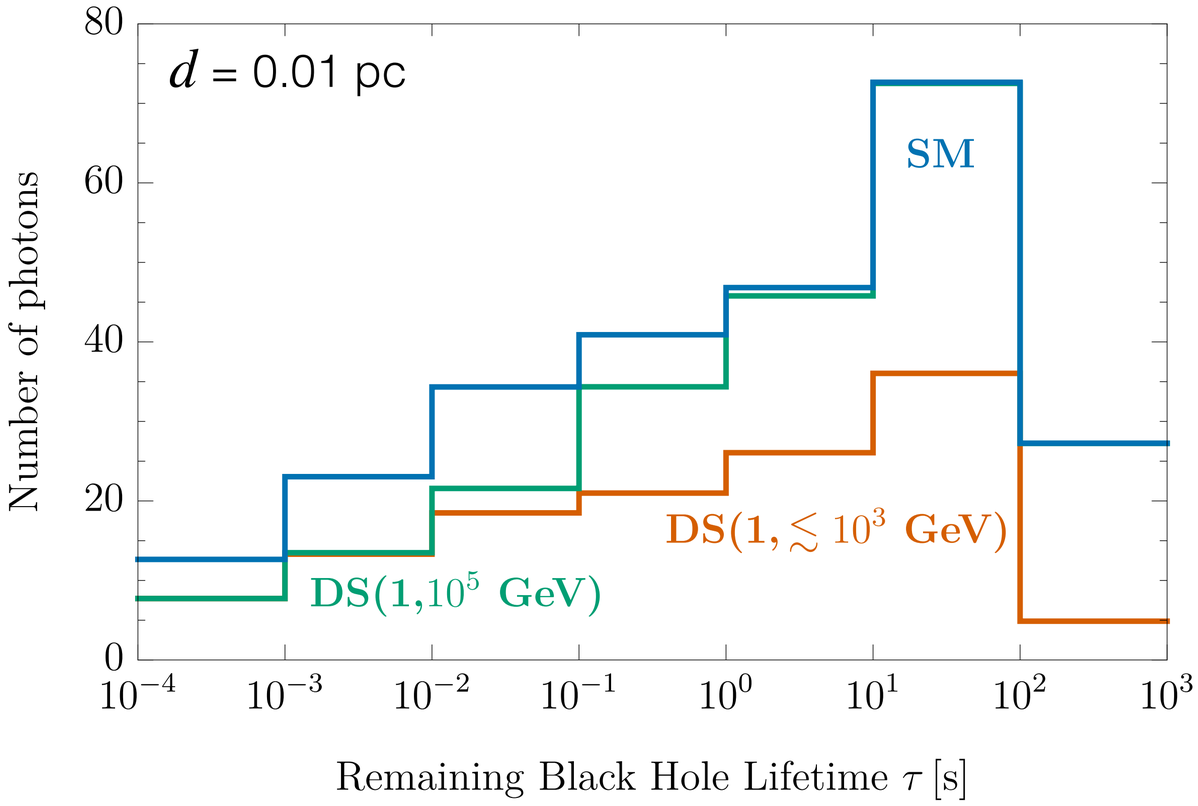

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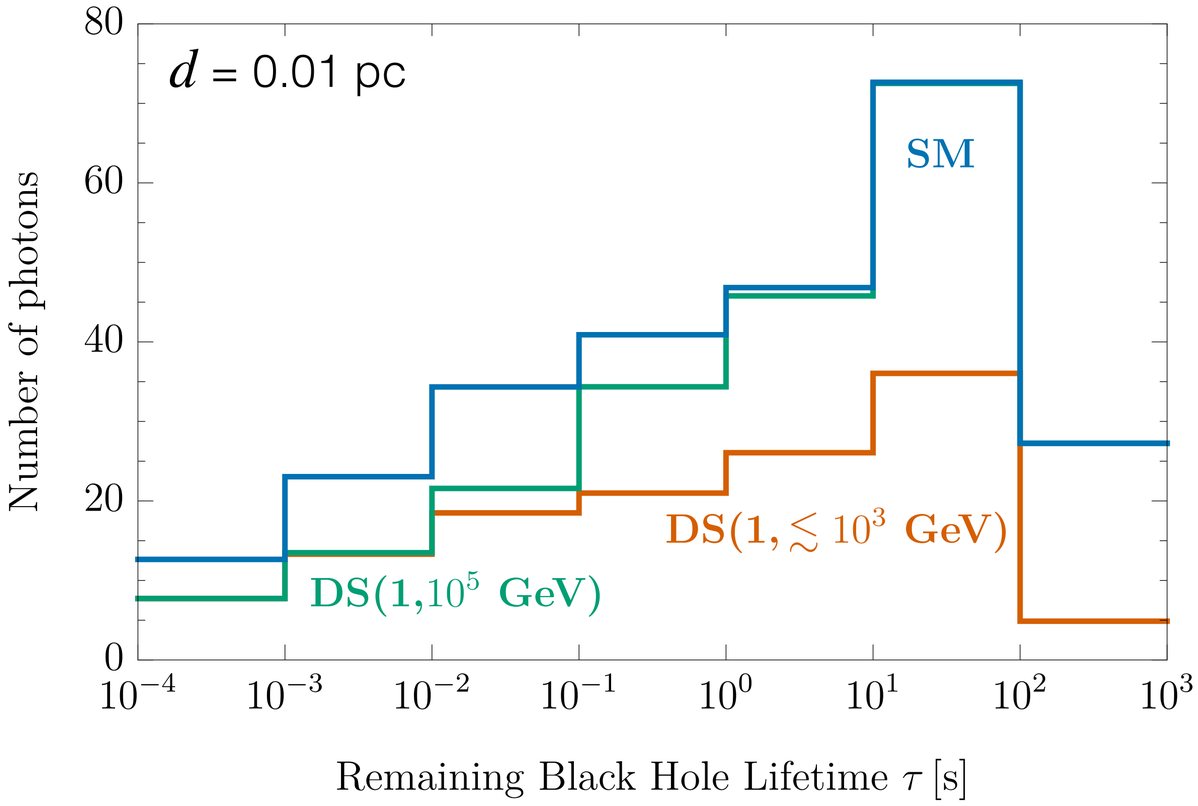
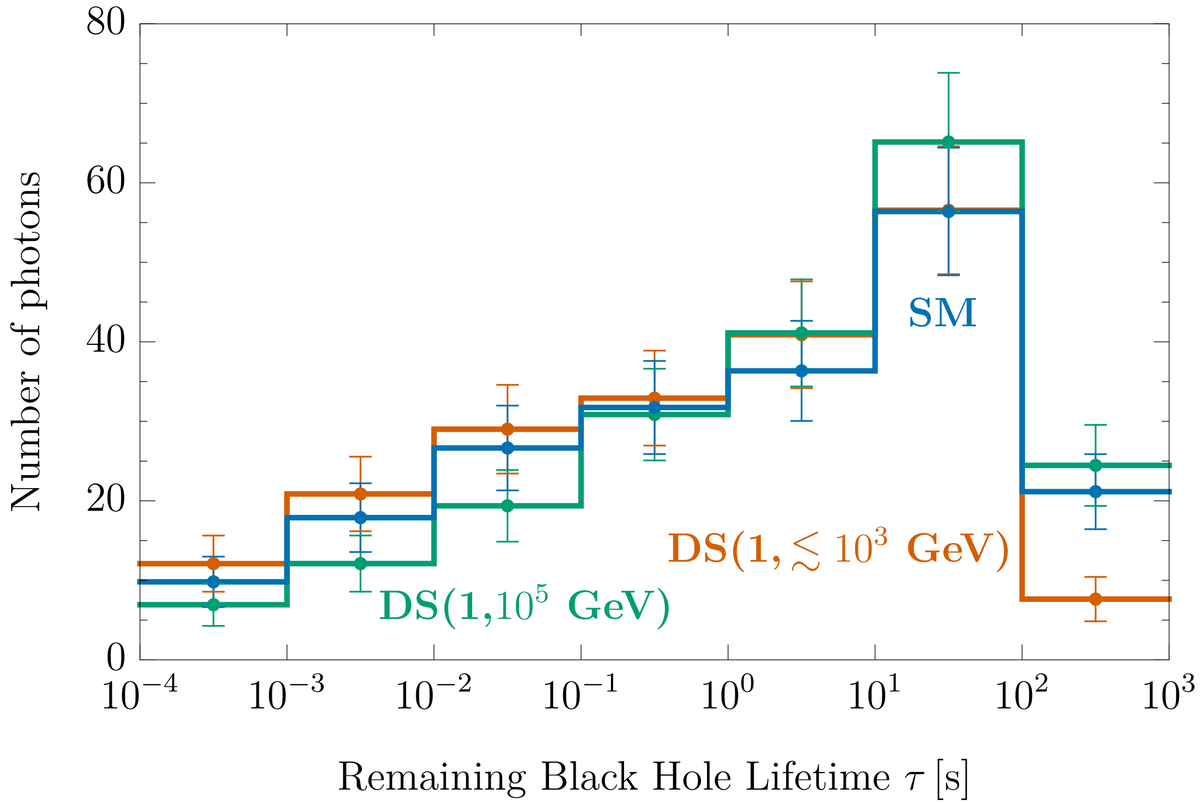
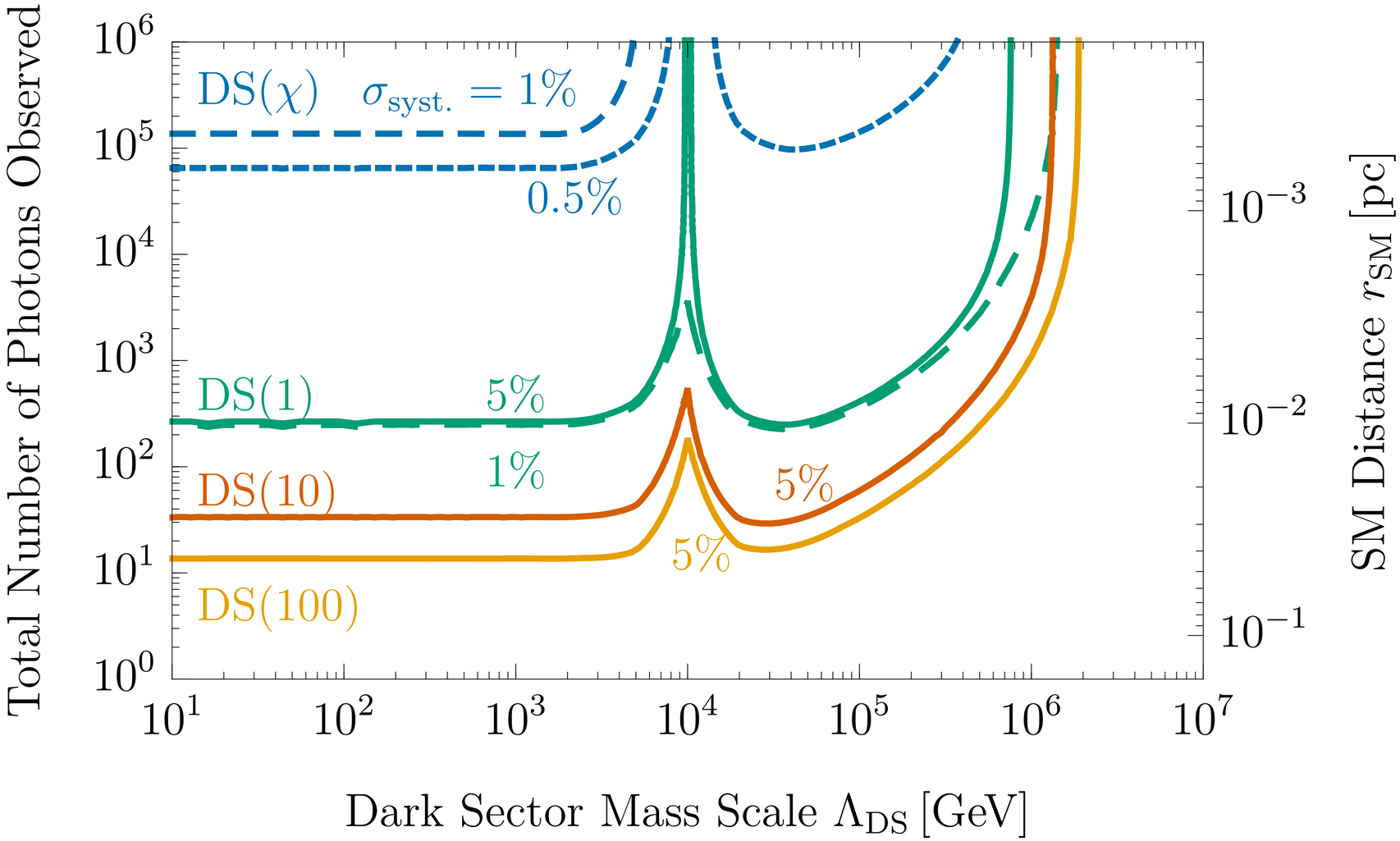


Normalised



Dark Sector Exclusion Plot



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If there are ~ 3000 EBHs $\mathrm{pc}^{-3}\,\mathrm{yr}^{-1}$, then 83% (1.4%) chance of at least one event closer than 0.05 (0.01) pc giving $\gtrsim$10 (200) photons at HAWC in next 5 years

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Cosmological Scale	$< 10^{-6}\,\mathrm{pc}^{-3}\mathrm{yr}^{-1}$	(1)	Clustering (e.g., by 7 orders of mag.), QCD, BSM
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Kiloparsec Scale	$< 0.0012\,\mathrm{pc}^{-3}\mathrm{yr}^{-1}$	(3)	
Parsec Scale	$< 4.6 \times 10^{5}\,\mathrm{pc}^{-3}\mathrm{yr}^{-1}$	(4)	

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Outline

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- Black Hole Evaporation
  - Standard Model
  - Beyond the Standard Model
- Conclusions

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Thank you!