High-frequency gravitational wave, or MeV gamma-rays to test light primordial black hole to be dark matter

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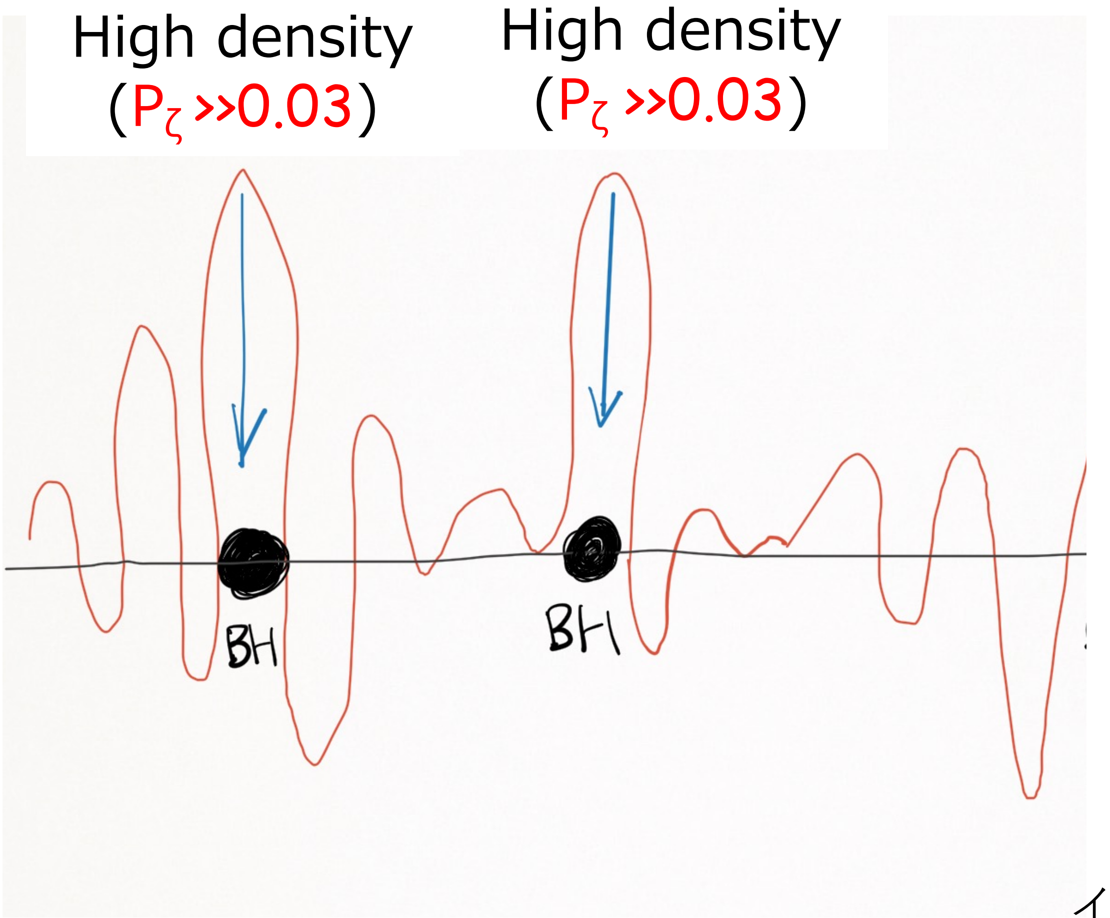
Primordial Black Holes

- High density perturbation ($\delta > 0.4$), or curvature perturbation ($P_\zeta > 0.03$) collapsed to PBH



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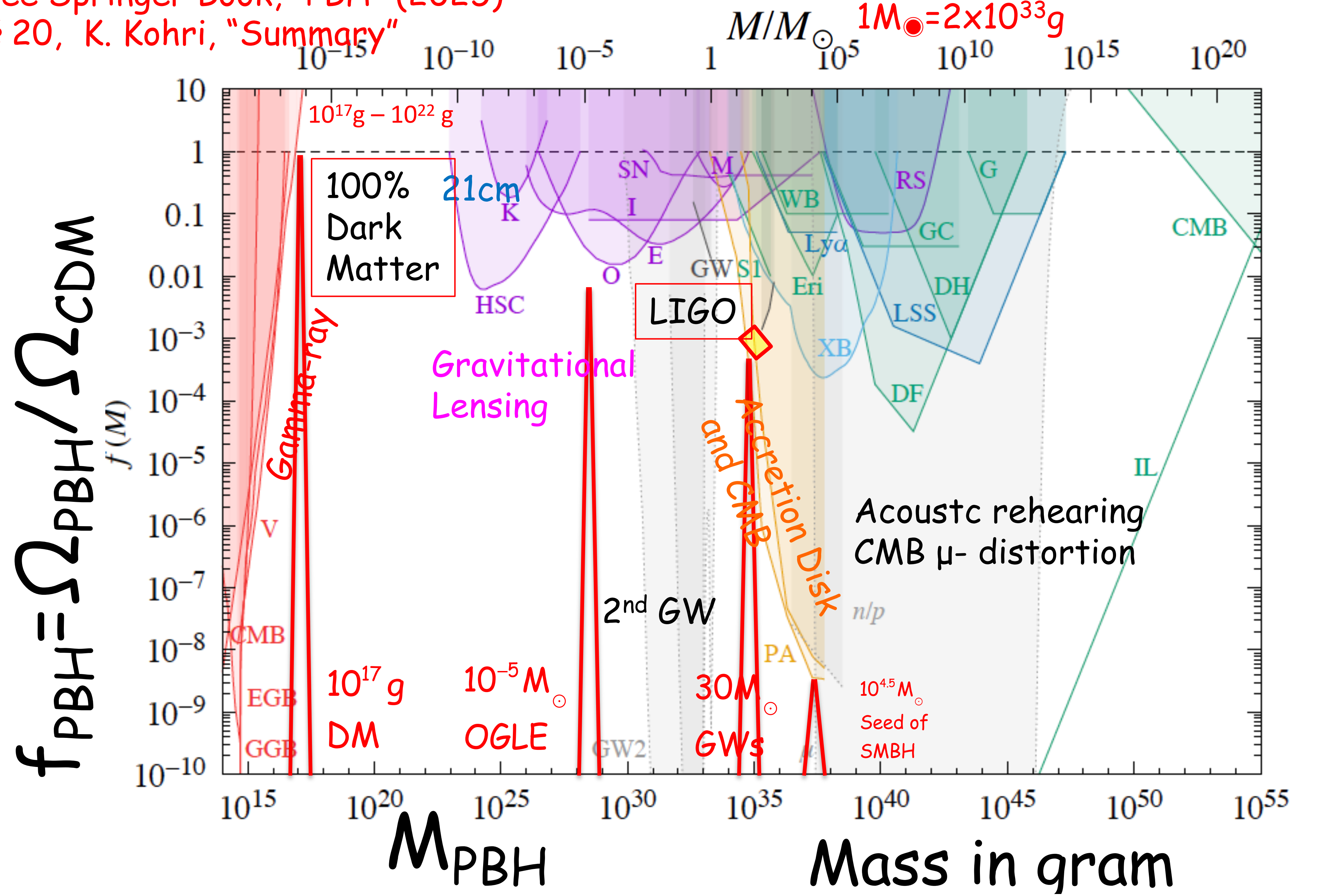
This is a cartoon

Upper bounds on the fraction to CDM

See Springer Book, "PBH" (2025)
§ 20, K. Kohri, "Summary"

Carr, Kohri, Sendouda, J.Yokoyama (2009)(2020)



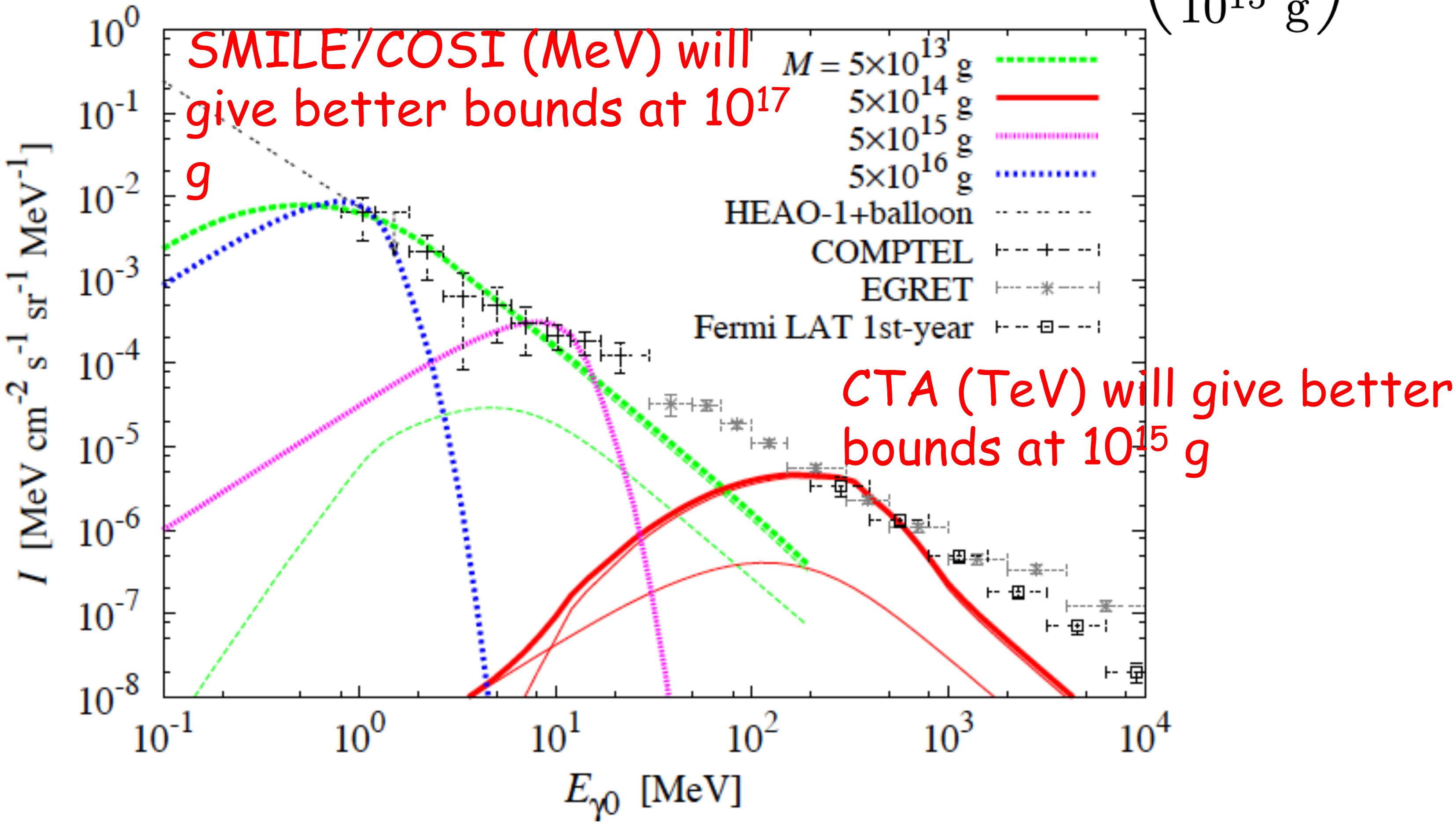
Evaporating PBHs through Hawking Process

Carr, Kohri, Sendouda and Yokoyama (2010)

$$d\dot{N}_s = \frac{dE}{2\pi} \frac{\Gamma_s}{e^{E/T_{\rm BH}} - (-1)^{2s}}$$

$$T_{\rm PBH} \sim 10{\rm MeV} \left(\frac{M_{\rm PBH}}{10^{15} g} \right)^{-1}$$

$$\tau_{\rm PBH} \sim 4 \times 10^{17}\, {\rm sec} \left(\frac{m_{\rm PBH}}{10^{15}\ {\rm g}} \right)^{3}$$

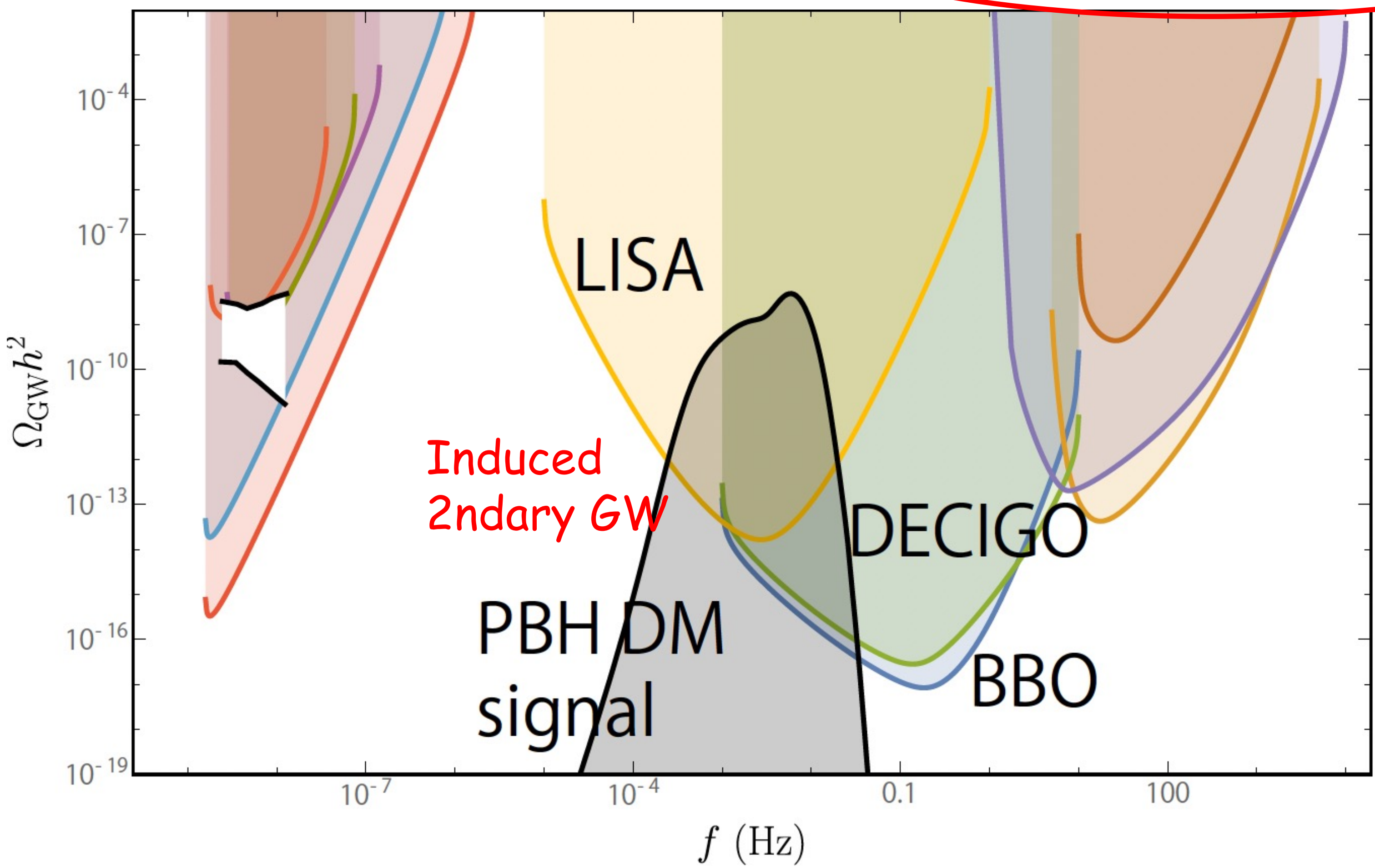


Induced Gravitational Wave

Dhong Yeon Cheong, Kazunori Kohri, Seong Chan Park, arXiv:2205.14813 [hep-ph]

See also, K. Kohri and T. Terada, arXiv:2009.11853

$$\Omega_{\mathrm{GW,c}}(f) = \frac{1}{12}\left(\frac{f}{2\pi a H}\right)^2 \int_0^\infty \mathrm{d}t \int_{-1}^{1} \mathrm{d}s \left[\frac{t(t+2)(s^2-1)}{(t+s+1)(t-s+1)}\right]^2 \times \overline{I^2(t,s,k\eta_c)}\,\mathcal{P}_\zeta\left(\frac{(t+s+1)f}{4\pi}\right)\mathcal{P}_\zeta\left(\frac{(t-s+1)f}{4\pi}\right)$$



Memory Burden in evaporating BHs

Gia Dvali, Lukas Eisemann, Marco Michel, Sebastian Zell, arXiv:2006.00011 [hep-th]
Valentin Thoss, Andreas Burkert, Kazunori Kohri, arXiv:2402.17823 [astro-ph.CO]

$$\frac{\mathrm{d}^2 N_{i,\mathrm{MB}}}{\mathrm{d}E\mathrm{d}t}(E, M, s_i) = \frac{1}{S(M)^k} \frac{\mathrm{d}^2 N_{i,\mathrm{SC}}}{\mathrm{d}E\mathrm{d}t}(E, M, s_i)$$

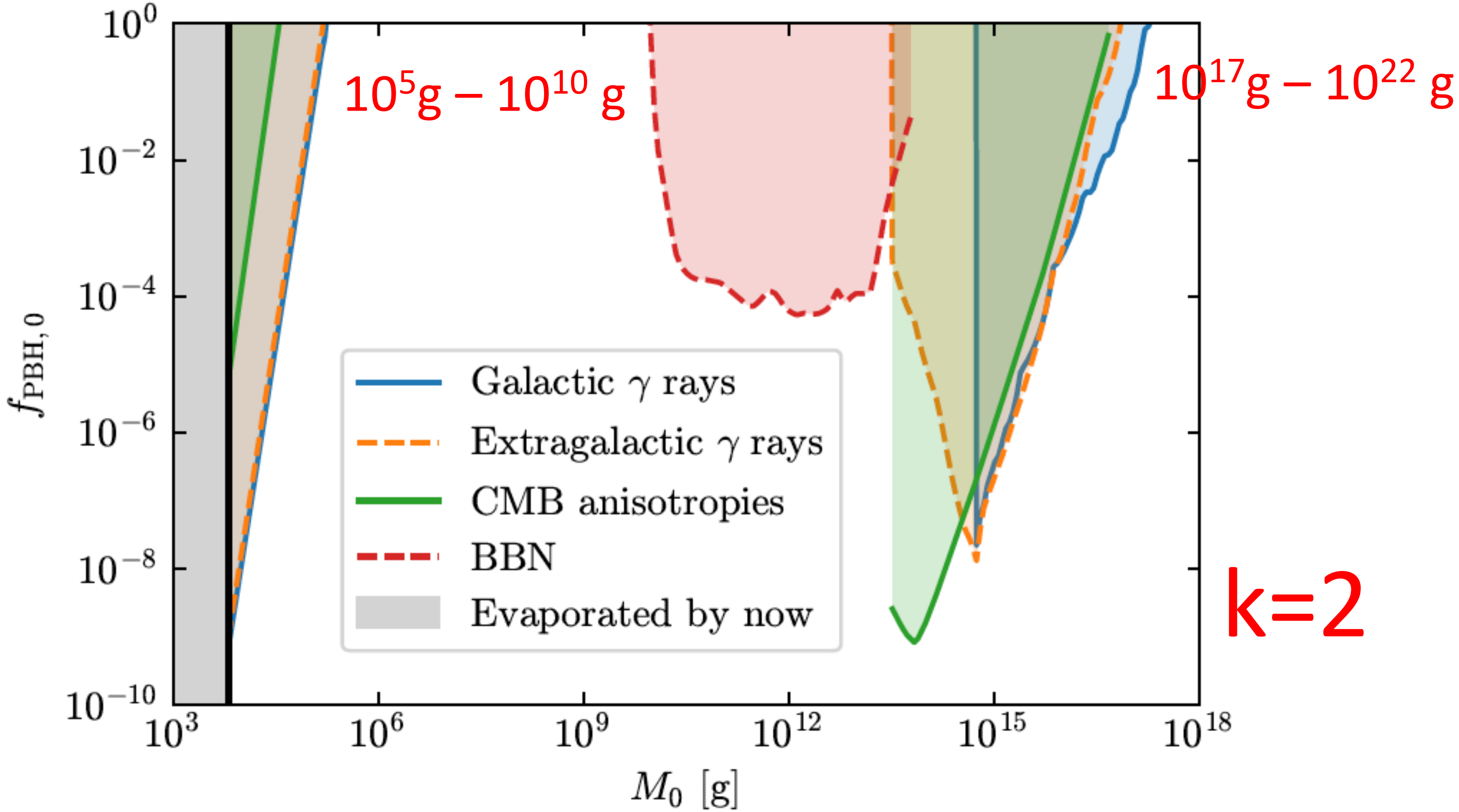
k=2

$$S = \frac{4\pi M^2 G}{\hbar c} \approx 2.6 \times 10^{10} \left(\frac{M}{1\,\mathrm{g}}\right)^2$$

$$\dot{M}_{\mathrm{PBH}} \sim \begin{cases} -\dfrac{M_{\mathrm{pl}}^4}{M_{\mathrm{PBH}}^2} & \left(M_{\mathrm{PBH}} \geq \frac{1}{2} M_{\mathrm{PBH,ini}}\right) \\ -\dfrac{1}{S^k}\dfrac{M_{\mathrm{pl}}^4}{M_{\mathrm{PBH}}^2} & \left(M_{\mathrm{PBH}} < \frac{1}{2} M_{\mathrm{PBH,ini}}\right) \end{cases}$$

Breakdown of Hawking Evaporation opens new Mass Window PBHs as DM

Valentin Thoss, Andreas Burkert, Kazunori Kohri, arXiv:2402.17823 [astro-ph.CO]

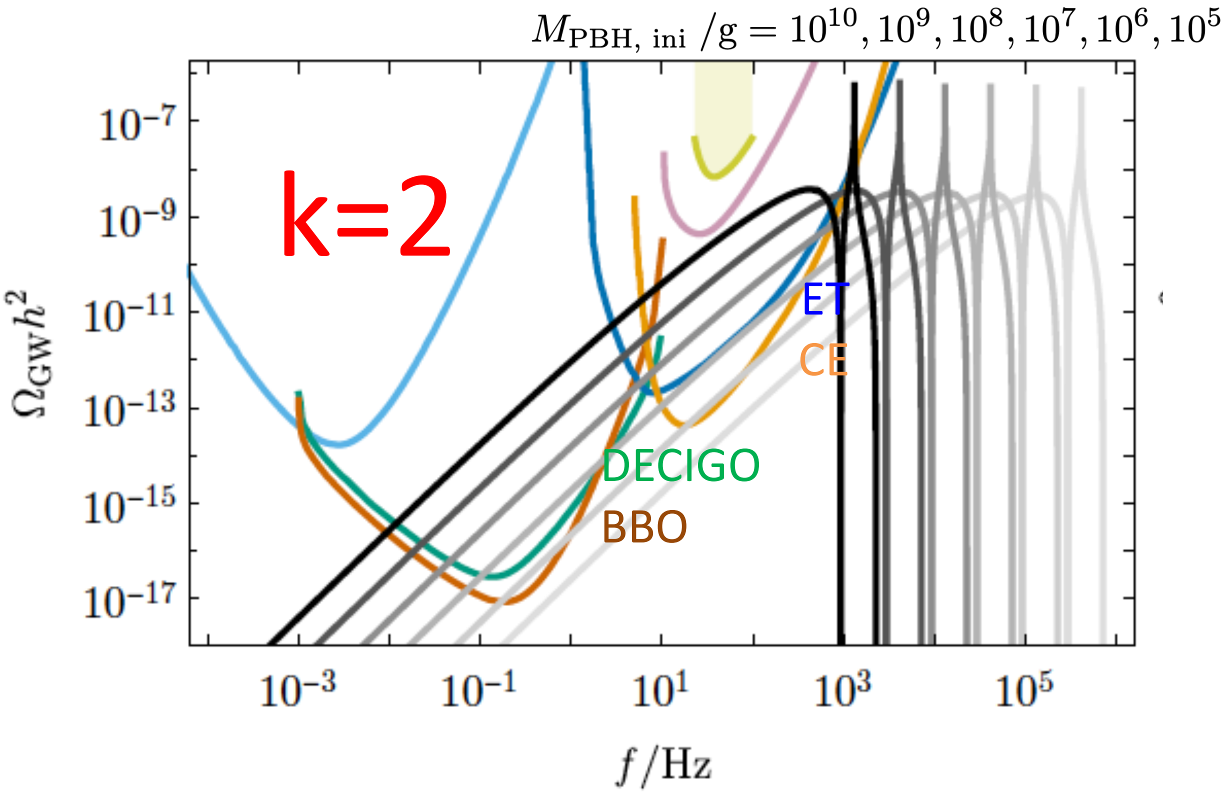


Induced Gravitational Wave probing Primordial Black Hole Dark Matter with Memory Burden

K. Kohri. T. Terada. T. Yanagida. arXiv:2409.06365

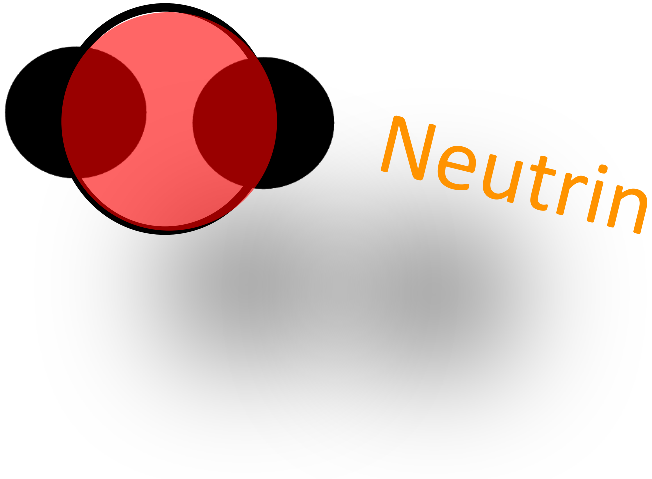
$$\Omega_{\mathrm{GW,c}}(f) = \frac{1}{12}\left(\frac{f}{2\pi a H}\right)^2 \int_0^\infty \mathrm{d}t \int_{-1}^{1} \mathrm{d}s \left[\frac{t(t+2)(s^2-1)}{(t+s+1)(t-s+1)}\right]^2 \times \overline{I^2(t,s,k\eta_c)}\, \mathcal{P}_\zeta\left(\frac{(t+s+1)f}{4\pi}\right) \mathcal{P}_\zeta\left(\frac{(t-s+1)f}{4\pi}\right)$$

K.Kohri and T.Terada, arXiv:1804.08577



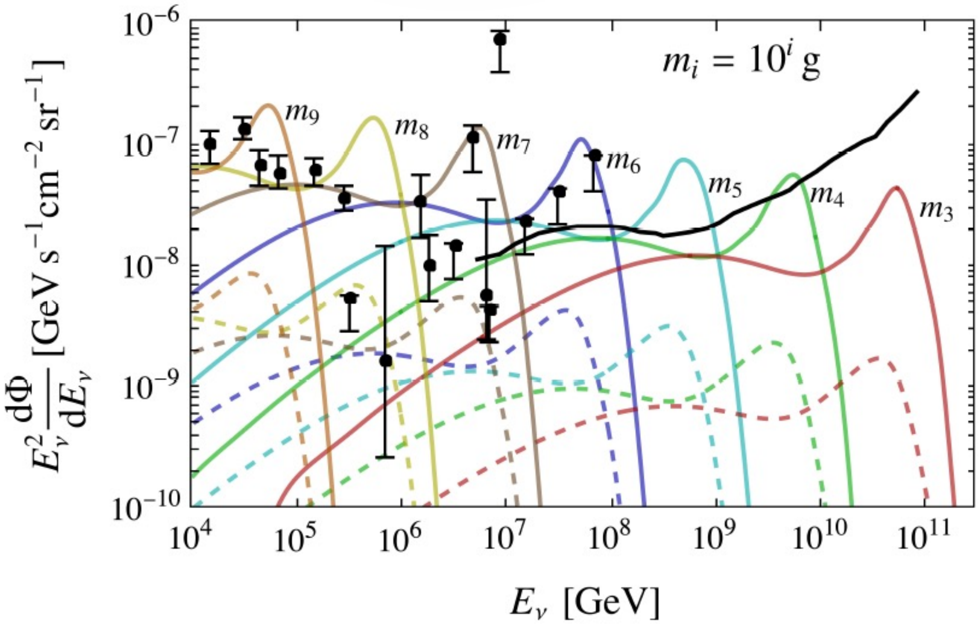
IceCube and Memory-Burden effects

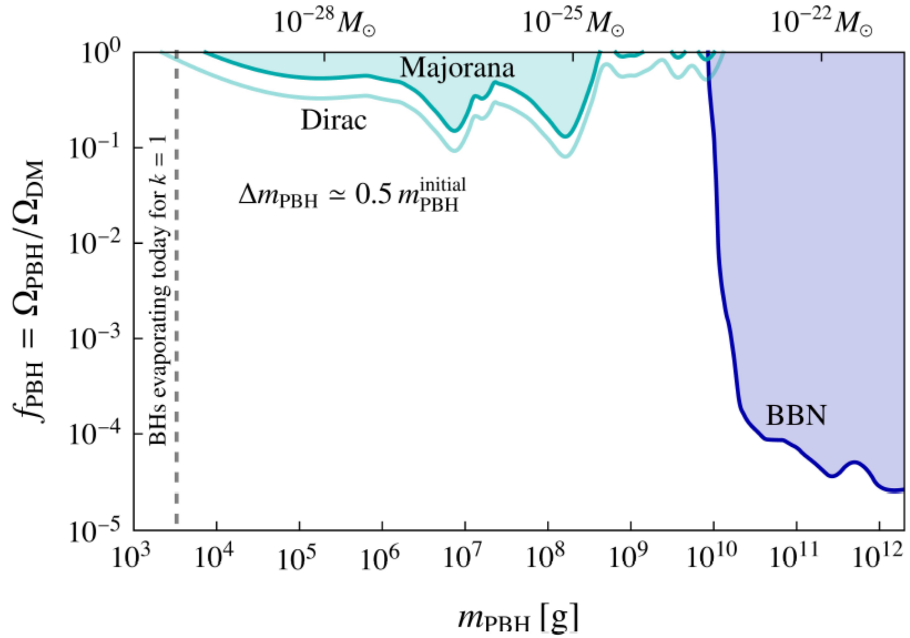
Michael Zantedeschi, Luca Visinelli, arXiv:2410.07037 [astro-ph.HE]



Neutrino emission →

Evaporation is initialized after mergers at present!





Conclusion

- We can search PBH dark matter (10^{17} g – 10^{22} g) by future MeV-gamma-ray and gravitational waves

- The memory burden effect gives a new window for PBH dark matter for 10^{5} g – 10^{10} g (k=2)

- We can test the memory burden effects with PBH dark matter scenario by using high-frequency gravitational waves

Induced Gravitational Waves probing Primordial Black Hole Dark Matter with Memory Burden

K. Kohri, T. Terada, T. Yanagida, arXiv:2409.06365