中国科学院大学
University of Chinese Academy of Sciences

Supermassive primordial black holes for nano-Hertz gravitational waves

Hai-Long Huang, Yun-Song Piao

University of Chinese Academy of Sciences, China

Based on: Huang H L, Piao Y S. arXiv:2312.11982,
Huang H L, Cai Y, Jiang J Q, et al. arXiv:2306.17577

New Horizons in Primordial Black Hole Physics, Edinburgh 20th June 2024

Motivations

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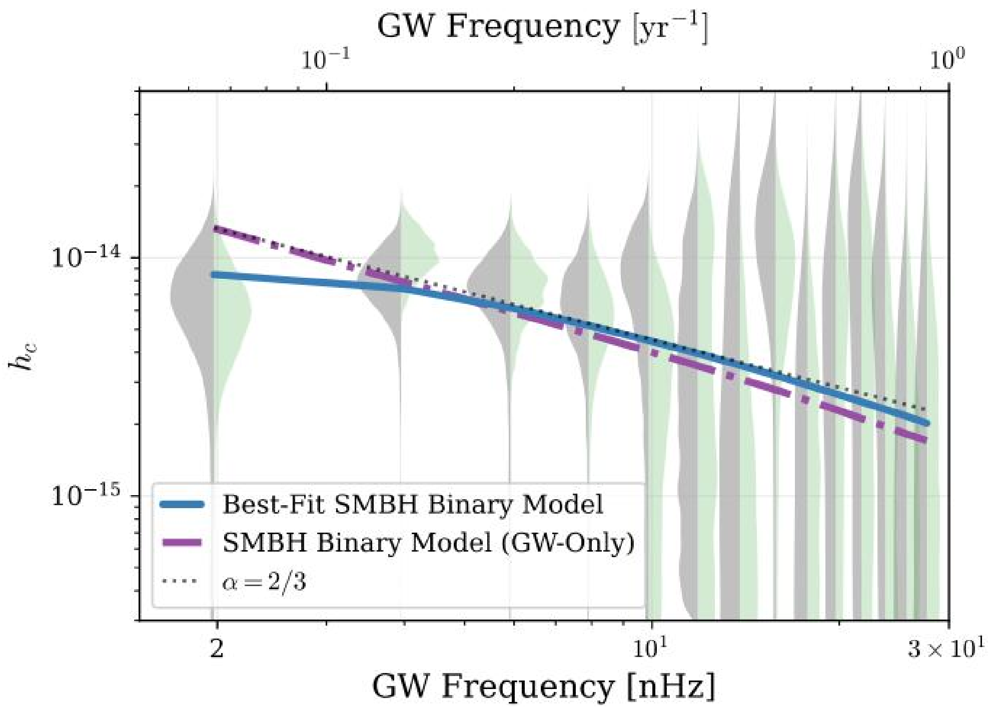
The nano-Hertz stochastic GW background found with PTA might be interpreted with a population of SMBH binaries



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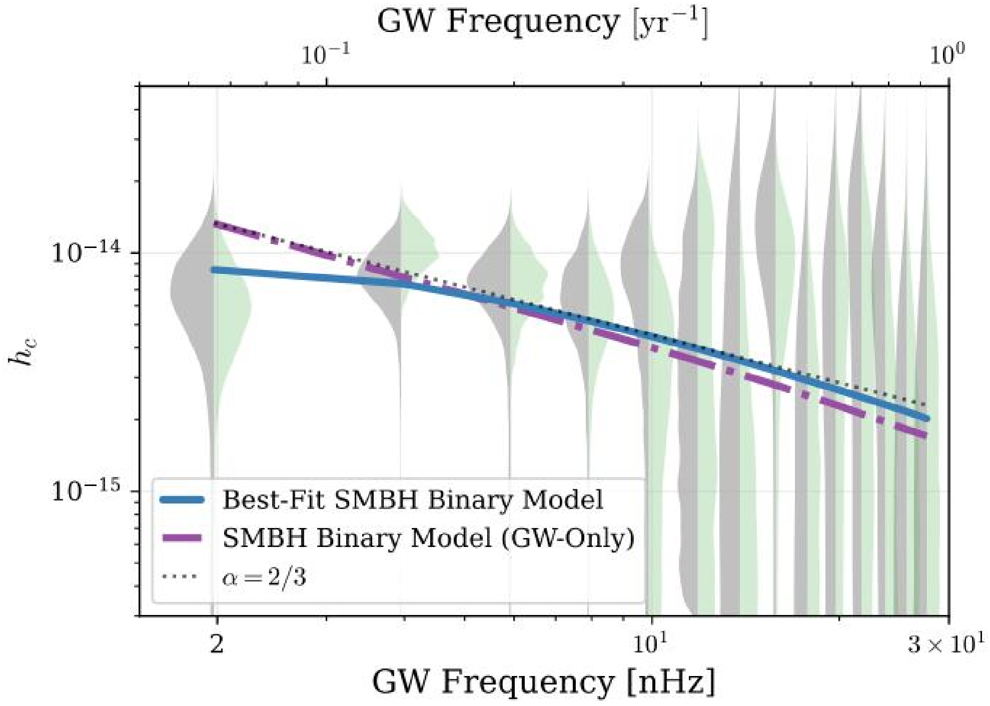

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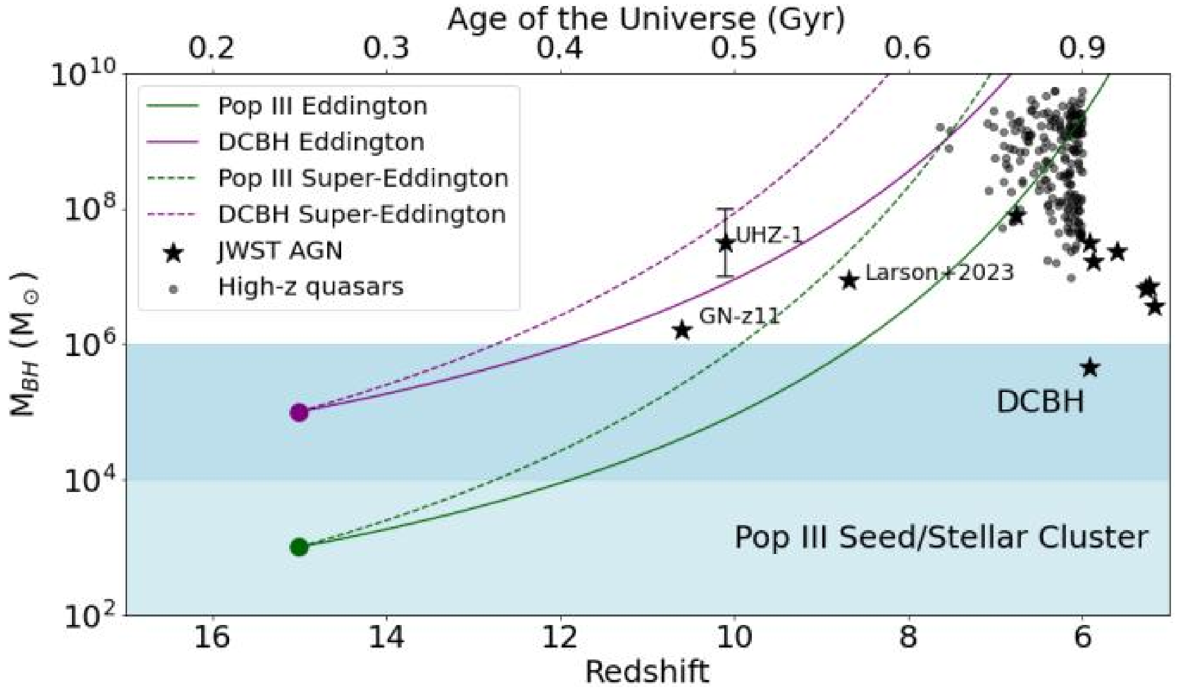

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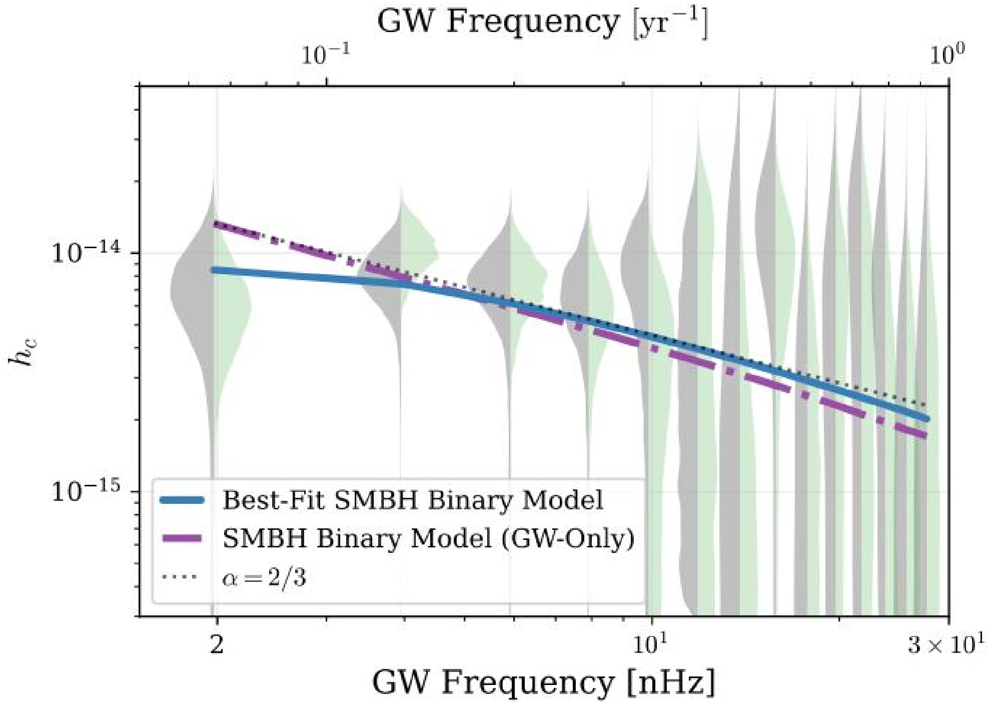

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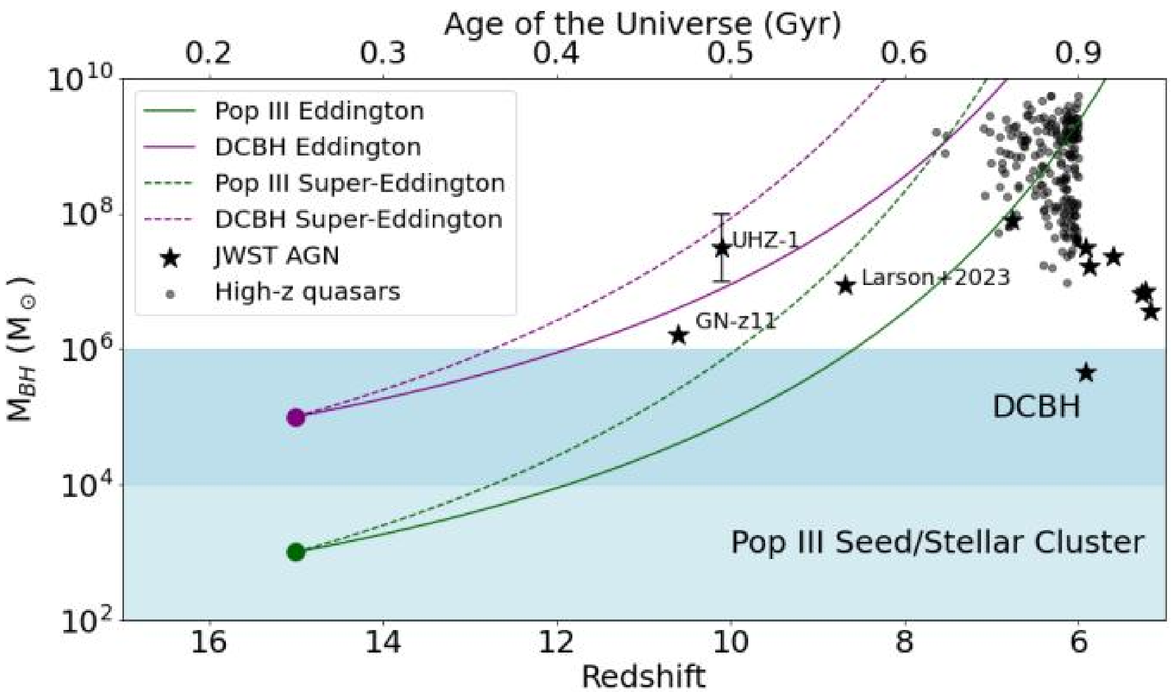

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➢ Could the SMBHs be primordial?

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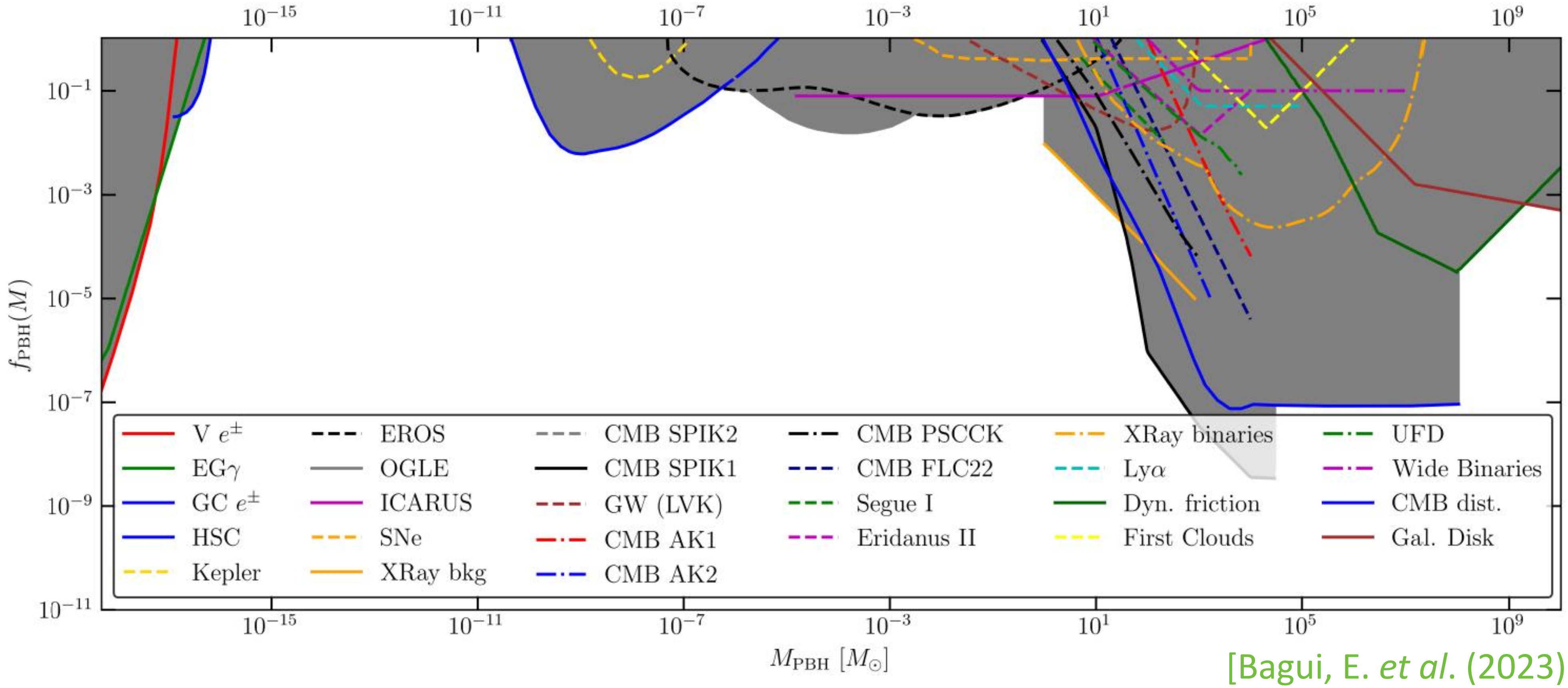

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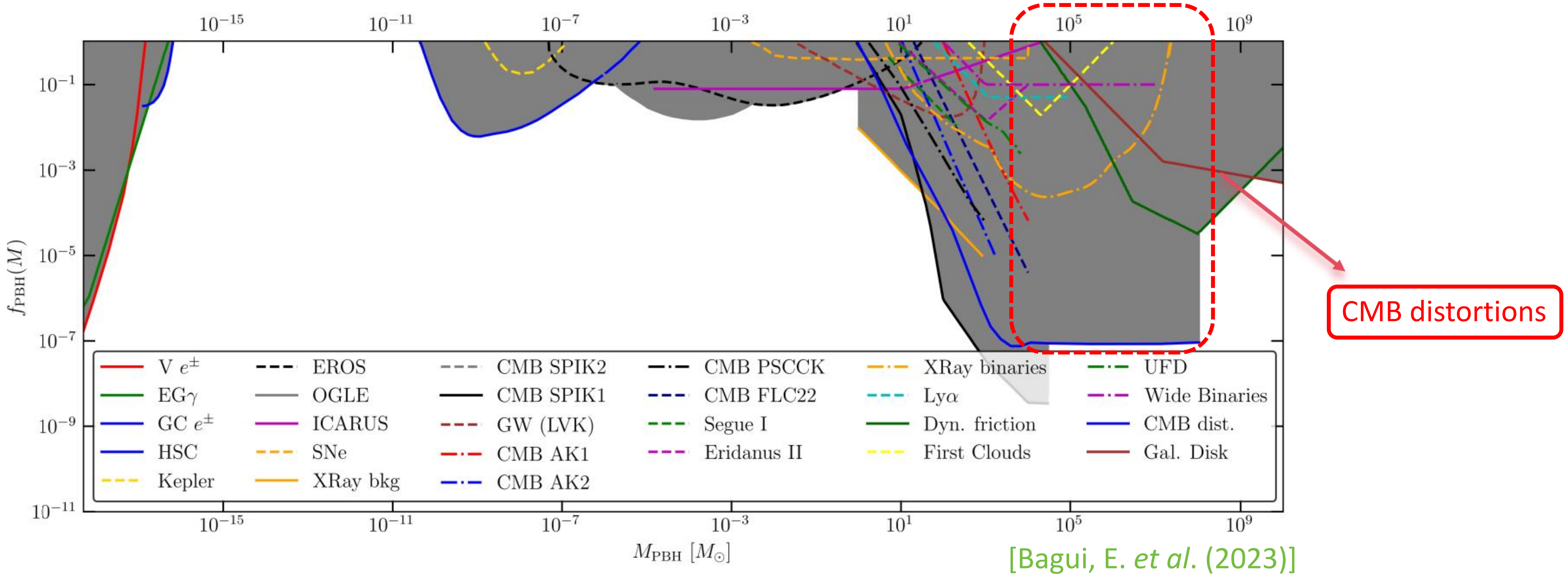

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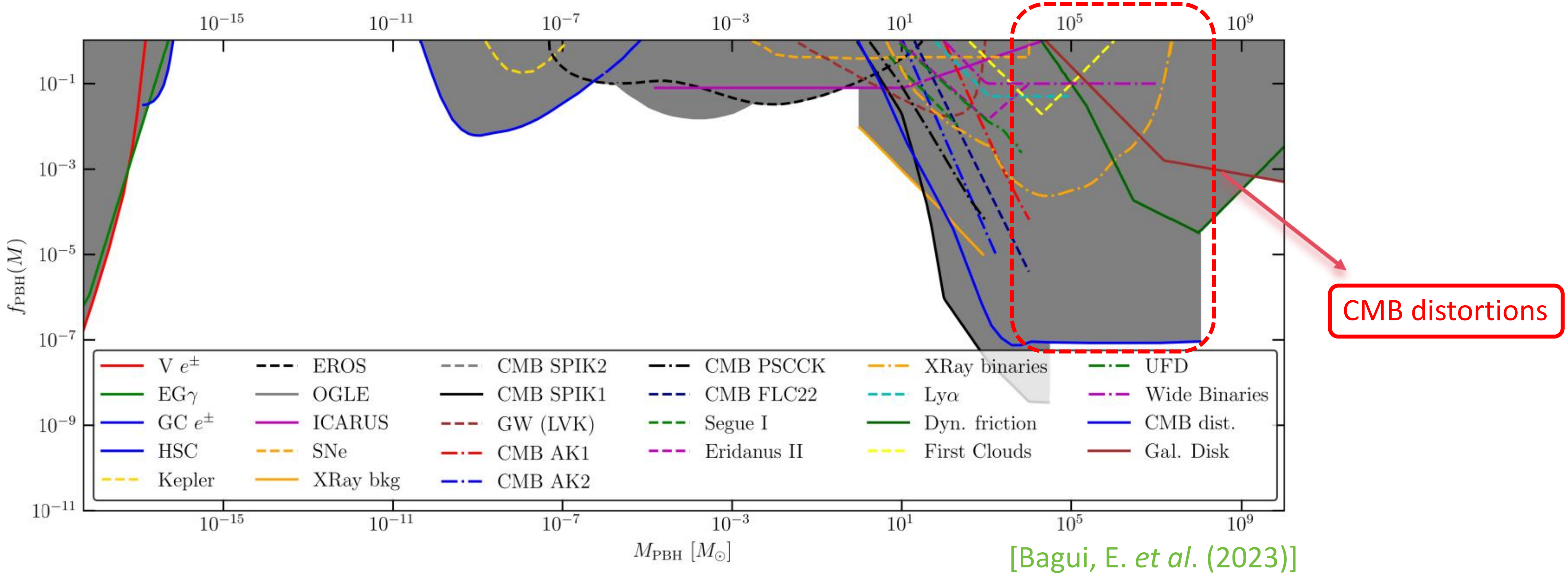

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- non-Gaussian perturbations & other PBH formation mechanisms?

SMPBHs sourced from supercritical bubbles

- PBH formed in a multiverse scenario

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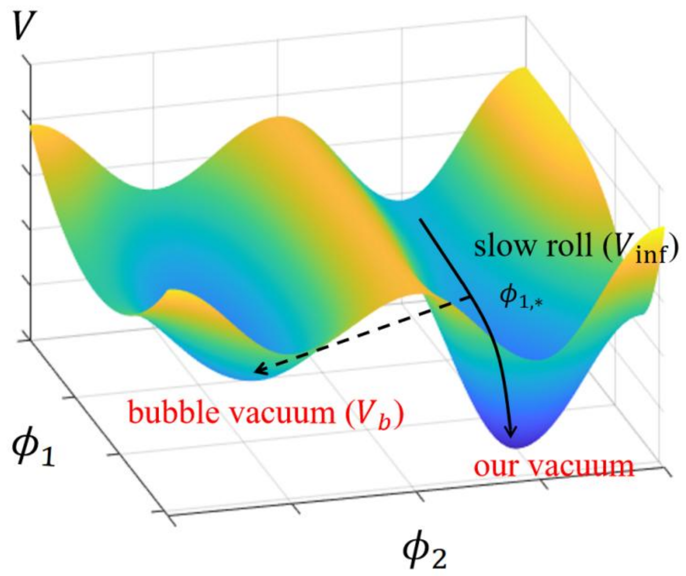

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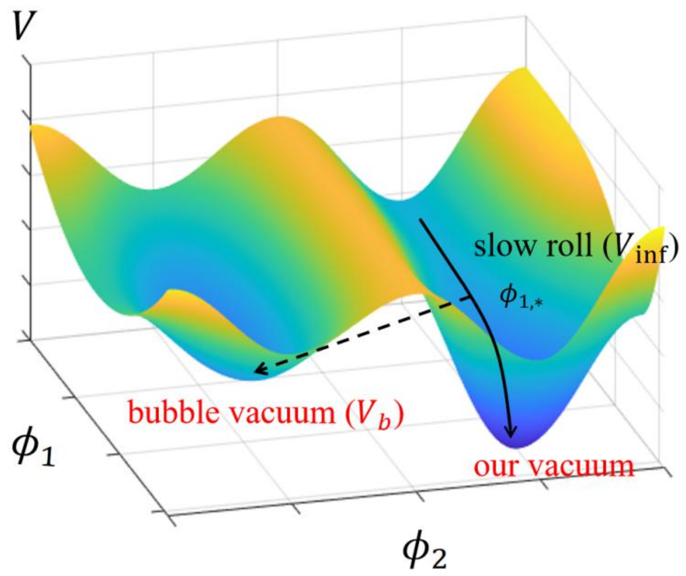

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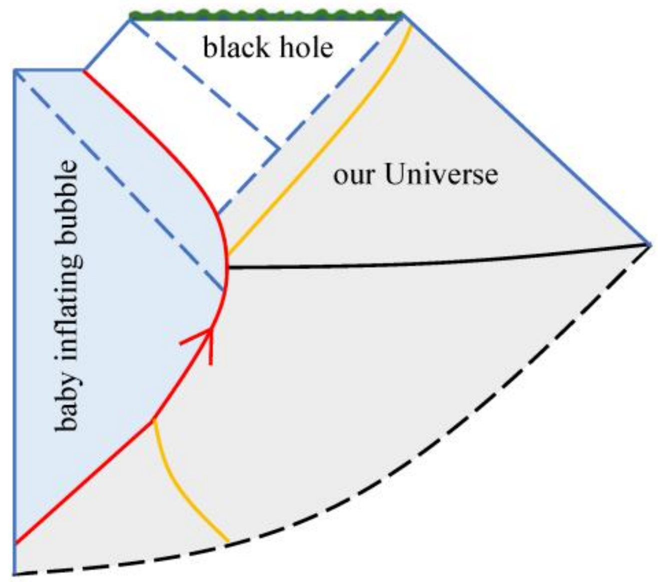

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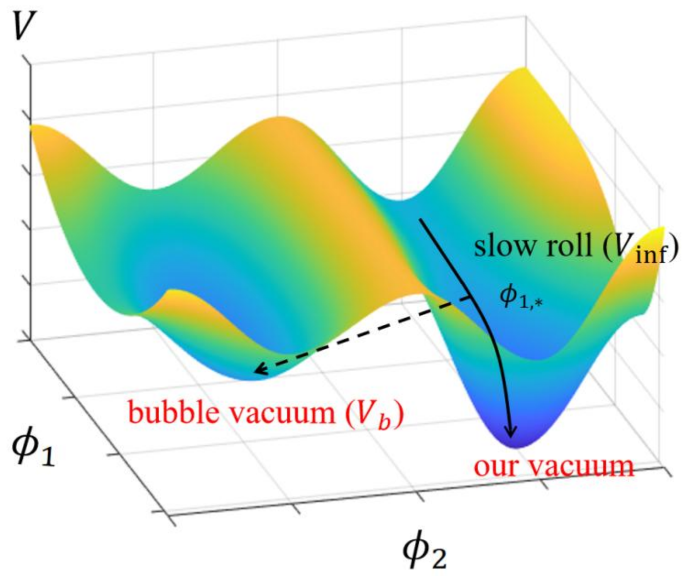

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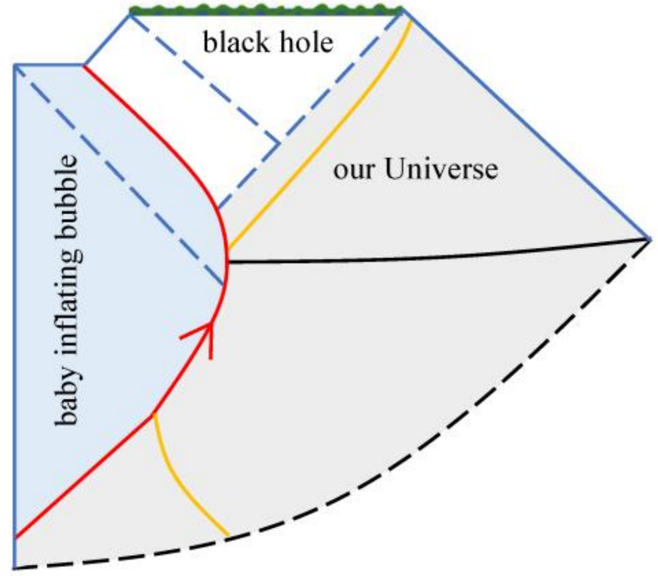

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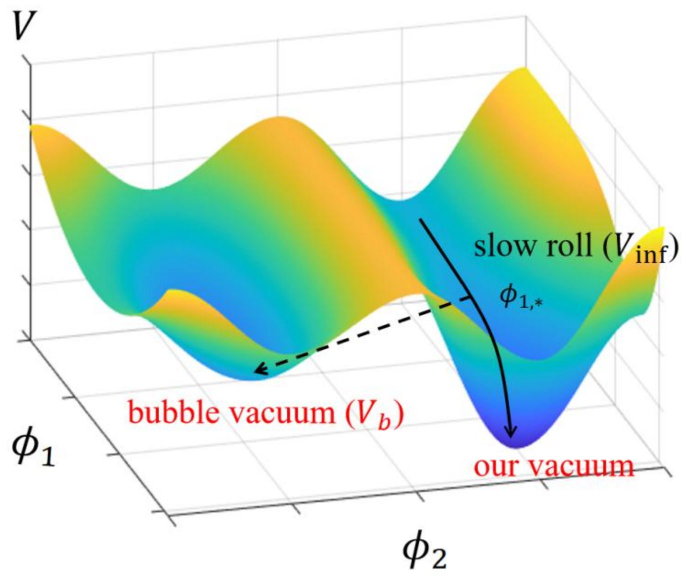

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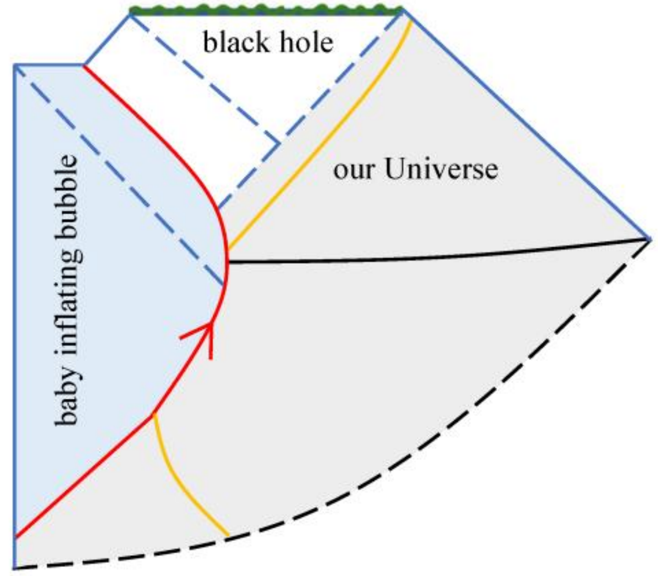

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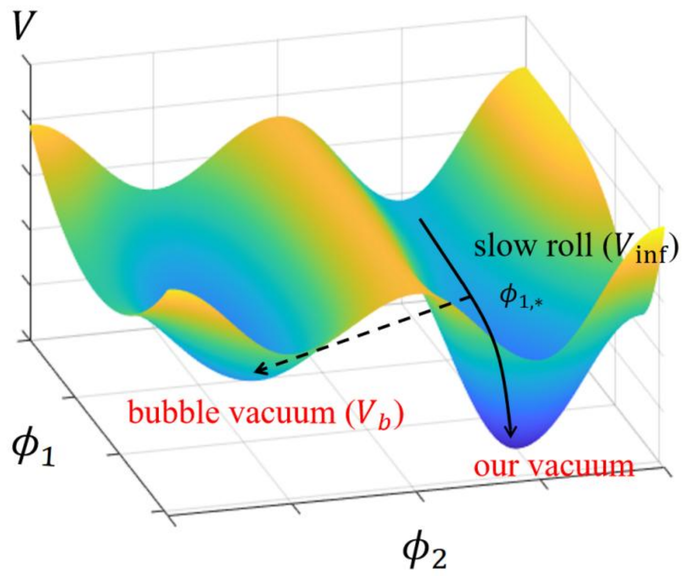

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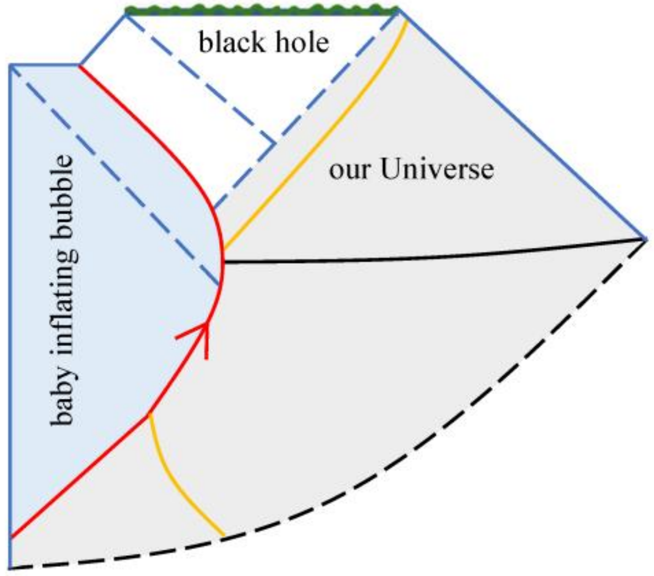

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SMPBHs sourced by supercritical bubbles

- The nucleation rate of the CDL bubble: $\lambda \sim e^{-B}$
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$$\psi(m) = e^{-\sigma^2/8} \sqrt{\frac{M_c}{2\pi\sigma^2 m^3}} \exp\left(- \frac{\ln^2(m/M_c)}{2\sigma^2} \right)$$

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    $\longrightarrow$ a multi-peaks spectrum

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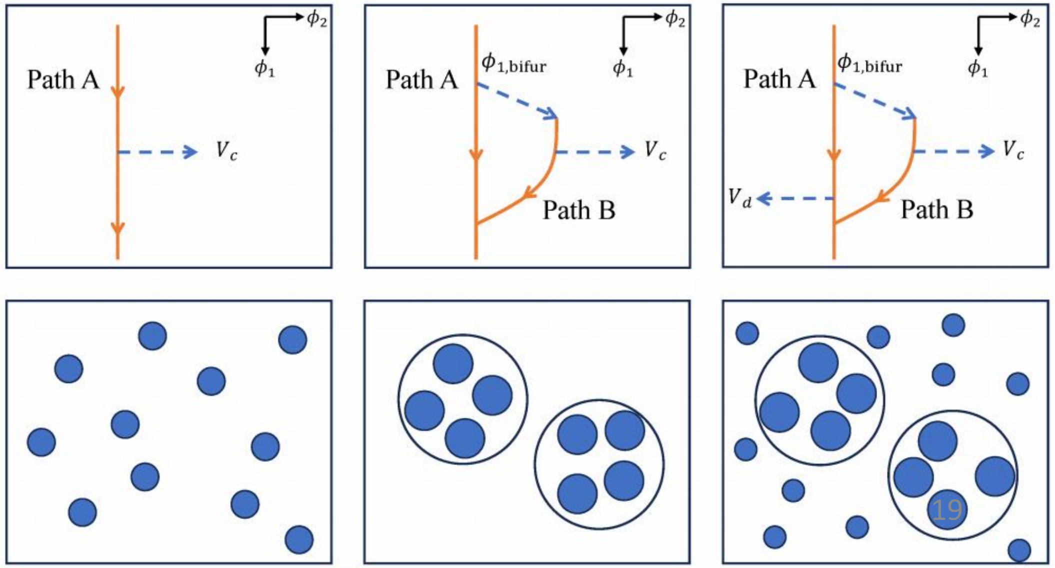
    ⟶ a multi-peaks spectrum
  - Multiple paths ⟶ cluster initially at different levels

$$f_{\text{PBH}} \equiv \frac{\rho_{\text{PBH}}}{\rho_{\text{DM}}} = \lambda_B \frac{\rho_{\text{PBH}}^B}{\rho_{\text{DM}}} = \lambda_B f_{\text{PBH}}^B$$



SMPBH binaries for nano-Hertz GWs

- GWs from SMPBH binary merges:
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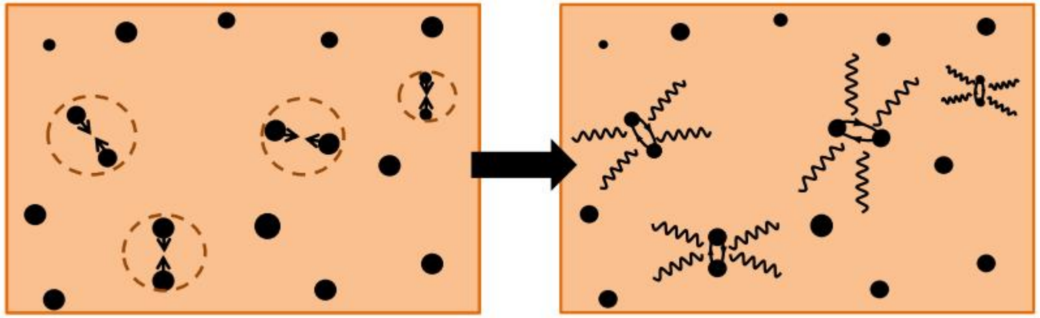

[Sasaki *et al*. (2018)]

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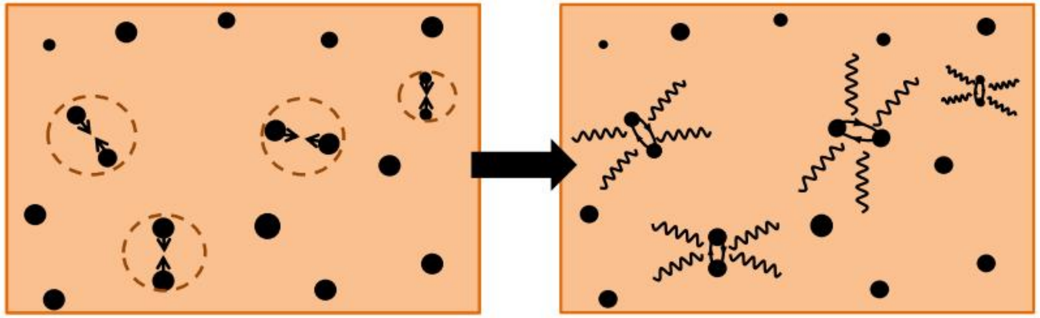

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  - The differential merger rate per unit volume at the time *t*

$$\mathcal{R}(m_i, m_j, t) \approx \frac{1.02\times 10^8}{\mathrm{Gpc^3 yr}} f^2 \left(\frac{M_\odot}{m_i}\right)\left(\frac{M_\odot}{m_j}\right)\left(\frac{m_i + m_j}{M_\odot}\right)\left(\frac{t_0}{t}\right) Y(y(m_i, m_j, t))\psi(m_i)\psi(m_j)$$

[Huang, H. L., Jiang, J. Q., & Piao, Y. S. (2024)]

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- The spectral density of GWs from unresolved SMPBH binaries :

$$h^2\Omega_{\rm GW}(f) = \frac{\nu}{\frac{\rho_c}{h^2}} \int \frac{dR(m_i, m_j, z)dz}{(1+z)H(z)} \frac{dE_{\rm GW}(f')}{df'}\Big|_{f'=(1+z)f}$$

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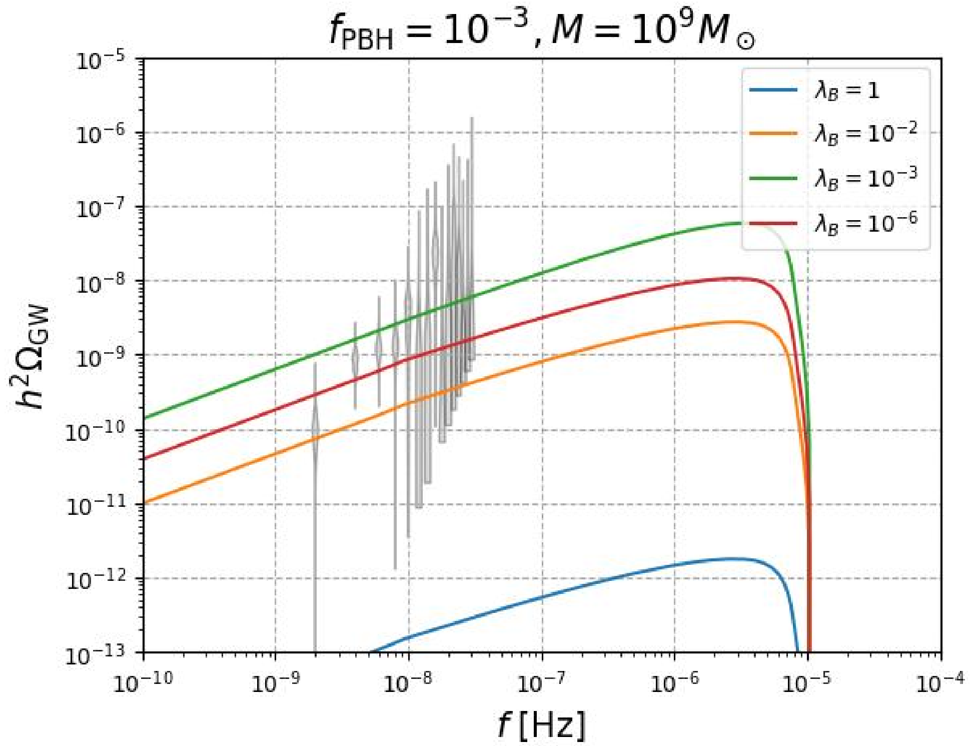

Conclusions

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