Spinning Primordial Black Holes from First Order Phase Transitions

Indra Kumar Banerjee

IISER Berhampur

20/12/2023

PHOENIX 2023

Based on *Spinning Primordial Black Holes from First Order Phase Transition*, **IKB**, U. K. Dey, arXiv: 2311.03406

Few important points about PBH

- PBHs were proposed as compact objects, more precisely, black holes formed in the early universe.

Few important points about PBH

- PBHs were proposed as compact objects, more precisely, black holes formed in the early universe.
- They can partially or completely play the role of dark matter in the standard cosmology.

Few important points about PBH

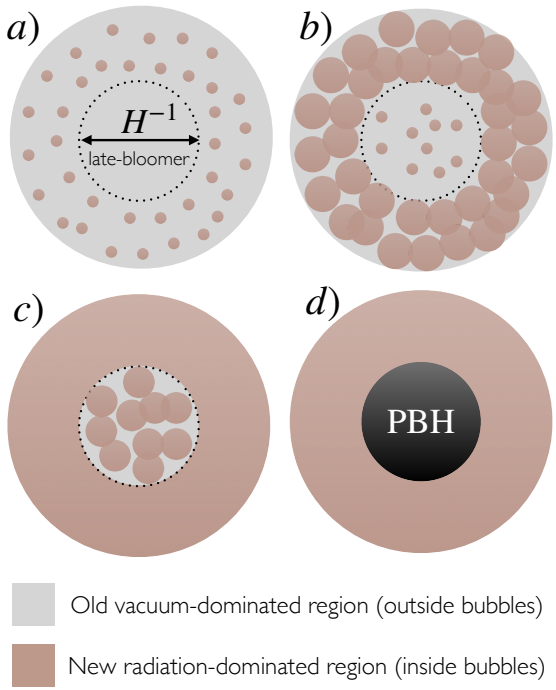
- PBHs were proposed as compact objects, more precisely, black holes formed in the early universe.
- They can partially or completely play the role of dark matter in the standard cosmology.
- Many theoretical predictions, such as Hawking evaporation or superradiant instability, can be verified from PBHs.

Few important points about PBH

- PBHs were proposed as compact objects, more precisely, black holes formed in the early universe.
- They can partially or completely play the role of dark matter in the standard cosmology.
- Many theoretical predictions, such as Hawking evaporation or superradiant instability, can be verified from PBHs.
- PBHs can originate from inflation, cosmic strings, first-order phase transitions (FOPT), etc

Creation of PBH

- In this study, we consider the delayed vacuum decay during a FOPT as the mechanism that creates PBH.



(taken from arXiv: 2305.04942)

Generation of PBH Spin

- The spectral moments:

$$\sigma_n^2 = \int \frac{dk}{k} k^{2n} \mathcal{P}_\zeta(k)$$

- The fraction that collapses:

$$\beta_0 = \sqrt{\frac{2}{\pi}} \frac{2}{5} \frac{\sigma_h}{\delta_{\mathrm{H,th}}} \exp\left[-\frac{25}{8}\left(\frac{\sigma_h}{\delta_{\mathrm{H,th}}}\right)^2\right]$$

Generation of PBH Spin

- Mass of the PBHs:

$$M_{\rm PBH} = 9.23 \times 10^{31} \left(\frac{T}{\rm GeV}\right)^{-2} \ {\rm g}$$

- Abundance:

$$f_{\rm PBH} = 1.26 \times 10^{26} \beta_0 \left(\frac{M_{\rm PBH}}{\rm g}\right)^{-1/2}$$

- Spin:

$$\langle a_*^2 \rangle^{1/2} = \frac{\mathcal{A}\sqrt{1-\gamma^2}}{\left(1 + 0.036\left[21 - 2\log_{10}\left(\frac{f_{\rm PBH}}{10^{-7}}\right) - \log_{10}\left(\frac{M_{\rm PBH}}{10^{15}{\rm g}}\right)\right]\right)}$$

Dependence on FOPT parameters

- The curvature power spectrum:(arXiv:2208.14086)

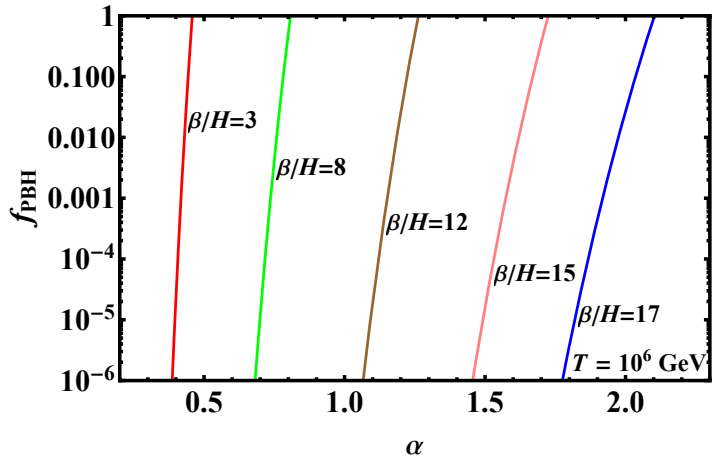
$$\mathcal{P}_\zeta(k) = 34.5[\sigma_H(\alpha, \beta/H)]^2(k/\mathcal{H})^3$$

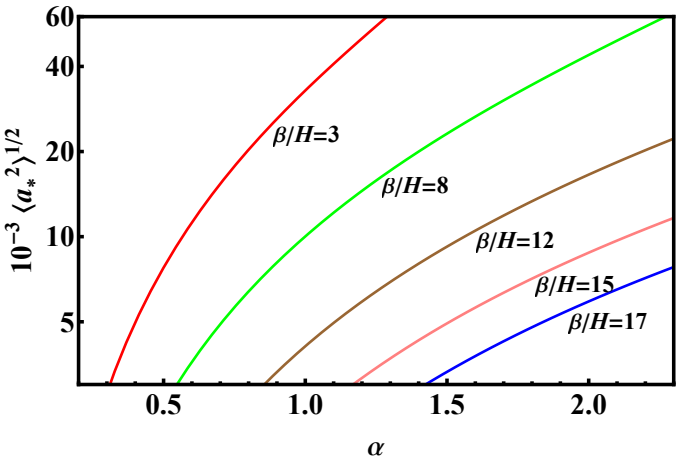
- Spin:

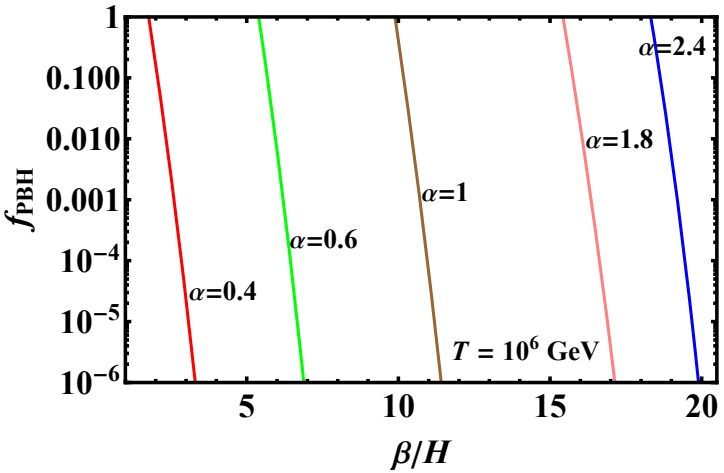
$$\langle a_*^2 \rangle^{1/2} = \frac{\mathcal{A}\sqrt{1-\gamma^2}}{\left(1 + 0.036\left[21 - 2\log_{10}\left(\frac{f_{\rm PBH}}{10^{-7}}\right) - \log_{10}\left(\frac{M_{\rm PBH}}{10^{15}{\rm g}}\right)\right]\right)}$$

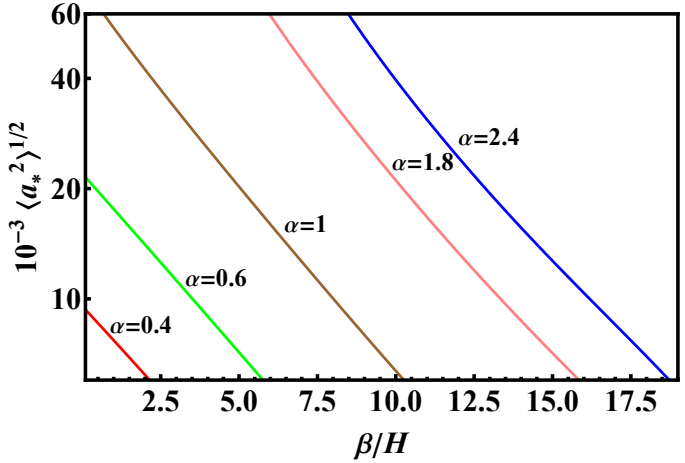
- Narrow power spectrum (arXiv: 2011.00710):
  $\mathcal{A} = 4.01 \times 10^{-3}$
- The power spectrum due to FOPT (arXiv: 2311.03406)
  $\mathcal{A} = 2.5 \times 10^{-2}$

Dependence on FOPT parameters

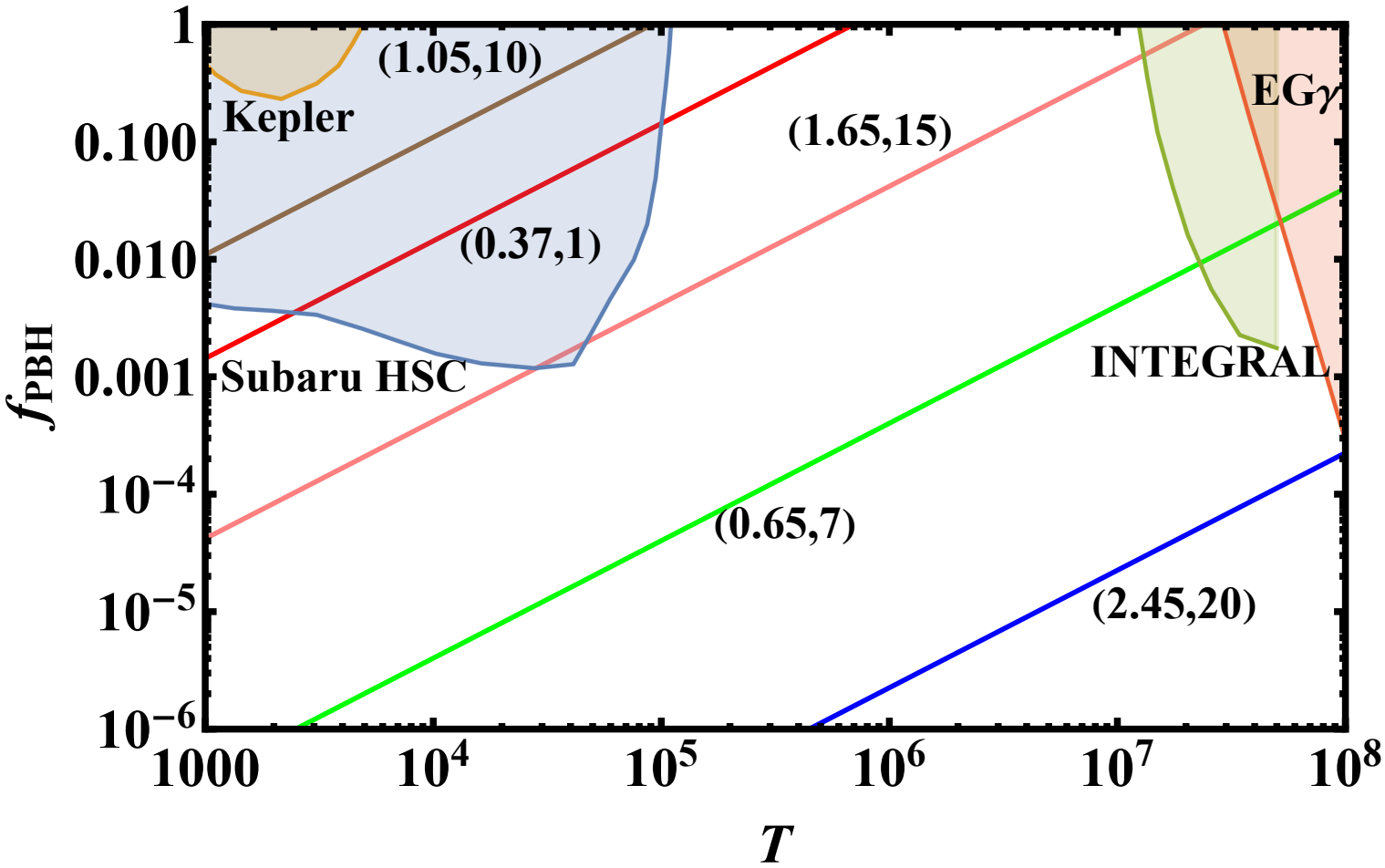








Dependence on FOPT parameters



Dependence on FOPT parameters

- PBH mass depends on the transition temperature, whereas the PBH abundance and spin depend on the strength of the FOPT (α), the inverse time scale of the FOPT (β), and the transition temperature.
- $\{T, \alpha, \beta/H\} \rightarrow \{M_{\rm PBH}({\rm g}), f_{\rm PBH}, 10^{-3}\langle a_* \rangle^{1/2}\}$
  $\{10^8\ {\rm GeV}, 3.22, 22\} \rightarrow \{9.23 \times 10^{15}, 0.00025, 4.74\}$
  $\{10^6\ {\rm GeV}, 2.1, 17\} \rightarrow \{9.23 \times 10^{19}, 0.918, 6.48\}$
  $\{100\ {\rm GeV}, 2.7, 18\} \rightarrow \{9.23 \times 10^{27}, 0.0176, 8.79\}$
  $\{26\ {\rm GeV}, 1.4, 12\} \rightarrow \{1.36 \times 10^{29}, 0.0161, 8.04\}$

Future Scope

- Supercooled cases, for which the order of the nucleation and the percolation temperatures are different than that of the critical temperature, might give rise to different temperature dependence.
- FOPTs in Non-standard cosmology, such as some early matter-dominated era, may give rise to PBH with high initial spin, which has implications in Hawking evaporation superradiant instability, gravitational waves, etc.

Thanks!