Correlating Gravitational Wave and Gamma-ray Signals from Primordial Black Holes

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Based Upon:
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Introduction

- GW from black hole mergers have been measured by LIGO/VIRGO.
- Depending on their mass, black holes can also produce SM particles through Hawking radiation.
- Because the GW and EM signals are uniquely dependent on black hole parameters mass and spin, being able to measure both would provide valuable information about the black holes.

Introduction

- Unfortunately, it is hard to measure the Hawking radiation and GW from merger events (Don't fall in the same observational window).
- Is there a mass range where it is possible to measure both GW and EM signals?
- If there is, what can we do with it?

BH Mass Range

- For Hawking radiation, the most ideal mass range is easy to find.
- We want the most brightest BH that are still around today.
- This corresponds to $M_{\rm BH} \sim 10^{14-16}$ g.
- Also, from EGB and CMB experiments, we know that the maximum observable monochromatic BH ($f_{\rm BH} = 1$) is $M_{\rm BH} \sim 10^{17}$ g.
- Therefore, our search range is $M_{\rm BH} = 10^{14-17}$ g, i.e. asteroid mass.

Producing PBH and GW

- These masses correspond to Hawking temperatures around $0.1 - 100$ MeV and will be measured by upcoming Gamma-ray detectors.
- This mass range cannot be produced by stellar collapse and falls under the name Primordial Black Holes (PBHs).
- Mergers of PBHs in this range cannot give a sizable GW signal.

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- Mergers of PBHs in this range cannot give a sizable GW signal.
- Remarkably, there is another source of GW!

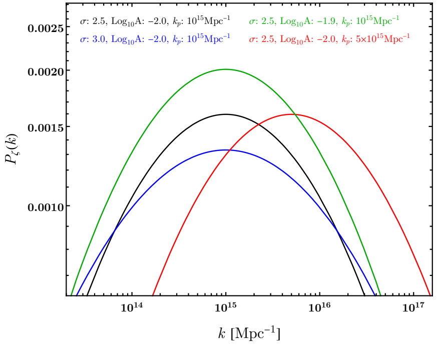
Producing PBH and GW

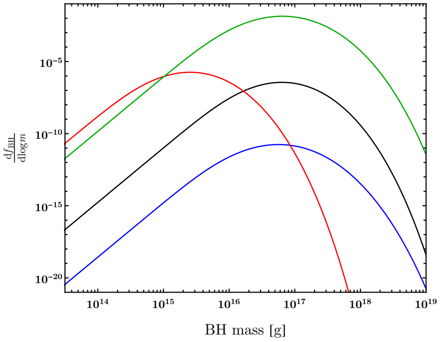
- Many theories predict the formation of PBHs through the gravitation collapse of order 1 density fluctuations. (2108.12475)
- These large density fluctuations also source GW. (1804.08577)
- Combining the two together, we can gain insight into the PBH production method.

Density Perturbations

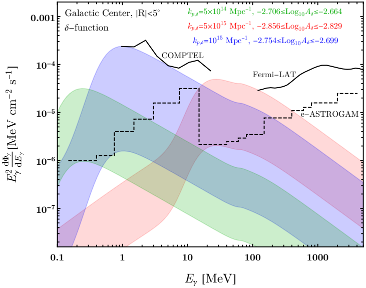
We consider the large curvature perturbations as either

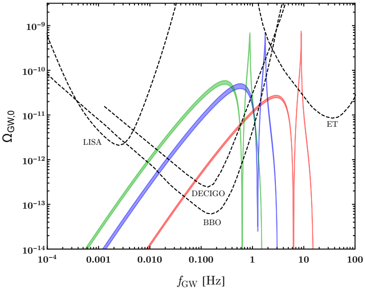
- Delta: $P_{\zeta,\delta}(k) = A_\delta \, \delta \left(\log \left(\frac{k}{k_{p,\delta}} \right) \right)$
- Log-Normal: $P_\zeta(k) = \frac{A}{\sqrt{2\pi\sigma^2}} \ \exp \left(- \frac{(\log k - \log k_p)^2}{2\sigma^2} \right)$

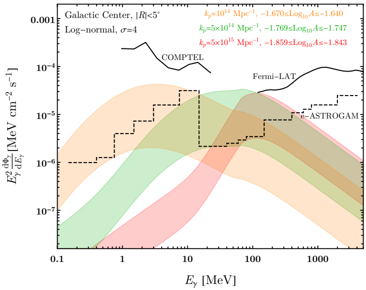


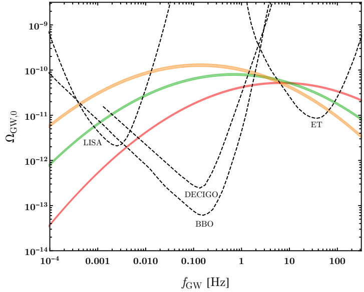


EM and GW Signals



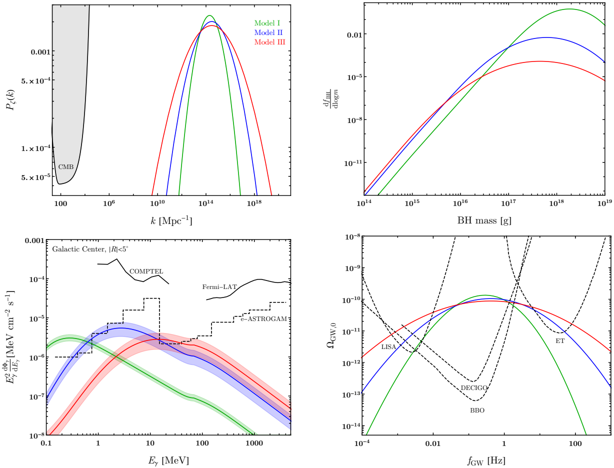






Example Models

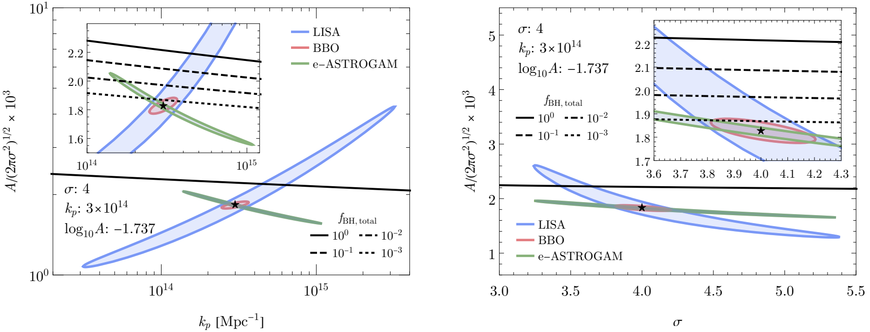
Model	σ	k_p [Mpc^{-1}]	$\log_{10} A$	$A(2\pi\sigma^2)^{-\frac{1}{2}}$	$f_{\rm BH,total}$	$m^{\rm peak}$ [g]	σ_m	$\gamma_{\rm eff}$
I	2	2×10^{14}	-1.933	2.327×10^{-3}	1.0	1.8×10^{18}	0.76	3.6
II	3	3×10^{14}	-1.820	2.013×10^{-3}	1.4×10^{-2}	6.1×10^{17}	1.0	2.8
III	4	3×10^{14}	-1.737	1.827×10^{-3}	3.7×10^{-4}	4.5×10^{17}	1.2	2.0



Model III

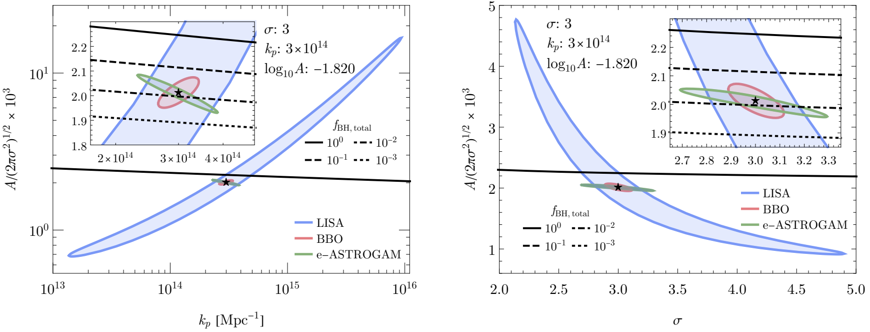
- High sensitivity to A and strong anti-correlation between the two data-sets permit a high precision determination of curvature parameters.

- Measurement with BBO can lead to further confidence in model.



Model II

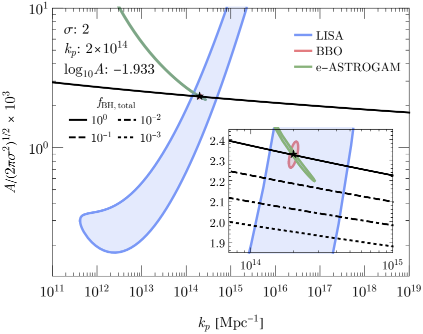
- Because the EM signal is so sensitive to A, the associated region can vary greatly while the GW doesn't.

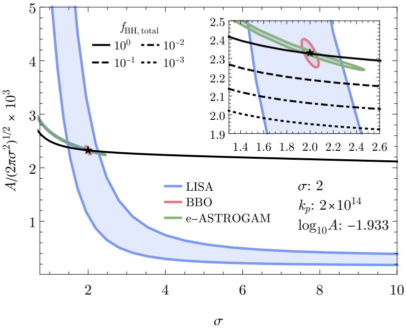


Model I

- Capable of obtaining $f_{\rm BH} = 1$.

- Individually, each experiment has poor confinement of parameters as large degenerate parameter spaces are found. (Note that most of these degenerate regions should be ruled out by other measurements.)





Summary

- The measurement of Hawking radiation from asteroid mass black holes produced by density perturbations can be correlated with the predicted GW signal from the density perturbations to lead to a smoking gun signal in order to distinguish them from other sources.
- Performing this correlation will allow for precise measurement of the Primordial Matter Spectrum at high k.
- Much more work needs to be done, particularly on theory leading to the generation of PBHs in order to be confident in the results.

Thank You!