

Search for Sub-Solar Mass Binary Black Holes



by Gravitational Waves

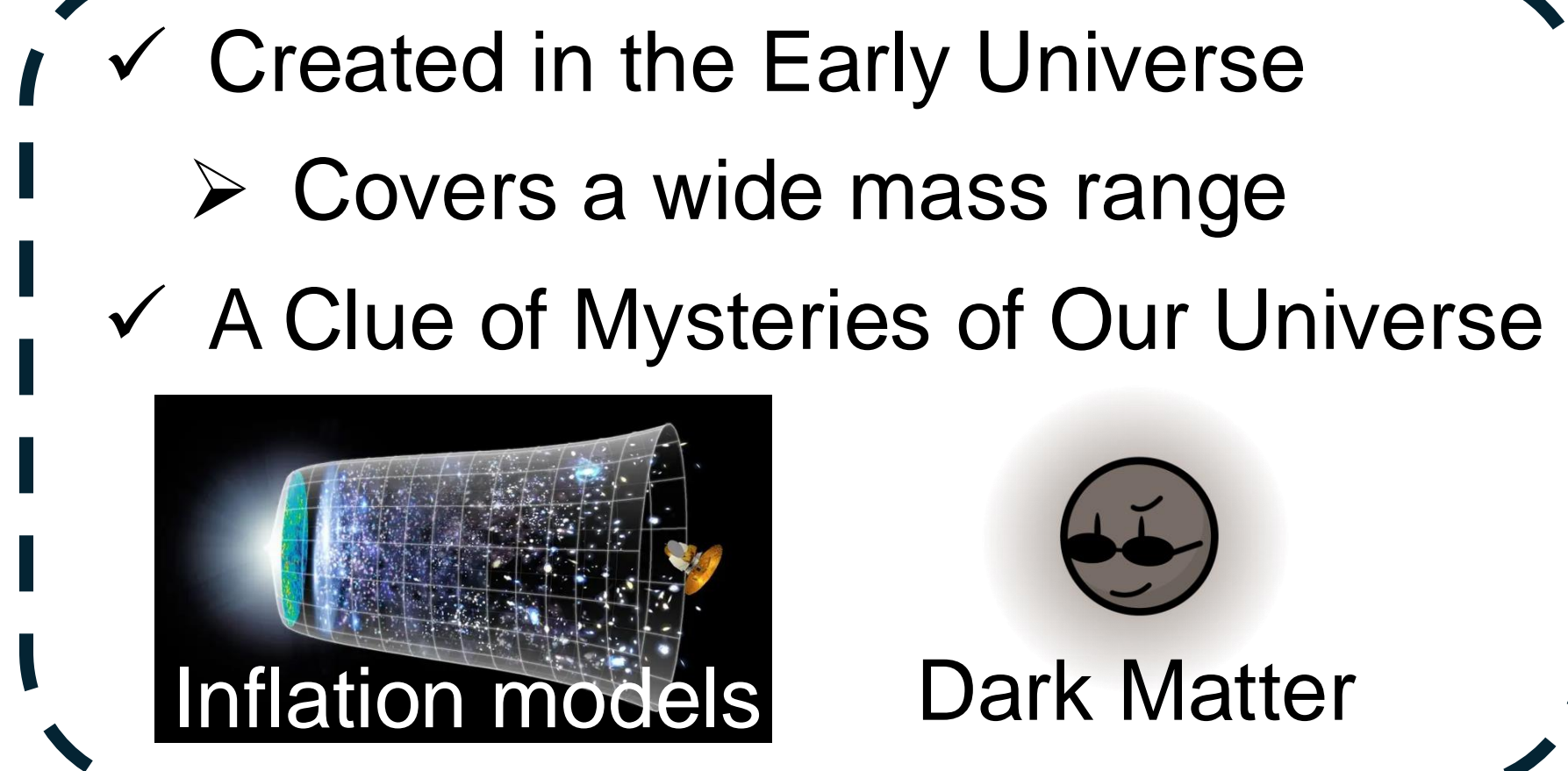
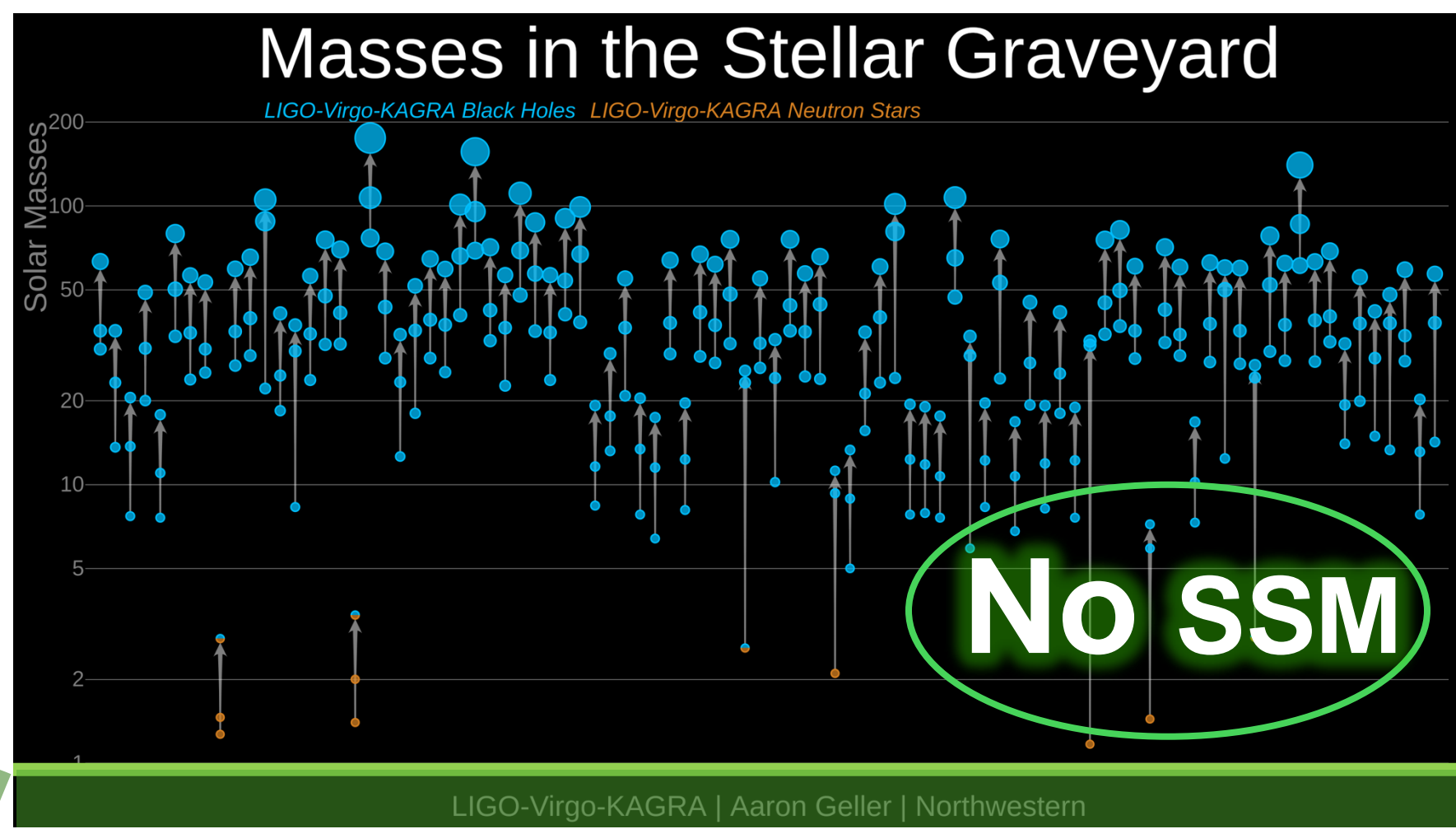
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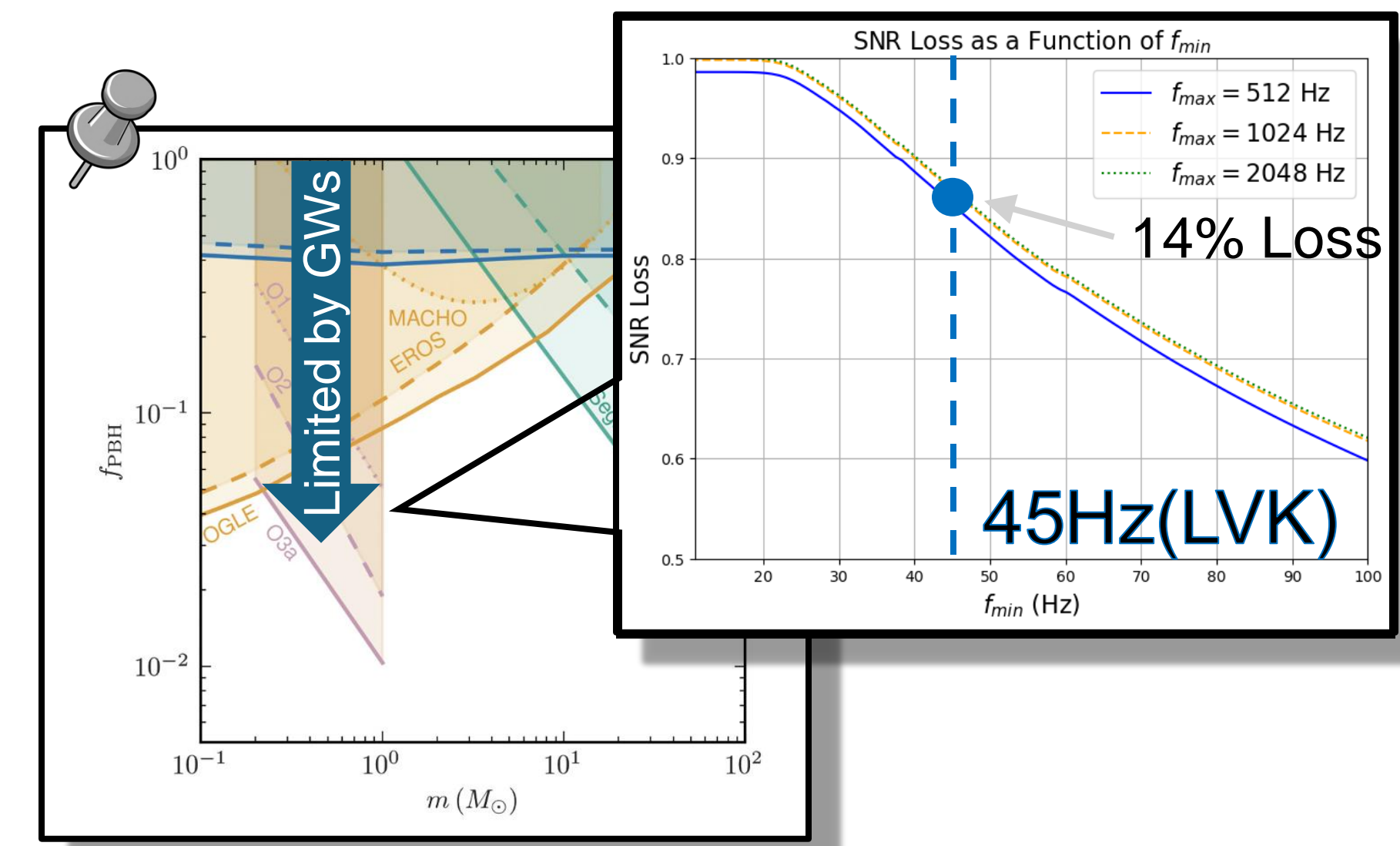


Motivation

Our Universe seen thorough GWs



LVK SSM search



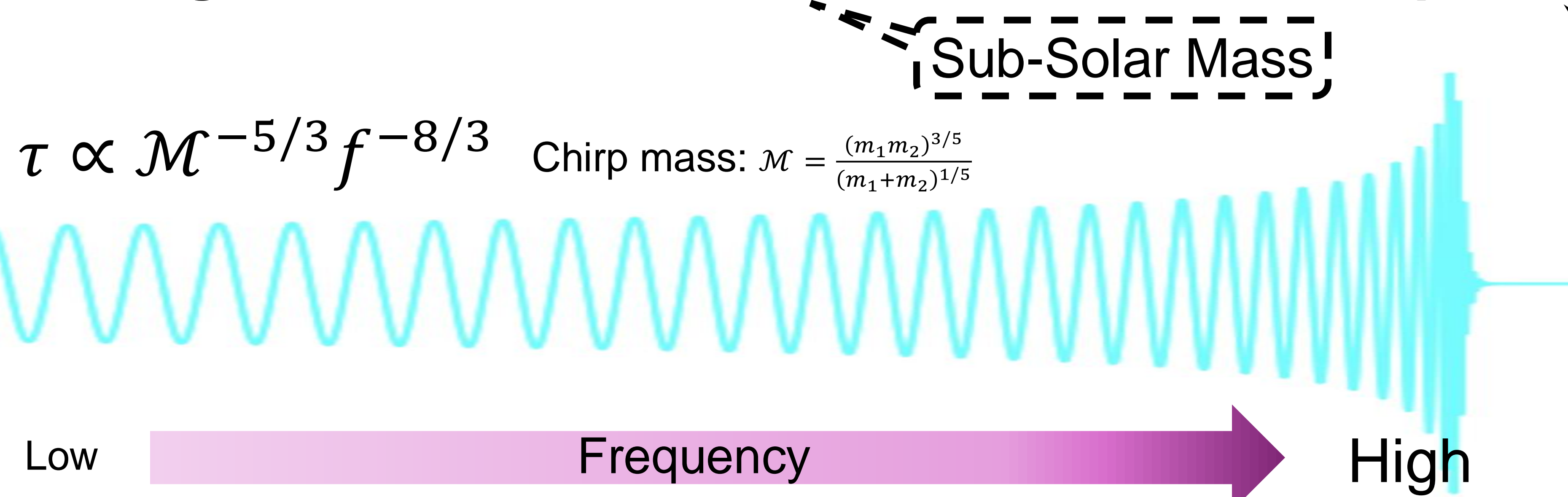
Candidates of SSM objects?

- ✗ Star formation
- Primordial Black Hole (PBH)

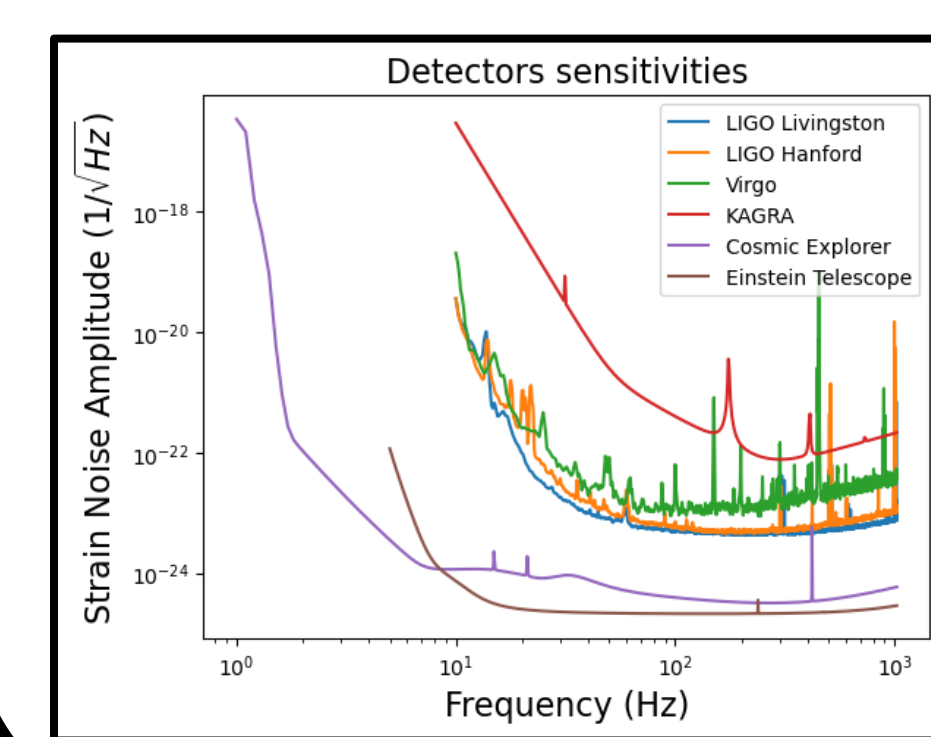
- ✓ LVK gives the strongest restriction
- ✓ But, LVK's search has deleted the observed data below 45Hz

Problems

Longer duration in Lower mass and Lower frequency



Extend sensitivity to lower frequency in future detectors



Even Longer !!

Need to prepare for future observations

Method

NEED for optimal SSM search

- Long time to make such long waveforms
- Can't track Noise(PSD)
- Earth's rotation effect ...

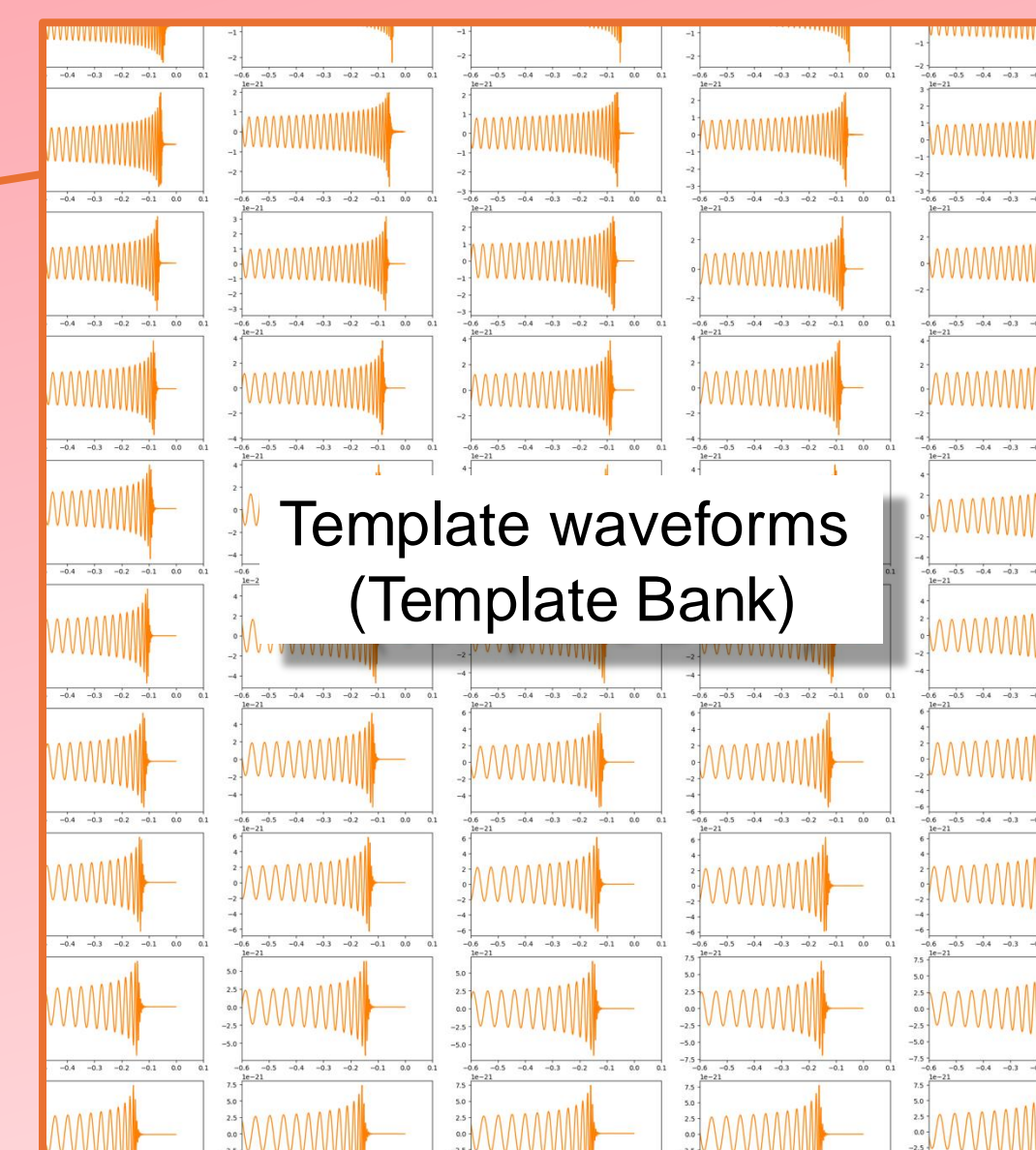
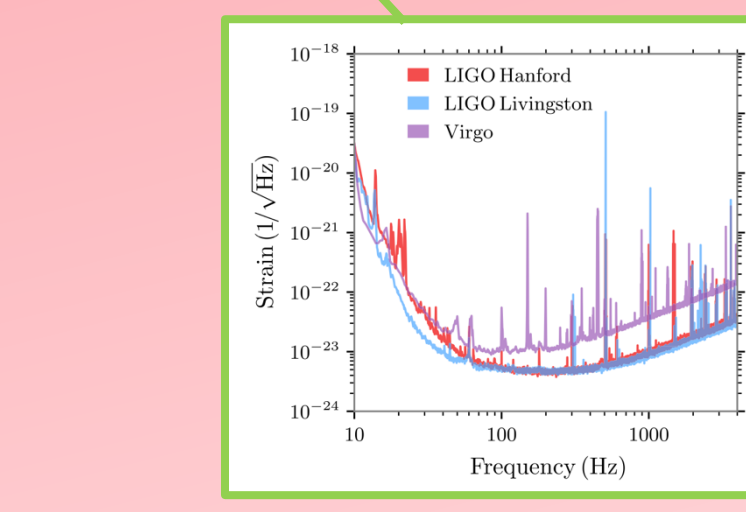
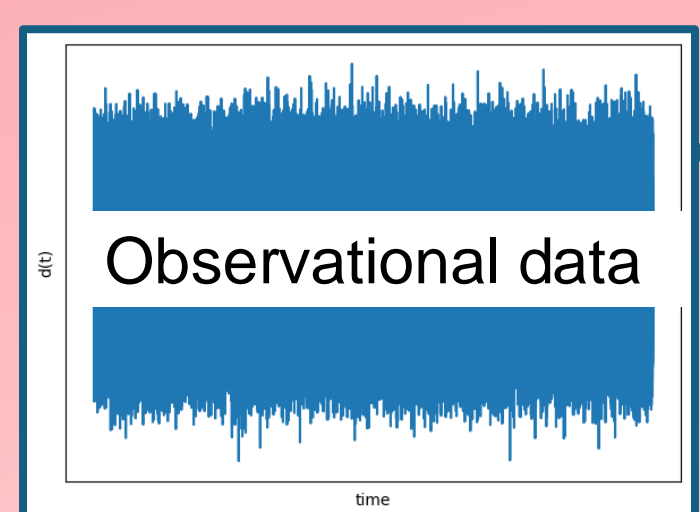
NEED more search efficiently

- Long-Waveforms are highly sensitivity to parameter changes
- Prepare many templates with various parameters

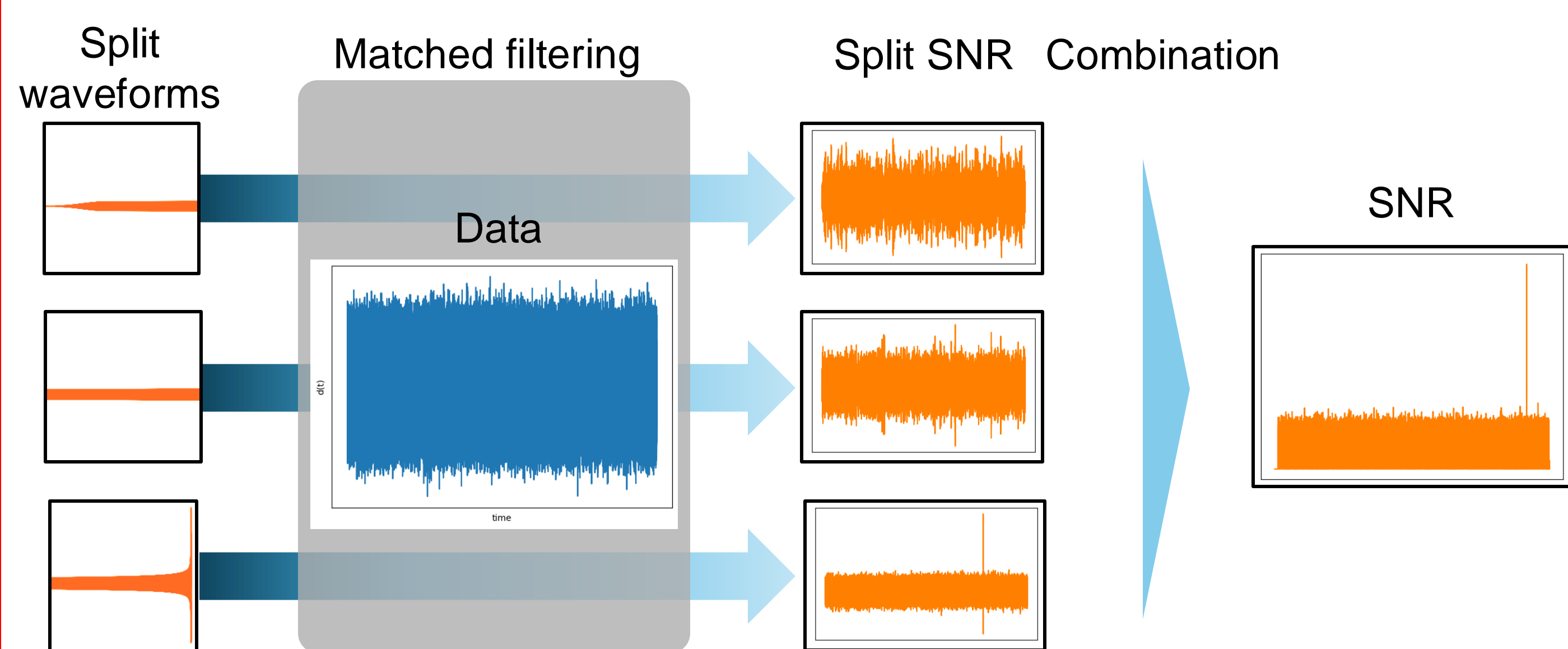
How to find Gravitational Waves: Matched filtering

- Noise < Signal
- Correlate between data and template waveforms (**Matched filtering**: right image)
- Never know what kind of GWs coming
- Prepare a lot of template waveforms (**Template Bank**)

$$\frac{\text{Signal}}{\text{Noise}} \propto \text{SNR}(t) = 4 \left| \int_{f_{\min}}^{f_{\max}} \frac{\tilde{d}(f) \tilde{h}^*(f)}{S_n(f)} e^{2\pi i f t} df \right|$$



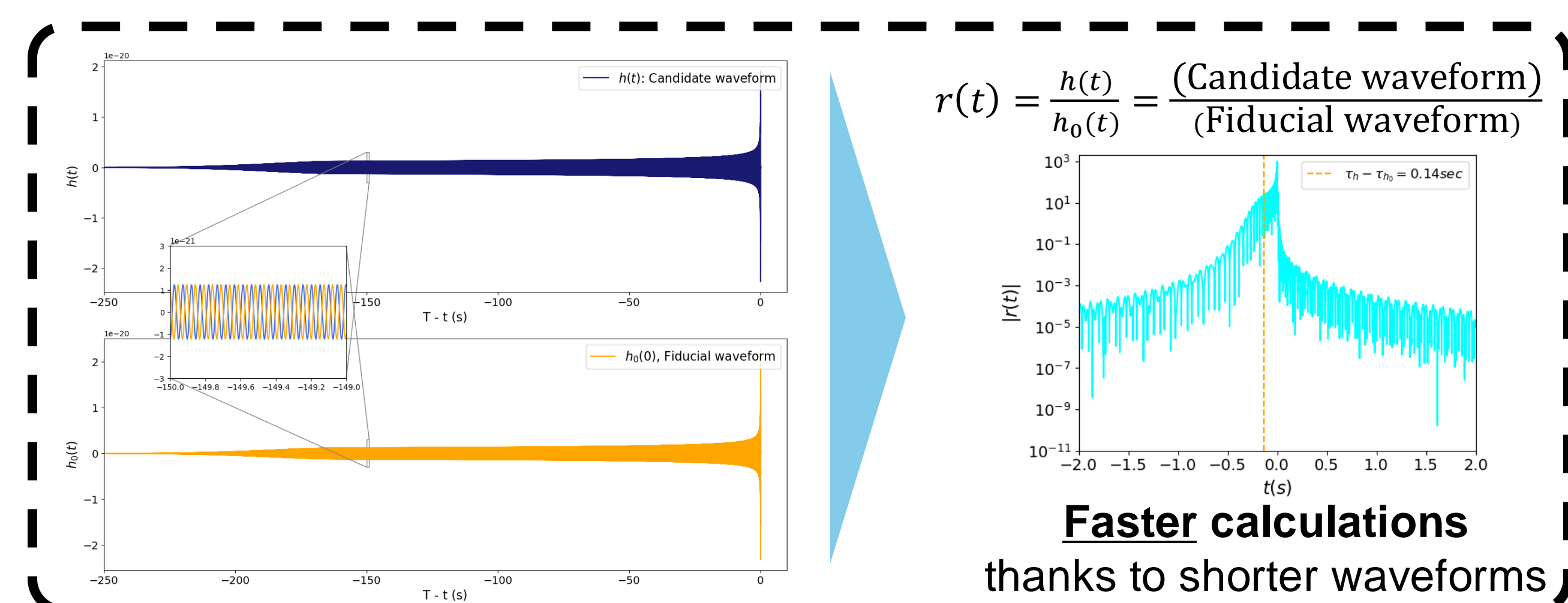
Split a long waveform and perform matched filtering



$$z(t) = 4 \int_{f_{\min}}^{f_{\max}} \frac{\tilde{d}(f) \tilde{h}^*(f)}{S_n(f)} e^{2\pi i f t} df = 4 \sum_{l=0}^{N_b-1} \int_{f_{\min}}^{f_{\min} + \Delta f} \frac{\tilde{d}(f) \tilde{H}^{(l)*}(f)}{S_n(f)} e^{2\pi i f t} df$$

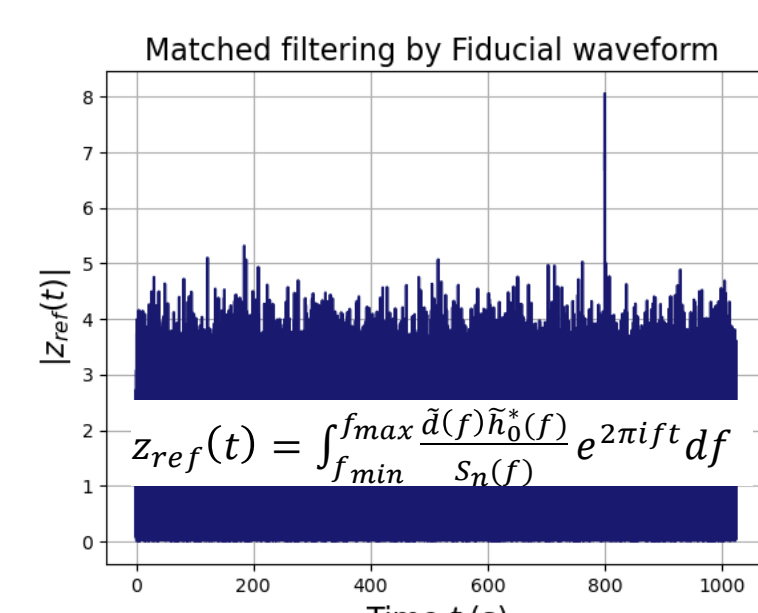
- $\tilde{H}^{(l)}(f)$: waveform with phase adjustment
- N_b : number of split waveforms

The duration of the ratio between waveforms is much shorter than each waveform.



$$r(t) = \frac{h(t)}{h_0(t)} = \frac{\text{(Candidate waveform)}}{\text{(Fiducial waveform)}}$$

Faster calculations thanks to shorter waveforms



Convolution
 $z(t) = \int z_{ref}(t) r(t-s) ds$
 Various ratio waveforms

