Gravitational wave memory may be detectable.

Detecting Orphan Memory from Gravitational Waves

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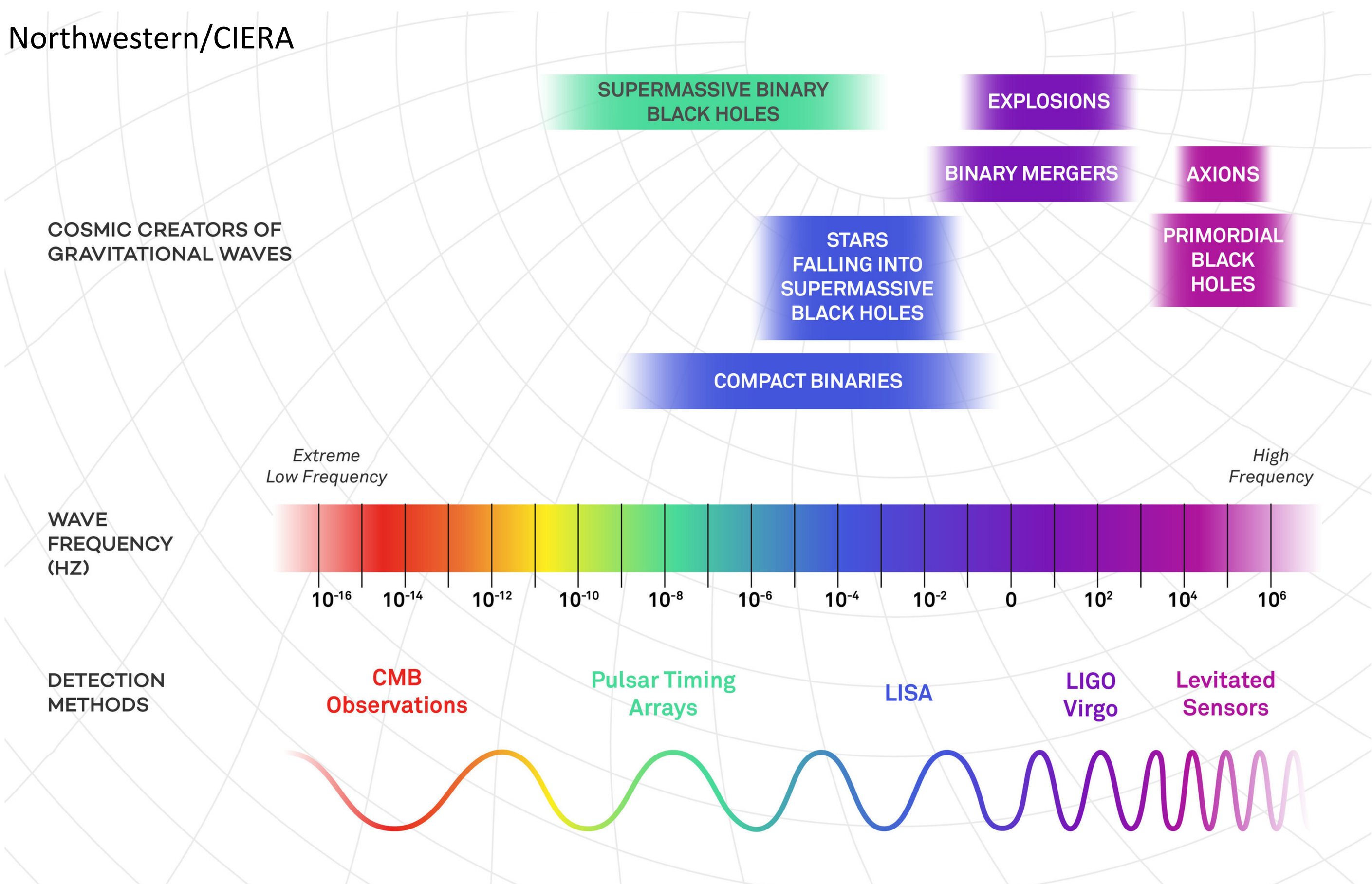
Background on Gravitational Waves

- Gravitational waves (GWs) are distortions in spacetime caused by accelerating masses.
- We have measured GWs from both neutron star and black hole mergers using the LIGO and Virgo detectors.
- Similar to sound and light, GWs occur in a spectrum of frequencies.

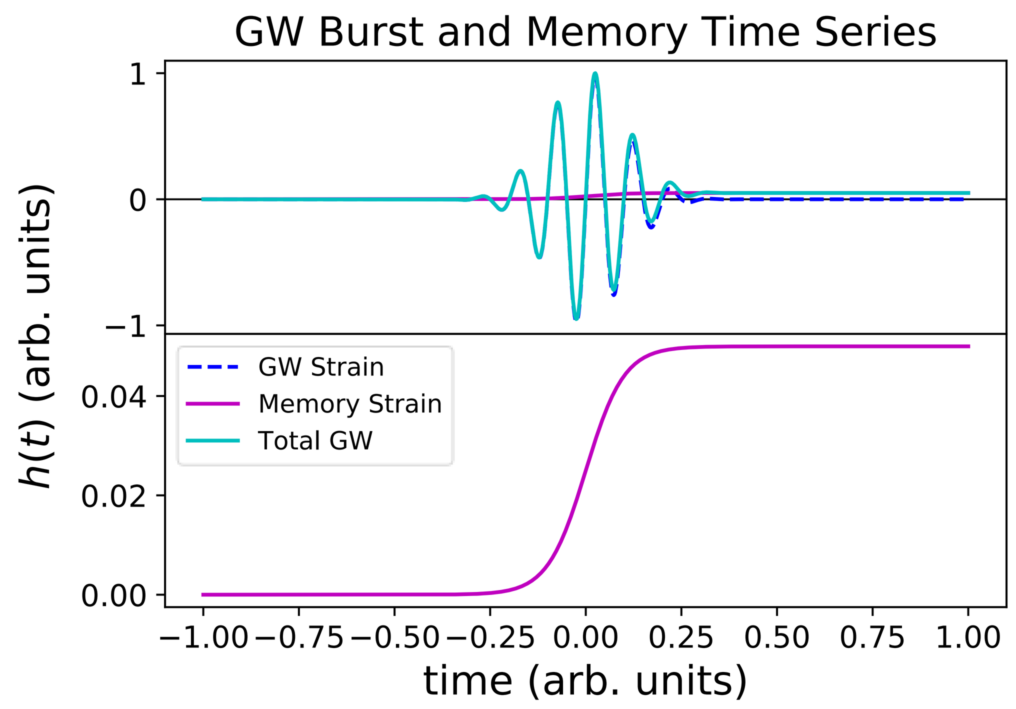


Our research looks at common sources between low and high frequency detectors, specifically those from which we may be able to observe memory.

Today's GW Detectors

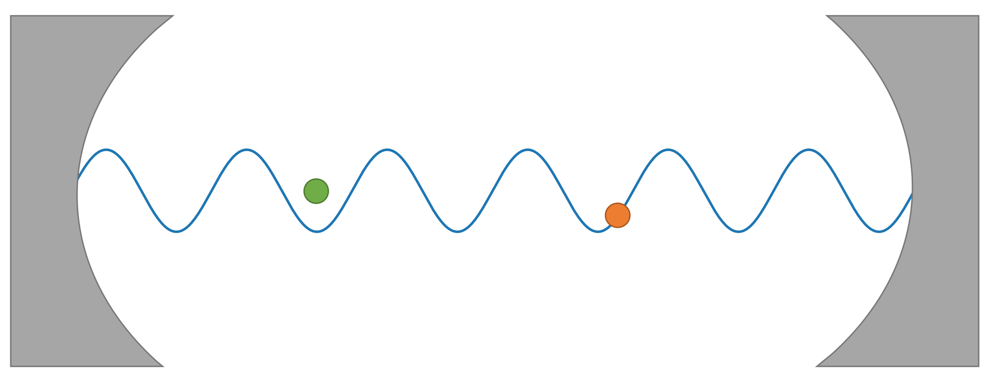
- The LIGO and Virgo detectors are large L-shaped detectors with arms extending over two miles.
- When a GW passes the LIGO detector, one arm is stretched more than the other, and that strain is measured.
- For binary black holes, the oscillatory strain, h, is approximately $\frac{\Delta L}{L} \sim 10^{-21}$.

Memory



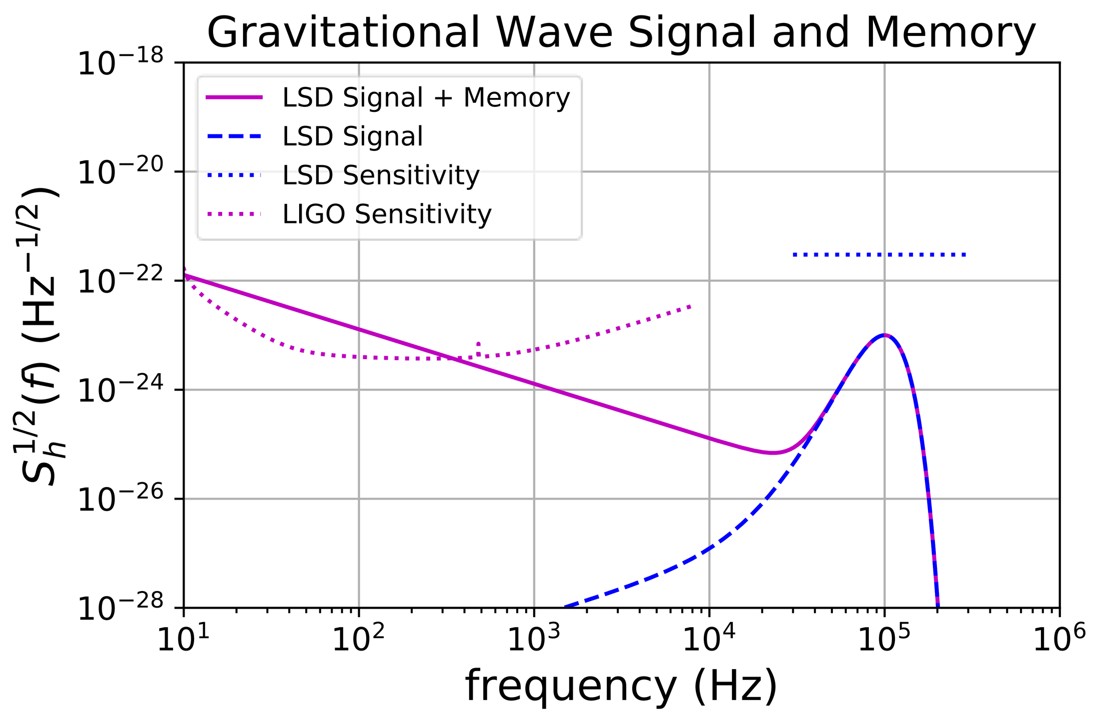
- In this work, we aim to study memory from gravitational waves: a permanent strain left in the spacetime after a GW has passed by.
- This displacement is small, leading to a memory strain which is ~ 20x smaller than the oscillatory strain.

Future GW Detectors

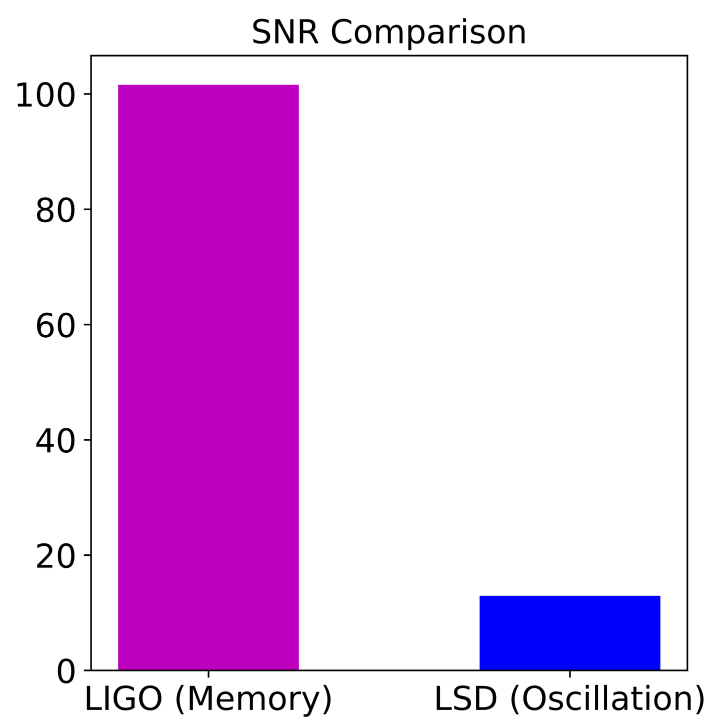


A future detector, called the Levitated Sensor Detector (LSD) will be a fraction of LIGO's size, and observe high frequency GWs. This high frequency detector is a small cavity with a nanosphere or microdisk optically trapped in an antinode (green circle). When a GW passes, the trap-equilibrium position shifts with respect to the particle (orange circle). This applies an effective force on the particle proportional to the strength of the GW. When the GW frequency is in resonance with the trap frequency, the particle undergoes a large displacement due to this force [1].

Orphan Memory



McNeil et al. show that if a high freq. detector like LSD were to observe the oscillatory part of the GW signal, LIGO would most likely observe the memory part of that signal. In the above plot, we see an example of this with a high frequency burst and memory trailing off to lower frequencies. The name "orphan" comes from the lack of a detectable parent GW signal [2].



- Above, we see a signal-to-noise ratio (SNR) comparison for a sample high frequency GW burst along with its memory counterpart.
- This shows that for such a high frequency burst detectable with an SNR of ~ 15 in LSD, the memory from it might be detectable in LIGO with an SNR of ~ 100.

References and Acknowledgements

[1] Arvanitaki, A., & Geraci, A. A. (2013). Detecting High-Frequency Gravitational Waves with Optically Levitated Sensors. *Physical Review Letters*, *110*(7), 071105. https://doi.org/10.1103/PhysRevLett.110.071105

[2] McNeill, L. O., Thrane, E., & Lasky, P. D. (2017). Gravitational Waves from Orphan Memory. *Physical Review Letters*, *118*(18), 181103. https://doi.org/10.1103/PhysRevLett.118.181103

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