Title: Echoes after GW170817 - Petra Duff

Speakers: Amanda Ferneyhough

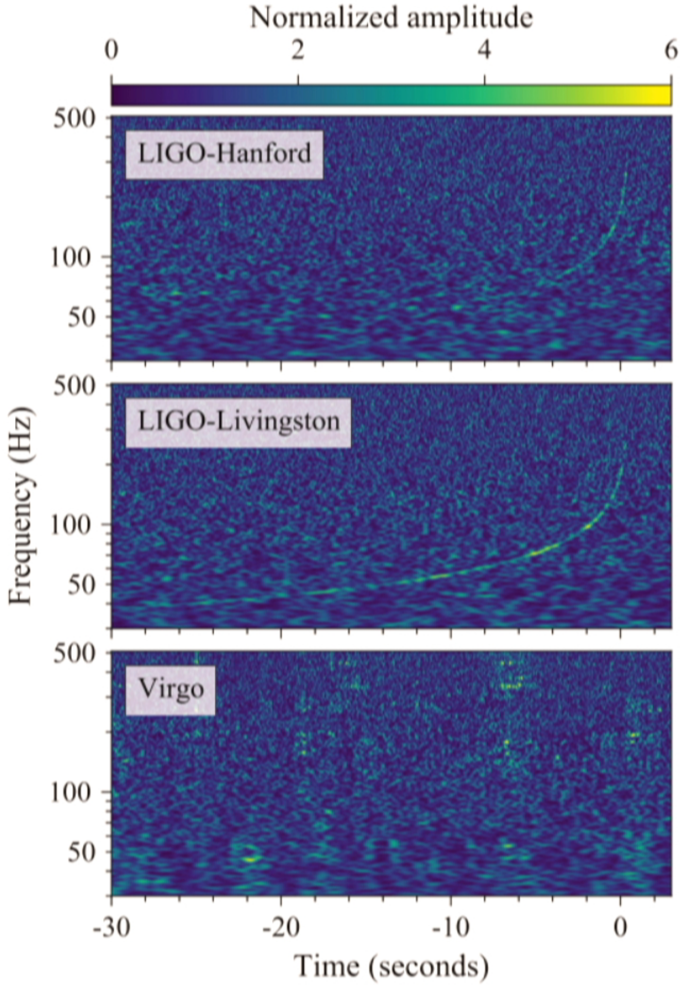
Collection: Echoes in Southern Ontario

Date: February 25, 2020 - 11:30 AM

URL: http://pirsa.org/20020092

GW170817

BNS Merger
August 17 2017,
12:41:04.43 UTC



Abbott, et. al

Gamma-ray burst detected by Fermi GBM 1.7s after the merger

Electromagnetic detection by Coulter et al. narrowed location range to near galaxy NGC 4993 at distance 40^{8}_{-14} Mpc.

Kienlin et al., Coulter et al., Abbott et al.

1. Immediately collapses into a black hole
2. Forms a hypermassive neutron star and collapses within < 1 s
3. Forms a supramassive neutron star and collapses within $10 - 10^4$
4. Forms a stable neutron star

Abbott, et. al

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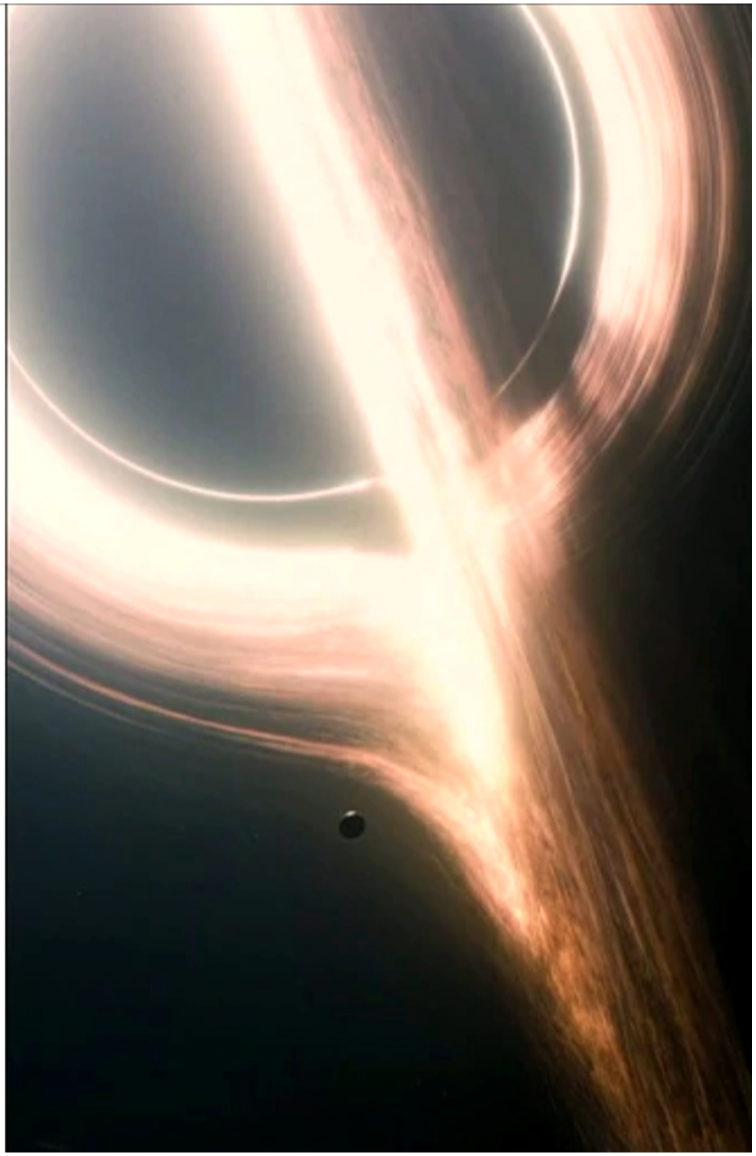
Abbott, et. al



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When Did the Remnant of GW170817 Collapse to a Black Hole?

Ramandeep Gill[1,2], Antonios Nathanail[1], and Luciano Rezzolla[1]
[1] Institut für Theoretische Physik, Max-von-Laue-Strasse 1, D-60438 Frankfurt, Germany
[2] Department of Natural Sciences, The Open University of Israel, 1 University Road, POB 808, Raanana, 4353701, Israel
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Abstract

The main hard pulse of prompt gamma-ray emission in GRB 170817A had a duration of $\sim$0.5 s, and its onset was delayed with respect to the gravitational-wave chirp signal by $t_{\rm del} \approx 1.74$ s. Detailed follow-up of the subsequent broadband kilonova emission revealed a two-component ejecta—a lanthanide-poor ejecta with mass $M_{\rm ej,blue} \approx 0.025\,M_\odot$ that powered the early but rapidly fading blue emission and a lanthanide-rich ejecta with mass $M_{\rm ej,red} \approx 0.04\,M_\odot$ that powered the longer-lasting redder emission. Both the prompt gamma-ray onset delay and the existence of the blue ejecta with a modest electron fraction, $0.2 \lesssim Y_e \lesssim 0.3$, can be explained if the collapse to a black hole (BH) was delayed by the formation of a hypermassive neutron star. Here we determine the survival time of the merger remnant by combining two different constraints, namely, the time needed to produce the requis

In this wa GW170817 must have collapsed to a BH after $t_{\rm coll} = 0.98^{+0.31}_{-0.26}$ s.

also discuss how future detections and the delays between the gravitational and electromagnetic emissions can be used to constrain the properties of the merged object.

Key words: gamma-ray burst: general – gravitational waves – stars: jets – stars: neutron – stars: winds, outflows

Model-Agnostic Search for Echoes

$$h(t) \propto \sum_n \delta_D(t - n\Delta t_{\mathrm{echo}} - t_0),$$

$$h_f \propto \sum_n \delta_D(f - n f_{\mathrm{echo}}),$$

Abedi & Afshordi, 2019

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Abedi & Afshordi, 2019

Method

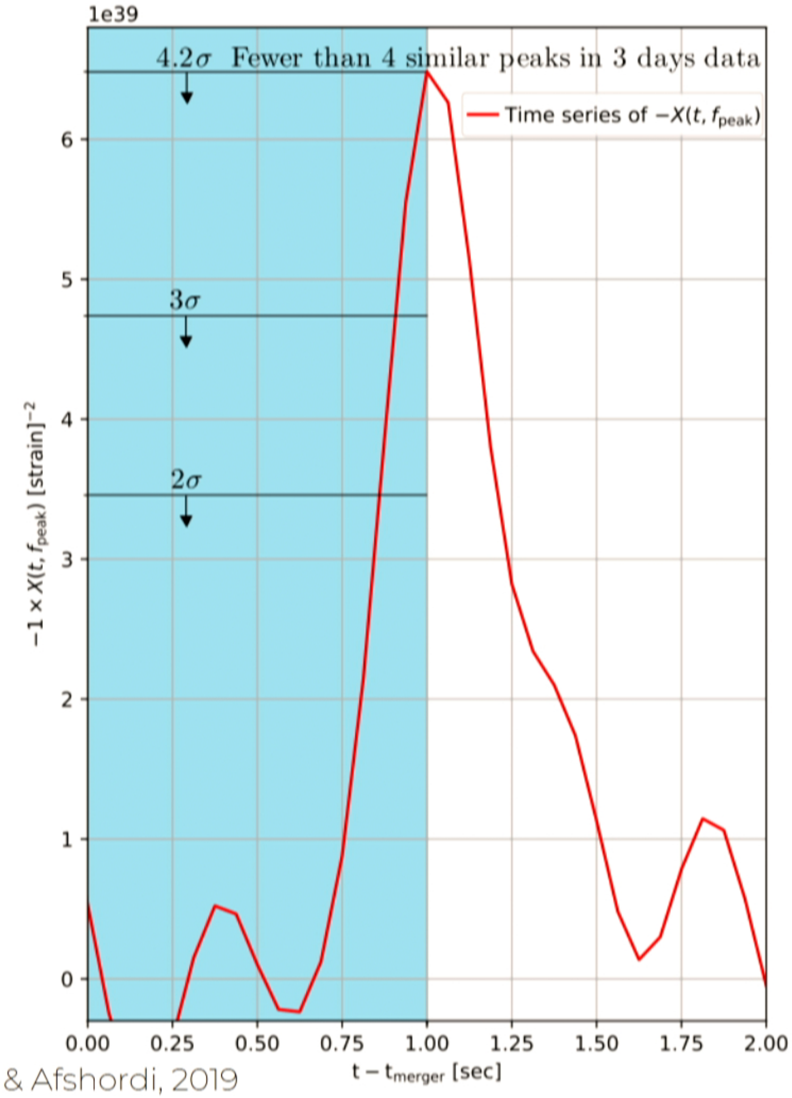
1. 90% credible range: $63 \leq f_{echo}$ (Hz) ≤ 92
2. Search in the time range $0 < t - tmerger \leq 1$ s
3. Wiener filter the strain (with 2.62 ms time delay) and find the spectrogram of each strain

$$H(t,f) = \text{Spectrogram}\left[\text{IFFT}\left(\frac{\text{FFT}(\text{h}_\text{H}(\text{t}-\delta\text{t}))}{\text{PSD}_\text{H}}\right)\right],$$
$$L(t,f) = \text{Spectrogram}\left[\text{IFFT}\left(\frac{\text{FFT}(\text{h}_\text{L}(\text{t}))}{\text{PSD}_\text{L}}\right)\right].$$

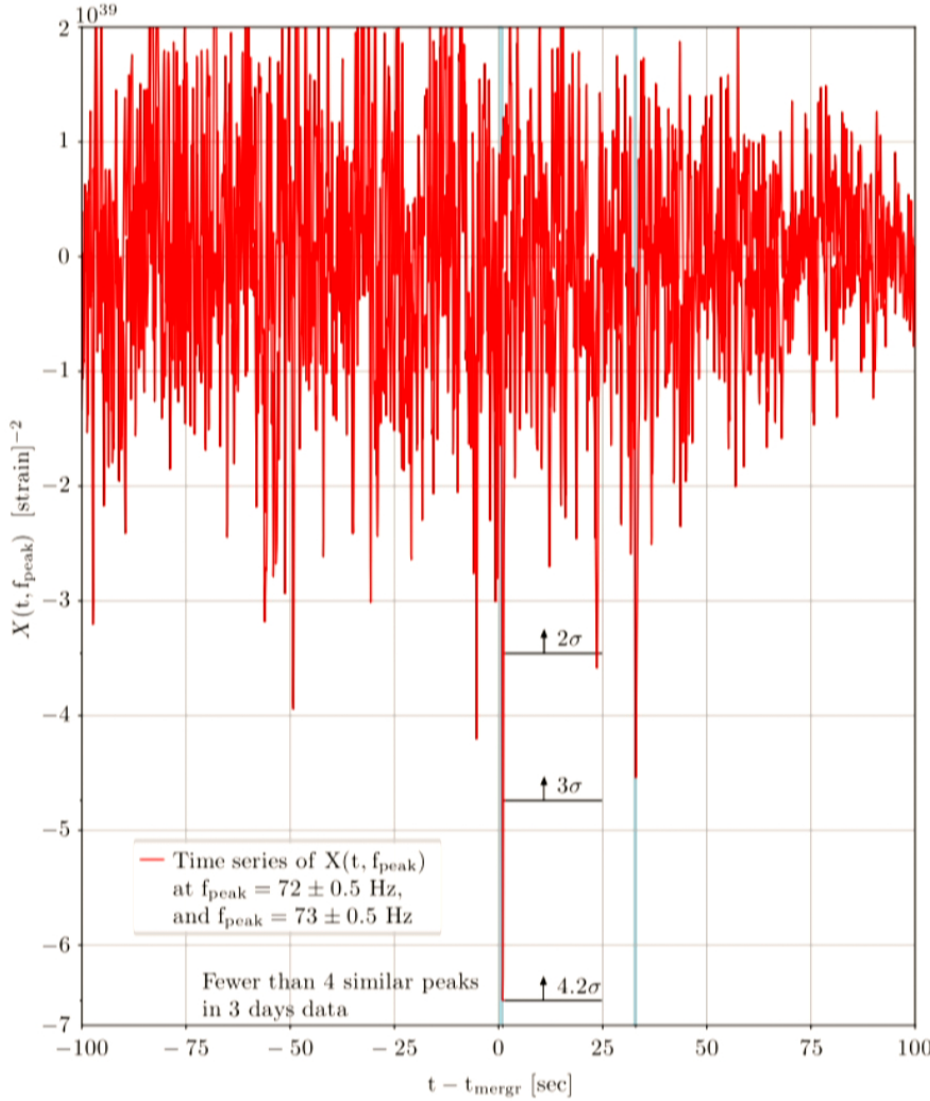
4. Cross-correlate the power spectra over harmonic frequencies

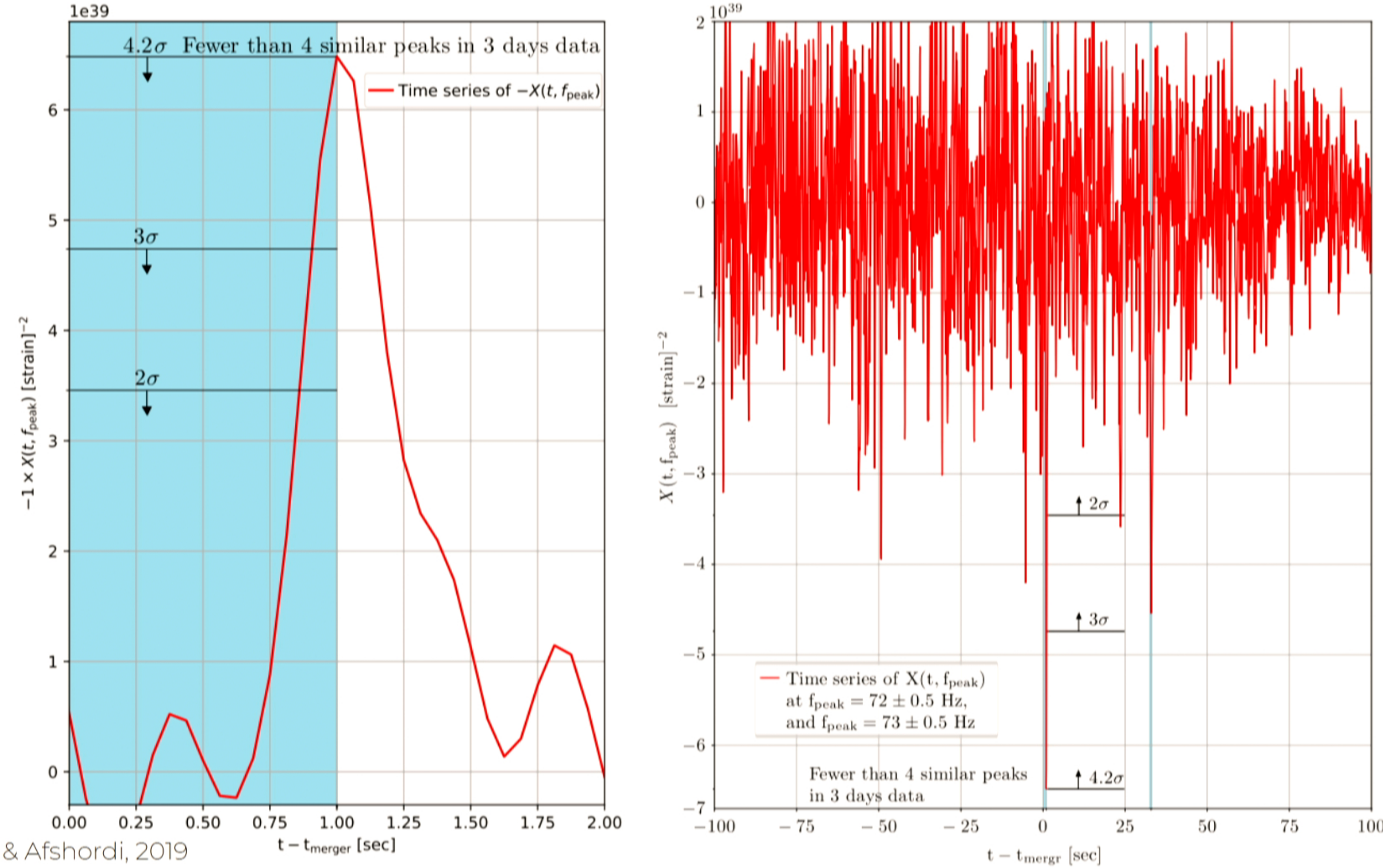
$$X(t,f) = \sum_{n=1}^{10} \Re\left[H(t,nf) \times L^*(t,nf)\right],$$

Abedi & Afshordi, 2019



Abedi & Afshordi, 2019

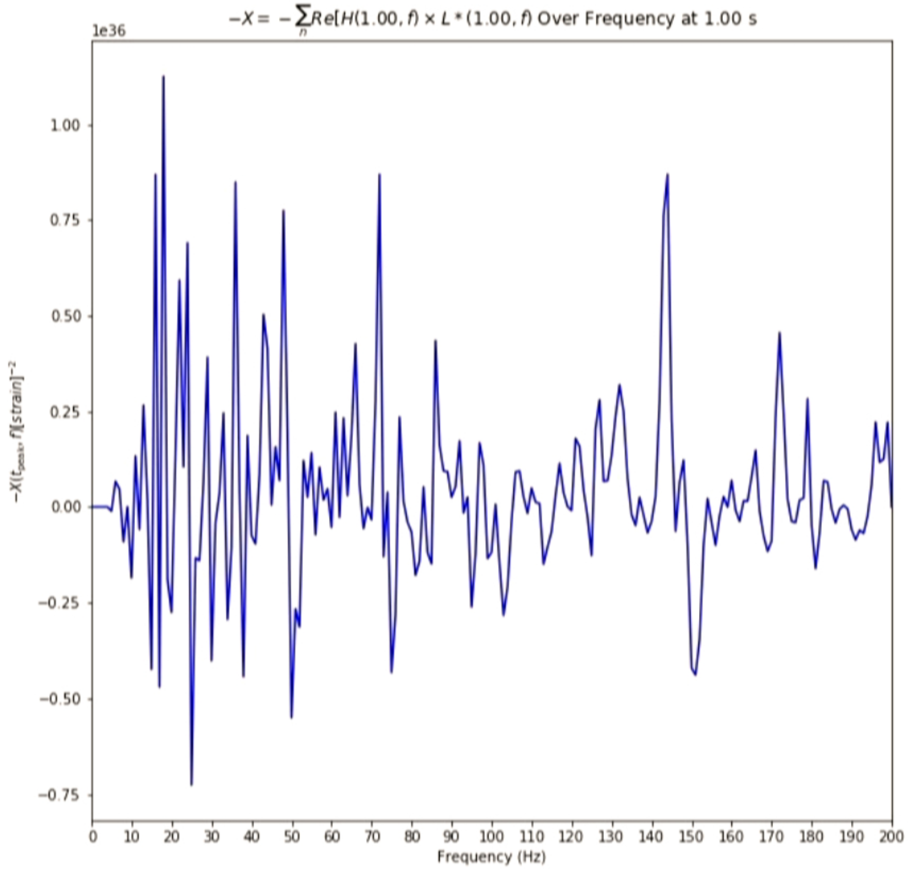


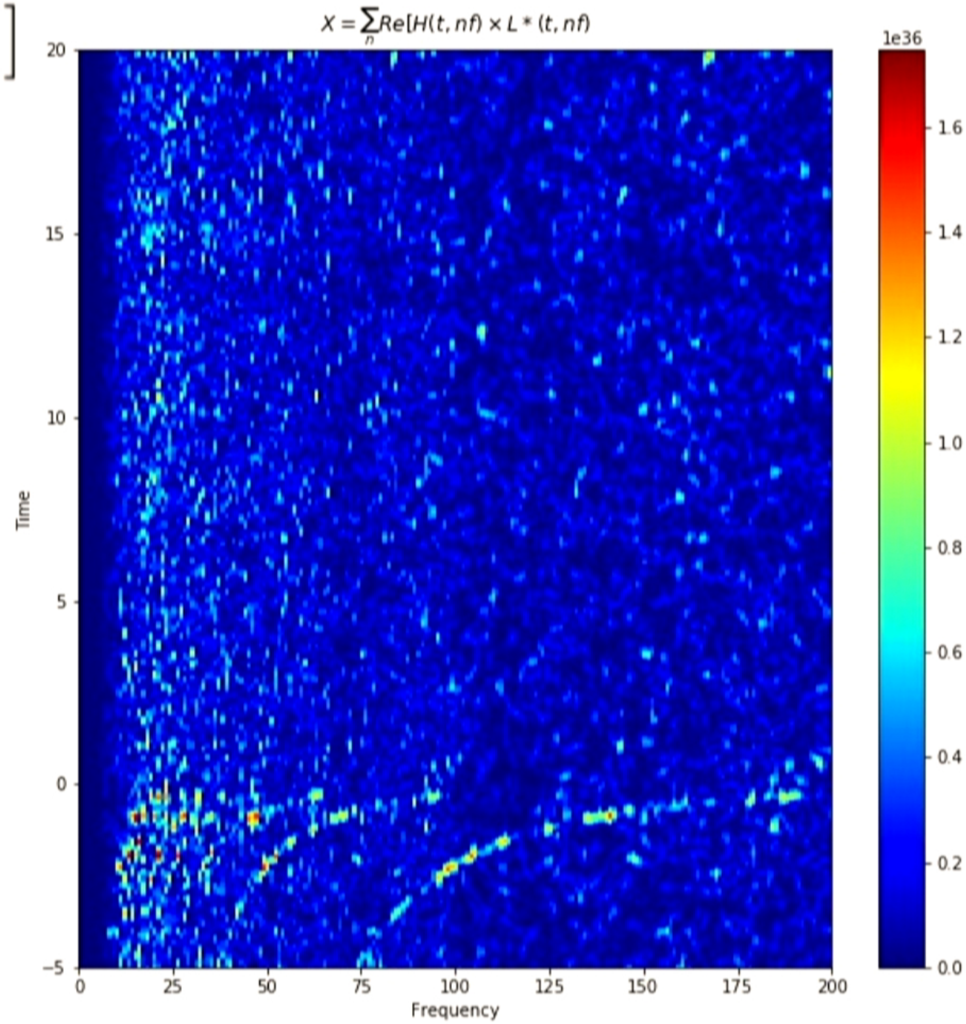


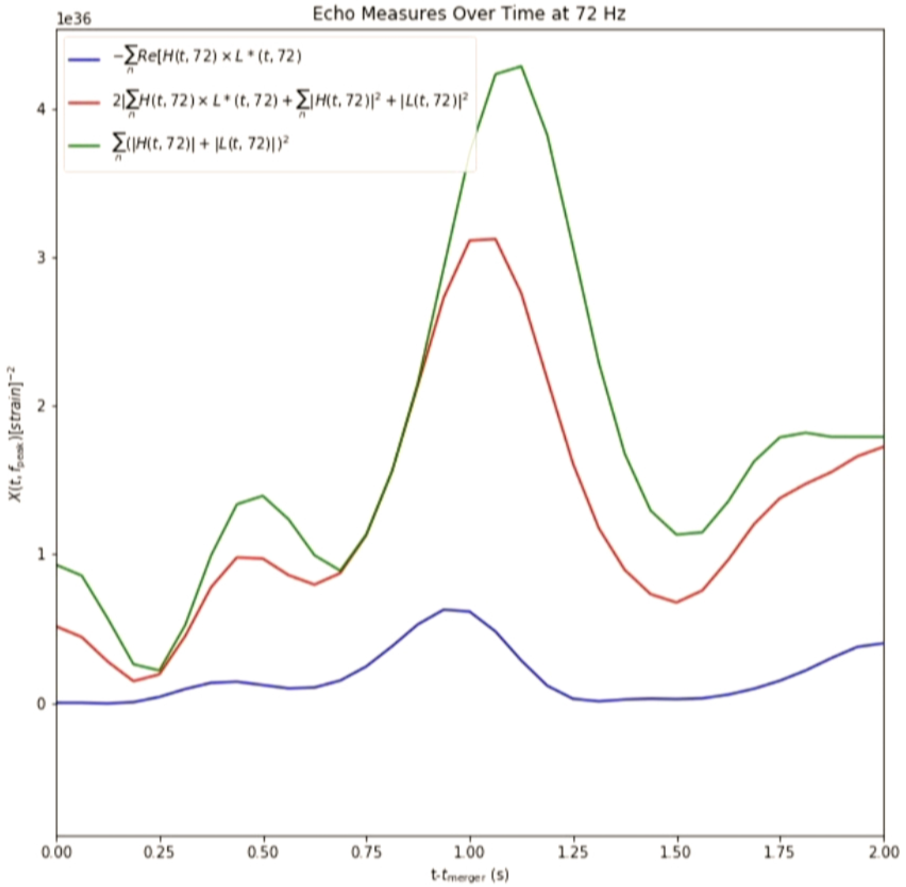
Abedi & Afshordi, 2019

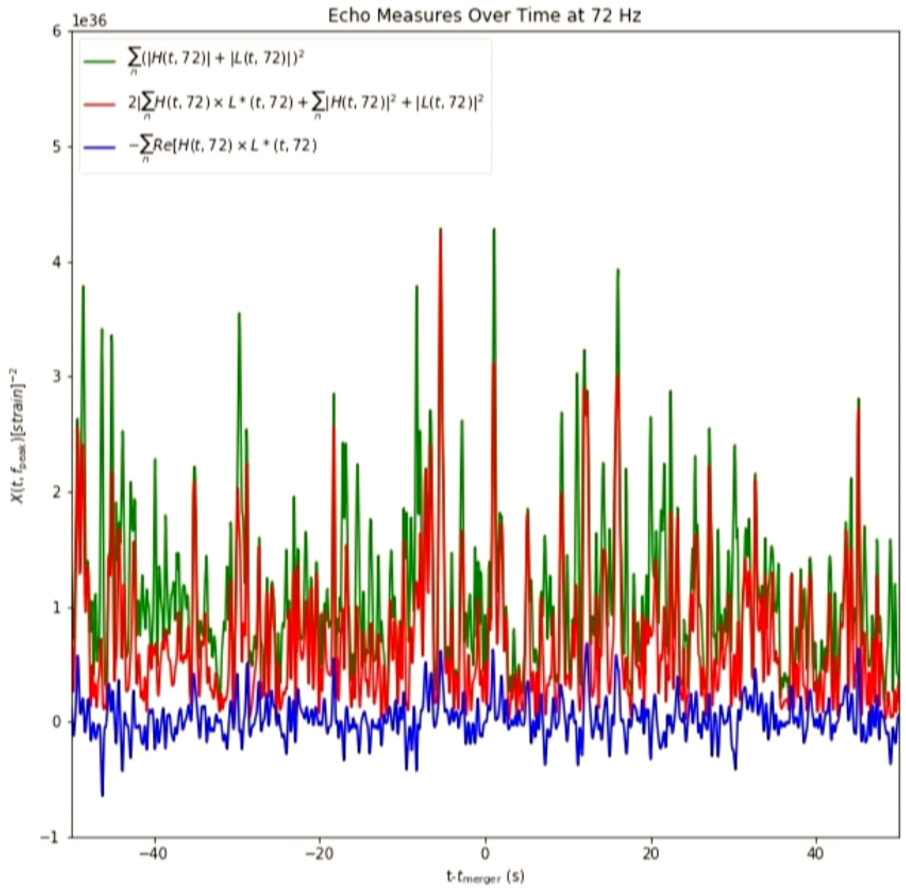
$$X = \sum_n Re[H(t, nf) \times L^*(t, nf)]$$

Time delay = 2.62 ms






Echo Measures Over Time at 72 Hz
1e36
$-\sum_n Re[H(t,72) \times L*(t,72)$
$2|\sum_n H(t,72) \times L*(t,72) + \sum_n |H(t,72)|^2 + |L(t,72)|^2$
$\sum_n (|H(t,72)| + |L(t,72)|)^2$
$X(t, f_{peak})[strain]^{-2}$
t-t_{merger} (s)


Echo Measures Over Time at 72 Hz
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$X(t, f_{peak})[strain]^{-2}$
t-t_{merger} (s)

Next steps...

Continue to optimize over SNR

Explore phase difference

p-values

Next steps...

Continue to optimize over SNR

Explore phase difference

p-values

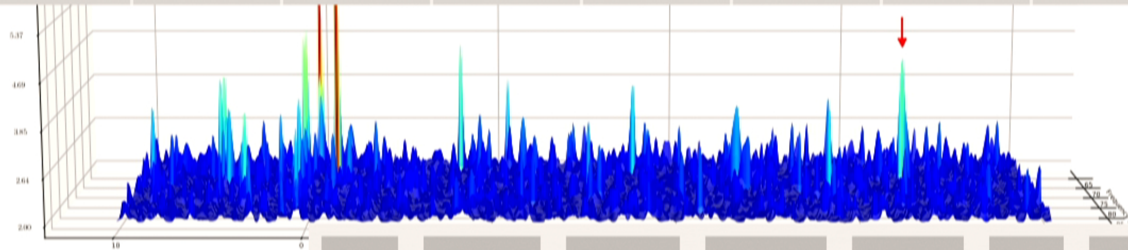


Figure 4: A 3d rendition of Fig. (3) within our echo search frequency range $f = 63 - 92$ Hz, showing that our tentative detection of echoes at $f_{\rm peak} = 72\ (\pm 0.5)$ Hz and $t - t_{\rm merger} \simeq 1.0$ sec clearly stands above noise.

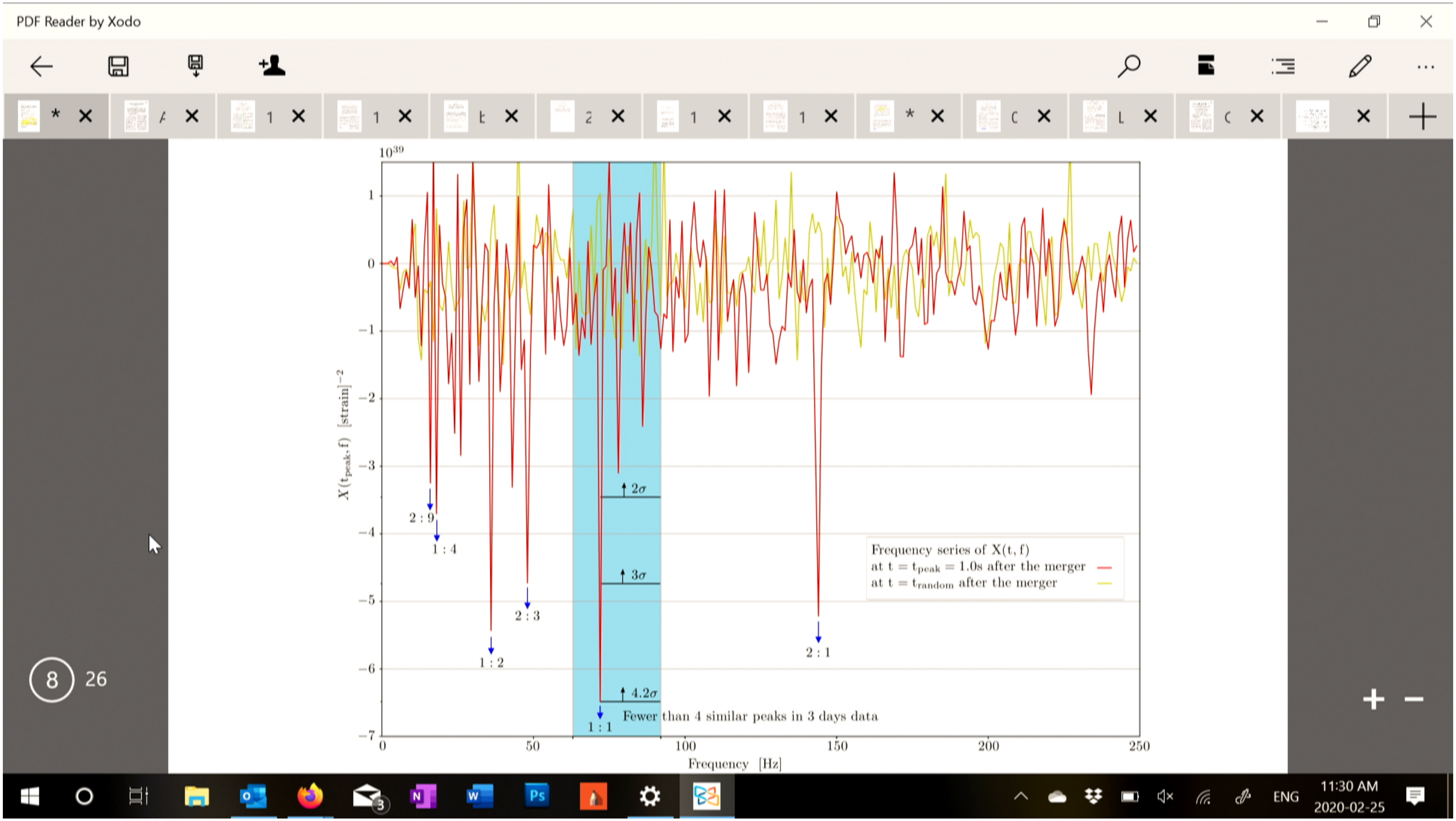
BNS), but assume that $2-5\%$ of the energy is lost during the merger [33]. For the dimensionless BH spin $a = 0.72 - 0.89$ (e.g., [26]), as well as an order of magnitude change in Planck length, we can constrain $\Delta t_{\rm echo}$ to be within:

$$0.0109 < \Delta t_{\rm echo}({\rm sec}) < 0.0159. \tag{2.3}$$

This range in echo time delay corresponds to echo frequency ($f_{\rm echo} = \Delta t_{\rm echo}^{-1}$) range:

$$63 \leq f_{\rm echo}({\rm Hz}) \leq 92, \tag{2.4}$$

which we shall use for our echo search and background estimates, for the rest of the paper.



10^{39}
$X(t_{peak}, f)$ [strain]$^{-2}$
Frequency [Hz]
2 : 9
1 : 4
1 : 2
2 : 3
1 : 1
2 : 1
2σ
3σ
4.2σ
Fewer than 4 similar peaks in 3 days data
Frequency series of X(t, f)
at t = t_{peak} = 1.0s after the merger
at t = t_{random} after the merger