An Investigation on the Effects of Non-Gaussian Noise Transients and Their Mitigations to Tests of General Relativity

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Motivation

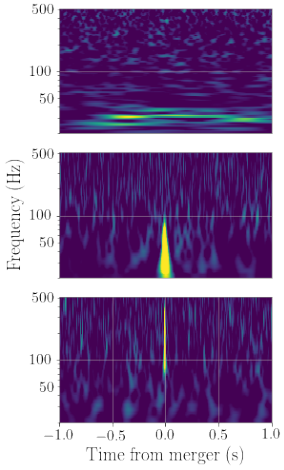
Non-Gaussian Noise Transients (Glitches)

- Mimic GW signals in searches
- Bias inference of source properties of gravitational waves (GW)?
- Lead to false violations of General Relativity?

A glitch overlapped with the GW170817 signal in Livingston

- Data was manipulated to remove the glitch
- Lead to false violations of General Relativity?

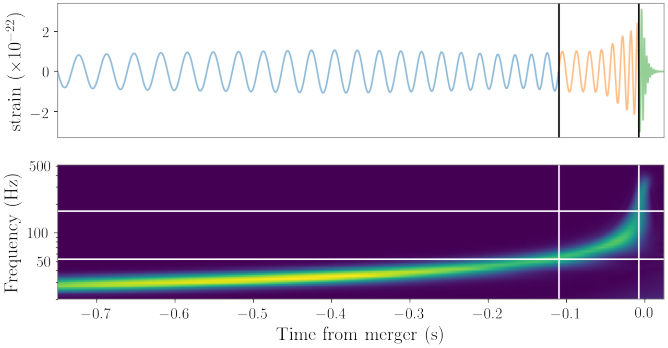
Sensitivity goes up $\rightarrow$ more frequent occurrence of glitch-overlapped signals



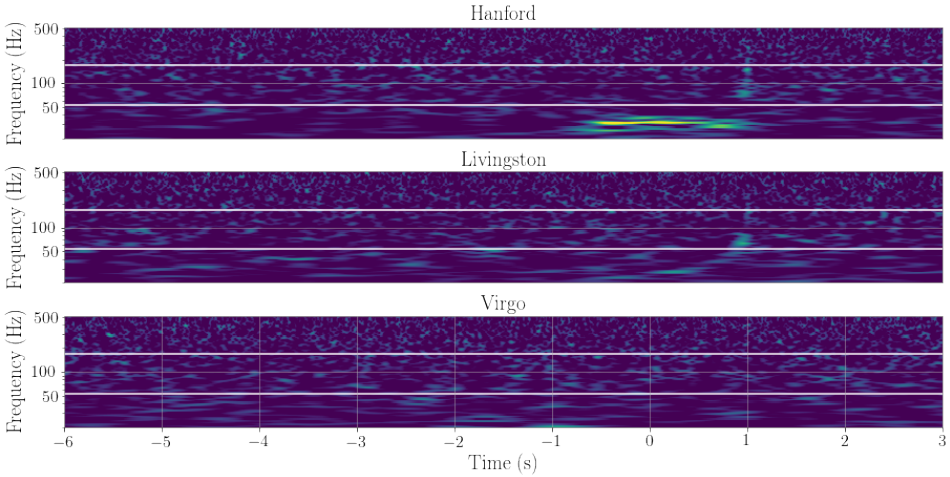
Parameterized Tests of General Relativity

Introduce parameterized deviations to the phase Ψ of `IMRPhenomPv2`

$$\Psi(f) = \underbrace{\begin{aligned}&\varphi_0 f^{-5/3} + \varphi_1 f^{-4/3} + \varphi_2 f^{-1} + \varphi_3 f^{-2/3} + \varphi_4 f^{-1/3} \\ &+ \varphi_5 f^{0} + \varphi_6 f^{1/3} + \varphi_7 f^{2/3} + \varphi_5^l \log(f) + \varphi_6^l f^{1/3}\log(f) \\ &+ \sigma_0 f^{0} + \sigma_1 f + \sigma_2 f^{4/3} + \sigma_3 f^{5/3} + \sigma_4 f^{2}\end{aligned}}_{\text{Inspiral}} + \underbrace{\begin{aligned}&\beta_0 f^{0} + \beta_1 f \\ &+ \beta_2 \log(f) + \beta_3 f^{-3}\end{aligned}}_{\text{Intermediate}} + \underbrace{\begin{aligned}&\alpha_0 f^{0} + \alpha_1 f \\ &+ \alpha_2 f^{-1} + \alpha_3 f^{3/4} \\ &+ \alpha_4 \tan^{-1}(af + b)\end{aligned}}_{\text{Merger-Ringdown}}$$



Methodology



Signal choice: S190828l maxL (high mass-ratio, highly precessing)

approx=IMRPhenomPv2PseudoFourPN, seglen=8, srate=1024, sampling=nested+MCMC

Caveats

- We are only considering 3 cases of overlapping using 1 signal and 1 glitch
- Too few to conclude any general trends
- However, this simulates what we will obtain when a GR signal overlaps with a scattered-light glitch

Effect of the Scattered-light Glitch to Tests of GR

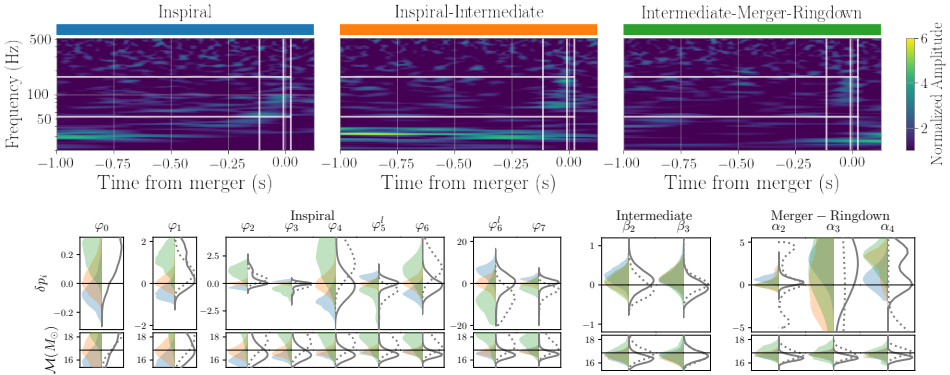
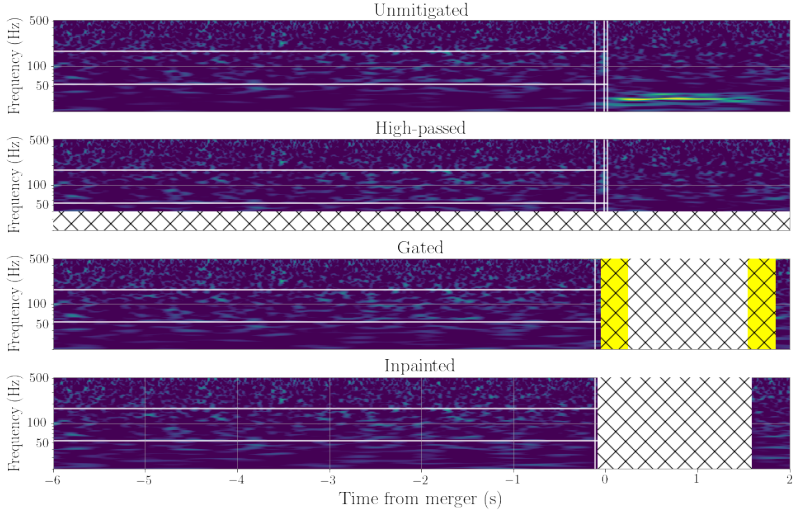


Figure 1: Posteriors of testing parameters for the three glitch-overlapped case (blue, orange, green), and that for the same signal in 2 realizations of colored stationary Gaussian noise (gray). Simulated Gaussian noise is colored using the representative best PSD in O3a.

Glitch Mitigations



Effect of the Glitch and its Mitigations to Tests of GR

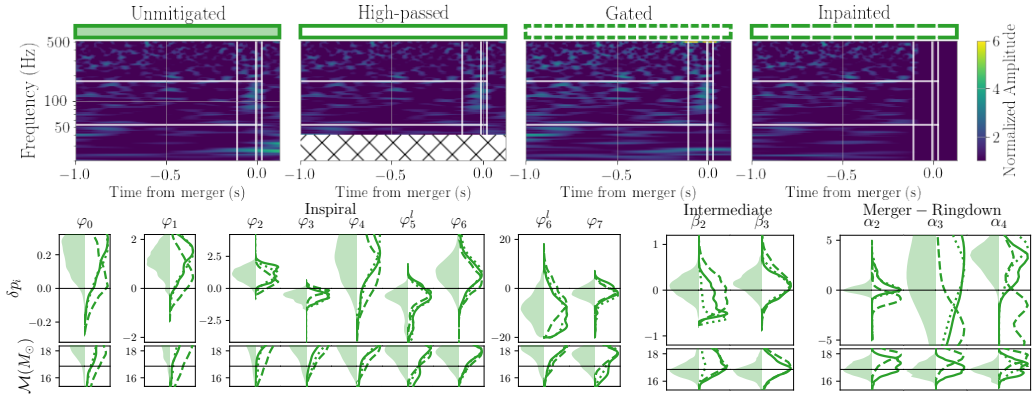


Figure 2: Posteriors of testing parameters (left: unmitigated, right: mitigated) for scattered-light-glitch-overlapped S190828l-like signal at intermediate-merger-ringdown stage in time domain.

Effect of the Glitch and its Mitigations to Tests of GR

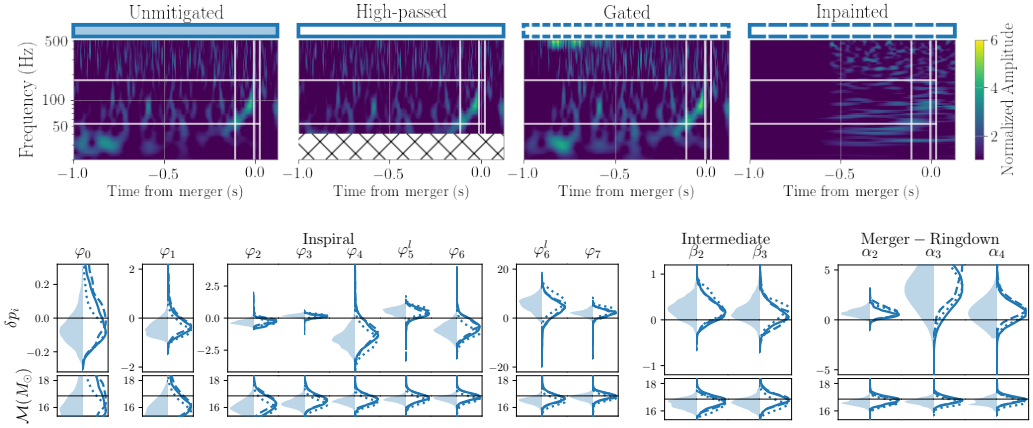


Figure 3: Posteriors of testing parameters (left: unmitigated, right: mitigated) for scattered-light-glitch-overlapped S190828l-like signal at inspiral stage in time domain.

Effect of the Glitch and its Mitigations to Tests of GR

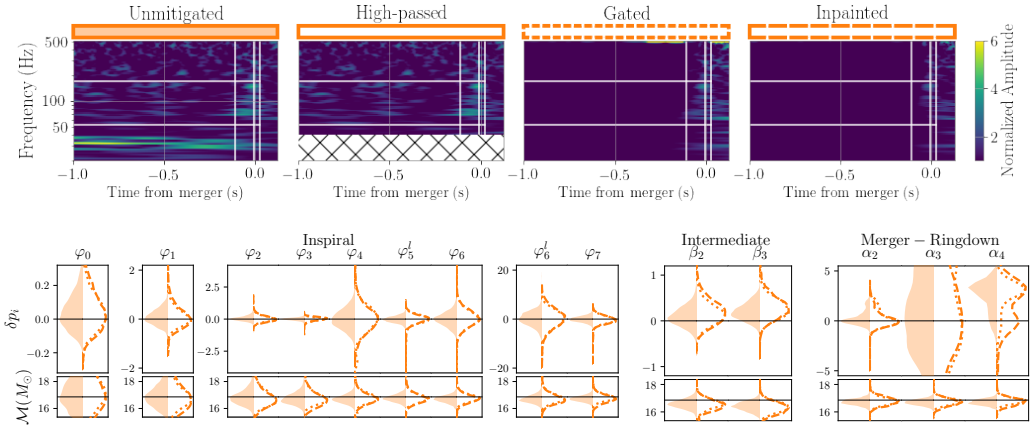


Figure 4: Posteriors of testing parameters (left: unmitigated, right: mitigated) for scattered-light-glitch-overlapped S190828l-like signal at inspiral-intermediate stage in time domain.

Conclusion

- We performed parameterized tests of GR on glitch-overlapped signals
- The particular scattered-light glitch has negligible effect for a three-detector observation.
- We *speculate* that removing a significant portion of signal will lead to bias.

FUTURE:

- Verify our speculations by reducing the contribution from the GW signal in small uniform step sizes
- Reproduce this study to high-frequency, broad-band glitches
- Perform `BayesWave` glitch subtraction

Questions?

Deviation from GR for $\delta\alpha_4$ for a stationary Gaussian noise case

Number of posterior samples: 49246

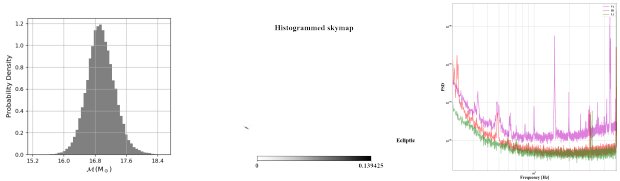


Figure 5: Recovery of chirp mass, sky location and PSD (left to right)

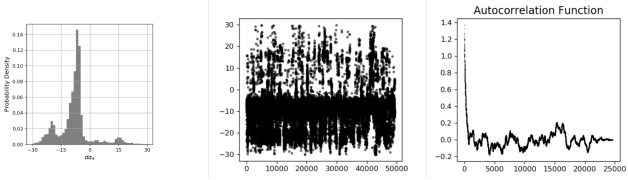


Figure 6: Marginal posterior distribution for $\delta\alpha_4$ (left), sample used (mid) and auto-correlation function (right)