Parameter estimation of gravitational waves in the presence of non-Gaussian transient noise

Yannick Lecoeuche (UBC), Jess McIver (UBC), Laura Nuttall (Portsmouth), Derek Davis (Caltech), Josh Pooley (Portsmouth), TJ Massinger (Caltech), Katie Rink (UMass Dartmouth), Vivien Raymond (Cardiff), Rory Smith (Monash)

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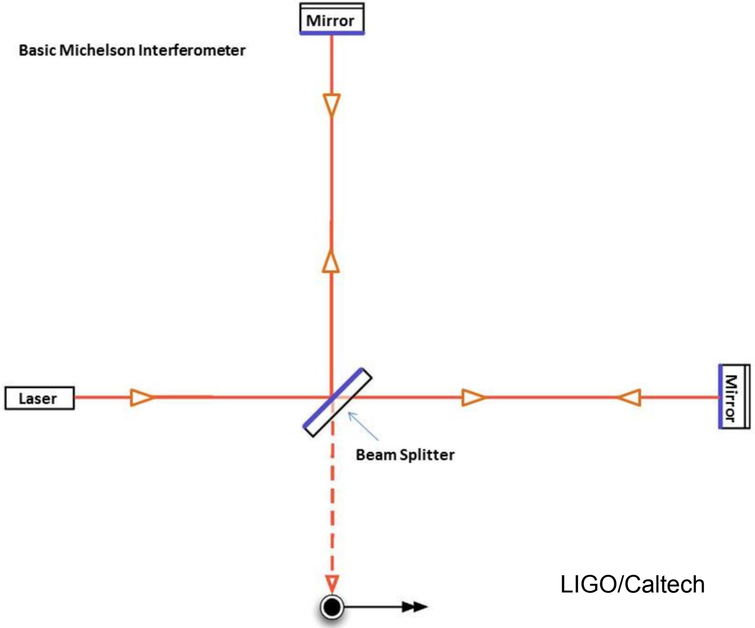
LIGO observatory

- LIGO (Laser Interferometer Gravitational-Wave Observatory) consists of observatories in Washington state and Louisiana, as well as research groups across 100+ institutions

How it works

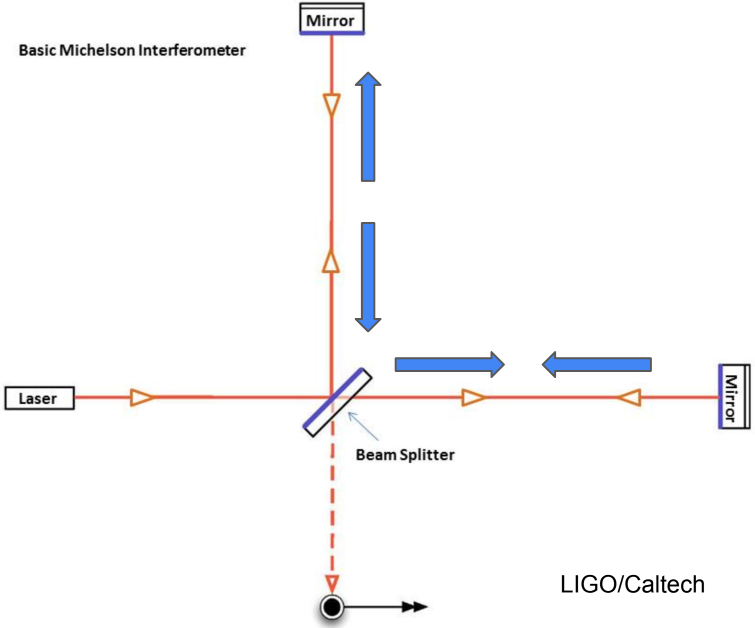
- Beam is split down perpendicular 4 km arms, reflects off mirrors, and recombined onto a sensor
- Arms lengths are controlled by actuators to keep recombined beams destructively interfering



LIGO/Caltech

How it works

- Beam is split down perpendicular 4 km arms, reflects off mirrors, and recombined onto a sensor
- Arms lengths are controlled by actuators to keep recombined beams destructively interfering
- Gravitational waves squeeze and contract space in perpendicular directions, changing relative phase between arms



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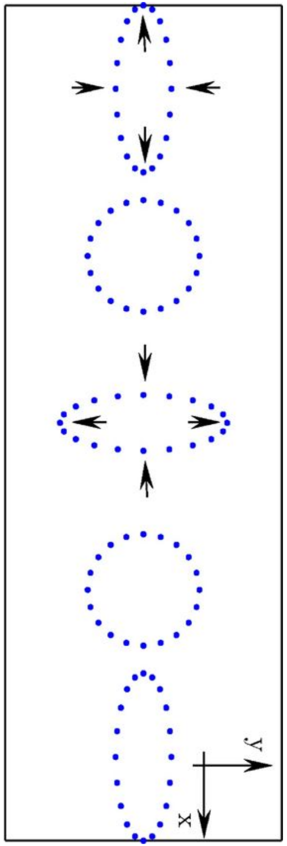
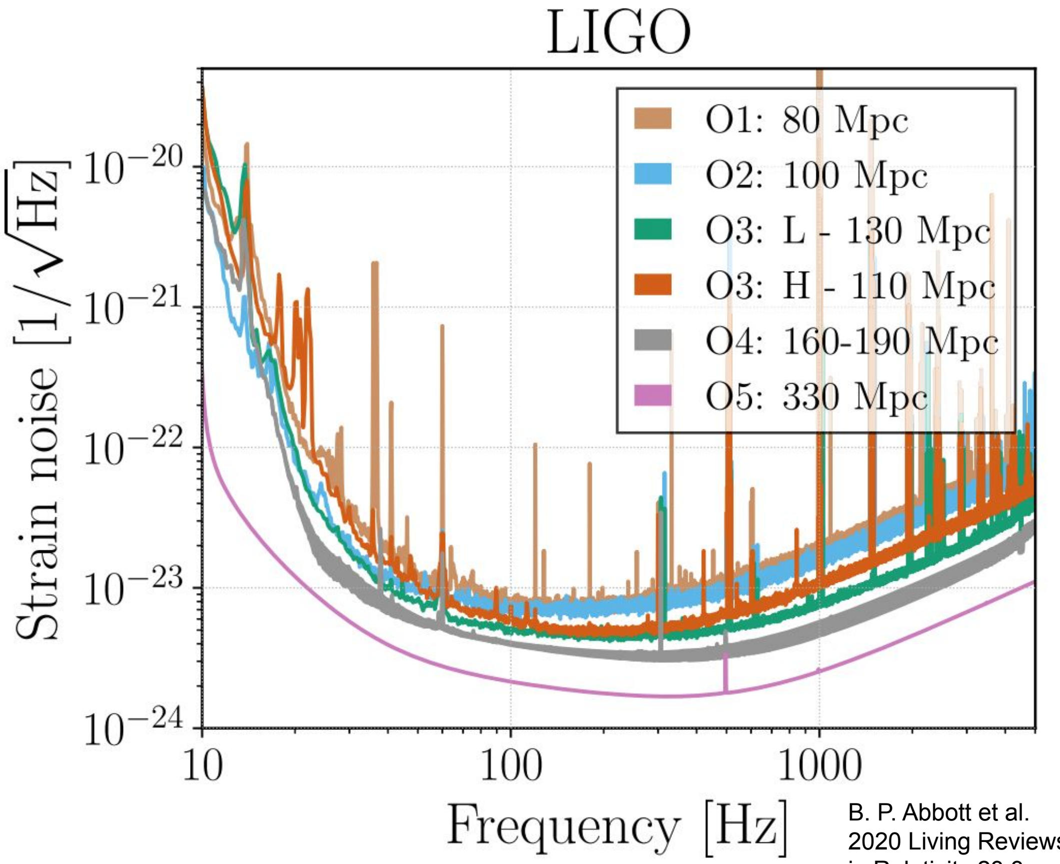


G. Hammond et al, 2014 Journal of Modern Optics 61(sup1): S10–S45.

Increasing sensitivity

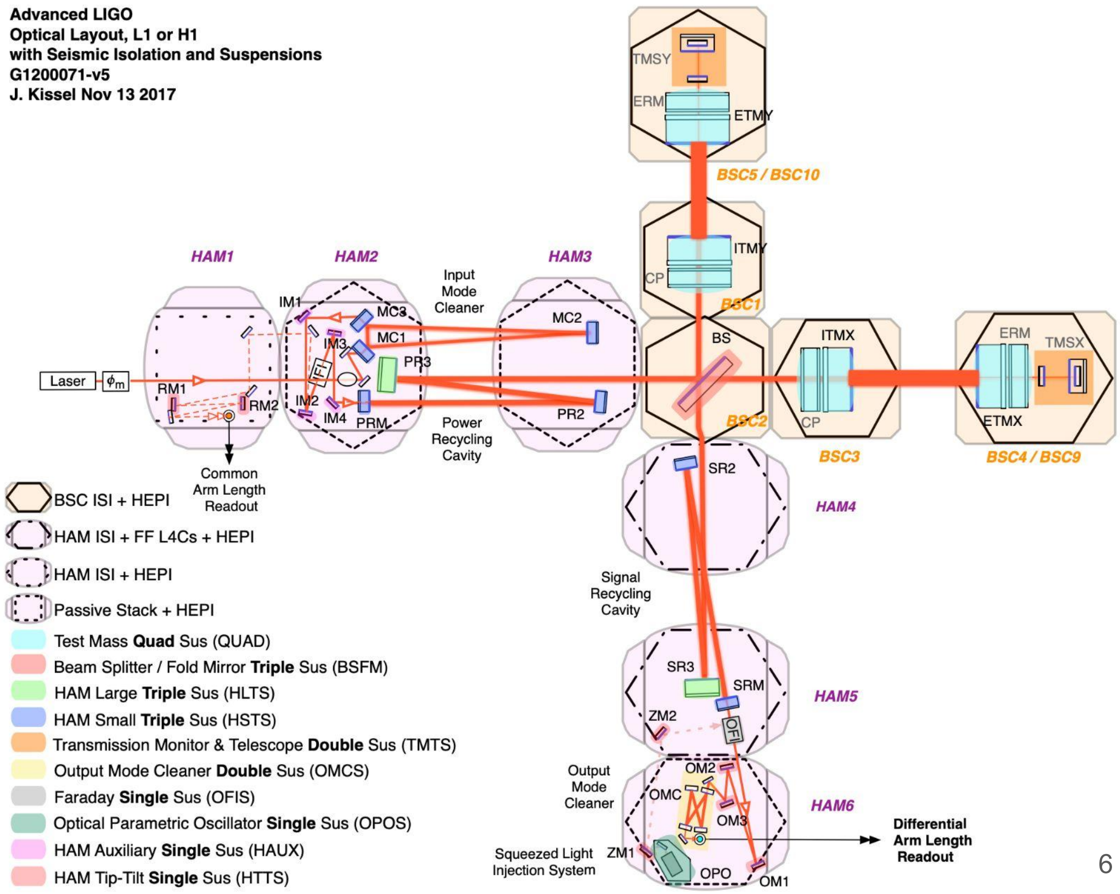
- Sensitive to length changes 1/10,000th proton radius
- Currently in upgrade phase between observing runs O3 and O4
- Higher projected sensitivity = more GW detections (up to 1/day in O4)



B. P. Abbott et al. 2020 Living Reviews in Relativity 23 3

Detector Complexity

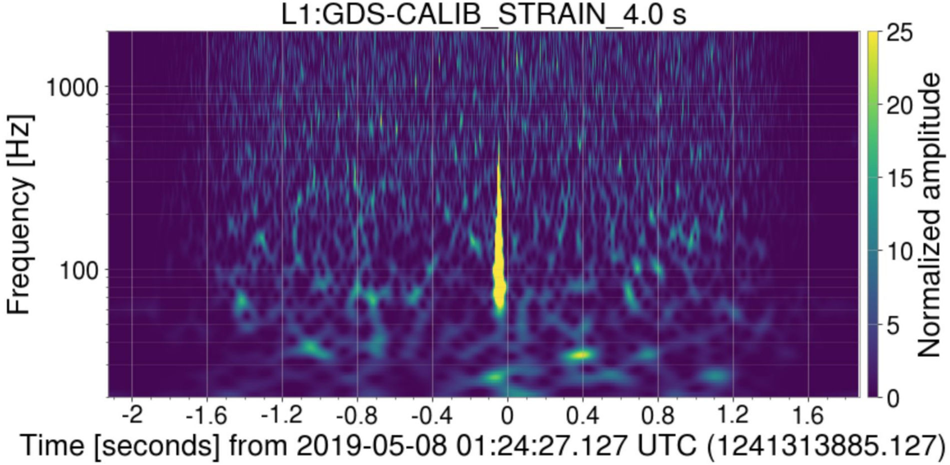
- Advanced LIGO is extremely complex, with multiple interacting systems working to increase sensitivity
- There are many ways for unwanted noise to impact measurements of gravitational strain



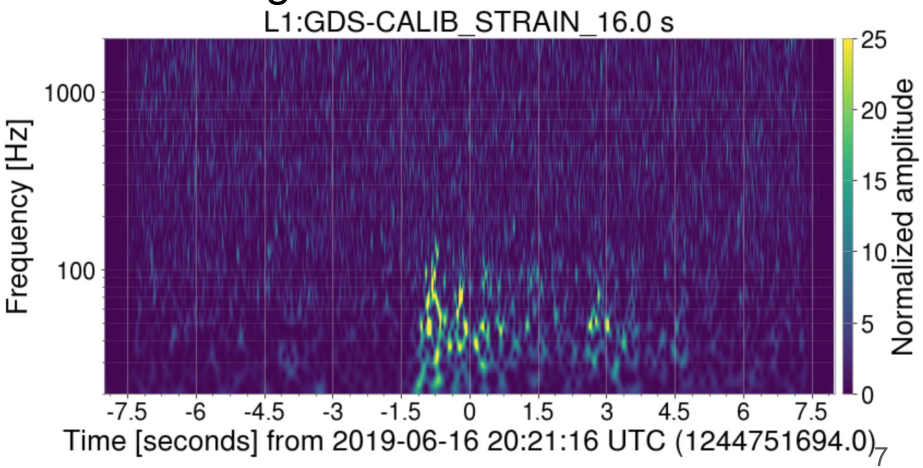
LIGO Detector glitches (arxiv 2101.11673)

- Glitches: frequent non-Gaussian transient noise measured by the recombined beam sensor
- Glitches can mask or mimic a true GW signal
- Increased detection rate means higher chance of glitches overlapping GW signals

Blip glitch



Thunder glitch



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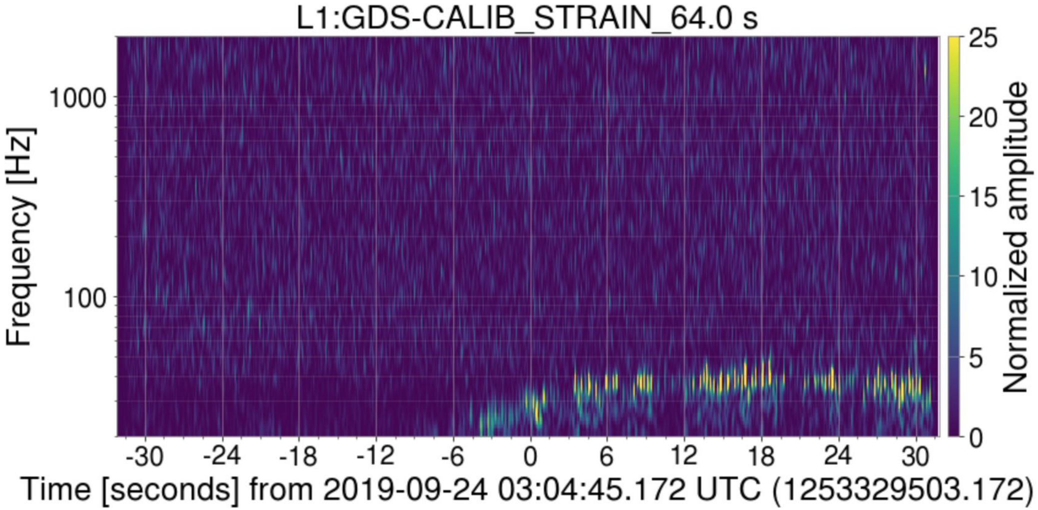
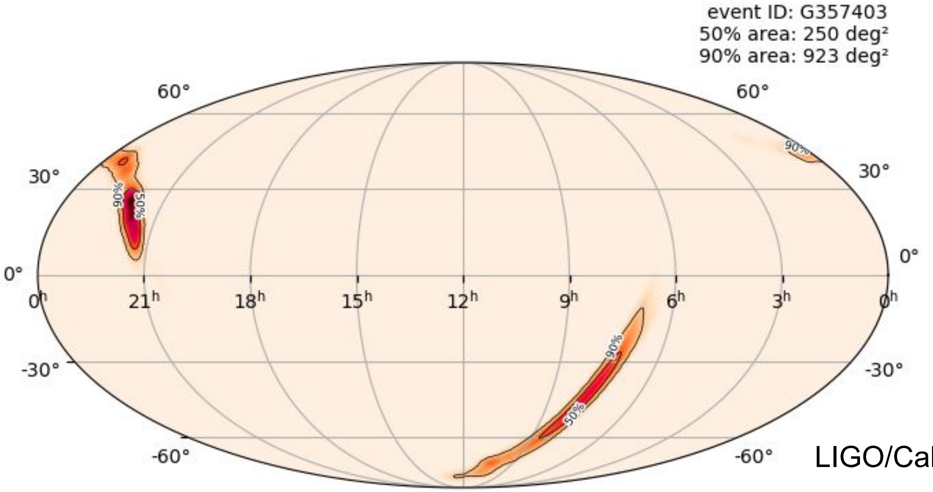
Fast scattering glitch



Investigating the impact of glitches on GW parameter estimation

- Loud glitches that directly overlap signal merger times can bias PE[1], and the effects of glitch mitigation on PE for BNS signals have been explored[2]
- Here we explore the impact of glitches on PE for a broader range of GW signals and as a function of time between the merger and the glitch
- Target parameters: binary components masses, spins, and sky localization



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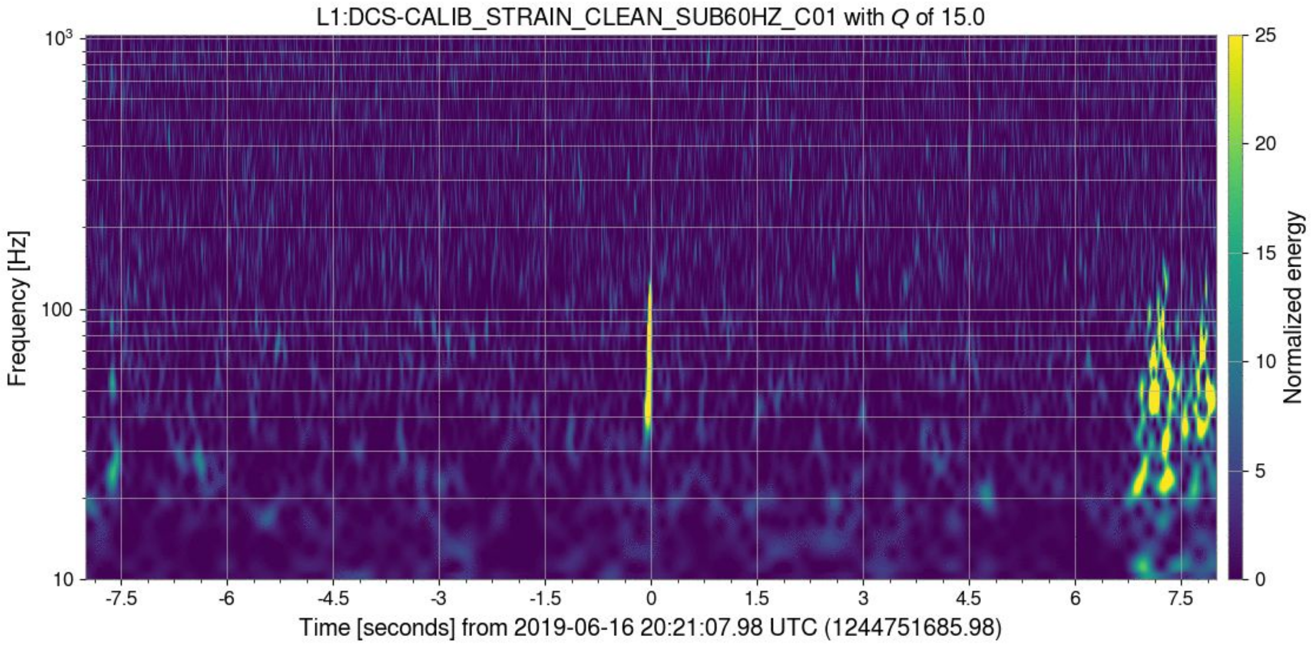
1: Powell 2018 *Class. Quantum Grav.* 35 155017

2: Pankow et al 2018 *Phys. Rev. D* 98, 084016

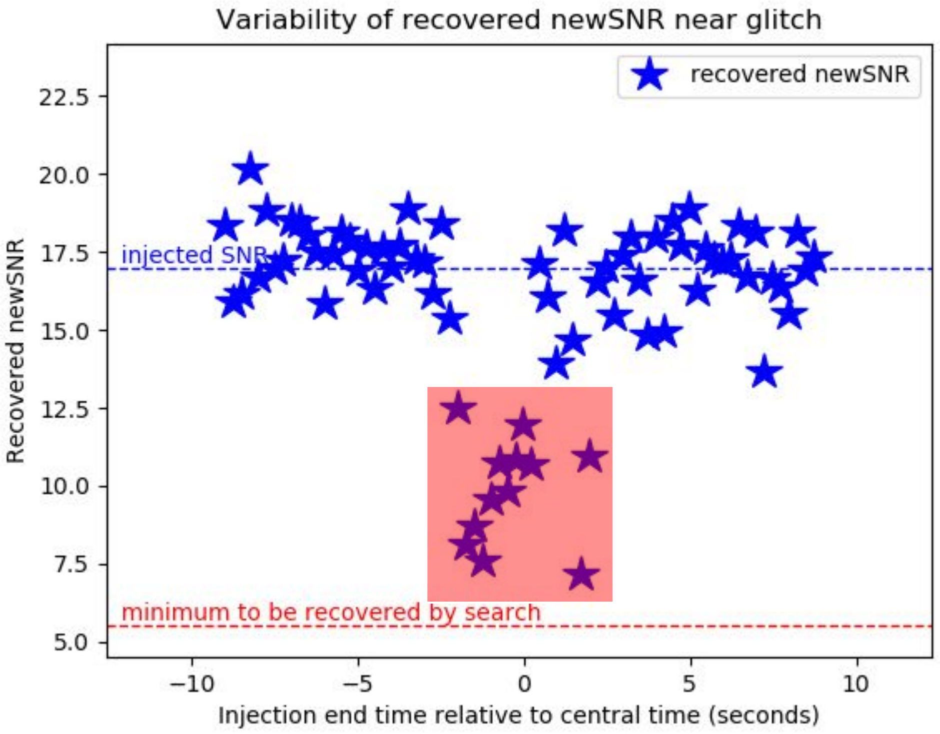
Procedure: injecting signals

- Inject simulated CBC signal on top of real glitch in LIGO GW strain channels
- Shift signal position in time relative to glitch, optimized to give full range of signal/glitch interaction

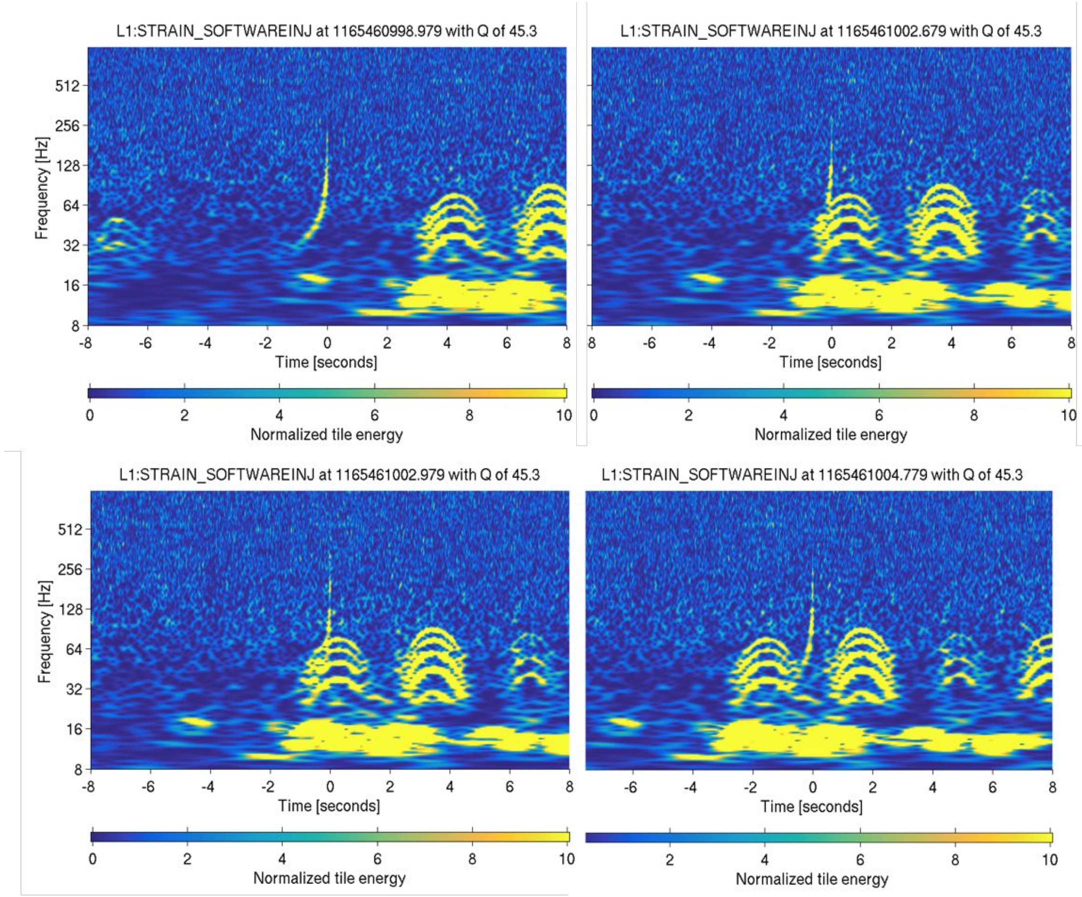


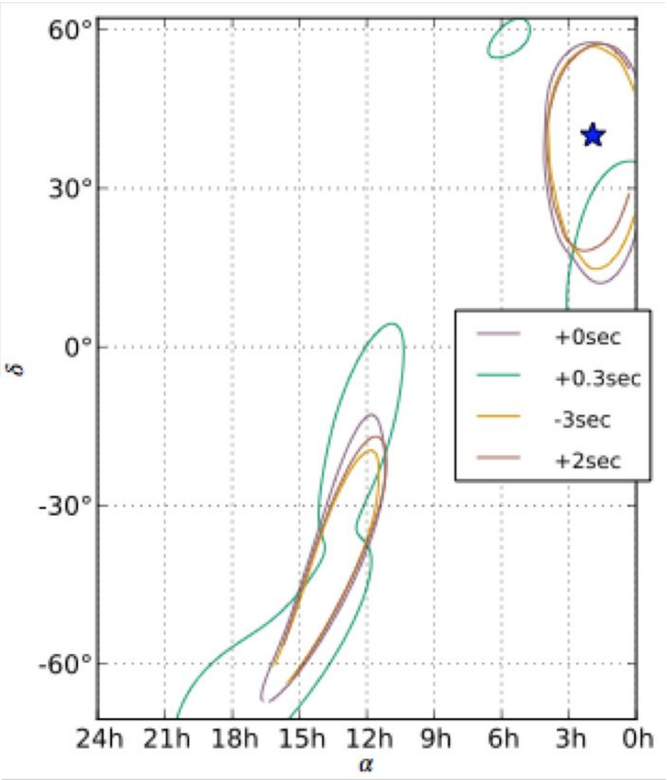
Procedure: matched filter search recovery

- For each frame of our sliding signals, recover SNR for the injected signal (denoted "newSNR")
- We are interested in the region where the signal is impacted by the glitch, but is still recoverable
- Next step: Perform parameter estimation



Preliminary results (with O2 data)





Conclusions and future steps

- For glitch classes and signal overlap cases we've studied, it's still possible for the signal to be identified by a search, but the true parameters are not accurately recovered
- There seems to be a “safe” time separation where the glitch overlaps with the signal far enough away from the merger time that parameter estimation is not biased
  - Characterizing this “safe” time separation for the most common types of LIGO glitches is a major goal to prepare for O4
  - We will also investigate consistent trends in parameter bias for different glitch types that could inform EM follow-up efforts

Acknowledgements

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