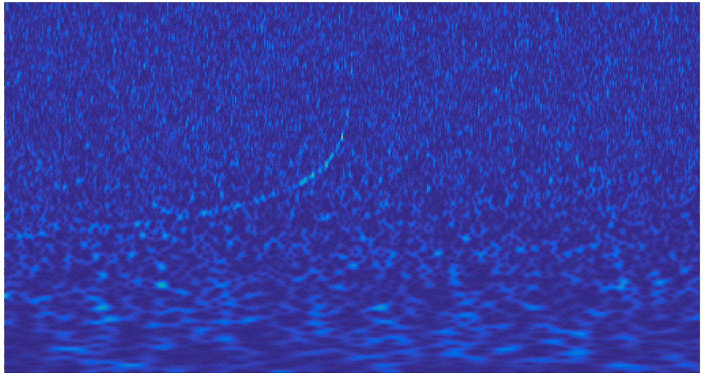
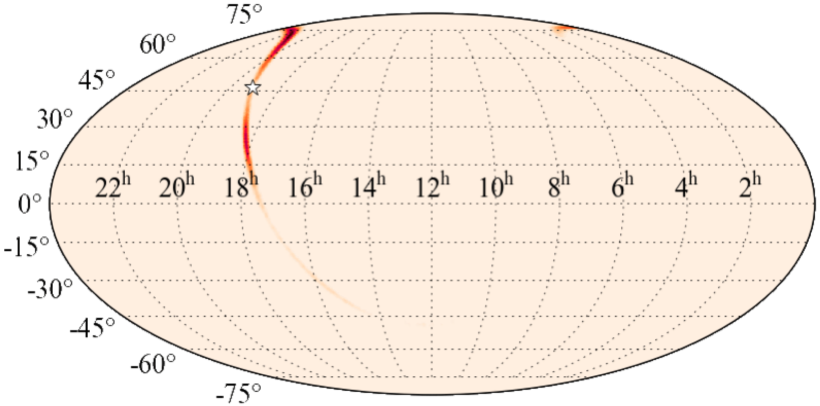
The impact of LIGO noise transients on accurate gravitational-wave event skymaps





J. McIver[1], T.J. Massinger[1], D. Davis[2], L. Nuttall[3], V. Raymond[4], R. Smith[5]

[1] LIGO Laboratory, Caltech; [2]Syracuse University; [3]University of Portsmouth; [4]Cardiff University; [5]Monash University

APS April Meeting 2019 in Denver, Colorado

Caltech

LIGO DCC G1802340

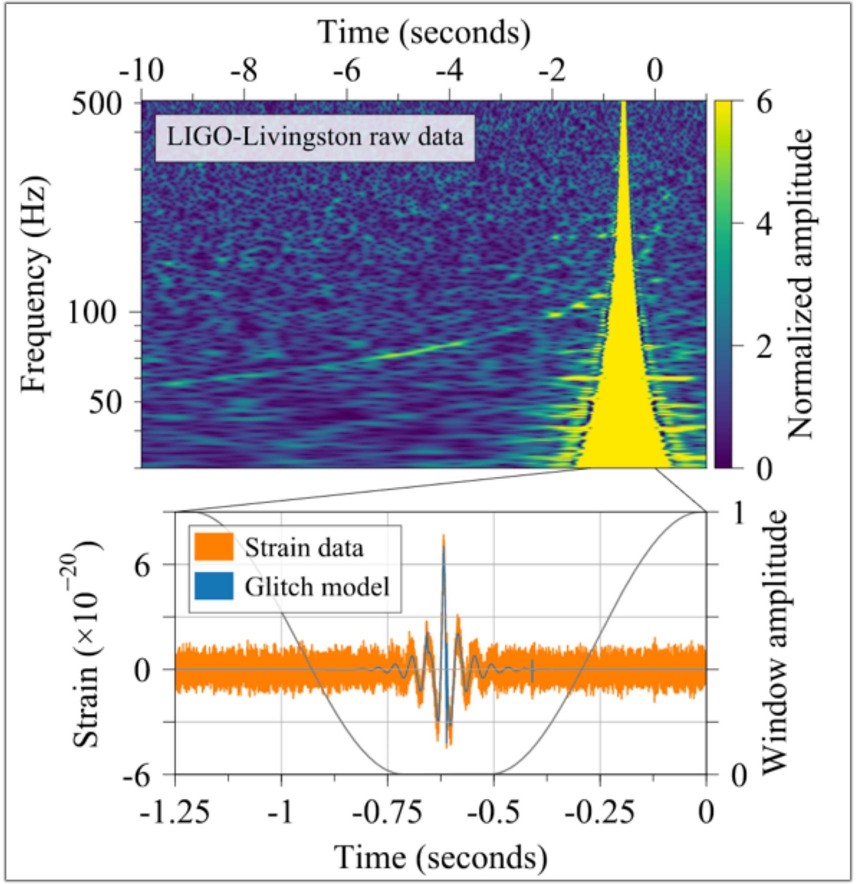
Motivation

What happens to our ability to estimate the properties of an astrophysical GW source that overlaps with a *glitch*?

Pankow et al. 2018 (arXiv 1808.03619) explored the impact of glitch mitigation methods.

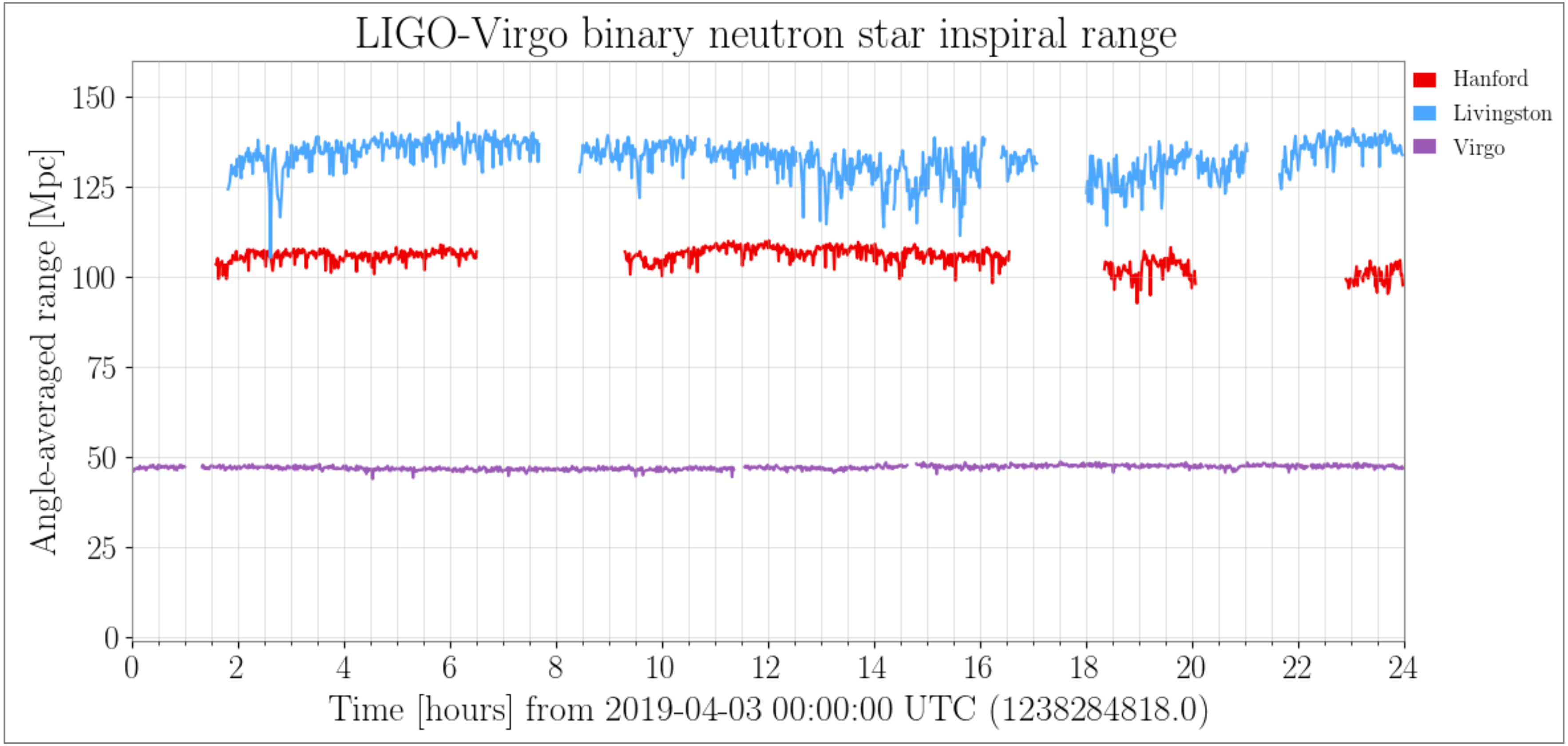
Powell 2018 (arXiv 1803.11346) studied glitch amplitude relative to injected signal for glitches directly overlapping merger times.

See also Sumeet Kulkarni's NNETFIX talk.



B.P. Abbott et al (LIGO-Virgo) PRL. (2017)

Motivation



Public detector status pages for a day of O3 on the Gravitational Wave Open Science Center (GWOSC): https://www.gw-openscience.org/detector_status/

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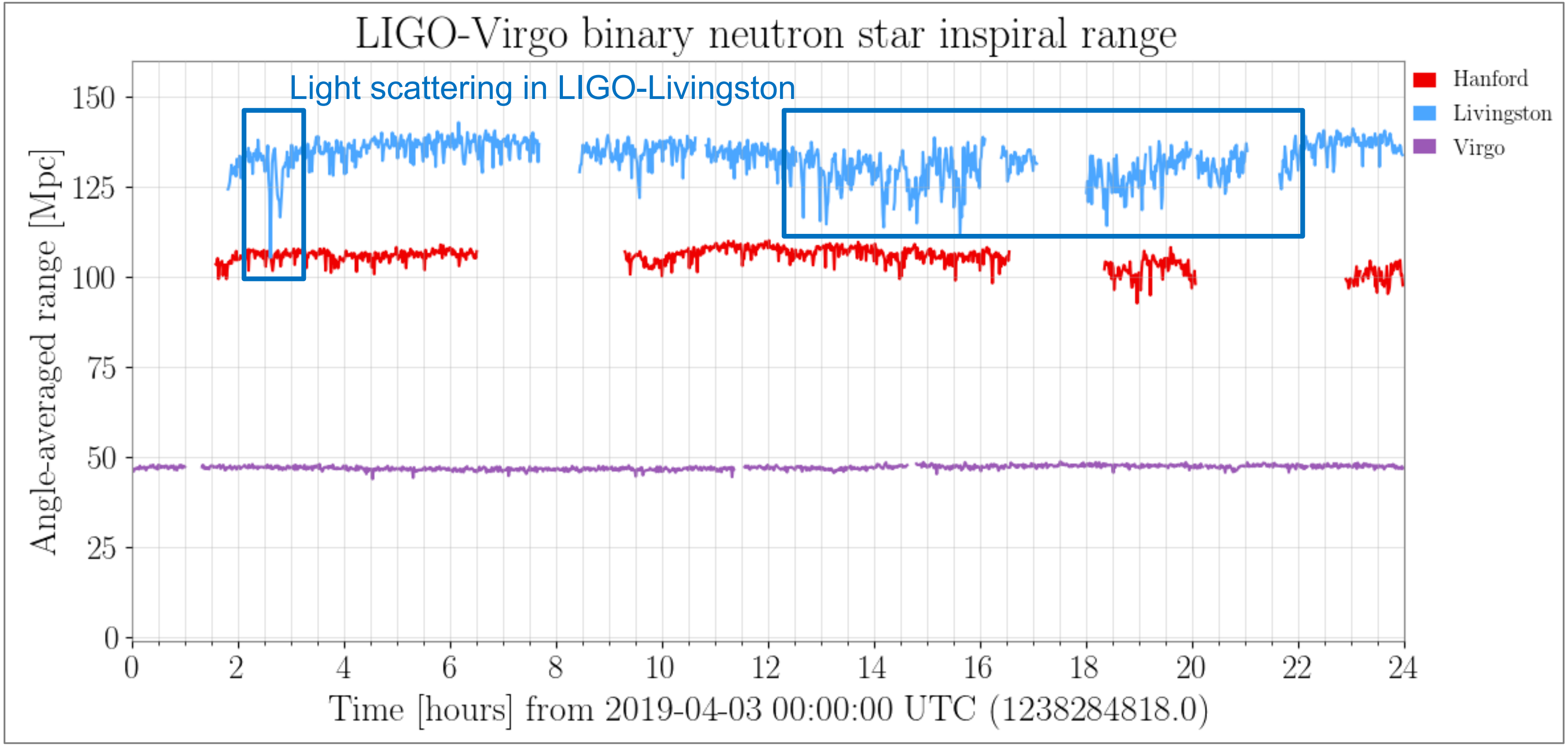

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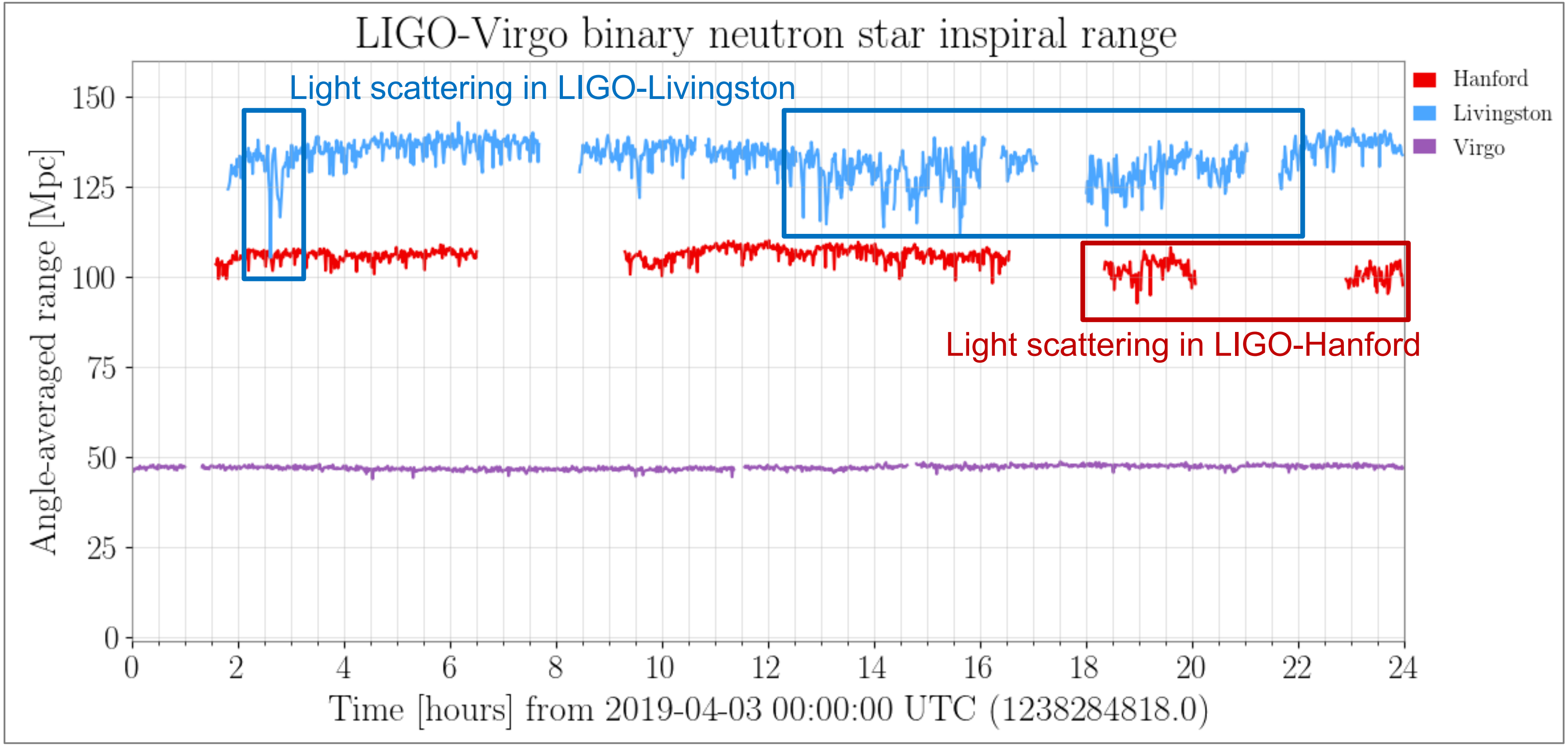

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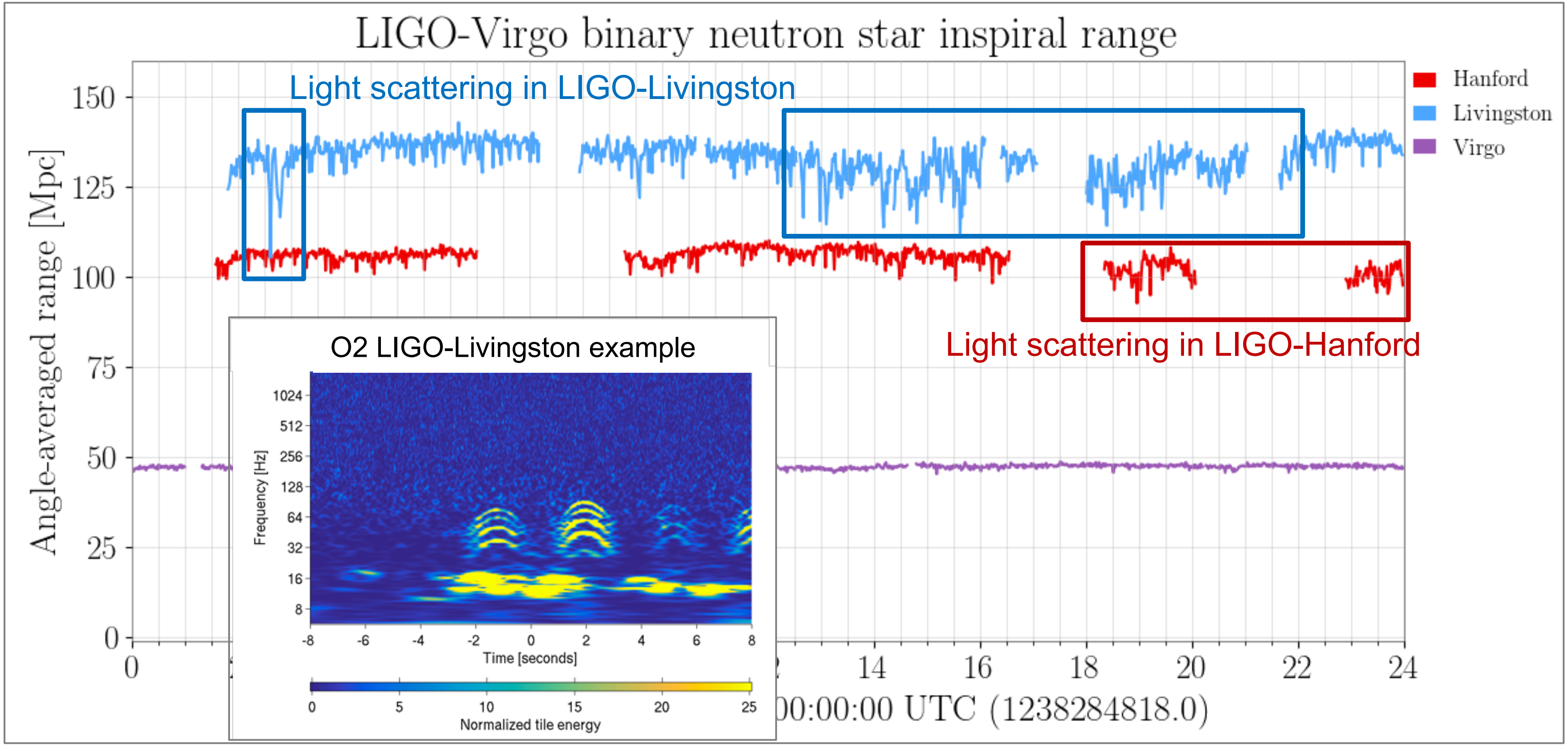

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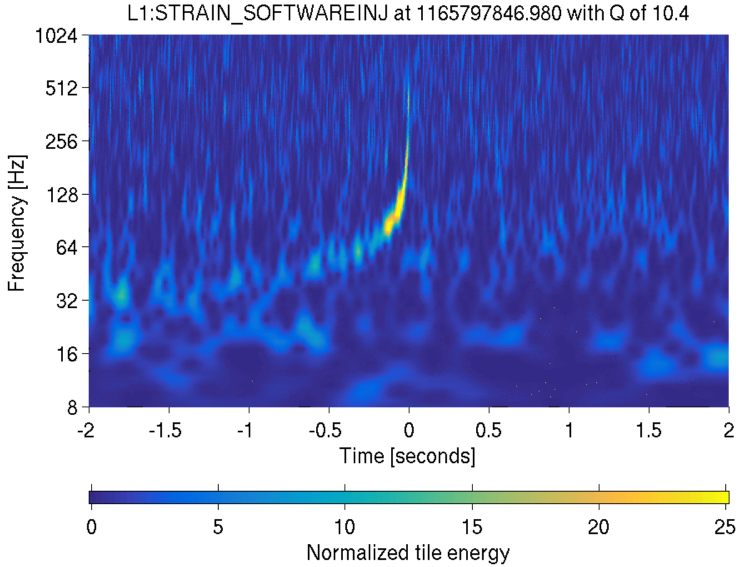
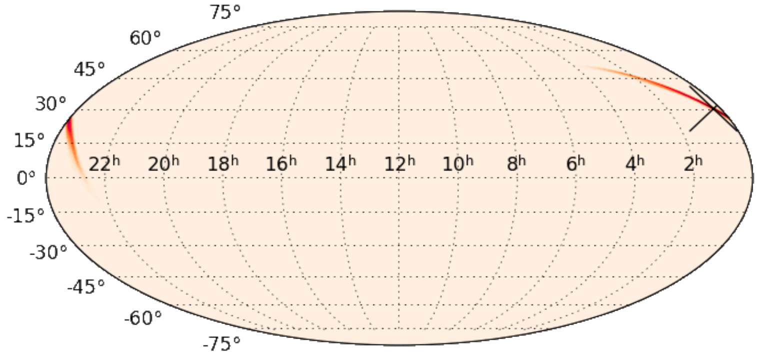
Approach

Method: slide simulated signals over examples of common/problematic LIGO glitches to assess how glitches impact parameter estimation for CBC signals.

Targeted source properties: masses (m_1, m_2, and m_{chirp}), spins (a_{z1}, a_{z2}), and sky localization (RA, dec, and 90% skymap area).



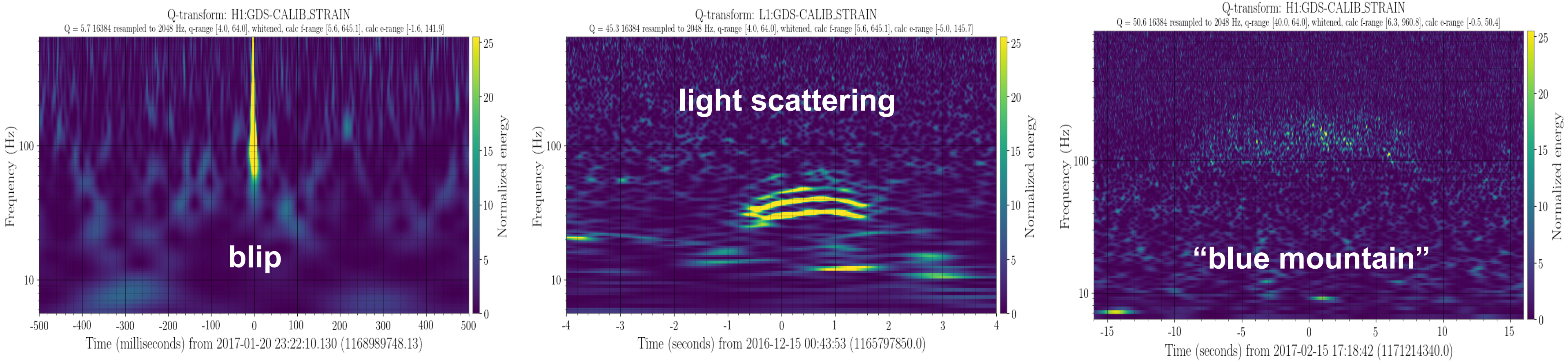


Approach: O2 LIGO glitch set

Targeted glitches: 3 examples each of blips, scattering, “blue mountains” (9 total)

- All are known to affect CBC signals, all are difficult to veto with aux channels

B.P. Abbott et al. (LIGO-Virgo) CQG (2017) arXiv /1710.02185



- All glitch examples have clean data in the other LIGO detector for the same time interval.

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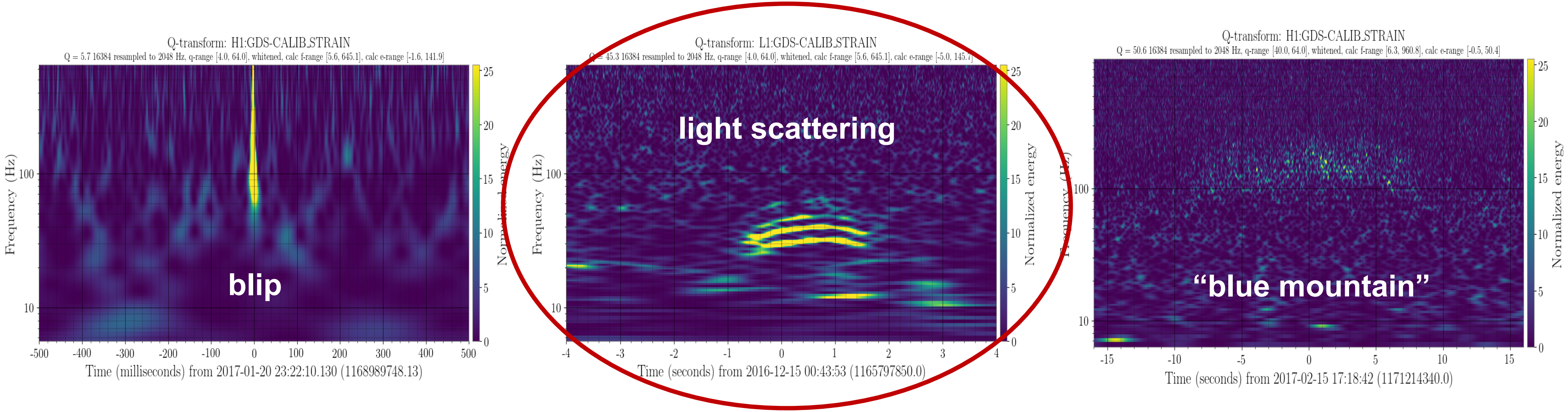

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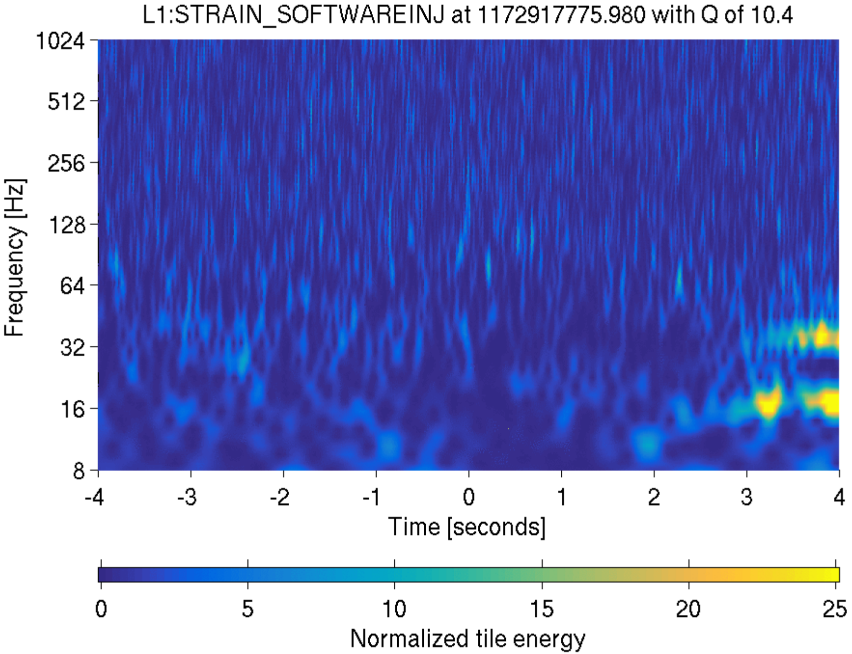
Results: scattering example

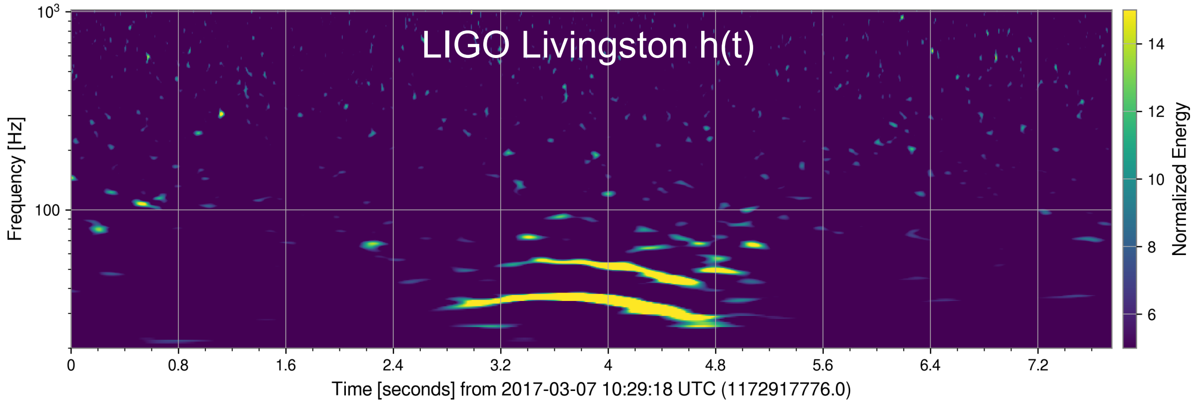
Light scattering in LIGO Livingston h(t) during O2 (clean time in LIGO Hanford)

Injected signal: BBH with component masses 7 $M_\odot$ and 12 $M_\odot$ ("GW170608-like")

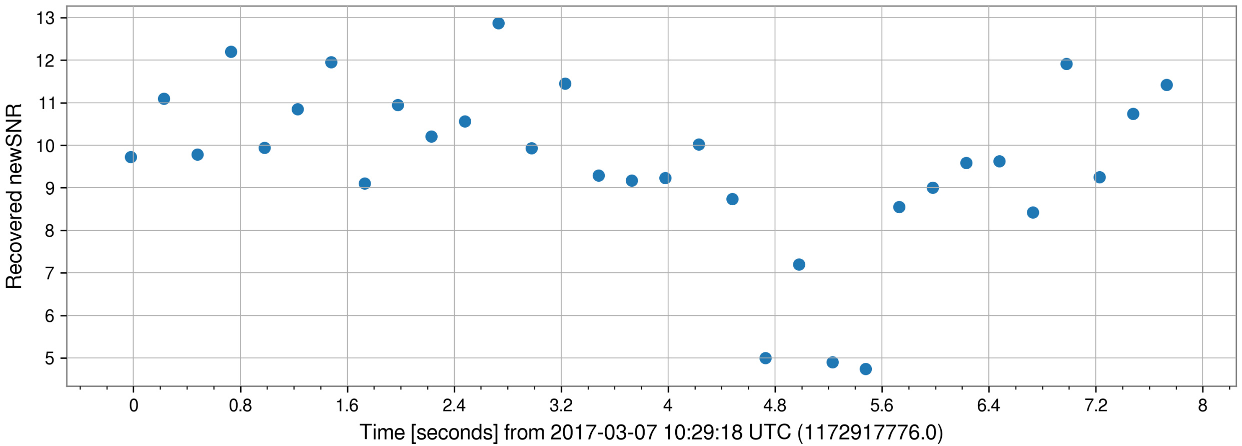


'Omega' time-frequency projection: S. Chatterji et al. CQG 21(20), 2010

Recovery by a matched filter search



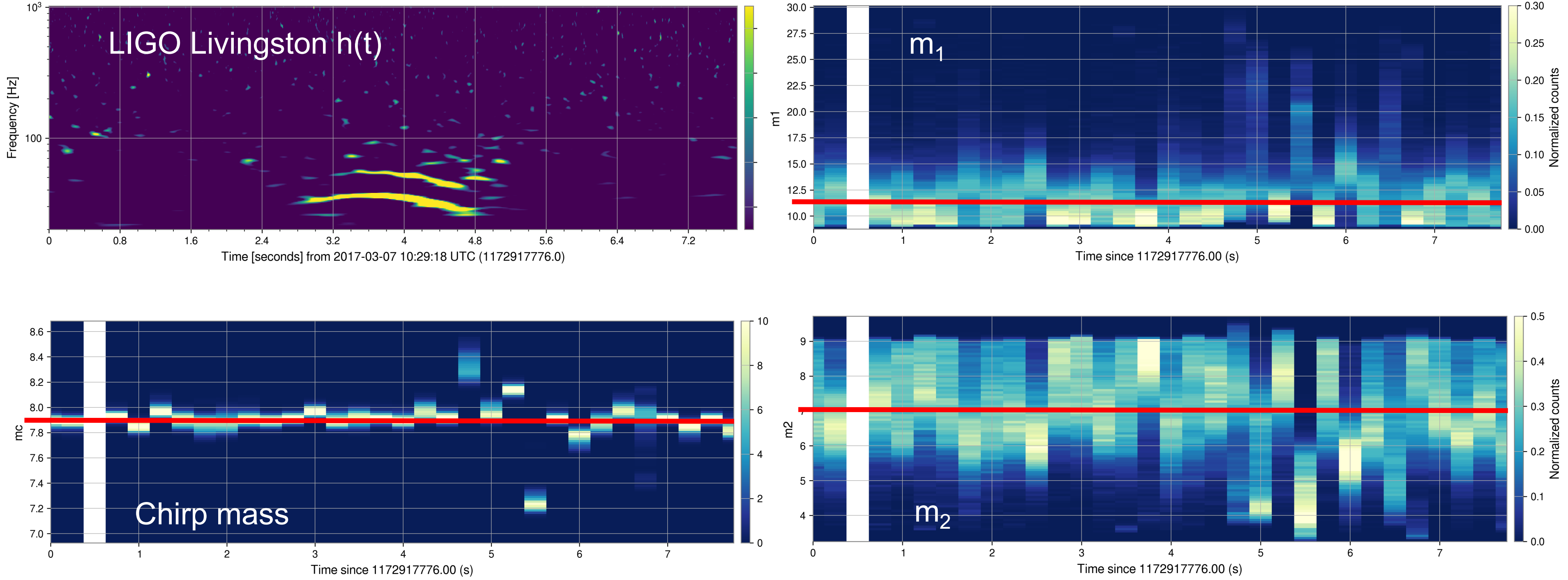
Recovered for L1 data with PyCBC:
S. Usman et al. CQG 33(21), 2016



Recovery of mass posteriors

Recovered for H1L1 network with lalinference:
J. Veitch et al. Phys. Rev. D 91, 042003 (2015)

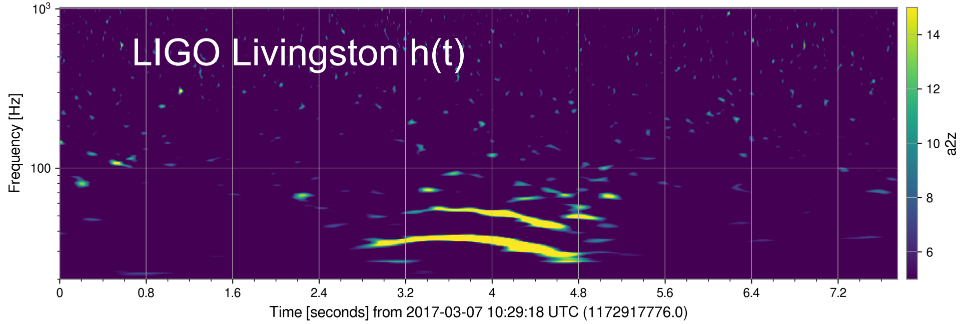
Injected values overlaid

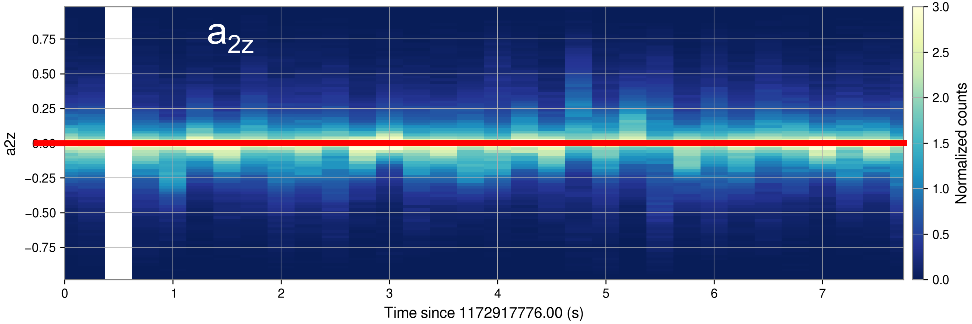


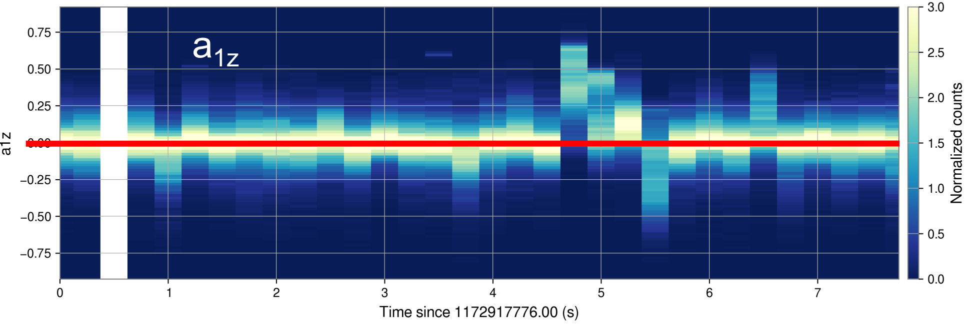
Recovery of component spins

Recovered for H1L1 network with lalinference:
J. Veitch et al. Phys. Rev. D 91, 042003 (2015)

Injected values overlaid

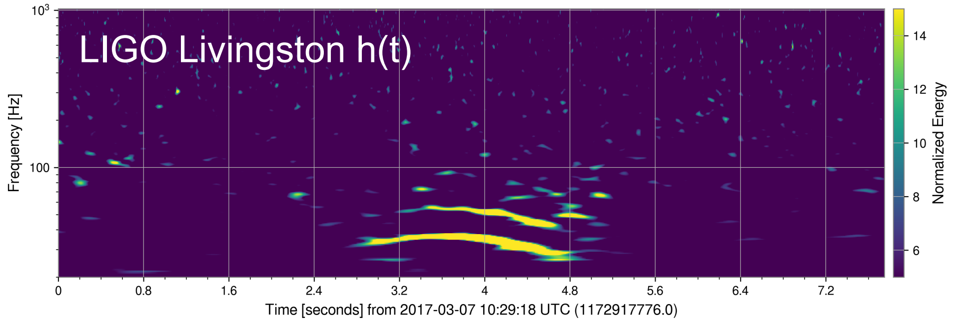






Recovery of source sky location

Recovered for H1L1 network with lalinference:
J. Veitch et al. Phys. Rev. D 91, 042003 (2015)



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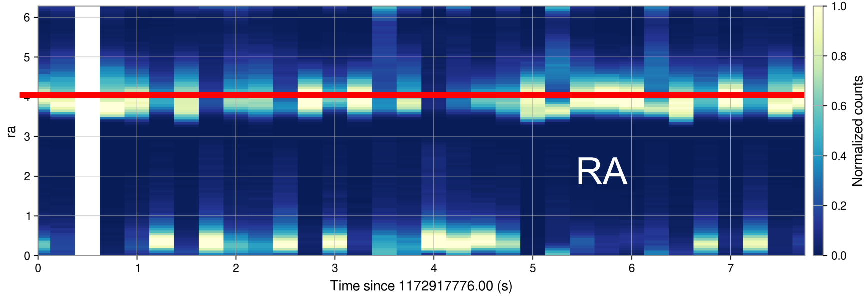
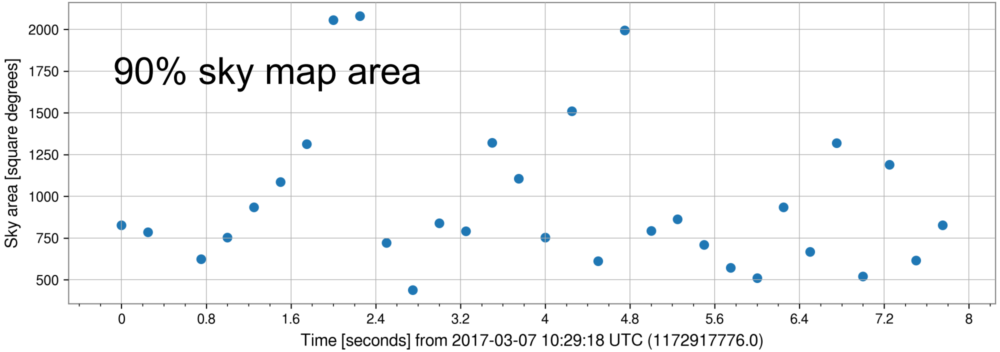
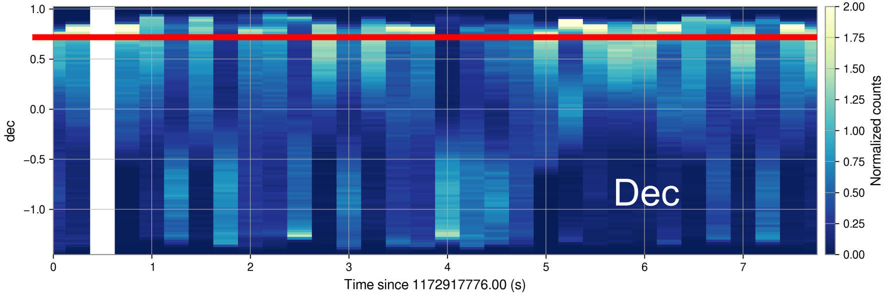
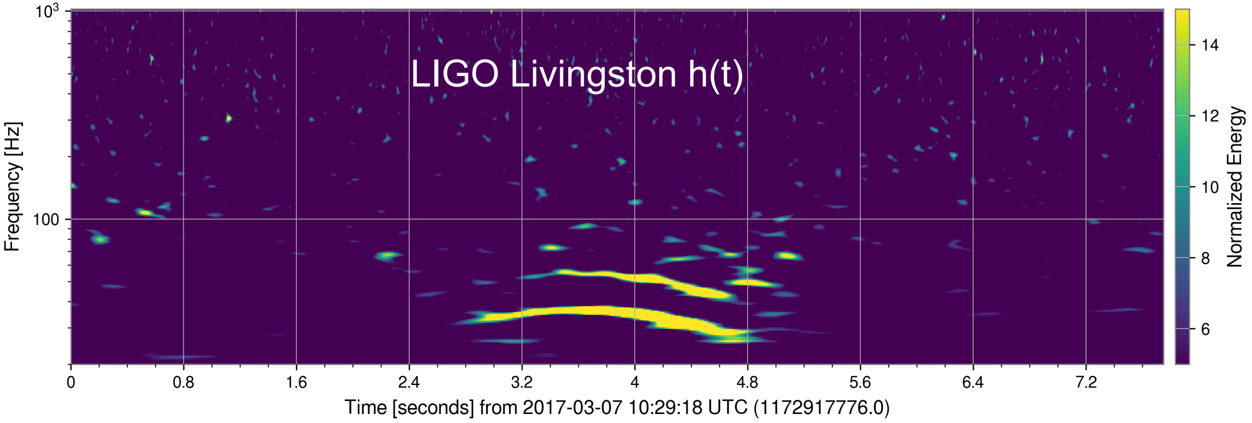


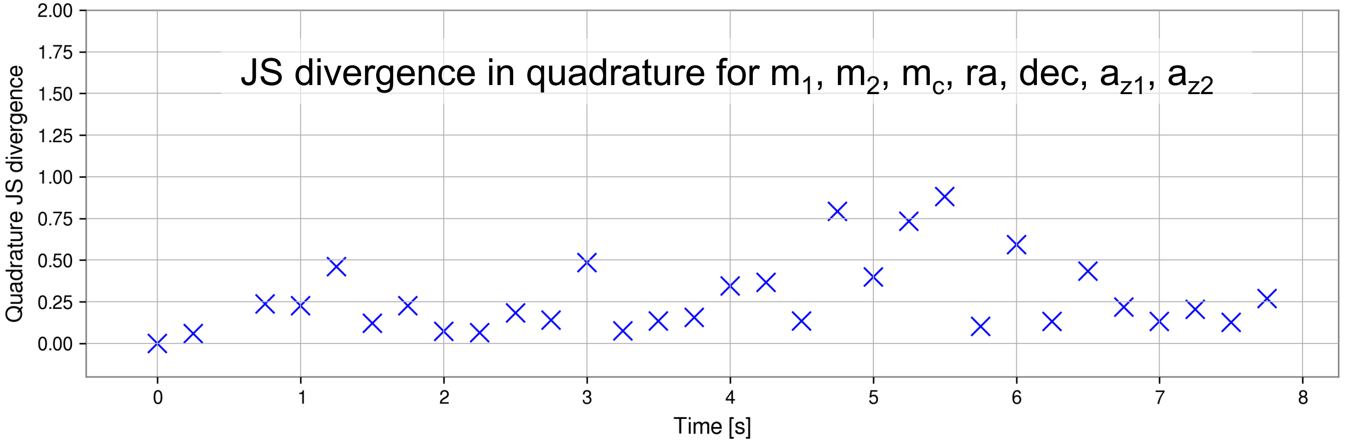




Jensen-Shannon (JS) divergence of posteriors



JS divergence, calculated relative to a clean reference time:
D.M. Endres et al. IEEE ToIT 49(7), 2003



Future studies

Paper in prep. that builds statistics for the three targeted aLIGO glitch classes.

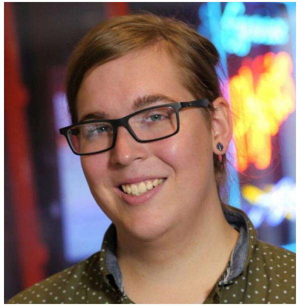
- How far away from merger time does a well-localized glitch need to be for the skymap to be unaffected, and how does this vary by template length?
- What types of noise introduce bias to skymap estimates for BNS or NSBH signals?
- Would we mis-characterize a signal as high mass instead of EM bright due to a nearby glitch?

Future targets:

- 3-detector scenarios
- Expanding to target other models/glitches
- Incorporating spin effects

Thank you! Questions are welcome!

Dr. TJ Massinger
LIGO Lab - Caltech



(Future Dr.) Derek Davis
Syracuse University

Dr. Laura Nuttall
University of Portsmouth

Dr. Vivien Raymond
Cardiff University

Dr. Rory Smith
Monash University

Extra slides

Approach

- Inject simulated signals into real LIGO data and use ‘vanilla’ parameter estimation to recover properties.
- Detector network: H1, L1

Four model templates chosen to sample different template lengths:

1. **GW170817-like**: 1.4 and 1.4 solar masses
2. **NSBH**: 30 and 1.4 solar masses
3. **GW170608-like**: 12 and 7 solar masses
4. **GW150914-like**: 36 and 29 solar masses

Injected coherently with network SNR=15 and zero spin.

Results: a guide

For each example, all results are shown on the same time axis.

- Omegascan[1] of ifo with the glitch example
- Example posteriogram for one of the targeted parameters
- Jensen-Shannon (JS) divergence[2]
- PyCBC single template newSNR[3] (single detector)

We can **add the JS divergence in quadrature** for multiple parameters (i.e. RA and dec; or chirp mass and component masses, or all parameters of interest) for a single-value summary of the divergence of the PE posteriors relative to a clean reference time

For two distributions, P_1 and P_2, the JS divergence is:

$$\mathbb{E}\left[-\ln\left(\frac{1}{2}P_1(x)+\frac{1}{2}P_2(x)\right)\right]-\left(\frac{1}{2}\mathbb{E}\left[-\ln P_1(x)\right]+\frac{1}{2}\mathbb{E}\left[-\ln P_2(x)\right]\right)$$

[1] S. Chatterji et al. CQG 21(20), 2010
[2] D.M. Endres et al. IEEE ToIT 49(7), 2003
[3] S. Usman et al. CQG 33(21), 2016

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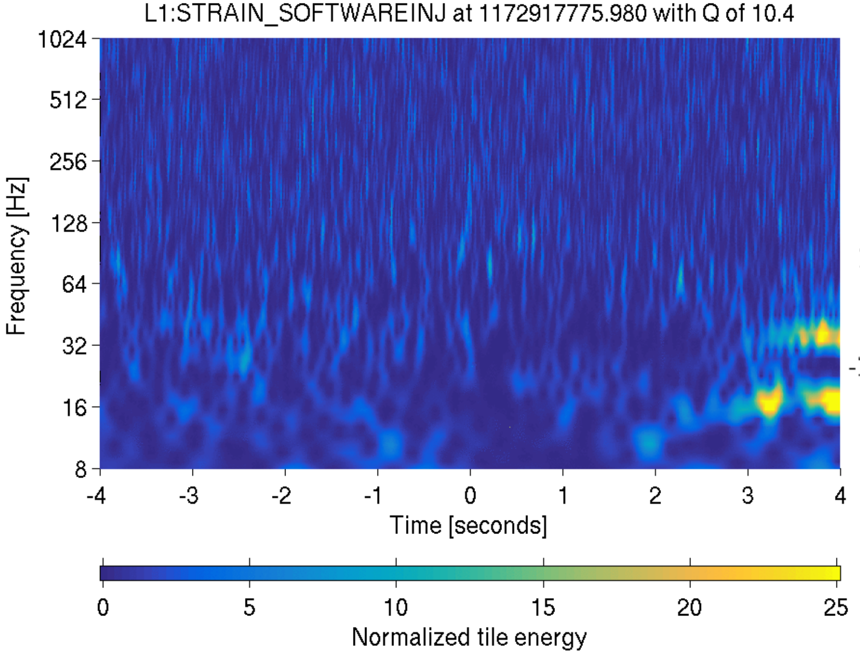

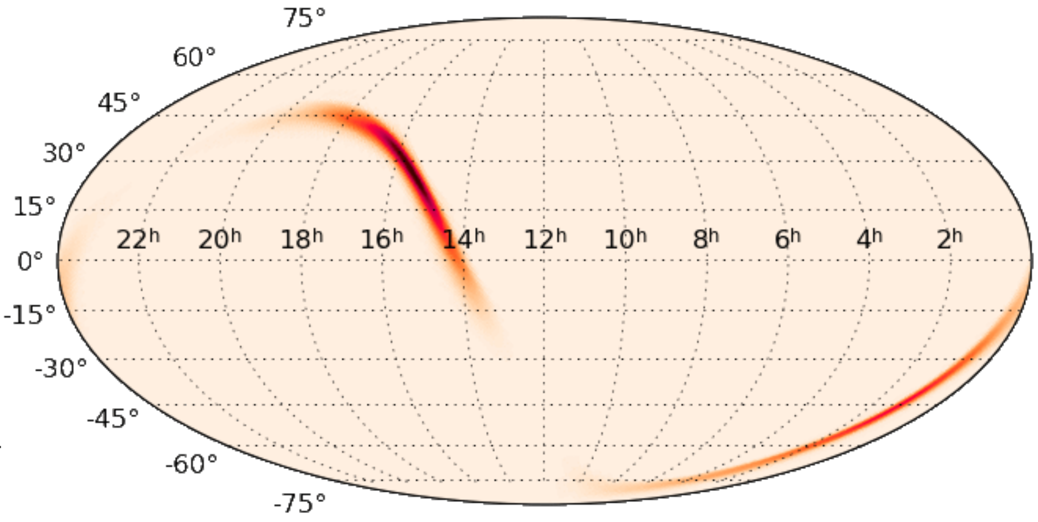

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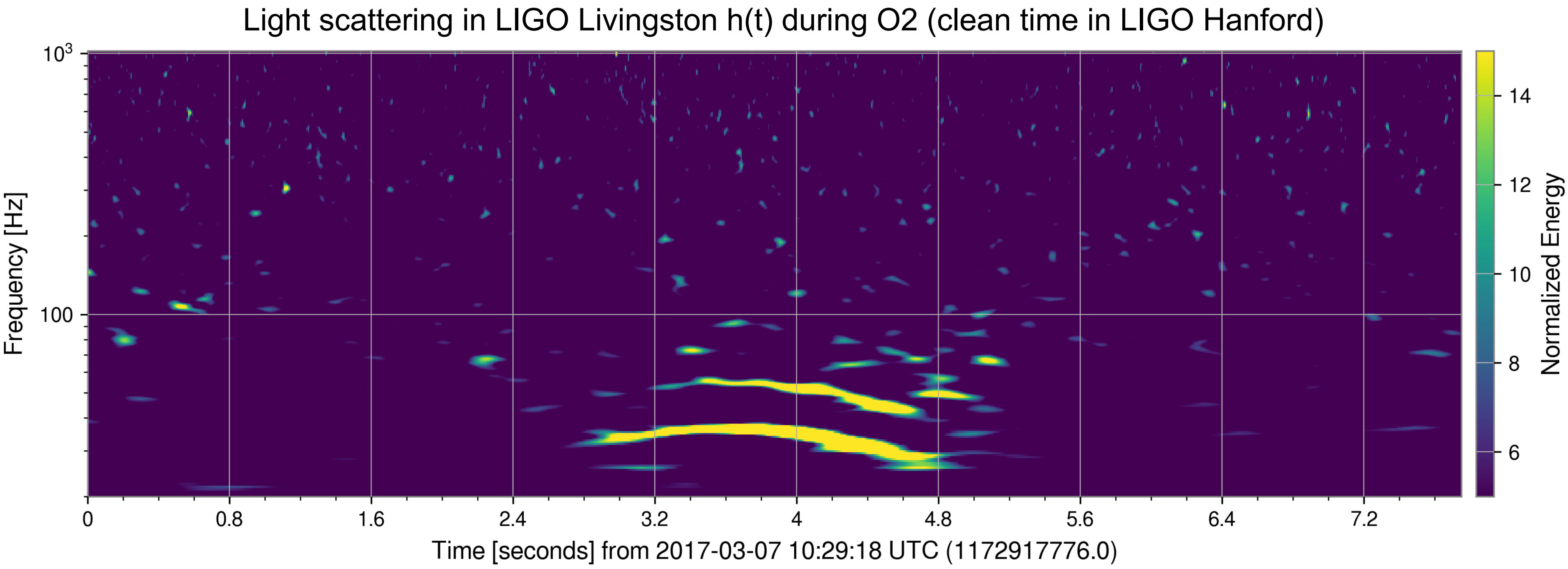

‘Omega’ time-frequency projection: S. Chatterji et al. CQG 21(20), 2010