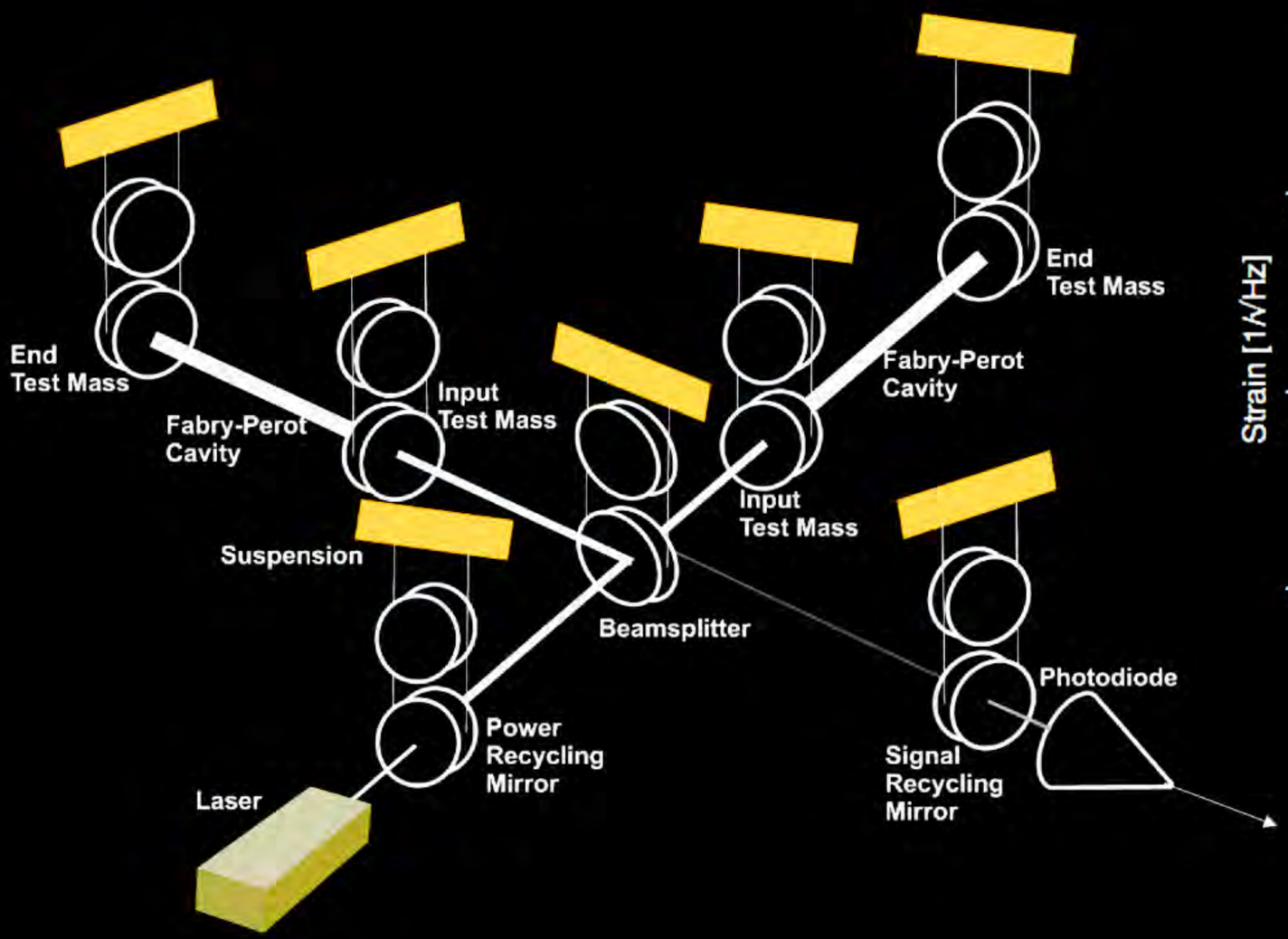
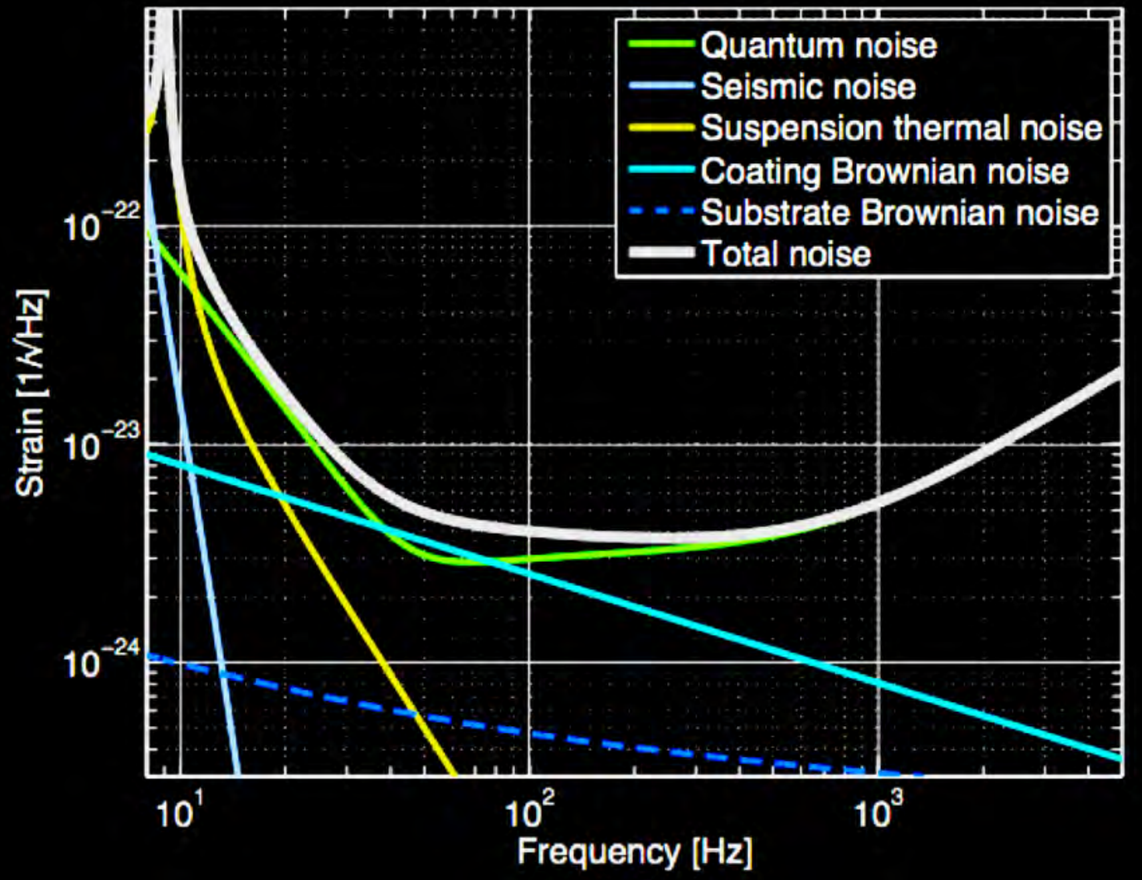
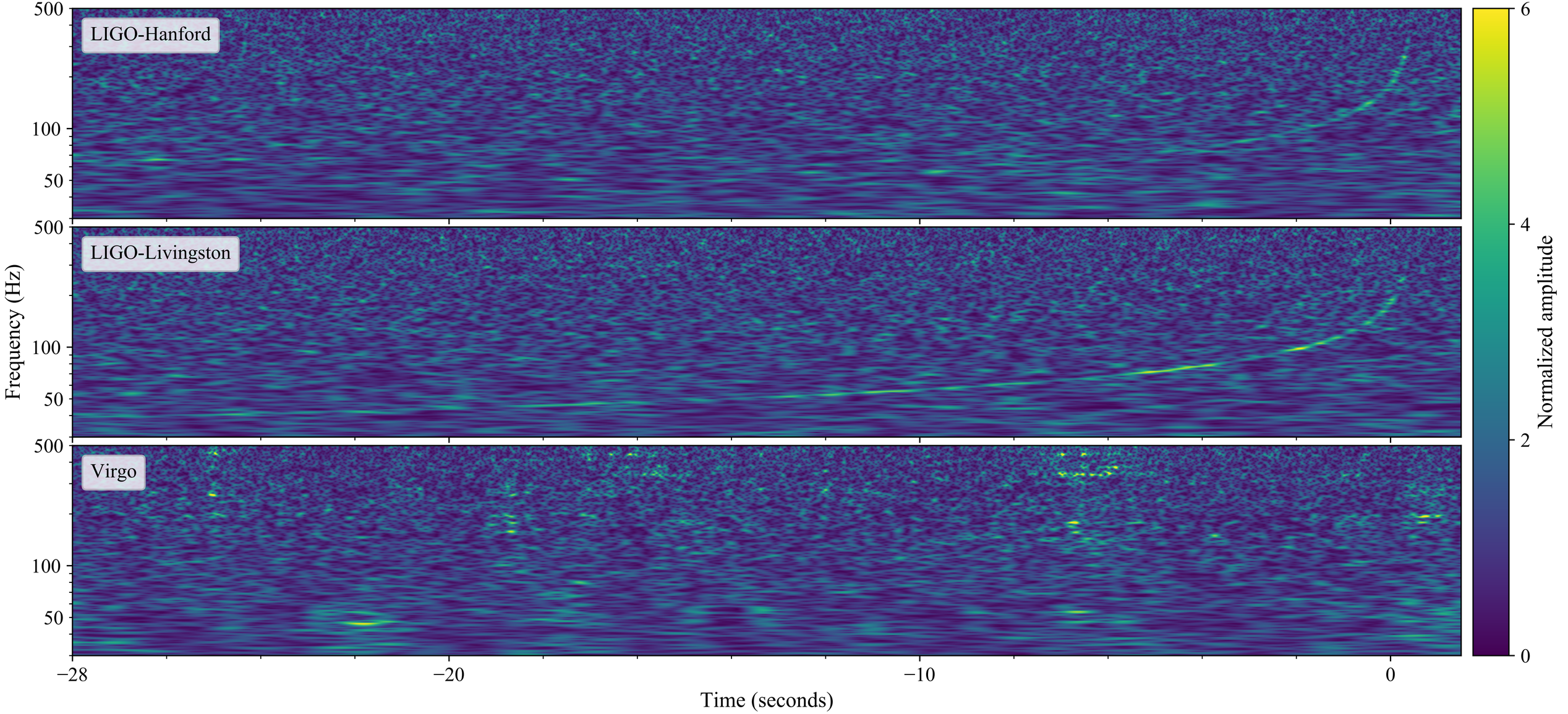
GW170817: The Detection of a Binary Neutron Star Merger

Duncan Brown
Syracuse University

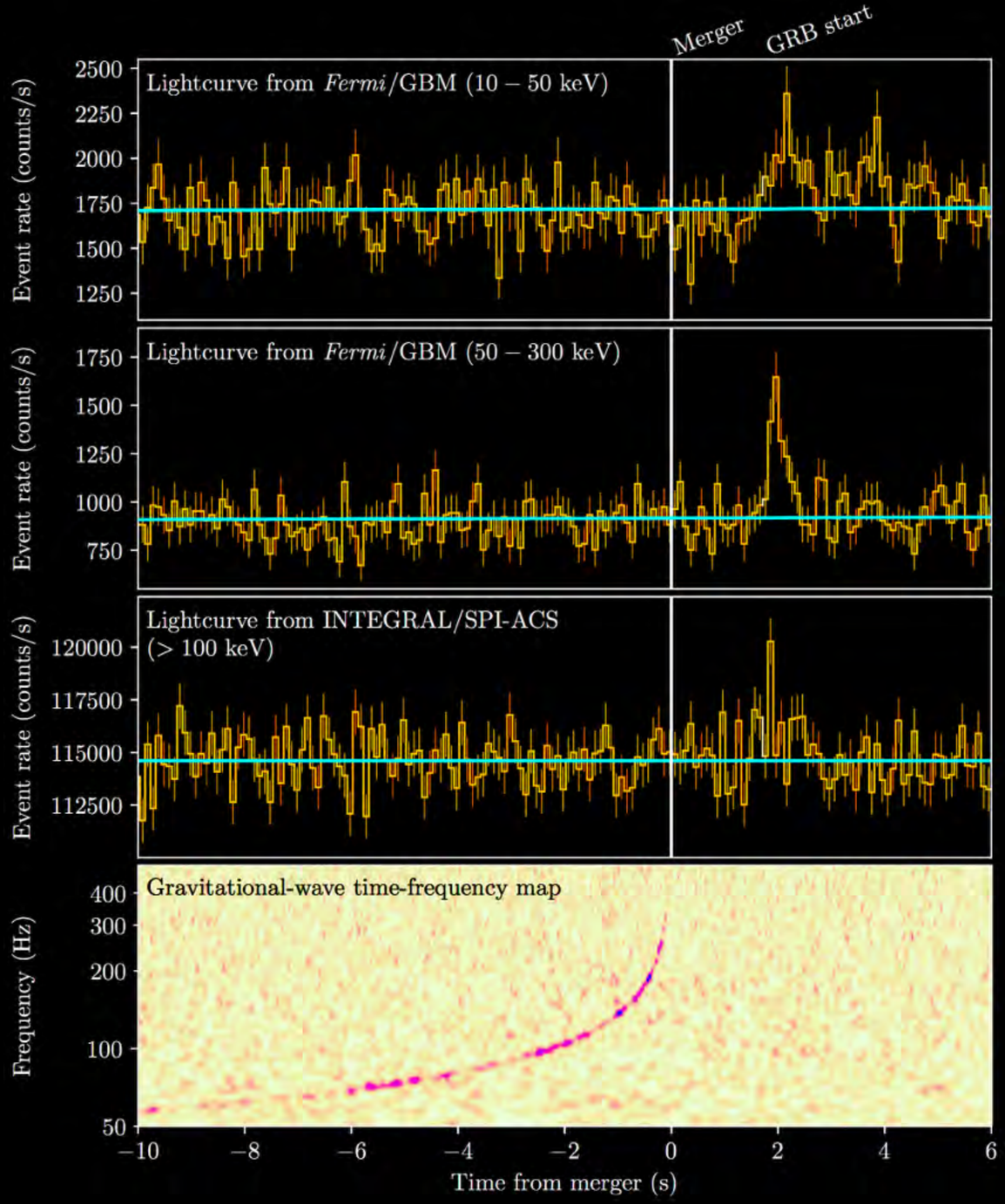
Advanced LIGO







Abbott,..., DAB et al. (LSC and Virgo) PRL **119** 161101 (2017)



- The probability of a chance temporal and spatial association of GW170817 and GRB170817A is 5.0×10^{-8}
- We can confirm binary neutron stars as the progenitors of short, hard gamma-ray bursts
- The time delay between the end of the gravitational-wave signal and the start of the gamma-ray burst is 1.74 (+/- 0.05) s

Abbott,..., DAB et al. (LSC, Virgo, Fermi, Integral) ApJ **848** L13 (2017)

Basic Info

UID	Labels	Group	Pipeline	Search	Instruments	GPS Time: Event Time	FAR (Hz)	FAR (yr^{-1})	Links	UTC: Submitted
G298048	EM_COINC H1OK ADVOK L1OK V1OK	CBC	gstlal	O2VirgoTest	H1	1187008882.4457	3.478e-12	1 per 9111.7 years	Data	2017-08-17 12:47:18 UTC

Coinc Tables

End Time (GPS)	1187008882.4457 s
Total Mass	2.7693 $M_\odot$
Chirp Mass	
SNR	
False Alarm Proba	
Log Likelihood Ratio	32.3969

Single Inspiral Tables

IFO H1

Low chirp mass

Fermi gamma-ray burst event
~ 2 second after merger!

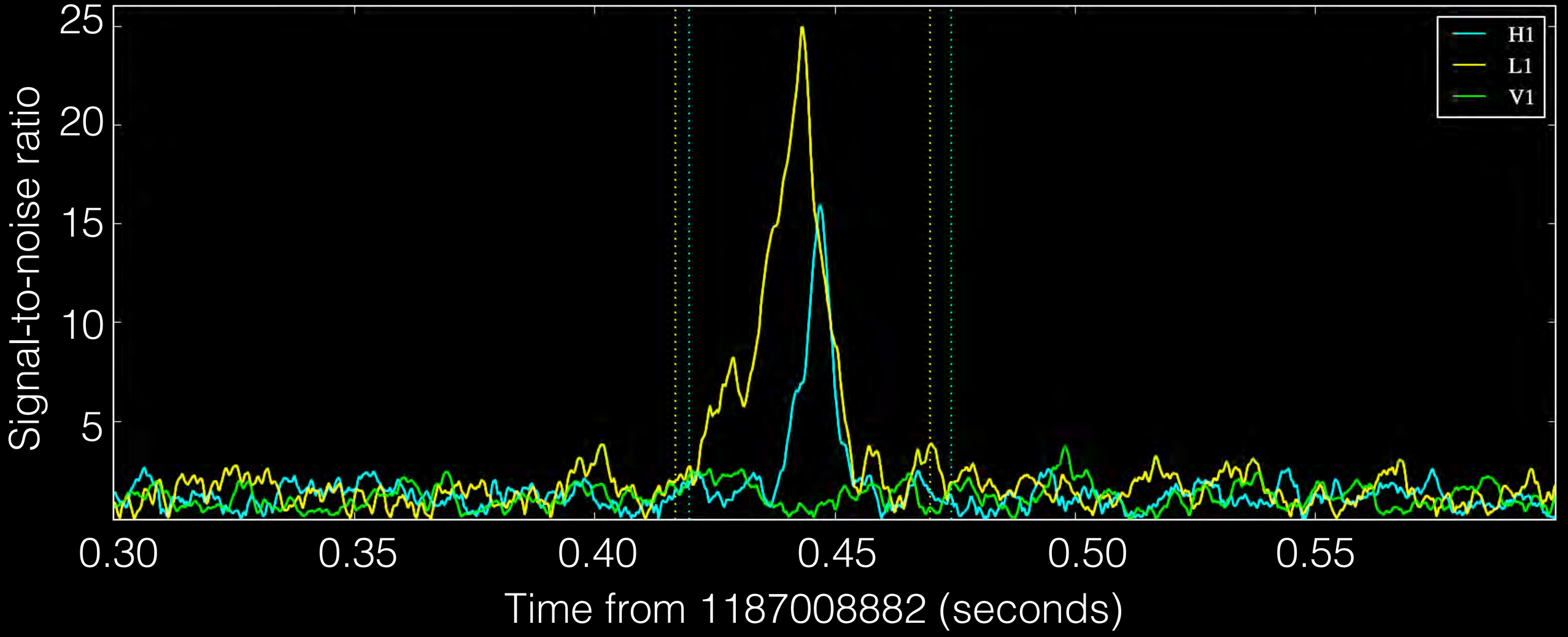
But only seen at Hanford, even though Livingston and Virgo were operating...

Neighbors [-5,+5]

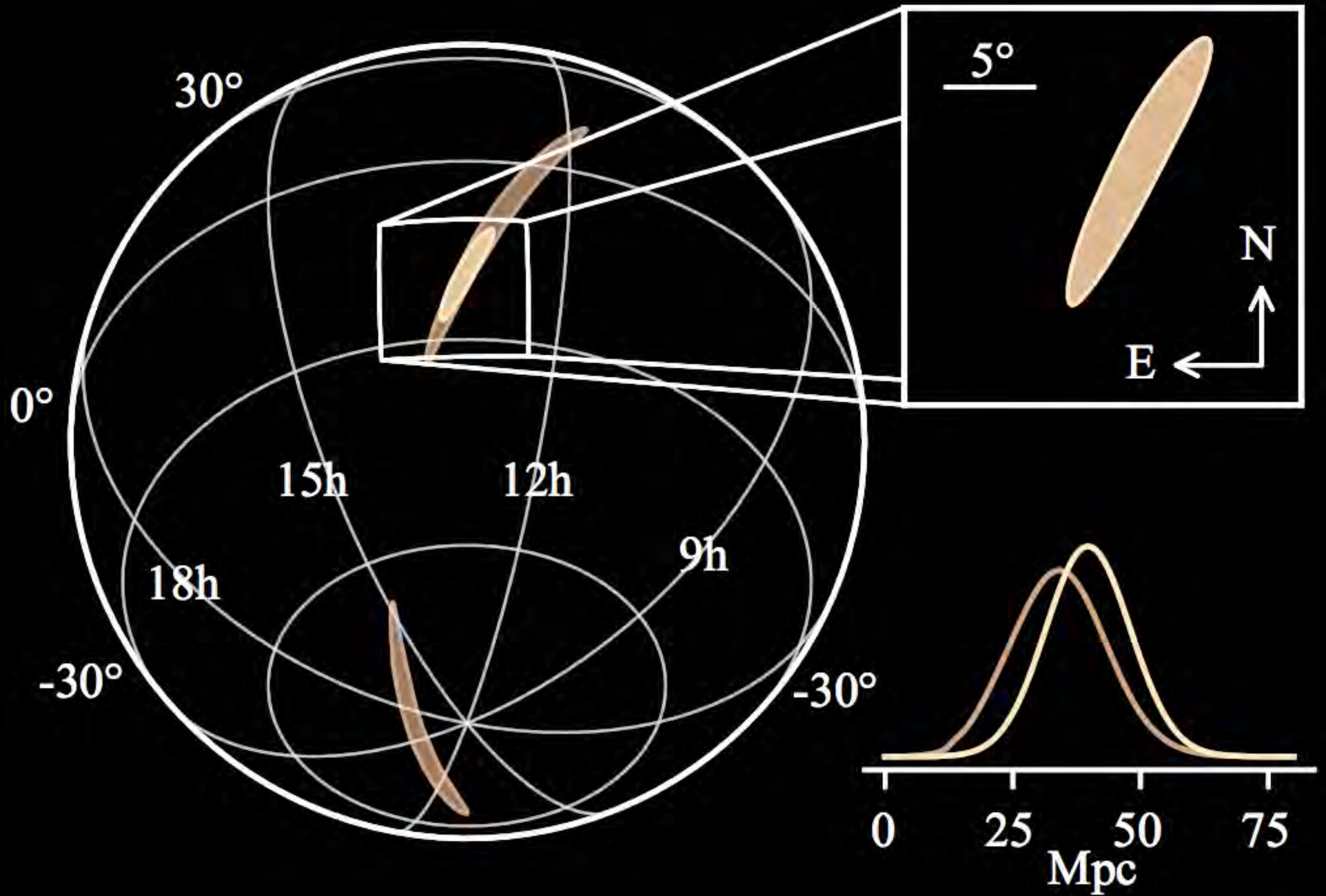
UID	Labels	Group	Pipeline	Search	Instruments	GPS Time: Event Time	Δgpstime	FAR (Hz)	Links	UTC: Submitted
E298046	EM_COINC	External	Fermi	GRB		1187008884.4700	2.024290		Data	2017-08-17 12:41:45 UTC

Cannon et al. ApJ **748** 136 (2012)
Messick et al. PRD **95**, 042001 (2017)

Rapid offline re-analysis of Hanford, Livingston, and Virgo data



Nitz,... DAB. ApJ **849** 118 (2017)



Singer and Price PRD **93**, 024013 (2016)

GCN 21513 at 1:54 pm EDT with localization...

TITLE: GCN CIRCULAR
NUMBER: 21513
SUBJECT: LIGO/Virgo G298048: Further analysis of a binary neutron star candidate with updated sky localization
DATE: 17/08/17 17:54:51 GMT
FROM: Leo Singer at NASA/GSFC <leo.p.singer@nasa.gov>

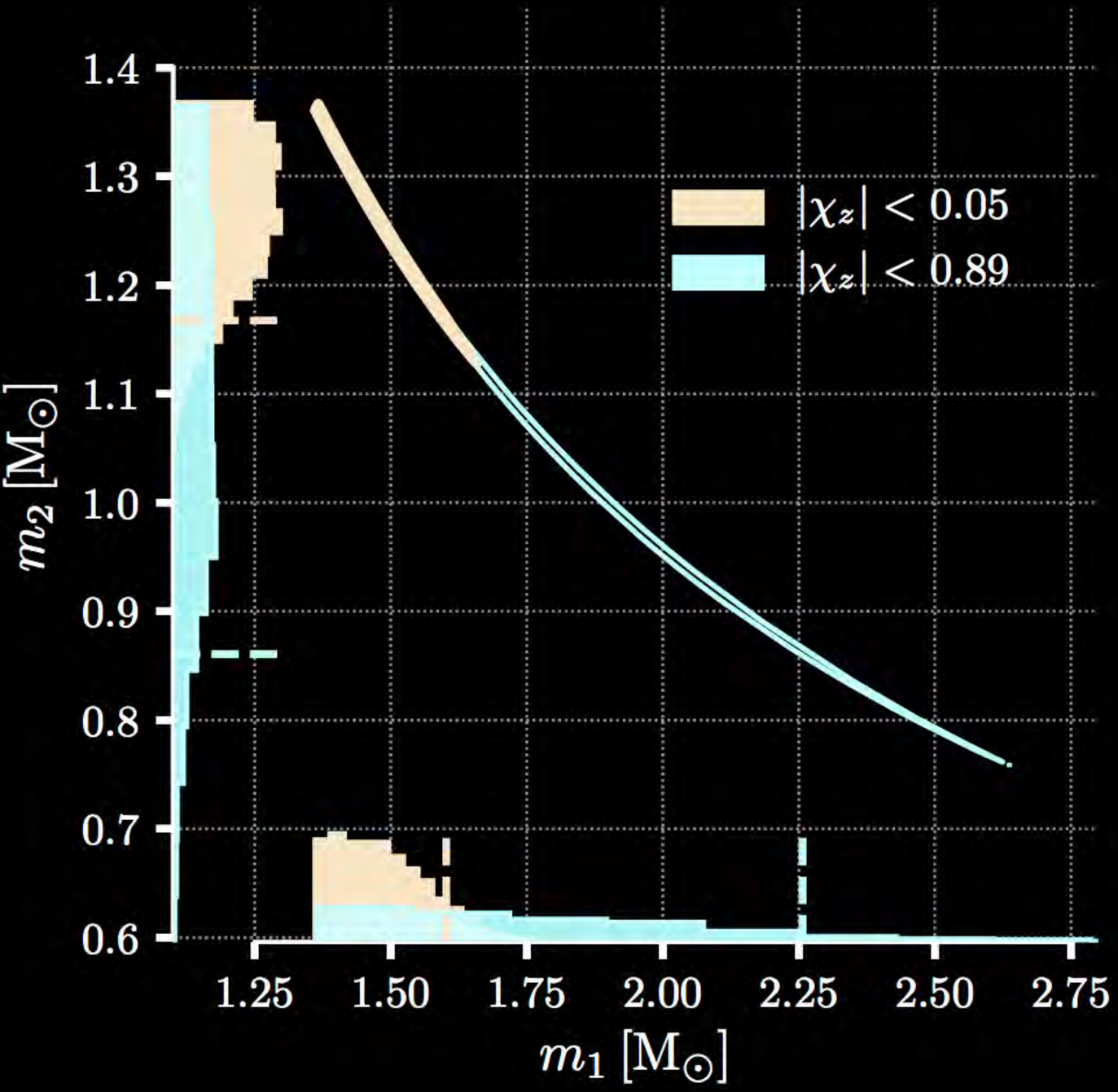
The LIGO Scientific Collaboration and the Virgo Collaboration report:

We performed a preliminary offline analysis using the PyCBC search (Nitz et al. arxiv:1705.01513, 2017) of the binary neutron star candidate G298048 (LSC and Virgo, GCN 21505, 21509, 21510) identified in low-latency by the gstlal online search (Messick et al. Phys. Rev. D 95, 042001, 2017).

A trigger consistent with a binary neutron star merger is observed at GPS time 1187008882.443 (2017-08-17 12:41:04 UTC) in both the LIGO Livingston (L1) and LIGO Hanford (H1) detectors. The trigger is below threshold in Virgo because of the antenna pattern for Virgo (V1) at the time and location of this event, but the Virgo instrument contributes to the localization. The duration of the gravitational-wave signal is approximately 74 seconds from the searchâ€™s low-frequency cutoff of 27 Hz to the binary merger.

Investigation of L1 data identified a noise transient from a known class of instrumental glitches during the inspiral signal. The duration of this glitch is a small fraction of a second and does not appear to affect the signal at times away from the glitch. To make an improved preliminary estimate of the sky position, we re-analyzed the data, removing the L1 noise transient at GPS time 1187008881.389 by multiplying the strain data with a Tukey window, such that the total duration of the zeroed data is 0.2 s and the total duration of the Tukey window is 1.2 s.

An updated BAYESTAR sky map (Singer et al. 2016, ApJL 829, 15) that uses data from all three gravitational-wave observatories (H1, L1, and V1) is available for retrieval from the GraceDB page (https://gracedb.ligo.org/events/view/G298048): bayestar-HLV.fits.gz. The centroid (maximum a posteriori) sky location is R.A.=12h57m, Dec.=-17d51m. The 50% credible region spans about 9 deg2 and the 90% region about 31 deg2. The luminosity distance is 40 +/- 8 Mpc (all-sky a posteriori mean +/- standard deviation). This is the preferred sky map at this time.



$$\chi = \frac{J}{m^2} \approx 0.4 \left(\frac{1\,\mathrm{ms}}{T} \right)$$

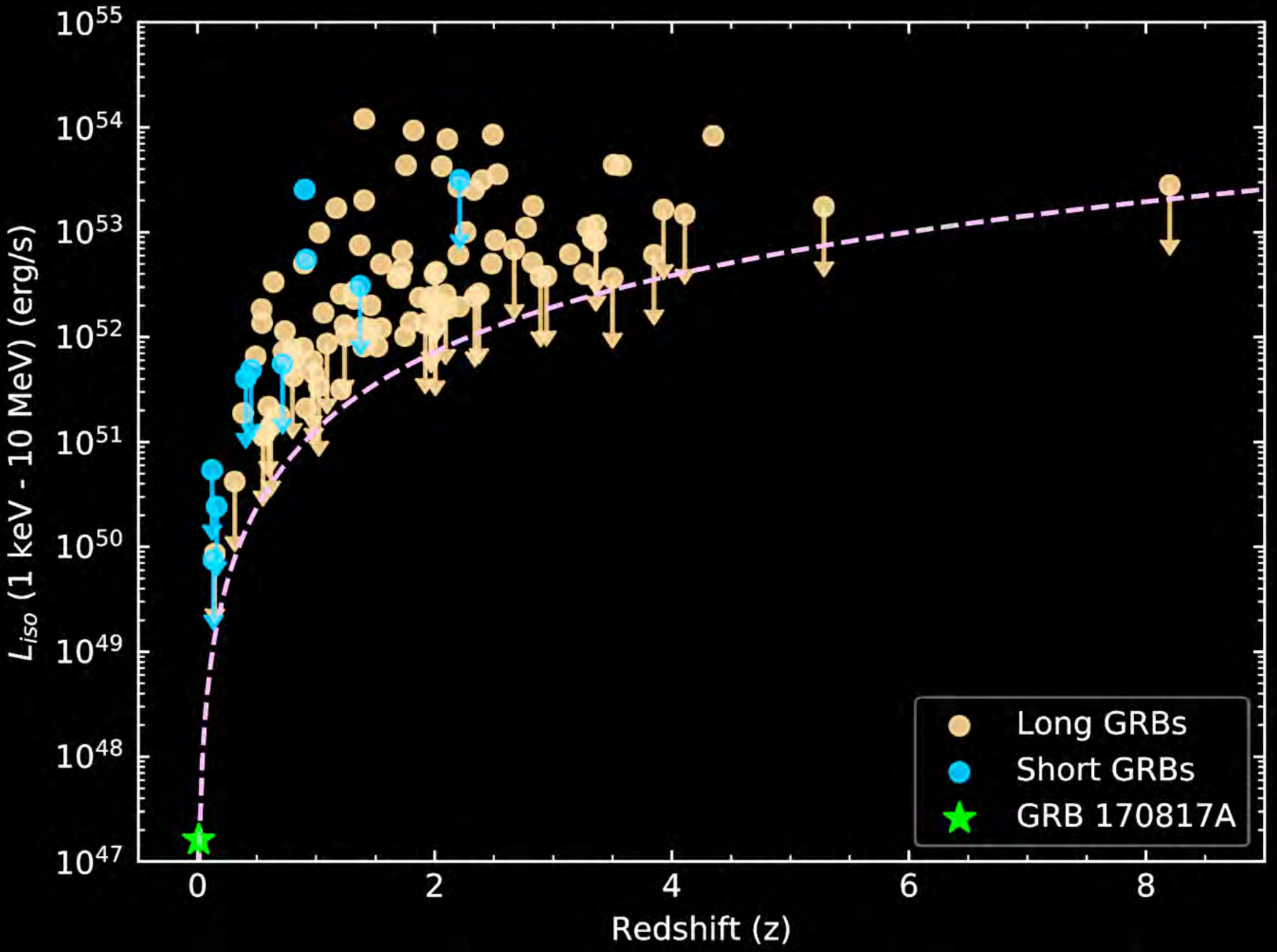
$$\mathcal{M} = \frac{(m_1 m_2)^{3/5}}{(m_1 + m_2)^{1/5}} = 1.188^{+0.004}_{-0.002} M_\odot$$

$$m_1 = 1.36 - 1.60 M_\odot \ (90\% \text{ credible})$$

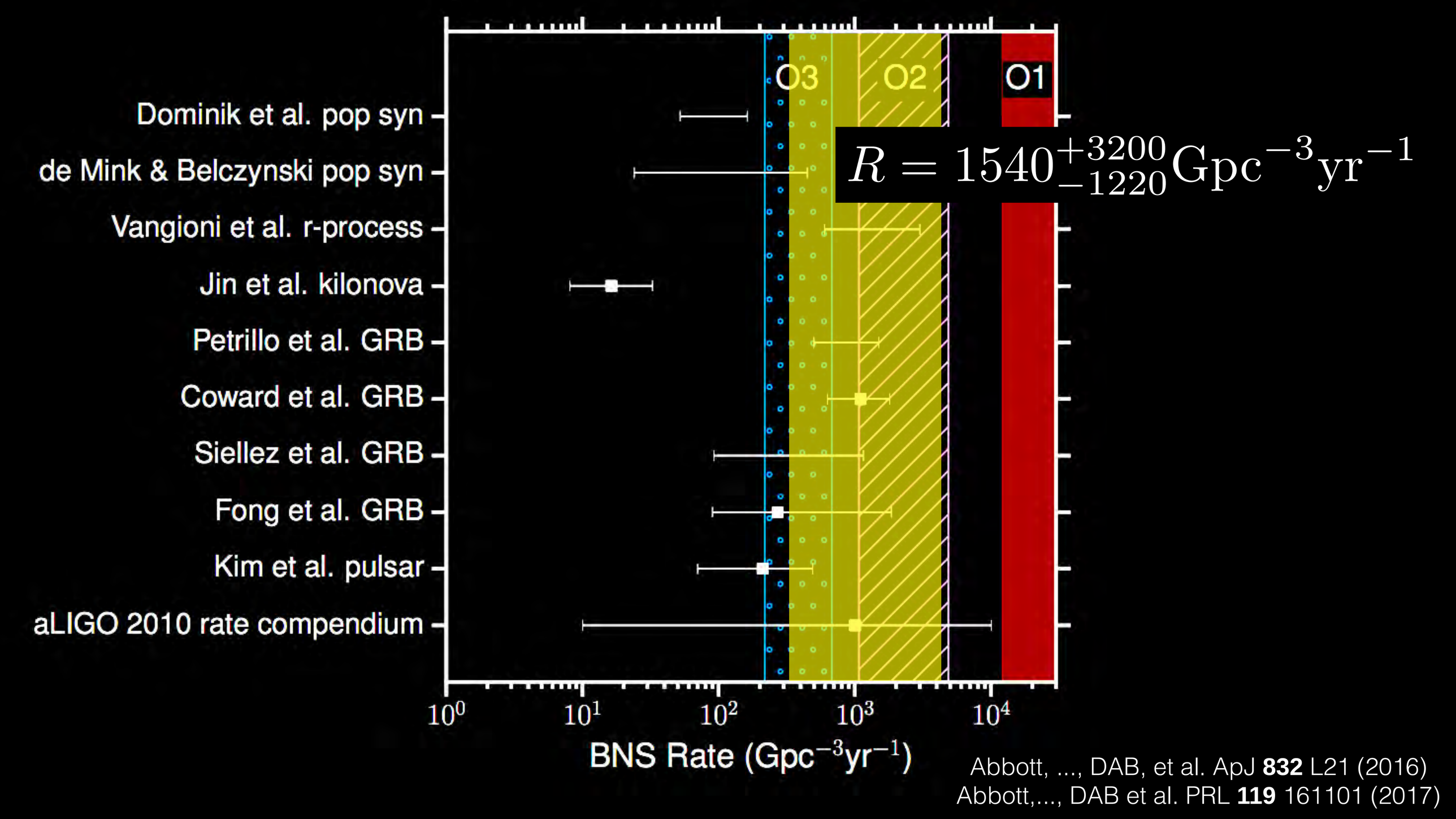
$$m_2 = 1.17 - 1.36 M_\odot (90\% \text{ credible})$$

$$D_\mathrm{L} = 40^{+8}_{-14}\ \mathrm{Mpc}$$

Abbott,..., DAB et al. PRL **119** 161101 (2017)



Abbott,..., DAB et al. ApJ **848** L13 (2017)



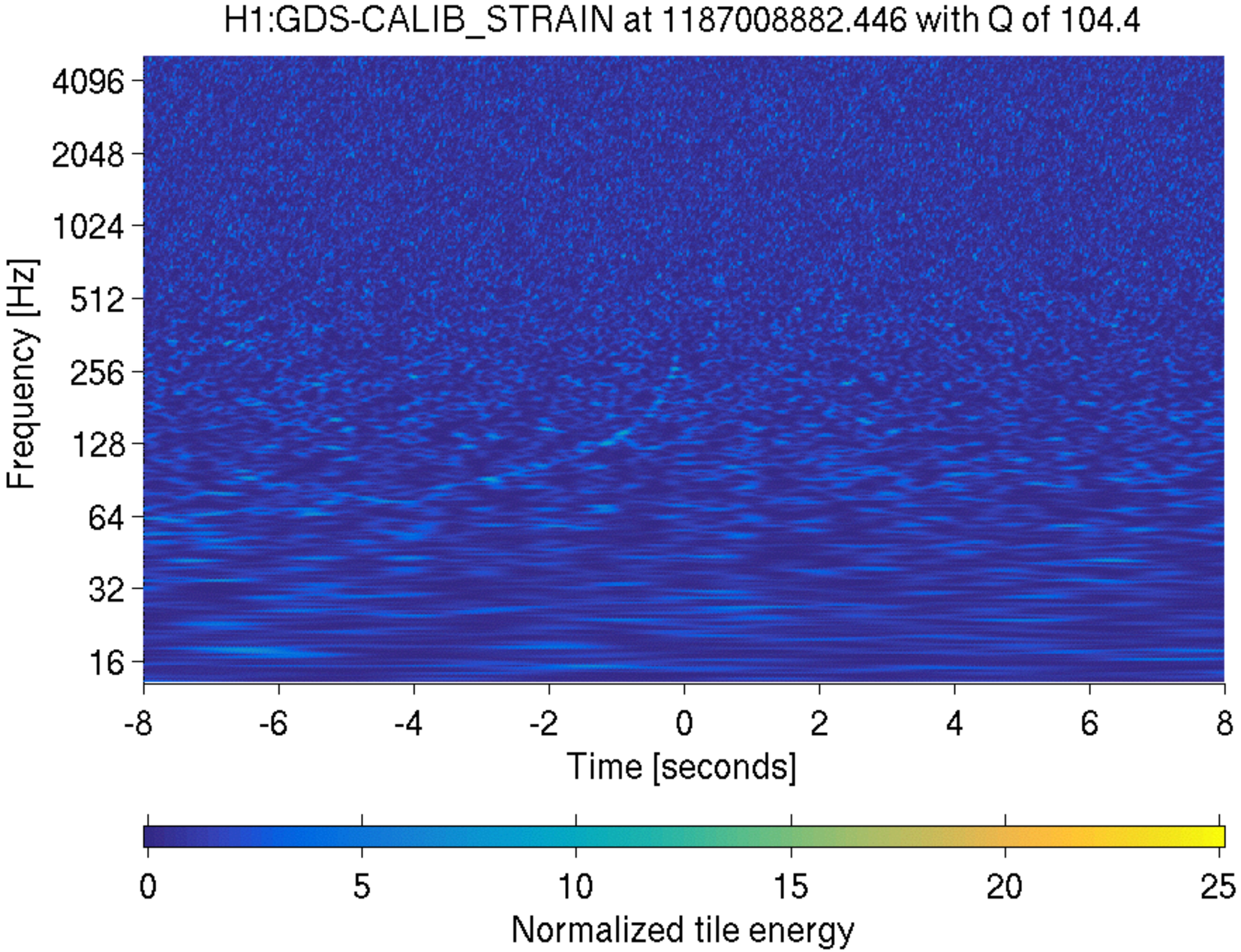
Abbott, ..., DAB, et al. ApJ **832** L21 (2016)
Abbott,..., DAB et al. PRL **119** 161101 (2017)

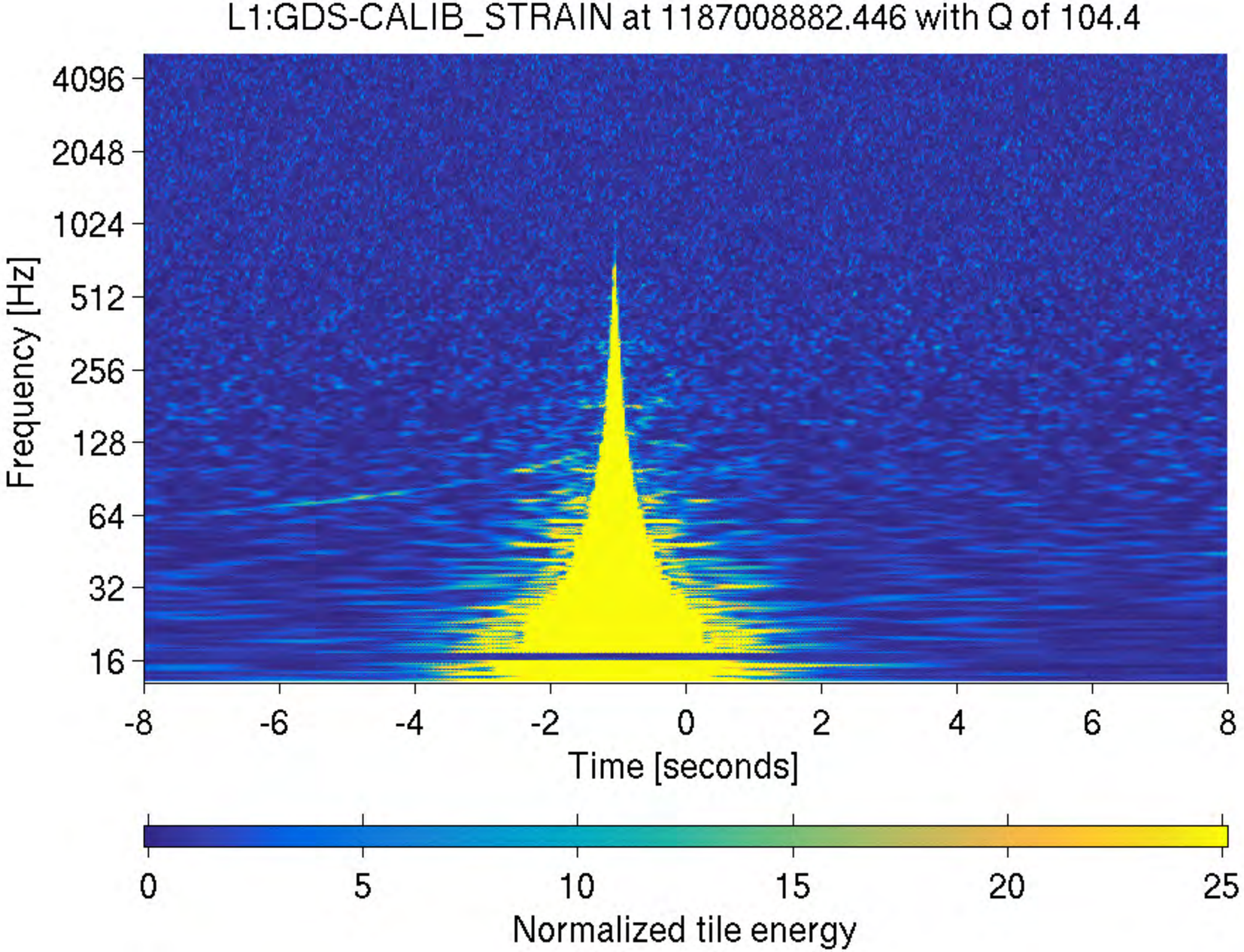
Extra Slides

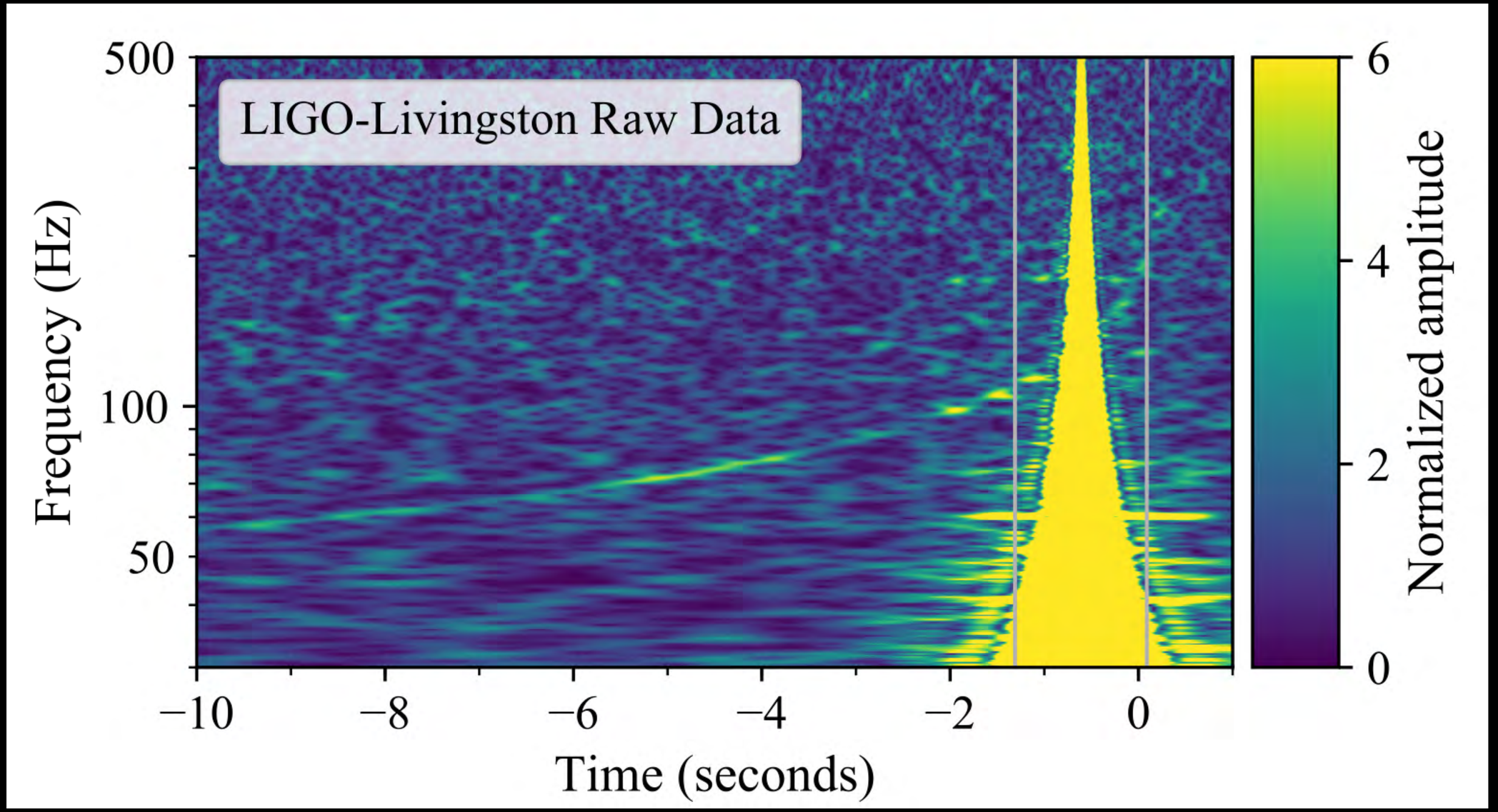
Virgo Localization

Leo Singer

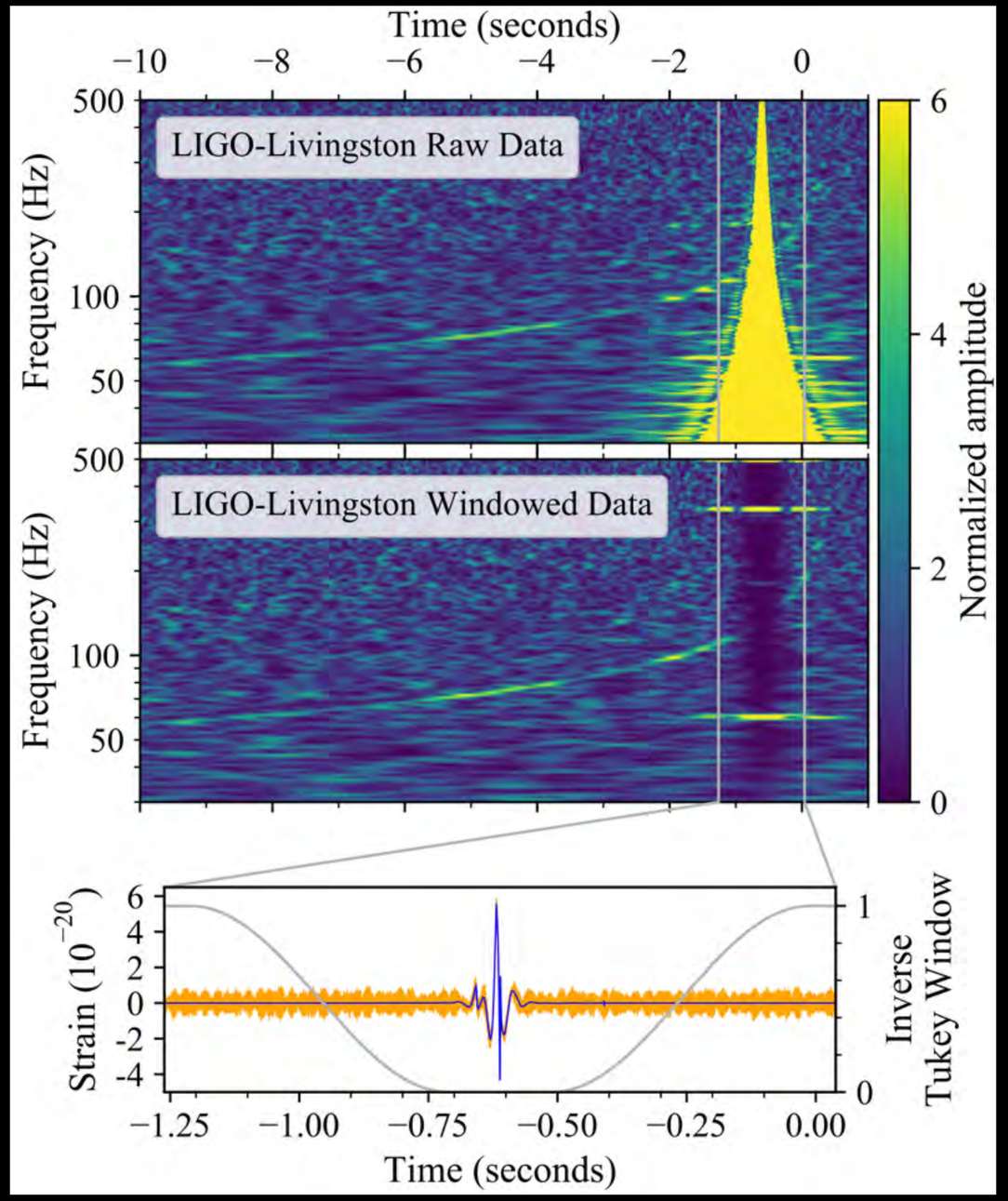
Glitch Removal


H1:GDS-CALIB_STRAIN at 1187008882.446 with Q of 104.4
Frequency [Hz]
4096
2048
1024
512
256
128
64
32
16
-8
-6
-4
-2
0
2
4
6
8
Time [seconds]
0
5
10
15
20
25
Normalized tile energy


L1:GDS-CALIB_STRAIN at 1187008882.446 with Q of 104.4
Frequency [Hz]
4096
2048
1024
512
256
128
64
32
16
-8
-6
-4
-2
0
2
4
6
8
Time [seconds]
0
5
10
15
20
25
Normalized tile energy



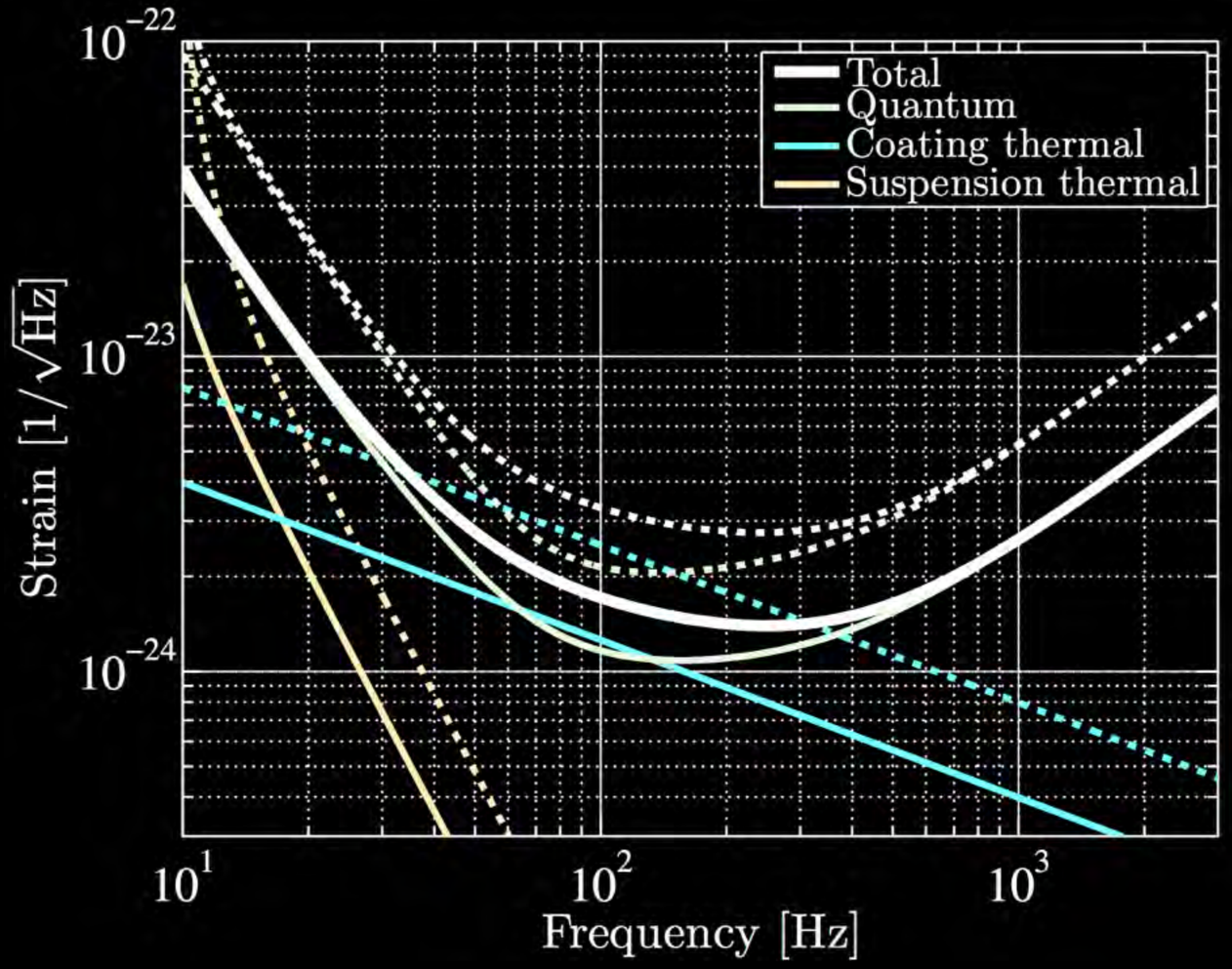
Usman,... DAB, et al. Class Quant Grav, **33** 215004 (2016)



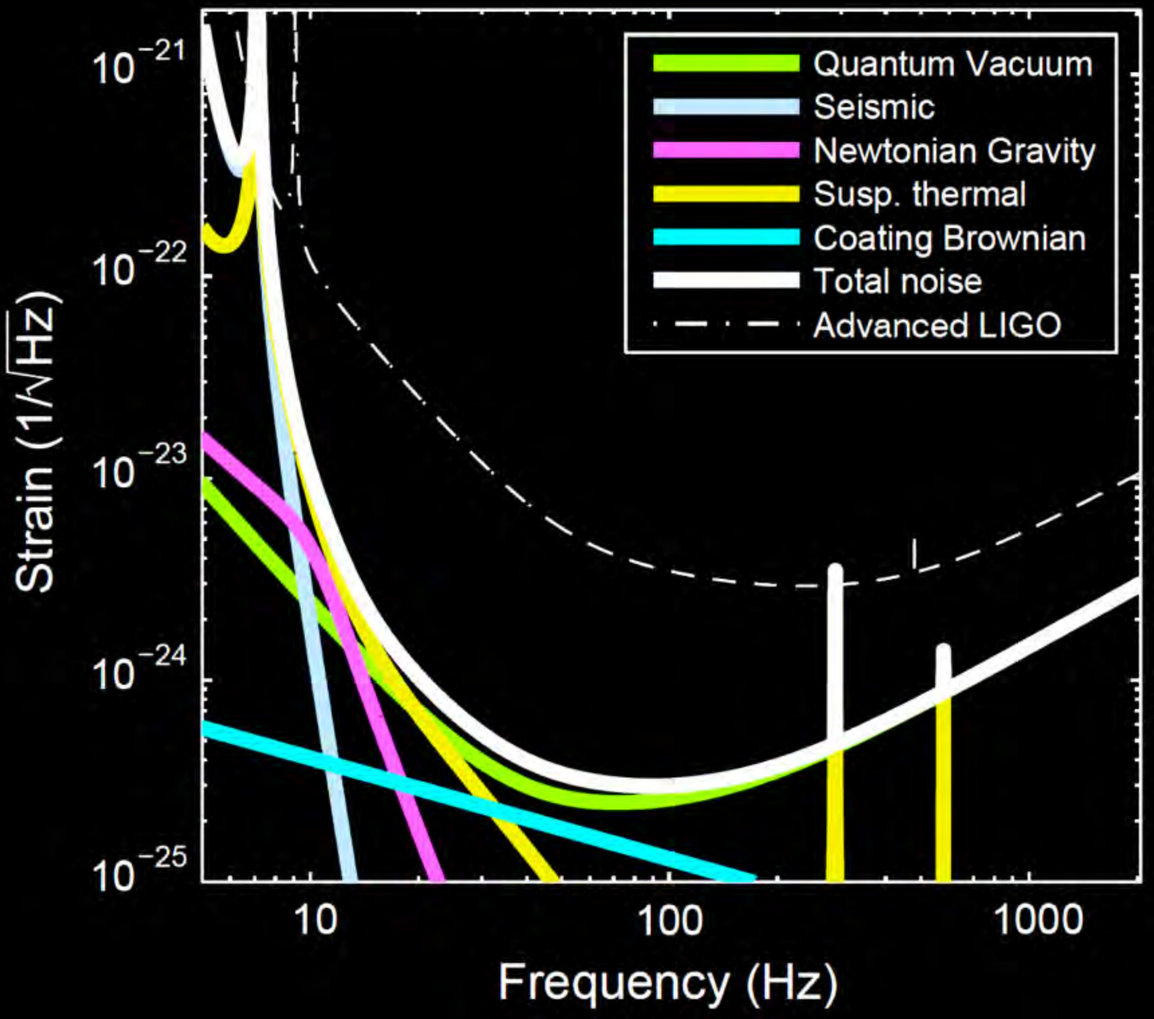
Cornish and Littenberg Class. Quant. Grav. **32** 135012 (2015)

Future Detectors

Beyond Advanced LIGO

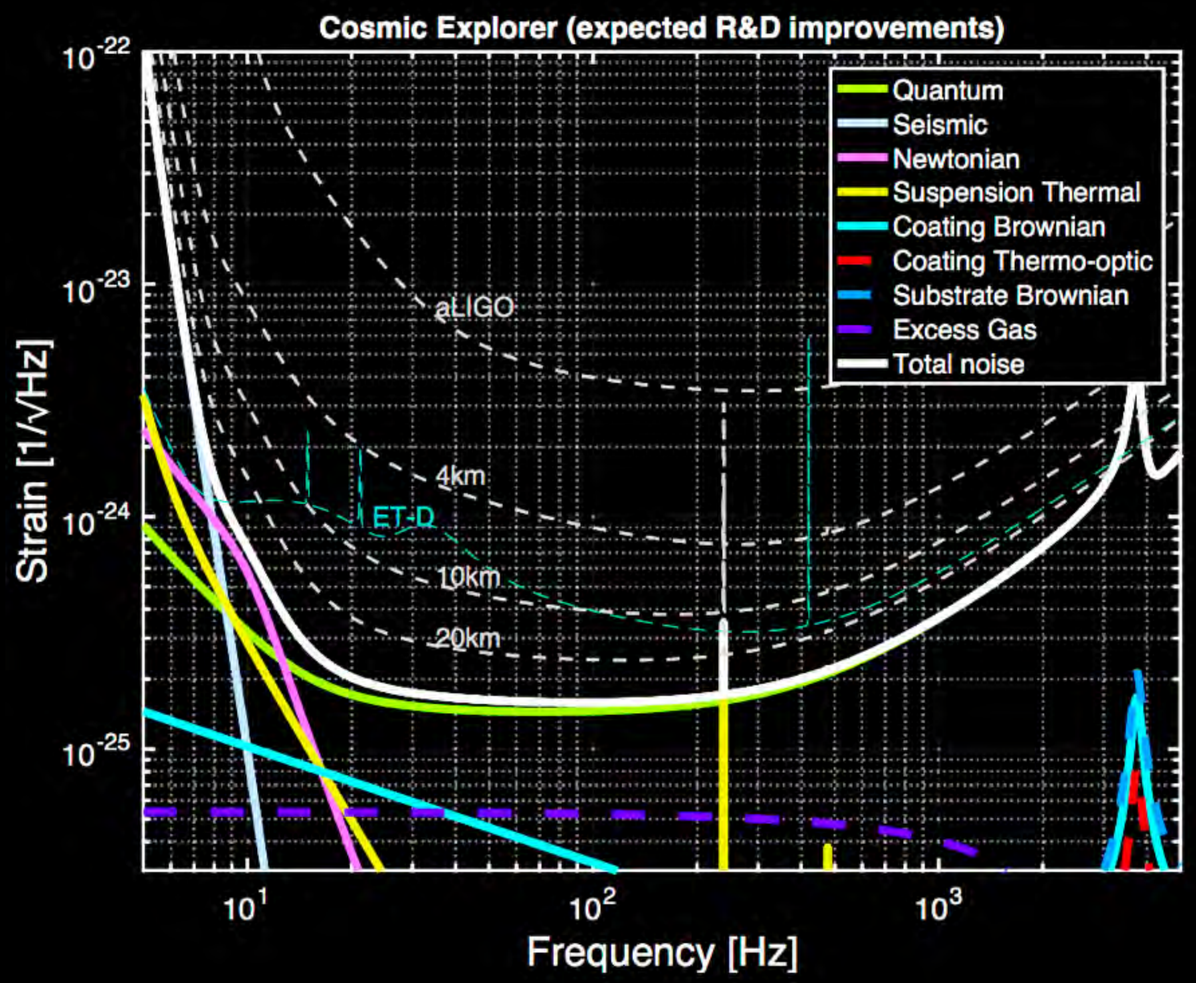


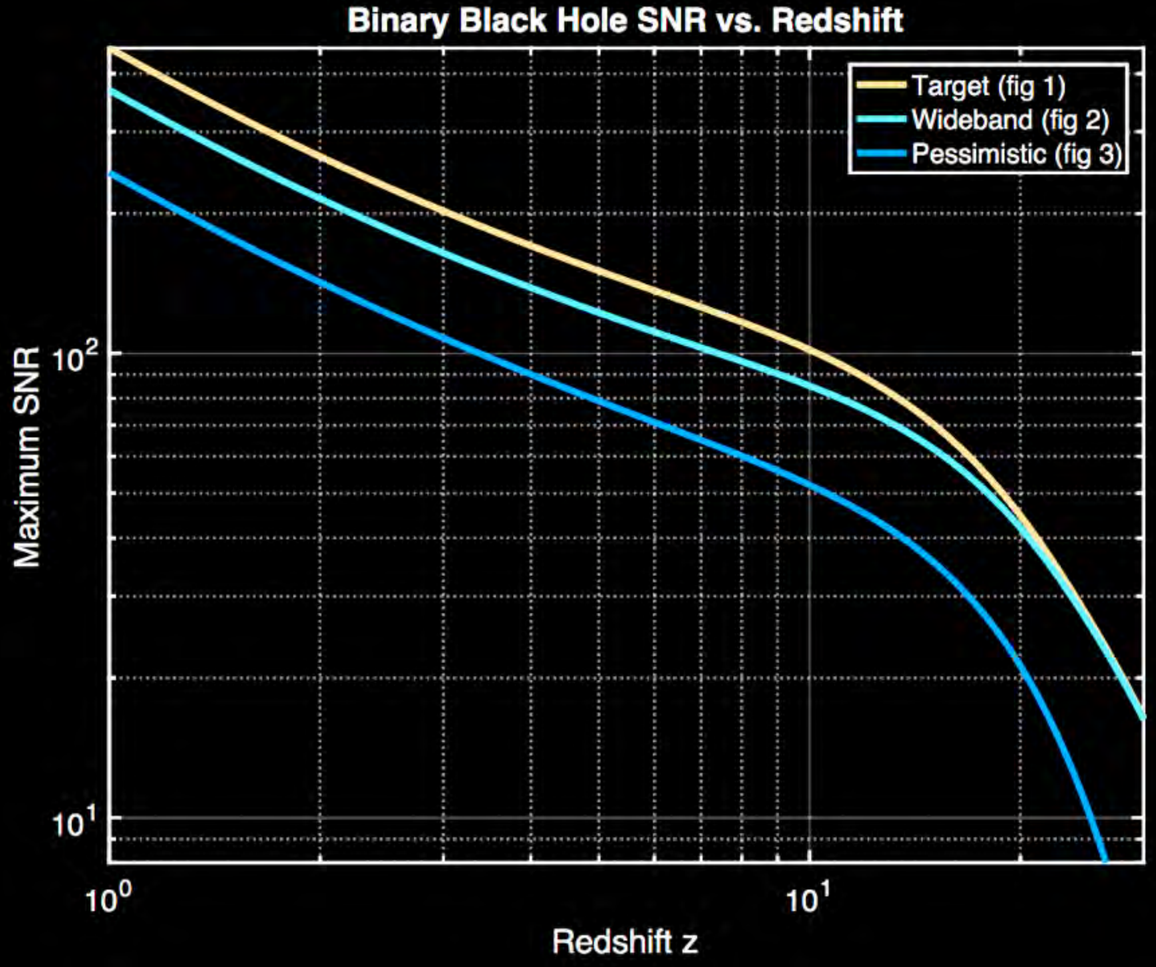
Miller et al. Phys. Rev. D 91, 062005 (2015)



Dwyer et al. Phys. Rev. D 91, 082001 (2015)

Cosmic Explorer





Abbott, ..., DAB, et al. Class. Quant. Grav. **34** 044001 (2017)