The event: Raw data and detector characterization

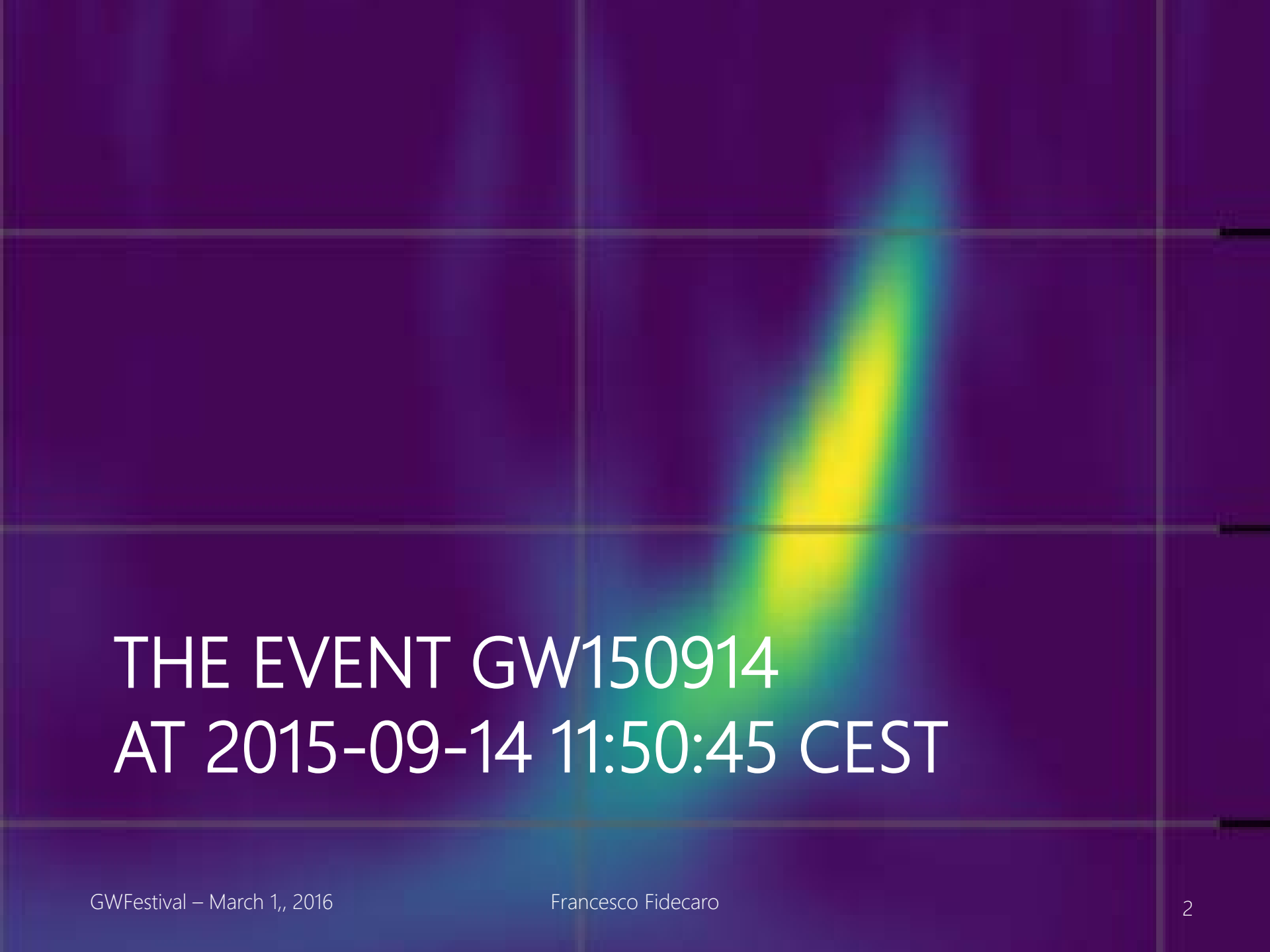
Francesco Fidecaro- Università di Pisa and *INFN Pisa*

On behalf of the LIGO Scientific Collaboration and the Virgo Collaboration

LIGO Livingston Observatory
Louisiana, USA

Virgo, Cascina, Italy

LIGO Hanford Observatory
Washington, USA



THE EVENT GW150914 AT 2015-09-14 11:50:45 CEST

September 14, 2015 – 12:56 CEST

From: Marco Drago <marco.drago@aei.mpg.de>
Sent: lunedì 14 settembre 2015 12:56
To: burst@sympa.ligo.org
Cc: cbc@ligo.org; The LIGO Data Analysis Software Working Group; Calibration; dac@sympa.ligo.org; burst@ligo.org; detchar@sympa.ligo.org; losc-devel@ligo.org; lsc-all@ligo.org
Subject: [dac] Very interesting event on ER8

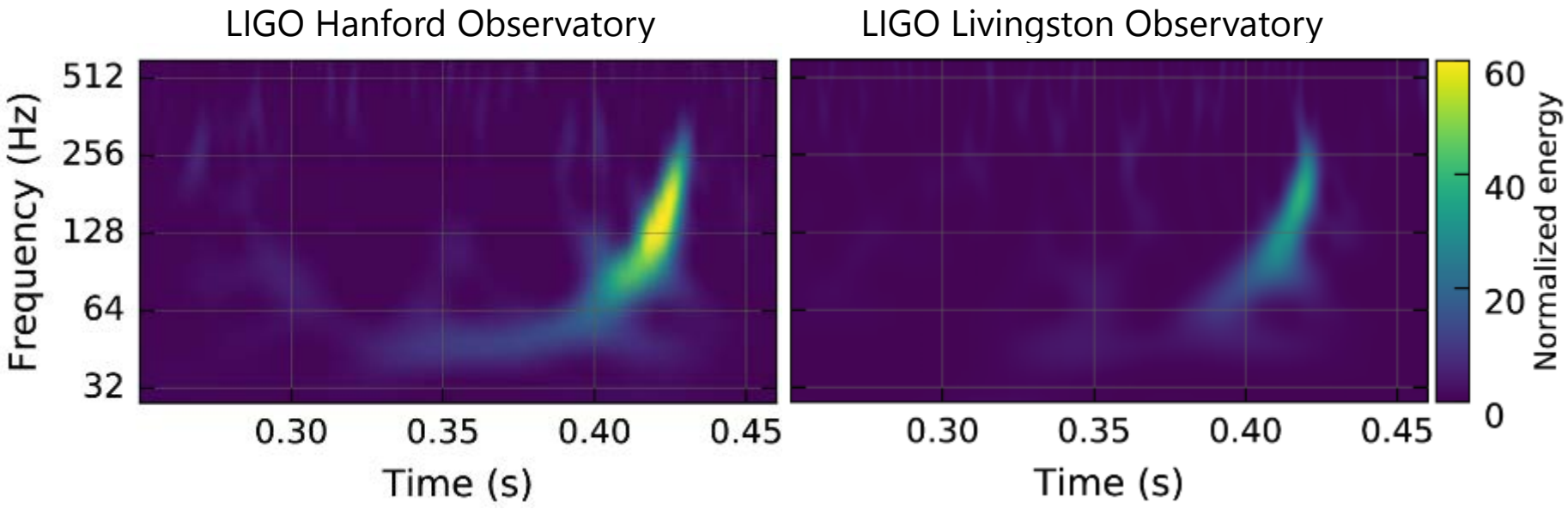
Hi all,
cWB has put on gracedb a very interesting event in the last hour.
https://gracedb.ligo.org/events/view/G184098

This is the CED:
https://ldas-jobs.ligo.caltech.edu/~waveburst/online/ER8_LH_ONLINE/JOBS/112625/1126259540-1126259600/OUTPUT_CED/ced_1126259420_180_1126259540-1126259600_slag0_lag0_1_job1/L1H1_1126259461.750_1126259461.750/

Qscan made by Andy:
https://ldas-jobs.ligo.caltech.edu/~lundgren/wdq/L1_1126259462.3910/
https://ldas-jobs.ligo.caltech.edu/~lundgren/wdq/H1_1126259462.3910/It is not flag as an hardware injection, as we understand after some fast investigation. Someone can confirm that is not an hardware injection?

Marco

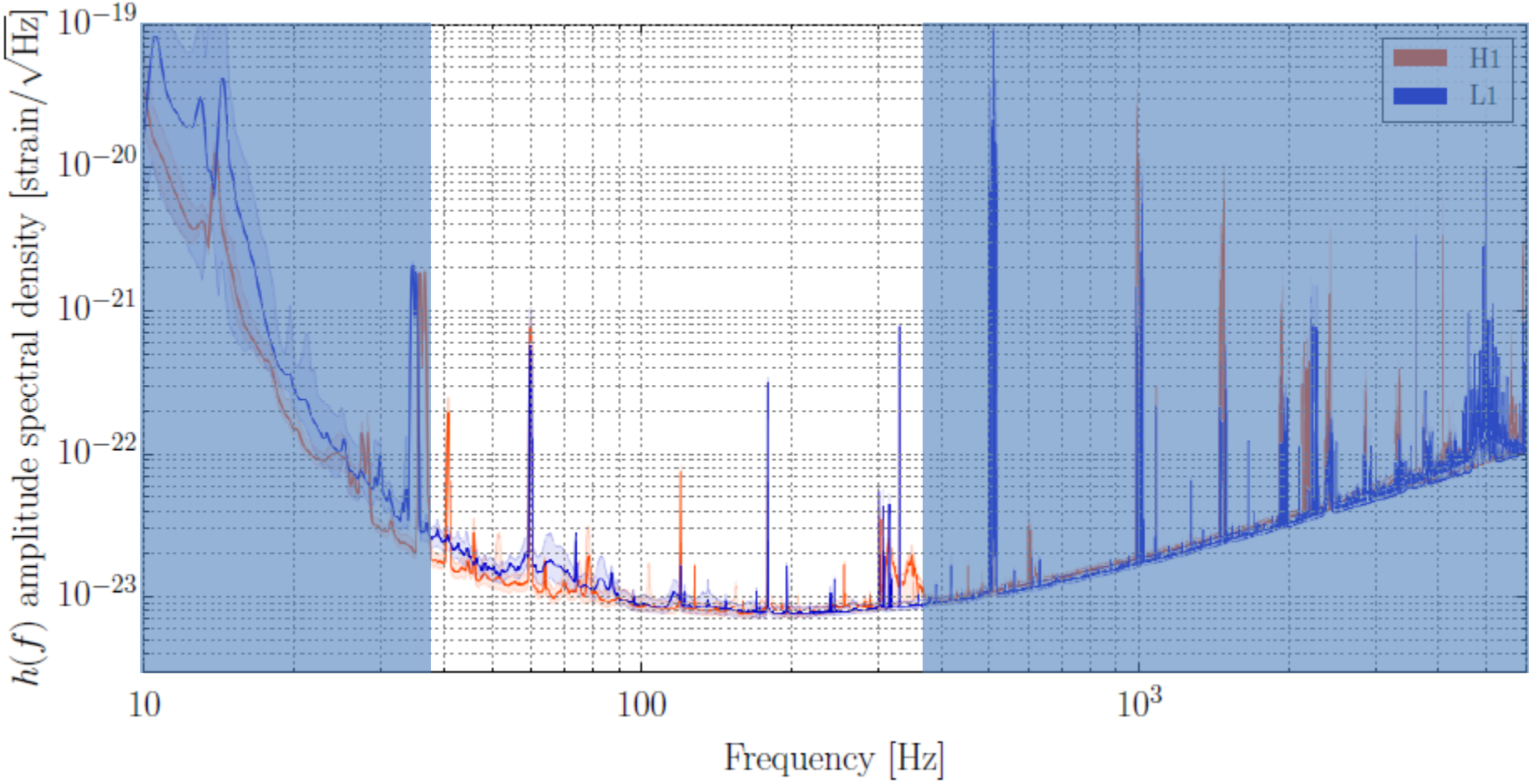
September 14, 2015 – 11:50:45 CEST



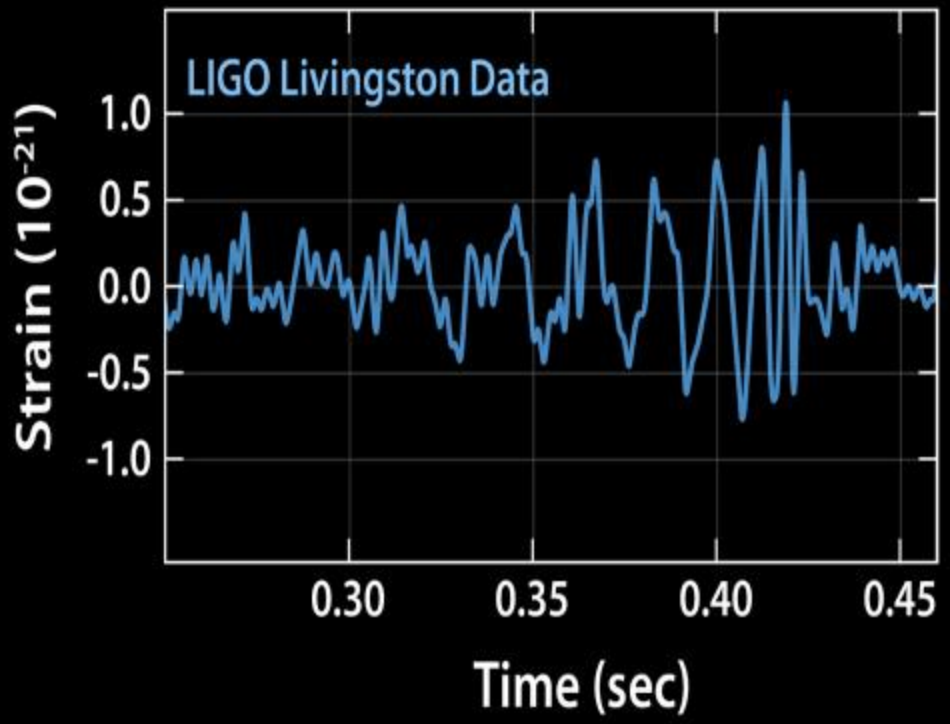
Initial detection made by a low latency searches for generic GW transients: **Coherent WaveBurst**

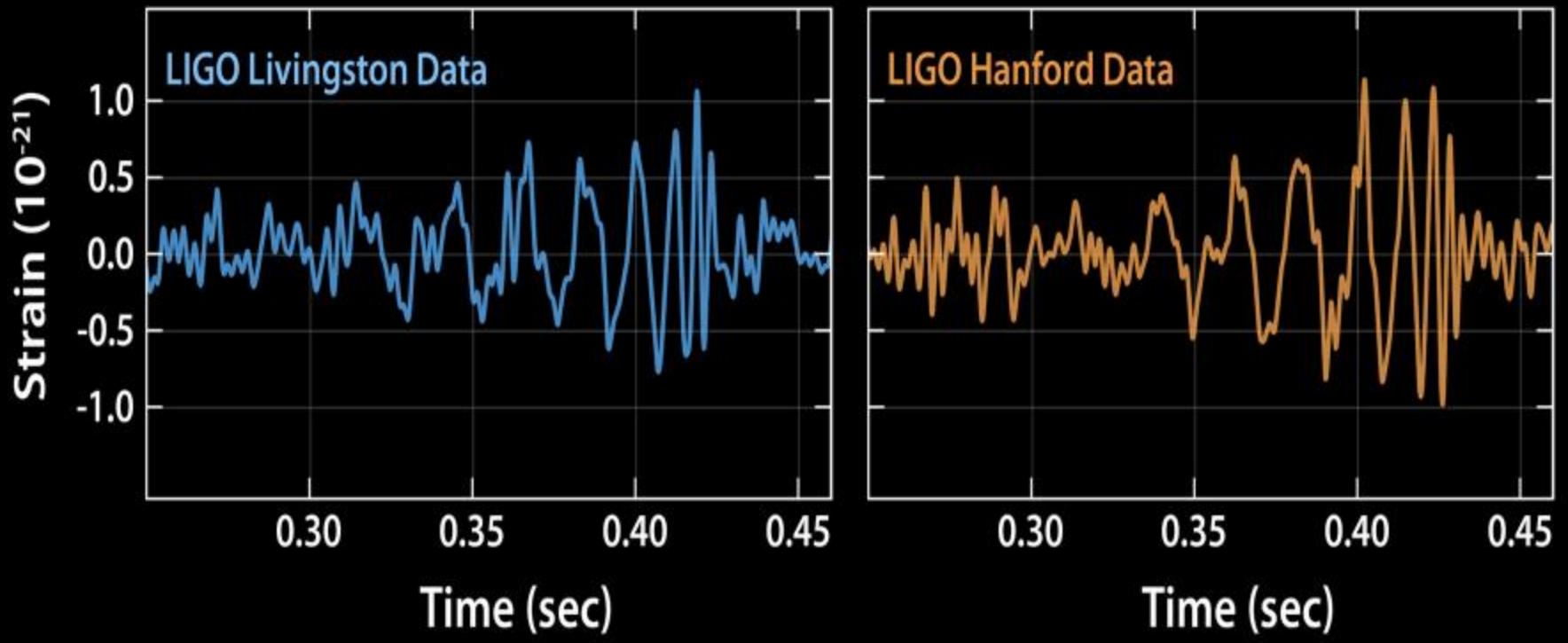
Reported within 3 minutes after data acquisition

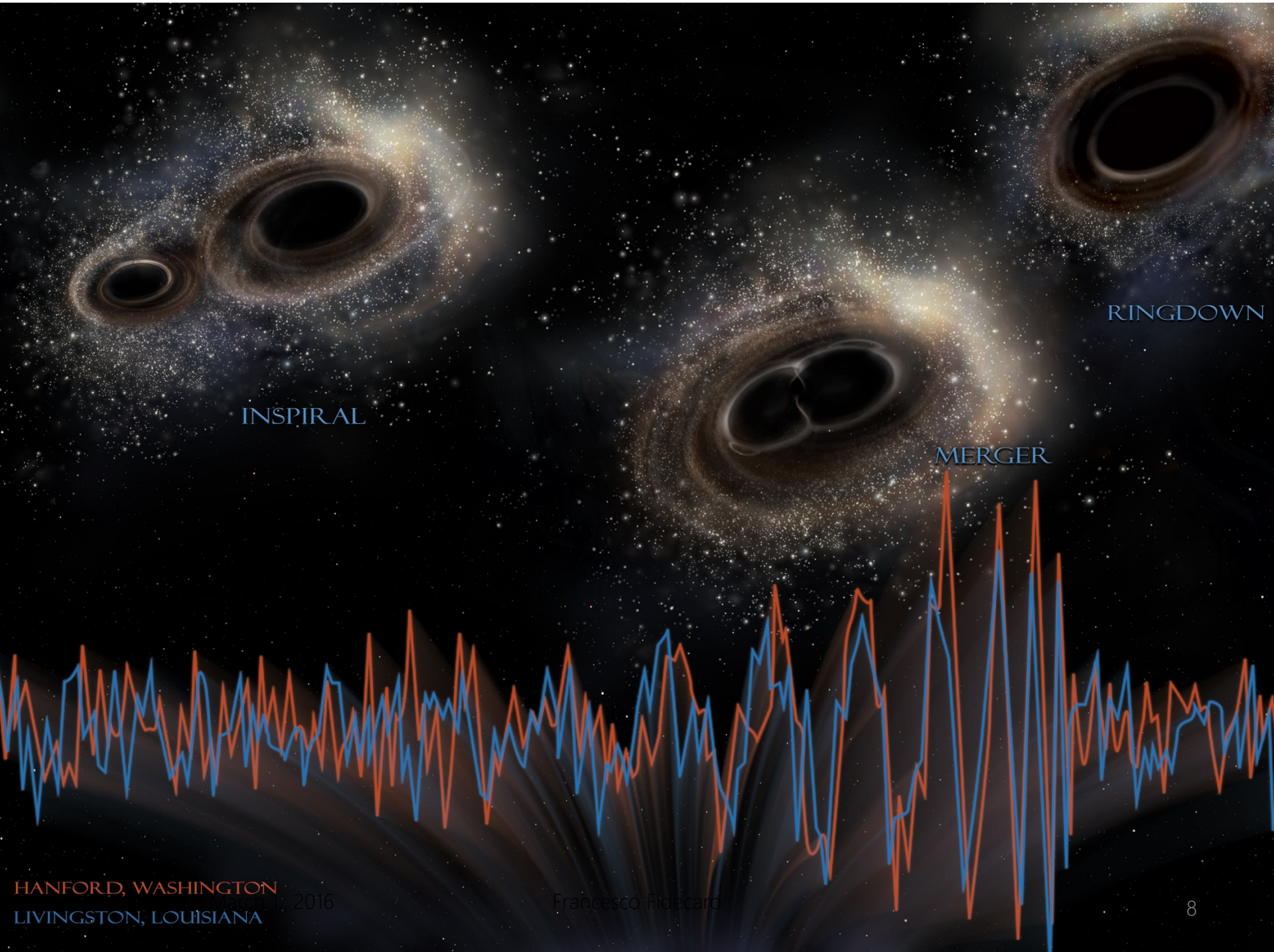
Detector noise



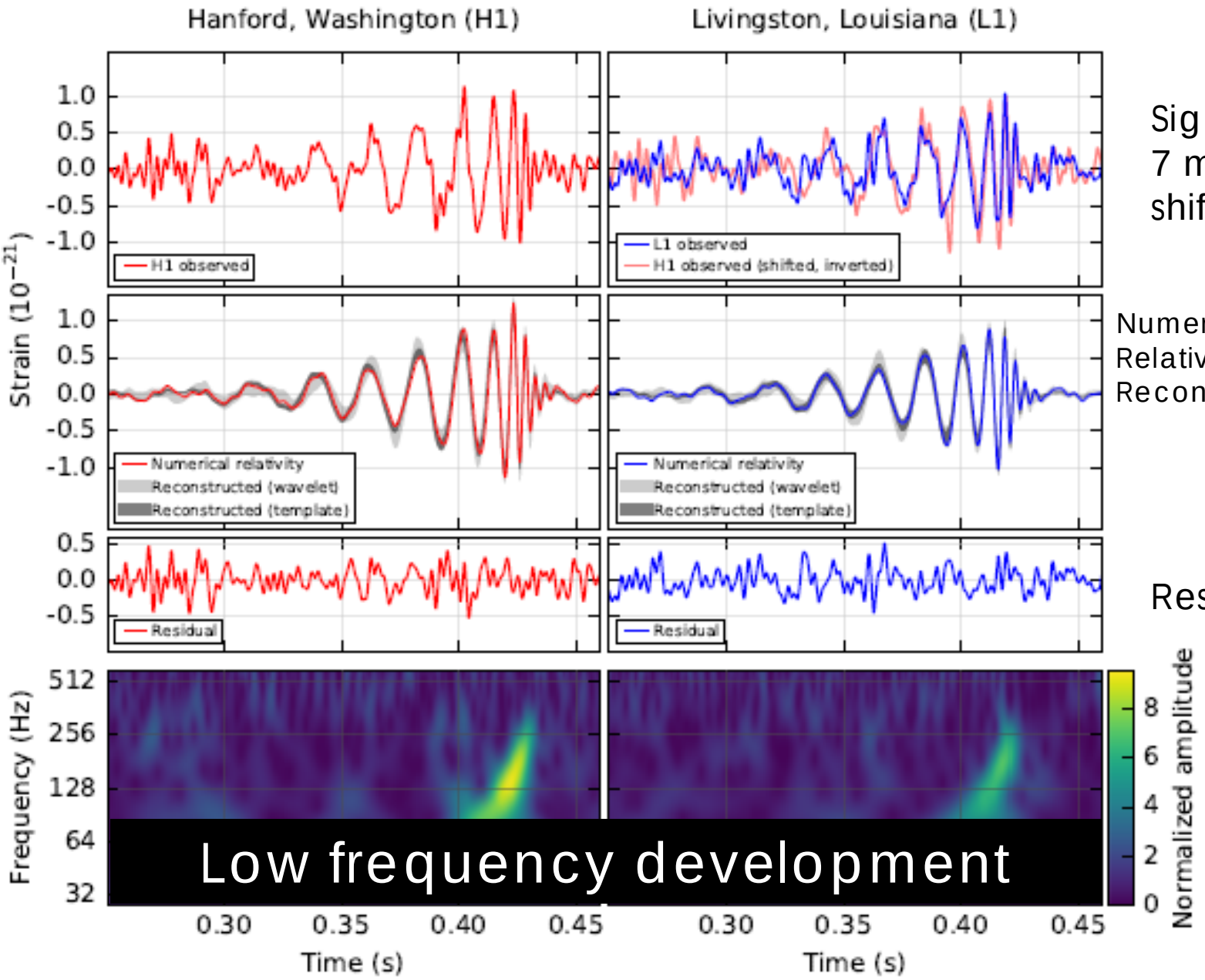
Signals are band passed 35-350 Hz and band stopped for instrumental spectral lines


LIGO Livingston Data
Strain (10^{-21})
1.0
0.5
0.0
-0.5
-1.0
0.30
0.35
0.40
0.45
Time (sec)


LIGO Livingston Data
LIGO Hanford Data
Strain (10-21)
1.0
0.5
0.0
-0.5
-1.0
0.30
0.35
0.40
0.45
Time (sec)
0.30
0.35
0.40
0.45
Time (sec)


INSPIRAL
MERGER
RINGDOWN
HANFORD, WASHINGTON
LIVINGSTON, LOUISIANA

Signals, residuals, time frequency plots



Signals 7 ms shift

Numerical Relativity Reconstruction

Residuals

Potential noise sources

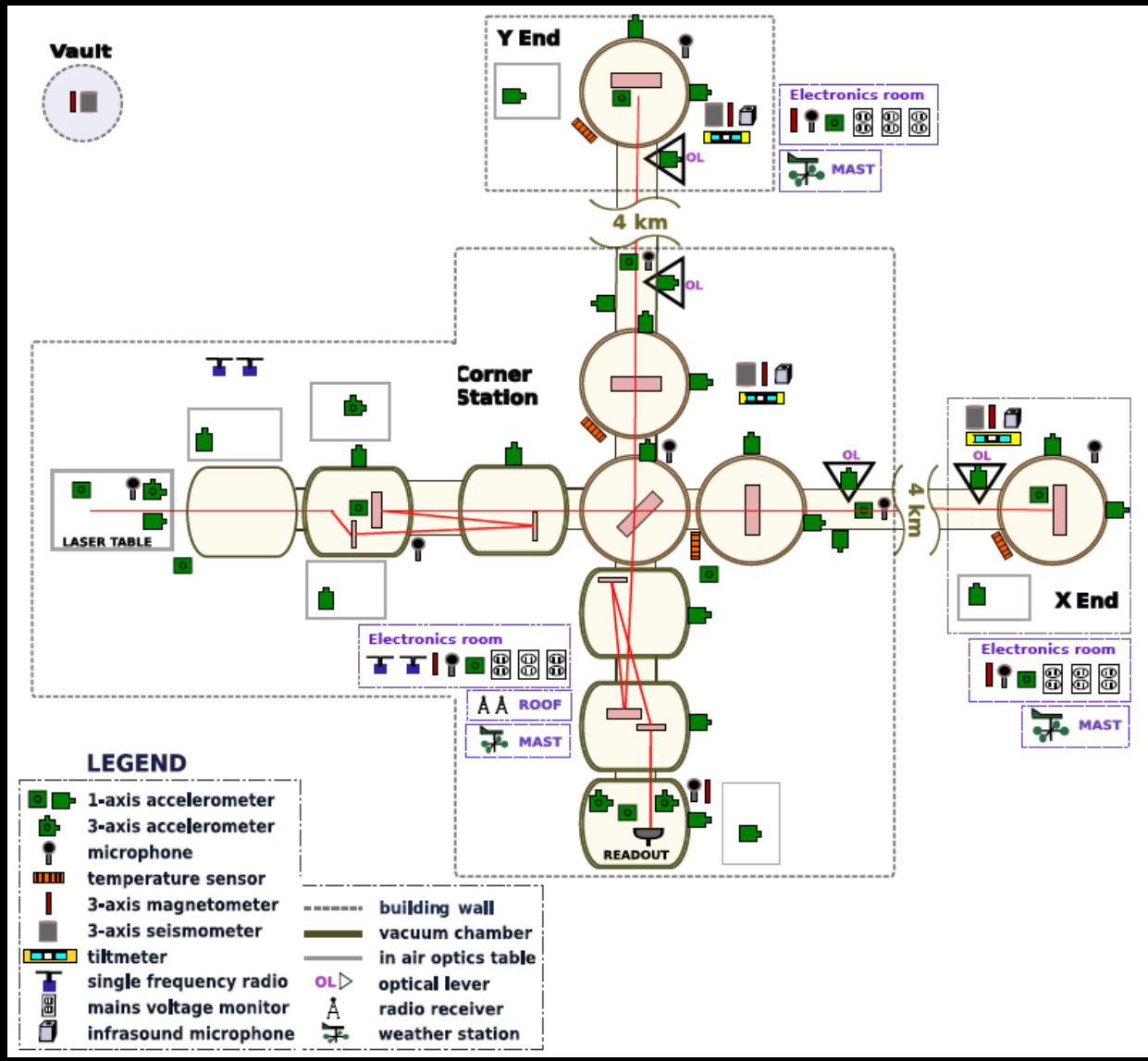
- In the same frequency band of expected astrophysical signals one will have stationary and transient noise
- The level of stationary noise is the result of the detector design and is constantly measured by maintaining a correct working point. It is represented by the sensitivity curve
- Transient noise can be identified by using auxiliary channels
- 2×10^5 auxiliary channels are monitored to identify sources that can couple to the dark fringe signal

Uncorrelated sources

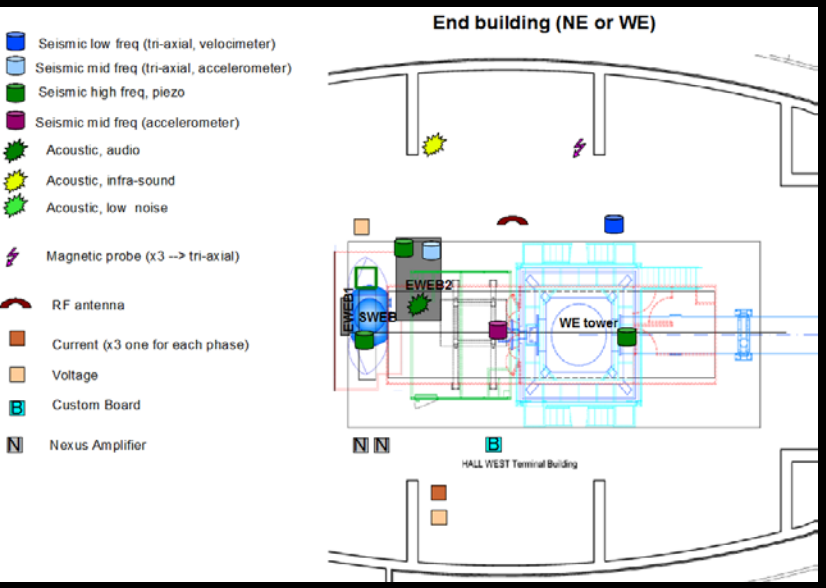
- Anthropogenic displacement noise: Accelerometers, Seismometers, Microphones
- Earthquakes with frequency 0.03 – 0.1 or higher, can upconvert into the instrument: Seismometers, Ground tiltmeter
- Magnetic noise: Magnetometers
- EM noise in radio frequency sidebands used to sense optical resonant cavities: EM antennas, amplitude and phase monitoring in circuits
- Blip signals entering in sensing and control loops: waveform consistency checks

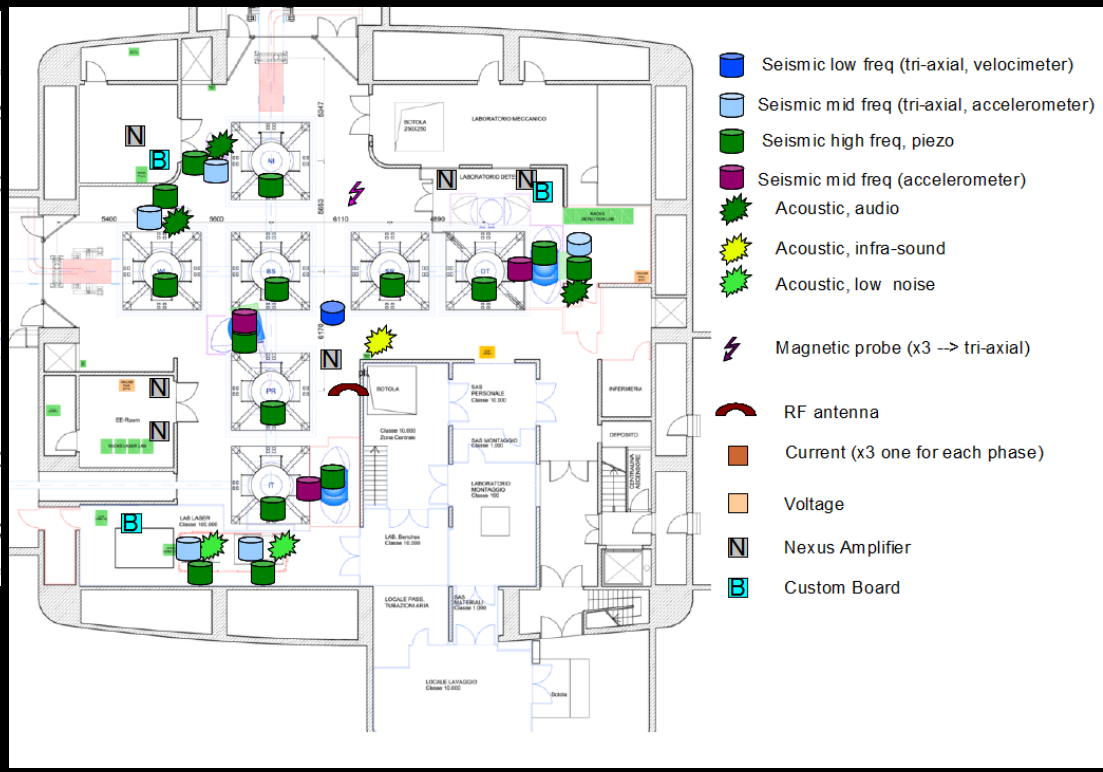
LIGO Environmental sensors

- Seismic / Vibrations
- Ground tilt
- Acoustic
- Infrasound
- Magnetic
- Radio EM
- Mains
- Weather
- Lightning
- Temperature



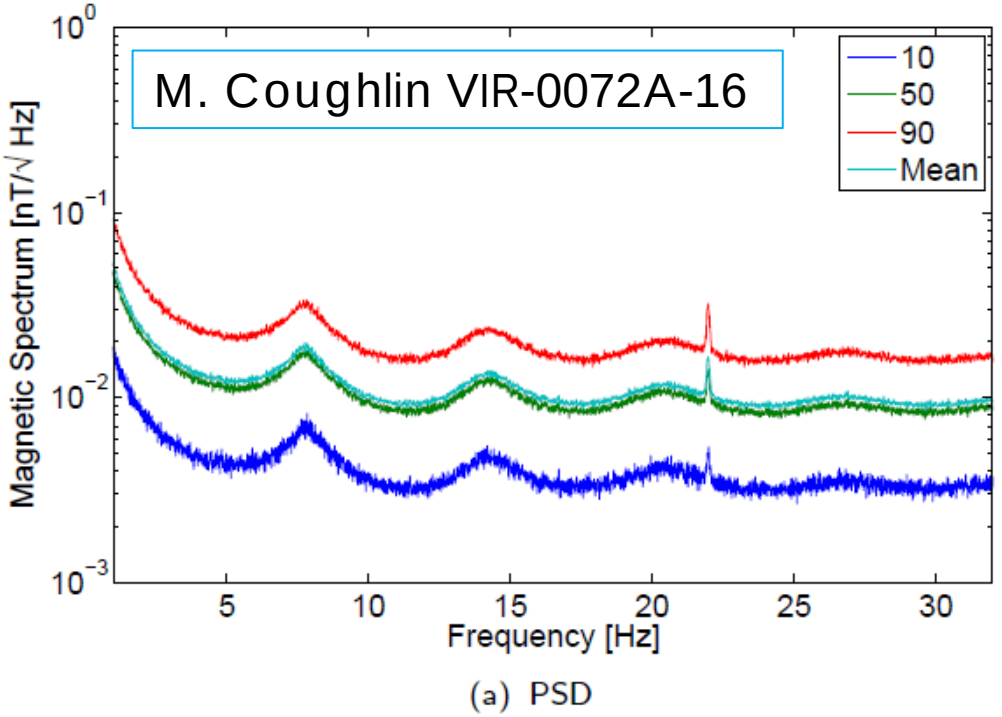
Virgo Environmental sensors





Correlated sources

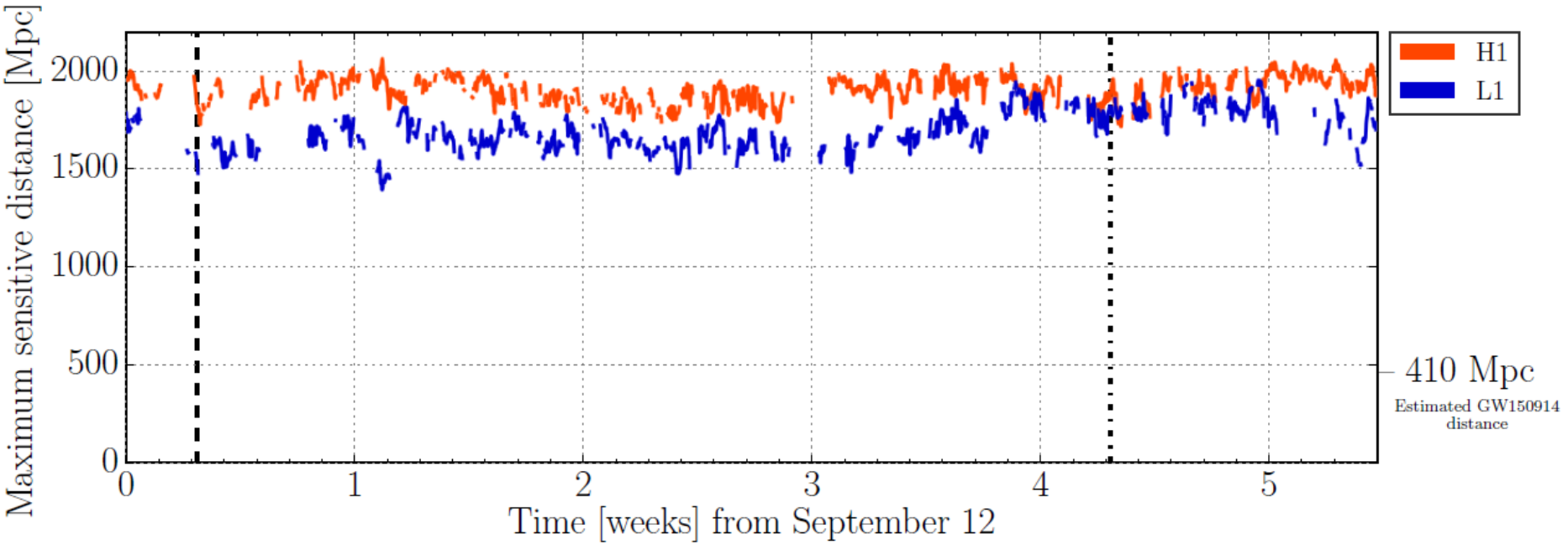
- Global (correlated) noise: Electromagnetic field sources:
  - Lightnings and Schumann resonance excitation
  - Solar events
  - Solar wind
  - RF communications
- Monitored by antenna
- Cosmic ray showers: e vibrational modes, wel decay



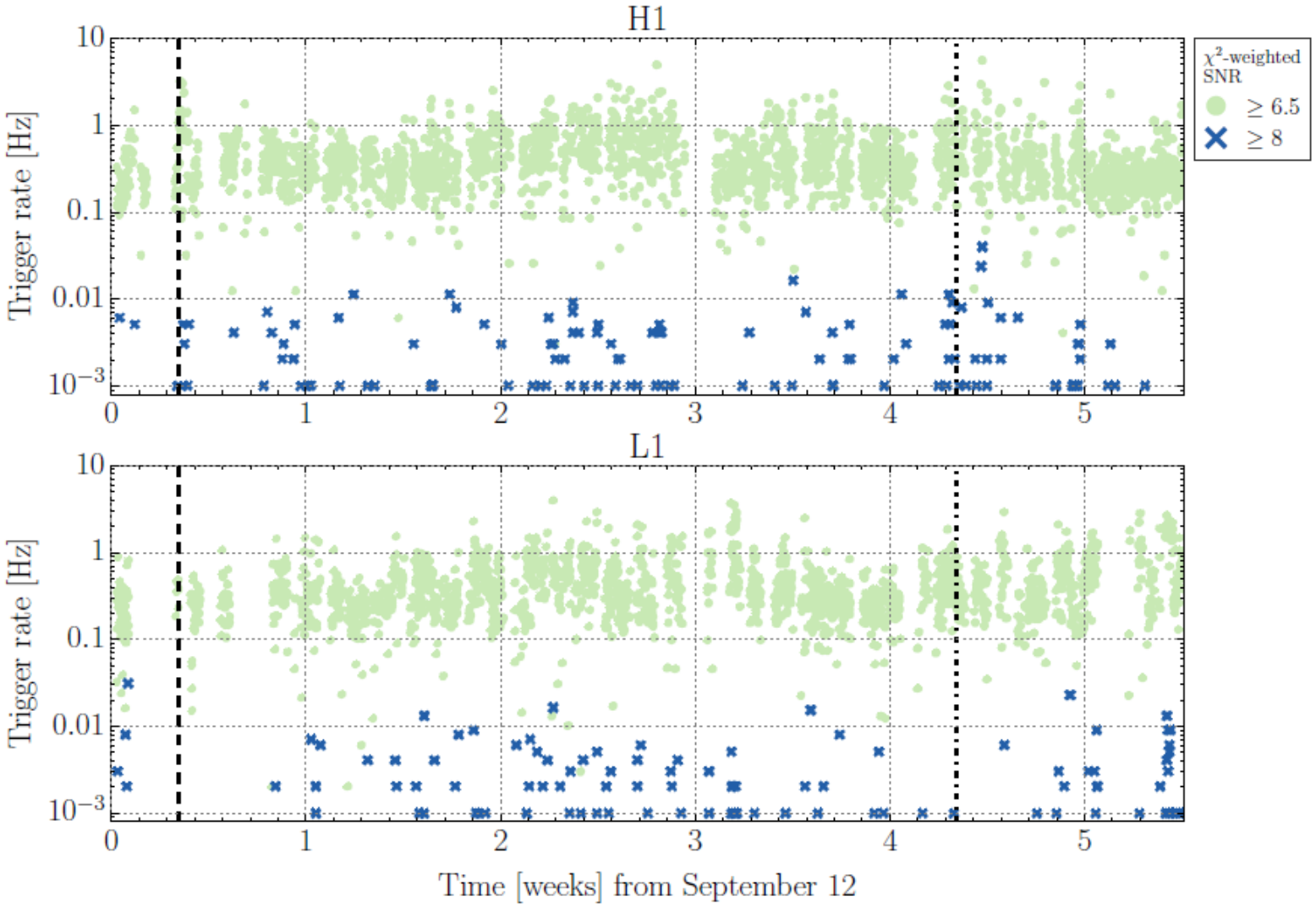
(a) PSD

Horizon stability for GW150914 likes

- Optimal source and detector orientation
- SNR 8

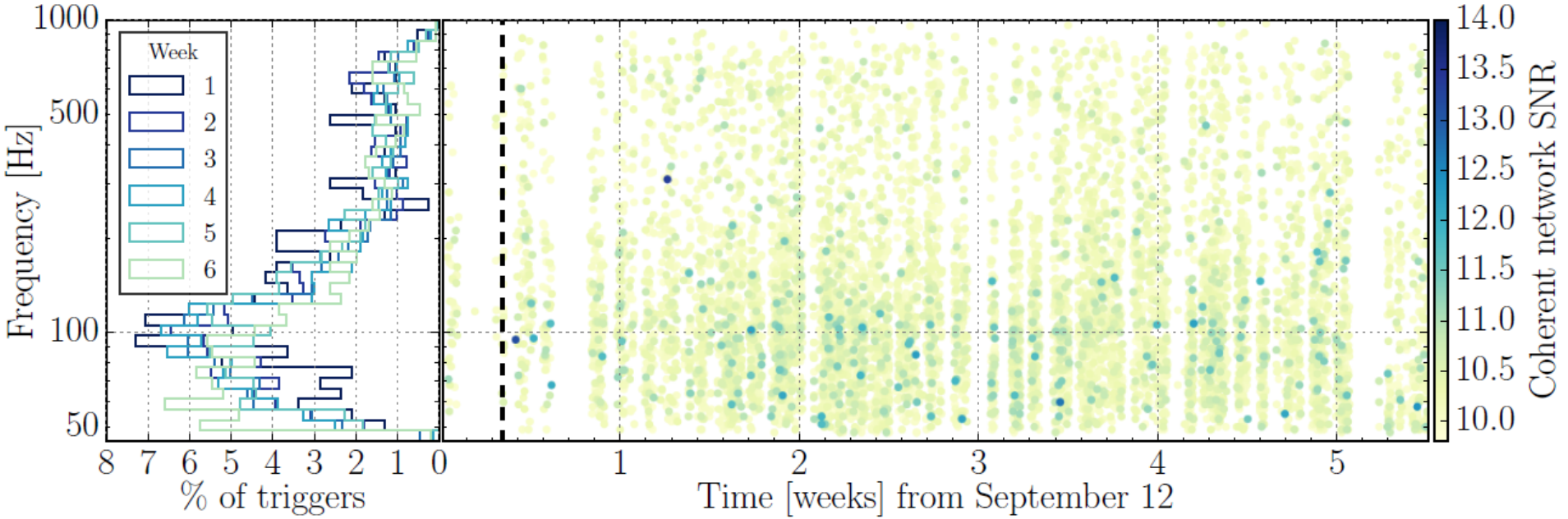


Single interferometer rate



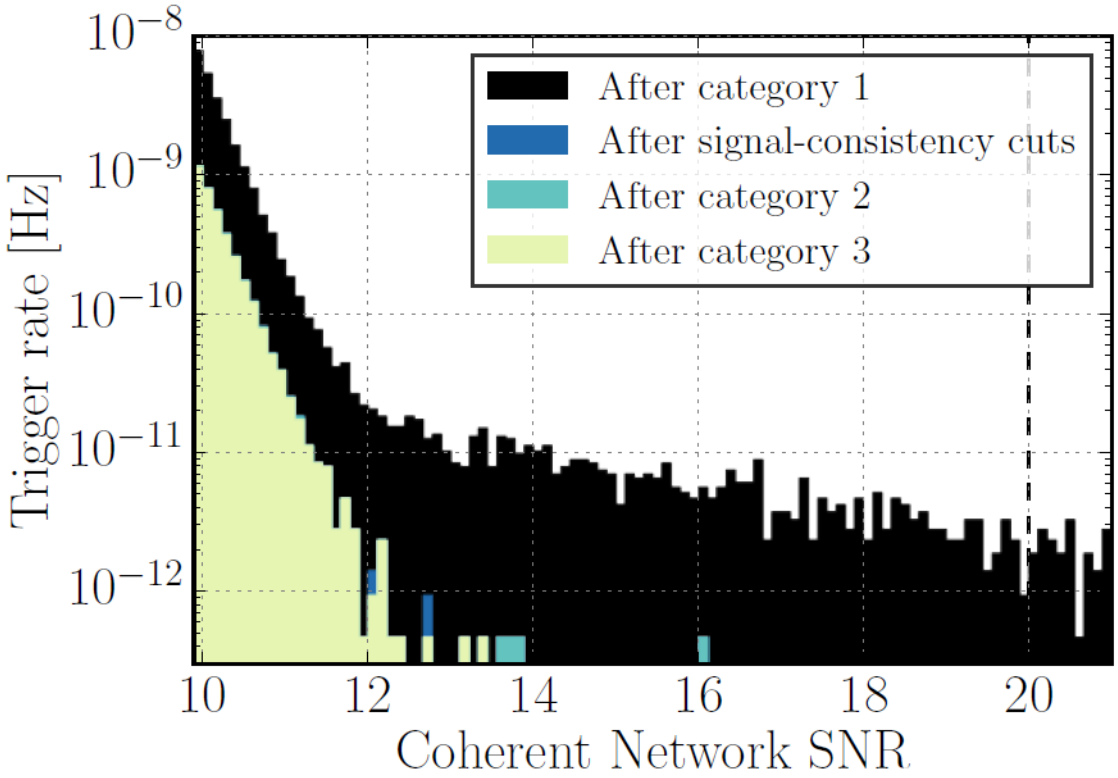
cWB Background triggers

- Coherent (2 interferometer) triggers



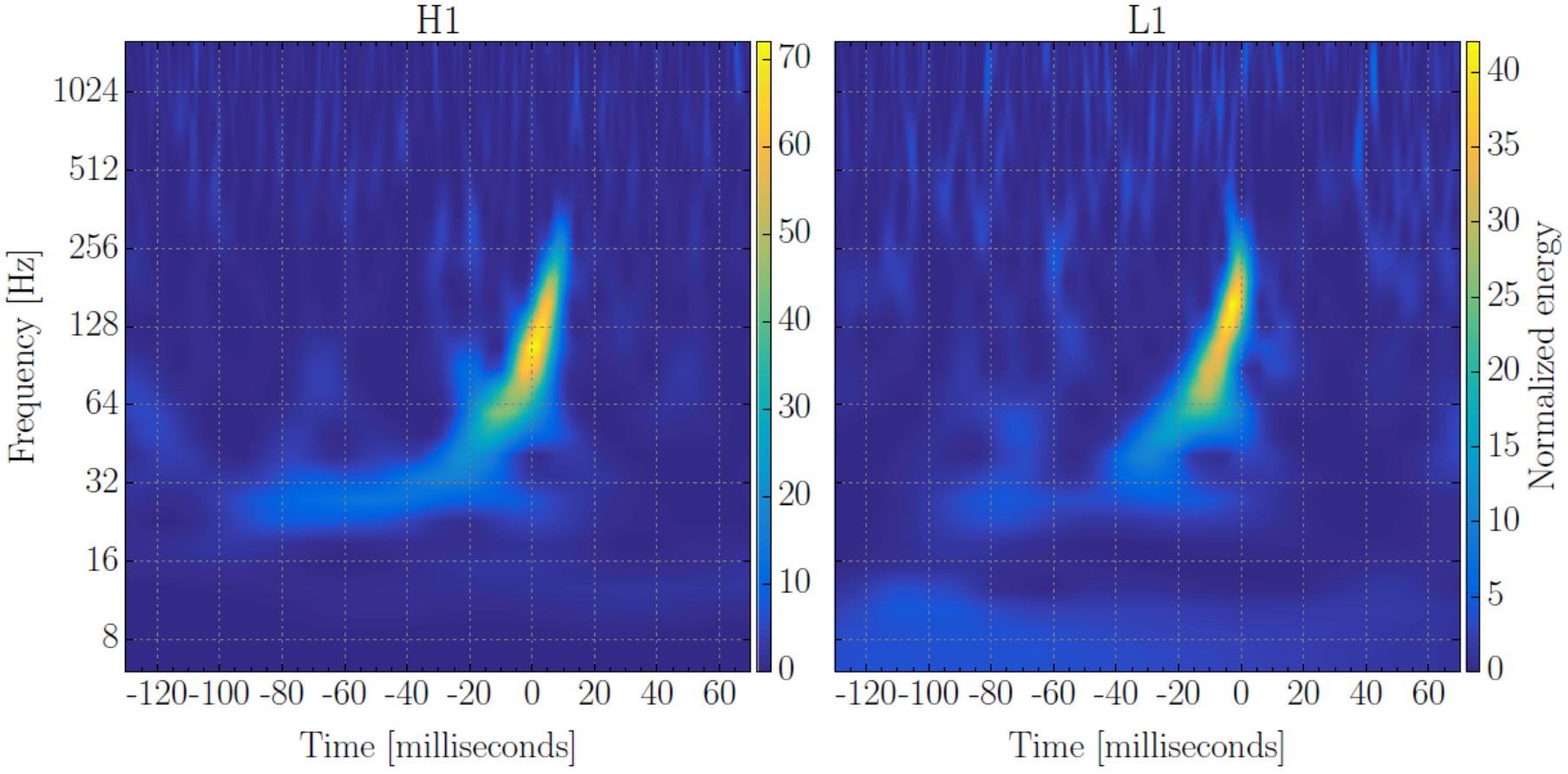
Data quality flags

- Based on the identification of reproducible instrumental problems (glitchy electronics,…)
- Must be safe (low probability to veto good events)



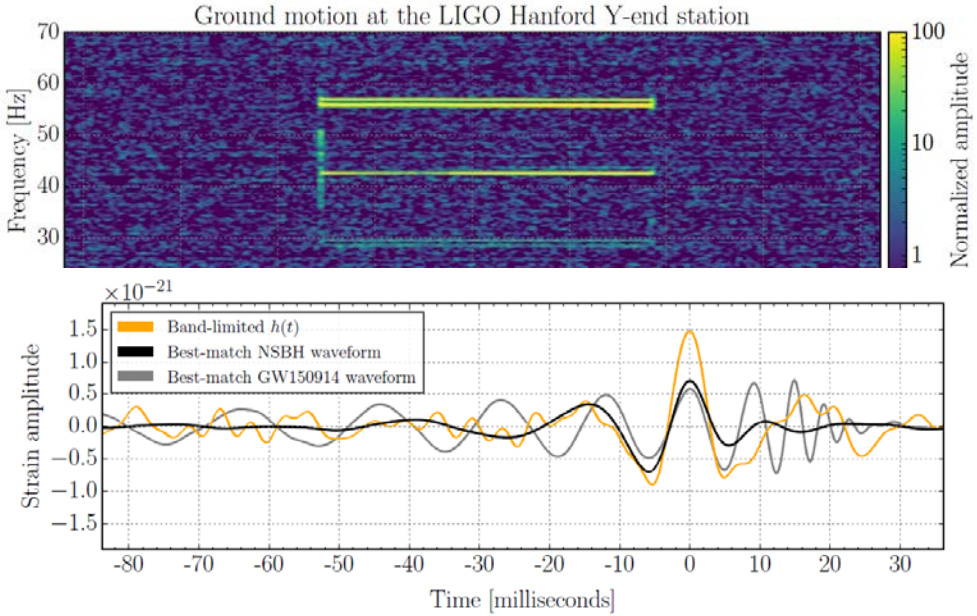
Transient noise around GW150914

- Immediately around the event data are clean and stationary



Additional checks

- Coincident sources of interference were found to produce negligible noise
- Activity of personnel on site was monitored
- Hardware injection signals were scrutinized
- No data quality vetoes were active
- Data calibration was also checked
- Eg:USGS reported 2 2.1 magnitude earthquakes within 20 minutes of GW150914:10 nm/s ground motion is too small to produce an impact
- Air compressor at Hanford active
- Occurences of blip transients in Li
- Collaboration generated check list
- Detection committee
- 4 step detection procedure ended



Detection procedure

	Step 1 (2 weeks)	Step 2 (4 weeks)	Step 3 (4 weeks)	Step 4 (3 weeks)
Search Group	**Notice, notify, launch studies of significance, PE**	**Organize info for paper; continue signif./PE studies**	On call	swer questions
DetChar + Instrumentalists	**Evaluate DQ and instrument state**	**Present DQ / instrument to DC**	call	Answer questions
Reviewers	**Review search procedure**	**Review search result**		Answer questions
Paper Coordinating Team		**Assemble ca sentati to DC; rdinate writing of per**	**Present Detection Claim, paper to DC**	Present to Collaborations
Detection Committee	ok i n DQ	**Review DQ**	**Review Detection Claim**	Present to Collaborations
EM follow-up	for **counterpart**	**Interpret observations**	On call	Answer questions
DAC	Facilitate communication	**Convene presentations, collect questions**	**Convene presentations, collect questions**	Prepare Collaborations meetings
Collaborations	Ask questions	Ask questions	Ask questions	**Make judgment**
Spokespersons	**Keep process moving**	**Appt. Paper Coordinating Team**	**Keep process moving**	**Plan publication, publicity**

DONE!

Conclusions

- After years of work LVC were prepared to detect faint signals from remote corners of the Universe
- The first signal was large, the task became easier
- We have detected gravitational waves!