Status of LIGO's 5th science run

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2006 October 31

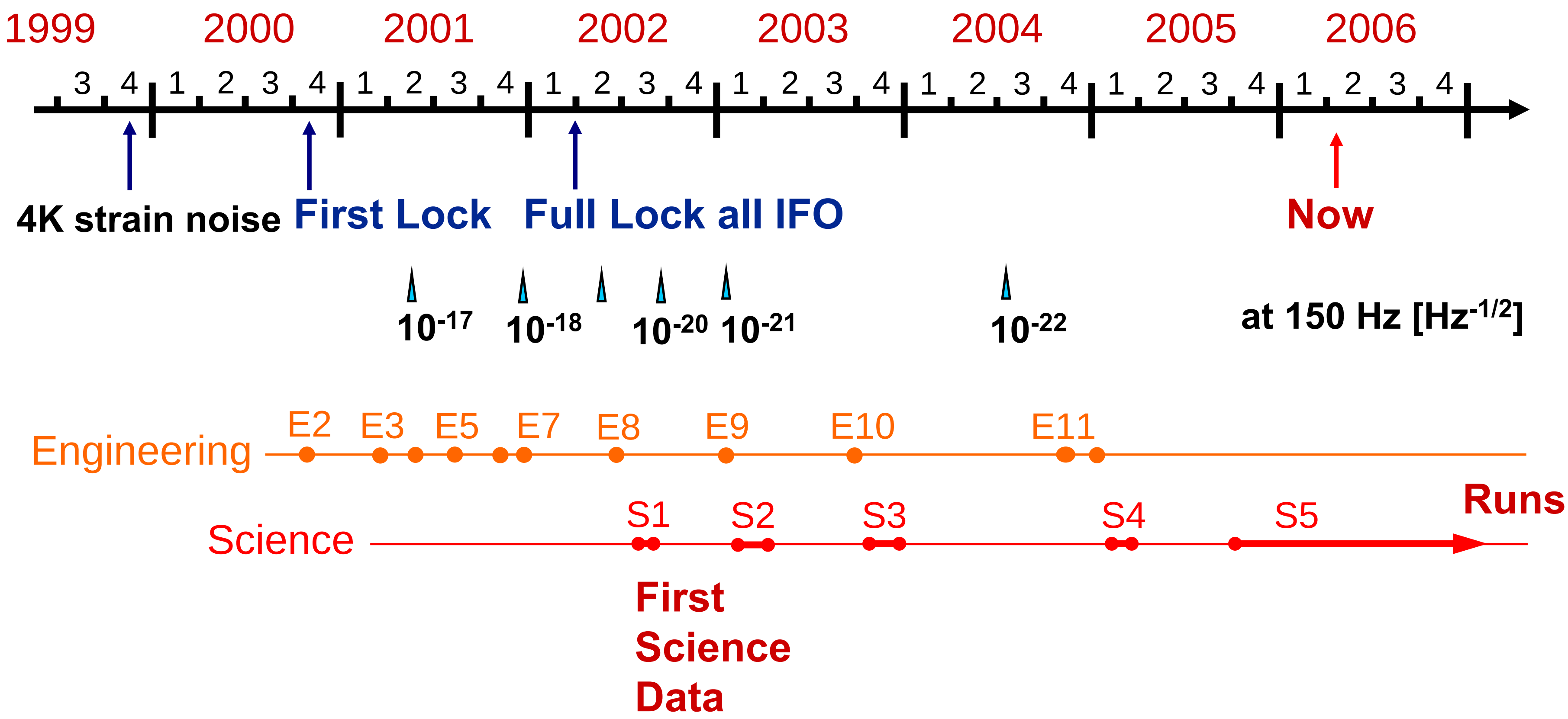
LIGO-G060545-00-Z

LIGO

- LIGO aims to observe gravitational waves from objects such as the coalescence of binary compact objects, core collapse supernovae, gamma ray bursts, spinning neutron stars, and an astrophysical or cosmological stochastic background.
- LIGO consists of three interferometric gravitational-wave observatories at two sites:
  - Hanford, Washington (LHO)
  - Livingston, Louisiana (LLO)

LIGO Time line

- Starting in August of 2002, LIGO initiated periods of science runs separated by periods of commissioning work.

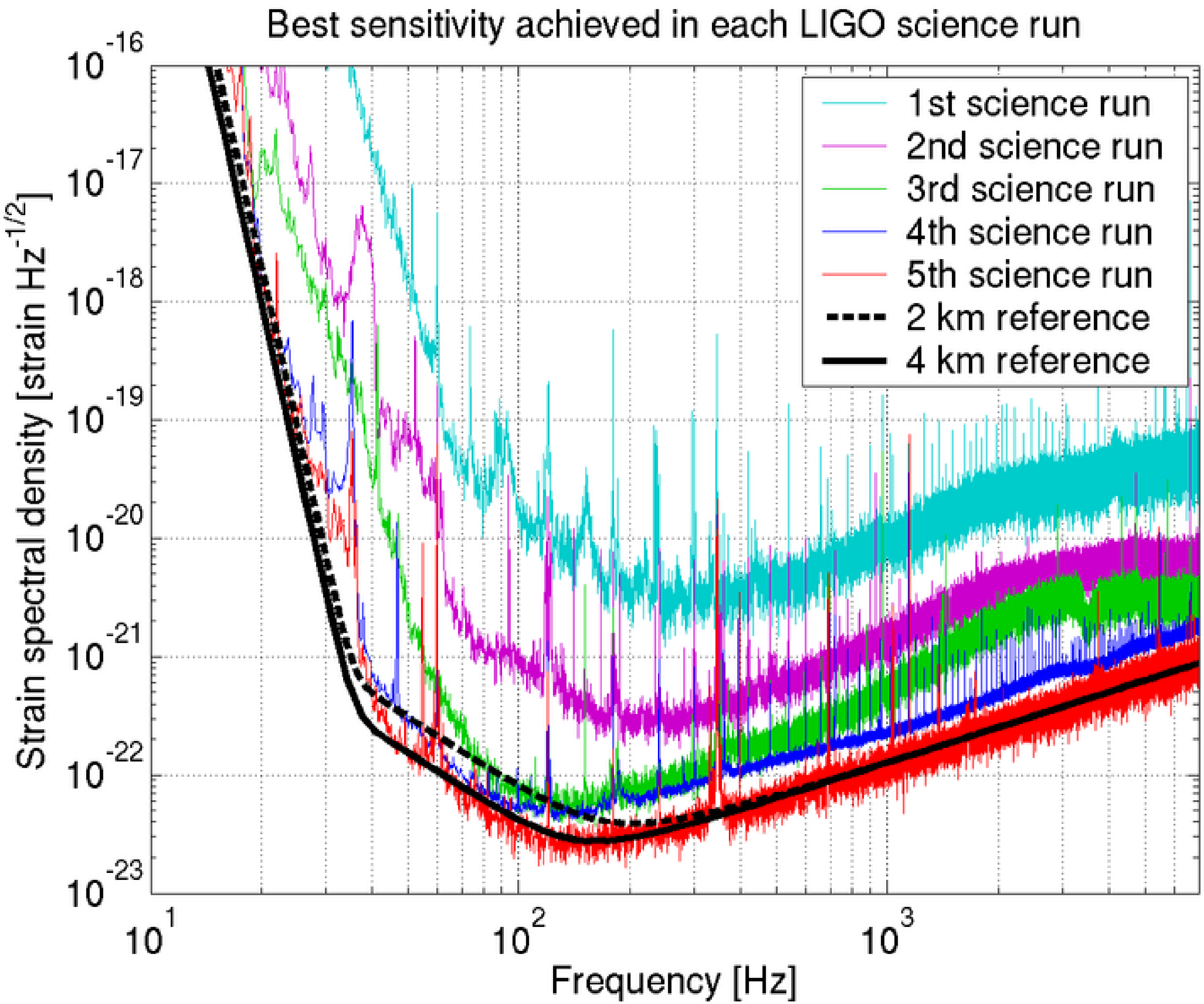


LIGO Science runs

- Starting in August of 2002, LIGO initiated periods of science runs separated by periods of commissioning work.

Sience run	Start date	Stop date	Real time
1	2002 Aug 23	2002 Sep 9	17 days
2	2003 Feb 14	2003 Apr 14	59 days
3	2003 Oct 31	2004 Jan 9	70 days
4	2005 Feb 22	2005 Mar 23	30 days

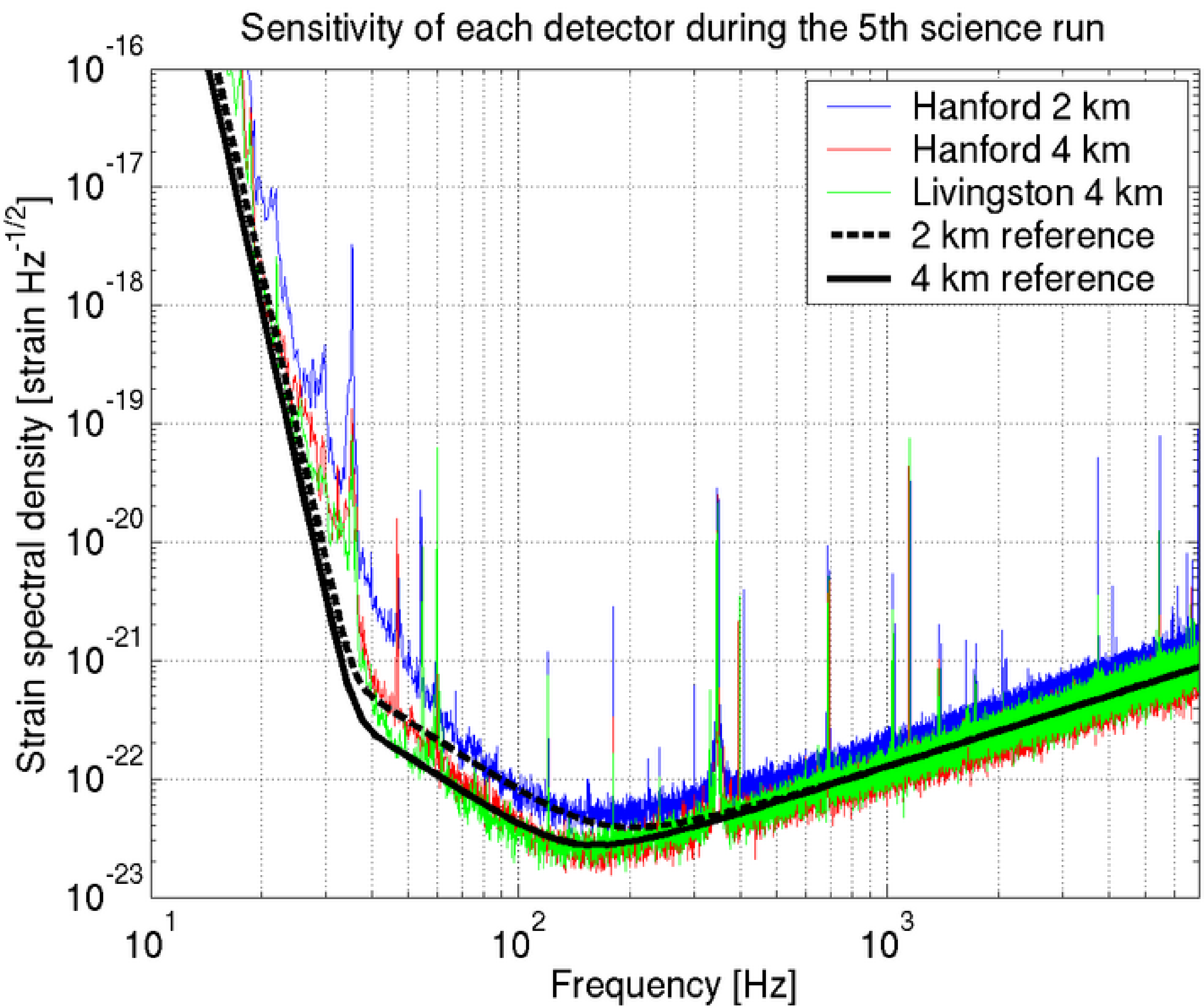
Science run sensitivities



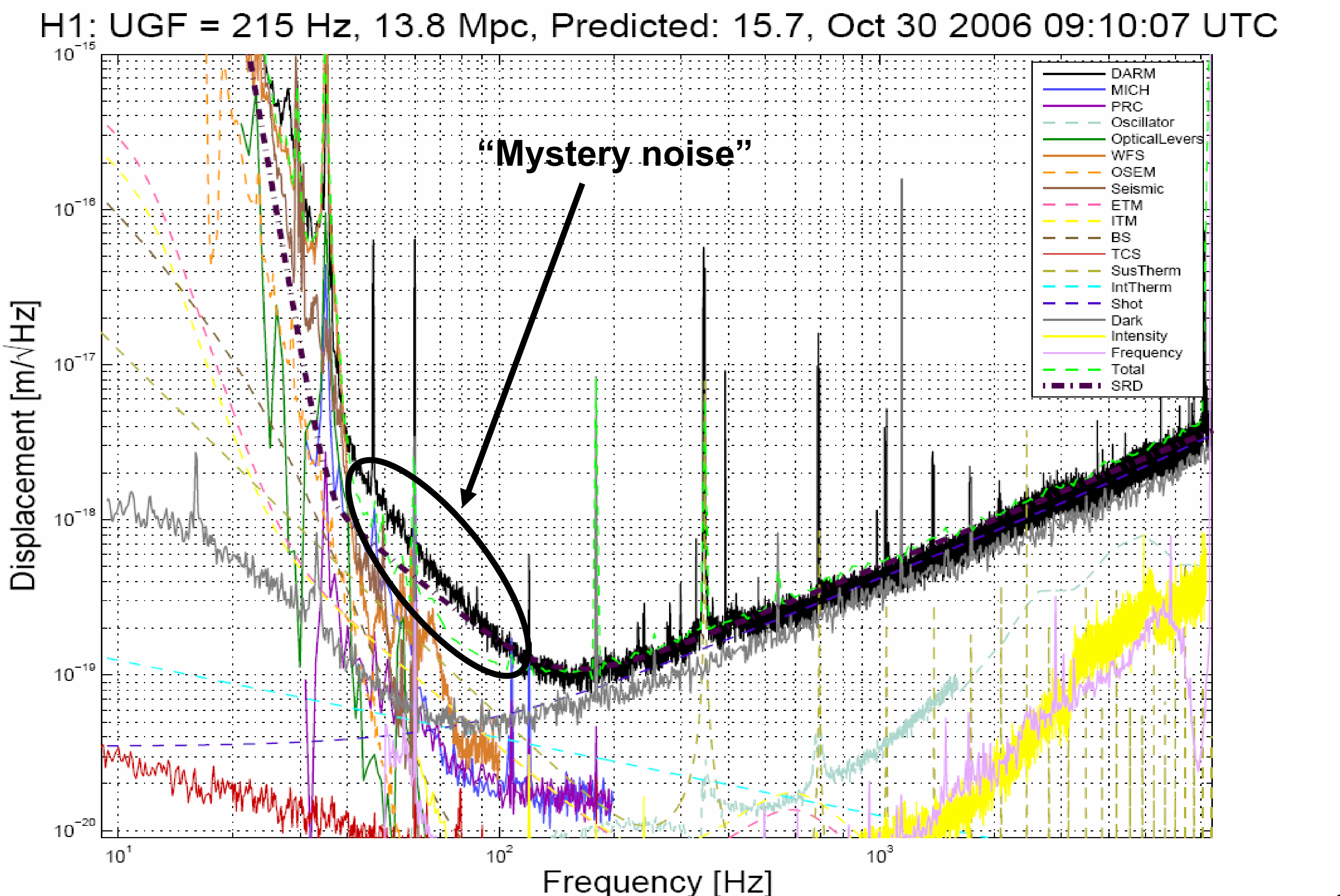
5^{th} Science run

- In the fall of last year, LIGO reached its agreed upon design sensitivity of 10^{-21} RMS strain in a 100 Hz band
- In November 2006, LIGO began its 5^{th} science run (S5)
- The goal is to accumulate one year of coincident science mode data at or above design sensitivity.
- Hanford started on 2006 November 4 at 8:00 PST
- Livingston joined on 2006 November 14 at 12:00 CST
- Expect to last between 1.5 and 2 years
- Schedule permits minor interruptions for maintenance and improvements

Sensitivities during 5th science run

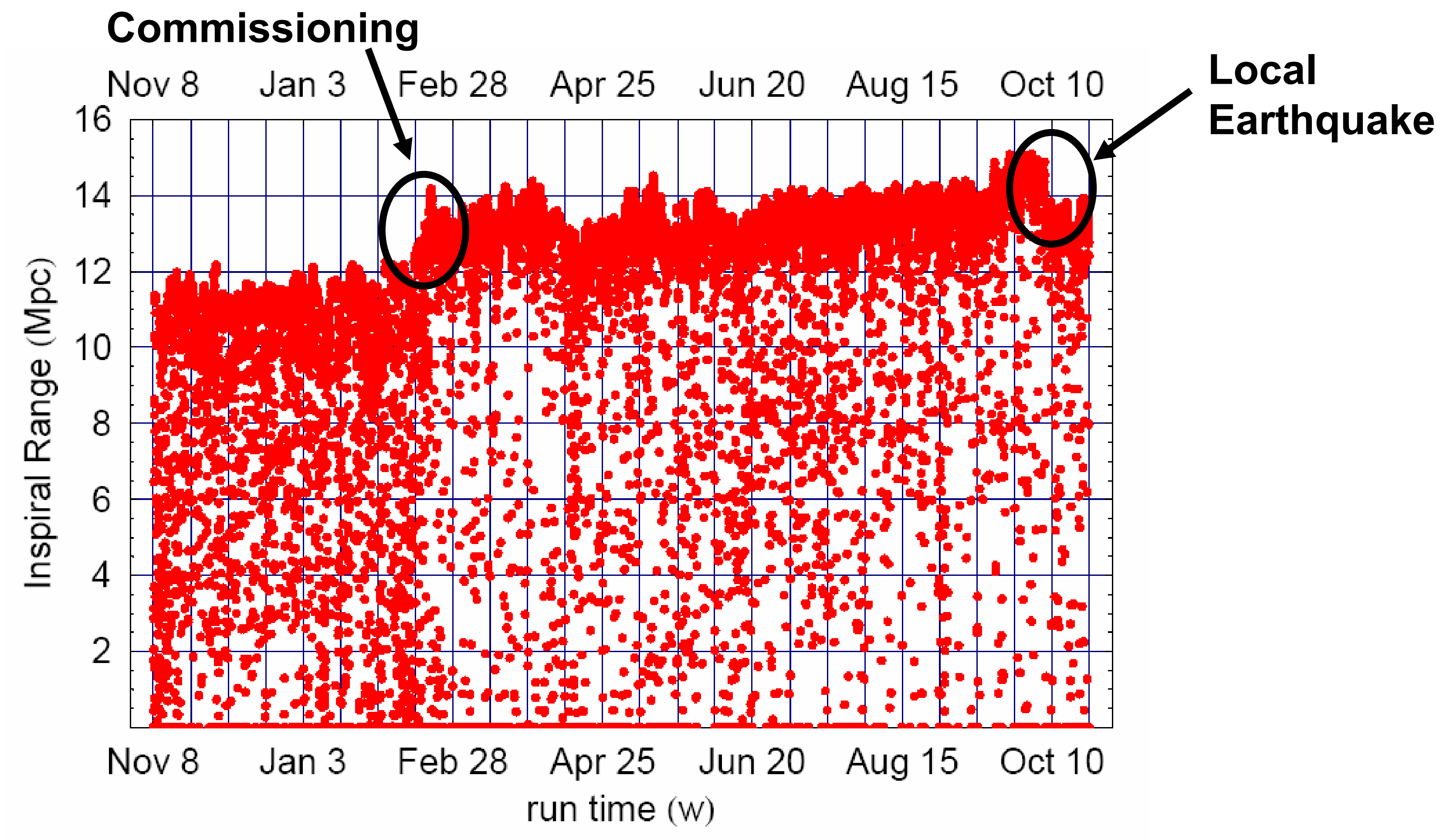


Noise budget



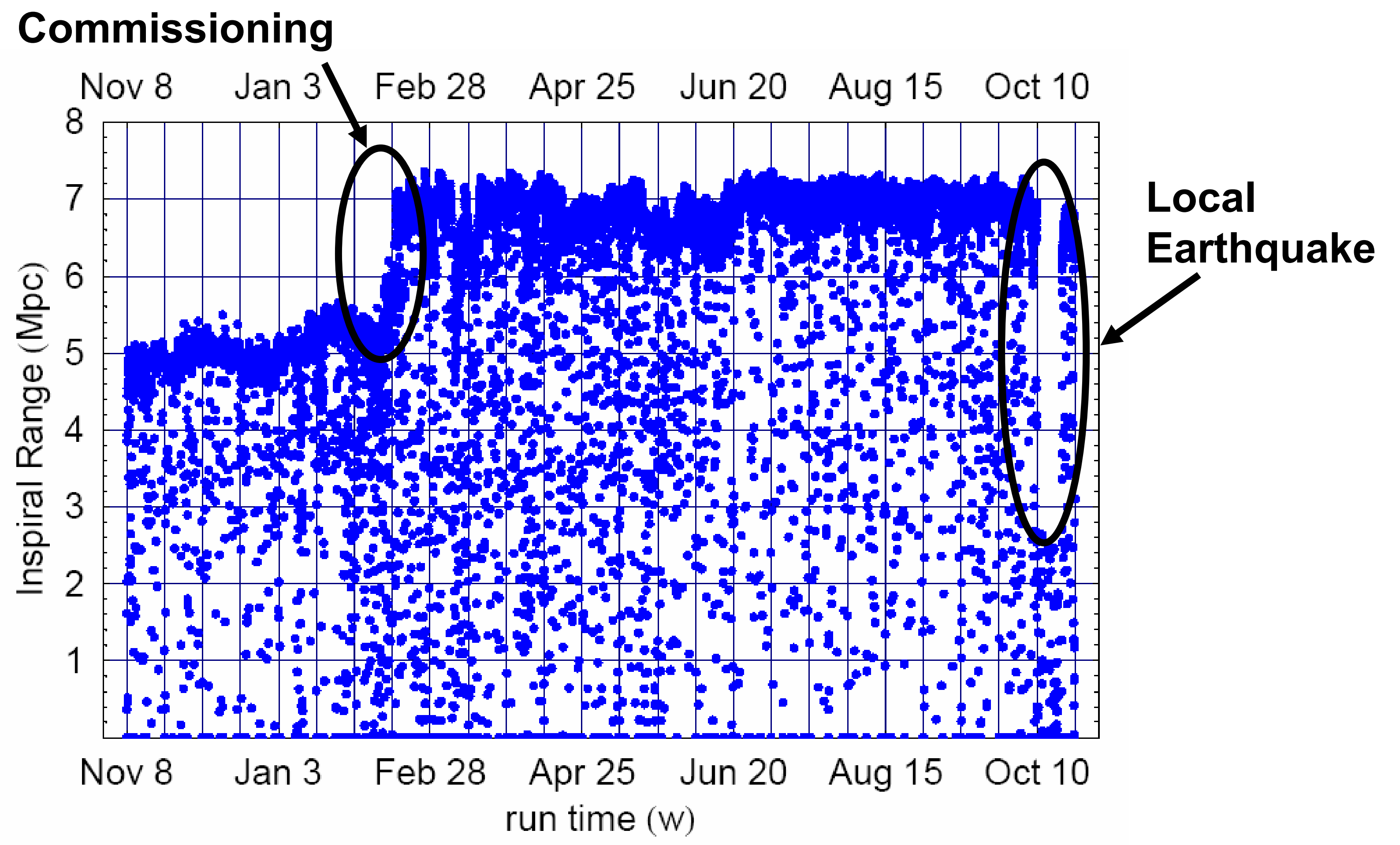
Hanford 4km sensitivity over time

- Detectable range to randomly oriented 1.4, 1.4 solar mass binary neutron star inspiral at an SNR of 8.



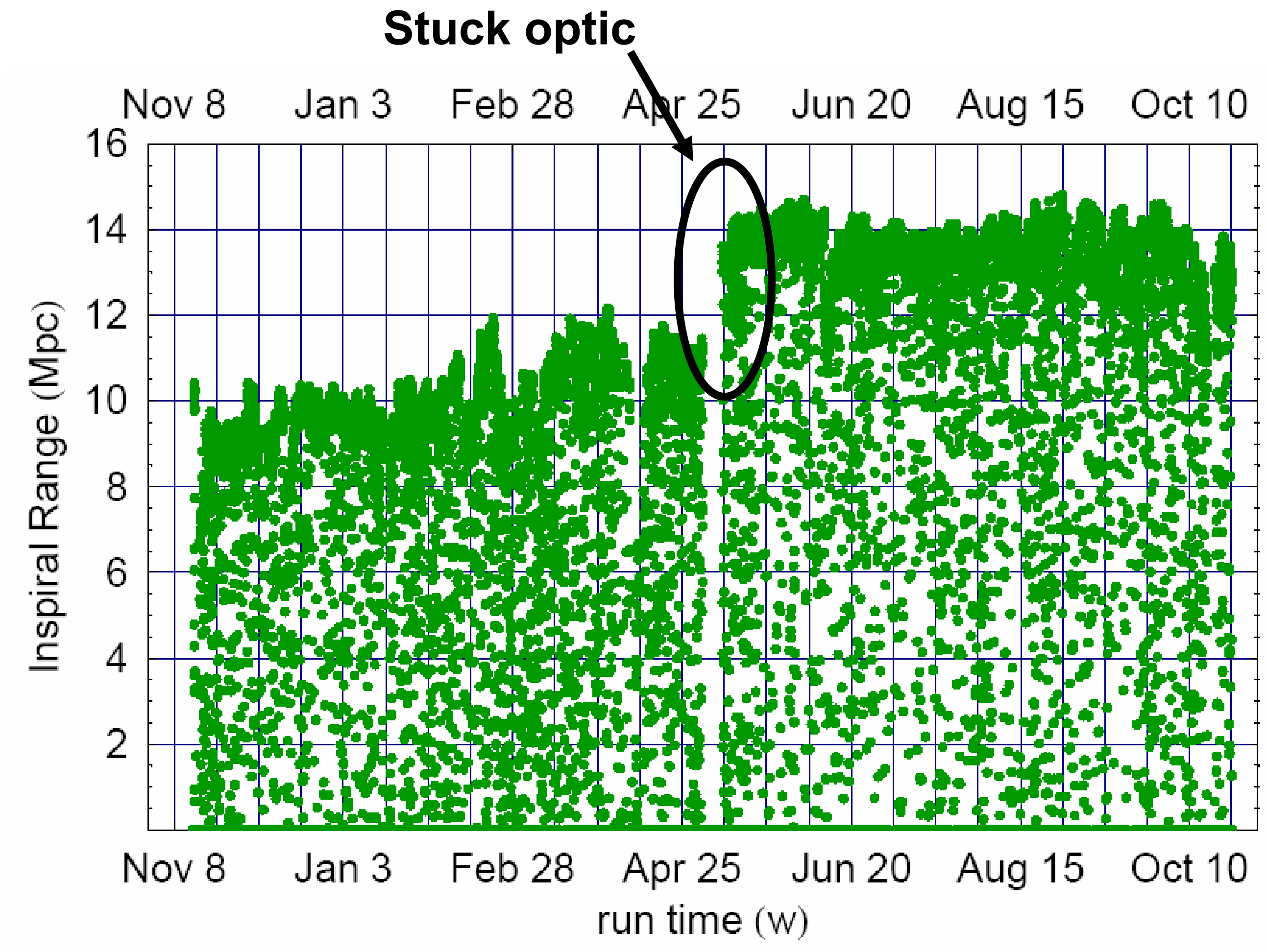
Hanford 2km sensitivity over time

- Detectable range to randomly oriented 1.4, 1.4 solar mass binary neutron star inspiral at an SNR of 8.



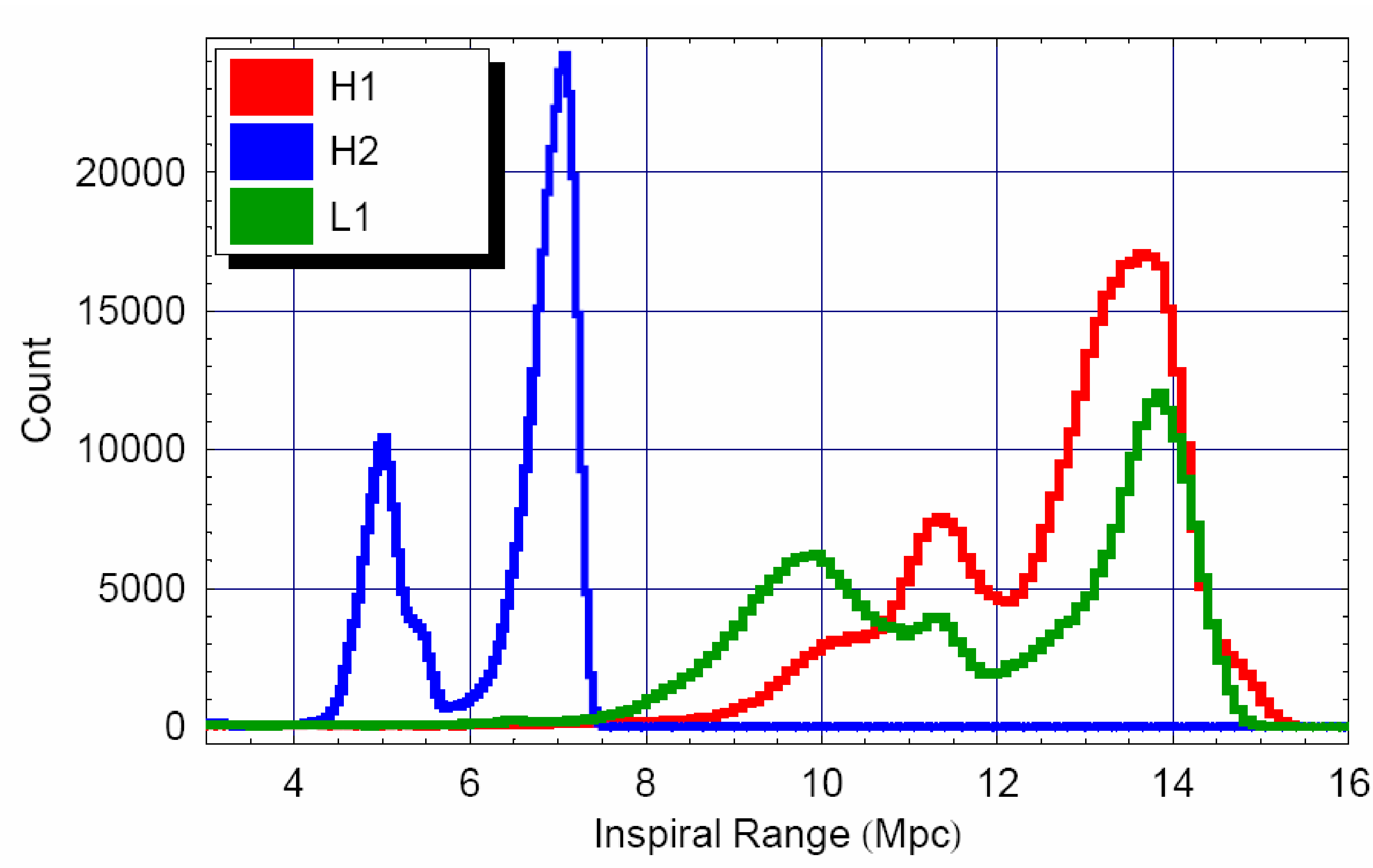
Livingston 4km sensitivity over time

- Detectable range to randomly oriented 1.4, 1.4 solar mass binary neutron star inspiral at an SNR of 8.

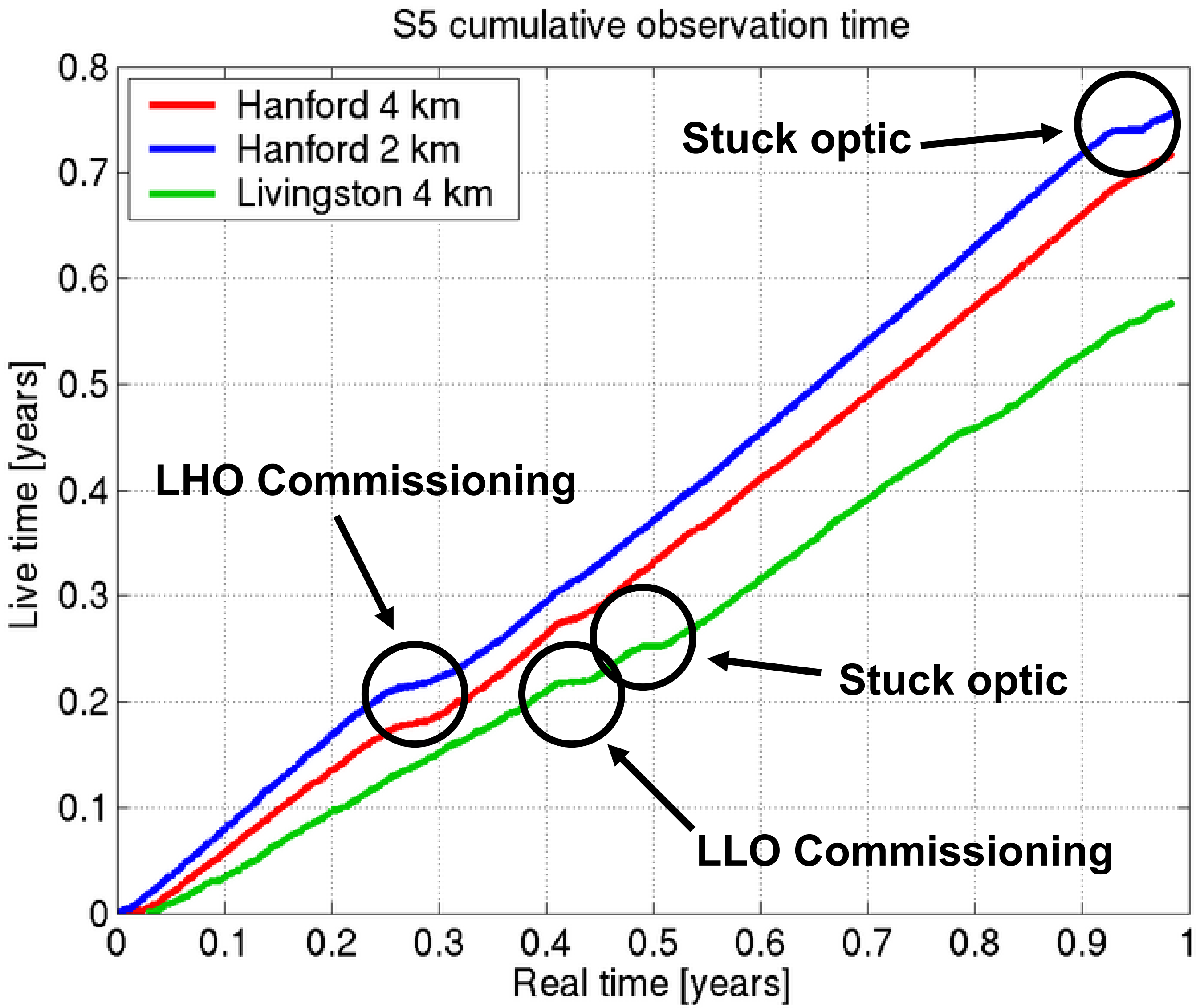


Histogrammed sensitivity over time

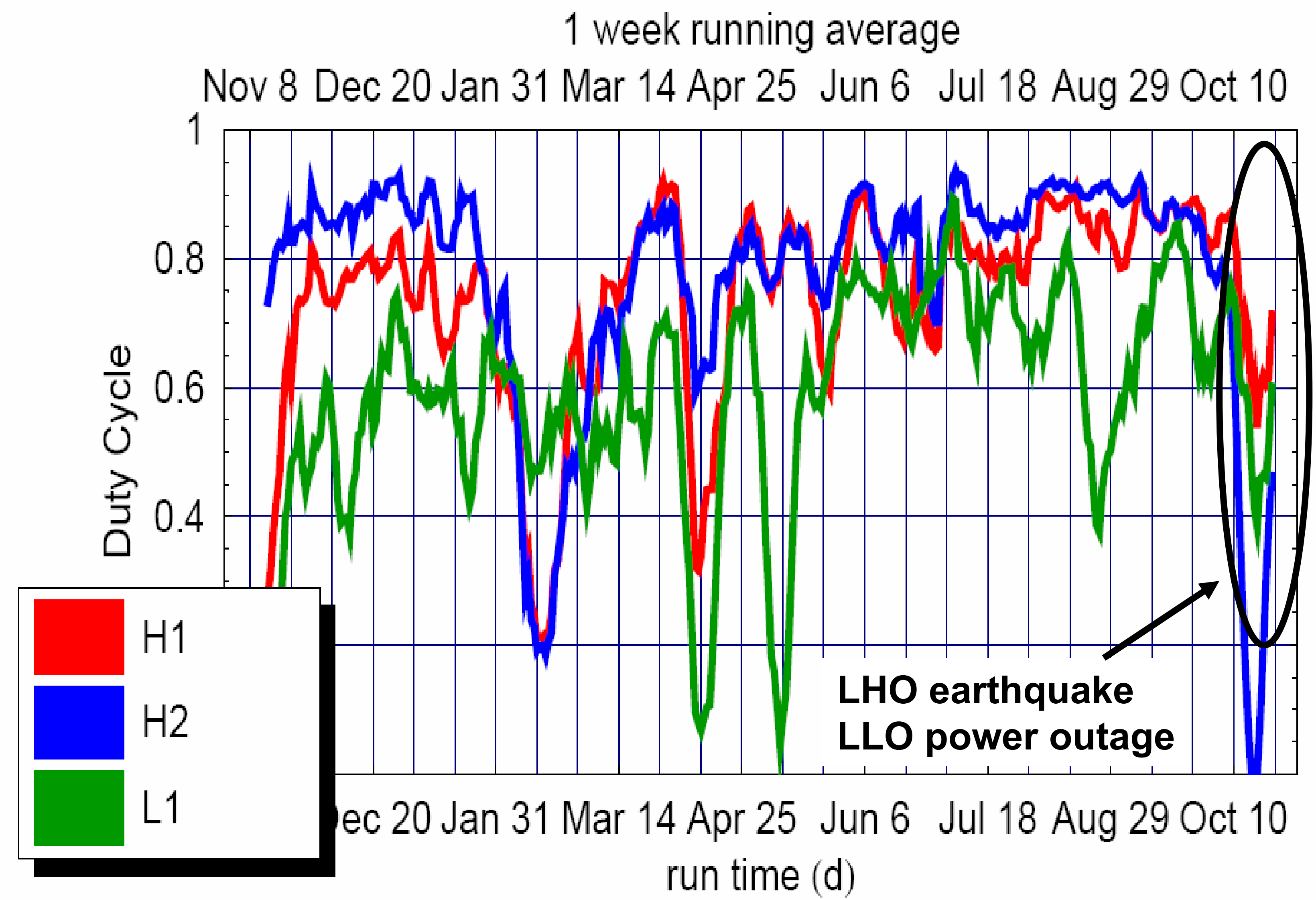
- Detectable range to randomly oriented 1.4, 1.4 solar mass binary neutron star inspiral at an SNR of 8.



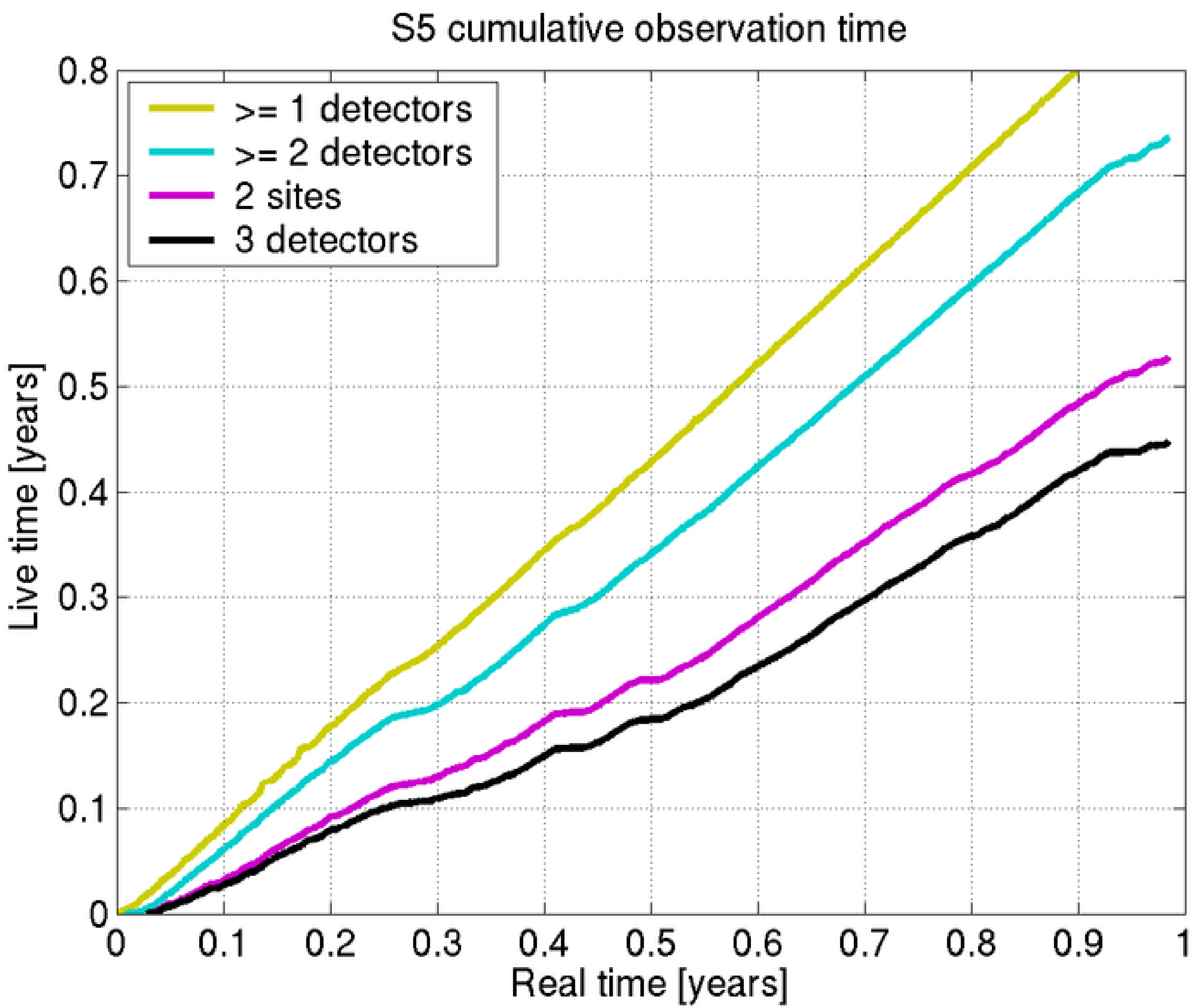
Detector observation time



Weekly detector duty cycles



Network observation time



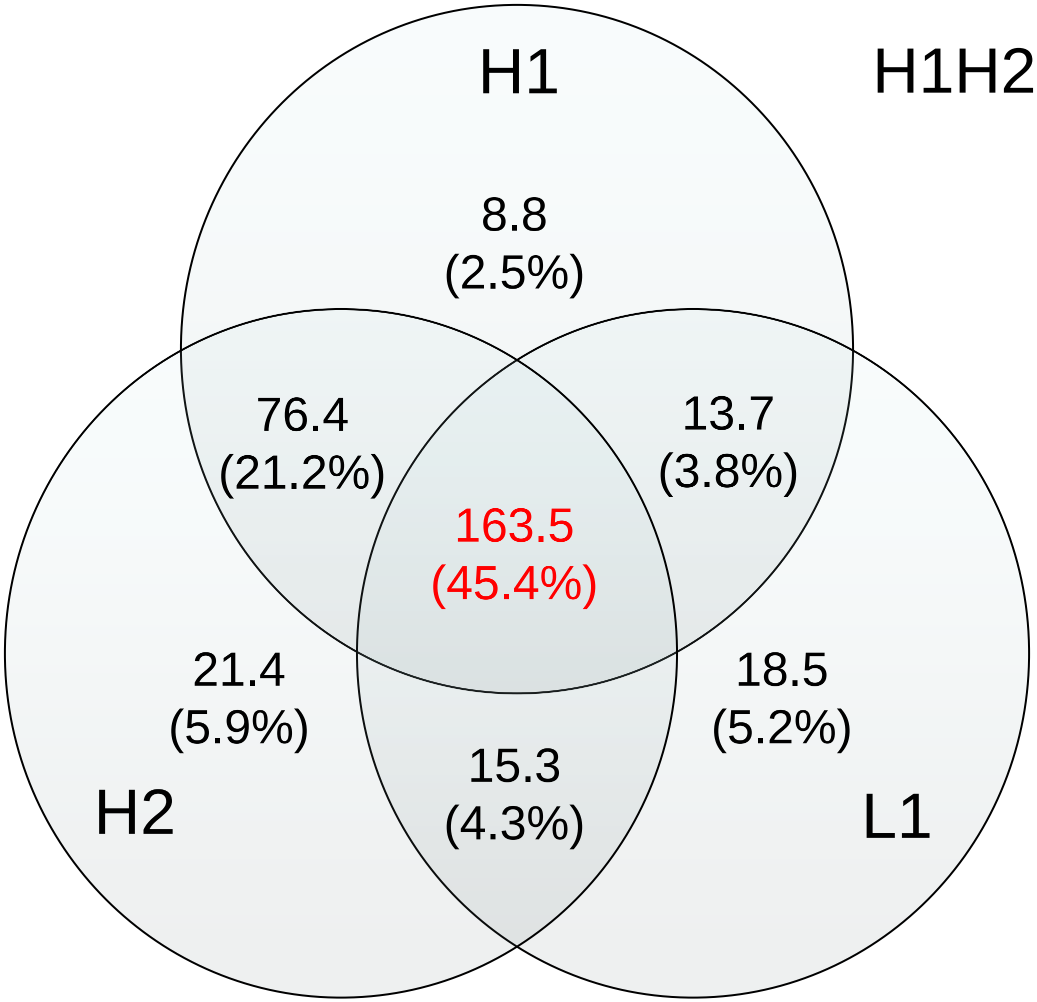
Summary of livetime and duty cycle

H1H2
239.9
(66.6%)

H1H2+H1L1+H2L1
192.5
(53.5%)

H1+H2+L1
317.7
(88.3%)

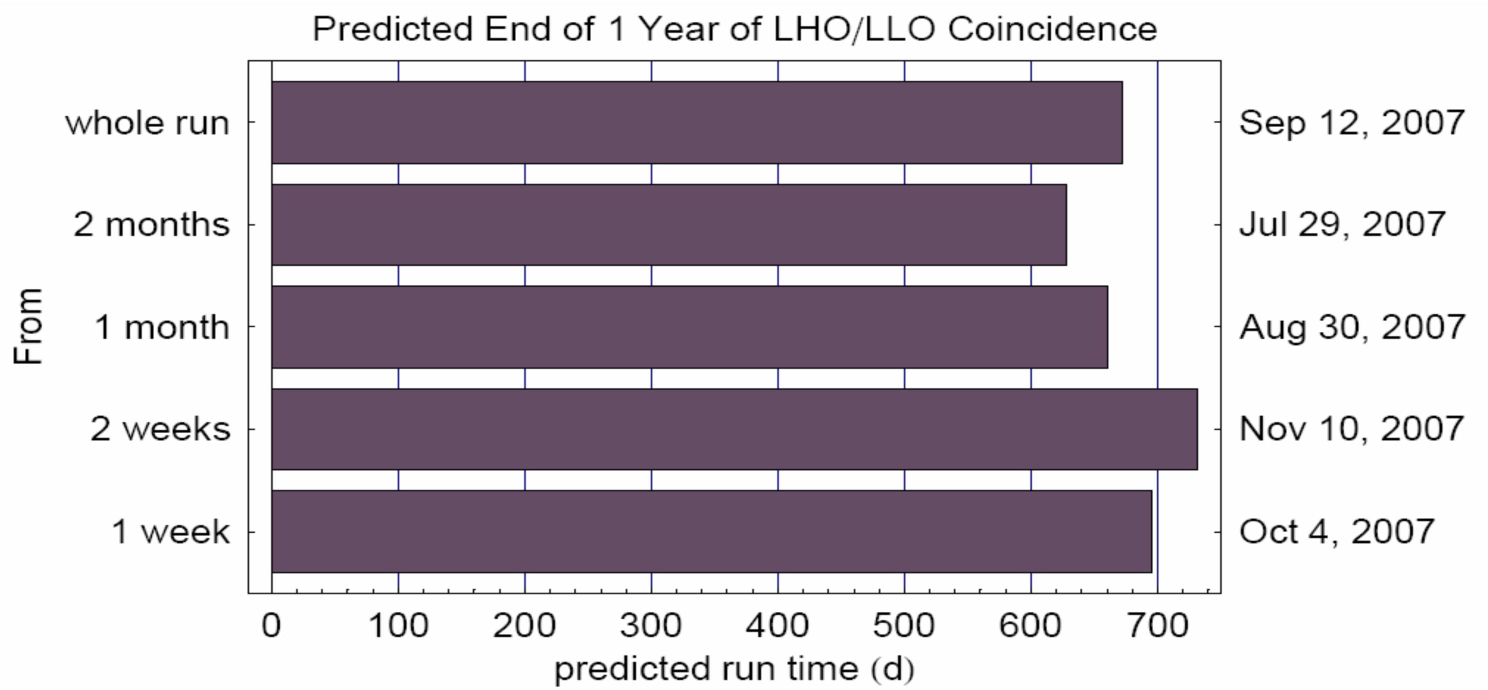
H1L1+H2L1
192.5
(53.5%)

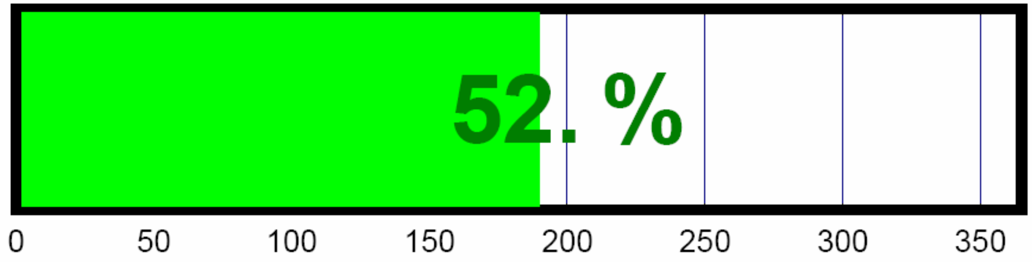


Livetime in days through Oct 30, 2006
Duty cycle relative to start of S5 at LHO

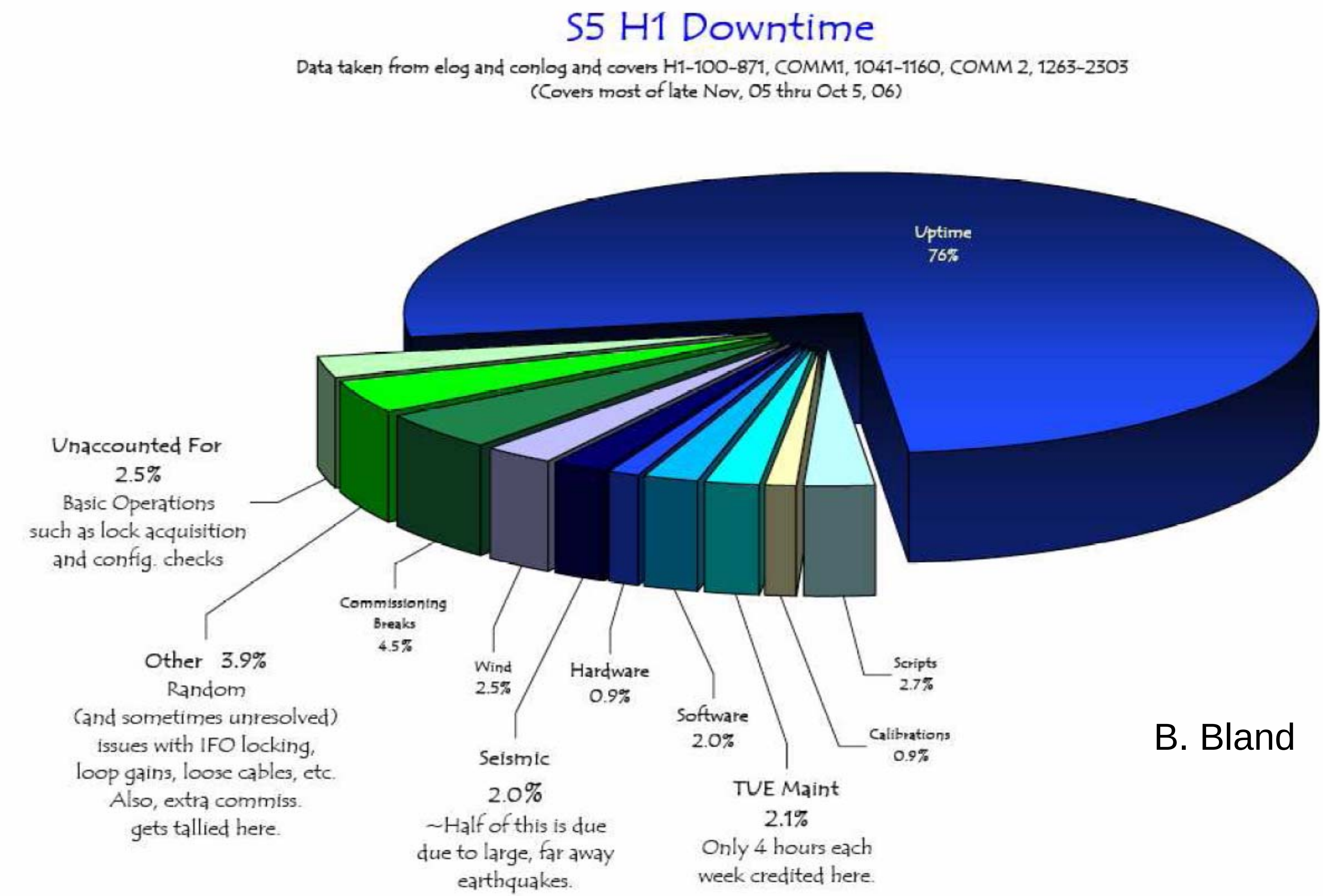
Predicted end of S5

- Extrapolated from two site coincident science mode duty cycle in the last week, 2 weeks, month, 2 months, and the entire run to date.





Downtime budget



B. Bland

S5 coordination

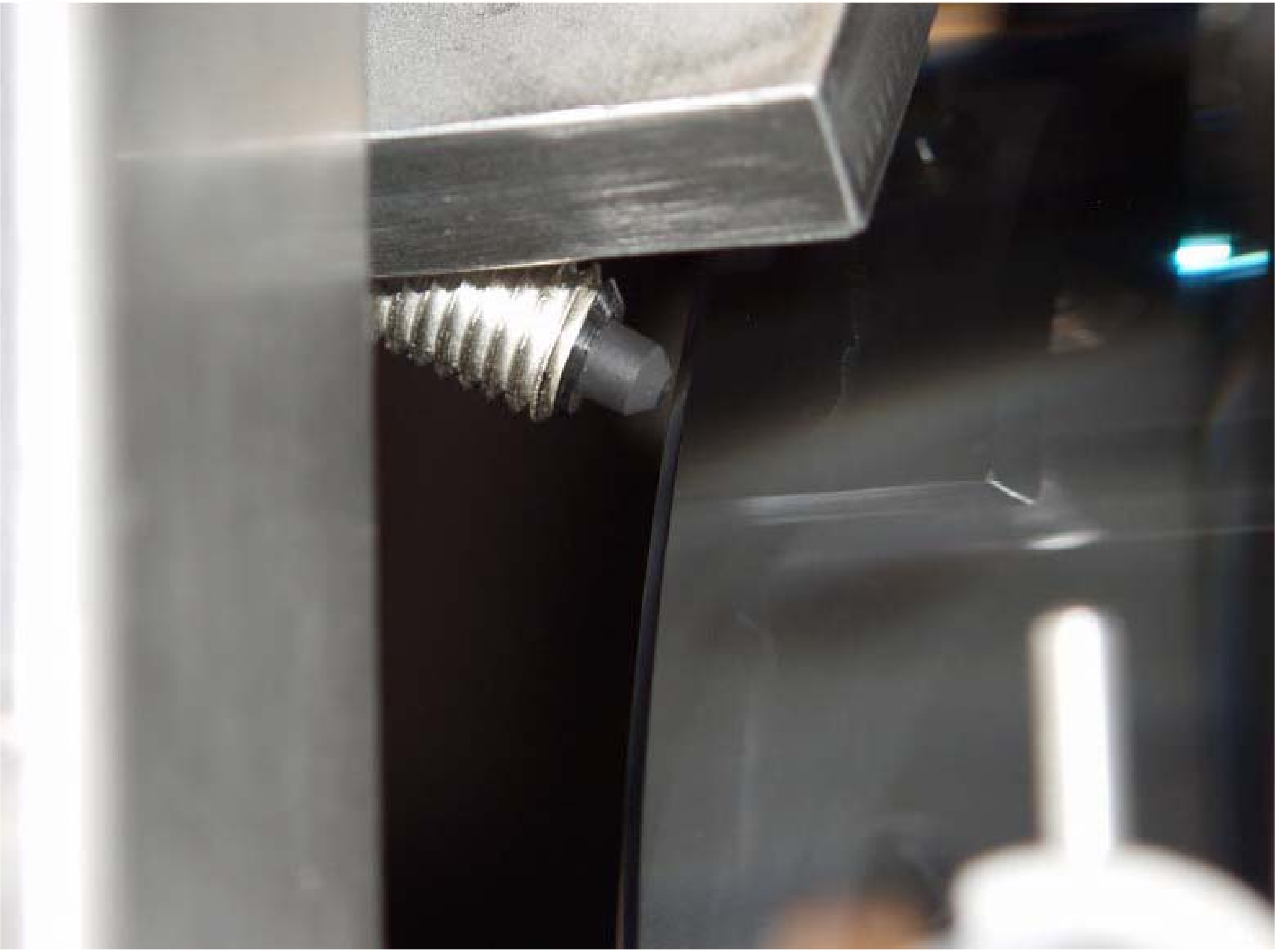
- Goals
  - Maximize coincident science mode time
  - Maintain optimal range and figures of merit
- Run coordinators
  - Global run coordinator
  - Site run coordinators
- Operator present 24 hours a day, 7 days a week
- Science monitor present 20 hours a day, 7 days a week
- Weekly run status teleconference
- Coincident 4 hour maintenance periods on Tuesdays
- 25 hours per month allowed for commissioning
- Occasional longer commissioning breaks

S5 milestones

2005 Nov 4	S5 run begins at LHO
2005 Nov 14	S5 run begins at LLO
2006 Feb 6–17	LHO intra-run commissioning period
2006 Apr 3–15	LLO intra-run commissioning period
2006 May 2-5	L1 mirror stuck against earthquake
2006 May 5	Venting resulted in improved L1 sensitivity!
2006 Oct 7	Strong local earthquake causes 2 Mpc drop in H1 sensitivity and 4 Mpc drop in H2
2006 Oct 19	Venting H2 y-arm end test mass restored sensitivity

Stuck optic improves sensitivity

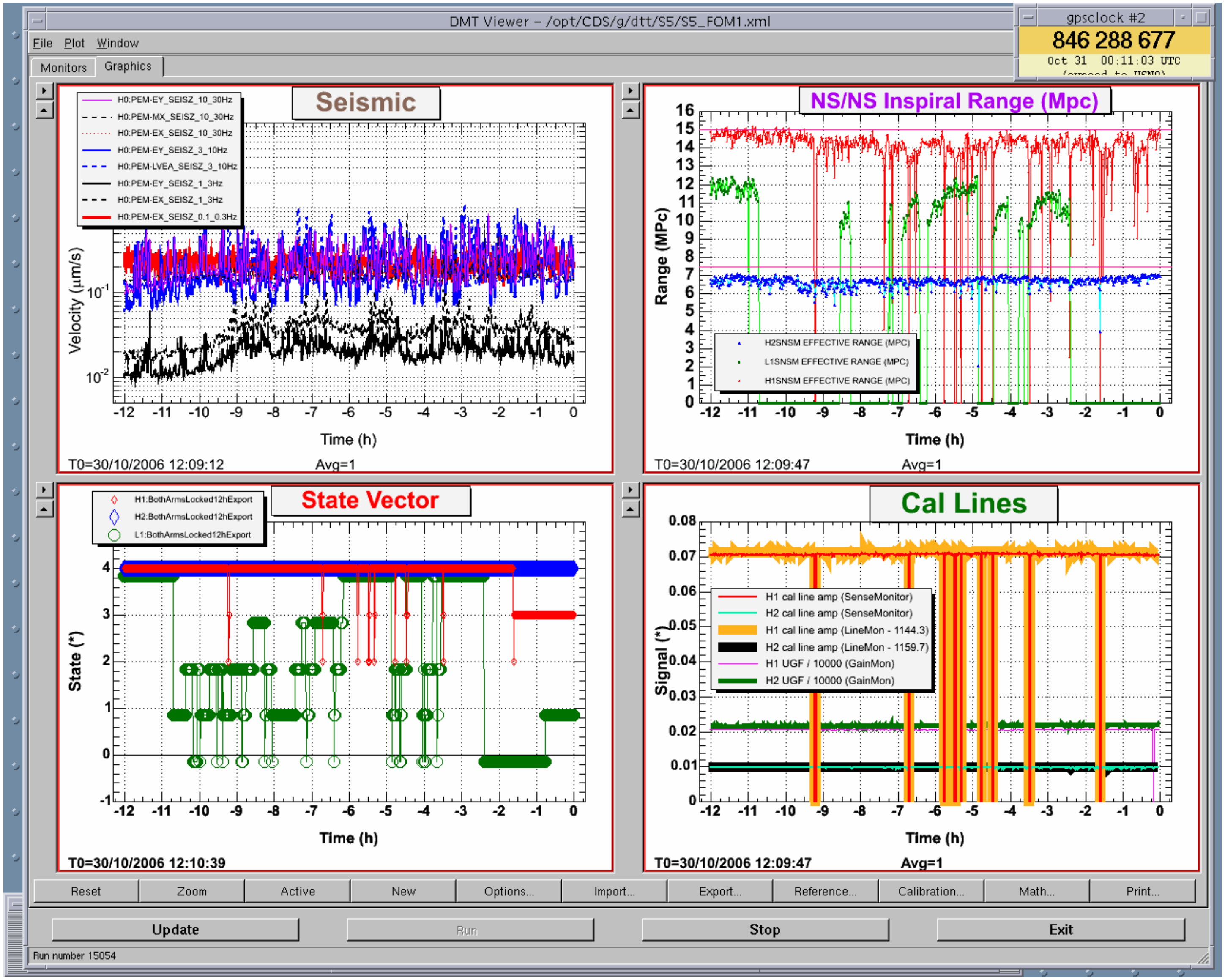
- The L1 y-arm input test mass was mechically stuck to one of its earthquake stops due to a passing truck.
- Freeing the mass required venting the test mass chamber and mechanically releasing it.
- This process resulted in a dramatic improvement in low frequency sensitivity and corresponding improvement in inspiral range!
- The viton tipped earthquake stops are thought to cause charging of the test mass, and venting the chamber is thought to discharge the optic.
- This was applied successfully to recover performance for the H2 detector earlier after suffering decreased senstivity earlier this month



Figures of merit

- Sensitivity and duty cycle are not the full story
- Many other figures or merit are available in the control room to quantify:
  - Predicted range to detectable binary neutron star inspirals
  - Non-stationarity of the data
  - RMS strain sensitivity in various bands
  - Most significant inspiral trigger every minute
  - 50 percent burst detectability for a variety of waveforms at a constant false rate
  - RMS seismic noise in various bands of importance
    - Microseismic activity, anthropogenic activity, etc.

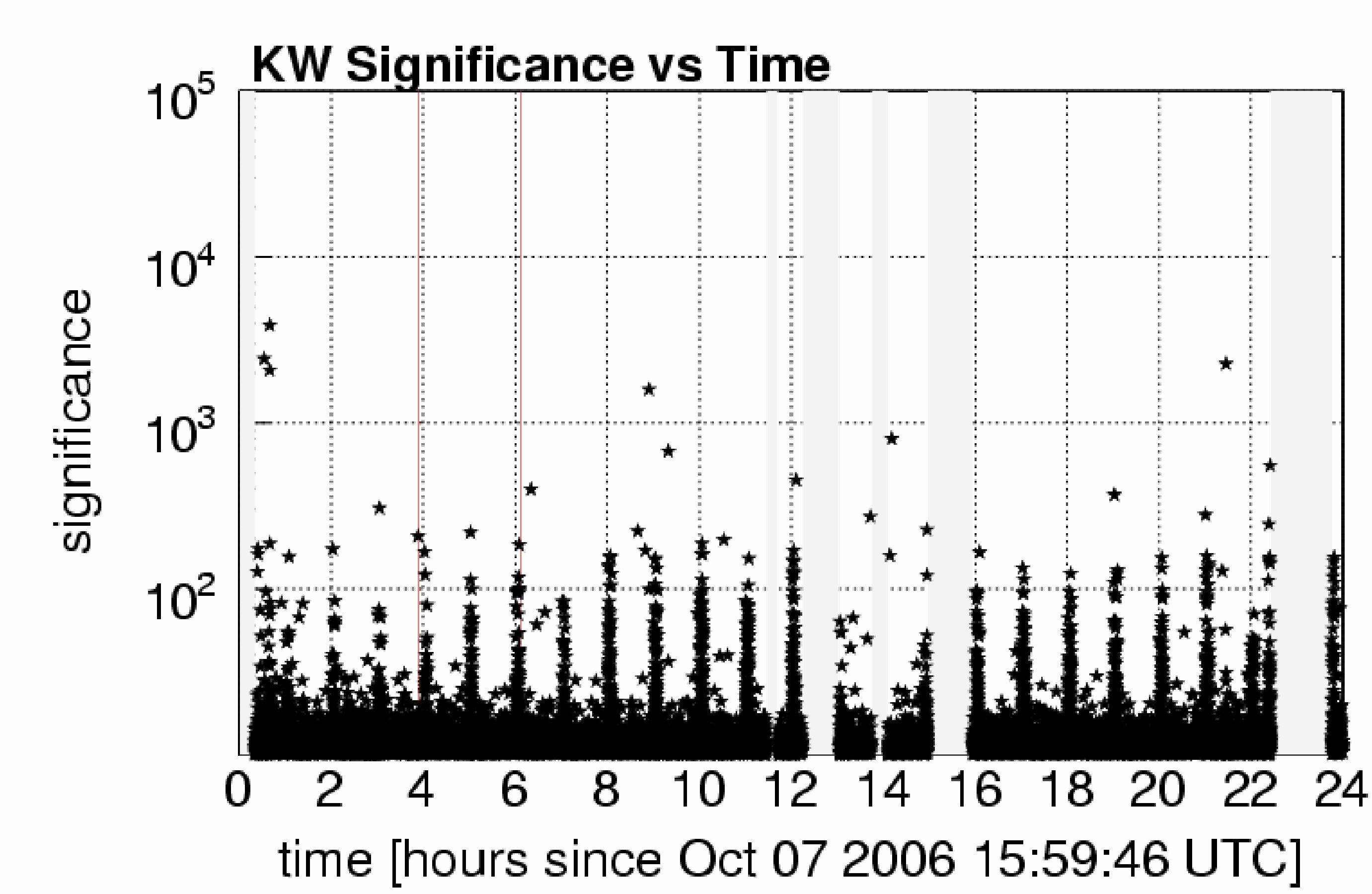
Example figures of merit



Example figures of merit

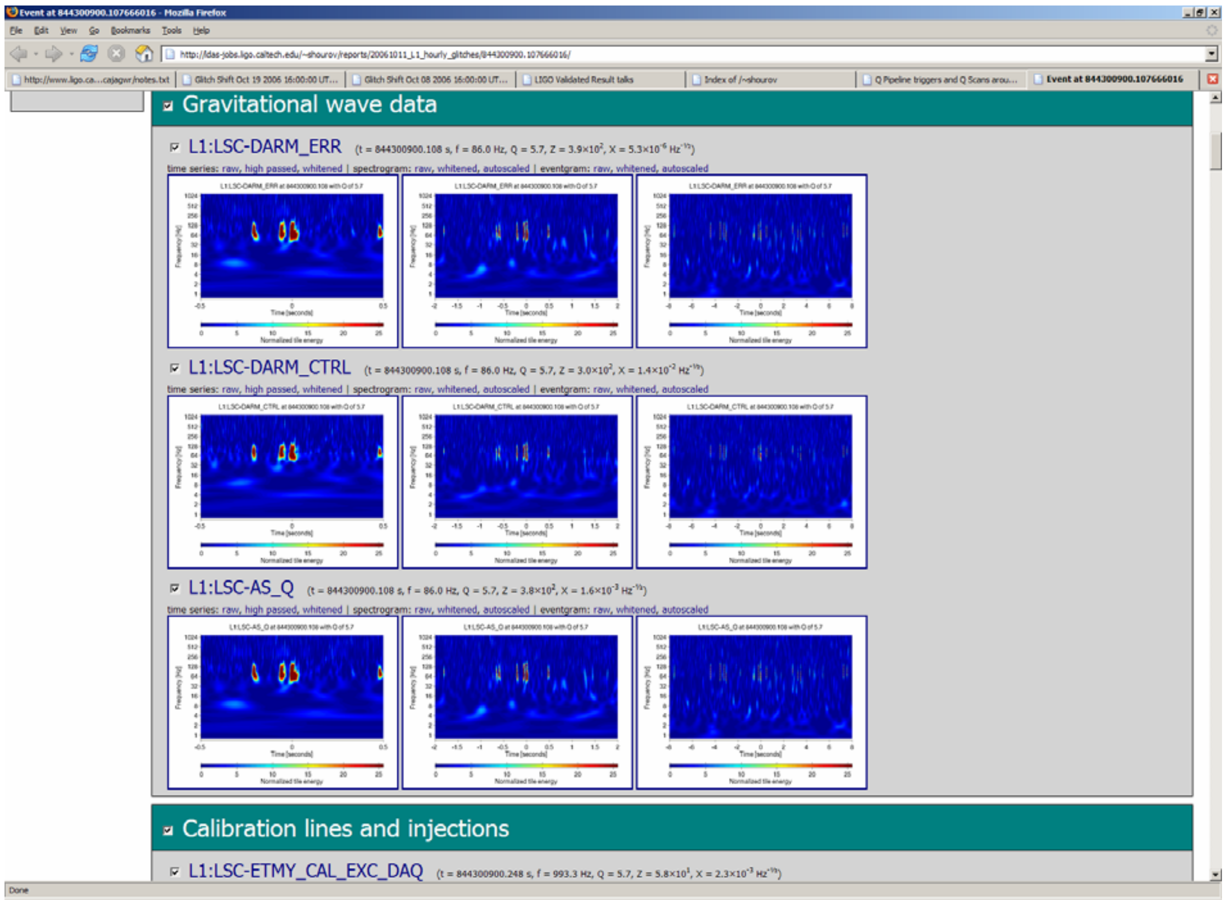
Detector characterization tools

- A number of tools are running “online” to provide rapid feedback to operators and commissioning teams when a problem develops.
- For example, a periodic data corruption was readily observed.

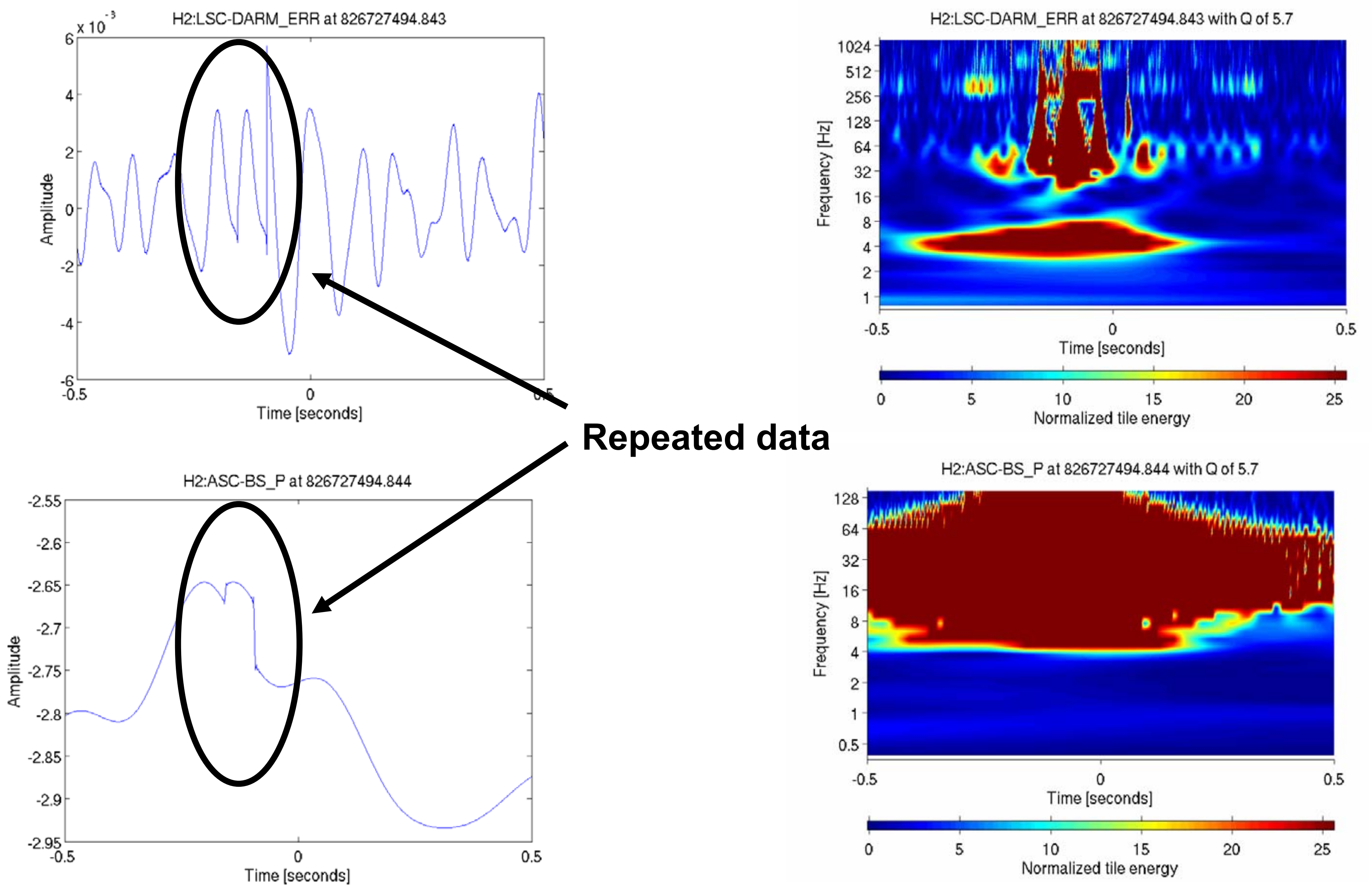


Detector characterization tools

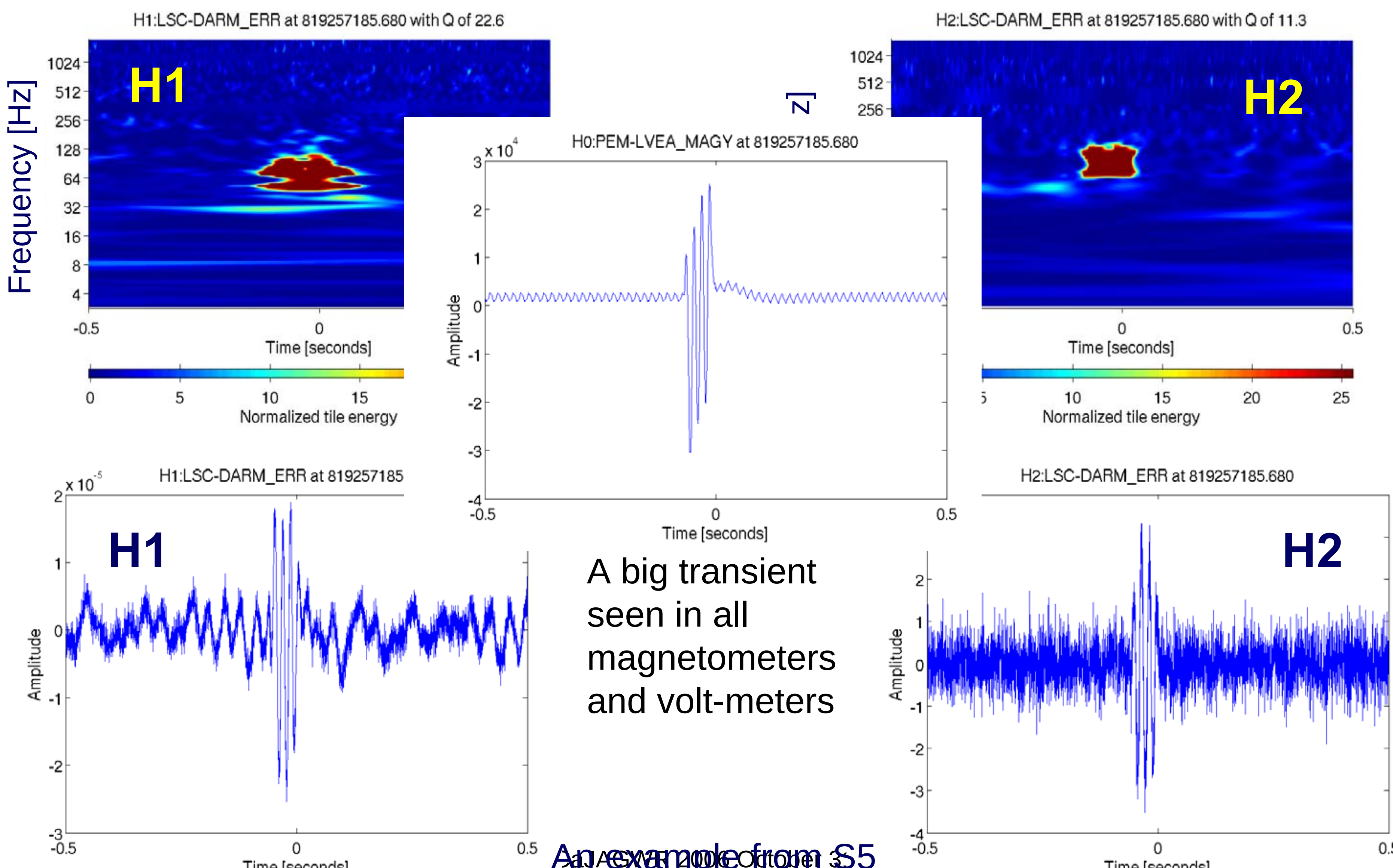
- Tools are also provided to rapidly follow-up interesting events such as glitches, hardware injections, or possible candidate events.



Data corruption



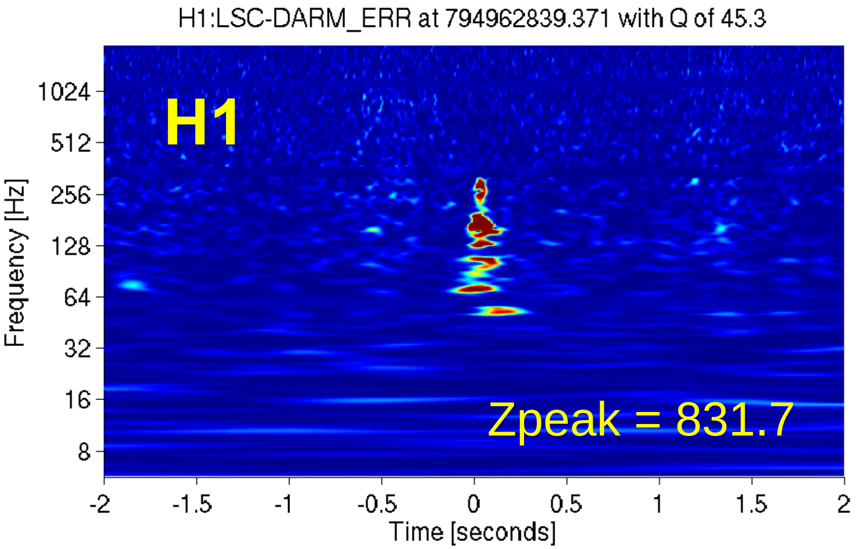
Magnetic field glitches

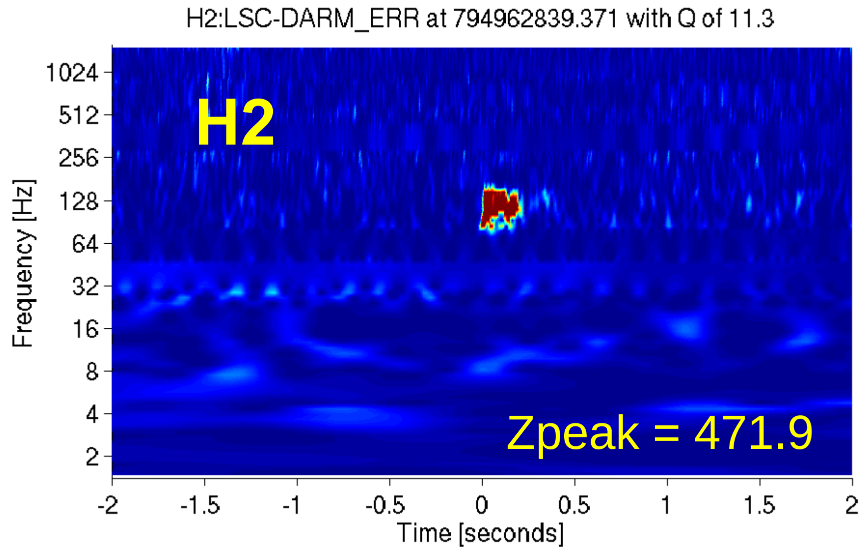


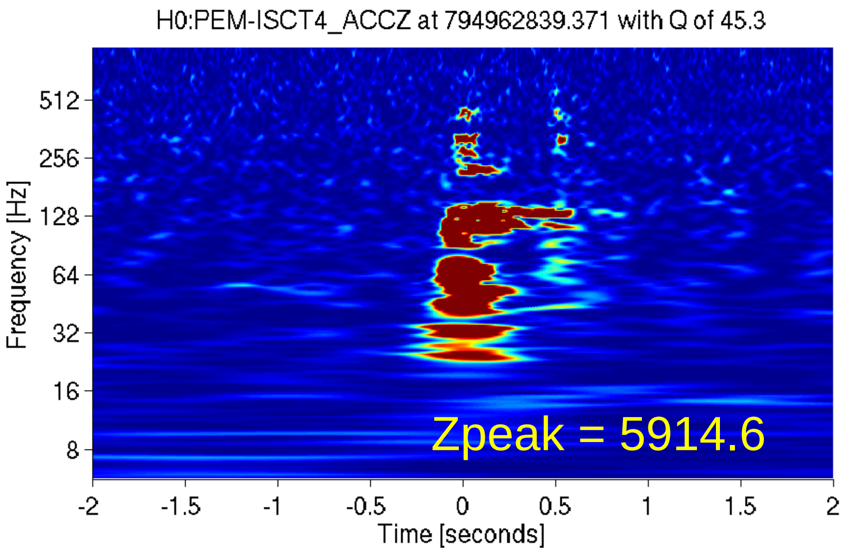
A big transient seen in all magnetometers and volt-meters

An example from S5

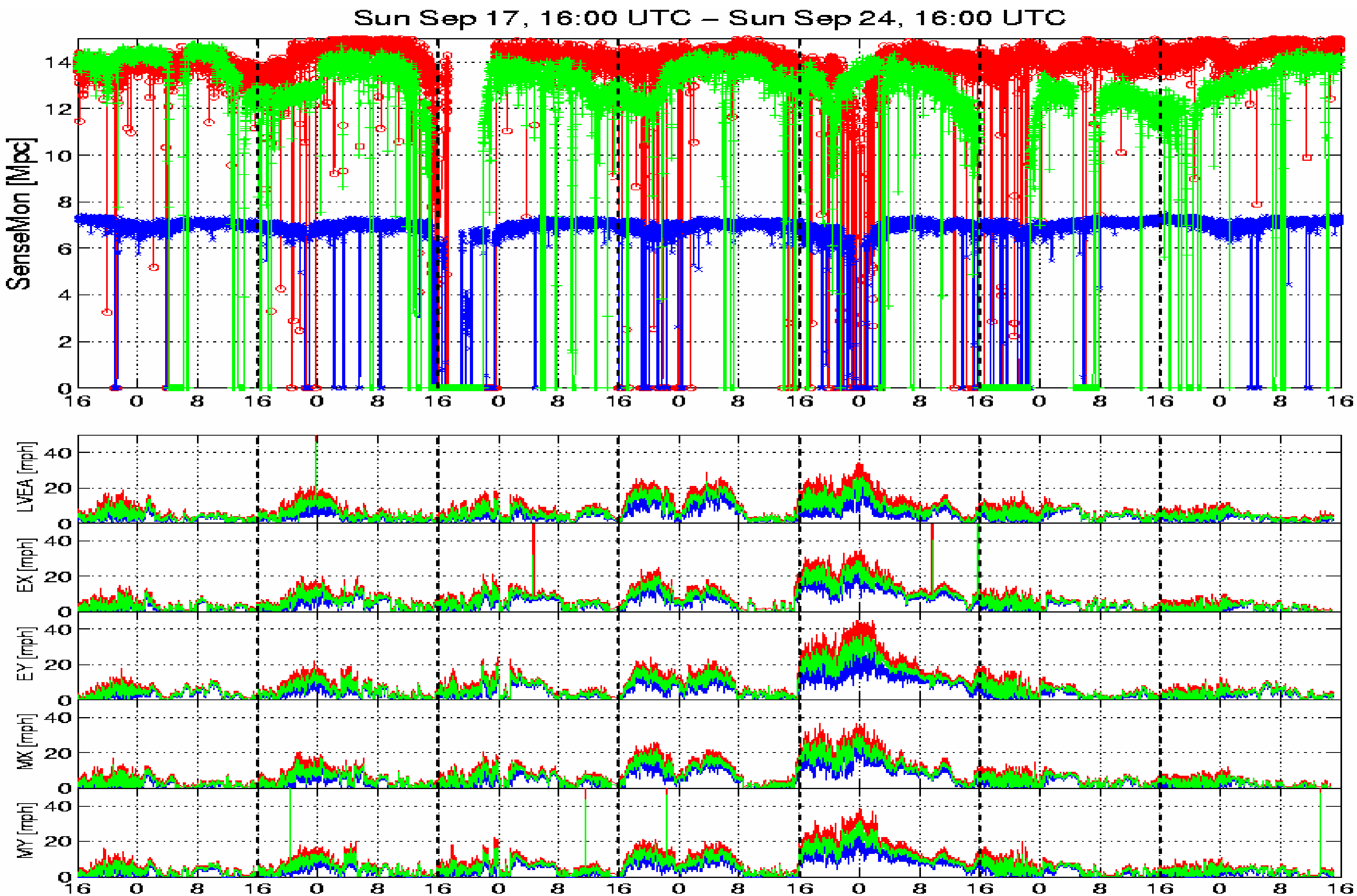
Local seismic disturbances



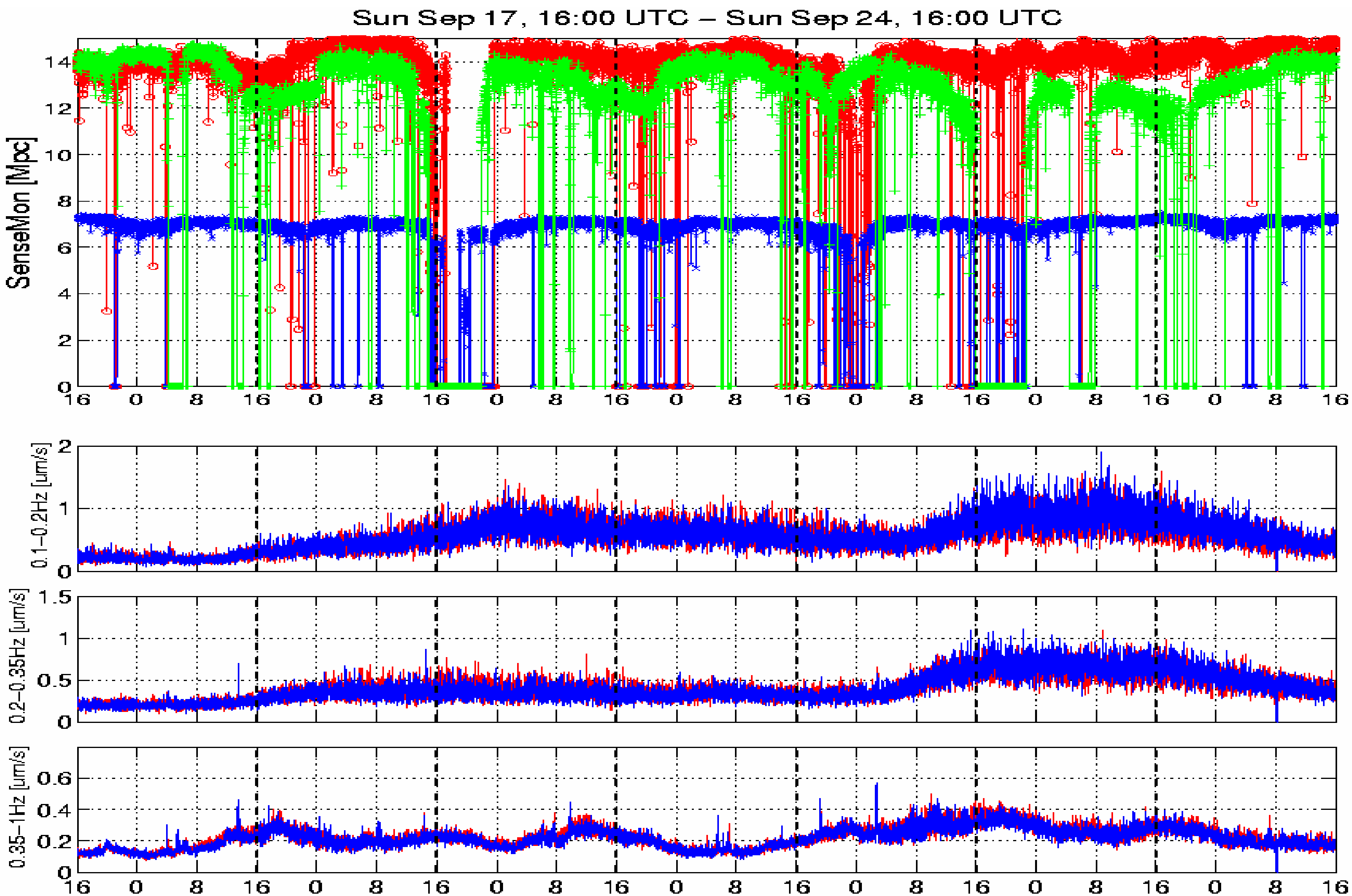




Wind activity



Microseismic activity



Seismic disturbances

- Construction of a science outreach center and logging activity affected early S5 duty cycle at LLO.

Data quality flags

- All of this information is used to produce data quality flags to guide subsequent searches:

ASC_Overflow
ASI_CORR_OVERFLOW
AS_TRIGGER
BAD_SENSING
CALIB_BAD_COEFFS_60
CALIB_DROPOUT_1SAMPLE
CALIB_DROPOUT_1SEC
CALIB_DROPOUT_AWG_STUCK
CALIB_DROPOUT_BN
CALIB_GLITCH_ZG
CHECKSUM_MISMATCH
DAQ_ERROR
H1_Not_Locked

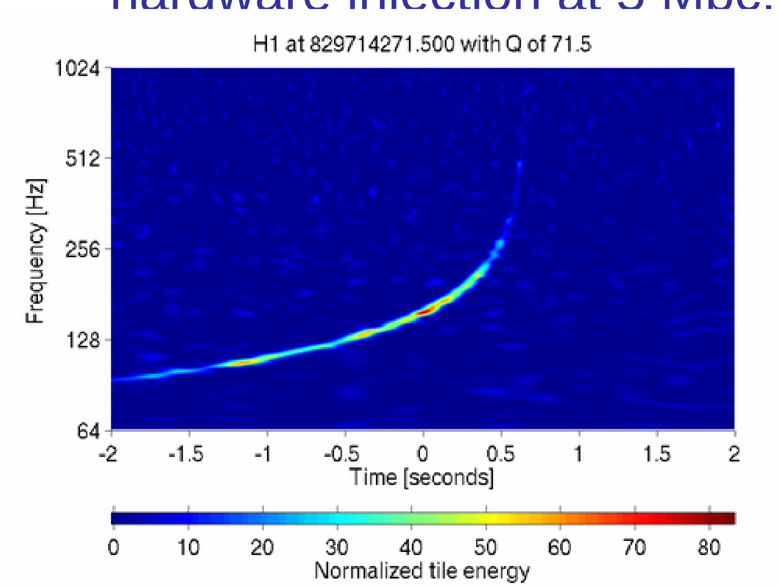
H2_Not_Locked
Injection
LIGHTDIP_*_PERCENT
LSC_OVERFLOW
MASTER_OVERFLOW_ASC
MASTER_OVERFLOW_LSC
MASTER_OVERFLOW_SUS_MC2
MASTER_OVERFLOW_SUS_RM
MISSING_RDS_C02_LX
MMT3_OPTLEVER
OSEM_GLITCH
OUT_OF_LOCK

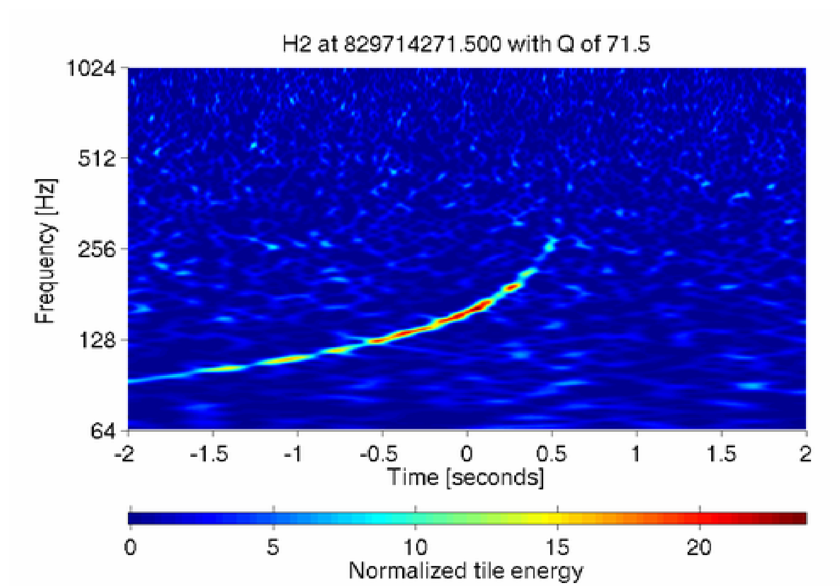
OUT_OF_SCIENCE_MODE
PD_Overflow
PRE_LOCKLOSS_*_SEC
SEISMIC_EY_99PCTL_3_10HZ
SEVERE_LSC_OVERFLOW
TRAIN_LIKELY
VOID_DQ_DO_NOT_USE
Wind_Over_30MPH

Hardware injections

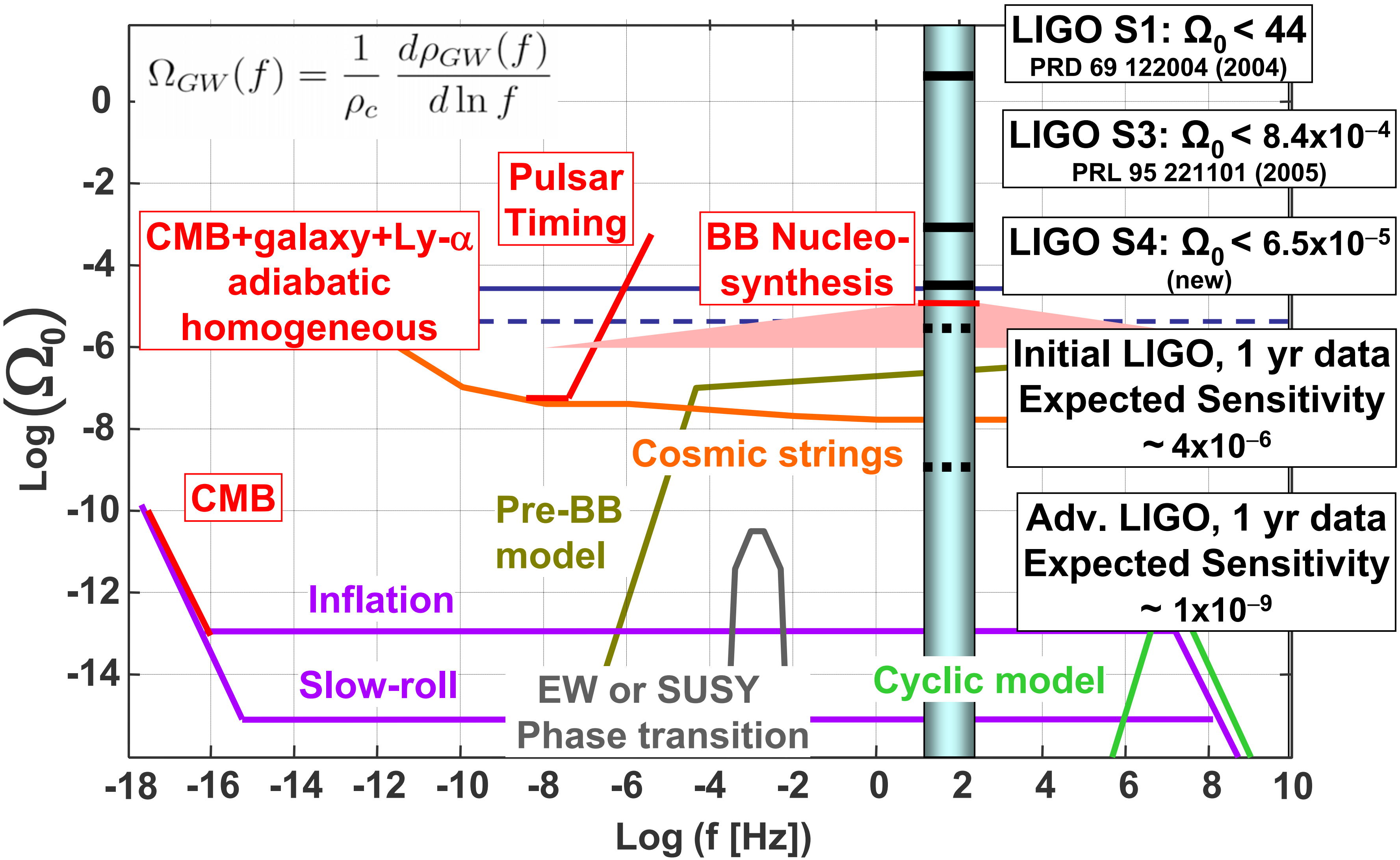
- A variety of waveforms are also physically injected into the instrument throughout the run.
- Binary neutron star and binary black hole inspirals
- Gaussians, sinusoidal Gaussians, cosmic string cusps, etc.
- Stochastic backgrounds
- Simulated pulsars

- Spectrogram of an optimally oriented 1.4,1.4 solar mass inspiral hardware injection at 5 Mpc:

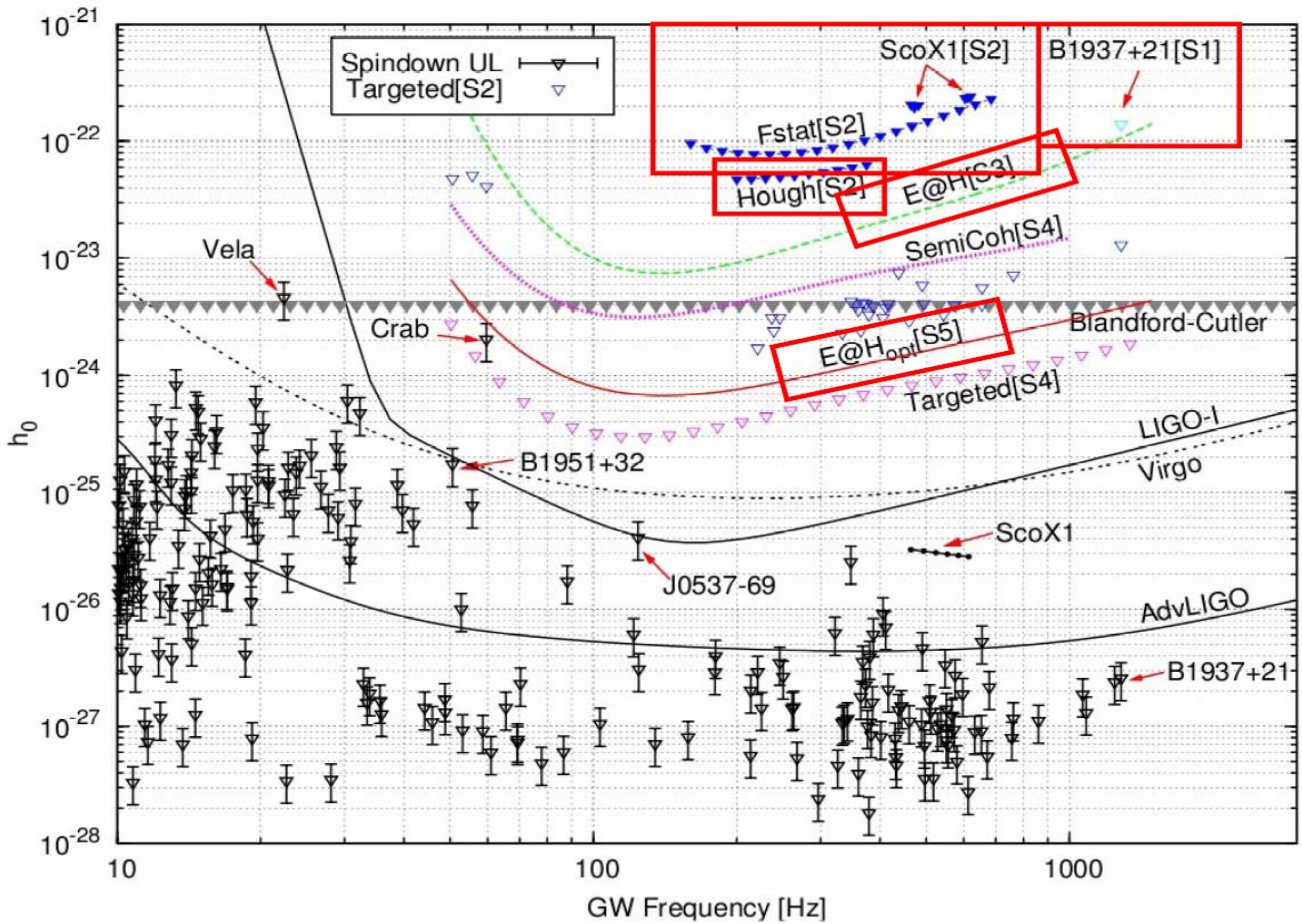




Predicted stochastic result



Predicted pulsar results



Predicted burst search results

- Projected burst upper limits for Q of 9 sinusoidal Gaussian waveforms for S4 and S5 compared with published results from previous science runs.

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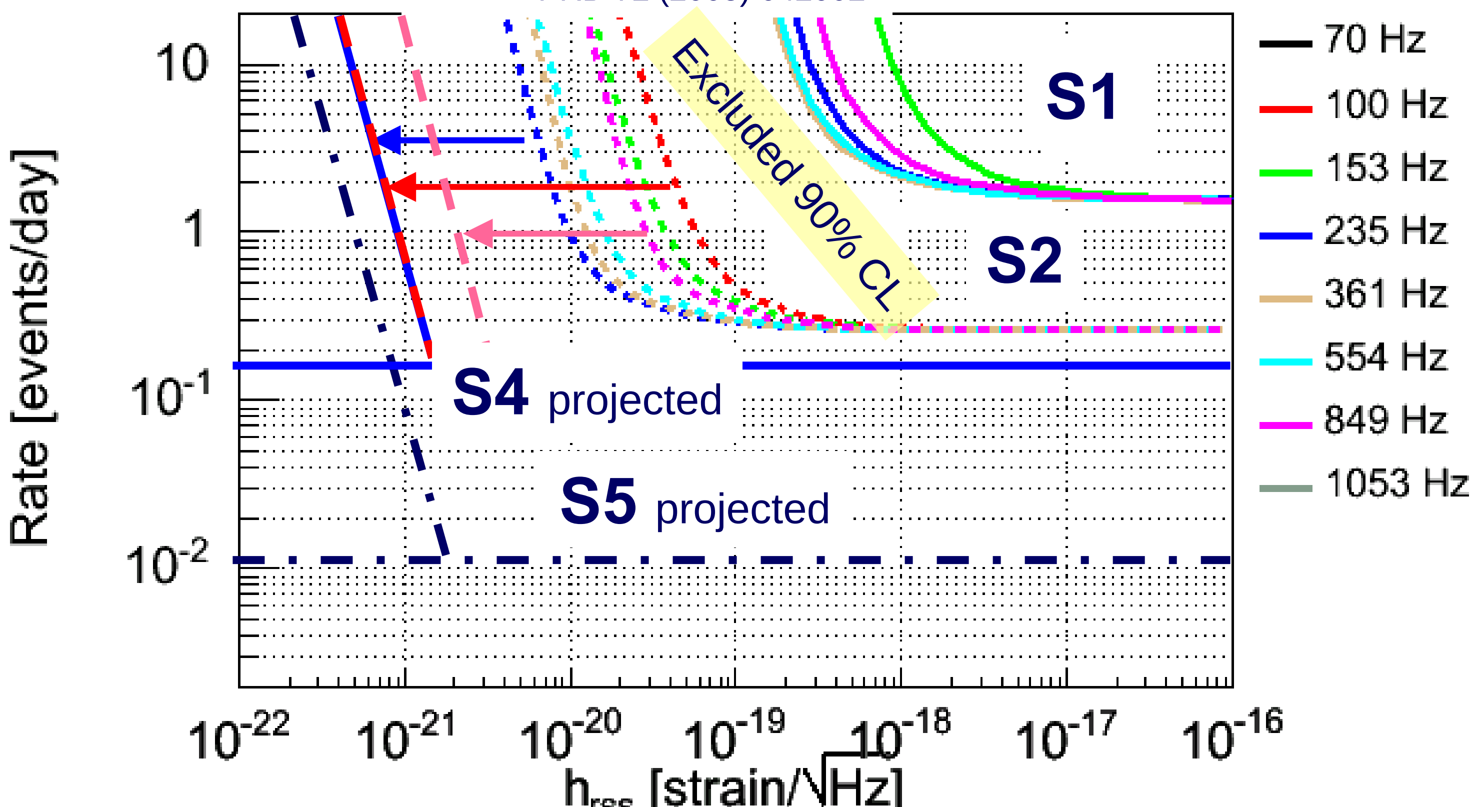
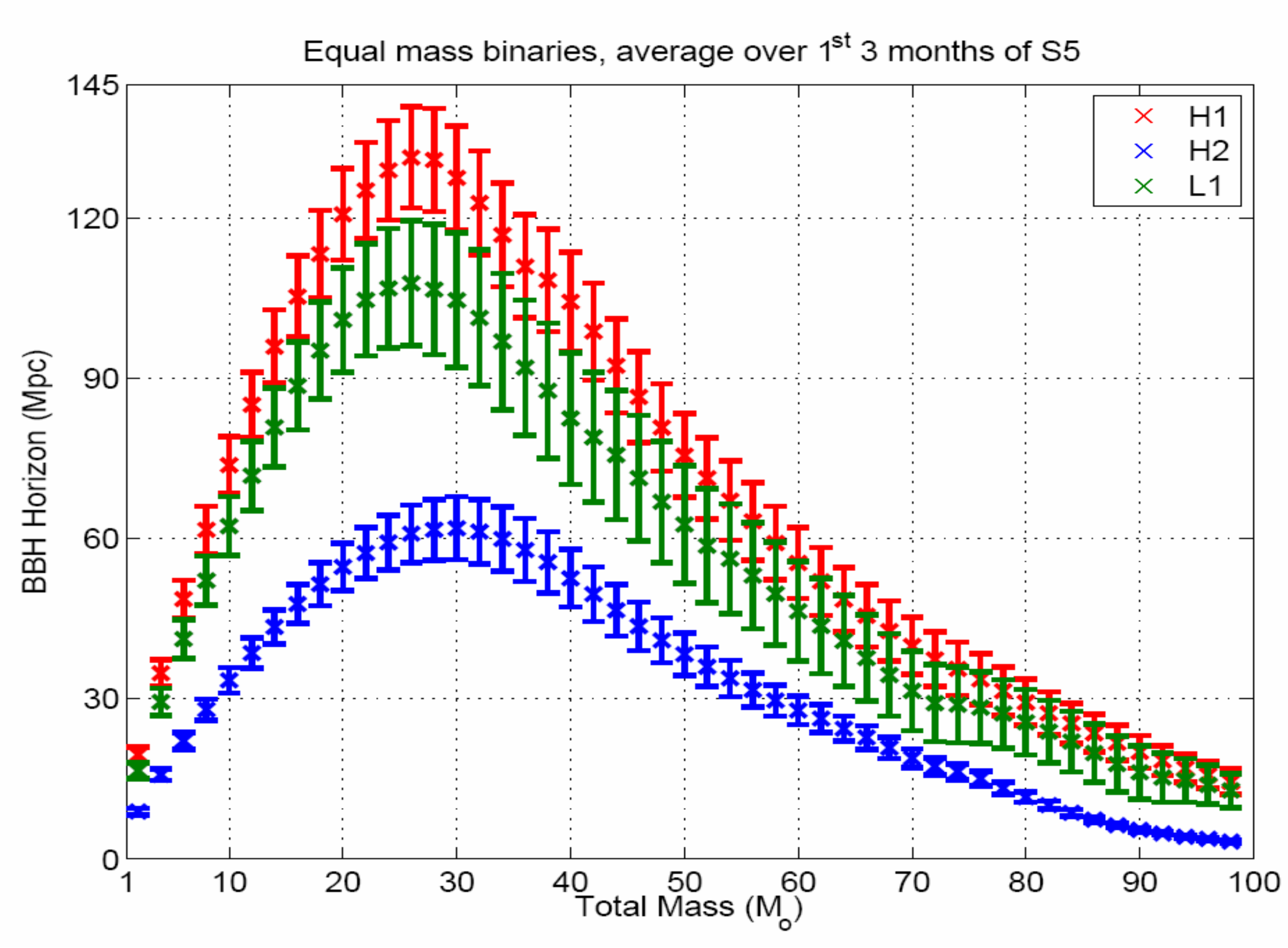


$$h_{rss} = \sqrt{\int_0^{\infty} |h(t)|^2 dt} = \sqrt{\int_{-\infty}^{\infty} |\tilde{h}(f)|^2 df}$$

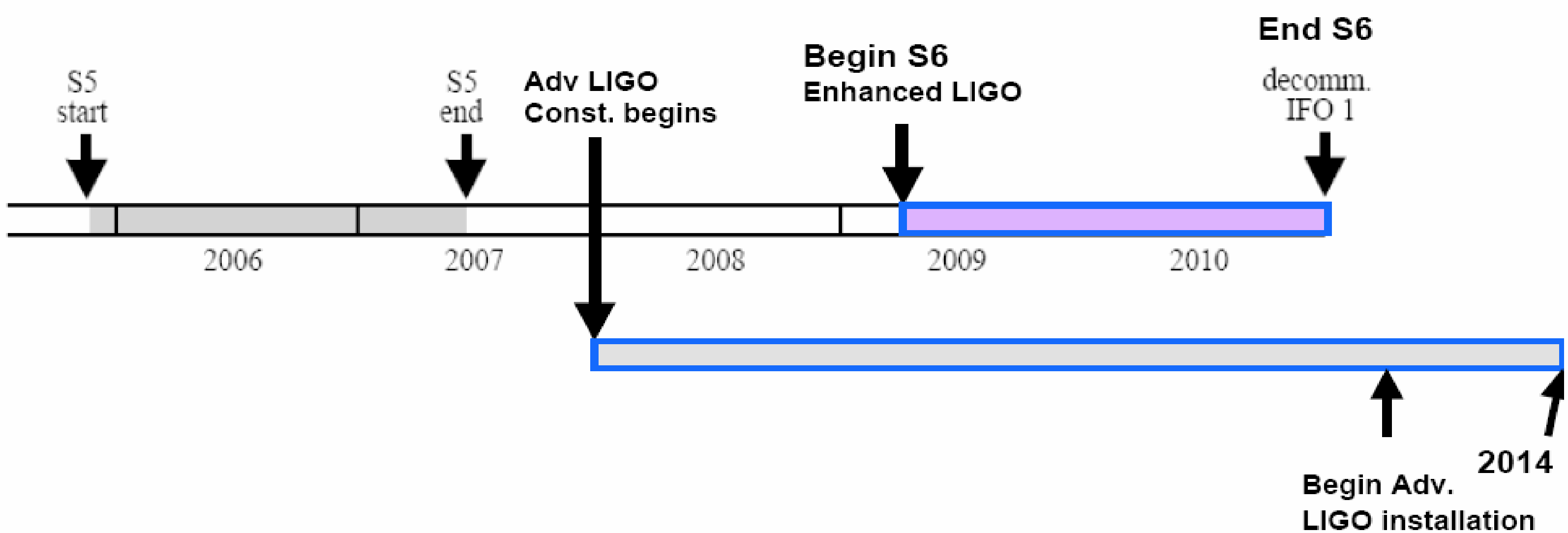
Predicted inspiral results

- Predicted detectable range to optimally oriented binary inpsirals at a signal to noise ratio of 8 over the first 3 months of S5.



Enhanced and advanced LIGO

- Planning for both enhanced LIGO and advanced LIGO is already well underway.
- Expect factor of ~2 increase in strain sensitivity and ~8 increase in volume sensitivity for enhanced LIGO
- Expect factor of ~10 increase in strain sensitivity and ~1000 increase in volume sensitivity for advanced LIGO



Enhanced and advanced LIGO

- Predicted detectable range to binary neutral star inspirals.