All-Sky Burst Search in the First Year of the LSC S5 Run

Laura Cadonati, UMass Amherst
For the LIGO Scientific Collaboration

GWDAW Meeting,
Cambridge MA, December 16, 2007

All-sky Burst Search

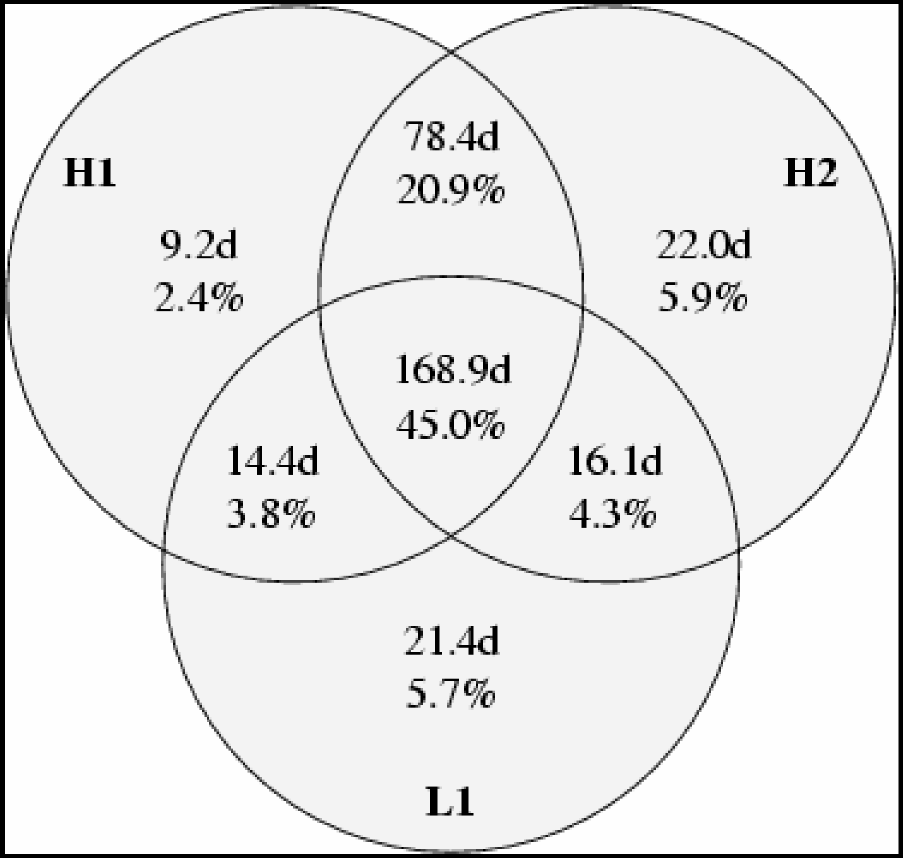
- All-sky search for un-modeled bursts of gravitational waves
  - Supernovae, black hole mergers, serendipitous sources
- approaching completion of the analysis for the first year of S5 (Nov 14, 2005 to Nov 14, 2006)
- 3 searches (different techniques)
- Exploring different network configurations
- Candidates must pass data quality and consistency tests, designed to suppress false alarms with minimal impact to sensitivity

Detector Combinations?

1st year: available data

after category 1 data quality flags

H1H2:	247.4 days	66.0%
H1L1:	183.3 days	48.9%
H2L1:	185.1 days	49.3%
H1H2L1:	168.9 days	45.0%
G1:	223.8 days	59.7%



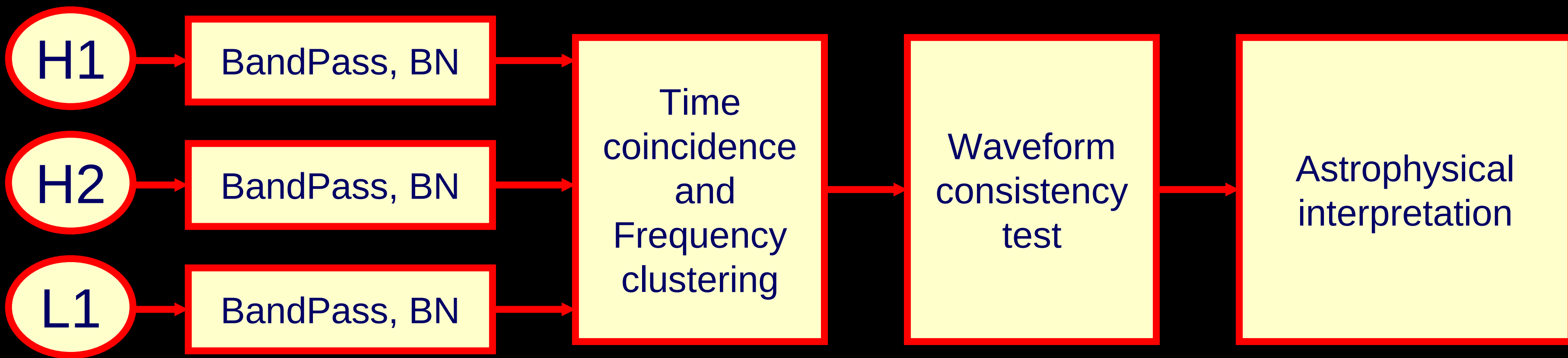
3 Analysis Techniques

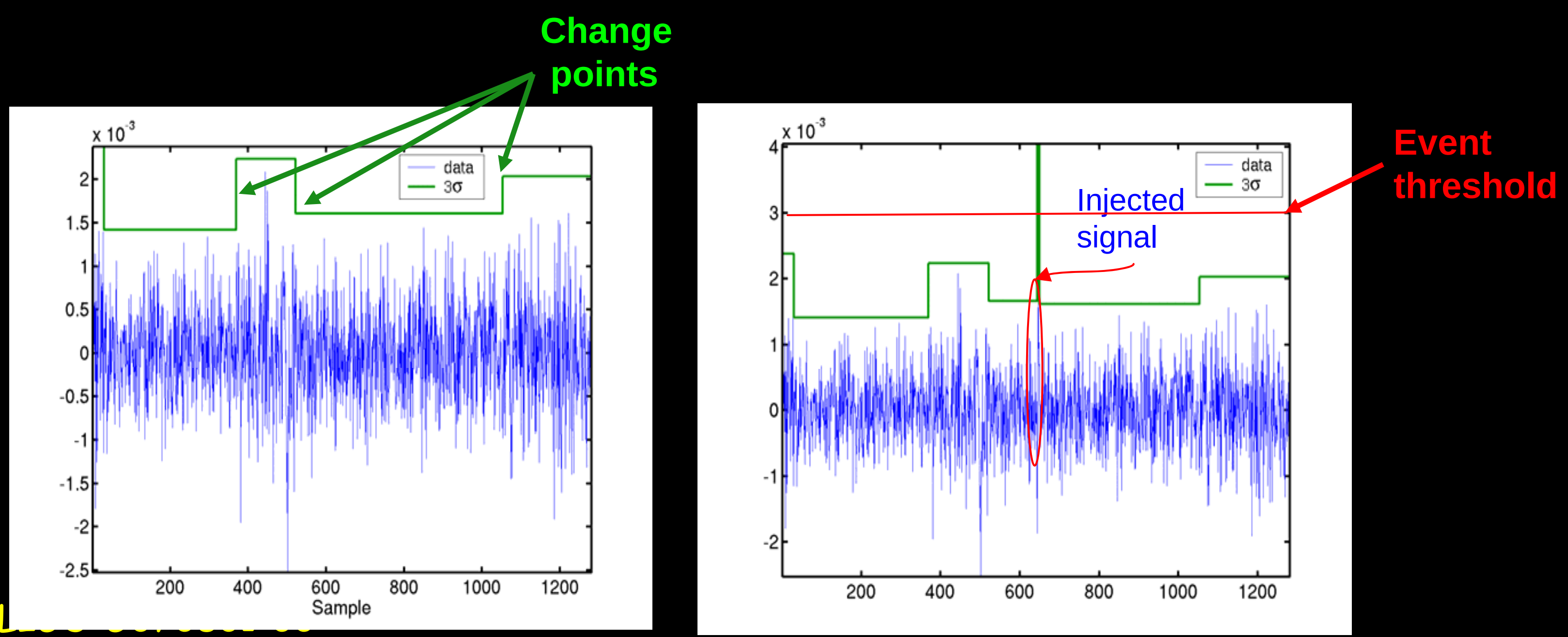
Actually..

3 complete analysis pipeline,

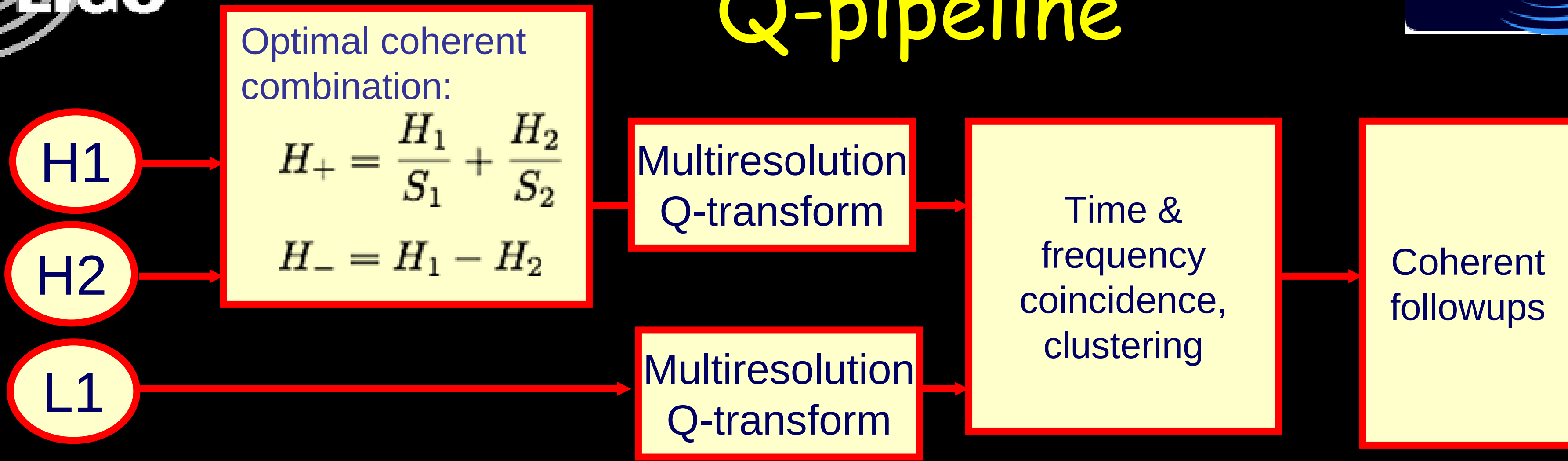
sharing data quality/veto, simulation engine and candidate follow-up

BlockNormal / AstroBurst

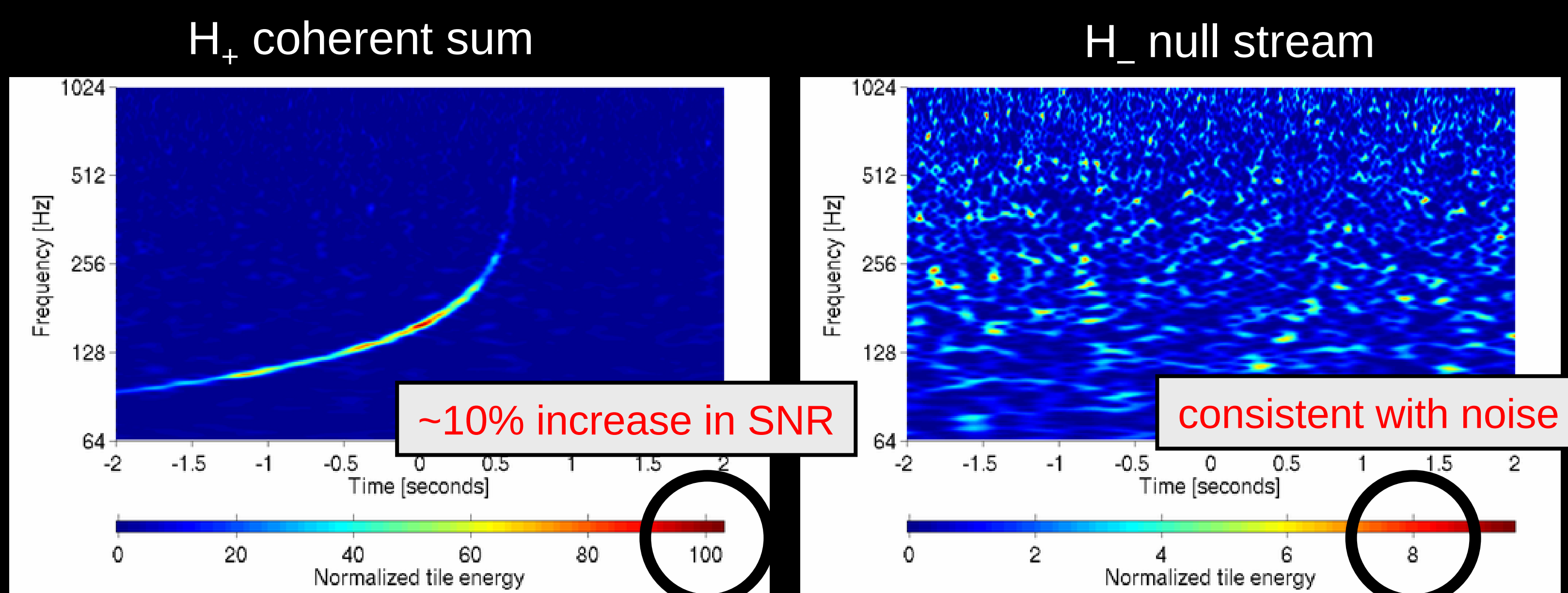




Q-pipeline



Simulated 1.4/1.4 $M_\odot$ inspiral at 5Mpc



Coherent WaveBurst

H1

H2

L1

$$2L = \sum_{i,j} \langle x_i x_j \rangle C_{ij} = E_{i=j} + E_{i\neq j}$$

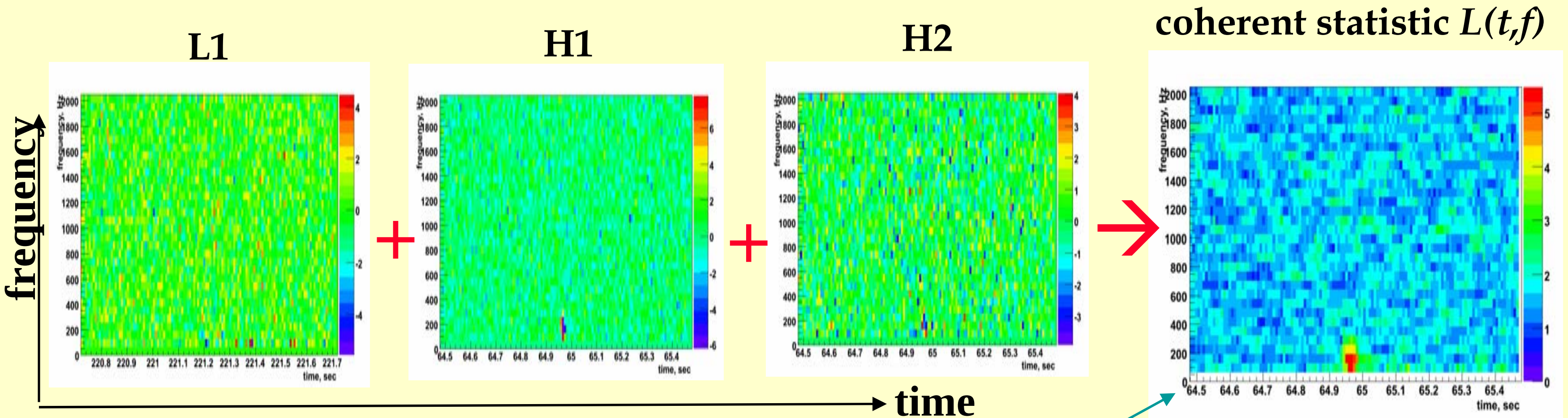
$$ecor = \sum_{i\neq j} L_{ij}$$

$$cc = \frac{ecor}{ecor + null}$$

$$\rho = \sqrt{\frac{|ecor|}{n}} \cdot cc$$

n = number of detectors

Burst Candidates



$$L(t,f) = \max_{h_+ h_\times \theta\varphi} \sum_k \frac{1}{2\sigma_k^2(f)} \left[x_k^2[t,f] - \left(x_k[t,f] - \xi_k[t,f]\right)^2 \right]$$

$$\xi_k = h_+ F_{+k} + h_x F_{xk}$$

Strengths of Each Analysis

BlockNormal/AstroBurst :

Statistical robustness. Avoids frequency regions of non stationary noise. Single-interferometer efficiency curves for astrophysical population interpretation.

Q-pipeline:

optimal use of H1 and H2 to maximize SNR and provide strong constistency test to distinguish burst candidates from noise transients.

Coherent WaveBurst:

coherent combination of data from an any detector network.

Status:

all three searches in advanced stage (background with time slides, efficiency studies, review). Current plan (may change…) is to “open the box” for all three simultaneously once they are ready and we have a plan for how to combine results.

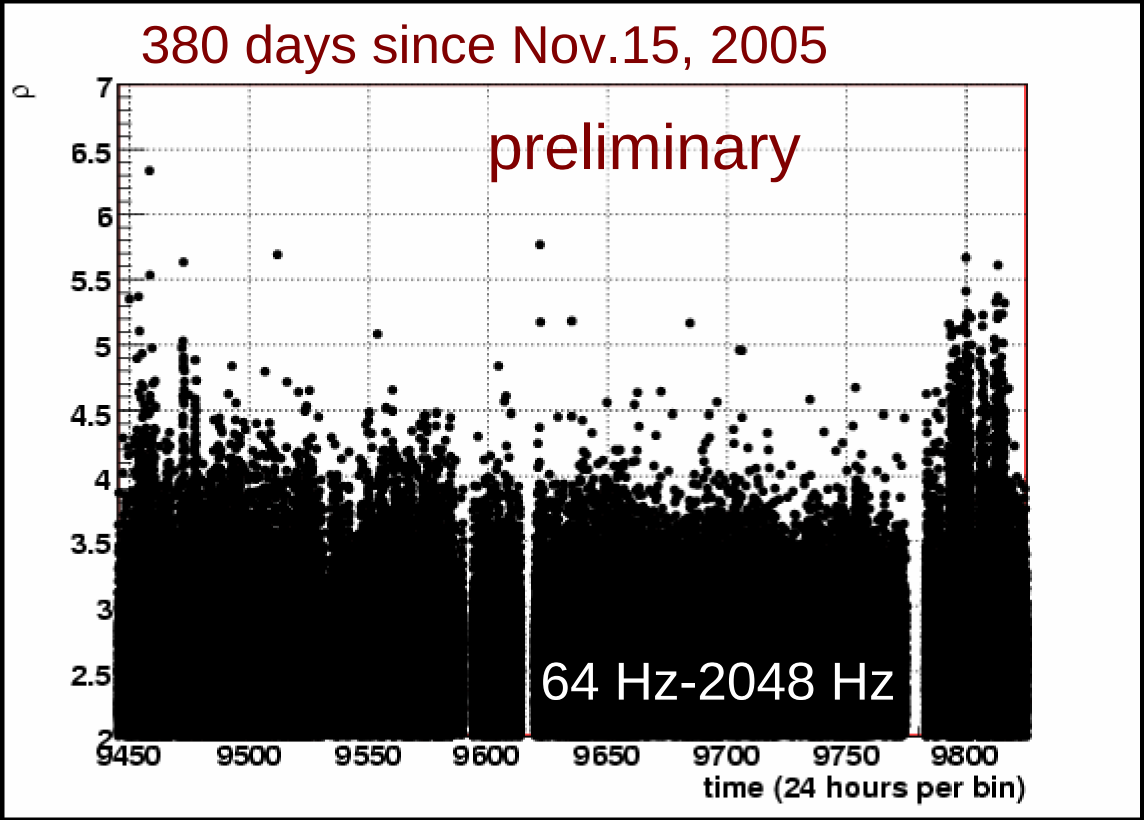
Some Issues / Highlights

Data Quality and Veto

- Known data quality issues flagged by detector characterization team used as veto
- Organized in 4 categories
- DQ veto classification decided a priori based on efficiency on removing single-interferometer transients and dead time and on accidental triple coincidences.
- For details, please see poster by L. Blackburn

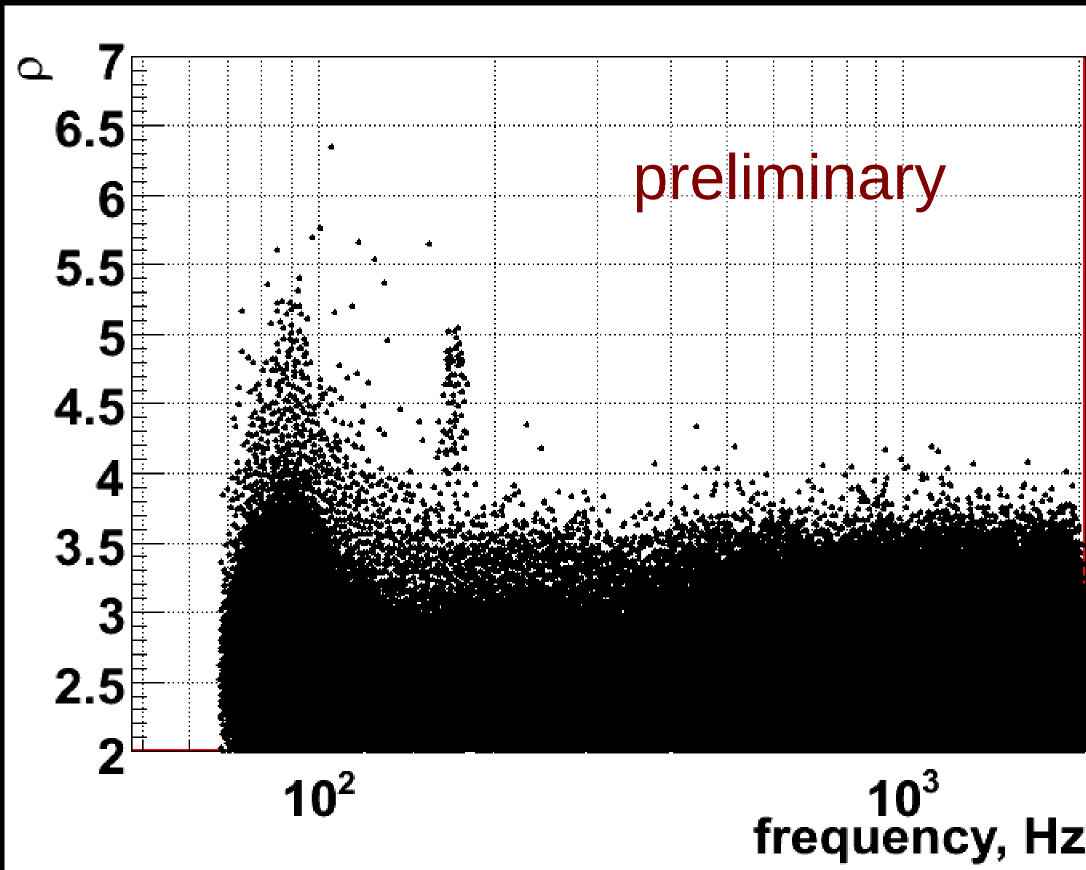
- Additional veto: correlations between single-interferometer transients on 300+ auxiliary channels and the gravitational-wave channel
  - Veto-yield on single-instrument glitches is ~ 10% of outliers (~10^{-21} sqrt(Hz) and above), with ~ 0.5% dead time
- However, veto efficiency for individual channels is strongly time-dependent during the S5 run: time-dependent tuning?
- Also considering different vetoes for each of the 3 analyses

Time Dependence



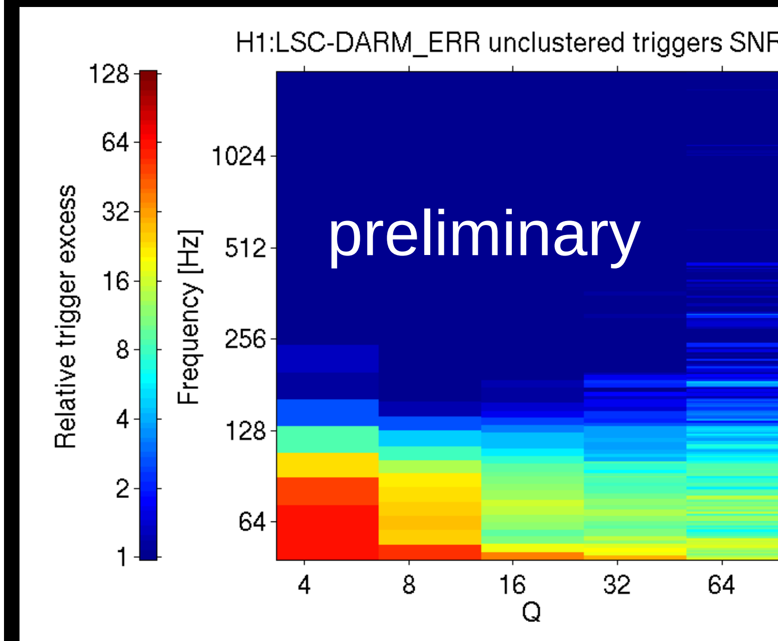
1 year of coherent WaveBurst triggers (100 time-lags)

Frequency Dependence



From coherent WaveBurst, after cut, on cross-correlation statistics, no data quality

100 time lags, total live time 46 years



From Q-pipeline,
Excess w/r/t gaussian
Unclustered triggers with SNR>5

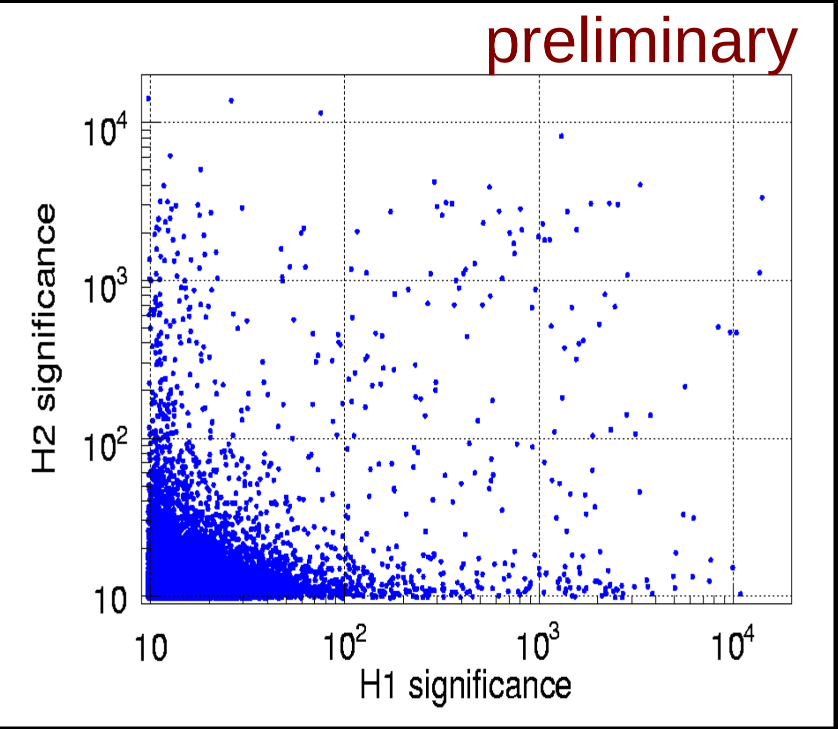
A random H1 day, no data quality

H1-H2

- Livetime in the first year:
  - H1H2L1 ~ 179 days
  - H1H2 ~ 257 days (additional 78 days to be searched)
- We are working on issues to be solved when comparing H1H2 and H1H2L1
- In particular, correlated noise transients in the two Hanford detectors (mostly at low frequency)

  ⇒ need the full veto power of

  a null-stream analysis

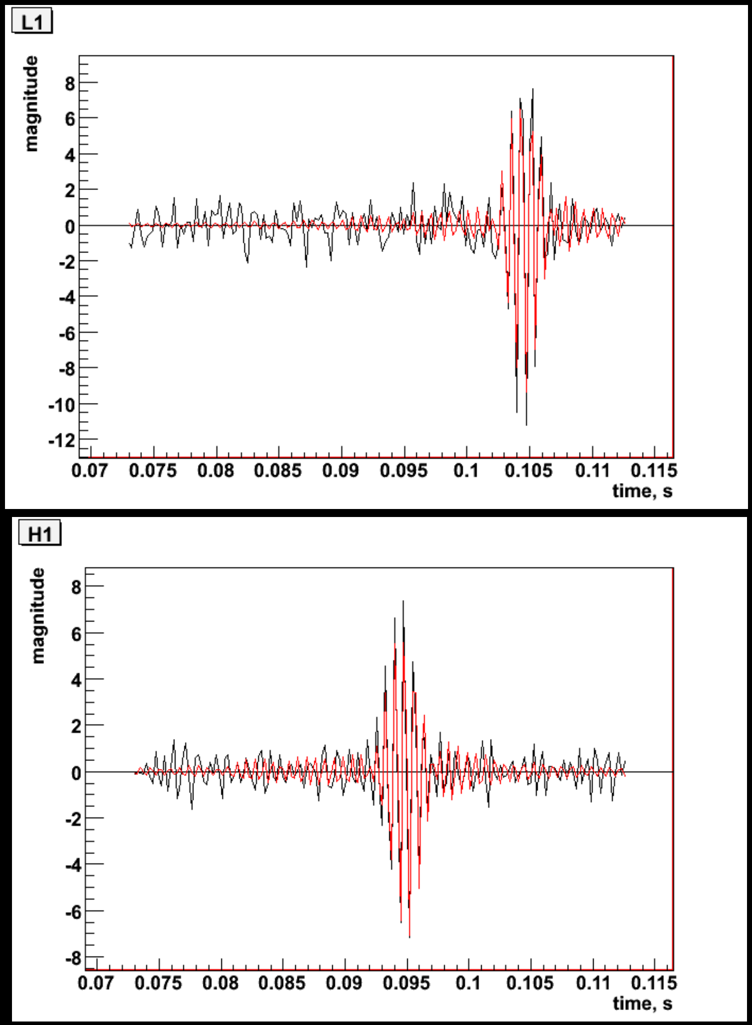


Strength of single-interferometer transients found within 50ms in H1 and H2.
First-year sample used for veto studies.

Follow-up

- Developed a “detection checklist” to follow up candidate events that pass the consistency tests built in each of the three analysis pipelines.
- For details, talk by R. Gouaty
- Among the new features, developing algorithms for waveform reconstruction and sky maps with the coherent event display (here is an example of simulated signal on band-limited noise).

  See Coherent Event Display poster by A. Mercer

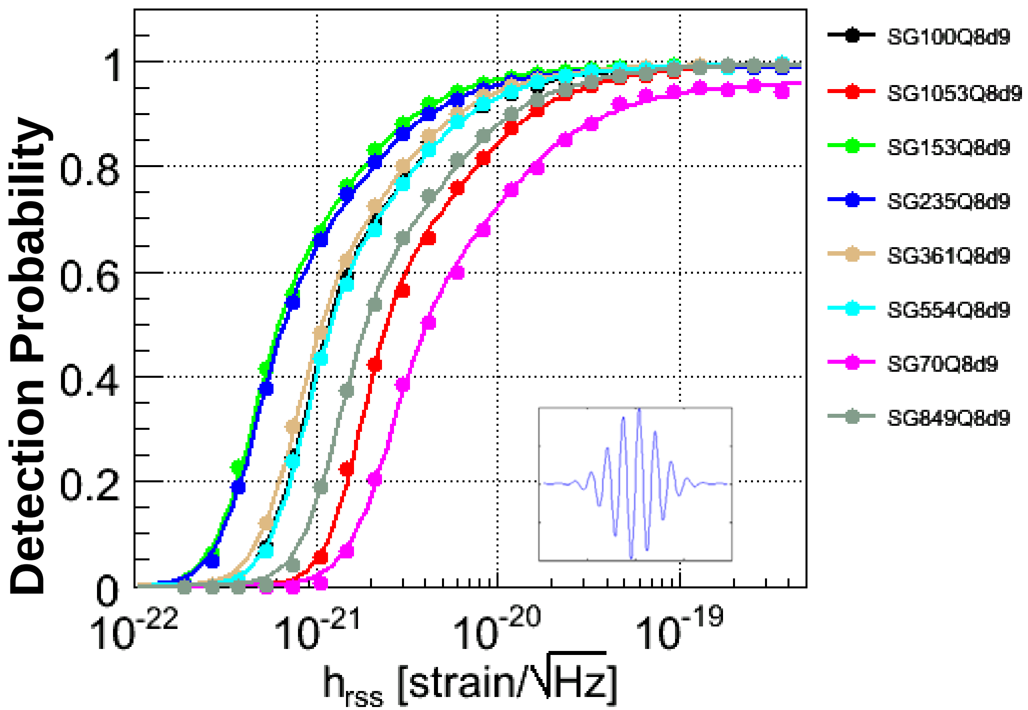


Simulated signal,
sine-gaussian 1304Hz Q=9
Red: reconstructed response

Expected Reach in S5

Estimated from the first 5 months of the run, with the same analysis method used in the previous run (S4)

Detection Efficiency / Range



$$h_{\rm rss} \equiv \sqrt{\int \left(|h_+(t)|^2 + |h_\times(t)|^2\right) dt}$$

Instantaneous energy flux:

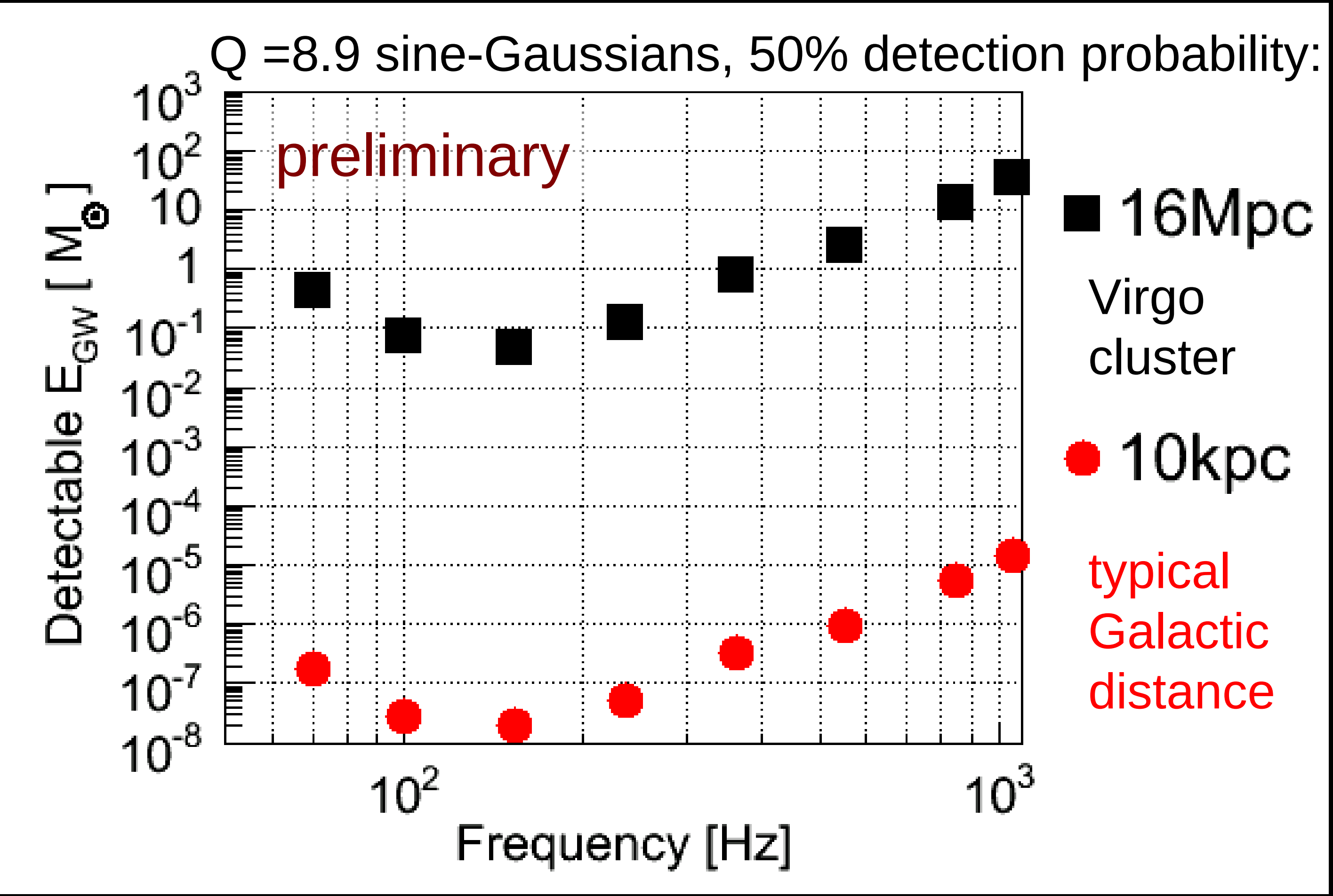
$$\frac{d^2 E_{\rm GW}}{dA\, dt} = \frac{1}{16\pi} \frac{c^3}{G} \left\langle (\dot{h}_+)^2 + (\dot{h}_\times)^2 \right\rangle$$

Assume isotropic emission to get rough estimates

For a sine-Gaussian with *Q*>>1 and frequency f_0 :

$$E_{\rm GW} = \frac{r^2 c^3}{4G} (2\pi f_0)^2 h_{\rm rss}^2$$

Detection Efficiency / Range



For a 153 Hz, *Q* =8.9 sine-Gaussian, the S5 search can see with 50% probability:

~ 2×10^{-8} $M_\odot c^2$ at 10 kpc (typical Galactic distance)

~ 0.05 $M_\odot c^2$ at 16 Mpc (Virgo cluster)

Order of Magnitude Range Estimate for Supernovae and BH Mergers

Model dependent!

Ott, Burrows, Dessart and Livne, PRL 96, 201102 (2006)

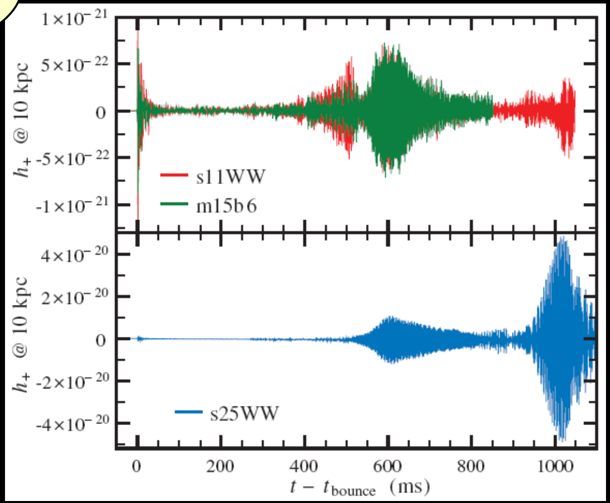
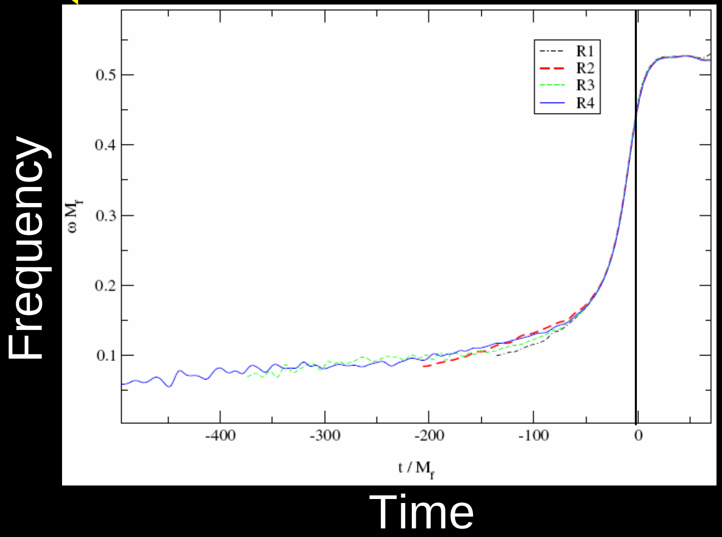


TABLE I. MODEL SUMMARY.

Model	Δt^{a} (ms)	$\lvert h_{+,max}\rvert^{b}$ (10^{-21})	$h_{char,max}^{b,c}$ (10^{-21})	$f(h_{char,max})$ (Hz)	E_{GW}^{d} $(10^{-7} M_\odot c^2)$
s11WW	1045	1.3	22.8	654	0.16
s25WW	1110	50.0	2514.3	937	824.28
m15b6	927.2	1.2	19.3	660	0.14

11 $M_\odot$ progenitor (s11WW model)
$\Rightarrow$ reach ~ 0.4 kpc
25 $M_\odot$ progenitor (s25WW model)
$\Rightarrow$ reach ~ 16 kpc



$$f_{\rm peak} \approx \frac{0.46}{2\pi M_f} \approx \frac{15\ \rm kHz}{(M_f/M_\odot)}$$

Baker et al, PRD 73, 104002 (2006)

Assuming ~3.5% mass radiates in the merger:
10+10 $M_\odot$ binary $\Rightarrow$ reach ~ 3 Mpc
50+50 $M_\odot$ binary $\Rightarrow$ reach ~ 100 Mpc

Conclusion

- All-sky S5 burst search in progress, using 3 independent pipelines.
- Exploring combinations of L1, H1 and H2; when available, GEO data used for follow-up. Details of how to combine results are still to be finalized.
- Also under discussion: how to combine results from the 3 searches.
- In the spirit of blind analysis, the current plan (may change!) is to “open the box” once 3 analyses are ready.