Searches for Gravitational Wave Bursts with LIGO

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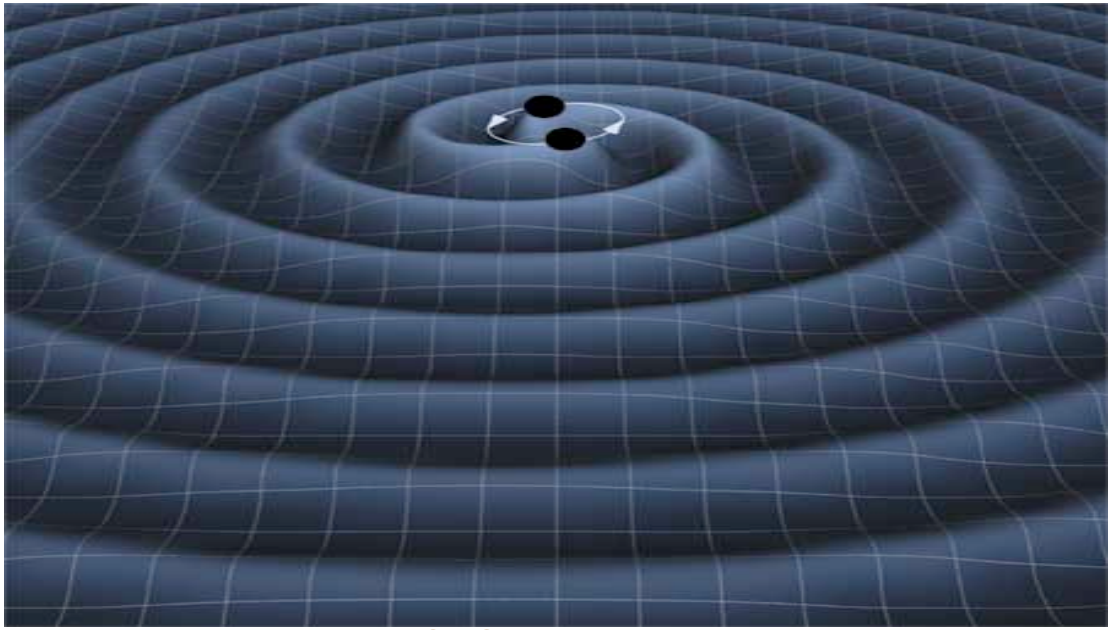
LIGO Scientific Collaboration



LIGO Detectors

- LIGO observatory contains 2 (H2) km and 4 km (H1) interferometers at Hanford, WA and a 4 km interferometer at Livingston, LA (L1). They are designed to detect gravitational waves from astrophysical sources.

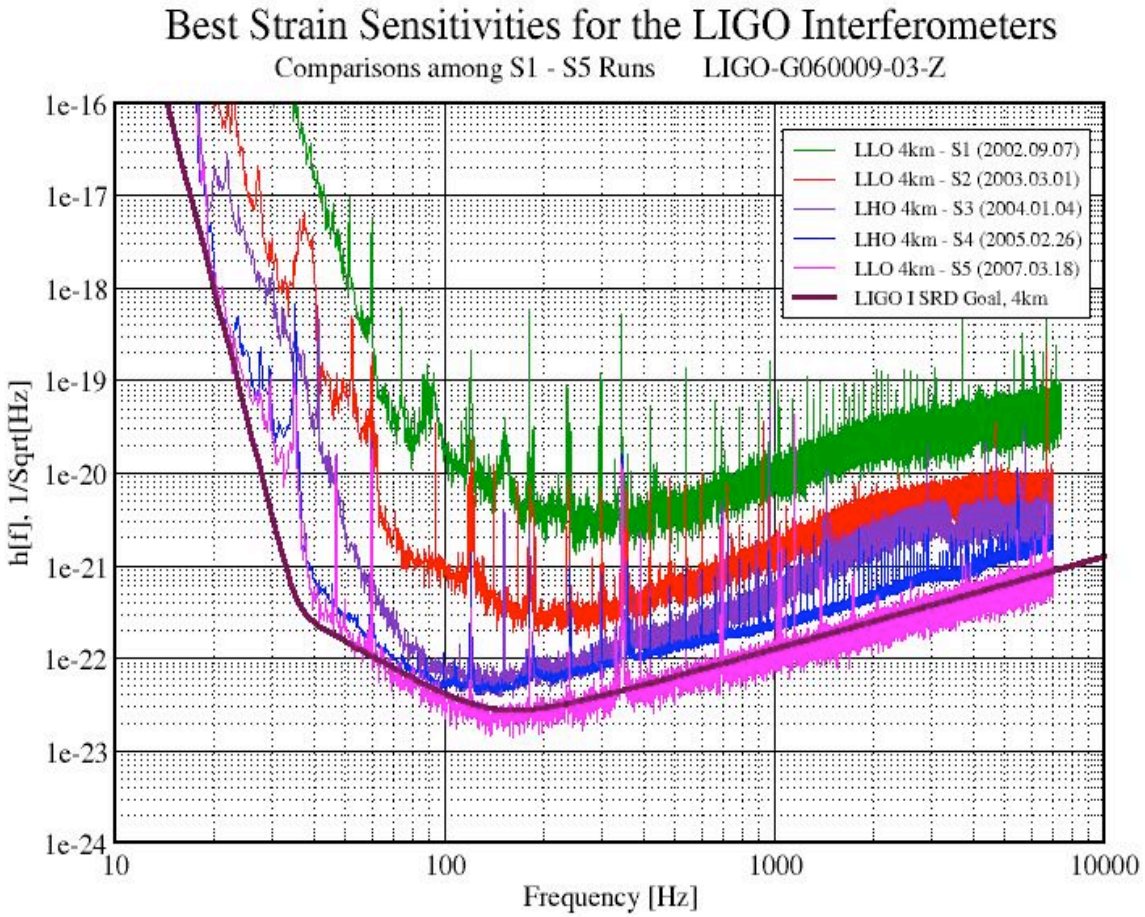
Hanford

Livingston

Inside the LIGO control room

LIGO Sensitivity

- Dimensionless strain ($h = \Delta L/L$) is the main observable measured by a gravitational wave interferometer.

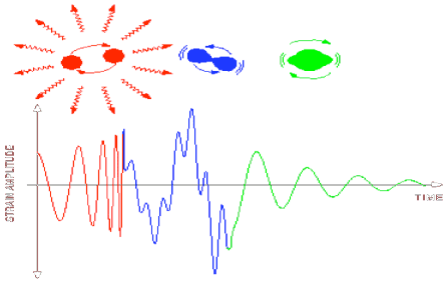


Latest LIGO science run (S5) in progress since Nov. 2005.

Expected to end in Fall 2007 after collecting one year of coincident data at design sensitivity.

LIGO Science Searches

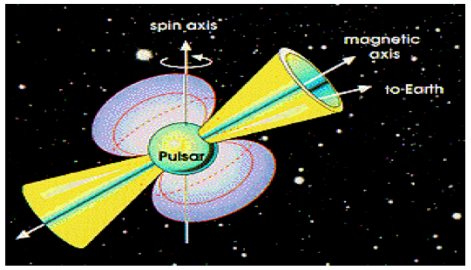
- Compact Binary Inspirals :
  - ➢Template based searches for merger of neutron star/black hole based binaries



- Unknown burst sources :
  - ➢Short duration transients(< 1sec) without any knowledge of waveform (core-collapse SN, GRBs etc)

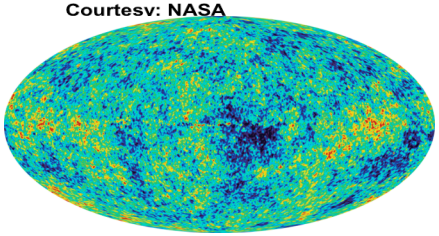
SN1987A

- Periodic sources :
  - ➢Known and unknown pulsars in our galaxy



Courtesv: NASA

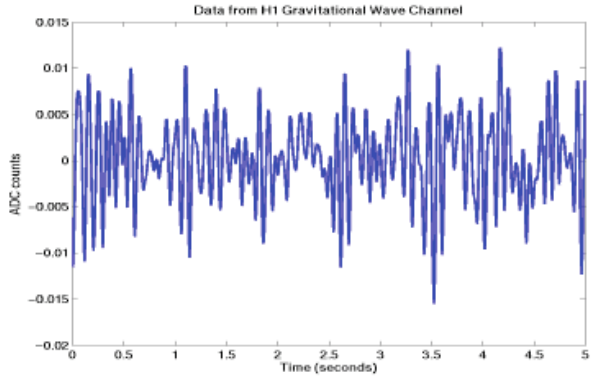
- Stochastic Background :
  - ➢Search for cosmological background from a variety of early universe processes.



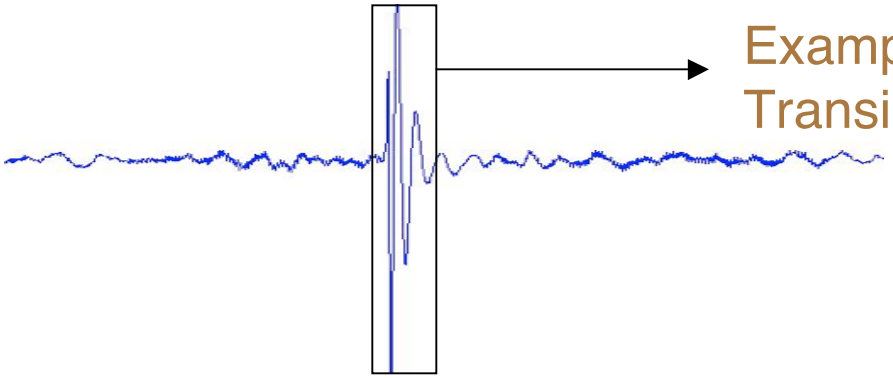
NASA WMAP

Rudiments of Burst Searches

- LIGO data containing possible gravitational wave signal is sampled at 16 KHz and digitized a data acquisition unit called gravitational wave channel (LSC-DARM_ERR)



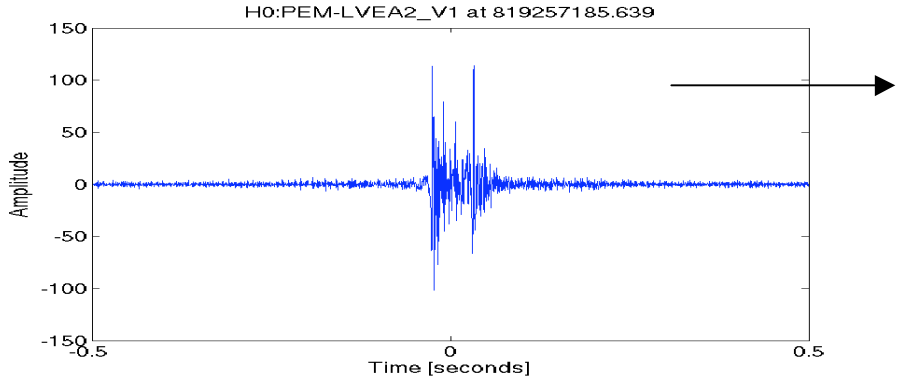
- Various algorithms (wavelet, Fourier,time-domain, etc) are applied to find transients in the time-series (after whitening).



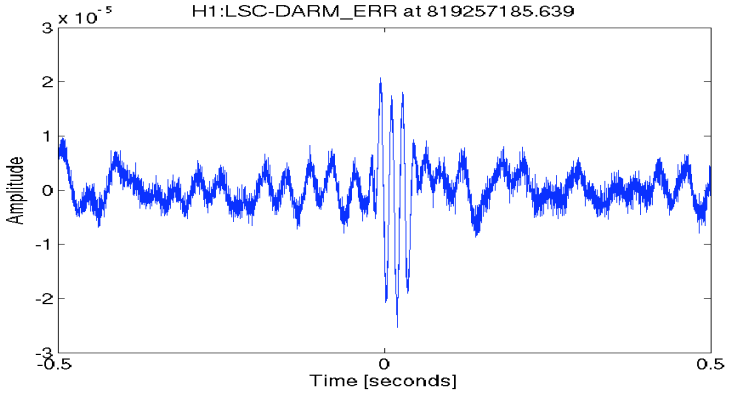
Data Selection

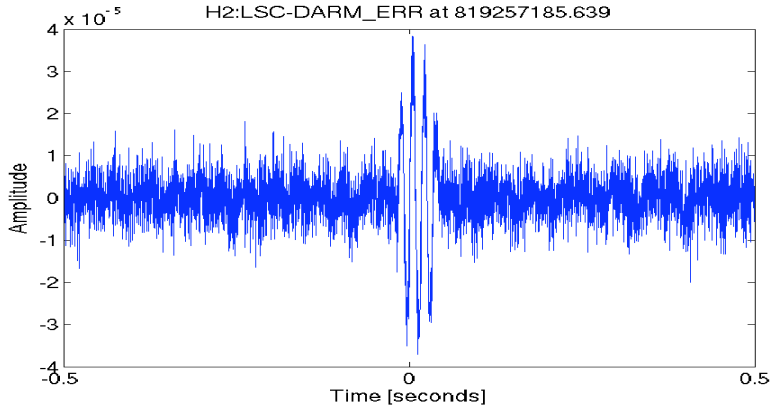
- LIGO data contains non-Gaussian noise transients that can masquerade as gravitational wave burst events.
- Lot of effort to identify such periods of bad data and to veto candidate burst candidate events using various diagnostic information.

Example : Disturbance of mains power causing simultaneous noise transients in H1, H2



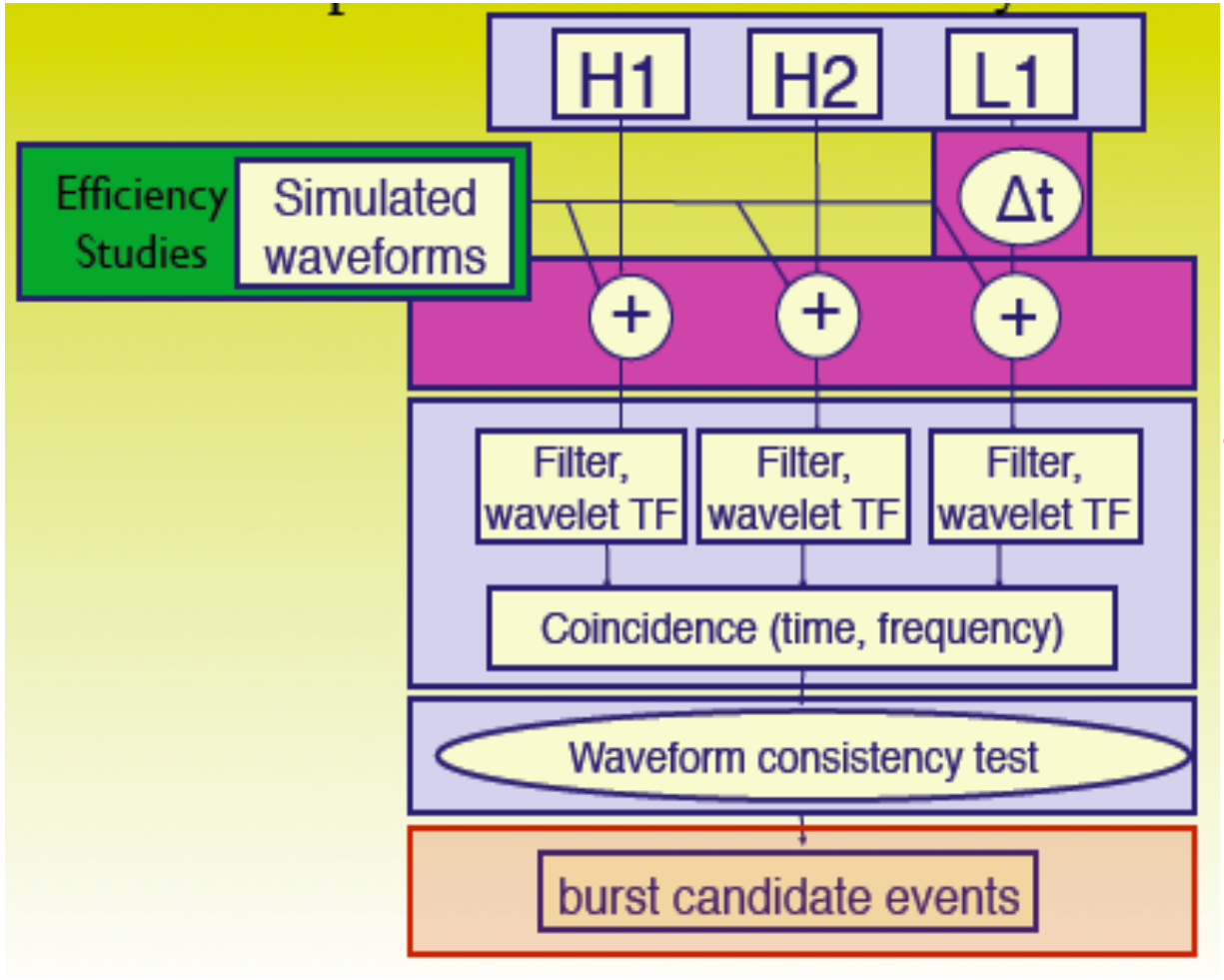
Mains power voltage monitor





All Sky Burst Search Flowchart

Wavelet-based search pipeline used in S2, S3, S4, S5 (1st 5 months)



Time Slides

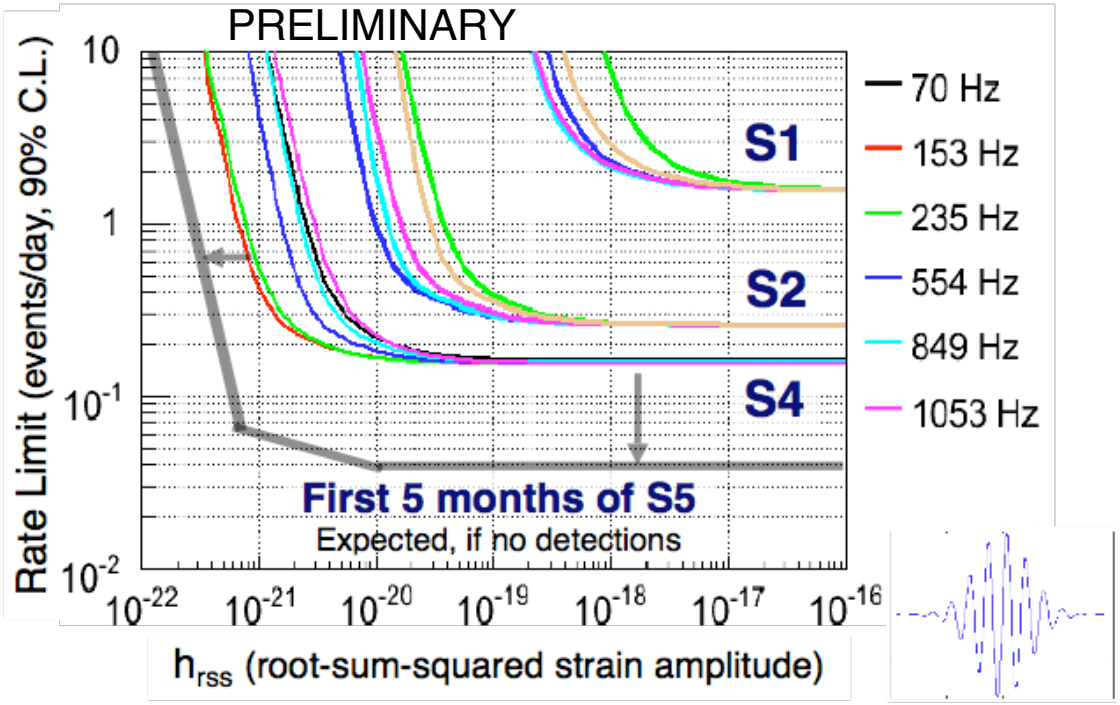
Threefold Coincidence

Transient event generation using wavelets

Cross-correlation test using waveform consistency

See arXiv:0704.0943 for more details of S4 searches

Results and Current Sensitivity



Efficiency Estimate :

E_{gw} @153 Hz with 50% detection probability:

~ 2×10^{-8} $M_\odot c^2$ at 10 kpc

~ 0.05 $M_\odot c^2$ at 16 Mpc

Core-collapse Supernovae : *Ott et al , PRL 96, 201102 (2006)*

11 $M_\odot$ progenitor ⇒ reach ≈ 0.4 kpc
25 $M_\odot$ progenitor ⇒ reach ≈ 16 kpc

Binary Black Hole mergers : *Baker et al PRD 73, 104002 (2006)*

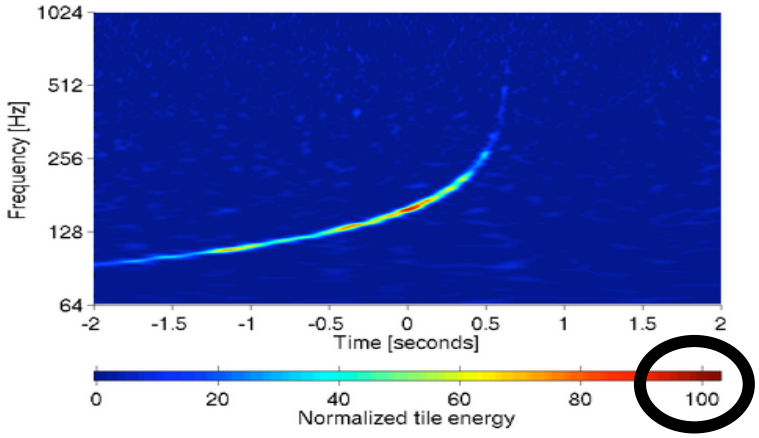
10+10 $M_\odot$ binary ⇒ reach ≈ 3 Mpc
50+50 $M_\odot$ binary ⇒ reach ≈ 100 Mpc

Other All Sky Searches

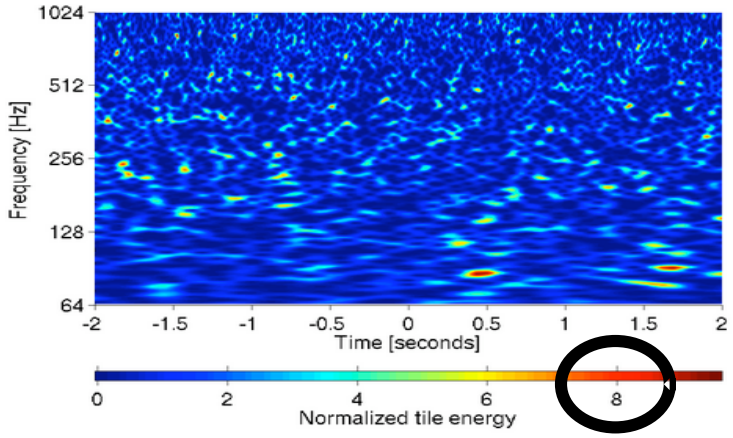
- Network analysis searches taking into account projections of antenna pattern onto detectors according to GR *Klimenko et al , PRD 72, 122002 (2005)*
- Single detector triggers based on time-domain change-point analysis followed by correlation consistency test. *McNabb et al , CQG 21, S1801 (2004)*
- Making coherent and null sum of two Hanford detectors using Q-transform.

  Simulated gravitational wave signal from 2 1.4 $M_{\odot}$ coalescence at 5 Mpc

H+ Coherent sum (10% increase in SNR)



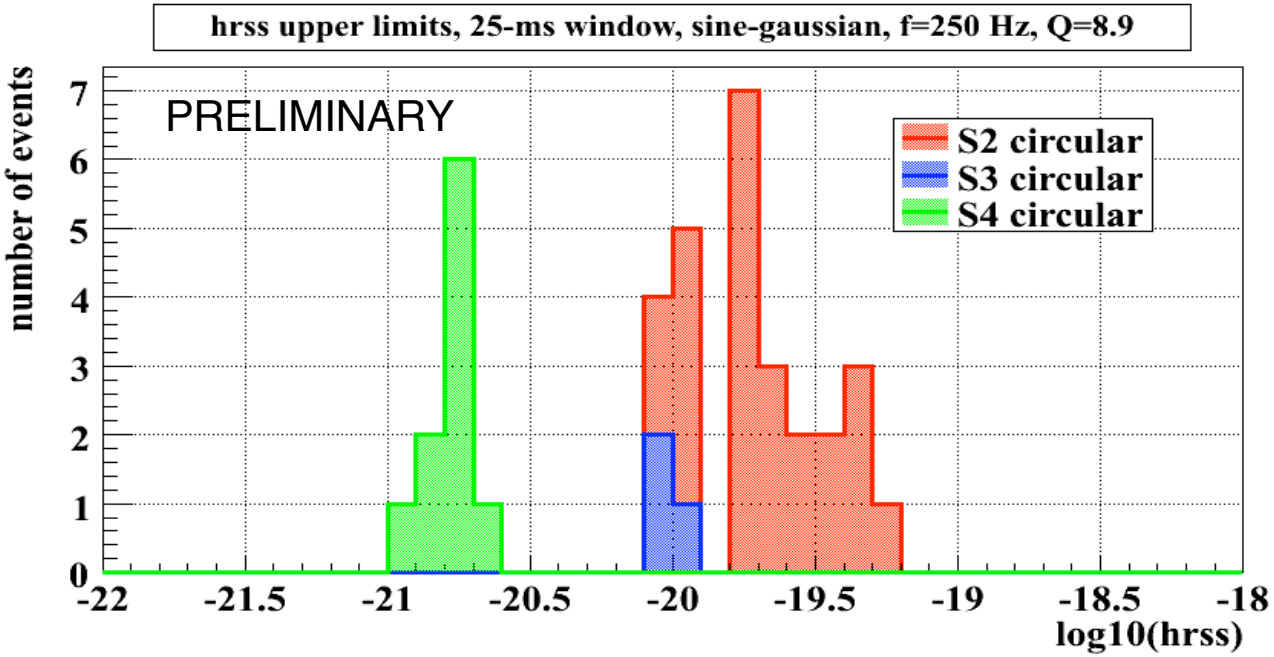
H- null sum (consistent with noise)



- Searches for cosmic string cusps and kinks

S2/S3/S4 GRB Searches

- Search for short-duration gravitational wave bursts coincident with GRBs with S2, S3, S4 data.
- Analysis based on pair-wise cross-correlation of two interferometers with target durations ~1 ms to ~100 ms and bandwidth 40 - 2000 Hz
- No gravitational wave signal associated with 39 GRBs in S2, S3, S4

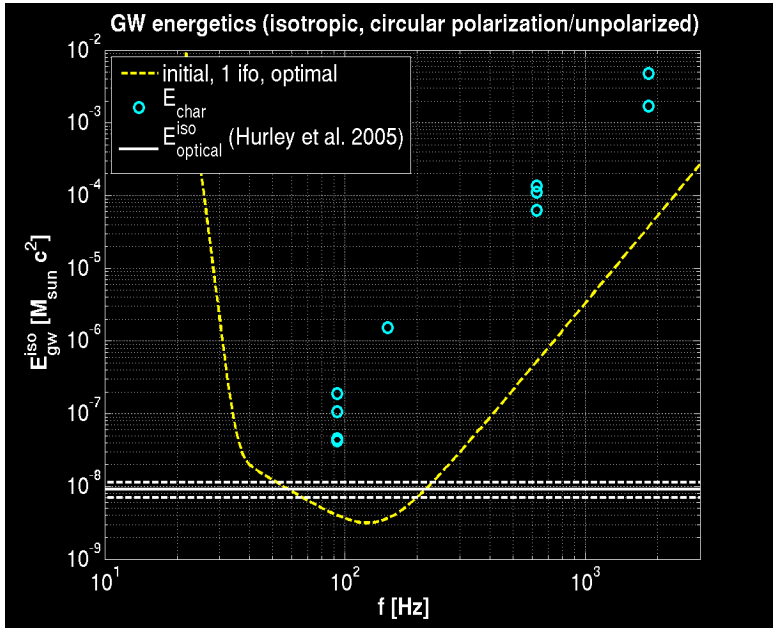


Sensitivity similar to untriggered searches

S5 search ongoing

SGR 1806-20 Search

- On Dec. 27 2004, SGR 1806-20 located at ~ 10 Kpc emitted a giant flare with energy ~10^{46} ergs with a pulsating tail lasting 6 minutes.
- Only 1 LIGO detector (4km Hanford) was in science mode.
- Band-limited excess power search for quasi-periodic GW signal.
- No gravitational wave signal found.



For the 92.5Hz QPO (150s-260s)

$E^{iso,90\%} = 4.3 \times 10^{-8}\ M_{sun}c^2$

Energy comparable to the energy released by flare in electromagnetic spectrum

See astro-ph/0703419 for more details

Conclusions

- All sky burst searches for first 4 science runs finished . No gravitational wave bursts detected so far.
- Rapid near-online searches for gravitational wave burst with many independent algorithms being done during S5.
- VIRGO detector near Pisa, Italy also started their science run in May. Data exchange and joint LIGO-VIRGO burst searches in progress.
- Many external triggered searches (such as GRBs, SGRs, pulsar glitches) are underway during S5.

For more details go to www.ligo.org.