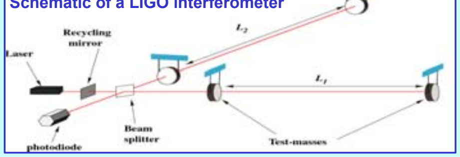
A High Frequency Search
for Gravitational Wave Bursts
In the 1st Year of LIGO's 5th Science Run

Abstract: Previous burst searches with ground-based interferometers have generally been limited to frequencies below 2 kilohertz. However, various models predict gravitational wave emission in the few-kilohertz range from gravitational collapse, neutron star modes, the mergers of some compact binaries or other astrophysical phenomena. In this poster, we present a more detailed look at the search for transient gravitational waves at frequencies up to 6 kHz during the first year of LIGO's 5th science run, as presented in the talk "All-sky Burst Searches for Gravitational Waves at High Frequencies by Salemi et al.

1. Introduction and Motivation

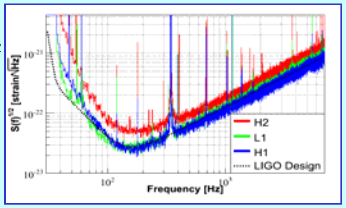
LIGO consists of 3 laser interferometers at 2 sites: a 4 km (H1) and 2 km (H2) interferometer located near Hanford, WA and a 4 km (L1) interferometer near Livingston, LA. The interferometers are designed to measure relative changes in the arm lengths of the interferometers on the order of $\Delta L/L = 10^{-21}$, with coincidence requirement between sites used to separate background noise from actual signal.

Schematic of a LIGO interferometer



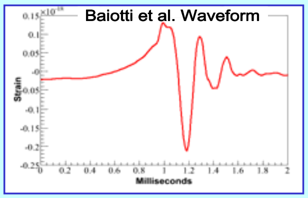
Previous LIGO all-sky burst analyses have focused on frequencies below 2 or 3 kHz. This analysis extends LIGO all-sky searches up to a maximum frequency of 6 kHz. Although this is not the region of optimal sensitivity (see sensitivity curve on the right) there are a number of reasons to conduct analyses in this frequency range:

- Most of this range is not covered by other detectors
- Shot noise dominated few kHz regime has fewer outliers
- A number of theoretical sources are predicted in this regime (see next section)



2. Potential sources of gravitational waves at a few kHz

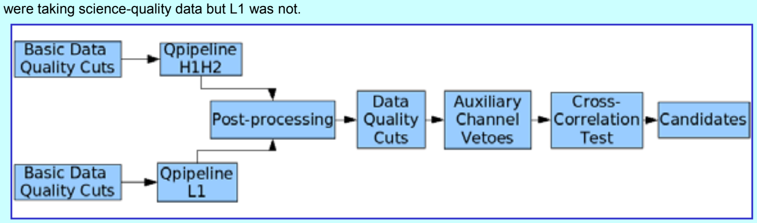
- Neutron star collapse scenarios resulting in rotating black holes
  L. Baiotti *et al*. Phys Rev. Lett. 99, 141101 (2007).
  L. Baiotti *et al*. Class. Quant. Grav. 24, S187 (2007).
- Nonaxisymmetric hypermassive neutron stars resulting from neutron star-neutron star mergers
  R. Oechslin and H.-T. Janka, Phys. Rev. Lett. 99, 121102 (2007).
- Neutron star f-modes
  B.F. Schutz, Class. Quant. Grav. 16, A131 (1999).
- Neutron stars undergoing torque-free precession
  J.G. Jernigan, AIP Conf. Proc. 586, 805 (2001).
- Low-mass black hole mergers
  K.T. Inoue and T. Tanaka, Phys. Rev. Lett. 91, 021101 (2003)
- SGRs
  J.E. Horvath, Modern Physics Lett. A 20, 2799 (2005).



3. Analysis Method

The analysis software QPipeline[1] runs on data passing basic data quality cuts and generates *triggers*, times in which there is excess power in the gravitational strain at each site. The two data streams from the co-located Hanford interferometers are processed as a single coherent stream. Data from the two sites are combined, requiring frequency-consistent coincident triggers within 20 ms (on the order of the predicted travel time for a gravitational wave between the two sites plus padding for uncertainties). Data quality flags and vetoes are applied to reject data which is known to be of poorer quality due to environmental disturbances or problems with the interferometer. Data quality criteria for this analysis was a subset of the data quality criteria applied in the low frequency burst analysis[2] which were empirically measured to be relevant in this frequency range. A cross-correlation follow-up is performed using the program CorrPower[3] to measure the consistency of the waveforms as measured in different interferometers.

The analysis was tuned on background data which was created by sliding the GPS times of Livingston data with respect to Hanford data by a few seconds. This is much greater than the actual travel time between the sites and therefore guarantees a background without a gravitational wave coincident at the two sites. Thresholds of 15 were placed on the normalized energy (Z) from QPipeline at the two sites and a cut was made on the cross-correlation measure from CorrPower, designated Γ, above a value of 6.2. A separate analysis with stricter thresholds was performed as a detection-only search during times when H1 and H2 were taking science-quality data but L1 was not.

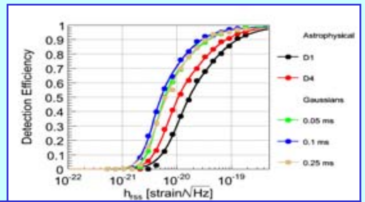


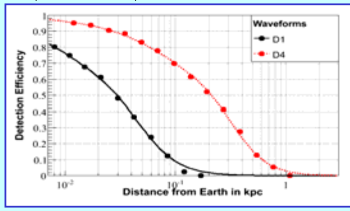
1. S. Chatterji et al. Class. Quant. Grav 21, S1809 (2004).
2. B. Abbott et al. (LSC) submitted to Phys. Rev. D. gr-qc/0905.0020
3. L. Cadonati and S. Marka, Class. Quant. Grav. 22, S1159 (2005).

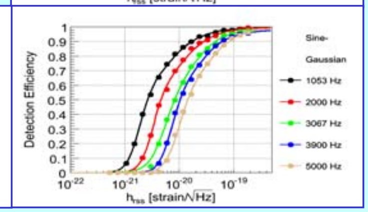
4. Detection Efficiencies

Efficiencies were tested with both ad-hoc and modeled astrophysical waveforms, including:

- Neutron star collapse models by Baiotti et al
  - D1 (1.26 M_{solar}, minimum deformity)
  - D4 (1.86 M_{solar}, maximum deformity)
- Gaussian waveforms
- Gaussian-enveloped sinusoidal waveforms (sine-Gaussians)



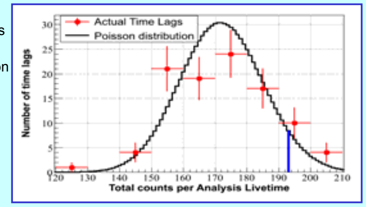




5. Results

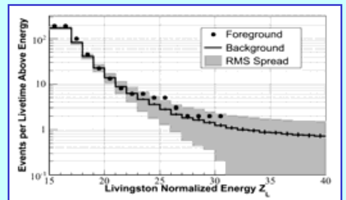
There were no events remaining in the foreground after all cuts were applied. The distribution of sub-threshold events in each background time slide is consistent with Poissonian expectation and the foreground count fits comfortably in this distribution. The separate H1H2-only check also did not produce any event candidates.

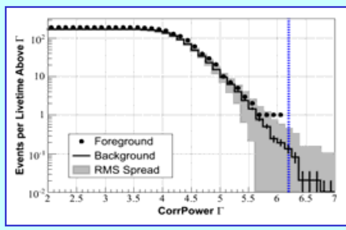
	BackgroundCounts	Normalized Background	Unshifted Count
Coincident Triggers	23361	242.9	265
After Data Quality Cuts	18831	195.8	223
After Vetoes	16547	172.0	193
After Γ>6.2 threshold	11	0.115	**0 (null result)**

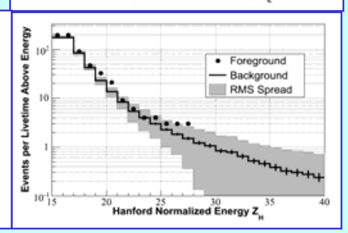


6. Trigger Distributions

Foreground trigger distributions are consistent with background distributions in all 3 variables used to tune the analysis.

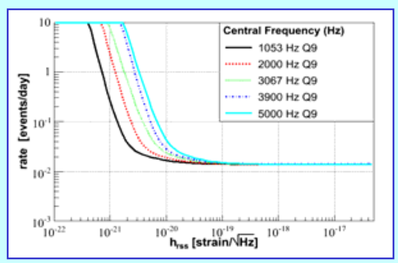






7. Upper Limits

Upper limits were placed on the rate of gravitational wave emission. Due to a livetime of 161.3 days, for strong gravitational waves the limits asymptote to 5.4 events per year.



Summary and Outlook: No gravitational wave burst candidates were identified in the first calendar year of S5 in the few-kilohertz regime, but upper limits were placed on gravitational wave emission in the few-kilohertz regime. See Marco Drago's poster for discussion of the 2nd year S5 / Virgo 1st science run high frequency analysis using a different methodology. We will continue to search for gravitational waves in this regime in future science runs. More details on the analysis described in this poster can be found in **arXiv/0904.4910**.

Document Number: LIGO-G0900539-v2