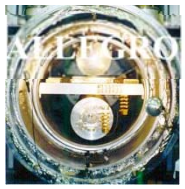


Stochastic background search using LIGO Livingston and ALLEGRO

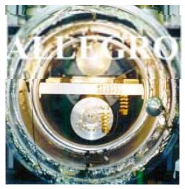
Martin McHugh

Loyola University New Orleans

on behalf of the

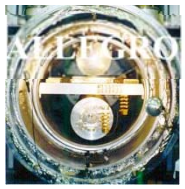
LIGO Scientific Collaboration

LSU-ALLEGRO group



Outline

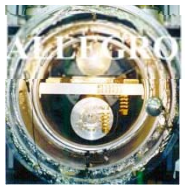
- Stochastic background searches
- Features of the LLO-ALLEGRO stochastic analysis
- Calibrated response of the ALLEGRO detector
- LIGO S2 science run data
- Expected sensitivity from S2 data



Stochastic background searches

- Set of unresolved gravitational wave sources
  - Cosmological or astrophysical in origin
- Characterized by $\Omega(f) = \frac{1}{\rho_{\mathrm{crit}}} \frac{d\rho_{\mathrm{GW}}}{d(\ln f)}$
- Search strategy -- look for correlations between two gravitational wave detectors
  - Assume background is isotropic, gaussian, stationary and $\Omega(f) = \text{constant}$ over the frequency band of the measurement
  - Assume instrument noise is uncorrelated between detectors
- Optimally filtered cross-correlation statistic

$$Y = \int df\, \tilde{s}_1^*(f)\, \tilde{Q}(f)\, \tilde{s}_2(f)$$



Stochastic background searches

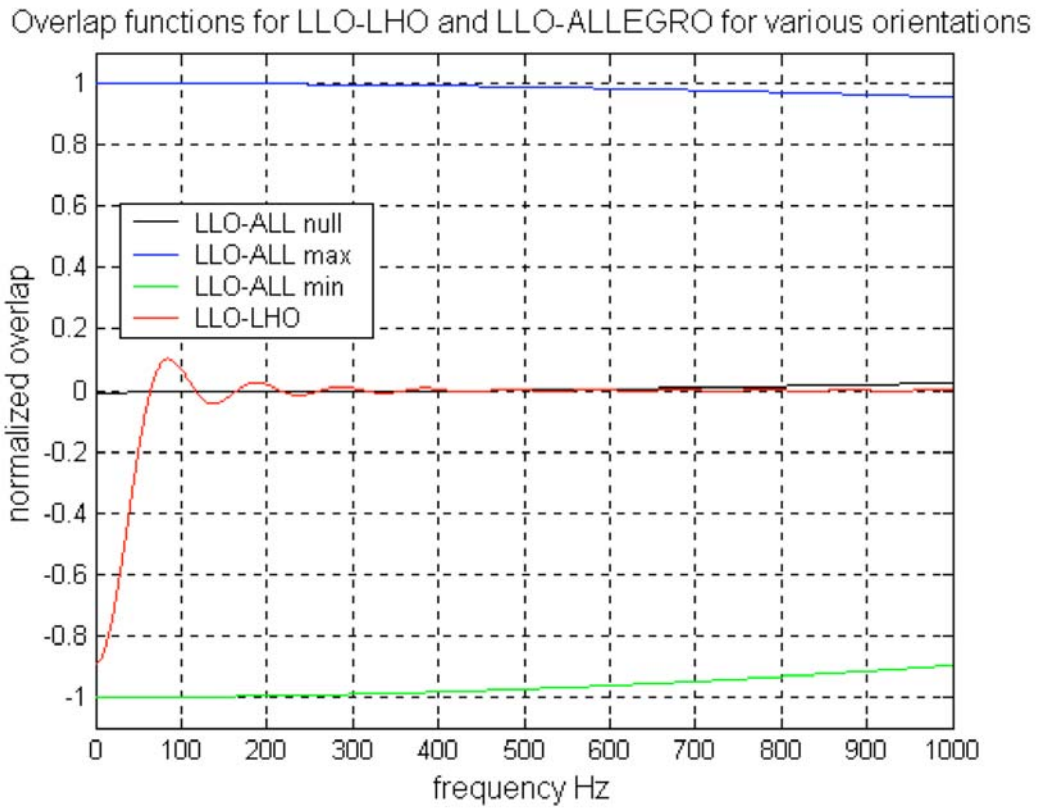
- Optimal filter $\tilde{Q}(f) \propto \dfrac{\gamma_{12}(f)\,\Omega_{\mathrm{GW}}(f)}{f^3\,P_1(f)\,P_2(f)}$

  - Weighted by the noise in each detector
  - γ is the frequency dependent overlap reduction function
  - Optimal for given Ω_{GW} spectrum

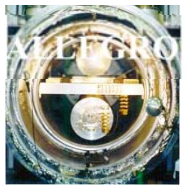
LLO - ALLEGRO correlation

Key features:

- Ability to modulate the signal – rotate to align/misalign antenna patterns -- get direct measure of non-GW correlations.
- Aligned orientation at 40km separation gives overlap near unity up to kHz frequencies -- higher range than LLO-LHO (sensitive band of resonant detector is limiting factor)

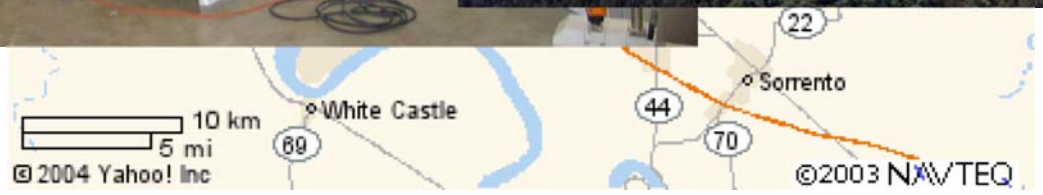


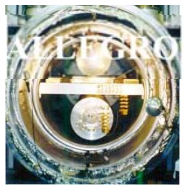
*Modulating the experimental signature of a stochastic gravitational wave background, **Finn and Lazzarini** Phys. Rev. D **64,** 082002 (2001)



L1

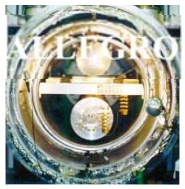
A1


22
Sorrento
44
70
10 km
5 mi
White Castle
69
©2004 Yahoo! Inc
©2003 NAVTEQ



Overview of technique

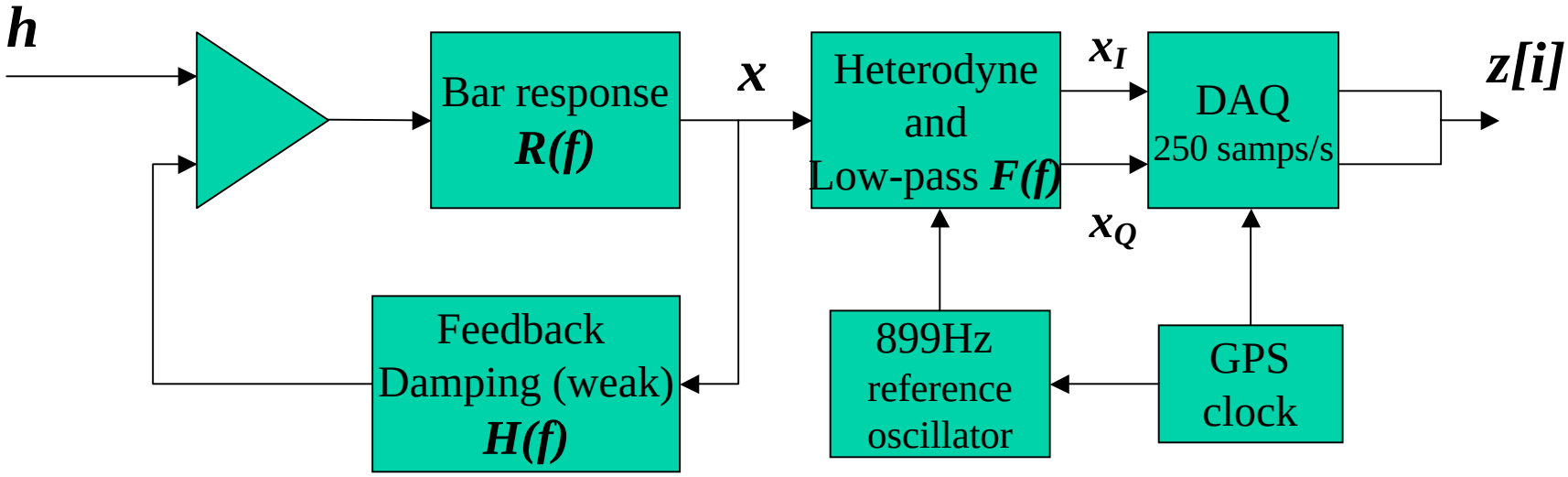
- Start with A1, L1 time domain data streams
  - A1 signal is heterodyned in hardware
    - reference frequency 899Hz for S2
  - different sampling rates
    - 250 samples/sec for A1 - complex time series,
    - 16384 samples/sec, downsampled to 2048 for L1
- Frequency domain
  - Equal time stretches give same frequency resolution
  - match bins over appropriate frequency band
    - 774Hz-1024Hz for A1
    - 0-1024Hz for L1



Calibration of A1 data

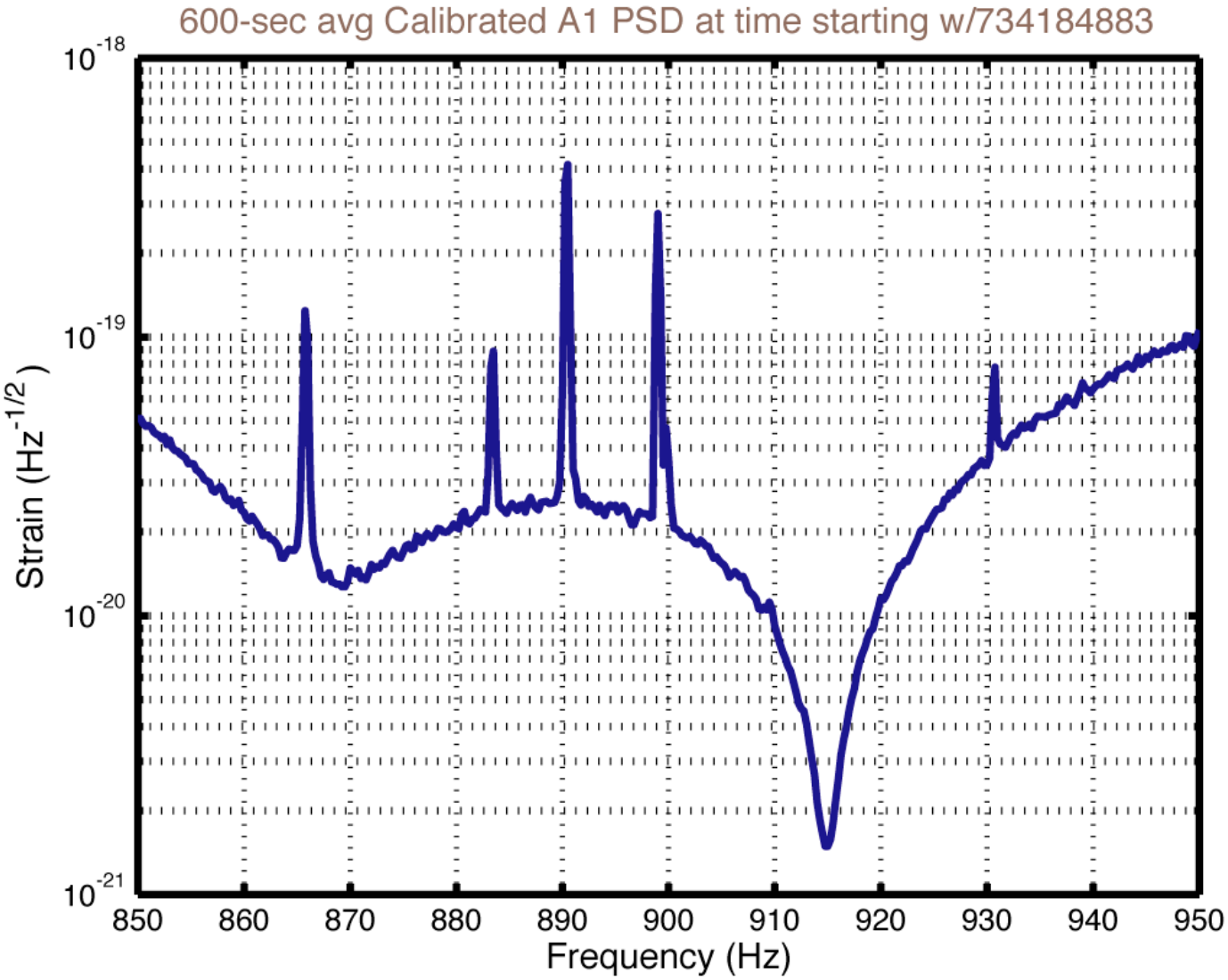
- This analysis is a fully coherent search, combining bar and interferometer data
- For event list based burst searches, a full phase consistent response function of the detector is not required
- New calibration code needed for this analysis

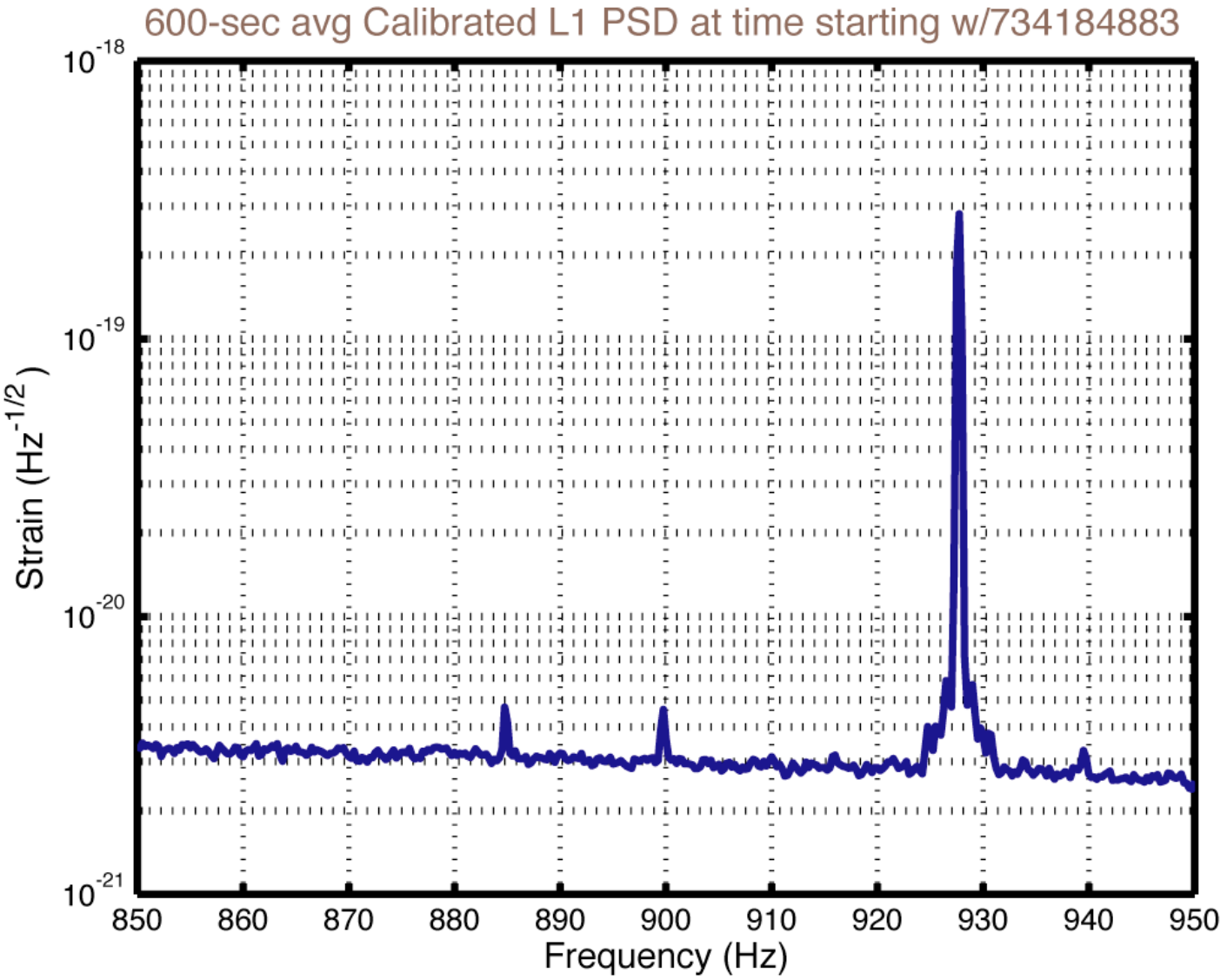
Signal path



$$\tilde{x}(f) = \tilde{h}(f)\frac{R(f)}{1 + R(f)H(f)} \cong \tilde{h}(f)\cdot R(f)$$

$$\tilde{z}(f) = \tilde{h}(f_{\text{ref}} + f)\cdot R(f_{\text{ref}} + f)\cdot F(f) \;\rightarrow\; \tilde{h}\left[k_{\text{ref}} + k\right] = \frac{\tilde{z}[k]}{R[k_{\text{ref}} + k]\cdot F[k]}$$


600-sec avg Calibrated A1 PSD at time starting w/734184883
Strain (Hz^-1/2)
10^-18
10^-19
10^-20
10^-21
850
860
870
880
890
900
910
920
930
940
950
Frequency (Hz)


600-sec avg Calibrated L1 PSD at time starting w/734184883
Strain (Hz^-1/2)
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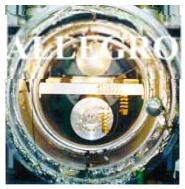
10^-19
10^-20
10^-21
850
860
870
880
890
900
910
920
930
940
950
Frequency (Hz)



ALLEGRO S2 data

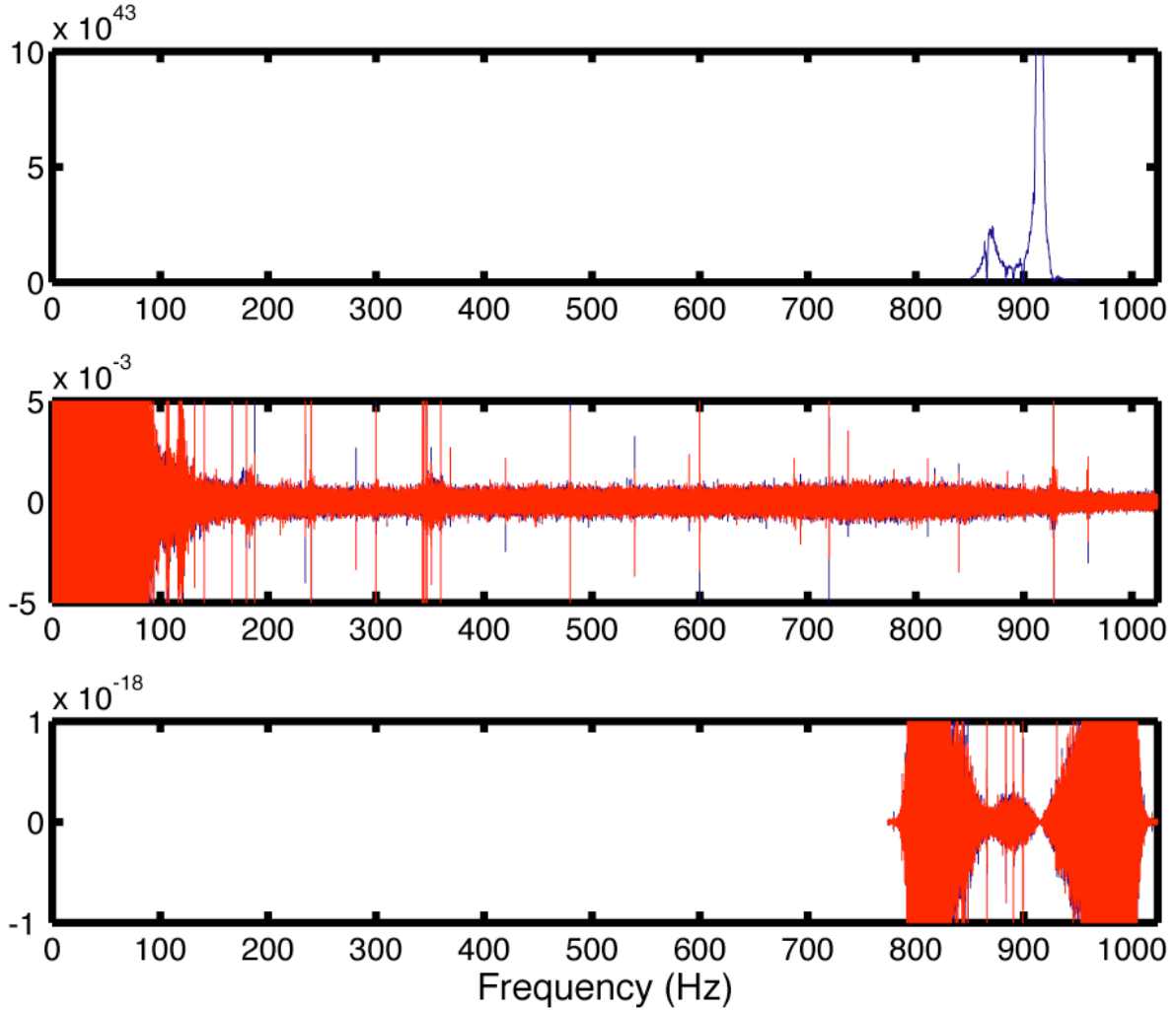
- LIGO S2 run -- Feb 14-Apr 14, 2003 -- is only science run for which ALLEGRO was operational
- Bar was operational for roughly half of S2
  - ~180 hrs coincident with LIGO science segments
  - made two rotations
    - ~101hrs in misaligned null orientation
    - ~45.5 hrs aligned with ifo Yarm
    - ~33 hrs aligned with if Xarm
- Current status of S2 analysis
  - Preliminary calibration for bar data
  - calibration applied to 58x600 second playground segments
  - Matlab analysis pipeline in place, have run playground jobs

Frequency domain

optimal filter

LIGO

ALLEGRO



Expected S2 sensitivity

- Over band 850Hz-950Hz, for ~75 hrs of aligned data (SNR=1), the projected sensitivity from the noise curves gives $\Omega_{GW} \approx 6$
- Corresponds to gravitational waves with amplitude noise spectral density of $\approx 5 \times 10^{-23} \frac{\text{strain}}{\sqrt{\text{Hz}}}$

  (for flat Ω_{GW} this is a $f^{-3/2}$ spectrum -- nearly constant over narrow band)