Stochastic Group Status

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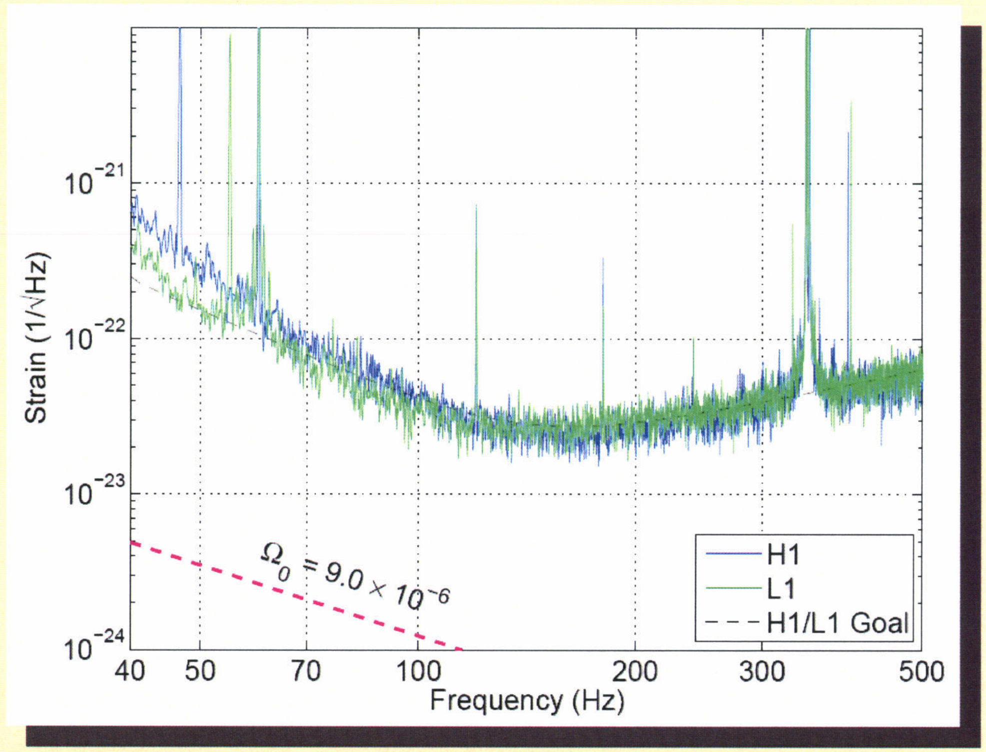
ON BEHALF OF THE LSC/VIRGO STOCHASTIC GROUP

Update on isotropic search: Analyzed Data

- New result uses data up to Jan 22, 2007.
  - About 140 days of effective observing time.
- Currently analyzing the rest of the run:
  - Duty cycle and sensitivity improved during the run.
  - Expect 2x more data and ~2x better final sensitivity.
  - Expect to complete the analysis ~2 months after v4 h(t) is available.
- Also looking at H2L1.
  - Expect ~10% sensitivity improvement.

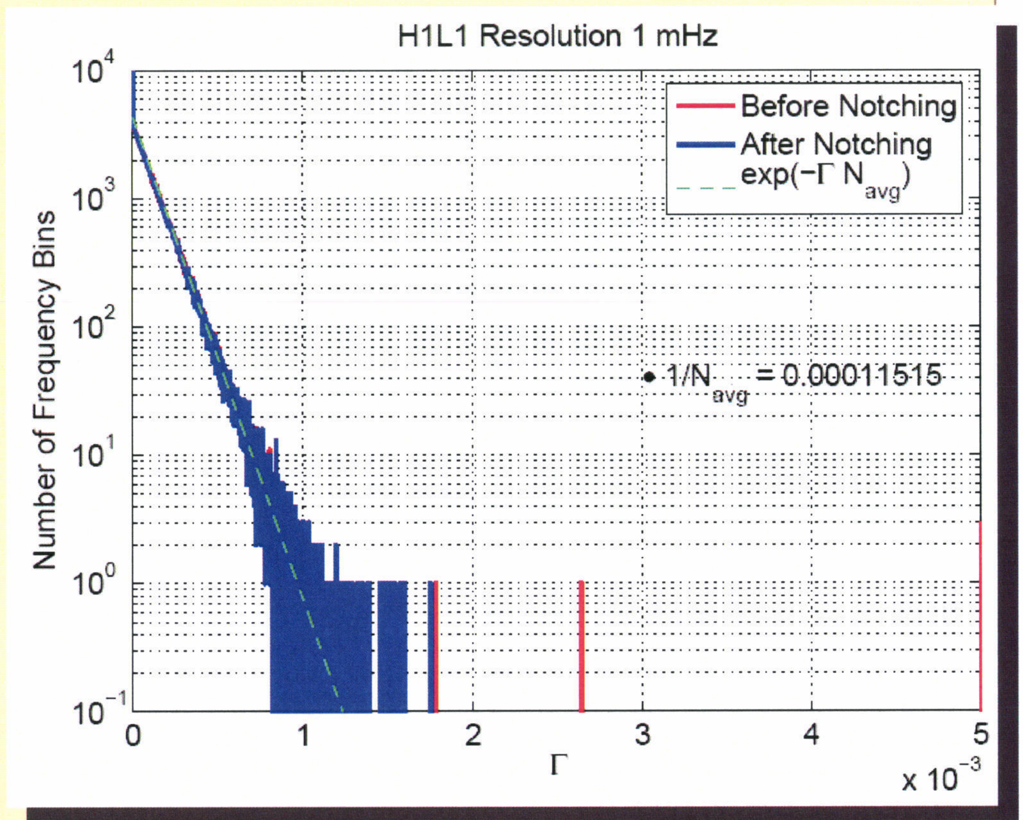
Typical strain sensitivities during S5.



S5: H1L1 Coherence

- Calculated using S5 data up to 04/07.
  - Using the same data segments as in stochastic analysis.
- Very clean:
  - 48.0 Hz (3rd harmonic of 16 Hz).
  - 108.85 Hz – simulated pulsar.
  - 60 Hz (only 0.1 Hz resolution).
  - Additional very weak lines at 46.45 Hz and 47.58 Hz (10 mHz resolution).
    - Likely instrumental.
    - Notching them has negligible effect on the final result.
    - Currently still included.
- No sign of the 1 Hz harmonics, which were present in the S4 search.

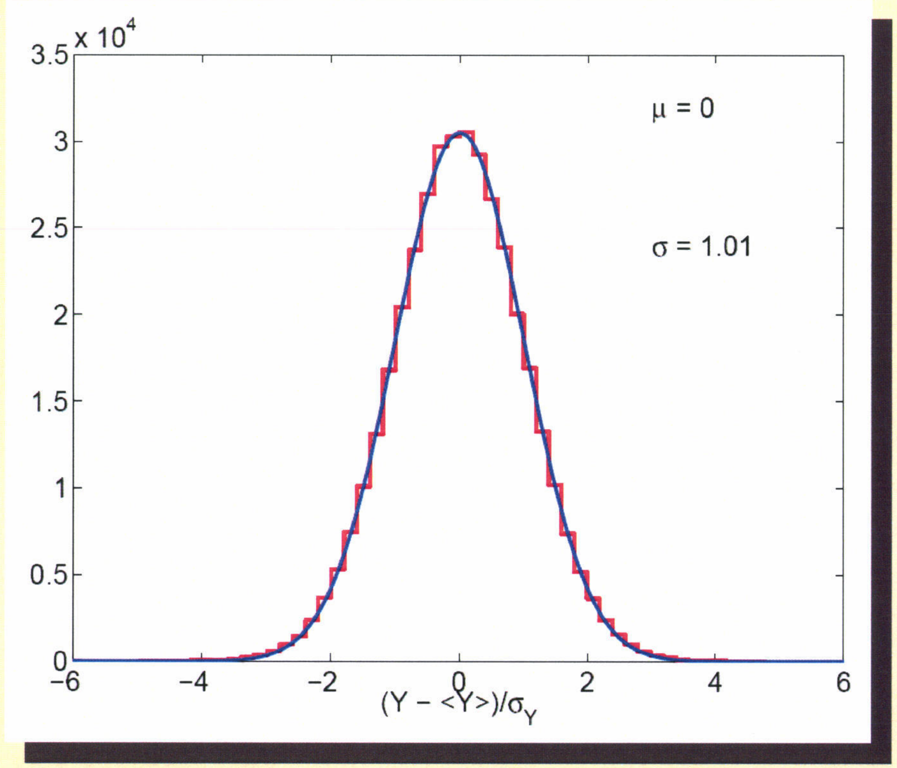
$$\mathrm{Coh} = \mathrm{CSD}^2 / \mathrm{PSD}_1 / \mathrm{PSD}_2$$



S5: Data Quality

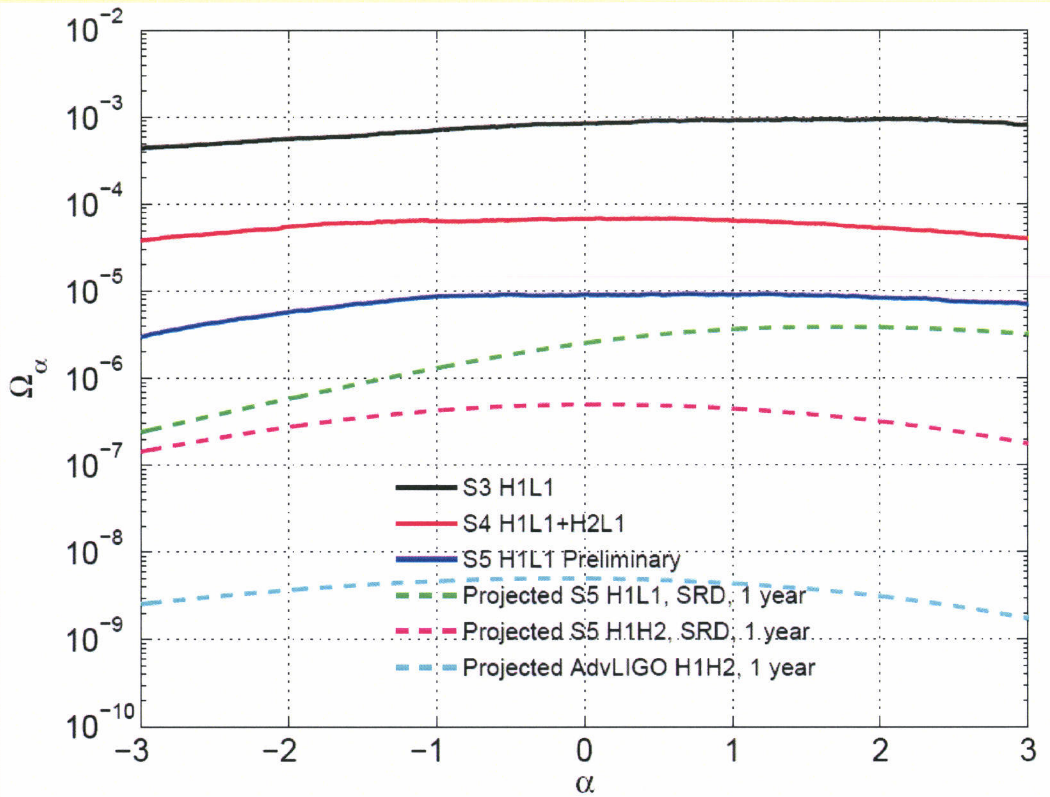
- Frequency notches:
  - 48.0 Hz
  - 60 Hz harmonics
  - Simulated pulsar lines
- Data Quality Cuts:
  - Require $|\sigma_{i\pm1} - \sigma_i| / \sigma_i < 20\%$ (removes 4-5% of the segments).
  - Reject a handful of segments identified to contain glitches in coherence studies.
- All cuts defined **blindly** (with unphysical time-shift).
  - Exception: a stretch of data was found to have bad v3 h(t) after the box was opened.
- Residual distribution consistent with gaussian.
  - Passes the Kolmogorov-Smirnov test.

Residual distribution is Gaussian.



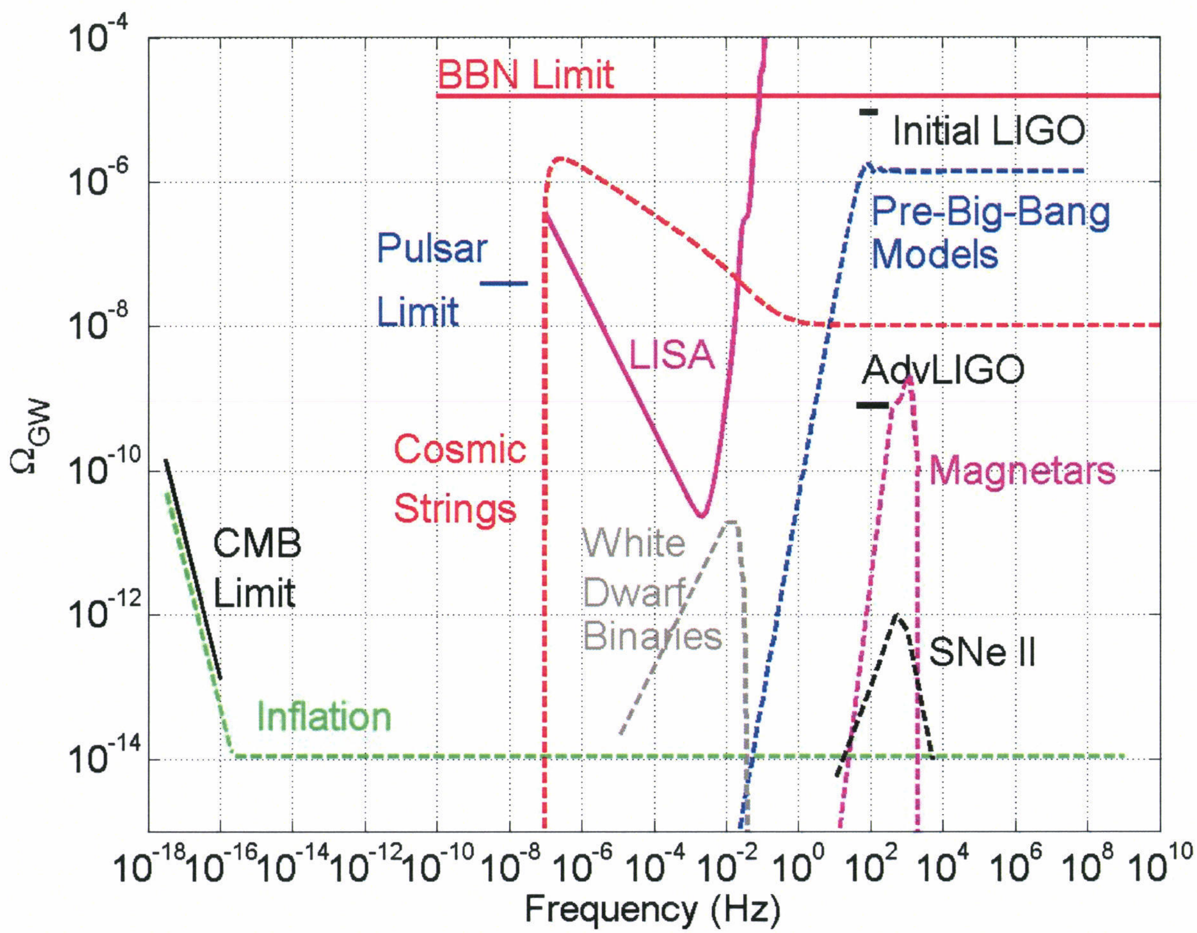
Reach as a Function of Spectral Slope

$$\Omega_t(f) = \Omega_\alpha (f/100\text{ Hz})^\alpha$$



- S3 H1L1: Bayesian 90% UL.
- S4 H1L1+H2L1: Bayesian 90% UL.
- S5 H1L1 preliminary: Bayesian 90% UL.
- Expected S5: design strain sensitivity and 1 year exposure.
- AdvLIGO: sensitivity optimized for binary neutron star search, and 1 year exposure.

Landscape



- Surpassed BBN bound

- Beginning to probe models.

H2L1 coherence studies (up to 22 jan 2007)

- Lines

Freq	Range
60.0	59.9 - 60.1
128.0	
430.3	
485.7	

$\Delta f = 10^{-1}$ Hz

Freq	Range
128.00	127.99 - 128.01

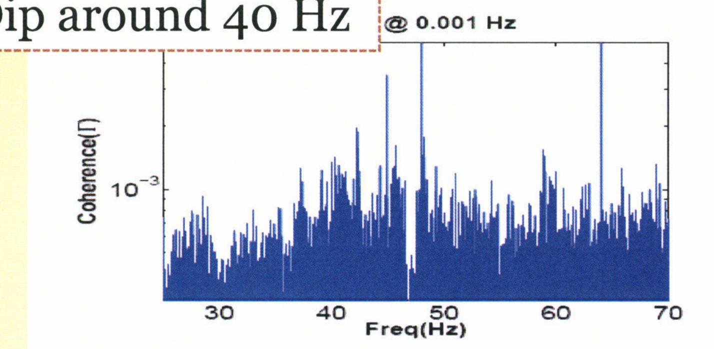
$\Delta f = 10^{-2}$ Hz

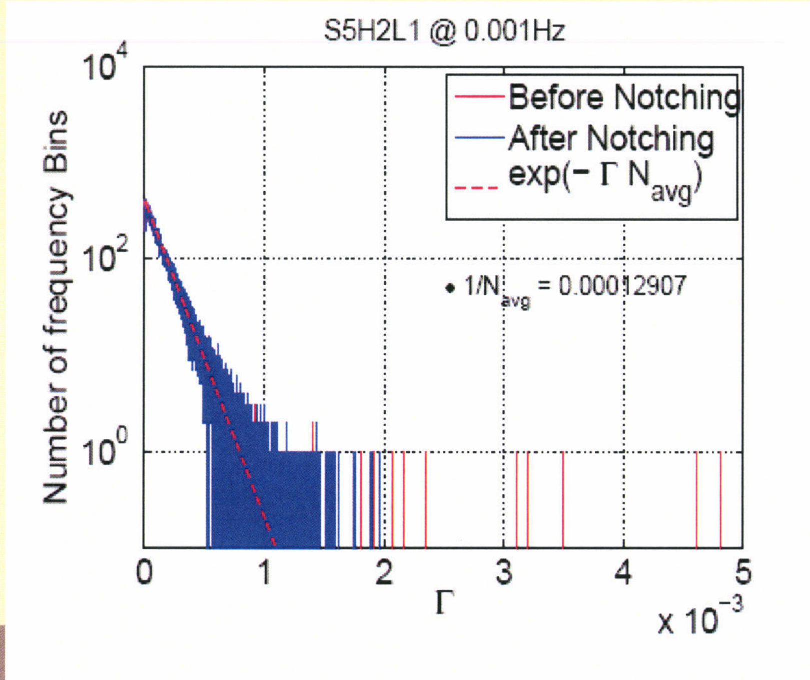
Freq	Range
44.912	44.912 - 44.913
48.000	47.999 - 48.000
64.000	
80.000	
100.000	
108.848	
128.000	
200.000	
256.000	

$\Delta f = 10^{-3}$ Hz

- Power line
- 16 Hz harmonics
- Pulsar injection
- Not identified

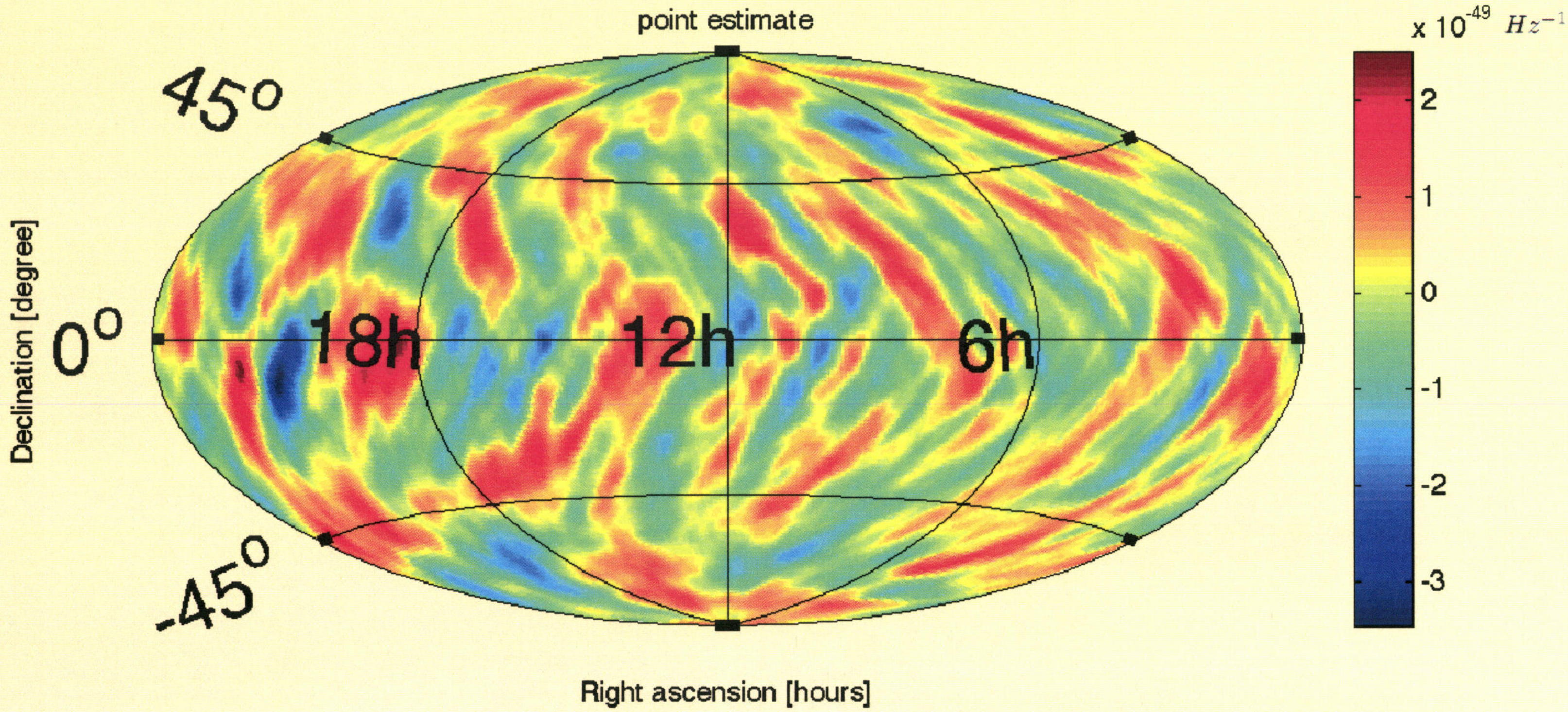
Dip around 40 Hz





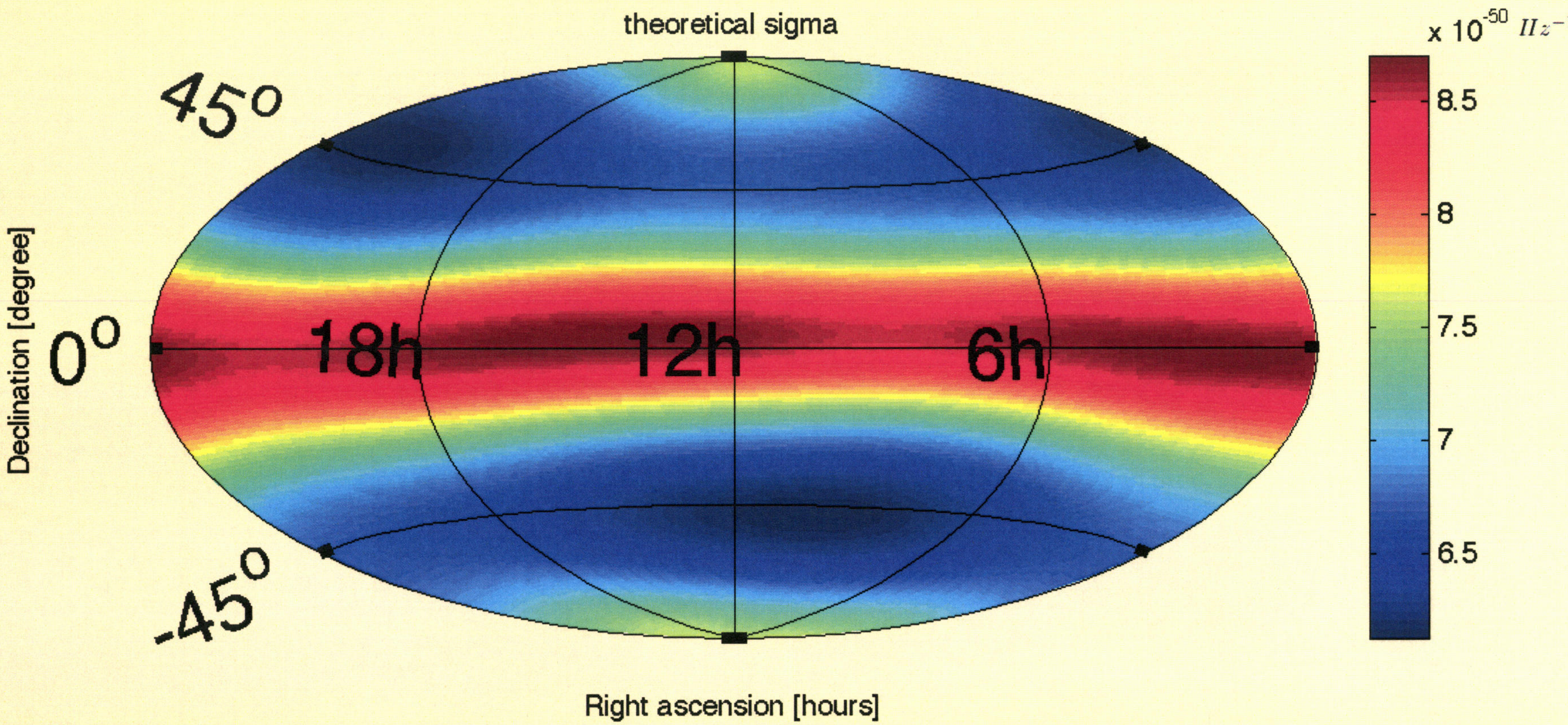
Preliminary. No data quality applied yet.

S5 first year preliminary results: Point Estimate

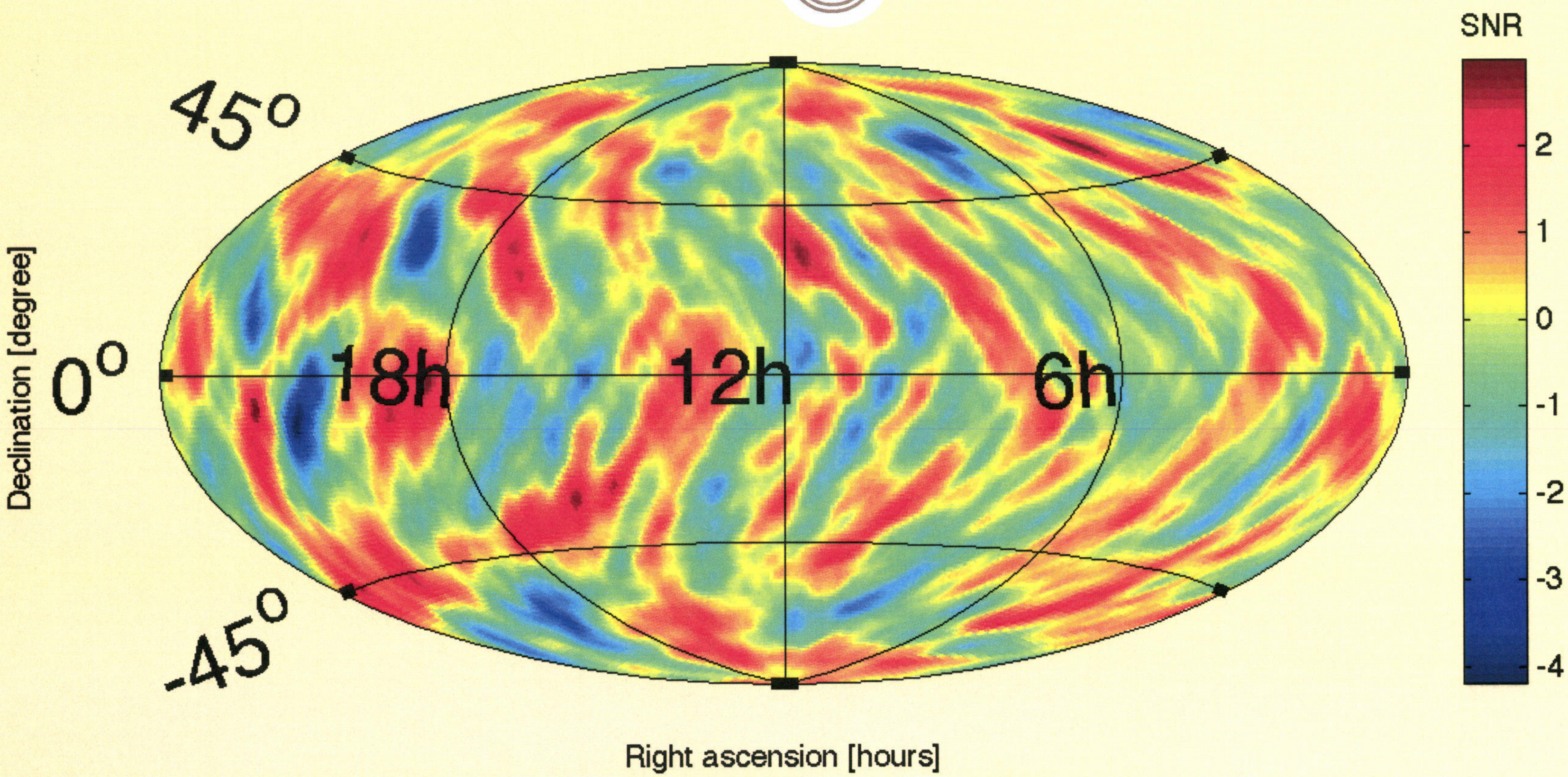


Vetoed 3529 out of 364371 60-second segments (0.96852%)

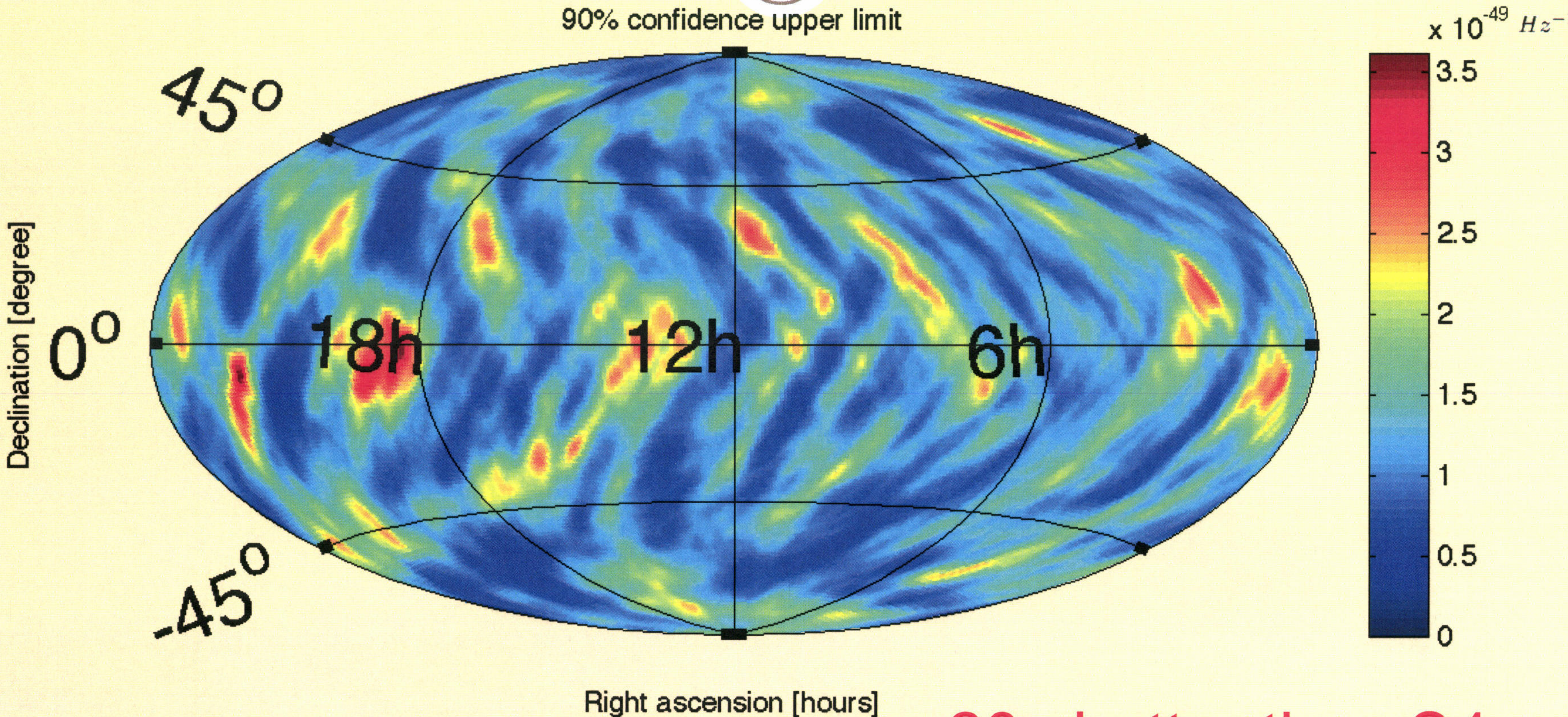
S5 first year preliminary results: Theoretical σ



S5 first year preliminary results: SNR



S5 first year preliminary results: 90% Upper Limit



~20x better than S4

Maximal upper limit: 3.62193e-49 @ ra=18.333333, decl= -2.000000
Minimal upper limit: 3.92539e-50 @ ra=19.333333, decl= 31.000000

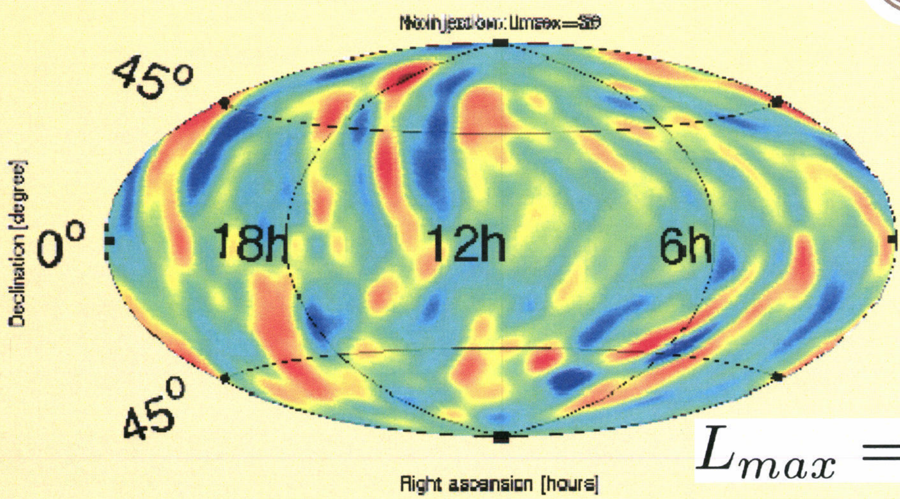
Spherical harmonics decomposition

- Decompose power on sky in terms of spherical harmonics Y_{lm} rather than pixels □ natural basis associated with Earth's rotation
- Deconvolving antenna pattern may be easier since beam correlation matrix Γ has:
  - fewer elements (multipoles vs. pixels)
  - symmetry ($\Gamma_{lm,l'm'}=0$ if Δl=odd; $\Gamma_{lm,l'm'} \approx 0$ if $m \neq m'$)
- Still some degeneracy between responses to certain Y_{lm}'s
- Reproduces isotropic and (approximates) radiometer results as special cases!!

Spherical harmonics decomposition: Status

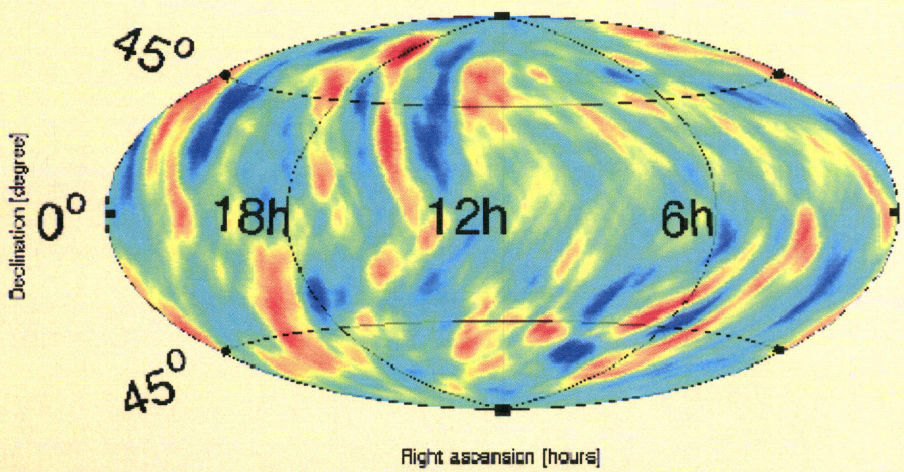
- Analysis routines written and tested (normalisation factors worked out)
- Injections routines now allow for arbitrary spatial distributions
- Currently testing pipeline via software injections (multipole moments, point sources, etc.) into one sidereal day of S5 data (~4 hours)
- Agreement between SpH, isotropic, and radiometer searches as expected
- Post-processing routines for overlapping segments still needed

SpH vs radiometer
(no injection, 1 sidereal day S5)



$L_{max} = 30$

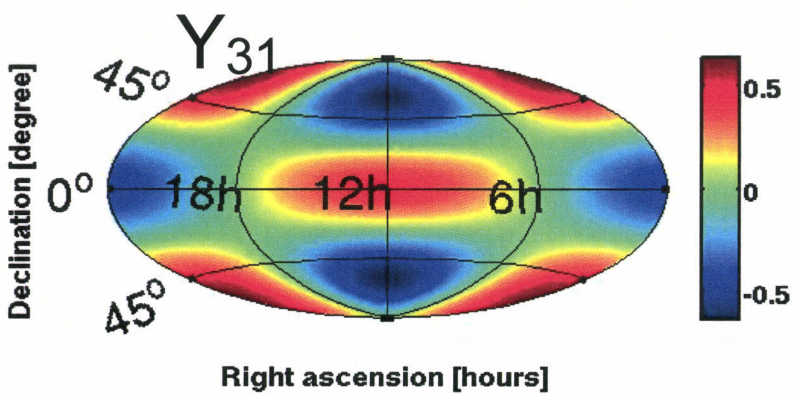
Spherical harmonic decomposition

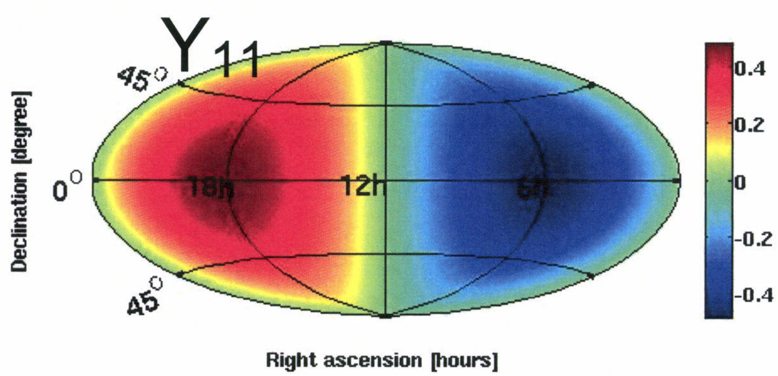


Radiometer

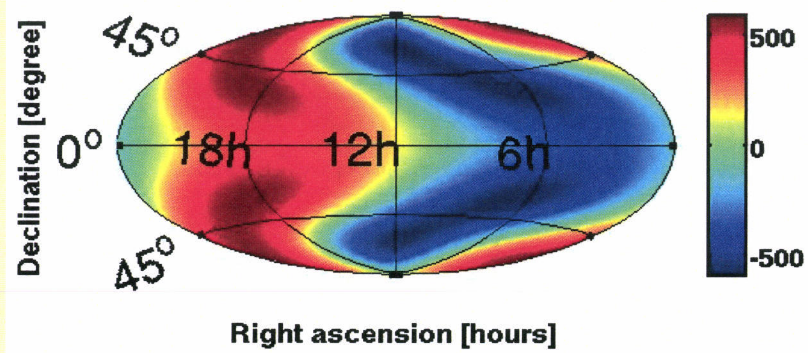
Degeneracies in the antenna response

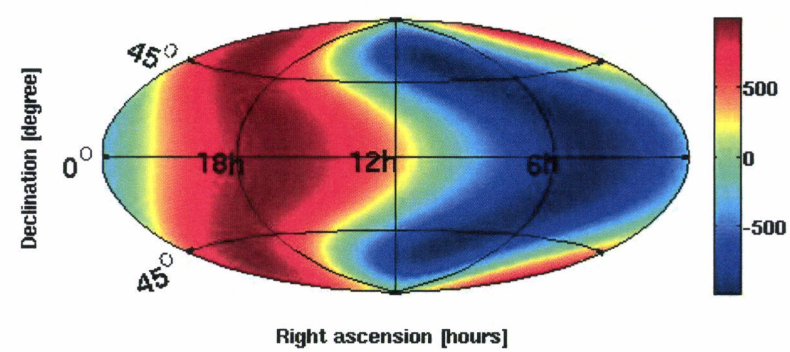
Actual background
(clean map)





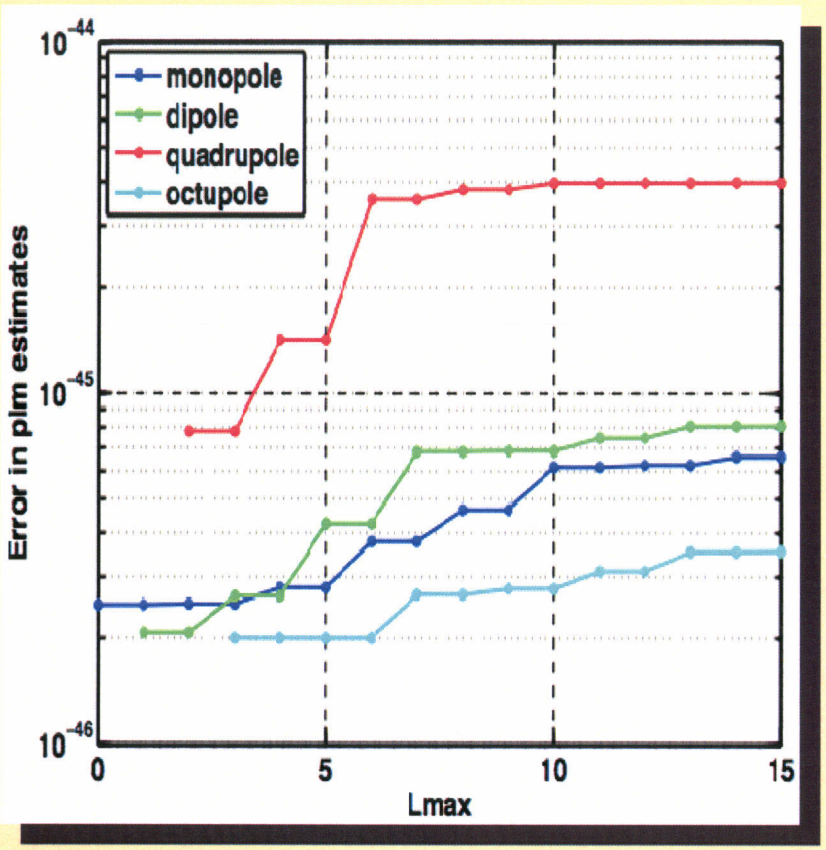
Measured signal
(before deconvolution)



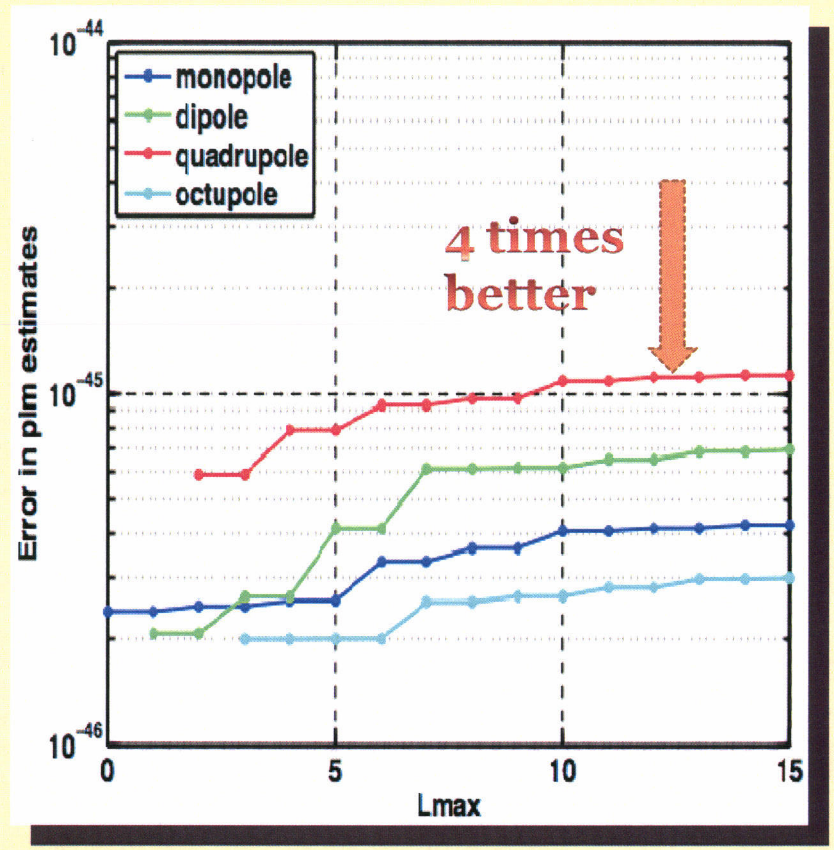


Errors vs Lmax

HL



HLV



Remaining tasks

- Finish testing pipeline via software injections
- Write post-processing routines to handle overlapping segments
- Look for ways to mitigate large errors from higher-order multipoles (e.g., multiple baselines, Bayesian priors, ...)
- Start running on S5 data!

Non Gaussian SB

- The number of bursts present at the detector is a Poisson process:

$$P_\lambda(n) = \frac{1}{n!}\lambda^n e^{-\lambda}$$

- Probability distribution of the GW strain amplitude:

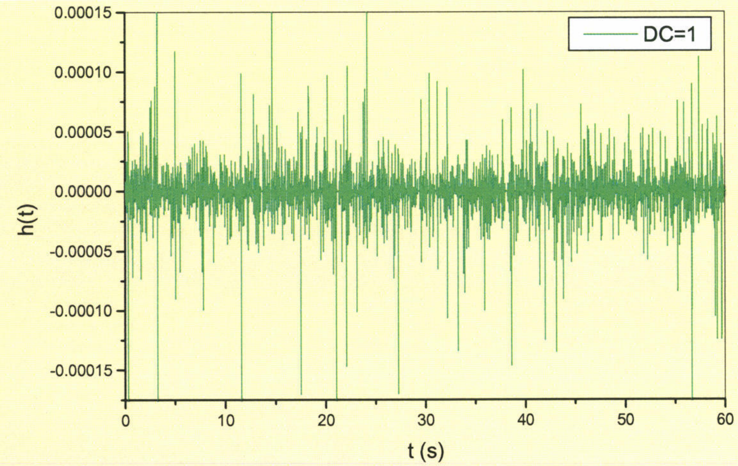
$$p_h(h) = P_\lambda(0)\delta(h) + \sum_{n=1}^{\infty} P_\lambda(n)\left[p_{burst}(h)\right]^{*n}$$

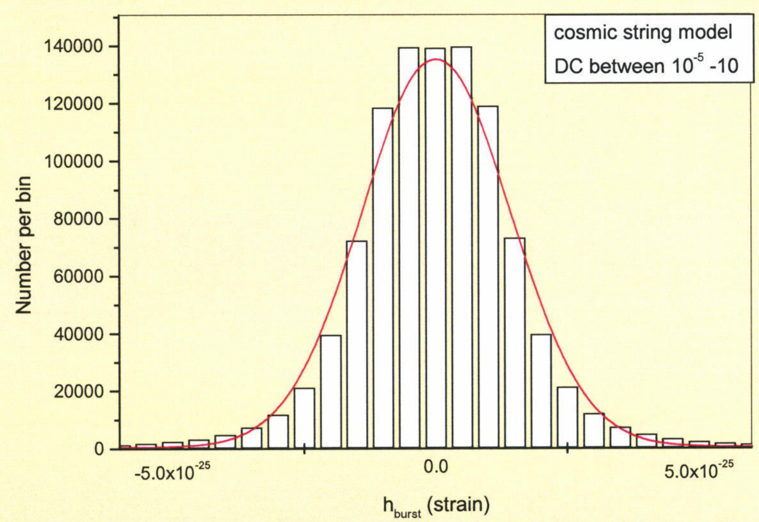
where $h = h_1 + h_2 + \cdots + h_n$

$$\left[N(h;0,\sigma)\right]^{*n} = N(h;0,n\sigma)$$

- Models

$$\begin{aligned} p_{burst}^{strings}(h) &= N(h;0,\sigma_a) \\ p_{burst}^{astro}(h) &= N(h;0,\sigma_a) + \underbrace{N(h;0,\sigma_b)}_{\text{large tails}} \end{aligned}$$





Non Gaussian SB

➢ Detection statistic (p_{burst} = gaussian):

$$\log \Lambda = \max_{\lambda,\sigma_1,\sigma_2,\sigma} \left\{ \log(\overline{\sigma}_1 \overline{\sigma}_2) - \log(\sigma_1\sigma_2) - \frac{\overline{\sigma}_1^2}{2\sigma_1^2} - \frac{\overline{\sigma}_2^2}{2\sigma_2^2} + \frac{1}{N}\sum_{k=1}^{N} \log P_\lambda(0) + \sum_{n=1}^{\infty} I(\lambda, n) \right\}$$

$$I(\lambda, n) = \frac{\sigma_1\sigma_2 P_\lambda(n)}{\sqrt{\sigma_1^2\sigma_2^2 + \sigma_n^2(\sigma_1^2+\sigma_2^2)}} \exp\left[\frac{(\sigma_1^{-2}s_1^k + \sigma_2^{-2}s_2^k)^2}{2(\sigma_1^{-2}+\sigma_2^{-2}+\sigma_n^{-2})}\right]$$

$$\sigma_n = \sqrt{n}\sigma \qquad \overline{\sigma}_i^2 = \langle s_i^k s_i^k \rangle$$

➢ Data Analysis

- pipeline popcorn.c in LALAPPS
- tested on gaussian noise and currently running on the full set of project1b data

```
bash-3.2$ ./popcorn --verbose --gaussian -N 1000000 -g 1 -G 1 -m 0.5 -s 0.8
will analyze 1 segments of length 61 s...
generate gaussian noise with variance sigma1=1.000000 and sigma2=1.000000...
generate gw signal with mu=0.5 and sigma=1 ...
estimate parameters...
mu=0.50 sigma=0.80 mean(var)=0.32 sigma1=1.00 sigma2=1.00
muest=0.489566 sigmaest=0.810045 mean(varmest)=0.32 1240
sigma1est=0.99952 sigma2est=1.00064
```

Conclusions

- LIGO/VIRGO: see E. Robinson's talk for isotropic search
  - A separate analysis will start this month, using VIRGO pipeline
- Bayesian approaches
  - Work in progress (Emma)
  - Worth to be further explored
- Multi baseline radiometry: see D. Talukder's talk