LTP Drift Mode Alternate Analysis
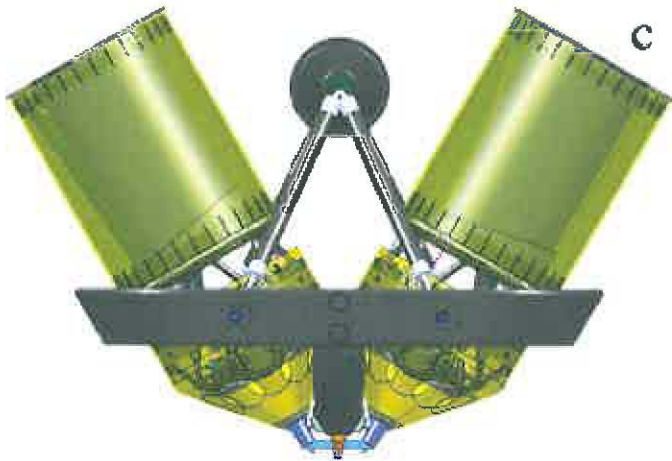
Ira Thorpe (NASA/GSFC), Curt Cutler (NASA/JPL)
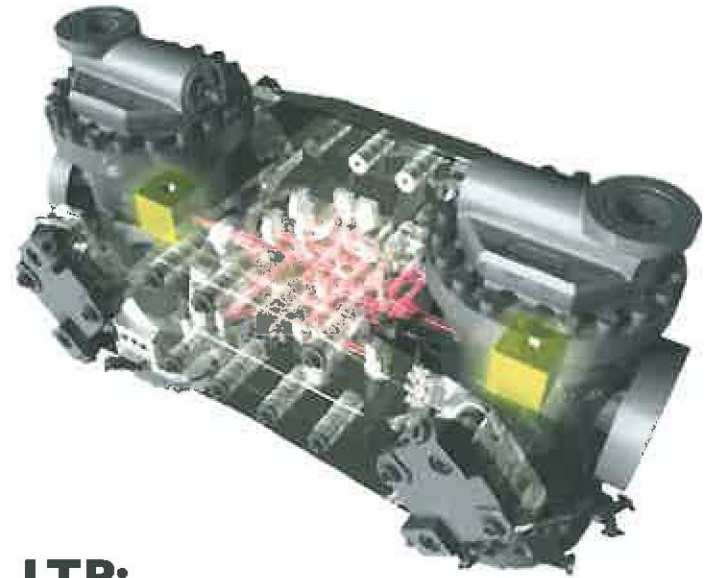
LTPDA Progress Meeting - Trento
17th April, 2012

Motivation

C

LISA/NGO:

- TM Sensitive directions are not co-linear

- Both TMs can be operated drag-free (within measurement band)

LTP:

- TM Sensitive directions are co-linear

- Only one TM can be operated drag-free, the other must be forced

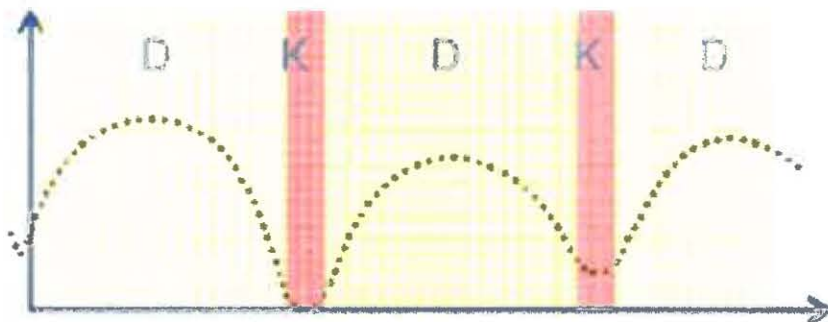- Potential noise source not present in LISA

Drift Mode

Concept:

- Concentrate TM2 forcing into small time windows, a.k.a. "kicks"

- Allow TM2 to fly free between kicks

- Compare measured TM noise with normal science mode to study force noise effects

Interferometer beam

Electrodes used to control ϕ_1

Electrodes used to control x_2 and ϕ_2
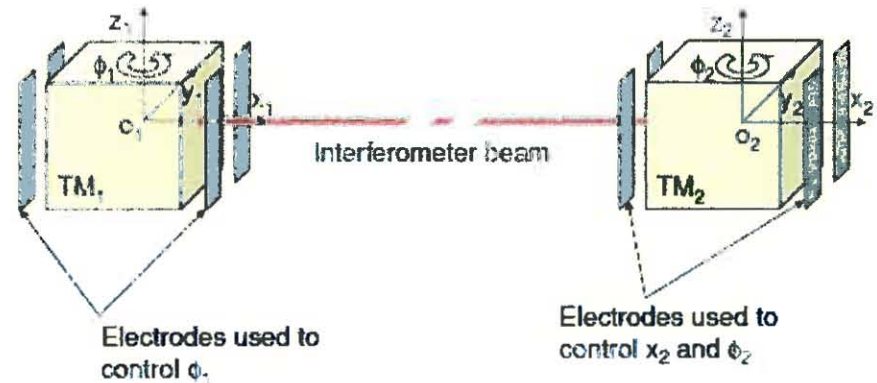
„Closed-Loop Kicks"

References:

- C&QG **26** 094007 (2009)

- Space Sci Rev **151**: 183-196 (2010)

- S2-iFR-TN-3008

- S2-iFR-TN-3006

- S2-UTN-TN-3091

Data Analysis Challenge

- Periods of low noise (free-flights) separated by short periods of high noise (kicks)

  - Must excise kicks

- Care about frequencies down to 1mHz but flights only last ~200s

  - Need to combine information from multiple free flights to get low-frequency information

  - have to remove deterministic part of the free-flight

- Desired Outputs

  - Residual spectrum or parameters that describe it

  - Parameters that describe Deterministic signal
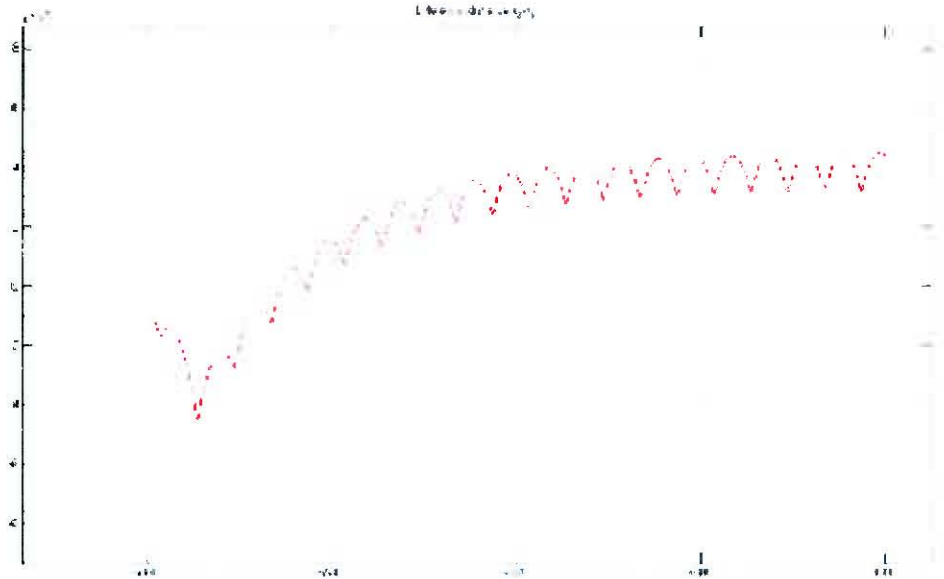
Pre-processing

- Read data from dynamical simulations into LTPDA

- Remove any known cross couplings

- Convert from displacement to acceleration

- Identify & excise kicks

- Remaining data stream has deterministic part plus quasi-periodic gaps.
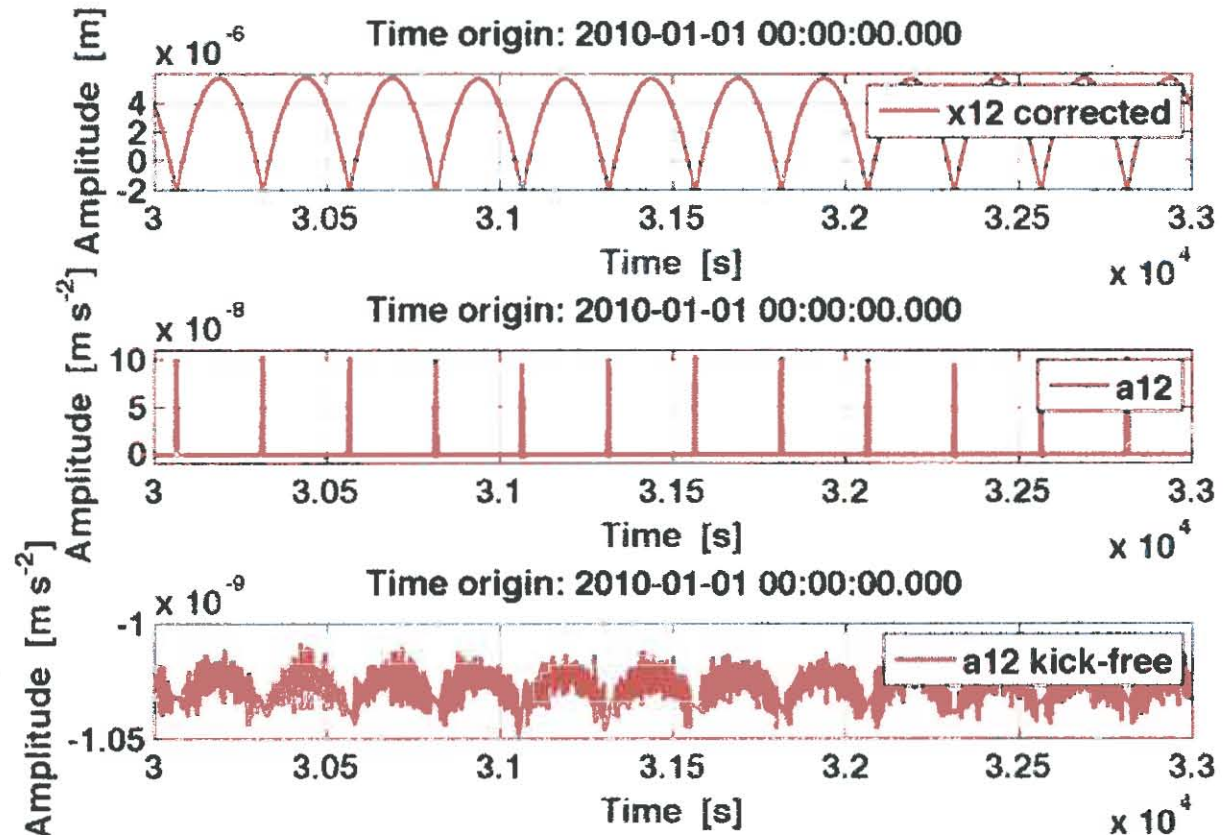
Data Analysis Approaches

- Apply window function to data that goes to zero during the gaps

- Fill the gaps with randomly generated noise with the correct statistical properties

- Compute and correct for spectral leakage effects caused by gaps

Gap-filling Approach

Simultaneously do noise estimation *and* Bayesian parameter estimation of deterministic signals.

$$a(t) = n(t) + \sum_{i=1}^{N} \lambda_i \phi_i(t)$$

1. Make a guess for underlying noise spectrum and coupling parameters

2. Remove estimate of deterministic signal

3. Fill gaps using "constrained Gaussian noise"

4. Re-estimate spectrum

5. Re-estimate deterministic pieces (Fisher matrix)

6. Repeat 2-5 as necessary

Does not require periodic gaps

Tuesday, April 17, 2012

Constrained Gaussian Noise

- Want data with correct spectrum in frequency domain

- In time-domain, this means correct 2-point correlation function

$$C^{ij} \equiv <x^i\, x^j> = \int_{-\infty}^{+\infty} e^{-2\pi i f(t_i - t_j)} \frac{1}{2} S_n(f) df$$

- Fill gaps with random data but adjust the mean of each data point based on correlation function and data outside gap

- *Caveat:* In practice, need to truncate Cij at finite length...requires white or rising spectrum. Will need to pre-whiten.
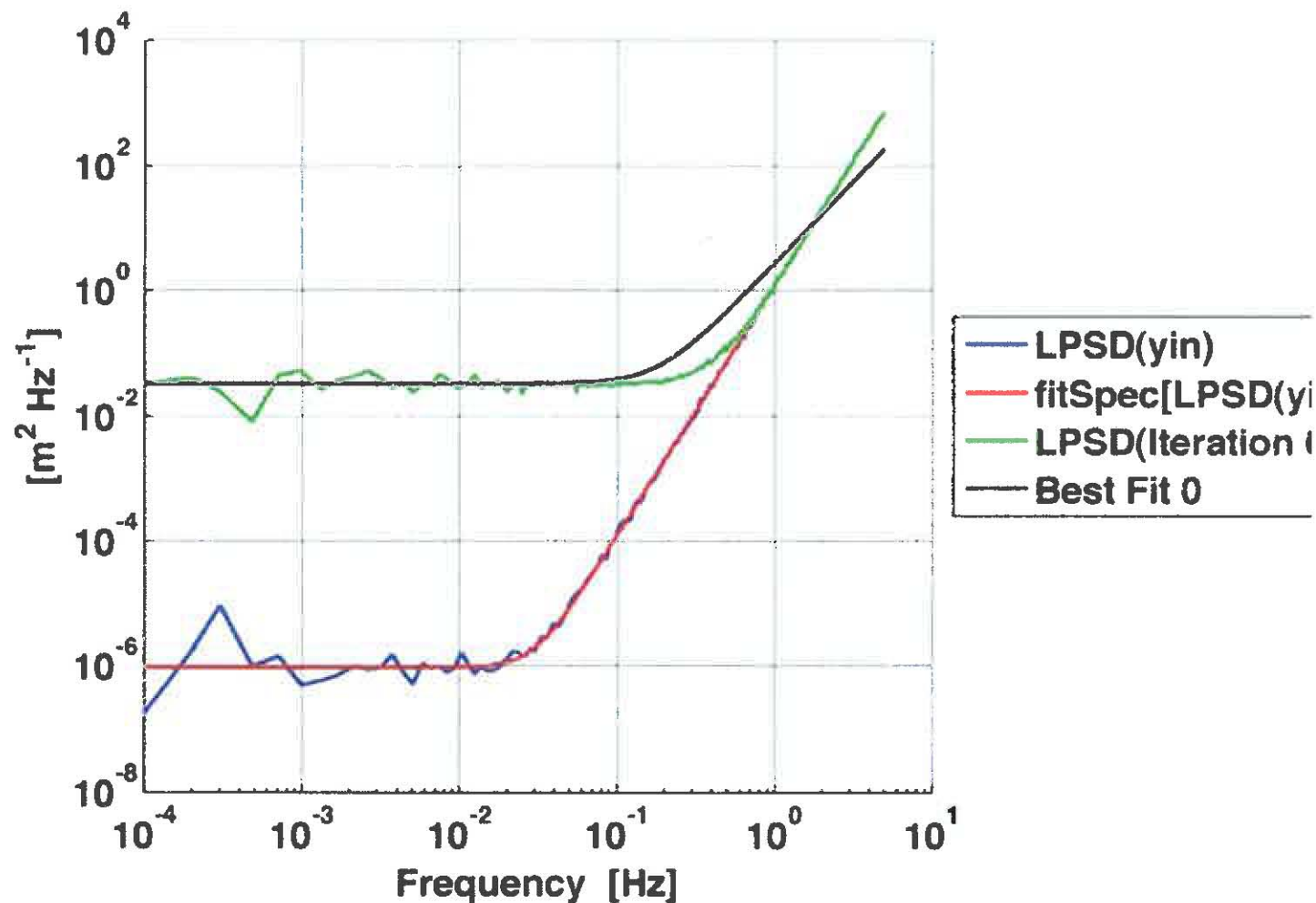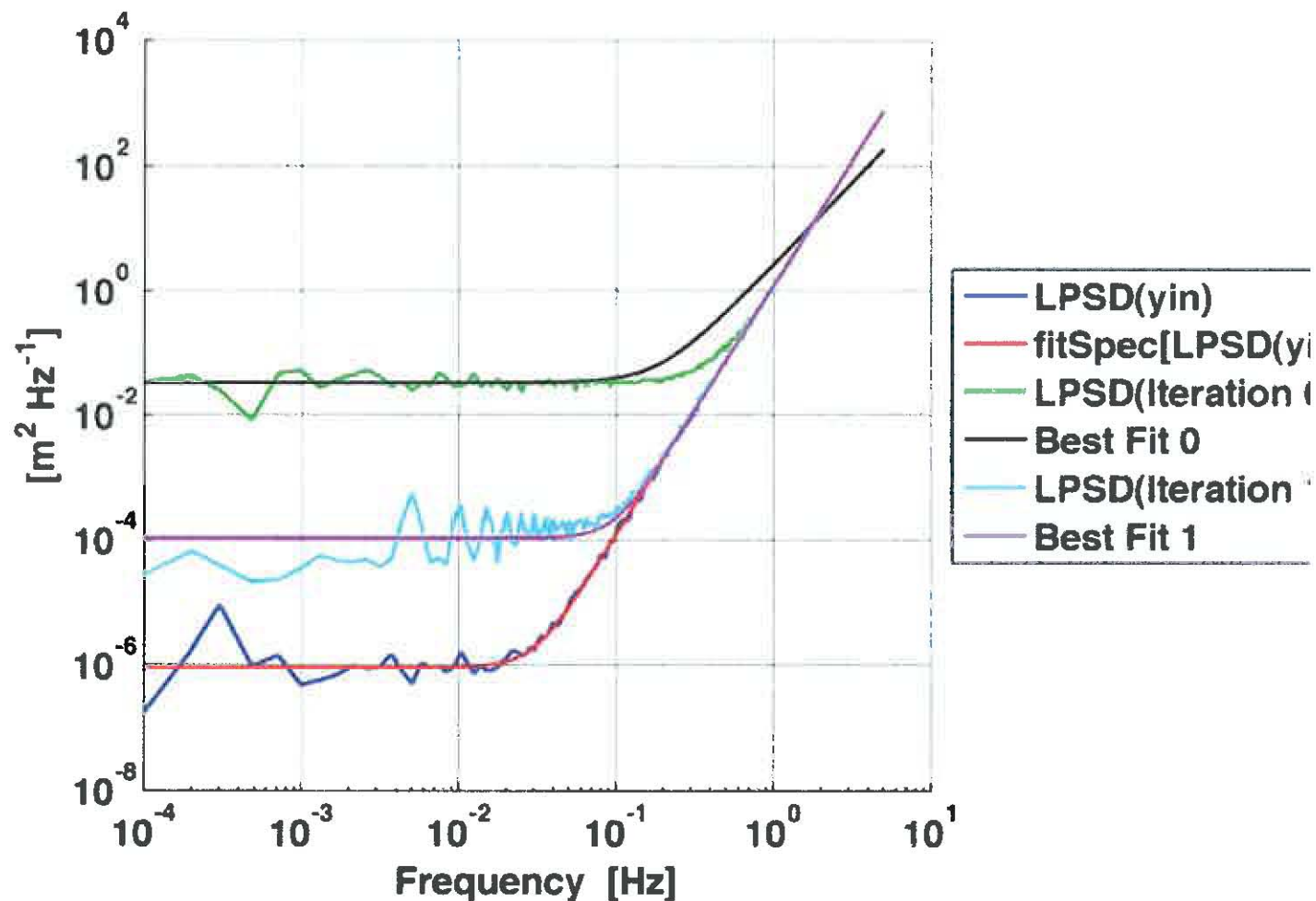
Noise filling example

Input Noise $S_n(f) = S_0 \left[1 + (f/f_0)^a \right]$
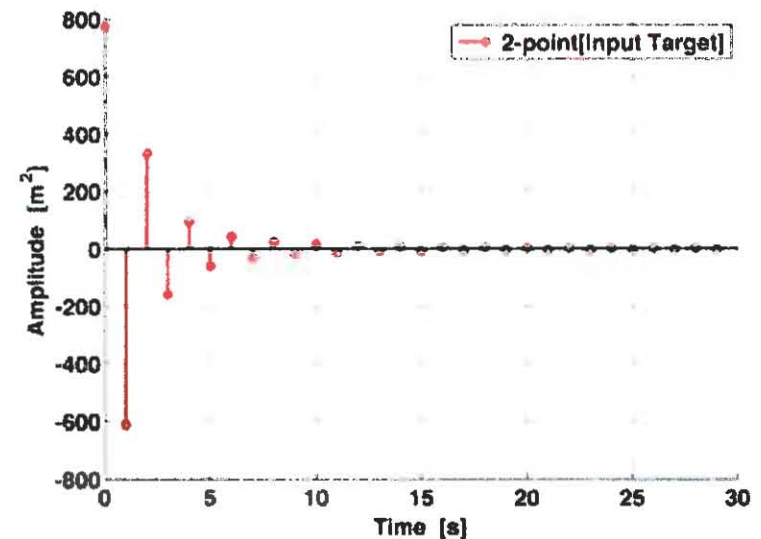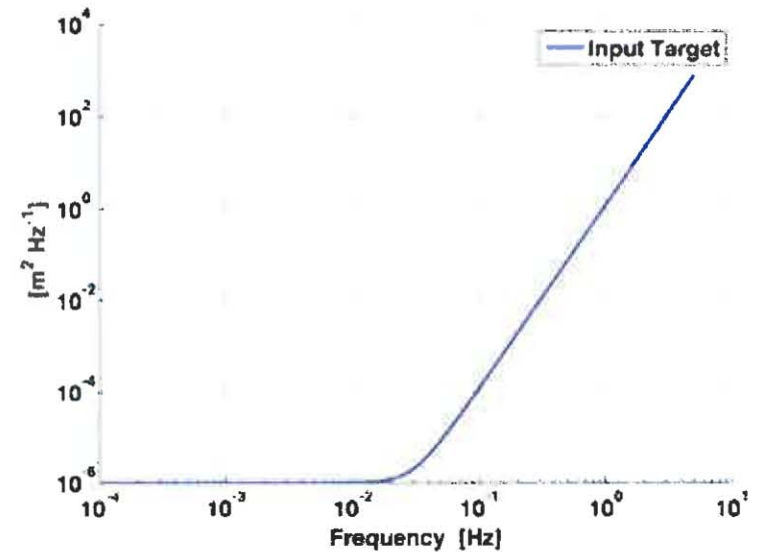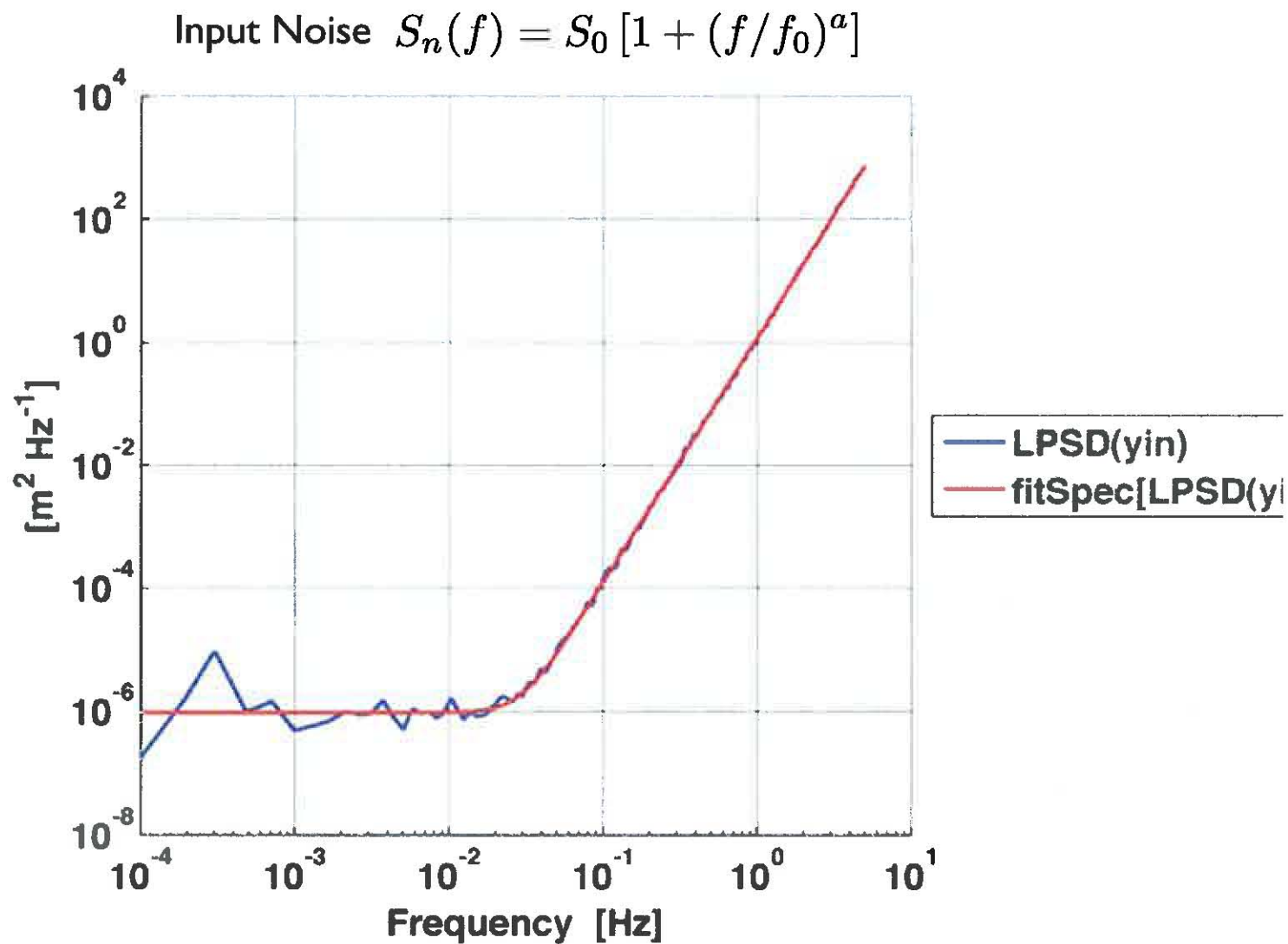
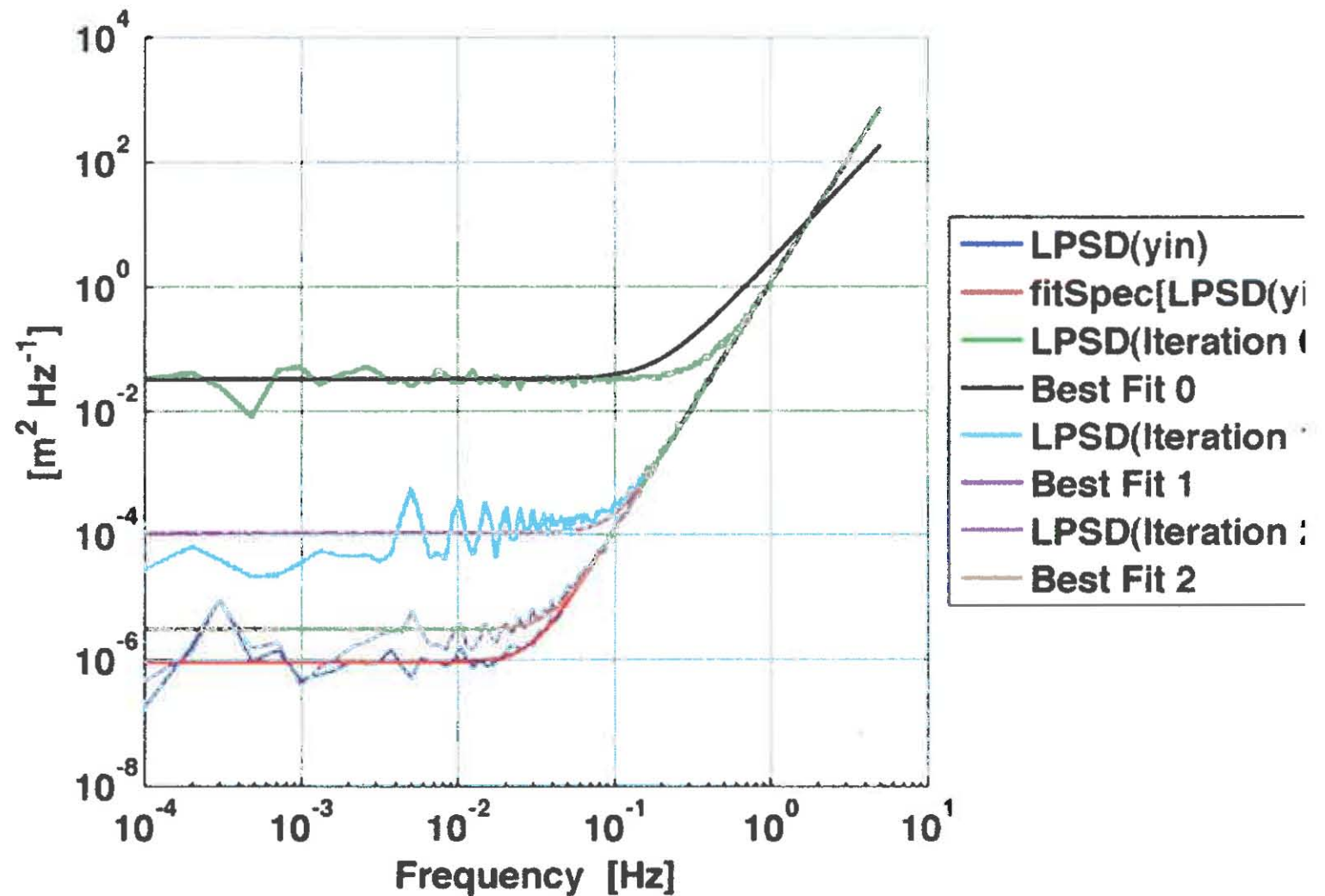# Noise filling example

Add gaps (1s duration at 200s intervals)

Noise filling example

First Iteration

Noise filling example

Second Iteration
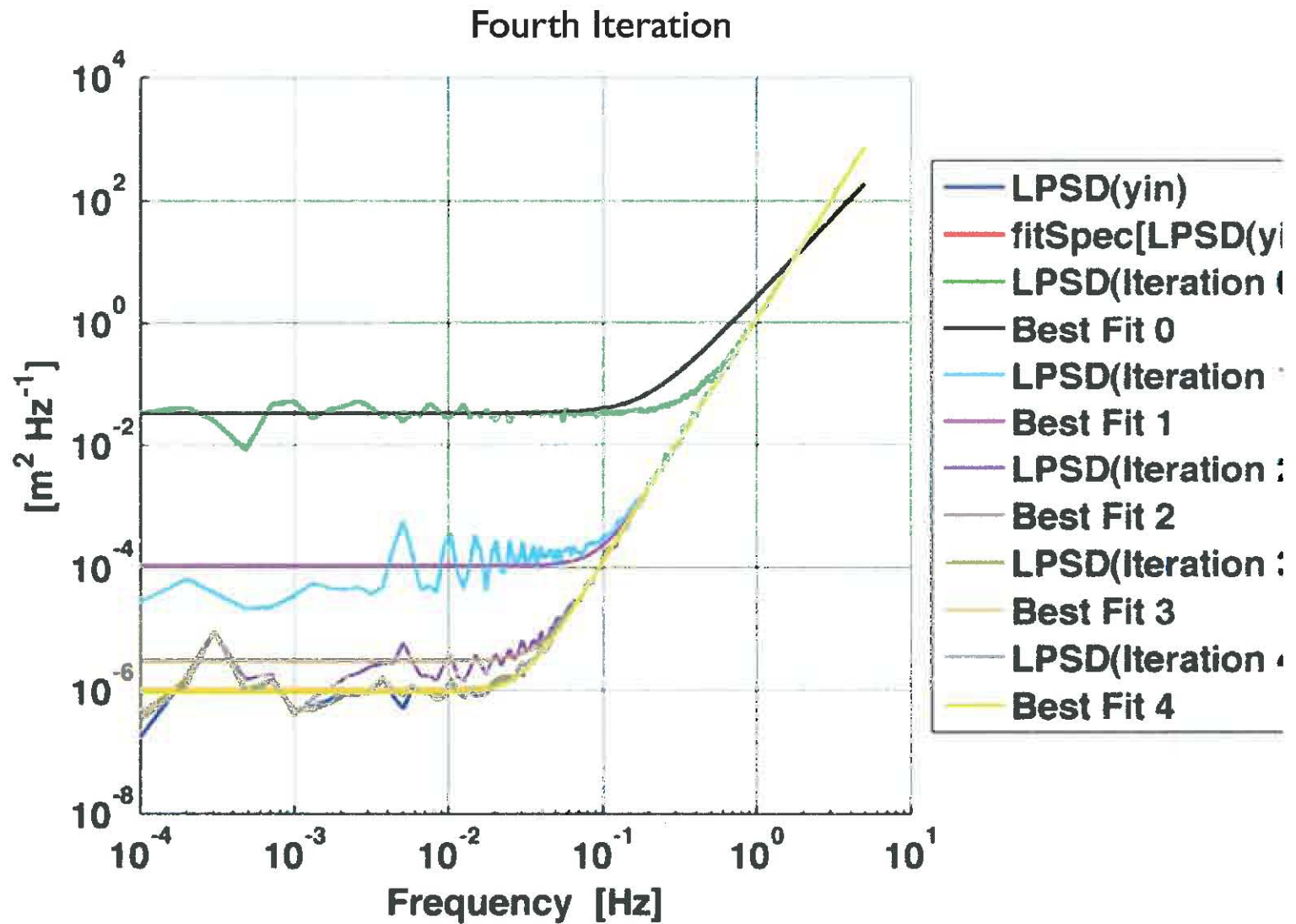
Noise filling example

Third Iteration

Noise filling example

Fourth Iteration
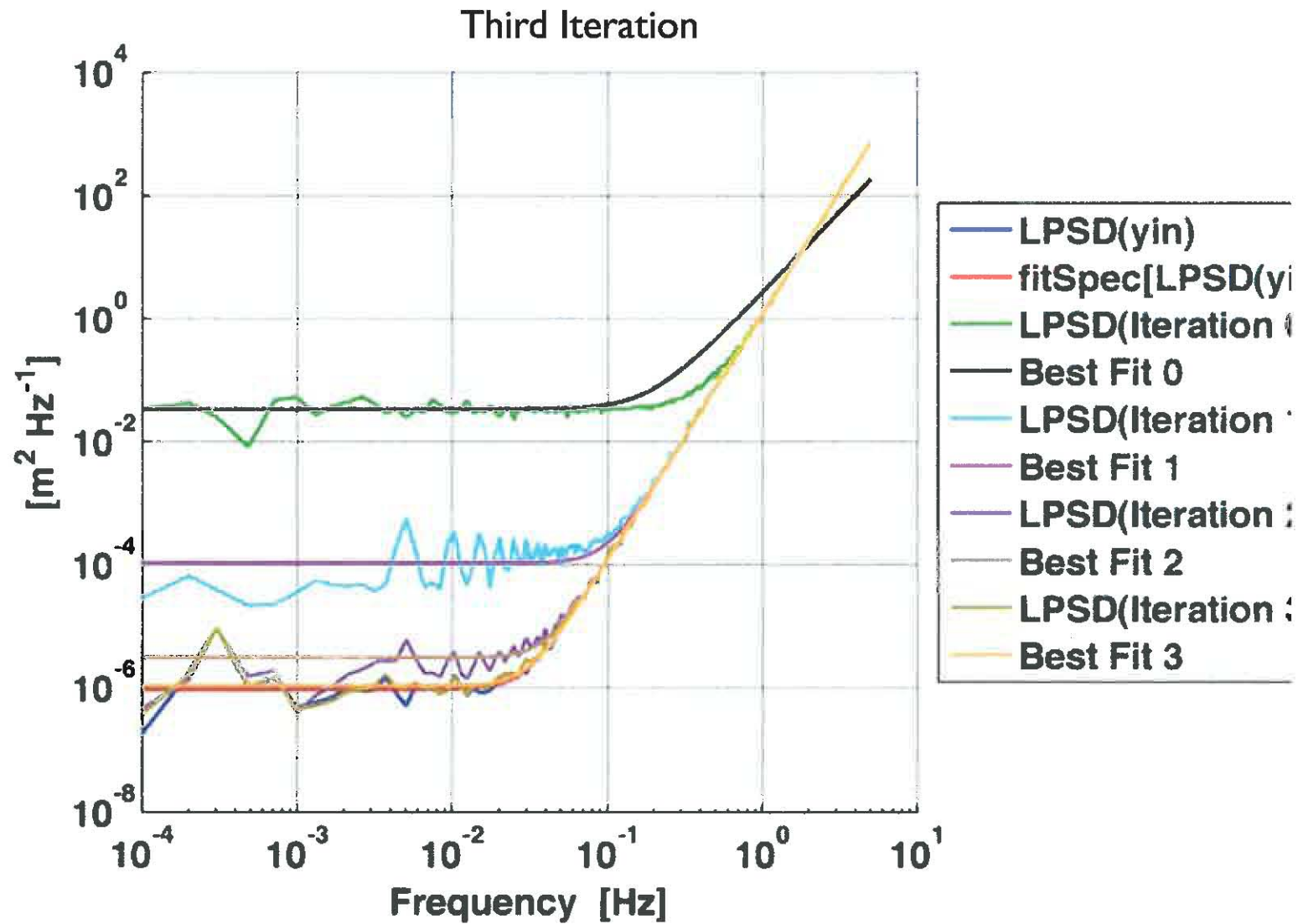
Convergence

$$S_n(f) = S_0 \left[1 + (f/f_0)^a\right]$$

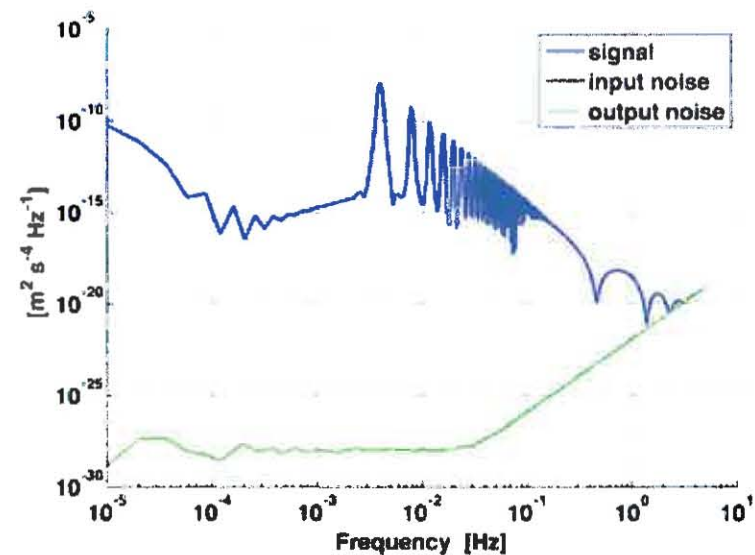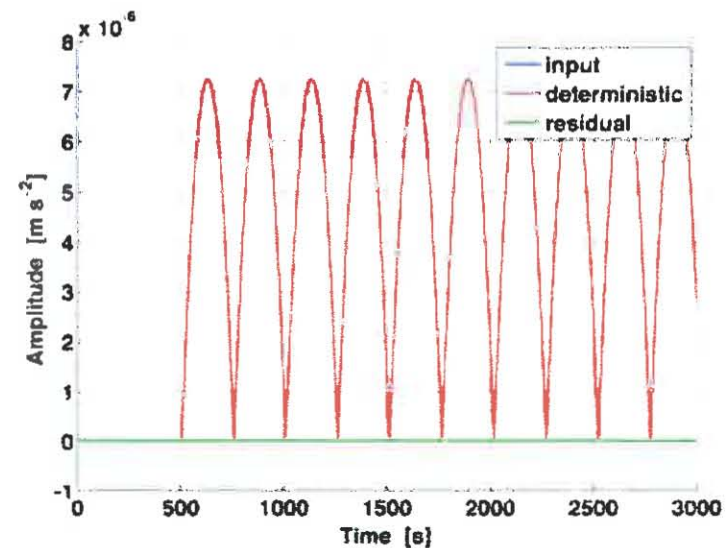| Spectrum	S_0	f_0	a	X^2
Input	9.50E-07	2.94E-02	3.990	1.07
Iteration 0	3.31E-02	1.88E-01	2.638	232
Iteration 1	1.09E-04	9.72E-02	4.002	7.51
Iteration 2	3.07E-06	4.00E-02	4.006	2.80
Iteration 3	1.08E-06	3.06E-02	3.998	1.23
Iteration 4	9.50E-07	2.94E-02	3.990	1.13

Time domain
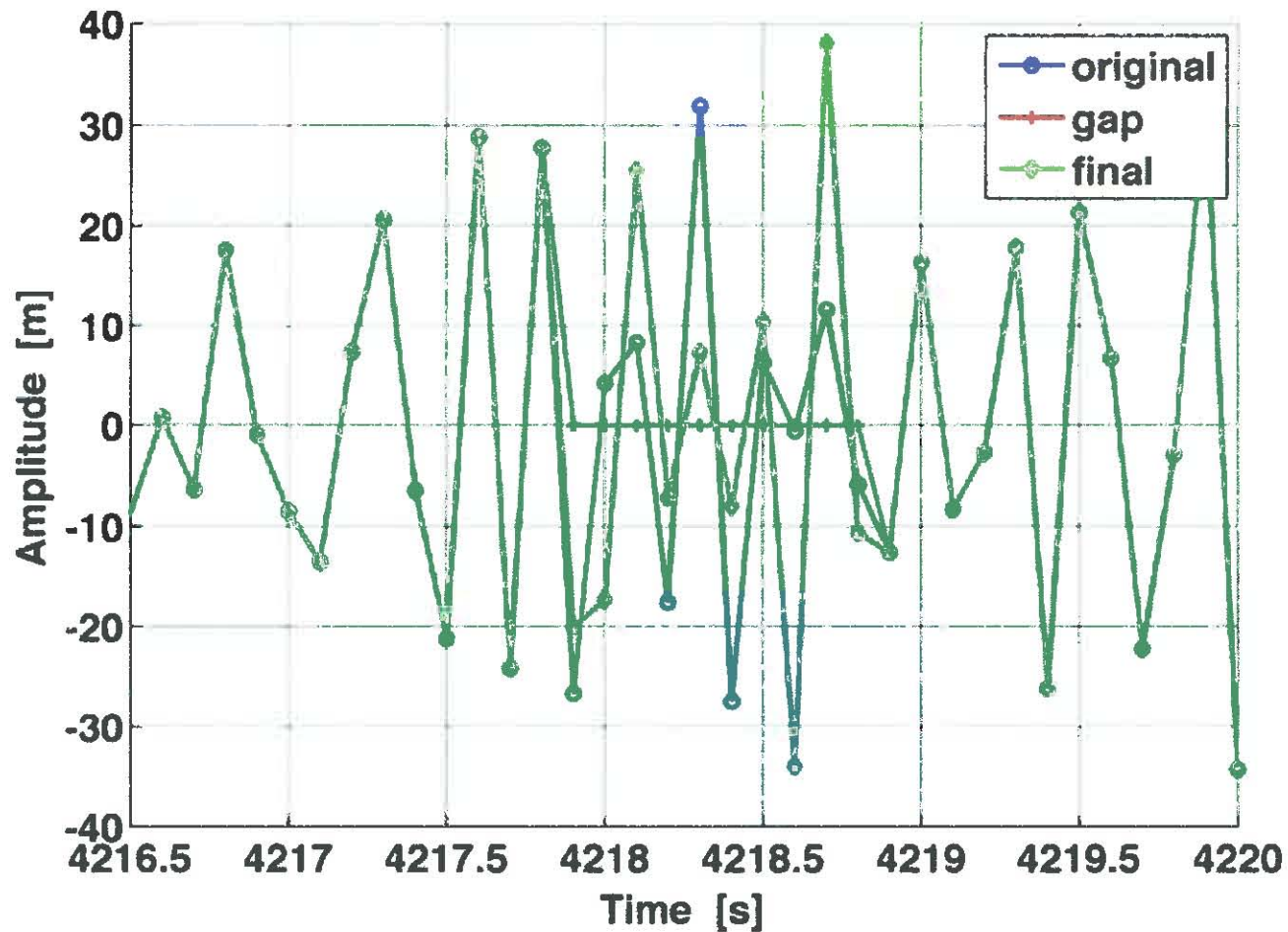
Bayesian Parameter Estimation
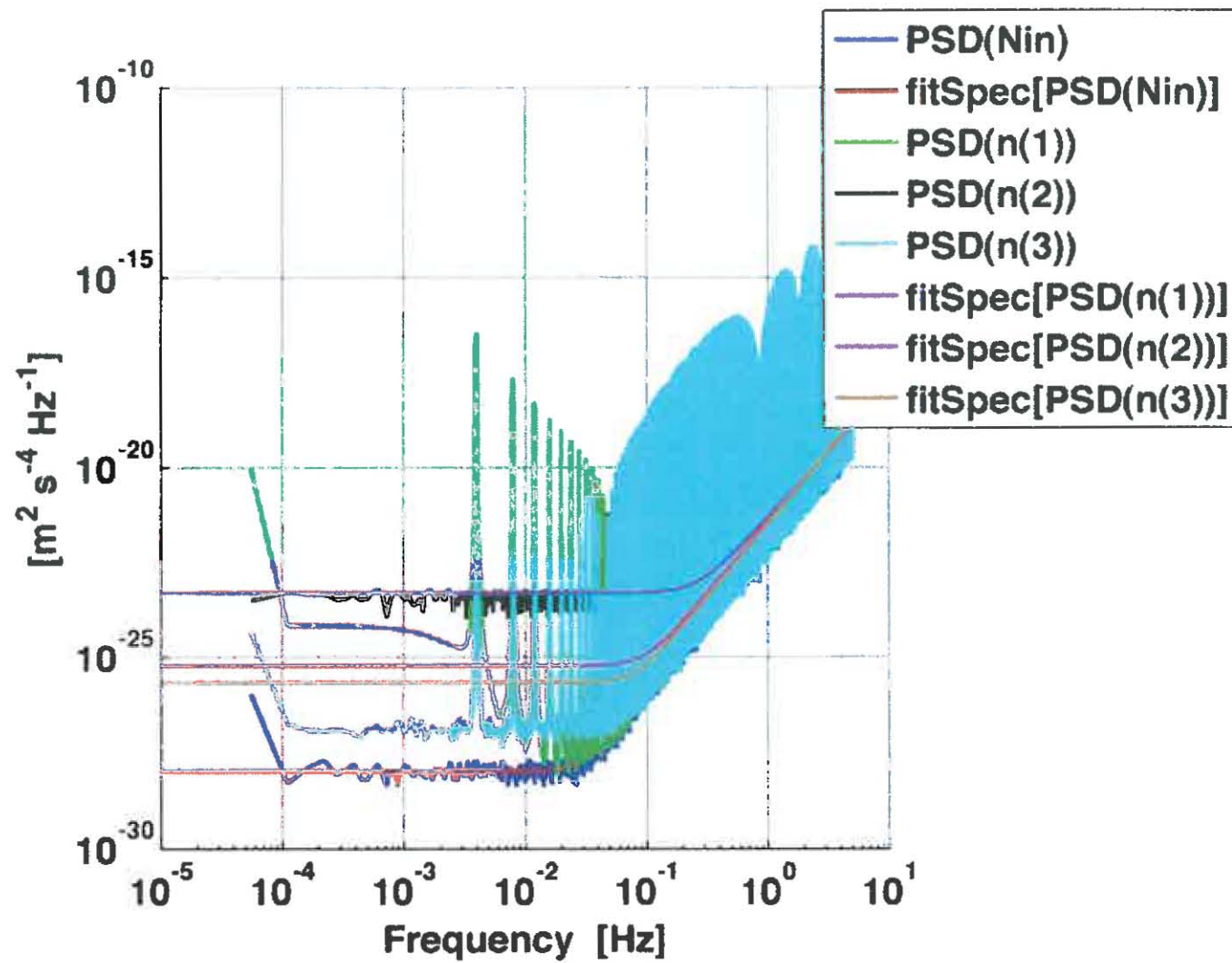
$$a(t) = \sum_k \lambda_k \phi_k(t) + n(t)$$

$$(\phi_k|\phi_l) \equiv 4\mathcal{R} \int_0^\infty \frac{\tilde{\phi}_k(f) \cdot \tilde{\phi}_l^\star(t)}{S_n(f)} df$$

$$\Gamma_{kl} \equiv \left(\frac{\partial a}{\partial \lambda^k} \Big| \frac{\partial a}{\partial \lambda^l} \right)$$

$$\lambda^k = \sum_l \left(\Gamma^{-1} \right)^{kl} (a|\phi_l)$$

Combine the two steps - first try

Next Steps

- Work on combined problem

- Investigate other noise shapes, esp. red noise (pre-whitening?)

- Apply to more realistic data (STOC?, SSM?)