Progress Report: PSU S2 Burst Analysis

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Introduction

- Yes/No:
  - » Is the energy *distribution* of events at zero delay the same or different than the background event energy distribution?
- Interpreted rate/strength bound:
  - » *Bound the contribution of a galactic distribution* of, e.g., ms Gaussian sources in a rate/strength diagram to the zero-delay distribution
- Detection:
  - » Examine in detail all zero-delay events whose expected rate, based on the properties of the parameterized background distribution, is greater than once per year
- Spectral analysis:
  - » Identify and partition events into spectral types (i.e., looking at events that have the same distribution of signal energy as a function of frequency)
- Acoustic detector comparison:
  - » Is the energy distribution of events with measured energy in the 900 Hz - 930 Hz band consistent or inconsistent with background?

Outline

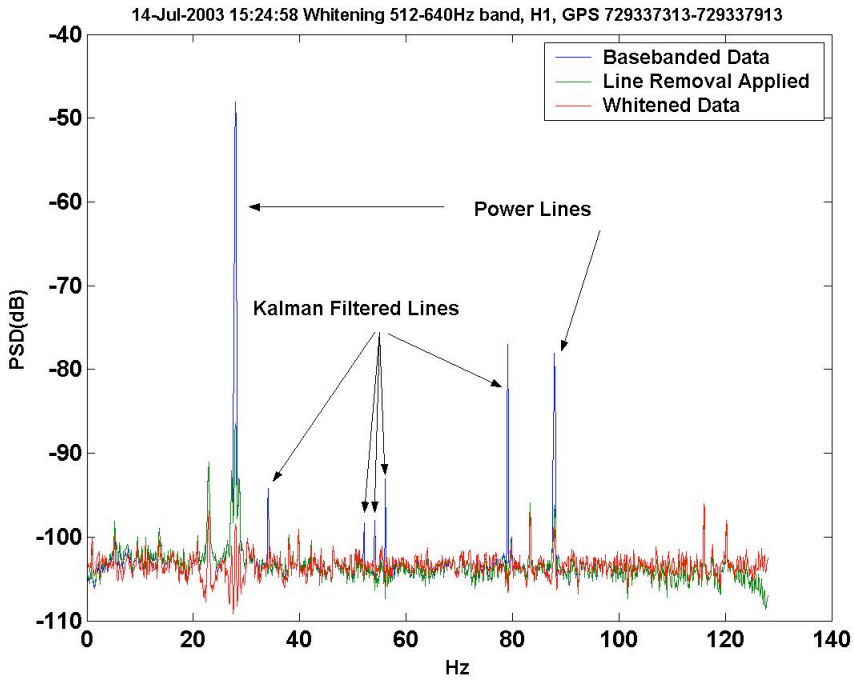
- Introduction (Sam)
- Data conditioning (Tiffany)
- BlockNormal tuning and running (Amber)
- Coincidence (John)
- Simulations, including background estimation (Patrick)
- Statistics (Sam)

Data Preconditioning

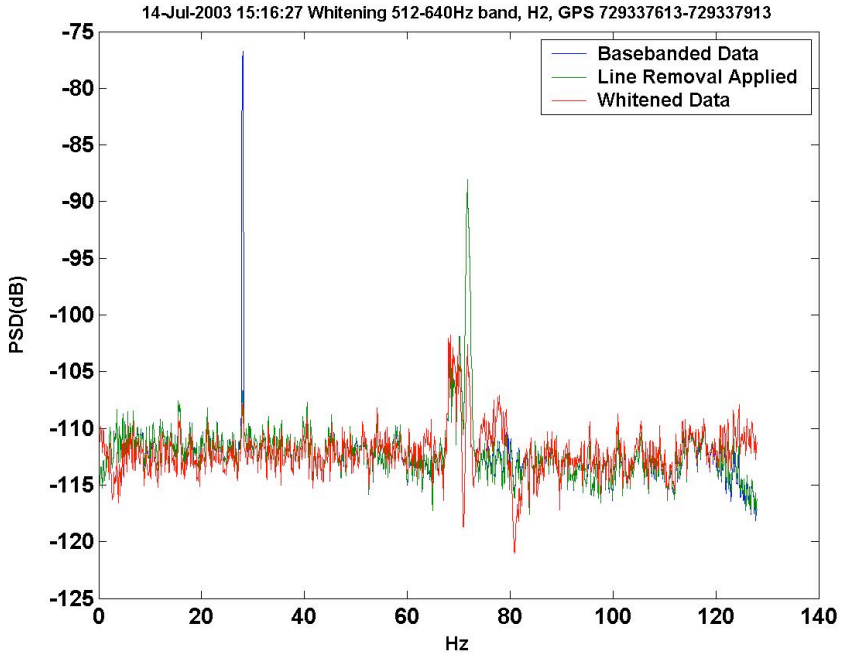
- Goal: Produce white data (data with equal power at all frequencies) for each frequency band of interest.
  - » Frequency bands: 128-192Hz, 192-320Hz, 384-512Hz, 512-640Hz, 704-1024Hz, 1024-2048Hz
- Step1 – Basebanding
  - » cf. T030027
  - » Highpass filter for low frequency suppression chosen
    - – Order 138, applied to all 3 detectors
  - » Lowpass filters to get rid of frequencies outside band.
    - – Order 55, for 512-640Hz band
    - – Order 31, for 384-512Hz band
    - – Order 50, for 128-192Hz band
  - » Filters found via Matlab's remez function (Parks-McClellan)

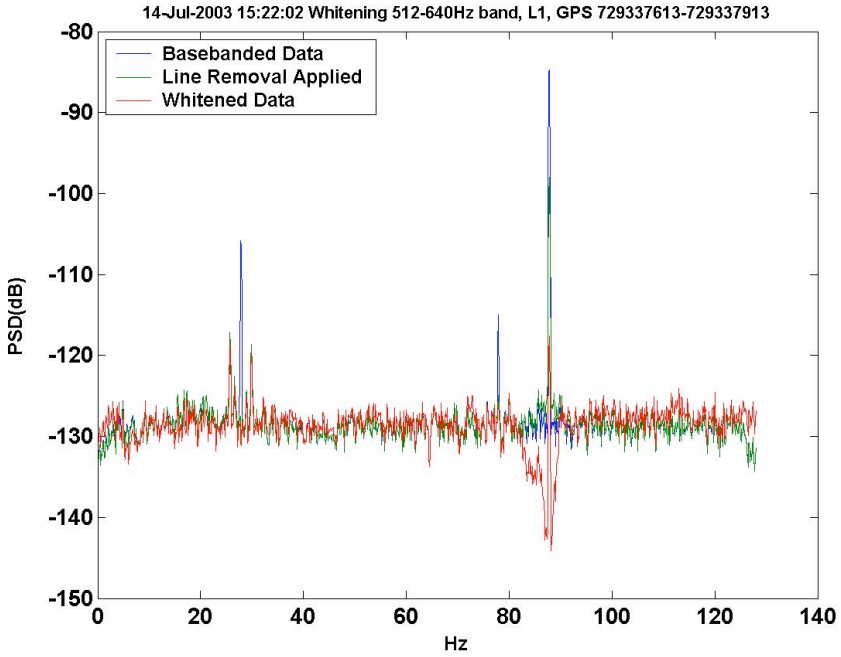
Data Preconditioning

- Step 2 – Line Removal, (ex. 512-640 Hz)
  - » Power lines – regressed from data using voltmeter channels
    - – Voltmeter data filter found with ARX model:
      $y(t) = b1 \cdot u(t - k) + \ldots + bn \cdot u(t - k - n) + e(t)$
    - – Filters found for each playground segment. Filter from nearest playground segment used.
    - – H1 – H0:PEM-LVEA2_V1
    - – H2 – H0:PEM-LVEA2_V3
    - – L1 – L0:PEM-LVEA_V1 - Unsatisfactory, investigating other channels suggested by Rana
  - » Other narrow lines removed via Kalman filtering
    - – Kalman action rmvm available in datacondAPI
    - – Process noise (line power) must be measured for each line.
    - – Process noise measured for each playground segment



Data Preconditioning



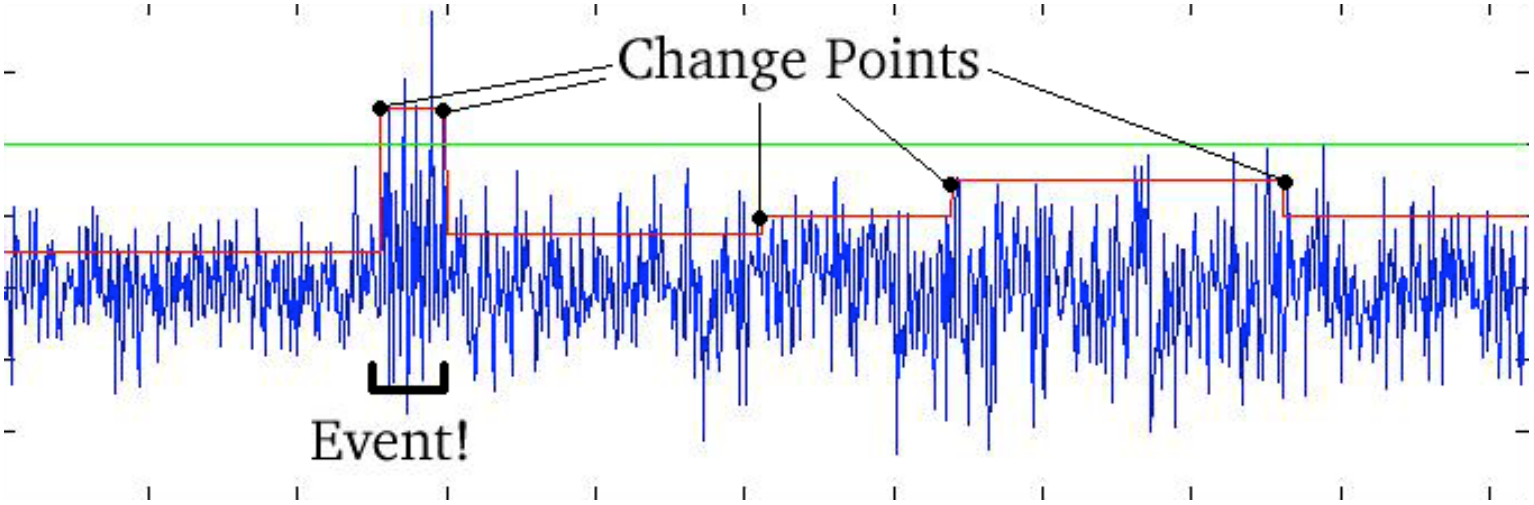


- Step 3 – Final Whitening
  - » Whitening filters generated for all playground segments. Nearest playground's filter used.
    - – Order 60 AR model used

$$y(t) + a1 y(t-1) + \ldots + an y(t-n) = e(t)$$

BlockNormal ETG

- Change points based on statistical changes (χ^2,μ)
- Change points are not events!
- Change points form ‘blocks’ of data
- Thresholded blocks form single IFO events



Threshold Tuning Objectives

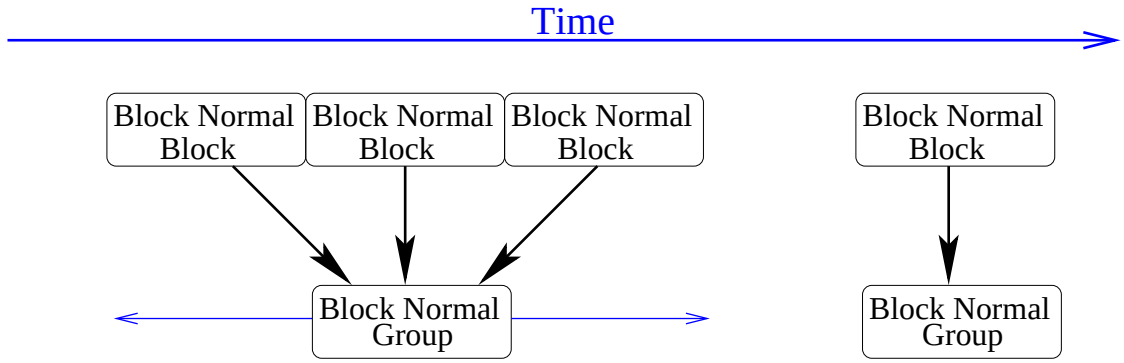
- Change point threshold
  - » IFO/band change point rate inversely proportional to in-band noise-equivalent strain
- Block threshold (for fixed change point threshold)
  - » Maximize number of events per unit time
  - » Minimize event duration
- Fix expected triple coincidence change point rate

Where we are...

- BlockNormal
  - » coded and in LAL
  - » has own LDAS database table
- Tuning underway

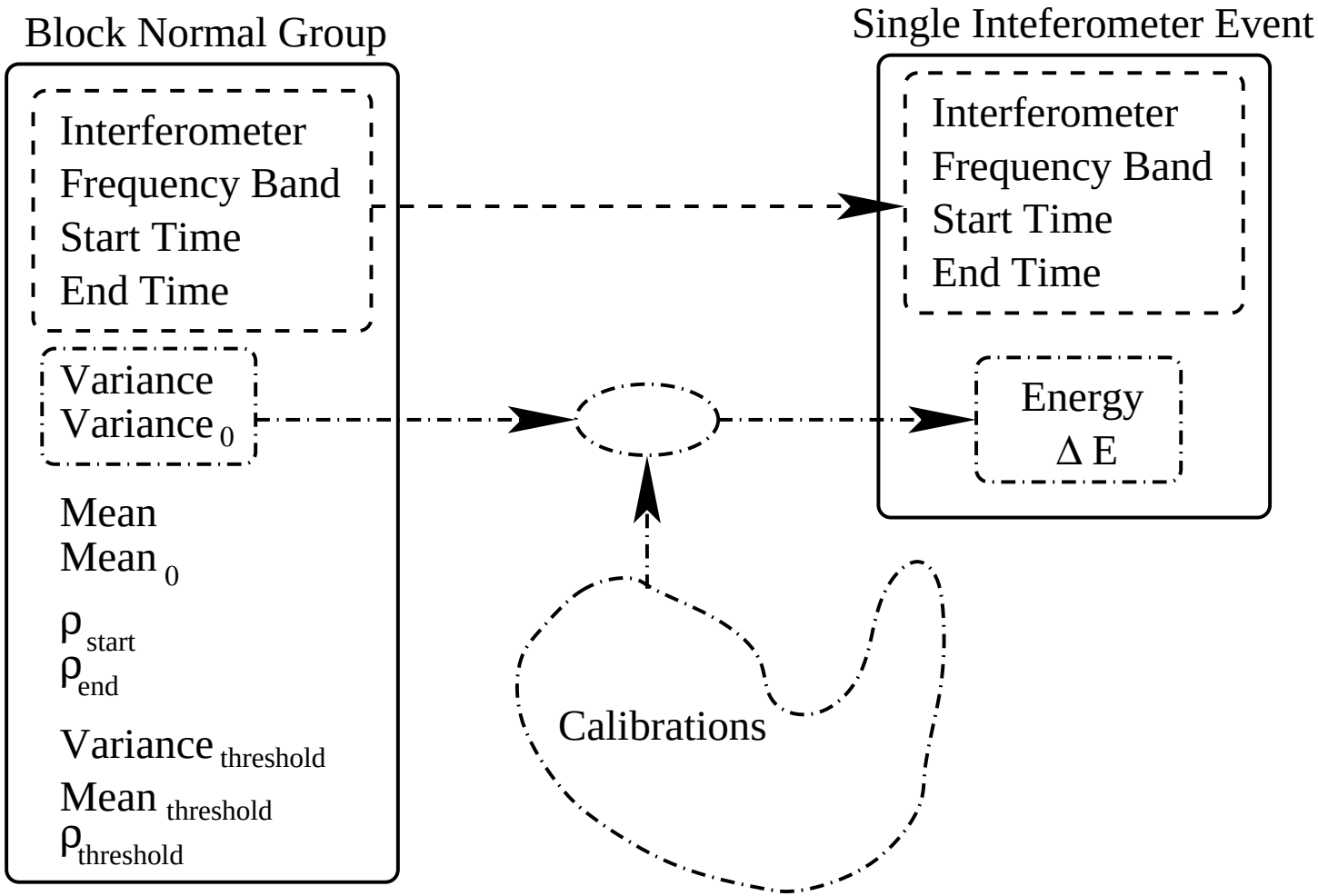
Coincidence

- Block Normal Trigger to Single Interferometer Event:
  - Cluster Neighboring Blocks into Group

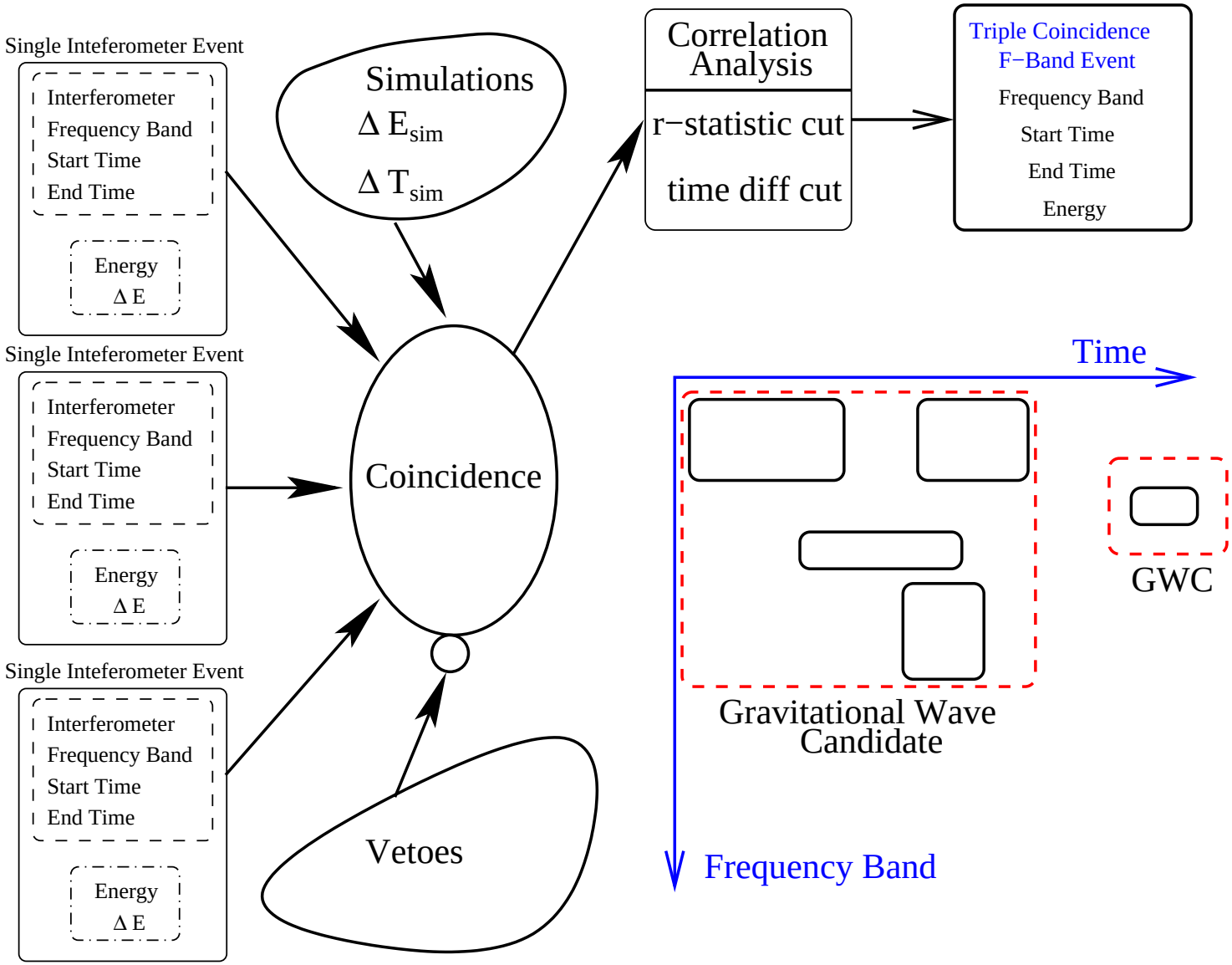


- Convert Block-Normal's variance into Single IFO Event calibrated Energy
- Select Gravitational Wave Candidates based on Timing and Energy Coincidences
- Perform Correlation Analysis (r-statistic, refined timing difference)

Coincidence



Coincidence



Background Determination

- Repeat coincidence tests with artificial time delays.
- Determining time delays is a critical issue.
  - » Must be larger than detector auto–correlation time and event clustering time, less than longest timescale on which any IFO is stationary.

Simulations: Goals

- Tolerance for coincidence tests:
  - » Start time
  - » Energy
  - » r–statistic (coordinate with Cadonati).
- Astrophysical interpretations:
  - » Detection efficiency.
  - » Spectrum determination (for additional cut).
  - » Foreground distribution (rate versus energy).
  - » Compute for specific source and population models.

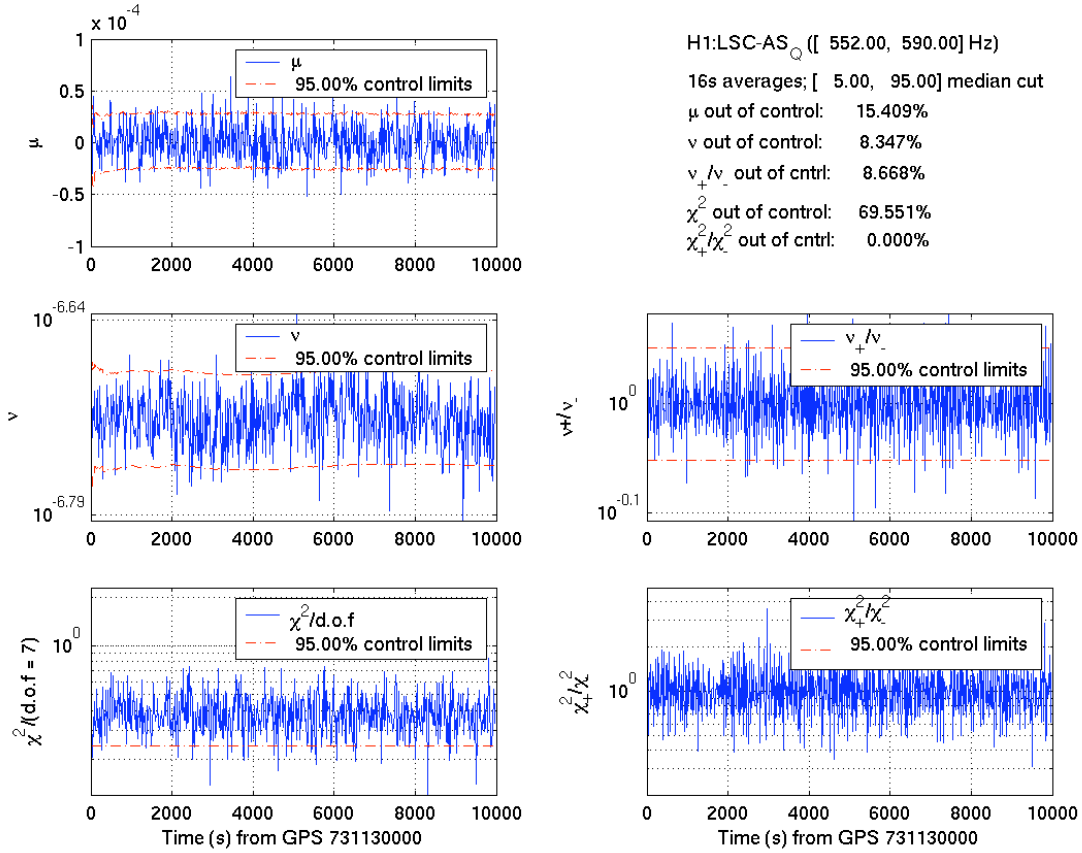
Simulations: Types

- Axisymmetric sources (linear polarization):
  - » Use single–IFO simulations with ‘‘zenith injections’’.
  - » Convolve results with population model for efficiencies.
  - » Simulations on playground for coincidence parameters; simulations on non–playground data for astrophysical interpretations.
  - » Compare to hardware injections for verification of procedure.
- Non–axisymmetric sources (general polarization):
  - » Use sky position and orientation (full source model) in the injections, therefore coordinated injections in each IFO.
  - » For astrophysical interpretations (non–playground data only).

Statistical Methods

- Analysis on stationary sub-segments
  - » Identify noise/calibration stationary sub-segments and evaluate joint likelihood based on separate analysis in each
  - » Cf. T030119-00-Z for quantitative method for identifying stationary sub-segments
  - » Cf. T030090-00-Z for method by which analyses on stationary sub-segments are combined
- Identification of stationary sub-segments
  - » Form cumulative mean, variance, χ^2 fit to normal distribution formed on short intervals (e.g., 16s)
    - – Work only with samples in [5, 95] percentile range to reduce sensitivity to outliers
  - » Mark segment end when interval mean, variance is inconsistent (at 95% conf.) with cumulative quantities twice in a row

medNoiseChar: Stationary Segment Identification



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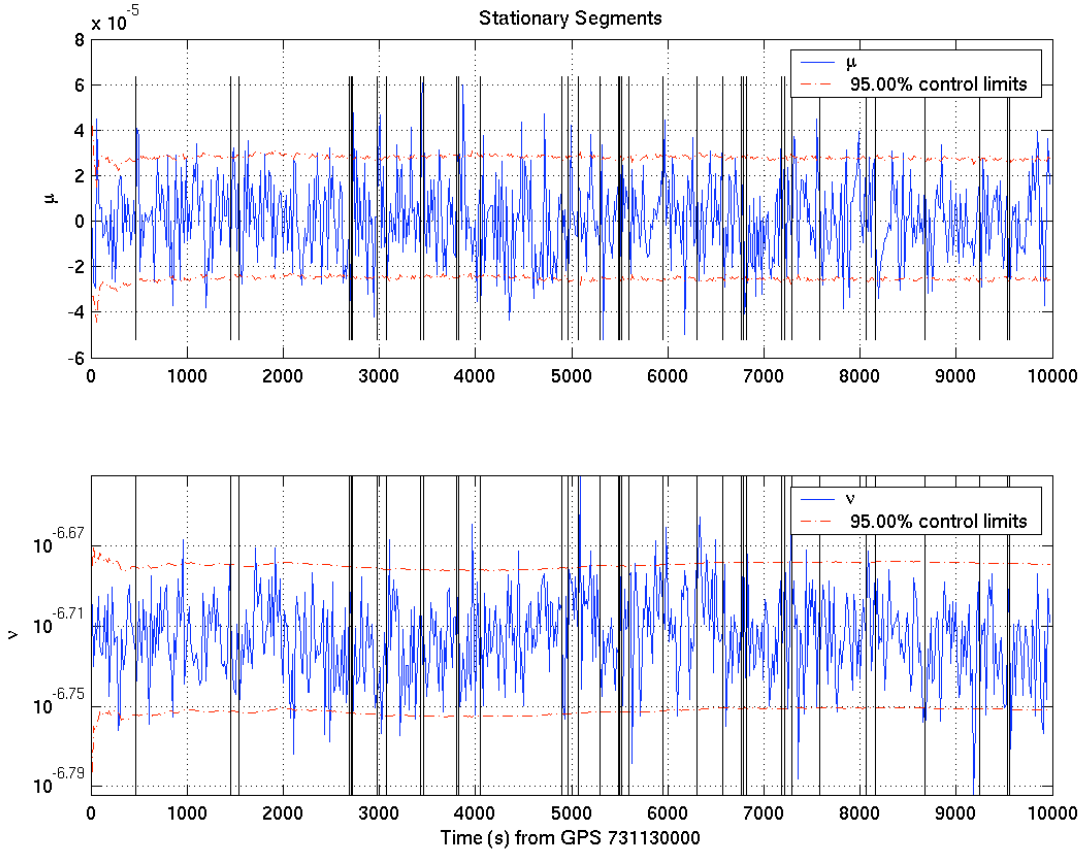
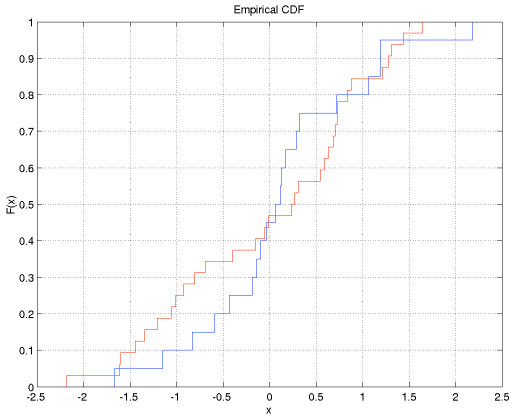
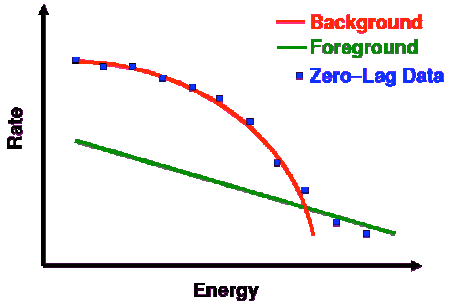


- This example:
  - 16s averaging interval
  - ID'd 38 stationary segments
  - median duration 208s
  - average duration 262s
  - duration < 64s: 26%
- Open Issue: choice of averaging interval

Statistical Methods

- Yes/No:
  - » Mann-Whitney statistic or K-S decides whether two sample sets are from same or different distributions
- Interpreted rate/strength bound:
  - » Bound the contribution of a galactic distribution of, e.g., ms Gaussian sources in a rate/strength diagram to the zero-delay distribution
- Detection:
  - » background analysis of # vs. energy determines energy above which fake triples are rarer than, e.g., 1/y.
  - » Carry-out detailed analysis of any/all zero-delay triples that are rare by this criteria.





Statistical Methods

- Spectral analysis:
  - » ID spectral types (similar energy distribution in time, band)
  - » *Yes/No* analysis on spectral types
- Operation Roman Candle:
  - » ID all events with energy in 900 - 930 Hz band
  - » *Yes/No* analysis on these events