LIGO

A Test for Nonlinear Couplings: Results from S1

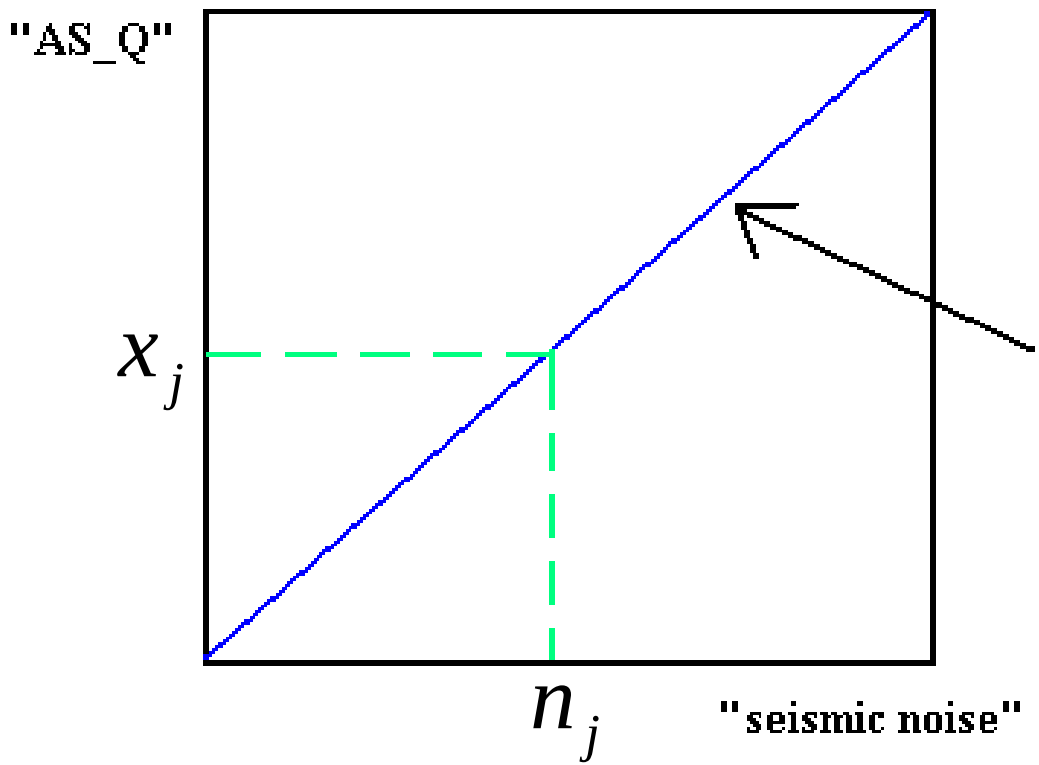
Tiffany Summerscales

Penn State University

LIGO-G030063-00-Z

Coupling in LIGO data

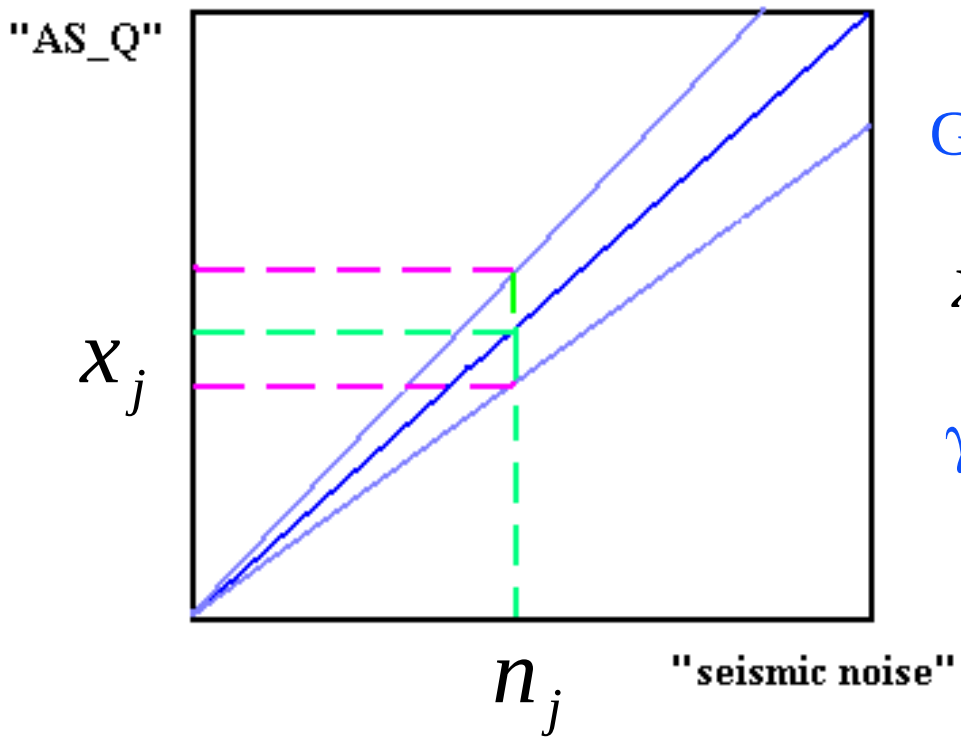
Noise may couple to signal linearly . . .



Slope = linear coupling

Coupling in LIGO data

Or non-linearly: e.g., hysteresis



Gain = $(1+\gamma n_{j-k})$

$$x_j = n_j(1+\gamma n_{j-k})$$

γ: nonlinearity parameter

Test for Non-Linear Coupling: Summary

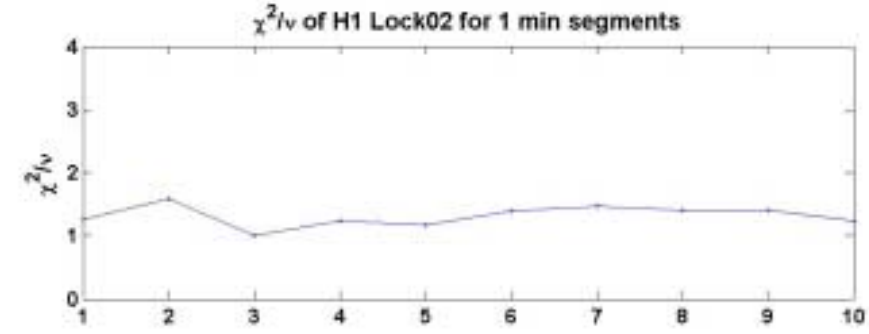
- Model: $x_j=n_j(1+\gamma n_{j-k})\rightarrow x_j=(\cos\theta)n_j(1+(\tan\theta)n_{j-k})$
  - » $\gamma\rightarrow\tan\theta$ more sensitive to small effects
- Apply a threshold and classify above-threshold data points as “events”
  - » A nonzero θ will cause the events to deviate from a Poisson distribution
  - » A nonzero θ will cause the intervals between events to deviate from an exponential distribution
- Evaluate χ^2 fit to exponential distribution
  - » χ^2 per degree of freedom ν will be ≈ 1 to be consistent with $\theta = 0$
- Use value of χ^2 statistic to set confidence bounds on θ

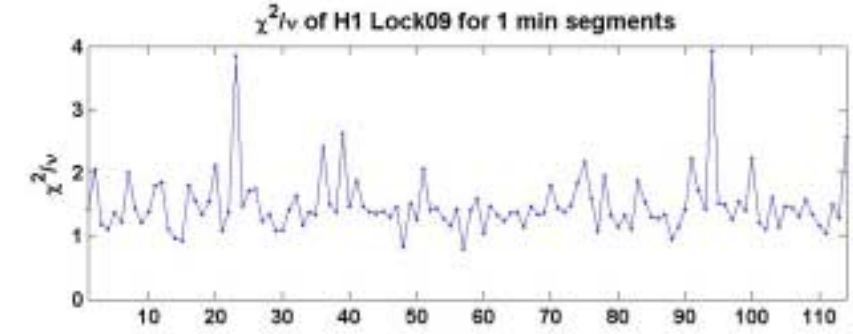
LIGO

Apply test to S1 data

- Test applied to all lock stretches of S1 Playground data
  - » Applied to 2 min and 1 min long segments
- Data first restricted to 256-1024Hz frequency band
- Whitened using an AR model with 28 coefficients
- First and last 50 samples thrown out to avoid end effects of the whitening filter
- For calculating χ^2 statistic: threshold = 2.5, number of bins = 100

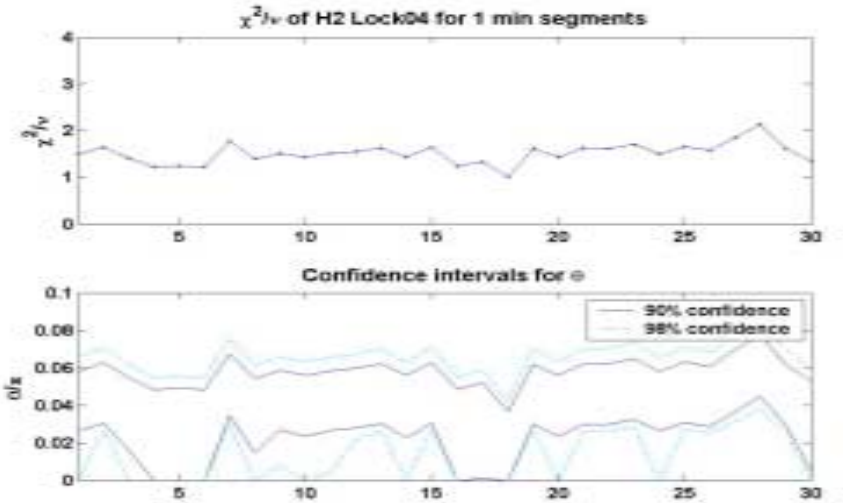
Results:H1

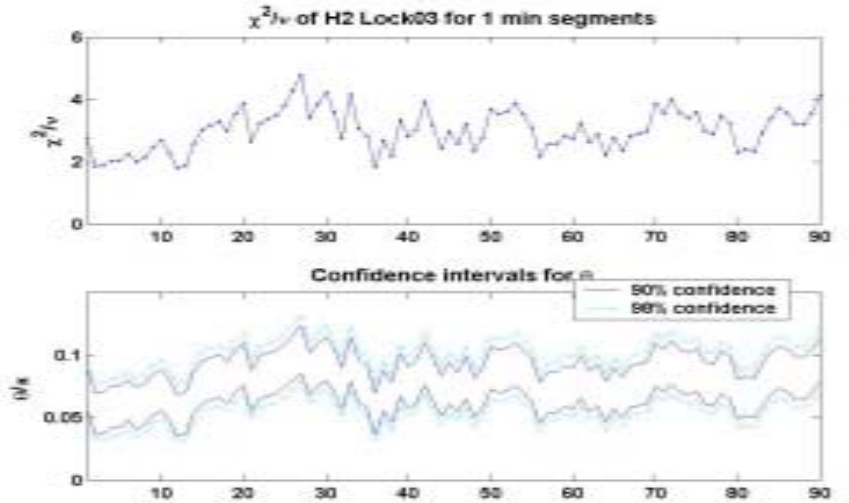




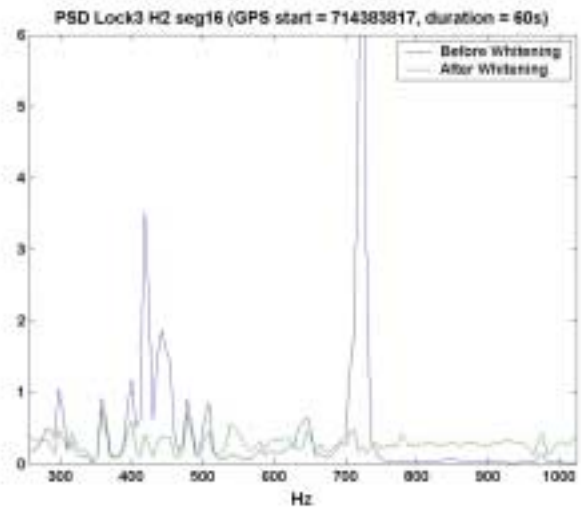
- H1 “best behaved” of all of the detectors
  - » $\chi^2/\nu<3$ almost all of the time
- Small deviations from θ consistent with 0 probably mostly due to inadequate whitening

Results: H2

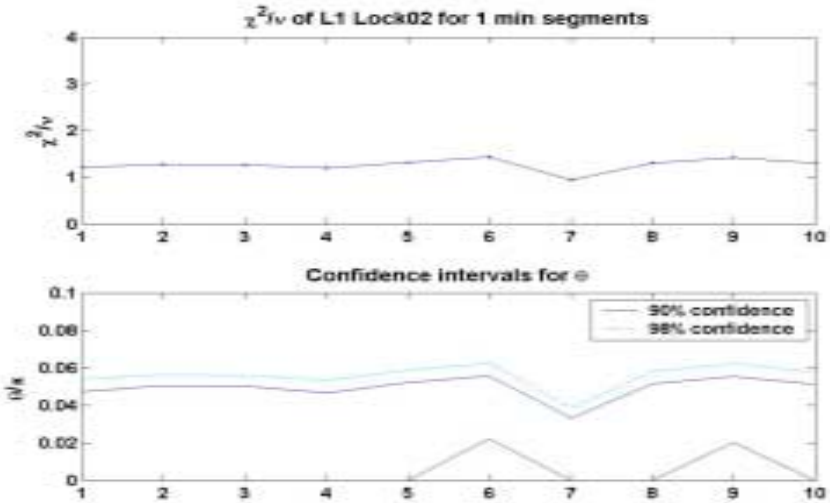


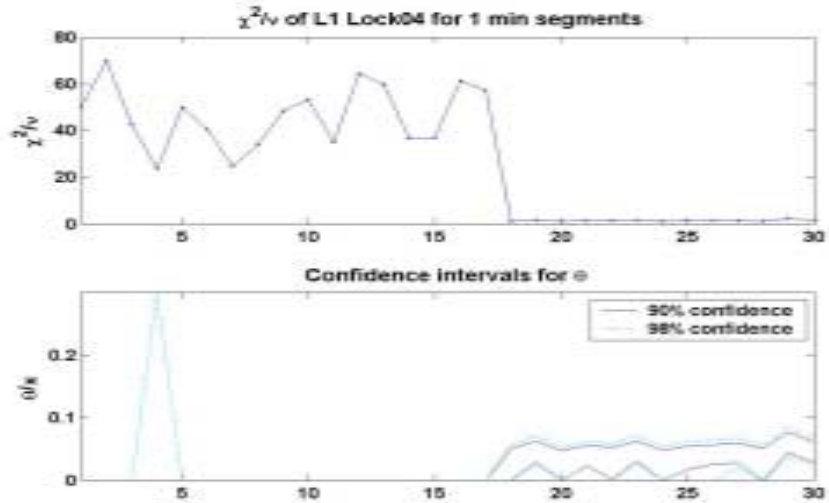


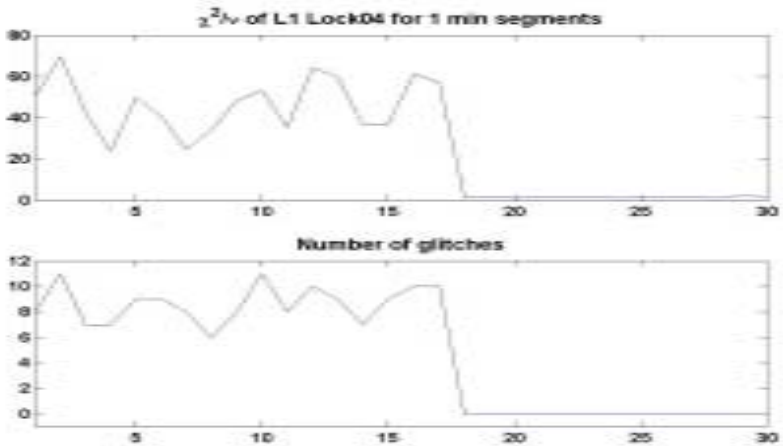
- H2's average χ^2/ν higher than H1
  - » χ^2/ν range mostly between 1 and 4
  - » Higher average may be due to larger power lines
- $\chi^2/\nu > 6$ present at the same time as rung up violin modes



Results: L1



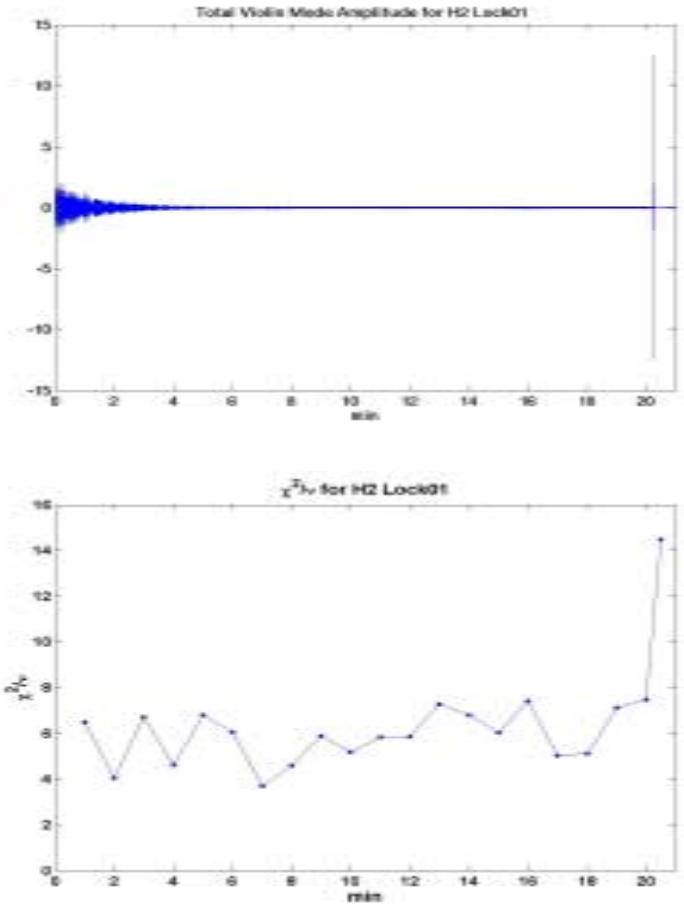




- Highest values of χ^2/ν
- Some high values correspond to violin mode ringup
- Most of the highest values seem to be caused by glitches
  - » Attempted removal of glitches since they skewed the normalization of the data causing the χ^2 test program to crash
  - » Evidently, not all effects of the glitches removed

LIGO Results from S1: Correlation between violin mode ringup and high χ^2

- All detectors have lock stretches with large amplitude violin modes
  - » H1 – Lock01
  - » H2 – Lock01, Lock05, Lock07
  - » L1 – Lock10, Lock12
- Kalman filter used to remove the violin modes
- Times of high violin mode excitation **still** produce the highest values of χ^2/ν.
  - » For most lock stretches, χ^2/ν jumps by an order of magnitude.
- Evidently, the effects of the violin mode are not removed completely with the Kalman filter.



LIGO

Conclusions

- High amplitude violin modes have effects which cannot be easily filtered out
- Insufficient whitening and glitches can fool the test
  - » Need to perfect whitening techniques and remove sources of large glitches
- Complete set of results posted on the web
  - » Available at http://gravity.phys.psu.edu/PSURG/
    - – Login/Password: Available upon request, subject to collaboration data policy
    - – Under Summerscales
- Test made into Matlab toolbox
  - » Available at http://gravity.phys.psu.edu/~tzs/toolbox/