Attendance

- In person
  - » Camp
  - » Centrella
  - » Kalogera
  - » Strohmeyer
  - » Clement
  - » Sylvestre
  - » Marka
  - » Baker
  - » Finn
  - » Norris (Friday only)
- On Phone (on and off)
  - » Daw
  - » Weinstein
  - » Zweizig
  - » Giaime
  - » Gaenezer
  - » Katsavounids
  - » Shoemaker

Slope Detector

Ed Daw

LIGO-G010153-00-Z

What does it do?

- See Daw's slides
- Slope filter
  - » Linear (or non-linear) filter: straight-line fit to "N" points
  - » Straight-line fit filters: find best fit ax+b
    - – "OD" (offset detector) returns b
    - – "SD" (slope detector) returns a
    - – "ALF" (non-linear function of a, b)
    - – Returns are at the sample rate
- Threshold filters
  - » "TH": Simple threshold: discriminant is the data amplitude in a sum of N successive bins (what does this mean?)
  - » "CG": Threshold on data convolved with a Gaussian of width N bins
  - » "CS": Threshold on data convolved with a single period of a sine wave of period N bins

What knobs can be twiddled?

- Tunable parameters
  - » Ordinarily three:
    - – Threshold: Threshold. The minimum signal level that fires a trigger
    - – Peak duration: The width of the peak. If data y_i causes a trigger, W is the minimum of j such that y_{i+j} causes a separate trigger
    - – Filter timescale: N is the number of successive bins used to calculate the discriminant
- This filter needs whitened data, and needs bandwidth selection
  - » Too much noise at low frequency, interested in the sweet spot
  - » How can it be made to work with heterodyned data? Use datacondAPI
- Jay Norris: Scargle's Bayesian block analysis. Change-point analysis
  - » GSFC has tools for constant rate change point analysis for binned data

What is sensitivity to different burst types?

How can you tune search?

What information is placed in database

- Written to database
  - » Name of dso
  - » Name of channel analyzed
  - » Start time of unfiltered data segment that caused the triggger
  - » Amplitude: how big is peak in the filtered data

Discussion

- Can this be generalized to apply a general (time domain) linear filter to data?
  - » Yes! But not high on Daw's list of priorities. Can be bumped-up.
- What constitutes a "threshold"?
  - » Currently if y-intercept is "large enough" or slope is "large enough". But these are meaningless criteria from perspective of what the signature of a signal is.
  - » Recommended threshold: Focus on mean of y-intercept in physical time and how it behaves over several filter correlation times: is it (in physical time) constant over many correlation times)? Similarly, slope. This criteria is indicative of signal.
- Conclusions
  - » DSO is behind
  - » Simple to understand and use
  - » Will be ready for E7 (some filters may be run offline)
  - » Don't know what kind of signals this is, isn't sensitive to

TFCluster

Julien Sylvestre

LIGO-G010153-00-Z

What does it do?

- See Julien's slides
- Algortihm
  - » Compute spectrogram
  - » Threshold on power, getting a binary "probability" distribution
  - » Look at "clusters" in the thresholded data set
    - – What is a cluster? Size of adjacent bits, or on size and distance for pairs of clusters
  - » Threshold on integrated power for significant clusters
- Two parts: build 2-d "image", identify clusters
  - » Distinct code modules: Can apply cluster detector to any 2-d rectangular data set

What knobs can be twiddled?

- Time resolution of spectrogram: T
  - » Frequency resolution 1/T
  - » # frequency bins = bandwidth x T -1
  - » Finite size effects when T is small
  - » In practice, T > 1/32 , I.e., tens of cycles in LIGO band
- Pixel trigger probability: p
  - » In white noise, theshold on power: p = exp(-eta/sigma^2)
  - » Precise control over false rate
  - » Should be kept large with most rejection done by clustering analysis
- Minimum cluster size
  - » Large clusters are exponentially unlikely to form in white noise
  - » Very efficient way to “denoise” a one-bit spectrogram

What knobs can be twiddled, cont'd

- Time resolution of spectrogram: T
  - » Frequency resolution 1/T
  - » # frequency bins = bandwidth x T -1
  - » Finite size effects when T is small
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What knobs can be twiddled, cont'd

- Maximum distance: d_{s1}, d_{s2}
  - » Generation to grouops of disconnected, small clusters
  - » Efficient way to capture weaker signals
  - » High-order terms cause 10% error in false alarm rate analysis
  - » S(s-1)/2 such terms, organized in a vector
- Total power threshold: alpha
  - » If only white noise, power integrated over cluster follows a chi-square distribution
  - » A threshold Q(alpha, s) is set so that only a fraction a of all clusters survive this cut if only noise is present (see expression in Julien's slides)
  - » This cut is similar to the excess power; main difference is in …

How can you tune search?

- Match T to signal duration and frequency evolution
- If signal is a blob in tf-plane, set large threshold on sigma, use d = 0
- If signal is a thin curve in tf-plane, set sigma to a small value use d!=0
- Use alpha to (dis)favor small tf-volume, intense bursts rather than large tf-volume bursts with moderate average

What information is placed in database

- Parameters
  - » Channel name
  - » Database table (GDS_TRIGGER or SNGL_BURST)
  - » Number of data
  - » Sampling frequency
  - » Size of segments
  - » Overlap between segments
  - » Implicity: type of power distribution estimate. White noise of unit variance, psd from datacondAPI, fit to Rice distribution
  - » Error goal on fit of power distribution
  - » Implicit: (square of) response function

GRB Pulse Paradigm

Jay Norris

- Some GRBs are nearby
  - » At least one correlated with a “type 1C supernova”
    - – But no one knows if this really a supernova: it was an odd thing thrown into a grab-bag class
  - » GRBs are becoming classifiable in terms of
  - » Duration (short bursts
  - » “spectral lag”
    - – Peak in cross-correlation of time profile in two different energy bins. Long-lag is several seconds.
- Long-lag GRBs appear to be confined to the supergalactic plane
  - » 4/5 in half the sky about supergalactic plane
- On order 8 long-lag per year in BATSE catalog

LIGO

Discussion

Discussion

- What goes in the database? Should there be a (set of) standard field(s), common for each search, that is useful for inter-comparison among filters? Can such a thing be defined?
- Uniformity of presentation
  - » Is “time” of event the time of “peak”
  - » If can’t define duration, can’t define the “beginning” or “end” or “middle” of a burst
- Uniformity of presentation
  - » Is “time” of event the time of “peak”
  - » If can’t define duration, can’t define the “beginning” or “end” or “middle” of a burst
- Conclusion
  - » Each filter must make its own definition
  - » Combination for analysis needs to take place after each filter is analyzed

Information and discussion points on gravitational wave sources

Joan Centrella

LIGO-G010153-00-Z

External Trigger Search

Szabi Marka

What does it do?

- Event Sources
  - » Non GW
    - – GRB (GCN for E7)
    - – Neutrino (SNO for E7)
    - – Optical SN searches
  - » GW
    - – ALLEGRO (E7)
    - – GEO (E7)
- Continuous (frame) data sources
  - » GEO - but not in realtime during E7. Will arrive after E7.
  - » ALLEGRO
  - » None other now (AURIGA)

- What are event rates from these?
  - » GRB: about 1/d
  - » Neutrino:
  - » Optical SN:
- Reliability of events?
  - » HETE: off-line randomly for large periods for calibration
- Information in database
  - » ALLEGRO, GEO: will we have enough
- ALLEGRO:
  - » No one in burst group appears to know anything about ALLEGRO data
  - » ALLEGRO may not be cool at E7

Discussion

- Optimal balance of event and data driven approaches

External triggers database table definition

- Trigger information
  - » Notice type, Trigger type, Trigger number, Trigger source
- Time of event
  - » Start time, Duration, Date of max? Discovery time
- Size of event
  - » Amplitude, intensity, magnitude, trigger magnitude
- Event/detector properties
  - » Frequency bandwidth, Counting rate, S/N, Local S/N, Rate, Maximum size
- Etc. Szabi will circulate for comments
- Why a monolithic database? Why not a hierarchical structure of databases?

- Do we have a way of recording when channel was lost, when it was recovered, and when the database has been brought up-to-date in that epoch?
  - » Not yet: need to implement
- Some points on GRB trigger driven analysis (instrumentalist approach)
  - » Lock-in technique for analysis: how do we define on, off-source
    - – Fair assumption: before, after GRB is on, off

Questions about data/statistics stationarity

- Must be tested/verified
- Is data sufficiently stable
  - » Within lock segment
  - » Between lock segments
  - » Time-scale for evolution
  - » Over time associated with optical SN, GRB, neutrino signals
- Don’t forget that black hole formation may be after fall-back
  - » Important for SN, not for GRB since GRB requires BH to power shock that produces GRB

Role of E7 for us

- Prototype of GRB trigger code will run close to real time
  - » Parameter will be set based on E6 datqa
  - » Need investigations of stationarity studies
- Results shortly after run?
  - » In case of no useful triggers
    - – We should still be able extract
      - Stationarity and parameter
      - Method sensitivity with current ifo (virtual upper limit)
- Upper limit work, if triggers with corresponding data are received

Excess Power Statistics

Patrick Brady

LIGO-G010153-00-Z

What does it do?/How it works

- See Patrick's slides
- Pick a start time, duration, and frequency band
- FFT a block of time (start time, duration)
- Sum the power in the frequency bands
- Calculation the probability of having obtained the summed power from Gaussian noise alone
  - » Use chi-square
  - » What is the expected? Assume that whitened to unit variance by some known calibration
- If probability significant record detection

Status

- LAL code: source,doc, test
- Dso: source, doc, example
- MDC: tested under ldas using simulated data produce events inserted into database
  - » Bug reports: none currently open
  - » Efficiency: improved by better communication (~8 times faster than real time)
  - » Duration/band: corrected some problems with how computed
- Run on inspiral challenge data:
  - » Code could detect weakest signal injected: binary inpsial with (m,m)=(2.2,3.6) at 55 Mpc in simulated LIGO-I noise, corresponding to matched filtering snr ~ 10–12, power statistic threshold

What knobs can be twiddled? (Command line parameters)

- Number data points in a segment
- Number of segments
  - » Number of overlapping segments
- Overlap between segments
- (Note that these three carry redundant information: a test of integrity of transmitted data is done based on this)
- Overlap between neighboring TF tiles
- Smallest extent in frequency of TF tiles to search
- Minimum time duration for a TF tile

- Lowest frequency in Hz to be searched
- Delta f: frequency resolution of first TF plane (finest frequency, coarsest time)
- Number of frequencies in first TF plane
- Threshold in number sigma
- Default value for false rate
- Number of segments sent to slave for analysis
- Identify events with alpha less than alpha0
- Number of events accepted from a serch over num points of data
- Channel name

What is sensitivity to different burst types?

- Search is good to go after signals where you know only product TF: I.e., product of duration and bandwidth
  - » Know more, probably better to use some other method
- Search good statement makes assumption that all signals (of same TF) equally likely
  - » Not true, since psd in signal space not white
  - » Need generalization to over-whitened data
    - – Divide by psd, not root(psd)

How can you tune search?

- See parameters
- Choice of TF size are interested in

What information is placed in database

Discussion

Discussion: Interpretation Style

Triggered Analysis: General

- Can trigger be another gw detector?
  - » No: This is coincidence
  - » Difference is that we know there is a source (or have high confidence) in a trigger, but not in a coincidence
- Trigger v. coincidence analyses are different
  - » Focus here on triggers
- Are we doing science, or doing a dry-run?
  - » Dry-run: we enter pretending and without expectation or plans to produce a paper or do a full analysis. I.e., an exercise in running LDAS.
  - » Science: we go at with every expectation that, if the data and conclusions warrant, we will place results before community
  - » Conclusion: science.

Triggered Analysis: Gamma-ray Bursts

- Upper limits
  - » Finn, Mohanty, Romano
    - – Including variations
- Extended discussion of upper limit blending in to detection
  - » Finn, Mohanty, Romano implementation of Feldman & Cousins
- What are allowed, disallowed uses of data?
  - » Examples of each: retrospective cuts that depend on data not allowed. Prospective cuts allowed. Termination criteria that depend on data not allowed.
- When do we have an obligation to publish? When do we have an obligation to not publish?

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- Statement we can make
  - » We have not detected an association
  - » Our sensitivity is h_{rms} over a band
- Depending on the character of the bursts we trigger on
  - » May also say something about different classes, by cutting on long vs. short, or ones we have distance on, or long spectral lag vs. short spectral lag
  - » May run in to small number statistics, but won't make mistake if we let the cuts be driven by grb science as opposed to gw data
- Model discussion
  - » Ratio of gw to gamma-ray burst flux/fluence
  - » Don't necessarily focus on existing model: report information and let community tell us useful or not

“As if” analyses

- Inspiral, Periodic searches discriminate target source from other sources. Burst searches do not discriminate between sources in as specific a way
- Can we make an “upper limit” without a discriminating source model?
- What is an “as if” source?
  - » Luminosity function, spatial distribution, *some characteristic that discriminates source from other sources* (and noise)
  - » Example: black hole ring-down
  - » But, do we have better ways of searching for an “as if” population given our knowledge of source character, and are we irresponsible in interpreting output of a non-discriminating filter in terms of this source?

Paper I

Triggered Search

(Draft by Vicky Kalogera)

Outline

- UWM Archive for paper
  - » REVTeX, master paper.tex with section includes
- Assumptions
  - » Instrument described elsewhere
  - » Overall nature/character of data is described elsewhere
- Section2: Astrophysical motivation
- Methodology section
  - » Classic theory + literature
  - » Choices/implementation
    - – Analysis method
    - – Data selection/astrophysical choices
  - » Properties of gamma-ray bursts in data selection
  - » Cuts

Outline, cont'd

- Calibration
  - » Simulations
  - » Determination of false rates (false alarm, efficiency)
  - » Anything done to assess confidence in results
- Results
  - » Review previous results from bar experiments, etc.
  - » Our results
  - » Figures or Tables
    - – On, off-source distributions and properties for each sectioning of the data (long v. short, etc.)
    - – Representative cross-correlations
    - – Follow-up analysis
- Discussion/Interpretation
  - » Ratios of energies, h_{rms}
  - » Subclasses

How to use the DSOs

Discussion

- Can we provide enough info in an instrumental paper to allow people to assess data against their own models?
  - » No: this is a data product that we don't have the knowledge to produce.
- What can we set upper limits on?
  - » Strain (averaged over, e.g., source population)
  - » Rate density (generalized density: per galaxy, per volume, per …)
  - » Something else?????
  - a c^2 fit of number vs. amplitude for noise and noise + signal of different rates and amplitudes/luminosity function

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Instrumental paper

- Example: histogram power in tiles in TF plane, test against null hypothesis (per tile) that noise is normal.
  - » Question: independence of tiles?
  - » Question: can we accumulate enough data to make test at interesting level?
  - » Question: where can the data be accumulated (frames? Not likely to be database)
  - » This is a “matlab” analysis
- Saulson drafts this paper

“Astrophysicaly motivated” paper

- Identify in, e.g., tfcluster, what certain things look like: e.g., bh ringdown has a shape that scales depending on where in tf plane, zm bounds certain regions of tf plane, ns merger occupies a particular place in tf plane, etc. Set upper limit bursts of these characters.
- Use signature not just in tfcluster, but in all three. Know whether or not using additional searches add discriminating power to test.
- If using, e.g., zm need to have discussion with burrow, Fryer, Woosely, etc., to see whether there are systematics, associated with the simulations, that bias the catalogs away from space that includes all waveforms
- Finn’s assignment

The Slope Detector DSO

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Abstract

The intent of Slope Detector the DSO is to provide tools for analysis of LIGO data for burst-like events by thresholding on the output of a set of simple time domain filters applied to arbitrary data channels from the LIGO detectors. I discuss the filters, their free paramters, and information about triggered events that the DSO places in the LDAS databases.

Time Domain Filtering Strategy

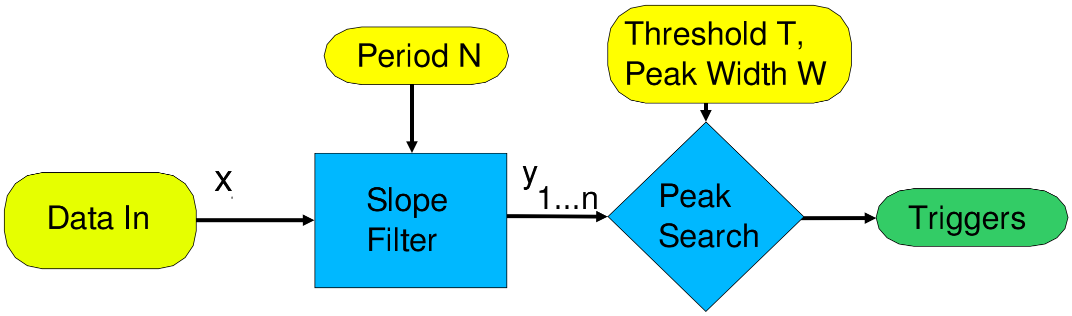

Figure 1: Applying a Slope Detector to Data

Advantages of Time Domain Filtering:

- Fast. Number of FLOPS per data point is small
- Output data has no boundries to deal with. Constant sensitivity.
- Few Tunable Parameters (ordinarily three: threshold, peak duration and a filter timescale)

Filter Techniques for E7

Straight Line Fit Filters

For each input data segment $x_{i+j}|j = 1 \cdots N$, fit to a straight line $b_i + ja_i$. Related filters are [1, 2]:

- 'OD' (offset detector) filter. Filter output is b_i.
- 'SD' (slope detector) filter. Filter output is a_i.
- 'ALF'. Outout is a nonlinear function of a_i and b_i.

Threshold Filters

- 'TH' Simple Threshold. Discriminant is the data amplitude in a sum of N successive bins.
- 'CG' Threshold on data convolved with a Gaussian of width N bins.
- 'CS' Threshold on data convolved with a single period of a sine wave of period N bins.

Tunable Parameters

- N. N is always the number of successive bins used to calculate the discriminant.
- T. The threshold. The minimum signal level that fires a trigger.
- W. The width of the peak. If data y_i causes a trigger, W is the minimum of j such that y_{i+j} causes a separate trigger.

The parameters N and W affect the duration of the pulse to which the search algorithm is most sensitive.

Written to LAL

- Name of this DSO
- Channel Name. What channel triggered the event
- Time. The start time of the unfiltered data segment that caused the trigger
- Amplitude. How big was the peak in the filtered data?
- Duration. An estimate of how long the event lasted.

Conclusions

This library....

- ....is in its early stages of development.
- ....is very simple to understand and use.
- ....will be ready for E7! (some filters may be run offline)

References

[1] Pradier *et. al.*, An efficient filter for detecting gravitational wave bursts in interferometric detectors, gr/qc-0010037.

[2] Arnaud *et. al.*, Detection of gravitational wave bursts in interferometric detectors, gr/qc-9812015.