ASIS Closeout

August 2003 LSC meeting

Bruce Allen

LIGO-G030478-00-Z

Stan's Challenge

Stan Whitcomb for the prosecution

Graham Woan (for Pulsar)

Joe Romano (for SB)

Patrick Brady (for Inspiral)

Erik Katsavounidis (for Burst)

Pulsar (Graham Woan)

The Scenario:

- 3e-24 signal S2/L1 80% confidence, whole galactic center
- Appears in other instruments at roughly same amplitude but does not add to confidence (inconsistent!)
- S3 – find signal 2e-24 at 0.7 mHz offset, same fdot

The Response:

- To appear in "the exact template" in two other detectors has prob of 10e-34
- 0.7 mHz is Vela-like glitch
- Probability of being in same template is 10e-13
- Evidence for a non-noise source is overwhelming

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Pulsar Scenario

- Consistency checks:
  - » Does SNR increase as root time?
  - » Signal consistent between IFOs? Derive parameters the same within uncertainties?
  - » Do signals respond correctly to diurnal antenna pattern?
  - » Consistent with sidereal time not solar time?
  - » Are individual IFOs subject to a coherent joint analysis?
- Any conclusions based on statistics arguments can't be believed – need to show antenna pattern modulation with sidereal rather than solar time.
- Some concern about frequency glitch and the effect that this might have.

Stochastic Scenario (Joe Romano)

- S2: L1/H1 Omega=0.3+- .2
- L1/H2 = 0.2+-0.3
- S3 L1/H1 0.2+-0.15 and L1H2 0+-0.2
- Consistent with power law slop 0.7 to 1.4 using a chi^2 test.
- Not statistically significant, these are 2 sigma not 5 detections.
- Consistency only meaningful at large SNR.
- Large Omega might be due to environmental correlations or statistical fluctuations. More work would be needed to investigate these.

Stochastic Conclusions

- Levels of Omega inconsistent with known astrophysics for either primoridal background or contemporary background
- Additional investigations needed of instrumental correlations. A plan is needed to do this systematically.

Inspiral (Patrick Brady)

- The Scenario
  - » Nothing in S2
  - » S3 has rho=18 in L1
  - » BH 6.6/4.8
  - » 8 Mpc
  - » Chi^2 flying colors
  - » Next rho =13
  - » H1 and GEO down
  - » H2 sees rho max in 7.8/6.2
  - » Just barely passes
  - » Time delay +130 to –60 msec depending upon which template

Response:

- Preface: waveforms of high mass systems are NOT well understood so passing chi^2 not convincing.

Inspiral Requirements/Follow Ups

Requirements

- Would require +- 11 msec
- Need SNR consistent with relative sensitivity
- Need masses, spins phase consistent
- Criteria choosen in advance of search
- Check coherent SNR and confirm low false alarm probability
- Apply same criteria to all template triggers exceeding threshold in L1

Follow up investigations:

- Look at environmental monitors
- Short lived (<0.7 sec) should be visible in cleaned L1 without strange noise. In S1 this showed PD saturation
- Were TAMA or bars working?
- Make fine grid of templates in parameter space to refine mass estimates
- Are template banks consistently excited?

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Conclusion

- Assuming none of the investigations provide a veto, we would be comfortable calling this a detection of false alarm probability is < 1.e-4
- Astrophysical follow-ups
  - » Any burst/ringdown triggers coincident?
  - » Any electromagnetic counterparts?
  - » Are parameters consistent with astrophysics?

Burst Group (Erik Katsavounidis)

- S2 event (Hanford H1/H2 and Tama) L1 down, event duration Q=10, central freq 700 Hz, good time delays. Location circle crosses galactic plane 20 and 35 degrees off of galactic center, out of 100 timeshifts only two show comparable event.
- S3 event less convincing H1, H2, L1, Tama and GEO down. Lots of convincing cross correlation, amplitude ratios convincing within 1 sigma, Q=10, 550 Hz, location circle doesn't cross galactic plane, 13/100 timeshifts include comparable event.

Burst Group Reponse

Instrumental or astrophysical?

- Q1: was it in other channels which DO couple to GW – can we use them as detection or veto
- Q2: what did environmental channels see? Examine them ALL.
- Q3: Wild scenarios, was the injection system triggered? Was it a data read/analysis artifact? Unknown terrestrial disturbance?
- Further investigation would be needed

How rare is such an event?

- Q1: what is error in background rate?
- Q2: tighten analysis cuts to remove two time-lag coincidences. Then, does zero-lag event survive?

Going public?

- Q1: is there more than one burst that we expect? Can we declare detection with just one?
- Q2: are there other checks to perform? Examine correlations with EM, neutrino and UHE at lower threshold. Would h_rss have been seen by previous experiment?
- Q3: do we wait until sensitivity is better? [S2/S3 easy, wait for S4.]
- Declaring a detections risks a Cabrera 1982 Valentine's day monopole event.

Xavier Siemens, UWM

Calibration for Frequency Domain CW Searches

- How to calibrate SFTs from 60-1800 sec long ?
  - » Stitching Dergachev/Riles
    - – Calibrate 60 sec SFTs, go into time domain, stitch with Hann windows, go back into frequency domain
  - » Dirichlet kernel to make 1 x 1800 s from 30 x 60 s
    - – Original intention was to check stitching
    - – But didn't include effects strong nearby lines. This might be a feature or a problem.
  - » Use average of 30 alphas to calibrate 1 x 1800 s SFT
    - – MAIN TOPIC OF TALK

Siemens

- Discussed use of average alphas for calibration
- Alphas determined from 973 Hz calibration line
- Looked at amplitude of 151 Hz calibration line based on average alphas.
- Better behaved amplitude/phase when using averaged alphas. True for H1, H2, and L1.
- Tentative conclusion: the largest variation in the alphas are due to alpha measurement noise **not** varying IFO response functions.

M.A. Papa AEI

- Automated estimation of S_n(f) for CW wide-frequency searches.
- In S1, just averaged <|SFT|^2> in small clean band.
- In S2, lots of bumps, features and spikes
- Obvious generalization – use running (in freq) mean. Doesn't work – sensitive to strong lines
- Running median works much better (Mohanty). Good block size (for 1800 secs of data) is 100 points = 56 mHz.
- But large lines not optimally normalized out.

Papa

- Modified method to remove very large lines up front.
  - » Sees when average spectra exceeds running median by more than threshold
  - » Then, reinsert the average spectral profile
- Method appears to work very well – removes frequency domain outliers.
- Need to decide where to put threshold (might remove astrophysical sources if they are too close!).
- Need chi^2 test

Alicia Sintes AEI/UIB

- Hierarchical Hough Search
- Concept of Hough transform as incoherent (sub-optimal) method
- Mark pixels in time-freq plane
- Count pixels consistent with particular source parameters
- Method can be use before a coherent search, or afterwards.
- Described S2 pipeline. Not a hierarchical search but a simpler incoherent one, using 1800-sec SFTs.

Sintes

- Peak selection: power in bin over threshold by some factor (say 40%).
- Get binomial distribution of Hough-map pixels.
- Set 95% frequentist upper limits by using signal injections to establish signal strength which gives 95% of the area to the right of this value.
- Hough routines in LAL for > 1 year..
- Stand-alone search code being tested.
- Other validation and test routines also being added.
- Developing condor submit scripts and test routines.

Badri Krishnan, AEI

- Statistics of Hough Maps
- Looks for pattern of f(t)
- Gets number count for each point in parameter space
  - » Select bins with power over threshold
  - » Then set threshold in number count
  - » **HOW TO SET THESE TWO THRESHOLDS?**
- For first threshold, distribution of power is exponential if no signal, else non-central chi^2 with 2dof
- These enter into a Binomial distribution, from which you can determine false alarm/dismissal probabilities

Krishnan

- Use Neyman-Pearson to set thresholds
- This is the locally optimal statistic
- By studying false alarm and false dismissal rates, get optimal values of rho_0 = 1.5 to 1.6
- False alarm rate of 20% in peak detection
- Now need to repeat using real data rather than theoretical Gaussian expectations

Graham Woan, Glasgow

Pulsar Timing Noise and implications for GW searches

- Spins evolve based on f and fdot determined at some epoch
- However some (especially young) pulsars depart from this simple timing models
- Timing noise and glitches, related to irregularities in rotation. Changes in the moment of inertia and/or angular momentum transfer from fluid core
- Young pulsars (high spindown rate) show largest timing noise and most frequent glitches

Woan

- Phi=phi0+ft+1/2 ft^2 + 1/6 f_t^3
- Delta_8 = log_10(1/6 vdotdot tau^3/6) for tau=3 years which is the log of the timing error over a three year period.
- Eg, magnetic dipole radiation vdotdot expected by dominated by timing noise. Youngest objects typically have Delta_8 = 10 msec. Good paper Hobbs 2003.
- Glitches – slow changes in rotation rate. Seen in 21 (3 %) of pulsars. Only 5 have glitched more than once. Theory: timing noise is very small frequent glitches. Vela shows sudden jumps in frequency of parts in 10^-4.
- Crab studied from 1969-1993. Remove 3rd order polynomial see three sharp glitches. Each associated with increase in spindown rate. Also increase in frequency.

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Woan

- Importance: pulsars are NOT fully coherent sources over periods of years. Consider searching over coherence time in addition to normal parameters.
- Even for targeted searches, must also be careful since old observations might have wrong frequency.
- Some glitches may correspond to changes in quadrupole moment.
- Timing noise is red/coherence time is long. Probably only affects Crab.
- Get observers to track frequency of pulsars which are GW candidates.

Duncan Brown, UWM

- Standalone inspiral code
- Uses LAL bank package and LAL_findchirp package.
- Only needs LAL and LALAPPS and FFTW
- Some modifications to chi^2 reported
- Template bank generation code reduces overcoverage
- Runs without anything else on a laptop
- Based on hierarchical search engine from 2000.
- Reads data from frames, templates from XML
- Writes output as LIGO lightweight XML

Brown

- New additions: streamline frame read/write
- Code to compute response from frame calib data
- Resampling code
- Grid infrastructure:
  - » Condor DAG to execute search
  - » LALdataFind to query LDR to find the data
  - » Runs lalapps_tmpltbank to generate banks
  - » Runs lalapps_inspiral to perform search
  - » Code available ot insert XML files into LIGO metadatabase
- DAG – human readable description of workflow – what jobs need to run, and in what order.

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Sukanta Bose, UW-Pullman

Coherent Detection Statistics

- Intro – single detector statistics
- For co-aligned detectors Lambda=|sum of compex signals|^2. But the time delays are sky-position dependent so this depends on theta and phi.
- Works by calling LALFindChirp twice to find \rho_1,2 and computes coherent statistic for all time delays < light travel time
- Describes some of the tests: 2048Hz sampled data, 512 seconds, 1.0-1.5 solar masses, 2.5 pN templates with coherent rho^2 threshold of 50.

Bose

- Gives out time of arrival, rho^2 at each detector, sky position relative to interdetector baseline.
- Did search for simulated signals in simulated noise.
- Graphs observed versus injected time delay – excellent match. Time delay errors < 0.5 msec.
- Graphs of Coherent SNR versus Chi^2. Good progress towards implementation on real data
- Timeline: validate coherent code by Aug 31, lalapps driver by Sept 9th, ready for S2 by Sept 31. Results for next LSC meeting

Soumya Mohanty, AEI

Time domain calibration

- Starts with R=(1+AGC)/C
- Standard approach: put in alpha and beta for gains of C and G.
- Discussed a different approach: kernel K(t-t').
- Model LIGO as g(t)K(t-t')
- So filter data through time-invariant K(t-t') and then multiply by g(t).
- Requires alpha(t) and beta(t). Beta changed five times, and alpha continuous. Rakhmanov trying to design K(t-t').

Finn, Ashley, Sutton, McNabb, PSU

Coordinated set of four talks on burst detection

- BlockNormal burst analysis description and update
- Change point search technique
  - » Is zero delay energy distribution same as background distribition
  - » Bound contribution of galactic ms pulses
  - » Examine zero lag time events in detail
  - » Partition events into spectral types
  - » Comparison with acoustic detector observations (cut on those with energy in 900-930 Hz band).
- Data conditioning
  - » Prefilter
  - » Kalman filtering for line removal

PSU Burst Group

  - » Coarse whitening
  - » Basebanding
  - » Calibration
  - » Line removal
- 6 bands for coarse freq analysis (avoid violin modes and harmonics). 1024-2048 band tricky – no PEM channels to use for regression
  - » Downsample to 4096 Hz
  - » Kalman filter (rmvm in LDAS) needs line model: freq, Q,background noise amplitudes, stochastic excitation. Method of Finn and Mohanty PRD.
- Coarse whitening: FIR high pass filter
- Basebanding: shift low freq band edge to zero freq

PSU Burst Group

- Line removal by regression. Train on nearest preceeding playground data.
- Fine whitening done with AR n=60 order filter MATLAB SYSID toolbox.
- This was fed into change point ID code: blocknormal.
  - » Looks for statistically significant change in statistical measures of data.
  - » Automatically looks for intervals of constant mean and variance.
  - » Threshold on variance (may also threshold on mean)
  - » Cluster events
- Tuning the thresholds, work underway since efficiency not yet known. Set threshold to maximize event rates.

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PSU Burst Search

- Coincidence engine using blocknormal
- Match based on start time, end time, calibrated energy.
- Cut on correlation statistic, refine timing info.
- Group coincidences in the same band across IFOs, then across bands.
- One band correponds to that of bar detectors.
- Can also introduce time-shifts and use this to get background rate.

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PSU Burst Search

- Take set of candidate events
- Addressing the questions:
  - » Dealing with non-stationarity. Some S2 noise varies on minute timescales.
  - » Analysis will take non-stationarity into account by grouping data into sets with similar PSD estimates.
  - » Obtain rate/strength bounds.
  - » Preliminary results by next LSC meetings

Patrick Brady, UWM

Excess Power Method

- Tile T/F plane, look for tiles defined by start time, duration, low freq and freq band.
- Illustrated method on S2 hardware burst injections
- Lalapps_power. Uses same code base as DSO. Reads frame data in, writes LLW XML out. Standalone now available.
- Can be run based on documentation.
- Recent enhancements – needs whitened data. Divides data by sqrt(S_h). So now uses a median-estimator-in-time to track S_h. Not biased by real bursts.
- Demonstrates power code performance for sine gaussian bursts. Can be run on a laptop, or under condor.

Segei Klimenko, UFL

- How optimal are wavelet TF methods?
- Comparison of optimal filters to bandpass filters when waveform is not known.
  - » Define e=method SNR/optimal SNR
- Analysis steps:
  - » Set black pixel probability
  - » Cluster events
  - » Set cluster threshold
- Analyze this for white Gaussian noise
  - » Sum of pixels is gamma distribution function.
  - » Shows effective distance (meaure of performance relative to optimal filtering) as function of SNR

Klimenko

- For optimal waveforms, need cluster sizes ~5
- Tested in BH/BH mergers (Flanagan & Hughes)
- Uses J. Baker et. Al. BH/BH simulations (5 cycles, 3 msec). Can pick a quasi-optimal basis.
- Effectiveness for BH/BH mergers being studied – it appears that the efficiency is 0.7 to 0.8.

Saikat Majumder, UWM

- Using information from astrophysical simulations in searches for bursts.
- Use models for SN core collapse, or BBH merger
- Waveforms not accurate enough for matched filter
- How to use available information? If all that's available is the time-freq window, then excess power is optimal.
- Automated process to make search method optimal for waveform set. Use Gram-Schmidt to form orthnormal set.

Majumder

- Project signal into this vector space and calculate sum of squares of amplitudes.
- For 78 Zweger-Muller waveforms, need only keep a set of ~30 to get 90% of the power.
- Will implement method within excess power statistic.

Scott Koranda, UWM

Introduction to Grid Tools

- A live installation of the LSC data grid client
  - » Download/install PACman (package manager)
  - » Download and install Virtual Data Toolkit
  - » Walked through getting a Grid Certificate

Patrick Brady, UWM

- Update on LSUG progress towards deployment of grid search codes
- Timeline proposed after March 2003 LSC meeting
  - 6 months – prototype applications
  - 12 months – revise and draft white paper
  - 18 months – write grid-computing howto
- New infrastructure in LAL
  - Interface to the frame library redone “grid aware”
  - Decimation/PSD estimation
  - LIGO LW output
  - Interface to calibration info
  - Improvements in filtering code, injection code, date package

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Prototype Grid Applications

- In LALAPPS, there are already three grid-enabled codes:
  - » Inspiral Code (did 600 hours S2 data in a weekend)
  - » Burst (analyzed all S2 playground in a few hours)
  - » Pulsar (used for S1, enhanced for S2)
- Howto by the end of September

John McNabb, PSU

Grid Wrapper for DMT and other stand-alone LIGO analysis software. Example: DMT in batch mode

- One solution: rewrite tools to be grid-savvy
- Second solution: a wrapper for “old” code
  - » Specify data by GPS time, IFO, etc
  - » Output into local subdirectory
  - » Potentially several config files per job
  - » Tool knows where LIGO data located, maintains security
  - » Wraps command-line arguments and environment variables
  - » Manages data flow and submits to condor or PBS job manager
- Submit with command-line script or via Web Portal
- System implemented and tested (locally at PSU)
- Will be incorporated into LSC Grid toolkit

Scott Koranda, UWM

Lightweight Data Replicator (LDR)

- Goal 10 MB/sec, robust and fault-tolerant
- Get URLs of data based on GPS time, lock status, science mode, etc.
- Flexible: sites have different storage systems
- Based on GridFTP
- Did it work?
  - » E7: moved 2TB, but failed (HPSS, LDAP, …)
  - » S1: worked for Caltech->UWM, but some problems
  - » S2: worked for UWM, almost there for PSU, AEI, Cardiff, MIT.
- Plans for S3: will get a better interface, faster database access, more robust. Will be deployed in September.

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Bruce Allen, UWM

- Wide band pulsar search planned for SuperComputing 2003.
- Run on distributed grid
- Search interesting areas of the galaxy:
  - » Core
  - » Gould belt
  - » Nearby globular clusters
  - » First spiral arm

Patrick Brady, UWM

Detection of high-mass black hole inspirals

- Frequency of last stable circular orbit is 125 Hz x (Msolar/M)
- But (especially if mass ratio extreme) you get radiation not just at second harmonic, but also at other harmonics.
- For high total mass objects, the power in the third harmonic becomes significant, and provides a useful discriminator.

Maurice Van Putten, MIT

- Detection Algorithm for determining black hole masses in GRB from rotating black holes
- Objective: establish Kerr black holes as inner engines of GRBs.
- Look for ~few % of BH energy in GWs, emitted as central black hole is spun down transfering energy to a surrounding torus.
- Estimate that actual rate is 500 times observed rate. Rate in Universe is 5e5/year = 1/year in 100 Mpc.
- Ought to be observable with initial LIGO @ 100 Mpc.

Van Putten

- Detection methods:
  - » Stochastic BG Omega ~ 6e-9 at 250 Hz.
  - » As point sources: matched filtering single-detector SNR would be 8 if the waveform were known.
  - » Look at time-frequency trajectories, perhaps using coherent methods

Greg Mendell, Independent Detector Response Test

- Has added test routine to LAL, based on code written by Brian Cameron (SURF student).
- Provides an indepenent test on the response function.
- Current code works for one special case – needs some memory leaks fixed.
- Use lalCachedDetectors (make independent)?
- Will eventually expand this to all detectors, sky octants, years, seasons, etc.
- Showed graph comparing F+ and Fx for crablike source over one day – agreement to parts in 10^4

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Greg Mendell, LHO

Young close neutron stars in the Gould belt – is this a good place to look?

- Pulsar group needs to look at this carefully
- X-ray missions have found more NS in the solar neighborhood. Possible explanation: Gould belt
- This is thin disk, 50-300 pc from sun, tilted at 18 degrees to the galactic plane
- Work by Popov et al shows that evolving a population of NS in the Gould belt could explain excess X-ray emission.
- Estimates by Tania Regimbau seem to indicate that there would be more than one observable NS in the freq range of 100-200 Hz.
- Not yet clear if what you gain by having Gould belt closer, you lose by having to search a great circle in the sky.