LIGO

Observing the Bursting Universe with LIGO: Status and Prospects

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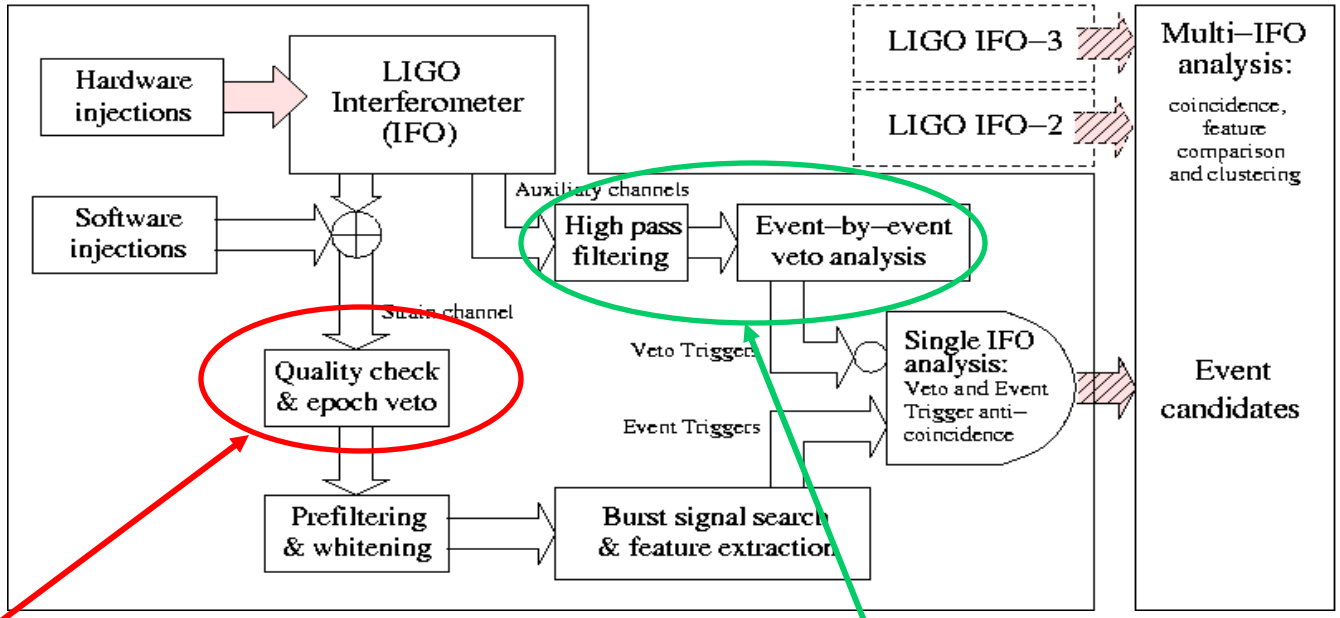
Bursts: what we are searching for

- Sources: known and unknown phenomena emitting short transients of gravitational radiation (supernovae, black hole mergers, Gamma Ray Bursts engines)
  - » **Untriggered:** Waveforms unknown or poorly modeled; generic feautures assumed:
    - – Durations in the few ms to hundreds of ms
    - – Enough power in the LIGO sensitive band of 100-4000Hz
    - – No astrophysical assumption about the nature and origin of the burst
  - » **Untriggered:** Waveforms suggested; templated search possible
    - – Zwerger-Muller/Dimmelmeir supernovae modeling
    - – Black Hole Ringdowns
  - » **Triggered:** Waveforms generally unknown; concentrate on inter-detector cross-correlation search with GRBs

Anticipated Analysis Goals

- Broad frequency band search for transients in order to
  - » establish a bound on their rate at the instruments
  - » interpret bound on a rate vs. strength exclusion plot by assuming bursts were originating from fixed strength sources fixes on a sphere centered around the earth
  - » invoke source population models
  - » perform analysis of energy spectrum of candidate events
  - » compare with bar results
  - » bound transient strengths coincident with gamma-ray bursts (see Marka's presentation)
  - » operate as part of an international network of detectors, e.g., by performing an up to 4-fold coincidence analysis with TAMA (see Sutton's/Kanda's presentation) during LIGO's Science Run 2
  - » search to establish a detection

Burst Search Analysis Path

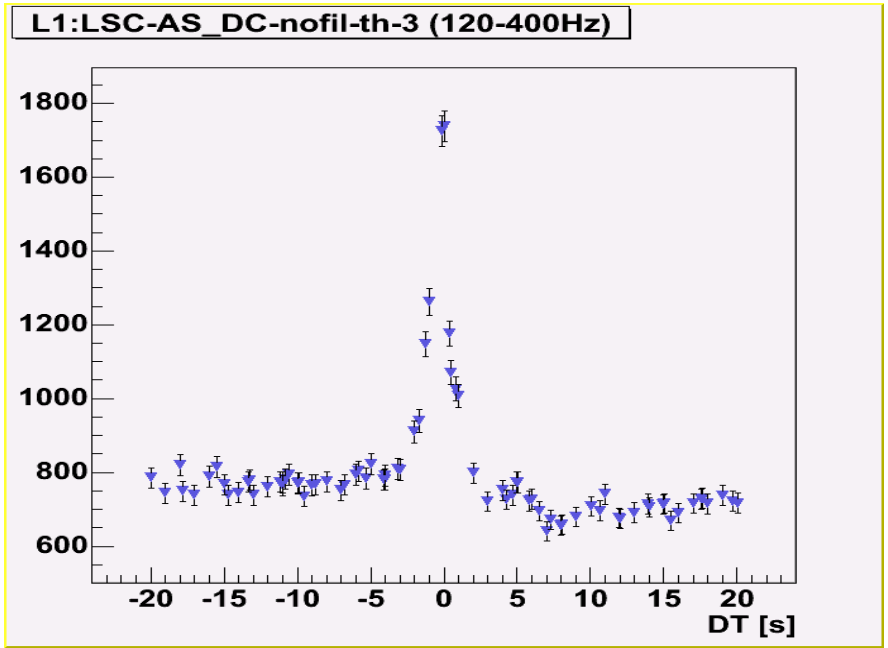


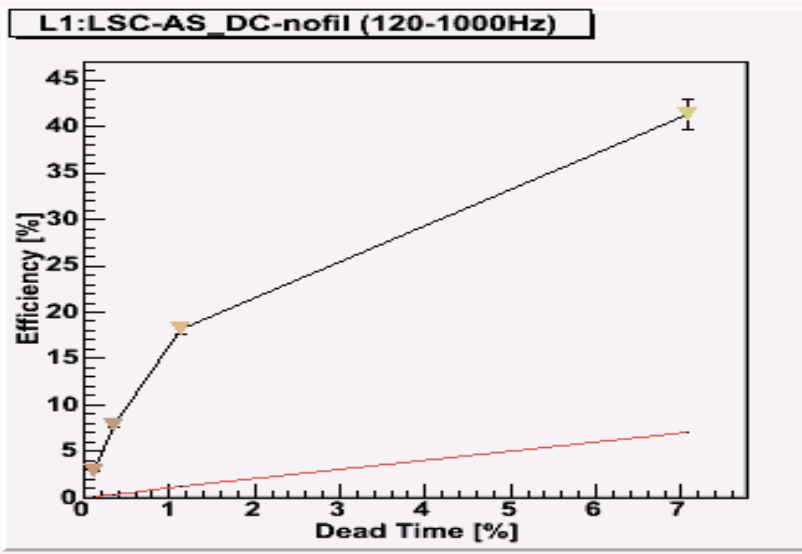
- **Data Quality:**
  - » Identify data that do not pass quality criteria
    - – Instrumental errors
    - – Band Limited RMS
    - – Glitch rates from channel
    - – Calibration quality

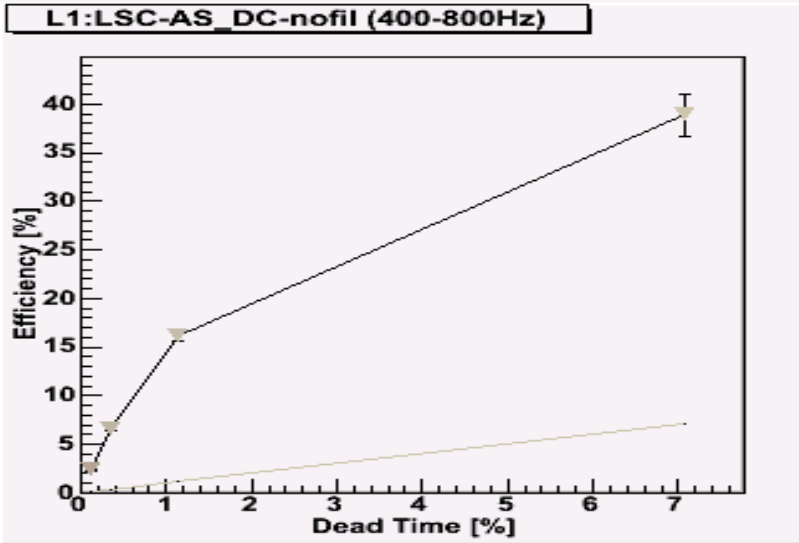
- **Veto Analysis:**
  - » Goal: reduce singles rates without hurting sensitivity
  - » Establish correlations
  - » Study eligibility of veto

A Veto Analysis Example

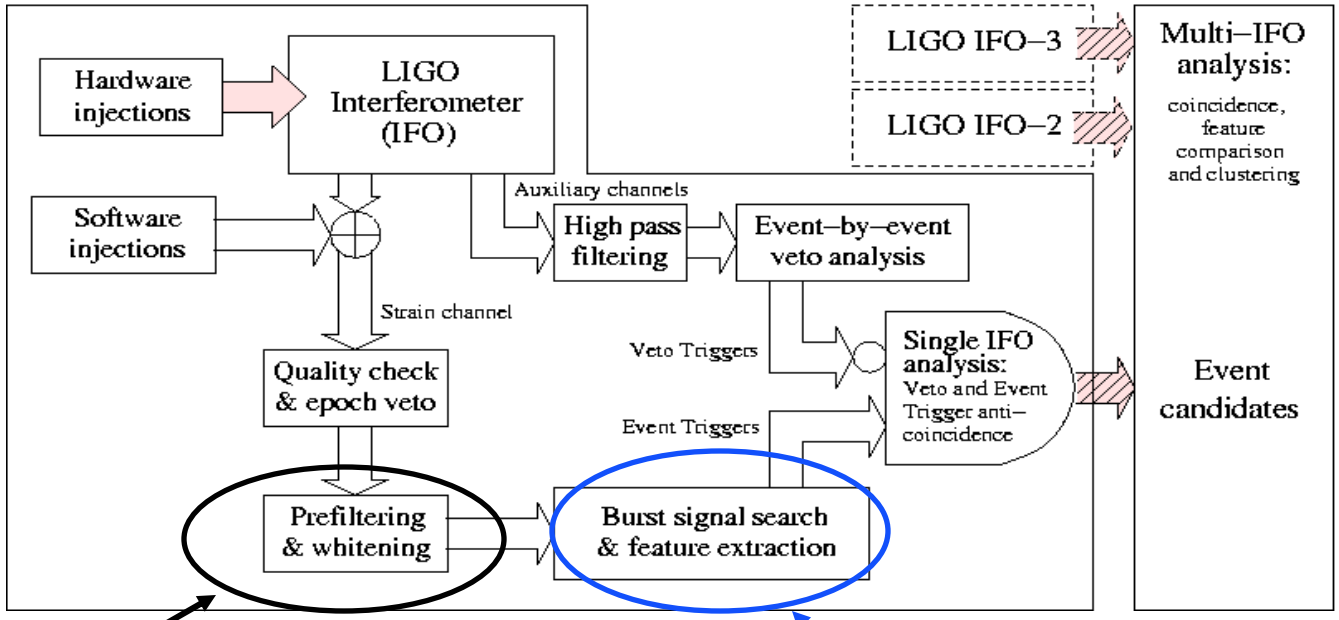
- **Strategy**: Selection of auxiliary channels with glitches that correlate better with burst triggers
  - » Choice among: Interferometer channels, Wavefront Sensors, Optical Levers, PEM channels
- **Method**: Coincidence analysis and time-lag plots
- **Preliminary - Currently being investigated**







Burst Search Analysis Path



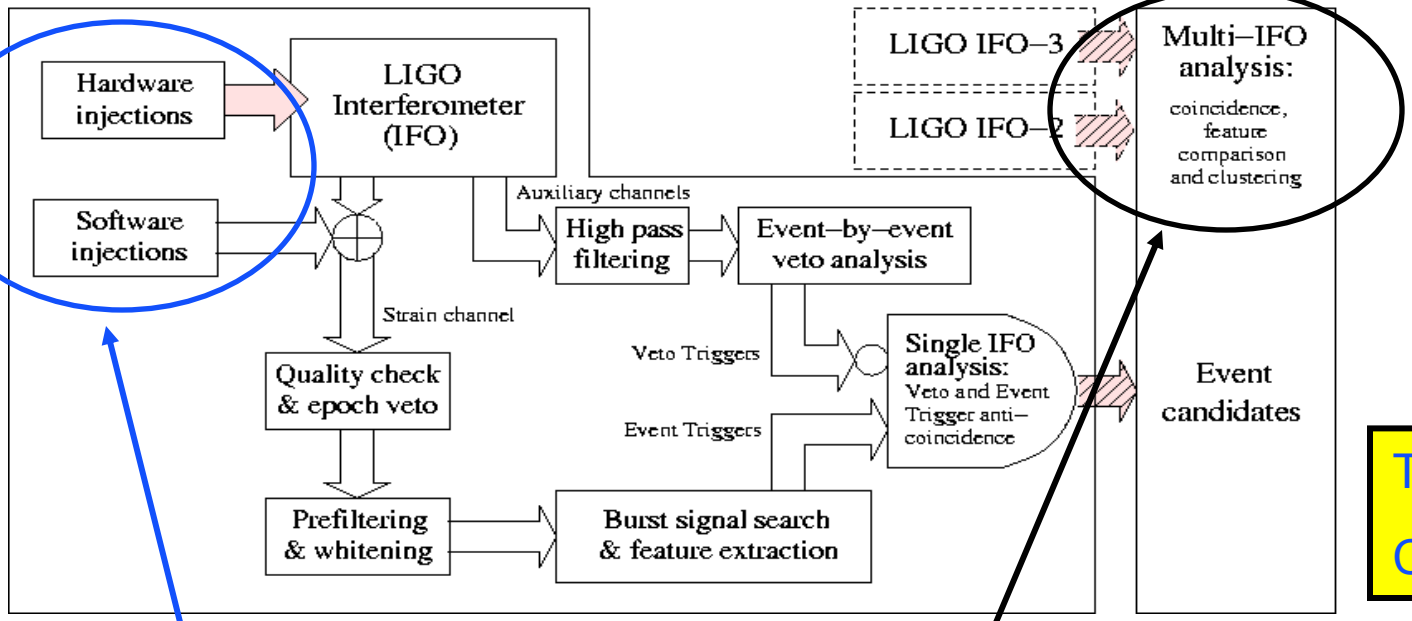
- **Data Conditioning:**
  - » High pass filtering and whitening using adaptive predictive algorithms, dynamically trained during the run
  - » Base-banding

- **GW Burst Trigger Generators:**
  - » TFCLUSTERS (Fourier domain)
  - » Slope (Time domain)
  - » Excess Power (Fourier domain)
  - » WaveBurst (Wavelet domain)
  - » Blocknormal (Time domain)

Burst Trigger Generators

- Excess power (Brady et al, see later talk)
  - » Works in the Fourier domain looking for signal power in a Δf, Δt tile that is statistically unlikely to come from noise fluctuations
- TFCLUSTERS (Sylvestre, see later talk)
  - » Searches for patterns of tiles with excess signal power in the Fourier time-frequency plane
- Waveburst (Klimenko et al, see later talk)
  - » Searches for patterns of tiles with excess signal power in the wavelet time-frequency plane
- Blocknormal (Finn et al, see later talk by McNabb)
  - » Time domain algorithm looking for changes of mean, variance of data
- Slope (Pradier et al, Daw)
  - » Time-domain templates for large slope or other simple features

Burst Search Analysis Path



Talks by: Cadonati

- **Simulations:**
  - » Use to optimize ETGs
  - » Employ astrophysically (and non) waveforms to measure efficiencies of the search
  - » Employ template matching to confront to optimal detection

- **Coincidence Analysis:**
  - » Tighter time and frequency coincidence
  - » Use of amplitude matching among IFOs
  - » Waveform consistency: perform a fully coherent analysis on candidate events

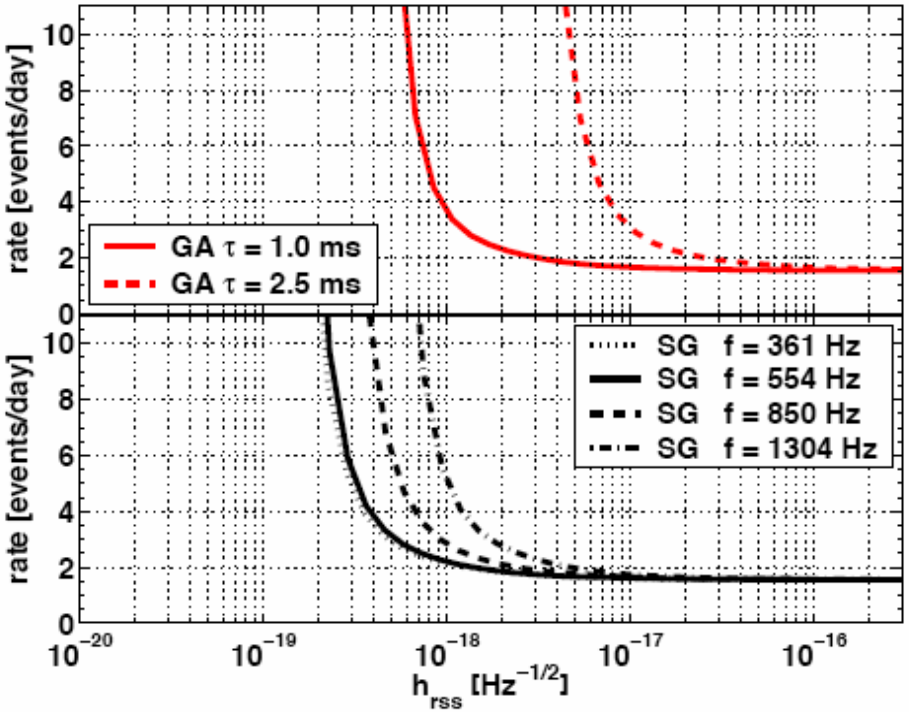
Science Run 1 ('S1') Analysis

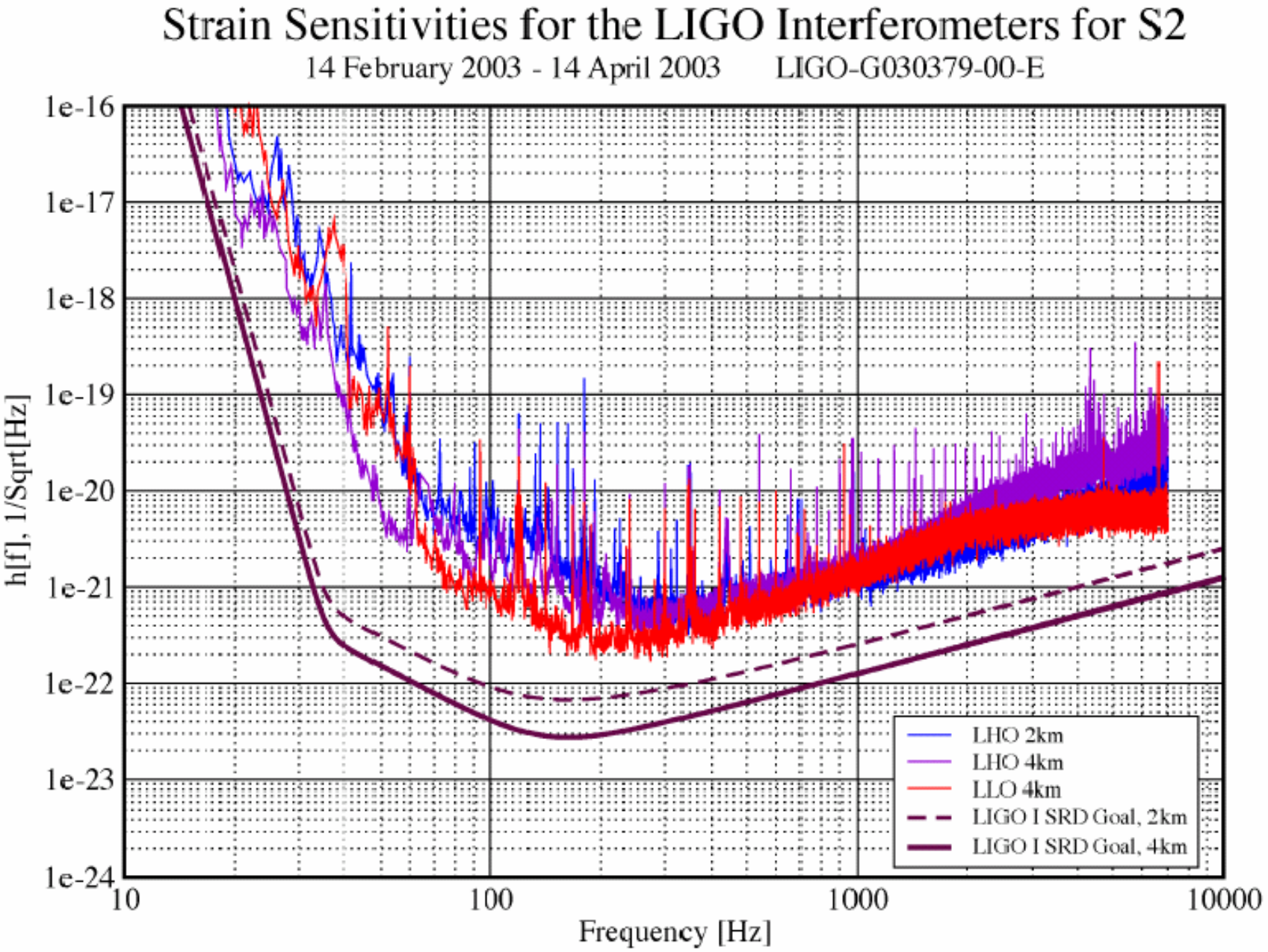
- The first science run (S1) of the LIGO detectors (Aug 23 – Sep 9, 2002) has given the opportunity to make a first and a very significant step in prototyping the LIGO burst search pipeline
- This was an upper limit search; first paper pre-print in the archives gr-qc/0312056
- It represents the most sensitive broad-band search for bursts
- It reflects progress toward better understanding of our detectors, exercising our data analysis procedures
- Many things were learnt; several improvements are currently being pursued in the Science Run 2 ('S2') analysis

Burst S1 Search Results

- End result of analysis pipeline: number of triple coincidence events
- Use time-shift experiments to establish number of background events
- Use Feldman-Cousins to set 90% confidence upper limits on rate of foreground events:
  - » TFCLUSTERS: <1.6 events/day
- Determine detection efficiency of the end-to-end analysis pipeline via signal injection of various morphologies.
- Assume a population of such sources uniformly distributed on a sphere around us: establish upper limit on rate of bursts as a function of their strength
- Obtain rate vs. strength plots

Burst model: Gaussian/Sine gaussian pulses





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Science Run 2 ('S2')

- Feb 14, 2003 – Apr 14, 2003
- Major operational improvements with respect to 'S1':
  - » Improved detector sensitivity by a factor 10 for all three detectors
  - » Four times longer run: at least 300 hours of triple coincidences
  - » Instruments more stationary, data quality cuts less severe than in S1
- Analyses well under way:
  - » Many 'lessons learnt' from S1 are implemented on all fronts of the pipeline
  - » Several complimentary ways of searching for unmodeled bursts
    - – Time-frequency/Time domain
    - – Alternative T-F tiling methods currently being investigated
    - – **Detailed method talks presented in this session by members of the LSC**
    - – **Sensitivities are compareable (within x2) among all methods at the h_{rss} ~ few 10^{-21}**
  - » Significant improvements all across the pipeline:
    - – special emphasis on tightening the coincidence window (resolution at the <10ms) for triggers coming for the interferometers
    - – frequency resolution at the 10-20% level
    - – invoking for the first time coherence analysis of the remaining triggers

Talk by: Chatterji

Summary

- Science analyses looking for Bursts with LIGO have begun
  - » S1 results demonstrate analysis techniques
  - » S2 data already 'in the can' are x10 more sensitive, analyses currently underway, results expected in Spring 2004
- A third science run (S3) started on Oct 31, 2003, expected to last till early January
  - » Instruments are improving and they are making steady progress toward design sensitivity
- Design performance both in terms of sensitivity and duty cycle should be achieved within 2004 and together we expect to:
  - » Prepare burst analyses for the long sensitive LIGO-I run
  - » Mature on how to operate the instruments as transient detectors that are part of a worldwide network of gravitational, electromagnetic and particle burst detectors
  - » Evolve our analyses and our thinking from 'upper limits' to 'real searches'

LSC Burst Presentations in GWDAW

- **15:15** Sylvestre *TFCLUSTERS: detection efficiency and parameter estimation*
- **15:30** Brady *Excess power event trigger generator*
- **15:45** Klimenko *Study of the WaveBurst detection efficiency using the LIGO S2 data*
- **16:00** Cadonati *Coherent coincident analysis of LIGO burst candidates*
- **16:45** McNabb *The Block Normal Event Trigger Generator*
- **17:00** McNabb *Tuning BlockNormal: comparative studies*
- **17:15** Marka *Search for the gravity wave signature of GRB030329*
- **Fri** Sutton *Status and Plans for the LIGO-TAMA Joint Data Analysis*
- **Sat** Klimenko *WaveBurst: Excess power method in wavelet domain for bursts*
- **Sat** Chatterji *Constant Q transforms for gravitational wave burst detection*