An Overview of LSC Data Analysis

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for the LSC

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Joint Data Analysis

Governed by MoU and Attachment

- Joint data analysis working groups
- Coordination of run scheduling
- Cooperation on detector development and commissioning
- Data exchange to begin when Virgo data is deemed to add scientific value

Data exchange began as of May 18, 2007

- Data is being copied between respective computing centers

Gearing up for actually analyzing data from "the other side"

- Scientific value of current Virgo data depends on the specific search

Test case: "Project 2b"

- Exchanged real data from a weekend in September 2006
  — but with secret time shifts
- Analyzed full network with two burst search pipelines

Data Analysis White Paper (Currently in Draft Form)

LIGO SCIENTIFIC COLLABORATION
VIRGO COLLABORATION

Document Type	LIGO-T070083-00-Z
The LSC-Virgo white paper on gravitational wave data analysis **Science goals, data analysis methods, status and plans** **(2007 edition)** **DRAFT as of 2007/06/13**	
The LSC-Virgo Data Analysis Working Groups, the Data Analysis Software Working Group, the Detector Characterization Working Group, the Computing Committee	

"… intended to facilitate:

- the understanding of the science that we are doing
- the identification of "holes" in our science plan and of tasks that demand more manpower
- the prioritization of our objectives
- the identification of areas when manpower should be shifted to and/or removed from
- the exploitation of synergies among the work carried out in different search groups
- an harmonious exploitation of common resources"

Data Analysis Working Groups

Compact Binary Coalescence

Before, during and after merger of two neutron stars and/or black holes

Bursts

Arbitrary transient signals

All-sky and triggered searches

Continuous Wave

Sinusoidal signals (with modulation)

Stochastic

Persistent stochastic signals, either cosmological or astrophysical

Detector Characterization

Also in white paper: computing and software management

Recently Completed and/or Published LSC Analyses

S4 isotropic stochastic search — published in ApJ
S2 coherent CW searches — accepted by PRD
S4 LLO+ALLEGRO stochastic search — submitted to PRD
S4 stochastic "radiometer" search — submitted to PRD
S3+S4 CW search from known pulsars — submitted to PRD
Pre-S4 SGR 1806-20 giant flare QPO search — submitted to PRD
S4 all-sky burst search — submitted to CQG
S3+S4 inspiral search (various mass ranges, no-spin templates)— preprint posted
Mature papers in the review pipeline:

- S2+S3+S4 burst search from GRBs
- GRB070201 inspiral/burst search
- S3 LIGO-AURIGA joint burst search
- S4 semi-coherent CW search
- S3 spinning binary inspiral search
- S4 cosmic string burst search
- S4 stochastic search at 37 & 75 kHz

Highlights: CBC Group

Science goals

Detect compact binary coalescence (or place upper limit on rate)

Measure or constrain properties of population of compact binaries

Probe disruption of neutron stars during merger

Test theory of gravity (scalar-tensor, graviton mass, strong field dynamics,…)

Basic approach

Matched filtering with template banks, coincidence; coherent filtering

Signal-based vetoes, aux chan vetoes; detection candidate follow-up checks

Some current and near-future activities

S5 searches with a few types of template families, without and with spin

Ringdown search, and inspiral-merger(burst)-ringdown trigger coincidence

GRB triggered inspiral search

Gearing up to use Virgo data for some searches

Want to test efficiency of search using numerical relativity waveforms

Study accuracy of parameter estimation for a detected signal

Highlights: Bursts Group

Science goals

- Search as broadly as possible for whatever signals may be in the data
- Stellar core collapse, binary merger (back up the CBC search), neutron star glitch, cosmic string cusp, etc.
- Measure or constrain energy emission from transient events

Basic approach

- Search using excess power, coincidence, cross-correlation, etc.
- Different types of searches: all-sky; triggered; spatially directed
- Data quality cuts; aux chan vetoes; detection candidate follow-up checks

Some current and near-future activities

- S5 all-sky and triggered searches (GRBs, SGR flares, neutrinos, SNe, …)
- Use LIGO, GEO and Virgo data together when available
- Extend searches to higher frequencies
- Fully coherent methods for searches and follow-up waveform recovery
- Want to test efficiency of searches using numerical relativity waveforms
- Improve online searches

Highlights: CW Group

Science goals

Measure or constrain GW emission by known pulsars

Constrain properties of “neutron star” material

Search for GW emission from unseen spinning neutron stars

Basic approach

Search using direct demodulation (using radio or X-ray timing info), long-duration matched filtering, or semi-coherent power sums

Parameter consistency tests

Some current and near-future activities

Search for GW from Crab and other pulsars over frequency ranges

S5 hierarchical all-sky search using Einstein@Home

Target supernova remnants and other “likely” sky locations

Search for GW from accreting neutron stars

Highlights: Stochastic Group

Science goals

Measure or constrain broadband continuous GW signal

Cosmological, or from population of astrophysical sources

Basic approach

Search using optimal cross-correlation of data streams

Isotropic and directional searches

Cuts on stationarity and outliers

Some current and near-future activities

S5 H1+L1 isotropic search result

Position deconvolution for radiometer search

Spherical harmonics search

H1+H2 search — Frequency selection, and estimation of systematics

High-frequency (FSR) stochastic search

Inclusion of Virgo data, especially for directional searches

Making Connections with Astronomy and Astrophysics

(Besides making an actual detection…)

Constraints on cosmic string parameters

Constraints on properties of rapidly spinning neutron stars

Constraints on population of emitters

Binary mergers in galaxies; GRB standard-candle GW emission; …

"Triggered" searches for GW bursts and/or inspirals from GRBs, SGR flares, etc.

GRB 030329, SGR 1806-20, GRB 070201, …

Use GW candidates to trigger prompt EM follow-up observations

Highlights: Detector Characterization

Done separately for LIGO, GEO, Virgo

Online and offline monitoring and investigations

Calibration, and generation of *h(t)* data streams

Glitch studies

- Regular examination and classification of glitches during S5
- Feed back to fix detector problems
- Suggest data quality flags and auxiliary-channel vetoes

Spectral line artifacts

Environmental disturbances

- Transients, continuous correlations
- Upconversion of low-frequency noise

Timing precision and stability

Hardware signal injections

- Check detectability of signals, safety of veto conditions

There's always room for improvement!

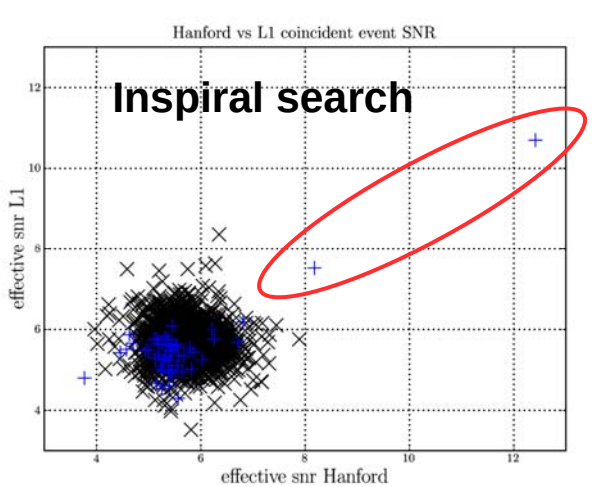
Blind Injection Challenge

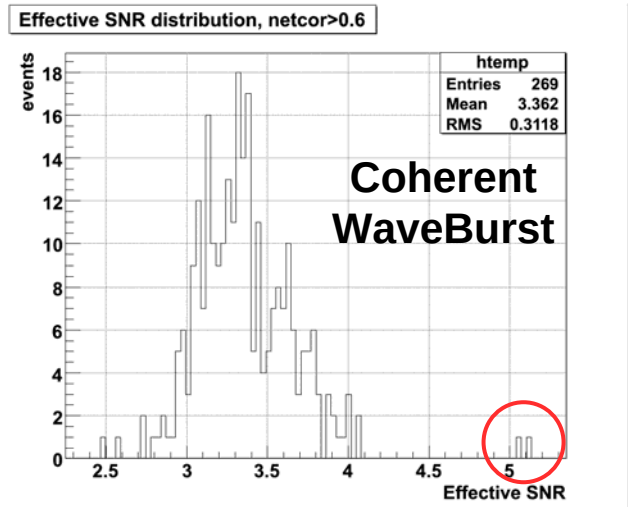
Goal: test full process of evaluating a detection candidate under conditions as realistic as possible

- Inject random signals at random times, unknown to people analyzing data
- Circumvent usual hardware injection logging
- Keep hidden log files and a record in the raw data — honor system

Tested last week

- Time window of test known, but otherwise blind
- Data analyzed with regular online searches, plus some offline searches





We will inject *N* more signals during rest of S5

How is LSC-Virgo Joint Work Going?

Co-chairs of joint data analysis working groups – good

Also joint Data Analysis Council

Mailing lists, web content – pretty good

Open access to both sides

Some merged, some separate mailing lists and web notebooks / wikis

Weekly teleconferences – pretty good

Some merged, some parallel (but freely open to both sides)

Joint collaboration meetings – good

But some dissatisfaction with the 5-per-year plan

Actual cooperative data analysis – to be seen

The two sides bring different methods

Given current sensitivity differences, many analyses may still only use LIGO data

Issue: Internal Reviewing

Reviewing of analyses has been a bottleneck in some cases

- Mainly in the Bursts Group – backlog of completed analyses / papers
- Has delayed release of results in papers and conferences
  - But even status reports at conferences require review attention
- Dampens motivation for analyzers to complete and document analyses

What is being done: Introduce parallelism in burst review process

- Small teams will be formed as needed to do the bulk of reviewing
- Also in CW reviews
- CBC group assigns an internal reviewer within the group

Involvement of Virgo in reviewing

- Manpower limitations
- Organizational challenges of joint reviewing

Author list and review issues for methods talks/papers demonstrated using real data