Status of LIGO Data Analysis

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**LIGO schedule**

**Goal**: integrate commissioning and data taking to obtain one year of integrated data at $h \sim 10^{-21}$ by end of 2006.

So far:

- **sensitivity progress**:  
  - within a decade of the goal sensitivity,  
  - two decades improvement in the last year.

- **data analysis progress**:  
  - three science runs in the last two years  
  - results from first science run (17 days),  
  - analysis almost complete for second science run (59 days)  
  - third science run (65 days) under way.
Data taking runs

• First LIGO Science Run S1 (Aug 23-Sep 9, 2002)
  ~100 hrs quadruple coincidence data
  Data analysis for inspiral, burst, continuous waves and stochastic sources completed.

• Second LIGO Science Run S2 (Feb 14-Apr 14, 2003)
  ~300 hrs triple coincidence,
  ~250 hrs with TAMA,
  ~150 hrs L1-ALLEGRO
  Data analysis in progress, preliminary results presented in this conference.

• Third LIGO Science Run (Oct 31, 2003-Jan 5, 2004) : in progress! (with TAMA, GEO)
A measure of progress

- Virgo cluster
- Milky Way
- M31
- M81
- BNS range
  - ~5 kpc
  - ~100 kpc
  - 0.9 Mpc
  - 3 Mpc

Dimensions:
- 0.9 Mpc
- ~100 kpc
- ~5 kpc
Duty cycles: S1

L1: 170 hrs, 42%  
H1: 235 hrs, 58%  
H2: 298 hrs, 73%

All three: 96 hrs, 23%
Duty cycles: S2

L1: 523 hrs, 37%  
H1: 1040 hrs, 74%  
H2: 818 hrs, 58%  

All three: 312 hrs, 22%
Progress in commissioning

• **Done:**
  – full recycled optical configuration in all three detectors for length degrees of freedom
  – partial control of angular degrees of freedom
  – acoustic isolation at antisymmetric port
  – higher power (multiple photodetectors)
  – lower noise suspension controllers

• **To do:**
  – even higher power: thermal compensation, output mode cleaner
  – seismic retrofit at LLO
  – full control of angular degrees of freedom
  – beam centering
  – more acoustic mitigation
S1 results

Papers by the LIGO Science Collaboration (~370 authors, 40 institutions):

• “Detector Description and Performance for the First Coincident Observations between LIGO and GEO”, accepted in Nucl. Inst. Meth, gr-qc/0308043
• “Setting upper limits on the strength of periodic gravitational waves using the first science data from the GEO600 and LIGO detectors” gr-qc/0308050, accepted for publication in PRD
• “Analysis of LIGO data for gravitational waves from binary neutron stars”, gr-qc/0308069, being reviewed by PRD
• “First upper limits on gravitational wave bursts from LIGO”, gr-qc/0312056
• “Analysis of First LIGO Science Data for Stochastic Gravitational Waves”, in preparation
Results from S1
Upper Limits on Periodic Sources

J1939+2134
(642 Hz x 2=1284 Hz)
upper limits on amp: \( h < 2 \times 10^{-22} \)
upper limit on ellip: \( \varepsilon < 2.9 \times 10^{-4} \)

Previous limits for same system:
- 40m: \(~10^{-17}\)
- Glasgow detector: \(~10^{-20} (2^{nd} \text{ harm.})\)

At other frequencies,
bars have set up limits \(~3 \times 10^{-24}\)

Upper limit on ellipticity from spindown, \( \varepsilon < 3.8 \times 10^{-9} \)

gr-qc/0308050, Setting upper limits on the strength of periodic gravitational waves using the first science data from the GEO600 and LIGO detectors, The LIGO Scientific Collaboration: B.Abbott, et al, accepted for publication in PRD
Results from S1

Upper Limits on NS Inspiral Sources

S1: L1 | H1=289 hrs,
L1 & H1: 116 hrs;
R< 170/yr BNS in Milky Way
Equivalent Galaxy, with masses
between 1 and 3 Ms.

(Expected: ~10⁻⁵/yr)

Previous searches:
• LIGO 40m (’94, 25 hrs) 0.5/hr, 25 kpc
• TAMA300 DT6: 82/yr (1,038 hr, D<33 kpc)
• Glasgow-Garching ’89 (100 hrs) no events, ~1kpc
• IGEC ’00-’01 (2yrs): no events, ~10 kpc

gr-qc/0308069, Analysis of LIGO data for gravitational waves from
Results from S1
Upper Limits on Burst Sources

17 days yielded 55 hrs for 3x analysis:
<1.6 events/day for bursts
with duration 4-100 ms and frequencies 150-3000 Hz.
For Gaussians and SineGaussians,
\[ h_{rss} \sim 10^{-17} - 10^{-19} / \sqrt{\text{Hz}} \]

Upper limit from bar results:
- IGEC 2000: <7/yr, \( H_t < 3.5 \times 10^{-21} / \text{Hz} \)
  ~1ms events, 3yrs yield 387d (2 or 3x), PRD68 (2003) 022001
- Astone et al. 2001: \( h \sim 2 \times 10^{-18} \) , 90d, 1/day, CQG 19 (2002) 5449-5463

First upper limits from LIGO on gravitational wave bursts, LIGO Scientific Collaboration: B. Abbott, et al, gr-qc/0312056
Results from S1
Upper Limits on Stochastic Background Sources

S1 (50 hrs, H2-L1): \( \Omega_0 h^2_{100} < 23 \)

Current best upper limits:

- **Inferred**: From Big Bang nucleosynthesis:
  \[ \int \Omega_{GW}(f) \, d\ln f < 1 \times 10^{-5} \]

- **Measured**: Garching-Glasgow interferometers:
  \( \Omega_{GW}(f) < 3 \times 10^5 \)

- **Measured**: EXPLORER-NAUTILUS:
  \( \Omega_{GW}(907\text{Hz}) < 60 \)
Ongoing work

S2 analysis almost complete (see talks in this conference!), S3 run in progress. S3 will have LIGOx3, GEO, and TAMA!!

- **Inspiral Sources:**
  - Binary Black Holes!
  - Better background estimation for Binary Neutron Stars
  - MACHOs in the Galaxy

- **Pulsars:**
  - All known pulsars
  - Special searches for Crab, Sco-X1
  - Non targeted search

- **Bursts:**
  - Untriggered search: more time, better data, more methods: better ULs
  - Triggered search: GRBs
  - Modeled search: black hole ringdowns, supernova explosions
  - coincidence analysis with TAMA

- **Stochastic Background:**
  - Optimal filters, expect $\Omega \sim 0.01$ UL for H1-L1
  - ALLEGRO-L1 analysis
Conclusions

- Good progress toward design sensitivity
- Data analysis science results

The future:
- S2, S3 analysis ongoing
- 6-months long S4 starting in 2004 (?).
- One year of integrated data at design sensitivity before the end of 2006
- Advanced interferometer with dramatically improved sensitivity – 2007+