



ANNUAL REPORT FOR AWARD # 0245109

James E Brau ; *U of Oregon Eugene*

A Search for Gravitational Radiation at LIGO: Oregon Experimental Relativity Group

Participant Individuals:

Senior personnel(s) : Raymond E Frey; Robert Schofield; David M Strom

Post-doc(s) : Isabel Leonor

Senior personnel(s) : Nikolai Sinev

Graduate student(s) : Masahiro Ito; Rauha Rahkola; Brian Stubbs; Emelie Harstad

Participants' Detail

Partner Organizations:

LIGO Laboratory: Collaborative Research

This project uses the observatory that was constructed, developed, and is operated by the LIGO Laboratory

LSC (LIGO Scientific Collaboration): Collaborative Research

The universities and laboratories of the LIGO Scientific Collaboration work together on the science of LIGO.

Activities and findings:

Research and Education Activities:

COMPLETED RESEARCH:

First searches for gravitational radiation with the LIGO interferometers have resulted in publications reporting limits. The publications are listed below. The Oregon group has specifically contributed to these results with the following completed investigations:

Contributed to documentation on S1 externally triggered burst analysis: LIGO-T030050-00-Z

In addition, set up and maintained a web site to collect and present the work of the External Triggers subgroup of the Burst analysis group:
<http://www.ligo.caltech.edu/~sn/>

Implemented a GRB notification system for the LHO control room in the event of receipt of a near-real time external burst trigger via a GCN circular. The system is used to warn operators to, if at all possible, leave the IFOs operating without interruption or substantial changes. This was commissioned during S3 at LHO and became integrated on the main control room EPICS status panel.

Alternative methods for performing externally triggered burst searches have been explored, leading to a revised search pipeline for S2 compared to S1. This pipeline has been tested with S3 data with the view of stabilizing it for all triggers received during S2. The S3 test can be viewed at:

http://www.ligo.caltech.edu/~sn/secure/analysis/s3_sensitivity/

Measured, using simulated gravitational waves, the coupling between GW and auxiliary IFO channels during S2. These studies were designed to prevent vetoes based on MICH_CNTRL and other IFO channels from vetoing GW waves and producing erroneously low upper limits.

(Schofield and Ito.)

For most recent update, see M. Ito web pages from Bursts face-to-face meeting 1/04:

http://darkwing.uoregon.edu/~masahiro/veto/H1_gm_tfc_040202/

(and similar pages for L1 and H2).

Made in-situ measurements of transfer functions from magnetic fields to IFO control signals. Talk at March 2003 LSC meeting.

Carried out PEM injections to determine couplings for PEM based vetoes. Talk at March 2003 LSC meeting. See also G030297-00.

Carried out studies on intersite transients. Report at Aug LSC meeting: G030641-00.

Participated in planning, organizing, and conducting hardware astrophysical injections for S2.

Presented preliminary report for the LIGO acoustic mitigation team. See G030329-00.

Refined proposals for acoustic mitigation, talk at Hannover LSC meeting: G030496-00.

Helped install and test acoustic mitigation hardware. See talk at August 2003 LSC meeting: G030640-00.

Measured resulting reduction of acoustic noise by a factor of about 1000, reducing this noise source below LIGO I SRD.

See Feb 9, 2004 contribution to Commissioning group:

<http://emvogil-3.mit.edu/commissioning/>

Began new investigation on influence of dust on glitches observed in AS_Q. (see LHO detector ELogs, under Schofield.)

Completed a number of investigations for commissioning and noise, including the following (for more information, see LHO detector ELogs, Schofield):

Studied upconversions associated with 12 Hz bounce mode.

Carried out dewar glitch studies.

Performed search for gravitational-waves coincident with GRBs which were observed during the LIGO S2 run.

http://www.uoregon.edu/~ileonor/ligo/s2/grb/ccstudy_v2.pdf

Slides of talk given at the March 14, 2004 Burst face-to-face meeting are available at:

http://zebu.uoregon.edu/~uoceph/talks/talks04/grbs_v2.pdf

Wrote various Matlab scripts and C programs needed in the studies described in the above document. There were many scripts written, and examples are:

grbsimran2sg/gausspar.m

response_v3.c

The former Matlab scripts inject calibrated waveforms into raw LIGO AS_Q data, perform whitening, phase correction, and output cross-correlation distributions for various cross-correlation integration lengths. The latter C program calculates and outputs the time-propagated response function for an interferometer.

Created tables with information about GCN GRB triggers which are relevant to LIGO analysis. These tables can be found at:

<http://www.uoregon.edu/~ileonor/ligo/s2/grb/s2grbs.html>

Aside from being easily-accessible references, these tables were used for independent verification of the GRB table made by Rauha Rahkola.

Wrote stand-alone programs in C which can be used to produce information about GCN GRB triggers which are relevant to LIGO analysis. These programs include but are not limited to:

```
grbAntenna.c -- calculates and outputs a variety of
               information about GRB external triggers.
LMST.c       -- calculates local mean sidereal time.
eqToHor.c    -- converts from equatorial coordinates to
               horizon coordinates.
lhoToEarth.c -- converts from LHO IFO local coordinates to
               Earth coordinates.
lloToEarth.c -- converts from LLO IFO local coordinates to
               Earth coordinates.
timeDelay.c  -- calculates time delay between LHO and LLO
               signal arrival times.
antenna.c    -- calculates antenna factors.
```

Corresponding code which includes the TAMA interferometer was also written and is available.

Included TAMA information in the GRB tables pointed to by the link given above. Some of this information can also be found at:

<http://www.uoregon.edu/~ileonor/ligo/s2/grb/s2grbstama.html>

Wrote Matlab scripts and C programs used by the External Triggers group to produce calibrated waveforms for software injection. These scripts and input waveforms can be found at:

<http://www.uoregon.edu/~ileonor/ligo/s2/inject/scripts/>

Performed digital processing on Dimmelmeier-Font-Muller supernova core-collapse gravitational waveforms so that these can be included in the suite of waveforms which can be used for software injections by the External Triggers group.

Verified the waveform calibration used by the External Triggers group by comparing with LDAS calibration (work done by I. Leonor with R. Rahkola). This comparison can be found at:

<http://www.uoregon.edu/~ileonor/ligo/s2/inject/codereview/comparecal.html>

Miscellaneous studies:

<http://www.uoregon.edu/~ileonor/ligo/s2/grb/inject/grbsim.html>
<http://www.uoregon.edu/~ileonor/ligo/s2/grb/crosscorr.html>

Participated in the monitoring of reduced data sets for the LIGO S3 run. I. Leonor was responsible for this LIGO-wide during the December part of the S3 run.

Completed survey of astrophysical models for determining input parameters for the GRB associated GW search. The report is in DCC as T030274-00-Z, 'Implications of GRB Source Scenarios on the Triggered

GW Burst Search'.

Chose the supernova wave forms for the hardware burst injection during S3. (with Alan Weinstein)

- 9 waveforms were chosen from each of the sets of the ZM/DFM waveforms.

- 3 distances (100pc, 300pc 1kpc).

- 226 ZM/DFM waveforms were injected during S3.

SEE THE ATTACHED FILE FOR ADDITIONAL ACTIVITIES

Findings:

The S1 Science Run resulted in the following results:

Detector Description and Performance for the First Coincidence Observations Between LIGO and GEO ,
B. Abbott et al. (LSC), Nucl. Instrum. Meth., A517 (2004) 154-179

First Upper Limits from LIGO on GW Bursts,
B. Abbott et al. (LSC), Phys. Rev. D 69 (2004) 102001

Setting Upper Limits on the Strength of Periodic GW from PSR J1939 + 2134 Using the First Science Data from the GEO600 and LIGO Detectors,

B. Abbott et al. (LSC), Phys. Rev. D 69 (2004) 082004

Analysis of LIGO Data for GW from Binary Neutron Stars,
B. Abbott et al. (LSC), Phys. Rev. D 69 (2004) 122001

Analysis of LIGO Data for Stochastic GW,
B. Abbott et al. (LSC), Phys. Rev. D 69 (2004) 122004

The S2 Science Run resulted in the following result:

Limits on Gravitational-Wave Emission from Selected Pulsars Using LIGO Data,
B. Abbott et al. (LSC), Phys. Rev. Lett. 94, 181103 (2005)

Training and Development:

Two graduate student research assistants, Masahiro Ito and Rauha Rahkola, have developed a broad base of research experiences through their work on the project.

This year, Emelie Harstad, a graduate student, has joined our team.

Research Associate Isabel Leonor's research on this project has increased her expertise on signal processing, data analysis, and interferometer instrumentation, as well as in the specific area of gravitational research.

Outreach Activities:

QuarkNet

The Oregon group hosted 7 high school physics teachers at Univ. of Oregon during the summer of 2003, and eleven high school teachers during the summer of 2004. A program is planned for the summer of 2005, with thirteen teachers, including four new to the program. Through this program, these teachers have direct contact with the research activities of the Oregon Experimental Relativity Group, and draw on this during the school year.

Ray Frey presented a talk on LIGO and the search for gravitational radiation for high school students at the 2003 IEEE Nuclear Science Symposium at a special educational session.

Jim Brau presented a public lecture to an audience of about 500 on May 19, 2005. This lecture, entitled 'Realizing Einstein's Dream: Exploring Our Mysterious Universe,' covered a broad picture of current topics in fundamental physics, including the search for gravitational radiation. See http://physics.uoregon.edu/~jimbrau/may19/Public_talk.pdf

A front-page story of the LIGO project, including the role of the Oregon group, appeared in the Sunday edition of the Eugene Register-Guard on May 22, 2005. This story resulted from interviews with Oregon researchers, and a visit to the LIGO Hanford facility by the Register-Guard reporter.

Journal Publications:

- B. Abbott et al., "Detector Description and Performance for the First Coincidence Observations Between LIGO and GEO", *Nuclear Inst. and Methods in Physics Research A*, vol. 517, (2004), p. 154. Published
- B. Abbott et al., "Setting upper limits on the strength of periodic gravitational waves using the first science data from the GEO600 and LIGO detectors ", *Physical Review*, vol. D69, (2004), p. 082004. Published
- S.D. Mohanty et al., "Gamma Ray Bursts and Gravitational Waves: Triggered Search Strategy in the LIGO Science Runs", *Class. Quant. Grav.*, vol. 21, (2004), p. S765. Published
- B. Abbott et al. (LSC), "First Upper Limits from LIGO on GW Bursts", *Physical Review*, vol. D69, (2004), p. 102001. Published
- B. Abbott et al. (LSC), "Analysis of LIGO Data for GW from Binary Neutron Stars", *Physical Review*, vol. D69, (2004), p. 122001. Published
- B. Abbott et al. (LSC) , "Analysis of LIGO Data for Stochastic GW", *Physical Review*, vol. D69, (2004), p. 122004. Published
- B. Abbott et al. (LSC), "Limits on Gravitational-Wave Emission from Selected Pulsars Using LIGO Data ", *Physical Review Letters*, vol. 94, (2005), p. 181103. Published

Book(s) of other one-time publications(s):

Other Specific Products:

Reports

(the following document numbers refer to the LIGO documentation system - <http://admdbsrv.ligo.caltech.edu/dcc/>)

G030039-00-Z 03/17/03

Ray Frey et al. (incl. Rauha Rahkola)

Status of the Triggered Burst Search - LSC Meeting, March 17th - 20th,

Livingston, LA

G030054-00-Z 03/17/03

Isabel Leonor
S2 Reduced Data Set Report - LSC Meeting, March 17th - 20th,
Livingston, LA

G030112-00-D 03/19/03

Isabel Leonor et al.
Introduction to Hardware Signal Injections - LSC Meeting, March 17th -
20th, Livingston, LA

G030263-00-Z 05/30/03

Rauha Rahkola
Implementation of LIGO's Triggered Burst Search

G030297-00-Z 07/01/03

Aleksandr Ageyev et al. (incl. Robert Schofield, Masahiro Ito)
Measurements of Environmental Coupling to the Gravitational Wave
Channel (PEM Injections)

G030298-00-D 06/02/03

Ray Frey et al. (incl. Rauha Rahkola)
Update on Analysis Methods for Externally Triggered Search with S2
Data

G030329-00-Z 07/01/03

Doug Cook et al. (incl. Robert Schofield)
Acoustic Mitigation Team Progress Report

G030330-00-Z 07/02/03

Robert Schofield
Progress on S1 Intersite Transients Study

G030430-00-D 08/20/03

Jordan Camp et al. (incl. Ray Frey, Isabel Leonor, Rauha
Rahkola) Externally Triggered Search: Results on GRB030329 - LSC
Meeting, August 18th - 21st, Hannover, Germany

G030496-00-Z 08/18/03

Doug Cook et al. (incl. Robert Schofield)
Acoustic Mitigation Progress - LSC Meeting, August 18th -21st,
Hannover, Germany

G030554-00-Z 11/12/03

Stuart Anderson et al. (incl. Isabel Leonor)
Data Reduction for S3 - LSC Meeting, November 10th - 13th, Hanford,
WA

G030554-01-Z 11/12/03

Stuart Anderson et al. (incl. Isabel Leonor)
Data Reduction for S3 - LSC Meeting, November 10th - 13th, Hanford,
WA

G030555-00-D 11/10/03

Peter Fritschel et al. (incl. Robert Schofield)
Vibration Reduction in ISC Periscope - LSC Meeting, November 10th -
13th, Hanford, WA

G030609-00-Z 11/10/03

Ray Frey
Astrophysical Implications of External Triggers

G030613-00-D 11/12/03

J. Cannizzo et al. (incl. Ray Frey)
Results of the GRB030329 Triggered Search - LSC Meeting, November 10th
- 13th, Hanford, WA

G030633-00-Z 11/10/03
Ray Frey, Rauha Rahkola, Brian Stubbs
Status of Software by U. Oregon: SuspensionMon & GRB notification -
LSC Meeting, November 10th - 13th, Hanford, WA

G030640-00-Z 11/10/03
Doug Cook et al. (incl. Robert Schofield)
Acoustic Mitigation Status for S3 - LSC Meeting, November 10th - 13th,
Hanford, WA

G030641-00-Z 11/10/03
Robert Schofield, Masahiro Ito
S2 Intersite Environmental Transients Investigation - LSC Meeting,
November 10th - 13th, Hanford, WA

T020072-02-D 01/27/03
Isabel Leonor et al.
The Signal Injection Handbook

T030050-00-Z 04/29/03
Ray Frey et al. (incl. Rauha Rahkola)
Triggered search analysis of S1 data associated with X-ray flash
XRF020903

T030109-00-D 04/08/03
S. Mohanty et al. (incl. R. Rahkola, R. Frey)
Time-domain Implementation of the Optimum Kernel in a Correlation
Based Triggered Search

T030110-00-D 04/16/03
Ray Frey et al. (incl. Isabel Leonor, Rauha Rahkola)
Upper Limits for Externally Triggered Searches Using Signal
Injections

T030111-00-D 04/22/03
Ray Frey et al. (incl. Rauha Rahkola)
Notes on the Sampling Distribution of the Correlation Coefficient and
Normal Density Fits

T030112-00-D 04/22/03
Ray Frey et al. (incl. Rauha Rahkola)
A Study of the Cross-correlation Coefficient Distribution in the
Presence of Additive Signals

T030113-00-D 04/25/03
Ray Frey et al. (incl. Rauha Rahkola)
Optimum Integration Length for Computation of the Cross-correlation
Coefficient

T030114-00-D 05/05/03
Ray Frey et al. (incl. Rauha Rahkola)
CORRGRAM: Towards Unifying Correlation Based Triggered Searches

T030274-00-Z 11/18/03
Ray Frey
Implications of GRB Source Scenarios on the Triggered GW Burst Search

P040007-03-D
A Search for Gravitational Waves Associated with Gamma Ray Burst
GRB030329 Using the LIGO Detectors

03/14/2004 Isabel Leonor
Search for Short Duration Gravitational Waves Coincident with S2 GRBs
LSC Burst Meeting, March 14, Livingston, LA.

G040159-00-Z 03/15/2004, Robert Schofield
S3 Environmental Disturbances
Acoustic Mitigation Update, Gravel Truck Bursts, Dust Bursts and

Pulsed Heaters, LSC Meeting, March 15 - 18th, Livingston, LA.

G040128-00-Z 03/17/2004, Rauha Rahkola,
Notifying the Control Rooms of GRBs in Real-Time, LSC Meeting, March
15 - 18th, Livingston, LA.

----- 05/21/04 Isabel Leonor,
Recent Results from the LIGO Experiment?, APS NW Section Meeting, May
21-22, 2004, Pullman, WA.

G040265-00-Z 06/05/2004,
Bruce Allen et al. (incl. Robert Schofield), Stochastic Review
Committee Activities, LSC Meeting, Tufts University, June 5-6, 2004.

----- June 2004,
Brian Stubbs, The Development of an Online Routine to Monitor
Transverse Oscillation Amplitudes in LIGO Test Masses, University of
Oregon Masters Thesis.

P040028-00-Z 07/09/2004, Bruce Allen et al. (incl. Isabel Leonor),
Towards the First Search for a Stochastic Background of Gravitational
Waves in LIGO Data: Applications of Signal Simulations.

G040391-00-W 08/19/2004 Robert Schofield, et al.,
Progress Since March on S3 Environmental Disturbances, LSC Meeting,
August 16th-19th, 2004, Hanford WA.

11/06/2004 Masahiro Ito (presented by Isabel Leonor),
Optimal Filtering Supernovae Event Search: Current Status, Burst
Face-to-Face Meeting, November 6-7, 2004, Massachusetts Institute of
Technology.

11/06/2004 Isabel Leonor,
Search for Short Duration Gravitational Waves Coincident With S2 and
S3 GRBs, Burst Face-to-Face Meeting, November 6-7, 2004, Massachusetts
Institute of Technology.

11/06/2004 Rauha Rahkola (presented by Isabel Leonor),
Triggered (Pulsed) Burst Search Method Update, Burst Face-to-Face
Meeting, November 6-7, 2004, Massachusetts Institute of Technology.

G040522-00-Z 12/16/2004 H. Bantilan et al. (incl. Robert Schofield),
Veto Studies for LIGO Binary Inspiral Triggers.

P040007-06-D0 1/24/2005 B. Abbott et al. (incl. Jim Brau, Ray Frey,
Masahiro Ito, Isabel Leonor, Rauha Rahkola, Robert Schofield, David
Strom)
A Search for Gravitational Waves Associated with the Gamma Ray Burst
GRB030329 Using the LIGO Detectors?, gr-qc/0501068.

LIGO Database

Internet Dissemination:

http://zebu.uoregon.edu/~rayfrey/LIGO/LIGO_UO.html

Contributions:

Contributions within Discipline:

The results of this research will advance the knowledge of
gravitational radiation, and the sources which generate such
radiation, a topic of fundamental interest in physics.

Contributions to Other Disciplines:

The techniques developed by LIGO will contribute to the technology base of the Nation.

Contributions to Education and Human Resources:

This project has contributed to human resource development in science and engineering through the involvement of individuals at many levels of expertise in the project. It has involved the main researchers, consisting of physics faculty, research associates and postdocs, and graduate students. Also involved and benefiting have been undergraduate students, high school teachers, and high school physics students.

Contributions to Resources for Science and Technology:

The results of this research has been made available through internet web pages. High school teachers and students have been trained to access this data and information.

Special Requirements for Annual Project Report:

Unobligated funds: less than 20 percent of current funds

Categories for which nothing is reported:

Participants: Other Collaborators

Products: Book or other one-time publication

Contributions Beyond Science and Engineering

Special Reporting Requirements

Animal, Human Subjects, Biohazards



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