



**Attachment DAT to the  
Memorandum of Understanding LIGO-M000125-00  
between the Carleton College Relativity Group (CCRG)  
and the  
Laser Interferometer Gravitational Wave Observatory (LIGO)  
For The Period  
August 15, 2008 - August 14, 2009**

This Attachment DAT to the Memorandum of Understanding LIGO-M000125-00 defines the role of the Carleton College Relativity Group (CCRG) as a Member of the LIGO Scientific Collaboration (LSC). In particular, it addresses data analysis activities in support of the initial LIGO interferometers. The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

## **1. Collaboration**

Together, the LIGO Laboratory and the LIGO Scientific Collaboration (LSC) are responsible for implementing and exploiting the initial LIGO detector through its science data runs. The LSC has organized the data analysis effort into search groups which coordinate analysis, review, and publication on behalf of the collaboration. LSC groups are encouraged to participate in one or more of these groups.

MOU Attachment DAT defines the contributions of each participating group to the data analysis development groups.

## **2. Participation**

During the period August 15, 2008 - August 14, 2009, the members of CCRG will participate in the analysis of initial LIGO data in the following areas:

### **a. Binary Inspirals**

Members of the CCRG will continue to study instrumental disturbances (glitches) with the intent of developing vetoes and data quality flags for all of the binary inspiral searches. The research will proceed with direction and supervision from the LSC Compact Binary Coalescence Group. This veto-glitch work will also be done with input and advice LSC glitch group, and the LSC Detector Characterization group. Efforts will be made to understand the physical mechanisms that generate the detected glitch events.

The CCRG will continue to develop and apply their Markov chain Monte Carlo (MCMC) parameter estimation codes as part of the the inspiral search. All of the parameter estimation programs will be used on candidate events, and hardware

injections in the LIGO data. The MCMC routines will continue to be incorporated into the follow-up studies of binary inspiral triggers. The CCRG will work on better incorporating these inspiral parameter estimation programs into the binary inspiral search and detection pipelines, and the LIGO/LSC Analysis Library (LAL). The CCRG will also begin work on expanding the MCMC program to incorporate the full inspiral, plunge and black hole ringdown signal.

The CCRG group will continue to collaborate with researchers at Northwestern and Birmingham on the development of a MCMC parameter estimation code for spinning black hole binary inspiral signals. Like the other MCMC inspiral routines, we will work on making this code useful for follow-up studies on spinning black hole binary triggers.

#### b. Bursts

Christensen, Roever and Meyer will continue to collaborate with Dr. Ik Siong Heng (Glasgow), Virgo burst group member Dr. Marie-Anne Bizouard (LAL-Orsay), and Dr. Harald Dimmelmeier (Max Planck, Garching) on a technique for extraction the physical parameters from supernova produced gravitational wave signals. In addition, this project has a statistics graduate student from the University of Auckland who will continue to attempting to devise MCMC methods that could incorporate realistic supernova created burst gravitational wave signals. The student, Sunny Chui, is supervised in this work by Meyer and Christensen. We will continue to take the tables of supernova produced signals generated by Dimmelmeier as the basis for our analysis; Siong will continue to use principal component analysis (PCA) to generate associated eigenvectors. The MCMC is then used to fit signals to a superposition of these eigenvectors. We will continue to optimize the MCMC code; initial results will be presented in the coming year.

Christensen, Dr. Marie Anne Bizouard (LAL - Orsay), and Carleton undergraduate Thomas Ballinger, will continue to investigate the implementation of a burst veto (for Virgo and LIGO data) based on the comparison of the amplitudes of the two phases of the dark fringe signal (AS\_Q and AS\_I for LIGO, B1\_ACp and B1\_ACq for Virgo).

We will continue to analyze KleineWelle triggers from Virgo PEM and interferometer channels in order to develop burst vetoes for Virgo data. We will identify candidate veto channels for the Virgo burst searches. This veto work by the CCRG will continue to be done in collaboration with Virgo scientists Dr. Marie Anne Bizouard, Dr. Nicolas Leroy, and Prof. Patrice Hello (LAL - Orsay).

#### c. Stochastic

The CCRG (Christensen and Isogai) will continue collaborate with Nick Fotopoulos (Wisconsin-Milwaukee) and Prof. Vuk Mandic (Minnesota) on the calculation of the H1-H2 correlation for the S5 stochastic search. We will continue to use the newly developed code by Fotopoulos to calculate H1:LSC-DARM\_ERR and H2:LSC-DARM\_ERR coherence with PEM channels on a daily, weekly and monthly time scale. At this point we have only analyzed the first 6 months of S5 data, and we will produce an estimate of  $\Omega_{GW}$  based on this 6 months of data, accounting for the PEM contribution to the correlation. We will then work to analyze all of the S5 H1, H2 and LHO PEM data, and subsequently produce a limit on  $\Omega_{GW}$ .

The CCRG will search their DARM\_ERR - PEM coherence database in order to try and find the origin of noise lines found via the stochastic search.

Christensen will continue to serve on the LSC Stochastic Review Committee, and will execute all of the tasks required.

d. Continuous

The CCRG will continue to calculate the coherence between the LIGO interferometers' output, and PEMs. These results will be used to try and determine if signals observed by pulsar searches might be caused by environmental noise. This work will also be coordinated through the LSC Detector Characterization Group.

e. Other Contributions

Christensen will continue to serve on the the LIGO Academic Advisory Council (LAAC), and advise the LIGO Directorate on issues related to education of students and postdocs who are participating in LIGO and to provide oversight of the quality of the education they receive through their participation in LIGO.

Christensen will continue to chair and serve on the LSC-Virgo remote participation working group. He will provide advice and recommendations in the planning and implementation of remote participation technology for LSC-Virgo collaboration meetings, face-to-face meetings, and other meetings by the collaboration.

### 3. Resource Sharing

The LIGO Laboratory will contribute resources including allocation of appropriate scientific and engineering personnel, research facilities, and funding in support of the effort in Item No. 2, as indicated below.

- a. Research accommodations for CCRG group members while on LIGO research assignment at any LIGO Laboratory site.

*Not Applicable*

- b. Access to LIGO data through established LSC channels in support of this work.

*Not Applicable*

### 4. Coordination and Reporting

CCRG will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate.

In particular, with reference to activities described above:

**2a** will be carried out within the LSC Inspiral Search Group.

**2b** will be carried out within the LSC Burst Search Group.

**2c** will be carried out within the LSC Stochastic Search Group.

**2d** will be carried out within the LSC Continuous Waves search Group.

This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, including progress against the milestones if any, significant accomplishments such as new insights/discoveries or publications, issues of concern if any, and an indication of invested time.

This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

## 5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.



Jay Marx  
**LIGO Laboratory Director**



Nelson Christensen  
**Principal Investigator(s)  
CCRG**



David Reitze  
**LSC Spokesperson**



**Attachment OPS to the  
Memorandum of Understanding LIGO-M000125-00  
between the Carleton College Relativity Group (CCRG)  
and the  
Laser Interferometer Gravitational Wave Observatory (LIGO)  
For The Period  
August 15, 2008 - August 14, 2009**

This Attachment OPS to the Memorandum of Understanding LIGO-M000125-00 defines the role of the Carleton College Relativity Group (CCRG) as a Member of the LIGO Scientific Collaboration (LSC) in the areas of detector commissioning, detector characterization, and operations support in the initial LIGO interferometers. The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

## **1. Collaboration**

Together, the LIGO Laboratory and the LIGO Scientific Collaboration (LSC) are responsible for implementing and exploiting the initial LIGO detector through its science data runs. LSC groups are encouraged to contribute to the commissioning, characterization, and operation of the LIGO detectors, as members of working groups established by the LIGO Laboratory and the LSC.

## **2. Participation**

During the period August 15, 2008 - August 14, 2009, the members of CCRG will participate in the initial LIGO detector research program in the following areas:

a. Detector Commissioning

*Not Applicable*

b. Detector Characterization

Nelson Christensen (faculty), Thomas Ballinger, Daniel Buckleitner, and Tomoki Isogai (undergraduates) will continue to be involved in detector characterization activities. We expect more undergraduate students to join our group and be involved in the 08-09 cycle.

The CCRG will continue to calculate the coherence between the LIGO interferometers' output, and PEMs. This work will be coordinated through the LSC Detector Characterization Group. The CCRG will attempt to identify and determine the cause of noise lines in the LIGO data. For S6 we will calculate and produce DARM.ERR - PEM coherence results, averaged over daily, weekly, and monthly

time scales. We will develop the means to calculate this DARM\_ERR - PEM coherence in near real time for S6.

Glitch Working Group: The CCRG will conduct research on identifying and characterizing glitches that appear in the LIGO interferometer output data. Specific attention will be given to identifying the cause of events that appear as triggers in the the LSC binary inspiral search pipeline. Inspiral vetoes will be developed. This work will be coordinated with both the LSC Glitch Working Group, and the LSC Inspiral Group. CCRG members will conduct glitch shifts for the LSC Glitch Working Group.

We will develop software whereby candidate veto channels can be developed immediately as binary inspiral, burst, and KleineWelle (on PEM and interferometer control channels) triggers are produced.

We will specifically target magnetometers with the intention of quickly producing magnetometer based data quality flags. We will develop tools that will quickly search the KleineWelle magnetometer triggers, and report events that occur simultaneously in multiple magnetometers at a particular observatory site.

c. Detector Operations

CCRG group members will fill in science monitor shifts as needed.

d. Other Contributions

*Not Applicable*

### 3. Resource Sharing

The LIGO Laboratory will contribute resources including allocation of appropriate scientific and engineering personnel, research facilities, and funding in support of the effort in Item No. 2, as indicated below.

- a. Research accommodations for CCRG group members while on LIGO research assignment at any LIGO Laboratory site.

*Not Applicable*

- b. Access to LIGO data through established LSC channels in support of this work.

*Not Applicable*

### 4. Coordination and Reporting

CCRG will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate.

In particular, with reference to activities described above:

**2a** will be carried out in coordination with the LIGO Laboratory Commissioning Leader.

**2b** will be carried out within the Detector Characterization Working Group of the LSC.

**2c** will be carried out in coordination with the LHO or LLO Site Head.

This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, including progress against the milestones if any, significant accomplishments such as new insights/discoveries or publications, issues of concern if any, and an indication of invested time.

This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

## 5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.



Jay Marx  
**LIGO Laboratory Director**



Nelson Christensen  
**Principal Investigator(s)  
CCRG**



David Reitze  
**LSC Spokesperson**



**Attachment Z to the  
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This Attachment Z to the Memorandum of Understanding LIGO-M000125-00 lists the members of Carleton College Relativity Group (CCRG) participating in LIGO Scientific Collaboration (LSC) development group activities in support of the initial LIGO interferometers. The period of performance for these activities is from August 15, 2008 - August 14, 2009.

**Faculty:**

The Faculty category includes all "faculty rank" LSC members. This includes professorial appointments, research faculty appointments, teaching faculty appointments, lecturer and reader appointments, and similar appointments, and visiting appointments in all these categories.

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Physics and Astronomy

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*Postal Code:* 55057

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**Technical Staff:**

The Technical Staff category includes all non-PI LSC members with scientist, engineer, computer systems administrator or programmer, technician, and similar appointments, and visiting appointments in all these categories.

**Postdoctoral Scholars:**

**Graduate Students:**

## Undergraduate Students:

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## Administrative Staff:

The Administrative Staff category allows the listing of administrative aides and other staff members who perform essential support services in or for LSC member groups, but are not involved in the LIGO Scientific Collaborations engineering or scientific work. *Personnel who are involved in the LSC's scientific or engineering work, including computer system administration and programming, should be listed under other categories.* Personnel listed as Administrative Staff may be designated as a point of contact or proxy, but do not appear as authors on LSC publications, do not count toward a group's council delegate allocation, may not serve as council delegates, and do not increase a group's shift obligation.

**FTE Commitment:**

#	Name	Category	Member	Research	LIGO
1	Ballinger, Thomas	undergraduate	100%	5%	100%
2	Buckleitner, Daniel	undergraduate	100%	5%	100%
3	Caride, Santiago	undergraduate	100%	5%	100%
4	Christensen, Nelson	faculty	100%	25%	100%
5	Ely, Gregory	undergraduate	100%	5%	100%
6	Isogai, Tomoki	undergraduate	100%	5%	100%
				Total FTE:	6.00

**Roles:**

**Principal Investigators:** Christensen, Nelson

**Membership Point-Of-Contact:** Christensen, Nelson

**Group PIO/Press Coordinator:**

**Proxies:**

Author Eligible	Council Delegates
Christensen, Nelson	Christensen, Nelson

**Approvals:**



Jay Marx  
**LIGO Laboratory Director**



Nelson Christensen  
**Principal Investigator(s)**  
**CCRG**



David Reitze  
**LSC Spokesperson**