



**Attachment DAT to the
Memorandum of Understanding LIGO-M050370-00
between the Columbia Experimental Gravity Group (GEC0)
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-M050370-00 defines the role of the Columbia Experimental Gravity Group (GEC0) 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 GEC0 will participate in the analysis of initial LIGO data in the following areas:

a. Binary Inspirals

Not Applicable

b. Bursts

GEC0 will continue to concentrate on and spearhead scientifically intriguing data analysis. In particular, we will put emphasis on astrophysical triggered searches. GEC0 will keep an eye on astrophysical triggers and start a specialized offline search for exceptionally close-by or remarkably energetic cosmic events. Depending on the nature of the astrophysical event we will use existing analysis methods or will develop specialized new approaches where absolutely necessary.

Feasible Contributions:

- **Untriggered Searches**

- Graduate Student Project: We will make advances towards the search for GW burst trains emitted during parabolic and eccentric encounters of black hole binary systems. The most recent detection rate estimates for eccentric orbit binary black holes based on Advanced LIGO design sensitivity goals are promising: 1-1000 events/year. Development of the data analysis, publication of the expected sensitivities for future detectors, and establishing the recovery accuracy of physics observables will be done first. Searches for such GW signal types during S6 is a good idea, as there is some chance for discovery. Collaboration will be done with Bence Kocsis (currently Harvard-cfA, soon at IAS, Princeton) and colleagues.
- Undergraduate project: Evaluate the realistic reach of future detectors for simulated supernova waveforms in extrapolated detector noise. Both detection and parameter extraction capabilities shall be mapped. In collaboration with A. Burrows, Princeton. Progress shall depend on student availability during the school year.

- **Triggered Searches**

- Multiple GECO contributors: Ensure the readiness of fully reviewed and approved analysis infrastructure and paper skeletons to enable fast response to possible exceptional triggers during S6 from GRBs, SGRs, supernovae, and other sources addressable through infrastructures that have already produced one or more science publications.
- Graduate Student project: Search for GW signatures associated with bursts of (at least) SGR1806-20 and SGR1900+14 soft gamma repeaters (SGRs) in S6 data. Our present upper limits are already within the theoretically predicted range of some SGR models. The increased sensitivity of the Enhanced and Advanced LIGO-Virgo detector network shall allow us to take advantage of improved data analysis approaches producing interesting scientific results. The traditional per flare search will also be expanded to search for the cumulative GW signatures of many flares together. In collaboration with Peter Kalmus (expected to leave for Caltech).
- Graduate Student project: We will make progress towards the search for GW events that are coincident in time and direction with events detected by high-energy neutrino observatories. Our recent simulations show that false alarm rates of the combined LIGO-Virgo-IceCube detector network are suppressed by several orders of magnitude when compared to a single detector, thereby improving the sensitivity to detect GW/neutrino events arriving from common astrophysical sources. Theoretical motivations also make this search a high priority. The student will develop the GW data analysis part of the project and execute the full search in collaboration with our Virgo, IceCube and ANTARES colleagues.
- Graduate Student project: Jameson Rollins will continue to spearhead the search for the gravitational wave signatures associated with the best characterized optical supernovae triggers.

- **Online Searches**

- Contribution to infrastructure for rapid online analysis for undirected and directed burst events with Omega Pipeline
- Enable rapid S6 publication
- Contribute to real time phase/timing calibration

- **Looc-Up**
 - Continue to contribute to automatization of the pipeline and science operations
- **Simulations**
 - Create simulated noise repository for future detectors
- **Infrastructure**
 - Omega and Flare development support
- **Service**
 - Co-coordinate ExtTrig team
 - Maintain Omega, Flare and XPipeline project management systems (wikis, code repository, etc.)
- **Other**
 - Quite possibly as time and talent allows

c. Stochastic

Not Applicable

d. Continuous

Not Applicable

e. 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 GECO 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.

(This includes data and computing infrastructure.)

4. Coordination and Reporting

GECO 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



Szabolcs Marka
Principal Investigator(s)
GEC



David Reitze
LSC Spokesperson



**Attachment OPS to the
Memorandum of Understanding LIGO-M050370-00
between the Columbia Experimental Gravity Group (GEC0)
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-M050370-00 defines the role of the Columbia Experimental Gravity Group (GEC0) 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 GEC0 will participate in the initial LIGO detector research program in the following areas:

a. Detector Commissioning

- GEC0 will continue to participate in calibration studies with special focus on the photon calibrator.
- GEC0 presently has two graduate students working on commissioning at LHO. If future funding allows, a regular GEC0 presence at the observatories is preferred.
- Timing work will continue.

b. Detector Characterization

- Marka will co-coordinate the Timing Stability Working Group (TSWG) that includes LIGO Laboratory (Daniel Sigg and Paul Schwinberg from LHO) and other LSC scientists. TSWG is responsible for the real time diagnostics as well as reports on the achieved timing accuracy. TSWG also works together

with the Calibration group to ensure the accurate phase and timing calibration of the gravitational wave data stream ($h(t)$).

- GEC0 will continue to enhance timing verification studies in order to ensure that the real time automatic timing diagnostic analysis is - at the very least - enough to support potential discoveries in S6;
- GEC0 shall set up representative assemblies of the Advanced LIGO timing distribution and diagnostics system towards in-situ tests with Enhanced LIGO;
- GEC0 shall further develop and test injection techniques to determine accurate timing through direct test mass excitations.
- GEC0 will maintain its data monitoring tools already in service.
- GEC0 might implement new ideas (depending on available manpower and LIGO lab priorities) for DMT monitors and related hardware.

c. Detector Operations

- GEC0 will participate in scientific shifts during science runs as required
- GEC0 will provide service work for various LIGO committees and review groups.

d. Other Contributions

- GEC0 will provide assistance if needed for the users of the LIGO-TriNet stations.
- Kalmus will contribute to the work of the LSC Calibration Committee.
- GEC0 will provide people to do service work for various LIGO committees and review groups.
- Marka will lead and coordinate the timing and timing diagnostic effort for LIGO, enhLIGO and advLIGO.

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 GEC0 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

GEC0 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



Szabolcs Marka
Principal Investigator(s)
GEC



David Reitze
LSC Spokesperson



**Attachment OUT to the
Memorandum of Understanding LIGO-M050370-00
between the Columbia Experimental Gravity Group (GECO)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
For The Period
August 15, 2008 - August 14, 2009**

This Attachment OUT to the Memorandum of Understanding LIGO-M050370-00 defines the role of the Columbia Experimental Gravity Group (GECO) as a Member of the LIGO Scientific Collaboration (LSC) in support of Education and Outreach to the broader community. The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

1. Education and Outreach

As a frontier physics effort, LIGO offers a unique opportunity to inspire interest in science among students and to educate the broader community. The LIGO Laboratory supports a broad program of education and outreach to take advantage of these opportunities.

Activities to attract and educate visitors take place at both Observatories, as well as the development of educational materials for use there and elsewhere.

The LIGO Laboratory is building a Science Education Center at the Livingston Observatory, and is participating with local partners to make it a vehicle for science education throughout the region. LSC groups are invited to participate in these activities, and to suggest others, with the goal of leveraging activities to make a greater impact.

This MOU Attachments defines the role and responsibilities of groups in this development group.

2. Participation

During the period August 15, 2008 - August 14, 2009, the members of GECO will participate in in LDG in the following areas:

a. Educational Materials Developed

Not Applicable

b. Other Contributions

- GECO members continuously spearhead successful activities targeting the public and the professional community. We will continue to have a strong outreach program during the next year serving the community in the most efficient way we can.

- GEC0 has the honor of organize the Amaldi8 conference in New York City in 2009. Organization continues this year and GEC0 will make sure that outreach will be a part of the program.

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 GEC0 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

GEC0 will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular, activities described in Item 2 will be carried out with the LIGO Observatories Educational and Outreach Leaders.

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



Szabolcs Marka
Principal Investigator(s)
GEC



David Reitze
LSC Spokesperson



**Attachment Z to the
Memorandum of Understanding LIGO-M050370-00
between the Columbia Experimental Gravity Group (GECO)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
For The Period
August 15, 2008 - August 14, 2009**

This Attachment Z to the Memorandum of Understanding LIGO-M050370-00 lists the members of Columbia Experimental Gravity Group (GECO) 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.

Name: Marka, Szabolcs**Phone:***Voice:* 1 212 854 8209*Fax:* 1 212 854 8121**Email:***@LIGO.Org:* szabolcs.marka@LIGO.Org*Forwarding:* smarka@phys.columbia.edu**Postal Address:**

1009 Pupin Laboratory

Columbia Astrophysics Laboratory

City: New York*State:* NY*Postal Code:* 10027*Country:* USA**Name:** Matone, Luca**Phone:***Voice:* 1 212 854 6429*Fax:* 1 212 854 8121**Email:***@LIGO.Org:* luca.matone@LIGO.Org*Forwarding:* matone@phys.columbia.edu**Postal Address:**

1009 Pupin Laboratory

City: New York*State:* NY*Postal Code:* 10027*Country:* USA**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.

Name: Marka, Zsuzsanna

Phone:

Voice: 1 212 854 8209

Fax: 1 212 854 8121

Email:

@LIGO.Org: zsuzsanna.marka@LIGO.Org

Forwarding: zsuzsa@astro.columbia.edu

Postal Address:

1009 Pupin Laboratory

City: New York

State: NY

Postal Code: 10027

Country: USA

Name: Raics, Zoltan

Phone:

Voice: 36 30 688 5376

Fax:

Email:

@LIGO.Org: zoltan.raics@LIGO.Org

Forwarding: raics.zoltan@t-online.hu

Postal Address:

Peterfia street 41

City: Debrecen

State: Hajdu-Bihar

Postal Code: 4026

Country: HUN

Postdoctoral Scholars:

Graduate Students:

Name: Bartos, Imre

Phone:

Voice: 1 917 455 6264

Fax:

Email:

@LIGO.Org: imre.bartos@LIGO.Org

Forwarding: imrebartos@gmail.com

Postal Address:

500 Riverside Dr.

City: New York

State: NY

Postal Code: 10027

Country: USA

Name: Kalmus, Peter Michael

Phone:

Voice: 1 212 854 6429

Fax: 1 212 854 8121

Email:

@LIGO.Org: peter.kalmus@LIGO.Org

Forwarding: peter@phys.columbia.edu

Postal Address:

1009 Pupin Laboratory

City: New York

State: NY

Postal Code: 10027

Country: USA

Name: Rollins, Jameson Graef
Phone:
Voice: 1 212 854 5762
Fax: 1 212 854 8121
Email:
@LIGO.Org: jameson.rollins@LIGO.Org
Forwarding: jrollins@phys.columbia.edu

Postal Address:
 1009 Pupin Laboratory
City: New York
State: NY
Postal Code: 10027
Country: USA

Undergraduate Students:

Name: Khan, Rubab
Phone:
Voice: 1 212 854 5762
Fax: 1 212 854 8121
Email:
@LIGO.Org: rubab.khan@LIGO.Org
Forwarding: rubab@astro.columbia.edu

Postal Address:
 5151 Lerner Hall
City: New York
State: NY
Postal Code: 10027
Country: USA

Name: Piscionere, Jennifer
Phone:
Voice: 1 212 854 5762
Fax: 1 212 854 8121
Email:
@LIGO.Org: jennifer.piscionere@LIGO.Org
Forwarding: jpiscionere@gmail.com

Postal Address:
 6005 Lerner Hall
City: New York
State: NY
Postal Code: 10027
Country: USA

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	Bartos, Imre	graduate	100%	75%	90%
2	Kalmus, Peter Michael	graduate	100%	100%	100%
3	Khan, Rubab	undergraduate	100%	25%	50%
4	Marka, Szabolcs	faculty	100%	66%	80%

FTE Commitment:

#	Name	Category	Member	Research	LIGO
5	Marka, Zsuzsanna	technical	100%	60%	80%
6	Matone, Luca	faculty	100%	10%	100%
7	Piscionere, Jennifer	undergraduate	100%	25%	50%
8	Raics, Zoltan	technical	100%	25%	100%
9	Rollins, Jameson Graef	graduate	100%	100%	100%
				Total FTE:	7.50

Roles:**Principal Investigators:**

Marka, Szabolcs

Membership Point-Of-Contact:

Marka, Szabolcs

Group PIO/Press Coordinator:

Marka, Szabolcs

Proxies:

Marka, Zsuzsanna

Author Eligible

Marka, Szabolcs

Matone, Luca

Marka, Zsuzsanna

Kalmus, Peter Michael

Rollins, Jameson Graef

Council Delegates

Marka, Szabolcs

Approvals:



Jay Marx
LIGO Laboratory Director



Szabolcs Marka
Principal Investigator(s)
GEC



David Reitze
LSC Spokesperson