Attachment DAT to the

Memorandum of Understanding (LIGO-M 050370 -00-M)

between the

Columbia Experimental Gravity Group (GECo)

and the

Laser Interferometer Gravitational Wave Observatory (LIGO)

August 15, 2006

This Attachment DAT to the Memorandum of Understanding LIGO-M 050370 -00-M defines the role of the Columbia Experimental Gravity Group as a Member of the LIGO Scientific Collaboration (LSC), in particular, its activities in data analysis in support of the initial LIGO interferometers. The period of performance for the activities in this Attachment is from August 15, 2006 to August 15, 2007.

1. 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 the analyses, perform detailed reviews, and prepare publications on behalf of the collaboration. LSC groups are encouraged to participate in one or more of these groups. MOU Attachments define the contributions of each participating group to the data analysis groups.

2. During the period August 15, 2006 to August 15, 2007, the members of GECo will participate in the analysis of initial LIGO data in the following areas:

b) Bursts

>> GECo will continue to concentrate on and spearhead the astrophysical trigger based analyses. Szabolcs Marka will continue the coordination of the work of the ExTrig group.

>> The review process for analyses of the SGR1806 hyperflare, including both the instantaneous gravitational wave emission at the burst trigger time and the emission of GWs during the following quasiperiodic seismic oscillations phase, are expected to be finished and the corresponding publications submitted within the timeframe of this MOU.

>> The following analyses are expected to have major advances towards publication during the timeframe of this MOU:

1. Algorithms developed for GW searches from quasiperiodic sources are nearing publication phase (Diploma Thesis of Peter Raffai, Eotvos University). The search algorithms are as model independent as possible, thus making them also viable for searches of GWs from various quasiperiodic sources (besides long GRBs).

2. Using the new specialized techniques (point 1. above), developed for searching for quasi-monochromatic gravitational wave signals, GECo will look for GWs in S5 data from GRBs lasting for a second to a minute time scale. The search is based on published theoretical predictions (e.g. M. van Puten).

3. There have been a number of intriguing optical supernovae targets with known type classification, distance and direction seen during S5 up to date. GECo is focusing on the relatively close by events with well detected light curve signatures to minimize the uncertainty in the timing of the event. We are searching for gravitational wave signatures associated with these best characterized optical supernovae triggers.

4. There have been a few relatively close by GRBs seen during S5 up to date. GECo is interested in these events. We are searching for gravitational wave signatures associated with these most promising GRB triggers.

5. GECo is searching for gravitational waves associated with ultra high energy cosmic ray and neutrino events provided by HiRes/Auger/IceCube experiments. Although the source and nature of these events might be fairly uncertain, the energy associated with them makes plausible that their source is a cataclysmic cosmic event capable of generating GWs with unprecedented strength. It is definitely an interesting scientific issue to tackle.

6. In addition to the above projects, GECo will keep an eye on received external triggers and to 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 code or will develope specialized new analysis.

>> One of GECo's goal is to develop novel search algorithms for specialized or opportunistic gravitational wave searches promising astrophysical results. The next algorithms are expected to be published or being close to publication within the timeframe of this MOU:

7. A specialized search code for repeating point source emitters on the sky is under development, with the goal of finding potential positions on the celestial sphere with an abundance of low strength events.

8. GECo is developing an algorithm capable of searching for repeating gravitational wave events with very similar waveforms plausibly present in the data at low signal to noise ratios. Even if the signal is too weak to be detected one can pool the information from several instances of the same type of signal and then use this aggregated signal to extract the representative waveform, followed by matched filtering techniques to find even more instances at weaker signal to noise ratios.

9. Another algorithm under development aims to reconstruct a self similar signal buried in different noise streams. If succeeds, the algorithm should be capable of reconstructing the relatively weak waveform. That would be highly advantageous for extracting astrophysical information from possible detections.

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

c) Access to LIGO computing resources and expertise in support of this work.
Access to all data.
Direct participation option in decision making bodies.

4. Coordination and Reporting -

GECo will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2a) will be carried out within the LSC Inspiral Search Group, Item 2b) will be carried out within the LSC Burst Search Group, Item 2c) will be carried out within the LSC Stochastic Search Group and Item 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 on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. 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.

Approved:

Jay Marx
LIGO Laboratory Director

Peter N. Saulson

Peter Saulson
LSC Spokesperson

Szabolcs Marka 2007.02.27 16:58:11 -05'00'

Szabolcs Marka
Principal Investigator
Columbia Experimental Gravity Group

Attachment OPS to the

Memorandum of Understanding (LIGO-M 050370 -00-M)

between the

Columbia Experimental Gravity Group (GECo)

and the

Laser Interferometer Gravitational Wave Observatory (LIGO)

August 15, 2006

This Attachment OPS to the Memorandum of Understanding LIGO-M 050370 -00-M defines the role of the Columbia Experimental Gravity Group 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, 2006 to August 15, 2007.

1. 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 Laboratroy and the LSC.

2. During the period August 15, 2006 to August 15, 2007, the members of GECo will participate in the initial LIGO detector research program in the following areas:

a) Detector Commissioning

GECo will contribute to detector stability and sensitivity improvements in areas where the group's expertise overleaps with LIGO's needs.

The new timing distribution system parts tested and assembled by CECo are awaiting implementation at the LIGO detector sites. We plan to continue to help this effort.

GECo will continue to participate in calibration studies with special focus on the photon calibrator.

b) Detector Characterization

GECo will spearhead the S5 timing investigation and diagnostic effort (timing studies, monitoring) in addition to its role in timing software/hardware improvement/maintenance.

Spectrum consistency/stationarity studies, including monitoring software improvement/maintenance.

GECo will maintain its existing data monitoring tools in service (PhotonCal, TimeMon, IRIG-B, SPI, WebView, etc.) and participate in DMT infrastructure development if need arises.

Implement needed new ideas (dependent of available manpower and LIGO lab priorities)

c) Detector Operations

Participate in scientific shifts during science runs.

Work with operators if necessary to make the control room tools developed by GECo members more and more useful. Listen and act on the ideas/request of operators to develop new tools (dependent of available manpower and LIGO lab priorities).

d) Other Contributions

GECo will provide user assistance for the users of the LIGO-TriNet stations.

Peter Kalmus will contribute to the work of the LSC Calibration Committee.

Szabolcs Marka will lead and coordinate the timing diagnostic effort.

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

4. Coordination and Reporting -

GECo will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2a) will be carried out in coordination with the LIGO Laboratory Commissioning Leader, Item 2b) will be carried out within the Detector Characterization Working Group of the LSC, and Item 2c) will be carried out in coordination with the LHO {or LLO} Site Head. Coordination will include 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 on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. 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.

Approved:

Jay Marx
LIGO Laboratory Director

2007.02.27 16:58:44 -05'00'
Szabolcs Marka
Principal Investigator
Columbia Experimental Gravity Group

Peter Saulson
LSC Spokesperson

Attachment OUT to the

Memorandum of Understanding (LIGO-M 050370 -00-M)

between the

Columbia Experimental Gravity Group (GECo)

and the

Laser Interferometer Gravitational Wave Observatory (LIGO)

August 15, 2006

This Attachment OUT to the Memorandum of Understanding LIGO-M 050370 -00-M defines the role of the Columbia Experimental Gravity Group as a Member of the LIGO Scientific Collaboration (LSC) in support of Educational and Outreach to the broader community. The period of performance for the activities in this Attachment is from August 15, 2006 to August 15, 2007.

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. MOU Attachments define the roles and responsibilities of groups in this development group.

2. During the period August 15, 2006 to August 15, 2007, the members of GECo will participate in Education and Outreach in the following areas:

b) Other Contributions

GECo members continuously spearheaded successful activities targeting the public, in particular the urban communities of New York city, to spark their interest in science. Many of these activities directly advertise the achievements of LIGO and the gravitational wave field. GECo actively works to maintain the high level of diversity in our group to provide young woman and man the rewarding research experience they deserve. A small subset of last year's projects as illustration:

• Peter Kalmus and Rebecca Grossmann are volunteering for the Columbia University Science Honors Program, specifically developed for New York City area high school students and Kalmus developed and taught a new and successful course on gravity and relativity.
• Several GECo talks on LIGO and pursuing science in college and beyond to high school and undergraduate classes.
• Rebecca Grossmann instituted a grassroots mentoring program for women, considering physics or astronomy majors at Barnard College, to tackle gender specific difficulties.
• Szabolcs Marka volunteered at the New York Hall of Science (a science museum targeting underrepresented minority students) by advising young staff on science experiments exhibited at the museum.

We are proud to reach many young male and female students from various ethnic and minority groups. We will continue to have a similarly strong outreach program during the next year serving the community the most efficient way we can at the time.

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

c) Access to educational materials and information developed by the LIGO laboratory
Access to the LIGO laboratories for educational projects (within reason, without disturbing operations)

4. Coordination and Reporting -

GECo will perform this 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. Coordination will include 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 on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. 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.

Approved:

Jay Marx
LIGO Laboratory Director

2007.02.27 16:59:16 -05'00'
Principal Investigator
Columbia Experimental Gravity Group

Peter Saulson
LSC Spokesperson

Attachment Number Z to the Memorandum of Understanding (LIGO-M **050370** -00-M) between the **Columbia Experimental Gravity Group** (**GECo**) and the Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory

This Attachment to the Memorandum of Understanding LIGO-M **050370** -00-M lists the coordinates of members of the **Columbia Experimental Gravity Group** who will participate in the LIGO Scientific Collaboration (LSC) as members of LIGO Development Groups. The period of performance for the activities in this Attachment is from August 15, 2006 to August 15, 2007. This period may be modified by agreement to a revision of this Attachment. This list may be extended by agreement to a revision of this Attachment.

Principal Investigator

First Name: **Szabolcs** Last Name: **Marka**

Affiliation: **Columbia University, Columbia Astrophysics Laboratory**

Address: **1009 Pupin Laboratory**

City: **New York** State: **NY** Zip Code: **10027**

Country: **United States** Primary Email: **smarka@phys.columbia.edu**

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Phone Number: **212 854 8209** Fax Number: **212 854 8121**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE: **60** % LIGO FTE: **80** % AdvLIGO FTE: **20** %

Author on LSC papers: ☒ LSC Council Delegate? ☒

Member #2

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Luca** Last Name: **Matone**

Affiliation: **Columbia University, Columbia Astrophysics Laboratory**

Address: **1009 Pupin Laboratory**

City: **New York** State: **NY** Zip Code: **10027**

Country: **United States** Primary Email: **matone@phys.columbia.edu**

Job Title: **Assistant Research Scientist** Secondary Email:

Phone Number: **212 854 6429** Fax Number: **212 854 8121**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **80** % LIGO FTE **90** % AdvLIGO FTE **10** %

Author on LSC papers: ☒ LSC Council Delegate? ☐

Member #3

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Peter Michael** Last Name: **Kalmus**

Affiliation: **Columbia University, Columbia Astrophysics Laboratory**

Address: **1009 Pupin Laboratory**

City: **New York** State: **NY** Zip Code: **10027**

Country: **United States** Primary Email: **peter@phys.columbia.edu**

Job Title: **Graduate Student** Secondary Email: **pmk2104@columbia.edu**

Phone Number: **212 854 5762** Fax Number: **212 854 8121**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **50** % LIGO FTE **99** % AdvLIGO FTE **1** %

Author on LSC papers: ☒ LSC Council Delegate? ☐

Member #4

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Jameson Graef** Last Name: **Rollins**

Affiliation: **Columbia University, Columbia Astrophysics Laboratory**

Address: **1009 Pupin Laboratory**

City: **New York** State: **NY** Zip Code: **10027**

Country: **United States** Primary Email: **jrollins@phys.columbia.edu**

Job Title: **Graduate Student** Secondary Email: **jgr2110@columbia.edu**

Phone Number: **212 854 5762** Fax Number: **212 854 8121**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **50** % LIGO FTE **90** % AdvLIGO FTE **10** %

Author on LSC papers: ☒ LSC Council Delegate? ☐

Member #5

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Sharmila** Last Name: **Kamat**

Affiliation: **Columbia University, Columbia Astrophysics Laboratory**

Address: **1009 Pupin Laboratory**

City: **New York** State: **NY** Zip Code: **10027**

Country: **United States** Primary Email: **sharmila@astro.columbia.edu**

Job Title: **Postdoctoral Research Scientist** Secondary Email:

Phone Number: **212 854 4030** Fax Number: **212 854 8121**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **50** % LIGO FTE **99** % AdvLIGO FTE **1** %

Author on LSC papers: ☐ LSC Council Delegate? ☐

Member #6

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Yoichi** Last Name: **Aso**

Affiliation: **Columbia University, Columbia Astrophysics Laboratory**

Address: **1009 Pupin Laboratory**

City: **New York** State: **NY** Zip Code: **10027**

Country: **United States** Primary Email: **aso@astro.columbia.edu**

Job Title: **Postdoctoral Research Scientist** Secondary Email: **ya2168@columbia.edu**

Phone Number: **212 854 6429** Fax Number: **212 854 8121**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **50** % LIGO FTE **80** % AdvLIGO FTE **20** %

Author on LSC papers: ☐ LSC Council Delegate? ☐

Member #7

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **John** Last Name: **Dwyer**

Affiliation: **Columbia University, Columbia Astrophysics Laboratory**

Address: **1009 Pupin Laboratory**

City: **New York** State: **NY** Zip Code: **10027**

Country: **United States** Primary Email: **jd2100@columbia.edu**

Job Title: **Undergraduate Student** Secondary Email:

Phone Number: **212 854 5762** Fax Number: **212 854 8121**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **50** % LIGO FTE **90** % AdvLIGO FTE **10** %

Author on LSC papers: ☒ LSC Council Delegate? ☐

Member #8

☒ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: **Zsuzsanna** Last Name: **Marka**

Affiliation: **Columbia University, Columbia Astrophysics Laboratory**

Address: **1009 Pupin Laboratory**

City: **New York** State: **NY** Zip Code: **10027**

Country: **United States** Primary Email: **zsuzsa@astro.columbia.edu**

Job Title: **Postdoctoral Research Scientist** Secondary Email: **zsuzsika@gmail.com**

Phone Number: **212 854 8209** Fax Number: **212 854 8121**

Begin Date: **Aug 15, 2006** End Date: **Aug 15, 2007**

Research FTE **50** % LIGO FTE **99** % AdvLIGO FTE **1** %

Author on LSC papers: ☐ LSC Council Delegate? ☐

Member #9

☐ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: Last Name:

Affiliation:

Address: **1009 Pupin Laboratory**

City: State: Zip Code:

Country: Primary Email:

Job Title: Secondary Email:

Phone Number: Fax Number:

Begin Date: End Date:

Research FTE % LIGO FTE % AdvLIGO FTE %

Author on LSC papers: ☐ LSC Council Delegate? ☐

Member #10

☐ Select this box if the contact information of this member is the same as that of the Principal Investigator.

First Name: Last Name:

Affiliation:

Address: **1009 Pupin Laboratory**

City: State: Zip Code:

Country: Primary Email:

Job Title: Secondary Email:

Phone Number: Fax Number:

Begin Date: End Date:

Research FTE % LIGO FTE % AdvLIGO FTE %

Author on LSC papers: ☐ LSC Council Delegate? ☐

Authorship:

Marka

Matone **Dwyer**

Kalmus

Rollins

Scientific Collaboration Council Delegate(s):

Marka

Approved:

Jay Marx
LIGO Laboratory Director

2007.02.27 16:59:56 -05'00'

Szabolcs **Marka**
Principal Investigator
Columbia Experimental Gravity Group

Peter Saulson
LSC Spokesperson