

**Memorandum of Understanding (LIGO-M050266-00-M)**  
**between the**  
**Michigan Gravitational Wave Group (MGWG)**  
**and the**  
**Laser Interferometer Gravitational Wave Observatory (LIGO)**  
**August 15, 2005**

The purpose of this Memorandum of Understanding (MOU) is to establish and define a collaborative relationship between the Michigan Gravitational Wave Group (MGWG) and the Laser Interferometer Gravitational-Wave Observatory (LIGO). Both parties to this agreement share the broad goals of developing the instruments and techniques for detecting and studying gravitational waves, and subsequently using them as an astrophysical probe. Under this MOU, the MGWG Group will become a member group of the LIGO Scientific Collaboration.

1. The Michigan Gravitational Wave Group (MGWG) consists of Professor Keith Riles, who will serve as Principal Investigator for research in LIGO, Research Scientist Dick Gustafson, and a small group of graduate and undergraduate students. The focus of the work done by the MGWG under this agreement will be searching for radiation from gravitational wave pulsars, LIGO detector characterization, and commissioning of the LIGO Hanford interferometers.
2. LIGO comprises two parts: the LIGO Laboratory and the LIGO Scientific Collaboration. These two entities report to the LIGO Directorate, consisting of the LIGO Director, the LIGO Scientific Collaboration Spokesperson, and the LIGO Laboratory Deputy Director. The design and construction of the LIGO Observatories were carried out by California Institute of Technology (Caltech) and the Massachusetts Institute of Technology (MIT) under a Cooperative Agreement between the National Science Foundation (NSF) and Caltech. The LIGO Oversight Committee supervises the realization of LIGO.
  - A. The LIGO Laboratory is responsible for the operation of the LIGO Observatories, the development and implementation of future detector systems, and participates in all aspects of the research with the LIGO detectors. LIGO is a system of three interferometric Fabry-Perot antennas, two of them 4 kilometers long and the third one 2 kilometers long, aimed at the simultaneous detection of gravitational waves in the frequency range 40-6000 Hz. LIGO Observatories are located in Hanford, Washington and in Livingston Parish, Louisiana (USA) and began observations in the year 2002. The LIGO Laboratory is funded through a Cooperative Agreement between the National Science Foundation and Caltech, with the portion of

the LIGO Laboratory at MIT funded through a subcontract.

- B. The LIGO Scientific Collaboration (LSC) is organized as a separate organization from the LIGO Laboratory. It includes scientists from the LIGO Laboratory, and those from collaborating institutions, and has its own leadership and governance. The Collaboration ensures equal scientific opportunity for individual participants and institutions. It organizes the research, publications, and all other scientific activities. The Collaboration reports to the LIGO Directorate for final approval of its research program, technical work, observational physics publications, and talks announcing new observations and physics results. This will be done through regular reports to the Directorate and its Program Advisory Committee. The organization of the LSC and its governance are defined in its Charter.
3. As a member group of the LSC, the MGWG Group will participate in the governance of the LSC and in setting its policies and procedures, as defined in the LSC charter. Similarly, it agrees to abide by the policies and procedures adopted by the LSC and posted on its website (<http://www.ligo.org/policies.html>), concerning publication, data access, software standards, and so on.
  4. Participation in the LSC brings with it responsibility for service functions to support the overall effort in achieving high detector sensitivity and high data quality. In particular, each LSC group is expected to assist in the staffing of scientific monitoring shifts during organized data runs. The staffing of these shifts is notable for both its importance and the travel burden it places on scientists.
  5. Each party to this agreement continues to be responsible for all support of its staff including travel costs associated with the activities under this agreement. Exceptional support of travel by the other institution may be allowed for travel requested by that institution.
  6. Attachments to this MOU will be prepared annually to define the specific activities and responsibilities of the MGWG Group and to define any resources to be provided by the LIGO Laboratory to the MGWG Group in support of those activities.
  7. MGWG Group will provide a status report on its activities in support of LIGO annually. The report will consist of a summary status on research by topic as indicated in the Attachments for that period 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 by each member of the group. The report will be due one month before the close of the period of performance under the Attachments in question.
  8. The LSC will review the progress report against the Attachments from the previous year and assess the Attachments for the up-coming year annually, under its established procedure, and recommend acceptance or rejection of the Attachment by

- the LIGO Director and the LSC Spokesperson.
9. The membership list of the MGWG group will be updated at least every six months. MGWG Group members and appropriate contact information will be provided in electronic form as Attachment Z to this Memorandum of Understanding. In cases where individuals who leave the group have had access to LIGO data and this access should be terminated, the MGWG Group Principal Investigator is responsible for timely notification to the Directorate and to the computing committee so access may be revoked.
  10. The LIGO Laboratory is responsible for obtaining NSF approval of collaborative Memoranda of Understanding where required. All Memoranda of Understanding will be provided to NSF for their information.
  11. The rights to intellectual property developed under this Attachment using LIGO Laboratory resources will be subject to the National Science Foundation Grant Policy as indicated in Section 730, Intellectual Property.
    - A. In the event a patentable invention is conceived or first actually reduced to practice during the work of a member of the ABC Group using LIGO Laboratory resources, he/she will:
      - i) make prompt disclosure of the invention to the Director of the LIGO Laboratory; and
      - ii) cooperate with LIGO Laboratory and supply all information and execute all papers including invention reports, records of invention, patent applications and powers of attorney, necessary and proper to fulfill the obligations of the LIGO Laboratory to the U.S. Government sponsor.
    - B. The ownership of inventions conceived solely by members of the MGWG Group or first actually reduced to practice at LIGO facilities solely by member of the ABC Group shall be owned by the University of Michigan, although the LIGO Laboratory shall be granted a license to use such invention for noncommercial research purposes at LIGO facilities. Inventions that are conceived or first actually reduced to practice by both members of the ABC Group and LIGO Laboratory staff shall be jointly owned by the University of Michigan and Caltech/MIT in proportion to the number of joint inventors from each institution.

In all other regards, the rights to intellectual property developed by members of the MGWG Group under this Attachment will be in accordance with the policies of University of Michigan.

12. This MOU supersedes the previous MOU between the LIGO Laboratory and the MGWG group (LIGO- M950073-00-M) and its amendments and attachments. This MOU will remain in force until the parties mutually agree to terminate it, or until it is terminated in accordance with LSC procedures.

Approved:

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Barry Barish  
LIGO Director

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Keith Riles  
Principal Investigator  
University of Michigan

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Peter Saulson  
LSC Spokesperson

**Attachment DAT to the**  
**Memorandum of Understanding (LIGO- M050266-00-M)**  
**between the**  
**Michigan Gravitational Wave Group (MGWG)**  
**and the**  
**Laser Interferometer Gravitational Wave Observatory (LIGO)**  
**August 15, 2005**

This Attachment DAT to the Memorandum of Understanding LIGO-M050266-00-M defines the role of the Michigan Gravitational Wave Group (MGWG) 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, 2005 to August 15, 2006.

1. Together, the LIGO Laboratory and the LIGO Scientific Collaboration 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, 2005 to August 15, 2006, the members of MGWG Group will participate in the analysis of initial LIGO data in the following areas:
  - a) **Burst Search:** Riles will continue chairing the burst group papers review committee for all S2/S3 publications and some S4 publications. He has asked, however, to be relieved of this duty in the coming year, to devote more time to the pulsar search analysis and to detector characterization.
  - b) **Pulsar Search:** Dergachev and Riles will continue a broadband, all-sky search for continuous-wave gravitational sources using Dergachev's PowerFlux analysis pipeline, based on incoherent averaging of power spectra with noise and antenna-pattern weighting. Final results for the S4 data run will be produced for publication. The S5 data will also be analyzed on a regular basis during the run, to improve upper limits and provide feedback to commissioners on spectral lines. Refinements and optimizations of the PowerFlux pipeline are also planned.
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 MGWG 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 – MGWG Group 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 Burst Search Group, Item 2b) will be carried out within the LSC Pulsar Search Group. 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:

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Barry Barish  
LIGO Laboratory Director

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Keith Riles  
MGWG Principal Investigator

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Peter Saulson  
LSC Spokesperson

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Erik Katsavounidis  
LSC Burst Search Group Leader

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Albert Lazzarini  
LIGO Laboratory Data and Computing  
Group Leader

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Mike Landry  
LSC Pulsar Search Group Leader

**Attachment OPS to the**  
**Memorandum of Understanding (LIGO-M050266-00-M)**  
**between the**  
**Michigan Gravitational Wave Group (MGWG)**  
**and the**  
**Laser Interferometer Gravitational Wave Observatory (LIGO)**  
**August 15, 2005**

This Attachment OPS to the Memorandum of Understanding LIGO-M050266-00-M defines the role of the University of Michigan (MGWG) as a Member of the LIGO Scientific Collaboration (LSC) in the areas of detector commissioning, detector characterization, and operations in support of the initial LIGO interferometers. The period of performance for the activities in this Attachment is from August 15, 2005 to August 15, 2006.

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 Laboratory and the LSC.
2. During the period August 15, 2005 to August 15, 2006, the members of MGWG Group will participate in the initial LIGO detector research program in the following areas:
  - a) *Commissioning* –
    - 1) Gustafson will continue to investigate and reduce systemic noise in the LHO interferometers and strongly support commissioning work toward reaching the SRD sensitivity goals for the LHO 4K and 2K interferometers.
    - 2) Gustafson will further refine the Recycling Cavity Sideband Analyzer System (compact demodulation electronics) including its extension to the other ports and LIGO interferometers.
    - 3) Gustafson will study the Recycling Cavity, pursuing noise reduction issues vis-a-vis sideband dynamics and operation; correlation of SB variation and the infamous AS-I signal will be investigated. Consequences of a non-perfect match of the recycling cavity free spectral range frequency to the laser-modecleaner tuned choice will be explored.
    - 4) Gustafson, with Kawabe [LHO] and a student, will further pursue Output Mode Cleaner Issues; optical simulation; possible 6 meter configuration (folded to 1 meter) is contemplated; a prototype test unit is possible. The Side Band Analyzer system will be employed. Perfectly identical treatment of sidebands and carrier is (we believe) key to

success. (The small non-resonant SB OMC, while seemingly beautiful, was a noise failure.)

5) Goetz (graduate student) will begin a 2-year residence at LHO in summer 2006 (having spent the three previous summers at LHO as a SURF student or Michigan graduate student). He will work primarily on commissioning and detector characterization.

b) *Detector Characterization* –

1) Riles will continue to chair the LSC Detector Characterization Working Group. He will continue coordinating the Group's efforts, together with LIGO liaison Daniel Sigg and the leaders of the data run investigation teams. All of this work will be done in coordination with the astrophysical search groups.

Riles will continue working with LIGO Laboratory physicists, primarily John Zweizig, to facilitate efficient contributions to detector characterization by LSC members. He will also continue contributing directly to software algorithms for the on-site Data Monitor Tool (DMT)..

2) Riles will maintain the DMT operational state condition software package.

3) Riles will maintain the LockLoss DMT monitor.

4) Riles will write a DMT monitor class based on the LAL code of Xavier Siemens of UWM for producing  $h(t)$  for general use by DMT monitors.

5) Dergachev (graduate student) will continue maintaining the `ligo_viewer` program for viewing LIGO data trends at the observatory sites remotely from unix/linux and Windows computers.

6) Dergachev will maintain the SpectrumFold DMT monitor to track pervasive combs of harmonic lines in real time.

7) Dergachev and Riles will continue contributing to cataloguing known instrumental lines in the gravitational wave channel.

8) Subtle lines seen in the pulsar group data will be pursued by Gustafson in the backend electronics, e.g., the class of lines derived from various crystal oscillators in the Pentium processors of the control computers beating ( at various harmonic levels ) with the LIGO GPS driven DAQ clocks.

c) *LIGO Operations* –

1) Riles will organize LSC participation in upcoming engineering and science runs, including staffing of scientific monitoring shifts, in coordination with lab-designated engineering run leaders at the sites.

2) Riles will continue maintaining data quality segment repositories for engineering and

science data runs.

3) Gustafson will assist in LIGO Hanford operations during S5 by helping with repairs and other necessary tasks as required.

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 MGWG 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 – MGWG Group will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. Activities described in Item 2) will be carried out in coordination with the LIGO Laboratory Commissioning Leader, the LHO Site Head, and the Detector Characterization Working Group of the LSC, as appropriate. 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:

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Barry Barish  
LIGO Laboratory Director

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Keith Riles  
MGWG Principal Investigator

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Peter Saulson  
LSC Spokesperson

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Daniel Sigg  
LSC Detector Characterization Co-Leader

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Fred Raab  
LHO Site Head

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Peter Fritschel  
LIGO Lab Commissioning Leader

**Attachment Number Z to the**  
**Memorandum of Understanding (LIGO-M050266-00-M)**  
**between the**  
**Michigan Gravity Wave Group (MGWG) in the Department of Physics of the**  
**University of Michigan**  
**and the**  
**Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory**  
**Draft- August 15, 2005**

This Attachment to the Memorandum of Understanding LIGO-M050266-00-M lists the coordinates of the members of the MGWG 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, 2005 to August 15, 2006**. This period may be modified by agreement to a revision of this Attachment.

<b>Name</b>	<b>Address</b>	<b>E-Mail</b>	<b>Phone Nos.</b>	<b>Begin Date</b>	<b>End Date</b>
Gustafson, Richard 100% LIGO I 100% AdLIGO 0 Faculty Prev FTE = 100%	LHO P.O. Box 1970 Richland, WA 99352	gustafso@umich.edu gustafso@ligo.caltech.edu	734-936-0812 (O) 734-764-9500 (L) Fax: 734-936-1817 LHO 509-372-8106 Fax:509-327-8137	Aug. 15, 2005	Feb. 15, 2006
Riles, Keith 90% LIGO I 90% AdLIGO 0 Faculty Prev FTE = 90%	Physics Dept. Univ. of Michigan, 450 Church St. Ann Arbor, MI 48109-1040	kriles@umich.edu	734-764-4652 (O) 734-963-7208 (L) Fax: 734-936-6529	Aug. 15, 2005	Feb. 15, 2006
Dergachev, Vladimir 20% LIGO I 20% AdLIGO 0 Grad. Student Prev FTE = 50%	Physics Dept. Univ. of Michigan, 450 Church St. Ann Arbor, MI 48109-1040	volodya@umich.edu	734-764-5146 (O) 734-763-7208 (L) Fax: 734-936-6529	Aug. 15, 2005	Feb. 15, 2006

Goetz, Evan 50% LIGO I 50% AdLIGO 0 Grad. Student Prev FTE = 10%	Physics Dept. Univ. of Michigan, 450 Church St. Ann Arbor, MI 48109-1040	egoetz@umich.edu	734-764-5146 (O) 734-763-7208 (L) Fax: 734-936-6529	Aug. 15, 2005	Feb. 15, 2006
Troyan, Peter 10% LIGO I 10% AdLIGO 0 Under. Grad New member	Physics Dept. Univ. of Michigan, 450 Church St. Ann Arbor, MI 48109-1040	ptroyan@umich.edu	734-764-5146 (O) 734-763-7208 (L) Fax: 734-936-6529	Aug. 15, 2005	Feb. 15, 2006

Scientific Collaboration Council Delegate: Keith Riles

Approved:

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Barry Barish  
LIGO Laboratory Director

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Keith Riles  
MGWG Principal Investigator

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Peter Saulson  
LSC Spokesperson