Attachment DAT to the Memorandum of Understanding LIGO-M050352-00 between the University of Texas at Brownsville Center for Gravitational Wave Astronomy (UTBRG) 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-M050352-00 defines the role of the University of Texas at Brownsville Center for Gravitational Wave Astronomy (UTBRG) 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 UTBRG will participate in the analysis of initial LIGO data in the following areas:

a. Binary Inspirals

Mohanty will continue to investigate the outcomes of the new implementation of matched filtering based on the multi-dimensional Fourier transform. A methods paper will be published if interesting results are found.

b. Bursts

1) Mohanty and graduate student E. Manoharan will complete the calculations behind the S5 GRB population study analysis. Manoharan will complete analytic (or
semi-analytic) derivation of the various required distributions. Mohanty will complete a formalism that can take redshifts and source directions into account to weight the different GRBS included in the population study. Mohanty will implement the above formalism in software (using the RIDGE pipeline codes which are already developed) and analyze S5 data to obtain science results.

Mohanty and Hayama will continue to develop the method of source tracking. This involves reconstructing the time series of the two GW polarization components and analyzing the reconstructed time series for various types of signals. One of the main challenges here is the contamination of the time series reconstructed for one direction by a source that occurs at a different location on the sky. We intend to publish a methods paper.

Mohanty will continue to participate in the internal review of the BlockNormal pipeline until a final report is produced.

2) Two new members of the UTBRG group, Daniel Bessis and Luca Perotti, will develop a new search technique. In their method, the Z-transform of the noisy data appears as an extension of the discrete Fourier transform to complex values of the frequency. In the complex plane the discrete Fourier transform is the restriction of the Z transform to values of z located at the roots of unity. However, the noise is not uniformly distributed in the complex z-plane and, unfortunately, the roots of unity are noise attractors as shown at the beginning of the attached paper. Therefore, the Fourier transform is not a good choice when the signal is embedded in high noise as it is the case in many circumstances. The analytic treatment of the noise they propose, distinguishes, in a drastic way, the signal from the noise by their totally different analytic properties. The fact that the noise presents an analytic characterization that is universal, independent of its statistical properties, has as consequence a much greater independence of the signal identification on the noise level. In principle, in the limit of very long signals, the signal extraction becomes independent of the signal to noise ratio.

The previous analysis was formulated for a unique detector. They intend to analyze the case of a network of detectors detecting the same signal but with different noise. This can be done by introducing a non commuting algebra of Z-transforms having the same singularities (the poles associated with the signal) but different residues that gives the signature of the sources.

Based on the above description they plan to present their preliminary results to the LSC burst group in the next couple of months, and plan further work on this method based on the recommendations made by the group.

3) Teviet Creighton has begun investigating potential science to be gained from collaborations between LIGO and radio observatories, specifically the Arecibo and Green Bank radio telescopes. One possibility is to use these observatories to follow up on gravitational-wave burst or inspiral triggers, along similar lines to the LOOC UP pipeline proposed in arXiv:0803.0312. Creighton plans to set up the necessary collaborations and pipelines to implement such radio follow-ups.

4) Matt Benacquista will participate in a new effort related to possible periodic broad-band bursts in the LIGO band (for enhanced/advanced LIGO) produced by stellar mass black holes in galactic cores.
O’Leary, Kocsis, and Loeb give interesting event rates for S6 and beyond. However, their work is preliminary and only done for equal mass black holes with a single mass. In order to develop a realistic search for these sources, we need to develop an astrophysically reasonable template bank for such highly eccentric systems. Szablocs Marka is organizing such a search for the Burst group, and Benacquista will participate in this collaboration.

Benacquista will be responsible for developing the template bank. Within the first year, he will produce a first-order parameterization of the template bank to include orbital evolution, a spectrum of both mass ratios and individual masses, and distances to likely host galaxies.

In order to capitalize on a detection, improvements in the evolution of the bursts such as orbital plane precession, spin-orbit coupling and other relativistic effects are needed. Some of these effects will require the application of numerical relativity. With Szablocs Marka, Benacquista will participate in the development of a menu of desired numerical relativity results which will most efficiently address these outstanding issues. This menu will also be completed by the first year. During the process of developing the menu, it is expected that some effects may be amenable to PN approximations or other non-numerical approaches. As appropriate, these will be addressed by Benacquista. The coordination with the numerical relativity community will be directed by Szablocs Marka. The first-order template bank will be produced independently of the numerical relativity community.

c. Stochastic

Short term: Joe Romano with collaborators in the SULG will finish writing the methods paper detailing the spherical harmonics decomposition search. They hope to have the paper completed by Fall 2008 and submitted for publication before the end of the year.

Long term: Analyse the S5 data using this new method and include the results in an LSC paper giving the S5 results for anisotropic stochastic backgrounds. Analysis of the S5 data will begin in Fall 2008. Writing of the LSC results paper will begin shortly after the results have been obtained, and will probably continue for several months thereafter (including the review process).

d. Continuous

Teviet Creighton will continue his involvement within PULGroup, acting as internal reviewer for PULGroup analyses, search codes, and publications. He will maintain and improve as necessary all LSC analysis code for which he is responsible, including code within the LIGO Algorithm Library and the Einstein@Home validator. Creighton will also coordinate between LIGO and the Arecibo and Green Bank radio telescopes to obtain timing information on sources of interest for LIGO known-pulsar searches. The Pulsar Arecibo L-band Feed Array (PALFA) survey is expected to discover several hundred pulsars in our Galaxy. Many of these will have weak radio signals, such that only large telescopes such as Arecibo and Green Bank will be able to time them accurately. Currently timing is arranged and communicated to the LSC on an ad-hoc basis. Creighton plans to formalize a collaboration with these radio observatories, making use of existing remote control facilities at UTB to involve students in pulsar observations and timing.

e. Other Contributions
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 UTBRG 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

UTBRG 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.
Attachment OPS to the
Memorandum of Understanding LIGO-M050352-00
between the University of Texas at Brownsville Center for
Gravitational Wave Astronomy (UTBRG)
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-M050352-00 defines the role of the University of Texas at Brownsville Center for Gravitational Wave Astronomy (UTBRG) 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 UTBRG will participate in the initial LIGO detector research program in the following areas:

a. Detector Commissioning

   Not Applicable

b. Detector Characterization

   1) Soma Mukerjee will direct the following effort: The multidimensional classification pipeline has yielded results for the entire S5. The results are archived at: bagroup.phys.utb.edu

   The results include a daily analysis of the kleine Welle glitches from the gravitational wave as well other auxiliary and environmental channels as listed by the kleine Welle database. Typically, the classes of glitches seen as are determined, along with their statistical properties. The loudest triggers in each class are also
tracked down further (through detector-wide channel scan analysis) and linked to possible detector sub-systems from which they may have arisen.

Mukherjee and students (in consultation with Gabriela Gonzalez of LSU) propose to now apply the above analysis to explore specific scientific questions, i.e. to go through some selected Data Quality (DQ) flags in the page: [http://ldas-jobs.ligo.caltech.edu/~gonzalez/S5/segments/DQflagsinfo.html](http://ldas-jobs.ligo.caltech.edu/~gonzalez/S5/segments/DQflagsinfo.html) and look for further information regarding the possible source of these types of glitches. For example,

1) ASC_Overflow in all the three LIGO interferometers.

2) L1: BS_OPTLEVER_GAINPEAKING flags.

3) L1: TRAIN_LIKELY flags.

4) More understanding of the magnetometer glitches: [https://www.gravity.phy.syr.edu/dokuwiki/doku.php?id=veto:8508dataqualityflagforl1lveamagylglitches](https://www.gravity.phy.syr.edu/dokuwiki/doku.php?id=veto:8508dataqualityflagforl1lveamagylglitches)

5) H2: MMT3_OPTLEVER glitches

6) H1/H2: SLEDGEHAMMER and H1H2_SCATTERING flags.

In addition, inspiral candidates from low mass 1st year search as given in [http://www.lsc-group.phys.uwm.edu/ligovirgo/cbcnote/JointS5/080713162339LowMassCbcFollowupCandidatesoftheLowMass_CBC_search_1st_yr%2C_upperlimit_V99_rerun](http://www.lsc-group.phys.uwm.edu/ligovirgo/cbcnote/JointS5/080713162339LowMassCbcFollowupCandidatesoftheLowMass_CBC_search_1st_yr%2C_upperlimit_V99_rerun) may also be explored.

3) Tang and Lei, together with Mukherjee, will continue to work on the multidimensional classification pipeline for Detector Characterization. An indexing scheme will be built and scalable clustering algorithm will be designed and tested to facilitate the analysis of S5 data. Experimentation with simulated LIGO data generated from more sophisticated noise model (than that of white noise) will also be performed.

4) Mario Diaz and Roberto Grosso plan to develop a method to study the signals produced by the photodiodes and the influence on the signal registered at the main channels. The LIGO laser beam is splitted twice into four laser beams which are then measured and digitalized by four photodiodes and finally summed up to build the signal for the main channel. They think, that it is important to understand the behavior of the signals obtained from these channels. One possible application is the detection of dust particles which produces glitches in the signal at the GW channels and therefore can be used as a veto.

5) Additionally Mario Diaz and Roberto Grosso plan to further explore the performance of the method of mutual information analysis between channels using non-parametric estimation of the kernel density based on Parzen windows and other similar techniques. Should the method provide any improved performance over standard techniques like coherence and cross correlation studies results will
be presented at the regular telecons of the group.

c. Detector Operations

    Not Applicable

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 UTBRG 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

UTBRG 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

Mario C. Diaz  
Principal Investigator(s)  
UTBRG

David Reitze  
LSC Spokesperson
This Attachment OPT to the Memorandum of Understanding LIGO-M050352-00 defines the role of the University of Texas at Brownsville Center for Gravitational Wave Astronomy (UTBRG) as a Member of the LIGO Scientific Collaboration (LSC), and a member of the Optics Development Group (LDG). The period of performance for the activities in this Attachment is from August 15, 2008 - August 14, 2009.

1. Collaboration

The Optics Development Group (ODG) is the scientific collaboration for defining and developing instruments in optics for use in advanced subsystems for the initial LIGO interferometers, or in entirely new advanced interferometers. MOU Attachment OPT defines the roles and responsibilities of groups in this development group.

2. Participation

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

a. Optics Characterization

Malik Rakhmanov will work on the following issues:

1) Building and Characterization of the LIGO PSL Pre-Modecleaners
M.Rakhmanov will continue the fabrication of the new Pre-Modecleaners for the LIGO Hanford Observatory. After building them, he and the students will conduct various measurements to assess their performance.

2) Characterization of the LIGO PSL Reference Cavity
PSL provides laser frequency stabilization by locking the laser to an external Fabry-Perot cavity (Reference Cavity). These cavities have been operational for nearly ten years. Thus far, very limited effort has been made to understand their losses as a function of time, although several width measurements were made in the past. M. Rakhmanov and his students plan to carry out systematic measurements of the performance of the PSL Reference Cavities which are currently installed in LIGO. This will result in better understanding of the PSL Reference Cavities and the long-term stability of the laser. This work will be done in collaboration with the senior scientists at the Observatory sites, e.g. Dr. Savage and Dr. Kawabe.

b. Other Contributions

Modeling of the effect of electro-static charges in Advanced LIGO test masses
Currently there is a serious gap in our understanding of basic mechanisms for electro-static charging of LIGO test masses and no detailed model exists. These issues will be even more important in Advanced LIGO. M. Rakhmanov joined the LSC Charging Working Group and will work on modeling of the basic charging processes in test masses and will try to estimate their effect on the displacement noise of Advanced LIGO interferometers.

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 UTBRG 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

UTBRG 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 within the Optics Development Working Group of the LSC. 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

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Attachment OUT to the Memorandum of Understanding LIGO-M050352-00 between the University of Texas at Brownsville Center for Gravitational Wave Astronomy (UTBRG) 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-M050352-00 defines the role of the University of Texas at Brownsville Center for Gravitational Wave Astronomy (UTBRG) 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 UTBRG will participate in LDG in the following areas:

a. Educational Materials Developed

   *Not Applicable*

b. Other Contributions

   The CGWA will organize the 5th South Padre Island Summer School in Gravitational Wave Astronomy in the summer of 2009. Funding from NSF will be utilized to this extent. (Martha Casquette and Mario Diaz will coordinate this activity).
The CGWA will also organize the 5th 21st Century Astronomy Ambassadors Program for local area high school students (also supported by NSF). The purpose of this school is to educate High School students in the lower Rio Grande valley region in gravitational wave astronomy. (Adrienne Zermeno and Soma Mukherjee will coordinate this activity).

High school students from Astronomy Ambassadors summer program will be invited to participate in the year-long Border Land Astronomical Study and Research Society (BLASARS). The BLASARS will meet weekly in CGWA facilities during the school year and include discussion of science relevant to LIGO. (Teviet Creighton and Fredrick Jenet will serve as scientific advisors for this group).

The CGWA will give LIGO-related lectures at the local, regional and national scale. We will capitalize on the International Year of Astronomy 2009 to bring public awareness to gravitational wave astronomy. Adrienne Zermeno will develop a hands-on workshop/presentation, "Windows on the Universe" that will compare traditional forms of astronomical observations and then extends this to gravitational wave astronomy.

Adrienne Zermeno will continue to serve on the LSC outreach committee and contribute to the outreach objectives and activities as needed.

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 UTBRG 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

UTBRG 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
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Attachment Z to the Memorandum of Understanding LIGO-M050352-00 between the University of Texas at Brownsville Center for Gravitational Wave Astronomy (UTBRG) 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-M050352-00 lists the members of University of Texas at Brownsville Center for Gravitational Wave Astronomy (UTBRG) 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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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 appoint-
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**Undergraduate Students:**

**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:**

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Total FTE: 10.00

### Roles:

**Principal Investigators:**

Diaz, Mario

**Membership Point-Of-Contact:**

Diaz, Mario

**Group PIO/Press Coordinator:**

**Proxies:**

Benacquista, Matt
Diaz, Mario
Grosso, Roberto
Mohanty, Soumya
Mukherjee, Soma
Rakhmanov, Malik
Romano, Joseph
Hayama, Kazuhiro
Stone, Robert

### Approvals:

UTBRG Attachment Z

Generated: September 9, 2008

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LIGO Laboratory Director

Mario C. Diaz
Principal Investigator(s)
UTBRG

David Reitze
LSC Spokesperson