

Attachment DAT to the
Memorandum of Understanding (LIGO-M 050320 -00-M)
between the
Northwestern U. Gravitational Wave Astrophysics Group (NUGWAG)
and the
Laser Interferometer Gravitational Wave Observatory (LIGO)
August 15, 2006

This Attachment DAT to the Memorandum of Understanding LIGO-M 050320 -00-M defines the role of the **Northwestern U. Gravitational Wave Astrophysics 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 **NUGWAG** will participate in the analysis of initial LIGO data in the following areas:

a) Binary Inspirals

The NUGWAG will continue its activities in the theoretical astrophysics of binary compact objects in connection to efforts related to data analysis and interpretation upcoming results (upper limits or detections). Our group has shrunk in size compared to last year (graduate student C. Kim has graduated and is not being replaced), and the list that follows reflects this reductions making prioritized choices for where to focus our efforts. We will be working on 3 main areas:

- (1) Astrophysical and astronomical guidance needed in the development of data analysis pipelines;
- (2) Theoretical astrophysics calculations and predictions for binary inspiral source rates and properties needed for the development of data analysis and interpretation methods;
- (3) Review and advising services

Although the focus of this group's contributions to the LSC is astrophysics, we will also try to contribute to:

- (4) Development and testing of efficient data analysis methods; provided some resource sharing becomes possible.

More specifically:

(i) BNS, BBH, and other mass distributions:

Continuing his work on BNS mass distributions, O'Shaughnessy will provide and interpret the mass spectra expected from BH-BH and BH-NS mergers as seen by LIGO. Because a priori population synthesis simulations do not uniquely determine this spectra -- different plausible astrophysical assumptions produce dramatically different spectra -- he will also thoroughly discuss the uncertainties involved. He will discuss the impact of these spectra and their uncertainties on inspiral group results (i.e., astrophysical upper limits), as well as their impact on search-strategy priorities.

(ii) Galaxy catalog:

Kalogera and O'Shaughnessy will work on the completion of the Galaxy Catalog paper in preparation by the Inspirial group for submission to a refereed journal. They will also develop and propose to the group one or more schemes for how to extend the galaxy data to larger distances, so that the scheme is consistent with the pencil-beam galaxy surveys and accounts carefully for incompleteness in the galaxy samples.

(iii) Binary black holes in elliptical galaxies and new normalization:

Black holes produced in old galaxies could possibly dominate the present-day merger rate, yet produce little blue light and thus be significantly under-represented in the present normalization scheme for all inspiral searches. O'Shaughnessy and Kalogera will continue their modeling of elliptical galaxies and extend it to BBH, so that a revised, theoretically- and empirically-motivated normalization scheme is developed to relate the present-day merger rate inside LIGO's detection horizon to the star formation history contained within it.

(iv) Short GRBs:

O'Shaughnessy and Kalogera will continue their interpretation of the short GRB observations (numbers, host types, and host offsets) as the sample grows and the statistical analyses become more reliable; our goal is to be able to decipher their nature (are they really binary mergers? are they BH-NS or BNS?) by comparing their properties (rate as a function of redshift, host properties and offsets) to model predictions for different types of NS mergers.

(v) Merger Rates:

Kalogera will continue to provide empirical rate prediction updates as new binary pulsars are discovered. O'Shaughnessy and Kalogera will continue to provide and updated predictions for the expected merger rate density from binary evolution, taking into account the heterogeneity of star-forming conditions (e.g., elliptical and spiral galaxies); the observed star formation history of the universe; the observational constraints on the Milky Way; and if appropriate the observational limits suggested from short GRBs.

(vi) Mergers in clusters of low-mass BHs:

O'Shaughnessy working in conjunction with non-LSC collaborators at Northwestern and elsewhere (i.e., John Fregeau, Fred Rasio, Ryan O'Leary), the NUGWAG will evaluate the possibility that merging binary black holes could be produced copiously in young, ubiquitous, densely interacting star clusters, with dramatic implications for initial and advanced LIGO. He will provide the best possible astrophysical constraints on such a scenario, including dense cluster formation and interaction rates, velocity dispersions, and causes for cluster infant mortality.

(vii) Kalogera will continue to serve as a Reviewer of the Inspiral Group analysis, publications, and presentations and as a Member of the LIGO-PAC committee.

(viii) Kalogera will continue to provide advice and perform calculations promptly when requested on issues related to source detection expectations (signal-to-noise ratios, rates, etc) as a function of future detector noise characteristics.

Depending on time availability once astrophysics projects are progressing well, O'Shaughnessy intends to complete and publish both his preliminary analyses from the previous year: one of generalized ("spiky") templates and another of efficient high-dimensional search algorithms, such as genetic algorithms.

Last, depending on training provided by other LSC Inspiral members who focus on data analysis (see Resource Sharing), O'Shaughnessy would be interested in contributing to: (1) dynamic template-based vetoing schemes, following up on preliminary investigations presented by Chad Hanna; (2) the development of a BBH template bank based on results from numerical relativity and the astrophysically-motivated exploration of BBH mass ratios.

d) Continuous

Alberto Vecchio (U. Birmingham) will be spending a sabbatical year as a Visiting Scholar at Northwestern University working with NUGWAG. Our focus will be the astrophysics of continuous sources and more specifically: (i) the radio pulsar population characteristics and their distribution in pulsar physical properties as well as in space in the Milky Way in connection to all-sky multi-frequency searches; (ii) the low-mass X-ray binaries and their distribution in physical and frequency space.

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 **NUGWAG** 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) PROPOSAL BY NUGWAG: If the practical data analysis contributions proposed by NUGWAG above for inspiral searches become critical and required, then in conjunction with other LSC groups, an established mechanism for training in and updates on critical Inspiral and general LIGO software infrastructure would be developed, so that NUGWAG (and of course new members of other Inspiral groups) can be trained efficiently in existing codes, pipelines, and computational resources. Such a mechanism will facilitate the increase of human resources needed for the timely completion of the LIGO data analyses.

4. Coordination and Reporting -

NUGWAG 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 Saulson

LSC Spokesperson



Vassiliki Kalogera

Principal Investigator(s)

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