

**Attachment Number A to the
Memorandum of Understanding (LIGO-M990086-00-M)**

between the

Cornell University Relativity Group (CURG)

and the

Laser Interferometer Gravitational Wave Observatory (LIGO) Laboratory

August 15, 1999

This Attachment A to the Memorandum of Understanding LIGO-M990086-00-M covers the role of Cornell University Relativity Group (CURG) as a Charter Member of the LIGO Scientific Collaboration (LSC) and a member of the LIGO I Development Group (LIDG). The period of performance for the activities in this Attachment is from August 15, 1999 to February 15, 2000. This period may be modified by agreement to a revision of this Attachment A.

1. LIGO Scientific Collaboration - The LIGO Scientific Collaboration (Collaboration) 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 will ensure equal scientific opportunity for individual participants and institutions. It will organize the research, publications, and all other scientific activities. The Collaboration will report to the Laboratory 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 semi-annual reports to the Directorate and its PAC.
2. Charter Membership - An initial period for formation of the Charter group of institutions in the LIGO Scientific Collaboration commenced on March 1, 1997 and ended following the first full meeting of the Collaboration at which the Collaboration Council assumed its role.

Following the charter period, proposals will be evaluated and approved, as appropriate, through the Collaboration Council. An MOU with the LIGO Laboratory, including Attachments defining specific work, will be required for any participating institutions.

3. This document is an agreement between the Cornell University Relativity Group (CURG) and the LIGO Laboratory concerning the activities of CURG as a Collaborating Institution in the LIGO Scientific Collaboration (LSC) and in the LIGO I Development Group (LIDG), and as indicated in the Item No. 9 below.
4. LIGO I Development Group - The LIGO I Development Group is the scientific collaboration for implementing and exploiting the initial LIGO detector and physics through the initial science data run. Only groups who establish a specific Attachment approved by the LIGO Labo-

ratory, which defines a sufficient contribution and participation in LIGO I development, implementation or data analysis, will be part of this initial LIGO data run and science. Participation in future data runs and science that follow LIGO I will be possible for other groups, with guidelines to be determined by the LIGO Scientific Collaboration. It is anticipated that LIGO I data will only be made available through formal collaboration within the LIGO I Development Group during the first two years following its collection.

The general guideline for institutional membership in the LIGO I Development Group is that the contribution per collaborator of any new group to the design, construction, and implementation of the initial LIGO detector and to the first data run be comparable to that of the LIGO Laboratory scientists.

5. Report of Progress - CURG will provide a status report on its activities in support of LIGO every six months. The report will consist of: a) a summary status on research by topic as indicated Item No. 9 below, 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, b) updated List of Collaborators, and c) a plan of activities for the succeeding six-monthly period. The report will be due one month before the close of the period of performance under the Attachment in question.
6. Term of Membership - The Membership will be renewed every six months upon evidence of satisfactory performance of agreed upon commitments.

The coordinates of CURG members are included in Attachment Z to the Memorandum of Understanding LIGO-M990086-00-M.

7. Intellectual Property Rights - The rights to intellectual property developed under this Attachment will be subject to the National Science Foundation Grant Policy as indicated in Section 730, Intellectual Property.
8. LLAL Software Conventions - It is necessary that any delivered code conforms to the LLAL style as laid out in the LLAL specification T990030. This includes: 1) coding style, headers, etc.; 2) use of function calls, etc.; 3) organization of software in the directory structures indicated in the document; 4) inclusion of test codes and validation tests to enable users to verify successful installation of implementation; and 5) documentation and users manuals (html or pdf) to enable users to understand and adopt code.
9. During the period August 15, 1999 to February 15, 2000, the members of CURG who will work in the LIGO I Development Group are: Eanna Flanagan, Wolfgang Tichy (Cornell 3rd year graduate student), and Steve Drasco (Cornell 1st year graduate student). S. Drasco was an undergraduate SURF student with Roy Williams at Caltech and has extensive experience working with GRASP. The following are CURG's research plans and goals for this LSC period:

a. Data Analysis for Stochastic Gravitational Waves

- a.1 CURG is leading the development of robust algorithms for detecting stochastic gravitational waves in the presence of non-Gaussian detector noise.

The paper on deriving the optimal algorithm will be completed and submitted. J. Romano of UTBRG, and Bruce Allen and Jolien Creighton of UMWRG will collaborate.

E. Flanagan and S. Drasco will implement this algorithm and test the code on simulated data. This will be done in a close collaboration with J. Romano in his implementation of the standard cross-correlation algorithm.

- a.2 As a lower priority task, E. Flanagan, J. Romano, B. Allen and J. Creighton will continue theoretical research on optimized algorithms for detecting stochastic waves in the cases where the statistical properties of the background itself are non-Gaussian, as may be produced by the superposition of signals from cosmological supernovae, for example.

Note: The LLAL style software development conventions in Item No. 8, will apply to the above algorithm development and implementation.

b. Data Analysis for Burst Waves of Unknown Form (Blind Searches)

- b.1 CURG is leading the implementation and testing of the excess power search method.

The paper on deriving the excess power search method will be submitted. Warren Anderson, J. Creighton and Patrick Brady of UWMRG will collaborate.

P. Brady has written a preliminary implementation of the algorithm. The method will be tested on simulated data and on the November 1994 40-meter data run. A comparison will also be made with similar algorithms developed by Soumya Mohanty in the Detector Characterization LSC subgroup.

- b.2 E. Flanagan will continue his literature search in a wide variety of disciplines for possible blind search methods. The preliminary search indicates that most of the existing work on ARMA state-space models applies to a high signal-to-noise regime irrelevant to LIGO. Some Bayesian techniques have been explored by the VIRGO group and were presented in posters at the Amaldi meeting in July 1999. E. Flanagan will investigate if the VIRGO methods are promising enough to be pursued and implemented.

c. Exploration of Methods to Increase Accuracy of Post-Newtonian Templates

E. Flanagan and W. Tichy have a draft of a paper which gives evidence that numerically solving the post-Newtonian equations of motion does not give higher accuracy than analytically solving them within the post-Newtonian approximation as is currently done. This paper will be completed and submitted.

d. Research Related to LIGO Facilities-Light Scattering Noise

E. Flanagan will complete a draft of the paper giving the foundational theory underlying analyses of light scattering noise in the LIGO beam tubes. Kip Thorne of CaRT will collaborate. The draft will be turned over to K. Thorne.

10. During the period August 15, 1999 to February 15, 2000, the LIGO Laboratory will share as requested and appropriate the LIGO data of relevance to the research focus in Item No. 9 above.

11. The research effort pursuant to this Attachment A will be coordinated by E. Flanagan and Albert Lazzarini on behalf of CURG and LIGO Laboratory, respectively.

12. 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. 9, as indicated below. These resources will be in addition to the coordination effort and data to be made available per Item No. 10 above.

a) Provide accommodations for investigators in Item No. 9 above while on research assignment on LIGO at Caltech.

Approved:

Barry Barish
Barry Barish
LIGO Laboratory Director

Eanna Flanagan
Eanna Flanagan
CURG Principal Investigator

Sept 21, 1999
Date

Oct 12, 1999
Date