Attachment DAT to the

Memorandum of Understanding (LIGO-M 0970077 -00-M)

between the

GEO Project (GEO)

and the

Laser Interferometer Gravitational Wave Observatory (LIGO)

August 15, 2006

This Attachment DAT to the Memorandum of Understanding LIGO-M 0970077 -00-M defines the role of the GEO Project 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 GEO will participate in the analysis of initial LIGO data in the following areas:

a) Binary Inspirals

AEI - Golm (H. Takahashi, S. Babak), J. Whelan):

-- Search for GWs from precessing binaries of spinning combact object
: In the previuos search (S3), we use the simple template bank based on the strong modulation approximation. However, we are planing to use the new template bank developed in 2005 for S4 and S5 searches. We will start software injections to check the efficiency of the new bank for physical spinning waveforms. After that, we will apply the new template bank to the data of S4 and S5.
-- Review committee
-- Provide insight to groups testing performance of black hole searches on injected waveforms from numerical relativity.

Cardiff University (T. Cokelaer, B.S.Sathyaprakash, A. Dietz, G. Jones, A. Turner, C. Robinson, A. Sengupta, Chris Van Den Broeck)

- A new template bank for spinning black hole binary searches: development continues on the extended template bank that will be used for future searches for spinning black hole binaries. The new bank will allow us to search regions of parameter space unavailable to the current bank. The Cardiff group working with H. Takahashi modified H. Tagoshi's initial implementation of the bank code allowing it to be incorporated into LAL. The bank is now operational within the framework of LAL and is currently being examined through systematic injections of physically motivated spinning black hole binary waveforms. [in collaboration with H. Tagoshi and H. Takahashi]

- Spinning BBH analysis: using the new spinning BCV template bank, we will search for spinning waveforms within S5 data.

- New non spinning template bank: fully validate the hexagonal template bank and possibly improve it over the next few months.

- S3 spinning BBH: complete upper limit calculation and writing of paper on S3 search for spinning black holes using phenomenological templates. This will represent the first publication of search results for spinning BBH in gravitational wave data.

- S3/S4 non-spinning BBH search: complete the S3/S4 joint paper for LSC.

- Follow-up of the BBH candidates using physical template families

- Parameter dependent coincident analysis: complete the parameter dependant coincident code/tests, and (hopefully) use for S4 follow-up, and S5 EOB searches (Anand) In particular, we will focus attention on 3/multi IFO coincidences by March 2007.

- Parameter estimation: Investigation into parameter estimation using matched filter techniques from the merger part of the binary's waveform will be completed. The results will be submitted for publishing specifying the extent to which different gravitational wave detectors will be able to test the area increase and no hair theorem by February 2006.

- Coincidence with GRB: Analysis of coincidences between GRB's with inspiral triggers in S5 data, with the aim of presenting a final result for at least one GRB within the next year. If possible, incorporate Virgo data in this coincidence search which will increase the confidence of a gravitational wave signal. [Alexander Dietz]

- Joint analysis LIGO/VIRGO: Joint analysis of LIGO and Virgo data, especially in searching for spinning BBH, in the first half of 2007.

- S4 BBH search: Complete S5 (first Quarter) BBH search using time domain EOB templates. Comparison of the search against the search using SPA templates. We believe that the reach of EOB templates should be greater than that of the SPA templates. We also would like to use the new tools (trigScan clustering, parameter dependent tuning etc) to see their efficacy in this search, by August 2007.

- Amplitude corrected waveforms: In the past, parameter estimation studies have relied almost exclusively on the restricted post-Newtonian approximation. Reinstating amplitude corrections to the waveforms greatly increases the information carried, and we are studying to what extent parameter estimation would be improved by this. This research is already in an advanced stage and we should be ready to publish before the end of the year.

- The time-domain follow up of BCV searches (developed by Robinson) can, in principle, be used to construct a pipeline to carry out the Extended Hierarchical Search as outlined in the PhD thesis of Anand Sengupta. Some new functionality need to be developed for this purpose. It will be quite interesting to implement this for the searches employing spin modulation in the templates as the number of templates become exceedingly large in such cases and we aim to have such a functionality by August 2007.

b) Bursts

AEI - Hannover (P Ajith, M Hewitson, B Schutz, in collab. with S Bose at Washington State University)

- finalise S4 H1-H2 analysis and publish results- run two detector nullstream on H1-H2 S5 triggers
- continue development and study of two optimal snr methods for network analysis: the one being developed in AEI, Hannover and the one being developed by Sukanta Bose in Washington State University

University of Glasgow

- have the LIGO-GEO S4 coherent and non-coherent results reviewed and a final draft of a paper comparing the efficiencies o coherent and non-coherent analyses available
- continue work towards the search for gravitational waves associated with glitches in pulsar timing and development of Bayesian algorithm to identify the ringdown signatures of gravitational waves associated with pulsar glitches
- generate Waveburst triggers for LIGO-GEO S5 data set

c) Stochastic

AEI - Golm (J. Whelan)

-- S4 LLO-ALLEGRO Analysis
** Finish LIGO review process, release results, and publish paper. (Intend to present paper to LSC at August meeting.)

-- LSC-Virgo Stochastic Analysis
** Compare LIGO and Virgo codes on simulated stochastic background signal.
** Develop a joint strategy for searching for anisotropic astrophysical backgrounds.
** Develop a generalized search pipeline in collaboration between LIGO and Virgo groups. This will entail taking a step back from the pipeline as it's developed historically in LAL, LALApps and matapps, and applying the lessons we've learned from practical data analysis to make more efficient use of intermediate data products.
** Apply all-sky and directed searches to LIGO, GEO, and Virgo data on a timetable determined by data exchange agreements and instrumental sensitivities.

University of Birmingham (D Kasprzyk, V Re and A Vecchio)

- We will submit to PRD the paper describing the method used in the S2 coherent Sco X-1 analysis

- We will complete the S4 analysis for Sco X-1 using the S2 pipeline and carry out a similar analysis on S5 data

- We will validate the coherent analysis pipeline for msec accreting X-ray pulsars using S4 data and analyze the S5 data set with the aim of producing science results to be reported in an LSC paper

- We will complete the S4 incoherent analysis aimed at Sco X-1 with the aim of producing science results to be presented in an LSC paper

- We will extent the coherent analysis pipeline for LMXBs to handle signals that drift in frequency. We will also extend the pipeline to work on the coherent multi-interferometers F-statistic

- Building on the coherent analysis pipeline and the incoherent stack-slide analysis pipeline, we will implement a 2 stage hierarchical search algorithm with the aim of analyzing the first year of S5 data for Sco X-1 and the other LMXBs. At the end of the period covered by this MoU we expect to have preliminary upper-limits for those sources.

d) Continous

AEI - Golm (I. Gholami, B. Krishnan, A. Krolak, B. Machenschalk, M.A. Papa, R. Prix)

-- Finish developing the hierarchical search and optimize it to run on Einstein@Home.

-- Upper Limit search of known pulsars for single IFO and multi using S5 data and the F-stat code.

-- Area search in some specific region in the sky using the S5 data and the F-stat code.

-- Derive an explicitly flat approximation of the pulsar-metric, and use this to build 'optimal' covering-grids with the already-implemented lattice-covering routines.

-- Continue followup-study on J0537-6910 using multi-IFO Fstat

-- Further speed up the current code (currently get another 40%)

-- Add some more exotic platforms (rather for fun than for actual computing power, but fun is important for participants)

-- Implementation of a faster Fstat computing algortihm by using the FFT:
* Construction of a constrained grid in the parameter space.
* Resampling of the time series to barycentric time

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University of Glasgow

- Complete the targeted pulsar search in S5 data, presenting estimates/upper limits in the gravitational wave strain from ~100 known radio pulsars together with diagnostic information on the validity of these results.

- Develop a small-area, F-statistic-based Bayesian search in the immediate vicinity of the targeted parameters to check for minor discrepancies between the EM and GW target parameters.

- Generate a final report on the use of MCMC methods pulsar parameter estimation and searches.

- Include evidence values in all statements of upper limits.

e) Other Contributions

Support and management:
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AEI - Golm (C. Aulbert, S. Grunewald, M.A.Papa)

Continue in:

* 24/7 Management and support of LSC users on Merlin (I and II)
* GEO data management and publishing
* European LIGO data replicator
* Evaluation of Merlin successor
* Writing "Ausschreibung" for new cluster
* Development of benchmarking code for bidding process

* GEO data analysis coordination

AEI - Hannover

Continue data characterization work as per commissioning needs.

University of Birmingham (D Stops and A Vecchio)):

- We will continue the sys admin of Tsunami and make it available to the LSC for production analysis
- We will continue to serve on the LSCComp Committee and the GEO-DA Committee

University of Cardiff

- Maintenance of the coma and explorer clusters.
- Procurement of a new cluster dedicated to search for spinning black hole binaries. The planning for this has already begun; we are aiming to have the cluster ready for searches by August 2007.
- Keep up-to-date S5 data on coma cluster.

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 **GEO** 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) Not Applicable

4. Coordination and Reporting -

GEO 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

2007.05.17 20:59:39 +02'00'

Karsten Danzmann

Principal Investigator(s)

GEO Project