LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
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LIGO Engineering Run: Periodic Gravitational Wave Flux Upper Limit Analysis Proposal

LIGO Science Collaboration Periodic Upper Limit Analysis Working Group (page 5)

Distribution of this draft:

LIGO Laboratory and LIGO Science Collaboration

This is a working document.
All data should be considered preliminary.

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1 ABSTRACT

We propose to conduct a preliminary search for periodic gravitational waves using data from the LIGO Hanford 2 km and 4 km and Livingston 4 km interferometers, the GEO600 interferometer, and perhaps collaborating acoustic gravitational wave detectors which are active during the scheduled Fall 2001 LIGO Engineering Data Run. The principal objectives of this search are:

- to discover or establish new upper limits on sources of continuous periodic gravitational radiation flux, from electromagnetically known objects and classes of objects as well as from unmodeled sources;
- to discover and mitigate detector background artifacts which may limit search sensitivity;
- to exercise and test the LIGO Data Analysis System (LDAS) infrastructure, and;
- to build and test software components of the LIGO Analysis Library (LAL).

We will pursue these objectives with the constraint of being fully prepared in the required time frame and without a substantial increase in available resources. As a result, some investigations may not yet exploit the full sensitivity, coverage or refinement available in principle. Nevertheless, it is fair to expect that even a suboptimal analysis of data from these newly commissioned instruments of unprecedented sensitivity will substantially advance our state of knowledge and will pave the way for more ambitious searches in the future.

2 PROPOSED APPROACH

We propose to apply the following analyses to all detector data sets which are viable during the appointed engineering data run, to whatever extent this proves feasible. Each task description lists a spokesperson who has offered to organize and coordinate software and hardware preparations for the analysis, and who will report progress to the group at regular intervals.

While members of this group will continue to contribute to global preparatory activities (commissioning the detectors, building LDAS, and generic data conditioning functions such as line removal and calibration, to name a few) we discuss here only those activities specific to the hunt for periodic signals. Stuart Anderson (LIGO Laboratory/Caltech) and Michael Zucker (LIGO Laboratory/MIT) co-chair this analysis team and report jointly to the LIGO Science Collaboration Spokesperson and the LIGO Laboratory Director.

All software generated under this proposal will conform to the standards of the LIGO Algorithm Library (LAL). Analysis products and results will be made accessible through LDAS using that system’s standard query and retrieval tools.

2.1 Infrastructure functions

The following functions enable subsequent analyses and provide future infrastructure. Results will be the subject of technical report(s) to the Collaboration; some may also result in method publications.

2.1.1 Characterization of periodic detector artifacts

We will assemble a database comprising known local periodic artifacts in the strain and selected auxiliary channels for each instrument. This is currently in progress for the LHO 2 km interferometer. Comparable databases for the LHO 4km and LLO machine and (if possible) GEO600, as well as tools to install and access these data in the LDAS system, remain to be developed. This catalog will be used by subsequent analysts to determine “deadbands” and reject known local disturbances.

Keith Riles (Michigan) has responsibility for comparable activities in connection with the LSC Detector Characterization Working Group, and has agreed to spearhead this task for the present effort as well.

2.1.2 Earth Doppler/GR correction & AM antenna pattern removal

Mechanisms will be provided to correct time series for amplitude and phase modulation due to the Earth’s acceleration and general relativistic effects, as well as to synthesize test signals which mimic physical extrasolar sources.

Curt Cutler (GEO/AEI) will lead on removal of Doppler and GR phase perturbations; Keith Riles (Michigan) will lead on removal of amplitude modulation due to rotating detector antenna patterns.

2.1.3 Detection efficiency analysis

Assuming there are no unequivocal detections, setting a useful upper limit on GR flux depends on knowing the probability that a real signal would have been missed by each attempted analysis, as a function of that signal’s amplitude. We propose to approach this question by a combination of direct calculation and Monte Carlo simulation, using test signals introduced in early analysis as well as in the detector itself (see below). Because many of the proposed searches are in fact limited by computational resources, a traditional “brute force” Monte Carlo approach may not be efficient or even feasible; we will investigate methods to extend to the full parameter space efficiency results obtained for limited parameter samplings.

Patrick Brady (UWM) will report on this task.

2.1.4 Test signal injection

To support the Monte Carlo efficiency analysis, and also to provide end-to-end test of the analysis system with the detector, artificial test signals will be injected into each detector electromechanically by a semi-autonomous system unaffiliated with the data analysis machinery. Some portion of these signal injections will be performed in a blind fashion (with respect to starting time, barycentric signal frequency, direction, amplitude and other search parameters) to reduce the possibility of experimenter bias.

Michael Zucker (LIGO Laboratory/MIT) will report on this function, with Harry Ward (GEO/Glasgow) serving as liaison for the GEO600 machine.

2.2 Astrophysics analysis products

Each of these analyses is expected to result in a Collaboration technical report and astrophysics publication.

2.2.1 Short-transform all sky search

The transforms developed for task 2.1.1 and/or the preparatory initial transforms for task 2.2.3 below permit a straightforward search for lines which are correlated in two or more detectors and yet cannot be ruled out as local interference. This search will be confined to data vectors short enough to be unaffected by Earth Doppler or antenna pattern effects (order of tens of minutes) and thus addresses the whole sky, albeit at limited sensitivity. Additional binary cuts based on detection in successive epochs and physically plausible frequency evolution between epochs may also be applied.

The spokesperson for this task will be assigned at the March, 2001 LSC meeting.

2.2.2 Known radio pulsar search

The radio pulse phase evolution for some number (order 10) of known, nearby fast pulsars will be used to perform a direct coherent search for gravitational waves from these objects, using folded periodogram and/or demodulation methods. The full time series spanning the engineering run will be used if possible.

Stuart Anderson (LIGO Lab/Caltech) will report on this task.

2.2.3 Semi-coherent wide area search with spindown

A prototype implementation of the Hough transform semi-coherent area search algorithm will be employed to exploit the full length of the engineering run (approximately one week). Certain specific sky patches (e.g., near the galactic center) may be selected to initially reduce the computational burden. A limited search over source spindown (first period derivative) is also proposed to allow detection of young objects (less than a few My in age) over this timespan. Parameter space gridding and coverage functions will be developed to insure adequate coverage without redundancy. Depending on locked stretch durations attained by the various interferometers, bridging of data dropouts and turn-on transients will also have to be addressed to some degree.

Teviet Creighton (UWM) will report on the search parameter space gridding activity; Maria Alessandra Papa (GEO/AEI) will report on the Hough transform detection code and other components.

3 SCHEDULE AND DELIVERABLES

We expect task 2.1.1 (local line catalogs) to be substantially ready by the end of the scheduled early summer (June '01) LIGO engineering run, and will test prototypes of code developed under tasks 2.1.2 (Doppler/AM removal), 2.1.4 (test signal injection), 2.2.1 (short transform search), and 2.2.2 (radio pulsar search) on "unofficial" data sets obtained from this run. This will leave some time for iteration of codes and data flow before the actual "Upper Limit" data run in September. We also expect to have the parameter space gridding and basic Hough transform engine components of the 2.2.3 (semi-coherent wide area search) completed by this time; the spindown parameter search function, method for bridging data gaps, and criteria for selecting or rejecting individual subtransforms in the global analysis of 2.2.3 will probably not be ready until about the time of the September run.

We will report progress on each task in Section 2 at the Summer 2001 LIGO Science Collaboration meeting. Active interventions in the Fall Engineering Run (e.g., signal injection & calibration) will be coordinated in advance with the acting Commissioning Directors at each detector site. A technical report detailing the methods and results of each analysis task or group of tasks will be submitted to the Collaboration, and the related publications prepared for submission, in the January 2002 time frame (assuming the currently envisioned detector schedule is realized).

4 Periodic Upper Limit Group Membership

(For updated list, see `http://www.lsc-group.phys.uwm.edu/pulgroup/`)

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