

LSC Six-Month Progress Report

Organization Carleton College Relativity Group (CCRG)

Report Date February 15, 2004

Attachment A / LIGO I

We have been extremely busy with LIGO related research. Carleton College is an active member of the LIGO Scientific Collaboration (LSC), and our research is coordinated with the LIGO Laboratory and the full LSC through Memoranda of Understanding. A description of our activities is presented below.

1. Demonstration of the Markov Chain Monte Carlo (MCMC) technique for parameter estimation

a) Pulsar Signals

Prof. Nelson Christensen is continuing to work on the development of a Metropolis-Hastings algorithm (a MCMC technique) in order to detect and estimate parameters for gravity wave signals from periodic sources (such as pulsars). This work is being done in collaboration with Graham Woan, John Veitch and Rejean Dupuis of the University of Glasgow, and statisticians Renate Meyer and Richard Umstaetter of the University of Auckland. Meyer and Umstaetter are working only on the development of MCMC techniques, which is where their interest lies; they never work with LIGO data. The continuous waves upper limit group recently conducted a time-domain signal search based on a Bayesian approach. This is a search for a signal from a pulsar where the source location and pulsar rotation frequency are known. We have modified this approach in order to estimate six parameters; gravity wave amplitude, polarization, pulsar rotation inclination angle, phase, uncertainty in the signal frequency, and the frequency derivative df/dt . This method is called 'delayed rejection in reversible jump Metropolis-Hastings.' The code has been written, tested, and now being applied to S3 data. The advantage of MCMC methods is that they are efficient for large parameter number. The initial results for this 6-parameter search were presented at GWDAW-03 in December of 2003. Further results will be presented at the March 2004 LSC meeting. Results of the 6-parameter code, applied to S2 injected signals, are posted at

<http://physics.carleton.edu/Research/ligo/S2injectCW.html>

John Veitch is a new graduate student at the University of Glasgow, under the supervision of Dr. Graham Woan. Veitch's primary research activity is in applying the 6-parameter MCMC to LIGO signals. The MCMC - continuous wave team consists of the Glasgow group and Christensen. This team is working in unison in applying this MCMC technique. We have found that the MCMC is proving to be an important complement with the CW time domain search.

When we have finalized the development and optimization of this 6 parameter study we intend to apply it to LIGO data in order to try and find a signal from SN1987A. There could possibly be a pulsar at that location, but the frequency of its spin-down parameters is uncertain at this time.

b) Binary Inspiral Parameter Estimation

Christensen, along with Carleton students Adam Libson and Mark Knight, continue to work on the application of a Metropolis-Hastings program for binary inspiral signal detection and parameter estimation. Our binary inspiral MCMC routine operates within the LALAPPS system. We are currently running this program on hardware injected signals in the S3 data. The results of S2 injected signals can be seen at <http://www.lsc-group.phys.uwm.edu/iulgroup//investigations/s2index.html>

This program can find events and estimate the signal parameters in the simplest sense; masses of the two binary stars, amplitude of the signal. The work is presently being extended in order to search for signals created by binary black hole inspiral events.

2. Detector Characterization for LIGO S2 and S3 runs

Christensen is part of a LIGO detector characterization investigation led by Prof. Keith Riles (Dept. of Physics, University of Michigan). Christensen is leading the group that is investigating correlations between LIGO interferometer signals and signals from environmental monitors. Carleton students Dave Steussy and Sarah Vigeland are also contributing to this effort.

The Carleton team is examining data from the LIGO S2 and S3 scientific runs. We have computed numerous correlations between interferometer control channels and environmental monitors in order to decipher sources of noise. Numerous correlations were observed, as well as a few places where LIGO noise was coherently coupled at differing frequencies. For the S3 data we are concentrating on acoustic coupling into the gravity wave signal channel. Initial results for LLO are posted at

<http://physics.carleton.edu/Research/ligo/S3LLO/S3-LLO-Corr.html>

while results for LHO are posted at

<http://physics.carleton.edu/Research/ligo/H1mics/S3H1MicsCorr.html>

The LHO signal (AS_Q) - microphone correlations were compared with the H1:LSC-AS_Q - H2:LSC-AS_Q coherence calculated by the stochastic group over the entire S2 data set. These results were also posted at

<http://physics.carleton.edu/Research/ligo/H1mics/S3H1MicsCorr.html>

In S3 the acoustic coupling was greatly reduced. These results are also posted at the web site above.

We have also calculated higher order statistical correlations, namely the bicoherence. Results of the correlation analysis were presented during detector characterization group telecons, with the results posted on the web: see S2 Correlations at <http://physics.carleton.edu/Research/ligo/7-10/S2noiseb.html>

We have also investigated intersite correlations between channels from LHO and LLO. The results of examinations of S2 data can be found at <http://physics.carleton.edu/Research/ligo/S2Corr.html>

3. Staffing shifts for LIGO Scientific Runs

Christensen worked shifts as an expert scientific monitor during S3 at LLO. In addition, Carleton students Adam Libson and Dave Steussy worked as trainee monitors. It is likely at least one of these students will go on in graduate school to study gravity wave detection.

4. Inspiral Upper Limit Group

Christensen is an active member in the LSC's effort dedicated to using LIGO data to set upper limits on astrophysical sources. One of the tasks is in the Inspiral Upper Limit (IUL) Group, and especially the IUL Detector Characterization Sub-Group. Christensen spends much time contributing to this detector characterization and veto development sub-group, and is working with many other LSC members on this effort. Carleton undergraduates Dave Steussy and Sarah Vigeland have contributed significantly to this research task as well. The sub-group has conducted extensive studies on numerous environmental monitor channels in order to quantify when environmental events influence the quality of the interferometer output data. We developed code in order to present veto flags for the data. We spent significant amounts of time analyzing data from various interferometer control signals in order to develop potential veto flags for spurious inspiral-like events in the AS_Q data. Calculations and plots were made to display the veto efficiency versus dead-time for potential vetoes. The results were presented to the IUL group, and also posted on the web:

S2 vetoes

<http://physics.carleton.edu/Faculty/Nelson/S2Veto/S2Veto.html>

<http://physics.carleton.edu/Research/ligo/7-10/S2noiseb.html>

and

<http://physics.carleton.edu/Research/ligo/S2veto/S2veto.html>

Our inspiral veto study results were also presented at GWDAW 2003.