LSC Six-Month Progress Report

Organization Carleton College Relativity Group (CCRG)
Report Date August 15, 2003

LIGO I / Attachment A

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 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 are modifying this approach in order to estimate all four parameters; gravity wave amplitude, polarization, pulsar rotation inclination angle and phase. The code has been written and presently being tested. The advantage of a MCMC method is that they are efficient for large parameter number. The results for this four parameter have been posted at
http://physics.carleton.edu/Faculty/Nelson/MCMCpulsar/MCMCpulsar.htm

This technique has been applied to injected signals in the S2 data. The signal was found and the parameters successfully estimated. These results can be found at
http://physics.carleton.edu/Research/ligo/S2injectCW.html

Do to the success of these initial results we expanded the technique to attempt to identify signals from sources where the location is known but the signal frequency is not (such as SN1987A). We have demonstrated the ability for the MCMC technique to account for uncertainty in the frequency of the signal (as well as the four other parameters mentioned above). The uncertainty in the frequency was 1/60 Hz. The technique could easily be expanded to a 5 Hz range by running the code on a 300 node Beowulf cluster. The results of the 5 parameter study can be found at
http://physics.carleton.edu/Faculty/Nelson/MCMCpulsarfreq/MCMCpulsarFreq.html

We are currently working on the inclusion of a 6th parameter, dfdot, the first derivative of the signal frequency, or the spin-down term. We have made good progress in this study by employing a modification of the MH algorithm; this method is called 'delayed rejection in reversible jump Metropolis-Hastings.' At this time we have not optimized the efficiency of this routine. This is a work in progress.

When we have finalized the development and optimization of this 6 parameter study we intend to apply it to S2 data in order to try and find a signal from SN1987A. There could possibly be a pulsar at that location, but the frequency its spin-down parameter are uncertain at this time.

b) Binary Inspiral Parameter Estimation
Nelson Christensen and Carleton student Adam Libson are continuing to work on the development of a Metropolis-Hastings program for binary inspiral signal detection and parameter estimation. During the summer of 2003 we have modified our program in order to take LIGO data and search for a gravity wave signal from the inspiral of a pair of compact objects (neutron stars, black holes). We have developed a MCMC routine that can operate within the LALAPPS system. We are currently running this program on hardware injected signals in the S2 data. 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 also being extended in order to search for signals created by binary black hole inspiral events.

2. Detector Characterization for LIGO S1 run and S2 Preparation.

Nelson Christensen is part of a LIGO detector characterization investigation led by Prof. Keith Riles (Dept. of Physics, University of Michigan). Nelson Christensen is part of the group that is investigating correlations between LIGO interferometer signals and signals from environmental monitors. Carleton student Dave Steussy is also making significant contributions to this effort.

The Carleton team examined data from the LIGO S2 scientific run. We 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 couple at differing frequencies. We also calculated higher order 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

3. Staffing shifts for LIGO Scientific Runs

Nelson Christensen worked shifts during S2 at LLO. He will also be staffing shifts during S3.

4. Inspiral Upper Limit Group

Nelson 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. Nelson 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 undergraduate Dave Steussy has 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 verses dead-time for potential vetoes. The results were presented to the IUL group, and also posted on the web:
S1 vetoes
http://physics.carleton.edu/Faculty/Nelson/S2Veto/S2Veto.html
and
http://physics.carleton.edu/Research/ligo/7-10/S2noiseb.html