LSC Six-Month Progress Report

Organization Carleton College Relativity Group (CCRG) **LIGO-M010245-00-M**

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Attachment A - LIGO I

Participation Nelson Christensen - 100%

Data Analysis, Statistics and Parameter Estimation for Binary Inspiral Searches

Nelson Christensen worked with Dr. Renate Meyer (Dept. of Statistics, University of Auckland) on the development and testing of a Gibb's sampler, Markov chain Monte Carlo (MCMC) program. This program was designed to take LIGO-like data and search for a gravity wave signal from the inspiral of a pair of compact objects (neutron stars, black holes). The signal templates used were 2.5 post-Newtonian order, and involved five parameters. In our recent publication (Christensen and Meyer, Using Markov chain Monte Carlo methods for estimating parameters with gravitational radiation data, Physical Review D, Vol. 64, p. 022001 (2001)) we demonstrated that the proposed Markov chain Monte Carlo (MCMC) method for estimating parameters from LIGO observed binary inspiral events holds great promise.

An undergraduate and myself are currently implementing this method within the LIGO Analysis Library (LAL) software system. This technique may be the only realistic method for estimating parameters when multiple interferometer data is used (source location and wave polarization would be additional parameters), or when effects such as the spin of the compact object are included in the inspiral event template.

Preliminary studies have demonstrated the ability of this technique to estimate more parameters. We have included the spin angular momentum of the binary objects in the signal and templates. These studies are continuing.

Presently also working with Sukanta Bose (AEI) on using the MCMC techniques to handle parameter estimation for inspiral events detected by multiple interferometer systems. The position of the source on the sky would add more parameters to estimate. This programming is ongoing, and is being done with the LAL software system.

Detector Characterization for LIGO Engineering runs

Nelson Christensen was part of a LIGO detector characterization investigation led by Prof. Keith Riles (Dept. of Physics, University of Michigan). Nelson Christensen was the leader of a sub-group investigating correlations between LIGO interferometer signals and signals from environmental monitors. Tom Robinson, a Carleton College undergraduate, and Assoc. Prof. Adrian Ottewill (University College Dublin) also collaborated on this work.

The sub-group initially examined data from the LIGO (Hanford) E2 engineering run. We computed numerous correlations between interferometer control channels and environmental monitors in order to decipher sources of noise. In addition, we also used higher order statistics, such as the bicoherence, in order to look for non-linear up-conversion of noise in the interferometer output. Numerous correlations were observed, as well as a few places where LIGO noise was coherently couple at differing frequencies. A LIGO technical report was written (E2 Correlations, LIGO Technical Document LIGO-T010017-00-Z, N. Christensen, T. Robinson, A. Ottewill), and Nelson Christensen presented the results in a talk at the LIGO Scientific Collaboration (LSC) meeting in Baton Rouge in March 2001.

The group has continued to study data from the E3, E4 and E5 runs. Subsequent results were presented at the LSC meeting in Hanford in August of 2001.

Our group (now expanded to also include Steve Penn, Syracuse University) will continue to analyze data and search for noise correlations in further LIGO engineering run data. We are presently examining data from the E5 run. Nelson Christensen will continue as the leader of this sub-group.

Inspiral Upper Limit Group

Nelson Christensen is an active member in two of the LSC's groups dedicated to using LIGO data to set upper limits on astrophysical sources. One of these is the Inspiral Upper Limit (IUL) Group. Christensen is concentrating his efforts in two specific sub-group activities.

a) Detector Characterization Sub-Group

Nelson Christensen is the leader of the Detector Characterization Sub-Group, and is working with other LSC members on this effort. The sub-group is conducted extensive studies on numerous environmental monitor channels in order to quantify when environmental events influence the quality of the interferometer output data. We are charged with developing code in order to present veto flags for the data. This effort has been going since December 2000, with the intent to have the code completed for the LIGO engineering/scientific run (E6) in December 2001. Nelson Christensen presented a talk on this work at the LSC meetings in Baton Rouge, March 2001, and Hanford, August 2001.

As part of the IUL detector characterization effort a study was conducted on detecting chirp-like events in environmental channels. The goal is to see if chirp-like events in the environment could influence the interferometer. This work was done with A. Rizzi of LLO. Rizzi used his GRASP chirp code on an accelerometer channel, as well as the output from the LLO interferometer. The data was 900s from the E4 run. Christensen used CorrMon (developed by A. Ottewill), a correlation DMT tool on the same stretch of data. Christensen also used NonMon (developed by J. Fenton, Reed College) to look for correlated glitches in the two channels. In the 900 s of data we were able to observe 4 chirps in the accelerometer, which also registered as correlated noise with CorrMon and correlated glitches with NonMon. This PEM - chirp research is on-going, and also now includes the efforts of Gregg Harry at MIT. We are developing an LDAS version of a chirp-finding code that will be optimized for finding events in environmental channels. We intend to implement this code for the E6 run.

b) Multiple Interferometers and Statistics Sub-Groups

Nelson Christensen is also a member of the Multiple Interferometers and Statistics Sub-Groups. His primary responsibility will be to develop a Metropolis-Hastings MCMC code in order to estimate parameters and produce summary statistics for events recorded by the binary inspiral template search. This will be the natural extension of the MCMC effort already conducted. This work commenced in February of 2001, and the code is under development at present. Carleton College undergraduate Tom Robinson is also working on this effort, and it will be his primary research activity for the summer of 2001. We are also working on the development of a Metropolis-Hastings code for parameter estimation when inspiral signals are detected by multiple interferometers. All programming is currently done with the LAL software system.

Stochastic Background Upper Limit Group

Nelson Christensen is a member of the LSC's Stochastic Background Upper Limit Group. Christensen is part of the detector characterization effort, with the goal being to identify possible sources of correlated noise between the two LIGO detector sites. This correlation effort makes use of correlation code already

being used in the other correlation studies. Nelson Christensen is working with Peter Fritschel (M.I.T.) and Mike Landry (LIGO-Hanford) on this effort. We are concentrating our search on seismic, magnetic and voltage line noise.

There is much overlap in interest between the Keith Rile's detector characterization group and the Upper Limit detector characterization sub-groups. As such, Nelson Christensen is working in close consultation with a number of LSC members on detector characterization.

Advanced Data Analysis

Data Analysis, Statistics and Parameter Estimation for Binary Inspiral Searches

An initial study of using Markov chain Monte Carlo (MCMC) methods for parameter estimation for binary inspiral searches was completed. The results of this study were written up, and distributed to various LSC members (including LIGO staff). The paper, entitled -Using Markov chain Monte Carlo methods for estimating parameters with gravitational radiation data- (Nelson Christensen and Renate Meyer, 2001) can be obtained on the Los Alamos pre-print server, gr-qc/0010052. Gravity wave signals to 2.5 post-Newtonian order were simulated, and added to simulated noise. The MCMC routine could identify the five signal parameters, and probability distributions were generated. We studied the accuracy of the parameter estimation as the signal-to-noise ratio was varied.

In addition, B.S. Sathyaprakash of Cardiff, generated mystery signals, and the MCMC was able to find the parameter values and generate probability distribution functions.

Currently we are working on using the MCMC for binary inspirals where the two compact objects have angular momentum (spin). This results in two angular momentum parameters. The seven parameter code is currently being tested. This is again a 2.5 post-Newtonian order study. Preliminary tests show successful performance.

E2 Engineering Run Analysis

Nelson Christensen is coordinating the effort to look for correlated noise in the various interferometer and environmental channels from the E2 engineering run. This work is being done in conjunction with Adrian Ottewill of University College, Dublin (Ireland). DMT code has been developed and used for this study. Preliminary results can be found on the web http://physics.carleton.edu/Faculty/res67/E2corr.htm and a report will be presented at the LSC meeting in March 2001 at Livingston.

Stochastic Background Upper-Limit Group

Nelson Christensen is a member of the LSC group that is charged with trying to use the LIGO detectors to set an upper limit for the strength of the stochastic gravity wave background.

Carleton group is utilizing their experience from the E2 correlation study, and is actively participating in the Estimation of cross-correlated noise- and -Line removal- sub-groups.

Inspiralling Compact Binary Upper-Limit Group

Nelson Christensen is a member of the LSC group that is charged with trying to use the LIGO detectors to set an upper limit for the event rates of coalescing binary systems.

Carleton group is a member of the following sub-groups: detector characterization, multiple interferometers and statistics.

Nelson Christensen is chairing the detector characterization sub-group. We will develop code to understand the interferometer performance and to provide vetos for possible events.

Carleton group is using their statistical experience in conjunction with the multiple interferometer and statistics sub-group. Carleton group is developing LAL (C) code for evaluating errors in parameter estimation. MCMC routine will be implemented for this task.