

LSC Six-Month Progress Report

LIGO-M020166-00-M

Organization Carleton College Relativity Group (CCRG)

Report Date February 15, 2002

Attachment A - LIGO I

Participation Nelson Christensen - 100%

Data Analysis

- 1) Demonstration of the Markov chain Monte Carlo (MCMC) technique for binary inspiral parameter estimation.

Prof. Nelson Christensen worked with Dr. Renate Meyer (Dept. of Statistics, University of Auckland) on the development and testing of a Gibb's sampler 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. We demonstrated that the MCMC technique did in-fact work. In addition to finding the parameter values for the signal we were able to also produce summary statistics, including probability distribution functions for the parameters. Our final program is a combination of a Gibb's sampler and another technique, simulated annealing. The results of this research were published (Using Markov chain Monte Carlo methods for estimating parameters with gravitational radiation data, Nelson Christensen and Renate Meyer, Physical Review D, Vol. 64, 022001, 2001). This Gibb's sampler program used existing MCMC software that could not be incorporated into LIGO's data analysis and computing pipeline, but was a successful proof of principal.

We have subsequently shifted our efforts to developing a MCMC routine that would operate with the LIGO-LSC Algorithm Library (LAL). The program is once again for binary inspiral parameter estimation, but this time it utilizes a Metropolis-Hastings algorithm. The core of the inspiral event program comes from the LAL program, findchirp, developed by Duncan Brown and Prof. Patrick Brady (University of Wisconsin, Milwaukee). We have written our routine so that it will call findchirp. This is important because as new and higher order templates are developed then they will automatically be incorporated and used through findchirp. Carleton undergraduate, Tom Robinson, did the bulk of the programming for this code over the 2001 summer and through the 2001-2002 academic year at Carleton College. This work has also been, and will continue to be done in conjunction with Carleton College undergraduate Adam Libson, who started work on the project in January, 2002, and will be employed as an undergraduate research assistant through the summer of 2002. A substantial amount of effort went into setting up the LAL system at Carleton, and then modifying our routines so that they would run in that environment. The program does run, and can be used to find events and estimate the signal parameters (masses of the two binary stars, amplitude of the signal). We continue to work on the code in order to optimize and quantify its performance and efficiency. Our aim and goal is to release the code into the LAL system during the summer of 2002, and write up the results for publication. Finally, we will be working with Dr. Massimo Tinto (of Caltech and JPL) in order to investigate the efficiency of the Metropolis-Hastings routine as a search tool for binary inspiral events.

Detector Characterization

- 2) Detector Characterization for LIGO E7 Engineering run.

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

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investigating correlations between LIGO interferometer signals and signals from environmental monitors. Russ Bainer (Carleton undergraduate), and Prof. Adrian Ottewill (University College Dublin), Dr. Steve Penn (Syracuse University) and Dr. Dennis Ugolini (Caltech) also collaborated on this work.

The sub-group examined data from the LIGO E7 engineering run. We computed numerous correlation between interferometer control channels and environmental monitors in order to decipher sources of noise. In addition, we also used higher order statistics, namely 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 (E7 Correlations, LIGO Technical Document, N. Christensen, R. Bainer, A. Ottewill, S. Penn and D. Ugolini), and Nelson Christensen presented the results in a talk at the LIGO Scientific Collaboration (LSC) meeting in Baton Rouge in March 2002. Our group will continue to scrutinize the LIGO data for deleterious noise correlations. Nelson Christensen will remain as the leader of this sub-group.

3) 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) IUL Detector Characterization Sub-Group

Nelson Christensen is the leader of the Detector Characterization Sub-Group, and is working with seven other LSC members on this effort. The sub-group 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. The E7 engineering run acquired much data over the span of December, 2001 through January, 2002. The IUL group is presently (as of March 2002) working furiously in order to complete an analysis of the data, derive upper limits to inspiral event rates, and publish the results. Christensen is contributing to this effort by creating vetoes that were determined through research on the playground part of the E7 data. Nelson Christensen presented talks on the veto research at the LSC meetings in Hanford (August 2001) and Baton Rouge (March 2002).

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 work is explained above. The extension of the Metropolis-Hastings code to accommodate data from multiple interferometers, and hence to estimate additional parameter values (source location on the sky, gravity wave polarization) is a task planned for the summer of 2002. We are collaborating with Prof. Sukanta Bose (Washington State University) on the multiple interferometer parameter estimation effort.

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4) 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 Riles' 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.