Development of a Cryogenic Silicon Reference Cavity for Laser Frequency Stabilisation
Matthew Arran
Mentors: Rana Adhikari and David Yeaton-Massey

Thermal noise is a major source of frequency variation in lasers stabilised by an external reference cavity. Among other effects, this is a significant limit on the sensitivity of gravitational wave detectors based on laser interferometry. Considerable reductions in thermal noise may theoretically be achieved by working at cryogenic temperatures, due to the reduction of Brownian noise; and near zeros of the coefficient of thermal expansion of the cavity spacer, due to reduction of thermoelastic noise. Progress was made in developing an optical system with a laser beam stabilised by a cryogenic fused silica reference cavity, by the attachment of heaters and temperature sensors, trial cooldowns of the system, and analysis of the thermal system. Transfer functions for the propagation of temperature perturbations were found analytically and proved, given the appropriate choice of parameters, to correspond closely to measurements of step responses. Further work will include the design of heater control systems and analysis of the effect of temperature fluctuations on beam frequency.

Investigating Crackle Noise in Metal Blade Springs
Igal Bucay
Mentors: Rana Adhikari, Jan Harms, and Eric Quintero

Systems crackle when exposed to slowly changing external conditions by responding with impulsive, discrete events. Crackling (or crackle noise) is the result of crystal domains changing or moving with respect to one another—the displacement analogy of Barkhausen noise. Some components in the mirror suspension system in Advanced LIGO (i.e. the cables and metal blade springs) are susceptible to crackle noise, which, in turn, may interfere with the detection of gravitational waves. In a lab experiment, crackle noise in blade springs will be quantified using a simple Michelson interferometer where the mirrors at the end of each arm are suspended from a blade spring. The interferometer sits on top of a seismic isolation stack composed of two steel plates with rubber legs, all held within a steel chamber which can currently be pumped down to 800 mTorr. When the springs are driven at a low frequency of 0.1 Hz, any change in the signal will ideally be due to crackle noise. So far, we have measured the time constants and eigenfrequencies of the two springs, as well as other sources of noise which may interfere with our measurements, such as seismic noise, laser shot noise, and electrical noise. We are currently in the process of calculating a noise budget, after which we will collect crackle noise data. At that point, we will calculate the characteristic coefficients that describe the relationship between the low frequency driving force and crackle noise, compare it to the current aLIGO noise budget and determine if crackle noise is a significant concern for the aLIGO detectors.

Visualization of Images Distorted by Black Holes
Darius Bunandar
Mentors: Mark Scheel and Nick Taylor

One of the most promising sources of gravitational waves for potential detection by LIGO is the inspiral and merger of two black holes. In an effort to aid LIGO data analysis, the Caltech-Cornell SXS collaboration is numerically solving Einstein's equations for a number of such binary black hole systems with varying mass ratios and spins. In this project, we investigate a novel way to visualize the structure of such a numerical solution by producing images of a distorted stellar background in the vicinity of black holes. This involves following the paths of photons through regions of strong gravitational field—produced by the black holes—from the observer to the light sources at distant locations in the background. We present some images and movies of the distorted stellar background; among these are some of the world's first distorted images of merging binary black holes.

The Role of Small Robotic Telescopes in Multimessenger Astronomy With Advanced Gravitational Wave Detectors
Cutter Coryell
Mentor: Stephen Privitera

Maximizing the scientific returns from observations of compact binary coalescence requires joint observation of gravitational waves and counterpart electromagnetic radiation. Small, robotic, rapid-response optical telescopes such as ROTSE III and TAROT were used to follow up gravitational wave candidates in the most recent joint LIGO-Virgo science run. We explore the role of such telescopes in following up gravitational wave candidates in the advanced detector era.

Tools to Analyze LIGO Trend Data
Alexandra Danilet
Mentors: Gregory Mendell and Richard Savage

The initial Laser Interferometer Gravitational Wave Observatory (LIGO) in Hanford, WA produced over 13,000 channels of data, collected at typical rates of 1024 to 16384 sample per second during the last Science Run (S6), from July 2009 to October 2010. Trends in LIGO data (for example, the mean value of channel computed every minute) have been found useful in Photon Calibration studies and Radio Frequency Amplitude Modulation studies, and can be used to determine correlations between various channels. The motivation of this project is to develop tools with which data from LIGO can more easily be gathered, formed into new trends, and then analyzed. Code was written in Matlab, html, php, tcl and condor to create a web user-interface through which researchers may enter the state vector, channels, duration and functions to be performed on the data to obtain an output file with the GPS time, the state of the detector and their requested calculations. We also plot the RFAM over S6 for times when the interferometer was in full science mode and look for trends with the hope of determining whether a correlation between RFAM and detector sensitivity exists.

Rapid Sky Localization of Binary Inspiral Sources
Ryan Darragh
Mentors: Larry Price, Leo Singer, and Stephen Privitera

Sky localization of gravitational wave sources is done using the time of arrival and signal to noise ratio in each detector. Taking a Bayesian approach requires creating a likelihood function and choosing priors. Our likelihood function tells us the probability of our parameters given our signal, and our priors express our beliefs about a given parameter. We investigate three different distance priors, uniform in volume, uniform in log distance and another astrophysically motivated prior based on rates of coalescence. We determine how sensitive each prior is to our parameters and choose the best one to be used in the sky localization procedure.

Detector Characterization Tools for Interferometer Commissioners
Elizabeth Davison
Mentors: Jameson Rollins and Rana Adhikari

The Laser Interferometer Gravitational-Wave Observatory (LIGO) detectors are dual-recycling interferometers with four kilometer Fabry-Pérot arm cavities. Complex control and data acquisition systems for these instruments are prototyped at the 40 meter interferometer on the Caltech campus. With the development of increasingly intricate subsystems, it has become important for the commissioners working at the 40 meter lab to have an accessible, effective overview of the instrument's behavior. This project required consultation with each scientist and an overall understanding of the interferometer in order to refine the considerable amount of information from the data channels into useful plots. Code that had been used for a full-scale interferometer website was modified to suit the 40 meter lab's objectives. The result of this project is a regularly updated website that contains calibrated plots of relevant channels and images of monitoring screens. It can be further adapted by the scientists at the 40 meter lab as the need arises and will be a helpful and informative tool.

Directional Gravitational Wave Search
Nick Eminizer
Mentor: Peter Kalmus

Data from two or more gravitational wave detectors contain many coincident glitches: short-duration blips in the data. We tend to assume these are all from coincident and independent noise events in the individual detectors, but some of them may actually be gravitational wave signals. Building on past searches, we will develop and refine a method that associates a sky position with each significant blip, and then we will look for sky directions with a statistical excess of these blips. The goal is to search the whole sky over long time periods in order to discover gravitational wave signals from repeating sources. We will characterize the sensitivity of our search via simulated waveforms that echo plausible astrophysical models and correlate it to simulated point sources and regional sources, as well as known bright matter.

Simulating the Response of LIGO Data Analysis Pipelines to a Population of Binary Black Hole Mergers
Irina Ene
Mentor: Alan Weinstein

I present an analysis of the response of the LIGO data analysis pipelines to a simulated population of gravitational wave sources consisting of binary black hole mergers. The analysis determines the detectability of the astrophysical sources as a function of source parameters (including component masses, sky location, and orbit orientation) and the detector network. Monte Carlo simulations are used to generate a population of astrophysical sources that are uniformly distributed across the sky and to map the response of the detectors across this parameter space. The detectability of each source is computed by determining the maximum distance at which the source could be located such that both single detector and detector network signal-to-noise ratios (SNR) are above certain thresholds.

Low-Noise Seismic Sensing and Actuation
Yaakov Fein
Mentors: Jenne Driggers and Rana Adhikari

Seismic noise is a significant noise source that limits the low frequency range of all terrestrial gravitational wave detectors. At the 40m Prototype Lab at Caltech, the STACIS 2000 active isolation system was implemented in order to reduce seismic noise, but proved ineffective at low frequencies. There is a dual motivation for further investigation of the STACIS: First, implementing active seismic isolation will push down the ever-present seismic wall and help the interferometer maintain lock. Second, the STACIS can be used as an actuation system to test and implement adaptive feed forward filtering techniques developed at the 40m Lab.

I have investigated ways to modify the STACIS to provide better isolation at low frequencies. Replacing the STACIS' internal sensors with higher quality sensors shows promise, but further work is needed to determine the extent of the benefit. Other options, such as modifying the STACIS sensors, also require further investigation. To use the STACIS as actuators, I have investigated two possible input points through which the STACIS can be actuated with an external signal. These points can be used for external actuation as long as the open loop gain of the STACIS is known accurately, because that is what determines how an input signal will be converted to motion.

Tools for Collaborative Electromagnetic Follow-Up of Gravitational Wave Candidates
Tobias Fleming
Mentor: Roy Williams

This project aims to provide tools for a collaborative follow-up after the detection of gravitational waves with electromagnetic telescopes. While the similar project BAYESTAR aims for an optimal follow-up with maximally coordinated observatories, the object of this approach is to allow observatories to react quickly to LIGO gravitational wave events on their own terms. The tools provided use generated probability maps or skymaps in creation of observing plans for available telescopes and known data. This pragmatic and dynamic processing of available information will enable available observatories and their operators to process detection events communally, while still allowing a coordinated gathering of valuable scientific data.

Spin Alignment Effects in Black Hole Binaries
Davide Gerosa
Mentors: Yanbei Chen and Emanuele Berti

We use Monte Carlo simulations to investigate the spin alignment of black hole binaries when they enter the Advanced LIGO detection band. Our simulations start at large separation, where the post-Newtonian (PN) approximation (a perturbative expansion of the Einstein equations in the ratio v/c, where v is the orbital velocity and c is the speed of light) is valid. We followed the evolution of a statistical sample of binaries by numerically evolving the PN equations of motion. We first tested our code by reproducing results in the literature, and then we add high-order PN corrections recently computed by Marc Favata. Stellar evolution calculations hint that comparable-mass binaries where both spins have the same misalignment angle with respect to the orbital angular momentum may be likely, so we focused on these configurations to initialize our Monte Carlo simulations. Our goal is to understand if the existence of PN resonances, that was originally pointed out by Schnittman, can simplify the construction of matched-filtering templates in binary black hole data analysis.

Real-Time Calibration of Gravitational-Wave Strain
Eric R. Hendries
Mentors: Jameson Rollins and Rana Adhikari

The Laser Interferometer Gravitational-wave Observatory (LIGO) uses a Fabry-Perot Michelson interferometer to measure the change in length between two test masses due to an incident gravitational-wave strain. Calibration of LIGO is necessary for a meaningful physical analysis of strains and their sources. Traditional calibration methods used multiple measurements of individual transfer functions of elements within the differential arm length control loop. A real-time calibration system has the advantage of taking the current state of the interferometer's time-varying components, allowing for a more accurate calibration and smaller errors. Moreover, immediately having data in calibrated units will allow for quick identification of the type of gravitational-wave event, reconstruction of the source position, and notification of follow-up telescopes. We begin by simulating the control loop at the LIGO 40 meter prototype. This simulation then guides the real-time model that we implement in the digital control system to calibrate the interferometer while in operation.

A Generalized Harmonic Formulation of Modified Gravity With Applications to Black Hole Inspirals
Matthew Heydeman
Mentors: Yanbei Chen and Bela Szilagyi

In this paper, our goal is to extend the Generalized Harmonic form of the Einstein field equations of General Relativity to a modified system describing effective theories of gravitation such as those arising as classical limits of string theory and loop quantum gravity. Such classical theories contain a power series of higher order curvature invariants that deviate from the Hilbert action, and generally the equations of motion of the metric tensor become fourth or higher order differential equations. These equations have some solutions that are high frequency and non-causal which makes the system appear ill-posed. Such apparent ill-posedness is a challenge for the Generalized Harmonic (GH) numerical evolution of black hole inspiral solutions in these modified theories. However, since these are classical limits of more fundamental quantum theories, these solutions are not expected to be physical because they involve lengthscales over which the classical theory breaks down. In formulating our modified Generalized Harmonic system we defined auxiliary fields to reduce the higher order system to a first order one. The dynamics of the newly introduced fields contain terms which temporally average over the higher derivative modes so that only the physical long wavelength classical modes appear in the solutions. In certain cases we have made progress in demonstrating that the system is hyperbolic and extract the characteristic fields and velocities, but our goal is to generalize our current results to include up to fourth order or higher derivatives of the metric tensor. In future work we will apply this GH form of the modified theories to black hole inspiral simulations and observe how the gravitational wave profile is modified by the effective quantum gravity theories.

Distinguishing Gravitational Wave Polarizations in Continuous Waves From Spinning Neutron Stars
Maximiliano Isi
Mentor: Alan Weinstein

According to the theory of General Relativity, gravitational waves (GWs) can present only two polarizations, both of them transverse to the direction of wave propagation. This is generally taken as an assumption in the models and templates used in the simulation and searches of gravitational waves. However, Einstein's theory has never been tested in the highly dynamical regime of GWs and alternative theories allow for the existence of a maximum of three extra polarizations. In light of this, we develop methods to identify signals containing all such polarizations in continuous GWs emitted by spinning neutron stars –the Crab pulsar in particular. We analyze the extent to which extra polarizations can be detected, making use of simulated signals and preliminary searches in actual LIGO data.

Camera Set-Up for Laser Beam Monitoring
Vidisha Jain
Mentors: Valery Frolov and Rana Adhikari

LIGO (Laser Interferometer Gravitational Wave Observatory) is the research hub aiming at gravitational wave detection, for which, large Michelson interferometer is used which has laser at its core. The laser beam travel towards the beam splitter, gets split, approaches the two mirrors placed at perpendicular direction, gets reflected back and then interfere. Due to the various noises, angular motion is induced in the laser which produces motion in beam spot. Hence beam spot motion is monitored which can be used to control the angular motion of the arm cavities and the laser. Camera is set up which takes continuous images of the beam spot. Images are analyzed and processed to get the beam position. For a continuous set of readings, fluctuations in beam spot are plotted and the amplitude spectrum obtained which is used to see the various noise levels. To get rid of the maximum noises, Dark frame is subtracted from all the grabbed images and camera is properly calibrated. Camera characteristics, such as, linearity and different camera noises are analyzed. This set up can then be used to monitor the angular motion of laser.

A Model-Independent Test of General Relativity Using Wave Signals of Binary Coalescence
Joon Sik Kim
Mentor: Parameswaran Ajith

Gravitational-wave (GW) observations of coalescing compact binaries (CBCs) are excellent testing grounds of general relativity (GR). This project aims to develop a model-independent test of GR using such observations. Since the expected gravitational waveforms from CBCs are well modeled in GR, if we subtract the modeled GW signal from the data, the residual should be consistent with the detector noise. If the residual is inconsistent with the detector noise, this would imply that the true theory might be different from GR. The "residual" from multiple observations can be stacked to enhance the sensitivity of such a test. A chi-square test or Kolmogorov-Smirnov test may be used to check the consistency between the residual and the detector noise.

Studying Dynamics of Macroscopic Quantum Entanglement With Future Advanced Gravitational-Wave Detectors
Oleg Kiriukhin
Mentors: Yanbei Chen and Haixing Miao

Future advanced gravitational-wave detectors will reach such high sensitivity that they possibly allow us to study quantum behaviors of the macroscopic test masses. One interesting issue, which is also of fundamental importance, is the observation of the Einstein-Podolsky-Rosen-type of quantum entanglement among macroscopic objects, for example, the kilogramscale test masses. We explore quantum dynamics of entanglement and study the possibility of observing it with future advanced gravitational-wave detectors or prototypes. In particular, we theoretically evaluate the characteristic lifetime of macroscopic entangled states under thermal decoherence in realistic setups and analyze its dependence on the different parameters of the system.

In this work we consider a system being under the continuous measurements and study the dynamics of quantum entanglement for the conditional quantum state. In order to obtain the conditional expectations we apply filtering approach which is a technique of minimization of error dispersion. Filter gives the best possible estimation of the variable by measurements with incomplete information and noise in the system being under the disturbance of an uncontrolled stochastic process.

Gravitational Waves From Core-Collapse Supernovae
Hannah E. Klion
Mentors: Christian Ott, Peter Kalmus, and Ernazar Abdikamalov

It was recently discovered that during the iron core collapse of rapidly rotating stars, there are correlated oscillations at 700-800 Hz in the central density of the star and in the neutrino and gravitational wave signals. It was hypothesized that these oscillations were due to quadrupolar excitations of the nascent neutron star. We aim to study this hypothesis by determining the range of initial angular velocities at which these oscillations occur, and characterizing the oscillations. To do so, we have simulated the iron core collapse of a 12 $M_\odot$ progenitor. To study rotation effects, we have applied one of ten initial central angular velocities to each model. These angular velocities ranged from 4.5 to 9.5 rad s^{-1}. We have used a 3-D hydrodynamic code employing octant symmetry. Oscillations between 700-800 Hz have been found to occur in models with initial angular velocities ranging from 4.5 rad s^{-1} to at least 8.5 rad s^{-1}. Models with initial angular velocities greater than 8.5 rad s^{-1} did not collapse due to centrifugal support for the infalling matter.

Adaptive Quantum Measurements in Future Gravitational-Wave Detectors
Mikhail Korobko
Mentors: Yanbei Chen and Haixing Miao

Advanced gravitational-wave detectors, such as Advanced LIGO, Advanced VIRGO, LCGT, are expected to be limited by fundamental quantum noise around the most sensitive frequency band. To further improve the detector sensitivity, various approaches based upon modifying the input or output optics of the interferometer have been proposed in the community. They usually require additional low-loss optical cavities to filter the input or the output. In our work we propose a new alternative type of scheme—adaptive linear measurements—that has not been explored in the community yet. This approach uses the time-dependent phase of the homodyne detector which changes depending on the results of the measurement.

Adaptive measurements provide new approach to the measurement of signal with unknown shape and arrival time, that makes possible detection the gravitational waves from different types of sources without any change in experimental scheme. In this work we propose the general scheme for such kind of measurements and consider the special case of detecting the impulse force with unknown amplitude and arrival time.

Modeling the Effect of aLIGO Thermal Compensation on Beam Scatter
Alexander Mauney
Mentors: Aidan Brooks and Rijuparna Chakraborty

A major problem in aLIGO is thermal lensing caused by the absorption of power in the testmass. In order to compensate for this a thermal compensation system (TCS) is used which uses other heating systems to even out the overall thermal effects. Understanding how the different distortions used in TCS impact the signal that is generated further down the beam line is crucial for the alignment of other systems, such as the output mode cleaner (OMC). In this project we use numerical models to simulate small differences in thermal compensation between beam lines and the impact they have on the output signal.

Detection of Short Gamma-Ray Bursts in Coincidence With Gravitational Waves
David Miller
Mentor: Leo Singer

The detection of gravitational waves from compact binary coalescence mergers are likely when the Advanced LIGO/Virgo detector network goes online as early as 2015. To maximize the science returns, an electromagnetic counterpart must be detected. I examine the ability of present and future high-energy telescopes to detect short gamma-ray bursts in coincidence with gravitational wave signals.

Comparing Numerical Relativity and Black Hole Perturbation Waveforms for Intermediate Mass Ratio Black Hole Binaries
Derek S. Nelson
Mentors: Christian Ott and Christian Reisswig

Advanced gravitational-wave observatories will soon be capable of detecting cosmic phenomena at both lower and higher frequencies than previous observatory specifications. It is essential to similarly broaden data analysis strategies and, in particular, improve the bank of template waveforms used to search for compact binary coalescence at the lower frequency end of the Advanced LIGO sensitivity band. Although post-Newtonian waveforms are the foundation for current searches at mass ratios near unity, it is unclear whether or not they are well suited to lower frequency Intermediate Mass Ratio Inspirals (IMRIs). As a possible substitute, the black hole perturbation waveform generation technique commonly referred to as the Numerical Kludge method is implemented and compared to waveforms created using full Numerical Relativity. The relative agreements between the modal decompositions of each waveform are analyzed to determine whether the Numerical Kludge method is a promising template generation technique for implementation by future Advanced LIGO pipelines.

Exploring the Signal Space of Spinning Compact Binary Coalescence Waveforms
Afina Neunzert
Mentors: Nickolas Fotopoulos and P. Ajith

Gravitational wave signals from the coalescence of compact binary systems (CBCs) are expected to be detectable by Advanced LIGO. The LIGO CBC search pipeline requires the use of template banks, or families of expected waveforms, against which to perform matched filter calculations and thereby recover signals. Few previous template banks have attempted to incorporate spin and precession effects, leading to an overly narrow searchable parameter space. This project explores and characterizes the signal space of spinning CBCs using a stochastic bank placement algorithm and several types of waveform approximant, including a reduced-spin and a precessing model. Preliminary results demonstrate the effectiveness of the reduced-spin template bank in detecting precessing waveforms, and lend insight into the bank parameter ranges necessary to optimize detection.

Machine Learning Techniques for Seismic Noise Classification and Interferometer Control Systems
Maria Okounkova
Mentors: Denis Martynov, Jenne Driggers, and Rana Adhikari

One of the most significant low-frequency noise sources in the Laser Interferometer Gravitational Wave Observatory (LIGO) experiment is seismic noise. While 40 Meter Prototype Lab has noise cancellation filters in place for constant seismic noise, transient seismic disturbances, such as earthquakes, vehicles, and other unforeseen events, which generate noise in the interferometer signals, require adaptive filtering to be removed. This project involved gathering training data of seismic disturbances from known sources at the 40 Meter Lab and applying various machine learning algorithms for online classification, so that a noise source can be identified in real time, and a specific filter for the noise source may be applied.

Machine learning techniques have other potential applications to the LIGO project as well, including applications to interferometer control systems. Thus, I experimented with using recurrent neural networks as adaptive control systems in simulations of noisy dynamic systems in order to assess the feasibility of training a neural network to internally approximate their dynamics. With rigorous training, such a system could potentially be implemented in the 40 Meter Lab to control the interferometer test masses.

Investigating Electromagnetic Interference in the Control Electronics of the Advanced LIGO Detectors
Mayowa Omokanwaye
Mentor: Joseph Betzweiser

The aim of this project is to investigate the installed electronics for the LIGO interferometers and examine their ability to cross talk amongst systems as well as their sensitivity to external electromagnetic fields. In order to determine if there was any electromagnetic interference in the electronic signals, a magnetometer was placed in various locations in LIGO's CDS (Control and Data Systems) Electronics Room. Power spectra for the magnetic field measured by the magnetometer were then analyzed to determine at which frequencies there were strong peaks in the magnetic field. These peaks were compared to peaks in the power spectra for various electronic signals. High coherence between the magnetic field and the electronic signals suggests that the magnetic field is inducing noise in the electronics. The strongest measured source of noise is a temporary power supply which will not be a part of the LIGO's final setup.

Thermal Noise in Ultra-Stable Fabry-Perot Cavities
Sarah Terry
Mentors: Tara Chalermsongsak and Rana Adhikari

According to calculations, Coating Brownian Noise dooms Advanced LIGO because it limits measurement precision. The *Coating Thermal Noise Measurement* experiment aims to measure this noise source at the frequency range of interest (50Hz - 300Hz). My objective is to further complete, understand the noise budget for the beat measurement, as well as minimize the technical noise. Further completing the noise budget includes obtaining the frequency noise due to power fluctuations of the laser (RIN induced noise), as well as finding the frequency noise due to the effects of acceleration on the cavity. Understanding the results of the noise budget involves identifying the sources of the different components of noise budget. Minimizing the technical noise consists of designing an Intensity Stabilization Servo (ISS) to reduce the frequency noise due to power fluctuations, and fixing the cavity supports to minimize mirror tilt and frequency noise due to acceleration acting on the cavity. The ISS will be approached by first identifying the RIN induced noise, and then creating a servo with a transfer function appropriate to suppress the noise to about 10^{-8} [1/\sqrt{Hz}] at 100Hz. The length noise due to acceleration on the cavity will be modeled using COMSOL Multiphysics Software. Understanding and optimizing the noise budget will allow for a more precise measurement on the extent to which Coating Thermal Noise effects the measurements made by the Advanced LIGO interferometers.

Setting Up the Physical Environment Monitor System for Advanced LIGO
Maggie Tse
Mentors: Robert Schofield and Daniel Sigg

The Laser Interferometer Gravitational-Wave Observatory (LIGO) makes use of an interferometer that is sensitive to arm-length changes of 10^-18m. Because of this sensitivity, environmental noise sources can make unwanted contributions to the gravitational-wave channel. Through a network of strategically placed sensors, the Physical Environment Monitor (PEM) system can be used to identify, characterize, and monitor environmental noise sources as well as coupling mechanisms and coupling sites through which environmental influences enter the gravitational-wave channel. The upgrade from initial LIGO (iLIGO) to advanced LIGO (aLIGO) will include an upgrade of the PEM system, as well as the introduction of a new system for locking the interferometer, the Arm Length Stabilization (ALS) system. We investigated performance issues found in the iLIGO PEM design and propose a new scheme for mounting accelerometers to optical tables using acrylic cubes and UV-curing epoxy. We are also providing support for the single-arm test stage of aLIGO commissioning, whose purpose is to investigate the performance of the ALS, by using PEM sensors to identify noise sources contaminating the signals the recently installed optical levers and investigate sources of vibration near the reference cavity used to lock the single-arm cavity. We will also measure environmental coupling to the single-arm test signal, in particular because aLIGO also introduces a new seismic isolation and suspension system that will be tested for the first time during the single-arm test. In addition, data from the aLIGO PEM system will be made easily accessible through a web interface we developed that allows users to search a database of PEM channels and look up calibration factors, sensor locations, and other information.

Modeling Efficiency of the Global Gravitational Wave Detector Network
Justin Wagner
Mentors: Nickolas Fotopoulos and Alan Jay Weinstein

Assessments of efficiency of the worldwide gravitational wave detector network are needed to draw conclusions about sensitive distance and the distribution of astrophysical phenomena. Current techniques used to find efficiency involve simulations of large numbers of sources distributed throughout a volume of space. Due to the high computational cost of processing these simulations, statistically strong declarations about efficiency consume computation time that will not be available during online analysis of aLIGO data. A simple model of detectors and the data analysis pipeline would allow vastly cheaper simulations.

Real-Time Simulation of a Suspended Cavity With the Advanced LIGO Digital Controls System
Alexandra A. Zhdanova
Mentors: Jamie Rollins and Rana Adhikari

An integral part of LIGO's interferometers are the Fabry-Perot cavities in the arms. Modeling them can show us how well we understand the noise in addition to serving as a test of the control system used to keep the interferometer in resonance. While time-domain simulations of the cavity have been done, a real-time simulation developed with the Real-Time Code Generator would provide a better comparison point for the noise while accurately modeling the cavity response. This presentation outlines such a real-time simulation, as well as a comparison between the results of the “fake” (or simulated) cavity and the “real” cavity. The closer these results are to each other, the more successful we count our simulation as an accurate representation of the real-life noise and mechanics in a Fabry-Perot cavity.