Summer Undergraduate Research Program Student Research Presentations

Dunlap Institute
Department of Astronomy and Astrophysics
Canadian Institute for Theoretical Astrophysics
University of Toronto

August 20th & 21st, 2013
Cody Hall
Introduction

For the past few months, the Dunlap Institute, Department of Astronomy and Astrophysics, and Canadian Institute for Theoretical Astrophysics (CITA) at the University of Toronto have been running the Summer Undergraduate Research Program (SURP) for undergraduate students in astronomy, physics, engineering and related sciences. The students’ research well represent the range in research in the three institutes, from planets to cosmology. They have also participated in weekly student meetings, research and presentation workshops, and outreach activities. In addition, they attended paper discussion seminars led by postdocs to improve their understanding of different fields of astronomy as well as their paper reading skills. To conclude their programs, students are presenting the results of their research project over the course of two days. Each talk is 12 minutes, with 3 minutes of questions.

Organized by the SURP committee:
Tuan Do, Rachel Friesen, Quinn Konopacky, Maria Montero-Castano
Schedule of Talks

Tuesday, August 20

10:00 AM Rahul Goel – Systems Design for High Altitude Polarized Microwave Calibration Source

10:15 AM George Stein – The Peak Patch Picture of Cosmic Structure Formation

10:30 AM Andrey Vayner – Resolving Host Galaxies of z=2 Quasars Using Adaptive Optics and Integral Field Spectroscopy

10:45 AM BREAK

11:00 AM Dan Clouston

11:15 AM Raissa Estrela – The alignment of cluster galaxies with host clusters in the Red-Sequence Cluster Survey-2

11:30 AM Fan Wu – The initial conditions for an N-body problem to simulate the evolution of Nuclear Star Clusters (NSCs)

11:45 AM Michael Pu – The Architecture of Kepler’s High-Multiplicity Planetary Systems

12:00 PM LUNCH BREAK

2:00 PM Bryn Orth-Lashley – Inferring Physical Properties of Ultracool Dwarfs Using High-Precision Dynamical Mass Measurements and Model Spectra

2:15 PM Nivedita Chandrasekhar – Unusual star-forming trails in the ram-pressure stripped galaxy, ESO137-001

2:30 PM Fangda Li – The physics of magnetar outbursts

2:45 PM BREAK

3:00 PM Morten Stostad – A Search for an Edge of the Young Stellar Disk in the Galactic Center

3:15 PM Hans Nguyen – Molecular cloud complexes & star formation activity surrounding the obscured giant H II region RCW106
Wednesday, August 21

10:00 AM Phil Isaac – Design of a Low Frequency Receiver at the Algonquin Radio Observatory for VLBI Observations of Pulsars

10:15 AM Jacob Peoples – Estimating the rate of gravitational-wave observations from compact binary coalescence

10:30 AM Miranda Jarvis – Simulating Observations for the Wide Integral Field Infrared Spectrograph

10:45 AM BREAK

11:00 AM Michael Winer – How Initial Density Perturbations Affect Dark Matter Microhalos

11:15 AM Dana Simard – Dragonfly Low Surface Brightness Survey of Nearby Galaxies: Automation of Data Reduction

11:30 AM Marat Mufteev – Non-gaussianity through the cross-power

11:45 AM Jake Gordon – IRIS Diffraction Gratings: Scattered Light and Efficiencies

12:00 PM LUNCH BREAK

2:00 PM Arthur Sowinski – Exploring the Sagittarius Stellar Stream: Multi-body interactions in the galactic halo

2:15 PM Paul Tan – Simulating CCD images for MaNGA

2:30 PM Ryan Cloutier – The Effect of Rotating MaNGA’s IFU on Recovering Accurate Science Results

2:45 PM BREAK

3:00 PM Carly Berard – Asymmetric Neutrino Interactions in Core-Collapse Supernova Explosions

3:15 PM Jessica Campbell – A Search for Infall Motion in the Perseus Molecular Cloud
Talk Abstracts

Systems Design for High Altitude Polarized Microwave Calibration Source
Rahul Goel, University of Toronto
Supervisor: Keith Vanderlinde
Tuesday, 10:00 AM

Since all cosmological theories must explain the CMB in the context of their claims, precisely measuring and understanding this phenomenon is essential. Previous experiments have measured the intensity patterns of the CMB, and the South Pole Telescope (SPT) is currently mapping the faint polarization patterns imprinted as a result of cosmological processes. Accurate measurements and their cosmological interpretation require calibration of the polarization sensitivity axes of the telescope. We are, therefore, developing a polarized calibration source which will be suspended from a high altitude balloon at an altitude of roughly 15 kilometers (the far-field of the SPT). Microwave light will pass through a polarizing grid, which must be rotated with sub-degree precision. Attitude control systems will orient the payload by using data from an inertial measurement unit, sun sensor, star camera, and GPS through a series of feedback loops. We have made progress in the development and understanding of these systems by testing and refining several aspects of a scratch built reaction systems mechanical, electrical, and control algorithm design. The greatest engineering challenge has been fitting all the required subsystems, chassis, failsafes, and power sources within a 5 pound limit. No complete system this small has flown successfully before.

The Peak Patch Picture of Cosmic Structure Formation
George Stein, University of British Columbia
Supervisors: Dick Bond, Marcelo Alvarez, Amir Hajian
Tuesday, 10:15 AM

We develop a picture of cosmic structure formation using the “Peak Patch” method of Bond and Meyers. This method identifies virialized cosmological objects through a point process in the initial Lagrangian space. It allows for very efficient constructions of three-dimensional dark matter halo catalogues which are orders of magnitude faster and less computationally intensive than standard N-body simulations. These halo catalogues can be
used to probe a variety of cosmological phenomena, such as the mapping of the Cosmic Infra-red Background (CIB), CO, and Hi regions, as well as to determine various auto-correlation and cross-correlation functions. We compare to both PINOCCHIO and the N-body code CUBEP3M across a series of redshifts and find sufficient evidence for the accuracy of Peak Patch. Having confirmed the Peak Patch method as a valid and efficient tool, we are beginning to apply it in a $\Lambda$CDM model to create maps of the CIB and to determine various bias factors.

### Resolving Host Galaxies of $z=2$ Quasars Using Adaptive Optics and Integral Field Spectroscopy

Andrey Vayner, University of Toronto  
Supervisor: Prof. Shelley Wright  
Tuesday, 10:30 AM

Understanding black hole formation and growth coupled with galaxy evolution is a key problem in astrophysics. Our survey of high redshift quasars focuses on understanding the relationship between the star formation in a quasar’s host galaxy and the rapid growth of the central black hole. In my talk I will present diffraction-limited observations of $z\sim2$ quasars designed to detect their host galaxies. Our data were obtained with W.M. Keck and Gemini - North Observatories using the integral field spectrographs (IFS) OSIRIS and NIFS, coupled with the laser guide star adaptive optics (AO) systems. The combination of AO and IFS provides the necessary spatial and spectral resolutions required to separate quasar emission from its host and allows us to derive key properties about the host galaxy such as the 2D kinematics of the gas, star formation rates and metallicities and additionally allows for morphological studies. Our set of targets show extremely quenched host galaxies with integrated star formation rates an order of magnitude below the average star formation rate of a typical galaxy at that redshift. Some of the targets show merger-like morphologies with ongoing star formation regions on kiloparsec scales, giving us a glimpse into how the bright central source affects the star formation in the host galaxy. Finally I will present some of the challenges that we face with the current AO systems and discuss how these challenges can be overcome with future large segmented mirror telescopes combined with next generation of AO and IFSs.
The alignment of cluster galaxies with host clusters in the Red-Sequence Cluster Survey-2
Raissa de Lourdes F. Estrela, University of Toronto
Supervisor: Prof. Howard Yee
Wednesday, 11:15 AM

In the hierarchical model of galaxy formation, individual galaxies or smaller groups tends to be accreted into group or clusters. Those galaxies falling into clusters experiences tidal torques which can produce a radial alignment between the galaxy major axis and the cluster center. Since the 1970s a number of groups have searched for evidences that galaxies could present a radial alignment effect towards the cluster center, finding both detections and non-detection. We search for this effect, using a sample of clusters drawn from the Red-Sequence Cluster Survey 2 (RCS-2), an imaging survey using the square degree imager, Megacam, on the Canada-France-Hawaii Telescope, covering 1000 square degree. Our sample of clusters lies at $0.2 < z < 0.5$. We measure the projected ellipticities of cluster galaxies and investigate alignment signals as a function of stellar mass, redshift, and cluster-centric radius. We find that over a range of redshift and radii, we detect a radial alignment for the most massive galaxies, consistent with expectations in the Lambda-CDM model of structure formation. The analysis of galaxy alignments due to tidal interactions could lead to a better comprehension of the evolution of galaxy clusters and the structure formation of the dark matter.

Characterizing the Atmosphere of a Hot-Jupiter Exoplanet Through High-Precision Spectrophotometry
Dan Clouston, University of British Columbia
Supervisor: Ray Jayawardhana
Tuesday, 11:00 AM

Since its discovery in 2005, the hot Jupiter orbiting the bright K-type star HD189733 has been the target of numerous attempts to characterize its atmosphere. The planets large transit depth (~2.6%) and the host star’s brightness make this system ideal for such investigations. However, despite significant efforts, the atmospheric properties of HD189733b are still in dispute: while some studies claim to find a featureless haze, others suggest the presence of molecules, such as H2O, CO, CO2, and CH4. In this talk, I will report on new spectrophotometric observations of HD189733b, taken at near-infrared H and K bands with the William Herschel Telescope. I
will discuss the data reduction and analysis techniques for this challenging ground-based dataset, and present our high-precision transit light curves. Using a Markov Chain Monte Carlo (MCMC) method, we fit the light curves simultaneously for both the transit parameters and a baseline model that is used to correct for systematic effects. By fitting the light curve over different wavelength bins, we can construct the planets transmission spectrum, enabling us to probe the atmosphere of HD189733b.

The initial conditions for an N-body problem to so simulate the evolution of Nuclear Star Clusters (NSCs)
Fan Wu, University of Rochester
Supervisor: Fabio Antonini
Tuesday, 11:30 AM

Nuclear Star Clusters (NSCs) are compact, barely resolved spheroids that occupy the center of galaxies. Over the last decade, stellar density profiles that are produced by Hubble Space Telescope (HST) images have revealed the seven major properties of NSCs, such as their common presence in almost all type of Hubble galaxies, occurrence of repetitive and frequent formation episodes, and their similar scaling relationships with host galaxies. These discoveries indicate that the formation of NSCs is intricately linked to galaxy evolution. However, the ceaseless effort on studying this type of clusters has not firmly established a method to explain how the NSCs are formed. In this sense, we conduct a project using N-body code to simulate the formation of NSCs in a dissipationless (merger model) environment. Our project first produced two initial conditions (initial position and velocity) for the evolution of NSCs in stationary equilibrium. Initial positions and velocities are derived from relationships (by Poisson equation) between mass/position and density/velocity of data points. Later, the inverse of these two relationships is calculated, and by plugging in initial conditions, an N-body simulation will be used to illustrate the process of spheroids merge in the center of galaxy as time progresses.

The Architecture of Kepler’s High-Multiplicity Planetary Systems
Bonan Pu, University of Toronto
Tuesday, 11:45 AM

One useful way of measuring the relative spacing between planets is to measure the distance between adjacent planets in units of their mutual Hill radius. We call this dimensionless quantity $k$. We performed numerical
N-body simulations of synthetic planetary systems and found that a typical spacing of $k_{cr} \approx 11$ is required for flat, low-eccentricity systems to not undergo any close encounters for at least $10^{9}$ yrs. For systems with larger inclinations and eccentricities, we found that as inclination and eccentricity dispersions of a system $\sigma_e$ and $\sigma_i$ increases, the increase in $k_{cr}$ is roughly exponential. Comparing our numerical results to the observed Kepler sample, we found that the $k$ distribution of high-multiplicity ($\geq 3$ planets) systems can be optimally fitted as a Gaussian distribution with $\mu = 12.5$, $\sigma = 3.8$. This result is an indication that higher multiple systems are packed to near the edge of stability with respect to $k$, and that hidden planets may lurk in the observed 4- and 5-planet Kepler systems.

**Inferring Physical Properties of Ultracool Dwarfs Using High-Precision Dynamical Mass Measurements and Model Spectra**

Bryn Orth-Lashley, University of Toronto  
Supervisor: Quinn Konopacky  
Tuesday, 2:00 PM

Very low mass stellar objects (VLMs) approaching and including the brown dwarf mass regime ($M < 0.076M_\odot$) have complicated interior structures and atmospheres and, consequently, are difficult to model. However by characterizing the physical properties of VLMs, evolutionary models of these ultracool dwarfs can be calibrated. We present the findings of a six-year survey of M to T-dwarf binary systems using astrometric and spectroscopic data obtained using the Laser Guide Star Adaptive Optics system mounted on the W.M. Keck II 10 m telescope. By monitoring the orbital evolution of these binaries, the orbital parameters of each system were determined through a $\chi^2$-minimization routine, and hence the mass of each binary component was calculated using K-band radial velocity measurements. We now average spectral data from the K-, J-, and H-bands of each component over the monitoring period to obtain high signal-to-noise and broad-wavelength spectra to be compared to a synthetic spectral grid generated by the PHOENIX atmospheric modeling code. Using a multi-dimensional least squares fitting routine, we determine the best-fit model parameters (effective temperature, surface gravity, metallicity) for each component spectra. Whereas previous studies characterized the physical properties of ultracool dwarfs using assumptions about their atmospheres, we use a more direct method of inference.
Unusual star-forming trails in the ram-pressure stripped galaxy, ESO137-001
Nivedita Chandrasekhar, University of Toronto
Supervisor: Suresh Sivanandam
Tuesday, 2:15 PM

We present results of photometry performed on HII regions in ESO137-001, a barred spiral galaxy, located in the nearby rich cluster Abell 3627 (z=0.01625). This galaxy has been shown to undergo ram-pressure stripping, a process that removes gas from galaxies in clusters, leaving behind trails. We examined HST images of this galaxy in I-, g-, H- and UV bands and identified a number of star forming HII regions in and around the stripped trails, the presence of which is in contradiction to theoretical predictions. Using synthetic spectra generated from the PEGASE stellar evolution model, we made comparisons with our observed photometric points to estimate the ages of these regions. Preliminary estimates indicated a slight age gradient, with clusters close to the galaxy centre being very slightly older than those farther away. These investigations will also help to explain the extent and properties of these regions, and their origin and evolution in a cluster environment.

The physics of magnetar outbursts
Fangda Li, University of Toronto
Supervisor: Prof. Christopher Thompson
Tuesday, 2:30 PM

Quasi-periodic outburst activity is observed in the class of compact objects known as Soft Gamma Repeaters (SGRs) and Anomalous X-ray Pulsars (AXPs). We propose that the sequence of catastrophic failure of the body-centered cubic lattice structure, propagation of a melting front through the crust, and subsequent runaway heating via plastic work offers a viable, novel mechanism explaining this phenomenon. The presence of inhomogeneities in the ultrastrong magnetic fields $B \sim 10^{15}$G found at the surface of highly magnetized neutron stars - magnetars - provides the requisite shear stress on the solid Coulomb crust of the star. We combine microphysical molecular dynamics simulations of the Coulomb crystal yielding at a fixed strain rate with a new 2D diffusion code that accounts for the magnetized, anisotropic thermal conductivity $\kappa_{\text{cond}}$ as well as the heat capacity $C_v$ of the crust, which are in general a function of pressure, temperature, and magnetic field strength, with contributions from electrons, ions (phonons),
and neutrons. The $^1S_0$ Cooper pairing of neutrons below the neutron drip density $\rho_{ND} \simeq 4.4 \times 10^{11} \text{ g cm}^{-3}$ strongly suppresses the heat capacity and raises the conductivity when the temperature falls below the strongly dense matter model-dependent critical temperature $T_c$. We account for magnetized neutrino loss rates from all relevant mechanisms in the neutron star crust. We find that magnetar-strength fields easily provide the necessary energy reservoir on the appropriate timescales to explain the intensity and duration of the observed outbursts.

A Search for an Edge of the Young Stellar Disk in the Galactic Center
Morten N. Stostad, University of Toronto
Supervisor: Tuan Do
Tuesday, 3:00 PM

Contrary to theoretical predictions, the central parsec of the Milky Way is one of the richest starforming regions in the Galaxy and contains a large disk of early-type (young, 4-6 Myr) massive stars. This paradox of youth, unanticipated due to the extreme tidal forces in the region, has prompted high-resolution analysis of the inner 0.5 parsec of the Galactic cluster. However, few spectroscopic observations have been made of the star population outside this innermost region. We present new results, obtained by adaptive optics assisted near-infrared spectroscopic observations, with a radial extent of 7" to 23" (0.28 pc to 0.92 pc) from Sag A*. Using Gemini North’s Near-Infrared Integral Field Spectrometer (NIFS), we are able to successfully separate early-type and late-type (> 1 Gyr) stars for stars 1 magnitude fainter than previous surveys. We find a surprisingly low density of young stars, which could indicate an edge of the disk of young stars at about 14" - 20" (0.56 pc to 0.80 pc) from Sag A*. Such a truncation in the disk could potentially strengthen the theory of the young stars originating from a massive gas disk instead of a tightly bound infalling cluster.

MOLECULAR CLOUD COMPLEXES & STAR FORMATION ACTIVITY SURROUNDING THE OBSCURED GIANT H II REGION RCW106
Hans Nguyen, University of Toronto
Supervisor: Quang Nguyen-Luong, Peter Martin
Tuesday, 3:15 PM

While it is well known that stars form in molecular clouds, the mecha-
nism for high-mass star formation (> $8, M_\odot$) is not fully understood. One aspect of interest is the effects of the morphology of giant molecular clouds (GMCs) on high-mass star formation due to their size and complicated structure.

As such, we choose to investigate the G333 molecular cloud complex due to its interesting configuration and because it hosts the massive star forming region RCW106. Using the data from Mopra, ATCA, Herschel and Spitzer telescopes we perform a multi-wavelength investigation on a 5° × 1° area that includes RCW106. We analyze the complex structure and divide the region into two distinct GMCs, RCW106 and GMC331.8 however the exact morphology is difficult to determine due to the kinematic distance ambiguity. Despite this, we perform estimates of the masses ($\sim 10^6 M_\odot$), sizes ($\sim 10^4 pc^2$) and other properties. The clouds were divided into 31 sub-regions whose masses range from $10^2 - 10^5 M_\odot$. The star formation rates of the sub-regions were also investigated using the 21 cm continuum emission and found to be $10^{-6} - 10^{-4} M_\odot$ year$^{-1}$. We show that RCW106 is indeed an interesting region of study due to the unique arrangement of the GMC which prompts for a further detailed investigation.

Design of a Low Frequency Receiver at the Algonquin Radio Observatory for VLBI Observations of Pulsars
Phil Isaac, University of Toronto
Supervisors: Keith Vanderlinde, Ue-Li Pen
Wednesday, 10:00 AM

In order to obtain high resolution images of radio pulsars, we use very long baseline interferometry (VLBI) – a technique in which we synchronize telescopes across the globe in order to achieve a large observing baseline.

At our intended observation frequencies of 100 to 350 MHz, the Giant Metrewave Radio Telescope (GMRT) in India, the Effelsberg radio telescope in Germany, and LOFAR in the Netherlands offer excellent facilities. However, telescopes further into the western hemisphere which offer receivers at low frequencies are in short supply.

The Algonquin Radio Observatory (ARO) in central Ontario is ideally situated to provide a long baseline to perform VLBI with the aforementioned observatories, however, it does not have low frequency receivers. Two new broadband low frequency receiver systems were designed for the ARO. The receiver systems consist of a feed, pre-amplifiers, filtration blocks, and a mixer. I will discuss the design, implementation, and performance of these systems.
On two trips to the ARO this summer, we have used these receivers to make VLBI observations. We achieved a signal-to-noise ratio matching that of the dishes at GMRT, allowing us to successfully obtain unique images of pulsars at low frequencies.

Estimating the rate of gravitational-wave observations from compact binary coalescence
Jacob Peoples, University of Toronto
Supervisor: Kipp Cannon
Wednesday, 10:15 AM

Establishing the detection of a gravitational wave due to a merger of compact objects using ground-based networks of gravitational-wave antennas will require showing that the candidate event has a false-alarm probability below 1 in a million ("5σ"). Previous work by Cannon et al. has demonstrated a likelihood-ratio based ranking statistic with high detection efficiency, which allows computation of false-alarm probabilities directly from single-instrument statistics, and that is suitable for use in low-latency analyses. We use an astrophysical source population model to develop a full probability density function for the parameters used in the ranking statistic, which can be used to account for instrument correlations by replacing the numerator of the likelihood-ratio. This improves the ranking statistic’s signal discrimination abilities, and through combination with Markov-chain Monte Carlo sampling provides a good model for the distribution of the ranking statistic in the signal population, which has not previously been obtained. Distributions for the ranking statistic in both the signal and noise populations are needed for application to the event rate estimation technique of Farr et al., which we demonstrate through several examples. The results of these applications establish the efficacy of our modified ranking statistic in helping detect gravitational waves.

Simulating Observations for the Wide Integral Field Infrared Spectrograph
Miranda Jarvis, University of Toronto
Supervisor: Suresh Sivanandam
Wednesday, 10:30 AM

We have created a spectral image simulator for the Wide Integral Field Infrared Spectrograph (WIFIS), in order to fuel scientific interest and make the limits and possibilities of the instrument apparent. WIFIS is currently
being built and tested to be on telescope early 2014. It is ideal for observing extended sources such as nearby galaxies and supernova remnants over a wavelength range of 900-1350nm. We create model data-cubes of the target and then simulate what the WIFIS observation would look like, taking into account the effects of the atmosphere, telescope and instrument, and including all noise sources. So far any elliptical galaxy can be simulated as long as certain properties are known. In particular we simulated observations of NGC7562, creating realistic data-cubes in which the initial spectra can be recovered well in regions with good signal to noise, and the noise values are what they should be. Overall, the spectral image simulator is a flexible code that can accurately model the on sky performance expected from WIFIS.

**How Initial Density Perturbations Affect Dark Matter Microhalos**

Michael Winer, University of Toronto  
Supervisors: Adrienne Erickcek and Marcelo Alvarez  
Wednesday, 11:00 AM

The first celestial structures to form in the universe are expected to be dark matter microhalos. We use N-body simulations to model the formation of such microhalos from different initial density perturbations. We consider three types of initial density perturbations. We first consider scale-invariant density perturbations. We then include a cut-off at small wavelengths caused by the free streaming motion of the dark matter particles. Then finally we consider an enhancement of perturbations on small wavelengths due to an early matter-dominated epoch prior to the hot radiation-dominated era. These changes in the density perturbations result in very different microhalo populations and also vary the internal properties of the microhalos themselves. We look at how these variations manifest themselves in the simulated microhalos. The properties of these microhalos determine the detectability of the gamma ray flux emitted from dark matter annihilation within microhalos that exist today. A better understanding of the connection between initial conditions and microhalos can therefore provide improved constraints to the physical characteristics of the dark matter particle.
Current hierarchical models of galaxy formation in a ΛCDM universe predict an abundance of smaller galaxies as well as the presence of intricate substructure within galaxies. Neither of these predictions have been confirmed observationally; one possible explanation is that these structures are at surface brightnesses of 30 mag/arcsec$^2$ or lower, below current detection limits of about 29 mag/arcsec$^2$. The Dragonfly array of 8 telephoto lenses, capable of detecting structures at surface brightnesses of 32 mag/arcsec$^2$ after approximately 10 hours of exposure with some binning, is currently being employed in the first survey of nearby galaxies at ultra low surface brightnesses in the search for missing substructure. Data reduction is facilitated through the use of a web-based application which manages the database of images, performing tasks including checking the quality of data and determining which data to include in reduction. The application allows a user to download the chosen images along with automatically generated input files for the Dragonfly reduction pipeline, and thereby simplifies and expedites the reduction of images from the survey. In this presentation, I will discuss the features of this application in the context of the Dragonfly survey as a whole.

An important part of the structure formation is the statistics of the matter density perturbation field. We study the deviation of it from the gaussian case, which is described by the $f_{NL}$ parameter. Recent attempts doesn’t exclude the possibility of a gaussianity due to low accuracy. One way is to reduce error bars using cross-power between 21cm maps and galaxy surveys. We expect this approach to give insight on the detectability of the non-gaussianity.
IRIS Diffraction Gratings: Scattered Light and Efficiencies
Jacob Gordon, University of Toronto
Supervisor Shelly A. Wright
Wednesday 11:45 AM

From characterizing the first galaxies in the universe to exploring our solar system, some of the most interesting research in modern astronomy has been made possible with the advent of integral field spectroscopy. Following the success of OSIRIS, the InfraRed Imaging Spectrograph (IRIS) is a groundbreaking instrument being built for the next generation of extremely large telescopes. The high angular and spectral resolution, the unique hybrid integral field unit, and multiple diffraction gratings sets IRIS apart from modern instruments - but demands careful consideration of its constituent parts and design. Ideally, a diffraction grating would disperse incident light completely into one diffractive mode, however, light can also be found in and in-between neighbouring modes. The way in which light is dispersed is an important consideration in selecting high performance diffraction gratings, as it affects the throughput and sensitivity of the spectrograph. We present efficiency measurements of selected test gratings for IRIS, as well as spot profiles which help characterize their scattered light properties. As test gratings from other manufacturers are made, these measurements will guide the selection of the final gratings for IRIS.

Exploring the Sagittarius Stellar Stream: Multi-body interactions in the galactic halo
Arthur Sowinski, University of Manitoba
Supervisor: David Law
Wednesday, 2:00 PM

We present a new model for the tidal disruption of the Sagittarius (Sgr) dwarf galaxy, in which the dark matter halo of the Milky Way is non-triaxial. This contrasts with the current triaxial model, in which the halo is a nearly oblate ellipsoid with minor axis lying in the galactic disk plane, a shape that is difficult to reconcile with galaxy formation theories. The new model contains a halo flattened only in the direction perpendicular to the galactic disk plane, and adds the gravitational influence of the Large Magellanic Cloud (LMC). The LMC orbit used is based on updated proper motion measurements, and has a greater period than previously thought. We perform a search of a 4-dimensional parameter space, to find the best fit between simulated orbits of the Sgr core obtained using our new model, and the or-
bit obtained using the triaxial model, as well as observational data. The best-fit model is then used to perform a full N-body simulation of the Sgr stream, which is compared to the observational data. The results can tell us whether or not the addition of the LMC to the model eliminates the need for a triaxial Milky Way halo.

Simulating CCD images for MaNGA
Paul Tan, University of Toronto
Supervisors: Brian Cherinka, David Law, Anne-Marie Weijmans
Wednesday, 2:15 PM

The MaNGA (Mapping Nearby Galaxies at APO) survey will obtain integral-field spectra for 10,000 nearby galaxies. These spectra will yield unprecedented kinematic and chemical information relating to internal galactic structures from their emission and absorption line features. However, the complexities of the MaNGA instrument – combining an imager with a fiber-fed spectrograph – and of the raw data necessitate a sophisticated data reduction and analysis pipeline capable of extracting useful scientific results. To that end, we have developed software to easily generate simulated CCD images, for arbitrary fiber layouts, that will closely resemble real MaNGA observations. This simulator will allow us to test the effectiveness of the current pipeline, expedite its further development, and will eventually be integrated into the pipeline itself.

The Effect of Rotating MaNGA’s IFU on Recovering Accurate Science Results
Ryan Cloutier, University of Toronto
Supervisors: Brian Cherinka, David Law, & Anne-Marie Weijmans
Wednesday, 2:30 PM

Mapping of Nearby Galaxies at APO (MaNGA) is an upcoming program that will obtain integral field spectroscopy of approximately 10,000 spatially resolved galaxies at $z \sim 0.05$. MaNGA’s hardware has yet to be built and the effect of the integral field unit (IFU) being rotated between exposures on image reconstruction is not yet fully understood. The aim of this project is to use simulated MaNGA observations of a galaxy to quantify this effect of IFU rotation and to recreate science results in the form of galaxy kinematic measurements. The known amount of IFU rotation ($\Delta \theta$) is executed between two exposures in the simulation. By making kinematic measurements of simulated MaNGA data with varying $\Delta \theta$, we gain an understanding of
the effect of rotation on our ability to make accurate measurements and can therefore optimize construction of the instrument to allow for up to the maximum amount of allowable IFU rotation. I present simulated integral field spectroscopy of NGC 2916 (z=0.0119) observed at various $\Delta \theta$ and the corresponding recovered kinematic measurements. Based on the results, we find that we are able to obtain significantly accurate results when $\Delta \theta \lesssim 5^\circ$.

Asymmetric Neutrino Interactions in Core-Collapse Supernova Explosions
Carly Berard, University of Toronto
Supervisor: Evan O’Connor
Wednesday, 3:00 PM

In the extreme environments of core-collapse supernovae (CCSNe), neutrinos and anti-neutrinos are sent hurtling across the universe, carrying away 99 percent of the gravitational binding energy of the newly-formed protoneutron star. The energy spectra of these neutrinos are indicative of the conditions inside these rare events; in particular, we focus on in-medium effects, hereafter $\Delta U$, which arise from an asymmetry in the potential energies of free protons and neutrons in low density nuclear matter ($\rho \sim 10^{10} - 10^{13}$ g cm$^{-3}$).

We develop a set of routines to calculate $\Delta U$ for different theories of nuclear interactions (equations of state). With the aid of GR1D, a general-relativistic, one-dimensional CCSNe simulator, and NuLib, an open-source library for neutrino interactions, we simulate and analyze the effects of including $\Delta U$ with 7 different equations of state in both failed and successful CCSNe and contrast these runs with those without the $\Delta U$ term for a total of 28 simulations. Using representatives of these simulations, this presentation will provide a brief overview of how supernovae simulations are built, the consequences of considering $\Delta U$, and conclude with a discussion of our findings in the context of supernovae nucleosynthesis.

A Search for Infall Motion in the Perseus Molecular Cloud
Jessica Campbell, University of Toronto
Project Supervisor: Rachel Friesen
Wednesday, 3:15 PM

Low mass stars form in the coldest and densest regions of the interstellar medium through gravitational collapse of dense cores within molecular clouds. Understanding the physical processes that occur on all size-scales of these regions is important when attempting to understand the earliest
stages of stellar formation. Since local environments vastly affect star forming processes, homogenous large-sky surveys of entire molecular clouds have become an efficient tool in understanding these regions. A molecular line survey of optically thin N2D+ (3-2) and thick HCO+ (3-2) are performed on 89 candidate star forming regions within the Perseus molecular cloud using the 30-m James Clerk Maxwell Telescope. Of these, 67 targets (75%) are detected in HCO+ and 10 targets (11%) in N2D+. By analyzing whether the line profiles exhibit an excess of redshifted self-absorption with respect to their systemic velocities as given by the optically thin molecular tracer, we can infer that there exists infall motion towards dense cores in Perseus. We look for correlations of large blueshifted line asymmetry and tracers of advanced evolutionary state such as deuterium fractionation, CO depletion and core concentration. This should be the largest combined infall and deuterium fractionation survey in a single molecular cloud to date.