Spectroscopic Calibrations for the Wide-Field InfraRed Survey Telescope (WFIRST)
Zachary R. Claytor
Mentors: Peter Capak and Dan Masters

WFIRST will measure distances to billions of galaxies using photometry, but a spectroscopic calibration must be performed to acquire the necessary precision. In order to estimate the minimum spectroscopy WFIRST will need, tools were developed to analyze a Self-Organizing Map (SOM), a two-dimensional representation of higher-dimensional galaxy photometry. Using these tools, Monte Carlo simulations were performed using different regions of a SOM to see how photometric error affected the layout of the map. While data sets with recorded photometric error usually had less than 5 pixels of scatter on a 75 x 150 pixel² map, data with missing errors caused more scatter. This lays the groundwork for estimating WFIRST’s spectroscopic requirement. Continuation of this work will build on the existing tools to predict what amount of spectroscopy will decrease the error in the map to the required precision, while future work should attempt to adjust for missing measurements in the data.

Characterization of CZT and CdTe Pixel Detectors for Future Astrophysical X-Ray Missions
Daniel Gawerc
Mentors: Fiona Harrison, Hiro Miyasaka, and Vikram Rana

The Nuclear Spectroscopic Telescope Array, or NuSTAR, has CdZnTe (CZT) hybrid detectors in its focal plane for x-ray observation. Next generation detectors can benefit from NuSTAR analysis. High quality CZT crystal yield is low. Studying CdTe crystals is important, as they were found to have a higher yield than CZT. CdTe crystals are crucial for wider focal plane missions, where more crystals are necessary. CZT and CdTe properties have different upsides and downsides for x-ray detection. Leakage current shot noise fluctuations may be incorrectly read out as x-ray signals in the detected spectrum. It is due to an applied bias voltage and the internal resistance of the crystal pushing a small current into the ASIC. It increases with HV, temperature, and crystal impurities. CZT was confirmed to have a constant leakage current over time. CdTe electrode contacts were compared to ascertain which exhibited the lowest leakage current. Gamma flood, or radioactive source illumination, tests are used to characterize the structure and uniformity of a crystal. $^{241}$Am was used to characterize CZT hybrid H79 by comparing the emitted and detected spectra. Additionally, the NuSTAR laser metrology optics tracking system power decay was estimated as a function of time and intensity.

Spectral Studies of Seyfert 2 Active Galactic Nuclei From the NuSTAR Hard X-ray Observatory
Nikita Kamraj
Mentors: Fiona Harrison and Liz Rivers

Active Galactic Nuclei (AGN) are some of the most luminous compact objects in the universe, frequently outshining their host galaxies. Unification schemes propose that all AGN are essentially the same physical object, with the diversity of AGN classes simply arising from different orientations of the AGN with respect to the observer. This project focuses on the study of the X-ray spectral features of Seyfert 2 AGN observed with the NuSTAR telescope. The high energy X-ray focusing optics of the NuSTAR satellite have enabled AGN spectral features to be resolved to unprecedented detail, allowing tighter constraints to be placed on the geometry of the circumnuclear material. I performed data reduction and extraction processes using the NuSTAR Data Analysis software, followed by spectral modeling of the data using the XSPEC fitting tool. My investigation has focused on modeling the spectra of NGC 4388, NGC 6300, NGC 7172, NGC 1052 and IC 5063, with the results interpreted in the context of Seyfert 1/2 unification schemes.

ClassLess: A Comprehensive Database of Young Stellar Objects
David E. Qu
Mentors: Lynne Hillenbrand and Nairn Baliber

Young Stellar Objects (YSOs) are stars in the early stages of evolution. This classification includes both protostars, contracting fragments of molecular clouds that are still accumulating mass, and pre-main-sequence stars, which have completed accretion but haven’t started burning hydrogen. Currently, there is no predictive model of star formation describing the transition from protostar to the main sequence. Modern advancements in optical and infrared spectroscopy as well as photometry at x-ray to millimeter wavelengths have produced a profusion of observations. However, no convention for compiling the expanding literature of YSO data has been established, unnecessarily scattering efforts to understand the phenomena. ClassLess is a web-based relational database that aims to solve this problem.
Designed with an HTML5/Bootstrap/jQuery user-interface and powered by a Python/Django/PostgreSQL backend, ClassLess allows YSO queries by any combination of coordinates, data columns, or numerical restrictions. Furthermore, we provide plotting, data export, and external cross-references to sites such as Simbad and IRSA. Our upload scripts give us the flexibility to dynamically determine the most fiducial measurements, so our queries can represent the pinnacle of YSO data, condensed in one central repository.

**On the Bounds of the Carbery Rectangle Problem**

Daniel Guth  
*Mentor: Nets Katz*

In attempting to extend a theorem on sublevel sets to higher dimensions, Carbery, Christ, and Wright observed that any measurable set $E$ in the unit square in $\mathbb{R}^2$ not containing the corners of an axis-parallel rectangle with area greater than $\lambda$ has measure bounded by $O(\sqrt{\lambda \log(\frac{1}{\lambda})})$. Under certain conditions the logarithm in this bound can be removed, but it is an open problem whether or not this bound is sharp in the general case. We examine the geometric properties of a specific case where part of the set is $E$ is known.

**Domain Adaptation for Classification in Astronomical Surveys**

Jingling Li  
*Mentor: Ashish Mahabal*

As the data from astronomical surveys increase rapidly due to technological improvements, we hope to transfer the knowledge obtained from existing surveys to better understand futures ones. Since different surveys have different sky coverage, cadence, filters, depth and so on, we can not directly apply the classification knowledge from light-curves of one survey to those of others. Therefore, by finding non-trivial domain adaptation approaches, we can map the information from one survey to another and better utilize the knowledge about existing surveys to explore future ones. As the classification of celestial objects is expensive, being able to use existing labelled information to conduct classification in future surveys will be more cost-effective and promote time efficiency as well. Starting with the light curve data of 50,000 periodic objects’ from Catalina Real-Time Transient Survey (CRTS), we have applied domain adaptation techniques such as Geodesic Flow Kernel (GFK) and Co-training for domain adaptation (CODA) with 35,000 points overlapping with Palomar Transient Factory (PTF), and 12,000 with Lincoln Near-Earth Asteroid Research (LINEAR). The results suggest that domain adaptation is an area worth exploring as the knowledge between these surveys is transferable and the approaches to find the mappings between these surveys can be potentially applied for future surveys such as Large Synoptic Survey Telescope (LSST).

**Ramified Coverings of the Complex Projective Line With Semisimple Galois Groups**

Tian Nie  
*Mentor: Dinakar Ramakrishnan*

Let $P^1$ be the complex projective line and $C$ a smooth projective algebraic curve. Suppose that $f: C \rightarrow P^1$ is a ramified covering of $P^1$ with ramification locus in $\{0,1,\infty\}$. Note that the fundamental group of $P^1 - \{0,1,\infty\}$ is $\mathbb{Z} \times \mathbb{Z}$, the free group of two generators. Hence any quotient of this free group can be realized as the Galois group of some curve $C$. Consider the Heisenberg group $H_n$ which is isomorphic to the matrix subgroup of $GL_3(\mathbb{Z}/n\mathbb{Z})$ generated by $\begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$ and $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{pmatrix}$. We studied the defining equation of a curve $C_n$ which has $H_n$ as its Galois group. We are also interested in the cusps of $C_n$.

**Upper Bounds for Non-Crossing Planar Graphs**

Chenchao You  
*Mentor: Adam Sheffer*

For a set $P$ of $n$ points in the plane, we are interested in an upper bound for the number of various crossing-free graphs that can embedded over $P$, including general planar graphs, spanning cycles, and matchings. Previous methods mainly relied on the triangulations of $P$. To improve upon those previous results, we perform a vertical decomposing a planar graph and define the rank of vertices and edges in it. By only removing and inserting edges of low rank, we obten a recursion for the number of graphs with respect to the number of the edges in them.
The Invariant Theory of the Order 3 Automorphism of \( so(8) \)
Jeffrey Gu
Mentor: Xinwen Zhu

The Lie algebra \( so(8) \) is unique since it is the only Lie algebra to have an order 3 automorphism. This automorphism induces a grading \( so(8) = g_0 + g_1 + g_2 \), where \( g_i \) is the eigenspace corresponding to \( \zeta^i \), where \( \zeta \) is a primitive 3rd root of unity, and the set of fixed points \( g_0 \) is the \( g_2 \) Lie algebra. We seek to describe the action of \( g_0 \) on \( g_1 \) and its invariants, such as the nilpotent cone and nilpotent orbits.