Quantifying Clusters Around Herbig Ae/Be Stars
Viktor Koehlin Lovfors
Mentor: Lynne Hillenbrand

The goal of this project has been to investigate how one distinguishes physically associated young stars from field populations, with an intended application to clusters around Herbig Ae/Be stars. To this end, we have developed a framework for establishing cluster membership and drawing conclusions about cluster parameters given an arbitrary point on the sky. We have written code that queries Gaia, 2MASS and AllWise, crossmatches these catalogs, and provides tools for data cuts and visualization. We differentiate cluster members from field stars using kinematic cuts based on Gaia data and color cuts, both in terms of color magnitude diagrams and IR excess cuts.

We are in the process of validating our code's capabilities on known clusters. Once this is done, it can be used on the full Herbig Ae/Be sample.

Validating Variable Star-formation Conditions in Galaxies
Ethan Garcia
Mentors: Charles Steinhardt and Dave Stevenson

The stellar initial mass function (IMF) describes how many stars at different masses are formed in a galaxy. The IMF should not be expected to be universal across galaxies based on theoretical models, but due to a lack of observational evidence, codes that determine galactic properties from photometry such as redshift, stellar mass, and star formation rate implicitly assume a certain IMF for all galaxies, an incorrect approximation. To resolve this, recent research parameterized the IMF in photometric template fitting of galaxy catalogs with the EAZY fitting code, suggesting that most galaxies form less light-mass stars and more higher-mass stars than in the Milky Way. In this paper, we also implement a parameterization of the IMF in photometric template fitting using "Le Phare", a separate fitting code that fundamentally differs from EAZY. The best fit Le Phare templates on the COSMOS catalog suggest systematic variations in the IMF over redshift consistent with the population distributions found with EAZY, verifying this relationship. Furthermore, not only does the fitting yield modified values for various key galactic properties, but it also validates a more complete picture of galactic evolution.

Modelling Galaxy Evolution With Gas Temperature-Stellar Mass Distribution Feedback
Riley Tam
Mentors: Charles Steinhardt and Stanislav G. Djorgovski

Galaxies exist in a myriad of shapes, sizes, colours, and environments but we observe that they follow a common evolutionary history. This uniformity implies that a feedback mechanism, which is not well modelled or understood, ties together the parameters that affect galactic star formation. Recently, a relationship has been found observationally between two such parameters: temperature in star-forming clouds and stellar Initial Mass Function (IMF), which describes the mass distribution of stars at formation. The resulting model has led to several new predictions such as inside out galaxy growth and compact, hot galaxies at high redshifts. Previous simulations which assume galaxies are monolithic cannot explore such radial variations. Here, we employ GIDGET, a one-dimensional radius dependent galaxy evolution model, incorporate into it a temperature-dependent IMF and compare its results to observations.

Connecting Galaxy Evolution to Black Hole Spin With the Chandra X-Ray Telescope
Shalini Kurinchi-Vendhan
Mentors: Francesca Civano, Laura Brenneman, and Philip Hopkins

The last two decades have revealed a strong connection between the cosmic evolution of galaxies and their central, supermassive black holes. Through constraining their spins, we can obtain a measure of the accretion and outflow processes by which black holes influence their host galaxies. However, current spin measurements are largely biased toward the nearest and most luminous black holes, which constitute only a small fraction of the entire population of active black holes in the Universe. In this project, we probe the full range of masses and accretions of active supermassive black holes by performing a spectral analysis of >3,000 sources from the newest release of the Chandra Source Catalog, covering a broad range of luminosities and cosmological distances. With this spectral analysis, we aim to obtain an average measurement of black hole spin as a function of several source properties, shedding light on their growth and co-evolution with galaxies.
**Constraining Models of M31’s Last Significant Merger Using Its System of Stellar Streams**
Sylvia Wang  
*Mentors: Ivanna Escala, Ana Bonaca, and Philip Hopkins*

Galaxy mergers play a significant role in the hierarchical assembly of large galaxies such as M31 or the Milky Way. M31 has a system of tidal shells which is thought to have originated from the same merger event that created a giant stream of stars extending south of M31. We use Python-based galactic and gravitational dynamics code Gala to model the formation of M31’s tidal stream and shell system. A composite potential with a disk, bulge, and halo component is used to model M31 and a Plummer potential is used to model the satellite galaxy involved in the merger. By varying parameters involved in the simulation, such as the mass of the satellite galaxy or M31, we can produce models with different tidal debris patterns after the disruption of the satellite progenitor. We will constrain these models by making statistical comparisons to the observations made in M31’s tidal streams and shells.

**Developing A Photometric Alert Stream for ZTF’s Lower Variance Transients**
Cason Shepard  
*Mentors: Matthew Graham and Niharika Sravan*

The Zwicky Transient Facility (ZTF) is a new optical time-domain survey that uses the Palomar 48 inch Schmidt telescope. ZTF’s main goal has been to detect and map changes in the brightness of transients to learn about their physical properties. Development of an alternate photometric alert stream algorithm will be critical in the function of LIGO O4, as one of the main targets of monitoring during this new LIGO run will be Active Galactic Nuclei (AGN) in the error volume of a LIGO source. This algorithm utilizes the SQL query pipeline of the Infrared Processing and Analysis Center (IPAC) to detect which sources from the specified catalog of sources have been observed in a given night. Photometric data of corresponding identified sources are then pulled from IPAC using ztfquery and astropy packages. This algorithm uses a cluster-based query system that helps increase database query efficiency and reduce runtime.

**Exploring the Dynamic Infrared Universe: Development of the Wide-Field Infrared Transient Explorer (WINTER) Data Pipeline**
Sulekha Kishore  
*Mentors: Mansi Kasliwal and Viraj Karambelkar*

Soon to be deployed at the Palomar Observatory, WINTER will be the most sensitive all-sky infrared time-domain survey and will search for exotic transients such as kilonovae accompanying binary neutron star mergers. WINTER will generate thousands of potential infrared source candidates per night. Real-time effective filtering and visualization of this enormous data set is necessary to identify transients of interest to conduct follow-up science.

To this end, we built a modular data pipeline that can process, detect, and visualize candidate transients. This data pipeline utilizes Apache Kafka, an open-source distributed event streaming platform, and Kowalski, a multi-survey data archive. All candidates observed by WINTER are broadcast using the Kafka alert stream, which is ingested into Kowalski. On Kowalski, each alert is cross-matched with astronomical catalogs, filtered using user-defined criteria, and saved into MongoDB, a database architecture.

This filtered, augmented data is integrated with Fritz, a science data platform used by the astronomical community to manage and visualize large sets of observational data. Astronomers will use Fritz to scan potential transients from WINTER, identifying those best suited for further study.

Hosted on Github, this modular data processing pipeline is open-source and can be used by other time-domain surveys to process data.

**Hunting for Kilonovae With ZTF and SkyPortal**
Leo Yang  
*Mentors: Mansi Kasliwal and Robert Stein*

Binary neutron star mergers release large amounts of energy through gravitational waves, and a subsequent kilonova releases electromagnetic radiation. Only one kilonova has ever been observed, making it a key topic of study. The electromagnetic radiation released from kilonovae are detected by observatories such as the Zwicky Transient Facility (ZTF), an optical telescope at Mt. Palomar, CA. This project focuses on how data from ZTF is managed and further analyzed to study kilonovae. This is done by improving SkyPortal, the main data platform of the ZTF collaboration. This platform lets astronomers manage, analyze, and collaborate on astronomical data. Improvements to Skyportal include finding associated classifications for transients saved in the database based on the time of their original detection and tracking follow-up observations reported by other observatories using NASA’s Gamma-Ray Coordinates Network. Automation by the means of SkyPortal will reduce the latency in scientific analysis and will lead to more efficient studies on kilonovae during LIGO/Virgo/KAGRA’s O4 observing run.
Updating M-Mode Mapping With the New OVRO-LWA
Xander Hall
Mentors: Gregg Hallinan and Ruby Byrne

The Owens Valley Long Wavelength Array (OVRO-LWA) is a low frequency radio interferometer. It is composed of 288 crossed broadband dipole antennas and cover 58 MHz of bandwidth below 88 Mhz. By utilizing Tikhonov-regularized m-mode analysis imaging we have been able to produce all sky radio maps. These maps provide valuable insight into the cosmic dawn of the universe and offer a powerful tool to identify radio transients.

Stellar Radio Transients in the Very Large Array Sky Survey
Carlos Ayala
Mentors: Gregg Hallinan and Dillon Dong

Stellar radio transients can be attributed to radio-emitting mechanisms associated with stellar magnetic activity. We present a sample of stellar radio transients brighter than 1 mJy in VLASS Epoch 2.1/2.2 but absent from VLASS Epoch 1.1/1.2, observed over the 34,000 square degree field of the Very Large Array Sky Survey (VLASS). We cross matched these transients with stars in Gaia DR3 to identify those with a low chance association probability, taking into account changes in proper motion and astrometric uncertainties. Our angular resolution of ~2 arcseconds accompanied by the low areal density of transients decreases the likelihood of false associations with background sources, allowing us to identify a robust sample of stellar radio transients. The high sensitivity and large sky coverage of VLASS further make this the largest blind search for stellar radio transients by volume. To better classify these stellar radio transients, we identified infrared and X-ray counterparts from WISE and ROSAT, while also obtaining Gaia properties and TESS lightcurves. The final sample consists of 75 stellar radio transients, including close binaries, young stellar objects, M dwarfs, and other classes of radio-emitting stars. Our sample will facilitate in-depth studies of radio-emitting systems, including young stellar objects and chromospherically active binaries, particularly with regards to the rate of the most energetic radio flares from these classes of objects.

Using Radio Transients From VLASS to Search for Binary Neutron Star Mergers
Evan Portnoi
Mentors: Gregg Hallinan and Casey Law

In recent years, advances in instrumentation and computing have allowed or an explosion in astronomical data available, such as sky surveys that image of 80% of the sky at once. This allows for the easy discovery of transients, where a signal becomes significantly brighter or dimmer over time. Hopefully, one of these transients will the collision between a system of two neutron stars, which has never been found before. This can be accomplished by first finding the host galaxy for each transient and using the characteristics of those galaxies to determine the best candidates. Follow-up observations can provide enough information to create light curves which can be compared to the theoretical light curves. Assuming they share enough characteristics, it would be the first recorded discovery of a binary neutron star merger.

Probing CDM Interactions in High-z Galaxy Clustering With the BUFFALO HST Survey
Adele Basturk
Mentor: Charles Steinhardt

Analyzing the clustering behavior of galaxies across a wide redshift range allows us to model the gravitational assembly of such structures over cosmic time. We achieve this by measuring the 2-point correlation of galaxies at 0.01 < z < 8.5, gravitationally lensed by the foreground cluster Abell370 in BUFFALO. With this understanding, we can probe our current model of Cold Dark Matter (CDM), specifically the assumption that it interacts solely through gravitation. More importantly, studying galaxies at high redshift gives us a more complete picture of clustering at various snapshots in time. In this talk, I will summarize how the correlation function informs us about galaxy clustering behavior, my results from running correlation functions in both the COSMOS 2020 and BUFFALO surveys, and share how predictive clustering calculations at different redshift and mass bins compare to measured correlations.