2021 Undergraduate Summer Research Presentations
Wed, Aug 4, Flatiron Institute

9:30 – BREAKFAST
9:50 – Welcome remarks: Tim Paglione

10:00 - Mohammad Refat (CUNY Baruch College)
Towards Mapping Brown Dwarf and Giant Exoplanet Atmospheres
Mentor: Johanna Vos (AMNH)

Brown dwarfs and exoplanets have atmospheres with complex clouds in their atmospheres. Variability monitoring is a powerful tool that can probe these clouds. Variability monitoring has been carried out for a large number of brown dwarfs in the literature, and a small but growing number of directly-imaged exoplanets. Recently, Tan et al. (2021) used three-dimensional atmospheric models to simulate the atmospheres of exoplanets and brown dwarfs. These models produce the most detailed surface maps to date and produce light curve variability similar to what has been observed in brown dwarfs. With this simulated dataset, we are able to test mapping techniques for potential future exoplanet research. The starry package is a set of tools which are used to map stars and exoplanets based on time series data. We used the Starry software (Luger et al. 2019) to investigate if it can produce the correct surface maps from the light curve data. We used Starry to produce maps that match the light curves, however degeneracies remain between different maps that can fit the light curves equally well. In future work, we will continue to work with Starry to try to identify and constrain non-degenerate parameters such as viewing inclination, spatial extent of atmospheric features and the timescale for evolution. We will also apply these tools to light curves from real brown dwarfs and exoplanets in the future.

10:15 – Sophia L. Miskiewicz (Stevens Inst. of Technology)
Using Inference to Trace Neutrino Flavor Evolution from Core-Collapse Supernovae
Mentor: Eve Armstrong (New York Inst. of Technology)

We evaluate the reliability of an optimization-based data assimilation (D.A.) approach when given varying sets of measurements for tracing neutrino flavor evolution from a core-collapse supernova (CCSN).
Neutrinos' interactions with matter, governed by the property of neutrino flavor, could play a significant role in setting the neutron-to-proton ratio within the supernova cloud. This in turn dictates which elements can be formed in the cloud. Considering the impact that neutrino flavor may have on nucleosynthesis and mechanisms of supernova explosions, we aim to trace how flavor evolves from the time when neutrinos are released at the neutrinosphere until they are detected near Earth.
Traditional computational techniques fall short of addressing this problem due to their inefficiencies and difficulties with nonlinearity. Instead, we use an optimization-based data assimilation (D.A.) procedure. The D.A. procedure seeks to optimize conformity to a model and a set of measurements to infer about the flavor state at each location. We seek to map out the reliability of D.A. in different parameter regions and to determine what information the procedure requires to make accurate estimates.
We find that by sampling vacuum oscillations at a few locations near the final Earth-based detector, the D.A. procedure can make an accurate prediction about whether bipolar oscillations occurred near the neutrinosphere. This means that vacuum oscillations taking place near Earth contain information about the initial flavor states and the bipolar oscillations close to the neutrinosphere. Flavor evolution in the form of bipolar oscillations could significantly impact nucleosynthesis within the envelope. Importantly, sampling vacuum oscillations at three to five locations near the Earth is a realistic possibility in the case of a detection from an actual supernova considering the current number of neutrino detectors and those anticipated in the near future.

10:30 – John Meftah (CUNY City College)
Hydrodynamic Simulations of Multiple, Low Mass, Migrating Black Holes in AGN Disks
Mentors: Saavik Ford, Barry McKernan (CUNY BMCC), Jillian Bellovary (CUNY Queensborough)

The Laser Interferometer Gravitational-Wave Observatory (LIGO) infers a high merger rate of stellar-mass black hole binaries (sBHBs). Active Galactic Nucleus (AGN) disks are likely locations for sBHBs. Those objects will feel the gravitational pull of gas on resonant orbits, forming spiral arms around them: head and tail arms. The head, or lead arm, accelerates the object in the outward direction, while the tail arm slows down that acceleration forcing it to move inwards. Thus, two compact objects in a system orbiting a Supermassive black hole (SMBH) are likely to merge at a faster rate over time. The gas torques force orbiting objects to migrate within the disk. The spiral gas arm act as a catalyst that speeds up the interaction between the two bodies. If there are regions of the disk where inward and outward migration torques cancel, migrators can stall at traps, possibly encountering each other and merging at high rates. Using the Pencil code, we simulate how stellar-mass black holes migrate in model AGN disks, and how the presence of more than one migrator may change the speed at which migration occurs. Our aim is to study the interference and interactions of spiral density waves of two migrators in the disk to see if this speeds up or slows down the migration and the merger of compact objects in AGN disks. Preliminary results suggest that the leading arm of an outer migrator interferes with the tail arm of an inner migrator, which may drive objects together faster than expected. If true, this could increase the number of sBHB mergers from AGN disks detectable by LIGO in gravitational waves.

10:45 – Hanh-Tu Do (Tufts Univ.)
P-T Estimates of Metabasites in the Eastern Blue Ridge, North Carolina
Mentors: Céline Martin, Steven Jarret (AMNH)

North Carolina Eastern Blue Ridge metabasites within the Ashe Metamorphic Suite have been largely recognized as eclogite bodies whose primary metamorphic assemblage includes garnet, omphacite, quartz, and rutile. Plagioclase and hornblende appear as retrograde phases. Two sites within the province, Boone and Bakersville, lie approximately 50-60km apart from one another. Their P-T estimates are insufficiently constrained, and Ti-bearing minerals can help refine their P-T paths. Indeed, rutile is stable at higher pressures than titanite, and both can incorporate Zr into their lattice structures with increasing temperature.
Using the CAMECA SXFive EMPA at the American Museum of Natural History (New York), X-ray maps and quantified profiles were obtained on thin sections from both sites and processed using XMapTools 3.4.1 (Lanari et al., 2014). Application of the Zr-in-rutile thermometry model established by Ferry & Watson (2007) generated the following temperature estimates: In three samples from Bakersville, rutile inclusions in garnet yield prograde temperatures of 625-630°C, while rutile grains in the matrix recorded peak temperatures of 700-720°C. Two samples from Boone contain some rutile grains mostly at the edge of garnet and in the matrix that both yield temperatures of 600-620°C.
These preliminary results allow for refinement of the previous estimates obtained using mineral equilibrium on Bakersville samples, as rutile in garnet crystallized during prograde path at ~630°C (previously estimated at 400-680°C) and matrix rutile during peak metamorphism at 700-720°C (previously estimated at 600-800°C). Previous estimates for Boone peak metamorphism are approximately 720°C based on re-integrated omphacite. Our results for rutile included in garnet are significantly lower at 600-620°C, which may indicate that rutile crystallized during prograde path

11:00 – Nathalia Torres (CUNY BMCC)
Connecting Weirdos in Binaries from X-rays to Gravitational Waves
Mentors: Katie Breivik, Mathieu Renzo (Flatiron Inst. CCA)

We use COSMIC (Compact Object Synthesis and Monte Carlo Investigation Code), a rapid population synthesis code to simulate binary star systems which evolve to become X-ray binaries and gravitational wave mergers. Rapid population synthesis is unique from typical stellar evolution codes because it is much faster; it models stellar populations from their birth until their death with the same computational resources as a traditional code would need to simulate a single binary star's evolution.
This project focuses on stellar objects: HMXB 153919 & GW 190814. It aims to simulate data of a binary system's evolution where the two objects do not merge before the X-ray binary forms. One way for this to happen is to require much angular momentum to be lost during mass transfer. During the formation of the black hole, the supernova explosion 'kicks' the compact object which can also stop the binary from merging. This project aims to

connect the "weirdo" in GW event (190814) coalescence and the other odd compact object in HD 153919. We are attempting to identify the similarities between these two systems by simulating several binaries using COSMIC. We should be able to recreate possible "lifelines" for these yet to be identified objects.

11:15 – Maya Merchant (Univ. of Toronto)
Investigating Properties of Protoplanetary Disk Structure
Mentor: Aleksandra Kuznetsova (AMNH)

Protoplanetary disks are the birthplaces of planetary systems like our own. Disk substructures such as gaps and rings are crucial in the detection of planetary formation, as the absence of material in their presence can reveal potential sites of planet-disk interaction. Specific radiative intensity emitted from disks can be compared to physical parameters such as surface density and temperature as a metric for disk structure, and interpretations of the relationships between these parameters can provide insight into potential planets and substructures within the disk. In this talk, I will discuss the effects disk substructure has on observed emission in the context of both steady-state and dynamical protoplanetary disk models; the steady-state models used are protoplanetary disks with differing surface density profiles, and the dynamical models are protoplanetary disks with infall and substructures at certain radii, as observed in simulations. We use the RADMC-3D radiative transfer code with intermediate inputs of dust density and opacity to create synthetic disk images, from which we compare intensity with surface density to consider a relationship between disk emission and observed material. We also look at this process in dynamical models to investigate the effects of more realistic disk substructures on observed emission profiles. Future studies will include expanding on these interpretations and determining other parameters needed to understand the relationship between emission and disk structure.

11:30 – BREAK

11:45 – Shawn Blackman, Samin Mahmood, Lenin Nolasco (CUNY LaGuardia)
Identifying Red Giants from APOGEE-2 within the Palomar 5 Stellar Stream
Mentor: Allyson Sheffield (CUNY LaGuardia)

Palomar 5, a tidally disrupted globular cluster with stellar streams, orbits in the outer halo of the Milky Way. The cluster itself was originally discovered in 1950, and its tidal streams were detected in 2002. The orbit of Palomar 5 is located in the outer halo of the Northern Galactic Hemisphere of the Milky Way. We attempt to identify new Red Giant Branch (RGB) members within the stream using spectroscopy from the APOGEE-2 DR17 and photometry and astrometry data from Gaia. From the full APOGEE-2 DR17 catalog of 691,635 stars, we isolated two fields that were pointed in the direction of the Palomar 5 system. From these two APOGEE-2 Palomar 5 pointings, we narrowed down 21 stars out of 997 that have a similar proper motion as the Palomar 5 stream. Looking at their metallicities, we then narrowed our sample down to five potential Palomar 5 candidates. We present the radial velocities and the color-magnitude diagram of these five candidates, and we then compared them to other known RGB stars within Palomar 5. We tentatively found two possible new members of the Palomar 5 system. For future work, we will look at the chemical abundances of these two possible members to determine whether they belong to the Palomar 5 system. By exploring the APOGEE-2 and Gaia catalogs, we look to expand the dataset of known RGB members of the Palomar 5 tidal stream.

12:05 – Sarah Medina (CUNY City College)
Solar-like Oscillation Diagnostics in Pre-Main Sequence Stars
Mentor: Joel Zinn (AMNH)

Because all stars pass through the pre-main sequence phase before entering other stages of evolution, understanding the physics of the pre-main sequence evolution is essential in understanding the foundation of all stars. However, existing models of pre-main sequence stars do not agree and are not well calibrated. To understand why these models are inconsistent, it is best to go beyond the traditional diagnostics like luminosity and temperature. Generally, stars oscillate in different modes when excited and the frequencies of these oscillations are dependent on the star's temperature, density, and stellar interior, among other contributing properties. Matching observed and modelled frequencies of oscillations in stars that are excited in the same way as the Sun, via convection, has improved our understanding of stellar interiors and evolution. In this project, I look at these so-called solar-like oscillations of pre-main sequence stars and in using asteroseismic metrics**,** I will show the potential of asteroseismology for constraining pre-main sequence models. I will discuss the calculation of these metrics from models using MESA, a code that runs stellar models, and GYRE, a code that extracts information from MESA and solves solar pulsation equations that also computes frequencies. I will show how these predictions will also be useful in evaluating claims of pre-main sequence solar-like oscillation detections. I will conclude with potential applications of TESS, Transiting Exoplanet Survey Satellite, to determine more pre-main sequence candidates that undergo solar-like oscillations.

12:20 – Destiny Howell (CUNY Hunter College)
Gravitational Waves is the key to the Binary Black Hole System
Mentors: Masha Okounkova, Tom Callister (Flatiron Inst. CCA)

This presentation will work to uncover the definition of the binary black hole parameters to learn more about their "typical" properties using gravitational wave observations. Gravitational waves are ripples in space when two black holes rotate and accelerate around each other. Those ripples help us to understand more about the properties in a binary black hole system. Additionally, this presentation will work to develop a comprehensive understanding of how well we measured these gravitational waves' parameters. Finally, I will explain the different parameters describing gravitational-wave sources. Python is used to create these data, plots, and graphs to learn more about the gravitational wave events. In our discovery, we learned which components were measured well while others we didn't measure well. Uncertainties are very prominent in this scientific research because there wasn't an effective way to measure some of these components in the presence of detector noise. These uncertainties made it harder to understand more about the gravitational waves' characteristics.

12:35 – Rheanna F. Fleming (Williams College)
Variations in Mineral Abundance and Morphology of LL3 Ordinary Chondrites
Mentors: Denton Ebel, Marina Gemma (AMNH)

Chondrites formed before the differentiation of the protoplanetary disk and contain some of the most primitive material in the solar system. Ordinary chondrites are the most abundant meteorites in collections globally. Meteorites are assigned a petrologic type based on the degree of metamorphic change they experience. Ordinary chondrites provide a snapshot of meteorites at a variety of metamorphic stages and collectively display changes across a petrologic range. Analyzing the morphology and mineral abundances of ordinary chondrites of differing petrologic types can reveal the chemical and physical processes that were occurring at the time of early solar system planet formation. Using the meteorites Semarkona (LL3.0), Krymka (LL3.2), and Parnallee (LL3.6) from the AMNH meteorite collection, I expect to find that the size of their metal grains increases parallel to the petrologic type, but changes in morphology are a challenge to predict. To examine the 3D structure of meteorites, I used data of the three samples from a computed tomography (CT) scanner, which shows the densities of each sample in grayscale values. In Dragonfly, a 3D visualization software, I manually segmented the iron and nickel rich metal, sulfides, silicates, and matrix by visual thresholding in 6 out of 1611 slices. These 6 slices were used to train the Artificial Intelligence algorithms in Dragonfly to identify these different mineral phases in the remaining 1605 slices. Once these mineral phases were segmented, I was able to calculate the volumes of each phase compared to the total volume of the sample and individually separate the phases in the 3D volume. The preliminary results show mineral volumes consistent with previously reported 2D and powdered samples.

12:50 – LUNCH

1:50 – Keisi Kacanja (CUNY Hunter), Kayla Docher (Barnard College)
Gamma-Ray Halos Around Luminous Stars
Mentor: Tim Paglione (CUNY York College)

Gamma-ray halos form around stars when cosmic ray electrons interact with stellar photons, in a process known as inverse Compton scattering. We have detected a gamma-ray halo around our Sun, but have not yet detected any around other stars. Our work attempts to detect this pattern of gamma-ray emission around stars outside of our Solar System. Using Fermi-LAT data, we generate a test statistic (TS) map for each star that indicates the likelihood of a gamma-ray halo source being present. Gamma-ray halo detections tend to be very faint, so we stack the TS maps in order to see a combined signal of stellar gamma-ray halos.

2:15 – Lauryn Williams (Univ. of Missouri)
Identifying Dynamical Masses of Long Period Companions Using Orbit Fitting Code with HGCA Astrometry
Mentor: Jackie Faherty (AMNH)

Sweeping advances in space telescopes paired with the innovative methods of computational astronomy give us a unique opportunity to detect and measure the dynamical masses of substellar companions orbiting stars outside our solar system. ESA's space based HIPPARCOS and Gaia observatories have yielded precise astrometric measurements that – when combined – open a window on the detailed astrometric behavior of stars. Brandt et al. 2021 recently created the cross-calibration Hipparcos-Gaia Catalog of Accelerations (HGCA). In this work, we concentrate on 46 accelerating stars within 20pc of our sun focusing on those objects with long-term precise radial velocity curves from Keck's HIgh Resolution Echelle Spectrometer (HIRES). Combining the acceleration information with the radial velocity curve, we use the complex orbit-fitting code called ORVARA (Orbits from Radial Velocity, Absolute, and/or Relative Astrometry), to obtain explicit constraints on the dynamical masses of the companions. Preliminary results have yielded the dynamical masses for companions around two well studied stars: 14 Her and 15 Sge. There remain 44 sources within 20pc that can be further analyzed. Studies of these accelerating stars are a pathway to understanding the hidden multiplicity fraction of our solar neighborhood.

2:30 – Marcus Dormena (CUNY City College)
Black Hole Mergers
Mentor: Jillian Bellovary (CUNY Queensborough)

Black Holes are really exciting! Especially when they merge, which is what I'm researching. I am studying black hole mergers using simulated data. This simulated data uses data of just before and after the collisions of binary black hole systems and I am using them to measure the properties of each black hole. I will use this information to find out where black holes are located within each galaxy as well as how abundant they are. I will determine what the galaxies are like and the typical distances between black holes and the galaxy centers.

2:45 – Charles Lee-Georgescu (CUNY LaGuardia)
Companion mMass Loss in Pulsar Binaries
Mentor: Josh Tan (CUNY LaGuardia)

Pulsars are fast-rotating, highly magnetic neutron stars. When they exist in binaries, mass transfer can occur in the system, and this is believed to be the origin of all millisecond pulsars. Apparent gaps in the distribution of masses of pulsar companions and binary periods help constrain binary evolution models and provide insight into binary pulsar lifecycles or possible recycling pathways. This research aims to evaluate ways companion mass loss in such systems might proceed to gain a better understanding of the evolution and transitions between types of binary pulsar systems.

3:00 – BREAK

3:15 – Jahmel Saltus (CUNY College of Staten Island)
Studying the Co-evolution of Galaxies and AGN During Reionization
Mentor: Sultan Hassan (Flatiron Inst. CCA)

We use semi-numerical models to generate plausible reionization realizations as predicted by Galaxy and AGN source models. We constrain these different source models against the neutral fraction measurements by the end of reionization, using a combination of machine learning and Bayesian inference techniques. We show how the neutral fraction measurements can be used to distinguish between different source models of reionization.

3:30 – Kaitlyn Goss (Mt. Holyoke College)
Lewis Cliff 87223, an anomalous enstatite chondrite with implications for the origin of Ear
Mentor: Mike Weisberg (CUNY Kingsborough), Mabel Gray (CUNY Grad Center)

Enstatite chondrites are a type of primitive (undifferentiated) meteorite critical to understanding the formation of the inner solar system, including formation of Earth. Lewis Cliff (LEW) 87223 is a unequilibrated (E3) enstatite chondrite with some unusual characteristics not observed in any other E3 chondrite, and provides the opportunity to consider a wider range of conditions these chondrites could have formed under. It was first classified as an E3 chondrite (Mason, Antarctic Meteorite Newsletter 1989). Later it was considered an "unusual E3 chondrite" and thought to be a possible link between the ordinary and enstatite chondrite classes (Grossman et al., 1993). More recently, after looking at its oxygen isotopic compositions, it was classified as a "unique E3 chondrite" and thought to be a possible new group of enstatite chondrites (Weisberg et al., 1995; Weisberg and Kimura, 2012). We used the polarizing light microscope, Electron Probe Microanalysis (EPMA), and the Scanning Electron Microscope (SEM) with backscattered electron (BSE) imaging to put together maps and images of a thin section of LEW 87223 to study the distribution of elements within the metal-rich nodules and chondrules, as well as do a quantitative analysis of the minerals. To compare this sample with a more typical E3 chondrite, we also studied the Asuka-881314 E3 chondrite. Plane polarized light images show the chondrules in LEW 87223 have been shock darkened, suggesting an impact event with pressures of 40-50 GPa. Element maps show that LEW 87223 has a higher amount of Ca-Al rich chondrules than any other E3 chondrite, some of which seem to be "hybrids" of Ca-Al-rich inclusions and typical chondrules. This is a primary feature that suggests a high amount of Al in this meteorite and makes this a notable feature of LEW 87223. From our quantitative analysis, we were able to determine that there are two types of metal in the sample: taenite with 10 wt. % Ni and a kamacite with 4% Ni, which has not been seen in other enstatite chondrites. However, the Si content of the metal (0.5 %) is typical of EL3 chondrites. The metal compositions record temperatures of ~700°C, and may indicate a heating event. LEW 87223 has notable features that separate it from any other enstatite chondrites, of which some are primary and some may be the result of an impact event on the EL3 parent asteroid. It has been suggested that Earth formed from material similar to enstatite chondrites, but one issue is their low Al/Si ratio. Therefore, the relatively high amount of Al-rich chondrules in LEW 87223 is an important observation. It suggests that some enstatite chondrites may have higher Al contents, potentially more similar to that found in Earth. Continuing to look into these features can provide a better understanding of how LEW 87223 originally formed, its thermal history, and give more insight to the origin of Earth.

3:45 – Ella Hort (Pomona College)
SIMPLE Brown Dwarf Database
Mentor: Kelle Cruz (CUNY Hunter College)

The SIMPLE Database (the Substellar and IMaged PLanet Explorer Archive of Complex Objects) is a collaboratively built and maintained database of brown dwarfs, as well as some low-mass stars and directly-imaged planetary mass objects. Eventually, we envision SIMPLE containing high numbers of lightly curated specs of these specific objects. The goal of the database is to make data about these brown dwarfs widely available to the scientific community as a whole while facilitating the sharing of information between interested parties. Additionally, we hope for the database to eventually be widely collaborative, with anyone being able to submit changes using the Github workflow. The database is being created and populated in real time, with both a web interface and an SQLite db Database. The website provides a way to visualize spectra and images of objects in the database, whereas the SQLite db file can be interacted with directly. Datasets are ingested into the database through python coding and interaction directly with the SQLite db file. Ingest scripts utilize a combination of general functions that will be usable for ingesting data across all datasets as well as individually tailored parameters specific to the dataset being ingested. Throughout the summer, I have ingested data on the faintest brown dwarfs (Y dwarfs) and a set of brown dwarfs observed with HST. I am currently working on ingesting over 2000 objects from the Best et al. (2020) compilation of brown dwarfs and low-mass stars, leaving the database with approximately 3000 objects.

In the future, I will continue to ingest data to populate the database, making it more useful for the scientific community as a whole.

4:00 – Mary Jimenez (George Mason Univ.)
Measuring Inclination Angles of Stars in Young Moving Groups
Mentor: Jackie Faherty (AMNH)

Measuring a stellar inclination angle, or the angle between a star's axis of rotation and our line of sight, is a key to understanding stellar formation and dynamical evolution. The gravitational collapse of a turbulent molecular cloud leads to the formation of a stellar cluster. The stars in this cluster share similar kinematic and physical properties and are predicted to adopt the angular momentum imparted at formation on the parent cloud. Previous studies have analyzed a handful of clusters but largely focused on a small subset of higher mass (F and G star) members. In this work, we introduce a new investigation on a very nearby (<100 pc) and young (~45 Myr) moving group with numerous low mass stars. We combined rotation rates acquired from TESS light curves, vsin(i) measurements from high resolution spectroscopy, and estimates of the stellar radii from Gaia astrometry to measure the inclination angles of stars in the Tucana-Horologium Association. We analyzed the sample for bulk spin-axis alignment (or not) as an indication that the angular momentum of its parent molecular cloud was conserved (or not). We also looked at the spatial distribution to see if there was any correlation with spin-axis clustering. We plan to continue our work to confirm the validity of these angles and extend this analysis to stars in other local moving groups.

4:15 – Closing remarks: Denton Ebel

4:30 – RECEPTION