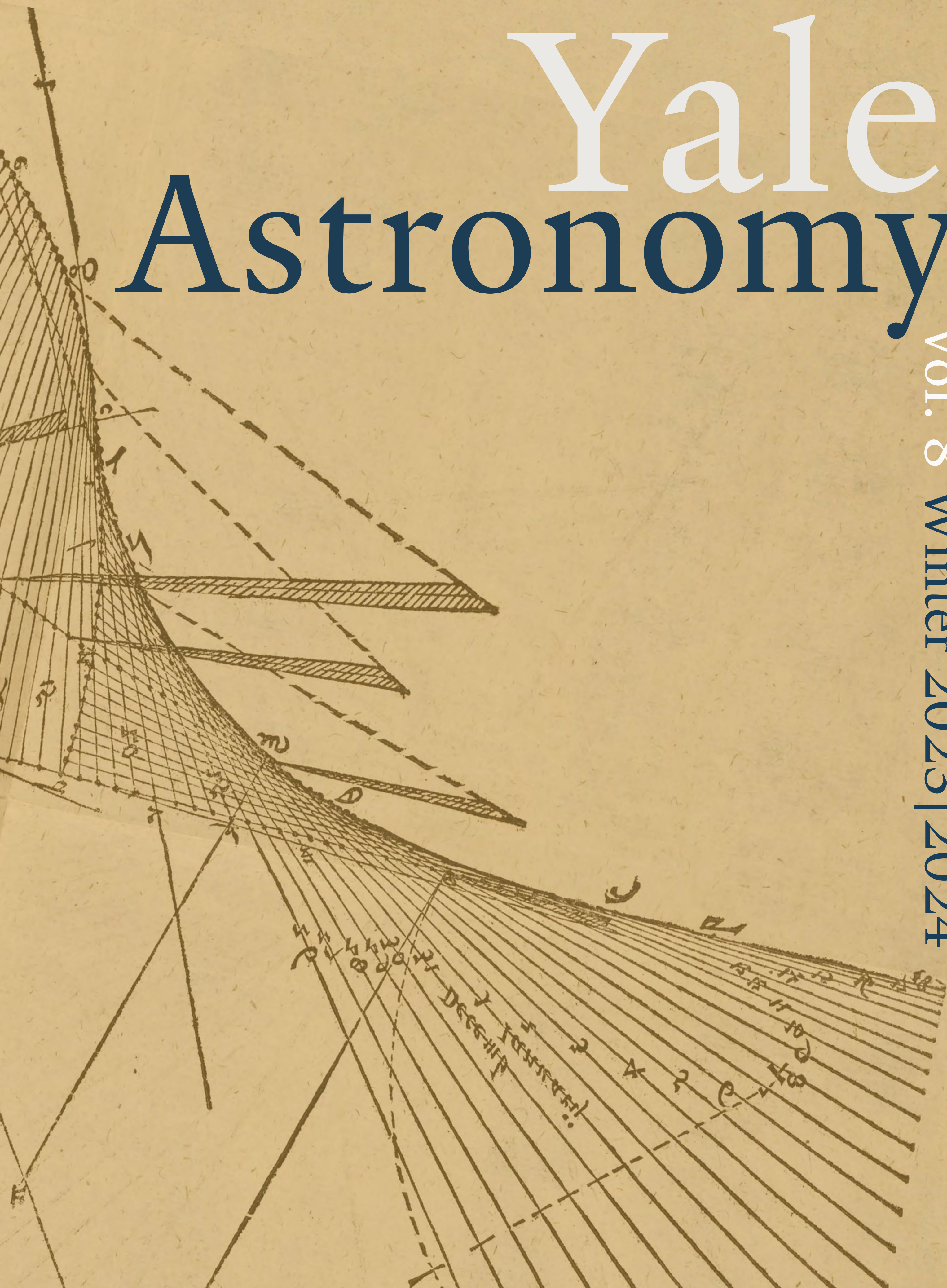
Yale Astronomy

Vol. 8 Winter 2023|2024



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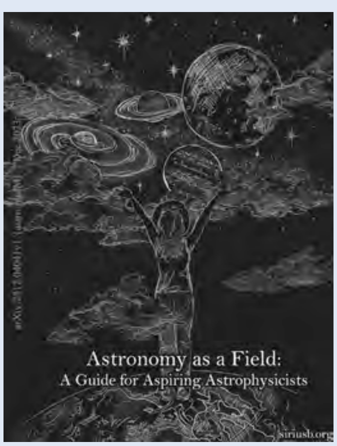
Astronomy as a Field: A Guide for Aspiring Astrophysicists

Congratulations to the current and alumni members of the **Yale Astronomy** and **Physics** departments for their contributions to the book ***"Astronomy as a Field: A Guide for Aspiring Astrophysicists."*** It's fantastic to see initiatives like the SIRIUS B VERGE program, the Women and Girls in Astronomy Program, the International Astronomical Union's North American Regional Office of Astronomy for Development, and the Heising-Simons Foundation supporting the development of educational resources in astrophysics.



Find the guide here on the arXiv

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About the cover:

The background image is a foldout image from Johann Kepler's De cometis libelli tres (which translates from Latin as Three booklets about comets). The first edition, published in 1619, is kept at the Beinecke Rare Book & Manuscript Library, Yale University.

Greetings from the Chair

Dear alumni, colleagues and friends,

Welcome to our annual Yale Astronomy Department newsletter. We have moved! We now occupy a triplet of internally connected floors in the renovated Kline Tower. We are in floor 5 and 6 and our colleagues, the Astrophysics group in the Physics Department are on the 4th floor. We are slowly settling down and enjoying the multiple communal spaces, meeting rooms and our new offices. It has been wonderful to interact, discuss science and convene in the 5th floor lounge over a slice of pizza on Thursdays. This more congenial layout has helped catalyze more interaction, and collaboration and is helping us forge a stronger sense of community.

And in further exciting news, we are eagerly waiting for our newest junior faculty recruit, Earl Bellinger, who works on data-intensive astronomy to join us this January. He comes to us from the Max Planck Institute for Astrophysics, where he was a group leader. He is a co-developer of the MESA stellar evolution code his work has centered on pulsating stars. We are thrilled to grow in this new, emerging intellectual direction. One that will help us take advantage of the upcoming data deluge with many new facilities and instruments poised to begin operations in the coming years.

Yet again, it has been an impressively productive year with many breakthrough science discoveries from our vibrant community of faculty, postdocs, grad students and our undergrads. Many of us have had exciting new results from JWST, with it revealing the most distant galaxies and accreting black holes.

In this issue, once again, I share with great pride the scientific results and on-going research projects of our senior graduate students. I am also delighted to share alumni notes, from many of you who sent us updates.

I close with a deep sense of gratitude and with warmest wishes for a wonderful holiday season and a healthy, happy 2024,

Priyamvada Natarajan

Chair, Department of Astronomy
Joseph S. and Sophia S. Fruton Professor of Astronomy & Professor of Physics
Director, The Franke Program in Science & the Humanities

PS: we invite you to consider supporting the Department's activities with a range of giving options that can be found on the giving page on our department website.

The Yale Department of Astronomy pursues a wide array of activities, ranging from public outreach with the Leitner Family Observatory and Planetarium to creating innovative instrumentation and obtaining observing nights with the world's largest telescopes. These represent an equally wide array of funding opportunities, and together with Yale's Office of Development, we are committed to finding optimal matches between donors and initiatives. These include naming opportunities for instruments, telescopes and programs.

To learn how you can support Yale Astronomy and its students, please contact the Chair of the Department of Astronomy, Priya Natarajan, at priyamvada.natarajan@yale.edu

Or, visit the Yale For Humanity giving page at https://forhumanity.yale.edu/ select "Strategic Initiatives," scroll down to click on "Other" and then select "Continue" then enter "Miscellaneous Gifts – Astronomy -14358" along with your gift amount.

Yale's mascot, Handsome Dan XIX, reading last year's newsletter

Image credit: Muttography & Co.

The Robert F. Wing Fund
for Undergraduate Research
GIVING CHALLENGE

Bob Wing '61 is pleased to announce that he has made a starter gift to the Robert F. Wing Fund for Undergraduate Research in Astronomy, and he would like to invite and challenge others to join him in supporting this important fund in the Yale Department of Astronomy.

The Wing Fund is a current use fund to support the Department of Astronomy. It will enable undergraduate students to participate fully in the research activities of the Department. It will permit the Department's students, including members of historically underrepresented groups, to experience the benefits of direct interaction with ground-based observational technology by supporting student travel to observatories and data-analysis skill building. The Fund will also support the cultivation of student outreach communication and presentation skills to all levels of audiences.

Y for Humanity
THE YALE CAMPAIGN

HOW TO GIVE

To support the Yale Department of Astronomy, please send a check payable to Yale University to the address below with "Robert F. Wing Fund for Undergraduate Research in Astronomy - 15108" in the memo line.

Yale University Office of Development
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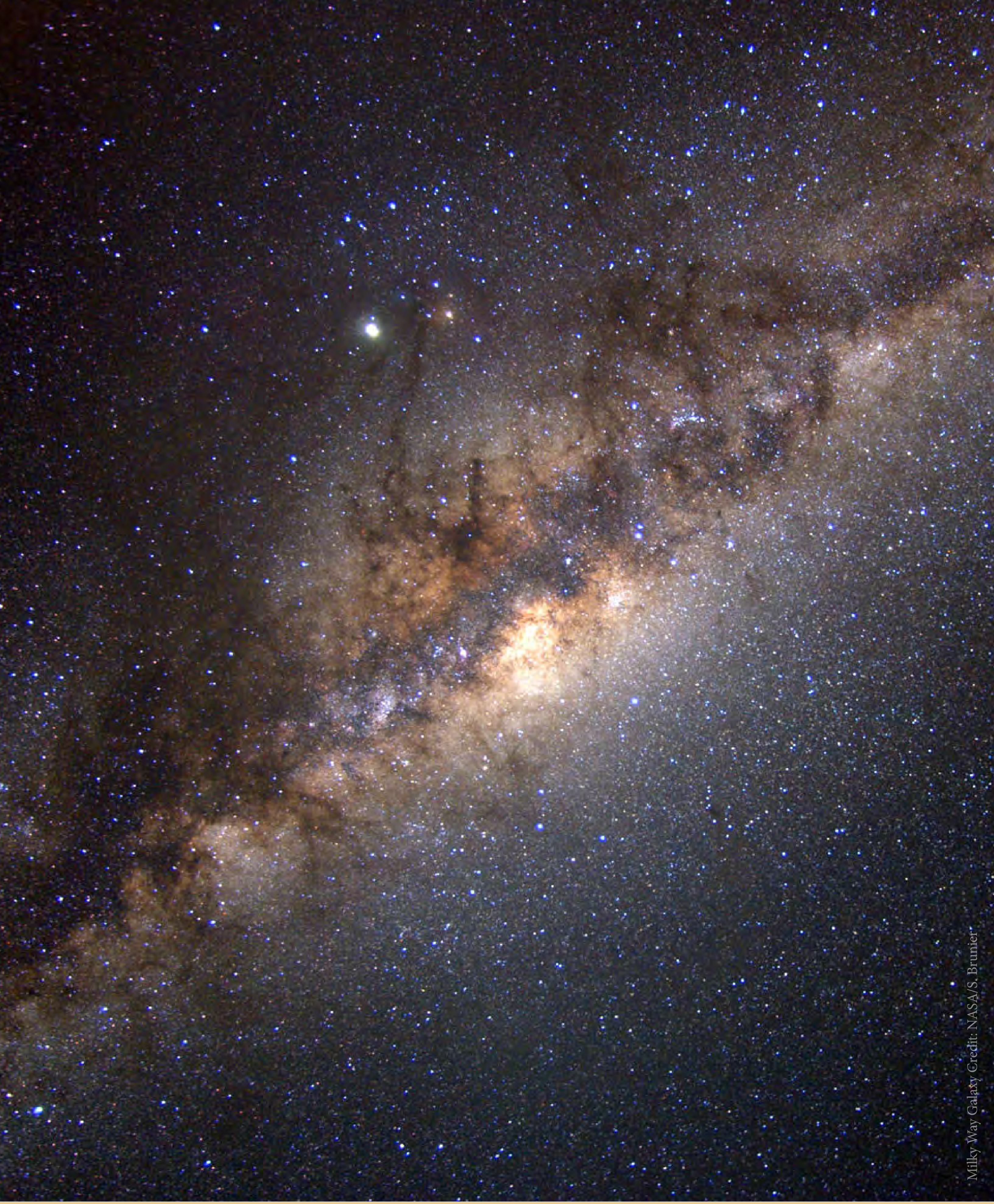
Visit the Yale For Humanity giving page https://forhumanity.yale.edu/, select "Strategic Initiatives," scroll down to click on "Other" and then select "Continue" to type in "Robert F. Wing Fund for Undergraduate Research in Astronomy - 15108", as the designation, with your gift amount.

If you have any questions about supporting the Robert F. Wing Fund or other efforts in Astronomy, please contact the Chair of the Department of Astronomy, Priya Natarajan at priyamvada.natarajan@yale.edu.



Milky Way Galaxy Credit: NASA/S. Brunier

MEASURING OUR MILKY WAY GALAXY

written by William van Altena, *Professor Emeritus of Astronomy*

From the beginning of the 20th century astrometric research at Yale focused on investigations into the distance scale, structure, and kinematics of our Milky Way Galaxy. With the arrival of the Heliometer in 1884, William Lewis Elkin carried out a series of pioneering determinations of stellar parallaxes leading to what the father of modern astrometry, Frank Schlesinger, called "… by far the most important single contribution to our knowledge of stellar distances up to that time." Following Elkin's retirement, Schlesinger moved to Yale in 1920 to continue research on stellar parallaxes using the techniques of photographic astrometry he had developed at Yerkes Observatory and Allegheny Observatory. During his 20 years at Yale, Schlesinger initiated the Yale Zone Catalogues in which he, Ida Barney and later Dorrit Hoffleit catalogued positions of a large number of stars in the northern hemisphere. Schlesinger also established the Yale Southern Station in Johannesburg from which he determined parallaxes of southern stars and then with Ida Barney created the General Catalogue of Trigonometric Parallaxes in 1924, 1935, 1953 and a supplement in 1962. A fourth and final edition was published in 1995 by van Altena, John T. Lee and Dorrit Hoffleit. (A more detailed account of the early years of astrometric endeavors at Yale can be found in Dorrit Hoffleit's 1992 book "Astronomy at Yale 1701-1968.")

In 1950, W. H. Wright at Lick Observatory initiated a photographic survey of stars north of -20° declination with a 20-inch double astrograph, in blue and visual passbands. Thus began the Northern Proper Motion survey, or NPM. His goal was to determine the proper motions of stars brighter than 18th magnitude with respect to faint galaxies and in this way establish the zero-point of the proper-motion system, thereby allowing determination of the true rotation of the Galaxy. Once the NPM was underway, the IAU called for an extension of the Lick survey to the south, to enable a full-sky study of Galactic rotation. Dirk Brouwer of Yale and Jan Schilt of Columbia partnered to respond to the IAU's request and with a Ford Foundation grant in 1960 established the Yale-Columbia Southern Observatory at El Leoncito in the pre-Andes mountains of Argentina, near the city of San Juan, in collaboration with Cuyo University, a part of which later became the National University of San Juan, or UNSJ . When Brouwer died in 1966, Gerald Clemence and Adriaan Wesselink assumed direction of Yale's part of the project. In San Juan, Carlos U. Cesco and Jose Augusto López organized and supervised the operations at El Leoncito for the first epoch, and Carlos E. López took over in 1980 for the remainder of the project. Additional administrative support came from the President of the UNSJ Tulio A. Del Bono and Dean of Sciences Rodolfo Bloch. The project would have been impossible without their invaluable support as well as the skilled work of the local observers and technical staff, including Danilo Castillo, Frederico Podesta, and others.

Measuring our Milky Way Galaxy, continued from page 7

In 1974, when the first-epoch observations of the Southern Proper Motion (SPM) survey were completed, Columbia withdrew from the project due to their changing research interests and I, William van Altena, came to Yale to continue the SPM project and the department's tradition of astrometric research. At this time a Photometric Data Systems (PDS) measuring machine was acquired, having sub-micron accuracy and the ability to accept the large 17x17-inch SPM plates. Post-doctoral associates George L.-T. Chiu, Jin Fuw Lee and Terrence Girard were instrumental in turning the machine into a highly accurate measuring device with the help of local electronic and programming technical support. The PDS would be used extensively, not just for the SPM project, but also by other Yale and visiting astronomers for a variety of projects requiring the digitization of photographic material. Over the years, the Yale plate vault would grow to house well over 100,000 telescopic plates, including the Yale parallax series, the SPM plates, and numerous other parallax, proper-motion, and photometric series.

A few years into observations for the repetition of the first-epoch SPM plates, Eastman Kodak decided to terminate its production of our large 17x17-inch photographic plates and it was necessary to search for an alternate detector system. In 2000, with the financial support of the NSF, two large-format (at the time) CCD cameras were installed on the double astrograph in order to complete the SPM second-epoch survey digitally. Graduate student Reed Meyer programmed the telescope and CCD camera operations while Girard developed programs to combine all of the observations and solve for the final proper motions. Girard continued to play a critical role throughout the project to its completion. In addition, several graduate students and post-doctoral associates contributed critically to the SPM project including Imants Platais, C. C. Lu, Rene Mendez, Dana Casetti-Dinescu, Xinjian Guo, Katherine Vieira and Carlos López from the observatory in San Juan.

The culmination of the SPM project was the late-2009 release of the final installment of the SPM catalogs, SPM4. It provides absolute proper motions of over 100 million stars, down to V=17.5, in the southern sky. This magnitude-complete catalog was made possible by also having the SPM plates scanned with the Precision Measuring Machine (PMM) at the US Naval Observatory's Flagstaff Station in collaboration with Dave Monet. The SPM4 and previous SPM catalog versions were used to develop a more precise kinematic description of the MW's major component systems. For example, in a project led by visiting scholar Vladimir Korchagin, structural parameters of the Thick Disk, including the vertical shear in its tangential velocity distribution, have provided insight into the potential and mass distribution of the MW disk.

Not only had Wright's 1950 goal of establishing a proper motion system free of rotation been accomplished but Platais then led a group that used the SPM proper motions to help define the proper-motion zero point for the European Space Agency's Hipparcos astrometric satellite.

In addition to the SPM catalog itself, the Yale astrometry group made use of the SPM material along with other, long-focus plates and ground-based CCD images to complete numerous, important proper-motion studies. As of 2012, the astrometry group at Yale had measured the absolute proper motions of 36 globular clusters; this represented 58% of the total number of all clusters measured up to that time. By this time we had also measured the absolute proper motions of five galactic satellites of the MW; the Sagittarius dwarf galaxy, both Magellanic Clouds, the Canis Major overdensity (thought to be the core of a disrupting satellite), and the Fornax dwarf galaxy. These results are the most accurate such ground-based measures, rivaled only by HST-based measurements. Finally, there are the numerous tidal streams and stellar overdensities known to inhabit the MW halo, having been detected from large-area photometric surveys. We have measured proper motions in three such major systems; the Sagittarius trailing stream, the Monoceros stream, and the Virgo Overdensity. These were the first 3-D kinematical studies of distant halo substructure. Such measurements allow us to lock down these various systems' orbits, which is crucial to understanding their formation and continued interactions with the MW. These studies were primarily led by Casetti-Dinescu.

Complementary to these systems for which absolute proper motions were determined, a number of relative proper-motion studies have been made of Galactic open clusters. These are important for determining cluster membership, establishing astrometric standard fields, and, in some cases, measuring the internal velocity dispersion of the system. Clusters of note include M67, NGC 188, NGC 2451, and IC2391. For several of these open-cluster studies, Platais was the lead.

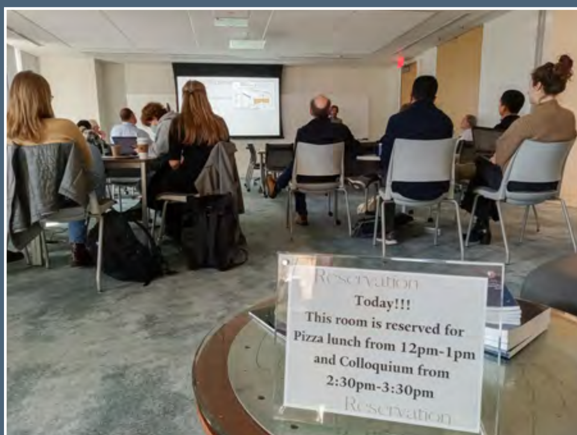
In 2015 the double-astrograph telescope and support facilities at El Leoncito were donated by Yale to the UNSJ for their astronomy group. A year later, in 2016, the majority of plates in the Yale plate vault and the PDS measuring machine were relocated to the Pisgah Astronomical Research Institute (PARI) in Rosman, North Carolina. The remainder of the plates were returned to their home observatories.

In 1972 van Altena was asked to lead the Instrument Definition Team for Astrometry in defining the characteristics of an instrument to make astrometric measurements on the proposed "Large Space Telescope." That group evolved into the Astrometry Science Team (AST) for the newly christened Hubble Space Telescope in 1978. In 1985 Girard was incorporated into the Yale part of the AST and played an important role in all our activities. Among our various support activities for the HST project was the preparation of a catalog of stars by Vera Kozhurina-Platais and Yang Ting-gao to be used by the star trackers on HST, to orient it for guiding while making the science exposures. Once HST was launched in 1990 we began our observations to help determine the local distance scale of the Galaxy, measure the internal motions in globular clusters, and collaborate with other members of the AST in their research programs.

Elliott Horch joined our astrometry group in 1992, bringing his expertise in the field of speckle interferometry of binary stars. During the course of a few years he used his interferometer on the 76-cm reflector at El Leoncito to measure the separations and position angles of a significant number of binary stars and subsequently determine the orbits and masses of several binaries. Also of note, in the realm of binary-star measurement, was the crucial redetermination of the orbit and component masses of the Procyon system based on 83 years of photographic material and a single HST exposure, a project led by Girard.

Lastly, an outgrowth of all our research was the development at Yale of a graduate-level course in astrometry and application of astrometric techniques to astrophysical problems. That course evolved into an introductory textbook edited by van Altena, "Astrometry for Astrophysics: Methods, Models and Applications", published by Cambridge University Press in 2013.

YALE ASTRONOMY HAS A NEW HOME *at Kline Tower*



Yale *Astronomy*

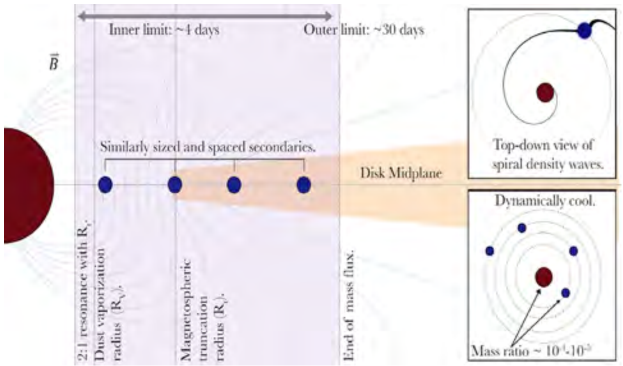
Graduate Student & Postdoc Research Highlights

W. Garrett Levine

Class of 2026

I grew-up in Columbus, Ohio, and I enjoy hiking, reading, and cooking.

One of the most remarkable discoveries from the Kepler telescope was the discovery of systems with multiple similarly-sized, similarly-spaced exoplanets with orbital periods shorter than Mercury. Compared to these commonly-found systems, our inner solar system is empty. These exoplanets have been nicknamed the "peas-in-a-pod" systems due to their orbital configuration.



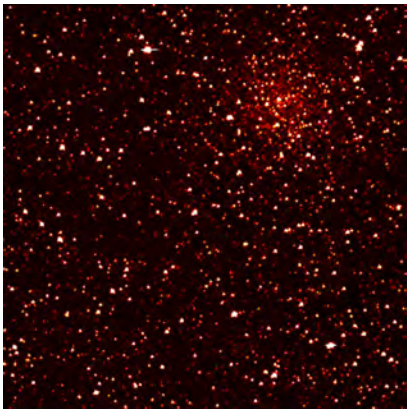
Although these Kepler discoveries have no planetary analog in the solar system, these exoplanets are strikingly reminiscent of the largest moons of Jupiter and Uranus. Their mass scales, scaled radii, spacing, multiplicity, and uniformity make the outer solar system satellite chains indistinguishable from the Kepler peas-in-a-pod planets. Capitalizing on this similarity, my current research is to examine the formation of these systems. The goal is to determine which astrophysical processes drive the formation of short-period exoplanet and moon systems in circumstellar and circumplanetary disks. Through a combination of analytic and numerical methods, I am striving to frame these distant exoplanetary systems in a context that's much closer to home.

Christopher Lindsay

Class of 2026

I am heavily involved in student government, currently serving as the Chair of Yale's Graduate Student Assembly.

I am primarily interested in using asteroseismology, or the study of oscillations in stars, to study interior mixing processes in evolved stars. Understanding what is going on inside stars requires a combination of data analysis and stellar modeling techniques, so this past year I have been working on stellar modeling and analyzing data from the Kepler and TESS space telescopes.



One project involves taking light curve data of many stars in our galaxy and extracting the star's oscillation mode frequencies. Light curves are temporal variations in a star's brightness, a data we obtain by staring at a star with a space telescope for a long duration of time. The power spectrum of a star's light curve shows prominent peaks, which correspond in frequency to the normal modes of the star's internal vibrations. Like a bell, whose construction dictates the qualities of its sound, the star's structure determines the frequencies of its oscillations. Hence, measuring these frequencies is an important step to understanding the interiors of giant stars. Other projects I am working on include matching the observed oscillation mode frequencies of subgiant stars to the oscillation mode frequencies of computer-generated stellar models.

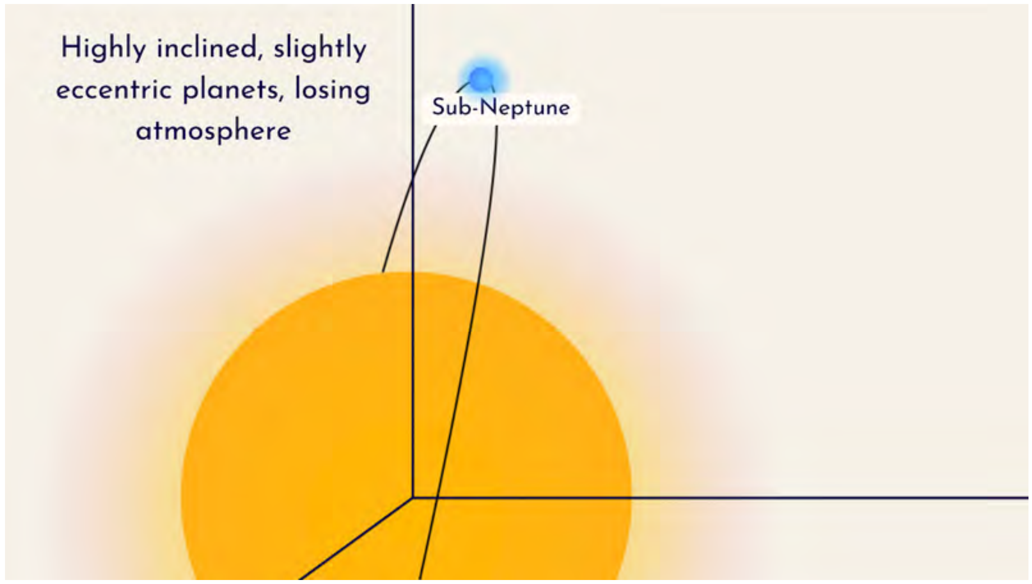
The overall goal of these recent projects has been to use asteroseismology to improve our understanding of convective overshoot, which is an extra source of mixing near convective boundaries. Convective overshoot can change how a star evolves, so understanding it is vital for understanding stellar evolution. Pinning down the details of stellar evolution has far-reaching consequences for our understanding of the evolution of exoplanetary systems and that of our Milky Way Galaxy as a whole.

Emma Louden

Class of 2026

Outside of research, I enjoy reading, hiking, and baking.

My work focuses on relating the current architectures of exoplanetary systems to their formation and evolution. Most recently, I submitted a paper relating the orbital migration of planets to their geophysical properties. My current work explores the stability of planets in orbits where the angle between their planetary orbital axis and the star's spin axis is high. We are probing how tidal and stellar evolution affects these systems.



Konstantin Gerbig

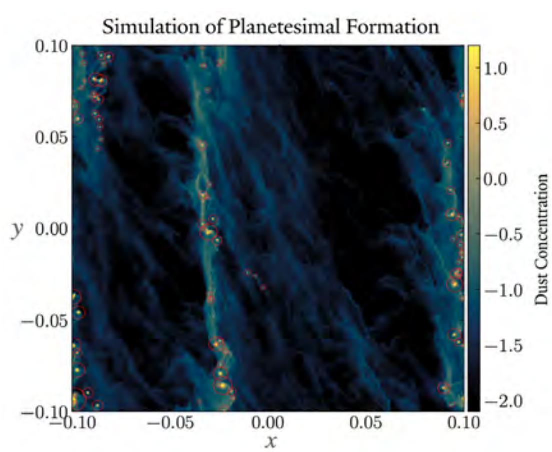
Class of 2026

Outside of research, my hobbies include lifting weights, watching movies, and dancing Latin dances. Originally, I am from Germany.

In my research, I delve into the intricate workings of protoplanetary disks, which are rotating disks of dense gas and dust surrounding a newly formed star. Protoplanetary disks are the birthplaces of planets, so they are of pivotal importance for understanding the formation of our Solar System and the many observed exoplanets. I explore these disks from a theoretical perspective, utilizing both large-scale, numerical simulations and analytical theory.

One of my key focus areas is the study of tiny ice-coated dust particles within these disks. These particles tend to move inwards towards the star. As they do, they can sublimate, releasing latent heat in the process. This phenomenon is analogous to how water evaporates from the oceans on Earth, providing energy for hurricanes. Recently, I've used hydrodynamical simulations to show that a similar mechanism might be at play in protoplanetary disks, potentially having a profound impact on the process of planet formation.

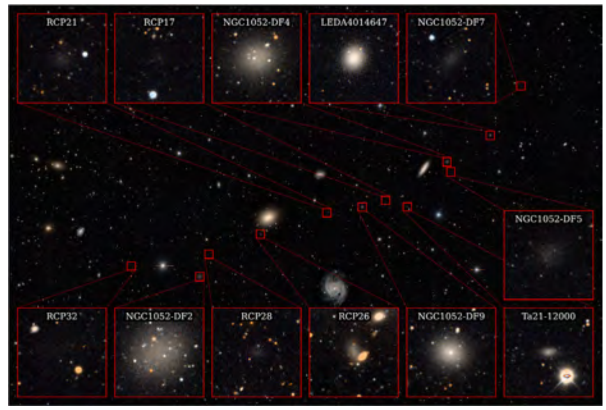
Additionally, I'm very interested in the collective stability of the dust within these disks, taking into account both hydrodynamic and gravitational forces. I derived a novel set of equations from first principles, and discovered new types of hydrodynamic instabilities that occur under specific conditions in protoplanetary disks. These instabilities can lead to the formation of dense bands of dust, setting the stage for the birth of planetesimals – the building blocks of planets. I also extended this study to include self-gravity, providing analytical predictions for the initial mass distribution of these planetesimals, contributing a crucial piece to the puzzle of how planets like those in our Solar System come into existence.



Michael Alan Keim

Class of 2026

Outside of research I enjoy hiking and camping, audiobooks and podcasts, and picking fruits and hosting dinner parties with friends.



The universe is teeming with galaxies engaged in a cosmic dance, orbiting and colliding with each other across the night sky. My research explores these interactions in order to understand their effect on galaxy evolution and probe the fundamental physics of dark matter which governs this dance.

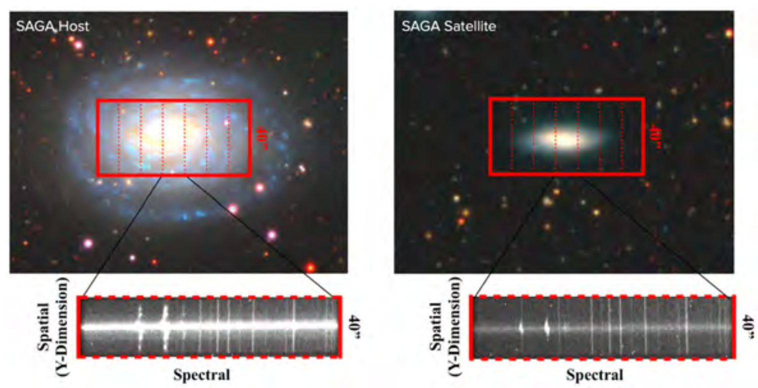
My current work focuses on a unique trail of galaxies lacking dark matter which likely formed through a high-speed collision. This extreme event separated out gas from its dark matter hosts producing remarkable galaxies with bright clusters of stars, large sizes, and almost no dark matter. By examining the properties of these galaxies we explore a unique mode of galaxy formation which occurs in shock-compressed, dark-matter-free gas. Moreover, by investigating the dynamics of this collision we may probe the nature of dark matter, characterizing how strongly it interacts with itself and potentially ruling out non-particle-based theories such as modified gravity.

To study this system I have employed 7 different telescopes, including the largest US optical telescope as well as the Hubble telescope in space. This includes data I took myself in classical mode observing, leading my own Keck Cosmic Web Imager dwarf program, and my first two observing proposals as PI, which were both successful totaling over 70 hours of data. I was also specially selected for an NRAO Award funding my next 2 years of research. By engaging in the entire process of proposing, planning, observing, and reducing data I have grown significantly as a scientist.

Yasmeen Asali

Class of 2026

I grew up in New York, and in my free time I love caring for my plants and solving sudoku puzzles.



Various factors can influence a galaxy's ability to form new stars, particularly in smaller galaxies. Often, star formation in low mass galaxies is influenced by external factors. For instance, many of the low mass satellite galaxies that revolve around our Milky Way have stopped forming stars, while small galaxies in isolation continue to do so. When a galaxy enters the dark matter halo of a larger host galaxy, it can lose its gas resulting in the cessation of star formation – a process known as quenching. Surprisingly, recent findings from the SAGA survey, which focuses on studying satellite galaxies around Milky Way-like systems, show that a higher proportion of satellite galaxies near Milky Way analogs are still actively forming stars compared to the Milky Way itself.

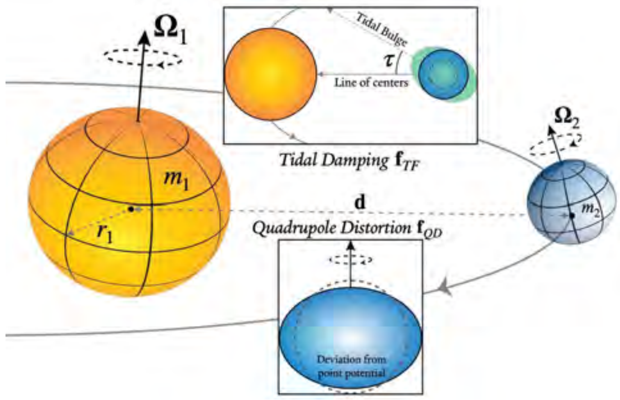
I study how star formation in these satellite galaxies evolves over time using photometric and spectroscopic observations, in order to understand how their surroundings impact them. By analyzing their star formation histories, we can gain insights into whether star formation occurs gradually or in short bursts, how quickly a galaxy can transition from star-forming to quenched, and how these features trend with galaxy mass. I also work on obtaining follow up observations for the SAGA satellites in order to investigate spatially resolved star formation and estimate dynamical masses based on the rotation of gas. This image shows some of our follow up data for a SAGA host galaxy and one of its satellites!

Tiger Lu

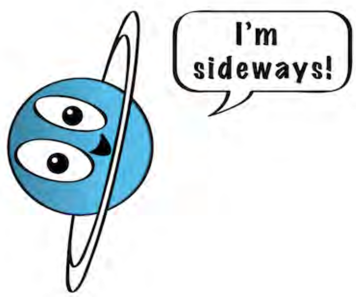
Class of 2026

I grew up in Shanghai, China. I like running and board games!

The motion of planets about their host stars are subtly influenced by a variety of seemingly minor second-order effects of planetary structure such as spin rate & direction, planetary shape, and tides. Understanding how all these effects evolve a planet's orbit (and vice versa) allows us to make powerful conclusions about planet formation and demographics, and ultimately help us understand our own place in the solar system.



My research focuses on using numerical simulations to better understand planetary dynamics. Observations of planets can only yield single snapshots in time of a system - only through simulations can we more deeply understand its evolution. I have contributed to the popular N-body integrator REBOUND, a software package which simulates the motion of planets under the influence of gravity. I have implemented 1) self-consistent spin and tidal evolution and 2) numerical methods for faster and more accurate simulation. My current research now focuses on applying these tools to a variety of exoplanetary systems with the aim of understanding their histories and interior structure.

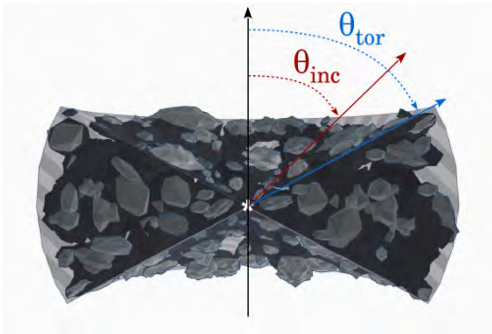


Mislav Baloković

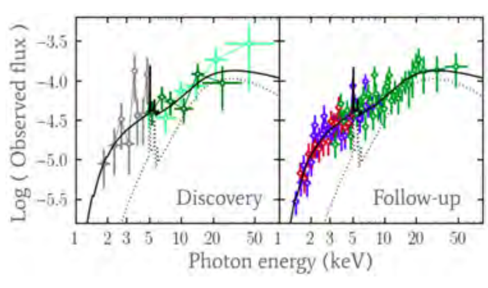
Associate Research Scientist

Outside of research, I enjoy cooking, travel, and long walks in nature and in cities.

Supermassive massive black holes (SMBHs) reside at the hearts of nearly all galaxies and regulate their hosts' development over cosmic time. The nature of this interaction is poorly understood at present, hindering our ability to fully explain how galaxies form and evolve. The observable phenomena associated with ongoing SMBH growth through accretion of surrounding material are collectively called active galactic nuclei (AGN). My research is focused on observations, data analysis, and theoretical modeling of AGN. Using observations at many different wavelengths, with particular emphasis on X-rays, I am trying to better understand the structures surrounding SMBHs.



Working with undergraduate students at Yale, I am trying to tease out how the structures responsible for obscuring the majority of AGN from our view depend on fundamental parameters such as luminosity, accretion rate, and mass, in order to shed light on their evolution over cosmic time. I am leading a survey primarily using the Hale 200-inch telescope at Palomar Observatory aimed at calibrating and improving the reliability of near-infrared estimators of SMBH mass in obscured AGN. Leaning more toward theory, I construct new models for AGN that allow us to constrain some of their structural parameters directly from observational data. While the study of obscuring structures is my main focus, my work has also led to better understanding of the source of X-rays in AGN, called the corona, and its likely extension into a strongly collimated outflow, called the relativistic jet.



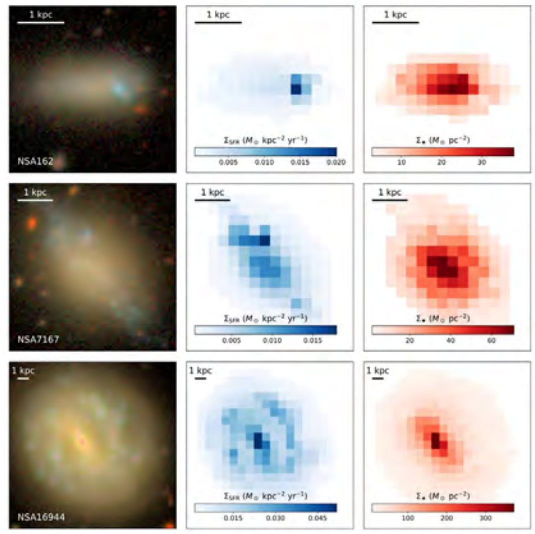
Erin Kado-Fong

YCAA Postdoc Fellow

In my free time, I enjoy getting outside to climb.

Galaxies are versatile and immutable laboratories; they are simultaneously tracers of larger scale cosmological processes and the laboratories in which smaller scale astrophysics proceeds. Given that we are not able to create either universes nor stars in the lab, my work focuses on how to best use the cosmic laboratories at our disposal to understand the physical processes that shape them.

My main interest is in the low-mass galaxy regime, where I think about how dwarf galaxies can inform our understanding of physics at both larger and smaller scales. I have a particular interest in the relationship between the star formation cycle and the dwarf population as a way to understand both the physics of star formation regulation and the creation of the galaxy population. Due to their low total mass, these dwarf galaxies are particularly sensitive to the details of how star formation self-regulates and enriches these galaxies' interstellar medium. My recent works have shown that the structure of dwarf galaxies (not simply the availability of star-forming material) is key in regulating their star formation, that dwarf galaxies can drive moderately efficient galactic-scale outflows, and that interactions between dwarf galaxies can both trigger massive bursts of star formation and temporarily quench star formation altogether.



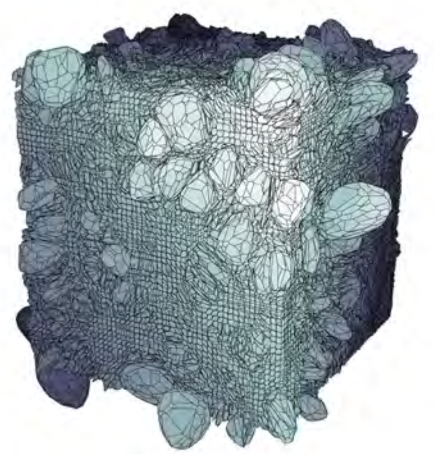
Farnik Nikakhtar

YCAA Postdoc Fellow

In my free time away from research, I love spending time with my dog - Leo, enjoying the outdoors and the simple joys of pet companionship.

The Universe is like old milk! Initially smooth and uniform with very tiny density fluctuations, it became clumpier over time as gravity pulled more matter into denser regions. Today, we observe late-time galaxies, and it is natural to ask whether we can track back the evolution of cosmic structures and find the initial patches from which they formed. Reconstructing these initial patches allows us to better understand the Universe's expansion history and how galaxies have evolved.

The answer to this question is Yes! In recent years, several algorithms have been proposed to reconstruct the initial density field; they are effective but closely tied to cosmological assumptions, and none can obtain the shape of these initial cosmic cells. I developed an assumption-free algorithm based on Optimal Transport Theory that can find the initial cells of the Universe precisely. Optimal transport is the general problem of moving objects from one place to another with the least possible effort. That is why it is very well-suited to the reconstruction problem in astrophysics. This method also opens up new possibilities for measuring cosmological parameters.



As a YCAA postdoctoral fellow at Yale, I am working with Nikhil Padmanabhan on developing this algorithm for applying to the Dark Energy Spectroscopic Instrument (DESI) observations. DESI will be a transformative cosmological survey in this decade, mapping 40 million galaxies and quasars. This analysis provides an important distance scale for measuring the expansion history of the Universe.

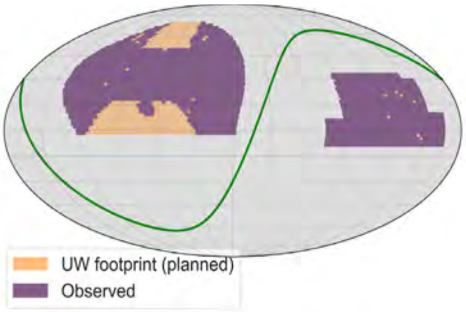
Will Bowman

Postdoc Associate

Outside of research, I enjoy fishing, kayaking, snowboarding, reading fiction, and hanging out with my two cats.

The low surface brightness universe encodes key information about galaxy formation and evolution, yet it is a challenging regime to study. The Dragonfly Telephoto Array, an array of 48 telephoto lenses that our group has built in New Mexico, is uniquely optimized for investigating low surface brightness phenomena. The design has a relatively unobstructed light optical path, leading to significantly less scattered light compared to traditional telescope designs. Additionally, its large (6 square degrees) field of view enables good control over the systematics. Both of these factors are crucial for low surface brightness imaging. The 48 lenses are housed on two mounts, one of which is displayed in the figure.

We are nearing the completion of the Dragonfly Ultrawide Survey, which covers roughly a quarter of the sky (~ 10,000 square degrees) in g- and r-band imaging and overlaps with the entire Sloan Digital Sky Survey footprint. The 30-minute integration times yield surface brightness limits below 29 magnitude per square arcsec on 1’x1’ scales. The large survey footprint (shown in the figure), combined with Dragonfly’s unprecedented sensitivity to low surface brightness features and exquisite control over background systematics, enables us to explore key questions about the low surface brightness universe. The primary science of the Ultrawide survey is to detect the largest, nearest (distance < 20 Mpc) Ultra Diffuse Galaxies (UDGs). This rich data set can be mined to study various astronomical phenomena, including stellar halos, intracluster light, Galactic cirrus emission, and tidal tails from accretion events and galaxy mergers.



David M. Hernandez

CycloAstro

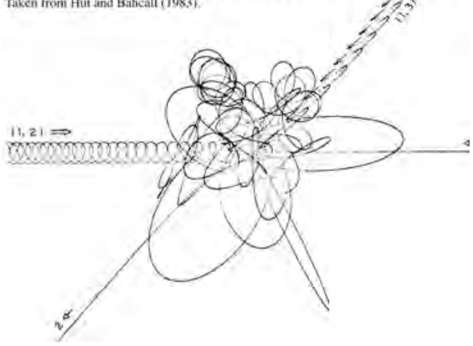
Postdoc Fellow

I enjoy bicycle riding, playing sports, playing percussion and drums.

To an excellent approximation, the Universe is time-reversible. More specifically, the equations of motion that particles obey under gravity remain the same regardless of the direction of the arrow of time. Also, these equations have the same solutions forwards or backwards in time. This simple fact is often overlooked when trying to understand and simulate the Universe.

As a concrete example, gravitational dynamics in the Universe is largely governed by the mathematical N-body problem, in which N particles all interact with each other via pairwise forces. The Newtonian N-body problem is useful for describing the formation and evolution of galaxies, planetary systems, or star clusters, and it consists of a set of ordinary differential equations. Differential equations can be difficult to solve and countless textbooks have been written on this rich subject. Approximate solutions to these equations have been developed since 1687 when Newton wrote his Principia. Herein lies our difficulty: while the equations of gravity may be time-reversible, the approximate solutions we use may not be. This is problematic for the gravitational dynamics studies we are interested in that explain the formation and evolution of the Universe: if the solutions we calculate are not time-reversible, the solutions are incorrect.

Chaotic three-body problem in which particle 3 scatters off binary (1, 2). In the final state, (1, 3) is now a binary and particle 2 is ejected. Taken from Hut and Bahcall (1983).



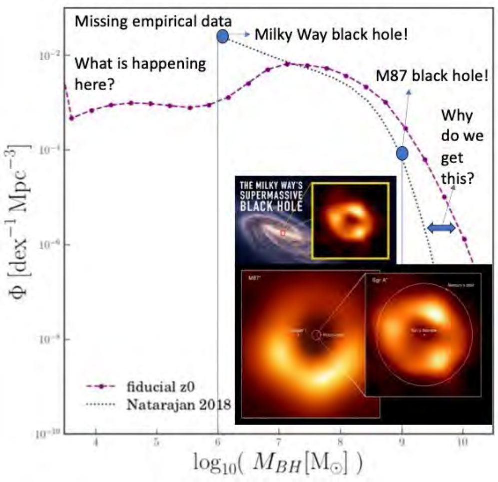
My recent work with Walter Dehnen and Yale student Tiger Lu develops solutions to the gravitational equations of planetary systems like our Solar System that are time-reversible. This allows us to accurately and efficiently study dynamics across a wide range of exoplanetary systems in ways that were previously not possible with other techniques.

Antonio J. Porras-Valverde

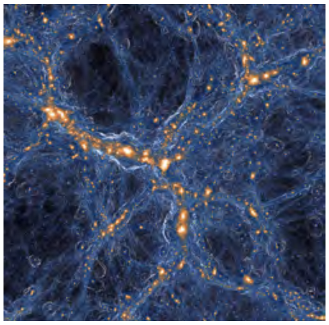
Heising-Simons

Postdoc Fellow

Originally from San José, Costa Rica, I am the co-founder of the Central American-Caribbean Bridge in Astrophysics.



I am a theorist in the field of galaxy formation and evolution, and I study galaxy properties, in particular, how their central supermassive black holes affect their growth. In a recent project, I investigated the link between galaxies and their dark matter halos. I use computer simulations that try to capture the evolution of the universe based on known physics. The goal is to theoretically explain observations, such as the properties of stars, galaxies, and their dark matter halos, and their change through cosmic history. Recently, my work showed a discrepancy between simulations and observations in terms of the scatter in stellar masses of galaxies. We found that active supermassive black holes play a big role in making such dispersion large in some simulations. Now, my focus is on understanding how black holes evolve to become supermassive and how this process affects the evolution of their host galaxy.



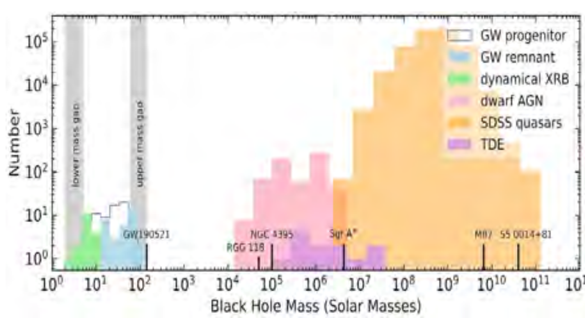
Alongside this work, I am passionate about creating a safe space for people from any background to do astrophysics research. I am the co-founder of the Central American-Caribbean Bridge in Astrophysics nonprofit organization, which creates and develops astronomy research opportunities in the region. Being a Costa Rican myself, it is important to have opportunities I had in my journey available for anyone who chooses to study astronomy.

Colin Burke

NSF AAPF

Postdoc Fellow

I obtained my PhD in astronomy from the University of Illinois Urbana-Champaign in 2023. Outside of astronomy, I enjoy cycling, cooking, and listening to podcasts.



How did supermassive black holes form at high redshift, grow over cosmic time, and come to occupy virtually every massive galaxy in the local Universe? In order to address these questions, I study the black hole population using accretion signatures in large survey data. This presents new opportunities to study the demographics of black hole populations, their origins, and the physics of black hole accretion.

The key is so-called intermediate-mass black holes — the elusive missing link between stellar-mass and supermassive black holes. Previously, I have studied the variability of the well-known intermediate-mass black hole in the dwarf galaxy NGC 4395 and have identified new sources from deep field variability survey programs. At Yale, I am taking this a step further by coupling semi-analytic models of black hole growth and seeding to these new observational constraints. Semi-analytic models allow us to track black hole growth by accretion and mergers over cosmic time from their initial seeds at high redshift using simple and flexible prescriptions. Coupling theoretical modeling to observational constraints will allow us to make observationally-informed predictions for new instruments such as the Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) and gravitational-wave observations with the Laser Interferometer Space Antenna (LISA).

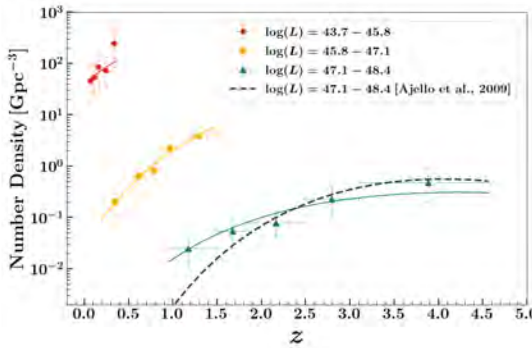
Lea Marcotulli

NASA Einstein

Postdoc Fellow

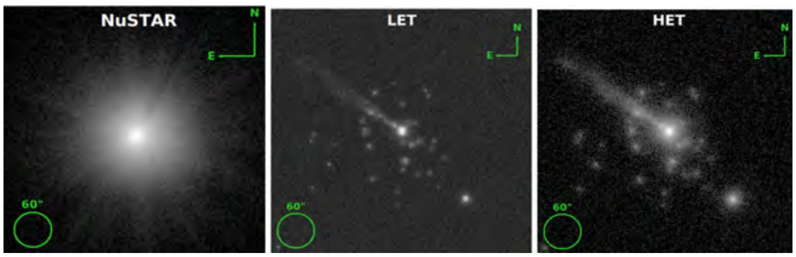
Being half French and half Italian, I really appreciate good food! So, I really enjoy cooking and going out to try different multicultural cuisines. My hobbies include hiking, playing volleyball, reading and spending time with my friends.

What triggers and fuels collimated relativistic outflows (i.e. jets) from the centers of galaxies? How do supermassive black holes form and grow in the early universe? And is there a relationship between these two phenomena? These are fundamental questions that my research is poised to answer.



About 10% of the supermassive black holes at the center of galaxies are actively devouring gas from their surroundings, making them shine as bright active galactic nuclei (AGNs). Moreover, a fraction of these AGNs is also capable of launching extreme relativistic jets from their core. Those that have jets pointed close to our line of sight are called blazars, others shine as beautiful radio galaxies. The most powerful of these jets are powered by monstrous black holes more massive than a billion Suns, and they are found at a stage when the Universe was barely a tenth of its present age. If we can follow blazars through time, and if we are able to chase them and find them in the early universe, we can trace the evolution of supermassive black holes through cosmic time and start answering those questions.

I use NASA satellites in space that explore the universe at the highest X-ray and gamma-ray energies, as well as ground-based infrared and optical facilities, to find and study the most powerful, most distant of these blazars. I am also involved in proposing new MeV (such as COSI) and X-ray missions (such as HEX-P) that will shape the future of high-energy astrophysics in the decades to come.



ASTRONOMY STUDENT PRIZES & AWARDS

BECKWITH PRIZE

Jay Baptista - 2023

"Measuring the Variance of the Macquart Relation in z-DM Modeling"

Sally Jiang - 2023

"Alignment of Magnetic Fields and Gas Structures in the Orion A Molecular Cloud"

BROUWER PRIZE

Darryl Seligman - 2022

"From The Stars: An Assessment of the Scientific Opportunities Provided by Interstellar Objects"

Joel Ong - 2023

"Stellar Surfaces in the Frequency Domain"

Lamiya Mowla - 2023

"The Structural Evolution of Massive Galaxies"

TINSLEY PRIZE

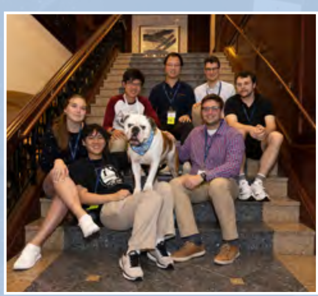
Imad Pasha - 2022

"Quenching in cosmic sheets: tracing the impact of large-scale structure collapse on the evolution of dwarf galaxies"

ERES 2023 at Yale

by W. Garrett Levine, Yale Astronomy PhD Candidate

Yale Astronomy proudly hosted the Emerging Researchers in Exoplanetary Science (ERES) symposium in June, where we welcomed 106 early-career scientists to New Haven. The organizing committee was composed primarily of Yale graduate students; it was our first time coordinating an event of such scale for any of us. Through a generous grant from the Heising-Simons Foundation, we provided food and lodging for all participants as well as travel support for those who needed assistance. Defraying these costs increased the accessibility of ERES, helping us to welcome attendees from diverse institutional and demographic backgrounds.


ERES organizing committee

The two-day scientific program consisted of 37 talks and 64 posters, and presenters were a mix of undergraduates, graduate students, and postdoctoral researchers. Topics spanned theoretical and observational research in exoplanet-related topics, including the detection and characterization of TESS systems, planetary system architectures and occurrence rates, atmospheric measurements and stellar activity, and long-term dynamical evolution. Outside of the scientific program, we held a professional development panel and welcomed a visit from Handsome Dan for group photos.

In total, ERES was successful in achieving our goals of promoting high-level scientific discussion and building community among early-career exoplanet researchers. We received positive feedback on a post-conference survey that was distributed to attendees, with all respondents selecting either 4/5 or 5/5 on the question “did the event meet your expectations?” On behalf of the organizing committee, we are grateful to Priya Natarajan, Greg Laughlin, and the Yale Astronomy business office for going above and beyond their usual duties to help make ERES a success.

To build on ERES 2023, we are documenting our lessons learned and are planning to publish a piece in the Bulletin of the American Astronomical Society aimed at other groups of early-career scientists who are organizing their own symposia. In addition, members of this year’s organizing committee will serve as advisors to the organizers of next year’s ERES to be held at Cornell in Summer 2024. With these efforts, we will ensure the long-term success of the conference and continue to foster a positive impact on the early-career exoplanet community.

NASA, ESA, Massimo Robberto (STScI, ESA), Hubble Space Telescope Orion Treasury Project Team

MAPPING THE MAGNETIC FIELDS IN MOLECULAR CLOUDS WITH PALOMAR

written by Héctor G. Arce, *Professor of Astronomy*

Stars form in the dense regions of molecular clouds. These regions are threaded by magnetic fields that can modify the turbulence in the cloud, provide pressure support against gravitational collapse, regulate the flow of gas that builds denser structures, and help in the propagation of feedback and cosmic rays over large scales. These processes affect the star-formation efficiency of the cloud. Understanding the relation between magnetic fields and gas in molecular clouds is therefore a crucial part of star formation research.

Mapping magnetic fields in the interstellar medium (ISM) is not trivial. One way to do so is by measuring the polarization of starlight. Light from stars is intrinsically unpolarized, but as it travels through the ISM it interacts with elongated dust grains that are preferably aligned with their long axes perpendicular to the magnetic field. The directional extinction of light caused by these grains will result in slightly polarized starlight. That is, elongated dust grains in the magnetized ISM act as a polarizer, where the resulting polarization direction of the polarized light is parallel to that of the magnetic field.

Over the last three years, my research group at Yale has been using a near-infrared polarimeter on the Palomar 200-inch telescope to map the magnetic field in the closest region of low- and high-mass star formation, the Orion A molecular cloud. We have painstakingly measured the polarization of light of about 80 stars background to Orion molecular cloud (see Figure 1). We compared the magnetic field direction, as traced by the polarization direction of starlight, with linear structures in the molecular cloud (CO) gas and find that in many regions the magnetic field is parallel to striations in the diffuse (low-density) regions of the cloud (see Figure 2). It thus appears that in certain regions, these filamentary wisps of gas can also trace the magnetic field orientation.

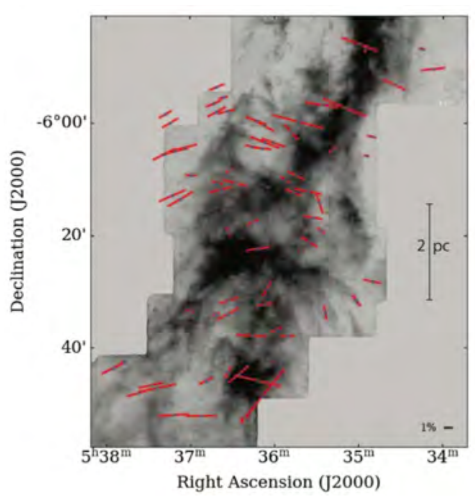


Figure 1 – *Polarization measurements (red lines) overlaid on map of molecular gas in a section of the Orion A molecular cloud. The polarization angle (line orientation) traces the magnetic field direction. The length of the line is proportional to the polarization strength.*

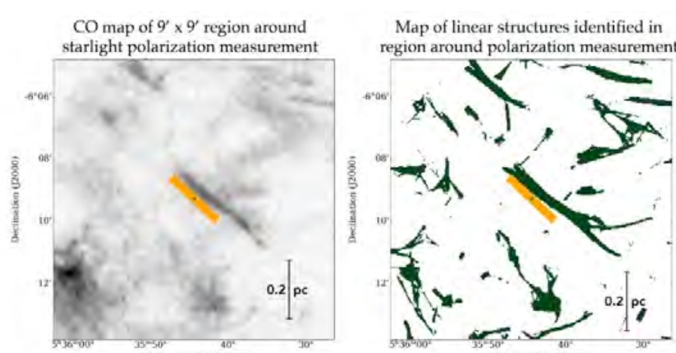


Figure 2 – *Comparison of polarization measurement and gaseous linear features in cloud. (Left panel) Zoom-in of a polarization measurement (orange line) close to a linear structure seen inthe molecular gas (gray scale). (Right panel) Same polarization measurement as in the left panel. Green structures show the linear features identified by the machine vision algorithm.*

We used a machine vision algorithm to identify linear features in the CO and compared their orientation with respect to the polarization angle of the light from adjacent stars. We select the structures with an orientation similar to that of the polarization angle of polarized light to produce an approximate map of the magnetic field structure in the Orion A cloud (see Figure 3). With this technique we showed that one can use molecular gas maps to fill-in the gaps between the sparsely sampled starlight polarization measurements, and produce a more detailed map of the magnetic field in a molecular cloud.

The project has only been possible thanks to Yale's 1/8 share of the science time on the Palomar 200-inch Hale Telescope and the great work of two Yale undergraduate student (Abby Mintz '22 and Sally Jiang '23), who used various aspects of this project as their senior thesis, and vital help from Yale graduate student Cheng-Han Hsieh. This project has served as a major training experience for these students. They planned and conducted the observations and reduced and analyzed the data. Sally is writing a paper presenting these results.

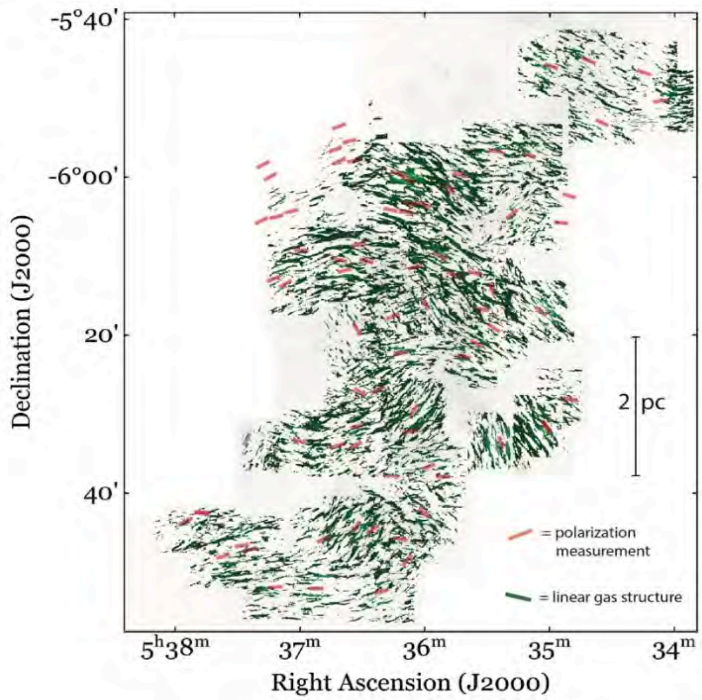


Figure 3 – *Approximate map of magnetic field direction in Orion. Green lines show the linear structures in the molecular gas map that are aligned to the polarization measurements (orange lines). We used the linear features in the gas to produce a more complete (better sampled) map of the magnetic field in the cloud.*

Below: Aerial view of Palomar Observatory. (Palomar/Caltech)

ASTRONOMERS FIND 'TILTED' PLANETS EVEN IN PRISTINE SOLAR SYSTEMS

By Jim Shelton, YaleNews

Understanding that even planets in pristine solar systems have some orbital tilt puts Earth's solar system into a larger perspective, researchers say.

Scientists have long puzzled over why all of the planets in Earth's solar system have slightly slanted orbits around the sun. But a new, Yale-led study suggests this phenomenon may not be so unusual after all. Even in "pristine" solar systems, planets exhibit a bit of a tilt.

Astronomers had long assumed that planets with pitchy, angled orbits — orbits that don't align with the spin axis of their host sun — are the result of some high-level cosmic hubbub, such as nearby stars and planets pushing around their neighbors. But a new study published in The Astronomical Journal indicates otherwise.

For the study, an international research team led by Yale astronomer Malena Rice conducted a comprehensive analysis of pristine, multi-planet solar systems, where the orbits of planets have remained relatively undisturbed since their formation.

"This type of configuration, where one planet's orbit is precisely ordered with another in an exact integer ratio of orbital periods, is likely common to find in a solar system early in its development," said Rice, an assistant professor of astronomy in Yale's Faculty of Arts and Sciences and lead author the study.

"It's a gorgeous configuration — but only a small percentage of systems retain it," she said.

And even in these solar systems, Rice and her co-authors found, planets can have an orbital tilt of up to 20 degrees.

The researchers began their work by measuring the slanty orbit of TOI-2202 b, a "warm Jupiter" planet in a pristine solar system. A warm Jupiter is a planet much larger than Earth with a significantly shorter orbital period than Earth's 365 days.

The researchers compared TOI-2202 b's orbit with orbit data from the full census of similar planets found in the NASA Exoplanet Archive. Put in this larger context, there was a typical tilt of as much as 20 degrees for such planets, with TOI-2202 b's system being one of the most strongly tilted such systems.

Rice said the discovery provides valuable information about early solar system development — and says something important about Earth's system: that a little bit of tilting is par for the cosmic course.

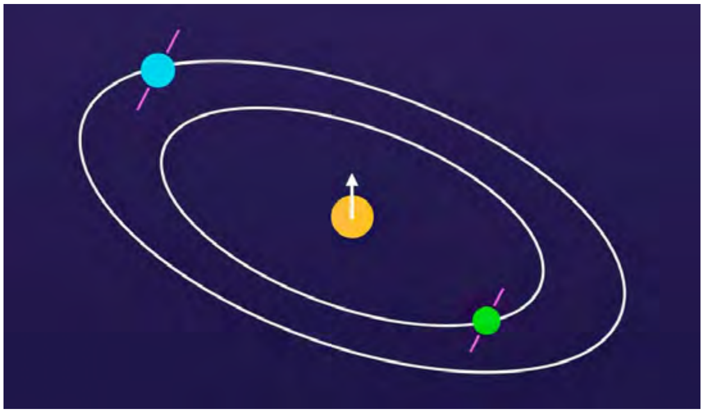
"It's reassuring," Rice said. "It tells us that we're not a super-weird solar system. This is really like looking at ourselves in a funhouse mirror and seeing how we fit into the bigger picture of the universe."

The new study also aids Rice in her research quest to understand "hot" Jupiter solar systems, which are systems that contain gas giant planets that may be similar to Jupiter, but with very short orbital periods.

"I'm trying to figure out why systems with hot Jupiters have such extremely tilted orbits," Rice said. "When did they get tilted? Can they just be born that way? To find that out, I first need to find out what types of systems are not so dramatically tilted."

The new study is the eighth result from the Stellar Obliquities in Long-period Exoplanet Systems (SOLES) survey, which was founded by Rice and co-led with previous Yale postdoctoral fellow Songhu Wang, who is now at Indiana University and co-author of the new study. Additional co-authors include researchers from Belgium, Spain, Chile, Australia, and the United States.

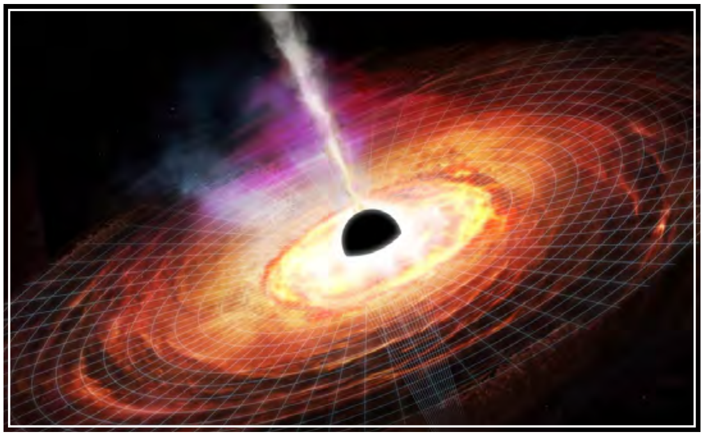
Support for the research came, in part, from the Heising-Simons Foundation and the 51 Pegasi b Fellowship Program.



In this diagram, two orbiting planets exhibit a slight tilt compared to the spin axis of their host sun. (Malena Rice image)

YALE ASTRONOMER LEADS THE WAY TO THE OLDEST KNOWN X-RAY QUASAR

By Jim Shelton, YaleNews



(Illustration by Michael S. Helfenbein)

Yale's Priyamvada Natarajan and colleagues have identified the oldest known X-ray quasar — offering compelling proof of a concept Natarajan helped pioneer.

Astronomers have found the oldest-known X-ray quasar in the universe — and its properties align exactly with predictions for a new class of distant objects made by Yale astronomer Priyamvada Natarajan and her research group.

In a new study in the journal Nature Astronomy, Natarajan and colleagues from Harvard and Princeton identified a celestial object, known as UHZ1, as the highest (or oldest) known "red shift" X-ray quasar in the universe. A separate study, to be published in The Astrophysical Journal Letters, provides an in-depth interpretation of the finding.

A quasar is a luminous, supermassive black hole. Its brightness comes from superheated gas that emits thermal radiation across the visible spectrum and beyond as gas falls into the black hole. The wavelength of light emitted by distant objects gets stretched to longer redder wavelengths as it reaches us and is quantified by a number called the redshift; a higher redshift denotes an older object whose light has traveled a greater distance to get to Earth.

According to the Nature Astronomy study, UHZ1 has a redshift of 10.1, which suggests that it takes light from UHZ1 13.72 billion light-years to reach Earth.

"It's thrilling to be able to reveal the presence of a supermassive black hole, in place at the center of a galaxy a mere 450 million years after the Big Bang," said Natarajan, the Joseph S. and Sophia S. Fruton Professor of Astronomy and professor of physics in Yale's Faculty of Arts and Sciences and chair of the Department of Astronomy. "NASA's Chandra space telescope detected X-rays from this distant quasar, which harbors an outsized black hole in its center."

Beyond its significance as the oldest-known X-ray quasar, UHZ1 offers compelling proof that the early universe is "seeded" with heavy black hole seeds with large birth masses that likely formed from direct collapse — a concept pioneered and developed by Natarajan and her collaborators that has gained traction in recent years among astrophysicists.

Previously, it was thought that black holes could only form from "light seeds" created in the aftermath of exploding stars. But there was a timing problem with that theory — it did not leave enough time for black holes to grow into the behemoths that astronomers are now able to observe farther and farther back in time.

Yale's Natarajan came up with a different theory. In papers published in 2006 and 2007, she developed a new model for the formation of "heavy" black hole seeds that could form in galaxies where star formation was suppressed — satellite galaxies that lie close to the galaxies that formed the first stars. In this model, large discs of gas in the satellite galaxies could collapse into heavy black hole seeds and then rapidly merge with their parent galaxies.

In 2017, Natarajan led a study with her Yale research group that suggested these supermassive black holes would have unique properties and be observable in the high-redshift universe — with help from the then-unlaunched (and now operational) James Webb Space Telescope (JWST). Natarajan predicted that over-massive black hole galaxies whose central black holes outweighed the stars in their host galaxies ought to be seen both by JWST and by the Chandra X-ray Observatory as X-ray quasars.

Natarajan even made note of potential candidate locations for high red shift, supermassive black holes, including a spot behind cosmic magnifying lenses, like the galaxy cluster named Abell 2744, where it has been found.

"UHZ1 is the first candidate that matches all our predicted properties for this transient class of over-massive black hole galaxies," Natarajan said.

Six years later, the prediction has been borne out with observations.

A team led by Akos Bogdan of the Harvard Smithsonian Center for Astrophysics and Andy Goulding of Princeton combined recent data from the Chandra X-ray Observatory and JWST to peer behind galaxy Abell 2744. They utilized a method called gravitational lensing — another focus of Natarajan's theoretical research — and treated Abell 2744 as a magnifying glass for looking even deeper into the cosmos.

There, they found Natarajan's "heavy seed," the oldest known X-ray quasar.

"JWST helped us find this extremely distant galaxy, and then deep Chandra observations revealed an X-ray bright supermassive black hole at its center," Bogdan said. "Combining the unique multi-wavelength capabilities of NASA's space telescopes made this discovery possible."

Goulding added, "UHZ1 may only be the tip of the iceberg. The Webb Space Telescope has opened a new window on the early universe. It will no doubt help us find more UHZ1s, and ultimately understand if over-massive black holes were commonplace."

Natarajan said there is now mounting evidence that nature likely produces black hole seeds via multiple scenarios, and it has required years of work modeling the details of these additional channels, pointing out where and how to find them feasibly.

"And now we're seeing compelling first evidence," Natarajan said. "This is an exciting intersection of topics, a culmination of all the things I have been working on."

Support for the research came, in part, from the Black Hole Initiative at Harvard University, which is funded by grants from the John Templeton Foundation and the Gordon and Betty Moore Foundation.

WELCOME

EARL BELLINGER

Earl Bellinger joins Yale University as Assistant Professor in the Department of Astronomy in January 2024. His research intersects astrophysics and artificial intelligence with a particular focus on stellar evolution, structure, and pulsations. He utilizes seismic data from stars to determine their inner structure and ages, which in turn enables further study of the exoplanets they host, the galaxies that host them, and their own underlying physics. He carried out his Ph.D. research at the Max Planck Institute for Solar System Research and Yale, and he held Postdoctoral Research Fellowships at the Stellar Astrophysics Centre in Denmark and at the Max Planck Institute for Astrophysics in Germany.

Yale *Astronomy*
ALUMNI NEWS & UPDATES

David Devorkin (MPhil 1970) reports: "Since my retirement in April 2021 from the National Air and Space Museum at the Smithsonian, after some 40 years of service, I have been happily researching and writing about the history of modern astronomy. I have some six articles, essays, and a book in progress and in press at the present time. The book is a biography of the space astronomer and aerospace engineer George Carruthers, who built a dual telescopic camera/spectrograph that became the first astronomical observatory on the Moon, during the Apollo 16 mission."

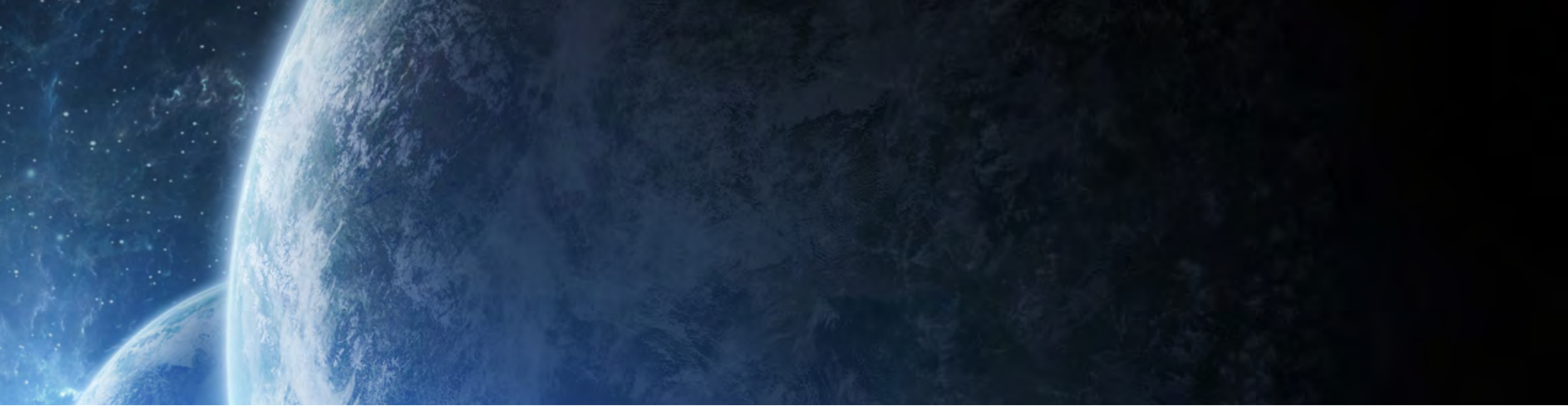
Jas Mercer-Smith (PhD 1980) recently celebrated his 40th anniversary at the Los Alamos National Laboratory where he is a Laboratory Fellow / Scientist 6 in the Primary Physics Group. He has no plans to retire.

Michael West (PhD 1987) spent six months in Finland as a 2021-2023 U.S. Fulbright Scholar, where he taught university courses on communicating science with the public and continued to research the role of culture in science communication. He is a tenured astronomer at Lowell Observatory.

Ata Sarajedini (BS 1987, PhD 1992) holds the Bjorn Lamborn Endowed Chair in Astrophysics at Florida Atlantic University and was a TEDx speaker at an event in Delray Beach, Florida in November of 2023.

TJ Lydon (PhD 1993) is still practicing medicine. He hosted Brian Chaboyer (PhD 1993 and currently Professor of Physics and Astronomy at Dartmouth College) and his wife Heather for a seafood lunch this summer.

Dimitri Veras (BS 2001) reports "I am now an Associate Professor working in the exoplanet, white dwarf, disk-based and space satellites/astrodynamics research groups at the University of Warwick in England. I graduated from Yale when exoplanetary science was a young field and not represented in the Department, and hence will always be thankful to Charles Bailyn for being willing to supervise an exoplanet-based Senior-year project for me."



Ezequiel Triester (PhD 2005) Associate Professor in the Physics Department of the Pontificia Universidad Católica de Chile reports: "I have recently been elected to become the next Director of the Center for Astrophysics and Related Technologies (CATA), for which I am currently the Alternate Director. I am expected to start my term in March 2024. This is the largest government-funded Astronomy Center in Chile, with the participation of ~60 researchers (about 1/3 of the astro professors in Chile with permanent positions) from 13 universities in the country. Research-wise we cover from Cosmology to exo-planets and solar system, while carrying out many outreach activities together with instrumentation and technology transfer."

Juan Cortes (PhD 2005) is a National Radio Astronomy Observatory (NRAO) Scientist, working at the Joint ALMA Observatory. His specific position is Acting Head of ALMA Department of Science Operations and Manager of the ALMA Program Group Management responsible for the ALMA data acquisition process.

Kate Whitaker (PhD 2012) has received tenure and been promoted to Associate Professor at the University of Massachusetts as of August 2023, and was awarded an NSF CAREER award in 2023. She notes that Rachel Bezanson, now at Pitt, also received a CAREER award in 2022.

Eric Murphy (PhD 2007) holds a Tenured, Full-Astronomer position at the National Radio Astronomy Observatory (NRAO), along with a Visiting Faculty appointment in the University of Virginia Astronomy Department. At NRAO, he serves as the next-generation Very Large Array (ngVLA) Project Scientist. The ngVLA was recently identified by the Astro2020 Decadal Review as a top priority major ground-based facility whose construction should begin this decade. His scientific research focuses on the study of star formation and its regulation in galaxies through associated feedback processes.

Allen Davis (2020) reports: "I'm now in my fourth year of teaching physics at the International School of Boston. Every week, we have a meeting of Astronomy Club, where 15 or so kids come to eat lunch and talk about recent astronomy news, or ask questions about the universe. We've been fortunate to be visited in the past year by Angelo, Sarah, and Malena! This April, I'm leading a field trip of a dozen students from my school to Texas to see the total solar eclipse. Fingers crossed for clear skies!"

If you would like to be included in next year's newsletter, please send your news and updates to info.astronomy@yale.edu

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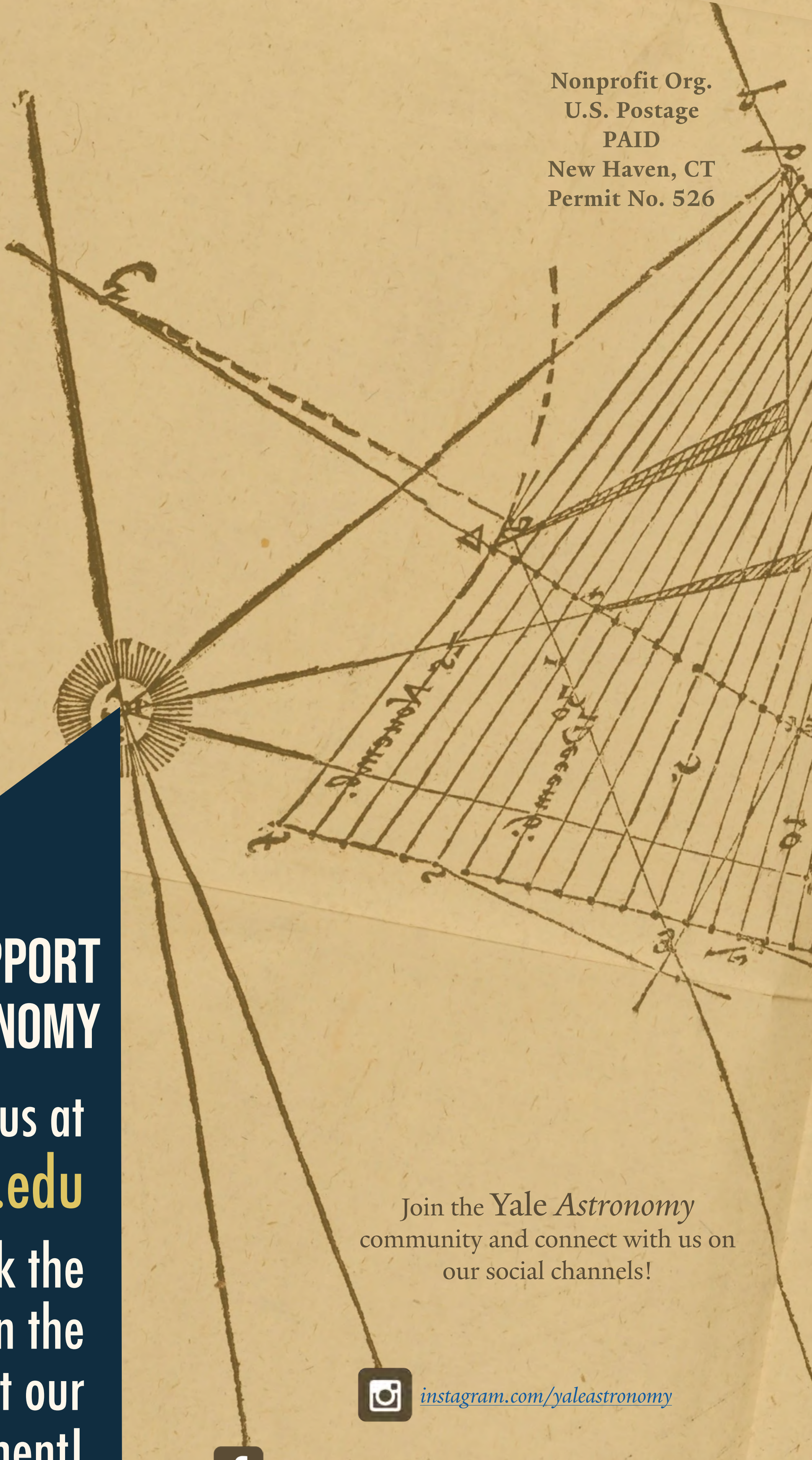

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