Yale *Astronomy*

Newsletter

Winter 2022

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Front Cover Photo: Yale's Olde English Bulldog mascot Handsome Dan XIX (Kingman) observing the Moon through the historic 8-inch Reed refractor at Yale's Leitner Family Observatory and Planetarium.

All Handsome Dan XIX photos by:
Robyn & John Lisone | Muttography & Co.

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Yale *Astronomy*

Dear alumni, colleagues and friends,

Welcome to this latest edition of the Yale Astronomy Department newsletter. Re-emerging slowly from the disruption of the pandemic, we swung into full gear with in-person departmental activities this Fall. It has been wonderful to interact, discuss science and convene again in the coffeeshop in 52 Hillhouse and other common spaces over a slice of pizza, a coffee or cookies. There have been some exciting developments at home - after nearly a decade, we were finally allowed to hire a junior faculty member in the exciting area of exoplanet science and are delighted to share the news that we successfully recruited Malena Rice (one of our own!) who is currently a 51 Pegasi Prize Postdoctoral Fellow at MIT. She will be joining us next Fall. Meanwhile, we are currently in the midst of another junior hire in data-intensive astronomy. To be able to grow in this new, emerging intellectual direction will help us exploit the upcoming data deluge with many new facilities and instruments poised to begin operations in the next 5 years. Speaking of newness – we are getting ready to move to our new home – renovated, connected floors in Kline Tower this coming summer. The entire department including the astrophysics group from the Physics department will be housed on three consecutive floors around a central atrium. I am optimistic that this more congenial layout will permit more interaction, and collaboration while also building a stronger sense of community. It has been impressive to watch the raft of breakthrough science discoveries from our vibrant community of faculty, postdocs, grad students and our undergrads - despite the debilitating effects of the pandemic. In this issue, I share with great pride the scientific results and on-going research projects of our senior graduate students. *Hot off the press! Excited to report that we will be hosting the upcoming Emerging Researchers in Exoplanet Science (ERES) Symposium 2023 at Yale next June; our graduate student organizers have just been awarded a grant from the Heising-Simons Foundation.*

We press on driven by curiosity and sense of joy in figuring things out…and as eloquently put by the astronomer poet Rebecca Elson –

We astronomers are nomads, Merchants, circus people,
All the earth our tent.
We are industrious. We breed enthusiasms,
Honour our responsibility to awe.

With warmest wishes for a wonderful holiday season and a healthy, happy 2023,

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: including the Bob Wing matching fund described here as well as other ways that can be found on the donate page on our department website.

YALE ASTRONOMY MOVES TO KLINE TOWER

SUMMER OF 2023

The Kline Tower Institute for the Foundation of Data Science (FDS), was inaugurated in November and will open formally in Fall 2023. The Kline Tower renovation, announced in 2019 and delayed by the COVID-19 pandemic, is finally set to complete by the summer of 2023. The 186,000 square foot renovation project is the newest step in re-imagining the Science Hill area to meet the needs of growing science departments. Astronomy alums may remember the days in the old Gibbs building, which has now been transformed into the new Yale Science Building and hosts biology departments and lab spaces. The current Astronomy department offices on Hillhouse Avenue have been reassigned to Yale's new public policy school – The Yale Jackson School of Global Affairs after astronomers move into the Kline Tower next year. In addition to Astronomy, the redesigned tower will host the Departments of Mathematics, and Statistics and Data Science, as well as parts of the Department of Physics, including the Astrophysics group.

After years of working in three separate buildings on Hillhouse Avenue, astronomy faculty, students, postdoctoral researchers and staff are excited to move into one building again. We will be occupying three inter-connected floors in Kline Tower. In addition to increasing departmental cohesion, the new Kline Tower is designed to foster collaborations across departments and promote interaction with the burgeoning field of data science.

The Kline Tower Institute, or KTI, for the Foundations of Data Science, will open in fall 2023. David Spielman, Sterling Professor of Computer Science and professor of statistics and data science and of mathematics at Yale, will be the inaugural director of the KTI. Currently, Astronomy faculty members Laughlin and Natarajan are members of FDS. The KTI plans to launch programs dedicated to specific research areas as well as week-long workshops. This drive towards collaboration is reflected in the building plan: large common areas will be connected by open staircases to adjacent floors, providing for greater in-

Kline Tower continued from page 5

teraction among faculty, students, and staff. Topping the tower will be a newly built event and meeting space with panoramic views of New Haven and its harbor.

Other planned elements include:

- A new classroom floor with multiple, smaller meeting rooms to allow instruction alongside flexible gathering space.
- A floor dedicated to lecturers and graduate students in order to build collaboration and community around Yale's teaching mission.
- An entry-level common space connected to a new pavilion, which will in turn provide a direct connection between Kline Tower, the Yale Science Building, and Sloane Physics Laboratory.
- A center for quantitatively focused teaching and learning, designed to reinforce Yale's educational mission in mathematical, statistical, and data sciences, as well as other quantitative methods. This will be located on the concourse level, below the usual entry level of the tower, on the same floor as the new O.C. Marsh Lecture Hall. There, faculty will lead workshops on teaching, run tutorials and reviews, and support spontaneous group study work.

"With its new design and new occupants, the tower will become a vital and thriving center for research in theoretical and applied mathematics, astronomy and astrophysics, particle physics, and statistics and data science," Jeffrey Brock, dean of the School of Engineering & Applied Science and the Zhao and Ji Professor of Mathematics, and Alan Gerber, FAS Dean of Social Sciences, wrote in a 2019 letter to faculty, "It will also house an outward-facing institute to signal to the world Yale's status as a center for foundational research in mathematics, computation, and data science."

Debra Fischer's

Search for 100 Earths

written by Konstantin Gerbig

Debra Fischer, Eugene Higgins Professor of Astronomy, was named director of the National Science Foundation (NSF) division of Astronomical Sciences last year. She was the first Yale faculty to be selected for this position. Professor Fischer spoke to us about her perspective on her outstanding career in Astronomy – from the discovery of the very first Exoplanets, her time at Yale and the development of the EXtreme PREcision Spectrometer (EXPRES), to her current and pivotal role at the NSF.

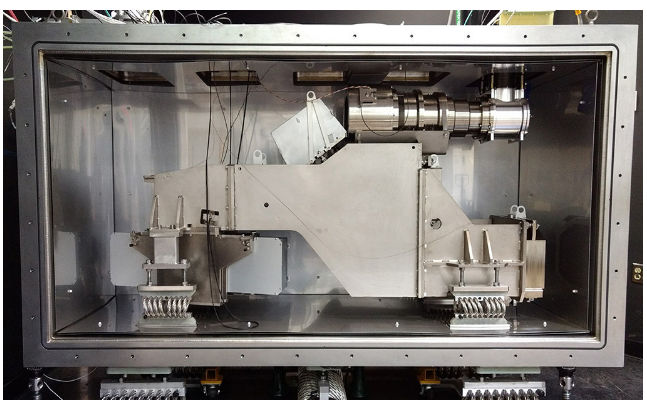
Discovery of Exoplanets

Debra Fischer grew up in Iowa and attended the University of Iowa as a first-generation college student pursuing a medical degree. During pre-med courses, her curiosity for understanding how things work drew her towards physics, mathematics and chemistry instead. Fischer thus went on to receive a master's degree in physics at San Francisco State University, and a PhD in Astronomy at University of California, Santa Cruz. Fischer was a non-traditional student therefore in multiple ways, including the fact that she started her family prior to attending graduate school, a challenge she overcame with the important support and step-by-step guidance of female role models and peers.

Fischer remembers her first years in Astronomy as an incredibly intense time. The field of exoplanets was in a vastly different state compared to today, when we know of thousands of confirmed exoplanets. In the 90s, some were pessimistic about the prospect of exoplanets even existing — a point of view fueled by the retraction of several supposed early exoplanet discoveries. Despite this uncertainty, Fischer remained optimistic and made the conscious decision to stay in academia in order to make an impact. And indeed, Fischer's decision paid off. The first exoplanet was discovered in 1995, revolutionizing the field, with Fischer right at the forefront of the early observational teams. The highlight for Fischer from these early years of exoplanet science was her discovery of the Upsilon Andromedae system (see page 21). This was the first system known to have three planets, and the first discovery of a multi-planet system. Fischer's discovery was received with skepticism at first, but a cross-check with Harvard's data, as well as current Yale faculty Greg Laughlin's confirmation that the triple system is indeed dynamically stable, confirmed this fascinating finding, and demonstrated to Fischer that persistence pays off. Another exciting discovery was the planet-metallicity relation, which describes the very strong trend of more metal-rich stars to be more likely to host planets. This finding pointed towards planets being common in the galaxy, and consequently to planet formation being a very robust process.

Yale Astronomy

Fischer joined Yale in 2009 and was recognized with a Eugene Higgins Professorship in 2019. During her time at Yale, her flagship project was the development of EXPRES, a high-resolution spectrograph designed with the goal of detecting highly precise radial velocity signals and thus detect small, rocky planets. Spectrographs at the time had precision of order 1 m/s, which rendered small exoplanets in the habitable zone invisible to radial velocity measurements. In order to detect small exoplanets, Fischer designed EXPRES to achieve a precision of up to 10 cm/s. EXPRES encompassed a number of novel instrumental innovations. Of particular importance are the fiber optic cables and the laser frequency comb, in the construction of which Yale Astronomy research scientist Andrew Szymkowiak played a key role. After initial challenges, Fischer's team took the first observations with EXPRES in January of 2019 and showed an incredible 30 cm/s precision when looking at stars. Since then, EXPRES has provided exciting and precise spectra of a multitude of complex systems.



The EXtreme PREcision Spectrometer (EXPRES)

At Yale, Fischer in particular appreciated the rich and collaborative environment, not just within the Astronomy department, but also with related departments: Physics, Electrical Engineering, Statistics, and Geology (now renamed Earth and Planetary Sciences). She also remembers the kind and resourceful students at Yale, an observation that was confirmed while serving on the Yale College admissions committee. In addition, Fischer served as the Dean of Academic Affairs, a role that likewise provided invaluable experience.

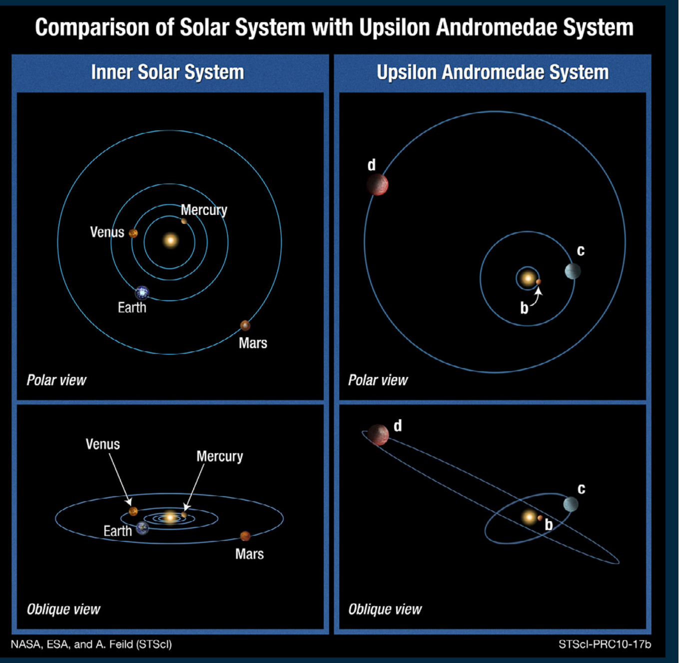
NSF Director for Astronomical Sciences

In 2022, Fischer was named the director of the National Science Foundation's (NSF) division of Astronomical Sciences. In this pivotal role, she leads NSF's mission to set national astrophysics science priorities, and in the process guide and support a broad range of ongoing research. Fischer highlights the Astro 2020 decadal survey, which made recommendations on a scale never seen before, as one of the key reasons for joining NSF. One particular area of interest is instrumentation, which, Fischer feels, is a field with many advances left to be made that necessitate prioritization. In addition to the Astro 2020 decadal survey, Fischer also notes the directional change coinciding with the new US administration, and climate change, as important factors for joining the NSF.

Fischer has been actively involved in the effort of making Astronomical research more climate friendly as underlined by her founding role in the '[Astronomers for Planet Earth]' project. At NSF Fischer aims to continue this important path. Specifically, this includes transforming key US-operated observatories into carbon-neutral facilities —- a goal achieved e.g., by installing photovoltaic plants to replace liquid methane generators.

Fischer also highlights advancing diversity, inclusivity and the democratization of science as important components of her new role at the NSF. This includes, for example, combined efforts by the NSF and NASA to make data products more accessible and readily available. Within this context, Fischer highlights the importance of inter-institutional collaborations, both between universities, but also involving NASA, industry or philanthropic organizations, all of which can be recipients of NSF funding.

Fischer remarks that the NSF is at times relatively invisible. Unlike for example. NASA, the NSF is not pushing forward and realizing its own projects, and instead funds and helps the community itself to do better research for the benefit of the general public. Fischer concludes that this is what makes the NSF an invaluable and precious resource for the United States.



This is an artist's illustration that compares our Solar System with the Upsilon Andromedae system.

Illustration Credit: NASA, ESA, and A. Feild (STScI).

Yale *Astronomy*

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.

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 challenge will run from December 2022 to June 2023, and those interested in participating will have the opportunity to do so during that time.

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

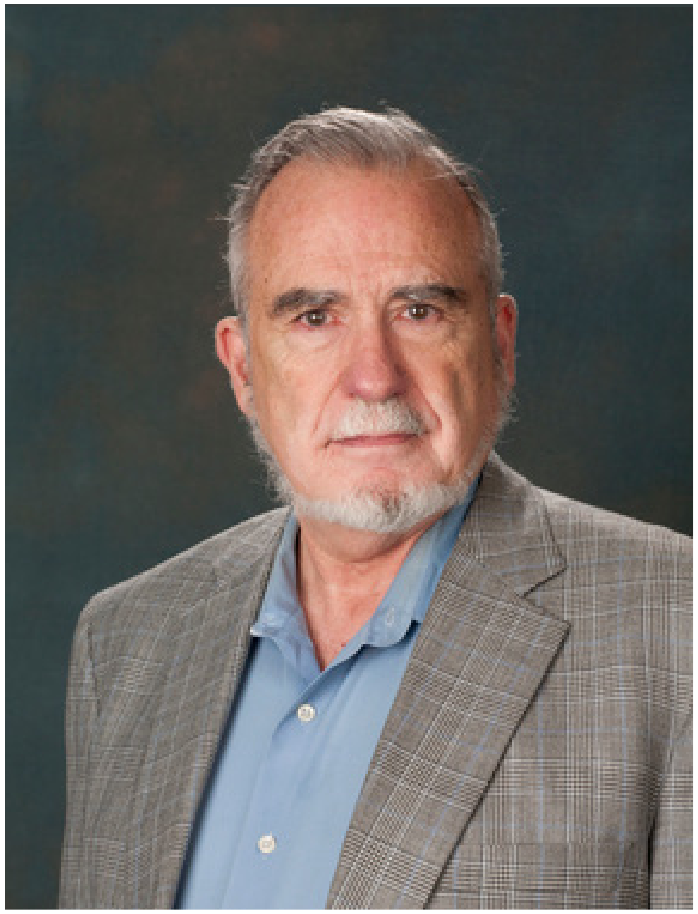
To support the Yale Department of Astronomy, please send a check payable to Yale University to the address below with "Robert F. Wing Fund for Undergraduate Research in Astronomy - 15108" in the memo line.

Yale University Office of Development
Contribution Processing
P.O. Box 2038
New Haven, CT 06521-2038

GIVE ONLINE

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.



Bob Wing - photo credit, The Ohio State University

ABOUT BOB WING

In the spring of 1959, Bob Wing '61 was the only student to sign up for a newly-offered major in "Astronomy and Physics," which would later become known as the Astrophysics major, so that Bob can be considered Yale's first Astrophysics major.

After graduating in 1961, Bob went to the University of California, Berkeley, for his PhD in Astronomy (1967). As a graduate student, while working on his dissertation on the near-infrared molecular spectra of late-type stars, he found himself -- rather by accident -- investigating the spectra of matches and thereby solving the puzzle of the reported "potassium flare stars." That sidelight on his research is an interesting story in itself, and it is told in full, for the first time, in this issue - THE SAGA OF THE POTASSIUM FLARE STARS - on page 13.

Since completing his PhD, Bob taught for many years in the Department of Astronomy at Ohio State University. While he no longer teaches, he maintains his interest in astronomical research, and in particular has supported Yale's participation in the SMARTS consortium.

ASTRONOMY STUDENT PRIZES AND AWARDS

BECKWITH PRIZE WINNERS
(Undergrad)

Abby Mintz - 2022
Charlie Gardner - 2021
Alexa Anderson - 2020
Samantha Berek - 2020
Daniel Heimsoth - 2020
Osasi Omoruyi - 2019
Stephanie Spear - 2019
Christopher Leet - 2018
Luis Fernando Machado Poletti - 2018
Isabella Trierweiler - 2018
Lauren Chambers - 2017
Kristo Ment - 2017

BROUWER PRIZE WINNERS
(Graduate)

Sarah Millholland - 2021
Angelo Ricarte - 2020
Johannes Ulf Lange - 2020
Joel Leja - 2019
John Brewer - 2019
Fangzhou (Arthur) Jiang - 2018
Joel Tanner - 2017
Ana Bonaca - 2017
Rachel Bezanson - 2016

TINSLEY PRIZE WINNERS
(Graduate)

Uddipan Banik - 2021
Sam Cabot - 2020
Joel Ong - 2019
Darryl Seligman - 2018
Sarah Millholland - 2017
Angelo Ricarte - 2016

THE SAGA OF THE POTASSIUM FLARE STARS

Written by Robert F. Wing
Professor Emeritus, Ohio State University

In my 50+ years as a professional astronomer, I have met a large number of astronomers, some of whom have had nice things to say about my research on late-type stars. But I can't help noticing that some others have seemed more aware of my "research" on the phenomenon of "potassium flare stars." And since there seems to be a lot of confusion as to who did what, and why, I thought it might be helpful to put the story in writing.

At Haute-Provence Observatory in southern France, a funny thing happened on the night of May 15, 1962. The observatory Director, Daniel Barbier, was using the coude spectrograph at the 193-cm telescope to record the spectra if solar-type dwarfs in a near infrared region that includes the atmospheric A band of O2 when one of them, HD117043 (G5 V) showed strong (saturated) emission lines at 7665 and 7699 A, easily identified as the resonance doublet of neutral potassium (K I). No trace of those lines was seen in other stars, or in the same star reobserved on the following night. This observation was noted in the ApJ, but it apparently received little attention until the same emission lines appeared two years later in the spectrum of another late-type dwarf, HD88230 (K5 V), observed with the same spectrograph. Surely this was a flare phenomenon that occurs in late-type dwarfs, which had heretofore escaped notice because few observers were photographing spectra in the near-infrared.

In the summer of 1966, as a third-year grad student at Berkeley, I had the opportunity to attend my first international astronomy conference, the "Colloquium on Late-Type stars" held in Trieste, Italy. On the program was a paper by Yvette Andrillat from Montpellier, entitled "Three Potassium Flare Stars." She had been observing with the same coude spectrograph at Haute Provence in June 1965, and to her great surprise, she recorded the third potassium flare. She was not interested in late-type dwarfs; her forte was hot stars with emission lines, the Be stars, and she wanted to examine their spectra in the seldom-used near infrared region. The star 4 Her (B9e) showed potassium emission on June 18 but not on the next night. Now that there were three potassium flare stars, she decided it was time to give a review paper.

As I sat there in Trieste listening to Dr. Andrillat's talk, I felt certain that something was wrong. At Berkeley, I had been studying "Stromgren spheres," the regions around stars where no neutral hydrogen can exist, their size depending on the star's ionizing ultraviolet flux (i.e. its temperature). An obvious extension of this concept made it clear that no neutral potassium -- one of the most easily ionized elements -- could exist anywhere near a B-type star.

I didn't contribute to the discussion after the Trieste talk -- some distinguished astronomers seemed to be taking the potassium flare phenomenon seriously, and who was I at age 26? But on returning to Berkeley, I shared my misgivings with my thesis advisor, Hyron Spinrad, and my officemate Manuel Peimbert. We also discussed the possibility of using a photoelectric spectrum scanner for a quick survey of many stars. Dr. Andrillat had mentioned a plan at Haute Provence to conduct a survey at lower dispersion, at a different telescope. But the Lick Observatory prime-focus scanner, which was designed by Joe Wampler and which I was then starting to use for my thesis observations, could be programmed to compare the counts in a band of a few Angstroms centered on one of the potassium lines to the counts in side bands, and would show in a minute or less if the star had strong emission in the line. Despite our doubts about the astrophysical origin of the emission, we decided that it would be worth a night of observing, to see how many stars we could check in this way. Then at least we could tell the French astronomers that we had a survey technique that was a order of magnitude faster than theirs.

We were given one night on the venerable 36-inch Crossley telescope to test our idea, and on September 27, 1966, I drove to Lick with Spinrad and

THE SAGA OF THE POTASSIUM FLARE STARS continued from page 13

Peimbert. At dinner, Spinrad asked me, "Bob, got a match?" I was the only one of us who smoked, and I remember replying, "Sure, and I even have some French ones" picked up the night before at a French restaurant in Berkeley.

While we waited for it to get dark, I programmed the scanner to do a three-point program setting on one of the potassium lines (7699 A) and two side bands. The scanner used a grating whose tilt was governed by a stepping motor, and programming was done by simply pushing pins into a control board. After setting an exit slot width and specifying an integration time appropriate for the star's magnitude, one just presses the "start" button and the scanner takes integrations up and down the program until being told to "stop." "OK," said Spinrad, "now let's see if we can detect potassium emission from matches." Standing on the platform at the top end of the telescope, I struck a match over the telescope mirror. Bingo! Thousands of counts in the central band, and nothing in the side bands. The three of us looked at each other, but I don't think we needed to say anything. We felt sure we knew the origin of the potassium emission, and the sky wasn't even dark yet. Should we go ahead with our observing plan? Well, why not -- we had been looking forward to observing together.

My observing list consisted of stars of all spectral types brighter than certain magnitudes and lying between delineations +15 and +25 degrees, from right ascensions 17h to 3h -- criteria that produced about 20 stars per hour of RA, which we hoped we could keep up with as the earth turned. With all three of us on the platform attached to the dome slit, Manuel kept the log and announced the name and coordinates of the star; I pushed the telescope to the star's position, adjusted the dome, centered the star in the aperture, and shouted "Go!"; and Hyron pressed the "start" button on the juke box controlling the scanner and monitored the counts until he was satisfied that we would know if we had statistically significant emission. Finally, Manuel would record the time and hour angle, and announce the coordinates of the next star.

This actually was a lot of fun. On that one night, we made 181 observations of 162 different stars; three of the stars were observed repeatedly to check whether the weak atmospheric lines of O2, from the tail of the A-band, were affecting our index (the effect proved to be very small). I made all 181 of the telescope settings -- I think some kind of record, at least for the days before computer control. But the next step was not so much fun -- back in Berkeley, I would have to punch the several thousand readings, recorded on paper at the telescope, onto IBM cards so that my reduction program could produce a "potassium index" for each star.

By the time I got up on the afternoon following the observing, Spinrad was already busy negotiating for the daytime use of the coude spectrograph at the 120-inch telescope. This involved getting the agreement of the 120-inch observer and also telephoning down to Santa Cruz to get the OK from George Preston, a Yale alum who was then in charge of the coude spectrograph. We needed to open the dome to record the spectrum of a G2 V star, our Sun, scattered in the daytime sky, and we needed permission to strike matches in the coude room. I believe this actually took several phone calls before permission was granted. But we acquired a nice set of spectra of matches (of several types), as well as that of a G2 V star with strong potassium emission, very similar to the spectrum first recorded by Daniel Barbier.

I decided I should write to Dr. Andrillat in Montpellier, to tell her of our activities and our reasons for suspecting that the potassium emission observed at Haute Provence was caused by the striking of matches. She replied quickly and politely, in English, to assure me they the French observers had considered artificial origins, and had contacted the military to make sure no unusual experiments were being conducted on the days of the flares -- and no, none of the three events had occurred on Bastille Day, the French equivalent of the 4th of July. And she reported that since the meeting in Trieste, the Haute Provence staff had been conducting a large survey at a smaller telescope, at lower spectral resolution, and that to date 1675 hours of telescope time had been devoted to obtaining near-infrared spectra of approximately 1000 stars. No potassium had been detected, apart from the three cases discussed in Trieste.

In a follow-up letter, Dr. Andrillat told us that she had tried to photograph the spectra of matches with the coude spectrograph at Haute Provence, as we had done at Lick. She found it very difficult to get light from matches into their spectrograph, and succeeded only when the match was held exactly on the optical axis, which of course would never happen during a stellar observation. She explained that their coude spectrograph was totally enclosed in a vacuum tank, and that no light could get inside except along the optical axis. To make this clear, she kindly sent us a set of engineering drawings for the spectrograph.

Aha, there it was! The engineering drawings showed that starlight entered the coude room through a piece of glass called a "guiding device" before crossing the room and entering the spectrograph. This "guiding device" was to be tipped back and forth during an exposure, under motor control, to produce nicely widened spectrograms. If a match was struck anywhere in the coude room, there was a small but non-zero probability that the guiding device happened to be tilted in the right way to reflect its light directly down the optical axis and into the spectrograph. No wonder that this didn't happen very often. And no wonder that potassium flares were never observed with other spectrographs.

Since Daniel Barbier, who had recorded the first two "flares,"had died in 1965, I went to the library to look for an obituary, to learn more about the man. And there I found a picture of him -- with a pipe in his mouth!

Manuel Peimbert and I decided to write up our experiences as a journal article. As a couple of students in our mid-twenties, we produced a paper that was entertaining, even hilarious, but which unfortunately made the French astronomers sound like fools. We submitted the paper to the PASP, then edited by Katherine Kron (the wife of the pioneering photometrist Gerald Kron) whose office was in the main building at Lick Observatory. After some two weeks, we received word from Mrs. Kron that a referee had advised not to publish the paper; he was concerned that it might cause bad international relations on the eve of the 1967 IAU General Assembly. Well, I guess we deserved that. I then completely rewrote the paper, emphasizing the scanner observations which showed that we had taken seriously the possibility of a stellar origin, with matches only discussed in the final section. The revised paper was submitted and quickly accepted (Wing, Peimbert, and Spinrad 1967, PASP 79, 351).

A decade or so later, I was serving as colloquium chairman for my department at Ohio State and invited Billy Bidelman to visit from the Case Institute (Cleveland) to give a talk. He was part of the old guard of stellar spectroscopists and knew by heart the HD numbers and spectral types of hundreds (thousands?) of stars. While socializing that evening after his talk, he approached me with a nervous smile and said, "Bob, there is something I think I should tell you. I was the referee of your potassium flare paper. I hope there are no hard feelings." No problem, I assured him. Although this was the only paper I've ever had rejected, the rewritten version was printed after only a short delay, and I agreed that the first version by smart-ass graduate students might have caused problems.

At some point (I think it was in August 1981) I was observing on the Kitt Peak 2.1-m telescope and happened to go into the associated darkroom. I was doing photometry, not photography, and probably just went into the darkroom to warm up (yes, the observing in those days was done from the platform, not a nice warm control room). I noted a spectrum displayed prominently on the wall over the sink where it couldn't be missed, and I immediately realized that it was an enlargement of the figure from my PASP paper showing a G2 V (sky) spectrum with potassium emission. Beside the figure was a note, in large letters: "WARNING: Do Not Smoke While Observing!" It had been put there by Art Hoag, the Kitt Peak astronomer responsible for that telescope and its darkroom.

Is there a moral to this story? Probably not, but I do have a few words of advice to today's graduate students. Although you can quite reasonably hope to gain fame from the wonderful work you are doing for your doctoral dissertations, you shouldn't be too surprised if fame comes from something altogether different!

Aritra Ghosh

Class of 2023

I grew up in Kolkata, a city in eastern India, and spend most of my non-research time cooking a wide variety of Bengali dishes & desserts, listening to music, and (like most astronomers) dabbling in photography. I have also led a variety of initiatives to improve graduate student life at Yale.

Aritra's research has been supported by the Dr. James I & Mary W. Herbert Scholarship, the Yale Dean's Emerging Scholars' Research Award, and the Yale Research Grants for Cloud Computing -- all of which were made possible by the generosity of previous Yale donors/alumni.

To learn how you can support Yale Astronomy and its students, please visit, https://astronomy.yale.edu/donate/support-yale-astronomy

The shapes and sizes of galaxies (galaxy morphology) hold crucial information about how galaxies evolve over time and can be used to identify specific formation scenarios that led to the wide variety of galaxies we see at different epochs of time in our universe. In the past, astronomers have primarily relied on manual analysis techniques to determine the morphology of galaxies. However, these techniques cannot be scaled to the petabytes of data expected over the next decade from future astronomical surveys such as the Vera Rubin Large Synoptic Survey Telescope and Euclid, which will begin operations as soon as 2023.

With this upcoming data deluge in mind, Aritra has focused on developing novel machine learning techniques that can determine the shapes and sizes of galaxies in less than a millisecond. Aritra's research over the last few years has helped overcome some of the major challenges associated with using machine learning techniques for astronomical analysis --- the ability to train algorithms without needing large training sets, the estimation of robust uncertainties associated with machine learning predictions, quantification of various biases inherent with using machine learning techniques.

Innovatively combining these new algorithms with the computing power of Yale's Grace supercomputing cluster, Aritra and other Yale astronomers have quantified the shapes and sizes of 8 million galaxies from the Hyper-Suprime Cam survey in a recent paper. This is one of the largest morphology studies ever performed, and millions of these galaxies have never been studied morphologically. Aritra is now exploiting this unprecedentedly large statistical sample to a) explore how the morphology of galaxies is correlated with the different environments that they live in; b) investigate how supermassive black holes affect galaxy morphology; c) quantify the buildup of mass in these galaxies over time by using their morphological information.

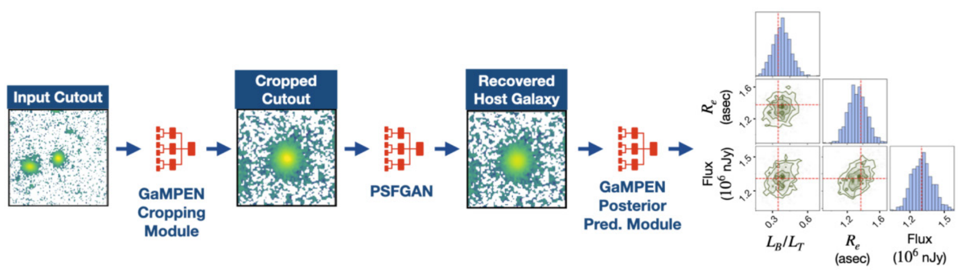


Figure 1 (above): Aritra's algorithms use successive collections of convolutional neural networks to efficiently identify galaxy morphology and predict different morphological parameters.

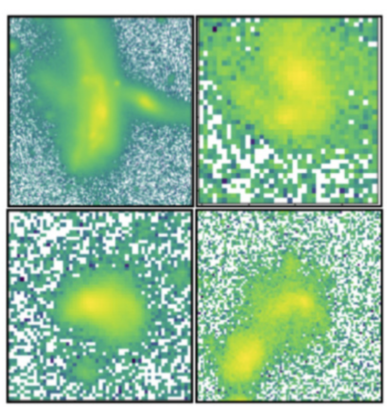
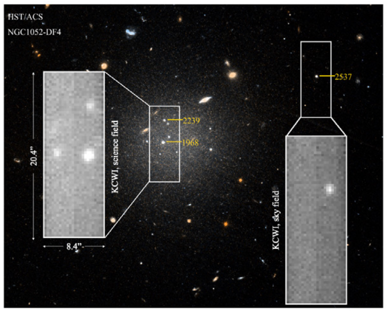


Figure 2 (left): A sample of galaxies with unusual morphologies identified from the Hyper Suprime-Cam survey using machine learning techniques. Aritra and other Yale Astronomers plan to observe some of these galaxies in detail using Yale's access to the Keck and Palomar telescopes.

Zili Shen

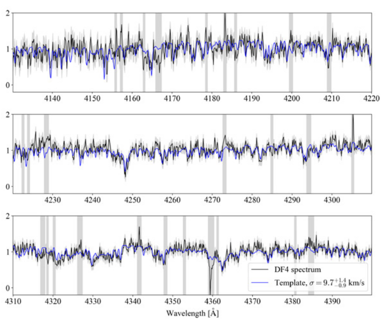
Class of 2025

I write Astrobite articles about research papers and navigating grad school; my favorite season is fall because I love foliage.



A spectrum contains much more information about the composition and kinematics of a galaxy, because the light is spread out along its wavelength and we can study spectral absorption lines. That also means it's much harder to take a spectrum for a faint galaxy than to take an image of it. Furthermore, if we want a high-resolution spectrum, the light becomes even more spread out and more difficult to observe. Thanks to the Keck Cosmic Web Imager (KCWI) on the Keck Telescope, we have taken the highest resolution spectrum of a diffuse galaxy that's fainter than the night sky. We pointed Keck telescope at NGC1052-DF4 and collected its light for four nights, and the resulting spectrum is shown in the figure.

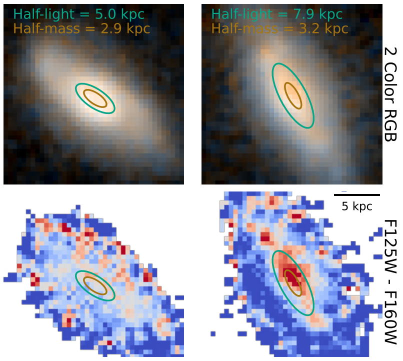
This high-resolution spectrum gives us the most accurate measurement of the dark matter content of this galaxy to date. NGC1052-DF4 is the second galaxy found to be lacking dark matter from the motion of its star clusters (the first one, NGC1052-DF2, is in the same group and is covered in another article in this newsletter). Using this new spectrum, we are able to accurately measure the width of the spectral lines by fitting models (blue line) to the data (black line). The width of the lines indicate the motion of the stars in this galaxy, which in turn is dictated by the total mass of the galaxy. The new measurement of the mass confirms the lack of dark matter, and due to the much smaller error bars, we can be much more confident of this result.



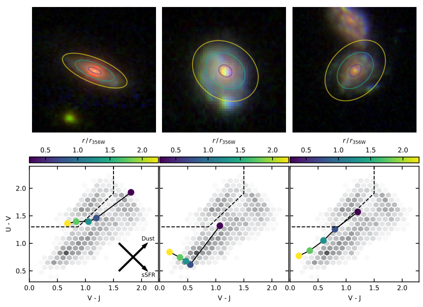
Tim Miller

Class of 2023

I grew up in Canada and in my spare time enjoy downhill skiing and watching my home-town Toronto Raptors

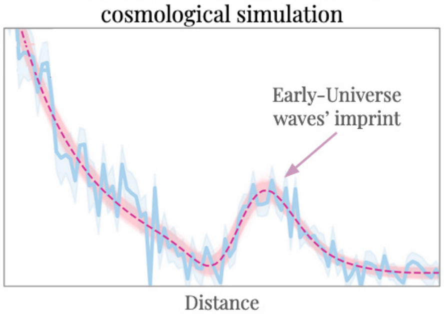


A Galaxy's morphology provides crucial constraints on its formation history. Most studies rely on measurements using a Sersic profile of the half-light radius of galaxies at optical wavelength measured. My research tries to question these assumptions and investigate how they biased our interpretation. The Sersic profile provides a convenient paramaterization, however it cannot fully capture the complexity of real galaxies. I developed an alternative based on multi-gaussian expansion, called imcascade. By representing the light profile as a series of gaussians and incorporating Bayesian inference it provides much greater flexibility. I apply imcascade to HST images of galaxies at z=1-2. These galaxies display strong negative gradients in their optical colors (i.e. redder in the center) which vary with stellar mass, redshift and galaxy type. By using this color to account for mass-to-light ratio gradients, I studied the relationship between the half-mass and half-light radii. The ratio of half-mass to half-light radii decreases from 0.8 at z=2 down to 0.5 at z=1. This leads to a slowly evolving half-mass size to stellar mass relation with a shallow slope. By applying imcascade to early JWST data I measure near-IR color gradient for a sample of star-forming galaxies at a redshift of two to investigate the physical causes. We find strong gradients in their NIR and optical colors indicating strong central dust attenuation as the main physical driver of color gradients.



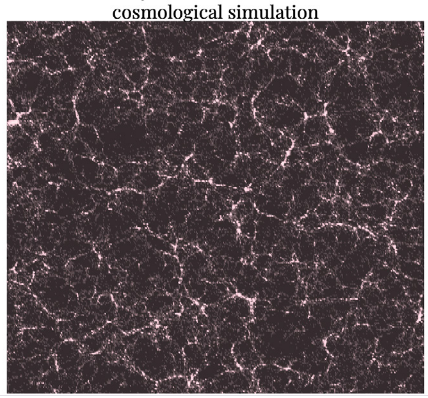
The early Universe looked quite different from today's. No grandiose galaxies or vast voids -- matter was featureless except for tiny variations, which appeared shortly after the Big Bang. Like pebbles thrown into a smooth lake, the variations sent waves through the smooth distribution of matter. Unimpeded, the waves traveled at the same speed until the Universe started to fragment and form galaxies. The waves traversed the same distance everywhere - and froze into the distribution of galaxies we see to this day. The location of the waves' imprint is called the BAO scale. Cosmologists can use this scale to determine distances in the cosmos.

Distribution of proto-halos in a cosmological simulation



Gravity's impact on galaxy formation complicates measuring the BAO scale. As the smooth soup of early Universe matter broke up into galaxy-forming clumps, the clumps attracted each other with gravity. This made them drift towards each other over time. This drift creates a gorgeous cosmic web. Sadly, it also blurs out the imprint of early-universe waves.

The fatally beautiful cosmic web in a cosmological simulation



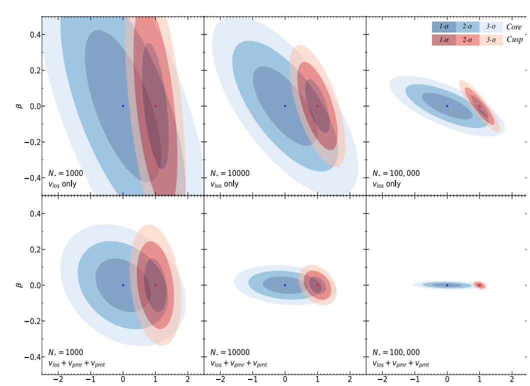
My research seeks ways to combat this effect. First, we find clumps of matter, called halos, that host galaxies in the current Universe. Using computer simulations, we trace the matter in each halo back in time, to a point when the Universe was still smooth. This early-Universe halo progenitor is called a proto-halo. Since gravity had not made proto-halos drift yet, centers of proto-halos were different from halos'. My research shows indicates that the distribution of proto-halos can improve the way cosmologists measure the BAO scale.

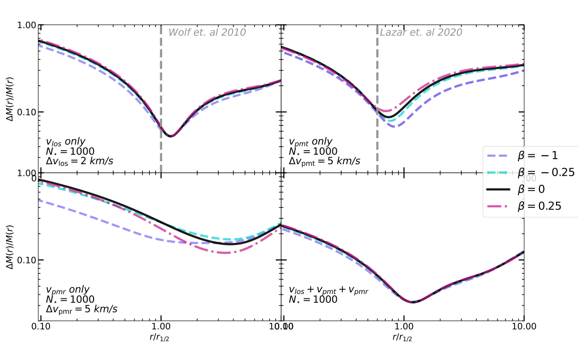
Sasha Safonova

Class of 2025

I first learned physics from my grandmother, a lifelong alternative energy researcher. Prior to Yale, I completed a Fulbright year at the Institute for Computational Cosmology in Durham, UK. I enjoy vegetarian cooking, aesthetics, and collaborative board games.

I study the internal dynamics of dwarf galaxies that orbit the Milky Way. These galaxies are sufficiently nearby to resolve individual stars, maximizing the available kinematic information. Using these resolved stars my work aims to determine how much dark matter these galaxies contain and how It is distributed. This has the potential to put constraints on the nature of dark matter as well as give us insights into the formation history of these galaxies. I've used Information theory to predict how well we can constrain the properties of these galaxies that we're interested in the limit in which our modeling assumptions are true, and how this will change with future observatories. I am now working with some of the highest resolution cosmological simulations to 1. Determine how true our assumptions about these galaxies are 2. Determine how to use additional information like metallicities to improve our modeling schemes.





Juan Guerra

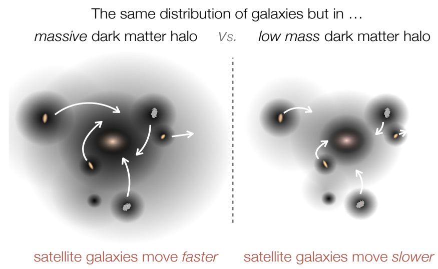
Class of 2024

Outside of Research, my interests include climbing, weightlifting, collecting records, and going to concerts.

Kaustav Mitra

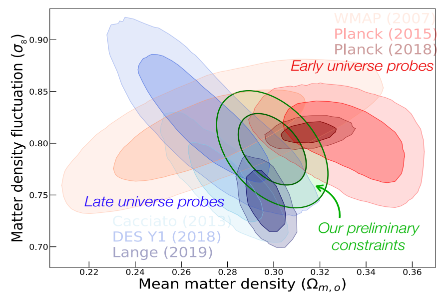
Class of 2024

I like painting, reading fiction, and really enjoy walking and cycling along leafy hiking trails.



Between first few million and few hundred million years of the universe, dark matter collapsed to form gravitationally-bound clumps called dark matter halos. Gas, mostly hydrogen and helium, flowed into the dark matter clumps, eventually cooled and collapsed to form the first stars, and subsequently, the largest collections of stars called galaxies. The mass of a dark matter halo can control gas inflow, star formation, colour and morphology of a galaxy residing in it, and even how it interacts and merges with its satellite galaxies. Thus, deciphering the link between dark matter and galaxies is crucial to fully understand and test the theories of galaxy formation and evolution. I study the motion of satellite galaxies to estimate the masses of dark matter halos and to infer the galaxy - dark matter connection with unprecedented precision.

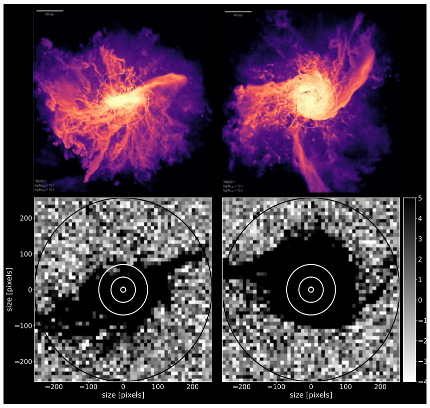
Cosmological parameters, such as the mean matter density of the universe and the strength of density fluctuations, control how large-scale structures grow and evolve. The galaxy - dark matter halo connection holds information about these global properties of the universe. Over the years, researchers have used clustering of galaxies and gravitational lensing of background sources by foreground galaxies to decode that information and measure these cosmological parameters. However, these measurements are in tension with inferences from probes of the early universe like the cosmic microwave background. This disagreement could be a hint of new physics, but might also be a result of systematic errors unaccounted for in clustering or lensing analyses. I use a new technique called satellite kinematics, along with galaxy clustering, to measure these cosmological parameters. Our preliminary analysis shows no tension with early universe probes. As our methodology improves, we will get better constraints of the cosmological parameters and get to the root of this major disagreement in the field.



Imad Pasha

Class of 2024

When not doing research, I enjoy climbing/bouldering, playing music and D&D, and working on side projects.



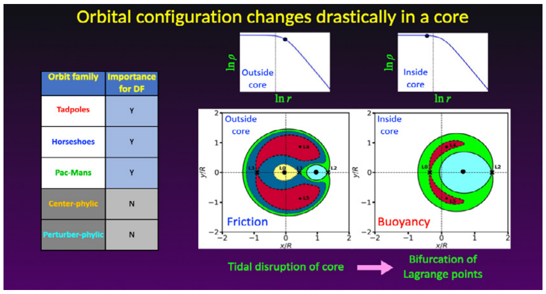
I study a variety of topics related to galaxy properties and evolution, primarily using observations, including imaging and spectra taken with the Keck Telescopes in Hawaii and the Dragonfly suite of instruments built by our group in New Mexico. I am particularly interested in the mapping between observable properties of galaxies and the actual underlying physical processes that drive their evolution. One way I have explored this connection is via SED fitting, a process by which we model the light output of galaxies using our best understanding of the physics, then attempt to match these models to data. More recently, my thesis has focused on the connection between the gas content and star formation within galaxies and their circumgalactic medium (CGM). The majority of galaxies in the universe have a bound CGM surrounding them which contains as much if not more gas than the galaxies themselves. The CGM is a critical but poorly understood source of gas for galaxies and a regulator of both inflows and outflows. I am in the process of commissioning a brand new instrument (*see the Dragonfly Spectral Line Mapper on page 21*) which will for the first time attempt to directly image the faint glow of this gas around nearby galaxies in H-alpha. In the figure above, one can see how the morphology of this gas might look based on simulations (top) and our best predictions for what our new instrument would be able to detect for such a system (bottom). By actually quantifying the extent and morphology of the CGM, we will learn a critical piece of the puzzle of galaxy evolution.

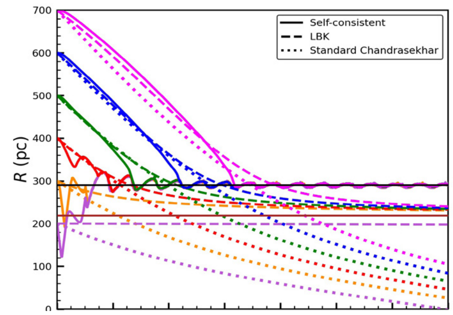
Uddipan Banik

Class of 2023

I sing Hindustani Classical Music, play chess and soccer, and go on treks in mountains and tropical rain forests.

My primary research areas are galactic dynamics, galaxy evolution and dark matter. The over-arching theme of my research is understanding how many-body self-gravitating structures like galaxies and dark matter halos (invisible 'dark matter' structures believed to embed galaxies) form and evolve in our Universe. Understanding how galaxies and halos respond to external perturbations (e.g., gravitational encounters with other galaxies/halos or with massive compact perturbers like black holes) and relax afterwards is a key component of understanding structure formation and is an essential element of my research. I study how galaxies and halos react to perturbations and how this response in turn affects the perturber, a phenomenon known as secular evolution or dynamical friction (DF). In the standard cosmological paradigm, it is DF that drives galaxy-galaxy mergers, resulting in a bottom-up hierarchical structure formation, i.e., smaller structures assembling to form larger ones. It is also believed to drive the formation of supermassive black holes by draining the angular momentum from black holes orbiting in host galaxies/halos and causing them to inspiral and merge. The efficiency of DF however depends on the density profile of the host galaxy, i.e., whether it has a central density cusp (steep) or core (shallow). N-body simulations have shown that while DF drives massive perturbers all the way to the center in a cuspy host, it becomes significantly weak in the core region of cored galaxies, causing an inspiraling perturber to stall (core-stalling). Sometimes the perturber can be pushed out from the core region by 'dynamical buoyancy' (DB), a secular phenomenon that opposes DF. I developed novel theories for secular evolution that for the first time explained the dynamical origin of core-stalling and DB, which was unexplained in the standard Chandrasekhar picture.



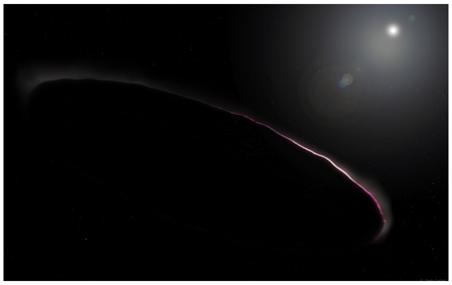


Samuel Cabot

Class of 2024

Outside of research, I enjoy photography (especially nighttime shots and astro-imaging).

Tens of thousands of craters lie on the Moon's surface, and a couple of them could reveal something extraordinary.



My research with my PhD thesis advisor Prof. Greg Laughlin aims to identify craters formed by interstellar interlopers. These mysterious objects form elsewhere in the galaxy, are ejected into interstellar space, and eventually encounter our own Solar System. At this time, only two interstellar interlopers have ever been discovered: 'Oumuamua and Comet Borisov. Their ephemeral passages yielded sparse, surprising, and at times, self-conflicting results. Their general compositions and origins remain unknown. However, identifying a crater formed by one of these objects could lead to a more detailed chemical analysis, and even the recovery of intact fragments.

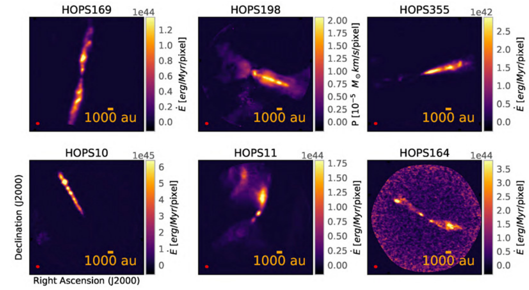
What makes an interstellar interloper crater stand out among a sea of "ordinary" craters? High-pressure chemistry might be the tell-tale signature, according to our investigation, which was recently published in the Planetary Science Journal. Comets and asteroids have a speed limit set by their orbits, and can impact up to about 180,000 miles per hour. Interstellar interlopers, however, can enter our Solar System much faster, beyond 220,000 miles per hour. When they impact the Moon's surface, they should leave behind more melted rock, in addition to other petrological indicators. We are hopeful that forthcoming Moon exploration missions, especially those under the Artemis initiative, might help identify these anomalous craters, and in turn shed light on the types of objects free-floating throughout our galaxy.

Cheng-Han Hsieh

Class of 2024

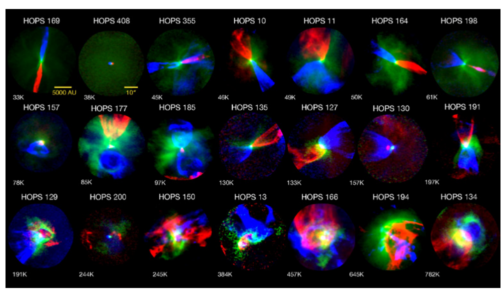
I grew up in Taiwan and in my spare time I play badminton, violin, read science fiction novels and play board games.

Have you ever looked up the night sky, and is amazed by the countless stars that light up the vast, unknown universe beyond our human eye? Stars are the building blocks of Galaxies, and each of them represents an exosolar system, distant worlds that are different from our own. My primary research interests are to understand how stars form, in particular how protostars accrete their mass, angular momentum, and the feedback effects of protostellar jets.



Stars form in dense molecular clouds. Clouds with sufficient mass would collapse under its own gravitational attraction. Due to the conservation of angular momentum, the collapsed dust and gas would form a disk-like structure in the center around the protostars. The magneto-centrifugal force in the center of the disk converts the gravitational energy of the accreted gas to kinetic energy, forming a high velocity protostellar jet and a wide-angle wind. These protostellar outflows are commonly found around protostars. Protostellar outflows would disrupt the accretion flows around the protostars, disperse the surrounding gas, setting the constraints on the accretion timescale. The feedback effects from the protostellar outflows are the key to the Initial Mass Function (IMF), the mass distribution of stars in the sky.

We developed a novel method to accurately measure the outflow rates and obtain the first instantaneous mass, momentum, and energy ejection rate maps for protostellar outflows. We use the Atacama Large Millimeter/submillimeter Array (ALMA), the largest existing astronomical interferometer with 66 antennas in the Atacama Desert to survey the protostellar systems in the Orion A molecular cloud. The surprising high protostellar outflows mass-loss rate from our survey challenges the idea that protostellar cores are a well-defined mass reservoir for protostars, and the simplified core to star conversion prescriptions.



ASTRO SIBS

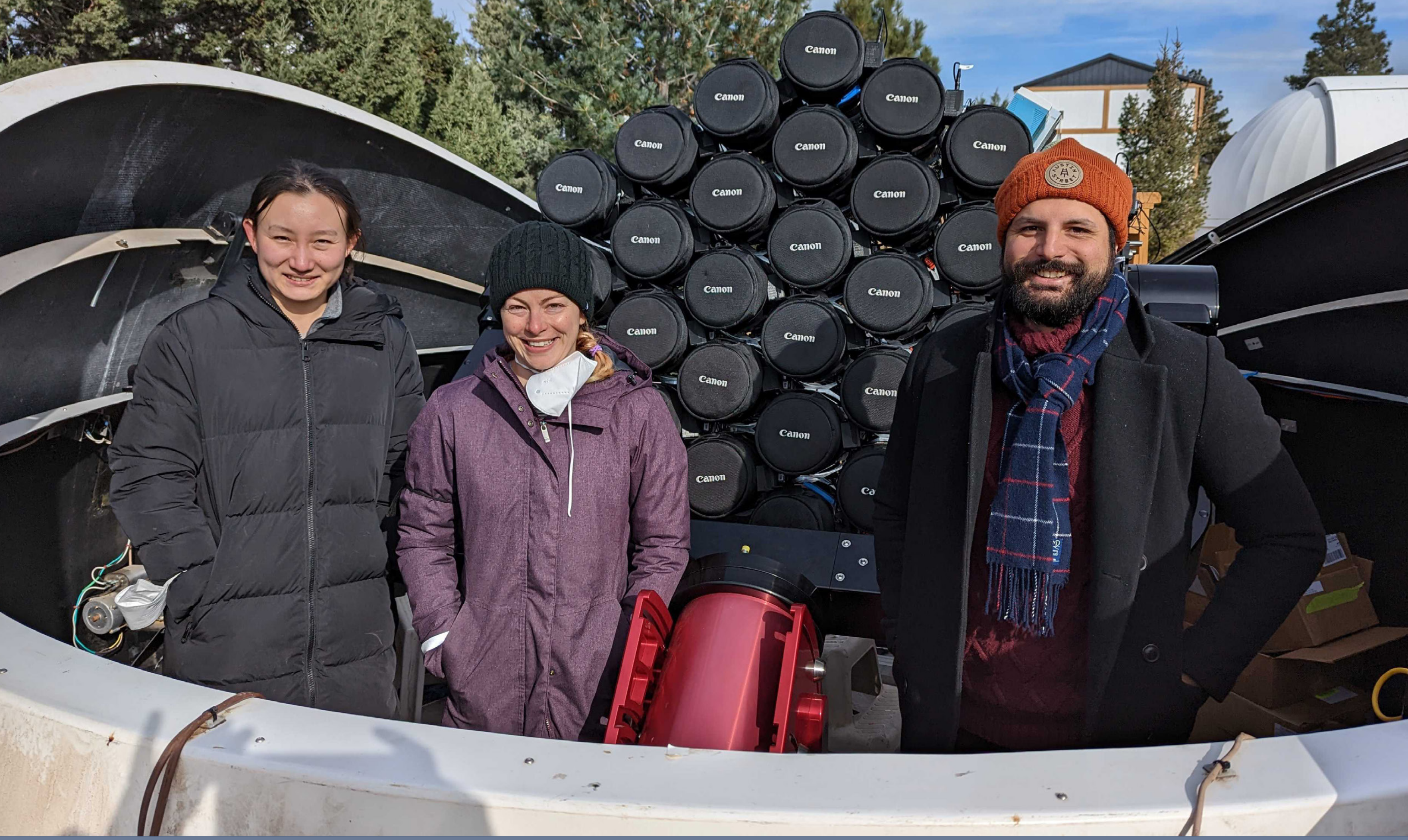
Undergraduate Mentorship Program

Astro Sibs is an informal mentorship system where Yale Astronomy undergraduate students are paired up with graduate students and postdocs in the department. Our goal is to ensure that undergraduate students feel welcome and comfortable in the department and that they have the resources available to ask for support where needed, whether academic or social. We aim to support undergraduate students on an individual basis through our pairings, while also providing larger group events and activities that encourage all members of the program to meet and get to know each other. These events include both informal gatherings and professional development events, such as internship and graduate school application panels. Astro Sibs was founded in 2018 and is now entering its fourth consecutive year, with roughly 12 mentoring pairs in each cycle so far. Astro Sibs program co-leaders are graduate students, Yasmeen Asali and Michael Keim.

Emerging Researchers in Exoplanet Science Symposium 2023 - Coming to Yale in June

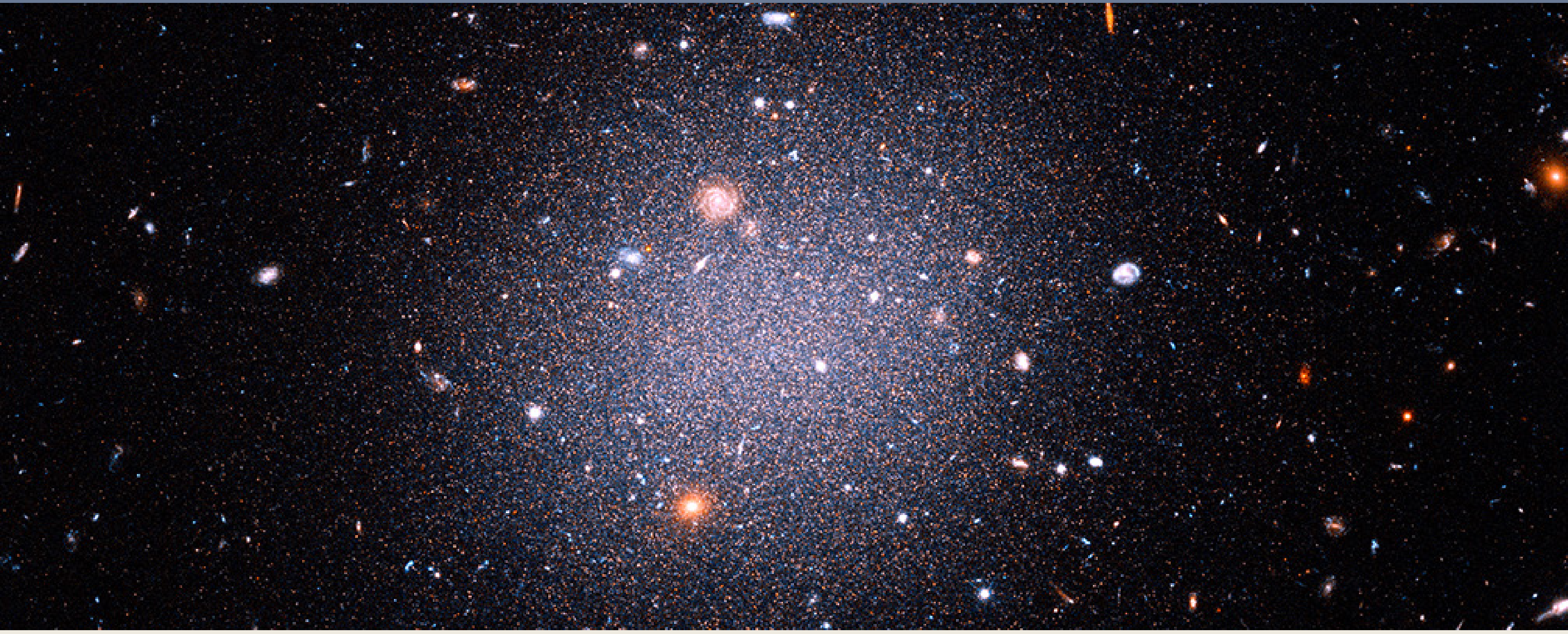
The Yale Astronomy department is thrilled to host the 8th Emerging Researchers in Exoplanet Science (ERES) symposium on June 19-20, 2023 at the Omni Hotel. This conference, established in 2015 through a partnership by Yale, Penn State, and Cornell, is aimed at advanced undergraduates, graduate students, postdoctoral researchers, and those with non-traditional pathways. This year's gathering is organized by a committee of Yale astronomy graduate students, postdoctoral scholars, faculty members, and external members to ensure the year-to-year continuity of the conference. We were recently awarded financial support via a generous grant from the Heising-Simons Foundation that will cover a substantial fraction of the expenses for participants to attend the conference such as transportation, lodging, food, and registration fees.

Since its inception, ERES has blossomed into one of the premier global venues for "exoplaneteers" to share their research, begin new collaborations, and build long-lasting community. In Summer 2023, we anticipate hosting around 80 early-career scientists studying exoplanets, stellar activity, brown dwarfs, planetary science, and astro-seismology, among other topics. In addition to the scientific program, the symposium will include panel discussions on topics of professional development such as proposal writing, building diverse and equitable teams, best practices for peer review, and effectively communicating science with the public. Hosting this year's ERES conference is an exciting opportunity that will further Yale's reputation as a leading center in exoplanet science for scientists at all career stages.



DRAGONFLY SPECTRAL LINE MAPPER

Pictured with Yale Astronomy Graduate Student, Imad Pasha (right), is Seery Chen (left) of the University of Toronto and Deb Lokhorst (middle) of the National Research Council Canada (Herzberg Astronomy & Astrophysics). Behind them is the first mount of 30 lens units for the Dragonfly Spectral Line Mapper, an in-construction instrument which will ultimately include 120 Canon telephoto lenses. The Dragonfly Spectral Line Mapper is located in Mayhill, New Mexico, at the New Mexico Skies Observatory.



Yale Astronomy Faculty

HÉCTOR ARCE

Héctor Arce's research concentrates on the study of protostars, stellar feedback, star-forming regions and the physical and chemical processes that take place in the interstellar medium. He served as Director for Graduate Admissions (DGA) from 2016–2019, and has served as Director of Graduate Studies (DGS) since 2019. In 2020 he was promoted to Full Professor.

CHARLES BAILYN

Charles Bailyn completed a four year term as Dean of Faculty at Yale-NUS College in Singapore in 2016. Upon his return to New Haven, he was appointed Head of College of Benjamin Franklin College, one of the new undergraduate Residential Colleges. He is currently in his final year of this appointment, and looks forward to returning full-time to teaching and research in 2023-24.

SARBANI BASU

Sarbani Basu completed six years as the Department Chair in 2022 and is currently on sabbatical as a Klaus Tschira Guest Professor at the Heidelberg Institute of Theoretical Studies (HITS) in Heidelberg, Germany. She is working with collaborators there to understand the physics of evolved stars, while at the same time continuing her research on the Sun. Her research about the Sun won her the George Ellery Hale Prize in 2018.

PAOLO COPPI

Paolo Coppi continues to work in high-energy astrophysics, most recently using space and ground-based gamma-ray detectors to probe the nature of the very rapid gamma-ray variability seen in blazars, supermassive black holes with powerful relativistic jets pointed at us. He is also active in the Rubin Observatory (LSST) science collaborations. To prepare for Rubin, which will image the sky to unprecedented depths every few days, he is leading the effort to reprocess and release Yale's La Silla QUEST variability survey.

MICHAEL FAISON

Michael Faison is a Senior Lecturer who teaches survey courses, observational astronomy labs, and special-topics courses, such as "Archeoastronomy". He is the Director of the Leitner Family Observatory and Planetarium on campus, and he is the Academic Director of the Yale Summer Program in Astrophysics, a research and enrichment summer program for high school seniors. His research background is in ISM observations through radio interferometry. He also pursues research in active-engagement pedagogy and effective teaching through hands-on lab exercises.

DEBRA FISCHER

Debra Fischer is an early pioneer in exoplanet detection and PI for three spectrographs: CHIRON (at CTIO in Chile), VUES (Villnius University in Lithuania) and EXPRES (at Lowell Observatory Flagstaff AZ). Fischer is on loan as the Divisional Director for Astronomical Sciences at the National Science Foundation through 2024.

MARLA GEHA

Marla Geha's research focuses on the study of low mass galaxies in the Milky Way and local Universe. She leads the SAGA Survey, an effort to understand the satellite galaxy population around 100 Milky Way-analogs. She is currently an HHMI Professor and serves on the Board of the Warrior Scholar Project. In 2022, she won the Dylan Hixon '88 Prize for teaching excellence in the natural sciences at Yale.

LARRY GLADNEY

Larry Gladney is an experimental particle physicist working with the Legacy Survey of Space and Time at the Vera Rubin Observatory. His primary interest is in determining the most accurate equation of state for dark energy. At Yale, he serves as Dean of Sciences and Dean of Diversity and Faculty Development for the Faculty of Arts and Sciences. (Primary appointment in the Yale Department of Physics)

JEFF KENNEY

The current research projects of Jeff Kenney include study of the highly disturbed ISM of the nearby radio galaxy NGC 1316 (Fornax A), where molecular gas on irregular orbits following a recent merger is being blasted by radio jets. This work is done largely with undergraduate students. He is also involved with ALMA-JELLY, an ALMA large program to observe molecular gas at high sensitivity and resolution in the nearest 'jellyfish' galaxies, which have long tails of ram pressure stripped gas undergoing star formation.

GREG LAUGHLIN

Since joining the Yale Astronomy Faculty in 2016, Greg Laughlin has had the opportunity to work with Yale graduate and undergraduate students on research that spans extrasolar planets and the planets and moons of the Solar System, as well as the newly-discovered interstellar objects that have been seen in transit through Earth's vicinity.

REINA MARUYAMA

Reina Maruyama is an experimental particle/atomic/nuclear physicist. She carries out experiments in direct detection of dark matter with terrestrial-based detectors for axions, WIMPs, and searches for neutrinoless double beta decay. The current experiments include COSINE-100, DM-Ice, IceCube, CUORE, and HAYSTAC. She has served as chair of Yale Women Faculty Forum since 2020. (Primary appointment in the Yale Department of Physics)

DAISUKE NAGAI

Daisuke Nagai is a Professor of Physics and Astronomy. He is also the Director of Graduate Studies at Yale Physics Department. Nagai's research focuses on computational and data-driven cosmology and astrophysics. He was a founding co-directors of the Yale Center for Research Computing, the Physics and Data Science Task Force Chair, and a member of Yale's university-wide Data Science Advisory Committee. (Primary appointment in the Yale Department of Physics)

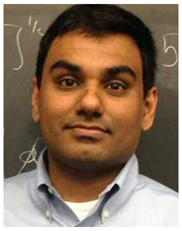
PRIYA NATARAJAN

Priya Natarajan's research focus is on the invisible Universe. She continues to work on open questions related to the nature of dark matter and the formation, fueling and feedback from supermassive black holes. Many of her predictions stand to be tested by the James Webb Space Telescope. Awarded the Gustav Ranis Prize (2018) and recognized with a Liberty Science Center Genius award (2022), she currently serves as the chair of the department and is the Director of the Franke Program in Science and the Humanities at Yale.

Yale Astronomy Faculty

LAURA NEWBURGH

Laura Newburgh is currently studying the past 13 billion years of cosmic history through measurements of the CMB and 21cm emission from faraway galaxies. She has held a postdoctoral fellowship at the Dunlap Institute, a postdoctoral position at Princeton University, and she got her PhD from Columbia University. Her work involves building instruments that go on telescopes in Chile and Canada. (Primary appointment in the Yale Department of Physics)



NIKHIL PADMANABHAN

Nikhil Padmanabhan is a cosmologist working at the interface of theory and experiment. He is broadly interested in the analysis of large galaxy surveys and the Lyman-alpha forest. His primary research focus is currently the baryon acoustic oscillation measurements with the DESI survey. He has recently become interested in the simulations and dynamics of ultra-light dark matter. (Primary appointment in the Yale Department of Physics)

MEG URRY

After four years in the presidential line of the American Astronomical Society, Meg Urry is enjoying research on supermassive black holes with a growing group of graduate and undergraduate students. She also runs the Granville Academy at Yale, a summer program on astronomy skills and issues surrounding equity and inclusion in STEM. (Primary appointment in the Yale Department of Physics)

PIETER VAN DOKKUM

Pieter van Dokkum's interests span a wide range, from stars and stellar populations to the most distant galaxies. Pieter is also interested in astronomical instrumentation and telescopes. He and Bob Abraham, University of Toronto, initiated the Dragonfly Telephoto Array in New Mexico, the largest working refracting telescope in existence. In addition to research and teaching Pieter is currently serving as Chair of the Physical Sciences and Engineering Tenure and Appointments Committee at Yale.

FRANK VAN DEN BOSCH

Frank van den Bosch, in collaboration with several students and postdocs, has continued his work on various aspects of galaxy formation, large scale structure, cosmology, and dynamics. In 2016 he co-founded HYPA, the HITS-Yale Program in Astrophysics, which was funded by the Klaus Tschirra Foundation. HYPA supported two postdoctoral researchers who worked on the physics of the circumgalactic medium.

BOB ZINN

Bob Zinn has continued his research on the Milky Way's Halo and its history of accreting satellite galaxies with the La Silla - QUEST RR Lyrae star survey, which will eventually cover much of the Halo south of declination +20. He is the faculty member in charge of the Hoffleit Scholarship program, and serves the University as Director of Summer Sciences for the Yale Summer Session.

MALENA RICE

Malena Rice joins Yale University as an Assistant Professor in the Department of Astronomy on July 1, 2023. She is appointed as a Research Scientist for the 2022-23 academic year. Her research centers on the formation and evolution of planetary systems, drawing from both the detailed evidence within the solar system and the broader, multivariate evidence provided by the thousands of known extrasolar systems. Her recent work has focused on constraining the most prominent formation pathways for hot Jupiter exoplanets; developing machine learning tools to characterize the compositional properties of extrasolar systems; and leading a search for the most distant solar system bodies. Malena received her Ph.D. (2022), M.Phil. (2020), and M.S. (2020) in Astronomy from Yale University, as well as her B.A. degrees in Physics and Astrophysics (2017) from UC Berkeley. Prior to the start of her faculty appointment, she will spend one year as a 51 Pegasi b Fellow at the MIT Kavli Institute for Astrophysics and Space Research.

Emeritus Faculty

CHARLES BALTAY

Eugene Higgins Professor Emeritus of Physics & Astronomy

Cosmology, Dark Energy, QUEST, Member of DESI Collaboration, WFIRST Science Definition Team

PIERRE DEMARQUE

Munson Professor Emeritus of Astronomy

Stellar Structure and Evolution, Solar & Stellar Astrophysics, Asteroseismology, Stellar Populations, Theory, Galactic Astronomy, Exoplanets, YaPSI, HST science

RICHARD LARSON

Professor Emeritus of Astronomy

Extragalactic Astronomy, Star Formation and ISM, Galaxy Evolution

SABATINO SOFIA

Professor Emeritus of Astronomy

Studies of the Sun, Solar rotation, Balloon-borne Solar experiments, Impact of rotation and convection on internal Solar dynamics, Effects of Solar variability on terrestrial climate.

WILLIAM VAN ALTENA

Professor Emeritus of Astronomy

Galactic Astronomy, Galactic Structure, Kinematics, Instrumentation, Stellar Astrophysics, Stellar Populations

YALE'S RESEARCH FACILITIES & OTHER RESOURCES

written by Zili Shen

KECK TELESCOPES

Yale astronomers share 24 nights per year on the Keck Telescopes, which are among the largest optical telescopes in the world. Keck telescopes sit 14,000 feet above sea level on the summit of Hawaii's Mauna Kea, one of the best observing sites in the world thanks to its perpetually clear skies, still atmospheric condition and elevation above a significant amount of the earth's atmosphere, which distorts incoming light from the cosmos.

Although faculty can propose projects and apply for time on other telescopes, such as the Hubble Space Telescope, owning a dedicated amount of time on a first-class telescope guarantees Yale faculty, postdocs and graduate students access to the caliber of equipment needed to remain at the forefront in a field where technology rules.

Thanks to the remote observing support from the department, Yale astronomers can observe on Keck in New Haven. The Keck remote room in the basement of 46 Hillhouse Avenue is equipped with video-conference hardware and two independent internet connections for redundancy. Since 2020, the remote observing capacity has been crucial to keep research going when travel became difficult.

W. M. KECK OBSERVATORY

Keck 10-meter Telescopes - image credit W.M. Keck Observatory

Snow-covered Hale Telescope dome - image credit Palomar/Caltech

PALOMAR HALE-TELESCOPE

While competition for Keck is fierce, the Palomar Observatory offers reliable observing time. The 200-inch Hale Telescope at Palomar Observatory was where extragalactic quasars were discovered in the 1960s. As the expanding San Diego area lights up the Palomar Mountains at night, the Palomar Observatory is pushed out of the frontier of research by new 10-meter class telescopes coming online.

Yale astronomers still find uses for this old workhorse, though. C. Megan Urry, the Israel Munson Professor of Physics and Astronomy in the Yale Faculty of Arts and Sciences and director of the Yale Center for Astronomy & Astrophysics, has used Palomar to survey supermassive black holes in a 2022 paper.

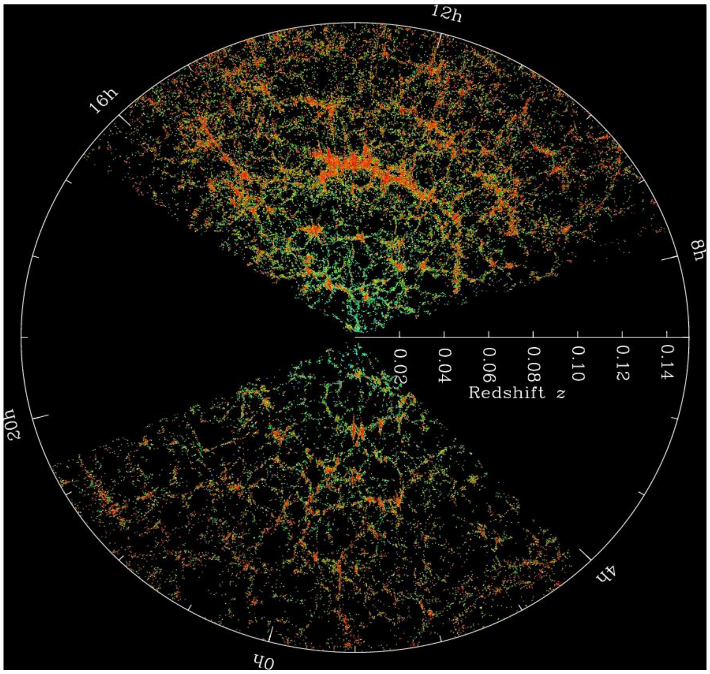
Although Palomar is a smaller telescope than Keck, it offers a better educational experience. Graduate students are encouraged to devise projects and share the 40 nights per year allocated to the department. They can travel to the observatory and sit right next to the telescope operator, controlling the telescope together throughout the night. They learn more about observational astronomy with this “do-it-yourself” approach, compared to observing on Keck.

SLOAN DIGITAL SKY SURVEY

After 20 years and four previous phases, the Sloan Digital Sky Survey's Phase V (SDSS V) is ready to give Yale astronomers a new look at the wonders of the cosmos. The new data has been released in December 2022.

The Survey's mission is ambitious: It aims to create a detailed, three-dimensional map of the universe, using a 2.5-meter, wide-angle optical telescope located at the Apache Point Observatory in New Mexico. Previous SDSS surveys have mapped one-third of the sky. SDSS data have been used in more than 7,700 peer-reviewed, scientific papers, offering insights into the chemical makeup of the Milky Way and the structure of distant galaxies. It has also helped produce multi-color imaging for hundreds of millions of stars, and gleaned information about 100,000 asteroids and other objects within Earth's solar system. The fifth iteration of the survey will add more information about each object observed.

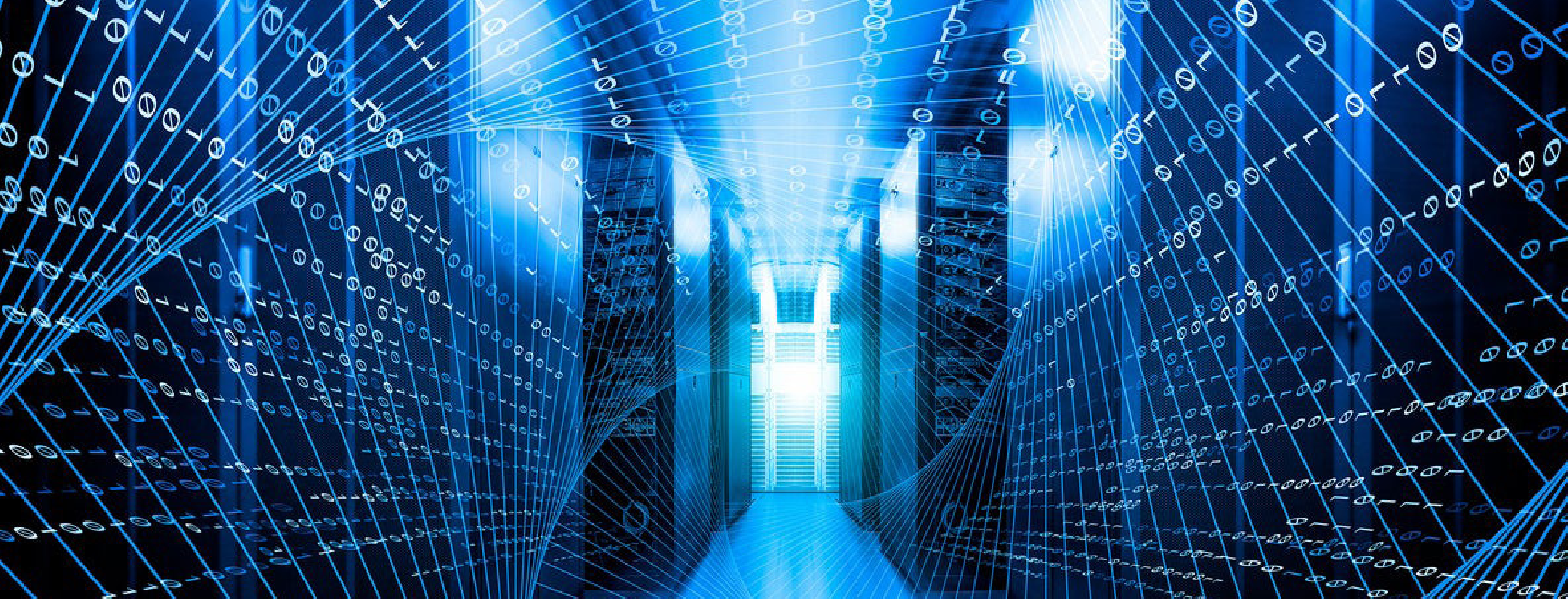
Yale is a full participating member of the SDSS collaboration, which includes dozens of research institutions around the world. Any student, postdoc, or faculty member at Yale has open access to all the data. All data become public eventually but institutional partners like Yale have an inside track to the early science, by virtue of having contributed to the cost of the survey. According to Meg Urry, Yale's Israel Munson Professor of Physics and Astronomy, Yale has been a long time partner in SDSS: "Yale was a partner in SDSS-III, which ran from 2008 to 2014, and SDSS-IV, which ran from 2014 to 2020. These are large efforts to take enormous amounts of data covering a large fraction of the sky, with increasingly sophisticated instrumentation. Each survey consists of a few sub-projects, each with its own instruments, and a dedicated telescope in New Mexico. Starting with SDSS-IV, we also have a telescope in the southern hemisphere, at Las Campanas Observatory in Chile."



Yale astrophysicists have used SDSS data to contribute groundbreaking research on black holes, quasars, galaxy formation, and other cosmological phenomena. For example, Yale researchers identified the first "changing-look" quasar, discovered dwarf galaxies that contain massive black holes, and helped find a rare group of galaxies called the "Green Peas."

Yale astronomy professor Frank van den Bosch has used SDSS data to study the connection between galaxies and their dark matter halos. The galaxy-halo connection is essential to our understanding of galaxy formation and evolution, as well as cosmology. In the van den Bosch group, Yale graduate student Kaustav Mitra analyzed SDSS DR7 (part of SDSS-IV) data to constrain the distribution of galaxies in dark matter halos, which gives an independent measure of cosmological parameters that characterize our Universe.

"Some of us – including Priyamvada Natarajan, Paolo Coppi, and myself – are interested in the Black Hole Mapper experiment, which will obtain spectra of all the X-ray sources from the eROSITA satellite, which was launched just over a year ago. This will greatly increase our understanding of the growth of the most massive, most distant black holes. In particular, Priya Natarajan plans to address the critical question of the origin of the first black holes, and I personally am excited about finalizing our census of black hole growth across the past approximately 12 billion years." - Meg Urry



COMPUTATIONAL RESOURCES

The Astronomy IT office maintains an internal computer network that is reserved for Astro research groups. Each faculty member is allocated a data storage disk and the department shares powerful computers all linked to the intranet.

Yale also has a Center for Research Computing which operates supercomputers. Yale owns supercomputer "clusters", where researchers can spread out their computing task over many fast CPUs to be completed in parallel. Yale also offers training to researchers who want to use supercomputers to solve their research problem. Learning how to write programs that can leverage thousands of CPUs to run a computational task is a key skill for modern astrophysicists.

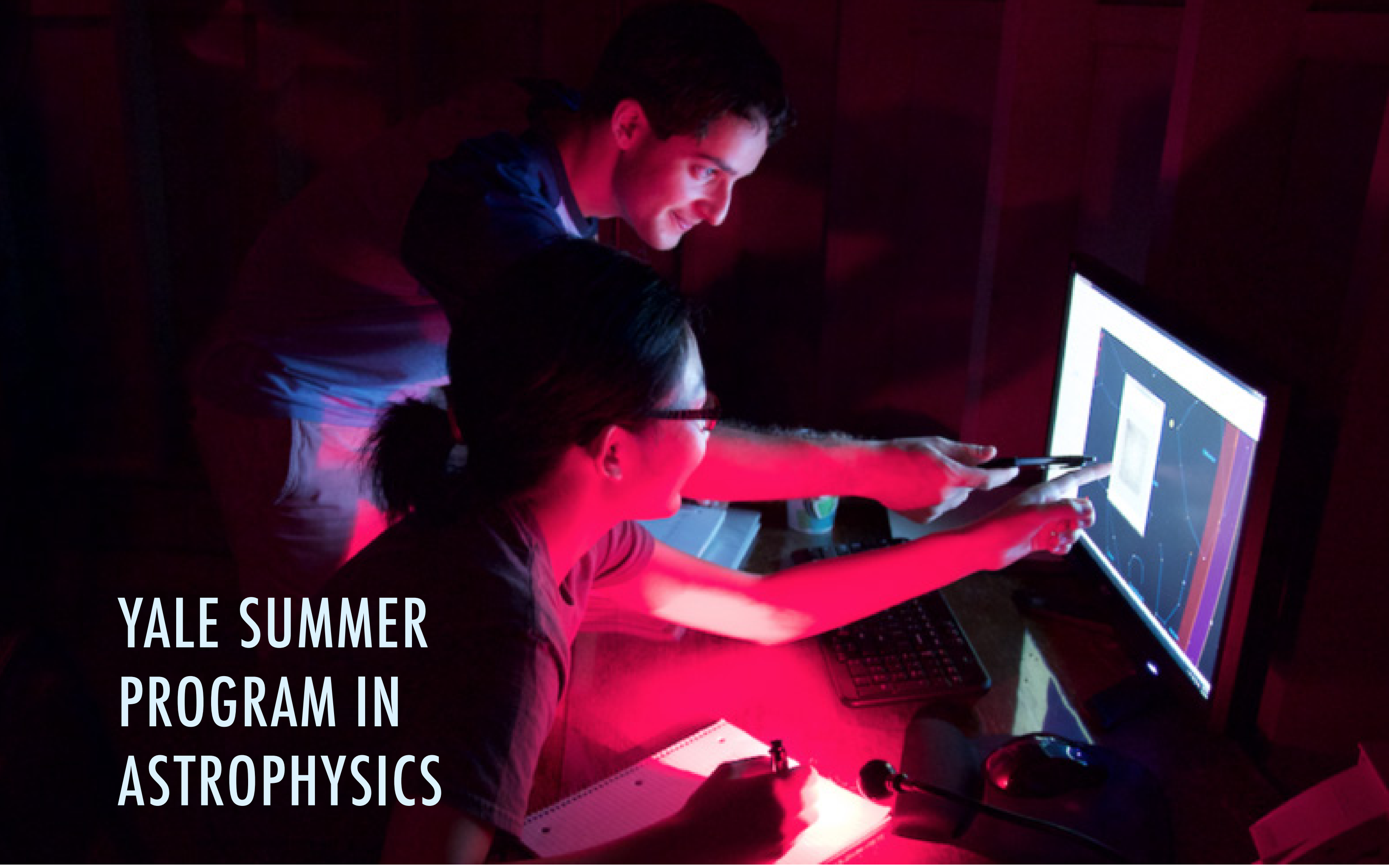
Yale offers access to major cloud services by Amazon, Google, and Microsoft. Students and faculty have free access to Microsoft Suite, OneDrive, Microsoft Teams, Box storage, Zoom, and a number of other software packages. Students also get unlimited space in Google Drive with their Yale account.

COLLABORATION

Yale Astronomy funds research exchange to Chile through the Yale-Chile Joint Program in Astronomy Research & Education. All department members can submit proposals which are evaluated by a department committee on a rolling basis. This fund can support a graduate or undergraduate student from Yale or from Chile to visit the other department. There is also a joint postdoctoral fellowship program which allows for a two-part postdoc in Yale and Chile.

Yale faculty are also involved in the Simons Observatory which will study the Cosmic Microwave Background. Yale graduate students have worked on building the hardware and software of the telescope. This collaboration spans thirty institutions around the world.

SIMONS OBSERVATORY



YALE SUMMER PROGRAM IN ASTROPHYSICS

Written by Michael Faison

The Yale Summer Program in Astrophysics (YSPA) successfully completed its 6th summer program in 2022, after a year on hiatus and a year online before that. 36 exceptional high school students were selected from more than 600 applicants for this research and enrichment program.

Through YSPA, talented high school students can come to Yale and work with faculty and other students. Since its launch in 2015, YSPA has included research and classes as key components. Students learn to observe with the telescopes at the Leitner Observatory, take accelerated classes (physics, programming, and math), and complete a research project.

Past research topics have included near-Earth asteroids and real extragalactic supernovae. During each project, students obtain their data on observing nights, then learn to analyze the data and build models to understand it. This end-to-end approach is meant to teach key research skills. Students need to pay close attention to details: for example, they must be careful to not observe at the wrong coordinates. They work in teams of four that are balanced for background and personality. At the end of the program, they write a journal-style paper and present their results as a team in a mini-conference.

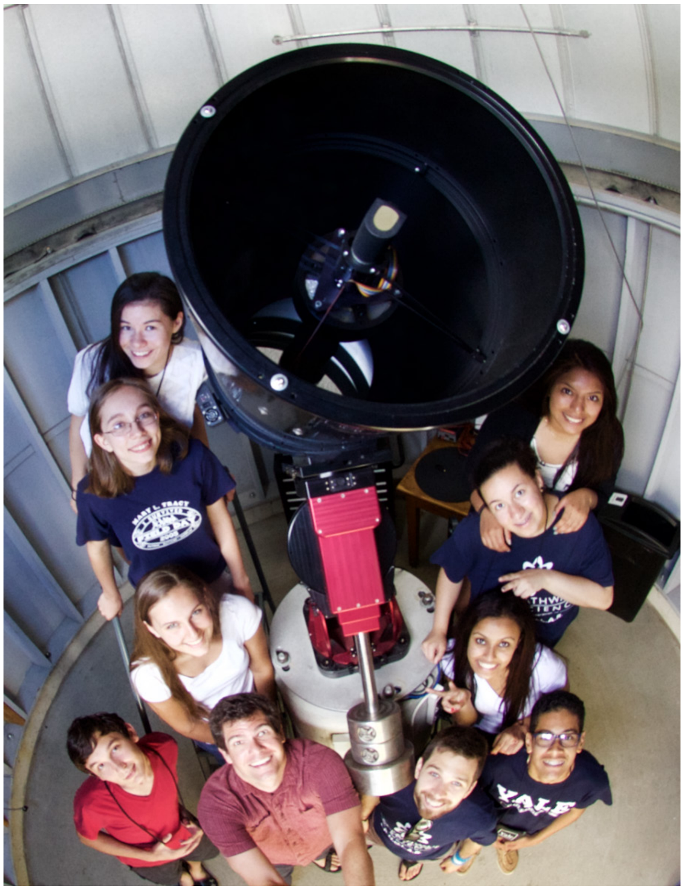
A typical day at YSPA is packed with activities. In the morning, students wake up at one of the residential colleges on campus and head to the Planetarium to take classes. They work on data analysis and programming tutorials in the computer lab in the afternoons. Evenings are reserved for observing with telescopes.

YSPA also wants students to have fun and build friendships. They spend a lot of time working in research teams and do group activities. They go on field trips and guest lectures. YSPA hosts a talent show, a New England-style contra dance, and water-bottle-rocket launch.

Students and faculty have described participating in YSPA as a formative experience, impacting their decisions about future careers in science. A large fraction of YSPA alumni have applied for admission at Yale and many of those have matriculated. Some students majored in astronomy and physics at Yale and continue to contribute to YSPA and other programs at LFOP.

Learn more about the Yale Summer Program in Astrophysics at https://yspa.yale.edu/

YSPA
The Yale Summer Program in Astrophysics



YSPA Class of 2022

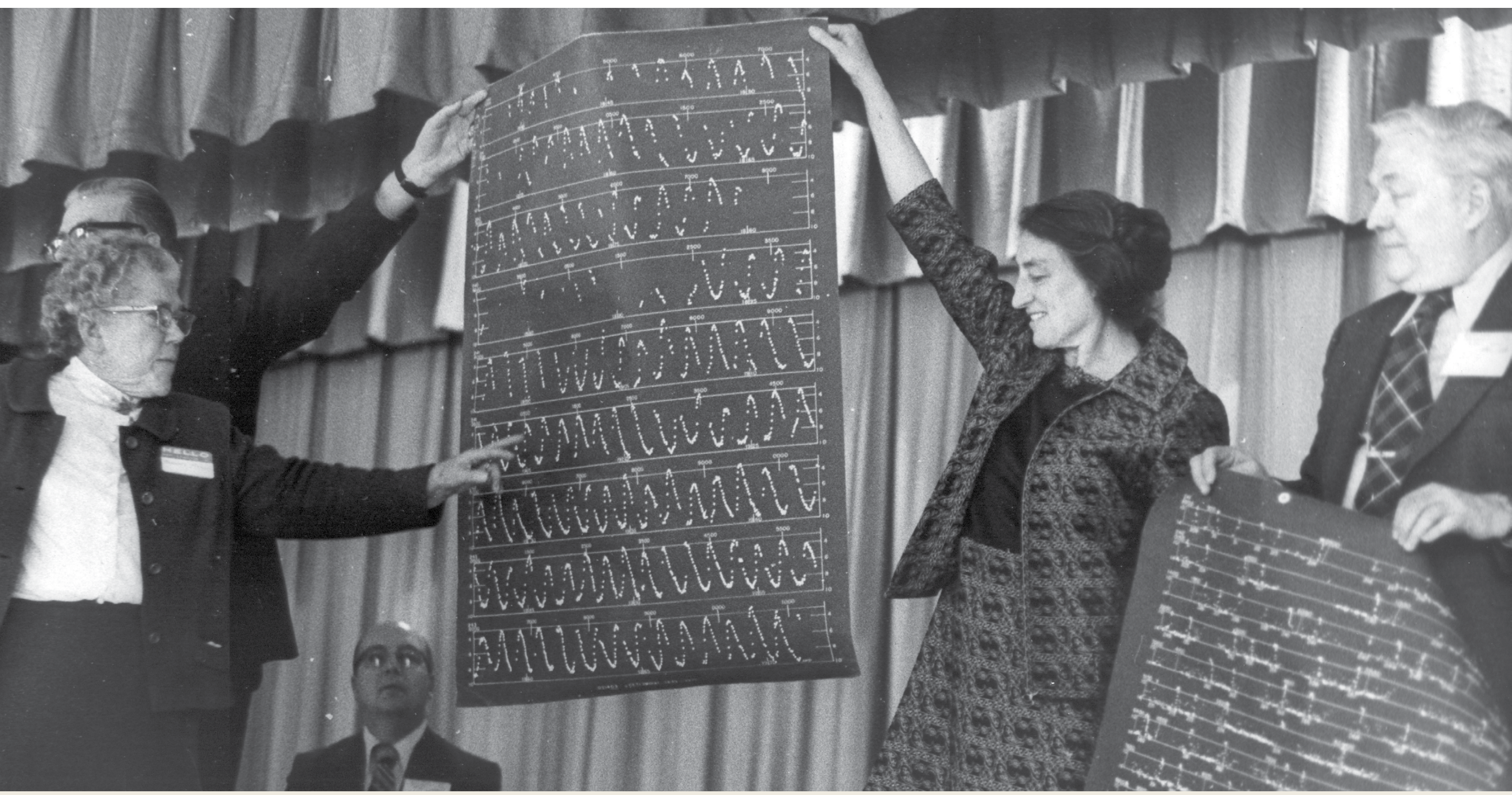
Dorrit Hoffleit
Undergraduate Research Scholarship

For 50 years, Dorrit Hoffleit was an integral member of Yale Astronomy department, and her legacy lives within the [Dorrit Hoffleit Undergraduate Research Scholarship](). Let us take a look back at Hoffleit's pioneering and illustrious career in Astronomy, as well as the great success that has been the Hoffleit Scholarship.

Dorrit Hoffleit, born in 1907, went to Radcliffe College, the all-female partner institution of the at the time all-male Harvard University, where she earned her PhD in 1938. She remained in Cambridge working at the Harvard College Observatory hunting variable stars. There she joined the famous legacy group of "human computers," women astronomers who since Edward Pickering's Directorship in 1877 skillfully processed astronomical data.
Hoffleit also was involved in the very early years of the American Rocket Program. During WWII, she worked for the US Army first at Aberdeen and then at White Sands, and calculated rocket trajectories. Hoffleit was one of the few female scientists working for the Army at the time, and faced systemic discrimination. Practice at the time was to pay female scientists less than their male counterparts. Hoffleit, who had faced the same injustice already at Harvard, was able to negotiate equal pay for female scientists with the commanding officer, thus setting an early example for the next generations of scientists.

After her time at Aberdeen and White Sands, Hoffleit returned to the Harvard College Observatory and stayed until 1956 when she came to Yale. At Yale, she took over the astrometric work of Ida Barney. Her most important contribution to Astronomy was probably her leadership in developing the Yale Bright Star Catalog, a compendium of information on the 9110 brightest stars in the sky, which has been a major resource for Astronomy. Together with William van Altena, she worked on the General Catalog of Trigonometric Stellar Parallaxes and thus contributed to homogenizing astronomical data from various telescopes.

In fact, Hoffleit was renowned for her ability to



written by Konstantin Gerbig

find inconsistencies amongst different telescopes, as current faculty member, Professor Bob Zinn, remembers. Even after her retirement, she would receive letters from all over the world from astronomers asking her to check their data for them — a situation that was aided by the virtue of Hoffleit's office being situated right next to Yale's extensive Astronomy library.

Still, Hoffleit enjoyed helping out colleagues in need, as she loved doing Astronomy, and was always excited to chat about the newest findings. Indeed, her passion for Astronomy also led her to dedicating a large portion of her career towards mentoring and teaching. Most famously, she served as a director of the Maria Mitchell Observatory on Nantucket Island from 1957 to 1978. There, she ran a renowned summer program that specifically targeted young women astronomers. Many of the summer program's participants continued on to careers in astronomy research, rendering Hoffleit's efforts towards diversifying the Astronomical community invaluable. Hoffleit's work at the Maria Mitchell Observatory was recognized with the prestigious George Van Biesbroeck Prize in 1988.

After Hoffleit passed away at the age of one hundred in 2007, her family donated funds to support a Summer fellowship in her honor. The Dorrit Hoffleit Undergraduate Research Scholarship at Yale, is a summer program that enables external undergraduates to spend the summer at Yale doing cutting edge research with the current faculty.

Dorrit Hoffleit. c. 1938

In the spirit of the Maria Mitchell Observatory summer program, the Dorrit Hoffleit Scholarships specifically target under-represented students from institutions that have fewer research opportunities as Yale. The scholarship encompasses a $450 per week stipend, a $1000 travel fund, free housing at one of the beautiful Yale colleges, and meal vouchers. Students typically spend eight weeks at Yale, working with a faculty mentor on a research project, during which they can get to know local students as well as life at Yale. The summer concludes with a research symposium, where Yale undergraduates as well as the Hoffleit scholars present their research results.

As many of the Hoffleit summer projects eventually get published in astronomy journals, the Hoffleit Scholarship offers a fantastic path to graduate school in Astronomy — one that many Dorrit Hoffleit Scholarship alumni have taken, thus continuing the legacy of Dorrit Hoffleit.

[Hoffleit Scholars 2014 - present]

Astronomy on Tap

Astronomy on Tap (AoT) New Haven was revived this year after a brief hiatus and has been running strong! AoT New Haven is a popular outreach event series led by members of the Yale Astronomy Department, bringing fun, engaging scientific talks to the local community during evenings in a bar. This year, graduate student Imad Pasha coordinated the event series, which includes 3-5 events per year. Events typically attract hundreds of attendees and have rapidly become a community favorite.

Three AoT events took place this fall at BAR New Haven, returning to the same venue where AoT took place before spring 2020. Each AoT New Haven event includes a few short talks by graduate students, postdocs, and faculty members from Yale's astronomy department. These talks span a diversity of disciplines and perspectives on exciting topics in astrophysics, covering anything from the speaker's research to breaking astronomy news and beyond. We cover the full gamut from the solar system to the largest scales of cosmology.

During intermission between speakers, audience members answer trivia questions themed after the talks, with spectacular space-themed prizes for the winners ranging from stunning books of Hubble images to customized AoT New Haven beer glasses/stickers, starry blankets, moon-shaped lamps, and more. With pizza, beer, astrophysics, and free glow sticks, every event is a great hit! We can't wait to see what our upcoming events will bring.

For more information on upcoming events, visit the AoT Facebook page: https://www.facebook.com/AoTNewHaven/

Yale
Astronomical Society

written by Sally Jiang and Annie Giman

Astronomy and astrophysics are increasingly popular majors for Yale undergrads. In lieu of a clear line of communication from the department, these students have been finding out about academics, research, and general department resources through word of mouth. Some students mention not even knowing which professors are still engaged in research and who to reach out to. The Yale Astronomical Society fills this gap in the community and creates a better experience for undergraduates to get involved in community and research opportunities.

The Yale Astronomical Society is a new student group designed to remedy these issues and address the increasing interest in undergraduate programming. In order to retain and support students, the Astronomical Society plans to engage them as early as their first year, before they can take astronomy courses. It also aims to improve the astronomy student experience through three aspects: community, connection, and outreach.

The Yale Astronomical Society will host regular meetings where undergraduate students can:

- engage in professional development workshops,
- have fun community-building events,
- talk about astronomy news and updates,
- attend telescope nights and,
- participate in outreach opportunities at Leitner Planetarium and New Haven schools.

Yale Astronomical Society also hosts an open board meeting every month where members discuss new ideas for the club's future events. In addition, they also focus on connecting Yale Astro majors with the department community, through graduate students, postdocs, faculty, and most importantly each other. An important goal of the Yale Astronomical Society is to foster a passion for astronomy in all interested students, regardless of major.

Undergraduate Astrophysics majors at the inaugural Yale Astronomical Society meeting November, 2022

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