Yale University Astronomy Department Newsletter

Vol. 5 Spring 2014 No. 1

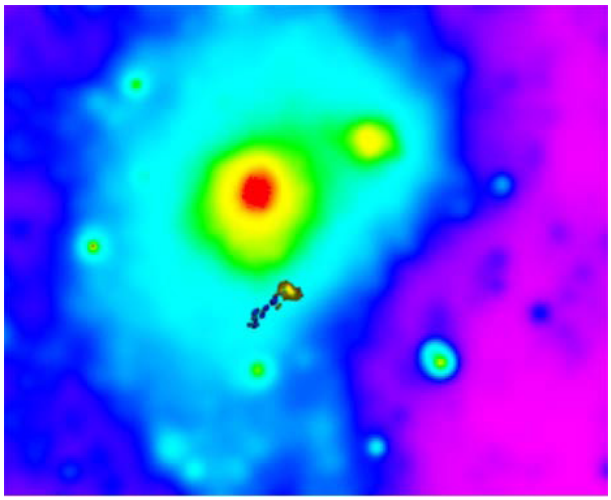
Kenney captures dwarf galaxy in the act of dying

Professor Jeff Kenney has found concrete evidence that dwarf galaxies stop forming stars due to the process known as ram pressure stripping.

Kenney and his team of researchers have caught the Virgo Cluster galaxy IC3418 in the act of transforming from a dwarf irregular galaxy into a dwarf elliptical galaxy. The metamorphosis happens as gas is stripped from the galaxy through ram pressure, a forceful wind that is caused by the collision of the gas in the galaxy with the gas in intracluster space.

With no gas available for star formation, dwarf elliptical galaxies are considered "dead." Therefore, Kenney and his team are witnessing the first clear example of a dwarf galaxy in the act of dying.

"We think we're witnessing a critical stage in the transformation of a gas-rich dwarf irregular galaxy (***SEE DWARF, p. 4***)



X-ray image showing hot gas in the Virgo cluster with an enlarged UV image of dwarf galaxy IC3418 sporting a tail of recently formed stars. *J. Kenney and P. Jachym.*

Massive black holes alive and well in dwarf galaxies

Depicted here is NGC4395, a low mass galaxy with a known central black hole. *Image courtesy of the researchers.*

Dwarf galaxies may be small, but astronomers now know that they can hold massive black holes.

Yale astronomer Marla Geha and collaborators have identified more than 100 dwarf galaxies that show signs of hosting massive black holes, a discovery that challenges the idea that they exist only in much bigger galaxies.

"These galaxies are comparable in size to the Magellanic Clouds, dwarf satellite galaxies of the Milky Way," said Geha, associate professor of astronomy. "Previously, such galaxies were thought to be too small to have such massive black holes."

Dwarf galaxies are small, faint, low-mass galaxies with relatively few stars compared with, say, the Milky Way, Earth's home galaxy. Black holes are points in space where matter is packed so densely that light itself cannot escape; massive black holes are an extreme form of black hole. (***SEE HOLES, p. 4***)

INSIDE THIS ISSUE

Greetings from the Chair

Looking back on the time since the last Newsletter, it is amazing to see how much has been achieved and how much the department continues to evolve. Among the most visible changes is the renovation of the library and the accompanying increased activity on that side of the hallway. Quite often, most of the new desks are occupied by majors, graduate students, postdocs, and the occasional bemused faculty member. The classroom also got a facelift, along with some much needed improvements behind the scenes. Next in line is a renovation of the kitchen and lounge area; the idea is that this becomes a single open space for informal gatherings and discussions.

We have maintained a very high level of science activity in the department, in large part owing to our outstanding postdocs and graduate students. Several achievements are highlighted in this Newsletter. We also interact a lot with each other, aided by events such as YODA (Yale Overarching Discussion of Astro), ST@Y (Stellar Tea at Yale), and Galaxy Lunch. It is impressive that we have an event or talk nearly every day of the week, and that these events all have dedicated groups of people who ensure their success. Perhaps inspired by these postdoc- and graduate-student-led activities, the faculty have restarted their Friday Scholarship lunches, where they discuss science or other topics such as teaching, mentoring, and applying for grants.

Our computer and telescope facilities continue to be productive, including the twin Keck telescopes which form the backbone of our private telescope access. We are in the midst of two transitions: we are moving to a more comprehensive and powerful computer cluster, and we are reorienting our 4m-class telescope access. Yale was a founding member of the 3.5m WIYN telescope consortium, but after nearly 24 years of successful use, we found that our scientific priorities had shifted in a different direction. As of April 1, 2014, Yale will no longer be a member of the consortium. Based on the results of a comprehensive survey of graduate students, postdocs, and faculty, we have shifted our focus in 4m-class science to the Palomar 5m telescope in California, as its instrumentation is an excellent match to our evolving needs.

Sadly, we had to say goodbye to Suzanne Tourtellotte this year. Suzanne passed away in June after a long illness. She dedicated her career to enabling others to experience the Universe, whether through teaching introductory courses or through the planning and execution of observations for the SMARTS consortium. She will be greatly missed by her SMARTS colleagues, by the staff, and by everyone who knew her. Charles Bailyn wrote a tribute to her in this issue (***SEE p. 19***).

Palomar 5m telescope with adaptive optics laser. Photo by W. S. Kardel.

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Arce gets foot in the door with early ALMA research

Hector Arce is part of a Yale-Universidad de Chile collaboration in star formation that was awarded coveted time for "Cycle 0" on the new Atacama Large Millimeter/submillimeter Array (ALMA) in Chile. Arce has also been awarded time for his "Cycle 1" proposals, but his observations have been delayed due to weather and engineering needs. ALMA's superb sensitivity and resolution have made it possible for Arce to detect features in the observed outflows of protostars much more clearly than previously.

Arce and his team used the ALMA time to discover that the outflows of a typical protostar in the Gum Nebula are moving at greater velocities than previously measured, which leads to a more dramatic impact of the outflow on the star formation environment than astronomers previously thought occurred. If the observed source is representative of outflows in general, Arce's research indicates that protostellar outflows could provide the energy to sustain turbulence in star-forming clouds and help in dispersing the gas around newly formed stars.

The ALMA observations additionally allowed Arce's team to discover more about the structure of the outflow launching mechanism and to find evidence that the outflow and disk accretion are both episodic.

ALMA is superior to previous radio telescopes for several reasons: 1) ALMA is in the Atacama desert—one of the driest places on Earth—so it is relatively free from the water vapor that can obstruct radio waves just as clouds obstruct optical sources. 2) The elevation of ALMA's site means that there is less contamination from the atmosphere. 3) The newer technology of ALMA makes it a better and more sensitive facility.

Arce remarked, "ALMA is like putting on new glasses when you know you need a new prescription. Everything becomes much more clear and you can see the details." Even though his observations only used 16 of the total of 66 antennas that the telescope array will eventually have, Arce believes that the results from his first use of the facility "are clear evidence that once completed, this telescope will revolutionize the field of star formation."

The paper presenting Arce's ALMA "Cycle 0" observations is titled *ALMA Observations of the HH 46/47 Molecular Outflow* and it appeared in the September 2013 issue of *The Astrophysical Journal*. Co-authors are Diego Mardones of the University of Chile, Stuartt Corder of ALMA, Guido Garay of the Universidad de Chile, Alberto Noriega-Crespo of the California Institute of Technology, and Alejandro C. Raga of Universidad Nacional Autónoma de México. The observations were supported by funding from the National Science Foundation.

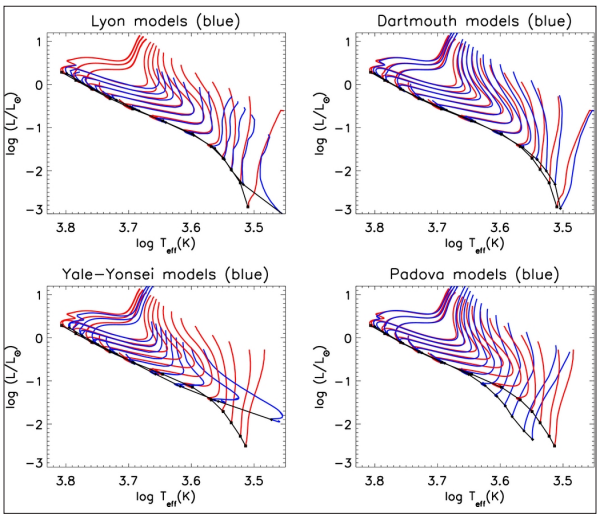
For ALMA's "Cycle 2," Arce has collaborated on a number of proposals on a wide range of topics including studying star-forming cores and the early stages of star formation in nearby clouds, the impact of outflows from massive protostars on their surroundings, and a survey of protoplanetary disks in the Orion nebula cluster.

New Yonsei-Yale Isochrones and models available

The Yonsei-Yale (Y2) Isochrones have been developed by a collaboration of researchers at Yale (led by Professor Pierre Demarque) and Yonsei University since 2001 and have recently been updated with a new set of stellar tracks and isochrones focusing on low mass stars (down to 0.1 Msun).

According to Professor Sukyoung Yi of Yonsei University, "Isochrones are currently the best tools for measuring the ages of star clusters and fundamental building blocks for galaxy population synthesis." Demarque added that "they should be useful to a lot of people, including both stellar population and exoplanet researchers."

The latest Y2 Isochrones are available for download on the Yale website http://www.astro.yale.edu/demarque/yyiso.html. A paper that accompanied the release, which was led by Federica Spada with Demarque, Yong Cheol Kim and Alison Sills, was published in the October 2013 volume of *The Astrophysical Journal*.



Comparison between models using the new Y2 (in red) and other sets of publicly available tracks and isochrones (in blue). *Figure from Spada et al, 2013.*

Ram pressure stripping quenches star formation

(***DWARF, from p.1***) into a gas-poor dwarf elliptical galaxy—the depletion of its lifeblood," said Kenney. "Until now, there has been no clear example of this transformation happening."

IC3418 was stripped quickly and is almost completely out of gas. The core of IC3418 stopped making stars between 200 and 300 million years ago. Prior to quenching, a strong starburst occurred that formed about 10% of the stars in the galaxy. But the galaxy is now generating a spectacular one-sided 17-kpc-length tail with UV-bright knots (mostly from linear, parallel streams of young stars), linear stellar features, and head-tail features nicknamed "fireballs."

The fireballs are created when ram pressure pushes the gas away from the galaxy and new stars are formed in the gas outside of the galaxy. The wind keeps the star-forming "head" of gas moving forward, but does not affect the newly-formed stars, which remain behind in a "tail." In IC3418, this effect can be seen by the fact that the only H-alpha emission arises from a few HII regions in the galaxy's tail, the brightest of which are at the heads of the fireballs, whose stellar tails point back towards the galaxy.

"If you hold popcorn and un-popped kernels of corn in your hand and stick it out the car window as you drive, the wind caused by the car's motion through the air will blow away the popcorn but leave the denser unpopped kernels in your hand," Kenney said. "This is like the gas clouds in galaxies being blown out of the galaxy by the wind of cluster gas, while the denser stars remain behind."

Most of the stars in the outer tail have velocities which exceed the escape speed and will join intracluster space. Some of the stars in the inner tail are likely bound; they will fall back into the galaxy forming halo streams that differ in properties from tidal halo streams.

Neither H-alpha nor HI emission are detected in the main body of the galaxy, despite structure in optical images resembling star forming regions and spiral arms.

Deep optical images show a relatively undisturbed stellar body and no smooth stellar component to the tail, only clusters and streams of young stars, which are properties inconsistent with a tidal interaction.

The fact that the tail is only on one side of the galaxy also rules out the possibility that star formation in the galaxy could be expelling all of the gas from the galaxy.

Kenney additionally noted that dead dwarf elliptical galaxies are found almost exclusively in dense regions—clusters, groups or near a larger galaxy. This is consistent with ram pressure stripping quenching the star formation in dwarf ellipticals.

Kenney and his team used optical imaging from the WIYN telescope, UV imaging from the GALEX space telescope, and optical spectroscopy from both of the Keck telescopes to obtain their results.

"It's gratifying to find a clear example of an important process in galaxy evolution," said Kenney. "I enjoy digging through evidence to assemble a story about what happens to galaxies. I've come to think of myself as an intergalactic forensic pathologist—someone who studies the bodies of galaxies, seeking evidence of traumatic events responsible for the present state of the galaxy."

Kenney is leading a paper about IC3418 that has appeared in *The Astrophysical Journal* entitled: ***Transformation of a Virgo Cluster Dwarf Irregular Galaxy by Ram Pressure Stripping: IC3418 and its Fireballs***. Co-authors include Hugh H. Crowl, '06 PhD; William Dague; Yale Professor Marla Geha; and Pavel Jachym.

Massive black holes reside in dwarf galaxies

(***HOLES, from p.1***) Geha and collaborators at the National Radio Astronomy Observatory (NRAO) and Princeton University presented their findings during the American Astronomical Society's annual meeting in Washington, D.C., the week of Jan. 6, 2013. The work was highlighted during a Jan. 8 press conference.

The scientists said that patterns of light emission from many of the galaxies suggest the presence of massive black holes. The black holes in the study are about 100,000 times the mass of Earth's Sun—massive, but vastly less dense than black holes seen in larger galaxies.

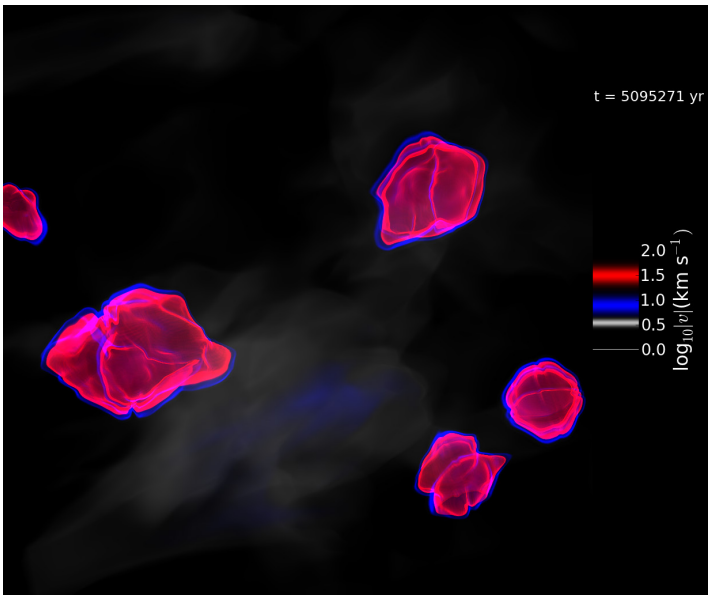
The research also offers new evidence for the origin of supermassive black holes, researchers said.

The team's work is based on data from the Sloan Digital Sky Survey.

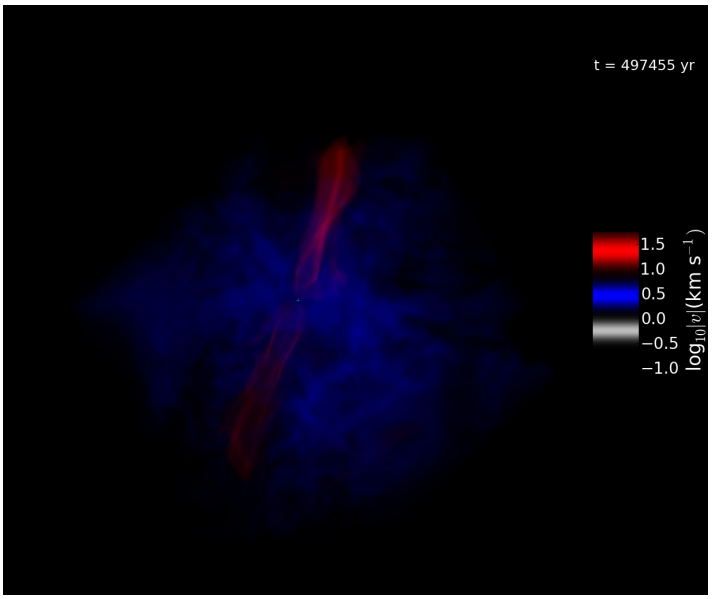
Amy Reines of NRAO is lead author of the team's research paper, ***Dwarf Galaxies with Optical Signatures of Active Massive Black Holes***. Jenny Greene of Princeton and Geha are co-authors. Further detail is also available on the NRAO website.

This article was written by Eric Gershon, Yale University.

Stella Offner, Hubble Fellow, simulates star formation



Gas velocity in a simulation in which evolved B stars are launching spherical winds within a molecular cloud. As the winds (red) interact with the cloud, they slow down (blue) and lose their symmetry. S. Offner.



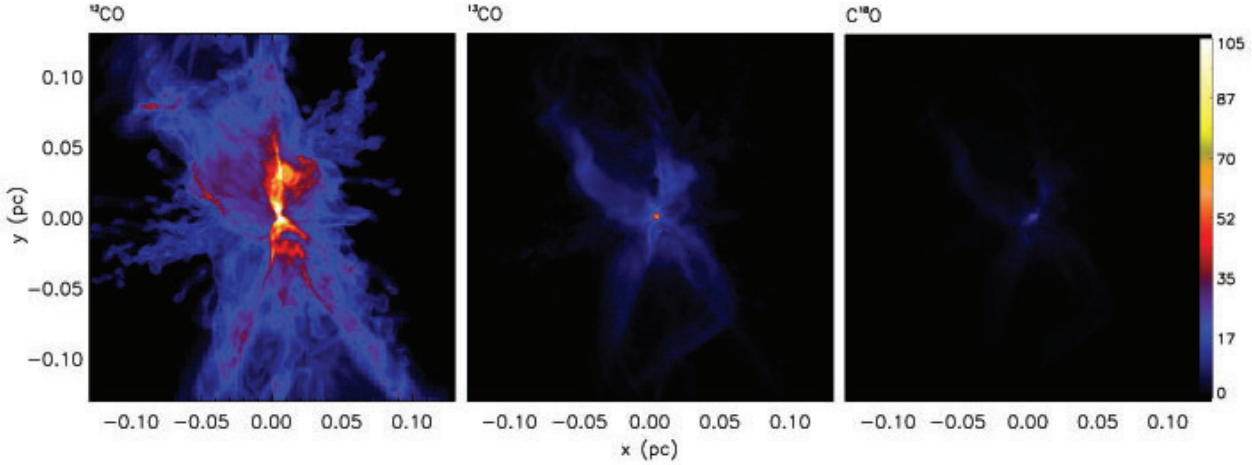
Gas velocity in a simulation of a forming protostar at 0.5 Myr. The mass outflow, which is higher velocity, is highlighted in red. At this time, most of the initial gas has been accreted or dispersed, but some very turbulent gas (blue) remains. S. Offner.

Stella Offner, a Hubble Postdoctoral Fellow at Yale, works on large-scale simulations of how low mass stars, like our sun, form. Most recently, she has been looking into the effects of feedback from low mass stars, especially how these stars affect their environment during star formation.

Offner is studying several environmental factors of low mass stars during star formation, including their ability to: 1) heat their environment (the calculations for this include radiative transfer) and 2) launch protostellar outflows (she uses a subgrid model that describes mass and energy being lost as a function of protostar mass). She also looks at how isotropic winds from older B stars shape the star-forming cloud and inject energy.

Offner uses a grid-based, adaptive code developed at Berkeley and Lawrence Livermore called ORION that is able to follow problems like the collapse and formation of a star easily. The code was originally created to model nuclear explosions, but since the gas dynamics of explosions and forming stars is similar, it was able to be adapted for use by astronomers.

In addition to modeling, Offner makes synthetic observations (e.g. molecular and dust emission maps) and compares them with observations such as those produced by Yale Professor Hector Arce.



Emission maps of three different molecules as might be observed at very high resolution with ALMA. S. Offner.

SMARTS Consortium approves new 3-year MOU

The SMARTS Consortium, founded by Yale Professor Charles Bailyn in 2001, has re-formed itself as "SMARTS3." The Consortium recently executed a 3-year contract to continue to operate the small telescopes at CTIO (0.9m, 1.3m and 1.5m) from October 2013 through September 2016. Yale's 1.0m telescope is not included in the contract; it is currently closed to science operations due to a shortage of funding.

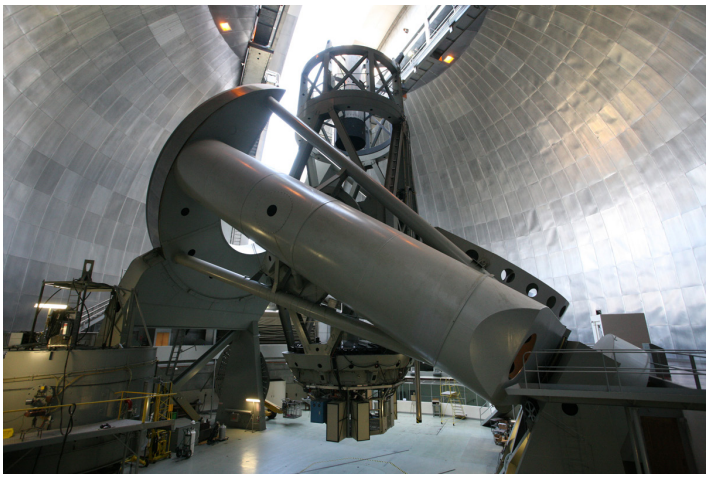
SMARTS3 differs from its predecessors in that the management of the telescopes has now been split. Yale still administratively manages and schedules the 1.3m and the 1.5m, but the 0.9m is now fully administered by Todd Henry at Georgia State University.

The SMARTS 0.9m is operated in user mode only; the 1.3m and 1.5m are both operated in service mode with a queue scheduling system. The instruments currently available at SMARTS are CFCCD, an optical imager (0.9m); ANDICAM, a dual-channel optical and IR imager (1.3m); CHIRON, a high-resolution Echelle spectrometer (1.5m); and SIMON, an infrared spectrometer that can also be used in imaging mode (1.5m).

SMARTS3 is somewhat unique in that any member of the astronomical research community is welcome to purchase any amount of observing time from SMARTS3 directly, as long as available time exists. All Yale Astronomy Department members have access to the suite of telescopes through a departmental membership, which also allows Yale a seat on the management council of SMARTS3.

The SMARTS 1.5m telescope at Cerro Tololo Inter-American Observatory (CTIO) in Chile. *Photo by V. Misenti.*

Yale leaves WIYN, Inc., joins Palomar 200-inch



The Palomar 200-inch Hale Telescope. *Photo courtesy of CalTech.*

Yale was one of the founding members of the WIYN telescope consortium, which was set up in 1990 as a partnership between The University of Wisconsin-Madison, Indiana University, Yale University, and the National Optical Astronomy Observatory. The consortium has operated the 3.5m WIYN telescope on Kitt Peak for the past 24 years. Yale's private access to WIYN has been a key resource for the Astronomy department, and has resulted in many PhD theses over the years.

The needs of the astronomers have evolved over time, particularly in the period after Yale gained access to the twin Keck telescopes in Hawaii. Recognizing that WIYN was not as central to the research in the Astronomy and Physics departments as it used to be, we decided to review how well our 4m access matched our needs. A comprehensive survey among graduate students, postdocs, and faculty ultimately led to the decision to enter a partnership with the Palomar 5m telescope in California and to withdraw from the WIYN consortium.

Since February 2014, Yale has a 1/8 share of the observing time on the Palomar telescope. The combination of Palomar and Keck is powerful, as the instruments on the two facilities are well matched.

The first round of proposals for the Palomar telescope showed that the Yale astronomy community has great interest in this new facility, and many science results are expected to come from this resource in the coming years.

Pieter van Dokkum contributed to the writing of this article.

Undergraduate class takes field trip to Arecibo

Professor Marla Geha's Astrophysics Research Methods course (ASTR 255) sent 17 undergraduates to Puerto Rico for its first annual Fall Break research trip to Arecibo Observatory, the world's largest single-aperture radio telescope (305m).

The group also included two Yale faculty members and two graduate student Teaching Fellows and was hosted by Fernando Camilo, the Director of Astronomy at the Observatory. Camilo gave the group a private tour of the telescope, which included walking on the catwalk suspended 150 meters above the radio dish (which itself is suspended just above the ground in the middle of the rainforest) that is inaccessible to most visitors.

The students successfully designed and observed their own science projects on the telescope. Upon their return to New Haven, the students analyzed their data for their final projects.

The ASTR 255 group stayed on-site in the astronomer dorms for two nights. Because Arecibo is a radio telescope, cell phone use is prohibited, which in itself was a remarkable experience for the students.

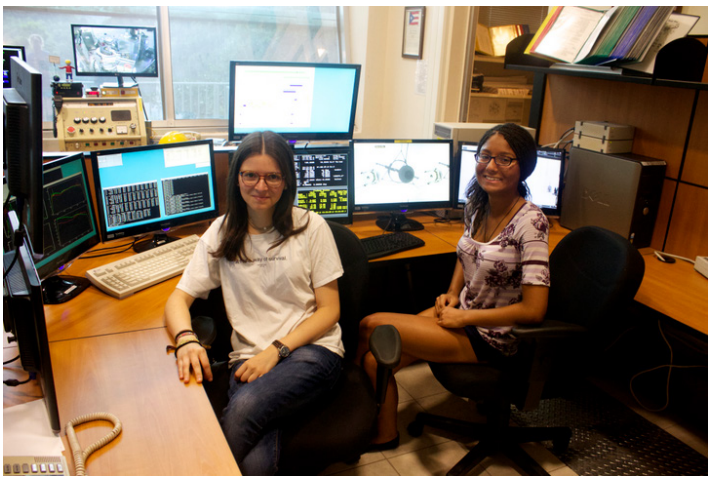
The Arecibo telescope has been featured in several movies, including the classic *Contact* and James Bond's *GoldenEye*.

Portions of this article were contributed by Marla Geha. Images courtesy of the participants.

An aerial view of the Arecibo Observatory.

Ted Papalexopoulous, '15 and Cyril Zhang, '15 on the catwalk.

Above: some of the participants pose for a group shot in front of the Arecibo dish. *Photo by V. Misenti.*



Right: Mariona Badenas, '16 and Aquiel Warner, '15 observing in the Arecibo control room.

Yale astronomy undergraduate

This past summer, the Astronomy Department was daily buzzing with the activities of undergraduate researchers working on such astronomical topics as exoplanets, galaxy evolution and blazars. The students were advised by Professors Debra Fischer, Louise Edwards, and Meg Urry

DEBRA FISCHER'S GROUP

When describing her group, Debra Fischer said, "This was an energetic and cohesive group! The students worked Monday through Friday. As part of the weekly routine, they met twice a week to review the latest astronomy papers posted to astro-ph; they met every Friday for a catered group lunch; and they met once a week for problem solving and computer clinics. The mentors for the students included Dr. Tabetha Boyajian (Yale), Dr. Ji Wang (Yale), Dr. Tom Barclay (NASA Ames Research Center), Dr. Ron Gilliland (Kepler Scientist) and Professor Debra Fischer. Mentors met regularly with the students. Outside of the work time, the group organized a trip to the Hayden Planetarium in NYC and met for movie night at the Leitner Family Observatory and Planetarium."

Ari Brill, '15 searched for microlensing events in the Kepler data. A small number of stars should have evolved binary companions, and when these objects transit they will also bend the light path of the primary star so that a brightening is observed. Ari is flattening the light curves and running a periodogram analysis to try to find these events.

Cory Combs, '14 followed up on stars that were found to transit by Planet Hunters and were added late in the Kepler mission (so the usual pipeline analysis has not been carried out by the Kepler team). When Kepler Mission specialist Tom Barclay visited the group from NASA Ames this summer, he and Cory worked on modeling these new planet candidates.

Miranda Kephart, '15 worked with postdoctoral fellow Tabetha Boyajian to model bolometric corrections for stars. This information is important for understanding the energy output of stars and for determining the temperature of orbiting planets.

Charles Margossian, '15 has been studying correlations between planet radii and the age of the host star as well as the orbital distance from the host star. The planets were either detected by ground-based surveys or by the Kepler Mission. He has identified several very young stars that host planets that have particularly inflated radii.

Michael Mossman is a senior high school student from Rye Country Day School. He helped to build some new iodine cells (used for wavelength calibration for exoplanet searches) and he designed an optical setup to evaluate the throughput and surface scattering of the cell windows. He finished up that task quickly and is now measuring the focal ratio degradation and throughput of optical fibers.

Ted Papalexopoulous, '15 searched for "trojan planets" in the Kepler data. These are two planets with the same orbital path and orbital period, but at different points on the orbital circle. He also worked on the analysis of alpha Centauri spectra obtained with the CHIRON spectrograph.

Victoria Parrish is a high school student who is learning to model transiting planets in the Kepler data.

Alyssa Picard, '14 modeled Kepler light curves with only one or two planetary transits. The transits were detected by Planet Hunters and these objects are especially interesting because the planets are in wide and potentially habitable orbits.

Will Rutter is an MIT sophomore who is developing an instrument that produces an extremely narrow line from the hyperfine transition of rubidium. Doppler broadening has been calibrated out and the line width is only due to "natural broadening" - a consequence of the Heisenberg Uncertainty principle.

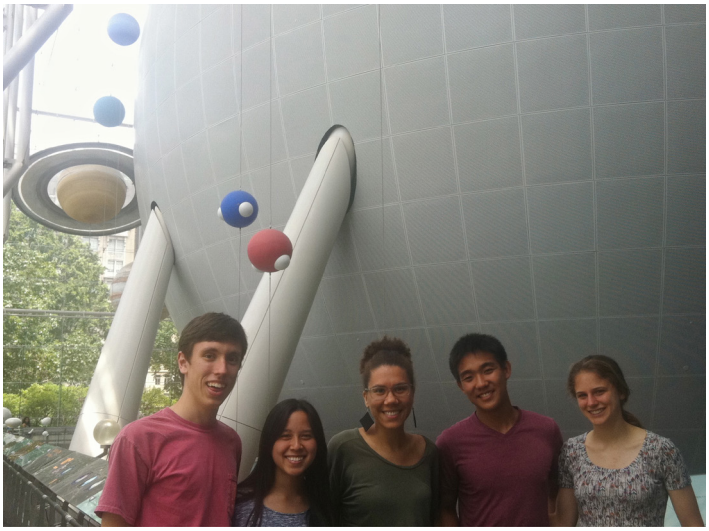
2013 summer research projects

In addition to daily working on their research projects, the students were privileged to attend a field trip to New York City, where they were given a tour of the American Museum of Natural History and its Hayden Planetarium.

LOUISE EDWARDS' GROUP

In addition to their research, Professor Edwards' group was excited to obtain a backdoor tour of the American Museum of Natural History in New York City, meeting astronomers and summer students who were working there.

Hannah Alpert, '15 observed with Professor Edwards for three nights at WIYN in Arizona using SparsePak at the end of the Spring 2013 semester. Through the summer, Hannah worked on reducing and analyzing this data to figure out how the most massive galaxies in the local universe build up and evolve. She also went to Leiden, in the Netherlands, for a week to work with a collaborator to obtain ages of galaxies. Hannah was one of our STARS summer research fellows and funding for her research came from the NASA national space grant consortium.



Vasilije Dobrosavljevic, '16 is working on some of the data that Hannah Alpert took (see above) to look at star formation rates of galaxies. Vasilije also volunteered at public nights at the Leitner Family Observatory and Planetarium. Vasilije's funding came from a Yale freshman research grant.

Renita Heng, '16 was also a STARS summer research fellow. She worked measuring the shapes of galaxies in a supercluster and found that those that appear to be falling into the cluster are more disturbed than elsewhere. In addition, Renita volunteered at public nights at the Leitner Family Observatory and Planetarium.

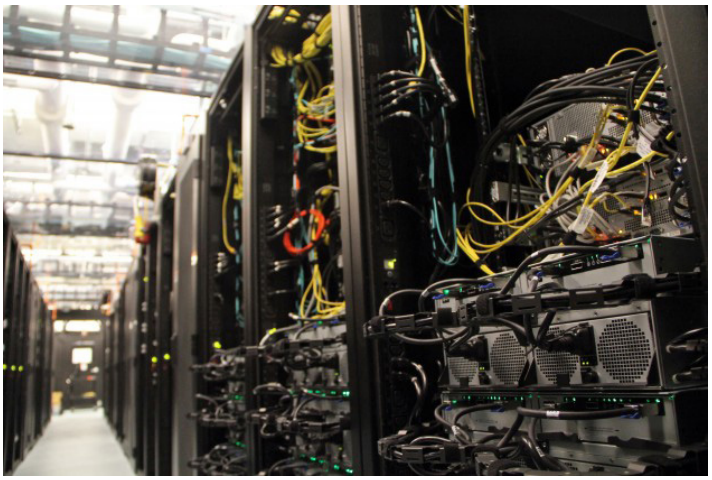
Eric Ho, '16 is a computer science major who built a 3D-rendering of the galaxy cluster Abell 1763, available here: http://www.astro.yale.edu/edwards/Rendering/awesome.html. Eric's funding came from a Yale freshman research grant.

Additionally, **Brooke Lamell, '16** was a STARS summer research fellow who worked with Professor Meg Urry and the Yale SMARTS Blazar Team on optical and near-infrared photometric monitoring of Fermi gamma ray-bright blazars. Within the project goal of constructing multiwavelength light curves to track the variable radiation of each blazar within the experiment sample, Brooke worked on the calibration of the team's luminosity measurements for the Two Micron All Sky Survey stars within each viewing field. She used five years of data from the SMARTS 1.3-meter telescope in Chile to produce standardized magnitude values for all the study's infrared comparison stars in both J and K bands. She was then able to constrain the error values in these calculations due to having potentially variable stars as standards, instrument limitations, and inherent measurement challenges.

This article includes text written by Debra Fischer.
Photos taken in New York City courtesy of the undergraduates.

Astronomy High Performance Computing update

In the Fall 2011 issue of the Astronomy Department Newsletter, we reported that Yale astronomers were benefitting from the use of Yale's High Performance Computing (HPC) clusters, especially from a machine called Bulldog M dedicated for use by Yale astronomers.



Bulldog M has been used extensively by Yale astronomers for their science. For example, Daisuke Nagai's group has used Bulldog M for computational modeling of galaxy cluster formation. By following the complex interplay between dark matter, stars, and gas, these simulations not only helped improve our understanding of the formation and evolution of galaxy clusters, but also provided the independent confirmation of the cosmic acceleration using galaxy clusters as probes. Nikhil Padmanabhan's group has also used Bulldog M to analyze and interpret datasets from the Sloan Digital Sky Survey. Through this work, Padmanabhan has measured the distances to galaxies more than six billion light-years away to an unprecedented accuracy of just two percent. These exquisite measurements have placed new constraints on the properties of Dark Energy. Other users include the research groups of Sarbani Basu, Priya Natarajan and Frank van den Bosch. Bulldog M has been the workhorse for some of the major scientific advances made by Yale astronomers in recent years.

The processors and storage on Bulldog M are now roughly four years old, and such systems usually only have a lifespan of about five years. To continue to meet their scientific needs, Yale astronomers have recently moved to Omega, a newer, faster system that is available for use by all of the members of Yale's Faculty of Arts and Sciences. (When Omega was purchased, it was ranked number 146 among the top 500 supercomputers in the world and the top supercomputer in the Ivy League.) Even though the Yale astronomers no longer have their own dedicated machine, Yale has given the astronomers high priority access to about 1,000 cores of Omega and significantly better access to storage space in the Omega system than they previously had. The priority access mechanism delivers the resources that the Yale astronomers require nearly immediately, while facilitating more efficient use of resources overall.

The astronomers have also benefitted from a 2012 National Science Foundation grant to Yale to build a better, faster network dedicated to movement of large datasets required in scientific research. When it is complete in mid-2014, it will allow Yale research collaborators from all around the world to access the data produced at Yale in a manner that was not possible previously.

Nagai said, "I am looking forward to using the Omega cluster, which should enable astronomers to address the next big challenges in the era of data-driven science… it is always challenging doing cutting-edge research." He continued, "the reason we [at Yale] are doing cutting edge research is because the other institutions are still struggling with these issues and have not managed to do what we have done."

Because Yale astronomers will likely need more computing power and storage for their research into the future, the astronomers are working closely with Yale's HPC team to make sure that the University can apply for grants to support acquisition of the next generation of advanced computers.

Portions of this article were contributed by Daisuke Nagai.
Photo by Z. Gorman of the Yale Daily News.

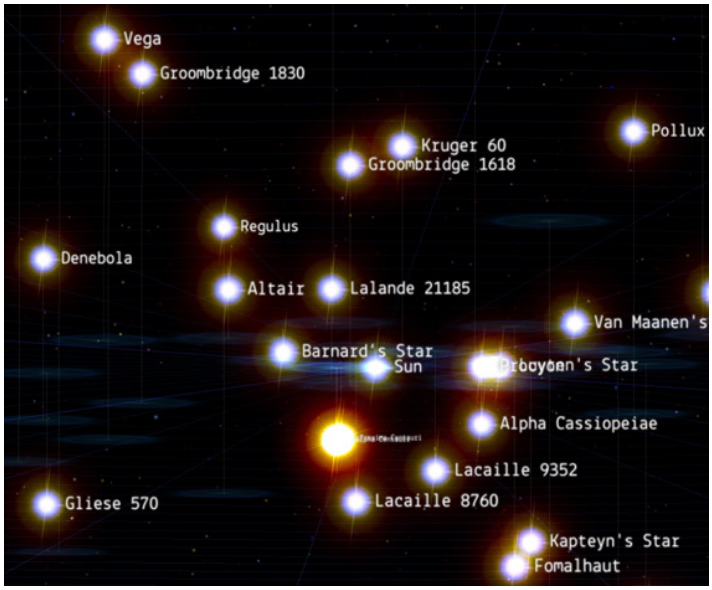
What Does a Black Hole Look Like?

Professor **Charles Bailyn** has recently published a new textbook, *What Does a Black Hole Look Like?* with Princeton University Press. A cutting-edge introduction for undergraduates and others who have some knowledge of introductory college-level physics to a subject that was once on the border between physics and science fiction, this book shows how black holes are becoming routine objects of empirical scientific study.

In his book, Bailyn goes behind the theory and physics of black holes to describe how astronomers are observing these enigmatic objects and developing a remarkably detailed picture of what they look like and how they interact with their surroundings. In addition, Bailyn discusses the possibility of observing theoretically-predicted phenomena such as gravitational waves, wormholes, and Hawking radiation.

The textbook will be available in both hardcover and electronic forms.

Yale's Bright Star Catalog integral in Google project



Yale's Bright Star Catalog recently played an important role in the creation of the Google project 100,000 Stars (see http://workshop.chromeexperiments.com/stars/). This project, developed by the Google Data Arts team, consists of an interactive website that visualizes the stellar neighborhood. Users can zoom in from a view of the Galaxy to a close-up image of the Sun, passing thousands of stars, the Oort Cloud, and the orbits of planets in the Solar System. In addition to freely zooming between galactic, stellar, and planetary scales, users can also opt to take a programmed tour of 100,000 Stars that displays educational facts about stellar distances, types, and colors.

100,000 Stars actually consists of 119,617 stars, 87 of which are individually named on the website and have accompanying information and images. Google engineers relied on three sources to accurately map the positions of the stars: Yale's Bright Star Catalog (YBS), the Hipparcos catalog, and the Gliese-Jahreiss catalog. The YBS is a catalog of the positions, photometry, proper motions, and parallaxes of approximately 9,100 stars with apparent magnitudes brighter than +6.5. Dorrit Hoffleit, a Professor of Astronomy at Yale from 1956-1975, compiled and edited the YBS.

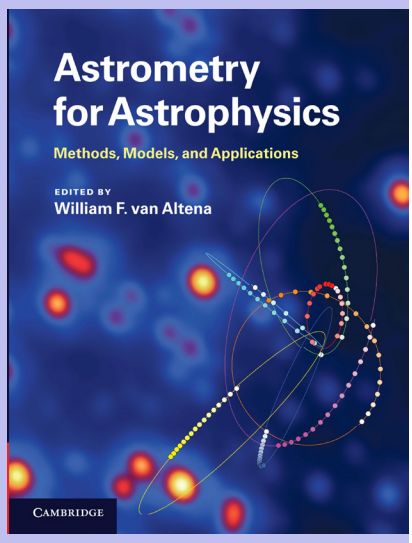
An instrumental score by Sam Hulick entitled "In a Strange Land" accompanies 100,000 Stars; users may recognize Mr. Hulick's work from the popular video games Mass Effect and Baldur's Gate.

100,000 Stars represents a powerful visualization of astronomical data and an effective way of sharing the results of scientific research with the public. "As you explore this experiment, we hope you share our wonder for how large the Galaxy really is," said Aaron Koblin, Creative Director of Google's Data Arts Team.

This article was written by Katherine Kornei, B.S. '06. Screen capture from 100,000 Stars application credit: Google.

Astrometry for Astrophysics: Methods, Models and Applications

Yale Astronomy Professor **William F. (Bill) van Altena** is the editor of a recent textbook published by Cambridge University Press called *Astrometry for Astrophysics: Methods, Models and Applications*. The textbook is intended as a one-semester introduction to the science of astrometry for advanced undergraduates, beginning graduate students and researchers in related fields.



Astrometry for Astrophysics covers many aspects of astrometry, ranging from the necessary mathematical background to its latest applications in a variety of currently interesting astronomical topics.

van Altena hopes that the students' exposure at an introductory level will lead to more advanced study of this exciting field. For researchers in other fields, the goal is to provide sufficient background to understand the opportunities and limitations of astrometry.

Astrometry for Astrophysics is the result of advice from many individuals in the worldwide astrometric community. The 28 chapters were written by 28 co-authors from 15 different countries.

Astronomy Library renovations create new study space

The Astronomy Library was recently renovated to create an improved study space for department members and visitors.

Librarian Kim Monocchi worked with Richard Larson to discriminately curate the size of the library's collection from 40,000 printed volumes, reducing it to its current size of about 17,000 volumes. The newly available space allowed for the addition of a new conference table in the rear of the library that is able to be reserved for meetings. In addition, the existing study space was completely transformed with new furniture that is more amenable to both individual and group study.

The undergraduate computer laboratory was also transplanted to the library and has become especially busy during the summer research season.

Monocchi said that the renovations, which included renovations to the circulation desk, have made her more accessible to users who require assistance. She said of the renovated library, "It is warm, exciting, a great atmosphere and it functions well." She also remarked, "I am no longer surrounded by an orange glow!"

The renovation started in August of 2012 and was completed in February of 2013. Standard Builders was the construction company. Clancey Cullen moved and shifted all of the books. Svigals & Partners were the architects. The millwork, custom-made cabinets, and end panels were done by Orion Manufacturing, LLC. *Photos by V. Robalino.*

The Astronomy Library, then and now

by Kim Monocchi, Librarian

When I stood in the middle of the Astronomy Library in 1993, it felt like being transported back into the '70s, but it also felt like home. Surrounded by orange, vinyl-upholstered chairs standing on worn, orange tweed carpeting, peeling paint and the smell of old books, I knew I wanted to spend my working days here. Many of the students felt the same warmth surrounded by this sea of orange and a few shared that they felt the library, in all of its orange glory, was the nicest space in the department.

Today, the library surrounds visitors in warm wood tones, with a study space, wireless internet, a workspace with computer access for undergraduate Astronomy majors and a space for small group meetings. Of course, there is more to be done, but the only place you may see a hint of that old, orange glow is in the stacks covering the bound journals.

It is a wonderful feeling when department members, [who have been] here longer than I, say, "I'm impressed." May this library continue to be considered one of the nicest spaces in the department. It was a pleasure to be part of this renovation and its evolution into something more than it once was.

Astronomy classroom gets “face lift” and new air conditioning

Yale University has implemented a global "Science Hill Plan" (SHP) to improve the quality of Yale's research and teaching facilities and to enhance contacts within and among departments.

As part of this plan, many of the classrooms on Yale's Science Hill have been renovated, including the Astronomy classroom (JWG 263).

The construction in JWG 263 began immediately after classes ended in May 2013 and finished at the beginning of July 2013, right before the Yale Summer Session courses began. The new furniture, which is easily mobile, did not arrive until the end of August, but was in place before the new academic year began.

A “behind-the-scenes” focus of the JWG renovation was to upgrade the air conditioning so that it is now quieter and functions well. The rest of the renovation included long-overdue cosmetic changes such as new carpet, new furniture, and a fresh coat of paint. The orientation of the classroom was also changed, and a series of nesting whiteboards and blackboards were installed on the same plane as the projector screen.

Standard Builders was the contractor for the renovation. *Photo (top right) by V. Robalino.*

Natives and the Stars at Leitner Family Observatory and Planetarium

On November 29, 2012, about 60 people attended a unique event at the Leitner Family Observatory and Planetarium (LFOP) called "Natives and the Stars."

The program was initiated by Maya Bernadett, a member of the Tohono O'Odham Nation in Arizona who had been working at Yale, and focused on the relationship between the Nation and astronomy.

The Tohono O'Odham own the land on which Kitt Peak National Observatory is situated. In addition to Bernadett, there were two other members of the Nation affiliated with Yale at the time of the program, and all were in attendance. Bernadett also flew in two members of the tribe from Arizona: Brian Hendricks, who cooked a delicious traditional meal for all attendees (see photo, above), and Michael Enis, who regaled the audience with traditional song and dance relating to astronomy and the world-view of the Nation.

In addition, there were two presentations from the astronomy department. First, Victoria Misenti gave a presentation about the history and unique features of the WIYN telescope and its organization, interweaving anecdotes about the interactions between astronomers and the Tohono O'Odham at WIYN and Kitt Peak throughout history. Second, Professor Marla Geha gave a talk about the science that Yale astronomers were currently doing on Kitt Peak.

The attendees were invited to observe with LFOP’s telescopes at the end of the night. Faithful LFOP volunteer Dave Noble assisted with observing.

The Natives and the Stars event was co-hosted by the Astronomy Department, the Native American Cultural Center, the Lamar Center for the Study of Frontiers and Borders, and the Intercultural Affairs Committee. *Photos by D. Noble.*

Louise Edwards joins Yale Astronomy Faculty

The astronomy department welcomed Dr. Louise Edwards to the faculty as a Lecturer in July 2012. Prior to that, she was an Assistant Professor of Physics at Mount Allison University. She has also held postdoctoral positions at the California Institute of Technology's Infrared Processing and Analysis Center and at Trent University. She received her PhD in Physics from Laval University in Quebec, Canada in 2007.

While at Yale, Edwards is teaching several courses, primarily for undergraduates. She also assists at the Leitner Family Observatory and Planetarium. Her research focus is in the formation and evolution of galaxies in various environments. She is particularly interested in the cores and infall regions of rich galaxy clusters.

In 2002, Edwards was pictured on a Canadian stamp. In her free time, she enjoys watching films and attending local music concerts. *Photo courtesy of L. Edwards. Stamp image credit: http://data2.collectionscanada.ca/ap/s/pos_b/posb1067.jpg*

Yale University Library hires new research support librarian for physical sciences

If you come to the Astronomy Department's second floor foyer at 4pm on Thursday afternoons, you will probably have a scintillating conversation with Kayleigh Bohemier, the new librarian at the Center for Science and Social Science Information (CSSSI) who supports the astronomy, geology, geophysics and physics communities at Yale.

Bohemier is no stranger to astronomy—she minored in astronomy as an undergraduate at Smith College before obtaining her graduate degree in library science with a focus in eScience Librarianship at Syracuse University. In addition, she was an intern with the Harvard-Smithsonian Center for Astrophysics' Astrophysics Data System—otherwise known as ADS—where she worked on an ontology for a semantic literature search interface, designed a workflow for mapping astronomer-provided target names to canonical astronomical object names in SIMBAD, and collaborated on ObsCore data ingestion into the semantic interface.

Bohemier has set up a useful guide to astronomy resources (one among many useful guides for scientific research) on her library website, below:
http://guides.library.yale.edu/profile/kayleigh-bohemier.

Personally, Bohemier enjoys cooking, yoga and science fiction. *Photo courtesy of K. Bohemier.*

Class of 2013 Senior Thesis Projects

Farris Gillman *Evaluating the Orbital Parameters of UW LMi* (advisor: Debra Fischer)
Margaret Lazzarini *Seeing through the Clouds: Determining the Intrinsic Structure of AGN in the Swift BAT Sample* (advisor: Meg Urry)
Zak Kaplan *Instrumentation for Exoplanet Detection* (advisor: Debra Fischer)
Casey Rhyne *Simulations of the PIXeY detector* (advisor: Dan McKinsey)
Ilya Uts *Exploring the Phases and Densities of Water up to 1 TPa and 24000 K* (advisor: Debra Fischer)

Yale and Chile: Spotlight on Adele Plunkett, Fulbright Scholar

Graduate student Adele Plunkett, GRD '15 took some time away from New Haven to spend eighteen months—nine months on her Fulbright Scholarship and the other nine through her NSF fellowship—studying astronomy in Chile. Plunkett said that the Fulbright Scholarship enhanced her cultural experience while in Chile, but the fact that the Yale-University de Chile (U de Chile) collaboration exists facilitated her ability to be connected to astronomy while she was there.

The Fulbright Scholarship is a program of the Department of State that facilitates exchanges between the United States and other countries through grant funding. Plunkett's grant was to enable her to complete a research project with Diego Mardones, a professor at the U de Chile and a close collaborator of Plunkett's advisor at Yale, Professor Hector Arce.

While Plunkett was not enrolled at the U de Chile, she did audit one of Mardones' classes, and she participated in the life of the department in general. Not being enrolled gave her the freedom to pursue other astronomical endeavors, and, for the first four months Plunkett was in Chile, she participated in commissioning projects at ALMA.

The additional nine months that Plunkett spent in Chile gave her the time she needed to apply for her own ALMA observing proposal and to gain observing experience at other observatories in Chile. She observed for Chilean observing time at the APEX observatory, was able to visit the VLT, and served as a substitute observer and telescope operator for SMARTS.

Adele Plunkett on a hiking trip with two friends and fellow Fulbrighters in the Andes mountains near Santiago. *Photo courtesy of A. Plunkett.*

Adele Plunkett visits the ALMA antennas at 5000m elevation on the Chajnantor Plateau in northern Chile. *Photo courtesy of A. Plunkett.*

Plunkett especially enjoyed that Chile seemed to be a "professional hotbed of astronomy." Experts from all over the world go there to live or work for short amounts of time and there are a lot of international collaborations. Plunkett said it was "fun to be in the middle of it… sitting in the control room and hearing four different languages all at once and thinking about…these are the experts in what I do and hopefully I'll be meeting them again elsewhere."

In addition to Plunkett, there were 11 other students with Fulbright research projects living in Santiago. Plunkett learned from these students that, in addition to astronomy, Chile is also the "hotbed" for studying many other topics, including sea life, earthquakes and human rights issues.

The Fulbright program encourages its participants to integrate into the community and society and to experience life outside one's research project. Plunkett travelled a lot to explore the country on weekends, and she enjoyed Santiago's prime location for hiking, biking, skiing and other fun extreme outdoor sports. In the latter part of her stay, Plunkett became involved with triathlons.

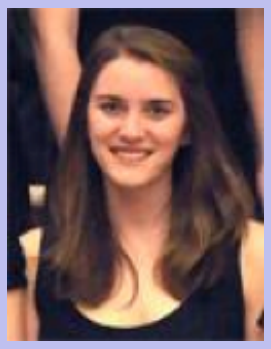
Pedro Capelo, '12 PhD
Currently a Postdoctoral Research Fellow in the Department of Astronomy at the University of Michigan, Ann Arbor.
Dissertation: *Theoretical Investigations on the Dark Matter and Gas Content of Large Spheroidal Systems* (advisors: Paolo Coppi and Priyamvada Natarajan)

The goal of my thesis work was to study the gas and dark matter content of large spheroidal systems from a theoretical point of view and to narrow the discrepancy between existing theoretical models and observed phenomenology in these massive structures. The results include observationally-calibrated theoretical prescriptions for early-type galaxies, groups and clusters of galaxies: I have weighed in on the robustness of the lens-redshift test for constraining cosmological and galaxy evolution parameters, utilizing the redshift distribution of galaxy lenses in known gravitational lens systems; produced a gravitational potential profile that accounts for the contribution of stellar matter in systems where its effect is appreciable and presented a new analytic formulation for the equilibrium gas density profile of early-type galaxies; and developed a novel, particularly flexible, model to constrain the gas and dark matter properties of groups and clusters of galaxies, by comparing X-ray scaling relations to theoretical expectations, obtained assuming that the gas is in hydrostatic equilibrium with the dark matter and follows a polytropic relation.

Rachel Bezanson, '13 PhD
Currently a Hubble Postdoctoral Fellow at the University of Arizona.
Dissertation: *Ten Billion Years of Growth: Massive Galaxy Evolution from Structures and Dynamics* (advisor: Pieter van Dokkum)

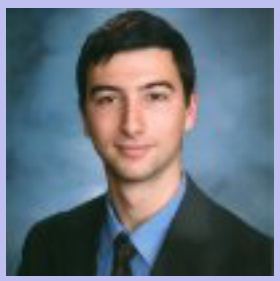
Once thought to be relics of a much earlier epoch, the most massive local galaxies are red and dead ellipticals, with little ongoing star formation or organized rotation. In the last decade, observations of their assumed progenitors have demonstrated that billions of years ago, massive galaxies were more compact and morphologically different, possibly with more disklike structures. The details of this observed evolution can place constraints on the physical processes that have driven massive galaxy evolution through cosmic time. The work presented in this thesis provides observational constraints on the dynamical and structural evolution of massive galaxies since z~1.5-2. Using a variety of photometric and spectroscopic surveys, including OBEY, SDSS, NMBS, and UDS, I (I) describe the structural evolution of massive galaxies by directly comparing their density profiles at z ~ 2 and locally, (II) quantify and model the number density evolution of galaxies as a function of velocity dispersion since z ~ 1.5, (III) present deep spectroscopic studies of massive galaxy dynamics at z ~ 1.5 and z ~ 0.8, and (IV) tie together the evolution of both galaxy structures and dynamics, showing that massive galaxies grow within the mass fundamental plane throughout the last 10 billion years. Overall, these results provide strong evidence for inside-out growth, minimal, but non-negligible, dynamical evolution and efficient quenching of massive galaxies since z ~ 2.

Yale Astronomy undergraduate class of 2013



Margaret Lazzarini

Farris Gillman



Ilya Uts

Casey Rhyne

Zak Kaplan

OMY GRADUATES

Brooke Simmons, '12 PhD
Currently a Postdoctoral Research Associate at the University of Oxford.
Dissertation: *Black Hole Growth and Host Galaxy Co-Evolution Over 8 Billion Years of Cosmic Time* (advisor: Meg Urry)

Although much progress has been made in the investigation of the co-evolution of black holes and galaxies, the nature of AGN accretion triggers and AGN-host feedback remain open questions. Using samples of hard-X-ray-selected, moderate-luminosity AGN and their host galaxies from $0.25 < z < 2.67$ in the GOODS deep multi-wavelength survey fields, this thesis assesses the growth rates and histories of these black holes and uses their host galaxy morphologies and colors to test the applicability of established quasar-triggering models to lower-powered AGN. The analysis includes simulations of over 50,000 AGN+host galaxy images to assess the reliability of AGN-host decomposition, as well as a new technique to separate the spectral energy distribution of an obscured AGN from its dominant host galaxy.

Because major mergers both form bulges and destroy disks, this result indicates that models requiring major mergers to trigger the growth of black holes do not describe the majority of AGN. The range of both black hole growth rates and host galaxy colors and morphologies in the sample imply that secular processes are important to the growth of moderate-luminosity AGN, which collectively comprise a substantial fraction of the overall black hole growth in the universe.

Tomer Tal, '12 PhD
Currently a NSF Postdoctoral Fellow at UC Santa Cruz.
Dissertation: *Feeding a Leviathan: The Growth of Massive Red Galaxies Through Minor Mergers* (advisor: Pieter van Dokkum)

When galaxies collide with the most massive elliptical galaxies in the universe, their stars are torn and get absorbed into the stellar body of their massive hosts. Such interactions, called "minor" mergers, may have a crucial contribution to the growth of massive ellipticals as these galaxies do not otherwise form stars of their own. In this dissertation, we study the importance of minor mergers to the growth of massive elliptical galaxies. We analyze data from the SDSS and OBEY surveys to quantify the rate of minor mergers and their contribution to the size and mass growth of nearby ellipticals.

Kate Whitaker, '12 PhD
Currently a NASA Postdoctoral Fellow at Goddard Space Flight Center, Greenbelt, MD.
Dissertation: *A Cosmic Metamorphosis: The quenching of star-formation in massive galaxies over the last 11 billion years* (advisor: Pieter van Dokkum)

Nearby galaxies exhibit a bimodal color distribution, whereas actively-star-forming galaxies have blue colors and quiescent galaxies have red colors. It is generally thought that red galaxies arise from blue galaxies when star formation is quenched. However, the origin of this color bimodality remains unknown. Furthermore, it is not well understood how actively-star-forming galaxies quench and migrate to form the well-defined color-mass relation, known as the "red sequence." In this thesis, direct evidence is presented that the massive end of the red sequence is most rapidly building up when the universe was only 3 billion years old, with an influx of young quiescent galaxies that are almost non-existent over the past 8 billion years. These recently quenched galaxies have fundamentally different spectral shapes than older galaxies at the same redshifts, resulting in an increasing observed color scatter. With the accurate photometric redshifts and rest-frame colors of the novel NEWFIRM Medium-Band Survey presented herein, we can now break the degeneracies between age and dust to resolve the color scatter, and hence age spread, of the quiescent population over the past 11 billion years. Interestingly, the sizes of the most recently quenched galaxies are not larger, and possibly even smaller, than older galaxies at these early times. We additionally investigate the properties of star-forming galaxies, finding that galaxies show strong trends of increasing dust attenuation with stellar mass and a decreasing specific star formation rate. The discovery that the most recently quenched galaxies are compact with apparently little dust, while massive star-forming galaxies at the same epoch have heavily obscured star-formation and larger sizes, provides important clues for the physical process responsible for shutting down star formation in galaxies.

HONORS

Professor **Debra Fischer** has been chosen by the national fraternity Kappa Alpha Theta as one of the 2012-2013 Top 10 Outstanding Faculty Members.

Matt Giguere, GRD '15, was awarded a prestigious NASA Earth and Space Science Fellowship.

Nhung Ho, PhD '13 was awarded the Insight Data Science Fellowship, which is an incredibly competitive and prestigious 6-week program "bridging the gap between academy and data science." The fellowship claims 100% job placement rates into companies like Facebook and Twitter.

Priya Natarajan has been elected to an honorary University Professorship in the Physics Department of the University of Delhi.

Pieter van Dokkum has been named the Sol Goldman Professor of Astronomy.

Meg Urry has succeeded David Helfand as President of the American Astronomical Society starting in June 2013. She will spend a year as incoming president, two years (June 2014-August 2015) as president, and a final year (August 2105-June 2016) as past-president. Urry also won the George van Biesbrock prize of the AAS for 2012, which was conferred in January 2013. She has also been named as a fellow of the American Association for the Advancement of Science (AAAS) for "exemplary dedication to research and teaching in physics and astronomy, and for leadership in promoting the participation of women in the physics profession."

In Memoriam: Suzanne Tourtellotte (1945-2013)

Suzanne Tourtellotte, who worked in the Department of Astronomy for many years as an Associate Research Scientist, passed away on June 20, 2013, after a long and courageous battle with cancer.

Below is an excerpt from a letter that Professor Charles Bailyn, B.S. '81, wrote to the department upon her passing that expresses "Suzanne's remarkable contributions to the Yale Department of Astronomy and to the field of astronomy more generally."

I first started working with Suzanne almost two decades ago. She came to us from her position as a Biology Professor at Albertus Magnus College, where she had been asked to teach an introductory course on astronomy. Typically for Suzanne, she was not satisfied to do a merely adequate job, which as an experienced teacher she could easily have done. Rather, she came into our department and volunteered to do anything that needed to be done in exchange for the opportunity to learn the subject in depth. Gus Oemler, who was department chair at the time, took her on as a research assistant for a time, and then she worked with me on a variety of projects. During those early years, she audited every 100 and 200 level course the department offered - several of us felt that she deserved to be awarded a PhD in Introductory Astronomy for her efforts. She also TA-ed several courses during this time - her experience and skill as a teacher of introductory courses was greater than any five members of our department put together, and those of us who were fortunate enough to have her assistance learned a great deal about teaching from her wisdom and good sense.

After a number of years, she chose to leave Albertus Magnus and join the Astronomy Department full time as a Research Scientist. Her work was primarily associated with the YALO project, which subsequently grew into the SMARTS consortium, which has operated four telescopes in Chile since 1992. Her official task might be described as "data wrangler" - every one of the hundreds of CCD images obtained by SMARTS every day passed through her hands. I suspect that she visually inspected more CCD images than anyone else in the world during that time. She was relentless in ferreting out anomalies in the data, no matter how small, and the high quality of data obtained at SMARTS over the years is due in large part to her insight and hard work. Every researcher who has worked with data from the ANDICAM instrument owes her a great debt. But she went far beyond simply managing the data, key though her contributions were in that area. She also took on significant roles in science analysis for projects led by Brad Schaefer and David Rabinowitz, among others. ADS lists 84 publications for her, including 11 refereed papers - a truly remarkable achievement for someone with no formal training in the field.

And through it all, her good sense and good cheer enlivened the SMARTS team, the department, and the motley crew of SMARTS PIs with whom she interacted on a daily basis. She had a fierce commitment to excellence, but she also had the knack of leavening her determination with wisdom and humor, keeping all of us grounded in important ways. She also brought a remarkable range of non-scientific talents into our midst - her artwork graces our department, and I personally treasure a number of small "arts-and-crafts" projects that she was kind enough to make for me. Toward the end, when her health began to fail and her suffering increased, I never once heard her complain, and she maintained a remarkably upbeat attitude toward work, life and the Universe as a whole.

She will be greatly missed. Photo by V. Misenti.

Michele Dufault Endowment for Yale Women in Science

Yale University is honored to announce that it has established the Michele Dufault Endowment for Yale Women in Science. The $14 million fund, designated by the Yale Corporation within the University Endowment, has been named in memory of Michele Dufault, B.S. '11, who died in 2011 in a tragic accident at Sterling Chemistry Laboratory while pursuing her dreams as a scientist.

In announcing the University's decision, Yale President Richard C. Levin stated, "No one better exemplified the intellectual drive, curiosity, talent, and energy of young women who will become leaders in science than Michele Dufault. Michele, a double major in physics and astronomy, was an evangelist for physics and for women in science, an explorer of ideas, a talented researcher and a leader of formidable capacity. She also was an accomplished saxophonist, a tireless organizer of events and programs and a mentor and source of inspiration to her many friends."

The endowment will continue in perpetuity, and its income will be applied to benefit women pursuing study at Yale in science, technology, engineering, and mathematics ("STEM"). The endowment will fund undergraduate scholarships and graduate fellowships to women studying at Yale, who will be known as Michele Dufault Scholars, as well as summer undergraduate research opportunities; Yale-sponsored conferences and workshops designed to encourage women to pursue study of STEM disciplines; travel for students to attend other such conferences; and Yale-sponsored outreach programs intended to spark the interest of younger girls in STEM fields—girls who one day may follow in the academic and intellectual footsteps of Michele Dufault.

This article was adapted from a Yale University press release from June 28, 2013.

Martin Altschuler, '64 PhD writes, "When I left Yale Dept of Astronomy in 1965, I went to work for the High Altitude Observatory (NCAR), Boulder, CO. Worked there until 1976 doing 3D mapping of the solar coronal density distribution and the 3D magnetic field density. Applied some of this work to 3D medicine, and from 1976 to 1981, worked on 3D tomographic algorithms at SUNYAB (Buffalo, NY). In 1981, I was hired by the U of Pennsylvania School of Medicine, Dept of Radiation Oncology (Philadelphia, PA), where I helped develop algebraic optimization for 3D radiation treatment planning. I also worked on robot vision by combining laser pattern (active) projections with stereoscopic (passive) imaging. After retirement in 2003, I worked on optimization algorithms for photodynamic treatment planning (optical red radiation inserted interstitially into the prostate—rod-like sources in a matrix pattern). Currently retracing the twists and surprises of quantum theory. Regards to Yale Astronomy. I have great memories of my time there."

Bill Jefferys, '65 PhD writes, "In my first year at Yale, Professor Harlan Smith gave me the task of measuring some Harvard plates of quasars, a hot topic at the time."

Harlan invited Jefferys to follow him to the new Astronomy Department at the University of Texas (UT), and in 1965, Jefferys joined the faculty, where he remained until retirement in 2004. Other Yalies who came to UT at the time were the late Jim Douglas (faculty), **Gerry Moseley, '69 PhD** and **Arak Bozyan, '69 PhD**.

In 1977, Jefferys became the Hubble Space Telescope Astrometry Science Team Leader, working with Yale Professor Bill van Altena and the late Raynor Duncombe, '56 PhD.

Jefferys writes, "In 2005, my wife, Sue, and I moved to a farm in Fayston, Vermont that my parents bought in 1957. I became an Adjunct Professor of Statistics at the University of Vermont and taught courses there from time to time, mostly on Bayesian statistics and decision theory, which I had become interested in during my work on the Hubble Telescope."

Dave Pierce, '66 PhD writes, "I recently retired from research and teaching (on-campus & online). Teaching began at Vassar in 1966, while working at Yale, and ended in So. Calif. in 2013. Part time research was at JPL over several decades. The most recent project was identifying asteroids which may visit someday."

"Since 1974, I've been involved with the Summer Science Program where gifted HS students devote six weeks to studying university-level Astronomy, Physics and Math. Nights are devoted to observing near-Earth asteroids and computing their orbits. I'm pleased to note that three other Yale astronomers have also been involved with SSP – two of my classmates, Carol Williams and Myles Standish, and Michael Faison, who's currently on staff at Yale. I consider this involvement to be the best thing I ever did professionally."

"Several evenings a week, I enjoy ballroom dancing. In addition, I make presentations at a UCLA discussion group on all that liberal arts stuff I managed to avoid during my Engineering-Astronomy training. Otherwise, I'm thoroughly enjoying life as a bum."

Julian Palmore, '67 PhD writes, "I have been a member of AIAA since 1955, first as a student member until 1960, then as a member. In 2010, after 50 years of membership, I became a Lifetime Member. My specialty is astrodynamics and celestial mechanics. At the University of Illinois in Urbana, I teach courses in spaceflight and differential equations. My Yale studies in the Astronomy Department have contributed greatly to my teaching and research career."

William Klepczynski, '68 PhD writes, "I am now completely retired from astronomy. I had been at the U.S. Naval Observatory for 35 years where I retired as Director of the Time Service Department. At USNO, I worked on the U.S. Master Clock, keeping time for the United States and GPS. Then did contract work for the FAA as an employee of Innovative Solutions International, working on the Wide Area Augmentation System (WAAS) to GPS. Next, I became a Fellow of American Association for the Advancement of Science (AAAS) and Institute of Navigation (ION) and was assigned to the U.S. State Department Space and Advanced Technology (SAT) Section and worked on GPS agreements with Europe, Brazil and Japan. After that, I became a contractor to the Institute of Defense Analyses (IDA) where I worked on the Military Critical Technology List (MCTL). Gloria and I live in the Annapolis, MD area and frequently visit our daughter and her children who live in Virginia. We spend our summers in the Portland, OR area where we visit our son and his children. Continuing the development of my programming skills which I learned at Yale, I now help maintain the web sites for the Friends of John Paul II Foundation, Washington, D.C. Chapter, and the Chesapeake Environmental Protection Agency (CEPA)."

Myles Standish, '68 PhD writes, "I'm now retired, living on Lake Keowee in South Carolina and enjoying the many friends that Jeannine and I have made here. I still do occasional astronomy things - refereeing journal papers, giv-

ing talks, providing various calculations and advice - and am continually reminded of how much my Yale experience contributed to my professional career. I was honored and humbled by the AAS Brouwer Award in 2000 and by the NASA Distinguished Service Medal in 2008. After all, I was just doing something that I truly loved, providing planetary ephemerides to the spacecraft missions, working with the navigation teams, and interacting with colleagues around the world. Though I miss the old gang at JPL, I do not miss the California population problems. Life is good here in Y'allville."

Bill Gutowski, '76 PhD continues to teach and do research on climate processes and climate change in the Department of Geological and Atmospheric Sciences at Iowa State University. He is a Lead Author for the newly released *Climate Change 2013: The Physical Science Basis, the Fifth Assessment Report* by Working Group 1 of the Intergovernmental Panel on Climate Change. He is also helping to coordinate regional climate research worldwide in various roles with the World Climate Research Programme. He was very happy to visit Yale early in 2013, after many years away, to participate in a forum on The Integration of Climate Change and Infectious Disease Research, sponsored by the Yale Climate & Energy Institute.

John Giuliani, '80 PhD received his Ph.D. in theoretical astrophysics under Prof. Richard Larson in 1980. After postgraduate work at the Institute for Advanced Study and Princeton University, he joined the Plasma Physics Division at the Naval Research Laboratory (NRL). Since then, he has published in many areas of plasma physics, including high altitude nuclear effects, laser target interactions, arc torch remediation, plasma processing, fluorescent and high intensity light sources, and KrF laser gas kinetics for fusion energy. Presently, he is Head of the Radiation Hydrodynamics Branch at NRL where he directs research activities on non-LTE ionization kinetics coupled to radiation transport and Z-pinch magnetohydrodynamics.

Horace Smith, '80 PhD formally retired from the Michigan State University Department of Physics and Astronomy last spring, but he has been allowed to maintain an office while in Emeritus status, and, aside from less teaching, things seem as busy as before retirement. He writes, "Now I have to do all the things that I told people I would do after I retired."

Christopher Carosa, '82 BS writes, "I continue to own and operate a small boutique investment adviser. In addition to offering private portfolio management to a modest number of clients, we operate two (smallish) proprietary funds as well as a division focusing on 3(38) fiduciary services to plans and their advisers. The bigger news comes from my wife's business, a company that focuses on "marketing, media and more." It is the repository of all my creative works (who goes through a publisher nowadays, anyway?). The on-line industry news journal called *FiduciaryNews.com* has grown to nearly 6,000 subscribers and seems to have built a significant following within the retirement plan industry. It has led to small freelance project and a somewhat larger consulting project with a large media firm. In the meantime, I've published two new books: *401k Fiduciary Solutions* (guess what that's about?) and *50 Hidden Gems of Greater Western New York* (a collection of personal essays describing interesting tidbits regarding places, events and people from the Greater Western New York Region). The first book seems to be selling consistently according to Amazon and the latter has led to plenty of speaking engagements at local service clubs, historical societies and other regional interest groups. I'm working on several more books, including two to be published this year. My hope is to ramp up my publication schedule so I publish two books a year - one in the finance/investing area and one in some other area (including fiction). Perhaps I'll have more to report for the next newsletter."

Michael West, '87 PhD is now Director of the Maria Mitchell Observatory (MMO) on the island of Nantucket, continuing Yale's connection to the MMO that began more than half a century ago with Dorrit Hoffleit. Prior to joining the MMO, he spent six years as Head of ESO's Office for Science in Chile.

Taft Armandroff, Jr., '88 PhD was recently named the new Director of the McDonald Observatory at the University of Texas at Austin (UT). He will also become a professor at UT.

(Cont'd on p. 22.)

Giving to Yale Astronomy

The Astronomy Department 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. For more information, please contact Angelika Hofmann at angelika.hofmann@yale.edu or 203-436-8510.

Jamie M. Howard, '93 PhD writes, "I'm mid-way through my 21st year of teaching science and math and my 15th year of teaching at the Albany Academies in Albany, NY. We even have an introductory astronomy class this year and a junior student who wants to do astronomy research over the upcoming summer and during his senior year. I consider myself very fortunate to get paid to do something I find incredibly enjoyable and rewarding, and I often find myself looking back to the examples of the faculty who taught me. Other than that, I work at spending as much free time as I can in the great outdoors and don't spend as much time as I'd like to keeping in touch with some of my former classmates."

Thomas Lydon, '93 PhD writes, "I am still working as a doctor in New Hampshire. Gave a talk at Dartmouth on managing chest pain at small hospitals. Recently elected as a Fellow of the American College of Emergency Physicians. I had a pleasant discussion with Dr. Paul Charbonneau on the latest advances in solar convection. But the big news is that after a lifetime of renting, I have purchased a home [in Rye, NH]. Visit me on the beach anytime."

Ray Jayawardhana, '94 BS has recently been appointed Dean of the Faculty of Science at York University. He will serve a five year term commencing July 1, 2014. Prior to his appointment at the University of Toronto in 2004, where he is currently on the Faculty, he held an appointment at the University of Michigan, Ann Arbor. He has co-authored close to 100 scholarly articles in his field, and is a co-editor of two books, *Star Formation at High Angular Resolution* and *Young Stars Near Earth: Progress and Prospects*. He is the recipient of a number of awards and honors, including the Royal Society of Canada's Rutherford Medal and the Steacie Prize for Natural Sciences.

Jayawardhana enjoys promoting the sciences with the media, government, the public, and external bodies. He is frequently featured in various radio, television and print media venues speaking to current issues in astronomy, and is the author of three popular books: *Neutrino Hunters: The Thrilling Chase for a Ghostly Particle to Unlock the Secrets of the Universe*, *Strange New Worlds: The Search for Alien Planets and Life Beyond Our Solar System*, and *Star Factories: The Birth of Stars and Planets*.

After 11 years working at Centro de Investigaciones de Astronomía (Venezuela), **Kathy Vivas, '02 PhD** took a new job as Assistant Astronomer at Cerro Tololo Inter-American Observatory (CTIO) in La Serena, Chile. She is now part of the support team of the Dark Energy Camera (DECam) installed at the 4m Blanco telescope. Kathy is using DECam to investigate the faint population of variable stars in nearby dwarf spheroidal galaxies. She also continues collaborating with Yale professor Bob Zinn on issues related with RR Lyrae stars in the halo of the Milky Way.

Brendan Cohen, '05 BA recently started working as an associate at the law firm of Cleary Gottlieb Steen & Hamilton in New York City, doing intellectual property transactions. Although not related to his work at the firm, Brendan has been writing about space law, and a paper of his that addresses issues of liability and damage caused by outer space activities will be published in the International Institute of Space Law's 2013 *Proceedings of the Colloquium on the Law of Outer Space*.

Meredith Hughes, '05 BS writes, "I've just finished my first year as an assistant professor of astronomy at Wesleyan University. I love my new job, particularly teaching Wesleyan's clever and creative students. Last summer, Geir Helleloid and I got married in the company of our family and close friends in Rhode Island."

Katherine Kornei, '06 BS is working as a space science educator and writer. She designs classes for the Oregon Museum of Science & Industry, and she helped to write content for the Sun Science smart phone and tablet application with the Lawrence Hall of Science. She also edits research manuscripts and writes astronomy-related articles for newspapers, observatories, and astronomy clubs.

Hannah Krug, '07 BS earned her Ph.D. this summer from the University of Maryland (thesis: N*eutral Gas Outflows and Inflows in Local AGN and High-z Lyman-alpha Emitters in COSMOS*). She decided to pursue a career in secondary education, so she began teaching upper-level math at the Holton-Arms School in Maryland this Fall. She writes, "I include astronomical examples where I can and the girls love it! I am thrilled with my choice of career and am forever indebted to Yale Astronomy for helping put me on this path!"

Eric Murphy, '07 PhD is now on the scientific research staff at Caltech and recently had a proposal accepted to use nearly 200 hrs on the VLA to conduct a deep survey of the Frontier Fields. These are survey fields centered on strong lensing clusters for which HST and Spitzer have both spent thousands of hours to detect galaxies at very high redshifts.

Nicole Thom, '10 BS finished her Master's degree in 2012 in Space Studies at the University of North Dakota. In October 2013, she began working as a support scientist at the Harvard Smithsonian Center for Astrophysics in Cambridge, MA. On a non-work-related note, she got married to Brad Schanche in May of 2013 in North Dakota.

James Kim, '11 BS writes, "After graduating from Yale, I spent a couple years teaching at an inner-city high school in Providence, RI. Although I taught math, I often incorporated astronomy and physics in my classroom, and through my mentorship, one of my former students was able to enroll at Rhode Island College as a prospective physics major. Currently, I serve as the Chief Academic Officer of 12+, a Philadelphia-based college access non-profit that has achieved an eight-fold increase in college-going rate at its partner schools and has recently been awarded a $5,000 social innovation grant to scale up its model."

Laura Kreidberg, '11 BS is in her third year of grad school at U. Chicago, working on exoplanets. She recently published a paper in Nature on the discovery of clouds in the atmosphere of the super-Earth exoplanet GJ 1214b. This observation was the first of its kind sensitive to an Earth-like atmospheric composition. She writes, "We're making big strides in the direction of characterizing an Earth-size planet!"

Jonathan Richardson, '11 BS is in his third year of graduate study at the University of Chicago, working with Profs. Stephan Meyer and Craig Hogan. As a member of the Fermilab Holometer, a high-precision laser interferometry experiment, he is seeking to detect and characterize the quantum nature of space-time on very small scales. Initial science runs are on-track to begin in early spring 2014.

Rachel Bezanson, '13 PhD is now at the University of Arizona as a Hubble fellow, living in Tucson and blissfully avoiding all polar vortices (and really cold winter weather in general).

STARS FORM AT YALE

About 100 astronomers, including several Yale alumni, travelled to New Haven in October 2012 for the Frontiers in Star Formation conference. Below are some pictures from the event. See article, p. 24, for more.

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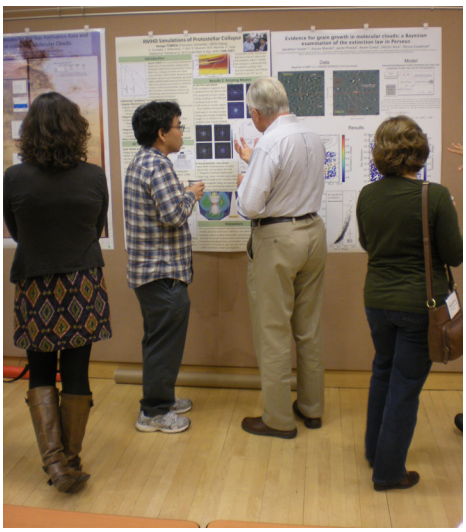
Yale Astronomy hosts conference in honor of Dr. Richard Larson



On October 26 and 27, 2012, about 100 astronomers from across the world descended upon Yale for the Frontiers in Star Formation Conference in honor of the retirement of Professor Richard Larson. The program included two days of talks from both observers and theorists in the field of star formation, at all cosmic scales, discussing the latest discoveries and the exciting research that will be conducted in the near future.

The program was divided into four sessions: The First Stars, The Heydays of Cosmic Star Formation (SF at z~2-3), Towards a Complete Picture of Galactic Star Formation, and Bridging the Gap between Galactic and Extra-Galactic Star Formation. Each session had two review talks and an average of 4 additional "targeted" talks. There was also a poster session with 16 posters.

The event was held at Yale's Luce Hall, with a conference banquet at Amarante's Sea Cliff on the coast of New Haven.

The program, talks and photos from the events can be seen on the conference website below:
http://www.astro.yale.edu/sf_frontiers/index.htm. *Photos by P. Coppi and V. Misenti.*