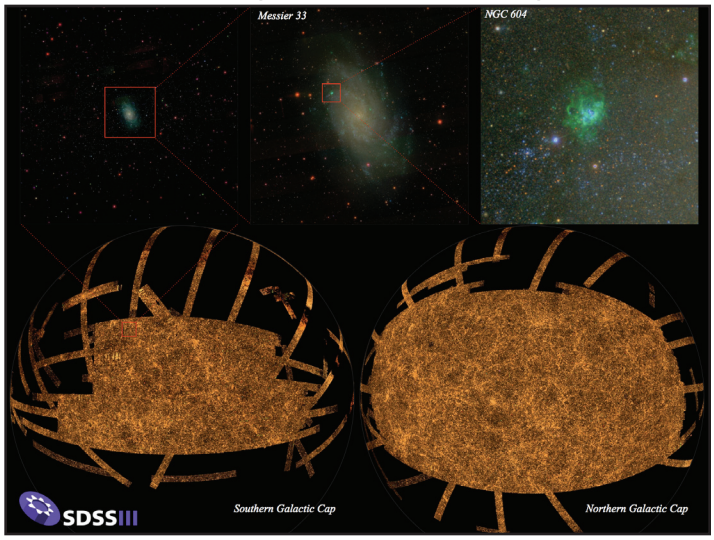
Yale University Astronomy Department Newsletter

Vol. 3 Fall 2011 No. 1

Yale joins Sloan Digital Sky Survey III

Yale is now a fully participating member of the Sloan Digital Sky Survey III (SDSS-III) Collaboration. Although Yale was not a member during the first two phases of SDSS, the success of SDSS and the excitement of Yale astronomers about the projects and data of SDSS-III led Yale to join now. Based on citations in refereed articles and meeting abstracts, SDSS has been rated as the telescope project with the biggest scientific impact in history, beating out even the Hubble Space Telescope and the Keck Telescopes (c.f. Madrid, Juan P. and Macchetto, Duccio 2009arXiv0901.4552M).

The previous incarnations of SDSS have imaged 13,000 square degrees, corresponding to about a third of the entire sky. SDSS-III is taking spectra of interesting objects that were found in these images, through a program of four surveys that cover three scientific themes. The Baryon Oscillation Spectroscopic Survey (BOSS) studies dark energy and the geometry of space. ***(SEE SDSS-III, p. 4)***



SDSS-III Data Release 8 image from January 2011

Gruber Foundation formed at Yale

with prizes and fellowships in astronomy and cosmology

In May of 2011, Patricia and Peter Gruber officially formed the Gruber Foundation at Yale University, dedicated to the advancement of science, support of young scientists, global justice, and women's rights. The Gruber Foundation at Yale will succeed The Peter and Patricia Gruber Foundation, originally established in 1993, and carry on its philanthropic mission, including its prestigious annual science prizes. It will encompass three major programmatic initiatives: the Gruber Prizes and the Young Scientists Awards; the Gruber Science Fellowship Program at Yale; and the Gruber Program for Global Justice and Women's Rights at Yale Law School. Yale astronomy and astrophysics will benefit from two of these programs.

The Gruber Foundation will continue to award three $500,000 Gruber Prizes each year in the physical and life sciences, including a Cosmology Prize, a Genetics Prize, and a Neuroscience Prize; as well as the Gruber Young Scientists Awards. Considered among the most prestigious awards in the sciences, the prizes honor contemporary individuals whose ***(SEE GRUBER, p. 8)***

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Greetings from the Chair

Photo by Michael Marsland

The 2010-11 academic year was a busy one for Astronomy, with 10 new postdocs and 5 new graduate students joining the department. It was also the first full year in New Haven for new faculty members Debra Fischer and Frank van den Bosch (*see p. 14*).

With all of the new people in the department, as well as new laboratory and remote observing facilities, the need for space has never been greater. As a result, the Astronomy Department is no longer contained by the second floor of Gibbs, and we have now spilled onto the first and fourth floors of Gibbs. The Astronomy Department now controls much of the space on the first floor, previously occupied by the Shared Sciences Support Group. Professor Debra Fischer's lab, the Yale Doppler Diagnostic Facility (*see p. 6*), is located on the first floor, along with a large "modern" office for her postdocs and students. There is also a large conference room, the new undergraduate computer room and the graduate student lounge. The fourth floor, controlled by the Physics Department, is the home of the new Keck Remote Observing Room (*see p. 7*). It may seem strange to have such growth during a bad economy, but much of this is the result of actions taken before the downturn.

We have been delighted by the success of our public outreach programs at Leitner Family Observatory and Planetarium, led by Michael Faison and Heidi Herrick (*see p. 11*). Since the planetarium opened and we began programs for public school children, the number of public visitors has grown dramatically, and we cannot always meet the demand. We view inspiring young minds about science as enormously beneficial to society. So we hope to continue these important outreach efforts, but in order to do so we will need to find funding! Please consider us!

The Astronomy Department reached a milestone this past year with the retirement of Prof. Richard Larson (*see p. 15*). Richard is rightly considered to be one of the "giants" in modern astronomy for his many contributions over the last 40+ years in the fields of star formation and galaxy evolution. On a local level he is legendary for many things, including his teaching of two key courses for much of his time at Yale. How many of you reading this have taken Astronomy 310: "Galactic and Extragalactic Astronomy" or Astronomy 360/560: "The Interstellar Medium and Star Formation" from Richard? While it's true that with his retirement he won't be teaching or going to faculty meetings (unless he really wants to), we would be more upset if we thought Richard was actually going to change much. We hope and think that Richard will be an active scientist in the Department for many more years.

All that has happened in the past year has a shadow cast over it by the tragic death of Michelle Dufault (*see p. 21*), an Astrophysics major in her senior year, only weeks from graduation. Michelle was a remarkably talented and giving person, someone who elevated those around her. It is hard to find words for something so sad, but we are consoled a bit by the thought that her memory will inspire those who knew her or learn about her.

This is my last newsletter as Chair, and as I start my sabbatical I leave things in the very capable hands of our new chair Pieter van Dokkum. Good luck Pieter!

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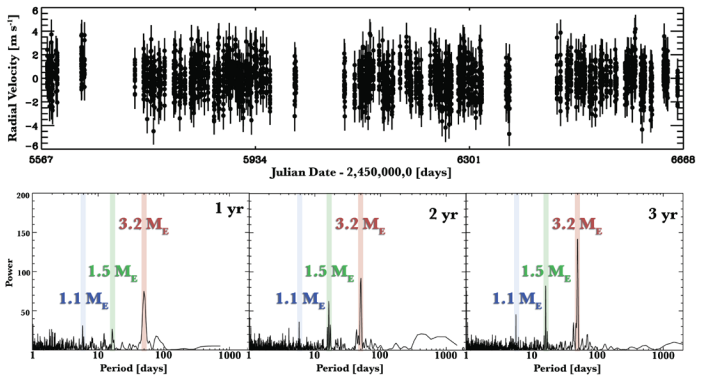
CHIRON searches for Earth-like planets

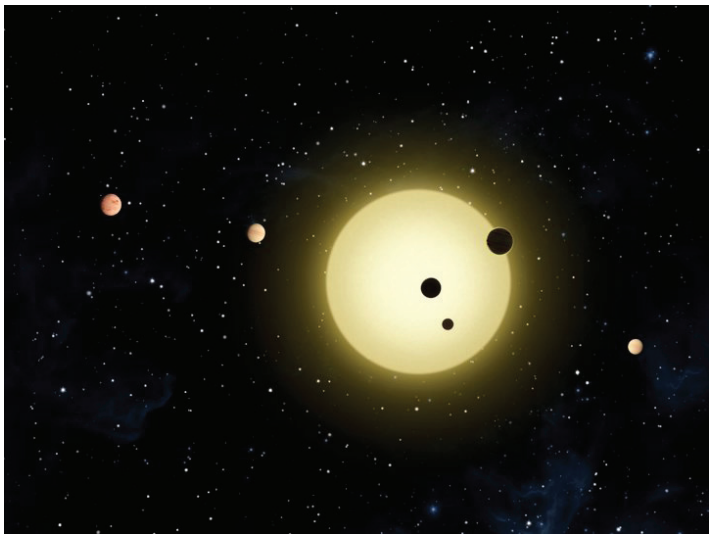
Yale astronomer Debra Fischer is leading several exoplanet searches with her team of researchers, dubbed the Yale Exoplanet Lab. One of these surveys is a search for low mass planets around stars in the binary system Alpha Centauri A and B. Fischer chose the Alpha Centauri system because these stars are the Sun's closest neighbors. These stars also have other properties that make them ideal for discovering low-mass exoplanets, including: brightness of the stars (which allows for short exposure times), low chromospheric activity (which minimizes periodic noise), high metallicity (which provides raw materials for rocky planet formation), and a nearly edge-on orbital inclination for maximum Doppler amplitude.

Fischer has been looking at Alpha Centauri A and B with the SMARTS 1.5m telescope at the Cerro Tololo Inter-American Observatory (CTIO) since 2007. In order to carry this out, the team needed a precision spectrometer. The team initially refurbished a decommissioned Echelle spectrometer from the Blanco telescope at CTIO. However, the instrument was not stable enough, so Fischer applied for funding to build a new spectrometer. Yale exoplanet team members, Christian Schwab and Julien Spronck worked with Andrei Tokivinen at CTIO to design and build a stable new fiber-fed spectrometer, the CTIO High Resolution Spectrometer (CHIRON).

CHIRON was commissioned in March of 2011 and can measure changes in stellar velocities with a precision of one meter per second, critical for searching for low-mass planets. If a star has orbiting planets, those planets will tug the star around a common center of mass. The changes in stellar velocities due to the tug of the planets can therefore be used to infer the presence of planets orbiting a star. With the improved precision and efficiency of CHIRON, the team has expanded their survey to a set of 100 stars in the southern hemisphere.



Simulated radial velocities of a star orbited by 3 low-mass companions of 1.1, 1.5 and 3.2 Earth masses with periods of about 6, 16 and 50 days, respectively. The times of observations were selected following a random extreme-cadence technique. All three planets would be easily detected after 3 years with CHIRON. Figure courtesy of Matthew Giguere.



Kepler 11 exoplanetary system. Image courtesy of NASA/Kepler.

Matt Giguere, a PhD student who is leading the data analysis for the CHIRON exoplanet search, said that most of the exoplanets that have been detected so far are gas giants, which have dense cores with masses thirty times of the earth or more and have mostly Hydrogen and Helium in their atmospheres. Low mass planets are much more difficult to detect, but they are important both because learning properties of low mass planets can constrain planet formation theories and because low mass planets are the most likely candidates for hosting life (as we currently know it) in the Universe.

Giguere also said that the frequency of low-mass planets is not well known and various planet formation theories predict different frequencies of low mass planets. Furthermore, the results to date from Kepler and other radial velocity planet searches differ widely in their values for the frequency of low mass planets. In addition, observations have recently shown that systems with low mass planets tend to have several planets. By adding an independent assessment for the frequency of low mass planets, the CHIRON planet search should be able to help determine the true frequency of low-mass planets and thereby help constrain how planet formation occurs.

It is currently not possible to directly image low-mass exoplanets because they are usually so close to the parent star that the brightness of the star—typically a billion times brighter than the planet—does not allow the planet to be seen. However, if the technology to image these planets develops in the future, the data from CHIRON will help scientists decide which stars to image (or to send probes to!).

SDSS-III resource available to all Yale researchers

(SDSS-III, from p. 1) The Sloan Extension for Galactic Understanding and Exploration (SEGUE) and the APO Galactic Evolution Experiment (APOGEE) are studying the structure, dynamics and chemical evolution of the Milky Way. The Multi-object APO Radial Velocity Exoplanet Large-area Survey (MARVELS) is studying the architecture of planetary systems. Begun in 2008, and continuing for six years, these four surveys of SDSS-III are using the wide-field spectroscopic capability of the Apache Point Observatory's 2.5-meter telescope.

As a member of SDSS-III, all Yale researchers (faculty, postdocs and students who have more than 50% of their salary paid by Yale) have immediate access to all of the SDSS-III data (both raw and reduced) and may use these for scientific projects. Furthermore, the SDSS-III project will continue to solicit ancillary projects that can piggyback on the existing spectroscopic survey. Because SDSS-III produces large volumes of calibrated spectroscopic data, it is particularly well suited to research projects for summer students, undergraduates and beginning graduate students. Jeff Kenney, chair of the Astronomy department, commented that "It helps a student project when the student can get the data instantly. If the student needs to get data on telescopes by writing a proposal there are huge lead times and uncertainty factors, which go against doing a short term observing project. A dataset like SDSS III is great for such projects."

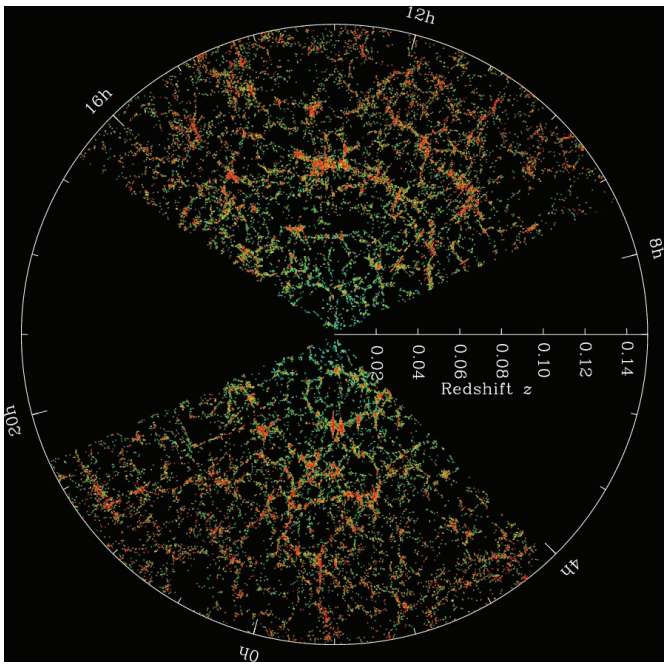
The Memorandum of Understanding in which Yale entered the collaboration was signed in August 2010. Yale will pay $900K for full institutional membership in SDSS-III, which extends from July 2008 through June of 2014. The funding comes from Yale faculty members and the Provost's office. The Yale funding will go toward new instruments, surveys done with the new and existing equipment, and sophisticated data reduction.

Even before Yale officially joined SDSS-III, Yale faculty have been playing leading roles in the SDSS surveys. Nikhil Padmanabhan is one of the architects of the BOSS project and has been involved with the SDSS-III project since its conception in 2006. He currently co-chairs the BOSS large scale structure working group and is the Yale representative on the Collaboration Council. Meg Urry is the Yale representative on the Advisory Council, which supervises the SDSS-III project. Becoming an institutional member will further broaden the Yale impact and allow Yale to continue to attract top-notch scholars.

The prospect of joining SDSS-III helped Padmanabhan, as well as Frank van den Bosch decide to join the Yale faculty. Already at Yale, Urry, Marla Geha and Pieter van Dokkum were also eager to join the survey. Padmanabhan said, "in practical aspects it means we are part of the biggest astronomical survey currently running… anyone at Yale can do any science with any data that is part of the survey…. It's been a big draw in terms of recruiting postdocs and grad students."

The faculty who are using SDSS-III are excited about the kinds of science they will be able to do with access to the data from the survey. Padmanabhan, for instance, is interested in using BOSS to probe the properties of dark energy and to better constrain the properties of the Universe we live in. BOSS will, on completion, measure the distances to 1.5 million galaxies over a quarter of the sky, and will produce one of the largest and highest fidelity three-dimensional maps of our Universe. These galaxies trace the underlying "dark matter" -- the scaffolding of the Universe. These data allow for exquisitely sensitive tests of the rate at which the Universe is expanding, the properties of the dark matter and dark energy that we believe dominates the Universe, as well as the physics in the very early Universe.

Urry works on understanding the growth of black holes over cosmic time and how they interact with their host galaxies. Her team is using BOSS to work on a field of SDSS-III, Stripe 82, which already has a lot of multiwavelength imaging data from other surveys, including earlier Sloan surveys. She said other large-area serendipitous X-ray surveys for growing black holes "have taken ten years or more to complete because it takes forever to get telescope time to do the follow up multiwavelength observations." Because much of the follow-up is already done in Stripe 82, Urry will be able to quickly and easily identify accreting black holes and study them in more depth as needed, instead of having to spend lots of telescope time just identifying potential candidates.



SDSS Distribution of local galaxies. M. Blanton / SDSS.

Observational Star Formation Group at Yale finds candidates for youngest known stellar objects

The Observational Star Formation Group at Yale, led by Professor Hector Arce and including Yale postdoctoral associates Xuepeng Chen and Michael Dunham, seek the youngest stellar objects in order to understand the very early phases of star formation. They are finding extremely young objects in the Perseus molecular cloud, one of the nearest clouds experiencing the formation of low-mass stars. They have even found candidates for a so-called "first hydrostatic core," a very early and distinct phase of star formation, theoretically predicted and replicated in simulations, but not yet observed.

Richard Larson, a longtime Yale faculty member and star formation expert (*see p. 15*), was the first to predict, through models published in 1969, the first hydrostatic core. All of the other stages of star formation have been observed and studied extensively, and much more is known about them.

A "first hydrostatic core" is the first time the interior part of a collapsing core becomes dense and opaque enough to become hot enough to generate enough thermal pressure to reach hydrostatic equilibrium. At this stage, while the interior core is roughly in equilibrium, the outer parts continue to collapse toward the center. The "first core" stage lasts until the core becomes hot enough (2000 K) to dissociate H_2. At this point most of the energy goes to dissociating H_2, and the temperature of the inner core cannot increase quickly enough to counteract the collapse, so the inner core (i.e., the first core) starts collapsing again. This marks the end of the first core phase, and the start of the so-called second collapse. The protostar (or second core) will form from the second collapse.

The Yale group is studying the first hydrostatic core stage in order to test and constrain models of the early phases of star formation. One reason it is important to study such systems is that the mass of a star may be set at the very early stages of the star formation process. The mass of a star is its most fundamental property, with ramifications throughout astrophysics, but we do not yet understand what determines stellar mass.

Arce said that the first hydrostatic core stage is low luminosity, very short lived, and cold, and therefore it is difficult to observe, at least with currently available telescopes. Highly sensitive infrared telescopes are needed to detect such objects, but ground-based mid-infrared observations do not have the needed sensitivity, and neither did the Spitzer Space Telescope.

Despite the difficulties in finding them, Chen noticed within the Perseus cloud a good candidate for a first hydrostatic core – an apparent outflow from a cold, very low luminosity submillimeter source. Chen then observed the object with the Submillimeter Array (SMA) and confirmed a molecular gas outflow emanating from the core. ***(See PERSEUS, p.20)***

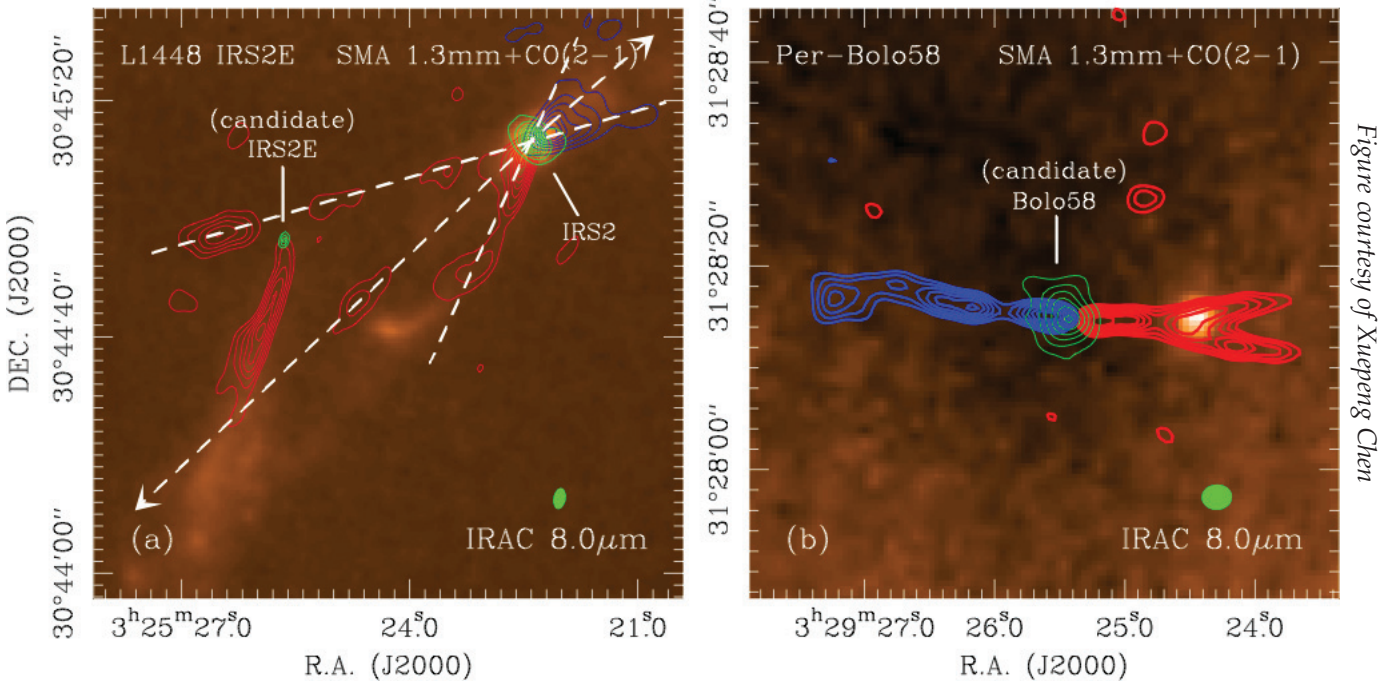


Figure courtesy of Xuepeng Chen

Spitzer 8.0 μ infrared images of the two first hydrostatic core candidates in Perseus. Red and blue contours show the outflows driven by the two candidates, suggested by the SMA CO line observations. Green contours show the 1.3mm dust continuum emission from the two candidates, while the green oval in the bottom right corner indicates the SMA angular resolution.

Yale Doppler Diagnostic Facility opens

Yale professor Debra Fischer's exoplanet research group has built an optics laboratory called the Yale Doppler Diagnostic Facility (YDDF) on the first floor of the J.W. Gibbs building. Postdoctoral fellows Julien Spronck and Christian Schwab use the YDDF to characterize the impact of hardware design on measurement precision. The lessons learned in the YDDF will help the team to design instruments to detect lower mass, Earth-like planets.

One of the two optical benches in the YDDF is almost entirely devoted to improving the coupling of light into fibers that feed the spectrograph. Julien Spronck, a postdoctoral associate who works at the YDDF, said that the purpose of the fiber testing is to characterize the fibers in order to discover what properties (shape, size length, material, etc.) yield the best fibers. He said that it is known that some fibers are better than others, but it is not yet known why. Even commercially manufactured fibers that are supposed to have the same properties often present different results. There is also a fiber agitator that tests the effects of shaking the fiber.

Zak Kaplan, '13, tests the fibers along with Spronck. Kaplan said, "working in an optics lab has been a great experience. Because of the exact nature of our measurements, we must build precise and complex set-ups to test multiple properties at the same time. Building these set-ups is like playing with LEGOs at 5 micrometer precision."

Ultimately, the goal for Kaplan, Spronck and the rest of the YDDF team is that they will find the best fibers to use in high resolution Echelle spectrographs that the team has already built, such as CHIRON, which is now on the SMARTS 1.5m in Chile, and also for those that they will build in the future for Keck and other observatories.

The second optical bench serves as the base for a high-resolution spectrograph. Both benches rest on pressurized air and are located in the basement where vibrations in the building are minimized. The team will change various hardware elements in a controlled state to optimize the performance of the spectrograph. Spronck said that current state-of-the-art instruments are able to measure stellar speeds with a remarkable precision of 1 meter per second. However, to detect analogs of our Earth, astronomers will need to obtain a factor of ten improvement and reach a precision of 10 cm per second. Schwab added "We want to build a spectrograph that is better than all that is out there. If you want to go to a new level of precision you have to explore new techniques. We have to try things people haven't done before."

Schwab said that he has spent a lot of time thinking about how to calibrate and test astronomical equipment efficiently and with a minimal use of telescope time so that when there is a clear sky one can "actually use it to do astronomy and not to calibrate your instrument". He said that often times "people build instruments and test them on the telescope." Schwab and the rest of the YDDF team are therefore building a spectrograph lab both to explore new pathways and to exhaustively test their instruments before bringing them to the telescope.

The test spectrograph at YDDF is unique, according to Schwab. He said that, since spectrographs are costly to build, most people build them to use directly on the telescopes and he does not know of anyone else who has built a spectrograph solely for the purpose of testing spectrograph technology. He said, "there are a couple of things I want to test, and I have no idea whether they are going to work. In the lab I can try them." He also said that they will start with the highest possible quality components and intentionally introduce sources of errors for the purpose of testing.

In order to build the test spectrograph, Schwab and Spronck interface with engineers and scientists to come up with innovative conceptual designs that give engineers what they need and scientists what they want. Some of the parts are manufactured using a student machine shop at Yale.
(See YDDF, p.20)

The two optical benches in the YDDF. Photo by Zachary Kenney.

Yale opens Keck remote observing facility

In 2009, Yale signed a 10-year, $12M agreement with Caltech for access to the W.M. Keck Observatory (Keck) telescopes. In 2011, Yale signed an agreement with the NASA Exoplanet Science Institute (NExScI) to provide Yale and NExScI observers access to a remote observing facility at Yale for the Keck telescopes. NEXScI will share the facility in exchange for helping to pay for the equipment and yearly operations.

The new Keck remote observing facility is housed in J.W. Gibbs Lab (JWG) room 471 and houses a local computer with four large flat-screen monitors that allows the observer to either completely control the telescope and associated instruments from New Haven or to simply "eavesdrop" on a member of their team who is controlling the telescope and instruments while located at Keck or at another remote site.

Yale observers and Visitors from NExScI will be able to apply to use the remote facility once they have been assigned time on either of the Keck telescopes.

Keck has other remote rooms in California, and one in Australia, but this is its first remote observing facility on the Eastern coast of the United States. For more information, see our website at www.astro.yale.edu/keckro.

Scene on Campus

J.W. Gibbs Laboratory (JWG) is all dressed up with nowhere to go. A project to reinforce the structural integrity of JWG has been underway since May 2011 and is expected to continue through November 2011.

Giordano Construction Company is the contractor and they have been working hard to come up with solutions for ways to reduce the sound and vibrations that inevitably come with construction. This is especially important for times in which our remote observers are using the building, as well for as many of our neighbor biologists who are undertaking experiments that are extremely sensitive to vibrations or noises.

Gruber Foundation benefits Yale astronomy

(GRUBER, from p. 1) groundbreaking work provides new models that inspire and enable fundamental shifts in knowledge.

Since 2001, the Cosmology Prize has been co-sponsored by the International Astronomical Union (IAU). According to the Gruber Foundation website, the Cosmology Prize "acknowledges and encourages further exploration in a field that shapes the way we perceive and comprehend our universe. In doing so, The. . . Gruber Foundation seeks to extend the pioneering legacy of, among others, Plato and Aristotle; Ptolemy and Copernicus; Brahe, Kepler, and Galileo; Newton and Halley; Einstein and Hubble". Also on the website, Peter Gruber is quoted as saying "Cosmology is the most scientifically rigorous, aesthetically elegant and the most poetic of the sciences."

Recent Gruber Cosmology Prize recipients have included astronomer Charles Steidel, whose studies of ancient galaxies have shed light on their formation and evolution over 12 billion years; and the team of Marc Davis, George Efstathiou, Carlos Frenk and Simon White, who demonstrated how matter gathered into galaxies and how superclusters of galaxies gathered into a cosmic web.

One of the key Gruber Young Scientist Awards is the IAU Fellowship, awarded annually to an extremely promising young investigator working in any field of astrophysics. Recent recipients have been Smadar Naoz, from Israel, M.B.N.Kouwenhoven from the United Kingdom and Karen L. Masters from the United States.

In continuing the Gruber Prizes as a legacy program, Yale is mindful that the prize program's integrity and independence needs to be preserved in order to keep its prestige and reputation. The Gruber Foundation has always entrusted the selection of each science prize to independent selection advisory boards that have been nominated by international organizations. Selection advisors for Cosmology are nominated by the IAU, and members of the Gruber Foundation are not involved in the selection process. Yale will continue the affiliation with the international associations that have played such an important role in the selection of the award winners and have ensured the high standards and integrity of the awards. In a manner similar to the award of the Pulitzer prizes at Columbia, Yale will not, either as an institution or through any of its employees, play a role in the selection process of the science awards, although faculty members are free to submit nominations to the selection committees. Over time, members of Yale's astronomy and physics faculty may be called upon to advise on the conduct of the awards programs. Yale benefits by being associated with these prestigious prizes, as they help draw public attention to Yale's commitment to astronomy and science.

In addition to maintaining the legacy prizes and awards, Pat and Peter Gruber and Yale have agreed to establish a number of new programs to be beneficiaries of the Gruber Foundation at Yale. One such program is the annual award of $2.5 million (eventually growing with the size of the invested endowment) in support of graduate fellowships in cosmology, astrophysics, and the life sciences. Each graduate fellowship will carry a 1-year award of $50,000 and the recipients will be known as Gruber Fellows. The program will initially provide approximately five graduate fellowships per year for both the astronomy and physics departments. These fellowships will make a huge impact on our program by helping us to attract and support top students, and over time increase the number of students.

Patricia Gruber said, "Through our international prize program, we have sought to promote excellence in science by highlighting and promoting leadership in fields that create a better world. Yale is an outstanding choice to carry this work forward and, with the Foundation's expanded programmatic focus, we can have an even greater impact."
--*Includes information written by the Yale Office of Public Affairs.*

Italian fashion magazine features seven Yale astronomers

Astronomers have never been known for their fashion sense, but *Amica* magazine, an Italian fashion magazine that was recently revamped for a more educated and sophisticated audience, featured seven Yale faculty members in its March 2011 issue. Hector Arce, Paolo Coppi, Jeff Kenney, Daisuke Nagai, Sabatino Sofia, Pieter van Dokkum and Bob Zinn were photographed by Newsweek photographer Charles Ommanney at the Leitner Family Observatory and Planetarium (LFOP). Ommanney posed them in front of projections of their research and also around the LFOP grounds. The faculty members were also interviewed in person by Felicia Lee from New York and by E-mail by Stephania Romani from Italy.

It turns out that *Amica* was no stranger to astronomy, as they had once done a feature on the Palomar Observatory for their February 2009 issue. But we think the Yale astronomers are much more fashionable and handsome than those at Palomar!

New Yale High Performance Computing facilities used for astrophysical research

Astronomers at Yale are benefitting from newly installed High Performance Computing (HPC) clusters at the West Campus High Performance Computing Center. "Bulldog M," a 128-node cluster with eight cores per node (for a total of 1024 cores), is managed by Yale's Information Technology Services (ITS) and is used primarily for astrophysics computation.

Sarbani Basu, Daisuke Nagai, Priya Natarajan, Nikhil Padmanabhan, and Frank van den Bosch, all faculty of the Yale astronomy department, are the Principal Investigators of the Bulldog M cluster, and contributed to its purchase.

Richard Easther, Associate Professor of physics and astronomy explained the need for HPC resources in astronomy, saying, "we now have very large quantities of data about the universe on large scales that were unavailable even fifteen years ago. We can measure the age of the universe to within a few percent, and our theoretical work now has to be accurate to within a few percent or better. Because of that, we have to do our calculations with a lot more precision, which means moving away from pencil and paper and moving towards serious computing." Basu said that an HPC cluster is "a theorist's telescope".

Before Bulldog M came on-line, astronomers used to either compete for time with other Yale researchers on one of Yale's existing HPC facilities or compete for time with astronomers all over the world by applying for time on a national supercomputing center facility. Needless to say, the astronomers found it difficult to get their work done. With Bulldog M, the astronomers are able to make collegial agreements about scheduling the resources and they are therefore often able to study a wider group of sources much more efficiently.

Basu and her PhD student, Joel Tanner, use Bulldog M in order to study the energy transport properties of stars through simulations of convection. Tanner and others, including Brian Dobbins from Geophysics, have modified a code that was first developed by Yale Emeriti Faculty Pierre Demarque and Sabatino Sofia and their team in the 1980s. According to Basu, the models of stellar structure are reasonably well defined, except when it comes to convection. Convection is modeled very crudely, which means that most stellar models are incorrect to some extent. Seismic observations of well known stars confirm that the models are incorrect. Until supercomputers came along it was difficult to find out what the properties of stellar convection really were. What Basu and Tanner are doing is to find out the convection properties using computer simulations and then reverse-engineering them back into the stellar models so that the complete stellar structure is defined correctly.

Daisuke Nagai and his computational cosmology group have also been using Bulldog M to run sophisticated computer simulations that they have developed in order to study the structure and evolution of galaxies and galaxy clusters.

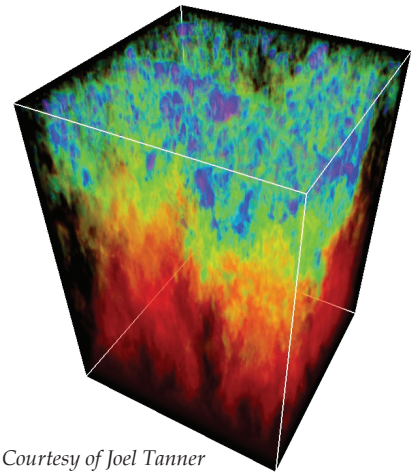
"Computer modeling holds the key for understanding some of the most complicated systems in the Universe and using them to shed new light on our mysterious Dark Universe, including the nature of dark matter and dark energy," said Nagai.

Nagai's group has recently used Bulldog M to perform one of the largest and most sophisticated simulations of galaxy cluster formation. This simulation followed the evolution of over 3000 galaxy clusters and incorporated most of the major components of the Universe—including dark matter, gas and stars—and their interactions.

During his PhD research it took Nagai two years to simulate sixteen clusters at the national supercomputing centers. With Bulldog M, both because he now has better access and because it is a faster, better computer, he could have completed all of these simulations in one week using a tiny fraction of the machine's capacity. "The Bulldog M [cluster] has been critical for pushing the cutting-edge," said Nagai.

Nagai's group is now developing a new algorithm for how black holes form and interact with their environment. "Our simulations will soon include all the major constituents of the Universe and their interactions with unprecedented scales and sophistication," Nagai said.

Nagai's group includes researchers at all levels, from undergraduate and graduate students to postdoctoral associates. He said "this kind of project is great for training students to do computational research; how to do parallel computing; how to optimize code; [and] how to use computers to do science and beyond, from global warming to the stock market." He continued, "we involve a lot of undergraduates with the hope of training them to use computers to advance human knowledge in all areas".



Courtesy of Joel Tanner

Science Highlights from Yale's Observatories

W. M. Keck Observatory

Professor **Debra Fischer'**s team is using Keck to search for exoplanets and has recently detected a triple-planet system orbiting HIP 57274 with a "Super-Earth" and two ~Saturn mass planets.

Professor **Marla Geha**'s team has used Keck to reveal that a newly discovered Milky Way satellite, Segue 3, is the lowest luminosity Milky Way globular cluster. They have also followed up on their previous Keck discovery of the darkest known galaxy in the universe, Segue 1, and found that this dwarf galaxy appears to have 3,400 times more mass than can be accounted for by its visible stars..

Professor **Pieter van Dokkum**'s team used Keck to discover that red dwarf stars are much more populous than previously thought. Because of this, the total number of stars in the universe is likely three times bigger than realized and the potential for habitable planets has also increased because red dwarfs are believed to be good hosts for habitable planets.

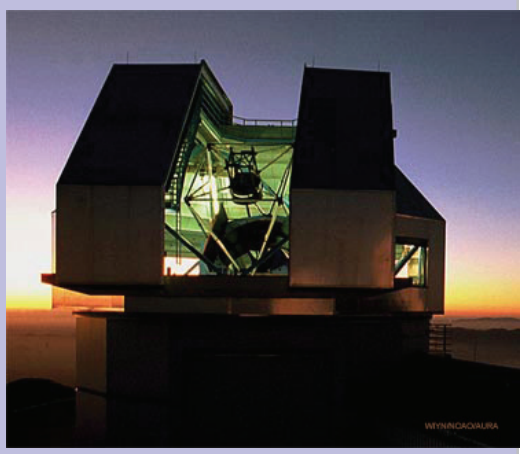
SMARTS

Professor **Charles Bailyn'**s team continues to use SMARTS to study blazars in optical wavelengths that are observed by the Fermi Gamma Ray observatory. Additionally, they continue long-term monitoring of X-ray Binaries, also with SMARTS.

Professor **Debra Fischer'**s team has built a new spectrograph, CHIRON, for SMARTS, and is using it for her ongoing search for low-mass exoplanets in the binary system Alpha Centauri A and B (*see article, p. 3 for more*).

Yale research scientist **David Rabinowitz** and his team continue to use SMARTS to provide astrometric and photometric follow-up of Yale's La Silla-QUEST Kuiper-Belt survey, which has discovered and analysed several plantesmials.

WIYN



Professor **Marla Geha** and her team have been using WIYN for a spectroscopic survey aimed at fully characterizing the velocity distribution of stellar streams in the Galactic halo.

Graduate student **Rachel Mac Donald** (**GRD '14**) and Professor **Charles Bailyn** are using both WIYN and Keck simultaneously to get simultaneous spectroscopy and photometry of a black hole X-ray binary to test the claims that it is the object with the lowest mass of any known black hole. This will be for MacDonald's PhD thesis.

Postdoctoral fellow **Meg Schwamb** is using WIYN to study the nature of the collision that occured on the dwarf planet Haumea.

The WIYN 3.5m telescope is one of the telescopes participating in a vigorous campaign to follow up on the discovery of the Type Ia supernova SN2011fe. This supernova, which is located in the galaxy M101, is the closest Type Ia SN discovered since SN 1972E, and thus presents an exciting opportunity for very detailed study with modern astronomical instruments. **Eilat Glikman** and **Brooke Simmons** of Yale were the first observers to observe this object with WIYN, along with NOAO astronomers Lori Allen and Dick Joyce..

Public outreach activity grows at LFOP

Attendance at the Leitner Family Observatory and Planetarium (LFOP) continues to increase and has become a "hot spot" for visiting school groups. About 4,000 children have participated in field trips to LFOP this year alone; over half of these are from New Haven schools. The school groups range from nursery school all the way to high school. Fifth grade school groups are the most common attendees.

Planetarium Instructor Heidi Herrick leads the groups through LFOP school programming, which typically runs for about forty-five minutes and includes a planetarium show, a question-and-answer session and a tour of the telescopes. She designs each group's curriculum according to the core science standards for each grade as enumerated by the state of Connecticut.

The planetarium shows begin with a "live" show, run by Herrick using LFOP's impressive Starry Night software, which she uses to demonstrate special features in the sky and anything relevant to the science standards for that group. Herrick then shows each group one of ten pre-recorded shows owned by LFOP, again chosen according to how it meets the science standards for the group.

Oasis in Space, the most watched school show, is a tour through the solar system and its planets; a subject to be covered in both the fifth and eighth grades. Other popular pre-recorded shows are SkyQuest, which is currently the only show suitable for younger children and covers the sun and how day and night are delineated, which is part of the first grade standards; and Two Small Pieces of Glass, which covers fifth grade standards on light, the sun and telescopes.

Herrick said "My favorite time is when the lights go down and the stars come out, people go "wow!" When we zoom out to a planet it feels like we're moving and students go "Ooo eee". Herrick continued, "I love it when the kids get excited about science. I get crayon-written thank you notes from students and I can tell they really enjoyed themselves."

In addition to running school programming, Herrick, along with LFOP Director Michael Faison and a host of volunteers from both the astronomy department and the community, run public nights every Tuesday night throughout the year. Programming for public nights includes two planetarium shows (each of which includes both a live and a pre-recorded show) and observing when the weather permits it. Public nights are free of charge (donations are welcome at the door) and are extremely popular, with an average of seventy people attending each week, totaling about 3,800 public night visitors annually (based on statistics from FY10-11). Visit http://leitnerobservatory.org/ for more information on public nights.

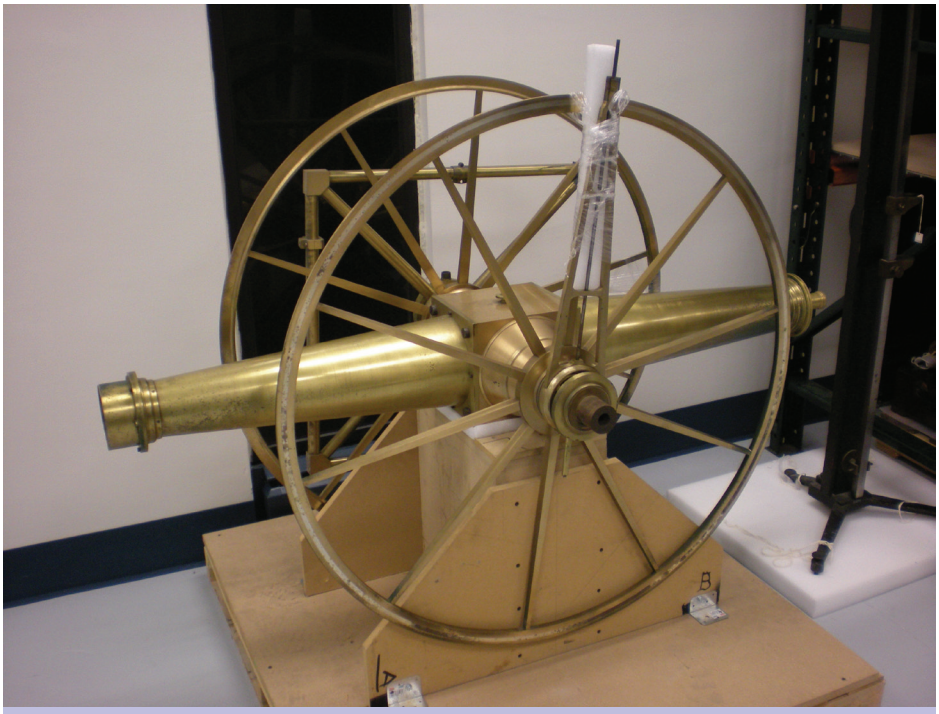
While many of the pre-recorded programs shown at LFOP are purchased (typical cost $2,000-$10,000), several of them have been made by Yale students and staff. For their senior projects, Nicole Thom, '10 B.A. made Discovering Dark Matter and Adam Payne '11 B.A. made The Search for Exoplanets, both of which will be turned into public shows. Faison has also created two shows, Tour of the Universe, which gives an understanding of our universe centered around the research done by Yale astronomers; and Celebrate the Solstice, which is shown each year in December. Faison is currently collaborating with members of the Forestry School to create a new show on global warming.

Occasionally, LFOP and the Yale Peabody Museum coordinate events together. In conjunction with the Peabody's exhibit on Black Holes in 2010-11, LFOP showed the planetarium show Black Holes every Sunday afternoon. This extra public show brought the number of people who visited the planetarium to 10,700 in 2010-11, up from 7,000 in 2009-10, LFOP's first full year of operation. LFOP also serves as a venue for several of the Peabody Summer Camps, including Astro Adventure I and II and Space Explorers.

LFOP also serves as an excellent venue for special events. For example, in May 2011, Story Musgrave, a legendary astronaut who helped repair the Hubble Space Telescope, gave a talk at LFOP. His visit was part of a fundraiser for Sheehan High School in Wallingford, CT, (*see* ***LFOP*** *p. 23)*

Robert Benson Photography

Astronomical instrument returns



Yale Meridian circle in its temporary West Campus home.

The Yale Meridian circle, which was on loan to the Franklin Institute in Philadelphia for over 70 years, and was discovered outside the Franklin Institute gift shop, was returned to the Yale Astronomy Department in August of 2010.

A Meridian circle is an instrument used for astrometry, the field of astronomy that measures the positions and movements of celestial objects. According to Ivano Dal Prete, Professor of History of Science and Technology at the University of Minnesota, Meridian circles were first developed by the British in the late 18th century to improve upon the quadrant.

Meridian circles are aligned with the local meridian line and are used to observe the transit of celestial objects through the local meridian line. The measurements made by Meridian circles could be used to keep accurate time and it is possible that the clocks of Yale University used to be set using the Yale Meridian circle.

The Yale Meridian circle consists of a 56-inch brass telescope and two 40-inch brass circles with graduated silver dials. The telescope has an aperture of 3.8 inches and a focal length of 58 inches. At the focal point are one horizontal and eleven vertical "spider lines" and a micrometer wire.

The original granite piers and mounting equipment are missing, along with other significant components, including six micrometer microscopes used to read the seconds dial and various eyepieces. The mount that came with the circle has no historical connection to it. At some point between 1838 and 1873, William J. Young of Philadelphia made alterations to the instrument , including changing what were once 30-inch wheels on the outside of the piers to the current 40-inch wheels on the inside of the piers.

The Yale Meridian circle is currently being stored at the Peabody Museum's Historical Scientific Instruments Collection on Yale's West Campus until the astronomy department can find other housing for it. The brass was slightly deteriorated with "bronze disease" from decades of unsecured public handling, so it is necessary to house the object in a secure and climate controlled space. The Peabody Museum Historical Scientific Instruments Collection usually does not "restore" damaged objects because to do so would be to take off "layers of history," according to Shae Trewin, who was Curator of the collection at the time the Meridian circle arrived, but the bronze disease has been stabilized.

History of the Yale Meridian Circle

The Meridian circle was originally purchased from Ertel and Son of Munich in 1838 by Lieutenant J.M. Gilliss of the Washington Observatory. Not much later, the Washington Observatory chose to replace the Ertel circle with a new Pistor and Martins circle, which was installed in 1865. The U.S. Government sold the Ertel circle for $2,500, which, according to the 1873 Sheffield Scientific School (SSS) report, was subsequently gifted to the SSS by Joseph E. Sheffield. (The SSS was a school for science and math that was housed at Yale from 1854-1956; though it was named for Sheffield only in 1861.)

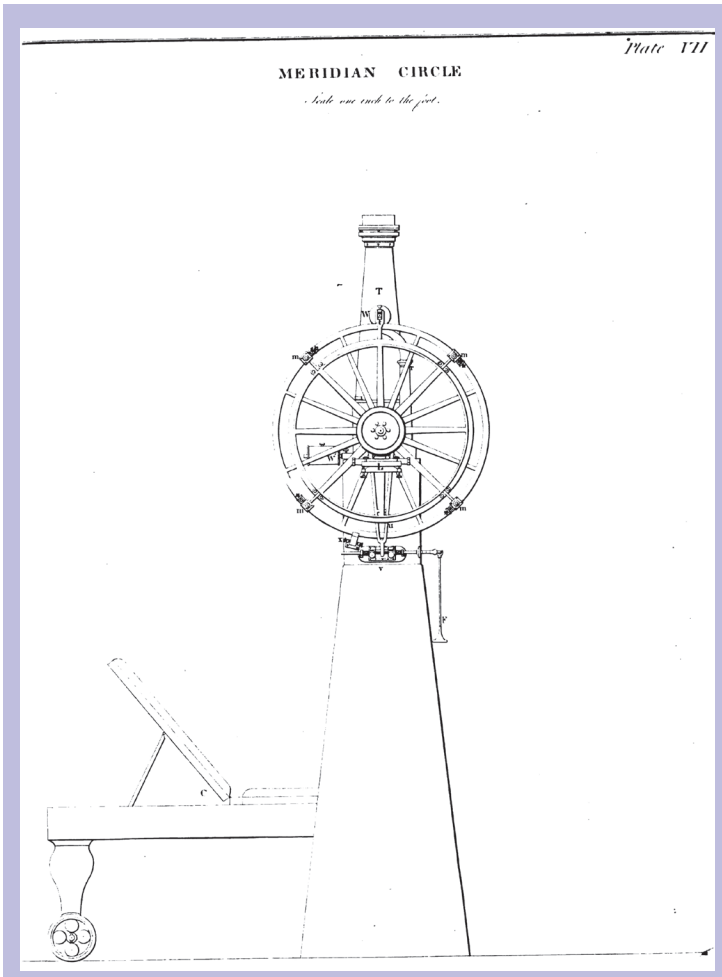
after being on loan for 70 years

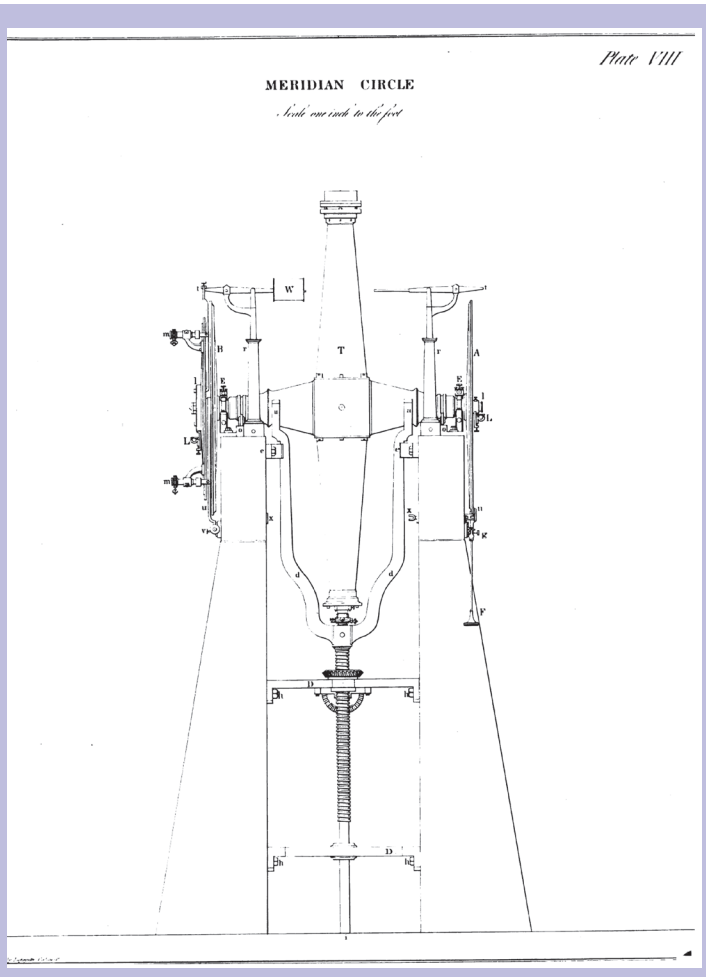
According to the SSS report, the 16-feet-square west tower of the new observatory at South Sheffield Hall was "erected... specially for the reception of the Meridian Circle" as well as for a sidereal clock made by Appleton of London that had been donated to Yale by William Hillhouse in 1853. The room had "a meridional opening from side to side, twenty inches in width, with roof-shutters, which are opened or shut by a single motion of a lever. The side shutters are ordinary doors."

The other tower held an equatorial telescope, also gifted by Sheffield.

Upon demolition of South Sheffield Hall in 1929 (presumably to make way for the construction of Sterling-Sheffield-Strathcona Hall, which took its place), the Meridian circle was moved to storage in the Yale Observatory.

In April of 1931, James Stokely of the Franklin Institute wrote to Frank Schlesinger at Yale to ask if the Franklin Institute might display items from the Yale Observatory in its new astronomy section. Schlesinger agreed to loan three objects to the Franklin Institute: a heliometer lens, the 1830 Dollond telescope and the Meridian circle. The objects were finally sent in June of 1932. At the time, the Meridian circle's lens was not included because it was being used on another object. Stokely decided to make a "dummy lens" for the circle. In 1933, Schlesinger also sent a clockwork orrery to the Franklin Institute. The heliometer lens and the Dollond telescope are both currently preserved in the exhibit hall of Yale's Leitner Family Observatory and Planetarium. Perhaps the Meridian circle may one day join them!





These two plates are drawings of the Yale Meridian Circle that came from the following collection: Astronomical observations made under the direction of M.F. Maury, Lieut. U.S. Navy, during the year 1845, at the U.S. Naval Observatory, Washington, vol. 1, *pages 592 and 596. The description of the instrument can be found in volume 2, page 50.*

Frank van den Bosch joins Yale Faculty as Assistant Professor

I did my undergraduate and graduate studies at the University of Leiden in the Netherlands, where I developed an early passion for cosmology and extra-galactic astronomy. I ended up doing a PhD thesis on the central regions of early-type galaxies. Using data from the Hubble Space Telescope (HST), which had just been launched a few months prior, I analyzed images of the central regions of a dozen early-type galaxies. The exquisite spatial resolution of the HST revealed a spectacular dust disk in the central 100pc of the active galaxy NGC 4261. This image made front page news; about one week into my PhD and I had my name appear on the front page of the New York Times! As my thesis supervisor, Tim de Zeeuw, used to say, my career could only go downhill from there.

Despite this success in my brief observational career, I quickly realized that I much more enjoyed modeling the dynamics of these galaxies (looking for evidence for supermassive black holes), which ended up being the prime focus of my thesis. As a Hubble Fellow at the University of Washington in Seattle I switched field somewhat and started to work on the formation of disk galaxies; understanding how these systems acquire their angular momentum is an intriguing problem, which still begs for proper understanding. Back in Europe (several positions in Germany & Switzerland) I also started to work on the structure and assembly of dark matter haloes, on large scale structure, and on a variety of techniques to constrain halo occupation statistics.

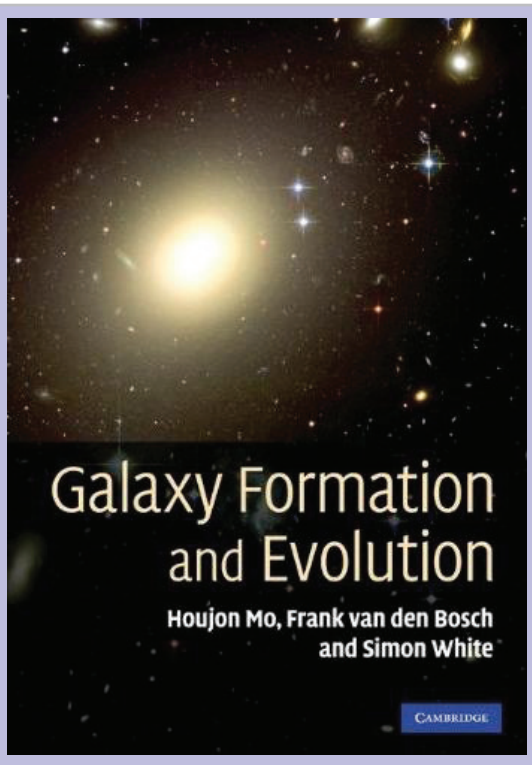
In 2009 I once again crossed the Atlantic, and after a brief period at the University of Utah, I started my position at Yale in July of 2010. The month before my long-time collaborator Houjun Mo, Simon White and I finally published our advanced graduate textbook on Galaxy formation and evolution (*see below for more information)*; an absolute must-have for any professional astronomer (at least until I pay off my mortgage). Writing this textbook was a wonderful (but looooong) experience which has dramatically increased my knowledge and understanding of astro-physics. In the end I am even more excited (but also more skeptical) about our cosmogony then I was when I fell in love with astronomy at age 7, and I look forward to sharing this excitement (and criticism) with my colleagues here at Yale for many years to come.

Frank van den Bosch's textbook, *Galaxy Formation and Evolution* has been awarded the the 2010 PROSE Award in the category Cosmology and Astronomy. The PROSE Awards, the American Publishers Awards for Professional and Scholarly Excellence, annually recognize the very best in professional and scholarly publishing by bringing attention to distinguished books, journals, and electronic content in over 40 categories. A summary of the textbook is below:

The rapidly expanding field of galaxy formation lies at the interfaces of astronomy, particle physics, and cosmology. Covering diverse topics from these disciplines, all of which are needed to understand how galaxies form and evolve, this book is ideal for researchers entering the field.

Individual chapters explore the evolution of the Universe as a whole and its particle and radiation content; linear and nonlinear growth of cosmic structure; processes affecting the gaseous and dark matter components of galaxies and their stellar populations; the formation of spiral and elliptical galaxies; central supermassive black holes and the activity associated with them; galaxy interactions; and the intergalactic medium.

Emphasizing both observational and theoretical aspects, this book provides a coherent introduction for astronomers, cosmologists, and astroparticle physicists to the broad range of science underlying the formation and evolution of galaxies.



Richard B. Larson retires after 43 years as a Yale faculty member

Professor Richard Larson officially retired in July 2011 after 43 years as a Yale faculty member. For career highlights, we reproduce this tribute to Richard, written largely by Professor Jeff Kenney, and entered into the minutes of the Yale College faculty meeting upon the occasion of his retirement.

Richard Larson, B.Sc., M.A., University of Toronto, PhD California Institute of Technology, faculty member at Yale since 1968.

You stand as a giant in modern astronomy because you have made immense contributions to our understanding of two of the key astrophysical challenges of our generation, star formation and galaxy evolution.

A true scholar of astronomy, you have a remarkable devotion to reading the literature, in part through your daily visits to the astronomy library, whose collection you have overseen. The intellectual life of the department has benefited from your numerous contributions, including service as Department Chair. As Director of Undergraduate Studies you have guided generations of astronomy majors. For decades you have taught twin pillars of the department's curriculum, imparting your wisdom in "Galactic and Extragalactic Astronomy," the first required course for undergraduate majors, and "Star Formation and the Interstellar Medium," a key course for graduate students. A department legend for your pointed questions at colloquia, you see sharply through even the foggiest talks to illuminate the key questions.

Your lifetime achievements towards understanding star formation are vast and unrivalled. You have taken a remarkably broad theoretical and phenomenological approach to the problem of star formation, combining analytic and numerical techniques, while also gleaning from the observations the crucial points that the observers themselves sometimes failed to see. You have an unerring physical intuition and a knack for cutting through complicated physics and confusing observations to pull out the essentials.

Your thesis pioneered numerical simulations of star formation. While these early calculations have been surpassed many times over in terms of numerical resolution and detail, your key conclusions have stood the test of time. You are an exemplar of how simulations should be guided by physics.

Of such fundamental importance are the relationships you first identified in your 1981 paper, *Turbulence and Star Formation in Molecular Clouds* that they are are now widely known as "Larson's Laws," although with typical modesty you refuse to call them that.

It is no exaggeration to call you the first "modern" thinker about galaxy formation. With your colleague Beatrice Tinsley (*see also article, p. 24*), you laid the quantitative foundations for the field of galaxy evolution modeling and wrote one of the most influential and highly cited papers on interacting galaxies ever written, which introduced the notion of starbursts triggered by galaxy interactions and mergers. In more recent years, along with Volker Bromm and Paolo Coppi, you have helped understand the formation of the first stars in the early universe, predicting that they are much larger than the stars of today.

In a world increasingly dominated by multi-author papers you have continued to be an intellectual leader through single author papers. Your review papers are generally considered masterpieces -- outstanding for their insight, synthesis and pedagogical qualities. Your highly lucid conference talks have guided and inspired countless students and colleagues.

The universe is illuminated by stars and galaxies, but the stars and galaxies themselves are illuminated by the brilliance of scientists like Richard Larson.

John Fox returns to Astronomy Department business office as the Lead Administrator

After being away from Astronomy for four years, John Fox was very happy to return to the department as part of a new administrative model called Regional Business Office (RBO). Fox had been the Business Manager for the astronomy department for two and a half years before being lured away to perform the same role in the physics department. In the RBO arrangement, Fox now oversees the administrative functions in both the astronomy and the physics departments, trying to find synergies by merging some functions of the two staffs, while still maintaining the autonomy of the two departments. With the ongoing budget issues, it has been quite a challenge yet there are more changes still to come! Most of the hard work is done by Magaly (*see article, below*) but John Fox takes the credit.

Outside of work and interacting with the wonderful astronomers, Fox takes pleasure in kayaking, traveling, and reading (when he doesn't fall asleep).

Magaly Cabrera-Robinson joins astronomy business staff as the Operations Manager

Magaly Cabrera-Robinson joined the Department of Astronomy in August of 2010 as the Operations Manager, a new position in the Astronomy business office that assists the Lead Administrator (formerly "Business Manager"). In her job, she manages and implements financial and administrative support services for the astronomy department; finding solutions for any operational challenges that may arise. This includes management of Leitner Family Observatory and Planetarium and the Yale Southern Observatory. Some may also know her as the expense enforcer. She also supplies Professor Pieter van Dokkum with his Dove milk chocolate.

Previously, Magaly worked as a financial assistant at the Physics department for 3.5 years. Before that, she was part of the School Development Program at the Child Study Center for 14.5 years, where she was the financial and logistic coordinator. When not at work, Magaly enjoys being a football mom and spending quiet evenings at home with her family.

2011 Astronomy Department undergraduate senior projects

Patrick Davis, B.A.	*The music of the spheres: from Pythagoras to Kepler*, advisor Charles Bailyn
Michele Dufault, B.S.	*Development of a Liquid Helium Dark Matter Detector*, advisor Daniel McKinsey
James Kim, B.S.	*An Evaluation of X-ray Excess Variance as an Estimator of AGN Black Hole Mass*, advisor Meg Urry
Laura Kreidberg, B.S.	*The Mass Distribution of Stellar Mass Black Holes*, advisor Charles Bailyn
Victor Mutai, B.S.	*Infrared and X-Ray monitoring of the microquasar GRS 1915+105,* advisor Charles Bailyn
Adam Payne, B.A.	*Other Worlds: An Introduction to Exoplanets*, advisor Michael Faison
Jon Richardson, B.S.	*Constraining the halo occupation distribution of Active Galactic Nuclei*, advisor Daisuke Nagai
Nick van Nispen, B.A.	*The M2K Planet Search: Planetary Companions to HD84334, HD156668, and Hip 57274,* advisor Debra Fischer





HONORS

Charles Bailyn '81 BS was named the A. Bartlett Giamatti Professor of Astronomy and was elected to the Connecticut Academy of Science and Engineering (CASE). [1, *photo by Michael Marsland*]

Debra Fischer was elected to the Connecticut Academy of Science and Engineering (CASE). [2, *photo by Tony Rinaldo*]

Marla Geha was awarded the 2010 Sloan Fellowship. [3, *photo courtesy of Geha*]

Richard Larson won an honorary fellowship in the Royal Astronomical Society for his significant and lasting contributions to the field of astrophysics. Larson received the honor for his work in star cluster formation and related research in galaxy formation and evolution. *See also article, p. 15.*

Priyamvada Natarajan was awarded a 2011 India Empire NRI award for Achievement in the Sciences in New Delhi, India. [4, *photo courtesy of Natarajan*]

Adele Plunkett '15 GRD was awarded a Fulbright Fellowship 2011 and will spend a year studying in Chile. [5, *photo courtesy of Plunkett*]

The **Dirk Brouwer Memorial Prize** is awarded to a student in the department for a contribution of unusual merit to any branch of astronomy. Normally this is awarded to a graduate student for an outstanding thesis.

2010 Prize

Eric Murphy '07 PhD: *Star Formation, Dust Heating, and Cosmic Ray Electron Cooling: A Far-Infrared and Radio Study of Nearby Galaxies".*

2011 Prizes

Peter Adshead '10 PhD: *Cosmological Perturbation Theory and the Early Universe.*

Gabriel Brammer '10 PhD: *Massive Galaxies Near and Far: The Evolution of an Unbiased Population over the Last Ten Billion Years.*

The **Beckwith Prize** is awarded annually to undergraduates who are the most proficient in some branch of astronomy or mathematics.

2010 Prizes
Aaron Bray, '10 BS
Katherine Rosenfeld, '10 BS

2011 Prizes
Michele Dufault, '11 BS
Laura Kreidberg, '11 BS

C. Megan Urry was awarded the Annual Women in Space Award, given by the Women's Board of the Adler Planetarium to "an outstanding woman in space science who exemplifies the characteristics that lead to success academically and in the work force".

Frank van den Bosch won a 2010 PROSE Award for his text book *Galaxy Formation and Evolution* published by Cambridge University Press. *See also article, p. 14.*

Camile Avestruz, '15 GRD; Erica Nelson, '15 GRD; Adele Plunkett, '15 GRD; and **Luis Vargas, '15 GRD** each received a 2010 NSF Graduate Research Fellowship.

University of Chile professors visit Yale

Photo coutesy of L. Campusano

Photo coutesy of P. Lira

Q: What did you like about coming to Yale?

LC: *Yale is an institution with a long tradition of excellence, with leadership to keep and enhance its strengths, and with strategies to invent the future. Feeling part of its faculty and in particular the participation in the academic life of the astronomy and physics departments, for a period, was a source of learning, insight and inspiration.*

Professor **Luis Campusano** has been a professor at the U. de Chile since 1976. He studies the large scale structure (LSS) of the universe as revealed by galaxies and quasars. He is best known for his contribution towards the Clowes Campusano Large Quasar Group Survey, which studied huge regions with quasar overdensities and looked for galaxies' overdensities in their associated environments.

While at Yale, Campusano worked on a few projects. First, he studied the distribution of clusters of galaxies in the local universe and the characterization of their constituent galaxy populations. Second, he worked on observational tests for the hypothesis of isotropy and homogeneity of the universe at large scales. Third, he evaluated the teaching of astrobiology as a tool for both general education at the undergraduate level and for the promotion of interdisciplinary research at the graduate level, based partially on the experience of astronomers at Yale.

Campusano obtained his Ph.D. in Astrophysics from the Universite de Toulouse. He also has degrees from the University de Paris VII and the U.de Chile. He was the third person to ever receive an advanced degree in astronomy in Chile in 1973. He is active in the astronomical community, serving on many committees, including the Gemini Board, and served as astronomy advisor to the government of Chile from 1999-2007.

Campusano has edited a book on stellar astrophysics and another on intelligent life in the universe, and has nearly 100 other publications. He is Chilean by birth and is married with three grown children and six grandchildren. He lives in Santiago with his wife, Sofia.

Q: What was your favorite thing that you did at Yale?

PL: *Walking in the snow! And the blue skies! I spent seven years in the U.K. where winters (and even summers) are really dark because it is always cloudy (the latitude doesn't help either). Also, winters are not very cold, so there is little snow but lots of rain. In New Haven I enjoyed lots of snow in sunny days with beautiful blue skies. I loved that. And the chipmunks.*

Professor **Paulina Lira** is also Chilean by birth and has been a faculty member in astronomy at the Universidad de Chile since 2002. She obtained her Ph.D. in astronomy in 1999 from the University of Edinburgh. Lira studies Active Galactic Nuclei (AGN).

While at Yale, Lira continued her monitoring program of high-z quasars, variable sources whose flux goes up and down with time. She uses their variability data and the technique of reverberation mapping to help determine the masses of the supermassive black holes (BH) and the structures of the surrounding accretion disks.

Lira also used (and continues to use) Yale's QUEST2 camera, along with Professor Paolo Coppi from Yale and Regis Cartier, a graduate student from U. de Chile visiting Yale, to determine the variability properties of a larger sample of AGN. This study will be an important precursor to the AGN surveys planned on the forthcoming Large Synoptic Survey Telescope (LSST).

Lira has served the astronomical community through membership on the European Southern Observatory, Gemini, Hubble Space Telescope and Chandra telescope time allocation committees (TACs), as well as scientific and local organizing committees (SOC and LOCs) of several international conferences and workshops. At the university she has been a seminar organizer, the postgraduate studies coordinator and an outreach coordinator.

Lira has published 57 refereed articles and has supervised several Master's and PhD students.

Recent astronomy department graduates

Carie Cardamone, '10 PhD
Currently a Post-doctoral Associate at MIT.
Dissertation: *The Role of Active Galactic Nuclei in the Co-evolution of Black Holes and Galaxies.*

A fundamental question in the field of galaxy evolution is the relationship between the growth of a galaxy's central black hole and that of the galaxy's stars. In her thesis, she describes new deep observations with the Subaru telescope in 18 medium-band optical filters and she leverages the wealth of existing data in the Extended Chandra Deep Field-South, in order to investigate the galaxies where black holes were growing (so called Active Galactic Nuclei). This study, part of the Multi-wavelength Survey by Yale-Chile (MUSYC), provides the community with highly accurate photometric redshifts and detailed spectral energy distributions for galaxies and AGN in this legacy field. Carie found that when the universe was roughly half its current age, black holes were growing due to accretion both in passively evolving galaxies and in dusty young galaxies. In the passively evolving host galaxies, the AGN may be heating up the galaxy's gas and preventing future episodes of star formation, while in dust-reddened young galaxies, the AGN may be ionizing the galaxy's interstellar medium and shutting down star formation. This study show that AGN activity is not limited to one particular stage of galaxy evolution. Therefore, a variety of fueling mechanisms, both secular and environmental are likely instigating AGN at different stages of the host evolution.

Dr. Cardamone's advisor was Professor Meg Urry.

Peter Adshead '10 PhD
Currently a KICP Fellow at the University of Chicago.
Dissertation: *Cosmological Perturbation Theory and the Early Universe.*

A successful cosmological model must account for the primordial perturbations that seed galaxy formation and produce the hot and cold spots we observe in the Cosmic Microwave Background. The leading proposal for generating these perturbations is "inflation", a hypothetical epoch immediately after the big bang during which the expansion-rate of the universe accelerates dramatically.

Adshead's thesis focused on ways to use measurements of the microwave background and the distribution of galaxies in space to test competing models of the inflationary epoch. Adshead developed elegant methods for calculating the interactions between perturbations in the very early universe. These interactions can induce a ``non-Gaussian'' component into the primordial perturbations. This contribution is small, but potentially detectable by experiments now underway or in the planning stages, and provides a vital probe of competing models of the very early universe.

Dr. Adshead's advisor was Professor Richard Easther.

Gabe Brammer '10 PhD
Currently an ESO Fellow at the European Southern Observatory in Chile.
Dissertation: *Massive Galaxies Near and Far: The Evolution of an Unbiased Population over the Last Ten Billion years.*

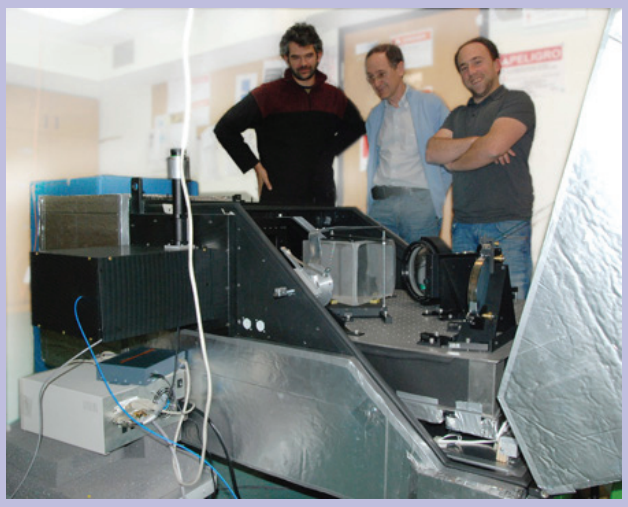
Brammer performed a comprehensive study of galaxies in the distant Universe. He developed a new technique to measure accurate distances to galaxies. Owing to the finite speed of light, these distances can be "translated" into particular epochs in the history of the Universe, allowing us to piece together how galaxies came into being. Using these distances, Brammer discovered that galaxies fall in two distinct classes, and that this bimodal distribution of properties was established within a few billion years after the Big Bang.

Dr. Brammer's advisor was Professor Pieter van Dokkum.

More from some of our featured articles. . .

(From YDDF, p.6) In addition to the spectrograph, Schwab is also building a telescope simulator, which includes a "seeing simulator" –glass plates that are etched so that when you move them in front of a beam of light they produce twinkling. His test star is the Sun, and light is brought in from fibers during the daylight working hours. The team uses optics to mimic the light cone coming from a telescope.

Spronck said that the team has learned lessons from building CHIRON and that he and Schwab will adapt the CHIRON design to reflect these lessons learned and also to experiment with some of the aspects of the mechanical design. For instance, they want to put the grating in a small vacuum chamber to dramatically reduce pressure changes at the face of the grating and ultimately stabilize the spectrum. The team has not done this before, and they are designing the vacuum chamber from scratch. The grating is one of the critical components for the spectrograph. It is also relatively small compared to the rest of the instrument so it will be easier and more efficient to vacuum-enclose the grating rather than putting the entire spectrograph in a vacuum chamber.



Christian Schwab from YDDF, Andrei Tokovinin from the Cerro Tololo Inter-American Observatory and Julien Spronck from YDDF with the CHIRON spectrometer. Building CHIRON, which is currently being used on the 1.5-meter SMARTS telescope in Chile, has influenced the YDDF team's work in building their current instruments here at Yale. Photo courtesy of YDDF team.

The YDDF team is also working on other, related projects. First, they are considering testing a second, higher dispersion grating. Second, Andy Szymkowiak of the Yale Center for Astronomy and Astrophysics is leading the team effort on detectors for the test spectrograph and on an exposure meter to determine photon-weighted exposure times for CHIRON. Third, A.J. Riggs '11 is building a solgel coating facility so that the team can apply anti-reflective coating to their optics. Fourth, a seeing simulator is planned to realistically simulate air turbulence and its effect on fiber coupling and spectrograph illumination stability. Finally, the team is building a fiber scrambler for the HIRES spectrograph at Keck Observatory.

(From PERSEUS, p.5) He also observed a compact submillimeter source in the core, probably arising from a young protostar. The protostar is low luminosity so it could either be very young or a very low mass source. Furthermore, the outflows driven by the first hydrostatic cores in models are predicted to be very slow and not collimated, but the outflow of this object was very fast and collimated. This means that the object could either be in the later stages of the first hydrostatic core stage or the early stages of the proto-stellar stage. More observations, especially deeper and more sensitive ones, need to be done to answer which. Therefore, it is most accurate to call the object a candidate for a first hydrostatic core.

Arce said "we see all the things that we expect to see from a first hydrostatic core but it could also be a very low luminosity young protostar. So no matter what, it is young. It is very interesting". Chen named the object L1448--IRS2E, as it is located in a core East of the IRS 2 source. Since that time, two other candidates have been studied by the Yale group through observations with the SMA. Because of the work of the Yale group, other astronomers have followed their lead and are discovering candidates as well.

The Yale group plans both to expand the number of candidate objects and to observe more deeply into the cores of the objects that they have already observed. They have applied for time on the Combined Array for Research in Millimeter Astronomy (CARMA) in California to try to understand the evolutionary status of the objects. The team is also gearing up to use the Atacama Large Millimeter Array (ALMA), now being built in Chile, in their research. ALMA will have 10-100 times the sensitivity and resolution of current millimeter telescopes, and is expected to revolutionize the study of star formation.

In Memoriam: Michele Elizabeth Dufault

Michele Elizabeth Dufault '11, a promising B.S. major in astronomy and physics, died in a tragic accident in a student machine shop on April 13, 2011 where she was working on building instruments for her thesis on investigating the possible use of liquid helium for detecting dark matter particles. Her advisor was Daniel McKinsey and she also worked closely with Wei Guo, a postdoctoral associate in the group, and other lab members. She had planned to pursue a graduate degree in oceanography after graduation.

While at Yale, Dufault was active in events encouraging young women to explore scientific fields, and helped organize annual science fairs for local students. She had a leadership role in the Women in Physics Conference. She was also part of the Yale Drop team, which involved a reduced gravity plasma physics experiment that the team deisgned and carried out at NASA. Last summer, she worked on underwater robotic vehicles as a fellow at the Woods Hole Oceanographic Institution in Massachussets.

Photo of Dufault in YPMB, courtesy of Facebook

Dufault played the saxophone and was a proud member of the Yale Precision Marching Band. She was originally from Scituate, Massachusetts.

Dufault graduated with distinction in the major and she also received a Beckwith Prize from the Astronomy Department. The Beckwith Prize is awarded annually to undergraduates who are the most proficient in some branch of astronomy or mathematics.

A card given out at a memorial for Dufault expresses how much of an impact Dufault made on all she knew:

"Michele Dufault's curiosity and sense of wonder extended from the depths of the ocean to the far reaches of the sky. Whether she was exploring the sea or the stars, she amazed us with her desire and ability to make sense of the world around her."

She is deeply missed by our department.

The Dorrit Hoffleit Undergraduate Research Fellowship Fund established

Margaret Doleman, niece of the late Dorrit Hoffleit, has made a donation to establish an undergraduate research fellowship fund in her aunt's memory. Dr. Hoffleit spent more than fifty years working in the Department of Astronomy at Yale University. "Dorrit always planned to establish this fellowship, and it is my pleasure to honor her wishes knowing of her relationship with the Department of Astronomy to the very end of her life," said Doleman. "I am delighted that it will be used to carry on an important aspect of her life's work."

Hoffleit was the creator of the *Bright Star Catalogue*, a compilation of data on the 9,110 brightest stars in the sky; she also co-authored The General Catalogue of Trigonometric Stellar Parallaxes, which contains distance measurements to 8,112 stars, information critical to understanding the kinematics of the Milky Way galaxy and the evolution of the solar neighborhood. She is the author of *Astronomy at Yale 1701-1968*, as well as her autobiography, *Misfortunes as Blessings in Disguise*. The International Astronomical Union named an asteroid after Hoffleit in 1987.

Hoffleit is considered a pioneer in inspiring young women to join the field of astronomy. For over 20 years she directed the Maria Mitchell Observatory in Nantucket, Massachusetts, where she provided research opportunities for young women.

The income from the newly established endowed fund will be used to support summer research fellowships in the Department of Astronomy, for both Yale College and non-Yale undergraduate students. Since Dorrit was a supporter of women, but also people in general, at least half the fellowships will be awarded to women, when averaged over more than a decade. The department plans to start the fellowships in 2012, and hopes it will benefit graduate student recruitment, by introducing top undergraduates to Yale.

YALE COLLEGE SCHOLARSHIP IN MEMORY OF MICHELE DUFAULT

On April 16, 2011, President Richard C. Levin and the members of the Yale Corporation established an endowed Yale College scholarship fund with a preference for a female student with an interest in the sciences to be named and awarded in Michele Dufault's memory. This scholarship will pay special tribute to the remarkable legacy that Michele leaves at Yale, including the countless people and programs aruond campus whose lives were touched by her academic leadership, compassionate spirit, and vibrant energy. For more information on the Michele Dufault Memorial Scholarship, please contact Joan O'Neill, Associate Vice President for Development, at joan.oneill@yale.edu or send contributions to: Yale University, Office of Development, P.O. Box 2038, New Haven, CT 06521, Attn: Joan O'Neill.

Morris Davis '50 PhD writes "I joined the Department of Physics at the University of North Carolina, Chapel Hill in 1952 as the lone astronomer. In 1970 we hired a second astronomer and from that time on interest in astronomy accelerated. With astronomers Wayne Christiansen, Bruce Carney and James Rose, Yale '77, a consortium was formed called SOAR, Southern Observatory for Astronomical Research. I retired in 1989 after four years as executive editor of *Celestial Mechanics and Dynamical Astronomy*, and have been keeping up with my family of six children and their families: 10 grandchildren and 5.5 great grandchildren. My interest in astronomy remains strong as I try to keep up with the burgeoning discoveries and knowledge gained with new modern technologies.

Doug O'Handley, '67 PhD writes "There is not much to report from northern California. I am still teaching at Santa Clara University but have the spring quarter off while I undergo radiation therapy for prostate cancer. This also resulted in my having to leave the Board of Governors of the AYA. I expect to continue as Director Emeritus for the NASA Academy for Exploration at the NASA Ames Research Center starting next month. I did appear on the NBC *Today in the Bay* shows on the occasion of the launch of STS 134. The new studio is robotically controlled with no cameramen in the studio. Getting the message out that we need to encourage young people into careers of science is important."

Julian Palmore '67 PhD writes "This fall, I'll be teaching a seminar course on spaceflight to campus honors students at the University of Illinois - Urbana."

Jeff Rosendhal '68 PhD is continuing to enjoy a variety of activities during his so-called retirement. He has traveled to more than 30 countries since September 2004. Next planned excursions are to Russia-Estonia-Finland (in August 2011) and Argentina-Brazil-Chile (in February 2012). He has also been teaching Astronomy courses at the local Osher Life-Long Learning Center affiliated with George Mason University. He just completed an 8-week course on "The Search for Life in the Universe" that had the largest registration (and attendance) of any course ever offered at the Reston campus.

Alan Hirshfeld '78 PhD writes "I just completed my 30th year in the Physics Dept. at UMass Dartmouth. My latest popular science book, *Eureka Man: The Life and Legacy of Archimedes*, will be published in September by Walker/ Bloomsbury. Also, my *Astronomy Activity and Laboratory Manual*, a history-based series of in-class exercises for college-level introductory astronomy courses, was published by Jones & Bartlett last September."

Linda Stryker '81 PhD has retired from 24 years teaching at Arizona State University. She taught Astronomy for a few years, then broadened her science background by co-creating the Integrative Studies Department, where she taught such courses as 'Science and Religion,' 'Women in Art,' and 'Evolution of Ideas,' among others. She currently concentrates on writing poetry, stories, and a novel; plays tennis several times a week; and does volunteer work with Recording for the Blind and Dyslexic.

Chris Carosa '82 BS is an investment adviser in Western New York, sharing the academic side of this research at conferences from coast to coast. He both serves as Chief Contributing Editor and writes a weekly column for *Fiduciary News*. He has not forsaken his first love, though, and maintains his AstronomyTop100.com site, where he periodically posts short articles on the results of his outreach project listing the top 100 images and imaginations in astronomy and space exploration. He's searching for ways to package this site to help elementary and secondary school teachers.

Daniel Alt '97 MS writes "After 13 years as a music teacher, I will be returning to the natural sciences fold. I have been accepted to Michigan State University's physics doctoral program beginning in the fall."

Meredith Hughes '05 BS writes "I am currently a Miller Fellow in the UC Berkeley astronomy department studying the structure and evolution of circumstellar disks using millimeter-wavelength interferometry. Last summer on my way to California I spent an amazing month in southern Utah volunteering in the astronomy outreach program at Bryce Canyon National Park (and checking out all of the other gorgeous Utah national parks in my spare time). I recently accepted a tenure-track faculty position at Wesleyan University and am looking forward to moving back to central Connecticut sometime around January 2013."

Katherine Kornei '06 BS writes "I'm finishing up astronomy graduate studies at UCLA and will be applying for jobs this fall. I've been dabbling in juggling and guitar and have been exploring a lot of Los Angeles on foot (yes, people do walk here). I recently traveled to Morocco and have enjoyed adding some new spices into my cooking."

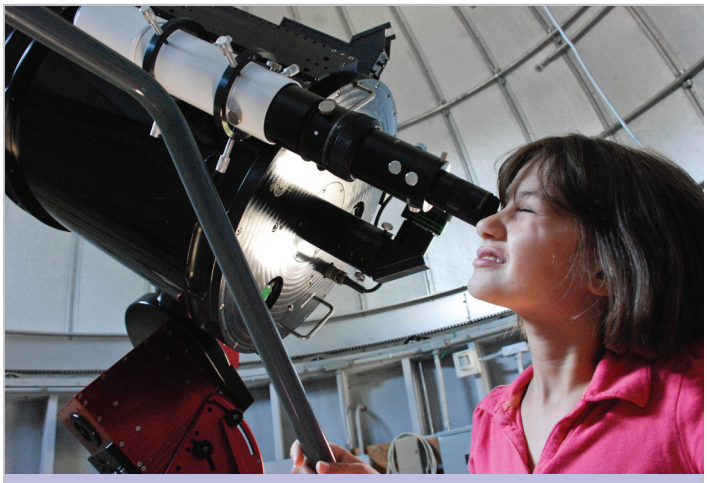
Hannah Krug '07 BS writes "I'm currently a PhD candidate in the Department of Astronomy at the University Of Maryland. I am working for Dr. Sylvain Veilleux, and my thesis is topic is a search for high-redshift Lyman-alpha emitters in the COSMOS field with the NEWFIRM camera. I miss Yale (and New Haven pizza!) but absolutely love this department and couldn't be happier here."

Eric Murphy '07 PhD writes "Nothing too much to report from my end other than a recent move from Caltech to The Observatories of the Carnegie Institution for Sciences as an independent postdoctoral fellow. My research focus largely remains the same. I am involved a number extragalactic programs that are panchromatic and span a large variety of topics. One project which I am spearheading is a detailed study of the physics of star formation and its associated feedback anchored by a new generation of high frequency radio data being taken with the GBT, EVLA, and soon ALMA. One unexpected result of this survey has been the first extragalactic detection of anomalous dust emission. This emission component, which plagues observational cosmology experiments at microwave wavelengths, is thought to arise from rapidly rotating ultrasmall grains having a non-electric dipole moment. By investigating the origin and prevalence of this emission component will significantly help inform models aimed at removing it from the foreground in CMB experiments."

Gabrielle Bentacourt '10 BS writes "I've been having a wonderful and much-needed year off after Yale. This past fall I was a Lloyd V. Berkner Space Policy intern at the Space Studies Board of the National Research Council in Washington, D.C. In the winter, I took a quick trip to Argentina and Brazil, then headed off again to Costa Rica to volunteer at a bilingual Quaker school for 2.5 months. I'm currently working on the legal issues behind a summer internship I've been given with the European Science Foundation in Strasbourg, France. Once I get back from that in August, I'll be moving down to Maryland to start a PhD program in astronomy at UMD (College Park) in the fall!"

Adam Solomon '10 BS writes "I'm about to take my exams for Part III of the Mathematical Tripos (a one-year masters in math) at the University of Cambridge. Afterwards I'll be staying on here to do my PhD, starting in October, at the Department of Applied Mathematics and Theoretical Physics, working under the supervision of Prof John Barrow. I'm interested in the boundary between theoretical physics and observational cosmology, and we'll be focusing in particular on modified gravity, dark energy, and inflation. I'm pretty excited!"

Matthew Adams '10 BA writes "I was an Astro BA major, so not doing a whole lot in the science-based realm. I just got a new job in NYC and will be doing private banking with Citibank starting on May 23rd. Nothing else really newsworthy coming down the line to be honest, but I've tried keeping up with astro news and I do my best to direct anyone who asks what my sign is to the Bad Astronomy blog. "



*(from **LFOP**, p. 11)* which is hoping to purchase a planetarium system similar to the one at LFOP.

The construction of the observatory, which opened in 2007, and the planetarium, which opened in 2009, were both funded by generous gifts from Jim Leitner and Sandra Leitner. However, funding is still needed for staff and resources to continue the important public education work done in this beautiful facility. Herrick is only a half-time staff member and Faison has other duties to attend to in the department, including teaching many undergraduate introductory courses as a Lecturer in Yale College. Herrick and Faison say they would like to be able to host more classes for local schoolchildren in order to meet the demand, purchase more planetarium shows so that they have shows appropriate for all different age groups, and fund new projector lenses that will improve the brightness and optical quality of the projected images. *Images courtesy of Heidi Herrick / LFOP.*

If you have news about yourself or others you would like to share, please E-mail it to astro.newsletter@yale.edu.

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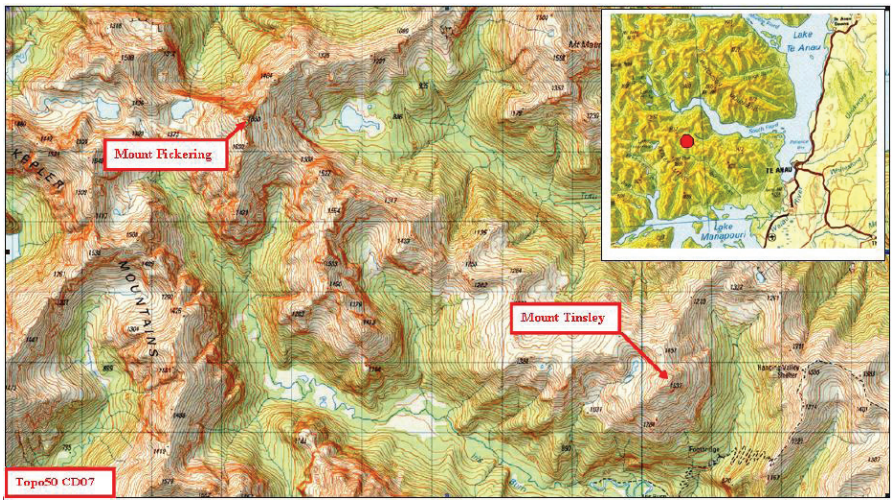
New Zealand names mountain peak after Beatrice Tinsley



The New Zealand and Geographic Board recently approved the naming of Mount Tinsley to commemorate the world renowned astronomer and New Zealander, Beatrice Tinsley (1941-1981). Tinsley, who was a Professor of Astronomy at Yale University from 1975-1981, was a world leader in modern cosmology and one of the most creative and significant theoreticians in modern astronomy. Tinsley died tragically at the young age of 40 while a Yale faculty member, but made enormous contributions in a short amount of time.

Mount Tinsley (1537m) is located within the Kepler Mountains (which are named for the astronomer Johannes Kepler) in Fiordland National Park, which is about 400 miles southwest of Christchurch, New Zealand. Mount Tinsley was one of two previously-unnamed peaks in the Kepler range recently named for legendary New Zealand astronomers or space scientists. Mount Pickering (1650m) was christened to honor William Hayward Pickering (1910-2004), who led the development of US unmanned space exploration.

If you would like a free copy of the book *My Daughter Beatrice,* a personal memoir of Dr. Beatrice Tinsley, written by her father Edward Hill, please contact Kim Monocchi at **kim.monocchi@yale.edu** and include your mailing address.

The map and photograph of Mount Tinsley, above, are provided by Aaron Nicholson, the amateur historian in New Zealand who first proposed the name of the peak to New Zealand's Geographic Board in 2009.