

DEPARTMENT OF

# ASTRONOMY

## Welcome to the new Department of Astronomy newsletter

We are excited to present the Department of Astronomy's first newsletter in our nearly 97 year history—or at least the first one of which the current faculty are aware. The 2017-2018 academic year started out with the amazing total solar eclipse (the first one in the continental U.S. in 38 years), which has set the mood for the rest of the year. With our award winning faculty, staff, and students, our level of research is awe-inspiring and indicative of a bright future. Learn more about the Department of Astronomy's recent happenings inside this newsletter, and the next time you are back in Urbana-Champaign, stop by and visit us.

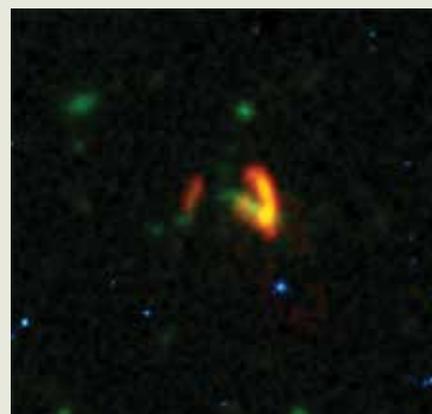


*The Astronomy Building*

## FACULTY SPOTLIGHT: Young and massive galaxies

Professor **Joaquin Vieira**, graduate students **Sreevani Jarugula** and **Kedar Phadke**, and alumna **Katrina Litke** (BS, '15, and the Layla Suzanne Ryan Scholarship winner '14 and '15, and now a graduate student at Arizona) were part of a team that observed a pair of the most massive distant galaxies known to date. The galaxies (named SPT0311-38) were first discovered by Professor Joaquin Vieira using the South Pole Telescope (see the SPT article), and the discovery was followed up using the Atacama Large Millimeter/sub-millimeter Array (ALMA), which provided their mass and distance. At a redshift of 6.9 (less than 800 million years after the Big Bang), they observed a pair of extremely massive star-forming galaxies that defy our understanding of how all galaxies formed. We used to think that the first galaxies, those that formed in the first few hundred million years after the Big Bang, would look more like today's dwarf galaxies. These early but small galaxies would combine and build the larger, more massive galaxies that we commonly see dominating the Universe in the first few billion years. This new Illinois discovery of early but massive galaxies will help us develop a better understanding

on the emergence of large galaxies and the role that dark matter plays in assembling the most massive structures in the universe.



*A composite image of the two galaxies in SPT0311-38, with ALMA data (red) over a background from the Hubble Space Telescope (green and blue). The ALMA data traces the dusty glow from both galaxies. Note that the galaxy on the right is distorted by gravitational lensing, and that the green object between the two ALMA galaxies is the lensing galaxy. Credit: ALMA (ESO/NAOJ/NRAO), Marrone, et al.; B. Saxton (NRAO/AUI/NSF); NASA/ESA Hubble*



# From the department chair



As the new chair of the Department of Astronomy this academic year, I am proud to present our first newsletter to our alumni and friends. This academic year started out with a spectacular total solar eclipse that many of us are still excited about. We are also a growing department. This year the Department of Astronomy has the largest number of undergraduate majors in our history, and our faculty, research staff, and graduate students are continuing to establish new exciting lines of research (using state of the art telescopes, theories, and computer simulations).

The department has been located in the Astronomy Building since 1990, and since that time we have not had many building upgrades. However, with the help of astronomy staff Judy Whittington and Cory Holt, we have transformed the Atlas Room, library, and the computer room. All of these have been upgraded with furniture from surplus to provide additional meeting room space and an oasis for undergraduates to study (with power and USB charging stations). Many of these rooms have gone from underutilized spaces (as journals and atlases were replaced with electronic versions) to being rooms full of undergrad students—bringing more students into the department on a regular basis, which fills the building with active learning. In addition, the department won third place in the Energy Conservation Award, which awarded us \$10,000 to use for department upgrades. We are already in the first stages of upgrading the classroom with a new projector and screen, with plans to upgrade the seats and desks (which require additional funds).

With the closure of our radio telescope CARMA, the department has turned its focus to surveys, with partnerships in the South Pole Telescope, the Dark Energy Survey, and the Large Synoptic Survey Telescope (among others). These projects are discussed later in this newsletter, and I encourage you to read and learn about the amazing science explored by Illinois Astronomers.

As a land grant university, one of our main missions is the education of the general public, as well as cutting edge research and exceptional teaching. The eclipse was a shining example of fulfilling one of our main missions, and our faculty, postdocs, and students are doing even more. The local Astronomy on Tap series (now in its second year) has been extremely successful in bringing astronomy to the public. The AstroIllini outreach group has provided outreach to numerous elementary afterschool and public library programs, and is hosting an Astronomy Girls Summer Camp for the second year in a row. We are also increasing our involvement with the Education Justice Project (EJP), presenting astronomical topic seminars at the Danville Correctional Center. This year, our Icko Iben Jr. Distinguished Lecture Series in Astronomy (“Exoplanets and the Search for Habitable Worlds” by MIT Professor Sara Seager), was highly successful, and exposed students and the community to the exciting future of exoplanets. Finally, the Friends of the Observatory have continued to support the Observatory, providing more access to its history and improving operations, thereby improving the Observatory Open House experience for everyone.

If you want to learn more about the department or about our current news events, check out our brand new website: [astro.illinois.edu](http://astro.illinois.edu).

Sincerely,  
Leslie Looney

## Newsletter credits

Caitlyn Buongiorno — writer

Adrienne Ertel — editor

Leslie Looney — contributor, editor

# GRADUATE SPOTLIGHT:

## Deep learning astronomy



**G**raduate student Daniel George, in collaboration with Professor Eliu Huerta at the Gravity Group at the National Center for Supercomputing Applications (NCSA), has created a new area of research at the interface of High Performance Computing, numerical

relativity and artificial intelligence. Their novel algorithms represent the first application of GPU accelerated deep learning for the rapid detection and characterization of gravitational waves. First proposed in 1916 by Albert Einstein, gravitational waves were first detected in September of 2015 by the LIGO and Virgo collaborations, earning the 2017 Physics Nobel Prize.

Deep learning, part of the broader family of machine learning, is based on learning of data representations. George and Huerta have used this technique to develop “Deep Filtering,” a method which is far more efficient and resilient than current gravitational wave detection algorithms and which has been proved to correctly identify and reconstruct new classes of gravitational wave sources that may otherwise go unnoticed.

To facilitate the adoption of deep learning for large-scale gravitational wave data analysis, they worked with NVIDIA and Wolfram Research to study and produce a scientific visualization of the neuronal activity of Deep Filtering during the detection and characterization of gravitational waves in raw LIGO data. These studies are a significant step towards understanding how information is processed and learned by deep neural networks.

# ALUMNI SPOTLIGHT:

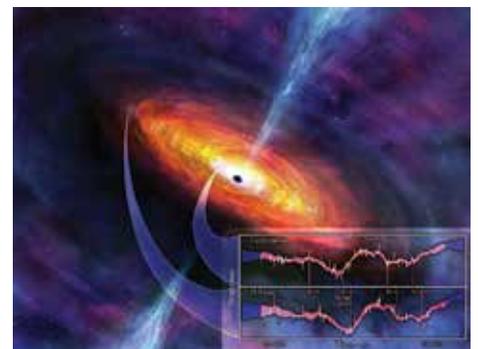
## Masses of supermassive black holes



**A**lumna Kate Grier (Astronomy and Physics 2007, winner of the 2007 Wyatt Award, and now a postdoctoral researcher at Penn State), in collaboration with Illinois Professor Yue Shen, Illinois postdoctoral fellow David Starkey, and Illinois graduate student Jennifer Li, is unraveling the mystery of supermassive black holes in the center of active galaxies.

Using a technique called reverberation mapping

on a large scale, the team has increased the total number of supermassive black hole mass measurements by two-thirds, and taken measurements further back in time than ever before to when the universe was just half of its current age. The team is continuing to observe 850 quasars with the use of the Sloan Digital Sky Survey (SDSS), allowing them to measure the masses of even more distant quasars. With these measurements, they hope to gain a better understanding of how supermassive black holes grow and form throughout time.



*Artist zoom-in impression of an active galaxy with a supermassive black hole at the center that is surrounded by a disk of infalling material and a jet of outgoing material at the poles. The graphs at the bottom right show how the brightness of light changes with time from two regions in the disk—inner region and outer region. The bottom plot follows the top plot with a delay of about 10 days. This time delay corresponds to a distance at the speed of light or 240 kilometers.*

*Credit: Nahks Tr'Ehnl ([www.nahks.com](http://www.nahks.com)), Kate Grier (The Pennsylvania State University), and the SDSS collaboration*

# Projects: The Dark Energy Survey

The Dark Energy Survey (DES) began searching the southern skies above Chile's four-meter Victor M. Blanco Telescope with the Dark Energy Camera (DECam) in August 2013. With one of the largest camera fields of view (2.2 degrees diameter or over four full moons), DECam is surveying 5,000 square degrees of sky, with Illinois processing and hosting the data. The team of more than 500 scientists from more than 30 institutions around the world has almost completed the deep, wide-area survey of five years and roughly 525 nights. With these data, they have observed 300 million galaxies in their first three years of operation, as well as discovered and studied thousands of supernovae and other astronomical events. Given such an abundance of data, DES collaborators hope to ultimately help uncover the nature of dark energy and dark matter, the main goal of the survey; however, the scientific applications of these data extend beyond cosmology.

The properties and origins of dark energy and dark matter are two of the biggest questions in cosmological science today. First proposed in the 1930s, dark matter is impossible to measure directly; thus we must measure its effect on visible matter. Despite never being directly observed, dark matter explains a number of otherwise puzzling astronomical observations. Similarly, dark energy (proposed in the 1990s) explains the accelerating expansion of the universe. A better understanding of either will change how we view the universe.

As part of their work, DES ensures that their data is made available to the scientific community, and in January 2018 DES released their first three years of data to the world. Although it's only one part of DES, this public availability is one of the more exciting aspects of the collaboration.

"It's a very important milestone, not only for the survey but also for NCSA [the National Center for Supercomputing Applications on campus] and Illinois, where we process and provide tools to access the data," said Matias Carrasco Kind (MS, '11; PhD, '14; astronomy), the DES release scientist at Illinois. "After three years of collecting this data, we made the first

public release which means that other people can do their own discoveries. I think there are more things 'hidden' in the data, and we're very excited to see what other people can discover from our datasets."

One such discovery enabled by the DES DR1 dataset was the detection of 11 new stellar streams around our Milky Way. Streams are created when a satellite galaxy is pulled into and torn apart by the Milky Way's gravitational field. Previously, we'd only known of two dozen streams due to DES's precursor: the Sloan Digital Sky Survey (SDSS). These streams paint a beautiful picture of our galaxy and its formation from multiple collisions of smaller galaxies. From such observations, we can deduce both the visible and invisible mass of the Milky Way, thereby measuring the dark matter distribution in our galaxy.

DES will continue to observe the sky and collect data until August 2018, at which point NCSA (in collaboration with the Department of Astronomy) will continue to analyze and prepare the images for the second and final DES data releases, which can be expected in 2020. Shortly after, the Large Synoptic Survey Telescope (see the LSST article) is scheduled to begin its own monumental survey in 2023.



*DES image of the galaxy NGC-1566.  
Credit: DES Collaboration.*

# Projects: The Large Synoptic Survey Telescope

There's something inherently exciting about a new telescope looking up at the sky for the first time. From Galileo first turning a telescope toward the night sky, every time a new telescope looks out into space, we shift our view of the universe. The Large Synoptic Survey Telescope (LSST) is exciting in exactly this way. Currently under construction in Chile, LSST will be unique—mapping the entire night sky every three nights.

“To have a dedicated survey that's observing the same area of sky as frequently as LSST is attempting to do is going to open up a whole new realm of science,” said Margaret Johnson (BS, '09; MS, '11, astronomy) assistant director of Astronomy Core Services at the National Center for Supercomputing Applications (NCSA), LSST technical manager, and associate director of the LSST Data Facility.

At 8.4 meters, LSST will use a special three-mirror design in order to create its exceptionally wide field of view. Located on the Cerro Pachón ridge in north-central Chile, LSST is set to begin its 10-year survey in 2023. It will provide the world with a 200 petabyte set of images and the first-of-its-kind cosmic movie (to put this into context, 200 petabytes is approximately 20 times the storage required by Netflix). LSST will address four specific scientific areas: the nature of dark matter and dark energy, cataloging the Solar System, exploring the transient night sky, and the formation and structure of the Milky Way.

“[LSST] has the ability to observe the whole sky every three nights and develop an actual movie of the sky [which] isn't something any other survey has been able to accomplish. We'll be able to detect how many near Earth objects there are, the kinds of asteroids, and, I'd imagine, new types of object. What's exciting is what you don't know you're going to find,” explained Johnson.

Following in the footsteps of and pushing beyond the Dark Energy Survey (see the DES article), LSST has committed to making their data available to the U.S. astronomical community as well as the general public. Ultimately, anyone with a computer will have access to a moving map of the universe, and

LSST will provide students and the public with the tools needed to participate in the process of scientific discoveries. LSST will also make their data available in classrooms with their public educational outreach. Students work best when they are engaged, and the best engagement is from authentic investigations. By providing investigative models, LSST will train the next generation of scientists.

NCSA will be the home to the data access center for American astronomers, with its sister center located in Chile. The access center will provide American astronomers with the resources needed to analyze their data, as well as with the data gathered by LSST, opening the doors to future discoveries. LSST and NCSA are excited to work with University of Illinois professors and students and encourage them to get involved in the construction process. By entering the project early, professors and students will have the opportunity to give feedback on the project and discover how LSST will help them with their future work.



*View of LSST construction from the summit in January.  
Credit: LSST Project/NSF/AURA3*

## Graduate student profile: Astronomy at the bottom of the world



*Andrew Nadolski, selfie with South Pole Telescope.*

Fewer than 50 people winter over at the South Pole each year. It is cold, dark, and isolated, but Illinois undergraduate alum and current astronomy graduate student, Andrew Nadolski, braved the harsh conditions while working on his PhD project—upgrading the camera on the South Pole Telescope (SPT).

SPT is a 10-meter millimeter radio telescope that, with its amazing bottom-of-the-world location, measures the whispers of the Big Bang. With these data, researchers explore the formation of the universe and probe galaxy

formation. Illinois is a key partner to the project, and Andrew was on location to ensure success.

For 10 months, he and another researcher set up and debugged the newest camera upgrade for SPT. With the increased wavelength, sensitivity, and field of view, SPT will continue to observe the Cosmic Microwave Background—the leftover glow of the Big Bang—and probe the polarization induced by lensing of the early universe’s mass. Andrew spent a majority of his time working to eliminate noise in the telescope camera. “All through the winter we made these tiny steps towards getting

it to work properly, and that was pretty rewarding in and of itself.”

While working on the camera, Andrew also ran the telescope for a month while it was taking data for the Event Horizon Telescope (EHT) project. EHT combines telescopes from all over the world to create a large telescope array and resolve the supermassive black hole at the center of our galaxy. The collaboration required coordinating with people all over the world to ensure that the time-critical data acquisition worked. This amazing research will produce an actual picture of the shadow that our galaxy’s supermassive black hole leaves on its accretion disk. This picture will be a key landmark for science and humankind, and an Illinois graduate student was there making it happen.

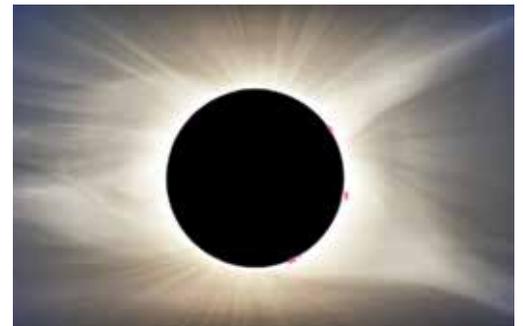


*The South Pole winter over crew. Credit: Hunter Davis and Matthew Smith*

## 2017 solar eclipse

The August 2017 total solar eclipse was an amazing event and an all hands on deck outreach opportunity for the Department of Astronomy. Southern Illinois was the best place in the world to view the eclipse in terms of the location of the longest duration. Led by Professor Leslie Looney, we organized six tour buses of alumni and friends to Goreville, Illinois—the town closest to the location of longest duration in the entire world. With about 80 faculty, postdocs, grad students, and undergraduates on hand during the eclipse, our event hosted 500 people at the Goreville High School (some people drove separately) and about 3,000 additional people at the City Park. At the park we set up an outreach pavilion with pinhole cameras, astronomy, geology, entomology, chemistry, and biology. We had great weather and the eclipse was a transcendental experience for everyone—astronomer and general public alike. We witnessed the beautiful corona, viewed Jupiter and Mars in the daytime, saw the 360-degree sunset-like colors, heard the noisy insects and other entomology effects, and much much more. In

addition, leading up to the eclipse we reached out to nearly 8,000 K-12 students in school presentations, more than 150 teachers at a Department of Astronomy/ Parkland Planetarium-led



*The sun's corona during the total solar eclipse in Goreville, Illinois. Credit: Professor Paul Ricker*

workshop, more than 650 adults in various locations, and we gave out almost 9,000 eclipse glasses (mostly to children and families). This was an amazing event and the Department of Astronomy shone in the shadow of the moon.

## Alumni news

Vicky Kelogera (PhD, '97, astronomy) is the Daniel I. Linzer Distinguished University Professor of Physics and Astronomy and the director of the Center for Interdisciplinary Exploration and Research in Astrophysics at Northwestern University. She was elected into the National Academy of Sciences and awarded the 2018 Dannie Heineman Prize for Astrophysics for her groundbreaking work studying black holes, neutron stars, and white dwarfs.

## Undergraduate student news

Astronomy students are in demand after graduation. Based on a recent survey over the last few years, 48 percent of our graduates go to graduate school and the rest have the second highest salaries in The College of LAS (\$67,500). We are proud of our graduates. This year, we are excited to announce our graduates for 2017/2018 (Astronomy and CS+Astronomy): Sushma Adari, Itamar Allali, Jeffrey Bandurski, Caitlyn Buongiorno, Arthur Choi, Harrison Davis, Alex Dittmann, Jianyang Fu, Derek Glennon, John Haug, Brian Hsieh, Enkh-Ider Jargalsaikhan, Cody Jensen, Jason Lepeska, Yang Lyu, Jessica Medintz, Jonathan Richman, Neal Schweighart,

Sibo Wang, Jacob Wilcoxon, Evan Wojciechowski, Kaan Yumlu.

The Layla Suzanne Ryan Memorial Scholarship was established to recognize outstanding undergraduates who also exhibit community service. The winner of the 2018 award is astronomy minor Sidney Lower.

The Stanley Wyatt Memorial Award is awarded annually to the graduating astronomy major or minor with the most outstanding GPA and track record of undergraduate research. The 2018 winner of the award is Alex Dittmann.

## Graduate student news

Graduate students play a critical and important role in our department. They are students, researchers, teachers, mentors, and leaders, and we acknowledge their achievements in all of these. In the last year, they were on approximately 35 papers whose topics spanned gravitational waves to gamma/radio electromagnetic waves, theory, simulations, observation, and data science.

One of the first steps for our graduate students is the preliminary exam in which they outline their PhD research. The graduate students who have passed their prelims this academic year are (ordered by date): Daniel George, Miguel Holgado, Taylor Tobin, Adrienne Ertel, Jesse Miller, Jennifer Li, and Sreevani Jarugula.

We are happy to announce our graduate students who have graduated with a PhD this academic year (ordered by date): Susmita Adhikari, Dom Segura-Cox, Ben Ryan, and Ricky Chue.

Every year, we present awards for our graduate students who have an article accepted for publication in a peer-reviewed scientific journal on which they are listed as first author. This year we recognize the following students: Erin Cox (3), Daniel George (2), Jennifer Li (1), and Ben Ryan (3).

The Mr. and Mrs. Hsiang-Pai and Wen-Hua Chu Department

of Astronomy Excellence in Research Graduate Student Award was founded by Professor Emeritus and former Department of Astronomy Chair You-Hua Chu, named in honor of her parents. The 2018 winner of the award is Ben Ryan. His research on radiatively inefficient accretion disks around black holes extends accretion disk simulations into a new and very important region of parameter space.

In addition to these departmental awards and milestones, our students are winning university-wide and external recognition. Some select highlights: Daniel George (NVIDIA Graduate Fellowship, Computational Science and Engineering Fellowship, LSST Data Science Fellowship, first place in ACM Graduate Student Research Competition at the Supercomputing Conference (SC 17), Best Poster Award at the IEEE International Conference for High Performance Computing, Data and Analysis (HiPC 17)), and Patrick Mullen (Excellent Teacher List).

## Staff news

We welcomed Cory Holt as our new office manager.

## Faculty news

We are excited to announce the following faculty recognitions. Professor Gabrielle Allen was elected as a 2017 American Physical Society Fellow. She provides international leadership in development of widely used simulation frameworks for numerical relativity, relativistic astrophysics, and other areas, laying a foundation for many groups to address complex problems in multi-messenger astronomy.

On campus, the Center for Advanced Study (CAS) awards faculty teaching release to explore new ideas and demonstrate early results. This year Professor Xin Liu is a CAS Fellow as she is working on a systematic search for merging black holes in the early universe. Next year, Professor Yue Shen will be a CAS fellow continuing his research (see above) on supermassive black hole physics and evolution to determine their masses. Also next year, Professor Jeff Filippini will be

a CAS fellow seeking evidence of primordial gravitational waves in the polarization of the Cosmic Microwave Background with his balloon telescope (SPIDER) over Antarctica.

Every year, the University of Illinois awards six people the Chancellor's Academic Professional Excellence (CAPE) Award. This year, professor and Assistant Chair Bryan Dunne was one of the winners for all the hard work he does for our department!

The William M. Staerkel Planetarium at Parkland College has renamed their "World of Science" lecture series to the "James B. Kaler Science Lecture Series" in honor of one of Professor Emeritus Jim Kaler, one of its longtime annual presenters.

We congratulate Athol Kemball on his promotion to Professor of Astronomy.

**I ILLINOIS**

Astronomy

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## Help us honor Professor Jim Kaler

**Professor Emeritus Jim Kaler** is one of our most beloved faculty members — a familiar face of astronomy education and outreach at Illinois since 1964. He has published over 120 research papers, been awarded multiple awards and honors, including the American Astronomical Society's 2008 Education Prize, and has served as president of the Board of Directors of the Astronomical Society of the Pacific. He has also written nearly 20 books, including two textbooks, and his popular STARS website has

recorded nearly 4 million visitors. In honor of his commitment to teaching and astronomy education, we are working to name the Astronomy Department Classroom after Jim: the James B. Kaler Astronomy Classroom.

We are seeking support from alumni and friends to upgrade the classroom into a state-of-the-art learning facility for students. For more information go to [astro.illinois.edu/kaler-classroom](https://astro.illinois.edu/kaler-classroom).