The Washburn Observer

DEPARTMENT OF ASTRONOMY
UNIVERSITY OF WISCONSIN-MADISON

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Inside this Issue:

The Washburn Observer is the newsletter of the Department of Astronomy at the University of Wisconsin-Madison

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How Wisconsin Changed Space Astronomy

"T-minus 10 minutes and counting..." All eyes are on the Atlas SLV-3C Centaur-D rocket, gleaming in the flood lights of Cape Canaveral, ready to launch into the night sky. It is December 7th, 1968 and the world is gripped by space fever. In exactly two weeks, Frank Borman will take his crew around the moon on the historic Apollo 8 mission. But tonight's launch will make a different kind of history: Atop this Atlas rocket sits the first successful space observatory in the modern sense, the Orbiting Astronomical Observatory 2 (OAO-2).

This story begins almost two decades earlier, with a young Art Code walking through the doors of Washburn Observatory as a newly-minted UW professor. Having served as an Electronics Technician in the Navy during World War II, Art was brimming with ideas. He was soon joined by another young Wisconsin astronomer, Bob Bless, and together, they set out to use the technological revolution sparked by the war to transcend the earth-bound limitations that confined astronomy to a tiny sliver of the electromagnetic spectrum. The atmosphere, for all its nurturing qualities, is a nuisance to most astronomers: It blocks light across a wide range of frequencies and blurs our images. To observe in the ultra-violet light, to see clearly, your telescope must be in space, above the atmosphere.

The UV, Art and Bob knew, held the key to a huge wealth of astronomical insight. That is because most atoms in the universe are in


Artist rendition of OAO-2 in orbit (image: UW-Madison)


OAO-2 Launch on December 7, 1968 (image: NASA)

their quantum-mechanical ground state, at the bottom of a tall energy ladder that its electrons can climb up or down. And the first step on that ladder is the tallest. To climb it, the atom must swallow (absorb) a UV photon. Jumping back down will make the atom regurgitate (emit) a UV photon. To study much of the gas in the universe, then, requires observations in the UV band and a telescope above the atmosphere.

The first rockets were able to send payloads above the atmosphere for a few tantalizing minutes at a time. Art and Bob created the scrappy Space Astronomy Lab (SAL) to respond to the new opportunities. They wanted to build a telescope that stayed above the atmosphere not for *minutes* but for *years*. It would take them almost two decades to reach this goal. With its launch on that fateful December night in 1968, OAO-2 became the first space observatory in the modern sense, the true predecessor to *Hubble*.

At the heart of OAO-2 sat the Wisconsin Experiment Package. It shared the spacecraft with the Harvard-built Celescope. Both were observing the sky in the UV. But while Celescope was turned off in April 1970, the WEP kept observing through 1973. The extended mission of OAO-2 and the WEP made it possible to involve astronomers beyond Wisconsin's primary instrument team, a very unusual approach in those days, so that guest observers could pro-

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Letter from the Chair

Being department chair automatically makes me the Directory of *Washburn Observatory*. For a theorist, this is a somewhat daunting responsibility, since I wouldn't trust myself with a $10,000 amateur telescope, let alone a 137-year old historical landmark. Thankfully, we have the multi-talented **Jim Lattis** on staff who *actually* oversees operations at *Washburn*.

Having the chair's office on the same floor as Jim's has been a real treat, because Jim, Director of *UW Space Place*, is not just great with telescopes, he is also our staff Ph.D. historian of science. I know of no other astronomy department that has their own historian, but I highly recommend it. Every hallway conversation with Jim invariably turns into a fascinating conversation about the proud history of UW-Madison Astronomy.

Starting with Washburn Observatory itself (in 1881 the third-largest telescope in the US), Wisconsin has been at the cutting edge of astronomy. Here are a few examples:

Joel Stebbins invented photo-electric photometry, turning measurements of star light into precision science. The structure of the galaxy was first mapped out by **William W. Morgan** from Yerkes Observatory in Williams Bay, WI, and **Albert Whitford** and **Art Code** at UW Madison. The nature of interstellar dust and extinction were characterized by **John Mathis**, **Bill Rumpl**, and **Ken Nordsieck** here at UW Madison in 1977.

And then there's what may be the crowning moment in our history: The topic of the cover story of this newsletter, the launch of the *Orbiting Astronomical Observatory-2* (OAO-2) in 1968, the first true space observatory. OAO-2 demonstrates Badger ingenuity at its finest. I hope you enjoyed reading how Wisconsin changed space science and urge you to celebrate with us at *UW Space Place* on December 7th and by following the coverage on our web site.

If you haven't had a chance to experience Jim Lattis' expertise in the history of all things Wisconsin Astronomy, a good place to start is the retrospective he wrote with student Peter Susalla as part of the 2009/2010 Wisconsin State Blue Book.

As chair, I want to continue my exploration of Wisconsin history, and that includes learning from all of our alumni about their connections to the department and what they have done with their degree, like **Dr. Ali Bramson**, who is profiled on the page across. Like last year, we will host our annual Astro Badger alumni reception at the 2019 Winter AAS meeting in Seattle. All department alumni are invited! We hope to see you there. And as always, if you are in Madison, please let us know and stop by for a visit.

On behalf of all Badger Astronomers, I wish you a peaceful and reflective holiday season and a successful new year.

Sebastian Heinz, Department Chair

50th Anniversary of OAO-2 *Continued from page 1*

pose and carry out observations not planned by the designers. Art and Bob would carry their experiences with WEP's observing programs into their work on the Hubble Space Telescope and the founding of the Space Telescope Science Institute, which Art guided in its earliest stages.

Left to right: Art Code, Ted Houck, John McNall, and Bob Bless

This open skies approach lives on in most NASA astronomy missions today and is arguably what has made NASA telescopes like *Hubble* and *Chandra* the successes they are: Using the collective insight and inspiration of world's astronomers to devise the best possible science program. With OAO-2, NASA began learning how to autonomously operate and optimize a space observatory.

Over the course of its four years in orbit, OAO-2 more than lived up to its promise of transforming astronomy, from discovering that comets are surrounded by huge hydrogen envelopes, to tracing the UV intensity of exploding stars. OAO-2 also launched Wisconsin on a trajectory of innovative space instrumentation, leading to SAL delivering one of the four launch instruments for the Hubble Space Telescope, flying telescopes on the Space Shuttle, and our sounding rocket program, to name a few. It also made Wisconsin the scientific center for studies of interstellar gas it remains today.

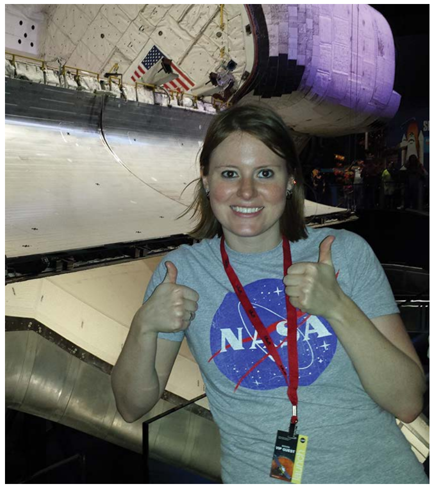
We are celebrating the 50th launch anniversary of OAO-2 with an evening of presentations, demonstrations, and refreshments at UW Space Place on December 7th, 2018. Please join us in honoring the legacy of OAO-2 and the people who made it happen.

Amount	What could it support?
$20	Sponsor field trip for one undergrad to Fermi Lab
$50	Print a conference poster for an undergrad student
$100	Lunch for visiting class of high school students
$500	Provide travel costs for one colloquium speaker
$800	Print one issue of the Washburn Observer
$1,000	Sponsor an undergrad to attend a scientific conference
$3,000	Support for our graduate student family leave policy
FUNDED $5,000	Sponsor long-term visitor to department
FUNDED $25,000	Re-build 16 inch Sterling Hall Roof Telescope
$50,000	High-Fiber Diet: An Integral Field Spectrograph for SALT
$80,000	Provide department share of start-up cost for new faculty
FUNDED $1,000,000	Endow a named graduate student fellowship
$3,000,000	Endow a named professorship

Badgers in Far Flung Places: Ali Bramson on a Journey to Mars

An interview by UW Freshman Kalli Anderson

What can you do with a UW degree in astronomy? *"I find ice on Mars and lava flows on the Moon"* Astro Badger and planetary scientist **Ali Bramson** exclaimed when I interviewed her about her current research. *"How cool is that?"*



Ali Bramson at Kennedy Space Center in 2012 for the launch of NASA's Maven mission to Mars

Bramson graduated in December of 2011 from UW-Madison with a double-major in astronomy / physics and physics and with a certificate in computer science. Now, after receiving her Ph.D. from University of Arizona, she is embarking on postdoc work in planetary science under the mentorship of Professor Lynn Carter.

Bramson came to UW Madison with an interest in physics well established. Under the mentorship of Dr. Kevin Metz in Prof. Joel Pedersen's soil science lab, and encouraged by Janet Branchaw's Undergraduate Research and Mentoring program, she studied how nanoparticles break down in the environment. *"Being at UW, there is a lot of research on campus so I was able to get a lot of experience,"* Bramson said. *"Just getting the foundation to learn what it means to be a researcher and understand what it means to do science."*

Bramson knew she wanted to study space and took all the physics and computer science classes she could, knowing these would set her up for her path to the stars. **Eric Wilcots**, her senior thesis advisor, encouraged her to get involved in astronomy research. *"Ali was the model undergrad student: Self-driven, curious, creative. I set her off on a topic, and she ran with it,"* says Eric.

"My project with [Eric] was the first time I got involved in astronomy research," said Bramson. *"Some of that involved using the Arecibo Observatory, which is where I ended up doing a [Research Experiences for Undergraduates] program in planetary radar. I started shooting radar beams at asteroids!"* Superhero-kind of stuff.

The following summer she went to the SETI (Search for Extraterrestrial Intelligence) Institute to look for lava flows on Jupiter's moon, Io.

Inspired by these research projects, Bramson dove into learning more about planetary science. *"Going to planetary science conferences and taking Eric Wilcots' planetary astrophysics class made me realize, 'oh yeah, this is the type of astronomy that I really want to focus on and can see myself spending my whole career on',"* Bramson said. *"I get to use robots, in space, to study the surfaces of other planets in our solar system."*

With her UW degree in hand, Bramson started her dissertation work at Arizona with a focus on understanding ice in the subsurface of Mars. By researching the ice on Mars, Bramson hopes to figure out how the planet's climate system works at mid-latitudes, which are between the poles and equator, roughly the location where Madison is on Earth. While ice isn't stable there at the surface today, she has found lots of ice beneath the surface.

"We figure this had to have formed in a different climate when Mars' obliquity, or axial tilt, was a lot higher," Bramson said. *"Earth wobbles a little bit, by about a degree or so, and that actually causes our ice ages. Mars undergoes a very similar thing."*

Bramson hopes that by figuring out where these ice deposits are, when they may have formed and their properties, scientists will be able to better understand climate cycles on Mars. This

Continued on Page 6

Support Badger Astronomers

Your support creates exciting opportunities for students, staff, and faculty. The stories you've read about here happened because of gifts from readers like you. You can contribute online at **www.supportuw.org/giveto/astronomychallenge**, at **www.astro.wisc.edu/giving**, or by mail to: UW Foundation, US Bank, Lockbox 78807, Milwaukee, WI 53278-0807.

❍ **I would like my gift to support the"High-Fiber Diet" matching opportunity (112120005). Funds raised in excess of our goal may be used to support other future department instrumentation projects.**

Name/s__________________ Address__________________

City__________________ State__________________ ZIP________

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My/our contribution of $________is enclosed. ❍ My company__________________will match this gift.

❍ My matching gift form is enclosed. ❍ I have initiated the matching gift process on the company's website.

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Questions about how your gifts may be used? Contact: Sebastian Heinz, chair@astro.wisc.edu, 608-890-1459, or UW-Foundation Director of Development, Troy Oleck, troy.oleck@supportuw.org, 608-308-5526. **Thank you for supporting Badger Astronomers!**

Department News

Don Michalski, 1941-2018

With profound sadness we note the passing of long-time department member **Don Michalski**. Don was with the department for 52 years and was an integral member of countless projects and instruments. He loved electronics, music, and space physics. Besides building orbital and sub-orbital payloads like the WEP on OAO and the High-Speed Photometer on the Hubble Space Telescope, he was a passionate HAM radio operator, acting as the Wisconsin Section Manager for the American Radio Relay League. We will miss him terribly.

Bob Mathieu, Albert Whitford Professor of Astronomy

We are thrilled to announce that **Professor Bob Mathieu** has been appointed Albert E. Whitford Professor of Astronomy. This named professorship from the Wisconsin Alumni Research Foundation "provides recognition for distinguished research contributions of the UW–Madison faculty. The awards are intended to honor those faculty who have made major contributions to the advancement of knowledge, primarily through their research endeavors, but also as a result of their teaching and service activities." Bob chose the name in memory of **Albert Whitford**, Director of Washburn Observatory, and internationally recognized UW Astronomer.

Matt Bershady SARChI Professorship

Professor Matt Bershady was awarded a prestigious South African Research Chair. The 5-year award at Capetown University and SALT will allow him to spend time in South Africa to develop new instruments for SALT and to work with students from both the US and South Africa on the science of galaxy structure and evolution. Congratulations, Matt!

2018 Graduates

Erin Boettcher defended her thesis on diffuse gas in galaxies using SALT, working with **Professors Jay Gallagher** and **Ellen Zweibel**. She is now a postdoc at the University of Chicago. **Stephen Pardy, Alisha Kundert, and Tim Heynes** received their Ph.D.s for their work with **Professor Elena D'Onghia**, studying the structure, evolution, and dynamics of galaxies. They have entered careers in industry. **Emily Leiner** and **Ben Tofflemire** did their Ph.D. work with **Professor Bob Mathieu**, studying alternative pathways of stellar birth and evolution. Emily is now an NSF Fellow at Northwestern, and Ben is a postdoc at UT Austin. Working with **Professors Ellen Zweibel** and **Eric Wilcots**, **Anna Williams** (now teaching at Macalester College) received her Ph.D. for studying the magnetic fields of interstellar and intergalactic gas. **David French** (now at STScI) received his Ph.D. for work with **Dr. Bart Wakker** on understanding the nature of interstellar gas through UV absorption line studies. **Erika Carlson** received a Masters degree for her work on speckle imaging of stars with **Professor Bob Mathieu** to pursue a career in science journalism at UC Santa Cruz. Congratulations, 2018 graduates!

Please Stay in Touch

We'd like to hear from you.

Please send any news that we can include in future newsletters or any changes in your contact information to: newsletter@astro.wisc.edu or UW-Madison, Astronomy Department, 475 N. Charter St., Madison, WI 53706, attention: Newsletter

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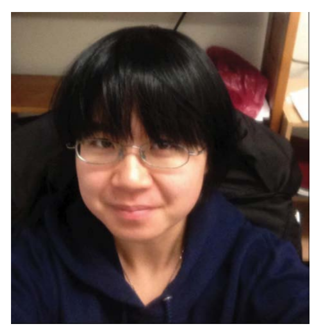
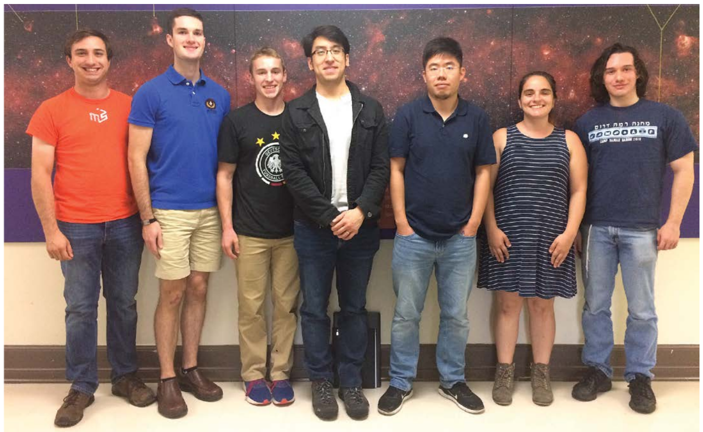
Arrivals: New Postdocs



Meng Sun is joining us from the University of Virginia. She specializes in studying stellar pulsations and asteroseismology. For her Ph.D. thesis, she investigated how oscillations in white dwarfs affect the orbits of binary stars through dynamical tides. At UW-Madison, she has joined the group of Professor Townsend and the MESA collaboration to develop new ways to model stellar pulsations so that anyone with a computer can generate models to explain data from spacecraft like TESS and Kepler, and to better understand how binary systems of stars evolve as their constituent stars age. Welcome to Madison, Meng!

Sabyasachi Chattopadhyay is a Washburn Labs Postdoctoral Fellow, joining us from IUCA in India. He is world expert in assembling and polishing fiber bundles for integral field spectrographs, having done his Ph.D. on the construction and commissioning of integral field spectrographs. Before joining UW-Madison, he also worked on detecting exoplanets using integral field spectrographs. At Washburn Labs, Sabyasachi will work on building the fiber bundles for the Local Volume Mapper which is part of the Sloan Digital Sky Survey V. We are thrilled to enrich our instrumentation program with arrival.

Department News



Arrivals: Welcome, Graduate Students!

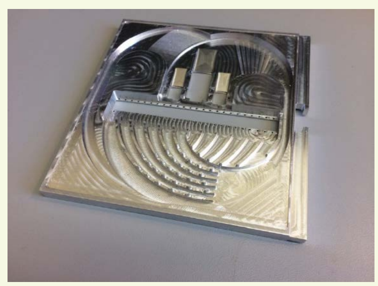
Andrew Nine, Indiana University, will work with Professor Bob Mathieu on understanding stellar evolution through observations of open clusters. **Anthony Taylor**, **Harvard University,** is working with **Professor Amy Barger** on high-redshift galaxy evolution. **Dan Rybarczik, Boston University,** will work with **Professor Snezana Stanimirovic** on using data from the 21 Sponge Survey with the VLA to study small scale structure in the interstellar medium. **Francisco Ley, Pontifica Universidad Catolica de Chile**, with work with **Professor Ellen Zweibel** on modeling particle heating in clusters of galaxies. **Ka-Ho Yuen, Chinese University of Hong Kong,** will work with **Professor Alex Lazarian** on using the new "velocity gradient technique" to trace magnetic fields in the Milky Way Galaxy. **Melissa Morris, University of Texas-Austin,** will work with **Professor Eric Wilcots** on the CHILES (Cosmos HI Large Extragalactic Survey) survey to illuminate the role of neutral gas in galaxy evolution. **Teva Ilan, Princeton University**, will work with **Professor Sebastian Heinz** on modeling the dynamics of relativistic jets to better understand the role black holes play in regulating star formation in galaxies.

Departmental Awards and Honors

2017/18 was another year to be proud of as Badger astronomers. We celebrated many awards and recognitions, including the following:

- **Professor Amy Barger** was inducted into the **American Association for the Advancement of Science**, one of five new members from UW-Madison. She is recognized for her contributions to our understanding of the evolution of black holes from the early universe to the present day.
- **Yi-Hao Chen** and **Diego Gonzalez Casanova Gallegos** were awarded **Bautz Travel Fellowships** to attend international conferences in Sicily, Italy, and Cozumel, Mexico, respectively.
- Astronomy graduate student **Melissa Morris** was awarded the **2018 Fluno Fellowship** to support her work on radio galaxies with **Professor Eric Wilcots**. The Fluno Fellowship is given to outstanding graduate students to afford them independence in pursuing their scientific goals.
- **Professor Elena D'Onghia** was awarded a **UW Vilas Fellowship** to study the motion of stars in the Milky Way using the data from the new Gaia satellite during her sabbatical.
- **Anthony Taylor** and **Teva Ilan** share the 2018 **Diermeier Family Foundation Graduate Fellowship** to support their first-year research with **Professors Amy Barger** and **Sebastian Heinz,** respectively.
- **Camilo Machuca** received an **NSF Graduate Fellowship** to study the life cycles of gas in galaxies using the MaNGA Survey, part of the Sloan Digital Sky Survey IV, with **Professors Matt Bershady** and **Eric Wilcots**. These competitive fellowships fully support a graduate student for three years.
- **Dr. Emily Leiner** received an NSF postdoctoral fellowship which she has elected to take to **Northwestern University**.
- The **WHAM** Team celebrated the 20-year anniversary of the WHAM telescope with the public release of the **first ever** spectroscopic map of ionized hydrogen of the entire sky.
- **Cory Cotter** & **Sam Carman** received the 2017 **Doherty Award** for excellence in research and academic performance by undergraduates in the UW-Madison Astronomy Department.
- **Chad Bustard** won the 2017 **Jansky Award** for Astronomy and Physics graduate students for his work with **Professor Ellen Zweibel** on Cosmic Ray driven winds.
- Badger alumna **Claire Murray** received the 2018 **Robert L. Brown Outstanding Doctoral Dissertation Award** from the National Radio Astronomical Observatory (NRAO) for her analysis of the thermal state of the interstellar gas of the Milky Way, work she did with **Professor Snezana Stanimirovic.**

One More Helping of our "High Fiber Diet"



We need your help to build a new instrument for SALT. Our High-Fiber-Diet design converts the Robert Stobie Spectrograph into an Integral Field Spectrograph, feeding light through 274 fibers, each creating a spectrum from a different part of a galaxy. At $50,000, this is an affordable way to give SALT a new instrument. You can see an early prototype our Washburn Labs have built in the image above.

At $46,681 raised to date, we are tantalizingly close to fully funding the instrument. Please help put us over the top. Any gift of $100 or more **adopts** a fiber in your name or in the name of somebody you wish to honor. We are thankful to announce a new way to double your impact: Every dollar you donate between now and the end of the year will be matched by a generous pledge by Astronomy BOV member and UW-Madison Chancellor Emeritus **John Wiley**, in memory of his late wife, **Georgia Anne Blanchfield** (up to a total of $3200). **Funds raised in excess of our goal may be used to support other future department instrumentation projects.** We aim for first light in 2019.

Will you pitch in to finish our fund drive so we can give SALT 274 new sets of fiber eyes? To find out how, see the contributions form on **page 3**.

Wisconsin's IceCube Helps Usher in the Multi-Messenger Era


IceCube neutrino observatory (image: WIPAC)

Welcome to the era of **multi-messenger astronomy,** realizing a decades-old promise of studying the cosmos using a combination of light, gravitational waves, and cosmic ray particles. Wisconsin has played a key role in this transformation.

On July 9th 2018, the IceCube Neutrino Observatory, designed and operated by UW Madison and the Wisconsin IceCube Particle Astrophysics Center, announced a major breakthrough: The discovery of an ultra-high energy neutrino emitted by a black hole belonging to a special class of so-called blazars. This discovery cracks open one of the longest standing problems in astrophysics: **where do cosmic ray particles come from?** Because of IceCube's discovery, we now know that supermassive black holes produce at least some of these cosmic ray particles.

IceCube scans a cubic-kilometer of Antarctic ice for ghostly Cherenkov light emitted by neutrinos zooming through the earth. By correlating the detection of a particularly high-energy neutrino with gamma rays observed by NASA's *Fermi* space craft, scientists from a large international collaboration led by UW Madison astrophysicists were able to locate the origin of that neutrino in a galaxy 5.7 billion light years away. The neutrino was produced by a jet of magnetized plasma shooting out from the supermassive black hole in the galaxy's center, pointing straight at us. Inside this jet, collisions between energetic protons and photons generate a shower of different sub-atomic particles, including neutrinos like the one detected by IceCube.

The discovery proves that jets from supermassive black holes are capable of producing *some* (though likely not all) of the highest energy particles in the cosmos, the first bona fide identification of such a source. It also demonstrates that blazar-like jets must contain protons, painting a richer picture of how black holes swallow and eject gas than was possible before.

After 20 years of planning and construction, the hard work of scientists, engineers, and support staff operating a massive observatory in one of the most inhospitable places on earth has paid off handsomely. **Jay Gallagher**, UW Astronomy Professor Emeritus and IceCube team member, says "*This discovery is a huge step towards understanding the still mysterious properties of cosmic high energy particle accelerators and their influence on galaxies.*"

The IceCube discovery comes on the heels of another exciting multi-messenger announcement: The first simultaneous discovery of gravitational waves and electromagnetic radiation from two merging neutron stars. This discovery solved a long-standing puzzle: The nature of so-called short gamma-ray bursts, which we now know are mergers of binary neutron stars. And it involved similarly heroic feats of detection by the LIGO gravitational wave observatory.

For the first time, we can augment light, the trusted workhorse of human astronomers for eons, with two amazing new tools. The ultimate prize, weaving all three of these threads into one exciting fabric of discovery, still awaits: The discovery of cosmic neutrinos from a source of gravitational waves. Neutron star mergers must emit copious amounts of neutrinos, albeit at lower energies than those detected by IceCube.

IceCube and LIGO have opened two brand new windows to the cosmos, and Wisconsin has a front row seat. Congratulations to fearless sifters and winnowers of the IceCube team, led by **Professor Francis Halzen**, who have added a brand new perspective from which to study our universe!

Profile: Ali Bramson *Continued from page 3*

Ali Bramson gives an outreach presentation about Mars

knowledge would enable astronomers to calculate how far down the ice is and if it would be accessible by humans if they were sent to Mars, as organizations such as NASA and SpaceX hope to do.

"*If we know there are resources [...] and we can get at them, that makes the possibility of sending humans there a lot more likely,*" Bramson said. "*I'm working to find out whether you have to just scrape away a couple centimeters of dust or you have to drill down meters.*"

In addition to researching ice on Mars and exploring whether it could be turned into drinkable water or rocket fuel, Bramson's postdoc research also focuses on understanding the volcanic history of the Moon and how it formed. Bramson works with Arecibo again in this research by sending a radar signal out from the telescope. The signal then bounces off the moon and into the Lunar Reconnaissance Orbiter at different angles, providing Bramson with data about what's happening on the lunar surface and subsurface. By researching the Moon and its physical features, scientists will be able to tell why the Earth-Moon system looks the way it does.

"*There is a renewed interest in sending people to the Moon,*" Bramson said. "*If we set up a base on the Moon, it may help us send humans further in the solar system. This goal is in the back of everybody's heads, including NASA, to send humans into space again beyond low-Earth orbit and to develop the ability to send humans to another planet to live. A lot of that will involve creating new technologies, which will stimulate innovation and economic development. It's not like we're just sending a rocket full of money up into space. That money all gets spent down here in our economy to make these things happen.*" Through the work of Badger Ali Bramson, the journey to Mars is turning from science fiction to science.

"*Follow your interests,*" Bramson said when asked what she would advise undergraduates to do. "*Pursue areas that you like until you find what career path or what skill set you really like working with. Some of my favorite classes were those that I wasn't doing because I had to, but because they were interesting and they reminded me that I love learning for the sake of learning.*"

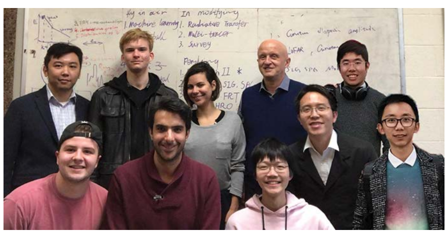
To learn more about Bramson, visit her website at https://www.lpl.arizona.edu/~bramson/

Innovations in Research and Teaching

Finding Order in Turbulence

The galaxy is permeated by magnetic fields, tangled and folded like a bowl of spaghetti in a colander. Measuring magnetic field strengths and orientations in space is useful for mapping the motions of gas in our galaxy, understanding the formation of stars, and cleaning up the foregrounds to measurements of the cosmic microwave background. It also turns out to be really *hard* and when the field lines are spaghettified by interstellar turbulence, the problem would appear to become intractable.

Badger ingenuity to the rescue: Professor **Alex Lazarian** and his group have invented a clever way to disentangle the mess. The solution, it turns out, lies in the turbulence itself.



The Lazarian Group in Chamberlin Hall

Lazarian, a world-expert in the nature of magnetic turbulence, started with the fact that the presence of magnetic fields affects the properties of turbulence just as the turbulence affects the magnetic fields: They are coupled. Turbulence in the presence of magnetic fields becomes anisotropic: Generally, it is stronger in directions *perpendicular* the field than *parallel* to it. If you have a way to measure the preferred direction of the turbulence, you can measure the direction of the magnetic field.

This turns out to do the trick: We can measure velocities and densities of turbulent gas using radio astronomy. And by looking for gradients, i.e., the magnitude and direction of changes in the velocity or density, we determine the directionality of the turbulence. *Bingo*: Field orientation measured. And because velocities in measurements of the interstellar gas encode distance information from the rotation of the Milky Way, this turns out to be a 3D measurement, distance included!

The new gradient technique enables many new types of measurements in astronomy. This was on full display at the 2018 Midwest Magnetic Fields Workshop, an annual gathering of connoisseurs of magnetic fields, organized by Lazarian and his group in Madison. It seemed like every other talk referred to this method and how it is transforming the study of interstellar plasmas. Madison astronomy—it's magnetic.

Astronomy 103-online

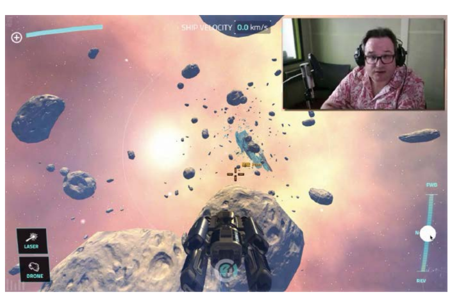
In the summer of 2018, we offered our very fist online course, Astronomy 103-online.

Online learning is both a challenge and an opportunity. It is harder to establish meaningful connections with students at a distance, when the social cues we use to read students' responses in class are not available. It is difficult to develop new teaching tools and new approaches at engaging students when we have been trained to provide content by lecturing at a black board.

But these difficulties are more than compensated for by the possibilities online learning offers. For one thing, it opens higher education up to a much wider audience. Students who have to leave campus during the summer can continue their education and complete their degrees faster. Enterprising High School students can enroll for credit even before entering college officially. And students from campuses that might not have an astronomy offering can study astronomy and transfer those credits later if needed.

And, more importantly, online courses offer completely new methods of teaching and learning: Videos, interactive learning experiences, citizen science, and video games are just the tip of the ice berg here.

UW Astronomy Professor **Rich Townsend** and graduate student **Dhanesh Krishnarao** built the course from the ground up around the UW-developed award-winning video game "*At Play in the Cosmos*." A lot of innovation went into their course: 5-Minute Universe videos where the two present bite-sized content. iPad-based tutorials that sketch physical concepts in real time. Real-world projects like devising a night sky guide for students' families. And guided video-game play-throughs and pre- and post game de-briefing videos to connect the video-game based homework to the rest of the course.



Rich Townsend narrating a play-through of the game

"*Overall, I think the course went really well. We're excited to run it again next year,*" said Townsend. "*Once the class grows to a couple hundred people, we will have to make some necessary compromises—perhaps fewer essays and more multiple-choice questions that can be graded automatically.*"

But the two-person team will definitely continue the interactive approach, with students joining frequent discussion forums and clarifying new ideas in live Q&A sessions.

Townsend and Krishnarao in 5-Minute Universe video

And even though lectures and videos were pre-recorded, the team set them up so students felt as if the professors were truly there. "*There definitely is an instructor presence throughout the course rather than being hands-off, and that's important to give students a sense they are not being taught by a machine,*" said Townsend. "*They are really being taught by a human.*"

Townsend and Krishnarao hope students will reach for the stars with their new knowledge of astronomy. "*[One of] the assignments we had the students do involved having them plan for the next total eclipse that will go across the United States in 2024,*" Townsend said. "*My big hope is that at least some of the students from the online class will actually make this trip because they already have a plan in place to see it.*"

Experiencing astronomy does not require sitting in a lecture theater. It requires innovative approaches at bringing students in contact with real astronomical data, with demonstrations, and, most importantly, with the night sky. Astronomy 103-online delivered that experience.

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The shiny domes of Sterling Hall: Our roof telescope refurbishing project is taking shape, with a fresh coat of paint for our three telescope domes. Thank you, **Peter Livingston** and **Sharon Stark**, for making our roof upgrade possible with your generous gift.

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Current and alumni Badger Astronomers at the CHILES team meeting in Newcastle, UK. From left to right: Catherine Witherspoon, Eric Wilcots, DJ Pisano, Kelly Hess, and Julie Davis