UNIVERSITY OF MICHIGAN

Fall 2018

Michigan Astronomy News

FOR ALUMNI & FRIENDS OF THE UNIVERSITY OF MICHIGAN ASTRONOMY DEPARTMENT

Letter From The Chair

Dear Friends of Michigan Astronomy!

Today, I am pondering the imponderable. What do I mean? In part my pondering relates to the status of astronomy writ large, but it also has to do with the future of your astronomy department and our wonderful scholars at all career stages. Astronomy at this moment is on the cusp of major discoveries as we are in the process of building some of the world's largest telescopes. These future observatories will take nearly a decade to build, but will then revolutionize our understanding of the universe and beyond. The largest of these, to be built by a European consortium, will be nearly ½ a football field in size! Well – 42 yards to be exact. What does this mean? You can think of telescopes as light buckets – the bigger the bucket, the more light you can catch. This means we can detect fainter and fainter objects. These faint light sources could be the light from the very first stars that were born approximately 300,000 years after the Big Bang or maybe, just maybe, finding out whether we are alone in the Universe.

Undergraduate poster fair 2018. (Photo Credit: S. Murphy.)

So why am I pondering? First, because this is really really cool. It is that, but this is also on my mind because Michigan Astronomy is trying very hard to have a seat at this table. Right now I can state that we have the support of you, our University, and our college. Next year, I hope to report back with more concrete information. But for now, I want you to ponder with me. If we did detect or believe that we have evidence for life elsewhere in the Universe – what would that mean? What are the implications for this in terms of religion, philosophy, or for society?

That is the seed for a fun conversation. Does it matter? To me it does. First, we have to recognize this question is abstract. Knowing that life might be present elsewhere does not mean you should expect a visit from ET tomorrow. The laws of physics (as we know them today) suggest that travel between the stars is very difficult, if not impossible. Maybe someday we will figure this out. But there is another factor here. Our Sun and its planets are 4.6 billion years old, while our galaxy is more than twice as old as our solar system. Thus, if life exists elsewhere, there should be civilizations that are billions of years old; these aliens should be touring the galaxy. And yet they have apparently not communicated! This conundrum is called the Fermi paradox after the famous physicist, Enrico Fermi, who first posited this question. Second, there is a strong argument that any detected life would not be "intelligent" or able to communicate. Our own planet's history is dominated not by our species, but rather by single-celled organisms such as the blue-green algae cyanobacteria. Even today, by mass, our planet is dominated by single-celled life. So no visits by ET and no communication. Given that, what does this mean? Well - ponder the imponderable….

As always, I wanted to send a big thank you to all our supporters! We remain grateful for your continued support of our department and our fantastic wonderful young scientists. So – thank you. If you are in town you are more than welcome to visit our department in West Hall. You are welcome anytime. If you do stop by, go ahead and ask someone to explain one of the beautiful astronomical images that grace our walls. Then you can see for yourself the joy of science come to life.

—Ted Bergin

Department of Astronomy Fast-Facts

People

- 25 Tenure-track Faculty (6 are within Physics & History)
- 6 Research Scientist/Professor Faculty
- 4 Emeritus Faculty
- 22 Postdoctoral Fellows/Lecturers/Visitors
- 32 Graduate Students
- 9 Administrative and Technical Staff
- 50 Undergraduate majors and minors

Computing

- University-wide Flux cluster, with approximately 27,000 cores, InfiniBand network, and 1.5 PB scratch storage.

Observatories

- Magellan Telescopes: 2 x 6.5-m telescopes at the Las Campanas Observatory, Chile
- MDM Observatory: a 1.3 and 2.4-m telescope on Kitt Peak, Arizona
- Curtis-Schmidt telescope at the Cerro Tololo Inter-American Observatory, Chile
- CHARA optical/infrared interferometer on Mount Wilson, California
- Angell Hall student telescopes and planetarium, and Detroit Observatory Fitz telescope, on Main Campus

News From West Hall

Undergraduate News

This was another great year for our undergraduates, with 22 graduating in either the Astronomy & Astrophysics program, or the Interdisciplinary Astronomy program. In the former group were Jesse Barnes (taking up a software engineer position at Logic Solutions, Ann Arbor), Marah Brinjikji (going to Arizona State for graduate work), Zachary Chipman, Benjamin Dittenber (continuing research on supermassive black holes), Zachary Felker (going to the University of Central Florida for graduate work), Miriam Gomez-Elegido (going on to a master's in Data Science at UM), Mariam Haidar (a Peace Corps volunteer in Tanzania and secondary math teacher before graduate school), Erica Hammerstein (going to the University of Maryland for graduate work), Helen Januszewski (taking a research internship with the Gemini Observatory), Christopher Kulwik (planning on technology consulting), Andrea Lin (going to Penn State for graduate work), Nicholas Mattes, Andrew Nassab, Stephen O'Keefe, Brendan Reed (going to Indiana University for graduate work), Adam Rubenstein (going to the University of Rochester for graduate work), Veenu Suri and Shangjia Zhang (going to the University of Nevada for graduate work). In the Interdisciplinary Astronomy program were Daniel Harris (who will attend medical school at Wayne State), Jiale Huang (joining the autonomous vehicle team at NVIDA), Chris Lee and Alexi Schnur (planning on graduate school after a gap year).

Recent graduate students and advisors at Winter Commencement. Back row: Drs. Marina Kounkel, Traci Johnson, Meghin Spencer, Jeb Bailey and Hui Li; Front row: Profs. Lee Hartmann, Keren Sharon, Mario Mateo and Oleg Gnedin. (Photo Credit: L. Johnson.)

Graduate Student News

Alejo Stark (advisor **Prof. Chris Miller**) defended "Galaxies, Gravitation and Cosmology: On Escaping Galaxy Clusters in Accelerating Universes" on December 15th. Alejo derived and tested a novel model that takes into account the effects of our accelerating universe at the scale of galaxy clusters. The model implies that in an accelerating universe, the escape velocity profile of galaxy clusters is lower than that expected from a universe that is not accelerating. If the universe is accelerating, galaxies confined to their clusters have an easier time escaping them. He studied how the observed profiles can be de-projected via a function that depends on the cluster velocity anisotropy profile, developing a novel approach to deriving such profiles with joint dynamical and weak lensing data. Additionally, the cosmology-dependent model of the escape velocity profile can be utilized to constrain cosmological models, with the capacity to set competitive constraints on models of the accelerating universe in the near future.

Traci Johnson (advisor **Prof. Keren Sharon**) defended "Focusing Cosmic Telescopes: Quantifying the Systematics of Strong Lensing Mass Models in the Era of Precision Lensing" on February 20th. Traci studied gravitational lensing, the bending of space-time near massive structures, a prediction of Einstein's General Relativity. In her research, she used simulations, as well as data from the Hubble Space Telescope and the University of Michigan's access to the Magellan Telescopes. Harnessing the magnification power of gravitational lensing, and a new algorithm she developed as part of her thesis, she measured the sizes of star forming regions in a distant galaxy that are smaller than what can be resolved even with the Hubble Space Telescope. Her recent work will inform studies of the modes of star formation at an epoch when the Universe formed most of its stars.

Kamber Schwarz (advisor **Prof. Ted Bergin)** defended "Evolution of the Volatile Inventory During Planet Formation" on July 17th. She explored one of the major results from the new facility in Chile, the Atacama Large Millimeter Array, regarding the primary carriers of carbon and nitrogen within protoplanetary disks. Knowing the abundance of gas phase species in the disk provides the starting composition for the atmo- *(continued on p. 5)*

Cover Images: Fish Lake star party (hosted by EMU) and the Table Mountain (north-central Washington State) star party, both by Astro Minor (Aerospace Major) class of 2019 Dylan Ma. See the article by Prof. Sally Oey on p. 4.
Newsletter Production: P. Hughes

Bringing The Milky Way Back To Michigan

Prof. Sally Oey discusses the Michigan Dark Skies program.

If you remember growing up under a starry sky, then either you're of a certain age or you're one of the lucky few from a rural area. Over 80% of people now live in a light-polluted environment where they never see the full glory of the star-studded night or glowing blaze of the northern lights. When I bring our Astro 461 students to the "Michigan-Dartmouth-MIT" Observatory on Kitt Peak, Arizona, fully half of them have never seen the Milky Way! That's right, we're so out of touch with the natural world that *half of Astronomy majors have never seen the Milky Way.* So one of the things on the curriculum in Astro 461 is the cost of light pollution.

Besides **skyglow** that destroys the night sky, there are two additional forms of light pollution: **Glare**, which impairs vision due to lights that are too bright or insufficiently shielded; and light **trespassing** where it's unwanted and often a nuisance. Since light is a form of energy, light pollution is literally wasted energy and dollars down the drain. According to the non-profit, International Dark Sky Association (IDA), light pollution in the US generates the equivalent of 3 billion cars' worth of carbon emissions, wasting about $3 billion annually. But even worse are the consequences of altering the natural ecosystem. Biologists are only beginning to understand some of the consequences of artificial light at night (ALAN), but almost all of the findings indicate significant disruptions to wildlife. For example, many species of songbirds migrate at night, navigating by the moon and stars; ALAN confuses birds and greatly exacerbates their collisions with buildings, which is by far the main cause of bird mortality. The Washington Post[1] reports that this causes up to a billion birds deaths annually. Since Michigan is on major Great Lakes migration routes, local organizations like Washtenaw Safe Passage and Detroit Audubon have run campaigns to raise awareness about turning off lights in large buildings at night. Other wildlife, including economically important species of fish and pollinating insects are also adversely impacted.

Humans are another species whose health is affected by light pollution. The American Medical Association[2] issued an 8-page report detailing how ALAN impacts our sleep cycles and the production of melatonin. The disruption of this important hormone is linked to cancer, diabetes, and cardiovascular disease. Blue-rich LED lights also contribute to permanent retinal damage in the eyes. Moreover, poor lighting can degrade safety. For example, glare hinders visibility, and over-illumination generates deep shadows and destroys night vision. As a daytime species, we are inherently afraid of the dark, but it's worth noting that after decades of research, there is no consensus[3] on whether lighting actually deters crime.

Having learned about light pollution in Astro 461 last year, our class returned to Ann Arbor to find that the city was planning to replace the pedestrian globe lights in Kerrytown with updated LED globe fixtures. This proved to be the catalyst for launching our local advocacy group, Michigan Dark Skies[4]. With support from our Chair, Ted Bergin, we started by writing a letter to the City Council explaining about light pollution and requesting that the City consider transitioning to dark-sky friendly lighting principles. The letter was signed by about 40 students, alumni, researchers, and faculty of the Astronomy Department. Ann Arbor is an environmentally aware city, even having issued a Climate Action Plan in 2012, so we were delighted to be invited to City Hall within a few weeks of submitting the letter. With Pat Seitzer, who serves on the light pollution committee of the American Astronomical Society, we had a productive meeting with city staff, who agreed to investigate options for the globe lights. Last March, the public was invited to critique some sample lights installed near Zingerman's Deli. After reviewing our feedback, the city decided to adopt a globe model with internal plates that block uplight and have the IDA-approved, "warm white" color for the Kerrytown project. These are currently being installed.

In the long run, city-wide change on these issues requires implementing new policies. A few City Council Members had contacted us directly to follow up on our original letter. One of them was then-Member Jason Frenzel, an advocate for environmental issues. He suggested approaching the City's Environmental and Energy Commissions about the possibility of developing a lighting ordinance. This had certainly been a long-term goal, so we were delighted to pursue this so soon. It helped that we'd been growing a broader coalition, reaching out to our local amateur astronomy club, the University Lowbrow Astronomers; local bird advocacy groups, Michigan Audubon and Washtenaw Safe Passage; astronomers at Eastern Michigan University; and various other faculty and community members. Michigan Dark Skies now includes members from physics, engineering, biology, optometry, law, architecture, political science, and K-12 to Ph.D. students. We also have some alumni in other parts of Michigan and elsewhere. The diversity of expertise, perspectives, and connections has been a tremendous asset.

The Energy Commission responded enthusiastically, and this spring decided to move forward with the lighting ordinance. Commissioner John Mirsky has championed the project and has partnered with us to develop the text, after it emerged that City staff would not be able to draft it. We're also fortunate to have connected with Mary Stewart Adams, founder of the Headlands International Dark Sky Park in northern Michigan, one of the first-ever IDA-designated dark sky parks, and the most prominent dark-sky advocate in the state. A UM alum who frequently travels to Ann Arbor, she's been a valuable resource and collaborator in drafting the ordinance. Along with Pat Seitzer, Charlie Nielsen and Norbert Vance of the Lowbrows club also provide critical support and expertise. The next step was to gain the support of the city Planning Commission, and we were again especially grateful that two of these commissioners have also joined our drafting working group. We obtained template ordinances from the IDA and the Pennsylvania Outdoor Lighting Council, which form the basis for our draft. We hope to present the final product to the City Council in 2019. Although this has turned out be quite a complex journey, we've been remarkably fortunate in finding terrific allies around every corner, and we're deeply grateful to all of them.

Meanwhile, Michigan Dark Skies continues advocacy on other fronts. Graduate student Ryan Farber built our gorgeous website, using photography by undergraduate Dylan Ma. Ryan and fellow Ph.D. student Gillen Brown are providing input to the city's Student Advisory Council and a new development project, Broadway Park. Aerospace graduate student Ben Greaves presented to the popular North Campus Sustainability Hour, and Physics Ph.D. student Stephanie Hamilton is slated to present at Nerd Nite Ann Arbor. Our group has also been featured in "The Green Room" show on WEMU radio and CTN community TV, as well as LSA Magazine on-line. Our message is simple: *Light only what you need, only when you need it, no more than needed, and no bluer than needed.* Please get in touch to support us and help spread the word!

https://sites.lsa.umich.edu/darkskies/

1. Susan Milius, Science News, "Windows may kill up to 988 million birds a year in the United States", January 27, 2014.
2. American Medical Association, "Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting", Council On Science And Public Health, CSAPH REPORT 2-A-16, 2016.
3. http://darksky.org/light-pollution/lighting-crime-and-safety/.
4. https://sites.lsa.umich.edu/darkskies/.

(continued from p. 3) spheres of gaseous giant planets, while the composition of ices influence the composition of solid bodies, such as terrestrial planets. She showed that volatile nitrogen is likely found mainly in molecular form, which remains in the gas phase throughout much of the disk. This makes it hard for nitrogen to be incorporated into terrestrial worlds. CO, one of the main carbon carriers, was found to be under-abundant in the disk of TW Hydrae. This is important because CO is a major tracer of the hidden mass of molecular hydrogen. Hydrogen, the most abundant element, dominates the disk mass but it is does not emit at typical conditions, so H_2 is hidden and CO is our proxy. This demonstrates that it is CO, and not the total gas, which is missing in this one system. Kamber also explored the fate of CO by chemical modeling suggesting that gas giants which form after a million years of chemical evolution may accrete envelopes under-abundant in volatile elements such as carbon, nitrogen, and oxygen.

Prof. Hugh Aller retired this year. He received his B.S. from the University of Michigan in 1964, his M.S. in 1966 and his Ph.D. in 1968, joining the faculty in 1969. He served as chair for a decade, and was named the Ralph B. Baldwin Professor in 2008. (Photo Credit: S. Murphy.)

Postdoc News

Dr. Bailey Tetarenko joined the department this Fall, the latest winner of the McLaughlin Fellowship.

Faculty News

Prof. Eric Bell has been honored as an Arthur F. Thurnau Professor, for his commitment to students and for excellence and innovation in teaching.

Alumni News

Prof. Ilse Cleeves, who recently joined the University of Virginia faculty, has received the Annie Jump Cannon Award of the AAS, for her groundbreaking work on planet formation and protoplanetary disks.

Dr. Anne Jaskot will join the faculty of Williams College in 2019, after completing her Hubble Fellowship in the Five College Astronomy Department.

Prof. Jessica Werk (Department of Astronomy, University of Washington) has been awarded an early career fellowship from the Alfred P. Sloan Foundation.

Binary Black Holes In Active Galaxies

Postdoctoral Researcher Dr. Jessie Runnoe explains why two black holes are better than one.

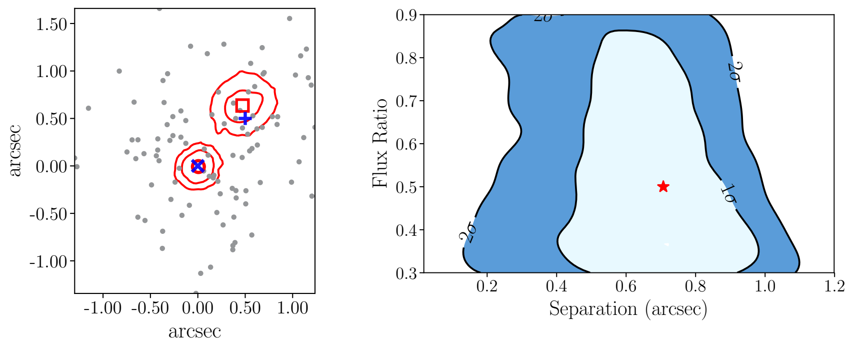

Figure 1. An illustration of how BAYMAX will evaluate Chandra images. The left panel shows a simulated Chandra image, where the blue crosses mark the location of the two AGN, the red contours show their likely positions from BAYMAX, and the grey points are photons that Chandra might detect. The right panel shows that this system is most likely to be a 0.7 arcsec separation dual AGN where one member is twice as bright as the other.

Active galactic nuclei (AGN) are the luminous result of gas falling onto supermassive black holes in the centers of distant galaxies. Since galaxies are thought to assemble via a hierarchical merger process over cosmic time, pairs of AGN should be an inevitable byproduct. Initially widely separated, the AGN will spiral in towards the center of the merged galaxy and eventually coalesce, emitting gravitational waves before they do. It is important to find these sources because at the closest separations they become bright gravitational wave sources for detectors like Pulsar Timing Arrays and the Laser Interferometer Space Antenna (LISA).

To date we have observed the wide-separation, dual AGN that represent the early stages of this evolutionary process. One of the best approaches for finding dual AGN is to use the space-based Chandra X-ray Observatory. Chandra detects luminous X-rays that are the hallmark of growing supermassive black holes, and if they are separated widely enough they are easy to distinguish. However, in the name of finding the closest duals in the distant universe, observers push the limits of what Chandra can do and there are many more claims than reliable detections. Close separation binaries are harder to find because they are too close together to be imaged directly, so we have to rely on indirect techniques. As a result, gravitationally bound binary supermassive black holes that are expected to follow the dual evolutionary stage have proven elusive with no unambiguous candidates known.

At the University of Michigan, we are working on all fronts to find both dual AGN and binaries. For her dissertation, graduate student **Adi Foord** (left) is working with **Prof. Kayhan Gültekin** (center) to develop a statistical tool called BAYMAX (Bayesian AnalYsis of Multiple AGNs in X-rays) that will find dual AGN at the limits of Chandra's ability to separate them. Current methods are completely subjective and become ambiguous for small separations, so the goal of BAYMAX is to provide a quantitative measure of the likelihood that a Chandra image has one or two AGN. Figure 1 shows an example of BAYMAX's current performance. It shows a computer simulation of two AGN at the blue crosses, while each gray point represents an X-ray photon that Chandra would detect. Statistically, this is most likely to be a dual AGN separated by 0.7 arcseconds on the sky, where one member is twice as bright as the other. When BAYMAX is finished, it will be possible to perform a census of all the dual AGN in the observable universe.

At the same time, I am using Michigan's time on MDM observatory to search for close-separation binaries by making an analogy with binary stars. In this approach, the binary sits in a disk of gas like the simulation shown in Figure 2 and a Doppler shift of the AGN light is taken as a signature of its bulk orbital motion. Periodic changes over several orbital cycles would be smoking gun evidence for a binary, but we cannot hope to observe that in our lifetimes because the periods are expected to be very long, a few hundred years. Instead, the name of the game is to compile as many lines of corroborating evidence to determine the nature of a candidate binary: a true binary will pass any test you throw at it, whereas interlopers will show their true colors eventually.

Another graduate student, **Kevin Whitley** (p. 6, right), is working with Profs. **Gültekin** and **Mateusz Ruszkowski** (left) on one such corroborating test. He is developing a theoretical model for how the binary would affect the disk of gas it is embedded in. The simulations show that the binary opens a gap in the disk, which will reduce the amount of light emitted from the system. Eventually, Kevin can compare his models to observations of AGN to search for the signature of the gapped disk, which would be indirect evidence for a close-separation binary.

The long-term goal of the group is to detect dual AGN and binaries at a range of separations. This will let us track the "flow" of systems as they spiral in, revealing the poorly understood underlying physics that governs this process.

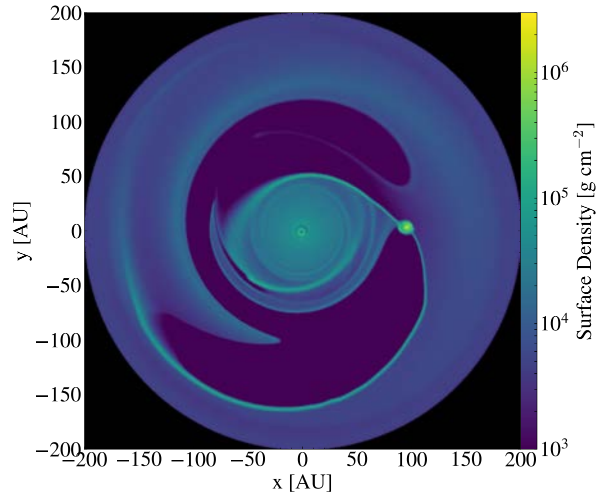

Figure 2. Kevin Whitley's simulation of a binary (point-like objects at center and right) embedded in a disk of gas. The binary opens a gap in the disk, which could manifest as an observable signature of the binary in AGN.

Dr. Michael LoPresto discusses efforts to assess and improve instruction in general education astronomy courses.

Prof. Eric Bell and I first began the development and implementation of assessments for the introductory general education courses ASTRO 101 and ASTRO 102 as well as ASTRO 142 in 2013. Assessment surveys are given to students both prior to and after instruction , on the first and last day of class. They consist of 20 topical and 10 demographic multiple choice questions. The first 10 topical questions on the 101 and 102 surveys are on material covered in both 101 and 102 and the final 10 are course specific. The demographic questions survey class standing, ethnicity and gender identity as well as student opinions and attitudes about the courses and subjects.

The questions are a combination of ones adapted from other existing assessments such as the Astronomy Diagnostic Test (ADT), The Solar System Concept Inventory (SSCI), The Star Properties Concept Inventory (SPCI) , the Light and Spectroscopy Concept Inventory (LSCI) and others as well as questions specifically written for topics covered in the courses. The first two years of implementation of the surveys served as test period during which revisions were made based on input from a number faculty who regularly teach the courses.

The purpose of these largely qualitative assessments is to attempt to measure which concepts students appear to be learning or not learning in order to evaluate whether or not instruction on those concepts has been more or less effective and how it can be possibly improved. The normalized gain, g=(post-test score –pretest score) / (perfect score-pretest score) is used to show much learning gain occurred on the entire assessment or on and individual item from the pretest at the beginning to the post test at the end of the term. Educational research standards are that a gain of g= 0.3-0.6 is satisfactory, greater than 0.6 is considered excellent and less than 0.3 is considered low unless it is caused by a high pretest score , in which case there is not room for as much gain.

Over the last three years since the current versions of the assessments have been being used, most sections of ASTRO 101, 102 and 142 have shown gains throughout the satisfactory range. Gains on individual items have varied from section to section but are usually satisfactory and at times have been excellent. Most unsatisfactory gains are a result of higher pretest scores, but those that are not can be used to attempt to improve instruction in those areas. The assessments are anonymous, participating students do not identify themselves, so gains are only measured for the entire survey and specific items not for individuals.

Plans for possible assessments of ASTRO 127 , 115 and 104 are underway as well as for ASTR 201 as part of a review of the departments undergraduate program.

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