THE OBSERVER

NEWS FROM THE GREEN BANK OBSERVATORY
APRIL 2018 - VOL II ISSUE 2

DIRECTOR'S NEWS

Spring is here in Green Bank, at least in theory (and if it would stop snowing that would be nice). This means we are now ramping up for our influx of summer staff and the many summer programs which we host on site. From workshops on single dish radio astronomy for undergraduate and graduate students, to REU and internship positions, summer camps for teachers and students, amateur astronomy gatherings, Pulsar Search Collaboratory meetings and training, and the annual Space Race Rumpus bike weekend, there is something for almost everyone going on here during the summer months. During this summer we are also spending time looking toward the future of the Observatory. As you will see in the ASTRO2020 article within this newsletter, we are actively soliciting input from the scientific community to help us shape our future and working with plan for what Green Bank Observatory should look like in 2020 and beyond.

Enjoy Your Spring!

Karen O'Neil
Director

IN THIS ISSUE

NEWS

EXPRESSION OF INTEREST INVITATIONS

Geen Bank Observatory, LBO and NRAO invite submissions of brief Expressions of Interest (EoI) in PI-led "eXtra Large Proposals" (X-Proposals) for the GBT, VLBA and VLA requiring 1000 hours or more of telescope time, and running over multiple semesters (and possibly multiple VLA configurations).

X-Proposals are expected to be resourced by the proposing team. Projects should have extraordinary scientific merit and community legacy value, and will be expected to specify why the science goals cannot be achieved through the standard SRP/TAC process.

Responses will be used to gauge the level of community interest in such proposals, and their scientific potential. The observatories may not proceed to a Call for X-Proposals if, for example, there is judged to be insufficient community interest, scientific merit, or differentiation from Large Proposals.

The call for submission of EoIs is expected to be issued on June 1 with a deadline of July 11.

See the 2016 and 2017 NRAO User Committee reports for further background.

[greenbankobservatory.org/sciencedoc/16UCR.pdf]
[greenbankobservatory.org/sciencedoc/17UCR.pdf]

REU STUDENTS COMING TO GREEN BANK

Green Bank Observatory will be welcoming eight summer students in late May as part of the Research Experience for Undergraduates (REU) program and the Physicists Inspiring the Next Generation (PING) program. Students will be joining scientific and engineering staff for 10-12 week research projects and professional development activities. PING students will also spend one week mentoring middle school students participating in a science camp at the observatory. This core component of PING is designed to enhance the participation of underrepresented minorities in Science, Technology, Engineering, and Mathematics (STEM) fields. Green Bank Observatory will also be welcoming a graduate intern working in the digital electronics group.

ASTRO2020 UPDATE

The Green Bank Observatory kicked off plans for the Astro2020 Decadal Survey at the Winter AAS Meeting in Washington, DC. The effort started with the "Transformative Science for the Next Decade with the Green Bank Observatory" workshop in October 2017, which identified some key science drivers for the Observatory in the next decade. At the AAS meeting, Observatory science staff conducted an information-gathering session along with many of those very important booth and hallway conversations that spark new ideas. In January, we announced the Astro2020 activities for Green Bank with a letter from the Director to all who participated in the workshop and AAS activities to join the Observatory in crafting a series of science white papers in anticipation of a late 2018 call for papers. Science interests have been divided into seven scientific discussion categories and we are establishing teams for each category to identify key science cases and develop papers. The categories are:

- Fundamental Physics (e.g. gravitational waves, general relativity, equivalence principle)
- The transient sky (e.g. FRBs, SETI, Pulsars)
- Stars & star formation (e.g. turbulence, magnetic fields, multi-scale molecular clouds, diffuse environments, ISM)
- Galaxies & Galaxy Clusters (Milky Way and beyond) (e.g. cosmic web, HI extent of galaxies, galaxy structure, galaxy clusters)
- Astrobiology & Astrochemistry (includes comets, SETI)
- Planetary systems (e.g. sun, stars, asteroid, comets, exoplanets, planetary weather/atmosphere)
- Cosmology & Large Scale Structure

Response has been excellent with more than 60 scientists and astronomy professionals signing up for one or more discussion groups. We encourage anyone with interest in future science at Green Bank to join the Astro2020 team. More information about the Astro2020 program and information for interested participants is available at http://greenbankobservatory.org/science/astro2020/.

We hope to hear from you. We will keep you posted on the progress of the teams in upcoming newsletter articles.

Astronomers see galaxies merging throughout the universe, some of which should result in binary supermassive black holes. Credit: NASA

PULSAR WATCHERS CLOSE IN ON GALAXY MERGER HISTORY

Fifty years after pulsar discovery published, massive new data set moves closer to finding very-low-frequency gravitational waves, researchers say.

Gravitational waves are wrinkles in space-time that stretch and squeeze the distances between objects. In 2015, a hundred years after Albert Einstein realized that accelerating massive objects should produce them, these waves were finally detected from black holes with masses roughly 30 times the mass of our sun colliding with each other. However, Einstein's theory also predicts another kind of wave, one that comes from the mergers of black holes with masses of hundred million times the sun's.

Astronomers believe that nearly all galaxies have supermassive black holes at their centers. When two galaxies collide, these black holes will slowly fall toward each other, finally merging long after the initial galaxy collision. In the last stage of this process, as the two black holes spiral closer to each other, strong gravitational waves can be produced.

While these waves travel at the speed of light, their strength varies quite slowly, on timescales ranging from months to years. This means that gravitational wave observatories on Earth can't measure them. For that, you need an observatory with detectors light-years apart.

"We know that galaxy mergers are an important part of galaxy growth and evolution through cosmic time. By detecting gravitational waves from supermassive binary black holes at the cores of merging galaxies, we will be able to probe how galaxies are shaped by those black holes," said Sarah Burke-Spolaor, assistant professor at West Virginia University.

Fifty years ago, the February 24, 1968 edition of the journal Nature provided the solution, with the discovery of a new kind of star. This new star was curious, emitting regular radio pulses once every 1.3 seconds. Graduate student Jocelyn Bell (now Dr. Bell Burnell) was the first to spot the signal, seeing it as "a bit of scruff" in her radio surveys. Zooming in on the scruff, Bell saw the regular pulses from the star.

After first entertaining the possibility that the pulses could be the result of LGM, or "little green men," the new star was dubbed a pulsar, with the understanding that the pulses represented the rotation rate of the star. Such a rapid rotation rate meant that the star must be small, about the size of a city. Only a few years later, a pulsar in a binary system was found, and the first mass estimate indicated that this tiny object held about one and a half times the mass of our sun.

Observations from Green Bank Observatory in West Virginia (top), and Arecibo Observatory in Puerto Rico (bottom) combine to give NANOGrav the most sensitive data in the world for this search. GBO image courtesy of NRAO/AUI. Arecibo image courtesy of the NAIC – Arecibo Observatory, a facility of the NSF.

"Before this time, no one thought stars so small could actually exist! It wasn't until a pulsar was found at the center of a supernova remnant in 1968 that astronomers realized that pulsars were neutron stars born in the explosions of massive stars," said Maura McLaughlin, professor at West Virginia University.

The fastest pulsars, called millisecond pulsars, spin hundreds of times every second (faster than your kitchen blender!), and are the most stable natural clocks known in the universe. Pulsar astronomers around the globe are monitoring these stellar clocks in order to form a new kind of cosmic gravitational wave detector known as a "Pulsar Timing Array." By carefully measuring when radio pulses arrive from millisecond pulsars, astronomers can track the tiny changes in the distance from the Earth to the pulsars caused by the stretching and squeezing of spacetime due to a gravitational wave.

In the US and Canada, a group called NANOGrav (North American Nanohertz Observatory for Gravitational Waves) is searching for these gravitational waves using some of the largest telescopes in the world, including the Green Bank Telescope in West Virginia and the Arecibo Observatory in Puerto Rico. NANOGrav routinely joins forces with groups in Europe and Australia to improve their sky coverage and sensitivity. Collectively known as the International Pulsar Timing Array, the combined observations from these groups constitute the most sensitive data set in the world for searching for low-frequency gravitational waves.

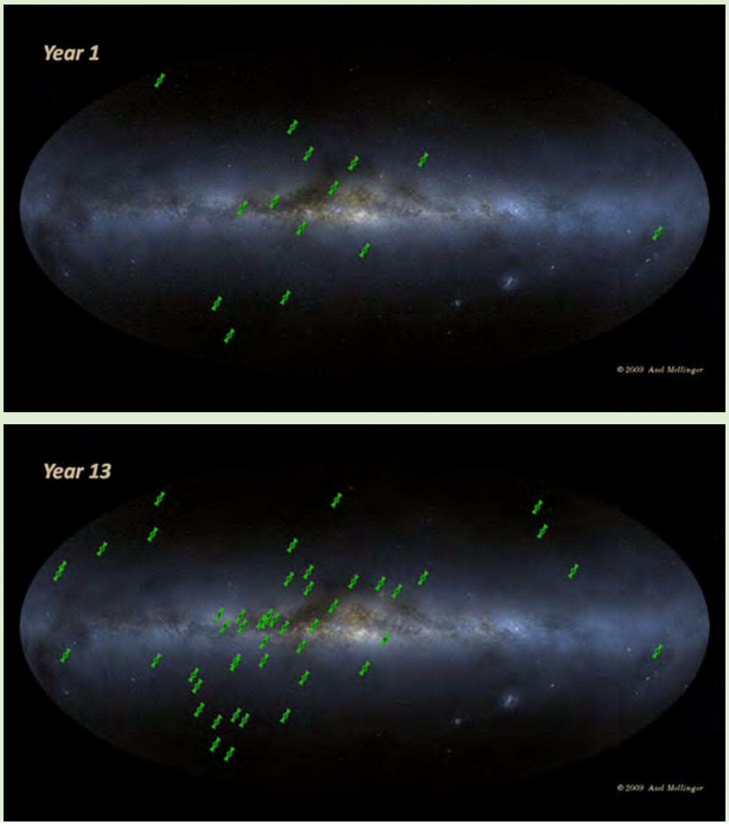
This month, fifty years after the publication of the first pulsar discovery, NANOGrav has submitted a pair of companion papers to the Astrophysical Journal describing eleven years of monthly observations of 45 millisecond pulsars along with the astrophysical implications of their results. For the first time, the data set includes a six-pulsar "high-frequency" sample, with measurements made every week to expand the pulsar timing array's sensitivity range. NANOGrav is able to set sensitive upper limits that constrain the physical processes at play in galaxy mergers. As their sensitivity improves, NANOGrav is uncovering new sources of background noise that must be accounted for. Most recently, uncertainties in the pull of Jupiter on the sun have been found to affect pulsar timing. As a result, the team is implementing new computational methods to account for this, in effect determining Jupiter's orbit more precisely than possible except by planetary missions.

"This is the most sensitive pulsar timing dataset ever created for both gravitational wave analysis and a host of other astrophysical measurements. And with each new release, we will add more pulsars and data, which increase our sensitivity to gravitational waves", said David Nice, professor at Lafayette College.

Last year, the journal that announced the discovery of pulsars once again played host to a pulsar first. In November, Nature Astronomy published their first-ever article describing the gravitational wave environment that pulsar timing arrays are working to uncover. By looking at galaxy surveys, the article estimates there are about 100 supermassive black hole binaries that are close enough to affect pulsar timing array measurements. Given their expected future sensitivity, the authors state that pulsar timing arrays should be able to isolate the gravitational waves from a specific individual galaxy within about 10 years.

"From city-sized pulsars spinning fast in galaxies to large, massive galaxies themselves and their merging central black holes, all in 50 years! That is a large step for humankind, and not one that we could have foreseen. What will the next 50 years bring? Pulsars and gravitational waves will continue to be big news, I'm sure!" said Jocelyn Bell Burnell.

A century after Einstein first predicted them, gravitational waves were finally detected. Now, 50



Since beginning regular observations in September 2004, NANOGrav has continued to add pulsars to their array. Sky image credit: Axel Mellinger; NANOGrav

years after Jocelyn Bell's discovery, pulsars have become a new tool for measuring both gravitational waves and the distant black holes that create them. If predictions are correct, the next decade will be an exciting period of discovery for radio astronomers, pulsars, and gravitational waves!

ASTRONOMERS SOLVE COSMIC "WHODUNIT" WITH INTERSTELLAR FORENSICS

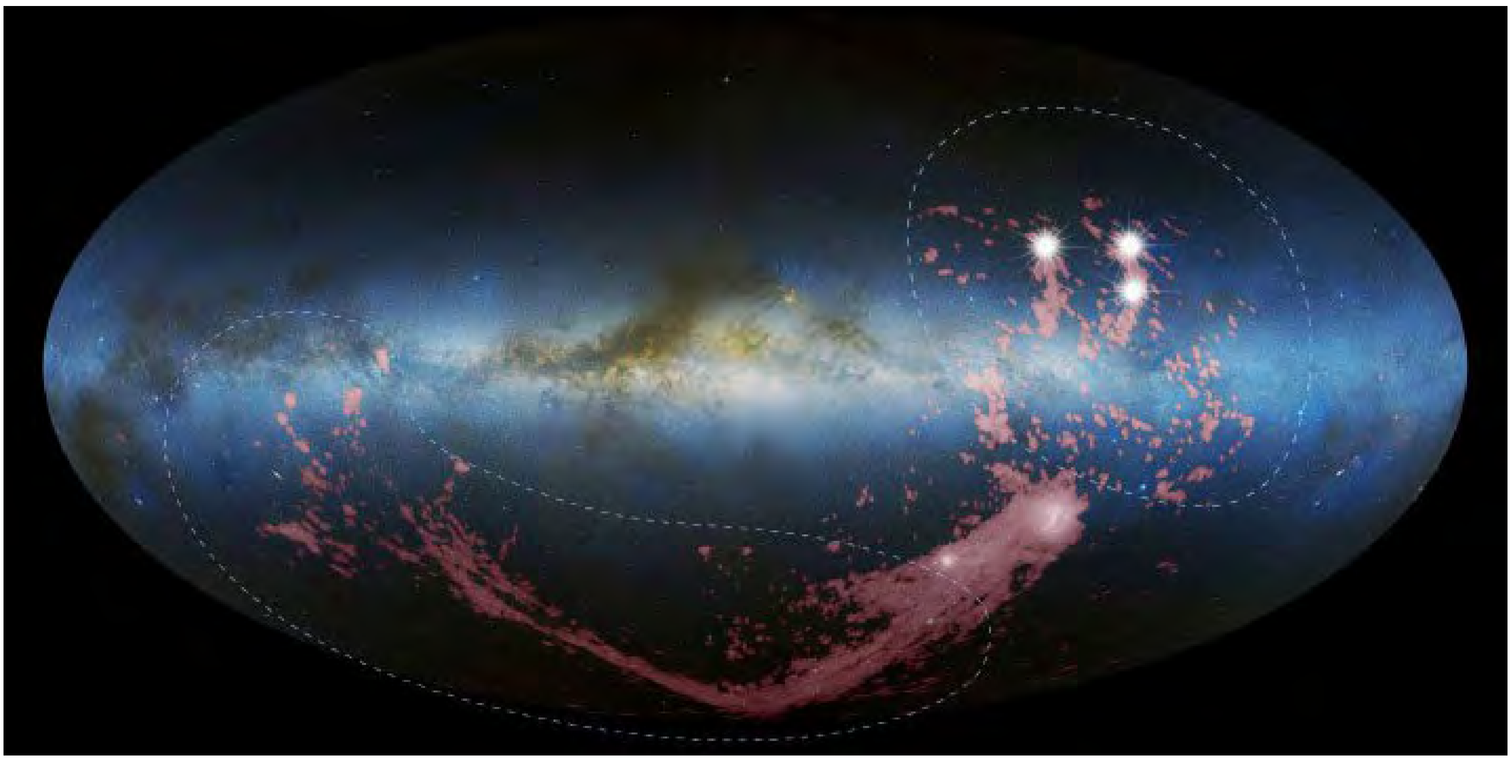
On the outskirts of our galaxy, a cosmic tug-of-war is unfolding. The players are two dwarf galaxies, the Large Magellanic Cloud and the Small Magellanic Cloud, both of which orbit our own Milky Way Galaxy. But as they go around the Milky Way, they are also orbiting each other. Each one tugs at the other, and one of them has pulled out a huge cloud of gas from its companion.

Called the Leading Arm, this arching collection of gas connects the Magellanic Clouds to the Milky Way. Roughly half the size of our galaxy, this structure is thought to be about 1 or 2 billion years old. Its name comes from the fact that it's leading the motion of the Magellanic Clouds.

The enormous concentration of gas is being devoured by the Milky Way and feeding new star birth in our galaxy. But which dwarf galaxy is doing the pulling, and whose gas is now being feasted upon? After years of debate, scientists now have the answer to this "whodunit" mystery.

"There's been a question: Did the gas come from the Large Magellanic Cloud or the Small Magellanic Cloud? At first glance, it looks like it tracks back to the Large Magellanic Cloud," explained lead researcher Andrew Fox of the Space Telescope Science Institute in Baltimore, Maryland. "But we've approached that question differently, by asking: What is the Leading Arm made of? Does it have the composition of the Large Magellanic Cloud or the composition of the Small Magellanic Cloud?"

Fox's research, published in the Astrophysical Journal,



Scientists used the Green Bank Telescope and Hubble's ultraviolet vision to chemically analyze the gas in the Leading Arm and determine its origin.

is a follow-up to his 2013 work, which focused on a trailing feature behind the Large and Small Magellanic Clouds. This gas in this ribbon-like structure, called the Magellanic Stream, was found to come from both dwarf galaxies. Now Fox wondered about its counterpart, the Leading Arm. Unlike the trailing Magellanic Stream, this tattered and shredded “arm” has already reached the Milky Way and survived its journey to the galactic disk.

The Leading Arm is a real-time example of gas accretion, the process of gas falling onto galaxies. This is very difficult to see in galaxies outside the Milky Way, because they are too far away and too faint. “As these two galaxies are in our backyard, we essentially have a front-row seat to view the action,” said collaborator Kat Barger at Texas Christian University.

In a new kind of forensics, Fox and his team used the ultraviolet vision of NASA’s Hubble Space Telescope to chemically analyze the gas in the Leading Arm. They observed the light from seven quasars, the bright cores of active galaxies that reside billions of light-years beyond this gas cloud. Using Hubble’s Cosmic Origins Spectrograph, the scientists measured how this light filters through the cloud.

In particular, they looked for the absorption of ultraviolet light by oxygen and sulfur in the cloud. These are good gauges of how many heavier elements reside in the gas. The team then compared Hubble’s measurements to hydrogen measurements made by the National Science Foundation’s Robert C. Byrd Green Bank Telescope at the Green Bank Observatory (GBO) in West Virginia, as well as several other radio telescopes.

“With the combination of Hubble and Green Bank Telescope observations, we can measure the composition and velocity of the gas to determine which dwarf galaxy is the culprit,” explained Barger.

“The key factor is the amount of oxygen and sulfur relative to the amount of hydrogen,” noted team member and GBO astronomer Jay Lockman. “Hubble gives us the oxygen and sulfur, and the radio telescopes give us the hydrogen.”

After much analysis, the team finally had conclusive chemical “fingerprints” to match the origin of the Leading Arm’s gas. “We’ve found that the gas matches the Small Magellanic Cloud,” said Fox. “That indicates the Large Magellanic Cloud is winning the tug-of-war, because it has pulled so much gas out of its smaller neighbor.”

This answer was possible only because of Hubble’s unique ultraviolet capability. Because of the filtering effects of Earth’s atmosphere, ultraviolet light cannot be studied from the ground. “Hubble is the only game in town,” explained Fox. “All the lines of interest, including oxygen and sulfur, are in the ultraviolet. So if you work in the optical and infrared, you can’t see them.”

Gas from the Leading Arm is now crossing the disk of our galaxy. As it crosses, it interacts with the Milky Way’s own gas, becoming shredded and fragmented.

This is an important case study of how gas gets into galaxies and fuels star birth. Astronomers use simulations and try to look for the inflow of gas in other galaxies. But here, the gas is being caught red-handed as it moves across the Milky Way’s disk. Sometime in the future, planets and solar systems in our galaxy may be born out of material that used to be part of the Small Magellanic Cloud.

As Fox and his team look ahead, they hope to map out the full size of the Leading Arm—something that is still unknown. They also look forward to the day the soon-to-be-launched James Webb Space Telescope will be able to study gas accretion in far-off galaxies in the distant universe.

# # #

The research is presented in a paper titled "Chemical Abundances in the Leading Arm of the Magellanic Stream," A. Fox, et al., published in the Astrophysical Journal [apj.aas.org].

SOLAR SYSTEM'S LARGEST TELESCOPE SEES NEW BLACK HOLE DETAILS

Using the RadioAstron Space VLBI Telescope, an international consortium of astronomers have been able to observe ten times closer to a black hole and see new details of the jet formation region of Perseus A. These observations challenge some of the current models by showing jets much wider than predicted. The Perseus jets are in their infancy and astronomers plan to continue these ultra-high resolution observations to see how the jets 'mature' and compare observations of other active Galactic Nuclei to see how these results compare with other black hole jets.

All of this is possible because the combination of the RadioAstron spacecraft's 10 meter telescope in orbit between the Moon and Earth, combined with multiple ground telescopes, like the GBT which contributed to the Perseus A observation, is able to resolve details beyond the capabilities of any ground-based telescope or array. Whenever the spacecraft is viewable in our hemisphere, the science data and spacecraft data are conveyed back to Russia by way of the 140' Telescope acting as a data downlink, often as the GBT is simultaneously observing the same source as the spacecraft. Green Bank is pleased to provide the vital data connection that make observations like these possible.

Part of the global network of ground radio telescopes that participated in the observations. Credit: Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of NASA Visible Earth (visibleearth.nasa.gov)

COMING THIS SUMMER - NEW GREEN BANK POST DOCS

Natalie Butterfield and Will Armentrout join the Green Bank Observatory Scientific staff in August as our newest Post Docs. Natalie has been an NRAO Reber Fellow attending the University of Iowa, and Will is currently finishing his PhD at West Virginia University with advisor, Loren Anderson. We look forward to their arrival this summer.

GBT PUBLICATIONS, 2018

The following GBT publications have appeared so far in 2018. For a list of recent GBT publications see [greenbankobservatory.org/science/publications/]

If we are missing your publication please let us know.

Anderson, L.D. et al. 2018 ApJS, 234, 33. A Green Bank Telescope Survey of Large Galactic HII Regions

Bietenholz, M.F. et al. 2018 MNRAS, 475, 1756. SN 2014C: VLBI images of a supernova interacting with a circumstellar shell

Burkhardt, A.M. et al. 2018 MNRAS, 474, 5068. Detection of HC$_5$N and HC$_7$N Isotopologues in TMC-1 with the Green Bank Telescope

Cadelano, M. et al. 2018 ApJ, 855, 125. Discovery of three new millisecond pulsars in Terzan 5

Cameron, A.D., et al. 2018 MNRAS, 475, 57. The High Time Resolution Universe Pulsar Survey - XIII. PSR J1757-1854, the most accelerated binary pulsar

Corby, J.F. et al. 2018 A&A, 610, 10. The molecular chemistry of diffuse and translucent clouds in the line-of-sight to Sgr B2: Absorption by simple organic and inorganic molecules in the GBT PRIMOS survey

Darling, J. 2018 RNAAS, 2, 15. The 87Rubidium Atomic Clock Maser in Giant Stars

Di Teodoro, E. , et al. 2018 ApJ, 855, 33. Blowing in the Milky Way wind: neutral hydrogen clouds tracing the Galactic nuclear outflow

Enriquez, E.J. et al. 2018 RNAAS, 2, 9. Breakthrough Listen Observations of 1I/•Oumuamua with the GBT

Fox, A. J. et al. 2018 ApJ, 854, 142. Chemical Abundances in the Leading Arm of the Magellanic Stream

Han, ,J. L. et al. 2018 ApJS, 234, 11. Pulsar Rotation Measures and Large-scale Magnetic Field Reversals in the Galactic Disk

Harrington, K. C. et al. 2018 MNRAS, 474, 3866. Total molecular gas masses of Planck - Herschel selected strongly lensed hyper luminous infrared galaxies

Jones, M.G. et al. 2018 A&A, 609, 17. The AMIGA sample of isolated galaxies. XIII. The HI content of an almost “nurture free” sample

Kaplan, D.L. et al. 2018 ApJ, 855, 14. A Gaussian Mixture Model for Nulling Pulsars

Kolesniková, L. et al. 2018 A&A, 609, A24. Rotational spectrum of methoxyamine up to 480 GHz: a laboratory study and astronomical search

Kutkin, A.M. et al. 2018 MNRAS, 475, 4994. The extreme blazar AO 0235+164 as seen by extensive ground and space radio observations

Lin, H.-H. et al. 2018 MNRAS, 475, 1323. Improved pulsar timing via principal component mode tracking

Lipnicky, A. et al. 2018 MNRAS, 476, 3097. The First Detection of Neutral Hydrogen in Emission in a Strong Spiral Lens

MacMahon, D.H.E. et al. 2018 PASP, 130, 4502. The Breakthrough Listen Search for Intelligent Life: A Wideband Data Recorder System for the Robert C. Byrd Green Bank Telescope

McGuire, B.A. et al. 2018 Science, 359, 202. Definitive Interstellar Discovery of the Aromatic Molecule Benzonitrile (c-C6H5CN) in TMC-1 with the Green Bank Telescope

Michilli, D. et al. 2018 Nature, 553, 182. An extreme magneto-ionic environment associated with the fast radio burst source FRB 121102

Pilipenko, S.V. et al. 2018 MNRAS, 474, 3523. The high brightness temperature of B0529+483 revealed by RadioAstron and implications for interstellar scattering

Pol, N. et al. 2018 ApJ, 853, 73. A Direct Measurement of Sense of Rotation of PSR J0737–3039A

Price, D.C. et al. 2018 RNAAS, 2, 30. No Bursts Detected from FRB121102 in Two 5 hr Observing Campaigns with the Robert C. Byrd Green Bank Telescope

Sokoliv, V. et al. 2018 A&A, 611, L3. Subsonic islands within a high-mass star-forming infrared dark cloud

Spekkens, K. and Karunakaran, A. 2018 ApJ, 855, 28. Atomic Gas in Blue Ultra Diffuse Galaxies around Hickson Compact Groups

Zhao, W. et al. 2018 ApJ, 854, 124. The Megamaser Cosmology Project. X. High Resolution Maps and Mass Constraint for SMBHs

EPO HAPPENINGS

GREEN BANK OBSERVATORY CHOSEN FOR NATIONAL LEAP INTO SCIENCE PROJECT

A diverse group of educators from the Green Bank Observatory, West Virginia University Extension Service, Pocahontas County Libraries and the Morgantown Public Library System have teamed up to become The West Virginia Leap into Science State Leadership Team. Out of more than 20 applications from around the nation, West Virginia was one of four state teams selected.

The Leap into Science initiative is led by The Franklin Institute, the National Girls Collaborative Project, and the Institute for Learning Innovation, with support from the National Science Foundation. Developed by The Franklin Institute, Leap into Science integrates open-ended science activities with children's books, designed for children ages 3-10 and their families. Leap into Science workshops help children think like a scientist through exploration of everyday concepts like balance, wind and air and light and shadows. Funding for this project provides resources, training and assistance to state teams through 2021.

What began as a local Franklin Institute program is now expanding nationwide as Leap Into Science builds state-based networks to bring literacy and science exploration activities to community settings like local libraries, youth club meetings, and after school programs. Over the next three years the West Virginia State Leadership team will provide training workshops to 60 informal educators each year, and they in turn will provide hands-on workshops for children and families.

GBO educators Sophie Knudsen and Sherry McCarty have just completed leadership training at the Franklin Institute, where they learned how to provide professional development to other educators in West Virginia through a train the trainer model. "This program is a perfect fit for the Green Bank Observatory," according to Sophie Knudsen. "The values and approach of Leap into Science closely align with those of our own education programs. Similar to the Leap program, we help students learn to question, and think like a scientist." Sherry McCarty finds added value in participating as it represents an opportunity to raise awareness of Green Bank Observatory in all 55 counties in West Virginia.

The next step is to recruit and train educators across the state. Educators who join the WV Leap into Science network will receive free professional development and training in leading STEM and literacy workshops for young children and families, free curricula, Leap Into Science material kits, and ongoing support.

The WV Leap State Leadership Team include Sophie Knudsen and Sherry McCarty from Green Bank Observatory; Sarah Palfrey from Morgantown Public Library System, Cree Lahti from Pocahontas County Public Library System, and Mollie Toppe, Shannon Cottrill, and Autumn Starcher from West Virginia University Extension Service.

GOVERNOR'S SCHOOL RETURNS TO GREEN BANK OBSERVATORY, UNDER A NEW NAME

After a two-year hiatus, the Green Bank Observatory successfully competed to host the West Virginia Governor's STEM Institute (GSI) for the next 3 years. GSI invites students to delve into projects that allow them the time and opportunity to think and work like scientists and engineers, using high level mathematics and thinking skills while employing the latest technology. The Green Bank Observatory program "Investigating the Universe", is an intensive two-week residential program that engages 60 talented rising ninth graders from all over West Virginia in radio astronomy research. Our program is truly unique in that is embedded within the day-to-day workings of a national research center. Our students will have the opportunity to join our professional STEM community; working in teams with scientist-mentors, rubbing elbows with undergraduate students, and using some of the most sophisticated radio astronomy technology on earth.

PHYSICS INSPIRING THE NEXT GENERATION (PING) CAMP ACCEPTING APPLICATIONS

The Green Bank Observatory also hosts a similar camp for rising ninth graders with an interest in STEM from all over the nation. PING is free of charge, except for travel (we do offer shuttle service to and from Green Bank from DC, and Charlottesville VA). We encourage applications from youth who are traditionally under-represented in the STEM fields. Please help us spread the word. For more information and application [greenbankobservatory.org/education/student_research/ping/]

MEET THE STAFF

Andrew Seymour officially joined the GBO Scientific Staff in January, 2018. He has been a visiting scientist in Green Bank since hurricane Maria stopped by the Arecibo Observatory for an unwelcomed visit. We talked to Andrew about his career, life in Puerto Rico and his journey to GBO.

Could you briefly explain your Scientific Career journey?

My career has been a bit of a "random walk". After earning my undergraduate degrees in Mechanical and Aerospace Engineering, I decided to go to graduate school for Physics. There I did research with lasers and optics, then moved on to Chaos theory, but eventually did my thesis work on Astronomy and Pulsars. After graduate school, I moved to Puerto Rico to use the William E. Gordon Telescope at Arecibo, famous for being in the films Goldeneye and Contact, to continue my pulsar work. While there, one of the collaborations that I work with found a millisecond extra-galactic radio source known as a Fast Radio Burst. Follow ups on this source have produced numerous events at Arecibo in the past three years. Yet, this is the sole source to date to repeat, and it is still unknown what is causing these events. All of which has kept the collaboration and me pretty busy.

What was the most fun about working at Arecibo?

Since Arecibo is in the tropics, there was a lot of beach fun to be had. Yet I think I had the most fun with my co-workers. It takes a special personality willing to move to Puerto Rico, and we grew to rely on each other. Be it through a hurricane or the uncertainty of a NSF-EIS, we learned to laugh our way through it all.

Were you involved with any of the projects where Arecibo and the GBT work together? If so, could you talk about them?

There are many projects that use the unique capabilities of both the Arecibo and the Green Bank Telescope.The obvious ones are the Pulsar surveys and Pulsar timing projects. This is where measuring the radio burst from neutron stars can eventually detect gravitational waves from merging super massive black holes, like that found in the center of some galaxies.

In order to achieve this, we need a large number of pulsars.Therefore we want to search far and wide to find them. Arecibo was the largest radio telescope in the world, which allows it to search for very deep and weak pulsars. Yet because of its size, it cannot be tilted, limiting what part of the sky it can observe. Using the largest steerable structure, that is the GBT, is great for finding pulsars in the other part of the sky that Arecibo cannot reach. Therefore Arecibo searches the far, while GBT searches the wide.

What is the major difference between Puerto Rico and West Virginia?

The weather.

What are their similarities?

Puerto Rico and West Virginia have more in common than you first realize. Both have their unique dialects. The mountains can make it hard to get where you want to go. Not all the information you need can be found online. Be weary where the GPS sends you. Your cell phone might not work. In spite or maybe because of these "hardships", both places have a tremendous amount of pride in the region they call home

EVENTS

Remote Observer Training Workshops

May 24 - 25; September 17 - 18

Learn more:

[greenbankobservatory.org/gbt-observers/observer-training-workshops/]

Single Dish Training Workshop

Formerly Single Dish Summer School

May 19 - 23

For grad students, post-docs and experts in other fields of astronomy. Learn more:

[greenbankobservatory.org/gbt-observers/single-dish-training-workshop/]

Chautauqua Short Course

May 30 - June 1

2½ day workshop, geared toward college faculty who teach at small non-research colleges or community colleges, and who have an interest in learning about radio astronomy research. The workshop consists of lectures, tours, and hands-on use of one of our 40 Foot radio telescope. This year the course runs from May 30th – June 1st

There is a $100 application fee, and a course fee of $195. For more info, contact the GBO Education Officer, Sue Ann Heatherly at [sheather@nrao.edu]

Space Race Rumpus

June 8 - 10

Space Race Rumpus is weekend-long cycling festival, based at the Observatory that raises funds for a Community Wellness Center. Guided road and mountain bike trail rides, clinics, kids' activities, races, great food and live music are all part of the Rumpus. Camp in the shadow of the GBT, and enjoy the beautiful surroundings.

Learn more: [https://www.spaceracerumpus.org/]

Society of Amateur Radio Astronomy Conference

June 10 - 13

Learn more: [http://www.radio-astronomy.org]

REU Bootcamp

June 4 - 8

For all summer students at NRAO and GBO sites.

ALFALFA-U Workshop

June 19 - 23

This workshop engages undergraduates and their faculty on radio astronomy projects with the ALFALFA Survey data. The workshop is part of an NSF-sponsored program to promote undergraduate research within the ALFALFA project.

ESS Passport Workshop

June 17 - 30

Professional Development workshop to prepare WV teachers to teach 9th grade Earth and Space Science.

Learn More:

[https://www.fairmontstate.edu/esspassport/ess-passport-synopsis]

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