Virtual Goody Bag

Contents:

Galaxy Gift Shop Coupon

Social Media Links

Site Maps/Trail Guides

GBO Booklet

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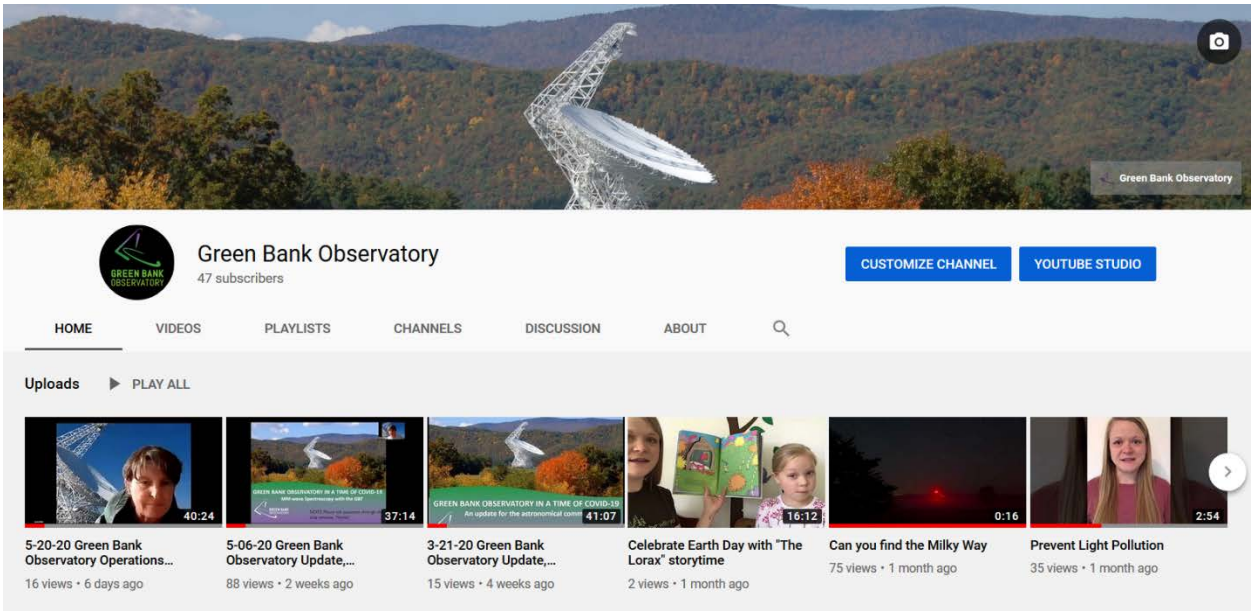

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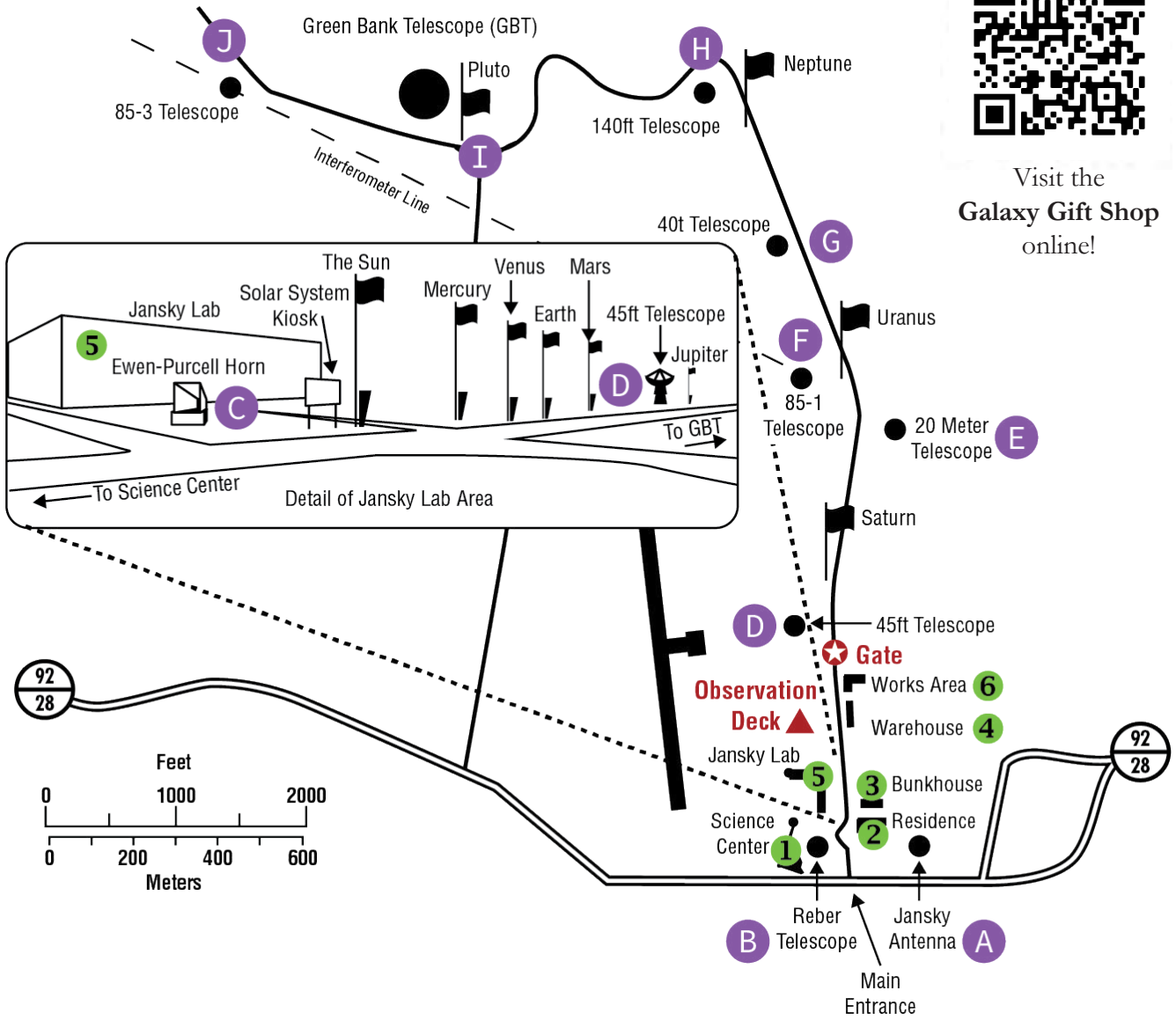
GREEN BANK OBSERVATORY

SELF-GUIDED WALKING TOUR & SITE MAP

The Self-guided walking tour may be taken anytime before dark. Visitors are welcome to walk their dogs or ride bicycles around the grounds. We request that once you pass the gate, shown in **red** with a star (✪), be certain that all electronics not vital to your health are completely turned off.

Telescopes - both active and inactive - are marked in purple letters. Points of interest are marked in green numbers. The best location to take pictures of the Green Bank Telescope is our Observation Deck, indicated by a triangle (▲), near the parking lot behind the Jansky Lab (❺).

A scale model of the solar system begins with the Sun in front of theJansky Lab (❺) and ends 1.5 miles away at Pluto, next to the Green Bank Telescope (I). This Scale model is 1 foot to 3 billion feet. The kiosk at the Sun flag provides more information.



Visit the **Galaxy Gift Shop** online!

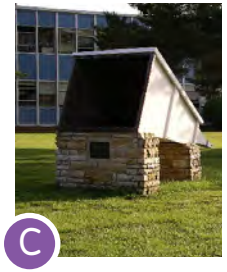
The Green Bank Science Center (❶) is open year-round and serves over 45,000 visitors a year. The 25,000 square foot facility contains the Catching the Wave Exhibit Hall, a 150-seat auditorium, classrooms, a gift shop, and a full menu at the Starlight Café.

Green Bank has two short-term housing buildings. The Residence Hall (❷) is used for visiting scientists, while the Bunk House (❸) is often used for students participating in educational programs. Part of the Warehouse (❹) was our original tour center, but now hosts Observatory and community events.

Sensitive receivers and state-of-the-art data collection systems are invented and designed in the Jansky Lab (❺). The parts are fabricated and assembled in the Works Area (❻) before being transported to the telescopes for use.

The Jansky Antenna (A) is an exact replica of the antenna used by Karl Jansky in the early 1930s. With it, he found three sources of radio static: two were caused by thunderstorms, but he concluded that the third was coming from the Milky Way! After hearing of Jansky's cosmic static, radio engineer Grote Reber was determined to investigate. He built the Reber Telescope (B) himself. It was the first dish-shaped radio telescope, and its success revolutionized radio astronomy!

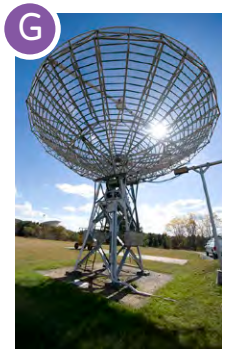
After the Second World War, radio astronomy took off due to newly-improved receiver technology. In 1951, Howard Ewen and Edward Purcell from Harvard University built the Ewen-Purcell Horn (C) and pointed it out of their lab window. Because of its shape, excessive rain caused it to flood their lab multiple times, and was a popular target for undergrads' snowballs. Eventually, they used it to discover the first hydrogen line emission at 1,420.4 MHz, revealing the spiral shape of the Milky Way. Today, scientists still use hydrogen line emission to investigate galaxies.



The 45-Foot Telescope (D) was designed to be mobile, and was moved around West Virginia to be the fourth telescope in the Green Bank Interferometer (GBI). In 1974, it aided the discovery of Sagittarius A*, the black hole in the center of our galaxy. It then did satellite tracking for a project with NASA and the Japanese space institute. From 2004 to 2012, it was the Green Bank Solar Radio Burst Spectrometer, which studied the Sun at radio wavelengths. Though still in working order, it awaits funding and a new project to continue its work.

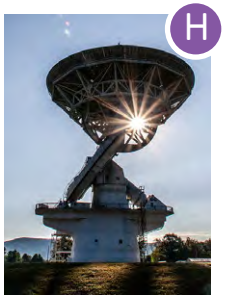
Designed and built by the US Naval Observatory, the 20-Meter Telescope (E) was built to measure highly accurate time, continental drift, and the Earth's wobble, or "precession." Now it is a part of the Skynet Robotoc Telescope Network, and is used by youth groups, educators, and undergraduates. Skynet is led by the University of North Carolina at Chapel Hill.

The Tatel Telescope (F) is the oldest telescope on site and saw extensive use from from 1959 until 2000. It was first used by Frank Drake to launch the Search for Extraterrestrial Intelligence (SETI) in 1960. Although Drake found no signals from extraterrestrials, SETI investigations continue today using the techniques established by Drake. The Tatel was also one of the telescopes that was part of the Green Bank Interferometer.



The 40-Foot Telescope (G) telescope was built in 1962 to determine if the intensity of radio sources varied over time. It was also the first fully automated radio telescope. The telescope is now used by teachers and students from across the country to observe the universe and experience research first-hand. It is the only remaining onsite telescope with a mesh dish and a separate control room, all other telescopes on site are controlled from the Jansky Lab.

The 140-Foot Telescope (H) was completed in 1965 and is the largest equatorially mounted telescope in the world. It was the first telescope to detect complex molecules and neutral hydrogen absorption from another galaxy. Until Spring, 2019, it was part of the international Radioastron astronomy project that tracked a Russian orbiting satellite called Spektr-R. The satellite works with radio telescopes on Earth to exapand our knowledge of black holes, interstellar plasma, pulsars, and other radio emitting objects in the universe.



Observatory staff designed the largest fully steerable telescope in the world. Named afer the West Virginia senator who advocated for its construction, the Robert C. Byrd Green Bank Telescope (GBT) (I) is an offset-parabolic dish 100x110 meters in diameter. GBT's feed arm rises above the dish to support sensitive receivers. Its placement on the side of the dish is unique, and ensures that it is not in the way of incoming radio waves The surface can be actively monitored and adjusted in response to temperature and gravitational changes to maintain a perfect surface and provide optimal data.

The 85-3 and the Green Bank Interferometer (J). Operational until 2000, the 85-3's final job was a long-term research project to monitor 35 pulsars every day. Alongside the 85-2, the Tatel Telescope, and the 45-Foot Telescope, it was part of the Green Bank Interferometer, or GBI. The dishes operated simultaneously to simulate a larger telescope, about a mile in diameter, with much higher resolution. The GBI was the prototype for interferometer systems like the Very Large Array (VLA) in New Mexico and the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile.

Green Bank Observatory is supported by the National Science Foundation and is operated by Associated Universities, Inc.

RFI Guidelines

All electronic devices give off radio frequency interference, or RFI. Just like you can't see the stars when the Sun is out, radio telescopes cannot detect distant objects when an electronic device is on nearby. Even if your cell phone were in orbit around Saturn, it would be the brightest object in the sky to the Green Bank Telescope.

For this reason, we ask you turn all electronic devices completely off (not just in airplane mode!) once you cross into the RFI Restriction zone (marked in red on the Trail Guide). If you cannot turn off your device, please leave it in your vehicle.

This policy includes:

- ★ Cell phones and MP3 players
- ★ Bluetooth devices, including headphones, earbuds, and smart shoes
- ★ Smart watches and fitness trackers
- ★ Segways, motorized bikes, etc.

Medical devices, like pacemakers, hearing aids, and insulin pumps, do

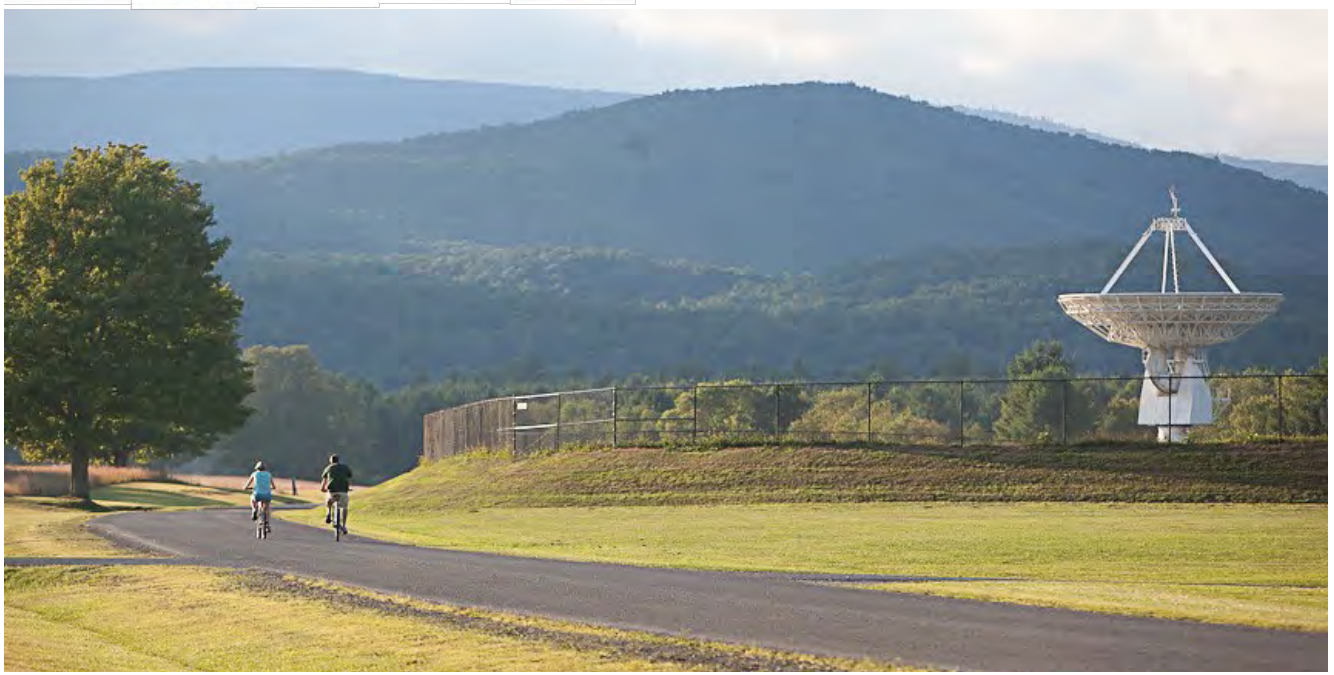
(304) 456-2011

155 Observatory Road, P.O. Box 2
Green Bank, West Virginia 24944

Visit us at greenbankobservatory.org,
and follow us on these social media platforms:

GREEN BANK OBSERVATORY AND SCIENCE CENTER

SITE TRAILS



This property is owned by the U.S. Government through the National Science Foundation and is therefore subject to all applicable laws related to government property. You must understand that by utilizing this site for trail use you indemnify the U.S Government and GBO/AUI from all liability, present or future claimed, and accept all risk for your activities.

NSF AUI GREEN BANK OBSERVATORY

Safety Tips

- ★ Tell someone when to expect you back.
- ★ Travel in groups, and be aware of your surroundings.
- ★ Look up when the Sun will set, and plan to be finished before dark.
- ★ Know your abilities, and respect your body's limitations.
- ★ Always keep your pets on a leash.
- ★ **Under no circumstances should you approach any wildlife.** If you do not know how to deal with native bears or snakes, please ask the front desk for a safety brochure.
- ★ Never eat any plants you find! Especially stay away from these, which can irritate your skin:


ANY mushrooms


Poison hemlock


Poison ivy

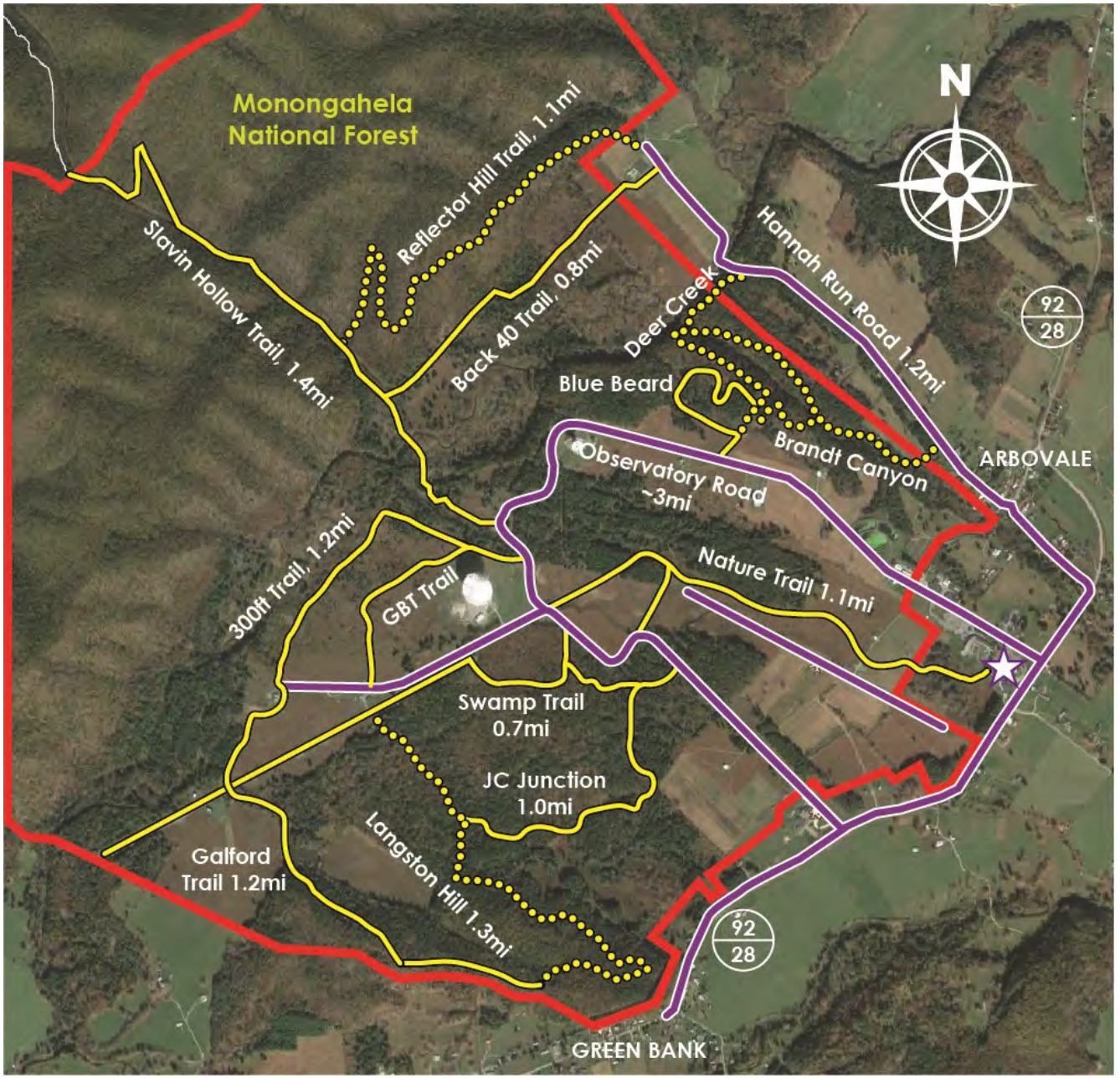

Poison oak


Poison sumac


Stinging nettle


Water hemlock


White baneberry



Yellow: Gravel or dirt track

Purple: Paved road

Red: RFI Restriction Zone boundary

Dotted lines: advanced/expert trails.

Solid lines: beginner/intermediate trails.

White star: Science Center. Potable water, food, ATM, and phones available.

A colorblind-friendly version of this brochure is available.

Map courtesy of Google Earth.

2024 GREEN BANK OBSERVATORY

welcome to GREEN BANK OBSERVATORY

The Green Bank Observatory (GBO) is the home of the 100-meter Robert C. Byrd **Green Bank Telescope (GBT)**, the world's largest fully steerable single-dish radio telescope.

Surrounded by the Allegheny Mountains in Deer Creek Valley, the Observatory's astronomical research is protected by two complementary radio interference protection zones—the **National Radio Quiet Zone** (NRQZ) and the **West Virginia Radio Astronomy Zone** (WVRAZ).

Green Bank is an attractive location for independent research experiments, and serves as the field station for several university-based research teams.

The Observatory **machine shop** and **electronics laboratories** have built state-of-the-art components and instruments for telescopes and research facilities around the world.

The nearly 2,700-acre site has significant infrastructure which allows for the installation of any instrument that may benefit from the radio quiet location. There is ample space for new projects, a **radio frequency test range**, and an **anechoic chamber.**

The Observatory campus includes our nationally acclaimed public **Science Center**, which welcomes thousands of students and visitors each year. GBO's educational and public outreach programs are for learners of all ages, with hands-on STEM experiences for students and educators.

Green Bank is a welcoming, creative, and tight-knit community. Our award winning staff come from the surrounding area, across the country, and around the world, and are proud to call this place home.

"The Green Bank Telescope continues to push foward our fundamental understanding of the Universe."
- Jim Jackson, GBO Director

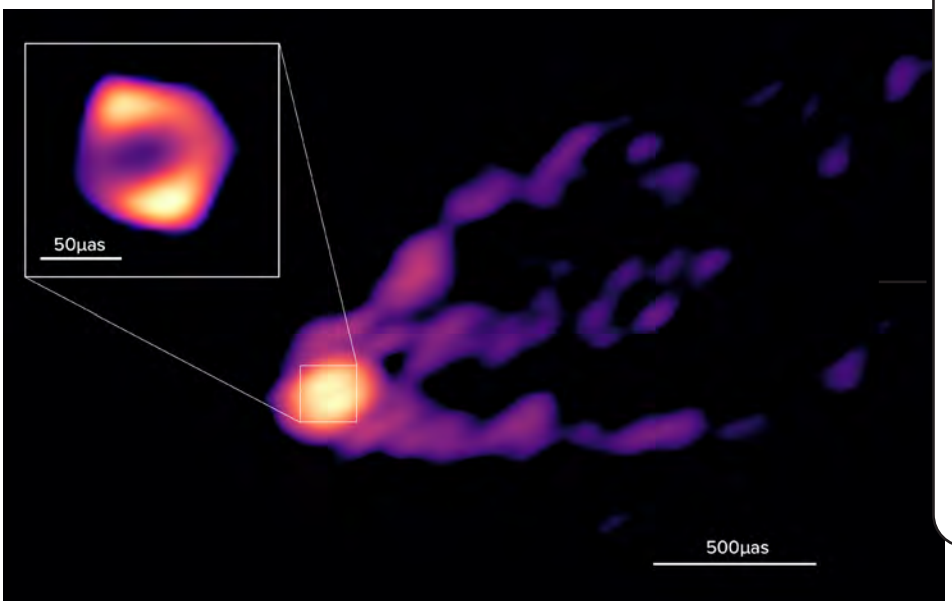
Astrophoto by Dave Green

Cover image photo credit Jee Seymour

low frequency gravitational waves detected for the first time with 15-years of GBT data

It was a front-page story around the world when the NANOGrav collaboration announced that 15-years of data revealed evidence for low frequency gravitational waves. As one of the collaboration's major instruments, the GBT's sensitivity allows it to be a powerful pulsar detector, the key cosmological object NANOGrav uses to observe these tiny ripples in spacetime.

M87's supermassive black hole and jet captured together —for the first time



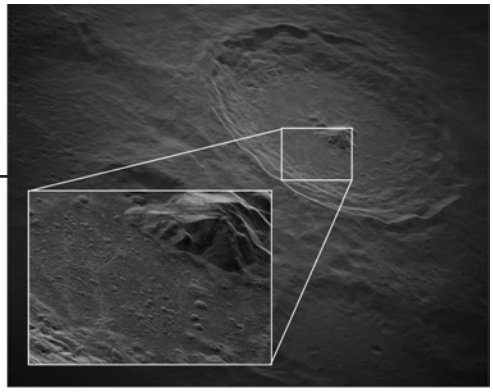
This GMVA+ALMA image shows M87's jet and black hole shadow together for the first time, giving scientists the context needed to understand where the powerful jet formed. The new observations also revealed that the black hole's ring, shown in the inset, is 50% larger than scientists previously believed. Credit: R. Lu and E. Ros (GMVA), S. Dagnello (NRAO/AUI/NSF)

The supermassive black hole at the center of the M87 galaxy is the most recognizable in the Universe. It was the first black hole to be captured in an image, created by the Event Horizon Telescope and made public in 2019.

These observations represent the first time that the jet and the black hole have been imaged together at the same time, using data from the Green Bank Telescope and fifteen other telescopes around the world, the Global mm-VLBI Array (GMVA). These observations also revealed that the black hole's ring is 50% larger than previously believed.

New space radar will hunt planet-threatening asteroids

GBO, the National Radio Astronomy Observatory (NRAO), and Raytheon are designing a high-power, next generation planetary radar system (ngRADAR) for the GBT. A pilot radar transmitter on the GBT combined with the receivers of the NRAO's Very Long Baseline Array generated the highest-resolution, ground-based images of the Moon ever collected, provided physical characterization of space debris, and detected a near-Earth asteroid more than five times farther away than the Moon.



A Synthetic Aperture Radar image of the Moon's Tycho Crater, showing 5-meter resolution detail. Image credit Raytheon.

LEARN MORE

greenbankobservatory.org/news

Robert C. Byrd GREEN BANK TELESCOPE

LEARN MORE

The GBT's 100-meter diameter collecting area, unblocked aperture, and excellent surface offer the scientific community unrivaled research capabilities at 0.29–116 GHz (1m–3.6mm wavelengths).

In 2024, the GBT plans to offer ~6,600 hours of science observing time.

The GBT receivers cover a frequency range from 290 MHz to 116 GHz (non-contiguous). In addition to several single-pixel receivers, the GBT also offers three array receivers: a 7-pixel heterodyne focal plane array at 18–26 GHz, a 16-pixel single-polarization array from 90–116 GHz and a 200+-pixel bolometer array at 81–100 GHz.

The GBT features industry-leading signal processing systems with a high dynamic range, a state-of-the-art system for high time and frequency resolution observations, and the capability for very wide bandwidth (≥10 GHz) observations for spectral line and pulsar detection experiments.

The GBT makes use of two backends, the Digital Continuum Receiver (DCR) and the Versatile GBT Astronomical Spectrometer (VEGAS), a multi-beam spectrometer with a variety of observing modes. Both backends are available to partners.

RECEIVER FREQUENCY (GHz)
GREGORIAN/ PRIME FOCUS

Prime Focus 1	0.290–395, 0.680–0.920	Prime Focus
UWBR*	0.7–4.0	Prime Focus
L-band	1.15–1.73	Gregorian
S-band	1.73–2.60	Gregorian
C-band	3.8–8.0	Gregorian
X-band	8.0–12	Gregorian
Ku-band	12.0–15.4	Gregorian
K-band FPA	18.0–26.5, 7 pixels	Gregorian
Ka-band	26.0–39.5	Gregorian
Q-band	38.2-49.8	Gregorian
W-band	67–93.3	Gregorian
ARGUS	80–115.3, 16 pixels	Gregorian
MUSTANG-2**	75–105, 223 pixels	Gregorian

** New in FY2024*

*** Not available to private partners*

HOW TO USE THE GBT

Proposal calls are held twice a year for Open Skies Time. The principle of Open Skies science is to maximize the scientific output of an instrument or facility through allowing any scientist in the world to apply for time on that instrument through a peer-reviewed process.

The time available for Open Skies is equal to the fraction of the operational funds contributed by the NSF.

GBO's proposal process is coordinated with the NRAO. All proposals are evaluated on the basis of scientific merit by science review panels.

Proposals for GBT Director's Discretionary Time can be submitted at any time to support targets of opportunity, exploratory observations, and time critical observations.

GBO staff provide training workshops several times a year on how to create proposals, how to use the GBT, and how single dish radio telescopes work.

PARTNERING FOR GBT OBSERVATIONS

Did you know that private entities can purchase time on the GBT? GBO is proud to be funded by the National Science Foundation, however, this funding only covers about 65% of the Observatory's operational costs. The remainder comes from partnerships with various organizations, including Breakthrough Listen and NANOGrav, who purchase time on the GBT.

Partnership requests and queries should be directed to: **gbo-partner@nrao.edu**

GBO encourages partners whose mission aligns with the Observatory's core science mission, and particularly seeks partnerships which offer opportunities for direct scientific collaboration or resources which could offer benefit to the Open Skies Community. However, the Observatory will consider all partnership opportunities. Partnerships must ultimately be approved by the National Science Foundation.

Partners should be aware that no more than 30% of available observing time in a given fiscal year will be made available for contracts. High Frequency availability is particularly limited, and the majority of this time is reserved for the Open Skies community. Currently, no more than 10% of purchased time may be for High Frequency observations on the GBT.

The GBO charges additional fees for high frequency time, LST ranges near the Galactic Center, time sensitive observations on short notice (< 8 weeks), or observations that use a substantial amount of observing time at the same position in the sky.

All partners will have access to the NRAO science helpdesk. Additionally, a member of the GBO scientific staff will be assigned to all partners as a dedicated project friend. This project friend will assist with training partners on observing and data reduction. They will also serve as the primary point person for any scientific support needs. Partners are responsible for conducting their own observations.

GBO cannot offer design or engineering resources to partners. The Observatory is currently developing documentation to provide interface requirements for partners and PIs interested in developing instruments to be used on the GBT, which will be made publicly available by the end of 2024. The standard rates, which are posted on the Observatory website, only cover the use of Observatory receivers and backends. If your project has special requirements, reach out to gbo-partner@nrao.edu to establish what may be possible and any affiliated costs.

TRAINING & PROPOSAL CALLS

Training workshops are offered in the spring, summer, and fall. See our website for current workshop dates and to register
greenbankobservatory.org/science/gbt-observers/observer-training-workshops/

Calls for proposals to observe using the GBT are issued twice a year
greenbankobservatory.org/science/gbt-observers/proposals

SHARING OUR SCIENCE

The Observatory hosts many public and private workshops and conferences each year, from special topics focusing on radio astronomy, to the Society of Amateur Radio Astronomers and other groups. Presentations from these events are often recorded, archived, and shared at our website.
greenbankobservatory.org/science/meetings-and-workshops

LEARN MORE

our SCIENCE

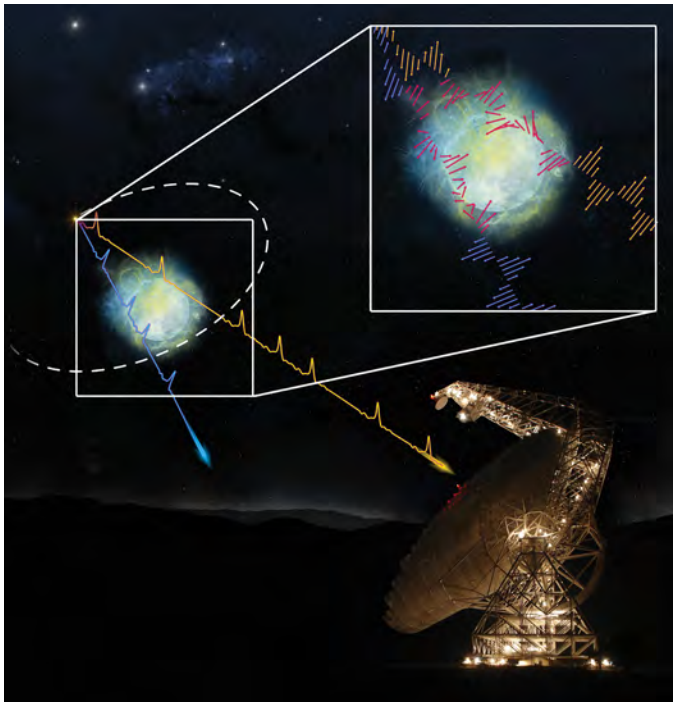
PULSAR AND FAST RADIO BURST OBSERVATIONS Pulsar timing and searching represents a core science mission for the GBT, and the flagship pulsar timing project on the GBT is NANOGrav.

FAST RADIO BURSTS Recent GBT observations, along with observations from other radio telescopes, have measured frequency dependent polarization of repeating FRB which provides insights into their origin.In 2022 the Canadian Hydrogen Intensity Mapping Experiment (CHIME) project built a cylindrical outrigger antenna at Green Bank to complement the four antennas already operating at the Dominion Radio Astronomy Observatory in Penticton, Canada. The expansion of the CHIME array will enable the discovery and localization of FRBs, which can then be characterized by follow up observations with the GBT and other telescopes.

ASTROCHEMISTRY Astrochemistry, the study of the formation of complex molecules in gas clouds, is a GBO core science mission. Large surveys to detect ever more complex molecules are underway, including GBT Observations of TMC-1: Hunting Aromatic Molecules (GOTHAM), Molecular Exploration of the Diffuse Interstellar Medium (MEDIUM), and the GBT L1544 Unbiased Complex Organics Survey (GLUCOSE). GOTHAM's latest discovery is the detection of methylcyanotriacetylene (CH3C7N).

STAR FORMATION IN OUR GALAXY & NEARBY GALAXIES Several large GBT programs focus on the star-forming molecular gas within star-forming regions in our galaxy and nearby galaxies. Dynamics in Star-forming Cores: a GBT-Argus Survey (DiSCo GAS) is measuring the kinematics of over 100 proto-stellar cores in the Perseus molecular cloud using the dense gas tracer N2H+. The Dense Extragalactic GBT+Argus Survey (DEGAS) is measuring the HCN(1-0) and HCO+(1-0) transitions in nearby star-forming galaxies, and the GBT Extragalactic Database for Galaxy Evolution (EDGE) is measuring CO(1-0) in 150 low-z galaxies with existing optical Integral Field Unit spectroscopy to compare the molecular gas distribution with that of the star-forming regions.

DISTANT GALAXIES AND GALAXY CLUSTERS The 3mm continuum bolometer array (MUSTANG-2) continues its successful observations of the SZ effect in clusters by measuring the gas bridge between Abell 399 and Abell 401 (Hincks+2022, MNRAS, 510, 3335). GMVA observations of 3C84 using the GBT have shown the double nuclear components have remained persistent from observations from 2008 through 2015 (Oh+2022, MNRAS, 509, 1024). They find a correlation in the brightness temperature and relative position angle of the two components which may indicate rotation within the jet.



The Green Bank Telescope was able to observe the directional changes of waves from FRB20190520B as viewed through the lens of a massive star's atmosphere. An international team, led by a graduate research assistant at West Virginia University, Reshma Anna-Thomas, found the first evidence of magnetic field reversal in an FRB. This discovery also strengthens the idea that at least a fraction of FRBs originate in a binary system. Image credit: NSF/GBO/P. Vosteen.

RADAR The GBT has long played an important role as a radar receiving station. With the collapse of Arecibo and the associated loss in the US radar science capabilities, the GBT role in radar science will expand greatly in the future. A planned Ku-band radar transmitter for the GBT would be transformational for solar system science and the study of Near-Earth Objects.

THE SEARCH FOR TECHNOSIGNATURES The search for life beyond the solar system can be divided into two primary research areas: astrobiology (the search for complexmolecules generated by life) and technosignatures (the search for signatures of a technological civilization).

The Observatory has long played a significant role in the search for technosignatures, beginning with Project Ozma's use of the Green Bank Tatel telescope to monitor Tau Ceti and Epsilon Eridani for technosignatures in 1960, and the formulation of the Drake Equation in 1961. At present, the majority of the Observatory's work in technosignatures is through the Breakthrough Listen which searches for extraterrestrial radio communication.

current & future SCIENTIFIC CAPABILITIES

ULTRAWIDEBAND RECEIVER The 0.7–4 GHz receiver, UWBR, is a precise tool for pulsar studies of low frequency gravitational waves and fast radio bursts and can be used for molecular spectrosopy and measurement of radio recombination lines. For the recent 2023A GBT proposal call, nearly 30% of the submitted proposals requested UWBR. *UWBR is funded in part by the Gordon and Betty Moore Foundation.*

X-BAND RECEIVER The new receiver, operating from 8–12 GHz, features improved bandpass coverage with upgraded cryogenics and hardware.

ALPACA The Advanced Cryogenic L-Band Phased Array Camera is under development by Brigham Young University and Cornell University. This 40-beam L-band phased array would operate from 1.3–1.7 GHz and boast a field-of-view of 0.35 deg^2, enabling wide-area searches of HI gas, FRBs, pulsars, and technosignatures. The project successfully completed its design review in 2023. If additional funding becomes available, the expected time period for the commissioning is 2026–2027.

ngRADAR GBO, AUI, NRAO and Raytheon Technologies Inc. are collaborating to develop a Ku-band radar transmitter on the GBT. A radar demonstration project using a low-power (700 W) radar transmitter produced the highest resolution image of the Moon ever obtained from the ground (~1.5 m or ~1 milliarcsec). Plans to build a high-power (500 kW) radar transmitter will provide unprecedented performance for solar system radar studies. Ongoing efforts to obtain funding anticipate deployment in the late 2020s.

CYCLIC SPECTROSCOPY CS is a powerful data processing technique for pulsar astronomy that provides higher time and frequency resolution than traditional methods. GBO is building an easy-to-use, pseudo-real time CS system in operation, and this process will advance multi-messenger astrophysics through its ability to measure and mitigate Interstellar Medium (ISM) induced noise, while also enabling the detailed study of the ISM along the line of sight to pulsars. The software is expected to be deployed and commissioned in 2024.

WIDEBAND DIGITAL SIGNAL PROCESSING Astrochemistry programs are limited by the available instantaneous spectroscopic bandwidth with the GBT. Currently, to achieve sufficient velocity resolution (< 0.1 km/s) at high frequency, GBT spectroscopic observations have a maximum instantaneous bandwidth of about 680 MHz. The GBO electronics team has developed a plan to improve the bandwidth for high spectral resolution on the Ka-, Q-, and W-band receivers by modifying the IF system and enhancing the VEGAS system. These modifications could increase the bandwidth for high spectral resolution to about 8 GHz, providing more than an order of magnitude increase in the speed for carrying out spectroscopic surveys. Hardware will be prototyped and tested in 2024.

SCIENCE DATA ARCHIVE A new data archive has been established onsite at GBO to preserve historical and ongoing GBT observation data, ensuring its longevity and accessibility for future generations of scientists. In 2024, GBO will coordinate with the NRAO to develop a plan to make this data accessible through the NRAO Archive Access Tool (AAT).

GBT LEGACY ARCHIVE The science teams of large GBT programs will provide Science Ready Data Products which will be distributed via a GBO web interface as part of the GBT Legacy Science Product Archive system. The initial test system for the Radio Ammonia Mid-Plane Survey (RAMPS) was deployed in 2023, and additional data from other large programs will be added in 2024.

DYSH GBT users have frequently requested a Python-based toolkit for data analysis. GBO is collaborating with the University of Maryland to develop a Python-based data reduction software system called Dysh. By the end of 2024, modules to reduce data from a few core observing modes for spectral line data (such as position switching) and a preliminary Graphical User Interface (GUI) will be ready for user demonstration and feedback.

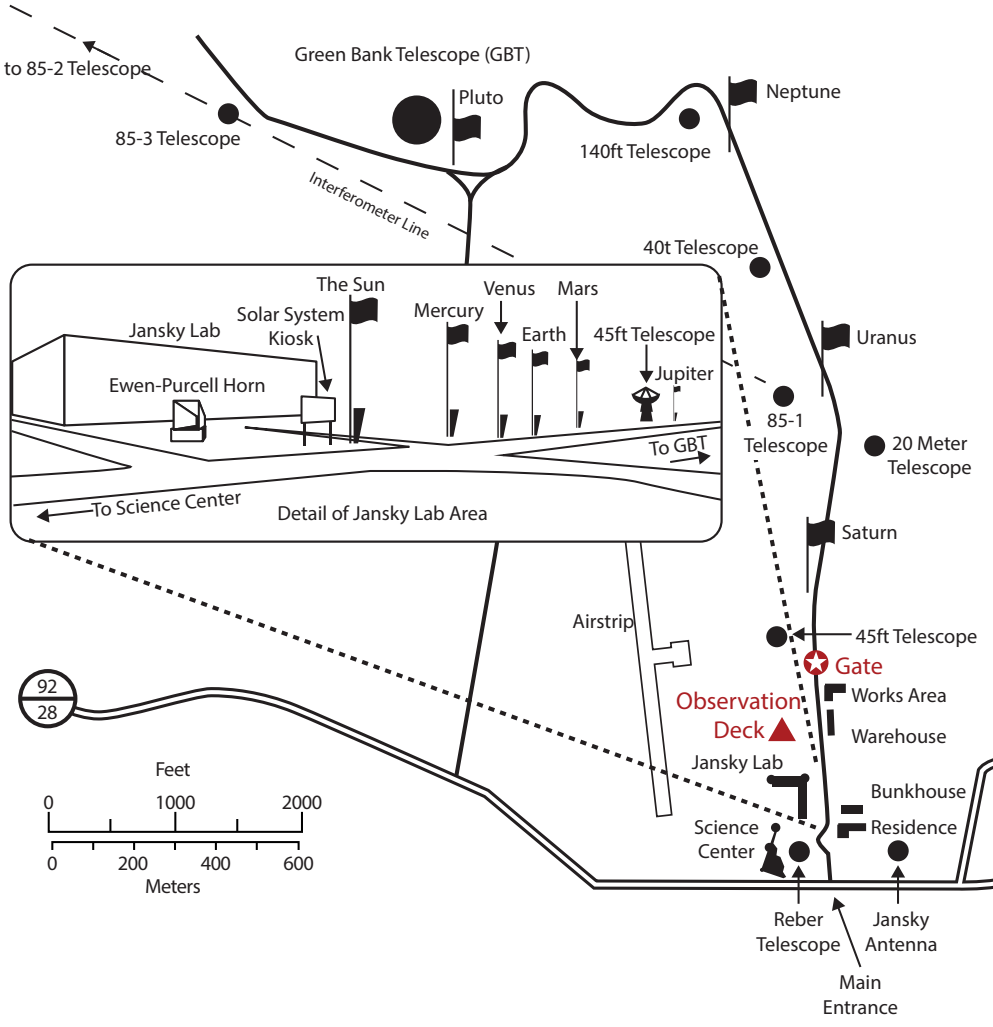
NEXT GENERATION VERY LARGE ARRAY The ngVLA will include several antennae at the Green Bank Observatory. This large project, highly ranked in the Astro2020 Decadal Review, will have 10x the sensitivity of the current VLA and a proposed frequency range (1.2–116 GHz) that complements the range of frequencies available to the GBT. The array design features a dense core of 18-meter antennae for low surface brightness imaging and extended baselines up to nearly 10,000 km for exquisite angular resolution. Site benefits include the radio quiet environment of Green Bank, geographic position compared to other planned antenna stations, and our readily available fiber, power, and infrastructure.

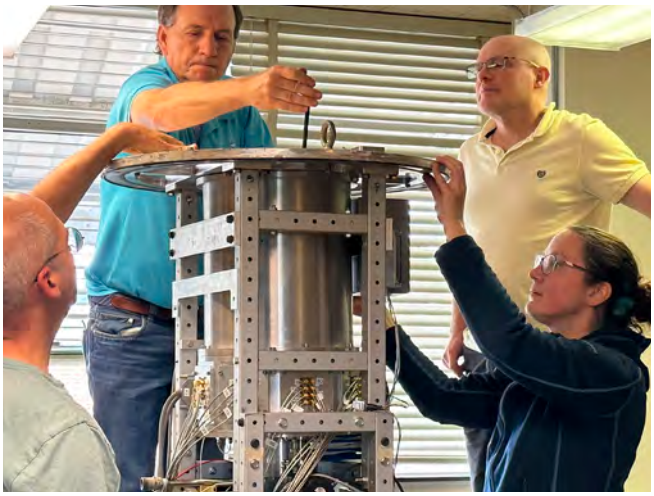
our STAFF & FACILITY CAPABILITIES

The Observatory is an attractive location for independent research experiments, and serves as the field station for several university-based research teams.

The site has significant infrastructure which allows for the installation of any instrument which may benefit from the radio quiet location, as well as a **radio frequency test range** for receivers and for testing antenna beam patterns, and a large **anechoic chamber** for testing radio emissions from all types of equipment.

With nearly 2,700 acres of land, good network connectivity, and reliable power, numerous groups have also taken advantage of the infrastructure and **radio quiet zones** to deploy their own instruments on site. These include several arrays of telescopes and antennas operating from 20–100 and 100–200 MHz, one station from a nation-wide magnetometer array, a GPS sensor deployed as part of West Virginia's geo-spatial array, along with a prototype array and a permanent outrigger for CHIME.





ELECTRONICS

The **Electronics Division** incorporates a multidisciplinary staff of engineering and technical specialists to maintain all electronic and cryogenic systems. The division works to improve the reliability of electronic systems, ensure data quality, and modify existing equipment for new applications, while also collaborating with the astronomical community at large to develop new products.

Within the division, the **Microwave Group** maintains the suite of receiver systems, and the **Digital Group** maintains the GBT's active surface, telescope control systems, and digital signal processing equipment.

The **Microwave Group** maintains a laboratory equipped with state-of-the-art test and measurement equipment, including a bonding machine and probe station for building and testing Monolithic Microwave Integrated Circuit (MMIC) devices, an Anritsu Vector Star network analyzer capable of measuring microwave components up to 115 GHz, and an assortment of RF and fiber optic devices. The RF laboratory routinely produces working RF board and optic designs up to 115 GHz using CST Microwave and Microwave Office development software. The staff also routinely experiments with commercially available MMIC devices to improve gain stability and baseline performance of the current GBT systems.

The **Digital Group** has experience with Field Programmable Gate Array (FPGA) design concepts and produces many specialized digital processing systems. This group experiments with digital servo control systems and metrology techniques for measurement and control of large radio telescopes.

SOFTWARE

The Observatory's software development division develops, maintains, and upgrades subsystems supporting the optimization, operation, and data reduction for all Observatory telescopes and systems, including: observation management, telescope monitor and control, telescope scheduling, data reduction, data archiving, visitor reservations, and site management and administration. The division simultaneously supports new development and ongoing operations using development methodologies that best support a given project and team. This makes effective use of automation, and carefully balances custom code development with open source solution integration.

MACHINE SHOP

The Shop's rapid repair capabilities maximize observation time and compress development schedules for GBO instruments. Without the Shop, the schedule would be difficult to maintain due to the limited availability of contractors who can produce custom, precision machining. The Shop engages with scientists and engineers in an iterative design/build/analysis development routine that is much more cost effective than a series of formal outsourced fabrications to a commercial facility.

The Shop has capabilities for machining both very large and very small parts and assemblies, from amplifier bodies and feed horns to large actuators and other equipment for the site instruments and facilities. In addition to several manual milling machines, the shop also has two conversational mills, similar to CNC mills, which can quickly be used to program a tool path in a complex pattern, especially useful for O-ring and seal grooves.

The fabrication area has a plate roller, a shear, a metal brake, and an ironworker often used for fabricating RFI boxes. Welding shop staff are skilled at TIG, MIG, and stick welding, and regularly weld aluminum, stainless steel, and steel. For complex shapes, the Shop has a CNC plasma cutting table that can cut out shapes in stainless steel, aluminum, or steel.

TELESCOPE OPERATIONS

The **Telescope Operations Division** performs preventive and corrective maintenance tasks on all the site telescopes and their systems. Preventive maintenance, testing, and calibration tasks are performed in accordance with a master preventative maintenance schedule. Engineers and technicians from the Electronics division guide and perform maintenance and repair tasks for the servo motors of the telescope, with assistance from Telescope Operations. Preventive maintenance tasks include routine lubrication, scheduled equipment change outs, painting, and inspections.

In addition to routine telescope maintenance, the team facilitates projects to revitablize overall Observatory infrastructure.

our STAFF & FACILITY CAPABILITIES

SPECIAL EVENTS

The Observatory hosts numerous public and private meetings, workshops, and events year round at auditoriums in the Jansky Lab and Science Center, with full presentation capabilities.

Several classrooms and a computer lab are available in the Science Center. While Wi-Fi is not available onsite to avoid interference with our observations, wired internet connections are available in numerous locations.

ACCOMMODATIONS

Several options for overnight stays are available at the Observatory, including apartments, houses, and a dormitory which is ideal for student and Scout groups. Other accomodations can be found in the surrounding area for larger groups.

The Observatory cafeteria can serve breakfast, lunch, and dinner. Catering is available across campus, including coffee breaks, receptions, and meals. Refreshments and meal options are also available directly from the Science Center Starlight Cafe, whose hours vary by season.

The Drake Lounge, located above the cafeteria, is a historic space that is often used for receptions and informal gatherings.

There is ample parking on site, with room for RVs, buses, and motorcoaches. Charging stations for electric vehicles are located next to the dormitory.

GALAXY GIFT SHOP

On site and online, the Galaxy Gift Shop offers a wide range of gifts for science lovers of all ages, including unique products made in our Observation machine shop. Members, conference attendees, and educators receive a discount. Visit shop.greenbankobservatory.org.

STARLIGHT CAFE

In the lobby of the Science Center you will find a variety of fresh made options, salads, pizzas, hand-dipped ice cream, and coffee. Grab a quick snack or meal as you explore our site.

RECREATION

The Observatory features a 1.5-mile (3-mile out and back) paved self-guided walking tour of the Solar System, ending at the GBT. Explore 10 miles of trails on paved, mowed, gravel, and single-track surfaces by foot or bicycle. Trail maps are available online, at the Science Center and Jansky Lab, and are posted at trailhead parking at the rear of the Jansky Lab parking lot. Primitive camping is available in specific locations, and is a part of several special events each year.

WHAT IS THE "QUIET ZONE"?

Did you know that the GBT could "see" your mobile phone, even in airplane mode, on Mars?

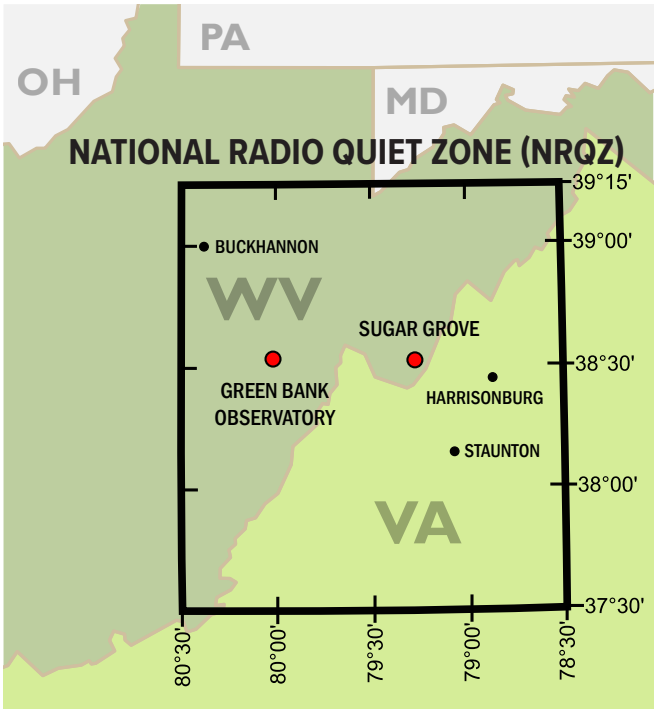
GBO's sensitive telescopes can detect cosmic phenomena billions of light years away from Earth. A wide variety of electronic devices, like those with Wi-Fi and Bluetooth, emit radio waves that interfere with our observations. They block out the distant signals astronmers are trying to detect.

When the Observatory was created, the FCC established two unique "quiet zones" to protect work being done here in Green Bank and at federal facilities in Sugar Grove, West Virginia. The **National Radio Quiet Zone** and the **West Virginia Radio Astronomy Zone** provide unique protection from many forms of human-made radio frequency interference.

The NRQZ covers approximately 13,000 square miles. Many people live in the quiet zone without even realizing it! Coordination is required for the construction of all new (or modified) permanent, fixed, licensed transmitters.

The WVRAZ defines a 10-mile radius immediately surrounding GBO within which the operation of any electrical equipment which interferes with radio astronomy is prohibited.

Despite popular misconceptions, the "quiet zone" does not mean "no internet." The Observatory relies on internet connectivity to do our work, to control the GBT, and to share our science with the world. GBO staff are advocates for improved internet service in our rural community.



EMPLOYMENT

GBO is routinely hiring permanent, temporary, and seasonal positions. Current openings can be found at **greenbankobservatory.org/careers**

LEARN MORE & APPLY NOW

EDUCATION

The Observatory's staff and facilities offer extraordinary STEM education through online and real world hands-on experiences for learners of all ages.

RADIO ASTRONOMER FOR A DAY Scientists routinely tackle questions that don't yet have answers. This overnight program for students provides an authentic research experience with tours, hands-on activities, and use of a working radio telescope. This program is open to all school and youth groups 5th grade and above and meets NGSS Nature of Science standards.

WEST VIRGINIA GOVERNOR'S STEM INSTITUTE Funded by the State of West Virginia, the Observatory hosts 60 8th graders for a 2-week summer camp focused on science, astronomy, and personal development.

PHYSICS INSPIRING THE NEXT GENERATION PING engages traditionally underrepresented students in science and engineering, with a focus on physics and radio astronomy. Launched in 2014, PING immerses rising 9th graders in a fully-funded, 2-week residential research camp and sponsors undergraduate students in a 10-week research experience that includes mentoring the campers.

FIRST2NETWORK With funding from the NSF, the Observatory coordinates a national program to connect underserved first generation college students from diverse groups to STEM career mentorships, training opportunities, and employment.

PULSAR SEARCH COLLABORATORY The PSC engages high school students and their teachers in the quest to discover new pulsars and transient sources by analyzing data from the GBT. Twice each academic year, the Observatory holds a 6-week online training course. Participants may apply to summer camp at the Observatory, and attend annual capstone events. Several PSC students have discovered new pulsars and become published authors before graduating from high school!

WEST VIRGINIA SCIENCE PUBLIC OUTREACH WV SPOT began in 2013 as a partnership with NASA's WV Space Grant Consortium. The program trains undergraduates to deliver interactive science, technology, and engineering presentations to K–12 classrooms and youth programs. To date, over 900 presentations have been given, impacting the lives of over 26,000 students.

SKYNET JUNIOR SCHOLARS SJS allows educators and students to gain access to telescopes around the world, including the Obsevatory's 20-meter radio telescope. Students remotely access telescopes to collect real project data and collaborate with each other in online communities. Educators and youth leaders can form their own clubs.

MISSION2MARS The Observatory partnered with The Franklin Institute to provide professional development to amateur astronomers and informal educators and build community networks. These networks host events to excite families about NASA's Artemis Missions and stargazing! ***mission2mars.fi.edu***

GBO & NRAO RESEARCH EDUCATION EXPERIENCE Each summer, nearly 60 students are paired with staff for immersive virtual and site-based research and training experiences.

LEARN MORE

VIRTUAL PROGRAMS

Can't come to the Observatory? Tune in from home, and we will come to you! Virtual Site Tours are offered for individuals and groups of all ages throughout the year.

Approved groups of 5 or more students can register for a Virtual Field Trip to learn about Observatory history, radio astronomy, our latest science, and more! These programs are tailored to your curriculum and availability.

FIELD TRIPS

Day trips with tours and activities are available free of charge for organized groups of K–16 students with advanced reservations. Field trips can be customized to complement classroom curricula and other field trips in the area.

SCOUTS

Overnight programs with opportunities to use a radio telescope are offered on select weekends. Scouts can earn their astronomy or electronics merit badge, and space-themed badges as well. Day-long activities are offered for Daisies and Brownies. See our events calendar for dates. Outside of these scheduled programs, Scouts may make fieldtrip reservations for tours and other hands-on science activities.

EDUCATORS

RESEARCH EXPERIENCE FOR TEACHERS

In conjunction with West Virginia University, this 6-week summer research program trains teachers in digital signal processing in radio astronomy. Learn how to use an inexpensive, versatile and rapidly developing technology (software defined radios) which can be implemented for astronomy applications as well as for receiving signals from satellites, like the NOAA weather satellites. Each summer, up to 8 teachers spend four weeks at WVU, and two weeks at the Green Bank Observatory.

CHAUTAUQUA SHORT COURSES

This 2.5-day course shares the fundamentals of radio astronomy and cutting edge scientific research with small college and community college faculty from around the nation. Each year between 25–30 participants interact with Observatory astronomers and engineers, enjoy behind the scenes tours and use educational radio telescopes to complete projects.

CAREER DEVELOPMENT

From high school through post-doctoral studies, students have several opportunities to explore career options in STEM and other work fundamental to the operations of the Observatory.

POST DOCTORAL POSITIONS Post docs are an integral part of the Observatory team and balance a variety of duties along with their own independent research. Two- to three-year positions are available on a rolling basis.

SUMMER EXPERIENCE FOR UNDERGRADUATES Summer positions can include astronomical research, and software, electrical, or hardware engineering, as well as working with plant maintenance and the machine shop. Students involved in basic research often attend scientific conferences and publish their results.

INTERNSHIPS These paid appointments provide staff support in a specific division, along with on-the-job training, tailored to meet specific academic requirements.

APPRENTICESHIPS Learn how to do a specialized job through on-the-job training, under the guidance of an experienced colleague. Paid appointments are available in mechanical engineering, machining, electronics and telescope maintenance/mechanics.

CO-OPS Academic institutions are encouraged to contact the Observatory directly with proposals for student placements.

SCIENCE CENTER

The Science Center offers hands-on science in the Catching the Wave Exhibit Hall, shopping in the Galaxy Gift Shop, and dining at the Starlight Café.

Presentations and site tours are offered at regular intervals throughout the day. Additional programs are scheduled seasonally or monthly, including High Tech tours of the Jansky Lab, SETI tours, monthly Star Parties, indoor StarLab programs, Family Science Labs, and other special events; see our online events calendar for dates. Visitors are also welcome to take a self-guided walking tour of the Observatory.

The **Science Center** is free, but fees are charged for all tours and some special events. Days of operation and hours change seasonally. Visit **greenbankobservatory.org** for the latest information.

Group rates are available for groups of 20 or more; Field Trips are free for K–16 student and youth groups. Advance registration required.

GUIDED SITE TOURS

These hour-long tours offer a fun introduction to the world of radio astronomy, with science demonstrations and a bus excursion into the restricted zone surrounding the telescopes. Tickets can be purchased in advance in our online shop or in person at the Galaxy Gift Shop.

BEHIND-THE-SCENES TOURS

Focusing on unique aspects of our site's history with limited tickets available. Reservations are highly recommended, as these sell out! Dates and times are available online.

HIGH-TECH TOURS Curious about how a radio telescope works? Join a conversation with an Observatory engineer for a sneak peek into our electronics lab and telescope control room.

SETI TOURS The Search for Extraterrestrial Intelligence began in Green Bank! This seasonal tour explores the fascinating history of SETI projects with access to historic telescope control rooms, a walk around the GBT, and a conversation with a staff astronomer. The historic nature of locations included on the tour do pose accessibility barriers, including narrow doors and stairs. Some accommodations can be made with advance notice; please call with any questions.

SELF-GUIDED NATURE WALKS There is more to the site than our astronomy. Enjoy a self-guided walk along our nature trail and discover the valley's ecology and geology.

DATES, TIMES & RESERVATIONS

greenbankobservatory.org/events

304-456-2150

Email **visit@gbobservatory.org** with questions and group reservation requests.

Purchase tour tickets at
https://shop.greenbankobservatory.org

FAMILY PROGRAMS

See our events calendar for availability.

STAR PARTIES Explore some of the best dark skies in West Virginia. Offered monthly after sunset, all ages welcome.

STAR LABS Family fun for all ages! Crawl into the planetarium balloon for a fascinating night sky tour. Reservations recommended.

FAMILY SCIENCE LABS Kids ages 4–9 enjoy hands-on science projects. Reservations recommended.

SPECIAL EVENTS

FAMILY SCIENCE DAY OPEN HOUSE This annual afternoon of fun offers FREE guided Site Tours along with hands-on science experiments, crafts, and games for all ages.

SPACE RACE RUMPUS* An annual weekend-long festival for mountain biking and road cyclists of all ages, from beginner to advanced. Clinics and rides on trails and roads, bike rodeo, star parties, bonfire, live music, and camping. Lots of fun for adventurous families!
Date and registration at **spaceracerumpus.org**

STARQUEST* The largest annual optical and radio telescope star party in the nation! Camp out for 4 days and 3 nights, with a full schedule of speakers, workshops, raffles, activities, and more.
Date and registration at **greenbankstarquest.org**

**These events are coordinated by community partners*

EXPLORE MORE

A visit can complement many other adventures in the region! The Observatory is surrounded by the Monongahela National Forest. There are many scenic natural areas, historic sites, and attractions for exciting day and overnight trips.

15 MINUTES Cass Scenic Railroad State Park, Greenbrier River Trail

40 MINUTES Snowshoe Resort, Durbin Rocket, National Youth Science Camp, Seneca Lake State Park

WITHIN 2 HOURS Seneca Rocks, Spruce Knob, Seneca Caverns, Smoke Hole Caverns, Blackwater Falls State Park, Davis, Cranberry Glades Botanical Area, Elkins, Marlinton, Lewisburg, Droop Mountain Battlefield, the Greenbrier, Monterey, Warm Springs, the Homestead Resort, and Garth Newel Music Center

MORE INFORMATION

Pocahontas County Visitors Bureau
naturesmtnplayground.com

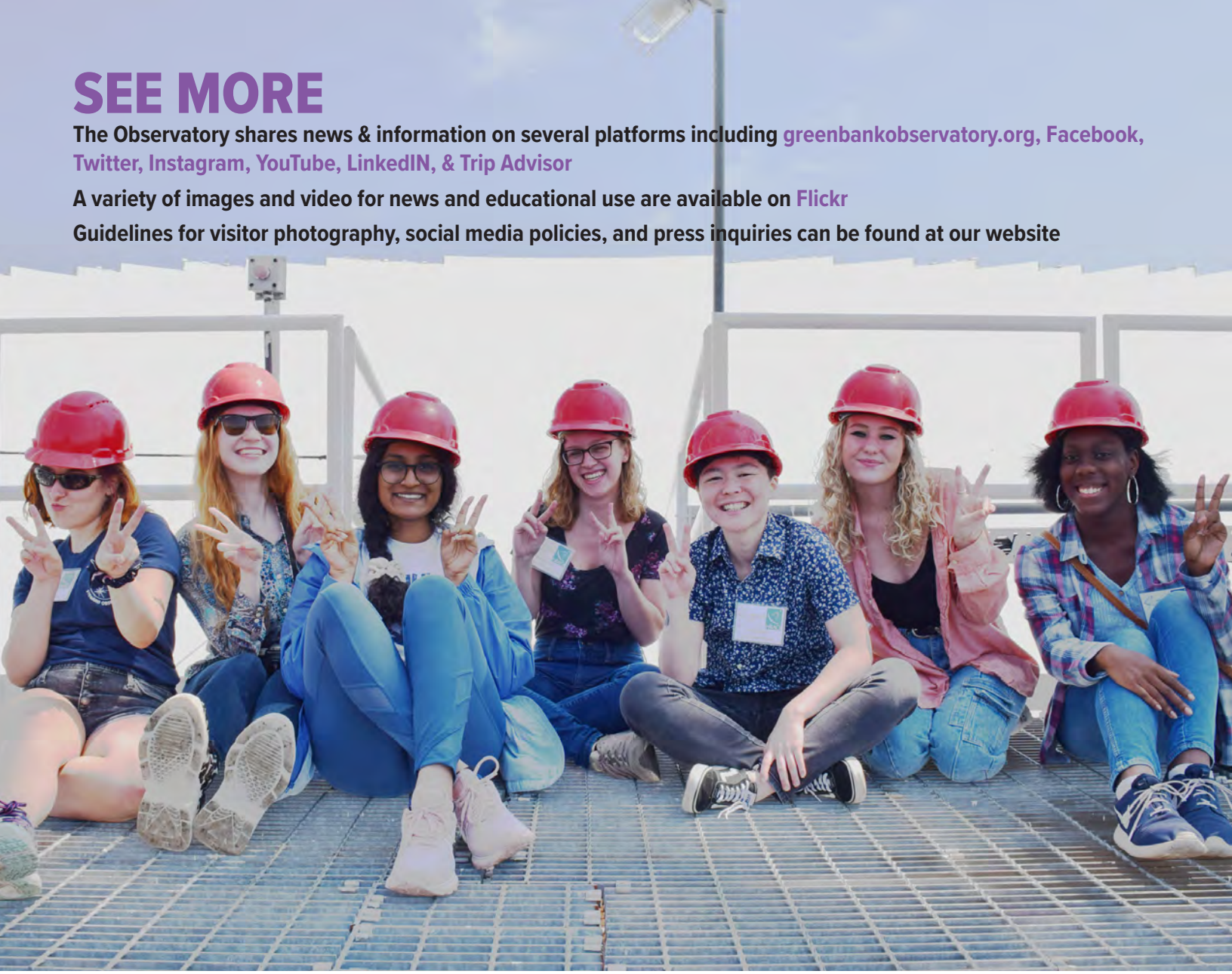
West Virginia Tourism
wvtourism.com

SEE MORE

The Observatory shares news & information on several platforms including greenbankobservatory.org, Facebook, Twitter, Instagram, YouTube, LinkedIN, & Trip Advisor

A variety of images and video for news and educational use are available on Flickr

Guidelines for visitor photography, social media policies, and press inquiries can be found at our website



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Any opinions, findings and conclusions or recommendations expressed in this material do not necessarily reflect the views of the National Science Foundation.

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