Welcome to Green Bank!
(virtually)
Welcome to Green Bank!

Green Bank Observatory enables leading edge research at radio wavelengths by offering telescope, facility and advanced instrumentation access to the astronomy community as well as to other basic and applied research communities. With radio astronomy as its foundation, the Green Bank Observatory is a world leader in advancing research, innovation, and education.
Original National Radio Astronomy Observatory, with world class telescopes for 60 years

Completed 1959

Completed 1962

Completed 1965

Completed 1995

Completed 1994

Completed 2000

Completed 1967
The GBT
A World Class Facility for Science Research

- 85% sky coverage
- 0.2 – 116 GHz range
- Unblocked aperture
- Phenomenal sensitivity ($\mu$Jy)
- 30% aperture eff. at 100 GHz
- 6800 hours available annually

User Community:

- >3000 individual scientists proposed to use the GBT in past 5 years*
- Span range of disciplines from planetary science to chemistry and physics
- Roughly 20% of proposers are new each semester

*Based on number of individual email addresses
The GBT: Unblocked Optics, High Dynamic Range
The GBT:

GBT Beam at 109 GHz; 6.4"

Argus/GBT 109.4 GHz
Beam FWHM 6.4 arcsec

Gaussian Profile Fit
The GBT:
Frequency Coverage from 0.2-116 GHz

- Most receivers are single/dual pixel, however...
  - Three multi-pixel ‘cameras’ now available on the GBT
- Primary backend is FPGA/GPU system
## The Future

Meeting the scientific needs of the next decade:

### The Advanced GBT

<table>
<thead>
<tr>
<th>Green Bank Telescope in the Next Decade (2020 – 2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infrastructure</strong></td>
</tr>
<tr>
<td>Increased hours: high frequency science</td>
</tr>
<tr>
<td>LASSI -&gt; LASSI2</td>
</tr>
<tr>
<td><strong>Optimized Feeds</strong></td>
</tr>
<tr>
<td>Wide-band Feeds</td>
</tr>
<tr>
<td>UWB (0.8 – 4.0 GHz) =&gt; Increase across all bands</td>
</tr>
<tr>
<td><strong>Shared spectrum</strong></td>
</tr>
<tr>
<td>Digitized IF =&gt; Improved RFI Resilience</td>
</tr>
<tr>
<td><strong>Data Archive</strong></td>
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<td>Archive tool =&gt; facility =&gt; clouds + hard storage</td>
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<tr>
<td><strong>Improved data processing tools</strong></td>
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<tr>
<td>Port of existing tools to pipeline</td>
</tr>
<tr>
<td><strong>Radio Cameras</strong></td>
</tr>
<tr>
<td>Traditional Feedhorn Arrays</td>
</tr>
<tr>
<td>KFPA -&gt; ARGUS -&gt; ARGUS+</td>
</tr>
<tr>
<td>Bolometer Arrays</td>
</tr>
<tr>
<td>MUSTANG -&gt; MUSTANG 1.5 -&gt; MUSTANG2</td>
</tr>
<tr>
<td><strong>New Capabilities</strong></td>
</tr>
<tr>
<td>ngVLA: Antenna site; More?</td>
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<tr>
<td><strong>GBT Radar System</strong></td>
</tr>
</tbody>
</table>

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**Green Bank Observatory**
$1.3M grant from NSF MSIP

- Place Terrestrial Laser Scanner on GBT to provide real time surface corrections
- Allows for high frequency observing during the day
- Minimize time needed for OOF Holography
- **Increase high frequency hours available to GBT**
- Will ease scheduling issues, benefit all science

- **Commissioning for instrument underway!**
- PI: Lockman
The Future

Ultra Wideband Feed

Moore Foundation award  (PI: Ransom – NRAO/NANOGrav)

- 0.7 – 4.0 GHz feed optimized for pulsar work
- Aim is $T_{\text{sys}} \sim 30$ K
- Doubles the sensitivity for most pulsar timing observations
- Under construction;

Left: Pulse profile versus frequency for J2214+ 3000 as observed by ASP, PUPPI, planned UWB
Right: Relative SNR as a function of observing bandwidth and center frequency for uniformly-weighted data and a typical pulsar spectral index of -1.7
The Future
Digitizing the RF

NSF ATI award (R.Lynch, PI)

• Designed for wide-band digital systems
• Increase the range of frequencies detected at any instant
• Allows for active RFI mitigation;
• Improves dynamic range, baselines
• Development underway; Goal is to deploy on UWBR

Data from the GBO 20-m telescope demonstrating our new, real-time robust recursive power estimation excision technique.
The Future

Data Archive Center

NSF WoU award

• Allow for onsite archiving of all GBT open skies data
• Data will be accesses through the NRAO AAT
• Cost effective means for data storage
The Future
X-band Receiver Replacement

Internally funded
• Replaces the current GBT X-band receiver at the Gregorian focus
• Increased frequency range
  – 8-12 GHz instead of 8-10.1 GHz
• Higher cooling capacity = less maintenance
• Improved baseline stability
• Commissioning planned for 2021
The GBT – Looking Ahead

CHIME Outrigger

• Proposed CHIME outrigger antenna on site
• Planned construction to start as soon as weather allows
The Future Radar Systems

Planning for new high power radar system on GBT

Phase I: low power demonstration
- Test system: 700W, 14 GHz
- Images Apollo 15 landing site
- Image show receive with Hancock VLBA only

Phase II: high power system
- 50-100s kW transmit on GBT
- VLBA then ngVLA as receive
- Project planning underway
- Not yet funded
The Future
The GBT – Radio Cameras

ARGUS 144

• Planned instrument
• 10 x 10 pixels; 85-116 GHz
• Pixel spacing 26.7” ; Footprint: 4’x4’
• $T_{sys}$: 50-60K
• FWHM: 8” at 89 GHz; 6.5” at 110 GHz
• $\geq$ 1 GHz instantaneous bandwidth
• $\geq$ 2 spectral windows of 100 MHz each
  – Frequency resolution $\sim$60 kHz (0.2 km/s)
• Project not yet funded
• Have applied to NSF MSIP program

Part of OMC-1 mapped by Argus in HNC(1-0). This map took 4.5 hours, including pointing, surface setting and calibration. The white circle (lower right) shows the Argus beam. With Argus+ and the planned GBT metrology improvements spectral lines images with identical sensitivity over a somewhat larger area will be acquired in <30 min.
(Figure courtesy of Alvaro Hacar).
Meeting the scientific needs of the next decade:

The Advanced GBT
The Future

Meeting the scientific needs of the next decade:

The Advanced GBT

Green Bank Telescope in the Next Decade (2020 – 2030)

- **New Capabilities**
  - ngVLA: Antenna site; More?
  - CHIME

- **GBT I**
  - Working on funding

- **Radio Cameras**
  - Phased Array Feed Technology
    - FLAG -> KPAF, FLAG2
  - Working on funding
  - Traditional
    - KFPA -> A
  - Working on funding

- **Bolometer Arrays**
  - MUSTANG -> MUSTANG 1.5 -> MUSTANG
  - DONE

- **Optimized Feeds**
  - Wide-band Feed
    - U/V (0.8 – 4.0 GHz) -> Increased
  - X-band underway
  - R&D underway

- **Infrastructure**
  - Shared spectrum
    - Digitized IF -> Improved RFI
  - Data Archive
    - Archive tool -> facility -> cloud
  - Improved data processing tools
    - Port of existing tools to pipeline
  - Increased hours: high frequency
    - LASSI -> LASSI2
  - Facility being built

Green Bank Observatory
The Future
What is next?

• Numerous new instruments and capabilities under development

• GBT will see many new capabilities within the decade

• After that?
  – Working to define GBT/GBO’s role in the era of the ngVLA
    • ngVLA antenna site; Role for GBT with zero spacing, high sensitivity?
  – Operational plans for radar system may also play into GBT+ngVLA plans

• But the long term GBT future is also up to you!
  – The GBT was built for the astronomy community
  – Community input is the basis for our long term goals and instrumentation
Welcome to Green Bank!
GBT Remote Observing Workshop

Virtual Workshop

May 24, 26, 28, 2021
Welcome to the Green Bank Observatory! (kind of)

Located in the “National Radio Quiet Zone”, protected from radio interference.

Come visit and explore the grounds

- Trail maps available upon request
- No electronic devices near the telescopes (past the gate)
- Be aware of wildlife

Gift shop/science center open online

- 10% off coupon in Informational email
Goals for the Workshop

- Become familiar with GBT observing modes and user interfaces
- Practice standard data reduction techniques
- Learn how to observe remotely
  - ...But come visit in person some day!
Schedule

- 9 am – 4:30 pm EDT on Monday & Wednesday
  - Lectures and Observation Prep
  - We’ll be on this Zoom for all of these

- 5:30 pm – 8 am: Monday Group Observations

- 5:30 pm – 8 am: Wednesday Group Observations
  - Each group has their own Zoom for overnight observations.

Friday Activities:

9 am – 10:30 am: Data Reduction Session
11 am – 12:30 pm: Project Presentations (Each Group)
<table>
<thead>
<tr>
<th>Time</th>
<th>Monday May 24</th>
<th>Tuesday May 25</th>
<th>Wednesday May 26</th>
<th>Thursday May 27</th>
<th>Friday May 28</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>Welcome</td>
<td></td>
<td>Continue Data Reduction &amp; Observing</td>
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<tr>
<td></td>
<td><em>(Karen O'Neil &amp; Will Armentrout)</em></td>
<td></td>
<td>Preparation w/ Project Friends</td>
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<tr>
<td>9:30</td>
<td>The Green Bank Telescope</td>
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<td>VLBI Discussion <em>(Optional)</em></td>
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<td></td>
<td><em>(David Frayer)</em></td>
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<td>10:00-10:30</td>
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<td>10:00</td>
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<td><em>(Tapasi Ghosh)</em></td>
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<tr>
<td>10:30</td>
<td>Introduction to Astrid and Cleo</td>
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<td></td>
<td><em>(Brenne Gregory &amp; Amber Bonsall)</em></td>
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<td>11:00</td>
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<td>Observing Recap &amp; GBT Public Relations</td>
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<td></td>
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<td></td>
<td><em>(Will Armentrout &amp; Jill Malusky)</em></td>
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<tr>
<td>11:30</td>
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<td></td>
<td>Review of High Freq. GBT Corrections</td>
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<td></td>
<td><em>(Natalie Butterfield)</em></td>
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<tr>
<td>12:00</td>
<td>Break (Speakers will be available)</td>
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<tr>
<td>12:30</td>
<td>Remote Observing / Connection Workshop</td>
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<td>GBT Dynamic Scheduling System</td>
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<td></td>
<td><em>(Andrew Seymour)</em></td>
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<td><em>(Toney Minter - Recorded)</em></td>
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<tr>
<td>13:00</td>
<td>Green Bank Computing Environment</td>
<td></td>
<td>&quot;Office Hour&quot; w/ Project Friends</td>
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<tr>
<td></td>
<td>- Linux, IDL, etc. <em>(Larry Morgan)</em></td>
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<td><em>(GBT Community Zoom - Natalie Butterfield)</em></td>
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<tr>
<td>13:30</td>
<td>Spectral Line &amp; Continuum Reduction</td>
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<td>Break</td>
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<td></td>
<td><em>(Pedro)</em></td>
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<td>How to Prepare and Submit a GBT Proposal</td>
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<tr>
<td>14:00</td>
<td>Pulsar Data Reduction</td>
<td></td>
<td><em>(Will Armentrout)</em></td>
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<tr>
<td>14:30</td>
<td>Group Observing Preparation w/ Project</td>
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<td>Frequently Asked Questions</td>
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<td>Friends</td>
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<td><em>(Amber &amp; Jesse)</em></td>
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<td>15:00</td>
<td>Break</td>
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<td>Break</td>
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<td>15:30</td>
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<td>(Speakers will be available)</td>
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<td>16:00</td>
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Night One Observing Begins at 5:30 pm

Night Two Observing begins at 5:30 pm
Observing Accounts

- If we have a new account for you, I’ll send you a message over Zoom with your account information.

- Otherwise, your project friend will be able to open up a remote session for you.

Two Options to Log In

- (1) Login using “ssh [username]@ssh.gb.nrao.edu”
- (2) Use “FastX” -- Link included in welcome email.

- Change password with “passwd” command.