Green Bank Telescope Science Program

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NRAO, Green Bank WV
The GBT

- Point source sensitivity of a ~120m telescope
  With its state-of-the art receivers it has
- Point source sensitivity $\sqrt{2}$ better than VLA at $\lesssim 2$ GHz

In 2014
6220$^h$ for science
$\sim \frac{1}{3}$ at $\nu \geq 18$ GHz
National Radio Quiet Zone

Appalachian Mountains
- Receivers cover 0.1 to >100 GHz
- >85% of total sky covered $\delta\geq-46^\circ$
- National Radio Quiet Zone
- Competitively Scheduled

The GBT frequency coverage overlaps and extends beyond that of the JVLA and ALMA
GBT Pointing

$\sigma \approx 2''$
GBT Proposers per Proposal Cycle
Total Proposers: 1712

Total GBT Users ~1200
Research areas of most-cited GBT publications

(November 2014)

Pulsars and compact objects
Gravity and General Relativity
Galactic Hydrogen surveys
Interstellar Chemistry
The internal structure of Mercury
Evolution of spiral galaxies
Star formation & pre-stellar objects
Studies of a binary black hole
Hydrogen content of galaxies
Molecules in highly redshifted galaxies
Anisotropies in the cosmic Infrared background
A radar return is speckled.
The radar return is speckled.
deep space network

70-meter antenna at Goldstone, California
“Large Longitude Libration of Mercury Reveals a Molten Core”
Margot et al. 2007 Science
Goldstone-GBT bistatic radar images

\(~18x\) the distance to the Moon

(85989) 1999 JD6

Jul 25, 2015
01:40-09:03 UT
7.5 m x 0.5 Hz and
19 m x 0.5 Hz, scaled
GBT -- The Premier Pulsar Telescope
Fastest Pulsar
Most Massive Pulsar
Pulsars in Globular Clusters
Tests of General Relativity
Relativistic Spin Precession
Pulsar in a three-body system
Coolest white dwarf star  (a diamond as big as the Ritz)
A Pulsar in a Triple System
ARECIBO+ GBT
Ransom et al. (2014) Nature

\[ F = ma = \frac{GmM}{r^2} \]
DETECTING GRAVITATIONAL RADIATION

Credit: D. Backer
Predicted Power in Gravitational Radiation

Characteristic strain, $\log_{10}(h_c)$

Frequency, $\log_{10}(\text{Hz})$

NANOGrav

SMBH-SMBH (stoch.)

Cosmic strings

Gal. BH/NS

eLISA/NGO

MBH-MBH (indiv.)

PSRs

BH-BH (indiv.)

LIGO

Advanced LIGO

Pulsar timing
A VLBI Resolution of the Pleiades distance controversy

Melis et al. (2014)
VLBA + GBT + Effelsberg + Arecibo

errors < 0.0001"

134.8 ± 0.5 pc
138.4 ± 1.1 pc
135.5 ± 0.6 pc
136.6 ± 0.6 pc

errors < 1%
A VLBI Resolution of the Pleiades distance controversy

Melis et al. (2014)
22 GHz H₂O Masers
Braatz, Kuo et al.

Discovered by the GBT
Monitored by the GBT
Imaged by the VLBA + GBT
The Chemistry of Interstellar Space

Some (of the 17+) New GBT Molecule Detections

propenal

cyanoformaldehyde

ketenimine

C₆H-
A digression on the sensitivity of radio telescopes

point source

\[ t \propto \frac{1}{A_e^2} \]

extended source

\[ t \propto f^2 \propto \frac{Diam^4}{A_e^2} \]
A digression on the sensitivity of radio telescopes

\[ t \propto f^2 \propto \frac{Diam^4}{A_e^2} \]

Diam = 100 m

Diam = 1000 m
A digression on the sensitivity of radio telescopes

<table>
<thead>
<tr>
<th>Instrument</th>
<th>$f^2$</th>
<th>21cm HPBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBT</td>
<td>1</td>
<td>9.1’</td>
</tr>
<tr>
<td>Arecibo</td>
<td>1</td>
<td>3.2’</td>
</tr>
<tr>
<td>VLA-D</td>
<td>$\sim 10^4$</td>
<td>46”</td>
</tr>
<tr>
<td>VLA-C</td>
<td>$\sim 10^6$</td>
<td>14”</td>
</tr>
<tr>
<td>VLA-B</td>
<td>$\sim 10^8$</td>
<td>4.3”</td>
</tr>
<tr>
<td>ASKAP</td>
<td>$\sim 10^6$</td>
<td></td>
</tr>
</tbody>
</table>

$$t \propto f^2 \propto \frac{Diam^4}{A_e^2}$$
A digression on the sensitivity of radio telescopes

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For a given collecting area, the brightness sensitivity is always greatest for a filled aperture.

For a given angular resolution, the brightness sensitivity is always greatest for a filled aperture.

This is not related to the issue of missing short spacings.
VLBA Limited to $T_b > 10^5$ K
The Chemistry of Interstellar Space

propenal

cyanoformaldehyde

propanal

ketenimine

Hot new chemistry discovery today!

Some (of the 17+) New GBT Molecule Detections

C₆H-
HC$_7$N: A Chemical “Clock” in a Molecular Cloud?
Friesen et al. (2013)

$[\text{NH}_3]/[\text{HC}_7\text{N}]$
Star Formation in a Filament in Taurus

Young Min Seo et al. 2015 ApJ 805, 185
GBT 67–93.6 GHz Survey of Orion–KL

\[ T_{\text{mb}} \text{ [K]} \]

LSR Frequency [GHz]

Frayer et al. 2015
GBT detection of mm-cm sized “dust” in star-forming clouds

Schnee et al. (2014)
No Hydrogen in the Milky Way’s Dwarf Galaxies

<table>
<thead>
<tr>
<th>Galaxy</th>
<th>$L$ ($L_\odot$)</th>
<th>$M_{\text{HI}}$ ($M_\odot$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segue I</td>
<td>340</td>
<td>$&lt;11$</td>
</tr>
<tr>
<td>UMa II</td>
<td>41,000</td>
<td>$&lt;74$</td>
</tr>
<tr>
<td>Bootes II</td>
<td>1,000</td>
<td>$&lt;38$</td>
</tr>
<tr>
<td>Coma Ber</td>
<td>3,700</td>
<td>$&lt;62$</td>
</tr>
<tr>
<td>Ursa Mi</td>
<td>280,000</td>
<td>$&lt;63$</td>
</tr>
<tr>
<td>Draco</td>
<td>280,000</td>
<td>$&lt;133$</td>
</tr>
<tr>
<td>Spitzer Cloud</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Hydra II</td>
<td></td>
<td>$&lt;200^*$</td>
</tr>
</tbody>
</table>

*GBT results from Spekkens et al. 2014*
GBT High-Resolution 3mm SZE in a Cluster

\[ X\text{-ray: } n_e^2 T_e^{1/2} \]

\[ SZE: \quad n_e T_e \]

VLA non-thermal
THINGS VLA Survey
Walter et al. 2008
30" 3σ=10^{19.5}
6" 3σ=10^{20.5}

HALOGAS WSRT Survey
Heald et al. 2011
15" to N_{HI} limit \sim 10^{19.0}
120 hours per galaxy
M31-M33 Clouds

$5 \times 10^{17}$
The GBT in 2016+
ARGUS -- 8” GBT spectroscopy at

- 16 element scalable 75-115 GHz FPA
- Stanford/CIT-JPL/UMd/Miami/NRAO (NSF grant to Stanford)
GBT MUSTANG - 2 (NSF grant to Univ Penn)

- 223 pixels
- >4’ FOV
- 35x faster than MUSTANG