Welcome, and Overview

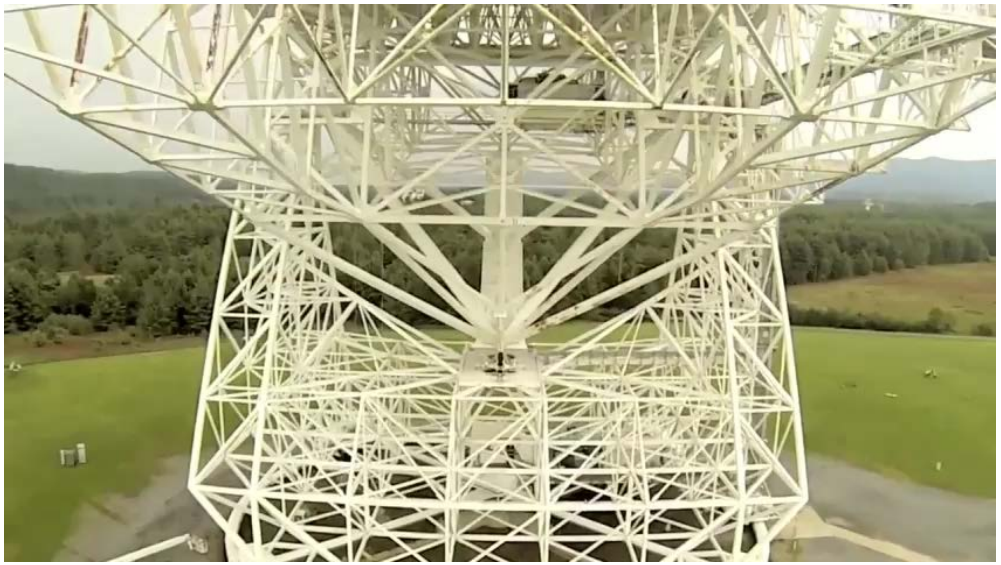
K. O'Neil, Director

GREEN BANK OBSERVATORY

Mission Statement

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.

The GBT

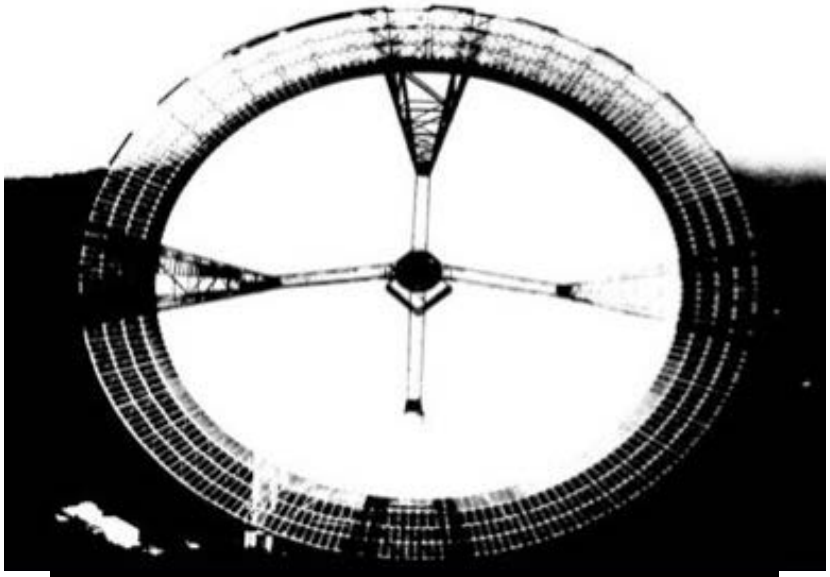


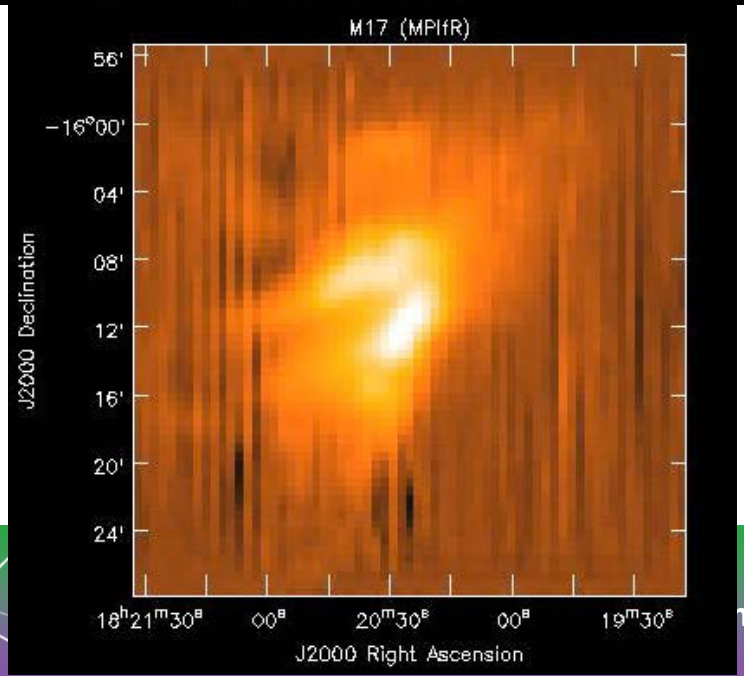
- 85% sky coverage
- 0.2 – 116 GHz range
- Unblocked aperture
- 30% aperture eff. at 100 GHz
- 6800 hours available annually

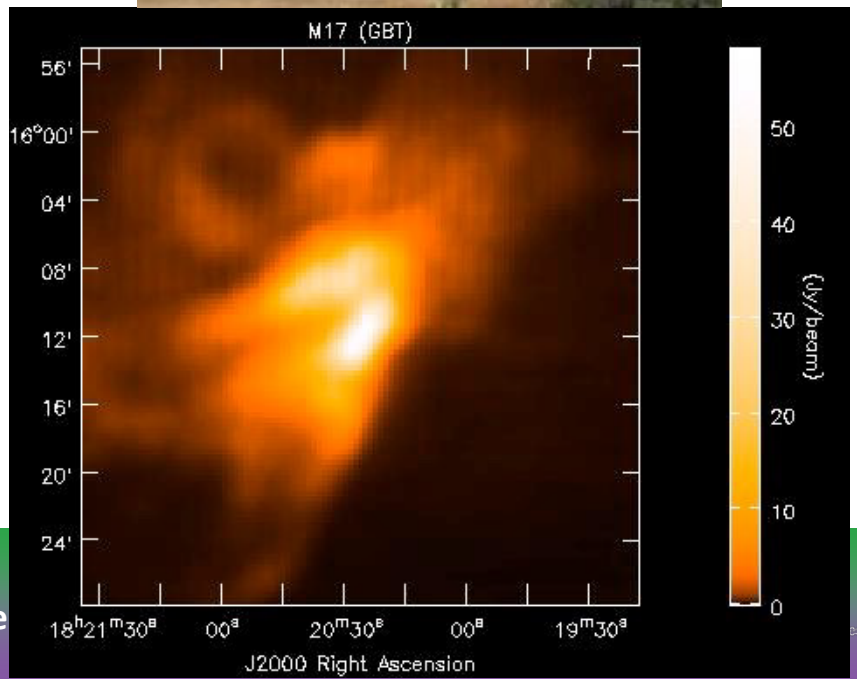
GBT Key Science:

- Fundamental Physics – Testing Matter at Extreme Densities
- Stellar Birth & Evolution – Understanding star formation
- Origin of Life
- Galaxies across Cosmic Time

GBT: Unblocked Optics, High Dynamic Range

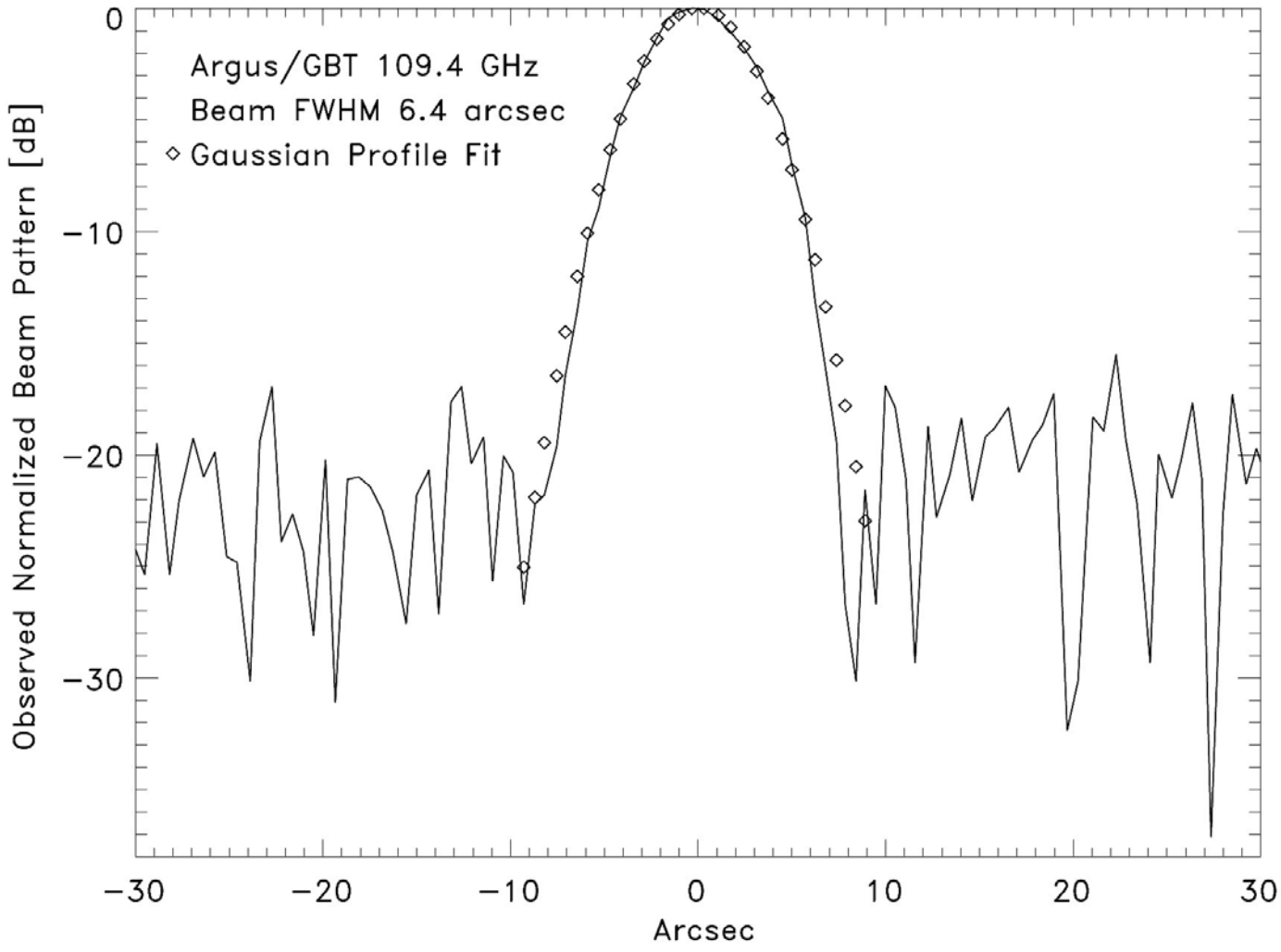






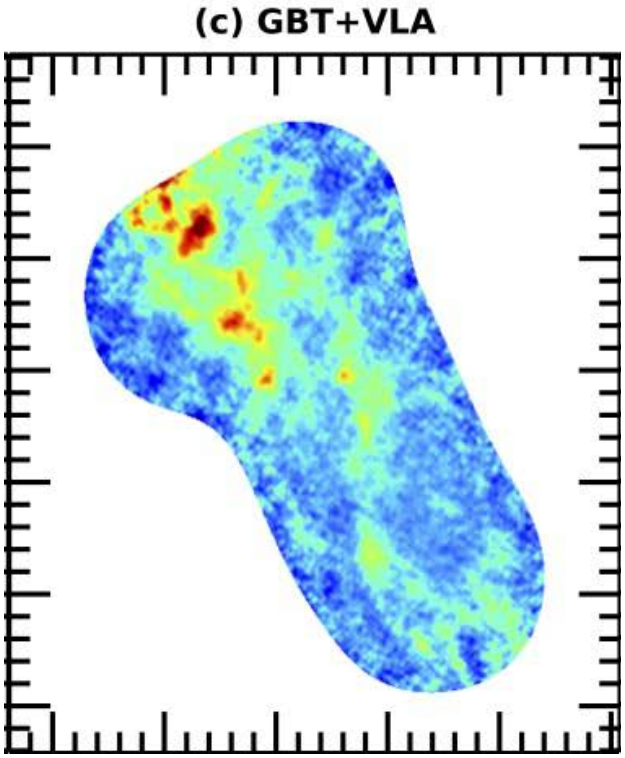
GBT: Beam Performance

GBT Beam at 109 GHZ; 6.4″

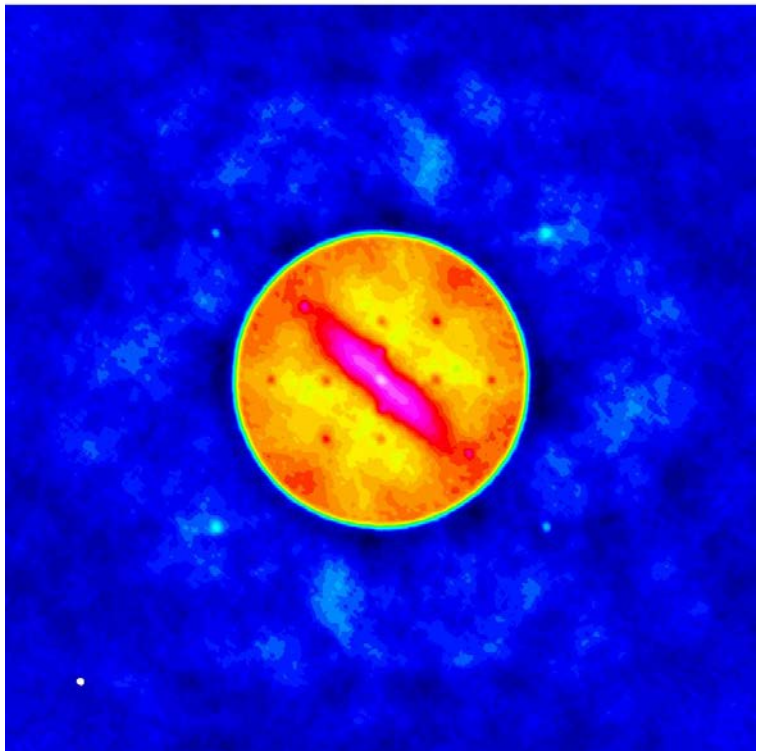


GBT & Interferometry

Provides Necessary Short Spacings for Interferometry

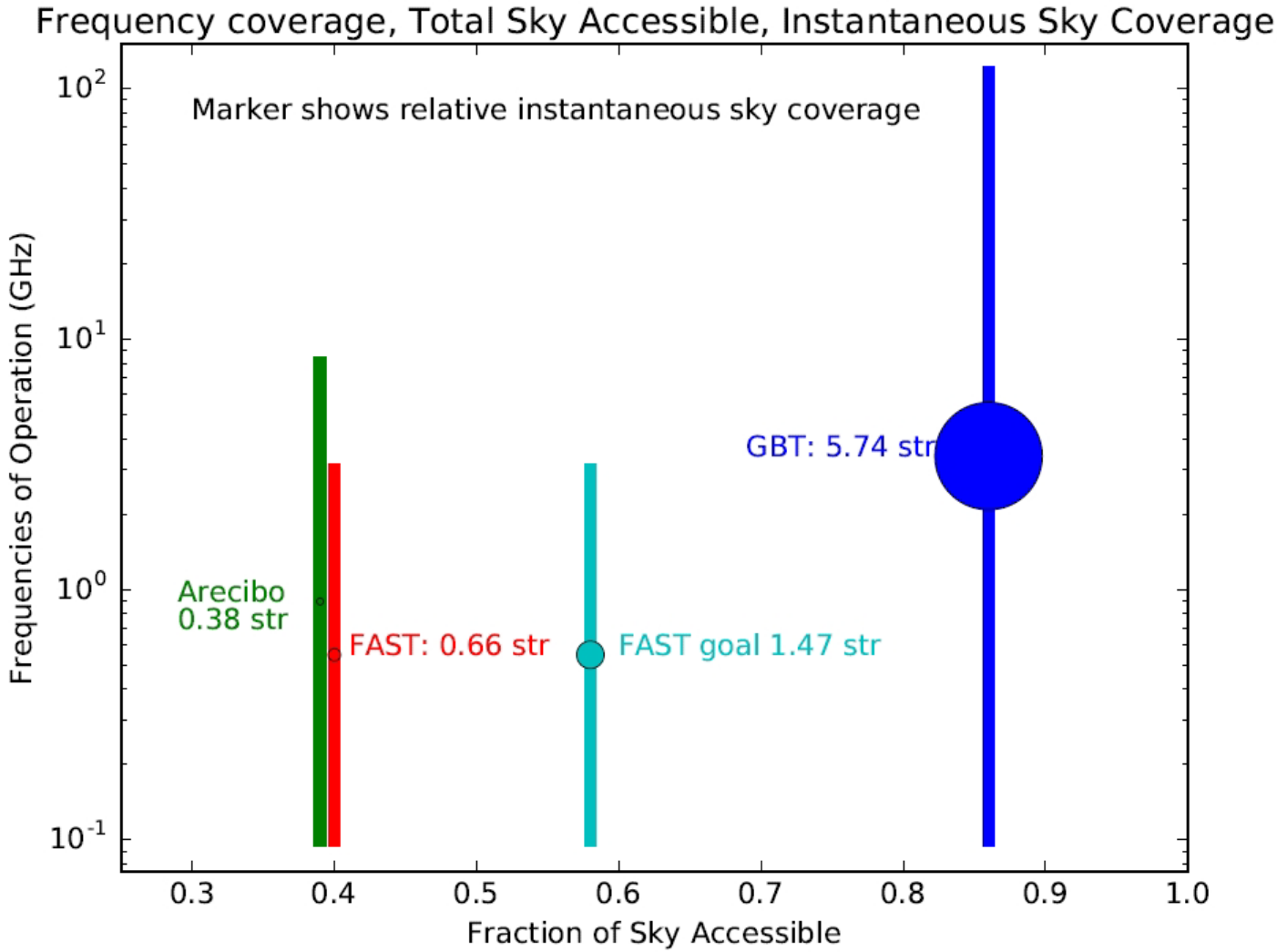


VLA, and GBT+ VLA imaging of NH_3 (Dirienzo, et al. 2015 AJ)

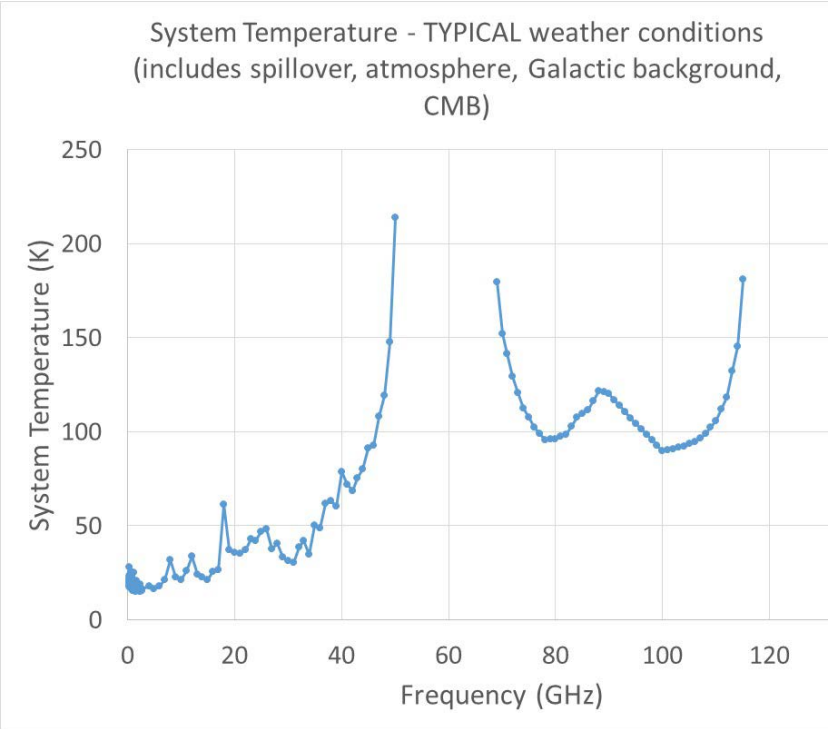


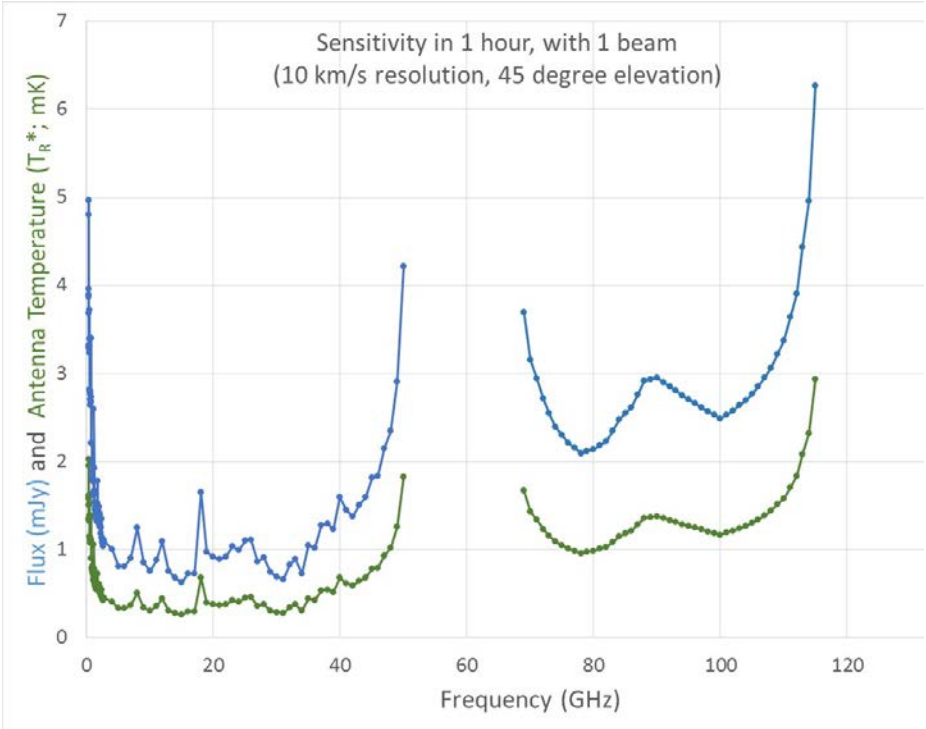
Simulated NGVLA, GBT +NGVLA imaging of input ("bright large source") image. NGVLA image recovers 8% of total flux after cleaning. GBT+ngVLA image recovers 95% of input flux (Frayer, 2017, ngVLA memo #14)

The GBT


Frequency coverage, Total Sky Accessible, Instantaneous Sky Coverage
Marker shows relative instantaneous sky coverage
Frequencies of Operation (GHz)
10^2
10^1
10^0
10^{-1}
Arecibo
0.38 str
FAST: 0.66 str
FAST goal 1.47 str
GBT: 5.74 str
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Fraction of Sky Accessible

The GBT



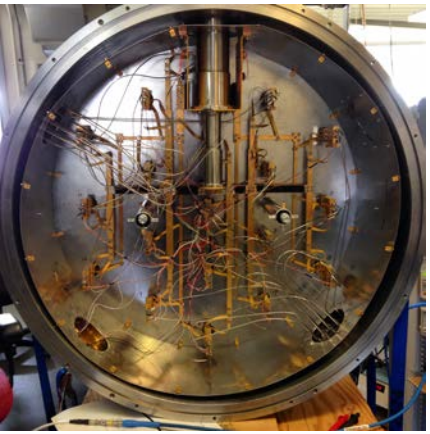


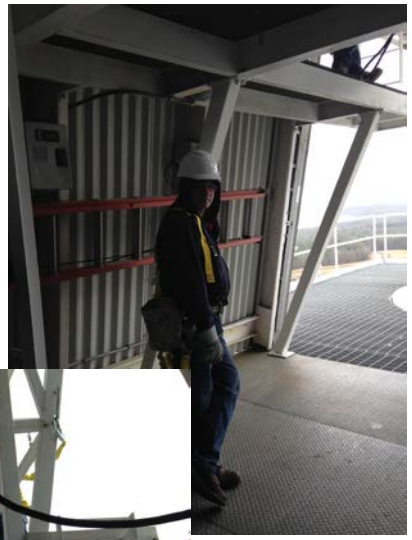
- Current frequency coverage from 0.2 through 116 GHz
- Most receivers are single/dual pixel, however…
  - Four multi-pixel ‘cameras’ now available on the GBT
- Primary backend is FPGA/GPU system

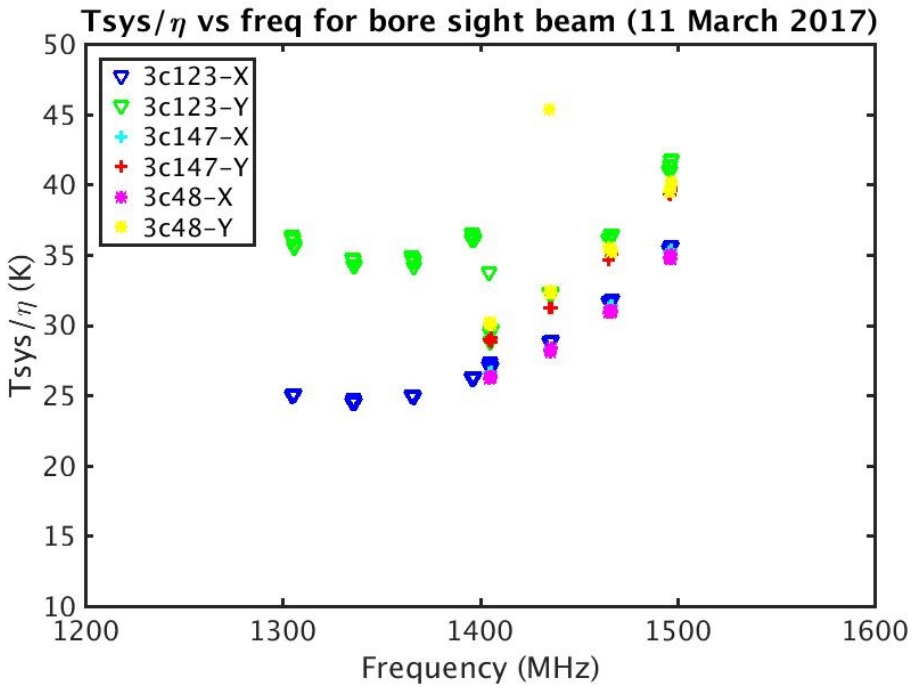
GBT: Multi-Pixel Instruments

Sensitive Phased Array Feed

NRAO and Green Bank Observatory break the record for the coldest, most sensitive phased array feed system on Earth!

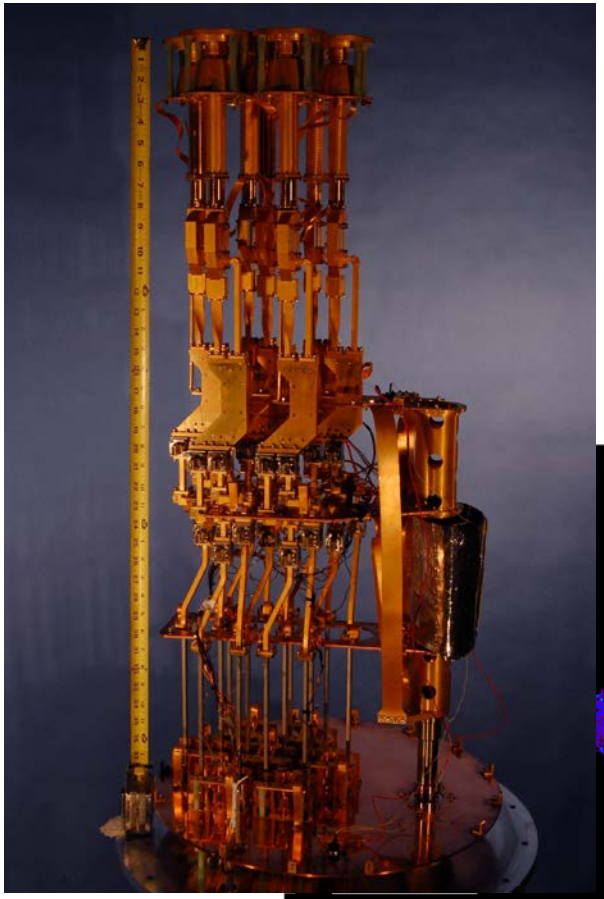




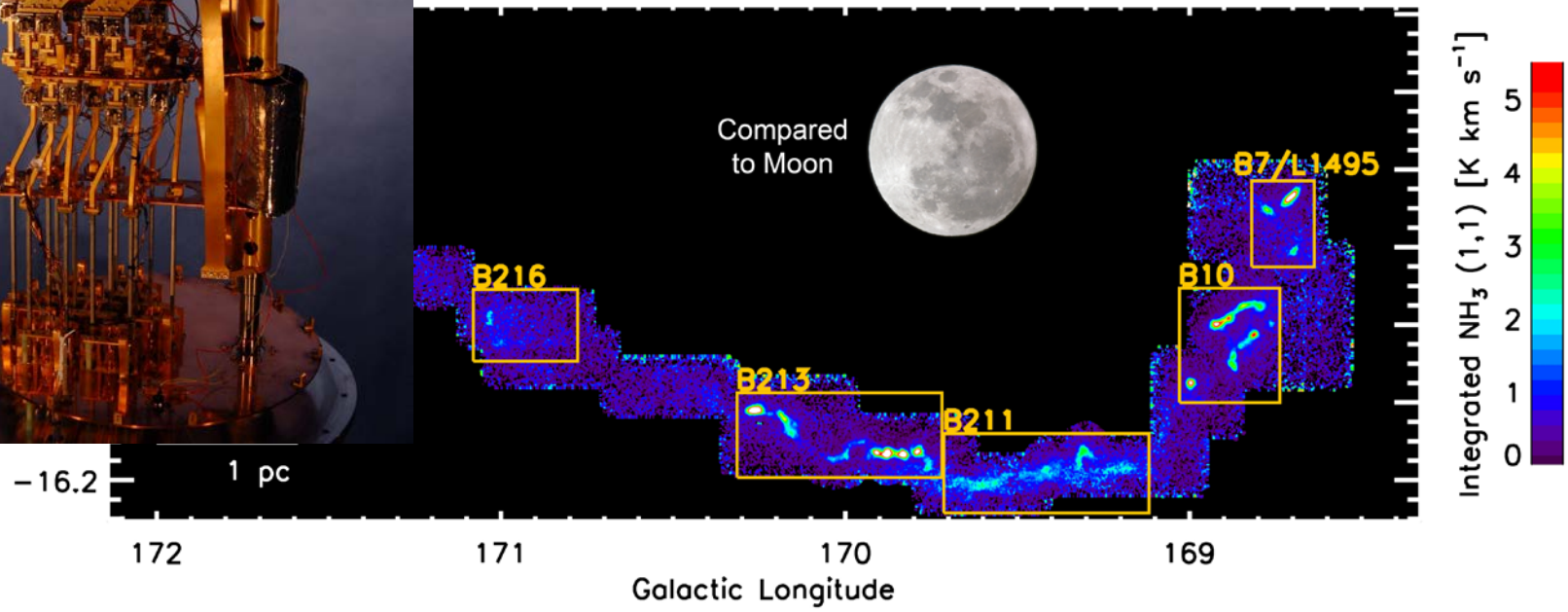


GBT: Multi-Pixel Instruments

7-pixel K-band Feed Array; 18-28 GHz

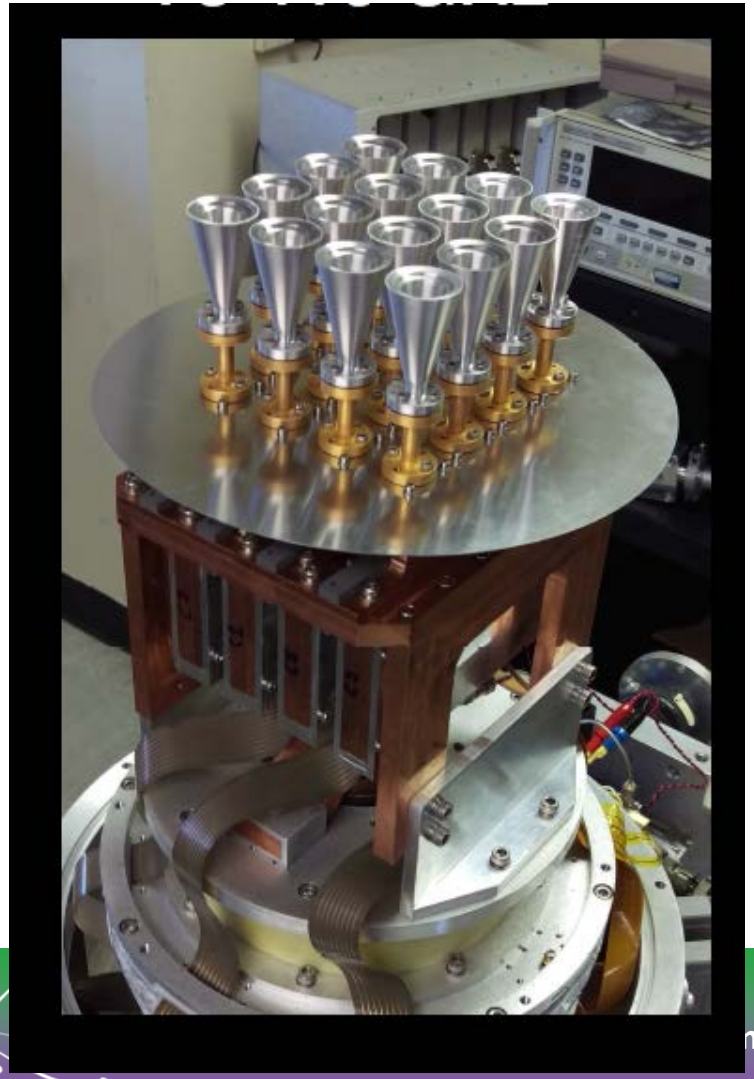


- Dual polarization
- Noise temperature < 40-50 K
- 1.8 GHz instantaneous bandwidth/beam
- Open for general use



GBT: Multi-Pixel Instruments

16-pixel W-band Feed Array; 75-116 GHz



- 16 InP MMIC RF amplifiers cooled to 15 K
- Noise temperature < 50-60 K
- Open for general use

- A collaborative effort: S. Church [PI], M. Sieth, K. Devaraj, P. Voll (Stanford); A. Readhead, K. Cleary, R. Gawande (Caltech); L. Samoska, P. Kangaslahti, T. Gaier, P. Goldsmith (JPL), A. Harris (U. Maryland); J. Gunderson (U. Florida)

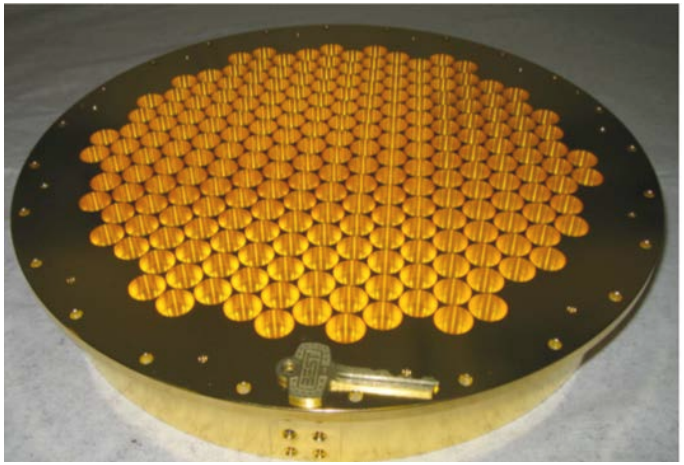
- Receiver described in Seith et al. 2014, Proc. SPIE 9153

GBT: Multi-Pixel Instruments

223 Feedhorn Bolometer Array

4′ FoV; 10″ beam

63 μJy; 0.062 mK (T_A^*) across a 5′× 5 ′ field in 1 hour



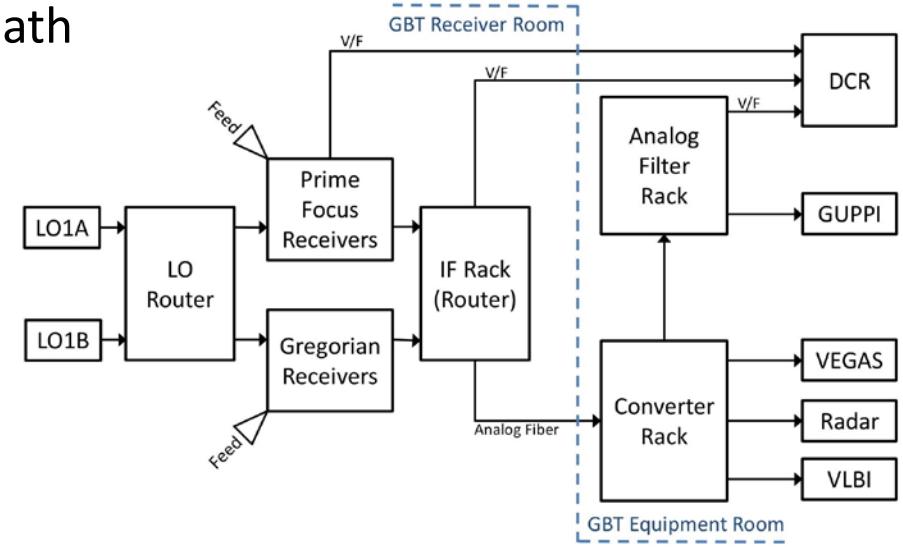
Orion Molecular Cloud complex: GBT+MUSTANG image of dust (orange) against the visible light (purple).

Data shows that Orion Nebulae contains large dust grains , 100-100x larger than typically found in interstellar space.

Collaboration: University of Pennsylvania (M. Devlin, PI), National Institute of STandards, Green Bank Observatory, National Radio Astronomy Observatory, University of Michigan, Cardiff University

GBT: Signal Processing

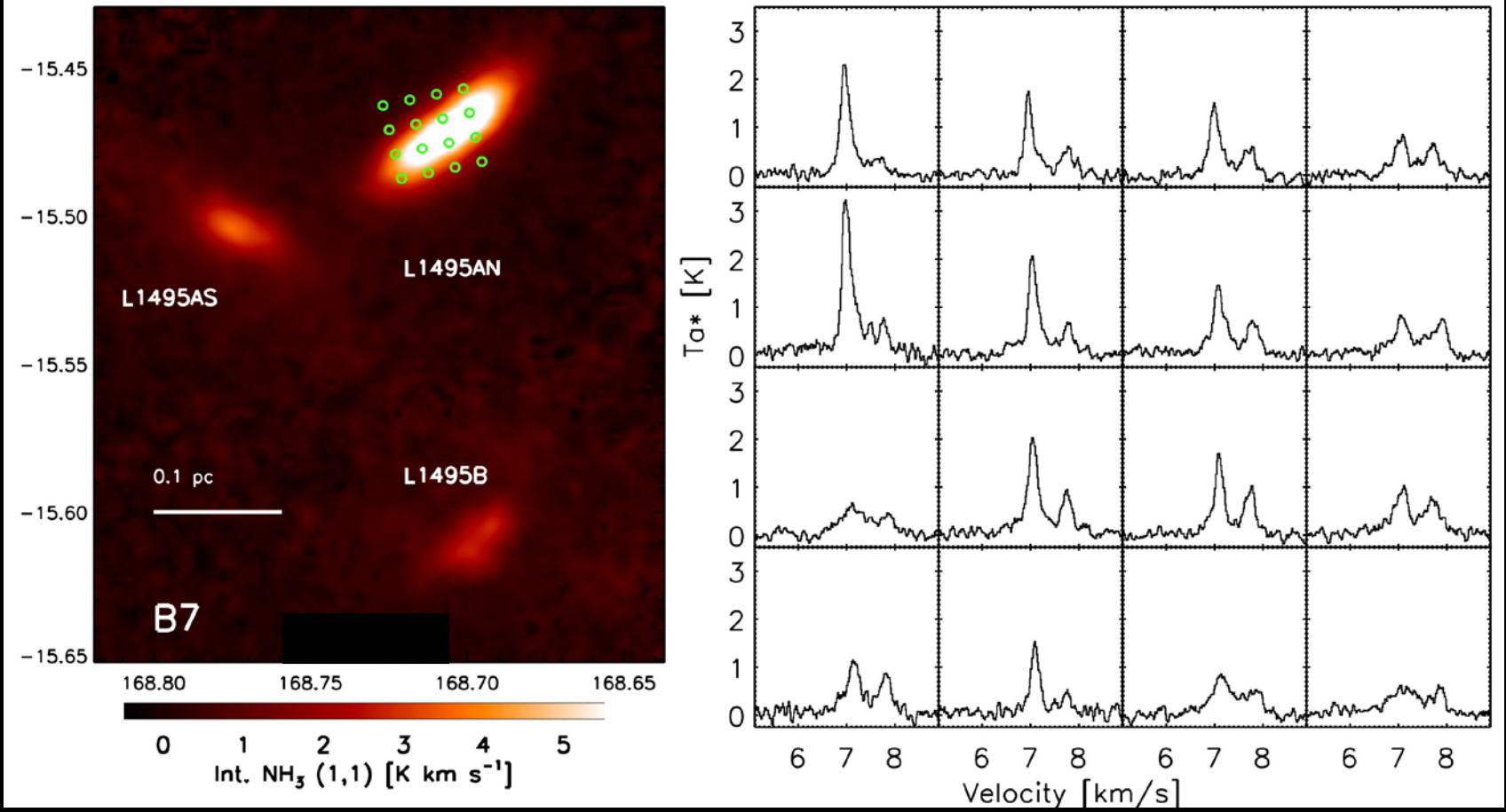
- Signal Transport
  - Most instruments use the GBT's IF path
  - Maximum bandwidth is 1.5-4 GHz
  - Possibility of digitizing signal at Rx
  - RFI/weight need to be considered



- Numerous backends currently available:
  - VEGAS (FPGA/GPU)
  - Digital Continuum Receiver (DCR)
  - Mark V (VLBA Disk Recorder)
  - Caltech Continuum Backend (CCB) (Ka only)
  - Addition of new backends straightforward

Recent Science Results

ARGUS: HCO+ 10 min snapshot; 8” <-> 0.005 pc at Taurus



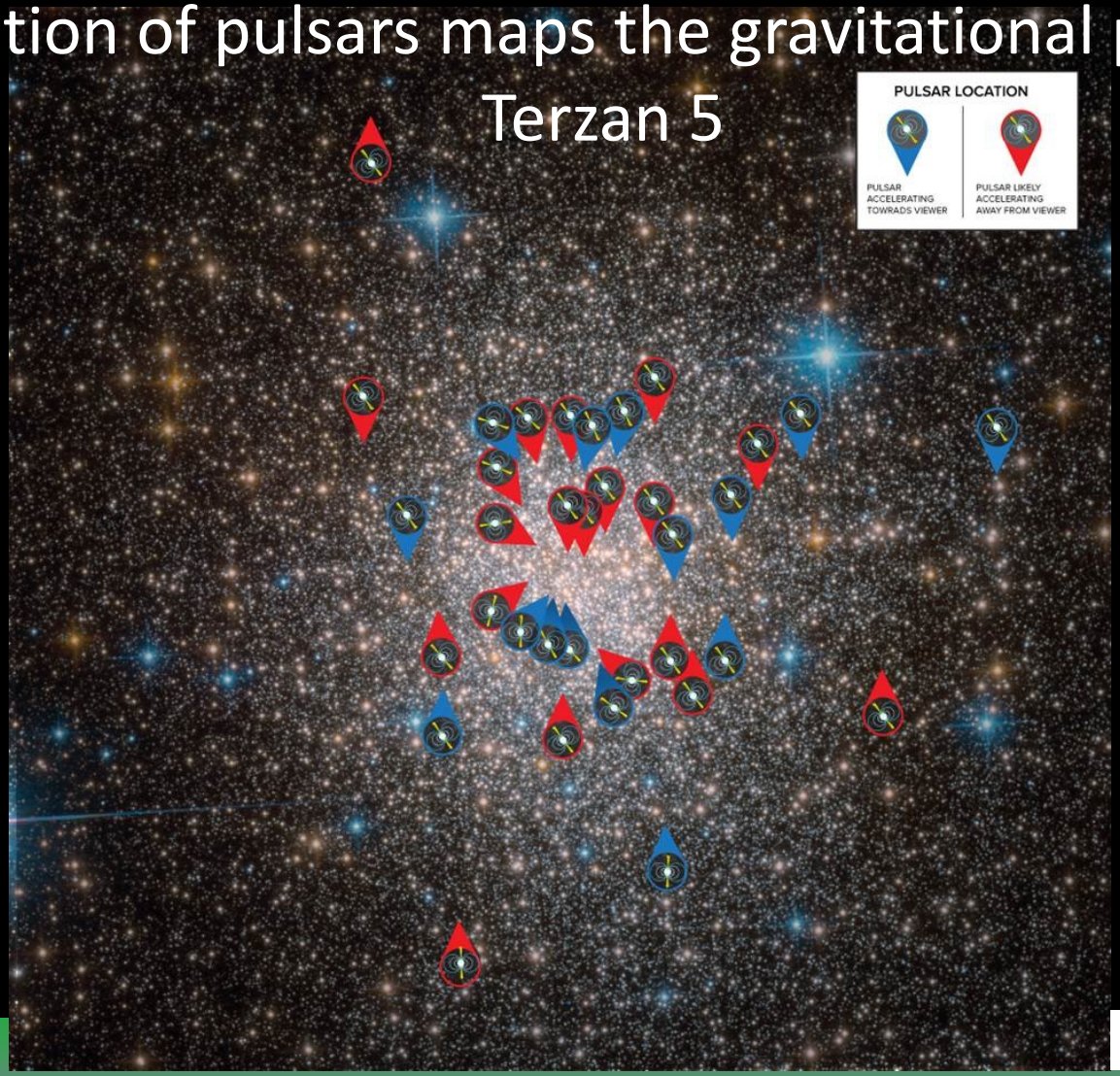
Seo et al. 2017 (in preparation)

Recent Science Results

New Arecibo-GBT Radar Map of the Moon

Recent Science Results

Acceleration of pulsars maps the gravitational potential of Terzan 5



Prager et al. 2016 (ApJ)

Recent Science Results

Chemistry of Interstellar Space – Discovery of HC_5O

THE ASTROPHYSICAL JOURNAL LETTERS, 843:L28 (5pp), 2017 July 10

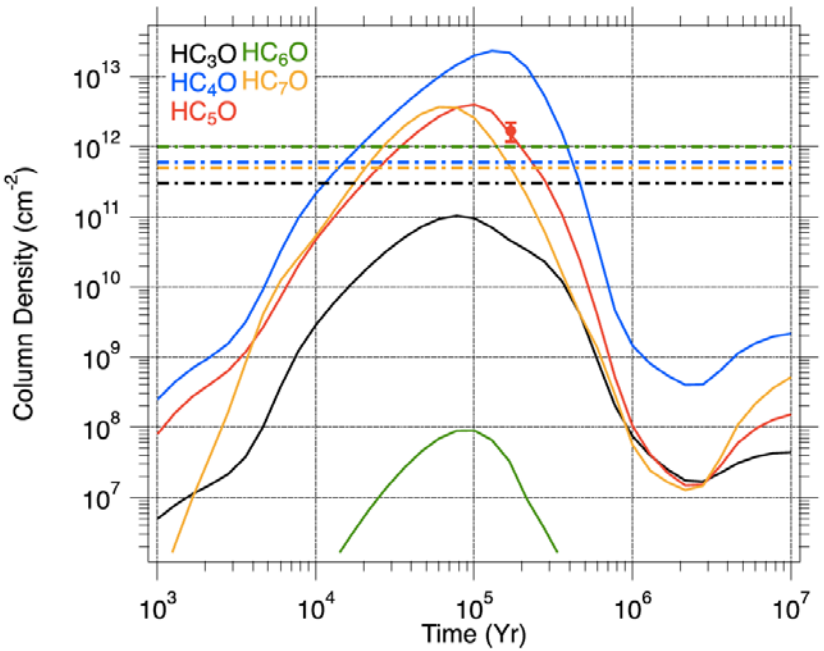


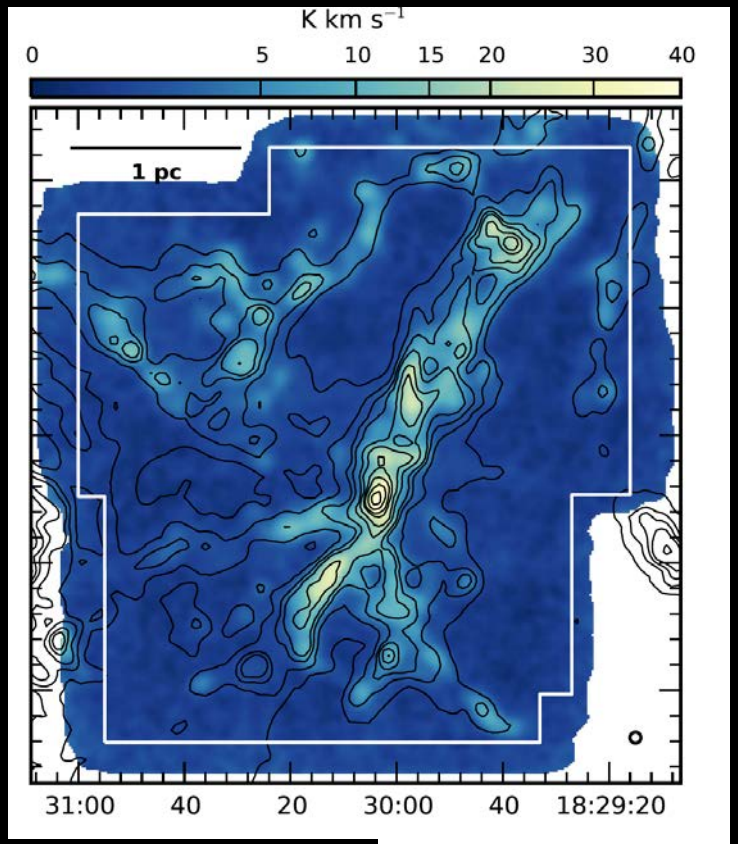
Figure 3. Results of the model of the HC_nO radicals discussed in Section 5.3. Gas-phase column densities predicted by the model as a function of time are shown as solid lines. Upper limits established by observation are shown as dashed lines. The observed column density of HC_5O at the best-fit cloud age ($\sim 2 \times 10^5$ years) is indicated with a red dot. An estimated error of 30% is shown based on assumed flux calibration accuracy.

McGuire et al. 2017 (in prep)

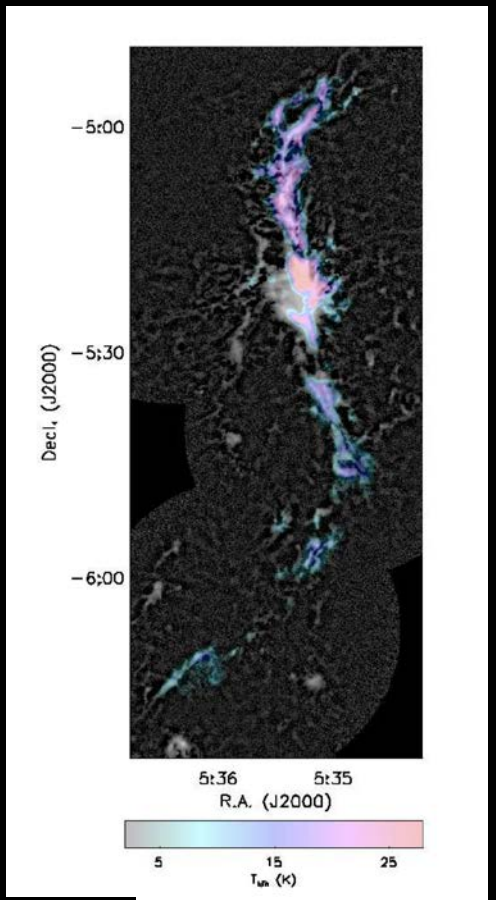
Recent Science Results

Star Formation and Dust

0.5°



Friesen et al. 2016



Kirk et al. 2017

Contours: dust
Color: GBT NH3

Recent Science Results

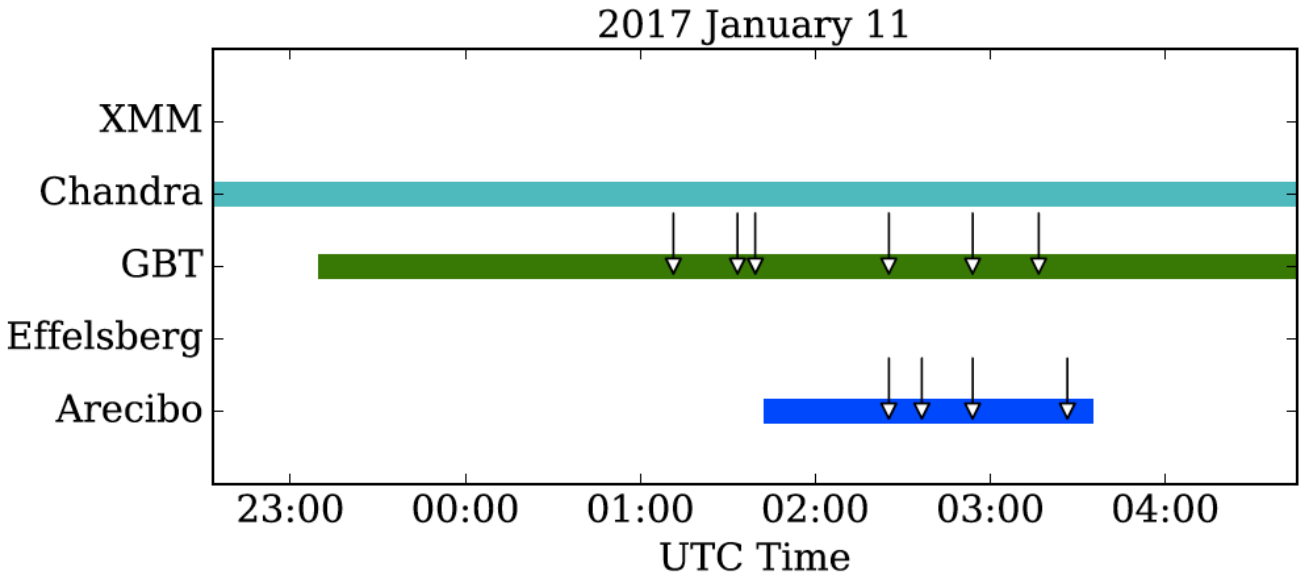


Figure 1. Timelines of overlapping radio and X-ray observations. Each bar represents the time when each telescope was observing. The arrows mark the times of detected bursts. Note that GBT bursts 1 and 2 are only ∼40 ms apart (see Figure 2) and so appear as a single arrow. Note that we only present the radio burst detections that have simultaneous X-ray coverage in this work.

Scholtz et al. 2016

Green Bank Observatory

- Site: 2,655 acres, 48 buildings, 8 telescopes
  - 28 dwellings, dormitory, small hotel
  - Café/cafeteria
  - 3 classrooms, 2 auditoriums
  - 8 telescopes ranging from 40ft – 300m in diameter

- Anechoic Chamber
- Indoor/Outdoor Antenna Test Facility
- Infrastructure (water, power, phone, network) across many miles

Green Bank Observatory

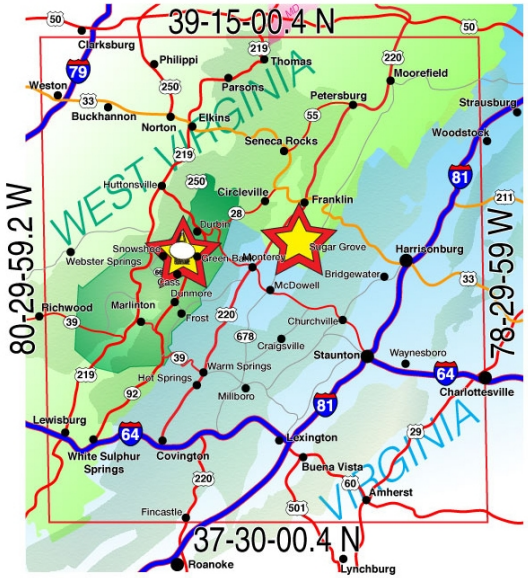
- World's largest fully steerable telescope (100-m GBT)
- Seven other site telescopes:
  - 140ft: Downlink (Earth) station for RadioAstron Satellite
  - 20m: Educational telescopes for remote and on-site observations
  - 40ft: Site education telescope (graph papers, hand calculations)
  - 3x85ft, 45ft telescopes: Not currently in use
- Extensive site infrastructure for hosting other site instruments
  - PAPER/HERA, LoFASM, GPS
- Onsite machine shop
  - Excellent for precision work, prototyping, etc
- Onsite electronics lab
  - Expertise in digital signal processing, microwave electronics, cryogenics, and more
- Active software development group

Green Bank Observatory

Maintains and protects two Radio Quiet Zones

- West Virginia Radio Astronomy Zone
  - 10 miles radius around the Observatory
  - Protects against any electrical equipment that causes harmful interference
  - State based protection with a fine for infractions
- National Radio Quiet Zone
  - 13,000 sq. mile region centered between

    Green Bank and Sugar Grove
  - Coordination: all fixed, licensed transmitters
  - Administered by GBO



Green Bank Observatory

World Class Facility for Science Research & Education

- Nationally acclaimed STEM programs
- 50,000 visitors annually
- Monthly star parties, family science labs
- SkyNet Junior Scholars
- SPOT (Space Public Outreach)
- PSC (Pulsar Search Collaboratory)
- PING (Physicists Inspiring the Next Generation)
- Bi-annual Single Dish Radio Astronomy schools
- Undergraduate Radio Astronomy Workshop
- Earth-Space Science Passport
- Chautauqua Workshops
- REUs, Co-ops, Internships
- Hosted events: StarQuest, SARA, Space Race Rumpus
- Boy Scout Badge Weekends
- Annual community open house
- Pocahontas County Science Fair
- Hour of Code
- 1,000s of school and community groups visit annually to take part in 1-3 day education programs
- Community and schools science partnerships

Current Partnerships/Contracts

National Science Foundation

- Supports “open skies” science on the GBT, educational programs
- Currently primary funding agency for the site (60-65%)

Breakthrough Listen

- Largest program looking for evidence of civilizations beyond earth
- Approximately 20% of GBT funding through 2020

NANOGrav (5% GBT)

- Aim is detection of Gravitational Waves through timing of millisecond pulsars

ROSCOSMOS

- Dedicated 140’ telescope as RadioAstron (Spektr-R) Earth Station

MISC

- Numerous other small partners for ≤3% of GBT time
- Contracts in place for development and fabrication work, usage of site, facilities

Green Bank Telescope: The Next Decade

- Likely have reduced fraction of NSF funded open skies time
  - 30%? 50%? ?? Still TBD

- Other programs may have significant impact of time availability for astronomical research
  - May put significant constraints on scheduling
  - Must be balanced against the need for continued funding

Green Bank Telescope: The Next Decade

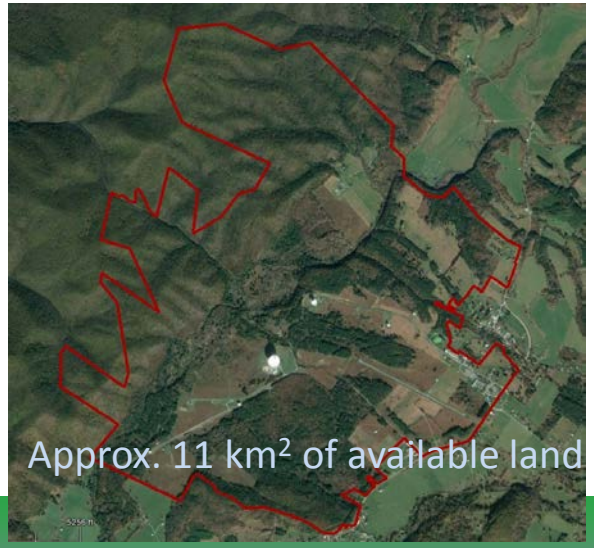
Possibilities Include:

- Radio 'cameras'
  - Both traditional feed horn arrays and phased array feeds
- Wideband Feeds
  - Improved sensitivity and flexibility for a variety of science cases
- Improved surface
  - Allow for day time high frequency observing (double available time)
- Pointing improvements
  - Active pointing through wind
  - Increased high frequency time; improved performance
- Infrastructure upgrades
  - Possibly needed to accommodate instruments (e.g. expanded IF, backends)

Green Bank Observatory: The Next Decade

Possibilities Include:

- Continued use of the majority of existing site telescopes
  - Astronomical and other research as primary uses
- Addition of 1-2 new major astronomy facilities
  - Dedicated arrays which can be run independently
    - Radio quiet zones; Operational cost savings
    - Science overlap with GBT
- Expansion of educational programs
  - Radio Astronomy training grounds
  - Increase student training opportunities

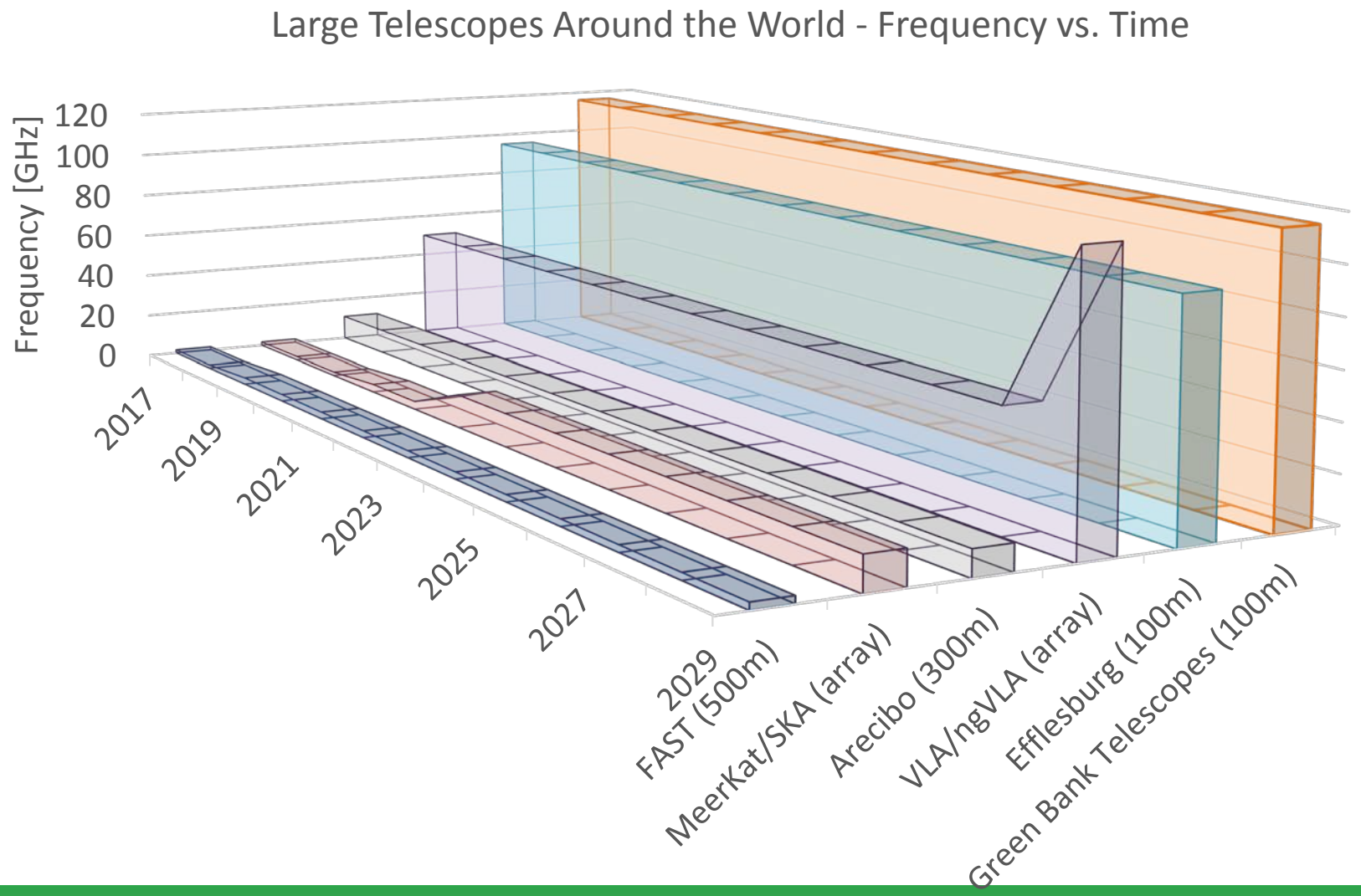


Workshop Goals

Science case for GBT, GBO in the next decade:

- What are the main scientific questions to be answered?
- How do we take advantage of the unique capabilities of the GBT/GBO to answer these questions?
- Are there ways the GBT could be better leveraged to complement the new astronomical facilities possible in the next decade?
- What new instrument(s), software, &/or policies are needed?
- What is the correct path to move these ideas forward?

Workshop Goals



Not shown:
ALMA
LMT

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GREEN BANK OBSERVATORY

greenbankobservatory.org

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