TWENTY YEARS OF INNOVATION AND DISCOVERY

A Celebration for the Robert C. Byrd Green Bank Telescope

GBT & ngVLA

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NSF AUI NRAO GREEN BANK OBSERVATORY


Robert C. Byrd Green Bank Telescope
20 years…

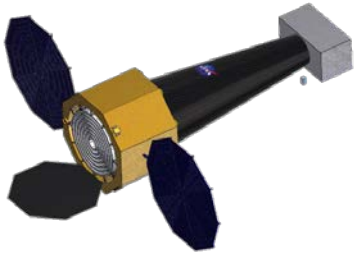

Jansky Very Large Array
40 years…

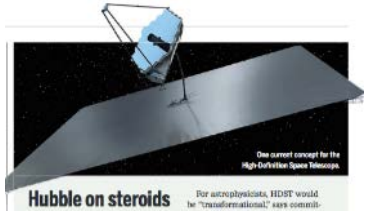
Very Long Baseline Array
25 years…

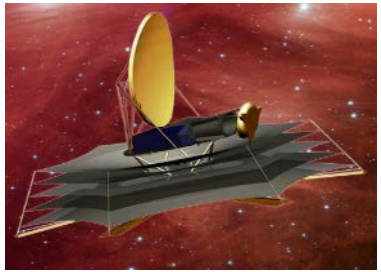
Atacama Large Millimeter/submm Array - ALMA
5 years…

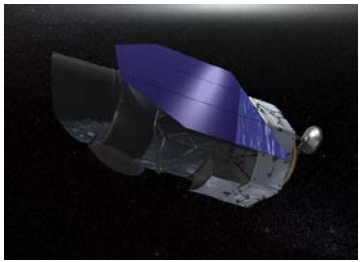
A New Decade

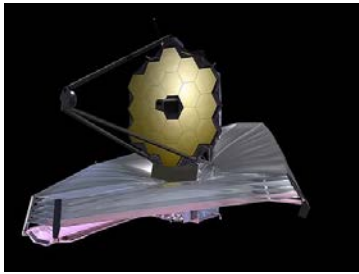
- SKA/Lynx
- Rubin
- ALIGO
- LUVOIR/HabEx
- OST (FIR surveyor)
- TMT/GMT
- JWST/WFIRST
- ALMA
- ??









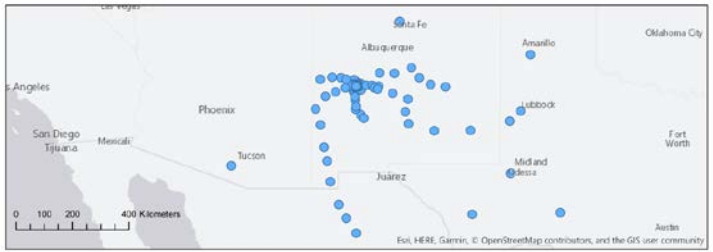


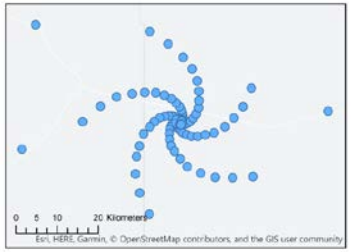
ngVLA Key Science Goals (ngVLA memo #19)

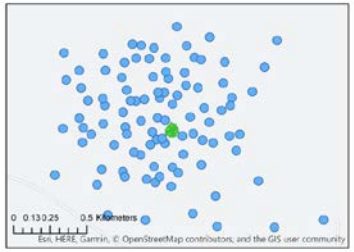
1. *Unveiling the Formation of Solar System Analogues on Terrestrial Scales*
2. *Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry*
3. *Charting the Assembly, Structure, and Evolution of Galaxies Over Cosmic Time*
4. *Using Pulsars in the Galactic Center as Fundamental Tests of Gravity*
5. *Understanding the Formation and Evolution of Stellar and Supermassive BH's in the Era of Multi-Messenger Astronomy*

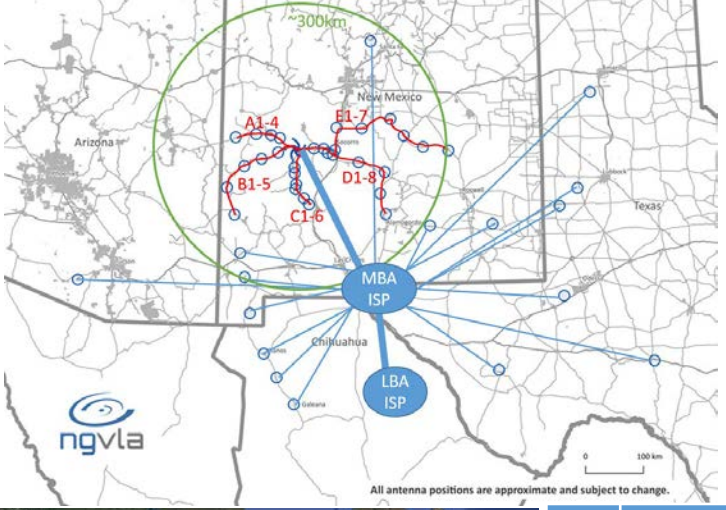
Reference Design Configuration

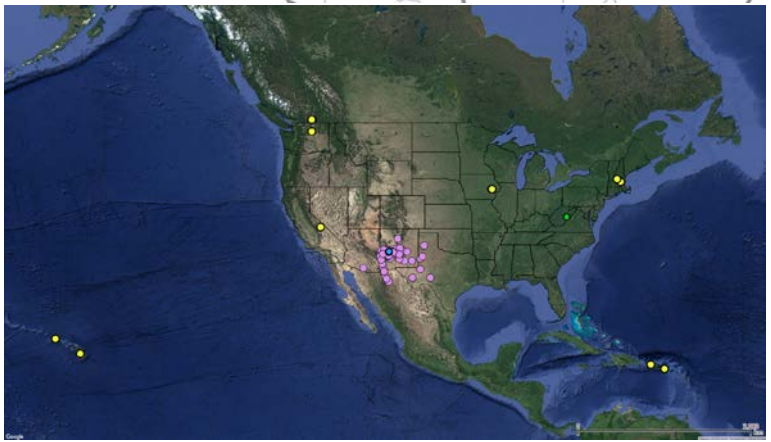
Radius	Collecting Area Fraction
0 km < R < 1.3 km	44%
1.3 km < R < 36 km	35%
36 km < R < 1000 km	21%



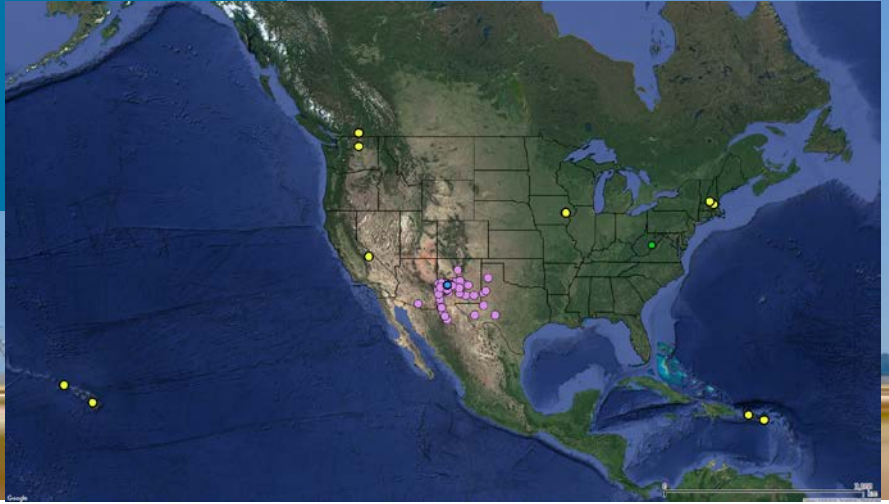








Qty	Location	Notes
3	Puerto Rico	Arecibo Site
3	St. Croix	Existing VLBA Site
3	Kauai, Hawaii	Kokee Park Geo. Obs.
3	Hawaii, Hawaii	Not MK Site
2	Hancock, NH	Existing VLBA Site
3	Westford, MA	Haystack
2	Brewster, WA	Existing VLBA Site
3	Penticton, BC	DRAO
4	North Liberty, IA	Existing VLBA site.
4	Owens Valley, CA	Existing VLBA site.



ngVLA Technical Baseline

- **1.2 - 116 GHz** Frequency Coverage
- **Main Array**: 214 x 18m offset Gregorian Antennas.
  - Fixed antenna locations across NM, TX, AZ, MX.
- **Short Baseline Array**: 19 x 6m offset Greg. Antennas.
  - Use 4 x 18m in TP mode to fill in (*u, v*) hole.
- **Long Baseline Array**: 30 x 18m antennas located across continent for baselines up to ~8860 km.

Band #	Dewar	f_L GHz	f_M GHz	f_H GHz	f_H: f_L	BW GHz
1	A	1.2	2.35	3.5	2.91	2.3
2	B	3.5	7.90	12.3	3.51	8.8
3	B	12.3	16.4	20.5	1.67	8.2
4	B	20.5	27.3	34.0	1.66	13.5
5	B	30.5	40.5	50.5	1.66	20.0
6	B	70.0	93.0	116	1.66	46.0

Specific Opportunities – ngVLA & GBT

- **ngVLA LBA site (3 ant)** → **GBO** (infrastructure, *uv* arguments)

- **Green Bank Array** – build ngVLA "supersite", 8-10 antennas distributed around the GBO property, create a standalone few-km interferometer + ngVLA bonus sensitivity
  - Science: GBI-like instrument; @higher freqs ~CARMA; ~3/4 x VLA-C config
  - Space Domain Awareness/Space Traffic Management – opportunities
  - Bistatic radar – standalone facility
  - ….
  - $100M+ project (cf DSA2000, AO-8, other AST mid-scale initiatives..)

GBT as ngVLA Total Power/Short Spacings

- ngVLA – plans Short Baseline Array (19 x 6m) plus Total Power Array (4 x 18m) – low surface brightness, zero-spacings
- Can GBT deliver some of that role?
- Analyses & simulations underway as part of ngVLA development.. Brian Mason/Will Armentrout

GBT as a Total Power & Short Spacing provider for ngVLA

Mason & Armentrout

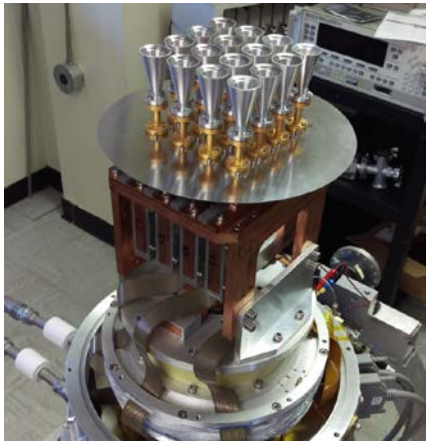
- Four ngVLA EOP projects require total power observations
  - HI around group Galaxies *(1.4 GHz, NGA2)*
  - CO in 17 nearby Galaxies *(110-115 GHz, NGA8))*
  - CO in 2 Local Group Galaxies *(110-115 GHz, NGA9))*
  - Dense Molecular Gas in Nearby Galaxies *(86-115 GHz, NGA10)*

- ngVLA EOP total power cases are weighted towards W-band *(ngVLA Band 6),* where the GBT will struggle to keep up.
  - With current GBT receivers, IF, & backends: **340 hours at L-band, 5700 hours at W-band** (!!)
    - *Most of the W-band demand is driven by the many spectral transitions NGA10 targets (595h for HCN only vs 4167h in total):* ***an IF bandwidth grade will be needed.***
  - These W-band observations are not possible with the time available in Green Bank
  - Needed improvements for W-band (Argus) – ***larger arrays, wider bandwidth***

GBT as a Total Power & Short Spacing provider for ngVLA

- The GBT could keep up with the ngVLA Envelope Observing Program, but it will require significant investment at W-band *(~$12M for upgraded Argus)*
- Allowing for daytime W-band observations *(LASSI)* will further decrease the pressure on these observations and allow a strong GBT-only observing program in addition to ngVLA EOP observations.
  - Note: ngVLA does not plan 3mm observations at night either, though it will probably get more good weather in late spring and early summer … LASSI may still be needed to hit the same targets.
- Caveat: These are just the ngVLA EOP cases that require total power observations.
  - Observed by the GBT, these projects would **not** require SBA observations to “bridge the UV gap”
  - ***If SBA information were to be independently provided, the GBT time demand would be ~5x lower.*** Achievable with modest upgrades to current instrumentation (LASSI and/or IF bandwidth upgrade only).
  - There are another 3 Envelope Observing Program science cases that request the ngVLA Small Baseline Array only where the GBT could also be useful *(K-Ka bands)* – we haven’t evaluated these yet.

Mason & Armentrout



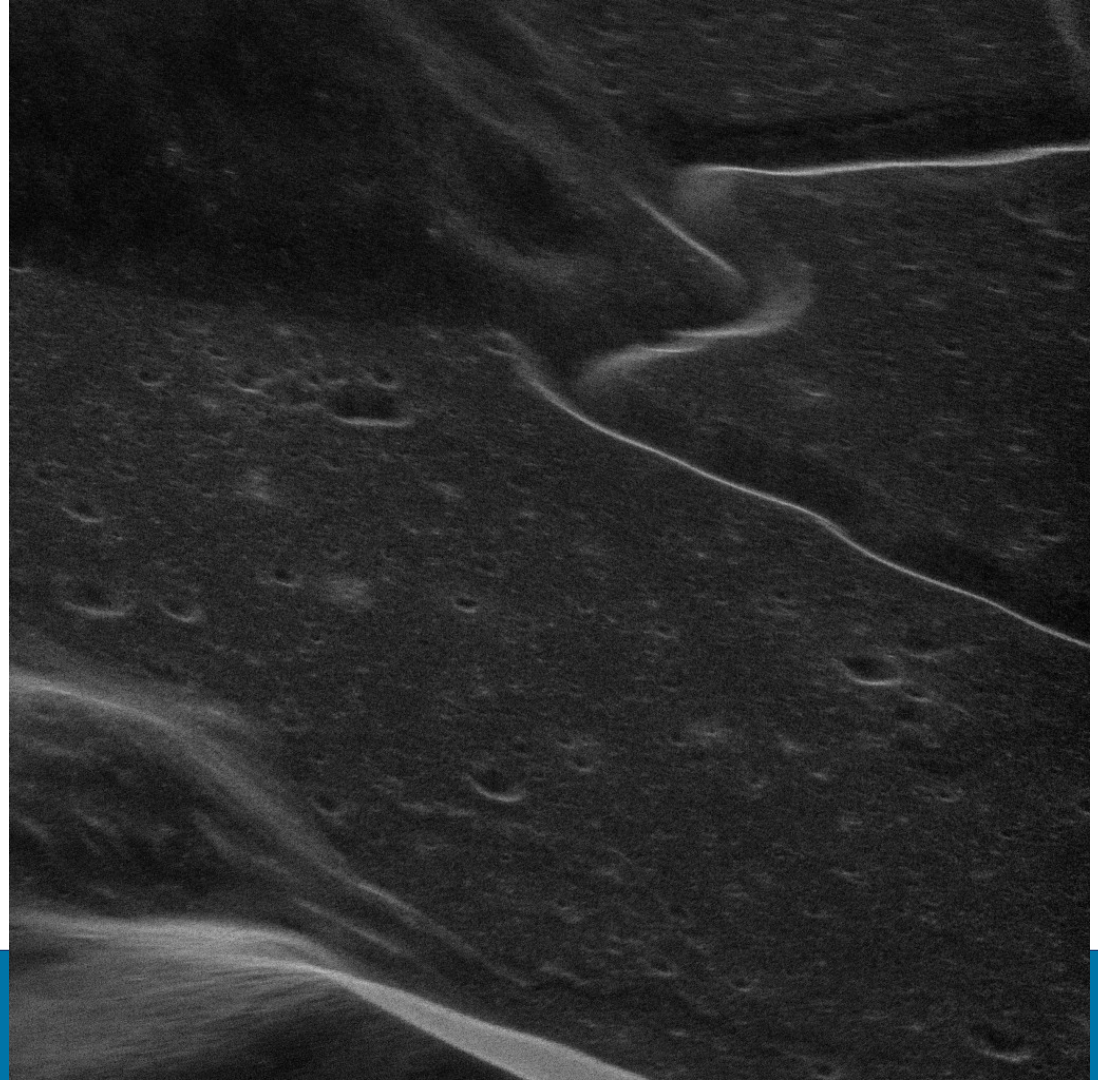
The current Argus-16 instrument, operating on the GBT from 74-116 GHz.

GBT as ngVLA Total Power

- ngVLA – plans Short Baseline Array (19 x 6m) plus Total Power Array (4 x 18m) – low surface brightness, zero-spacings
- Can GBT play some of that role?
- Analyses & simulations underway… ngVLA development
- My impression: some complementary science advantages, but most interesting use cases significant constrain future GBT observing/HW

GBT Integrated Radar with ngVLA

- GB/GBT Radar History – Margot, O'Neil talks
- "Radar Prospects" conference in GB – 2016
- 2019 – opportunity to pursue transmit/receive role emerged
- Prototype system – 2020, 2021 – highly successful



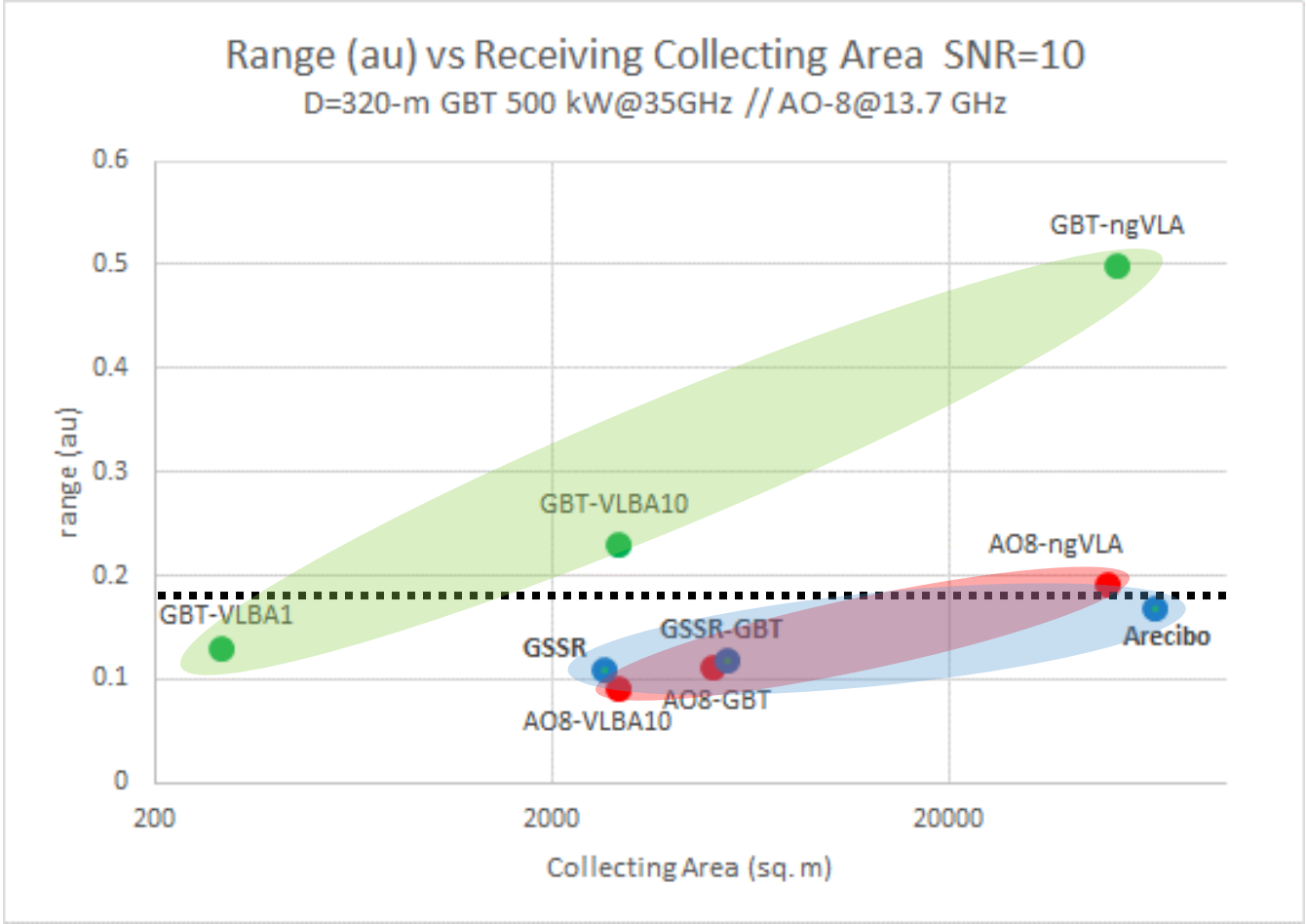
GBT-VLBA

Apollo-15 site
700 W
13.9 GHz
5m x 5m resolution

3 milliarcsecond resolution…

Integrated Radar (T:GBT, R:ngVLA)

- GB/GBT Radar History – Margot talk
- “Radar Prospects” conference in GB – 2016
- 2019 – opportunity to pursue transmit/receive role emerged
- Prototype system – 2020, 2021 – highly successful
- Proposals/requests underway – higher power (100-500 kW) system for solar system research/planetary defense/SDA/STM
- Multi-frequency radar transmit systems
- Joint projects with JVLA, VLBA, ngVLA, ngVLA-GB, ….


Range (au) vs Receiving Collecting Area SNR=10
D=320-m GBT 500 kW@35GHz // AO-8@13.7 GHz
range (au)
0.6
0.5
0.4
0.3
0.2
0.1
0
200
2000
20000
Collecting Area (sq. m)
GBT-ngVLA
GBT-VLBA10
AO8-ngVLA
GBT-VLBA1
GSSR
GSSR-GBT
Arecibo
AO8-GBT
AO8-VLBA10

GBT-ngVLA

- Numerous exciting joint opportunities – some will be competitive in science marketplace… TBD.
- New science/roles: large impacts to current science portfolio…
- **Trend: US ground-based instruments: become mission-based to enable new priorities and major growth/upgrade OR … face incremental development, and sometimes slow downward spiral… OR other key factors needed (technologies, politics, new science foci…)**
- Instrument mission lifetimes ~20 yrs? *GBT @ 20 yrs…*
- GBT future lies in mix of science seen this week + ngVLA + ??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