



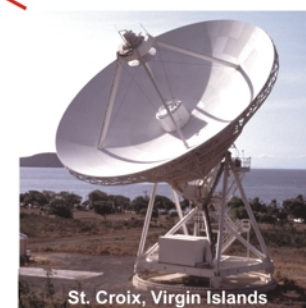
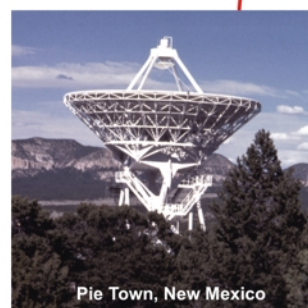
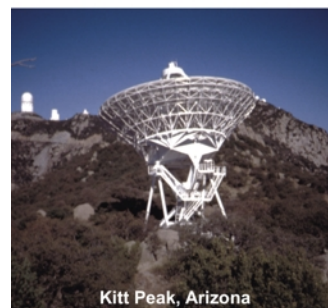
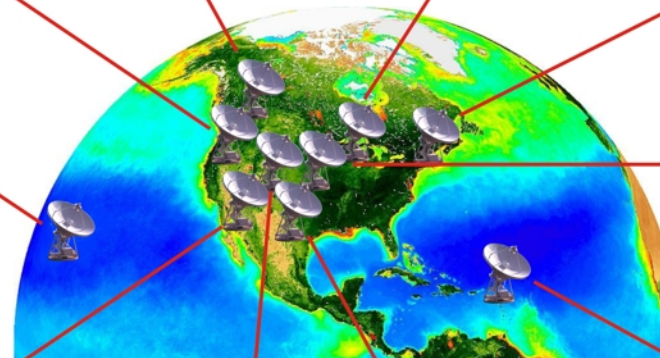
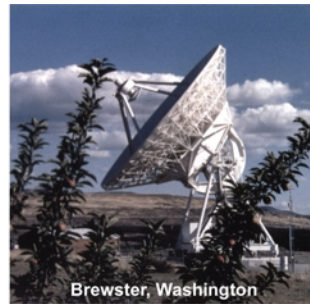
# VLBA Call for Proposals 2022B

Justin Linford



# The Very Long Baseline Array (VLBA)

- 10 stations
- Shortest baseline: 236 km
- Longest baseline: 8611 km
- Receivers: 90cm, 50cm, 21cm, 13cm, 6cm, 4cm, 2cm, 1cm, 7mm, 3mm



# The High Sensitivity Array (HSA)

VLBA +

Phased VLA (Y27)



NRAO/AUI

Green Bank Telescope (GBT)



GBT/NRAO/AUI

## Effelsberg Radio Telescope



Raimond Spekking / CC BY-SA 4.0  
(via Wikimedia Commons)

# VLBA and VLA semesters

- VLA semesters do not always align with VLBA semesters
  - VLBA semesters depend on the calendar
  - VLA semesters depend on the configuration of the array

<b>VLBA 2022B</b>	<b>VLA 2022B</b>
Start: August 01, 2022	Start: October 06, 2022
End: January 31, 2023	End: January 17, 2023

# VLBA Observing Systems

Also known as “personalities”

- **Polyphase Filterbank (PFB):** 16 data channels, 32 MHz bandwidth each
  - 2048 Mbps data rate
- **Digital Downconverter (DDC):** 1, 2, 4, or 8 data channels, 1 to 128 MHz bandwidth each.
  - 4 Mbps to 4096 Mbps data rate
    - 4096 Mbps (4 Gbps) recording available for 6cm, 4cm, 2cm, 1cm, 7mm, and 3mm receivers with DDC
    - 90cm limited to 256 Mbps
    - 50cm limited to 32 Mbps
    - 21cm and 13cm limited to 2048 Mbps

# VLBA Capabilities for 2022B

## I of 2

- 4 Gbps (4096 Mbps) data rate
  - DDC only
  - 6cm, 4cm, 2cm, 1cm, 7mm, and 3mm receivers
- S/X simultaneous observing
  - Up to 4096 Mbps data rate, but sensitivity reduced slightly
- VLBA + Y1
  - Add single VLA antenna for a short (~50km) baseline
- Multiple phase centers
  - Up to 300 phase centers, single polarization, at 4096 Mbps
  - Up to 150 phase centers, dual polarization, at 4096 Mbps

# VLBA Capabilities for 2022B

## 2 of 2

- Flexible frequency setup with DDC
  - 1, 2, 4, or 8 data channels with bandwidths from 1 to 128 MHz, each
  - More flexibility in where to place the channels in the band than PFB
- Flexible spectral resolution
  - Up to 4096 spectral channels per data channel
  - Minimum spectral channel spacing of 2 Hz
- Spectral zooming
  - Select a small region of a data channel for large number of spectral channels (during correlation)
- Pulsar modes
  - Binary gating, matched-filter gating, or pulsar binning modes

# VLBA Shared Risk Observing 2022B

## Baseband Data Copy

- Proposers can ask for some of the raw data from the VLBA stations
- Proposer must fully justify their need for this in the proposal (technical justification or science justification)
- Acceptance is subject to NRAO resources, and the following conditions:
  - No more than 5 TB can be copied per station, per month
  - Channel and/or polarization selection is not available
  - Proposers must provide properly formatted, compliant hard drives prior to their observation(s) being correlated



# Possible RSRO projects

## I of 2

- Many pulse cal tones per channel
  - Currently use 2 tones per channel, but DiFX can handle up to 128.
- Improved troposphere model
  - Evaluate the effectiveness of using the new Vienna Mapping Function.
- Rapid response capability
  - Possibly for a very fast response (5 to 10 minutes) to a transient event. May require special permission to interrupt active observations.
- L/P dual-band observations
  - Simultaneous 21cm + 90cm observations. 90cm sensitivity will be degraded by ~33% in this mode.

# Possible RSRO projects

## 2 of 2

- Y3 observing with the VLBA
  - Add 3 VLA antennas (notionally, the three at the ends of the arms).
  - Can enable interferometric reference pointing on the VLA antennas.
  - Can add shorter baselines for observations (mainly in A config).
- Recording wide-band VLA visibilities in parallel with VLBA
  - When using Y27, simultaneously process the full VLA bandwidth through the WIDAR correlator as a separate VLA observation while recording the VLBI data to disk.
- VLBA real-time correlation
  - This requires transferring telescope data to the DiFX correlator.
  - Data rates are currently limited to 128 Mbps from most VLBA antennas.

# VLBA Current Known Issues

I of 2

- **7mm sensitivity:** The sensitivity at 7mm is currently worse than normal on some antennas due to some focus and collimation issues. It is being worked on, and we hope to have it corrected very soon.
  - <https://science.nrao.edu/facilities/vlba/data-processing/7mm-performance-2021>
- **S-band at Pie Town:** The S-band (13cm) receiver on the Pie Town antenna is having issues in LCP. The problem appears to be intermittent and the cause is unknown.
- **GBT availability:** The Green Bank Telescope is heavily oversubscribed and is often difficult (but not impossible) to schedule as part of HSA observations.
  - Request GBT if you need it! But be prepared to have limited windows when it is available.

# VLBA Current Known Issues

2 of 2

- **2cm flux density scale using DDC:**
  - LCP flux density scale is usually ~10% lower than the RCP values for 2cm (Ku-band), DDC only.
  - Other bands also appear to be affected, but with less severity.
  - Hardware problem (RDBEs); no trivial fix.
  - We are testing a work-around in post-processing.
  - [https://science.nrao.edu/enews/14.4/index.shtml#vlba\\_flux](https://science.nrao.edu/enews/14.4/index.shtml#vlba_flux)

Updates on known issues:

<https://science.nrao.edu/facilities/vlba/data-processing/post-observing-notes-issues>

# UTI-UTC Observations

- The US Naval Observatory uses the VLBA for the UTI-UTC observations every other day. These observations use MK and HN, and are allowed to take these stations from other active observations.
- The UTI-UTC observations are between 1.5 and 2 hours long, and occur between 1715 and 1945 UT.
- The VLBA schedulers work hard to ensure that science projects are not impacted by this, but it is sometimes unavoidable.
- See the VLBA UTI-UTC webpage for more information, including how to avoid losing the stations during your observation
  - <https://science.nrao.edu/facilities/vlba/observing/daily-utl>

# The Technical Justification

## I of 3

- **Stations requested:** In general, assume that 1 or 2 VLBA antennas will be unavailable. If your science absolutely requires 10 antennas, it may be harder to schedule.
- **Scheduling issues:** Estimate the length of your scheduling blocks, specify acceptable weather conditions, and state the cadence required (if applicable). Also be aware of sources that may be near the Sun at certain times (e.g., 3C279).
- **Target flux densities and self-calibration:** If known, give the approximate flux densities of your targets at the requested band(s). If phase-referencing will be used, give the names of the phase reference calibrators to be used (if known).  
**NOTE:** You can request extra time to identify a good calibrator!

# Technical Justification

## 2 of 3

- **Sensitivity:** Clearly state the sensitivity required to achieve the science goals of the proposal.
- **On-source integration time:** Use the EVN Sensitivity Calculator to estimate the on-source time needed to reach the specified sensitivity. Make sure to use the minimum number of antennas specified in the first entry of the technical justification and account for RFI.
  - If  $(u,v)$  coverage is more important than sensitivity, clearly state that and justify the increased time over the calculated value.
- **Sensitivity limited, dynamic range limited, or both:**
  - Detection experiment, probably sensitivity limited
  - Imaging something complicated, probably dynamic range limited

# Technical Justification

3 of 3

- **Polarization calibrators:** The VLA monitors standard polarization calibrators every 3 months under TPOL0003. If you need VLA observations of other sources, make that clear.
- **Flux calibration accuracy:** The typical VLBA calibration produces flux density accuracy of  $\sim 10\%$ . If you need better accuracy than this, provide a plan for achieving it.
- **Min/max GST:** When defining your Sessions, if you entered something different than the PST calculates for the min or max GST, you will get a warning and be prompted to enter something here. It does not need to be detailed.
  - Example: “The entered GST range takes into account our need for scans on the fringe finder 3C84.”



# Technical Justification

## The 3 most common mistakes on VLBA proposals

1. Proposers state that they only need 7 or 8 antennas for the observation, but they do the sensitivity calculation with all 10 antennas.
  - Always do the sensitivity calculation using the *minimum* number of antennas you specified are necessary.
2. Proposers for L and S bands (21cm and 13cm) do not take RFI into account when doing the sensitivity estimate.
  - Assume the bandwidth at L and S is reduced by a factor of ~30%
3. Proposers state that they need flux density calibration accurate to within 5%, but do not provide the details about how they will achieve this accuracy.
  - The nominal VLBA flux density calibration is accurate to within ~10%

# EVN Sensitivity Calculator

[go.nrao.edu/ect-evn](http://go.nrao.edu/ect-evn)

## EVN Calculator

1. Select stations:  
Click “VLBA”, then  
remove some antennas  
in order to match the  
minimum number of  
antennas needed.  
Add Y1 or HSA  
stations, if necessary.



2. Select band and  
data rate



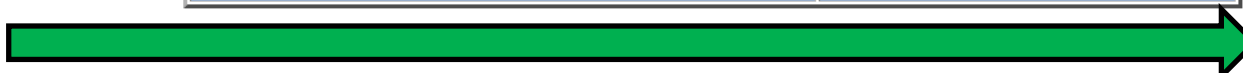
3. Select spectral  
channels,  
integration time,  
and max baseline

EVN	e-EVN	VLBA	GLOBAL	GMVA	RESET	GO	
Observing band & data rate [Mbit/s]				On-source integration time [min]			
C-6cm 4096				210			
<input type="checkbox"/> Ef	<input type="checkbox"/> Nt	<input type="checkbox"/> My	<input type="checkbox"/> Pv	<input type="checkbox"/> Pa	<input type="checkbox"/> Hn	The image thermal noise is estimated to be 11.17 uJy/beam (1 sigma) using natural weighting.	
<input type="checkbox"/> Mc	<input type="checkbox"/> Sh	<input type="checkbox"/> Km	<input type="checkbox"/> Ro70	<input type="checkbox"/> Ho	<input checked="" type="checkbox"/> Nl		
<input type="checkbox"/> On	<input type="checkbox"/> Tm65	<input type="checkbox"/> Sv	<input type="checkbox"/> Ro34	<input type="checkbox"/> Cd	<input checked="" type="checkbox"/> Fd		
<input type="checkbox"/> Tr	<input type="checkbox"/> Ur	<input type="checkbox"/> Zc	<input type="checkbox"/> Pb	<input type="checkbox"/> Ap	<input checked="" type="checkbox"/> La		
<input type="checkbox"/> Jb1	<input type="checkbox"/> Mh	<input type="checkbox"/> Bd	<input type="checkbox"/> Ku	<input type="checkbox"/> Go	<input checked="" type="checkbox"/> Kp		
<input type="checkbox"/> Jb2	<input type="checkbox"/> Ys	<input type="checkbox"/> Wz	<input type="checkbox"/> Ky	<input type="checkbox"/> Gb	<input checked="" type="checkbox"/> Pt		
<input type="checkbox"/> Cm	<input type="checkbox"/> Sr	<input type="checkbox"/> Ka	<input type="checkbox"/> Kt	<input type="checkbox"/> Y1	<input type="checkbox"/> Ov		
<input type="checkbox"/> Wb	<input type="checkbox"/> Ar	<input type="checkbox"/> Ir	<input type="checkbox"/> At	<input type="checkbox"/> Y27	<input checked="" type="checkbox"/> Br		
<input type="checkbox"/> W1	<input type="checkbox"/> Hh	<input type="checkbox"/> ALMA	<input type="checkbox"/> Mp	<input checked="" type="checkbox"/> Sc	<input checked="" type="checkbox"/> Mk		
Number of spectral channels per subband, integration time [s], and maximum baseline length				Number of polarizations, subbands per polarizations, and bandwidth of a subband [MHz]			
16 ch 2 s 9000 km (VLBA)				2 pols 4 sb 128 MHz			
The field of view limited by bandwidth-smearing is 0.687 arcseconds (assuming 9000.0 km for the maximum baseline). The field of view limited by time-smearing is 6.186 arcseconds. These values are calculated for 10% loss in the response of a point source, and they give the FoV radius from the pointing center.				The resulting FITS file size will be about 191.4 MBytes. This combination of channels and polarizations results in an aggregate bit rate of 4096 Mbps, assuming 2 bit sampling.			
RESET				GO			

5. Enter on-source  
time (minutes)  
and click “GO”.  
Check that resulting  
data rate matches  
selected data rate.  
Note thermal noise  
level. Adjust time as  
necessary. Take a  
screenshot.  
Repeat for each  
band.



4. Select # of  
polarizations,  
# of subbands,  
and bandwidth  
per subband



# EVN Sensitivity Calculator

[go.nrao.edu/ect-evn](http://go.nrao.edu/ect-evn)

EVN	e-EVN	VLBA	GLOBAL	GMVA	RESET	GO
Observing band & data rate [Mbit/s]					On-source integration time [min]	
X - 3.6cm					240	
<input checked="" type="checkbox"/> Ef <input type="checkbox"/> Nt <input type="checkbox"/> My <input type="checkbox"/> Pv <input type="checkbox"/> Pa <input checked="" type="checkbox"/> Hn <input type="checkbox"/> Mc <input type="checkbox"/> Sh <input type="checkbox"/> Km <input type="checkbox"/> Ro70 <input type="checkbox"/> Ho <input checked="" type="checkbox"/> Nl <input type="checkbox"/> On <input type="checkbox"/> Tm65 <input type="checkbox"/> Sv <input type="checkbox"/> Ro34 <input type="checkbox"/> Cd <input checked="" type="checkbox"/> Fd <input type="checkbox"/> Tr <input type="checkbox"/> Ur <input type="checkbox"/> Zc <input type="checkbox"/> Pb <input type="checkbox"/> Ap <input checked="" type="checkbox"/> La <input type="checkbox"/> Jb1 <input type="checkbox"/> Mh <input type="checkbox"/> Bd <input type="checkbox"/> Ku <input type="checkbox"/> Go <input checked="" type="checkbox"/> Kp <input type="checkbox"/> Jb2 <input type="checkbox"/> Ys <input type="checkbox"/> Wz <input type="checkbox"/> Ky <input checked="" type="checkbox"/> Gb <input checked="" type="checkbox"/> Pt <input type="checkbox"/> Cm <input type="checkbox"/> Sr <input type="checkbox"/> Ka <input type="checkbox"/> Kt <input type="checkbox"/> Y1 <input checked="" type="checkbox"/> Ov <input type="checkbox"/> Wb <input type="checkbox"/> Ar <input type="checkbox"/> Ny <input type="checkbox"/> At <input checked="" type="checkbox"/> Y27 <input checked="" type="checkbox"/> Br <input type="checkbox"/> W1 <input type="checkbox"/> Hh <input type="checkbox"/> ALMA <input type="checkbox"/> Mp <input checked="" type="checkbox"/> Sc <input checked="" type="checkbox"/> Mk					The image thermal noise is estimated to be 2.564 uJy/beam (1 sigma) using natural weighting.	

The EVN Calculator gives the R.M.S. noise value for the full bandwidth.

For spectral-line observations:

- Get the value for wider bandwidth then multiply it by sqrt of # of channels.
- E.g.  $\sigma = 2.564 \mu\text{Jy}/\text{beam}$  for 256MHz, so for 125 kHz channels (i.e., 2048 channels):

$$\sigma = 2.564 \times \sqrt{2048} = 116 \mu\text{Jy}/\text{beam}$$

# EVN Sensitivity Calculator vs. VLBA Resources

A subtle difference in calculating bit rate

EVN Calculator

Number of polarizations, subbands per polarizations, and bandwidth of a subband [MHz]

2 pols ▾ 4 sb ▾ 128 MHz ▾

Polarizations & subbands

vs.

Baseband channels

VLBA Resources

Observing Parameters	
Observing System	DDC System ▾
Bandwidth	128 MHz ▾
Baseband Channels	8 ▾
Polarization	Dual ▾
Agg. Bit Rate (Mbits/sec)	4096

- # of baseband channels = (# of polarizations) × (# of subbands)
  - LCP only, 8 subbands = 8 baseband channels
  - Dual polarization, 4 subbands = 8 baseband channels
  - Full polarization, 4 subbands = 8 baseband channels
    - For Full Polarization, only 2 polarizations are recorded at the site. The cross-hand polarizations are determined during correlation.

# EVN Observation Planner <https://planobs.jive.eu/>

A new tool with many uses!

- Includes VLBA and HSA stations
- Estimates the imaging thermal noise of an observation
- Estimates per spectral channel sensitivity
- Estimates synthesized beam dimensions and field of view limitations
- Shows the times when a source is visible at each antenna
- Estimates the  $(u,v)$  coverage of the observation
- Guided mode for newer users
- Manual mode for experienced users

**NOTE:** NRAO still requires VLBA proposers to submit a screenshot from the older EVN Sensitivity Calculator as part of their proposal



Antenna Selection | **Summary** | Elevations | UV Coverage | Documentation

COMPUTE OBSERVATION

Your observing Band?  
C band (6cm or 5 GHz) x

Real-time correlation?  
 e-EVN mode

Source (name or coordinates)?  
12:03:03.5094 60:31:19.129

Epoch for observation  
 I don't have a preferred epoch  
 I know the observing epoch

Start of observation (UTC)?  
27-12-2021 (361) 12:00 x

Duration of the observation (in hours)  
3

% of on-target time?  
70% of the total time (2.1 h)

Datarate per station?  
2 Gbps x  
The total bandwidth is 256.0 MHz.

Number of subbands?  
4 subbands x

Number of spectral channels?  
128 channels per subband x

### Observing Time

27 December 2021  
12:00-15:00 UTC  
GST range: 18:25-21:25

The observation lasts for 3 h, of which 2.1 h are on target.

With a time integration of 2 s the expected FITS file size is 2.05 Gbyte.

### Frequency Setup

The central frequency is 5 GHz (6 cm).

The total bandwidth of 256 MHz will be divided into 4 subbands of 64 MHz each, with 128 channels (500 kHz, or 30 km/s, wide).

Recording dual circular polarization.

### Antennas

10 participating antennas: Br, Fd, Hn, Kp, La, Mk, Ni, Ov, Pt, Sc.

Mk-Sc is the longest (projected) baseline with 8611.5 km (144 Mλ).

La-Pt is the shortest one with 234.55 km (3.91 Mλ).

### Resolution

The expected synthesized beam will be approx.  $2.49 \times 1.44 \text{ mas}^2$ , PA = 177 deg.

Note that the synthesized beam can significantly change depending on the weighting used during imaging (natural weighting assumed here).

### Sensitivity

The expected rms thermal noise for your target is 16.1  $\mu\text{Jy}/\text{beam}$  using natural weighting during imaging. Note that ~20% higher values may be expected for RFI-contaminated bands.

The achieved sensitivity implies a rms of 364  $\mu\text{Jy}/\text{beam}$  per spectral channel, or approx. 1.18  $\text{mJy}/\text{beam}$  per time integration (2 s).

### FoV limitations

The Field of View would be limited by time smearing to 6.47 arcsec and by frequency smearing to 11.5 arcsec (considering a 10% loss), if no further time/frequency averaging is performed.

Considering the shortest baseline in the array, you will resolve out emission on angular scales larger than 52.8 mas.



# Resources

- NRAO helpdesk: [help.nrao.edu](https://help.nrao.edu)
- The VLA and VLBA Call for Proposals: [go.nrao.edu/cfp](https://go.nrao.edu/cfp)
- The VLA and VLBA Observational Status Summaries:
  - VLA: [go.nrao.edu/vla-oss](https://go.nrao.edu/vla-oss)
  - VLBA: [go.nrao.edu/vlba-oss](https://go.nrao.edu/vlba-oss)
- Proposing Guides:
  - VLA: [go.nrao.edu/vla-prop](https://go.nrao.edu/vla-prop)
  - VLBA (and HSA & Global VLBI): [go.nrao.edu/vlba-prop-doc](https://go.nrao.edu/vlba-prop-doc)
- 2022B Proposal Deadline: February 1, 2022 at 5:00PM EST
  - 2022-02-01 22:00:00 UT



**[www.nrao.edu](http://www.nrao.edu)**  
**[science.nrao.edu](http://science.nrao.edu)**  
**[public.nrao.edu](http://public.nrao.edu)**

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operated under cooperative agreement by Associated Universities, Inc.*



# Proposal Components

- General (Title, Type, Abstract, etc....)
- Authors
- Science Justification
- Technical Justification
- Sources – what do you want to observe
- Resources – instrumental setup
- Sessions – sources + resources + duration
- Disposition Letter (will contain a copy of the disposition letter after the proposal review process)

# What Makes a Good Proposal?

## Scientific Justification

- One Central Question
  - Can be a very broad question:
    - “How big is the Milky Way?”
    - “How old is the Universe?”
  - Or more focused:
    - “What is this weird source discovered at another wavelength?”
- Scientific Context and Motivation
  - Why is this interesting?
  - How does it relate to other areas of astrophysics?
- Science Goals
  - How will the proposed observations answer the question?
  - How will the results benefit other areas of research?

# Proposal Tips

- Start working on your proposal early!
  - DO NOT start your proposal the day before the deadline
- Review the Call for Proposals carefully
  - Pay close attention to the deadline (including the time!)
- Look over the “Offered Capabilities” section of the OSS
  - VLBA: [go.nrao.edu/vlba-capabilities](http://go.nrao.edu/vlba-capabilities)
- Try filling out the Technical Justification section first
  - If you can put something in the TJ, that gives you more room in your Science Justification
- Submit your proposal AT LEAST 2 hours before the deadline
  - Things go wrong sometimes. It helps to have a buffer.