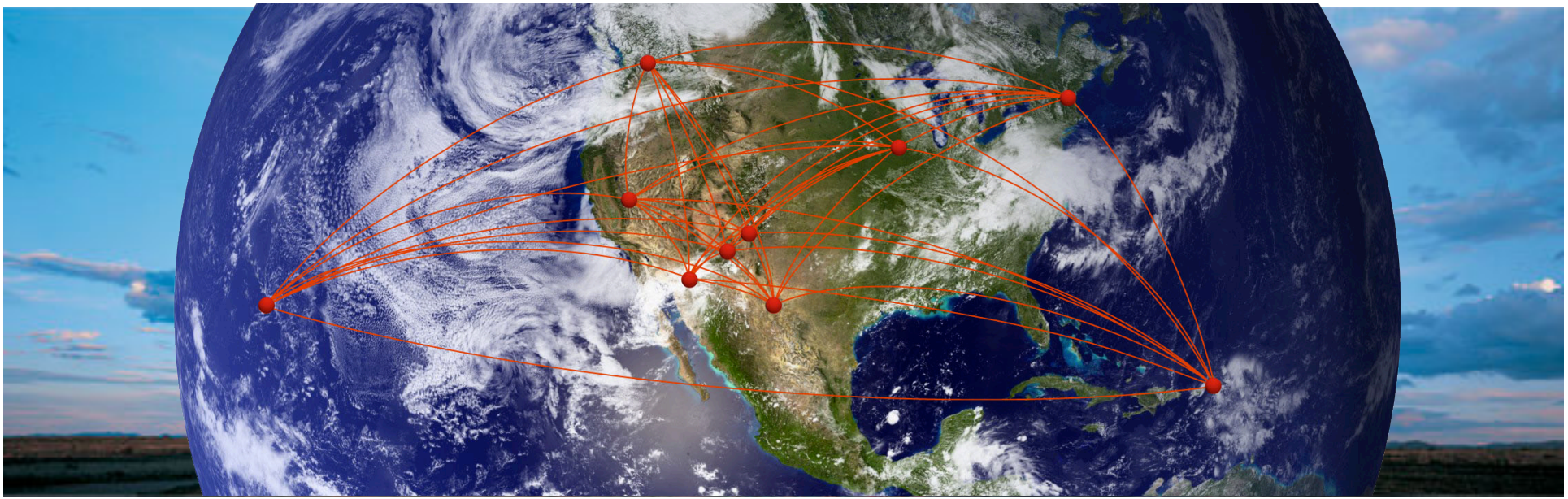
The Very Long Baseline Array



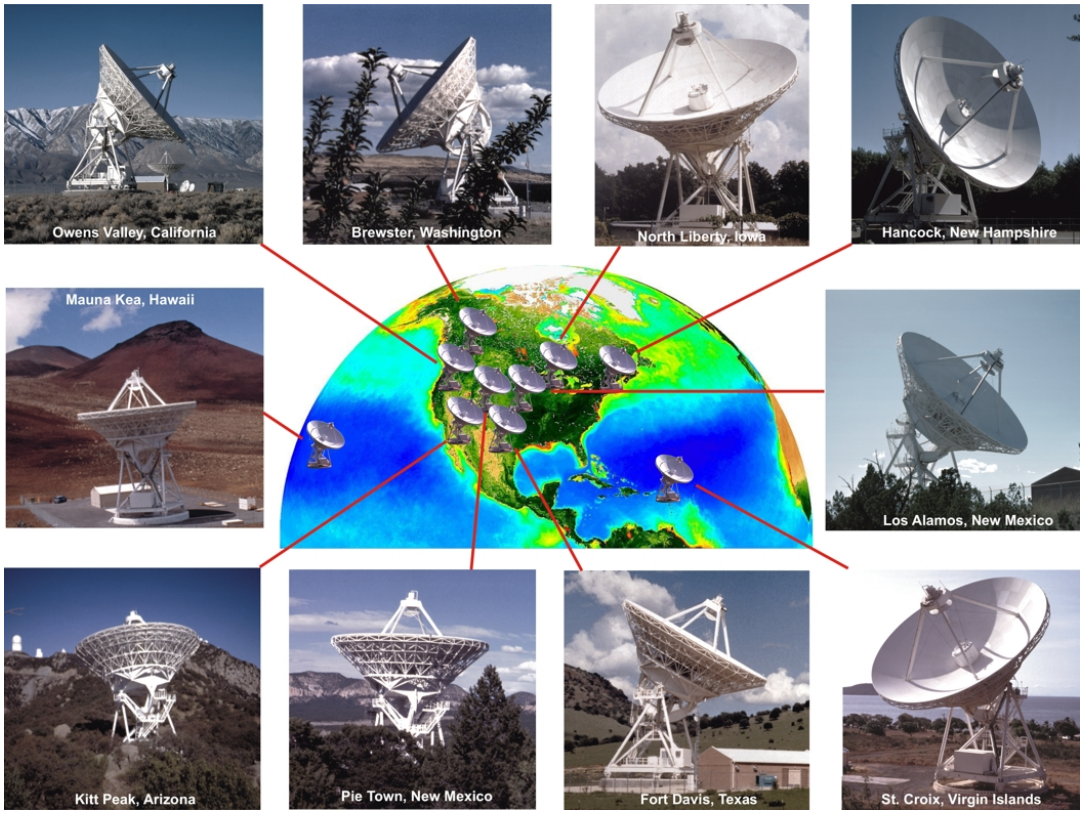
Jim Braatz (NRAO)

Atacama Large Millimeter/submillimeter Array
Karl G. Jansky Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

The VLBA

- A dedicated VLBI array
- 10 identical 25 meter antennas
- Spanning from Mauna Kea to St. Croix
- Baselines 200 to 8600 km
- Sensitive to compact structures with $T_b > 10^5$ K



VLBA Frequency bands and Sensitivity

λ (cm)	ν (GHz)	σ (μJy/beam) 4 hrs at 2 Gbps
90 cm	0.312 - 0.342	277*
50 cm	0.596 - 0.626	782*
21 cm	1.35 - 1.75	13
13 cm	2.15 - 2.35	14
6 cm (upgrade)	3.9 - 7.9	8
4 cm	8.0 - 8.8	13
2 cm	12.0 - 15.4	24
1 cm	21.7 - 24.1	20
7 mm	41.0 - 45.0	66
3 mm	80.0 - 90.0	316†

2 Gbps recording delivers a bandwidth of 256 MHz with two polarizations.

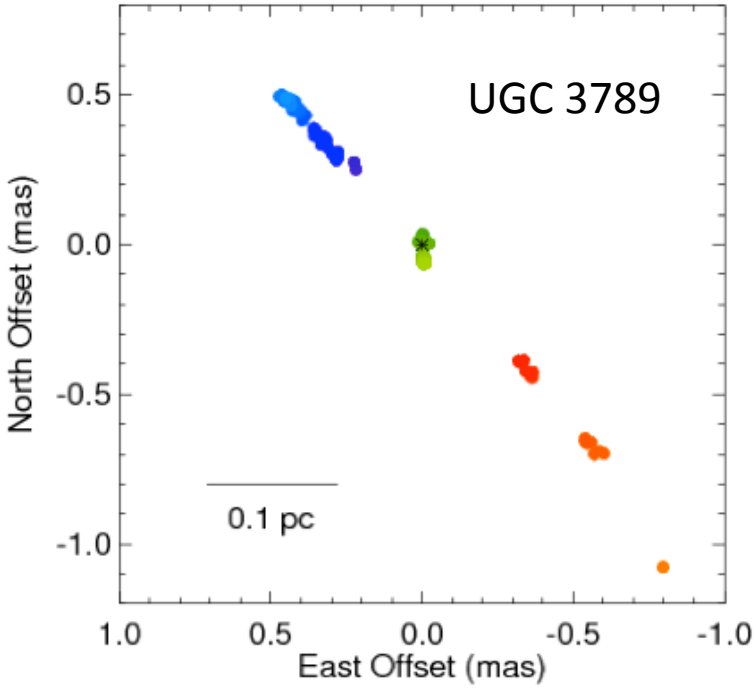
* Narrower bandwidths

† 8 stations

Resolution!

- 25 *milli* arcsecond at 330 MHz.
- 80 *micro* arcsec at 90 GHz.

  - 1 mas is
    - 0.1 AU at 100 pc (Galactic)
    - 10 AU at 10 kpc
    - 1000 AU at 1 Mpc (Extragal)
    - 5 pc at 1 Gpc

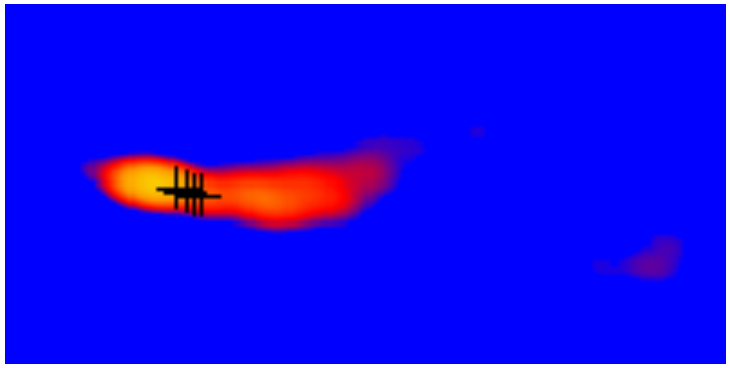


The Megamaser Cosmology Project (Braatz et al.)

Mapping H_2O maser disks to measure H_0 and determine SMBH masses

Fast Response & Monitoring

- Dedicated array with Dynamic Scheduling
  - Targets of Opportunity
  - Monitoring



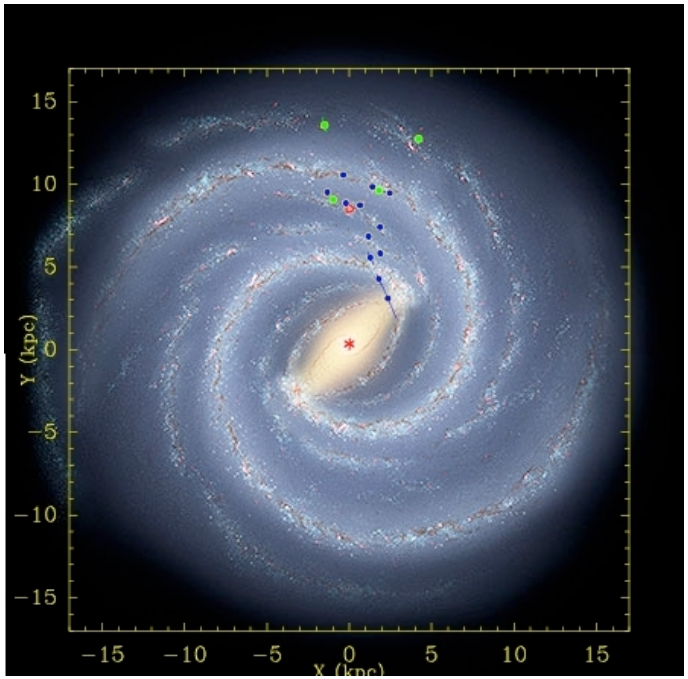
AGN 1222+216

The MOJAVE project (Lister et al.)

Examining the evolution of AGN jets and their magnetic fields, and the medium into which the jets are expanding

Astrometry

- High-precision parallax and proper motions
  - Instrumental stability and long baselines
  - < 0.1 mas position accuracy is routine
  - ~ 0.01 mas demonstrated in some cases
    - c.f. Gaia at 0.024 mas
  - Allows 1% distance measurements at 1 kpc



The BeSSeL project (Reid et al):

Mapping Galactic structure and measuring fundamental parameters by measuring parallaxes and proper motions of SF regions

$R_0 = 8.4 \pm 0.6$ kpc
$\Theta_o = 254 \pm 16$ km/s

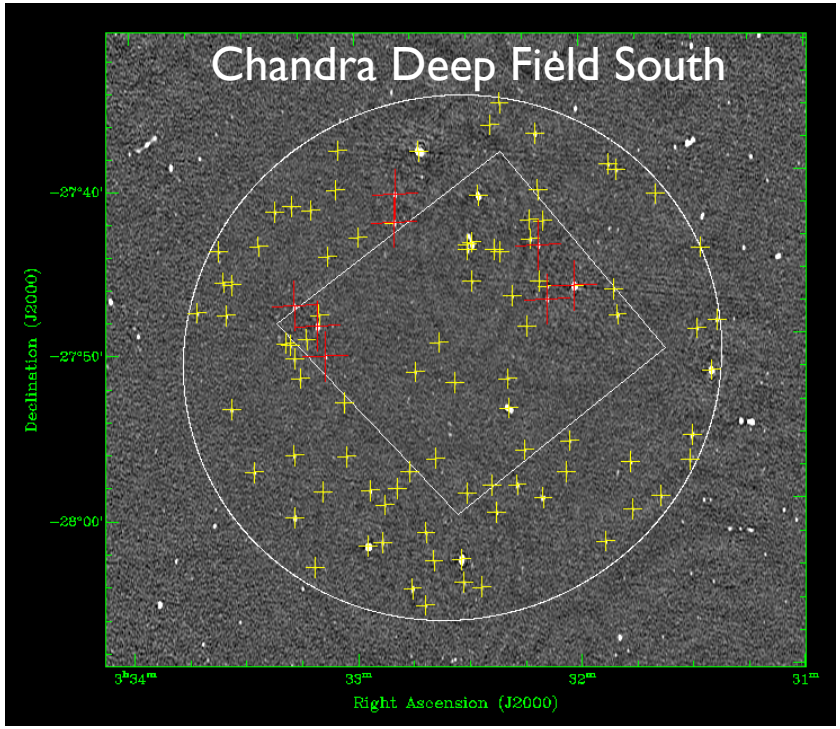
VLBA Correlator (DiFX) Capabilities
Spectral Resolution

- DiFX is a flexible software correlator in Socorro, NM
  - 1-8 sub-bands up to 128 MHz wide
  - 4K channels per sub-band is routine; 32K with justification
- Spectral zooming – higher resolution in narrower windows. Useful for:
  - Masers with in-beam continuum calibrators: wide bands for maximum sensitivity on calibrator + high spectral resolution for the masers.
  - Masers with multiple transitions: wide bands to cover a large number of widely separated maser transitions + high spectral resolution for each transition.

VLBA Correlator (DiFX) Capabilities
Multi- Field Imaging

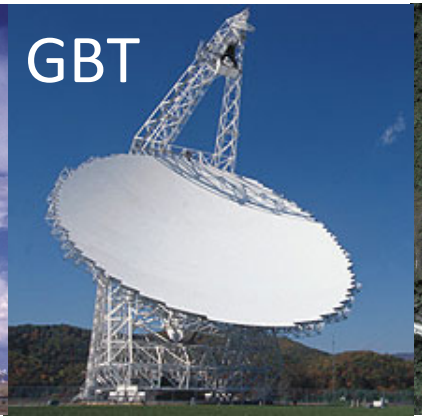
- The sky is almost entirely empty at VLBI resolution
  - "full beam" imaging not needed; rather, many small "fields" (phase centers)
  - DiFX allows many phase centers in one correlator pass
  - Low overhead (~2.5X) is only weakly dependent on number of phase centers

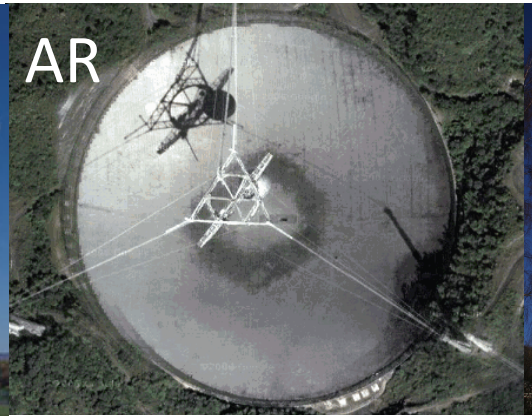
- 200 phase centers require only 20% more correlator time than 2 phase centers.



Middelberg et al., 2011

The High Sensitivity Array





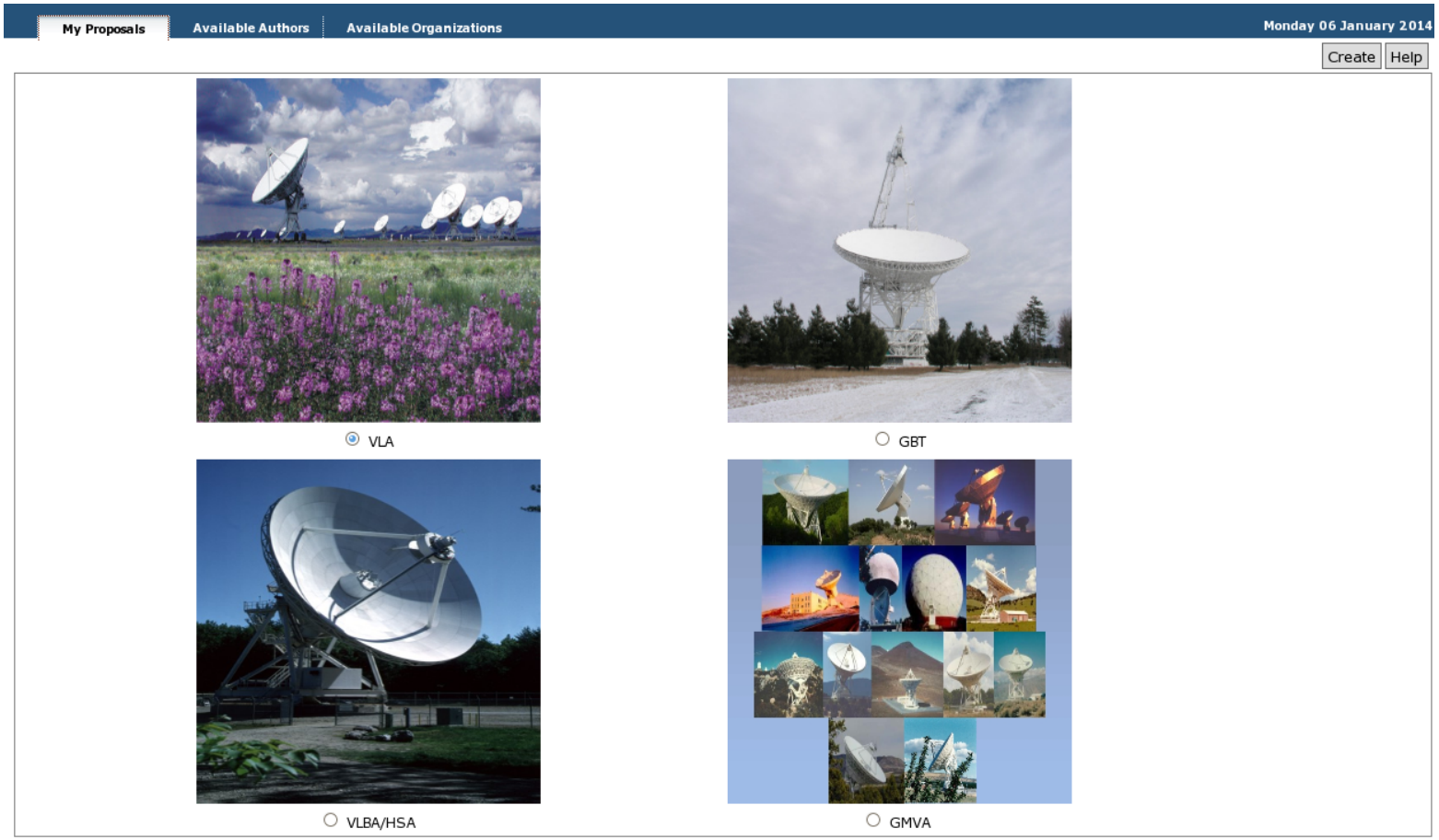
To boost the sensitivity of the VLBA by an order of magnitude

Recent Upgrades and Special Notices

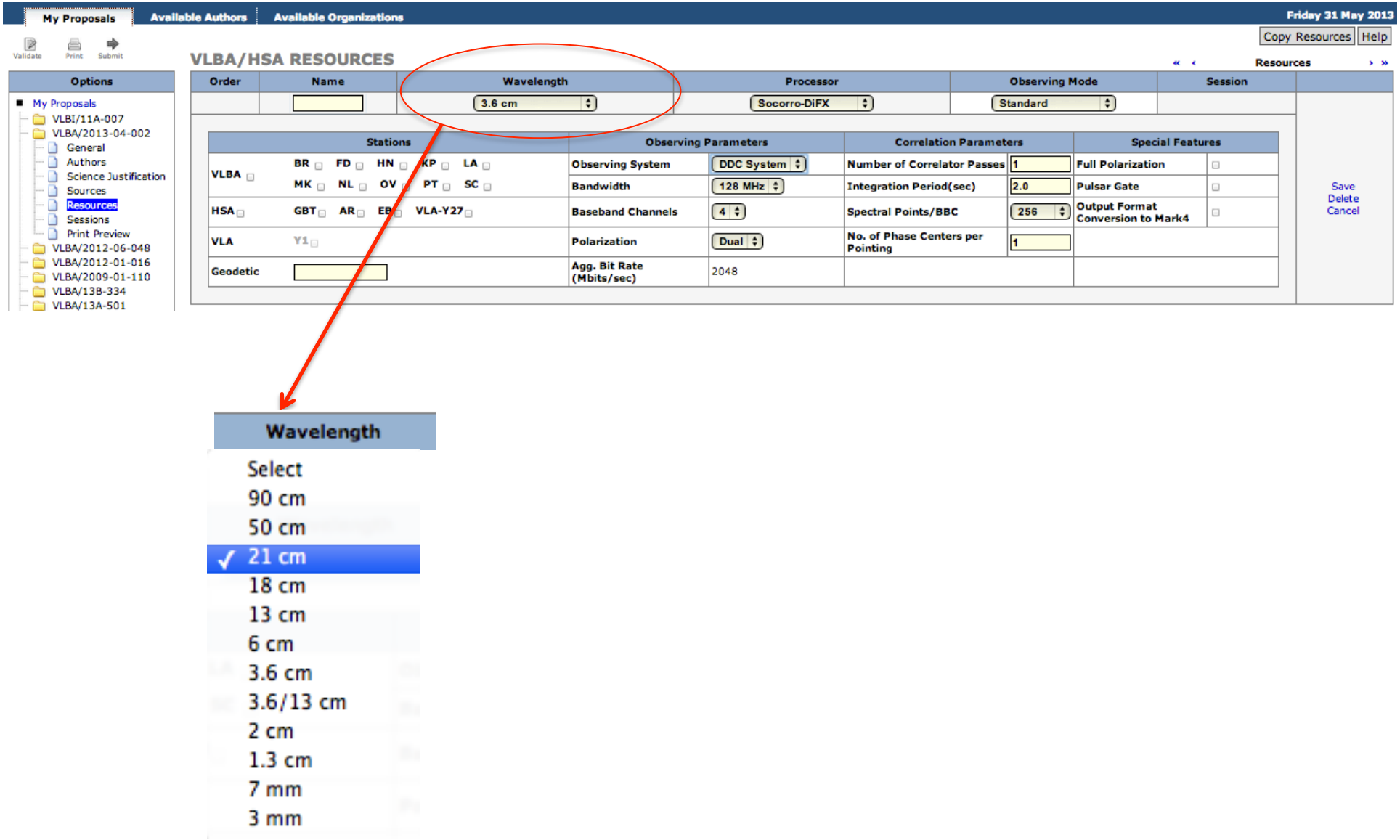
- Recent Development Efforts:
  - New wide-band “6 GHz” receivers (4.9-8.9 GHz) cover the 6.7 GHz methanol line
  - New recorder systems provide 2 Gbps capability to improve continuum sensitivity (256 MHz in dual pol)
  - Phased VLA now part of HSA

- Notices:
  - Resident Shared Risk Observing (RSRO) program available
  - NRAO is soliciting large “Filler” programs
  - Global Millimeter VLBI Array (GMVA) proposals accepted through NRAO PST

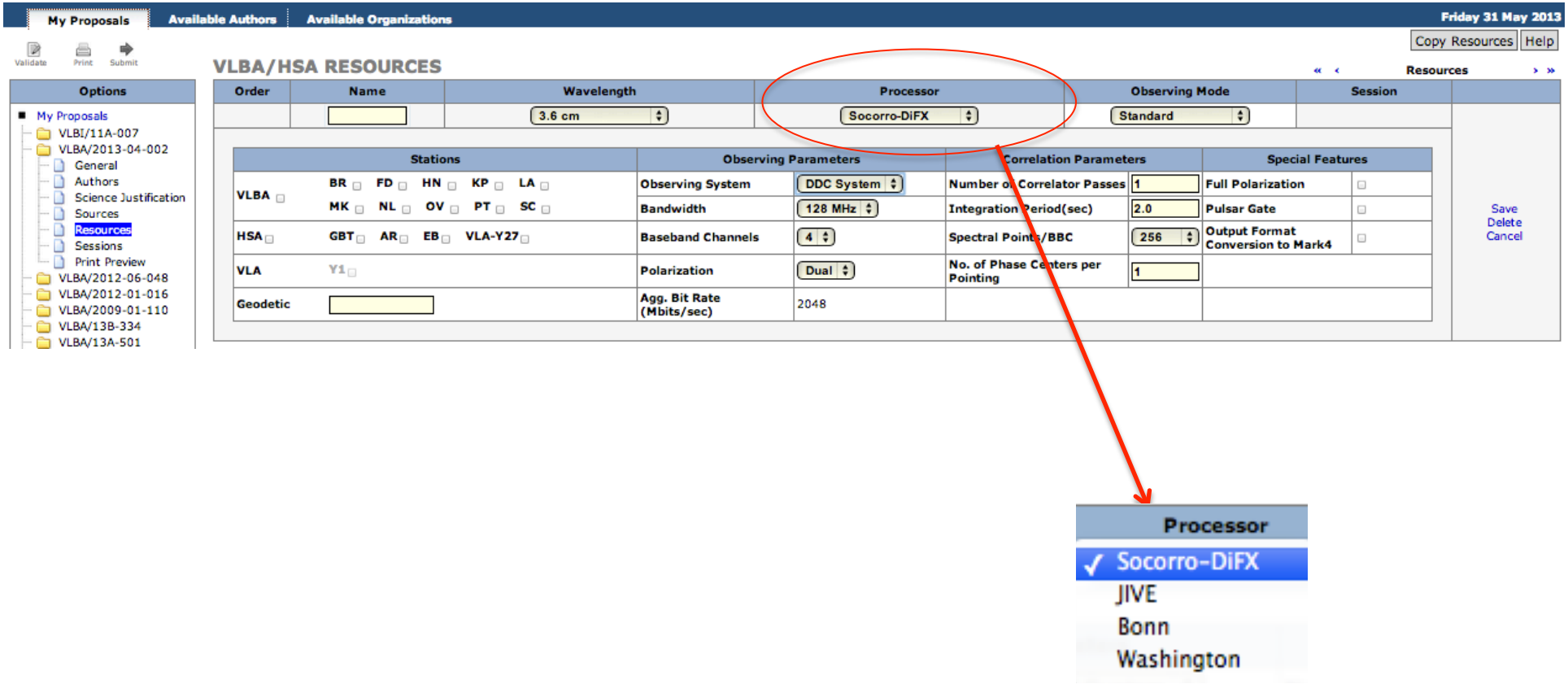
Proposing for VLBA/HSA



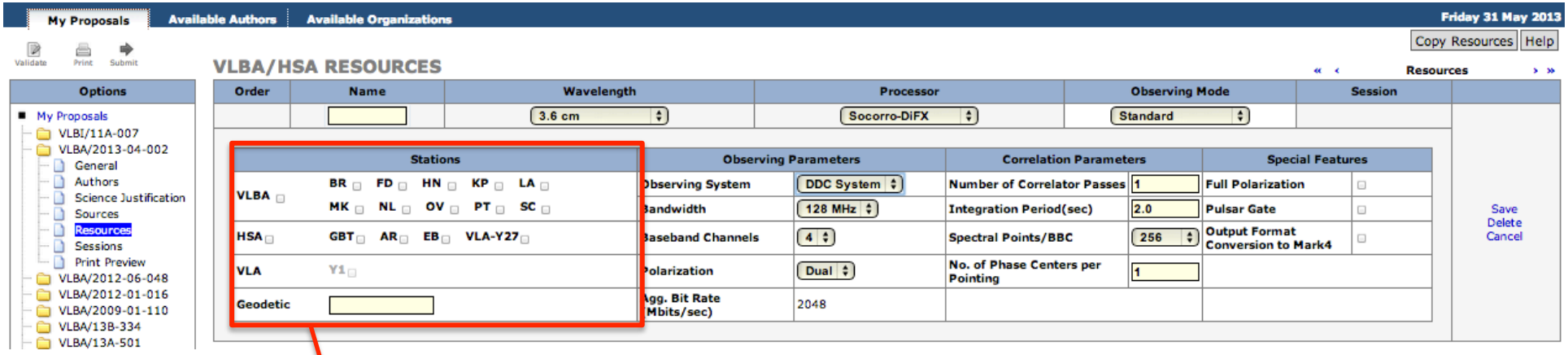
VLBA/HSA Resources in the PST

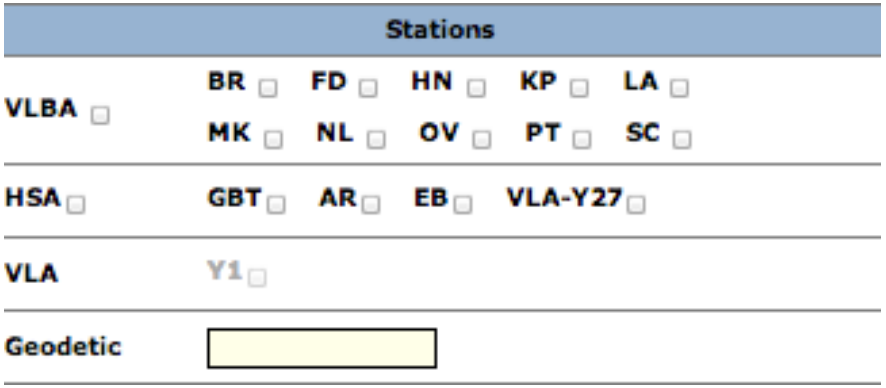


VLBA/HSA Resources in the PST

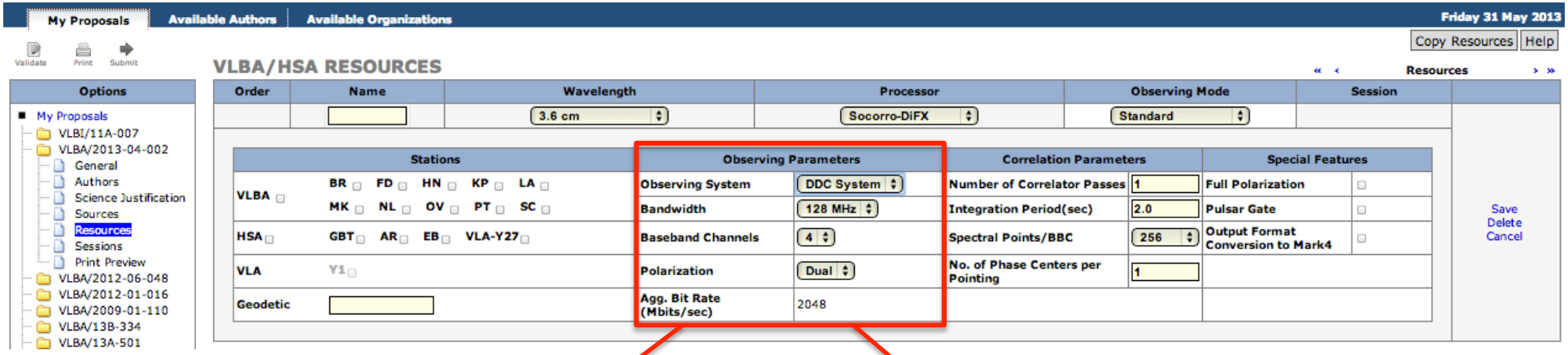


VLBA/HSA Resources in the PST





VLBA/HSA Resources in the PST



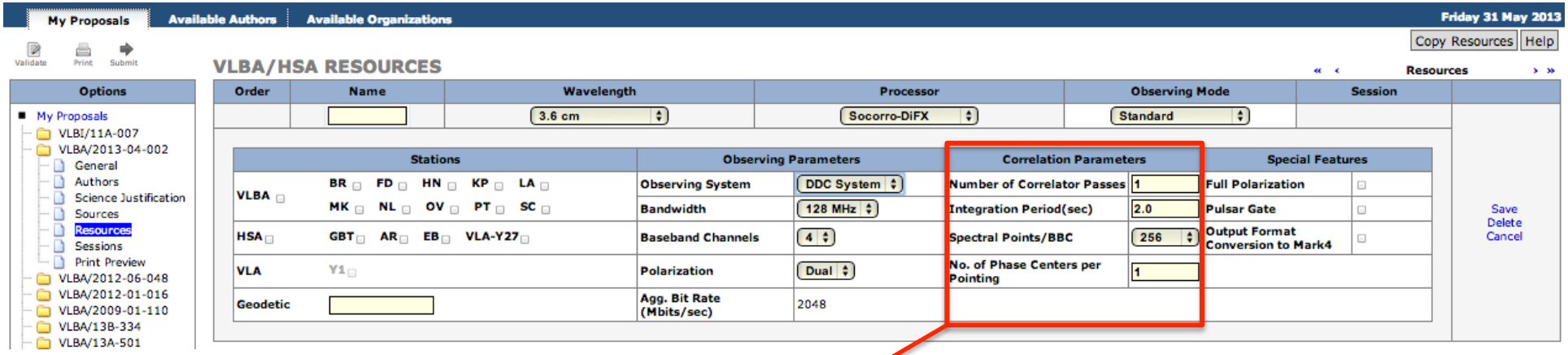
Observing Parameters	
Observing System	PFB System
Bandwidth	32 MHz
Baseband Channels	16
Polarization	Dual
Agg. Bit Rate (Mbits/sec)	2048

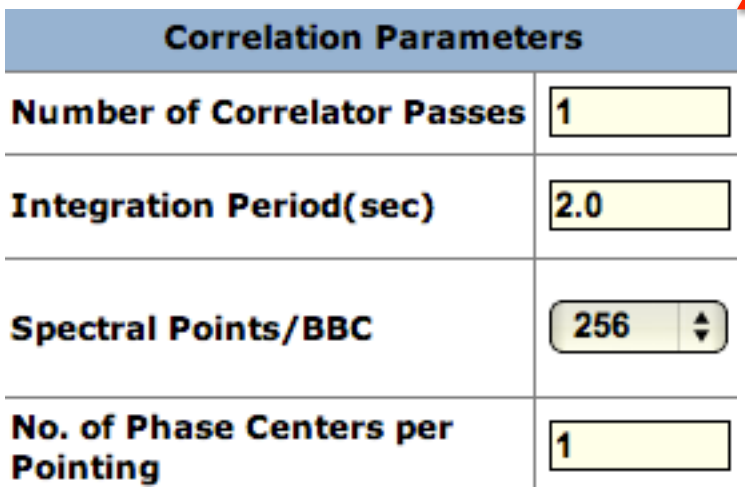
Observing Parameters	
Observing System	DDC System
Bandwidth	128 MHz
Baseband Channels	4
Polarization	Dual
Agg. Bit Rate (Mbits/sec)	2048

Polyphase Filter-Bank (PFB)
16 channels, each 32 MHz wide
Coarse tuning
For continuum science

Digital Down-Converter (DDC)
1, 2, 4, (or 8) channels, each 1- 128 (or 64) MHz wide
Finer tuning capability
For continuum and spectral line science

VLBA/HSA Resources in the PST



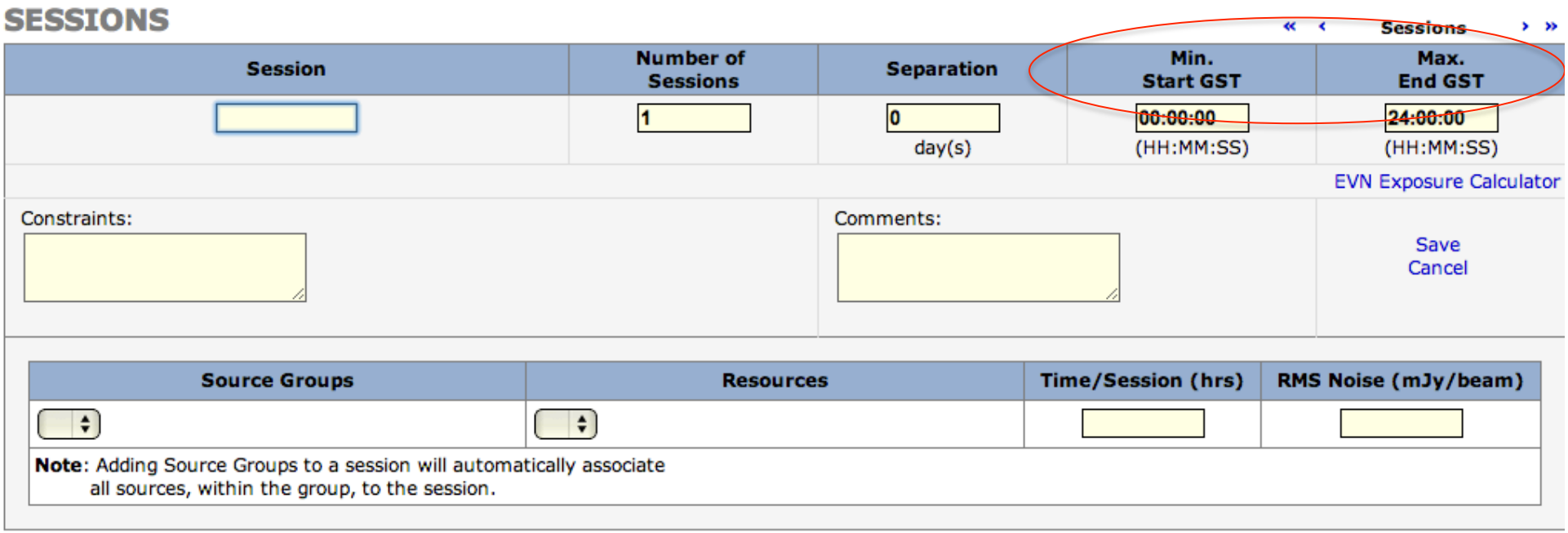


If both wide bandwidth and spectral zooming are desired, this would be 2

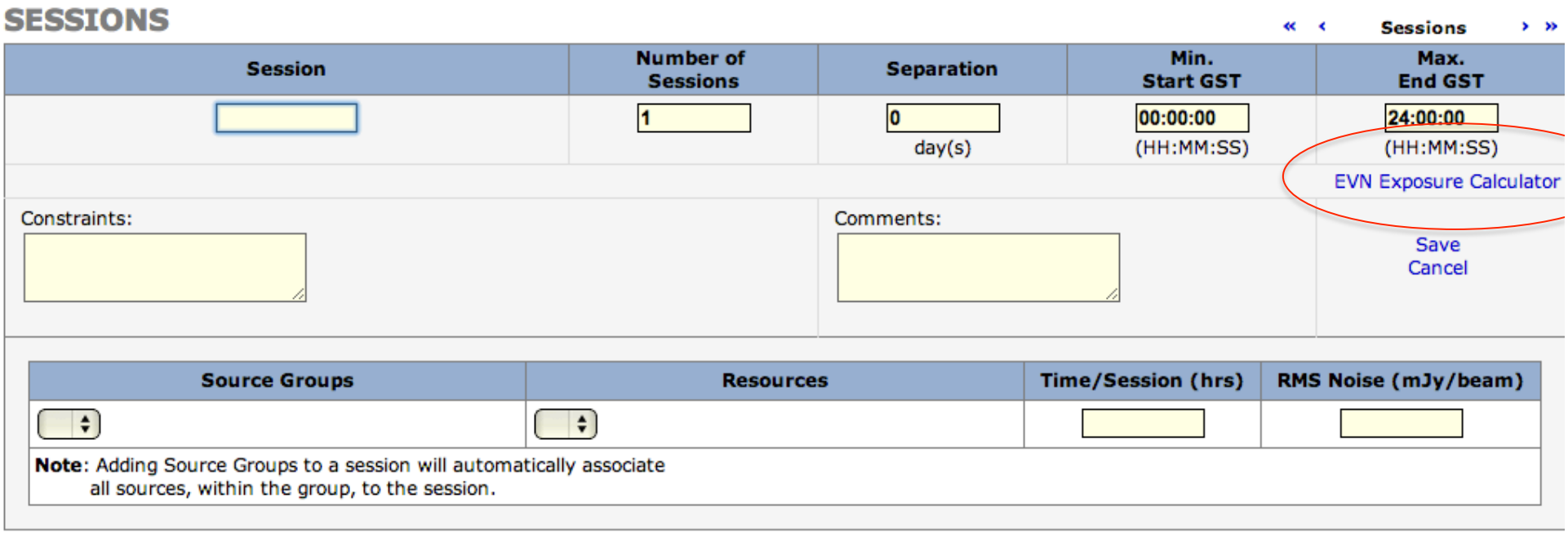
Up to 32768 spectral channels

For multi-field imaging

VLBA/HSA Sessions in the PST



VLBA/HSA Sessions in the PST



http://www.evlbi.org/cgi-bin/EVNcalc

EVN Calculator

EVN | e-EVN | VLBA | GLOBAL | GMVA — RESET | GO

Observing band & data rate [Mbit/s]	On-source integration time [min]
L – 18cm, 2048	150

☐ Ef	☐ W1	☐ Hh	☐ Ka	☐ Gb	☑ Kp
☐ Mc	☐ Nt	☐ My	☐ Ny	☐ Y1	☑ Pt
☐ On	☐ Sh	☐ Km	☐ Tc	☐ Y27	☑ Ov
☐ Tr	☐ Ur	☐ Sv	☐ Pv	☑ Sc	☑ Br
☐ Jb1	☐ Mh	☐ Zc	☐ Ro70	☑ Hn	☑ Mk
☐ Jb2	☐ Ys	☐ Bd	☐ Ro34	☑ Nl	
☐ Cm	☐ Sr	☐ Wz	☐ Pb	☑ Fd	
☐ Wb	☐ Ar	☐ Sm	☐ Go	☑ La	

The image thermal noise is estimated to be 21.27 uJy/beam (1 sigma) using natural weighting.

Number of spectral channels, integration time [s], and maximum baseline length	Number of polarizations, subbands per polarizations, and bandwidth of a subband [MHz]
16 ch, 2s, 10000 km (Full EVN)	2 pols, 8 sb, 32 MHz

The field of view limited by bandwidth-smearing is 2.475 arcseconds (assuming 10000.0 km for the maximum baseline).

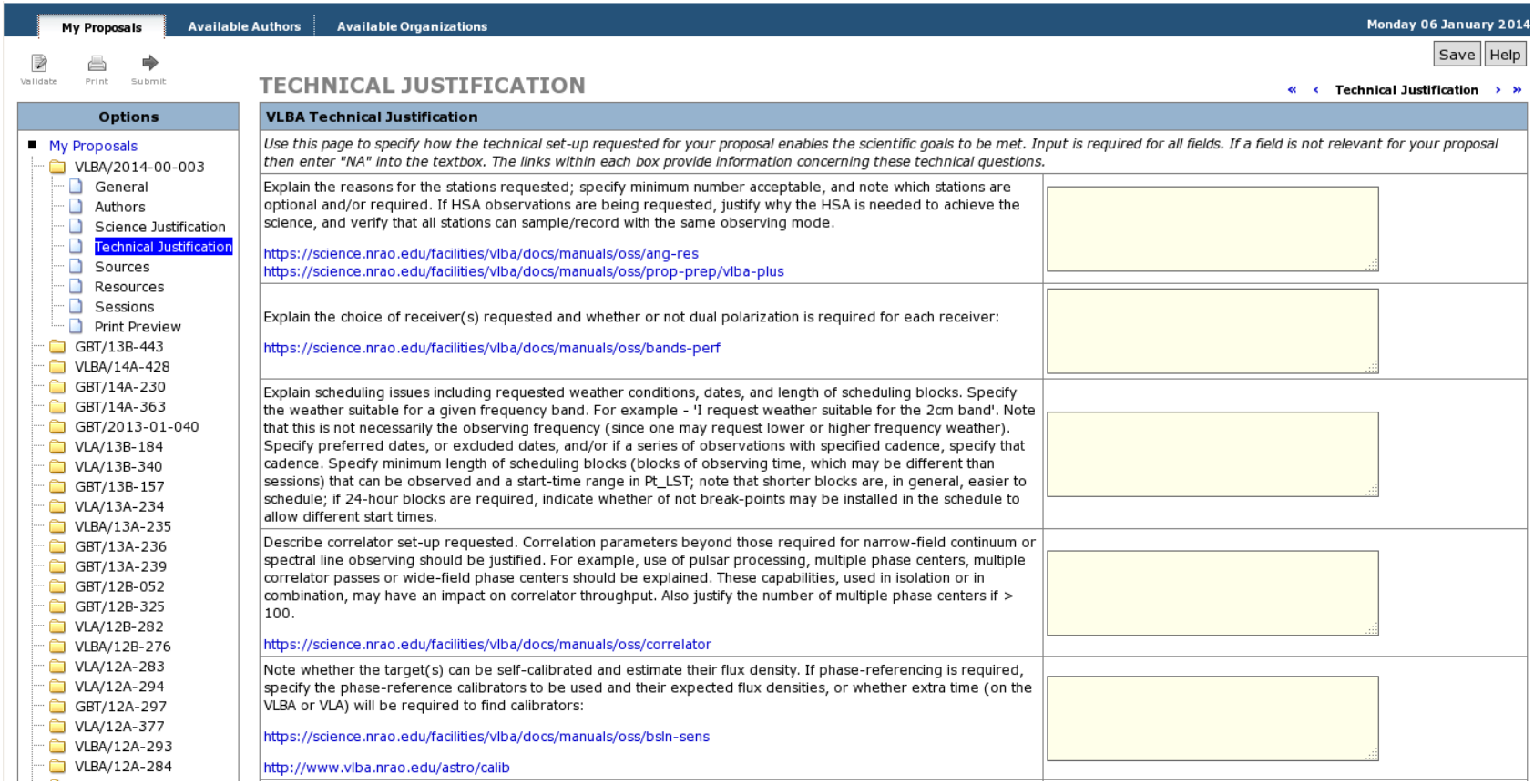
The field of view limited by time-smearing is 16.70 arcseconds. These values are calculated for 10% loss in the response of a point source, and they give the FoV radius from the pointing center.

32 MHz subbands are not available operationally at the EVN yet. The resulting FITS file size will be about 427.24 MBytes.

This combination of channels and polarizations results in an aggregate bit rate of 2048 Mbps, assuming 2 bit sampling.

RESET | GO

VLBA/HSA Technical Justification



Important Links

- NRAO Help Desk

  https://help.nrao.edu

- VLBA Observational Status Summary

  https://science.nrao.edu/facilities/vlba/docs/manuals/oss

- EVN Sensitivity Calculator

  http://www.evlbi.org/cgi-bin/EVNcalc

- Proposal Submission Tool

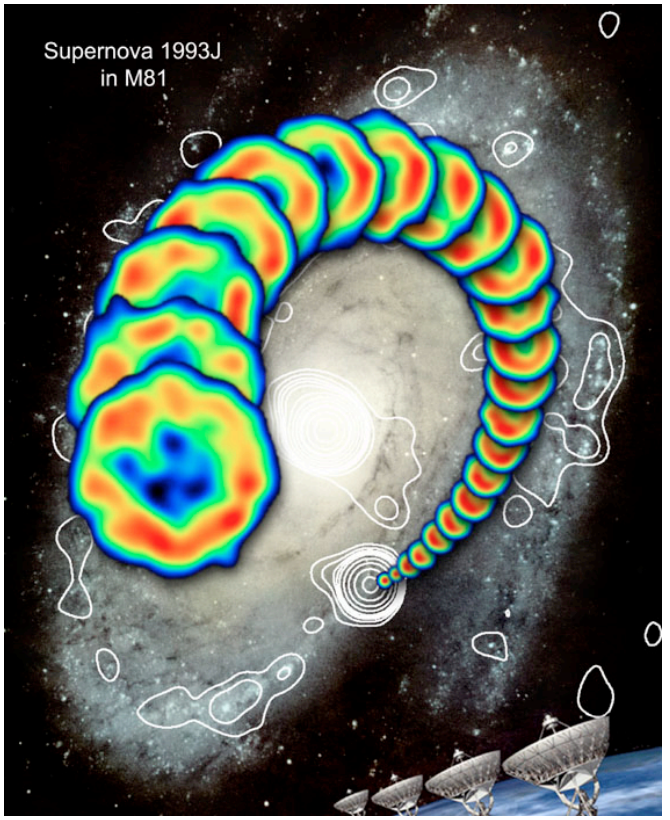
  http://my.nrao.edu

- SCHED – observation preparation software

  http://www.aoc.nrao.edu/software/sched/index.html

- AIPS – data reduction software

  http://www.aips.nrao.edu/index.shtml



SN1993J, Bartel et al.
Image courtesy Michael Rupen