NATIONAL RADIO ASTRONOMY OBSERVATORY

Key Requirements

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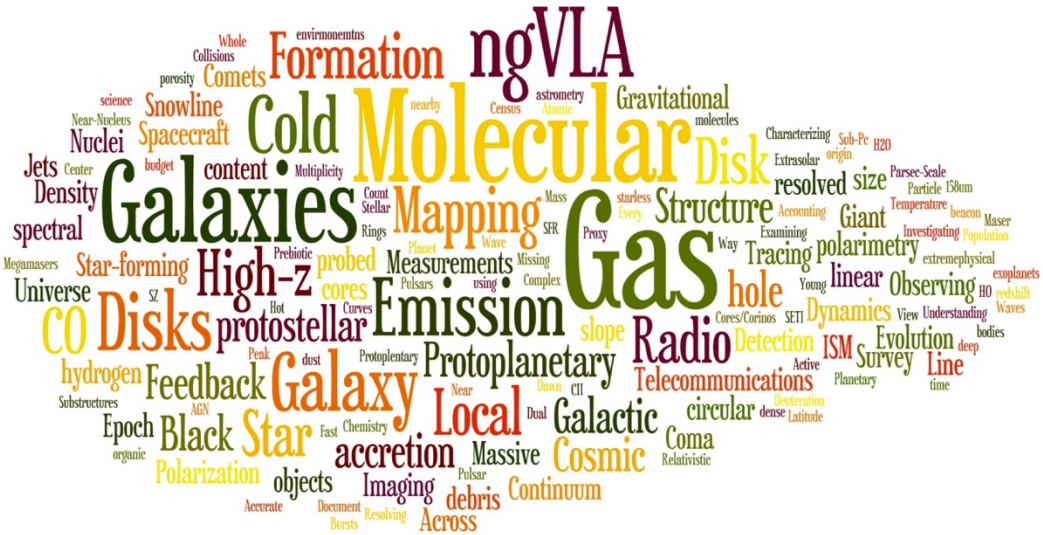
Associated Universities, Inc.

ngVLA

The Next Generation Very Large Array

Outline

- Science Case Summary
- System Specifications
  - Key Technical Parameters
  - Key Open Questions

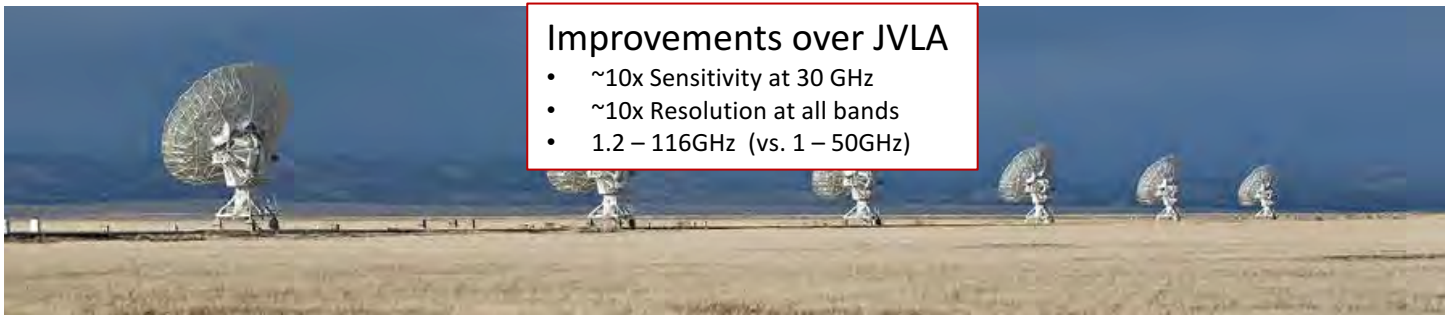


Word Cloud for Titles of 75 Science Use Cases

Previous Estimates of Performance Specifications

Carilli et al. 2015, ngVLA memo #5

	2GHz	10GHz	30GHz	80GHz	100GHz
Field of View FWHM (18m[a]) arcmin	29	5.9	2	0.6	0.51
Aperture Efficiency (%)	65	80	75	40	30
A^b_{eff} x10^4 m^2	5.1	6.2	5.9	3.1	2.3
T^c_{sys} K	29	34	45	70	80
Bandwidth[d] GHz	2	8	20	30	30
Continuum rms[e] 1hour, μJy beam^{-1}	0.93	0.45	0.39	0.96	1.48
Line rms 1hour, 10 km s^{-1}, μJy beam^{-1}	221	70	57	100	130
Resolution[f] FWHM milliarcsec	140	28	9.2	3.5	2.8
T^g_B rms continuum 1hr K	14	7	6	15	23
Line[h] rms 1hour, 1" taper, 10 km s^{-1}, μJy beam^{-1}	340	140	240	860	–
T^i_B rms line, 1hour, 1" taper, 10 km s^{-1}, K	100	1.8	0.32	0.17	–

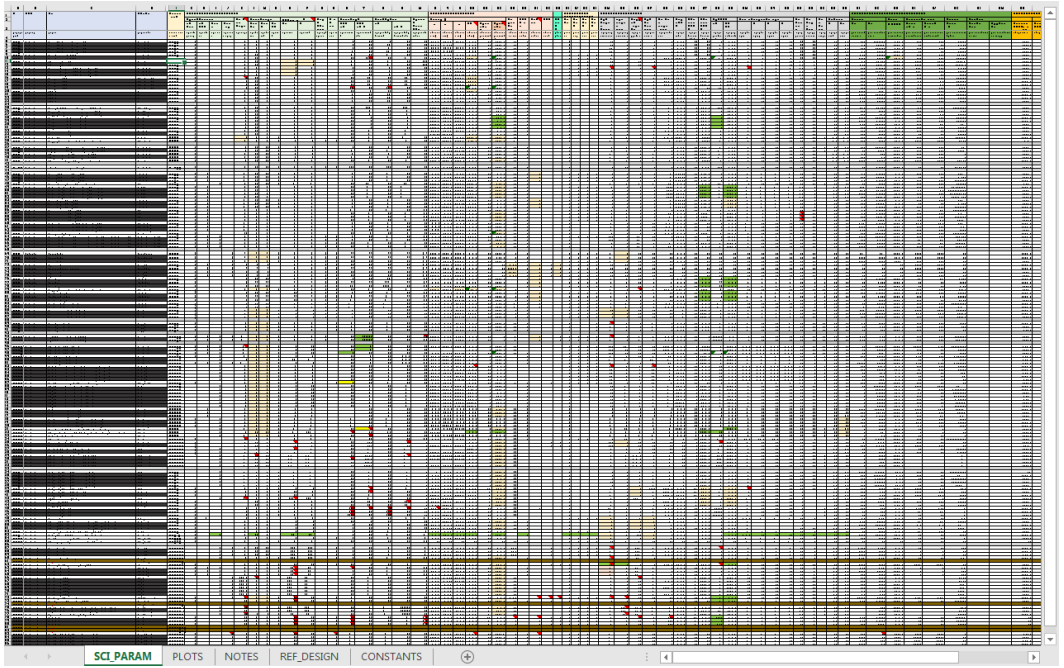


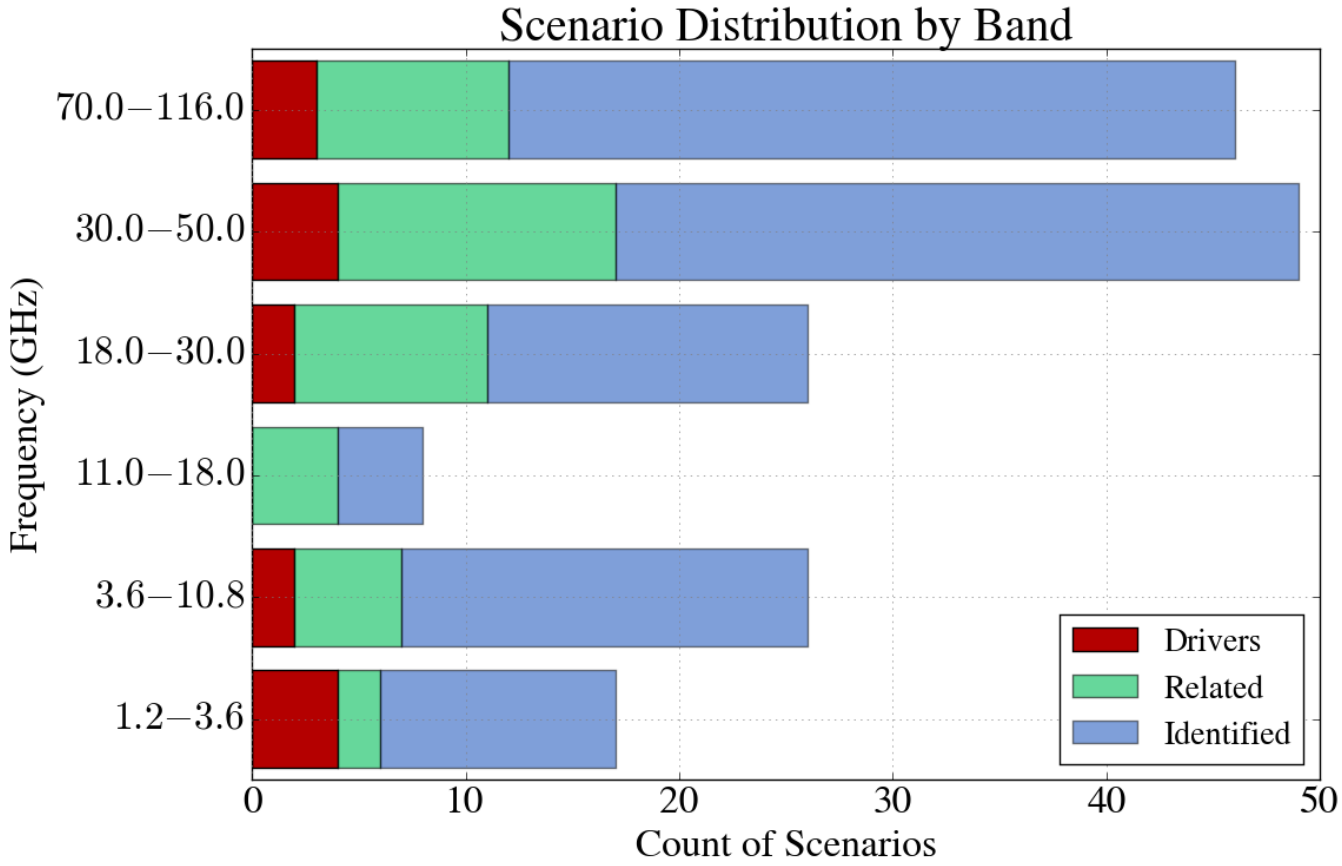
Improvements over JVLA

- ~10x Sensitivity at 30 GHz
- ~10x Resolution at all bands
- 1.2 – 116GHz (vs. 1 – 50GHz)

Science Use Case Parameterization

- 75 Science Use Cases developed into 180 discrete observations.
- Derived a number of parameters from each observation to determine what the community needs from this array.





Band 6

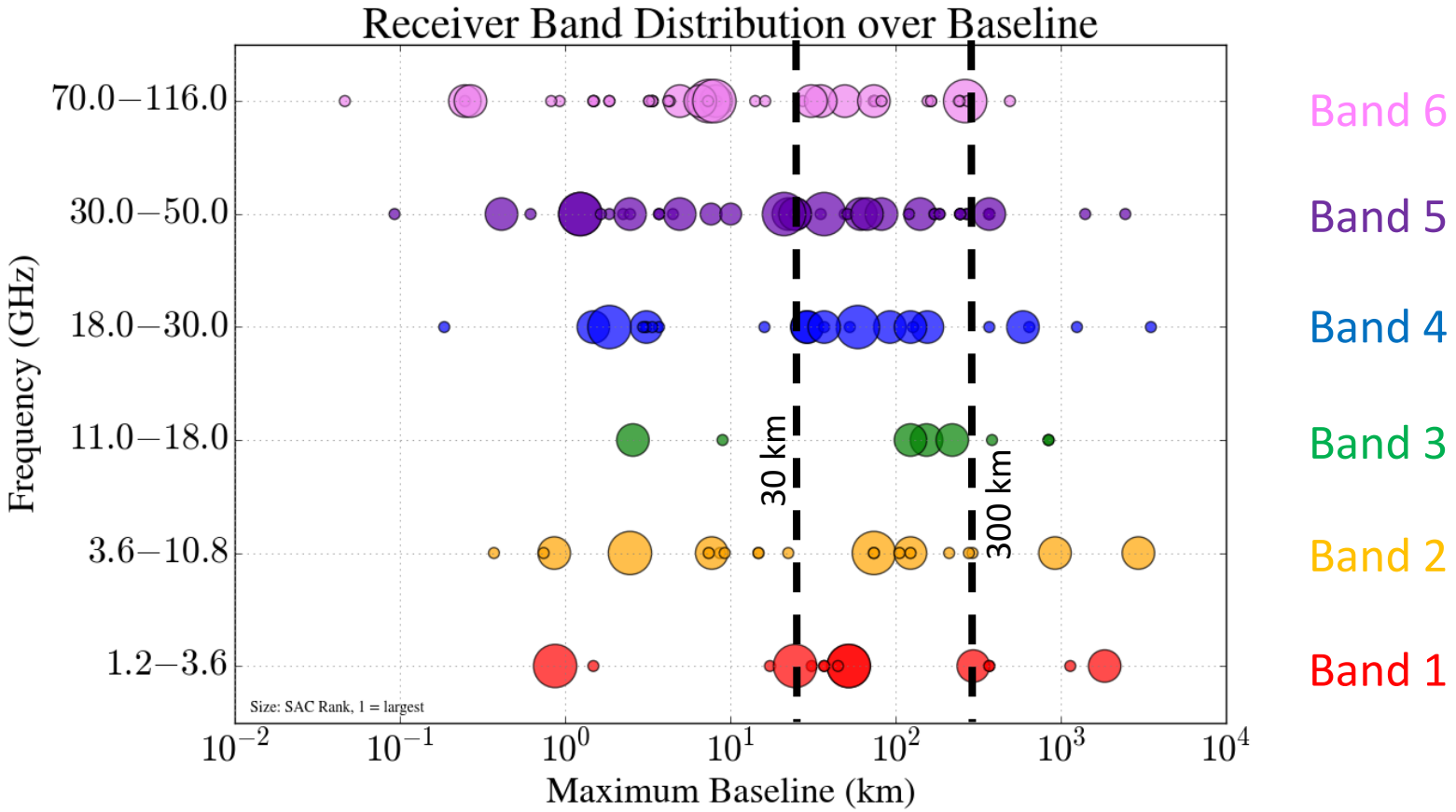
Band 5

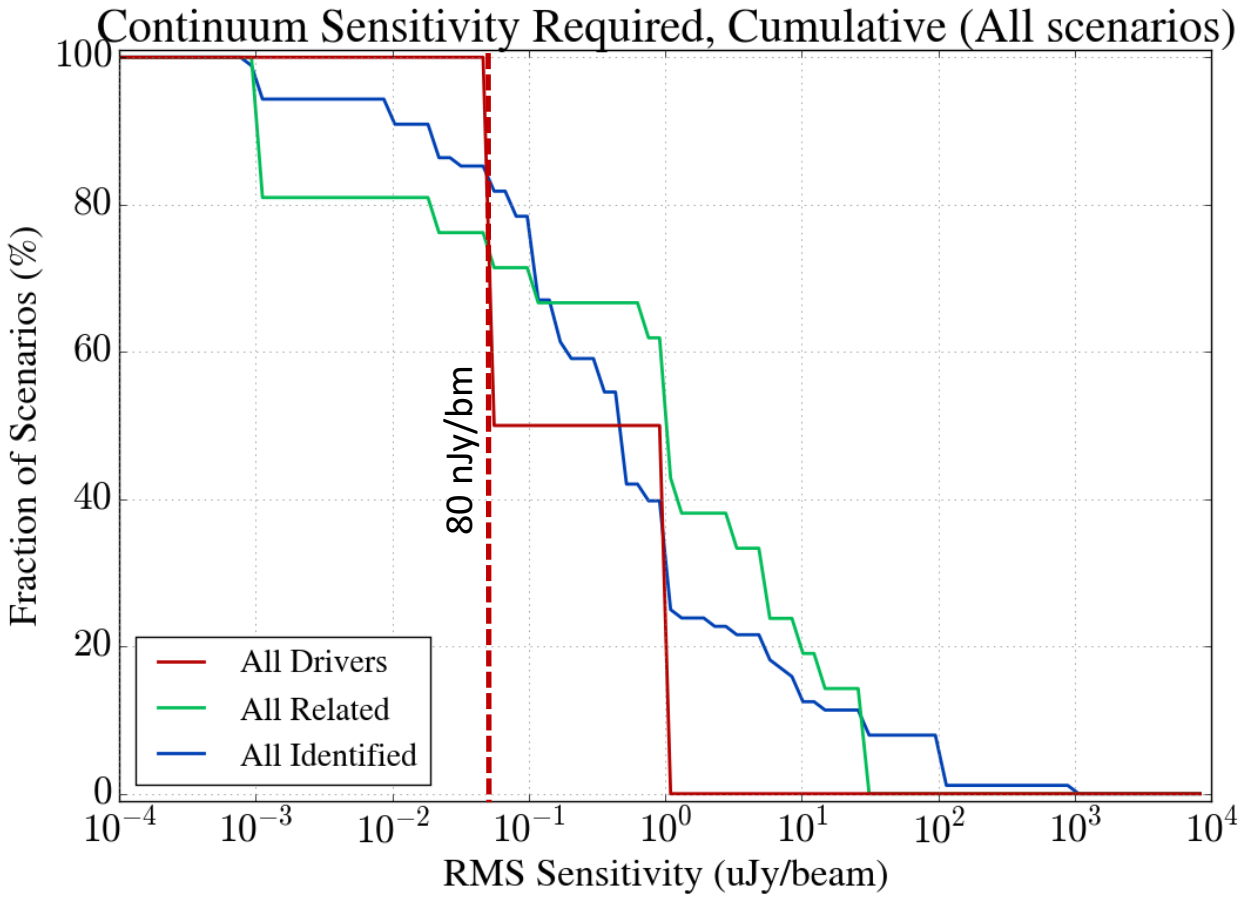
Band 4

Band 3

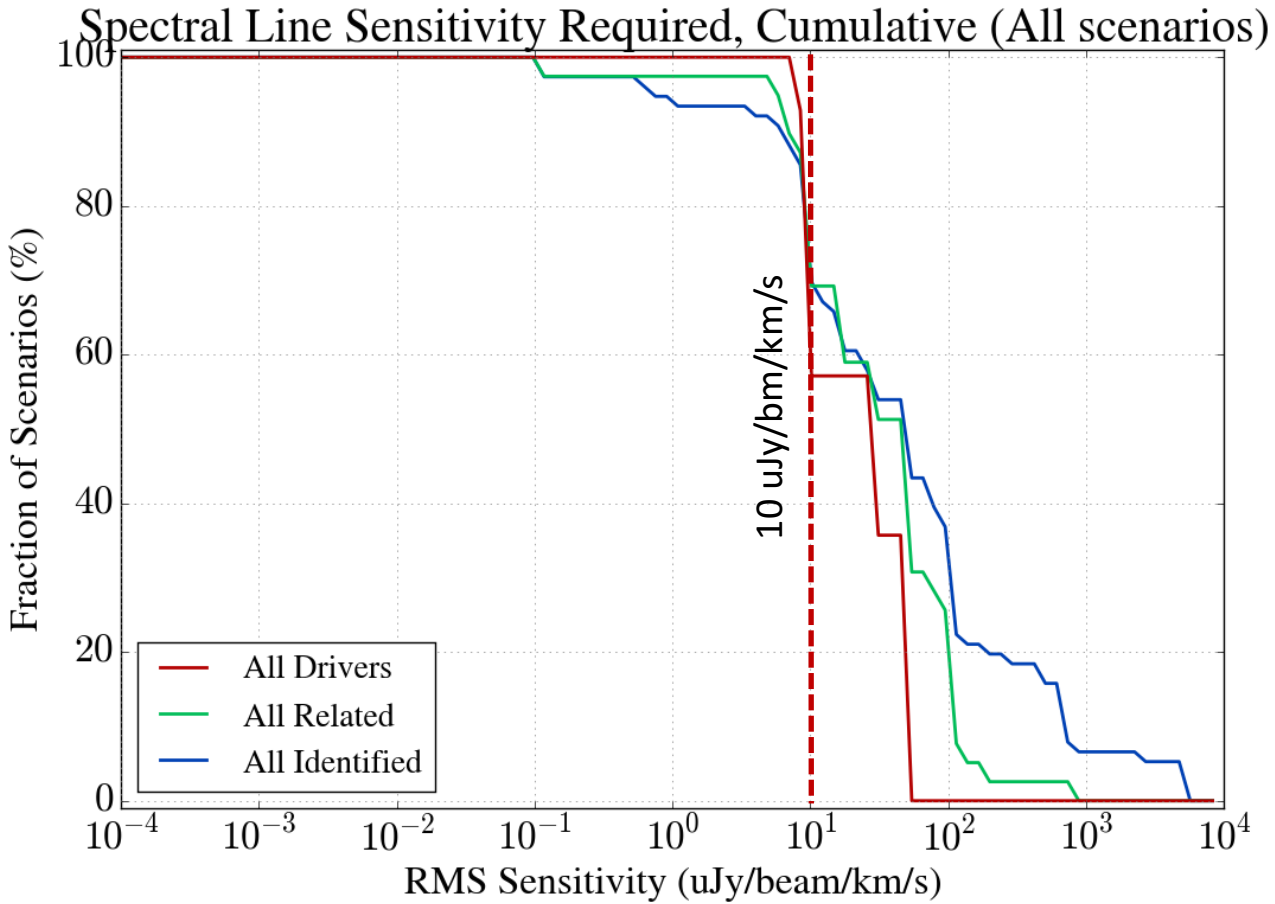
Band 2

Band 1


Receiver Band Distribution over Baseline
70.0–116.0
30.0–50.0
18.0–30.0
11.0–18.0
3.6–10.8
1.2–3.6
Frequency (GHz)
30 km
300 km
Size: SAC Rank, 1 = largest
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Maximum Baseline (km)
Band 6
Band 5
Band 4
Band 3
Band 2
Band 1

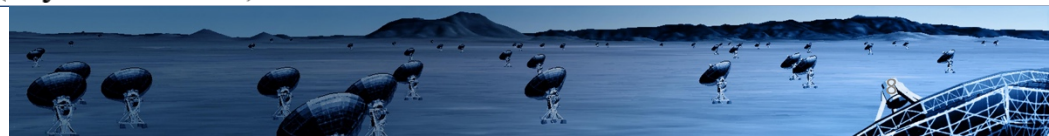

Continuum Sensitivity Required, Cumulative (All scenarios)
Fraction of Scenarios (%)
RMS Sensitivity (uJy/beam)
80 nJy/bm
All Drivers
All Related
All Identified
100
80
60
40
20
0
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

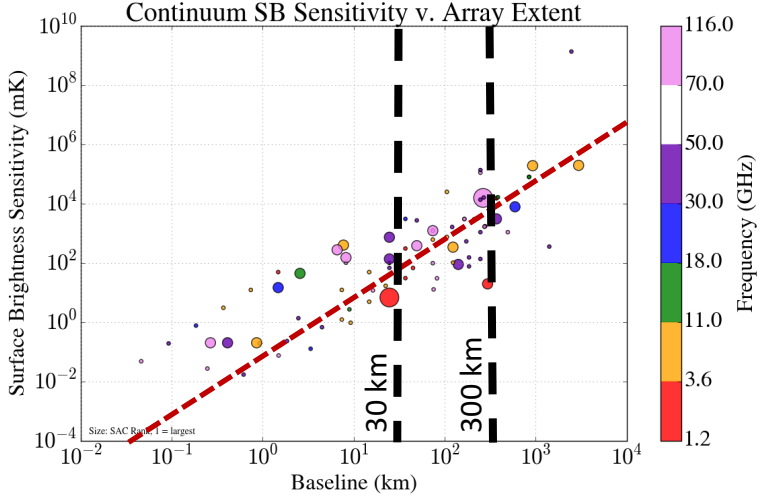
v23

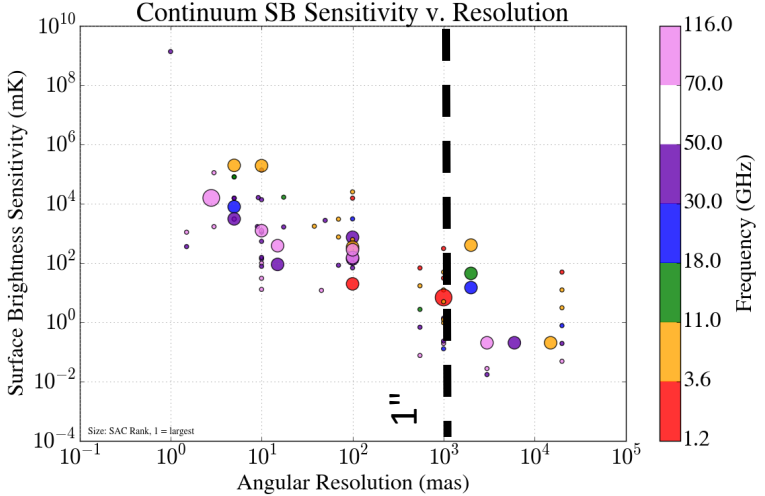


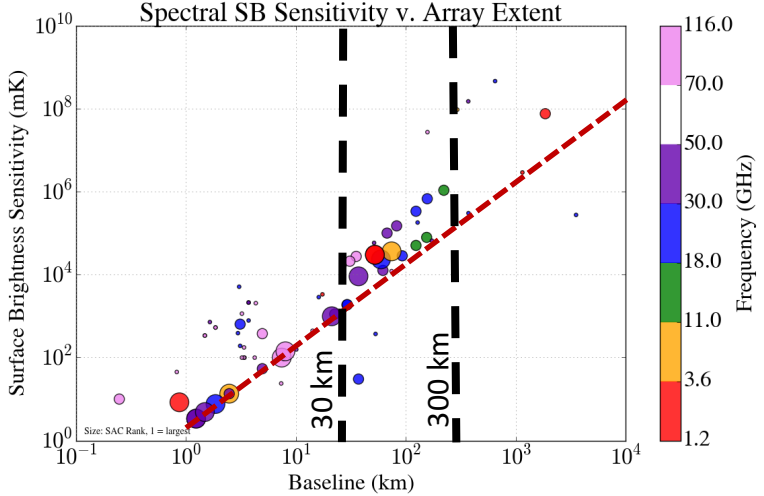
v23

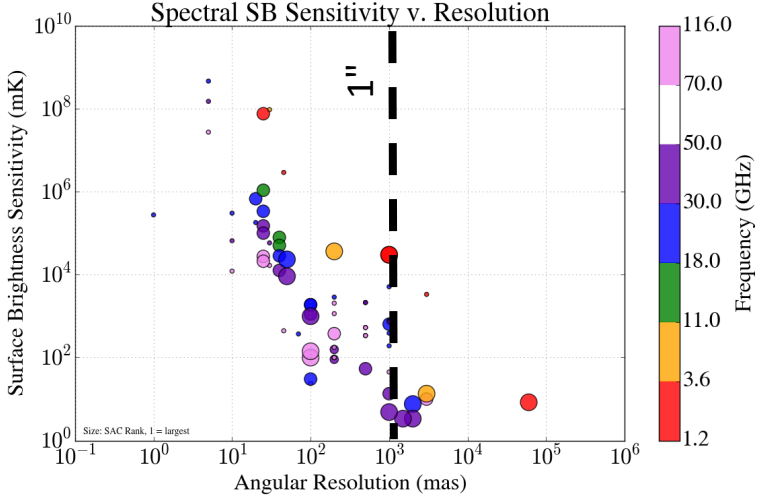
The Next Generation Very Large Array



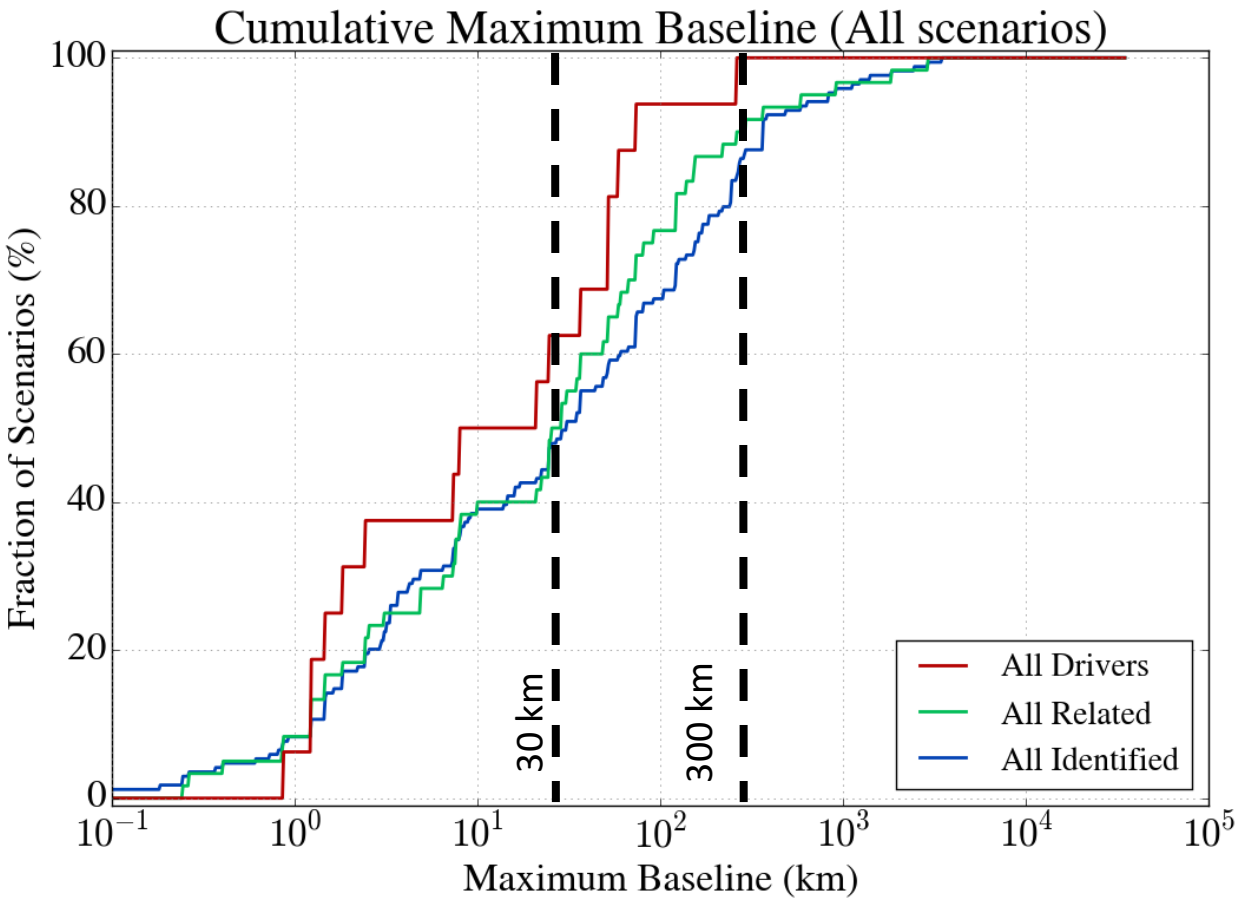

Continuum SB Sensitivity v. Array Extent
Surface Brightness Sensitivity (mK)
Baseline (km)
Frequency (GHz)
116.0
70.0
50.0
30.0
18.0
11.0
3.6
1.2
30 km
300 km
Size: SAC Rank, 1 = largest


Continuum SB Sensitivity v. Resolution
Surface Brightness Sensitivity (mK)
Angular Resolution (mas)
Frequency (GHz)
116.0
70.0
50.0
30.0
18.0
11.0
3.6
1.2
1"
Size: SAC Rank, 1 = largest


Spectral SB Sensitivity v. Array Extent
Surface Brightness Sensitivity (mK)
Baseline (km)
Frequency (GHz)
116.0
70.0
50.0
30.0
18.0
11.0
3.6
1.2
30 km
300 km
Size: SAC Rank, 1 = largest


Spectral SB Sensitivity v. Resolution
Surface Brightness Sensitivity (mK)
Angular Resolution (mas)
Frequency (GHz)
116.0
70.0
50.0
30.0
18.0
11.0
3.6
1.2
1"
Size: SAC Rank, 1 = largest

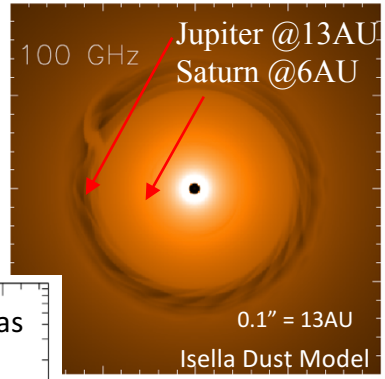
v23

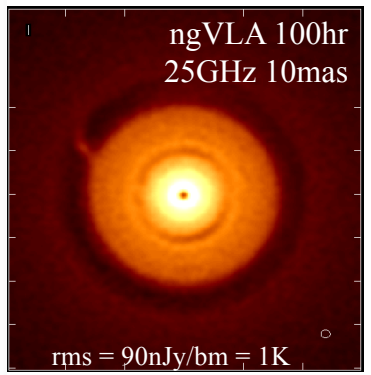

Cumulative Maximum Baseline (All scenarios)
Fraction of Scenarios (%)
Maximum Baseline (km)
30 km
300 km
All Drivers
All Related
All Identified

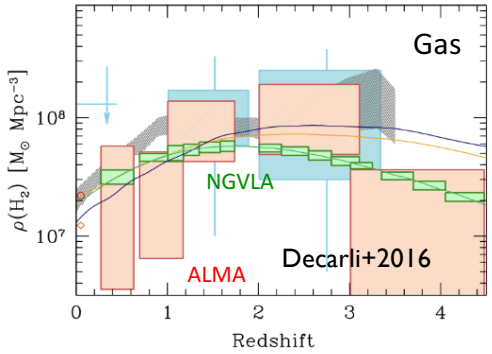
v2.3

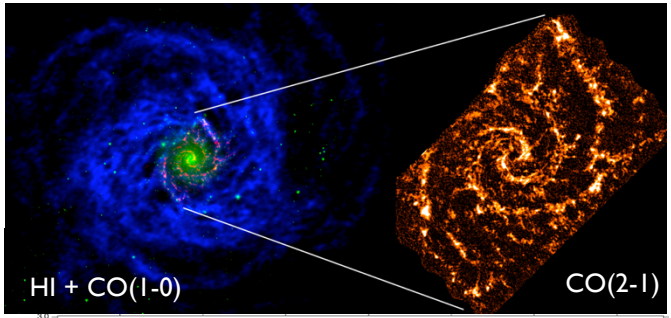
Significant Requirements & Take-Aways

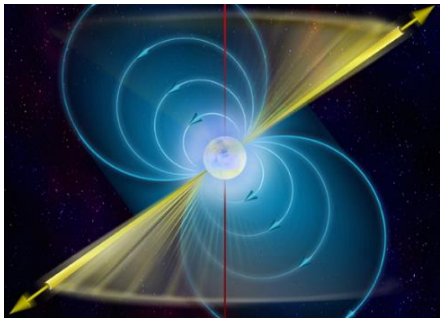
- PI driven / pointed operations model.
- Need full 1.2 – 116 GHz Frequency coverage across the full array.
- Most science achievable with ~300 – 1000 km scale array, with a long tail extending out to VLBI scales.
  - ➢ *What is the best compromise on array extent?*

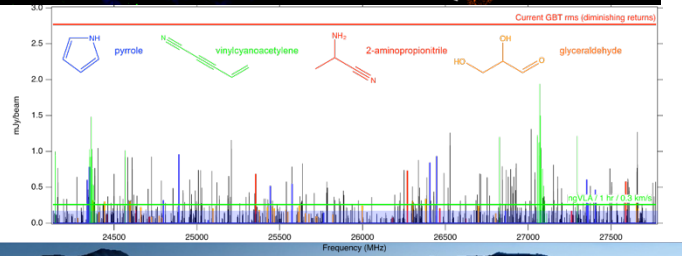












Operating Modes / Functional Capabilities

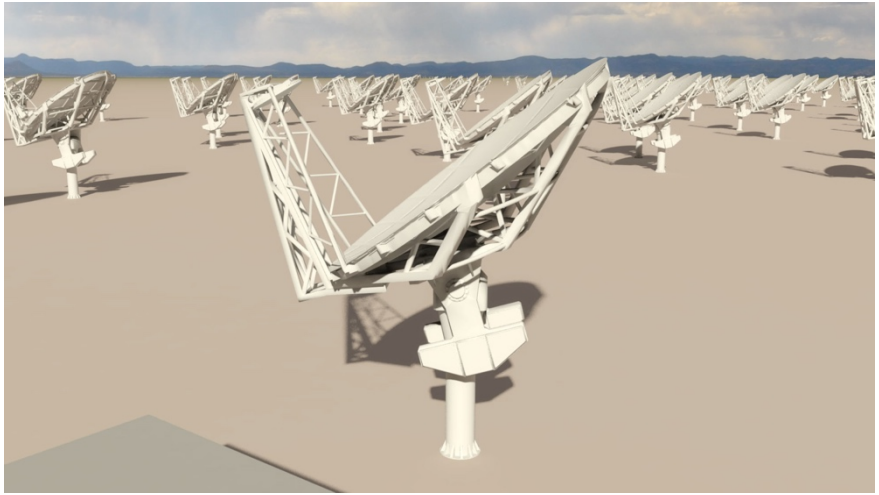
- Spectral Line & Continuum Modes
- Time Domain Capabilities
- VLBI Capabilities (?)
- Phased Array Capability
- Total Power Measurements (?)
- Sub-Array Capabilities (?)
- Solar Observation Capabilities (?)

- ➢ *Goal to maximize flexibility of both modes. Both equally represented.*
- ➢ *Time domain search capabilities on msec scales.*
- ➢ *Intermediate scales (500-1000km) out to continental scales?*
- ➢ *Operate as both an interferometer and phased array.*
- ➢ *Or single dish?*

- ➢ *Flexible sub-array capability desired, but emphasis on sensitivity.*
- ➢ *Support Solar/Solar System Science cases.*

Requested Key Technical Parameters

- Frequency Range – **1.2 – 116GHz**
- Requested Sensitivities *@ 30 GHz*
  - Continuum Imaging Sensitivity – **0.08 uJy/bm**
  - Line Imaging Sensitivity – **10 uJy/bm/km/s**
  - Surface Brightness Sensitivity – **1 mK @ 1 arcsec**
- Angular Resolution – **< 10mas @ 30GHz**
- Dynamic Range – <~**10^5**
- Polarization **– 0.1% Purity, 1-degree**



An artist's rendering of the ngVLA core, centered on the current JVLA site, which may include ~85 of the ~214 18m diameter dishes that comprise the array.

Key Open Questions – Specification Decisions

- Long Baselines
  - ➢ *Do we need to extend beyond ~300 – 1000 km in the baseline design?*
- Short Spacings
  - ➢ *Is 30 – 40m minimum spacing good enough?*
    - ➢ *Require a large single dish w/ FPA (e.g., 45m x 20 beams – D. Frayer, ngVLA memo 14)?*
    - ➢ *Short-spacing array of small dishes (e.g., 6m – Murphy/Condon+, Scicase NGA-3)?*
- Autocorrelation Total Power
  - ➢ *Do we need to include accurate total power measurements in the baseline design?*

Lots more about 'Options' in next talk...

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