The Karl G Jansky Very Large Array
(formerly known as the EVLA)

Current and future capabilities

Jürgen Ott / Michael Rupen / Gustaaf van Moorsel
What is the EVLA?

- The Expanded VLA (EVLA) is a major conversion of the Very Large Array
- First light/fringe in 2010, full operation beginning of 2013
- 5-10 times better continuum sensitivity
- Accessibility of entire 1-50 GHz frequency range (8 feeds)
- Up to 8 GHz bandwidth per observation and polarization
- High dynamic range imaging
- Spectral channels up to 16000 - $4 \times 10^6$ channels in up to 64 independent subbands (equivalent to 64 independent correlators)
- Correlator supports up to 32 antennas
- Dynamical scheduling (based on scientific priority, weather conditions, and scheduling efficiency)
- Pipeline-calibrated visibility data plus reference images
- New observation preparation software (OPT)
- New data reduction software (CASA)
What is the EVLA?

• 27x25m VLA antennas reconfigurable on baselines 35m to 36km
• located in Southern New Mexico at 2100m altitude
What is the EVLA?

- 27x25m VLA antennas reconfigurable on baselines 35m to 36km
- located in Southern New Mexico at 2100m altitude
Spatial Resolution

- With reconfiguration of the antennas, the EVLA can vary its spatial resolution by a factor of ~50 (depending on largest baseline/telescope separation)
- Reconfiguration every 4 months (modifications during commissioning)
Largest Angular Scale

- The **shortest** baseline sets the largest angular scale that an interferometer is sensitive to.
- Compact configurations images have less spatial resolution but cover larger angular scales and increase surface brightness sensitivity.

### Field of view

(depends on diameter of a single antenna)
- 608’
- 30’
- 15’
- 7.5’
- 5.3’
- 3’
- 2’
- 1.4’
- 1’

### Table

<table>
<thead>
<tr>
<th>Configuration</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_{max}$ (km$^{-1}$)</td>
<td>36.4</td>
<td>11.1</td>
<td>3.4</td>
<td>1.03</td>
</tr>
<tr>
<td>$B_{min}$ (km$^{-1}$)</td>
<td>0.68</td>
<td>0.21</td>
<td>0.035$^5$</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Largest Angular Scale $\theta_{LAS}$ (arcsec)$^{1,4}$

- 74 MHz (4 band): 800, 2200, 20000, 20000
- 1.5 GHz (L): 36, 120, 970, 970
- 3.0 GHz (S)$^6$: 18, 58, 490, 490
- 6.0 GHz (C): 8.9, 29, 240, 240
- 8.5 GHz (X)$^7$: 6.3, 20, 170, 170
- 15 GHz (Ku)$^6$: 3.6, 12, 97, 97
- 22 GHz (K): 2.4, 7.9, 66, 66
- 33 GHz (Ka): 1.6, 5.3, 44, 44
- 45 GHz (Q): 1.2, 3.9, 32, 32
Receivers

- 8 wideband receivers
- Switching receivers can be as fast as 20s

<table>
<thead>
<tr>
<th>Band</th>
<th>Range (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 cm (L)</td>
<td>1.0–2.0</td>
</tr>
<tr>
<td>13 cm (S)</td>
<td>2.0–4.0</td>
</tr>
<tr>
<td>6 cm (C)</td>
<td>4.0–8.0</td>
</tr>
<tr>
<td>3 cm (X)</td>
<td>8.0–12.0</td>
</tr>
<tr>
<td>2 cm (Ku)</td>
<td>12.0–18.0</td>
</tr>
<tr>
<td>1.3 cm (K)</td>
<td>18.0–26.5</td>
</tr>
<tr>
<td>1 cm (Ka)</td>
<td>26.5–40.0</td>
</tr>
<tr>
<td>0.7 cm (Q)</td>
<td>40.0–50.0</td>
</tr>
</tbody>
</table>
Receivers

- Wideband receivers 1 GHz @ L-band to 13.5 GHz @ Ka-band (correlator can go up to 8 GHz)
- Better sensitivity (cf. VLA max. bandwidth 50 MHz)
- Better image fidelity, higher dynamic range with a goal of $10^6$ (filling in gaps in the uv-coverage/multi-frequency synthesis; better RFI isolation)
- Determination of spectral indices in single observations
- Multi-line observations at identical weather conditions for accurate line ratios

<table>
<thead>
<tr>
<th>Band</th>
<th>Range (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 cm (L)</td>
<td>1.0–2.0</td>
</tr>
<tr>
<td>13 cm (S)</td>
<td>2.0–4.0</td>
</tr>
<tr>
<td>6 cm (C)</td>
<td>4.0–8.0</td>
</tr>
<tr>
<td>3 cm (X)</td>
<td>8.0–12.0</td>
</tr>
<tr>
<td>2 cm (Ku)</td>
<td>12.0–18.0</td>
</tr>
<tr>
<td>1.3 cm (K)</td>
<td>18.0–26.5</td>
</tr>
<tr>
<td>1 cm (Ka)</td>
<td>26.5–40.0</td>
</tr>
<tr>
<td>0.7 cm (Q)</td>
<td>40.0–50.0</td>
</tr>
</tbody>
</table>
Wideband Imaging

• Relics and Jets in Abell 2256
• Color: spectral index

Owen, Rudnick, Eilek, Rau, Bhatnagar, Kogan
Wideband Imaging

- Wide-band, wide-field imaging
- Multi-scale cleaning
- A-projection for wide-field imaging

Bhatnagar, Green, Rau, Golap, Rupen & Perley

G93.3+6.9
Sensitivity

- At 10 GHz: in 1h, a 1σ noise of 2 μJy continuum
- 0.8 mJy in 1 km s⁻¹ channel
## VLA – EVLA Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>VLA</th>
<th>EVLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuum sensitivity (1s, 9 hr)</td>
<td>10 µJy</td>
<td>1 µJy</td>
</tr>
<tr>
<td>Maximum bandwidth</td>
<td>0.1 GHz</td>
<td>8 GHz</td>
</tr>
<tr>
<td>Number of frequency channels at maximum bandwidth</td>
<td>16</td>
<td>16,384</td>
</tr>
<tr>
<td>Maximum number of frequency channels</td>
<td>512</td>
<td>4,194,304</td>
</tr>
<tr>
<td>Coarsest frequency resolution</td>
<td>50 MHz</td>
<td>2 MHz</td>
</tr>
<tr>
<td>Finest frequency resolution</td>
<td>381 Hz</td>
<td>0.12 Hz</td>
</tr>
<tr>
<td>Frequency coverage, 1 - 50 GHz</td>
<td>22%</td>
<td>100%</td>
</tr>
<tr>
<td>Number of baselines</td>
<td>351</td>
<td>351</td>
</tr>
<tr>
<td>Maximum spatial resolution (5GHz)</td>
<td>0.3”</td>
<td>0.3”</td>
</tr>
</tbody>
</table>
Receiver Availability

- Majority of receivers is already installed, a few more remaining, installation of 3-bit samplers (required for 8 GHz bandwidth) will commence soon.

![Graph showing availability of remaining wide-band receivers](image-url)

**Complete:**
- C: 4-8 GHz
- K: 18-26.5 GHz
- Ka: 26.5–40GHz
- Q: 40-50GHz
WIDAR Correlator

- WIDAR: Wideband Interferometric Digital Architecture
- $10^{16}$ calculations/s
- Fiber bandwidth: 3 Tbits/s = 48 million phone calls
- 16 GHz per antenna = 2600 TV channels
- 175 kW = 350 refrigerators electricity usage
- 160 Gbits/s output
- 160 baseline boards
- 120 station boards
WIDAR Correlator

Final specs:

- 64 independent subbands act like 64 independent correlators independent in bandwidth, channelization, polarization products

- Each subband:
  - Up to 4 polarization products
  - 31 kHz – 128 MHz bandwidth
  - Up to 16384 channels
  - 2 Hz – 2 MHz bandwidth

- Baseline board stacking (trading subbands for additional channels)
- Recirculation (trading integration time for additional channels)
Examples:

- **Ka-band (1 cm):** 2x1 GHz imaging (captures tens of important molecular lines) with 3 km/s spectral resolution (dual pol), 1 s integration times, even more channels with recirculation.

- **L-band (21 cm):** Full stokes continuum at 2 MHz resolution (using 8 subbands) plus sub km/s imaging on HI, OH, radio recombination lines (up to 56 additional subbands!), all simultaneously.

- **S-band (13 cm):** 31 Radio recombination lines at once with sub-km/s resolution; sensitivity increase by stacking.
Multi-Line Imaging: Orion KL

- Wide-band, wide-field imaging
- Multi-scale cleaning
- A-projection for wide-field imaging

96x96x24012 spectral cube

End to end data processing in CASA
High z spectral surveys

- EVLA is giving access to low excitation CO lines at intermediate z and high excitation lines at high z
- Wideband enables blind CO surveys
- Perfect complement to ALMA and other (sub)mm observatories

Extended, low excitation CO in z~2.3 SMG (Ivison ea)

Multitransition CO study of most distance SMG z=5.3 (Riechers, Capak ea)

Courtesy C. Carilli
OSRO modes

• During commissioning we offer open shared risk (OSRO) observing and resident shared risk observing (RSRO) for those who come to Socorro and help to commission the EVLA for at least 3 months

• OSRO capabilities are better tested but more limited than RSRO correlator modes

• For the 1 Feb 2012 deadline, we offer the following OSRO capabilities:
  • 2 GHz bandwidth, 1 GHz on each baseband, each up to 8 subbands
  • Doppler setting
  • Each subband:
    • 31kHz – 128 MHz bandwidth with 64 channels, 4 polarization products or
    • 31kHz – 128 MHz bandwidth with 128 channels, 2 polarization products
  • subbands must be contiguous in frequency
RSRO modes

- 2 or 8 GHz bandwidth (use of 3-bit samplers)
- 64 subbands
- Independently tunable
  - Basic subband setting: 31 kHz-128 MHz bandwidth, 64 channels, full pol or
  - 31 kHz – 128 MHz bandwidth, 128 channels, dual pol
  - Baseline board stacking (trading subbands for additional channels)
  - Recirculation (trading integration time for additional channels)

- Data rates can be very large and some restrictions apply
Advanced Modes for RSRO

• Capabilities:
  • Multiple sub-arrays
  • OTF mosaicing
  • Phased EVLA and single-dish VLBI \(\rightarrow\) Amy Mioduszewski’s presentation
  • Solar and planetary observing
  • Pulsar observing
  • Observing with the 3-bit sampler system
  • Fast correlator dumps
  • Low frequency (<1 GHz) observing

• Other commissioning activities:
  • Pipeline heuristics, including automated flagging and data quality analysis
  • Testing of new full-field, wide-bandwidth imaging algorithms
  • Advanced data analysis tools
Data Reduction

• OSRO data reduction is possible in CASA and AIPS
• RSRO and full EVLA data reduction in CASA only
• Data volumes can be very large and parallelization of the software is currently underway
• CASA contains new wide-band, wide-field imaging algorithms
• On-the-fly Interferometry/Mosaicing
• Development of automatic RFI flagging
• A computing cluster will be available for users in Socorro
• Hardware recommendations are provided on our webpage for those who decide to upgrade their own computing equipment
Next proposal deadline: 1 Feb 2012
science.nrao.edu

http://science.nrao.edu/evla/earlyscience/demoscience/