The Very Large Array after the Upgrade

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Abstract

The Jansky Very Large Array (JVLA) is the result of the expansion of the original VLA. The Expanded VLA (EVLA) project has vastly improved a number of key aspects of the VLA. In this presentation I intend to describe the main improvements, summarize current capabilities, and describe plans for the future. I will also present a number of examples of the great new science the upgrade of the VLA has enabled.

The Old and the New

The Very Large Array is a 27-element, reconfigurable interferometer array, located in west-central New Mexico, USA (latitude = 34.1, longitude = 107.6). Its high elevation (2,100 m) and desert climate means good observing conditions most of the year. It was constructed in the late 1970s and started operations in 1980. There are four major configurations, offering a range of 35 in maximum baselines and hence imaging resolution. The configuration changes once every 4 months.

The Expanded VLA project began in 2001, and was completed early in 2012. This was a major expansion of the Very Large Array, now called the Jansky Very Large Array. The project was completed on budget and on schedule.

The fundamental goal of the project was at least one order-of-magnitude improvement in all observational capabilities, except spatial resolution. One key aspect is that this was a leveraged project, building on existing VLA infrastructure, such as antennas, railroad tracks, buildings, and staff. Observing continued throughout the project apart from a 6 week interruption early 2010 when the old VLA correlator was replaced by the new WIDAR correlator.

Major improvements

The main improvements the VLA upgrade has brought are:

- 100% frequency coverage from 1 to 50 GHz. In the old VLA this was only 21%. This coverage is provided by 8 frequency bands, of which 2 (S and Ka) are totally new. For many other, existing, bands the frequency range had to be greatly increased, requiring entirely new receivers. In addition, the 50 – 450 MHz band is now covered by a ninth receiver, although formally this was not part of the EVLA project.
- Up to 8 GHz instantaneous bandwidth, which is a dramatic two orders of magnitude increase from the old 100 MHz? This bandwidth is provided by two independent dual-polarization frequency pairs, each of up to 4 GHz bandwidth per polarization. It uses new 3-bit samplers; use of the older 8-bit samplers gives a maximum of 2 GHz instantaneous bandwidth. It is an all digital design to maximize instrumental stability and repeatability, and enables 4 μJy/beam (1-σ, in 1 hour) continuum sensitivity at most bands.
- A new correlator with 8 GHz/polarization capability, which was designed, funded, and constructed by our Canadian partners, HIA/DRAO. This WIDAR correlator provides unprecedented flexibility in matching resources to science goals.
- Noise-limited, full-field imaging in all Stokes parameters for most observational fields. The vastly increased bandwidth and sensitivity requires new, state-of-the-art software for calibration, imaging, and deconvolution. This still is an ongoing area of research at NRAO.
- Routine Dynamic Scheduling of almost all observations. As this allows us to match projects with their required atmospheric conditions, this guarantees a much more efficient use of telescope time. Dynamic Scheduling has been a great learning experience for VLA staff and observers alike

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- A calibration pipeline, based on the CASA system, was developed in-house. This pipeline has been run on all continuum data being taken since January 2013. We expect to extend it to spectral line data in the coming year.

Table 1 provides a side-by-side comparison between a number of parameters of the old VLA and the current JVLA. Note that we have reached the goals in most parameters, with the exception of total number of channels/finest frequency resolution, which we currently restrict because of data throughput and data volume concerns

Parameter	VLA	JVLA	factor	current
Point Source Cont. Sensitivity (1s,12hr.)	10 μJy	1 μJy	10	1 μJy
Maximum BW in each polarization	0.1 GHz	8 GHz	80	8 GHz
# of frequency channels at max. BW	16	16,384	1024	16384
Maximum number of freq. channels	512	4,194,304	8,192	131,072
Coarsest frequency resolution	50 MHz	2 MHz	25	2 MHz
Finest frequency resolution	381 Hz	0.12 Hz	3,180	1 Hz
# of full-polarization spectral windows	2	64	32	64
(Log) Frequency Coverage (1 – 50 GHz)	22%	100%	5	100%

Table1: Comparison between old VLA and current JVLA in some important parameters

Recent Developments

For each proposal new capabilities are made available for general observing, in particular when going from A configuration (longest baselines) to D-configuration (shortest baselines). In the last two calls (last 12 months) new capabilities introduced include:

- Full bandwidths (3-bit samplers) at C, X, Ku bands. Routine 3-bit observing already had been on offer at the higher frequency bands, which are wider than the full 8 GHz bandwidth 3-bit observing allows
- For 3-bit observing, more flexible tuning of subbands, which now can be non-contiguous, and with widths ranging from 128 MHz down to 31.25kHz. This flexibility had already been available for a while for 8-bit observing
- Data output rates up to 60 MB/sec
- 3 simultaneous subarrays in 8-bit mode.
- Mixed 3-bit and 8-bit modes
- 27-antenna Phased Array mode enabled for VLBI

Upcoming Developments

For the next proposal deadline on 1 August 2014, for observing during cycle 2015A, we plan to provide:

- Integration times as short as 50 msec
- Recirculation up to factor 4, which should provide a further boost in spectral resolution
- P band (230 – 470 MHz) Stokes I

These capabilities already have been available to observers but as 'shared risk'. In the not too distant future (most likely in 2015), we intend to make available as well:

- 3-bit sub-arrays
- On-the-fly (OTF) mapping
- 'Y1', where only one VLA antenna takes part in VLBI observing, while the other 26 continue as regular VLA

VLA Science

The JVLA, like the old VLA, was designed for flexibility. There were no 'key science' projects in the proposal, nor where there 'guaranteed time' proposals or consortia. The JVLA is an open skies instrument, with time granted solely on the basis of scientific merit. Approximately 200 proposals have been submitted for each semester, and the oversubscription ratio hovers between 2.5 and 3.5, depending on configuration. We see in particular a large increase in high frequency proposals (ν>20 GHz), driven by the new availability of 8 GHz bandwidth, and hi-z studies.

About 65% of the array time (2013) is now used for science observing – we aim to reach 70% soon. Daytime observing is still at a premium, due to ongoing commissioning activities, but there is little actual 'down' time. The following two science examples intended to highlight both the vastly increased flexibility of the correlator, where a large total bandwidth no longer compromises spectral resolution, and of the significantly improved continuum sensitivity.

1 - The Cosmos field was observed for 50 hours as a pilot search for neutral hydrogen in distant galaxies. 33 galaxies were detected in HI at z=0 to 0.2, including three without a previously known spectroscopic redshift (2013, Fernandez et al). The new flexible correlator allows a search for all HI from z=0 to z=0.2 – with the old correlator only a tiny fraction of this redshift range would have been available at a time. Full use of new correlator capabilities means 230 MHz total bandwidth, 15 kHz (3 km/s) resolution, and 16,000 channels. This pilot will be followed up with the deep study mapping all galaxies in the COSMOS field between z=0 and 0.5. A side product of this study is a 500 MHz wide continuum map with sub μJy rms noise.

2 - A second example is the detection of fragmented disks in young protostars, where simultaneous 2 GHz bandwidth at Q-band leads to 20 μJy/bean rms after 1 hour on source (2013, Tobin et al). Such a result would have been impossible with the old VLA and its 100 MHz bandwidth.

References

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