The Expanded Very Large Array

- What is the VLA Expansion Project?
- New capabilities
- Challenges
- Current status

Why Expand the VLA?

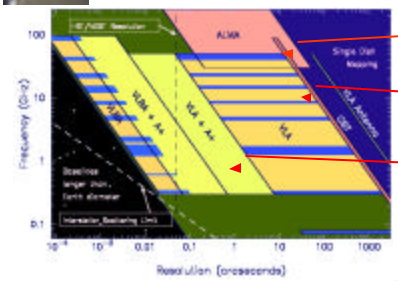
The VLA is still the most flexible and sensitive radio telescope in the world. But…

- it's over 25 years old: the first VLA antenna came on-line on 24 October 1975
- we can do a *lot* better, at very little cost: keep the infrastructure (antennas, railroad track, buildings, …), but replace the electronics

EVLA Overview

- wider bandwidths: 8 GHz vs. 100 MHz per polarization
- new correlator: 262,144 vs. 8 channels in 100 MHz
  - n.b. allows *pulsar searches* on an interferometer!!
- new receivers: continuous frequency coverage, 0.3-50 GHz
- longer baselines: 4 mas vs. 50 mas (at 45 GHz)

Resolution-Frequency Coverage of NRAO Telescopes



Blue bars – VLA now

Golden yellow – Phase I

Bright yellow – Phase II

EVLA Overview (cont'd)

⇒continuum sensitivity (~ 1μJy vs. ~ 10μJy in 12 hrs)

⇒ mas imaging of thermal sources (30 K in 12 hrs, Θ~ 6 mas)

⇒ instantaneous spectral indices, rotation measures, uv-coverage

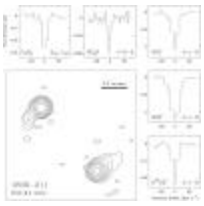
⇒ instantaneous velocity coverage (53,300 km/s vs. 666 km/s at 45 GHz; HI z=0.0-0.6 vs. z=0.0-0.07)

⇒ lines at arbitrary redshift

EVLA Overview (cont'd)

The difference between the expanded and the current VLA roughly corresponds to the difference between a fully-equipped NGST and a ground-based telescope with photographic film and no spectrograph.

Quasar Absorption Line Surveys



Absorption lines at z=0.88582 towards PKS 1830 -211 (C. Carilli)

Unbiased line surveys:

- no dust obscuration
- lots of *random* background sources
- HI, CO, HCN, HCO+, …

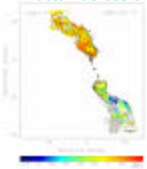
⇒ evolution of cosmic neutral baryons from z=0 to 3

⇒ large-scale structure

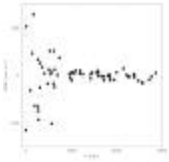
⇒ estimates of CMB temperature

Magnetic Fields in Galaxy Clusters

with X-rays, map magnetic fields & electron density in detail across entire, individual clusters



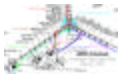
Rotation measures towards Hydra A (G. Taylor)

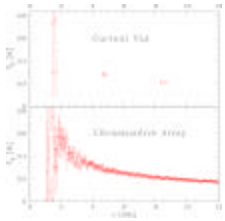


Residual RM towards 22 Abell clusters (T. Clarke)

- unambiguous rotation measures
- much less depolarization
- >100 sources per beam (vs. current 1-2) for scattering & polarization studies

Galaxies





3x8 hours on a typical spiral galaxy

In **one** observation of a galaxy:

- deepest radio continuum image yet made, with spectral index too
- image *all* (UC) HIIs & SNRs
- map HI emission & radio recombination lines
- measure magnetic field orientation, Faraday rotation, and Faraday depth
- absorption measurements against 100s of background sources
  - also rotation measures!
- simultaneous "blind" HI survey

Astrometry

Pulsars with distances measurable to 3 kpc and 8 kpc

- 10-100 μarcsec positions for 1 mJy sources (in 2 hours, from 2 to 50 GHz)

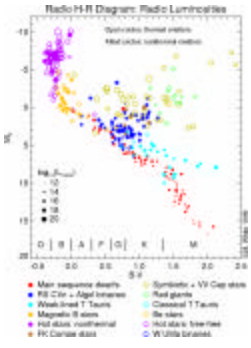
⇒ parallaxes of active stars to several kpc

⇒ angular expansion rates (10s of km/s) of planetary nebulae & stellar winds

⇒ pulsar parallaxes: 150 out to 3 kpc, 50 out to 8 kpc

⇒ accelerations of ionized gas & masers near the Galactic center

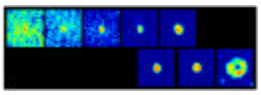
Stars



Stars detected with the VLA (S. White)

- first detections of ordinary stars like the Sun
- track radio emission from young stars (10^6 to 10^7 years)
- flares in pre-main-sequence stars
- imaging nearby stars
- 3D imaging of Galactic novae

Novae



- Imaging every nova in the Galaxy, within a few days of the explosion:

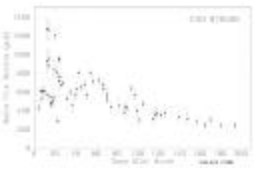
$\Theta = 0.57\ v_{1000}\ t_{day}/d_{kpc}$ milliarcseconds

→ Evolution from optically thick to thin

→ Mass estimate

→ 3D temperature/density distributions

Gamma-ray Bursts

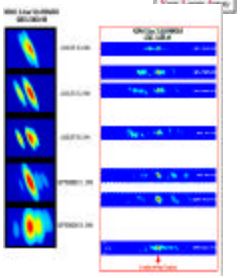


8.46 GHz lightcurve of GRB 970508 (D. Frail)

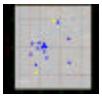
- find & track ~100/yr
- measure size & expansion rate (from scintillation)
- follow evol'n from ultrarelativistic to non-relativistic shock
- progenitors: where do they live? (astrometry)
- detection statistics: are they optically obscured? beaming angles?
- types of GRB: SGR, Sne, classical GRB all distiniguishable at radio wavelengths

Galactic Black Holes

- Ubiquity of jets
- Monitoring: continuous multi-freq. coverage
- Quiescent source imaging
- Check jet "prejudices" (one-sided, flip-flopping, pattern speeds, orientations)



Current Status



- Joint project of US + Mexico + Canada
- First part approved & funded (fiber, correlator, 1-50 GHz receivers)
- Currently undergoing detailed design & development
- Fiber purchase has been approved
- Plan for 2nd part under development, to be submitted this fall (New Mexico Array, 0.2-1 GHz, E configuration)

EVLA-I Schedule

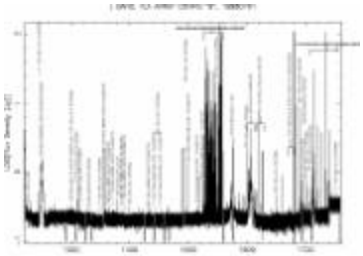
(Calendar years)

Start installation of fiber optics cables on Y	Q4 2002
Prototype EVLA system lab integration and test	Q1 2003
Install prototype EVLA system on EVLA Test Antenna	Q2 2003
Subsystem CDRs	Q4 2003
Start EVLA electronics production	Q4 2003
Start retrofitting 7 antennas/year with new system	Q2 2004
Start observing in "transition" mode	Q2 2004
Test of prototype correlator on 3 or 4 antennas	Q4 2005
Start outfitting new correlator room	Q2 2006
Start tests of first correlator subset at VLA	Q4 2006
First "shared-risk" science with new correlator subset	Q2 2007
Last antenna retrofitted to EVLA design	Q1 2008
New correlator declared "operational"	Q1 2009
Last EVLA receiver installed	Q1 2010

EVLA-I Funding ($M 2001)

New NSF Funds	51.5
NRAO Operations (personnel)	12.0
Canadian Correlator	12.0
Mexican Contribution	2.0
Total	77.5

Challenges: Radio Frequency Interference



Challenges: Data Processing

- Data rates
  - peak from correaltor backend: ~25 MB/s
  - 8-hour "peak" observation ~ 700 GB (average is factor 10 lower)
  - data for 1 year ~ 80 TB
- Analysis
  - data flagging
  - sources everywhere
  - full (wide!) bandwidth synthesis (must account for spectral index, pol'n, rotation measure, etc.)
  - high-fidelity imaging (10 mJy $\Rightarrow 10^4$:1)

Challenges: Looking Ahead

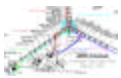
- Higher resolution: how can we tie in the VLBA?
  - bring high bandwidth (= sensitivity) to the world array
- Higher sensitivity: more collecting area for spectral line studies (the Square Kilometer Array)
  - requires economies of scale, for the antennas, the feeds & receivers, the correlator, etc. etc.
  - much overlap with the EVLA, esp. the New Mexico Array

A New Era for Radio Astronomy

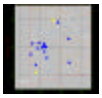
After a long dry spell, telescopes galore:

- Already constructed: GMRT
- Funded & under way: EVLA, ALMA, ATA, eMERLIN
- Actively moving forward: LOFAR (x2?), DSN-A
- Looming on the horizon: the Square Kilometer Array

This is the perfect time to be a graduate student!!



NMA Sites



Quad-Ridge OMT View of ridges

OMTs

Quad-ridge

Bøifot Symmetric Junction