EVLA Planning Workshop: Defining the Second Phase

Answers from the Scientific Working Group on Active Galactic Nuclei and Jets

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I. The New Mexico Array (A+ Configuration)

A. What are the key science drivers for the NMA?

1) Tracing collimated flows from the pc to kpc scales, especially in LLAGN (e.g. Seyferts). The NMA will provide surface brightness sensitivity to trace the outflows over a greater length and breadth. Understanding energy transport on $\sim$10 pc scales, through studies of morphology, opening angle, deceleration, and polarimetry (to search for oblique shocks). Looking for cocoons or mixing regions between the outflow and ambient materials.

2) Monitoring projects (including linear and circular polarizations) with the NMA as a stand-alone instrument. For example: studying SgrA* and its cousins in nearby galaxies. With a fixed array available 24/365 and capable of achieving high resolution we can separate the active source from surrounding complex emission.

3) Studies of the AGN environment through Faraday rotation, free-free absorption, and HI absorption (and other lines). Right now we have sensitivity to study a few famous sources. With the EVLA + NMA + VLBA we have the right combination of surface brightness sensitivity and resolution to study the gaseous and magnetic environment over a wide range of spatial scales. This will allow us to perform statistical studies and extend these techniques to new classes of objects (FRIs, Seyferts, etc.) not just the brightest sources. We can hope to understand the accretion disk structure, and the role of magnetic fields.

4) Distinguishing AGN from starburst regions in galaxies. Imaging and understanding the milli-halos in objects like Mrk231 (see figure) requires both the sensitivity of the EVLA and the resolution of the NMA. By measuring spectral indices of discreet continuum sources over a wide range in frequency it will be possible to distinguish thermal and non-thermal sources. Comparing these results to the H_2O masers and HI absorption in the star forming regions is also of interest, as is the direct identification of starburst activity by imaging of radio SNe.

B. Should we build the NMA?

Yes!!! and FAST. Young people want it now while they are still interested in radio astronomy as a viable career. Experienced astronomers want it before they retire. Waiting for cheaper technology beyond 2005 is not good. We strongly endorse/plead for the NMA to come on line at the same time as the EVLA phase I completes. We would like to see NMA construction begin in 2005.

C. Within the scope of this project, is the baseline plan of 8 new antennas plus PT/LA about right?

We don't want to lose LA and PT from the VLBA for 4-6 months/year. We admit that some scheduling headache is well worth the great increases in capability provided by the NMA to the VLA and VLBA, so some tradeoffs are to be expected. But we wonder:

Is stand-alone 8 NMA (w/o LA and PT) performance adequate? What about 8 NMA (w/o LA but with Y1) performance?

We endorse 10 NEW antennas to make the NMA a powerful stand-alone instrument. We adopt the VLBA (10 stations, non-reconfigurable) as a successful and well understood instrument. We appreciate how much it hurts the VLBA to lose even one antenna.

We may want to make the array elliptical N-S to improve the beam shape for sources at low declinations. Maybe optimizing for sources at the equator would be a good compromise. Further studies should be carried out.

D. What is the required maximum frequency?

- 98 GHz – We like SiO maser studies (86 GHz) at high angular resolution. Also methanol at 98 GHz. High frequencies provide the maximum resolution. Short spacings for the VLBA are critical at high frequency. To exploit 3mm observing we need full bandwidth (8 GHz/polarization). Full bandwidth also enables phase referencing at 3mm (see also below in section II).

D2. Would you be willing to trade frequency coverage for collecting area? (freq. coverage here refers to max. freq., not bandwidth)

No. Increased performance at low frequencies by a factor of a few is not worth sacrificing higher frequencies for.

We need 32 GHz capability in order to allow NMA use with the DSN for spacecraft navigation.

We don't want to give up capability (freq. coverage, polarization performance, sky coverage) to get an increase in collecting area.

The niche of VLA + NMA + VLBA may well be at high frequencies! With respect to ATA, eMERLIN, and SKA which have reduced or no capability at high frequencies.

E. How important is "stand-alone" NMA operation? i.e., should we ensure good sensitivity & imaging capability (and what is "good") when the NMA is operating independently of the VLA/VLBA?

Very important! Need both sensitivity and imaging capability.

For monitoring of compact objects (e.g. SgrA* example described in item A, also gravitational lenses).

NMA could contribute to DSN observations. For this it is important to guarantee that the data flow is uninterrupted (e.g. waveguide cycle). This is needed for bringing home weak signals from satellites, and spacecraft navigation.

F. What field-of-view is required for the NMA? (as a function of frequency)

Motion studies of kpc scale jets (e.g. 3C120), or hot spot motions in CSOs and MSOs require a field-ov-view up to 50 arcsec. This approaches the primary beam at high frequencies. With 4 mas resolution at 43 GHz we expect 100 microarcsec relative astrometry. This would provide sensitivity to a motion of 20,000 km/s in Cygnus A, or 2000 km/s for M87 on a 3 year time baseline.

The study of hotspots (angular sizes of few arcsec, with separation from nucleus of 50 arcsec) is somewhat more efficient if the entire primary beam is accessible.

Patches would have an advantage for phase calibration in that one could allocate some antennas to the target and some to calibrator.

G. Rank the relative importance of:

- 1. getting the NMA done as soon as possible → using traditional antenna technology (25m dishes)

  Don't depend on other people (e.g. eMERLIN) to provide the capability we want ASAP.
- 2. allow for a plug and play SKA station prototype. But don't slow things down waiting for it.
- with lower priority:
- 3. developing new technology specifically for the EVLA-II, to increase its capabilities (e.g., to give more collecting area)
- 4. developing new technology related to SKA, even if this is not optimal for the EVLA itself (i.e., think of the EVLA as a working scientific array built on the way to SKA)

II. Integrating the VLBA with the (E)VLA

A. How far should we go in integrating the VLBA with the VLA, as part of EVLA-II?

ALL THE WAY. Wide band (8 GHz/polarization). We don't require real time correlation right away, although that would be good. This does require an investment of $15M plus fiber access.

key science:

The VLBA has opened up the sky to the mJy population. With full bandwidth capability of 8 GHz/pol'n on the VLBA it would open up the sky at 7mm and 3mm by having the sensitivity required to perform phase-referencing at these frequencies. Sensitivity is needed to observe nearby (weak) phase calibrators and get back on source within the coherence time.

Study of black hole environment. Weak polarimetry, absorption studies, free-free absorption (especially at high frequencies and low luminosities). Magnetic fields and gas content.

M87 image at 43 GHz. Faraday RM observations of 3C273/3C279.

Studying the weak jets in H_2O maser sources. Testing Gallimore's claim of detecting the accretion torus in NGC1068 and searching for tori in other LLAGN. This requires the VLBA + NMA at high bandwidth.

For EVLA to contribute to DSN observations, it is important to guarantee that the data flow is uninterrupted (e.g. by the waveguide cycle). This is necessary to receieve weak telemetry signals. Spacecraft navigation requires high resolution.

As part of NMA, a plan for widebanding PT and LA will be costed out. Do the conversion with full bandwidth for the VLBA in mind. We strongly recommend that by 2005 we assess the ability to do 16 GHz in real time. If this capability exists then choosing the 48 station model of the WIDAR correlator will be required.

Low sensitivity on long baselines is not useful.

Important operationally as well as scientifically. Bring VLBA into the mainstream of astronomy.

III. The E Configuration

A. What are the key science drivers for the E configuration?

Relic and halo sources are obvious. Large radio lobes of AGN are another science driver.

Constant resolution spectral index imaging to the largest sizes of AGNs.

B. Should we build the E configuration?

Sure, we like it even though it isn't particularly relevant to AGNs.

B2. If we build the E configuration, which approach seems most appropriate:

* 300m max spacing: $\sim$ 15 new pads, matches configuration sequence. New Kogan E3 array for $2.2M.

C. How important is shadowing (i.e., observing low declinations)?

Make the E3 configuration elliptical. Optimize it for sources at zero declination.

D. What frequency range is required?

Same as VLA. 1-50 GHz.

IV. Low Frequency Expansion (300–1000 MHz)

A. What are the key science drivers for low frequencies on the EVLA?

HI and free-free absorption in AGN at moderate redshifts. Matched resolution studies. VLBA at 500 MHz matches NMA at 5 GHz matches VLA A config at 50 GHz.

VLBA antennas can put feeds at prime focus. Small cost to upgrade VLBA to reach 300-1000 MHz. NMA can be built with 300-1000 MHz coverage.

B. Should we provide this improved low frequency (300–1000 MHz) capability?

Yes on the NMA and VLBA, but lower priority on the VLA. Don't damage the high frequency performance.

C. What frequencies must be covered?

250 - 1000 MHz; contiguous. Dovetails with LOFAR and L Band on EVLA.

V. Connections to Other Initiatives: how does the EVLA fit in with other major astronomical facilities coming on-line over the next decade(s)?

EVLA (EVLA+NMA+VLBA) will be the premier high frequency instrument for the forseeable future (until Kristy retires). It will be complemented by ALMA, NGST, SIM, GLAST, Constellation X, and LOFAR. With very high sensitivity at the same resolution as HST/NGST, it will complement studies of star formation, AGN, etc.

The physics of accretion processes studies by EVLA and Con-X will be highly valuable.

A. What should be the plan for radio astronomy in the next several decades, and how does the EVLA fit into that plan?

Maintain and enhance Radio Astronomy community. Keeping state of the art instruments available for scientific use. Staying active in technology developments to enable the timeline below.

2002 SMA operational
2005 Start construction of NMA
2005 Wideband (8 GHz) retrofit at LA and PT
2005 Finish CARMA
2005 Finish eMERLIN
2006 Finish ATA
2006 Deploy LOFAR, possibly sharing stations/fiber with NMA.
2007 Complete prototype US SKA station (as plug and play element of EVLA)
2007 Deploy E2E data pipeline. Prototype for SKA?
2009 Present SKA and BHI to decade committee
2009 Launch VSOP2
2010 Finish ALMA
2010 Finish EVLA including NMA and VLBA integration
2010 Kristy gets tenure.
2012 Complete SKA prototype array
2020 Complete SKA
2020 Launch space vlbi array (BHI)

Things left out: LMT, VERA, FASR, GBT improvements, new EVN antennas, others.

B. How should the EVLA relate to LOFAR?

The frequencies should dovetail (around 250 MHz), station/fiber sharing should be investigated. Site selection and development. RFI excision techniques should be shared. Software for MCS, wide field imaging, etc. can be shared.

C. How should the EVLA relate to the SKA?

Train the next generation of SKA users. See common technology and software developments above. Possibility of EVLA morphing into SKA prototype, component of SKA, or SKA.

Provide the high-frequency component of SKA above its maximum range. We recommend that the SKA cover the 22 GHz H_2O line.

Investigate sub-microJy source population. (See diagram from Ken)