e-VLBI... a Wide-field Imaging Instrument with Milliarcsecond Resolution & microJy Sensitivity

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Abstract. The European VLBI Network (EVN) is in the process of establishing an e-VLBI array in which the radio telescopes and the EVN correlator at JIVE are connected in real-time, via high-speed national fibre optic networks and the pan-European research network, GÉANT. This paper reports on recent test results, including the production of the first real-time e-VLBI astronomical image. In a parallel and related development, the field-of-view of VLBI is also expanding by many orders of magnitude, and the first results of deep, wide-field surveys capable of detecting many sources simultaneously are summarised. The detection of sources as faint as 10 microJy should soon be possible in the era of "Mk5" and e-VLBI.

1 Introduction to e-VLBI

The application of fibre optic network technology to existing radio telescope facilities (e.g. EVLA & e-MERLIN), will permit these instruments to achieve sub-microJy continuum sensitivity noise levels in very modest integration times (e.g. 12-24 hours). In addition, new telescopes such as LOFAR will employ advanced digital processing techniques, in order to survey huge areas of the sky simultaneously via independently steerable, so-called "multiple" beams.

The VLBI community around the world is also engaged in the first attempts to connect VLBI antennas and correlator centres in real-time (e-VLBI) using commercial optical fibre networks (e.g. Whitney 2003, Parsley et al. 2004). In addition, improvements in data storage media and the emergence of affordable PC clusters, are poised to transform VLBI into a wide-field, all-sky survey instrument. This paper presents some recent results in these areas, describing technical and scientific developments that are relevant to the SKA.

2 e-VLBI: The first real-time e-EVN Image

By definition, VLBI antennas and correlators are separated by many hundreds, indeed thousands of kilometers. Typically they are also located in remote areas, far from centres of population and network services. The goal of connecting together these antennas and correlators is therefore challenging, especially as it also requires connections to be made across national and international boundaries. Despite these difficulties, the prospect of achieving this goal is becoming an



Fig. 1. The first real-time e-EVN image. The target source was the well-known, small-separation gravitational lens system, B0218+357. The lensed images are separated by ~ 334 milliarcseconds.

increasingly realistic proposition, as advanced national, continental and transcontinental research networks begin to interconnect across the globe.

In Europe, the EVN has entered into a collaboration with the major European National Research Networks (NRENs) and the pan-European research network GÉANT, operated by DANTE. Progress has been aided by the introduction of the new Mk5 PC-based recording systems (Whitney 2003) at the major telescopes across the EVN, including those with good network connections. The first eVLBI tests in Europe began in September 2002, and recently culminated in observations that have included three telescopes (Westerbork, Onsala & Jodrell Bank) simultaneously transmitting data at rates of 32 Mbps to the EVN correlator at JIVE. The first real-time e-VLBI image (see Fig. 1) was produced by this array in April 2004 (Parsley et al. 2004), the data flowing without interruption from the telescopes to the correlator, where fringes were generated at JIVE in real-time. After real-time correlation, the data were automatically processed using the EVN data pipeline. Some plots of the visibility data and the pipelined image are presented in Fig. 1.

In terms of local logistics and network reliability, e-VLBI offers many advantages over conventional VLBI data transport systems. From the astronomers perspective, the prospect of immediate results and unlimited access to the high data rates (currently restricted by the available disk resources) are also important new features. Progress in this area continues as other EVN telescopes come "on-line", including the Torun and Medicina 32-m telescopes.



Fig. 2. A wide-field VLBA+GBT survey of part of the NOAO-N Deep Field region. With an r.m.s. noise level of 9 μ Jy, many sources are detected simultaneously. A significant fraction of radio sources are not detected in the optical images also presented.

3 VLBI Sensitivity and Deep Wide-Field VLBI Surveys

The current sensitivity of existing VLBI arrays is "embarrassingly" good. The new Mk5 system currently being introduced across the EVN, permits data rates of 1 Gbps to be recorded robustly and without error. The expectation is that a global VLBI array, also equipped with Mk5, could achieve $1 - \sigma$ r.m.s. noise levels better than a few microJy per beam for an on-source integration time of ~ 24 hours. At these sensitivity levels, VLBI can expect to simultaneously detect many sources within the primary beam of an individual antenna (see Fig. 2). Currently deep, wide-field observations (Garrett, Morganti & Wrobel 2004), achieve noise levels of 9 microJy/beam and are capable of detecting mJy, sub-mJy and microJy radio sources (AGN) detected by VLBI falls from ~ 29% at mJy levels to only 8% at sub-mJy flux density levels. The results are in good agreement with less direct studies – these suggest the emergence of a dominant star-forming radio source population at these faint flux density levels.

Fig. 3 shows an example of the compact radio sources that might be simultaneously detected in a typical region of sky by a Mk5 equipped Global VLBI



Fig. 3. A view of the faint but compact (AGN) radio sky as viewed by a wide-field global VLBI array. Representation: large dots (S > 1 mJy), medium dots $(S \sim 100 - 1000\mu\text{Jy})$ and small dots $(S \sim 10 - 100\mu\text{Jy})$.

array, assuming the fractional detection rate of 8% (as observed for sub-mJy sources) is also appropriate for the microJy radio source population. Current and future wide-field VLBI surveys are likely to be highly efficient AGN detectors, and in addition, may be sensitive to cold, very high-redshift, dust-obscured systems that will be difficult to detect in other wave-bands.

References

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