Resolving Key Questions in Extragalactic Jet Physics: an e-MERLIN Legacy Proposal

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1 Scientific Aims

We propose to image a carefully-selected sample of bright, extragalactic radio sources with e-MERLIN at L and C bands. Our primary science questions include:

1. What triggers the deceleration of low-luminosity radio jets on sub-kpc scales? What are their velocities, magnetic-field structures, powers, mass fluxes and entrainment rates? The key new aspect of the e-MERLIN observations is the ability to resolve the jets where they first brighten.
2. What are the three-dimensional structures of powerful jets? Do they have highly relativistic "spines"? e-MERLIN will allow transverse resolution of the jets with good sensitivity for the first time.
3. What are the magnetic field configurations immediately surrounding jets, as inferred from Faraday rotation? Is there evidence for confining fields? e-MERLIN will be able to determine rotation measures within a single observing band at high spatial resolution.
4. Where and how are particles accelerated in the hot-spots and jet knots of powerful sources? By allowing us to measure synchrotron spectra and polarization in many discrete regions across these kpc-scale regions, e-MERLIN will enable studies of their electron populations and magnetic field sub-structures.

Our approach will be to select the brightest few representative examples of distinct types of source from well-defined samples limited by flux density and redshift and to observe with high sensitivity and image fidelity. Our targets are the defining members of their classes, and include famous objects such as Cygnus A, M 87 and 3C 273. Without exception, they have a wealth of data available at radio and other wavelengths, and the new observations will have enduring legacy value.

2 Resources

Targets will be chosen from well-defined flux-limited samples selected at low frequencies (primarily 3CRR) and restricted to Northern declinations.[1] We will observe using the maximum available bandwidth in L and C bands, in full polarization. Although the sources are strong, the structures we wish to image are typically heavily resolved by e-MERLIN: except in the very brightest cases, we will be limited by the sensitivity required to image linearly polarized emission. Our target rms sensitivities are $\approx 2\mu$Jy/beam at C-band and $\approx 5\mu$Jy/beam at L-band, except for the brightest sources, for which we expect to be limited by dynamic range in total intensity. We will therefore benefit from use of the Lovell Telescope for a majority ($\sim 3/4$) of the observations. In almost all cases, the sources are sufficiently complex that we require very good u-v coverage. We estimate an average of 10 hours/track, although some sources will require more than this. We will observe four sub-samples, choosing the observing frequencies to match the known spatial scales:

FR I Jets Sources with $z < 0.03$: 12 tracks L-band; 2 tracks C-band.

Proper motions Monitoring of the evolution of the closest bright radio jets in the North: M 87 (5 epochs) and M 84 (3 epochs, subject to successful pilot observation). 8 tracks, C-band.

Brightest hot-spots 3CRR sources with the brightest hot-spots in two redshift ranges. 10 tracks C-band, 6 tracks L-band.

Powerful radio jets A sample of the brightest one- and two-sided jets in powerful sources. 6 tracks L-band, 6 tracks C-band.

Total: 24 tracks at L-band + 26 tracks C-band (roughly 500 hours)

Our programme depends critically on the availability of effective algorithms for multi-frequency synthesis (combined with self-calibration) and the removal of distant confusing sources (at least at L-band). Until EVLA observations become available (see below), we will need to combine e-MERLIN and VLA data taken with very different spectral configurations. We will also require improved algorithms for polarization imaging (e.g. RM synthesis). We are prepared to contribute to algorithm development in these areas. e-MERLIN observations will meet our initial science goals either alone or in combination with existing VLA imaging: we will propose complementary EVLA observations later.

[1] We note, however, that comparison with ALMA imaging would be extremely interesting, especially for hot-spot physics, and would strongly support the incorporation of the Chilbolton antenna into e-MERLIN.

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