Future Prospects: *e*-MERLIN

The key to MERLIN's success is its resolution; it is the only ground-based facility in the world that can routinely match the resolution of the Hubble Space Telescope. As the astronomical world converges on a resolution of ~0.1 arcsec, MERLIN can be seen as the natural radio partner in an international suite of telescopes comprising, amongst others, HST, Gemini and VLT (with adaptive optics), ALMA and NGST.

In order to remain competitive with, and complementary to, this new generation of telescopes MERLIN must also be developed. A proposal has been produced that lays out the science case and technical implementation plan for *e*-MERLIN, an upgrade of MERLIN that will produce a telescope with up to 30 times the sensitivity of the current array. As described in detail in the *e*-MERLIN science case, the new instrument will have a great breadth of applications and in particular will open up new areas of science, particularly in fields such as extragalactic astronomy and cosmology, star formation across the Universe, stellar evolution and studies of the extreme conditions around black-holes.

This dramatic increase in sensitivity will be achieved by replacing the current narrow-band microwave link system, used to transmit data from the telescopes to Jodrell Bank, with fibre-optic cables. This will increase the bandwidth available for observing from an effective 14 MHz/polarisation to 2 GHz/polarisation, resulting in a factor of ~11 increase in sensitivity. When combined with the JIF-funded upgrade of the 76m Lovell Telescope and a ~30% improvement in receiver performance, the total improvement in sensitivity will be a factor of 30 at MERLIN's prime observing frequency of 5GHz. The processing of 2GHz wideband data will require additional enhancements to the existing equipment, in particular a new broad-band correlator, the replacement of much of the digital electronics, and also significant IT developments to handle the 320Gbps data rates that will result from the use of the optical fibres. The capabilities of the proposed system are summarized in the table below.

In addition to an enormous increase in sensitivity (equivalent to replacing an 8m optical telescope with one of 44m diameter), *e*-MERLIN will provide two other major advances to astronomers. It will routinely image wide

Below: A comparison of capabilities of the current MERLIN and the proposed *e*-MERLIN. The sensitivity is defined as the 1σ RMS noise level in the image after 12 hours on source. The brightness is the equivalent surface brightness assuming an object of angular size equal to the synthesised beam.

Band	Frequency (GHz)	Current Sensitivity (μJy)	*e*-MERLIN Sensitivity (μJy)	Brightness (K)	Resolution (arcsec)
UHF	0.327 - 0.408	700	**200**	7020	0.5
L	1.0 - 2.0	35	**4.0**	140	0.14
C	4.0 - 8.0	50	**1.4**	47	0.04
X	8.0 - 12 .0	N/A	**1.4**	47	0.02
U	12.0 - 18.0	N/A	**3.0**	104	0.013
K	18.0 - 26.0	400	**11.3**	390	0.008

fields: the field of view at 1.4GHz will be 0.5°, that at 5GHz will be 10 arcmin. The output data rates will reach 0.5TB/day and images will contain 20000^2 pixels. The enormous sensitivity of *e*-MERLIN will mean that each 12-hour pointing will detect many hundreds of background objects.

Secondly, the wide bandwidth and multi-channel observing technique that will be routine, mean that *e*-MERLIN's ability to image complex sources will be immense. The figure below shows MERLIN's current uv-coverage for a source at 30° declination and the uv-coverage possible with *e*-MERLIN. The filling-in of the uv-plane means that essentially all Fourier components will be sampled, thus enabling the generation of images of highly complex sources. The small holes in the centre of the uv-plane can be filled with complementary VLA observations.

The cost of the sensitivity upgrade is estimated at £8.6M, which includes the funding of the additional manpower required to implement the project, VAT and a 10% contingency budget. The timescale for the upgrade is ~5 years from funding to completion. The full science case and a summary of the technical implementation plans can be found at: http://www.merlin.ac.uk/e-merlin.

In addition to its value in working with the new generation of optical telescopes, *e*-MERLIN and ALMA will also complement each other well. They will provide similar resolutions but operate at wavelengths differing by a factor of 100. Together, ALMA and *e*-MERLIN will provide a powerful probe of the gas (*e*-MERLIN the warm, ALMA the cold), dust and magnetic field components of star-forming regions in our Galaxy and in starburst galaxies. This capability will be unique to the UK.

Looking further ahead, *e*-MERLIN will be a natural pathfinder for the Square Kilometre Array (SKA). It will provide glimpses of the science achievable with nano-Jy sensitivity and will be crucial as a test-bed for many of the techniques required to build the SKA. *e*-MERLIN is very similar in size to the proposed SKA core (albeit having <1% of the collecting area) and so the techniques of wide-band data transfer over several hundreds of kilometres, RFI mitigation (especially at longer centimetre wavelengths) and remote operation of telescopes required for SKA can be developed over the next few years as a natural consequence of upgrading MERLIN.

In summary, *e*-MERLIN is a concept whose time has come. The technology of fibre-optic links is available. At a modest cost, it is possible to capitalize on the investment made in the existing infrastructure and to follow a cost-effective route to a superbly competitive facility. The range of science that can be addressed through *e*-MERLIN is unmatched. The upgrade will keep the UK at the forefront of world radio astronomy and will provide a natural route for a leading role in the SKA.

Below: Comparison of the uv-coverage of the current MERLIN (single frequency) with the multi-frequency coverage provided by *e*-MERLIN.