The e-MERLIN Legacy Programme

We announce the opportunity for the international astronomical community to propose Legacy Projects for the *e*-MERLIN high-resolution radio imaging facility. The *e*-MERLIN upgrade is well underway and the full network should be available in 2009/10, offering μJy sensitivity and 0.05 to 0.15-arcsec resolution at 5 and 1.5 GHz. An initial meeting will be held at Jodrell Bank Observatory (JBO) on 17th July 2007 and provisional deadlines of 30th April 2008 and 31st July 2008 have been set for letters of intent and final proposals to be submitted.

Background:

e-MERLIN is a major upgrade to the MERLIN array of seven linked radio telescopes across the UK, operated by the University of Manchester on behalf of the UK's Science and Technology Facilities Council. The project involves installing new receivers, optical fibre links and a new correlator at JBO. Operating at 1.5, 5 and 22 GHz, *e*-MERLIN will provide imaging with an angular resolution of 0.01-0.15 arcsec at a sensitivity well below 10 μJy beam^{-1} (12 hr) across fields of view as large as 30 arcmin. Applications where the angular resolution of *e*-MERLIN can play a vital role may include detailed imaging of young stellar objects, characterisation of RSN and SNR in nearby galaxies, studies of AGN and star-forming galaxies at cosmological distances and investigations of dark matter sub-structure in gravitational lenses, amongst many other examples.

e-MERLIN is expected to be available in 2009/10 and the MERLIN Steering Committee (SC) have tasked a Legacy Steering Group (LSG) with soliciting and establishing a Legacy Programme capable of fully exploiting the new instrument, presenting a detailed plan to SC in autumn 2008. The time available for the Legacy Programme will depend on the scientific excellence of the projects put forward by the community. The ambition of the LSG is an allocation of around 5,000 hrs during the first five semesters of *e*-MERLIN operations, enhancing the programme that will arise through PATT.

LSG members have waived their right to lead *e*-MERLIN Legacy proposals and are available as scientific or programmatic advisors, with no strings attached. They are: Rob Ivison (rji@roe.ac.uk), Clive Tadhunter (C.Tadhunter@sheffield.ac.uk), Tom Ray (tr@cp.dias.ie), Ian Browne (ian.browne@manchester.ac.uk), Javier Alcolea (j.alcolea@oan.es), Elias Brinks (E.Brinks@herts.ac.uk), Jacco van Loon (jacco@astro.keele.ac.uk) and Diana Worrall (d.worrall@bristol.ac.uk). Technical queries should be directed to Tom Muxlow (twbm@jb.man.ac.uk), technical advisor to this group.

Workshop:

A kick-off workshop will take place at JBO on 17th July 2007, 11am-5pm. Its goal is to build teams of scientists and to develop their ideas into ambitious proposals and, ultimately, excellent experiments. To register for the workshop, contact Janet Eaton (je@jb.man.ac.uk). The workshop will cover the technical capabilities of *e*-MERLIN, preparation and evaluation of legacy proposals, lessons learned from other legacy

programmes and operational issues relating to legacy projects. It will offer opportunities to present science ideas, break-out sessions for legacy project teams, technical expertise on operational and data-processing issues. Involvement in early stages of *e*-MERLIN operations as well as technical developments (e.g. software, hardware, operations) will be discussed.

An evening session on 1st October 2007, part of the conference "The Modern Radio Universe" at the University of Manchester, will also be devoted to the Legacy Programme – an opportunity to present ideas in a more international forum (see http://www.jb.man.ac.uk/mru2007).

Legacy Proposals:

The *e*-MERLIN Legacy Programme is open to the worldwide community. Broad participation is encouraged, particularly amongst young researchers and those new to the radio waveband. You can sign up to the Legacy Programme e-mailing list at https://lists.roe.ac.uk/cgi-bin/mailman/listinfo/emerlin-legacy. Information is also available via http://www.merlin.ac.uk/e-merlin_legacy.html, including a link to the Legacy Programme wiki – a site devoted to developing proposal ideas, building strong teams and discussing how team contributions to software, hardware and operations can enhance *e*-MERLIN.

In brief, a successful legacy proposal will be self-contained and address important scientific questions. It will fully justify the need for legacy status, rather than that of a conventional PATT proposal, and include a viable management and resource plan. It will identify its requirements with regard to pipeline processing and data archiving, justify any deviation from the default 12 months of data rights and promise delivery of data products compliant with the Virtual Observatory. It will identify and explain link(s) to related data sets or Legacy Programme proposals and be preceded by a Letter of Intent, delivered by a provisional deadline of **30th April 2008**, including a brief summary of the proposal's likely requests and objectives (1 page, maximum). Proposals, for which detailed rules will be provided in due course, must be delivered by a provisional deadline of midnight GMT, **31st July 2008**.

Assessment of scientific potential, legacy value, feasibility and management plans will be undertaken by expert, international reviewers.

Prof. Rob Ivison (Chair, *e*-MERLIN LSG)

e-MERLIN Technical Information

S. Garrington, T. Muxlow – June 2007

1. Introduction

MERLIN is an array of seven radio telescopes across the UK, connected to a central correlator at Jodrell Bank Observatory (JBO) and operated as a dedicated radio interferometer to produce high-resolution images. With a maximum baseline length of 220 km, MERLIN provides a unique capability for radio imaging at 0.01-0.15-arcsec resolution at frequencies of 1.5, 5 and 22 GHz (L, C and K bands). The *e*-MERLIN project is a major upgrade to the instrument involving the installation of new receivers, analogue and digital electronics, optical-fibre links to each telescope and a new correlator at JBO. This will increase the useable bandwidth by more than two orders of magnitude, and hence the continuum sensitivity by more than 10×. In addition, the increase in bandwidth will dramatically improve aperture coverage for continuum observations resulting in enhanced image fidelity together with simultaneous spectral-index imaging.

The *e*-MERLIN upgrade is now well underway: new receivers are in service, the optical fibre network has been installed and the digital transmission equipment has been tested. First fringes between nearby telescopes using a prototype correlator are expected in 2008 and the full network with the complete correlator will be available in 2009/10.

2. Technical Capabilities

Table 1: Basic observing capabilities of *e*-MERLIN.

Observing frequency	1.5 GHz L band	5 GHz C band	22 GHz K band	Comments
Resolution (mas)	150	40	12	Uniform weighting at central frequency
Field of view (arcmin)	30	7	2.0	FWHM of 25-m dishes; reduced when Lovell Telescope included at 1.5 or 5 GHz (1)
Freq. range (GHz)	1.3-1.7	4-8	22-24	
Bandwidth (GHz)	0.4	2	2	Max. bandwidth per polarization. Can use 4-GHz bandwidth, single polzn, at 5 or 22 GHz
Sensitivity μJy/beam (full imaging run)	5-6	1.8-2.3	~15	Final performance will depend on useable bandwidth, final receiver optimization, Lovell Telescope performance. These figures are for *e*-MERLIN with the Lovell Telescope (1)
Surface brightness Sensitivity (K)	~190	~70	~530	As above
Astrometric performance (mas)	~2	~1	~2	WRT the ICRF (typical 3-deg target–calibrator separation using VLBA Calibrator Survey)
	~0.5	~0.2	~1	Day-to-day repeatability using surveyed or in-beam sources, and assuming full imaging run
Amplitude Calibration	2%	1%	10%	Targets for day-to-day repeatability.

Notes: (1) The Lovell telescope may be included in *e*-MERLIN at 1.5 and 5 GHz (L, C). Its inclusion increases the sensitivity by a factor of between 2 and 3 and reduces the field of view to approximately 20/(ν/1.4 GHz) arcmin, depending on the data-weighting scheme adopted.

The new *e*-MERLIN correlator, being developed by DRAO, will provide unsurpassed capabilities with very large numbers of configurations – Tables 1 and 2 illustrate some of these. Further, narrower bands are also available. 3-bit sampling is standard at 5 and 22 GHz (C, K). 8-bit sampling is the preferred choice at 1.5 GHz (L) where the total available bandwidth is less and where the RFI environment is likely to be significantly worse. The centre frequencies, bandwidth and frequency resolution of each sub-band can be set individually, allowing a wide variety of mixed spectral-line and wide-band modes. Sensitivities per channel in spectral line modes can be estimated from the continuum sensitivities given above and by scaling with $(\delta\nu/\Delta\nu)^{1/2}$ where $\delta\nu$ is the channel width and $\Delta\nu$ is the total bandwidth: 0.4 GHz at 1.5 GHz (L), or 2 GHz at 5 or 22 GHz (C, K). Sub-bands can be placed anywhere within integer sub-slots corresponding to the sub-band width. Recirculation will produce very narrow channels but potentially very large datasets. For continuum modes, the quoted field of view is the diameter assuming 10% radial smearing at the field edge, but other effects may dominate beyond the half-power point of the telescope primary beam.

Table 2: Correlator capabilities.

Bandwidth (MHz)	Bits Sampling/ correlation	Sub-bands	Sub-band bandwidth (MHz)	No. of polzn	No. of channels (per polzn, per sub-band)	Channel width (kHz)	Field of view (arcmin)
5- and 22-GHz (C, K) continuum modes:							
2048	3/4	16	128	4	512	250	9.3
2048	3/4	16	128	2	1024	125	18.6
1.5-GHz (L) continuum modes:							
512	8/7	16	32	4	512	62.5	37.3
512	8/7	16	32	2	1024	31.25	74.6
Spectral-line modes (maximum recirculation, 4-bit correlation):							
1024	3/4	16	64	4	1024	62.5	(2)
512	3/4	16	32	4	2048	15.6	
↓	↓	↓	↓	↓	↓	↓	
8	3/4	16	0.5	4	131072	0.003815	
4	3/4	16	0.25	4	131072	0.001907	
Spectral-line modes (maximum recirculation, 7-bit correlation):							
512	8/7	16	32	4	512	62.5	(2)
256	8/7	16	16	4	1024	15.6	
↓	↓	↓	↓	↓	↓	↓	
8	8/7	16	0.5	4	32768	0.015259	
4	8/7	16	0.25	4	32768	0.007629	
Spectral-line modes (no recirculation, 4-bit correlation):							
1024	3/4	16	64	4	512	125	(2)
512	3/4	16	32	4	512	62.5	
↓	↓	↓	↓	↓	↓	↓	
8	3/4	16	0.5	4	512	0.976563	
4	3/4	16	0.25	4	512	0.488281	

Notes: (2) The field of view for spectral-line modes is ultimately limited by the telescope primary beam but may in some cases be limited by the output data rate.

3. Operational opportunities and constraints

e-MERLIN will be dynamically scheduled in order to optimize the efficiency of full-track observations, making the best use of observing conditions, and fitting in low-

priority observations when one or more telescopes are unavailable. Specific scheduling for monitoring purposes, or to catch particular phases of target source behaviour can be accommodated, but will have an increased impact on the overall observing efficiency. Surveys requiring short observations of large numbers of targets in individual pointings are feasible but may require careful optimization. Deep field observations (especially at higher declinations) can make good use of periods when one telescope is unavailable, in order to build up total integration time.

Legacy Programmes may be encouraged to assist in the preparation of their schedules. System scheduling tools are well developed, and translation from other (distributed) schedule preparation tools is being evaluated.

Participation in the observing process (and/or provision of resources for observing) at JBO, or the Jodrell Bank Centre for Astrophysics (JBCA) in Manchester, may be considered.

4. Data handling and processing issues

We anticipate that *e*-MERLIN data will be processed using a combination of AIPS, casa and other interferometry data-reduction packages, using scripts which may also allow inter-operability between different packages.

Raw data volumes are likely to be large (several TB) for Legacy Programmes and the data will be distributed on hard disks. Data will be made available as UVFITS files with associated calibration tables. Options for making data available in other formats (casa Measurement Sets; ALMA/EVLA SDM and binary data) are under consideration.