Legacy e-MERLIN Multi-band Imaging of a Nearby Galaxy Sample
(LeMMINGS[1])

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1.   Scientific Overview and Scope of Project

We are proposing a Legacy programme which will exploit the transformational new capabilities of e-MERLIN to investigate the detailed interplay between the interstellar medium (ISM), star formation and nuclear activity in nearby galaxies. This project will image, with unprecedented sensitivity and resolution, 50 galaxies within 30Mpc, with the primary science driver of understanding the detailed astrophysics underway in each of these sources. Specifically this project will address fundamental science questions regarding the role of star formation and activity in galaxies, critical to a wide range of important astrophysical issues, such as the star-formation history of individual galaxies, the physics of high-energy sources within extreme environments, and the causes and consequences of star formation and of starburst and AGN activity.

In order for these questions to be addressed high quality, multi-wavelength observations of a wide range of galaxy types in the local Universe are required. Within galaxies, both thermal and non-thermal radio emission are produced by a variety of physical mechanisms, originating in the formation, evolution and death of stars, as well as via accretion onto compact objects such as intermediate and supermassive black-holes. e-MERLIN observations will uniquely allow these diverse physical processes to be investigated at milliarcsecond resolutions, and by virtue of not being obscured by intervening material importantly allows the centres of galaxies to be viewed in an unbiased and systematic way. These observations will allow us to study a very wide range of astrophysical phenomena, such as supernovae and their remnants, HII regions, potentially extragalactic X-ray binaries, intermediate mass black holes, ULX sources, planetary nebulae, AGN and jets and much more, creating a census of the constituent components of galaxies at unprecedented depths and at parsec-scale linear resolutions. Additionally, this project will observe several key neutral and molecular spectral line transitions to trace the cool gas which fuels both star-formation and accretion.

This legacy project will result in a detailed physical understanding of the inner workings of nearby galaxies and will provide nearby analogies of sources in the high-redshift Universe (the focus of proposed distant Universe legacy projects [e.g. *eMXS, Co-PI Muxlow*]). Equally importantly this study will link with proposed Galactic legacy programmes investigating various phases stellar evolution *("Massive star formation" led by Hoare [also Co-I of this project]* and *"COBRAS" led by Prinja [mutual co-Is include Diamond, Fenech & Stevens])* placing them in a wider cosmological context.

2.   Preliminary details of source selection and resource requests

The philosophy of this legacy programme will be to provide the definitive parsec-scale, microJy sensitivity radio images of a large sample of well-known galaxies in the nearby Universe. As such this project will not only address numerous key science questions regarding star formation and activity in galaxies but is specifically designed to be a *lasting* Legacy data-set for the wider community, with the sample selected to maximize multi-wavelength coverage and consequently the amount of legacy science achievable. The project intention will be to very rapidly make these data and calibration products publicly available in an easily useable form (VO etc).

Sample Selection: The sample selection for this Legacy survey is specifically designed to match existing and underway legacy programmes on other instruments. Specifically this sample will be made up of 50 northern ($\delta>0$) galaxies, the predominate basis of which will be the SINGS survey; selected and augmented to span the full range of parameters governing star formation and nuclear activity in the local Universe and to match the available imaging capabilities of e-MERLIN (FoV, declination range etc).

Observations: This project will request observations of 50 galaxies in both L (1.3-1.7GHz) and C-band (4.5-7GHz). The aim will be to observe each source (including the Lovell telescope) for one epoch for ~12hrs in each band of the two bands **(i.e. Total request ≈ 50 × 2 × 12hrs ≈ 1200hrs)** resulting in a rms sensitivity approaching 5 and 2μJy/bm respectively. The built-in flexibility of the new e-MERLIN array means that it is possible to simultaneously observe several radio spectral lines alongside deep continuum observations with minimal loss in continuum sensitivity. Using this facility, this programme will also obtain deep, high velocity resolution observations of important neutral and molecular tracers (HI, OH, H_2CO, etc), via absorption and maser emission, this will piggy-back upon these deep continuum observations, thus not requesting any additional observational time.

3.   Anticipated contributions of the project and investigator team

The large international team of investigators assembled, includes some of the World's leading experts in the science areas under consideration. The breadth of scientific interests of this team is representative of the exciting and diverse range of science possible with this survey. Many of these applicants have *significant* radio interferometric experience (both technical and observational) which will contribute to the success of this project and e-MERLIN as whole. Equally many of the collaboration will contribute dedicated observations with other instruments (see Sec 4) and have or plan to pledge PDRA and PhD support. Whilst still at a preliminary stage, it is envisioned that this effort will at least include effort from Manchester (PDRA and PhD), Hertfordshire (PDRA, application pending), Onsala (PhD), Saclay (PhD) and Birmingham (PhD) .

4.   Links and associations with other programmes

Other proposed e-MERLIN Legacy projects: There are clear strong scientific links with several other proposed e-MERLIN legacy programmes, including deep fields *("eMXS")* and galactic projects *("Massive star formation" and "COBRAS").* In each of these cases team members and coordinators are co-investigators in this project, thus insuring close collaboration in terms of both science and technical developments. In particular this project has strong links (including shared investigators) with two e-MERLIN

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[1] Further details about the LeMMINGS project is available at http://www.jb.man.ac.uk/~rbeswick/LeMMINGS

extragalactic legacy proposals *(Intermediate luminosity IR galaxies: coordinator John Conway and the Palomar galaxy survey: coordinator Ian McHardy)*. These proposals will be coordinated with the LeMMINGS project. Each is mutually complimentary to one another but each has different science goals, techniques and sample selection.

Supporting datasets in hand: The sample selection of this Legacy survey is specifically designed to match existing and ongoing legacy programmes on other instruments (SINGS etc). Consequently, a wide range of complimentary multi-wavelength data-sets are available, either publicly or via this collaboration; including *Spitzer* (SINGS, PI: Kennicutt), complete ground based imaging of the sample in UBVRIJHK and Hα, and Paα and H-band using *HST* (ancillary data associated with SINGS), VLA HI emission data (THINGS, PIs: Walter, de Blok & Brinks), CO data via SONGS, *GALEX* Nearby Galaxies Survey, JCMT Local Universe Survey, VHIKINGS private VLA HI survey (Mundell),), IRAM-30m HERA (CO follow-up to THINGS), *Herschel* (KINGFISH, approved *Herschel* extension to SINGS), WSRT, UKIRT NGS and *Chandra* imaging. In addition, this sample has been chosen to have a large overlap with existing archival data (e.g. *HST, Chandra & XMM*).

Associated planned projects: Complimenting this e-MERLIN programme, associated observations of this sample are being planned with the EVLA (Schinnerer), European-LOFAR (Beswick & Conway) and the GMRT alongside various optical programmes, to be initiated as direct consequence of this project, including using WIYN (Gallagher) and the GranTeCan and WHT on La Palma (Knapen, using the Fabry-Perot instrument GHaFaS on the latter). In addition, mm-wave continuum and spectral line observations, in support of this programme, are being planned, including CO2-1 and 1mm continuum surveys using SMA (Peck) and single dish mm-wave lines and continuum using APEX (Aalto), JCMT, OSO-20m and other appropriate instruments (Baan) which will add greatly to our understanding of the ISM in the nuclear regions of these sources.

Preliminary List of Investigators:

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