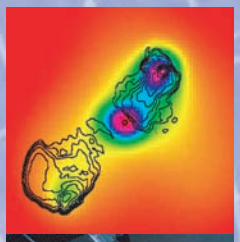
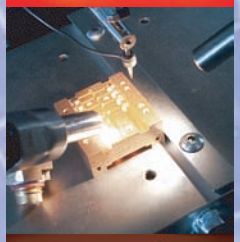
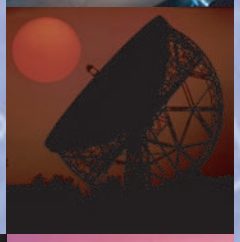
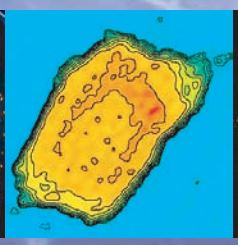
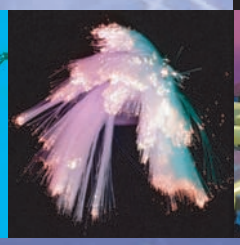
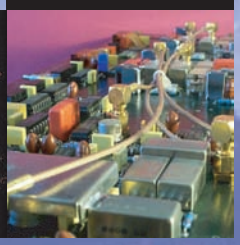
MERLIN/VLBI NATIONAL FACILITY


MERLIN

EUROPEAN VLBI NETWORK

Biennial Report

1999-2000

PPARC

THE UNIVERSITY of MANCHESTER

MERLIN/VLBI National Facility

Biennial Report

1999 - 2000

Written by the MERLIN/VLBI National Facility Staff
Edited and designed by A. G. Gunn

MERLIN/VLBI National Facility
Jodrell Bank Observatory
University of Manchester
Macclesfield
Cheshire SK11 9DL

Tel: +44 (0)1477 571321
Fax: +44 (0)1477 571618

http://www.merlin.ac.uk

Cover illustrations (from bottom left to top right): MERLIN 22GHz maser observations of the Mira-like star RT Vir; the National Facility's 32m telescope at Cambridge; welding receiver components in the National Facility workshops; a MERLIN+VLA image of the young planetary nebula NGC 7027; optical fibres, an essential part of the e-MERLIN project; a circuit board from the MERLIN correlator; the 76m Lovell telescope at sunset; construction of a low-noise amplifier in the National Facility receiver workshops; 1.4GHz MERLIN contours plotted over the Chandra image of the bright, compact DRAGN, 3C 295.

CONTENTS

APPENDICES

Jodrell Bank | Tabley | Knockin | Cambridge | Darnhall | Defford

The MERLIN/VLBI National Facility, operated by the University of Manchester on behalf of PPARC (the Particle Physics & Astronomy Research Council), is the radio astronomy cornerstone of the United Kingdom's astronomy programme. MERLIN is a sensitive 6-element interferometer network (7 when the Lovell telescope is included) with baselines of length between 11 and 217 km that routinely produces radio images with an angular resolution that matches that of the Hubble Space Telescope (HST). The National Facility is also a regular participant in European and global VLBI (Very Long Baseline Interferometry) observations, which achieve the highest resolution of any branch of astronomy. This report covers the activities of the National Facility during the calendar years 1999 and 2000.

INTRODUCTION

MERLIN (Multi Element Radio Linked Interferometer Network) is one of the five common-user ground-based astronomical facilities operated either wholly or in part by the United Kingdom, the other four being GEMINI, in Hawaii and Chile, the Isaac Newton Group on La Palma, the Anglo Australian Observatory at Siding Spring and the Joint Astronomy Centre in Hawaii. The MERLIN and VLBI National Facility is the only one of these facilities located in the UK. These world-class instruments enable UK astronomers to carry out leading-edge science across a wide range of the electromagnetic spectrum. The recent announcement that the UK intends to join the European Southern Observatory (ESO) will result in a major enhancement of the level of optical, IR and sub-mm facilities available to UK astronomers and will also enable the UK to play a major role in the Atacama Large Millimetre Array (ALMA). This initiative means that UK astronomers will have access to sub-arcsecond imaging capabilities from optical to radio wavelengths. MERLIN is the radio cornerstone of this suite of instruments and, through the *e*-MERLIN upgrade, is poised to become one of the most powerful astronomical instruments in the world.

Above: The Mk2 telescope at Jodrell Bank.

MERLIN is an array of six radio telescopes distributed over central England and controlled from Jodrell Bank Observatory. Five of the telescopes are 25m diameter antennas. The sixth, which is located at Cambridge and anchors MERLIN's longest baselines, is a 32m diameter antenna. For highly rated proposals at wavelengths longer than 6cm, the 76m Lovell Telescope at Jodrell Bank can be added to the array, more than doubling its sensitivity. The outlying telescopes are connected via microwave links to a central correlator situated at Jodrell Bank. At the present time the telescopes can be equipped with receivers covering six observing bands (see Table below). Frequency flexibility is currently available between 5 and 22GHz, but it is not yet possible to switch between these bands and 1.4/1.6GHz across the whole array.

Below: Capabilities of MERLIN.

Band (Wavelength)	K (1.3 cm)	C (5 cm)	C (6 cm)	L (18/21 cm)	P (73 cm)	VHF (2 m)
Frequency Range (MHz)	21 - 24 GHz	6000-7000	4500-5200	1300-1430 1550-1730	406-410	150.5-151.5
No. of Telescopes	5	2	6	6 (7)[a]	6 (7)[a]	6 (7)[a]
Resolution (arcsec)	0.008	0.04	0.04	0.15/0.13	0.5	1.4
RMS Noise Level[b,c] after 12 hours (μJy/beam)	400	500	50	60 (35)[d]	700	7000

(a)The Lovell Telescope can be used instead of, or as well as, the Mk2 telescope at Jodrell Bank at the lower frequencies.
(b) Subject to a maximum dynamic range. This depends on source structure, declination and u-v coverage, but is typically 10,000:1 (peak:RMS) for full track observations.
(c) Adverse weather conditions can significantly degrade the performance, especially at the highest frequencies.
(d) Inclusion of the Lovell Telescope reduces the RMS noise to ~35 μJy/beam.

MERLIN is a unique facility for subarcsecond radio imaging, playing an invaluable role in being the only sensitive ground-based facility at any wavelength that routinely matches the angular resolution of the Hubble Space Telescope (HST). It is also the only radio interferometer that enables high quality imaging on spatial scales between that of the VLA and VLBI. When data from MERLIN is combined with that from the VLA or VLBI it is possible to produce combined-array images with high sensitivity and excellent image quality on all angular scales from many arcseconds to less than a milliarcsecond. With these capabilities, MERLIN enables UK astronomers to study a wide range of astronomical targets including stars, circumstellar envelopes, stellar winds, novae, planetary nebulae, the interstellar medium (ISM), the interplanetary medium, both nearby and distant radio galaxies, quasars and gravitational lenses.

VLBI achieves the highest angular resolution of any branch of astronomy, enabling imaging at angular scales as small as 100 microarcseconds. Such capabilities enable astronomers to probe targets at sub-AU scales within our galaxy and sub-parsec scales in other galaxies. The National Facility regularly contributes two or more telescopes to European and global VLBI networks and also, in one or more sessions per year, takes part in coordinated MERLIN+VLBI observations. The VLBI capabilities of the European VLBI Network (EVN) are listed below. EVN activities are coordinated by the EVN Consortium Board of Directors and its associated Programme Committee and Technical & Operations Group. In 1993 the EVN Board of Directors set up the Joint Institute for VLBI in Europe (JIVE) based in Dwingeloo, the Netherlands, as the home of the new EVN data processor. This became operational in July 1999. The newly-upgraded MkIV tape recording system and data processor provide the world's first 1 Gbit/sec VLBI system. This major transformation of European VLBI capabilities will be of great benefit to all astronomers. The EVN data processor, together with the large radio telescopes at Effelsberg, Jodrell Bank and Westerbork, make the EVN the instrument of choice for high sensitivity VLBI.

The MERLIN/VLBI National Facility is operated by the University of Manchester on behalf of the Particle Physics and Astronomy Research Council (PPARC). The remit of the National Facility is to operate MERLIN for nine months of the year and to provide the support necessary to ensure participation in European and global VLBI observations. The operation and development of the facility are monitored by the MERLIN Steering Committee. Observing time for MERLIN is allocated on an open-access peer-review basis by the MERLIN Time Allocation Group of the Panel for Allocation of Telescope Time (PATT). Observing time for VLBI, or for MERLIN with VLBI, is allocated separately by an international time allocation group that is independent of, but liaises with, PATT.

Below: Capabilities of the EVN. Note that the EVN also observes at 30cm, 3.6/13cm and 7mm but the National Facility telescopes are not equipped at these wavelengths. The sensitivity estimates are from the EVN User Guide and assume 8 hours on source with 128 Mbit/sec data rate (equivalent to 4 x 16 MHz with 1 bit sampling). The 92 and 49cm values are based on these but scaled using estimates of system performance and available bandwidth at these wavelelngths.

Wavelength	1.3 cm	5 cm	6 cm	18 cm	49 cm	92 cm
No. of EVN Telescopes	10	5	10	10	4	5
EVN Resolution (mas)	0.3	5	1.5	5	16	30
Global Resolution (mas)	0.25	-	1.0	3	10	19
EVN Sensitivity (µJy/beam)	200	160	38	45	300	1000

DIRECTOR'S REPORT

The past two years have been a period of intense activity in all areas of the National Facility's operation. As always, the scientific outputs of MERLIN and the EVN have been impressive, with some fascinating results being produced. Some of these are discussed in more detail in the section on Astronomy, but some highlights to note are:

- the 6cm images of the Proplyds in Orion (a MERLIN Key Programme)
- recent results on starburst galaxies through observations with MERLIN and global VLBI
- the EVN detection and imaging of μJy sources in the Hubble Deep Field
- polarisation images of masers in the envelopes surrounding giant and supergiant stars
- combined-array observations of SS433.

The production of such high-quality scientific results requires a dedicated team of professionals to keep the telescopes, receivers, microwave links, correlator, VLBI backends and software running. It also requires a dedicated operational team who schedule the array, operate the telescopes and then provide the excellent support that our users have come to expect. I wish to publicly thank all staff of the National Facility for their efforts, which are often above and beyond the call of duty.

There has been significant engineering work over the period covered by this report, the major part of which has been the replacement of the drive systems for the three E-systems telescopes funded by part of a PPARC-funded restructuring programme. Other developments have resulted in the construction and installation of a cooled 6-7GHz receiver system for the 32m telescope at Cambridge, the construction of a dual-frequency prime-focus receiver box for Defford and the design and installation of a novel remote diagnostic system for outstation telescopes. The scope and progress of these and other projects are described in the section on Developments. Another major development at Jodrell Bank Observatory is the funding by the Joint Infrastructure Fund (JIF) of the upgrade of the Lovell Telescope (LT). The ~£2M grant is enabling the replacement of the surface of the LT (for current status see http://www.jb.man.ac.uk/tech/lovellupgrade), the refurbishment of the foundations and the installation of a new telescope drive system. When finished at the end of 2002, the LT will be a revitalised telescope capable of operating with almost full efficiency at ~8GHz. It will be an invaluable addition to MERLIN at 5GHz, increasing the sensitivity of the array by a factor of ~2.5.

In September 2000 an international panel of astronomers was asked to review the operation and future development of the National Facility. The panel consisted of Dr. Miller Goss (NRAO: chairman), Prof. Alain Baudry (Observatory de Bordeaux), Prof. Richard Hills (Cambridge University) and

Dr. Karl Menten (MPIfR). The panel spent three days at JBO receiving presentations on various aspects of the facility and conducting interviews with many NF staff and JBO academics. They produced a comprehensive report, which can be found in full on the internet at http://www.merlin.ac.uk/review-report. The panel's report was highly complimentary of the science performed and the operation and management of the facility. The panel strongly endorsed the *e*-MERLIN proposal.

Earlier in 2000, National Facility staff participated in a review of the EVN and its Joint Institute for VLBI in Europe (JIVE). This was conducted under the auspices of the European Science Foundation (ESF) and carried out by a panel consisting of Prof. Jens Fenstad (University of Oslo: chairman), Prof. Len Culhane (UCL), Prof. Calogero Natoli (INFN, Frascati) and Dr. Paul Vanden Bout (NRAO). The review was, like the review of MERLIN, very successful. The panel concluded that the science was 'rich in substance and impact', the user community was of 'sufficient critical mass' and that the EVN had 'professionalised a dedicated networking approach which capitalizes on the availability of the world's largest diameter telescopes'. A report of the review appeared in *Nature* (Volume 407, p. 437).

In 2000 a major effort was put into the preparation of the proposal for *e*-MERLIN, the optical fibre-based upgrade that is planned for MERLIN. Working groups at JBO were formed to translate a straw man specification into a full technical specification and associated costs. In addition, 54 astronomers from the UK and around the world participated in the generation of the science case for the upgrade. This huge effort culminated in the submission of a highly professional proposal to PPARC in November 2000. A copy of the proposal can be found on the internet at http://www.merlin.ac.uk/e-merlin. At the time of writing, funding for the £8.6M capital cost of *e*-MERLIN is being sought. We are hopeful of success sometime over the summer of 2001.

In late April 2000 we hosted a radio imaging school at JBO attended by ~50 'students'. Of these, about 2/3 were from one of fourteen institutes in the UK, the rest were from six countries across the EC and associated states, from Ireland to Poland. Astronomers from Russia and South Africa also attended. Lectures were presented by speakers from various UK and European institutes. The school provided a balanced mixture of basic radio astronomy practice and the more specialised techniques required to produce some of the spectacular results possible with today's instruments. Significant financial assistance was provided by the European VLBI Network through the EC grant 'Access to Large Scale Facilities'. The University of Manchester and PPARC also provided some financial help.

P. J. Diamond
Director, MERLIN/VLBI National Facility

ASTRONOMY

Overview & Highlights

The MERLIN/VLBI National Facility has been used to study many diverse astronomical phenomena during the reporting period. Their scales range from only a few solar radii (solar wind studies) to the cosmic distances revealed by gravitational lens studies. These observations have continued to support world-class science, particularly in fields such as extragalactic astronomy and cosmology, star-formation across the Universe, stellar evolution and investigations of the extreme conditions around compact objects.

Above: The National Facility's 32m telescope at Cambridge.

The range of objects routinely studied by the National Facility include radio galaxies and quasars, Seyfert and starburst galaxies, the Galactic interstellar medium (ISM), planetary and proto-planetary nebulae, young stellar objects (YSOs), main-sequence and evolved stars and their winds, circumstellar envelopes, star-forming regions, classical novae, micro-quasars and pulsars. An equally broad range of physical conditions and processes are encompassed by such observations, from the highly-energetic synchrotron-emitting regions of active galactic nuclei (AGN) to the complex maser shells surrounding evolved stars and the beamed radio emission from rapidly-rotating neutron stars.

The key scientific achievements of the National Facility during the reporting period continue to be based primarily on the available angular resolution. However, not only the determination of the detailed structure of the radio emission, but also the probing of magnetic fields using polarisation studies and the relative accuracy with which astrometry may be performed, have undoubtedly enhanced the National Facility's recent core science. Unprecedented sensitivity has also been achieved using very long observations of Deep Fields.

In addition to conventional synthesis imaging using UK-based and continental baselines, National Facility antennas have also been used individually and in single baselines to measure interplanetary scintillation and pulsar proper motions. MERLIN has responded rapidly to reports of flares from X-ray Binaries (XRBs) and other target-of-opportunity (ToO) triggers. Other long-term monitoring projects, massive surveys and Key Programmes have also been successfully pursued.

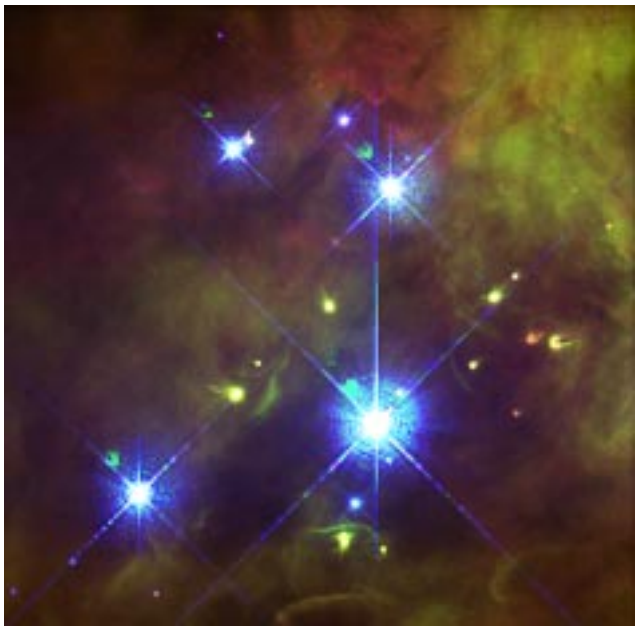
Following the successful 18-day MERLIN observations of the Hubble Deep Field, five more Key Programmes were started during 1999/2000. These were; a deep radio/sub-millimetre survey (Eales et al.), sub-mJy radio galaxies and the X-ray background (McHardy et al.), a deep MERLIN survey of the Orion Nebula (Meaburn et al.), radio imaging of star-formation in distant galaxies (Richards et al.) and a study of galaxy haloes using radio-microlensing (Koopmans et al.).

The core scientific results presented here represent a science programme that is both productive and innovative.

The Birth Process of Stars: The Orion Proplyds

Recent spectacular HST images of the Trapezium Cluster in the Orion Nebula, M42, have fuelled interest in the complex processes of star-formation and the interaction of YSOs with their environments. MERLIN observed this region at 6cm in 1998 and 1999. Over 100 hours of data have now been combined in an attempt to produce one of the deepest high-resolution radio images of the closest example of a star-forming region with both low-mass and high-mass stars. The prime targets of this observation were the proplyds; YSOs embedded in knots of gas photo-ionised by one of the bright Trapezium stars. Comparison of the accurately aligned MERLIN and optical HST images has already produced some surprising and unexpected results.

Below: HST montage of the Orion proplyds.

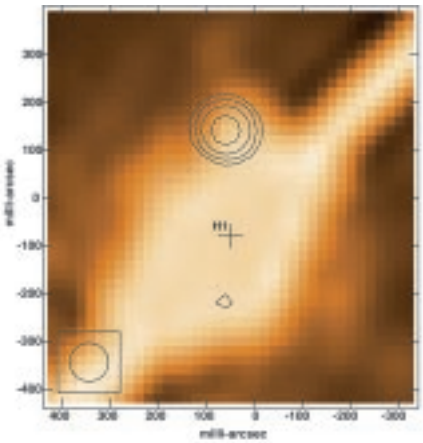


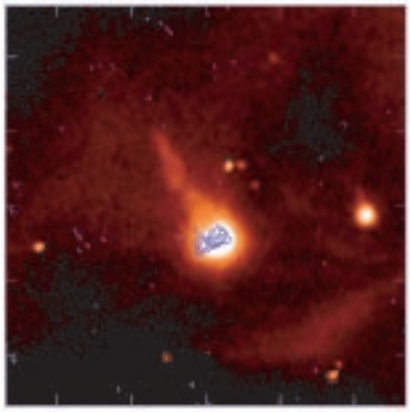
The superb MERLIN images have revealed that the bright radio star, which had always been associated with θ^1 Orionis A, is, in fact, displaced by 220 milliarcseconds from the Hipparcos optical position. Recent 2.2μ speckle images have shown that there is a $5M_\odot$ pre-main-sequence companion star at precisely the radio position. Global VLBI observations have recently been performed to investigate the nature of the nonthermal emission from this enigmatic target.

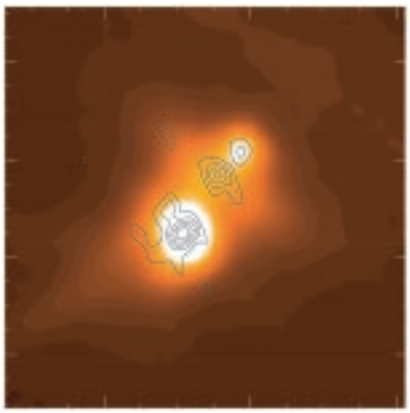
The proplyd LV2 is a superb example of a star recently formed. The MERLIN image shows the ionisation front as a narrow cusp where the evaporation flow from the circumstellar/proto-planetary disk is ionised by soft UV photons from θ^1 Orionis C. Also visible is the one-sided jet that emerges, thought to be perpendicular to this disk, at a velocity of 100-150kms^{-1}.

Below: (left) MERLIN contours overlaid on an overexposed HST image of θ^1 Orionis A. The radio source is displaced 220mas from the Hipparcos position (H1). (centre) MERLIN 5GHz contours overlaid on an HST Hα frame of the proplyd LV2. (right) MERLIN contours of the proplyd LV1.

Another proplyd, LV1, was first resolved as two radio sources in 2cm VLA images and then by the HST as two optical objects separated by 400 milliarcseconds. The MERLIN 5GHz image clearly shows that much of the radio emission at this frequency comes from between the two optical objects, but whether this could be due to the collision of 100-200kms^{-1} jets is still being investigated.





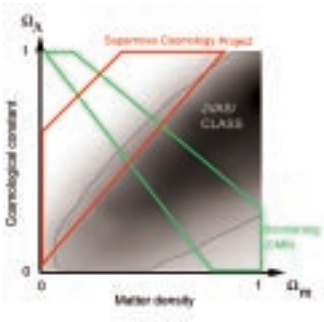


Evaluating Cosmological Parameters Using Gravitational Lenses

The pursuit of reliable values for the expansion and density of the Universe is a crucial aspect of modern astronomy. Gravitational lenses provide one method of investigating these cosmological parameters and the National Facility has continued to contribute significantly to this active field.

The JVAS/CLASS survey is the world's major gravitational lensing survey. The observations have so far covered 16,545 flat-spectrum radio sources with the VLA. Candidate complex sources were then mapped at higher resolution with MERLIN to distinguish between intrinsic structure and the multiple point-like components suggestive of gravitational lensing. MERLIN images resulted in the rejection of 80% of the VLA candidates at this stage. VLBI observations provided final confirmation for the few objects whose identification remained uncertain following the MERLIN observations. More than 20 new gravitational lenses have been identified.

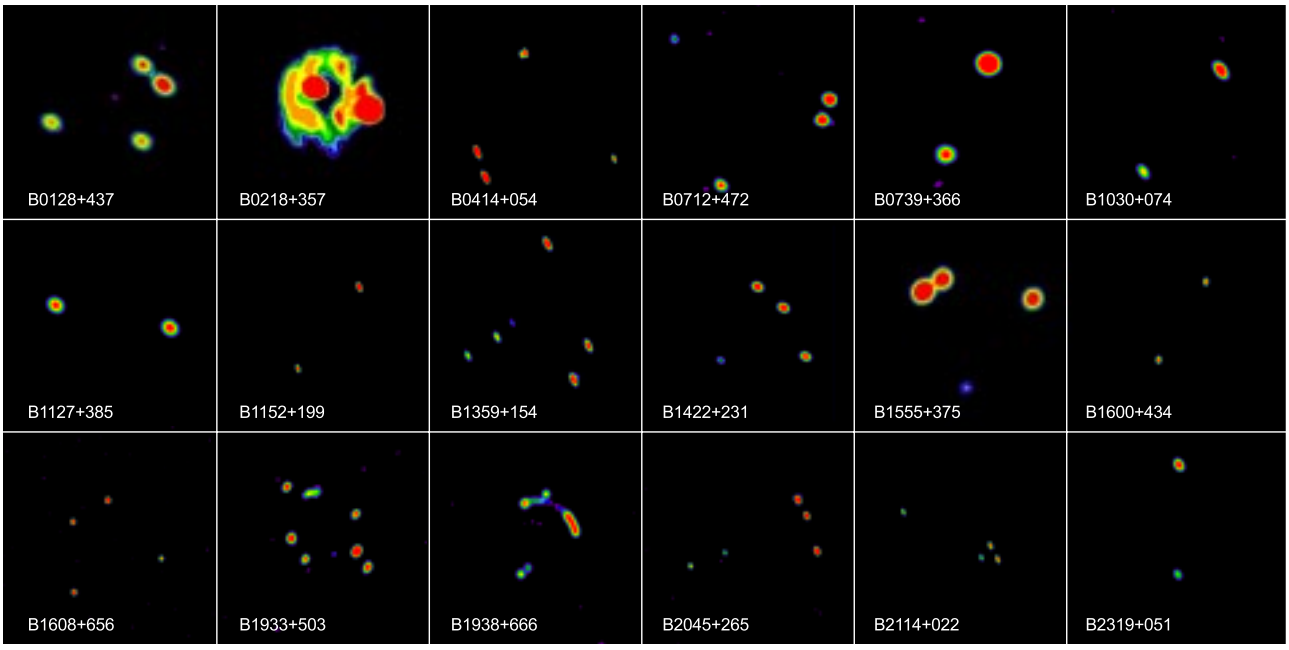
Below: Constraints at the 90% confidence level in the Ω_m-Ω_Λ plane from the JVAS/CLASS results compared to results from the Boomerang CMBR satellite and Type Ia supernova studies.



The statistics of gravitational lensing can lead to tight constraints on cosmological parameters. Individual lens systems can give a determination of H_0 if the source is variable and the brightness or polarisation variations in the multiple images show a time delay. Also, the fraction of sources that are lensed is sensitive to the universal matter density Ω_m and the cosmological constant Ω_Λ. For this method to be useful it is vital that all the lenses within well-defined limits are identified. Radio surveys are well suited to this aim due to their immunity to dust extinction and their reliably high resolution. The complete JVAS/CLASS lens search has only been possible because of the complementary characteristics of all three radio synthesis arrays (the VLA, MERLIN and VLBI) covering over two orders of magnitude in resolution.

The constraints in the Ω_m-Ω_Λ plane (at 90% confidence) from the JVAS/CLASS results put a strong upper limit of Ω_Λ<0.6, implying a flat universe. The limits on Ω_Λ will become better determined when the final number of lenses is known in JVAS/CLASS and the redshift distribution of the parent sample is better known.

Below: MERLIN/VLA images of 18 new gravitational lenses from the JVAS/CLASS survey.



Fuelling Active Galactic Nuclei: HI in 3C293

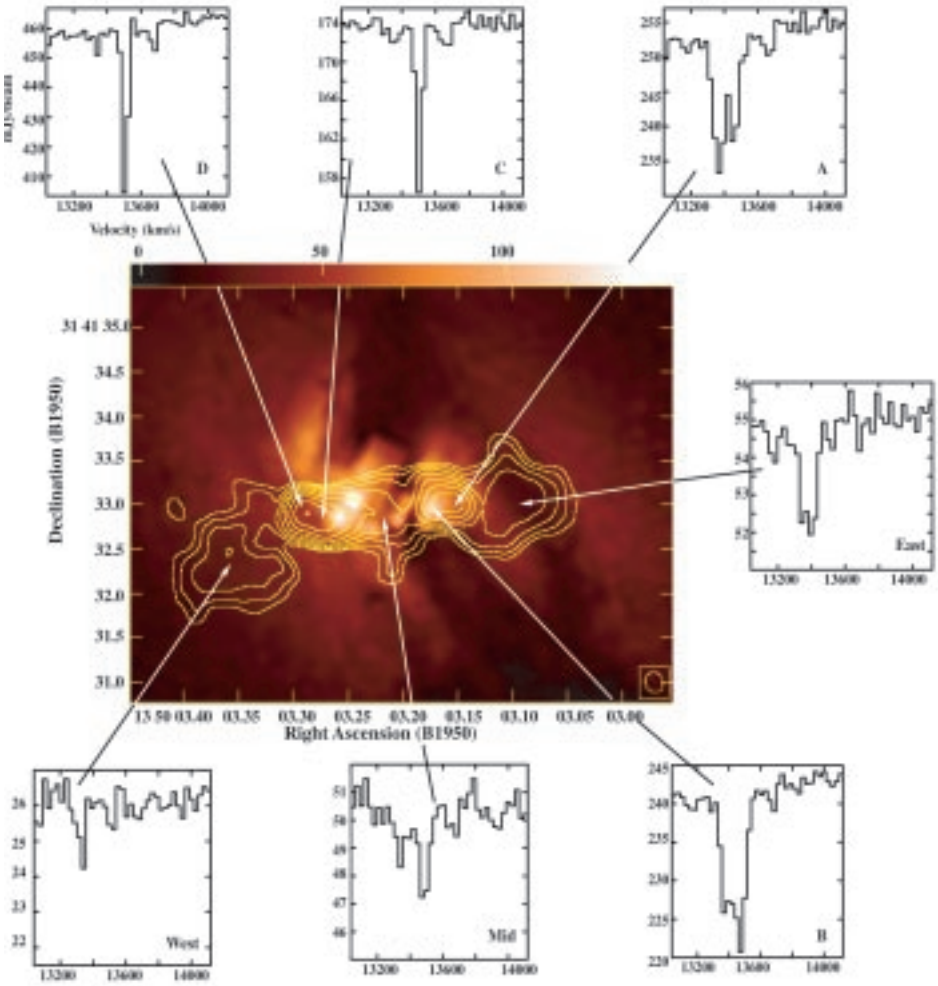
The study of the dynamics of neutral gas in the centres of active galaxies is essential if the fuelling and triggering of active galactic nuclei (AGN) and starburst galaxies are to be understood. MERLIN is supremely suited to this kind of study since the VLA does not achieve the required resolution and VLBI observations typically over-resolve the important features.

A recent study of the HI absorption towards the central region of the radio galaxy 3C293 using MERLIN represents one of the highest resolution studies of the neutral ISM in a radio galaxy. At the distance of 3C293 (~180Mpc), the ~0.2-arcsecond 18cm MERLIN resolution corresponds to ~180pc, which means that individual clumps of gas in the centre of the galaxy can be resolved.

3C293 is a peculiar radio galaxy which shows signs of interaction with another galaxy only 28 arcseconds away. The HST WFPC2 image shows clear signs of disruption, as does a MERLIN 18cm continuum image, which shows emission elongated in an E-W direction, in marked contrast to the NW-SE aligned arcsecond-scale radio jets detected in VLA observations. The presence of large quantities of neutral gas, already known from previous low-resolution observations, also suggests the 'cannibalisation' of gas from the nearby companion.

Below: HST WFPC2 image of 3C293 overlaid with MERLIN image contours. Also shown are seven of the HI absorption spectra.

In the most recent MERLIN observations, HI is seen in absorption across the entire radio continuum source detected at 0.2-arcsecond resolution. So high is the spectral signal-to-noise that it has been possible to map the optical depth of foreground HI in 3C293, revealing structure that is independent of the background radio continuum. There is a factor of four difference in optical depth in three bands running approximately N-S across the centre of 3C293 and which appear to be co-spatial with the dust lanes seen in the HST WFPC2 image at a similar resolution. The gradient of the HI velocity across the source implies a mass of $4.5 \times 10^9 M_\odot$ within 600pc of the galaxy's core. Such observations represent a crucial tool in the study of gas dynamics in the cores of galaxies.



Faint Sources in the Hubble Deep Field

The spectacular Hubble Deep Field (HDF) is awash with faint galaxies of many morphological types at differing distances and stages of evolution. Analysis of this region and the surrounding Hubble Flanking Fields (HFF) continue to provide important clues to crucial problems in cosmology and galactic evolution. Both MERLIN, the VLA and the EVN have observed these regions; MERLIN integrating down to levels ten times fainter than ever before and the EVN producing the most sensitive high-resolution observations of radio galaxies ever achieved.

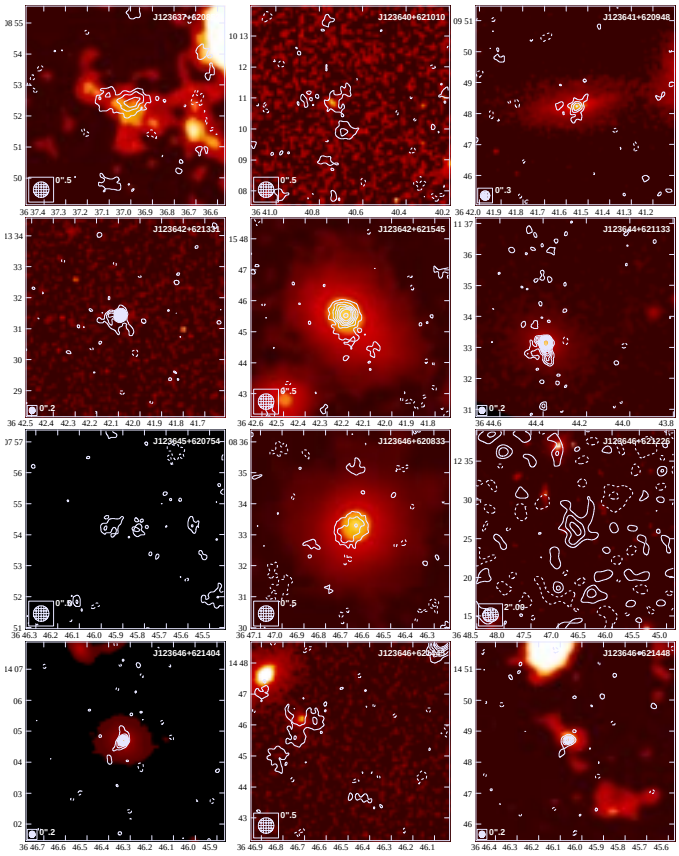
In all, 90 radio sources were detected above 27μJy/beam (7σ) by the combined MERLIN and VLA observations. Most objects are unresolved by the VLA alone but MERLIN has revealed the nature of these galaxies for the first time. The majority are identified with relatively bright galaxies, of which 30% are low luminosity AGN and 70% are powerful starbursts. Approximately 15% of sources are unidentified optically and probably represent a new population of very distant dust-enshrouded starbursts, some with embedded AGN.

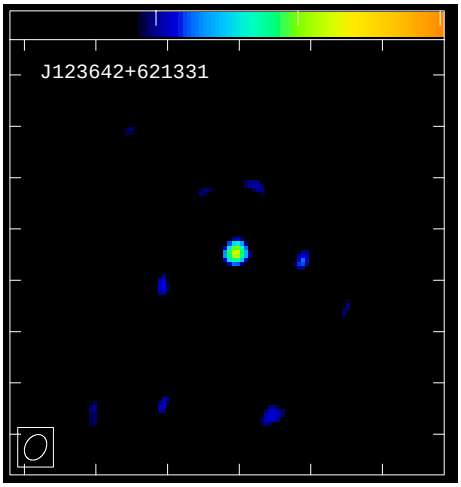
A more detailed analysis of this unique dataset has shown that the detection of radio sources weaker than ~10μJy is statistically significant at the position of optical galaxies with I magnitude <26. These objects are the tail end of the distribution of radio sources larger than 0.5 arcseconds in size, or less energetic or very distant starbursts.

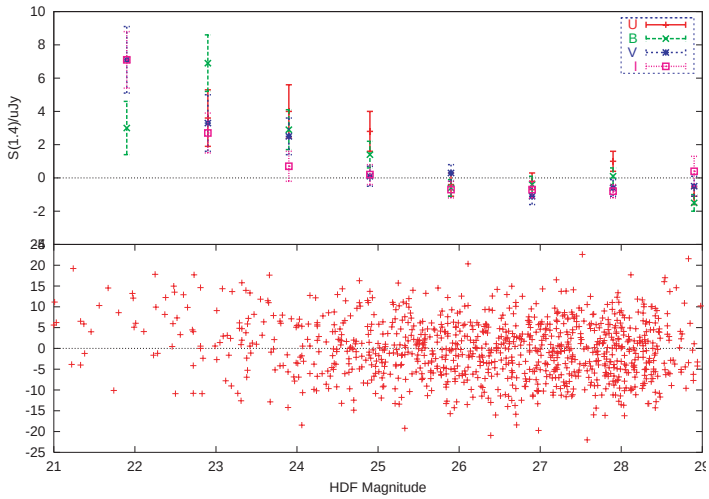
The positions of 12 of the MERLIN sources in the HDF were searched using the EVN. Three were detected, including J123642+621331, thought to be a dusty starburst at z=4.4. The other two detections are of an elliptical and a spiral galaxy. Intriguingly, the detection of compact bright radio cores suggests that all three galaxies conceal an AGN.

Bottom : (right) Radio flux densities at the position of optically detected galaxies in the HDF plotted against binned galaxy magnitudes in each of the four optical bands. (left) EVN map of J123642+621331.

Below: MERLIN+VLA radio contours superimposed on the HDF/HFF for 12 of the 90 detections.







Maser Emission in the Red Supergiant VX Sgr

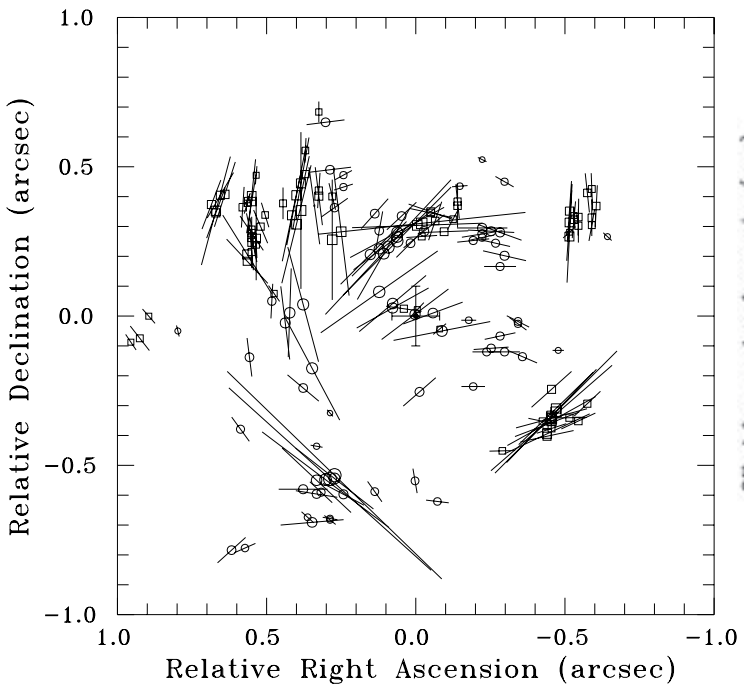
MERLIN's capability for routinely recording full polarisation information during observations is now proving crucial to the study of magnetic fields in many types of objects. In addition, MERLIN's unique resolution range perfectly matches the sizes of features found in many stellar environments. Consequently, observations of the red supergiant (RSG) star VX Sgr, have recently revealed some fascinating details of the complex environments around evolved stars.

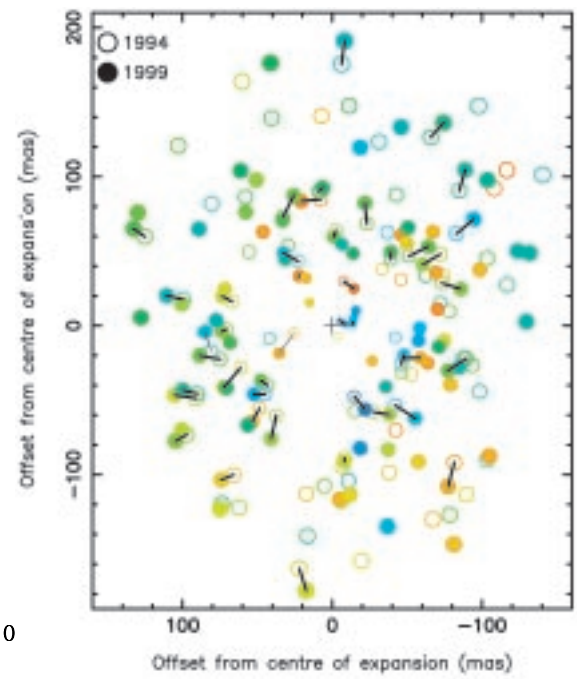
MERLIN results show that the linear polarisation vectors for the OH 1612MHz maser emission in the wind from VX Sgr are aligned tangentially. This, together with the segregation of circularly polarised components, suggests that VX Sgr produces a dipole magnetic field at a position angle of ~210° tilted at 20-30° to the line-of-sight. This is consistent with slight asymmetries in the velocity field in the H_2O and OH maser region. The magnetic field strength measured from the OH 1612MHz data is 0.3mG at 100 stellar radii, aligned toward the observer, compared with 2mG at a few tens of stellar radii deduced from MERLIN, EVN and global VLBI OH mainline observations, again aligned toward the observer. This field is strong enough to influence the direction of the stellar wind.

Below left: Linear polarisation vectors for OH 1612MHz emission in the wind from VX Sgr.

MERLIN observations are sensitive enough to reveal faint maser emission at all position angles, suggesting the wind is accelerated radially away from the star in all directions. However, H_2O maser emission (associated with dense, dusty clumps) is brightest in an equatorial belt (using the magnetic field axis to define the poles). Proper motion measurements confirm the general expansion and rule out significant rotation. This is consistent with less dense, possibly slightly ionised, parts of the wind being directed towards the poles. MERLIN is uniquely able to measure proper motions of a few milliarcseconds but not resolve out significant emission, and as more stars are studied this will reveal whether more pronounced asymmetries are related to stronger magnetic fields.

Below right: The positions of water maser clouds around VX Sgr observed in 1994 and 1999 (open and closed circles, respectively) and the corresponding proper motion vectors.

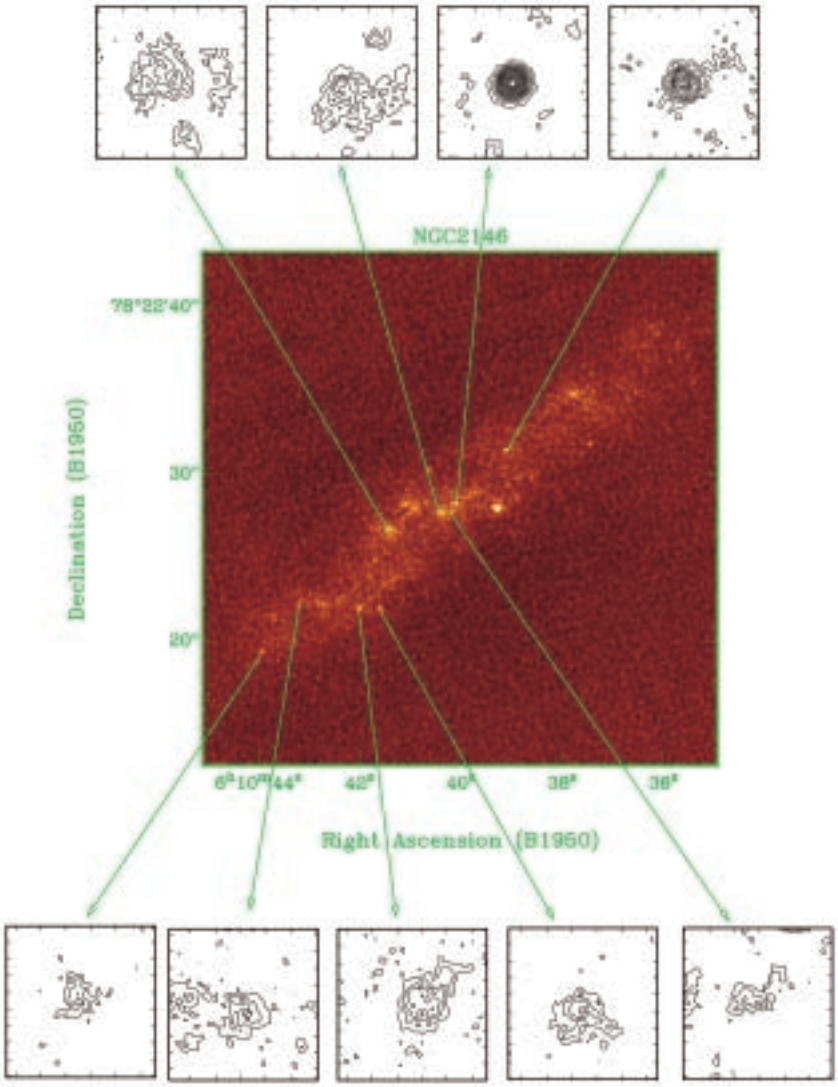




Starburst Galaxies: NGC 2146

MERLIN has an impressive legacy in studies of starburst galaxies. Such investigations not only provide information on extragalactic supernova remnants (SNRs) themselves but also provide a direct measure of the supernova rate, and hence, via the initial mass function, the star-formation rate.

Below: MERLIN and VLA 5GHz images of NGC 2146.



One such starburst galaxy, NGC 2146, at a distance of 14.5Mpc, has a nuclear region highly obscured at optical wavelengths. Early VLA radio observations revealed a population of ~20 unresolved sources, which have been interpreted as supernova remnants or radio supernovae.

Recent MERLIN+VLA observations at 5GHz and MERLIN (only) observations at 1.4/1.6GHz with a resolution of ~150 milli-arcseconds (corresponding to ~10pc at the distance of NGC 2146) have shown that seven of the sources have a shell-like structure. Three of these sources, though still unresolved, have spectral indices that are also typical of supernova remnants. Six sources, mostly unresolved or having extended diffuse emission, have thermal spectral indices indicating that they are possibly ultra-compact HII regions associated with super star clusters. However, such spectra could also be explained by strong, free-free absorption by high emission measure, foreground, ionised gas. Observations such as these demonstrate the need for high resolution in understanding the physics of such objects.

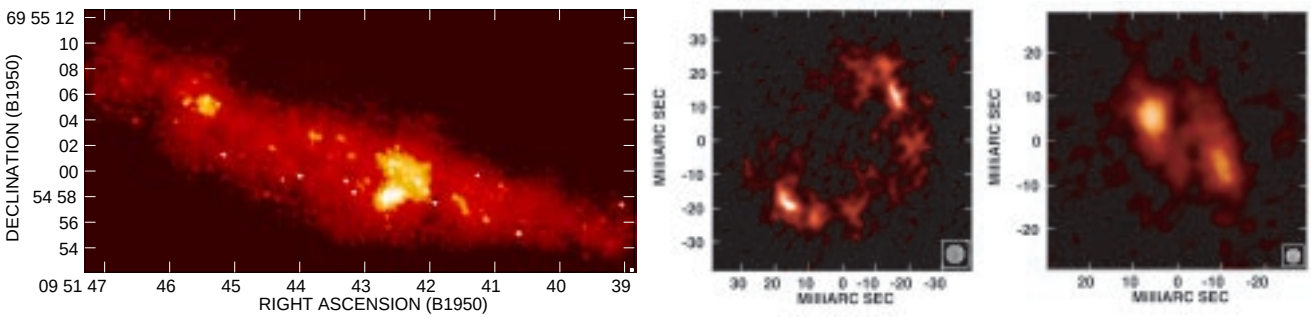
Starburst Galaxies: M82

M82 is the archetypal starburst galaxy showing strong nonthermal radio emission from a central region ~1kpc across. Since the initially unresolved point sources in M82 were first resolved over a decade ago by MERLIN, most of them have now been conclusively shown to be supernova

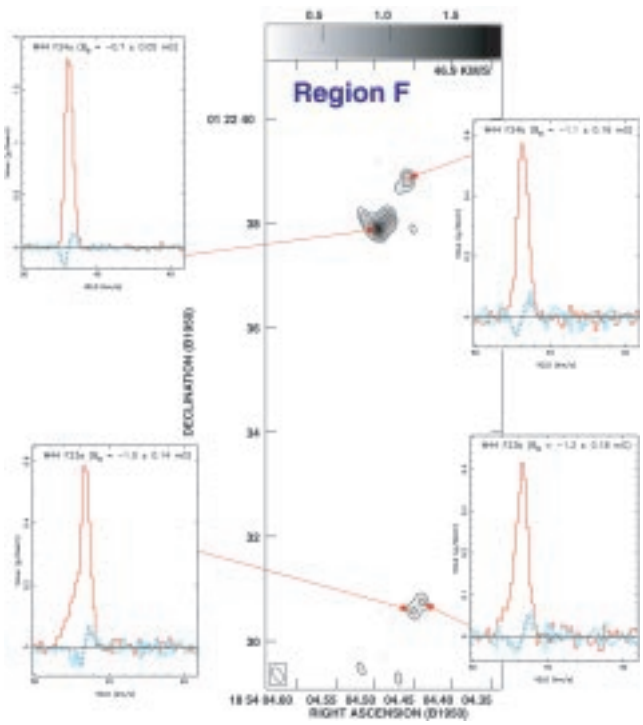
remnants. Regular monitoring of the expansion of these compact components has been continuing with MERLIN. In recent years, the first detailed images of SNRs in M82 have been made with global VLBI and MERLIN.

Most remnants, such as 43.31+592, have expansion velocities of ~10,000kms^{-1}, as expected for typical SNRs. However, 41.95+575 appears to be an enigmatic object. Firstly, the data show that the structure of this unusually bright SNR does not resemble a shell, but comprises extended diffuse emission in which are embedded two compact sources. These are separating at only 1/5 of the mean expansion velocity of the other supernova remnants in M82, which implies a zero-size birth in 1915. Secondly, unlike the other SNRs, which show no measurable flux density variations, the flux density of 41.95+575 has been decreasing at a rate of 8.5% per year. Thus, if 41.95+575 is a SNR, it is anomalous; in its youth it probably resembled the extremely luminous radio supernovae detected in Arp 220, which are thought to be of a class of which radio supernova 1986J is a prototype.

Below: (left) M82 observed with MERLIN at 5GHz. (centre) SNR 43.31+592 and (right) 41.95+575 observed in 1998 with global VLBI.



Below: MERLIN map and polarisation spectra of OH 1720MHz maser clouds in W44.



Galactic Supernova Remnants

Supernova remnants in our Galaxy provide us with some of the most spectacular images of the aftermath of the violent death of massive stars. However, the study of the physics of SNR is difficult due to the lack of useful probes of the various phenomena observed.

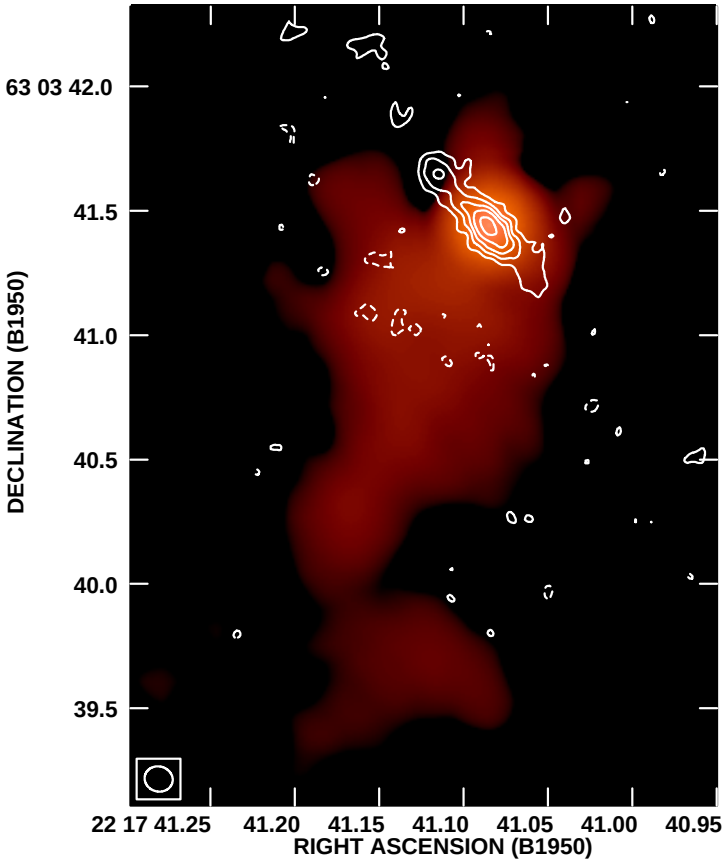
MERLIN and the VLBA have been used to measure the sizes of 1720MHz OH maser clouds that are associated with ~10% of Galactic SNR. The measured diameters, of order 5x10^{13}m, confirm the predicted column densities for these collisionally pumped masers at 100K. MERLIN full polarisation results provide details not only of the shock structure in the SNR, but also the detailed magnetic field. Thus, for the first time astronomers can study the shocks with the level of detail required to obtain some understanding of the processes involved.

In recent decades, astronomers have made significant advances in understanding the processes by which stars form. MERLIN continues to make substantial contributions to this field with its ability to observe magnetic fields and peer through dust-enshrouded regions. In particular, MERLIN has been used to investigate radio continuum and maser line emission from Galactic Young Stellar Objects (YSOs) in order to help distinguish between jets and discs.

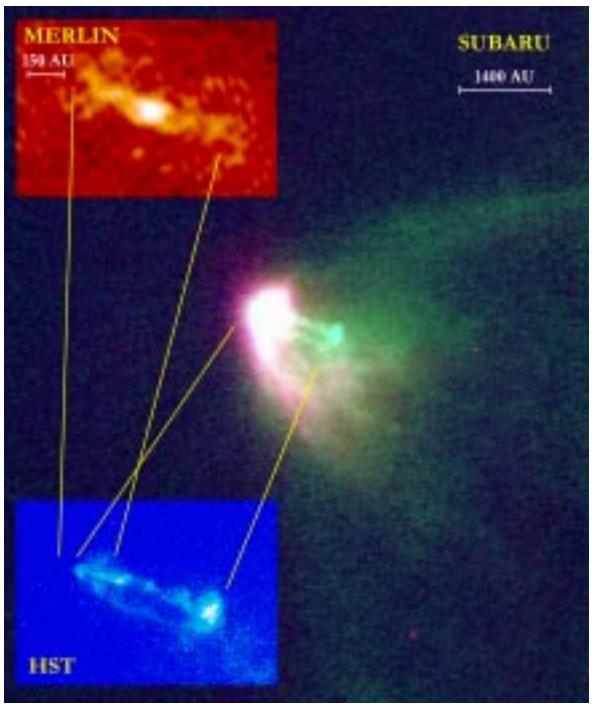
Below: An IR K-band speckle interferometry image of S140 IRS1, overlaid with MERLIN 5GHz radio contours.

Bottom: MERLIN, HST and Subaru images of the protostellar jet L1551 IRS5 in Taurus.

Spectral shifts in the H_2O 22GHz maser emission from the massive YSO, S140 IRS1, have previously been interpreted as clumpy material in Keplerian rotation around a condensation of a few solar masses. High angular resolution MERLIN mapping has shown that the spectrum is a blend of emission from regions too far apart to be all orbiting the same YSO. These individual maser features appear to be associated with a mix of rotating discs and outflowing jets. In addition, MERLIN 5GHz continuum imaging of this object has detected thermal radio emission from the ionised wind which is orientated perpendicular to the bipolar outflow seen in the near IR, and is probably an equatorial wind being driven off the surface of a disc.

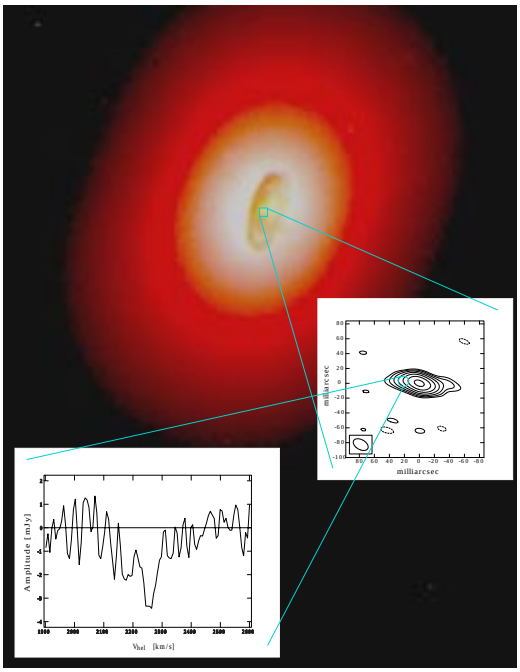


L1551 IRS5 is a proto-stellar jet enshrouded by 150 magnitudes of interstellar extinction. MERLIN observations have peered through the obscuring dust and revealed what appears to be a helical jet emanating from the core, especially on the side where no optical or infrared emission can be seen. The jet seems to originate in a binary system (seen in MERLIN 5GHz and VLA 43GHz images) and is directed perpendicularly to the projected orbital plane of the binary. High-resolution circular polarisation observations from MERLIN have also resolved the emission from the magnetised plasma for the first time. Radio observations, which peer unhindered through obscuring gas and dust, are the only way to discover the inner workings of these jets in young solar-mass stars.



Active Galactic Nuclei

Circumnuclear Neutral HI in NGC 4261



Above: The nucleus of NGC 4261 with the EVN 1420MHz map superimposed on the HST image.

The rotation curves of material orbiting galactic nuclei at radii from kpc to pc may be measured using HI absorption or OH and H_2O masers. High spatial and spectral resolution is required to separate disks from inflows or jets and thus discriminate between starburst and AGN activity. Within the EVN, the Lovell telescope's inclusion is vital in achieving the sensitivity needed to detect HI absorption on milliarcsecond scales.

During the reporting period the new EVN correlator, located at JIVE, Dwingeloo, has begun scientific operations and greatly increased the opportunities for spectral line VLBI. The first scientific results from this correlator involved a study of circumnuclear material in the galaxy NGC 4261, thought to contain a supermassive black hole.

The observations showed HI orbiting within only 7pc of the nucleus of NGC 4261. The HST, with three times lower resolution, found mainly molecular material in a disc orbiting the nucleus. The atomic hydrogen is presumably in a warmer region that is heated as material falls into the accretion disc feeding the black hole.

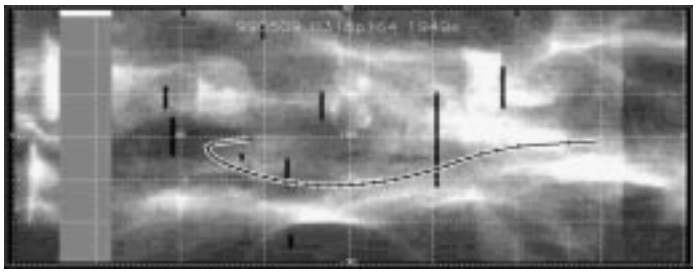
Measuring Stars & Their Winds

Interplanetary Scintillation

The mechanisms of solar coronal heating and wind acceleration are not fully understood. Two different forces may be at work; one producing the fast low-density wind above coronal holes and the other the slow, dense, highly variable wind observed above coronal streamers. With its real-time correlation and long baselines, MERLIN has the unique ability to probe the inner regions of the solar wind by measuring the interplanetary scintillation of signals from distant, compact radio sources.

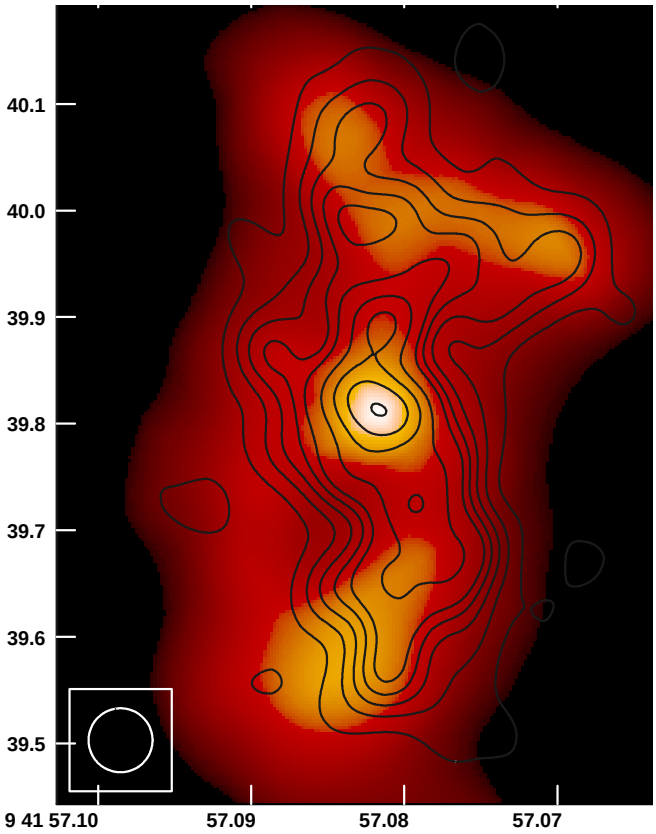
Below: Ray-paths for MERLIN and EISCAT measurements of the IPS during May 1999 projected ballistically back to $2.5R_\odot$ overlaid on a white-light LASCO image.

MERLIN observations of the solar wind were made at 5GHz in 1999 and 2000. These were co-ordinated with observations using EISCAT (probing the wind at a few tens of solar radii at 0.913GHz) and the white-light imager, LASCO, on the *SoHO* spacecraft. These show an intrinsically variable, slow wind outflowing at ~100kms^{-1} at 4-10$R_\odot$, accelerated to its cruising speed of 3-400kms^{-1} by 25-30$R_\odot$. The fast wind (seen above coronal holes) is at 500kms^{-1} by 6$R_\odot$ and reaches its top speed much more rapidly by 10-12$R_\odot$. This unique combination of instruments has thus allowed the fast and slow winds to be distinguished and their structures investigated. The results have given crucial clues to the location of acceleration regions within the solar wind and have shown for the first time that the wind behaves similarly at solar maximum and minimum.



MERLIN has disentangled the distinct emission mechanisms of numerous stellar winds using brightness temperature and spectral index maps. It has been possible to distinguish between thermal and nonthermal emission, and identify the processes involved, such as ionisation fronts or shocks. This has allowed an explanation of the complex shapes of the nebulae surrounding novae and other active stars.

Below: The innermost regions of the symbiotic nova HM Sge (MERLIN contours overlaid on an HST image).

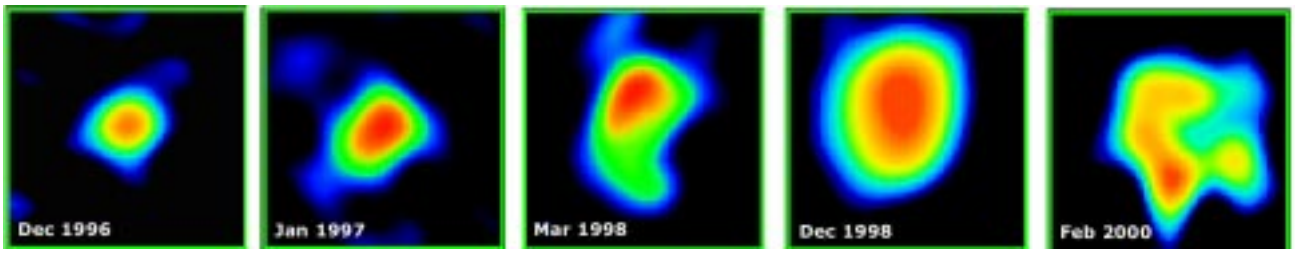


High-resolution 5GHz MERLIN images of the puzzling binary system β Lyrae reveal an extended radio nebula. It is ~40AU across with a brightness temperature <11000 K. This definitively confirms the thermal origin of the radio emission, which is consistent with emission from the wind of a B6-8II component (mass loss rate ~$10^{-7}M_{\odot}$/yr), ionised by the radiation field of the hotter companion. Present measurements indicate that almost $0.015M_{\odot}$ have been completely lost from the system despite the onset of the Roche lobe overflow phase.

The evolution of the symbiotic nova HM Sge is complex and includes mass transfer onto a compact white-dwarf (WD) component and the effects of its intense radiation on the cool star. Optical imaging by the HST with different filters, and the precise radio astrometry at 5GHz with MERLIN, has allowed the binary star positions to be deduced. The peak emission in both datasets locates the WD in the system and has revealed the system's evolution since 1995 when there was only faint radio emission from the direction of the WD. The ridges of emission, seen either side of the WD, mark the shock fronts between the spiralling, colliding winds.

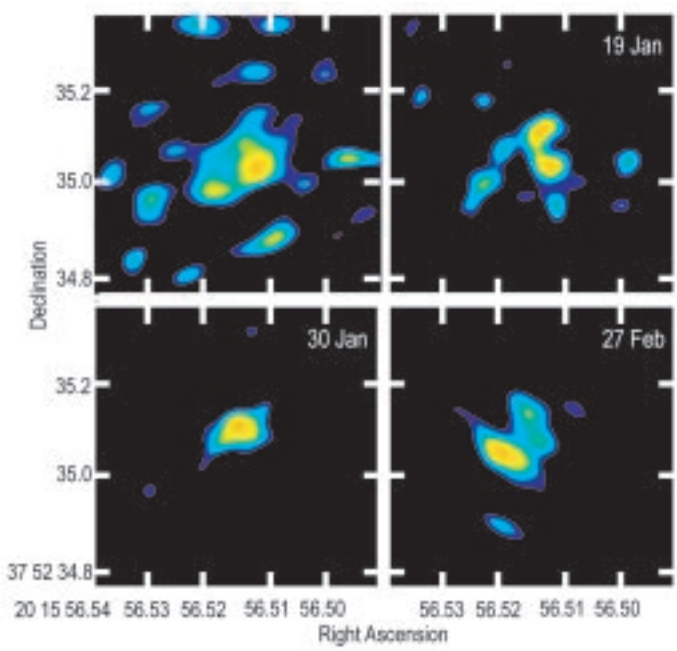
MERLIN has continued to monitor the expanding, cooling shells of several novae such as V723 Cas, which exploded in 1995. The shell is expanding at ~200kms^{-1} and has recently become optically thin. High resolution observations at different frequencies and different epochs reveal that the internal structure of the shell can be asymmetric, in contrast to the smoother outer surface of early images which gave rise to spherically symmetric models. MERLIN data, as well as optical studies, imply that multiple ejection episodes occur in a single outburst, and that interactions between the ejecta and with the binary companion, combined with shadowing by the accretion disc, are significant in shaping the outflow.

Below: MERLIN 5GHz images of the slow classical nova V723 Cas.



Understanding the later stages of stellar evolution is important for our knowledge of stellar populations and the chemical enrichment of galaxies, as well as for the life cycles of stars. MERLIN has continued studying many types of solitary evolved stars during the reporting period.

Below: MERLIN 5GHz images of P Cygni.

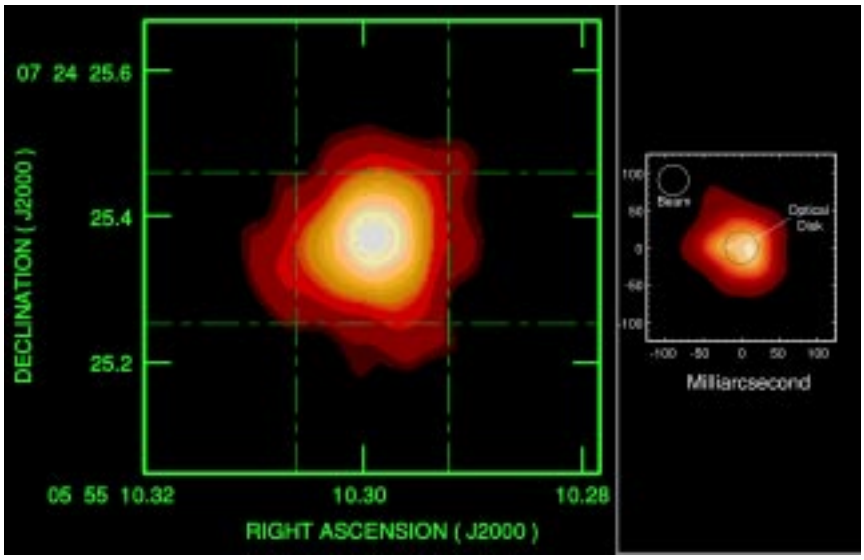


Further monitoring of the Luminous Blue Variable (LBV) star P Cygni has revealed that clumps in the wind structure vary on a timescale of a few days. These clumps are <90 AU in size and can change their flux density by ~20% in a week. This is too fast to be explained by the wind velocity of ~200kms^{-1} and may be due to recombination from small dense knots with high brightness temperatures.

MERLIN has been used to measure the size of the red giant star α Ori. At 5GHz, the radio emission is found to emanate from a region with a mean diameter three times the size of the optical photosphere. Furthermore, the emission is asymmetric. This asymmetry is also seen optically by the HST and is thought to be associated with spot activity. This may provide a key to understanding the clumpy, often axisymmetric winds from other red giants and supergiants.

Below: MERLIN 5GHz (left) and VLA 43GHz (right) images of α Orionis shown at the same scale.

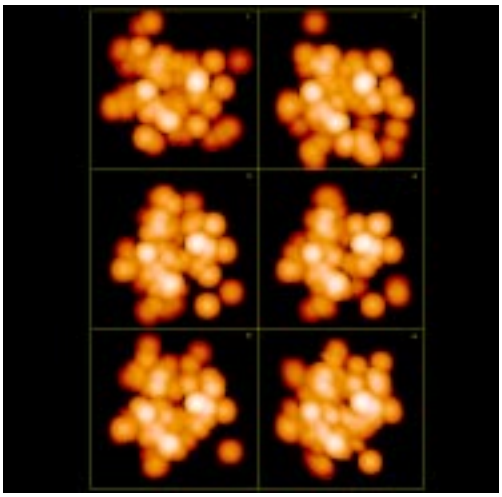
Maser emission is used to investigate the mass loss from red supergiants (RSGs), Asymptotic Giant Branch (AGB) and post-AGB stars on scales as small as an AU. MERLIN and the EVN have been used to monitor and image OH and H_2O maser emission from around a dozen objects. The combination of Doppler and proper motion measurements together with full polarisation imaging allows a complete 3-dimensional modelling of the stellar wind.

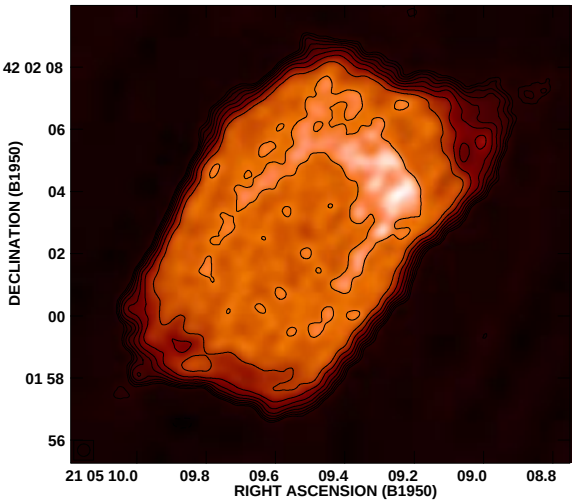


RT Vir is a solar mass Mira-like SRb star. Six epochs of monitoring H_2O 22GHz maser emission using MERLIN has shown the dramatic evolution of the wind over a ten-week period. Each clump in the wind is ~1-2AU in size. MERLIN OH mainline maser data have also shown a significant magnetic field to be present, implying that similar mechanisms may be shaping the winds in AGB stars as in red supergiant systems which are around ten times larger.

MERLIN has also been used to provide high angular resolution images of young planetary nebulae. At low resolution, the young planetary nebula NGC 7027 appears to be a smooth skewed rectangle. However, combining MERLIN and VLA data at 1.7GHz provides higher angular resolution and shows that the long edges have steeper flux gradients than the polar regions. Small-scale structure to the NW suggests that a collimated outflow has punched its way out of the shell at a slight angle to the long axis.

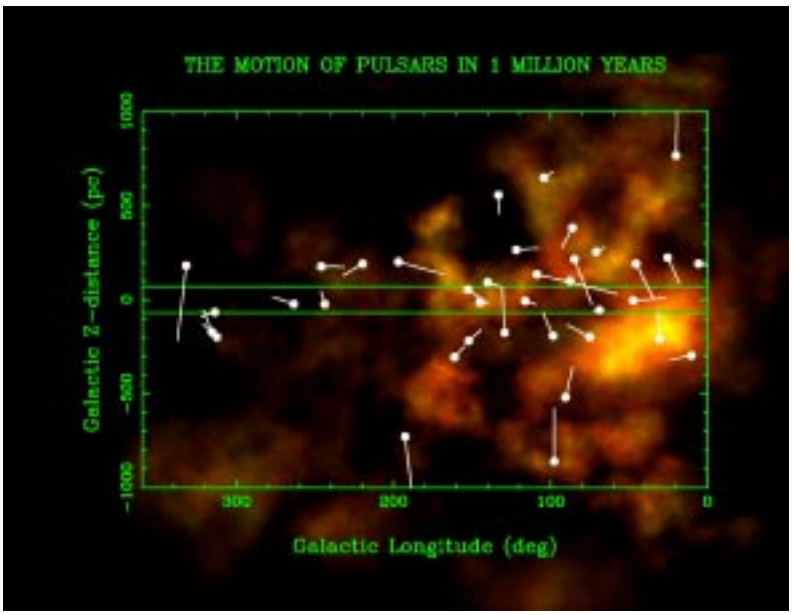
Below: (left) Six epochs of MERLIN 22GHz maser observations of RT Vir taken over ten weeks. (right) NGC 7027 MERLIN+VLA image.





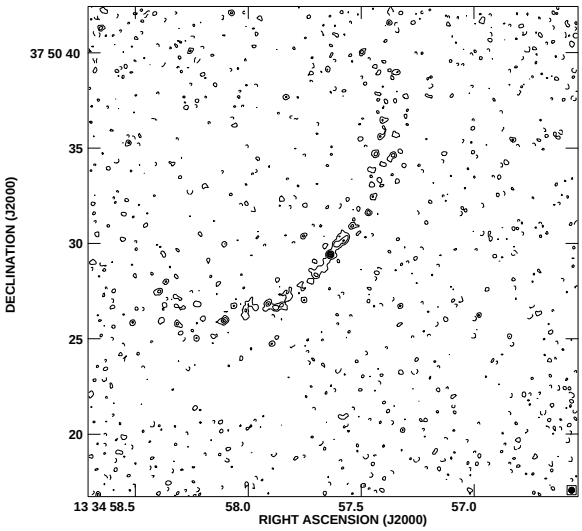
Pulsar Proper Motions

Pulsars are believed to be born with an energetic recoil resulting in high proper motions. Currently, the most accurate means to test this uses radio interferometry to measure their proper motions with respect to an extragalactic reference source. The proper motions of a sample of seven young pulsars have been measured with MERLIN over a three-year period. This involved measuring the phase difference between the pulsar and a reference source lying in the same antenna primary beam, so that the propagation and instrumental effects on the two sources were almost identical. The measured proper motions suggest more than half the sample had birth velocities ~450kms^{-1}. The results are also consistent with an RMS spatial velocity of the pulsar population of 300kms^{-1}.



Left: Pulsar proper motions measured by MERLIN. Dots show the current positions and the tails show the tracks of their motions during the last million years.

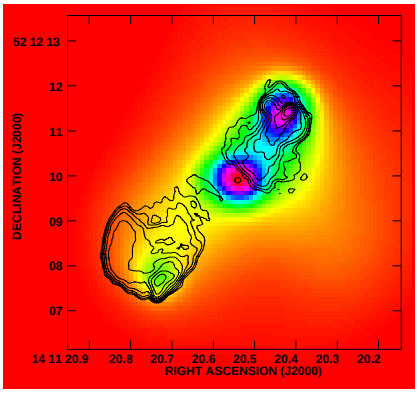
The XMM Deep Field & Other Radio-X-ray Comparisons



Above: A combined MERLIN and VLA image of a small region of the *XMM* Deep Field.

From its birth, radio astronomy has provided a window on the universe of extreme environments. The most startling discoveries have been the ubiquity of relativistic jets in contexts ranging from AGN to X-ray binaries (XRBs). During the reporting period the National Facility has continued to add to our knowledge of these spectacular objects.

A MERLIN Key Programme is investigating the relationship between mJy radio sources and the X-ray background. *XMM* observations of a 'quiet field' were made in 2000. This field, in the form of four adjacent pointing centres, has also been observed with MERLIN for 16 days. A MERLIN/VLA combination image gave an rms noise level ~7μJy/beam and showed that the weak X-ray emission is most often associated with Narrow Emission-Line Galaxies. The radio images will determine whether this originates from massive black holes or from starburst systems. One of the first radio maps shows a relatively bright 5-mJy AGN system associated with a faint optical galaxy which is the brightest member of a cluster. The compact 105-μJy AGN core component is clearly visible together with the inner parts of the curving radio jets, confirming that this is a classical head-tail radio galaxy.



Above: 1.4GHz MERLIN contours overlaid on the *Chandra* X-ray image of 3C295.

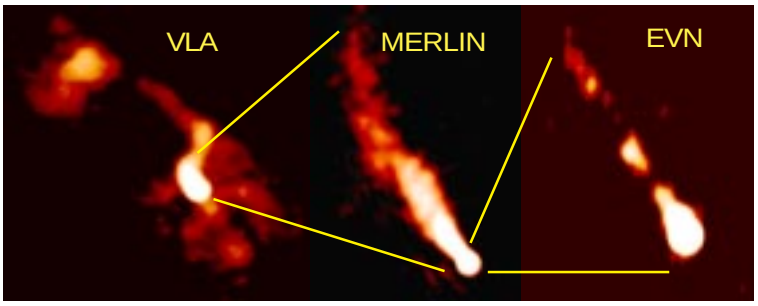
3C295 is a bright, compact DRAGN (Double Radio source associated with an AGN) at redshift 0.46 with a linear size of ~30kpc and a luminosity similar to Cyg A. The central peak in the *Chandra* image is probably X-rays from the AGN and the peaks close to the radio hot-spots are likely to be Synchrotron Self-Compton (SSC) emission. Comparing the MERLIN and X-ray maps results in an estimate of the magnetic field strength, which is very close to that predicted by the conventional minimum energy formula, only previously confirmed in a few cases, such as Cyg A.

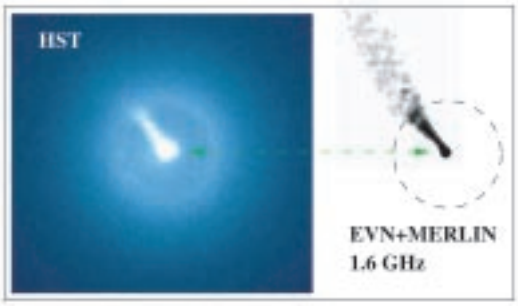
Understanding Jets Through Multi-Frequency, Multi-Scale Imaging & Polarimetry

Radio galaxies can be mapped over two orders of magnitude in linear size at multiple frequencies and in full polarisation using the VLA, MERLIN and VLBI. Such data have been used together with HST images and, notably, new *Chandra* data, to investigate proper motions and variability in young and/or superluminal AGN ejecta, the mechanisms for decelerating relativistic jets and the applicability of equipartition.

The VLA, MERLIN and the EVN have been used to image the radio-optical jet of 3C264 on sub-kpc to pc scales. The VLBI jet is one-sided, while the large-scale morphology shows 3C264 is a classical double radio source (type FRI), with evidence for interaction with a dense intergalactic medium. The optical ring encloses a region that appears to have been cleared of dust. The HST jet is remarkably similar to the radio image at a matching angular resolution, with an almost constant optical-radio spectral index over the whole ~400pc. The position of the optical ring (the dashed line on the EVN+MERLIN image) coincides with a change in the radio properties of the jet. The optical emission is most likely to be of synchrotron origin, but it is difficult to reconcile this with equipartition.

Below: Multi-scale radio observations of 3C264 and the HST image of NGC 3862, the host of 3C264.



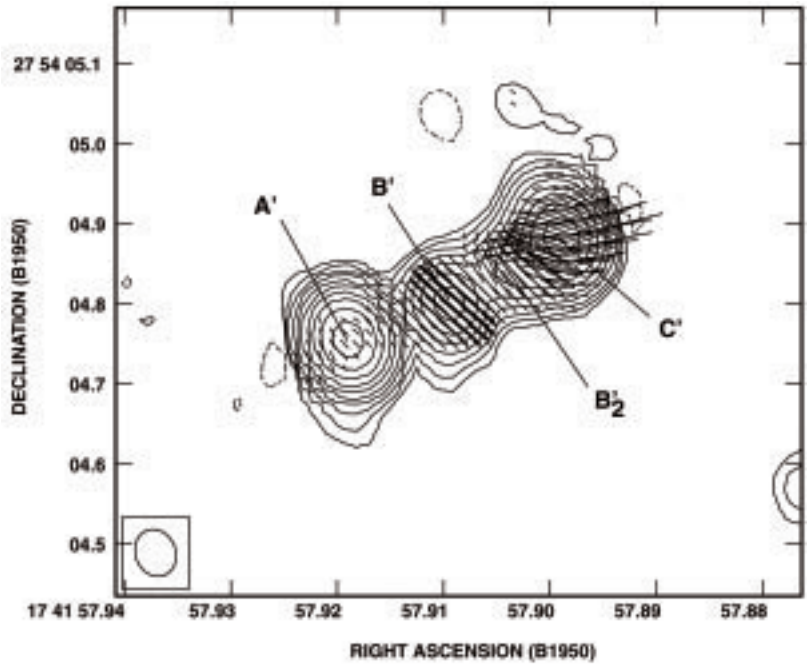


Compact Steep Spectrum Sources

The 'youth versus frustration' debate for the origin of Compact Steep Spectrum (CSS) sources continues, but observations such as those described below suggest that although the environment in which the sources are embedded has an effect which can occasionally be dramatic, such sources are in general young.

MERLIN observations of 50-80kpc radio sources have given some surprises. In 1741+279 and 1422+202, no depolarisation was detected and the low rotation measures in all the components with detected flux suggest a low level of interaction with the ambient medium. However, earlier VLBI observations had suggested that a north-south elongation of the western component represented a sharp cusp or bend in the jet at this point. The MERLIN polarisation images provide a beautiful confirmation of this suggestion with the electric vectors following the bend of the jet from an E-W direction to a Northerly direction. The most probable explanation is that the jet is running into dense material in the surrounding environment, which is somewhat at odds with the rotation measure data.

Below: MERLIN multi-frequency synthesis 5GHz image of 1741+279.



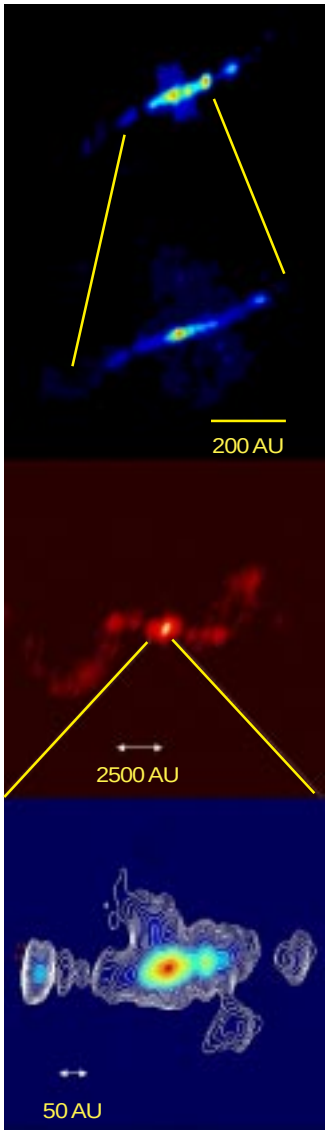
X-ray Binaries

X-ray binaries (XRBs) produce some of the highest energy photons within our own Galaxy. MERLIN has previously produced some excellent results by their study and observations of several systems have been continuing.

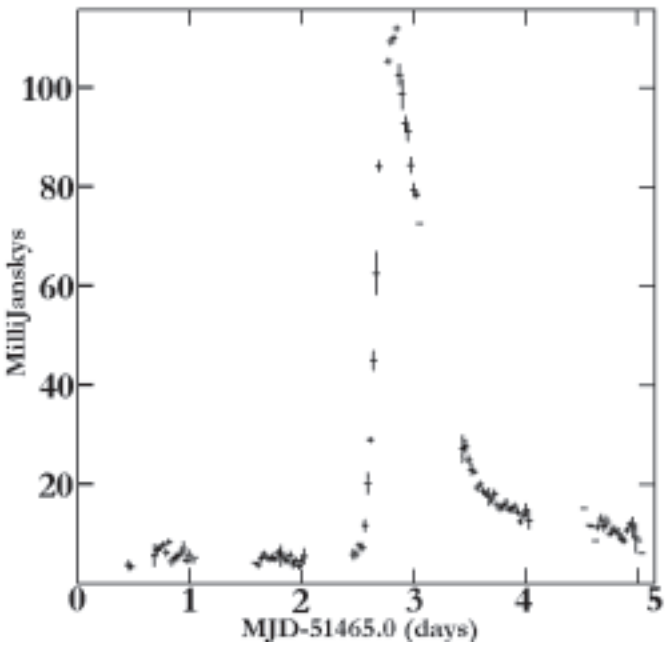
SS433 is the best-known XRB with approximately E-W jets expanding at 0.26c. Two independent groups have detected its unexpected N-S aligned extended region of equatorial emission. This was first suggested by VLBA observations in 1995, which revealed the existence of radio components perpendicular to the well-studied radio beams. MERLIN/global VLBI observations of SS433 confirmed the existence of this structure, sometimes referred to as the 'Elizabethan Ruff', which may be produced by a distinct mechanism separate from the ejection of plasmons along the precessing jet axes. This region might be related to an outflow in the orbital plane of the central binary system. The existence of such an outflow was indicated by observations in the optical and X-ray regimes also.

EVN monitoring of GRS 1915 during a minor flare also produced a surprise, in that no proper motions were detected, although assuming intrinsic symmetry the jet/counterjet brightness ratio suggests relativistic beaming in the velocity range 0.2-0.6c. During major outbursts it has apparently superluminal ejecta, but it seems that at other times moderately increased radio flux is due to continuous injection into a stable jet.

On October 11, 1999, the Rossi XTE satellite discovered a bright new transient X-ray source, XTE J1859+226. Subsequent X-ray observations revealed variability characteristic of an accreting black hole, and an optical counterpart was rapidly identified. Two days after the initial discovery, radio observations at 15GHz with the Ryle Telescope (RT) in Cambridge detected a radio counterpart subsequently confirmed with the VLA. A MERLIN ToO proposal was activated rapidly enough to capture the rise, peak and decay of a 100-mJy flare event in a few hours. Radio flares such as this almost certainly correspond to the ejection of large masses of high-energy electrons, probably at relativistic bulk velocities.



Above: 5GHz MERLIN+VLBA (top), 1.6GHz MERLIN (middle) and 1.6GHz global VLBI (bottom) observations of SS433.



Right: MERLIN monitoring of XTE J1859+226 at 1.7GHz capturing the rise, peak and decay of a 100-mJy flare event over a few hours.

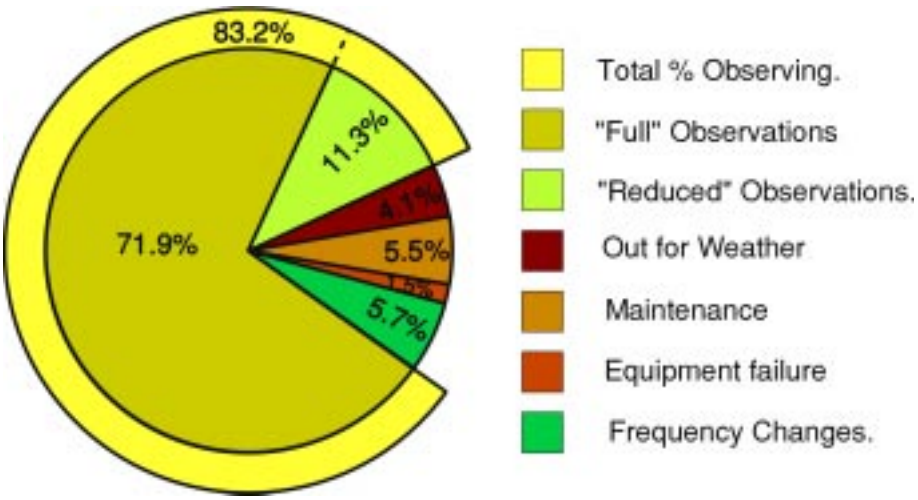
MERLIN OPERATIONS

Operating Period

The MERLIN target for operation is normally 24 hours per day for 9 months of the year except for a weekly maintenance period not exceeding 8 hours and the time required for PATT-requested frequency changes. During the remaining 3 months of the year, usually in the summer/early autumn, major mechanical maintenance work, painting of telescopes and development takes place. A frequency change also usually takes place during this 3 month period. During the two years covered by this report, the MERLIN Steering Committee authorised extensions of the summer maintenance period to four months, to facilitate major engineering works as part of the restructuring programme. Efficient scheduling of the engineering work held the actual down time to 3.8 months, 0.75 months of which was used for EVN observations by the Mk2 and Lovell telescopes. The frequency flexibility implemented as part of this engineering programme is already paying dividends when considering the number of K-Band astronomical programmes that are being completed. The new ability to switch almost instantaneously between C-Band and K-Band has resulted in more K-Band proposals being completed during the past 2 years than ever before. When one considers the appalling weather during these 2 years, this represents a major improvement in the operational efficiency of MERLIN. In the past it could have taken a few weeks to make this frequency change with no guarantee of good weather. With further investment, the benefits of frequency flexibility can be extended to include L-Band. This is already available on the Cambridge and Mk2 telescopes and will be implemented at Defford from Autumn 2001.

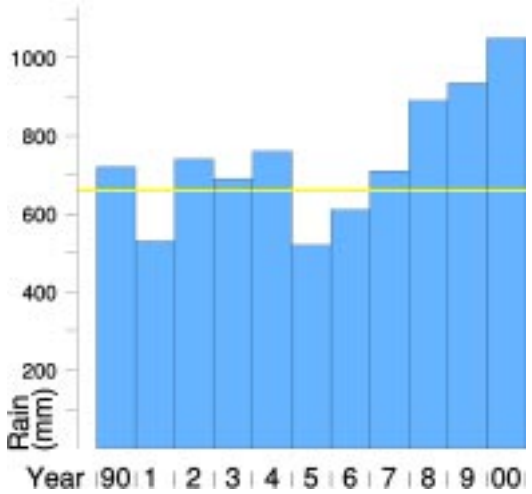
A summary of the operational status of MERLIN is given in the pie chart for the period of time which was available for observations during the Calendar years 1999 and 2000. Included in the time for maintenance is almost a day at the millennium, during which time MERLIN was not operated for safety reasons in case of possible computer or utility failure. As a result of a systematic and comprehensive programme to identify and correct potential Y2K faults, none occurred within the MERLIN system. The sector labelled 'reduced' observations indicates the sum total of short

Statistics



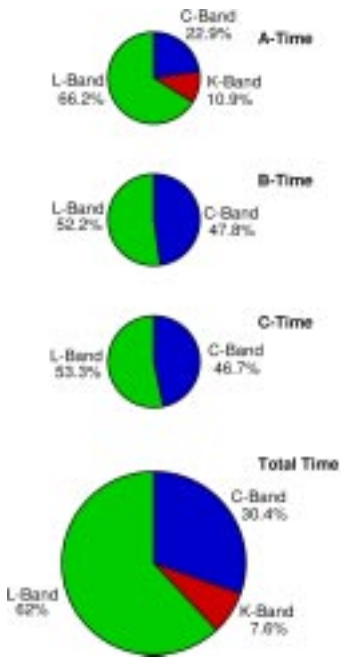
Left: Summary of the operational status of MERLIN during 1999 and 2000.

periods when some fault or bad weather affected or prevented the operation of a single telescope, the loss of which was not considered to have a significant effect on the final images produced other than a degradation in the signal-to-noise. This figure is significantly higher than in previous periods primarily due to 'teething' problems with the new drive system of the Darnhall telescope - the first to be replaced. Low-level faults continued to occur over many months before their cause was finally eradicated by the National Facility engineers in conjunction with the company supplying the drive system. It can be seen that, including this time, observations were made for 83.2% of the time. The 4.1% down time caused by weather is, as for the period of the previous biennial report, once again unusually high in comparison with that prior to the past four years. The highest ever recorded rainfall in 1998 was superseded in 1999, which in turn was further superseded in 2000, during which year it was over 400 mm above the yearly average at the Jodrell Bank site. Although rain does not prevent the actual operations of the telescopes, it does result in a degradation of observations at the higher frequencies.



Above: Rainfall figures for the Jodrell Bank site from 1990 to 2000.

During Semesters 99A, 99B, 00A and 00B, MERLIN has operated in its three main frequency bands; L-Band, C-Band and K-Band. The actual time spent in observations within each band has been set by astronomical demand as determined by the MERLIN Time Allocation Group, the EVN Programme Committee for the MERLIN+VLBI observations and, in the case of K-Band observations, the state of the weather. As indicated earlier, the value of the 'frequency flexibility' programme was demonstrated in the number of K-Band proposals completed, more than ever before. The apparent imbalance in the time allocated to the different observing bands has been due to three L-Band programmes classified as 'key-programmes' which required very deep integrations and hence a lot of time, and also to a greater demand for L-Band observations. However, it is already known that for the year 2001, C-Band proposals will dominate.



Of the programmes allocated time by PATT during 1999-2000, 92% of the A-priority and 86% of the B-priority were completed (Appendix B). Less than 100% completion of the L-Band programmes allocated time was primarily due to interference preventing observations at some frequencies corresponding to redshifted hydrogen. Interference at L-Band frequencies is increasing all the time, though it has recently been possible to have some of the interfering signals switched off for periods of time. Weather prevented the K-Band A-priority programmes from being completed. The adjacent pie charts show the distribution of actual observed time by observing band.

Above: Summary of MERLIN time allocations for each observing band and proposal rating.

The flexible scheduling policy for MERLIN means that a number of time-constrained observations, such as those of a new nova, can be made at short notice. The MERLIN Director also has at his disposal 2 days per Semester for observations of an immediate urgency. Such Target-of-Opportunity observations are provisionally allocated by PATT and, when made, are classified as A-priority observations and have been included as A-priority in the pie-charts.

VLBI OPERATIONS

The European VLBI Network (EVN) carries out VLBI observations which typically involve 9 telescopes from 6 European countries plus China. This array has a maximum baseline length of over 9000km, but is often used in conjunction with 10 or more other telescopes around the world to provide a Global Array with milliarcsecond resolution and sensitivity capable of imaging μJy radio sources.

The National Facility plays a key role in the EVN, with the Lovell Telescope providing one of its cornerstone large telescopes. Since all the telescopes are permanently staffed, the EVN can sustain the highest data-rate of any VLBI array, which in conjunction with its large telescopes makes it the most sensitive VLBI network in the world.

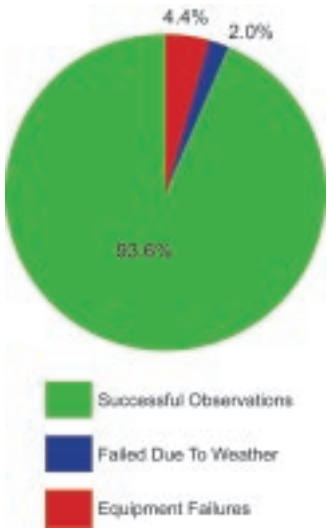
The EVN observations of the Hubble Deep Field (Garrett et al. 2001), carried out in November 1999, detected, for the first time, distant μJy radio galaxies with 20mas resolution.

In 1999 and 2000, the EVN operated four sessions per year, each for three to four weeks. National Facility telescopes participate in the vast majority of observations, except those at 7mm and 3.6/13cm. Except for the September sessions (when MERLIN is undergoing maintenance/development) all EVN sessions now include some joint MERLIN+EVN observations. Data from the Cambridge telescope are recorded on a second VLBI terminal, which results in the shortest EVN baseline between Jodrell Bank and Cambridge and also provides a common baseline between the two arrays. The combined array provides a unique capability in the world for imaging intermediate-sized sources (0.05 - 5 arcsec) at milliarsecond resolution.

The EVN Program Committee received 135 proposals in this period, of which 21 had UK PIs and a further 20 had UK co-Is. Twenty-five of the EVN proposals requested joint MERLIN+EVN observations. The oversubscription factor for the EVN is close to 2.

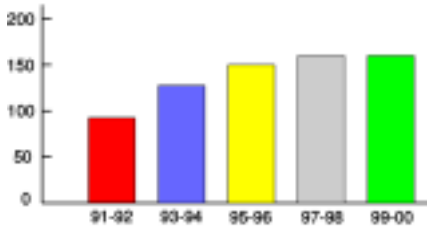
Due to fixed scheduling, and because there is no real-time feedback indicating that fringes will be found at correlation time, operational reliability is crucial for VLBI. Detailed checks and vigilant observing techniques are thus required. In the past, much of the VLBI observing at Jodrell Bank has been carried out by experienced staff and students, but during 2000 all of the MERLIN Telescope Array Controllers have been trained to carry out VLBI observations. The introduction of automated control and checking of almost all of the VLBI 'back-end' equipment has had a significant positive impact on the reliability of VLBI observations.

The EVN correlator at JIVE in Dwingeloo, formally opened in October 1998, produced its first scientific results in 1999, the detection of HI absorption in NGC 4261 on the Jodrell-WSRT baseline. The EVN correlator now correlates almost all EVN observations.



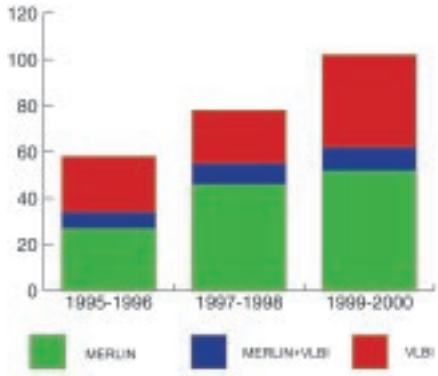
Above: Operational statistics for VLBI observations carried out by the National Facility.

STATISTICS



Above: The number of MERLIN proposals received in the period 1991-2000.

- During 1999 and 2000, the National Facility was in operation for an average of 8.2 months each year
- During the operating period, MERLIN observations were made for 83.2% of the time. A further 5.7% of the operating time was taken up by frequency changes requested by PATT
- 92% of MERLIN PATT Priority A observations and 86% of Priority B observations were completed successfully
- 160 proposals were received for the use of MERLIN during Semesters 99A, 99B, 00A and 00B. 86% of these had at least one UK proposer and 66% had UK PIs
- The number of MERLIN proposals received during Semesters 99 and 00 was very comparable with that in the previous 2 years. The 'oversubscription' factor was ~2.6
- During 1999 and 2000, 276 individuals were named on MERLIN proposals. 117 of these were based in the UK, from 26 different institutes
- Excluding JBO researchers, 33 separate MERLIN observers came to the National Facility to process their data during 1999 and 49 during 2000. Some came on more than one occasion. Particular visits were for as short as one day or as long as two months, with a typical duration of approximately 10 days. Data processing was also carried out by National Facility staff for 38 observers in absentia during the combined period 1999 and 2000
- The National Facility was scheduled to take part in 2328 telescope hours of VLBI observations during 1999 and 2000. The success rate was 93.6%
- During the period 1999 to 2000 the EVN programme Committee received 135 proposals, of which 21 had UK PI's and a further 20 had UK Co-I's
- The number of papers based on National Facility observations published in refereed journals has increased again during the period covered by this report. The average yearly publication rate now stands at ~50



Above: National Facility publications over the period 1995-2000. The bar chart excludes publications by National Facility Staff that do not contain observations resulting from National Facility telescopes (even the EVN if one of the National Facility telescopes has not been included in the array), or theoretical papers.

DEVELOPMENTS

Telescopes & Receivers

Telescope Control

A major part of the MERLIN Restructuring Grant to enhance the reliability of MERLIN was the replacement of the main axis drives on the three E-Systems telescopes together with their associated servo-control systems. The E-systems servo-control hardware has now been replaced on all three telescopes and the servo loop closed by their on-site computers, so removing a life expired system and thus improving system reliability. The replacement of the drive motors and associated power control systems were implemented for two of the telescopes in the summers of 1999 and 2000. The third is to be replaced during the summer of 2001. A Programmable Logic Controller (PLC) based system, located in the Pedestal Room of the telescopes as part of the monitoring and control of the drive system, has greatly reduced the wiring between the telescope structure and control room, thus ensuring improved system reliability. A working group has been looking at the phased replacement of the telescope control computers with new computer systems suitable for the greater role that they would be called upon to play in the additional control and monitoring of the Optical Fibre Link systems envisaged in *e*-MERLIN.

Above: New drive system for the E-systems telescopes.

Frequency Flexibility

Frequency flexibility, in particular the ability to switch quickly between C-Band (5GHz) and K-Band (22GHz) to take advantage of suitable periods of weather for K-Band observations, has now been achieved, with remotely controlled frequency changing in operational use on all 5 MERLIN telescopes capable of operating at K-Band. To this end, three nonstandard C-Band cryostats have been rebuilt to provide full interchangeability. The opportunity has also been taken to improve their sensitivity. A new focus box has been designed and built for the Defford Telescope. This will allow almost instantaneous switching between L-Band (1.3 to 1.7 GHz) and C-Band receivers. As the new box (and contents) will be substantially heavier than the existing (single frequency) box it has been necessary to assess its effect on the structure of the telescope, design and build new hoisting arrangements and obtain new certification for the entire focus box handling system.

Above: Building the new Defford dual band focus box.

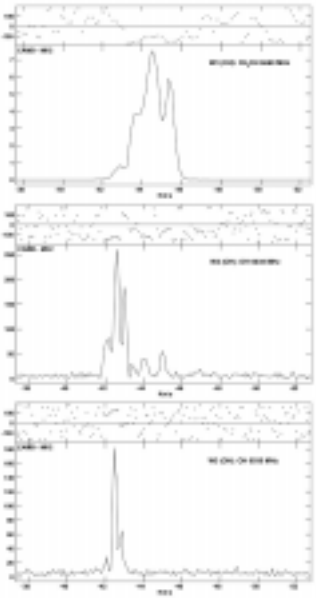
L-Band Lens

At present, the L-Band feeds on the E-Systems telescopes are mounted at the prime focus. To allow full frequency flexibility they will need to be mounted on the carousel at the secondary focus. However, it is not possible to mount a sufficiently large feed to illuminate the secondary reflector efficiently so a lens will have to be incorporated into the feed system. The lens will be mounted on a swing arm at the side of the carousel and swung into position when the L-Band observations are made. Development work on the design of a suitable lens and the associated feed horn is taking place and tests have been made using a small prototype system scaled to K-Band.

Above: Scaled L-Band horn and lens.

Methanol Receivers

To enable Jodrell Bank Observatory to take part in VLBI methanol observations, a room temperature methanol receiver for the Mk2 telescope had been produced at very low cost. This receiver has now been improved by replacing the LNAs to give an estimated noise temperature of 75-85K. In a further development, a cooled receiver with an estimated noise temperature of 35-40K has been completed for the Cambridge 32m telescope. Both the Mk2 and Cambridge telescopes are therefore available for VLBI methanol observations, a considerable enhancement to the system. The Cambridge - Jodrell Bank baseline can also be used independently for both methanol and excited OH detection and astrometric measurements. Some of the first results using these receivers are shown opposite. Many MERLIN observations have already been proposed for the use of this new system in Semester 01A.



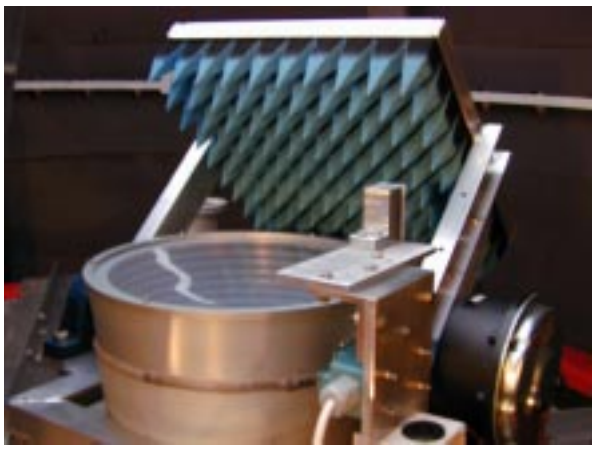
Above: MERLIN spectra of excited-state OH at 6030 and 6035MHz (bottom two frames) and methanol at 6668MHz from W3(OH).

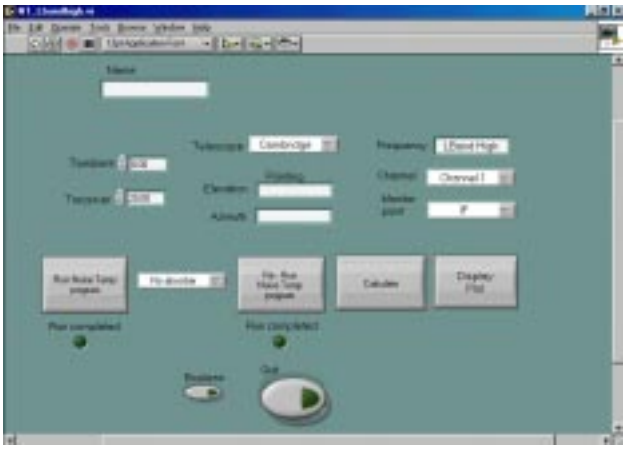
Receiver Remote Diagnostics

Limited monitoring and diagnostic information for the receiver in use at each MERLIN outstation is sent back over the telephone landline used for telescope control. However, in the event of a receiver fault, it is often necessary for engineers and/or technicians to visit the remote site (the furthest being 160 miles away by road) in order to determine the cause. Once diagnosed, a second visit is commonly required. Recently, a comprehensive remote diagnostic system for the MERLIN receivers, based on National Instruments LabVIEW software, has been developed and a prototype system installed at the most distant site - Cambridge. This allows engineers and technicians to perform a range of investigations and measurements on the telescope receivers from JBO, or from any location with a telephone line, simply using a PC and modem. The system provides a number of measurement facilities which were previously only available to engineers and technicians visiting the remote sites. These include spectrum analysis of the receiver pass bands, measurements of the system noise temperature, system sensitivity, antenna gain and system power stability. There are substantial benefits of this scheme: causes of faults can be determined remotely, allowing repairs to be carried out more efficiently, and so reducing the number of costly site visits; routine testing of receivers is made very easy, allowing faults to be picked up early and facilitating the detection of degraded receiver performance.

Below left: The mechanical absorber arm mounted on the 5 GHz feed at Cambridge. This is used for noise temperature measurements and is rotated away when not in use.

Below right: Example front panel of a LabView program. Once the user has chosen from various options on the panel, the program calculates and displays the results.





Control & Observing Room Integration

The (renamed and regraded) Telescope Array Controllers have already made significant contributions to both MERLIN and VLBI operations and this experience has been used to assess the additional displays, alarms, security measures, etc. needed to ensure efficient, safe and secure operation. Detailed plans have been developed for the creation of the Extended Control Area, which will form the Controllers' future working environment, and this will be implemented during summer 2001. An internal retraining programme has been established to give the Controllers the additional skills they need as their new role develops. Software developments to support this reorganisation are in hand.

VLBI Developments

The MKIV - VLBA tape recording system upgrade has been completed over a period of approximately four months in a European collaborative effort. A Formatter was supplied by external contractors and tested by colleagues at the Max Planck Institute for Radioastronomy in Bonn. The recorder read/write electronics were supplied by the Metsahovi Observatory, Finland, in a partly assembled form. These have been completed, installed and tested as have the head drivers which have been built up from components at Jodrell Bank Observatory. The upgrade increases the recorded data rate from 128 Mbit/sec to 512 MBit/sec and thus provides a factor of two increase in sensitivity. Fringes have been obtained from data recorded with the finished system during the most recent VLBI session.

There have been two major initiatives to increase operational reliability:

(1) A program to automate the switching of intermediate frequency (IF), local oscillator (LO) and calibration (CAL) signals between single-dish, MERLIN and VLBI observations. This has required the construction of active splitter units, LO and CAL switches and computer-controllable filters along with development of suitable control software. The system has substantially reduced the need to carry out re-routing of cables when observations change, thus helping to elimininate a possible source of error which could cause failure of the VLBI observations.

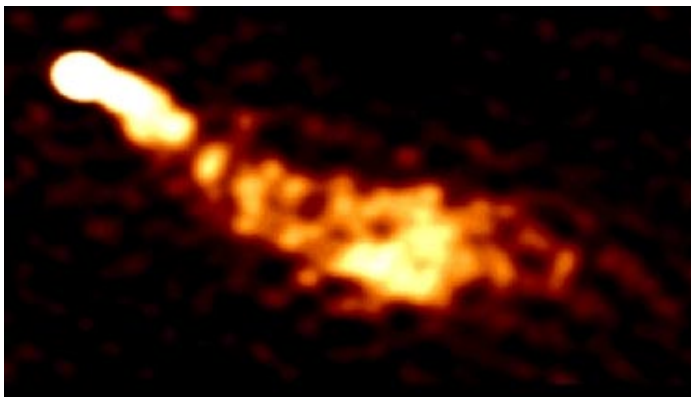
(2) The antenna control and monitoring software for the VLBI 'Field System' at Jodrell Bank has been redesigned and reimplemented to produce a much more robust and better-integrated control system which includes additional checks and monitoring of antennae and receiver/LO hardware. Additional computer-based monitoring and control procedures have allowed relatively complex receiver setups to be pre-programmed, so reducing operator intervention and possible consequent errors.

In addition, the VLBI operations team have been working closely with the Telescope Array Controllers to enable them to play a major role in the supervision of day-to-day observations and tape changing. This is providing continuity in the running of the VLBI system and greatly helping in the smooth running of the observing sessions.

Above: A VLBI technician installs the Mk IV recording upgrade.

MERLIN Data Archive

MERLIN, like almost all other major national facility telescopes, has a policy of placing data in the public domain roughly one year after the observations are taken. Over the last few years, the use of archive data from optical, IR and X-ray telescopes has grown enormously, thanks to the web-based archive browsers and sufficiently fast connections to allow users rapid access to the images.

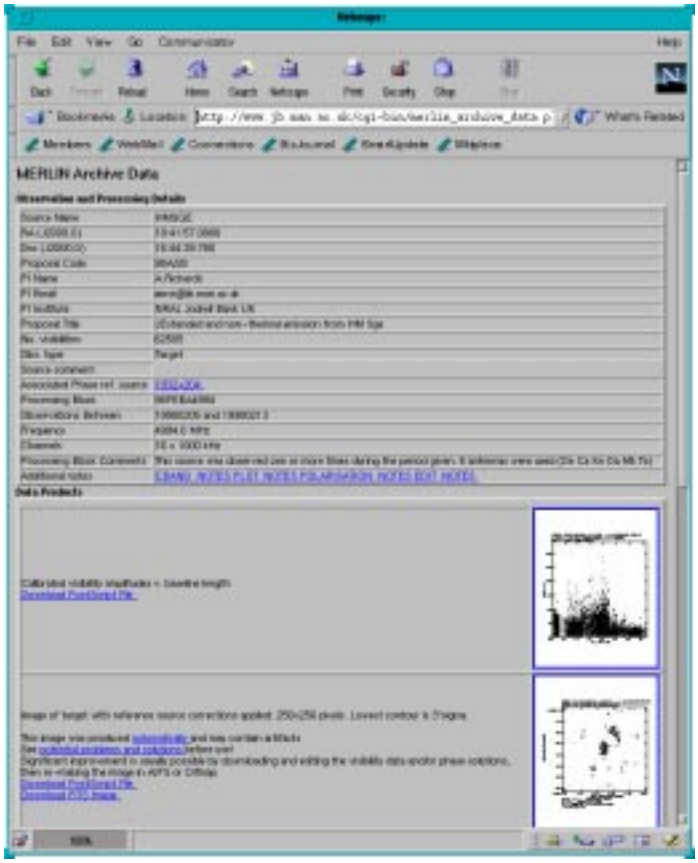


Above: 3C371 image recently made with MERLIN archive data by Cheung et al.

However, the hurdle of reducing the raw data as archived for radio interferometers like MERLIN, the VLA or the EVN, means that only the most committed users make use of archive data. Over the last two years, we have therefore started a project to make all MERLIN continuum data available via a simple web browser both as processed images and calibrated datasets.

The calibration and production of reference images is done by a semi-automatic pipeline (in order that intelligent editing of the data can be done). These reference images are not designed for publication (although in many cases the image quality is perfectly adequate) but primarily for archive users to make a quick decision on whether to download or request the calibrated visibility data and produce an image which meets their requirements. The pipeline process retains the data in their original multi-channel form in order to maximise the field of view available for future serendipitious use. The MERLIN Archive web pages (http://www.merlin.ac.uk/archive) allow users to search for archive data in various ways and allow preview images to be retrieved in various formats.

Below: Example of web-based access to the new MERLIN data archive.



The MERLIN Archivist also supports idividual requests for data. Cheung et al. obtained MERLIN archive data to support analysis of an X-ray jet in the blazar 3C371 newly discovered by *Chandra*. This continuum image, showing a radio jet extending for more than 5kpc to the west, goes much deeper than any published radio map of 3C371. These data were originally taken in order to map HI absorbtion in the central regions.

Jodrell Bank is now a partner in AVO and AstroGrid. Work done as part of these projects will concentrate on interoperability issues of using radio aperture synthesis data and on-the-fly imaging to allow archive users to produce small images from large visibility datasets held at Jodrell Bank.

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.

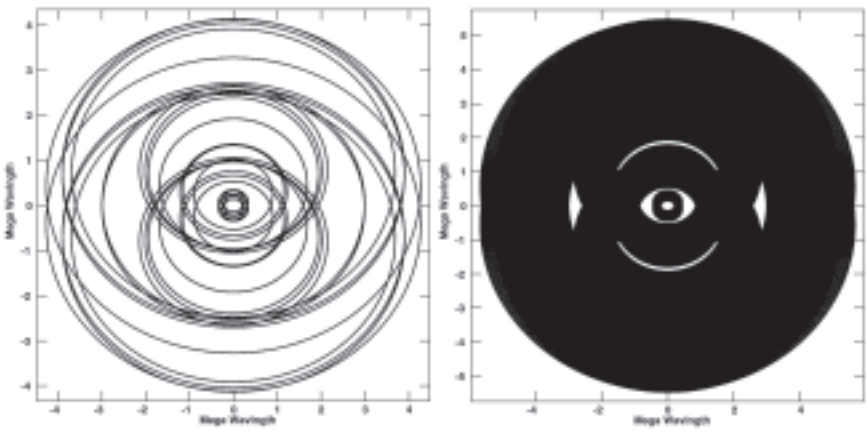
The cost of the sensitivity upgrade is estimated at £8.6M, which includes the funding of the additional manpower required to implement the project, VAT and a 10% contingency budget. The timescale for the upgrade is ~5 years from funding to completion. The full science case and a summary of the technical 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.

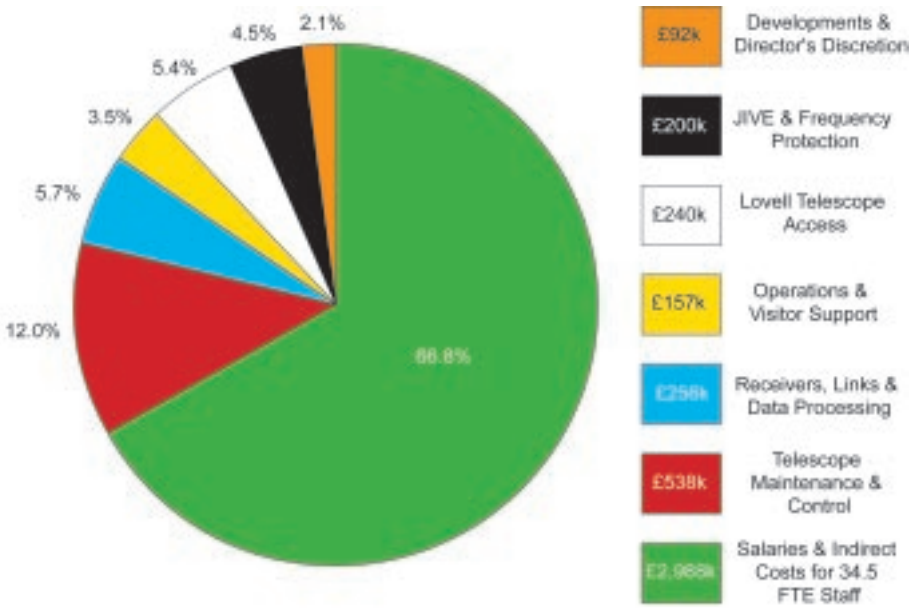


FINANCES

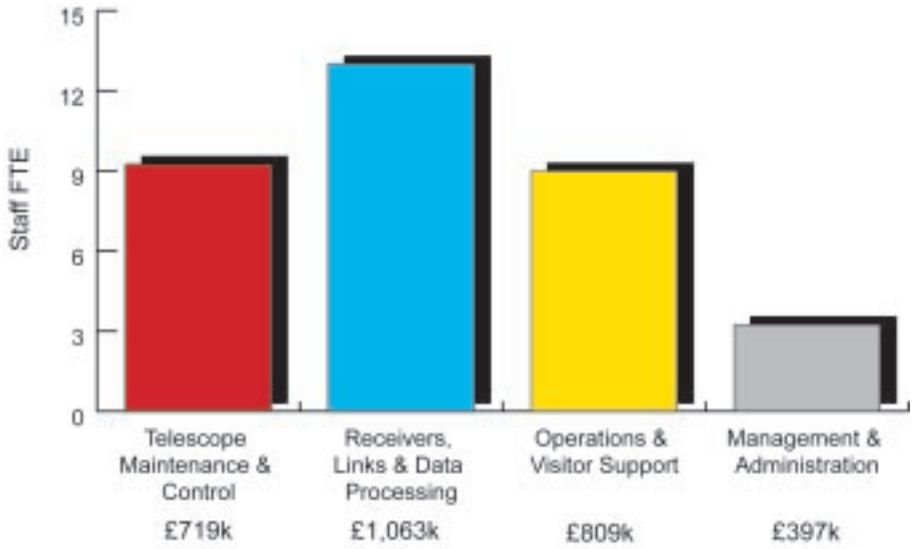
The operation of MERLIN and VLBI as a National Facility is funded by a special rolling grant awarded by PPARC to the University of Manchester. The grant holder is Professor A. G. Lyne, the Director of Jodrell Bank Observatory, and the value of the current award is £4,471,288 for the period October 1999 to September 2001. The disposition of the budget is shown below, together with a breakdown of staff support by activity area. Specific provision is included within the grant for the UK contributions to the cost of VLBI support activities at JIVE, the employment of a European CRAF frequency protection manager and the temporary appointment of a MERLIN data archivist.

PPARC Research Grant
PPA/G/O/1998/00687

Spend Profile



Staff Activity



The National Facility is now benefitting from infrastructure improvements funded by a special £996,066 restructuring grant, the work programme of which will be completed in September 2001.

PPARC Research Grant
PPA/G/O/1997/00189

APPENDIX A

National Facility Committees & Personnel (31/12/00)

NATIONAL FACILITY STEERING COMMITTEE

Professor M. J. Barlow* (Chairman)
University College London

Dr S. A. Eales
University of Wales, Cardiff

Dr J. A. Yates
University of Hertfordshire

Dr S. Rawlings
University of Oxford

PPARC Secretary: Mr A Thompson

*To be superseded in 2001 by Professor M. F. Bode, Liverpool John Moores University

PATT MERLIN TIME ALLOCATION GROUP

Dr S. A. Eales (Chairman)
University of Wales, Cardiff

Dr R. J. Cohen
University of Manchester

Dr G. G. Pooley
University of Cambridge

Professor T. P. Ray
Dublin Institute for Advanced Studies

TAG Secretary: Dr T. W. B. Muxlow
(MERLIN National Facility)

The National Facility employs 33.5 FTE staff, with currently an additional data archivist and two temporary staff working on the restructuring programme. Some of the personnel listed opposite spend only part of their time on National Facility activities.

NATIONAL FACILITY PERSONNEL

Management & Administration 3.25 FTE

Dr P. J. Diamond	National Facility Director
Dr J. A. Battilana	Chief Engineer
Dr D. Stannard	Scientific Administrator
Mrs J. Eaton	Personal Assistant to JBO Directors
Mrs S. M. Freer	Accounts Administrator

Telescope Maintenance & Control 9.25 FTE+1.0 restructuring

Mr R. J. Comber	Engineer (telescopes)
Mr G. J. Kitching	Experimental Officer (mechanical engineering)
Mr C. J. Scott	Telescope Maintenance Supervisor
Mr J. Bartle	Telescope Fitter
Mr D. T. Clarke	Telescope Fitter
Mr P. Clarke	Telescope Fitter
Mr F. P. Manning	Electrical Supervisor
Mr J. B. Newton	Electrician
Miss A. M. Bayley	Systems Programmer
Mr I. D. Freer	Senior Controller & Control Supervisor
Mr C. I. Mance	Control Technician
Mr J. Dyer	Control Technician

Receivers & Links 7.0 FTE

Mr N. Roddis	Engineer (receivers)
Mr E. J. Blackhurst	Receiver Technician
Mr J. A. Edgley	Receiver Technician
Mr D. Lawson	Receiver Technician
Mr C. D. Baines	Senior Experimental Officer (cryogenics)
Mr J. W. Marshall	Cryogenics Technician
Mr M. H. Butlin	Engineering Technician
Dr M. Bentley	Senior Experimental Officer (links)
Mr A. Blackburn	Links Technician

Signal & Data Processing 6.0 FTE + 1.0 restructuring

Mr I. Morison	Engineer (operations)
Mr D. C. Brown	Senior Experimental Officer (digital)
Mr P. Burgess	Senior Experimental Officer (VLBI)
Mr L. R. Parry	Digital Technician
Dr A. J. Holloway	Systems Manager
Dr C. A. Jordan	Systems Programmer
Mrs B. V. Hancock	Computer Assistant
Dr R. G. Noble	Senior Experimental Officer (developments)
Mr E. Troup	Systems Programmer

Operations & User Support 8.0 FTE + 1.0 Archivist

Dr P. Thomasson	MERLIN Manager
Dr S. T. Garrington	Senior Experimental Officer (operations/VLBI)
Dr T. W. B. Muxlow	Senior Experimental Officer (operations)
Dr A. G. Gunn	VLBI Support Scientist
Dr A. M. S. Richards	Archivist
Mr A. MacKay	Telescope Array Controller
Mr A. M. Howson	Telescope Array Controller
Dr M. W. Asif	Telescope Array Controller
Mr I. J. Manfield	Telescope Array Controller
Mr M. E. Roberts	Telescope Array Controller
Mr D. A. Wynn	Telescope Array Controller

APPENDIX B

MERLIN Observations in Semesters 99A to 00B

Categories For Approved Time

The MERLIN Time Allocation Group (TAG) awards time in the following categories:

A and TO: Highest Priority - Observations are not guaranteed, but in the past all of the observations in this category have usually been completed. TO time is for Target of Opportunity observations. Should these not arise they are covered by additional B priority time.

B: Lower Priority - No commitment is given to complete observations in this category, though a significant number are usually observed. For certain projects, this may include observations with a subset of the MERLIN array.

C: Fill-in - Short observations of a few hours duration for projects in this category may be used to fill scheduling gaps in the A and B programme.

A time is allocated for 80% of the contracted time within a semester when all MERLIN antennas are available and after provision has been made for National Facility EVN commitments and any agreed outstanding engineering programmes.

Observing Success Rate - Semesters 99A to 00B

Runs Observed / Runs Approved	A-Time	B-Time	C-Time	TO-Time
L-band	162/176 (92%)	47/60 (78%)	16	20
C-band	44/44 (100%)	43/45 (96%)	14	19
K-band	30/36 (83%)	-	-	-

Programmes for MERLIN Semester 99A

Project	TITLE	P.I.	L-Band	C-Band	K-Band
99A/01	Do Supernova Remnants Survive in Super Star Clusters? The Case for NGC1569	A. Greve	1A	1A	
99A/02	Observations of Stephan's Quintet	E. Xanthopoulos	2A	1B	
99A/03	Co-ordinated Interplanetary Scintillation Measurements of Solar Wind Acceleration	A. Breen	Scans on 0318+164		
99A/04	OH Maser Observations of R Cas & R Aql	K. Justtanont	2B		
99A/05	Spectral Index Maps of kpc-Scale Flat-Spectrum Sources	P. Augusto	1A		
99A/06	Monitoring & ToO Observations of Classical & Recurrent Novae	M. Bode	1TO	1TO	
99A/07	Large-Scale Structure in the Outer Wind of ε Ori	R. Prinja		3A	
99A/08	Observations of the Expanding Remnant in CI Cam	A. Mioduszewski	1TO	2TO	
99A/09	Combined Radio/X-Ray Observations of SS433	C. De la Force	3TO		
99A/10	Full Polarization Mapping of Circumstellar OH Shells	M. Szymczak	5A		
99A/11	A Deep Radio/Submillimetre Survey	S. Eales	6A		
99A/12	Further Observations of the Plateau of GRS 1915+105	G. Pooley	3TO	3TO	
99A/13	Continuum Observations of Young Planetary Nebulae	M. Bryce	2A		
99A/14	Symbiotic Stars: Component Motions & Stellar Positions	S. Watson	2B	3B	
99A/15	C & L Band Imaging of OH Masers in Cep A	M. Szymczak	2A+C	1B+C	
99A/16	Imaging the Possible Accretion Torus in NGC2110	C. Mundell		1B	
99A/17	A New Optically-Bright CLASS Lens	N. Jackson	1A	1A	
99A/18	Non-Thermal Components in Radio-Quiet Quasars	N. Jackson	6B		
99A/19	Continuum, OH & HI Line Observations of PKS1830-211	L. Coopmans	1A	1A	
99A/20	Supernova Remnants in NGC4490; A 'Young' Galaxy	M. Clemens	2A	1B	
99A/21	Radio Structures of Narrow Line Seyfert 1s	D. Law-Green			
99A/22	Imaging of X-Ray Luminous Starburst Galaxies	D. Law-Green	6B		
99A/23	CSS Sources in a Fainter Complete Sample	M. Lacy		1B	
99A/24	Lensing in a Complete Sample of Steep-Spectrum Radio Sources	M. Lacy	3A		
99A/25	0850+331 – A Weak CSS with a Precessing Jet	A. Marecki			
99A/26	Imaging the OH Maser Shells Around PPN Objects	T. Gledhill	10A		
99A/27	Reobservation of HI Absorption in 3C293	A. Pedlar	1A		
99A/28	Studies of Selected Seyferts at 20cm	A. Thean	5B+C		
99A/29	MERLIN Observations of Ultraluminous IRAS Galaxies	K. Wills	5B+C		
99A/30	6cm Observations of SNR in M82	K. Wills		1B	
99A/31	H & OH Absorption Against the Starburst in NGC2146	A. Tarchi	2A		
99A/32	1.6 & 5GHz Observations of the Starburst Galaxy NGC2146	A. Tarchi	C	C	
99A/33	Sub-mJy Radio Galaxies & The X-Ray Background	I. McHardy	8A+2B		
99A/34	Search for a Central Star in the Class 0 Source S106 FIR	R. Furuya		C	
99A/35	Towards a Detailed Understanding of Symbiotic Novae	A. Richards		2B	
99A/36	Mapping Excited OH Masers Close to Late-Type Stars	A. Richards		2A+2B	
99A/37	OH MERLIN Observations of the Binary Mira Star O Cet	E. Gerard	1A		
99A/38	OH Maser Polarimetry of S Persei	J. Yates	2A		
99A/39	A Deep MERLIN Survey of the Orion Nebula	J. Meaburn		8A	
99A/40	OH Masers in SS433 Sprinkling Disk	A. Stirling	1A		
99A/41	Thermal & Non-Thermal Behaviour in WR147	S. Watson			
99A/42	Radio Burst Observations of Extra-Solar Planetary Systems	Y. Shiratori			
98B/18	Sakurai's Object - A Star Undergoing a Final Helium Flash	S.Eyres		4TO	
99A/A	1237-101	P. Barthel	0.5Dir		
99A/B	G111.8	M. Bryce	0.5Dir		
99A/C	NGC0253	A. Pedlar		2x0.2Dir	
99A/D	0957+281	P. Wilkinson		0.6Dir	

Programmes for MERLIN Semester 99B

Project	TITLE	P.I.	L-Band	C-Band	K-Band
99B/01	MERLIN & HST Observations of Symbiotic Stars	M. Crocker	6A	4A	
99B/02	A Jet in the Sombrero?	M. Fihlo			
99B/03	Eclipse Mapping of Active Binary Stars	A. Gunn			
99B/04	Radio Jets and Dynamics of FRII Radio Sources	G. Pooley		C	
99B/05	Jets & Masers in YSOs	P. Diamond			2A

99B/06	High-resolution Mapping of H_2O Masers in AGN	Y. Hagiwara			
99B/07	Jet Evolution in Nearby FR1 Radio Galaxies	S. Baum			
99B/08	The Nature of Low-Luminosity AGN	N. Nagar	5A		
99B/09	The Origin of H-α Shells in NGC4449	M. Clemens	1A	1A	
99B/10	A Second Epoch Observation of the Massive YSO S140 IRS 1	M. Hoare		1A	
99B/11	A High Resolution Study of Massive YSO with a Methanol Maser Disk	M. Hoare			1A
99B/12	Imaging of X-Ray Luminous Starburst Galaxies	D. Law-Green		C	
99B/13	Resolving the Synchrotron Jet in W3-H_2O	A. Gibb		1A	
99B/14	Relativistic Ejections From X-Ray Transients	R. Fender	6TO (Any Band)		
99B/15	Identification of Cores In Compact Symmetric Objects	P. Augusto			
99B/16	MERLIN/VLBA Monitoring of WR140	A. Beasley			
99B/17	A Pilot Study for Astrometry of Stars with Water Masers: U Her	W. Vlemmings			1A
99B/18	Mapping the Winds of Four Stars in CYG OB 2	G. Umana			
99B/19	4.7 GHz OH Maser Outburst in W 75N	M. Szymczak		1A	
99B/20	A Search for 22GHz H_2O Maser Emission From PPN Objects	T. Gledhill			2A
99B/21	Evolution of Circumstellar H_2O Masers in Miras & SRs	J. Yates			5A
99B/22	Evolution of H_2O Masers in the CSE of Red Supergiants	J. Yates			
99B/23	22 GHz Masers & Continuum in Seyfert 2 Galaxies & LINERs	E. Xanthopoulos			4A
99B/24	22 GHz Masers & Radio Continuum Observations of Miras	A. Richards			
99B/25	Velocity Variations of H_2O Masers in Star-forming Regions	A. Richards			
99B/26	Targets of Opportunity: Classical & Recurrent Novae	S. Eyres		4TO(C or K)	
99B/27	Symbiotic Stars: Observations of HST Snapshot Targets	S. Eyres			
99B/28	Monitoring of the Slow Nova V723 Cas	S. Eyres			
99B/29	Imaging the H_2O Masers in S68 FIRS 1	J. Yates			1A
99B/30	HI Absorption Observations of OH Megamaser Galaxies	A. Polatidis	5A		
99B/31	TO Observations of New X-ray Transients	R. Ogley			
99B/33	Multi-wavelength Observations of Cyg X-3	R. Spencer			
99B/34	Combined Radio/X-ray Observations of SS433	C. de la Force	3B		
99B/35	Further Observations of the Plateau State of GRS1915+10	G. Pooley	3TO(Any Band)		
99B/36	A High-Resolution L-Band Image of NGC1275	M. Donahue			
99B/37	A Search for Compact Luminous SNR in Nearby Galaxies	K. Wills	1A+3B		
99B/38	Follow-up of 6" to 60" Lens Candidates	P. Phillips	3B		
99B/39	A Variable Radio Core in Markarian 3?	G. Cole			
99B/40	Using Supernova Remnants to Calibrate SFRs in Galaxies	A. McDonald	9B	3B	
99B/41	Origin of Non-Thermal Emission in O-Stars	S. Dougherty		5B	
99B/42	Time-Resolved Coronal Observations of ER Vul	R. Osten	3A		
99B/43	Two Component Radio Structure in WR146?				
99B/44	Radio Imaging of Star Formation in Distant Galaxies	E. Richards	17A		
99B/45	The Proper Motions of Young Pulsars	N. McKay	9A		
98B/18	Sakurai's Object - A Star Undergoing a Final Helium Flash	S. Eyres		4TO	
99A/11	A Deep Radio/Submillimetre Survey (Lovell)	S. Eales	10A		
99A/33	Sub-mJy Radio Galaxies & The X-Ray Background	I. McHardy	8A		
99B/A	SN1999EB	K. Wills	2Dir (Commissioning)		
99B/B	3 Source Snapshots	K. Blundell	1Dir		

Programmes for MERLIN Semester 00A

Project	TITLE	P.I.	L-Band	C-Band	K-Band
00A/01	Acceleration of the Solar Maximum Solar Wind	A. Breen		2A	
00A/02	Observations of the 1720MHz OH Masers in IC443	M. Claussen	1A		
00A/03	Sakurai's Object – A Star Undergoing a Final Helium Shell Flash	S. Eyres		4TO	
00A/04	Relativistic Ejections X-Ray Transients	R. Fender	6TO(Any Band)		
00A/05	Young Radio Sources in the Nearby Universe	I. Snellen			
00A/06	Combined Radio/X-ray Observations of SS433	C. de la Force		1A	
00A/07	Study of the Kinematics of OH Masers Around RT Vir	K. Murakawa	1A		
00A/08	MERLIN Studies of HI Absorption in Starbursts	A. Pedlar	5A		
00A/09	Location of the Core in Three CSSs	F. Mantovani			
00A/10	Is Free-Free Absorption in Seyferts Common at 20cm?	A. Pedlar			
00A/11	OH Maser Emission From Low Mass Protostars	T. Gledhill			
00A/12	Probing the Structure of AG Draconis	R. Ogley		1A	

00A/13	Multi-Frequency Synthesis Observations of B1938+666	A. Biggs			
00A/14	Classical & Recurrant Novae: Targets of Opportunity	S. Eyres		4TO	
00A/15	A Double OH Maser Shell Around 15540+0910	B. Lewis			
00A/16	Does the Magnetic Field Shape AGB and SG Outflows?	A. Richards			
00A/17	Follow-up of Gravitational Lens Candidates	J. Winn		5B	
00A/18	H_2O Masers in Protoplanetary Disks	J. Gallimore			4A
00A/19	Exploring the Nature of the SCUBA Galaxy Population	J. Dunlop			
00A/20	Circular Polarization Studies of SS433	A. Stirling		2B	
00A/21	Multi-epoch Imaging of the Symbiotic Star CH Cygni	M. Crocker			
00A/22	Linear Polarization Studies of SS433	A. Stirling			
00A/23	A Survey of DRAGNs at High Redshift	M. Sandell			
00A/24	High-resolution Mapping of the Jets in 3C31	R. Laing	1A		
00A/25	A Radio Search for Compact Supernova Remnants	K. Wills	1A		
00A/26	The 'Plateau' State of GRS 1915+105	G. Pooley	2TO(Any Band)		
00A/27	The Nature of Radio-Intermediate Quasars	M. Lacy			
00A/28	Final MERLIN Observations of CLASS Lens Candidates	M. Norbury		2A	
00A/29	Imaging of X-ray Luminous Starburst Galaxies	D. Law-Green		4B	
00A/30	HD 125858: Possible Planetary Companion?	D. Law-Green			
00A/31	Symbiotic Stars: Observations of HST Snapshot Targets	S. Eyres		2B	
00A/32	Core Identification in Large CSOs - 2	P. Augusto			
00A/33	22 GHz Masers in Seyfert 2 Galaxies and LINERs	E. Xanthopoulos	1A	3A	
00A/34	The Evolving Shell of the Unusually Slow Nova V723 Cas	T. O'Brien		1B	1A
00A/35	MERLIN/VLBA Monitoring of WR140	A. Beasley	3A		
00A/36	Weak Compact Sources in NGC2146	A. Tarchi			
00A/37	Mass-Loss From the Herbig Be Star MWC297	M. Hoare		1B	
00A/38	Origin of Non-Thermal Emission in O-Stars	S. Dougherty		4A+1B	
00A/39	Resolving the Shocks in Powerful Radio Galaxies	K. Wills		2A	
00A/40	Evolution of H_2O Masers in the CSE of Red Supergiants	J. Yates			2A
00A/41	H_2O Masers in Star-Forming Regions	A. Richards			3A
00A/42	Bright Objects in HII Regions at L & C-Band	H. Kobayashi			
00A/43	Mapping the Winds of Three Stars in CYG OB2	G. Umana		2B	
00A/44	Stellar Activity and Circumstellar Shocks in Miras	A. Richards			1A
00A/45	Continuum Observations of Selected Planetary Nebulae	M. Redman			
00A/46	MERLIN C-Band Observations of 3C171	P. Scheuer		1A	
00A/47	Observations of the Planetary Nebula G111.8	P. Thomasson			
99B/21	Evolution of Circumstellar H_2O Masers in Miras & SRs	J. Yates			6A
99B/29	Imaging the H_2O Masers in S68 FIRS 1	J. Yates			1A
99B/44	Radio Imaging of Star Formation in Distant Galaxies	E. Richards	9A		
00A/A	AD Leo	A. Gunn			1Dir
00A/B	Hen1341	J. Sokoloski			1Dir

Programmes for MERLIN Semester 00B

Project	TITLE	P.I.	L-Band	C-Band	K-Band
00B/01	Relativistic Ejections from X-ray Transients	R. Fender		6TO	
00B/02	Evolving Post-AGB Stars	A. Zijlstra			
00B/03	The Nature of Radio-Intermediate Quasars	M. Lacy	5A+5B		
00B/04	OH Absorption Studies of Selected Starburst Galaxies	R. Beswick	2B		
00B/05	OH Maser Emission from an Unusual Post-AGB Star	M. Sevenster	3A		
00B/06	Probing the HI Absorbing Gas in NGC4261	Y. Pihlstrom	2A		
00B/07	Young Radio Sources in the Nearby Universe	I. Snellen	1B+C		
00B/08	Do Jets Remove Angular Momentum From Circumstellar Disks?	A. Chrysostomou			
00B/09	Exploring the Nature of the SCUBA Galaxy Population	R. Iveson			
00B/10	Core Identification in Large Compact Symmetric Objects	P. Augusto			
00B/11	Probing the Haloes of Galaxies Using Radio-microlensing	I. Koopmans		36A	
00B/12	Observations of New CLASS Lens Systems	P. Phillip	1A	2B	
00B/13	H_2O Maser Distribution & Kinematics in Sgr B2	J. Mendoza-Torres			
00B/14	Observations of SCUBA Galaxy Sample	P. Alexander	5B		
00B/15	A Survey of DRAGNs at High Redshift	M. Sandell	C		
00B/16	HD 125858: A Highly Unusual Radio Star	D. Law-Green	1A	1B	
00B/17	Nucleus of the Andromeda Galaxy at 1.7 GHz	L. Sjouwerman	8A		

99A/20	Supernova Remnants in NGC 4490; A 'Young' Galaxy	M. Clemens	2A	1B
00B/18	Investigating Radio Source Evolution Using Faint CSS Sources	H. Sangera		
00B/19	HI Absorption & OH Megamaser Observations of Starbursts	A. Polatidis	5A	
00B/20	HI & OH Absorption in Galaxy Mergers	P. Alexander	5A	
00B/21	A New Sample of Faint Compact Steep Spectrum Sources	W. Tschager	2A	
00B/22	Deep EG Survey of Optically Identified Objects: Pilot Observations	S. Frey		1A+1B
00B/23	The Evolving Shell of the Unusually Slow Nova V723 Cas	T. O'Brien		2A
00B/24	The Bent Jets of 3C43 & 3C454	R. Spencer		2B
00B/25	A Deep 20cm MERLIN Study of the Hickson Group 16	M. Ward		
00B/26	A MERLIN Study of X-ray Luminous Starburst Galaxies	M. Ward	6B	
99B/44	Radio Imaging of Star Formation in Distant Galaxies	E. Richards	11A	
00A/08	MERLIN Studies of HI Absorption in Starbursts	A. Pedlar	5A	
00A/14	Classical & Recurrant Novae: Targets of Opportunity	S. Eyres		4TO
00A/24	High-resolution Mapping of the Jets in 3C31	R. Laing	1A	
00A/35	MERLIN/VLBA Monitoring of WR140	A. Beasley	3A	
00B/A	M1-92	J. Desmurs	0.7Dir	
00B/B	3C310	N. Gizani	0.5Dir	
00B/C	Orion-WF	J. Meaburn	0.8Dir	

APPENDIX C

VLBI Observations 1999 - 2000

Code	PI	λ	Telescope	hrs	Title
FTT02	Polatidis	6	Mk2+Cm	1	Fringe Test Experiment
v026b1	Walker	6	Mk2	12	VSOP Observations of 3C120 at 5 GHz
v129c4	Inoue	6	Mk2	10	VSOP Observations of 3C84 at 5 GHz
EK009A	Kovalev	6	Mk2	15	EVN Polarisation Observations of 6 AGNs After Radio Outbursts
v030k	Preston	6	Mk2	7	VSOP Observations of 0859+470 at 5 GHz
v003c	Fejes	6	Mk2	9	VSOP Observations of 3C216 at 5 GHz
v085c	Schilizzi	6	Mk2	12	VSOP Observations of 0248+430 at 5 GHz
EW010	Wills	6	Mk2+Cm	13	6cm EVN Observations of SNR in M82
C99C1	Sjouwerman	6	Mk2+Cm	4	Network Monitoring Experiment
EM021A	Mantovani	6	Mk2+MER	13.5	Structure Changes in Blazars with Long-term Luminosity Trends
EH004	Hong	6	Mk2+MER	7	Observation of OVV NRAO530 at 5 GHz
FT004	McKay	6	Mk2+Cm	4	MkIV Modes Test
EH005	Hong	6	Mk2+MER	12	EVN/MERLIN Observations of 1156+295
EM021B	Mantovani	6	Mk2+MER	13.5	Structure Changes in Blazars with Long-term Luminosity Trends
EL023	Langevelde	18	LT	10	HI Absorption in NGC 4261
EY004A	Yates	18	LT	24	Study of Latitude-dependent Mass-loss in Mira Variables
EE003B	Etoka	18	LT	12	OH in the Mira R LMi
C99L1	Sjouwerman	18	LT+Cm	4	Network Monitoring Experiment
GY001C	Yates	18	LT	12	Measuring the Mass-loss From a Mira
GS014	Snellen	18	LT	13	Self-similar Evolution of Young Radio Galaxies
EP025	Pedlar	18	LT	24	18 cm European VLBI Observations of Seyfert Nuclei
FTT03	Polatidis	18	Mk2+Cm	1	Fringe Test Experiment
GS013B	Szymczak	18	Mk2+MER	11	OH Maser Observations
W018f	Snellen	18	Mk2	14	VSOP Observations of J1335+45 at 1.6 GHz
ES023B	Schilizzi	18	Mk2+Cm	8	Studies of Complex Peaked Spectrum Radio Sources
w027b1	Murphy	18	Mk2	15.5	VSOP Observations of J1927+73 at 1.6 GHz
C99L2	Sjouwerman	18	Mk2+Cm	3	Network Monitoring Experiment
GK019B	Koopmans	18	Cm	6	Multifrequency Observations of a Dark Lens or Binary Quasar
w035g	Gurvits	18	Mk2	10	VSOP Observations of J1746+62 at 1.6 GHz
EY004B	Yates	18	Mk2	24	Study of Latitude-dependent Mass-loss in Mira Variables
ED014	Desmurs	18	Mk2+MER	14	OH Masers in M1-92
EF006	Fanti	18	Mk2+MER	48	VLBI Structure of a New Sample of CSS/GPS
EA025	Alberdi	18	Mk2+MER	11	Observations of 0829+046 at 18 cm
EC010	Cawthorne	18	Mk2+MER	24	Total Intensity & Polarisation Structure of BL Lacertae Objects
ES029	Szymczak	6	Mk2	13	Excited OH Masers
GM035D	Marcaide	6	Mk2	11	Monitoring of the Expansion of SN 1993J at 6 & 18 cm
FR004	Langevelde	6	Mk2	4	Phase Reference Correlator Test Observation
GF007C	Fomalont	6	Mk2	8	Formation & Rapid Variability of the Hot Spots in Sco X-1
ES030A	Spencer	6	Mk2	8	A Variable Jet in Cyg X-1?
GF007F	Fomalont	6	Mk2	8	Formation & Rapid Variability of the Hot Spots in Sco X-1
ES030B	Spencer	6	Mk2	8	A Variable Jet in Cyg X-1?
GG040	Garrington	6	Mk2	10.5	Faint GPS Sources Selected from a VLBI+MERLIN Survey
w035f	Gurvits	6	Mk2	9.5	VSOP Observations of J1746+62 at 5 GHz
FC006	McKay	6	Mk2	4	Real Time Correlator Test Observation
w035e	Gurvits	6	Mk2	9	VSOP Observations of J1510+57 at 5 GHz
C99C2	Sjouwerman	6	Mk2+Cm	6.5	Network Monitoring Experiment
w027a1	Murphy	6	Mk2	16	VSOP Observations of J1927+73 at 5 GHz
w027a2	Murphy	6	Mk2	16	VSOP Observations of J1927+73 at 5 GHz
EO004A	O'Dea	30	LT	14	Probing the Environments of GPS & CSS Sources
EO004B	O'Dea	30	LT	11	Probing the Environments of GPS & CSS Sources
EV008A	Vermeulen	30	LT	12	Complex Disposition of Neutral Gas in Compact Symmetric Objects
EV008B	Vermeulen	30	LT	17	Complex Disposition of Neutral Gas in Compact Symmetric Objects

EM034	Moore	30	LT	11.5	Mapping the HI Absorption in 1504+377
EP031A	Pihlstrom	30	LT	3.5	HI Absorption Observations of the 2 CSS Sources 0023-26 & 3C459
EP030	Pihlstrom	30	LT	12	HI Absorption in the Superluminal Steep Spectrum Quasar 3C216
EB015A	Briggs	30	LT	8	Gas Kinematics in a Normal Spiral Galaxy at z = 0.437
EB015B	Briggs	30	LT	12	Gas Kinematics in a Normal Spiral Galaxy at z = 0.437
EO004C	O'Dea	30	LT	12	Probing the Environments of GPS & CSS Sources
C99C3	Sjouwerman	6	Mk2	8	Network Monitoring Experiment
w048a	Taylor	6	Mk2	46	VSOP Observations of J0240+61 at 5 GHz
v085g	Schilizzi	6	Mk2	11	VSOP Observations of J0626+82 at 5 GHz
v085i	Schilizzi	6	Mk2	14	VSOP Observations of J0642+67 at 5 GHz
v085k	Schilizzi	6	Mk2	11.5	VSOP Observations of J0650+60 at 5 GHz
v026b2	Walker	6	Mk2	11.5	VSOP Observations of 3C120 at 5 GHz
GM035E	Marcaide	6	Mk2	16	Monitoring of the Expansion of SN 1993J at 6 & 18 cm
ES034A	Snellen	6	Mk2	7.5	High Resolution Imaging of the Most Distant Quasars
EK009B	Kovalev	6	Mk2	17	Polarisation Observations of 6 AGNs After Radio Outbursts
EY004C	Yates	18	LT	24	Study of Latitude-dependent Mass-loss in Mira & Semiregular Variables
EP027A	Pedlar	18	LT	17	A VLBI Search for Compact Ultra-luminous SNR in Starbursts
EP027B	Pedlar	18	LT	23	A VLBI Search for Compact Ultra-luminous SNR in Starbursts
w018e	Snellen	18	LT	12	VSOP Observations of J0650+60 at 1.6 GHz
GB035A	Bartel	18	LT	11.5	The Evolving Spectral Index Distribution in the Images of SN 1993J
w018h	Snellen	18	LT	12	VSOP Observations of J2022+61 at 1.6 GHz
EB014A	Baan	18	LT	11	Emission Structure of OH Megamasers
GAH2	Garrington	18	LT	4	Phase Calibrator Test Observations
C99L3	Sjouwerman	18	LT	4	Network Monitoring Experiment
EB014B	Baan	18	Lt	11	Emission Structure of OH Megamasers
FTT04	Polatidis	18	LT	1	Fringe Test Experiment
ER008A	Roy	18	LT+MER	16	Jet Structure & Motion in Seyfert Galaxies
C99L4	Sjouwerman	18	LT+Cm	3	Network Monitoring Experiment
EM035A	Garrett	18	LT+MER	16	EVN-MERLIN Test Observations of the Hubble Deep Field
ES027	Stanghellini	18	LT+MER	8	The Search of CSOs in GPS Samples
EM035B	Garrett	18	LT+MER	16	EVN-MERLIN Test Observations of the Hubble Deep Field
ES028	Sjouwerman	18	LT+MER	8	V720 Oph OH - A Member of NGC 6171?
GD013	Diamond	18	LT	12	Global VLBI of the 1612 MHz Masers Towards OH127.8-0.0
EG021	Gizani	18	LT+MER	11	Probing the pc-scale Environment of Hercules A
EY004D	Yates	18	LT	24	Study of Latitude-dependent Mass-loss in Mira & Semiregular Variables
GR019A	Rioja	18	LT+MER	6	Phase Referencing Studies at L-band Using Cluster-Cluster Mode
GR019B	Rioja	18	LT+MER	6	Phase Referencing Studies at L-band Using Cluster-Cluster Mode
EP032	Polatidis	18	LT+MER	12	HI Absorption Observations of Starburst/Merging Galaxies
C99C4	Sjouwerman	6	Mk2	7	Network Monitoring Experiment
SAH6A	Stirling	6	Mk 2	6	ToO Observations of XTE 1859+226
EJ002	Jiang	6	Mk2	16	Compact Structure of Intermediate BL Lacs
GB035B	Bartel	6	Mk2	12	The Evolving Spectral Index Distribution in the Images of SN 1993J
SAH6B	Stirling	6	Mk2	6	ToO Observations of XTE 1859+226
ES034B	Snellen	6	Mk2	9.5	High Resolution Imaging of the Most Distant Quasars
EM033A	Minier	5	Mk2	17.5	Observations of 6.7 GHz Methanol Masers Using the EVN
EP028	Phillips	5	Mk2	10	A 6.7 GHz Methanol Maser Associated With a Proto-B Star
EM033B	Minier	5	Mk2	27	Observations of 6.7 GHz Methanol Masers Using the EVN
EK010A	Klockner	18	LT	11.5	Emission Structure of OH Megamaser Sources
GA018	Augusto	18	LT	12	B2114+022 - A Unique & Puzzling Gravitational Lensing Candidate
GX006A	Xanthopoulos	18	LT	14	Resolving Core & Jet Structure of the JVAS Gravitational Lens B1030+074
GP025A	Paragi	18	LT	10.5	The Anomalous Equatorial Emission Region of SS433
EK010B	Klockner	18	LT	12	Emission Structure of OH Megamaser Sources
GK020	Koopmans	18	LT	6	Scatter-broadening in the Edge-on Disk Gravitational Lens B1600+434?
GS016A	Snellen	18	LT	12	Young Radio Sources in the Nearby Universe II: EVN Imaging at 18cm
EV009	Vlemmings	18	LT	15	The Amplified Stellar Image in OH Main & Satellite Line Masers
EH007A	Hagiwara	18	LT	12	HI Absorption in AGN: A Search for Circumnuclear Gas
EH007B	Hagiwara	18	LT	13	HI Absorption in AGN: A Search for Circumnuclear Gas
GM036	Momjian	18	LT	19	High-sensitivity Observations of High-velocity HI Absorption Against 3C84

GP025B	Paragi	18	LT	13.5	The Anomalous Equatorial Emission Region of SS433
GG042A	Greenhill	1.3	Mk2	8.5	Why is the Maser Accretion Disk in NGC1068 Unlike NGC4258?
GD014	Dennett-Thorpe	1.3	Mk2+Cm	24	The Evolution of the Smallest Radio Galaxies
GG042B	Greenhill	1.3	Mk2	8.5	Why is the Maser Accretion Disk in NGC1068 Unlike NGC4258?
GAH03	Gabuzda	6	Mk2	2	Test of Frequency Agility at EVN Telescopes
ER008B	Roy	6	Mk2+MER	16	Jet Structure & Motion in Seyfert Galaxies
FR005	Langevelde	6	Mk2	4	Phase Reference Test Observation
C00C1	Sjouwerman	6	Mk2+Cm	12	Network Monitoring Experiment
ER011	Ribo	6	Mk2+MER	23.5	EVN Observations of Radio Emitting X-ray Binary Candidates
GS016B	Snellen	6	Mk2	12	Young Radio Sources in the Nearby Universe II: 18cm EVN Imaging
FT002	Polatidis	18	LT	1	Fringe Test Experiment
GO003A	Owsianik	18	LT	24	Testing Source Physics in CSOs via Multifrequency Observations
EM037A	Mantovani	18	LT	7	The 1320+299 Complex
GR021A	Paredes	6	Mk2+MER	8	Exploring the Jets of a New Microquasar
ET008	Tarchi	6	Mk2	11	The Nature of the Central Radio Source of NGC 2146
C00C2	Sjouwerman	6	Mk2+Cm	4	Network Monitoring Experiment
EC014	Caccianiga	6	Mk2	12	A Search for Relativistic Jets in Radio-quiet AGN
GG041	Gabuzda	6	Mk2	24	The Magnetic Field Structure in High Redshift Quasars
GM035	Marcaide	6	Mk2	11	Monitoring of the Expansion of SN 1993J at 6 & 18 cm
EAH001	Edwards	6	Mk2	4	5 GHz Observations of B1755+578
viv001	Garrett	6	Mk2+Cm	1	Test of the MK IV Formatters
ES031	Stanghellini	6	Mk2	7	Proper Motions in OQ208
GR021B	Paredes	6	Mk2+MER	8	Exploring the Jets of a New Microquasar
EH006	Hong	6	Mk2	15	Second Epoch VLBI Observations of a Sample of 15 EGRET AGNs
FT003	Polatidis	6	Mk2+Cm	1	Fringe Test Experiment
w313c	Preston	6	Mk2	10	VSOP Observations of J0217+73 at 5 GHz
EC015	Chen	6	Mk2	12	Polarisation Radio Structure of EGRET Blazars with Low Flux Density
PAH001	Phillips	6	Mk2+Cm	3.25	JIVE Oversampling Test Observation
C00C3	Sjouwerman	6	Mk2+Cm	4	Network Monitoring Experiment
w083f	Wajima	6	Mk2+Cm	14	VSOP Observations of J1740+52 at 5 GHz
EM039	MacDonald	5	Mk2	15	Methanol Masers in Star-forming Regions
EP038	Pestalozzi	5	Mk2	24	Further Observations of Methanol Masers at High Resolution
EP037A	Phillips	5	Mk2	18	Distribution of Maser Molecules in High Mass Star Formation Regions
ES033	Slysh	5	Mk2	24	Mapping Methanol Masers From the Medicina Survey
ES036	Szymczak	5	Mk2	14	Methanol Masers Associated with Infrared Sources
ED015	Desmurs	5	Mk2	16	OH Structure & Magnetic Field in the Isolated Starforming Region ON1
EM040	Minier	5	Mk2	8	6.7 GHz Methanol Masers as Signposts for Hot Cores
ET007	Tschager	18	LT+Cm	18	A New Sample of Faint Compact Steep Spectrum Sources
EP037B	Phillips	18	LT	18	Distribution of Maser Molecules in High Mass Star Formation Regions
FT004	Polatidis	18	LT	1	Fringe Test Experiment
GM043A	Moscadelli	1.3	Mk2	12	Proper Motions of H_2O Masers Tracing a Jet in IRAS 20126+4104
ES035	Shibata	18	LT	10	HI Absorption in the Nucleus of NGC 1052
GO005A	Owsianik	18	LT+MER	12	The Study of the Inner Jet in 3C236
C00L4	Gabuzda	18	LT+Cm	5.5	Network Monitoring Experiment
EK012	Klockner	18	LT+MER	12	OH Absorption Structure of Starburst Nuclei
EK011A	Klockner	18	LT+MER	12	Active Galactic Nuclei in Luminous Infrared Galaxies
FP002	Campbell	18	LT	4	Pulsar Gate Test Observation
EK011B	Klockner	18	LT+MER	12	Active Galactic Nuclei in Luminous Infrared Galaxies
MT001	Polatidis	18	LT	5	Multifield Imaging Test Observation
w330v	Kameno	18	LT	12	VSOP Observations of J2052+36 at 1.6 GHz
EP036	Polatidis	18	LT+MER	12	HI & OH Absorption Observations of the Starburst Galaxy NGC 2623
EB016	Beck	18	LT+MER	8	Search for Radio Supernovae in Very Young Starbursts
GM040A	Marcaide	18	LT	11	Monitoring of the Expansion of SN 1993J at 6 & 18 cm
GP028	Pihlstrom	18	LT	12	The HI Absorbing Gas in NGC 4261
EP035	Pihlstrom	18	LT+MER	18	Broad HI Gas Towards 3C84
TP001	Charlot	6	Mk2+Cm	24	Telescope Position Test Experiment
GM040B	Marcaide	6	Mk2	11	Monitoring of the Expansion of SN 1993J at 6 & 18 cm
GM043B	Moscadelli	1.3	Mk2	12	Proper Motions of H_2O Masers Tracing a Jet in IRAS 20126+4104

APPENDIX D

National Facility Visitors

National Facility Visitors - 1999

G. Gilbert - UK - MRAO, University of Cambridge
E. de Silva - UK - MRAO, University of Cambridge
M. Lacy - UK - Oxford University
I. McHardy - UK - University of Southampton
M. Masheder - UK - University of Bristol
N. Seymour - UK - University of Southampton
C. Brocksopp - UK - University of Sussex
A. Breen - UK - University of Wales at Aberystwyth
S. Colley - UK - University College, London
P. Williams - UK - ROE, Edinburgh
K. A. Wills - UK - University of Sheffield
A. Zijlstra - UK - UMIST
A. Stirling - UK - University of Central Lancashire
J. A. Yates - UK - University of Hertfordshire
K. Murakawa - UK - University of Hertfordshire
S. P. S. Eyres - UK - Liverpool John Moores University
N. Ridge - UK - Liverpool John Moores University
V. Tyne - UK - University of Keele
A. Tarchi - Germany - R.A.I. Universität, Bonn
G. Umana - Italy - NOTO
C. Trigilio - Italy - NOTO
F. Mantovani - Italy - Bologna
H. Kobayashi - Japan - NAO, Metaka
I. Shimoikura - Japan - Kagoshima
A. Thean - Netherlands - NFRA
W. Vlemmings - Netherlands - University of Leiden
P. Augusto - Portugal - University of Madeira
N. Gizani - Portugal - University of Madeira
D. Smits - South Africa - Hartebeesthoek
Y. Pihlstroem - Sweden - Onsala Observatory
E. A. Richards - USA - Arizona State University
D. Marlow - USA - University of Pennsylvania
D. Rusin - USA - University of Pennsylvania

National Facility Visitors - 2000

R. A. Laing - UK - University of Oxford
J. Canvin - UK - University of Oxford
K. Blundell - UK - University of Oxford
M. Clemens - UK - MRAO, University of Cambridge
J. A. Yates - UK - University of Hertfordshire
T. Gledhill - UK - University of Hertfordshire
K. Murakawa - UK University of Hertfordshire
S. Wilson - UK - University of Hertfordshire
N. Seymour - UK - University of Southampton
R. Fallows - UK - University of Wales at Aberystwyth
R. Morris - UK - University of Wales at Aberystwyth
K. A. Wills - UK - University of Sheffield
A. Stirling - UK - University of Central Lancashire
M. Hoare - UK - University of Leeds
S. P. S. Eyres - UK - Liverpool John Moores University
N. Ridge - UK - Liverpool John Moores University
E. Xanthopoulos - UK - University of Manchester
M. Gray - UK - UMIST
C. Brocksopp - UK - University of Sussex
S. Colley - UK - University College, London
R. Blomme - Belgium - Royal Observatory, Brussels
A. Greve - France - IRAM, Grenoble
R. Ogley - France - SACLAY
A. Tarchi - Germany - RAI, University of Bonn
A. Patnaik - Germany - MPIfR
A. Roy - Germany - MPIfR
S. Jester - Germany - Heidelberg
M. A. Garrett - Netherlands - JIVE, Dwingeloo
H. -R. Klöckner - Netherlands - ASTRON
C. Phillips - Netherlands - ASTRON
L. Sjouwerman - Netherlands - JIVE, Dwingeloo
W. Cotton - Netherlands - University of Leiden
N. Gizani - Netherlands - ASTRON
W. Vlemmings - Netherlands - University of Leiden
A. Marecki - Poland - Torun
P. Augusto - Portugal - University of Madeira
M. Ribo - Spain - University of Barcelona
J. -F. Désmurs - Spain - OAN, Madrid
S. Dougherty - Canada - DRAO, Penticton
Liu Xiang - China - Urumqi
X. Y. Hong - China - Shanghai
B. Kramer - Thailand - Bangkok
R. A. Osten - USA - Colorado
A. Brown - USA - Colorado
J. Winn - USA - MIT
J. Gallimore - USA - NRAO, Charlottesville
M. Thornley - USA - NRAO, Charlottesville
C. Lonsdale - USA - Haystack
A. Kemball - USA - NRAO

Data Processing by MERLIN Staff for Observers In Absentia - 1999

G. Gilbert - UK - MRAO, University of Cambridge
E. de Silva - UK - MRAO, University of Cambridge
M. Lacy - UK - Oxford University
I. McHardy - UK - University of Southampton
M. Masheder - UK - University of Bristol
N. Seymour - UK - University of Southampton
C. Brocksopp - UK - University of Sussex

A. Breen - UK - University of Wales at Aberystwyth
S. Colley - UK - University College London
P. Williams - UK - ROE, Edinburgh
K. A. Wills - UK - University of Sheffield
A. Zijlstra - UK - UMIST
A. Stirling - UK - University of Central Lancashire
J. A. Yates - U.K. - University of Hertfordshire
K. Murakawa - UK - University of Hertfordshire
S. P. S. Eyres - UK - Liverpool John Moores University
N. Ridge - UK - Liverpool John Moores University
V. Tyne - U.K. - University of Keele
A. Tarchi - Germany - RAI, University of Bonn
G. Umana - Italy - NOTO
C. Trigilio - Italy - NOTO
F. Mantovani - Italy - Bologna
H. Kobayashi - Japan - NAO, Metaka
I. Shimoikura - Japan - Kagoshima
A. Thean - Netherlands - NFRA
W. Vlemmings - Netherlands - University of Leiden
P. Augusto - Portugal - University of Madeira
N. Gizani - Portugal - University of Madeira
D. Smits - South Africa - Hartebeesthoek
Y. Pihlstroem - Sweden - Onsala Observatory
E. A. Richards - USA - Arizona State University
D. Marlow - USA - University of Pennsylvania
D. Rusin - USA - University of Pennsylvania

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M. Clemens - UK - MRAO, University of Cambridge
J. A. Yates - UK - University of Hertfordshire
T. Gledhill - UK - University of Hertfordshire
K. Murakawa - UK University of Hertfordshire
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A. Roy - Germany - MPIfR
S. Jester - Germany - Heidelberg
M. A Garrett - Netherlands - JIVE, Dwingeloo
H. -R. Klöckner - Netherlands - ASTRON
C. Phillips - Netherlands - ASTRON
L. Sjouwerman - Netherlands - JIVE, Dwingeloo
W. Cotton - Netherlands - ASTRON
N. Gizani - Netherlands - ASTRON
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A. Marecki - Poland - Torun
P. Augusto - Portugal - University of Madeira
M. Ribo - Spain - University of Barcelona
J. -F. Désmurs - Spain - OAN, Madrid
S. Dougherty - Canada - DRAO, Penticton
Liu Xiang - China - Urumqi
X. Y. Hong - China - Shanghai
B. Kramer - Thailand - Bangkok
R. A. Osten - USA - Colorado
A. Brown - USA - Colorado
J. Winn - USA - MIT
J. Gallimore - USA - NRAO, Charlottesville
M. Thornley - USA - NRAO, Charlottesville
C. Lonsdale - USA - Haystack
A. Kemball - USA - NRAO

APPENDIX E

National Facility Publications 1999 - 2000

Augusto P., Gonzalez-Serrano J. I., Edge A. C., Gizani N. A. B., Wilkinson P. N. & Perez-Fournon I., 1999, *The kpc-scale Radio Source Population*, New AR, 43, 663

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Breen A., Tappin S. J., Jordan C. A., Thomasson P. T., Moran P. J., Fellows R. A., Canals A. & Williams P. J. S, 2000, *Simultaneous Interplanetary Scintillation and Optical Measurements of the Acceleration of the Slow Solar Wind*, Ann. Geophysicae, 18, 995

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Hirabayashi H. et al., 2000, *The VLBI Space Observatory Programme and the Radio-Astronomical Satellite HALCA*, PASJ, 52, 955

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The deadlines for the receipt of applications for MERLIN time occur twice a year, on April 7 and October 7. A call for MERLIN proposals is issued several weeks prior to each deadline. Full details on the capabilities of MERLIN and on how to apply for time can be found on the MERLIN home page http://www.merlin.ac.uk.

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