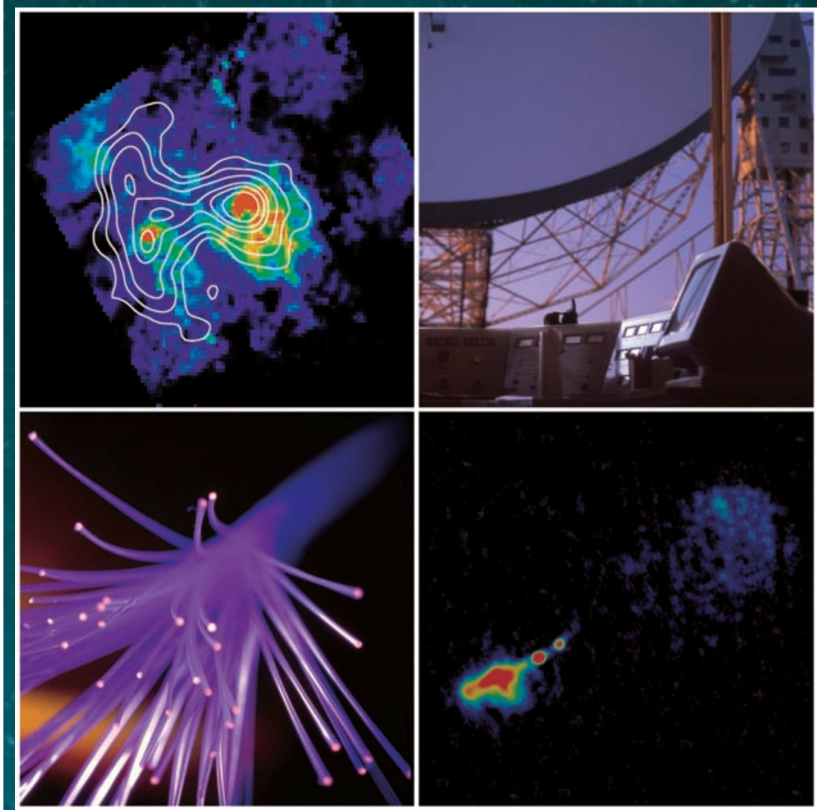
PPARC

MERLIN/VLBI National Facility

Biennial Report

2001-2002



MERLIN

EUROPEAN VLBI NETWORK

THE UNIVERSITY of MANCHESTER

MERLIN/VLBI National Facility

Biennial Report

2001 - 2002

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Particle Physics and Astronomy Research Council

THE UNIVERSITY of MANCHESTER

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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 2001 and 2002.

INTRODUCTION

MERLIN (the Multi-Element Radio Linked Interferometer Network) is an array of seven radio telescopes distributed over central England and operated from Jodrell Bank Observatory (JBO) as a National Facility by the University of Manchester on behalf of the Particle Physics & Astronomy Research Council (PPARC). The outlying telescopes are connected via microwave links to a central correlator situated at Jodrell Bank. This combination of radio antennas forms the equivalent of a single, integrated radio telescope and is able to image astronomical objects with very high resolution at frequencies from 151 MHz to 24 GHz. MERLIN is the only world-class astronomical facility based entirely within the UK. The key to MERLIN's success is its high angular resolution. With radio telescope separations of up to 217 km, it is the only ground-based facility in the world that routinely matches the resolution of the Hubble Space Telescope (*HST*) and the new generation of 8-m class optical/IR telescopes such as Gemini and the Very Large Telescope (VLT). The capabilities of MERLIN are listed in the table below. Further details concerning the array are available at http://www.merlin.ac.uk.

MERLIN was developed 25 years ago from pioneering experiments in long-baseline interferometry at Jodrell Bank. It was designed to provide sub-arcsecond imaging of astronomical sources at centimetre wavelengths, primarily to study in more detail the radio galaxies and quasars imaged by the Cambridge aperture synthesis arrays. The original design goals were quickly surpassed, both technically and astronomically, and MERLIN was immediately recognised as a world-class instrument, evidenced by the many initial publications in *Nature*. A major upgrade in 1990, in which the resolution was increased by nearly a factor of 2 and the sensitivity by almost an order of magnitude, ensured that MERLIN was transformed into a general-purpose instrument capable of attacking a wider range of astrophysical problems. It has thus remained a world-class facility and is recognised as one of the leading strengths of UK astronomy.

MERLIN is a National Facility open to all users. As with other UK telescopes, the observing year is divided into two observing semesters (February to July and August to January). All observing

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.

proposals are peer-reviewed and, if appropriate, allocated observing time by the Panel for the Allocation of Telescope Time (PATT) of the UK's Particle Physics and Astronomy Research Council (PPARC). PATT allocates MERLIN observing time based on the perceived scientific merit of proposals and the actual observing time available in a given semester. Typically 30-40 proposals are received per semester, requesting a total of approximately 3000 hours of observing time. In order to maximise the efficiency of operation, flexible scheduling is employed so that observations are not normally scheduled in detail more than a few days in advance. This allows the array to take maximum advantage of prevailing weather/ atmospheric conditions or technical limitations. Observers are not normally expected to be present during observations but are encouraged to visit Jodrell Bank Observatory to perform the data reduction.

MERLIN often observes simultaneously with the European VLBI Network (EVN), an array of 13 telescopes distributed across Europe and Asia. In fact, joint MERLIN/EVN observations are an increasingly popular mode of observation within the EVN at 1.4 and 5 GHz due to the ability of the joint array to provide images of a wide range of radio structures from the arcsecond scale down to the milliarcsecond scale. The EVN Consortium Board of Directors and its associated Programme Committee and Technical & Operations Group coordinates EVN activities.

VLBI achieves the highest angular resolution of any branch of astronomy, enabling imaging at angular scales as small as 100 microarcseconds. 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 EVN data processor. The EVN has been at the forefront of VLBI developments, transforming its capabilities with new technologies. The MkIV tape recording system and data processor provide the world's first 1 Gbit/second-capable VLBI system. This capability, together with the large radio telescopes at Effelsberg, Jodrell Bank and Westerbork, make the EVN the instrument of choice for high sensitivity VLBI. The VLBI capabilities of the EVN are listed below.

A £2.2M upgrade of the 76-m diameter Lovell Telescope at Jodrell Bank Observatory, the world's third-largest fully-steerable radio telescope, which forms an integral part of MERLIN and the EVN, is almost complete. A major part of this upgrade was the replacement of the telescope's 340 surface panels, thus enabling the instrument to be used at higher observing frequencies. The inclusion of the refurbished Lovell telescope in 5-GHz MERLIN and EVN observations (from the autumn of 2003) will result in a sensitivity increase of a factor of ~3.

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

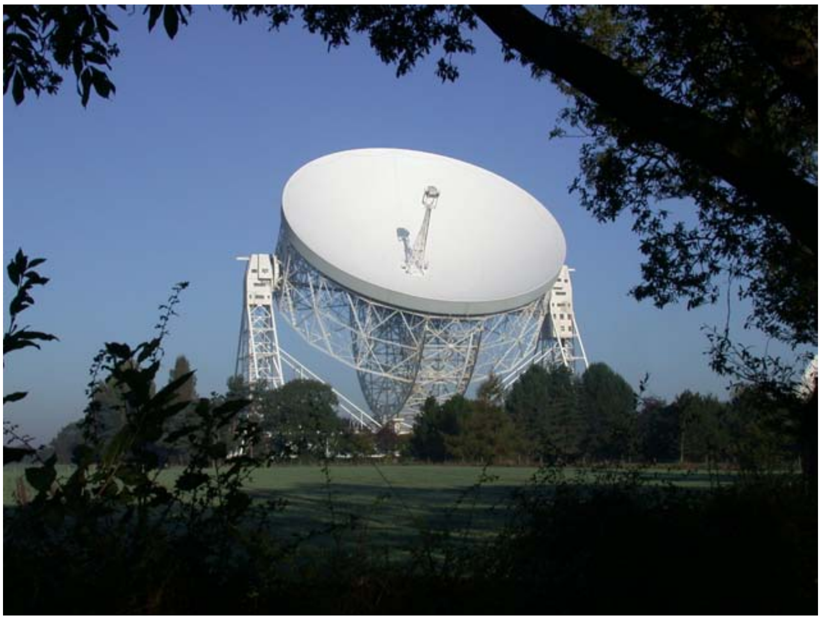
DIRECTOR'S REPORT

The major success of the period 2001-2002 has been the funding of the MERLIN upgrade, *e*-MERLIN. The project will be completed by early 2007 and represents a £6.8M investment that will completely transform MERLIN's capabilities. Funding has been provided by a consortium of three universities - Manchester, UMIST and Cambridge - by the North West Development Agency and by PPARC. *e*-MERLIN will result in the array remaining competitive with and complementary to the new generation of telescopes around the world. The new instrument will have enormously greater sensitivity than at present, allowing new areas of science to be opened up, particularly in the fields of extragalactic astronomy and cosmology, star formation across the universe, stellar evolution and studies of the extreme conditions around black holes.

The 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 broad-band fibre-optic cables. Once installed and connected to a new broad-band correlator, each telescope in the *e*-MERLIN array will transmit data at 30 Gbps to Jodrell Bank Observatory. The total data rate will be a staggering 210 Gbps; more than the combined Internet traffic of Western Europe. When coupled with the upgrade of the Lovell Telescope and a 30% increase in receiver efficiency currently under development, the improvement in sensitivity will be a factor of 30-40 at the array's prime observing frequency. *e*-MERLIN will image in detail objects that can now only be glimpsed in the deepest observations and will detect objects previously unseen at radio wavelengths with unprecedented resolution. The range of science that will be addressed by *e*-MERLIN will be much wider than currently possible with MERLIN, especially with regard to thermal emission from warm and ionised gas. More details on the upgrade are presented elsewhere in this report.

The Lovell Telescope (LT) is once again fully operational following a £2.3M facelift. The surface of the telescope has been replaced and, following panel adjustments over the summer of 2003, it is hoped that the telescope will have appreciable gain at 8.4 GHz (X-band). In order to enable accurate pointing of the telescope at these high frequencies a new drive system has also been installed. Our target is to have the Lovell Telescope participate as part of MERLIN in Semester 03B at 4-7 GHz (C-band). The factor of ~2.5-3 increase in sensitivity that will result from the inclusion of the LT and the installation of upgraded C-band receivers will be the first tangible result of the *e*-MERLIN project. The upgrade will also have significant benefits to the sensitivity of the European VLBI Network at C-band and, in the future, at X-band.

Below: The newly resurfaced 76-metre Lovell Telescope at Jodrell Bank Observatory.



However, all of this good news must be tempered by continuing concerns over the level of operational funding in the long-term. In order to afford entry into the European Southern Observatory (ESO), the Particle Physics and Astronomy Research Council (PPARC) has had to impose severe cuts on the operational budgets of most of the UK's observatories. For the MERLIN and VLBI National Facility this amounts to a cut of ~18%. This reduction is mitigated somewhat by the additional funding obtained for *e*-MERLIN but has meant that there will inevitably be a major impact on our ability to deliver science during the next few years at the high level of efficiency our users have come to expect. Effects visible to MERLIN users will be: less Lovell Telescope time available; the necessity for observations in fixed frequency bands (L-band or C/K band) for a year at a time until frequency flexibility is in place; longer summer engineering periods (required for *e*-MERLIN); and a reduction in the support available for visitors and remote users. In addition, readers will notice that this biennial report is a slimmer version of those issued previously. This is deliberate and is a conscious decision to ensure that the National Facility staff are not over-stretched.

The scientific output of users of MERLIN and VLBI, principally through the EVN, continues to impress. Over the period covered by this report the number of papers published that use National Facility telescopes has risen to 123, an all-time high. In addition, National Facility staff have published an additional 12 papers using other telescopes. The range of science addressed by the National Facility continues to be broad, as is shown in the scientific highlights section.

Not all engineering developments have been concentrated on *e*-MERLIN. We have seen significant work in the VLBI area with improvements to the tape recording systems; the introduction of a simple switching mechanism between different observing modes designed to increase the reliability of VLBI (funded by the EU); and a major level of effort on the new generation of disk-based recording systems. The greatest success though was the participation of NF staff in the highly successful eVLBI tests at the iGRID2002 meeting. These tests are described in more detail elsewhere in this report.

Finally, the MERLIN archive is now accessible. At the time of writing, all existing L- and C-band continuum data since 1990 is available via the Internet. Jodrell Bank Observatory is one of the founding members of the EU-funded Astrophysical Virtual Observatory (AVO). The AVO, along with its international partners, is developing the next-generation system to access electronic archives; JBO's participation within AVO will ensure that the MERLIN and *e*-MERLIN archives are major components of the 'second sky'.

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

ASTRONOMY

Overview & Highlights

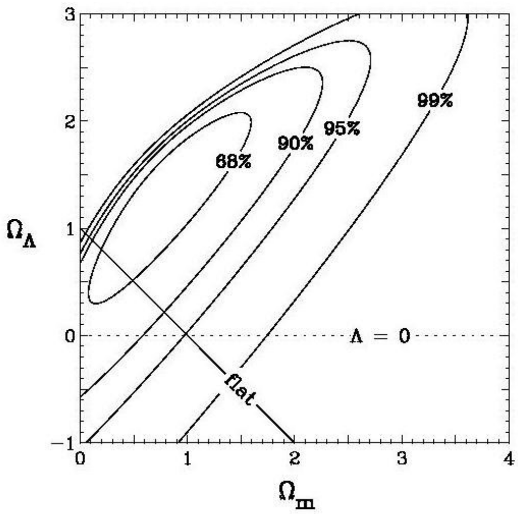
The instruments of the MERLIN/VLBI National Facility have continued to study diverse astronomical phenomena during the reporting period, from scales as small as a few AU to the cosmic distances revealed by gravitational lens studies. These phenomena include the solar wind (Breen et al. 2002), stellar winds (e.g. Blomme et al. 2002), supernovae (e.g. Marcaide et al. 2002), X-ray binaries (e.g. Massi et al. 2002), symbiotic stars (e.g. Crocker et al. 2002), microquasars (e.g. Fender et al. 2002), Galactic masers (Minier, Booth & Conway 2002), extragalactic masers (Pihlstrom et al. 2001), normal galaxies (Momjian, Romney & Troland 2002), Seyfert galaxies (e.g. Thean et al. 2001), starburst galaxies (e.g. Wills, Pedlar & Muxlow 2002), radio galaxies (e.g. Gizani et al. 2002), gravitational lenses (e.g. Augusto et al. 2001) and quasars (e.g. Fanti et al. 2002), as well as many others. Studies using National Facility instruments have resulted in a total of 123 publications during the reporting period, the diversity and importance of which can be seen in Appendix E. This excellent scientific output shows that MERLIN has reached a stage of maturity, consolidating in areas where its strengths have previously been demonstrated and expanding in other innovative fields. These observations have supported world-class science and continue to be based primarily on the instrument's unique angular resolution. The limited examples of scientific results presented below are representative of a science programme that is both productive and original.

Gravitational Lenses & Cosmological Parameters

Current interest within cosmology focuses on the development of large-scale structures, the nature of dark matter, and the determination of the fundamental cosmological parameters. Gravitational lenses provide a versatile method for investigating these topics. MERLIN has played a key role in CLASS, the world's major gravitational lensing survey, by mapping candidate systems, initially identified with the VLA, at high resolution in order to distinguish intrinsic structure from multiple point-like gravitational images. The search and confirmation part of the CLASS project has been completed during the period of this report (Myers et al., 2003, MNRAS, 341, 1; Browne et al., 2003, MNRAS, 341, 13). Twenty-two lens systems have been discovered, approximately one third of all known systems.

Augusto et al. (2001) reported the discovery of one of the most puzzling CLASS lens systems. It has four compact components, at least two of which are lensed images. What is odd about the system is that the spectra and morphology of the compact components are greatly modified as the radio emission propagates through the lens. Intriguingly, Winn et al. (2002b) have reported a not dissimilar system, PMN J0134-0931, in their Southern lens survey, which also uses the same MERLIN strategy as CLASS.

Below: Contraints in the Ω_Λ-Ω_m plane from the JVAS/CLASS results.



The number of lenses found in a survey is sensitive to the cosmological constant Ω_Λ. CLASS is far superior to other lens surveys because of its size, immunity to dust extinction and reliably high resolution. CLASS results constrain Ω_Λ to be <0.83 and rule out models with zero cosmological constant (Chae et al., 2002, PhRvL, 89, 1301). Recent CMB measurements from *WMAP* have greatly improved on these limits but the lensing result is still important since it is based on completely different physical assumptions, yet reaches the same conclusion.

Lensing can provide information on the dark matter distributions in galaxies invisible by other means. Rusin et al. (2002) have reported high resolution MERLIN and VLBI observations of the CLASS system B1152+199 which show jets in both the lens images. Metcalf (2002, ApJ, 580, 696) has used the radio data to infer that the mass distribution of the lensing galaxy must have substructure in order to account for the bend which is seen in one of the jet images and not the other. This is one of the first bits of observational evidence for galactic substructure of the kind which is a generic prediction of CDM structure formation models.

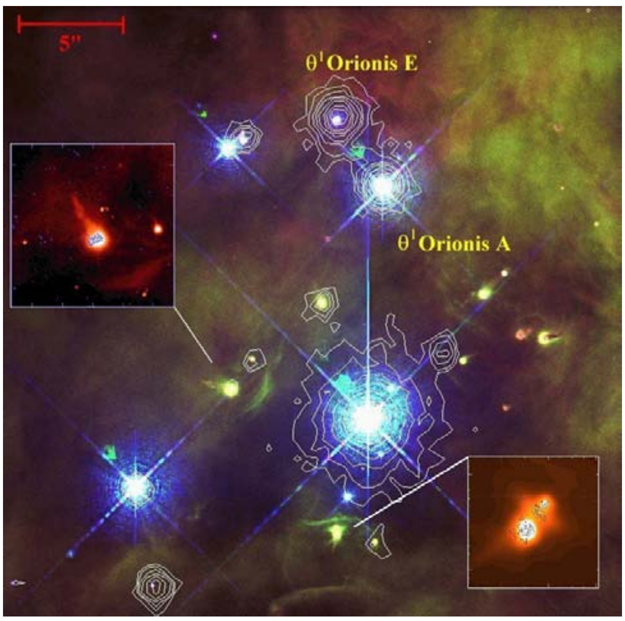
The Birth Process of Stars: The Orion Proplyds

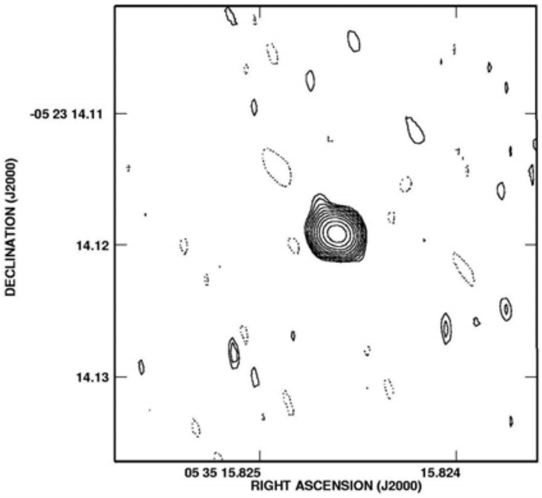
The Orion Nebula Cluster (ONC) offers a unique opportunity to study the formation of both low and high-mass stars. The Trapezium Cluster lies within the central 0.1pc of the nebula and is the densest stellar clustering known in the Galaxy. Recent results from one of the first MERLIN key projects, involving over 100 hours of data, have provided high-resolution images of the Trapezium cluster 'proplyds' - Young Stellar Objects (YSOs) embedded in knots of gas photo-ionised by one of the bright Trapezium stars in the Orion Nebula. These observations also revealed a number of variable, active stars, the richness of which were recently demonstrated by *Chandra* observations (Schultz et al., 2001, ApJ, 549, 441).

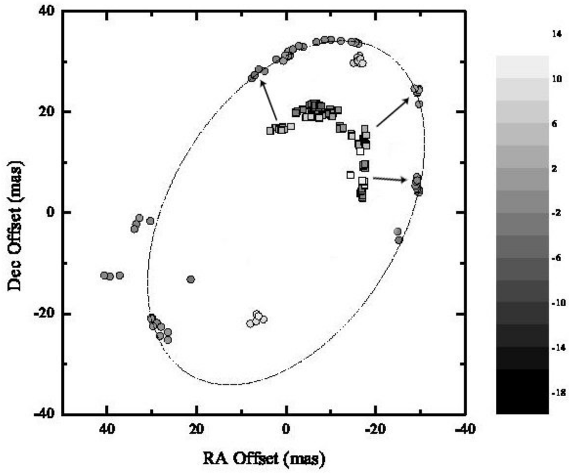
The 6cm MERLIN images (Garrington et al., 2002, EVN Symposium, p. 259) reveal that the bright radio object normally associated with the Trapezium star θ^1 Orionis A, is in fact displaced by 220 millarcseconds from the Hipparcos optical position. IR speckle imaging by Weigelt et al. (1999, A&A, 347, L15) shows a companion, θ^1 Orionis A2, exactly 220 mas north of the primary star. The star also has a closer companion, with a 65 day period (~1 AU orbit), and previous investigations have suggested that the radio emission might be related to this close binary system.

Global VLBI observations with the VLBA and 7 EVN telescopes at 6cm clearly confirms the MERLIN position of the radio emission and shows that it is compact on scales of a few milliarcseconds (~1 AU). The implied brightness temperature is 10^8 K. The IR colours of θ^1 Orionis A2 place it on the evolutionary track of a 4-5$M_\odot$ pre-main sequence (PMS) star of approximately 1 Myr age. PMS stars with non-thermal emission have been identified with weak-lined or diskless T-Tauri stars without significant wind ionization. The radio emission

Below: An *HST* optical image of the Trapezium Cluster with *Chandra* X-ray contours overlaid. The inserts show two of the *HST* Hα images of proplyds within the cluster with MERLIN 5 GHz contours overlaid.







from θ[1] Orionis A2 implies strong magnetic fields, but their generation by the dynamo mechanism in this object is an enigma since early-type PMS stars generally do not have convective envelopes.

Top (left): Global VLBI 6 cm image of θ[1] Orionis A2. The slight east-west extension is resolved and may represent large-scale magnetic structure on a scale of about 0.5 AU.

Proto-planetary Discs: Water-vapour Masers in Cepheus A HW2

Interstellar H_2O masers can be used to trace the warm, dense molecular gas associated with young stellar objects and star-forming regions. Most identified interstellar masers are associated with molecular outflows and trace the expanding shock front between the outflow and the ambient interstellar medium. However, a few appear to be associated with circumstellar discs or rings rather than the molecular outflow. The nature of these discs ultimately bears on the origin of planets since they are thought to form out of condensations within the discs. H_2O masers provide a unique probe of the dynamics of such systems.

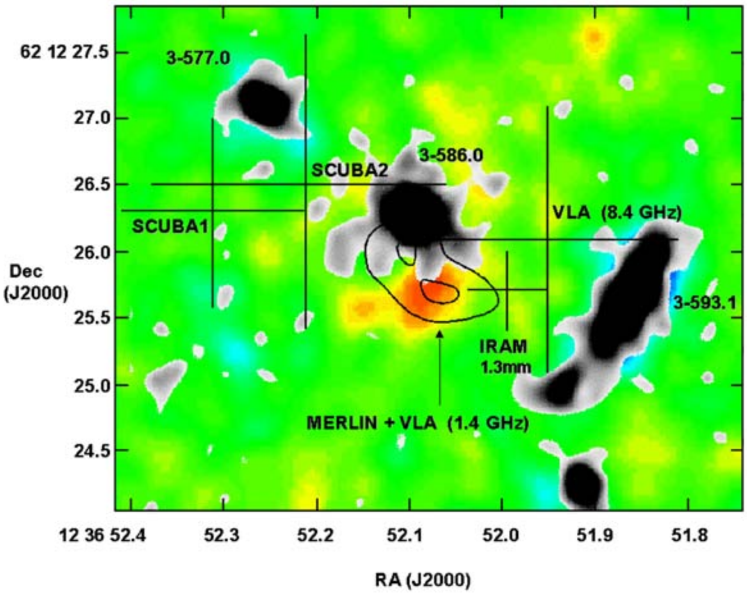
Top (right): MERLIN epoch 2000 data (circles) and VLBA 1996 data (squares) showing the change in maser positions in the R4 complex. The line traces the best-fit rotating ring model.

Gallimore et al. (2003, ApJ, 586, 306) have imaged the maser complex which lies close to the continuum source Cepheus A HW2. They find a self-contained system which they have modelled with a hydrodynamic shock (v_s~13 km s^{-1}), expanding into a rotating circumstellar disc around a central unseen protostar of ~3$M_{\odot}$. MERLIN's supreme astrometric capabilities enables such revealing proper motion studies to be performed with relative ease.

Star-formation At High Redshift: The Identification of SCUBA 850.1

The extragalactic background radiation, which contains all the energy ever emitted by galaxies, is dominated by emission in two wavebands: the optical/near-IR emission is due to starlight and the sub-mm emission is characteristic of dust. Since the energy densities in these two bands are comparable, approximately half of the energy ever emitted by stars or AGN has been absorbed by dust and re-radiated at longer wavelengths. Only at radio and hard X-ray wavelengths can this dust be penetrated and investigations carried out on the environments in which perhaps the bulk of star formation has occurred.

SCUBA on the JCMT has been able to demonstrate that much of the sub-mm background is associated with individual galaxies. Estimates of the fraction resolved vary from 20% to 100% but there is a consensus that the galaxies detected are powerful analogues of the local ultra-luminous IR galaxies (ULIRGs) with star-formation rates of typically 300$M_{\odot}$ per year. Star-formation rates inferred from the sub-mm results have been used to study the overall star-formation density as a function of redshift. While all estimates agree on the rapid increase from z=0 to z=1, the key questions of what fraction of star-formation was obscured by dust and whether the star-formation density declines at z>2 remain unanswered because the redshift distribution of the SCUBA sources is still uncertain.



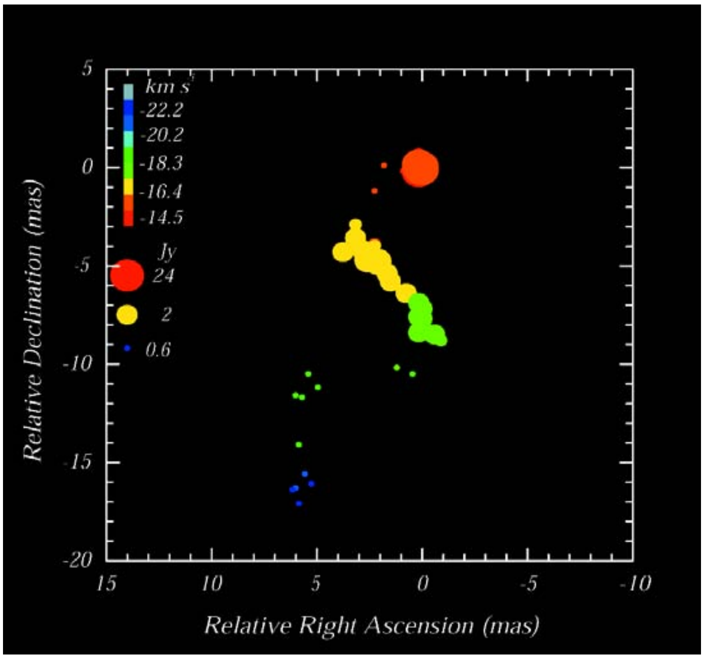
Above: MERLIN+VLA image (contoured) showing the 16µJy radio source associated with SCUBA 850.1. The original and revised SCUBA positions (SCUBA 1 and 2) are also marked together with the IRAM position and a VLA 8.4 GHz detection. A residual Subaru K band image (false colour) shows the identification to be a very red object lying 0.8 arcseconds to the SSE of elliptical galaxy 3-586.0.

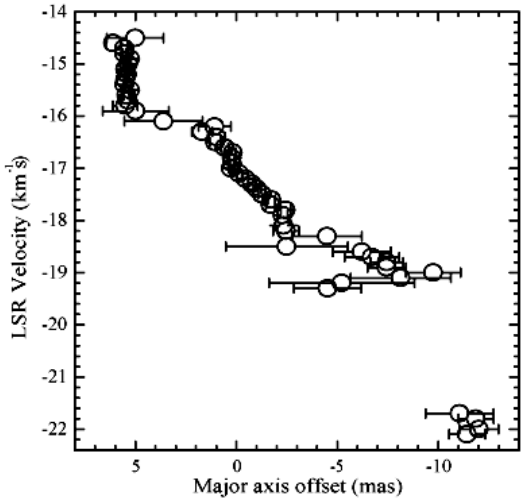
Identification of the SCUBA sources has proved very difficult because of their limited positional accuracy. However, deep, high-resolution imaging of the Hubble Deep Field (HDF) North with MERLIN and the VLA has detected a 16µJy radio source associated with SCUBA 850.1. Careful astrometric alignment of the *HST* WFPC2 R-band images has allowed the optical frame to be aligned to the radio ICRF to better than 50 milliarcseconds. Based on this astrometry, Dunlop et al. (in press) have used the Subaru 8.2m telescope to detect a very red object at the position of the MERLIN+VLA source and close to the sub-mm position measured by IRAM, whose positions are also derived with respect to the ICRF. MERLIN's astrometry has been crucial in allowing the accurate identification of this object in such a crowded field. The object is extremely red (I-K>5.2) and the spectral energy distribution implies a redshift of z=4.1±0.5.

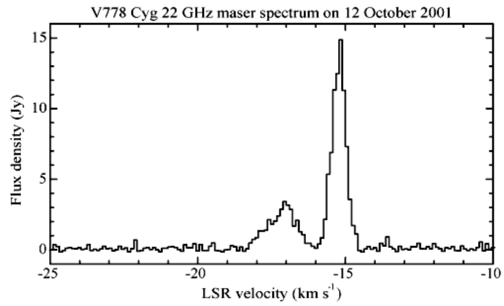
A Resolved Oxygen-rich Disc Near the Carbon Star V778 Cyg

The nature of genuine carbon stars with an oxygen-rich environment during a phase of copious mass-loss as the star moves along the Asymptotic Giant Branch has been unclear since their discovery. Their spectra up to ~6.5µ are almost identical to those of true carbon stars, while longward of ~6.5µ they are dominated by strong silicate emission typical for O-rich Miras. Detection of OH and H_2O masers confirmed the O-rich chemistry.

MERLIN observations of water maser emission from one of these objects, V778 Cyg, have revealed a molecular disc for the first time (Szymczak et al., in preparation). The maser components form a distorted S-shaped structure along a direction of position angle -20 degrees. There is a clear velocity gradient along this structure with weak components in the south blue-shifted with respect to the brighter northern components. The distribution of maser spots is consistent with a model of a disc with a major axis of 18.5 mas







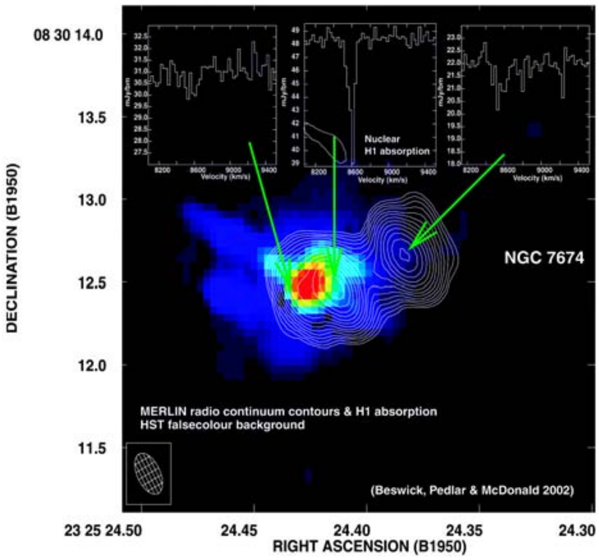
Above: MERLIN observations of V778 Cyg. The overall structure of H_2O maser emission can be seen in the map. The plot of velociy components versus the distance along the major axis clearly confirms the presence of the disc.

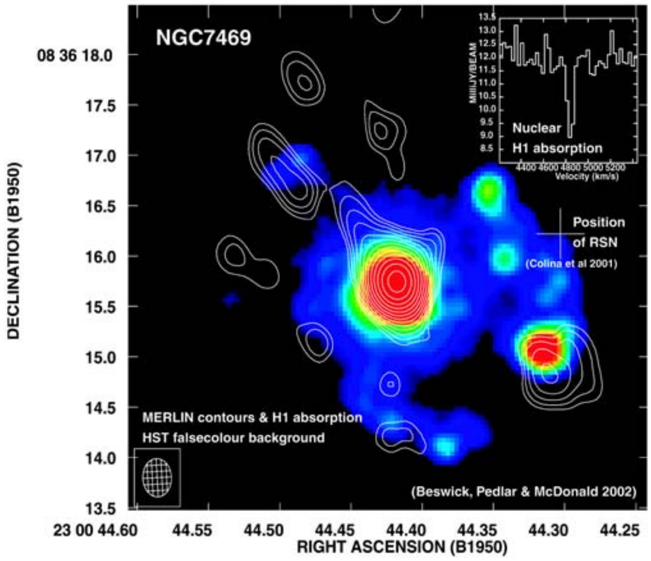
displaced by 0.30±0.07 arcseconds from the optical position of V778 Cyg (as measured by Tycho2). This implies that the oxygen-rich matter is stored in a disc around a companion star in a widely separated system. The overall structure of the H_2O maser emission can be seen in the accompanying figure. The plot of the velocity of the components versus the distance along the major axis clearly confirms the presence of the disc.

HI Absorption in Seyfert Galaxies NGC 7469 & NGC 7674

Active galaxies are thought to be both fuelled and obscured by neutral gas removed from the host galaxy and funnelled into a central accretion disk. As such, it is crucial that the neutral gas in these sources is studied on a wide variety of angular scales ranging from gas within galaxy clusters and galactic disks down to scales comparable with the theoretical obscuring torus. One method of obtaining high resolution observations of neutral gas is via absorption studies. MERLIN is supremely suited to such studies since its resolution provides information on scales of tens of parsecs for the nearby AGN whilst not over-resolving important features.

Recent examples of these studies have been observations of strong and highly localised HI absorption against the Seyfert 1 nucleus of NGC 7469 and the Seyfert 2 nucleus of NGC 7674. Against NGC 7674 the HI absorption is isolated to within 100pc of the suspected position of the AGN. These observations imply that the HI exists in a ring or torus close to the AGN, consistent with the dusty torus model. This source is only the second Seyfert galaxy, following NGC 4151, which was also studied with MERLIN, that has been observed to have such localised nuclear absorption. Similarly the





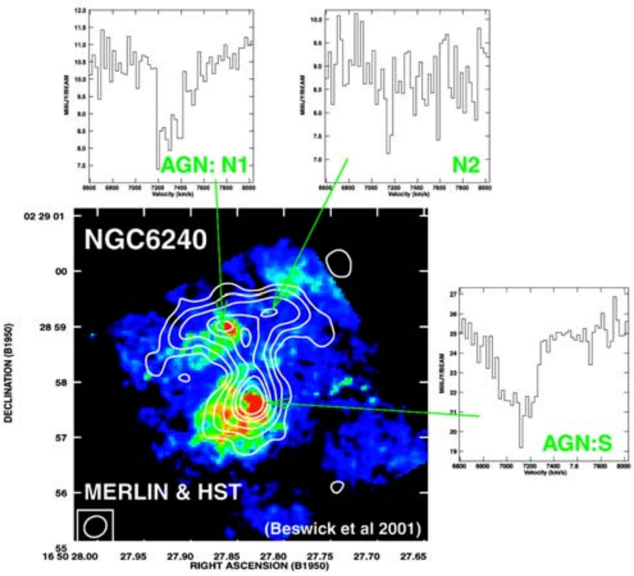
Top (left): The sub-arcsecond MERLIN 21 cm nuclear structure of the Seyfert 2 galaxy NGC 7674, shown as contours overlaid on a false-colour optical image. The higly localised absorption against the AGN is evident in the inset spectra.

Top (right): MERLIN 21 cm radio continuum structure of the nuclear region of the Seyfert 1 galaxy NGC 7469 overlaid on a false-colour *HST* WFPC-2 image. Both the radio and optical images show the bright nucleus and diffuse emission from a circumnuclear starburst. The inset spectra show deep nuclear HI absorption detected with MERLIN.

Below: MERLIN 21 cm contours overlaid on the *HST* image of the 'binary AGN' of NGC 6240. The insets show HI absorption spectra against the nuclear components.

Seyfert 1 NGC 7469 has been observed to have deep nuclear HI absorption, localised to within a few tens of parsecs. Although the standard dusty torus model does not require obscuration of the nucleus in Seyfert 1s, these observations are still not incompatible with this interpretation. NGC 7469 is a peculiar Seyfert/starburst hybrid with a circumnuclear starburst ring that has recently come to the fore because of the discovery of a luminous Radio Supernova (RSN). This starburst/Seyfert galaxy is awash with neutral gas, thus making it highly probable that the HI absorption is the result of foreground gas which is fuelling the starburst.

Recent X-ray observations of Ultra Luminous Infrared Galaxies (ULIRGs) have highlighted the fact that these peculiar and powerful merging galaxies often display a dichotomy of power sources; both starburst and hidden AGN. Additionally, *Chandra* has now afforded X-ray observers the angular resolution to separate individual nuclei within these merging galaxies and in one case, NGC 6240, has identified the hidden AGN within both the remnant merging galaxy nuclei within a single ULIRG.



Radio observations, using MERLIN, of these gas rich and highly morphologically disturbed galaxies provide a still higher resolution picture of the interiors of these dust enshrouded sources. One such example has been the recent MERLIN HI absorption observations of the 'binary AGN' system in NGC 6240. Extremely broad and high opacity HI absorption is observed against both of the nuclei of NGC 6240 with only comparatively narrow absorption detected against the surrounding extended radio continuum. The relative dynamics of the two cores, derived from the MERLIN HI observations, imply that the two nuclei are dynamically bound and rotating about each other. Additionally, the two nuclei are unresolved by MERLIN at 5GHz implying a linear size of less than 25pc, consistent with the AGN interpretation of both of these two cores.

VLBI, MERLIN & HST Observations of 3C 236

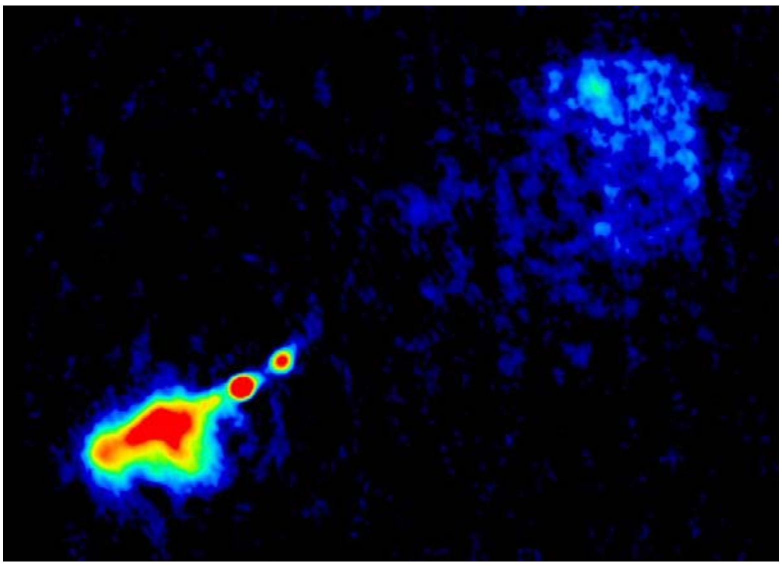
3C236 is classed as a Giant Radio Galaxy (GRG). GRGs are among the largest radio sources in the universe and 3C236 is the largest in this class. On large scales it shows an asymmetric double-lobed structure, with the lobe separation about 3.9 megaparsecs (12.7 million light years). VLBI observations (which image only the inner core) show a core straddled by two asymmetric mini-lobes, with the asymmetry opposite to that of the large scale lobes. Thus this source is known as a 'double-double', although in the case of 3C236 the ratio in size between the outer and inner doubles is much larger than most other examples. The interpretation is that the jets turn on and off with some 'duty cycle'. If the 'off' cycle is short then the large scale structure stays visible, but if the 'on' cycle is short, then the large scale lobes may fade until they are unobservable. Its size, as well as the presence of both large-scale (FRI/II) and small-scale (CSS) structures, makes 3C236 an important object for radio source evolution studies.

Schilizzi et al. (2001) recently studied 3C236 with a combination of VLBI, MERLIN and *HST* data. These data consisted of 1.6 GHz global VLBI data taken in 1984, 5 GHz global VLBI data from 1989, MERLIN data at both frequencies taken in 1991 and 1993 and a *HST* WFPC-2 snapshot of the object centred near 7000 Å.

The VLBI data confirmed that the central region of 3C236 looks like a CSO; the central core straddled by the two lobes of emission, the eastern one of which is fed by a bright jet. Re-examination of the *HST* data on 3C236 reveals that the normal to the plane of the dust ring in the center of the galaxy is at ~60° to the line of sight and approximately parallel to the projected elongation of the radio structure. Assuming that the radio axis is parallel to the normal to the dust disk, the short north-west jet is probably on the approaching side and the longer south-east jet on the receding side. This would imply the true size of 3C236 is 4.5 Mpc rather than the 3.9 Mpc determined from assuming the source is in the plane of the sky. The coincidence of a dust feature and the south-east compact jet, within the astrometric errors, suggests that the dust may be in the form of a cloud encountered by the jet in the first ~400 pc of its journey out from the nucleus.

Previous WSRT observations of 3C236 showed that the south-east jet appears essentially continuous over a distance of 2.5 Mpc from the nucleus to the hotspots, making this the largest jet known in the universe. It is likely, however, that the central activity is episodic but with a shorter duty cycle than for other double-double radio galaxies. The current central radio emission in 3C236 is evidence of a recent major burst of radio emission superimposed on a more uniform level of activity, perhaps as a result of subsuming a companion galaxy.

Below: A 1.6 GHz image of the giant radio galaxy 3C 236. With a linear extent of ~4 Mpc, this is the largest known raio source in the universe, although this image shows only in the inner part (~2 kpc) of the source.



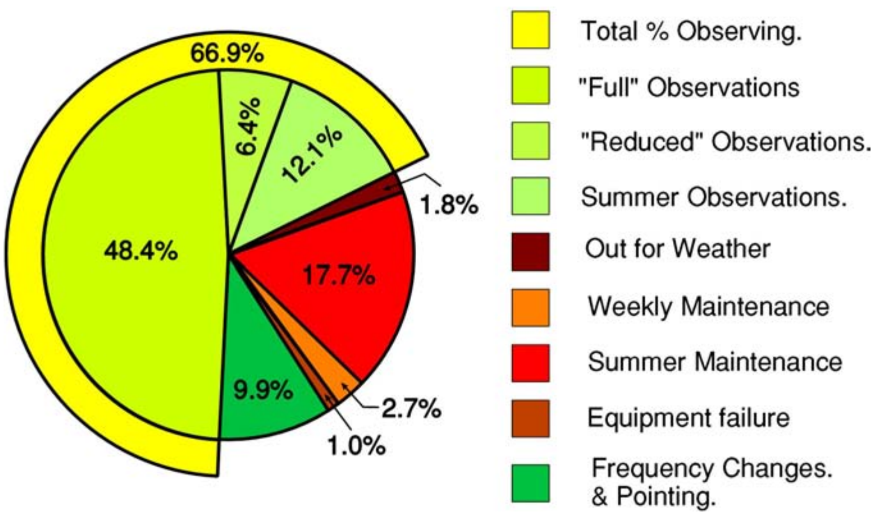
MERLIN OPERATIONS

The normal yearly pattern of 9 months of observations and 3 months of engineering, development and telescope painting during the summer/early autumn[1] was disrupted in 2001 by an outbreak of foot and mouth disease, which prevented access to some of the telescope sites other than in emergency situations and then only following strict precautionary procedures. The effect of this was that major engineering work could not take place in 2001 as originally planned. Consequently, observations continued throughout the summer period, albeit at a reduced level and usually with only a full complement of telescopes at the weekends, since it was essential to carry out maintenance where and whenever possible. The Mk2 telescope was also allocated for 'single dish' observations for a time during this period.

There have been two major developments during the past two years that increase the operational efficiency of MERLIN and also its capability. These have been the installation of a new focus box on the Defford telescope which can be equipped with both C- and L-Band receivers at the same time, and the development of 6 GHz receivers covering excited OH and methanol spectral lines, installed on the Cambridge and Mk2 telescopes. Thus, Defford is now frequency agile between L-Band and C-Band (switching time - a few seconds) and the Cambridge and Mk2 telescopes are permanently equipped with 4 receivers. A number of single baseline observations of excited OH and methanol maser sources have already been allocated by PATT. During the latter part of 2003, as part of the implementation of *e*-MERLIN, all the telescopes will acquire a 6 GHz frequency capability.

A summary of the operational status of MERLIN is shown below for the calendar years 2001 and 2002. The summer 2001 observations, some of which were for key programmes requiring deep integrations or long-term monitoring, are shown separately, since it is felt that the lack of a telescope at any particular time, development work and fault occurrence were so intermixed with the observations that no sensible statistics could be presented that would give a true picture of the operations at that time. This continued operation throughout the summer was of great benefit to a key programme which involved the monitoring of a time varying gravitational lens system. The lens was observed almost every day for approximately 2 hours. The results from these and other observations have been used in a determination of Hubble Constant, H_o. The sector labelled 'reduced'

Below: Summary of the operational status of MERLIN during 2001 and 2002.

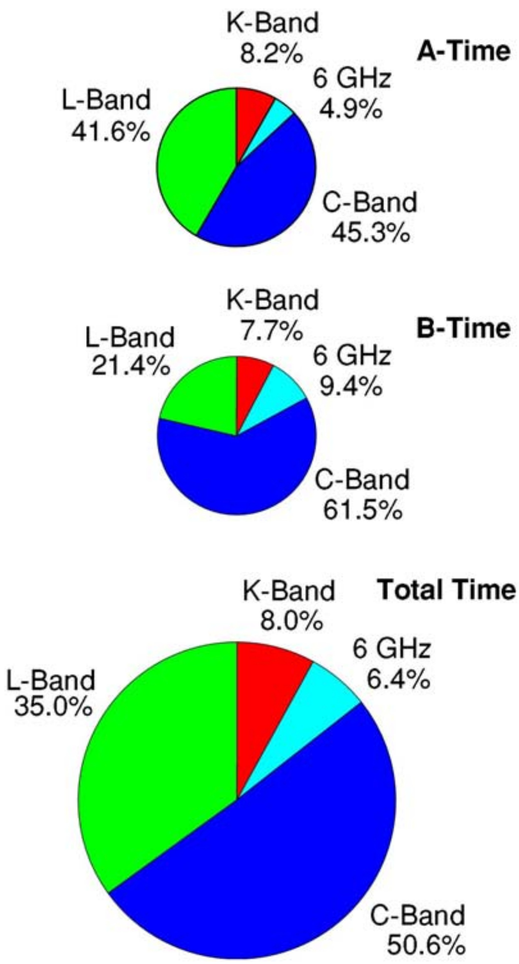


[1]The MERLIN target for operation of 24 hours per day for 9 months of the year, except for a weekly maintenance period of ~8 hours and the time required for frequency changes, was changed in October 2002 to be 24 hours per day for 7 months to facilitate the implementation of *e*-MERLIN.

observations indicates the sum total of short 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. The time allocated to frequency changes and pointing measurements (9.9%) is particularly high as it includes the time taken for a 'once-off' detailed re-measurement of the pointing of the Pickmere telescope, necessary following the complete replacement of its drive system in 2002. It also includes the installation, equipping and testing of the new Defford focus box and the installation and testing of the new 6 GHz receivers on the Cambridge and Mk2 telescopes, both of which were carried out during 'winter' frequency change periods. Even assuming that only half of the summer observing period should be considered as full-time observations (an underestimate) and that the frequency change period 'allowed' be 4.9%, (approximately that of the previous 4 years), the resulting percentage total observing period of 68.5%, equivalent to 91.3% over a 9 month observing period, is considerably above the 80% target.

During Semesters 01A, 01B, 02A and 02B, MERLIN has operated in all its three main frequency bands and single baseline 6 GHz observations have also been made. 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. Once again, periods of very good weather in the spring of 2001 and 2002 enabled many more K-Band observations to be made than had been possible prior to the year 2000. Of the programmes allocated time by PATT during 2001 - 2002 (including long-term status programmes carried forward from Semester 00B), 89% of the A-priority and 90% of the B-priority have been completed to date (Appendix B). All except one of the A-programmes not completed are L-Band programmes, some of which have long-term status to Semester 03A and are still to be completed. Interference at red-shifted hydrogen frequencies is the main cause for non completion of the remaining programmes. The summer 2001 observing provided significant additional time for C-priority (fill-in) observations, which was mostly allocated to the two Key programmes. The MERLIN Director also has at his disposal 2 days per Semester for observations of an immediate urgency. These and a further 6 observations of possible gravitational lenses made with a reduced system during summer 2001 have been included as Target of Opportunity observations in Appendix B. The 'good' lens candidates represented the final 6 sources from a total of thousands of sources investigated in the JVAS and CLASS surveys and ensured that the samples were complete. The above statistics only refer to the PATT allocated programmes and therefore do not include MERLIN+VLBI runs allocated by the EVN programme committee.

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

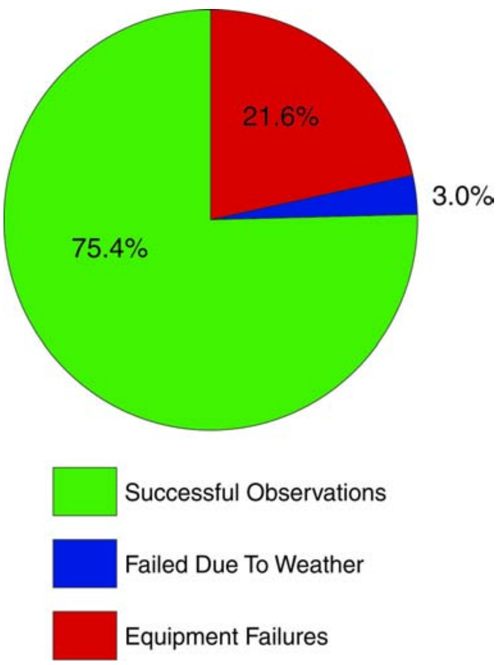


VLBI OPERATIONS

The European VLBI Network (EVN) carries out VLBI observations that typically involve 9 telescopes from 6 European countries plus China. The array has a maximum baseline length of over 9000 km, but is often used in conjunction with 10 or more other telescopes around the world to provide a global array with milliarcsecond resolution. 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 network in the world.

During the period 2001-2002, the National Facility participated in all six EVN observing sessions. These involved the 25-m Mk2 telescope at 1.3, 5, 6 and 18/21 cm, the 76-m Lovell telescope at 18/21 cm and the 32-m Cambridge telescope at 1.3, 5, 6 and 18/21 cm. National Facility telescopes were scheduled to observe 112 VLBI projects, for a total of 1824 telescope hours. 28 of these experiments were joint EVN+MERLIN observations, during which MERLIN provides short baselines allowing source structure to be mapped on scales from a few milliarcseconds to several arcseconds. Unfortunately, a total of 444 telescope hours (24.6%) were lost due to technical problems at the time of observation and due to weather. This high rate of failure was due primarily to serious problems during the February and November 2002 sessions. During February 2002 the Cambridge microwave link failed due to the ingress of water into an underground section of the waveguide at one of the repeater sites. This was the first time such a problem had arisen in the 20-year history of MERLIN. At the same time a problem with the inserts between the headstacks and the carriers on the VLBA recorder developed. This resulted in none of the scheduled 18cm observations being carried out for Cambridge in February 2002. The entire November 2002 session at L-band was lost for the Lovell telescope because the LO had been wrongly connected prior to the telescope being recommissioned following the replacement of the surface. It is worth pointing out that less than 4% of observing time was lost during the whole of 2001.

Below: Operational statistics for VLBI observations carried out by the National Facility in the period 2001-2002.



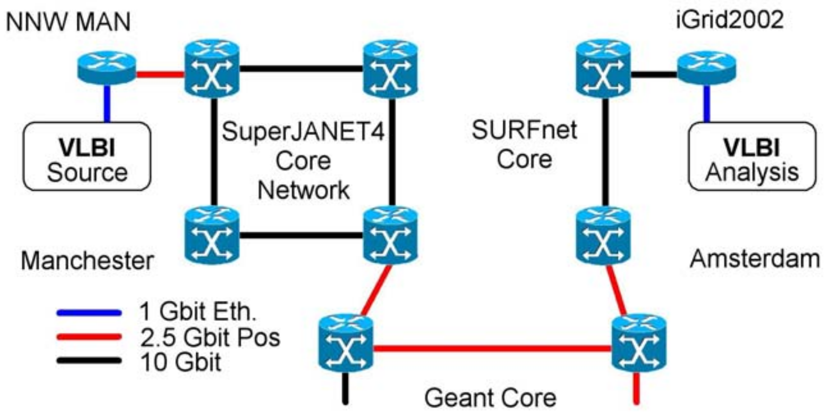
The upgrade of the VLBA (Cambridge) recorder, which now has two headstacks, new read-write electronics and a MkIV formatter, was completed in 2001. Both heads can be used for recording, with a total data rate of 512 Mb/s, and fringe tests have confirmed the success of the upgrade. The Mk4 recorder was also upgraded for dualhead recording and 512 Mb/s tests were successful. A new decoder has been installed, improving the ability to check recording quality on-site. After major difficulties with recording heads coming loose on the VLBA recorder, the carrier on the first head was replaced. It was necessary to re-lap the heads, using an ultrasonic humidifier to raise the room humidity above 35%. A failed power unit on the Mk4 recorder, which caused problems during the May 2002 session, was repaired. New TAC CNS GPS units are now installed and are running TAC32 Plus software. Work is beginning in order to replace the VLBA recorder with a Mk5 disk-based unit.

Above: The Mk5 '8-pack' disk system designed as a direct replacement for VLBI magnetic-tape storage.

Considerable work has been done to integrate the control of the back-end synthesisers, filters and calibration units into the VLBI Field System and to generally strengthen the local diagnostics. The telescope control interface has been rewritten to include continuous checking of parameters, including telescope pointing as well as the back-end synthesisers and filters. A program (funded by the EU-funded Infrastructure Cooperation Network RadioNet) to automate the switching of IF, LO and calibration signals between single-dish, MERLIN and VLBI observations has been completed. This has made the switch over between observing modes much easier. Significant effort has also been expended in investigating calibration issues at JBO, namely in the implementation of the standard Field System calibration routines which initially caused conflicts in the local antenna control software. This work is ongoing but should be completed by summer 2003.

The National Facility has been active in the recent development of the PC-EVN disk-based VLBI recording system. In a special test observation, data were recorded on tape at JBO and on disk (in parallel with tape) at Westerbork. Later tape-tape and tape-disk correlation at JIVE yielded identical fringes at 256 Mb/s data rate. JBO was also involved in one of the first eVLBI demonstrations. On 24th October 2002, PC-EVN hard-disk units were used to record data at JBO and Westerbork in the first disk-disk trial of the system. The unit at JBO was built using a locally purchased PC with interface boards and software supplied by Metsahovi. Four passes of MkIV data were recorded, comprising 32 tracks at 8 Mb/s giving an aggregate data rate of 256 Mb/s. The data were then transferred within a few hours over an international network to JIVE and correlation produced normal fringes.

Recent developments in VLBI are aimed at improving reliability and reducing the cost of operations by moving from a custom made tape based system to using exchangeable disks in PCs. The advent of the iGRID2002 exhibition at SARA Amsterdam in



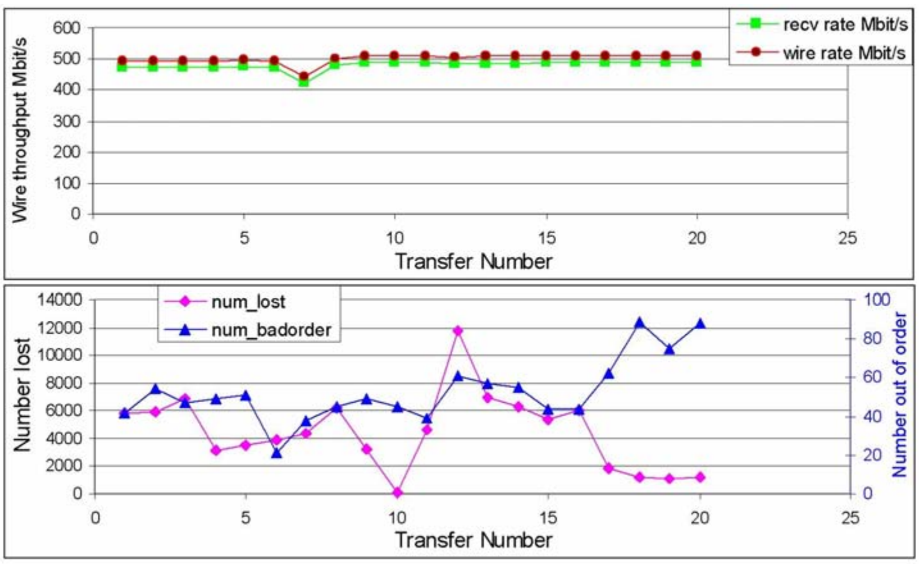
Right: Network topology of the VLBI iGrid2000 demonstration. The data were sent as a simple stream of UDP packets in files of 1.8 Gbytes, each packet containing 1452 bytes. Data throughputs of 500 Mbits/sec were readily obtained even during periods of intense traffic during the iGrid demonstration. Packet loss was significant, though not enough to cause synchronisation problems for VLBI. The data were later stored on disk via the PC-EVN system at JIVE and fringes were successfully obtained.

September 2002, with the availability of high data rate international links, gave an opportunity to attempt data transfer via the Internet. This would not only test the capacity of the links but also prove the viability of the use of the Internet for VLBI. This development would also eventually lead to instant turn-around of VLBI data, which currently stands at several weeks. The tests were successful in achieving data rates from Manchester of 500 Mbps over the production network. This was the first demonstration of fibre-optic link connected international VLBI.

The data were collected in a single baseline VLBI experiment between the Westerbork array in the Netherlands and the Jodrell Bank Mk2 telescope. Observations of the quasar DA193 were made in the afternoon of 12 July 2002, at an observing frequency of 5 GHz and at data rate of 256 Mbps in a test of the disk based PC-EVN system. The normal magnetic tape system was used at Jodrell Bank, whereas the new disk based system was used at Westerbork. The exchangeable disks from Westerbork were later taken to a machine in the Regional Computer Centre in Manchester and connected into the national network, since there is only a 155 Mbps link into Manchester from Jodrell Bank Observatory at the moment.

The networks used in the VLBI demonstration were all production networks that carried normal user traffic during the demonstration. The VLBI data was sent from the server at Manchester, over the Net North West Metropolitan Network, MAN, and onto the UK Academic Network, SuperJANET4. Geant connected the UK with SURFnet, the academic network in the Netherlands, and this in turn was connected to the iGrid2002 Network with the server that acted as the data sink.

The data were sent as a simple stream of UDP packets in files of 1.8 Gbytes, each packet containing 1452 bytes. Data throughputs of 500 Mbits/sec were readily obtained, even during periods of intense traffic during the iGRID demonstration. Packet loss was significant, though not enough to cause synchronisation problems for VLBI. The data were later stored on disk via the PC-EVN system at JIVE and fringes were successfully obtained.



Left: The upper plot shows a graph of the user and wire data transfer rates for a series of 1.8 Gbyte data transfers taken during the iGrid2000 bandwidth attempt. The lower plot shows the corresponding number of packets lost and the number that arrived out of order.

Telescope Control

Most of the exciting new MERLIN results highlighted in this report show that radio observations at 0.1 arcsecond resolution provide an essential complement to sub-arcsecond optical, infra-red and X-ray images. However, in many cases, MERLIN is operating at its sensitivity limit, and what is needed now is not more resolution, but higher sensitivity. The radio links which give MERLIN its high resolution capability also impose the chief limit on its sensitivity, since they transport less than one percent of the energy which could be gathered by a modern 4-8 GHz receiver.

Optical fibres are now capable of transporting data at several hundred Gb/s per fibre: by connecting the existing MERLIN telescopes with optical fibre, the observing bandwidth can be increased from 15 MHz to 2 GHz per polarization. Together with the JIF-funded upgrade to the Lovell telescope, significant improvements in receiver performance and a new correlator, this will increase the sensitivity of MERLIN by a factor of at least 30 at the prime observing frequency of 5 GHz. The *e*-MERLIN upgrade is now funded and underway.

The science case for *e*-MERLIN was prepared during 2000 and highlights the following areas:

- The study of the structure of galaxies detected at sub-mm wavelengths, the separation of starburst/AGN systems and the identification of AGN in ULIRGS at high-*z*
- The study of star-formation rate as a function of redshift
- The imaging of thermal and non-thermal jets from YSOs, probing the physics of star-formation
- The imaging of circumstellar dust disks and methanol masers around young stellar objects
- The study of the physics of mass ejection in novae, planetary nebulae and evolved stars
- The study of the physics of jets via matched resolution images, such as radio/optical movies of M87
- The study of GRB hosts through the measurement of star-formation rates
- The determination of cosmological parameters (e.g. Ω_m and Ω_Λ) through deep observations of gravitational lenses
- The study of microlensing in high-redshift dark matter haloes

The capital funding for *e*-MERLIN has come from The University of Manchester, the Northwest Development Agency, UMIST and the University of Cambridge. PPARC has agreed to some transfer of funding from the National Facility operating grant to the *e*-MERLIN project as well as placing *e*-MERLIN on a firm footing in its roadmap for the future. The funding arrangements were agreed in January 2002 and the project definition and overall design was clarified in the first half of 2002 and reviewed at an externally-led Preliminary Design Review in May 2002. The *e*-MERLIN Project Management Committee, led by Mr Peter Wainwright, a member of The University of Manchester Council, and with representatives from all the funding partners as well as the MERLIN Steering Committee, meets every six months to review the progress of the project.

The key design goals are restated as follows;

- Maximum bandwidth: 2 GHz in each of 2 polarizations. With the receiver upgrades discussed below, this would provide a sensitivity (1-σ) of 1.7-2.5 μJy/beam for a 12-hr observation at 5 GHz, equivalent to a brightness temperature sensitivity of 25-35K
- Receiver systems at 1.5, 6 and 22 GHz: dual circular polarization with target system temperature values of 30K, 25K, and 50K respectively
- IF equipment capable of delivering ~1 or ~2 GHz instantaneous bandwidth with 10kHz tuning and repeatable LO phase anywhere in the receiver band
- A phase transfer link to ensure all telescope LOs are coherent with the central H-maser
- Digital data transport to the correlator with at least 3 bits at 2 GHz bandwidth and 8 bits at reduced bandwidth
- A monitor and control system to allow remote operation of receivers
- A correlator capable of handling up to 2 GHz/polarization. It should be possible to correlate the full bandwidth with spectral channels of 0.5 MHz or narrower. Spectral line modes must encompass 1.6-1.7 GHz OH observations with 0.5 kHz resolution in all polarizations and 200 MHz wide $H_2 0$ megamaser observations at 100kHz resolution.
- A data acquisition system to handle 0.5 TB/day sustained correlator output for default wide-field continuum operation and peak data rates of up to 5 TB/day for periods of up to 24 hr.

The principal change from the original project scope, as described in the previous Biennial Report is the deferral of the construction of new receiver systems to cover the 8-12 and 12-18 GHz band. This is due to the reduced funding available from PPARC during the *e*-MERLIN construction period.

The revised design goals were reviewed and approved in October 2002 by a Science Working Group (SWG), chaired by Dr I. Browne (JBO) and with representatives from eight other institutes in the UK who are likely to be prime users of *e*-MERLIN. The SWG has also defined a series of Science Reference Missions, initially designed as hypothetical key programmes, against which the design of *e*-MERLIN could be evaluated, but also as potential commissioning observations.

Telescope Infrastructure

e-MERLIN is primarily a sensitivity upgrade, enabled by broad-banding the connections from the telescopes to the correlator. There is no increase in the range of operating frequencies or any change to the mode of observation, so there is no requirement to make any changes to the physical infrastructure of the telescopes. The Lovell Telescope which has been upgraded via a separately funded project, will participate with full efficiency at 4-8 GHz. The performance of the Defford telescope is much worse than the other MERLIN telescopes at 5 GHz. A low-cost upgrade, involving replacing the existing panels with those from its sister telescope in Dwingeloo, is being considered.

Receivers

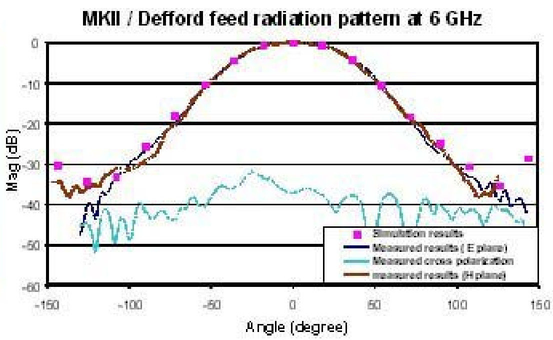
MERLIN currently operates in three prime frequency bands: 1.3-1.7 GHz (L), 4.5-5.2 GHz (C) and 22-24 GHz (K). The observing demand for these three bands is roughly in the ratio 40:40:20, but has varied considerably due to the promotion of key programmes at 1.4 or 5 GHz. The *e*-MERLIN SWG has endorsed the view that *e*-MERLIN should concentrate on enhancing the performance of the current L, C and K-band receivers rather than over-stretch the project budget to build new receivers in the 8-12 or 12-18 GHz band.

The L- and C-band feeds, polarizers and receivers will be upgraded to increase their frequency coverage in order to gain the bandwidth advantage of *e*-MERLIN. At the same time, their low noise RF amplifiers will be replaced with some of the best low-noise HEMT amplifiers currently available. Access to and experience with these transistors has come through the work of the JBO engineers on the *Planck* satellite. The existing K-band receivers already cover 2 GHz but can benefit from a simple replacement of the LNAs.

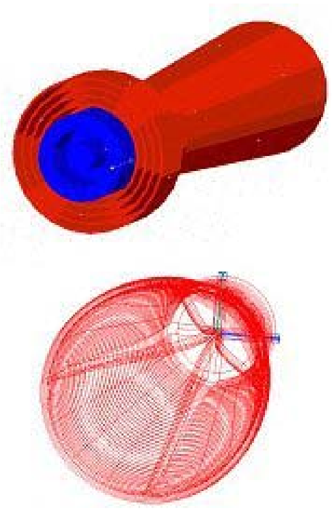
The Mk2 and Cambridge 32-m telescopes are both currently fully frequency-flexible. All receivers are mounted on carousels which can be rotated to the desired position within a couple of minutes. The Defford telescope has both L and C-band receivers mounted at prime focus, so that the observing frequency can be changed simply by changing the pointing offset. The E-systems telescopes (Knockin, Darnhall and Pickmere) have secondary focus carousels, which currently house C and K-band receivers, but L-band receivers have to be mounted at prime focus. A lens has been designed, based on a 22 GHz scale model, to allow L-band to be mounted in the carousel at the secondary focus of the three E-systems telescopes. The lens will be under remote control, so that the observing frequency can be changed within one minute. The lens and its mechanism are being designed and the first system will be installed later in 2003.

The limits of the useable band at L-band are set by the local radio-frequency interference environment and hence the specification for the L-band lens and horn is 1.2 – 1.8 GHz, but initially the band will be limited by a front end High Temperature Superconducting Filter to 1.33 – 1.73 GHz. The target noise figure for the L-band receiver is 30K at the secondary focus. This would give a sensitivity of 3.5 nJy/beam for a 12hr observation (on source) with the Lovell Telescope included.

At C-band, RFI is currently less severe and the original specification calls for a 4-8 GHz band. New horns, polarisers and low-noise amplifiers are being designed and the first complete systems should be in place at the end of 2003. The existing K-band receivers already cover a band of 22 – 24 GHz and no modifications to the horns or front ends are specified. New amplifiers should achieve T_{sys}~60K on the telescope.



Left: The Mk2/Defford feed prototype (a wide flare-angle scalar horn) for *e*-MERLIN and its radiation pattern measurements and simulations. The overall diameter of the feed is 150 mm.



Above: The feed model (top) of the Lovell telescope and its Ortho-Mode Transducer (OMT) design (bottom).

IF System & Phase Transfer

The maximum instantaneous bandwidth has been specified as 2.0 GHz in each of two polarizations. The option of observing 2 x 2 GHz in one polarization may be useful for experiments which wish to maximise the instantaneous bandwidth (such as group delay measurements for astrometry). A narrow band mode with more sampling bits is required for observing at low frequencies or where more sampling bits are required (at the expense of bandwidth). 500 MHz with 8-bits would be an easy option at this stage. Other users of the telescopes may require an analog IF output, say 0-500 MHz. This is desirable but not essential.

Thanks to many years of development of the synthesisers and L-band link, MERLIN has comparable phase stability to cable-connected interferometers. The current L-band link, which maintains coherent frequency standards at each remote telescope will be retained, subject to some modification of the frequencies used. The current synthesisers were designed to return to the same phase after a frequency change within an observing band and although this feature will be rarely called upon given the wide instantaneous bandwidths available with *e*-MERLIN, these synthesiers will be retained in the design.

Optical Fibre Transmission Network

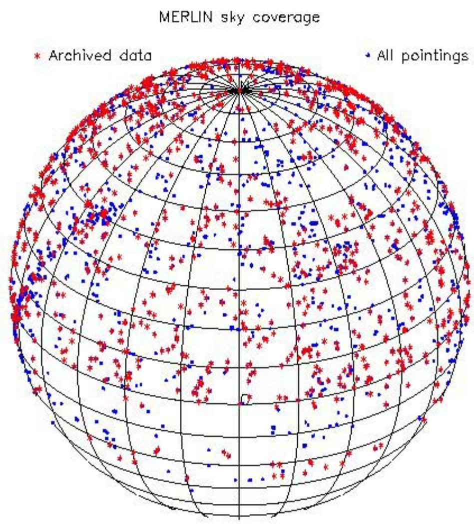
The optical fibre transmission network is the key part of *e*-MERLIN and accounts for almost half of the total budget. The network will consist of leased fibres or bandwidth on a commercial network plus some tail digs to the individual telescope sites, including Jodrell Bank itself. Since Jodrell Bank is developing the optical transmission equipment for the ALMA array, a simple and cost-effective option would be to use similar transmission equipment for *e*-MERLIN. This uses 3 x 10 Gb/s channels to transmit the total payload of 24 Gb/s. An invitation to tender for the optical transmission network was issued in December 2002, and the contractor will be chosen in Spring 2003. The total traffic which will be carried by the *e*-MERLIN data transmission network is comparable to the total available bandwidth between Europe and US/Canada and a single *e*-MERLIN telescope will return a higher data rate than the peak UK Internet traffic (as of December 2002).

Correlator

A substantial new correlator will be required to handle the 2 GHz bandwidth per polarization coming from each *e*-MERLIN telescope. Wide-field imaging will be a routine mode for *e*-MERLIN: each standard 12-hr *e*-MERLIN observation will provide deeper images than the deepest 18-day integrations on the Hubble Deep Field made so far and hence there will be considerable scientific interest in these ‘background sources’. Also, to achieve the ultimate sensitivity on target sources in the centre of the field, it will be necessary to accurately subtract the effects of these background sources. This wide-field imaging requires narrow frequency channels (< 0.5 MHz) as well as rapid sampling of the correlator output (<1 sec). Hence the key specification for the new correlator is the ability to correlate wide bandwidths in a large number of frequency channels. Spectral line observations will require finer frequency resolution, but only over limited portions of the band. The new correlator will be able to make simultaneous continuum and line observations over multiple OH lines in the 18-cm band.

THE MERLIN ARCHIVE

Access to all the MERLIN continuum data between 1992 and 1999 at L-Band (1.33 GHz to 1.73 GHz) and C-band (4.5 GHz to 5.2 GHz) is currently available on-line at http://www.merlin.ac.uk/archive. This processed data archive, which contains almost 5000 observations, is stored on a RAID array as visibility (uv) data sets in FITS format, with accompanying tables of basic calibration and flags. The accompanying figure shows an example of the archive sky coverage for the region between approximately -6 hrs < Right Ascension < +6 hrs and -40° < Declination < +90°.



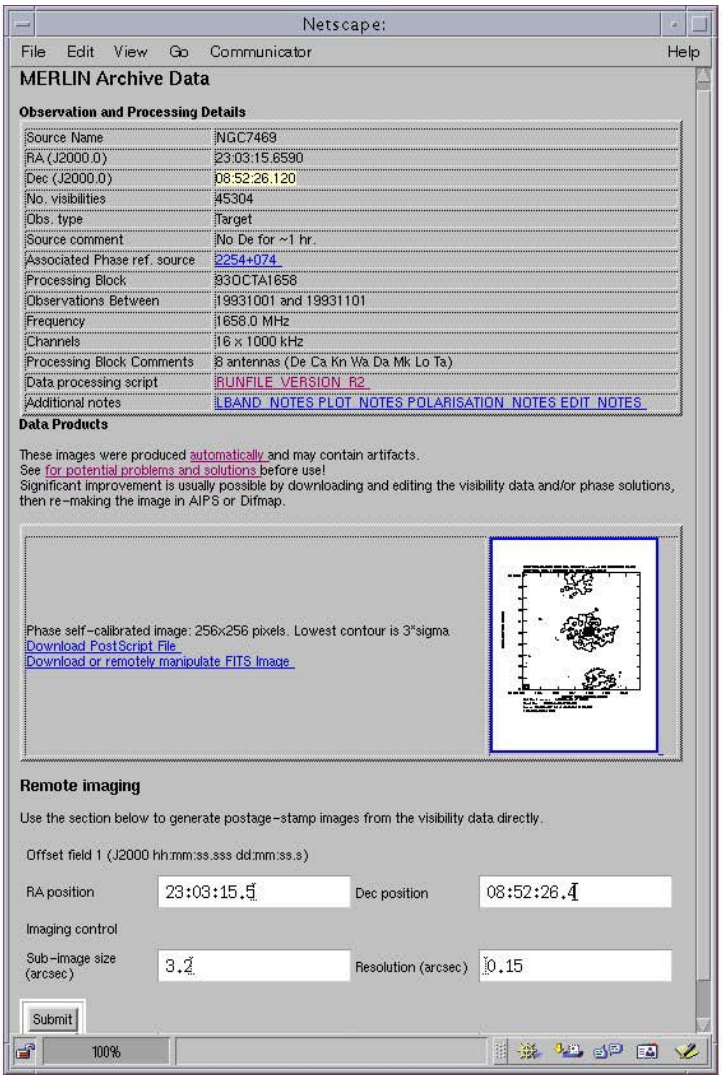
Above: The sky coverage of the MERLIN Archive data now available. The diagram shows all MERLIN pointings between 1992 and 1999; those in red are included in the MERLIN Archive.

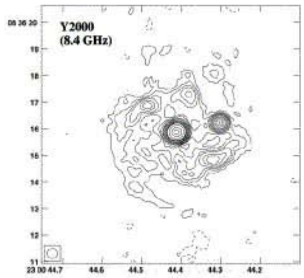
The archive can be searched for observations of particular sources or regions of sky and preliminary images resulting from a 'pipeline' processing of the data displayed. However, these images cover only a small fraction of the field observed in the direction of the pointing centre. Typically, the MERLIN field of view at 1.6 GHz is 1' - 10', depending on the observing mode. Therefore, at a resolution of 0".1 - 0".3 almost 1000 separate conveniently sized images (512x512 pixels) would be required to image the field-of-view. Already implemented, but not yet released generally, is the facility to interactively reprocess the original calibrated data to produce off-centred images. Such 'on-the-fly' reprocessing of the data can also be used to generate calibrated visibility data for model-fitting and radio light-curves for objects like rapidly varying X-ray binaries.

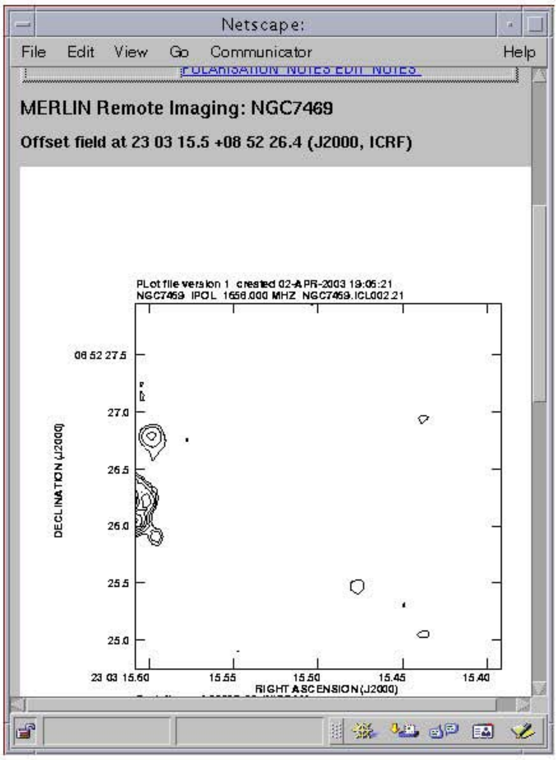
Examples of how the archive has been used recently are the images of a radio supernova discovered in one of the spiral arms of the Seyfert galaxy, NGC 7469 (Colina et al. 2001 ApJ, 553, L19; 2002, IAUC, 7838, 1). Although the supernova was only discovered in 2000, MERLIN had observed NGC 7469 in 1993 for an unrelated study of HI absorption towards the nucleus. Using the prototype archive form, the displaced position of interest and the image size were simply entered and within ten seconds the appropriate data had been located and a preliminary image of the field containing the supernova displayed, together with an option to retrieve the calibrated FITS data.

VLBI data are more complex and the primary EVN archive, maintained by Venturi and coworkers at Bologna (http://www.ira.cnr.it/~tventuri/cata.html), contains a list of sources and experiment codes which provide the information needed to request and manually reduce public-domain data. Rapid progress is also being made by Reynolds and coworkers at JIVE, Dwingeloo, to automatically image data processed with the EVN correlator, the latter first coming into operation in 1998. Users can access experiment information, calibration tables and plots at http://www.evlbi.org/pipeline/user_expts.html. In the near future all these resources will be available via a single interface and discussions are ongoing about how to expand data access.

All the above developments are taking place in the context of the birth of Virtual Observatories. JBO is a partner in the UK initiative,







Above: A MERLIN Archive search for the radio supernova discovered in one of the spiral arms of the Seyfert galaxy NGC 7469 by Colina et al. (2001; 2002). The target, found in VLA data from 2000, was missing in the MERLIN observations performed for an unrelated HI absorption study in 1993.

AstroGrid, and in the European Astronomical Virtual Observatory (AVO), which liaise with world-wide counterparts via the International Virtual Observatory Alliance (see http://www.astrogrid.org, http://www.euro-vo.org and http://www.ivoa.net). Within a few years, astronomers anywhere will be able to use a single browser interface to access multi-wavelength, multi-format data and source information to obtain answers to complex queries.

ENGINEERING

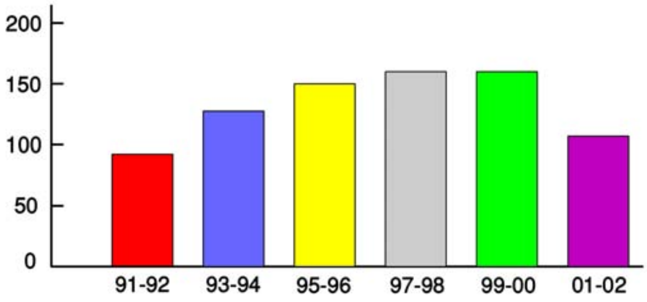
Several engineering projects have been completed and/or continued during the reporting period. The Pickmere telescope received a replacement control system. This was the final phase of a programme to replace the main axis drives of all three E-Systems telescopes, as part of the MERLIN restructuring process. The first two (Darnhall and Knockin) were replaced during the 1999 and 2000 summer maintenance periods. Replacement of the drives at Pickmere was scheduled for summer 2001, but was prevented when an outbreak of foot and mouth disease deprived us of access to the telescope shortly before work was due to begin. The work was deferred to summer 2002, when it was satisfactorily completed without incident.

With the approval of the Steering Committee, funding awarded within the Restructuring Grant for the replacement of obsolete control computers was reassigned to the development of a prototype of the new facilities that will be required for *e*-MERLIN. A test system has been produced and work is in progress to run trials on a small telescope at Jodrell Bank, thus avoiding any interruption to the MERLIN observing programme.

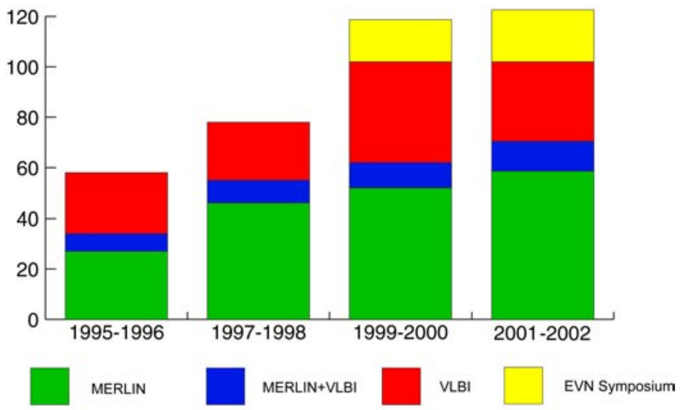
In 2001, we reported that a prototype remote diagnostic system for the MERLIN receivers, based on National Instruments LabVIEW software had been installed at Cambridge. This provides access, via a dial-up modem, to measurement facilities that were previously available only by visiting the remote site (e.g. system noise temperature, sensitivity and stability, antenna gain and spectrum analysis). It increases efficiency and reduces risk by reducing the number of journeys to outstations associated with fault diagnosis and routine testing. Following the successful commissioning of the prototype, further systems were deployed at Defford and Knockin in 2002. There is provision within the *e*-MERLIN budget to install an upgraded version of this system at all sites.

A new focus box for the Defford Telescope was designed and constructed (in-house) during 2001 and installed on the telescope in early 2002. It is now possible to have the L-band and C-band receivers available simultaneously at Defford, with provision for remotely controlled switching between them. The new focus box is substantially heavier than the original one, but appropriate structural modifications have been implemented and the (upgraded) lifting gear has been certified for the new load.

The new paint systems, first applied to the structural steel work of the telescopes in the early 1990s, have proved effective in doubling the recoating interval (from 5 to 10 years) at little extra cost. However, a full cycle of repainting is now required to preserve the structural integrity of the telescopes, and Darnhall was recoated in 2002, using one of the proven systems.



Above: The number of MERLIN proposals received in the period 1991-2002. Although the number of proposals itself has dropped significantly during the reporting period, the total amount of requested time has increased. The over-subscription factor has increased from ~2.6 in 1999-2000 to ~2.9 in 2001-2002.



Above: National Facility publications over the period 1995-2002. The bar chart includes all refereed publications involving NF telescopes. An indication of the total number of NF publications is given by the addition of EVN Symposium papers for the preceding four years. The chart excludes publications by NF staff that do not contain observations resulting from NF telescopes (12 papers).

o During the two-year period covered by this report, MERLIN observations were made for 66.9% of the time. A further 9.9% of the operating time was taken up with frequency changes and essential pointing calibration

o 89% of MERLIN PATT Priority A observations and 90% of Priority B observations were completed successfully

o 107 proposals were received for the use of MERLIN during Semesters 01A, 01B, 02A and 02B. 75% of these had at least one UK proposer and 47% had UK PI's. The over-subscription factor for the period averaged ~2.9

o During 2001 and 2002, 225 individuals were named on MERLIN proposals, from 93 institutions worldwide. 95 of these were based in the UK, from 24 institutions

o Excluding JBO researchers, 31 separate MERLIN observers came to the National Facility to process their data during 2001 and 39 during 2002

o The National Facility was scheduled to take part in 1824 telescope hours of VLBI observations during 2001 and 2002

o During the period 2001 to 2002 the EVN Programme Committee received 111 proposals, of which 18 had UK PI's and a further 22 had UK Co-I's

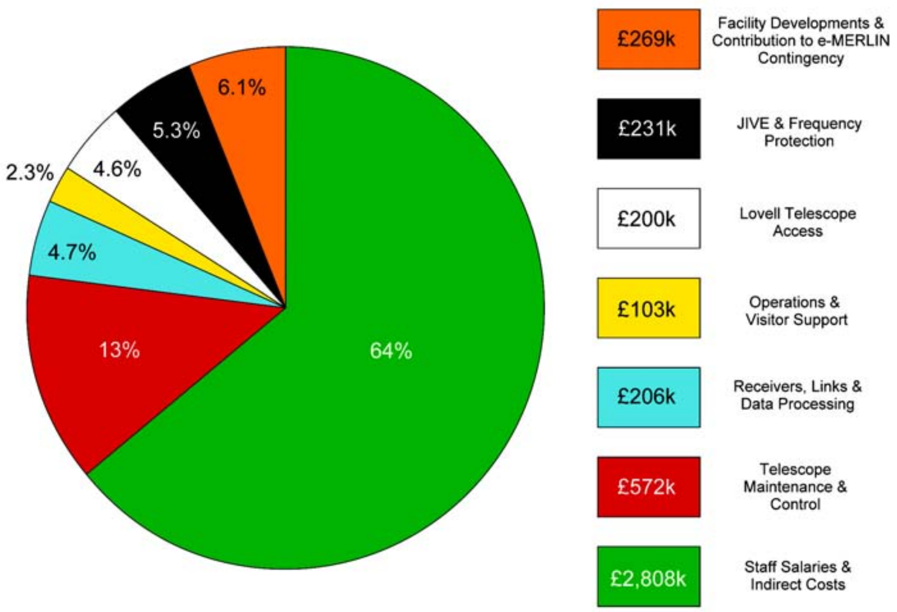
o The number of papers based on National Facility observations in refereed journals during the reporting period is very similar to the preceding two years (~50 per year). However, the proportion of MERLIN and joint MERLIN+VLBI papers has increased relative to papers based solely on VLBI data. National Facility staff have published a further 12 refereed papers that do not contain observations resulting from NF telescopes. Inclusion of the 2002 EVN Symposium papers relating to the NF telescopes brings the total number of publications to 135.

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 (PPA/G/O/2000/00663). The grant holder is Professor A. G. Lyne, the Director of Jodrell Bank Observatory, and the value of the current award is £4,389,390 for the period October 2001 to September 2003.

The disposition of the budget by activity area is shown below. Specific provision is included within the grant for the UK contributions to the cost of VLBI support activities at JIVE and the employment of a European CRAF frequency protection manager.

A cut of approximately 16% in the provision for operation of the National Facility towards the end of the grant period has led to the number of staff employed decreasing from 33.5 FTE to 26.0 FTE. The MERLIN data archivist post has been lost, but most other staff involved are working on the implementation of *e*-MERLIN funded by project development monies.



Left: Summary of MERLIN finances for the period 2001-2002.

National Facility Committees & Personnel (31/12/02)

NATIONAL FACILITY STEERING COMMITTEE

Professor M. F. Bode (Chairman)
Liverpool John Moores University

Professor G. de Bruyn
ASTRON, Netherlands

Dr G. A. Fuller
UMIST

Dr. G. G. Pooley
University of Cambridge

Dr J. A. Yates
University College London

Dr S. A. Eales
University of Wales, Cardiff

PPARC Secretary: Dr S. Berry

PATT MERLIN TIME ALLOCATION GROUP

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

Dr K. M. Blundell
University of Oxford

Dr G. G. Pooley
University of Cambridge

Dr A. M. S. Richards
University of Manchester

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

The National Facility employs 26.0 FTE staff on the operation of MERLIN & VLBI and development activities for *e*-MERLIN. The *e*-MERLIN project funds an additional 5.5 FTE. Some of the personnel listed opposite spend only part of their time on National Facility ativities.

NATIONAL FACILITY PERSONNEL & ASSOCIATED STAFF WORKING ON *e*-MERLIN & FIBRE DEVELOPMENTS

Management & Administration	3.25 FTE funded by the NF
Prof. 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	8.75 FTE funded by the NF
Mr R. J. Comber	Engineer (telescopes)
Mr G. J. Kitching	Senior Experimental Officer (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 G. A. Johnson	Control Technician
Mr J. Dyer	Control Technician

Receivers, Links & Data Processing	6.75 FTE funded by the NF
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	Engineer (operations)
Mr J. W. Marshall	Cryogenics Technician
Mr M. H. Butlin	Engineering Technician
Dr M. Bentley	Senior Experimental Officer (links & developments)
Mr A. Blackburn	Links Technician
Mrs R McCool	Engineer (fibres)
Mr I. Morison	Engineer (operations) & PR Officer
Mr D. C. Brown	Senior Experimental Officer (digital & fibres)
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 (data processing)

Operations & User Support	7.25 FTE funded by the NF
Dr P. Thomasson	MERLIN Manager
Dr S. T. Garrington	*e*-MERLIN Project Manager
Dr T. W. B. Muxlow	Senior Experimental Officer (operations)
Dr A. G. Gunn	National Facility Support Scientist
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 C. I. Mance	Telescope Array Controller

APPENDIX B

MERLIN Observations in Semesters 01A to 02B

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

Categories For Approved Time

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 01A to 02B

Runs Observed / Runs Approved	A-Time	B-Time	T.O.-Time
L-Band*	75 / 101 (75%)	21 / 25 (84%)	3
C-Band	109 / 110 (99%)	64 / 72 (89%)	27
6 GHz	12 / 12 (100%)	11 / 11 (100%)	
K-Band	20 / 20 (100%)	9 / 9 (100%)	

* Note: Some of the L-Band observations have long-term status to Semester 03A and have not yet been completed.

MERLIN Semester 01A Time Awards

CODE	TITLE	PI	L-Band	C-Band	K-Band
01A/01	Imaging Symbiotic Stars	S. Eyres		2A+1B	
01A/02	Classification of Large-Compact/Medium Symmetric Objects	P. Augusto			3B2
01A/03	IPS Measurements of the Solar Wind Near Solar Maximum	A. Breen		1A	
01A/04	MERLIN Imaging of Selected X-ray/Optical Jets	C. Cheung	3A(in 01B)	3A	
01A/05	MERLIN HI Studies of Radio Galaxies	R. Beswick			
01A/06	A Survey for Ultra-dense HII Regions in Wolf-Rayet Galaxies	K. Johnson		2A+2B	2A+2B
01A/07	Astrometry of Excited OH Masers at 6.0GHz	R. Cohen		2A+2B	
01A/08	Monitoring the Variability of the Radio Sources in M82	A. Pedlar		2A	
01A/09	Searching for High Asymmetry Gravitational Lens Systems	I. Browne		2A	

01A/10 Unusual Water Masers in M16A	V. Slysh			1B2
01A/11 Prototypical Symbiotic Star Z And During Outburst	J. Sokoloski		1A	
01A/12 The Excited Shell of VY 2-2	A. Zijlstra		C Time	
01A/13 Testing Source Physics in Compact Symmetric Objects	J. Conway			4A
01A/14 Study of Massive YSOs with a Methanol Maser Disk	M. Hoare			1A
01A/15 Search for Methanol Maser Emission from Well-studied YSOs	M. Hoare		1B	
01A/16 Imaging of Gravitational Lens Candidates	J. Lovell		5B2	
01A/17 Imaging Survey of Northern Methanol Masers	C. Phillips		1A	
01A/18 Astrometry of Stars with Water Masers: U Her (Pilot)	W. Vlemmings			1A
01A/19 The Methanol Maser IRAS18556	G. Fuller		1A	
01A/20 6.7GHz Methanol Masers: Probing the Extended Emission	M. Prestalozzi			
01A/21 Structure in Methanol Masers from the Onsala Blind Survey	M. Prestalozzi		2A	
01A/22 Proper Motion of H_2O Masers in AGB Mass Outflows	J. Yates			5A+3B
01A/23 Probing the Inner Core of the Beta Lyrae Radio Nebula	G. Umana			2B2
01A/24 Search for Micro-jets in the Core of M2-9	G. Umana		1A+1B	
01A/25 Imaging of the Crab with Chandra, HST, and MERLIN	A. Lyne		2A+8B	
01A/26 Observations of OH Megamasers in IRAS10173+0828	Y. Zhi-yao			
01A/27 Deep, High-resolution Observations of YSOs in HH7-11	P. J. Diamond			
01A/28 Investigation of Subarcsec Structures of LSI 61303	M. Massi		2B2	
01A/29 Resolving the Starburst in ULIRG Galaxies	C. Lonsdale		5B	
00A/14 Classical and Recurrent Novae Targets of Opportunity	S. Eyres		4TO	
00B/01 Relativistic Ejections from X-ray Transients	R. Fender		6TO	
00B/11 Probing the Haloes of Galaxies Using Radio Microlensing	L. Koopmans		36A	
00B/12 Observations of New CLASS Lens Systems	P. Phillips		2B	
00B/16 HD 125858: A Highly Unusual Radio Star	D. Law-Green		1B	
00B/22 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 and 3C454	R. Spencer		2B	
Director's Override 2 Runs TO				

MERLIN Semester 01B Time Awards

CODE TITLE	PI	L-Band	C-Band	K-Band
01B/01 Observations of OH Megamasers in IRAS10173+0828	Z. Yu	2A		
01B/02 Astrometry of Newly Detected Methanol Masers	G. Macdonald		1A	
01B/03 Radio Supernova in the Circumstellar Starburst of NGC7469	L. Colina	2A	2A	
01B/04 A Snapshot Survey of Nearby Active Galaxies	M. Filho		2B	
01B/05 Mapping the Einstein Ring in Gravitational Lens B0218+357	A. Cohen	1A		
01B/06 Observation of the 1720 MHz Masers in W28, W44, & W51	I. Hoffman	8A		
01B/07 Radio Emission in the Nuclei of Nearby Seyfert Galaxies	S. Leon			
01B/08 The Galaxy IRAS 02483+4302 and Quasar S4 0248+430	A. Foley			
01B/09 Deep High-resolution Observations of YSOs in HH7-11	P. J. Diamond		8A+8B	
01B/10 A Microquasar in the Nucleus of M33?	R. Fender	1A	1A	
01B/11 Relativistic Ejections from X-ray Transients	R. Fender		6TO	
01B/12 Angular Expansion Measurement of NGC7027	I. Bains		1B	
01B/13 Imaging the Off-nuclear Water Maser in NGC1068	Y. Hagiwara			2B
01B/14 Imaging Survey of Northern Methanol Masers	C. Phillips		1A+3B	
01B/15 Atomic Gas-dust Correlation in Radio Galaxies	R. Beswick	3B		
01B/16 MERLIN Imaging of Newly Discovered X-ray/Optical Jets	C. Cheung	4A		
01B/17 Full Stokes Images of the H_2CO Maser in H II Region NGC7538	I. Hoffman		1B	
01B/18 Water Maser Emission from Carbon Star V778 Cyg	R. Szczerba			1B
01B/19 The Magnetic Field Close to VX Sgr	A. Richards	2A		
01B/20 Toward Circular Polarisation Measurements with MERLIN	R. Spencer		1B	
01B/21 Continued Monitoring of the Radio Sources in M82	T. Muxlow		1A	
01B/22 A MERLIN Survey of Distant OH Megamasers	E. Rovilos			
01B/23 The OH Masers of the Hypergiant Star IRAS19566+3423	B. Lewis			
01B/24 The Proper Motions of Young Pulsars	B. Anderson	6A		
01B/25 ToO Long-Track Observations of the Final CLASS Lens Sample	N. Jackson		4A	
01B/26 Polarization Imaging of the T Tau System	K. Johnston		2A	
01B/27 Radio Star Observations for a FAME/ICRF Frame Tie	K. Johnston		2A+C Time	
01B/28 2nd Epoch Observations of OH Around IRC+10420	P. J. Diamond	5B		
00A/14 Classical and Recurrent Novae Targets of Opportunity	?		4TO	
01A/NN Missed A Priority Runs Due To Poor Weather				5A
Director's Override 2 Runs TO				

MERLIN Semester 02A Time Awards

CODE	TITLE	PI	L-Band	C-Band	K-Band
02A/01	Nebulosity Around AG Dra	R. Ogley		1A	
02A/02	Imaging the OH Maser Shells Around PPN Objects II	I. Bains	6A		
02A/03	HI Absorption & OH Megamaser Observations of Starbursts	A. Polatidis	3A		
02A/04	HD125858: An Unusual Radio Star?	D. Law-Green			
02A/05	Classical and Recurrent Novae as Targets of Opportunity	S. Eyres		4TO	
02A/06	5GHz Radio Continuum Maps of Saturn & Cat's Eye Nebulae	X. Liu			
02A/07	H_2O Maser Emission in M82: Candidate for a Micro Black Hole	Y. Hagiwara			1A
02A/08	High Resolution Radio Observation of P Cygni Variable Wind	K. Exter		1A	
02A/09	Free-free Absorption in the LIRG IIIZw35	Y. Pihlstrom		1B	
02A/10	H_2O Maser Motions in Cepheus A HW2	J. Gallimore			1A
02A/11	Parsec Scale Emission in Nuclei of Nearby Seyfert Galaxies	S. Leon	1A		
02A/12	MERLIN Observations of PSR 1951+32's Synchrotron Nebula	A. Golden	1A		
02A/13	H_2O Masers in Protoplanetary Disks	J. Gallimore			2A
02A/14	OH absorption in IC883	P. Alexander	2A		
02A/15	Small-scale Lenses and the Density of Compact Objects	N. Jackson		1A+5B+C Time	
02A/16	The Masers of IRAS20126+4104	G. Fuller	1A	1B	1B
02A/17	Astrometry of Methanol Masers Detected in Unbiased Survey	M. Szymczak		4A+4B+C Time	
02A/18	Extended Jet Emission from Symbiotic Star Z And in Outburst	C. Brocksopp		2A+2B	
02A/19	The Search for Water Masers in Supernova Remnants	J. J. Woodall			
02A/20	High-resolution Obs. of Orion KL Polarized Water Masers	S. Horiuchi			1A+2B
02A/21	Co-ordinated IPS and Optical/UV Observations of Solar Wind	A. Breen		2A	
02A/22	Mapping OH Masers in the Hypergiant Star IRAS19566+3423	B. Lewis	3A		
02A/23	Evolution of the Supergiant NML Cyg	S. Etoka	1A		1A
02A/24	Full Polarisation Mapping of AGB Stars	M. Szymczak	2A+3B		
02A/25	Radio Microlensing as a Means of Studying Quasars	E. Xanthopoulos			
02A/26	High-resolution Observation of Low Galactic Lat. Sources	D. Saikia	3A	3A	
02A/27	Deep MERLIN Imaging Of The Starburst Galaxy M82	T. Muxlow		9A	
02A/28	A New Planetary Nebula?	P. Thomasson	2B		
01A/NN	Various Missed A Priority Runs Due To Poor Weather				4A
01B/11	Relativistic Ejections from X-ray Transients	?		4TO	
Director's Override 2 Runs TO					

MERLIN Semester 02B Time Awards

CODE	TITLE	PI	L-Band	C-Band	K-Band
02B/01	Imaging of an Unbiased Sample of SCUBA-selected Galaxies	R. Ivison	20A		
02B/02	Looking for MSO Faders, the Prematurely 'Dying' CSS Sources	M. Kunert			
02B/03	An HI Absorption Study of the Medusa Galaxy	S. Aalto			
02B/04	Final MERLIN Images of Newest Chandra/HST Jets	C. Cheung	2A		
02B/05	Radio Emission in the Nuclei of Nearby Seyfert Galaxies	M. Krips		7B+C Time	
02B/06	Relativistic Ejections from X-ray Transients	R. Fender		6TO	
02B/07	The Radical Shell of Vy 2-2	A. Zijlstra	1A	1A+C Time	
02B/08	The Dust Distribution in Cold Luminous Galaxies	R. Ivison			
02B/09	Re-Observation of OH Absorption Against NGC 6240	R. Beswick			
02B/10	Radio-loud BALQSOs: Massive Galaxies in Formation?	S. Rawlings	12B		
02B/11	Radio Properties of Typical High-redshift Radio Sources	S. Rawlings	8A		
02B/12	The Star Formation of the ULIRG Arp 193	M. Clemens		2A+C Time	
02B/13	Radio Jets and Dynamics of FRII Radio Sources	G. Pooley		3A+C Time	
02B/14	Structures of Radio Sources in a Sample Selected at 15 GHz	G. Pooley		2A+8B	
02B/15	The Peculiar Dumbbell Radio Galaxy NGC 326	E. Xanthopoulos			
02B/16	Kinematics of the Proto-planetary Nebula IRAS19312+1950	H. Imai			1A+CTime
02B/17	The Density Structure of Very Young HII Regions	S. Kurtz		5A+2B+C Time	
02B/18	High-resolution Observations of SDSS-based Galaxies	J. Zuther			
02B/19	Observation of Radio Loud Narrow Line Seyfert 1 Galaxies	T. Wang		4B+C Time	
02B/20	Observation of Galactic Gamma-Ray Sources with INTEGRAL	R. Spencer	10A	2A	
02B/21	A Compact Source in 3C58?	R. Spencer		1A+C Time	
02B/22	Shock Structure(s) Within PSR B1951+32's Plerion & CTB80	A. Golden	8A		
02A/05	Classical and Recurrent Novae as Targets of Opportunity	S. Eyres		4TO	
Director's Override 2 Runs TO					

APPENDIX C

VLBI Observations 2001 - 2002

Code	PI	λ	Telescope	hrs	Title
F02C2	Polatidis	6cm	CmMk2	1	Fringe Test Tape Session 3 2002
GM048A	Marcaide	6cm	Mk2	11	SN1993J at 6cm
EB023A	Bondi	6cm	CmMk2+MER	11	3C270
GG048A	Garrington	6cm	Mk2	11	Global Observations of θ^1 Orionis A2
ES046	Smith	6cm	Mk2	12	Radio Imaging of QSOs
GB045	Bartel	6cm	Mk2	12	5th Epoch Observations of SN1986J in NGC 891
EB024A	Beswick	21cm	LT	12	HI Absorption in NGC 7674
EB024B	Beswick	21cm	LT	12	HI Absorption in Arp 220
EK015A	Krips	18cm	LT	9.5	Parsec-scale Emission in Seyfert Galaxies
EF009B	Filho	18cm	LT	6	AGN in Nearby Galaxies
EB024C	Beswick	21cm	LT	12	HI Absorption in NGC 7469
GL026B	Lonsdale	18cm	LT	12	Arp220 at 18cm
N02L3	Paragi	18cm	CmLT	4.5	Network Monitoring Experiment
GM048B	Marcaide	18cm	LT	14	SN1993J at 18cm
GM047	Marcaide	18cm	LT	13	SN1979C at 18cm
GV016	Vermeulen	18cm	CmLT	11.5	The OH Shroud Around NGC 1052
S02K1	Volvatch	1.3cm	Mk2	4	Simeiz Test
N02K1	Paragi	1.3cm	CmMk2	4	Network Monitoring Experiment
ED023	Diamond	1.3cm	CmMk2+MER	13	MERLIN/EVN Observations of NML Cyg Masers
F02C1	Polatidis	6cm	CmMk2	1	Fringe Test Tape Session 2 2002
GB042C	Bartel	6cm	Mk2	12.5	30th Epoch Observations of SN1993J in M81
EG024	Gabuzda	6cm	CmMk2+MER	24	Search for New Galactic Microquasars
ER014	Rector	6cm	CmMk2+MER	24	HEP BL Lacs
EG026	Giroletti	6cm	CmMk2+MER	12	Observations of Two BL Lacs
EL029A	Lobanov	6cm	CmMk2+MER	12	3C75
GAH5	Garrett	6cm	Mk2	5	SIRTF FLSv Calibrator Search
DAH3	Dougherty	6cm	Mk2	4	Test Observations of Potential Phase-Reference Sources
EG025	Garrington	6cm	CmMk2+MER	11	6cm Polarisation Observations of 3C67
EF009A	Filho	6cm	Mk2	6	AGN in Nearby Galaxies
N02C1	Reynolds	6cm	CmMk2	5	Network Monitoring Experiment
GF010	Frey	6cm	Mk2	14	Deep Extragalagtic Survey (DEVOS)
EG023	Giroletti	18cm	Mk2	12	Observations of BL Lacs
N02L2	Reynolds	18cm	Mk2	5	Network Monitoring Experiment
EF010	Frey	18cm	Mk2	5	The Highest Redshift Quasar SDSS J0836+0054 at 1.6 GHz
F02L1	Polatidis	18cm	CmMk2	1	Fringe Test Tape Session 1 2002
EV012B	Voronkov	5cm	CmMk2	11	Milliarcsecond Structure of Methanol Masers L1206 and GL2789
EP039B	Pestalozzi	5cm	CmMk2	24	Probing the Extended Emission of 6.7 GHz Methanol Masers
EP041B	Phillips	5cm	CmMk2	12.5	Methanol in W51
EM047	Mantovani	18cm	CmLT+MER	36	CSSs from the S4 Survey
EC018	Conway	18cm	CmLT+MER	36	IRAS-BGS at 18cm
N02L1	Reynolds	18cm	CmLT	6	Network Monitoring Experiment
ED020	Diamond	18cm	LT	16	Distant Megamasers
EL028	Leon	18cm	LT	12	Parsec-scale Emission in Seyfert Galaxies
ER012A	Rovilos	21cm	CmLT+MER	12	A survey of distant OH megamasers: 08201+2802
ER012B	Rovilos	21cm	CmLT+MER	12	A survey of distant OH megamasers: 10339+1548
ER012C	Rovilos	21cm	CmLT+MER	12	A survey of distant OH megamasers: 12032+1548
EP040	Pihlstrom	18cm	CmLT+MER	12.5	IIIZw35 at 18cm
EP042A	Polatidis	18cm	CmLT+MER	12.5	OH and HI Absorption of Starbursts - OH in Zw049.57
EP042B	Polatidis	21cm	CmLT+MER	12.5	OH and HI Absorption of Starbursts - HI in Zw049.57
ES042B	Snellen	18cm	CmLT+MER	11.5	Young Radio Sources in the Nearby Universe
EP042C	Polatidis	21cm	CmLT+MER	12	OH and HI Absorption of Starbursts - HI in IIIZw35
EB018A	Beswick	21cm	LT	24	NGC 7674 and Arp220 HI Absoprtion
EB022	Baan	18cm	CmLT+MER	12	The Arp220 OH Megamaser
GL026	Lonsdale	18cm	CmLT+MER	12	Arp220 at 18cm
GP030B	Porcas	18cm	LT	12	Observations of Gravitational Lenses
EB018B	Beswick	21cm	LT	12	NGC 7469 HI Absorption
F01L3	Polatidis	5cm	CmMk2	1	Fringe Test Tape Session 3 2001

EP039	Pestalozzi	5cm	CmMk2	24	Probing the Extended Emission of 6.7 GHz Methanol Masers
ED018A	Desmurs	5cm	CmMk2	3.5	6 GHz OH Maser Observations in Massive Star-Forming Regions
ED018B	Desmurs	5cm	CmMk2	3.5	6 GHz OH Maser Observations in Massive Star-Forming Regions
EP041	Phillips	5cm	CmMk2	12	Methanol in the W51 Complex
EV012	Voronkov	5cm	CmMk2	12	Milliarcsecond Structure of Methanol Masers L1206 and GL2789
EC016	Caccianiga	6cm	Mk2	24	Relativistic Jets in Radio Quiet AGNs
ED019A	Desmurs	6cm	CmMk2+MER	12	The 4.7 GHz Maser Line in ON1
ES043A	Shastri	6cm	CmMk2+MER	24	Radio Jets in Seyferts
GP030A	Porcas	6cm	Mk2	12	The Gravitational Lens 2016+112
GM046	Marcaide	6cm	Mk2	11	SN1993J at 6cm
N01C3	Reynolds	6cm	CmMk2	4	Network Monitoring Experiment
S01L1	Foley	18cm	Mk2	2	TADU Test at Westerbork
EP034A	Pihlstrom	18cm	Mk2	10	HI Absorption in NGC 4261
EP034B	Pihlstrom	18cm	Mk2	10	HI Absorption in NGC 4261
N01L3	Reynolds	18cm	Mk2	4	Network Monitoring Experiment
ED019B	Desmurs	18cm	Mk2	12	The 1.6 GHz Maser Line in ON1
GM045	Morganti	18cm	Mk2	24	NGC 315 and B21322+36
GB042B	Bartel	18cm	Mk2	12	29th Epoch Observations of SN1993J in M81
F01L2	Polatidis	18cm	CmMk2	1	Fringe Test Tape Session 2 2001
EJ004	Jiang	18cm	Mk2	5	The Compact Structure of Radio-loud BAL Quasars
ES042A	Snellen	18cm	Mk2	12	Young Radio Sources
ES042B	Snellen	18cm	Mk2	12	Young Radio Sources
GAH4A	Gabuzda	6cm	Mk2	3	Polarization Test Observations
GG046	Gabuzda	6cm	Mk2	24	IDV Studies Using Global Polarization Observations
GAH4B	Gabuzda	6cm	Mk2	3	Polarization Test Observations
EB019	Barthel	6cm	CmMk2+MER	6	NGC 4418: Starburst or AGN?
EE004	Exter	6cm	CmMk2+MER	13	The P Cygni Compact Nebula
EM043A	Massaro	6cm	CmMk2+MER	9	Structure Changes in Two Blazars - ON231
R01C1	Reynolds	6cm	Mk2	2.5	Formatter Test Observations
EM043B	Massaro	6cm	CmMk2+MER	9	Structure Changes in Two Blazars - OQ530
PAH4	Porcas	6cm	Mk2	4	Test Observations of Potential Phase-Reference Sources
GM044	McDonald	6cm	Mk2	12	6cm Global Observations of M82
GG047	Garrington	6cm	Mk2	11	Global Observations of θ^1 Orionis C
EM041	Marecki	6cm	Mk2	11	1123+340 - a Prototype of a Mini-WAT?
N01C2	Sjouwerman	6cm	CmMk2	8	Network Monitoring Experiment
GB042A	Bartel	6cm	Mk2	18	28th Epoch Observations of SN1993J in M81
F01C1	Polatidis	6cm	CmMk2	1	Fringe Test Tape Session 1 2001
w414a	Sudou	6cm	Mk2	8.5	VSOP Observations of J0223+42 at 5 GHz
EM042A	Marecki	6cm	Mk2	9	A Study of Very Compact Steep Spectrum Objects - Part II
N01C1	Gabuzda	6cm	CmMk2	3	Network Monitoring Experiment
EM042B	Marecki	6cm	Mk2	10.5	A Study of Very Compact Steep Spectrum Objects - Part II
ED017A	Dougherty	6cm	CmMk2+MER	12	EVN Observations of WR146 and WR147
EF008	Foley	6cm	Mk2	3	Observations of the Field Around NGC 3516
ED017B	Dougherty	6cm	CmMk2+MER	12	EVN Observations of WR146 and WR147
GO005B	Owsianik	6cm	CmMk2+MER	12	Observations of 3C236
GM040C	Marcaide	6cm	Mk2	12	SN1993J at 6cm
ED016	Diamond	21cm	LT	15	Distant Megamasers
ED017C	Dougherty	18cm	LT	12	EVN Observations of WR146 and WR147
GX007A	Xanthopoulos	18cm	LT	13	B1030+074 at 18cm
GG045	Gizani	18cm	LT	11	Probing the Parsec-scale Environment of 3C310
EV009B	Vlemmings	18cm	LT	16	The Amplified Stellar Image in OH Main and Satellite Line Masers
GB036	Bartel	18cm	LT	12.5	7th Epoch Observations of SN1979C in M100
N01L1	Gabuzda	18cm	LT	4	Network Monitoring Experiment
GM038	McDonald	18cm	LT	30	18cm Global Observations of M82
GM043C	Moscadelli	1.3cm	Mk2	12	Proper Motions of H2O Masers in IRAS 20126+4104

APPENDIX D

National Facility Visitors

Visitors 2001

M. Clemens - UK - MRAO, University of Cambridge.
L. Close - UK - University of Oxford
I. Bains - UK - University of Hertfordshire
E. Xanthopoulos - UK - University of Manchester
S. Eales - UK - University of Cardiff
K. Wills - UK - University of Sheffield
C. Brocksopp - UK - Liverpool John Moores University
T. York - UK - The University of Manchester
G. Fuller - UK - UMIST
A.M. Stirling - UK - University of Central Lancashire
J.A. Yates - UK - University College, London
K. Exter - UK - Queen's University Belfast
M.G. Hoare - UK - University of Leeds
A.Breen - UK - University of Wales at Aberystwyth
R. Fallows - UK - University of Wales at Aberystwyth
Y. Hagiwara - Germany - MPIfR, Bonn
W. Tschager - Netherlands - University of Leiden
L. Gurvits - Netherlands - JIVE
A. Biggs - Netherlands - ASTRON
A. Polatidis - Sweden - Onsala
M. Pestalozzi - Sweden - Onsala
P. Augusto - Portugal - University of Madeira
B. Kramer - Thailand - Bangkok
Y. Ishihara - Japan - Nobeyama
S. Naoko - Japan - Nobeyama
K. Murakawa - Japan - Subaru Telescope, Hawaii
D.R. Gonzales - Mexico - UNAM
D.J. Saikia - India - NCRA, TIFR, Pune
S. Dougherty - Canada - DRAO, Penticton
D. Russel - USA - STScI
L. Davis - USA - Agnes Scott College, Georgia

Visitors 2002.

I. Bains - UK - University of Hertfordshire
A. Beardsmore - UK - University of Kent
A.Breen - UK - University of Wales at Aberystwyth
C. Brocksopp - UK - Liverpool John Moores University
S.P.S. Eyres - UK - University of Central Lancashire
I. Snellen - UK - IoA, Cambridge
A.M. Stirling - UK - University of Central Lancashire
C. Willson - UK - University of Wales at Aberystwyth
E. Xanthopoulos - UK - University of Manchester
J. Yates - UK - University College, London
A. Zijlstra - UK - UMIST
K. Edris - UK - UMIST
A. Golden - Eire - University of Galway
H. Falcke - Germany - MPIfR, Bonn
Y. Hagiwara - Germany - MPIfR, Bonn
S. Leon - Germany - Universität Köln
M. Krips - Germany - Universität Köln
A. Biggs - Netherlands - ASTRON
W. Vlemmings - Netherlands - University of Leiden
C. Phillips - Netherlands - JIVE
W. Cotton - Netherlands - ASTRON
M. Szymczak - Poland - Torun
A. Niezurawska - Poland - Torun
M. Kunert - Poland - Torun
P. Augusto - Portugal - University of Madeira
R. Ogley - France - SACLAY
Yu Zhi-yao - China - Shanghai Astronomical Observatory
D.J. Saikia - India - NCRA, TIFR, Pune
D Smits - South Africa - HartRAO
B. Kramer - Thailand - Bangkok
I. Hoffman - USA - NRAO, Socorro
K. Johnston - USA - NRAO, Socorro
A. Fey - USA - USNO, Washington DC
R. Gaume - USA - USNO, Washington DC
M. Lacy - USA - Caltech
J. Gallimore - USA - Bucknell University, Lewisburg
M. Thornley - USA - Bucknell University, Lewisburg
C.C. Cheung - USA - Brandeis University
A. Kemball - USA - NRAO, Socorro

APPENDIX E

National Facility Publications 2001 - 2002

An, T., Hong, X., Wang, W., Jiang, D., Chen, Y., 2001, *VLBI Observations of the Blazar 1611+343 at 5 GHz*, Chinese Journal of Astronomy and Astrophysics, 1, 305

Anton, S., Thean, A. H. C., Pedlar, A., Browne, I. W. A., 2002, *The Orientation of the Seyfert Nucleus in Markarian 348*, MNRAS, 336, 319

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Bartel, N. et al., 2002, *SN 1993J VLBI. II. Related Changes of the Deceleration, Flux Density Decay and Spectrum*, ApJ, 581, 404

Beswick, R. J., Pedlar, A., Mundell, C. G., Gallimore, J. F., 2001, *A MERLIN Neutral Hydrogen Absorption Study of the Luminous Infrared Merger NGC 6240*, MNRAS, 325, 151

Beswick, R. J., Pedlar, A., Holloway, A. J., 2002, *A Radio Study of Neutral Gas and Dust in the Radio Galaxy 3C 293*, MNRAS, 329, 620

Beswick, R. J., Pedlar, A., McDonald, A. R., 2002, *Sub-arcsecond Atomic Hydrogen Absorption in the Seyfert Galaxies NGC 7674 and NGC 7469*, MNRAS, 335, 1091

Biggs, A. D., Browne, I. W. A., Muxlow, T. W. B., Wilkinson, P. N., 2001, *MERLIN/VLA Imaging of the Gravitational Lens System B0218+357*, MNRAS, 322, 821

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Blundell, K. M., Mioduszewski, A. J., Muxlow, T. W. B., Podsiadlowski, P., Rupen, M. P., 2001, *Images of an Equatorial Outflow in SS 433*, ApJ, 562, L79

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Brocksopp, C. et al., 2002, *Initial Low/Hard State, Multiple Jet Ejections and X-ray/Radio Correlations During the Outburst of XTE J1859+226*, MNRAS, 331, 765

Caccianiga, A., Marcha, M. J. M., Thean, A., Dennett-Thorpe, J., 2001, *EVN Observations of Low-luminosity Flat-spectrum Active Galactic Nuclei*, MNRAS, 328, 867

Cassaro, P., Stanghellini, C., Dallacasa, D., Bondi, M., Zappala, R. A., 2002, *Bendings of Radio Jets in BL Lacertae Objects. I. EVN and MERLIN Observations*, A&A, 381, 378

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ACCESS TO THE MERLIN/VLBI NATIONAL FACILITY

Observing time on the National Facility is allocated on an open-access, peer-review basis to all astronomers worldwide. Observing time for MERLIN is allocated by the MERLIN Time Allocation Group of the Panel for Allocation of Telescope Time (PATT), while that for VLBI is allocated by the European VLBI Network's Programme Committee. Two days per semester are available to be used at the discretion of the Director of the National Facility.

The deadlines for the receipt of applications for MERLIN time occur twice a year, on March 15 and September 15. 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.

The deadlines for the receipt of applications for time on the European VLBI Network, the global VLBI network and for joint EVN+MERLIN observing time occur three times a year, on February 1, June 1 and October 1. A call for proposals is issued several weeks prior to each deadline. Full instructions on how to apply for time and on the capabilities of the Network can be found on the EVN home page http://www.jive.nl/jive/evn/evn.html.

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