The Astronomical Potential of the LBA

AT/20.1/012
Overall Systems
and Performance

Ray Norris

16 April 1984

1.0 SUMMARY

By comparing the performance of the 4 station LBA with that of MERLIN, it is shown that the LBA, even with only 4 telescopes, is capable of producing high resolution sunthesis maps. Furthermore, the high sensitivity and resolution of the LBA mean that it will be the only instrument in the world capable of mapping some classes of structure, and the tapping of these unexplored fields is likely to produce a flow of new discoveries. In this note, the potential of the LBA is evaluated, and two concrete proposals regarding its development are formulated.

2.0 INTRODUCTION

Whilst the compact array (CA) of the AT will be the only telescope of its type in the Southern Hemisphere, the LBA, (defined here as consisting only of Parkes, Culgoora, Siding Spring, and Tidbinbilla) will be the only telescope in the world capable of mapping some compact structures.Consequently it is likely we can expect a rich crop of new discoveries from the as yet unexplored fields to be mapped with the LBA.

It is the purpose of this filenote to draw attention to the potential results obtainable with the LBA in its initial (i.e. 4-telescope) state, by comparing its performance with that from the only comparable (but smaller) array: MERLIN. Because of the high sensitivity (greater than the entire US VLBA network at full bandwidth) and high resolution of the LBA, nothing in the world will be able to approach the LBA for the study of sub-arcsec structure.

For this study I have assumed the LBA to consist of just 4 telescopes. Others may be added to these, with corresponding improvements in uv coverage and map quality, but emphasis here is to stress that the LBA will be a powerful synthesis instrument from the moment of its inception. As this discussion is restricted to the synthesis capabilities of the LBA, I do not consider here other areas of study in which the LBA's capabilities are already self-evident, such as astrometry, mapping of unresolved maser components, pulsar parallax and proper motion.

3.0 COMPARISON WITH MERLIN

Whilst it is true that the highest quality maps from MERLIN have been produced using six telescopes, it is perhaps not generally appreciated that a substantial fraction of the most significant results from MERLIN have been obtained using only 4 telescopes. In particular, to maximise frequency resolution with the available correlator space, all spectral line work on MERLIN has been done with 4 telescopes. In general these 4 telescopes are the 75m Mk1a, with three other 25m telescopes (usually Wardle, Knockin,and Defford). Like the AT LBA, these baselines are predominantly North-South, which may be seen as an advantage in that the uv coverage remains adequate down to low declinations.High quality synthesis maps have been made with MERLIN (at latitude 50°) down to declination -10° , and low dynamic range (13dB) maps which have been made down to declination -27° have still carried great astrophysical significance (for the simple reason that no-one else can map these structures at all!)

Figures 1 to 3 show examples of MERLIN maps made with just 4 telescopes.These examples have been chosen to illustrate the range of declinations, and the complexity of structure, that can successfully be mapped with 4 telescopes. Whilst such maps rarely exceed 20dB in dynamic range, and are insensitive to extended structures, there is clearly a great deal of new astrophysics obtainable from such maps.

It should be noted that all these maps have been made using closure phase, (or the spectral line adaptation of it), which is equivalent to 'Selfcal'. Use of these techniques on both MERLIN and VLBI data (see e.g. Wilkinson 1983, Norris 1983) have shown them to be capable of reaching dynamic ranges limited by thermal noise, provided that the flux density of the strongest component in the field is a few times greater than the closure noise (see Section 4 below).

4.0 UV COVERAGE

A commonly encountered myth is that since the LBA consists largely of North-South baselines, it is therefore inadequate as it stands for synthesis mapping of anything more complicated than point sources. On the other hand, it is apparent that mapping of fairly complicated sources with MERLIN has been extremely successful. Here I compare the uv coverage of the LBA and MERLIN.

In Figures 4 and 5 I show the uv coverage of MERLIN at declinations near those of the maps in Figures 1 to 3. These should be compared with the uv coverage for the LBA shown in Figures 6 and 7. The uv coverages for the two instruments appear comparable. A meaningful quantitative measure for sparsely sampled uv planes is difficult to construct, but reasonable criteria are that:

a) The area of the uv plane sampled should not be much longer (by, say, a factor of 2) in one direction than in another, so that the beam is not too elongated.

b) The size of the holes between uv tracks should be a minimum, as these define the size of the largest smooth, exteneded, structure that can be mapped (see e.g. Wilkinson 1983).

These criteria appear to be satisfied by the LBA. Quantitatively, the maximum size of hole is about 100km, so criterion (b) implies that the maximum size of a mappable extended structure is about 6 beamwidths. However MERLIN experience shows that this criterion is correct only for smooth extended structure, and complex structures much larger than this can be mapped successfully. For example, the circumstellar shells in Figure 1 are several times larger than the maximum size deduced from this criterion. A useful analogy is to regard the telescope as a high pass filter for spatial frequencies. Although rejecting frequencies below the cut-off frequency f_c , such a filter obviously passes higher frequencies modulated by an envelope of frequency $f \ll f_c$.

5.0 SIMULATIONS OF LBA MAPS

In Figures 8 to 10 I show examples of simulations of sources observed with the LBA. All have been produced using 'blind' CLEANing, and uniform weighting.

Figure 8 is a simulation of the jet in Virgo, and demonstrates that it can be mapped successfully even though the length of the jet exceeds the size defined by criterion (b) above. Since it has been produced by 'blind' cleaning, there has been no interaction with the data or analysis in order to improve the map. Such interaction is, however, permissible if done with care and objectivity, and in fact 'boxing' of the jet in Fig. 8 yields a map without the North-South sidelobes. That these sidelobes are not astronomical can be deduced in such a case by noting that the residuals after cleaning are not increased by the boxing. (This process is roughly equivalent to a manual-maximum-entropy-method !)

Figure 9 shows a simpler source, and is a simulation of the source IC4553, whose MERLIN map is shown in Fig. 3. Because of the simpler structure, CLEAN has performed very effectively to yield a map which is essentially free of sidelobes. As an indicator of the usefulness of such maps, the corresponding MERLIN map in Fig. 3 was the first time any structure had been seen in this source: VLA maps simply show a slight resolution, whereas the MERLIN maps (only one of many is shown here) show a wealth of structure which has transformed the interpretation of this source.

Figure 10 shows a deliberately complex source. Although the spiral structure curving round to the East and South has been lost, the map is nevertheless reliable down to the level of the first negative contour (the traditional criterion of reliability of such maps), and does show the spiral structure above this level. This source would appear unresolved with the VLA, and would show just a slight resolution with MERLIN. On the other hand, the extended size of the individual components would mean that they would be resolved out by nearly all VLBI observations. Thus if this source had been observed by the VLA, MERLIN, and (say) the European VLBI network, it would be concluded that it was a single gaussian component with a half width of about 0.2 arcsec. Only LBA observations would show that it actually had spiral structure.

6.0 THE PERFORMANCE OF THE LBA

In Table 1 I list the resolution at various frequencies. In each case, the maximum size of a smooth extended structure that can be mapped is approximately 6 beamwidths, but the maximum field of view is very much larger. The smallest size of object that can be measured depends on the signal-to-noise ratio, but with a strong source can be as small as one tenth of the beamwidth.

Table 1: The Resolution of the LBA

Frequency(GHz)	Beamwidth (arcsec)
.408	0.25
1.6	0.06
22.2	0.005

In Table 2 I list the approximate sensitivity of the LBA. A system noise of 50K has been assumed on each telescope, and it is assumed that only one 22m dish is used at Culgoora. The "closure noise" is defined as the rms noise in one integration period (10s) on the most insensitive baseline (Siding Spring-Culgoora). In practice longer coherence times may be possible, therefore increasing the closure sensitivity. Map noise is defined as the rms noise/beam in the resulting maps,after a 12h observation. Thus, any source a few times stronger than this can be mapped provided that either

a) The system and atmosphere are phase stable

or b) There is a nearby phase reference source which is either stronger than the closure noise, or which is known to be unresolved.

or c) The source itself is stronger than the closure noise

Table 2: LBA Sensitivity

Bandwidth (MHz)	RMS closure noise(mJy)	RMS map noise(mJy)
10.0	40	0.4
2.0	89	0.9
1 kHz (line)	4Jy	40mJy

It may be seen from Table 2 that the map noise is extremely small, because of the large collecting area, and in fact will be smaller than any synthesis instrument in the world. It is the combination of this high sensitivity with the high resolution listed in Table 1 which will allow us to map structures which at present are unobservable. The limitation of the LBA will be the relatively high closure noise , although this may be bypassed by use of phase referencing, or may be alleviated either by using all the Culgoora antennas as a tied array, or by increasing the integration time.

7.0 WHAT CAN WE MAP WITH THE LBA?

It would be both presumptuous and foolhardy to attempt to catalogue all the types of observation possible with the LBA. However, based on VLBI and MERLIN experience, it is possible to compile a list of projects which may serve as examples for the discussions in this note. This list consists simply of my own favourites, and makes no attempt to be exhaustive, but does give an idea of the sort of project which is feasible.

7.1 Compact Jets In Quasars And Radio Galaxies

The resolution of the LBA will allow us to map the subarcsec jets seen by MERLIN and the VLA, but with a resolution such that we can resolve detail within the jet.This in turn may shed light on such areas as the emission mechanism, the containment, and the instabilities within the jet. Polarimetry will in addition give information on the magnetic fields within the jet.

In addition to the study of known jets, the high sensitivity of the LBA will allow us to look for weak counterjets, and so investigate the hypothesis of relativistic beaming in superluminal sources. A further possibility is to search for weak jets in steep spectrum objects, where we see the outer hotspots but cannot at present see the energy that fuels them.

7.2 Flat Spectrum Cores In Active Galactic Nuclei

In many sources (often in Seyfert galaxies) there is a flat spectrum core but no obvious jet. This core probably represents ionised material around an accretion disc which is fuelling a black hole or other compact object. Such cores are starting to be resolved with MERLIN, but the LBA would be able to map the structure of these cores in detail.

7.3 The Galactic Centre

Our position in the Southern hemisphere gives us an unparalelled opportunity to study the compact sources in the galactic centre. Multi-frequency observations with the LBA, with associated polarimetry, could provide a key to understanding the compact core of our own galactic centre.

7.4 H20/OH/IR Stars

The OH and H20 masers in circumstellar shells show structure from a few arcsec (representing the overall shell structure) down to milliarcsec (representing the amplified thermal stellar emission). Observations of the small scale structure could be used to study the mass loss mechanism, and perhaps even answer the question of how stars lose their angular momentum. In addition, recent VLBI observations (Norris et al. 1984) indicate that the maser hotspot represents the amplified stellar image, so that studies of the very compact structure may be used both for imaging of late type stars and binary systems, and for astrometry, in which capacity they will provide an important link between the radio and optical reference frames.

A further application of these stars is as primary distance indicators. By mapping the OH in the circumstellar shell, the angular diameter of the shell may be measured. By measuring the phase lag between the light curves of the OH emission from the front and back of the shell, the linear diameter may be measured. Combining these linear and angular diameters allows the measurement of the distance of the star to a few percent accuracy (e.g. Herman 1983). Since there are a number of such stars close to the galactic centre, we are in a prime position to use this technique to measure the distance to the galactic centre.

7.5 Radio Stars

The history of studies of radio stars is one of frustration because of the simultaneous requirements of high sensitivity and high resolution, which have heretofore been difficult to achieve. The LBA satisfies these requirements, so that we may confidently expect rapid progress to follow LBA observations of these stars.

Some areas which are of current astrophysical interest are

a) RS CVn binaries. The emission mechanism is at present unknown, although the high circular polarisation (upto 70% ; Mutel et al. 1978) indicate some sort of gyro or synchrotron emission in a strong magnetic field.

b) Symbiotic stars. These are currently the subject of study at Radiophysics, and the LBA would be able to resolve the ionized gas and so determine its structure. Already one such star (R Aqr) has been found to have a jet (Sopka et al. 1982), whose appearance showed we have still a great deal to discover about these stars.

c) As well as studying the astrophysics of radio stars, astrometric observations of radio stars will provide another link between the radio and optical reference frames. At present, the only interferometers capable of such astrometry are severely sensitivity limited (e.g. Lestrade et al. 1983)

8.0 CONCLUSION AND PROPOSALS

The CA presents a greater technological challenge than the LBA, and will certainly be capable of tackling many outstanding problems in astrophysics. However, this should not be allowed to obscure the likelihood that the LBA in 1988-89 will have just as much impact on the astronomical community as the CA, because the LBA will be able to map classes of objects which just cannot be mapped with any other real-time instrument. This being so, perhaps consideration should be given to the following two proposals:

1) If progress on the AT seems to be slowing for any reason, such that there is a danger of its completion date falling after 1988, the LBA completion date should be maintained within 1988. This is because the technical problems of the LBA are likely to be less severe than for the CA, and, in this fall-back position we would still have a major world-class instrument completed in 1988.

2) A working group should be set up to examine the problems peculiar to the LBA. The reasons for this are twofold. Firstly, as the CA is the most technically challenging part of the AT, there is a danger that the needs of the CA alone will largely determine the conclusions of the various working groups concerned with the different aspects of the AT. Secondly, there are aspects of the LBA design and operation (e.g. atmospheric stability, use of other telescopes within Australia) which do not come within the terms of reference of any other working group, and so may not receive the attention they deserve.

Such a working group need only meet occasionally as and when necessary, but once formed would provide both a forum and a focus for dealing with questions specific to the LBA.

9.0 REFERENCES

Diamond,P.J., Norris,R.P., Booth,R.S., 1983 Astron.Astrophys. 124,L4.

Herman,J., 1983, Ph.D. Thesis, Sterrewacht Leiden.

Lestrade,J.F., Preston,R.A., Slade,M.A., 1983, in 'VLBI Techniques' ed. F.Biraud,CNES,Toulouse.

Mutel,R.M., Weisberg,J.M.,1978, Astron.J., 83,1499.

Norris,R.P., 1983, in 'VLBI Techniques',ibid.

Norris,R.P., Diamond,P.J., Booth, R.S., 1982, Nature, 299,131.

Norris, R.P., Booth,R.S., Diamond,P.J., Nyman,L.A., Graham,D.A., Matveyenko,L.I., 1984a, MNRAS ,in press.

Norris,R.P., Baan,W., Haschick,A., Diamond,P.J., Booth,R.S., 1984b, in preparation.

Sopka,R.J., Herbig,G.H., Kafatos,M., Michalitsianos,A.G., 1982, Ap.J., 258,L35.

Wilkinson,P.N., 1983, in 'VLBI Techniques',ibid.

AJP

Erratum to Filenote AT/20.1/012

There seems to be some uncertainty in the way in which the sensitivity of an array should be defined. In particular, the published sensitivity of the VLBA (VLBA Design Study, Feb 1981, Table I-1), upon which the sensitivity comparisons in this note were based, appear rather pessimistic. Consequently, the following two comments should be deleted:

p.2, para 2, "(greater....bandwidth)"

p.5, last para, "and in fact....world"

The arguments and conclusions of the filenote are unaffected.

RPN 18/4/84

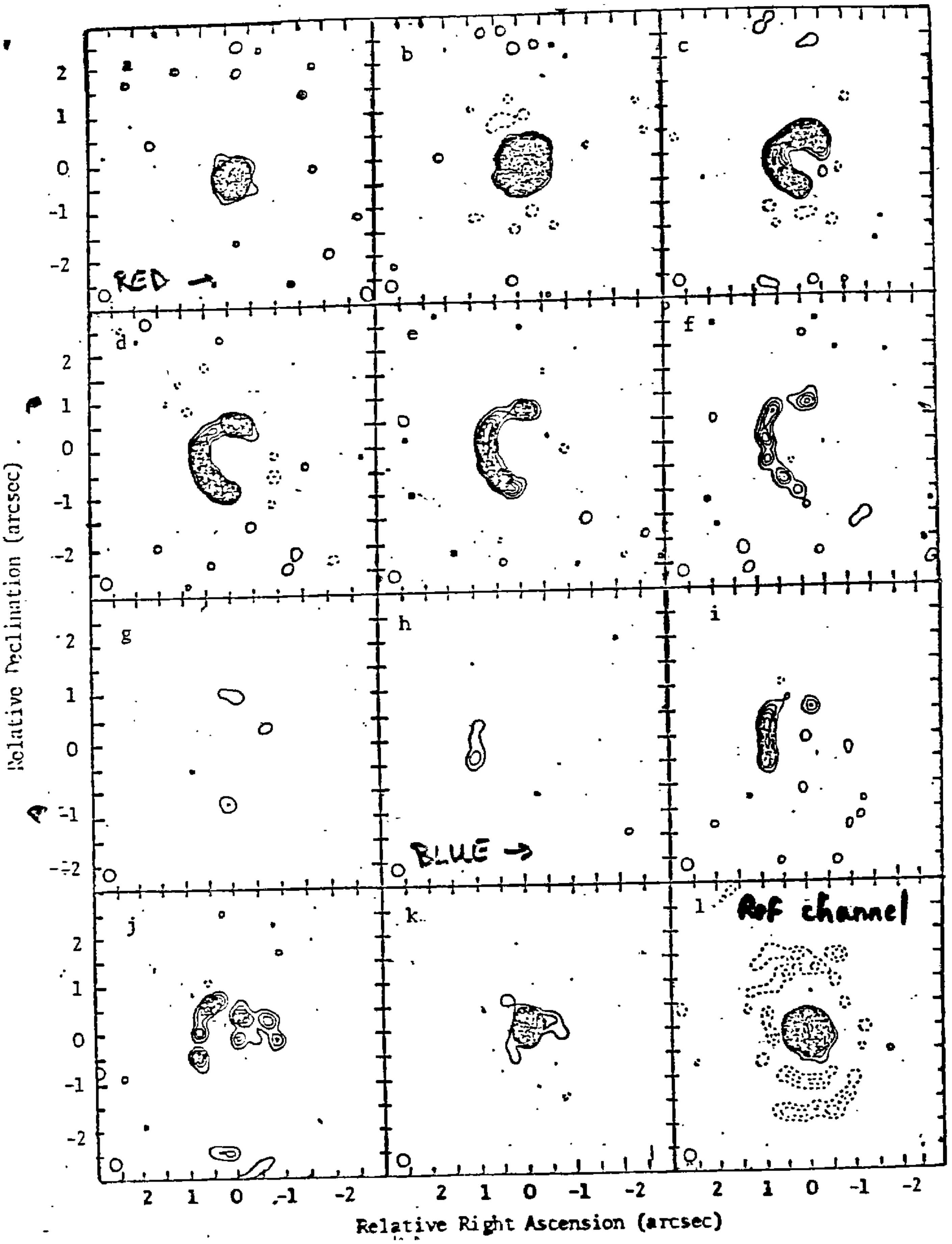


Figure 1. MERLIN maps of the circumstellar shell around OH127.8 (declination +62°), from Morris et al. 1982. Each map represents a different velocity. They were made using closure phase and CLEAN on 4 telescopes of MERLIN.

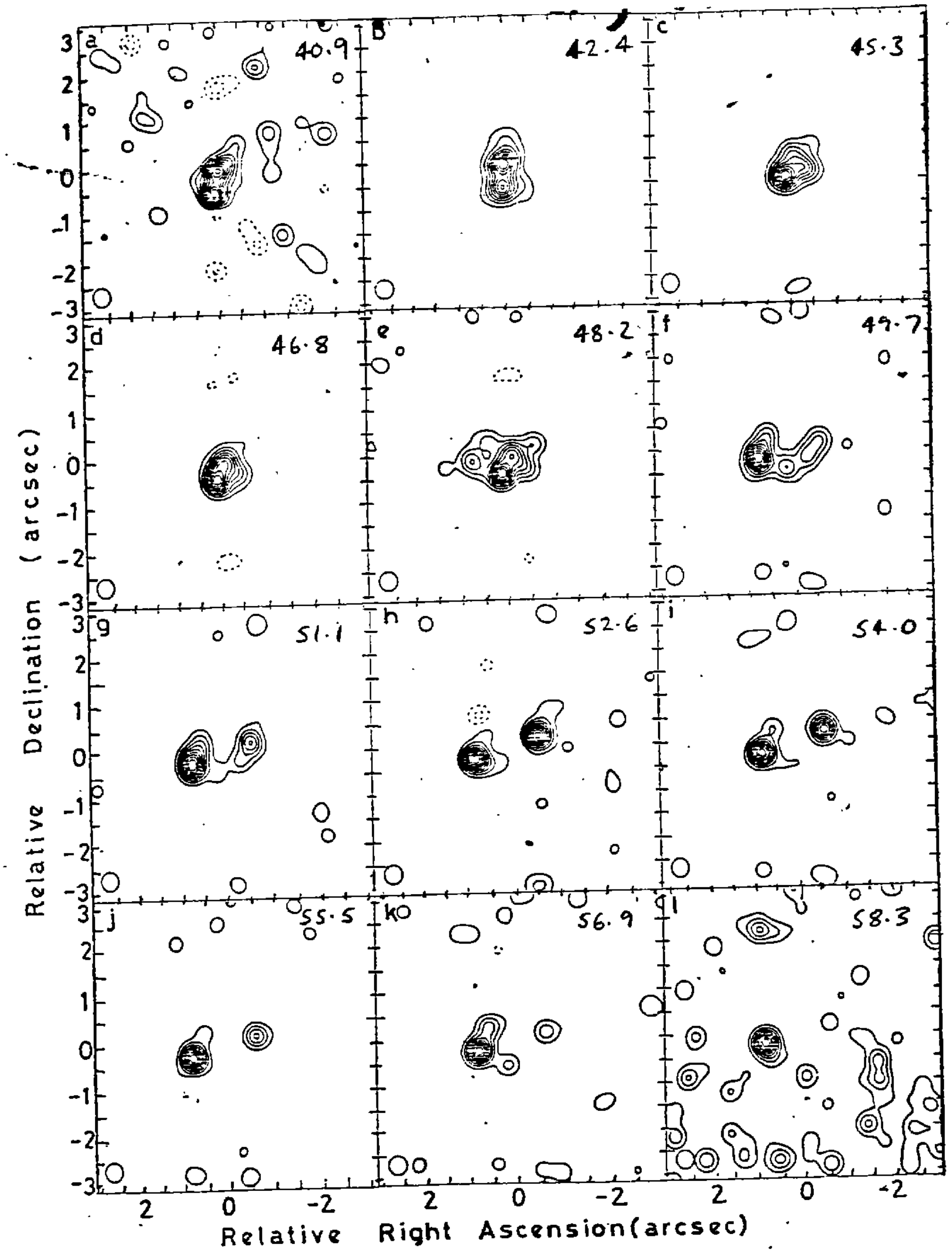


Figure 2. **MERLIN maps of the OH** around the putative bipolar nebula **IRC10420** (declination +11°), from Diamond et al. 1983.

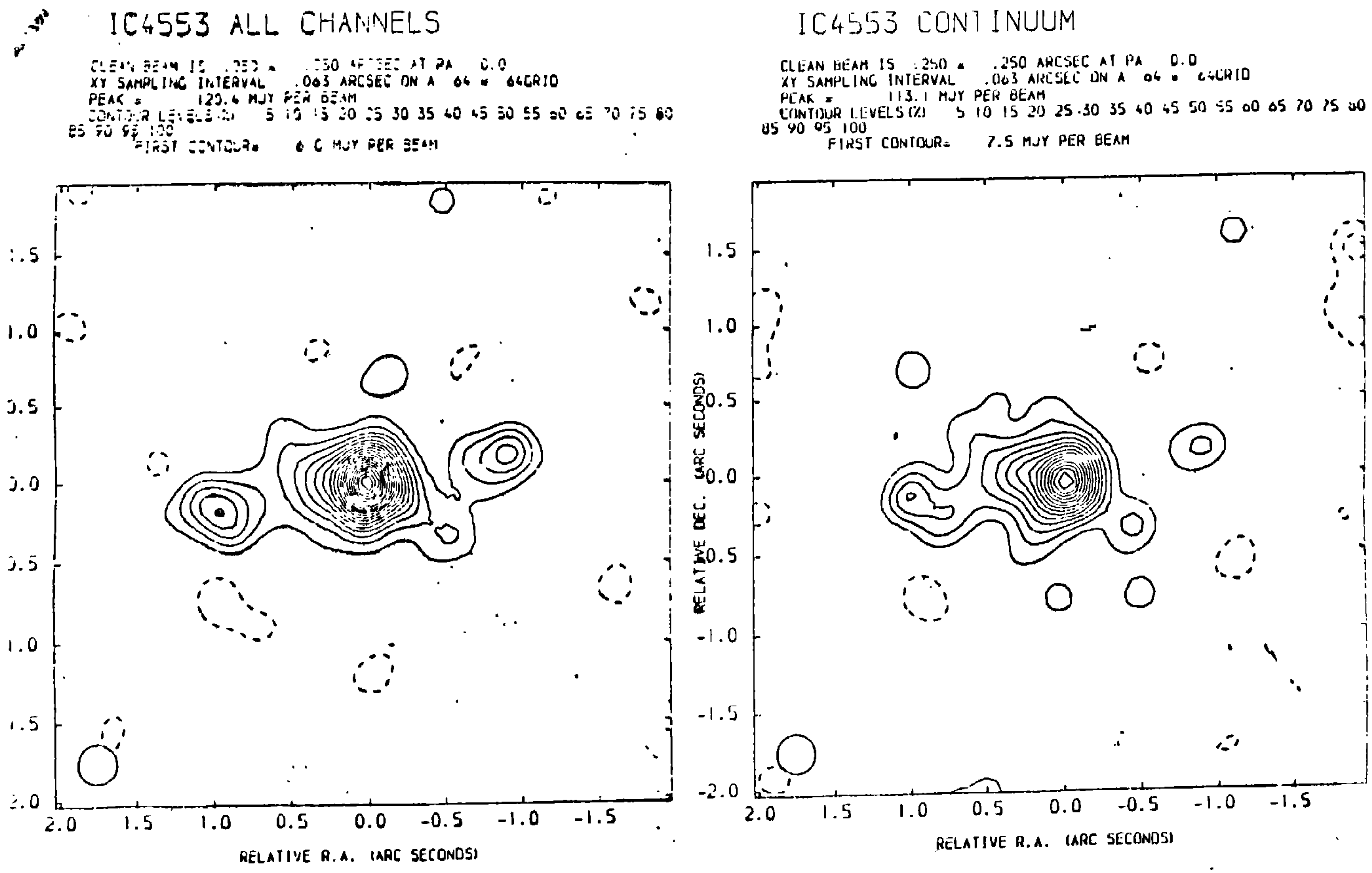
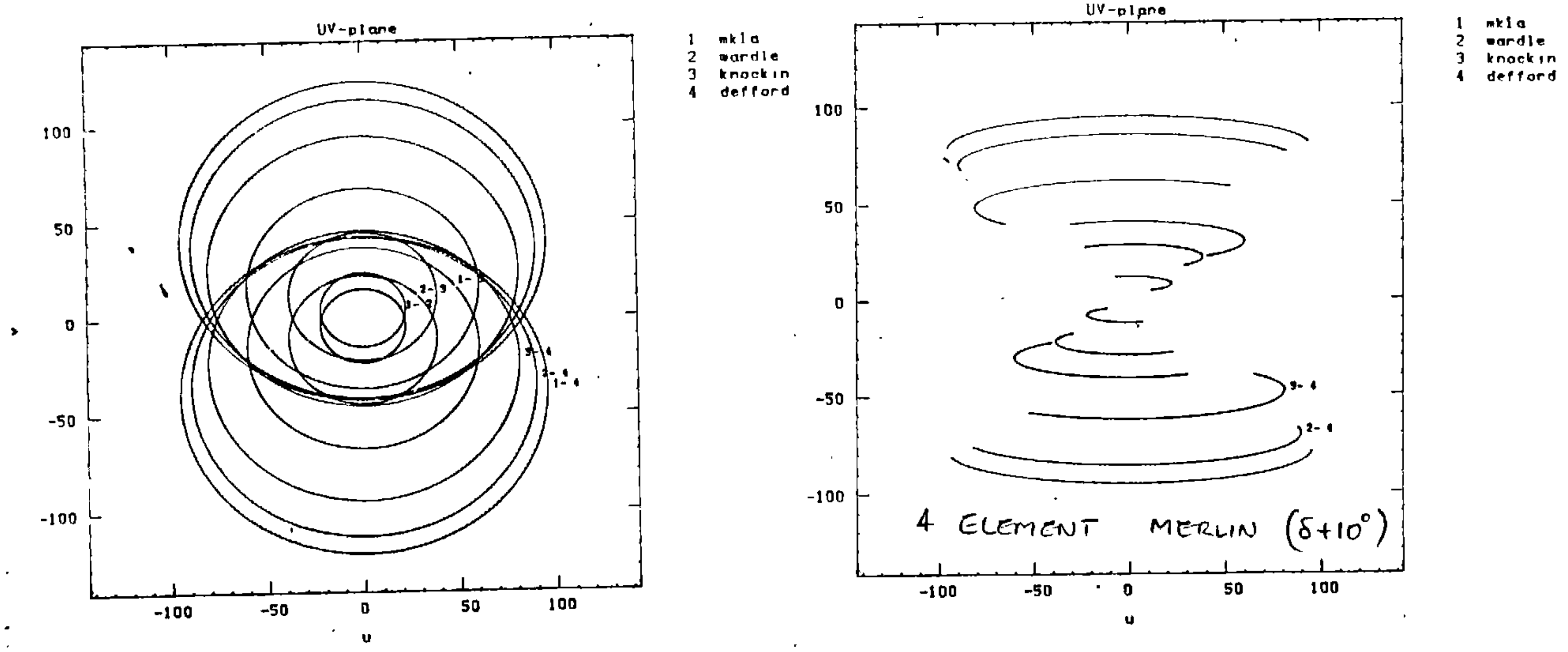
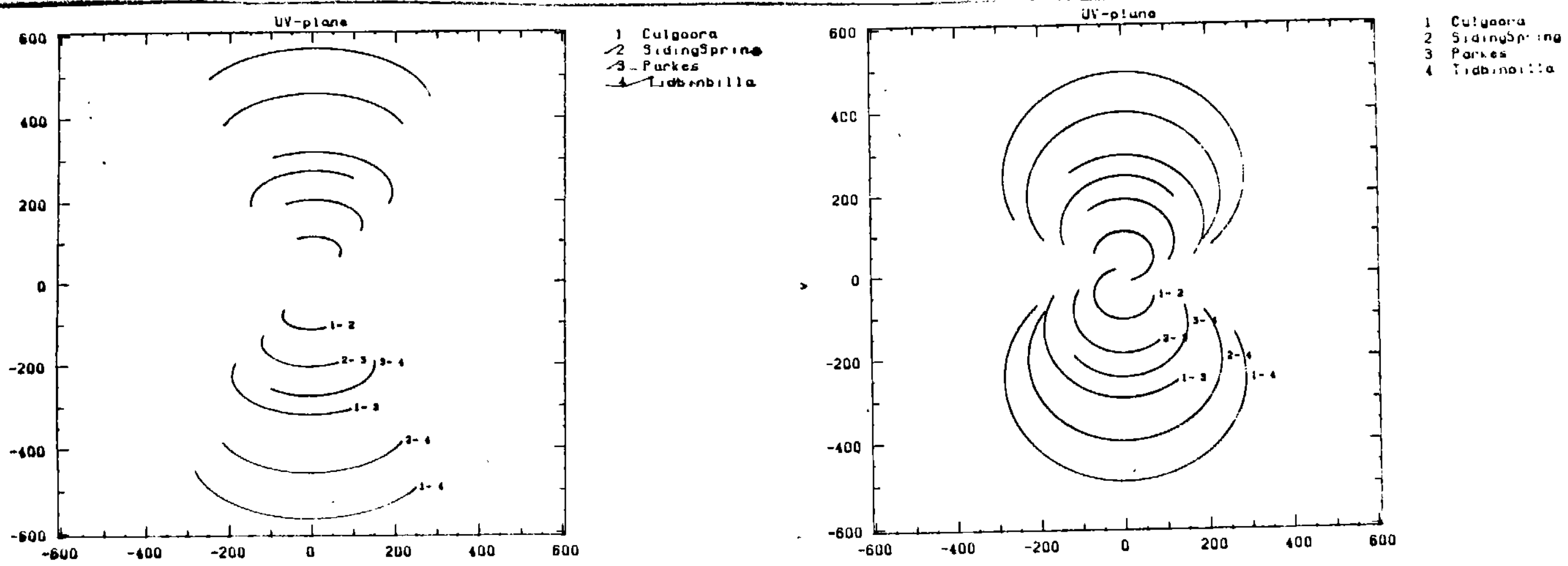


Figure 3. MERLIN map of the integrated OH and continuum emission from the Starburst galaxy IC4553 (declination +23°), from Norris et al. 1984b.



Figures 4 and 5. **The uv coverage of the 4 telescope MERLIN at declinations 60° and 10° respectively.**



Figures 6 and 7. The uv coverage of the 4 telescope LBA at declinations -30° and -60° respectively.

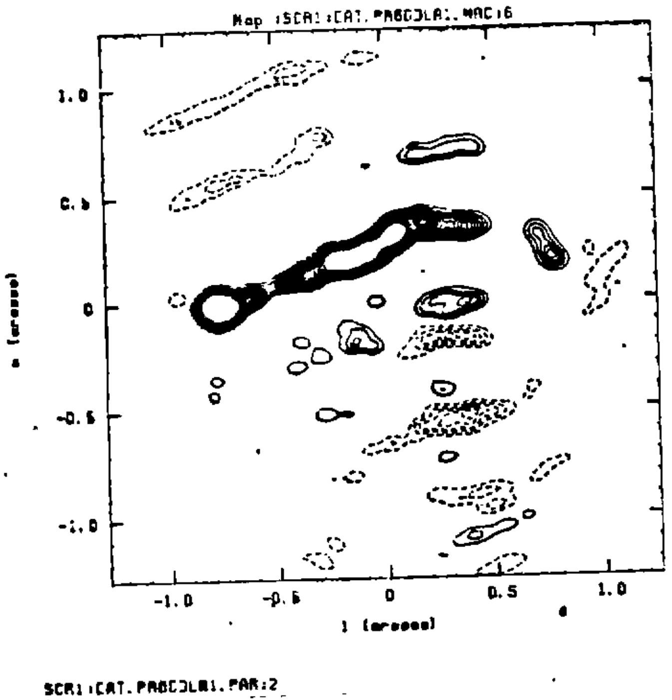


Figure 8. A simulated map of the Virgo jet observed with the 4 telescope LBA, at declination -60° . Boxing and further cleaning would remove the sidelobes to the North and South. Contours are at 1% intervals.

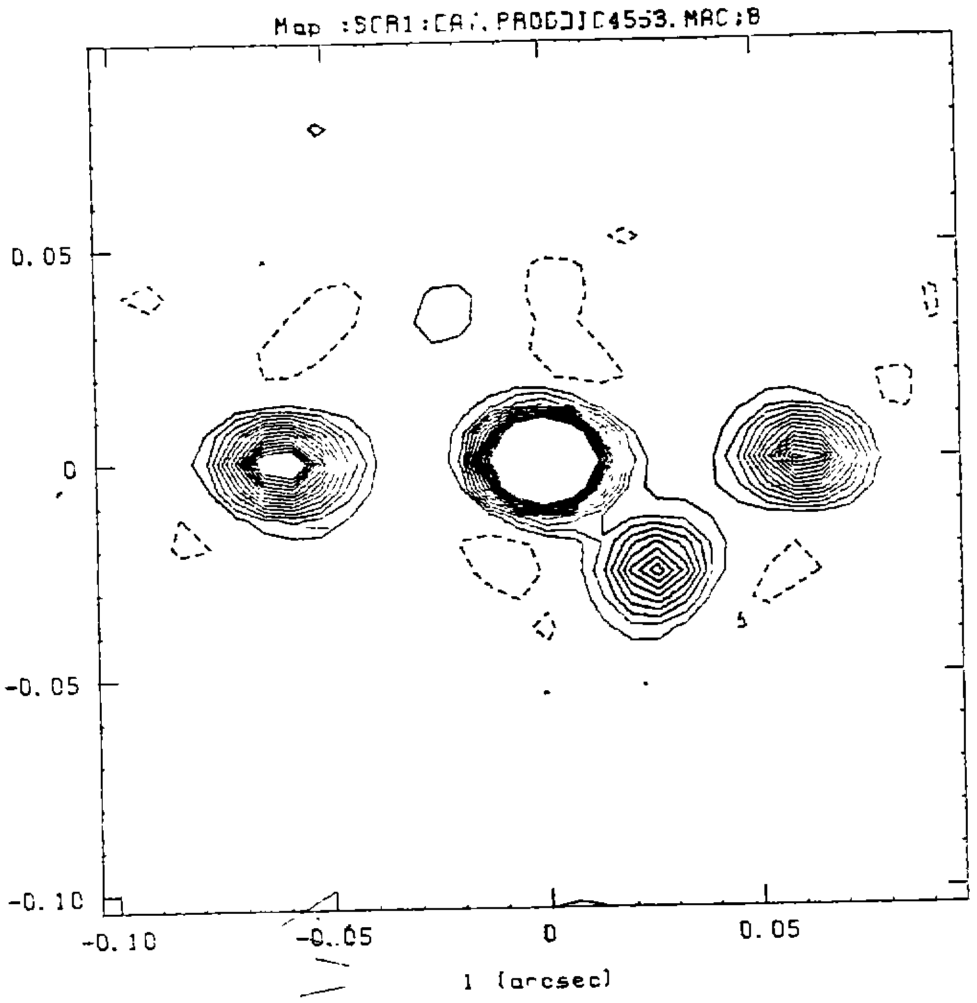


Figure 9. A simulated LBA map of the active galactic nucleus IC4553, at declination -60°. The absence of sidelobes is due to the simpler structure. Contours are at 2% intervals.

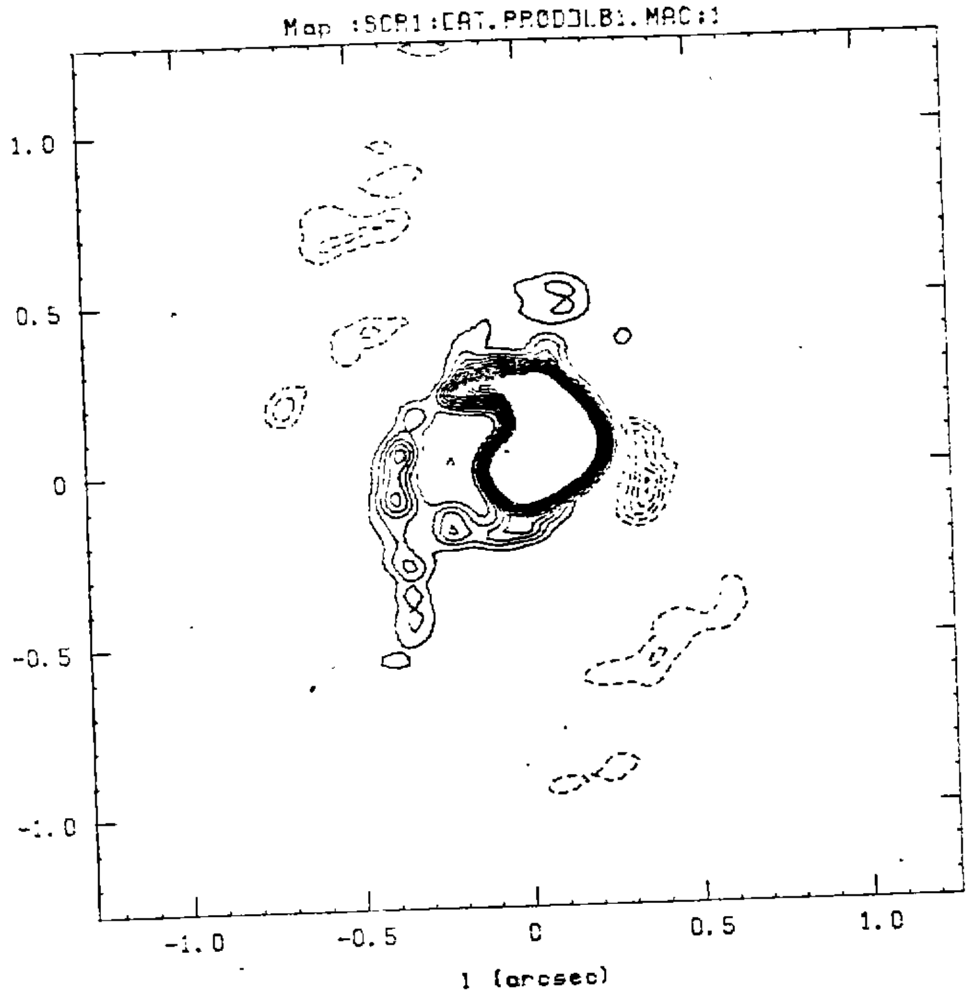


Figure 10. A simulated LBA map of the test source "Spirall",suitably scaled, at declination -60° . This source would be virtually unmappable by any other synthesis array presently operating (see text). Contours are at 1% intervals.

The Astronomical Potential of the LBA

AT/20.1/012
Overall Systems
and Performance

Ray Norris

16 April 1984

1.0 SUMMARY

By comparing the performance of the 4 station LBA with that of MERLIN, it is shown that the LBA, even with only 4 telescopes, is capable of producing high resolution sunthesis maps. Furthermore, the high sensitivity and resolution of the LBA mean that it will be the only instrument in the world capable of mapping some classes of structure, and the tapping of these unexplored fields is likely to produce a flow of new discoveries. In this note, the potential of the LBA is evaluated, and two concrete proposals regarding its development are formulated.

2.0 INTRODUCTION

Whilst the compact array (CA) of the AT will be the only telescope of its type in the Southern Hemisphere, the LBA, (defined here as consisting only of Parkes, Culgoora, Siding Spring, and Tidbinbilla) will be the only telescope *in the world* capable of mapping some compact structures.Consequently it is likely we can expect a rich crop of new discoveries from the as yet unexplored fields to be mapped with the LBA.

It is the purpose of this filenote to draw attention to the potential results obtainable with the LBA in its initial (i.e. 4-telescope) state, by comparing its performance with that from the only comparable (but smaller) array: MERLIN. Because of the high sensitivity (greater than the entire US VLBA network at full bandwidth) and high resolution of the LBA, nothing in the world will be able to approach the LBA for the study of sub-arcsec structure.

For this study I have assumed the LBA to consist of just 4 telescopes. Others may be added to these, with corresponding improvements in uv coverage and map quality, but emphasis here is to stress that the LBA will be a powerful synthesis instrument from the moment of its inception. As this discussion is restricted to the synthesis capabilities of the LBA, I do not consider here other areas of study in which the LBA's capabilities are already self-evident, such as astrometry, mapping of unresolved maser components, pulsar parallax and proper motion.

3.0 COMPARISON WITH MERLIN

Whilst it is true that the highest quality maps from MERLIN have been produced using six telescopes, it is perhaps not generally appreciated that a substantial fraction of the most significant results from MERLIN have been obtained using only 4 telescopes. In particular, to maximise frequency resolution with the available correlator space, *all spectral line work* on MERLIN has been done with 4 telescopes. In general these 4 telescopes are the 75m Mk1a, with three other 25m telescopes (usually Wardle, Knockin,and Defford). Like the AT LBA, these baselines are predominantly North-South, which may be seen as an advantage in that the uv coverage remains adequate down to low declinations.High quality synthesis maps have been made with MERLIN (at latitude 50°) down to declination -10° , and low dynamic range (13dB) maps which have been made down to declination -27° have still carried great astrophysical significance (for the simple reason that no-one else can map these structures at all!)

Figures 1 to 3 show examples of MERLIN maps made with just 4 telescopes.These examples have been chosen to illustrate the range of declinations, and the complexity of structure, that can successfully be mapped with 4 telescopes. Whilst such maps rarely exceed 20dB in dynamic range, and are insensitive to extended structures, there is clearly a great deal of new astrophysics obtainable from such maps.

It should be noted that all these maps have been made using closure phase, (or the spectral line adaptation of it), which is equivalent to 'Selfcal'. Use of these techniques on both MERLIN and VLBI data (see e.g. Wilkinson 1983, Norris 1983) have shown them to be capable of reaching dynamic ranges limited by thermal noise, provided that the flux density of the strongest component in the field is a few times greater than the closure noise (see Section 4 below).

4.0 UV COVERAGE

A commonly encountered myth is that since the LBA consists largely of North-South baselines, it is therefore inadequate as it stands for synthesis mapping of anything more complicated than point sources. On the other hand, it is apparent that mapping of fairly complicated sources with MERLIN has been extremely successful. Here I compare the uv coverage of the LBA and MERLIN.

In Figures 4 and 5 I show the uv coverage of MERLIN at declinations near those of the maps in Figures 1 to 3. These should be compared with the uv coverage for the LBA shown in Figures 6 and 7. The uv coverages for the two instruments appear comparable. A meaningful quantitative measure for sparsely sampled uv planes is difficult to construct, but reasonable criteria are that:

a) The area of the uv plane sampled should not be much longer (by, say, a factor of 2) in one direction than in another, so that the beam is not too elongated.

b) The size of the holes between uv tracks should be a minimum, as these define the size of the largest smooth, exteneded, structure that can be mapped (see e.g. Wilkinson 1983).

These criteria appear to be satisfied by the LBA. Quantitatively, the maximum size of hole is about 100km, so criterion (b) implies that the maximum size of a mappable extended structure is about 6 beamwidths. However MERLIN experience shows that this criterion is correct only for smooth extended structure, and complex structures much larger than this can be mapped successfully. For example, the circumstellar shells in Figure 1 are several times larger than the maximum size deduced from this criterion. A useful analogy is to regard the telescope as a high pass filter for spatial frequencies. Although rejecting frequencies below the cut-off frequency f_c , such a filter obviously passes higher frequencies modulated by an envelope of frequency $f \ll f_c$.

5.0 SIMULATIONS OF LBA MAPS

In Figures 8 to 10 I show examples of simulations of sources observed with the LBA. All have been produced using 'blind' CLEANing, and uniform weighting.

Figure 8 is a simulation of the jet in Virgo, and demonstrates that it can be mapped successfully even though the length of the jet exceeds the size defined by criterion (b) above. Since it has been produced by 'blind' cleaning, there has been no interaction with the data or analysis in order to improve the map. Such interaction is, however, permissible if done with care and objectivity, and in fact 'boxing' of the jet in Fig. 8 yields a map without the North-South sidelobes. That these sidelobes are not astronomical can be deduced in such a case by noting that the residuals after cleaning are not increased by the boxing. (This process is roughly equivalent to a manual-maximum-entropy-method !)

Figure 9 shows a simpler source, and is a simulation of the source IC4553, whose MERLIN map is shown in Fig. 3. Because of the simpler structure, CLEAN has performed very effectively to yield a map which is essentially free of sidelobes. As an indicator of the usefulness of such maps, the corresponding MERLIN map in Fig. 3 was the first time any structure had been seen in this source: VLA maps simply show a slight resolution, whereas the MERLIN maps (only one of many is shown here) show a wealth of structure which has transformed the interpretation of this source.

Figure 10 shows a deliberately complex source. Although the spiral structure curving round to the East and South has been lost, the map is nevertheless reliable down to the level of the first negative contour (the traditional criterion of reliability of such maps), and does show the spiral structure above this level. This source would appear unresolved with the VLA, and would show just a slight resolution with MERLIN. On the other hand, the extended size of the individual components would mean that they would be resolved out by nearly all VLBI observations. Thus if this source had been observed by the VLA, MERLIN, and (say) the European VLBI network, it would be concluded that it was a single gaussian component with a half width of about 0.2 arcsec. Only LBA observations would show that it actually had spiral structure.

6.0 THE PERFORMANCE OF THE LBA

In Table 1 I list the resolution at various frequencies. In each case, the maximum size of a smooth extended structure that can be mapped is approximately 6 beamwidths, but the maximum field of view is very much larger. The smallest size of object that can be measured depends on the signal-to-noise ratio, but with a strong source can be as small as one tenth of the beamwidth.

Table 1: The Resolution of the LBA

Frequency(GHz)	Beamwidth (arcsec)
.408	0.25
1.6	0.06
22.2	0.005

In Table 2 I list the approximate sensitivity of the LBA. A system noise of 50K has been assumed on each telescope, and it is assumed that only one 22m dish is used at Culgoora. The "closure noise" is defined as the rms noise in one integration period (10s) on the most insensitive baseline (Siding Spring-Culgoora). In practice longer coherence times may be possible, therefore increasing the closure sensitivity. Map noise is defined as the rms noise/beam in the resulting maps,after a 12h observation. Thus, any source a few times stronger than this can be mapped provided that either

a) The system and atmosphere are phase stable

or b) There is a nearby phase reference source which is either stronger than the closure noise, or which is known to be unresolved.

or c) The source itself is stronger than the closure noise

<u>Table 2: LBA Sensitivity</u>

Bandwidth (MHz)	RMS closure noise(mJy)	RMS map noise(mJy)
10.0	40	0.4
2.0	89	0.9
1 kHz (line)	4Jy	40mJy

It may be seen from Table 2 that the map noise is extremely small, because of the large collecting area, and in fact will be smaller than any synthesis instrument in the world. It is the combination of this high sensitivity with the high resolution listed in Table 1 which will allow us to map structures which at present are unobservable. The limitation of the LBA will be the relatively high closure noise , although this may be bypassed by use of phase referencing, or may be alleviated either by using all the Culgoora antennas as a tied array, or by increasing the integration time.

7.0 WHAT CAN WE MAP WITH THE LBA?

It would be both presumptuous and foolhardy to attempt to catalogue all the types of observation possible with the LBA. However, based on VLBI and MERLIN experience, it is possible to compile a list of projects which may serve as examples for the discussions in this note. This list consists simply of my own favourites, and makes no attempt to be exhaustive, but does give an idea of the sort of project which is feasible.

7.1 Compact Jets In Quasars And Radio Galaxies

The resolution of the LBA will allow us to map the subarcsec jets seen by MERLIN and the VLA, but with a resolution such that we can resolve detail within the jet.This in turn may shed light on such areas as the emission mechanism, the containment, and the instabilities within the jet. Polarimetry will in addition give information on the magnetic fields within the jet.

In addition to the study of known jets, the high sensitivity of the LBA will allow us to look for weak counterjets, and so investigate the hypothesis of relativistic beaming in superluminal sources. A further possibility is to search for weak jets in steep spectrum objects, where we see the outer hotspots but cannot at present see the energy that fuels them.

7.2 Flat Spectrum Cores In Active Galactic Nuclei

In many sources (often in Seyfert galaxies) there is a flat spectrum core but no obvious jet. This core probably represents ionised material around an accretion disc which is fuelling a black hole or other compact object. Such cores are starting to be resolved with MERLIN, but the LBA would be able to map the structure of these cores in detail.

7.3 The Galactic Centre

Our position in the Southern hemisphere gives us an unparalelled opportunity to study the compact sources in the galactic centre. Multi-frequency observations with the LBA, with associated polarimetry, could provide a key to understanding the compact core of our own galactic centre.

7.4 H20/OH/IR Stars

The OH and H20 masers in circumstellar shells show structure from a few arcsec (representing the overall shell structure) down to milliarcsec (representing the amplified thermal stellar emission). Observations of the small scale structure could be used to study the mass loss mechanism, and perhaps even answer the question of how stars lose their angular momentum. In addition, recent VLBI observations (Norris et al. 1984) indicate that the maser hotspot represents the amplified stellar image, so that studies of the very compact structure may be used both for imaging of late type stars and binary systems, and for astrometry, in which capacity they will provide an important link between the radio and optical reference frames.

A further application of these stars is as primary distance indicators. By mapping the OH in the circumstellar shell, the angular diameter of the shell may be measured. By measuring the phase lag between the light curves of the OH emission from the front and back of the shell, the linear diameter may be measured. Combining these linear and angular diameters allows the measurement of the distance of the star to a few percent accuracy (e.g. Herman 1983). Since there are a number of such stars close to the galactic centre, we are in a prime position to use this technique to measure the distance to the galactic centre.

7.5 Radio Stars

The history of studies of radio stars is one of frustration because of the simultaneous requirements of high sensitivity and high resolution, which have heretofore been difficult to achieve. The LBA satisfies these requirements, so that we may confidently expect rapid progress to follow LBA observations of these stars.

Some areas which are of current astrophysical interest are

a) RS CVn binaries. The emission mechanism is at present unknown, although the high circular polarisation (upto 70% ; Mutel et al. 1978) indicate some sort of gyro or synchrotron emission in a strong magnetic field.

b) Symbiotic stars. These are currently the subject of study at Radiophysics, and the LBA would be able to resolve the ionized gas and so determine its structure. Already one such star (R Aqr) has been found to have a jet (Sopka et al. 1982), whose appearance showed we have still a great deal to discover about these stars.

c) As well as studying the astrophysics of radio stars, astrometric observations of radio stars will provide another link between the radio and optical reference frames. At present, the only interferometers capable of such astrometry are severely sensitivity limited (e.g. Lestrade et al. 1983)

8.0 CONCLUSION AND PROPOSALS

The CA presents a greater technological challenge than the LBA, and will certainly be capable of tackling many outstanding problems in astrophysics. However, this should not be allowed to obscure the likelihood that the LBA in 1988-89 will have just as much impact on the astronomical community as the CA, because the LBA will be able to map classes of objects which just cannot be mapped with any other real-time instrument. This being so, perhaps consideration should be given to the following two proposals:

1) If progress on the AT seems to be slowing for any reason, such that there is a danger of its completion date falling after 1988, the LBA completion date should be maintained within 1988. This is because the technical problems of the LBA are likely to be less severe than for the CA, and, in this fall-back position we would still have a major world-class instrument completed in 1988.

2) A working group should be set up to examine the problems peculiar to the LBA. The reasons for this are twofold. Firstly, as the CA is the most technically challenging part of the AT, there is a danger that the needs of the CA alone will largely determine the conclusions of the various working groups concerned with the different aspects of the AT. Secondly, there are aspects of the LBA design and operation (e.g. atmospheric stability, use of other telescopes within Australia) which do not come within the terms of reference of any other working group, and so may not receive the attention they deserve.

Such a working group need only meet occasionally as and when necessary, but once formed would provide both a forum and a focus for dealing with questions specific to the LBA.

9.0 REFERENCES

Diamond,P.J., Norris,R.P., Booth,R.S., 1983 Astron.Astrophys. 124,L4.

Herman,J., 1983, Ph.D. Thesis, Sterrewacht Leiden.

Lestrade,J.F., Preston,R.A., Slade,M.A., 1983, in 'VLBI Techniques' ed. F.Biraud,CNES,Toulouse.

Mutel,R.M., Weisberg,J.M.,1978, Astron.J., 83,1499.

Norris,R.P., 1983, in 'VLBI Techniques',ibid.

Norris,R.P., Diamond,P.J., Booth, R.S., 1982, Nature, 299,131.

Norris, R.P., Booth,R.S., Diamond,P.J., Nyman,L.A., Graham,D.A., Matveyenko,L.I., 1984a, MNRAS ,in press.

Norris,R.P., Baan,W., Haschick,A., Diamond,P.J., Booth,R.S., 1984b, in preparation.

Sopka,R.J., Herbig,G.H., Kafatos,M., Michalitsianos,A.G., 1982, Ap.J., 258,L35.

Wilkinson,P.N., 1983, in 'VLBI Techniques',ibid.

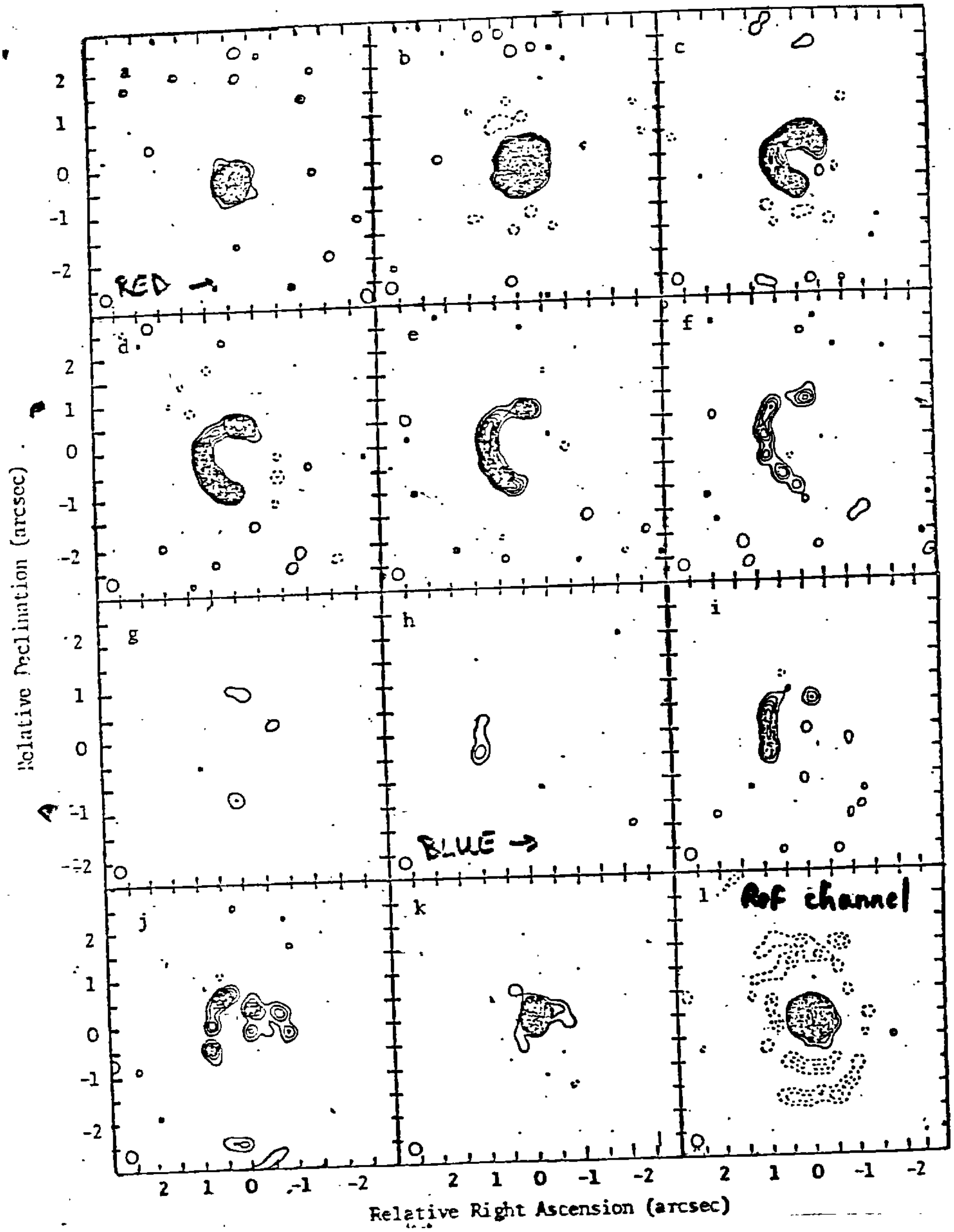


Figure 1. MERLIN maps of the circumstellar shell around OH127.8 (declination +62°), from Norris et al. 1982. Each map represents a different velocity. They were made using closure phase and CLEAN on 4 telescopes of MERLIN.

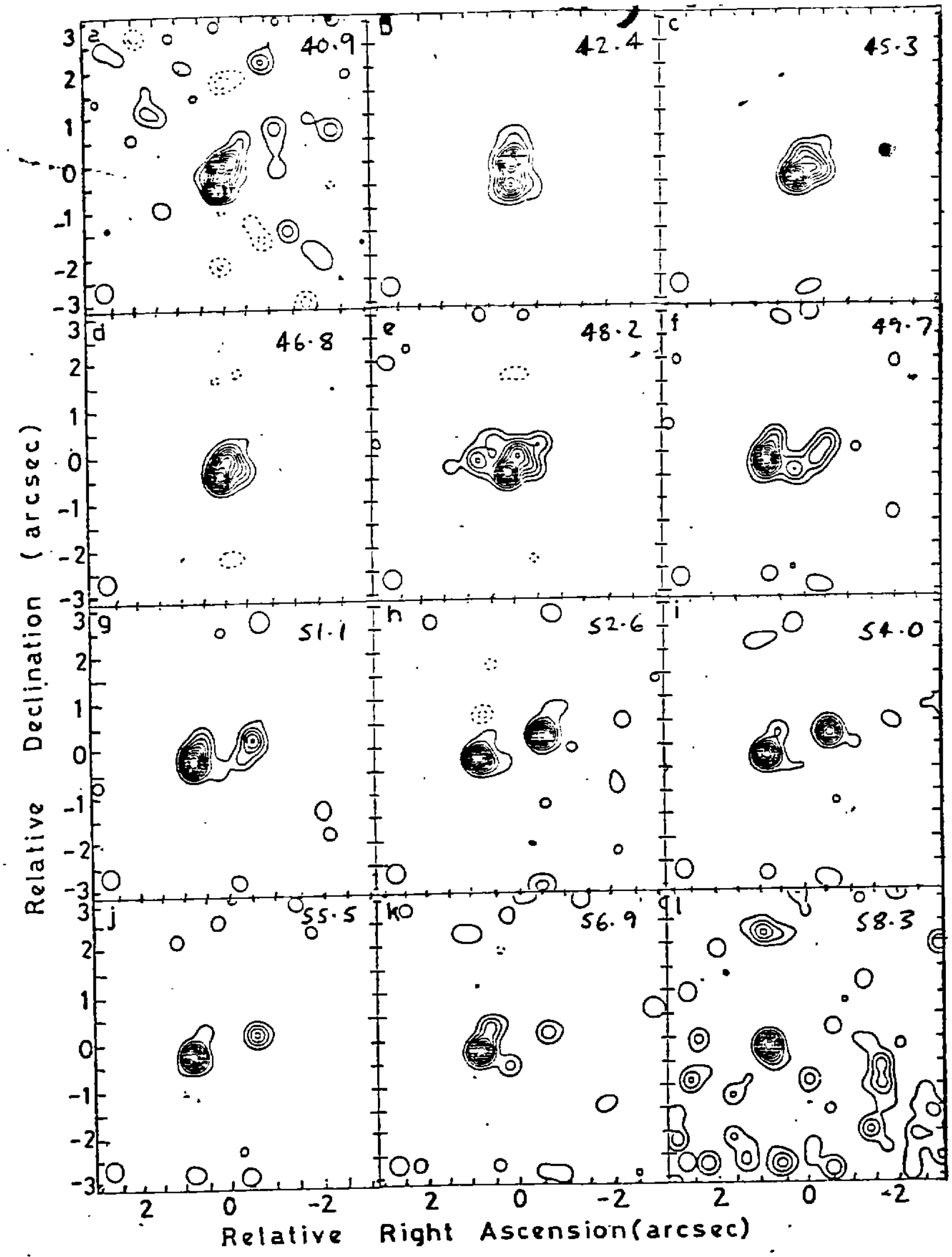


Figure 2. MERLIN maps of the OH around the putative bipolar nebula IRC10420 (declination +11°), from Diamond et al. 1983.

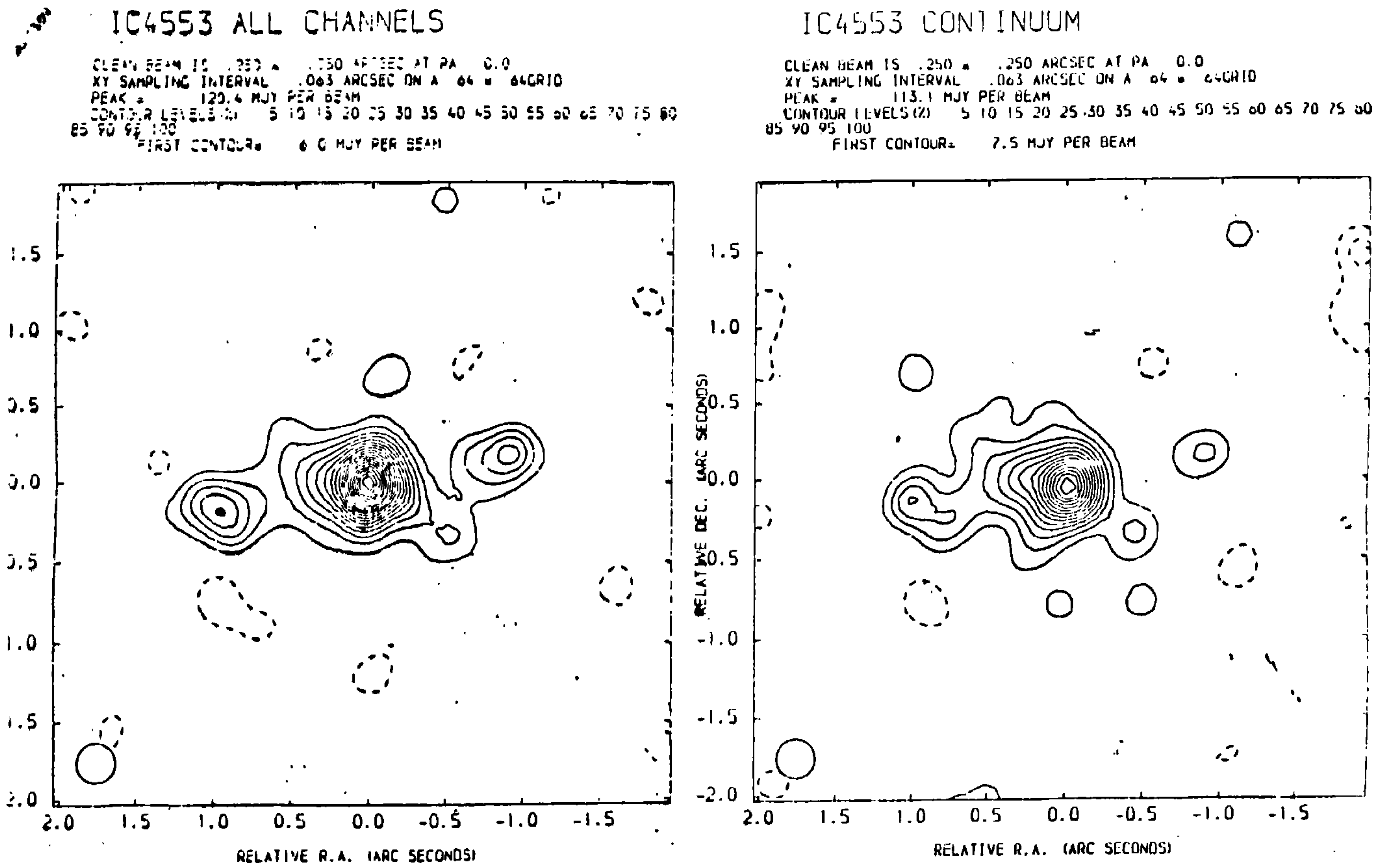
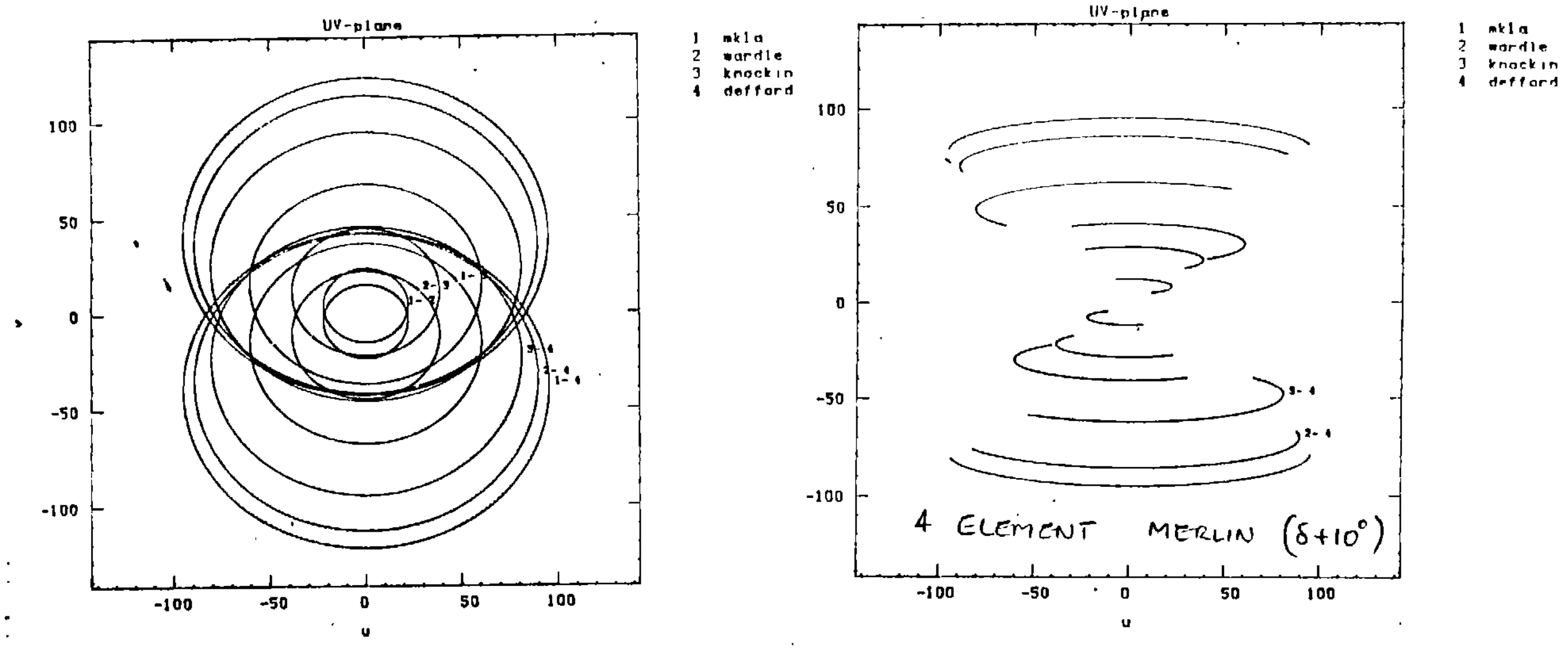
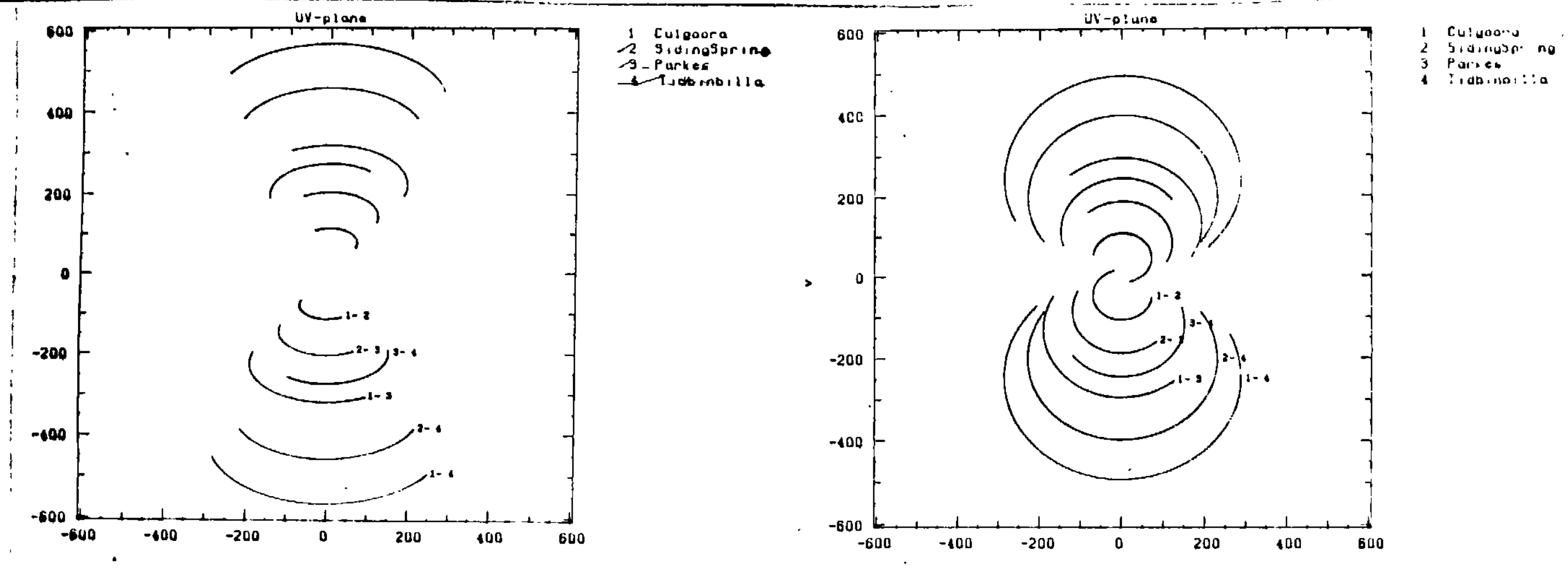


Figure 3. MERLIN map of the integrated OH and continuum emission from the Starburst galaxy IC4553 (declination +23°), from Norris et al. 1984b.



Figures 4 and 5. The uv coverage of the 4 telescope MERLIN at declinations 60° and 10° respectively.



Figures 6 and 7. The uv coverage of the 4 telescope LBA at declinations -30° and -60° respectively.

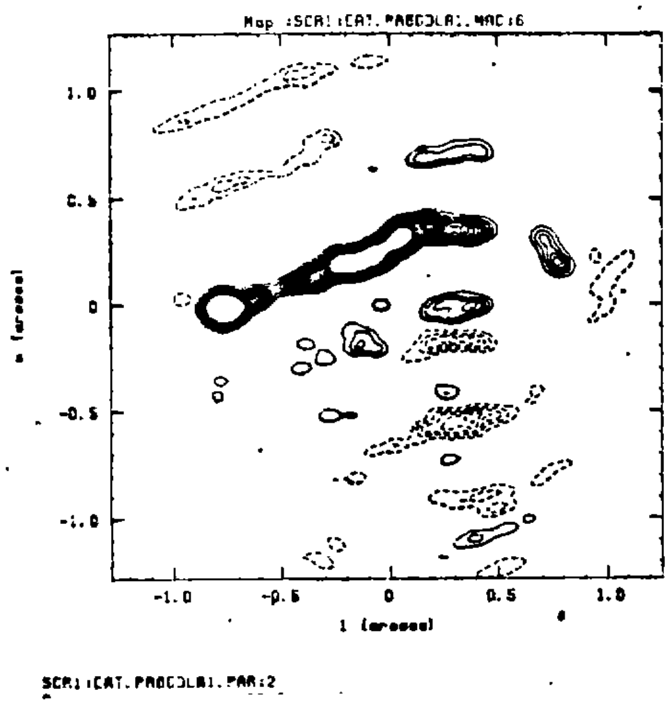


Figure 8. A simulated map of the Virgo jet observed with the 4 telescope LBA,at declination -60° . Boxing and further cleaning would remove the sidelobes to the North and South. Contours are at 1% intervals.

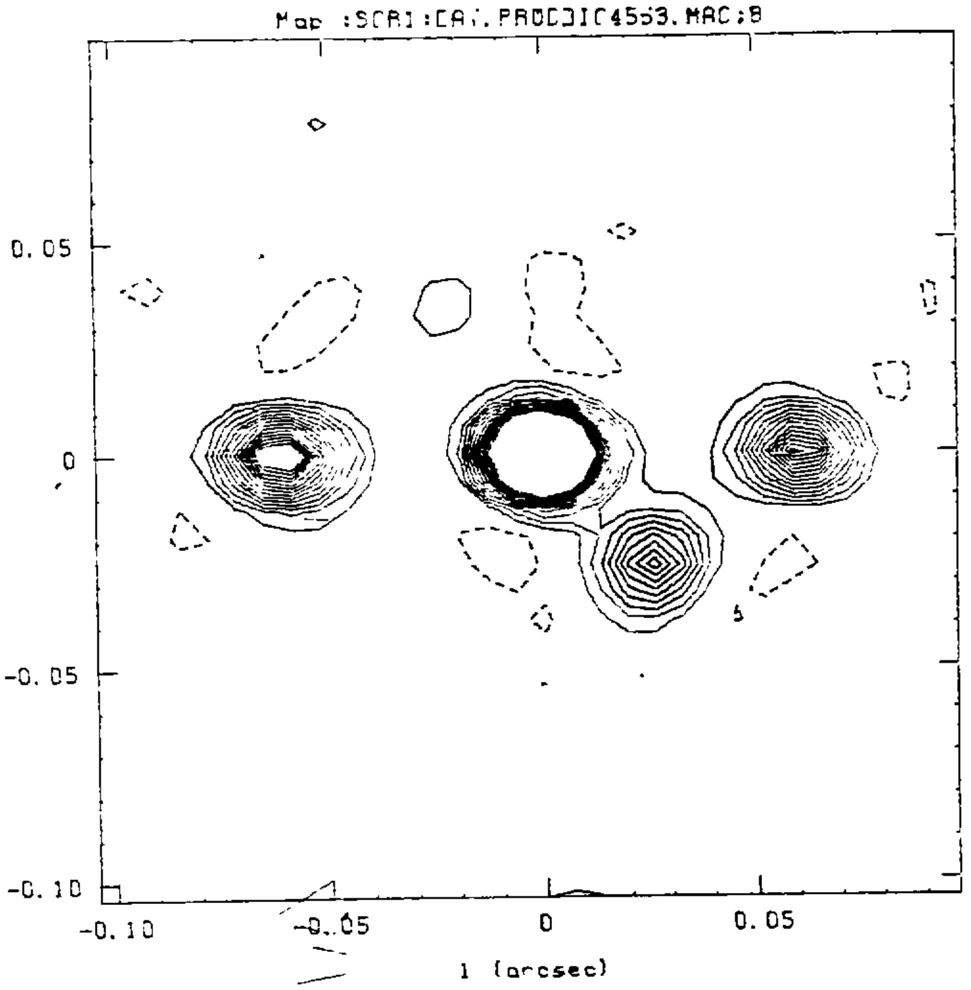


Figure 9. A simulated LBA map of the active galactic nucleus IC4553, at declination -60°. The absence of sidelobes is due to the simpler structure. Contours are at 2% intervals.

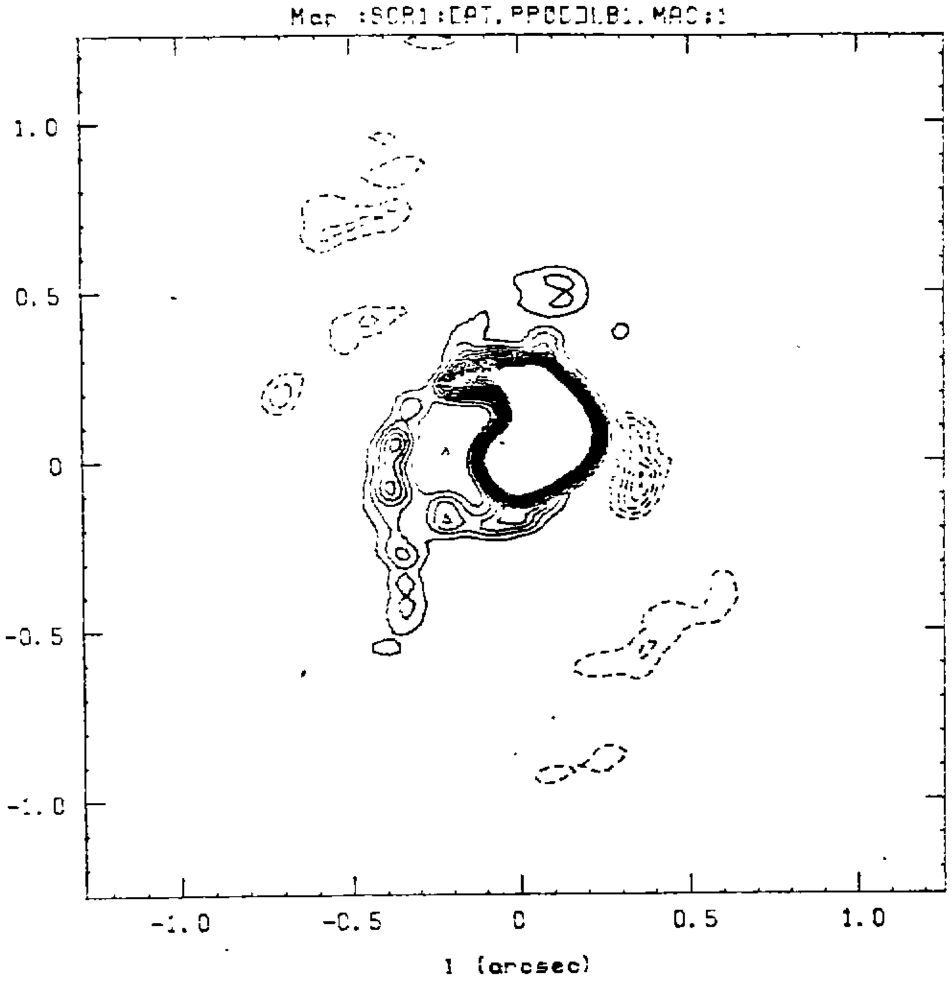


Figure 10. A simulated LBA map of the test source "Spirall",suitably scaled, at declination -60° . This source would be virtually unmappable by any other synthesis array presently operating (see text). Contours are at 1% intervals.