BIMA Memoranda Series #9

SYNTHESISED BEAMS AND INTERFEROMETER ARRAY RESPONSE TO EXTENDED STRUCTURE

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ABSTRACT

Large scale structure is poorly represented in images made from interferometer observations because of missing low spatial frequencies. In this memo we plot the BIMA array beam patterns for the standard arrays, and tabulate the response as a function of the source size. We briefly review the methods used to estimate the integrated flux density for an extended source.

ARRAY CONFIGURATIONS FOR 3 ANTENNAS

The standard BIMA array configurations were designed to provide approximately circular beams over a wide range of declinations, and with a low sidelobe level using equal weighting for each sampled uv point (natural weighting). The sidelobe level can be reduced, and the resolution improved, by weighting the uvdata to obtain a more uniform sampling in the uv plane. The SNR and the array response to extended structure are both degraded by using uniform weighting. Table 1 lists the standard arrays. Some attention has been paid to minimizing the number, and changes in direction, of the antenna moves.

TABLE 1 - BIMA ARRAYS FOR 3 ANTENNAS.

a-array				b-array			
a1	40E	500N	580N	b1	40E	260N	320N
a2	500W	100N	320N	b2	180E	100N	200N
a3	240W	260N	380N	b3	100W	140N	200N
a4	400E	200N	380N	b4	240W	40N	140N
a5	400E	240W	0N	b5	180E	100W	0N
a6	400E	380W	580N				
a7	500E	500W	580N	c-array			
				c0	15E	15W	20N
				c1	40W	80E	0N
				c2	40W	40N	100N
				c3	40E	60N	140N

SYNTHESISED BEAMS

The synthesised beams were made with equal weighting for each sampled uv point (natural weighting), and with an elevation limit of 15 degrees. The FWHM of Gaussian fits at 100GHz are listed in Table 2. The a-array consists of the first 5 configurations. The a+ array consists of all 7 configurations. The ab-array is the b-array together with the a1 configuration (6 configurations) to improve the resolution at low declinations. The b+c array is the combined b-array and c-array (9 configurations). The synthesised beams are plotted in Figures 1-8.

TABLE 2 - SYNTHESISED BEAMWIDTH FOR BIMA ARRAYS

	Declination			
array	-30	-5	20	45
a+	5.5 x 2.0	2.9 x 2.1	2.4 x 2.1	2.4 x 2.0
a	6.8 x 2.4	3.8 x 2.5	3.1 x 2.7	3.2 x 2.5
ab	9.8 x 5.4	6.9 x 5.5	6.0 x 5.5	6.2 x 5.1
b	13.8 x 5.0	7.3 x 5.4	6.1 x 5.6	6.3 x 5.1
b+c	16.9 x 7.9	10.2 x 8.5	9.1 x 8.4	9.4 x 7.9
c	33.3 x 15.8	17.6 x 16.6	17.2 x 14.3	17.7 x 14.1

RESPONSE TO EXTENDED STRUCTURE

In an attempt to quantify the interferometer array response to extended structure I made a series of Gaussian models with fwhm from 5 to 60 arcsec and convolved them by the synthesised beam. The Gaussians were truncated at 10% to provide models with a realistic source distribution and a finite overall size equal to twice the fwhm. The ratio of the integrated flux in the convolved image (units: Jy/beam) and in the initial model (units: Jy/pixel) give a measure of the effective beam area (in pixels) as a function of source size. This is analogous to the "main beam coupling factor" for single dish antennas. An important difference is that an aperture synthesis beam pattern has negative sidelobes and can give a negative effective beam area, or coupling factor, when observing large scale structure. This can lead to large negative values on an aperture synthesis image. A similar analysis for disk models can be obtained from a radial integration of the beam in elliptical annuli.

Table 3 gives the effective area (in pixels) as a function of source size. Table 3 shows how the effective area decreases as the source size increases for the b-array, i.e. the synthesised beam is poorly coupled to extended sources. The negative values indicate that a 20" fwhm Gaussian is completely resolved except at declination -30 where the beam is more extended in declination. For the bc-array the effective beam area at first increases for larger sources. This is similar to the typical single dish response which has a larger main beam efficiency, or coupling factor, for larger source sizes. However, when the source size exceeds the fringe spacing of the lowest spatial frequency, then the source is rapidly resolved with increasing size. Table 3 also lists the effective beam area, or clean beam oversampling factor, cbof, for a Gaussian beam with the beamwidths given in Table 2. For a Gaussian beam cbof = pi*bmaj*bmin/(4log(2)), where bmaj and bmin are the fwhm beamwidths. We have chosen the pixel size as 1 arcsec so that the units in Table 3 are also the beam area in arcsec**2.

TABLE 3 - EFFECTIVE BEAM AREA AS A FUNCTION OF SOURCE SIZE

	declination			
	-30	-5	20	45
a-array				
cbof	18	11	9	9
5	27	14	10	11
10	53	9	3	5
15	52	-	-	-
20	40	-	-	-
b-array				
cbof	78	45	39	36
5	52	39	35	34
10	105	47	33	34
15	159	23	9	8
20	78	-	-	-
bc-array				
cbof	134	87	76	74
10	192	133	117	115
20	338	169	156	144
30	281	163	155	131
40	177	126	75	45
50	66	77	-	-
60	6	47	-	-

INTEGRATED FLUX DENSITY OF AN EXTENDED SOURCE.

It is often quite difficult to obtain reliable estimates for the integrated flux density of an extended source from an image made with missing spatial frequencies. Several methods are commonly used.

1) Integration of a cleaned image.

If the source distribution is confined to some well defined portion of the image, then an estimate of the integrated flux density can be obtained by summing over the source, and dividing the integral by the beam oversampling factor. The beam oversampling factor is well defined on a deconvolved, or "cleaned" image, which has been convolved by a Gaussian beam. The integrated flux density is obtained by summing the pixel values over the area of interest and dividing by cbof for the Gaussian beam. However, for the original synthesised images, the effective beam area of the synthesised beam is a function of the source size and the cbof is not so well defined. A clean image, obtained by deconvolving the synthesised beam, and convolving by a clean beam may distort the integrated flux. The clean beam is usually estimated from a Gaussian fit to the synthesised beam, but the integral over the synthesised beam will depend on the size of the source. If the Gaussian clean beam has a larger effective beam area than the synthesised beam, then the clean, convolved image will have a higher integrated flux than the synthesised map, and vice-versa.

2) Integration of a deconvolved image.

A better estimate may be obtained by integrating a deconvolved image, or model of the source distribution which has units of Jy/pixel. This estimate must be corrected if some flux remains in the residual image (residual = map - model*beam; here * denotes convolution). Note that the residual image has a beam oversampling factor appropriate to the synthesised beam.

3) Correction for missing short spacing uvdata.

For interferometer observations where the zero spacing is missing, the integral over the whole image is zero, thus the positive source distribution must be balanced elsewhere on the image by negative regions. An antenna array usually samples the uvdata over some region with an outer boundary, which determines the resolution, and an inner boundary defined by the closest antenna spacings. If we think of this as a uniformly sampled region with a hole in the center, then the missing information on the synthesised map is the source distribution convolved by a beam corresponding to the hole. Thus a compact source appears to sit in a shallow basin whose size corresponds to the spatial frequency of the hole. A better estimate of the integrated flux from the source is obtained by correcting for the zero level around the image of the source. To some extent the clean algorithm fills in the hole when the deconvolved image is convolved by a Gaussian beam which has a higher effective area (better coupling to extended source structure) than the synthesised beam. This extrapolation may not be reliable.

4) Total flux estimates from uvdata.

It is sometimes possible to estimate the "zero spacing flux" by plotting the measured visibility flux density versus the uv-spacing, and extrapolating to zero spacing. It is usually necessary to average the uvdata to obtain sufficient signal to noise. If the source contains extended structure which is unsampled by the uvdata, then the extrapolation will be unreliable.

5) Spatial filtering to remove sidelobes from undersampled source structure.

Large negative values on a synthesised image can result from partially sampled extended structure. A cleaner image of the compact source structure may result by omitting the low spatial frequencies which are poorly sampling the extended structure. One of the advantages of interferometer observations is that the uvdata may be selected to filter out confusing structure.

6) Including estimates of large scale structure from other data.

A better image is obtained by including the missing low spatial frequencies in the image. These can be obtained either from more compact interferometer configurations, or from a single dish image. This is discused elswhere.

FIGURES

Figure 1 Synthesised beams for a-array for declinations -30 -5 20 and 45. The a-array consists of the first 5 configurations. The contours are plotted at intervals of 10%. Negative contours are shown dotted.

Figure 2 Synthesised beams for ab-array. Declinations and contours as above. The ab-array is the b-array + the a1 configuration to improve the resolution at low declinations. (6 configurations)

Figure 3 Synthesised beams for b-array. Declinations and contours as above.

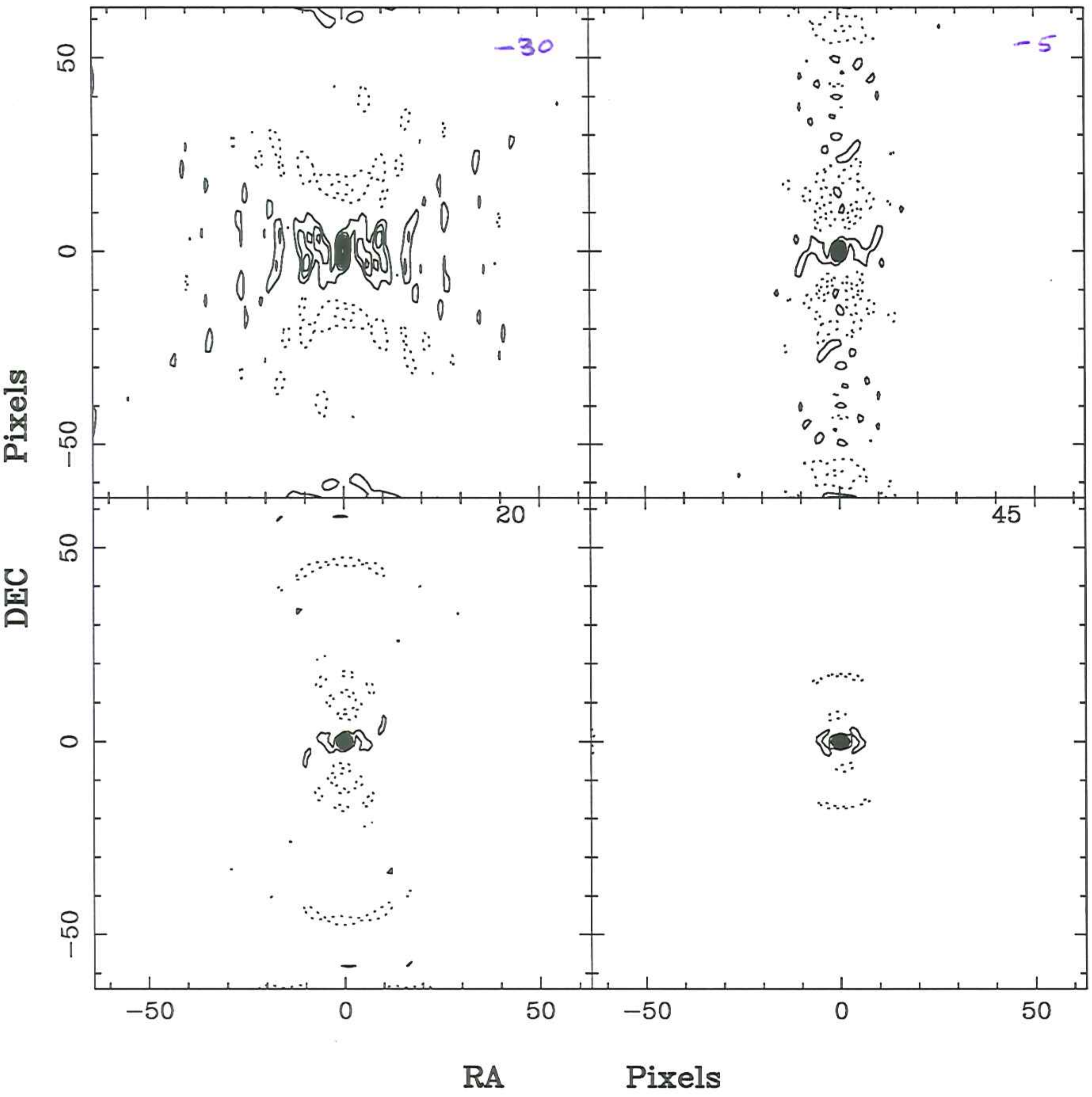
Figure 4 Synthesised beams for b+c arrays. Declinations and contours as above. The b+c array is the combined b-array and c-array (9 configurations).

Figure 5 Synthesised beams for c-array. Declinations and contours as above.

Figure 6 Synthesised beams for a+ array. Declinations and contours as above. The a+ array consists of the 7 configurations listed in Table 1.

Figure 7 Synthesised beams for a+b array. Declinations and contours as above. This uses the standard a+b arrays (10 configurations)

Figure 8 Synthesised beams for a+b+c array. Declinations and contours as above. This uses the standard a+b+c arrays (14 configurations)



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Units: JY/BEAM

Axes: 128 x 128 x 4
−1.00 x 1.00 x 25.00

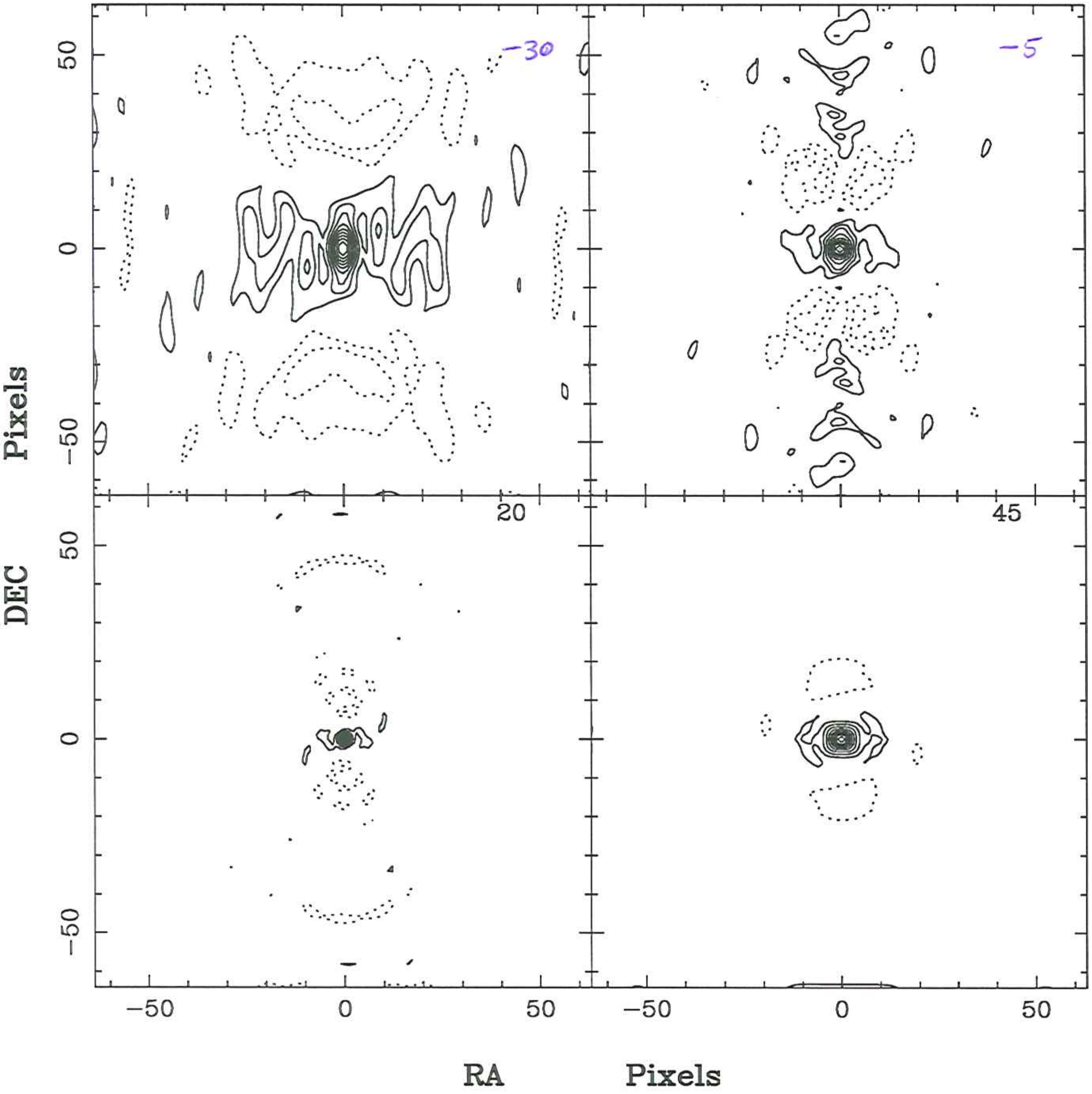
Contours: 10

0.100 0.200
0.300 0.400
0.500 0.600
0.700 0.800
0.900 1.000

Figure 1

DEC−30.0

00:00:00.00   00:00:00.00



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−1.00 x 1.00 x 25.00

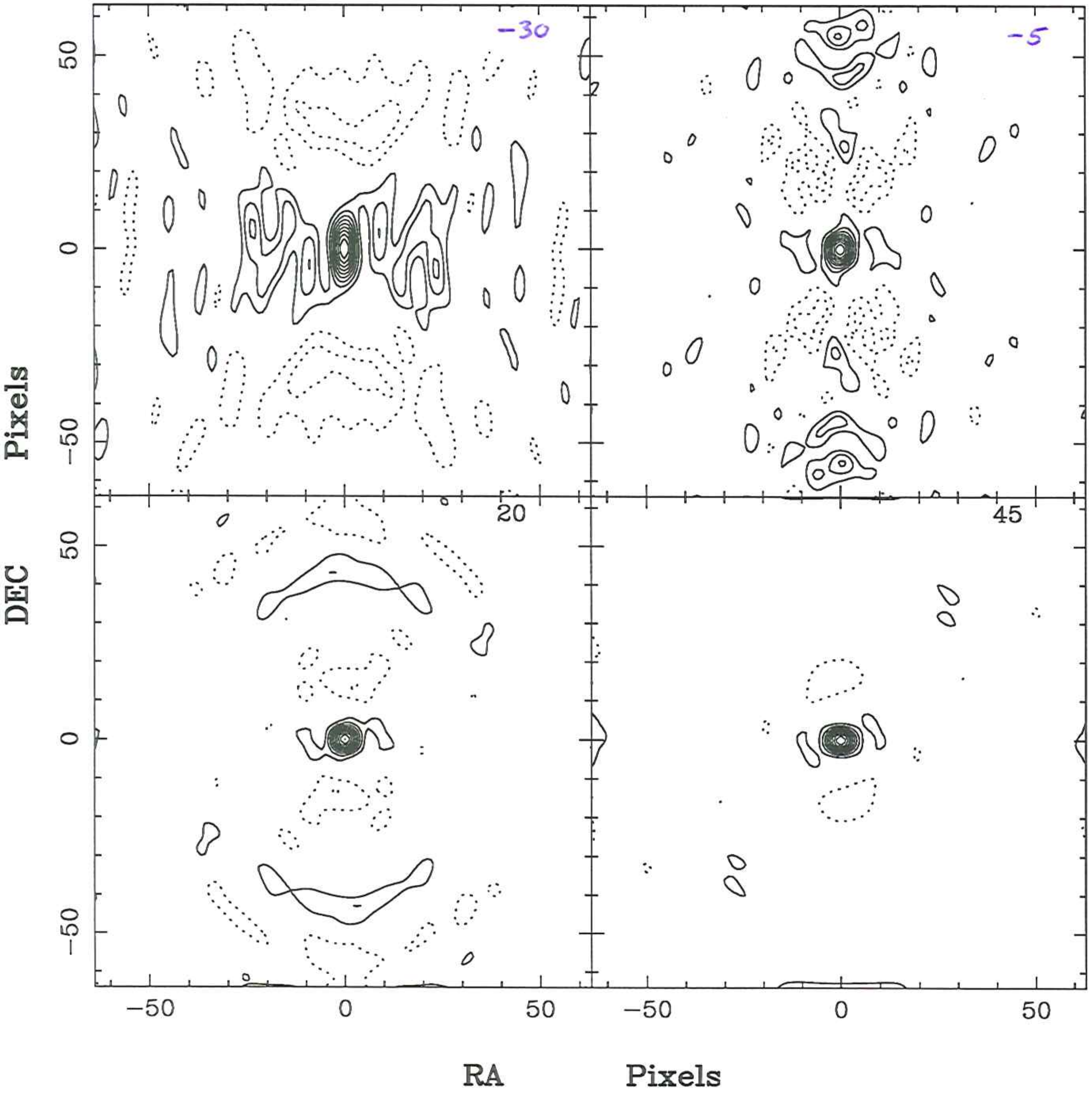
Contours: 10

0.100	0.200
0.300	0.400
0.500	0.600
0.700	0.800
0.900	1.000

Figure 2

DEC−30.0

00:00:00.00 00:00:00.00



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Contours: 10

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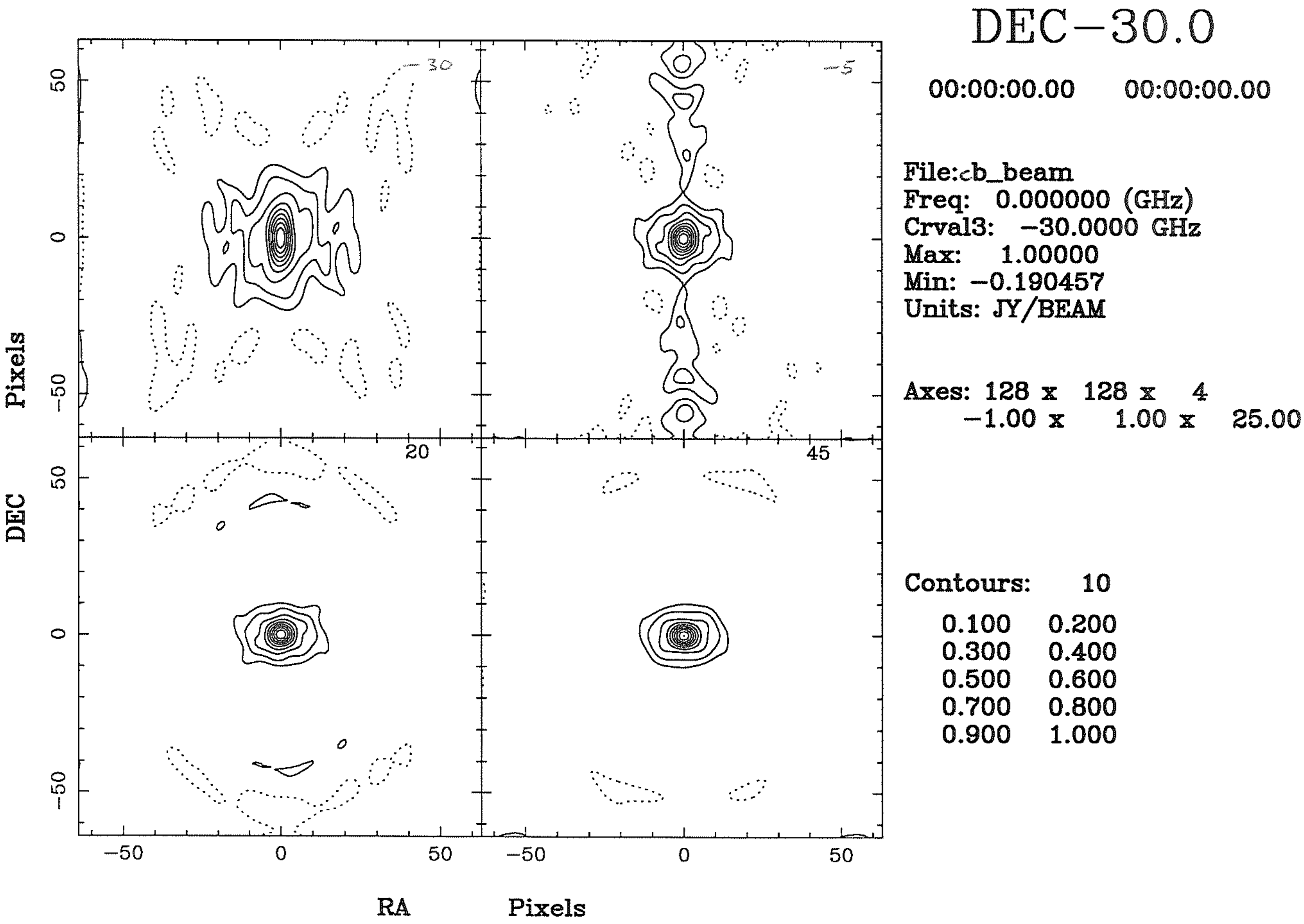
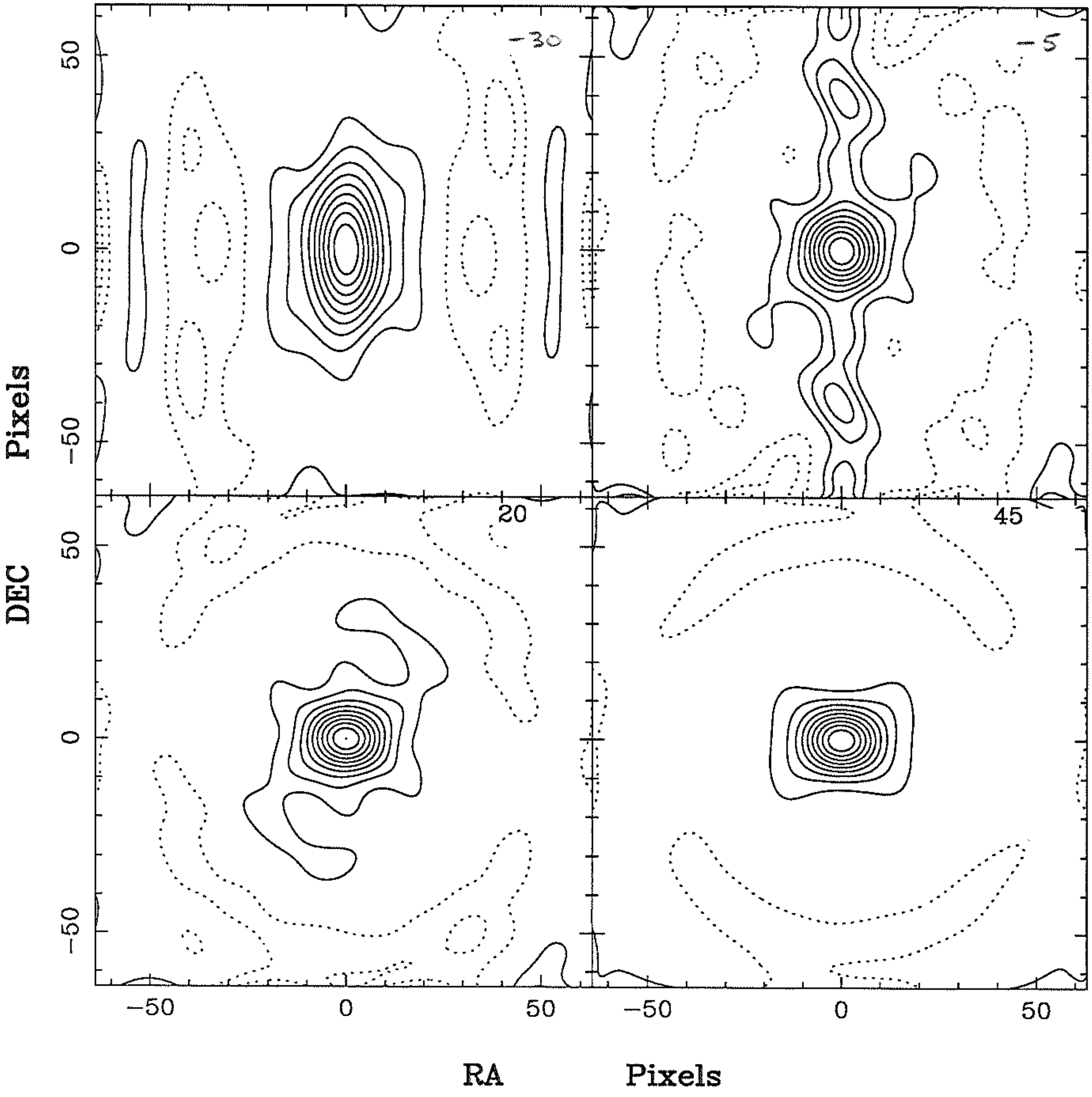
0.500 0.600
0.700 0.800
0.900 1.000

Figure 3



b+c arrays. Figure 4



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00:00:00.00   00:00:00.00

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Contours: 10

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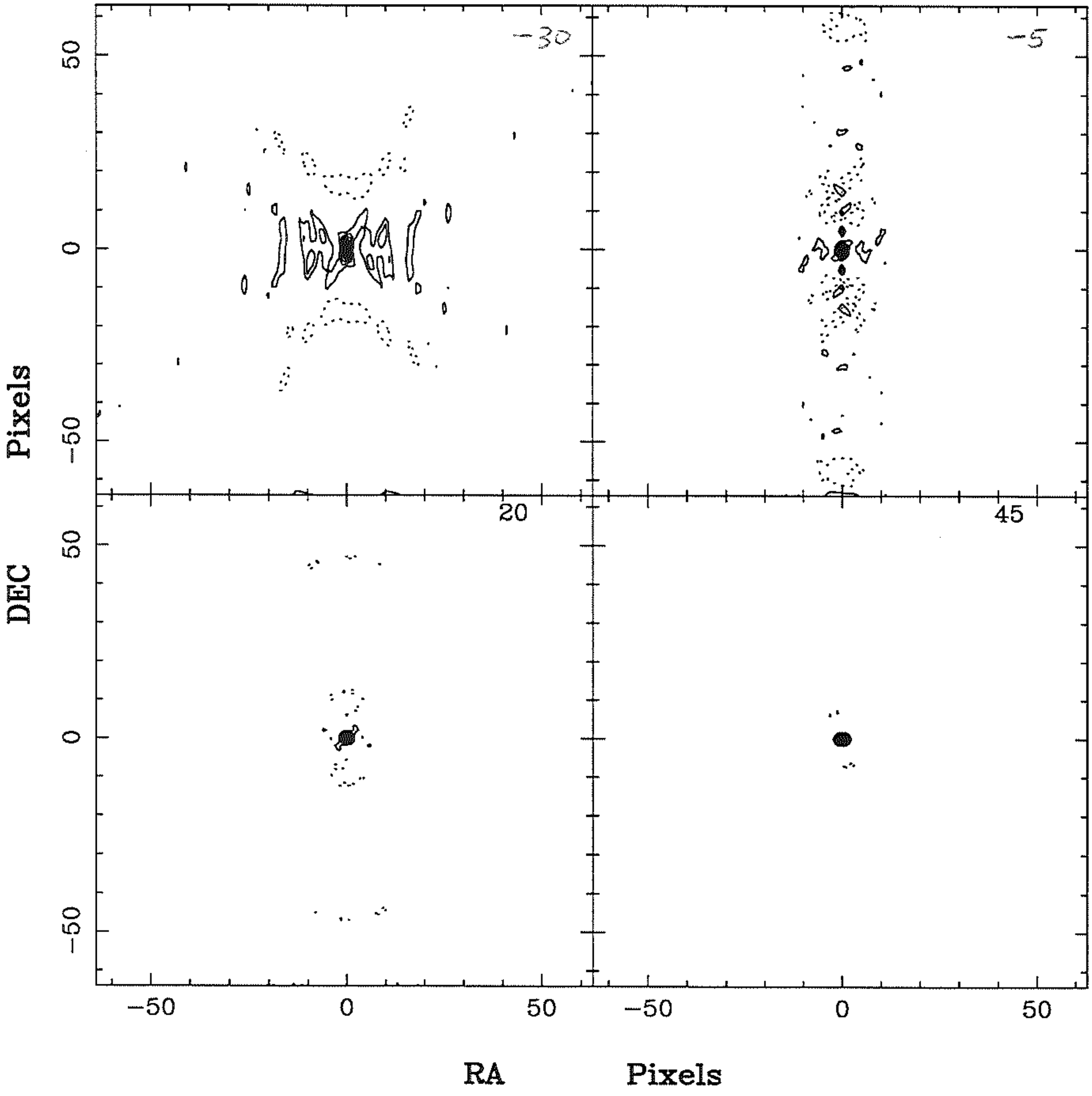
0.700	0.800
0.900	1.000

c-array   Figure 5



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Contours: 10

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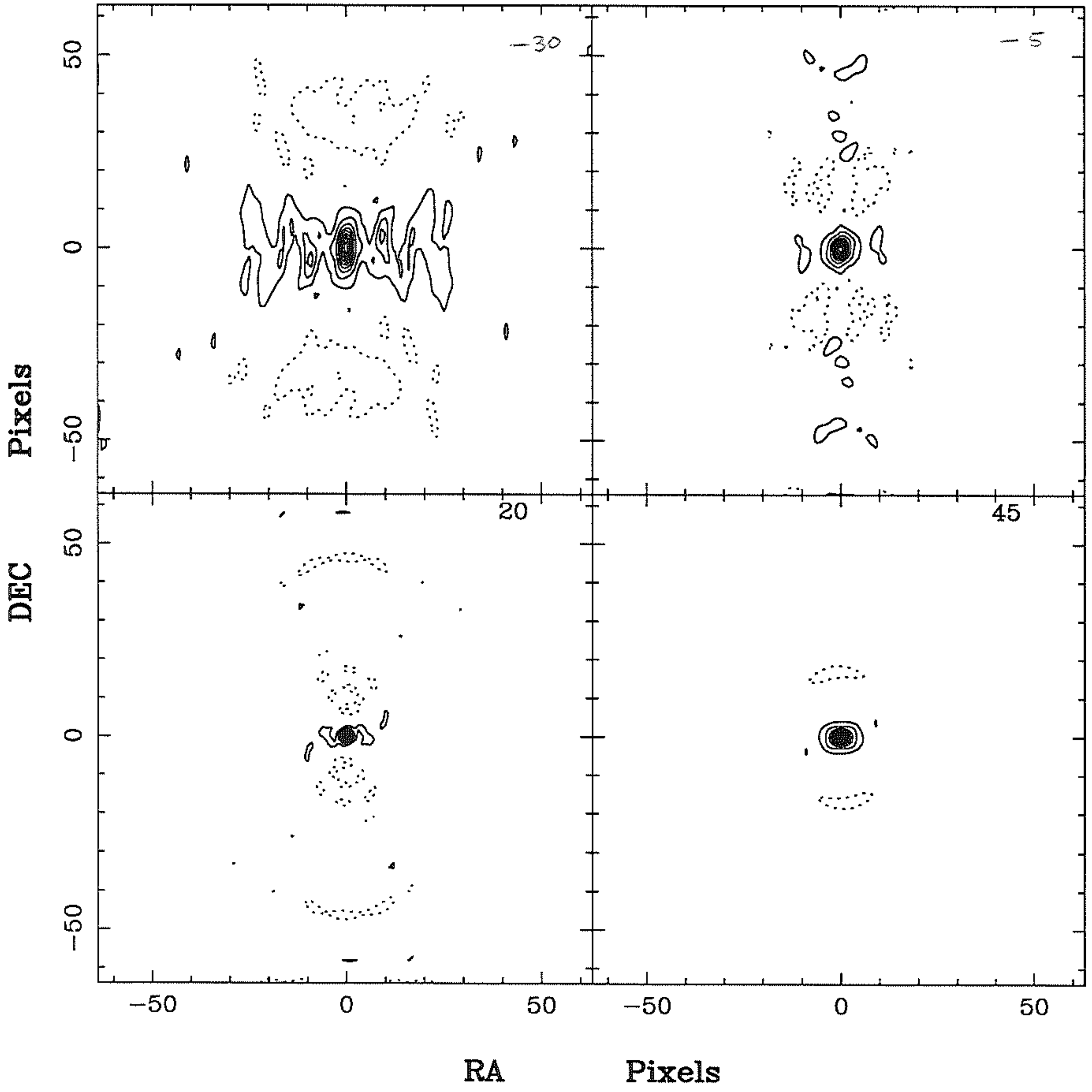
0.900	1.000

Fig. 6: 7 configurations a+ configuration



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Contours: 10

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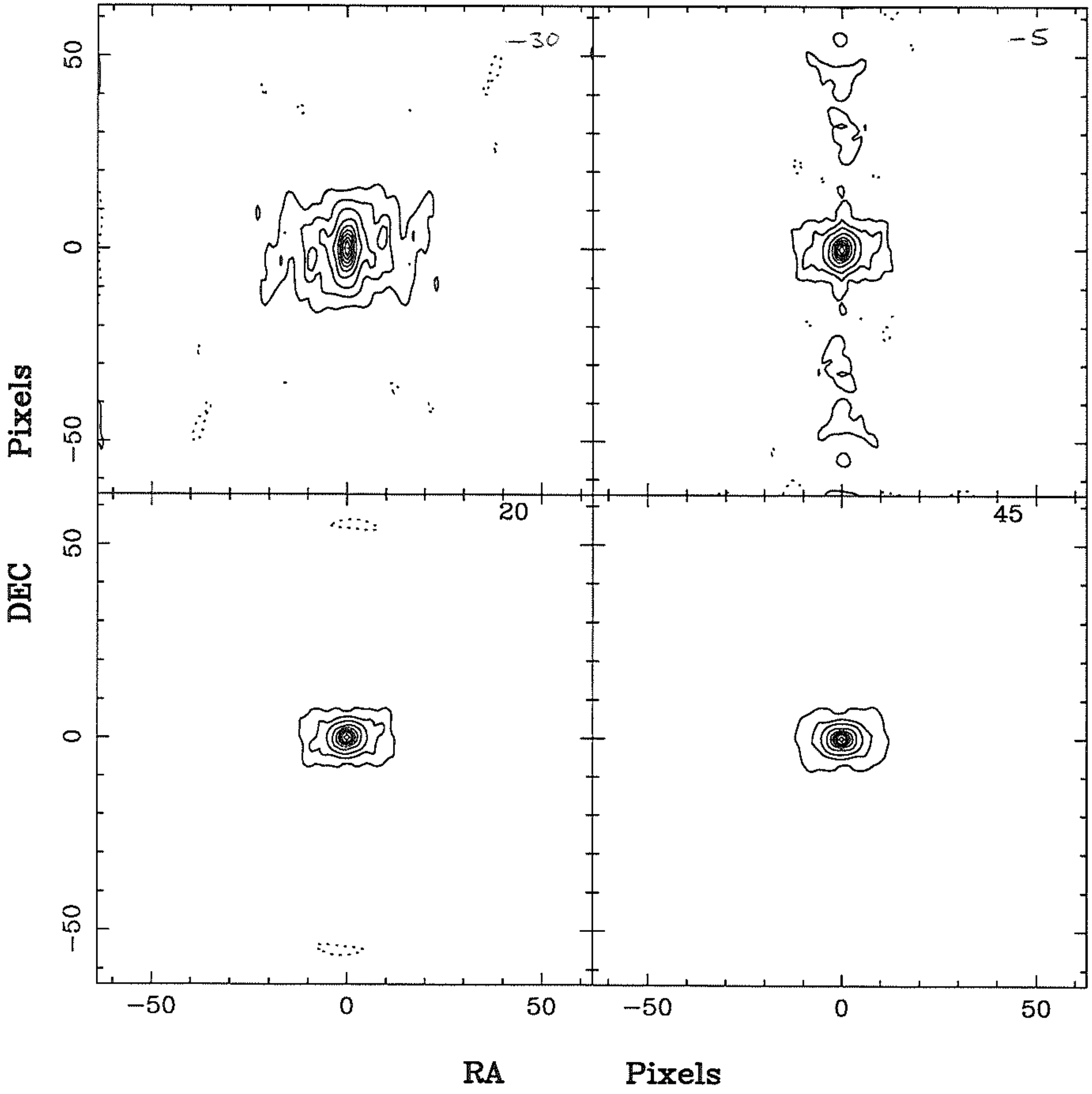
0.700	0.800
0.900	1.000

Fig 7 : a-array + b-array



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Units: JY/BEAM

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−1.00 x 1.00 x 25.00

Contours: 10

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0.500	0.600
0.700	0.800
0.900	1.000

Fig 8: a+b+c-arrays.