Center for Astrophysics
Harvard College Observatory
Smithsonian Astrophysical Observatory

MEMORANDUM

April 26, 1989

To: SMA Distribution

From: Vivek and Colin

Subject: Design Study Memo #2: Array Configurations

This memo consists of the two reports produced by Vivek Dhawan on his study of possible configurations for the array.

Center for Astrophysics

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Jan 89
~~Nov 1988~~

Array Configurations and Imaging, I

As summarized in NRAO Millimeter Array Memo No.47, (Hjellming and Hoyer),

The best configuration for uniform sampling of the U-V plane out to the configuration "diameter" is a circle (ellipse for low-dec), with random antenna locations. Has excellent snapshot coverage (see Cornwell, MMA memo No.38). Hereafter called the O array.

The best configuration for enhanced sensitivity at short spacings is a VLA-like Y array; an alternative for denser packing of antennas is an array with 5 radial arms. Both O- and Y-arrays have good imaging properties, the choice depending on the desired distribution of sensitivity in U-V plane.

For the Submillimeter Array, the topology forces non-ideal arrays, [fig.1], and there will be about 6-8 antennas, to the 40 in the NRAO study. Do things change drastically for small numbers of antennas? Not much.

Antenna locations have been tried out as follows:

1. Using Phil's map of SAO site on Mauna Kea, [fig.1]. The longest baselines obtainable in the earmarked area are about 750m. The U-V coverage is lopsided, with most of the tracks in just 2 diagonal quadrants, [fig.2a].

2. The longest baselines giving acceptable U-V, (mostly) within the SAO site are about 280-300m, [fig.2b].

3. Y-like arrays, which are not confined to the SAO site. I have tried to fit the topology, but some sort of construction estimate is needed. Two locations for Y's are possible, [fig.1], each with about 650-700m baselines. Comments?

Qualitatively, O's do have good snapshot coverage, and uniform U-V sampling; Y's give more short spacings, and slightly poorer snapshots. Y's do better at imaging than O's, for reasons I do not fully understand; [see fig.8]. I have found two 6-element Y's which give roughly equivalent coverage, [fig.4], though they are not excellent at all declinations.

How many configurations do we need to span, say, a range of 100:1 in baseline lengths? A 6-antenna O has a range of 3:1 (see memo 38) which can be pushed higher only at the expense of some holes in U-V coverage. The 6-Y arrays mentioned above have ranges of 3.3 and 3.6. An 8-Y (lopsided) gives about 6:1, with good UV coverage, [figs. 5, 6].

Imaging simulations, [fig.3], show that a 1Jy source can be easily mapped with about 10:1 dynamic range with a 7-antenna O-configuration.

Simulations with the 6-Y array were done with a fairly complex source of 10Jy with both compact and extended structure, [fig.7]. The compact structure can be mapped, even with completely random phases, in a 4-hour synthesis, [fig.8]. The extended structure is hard to map with a single 6-array, but using an 8-antenna array improves matters considerably, [fig.9].

Note: combining two 6-antenna configurations gives about as many baselines as a single 8-array. Any comments on configuration turn-around time vs. cost of 2 extra antennas?

Some questions:

. What should be the scaling factor between configurations? Should successive configurations be disjoint? Do we want/need arrays that give the same resolution in different frequency bands?

. To minimize shadowing in compact configurations, the O-array may be better than a Y, because the O has no redundant directions. The Y's seem to be better at imaging with a small number of antennas, [fig.8], and would require the least road/track for configuration changes. Comments?

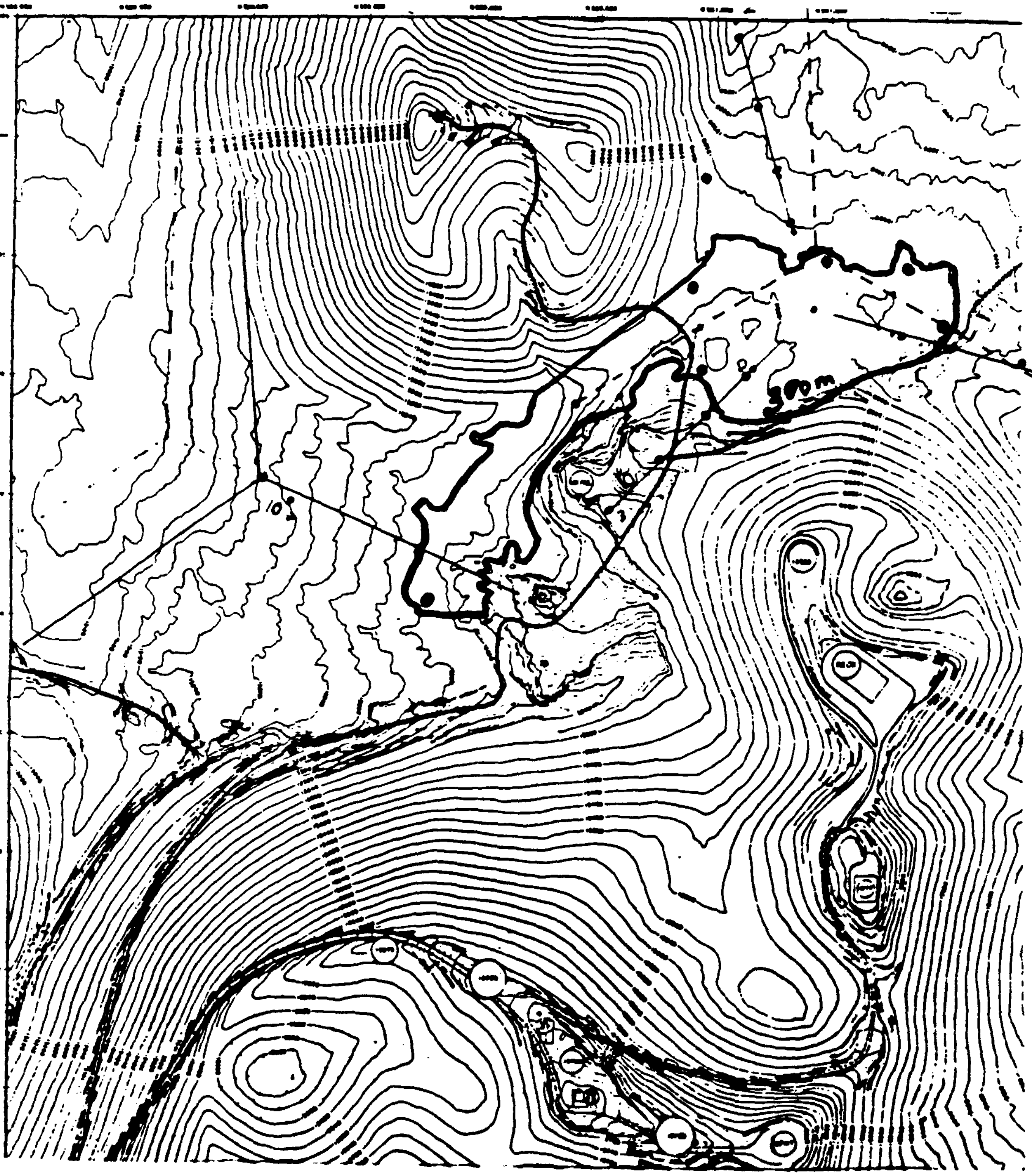
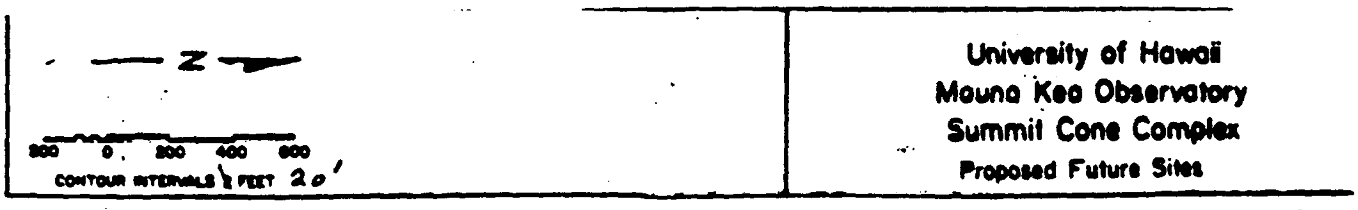


Figure 1. Map of Mauna Kea showing the present SAO site. Two possible ranges for locating Y-arrays are also shown, lying mostly outside the site.



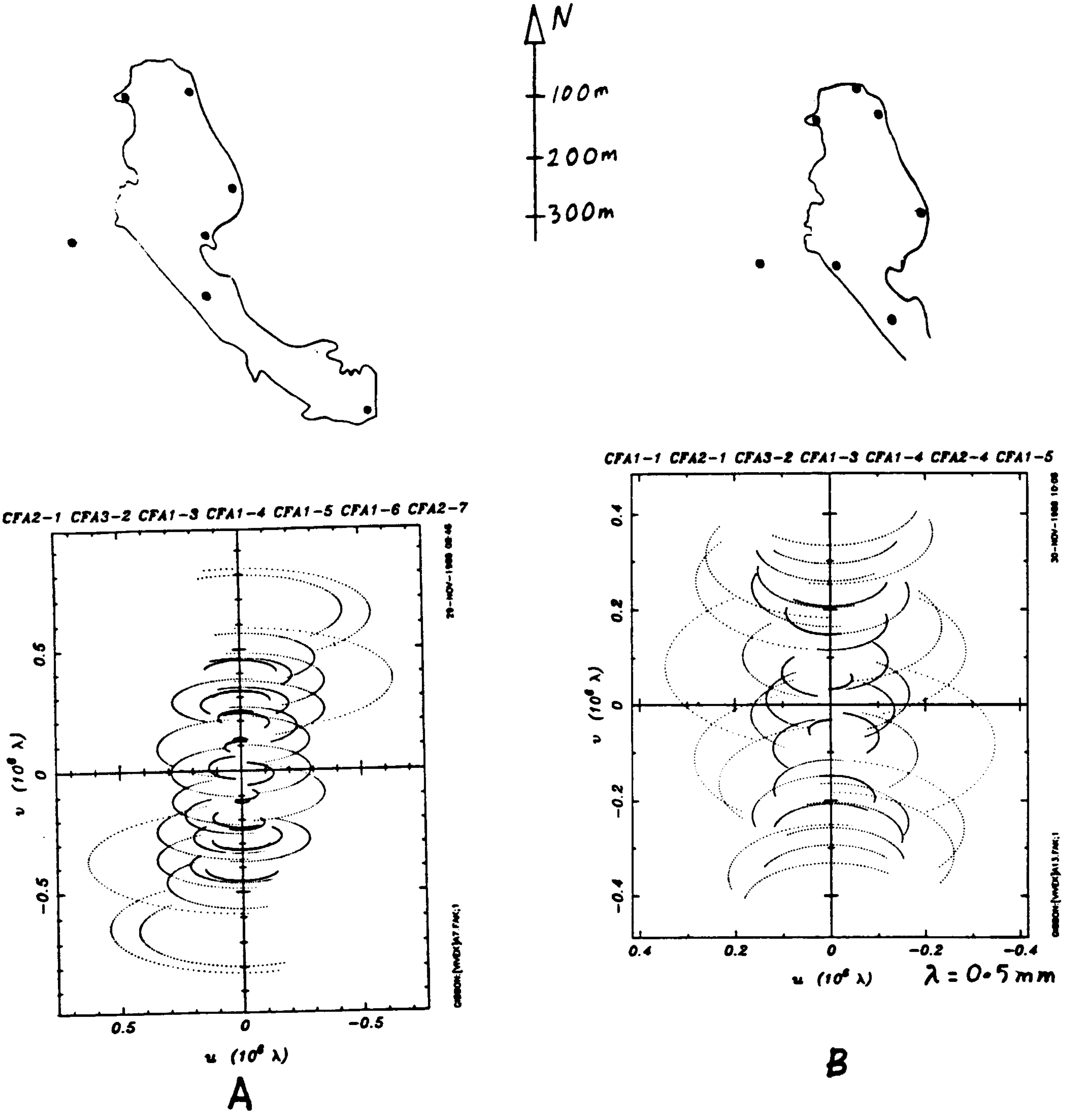


Figure 2.A. & B. 7-antenna arrays loosely based on the O-array (i.e., antennas randomly spaced around allowed perimeter, elongated N-S for good coverage at low declinations). The shorter spacings can be improved by relocating antennas, but the longest spacings are not going to get better. (Dec. =+20, -30 respectively; full tracks with elevation limits of 15^0 for each antenna.)

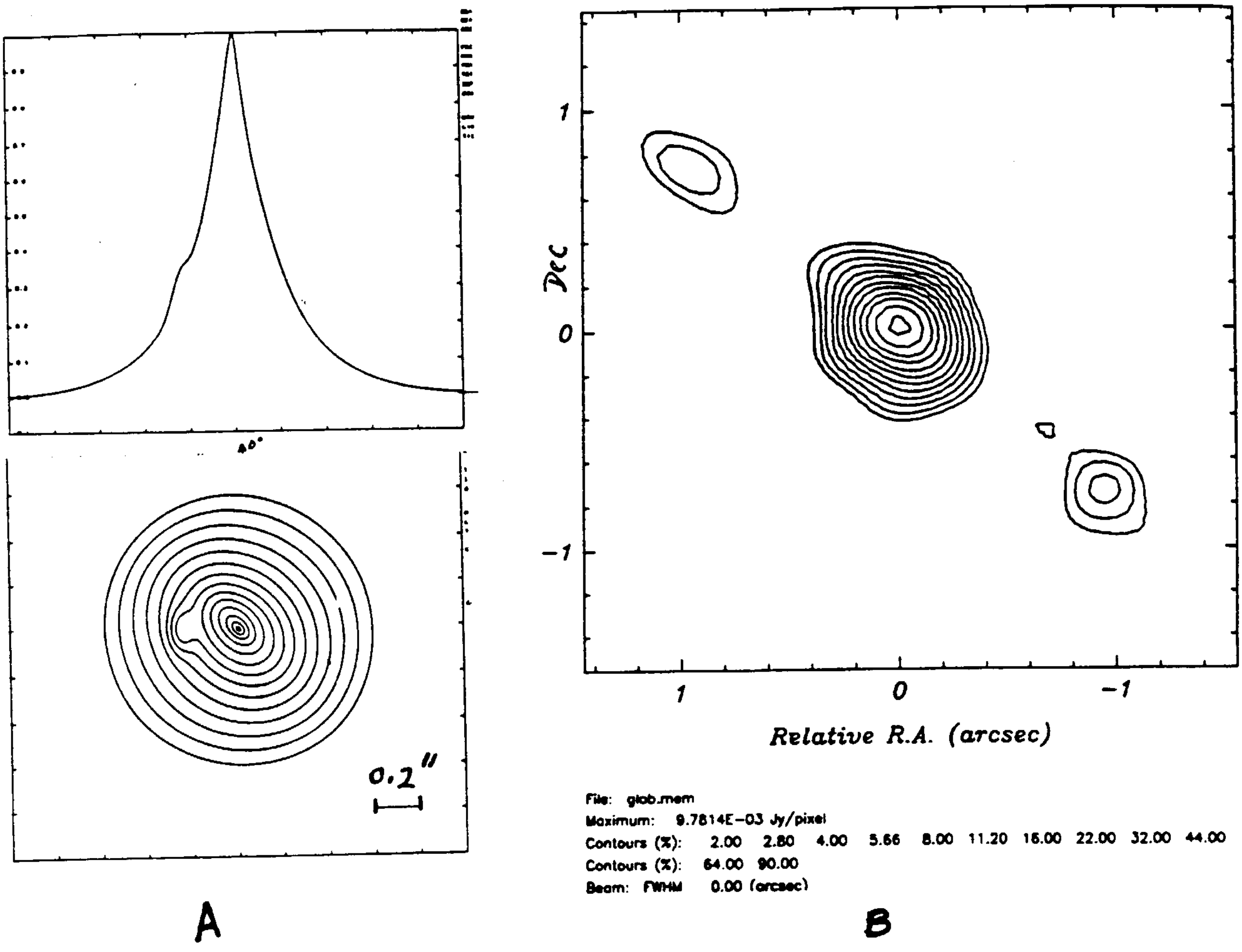


Figure 3. Image of a fake 1Jy source (A) with the array of (2.B), roughly a 4-hour synthesis.

Thermal noise was simulated in the visibilities assuming Tsys=500K and aperture eff.=0.60 The data was uncorrupted by pointing errors and phase fluctuations. Even so, CLEANING proved difficult. The MEM solution (B) recovers the position angle of the original, but misses the blob at 15% of peak, and some of the extended structure. Residual sidelobes are at 2-4%.

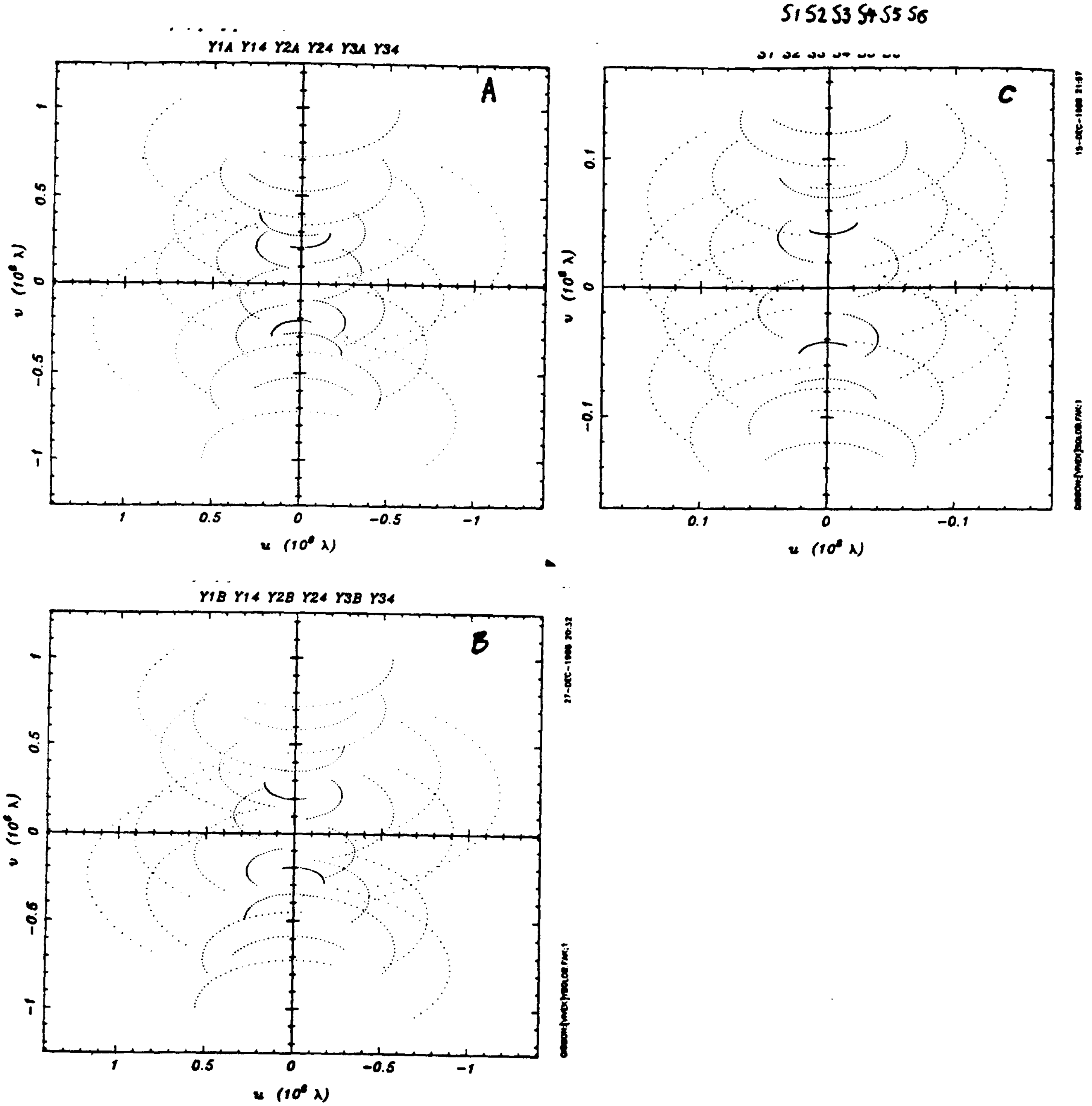


Figure 4. UV tracks from 6-element arrays, unconstrained by topology. Dec=-30; full tracks.

(A), (B): Y-arrays with symmetric arms, and normalized antenna locations along an arm at (0.278, 1.00 for A) and (0.476, 1.00 for B).

UV coverage is somewhat more centrally condensed in the two Y's, compared to (C): O-array from Cornwell, [NRAO Millimeter Array Memo 38].

The ratio of largest to smallest baseline in a snapshot is about 3.6, 3.3, and 3.0 for (A), (B), and (C).

Images produced by these arrays are shown in Figure 8.

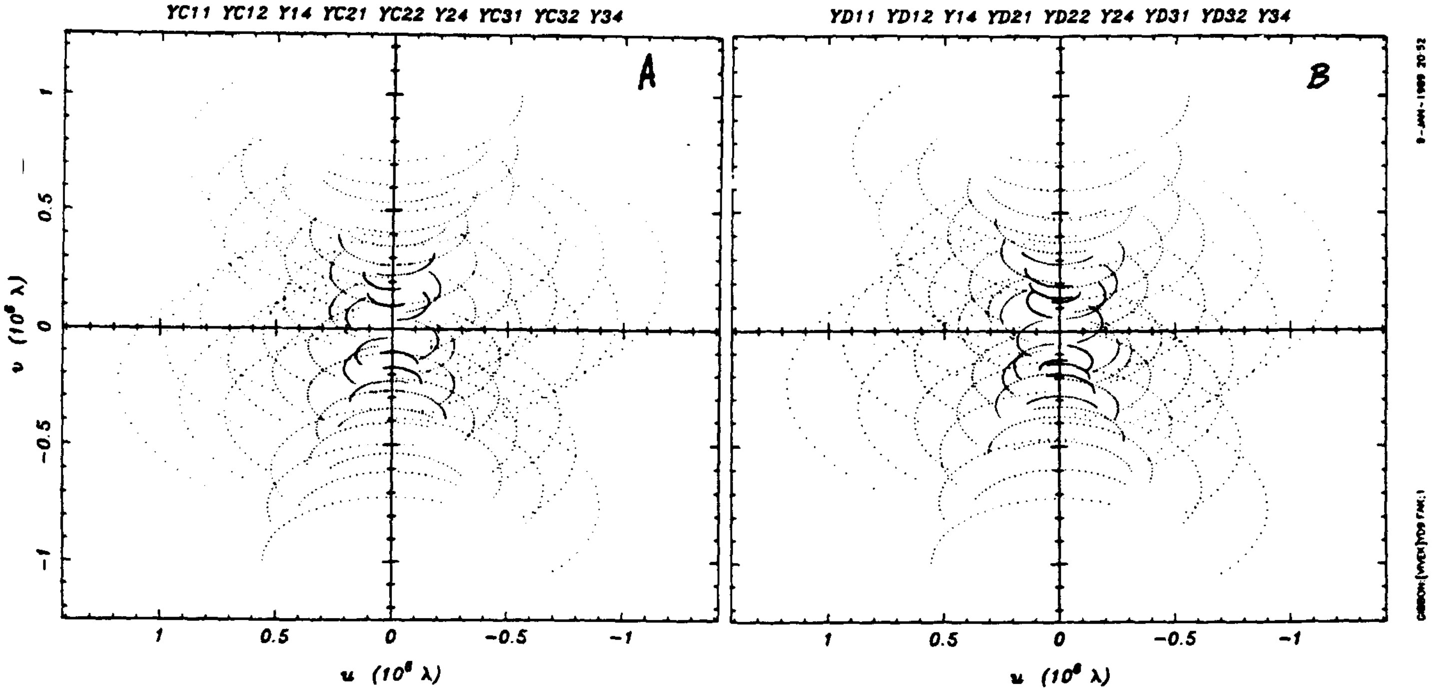


Figure 5. Full UV tracks at dec.=-30 for Y-arrays with 3 antennas per arm, located at 0.168, 0.529, 1.00 for (A) and at 0.304, 0.605, 1.00 for (B).

The program YBASE computes baseline lengths, given antenna locations along an arm. A few trials yielded the two arrays shown above, which have baseline lengths distributed as far as possible in geometric progression. The UV coverage is quite good, but breaking the high symmetry of the identical-armed Y must give lower sidelobes. Any comments on whether this is desirable, how much it would affect the construction, etc?

For N_B baselines, one can expect, at best, the UV points in a snapshot to be spread evenly over an area $N_B^{1/2}$ on a side. That is, a range of baseline lengths of 6:1 for a 9-element array. Actual values are 5.9 and 5.7 for (A) and (B).

```
        PROGRAM ybase
C
C         CALCULATES BASELINE LENGTHS OF Y-ARRAY WITH 3-ANTS PER ARM
C
        REAL BASE(9), RBASE(9), BLR(9)
        REAL SID, SAV, RAV, RID, A, B, S
        CHARACTER*80 HEADER1, HEADER2
        PARAMETER (INC=5)       ! terminal input unit
        PARAMETER (OUTC=6)      ! terminal output unit
C  get input parameters of Y:
   5    WRITE (OUTC,'(A)') '$ input a and b for Y array: '
        READ (INC,500) A,B
C compute baselines
        BASE(1) = SQRT(3.0)
        BASE(2) = BASE(1)*A
        BASE(3) = B-A
        BASE(4) = SQRT(1.0 + A + A*A)
        BASE(5) = SQRT(1.0 + B + B*B)
        BASE(6) = A-1.0
        BASE(7) = B-1.0
        BASE(8) = SQRT(A*A +B*B +A*B)
        BASE(9) = BASE(1)*B
C Normalize to longest baseline
        DO 198 I=1,9
                RBASE(I) = (BASE(I)) / (BASE(9))
 198    CONTINUE
C sort normalized array in ascending order.
        DO 112 J=2,9
                S=RBASE(J)
                DO 111 K=J-1,1,-1
                        IF(RBASE(K).LE.S)GO TO 110
                        RBASE(K+1) = RBASE(K)
 111            CONTINUE
        K=0
 110    RBASE(K+1)=S
 112    CONTINUE
C   compute ratio of successive baselines.
        BLR(1) =1.0
        DO 119 L=2,9
            BLR(L) = (RBASE(L)) / (RBASE(L-1))
 119    CONTINUE
C   "ideal" ratio of baselines is 6.0**0.125
C   "available" ratio is (max/min)**0.125
        RID = 6.0 **0.125
        RAV = ( 1.0 / RBASE(1))**0.125
C   compute sum of squares of deviations from RID and RAV
        SID = 0.0
        SAV = 0.0
        DO 129 L=2,9
                SID = SID + (BLR(L)-RID)**2
                SAV = SAV + (BLR(L)-RAV)**2
 129    CONTINUE
C   write output file.
        HEADER1 = 'BASELINES FOR Y-ARRAY WITH ANTENNAS AT 1,  A, AND B'
        HEADER2 = 'BASELINES     SORTED & NORMLIZED     INCREMENT RATIO'
        OPEN (UNIT=12,STATUS='NEW',NAME='yarray.dat',DISPOSE='KEEP')
        WRITE (12,601) HEADER1
        WRITE (12,601) HEADER2
        WRITE (6,601) HEADER1
        WRITE (6,601) HEADER2
        DO 199 I=1,9


                WRITE (6,600) BASE(I), RBASE(I), BLR(I)
                WRITE (12,600) BASE(I), RBASE(I), BLR(I)
 199        CONTINUE
        WRITE(12,602) A, B, SID, RID, SAV, RAV
        WRITE(6,602)A, B, SID, RID, SAV, RAV
 22     CLOSE (UNIT=12)
C
C++++++++++++++++++
C
 500    FORMAT (F6.3,1X,F6.3)
 600    FORMAT ( 3(5X, G10.4))
 601    FORMAT (5X, A80)
 602    FORMAT(2X,'A=',F6.3,5X,'B=',F6.3,5X,'SID=',F8.4,5X,
     +          'RID=',F8.4,5X,'SAV=',F6.3,5X,'RAV=',F6.3)
        END
```

9.8.

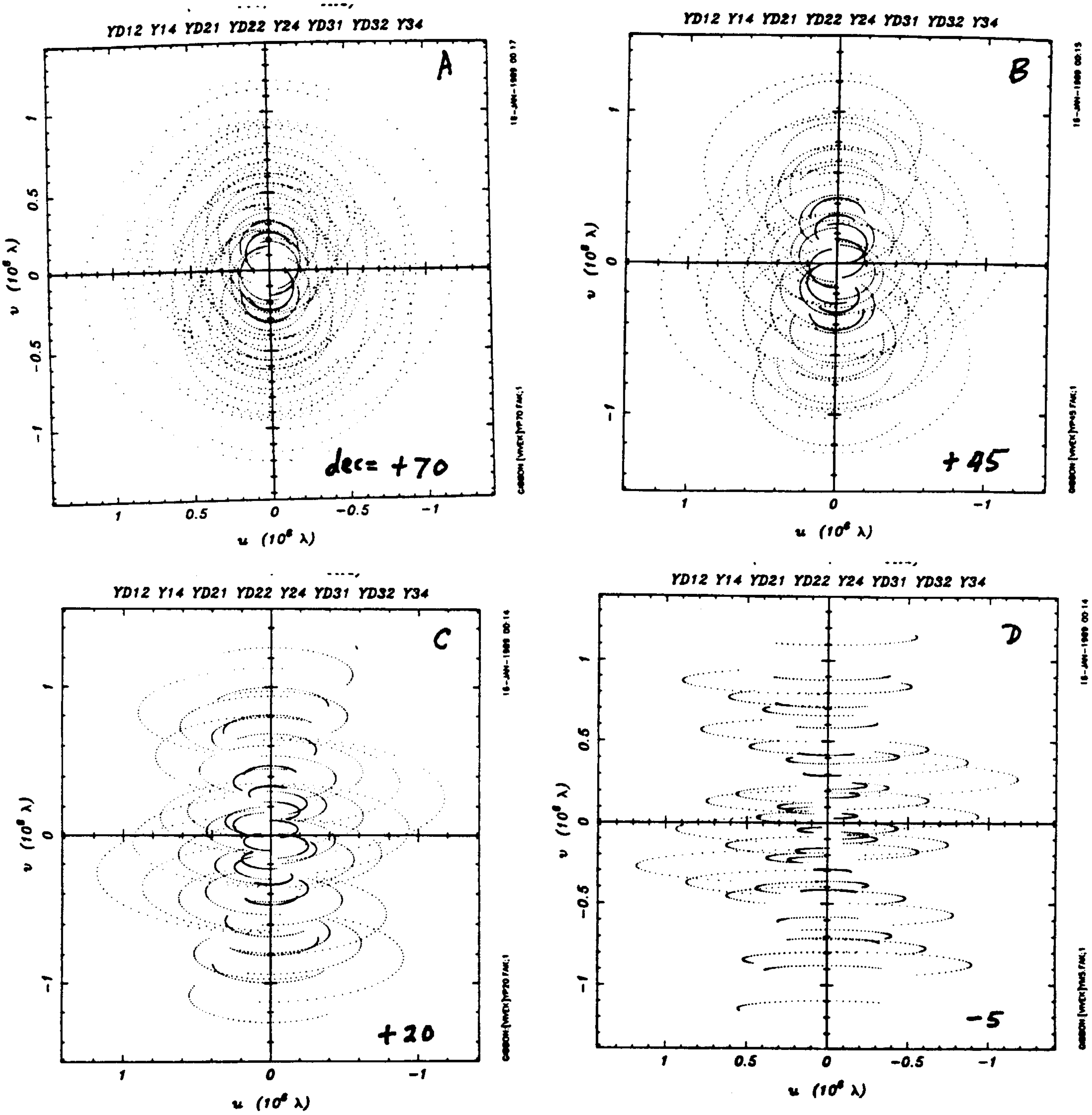
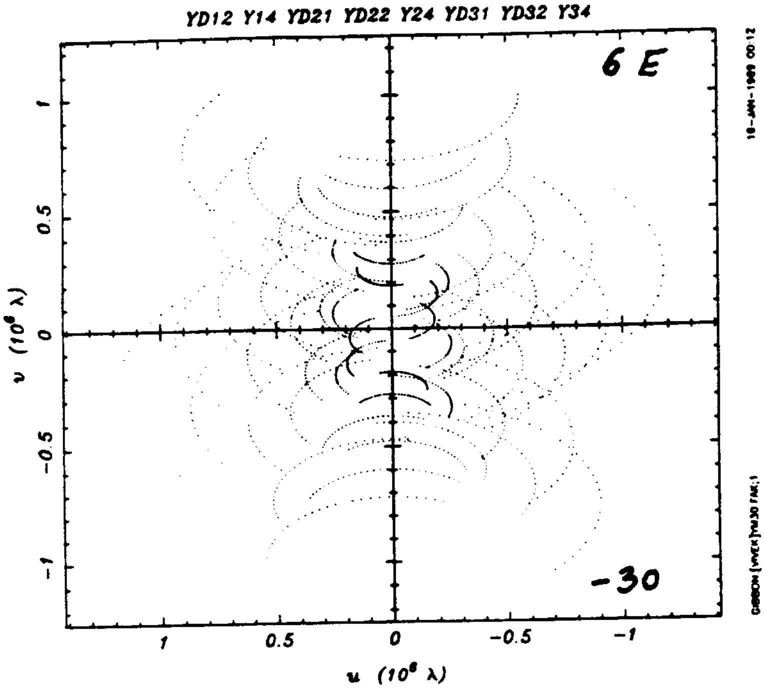
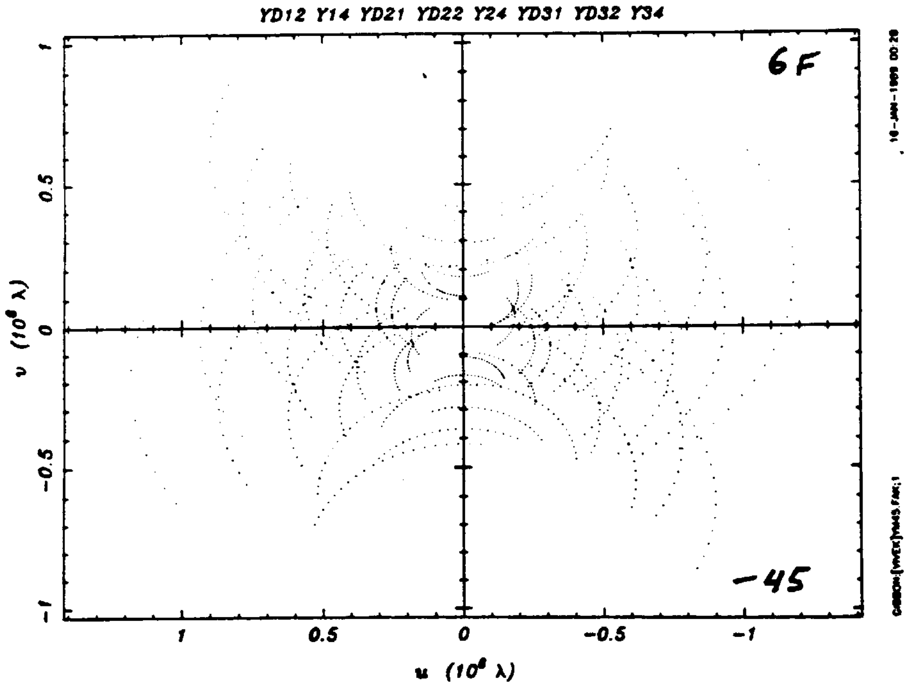


Figure 6. Dropping the central antenna from one arm of the array in Fig.5.B. gives this array. Full tracks are shown for a variety of declinations. (f = 600GHz; dots every 1000sec.)

Useful coverage is obtained down to dec=-45, and more if a N-S stretched array is used. (I have not yet looked at this.)





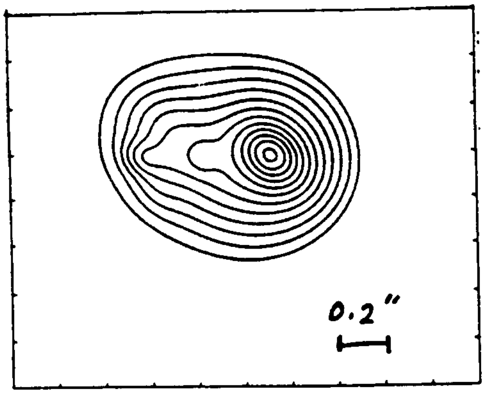


Figure 7. Fake source, 10Jy total flux, for subsequent imaging simulations. Contours are

1, 1.4, 2, ..., 64, 90 %.

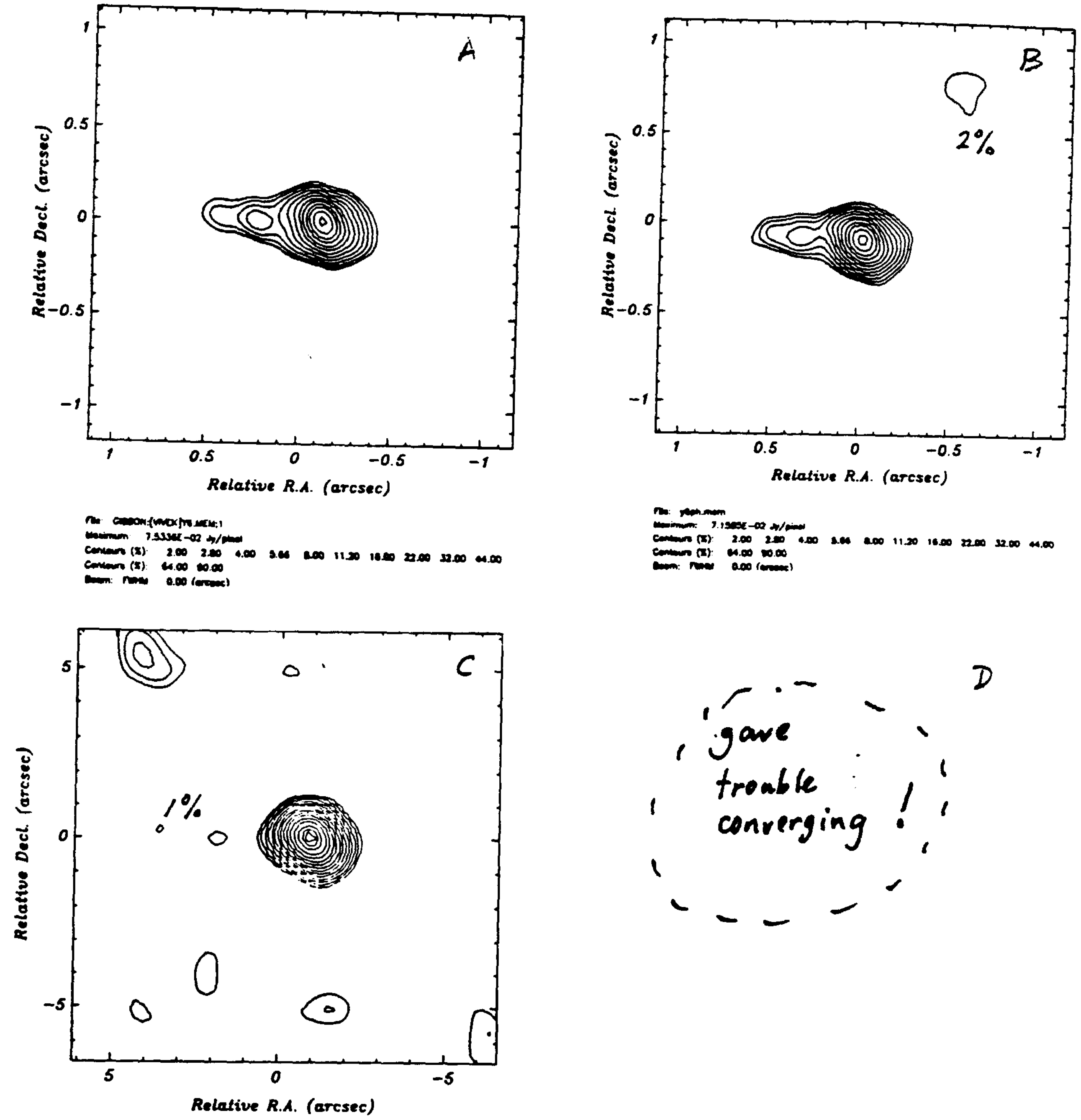


Figure 8: Fig.7 viewed by arrays in fig.4.

(A): Thermal noise and no phase fluctuations. (B): Thermal noise plus station-based phase errors uniformly distributed over 2π and uncorrelated in time. Comparing these images with the original shows the lack of short baselines.

(C) and (D): fig.7 viewed by 6-O array of fig.4c.; without and with phase fluctuations. Even fewer short baselines result in poor recovery of extended structure.

Roughly speaking, the left images test UV coverage, the right ones test self-calibration with the same array.

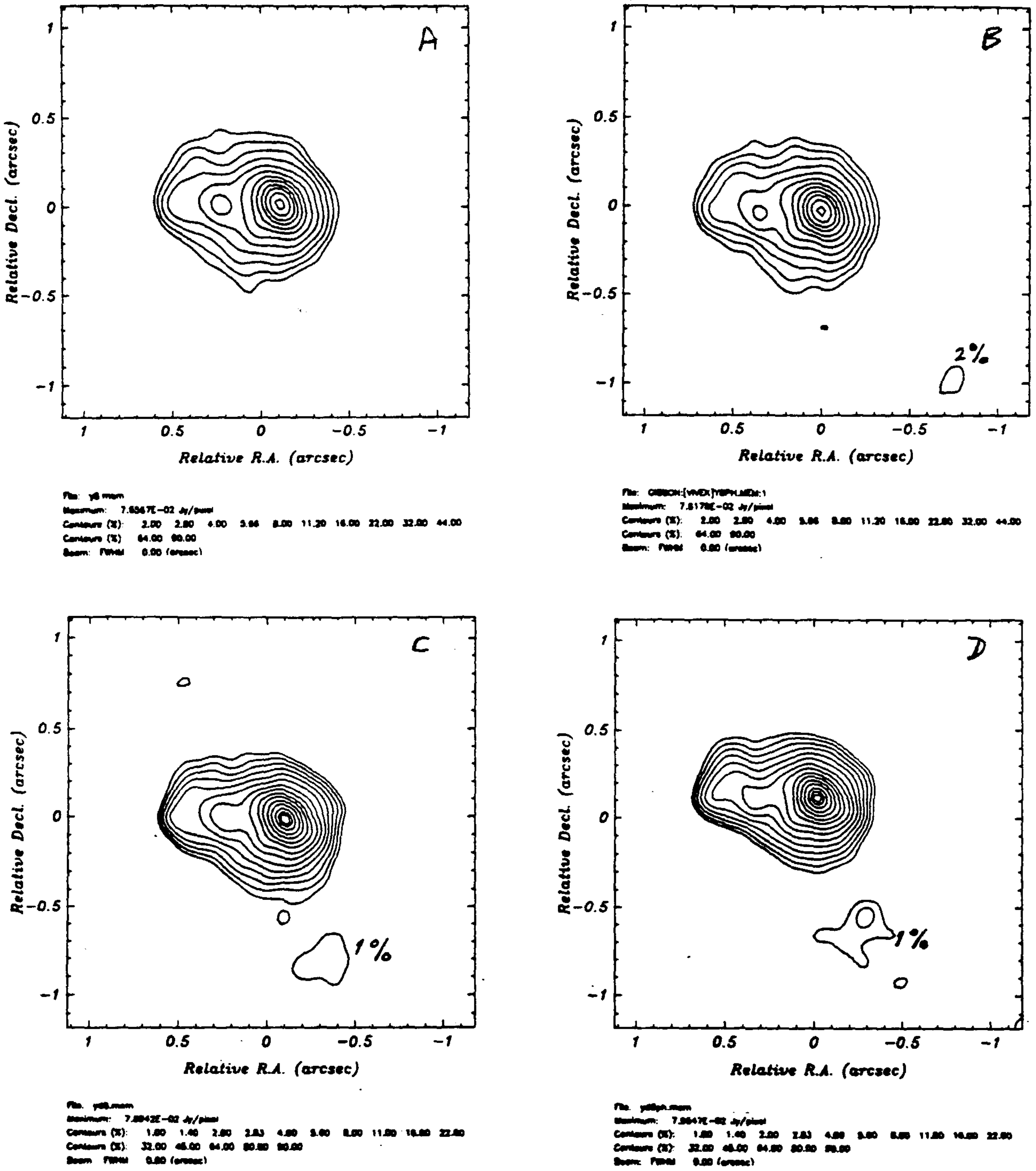


Figure 9. (C) and (D): Fig.7 viewed by the 8-Y array of Fig.6e. The extended structure is well imaged, in both perfect and poor seeing.

(A) and (B) show images with an 8-Y array that is not optimal, but still does almost as well as the array in (C) and (D).

All images are MEM restorations. All arrays have the same longest baselines.

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22 April 1989

Array Configurations and Imaging, II

Many aspects of the array design are interdependent, and much remains to be determined. I hope that this study answers some questions, and serves as the starting point for further discussion. Here is an index of the questions addressed so far, with summary answers. For more details, see the pages indicated in brackets.

1. Questions, and some answers.

a. **What are the maximum baselines available on Mauna Kea, and what are the attendant compromises? [p.4, 7]**

Max Baseline: 1.7 - 1.9 Km; Max height differential of 300' across array; worst elevation blockage for any antenna in any direction : 15 degrees. See Section 2 for more.

b. **Comparison of different (ideal) array geometries.**

Y-arrays with different constraints, [p.8] O-arrays, [p.9]

Many different Y-arrays are possible, giving equally good UV coverage. I tried several layouts, with antennas arrayed according to:

(i) a power law; (ii) in geometric progression; and (iii) "hand crafted" arrays, with 3 identical arms, but locations along an arm adjusted to give uniform UV coverage.

Option (ii) can give arrays not noticably worse than the others, with the advantage of being self-similar, i.e., needing fewer setdown positions for configuration (scale) changes.

Y's have more short spacings than O's with the same no. of antennas and same max baseline; i.e., Y's span a larger range of baseline lengths, and so do better at imaging sources containing structure on a wide variety of scales. The two types seem to do equally well at self-cal. A Y array requires less road than the comparable O-array.

c. Effect of distorting ideal arrays to conform to the site.

Distortions are not necessarily bad. E.g. NS elongation helps at low declination; Y-like arrays with unequal angles or arms can have lower sidelobes than the undistorted array, which has higher symmetry. See section 3 on how to check the UV coverage or imaging for the specific array. See sec. 2 for UV coverage of the recommended array.

d. Effect of rotating the array. [p.12]

For an O-array, rotation does not affect the UV coverage much. Rotating a Y makes little difference at high declination. At low declination, avoid lining up an arm with either X or Y axis (within about 10 deg.)

e. Effect of limiting Zenith angle. [p.13]

Airmass < 2 or $Z < 60^\circ$ will restrict synthesis maps longer than 3 hours to the declination range of -20 to +75 (for Mauna Kea, lat=19deg).

A 3-armed Y requires 4 hours for tracks from the different arms to overlap; falling short of this takes wedges out of the UV coverage, making hexagonal sidelobes in the beam.

f. UV coverage as a function of declination. [p.9,10 of previous memo]

g. How many antennas are needed for good imaging in one day? [Memo I, p.11,12; Memo II, p.10]

Six antennas are sufficient for self-cal on simple sources; 9 recommended.

h. How many configurations are required? [I, p.7; II, p. 10,11]

To span a 300:1 range of baselines, from 6m to about 1800m, requires :

5 or 6 configurations, (with 6 antennas, which give a range of about 3-4 per configuration, and successive baseline lengths within a single configuration spaced by a ratio of about 1.5)

3 or 4 configurations, (with 9 ants/config, range of 6-7, spacing of 1.3)

2 or 3 configs, (with 12 a/c, range of 12-14, spacing under 1.2)

i. Arrays allowing scaling (size change) and expansion (more antennas).

The recommended siting plan, [p. 4, 14], gives Y arrays with 6, 9 or 12 elements, which can be scaled in steps of 2.

j. How well does self-cal (phase recovery) work on weak sources? [p. 20]

On barely and heavily resolved sources alike, sources with peak flux per beam as little as 5-6 times the theoretical noise level could be mapped with completely random phases. (For the simulations, I assumed Tsys = 180K, nine 6m dishes with 60% efficiency, and a four hour synthesis, resulting in a noise level of 0.85 mJy)
(1000 sec integ. time)
Also see item (k) below.

k. Comparison of deconvolution algorithms (Clean and Max Entropy).

The procedures are:

(i) UVMAP and APCLN (in AIPS). This requires 1 iteration only, if the phases are stable, and takes about 1.5hr for a 256 × 256 map. 3 or more iterations, each preceded by VSCAL, are required for mapping with completely scrambled phases.

(ii). VLBMEM (CalTech VLBI package) requires under 0.5hr with stable phases, 1hr with scrambled phases, for the same 256× 256 map.

With either algorithm, spurious features of maps with bad phases were typically no more than a factor of 2 worse than the same map made with stable phases.

Puzzle: The spurious features on MEM maps look like remnants of the dirty beam; however, they are well below the expected noise.

l. Effect of including other antennas, e.g. CSO, JCMT.

For comparable dish efficiencies, adding CSO and JCMT doubles the collecting area of 9 six-meter dishes. For the site chosen, the additional baselines lie mostly in the NE/SW quadrants, and contribute mostly to the medium and short spacings (in the largest array.)

m. Unexplored questions

- Totally asymmetric arrays, (i.e., three different arms, at random angles) might give lower sidelobes, but have not been explored. May be forced by site topology.

- Other sites.
- Focal plane arrays could (i): be used to get multiple beams, hence larger total field of view from large antennas; (ii):compensate for main dish surface errors, if cross-products between focal-plane elements are formed. (See paper by Cornwell and Napier). Both these effects would increase the optimum dish size, at the expense of silicon and software to handle multibeams and mosaicing. I think this needs to be carefully looked at.
- Are different sized antennas desirable?
- Mapping large/multiple fields : effects of amplitude calibration and pointing errors on combining data from different arrays?
- ??

2. Recommended site and configuration.

a. Configuration

The recommended configuration is one with antennas in geometric progression along each arm, with a ratio of 2.06;

This has the advantage [see UV plots etc in Fig.7] of allowing good imaging with either 6, 9 or 12 antennas. Just 8 antenna stations along an arm, located at 6.2, 12.8, 26.3, 54.2, ..., 976.0m, would give a range of baselines extending from the single dish diameter, (6m), out to 1700m. Configuration changes involving scaling by $(2.06)^n$ would require moving n antennas per arm.

b. Site

The logistics, site 'seeing' quality, etc. still remain to be compared to other possibilities, to see if a better tradeoff is possible. Such questions aside, the advantages of the site suggested in Fig.1 are:

(i) The array lies partly within the earmarked "SAO area", and gives long baselines with minimal additional acquisition of land.

(ii) The center of the array is on fairly flat ground within the SAO area, which is good for compact arrays, operations buildings, etc.

(iii) The array is not too far away from other large single-dish sub-mm telescopes.

3. Simulation procedures : How to make and test a new array.

a. To make a new array, with arbitrary antenna locations, type in x, y, and z coordinates into the file SMMXY.DAT (or a copy thereof, containing the same header). The units for x-y are cm on map, with a default scale of 1cm=75meters. The units for altitude are feet, read off a contour map (if required). North and West are positive, with the grid origin at the CSO, whose coordinates were assumed to be : 19.82667 N, 155.47167 W (degrees), ALT 4072m.

Run XLAT to convert x - y - z (cm - cm - feet) to and from lat - longit - z (deg - deg - meters). The direction of conversion is automatically determined by reading the header record in the input file, which must correspond exactly to the format of the *.DAT files in my area chimp:[vivek.submm-array] .

To change scale, or rotate the basic array, use the options in XLAT. A scale factor of 1.00 gives 1cm=75m; scale factor of 3.20 gives 1cm=240m. (These are the two maps I had).

Include the output file from XLAT in the file SMMSTAT.DAT, which is the master file of station locations. Make sure the formats match, and remove all header or comment lines from this file.

XLAT also automatically generates a data file called GENPLOT.DAT, for plotting out the antenna locations. See the command file GENPLOT.COM

b. To make a Y-array with N antennas per arm, having relative locations at x1=1.00, x2, x3, ..., xN : edit the file YMAKE.COM and run it. The rotation parameter accepts upto 4 numbers, and works as follows: The first number is the angle through which to rotate the entire array (CCW from N). The next three numbers independently specify the rotation of the three arms, to make an asymmmetric Y.

E.g.: specifying 10.0 -10.0 -40.0 +20.0 makes an inverted T.

[Note: A rotation, for symmetric Y array, of 10-20degrees off from N, gives better UV coverage, compared to rotations of n*30 degrees, [n = 0, 1, 2 ...]

To compute the baseline lengths for a given set of antenna locations, run YBASE.

Include the output file from YMAKE in the file SMMSTAT.DAT, which is the master file of station locations. Make sure the formats match, and remove all header or comment lines from this file.

c. **To generate fake UV data with a trial array:** Edit the command file FAKE.COM to put in station names, antenna diameters and efficiencies, system temperatures, model source, RA & DEC, observing time, etc. for a hypothetical experiment. The output is in CalTech MERGE format.

(name.MOD)

To make a fake source, modify an existing one or see CalTech programs MODSUM, MODFIX, and MODELFIT.

d. **To view UV tracks from a MERGE dataset:** Run TEKUV.COM from a tektronix window, or QUV.COM for QMS printer output. Else, to plot out UV tracks without saving the fake visibilities, set the plotting switches and disable the data switches in FAKE.COM

e. **To produce a maximum entropy image:** from MERGE data with 10 or fewer stations, run VLBMEM.COM; To view the map, edit and run MAPPLOT.COM from a TEK terminal. For over 10 stations, convert to FITS and run VM.

f. **To make a hybrid map from MERGE data:** edit and run HYBRID.COM

g. **For help on all the CalTech VLBI programs:** type VH.

h. **To go AIPS,** convert MERGE data to FITS by editing and running the file MERGEFITS.COM .

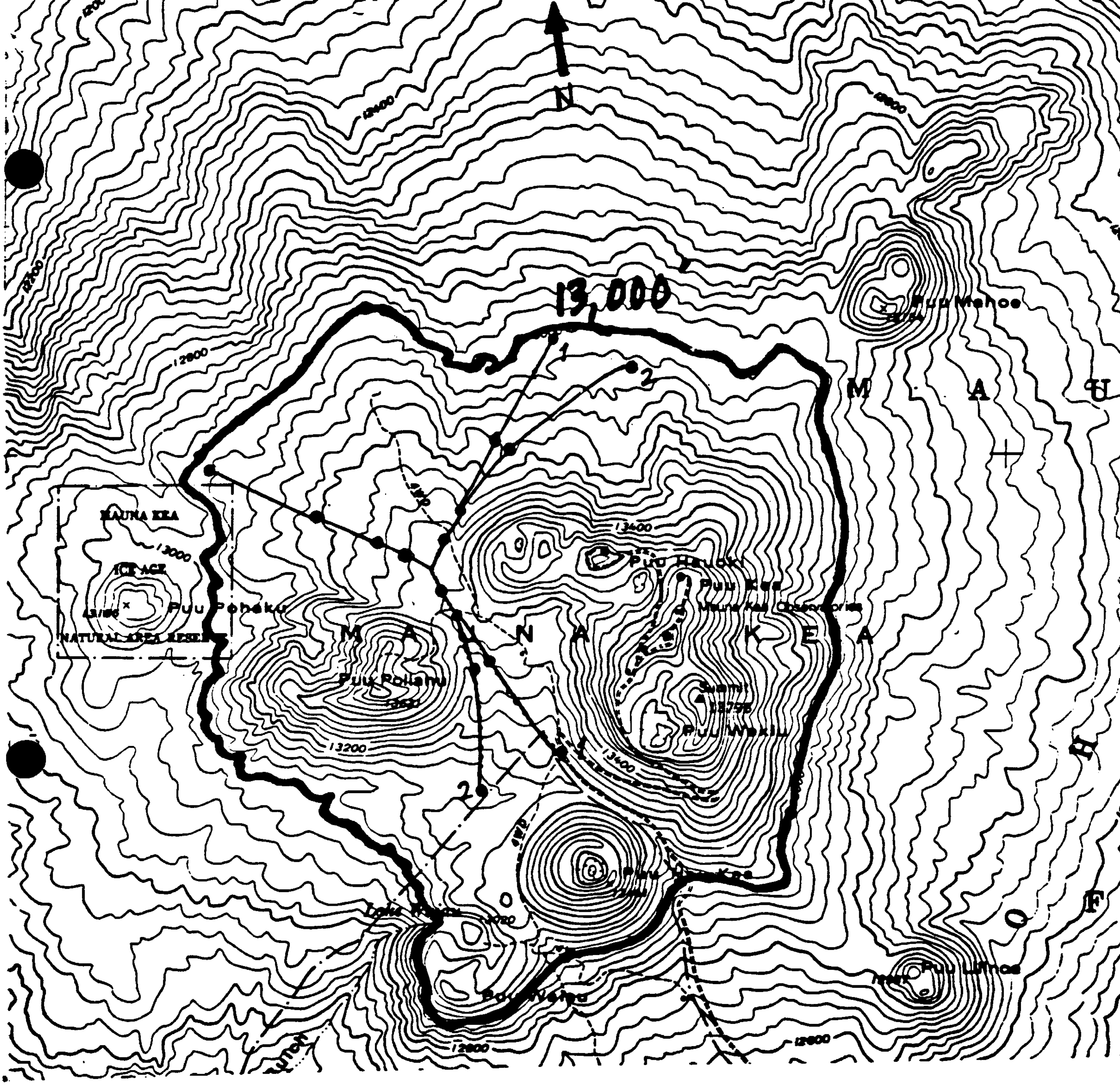
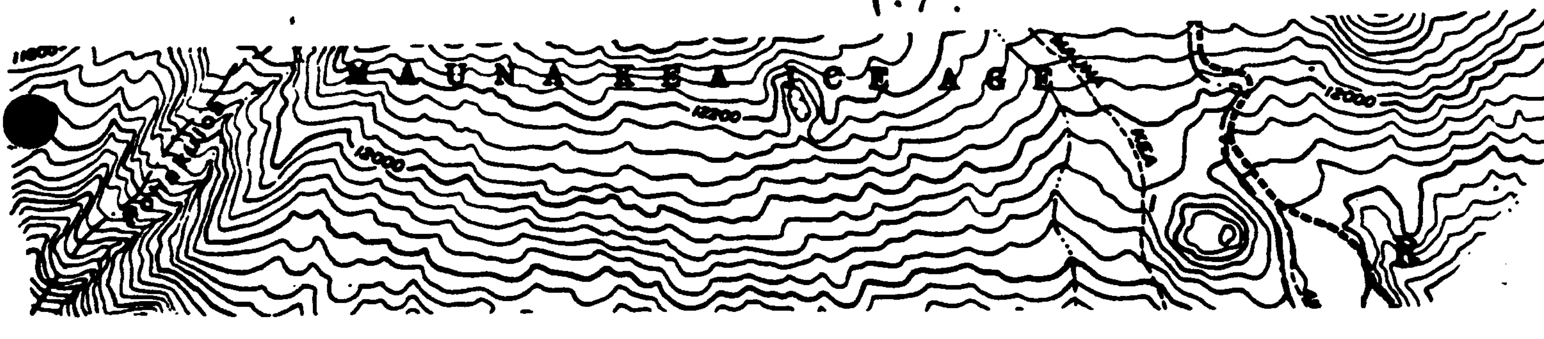


Figure 1. Expanded map of Mauna Kea, (1cm = 240m), showing the recommended site for the submillimeter array. The longest baselines are about 1.8 Km. Two alternate layouts of the N and S arms are labelled. Antennas may be arrayed along the arms according to any of the schemes discussed in the following sections, [p.8,9]. The best scheme I have found is detailed in section 2, [p.4, 14]

P.7.



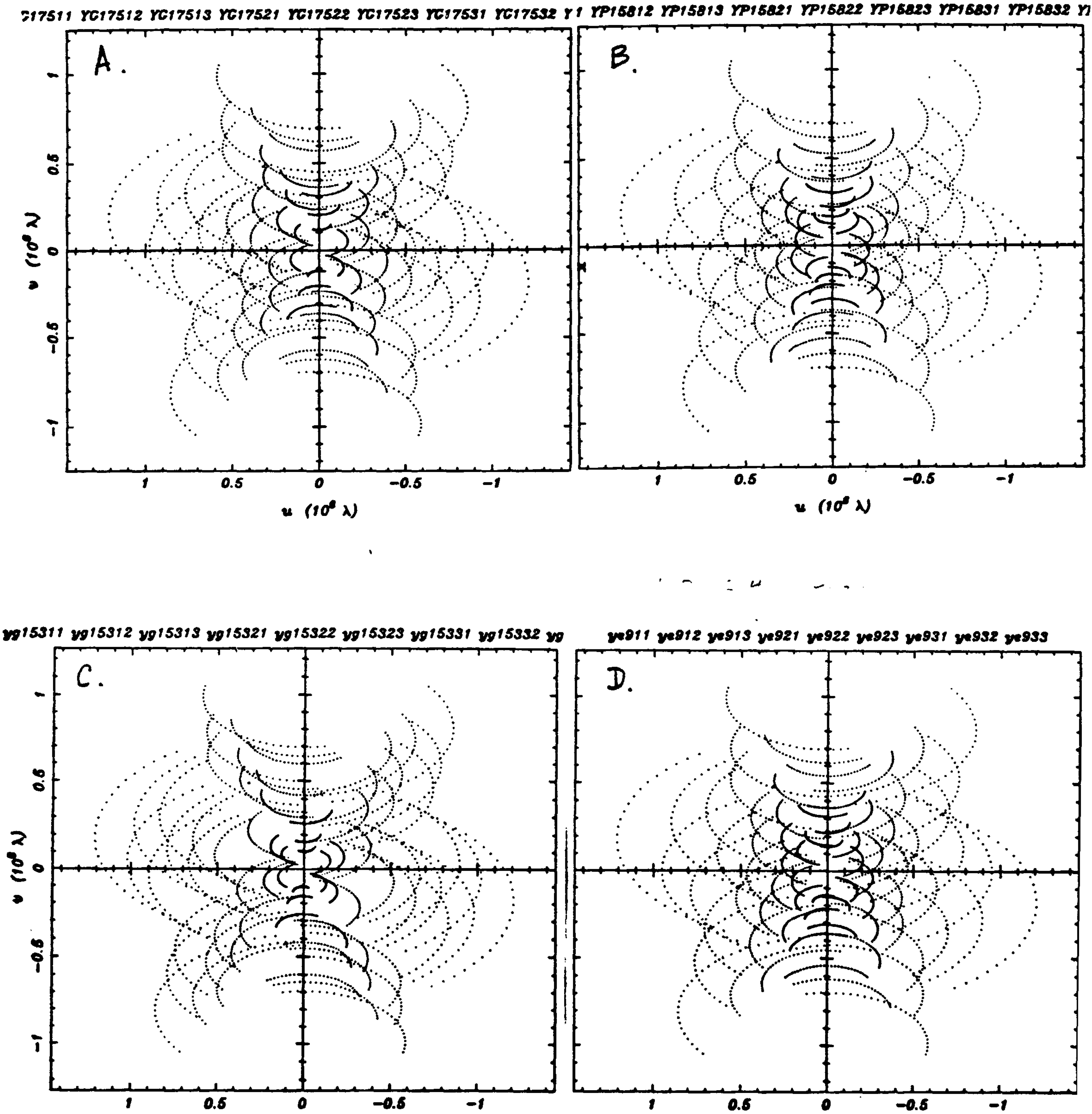


Figure 2. Four different 9-element Y arrays are shown, observing a source at dec=-30.

(a) Antennas along an arm in geometric progression, g^n with ratio g = 1.75, i.e., locations at 0.326, 0.571, 1.0

(b) power-law n^p with index p = 1.58, locations at 0.176, 0.334, 1.0

(c) With g = 1.53, locations at 0.427, 0.654, 1.0

(d) 'Random', with locations at 0.217, 0.415, 1.0

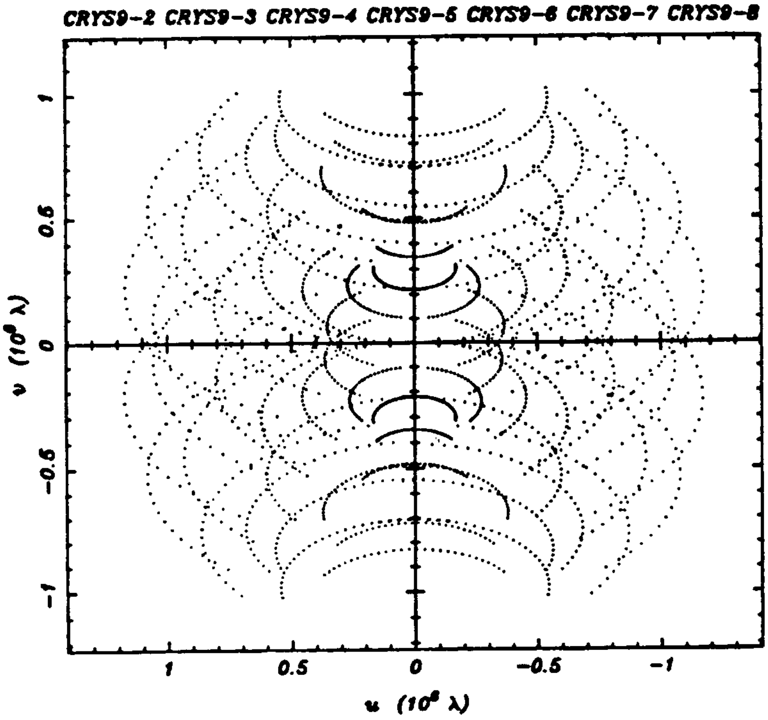


Figure 2, contd.:

Other arrays with random locations were shown in figure I.5 [see previous report]. These arrays have similar ranges of baseline lengths, the principal differences being that the shortest baselines arise from various combinations of radial and circumferencial directions. 'C' clearly has worse U-V holes than the others.

(e) 9-element O array from Cornwell's memo. Note the uniform coverage at long baselines and the consequent lack of shorter spacings, compared to (a)-(d). See also figures I.8 and II.3

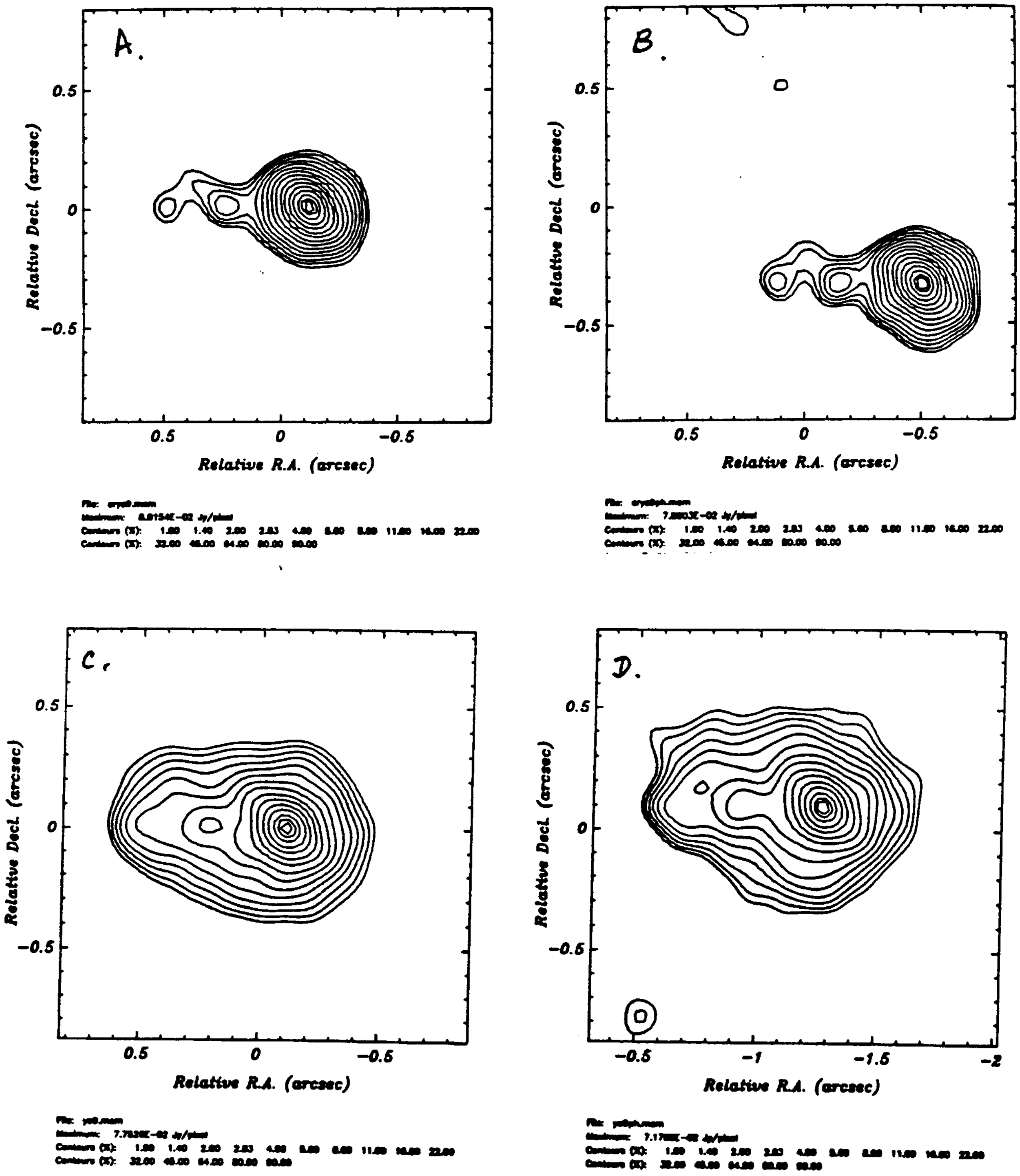


Figure 3. Fake source of figure I.7, mapped with two different 9-element arrays.

(a) O-array of figure II.2(e), stable phases; (c) O-array, scrambled phases; (b) Y-array of figure II.2(d), stable phases; (d) Y-array, scrambled phases. See also figure I.8, and comments therein.

[illegible] 0.156 .320 .532 1.00

[illegible] 0.169 0.315 [illegible]

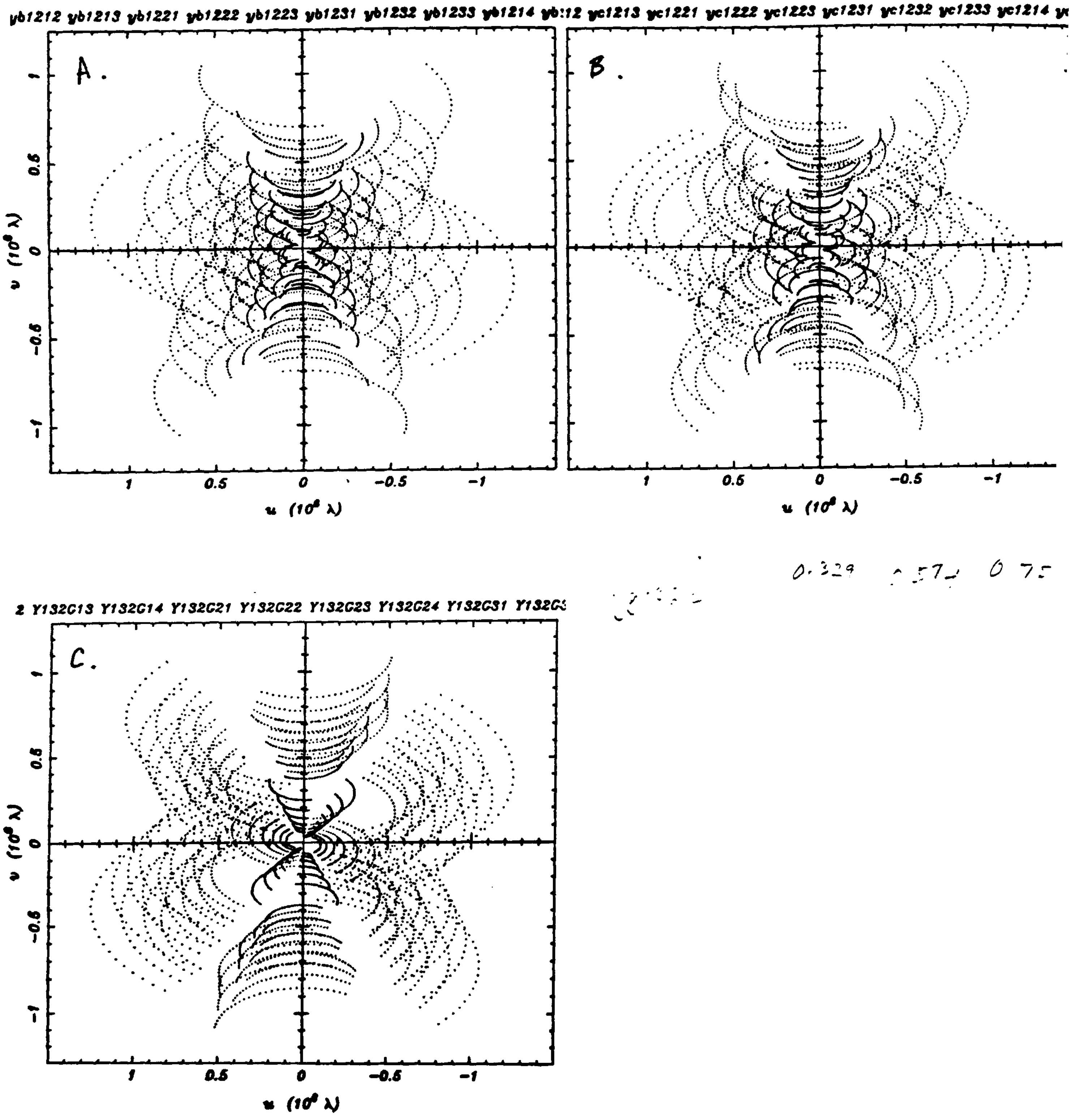


Figure 4. 12-element Y arrays, antennas at : (a) random: 0.156, 0.320, 0.532, 1.0
(b) random: 0.169, 0.315, 0.788, 1.0
(c) in geometric progression, g=1.32, locations at 0.329, 0.574, 0.758, 1.0

Compare with the final recommended array in figure II.7(d), which is scalable, expandable, and no worse than any of these.

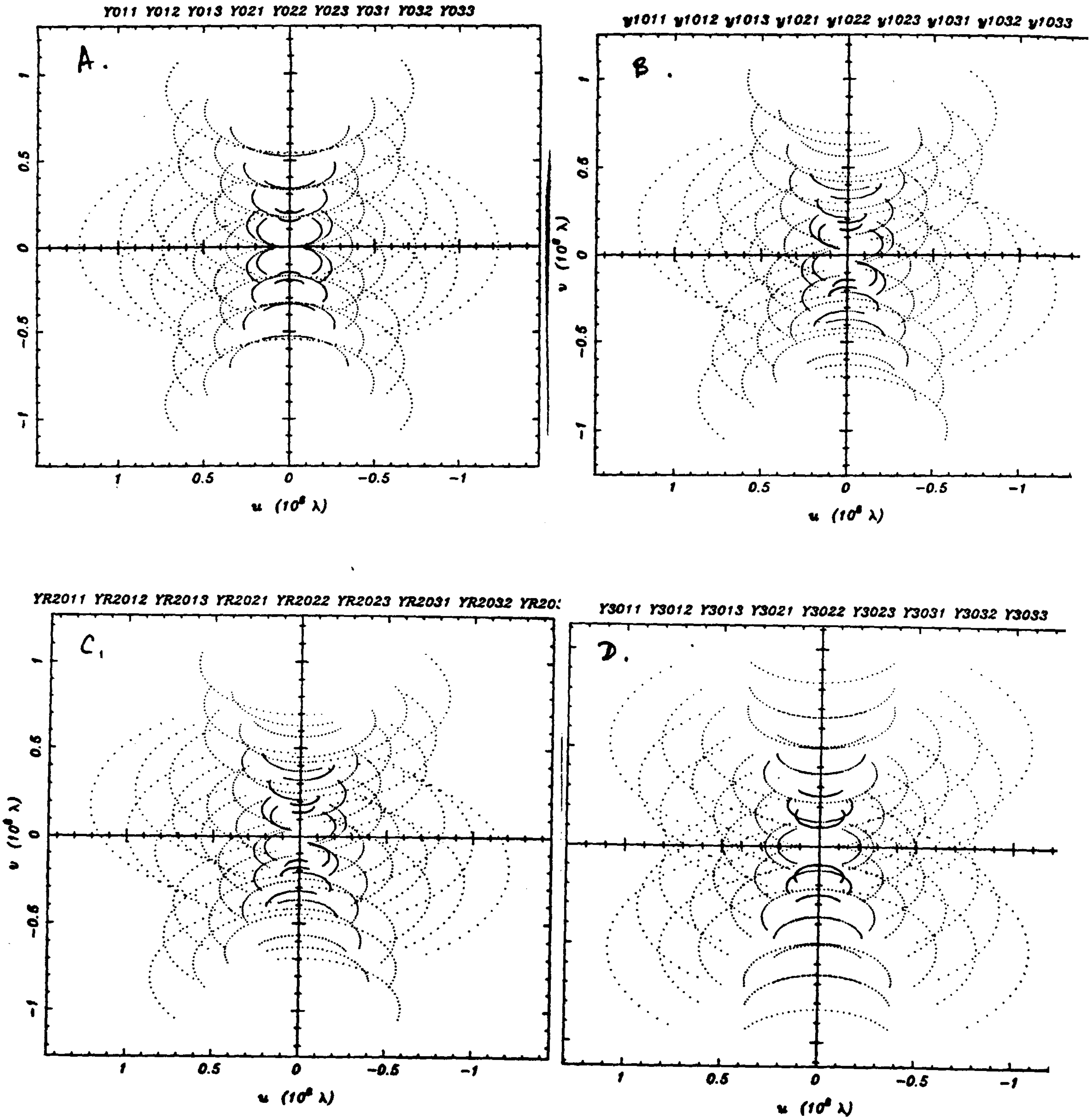


Figure 5. U-V coverage of the array of figure II.2(d), with the 'North' arm rotated CCW from N by: (a) 0 degrees, (b) 10 deg, (c) 20 deg, (d) 30 deg.

The higher symmetry of (a) and (d) shows up as coinciding baselines, leading to bigger holes along the V-axis, compared to (b) and (c).

(All arrays before this figure were shown at a rotation of 10 deg.)

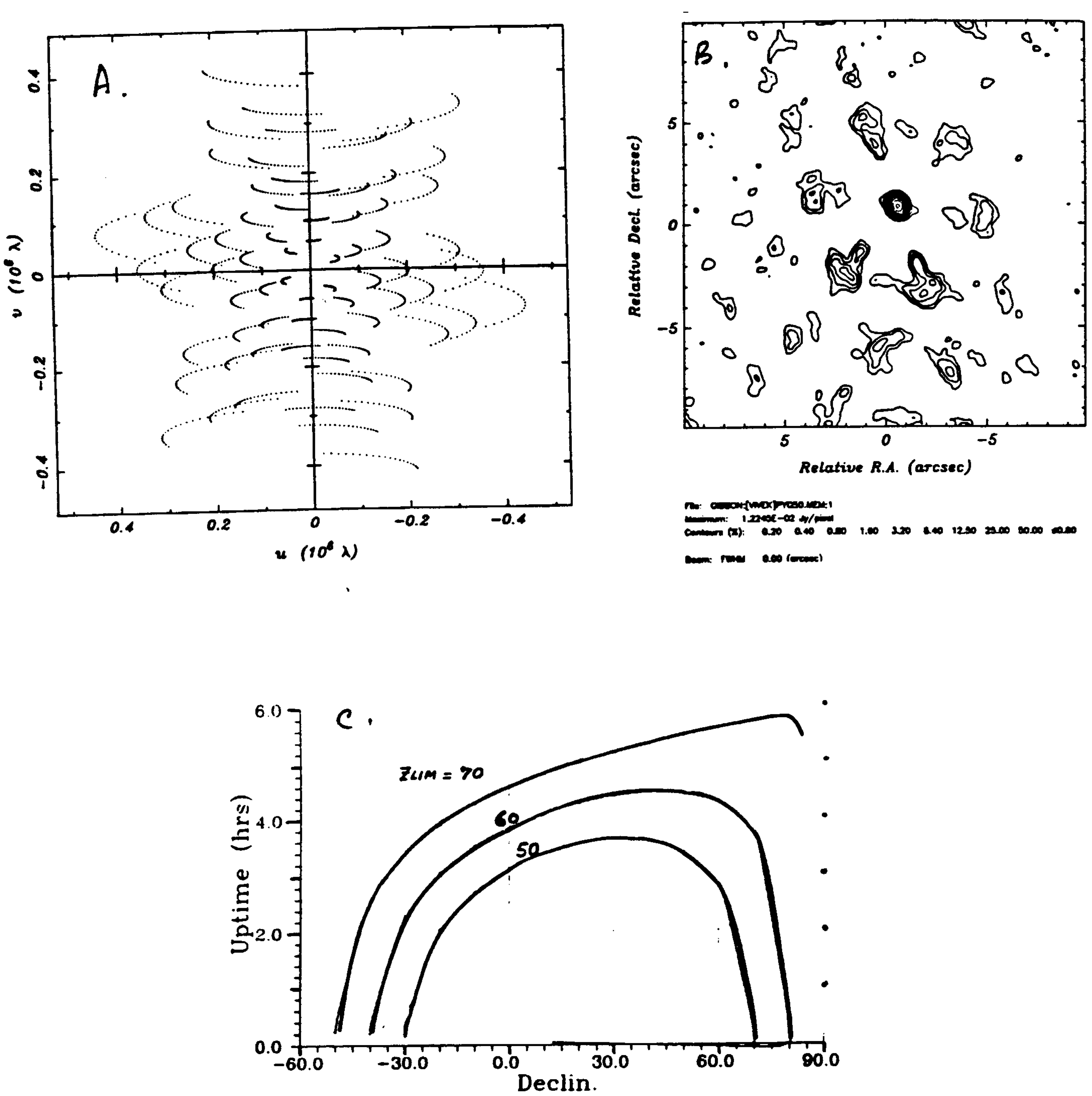


Figure 6. (a) Effect on U-V coverage (at dec = -10) of limiting the zenith angle travel of each telescope of a 9-element array to under 50deg.

(b) A simple 1.7Jy source mapped at 220GHz (Tsys=180K) for full tracks under the restrictions of (a), with scrambled phases. The haxagonal sidelobes that remain after MEM has converged are at the 2% level.

(c) Plot showing the available uptime for sources at various declinations, viewed from Mauna Kea (lat=19 deg), under different zenith angle restrictions.

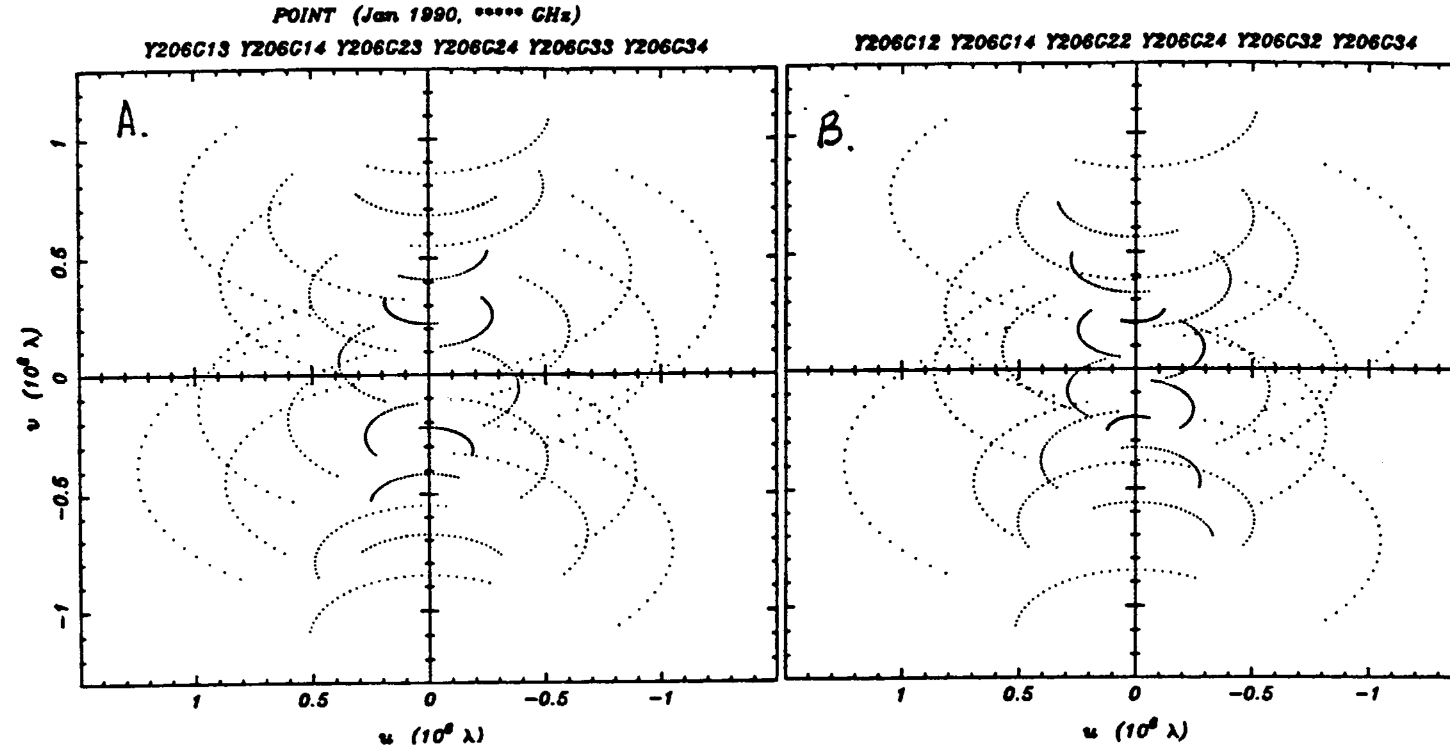
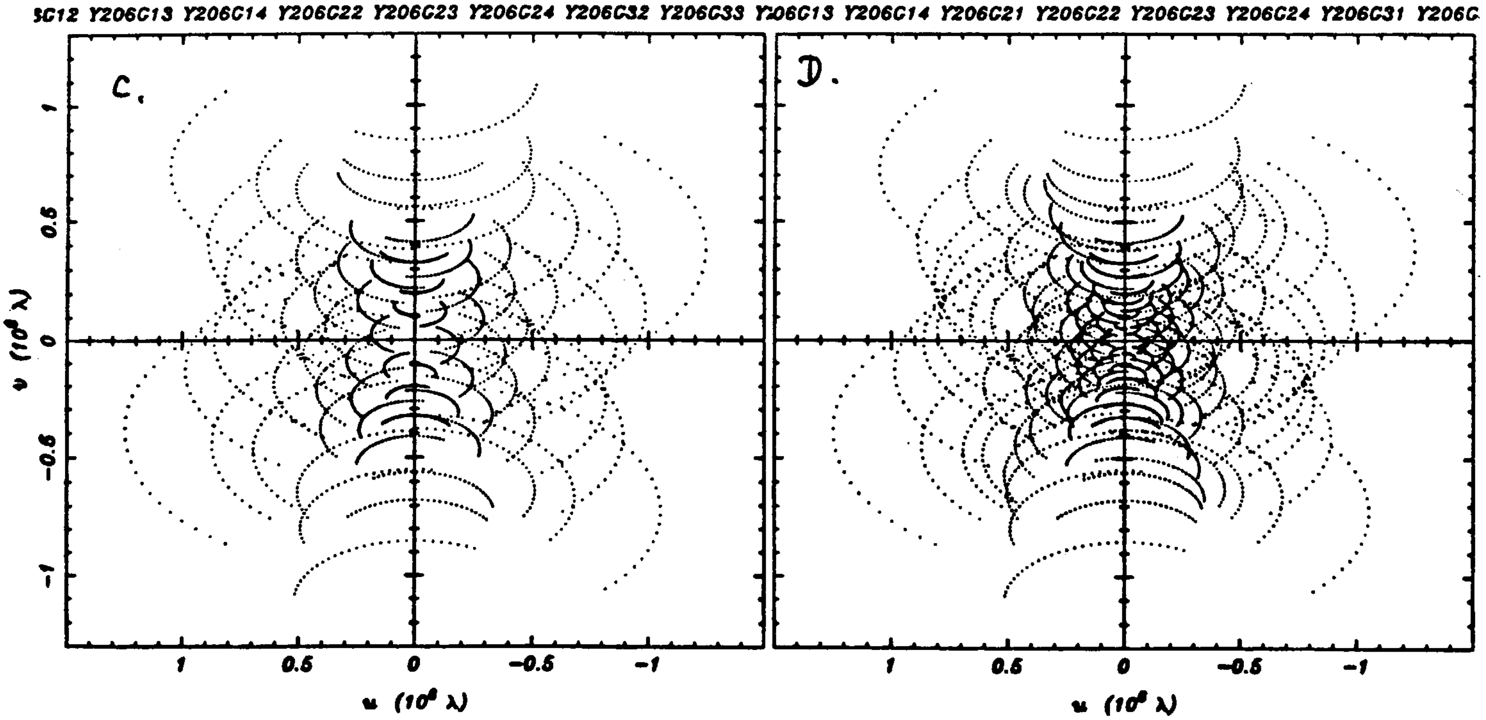


Figure 7. U-V plots for an array with antennas in geometric progression, with a ratio g = 2.06 and hence relative antenna locations at : 0.114, 0.236, 0.485, 1.0, 2.06, ... All plots have the same longest baseline.



(a) Six elements, using locations 3 and 4 along each arm.

(b) Alternate six-array, locations 2 and 4 along each arm.

(c) 9-array, locations 2,3,4.

(d) 12-array, locations 1,2,3,4.

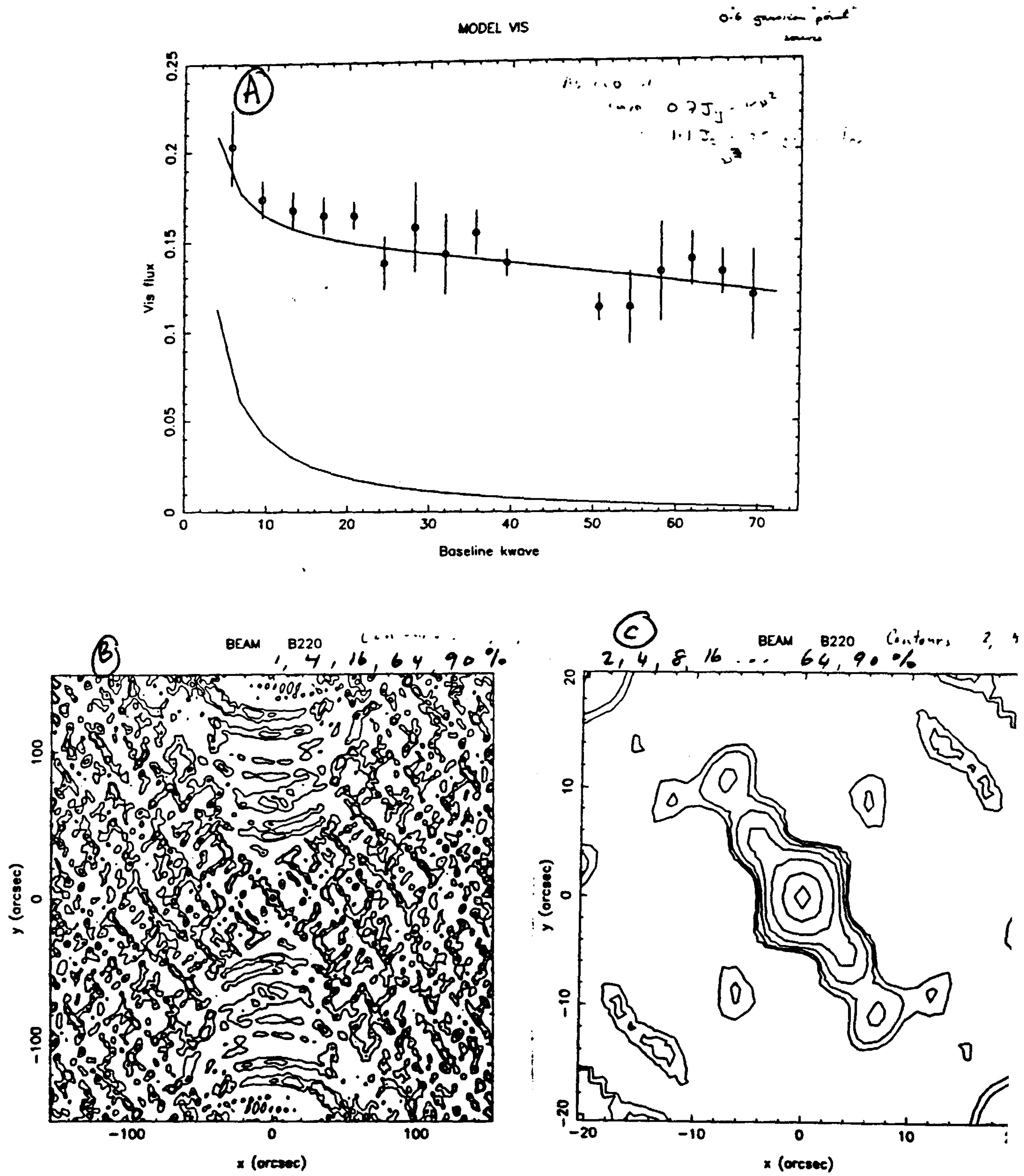


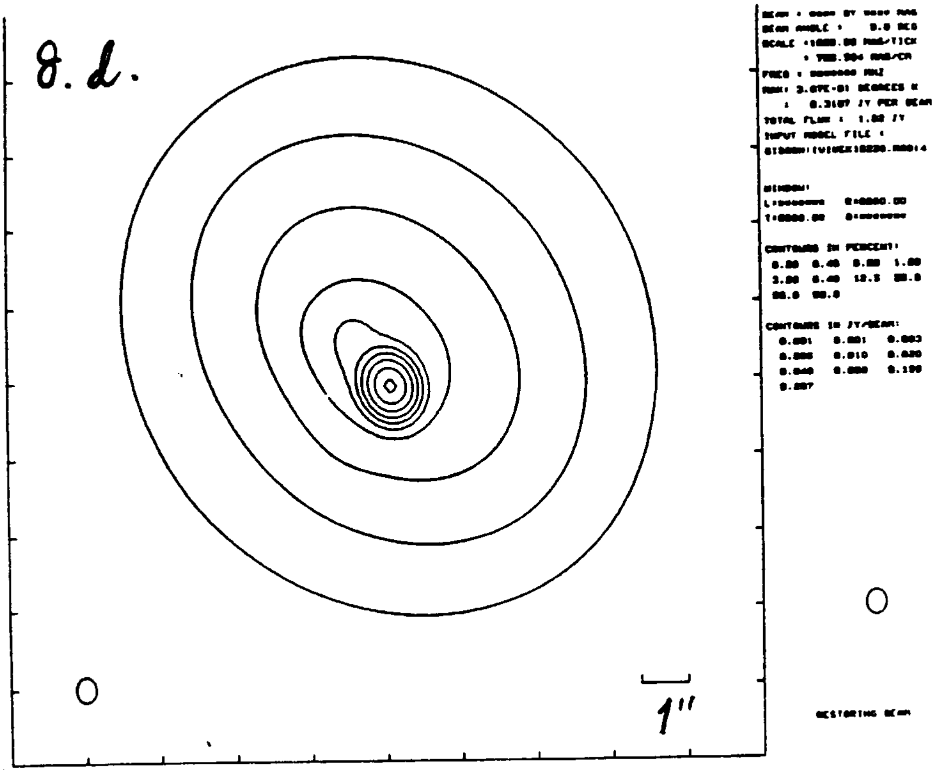
Figure 8. (a) Colin's data & model of L1551 at 2.7mm; based on this, I faked a source with a 0.6" 'point' of 0.7Jy at 220GHz, embedded in a 1.1Jy 'halo' having an approximate 1/r radial dependence out to 15".

(b) and (c): Synthesized beam for the array of figure II.2(a) at 220GHz, for dec=-30.

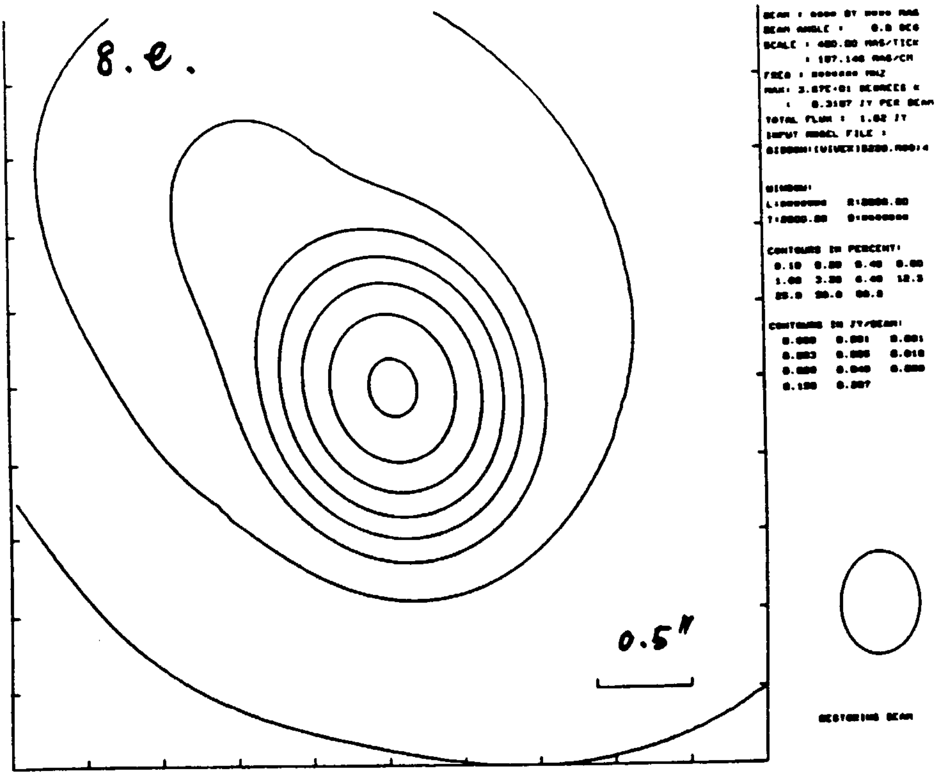
(d) and (e): Fake L1551 at two scales. Contours are logarithmic, 0.2, 0.4, ... 25, 50, 90 %.

F15

8.d.


BEAM ANGLE :
SCALE :
TOTAL FLUX :
INPUT MODEL FILE :
WINDOW:
CONTOURS IN PERCENT:
CONTOURS IN JY/BEAM:
0.010
1''
RESTORING BEAM

8.e.


BEAM ANGLE :
SCALE : 400.00 MAS/TICK
: 107.140 MAS/CM
TOTAL FLUX :
INPUT MODEL FILE :
WINDOW:
CONTOURS IN PERCENT:
0.10
12.5
CONTOURS IN JY/BEAM:
0.010
0.5''
RESTORING BEAM

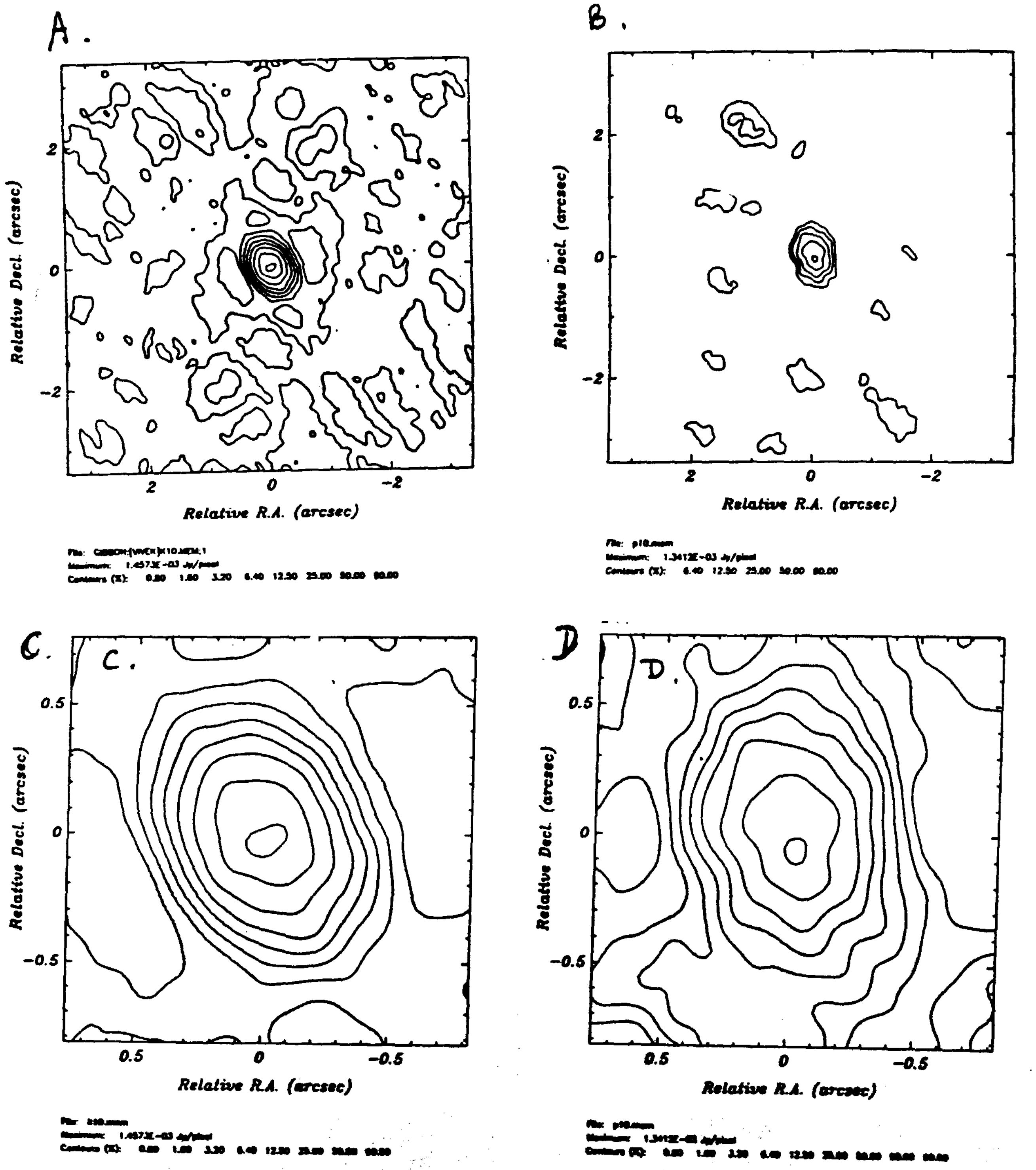


Figure 9. MEM images of "L1551", total flux 1.8Jy at 220GHz, viewed with Y-9 array of max baseline 1.8Km, so that the source is well resolved; Tsys=180K; coherent integ. of 1000sec. 3.9hrs synthesis at dec=-30 (full tracks with zenith lim = 75deg)

(a) Full map, stable phases;

(c) Central region of (a).

(b), (d) Scrambled phases.

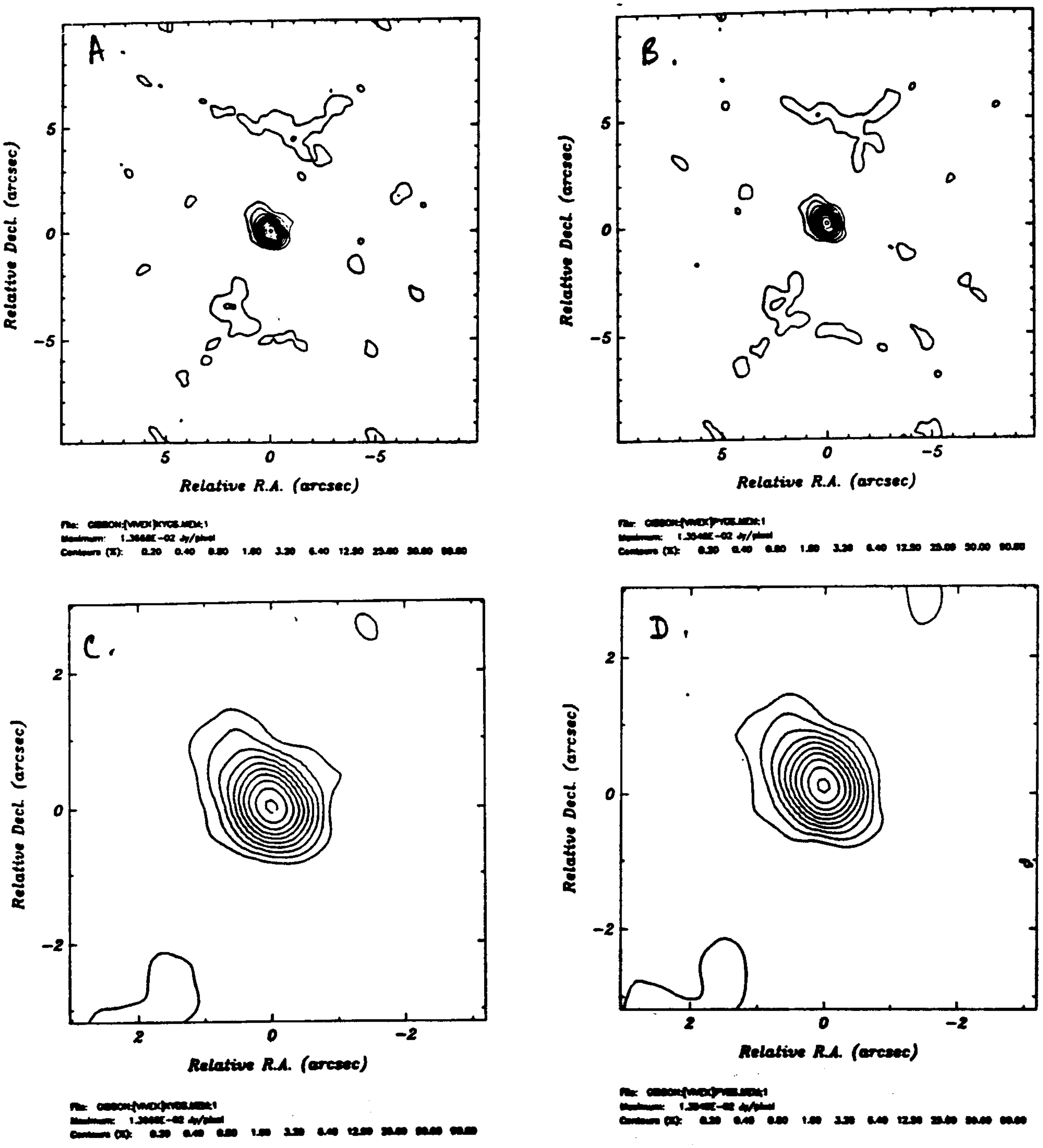


Figure 10. MEM maps of "L1551", same conditions as figure II.9, except 2.5 times lower resolution, with the 0.6" component barely resolved.

(a) and (c): Stable phases;

(b) and (d): Scrambled phases.

The self-cal'd images on the right are true to those on the left down to the 0.5 % level on this 1.8 Jy source. [Note residual beamshape in the top images, well below the expected noise level!]

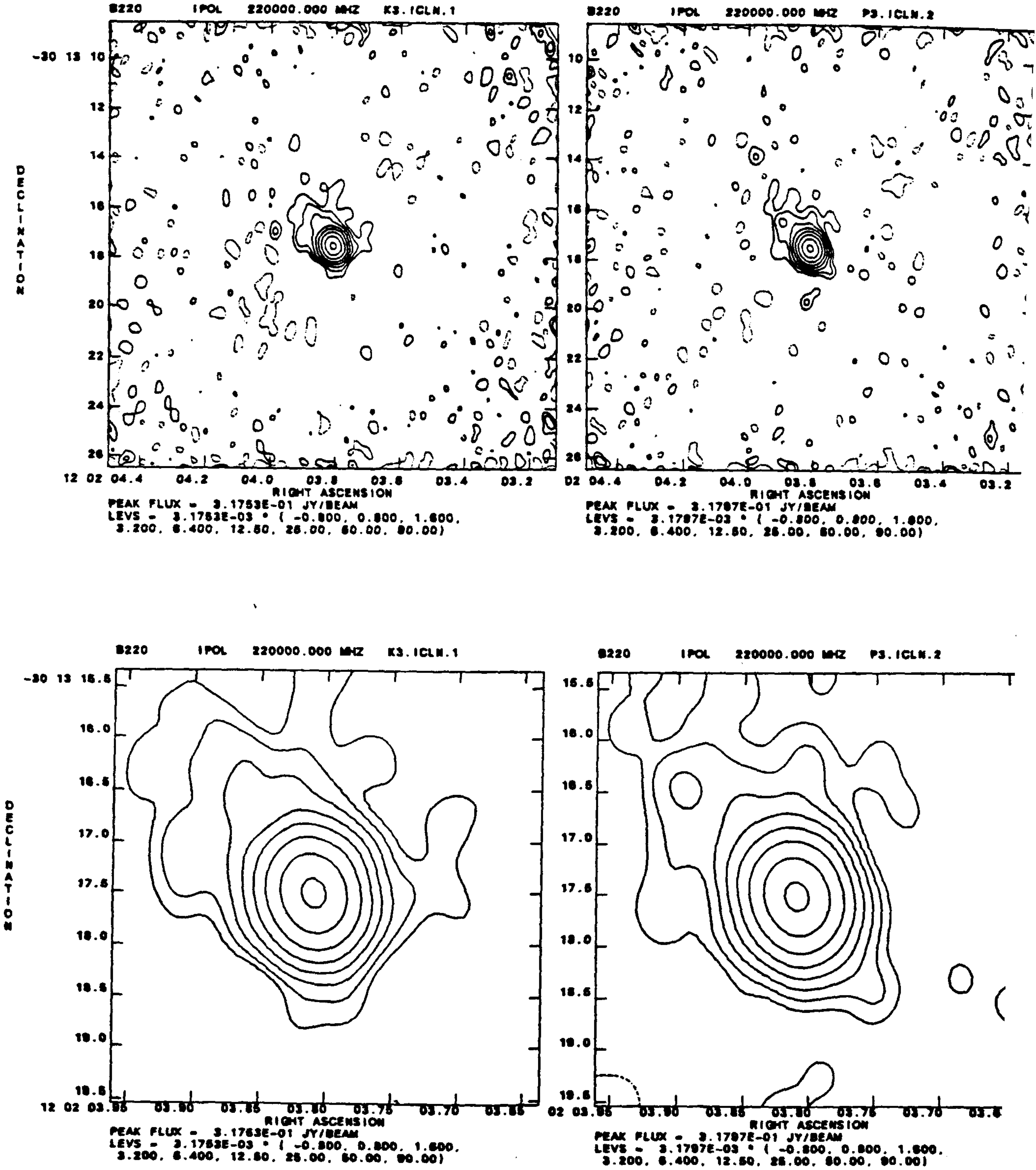


Figure 11. CLEAN maps of the same data sets as in the previous figure II.10; residuals are at roughly the expected level. As before, maps at left are from data with stable phases, those on right are from data with scrambled phases.

The one-sided structure of fake source is retrieved down to the 2% level (total flux of 1.8Jy), despite having a beam that is extended along the same direction. MEM/Self-cal thus works very well with 9 antennas on a simple source of this strength. [See the following figure for a test on weaker sources.]

Figure 12. To see how selfcal works on weak sources, the following test was done:

From the fake source was generated a sequence of sources, each a factor 2 weaker than the previous one, but otherwise identical. Data sets were generated for the sequence, all with scrambled phases. A sequence of maps was made, that followed the descent of the source into the noise. The entire operation was repeated at another resolution . The weakest source in each sequence is shown:

(a) and (c), for the heavily resolved configuration;

(b) and (d), barely resolved. The fluxes/pixel on the final maps are 4-6 times the "noise", defined as follows:

$$\frac{T_{sys}}{\sqrt{B\tau}} \cdot N_{ant} \cdot S.$$

$S \left\{ \begin{array}{l} \eta = 60\% \\ \text{diam} = 6\,\text{m}. \end{array} \right.$ $S = \left(\frac{A_{eff}}{2k}\right)$

$B = 10^9$ Hz $N_{ant} = 9$

$\tau = 4$ hrs.   coherent integ. = 1000

I suggest (for your e^{a}rnest consideration) that a study of coherence effects could proceed as follows, at great expense of CPU time:

(a) Generate a sequence of weakening sources, all with the same (coherent) integration time, say 300sec.

(b) INcoherently average each data set to 1000sec per data point.

(c) Map the sequence, note the flux/pixel (or flux/beam) where the source is last mapable.

(d) Repeat for the same coherent integ time, but at a different resolution.

(e) Repeat steps (a) thru (d) for 100sec, 30sec, 10sec.

(f) Plot and savour the results: "coherence" time vs. minimum self-cal'able flux/beam.

(f) If ambition persists, repeat entire exercise with a really complex source, and hope that the plot in (f) is a general result.

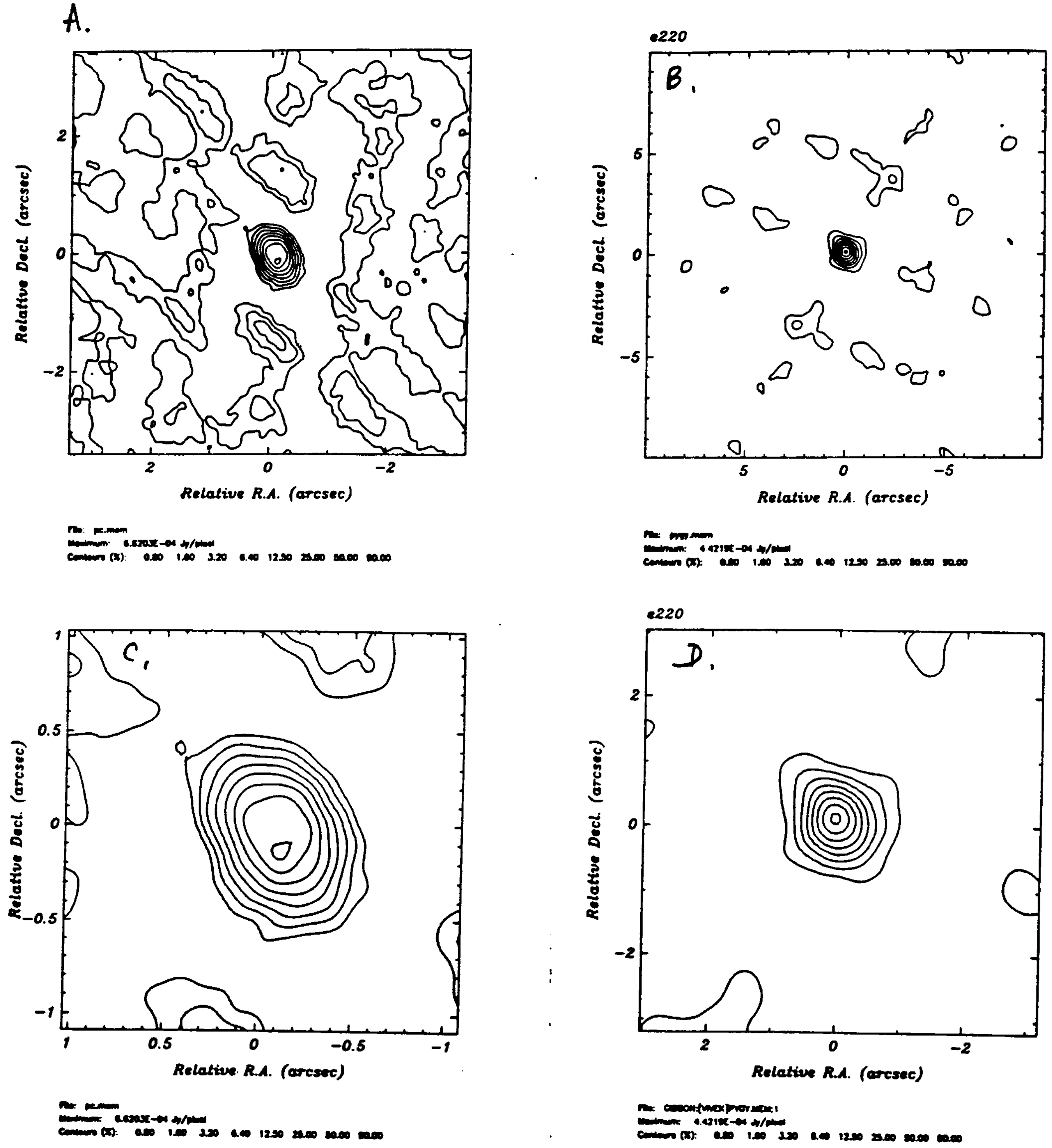

A.
Relative Decl. (arcsec)
2
0
−2
Relative R.A. (arcsec)
File: pc.mem
Maximum: 6.6703E−04 Jy/pixel
Contours (%): 0.80 1.60 3.20 6.40 12.50 25.00 50.00 90.00
e220
B.
Relative Decl. (arcsec)
5
0
−5
Relative R.A. (arcsec)
File: pygy.mem
Maximum: 4.4219E−04 Jy/pixel
Contours (%): 0.80 1.60 3.20 6.40 12.50 25.00 50.00 90.00
C.
Relative Decl. (arcsec)
1
0.5
0
−0.5
−1
Relative R.A. (arcsec)
File: pc.mem
Maximum: 6.6703E−04 Jy/pixel
Contours (%): 0.80 1.60 3.20 6.40 12.50 25.00 50.00 90.00
e220
D.
Relative Decl. (arcsec)
2
0
−2
Relative R.A. (arcsec)
File: GIBBON:[VMEX]PYGY.MEM;1
Maximum: 4.4219E−04 Jy/pixel
Contours (%): 0.80 1.60 3.20 6.40 12.50 25.00 50.00 90.00

Figure 12.