Configurations for the Joint Array

Lee Mundy – July 31, 1997
Updated March 6, 1998

This report summarizes the results of a first study of configurations for the joint array. The objective of this report is to give a short explanation of the logic behind a proposed 5-arm star pattern and to show the characteristic coverages and beams obtained. The star pattern has several adjustable parameters which we can choose to optimize at a later date.

Assumptions and Goals:

The following physical assumptions were made to limit the parameter space of possible array configurations:

- The array will consist of 16 antennas, ten 6.1-m and six 10-m antennas. The latter mix is relevant to the most compact array.

- All antennas will be able to work together to form 120 instantaneous baselines.

- The site is topologically unconstrained for baselines shorter than 700-m E-W and 900-m N-S.

- Concentric or tangential circular arrays, such as proposed for the MMA, are less desirable based on environmental and operational concerns (i.e. larger lengths of runway, larger number of antenna stations, and greater difficulty in making moves). This assumption can be revisited.

The following are treated as design goals to be achieved in one or more configurations of the joint array:

- Good uv coverage in both 2-4 hour "snapshots" and in full tracks.

- Minimum redundancy in baselines.

- The ability to make maps with excellent brightness temperature sensitivity – i.e. "low resolution" maps with good coverage in the inner uv plane.

- The ability to make "high resolution" maps with good sampling of the outer part of the uv plane.

Statements of Philosophy

The goal of having a good "snap-shot" coverage requires that the antennas create baselines with as wide a variety of instantaneous orientations as possible. For the MMA design, this consideration lead to circular configurations, rounded triangle configurations, and configurations with the antennas placed freely within a given circular area. In this report, *I propose a 5-arm star pattern* as an intermediate solution. This pattern gives more instantaneous baseline orientations than the traditional 'T' pattern yet allows for significant reuse of pads and runways between scaled array configurations. The 5-arm pattern gives us most of the benefits of a freely filled circular-area configuration while preserving a linear order for cabling and transport. Star patterns with more arms will give better instantaneous coverage at the cost of more runways. The 5-arm star pattern becomes progressively less desirable as one considers arrays with increasing numbers of antennas as it give you less access to the surface area with a given radius.

The goal of acquiring good images at both "low resolution" and "high resolution" can only be achieved by using multiple configurations of the 16 element array. The natural "low resolution" mode of the array is set by the size of the u,v hole for the 6.1-m antennas (20 nsec) and the size of their primary beam (115" at ν=100 GHz). Hence, the "low resolution" array should give 15-20 pixels across this primary beam and have good coverage down to u,v distances of 20-30 nsec.

There are two natural scales for the "high resolution" mode of the array: the maximum size of the unobstructed flat area and the maximum baselines that can be achieved following favorable contours of the land. The first scale (roughly 700m by 900 m) yields a roughly 1" synthesized beam at 100 GHz. The second scale is 2 km or more North-South and roughly 1.4 km East-West, yielding a 0.3"-0.5" beam at 100 GHz.

This report will ignore the largest possible array and concentrate on arrays which can be placed on the unobstructed flat area. The obvious question is: *Are two or more array configurations needed to properly sample the uv plane out to 2200 nsec?* The "low resolution" array will cover uv spacings from the shadowing limit of 20 nsec to 10-12 times that limit, or 200-240 nsec. The "high resolution" array must have good coverage of the uv plane from 1000 to 2500 nsec (visibility fringe spacings of 2" to 0.8" at ν=100 GHz). The annulus between these two preferred regions of coverage in the uv plane is large and is poorly covered by arrays which give good coverage of at the two extremes in resolution. Hence, *it is proposed that we utilize three arrays*, designated D, C, and B. As a practical comparison, the VLA D, C, B, and A arrays are different in size by factors of three; the size difference between the "low resolution" and "high resolution" arrays is a factor of 5 - 10.

The Proposed 5-arm Star Patterns

The star patterns for the D, C, and B arrays are given at the end of this section. The figure figure shows the proposed D-array. The listed configurations result from optimizing the u,v coverages for uniformity and lack of holes, and optimizing the synthesized beams for minimum sidelobes. The current arrays *do not* represent the result of an exhaustive search but are the product of some thought and testing.

The following points summarize the common characteristics of the proposed configurations.

- The arms are separated by equal angles of 72 degrees.

- The star pattern is tilted by 9 degrees with respect to having an arm point due north. This breaks some of the symmetry of the configuration – filling holes along the v-axis.

- One antenna is placed in the center of the star and three antenna are placed along each arm.

- The spacing of antennas along each arm are in a ratio of 1 unit to 2.5 units to 4.5 units. This yields intrinsic spacings of 1, 1.5, 2, 2.5, 3.5, and 4.5 times the unit spacing along each arm.

- The unit spacing for each arm is different. Numbering the arms from 1 through 5 as you count counterclockwise from north, the unit spacings are 1.4, 1.0, 1.35, 1.45, and 1.05 for arms 1, 2, 3, 4, and 5. The larger factors for arms 1, 3, and 4 extends the N-S extent of the array, making the beam more circular for southern sources; this factor can be adjusted as desired. The small variations in factors again helps to break the symmetry of the star pattern.

The D, C, and B arrays are scaled versions of each other with the unit spacing multiplied by a factor of 2.5 each time. A unit spacing of 1.0 corresponds to 38, 95, and 237.5 nsec in the D, C, and B arrays. This multiplicative spacing of pads allows 6 of the D-array stations to be re-used in the C array and six of the C-array stations to be reused in the B-array. At 100 GHz, the arrays have rough synthesized beams of 6.3", 2.5", and 1".

The unit spacing values and the scale factor between arrays can be adjusted to fine-tune the configurations and resulting beams. In order to re-use pads between adjacent array configurations, the the scale factor between arrays must match the spacing factor between one of the pad locations on the arms; currently the matching factor is 2.5.

D-Array Antenna Locations in nanoseconds

East	North
0.0	0.0
-8.0	52.6
-19.9	131.5
-35.8	236.7
34.0	17.0
84.9	42.5
152.9	76.6
36.0	-36.5
90.0	-91.3
162.1	-164.4
-25.4	-48.9
-63.4	-122.3
-114.1	-220.1
-39.4	6.5
-98.4	16.3
-177.1	29.3

C-Array Antenna Locations in nanoseconds

East	North
0.0	0.0
-19.9	131.5
-49.7	328.8

-89.4	591.8
84.9	42.5
212.4	106.3
382.3	191.4
90.0	-91.3
225.1	-228.3
405.2	-411.0
-63.4	-122.3
-158.5	-305.7
-285.3	-550.3
-98.4	16.3
-246.0	40.8
-442.8	73.4

B-Array Antenna Locations in nanoseconds

East	North
- - - -	- - - - -
0.0	0.0
-49.7	328.8
-124.2	821.9
-223.6	1479.4
212.4	106.3
530.9	265.8
955.7	478.4
225.1	-228.3
562.8	-570.8

1013.0	-1027.4
-158.5	-305.7
-396.3	-764.3
-713.3	-1375.8
-246.0	40.8
-615.1	101.9
-1107.1	183.4

U,V Coverages and Beams

Plots of the uv coverages and beams are given in the accompanying figures for three declination (-20, 18, and 50 degrees) for tracks both ± 1 hour and ± 4.5 hours from transit (constrained to have zenith angle $<$87 degrees). As you can see from the second plot for each declination, the uv coverage for a 2-hour snapshot around transit is quite good. For most source declinations, the maximum sidelobes in a full track are at the $\pm 5\%$ level; in a ± 1 hour track, the maximum sidelobes grow to ± 7 to 10%.

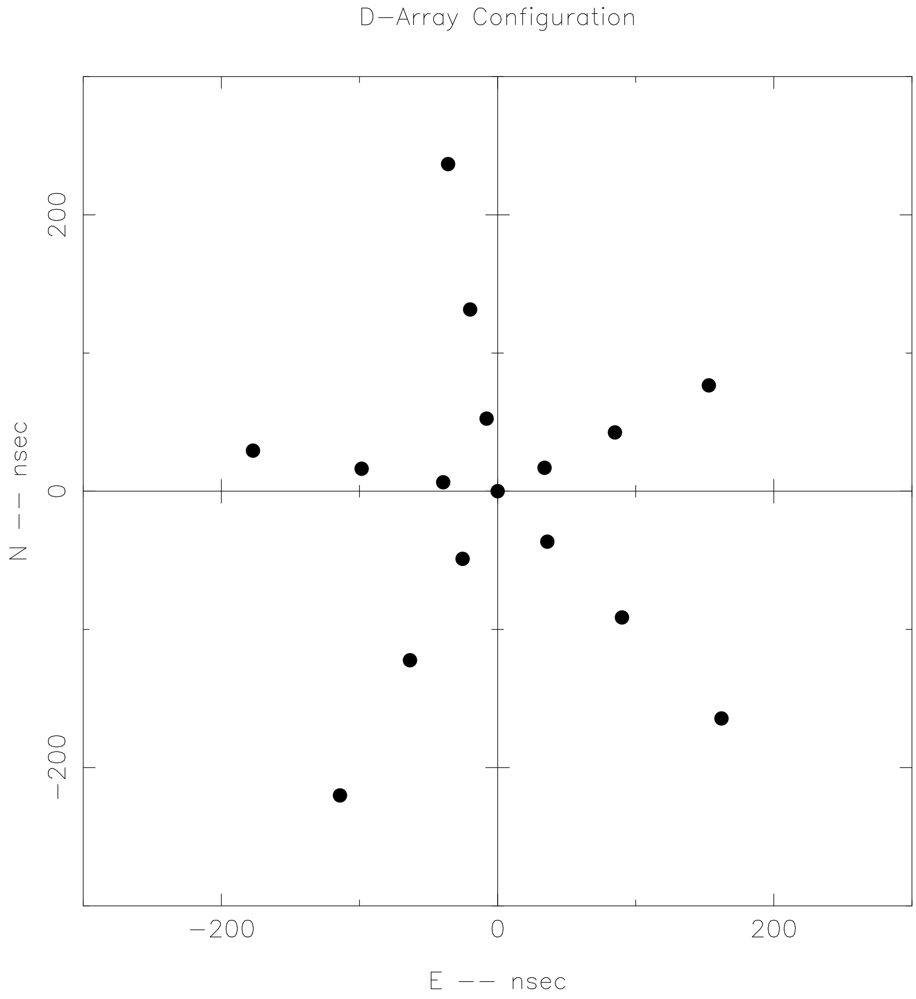
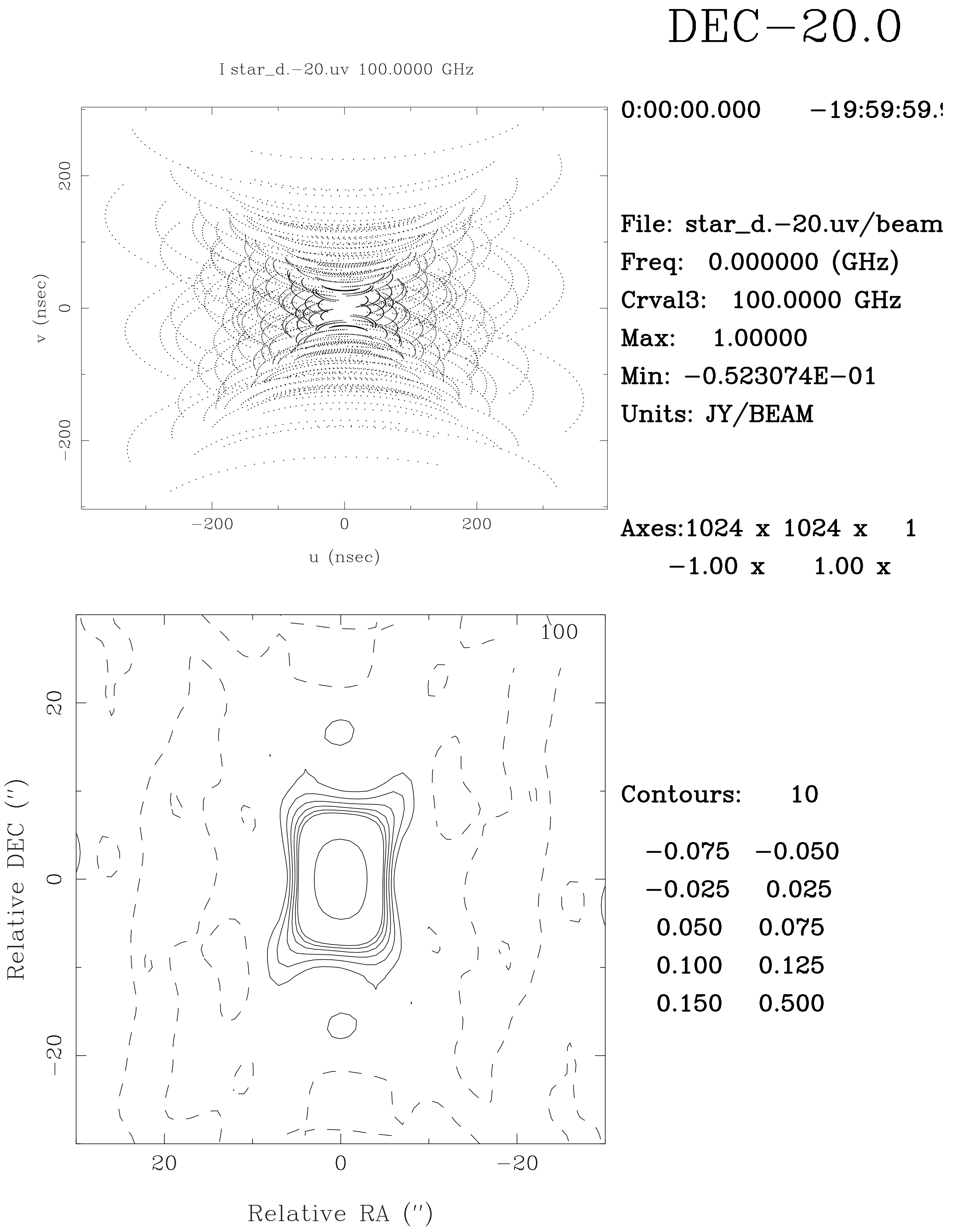
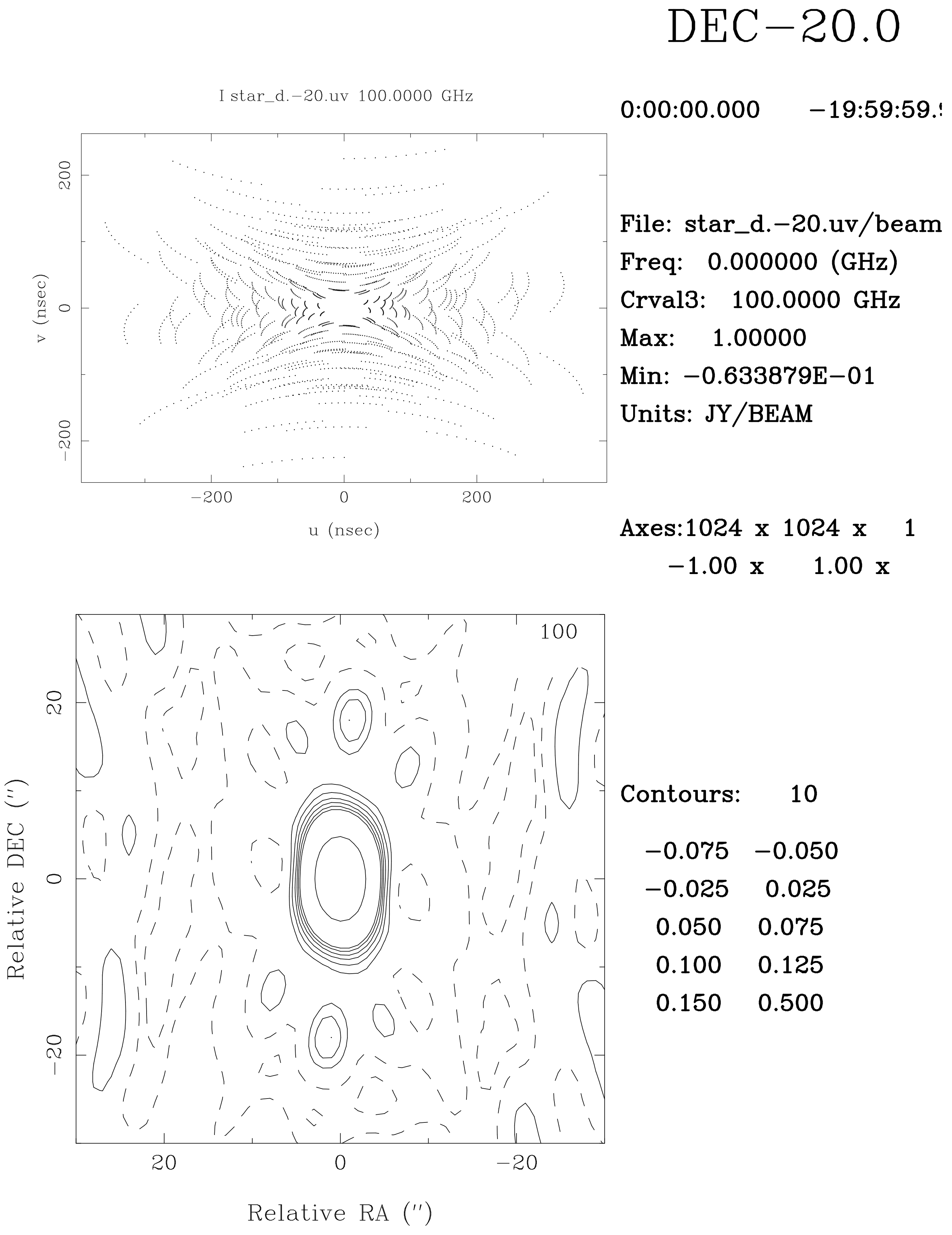
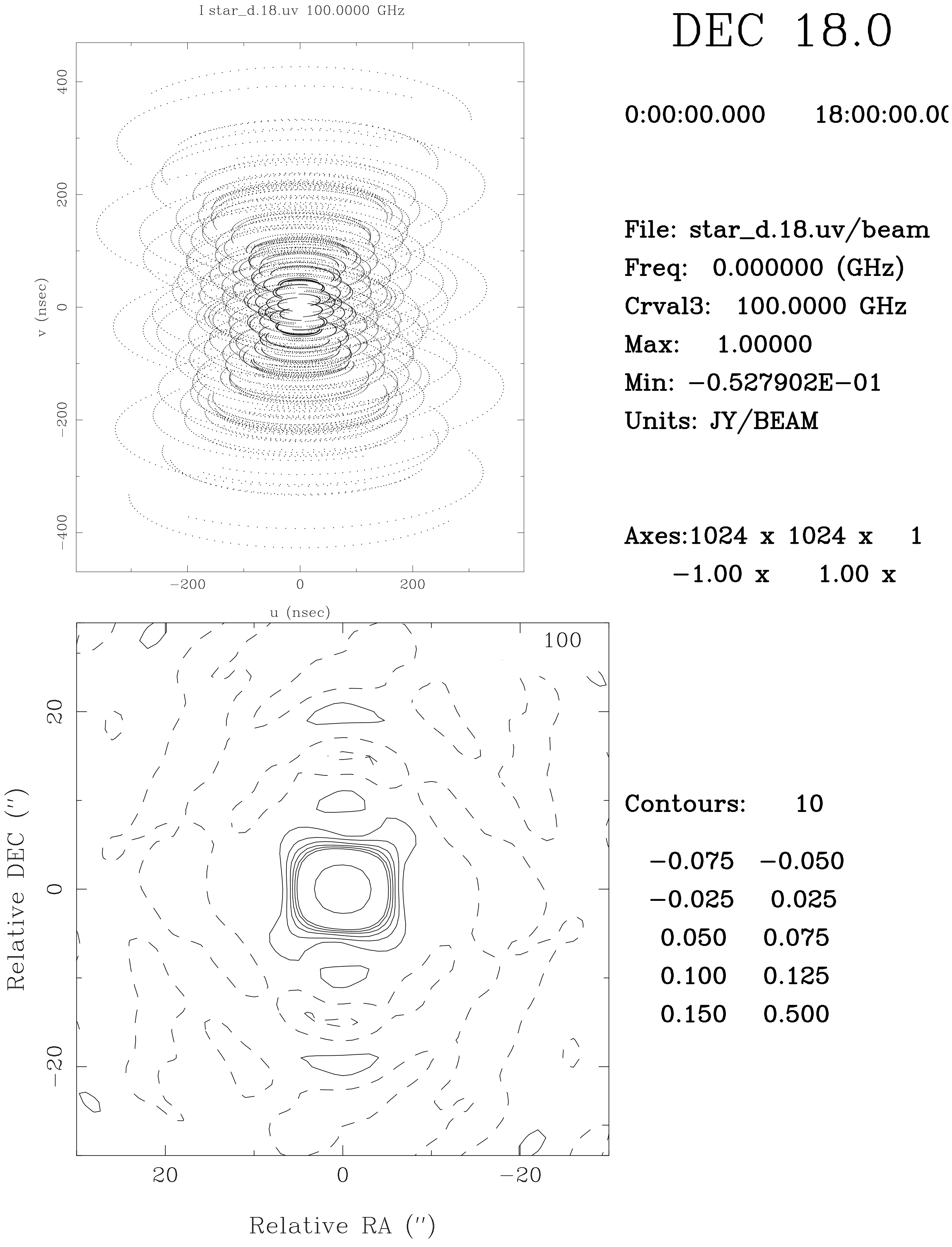


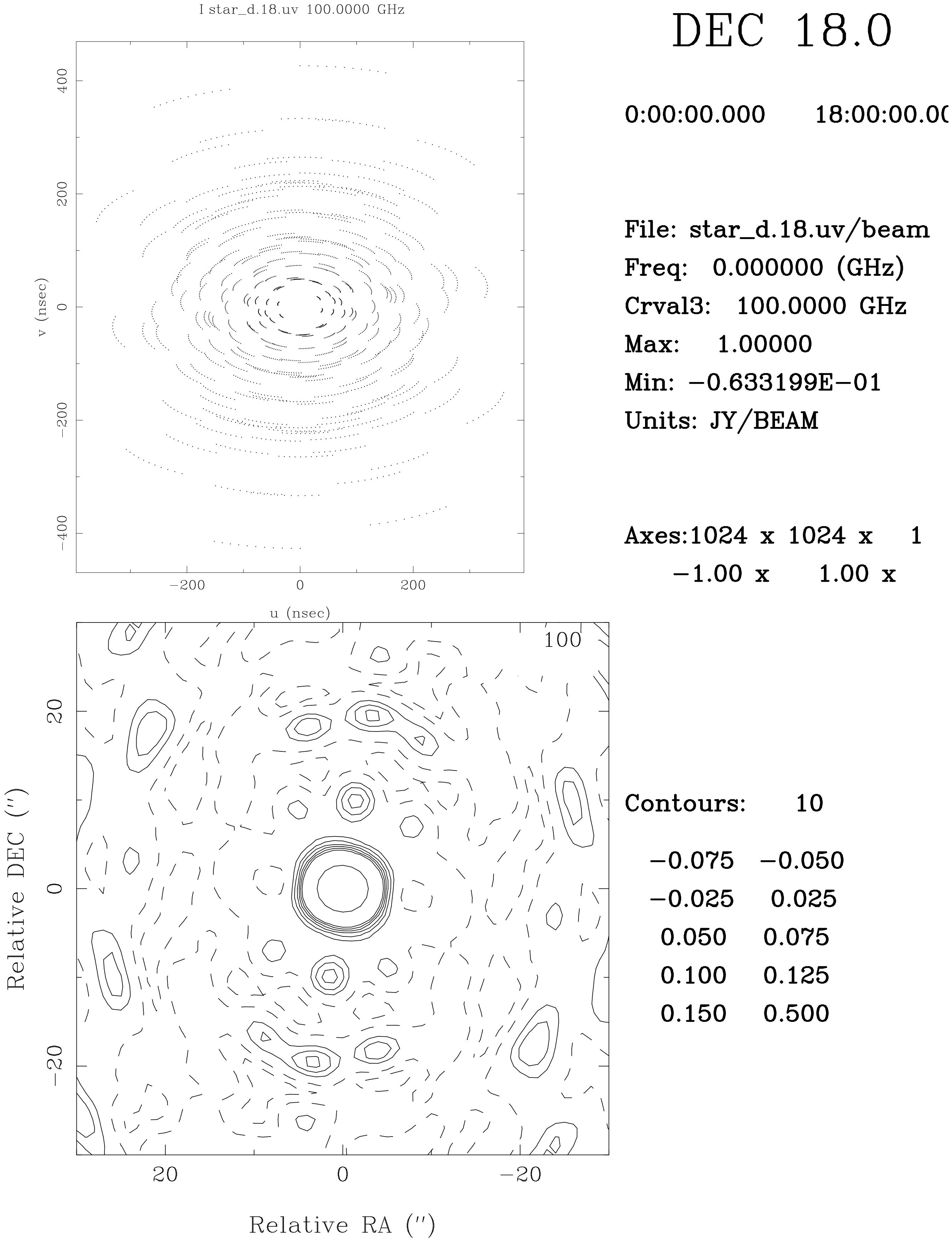
Fig. 1.— Antenna locations for D-array

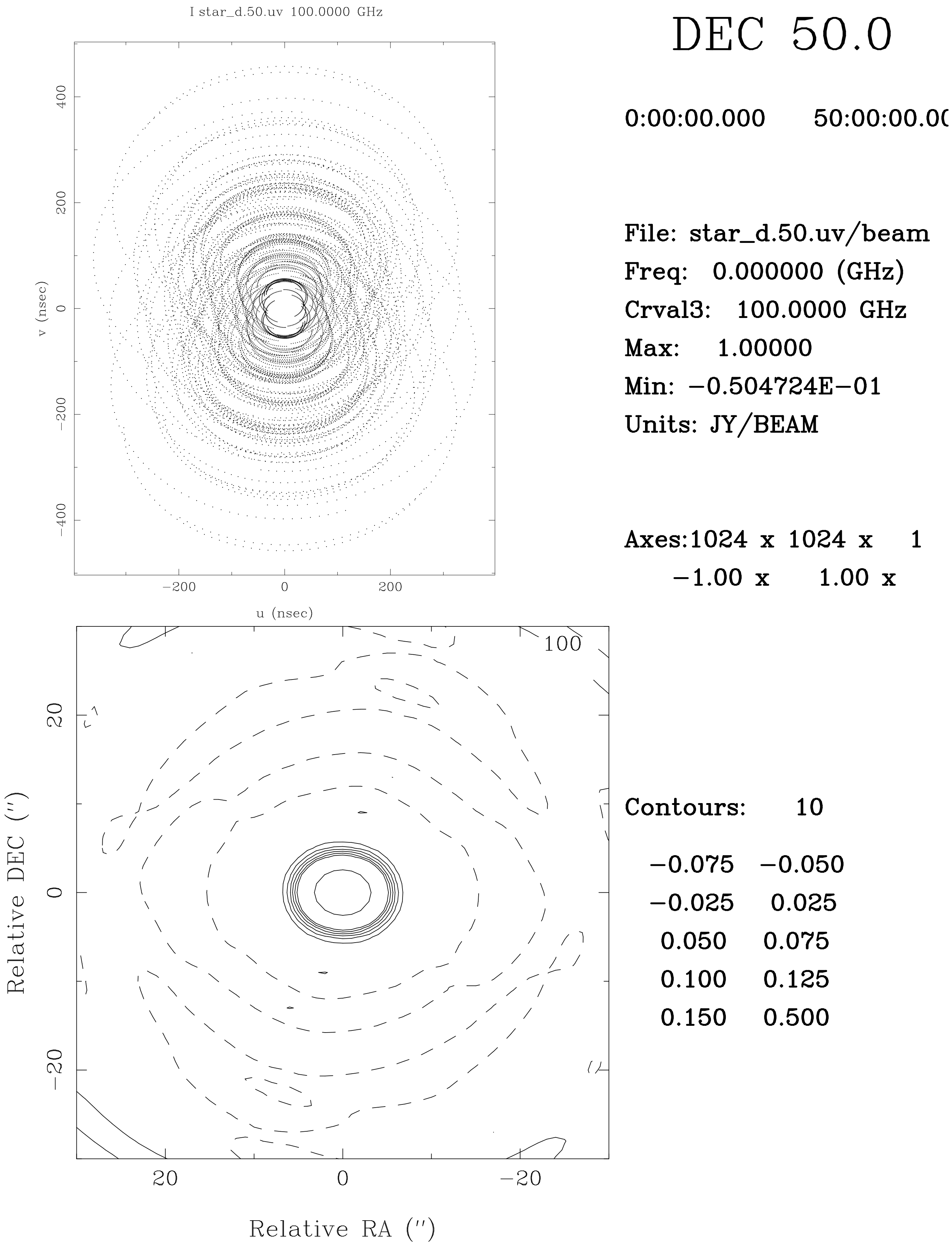

DEC−20.0
I star_d.−20.uv 100.0000 GHz
0:00:00.000 −19:59:59.9
File: star_d.−20.uv/beam
Freq: 0.000000 (GHz)
Crval3: 100.0000 GHz
Max: 1.00000
Min: −0.523074E−01
Units: JY/BEAM
Axes:1024 x 1024 x 1
−1.00 x 1.00 x
v (nsec)
u (nsec)
200
0
−200
100
Contours: 10
−0.075 −0.050
−0.025 0.025
0.050 0.075
0.100 0.125
0.150 0.500
Relative DEC (″)
Relative RA (″)
20
0
−20

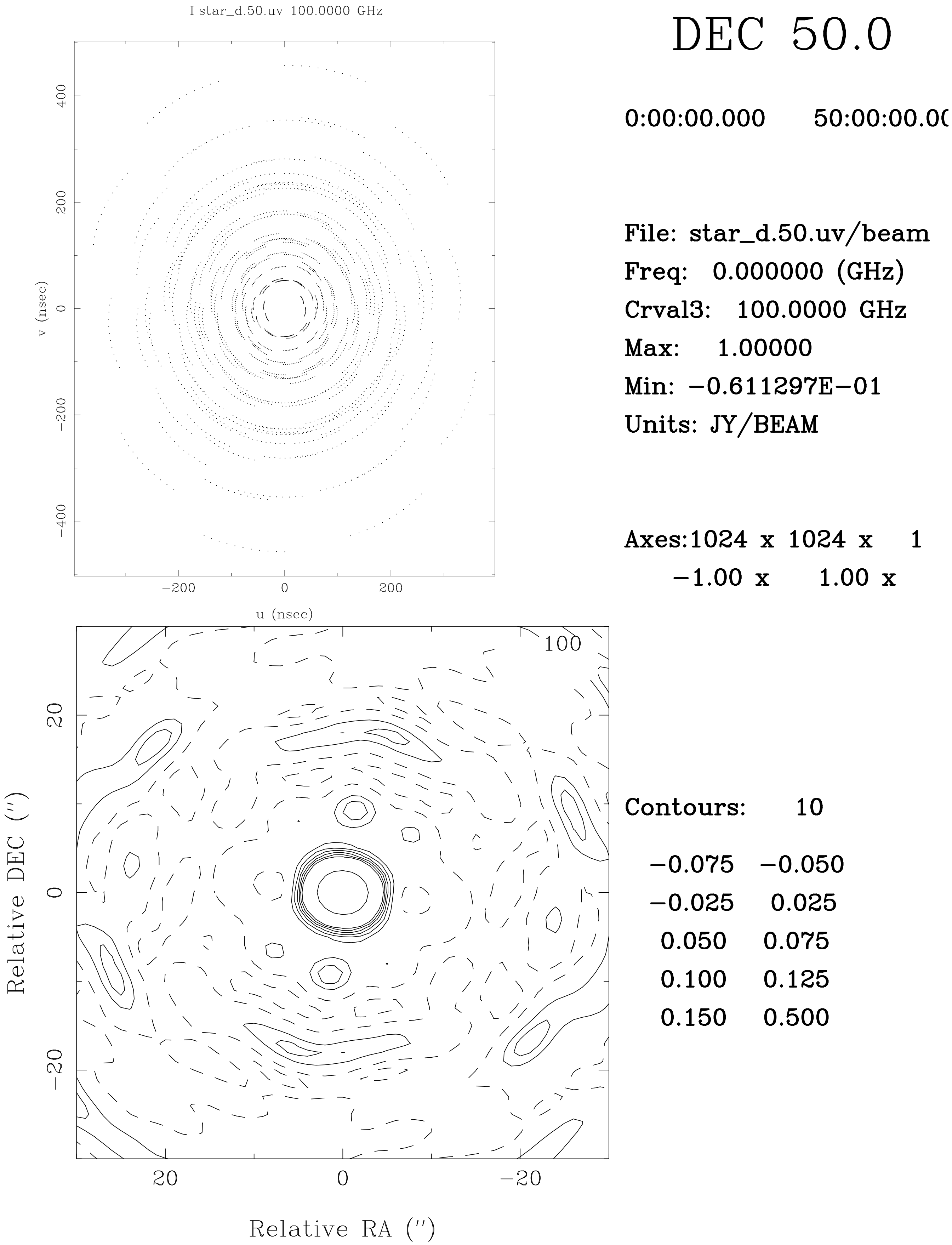


DEC−20.0
I star_d.−20.uv 100.0000 GHz
v (nsec)
u (nsec)
200
0
−200
0:00:00.000 −19:59:59.9
File: star_d.−20.uv/beam
Freq: 0.000000 (GHz)
Crval3: 100.0000 GHz
Max: 1.00000
Min: −0.633879E−01
Units: JY/BEAM
Axes:1024 x 1024 x 1
−1.00 x 1.00 x
100
Relative DEC (″)
Relative RA (″)
20
0
−20
Contours: 10
−0.075 −0.050
−0.025 0.025
0.050 0.075
0.100 0.125
0.150 0.500


I star_d.18.uv 100.0000 GHz
v (nsec)
u (nsec)
DEC 18.0
0:00:00.000 18:00:00.00
File: star_d.18.uv/beam
Freq: 0.000000 (GHz)
Crval3: 100.0000 GHz
Max: 1.00000
Min: −0.527902E−01
Units: JY/BEAM
Axes:1024 x 1024 x 1
−1.00 x 1.00 x
100
Relative DEC (″)
Relative RA (″)
Contours: 10
−0.075 −0.050
−0.025 0.025
0.050 0.075
0.100 0.125
0.150 0.500


I star_d.18.uv 100.0000 GHz
DEC 18.0
0:00:00.000 18:00:00.00
File: star_d.18.uv/beam
Freq: 0.000000 (GHz)
Crval3: 100.0000 GHz
Max: 1.00000
Min: −0.633199E−01
Units: JY/BEAM
Axes:1024 x 1024 x 1
−1.00 x 1.00 x
v (nsec)
u (nsec)
400
200
0
−200
−400
100
Relative DEC (″)
Relative RA (″)
20
−20
Contours: 10
−0.075 −0.050
−0.025 0.025
0.050 0.075
0.100 0.125
0.150 0.500


I star_d.50.uv 100.0000 GHz
400
200
0
−200
−400
v (nsec)
−200
0
200
u (nsec)
DEC 50.0
0:00:00.000 50:00:00.0(
File: star_d.50.uv/beam
Freq: 0.000000 (GHz)
Crval3: 100.0000 GHz
Max: 1.00000
Min: −0.504724E−01
Units: JY/BEAM
Axes:1024 x 1024 x 1
−1.00 x 1.00 x
100
20
0
−20
Relative DEC (″)
20
0
−20
Relative RA (″)
Contours: 10
−0.075 −0.050
−0.025 0.025
0.050 0.075
0.100 0.125
0.150 0.500


I star_d.50.uv 100.0000 GHz
v (nsec)
u (nsec)
400
200
0
−200
−400
−200
0
200
DEC 50.0
0:00:00.000 50:00:00.0(
File: star_d.50.uv/beam
Freq: 0.000000 (GHz)
Crval3: 100.0000 GHz
Max: 1.00000
Min: −0.611297E−01
Units: JY/BEAM
Axes:1024 x 1024 x 1
−1.00 x 1.00 x
100
Relative DEC ('')
Relative RA ('')
20
0
−20
Contours: 10
−0.075 −0.050
−0.025 0.025
0.050 0.075
0.100 0.125
0.150 0.500