Tutorial examples

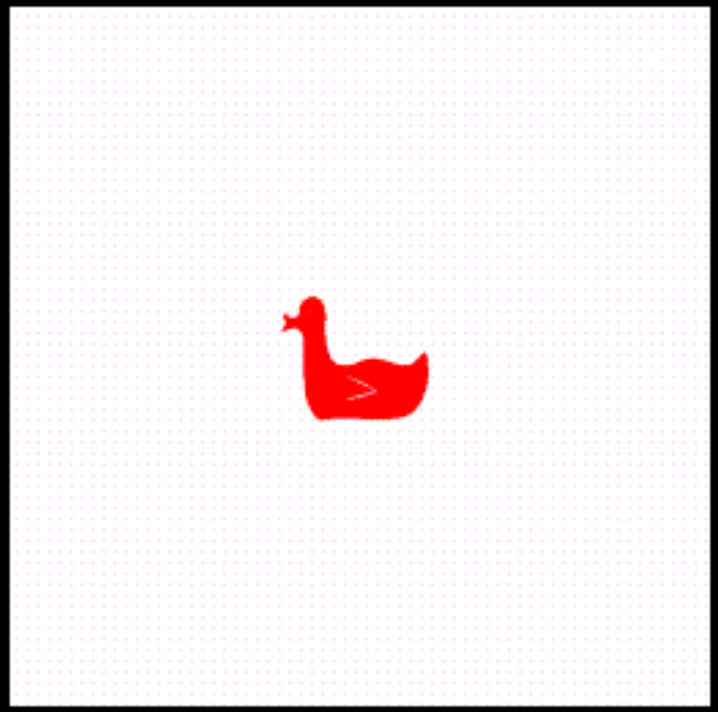
Phil Edwards (ATNF)

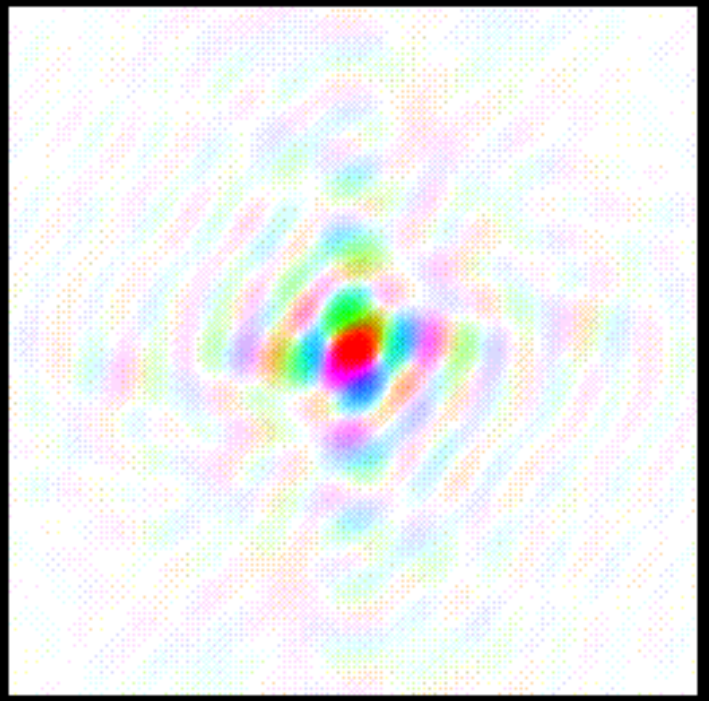
Radio Astronomy School
September 2010

Introduction to Interferometry

- Synthesis Imaging in Radio Astronomy
  - I (1989) ASP Conf. Series vol. 6
  - II (1999) ASP Conf. Series vol. 180
- Interferometry and Synthesis in Radio Astronomy
  - Thompson, Moran & Swenson (2001)
- http://www.atnf.csiro.au/whats_on/workshops/synthesis2008/

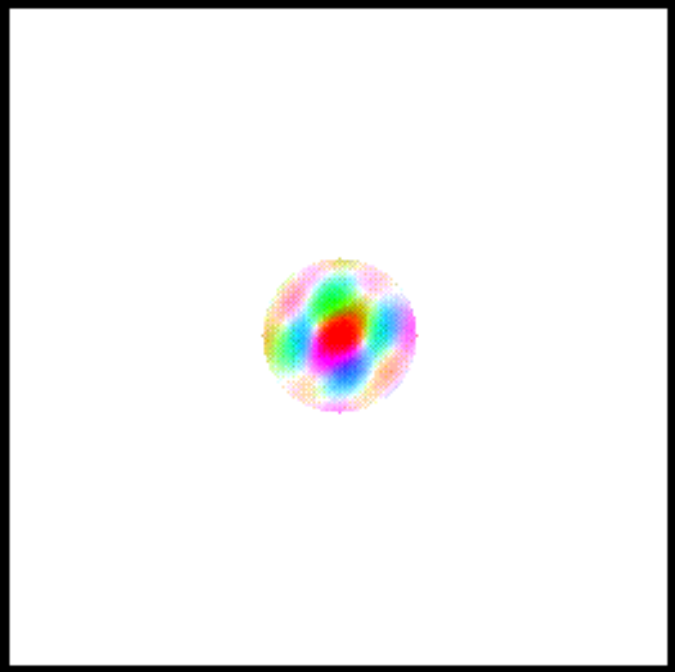
Fourier Transform examples

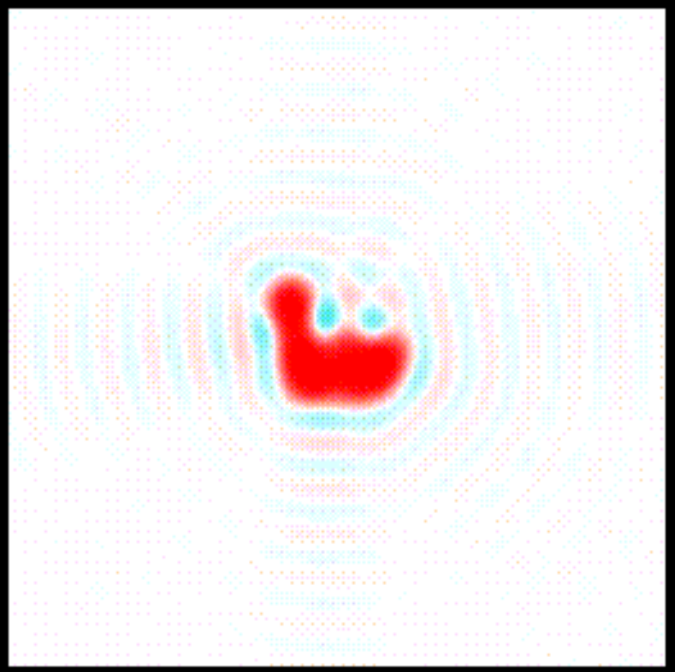




- A duck and its Fourier Transform
- http://www.general.uwa.edu.au/u/vpatrick/fourier/fourier.html

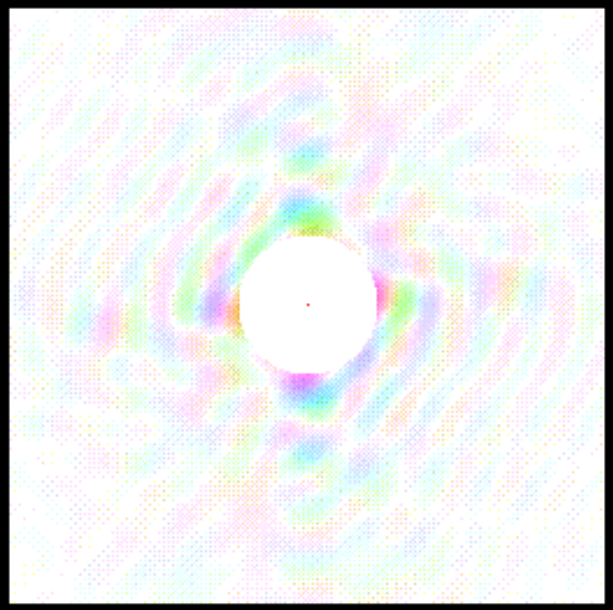
Fourier Transform examples

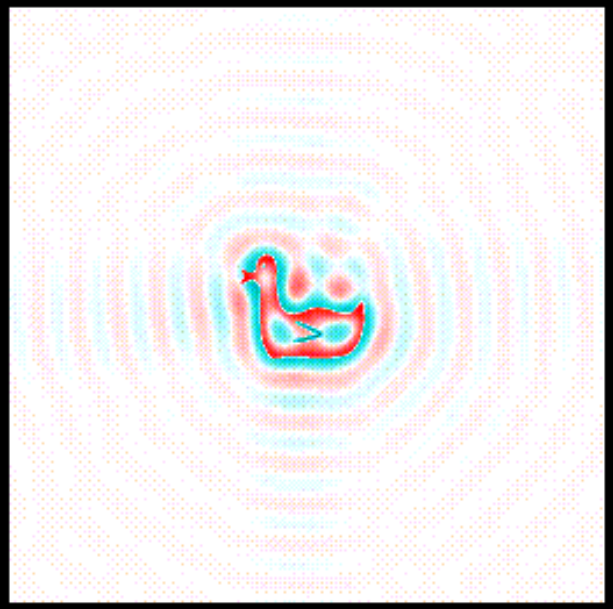




- If we only have the low resolution terms of the diffraction pattern, we only get a low resolution duck
- There is considerable loss of detail. Note the ripples around the duck.

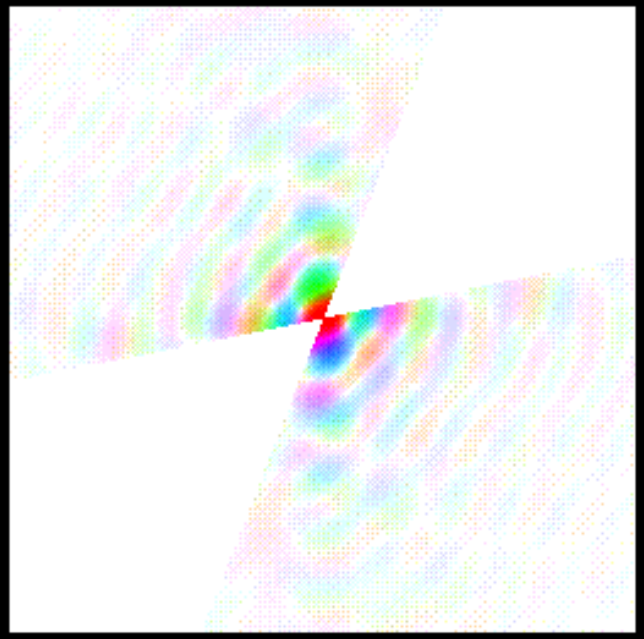
Fourier Transform examples

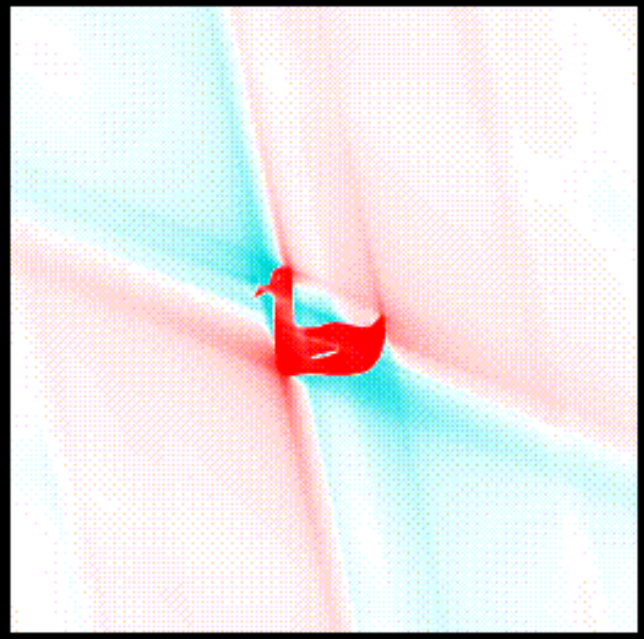




- If we only have the high resolution terms of the diffraction pattern, we see only the edges of the duck
- Do not omit your low resolution data. Collect it and use it!

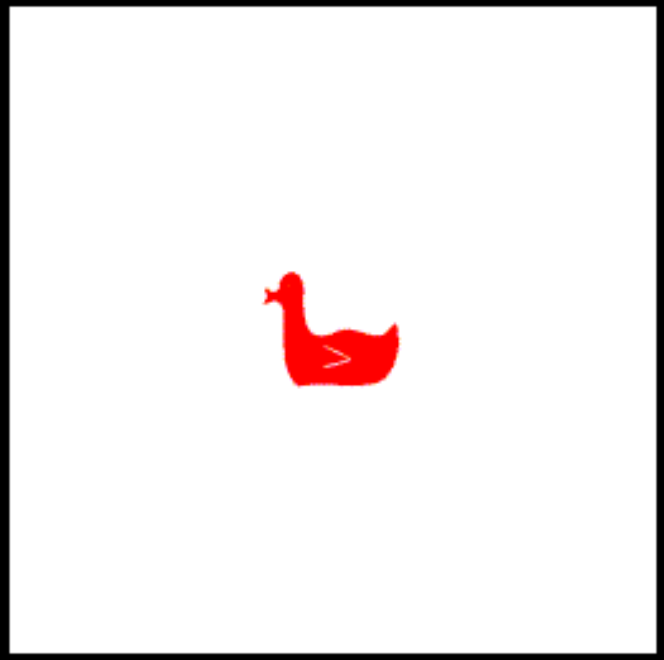
Fourier Transform examples

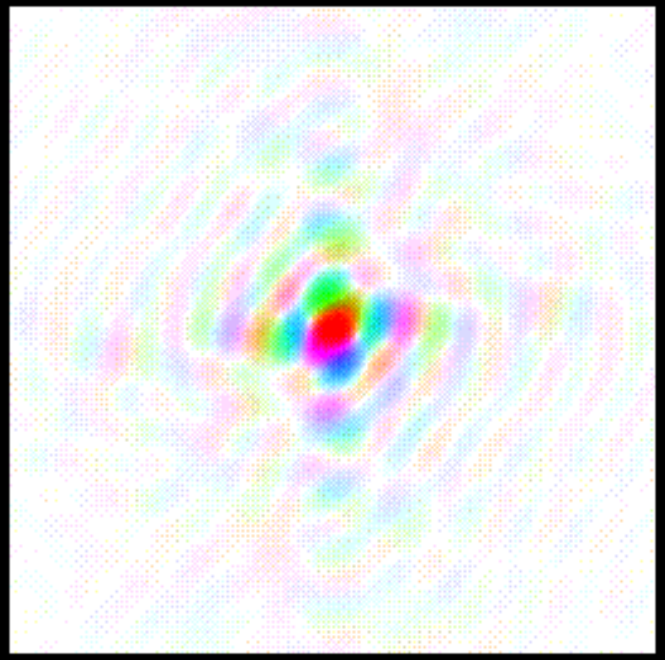




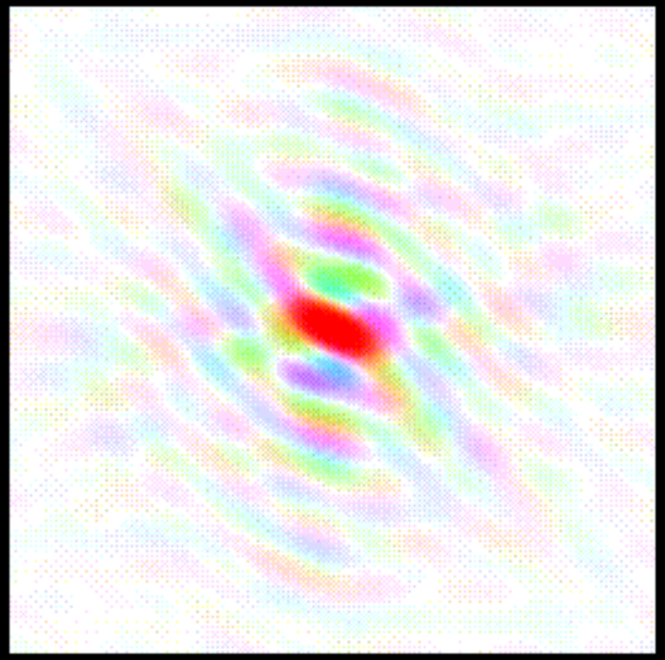
- If a segment of data is missing, features perpendicular to that segment will be blurred.

The duck and its FT

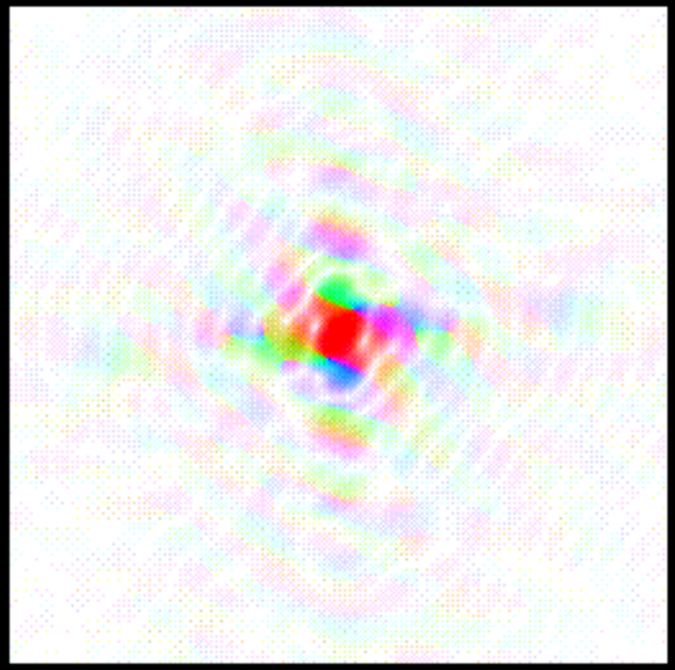




A cat and its FT



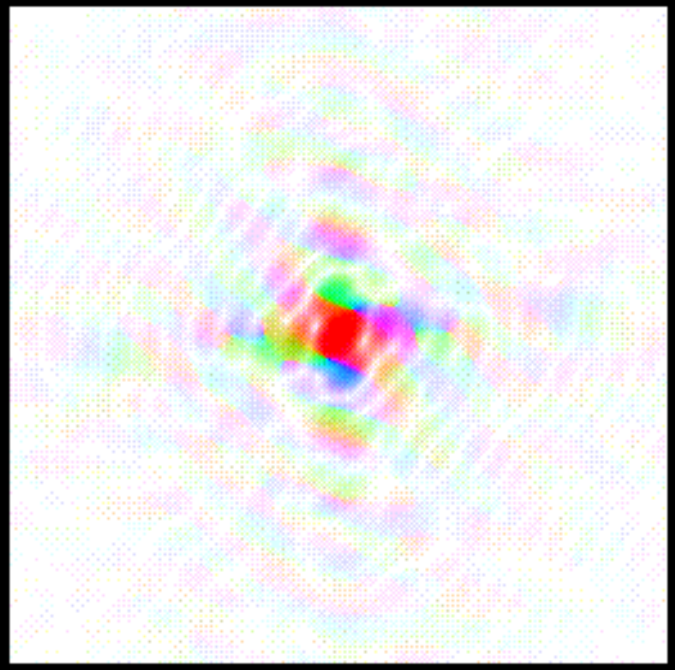
Fourier Transform examples

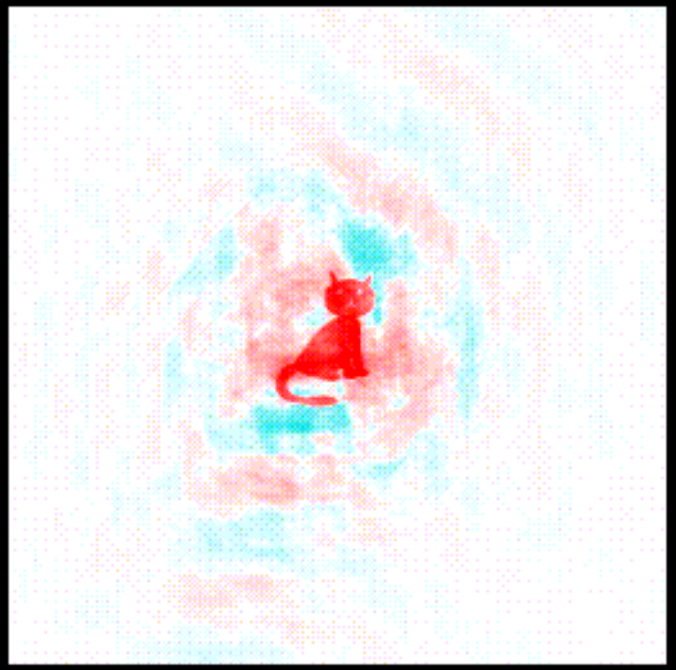


FT = ?

- Let us combine the magnitudes from the Duck transform with the phases from the Cat transform.

Fourier Transform examples





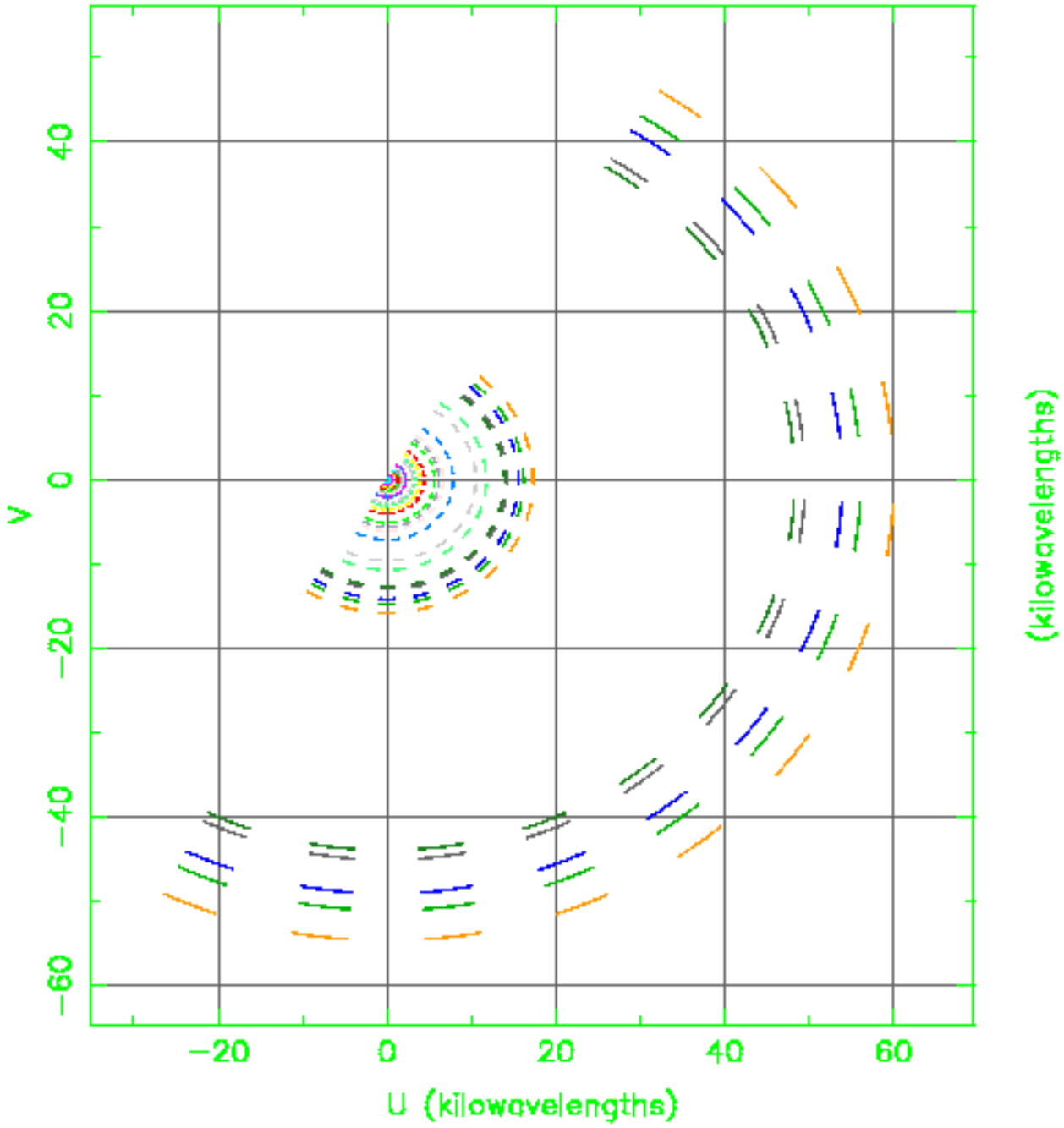
- Let us combine the magnitudes from the Duck FT with the phases from the Cat FT.
- The image which contributed the phases is still visible, whereas the image which contributed the magnitudes has gone!

“Anthropomorphism” in Astronomy

- Snake
  - ApJ 443, 638 (1995); ApJ, 462, 768 (1996)
- Kookaburra
  - ApJ 561,L187 (2001)
- Rabbit
  - ApJ 515, 712 (1999)
- Duck
  - ApJ 573, L111 (2002); ApJ 652,1523 (2006)
- CaT
  - MNRAS 393, 846 (2009)

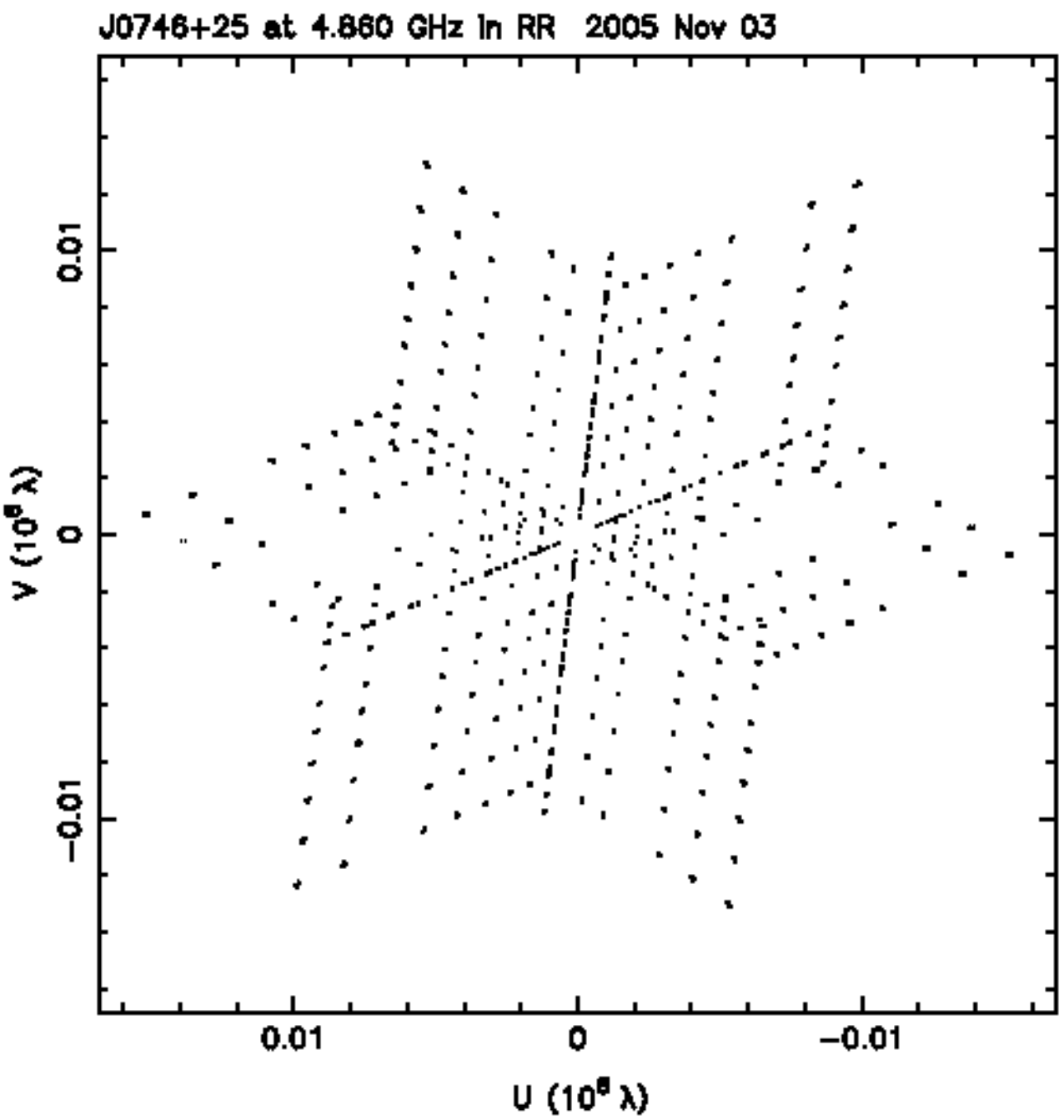
Next exercise

- Look at the following three (u,v) coverages and determine what kind of array was used to make the observation


40
20
0
−20
−40
−60
V
−20
0
20
40
60
U (kilowavelengths)
(kilowavelengths)

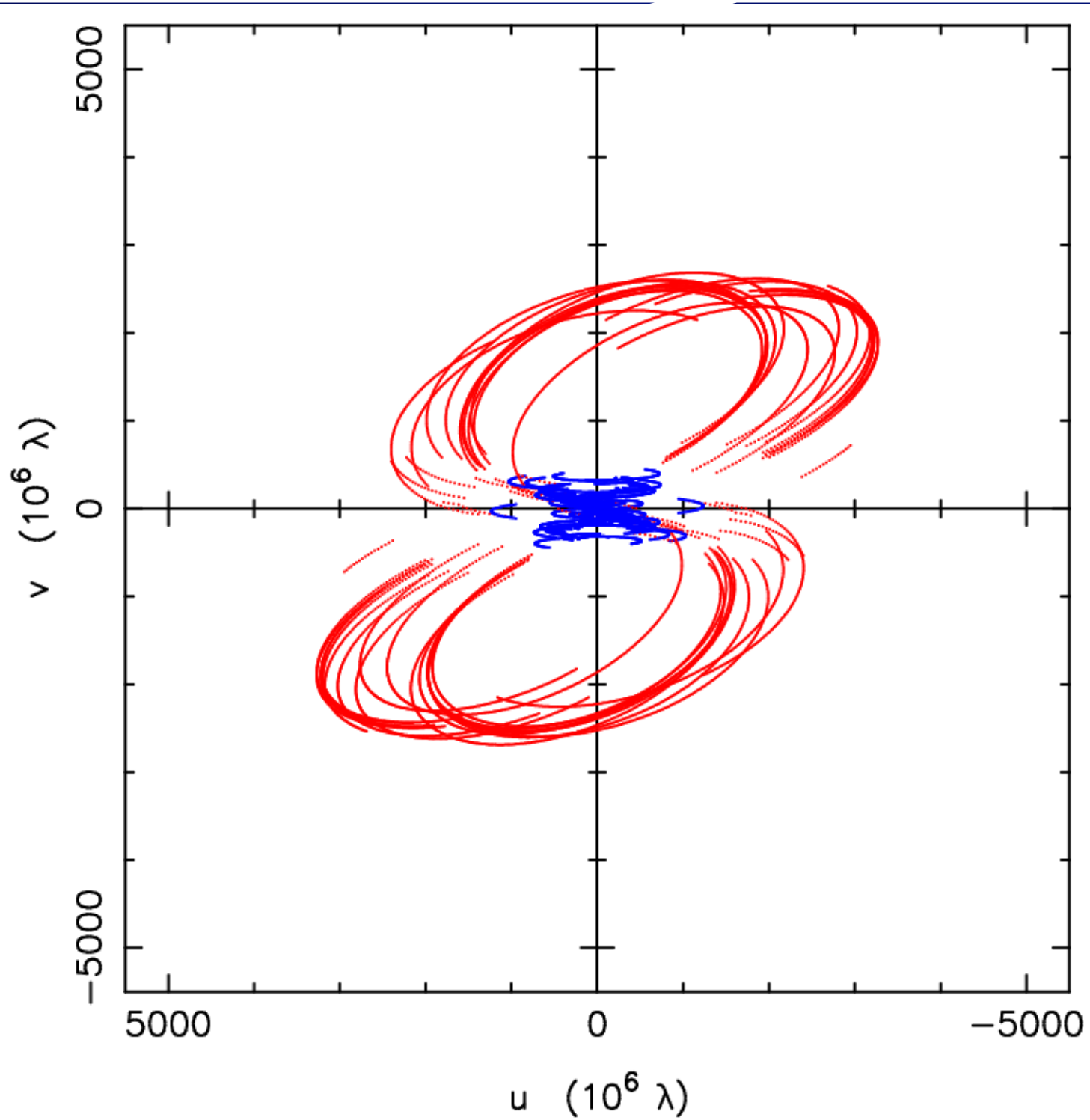
Answer

- This (u,v) coverage is from a 12 hour observation with the ATCA, with frequency switching every 30 minutes between lower frequencies -- (u,v) tracks closer to the origin – and higher frequencies, with (u,v) tracks more distant from the origin. Only half the (u,v) plan is shown in this example.


J0746+25 at 4.860 GHz In RR 2005 Nov 03
0.01
0
−0.01
V (10^6 λ)
0.01
0
−0.01
U (10^6 λ)

Answer

- This (u,v) coverage is from a snapshot (several minutes only) observation with the VLA. Looking closely, you can see some gaps in the (u,v) coverage, indicating that not all 27 antennas were used for this observation.

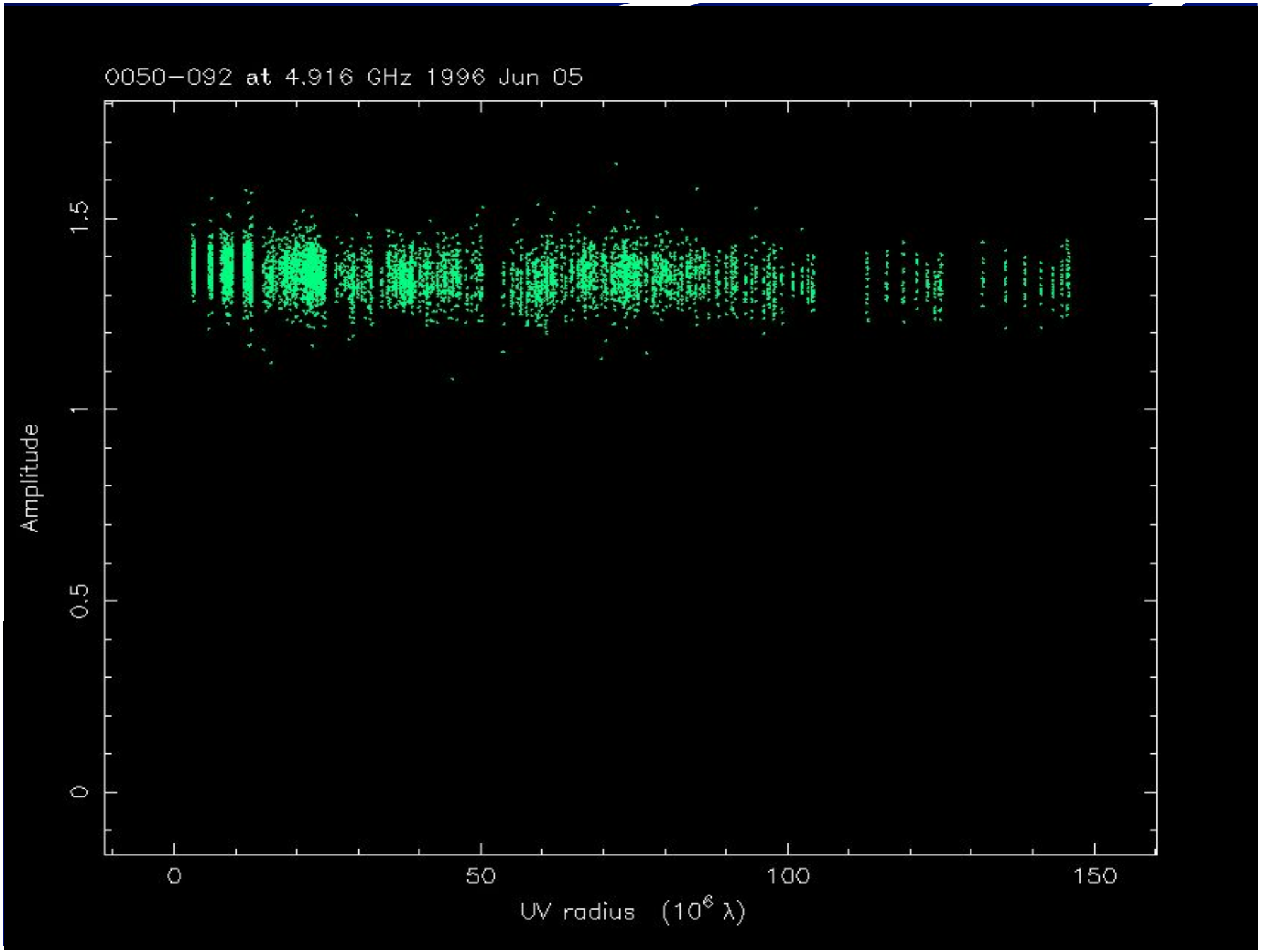

5000
0
−5000
v (10^6 λ)
5000
0
−5000
u (10^6 λ)

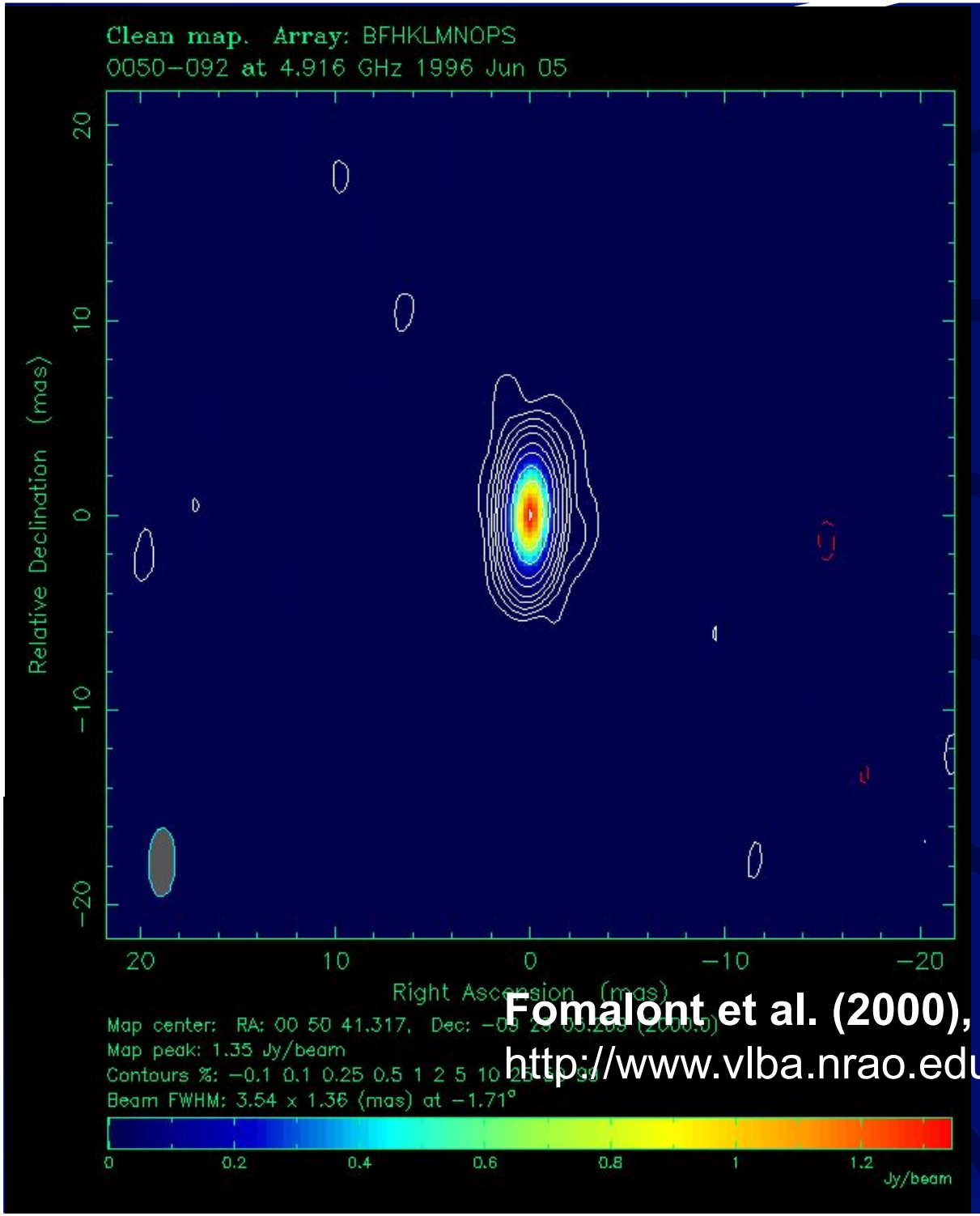
Answer

- This is a trickier one! A big clue comes from the scale of the u and v axes. Unlike the previous two examples, with axes in 10's of kilo-lambda, this example is in giga-lambda! It is the (u,v) coverage from a simulated space VLBI observation, with ground-ground baselines in blue, and ground-space baselines in red.

More examples

- Now let's do some Fourier Transforms in our head!
- The following examples show the amplitude of the correlated flux density as a function of (u,v) radius projected onto the u-axis.
- The Fourier Transforms of these visibilities (amplitude and phase) gives the source structure


0050−092 at 4.916 GHz 1996 Jun 05
Amplitude
0
0.5
1
1.5
0
50
100
150
UV radius (10^6 λ)



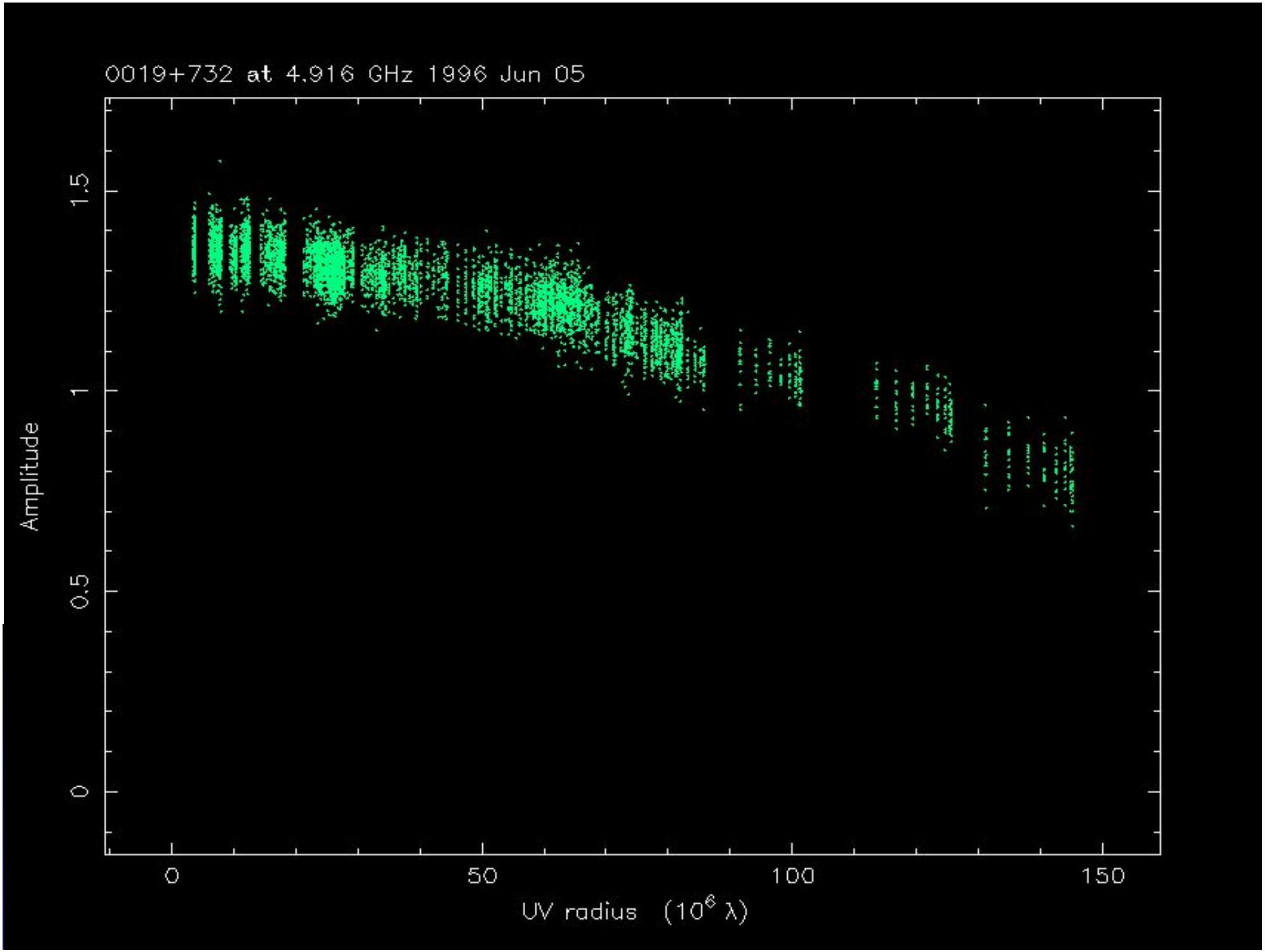
A point source
(at this resolution)

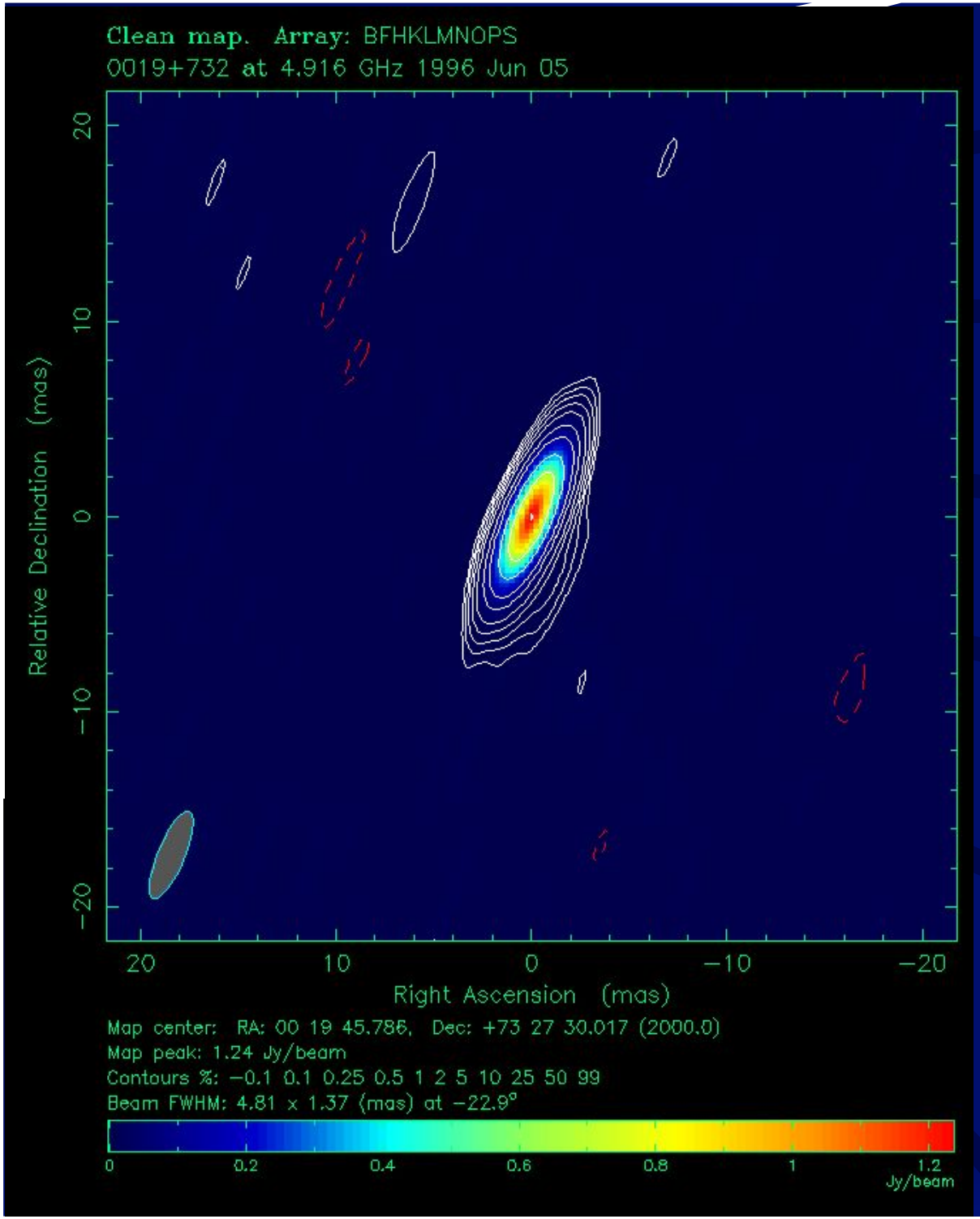
Map peak .135 Jy/beam

Model-fit:
1.35 Jy
a < 0.6 mas
b < 0.2 mas

a & b are semi-major and semi-minor axes of a gaussian fit

Fomalont et al. (2000), ApJS, 131, 95
http://www.vlba.nrao.edu/astro/obsprep/sourcelist/6cm/

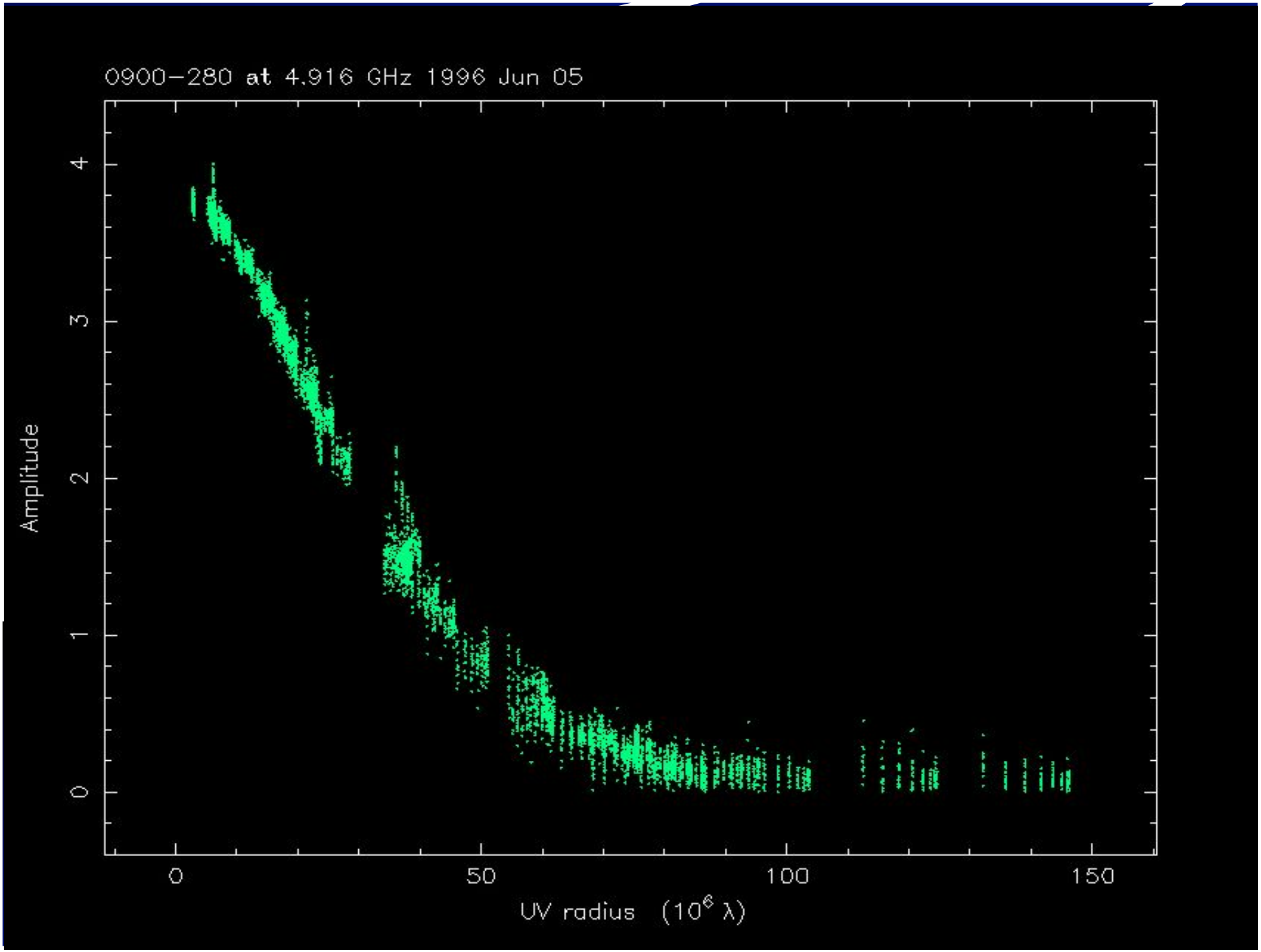

0019+732 at 4.916 GHz 1996 Jun 05
Amplitude
0
0.5
1
1.5
0
50
100
150
UV radius (10^6 λ)

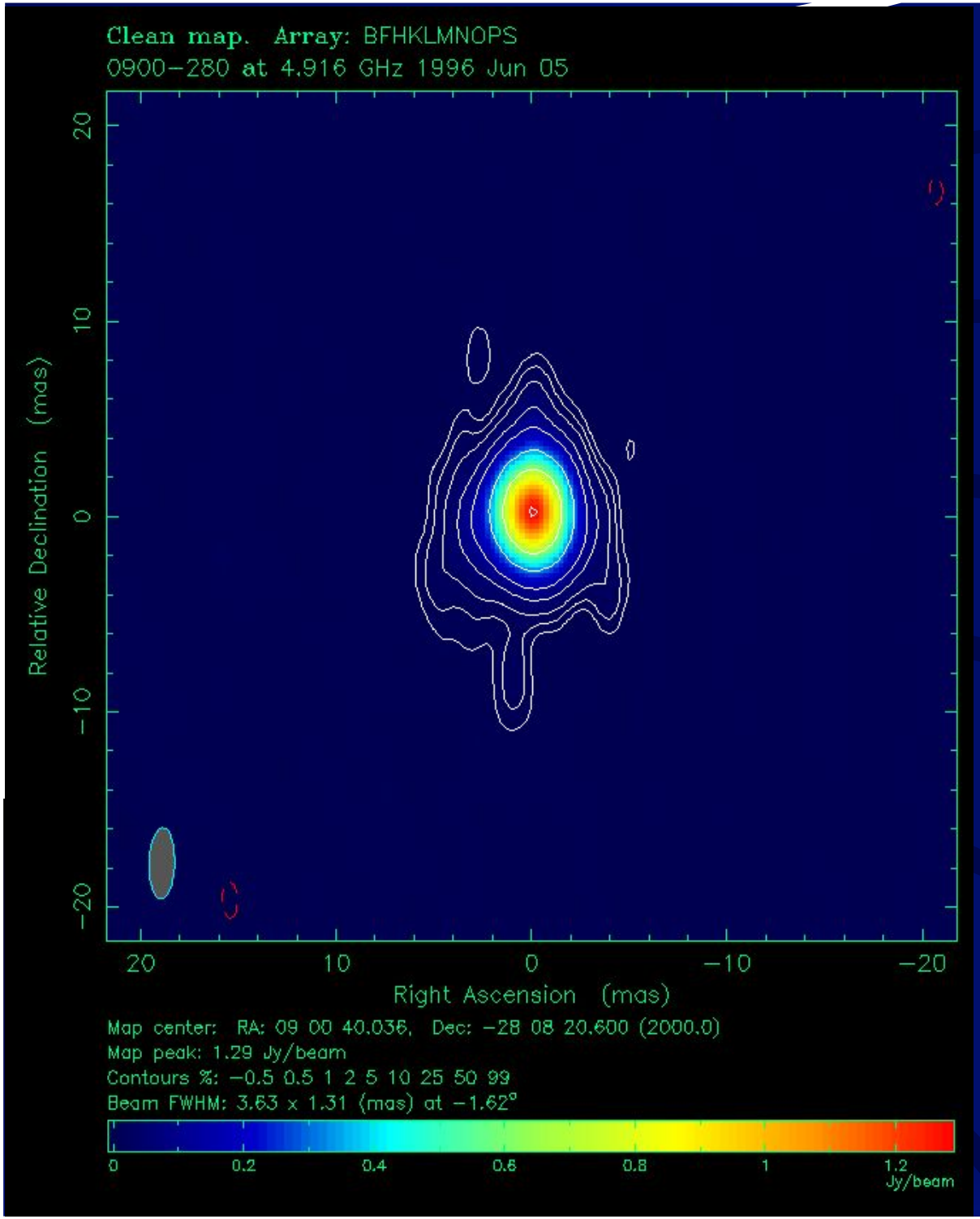


Partially resolved

Map peak 1.24 Jy/beam

Model:
1.33 Jy
a = 0.7 mas
b < 0.3 mas

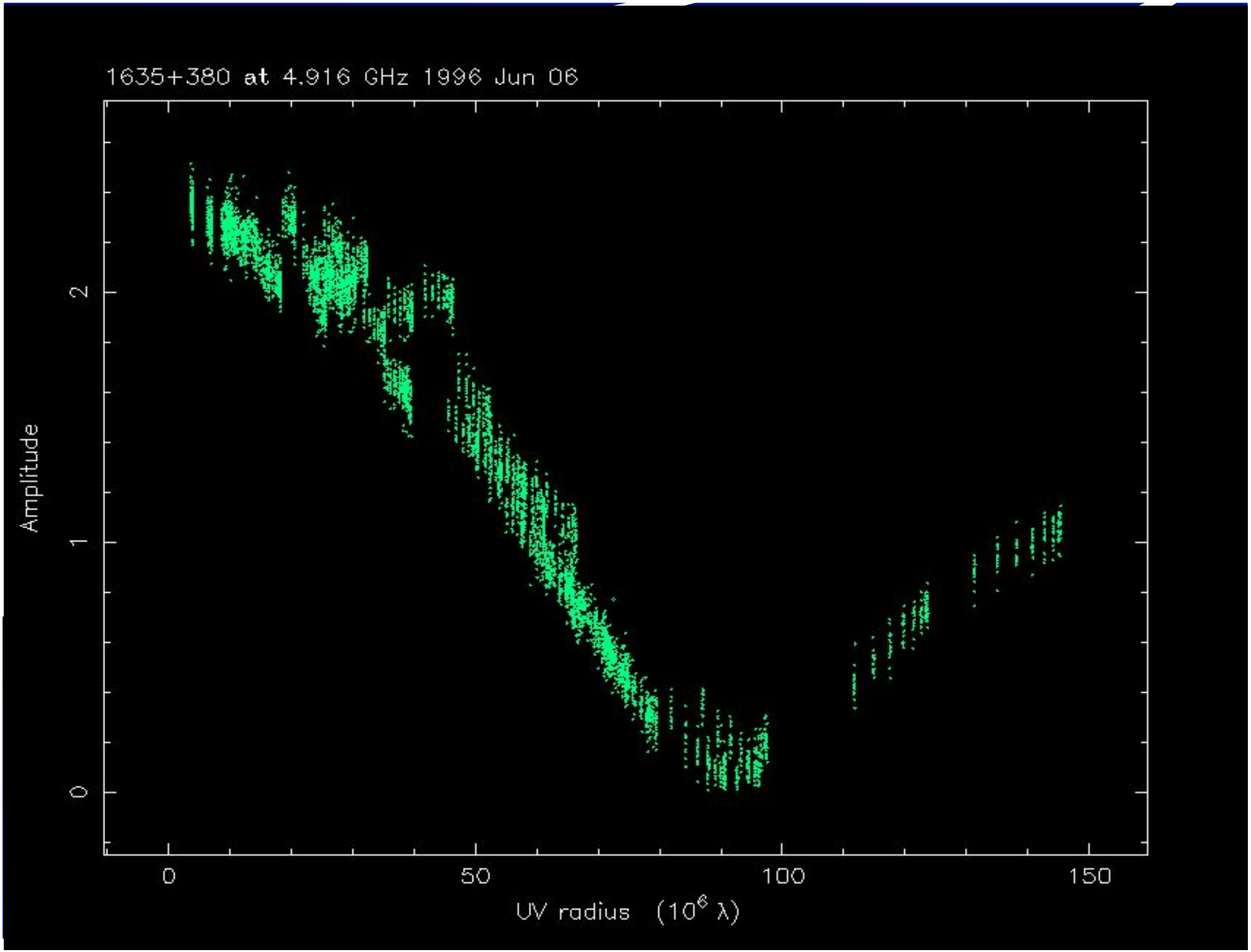

0900−280 at 4.916 GHz 1996 Jun 05
Amplitude
0
1
2
3
4
0
50
100
150
UV radius (10^6 λ)

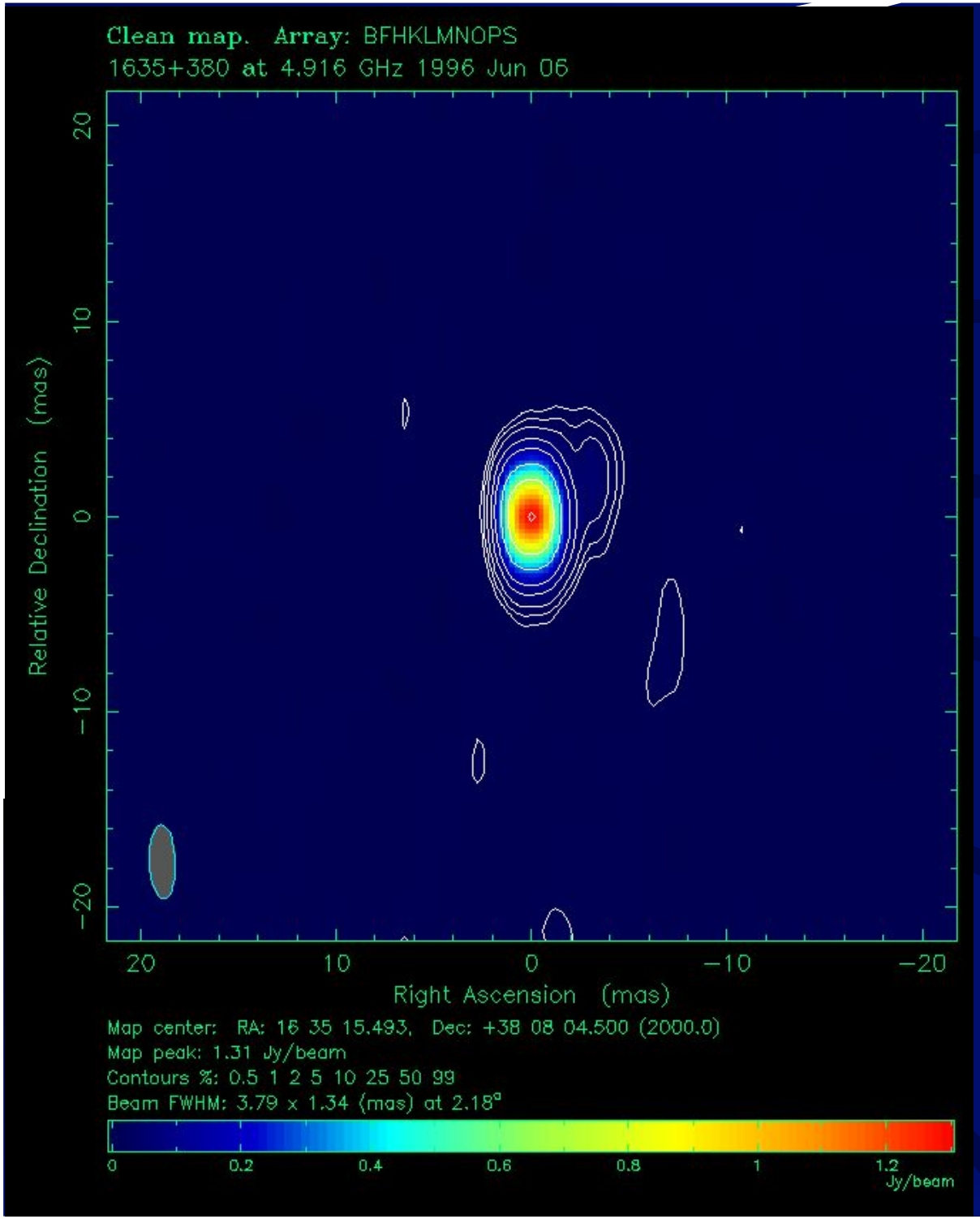


Resolved out on longest baselines

Map peak 1.3Jy/beam

Model:
3.7 Jy
a = 2.8 mas
b = 1.9 mas


1635+380 at 4.916 GHz 1996 Jun 06
Amplitude
0
1
2
0
50
100
150
UV radius (10^6 λ)



A close double

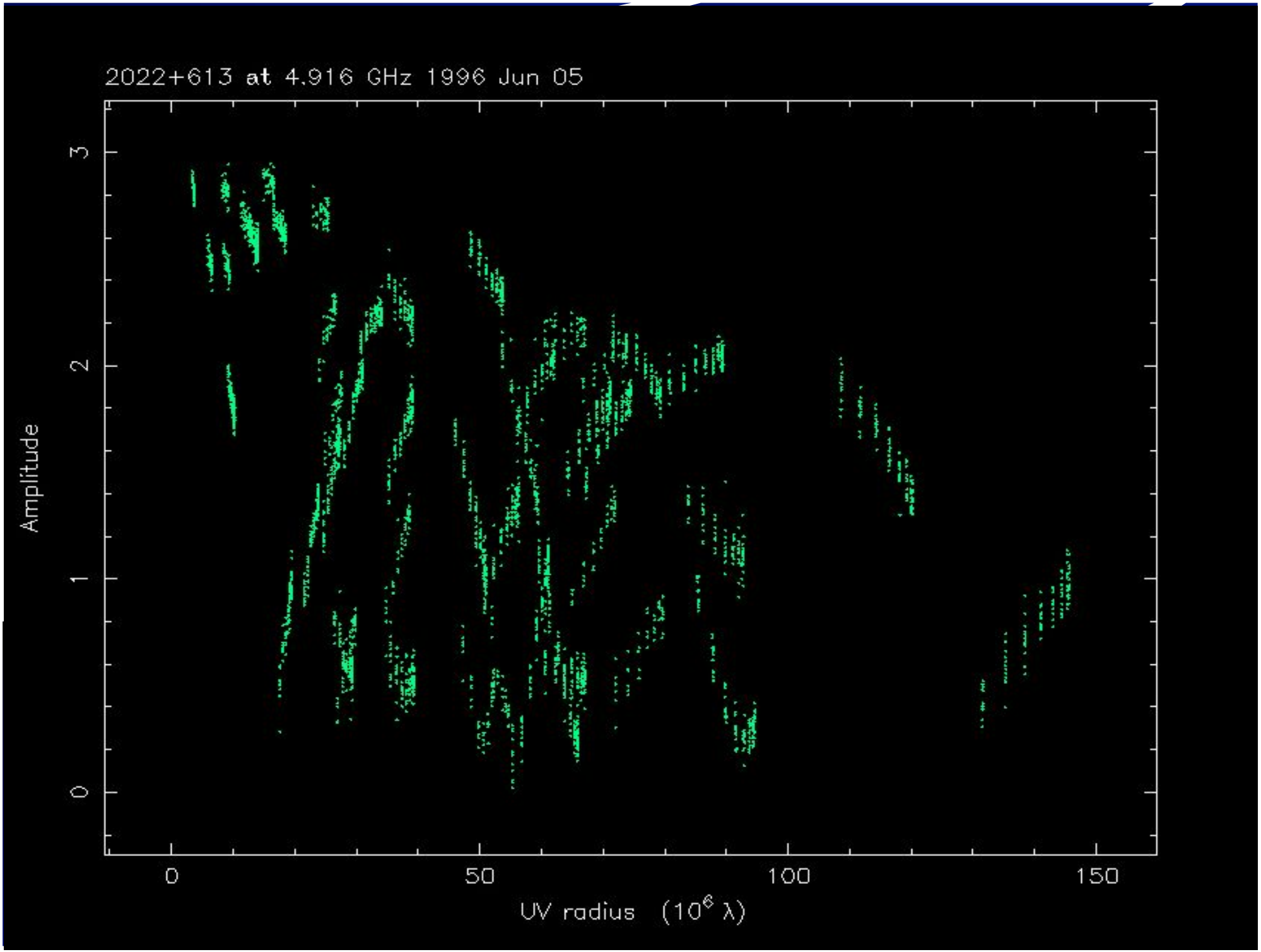
Map peak 1.3 Jy/beam

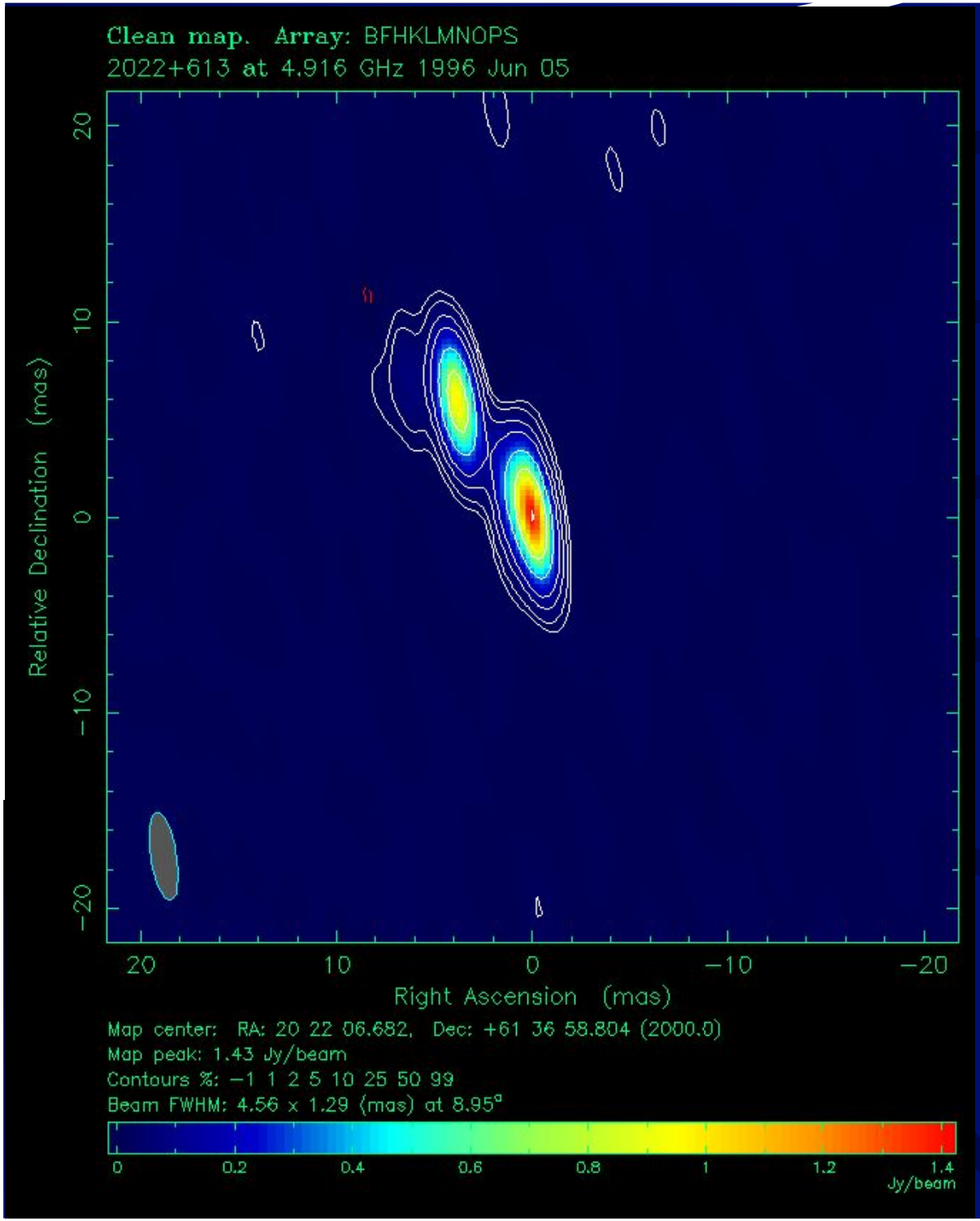
Model:

(i) 1.4 Jy
a = 0.9 mas
b < 0.3 mas

(ii) 0.8 Jy
a < 0.7 mas
b < 0.3 mas

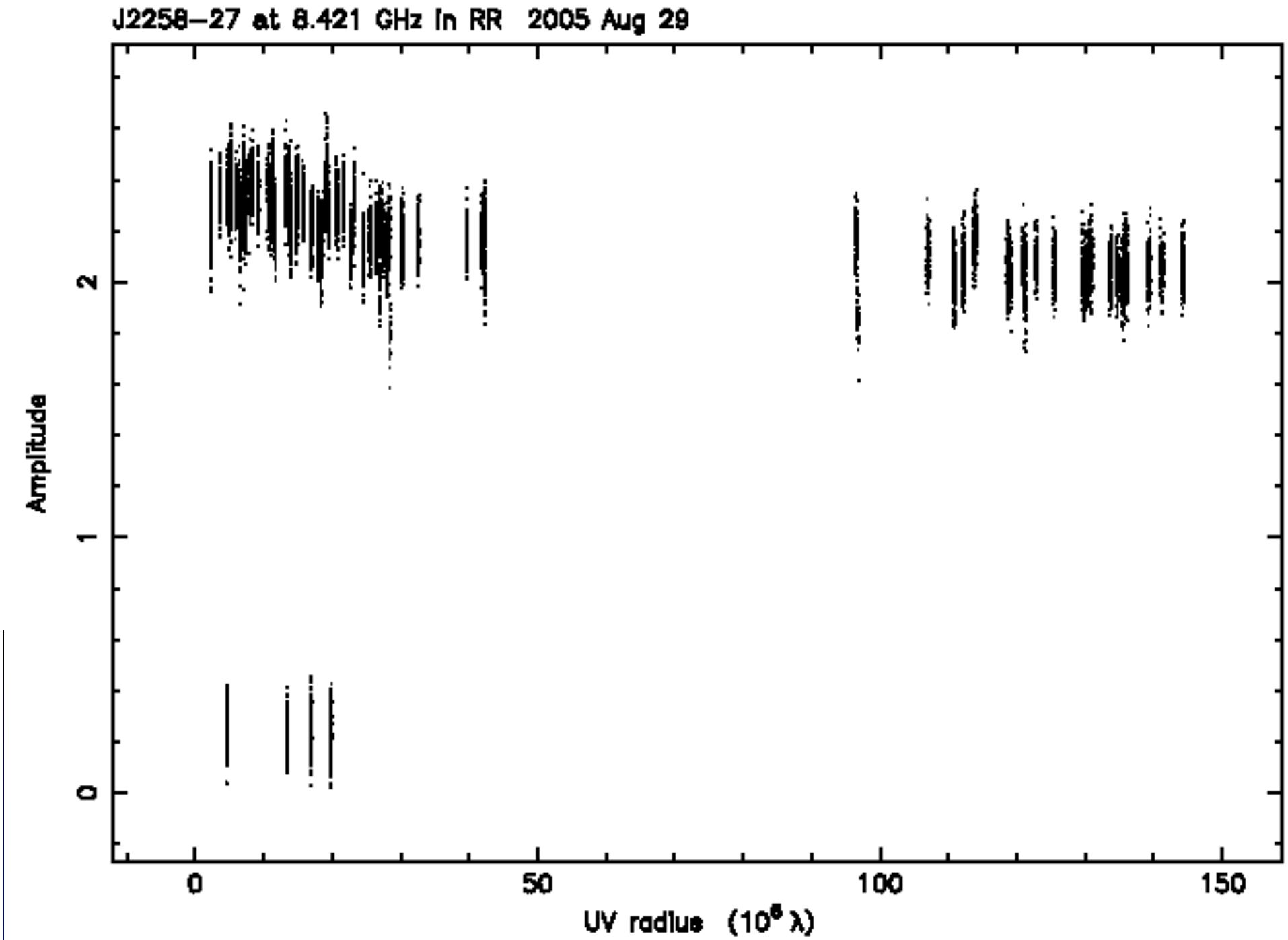
Separation 1.1 mas


2022+613 at 4.916 GHz 1996 Jun 05
Amplitude
0
1
2
3
0
50
100
150
UV radius (10^6 λ)



Impossible to do the FT in your head in this case – the source is more complex and the visibilities are not projected on the best axis to infer the structure.

Sometimes it is necessary to image the source with software!

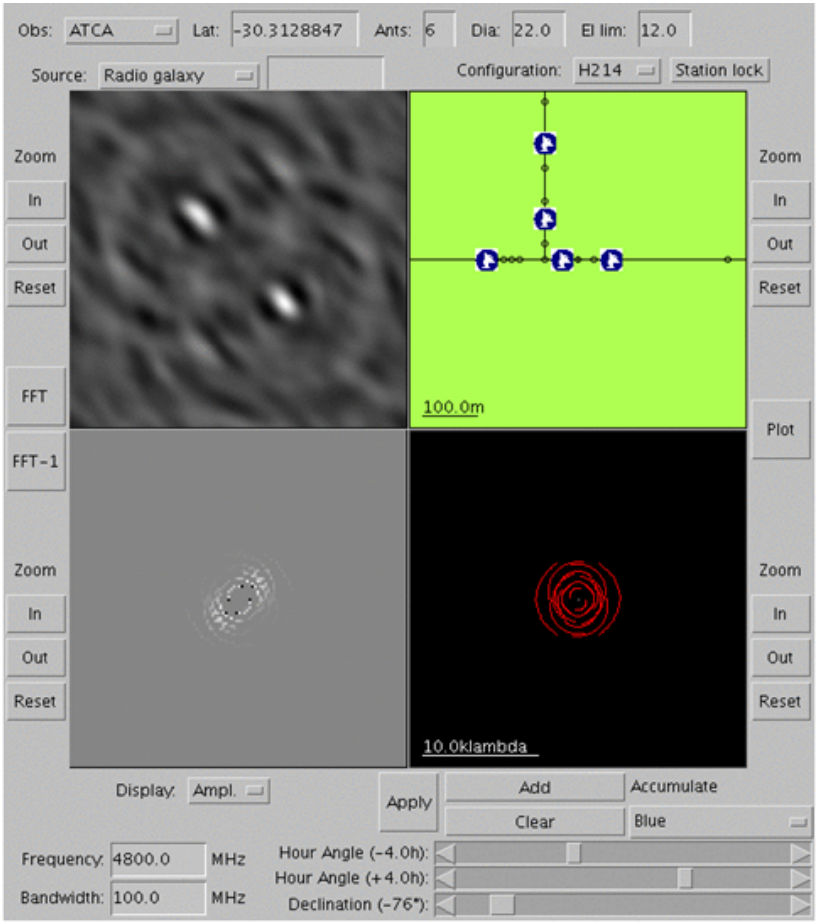

J2258−27 at 8.421 GHz In RR 2005 Aug 29
Amplitude
0
1
2
0
50
100
150
UV radius (10^6 λ)

Answer

- This was a trick question: the low amplitude points at small (u,v) distances need to be flagged, or edited out in this case, and probably arise because one antenna was late slewing to the source. With those points edited out, the source appears to be dominated by a point source, but with some lower level extended structure visible on the shortest baselines.

VRI

- VRI, the virtual radio interferometer
  - Type vri in searchbox on ATNF website or the URL link below
  - Lets you experiment with Fourier transforms and ATCA configurations



http://www.narrabri.atnf.csiro.au/astronomy/vri.html