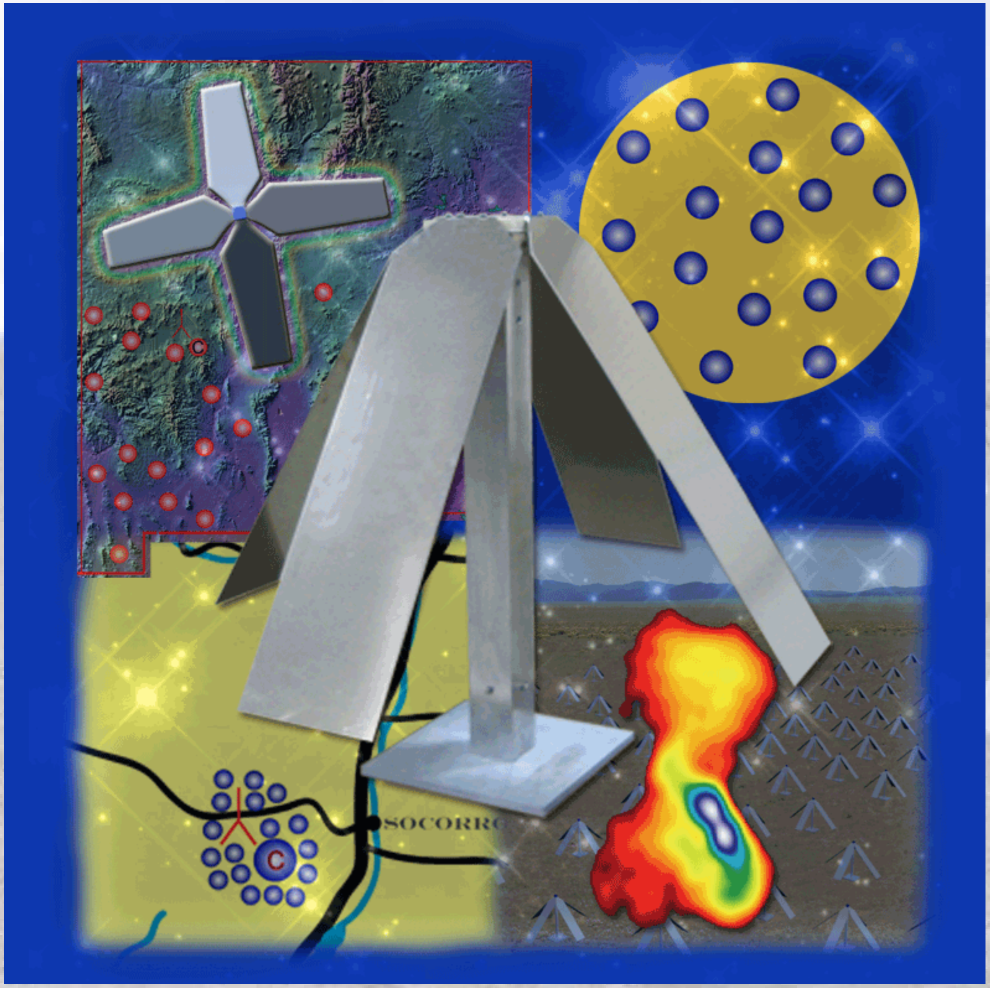
# *Simulations for the Long Wavelength Array*

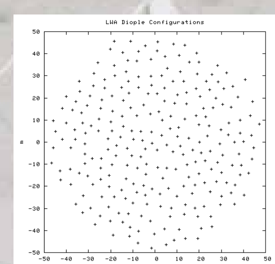
Masaya kuniyoshi (UNM), Sanjay Bhatnagar (NRAO), Greg Taylor (UNM)

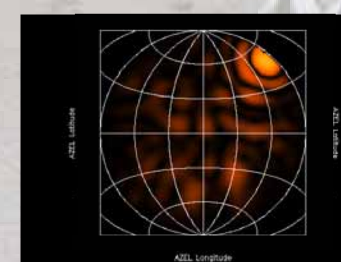
(The LWA Project collaboration)

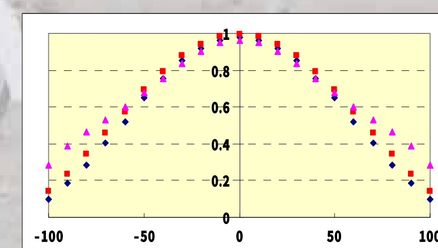


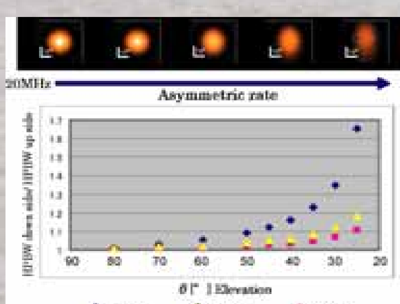
# Outline

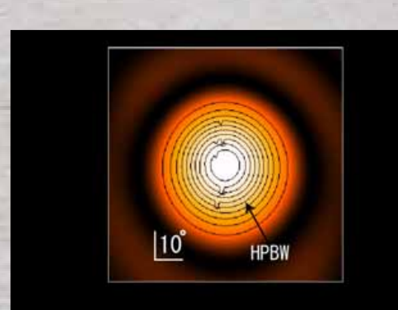
1. Long Wavelength Array
2. LWA station beam
   - Elliptical beam
   - Asymmetric beam
   - Pointing error
3. LWA imaging simulation
4. Summary

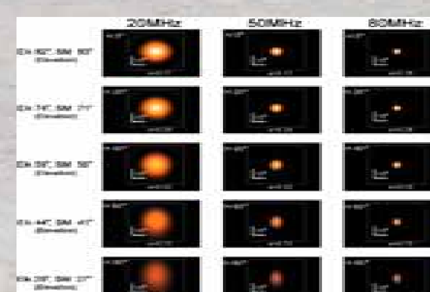






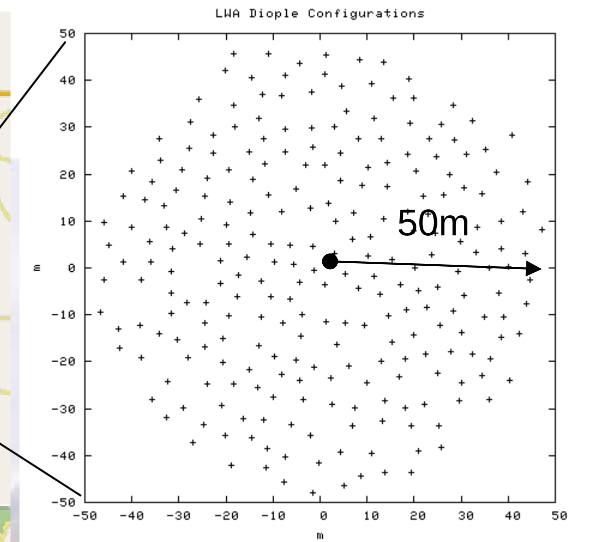




# Long Wavelength Array (LWA)

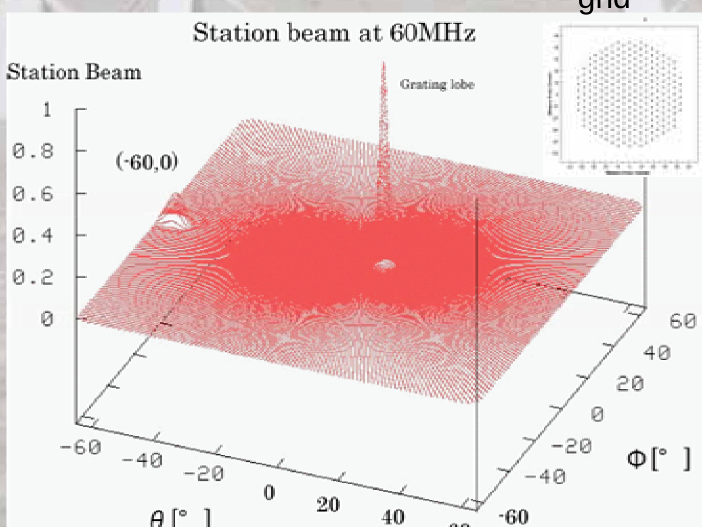


Distribution of 53 LWA stations

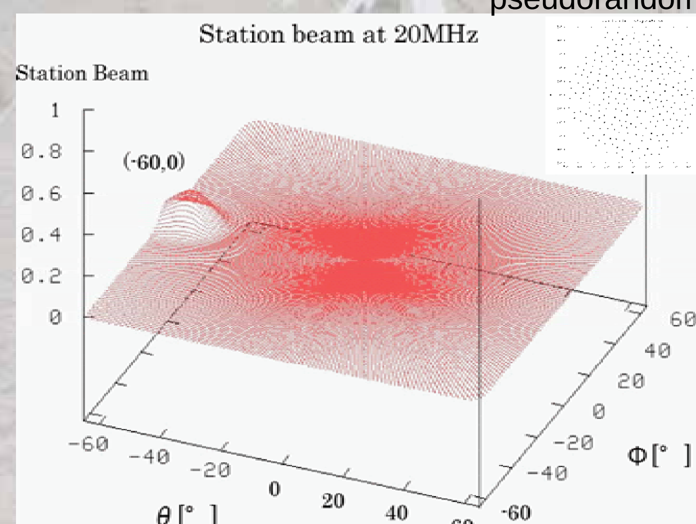



Dipole configuration in one station
(L.Kogan and A.Choen)

grid




pseudorandom



# Need for a simulator to analyze the LWA

LWA station beam reception pattern

→ A LWA station beam changes with elevation angles.

CASA

Common Astronomy Software Applications

Many many useful modules

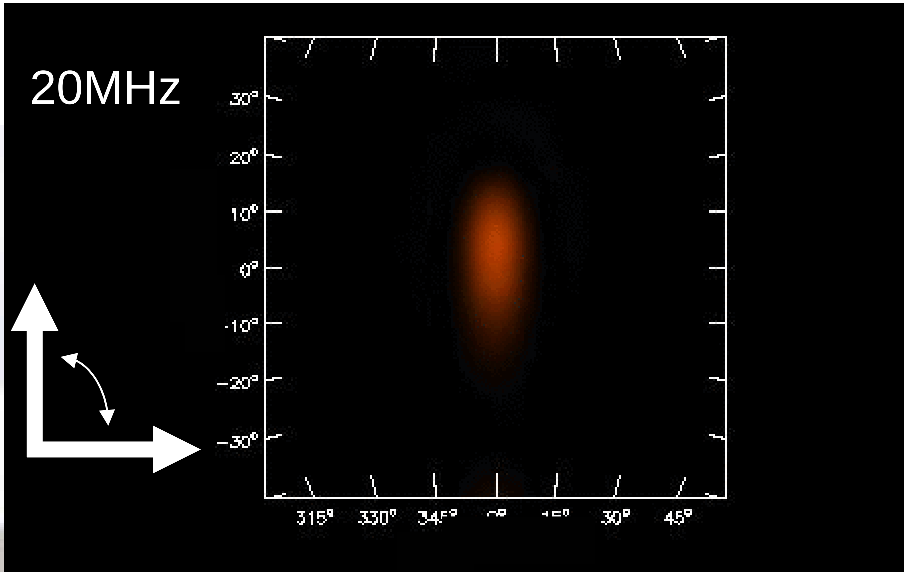
The beam patterns of VLA, ALMA,GBT,,, are already in CASA.

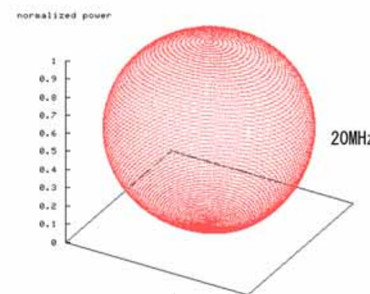
simulator.simulator - Function
simulator.open - Function
simulator.openfromms - Function
simulator.close - Function
simulator.done - Function
simulator.name - Function
simulator.summary - Function
simulator.type - Function
simulator.settimes - Function
simulator.observe - Function
simulator.setlimits - Function
simulator.setauto - Function
simulator.setconfig - Function
simulator.setknownconfig - Function
simulator.setfeed - Function
simulator.setfield - Function
simulator.setmosaicfield - Function
simulator.setspwindow - Function
simulator.setdata - Function
simulator.predict - Function
simulator.setoptions - Function
simulator.setvp - Function
simulator.corrupt - Function
simulator.reset - Function
simulator.setbandpass - Function
simulator.setgain - Function
simulator.setpointingerror - Function
simulator.setleakage - Function
simulator.setnoise - Function
simulator.setpa - Function
simulator.setseed - Function

1.1 images - Module images
.1 image - Tool

measures.observatory - Function
measures.obslist - Function
measures.linelist - Function
measures.spectralline - Function
measures.sourcelist - Function
measures.source - Function
measures.frequency - Function
measures.doppler - Function
measures.radialvelocity - Function
measures.uvw - Function
measures.touvw - Function
measures.expand - Function
measures.earthmagnetic - Function
measures.baseline - Function
measures.asbaseline - Function
measures.listcodes - Function
measures.measure - Function
measures.doframe - Function
measures.framenow - Function
measures.showframe - Function
measures.toradialvelocity - Function
measures.tofrequency - Function
measures.todoppler - Function
measures.torestfrequency - Function
measures.rise - Function
measures.riseset - Function
measures.posangle - Function
measures.separation - Function
measures.addxvalue - Function

# Station Primary Beam



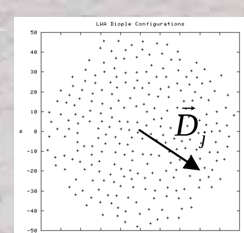




Big Blade power pattern (BBP) with ground screen 3m x 3m (N. Paravastu)

$$A(\theta,\phi) = \sum_{k=1}^{ch} EE^*$$

$$E_k(\theta,\phi) = \sum_{j=1}^{256} \Delta\nu \exp(is_j\nu_k) \frac{\sin(s_j \frac{\Delta\nu}{2})}{(s_j \frac{\Delta\nu}{2})} \cdot \sqrt{BBP(\theta,\phi)}$$

$$s_j = \frac{2\pi}{c} \vec{D}_j \cdot (\vec{a} - \vec{b})$$

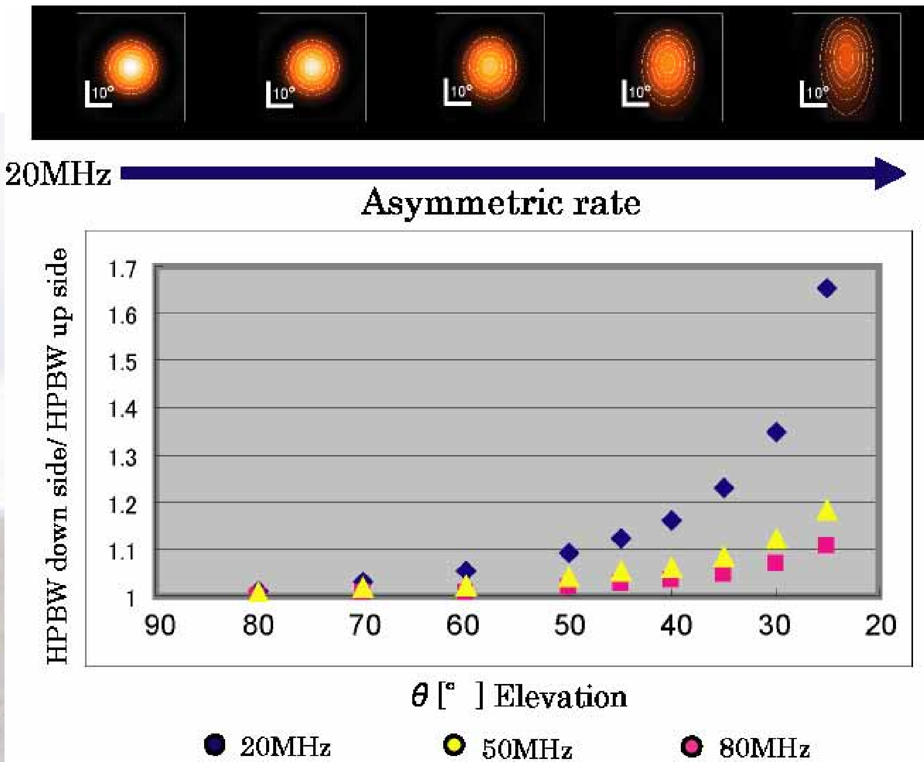


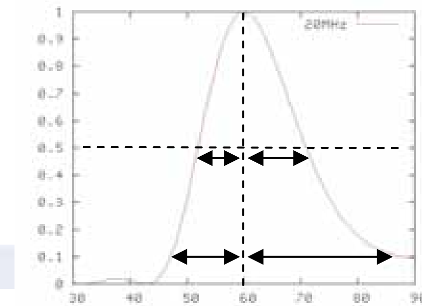

$$\Delta\nu = \frac{Bandwidth}{channel}$$

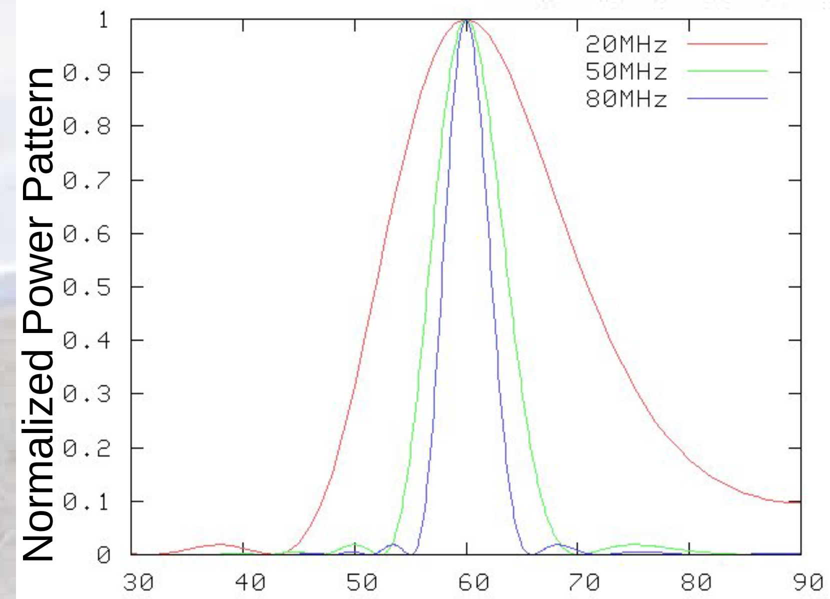
$\vec{a}$ (unit vector)

$\vec{b}$ (unit vector with a direction where the station beam is trained.)

# Asymmetric Station Beam

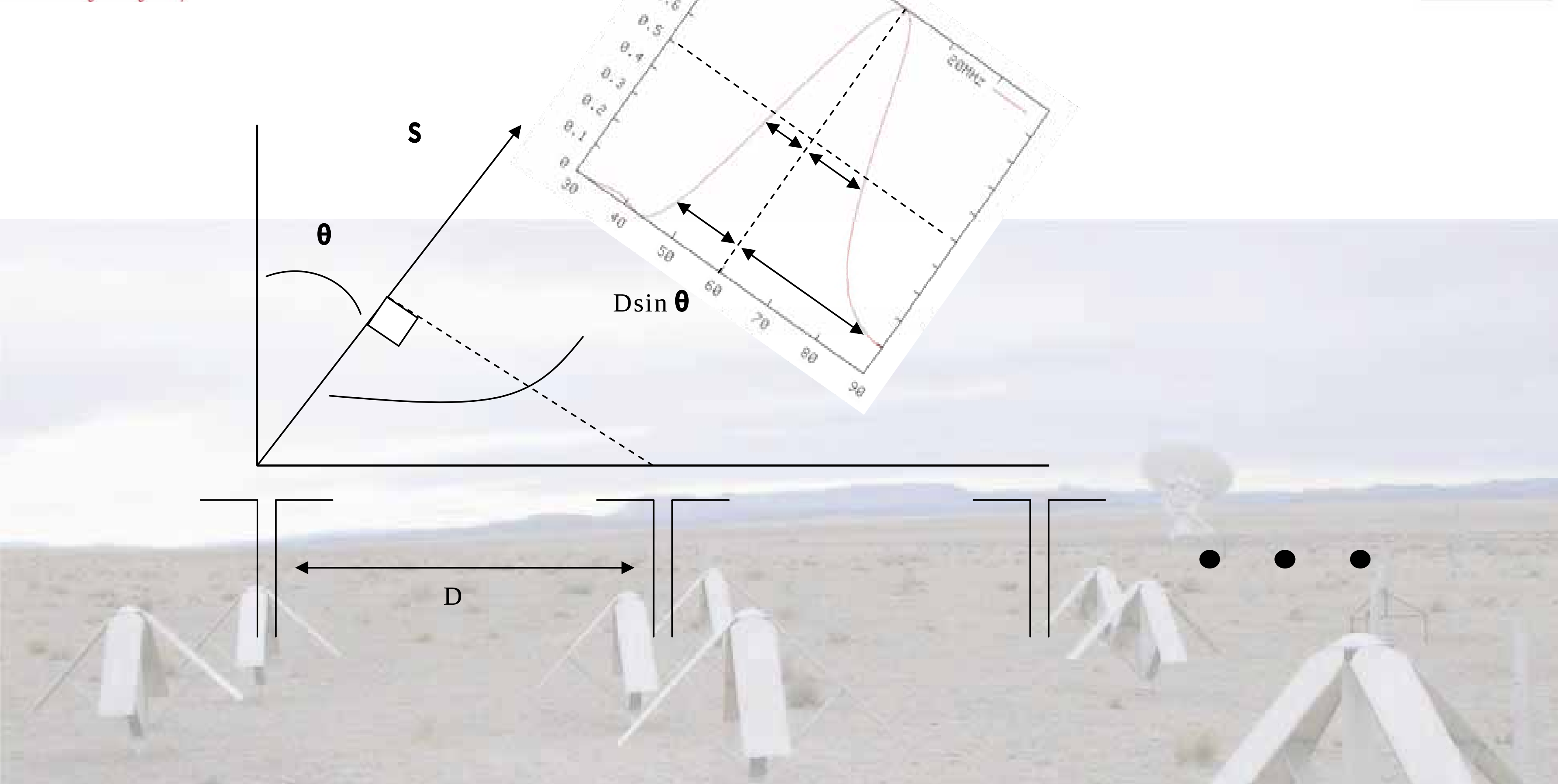


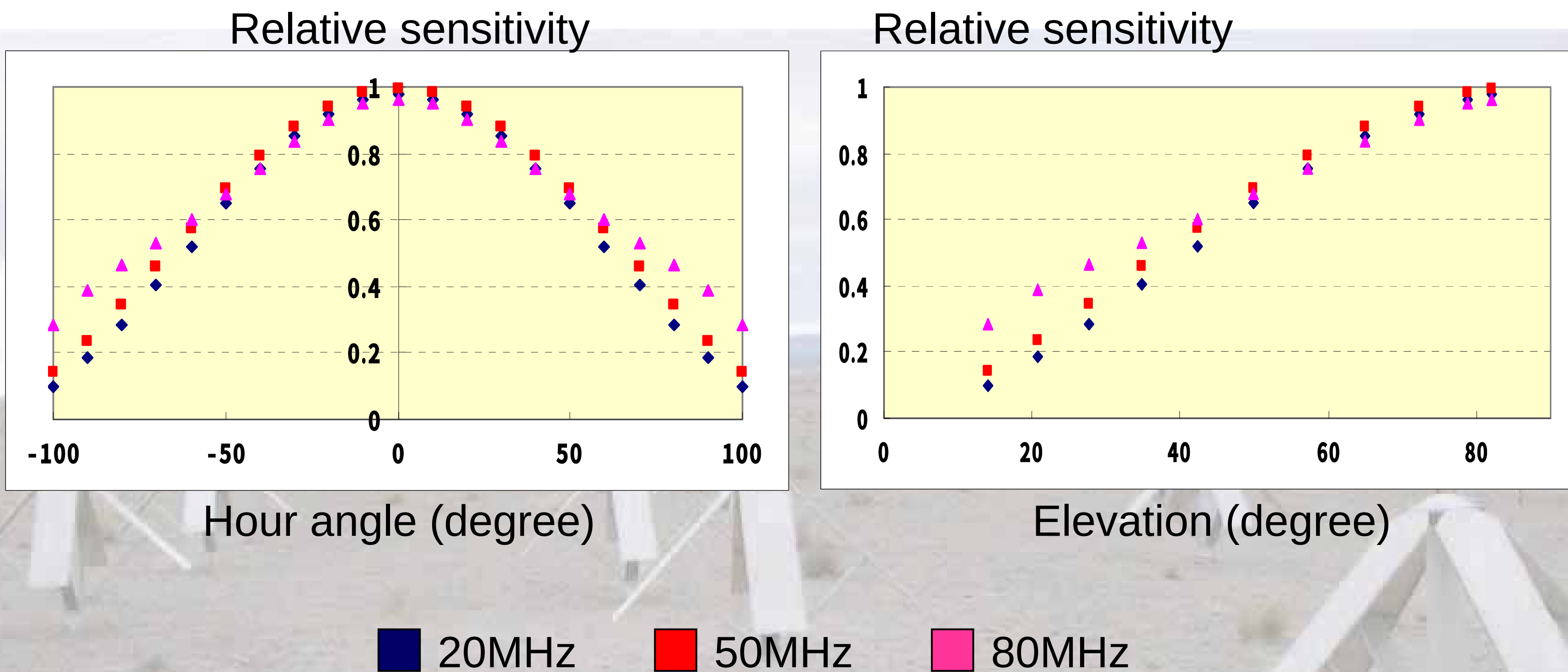

θ [ ° ] (angle form zenith)

The left graph shows the longitudinal asymmetry of a station beam as a function of elevation at 20MHz, 50MHz and 80MHz. A transverse direction of the beam is always symmetric. A station beam becomes asymmetric as the elevation decreases. The asymmetric effect becomes stronger as the observing frequency becomes lower.




As the angle $\theta$ goes from 0 to $\pi/2$,
the value of cos $\theta$ (differentiation of sin $\theta$) gets smaller.
As a result, the beam becomes asymmetric.
This effect increases as the frequency decreases.

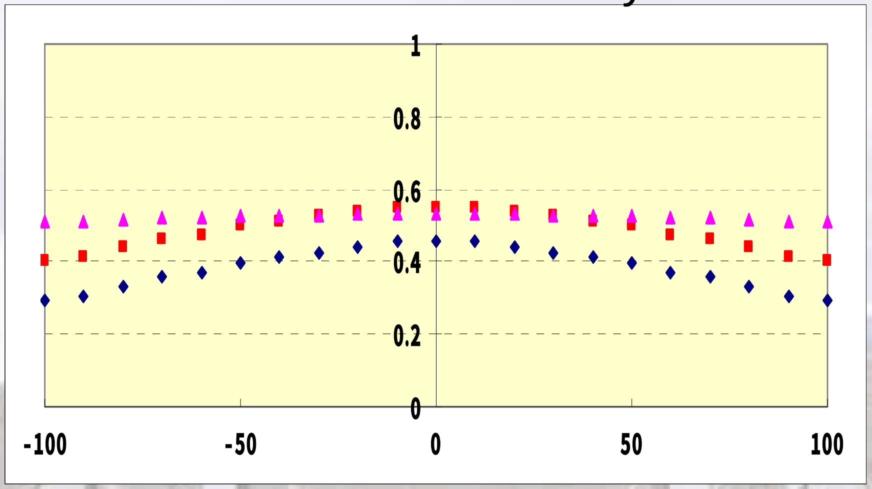
# Sensitivity (example1)




Above shows the simulation results when the LWA Elk station beam (latitude32.9$^{\circ}$) tracks the CygA position (Dec 40.7$^{\circ}$).

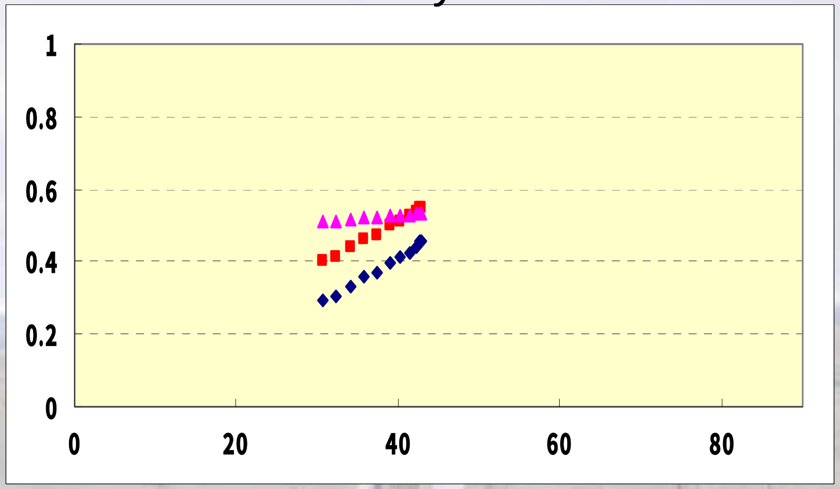
# Sensitivity (example2)

Relative sensitivity




Hour angle (degree)

Relative sensitivity

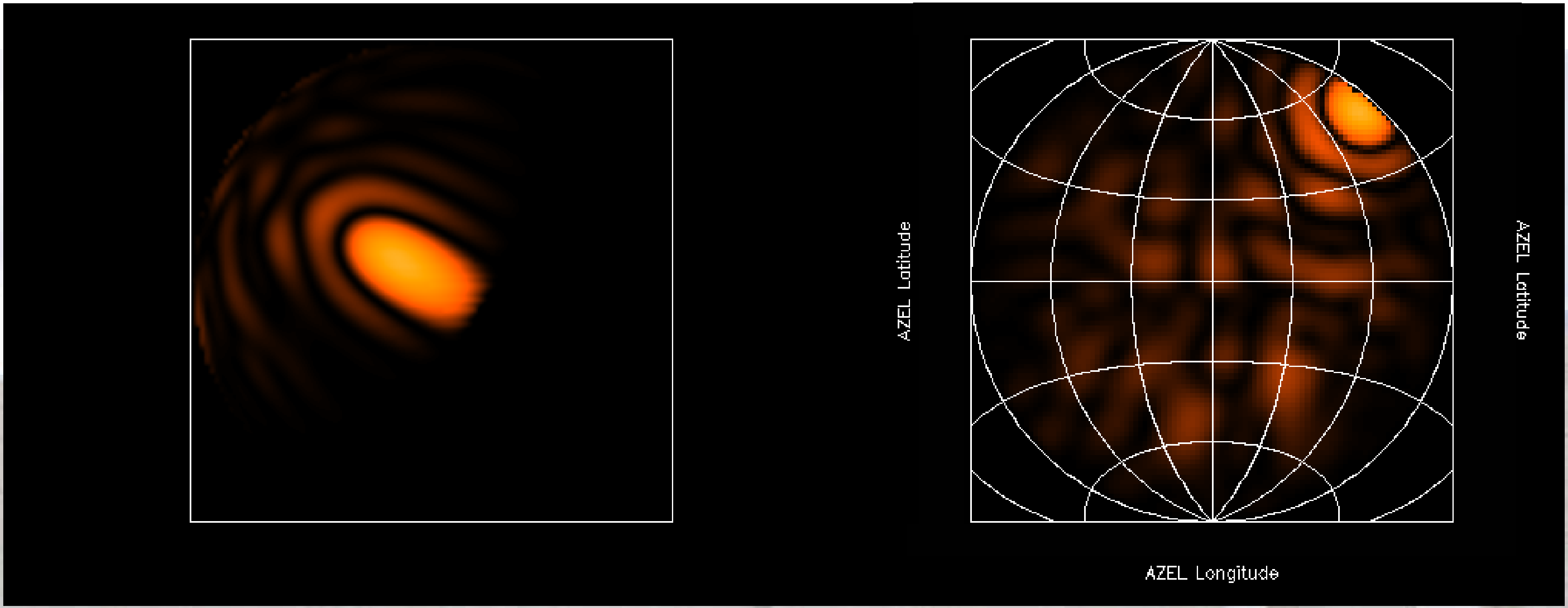



Elevation (degree)

20MHz 50MHz 80MHz

Above shows the simulation results when the LWA Elk station beam (latitude32.9°) tracks Dec 80° position.

# Elk station beam at 20 MHz

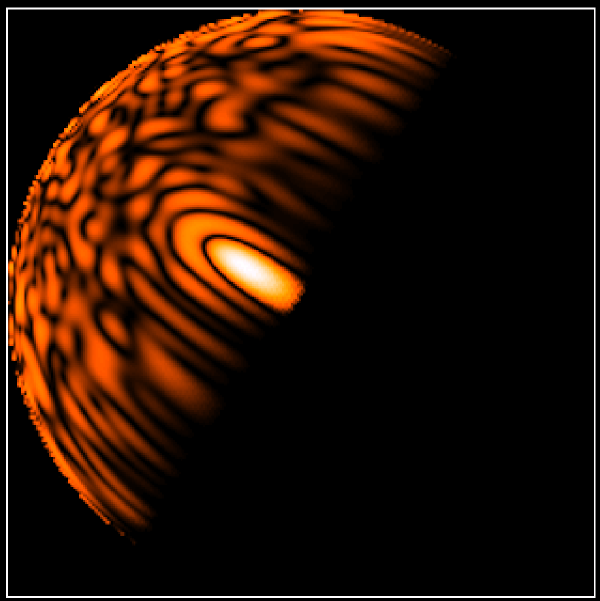


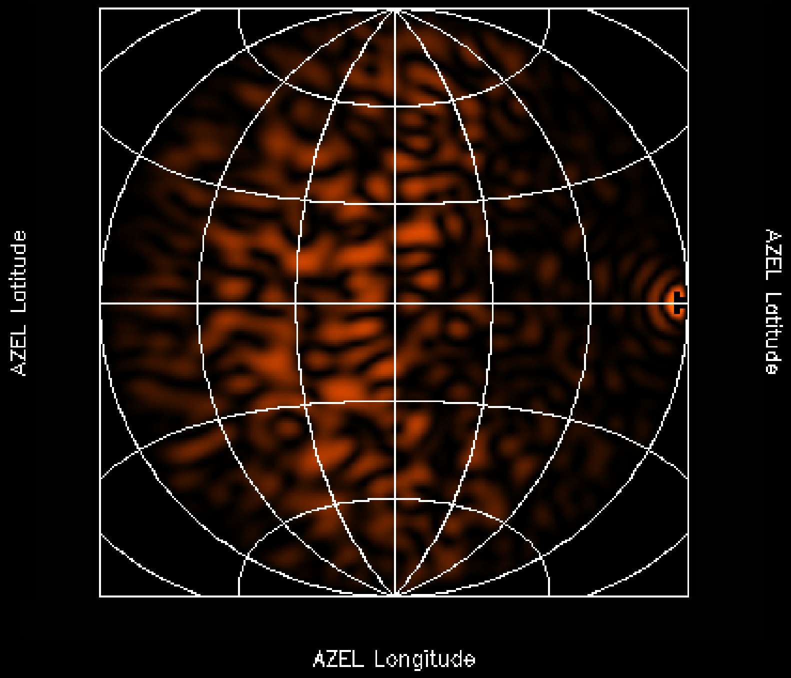

l m coordinate
(-100d to +100d)

Ground coordinate

Above shows the simulation results when the LWA Elk station beam (latitude32.9° ) tracks the CygA position (Dec 40.7 °).

# Elk station beam at 50 MHz



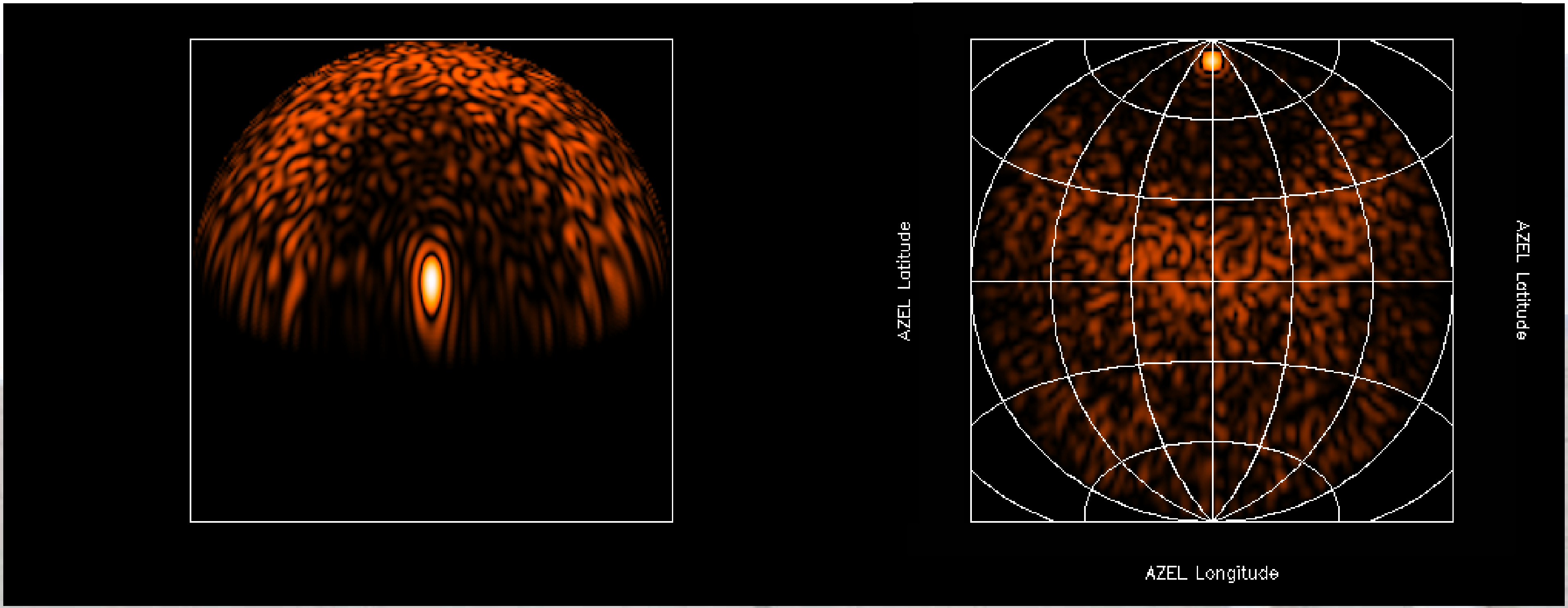



l m coordinate
(-90d to +90d)

Ground coordinate

Above shows the simulation results when the LWA Elk station beam (latitude32.9$^\circ$) tracks Dec 0$^\circ$ position.

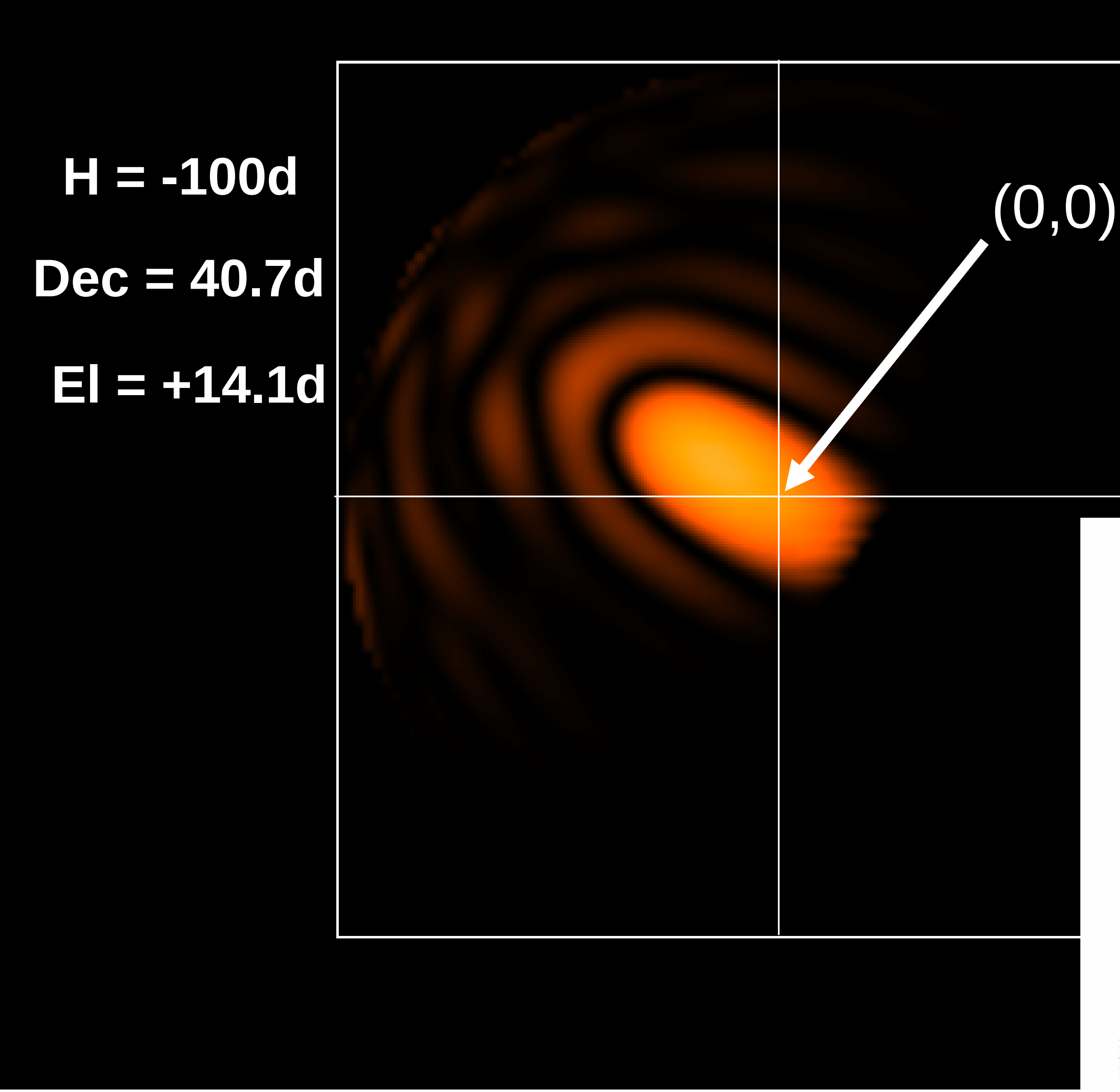
# Elk station beam at 80 MHz



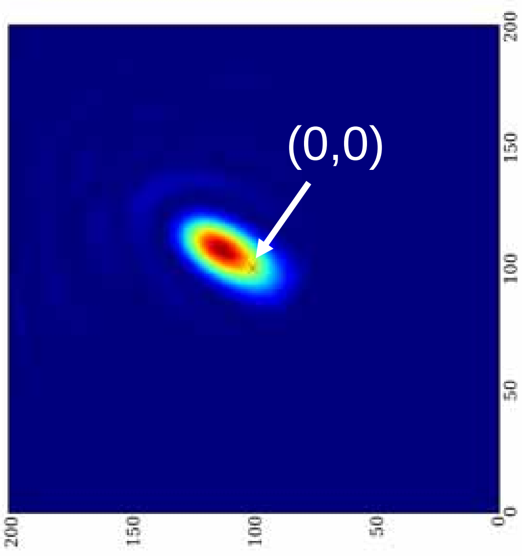

l m coordinate
(-180d to +180d)

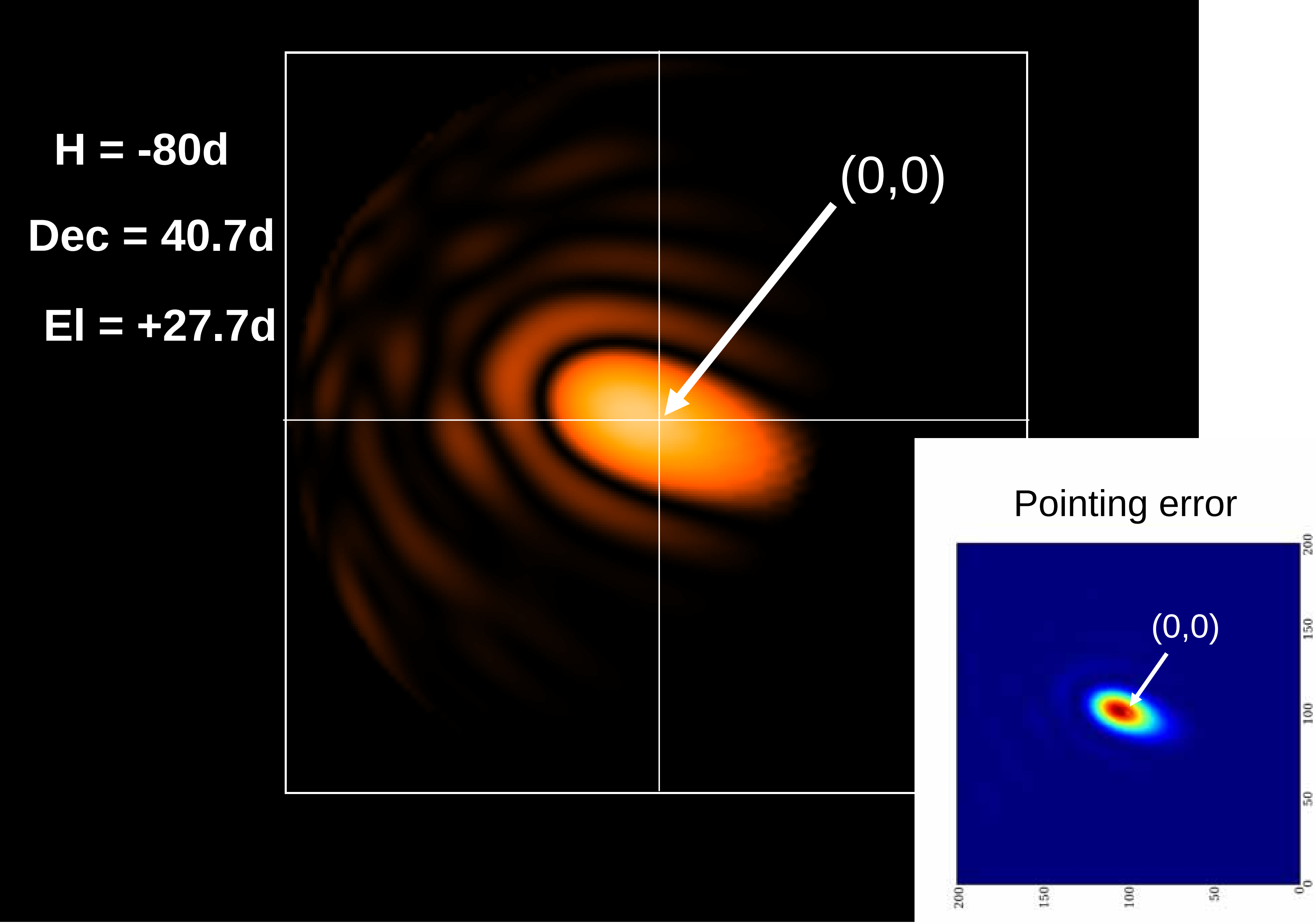
Ground coordinate

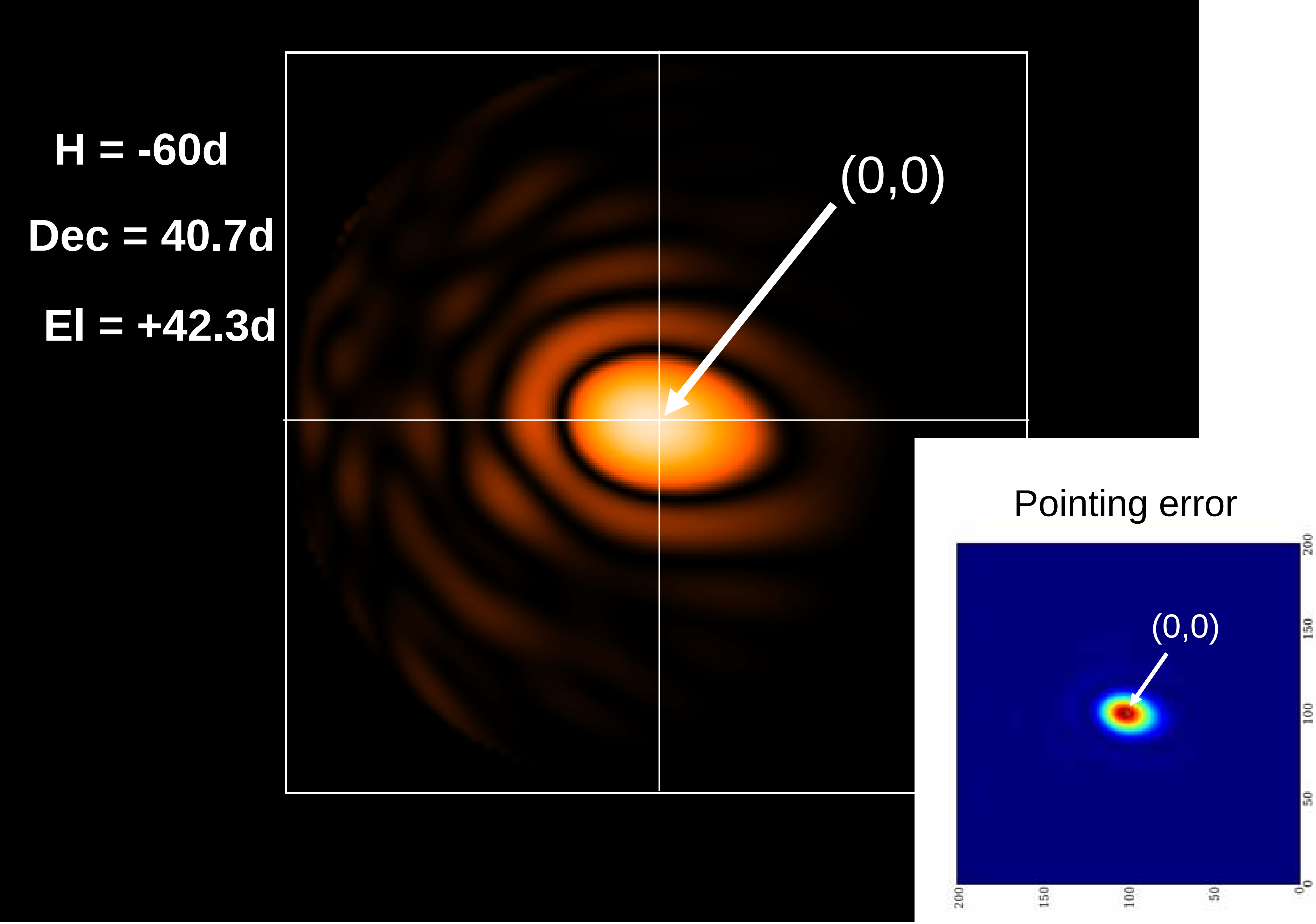
Above shows the simulation results when the LWA Elk station beam (latitude32.9$^\circ$) tracks Dec 80$^\circ$ position.




Pointing error



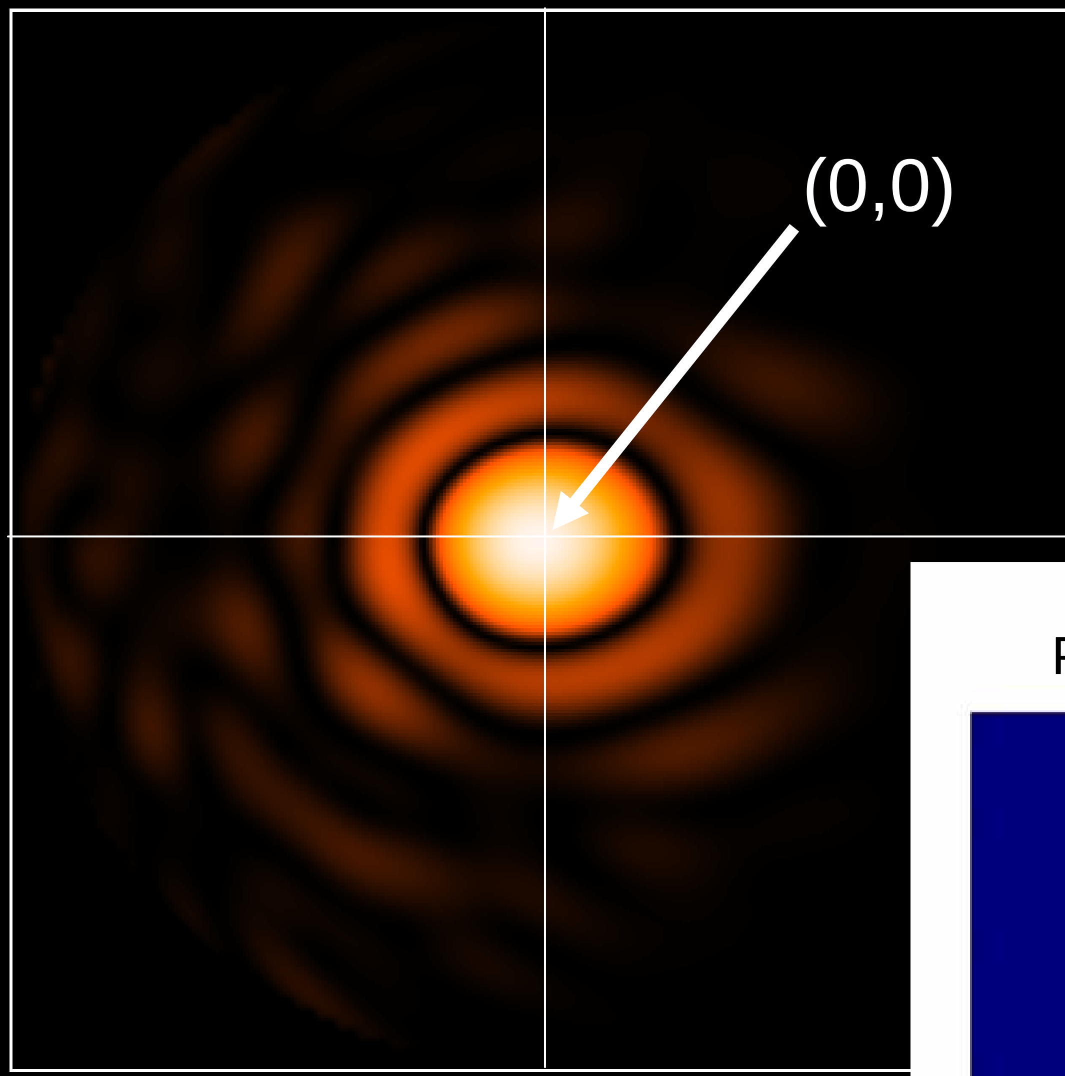

H = -80d
Dec = 40.7d
El = +27.7d
(0,0)
Pointing error
(0,0)
200
150
100
50
0
200
150
100
50
0


H = -60d
Dec = 40.7d
El = +42.3d
(0,0)
Pointing error
(0,0)
200
150
100
50
0
200
150
100
50
0

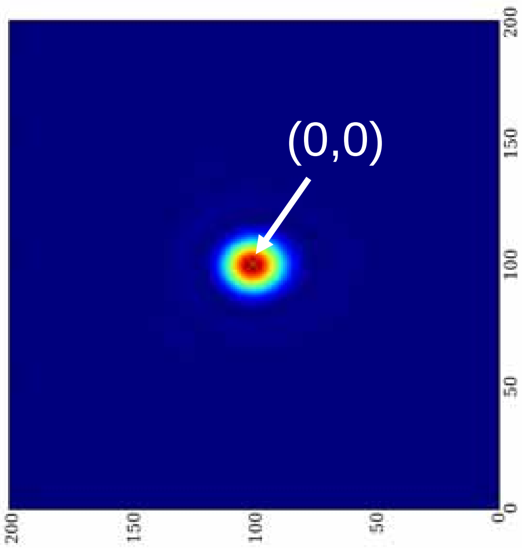
**H = -40d**

**Dec = 40.7d**

**El = +57.3d**



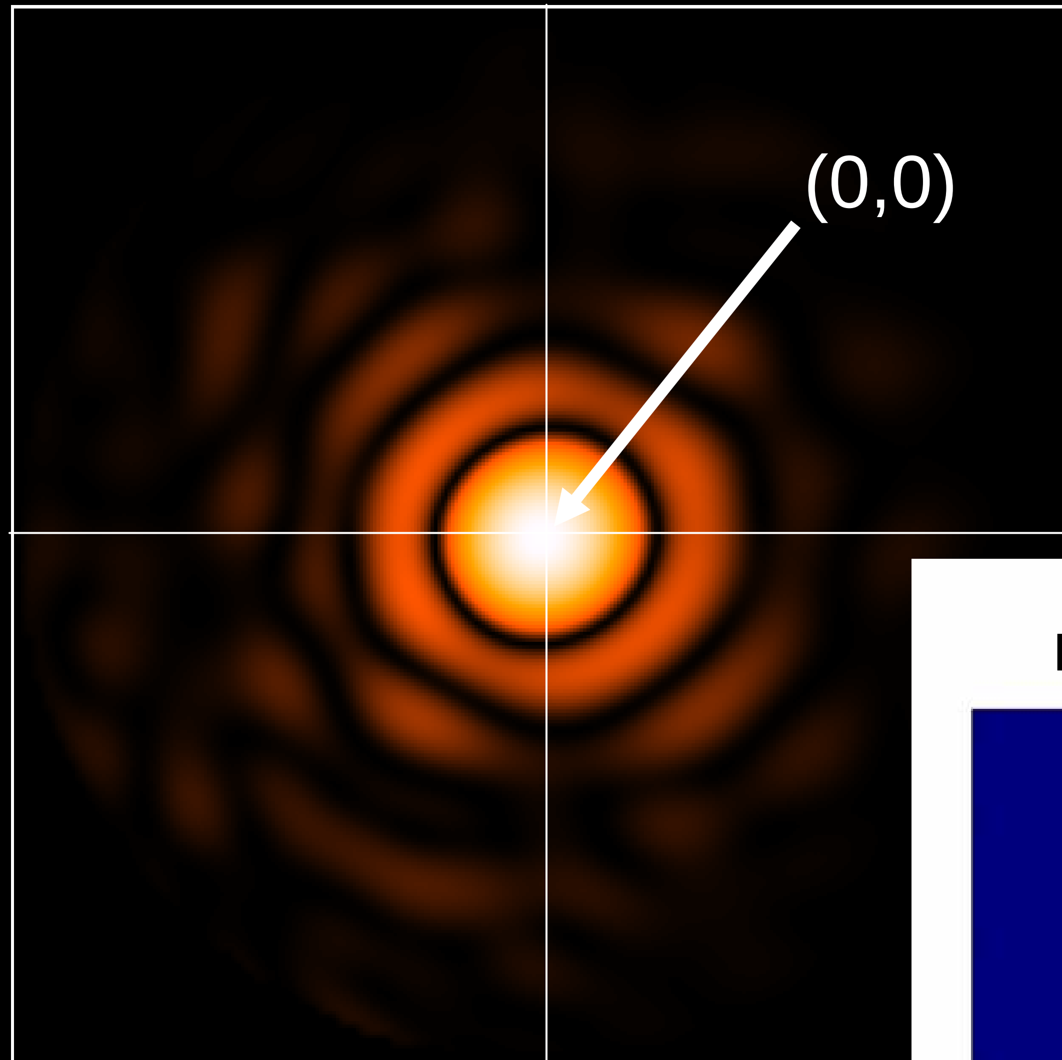

Pointing error



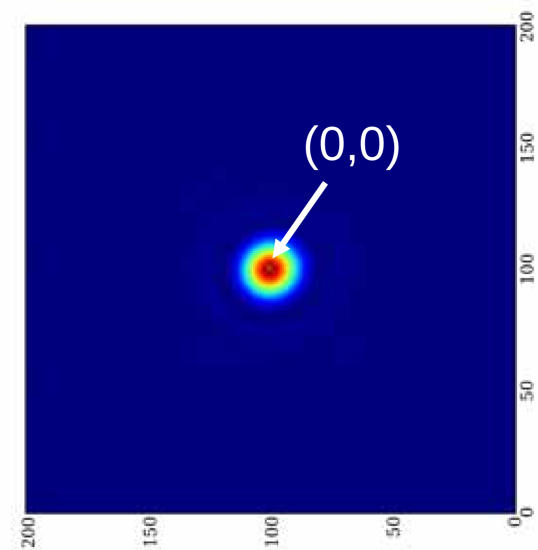
H = -20d

Dec = 40.7d

El = +72.2d



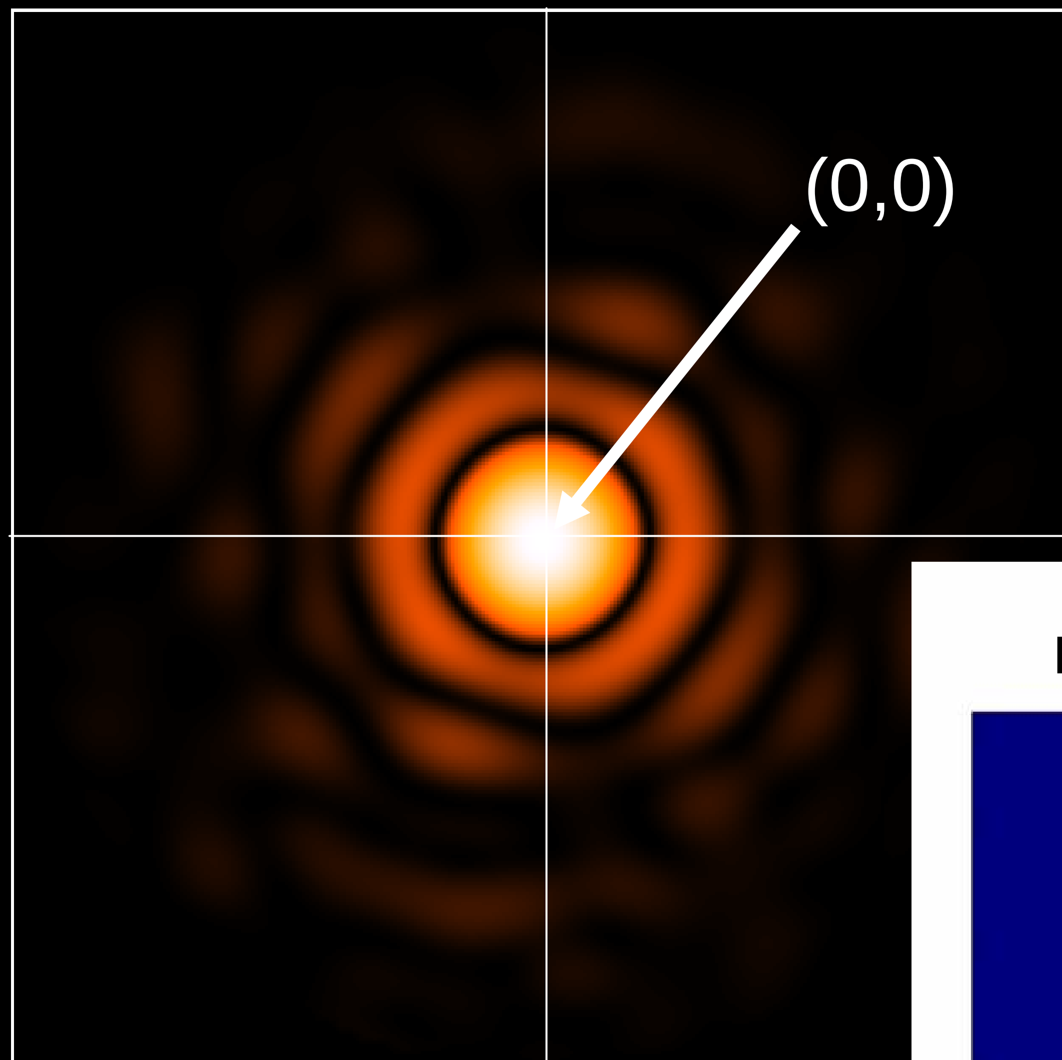

Pointing error



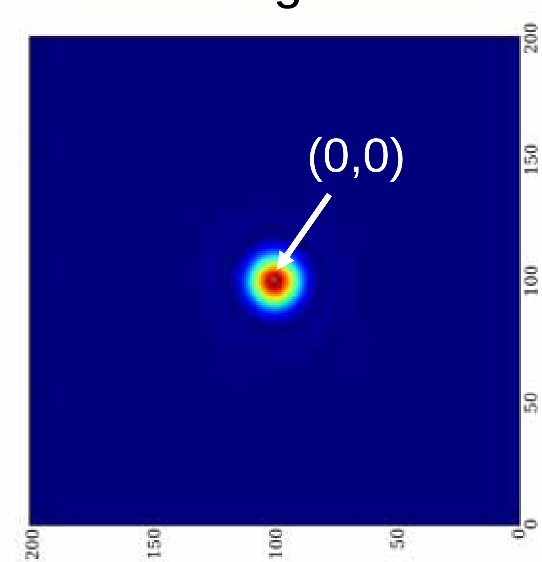
**H = 0d**

**Dec = 40.7d**

**El = +82.0d**



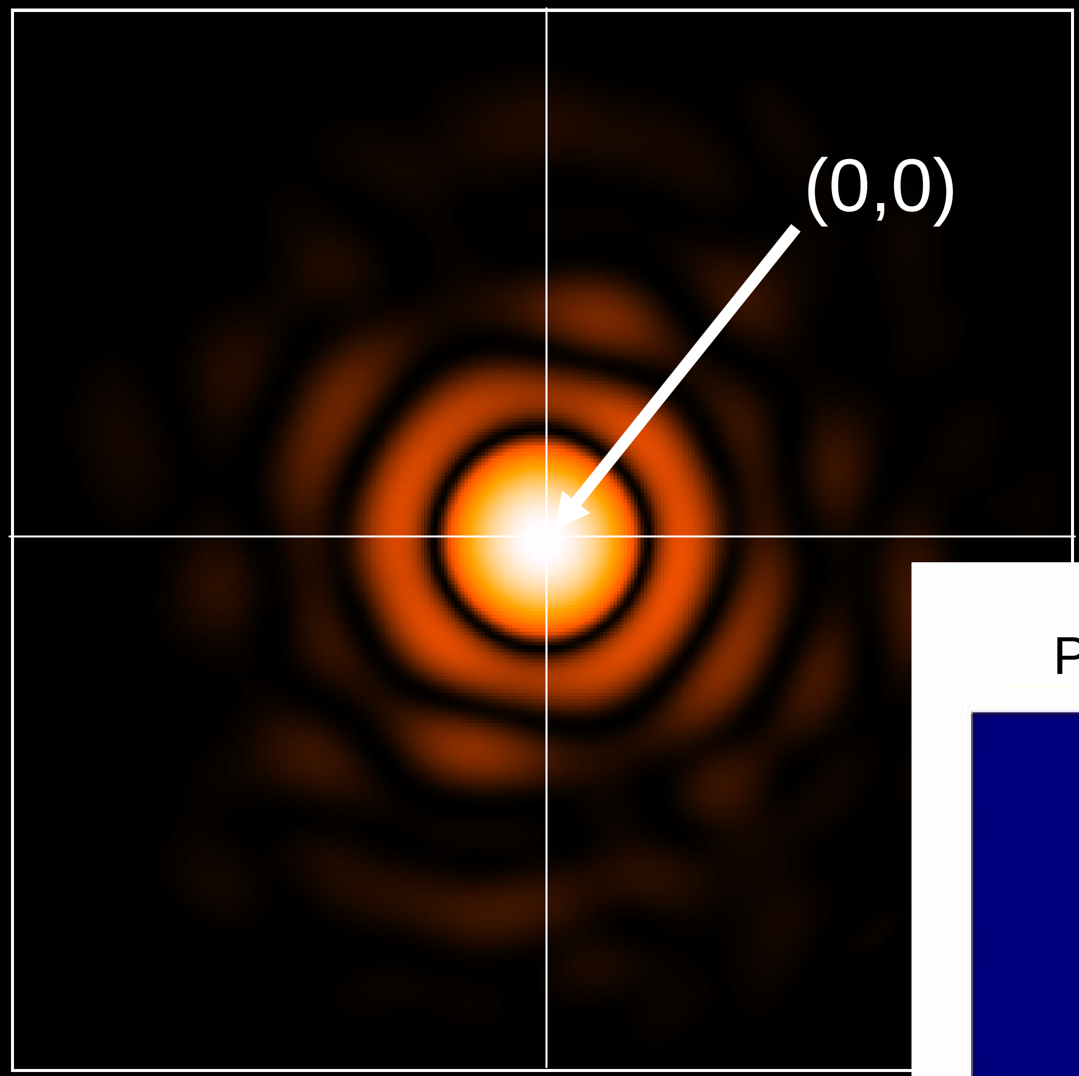

Pointing error

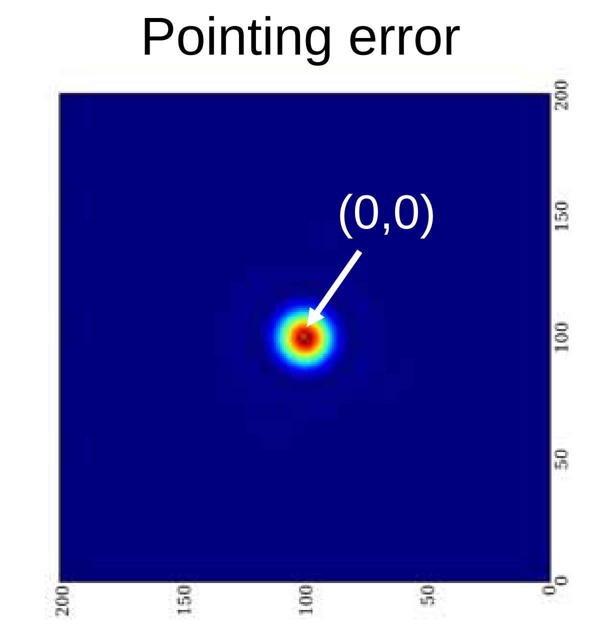


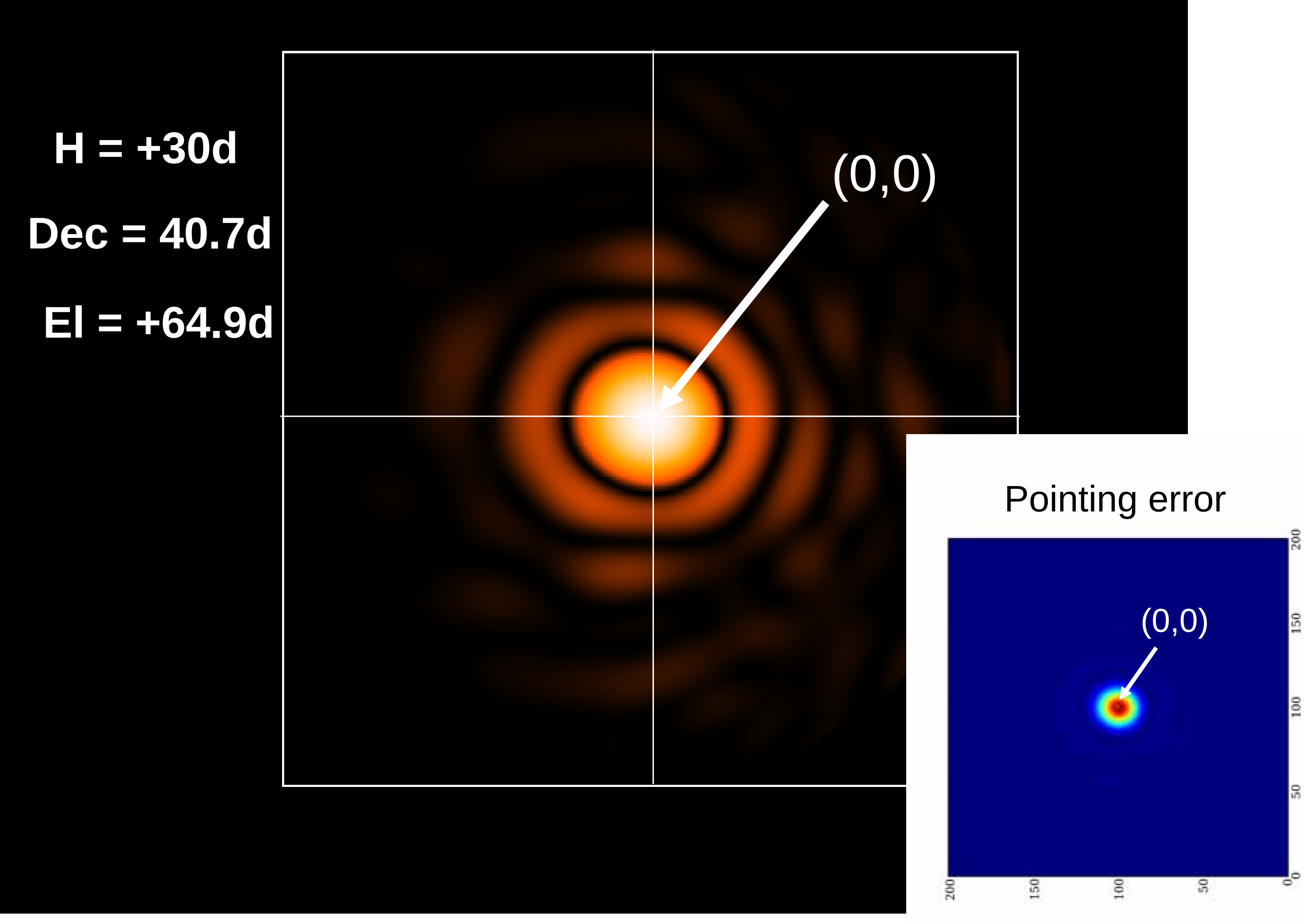
**H = +10d**

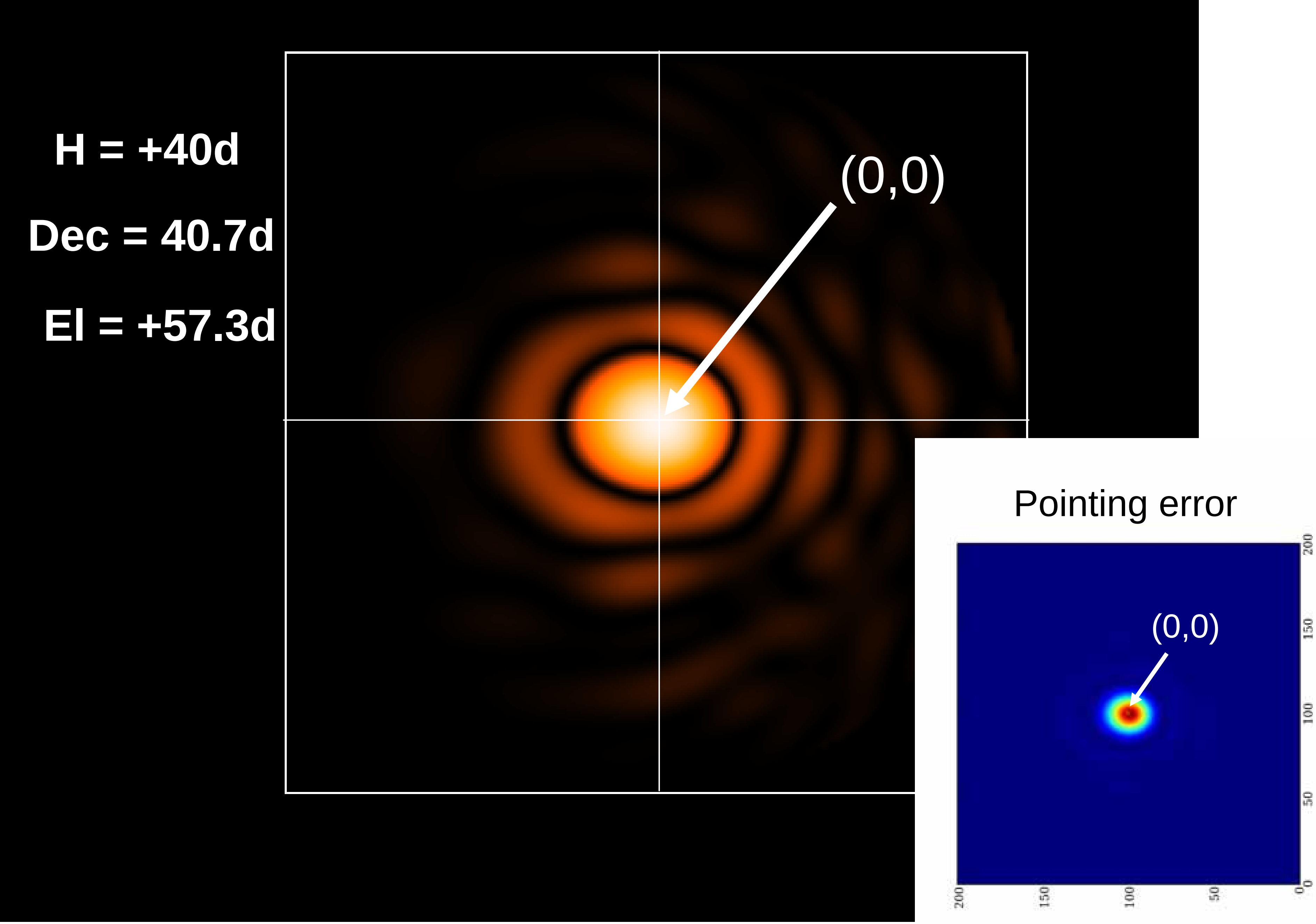
**Dec = 40.7d**

**El = +78.8d**



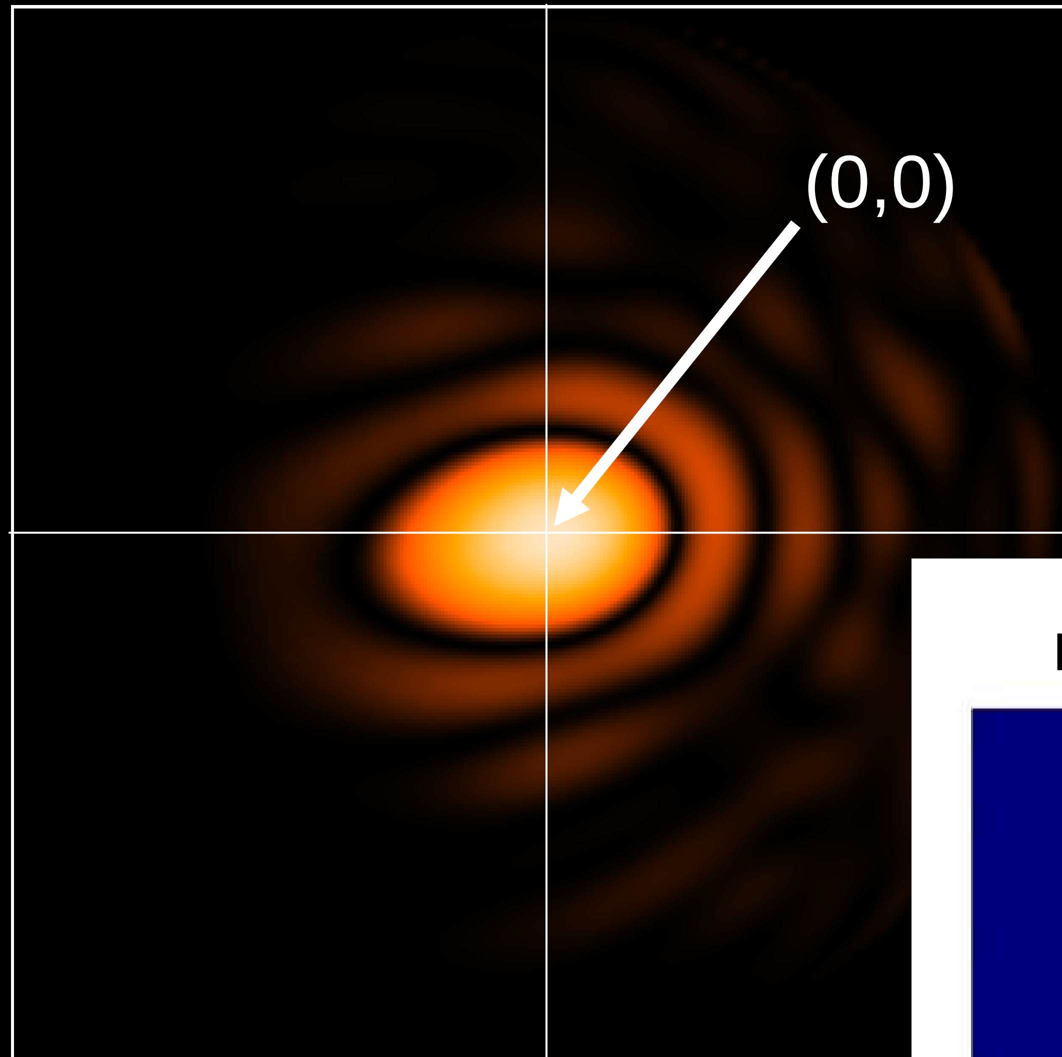

H = +30d
Dec = 40.7d
El = +64.9d
(0,0)
Pointing error
(0,0)
200
150
100
50
0
200
150
100
50
0

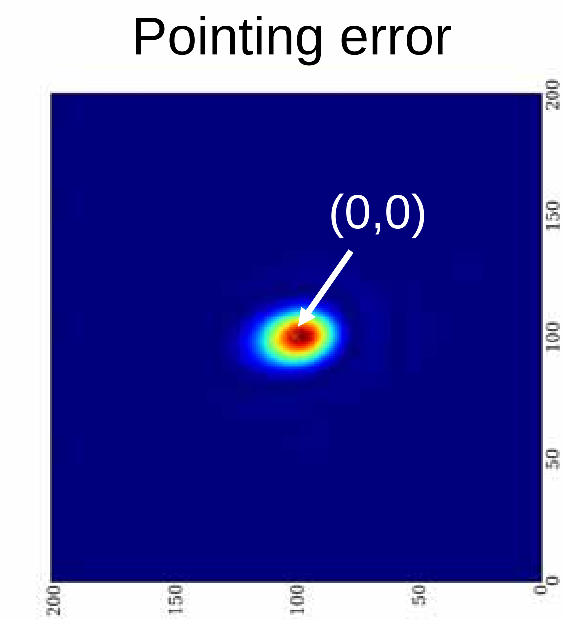

H = +40d
Dec = 40.7d
El = +57.3d
(0,0)
Pointing error
(0,0)
200
150
100
50
0
200
150
100
50
0

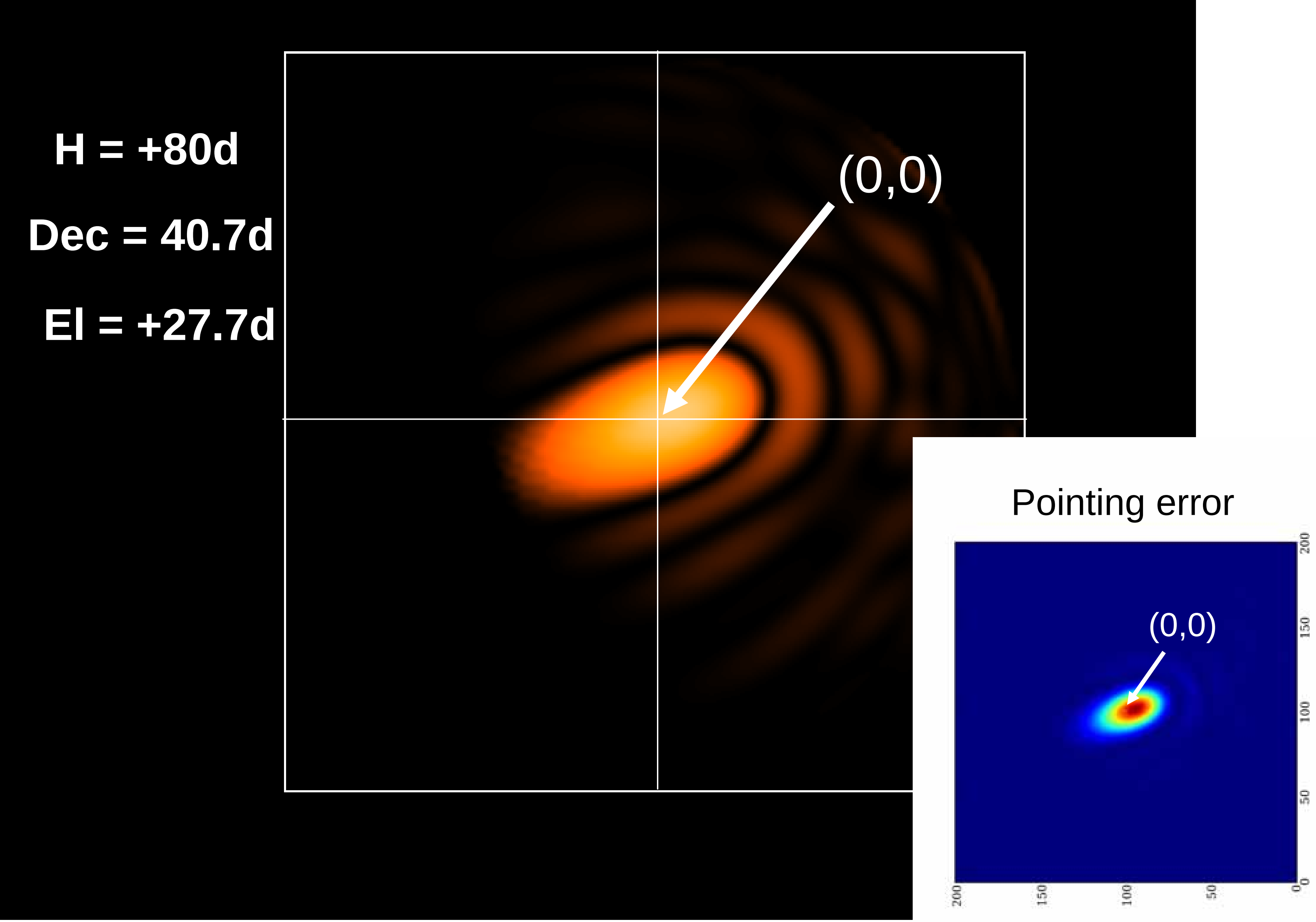
H = +60d

Dec = 40.7d

El = +42.3d



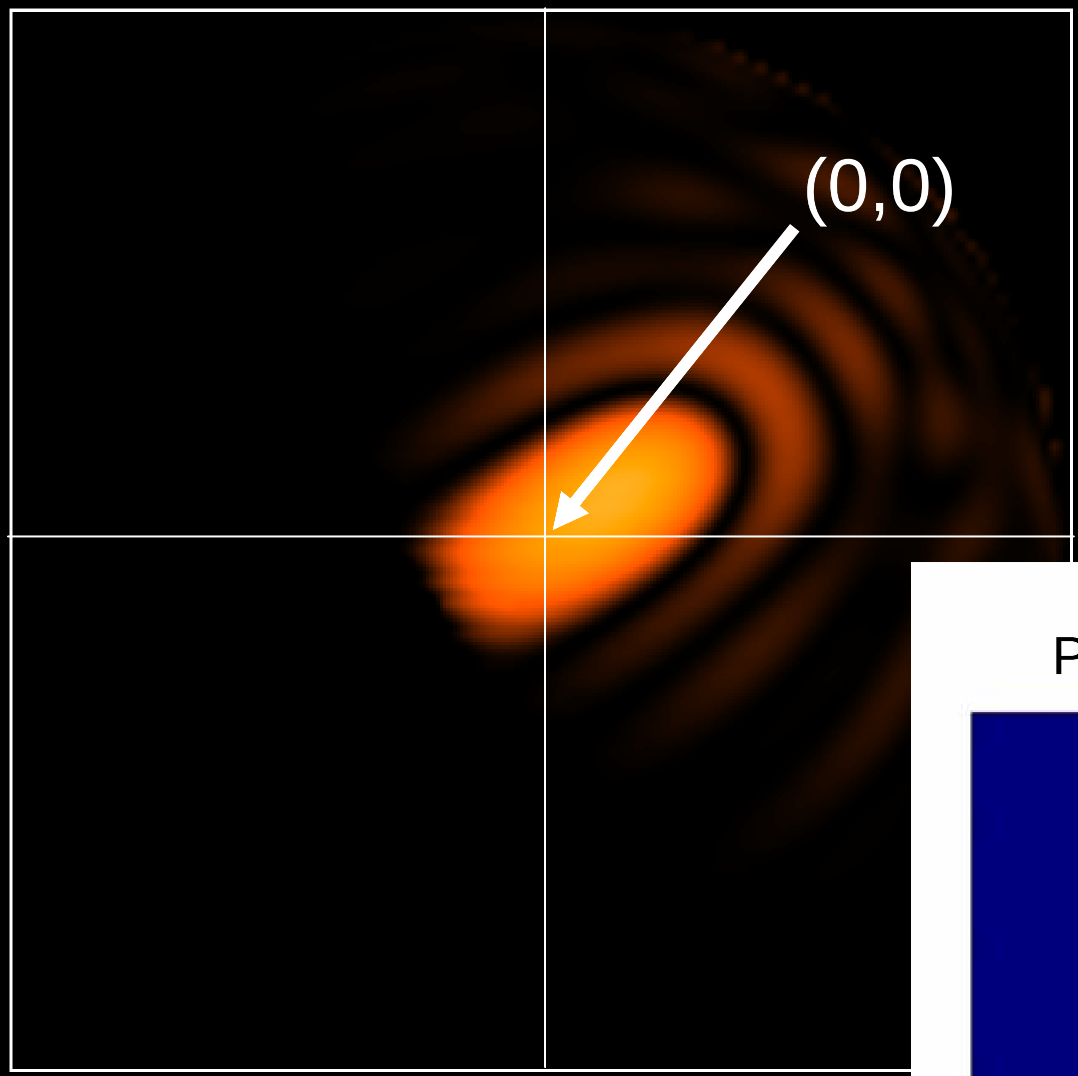




H = +80d
Dec = 40.7d
El = +27.7d
(0,0)
Pointing error
(0,0)
200
150
100
50
0
200
150
100
50
0

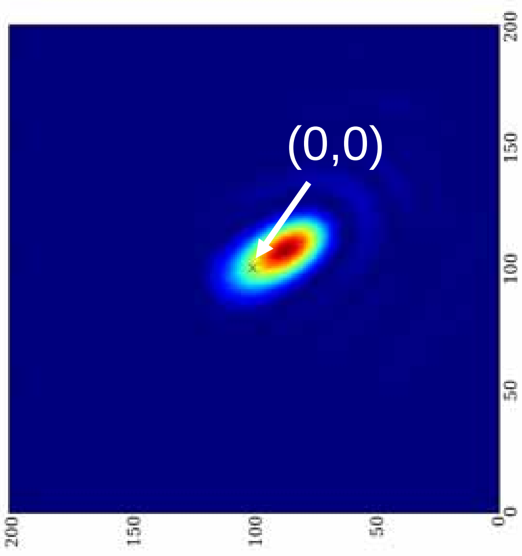
H = +100d

Dec = 40.7d

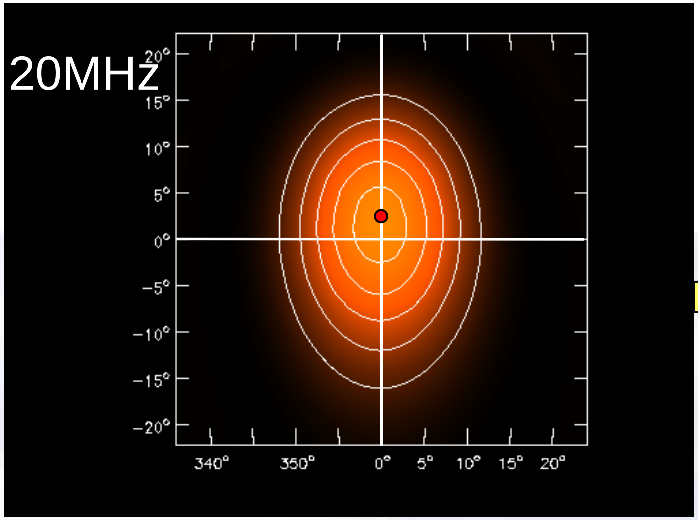
El = +14.1d

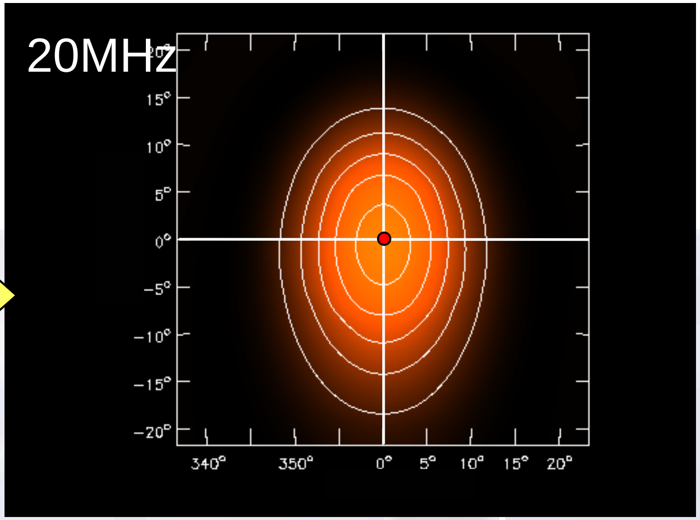



Pointing error



# Pointing error



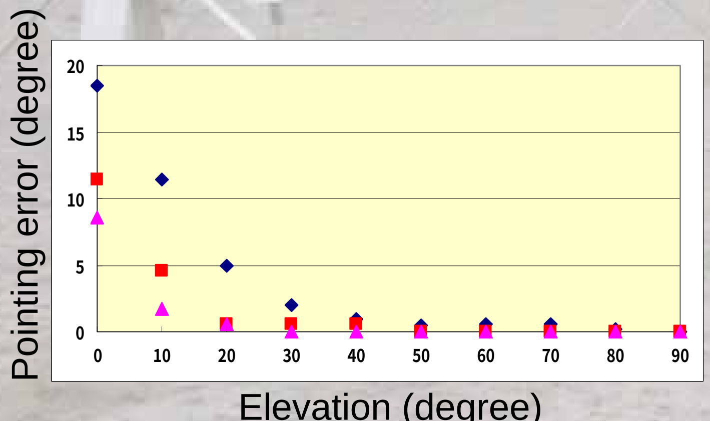



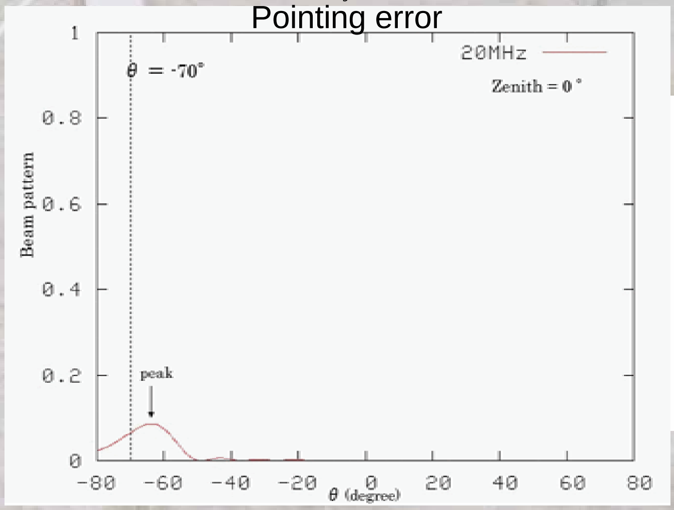

$\sqrt{BBP}$ causes pointing error

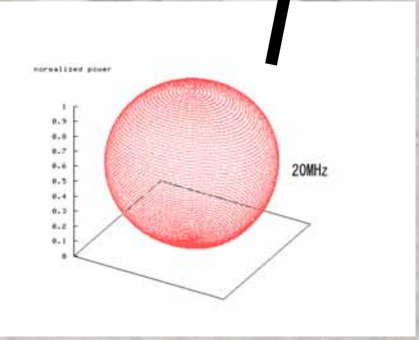
Correction by adding $\exp(i\alpha)$

The left shows a pointing error in a station beam.
The pointing errors depend on the observing frequency and elevation. The right is the beam after the correction.

$$E_k(\theta,\phi) = \sum_{j=1}^{256} \Delta\nu \exp(i s_j \nu_k + i\alpha_{kj}) \frac{\sin(s_j \frac{\Delta\nu}{2})}{(s_j \frac{\Delta\nu}{2})} \cdot \sqrt{BBP(\theta,\phi)}$$

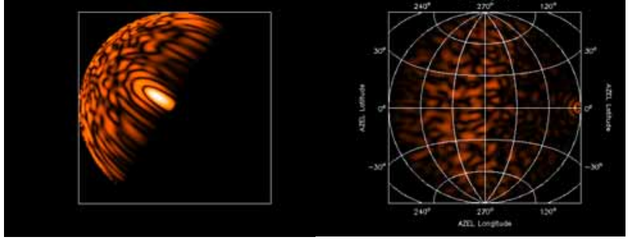


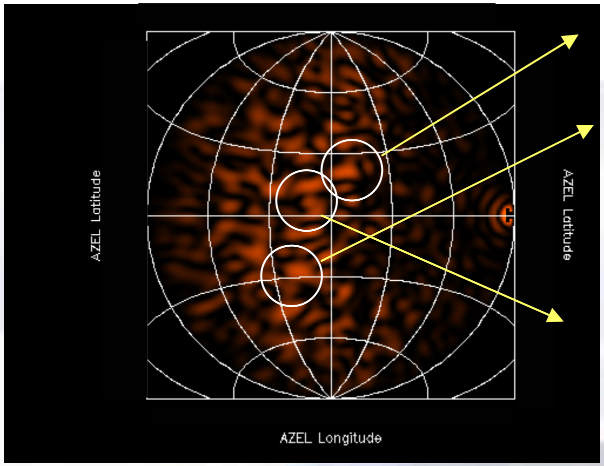




Big Blade antenna reception pattern

# Side lobe at 50MHz



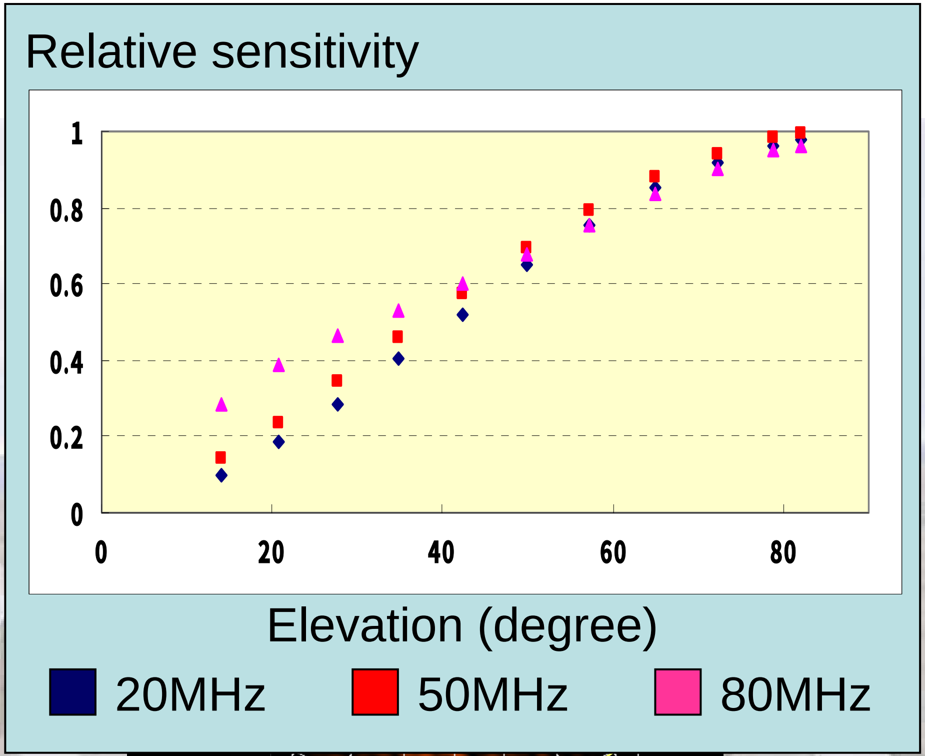


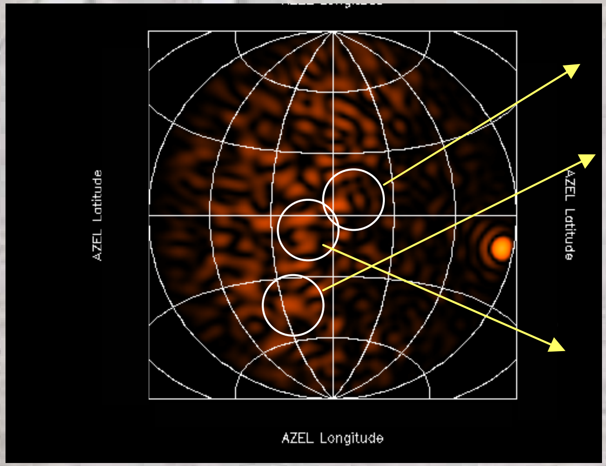

-5.8dB

-6.4dB

-6.3dB

El 32.3 °



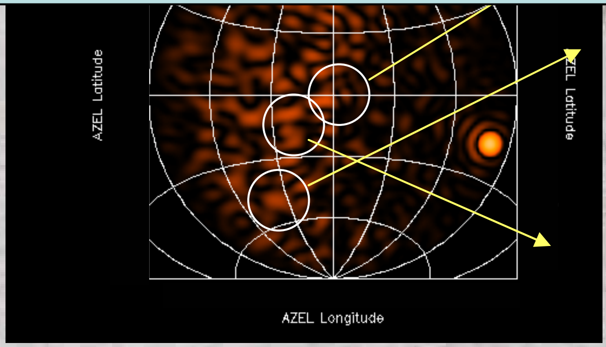




-10.3dB

-10.8dB

-11.9dB

El 35.8 °

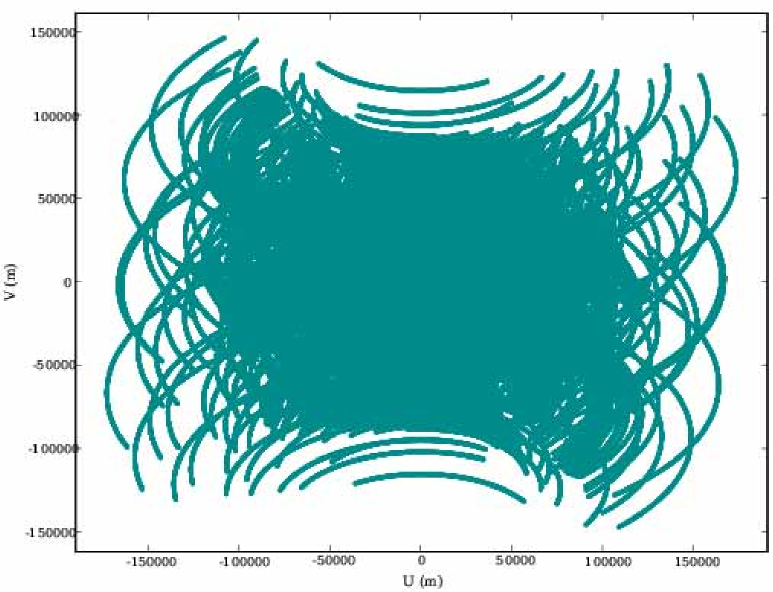


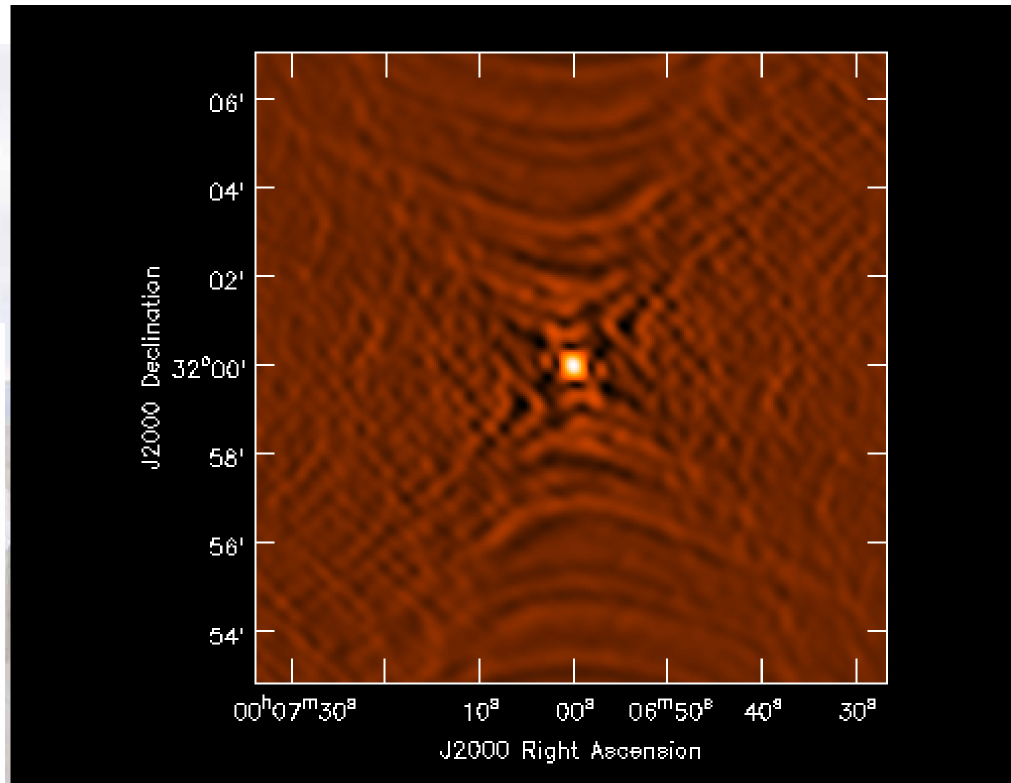

-13.6dB

-14.9dB

El 37.4 °

# UV coverage and PSF

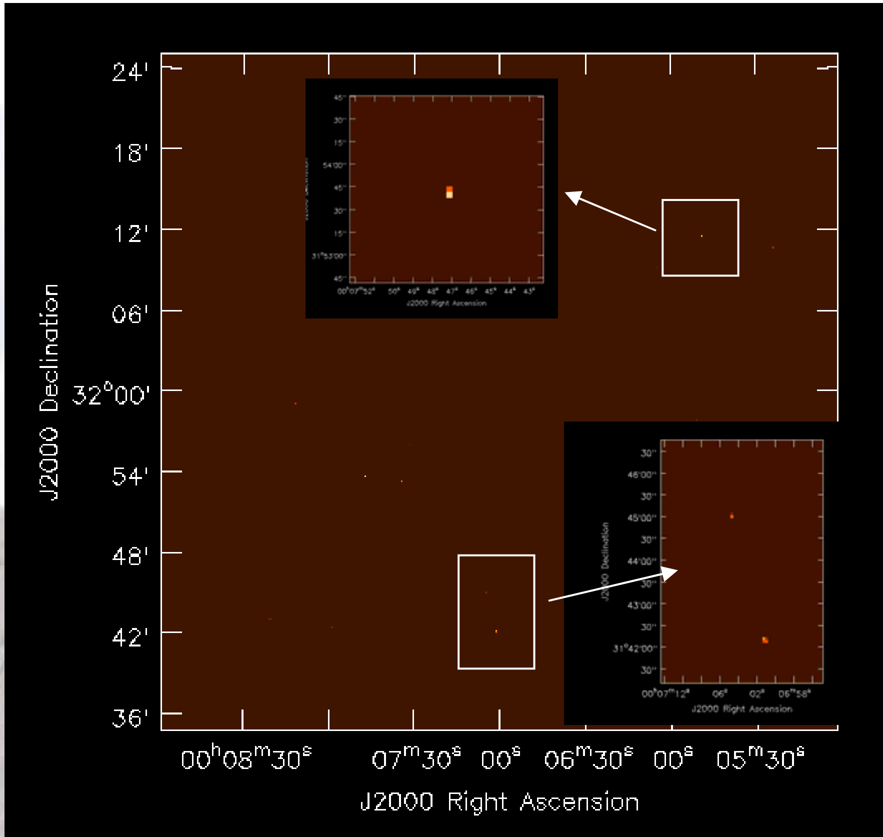




Dec 32.9 degrees [ -38°: +38° ]

# LWA image at 20MHz (preliminary)

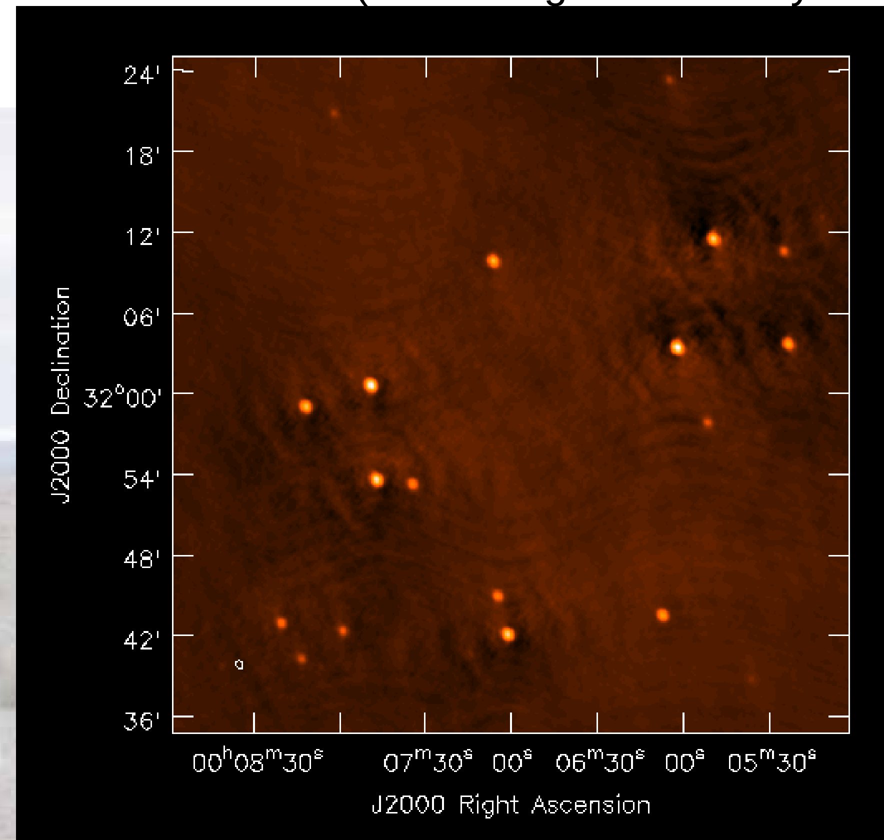
(S.Bhatnagar & M.Kuniyoshi)




Simulation model

(Jy/pixel)

| Std Dev | RMS | Mean |
|---|---|---|
| 5.974e-05 | 5.974e-05 | 3.694e-07 |
| **Median** | **Min** | **Max** |
| 0.00 | 7.868e-05 | 0.01981 |

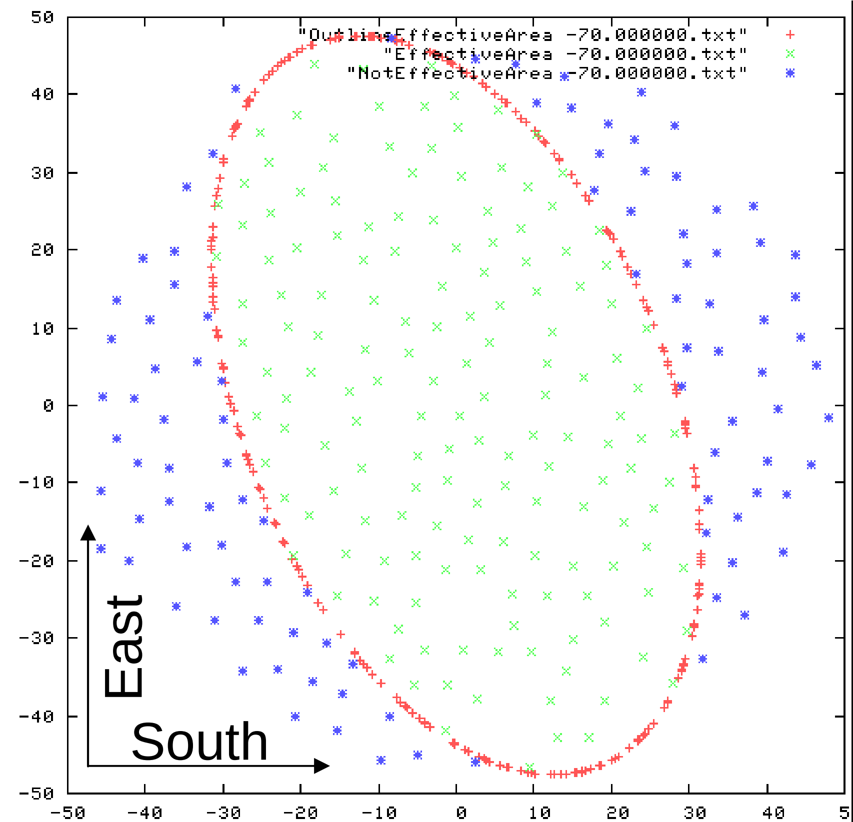


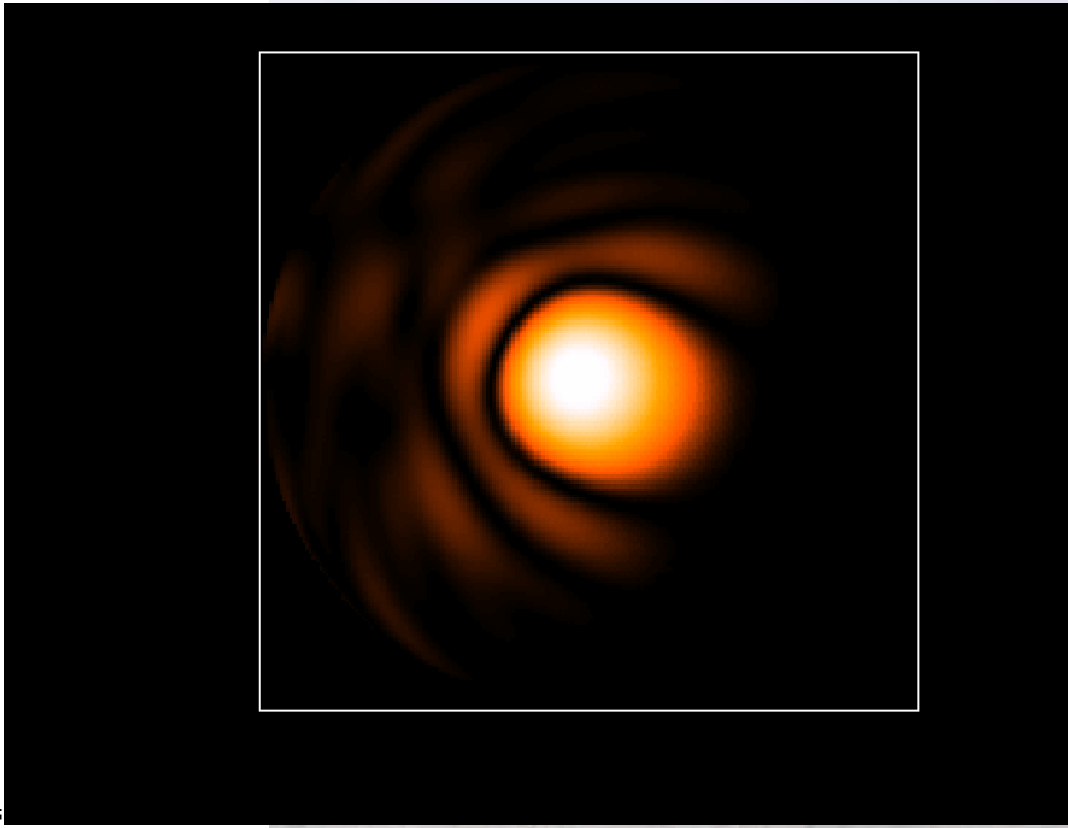

LWA image at 20MHz

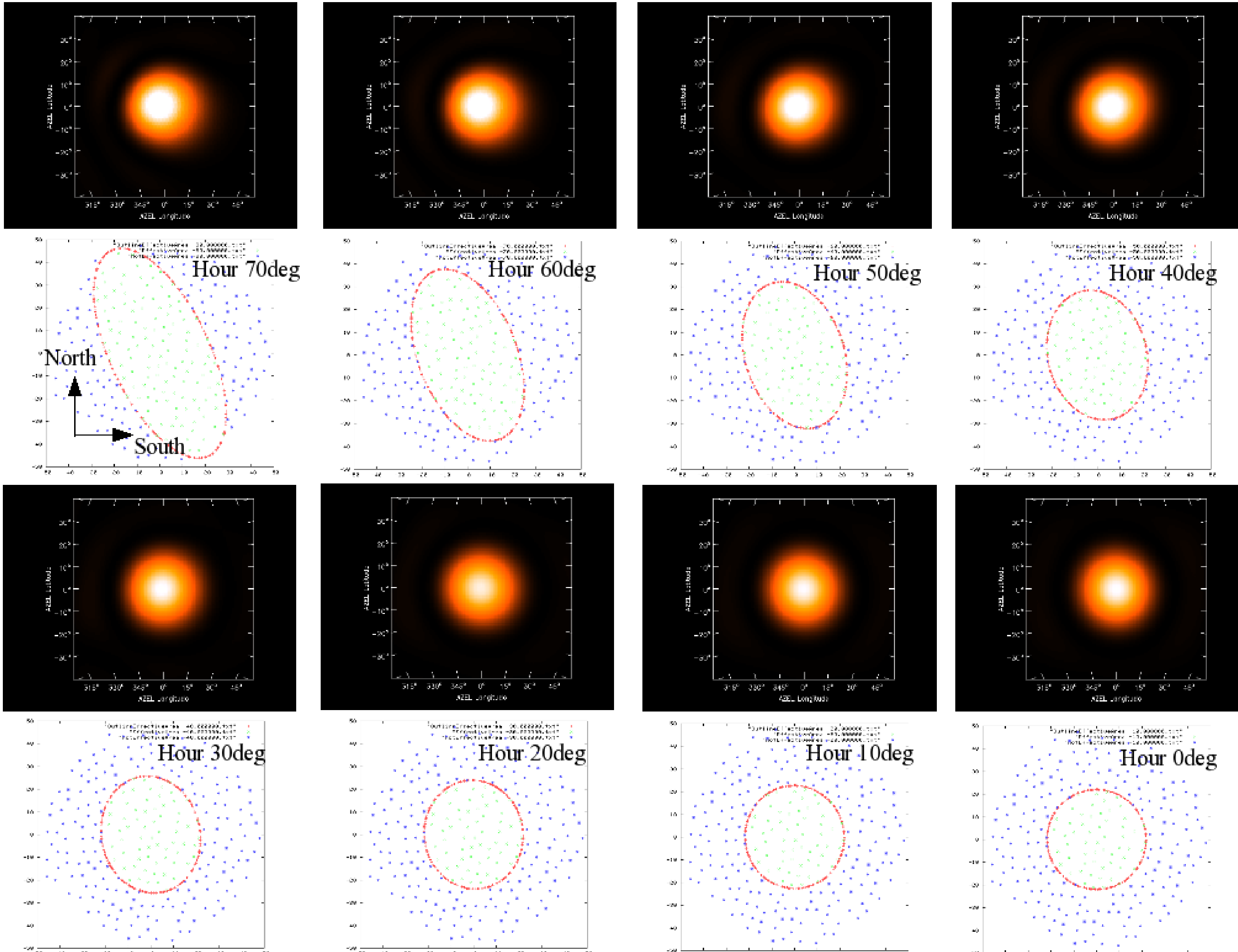
(Jy/beam)

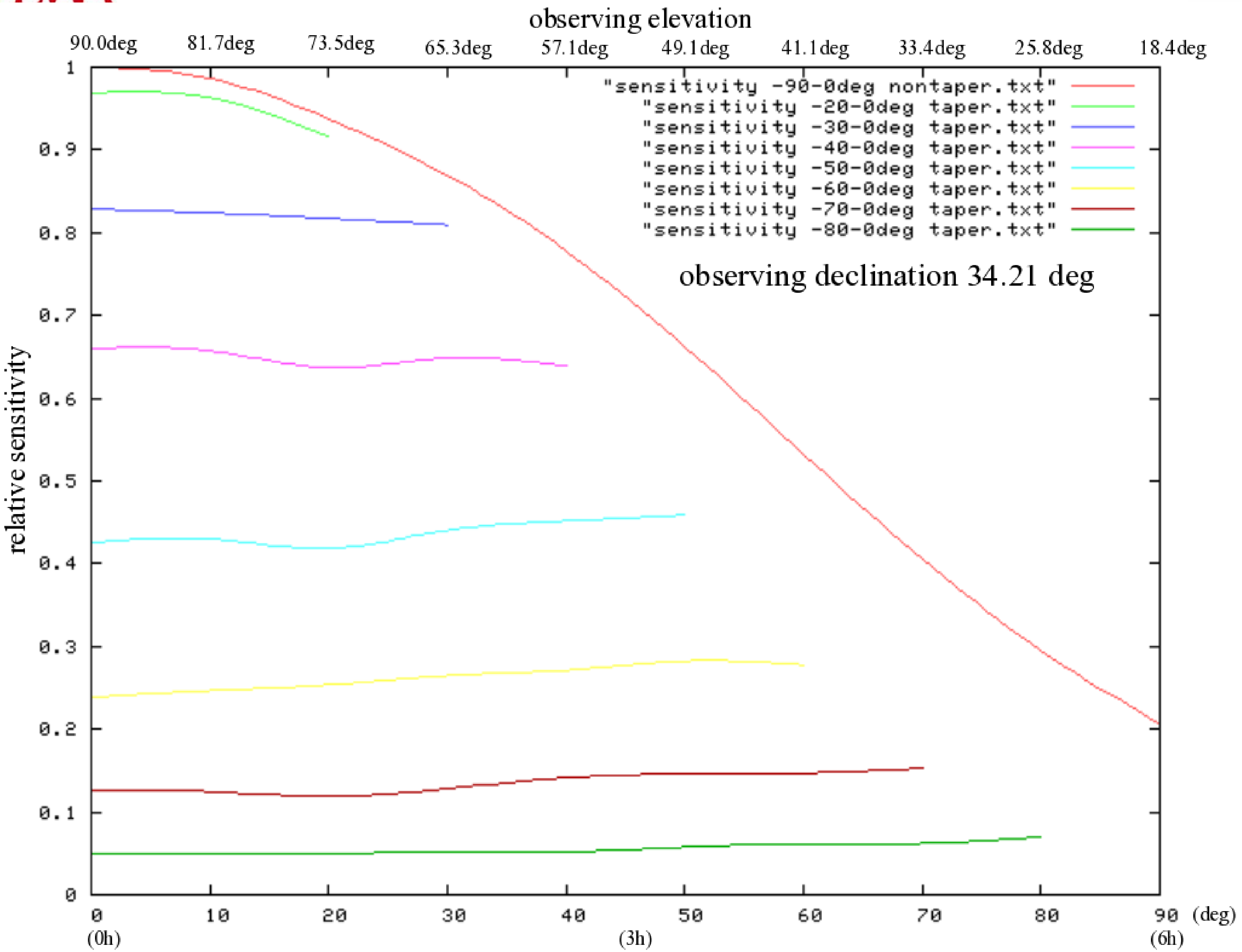
| Std Dev | RMS | Mean |
|---|---|---|
| 0.0005373 | 0.0005528 | 0.0001299 |
| **Median** | **Min** | **Max** |
| 0.0001221 | -0.0007181 | 0.02770 |

# Circular Beam by changing the effective area in a station




Hour 70deg
North
South
Hour 60deg
Hour 50deg
Hour 40deg
Hour 30deg
Hour 20deg
Hour 10deg
Hour 0deg

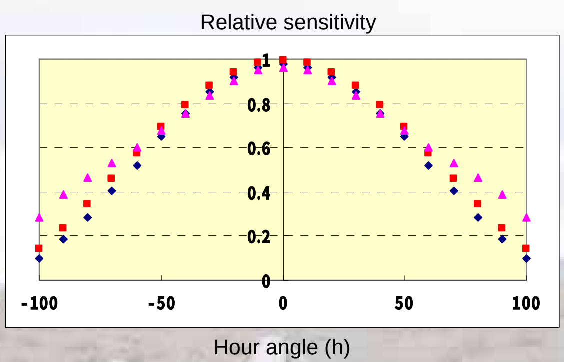

observing elevation
90.0deg
81.7deg
73.5deg
65.3deg
57.1deg
49.1deg
41.1deg
33.4deg
25.8deg
18.4deg
"sensitivity -90-0deg nontaper.txt"
"sensitivity -20-0deg taper.txt"
"sensitivity -30-0deg taper.txt"
"sensitivity -40-0deg taper.txt"
"sensitivity -50-0deg taper.txt"
"sensitivity -60-0deg taper.txt"
"sensitivity -70-0deg taper.txt"
"sensitivity -80-0deg taper.txt"
observing declination 34.21 deg
relative sensitivity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
(deg)
(0h)
(3h)
(6h)

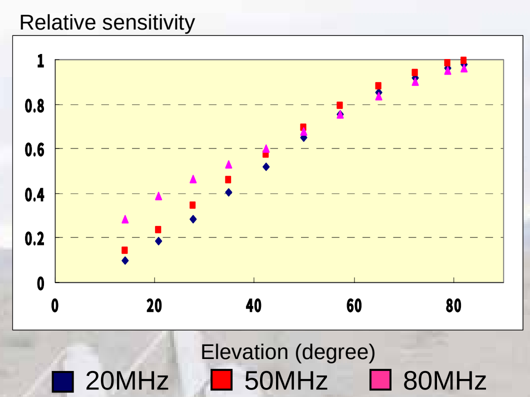
# Summary

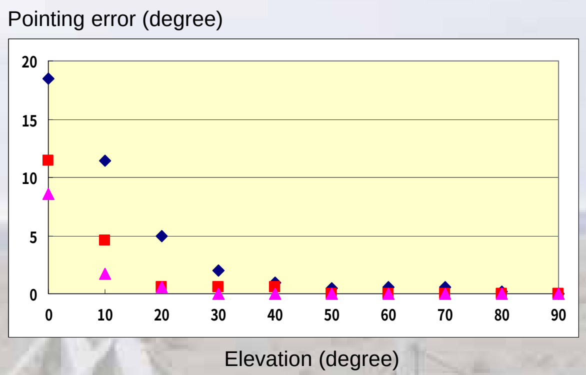
**Station beam**

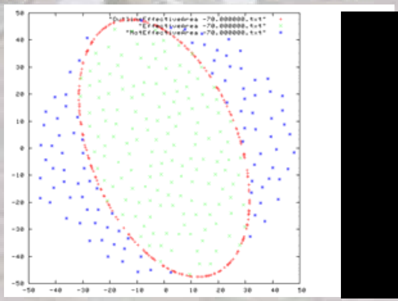
-Pointing error becomes larger with decreasing observing frequency and elevation.

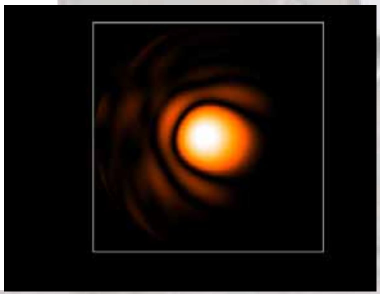
-Sensitivity changes with observing elevation due to the primary beam of the dipole in the station.

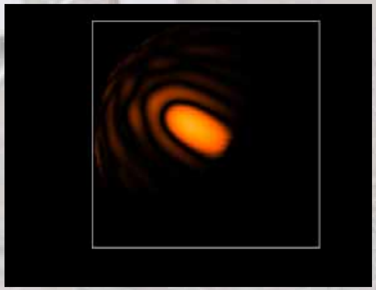


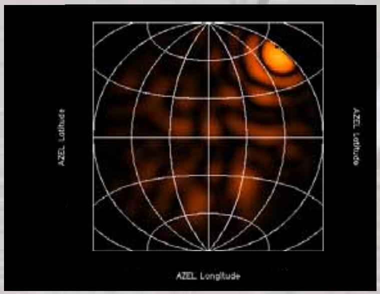



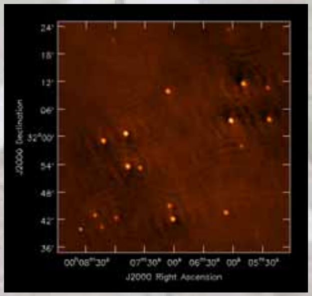










**Now**

We are in the process of creating **more appropriate** images (images from VLSS + 408MHz all sky maps + adding confusion noise) with CASA.

# Thank you