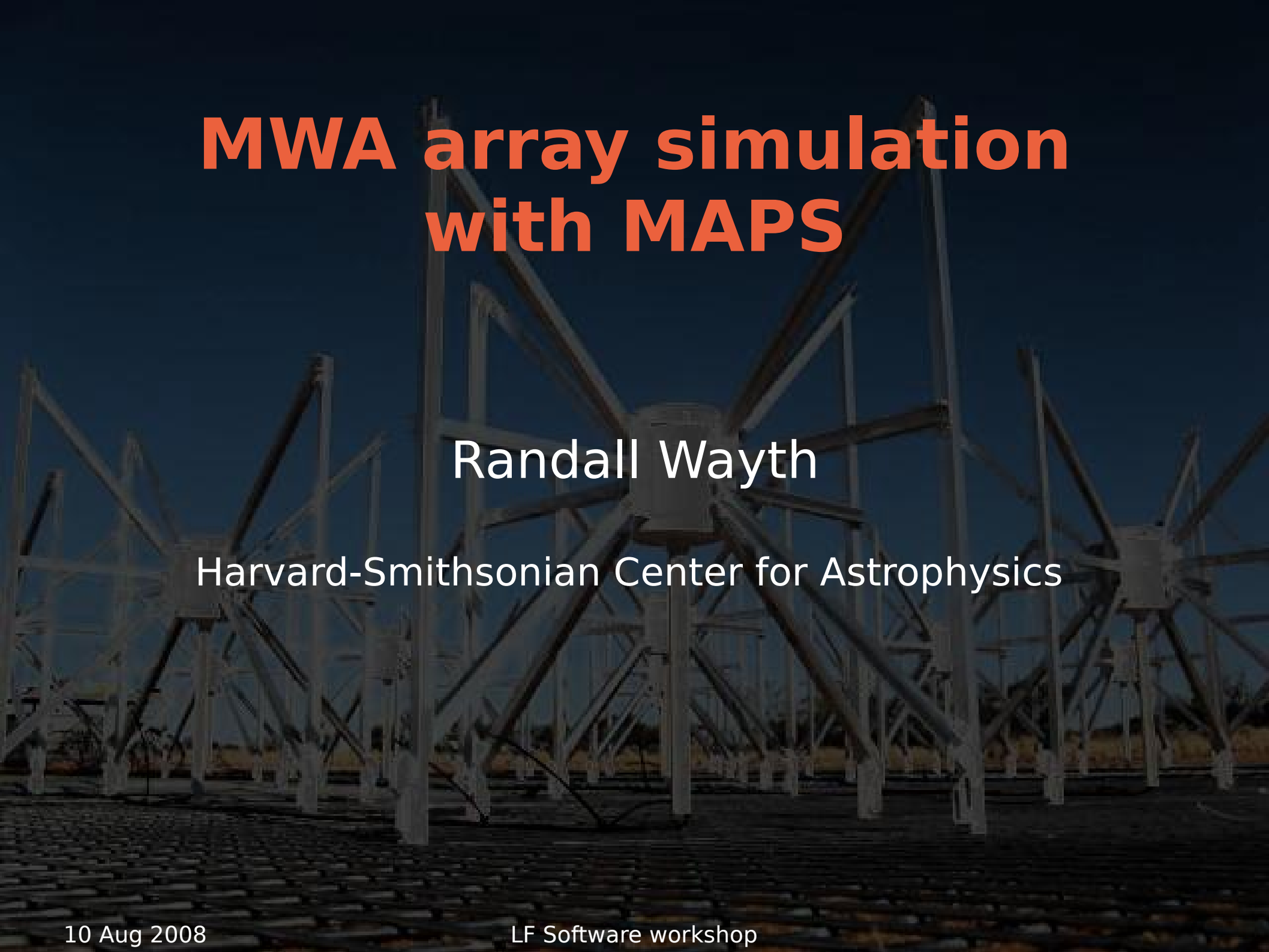


MWA array simulation with MAPS

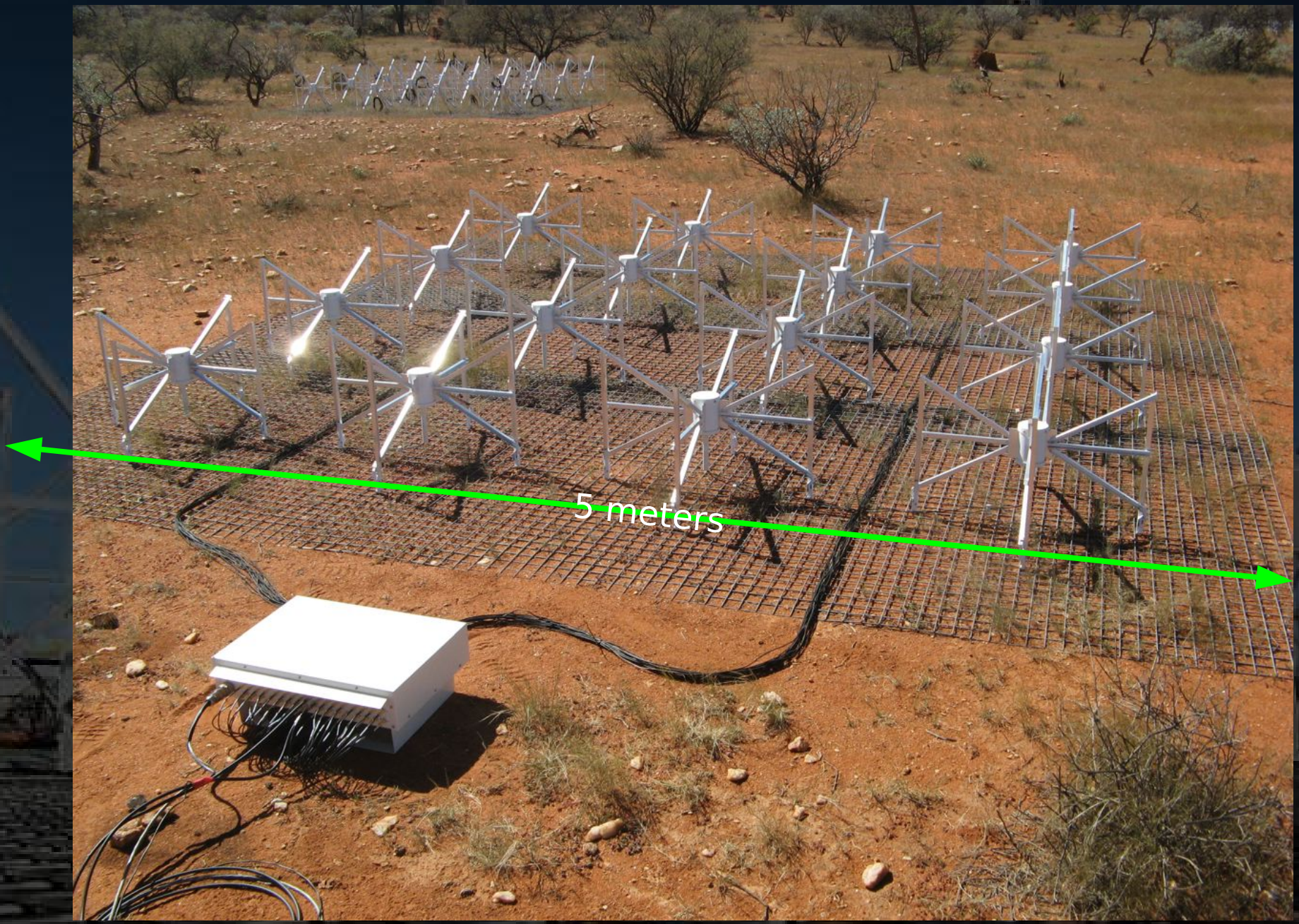
Randall Wayth

Harvard-Smithsonian Center for Astrophysics

Array Specs

- 512 antennas
  - 15-50° field of view
- A wide frequency range
  - 80 – 300 MHz, 31MHz at any one time
- Full cross correlation of all 512 antennas
  - full Stokes, 31 MHz bandwidth, 40 kHz resolution

MWA antennas



Coplanar enough for you?

Photo: Divya Oberoi

Simulations – 'MAPS'

- MAPS = MIT Array Performance Simulator
- MAPS simulates what an interferometer sees, from ionosphere through to correlator including station beams
- Original development at MIT Haystack (Cappallo, Doeleman, Lonsdale, Oberoi, et al.)
- Significant enhancements for MWA (Wayth, Mitchell, Ord, Kasper):
  - antenna beams
  - polarized response
  - all-sky

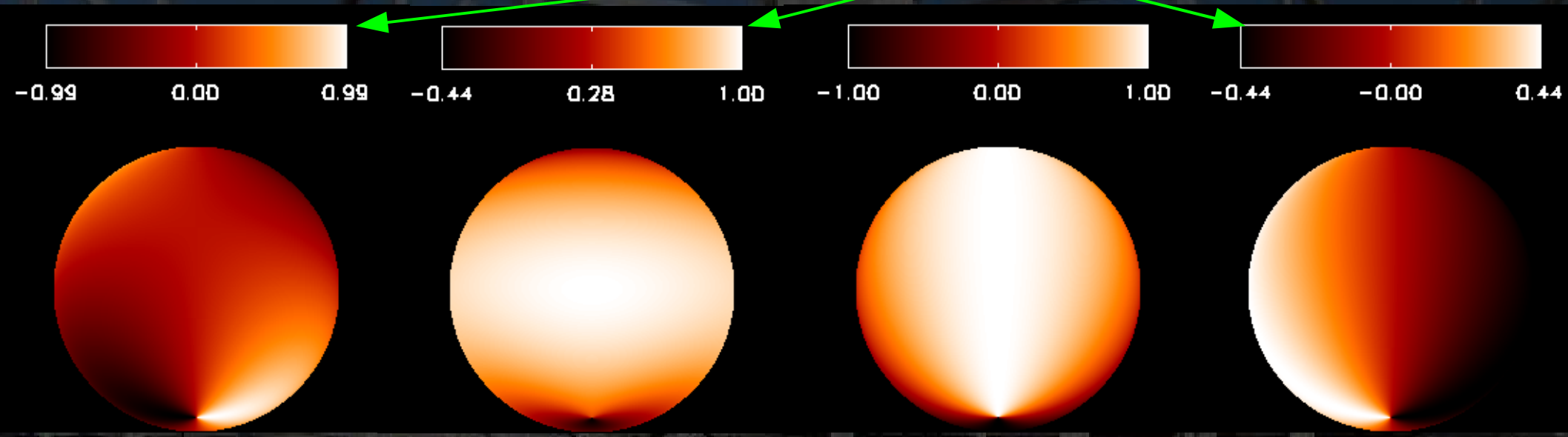
Simulator Status

- Fully polarized instrument response ✓
- Realistic, non-equal, dual-pol antennas ✓
- Sky comprising diffuse and point sources with polarized description of sky NEW ✓
- All sky coverage ✓
- Different pointing and phase centers NEW ✓
- Ionosphere model with large scale density and small scale turbulent structure. NEW ✓
- Ionospheric Faraday rotation ✗

Fixed dipole polarised response

- For lat -26^0
- dipoles aligned with E-W or N-S
- Response to E field aligned with RA or DEC

Note linear scales



+DEC onto EW dipole

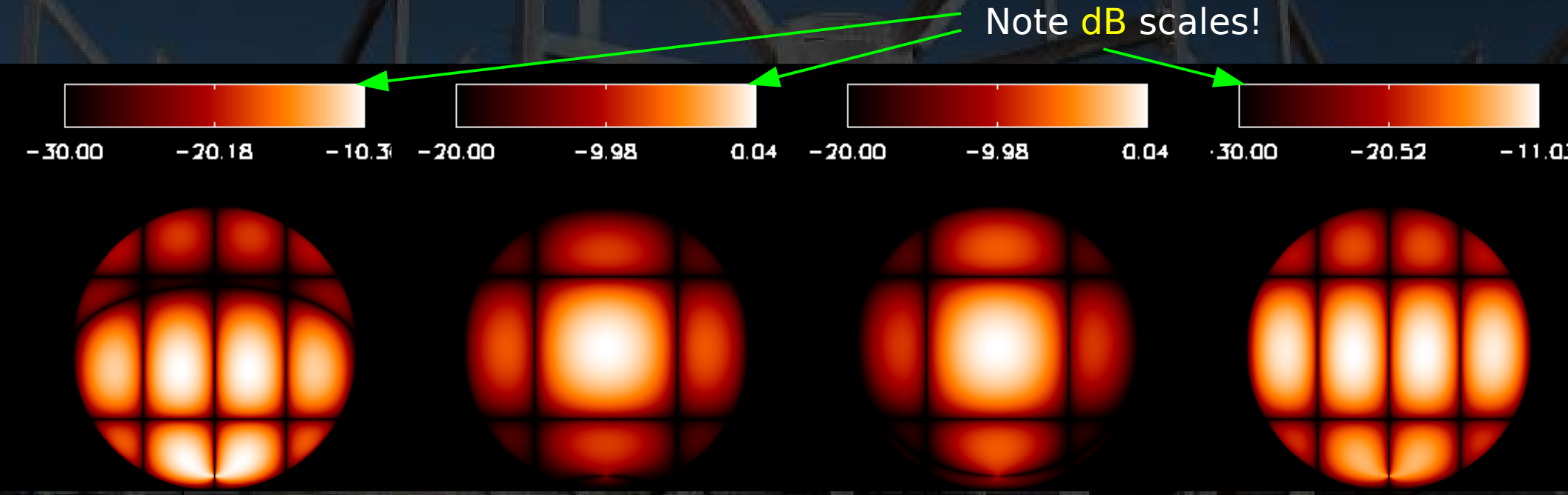
+DEC onto NS dipole

+RA onto EW dipole

+RA onto NS dipole

MWA antenna Jones matrices

- Phased arrays overlay array pattern and groundscreen attenuation.
- Examples at 140MHz



+DEC onto EW antenna

+DEC onto NS antenna

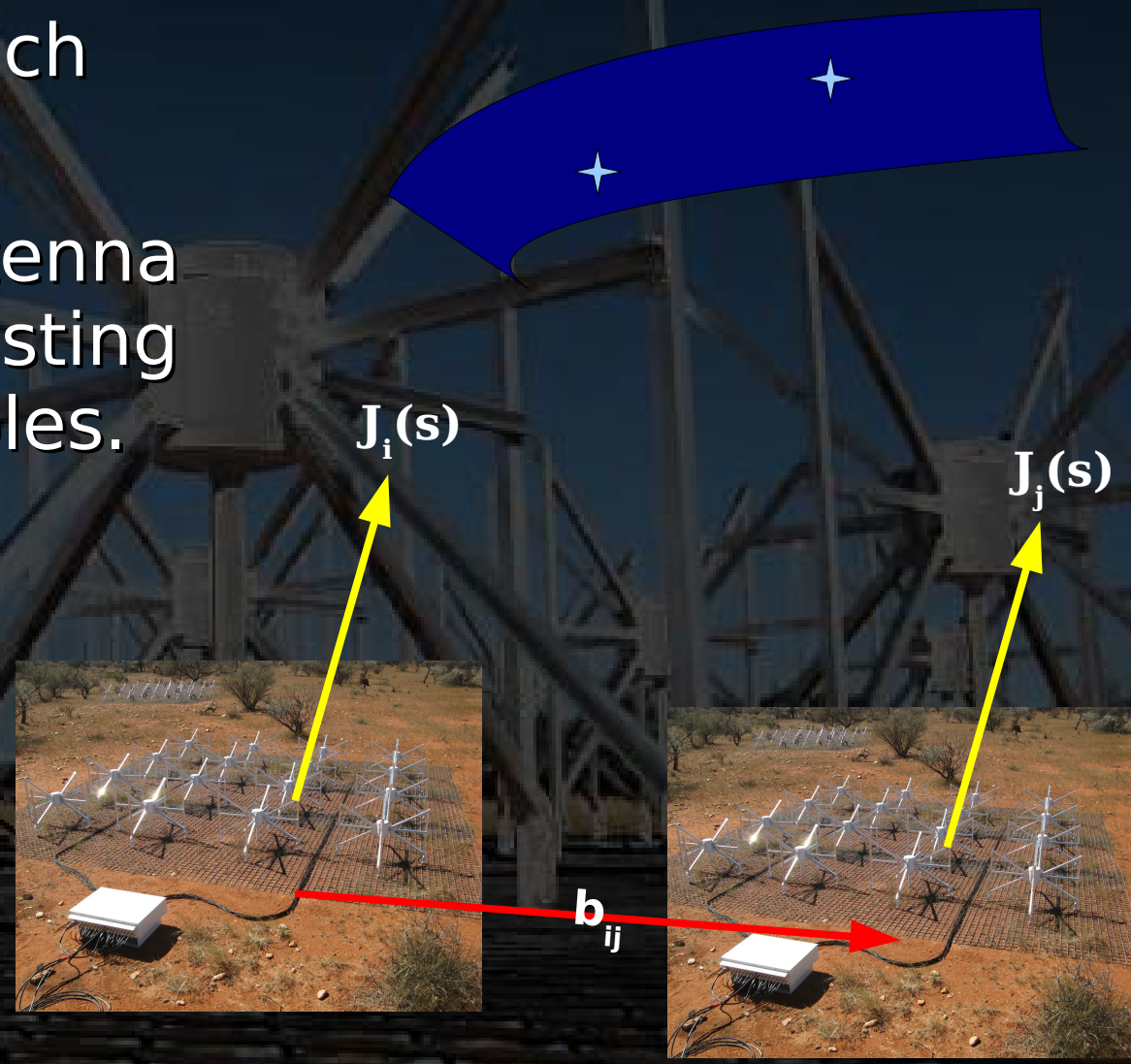
+RA onto EW antenna

+RA onto NS antenna

MAPS – point sources

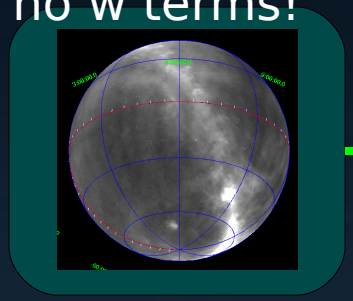
$$\mathbf{V}_{ij} = \mathbf{M}_{ij}\mathbf{M}^{S}_{ij}(\mathbf{s})\mathbf{SI}(\mathbf{s})e^{-2\pi i\mathbf{b}_{ij}\cdot(\mathbf{s}-\mathbf{s}_0)}$$

- Evaluate ME for each source...
- For MWA, each antenna is a “station” consisting of 16 dual-pol dipoles.



MAPS – diffuse sky

Entire sky centered on zenith
- no w terms!



Sky(l,m)
(I,Q,U,V)

FFT

u

v

Σ

Visibility (XX,XY,YX,YY)

Sky(u,v)
(I,Q,U,V)

Primary beam sample (l,m) 32x32 pix

St 1(l,m) Jones

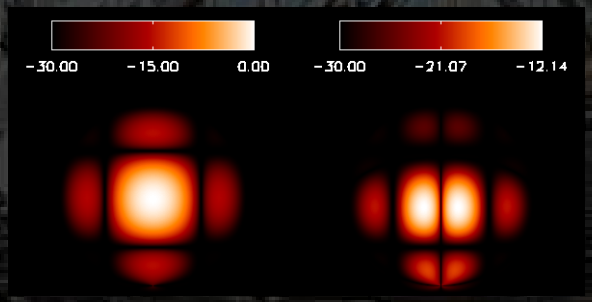
St 2(l,m) Jones

...x16

Baseline Mueller (l,m)

FFT

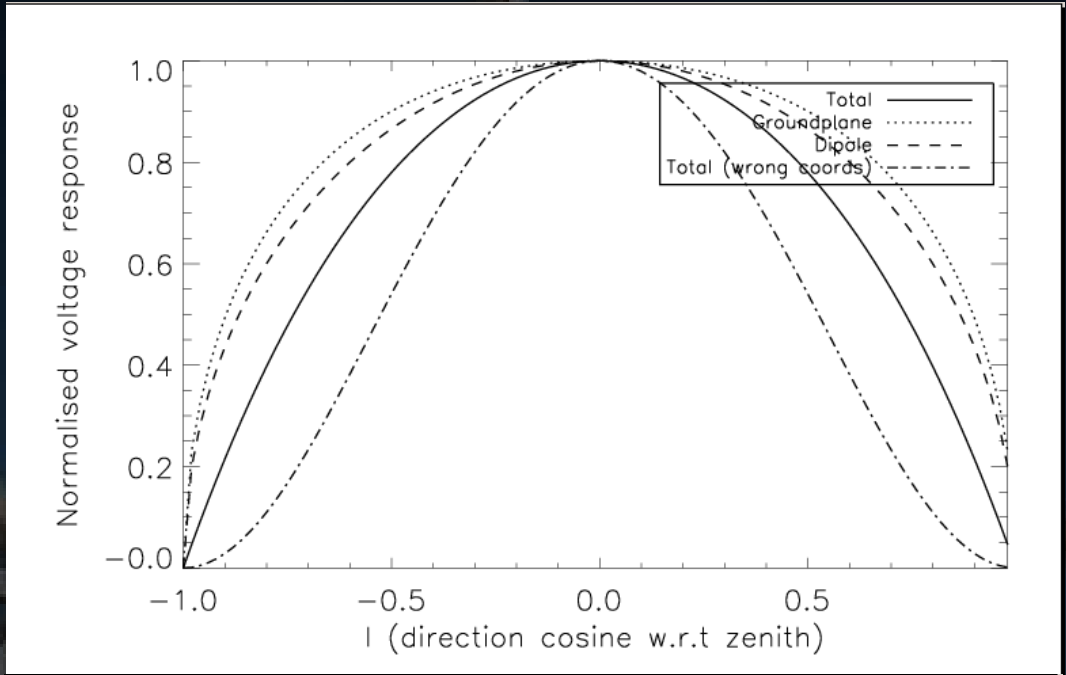
Baseline Mueller (u,v)

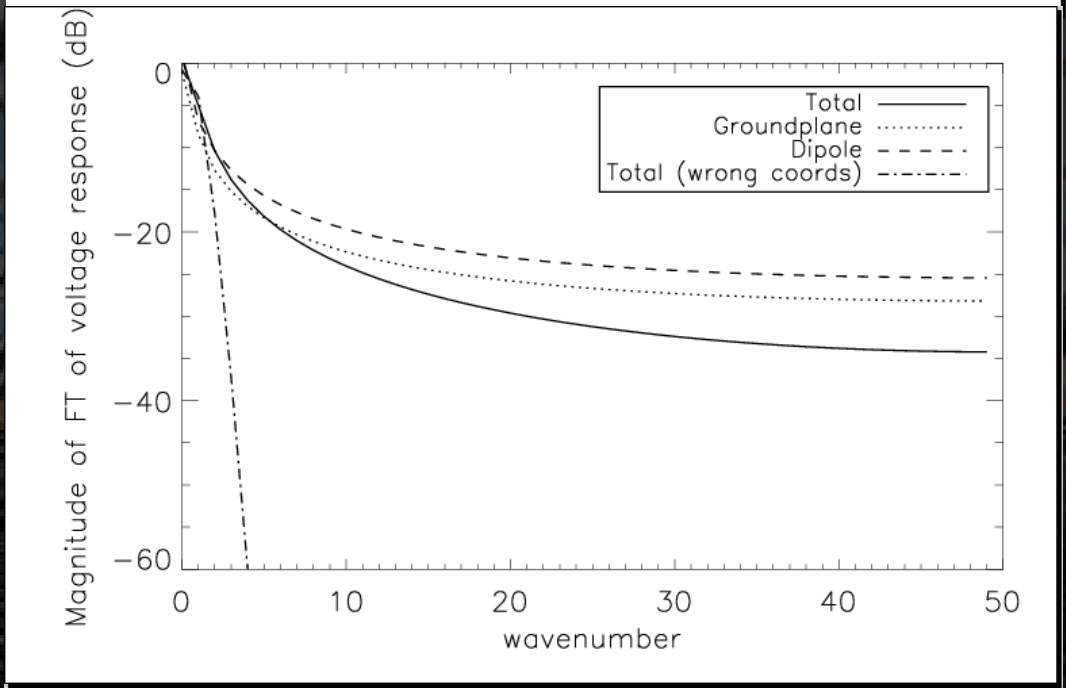


- Time, freq averaging possible
- Ionosphere goes into station Jones matrix
- Sky sampling grid must adequately sample sky

Primary beam convolution kernels (1)

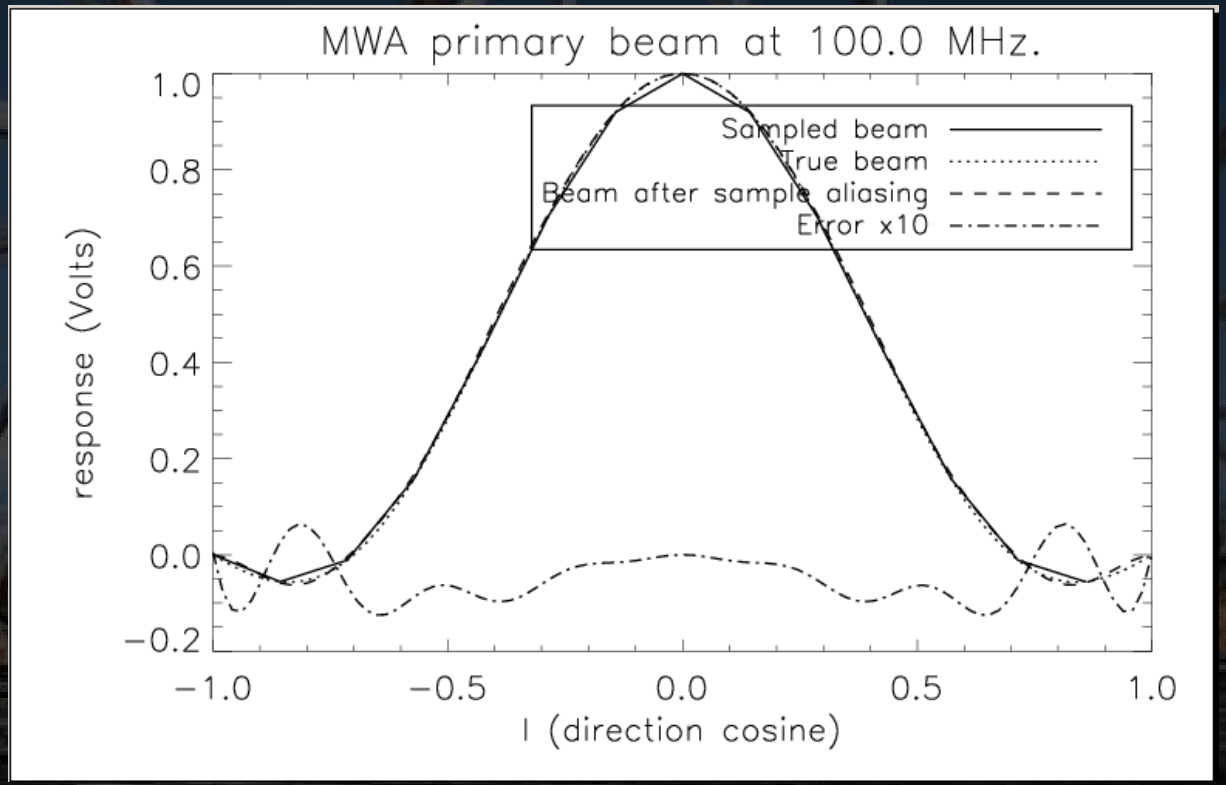
- A short dipole over groundscreen does not have a (perfectly) compact (u,v) space representation
- This is a “wide field” effect: in the wrong coords (angle instead of direction cosine), the response is compact.





Primary beam convolution kernels (2)

- The MWA primary beam is non-negligible over the entire sky
- Sub-sampling the primary beam risks aliasing!



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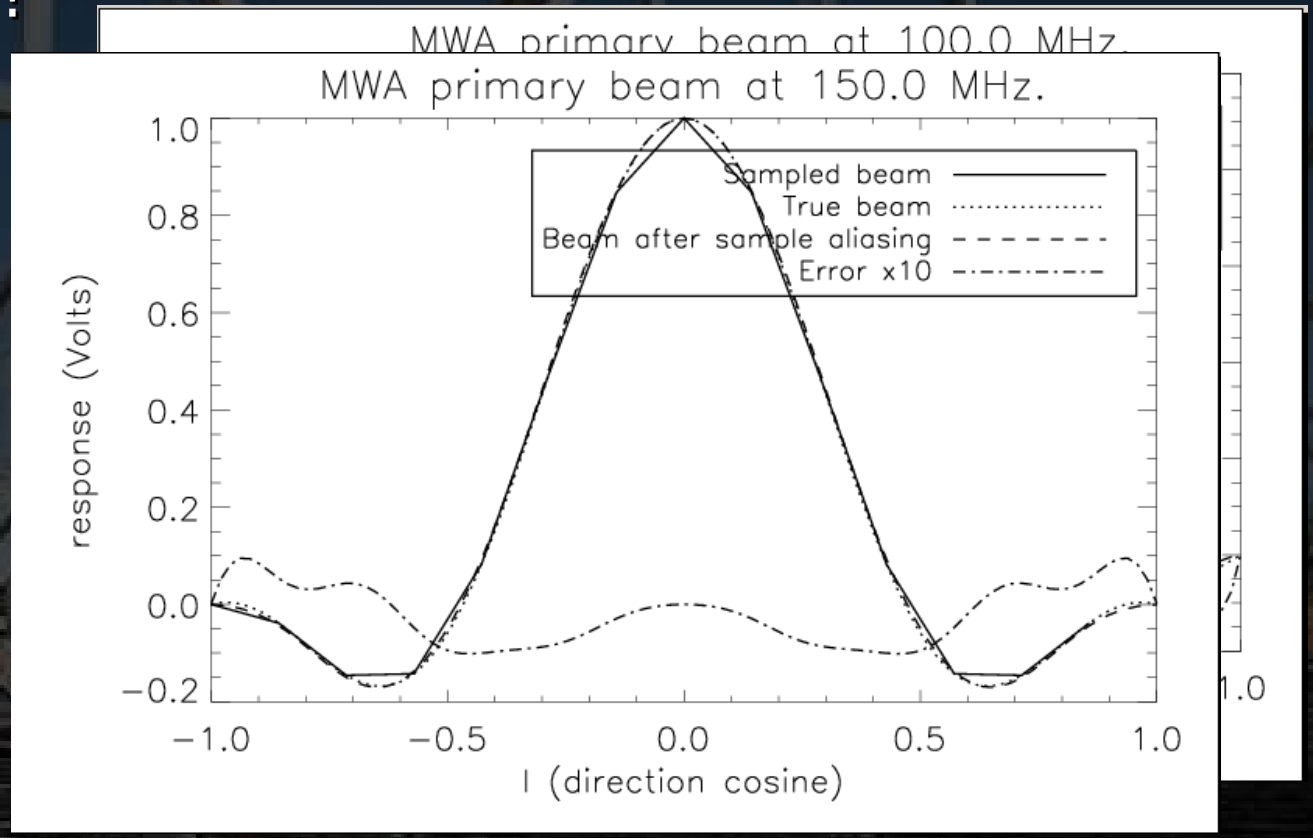

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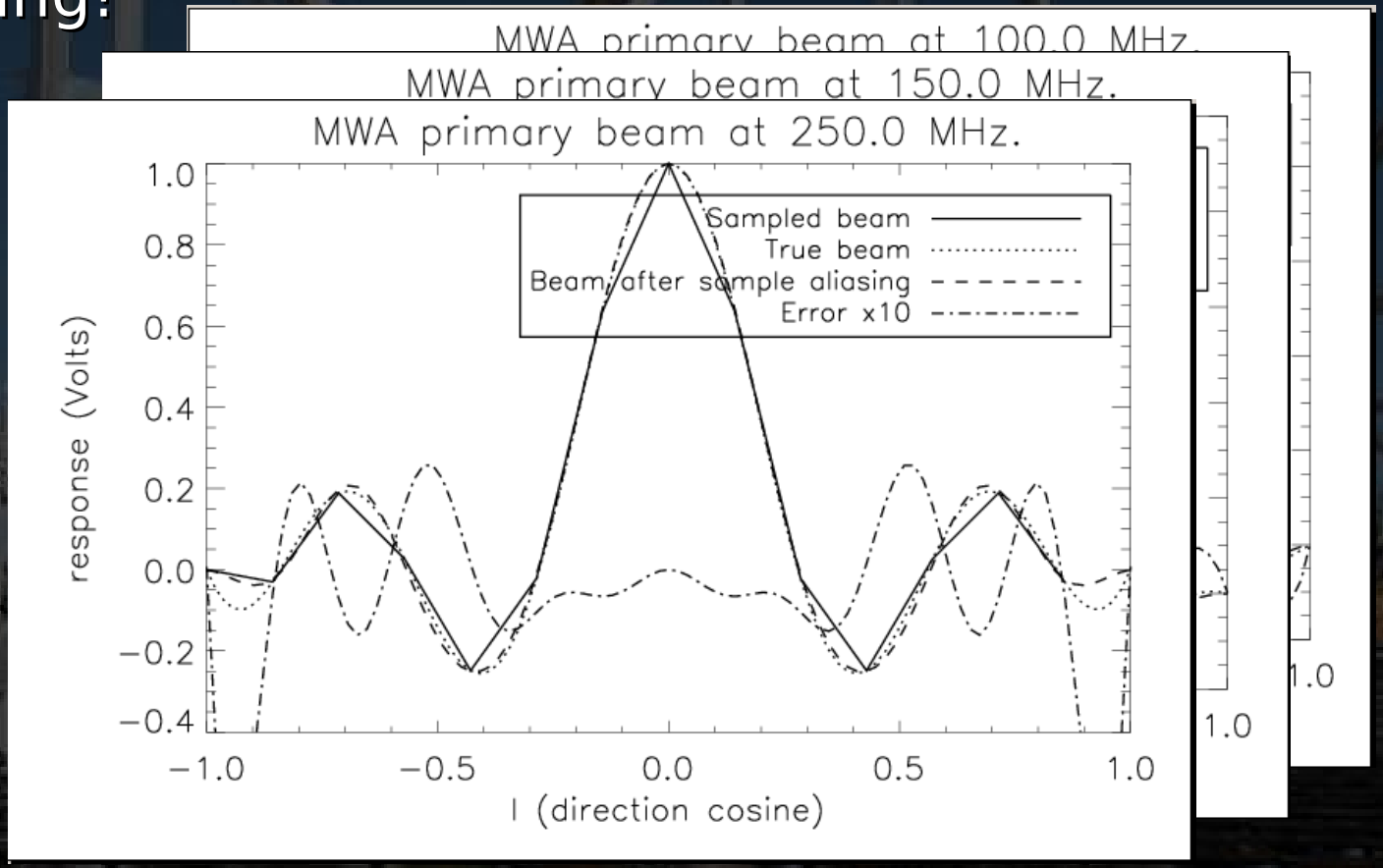
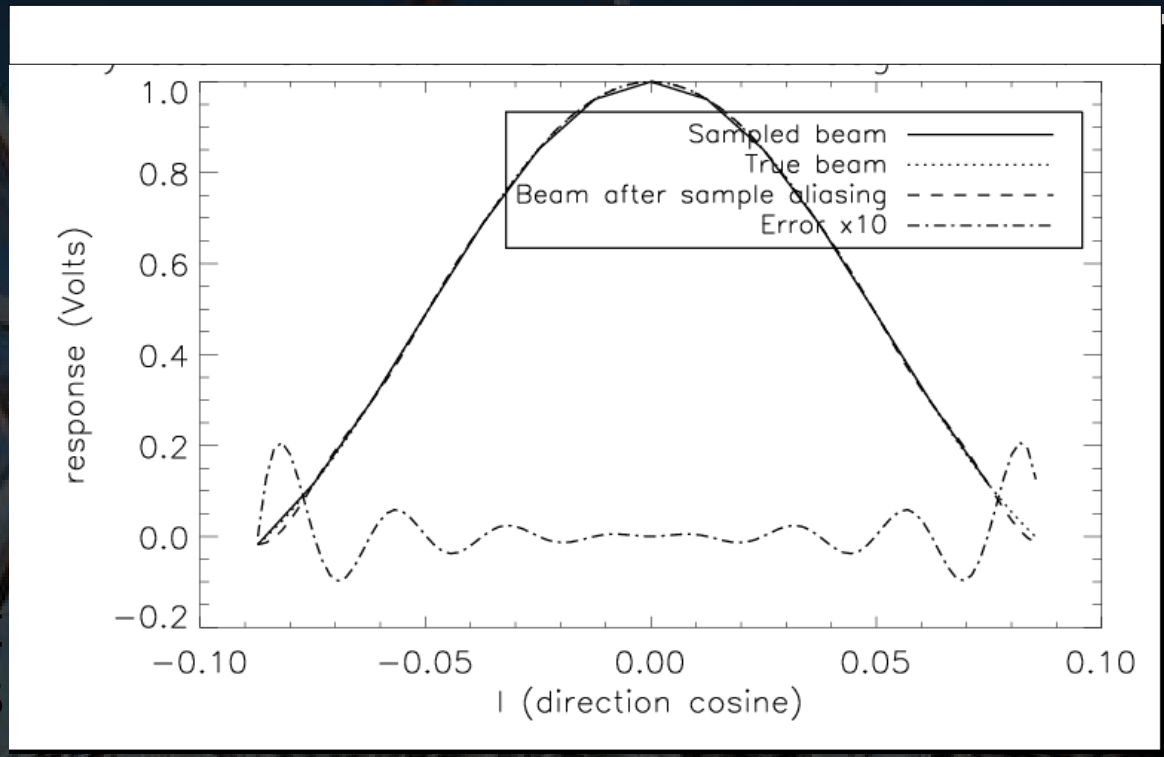
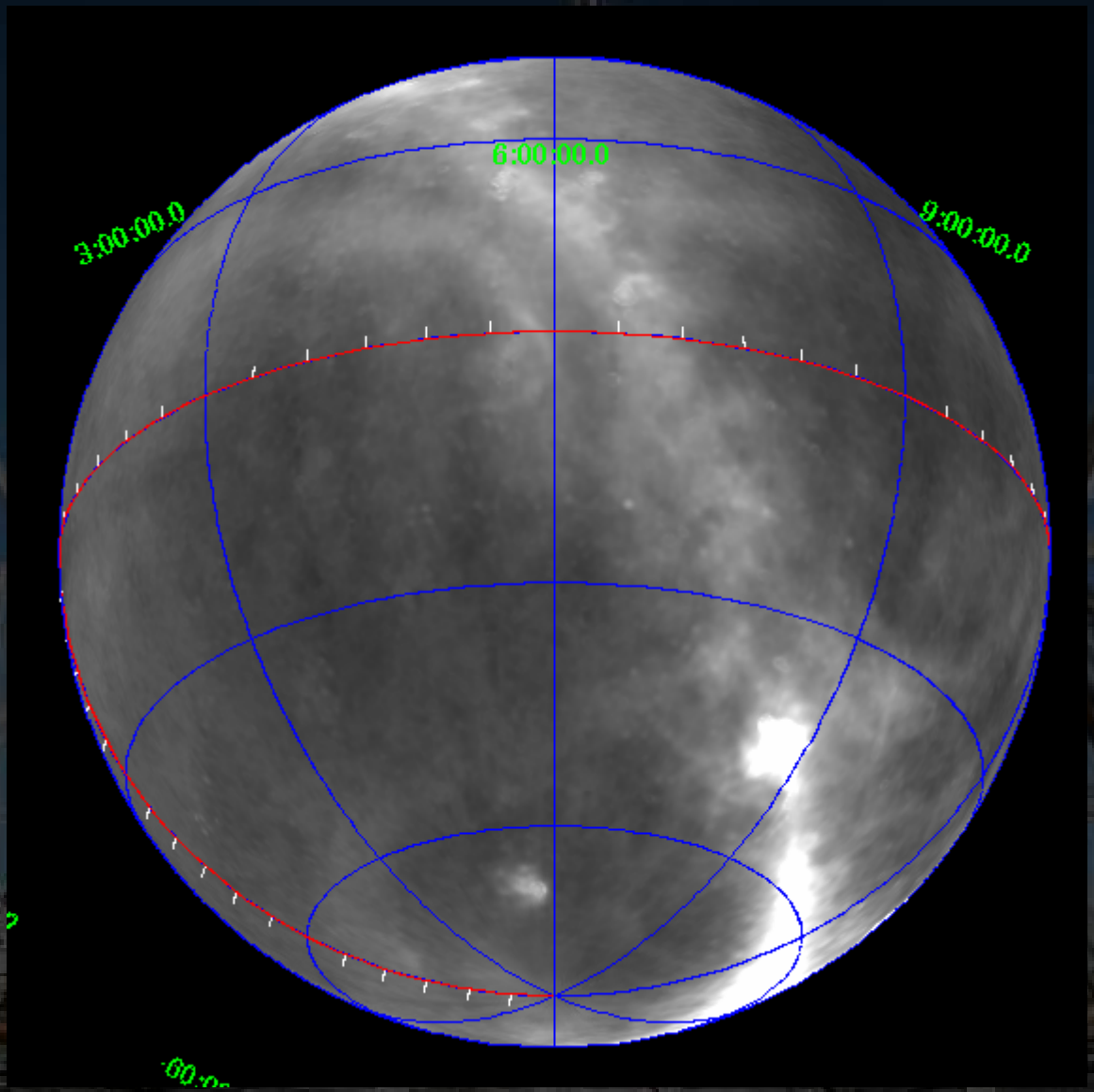


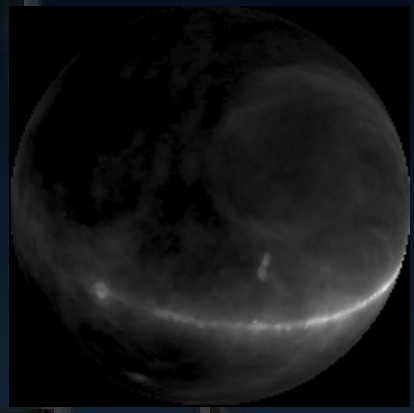
Primary beam convolution kernels (2)

- The MWA primary beam is non-negligible over the entire sky
- Sub-sampling the primary beam risks aliasing!
- Not just MWA... any time the beam is sampled with a discontinuous gradient will cause aliasing...
- E.g.: Uniformly illuminated circular aperture out to first null (FWHM = 4 degs in this case)



MAPS inputs: diffuse sky

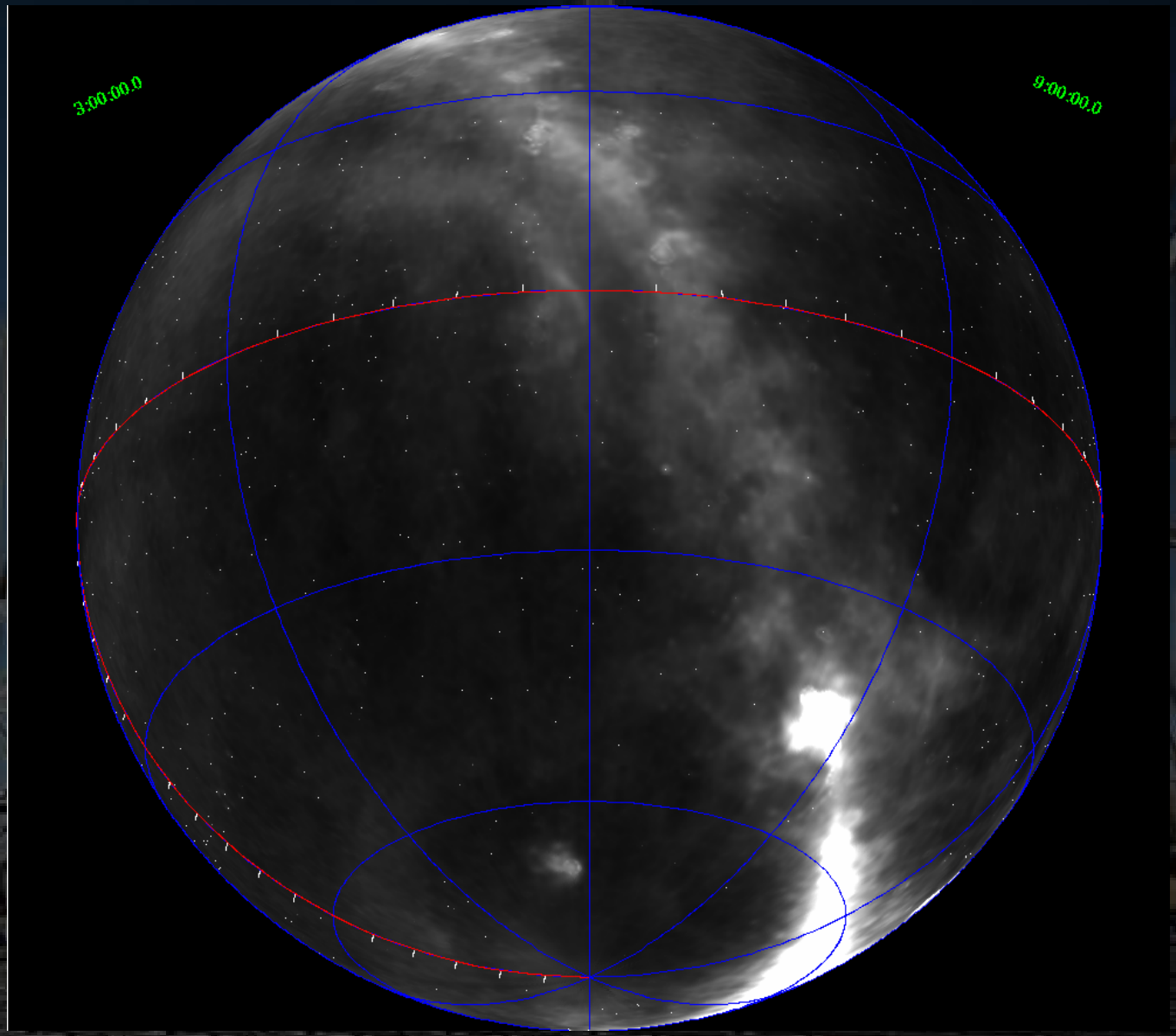




Model 140MHz radio sky at lat -26 deg

Diffuse sky model from Angelica de Oliveira-Costa
http://space.mit.edu/home/angelica/gsm/

Example – input sky for LST 6h

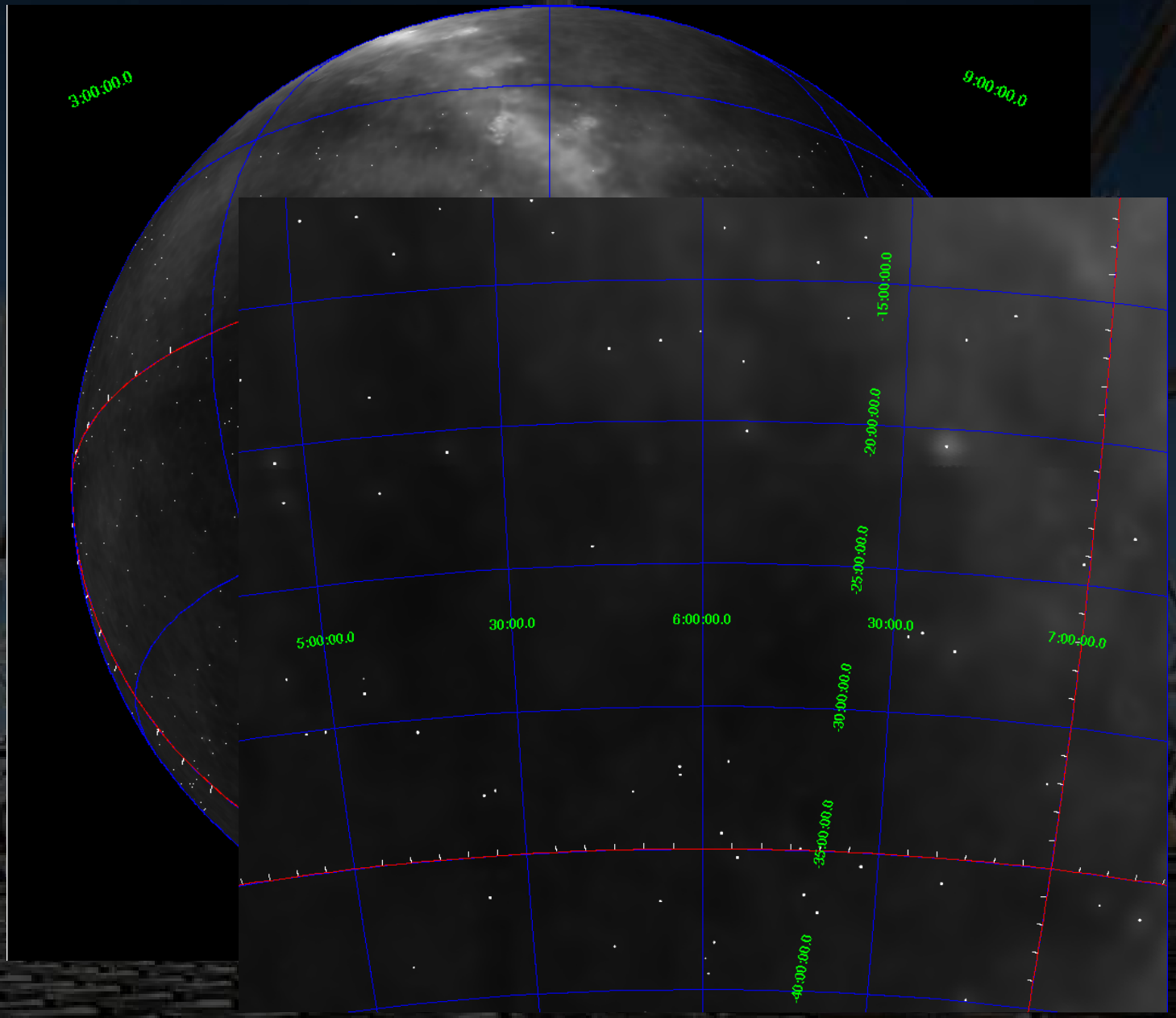


Point sources from Parkes cat 90.

Pure Stokes I input (in this example)

Image size: ~6000x6000 pix

Example – input sky for LST 6h

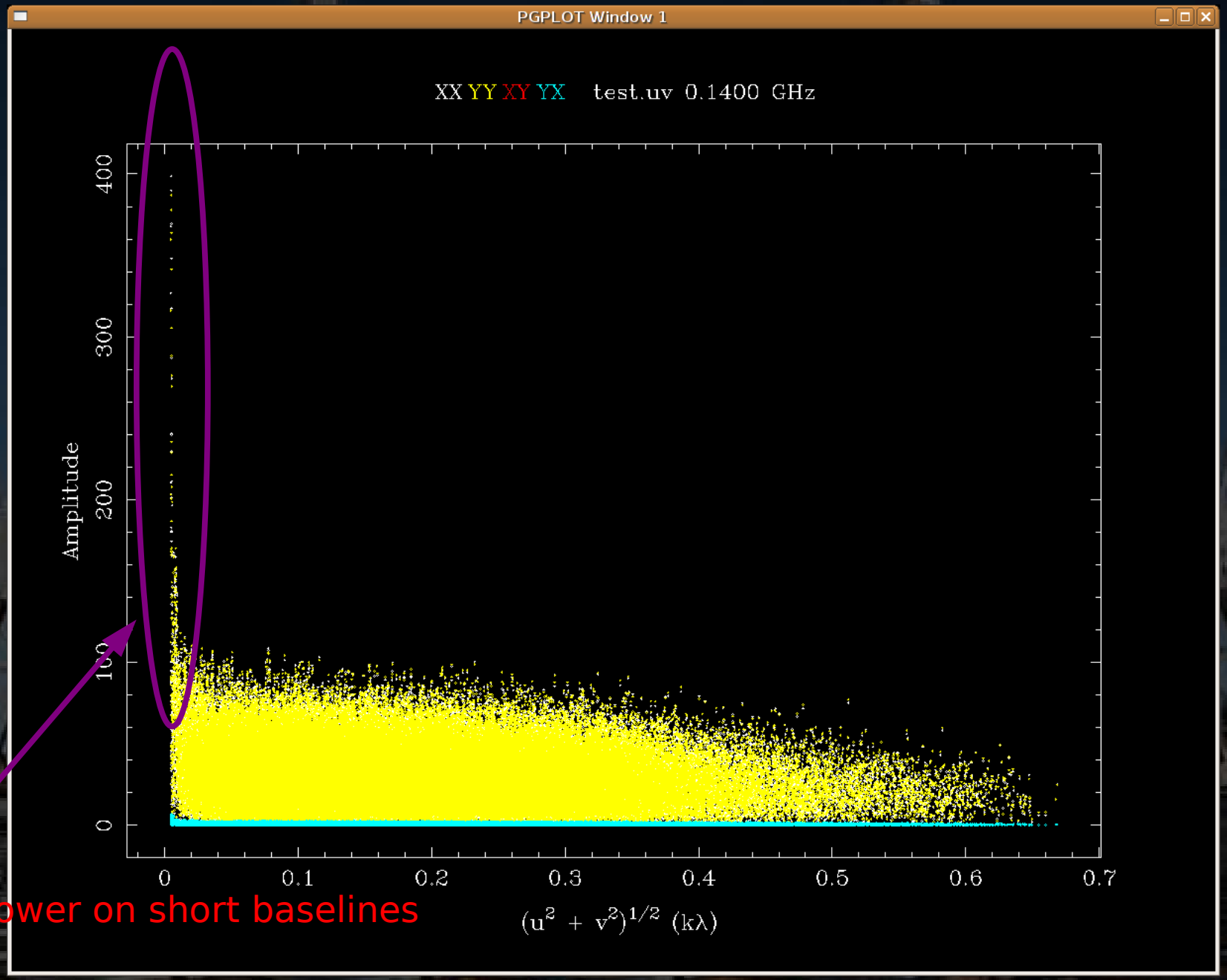


Pure Stokes I input (in this example)

Image size: ~6000x6000 pix

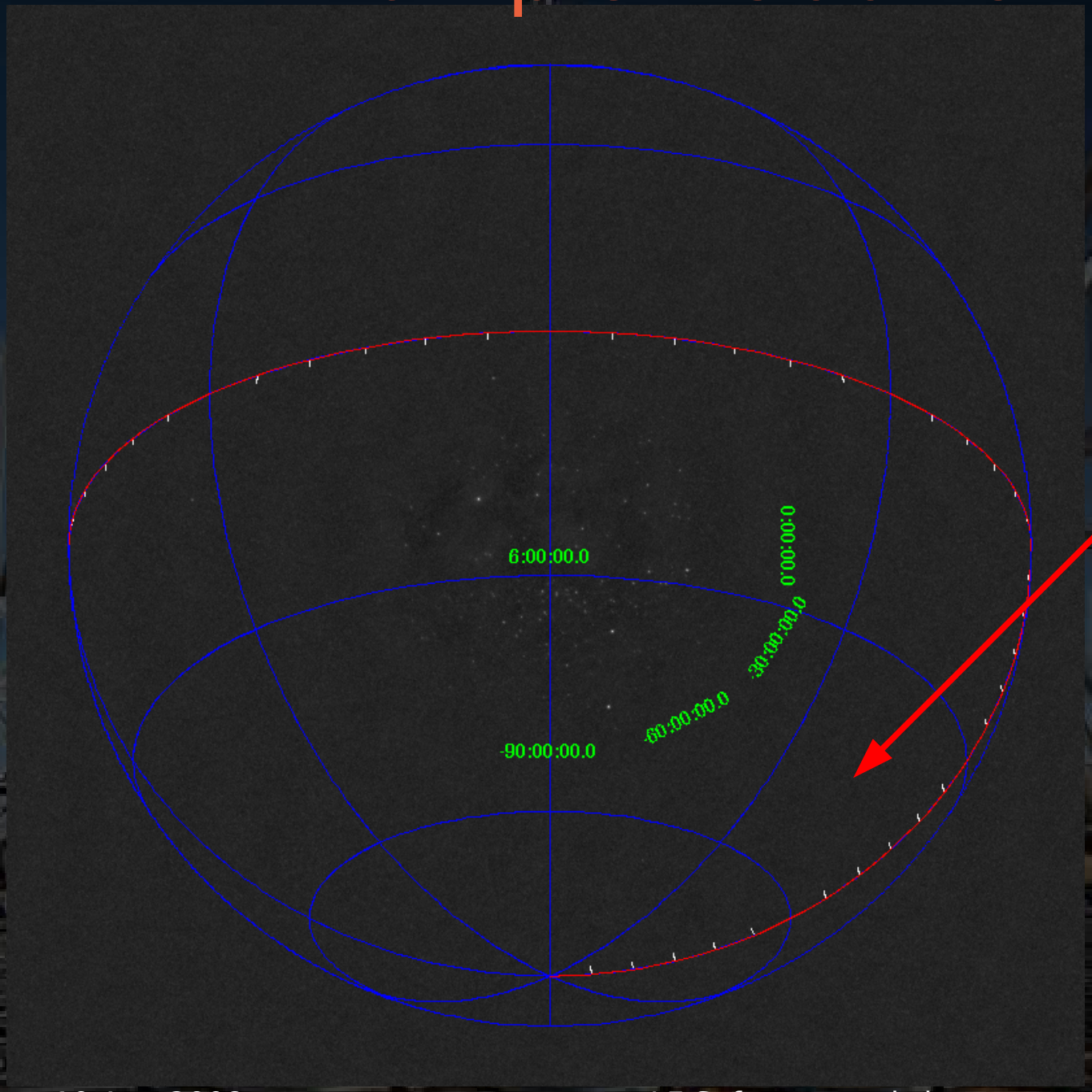
zoom on central ~30 x ~30 deg

Example – 500T snapshot



Huge power on short baselines

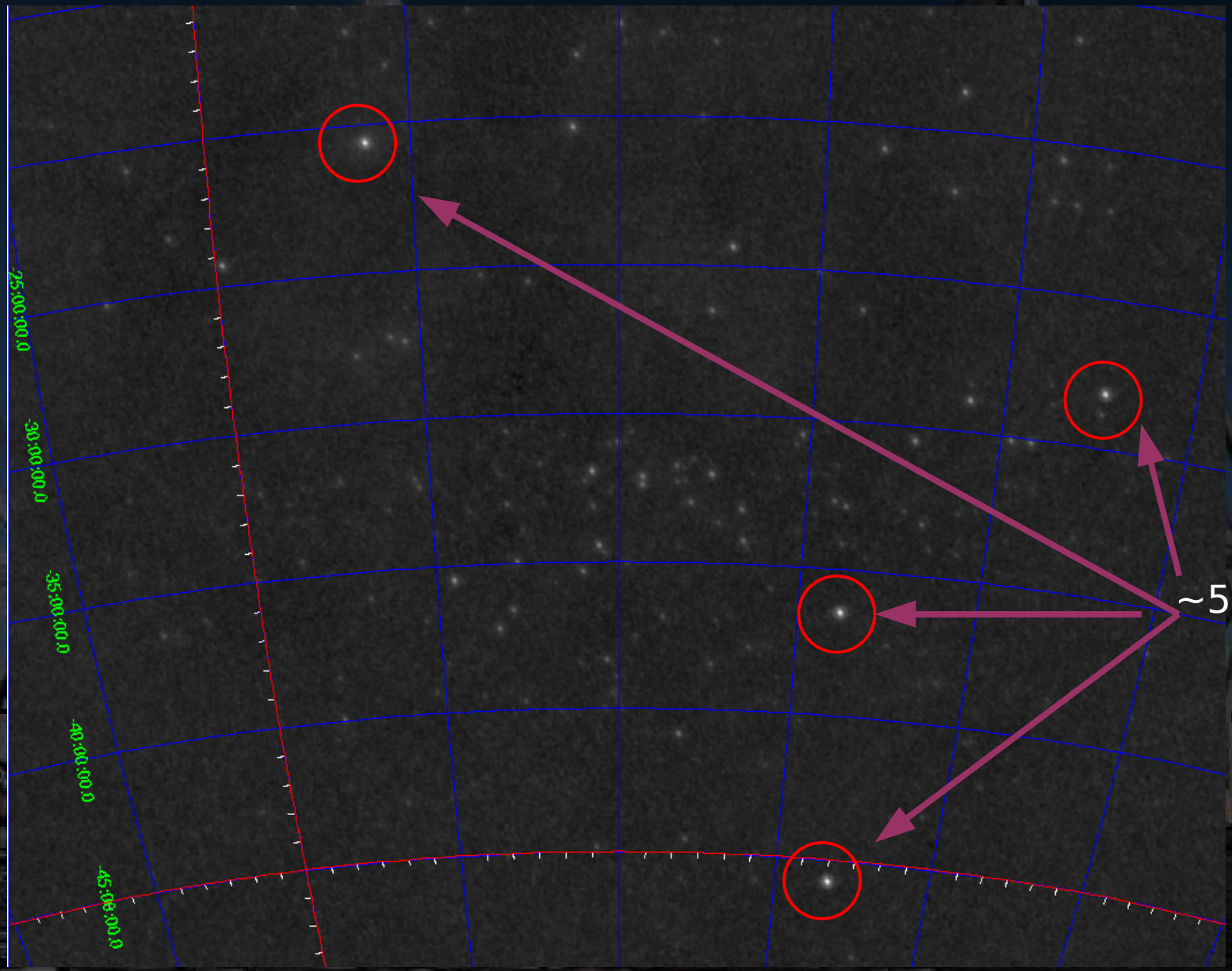
Example – 500T snapshot



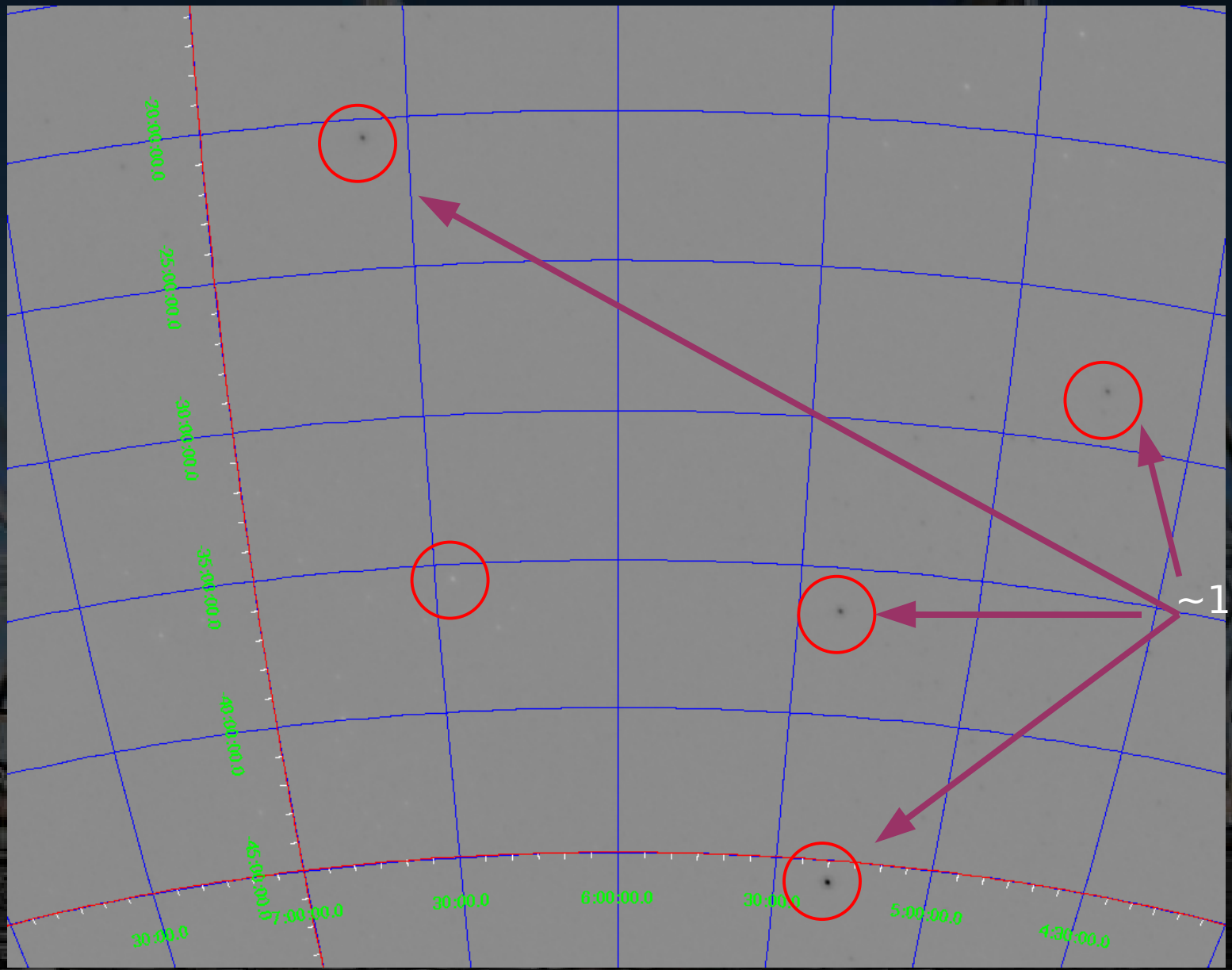
Note: sqrt stretch

Galactic plane is gone from antenna beams

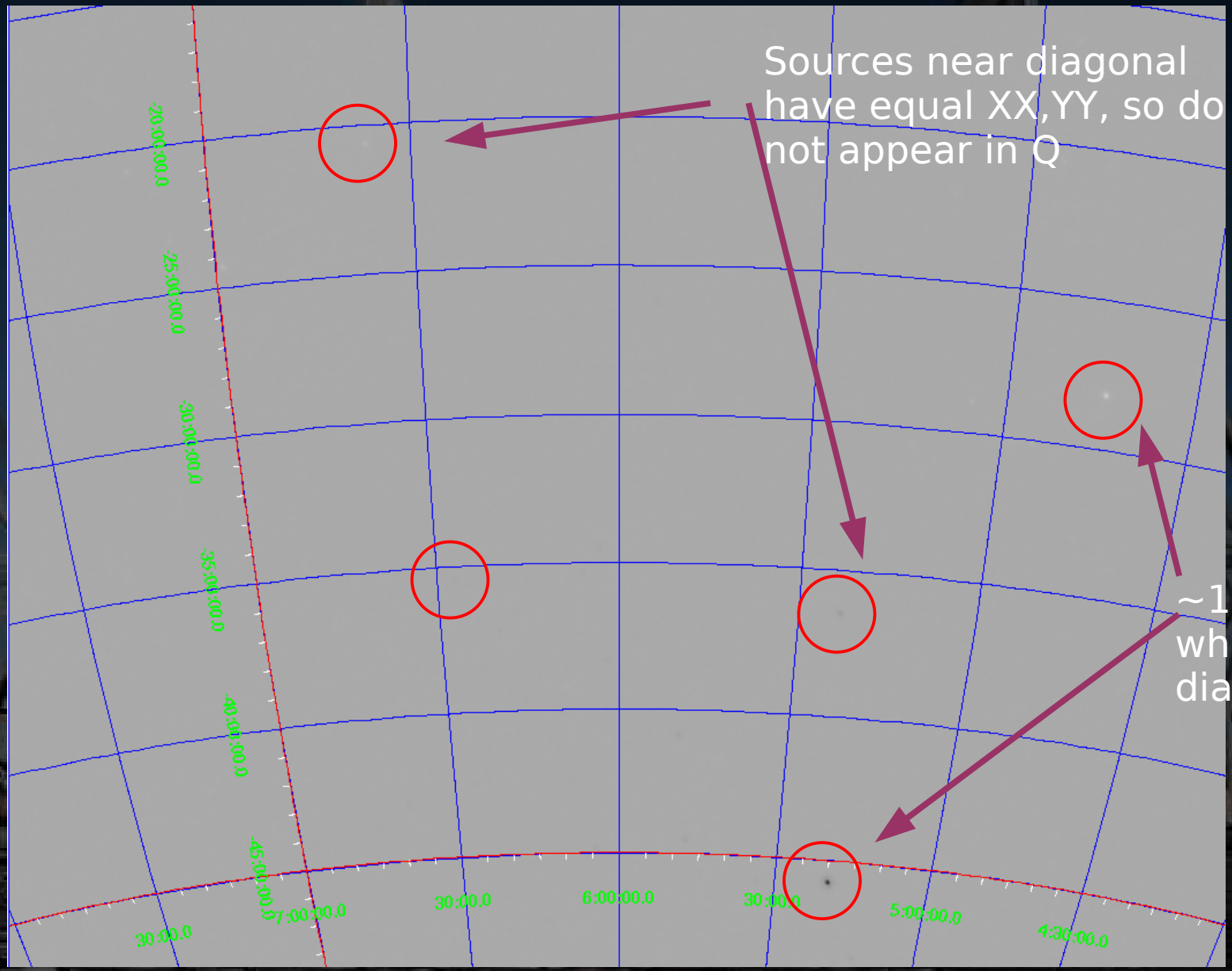
Example – 500T snapshot: Stokes I



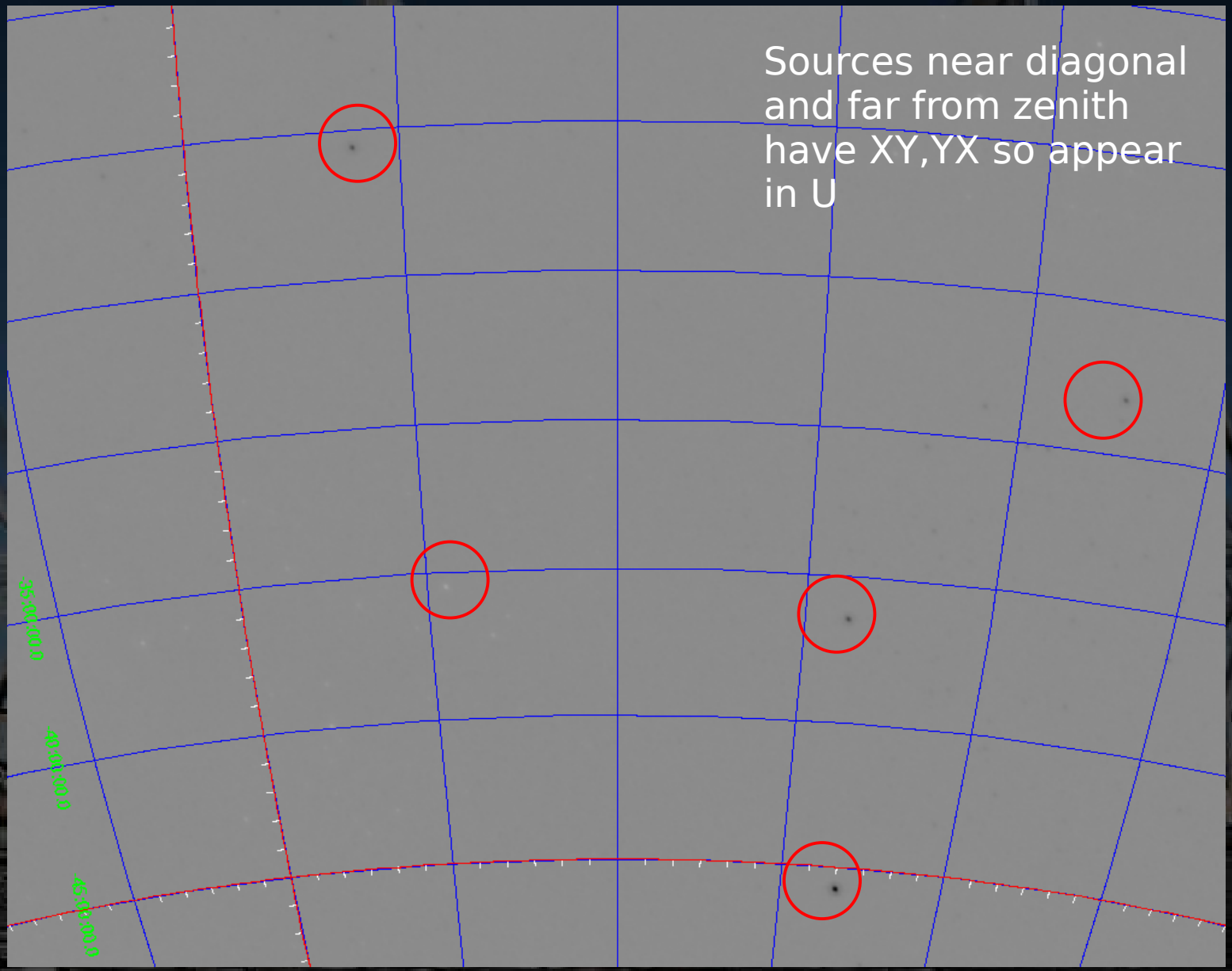
Example – 500T snapshot: XY



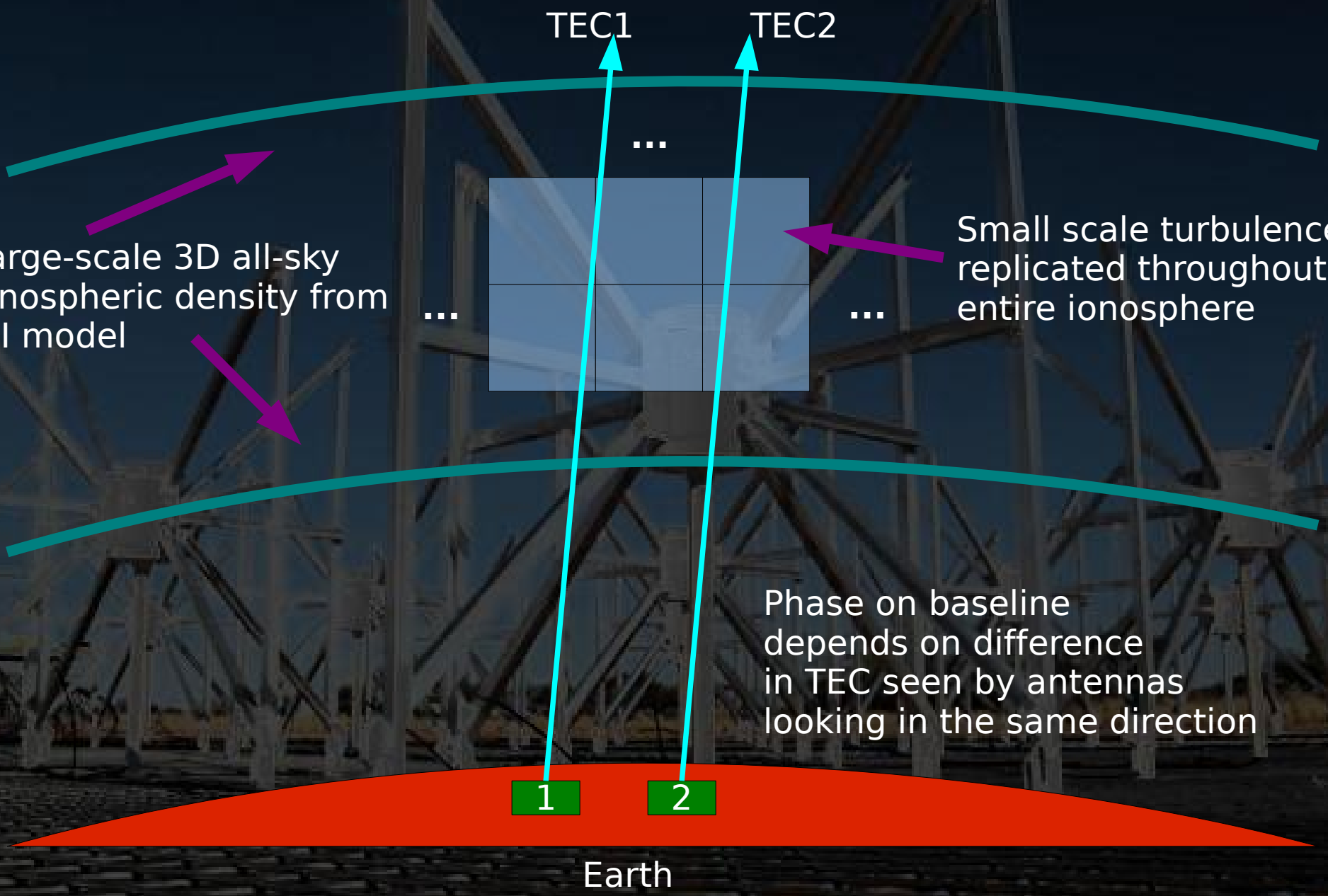
Example – 500T snapshot: Stokes 'Q'



Example – 500T snapshot: Stokes 'U'



New and improved ionosphere



Questions?