Progress Toward the SKA:

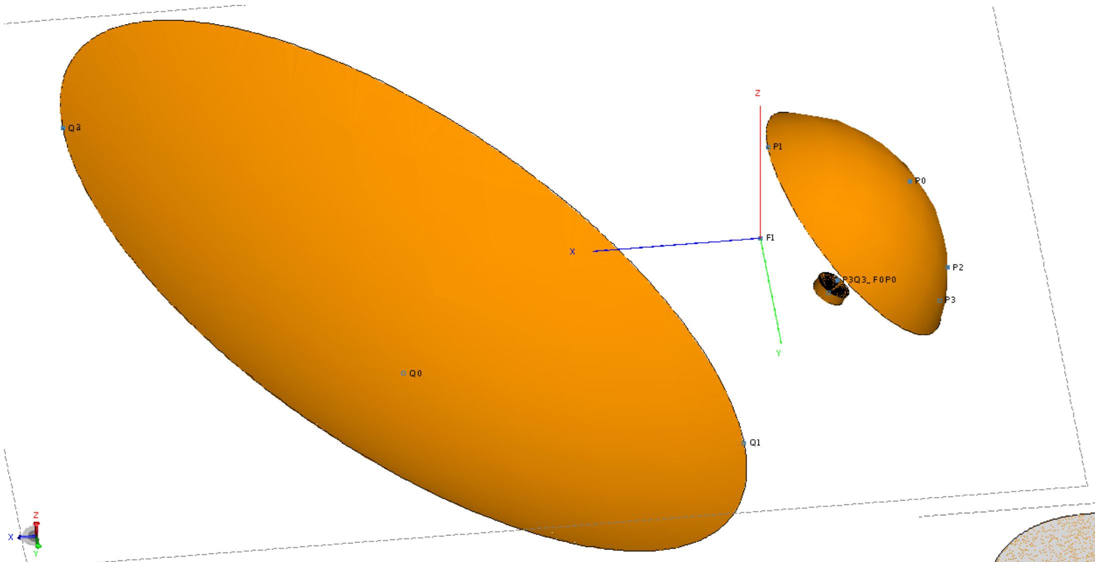
Views on Modeling & Imaging

Tobia D. Carozzi

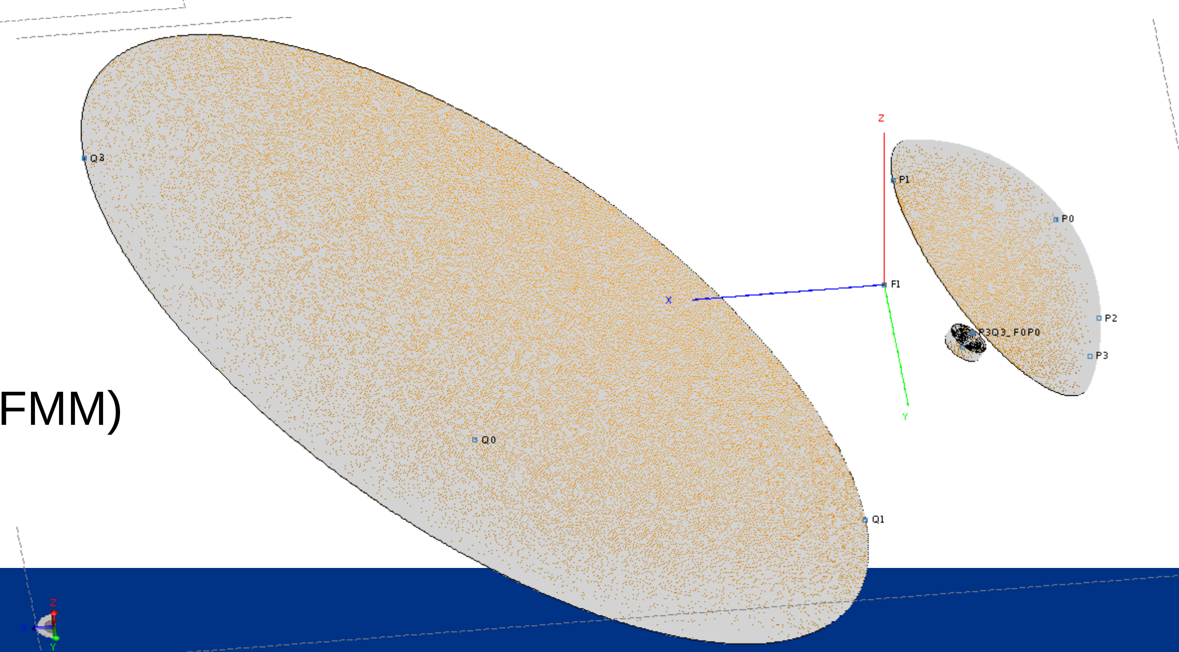
SKA feed modeling

- Chalmers/OSO is involved in
  - Band 1
    – 350 – 1050 MHz
  - Band B
    – 4.6 – 24 GHz
- These are wideband bands >1:2 (wider than octave)
- Have used numerous modeling tools
  - FEKO, CST, GRASP, in-house sensitivity S/W

FEKO modeling multiscale modeling



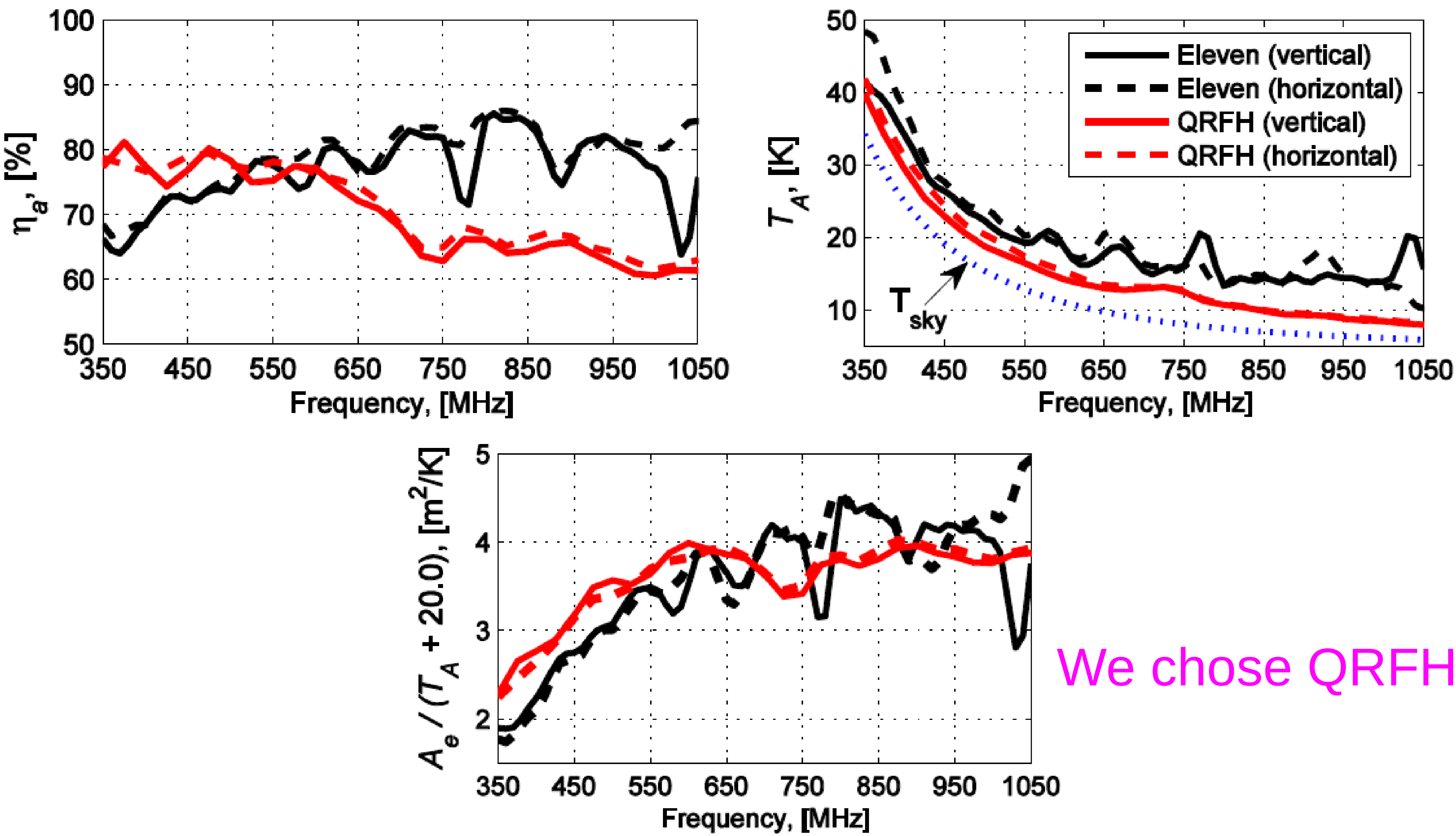
- Mesh has ~200k mesh elements
- Largest wavelength ~1 m
- Smallest wavelength ~30 cm
- => Multilevel Fast Multipole Method (MLFMM)



Considered Wideband technologies

- Eleven feed
  - Original feed invented at Chalmers
  - Based on two side-by-side (wideband) dipoles
- Quadridge feed horn (QRFH)
  - Legacy feed

Down select results band 1



We chose QRFH

Additional modeling required

- Interferometry modeling
  - SKA sky models
  - MeqTrees
- RFI modeling
  - Widebands imply more RFI
    - Potentially limiting
  - Site characterization not enough
  - Need parametric models
    - Need more research and onsite measurements!
  - E.g.: recent discovery of a peryton cause…

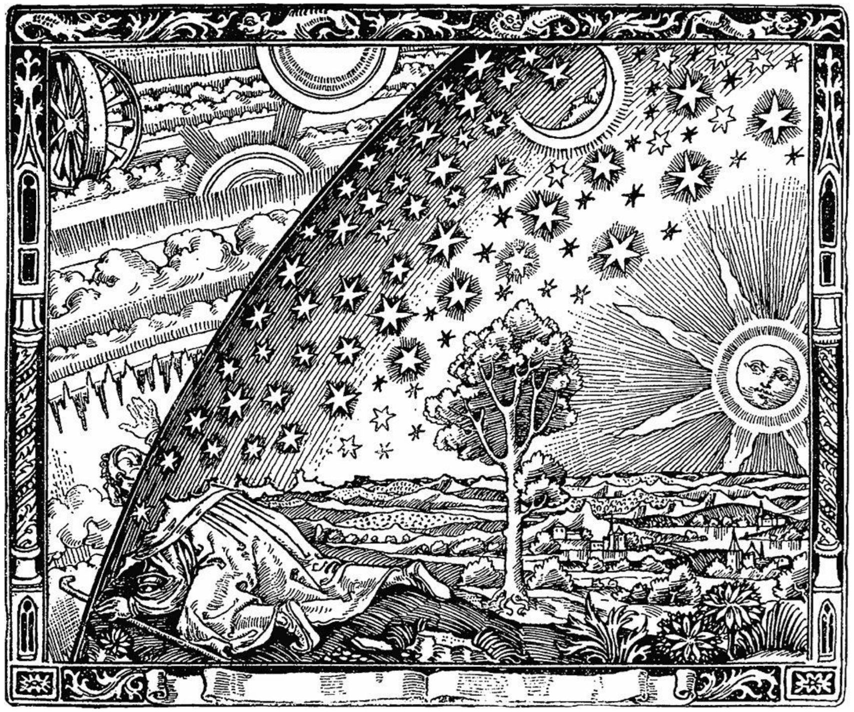
New Interferometric Imaging Paradigm: Spherical Wave Transform

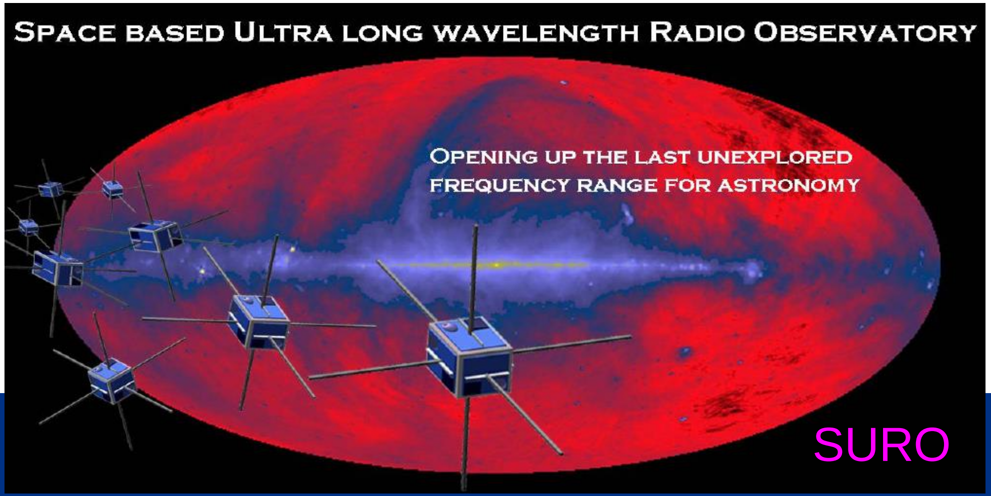
Imaging on Sphere

- All astronomical imaging is ultimately of the celestial sphere
- Yet historically interferometry is based on planar domains
  - Leads to use of Cartesian Fourier transform
- Cartesian Fourier paradigm becomes messy when dealing with Celestial sphere
  - Faceting
  - W-term corrections
  - etc

Flat Earth syndrome

- As Earthlings we have an innate preference for planarity
  - So Cartesian Fourier transform is natural in groundbased interferometer
- Consider a space based interferometer
  - No planes here!
- Spherical Fourier transform more natural





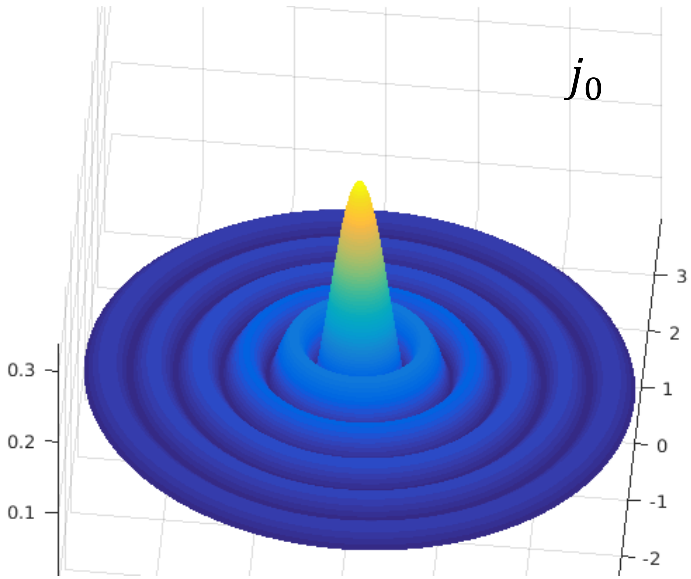
Spherical Measurement Equation

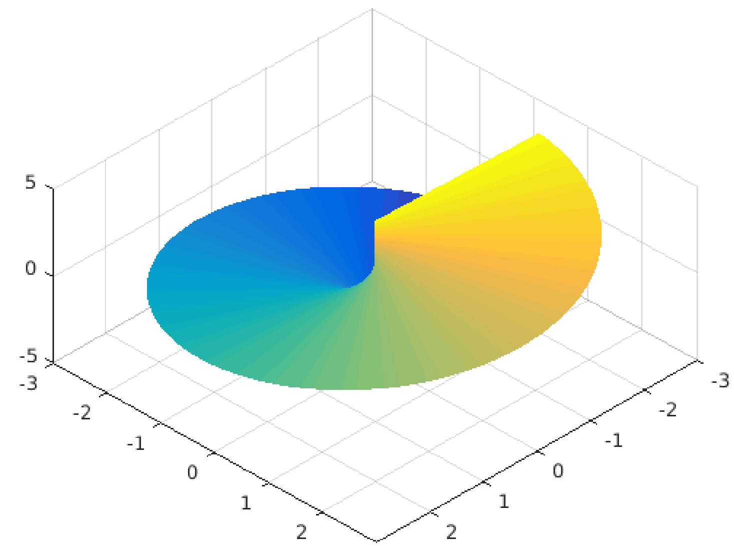
- Radio interferometric Meq is now the standard formalism in imaging and calibration
- i.e. $V(u,v,w) = \int B\,(l,m)\exp\left(i\left(lu + mv + \sqrt{1 - l^2 - m^2}w\right)\right)d\Omega$
- If we rexpress this on a spherical domain
- we get $\tilde{V}_{LM} = 4\pi i^l \tilde{B}_{LM}$
  - where L,M are spherical harmonics quantal indices
- No explicit integration!

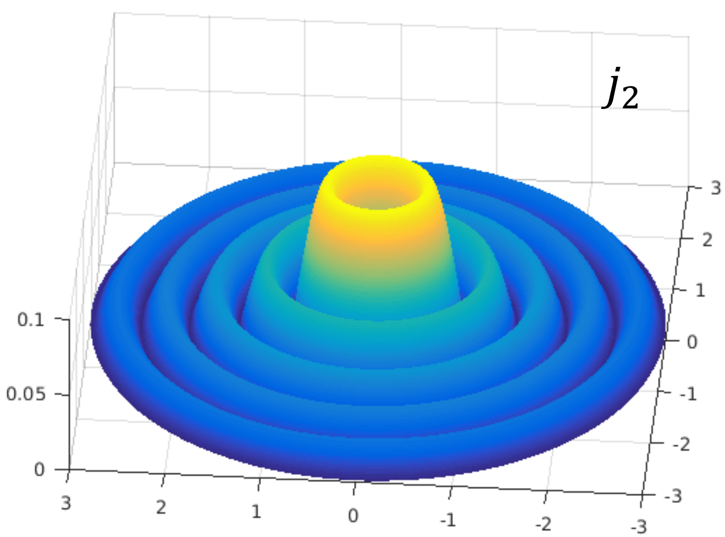
Spherical wave harmonics transform

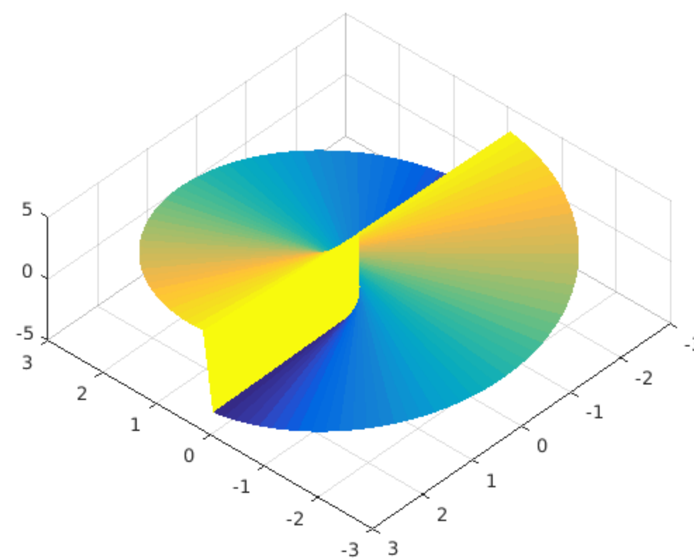
- To get the L,M coefficients of the visibility function requires a transform which I call the spherical wave harmonics (SWH) transform
- It amounts to multiplying the visibility with spherical wave functions x spherical harmonics

Spherical wave harmonics

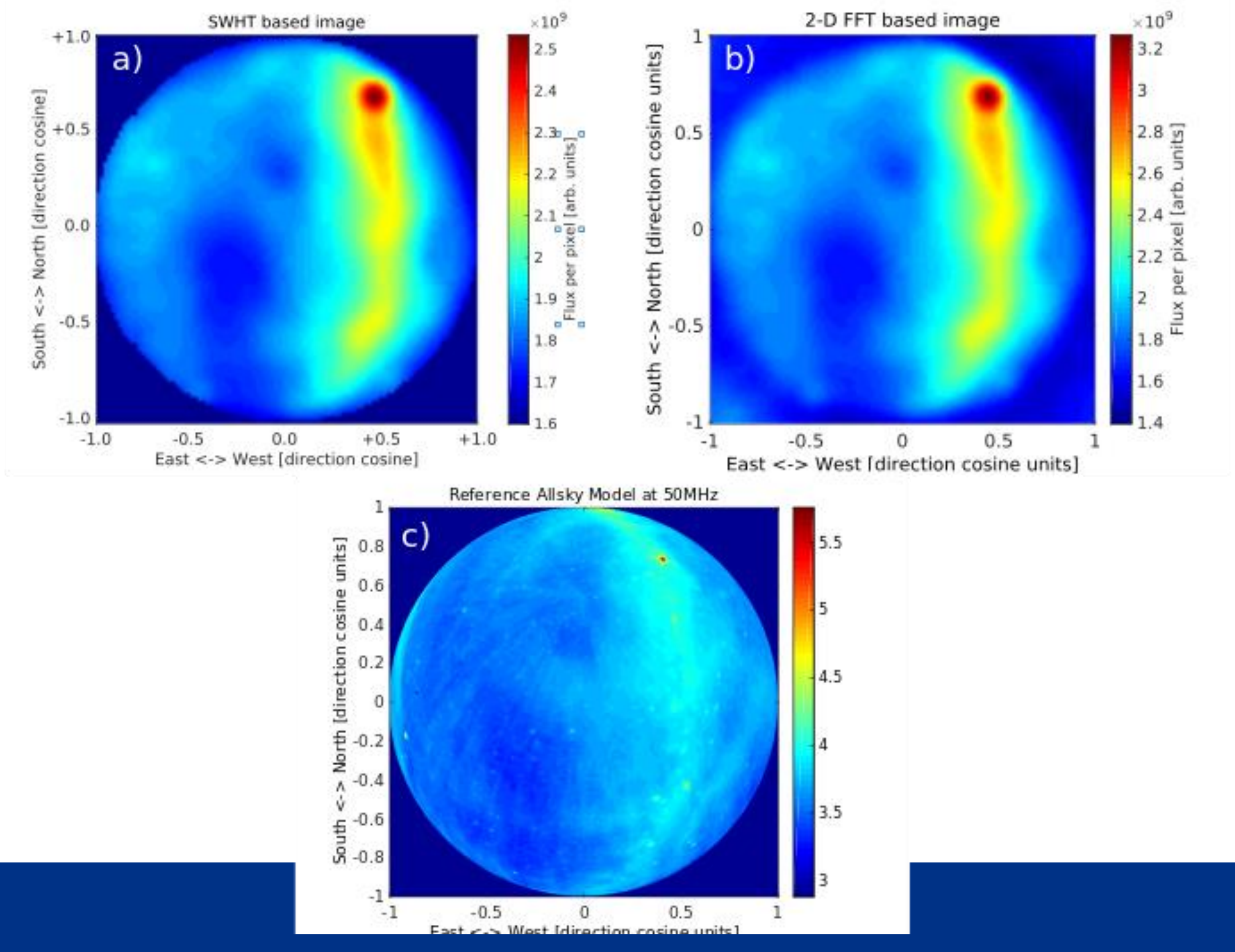








SWH transform applied to LOFAR single station data



Areas of Application

- Wide field imaging
  - Extended sources
  - Far out sidelobe mapping
- Non-coplanar visibilities
  - No w-terms to correct for
- Multipole moment calculations
- Space-borne interferometers
- Will benefit from future MIDPREP exchange with SA institutes (modeling, imaging s/w)

Thanks

- For more info see http://arxiv.org/abs/1504.04485