Image simulations and the UVBrick:

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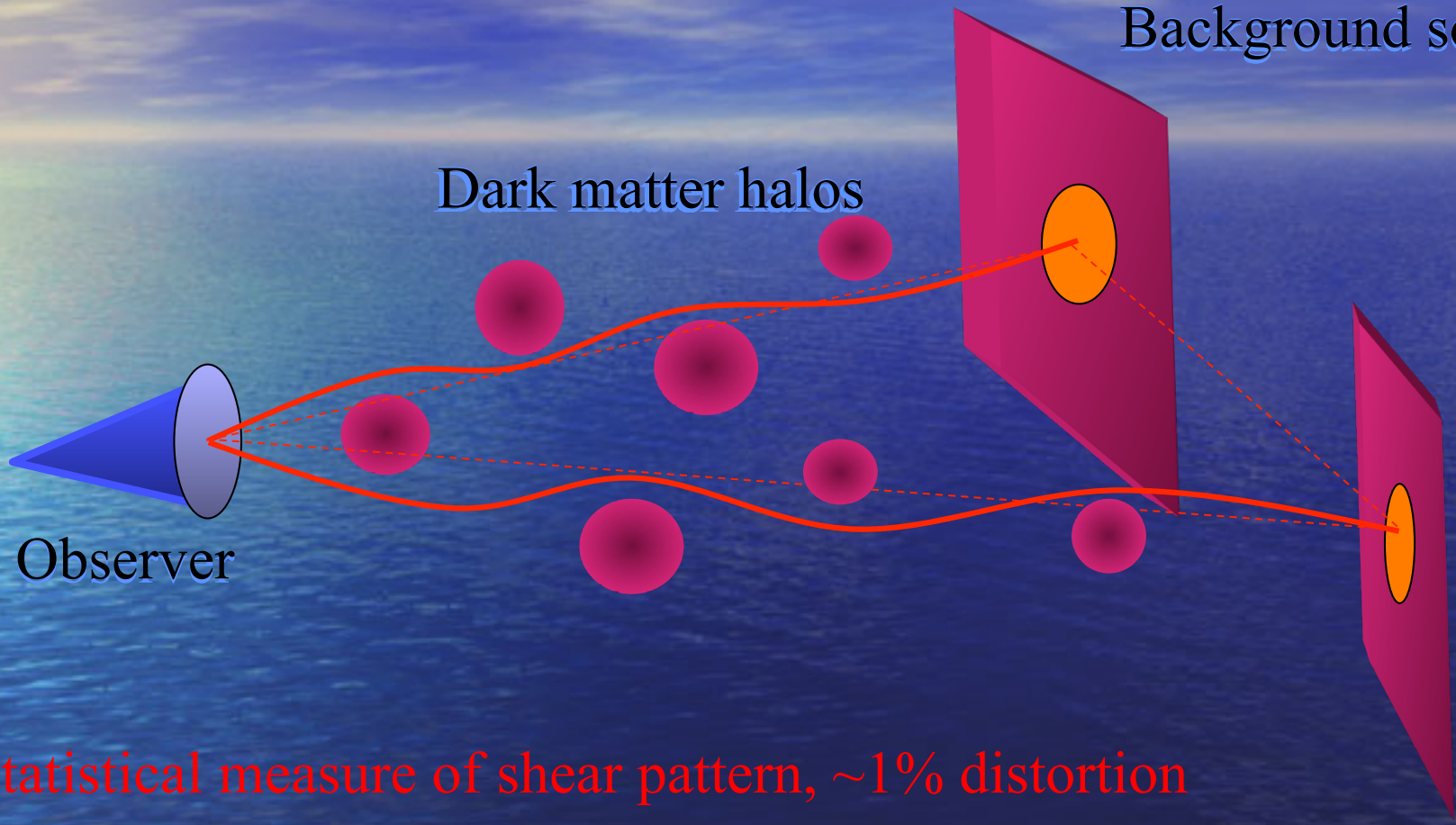
UCL

Outline

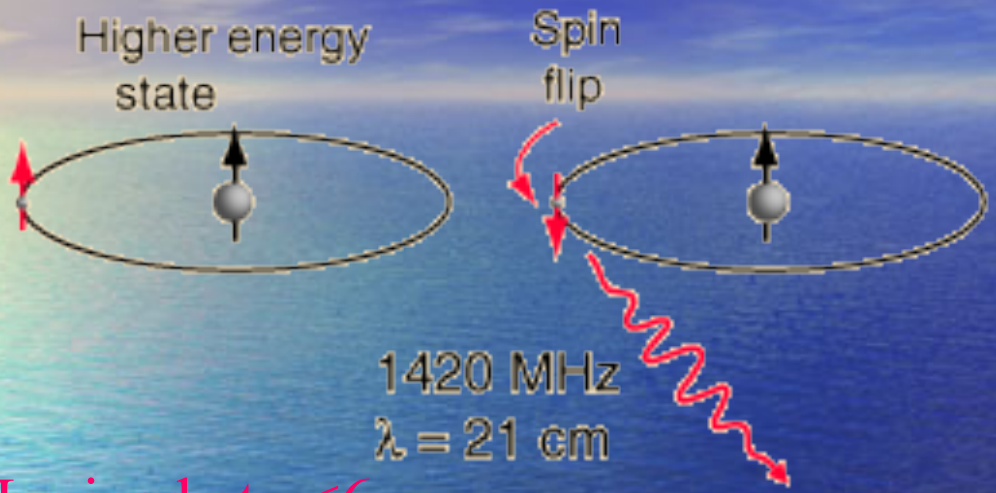
- Scientific motivation
- Gridding and degridding
- Why, When and When not...
- YOUR GO
- The next steps...

Weak Lensing: Cosmic Shear

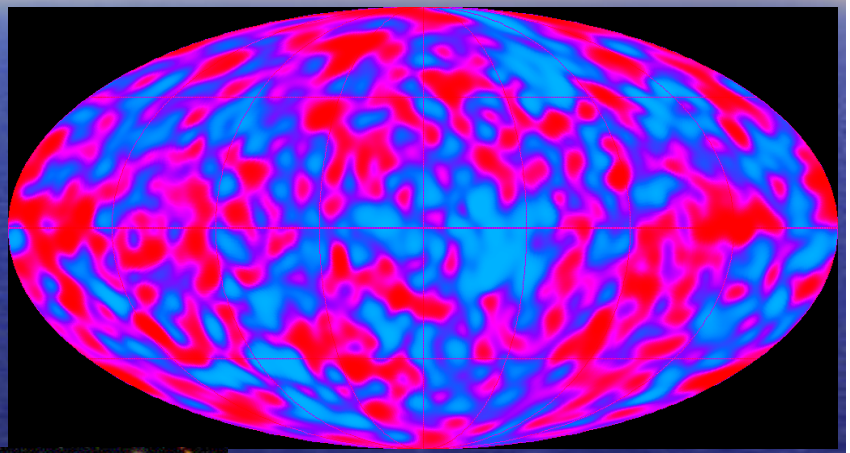


- Statistical measure of shear pattern, ~1% distortion
- Radial distances depend on *geometry* of Universe
- Foreground mass distribution depends on *growth* of structure

EoR: the end of the dark ages

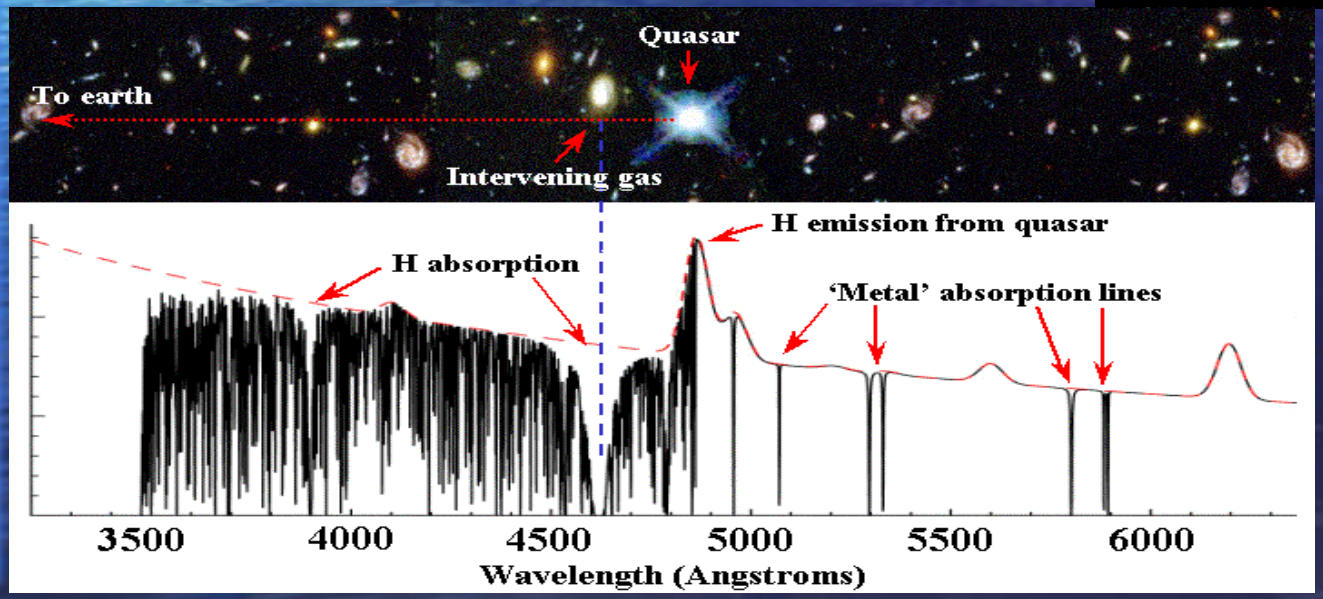


Neutral at z=1000

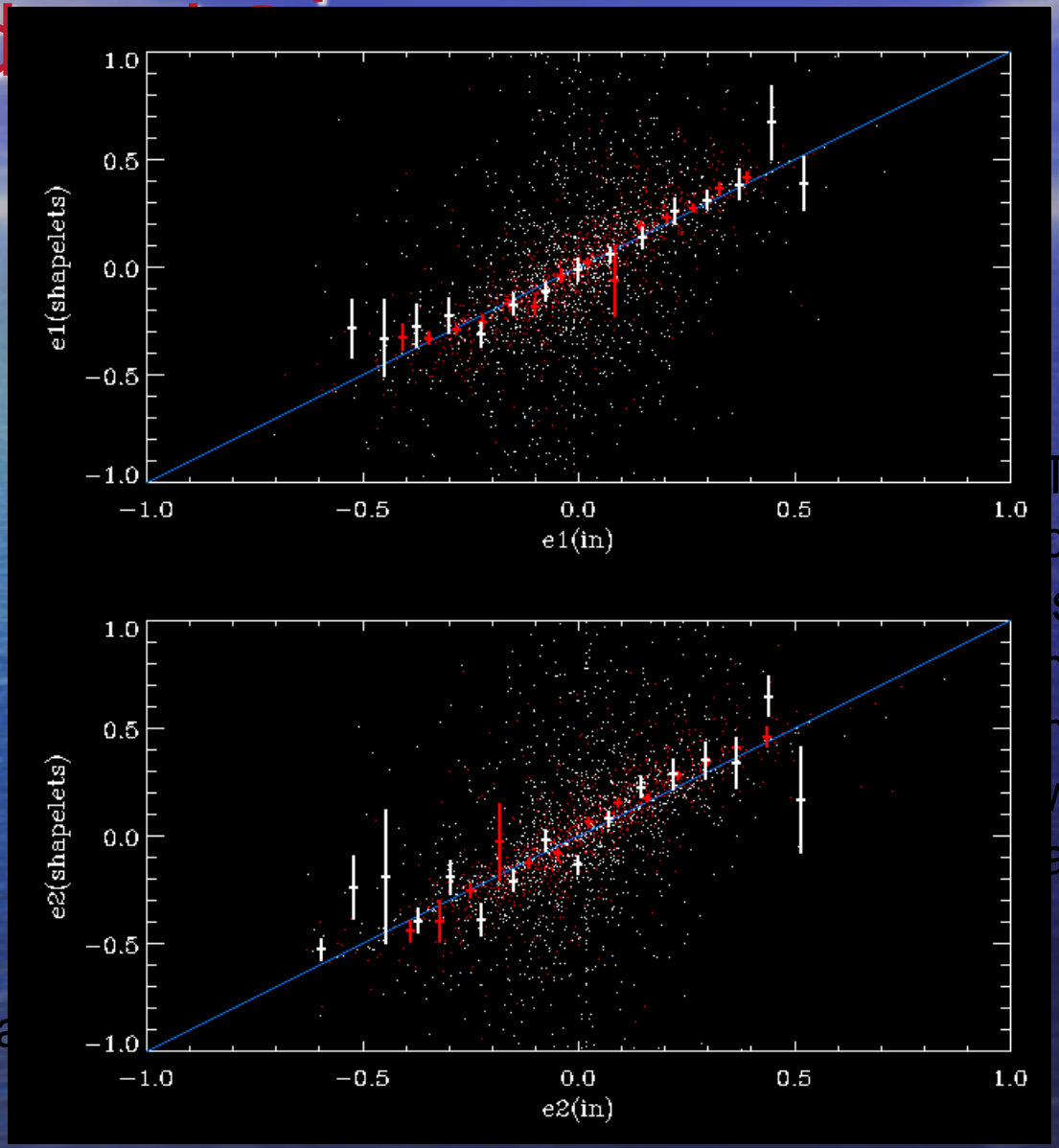


COBE

Ionized at z<6



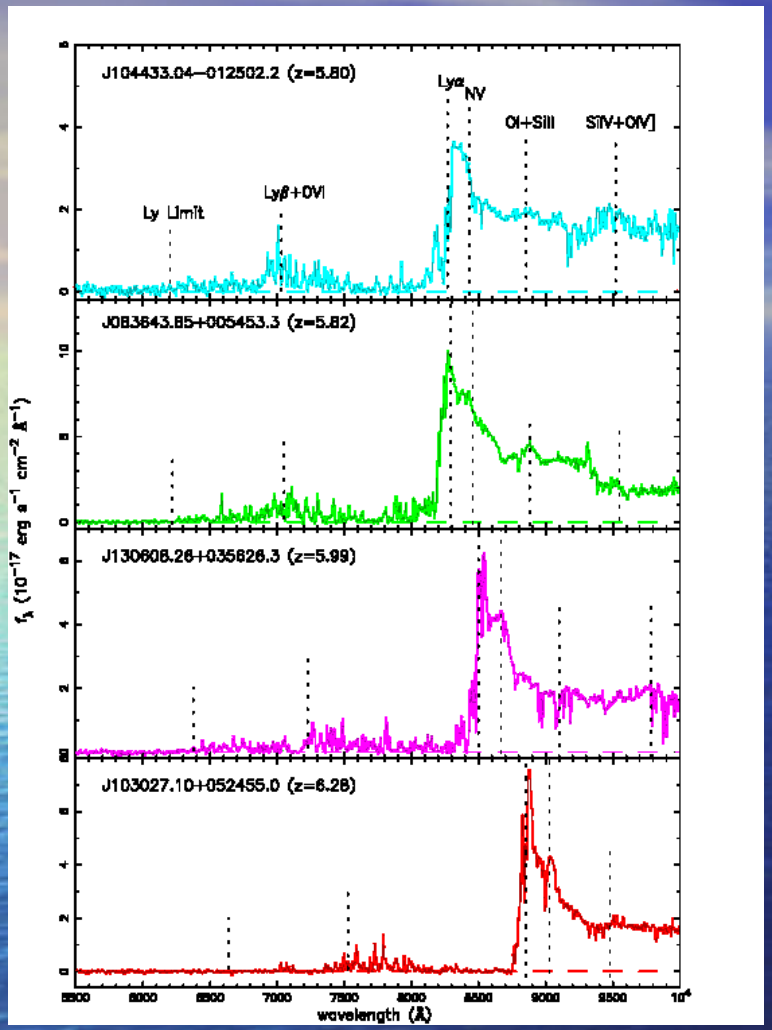
Shear Data: Optical Ground

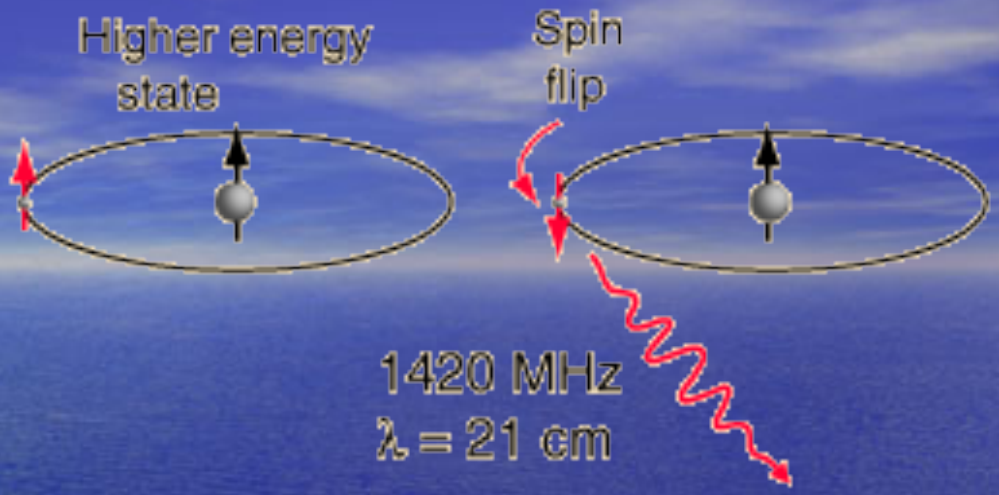


Typical cosmic shear is ~ 1%, and must be measured with high accuracy

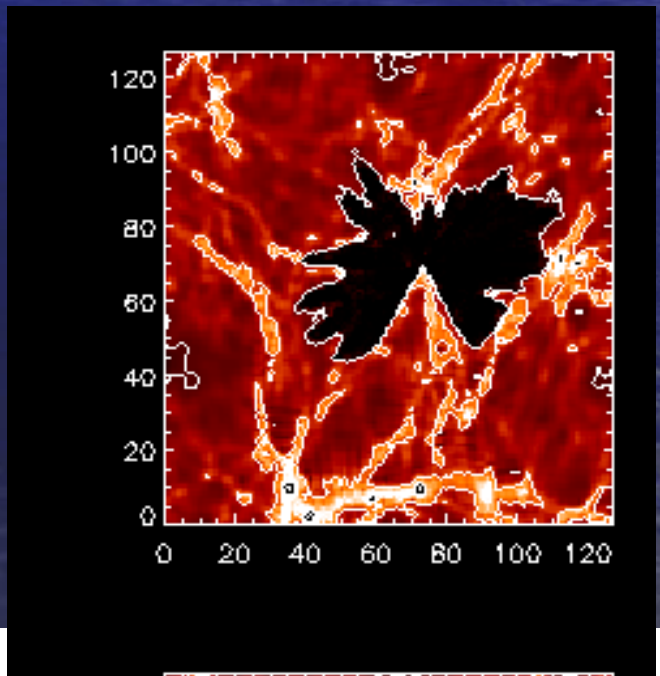
Spa

- reduced systematics





Ciardi et al.



EoR what you will see...

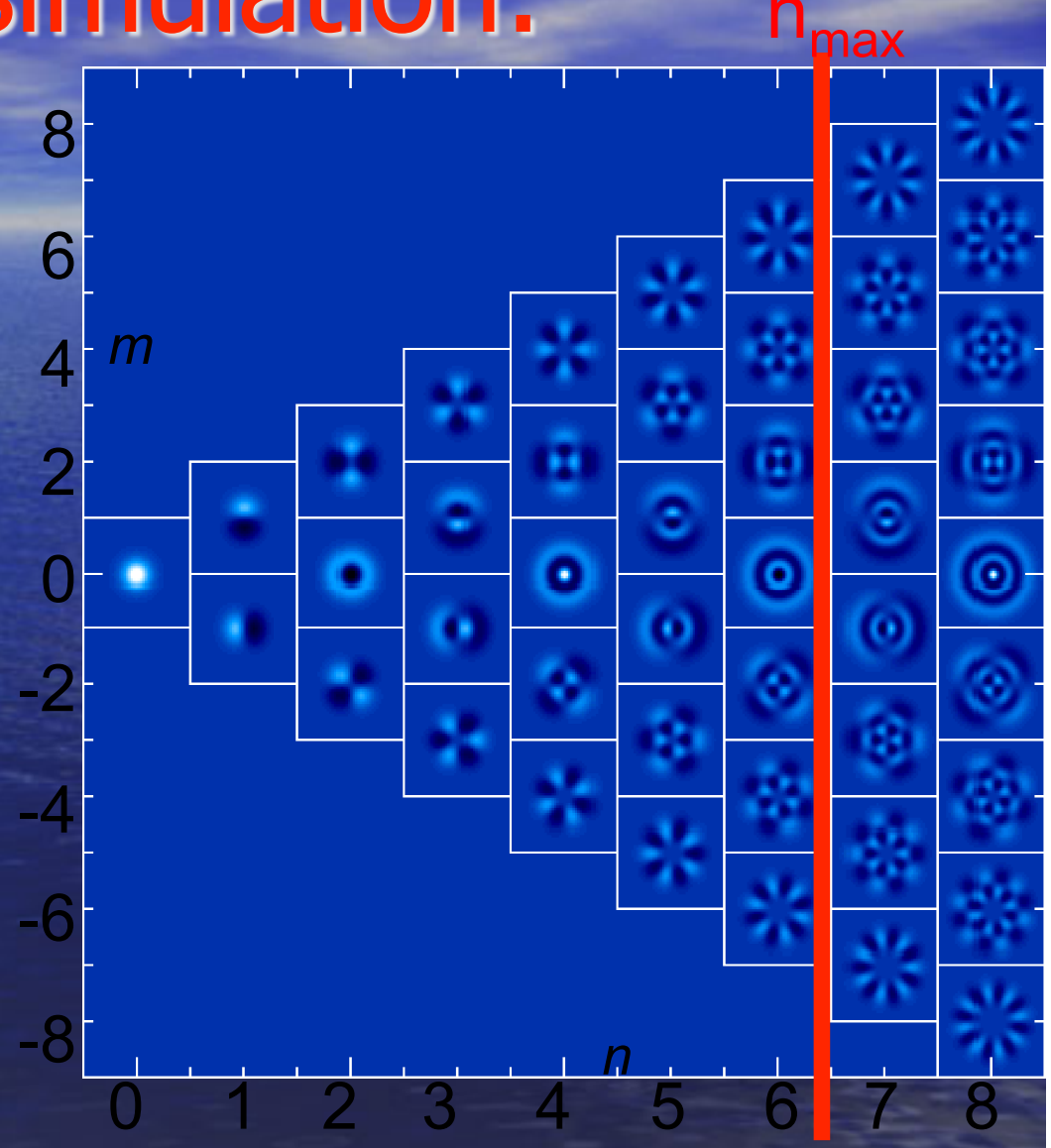
Shapelets for simulation:

Refregier 2003, Refregier & Bacon 2003,
Massey & Refregier 2005

- Complete orthogonal basis functions
- Capture all shape information of an object
- Simple and analytic form for convolution and shear
- Adapted to cosmic shear

$$f(r,\theta) = \sum_{n=0}^{\infty} \sum_{m=-n}^{n} f_{n,m}\, \chi_{n,m}(r,\theta;\beta)$$

$$f_{n,m} = \int\int_{\mathbb{R}} f(r,\theta)\, \chi_{n,m}(r,\theta;\beta)\, r\, \mathrm{d}r\, \mathrm{d}\theta$$



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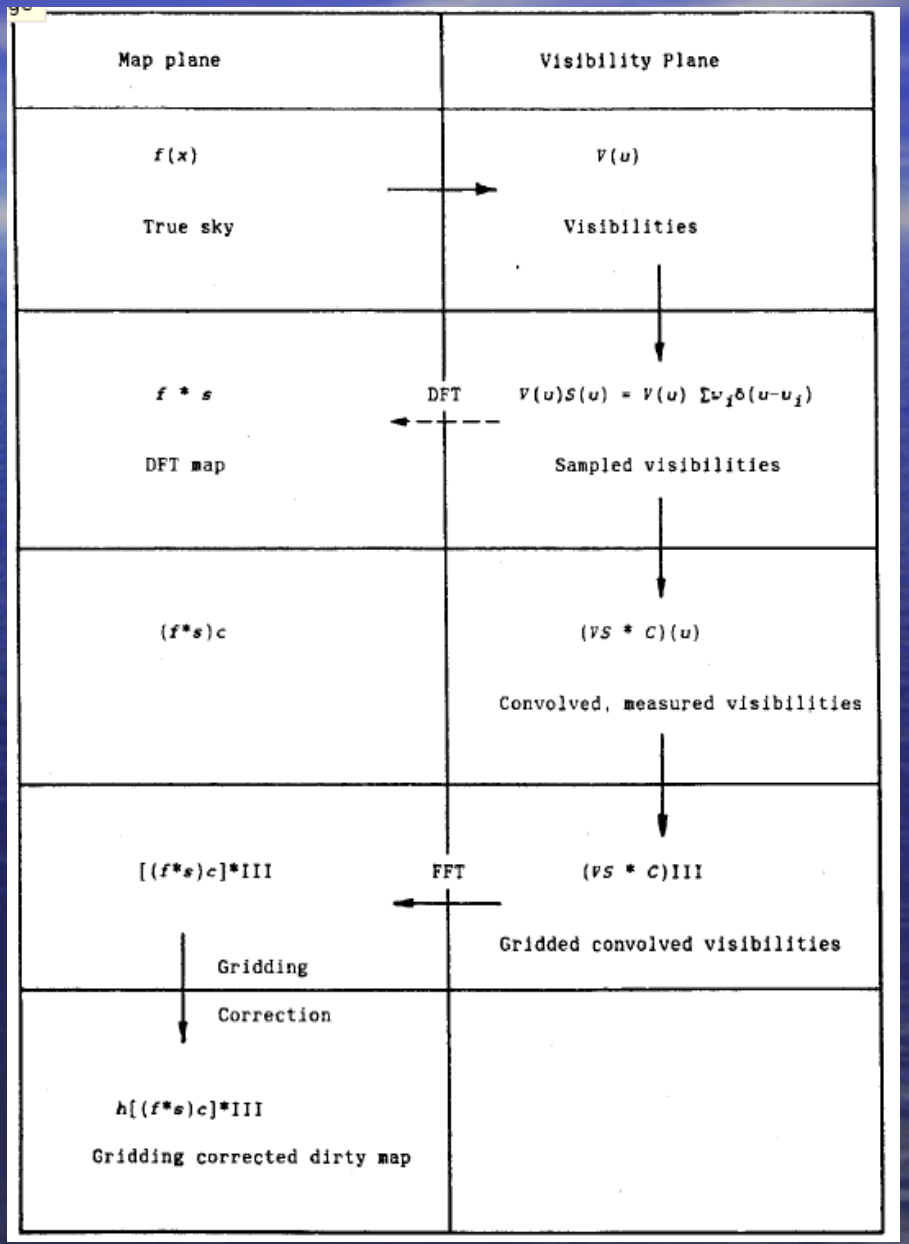
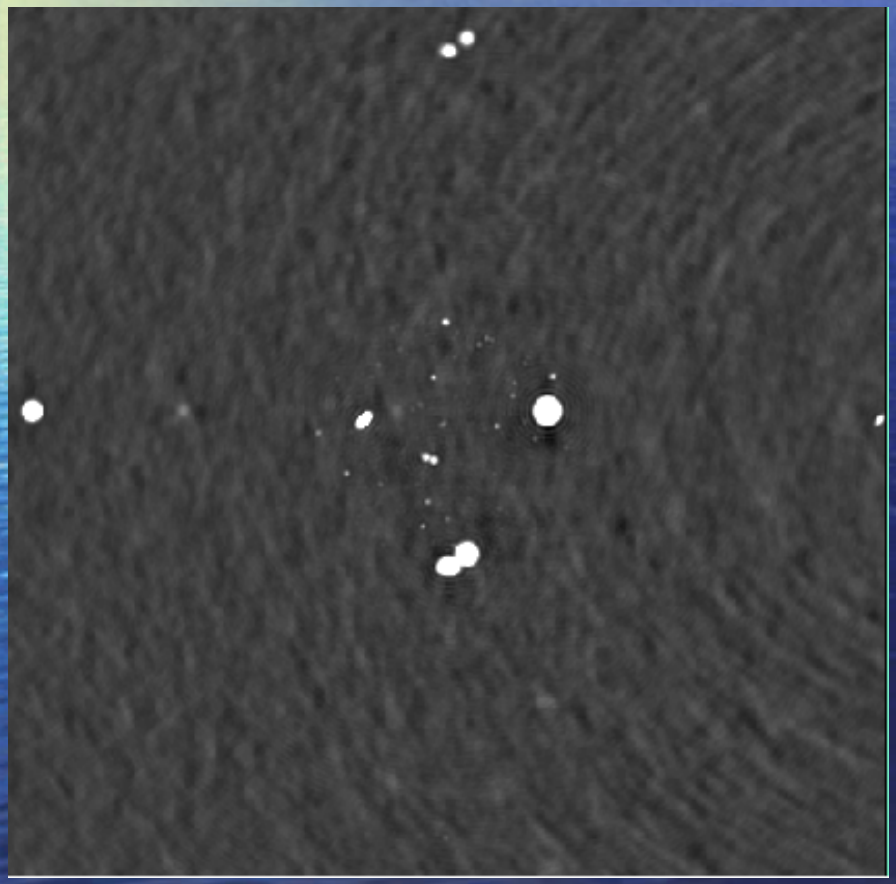
Gridding and degridding

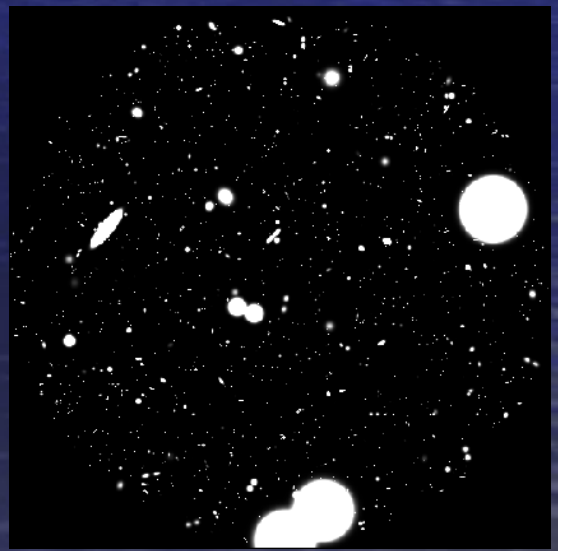
- UVBrick is flipping an image into the UV plane
- Step zero: a Fourrier transform
- Step one: interpolation of UV data points (but interpolation is a convolution) -> image plane corrections
- Step two: correction DFT FFT (padding) and correction in the image plane...



UVBrick background:



- Used here are convolution functions spheroid functions (not the most accurate solution to the problem according to some!!!) (padding)
- Within MeqTrees framework all other directional independent effects (DIE) can be included.
- Not everything the final Brick will do.

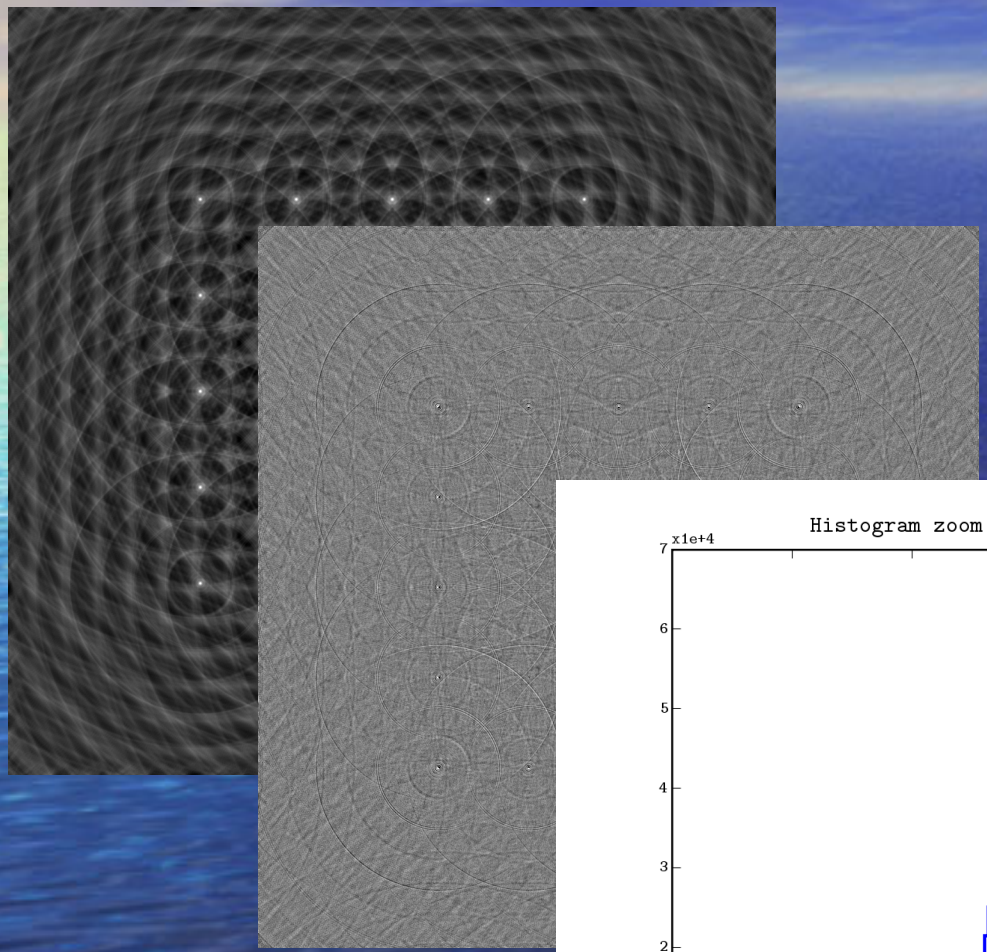


Apologies to the Black belt radio astronomers in the room if this is too simple

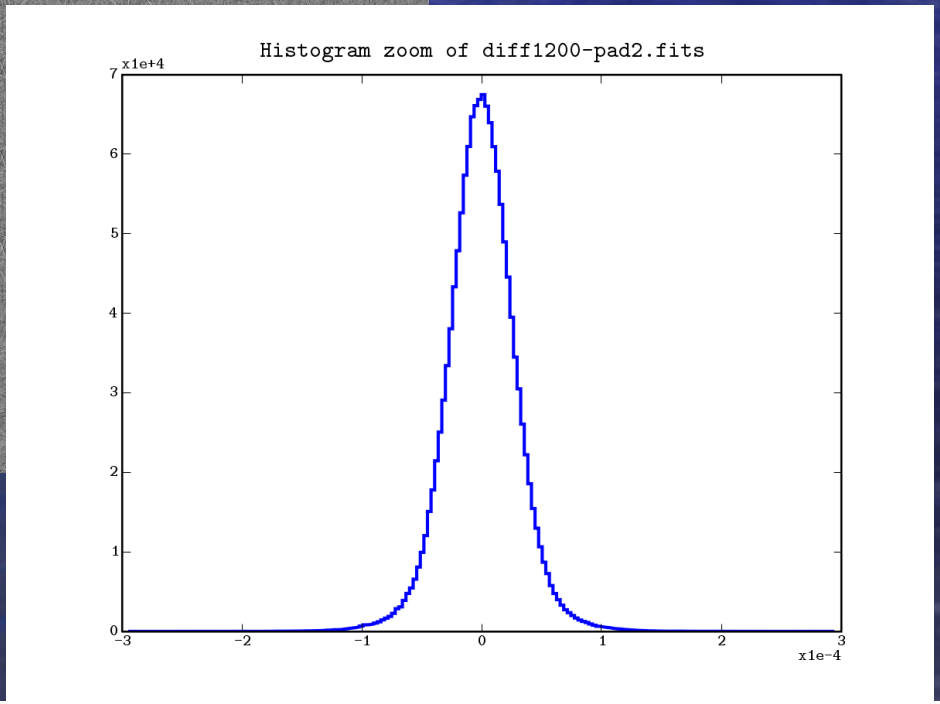
Why an UVBrick?

- UVBrick is flipping an image into the UV plane
- First reason is to simulate extended sources
- Second is that it may be faster than doing one DFT per simulated object as they are all treated simultaneously in the FFT
- Scalings:
  - Direct simulations: scales as the number of sources
  - Brick: scales with baselines if degridding is limit
  - Brick: scales as resolution^2 if FFT is limit
- Small overhead of convolution (support used is 4*4 so 16 operation convolution)

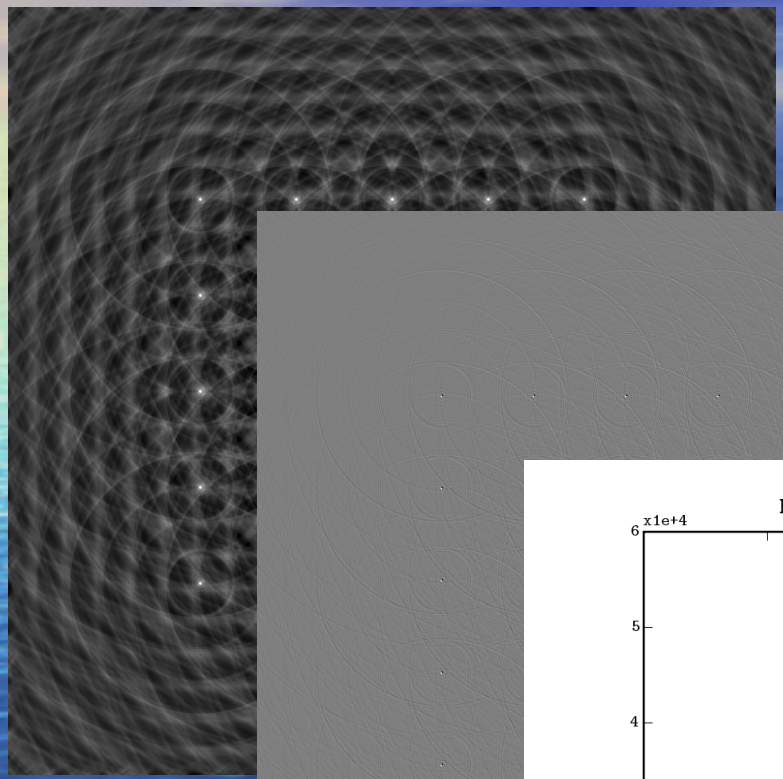
UVBrick accuracy:



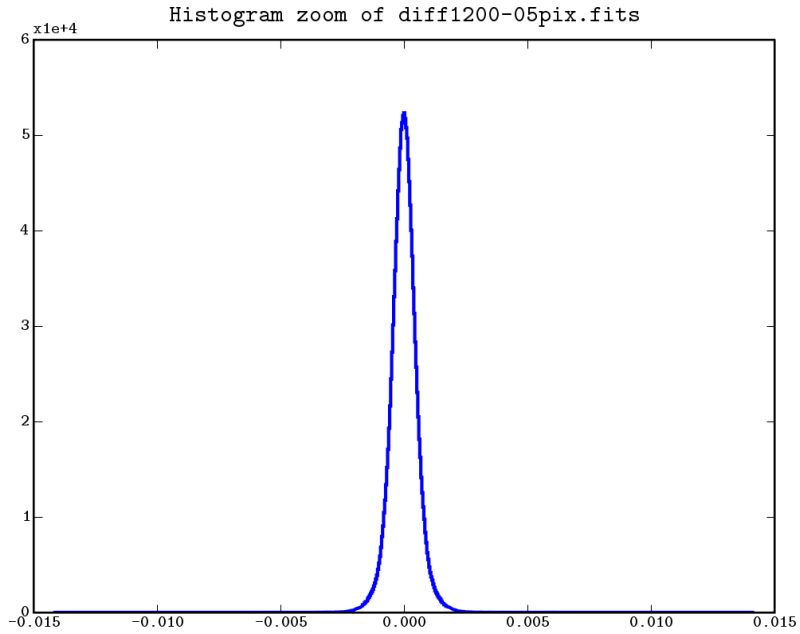
- Simulate a grid of points with DFT's -> fill MS
- Simulate the same points with the UVBrick -> subtract the UV values from MS.
- Image difference.
- sigma:3.02036e-05
- 1200x1200 at 120'



UVBrick accuracy:



- Simulate a grid of points with DFT's -> fill MS
- Simulate the same points 0.5 pix offset with the UVBrick -> subtract the UV values from MS.
- Image difference.
- sigma:0.000555845
- 1200x1200 at 120'



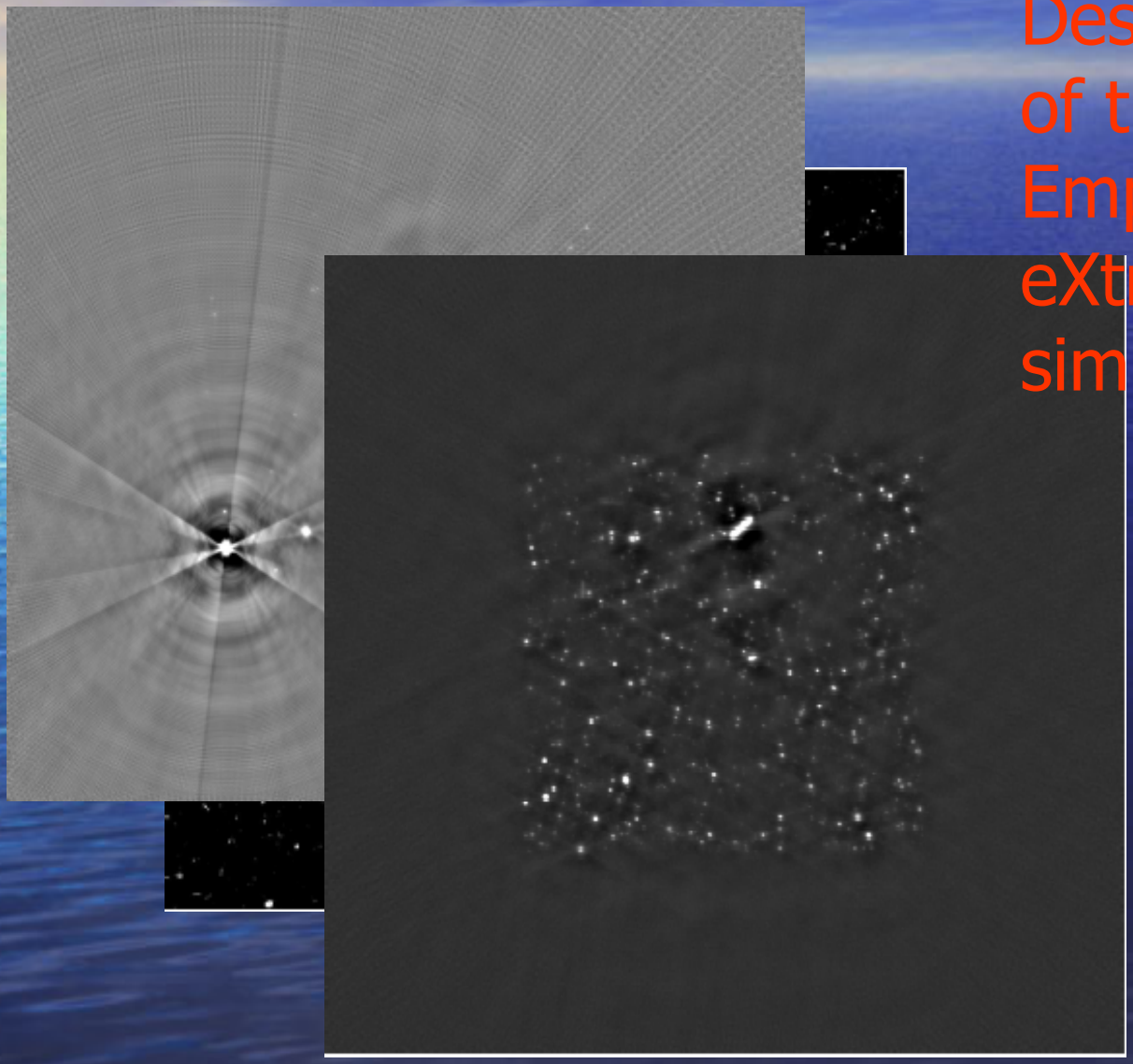
What does this mean?

- When simulating or using the brick to make a sky model:
- Simulate the brighter sources with DFT's they are not many as they are bright
- Simulate the fainter remembering there is a 'dynamic range' introduced by the brick.
- This error is a function of convolution functions and the resolution.
- I.e. if you want to simulate sources over 6 orders of magnitude and the gridding errors are 5e-4 then the top two orders have to be simulated with DFT's the bottom 4 magnitudes can be done with the Brick.
- Warning: can always increase resolution but the limit is the convolution functions but better convolution functions are claimed to exist

MeqTrees sims -- YOUR TURN:

- Use supersim.py
- Simulate a series of sources
- Simulate a brick (check speed...)
- Brick is for speed but has errors associated to it.
- Exercises:
  - Change the support from 4 to 2 on UVInterpolWave.cc remake code. Use (s3-all.fits and test.MS)
  - Make square of 1s and 0s around (pixel bigger than PSF). Simulate and re-image more resolution. (pixelisation effects, use ipython and any MS)
  - LOFAR.MS and testeor.fits. OR EMERLIN.MS or test.MS and zuserver2.star.ucl.ac.uk/~fba/FILES/radio_wl/images Simulate your own EoR signalor wl simulations...

UVBrick simulations at work SKA:



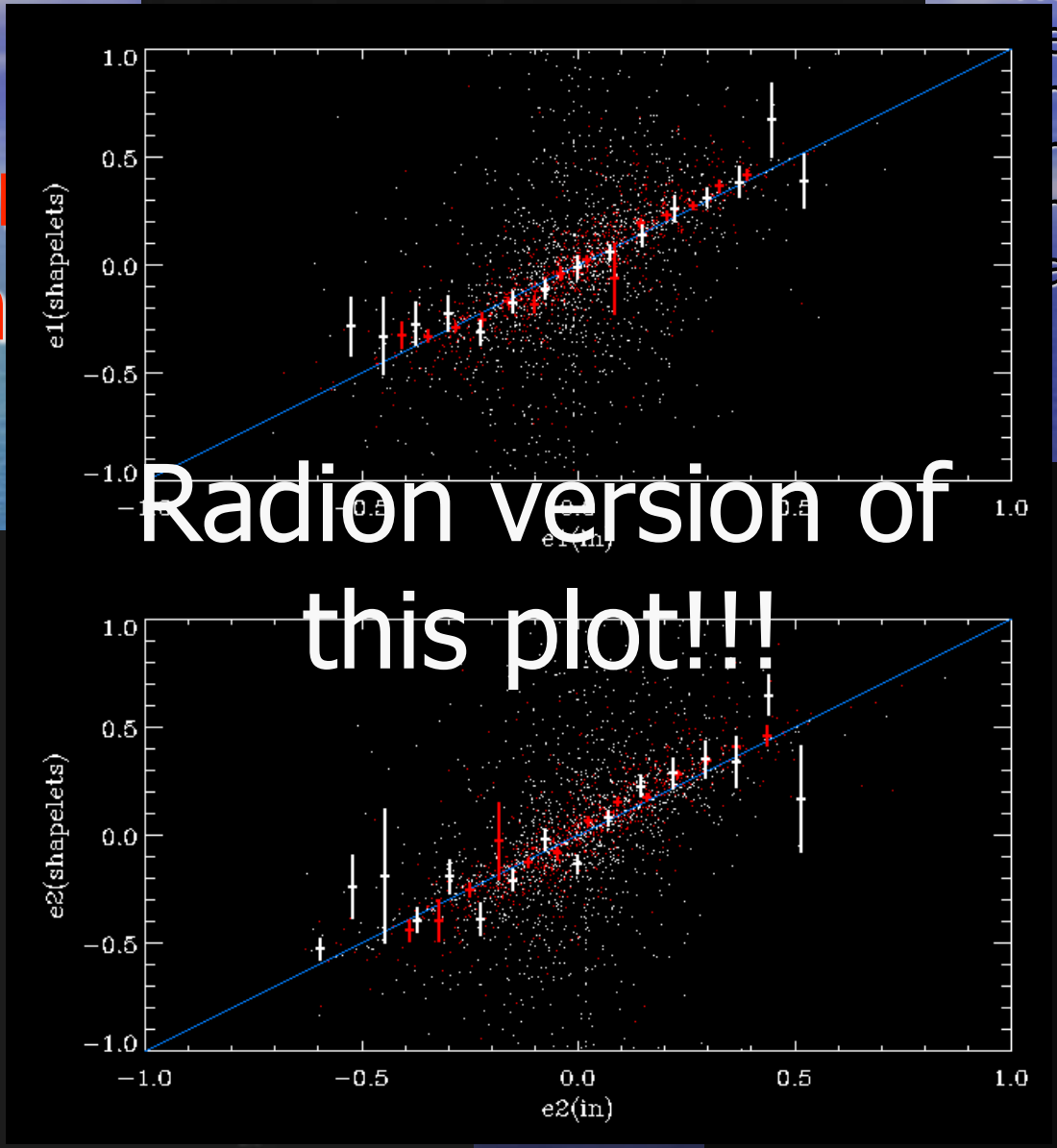
Design requirements of the Semi-Empirical eXtragalactic (SEX) simulation:

Size of support convolution is important, if smaller than 4 we get ghosts

s-cubed.physics.ox.ac.uk

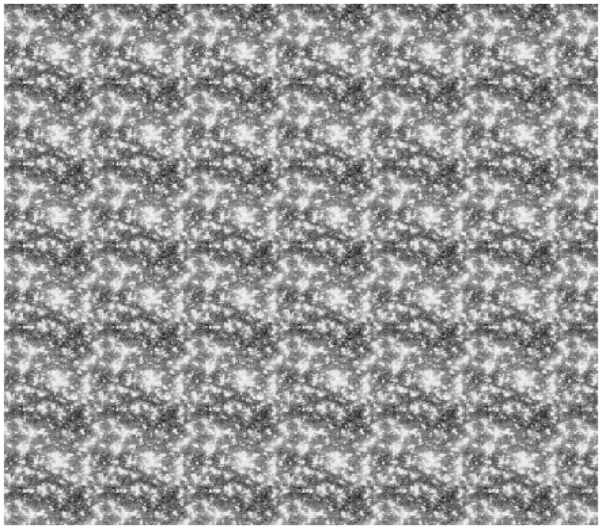
UVBrick simulation for lensin

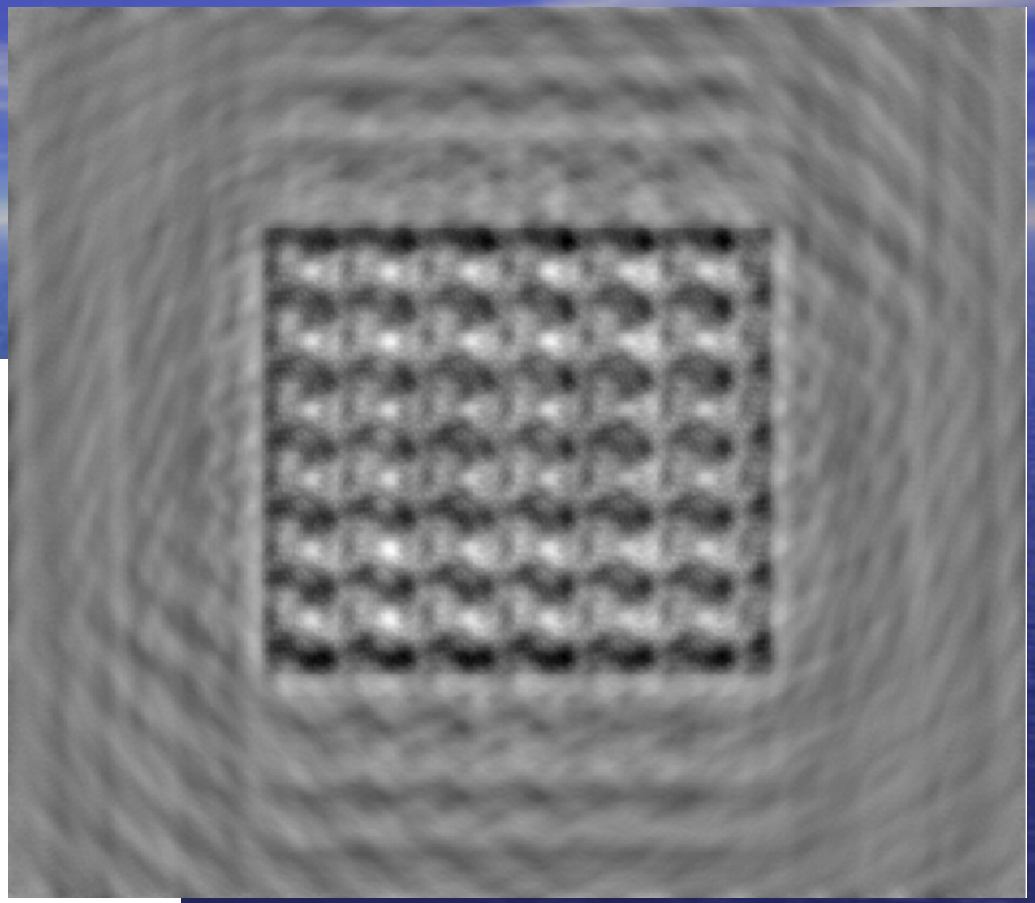
- VLA shape array
- Need to go to the econvolved images nd measure shapes go to UV data nd find shapes arameters



Radion version of this plot!!!

UVBrick simulation for EoR:

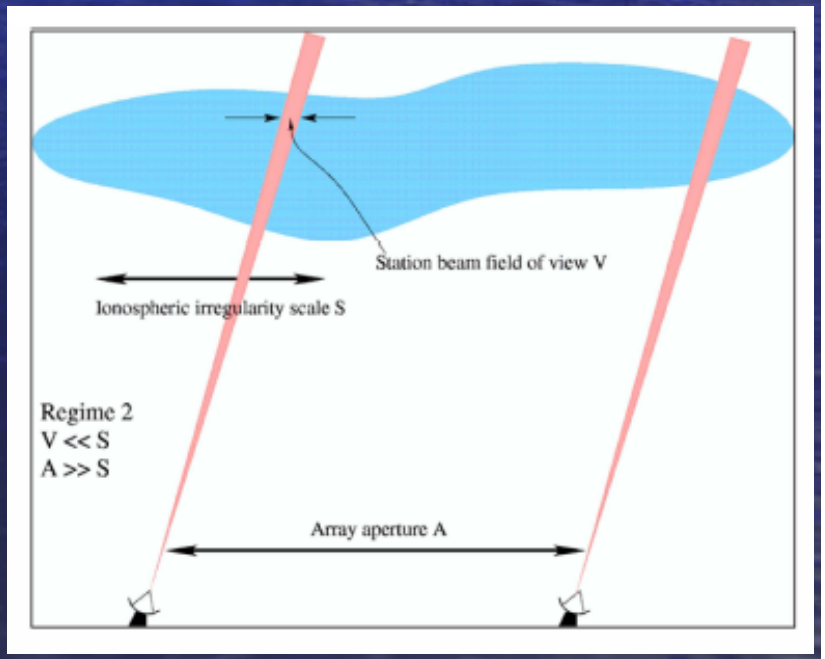




MeqTrees and the Measurement Equation

$$\mathbf{V}_{pq} = \mathbf{J}_p \mathbf{B} \mathbf{J}_q^{\dagger}$$

- *uv-plane effects* apply to all directions (i.e. all sources) equally
  - e.g. receiver gain
- *image-plane effects* depend on direction
  - e.g. ionosphere
- *source coherency* is (in a sense) intrinsic.
- Given that there is a small convolution in the brick this could handle DDE in principle if the kernel is small. Next step.



$$\mathbf{V}_{pq} = \mathbf{J}_{pn} \cdots \mathbf{J}_{p2} \mathbf{J}_{p1} \mathbf{B} \mathbf{J}_{q1}^{\dagger} \mathbf{J}_{q2}^{\dagger} \cdots \mathbf{J}_{qm}^{\dagger}$$

The next steps…

- Include w projection effects
- Include other convolution functions (implemented so that any convolution function can be used at the users choice)
- Finish the DDE or image plane effects so that ionosphere effects can be included in a Brick…
- Test Test Test… and try to find what else is required to make this the most usefull…

Conclusions

- Important to see and model what telescope properties/calibration requirements match the requirements from weak lensing/EoR
- By product is the UVBrick, can be used for simulation or for calibration.
  - Extended sources/emission
  - Speed up at the expense of errors…
- Need to add w projection, extra convolution functions and most important image plane effects.