MEM and CLEAN Imaging of Polarisation Observations of Compact Active Galactic Nuclei

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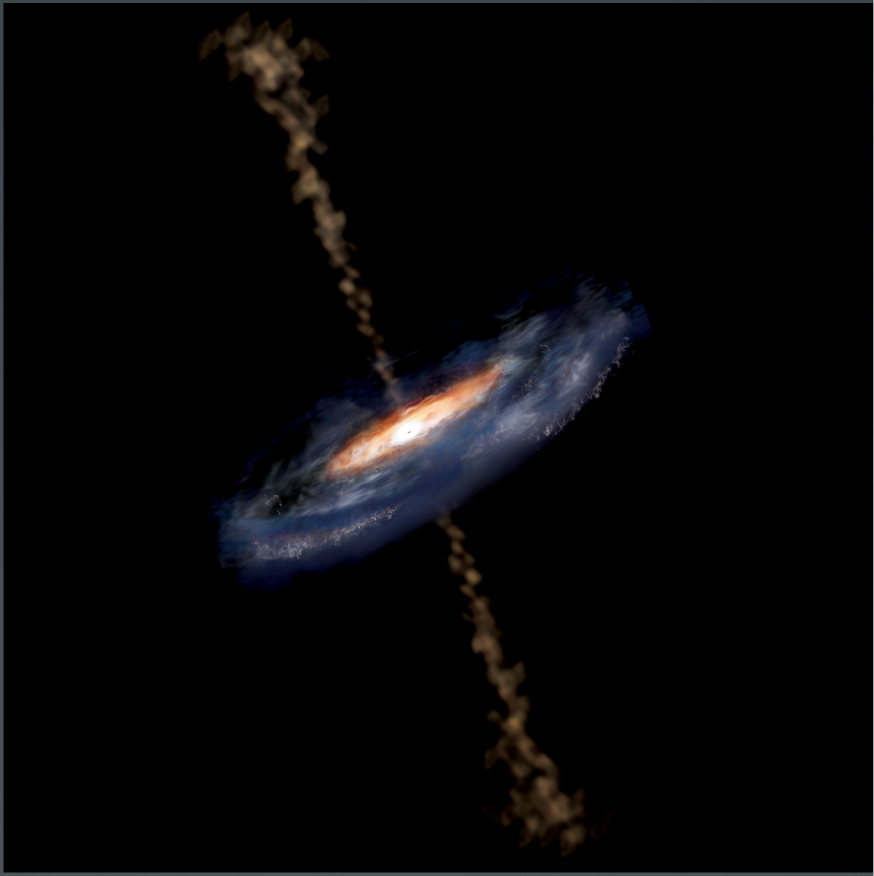
Observing an AGN



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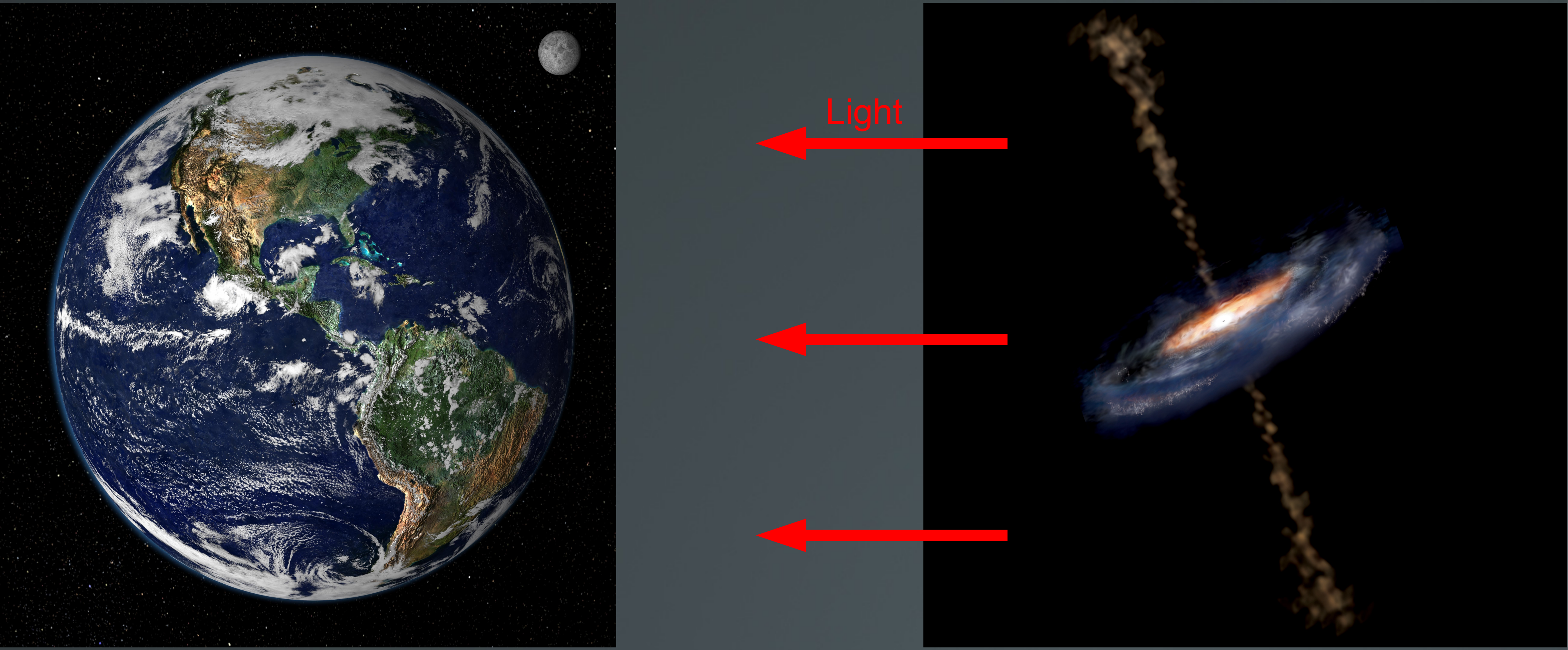

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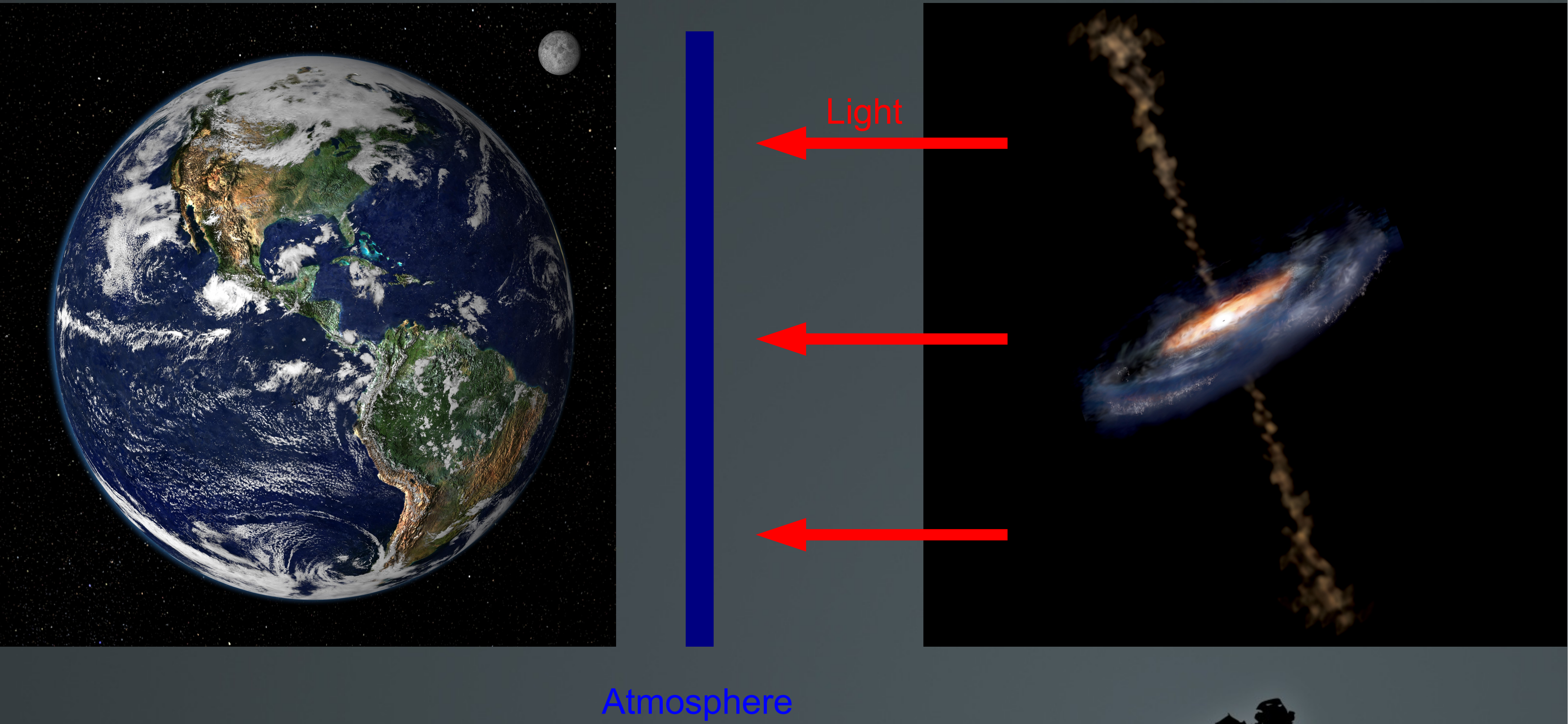
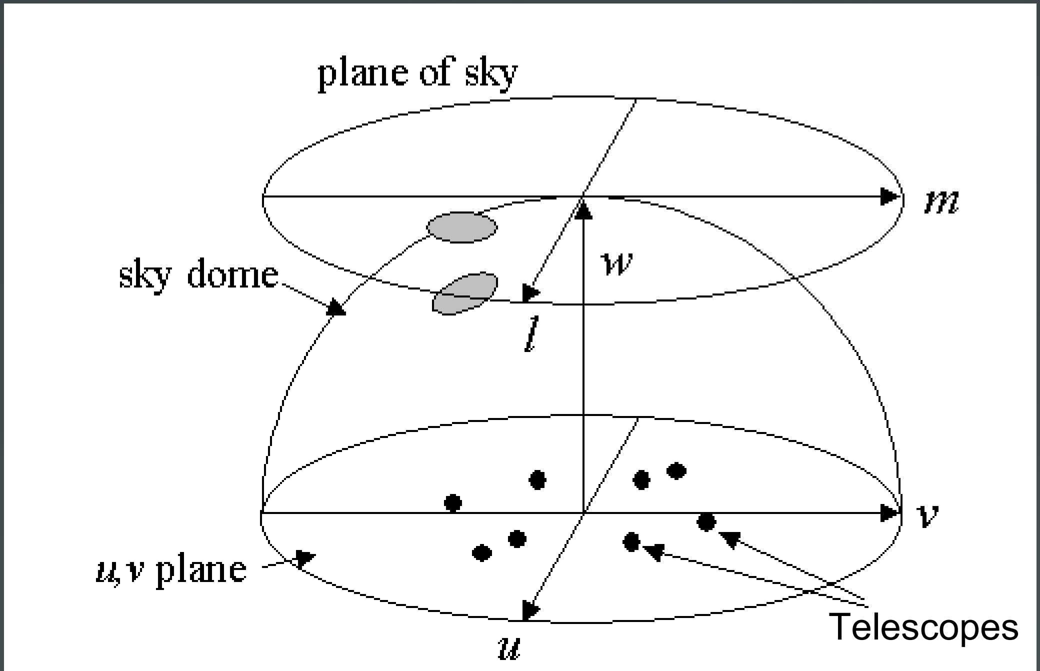


Atmosphere acts as a lense
=> Fourier Transform

Observing an AGN

Fourier Transform relationship between image in sky and the visibilities as observed by telescopes on the ground



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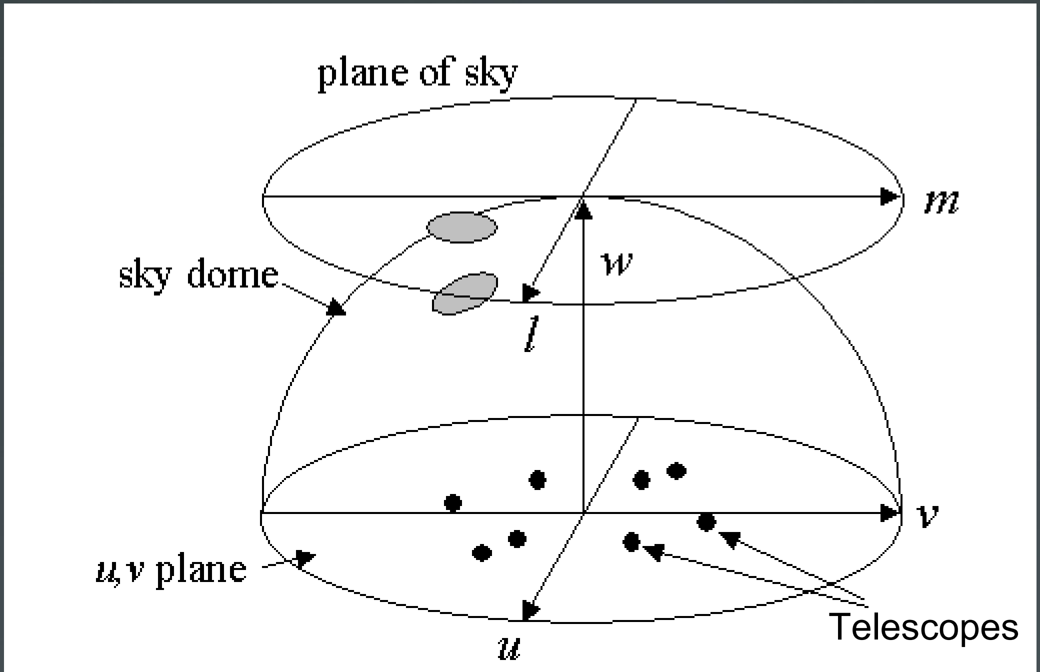
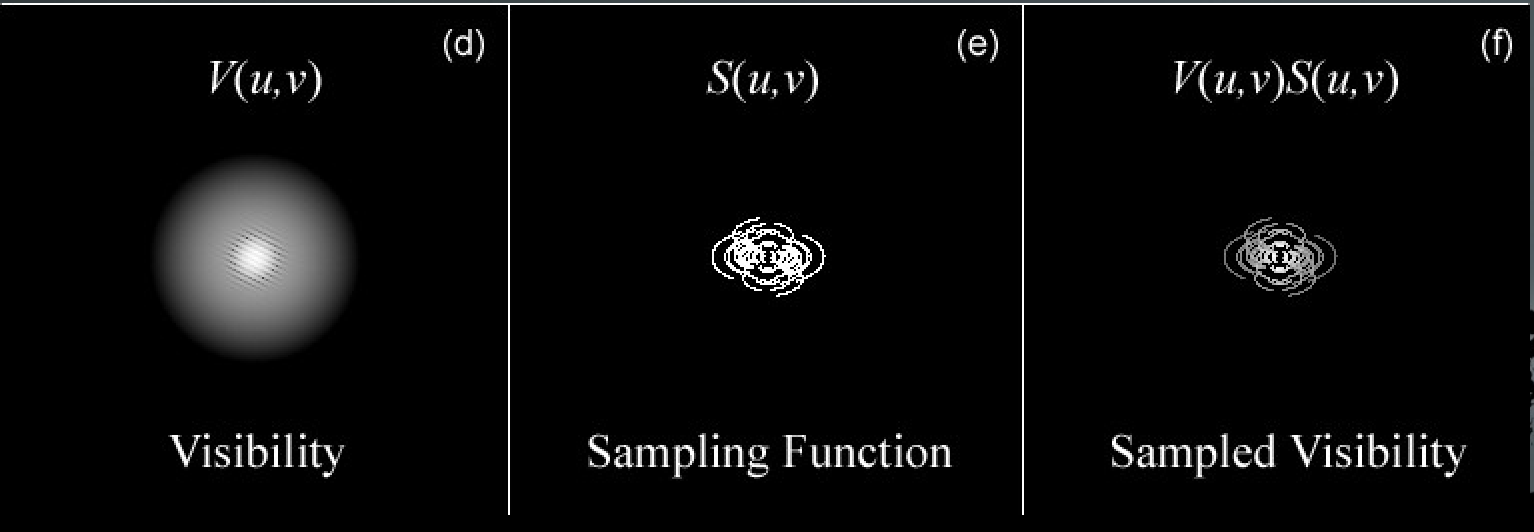
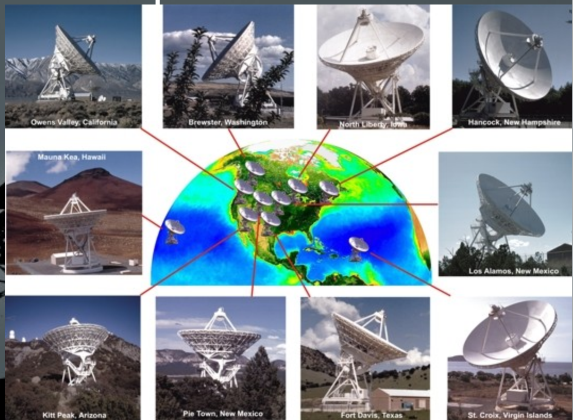




Not all visibilities are sampled



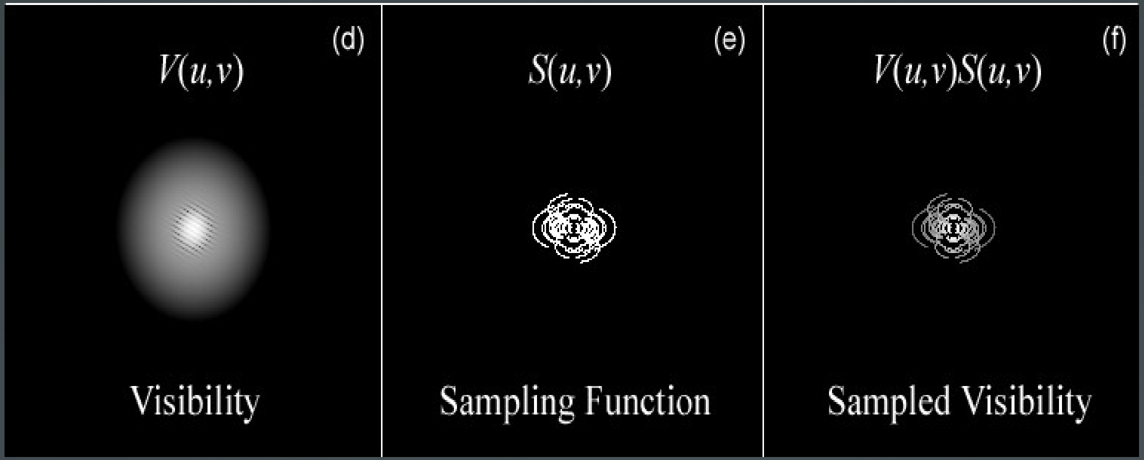
Observing an AGN

We cannot recover the original map

- some data has been lost

- noise

$$V(u,v) = \hat{I}(x,y)$$



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If we try invert the FT relation, we get a 'dirty' version of the original map

Need a way to 'clean' up this dirty map – to scrub out noise and simulate the effect of the missing visibilities.

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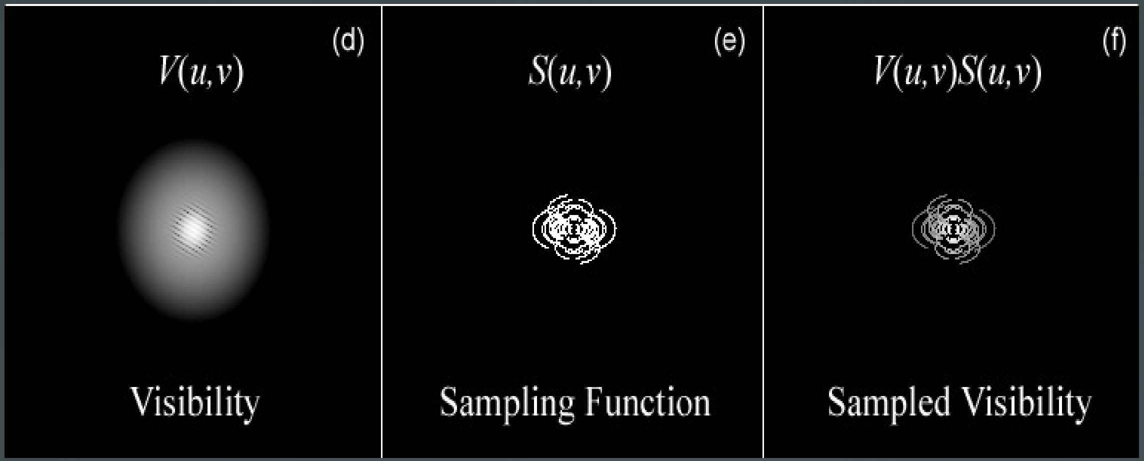

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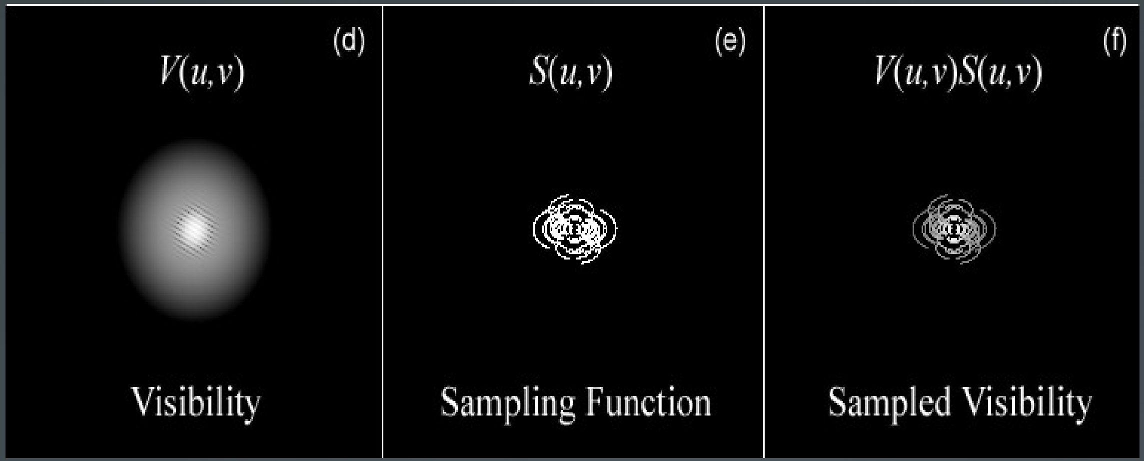

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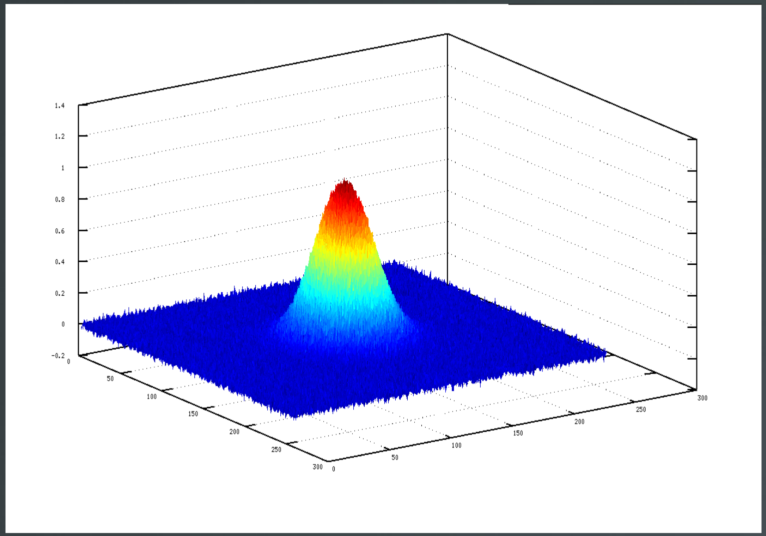
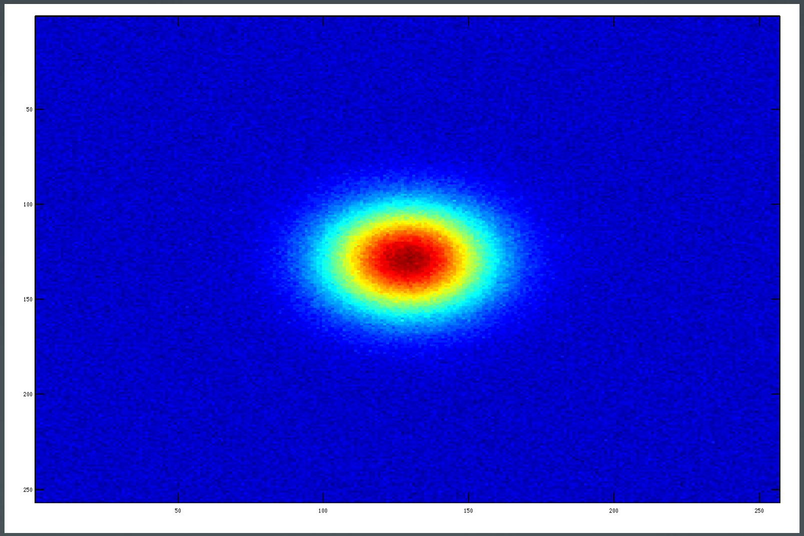
The CLEAN algorithm

Maximum Entropy Method

The CLEAN algorithm

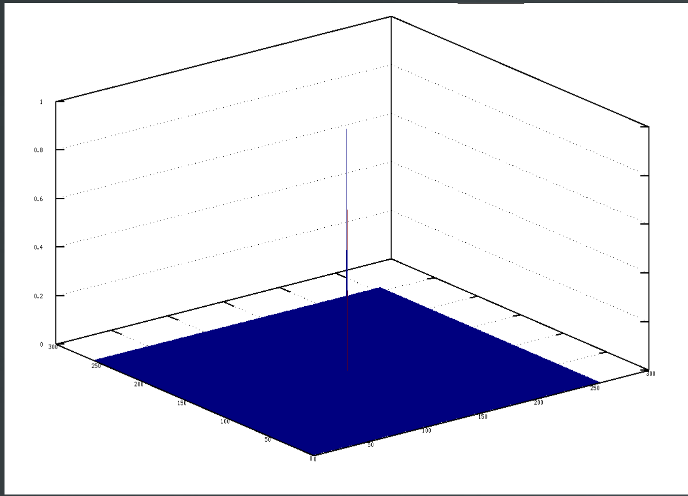
Obtain the dirty map by inverting the observed visibilties





The CLEAN algorithm

Find the peak of the map



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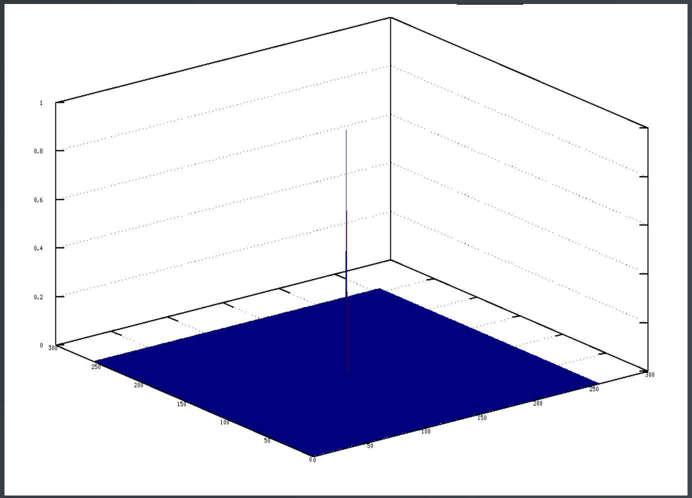
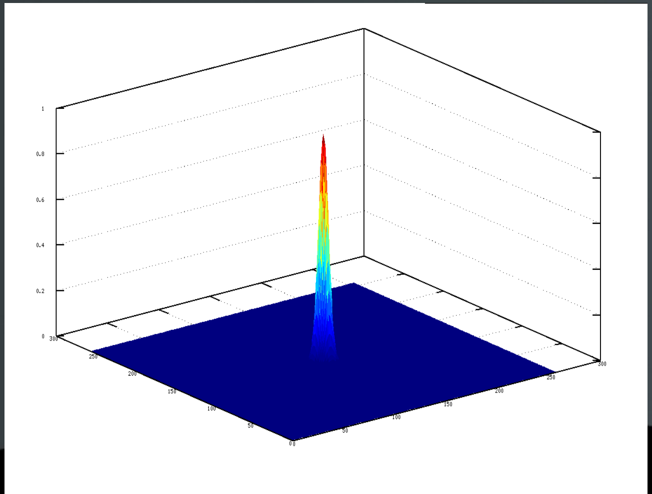
Find the peak of the map



Multiply it by the dirty beam



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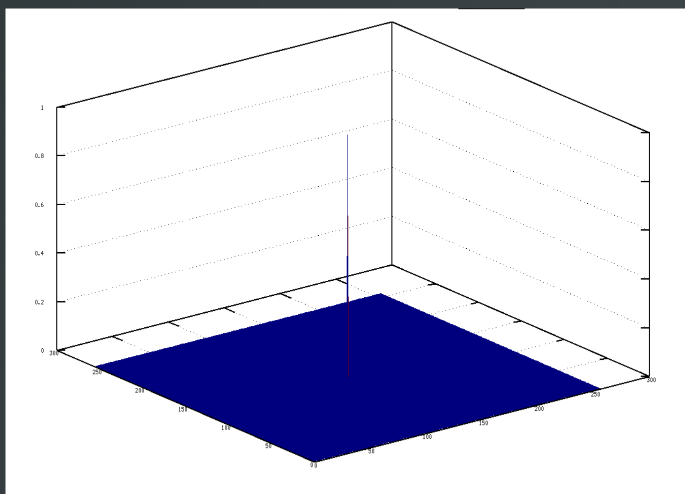

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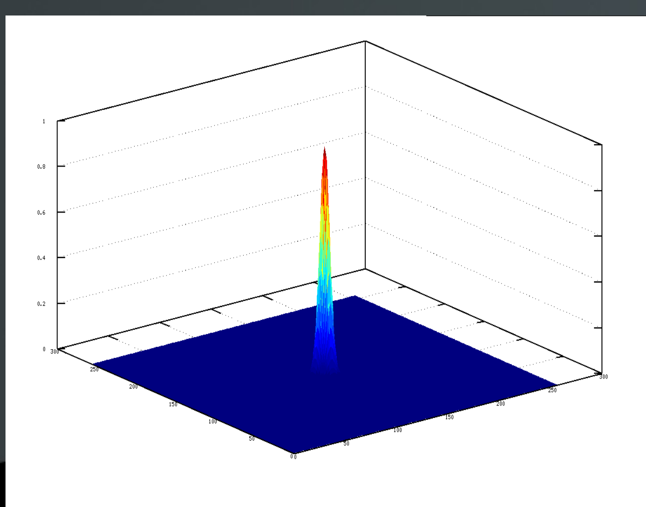
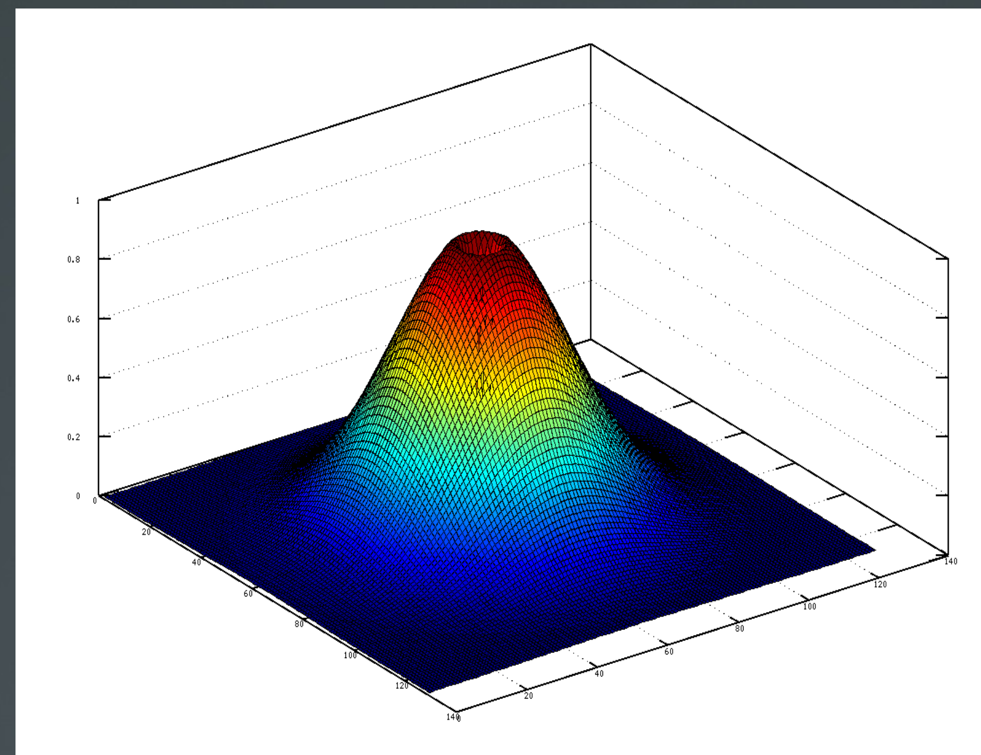
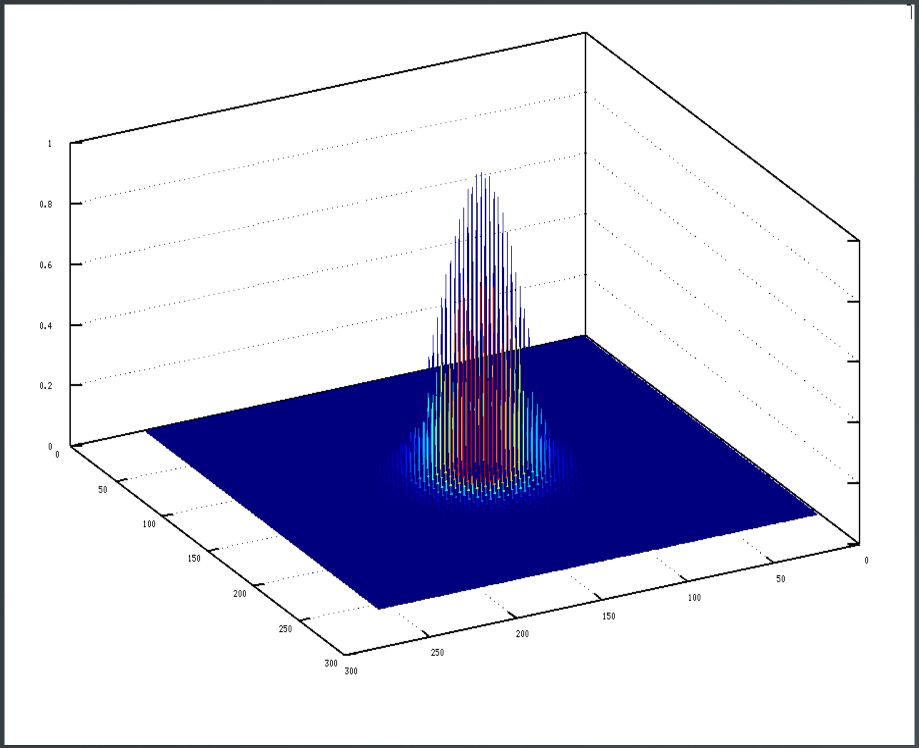




Subtract this from the original map

The CLEAN algorithm



Keep identifying real peaks until the residual map is at noise level

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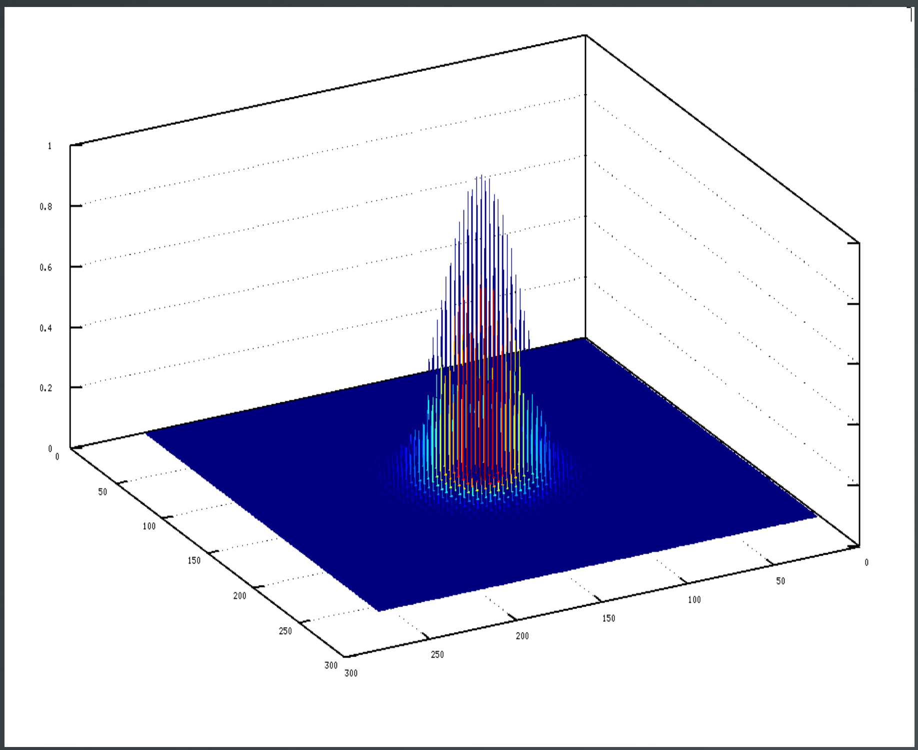

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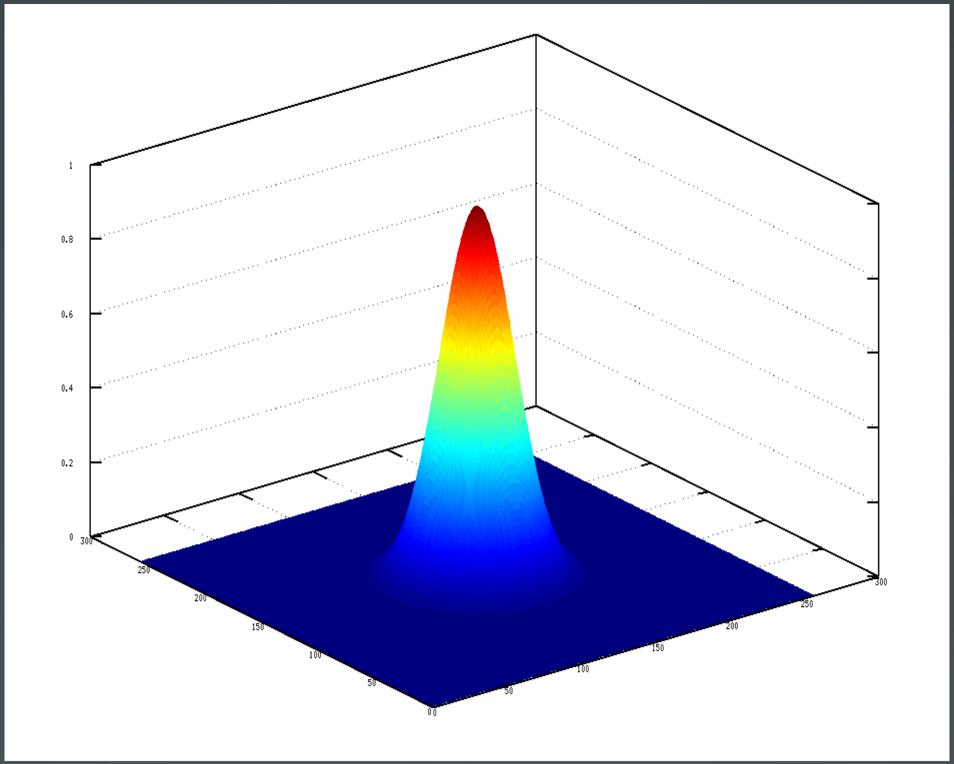

Convolve clean component table with clean beam and add in residuals

The CLEAN algorithm

Intuitive

Simple

Easy to implement

Suitable for polarised emission

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Subjective

Difficult to define resolution

Deconvolution via MEM

CLEAN

Breaks observations down to believable elements

Constructs 'clean' map from these elements

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Maximum Entropy Method

Starts assuming blank map

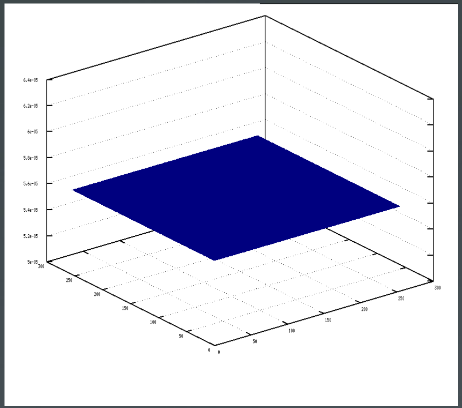
Iteratively changes map to look more like dirty map

Does this in the most conservative way possible

Ensures each successive image has maximum entropy

Maximum Entropy Method

Start with flat map with total flux equal to zero spacing flux



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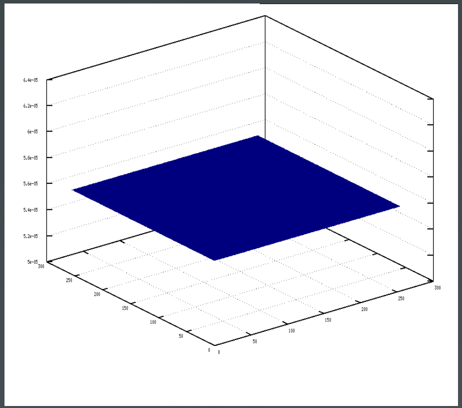
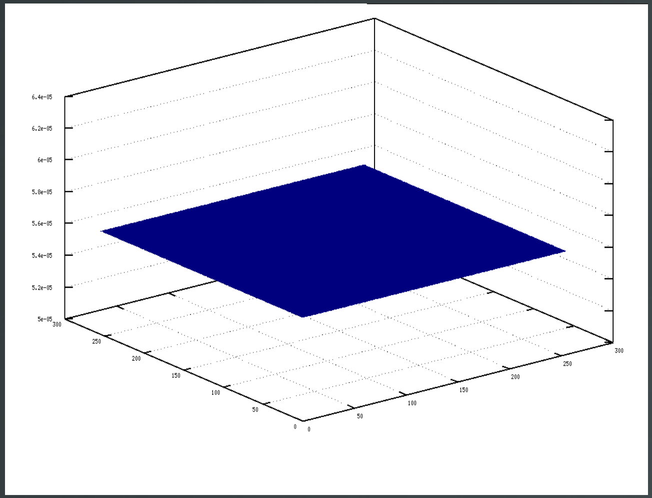


$$J = H(I_m, P_m) - \alpha\chi^2(V_{Im}, V_d)$$

Change the map by a small amount in a direction that maximises J

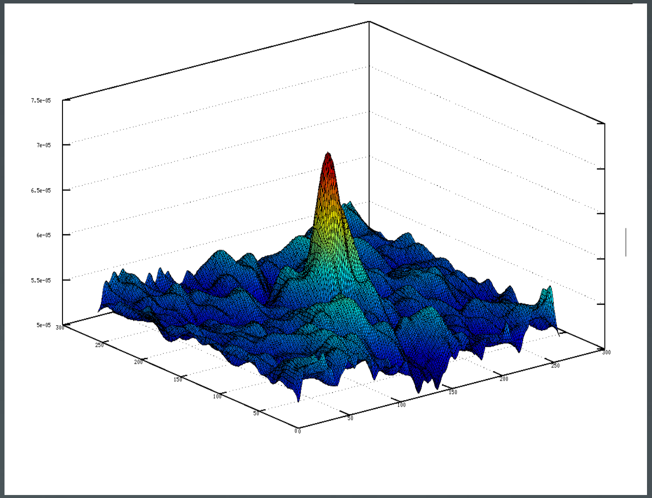
Balance between entropy (representing noise, and the effect of unsampled visibilities) and fidelity to observed data (very desirable)

Maximum Entropy Method



$$J = H(I_m, P_m) - \alpha\chi^2(V_{Im}, V_d)$$

One iteration



Each step is kept small to ensure that all of the detail is teased out while ensuring that the model map does not converge to the dirty map

'Tug of war' between randomness and reality results in objective model map – only the most persistant features will be included in the model map

Forms of Entropy

Shannon Entropy

$$H = -\sum_k I_k(log(\frac{I_k}{IB_k}))$$

Suitable for Stokes I (intensity) imaging.

IB is a bias map (normally taken to be a flat map)

Implemented widely

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Gull and Skilling Entropy

$$H = -\sum_k I_k(log(\frac{I_k}{IB_k e}) - \frac{1+m_k}{2} log(\frac{1+m_k}{2}) - \frac{1-m_k}{2} log(\frac{1-m_k}{2}))$$

Suitable for imaging both intensity and polarisation (Stokes Q and U)

M is the fractional polarisation

Not implemented widely

MEM in AIPS

Shannon Entropy MEM deconvolution implemented in AIPS (Astronomy Image Processing System) as the task 'VTESS'

Useful to investigate MEM

Not useful for polarisation studies – largely because Stokes I is always positive, while Stokes Q and Stokes U may be negative

$$P = \sqrt{Q^2 + U^2}$$

$$\chi = \frac{1}{2} ArcTan(\frac{U}{Q})$$

C++ program written to implement MEM with Gull and Skilling entropy – can process polarisation data

Resolution

CLEAN

Resolution often taken as the FWHM of a gaussian fitted to the dirty beam.

This is partly due to the fact that CLEAN's 'model' map is a series of delta functions – an unrealistic approximation for most sources

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Maximum Entropy Method

Resolution can be explicitly calculated

$$x_{min} = \frac{1}{4u_{max}}$$

MEM's underlying model is much more realistic than that of CLEAN (but has its own flaws)

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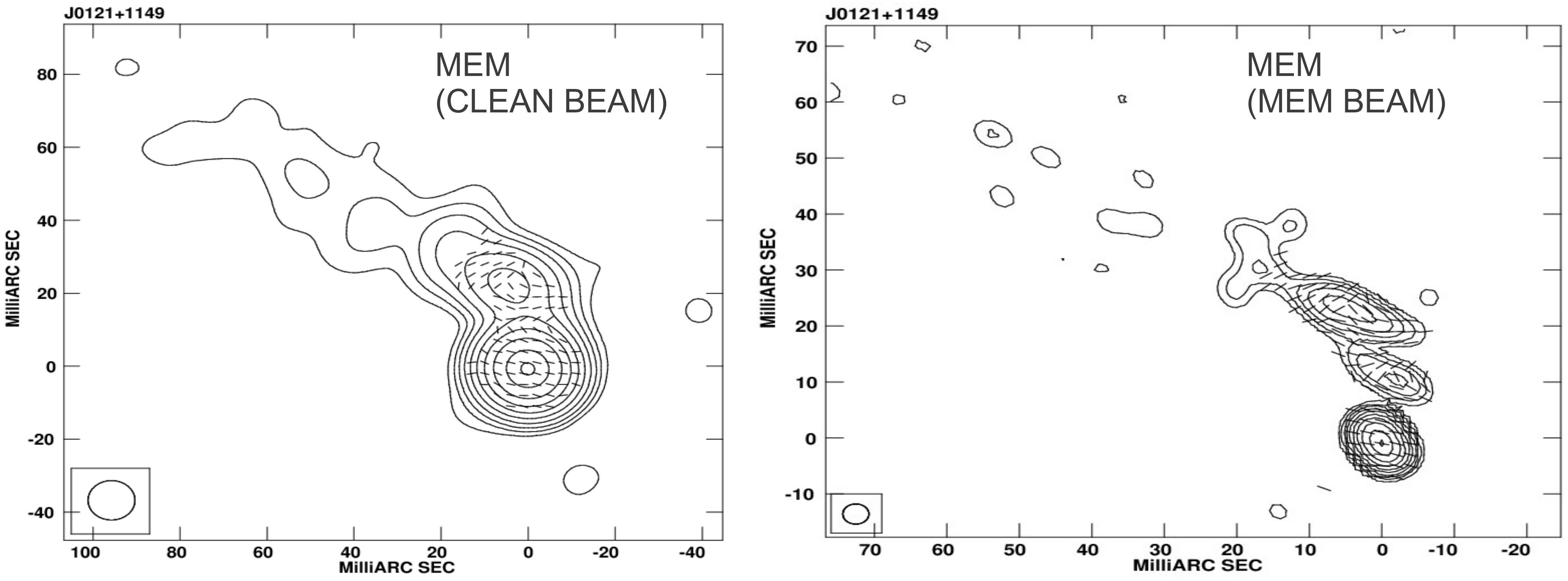
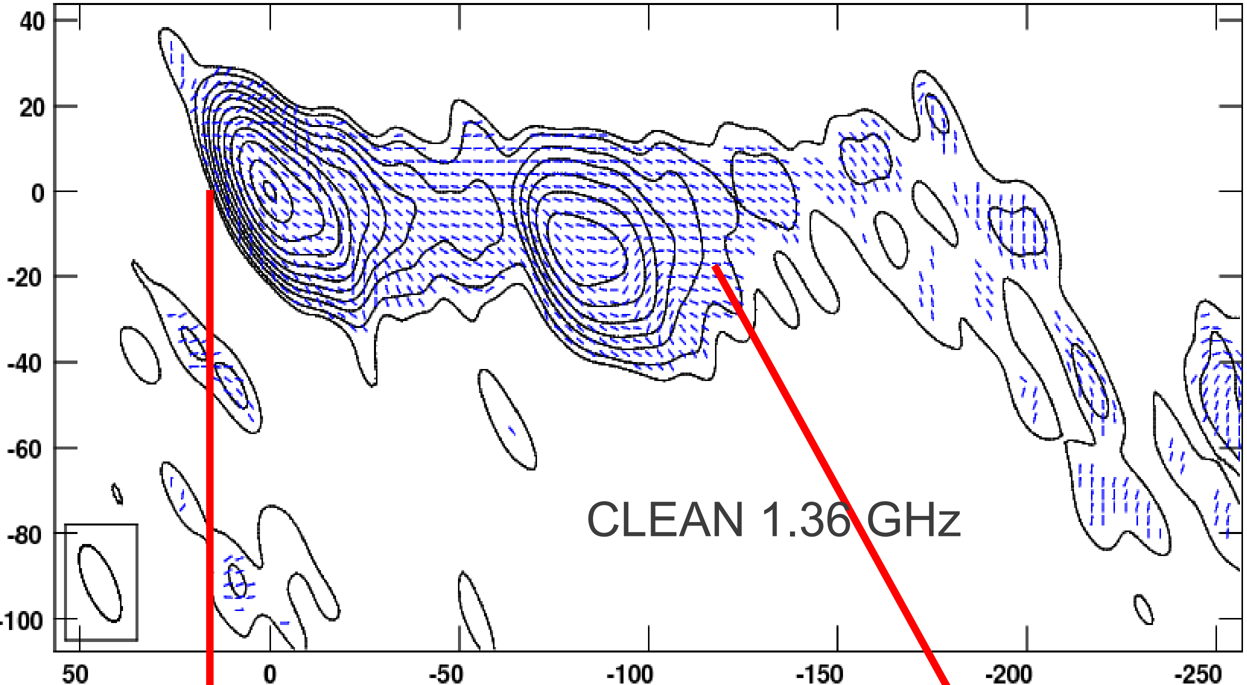
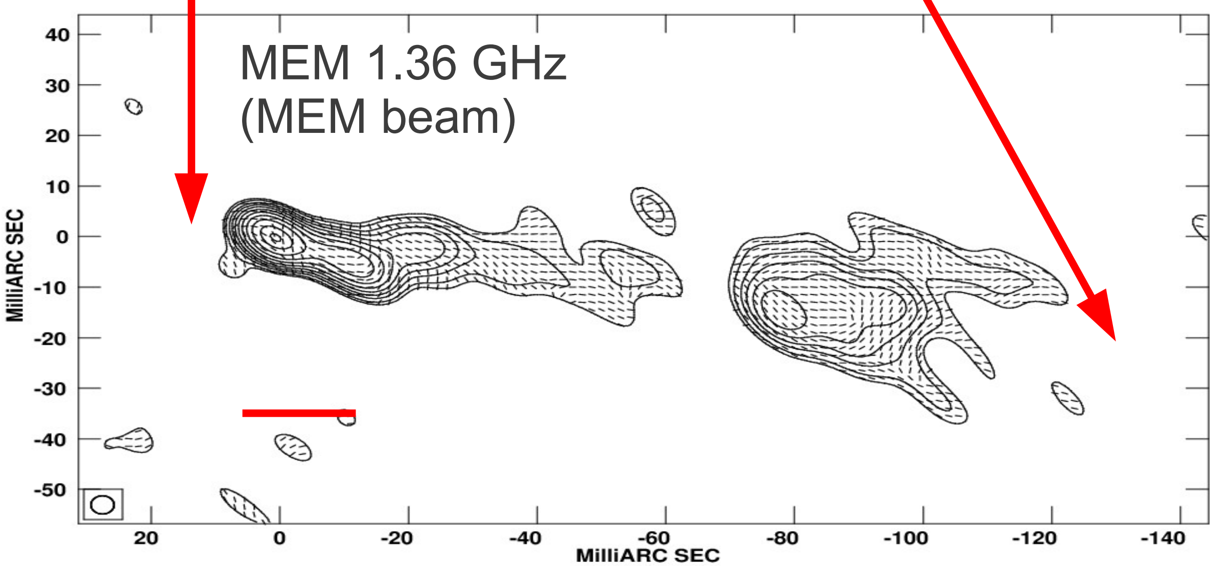
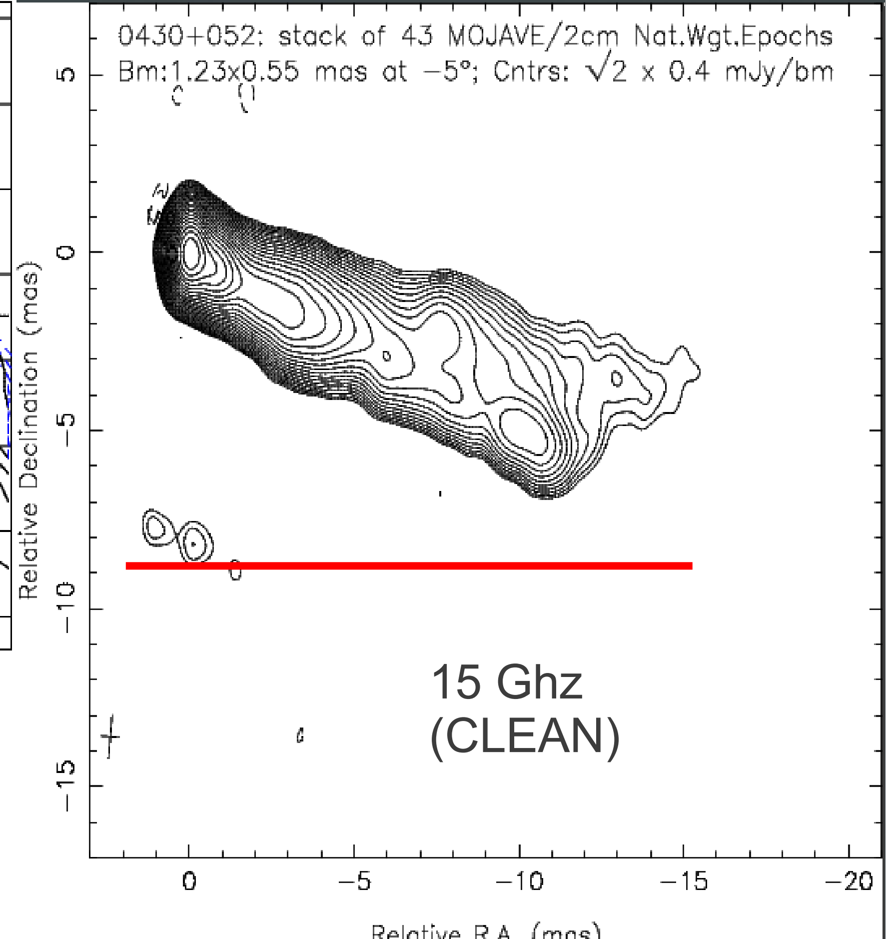


The smalller beam loses some of the extended flux, but can reveal new details

3C 120







Good agreement between 3 maps at different scales

Summary

MEM is potentially a useful tool in imaging polarised VLBA sources.

Its enhanced resolution over CLEAN could be useful in the study of polarisation phenonema such as Faraday rotation.

MEM is objective and mathematically well based.

MEM can be more difficult to implement than CLEAN. Parameters have to be chosen carefully to get optimal deconvolution.

While MEM and CLEAN maps cannot be compared directly, together they can give a fuller understanding of the source.

Thanks for your attention