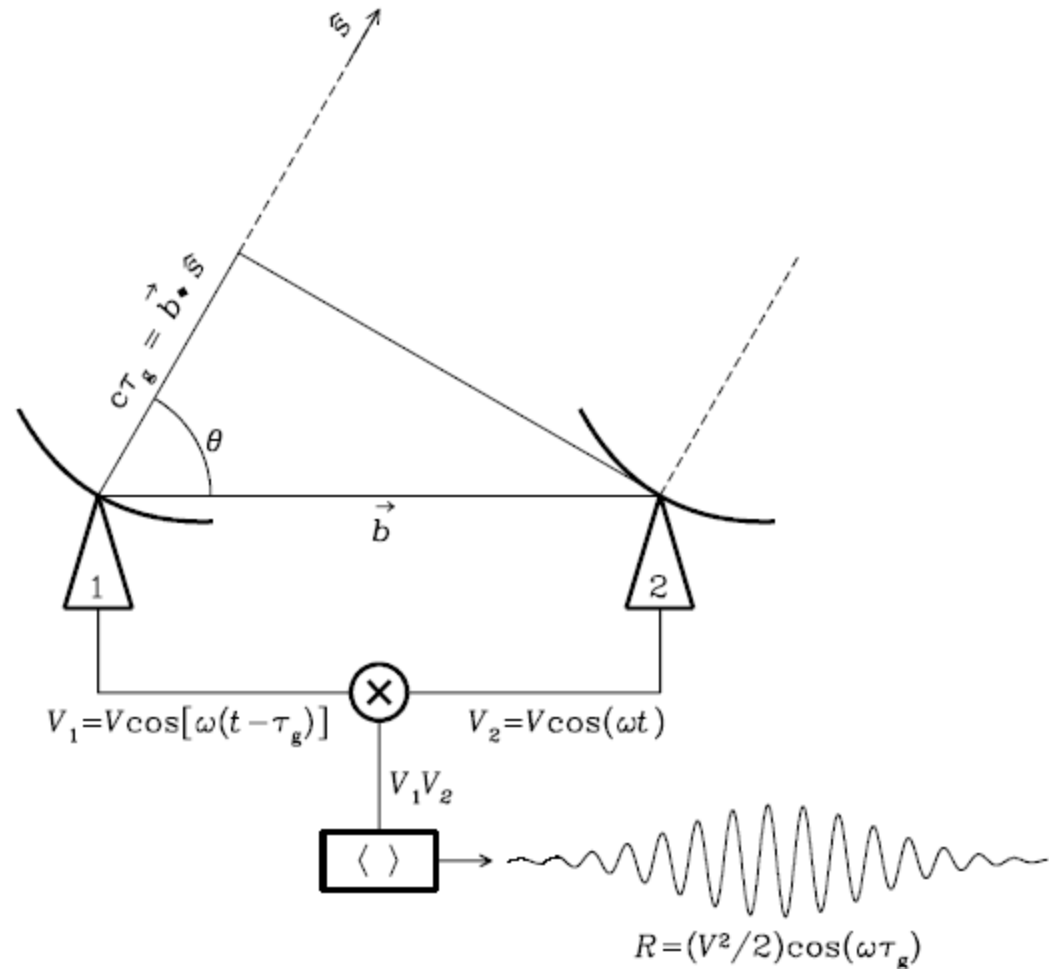


Radio Interferometry

- Two-element interferometry
- Visibilities
- Aperture synthesis
- Imaging considerations

Two-element Interferometer

- Correlate and integrate the signals from two antenna separated by baseline, b , pointing at the same source
- Produces an interference fringe



- The term modulating the fringes $\cos(\omega\tau_g)$ can be rewritten using

$$\omega = 2\pi\nu \quad \text{and} \quad \tau_g = \frac{b \cos \theta}{c} = \frac{\vec{b} \cdot \hat{s}}{c}$$

to become

$$\cos\left(2\pi\nu \frac{\vec{b} \cdot \hat{s}}{c}\right) = \cos\left(2\pi \frac{\vec{b}}{\lambda} \cdot \hat{s}\right) = \cos(2\pi \vec{b}_\lambda \cdot \hat{s})$$

where \vec{b}_λ is the baseline measured in wavelengths representing a *spatial frequency*

Complex Visibility

- For an extended source we must integrate over solid angle and the response of the interferometer can then be written as

$$V_\nu = \int I_\nu(\hat{s}) e^{(-i 2 \pi \vec{b}_\lambda \cdot \hat{s})} d\Omega$$

where this *visibility* is a complex number that can be expressed in terms of *amplitude* and *phase*

$$V = A e^{-i\phi}$$

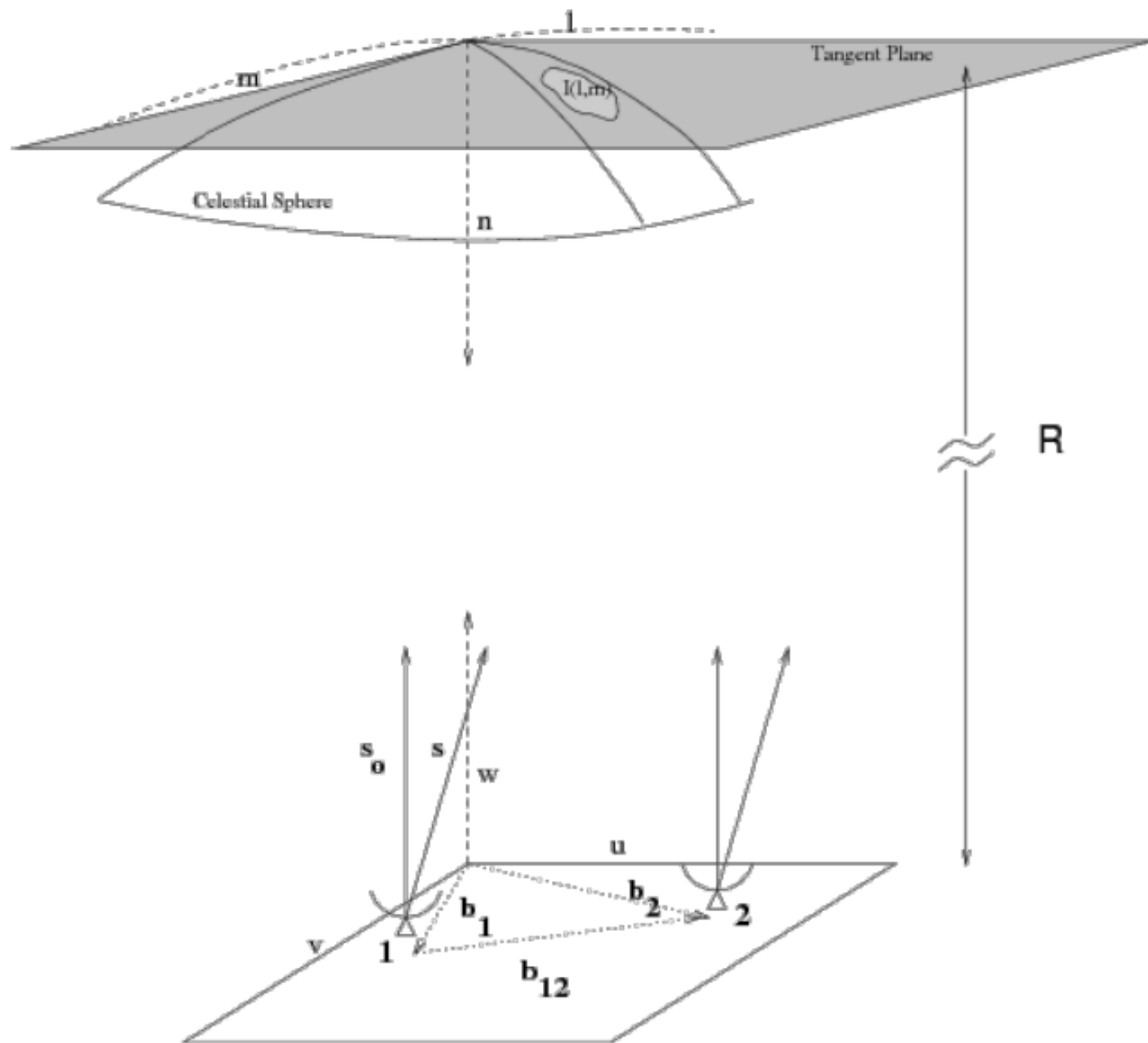
uv plane

- In 2D we can define a plane perpendicular to the source direction in which to define the baseline vector in terms of spatial frequency coordinates u and v , i.e.

$$\vec{b}_\lambda = u + v$$

- And the source position unit vector is defined by direction cosines projected on the uv plane

$$\hat{s} = l + m$$



- The visibility now becomes

$$V_v(u, v) = \int I_v(l, m) e^{(-i 2\pi (ul+vm))} dl dm$$

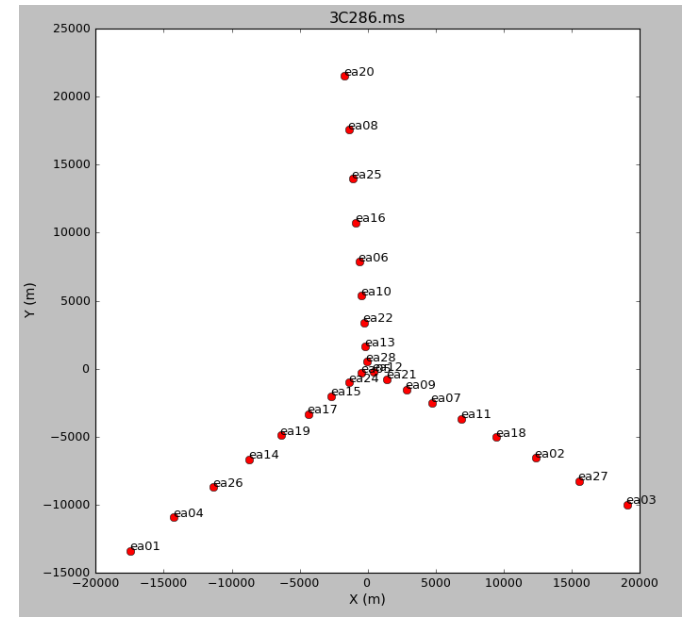
which is the Fourier transform of the intensity distribution

- Hence the intensity distribution can be recovered from the inverse Fourier transform of the visibilities

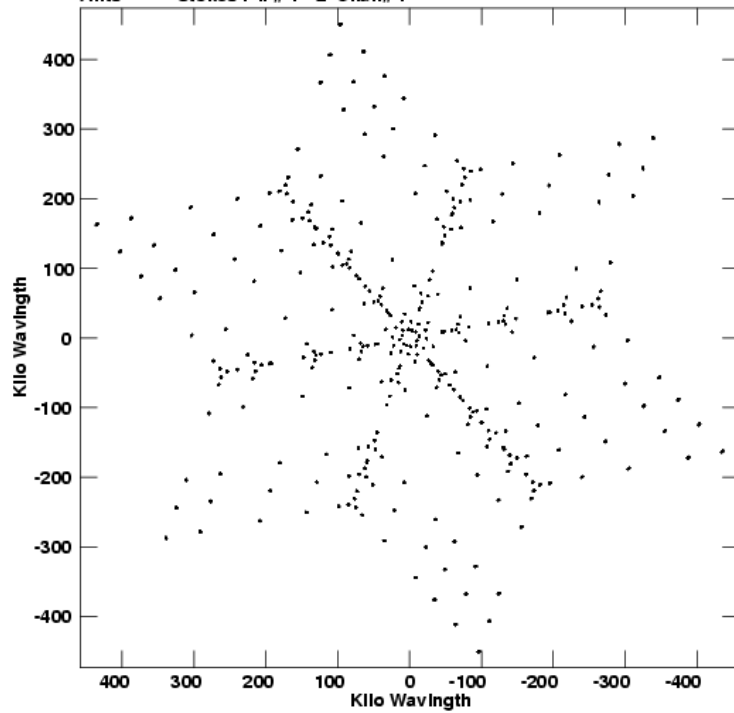
$$I_v(l, m) = \int V_v(u, v) e^{(i 2\pi (ul+vm))} dudv$$

Aperture Synthesis

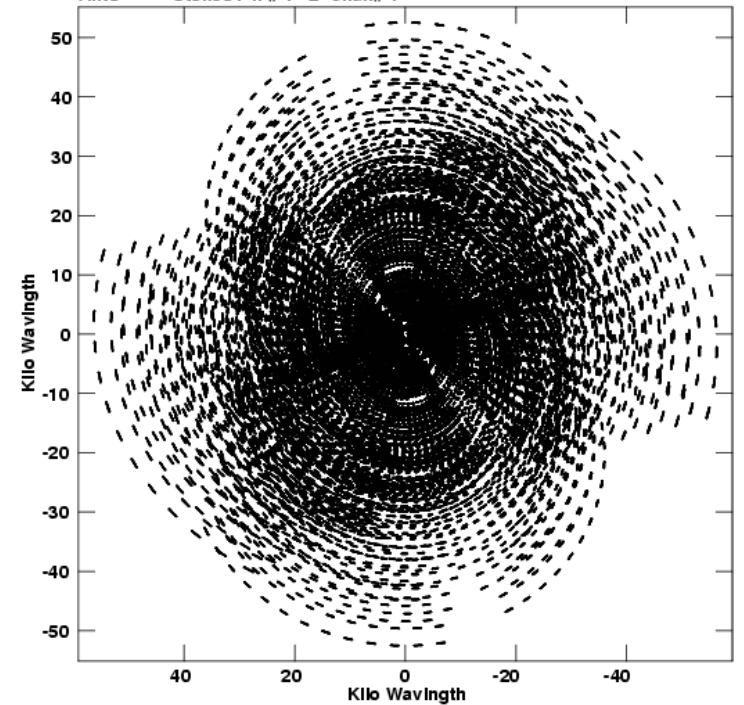
- One short integration with a single baseline at one wavelength gives one point in the uv plane
- The Earth's rotation will complete a track in the uv plane
- N telescopes gives $N(N-1)$ baselines
- Wider bandwidth fills the gaps in the uv plane



V vs U for 0005+383.Q BAND.1 Source:0005+383
Ants * - * Stokes I IF# 1- 2 Chan# 1

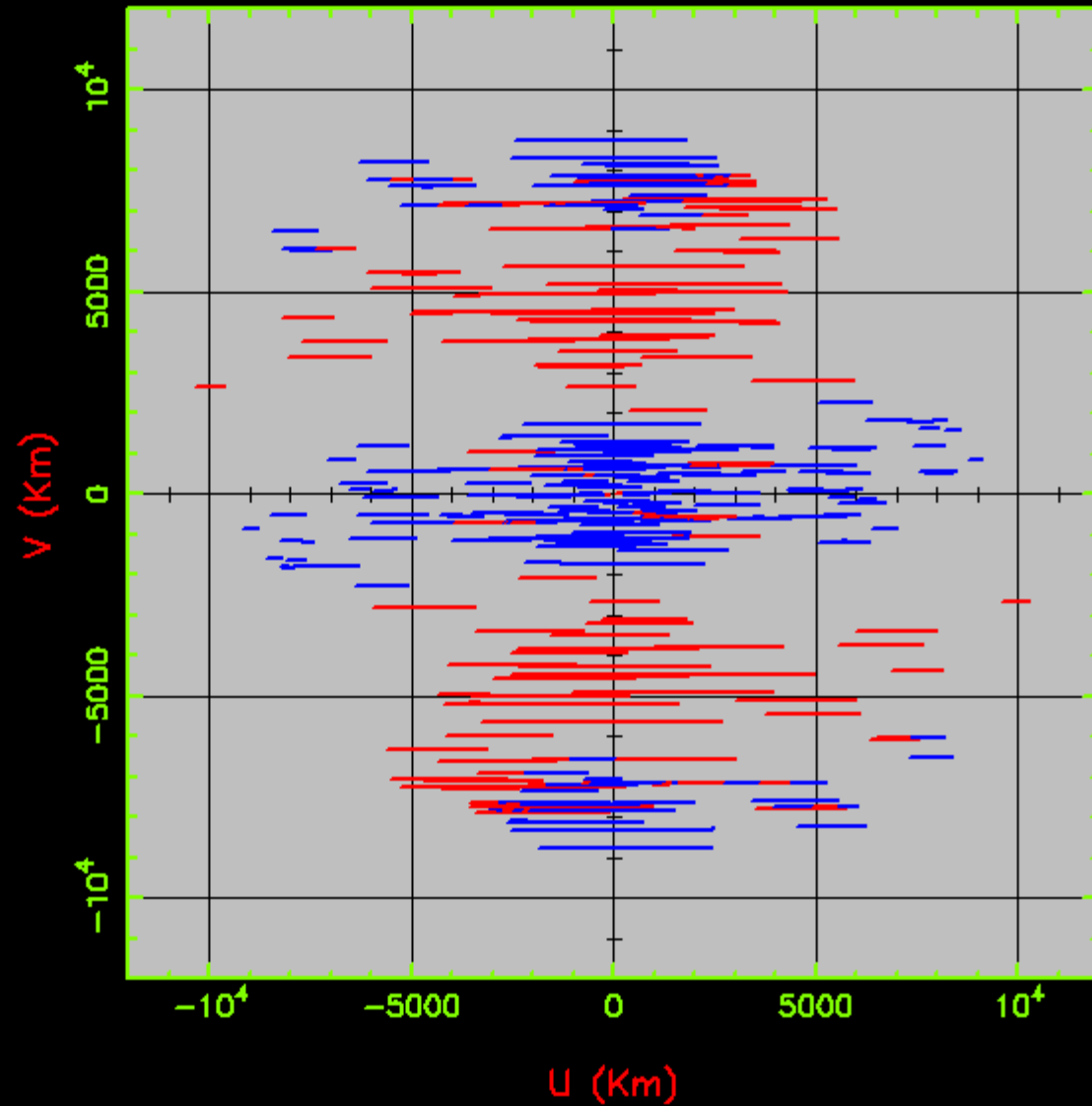


V vs U for CASA.CBAND1.1 Source:CASA
Ants * - * Stokes I IF# 1- 2 Chan# 1



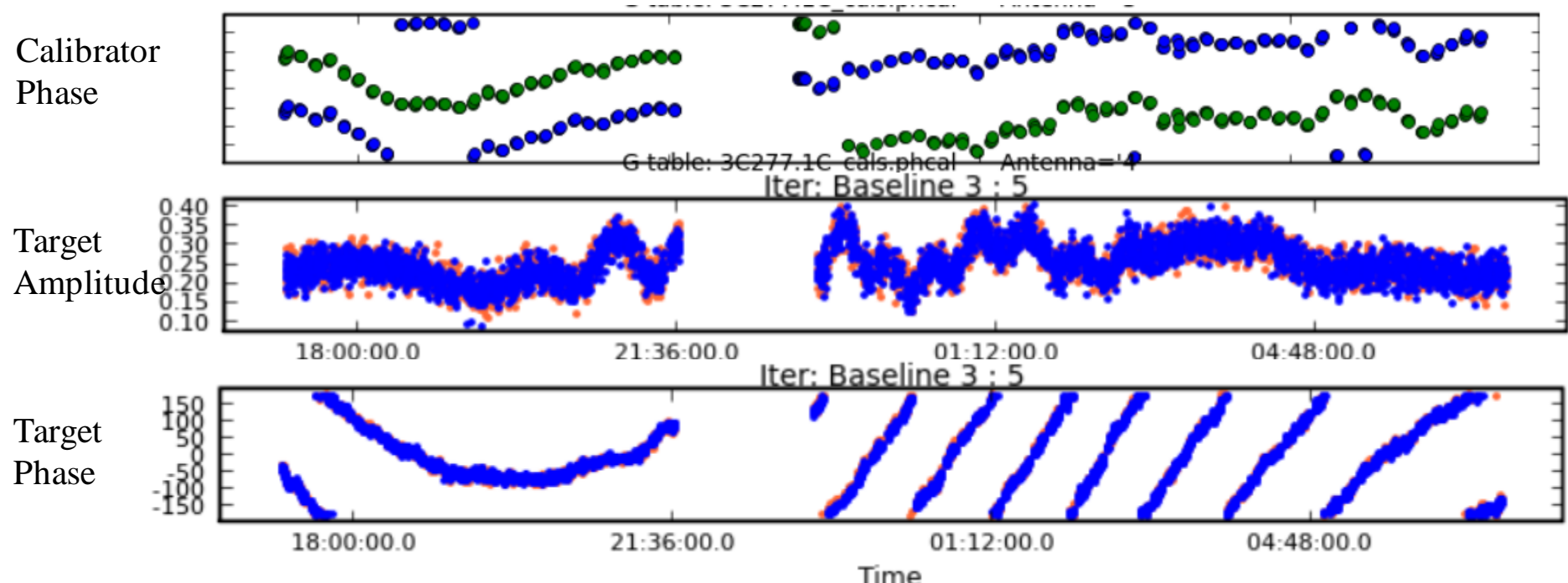
UV Coverage for Africa

- HART
- MEERKAT
- GHANA
- KENYA
- MOZAMB
- MAURIT
- EB_VLBA
- NOTO
- TORUN
- YEBES40M
- MEDICINA
- WSTRBORK
- JODRELL1
- GOONHILL
- SHANGHAI
- BADARY
- ZELENCHK
- SVETLOE
- URUMQI
- DECL=0



Calibration

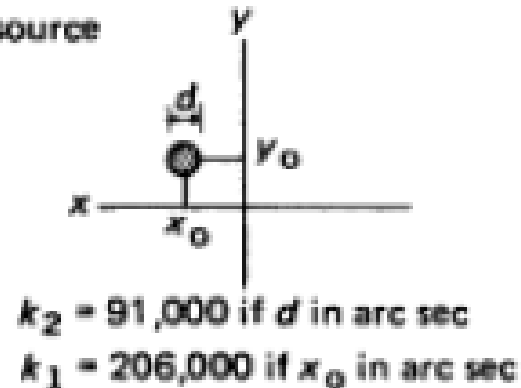
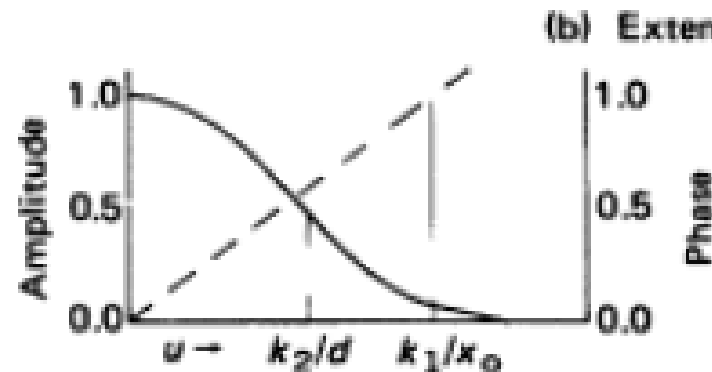
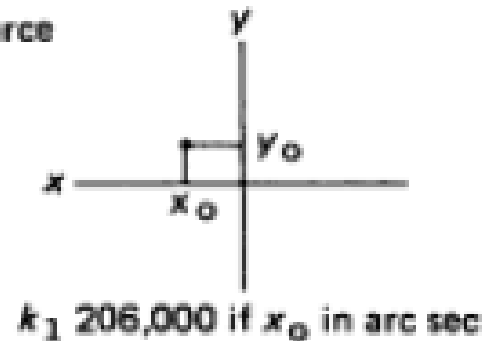
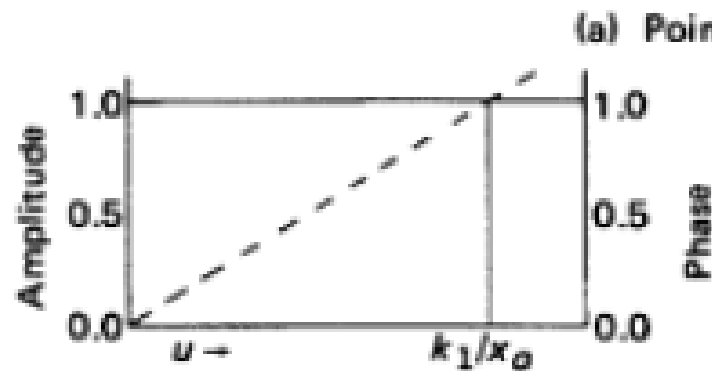
- The effects of the atmosphere on the amplitude and phase are corrected by regular observations of a nearby, bright, point source e.g. a quasar



Amplitude vs Baseline plots

Visibility function

Brightness distribution



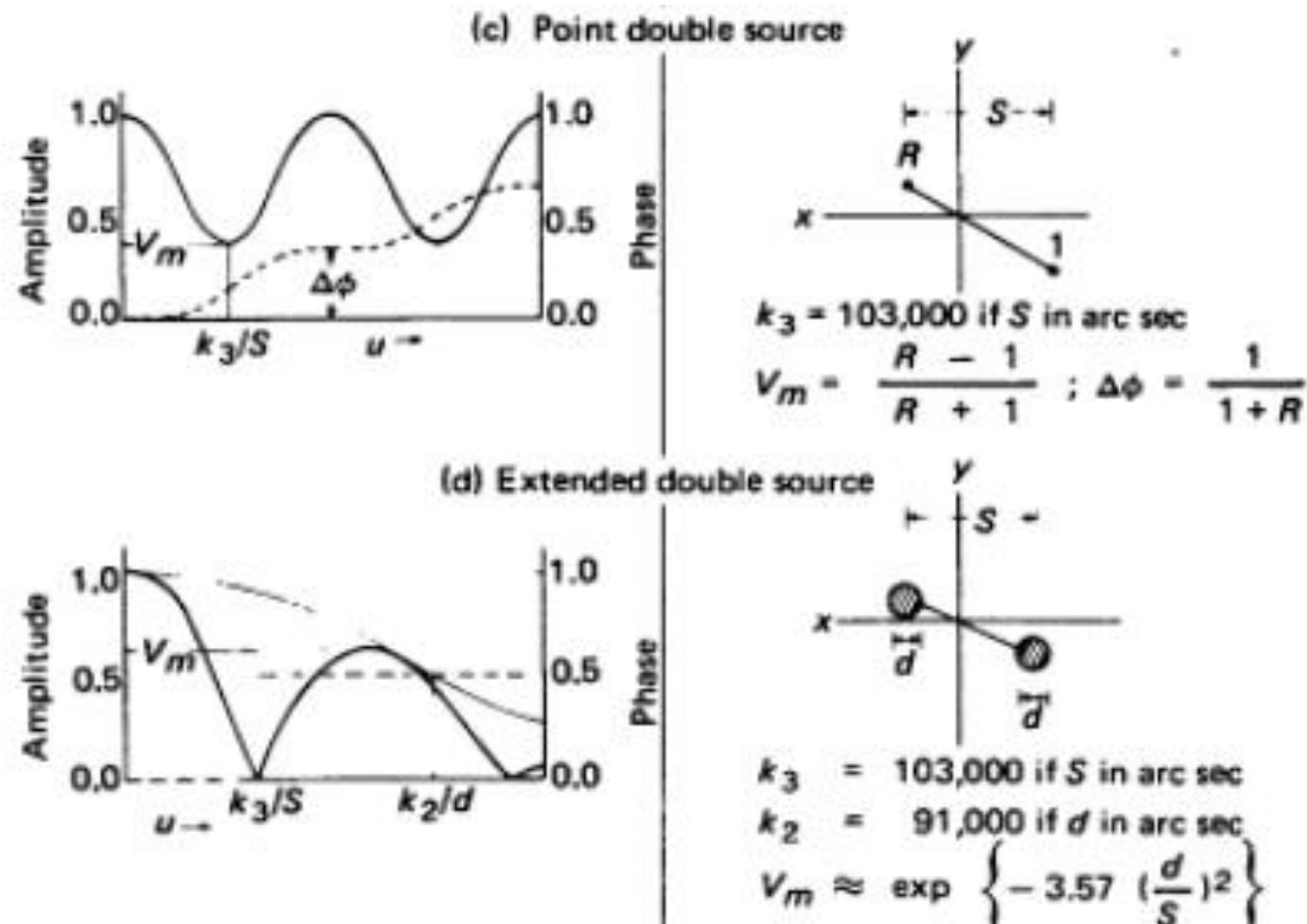


Figure 16-1. The visibility functions for various brightness distribution models (reproduced from Fomalont & Wright 1974; © Springer, Berlin).

Image Fidelity

- Maximum baseline determines the resolution or synthesised beam

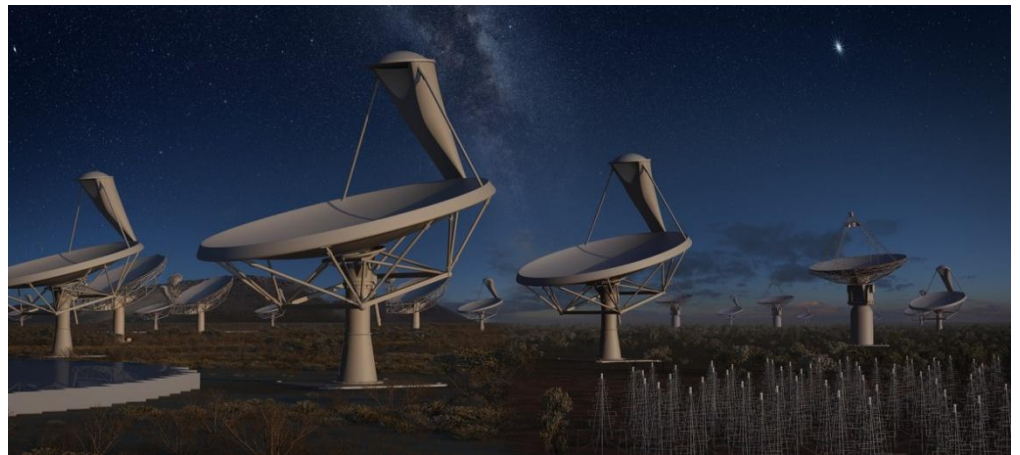
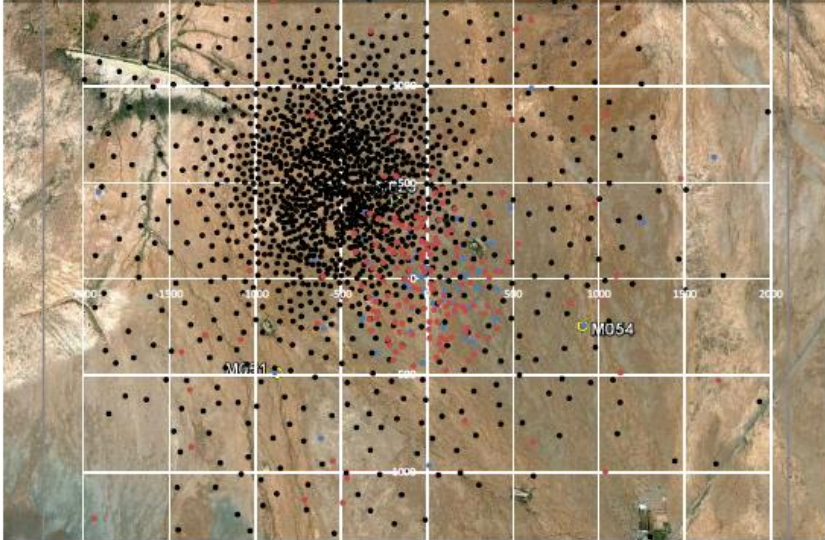
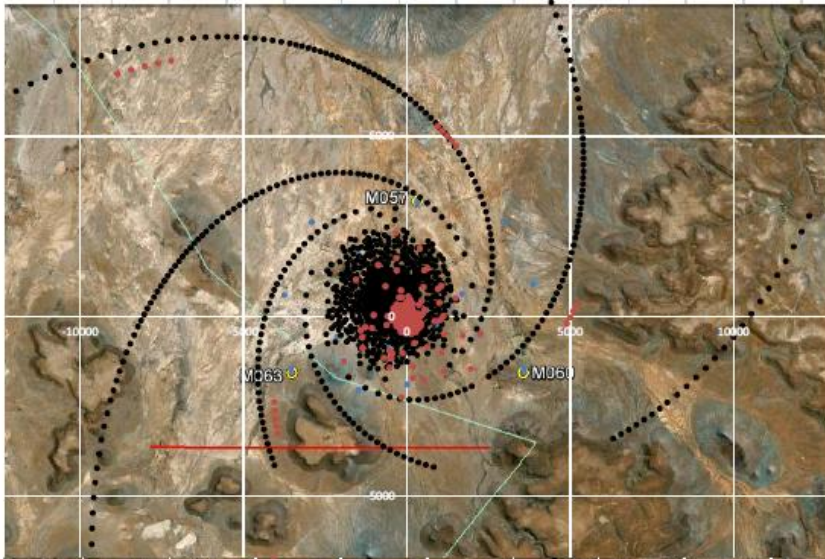
$$\theta_{beam} \approx \frac{\lambda}{b_{max}}$$

- Minimum baseline determines the largest angular scale that the interferometer can image

$$\theta_{LAS} \approx \frac{\lambda}{b_{min}}$$

- Emission at spatial frequencies larger than θ_{LAS} are not detected
- Often leads to *missing flux* issues
- Need to fill in missing short spacing information
- Image fidelity is determined by number of antenna in the array
- SKA with 3000 dishes and baselines from 30 m to 5000 km will solve many of these problems

SKA



Summary

- Interferometers observe the Fourier transform of the intensity distribution on the sky
- Only sensitive to a limited range of spatial frequencies
- SKA will be a massive leap forward

