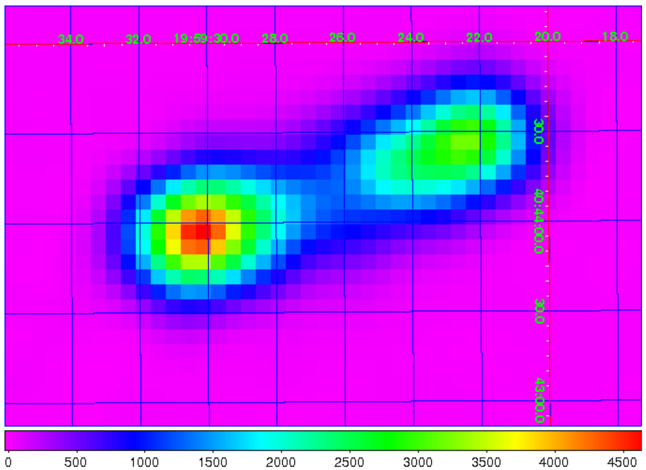
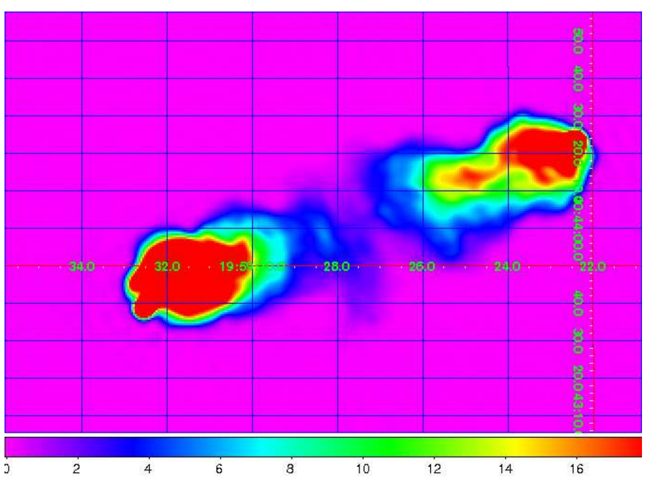
WSRT LFFE CygA
5000 to 150000

Sarod Yatawatta, Ger de Bruyn and Michiel Brentjens

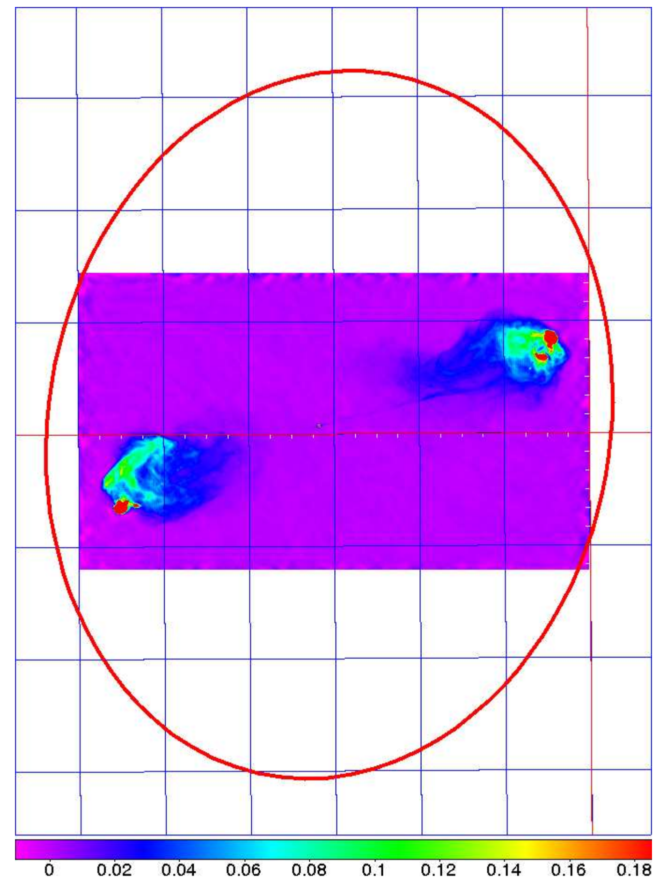
Cygnus A



VLA 74 MHz



VLA 327 MHz

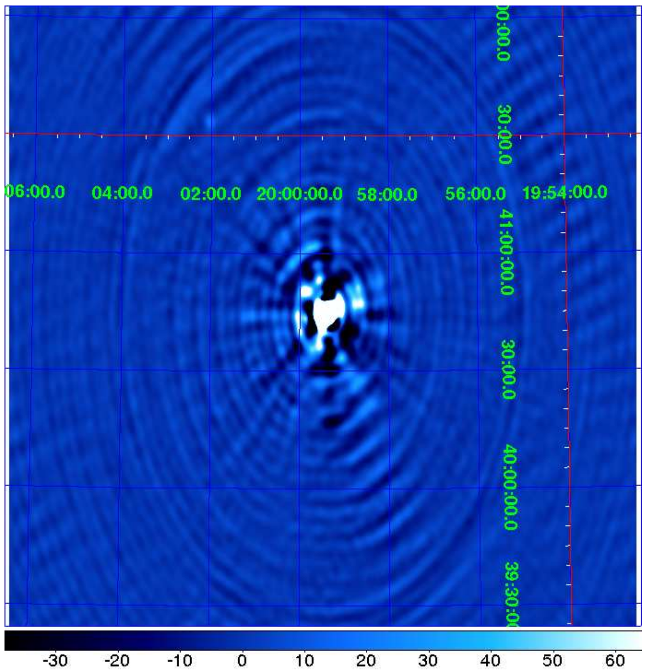


VLA 4.5 GHz, WSRT PSF at 140 MHz

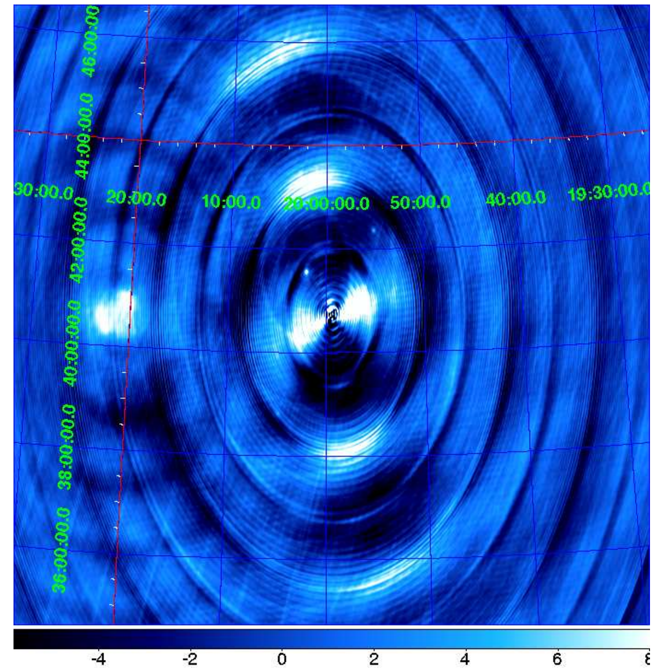
Credits: R.A. Perley, J.W. Dreher, J.J. Cowan, J. Lazio

university of groningen ASTRON

Cygnus A



WSRT 138.84 MHz image

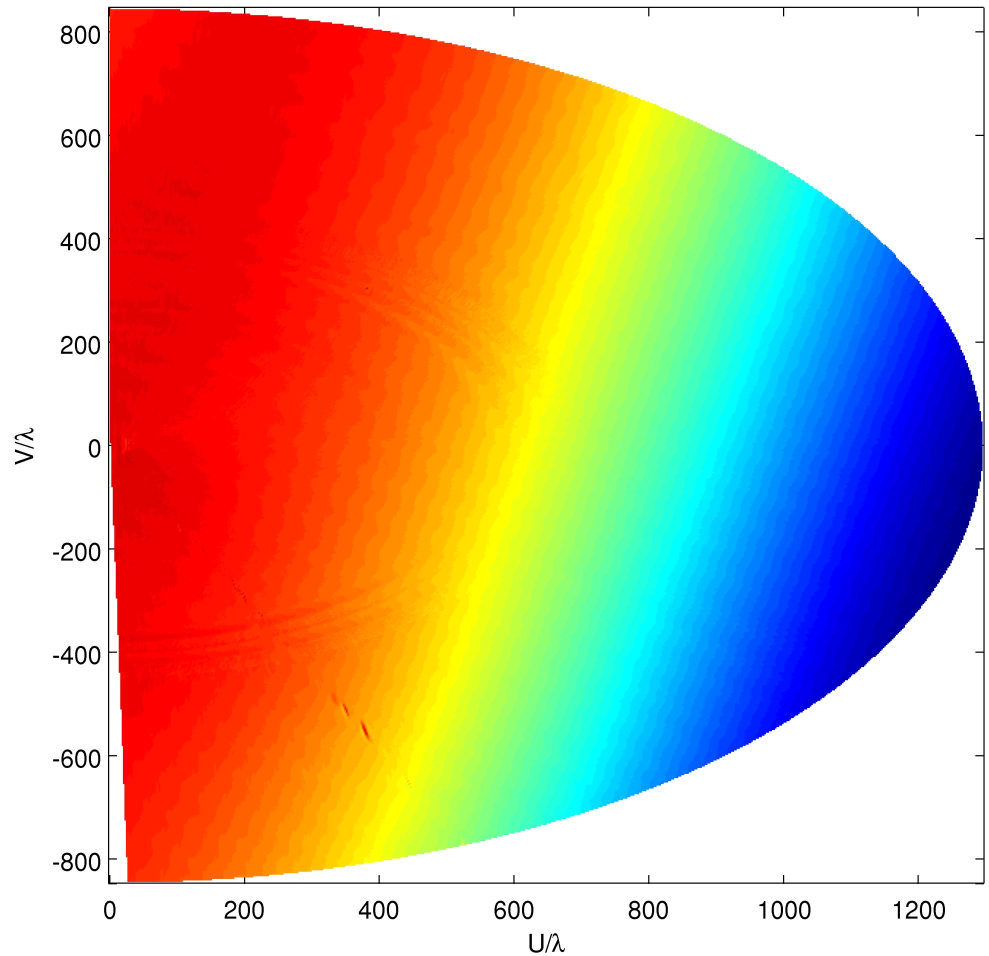


WSRT 138.84 MHz image, HB20 on left

- ☐ Clean dynamic range ≈ 5000

university of groningen
ASTRON

Visibilities



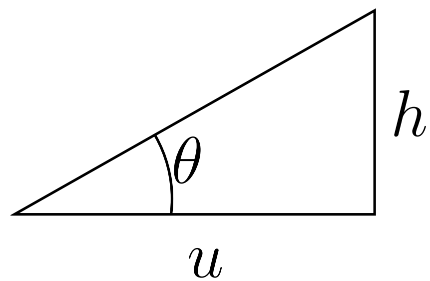
Calibrated $|I|$

Clean fails because...

Elementary Fourier transform:

$$f(l-a, m-b) \Leftrightarrow \exp(-j2\pi(au+bv))F(u,v)$$

Estimation of phase (position) of a clean component:



$$\tan\theta = \frac{h}{u}$$

$$\Delta\theta = \frac{u}{u^2+h^2}\Delta h - \frac{h}{u^2+h^2}\Delta u$$

$$E\{\Delta\theta^2\} = \frac{u^2}{(u^2+h^2)^2}\sigma^2$$

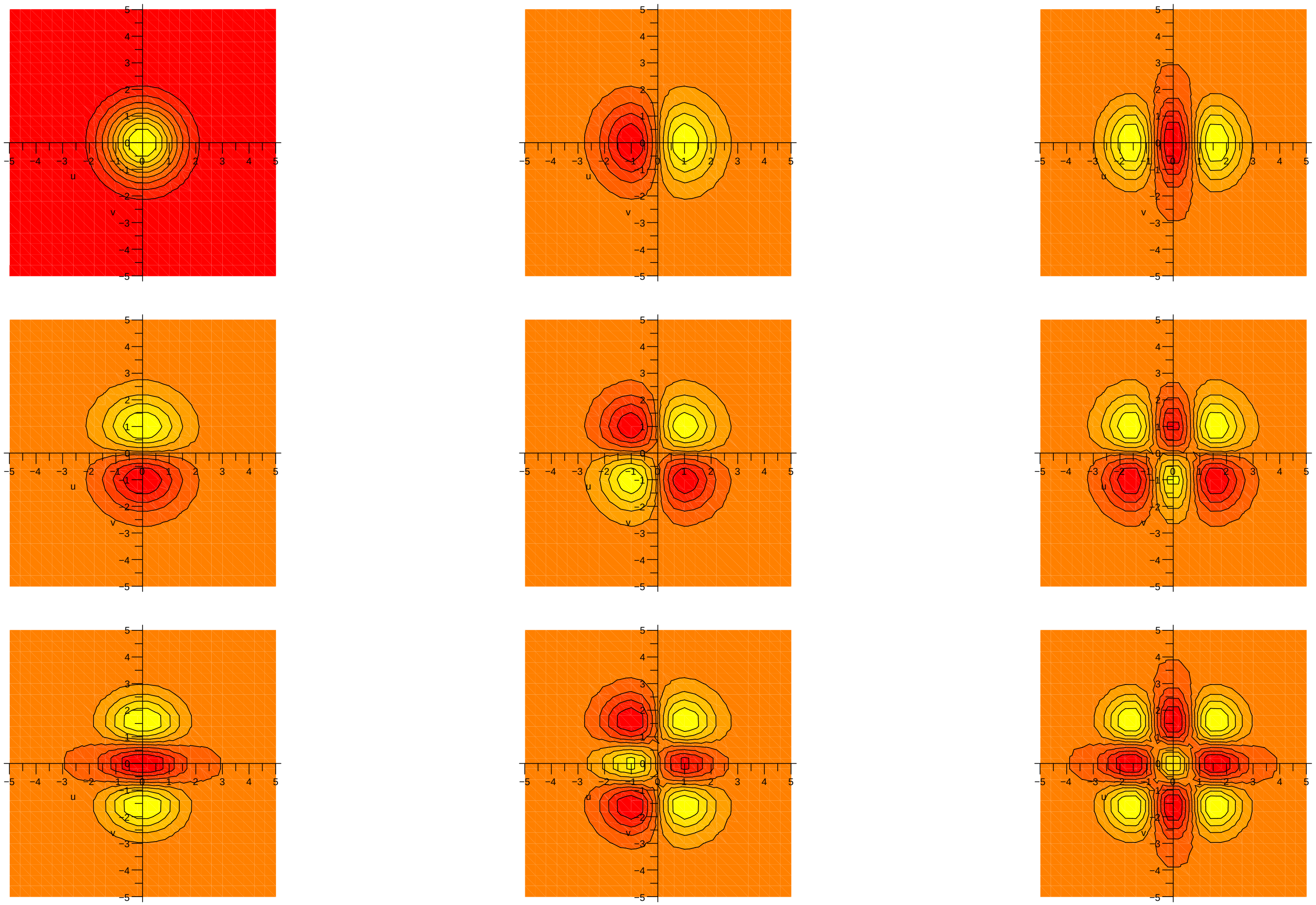
Shapelets

- Quite popular and well studied: [Refregier 2001] Paper I, [Refregier and Bacon 2001] Paper II,[Massey and Refregier 2003] Paper III
- Hermite Gaussian Orthonormal basis functions, (also polar shapelets)

$$\phi_{m,n}(x,y) = \frac{H_m(x/\beta)H_n(y/\beta)}{\beta\sqrt{m!n!2^{(m+n)}\pi}} e^{\left(-\frac{(x/\beta)^2}{2} - \frac{(y/\beta)^2}{2}\right)}, \ x,y \in \mathbb{R}, \ m,n \in [0, K-1]$$

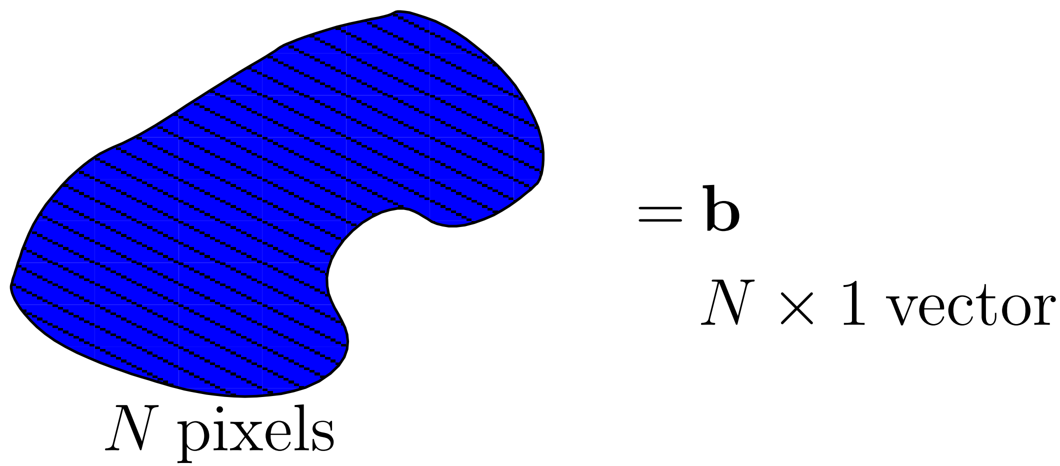
  where $H_n(x)$: n-th order Hermite function, K: order, β: scale
- Analytic relationships for Fourier transform, Convolution, Integration, Linear transform etc.
- Simple to evaluate using recursive relationships.
- Problems: hard to find optimal linear transform, order and scale for Shapelet Decomposition (mixed mode optimization problem). Shapelet evaluation can become negative or even complex.

Some basis functions



Shapelet Decomposition

Represent an arbitrary image

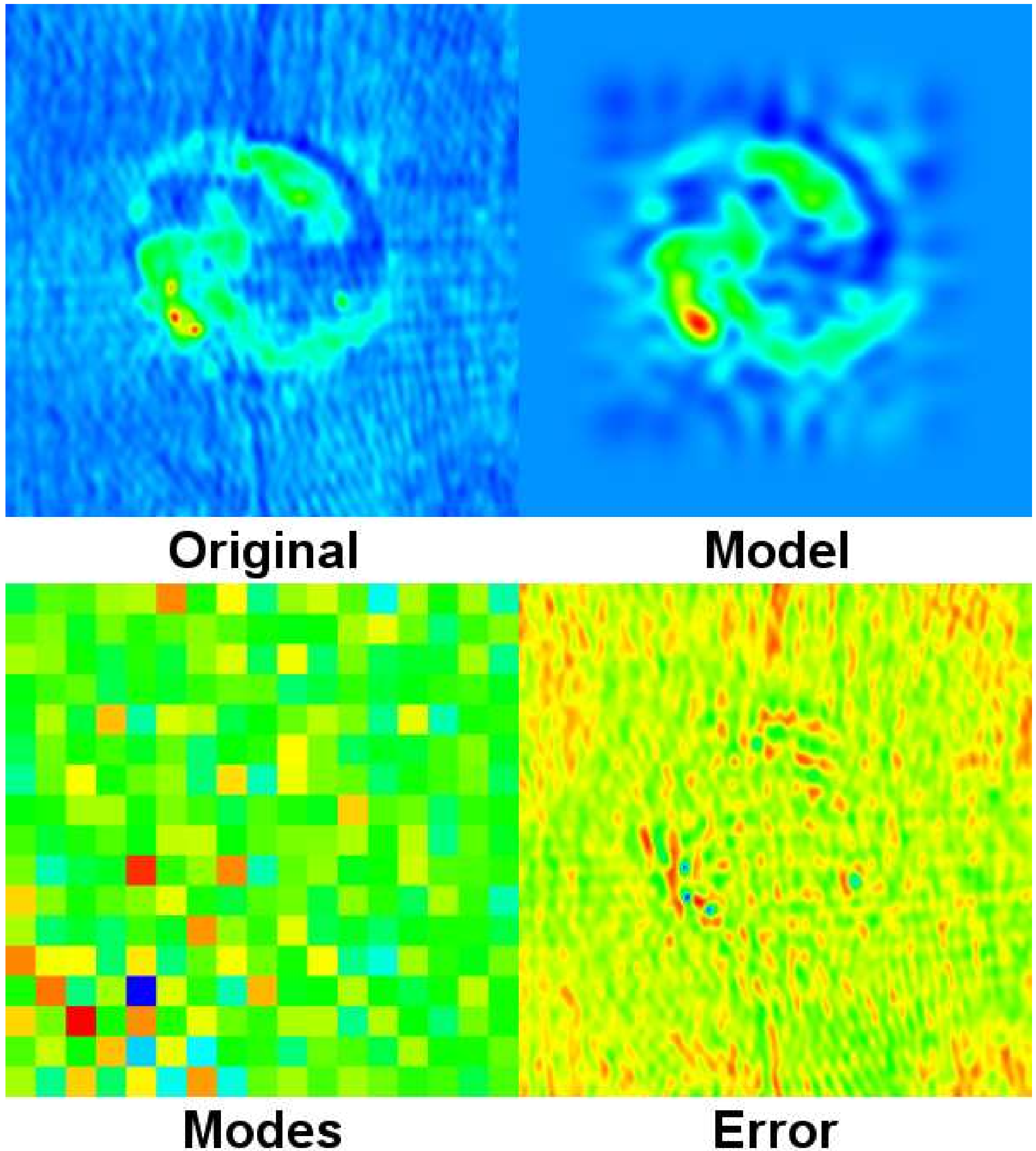


$$\mathbf{A}\mathbf{c} = \mathbf{b}$$

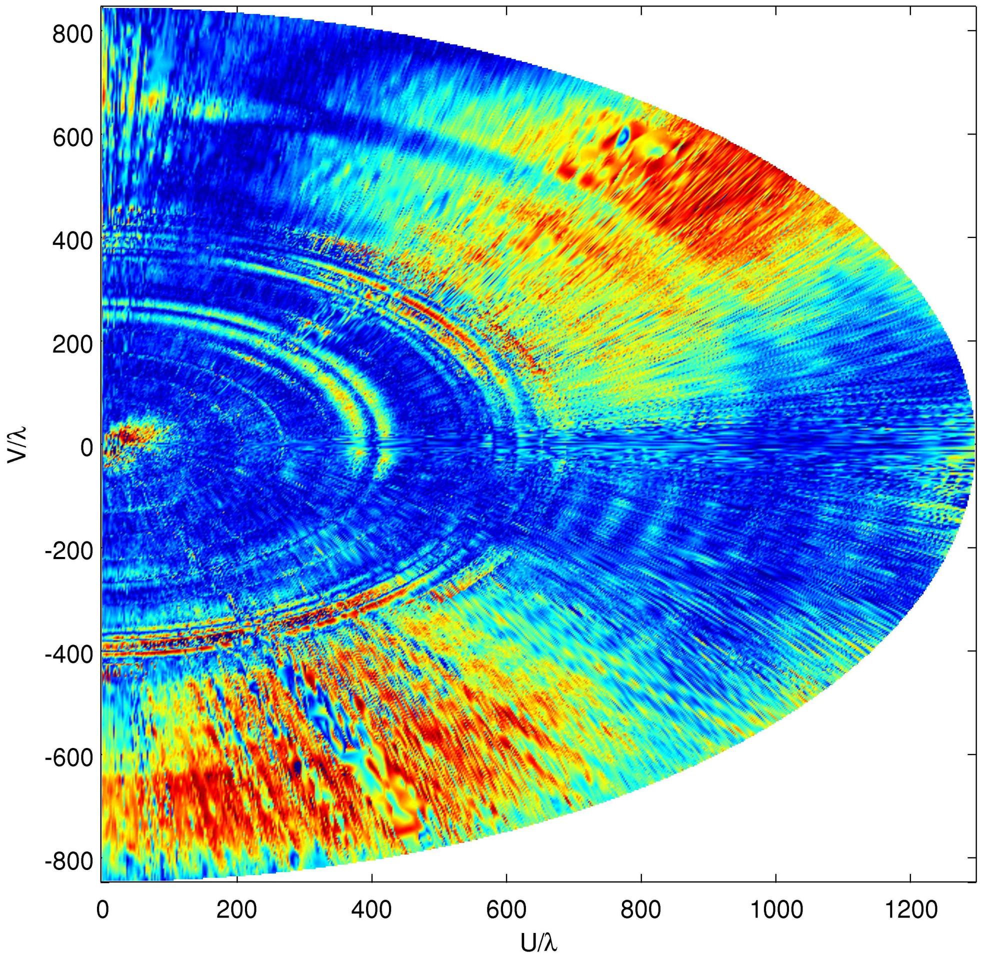
where columns of $\mathbf{A}$: shapelet basis functions ($N \times M$),
$\mathbf{c}$ coefficients of shapelet decomposition ($M \times 1$),
$\mathbf{b}$ image vector ($N \times 1$). ($N \gg M$)

- $\mathbf{c} = \mathbf{A}^{\dagger}\mathbf{b}$.
- $\mathbf{A}^{\dagger}$ found using SVD, can also use Tikhonov regularization.

Example



Residual

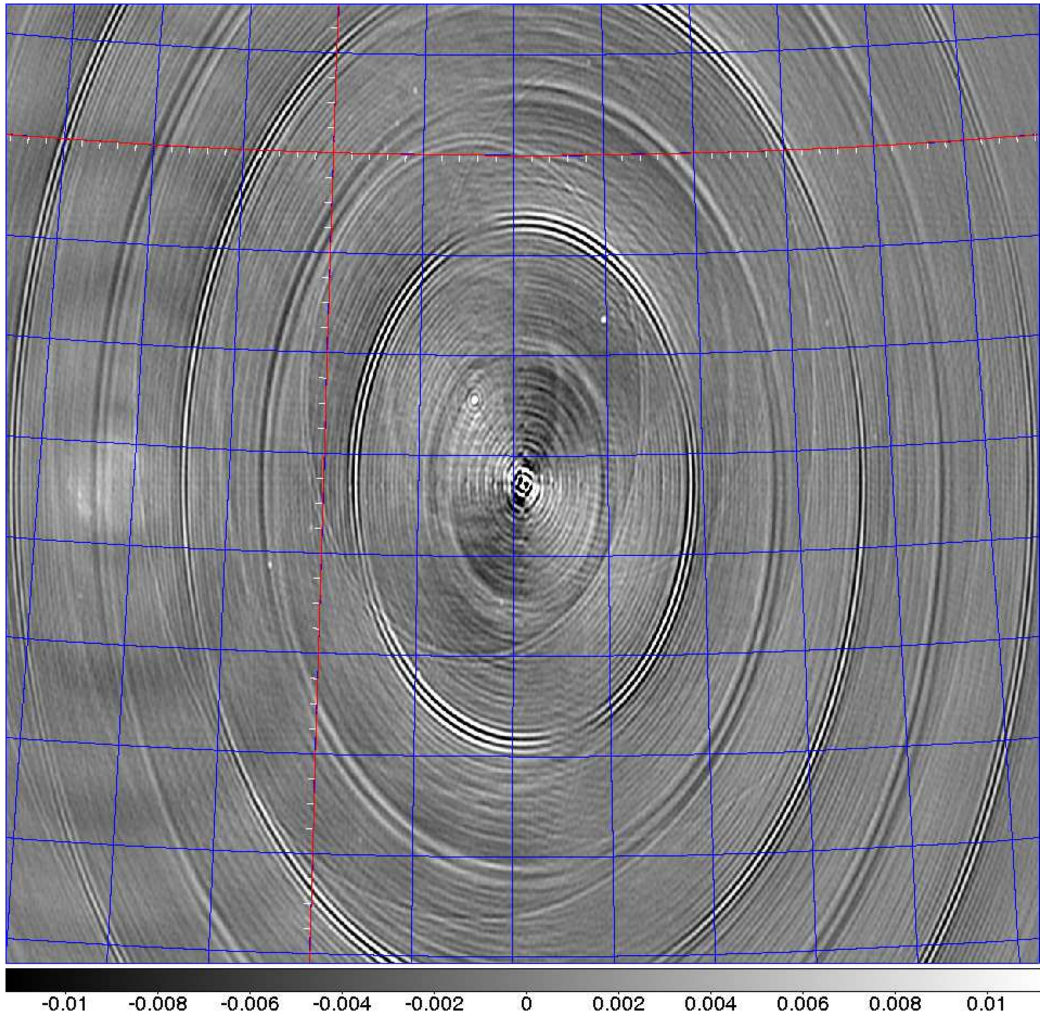


Residual $|\mathrm{I}|$

university of groningen

ASTRON

Example

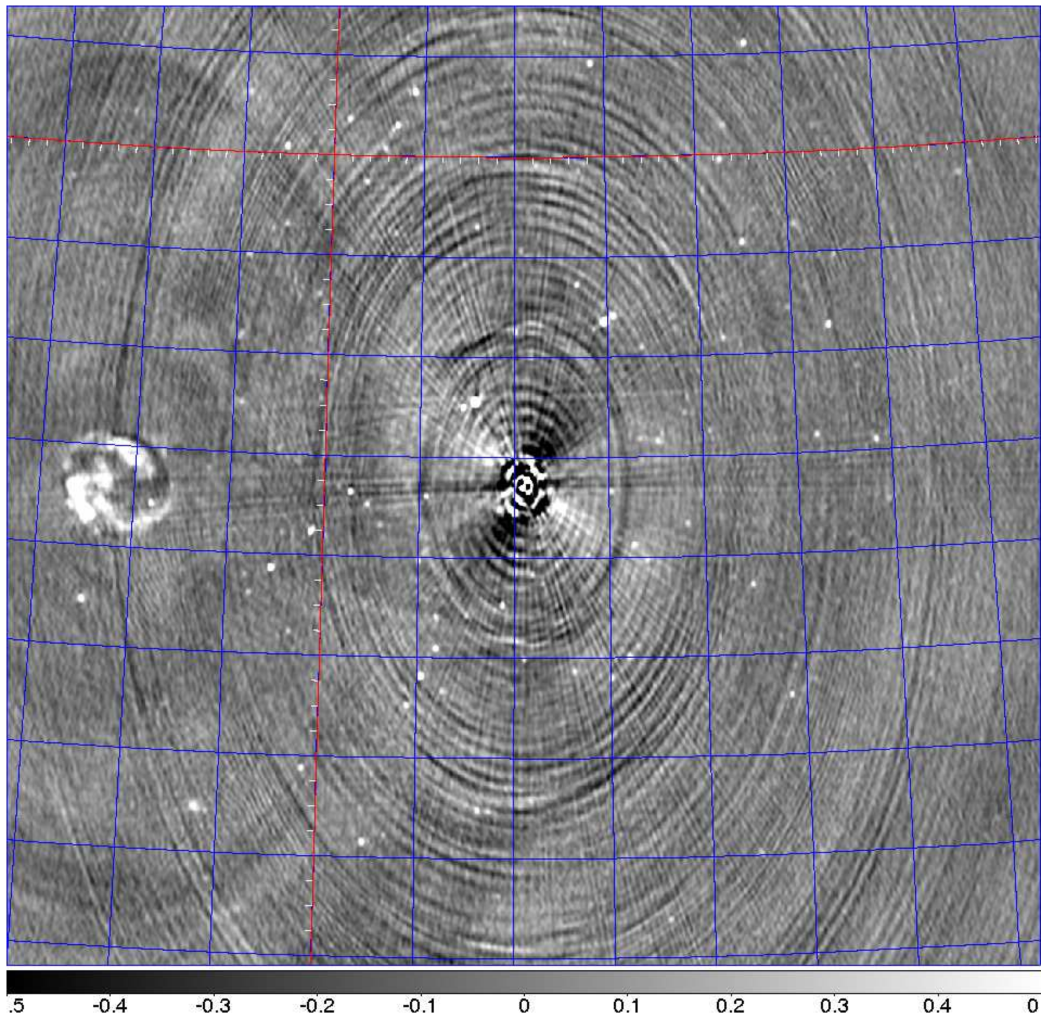


Peak $\approx$ 10000 Jy, Noise I 500 mJy, Q 225 mJy, (140 MHz)

university of groningen

ASTRON

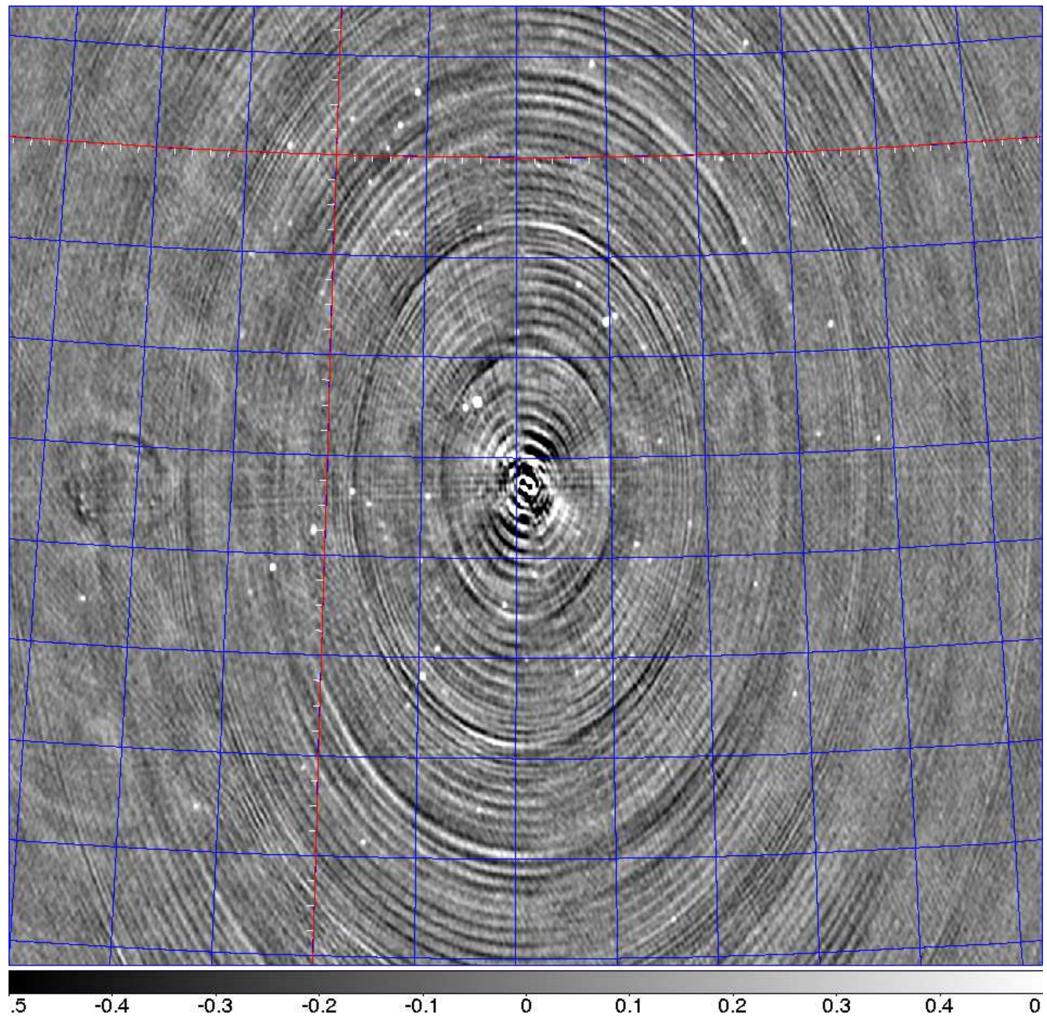
Example



Peak ≈ 10000 Jy, Noise I 65 mJy, Q 14 mJy, U,V 10 mJy (116.8-146.7 MHz)

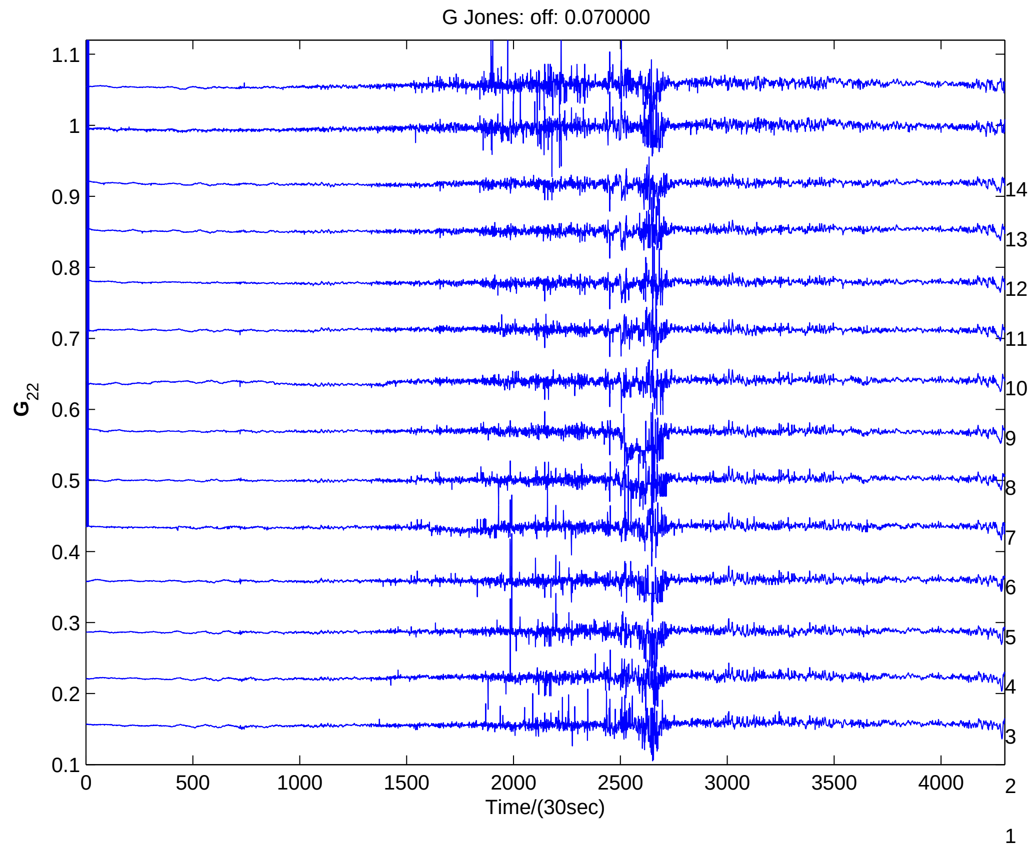
university of groningen ASTRON

Example

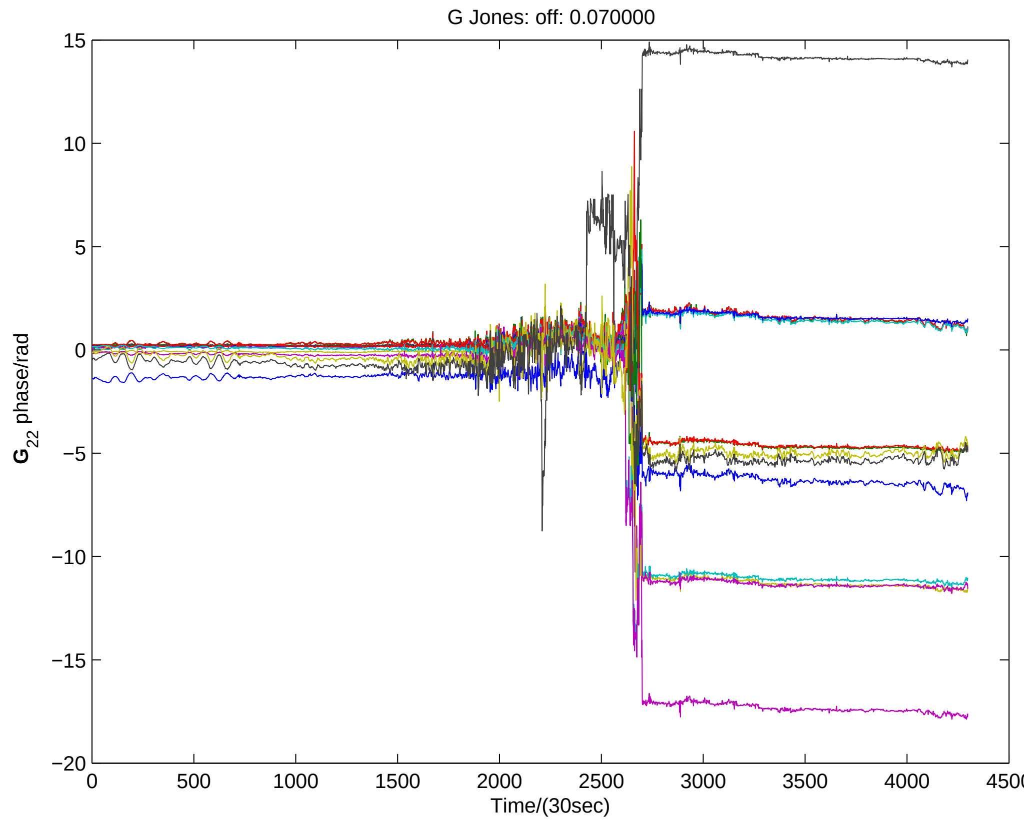


Peak ≈ 10000 Jy, Noise I 80 mJy, Q 15 mJy, U,V 12 mJy (138.7-140.7 MHz)

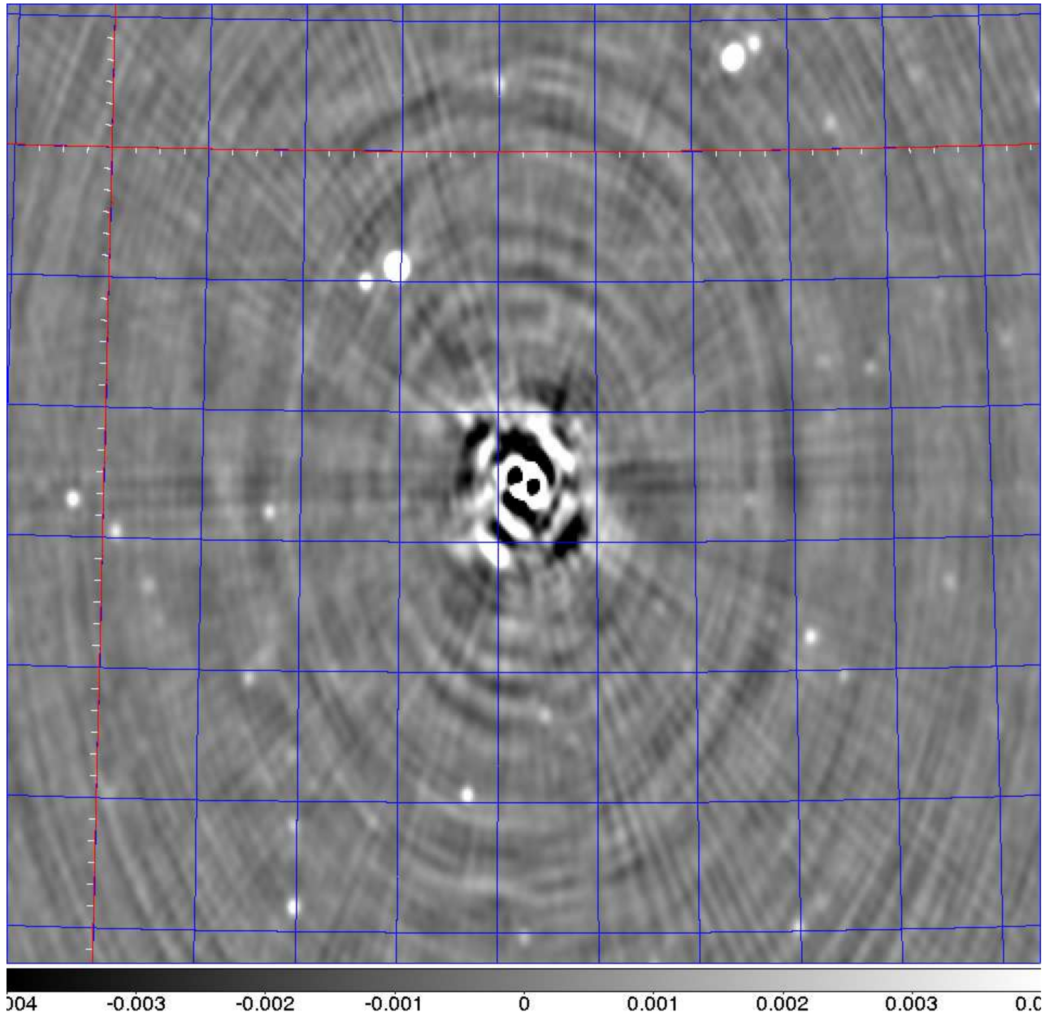
Calibration



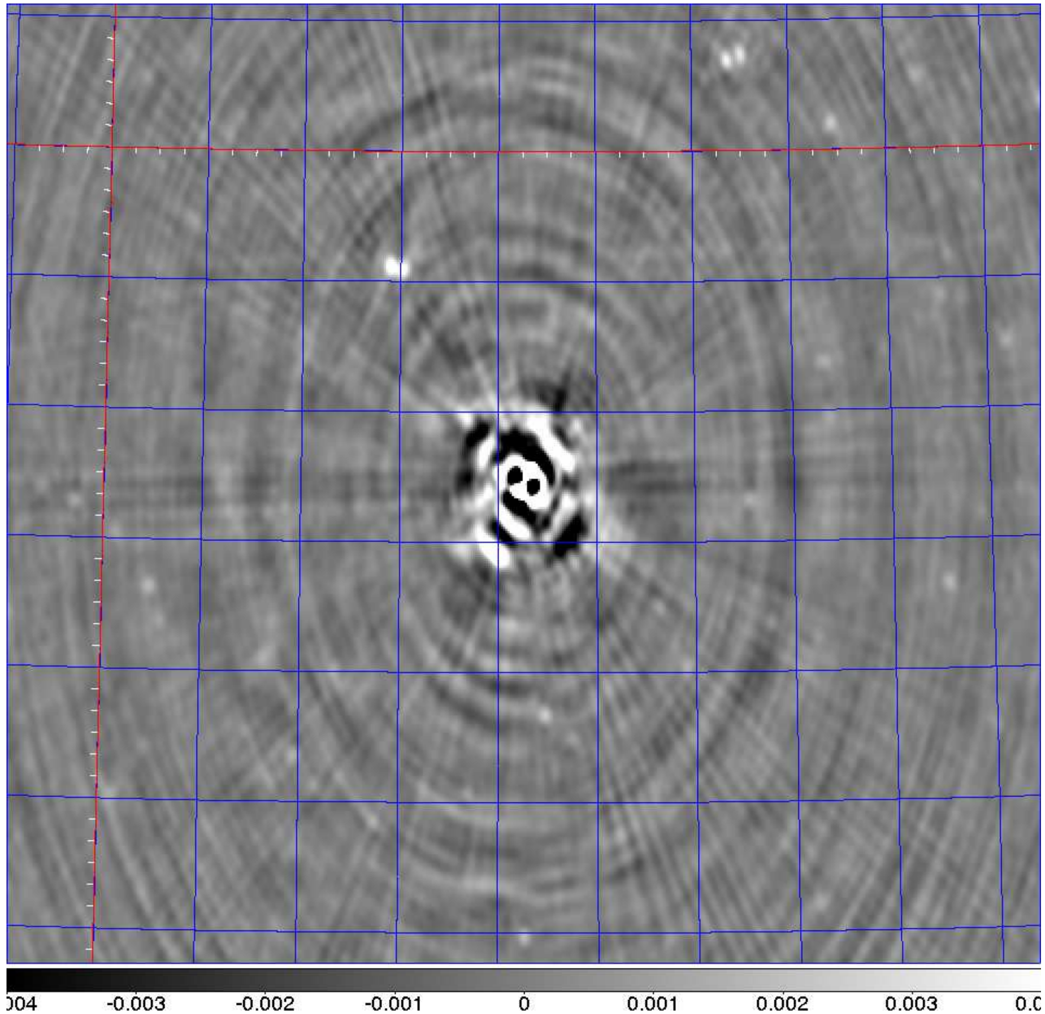
Calibration



Example



Example



About 45 sources subtracted *without !* direction dependent solving

university of groningen

ASTRON

Conclusions

- Shapelets provide a way to model extended sources (much larger than the PSF) as well as sources smaller than the PSF.
- Model construction in image plane and uv plane is possible.
- Hard part is to find the right scale β and the number of modes.
- For the CygA observation a dynamic range $\approx$ 150000 possible. This is still a factor above the noise. Limitations are due to faint RFI, scintillation and the galactic plane.