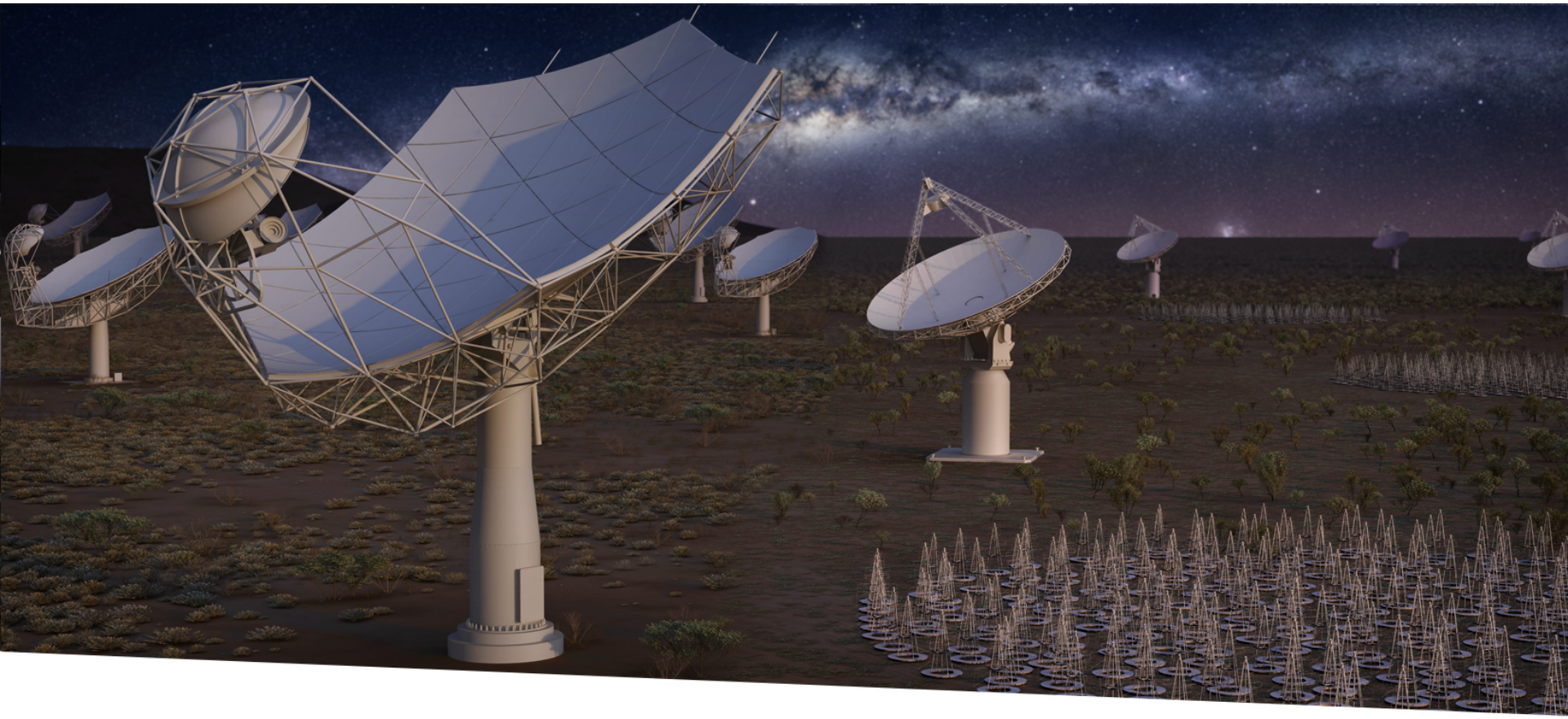
T1: Fun with Interferometry

…or how you can come to love Fourier Transforms



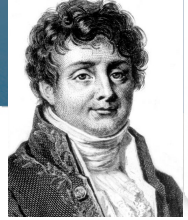
SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Robert Laing
ASTRON, Oct 16 2017

Who is this?

Fourier Transforms for Birdwatchers



$$V(u) = \int_{-\infty}^{+\infty} I(l) \exp(-2\pi i u l) dl$$

$$I(l) = \int_{-\infty}^{+\infty} V(u) \exp(2\pi i u l) du$$

Inversion (in 1D)

$$C(l) = \int_{-\infty}^{+\infty} I(l') B(l - l') dl'$$

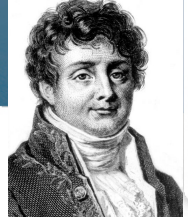
$$\hat{C}(u) = \hat{I}(u)\hat{B}(u)$$

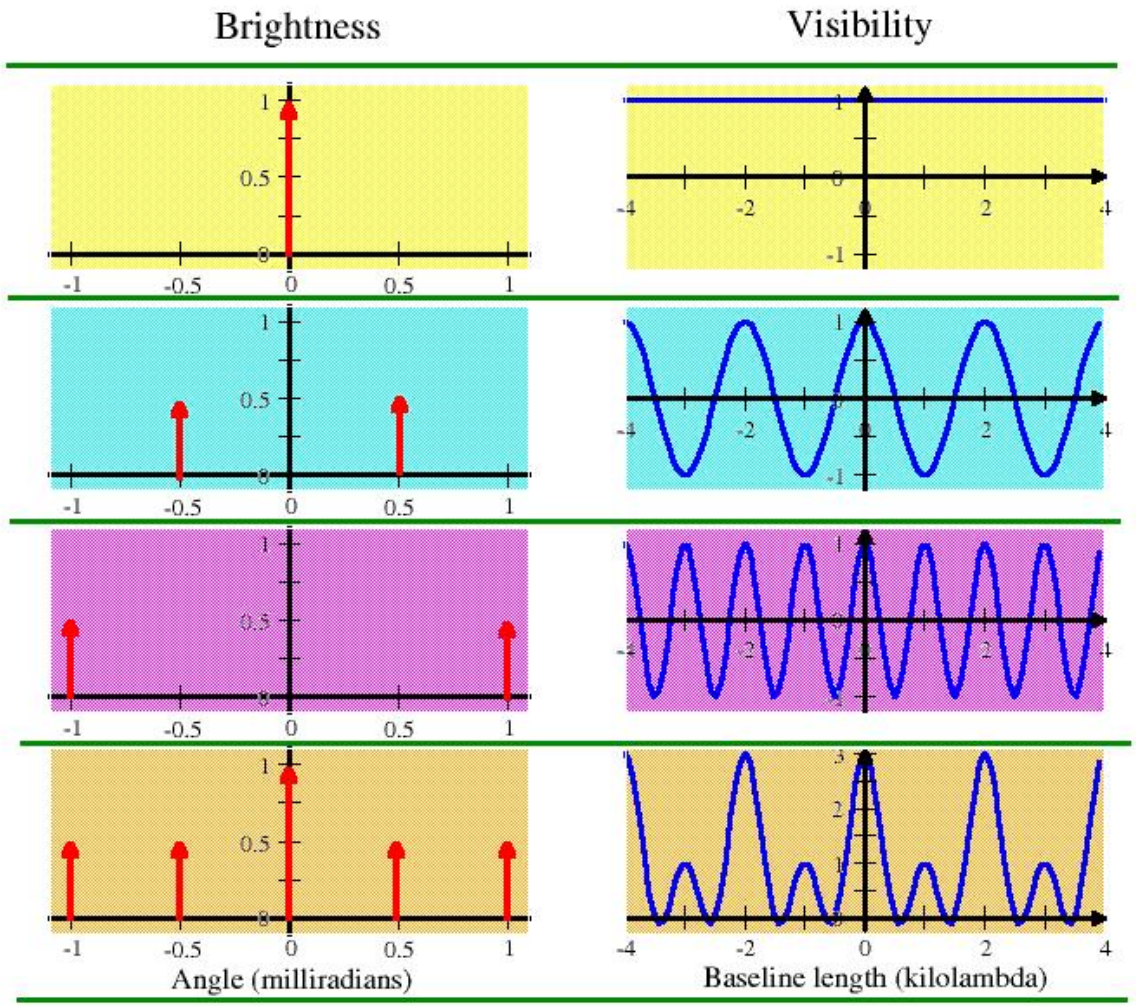
$$\hat{I}(u) = \int_{-\infty}^{+\infty} I(l) \exp(-2\pi i u l) dl$$

$$= V(u)$$

Convolution (ˆ denotes a Fourier transform)

Simple 1D Fourier Transforms





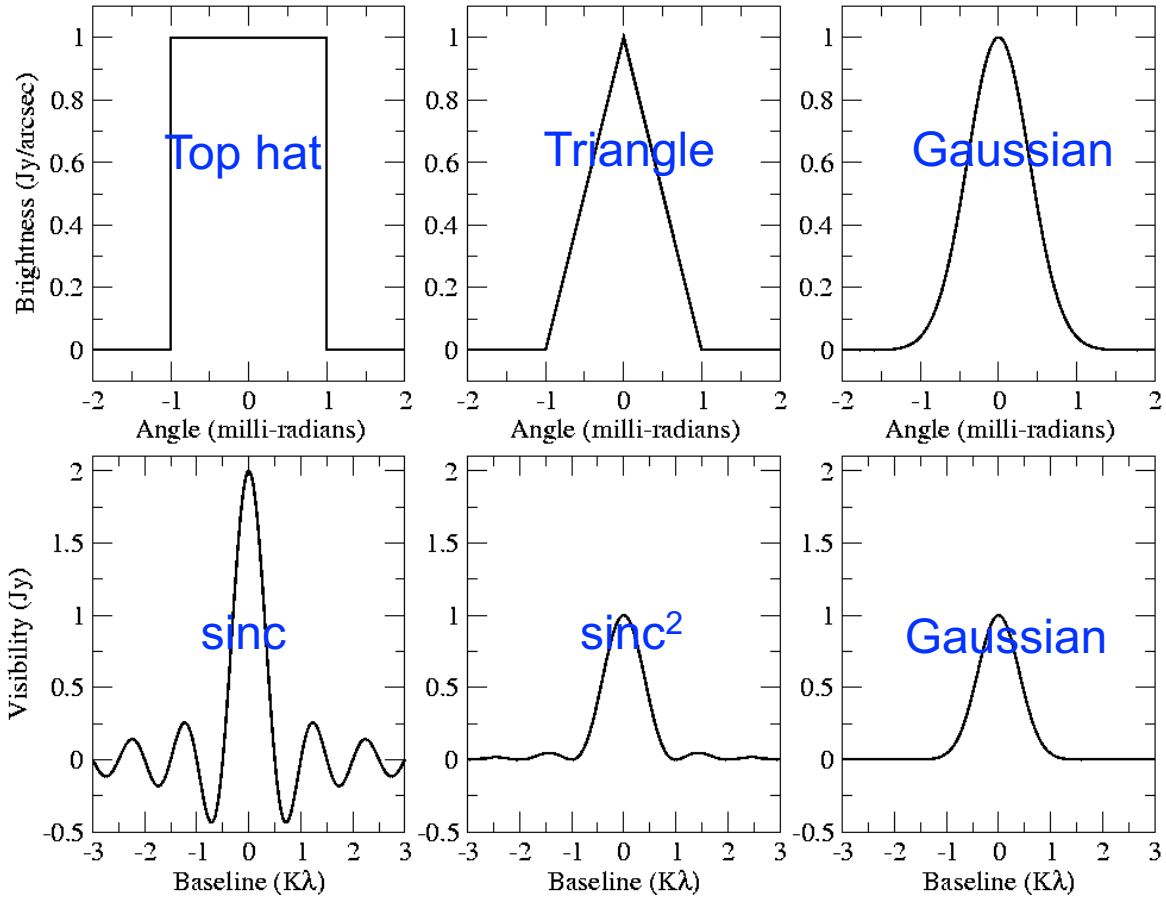
Point source at the phase centre

Symmetrical double source. cosine visibilities

Wider double source
Narrower cosine

l u

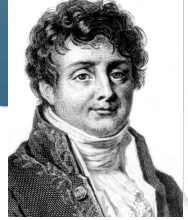
More 1D Fourier Transform Pairs

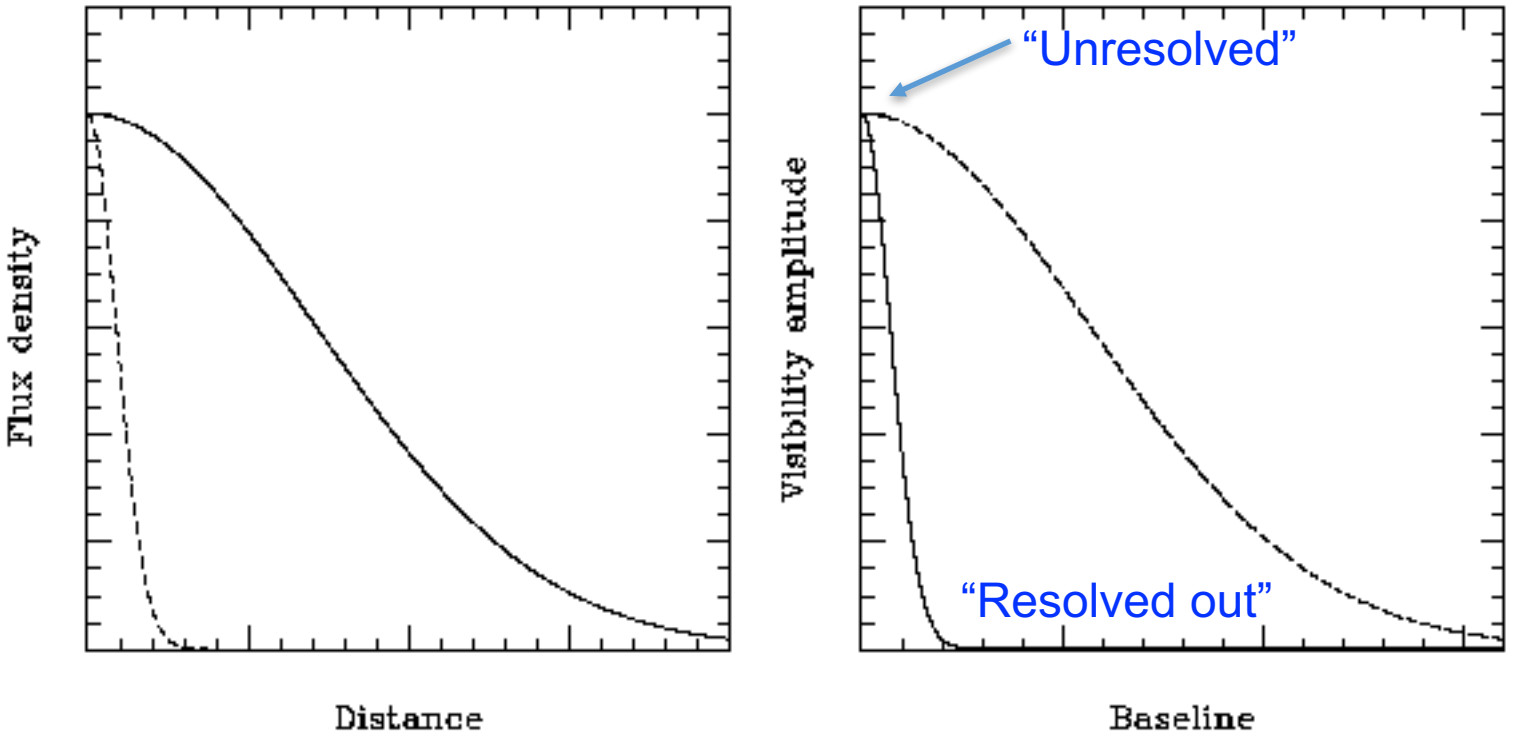


FT

Sharp edges in the image give ripples in the visibilities and vice versa

Gaussian functions





The Fourier transform of a Gaussian function is another Gaussian.

FWHM on sky is inversely proportional to FWHM in spatial frequency: fat objects have thin Fourier transforms and vice versa.

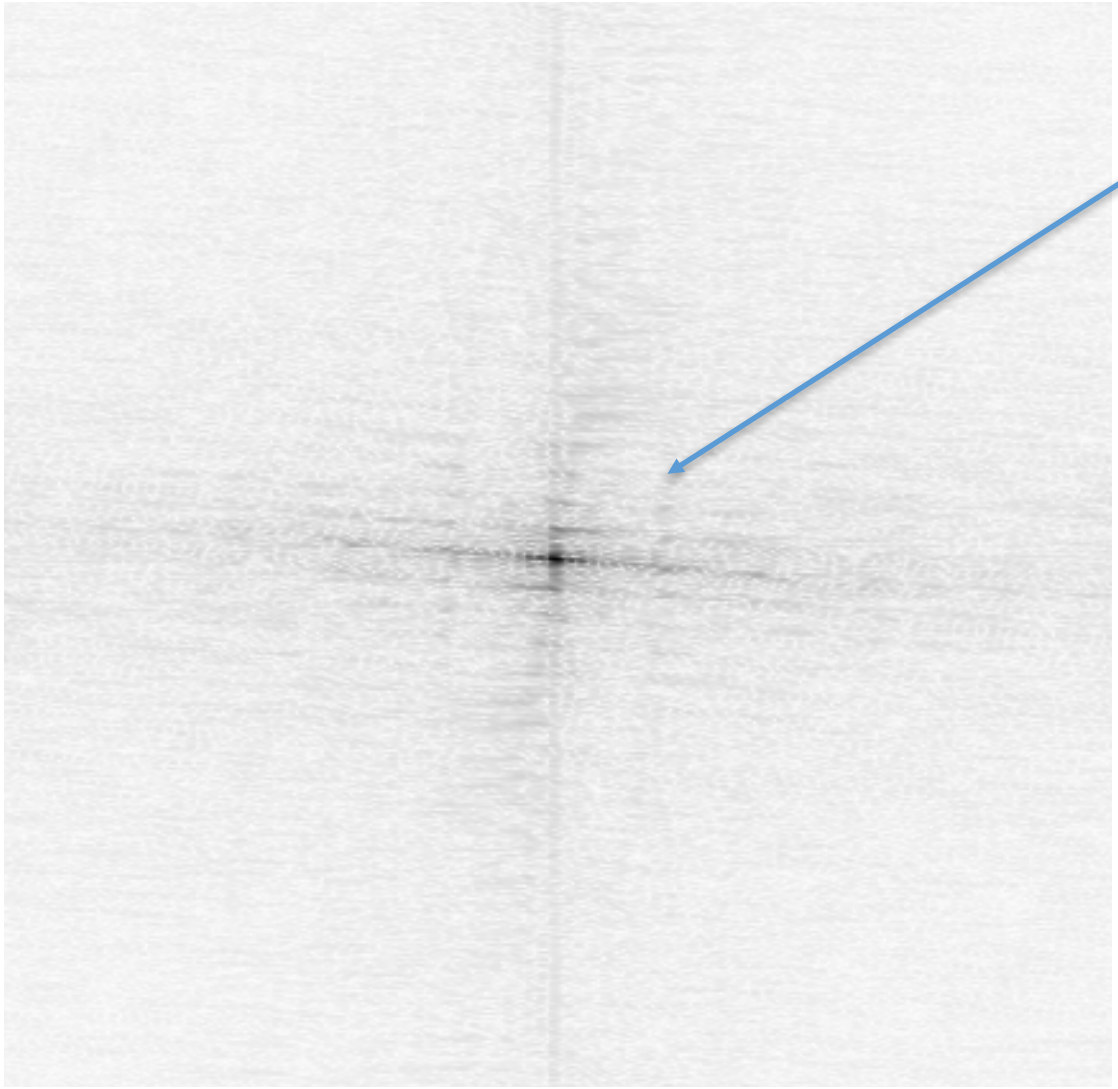
The importance of phase

Chancellor

(Unfortunately ex-)
President

President's amplitudes
Chancellor's phases

Guess the object

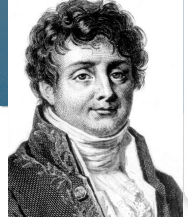


Note the symmetry: if you only know the amplitude, there is always a 180^{o} ambiguity.

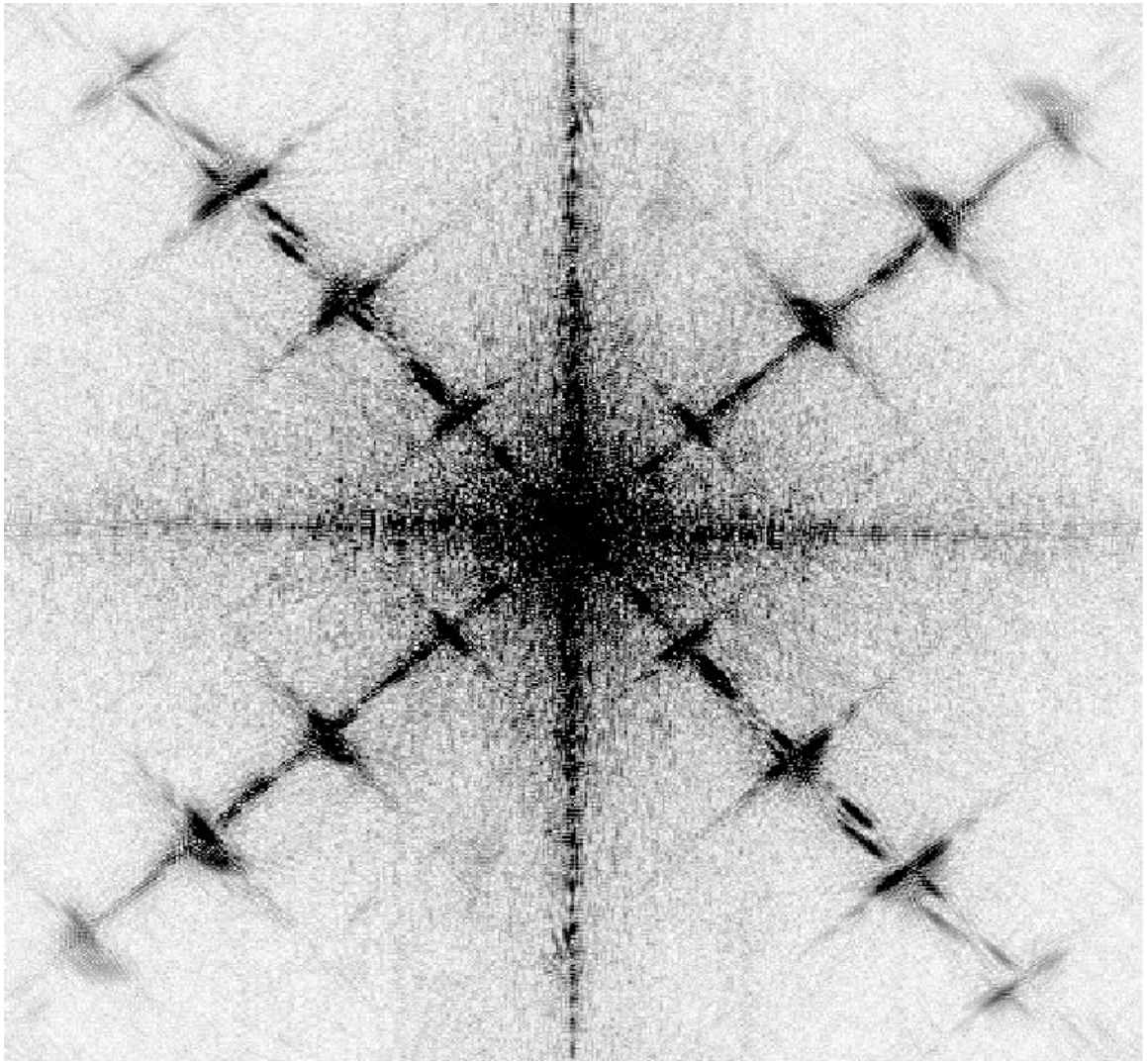
This is the amplitude of the Fourier transform of a picture of a well-known object.

Can you say something about its fine-scale structure as well as size, shape and orientation?

The Answer



Closer to home

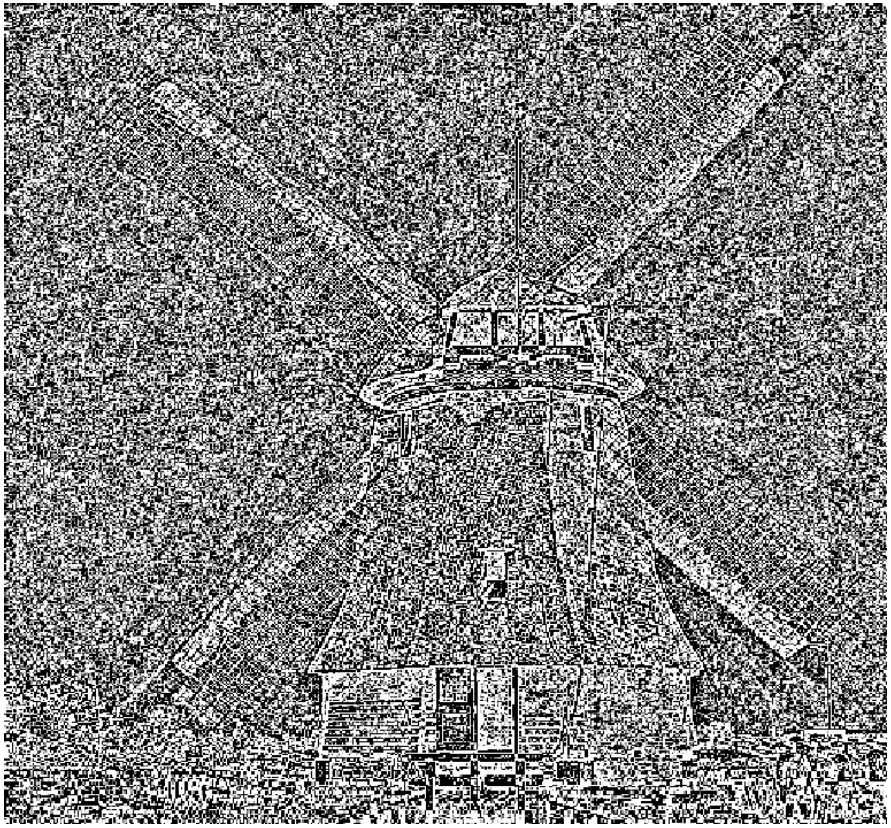


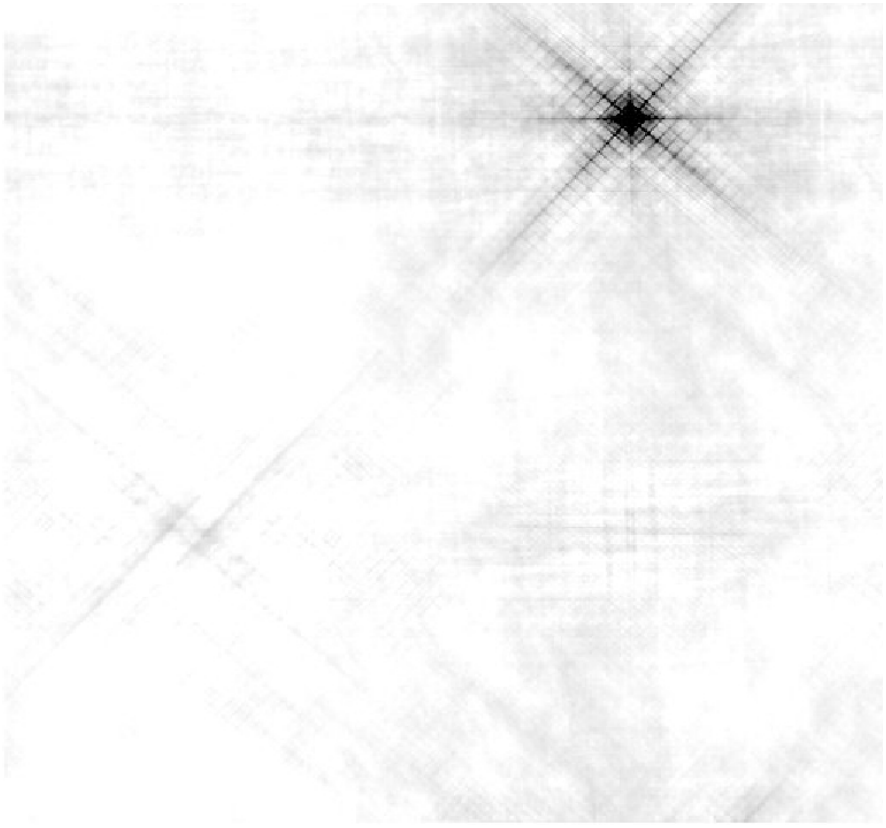
Somewhat more complicated case.

Can you say something about its fine-scale structure as well as size, shape and orientation?

The answer

Phase and amplitude again

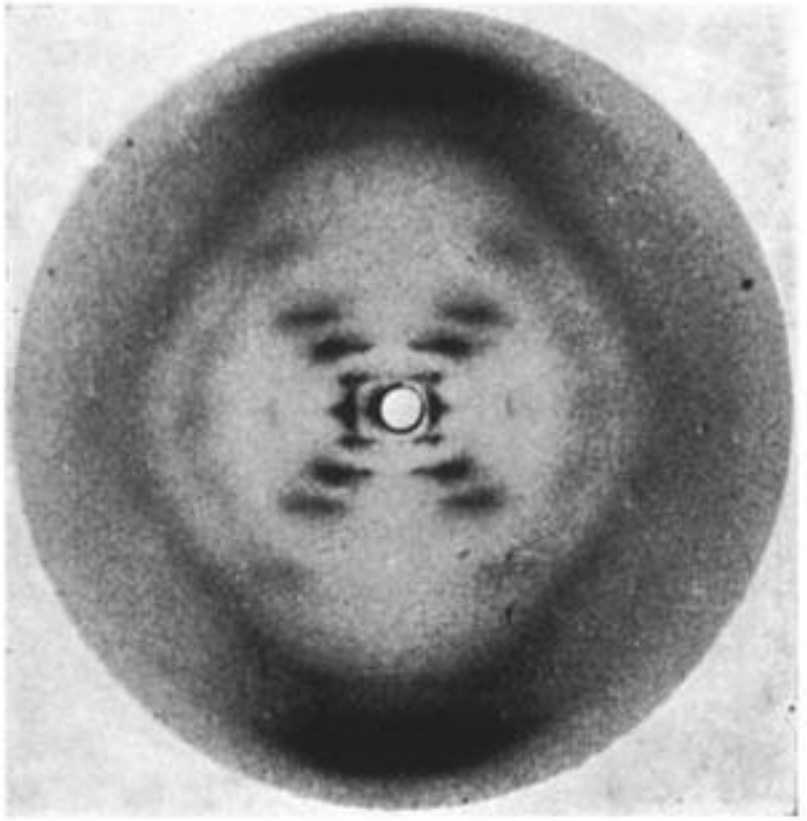




Unit amplitude + correct phase

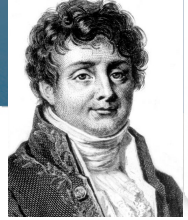
Zero phase + correct amplitude

And finally



Helical structure of DNA

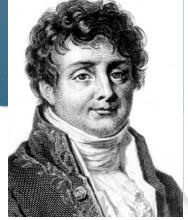
pynterferometer

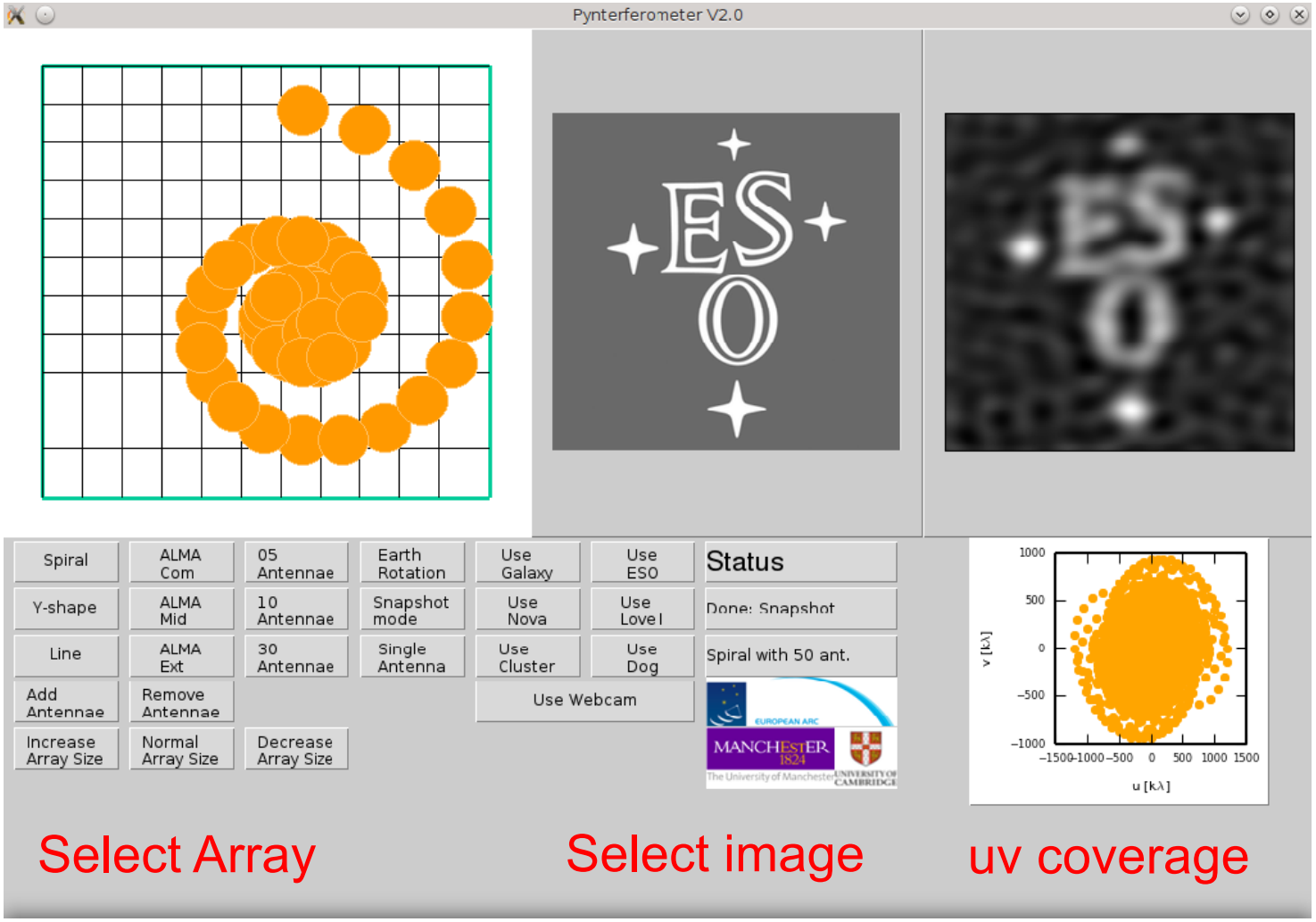


- This program (written by Adam Avison and Sam George) shows you the results of “observing” an object with a variety of array configurations.
- There is no set script to follow: experiment with different configurations to get an intuitive feel for how well they can reproduce the image.
- To start, cd to the directory where you have installed the package and type

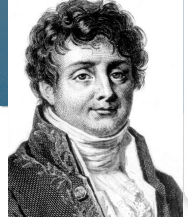
python Pyntv2ERIS.py

(You may need to activate a virtual environment first)



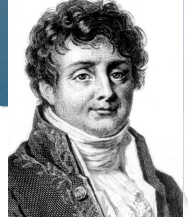

Pynterferometer V2.0
Spiral
ALMA Com
05 Antennae
Earth Rotation
Use Galaxy
Use ESO
Status
Y-shape
ALMA Mid
10 Antennae
Snapshot mode
Use Nova
Use Lovel
Done: Snapshot
Line
ALMA Ext
30 Antennae
Single Antenna
Use Cluster
Use Dog
Spiral with 50 ant.
Add Antennae
Remove Antennae
Use Webcam
Increase Array Size
Normal Array Size
Decrease Array Size
Select Array
Select image
uv coverage

Things to try



- Select your favourite object – doesn't really matter which
- Start with the 5 antenna linear array
  - Remove all but 2 antennas (single baseline)
  - Change the spacing (increase/decrease array size)
- Add antennas
- Turn on Earth rotation
- Look at other configurations
  - Y for VLA
  - ALMA
- What happens when you make the array too large or too small?

Other Teaching Packages



- APSYNSIM
  - https://launchpad.net/apsynsim
  - Ivan Marti-Vidal (one of our lecturers)
- FriendlyVRI
  - https://crpurcell.github.io/friendlyVRI/

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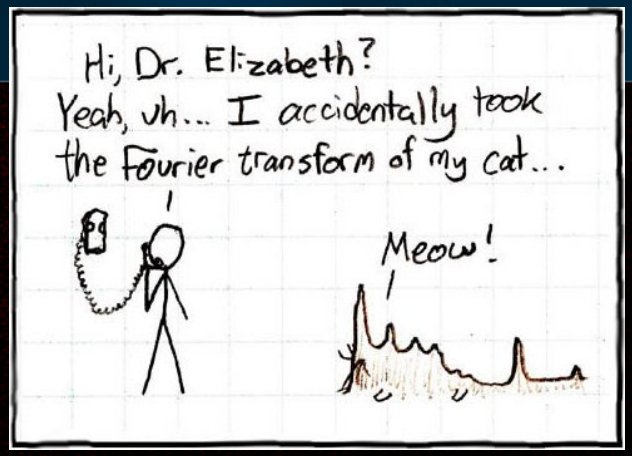

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