Tutorial 1: Fun with Fourier Transforms

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Fourier Transforms for Birdwatchers

Some useful properties of Fourier transforms in 1D

$$F(\nu) = \int_{-\infty}^{\infty} f(t)\exp(-2\pi i\nu)dt$$

$$f(t) = \int_{-\infty}^{\infty} F(s)\exp(2\pi i\nu)d\nu$$

Inversion

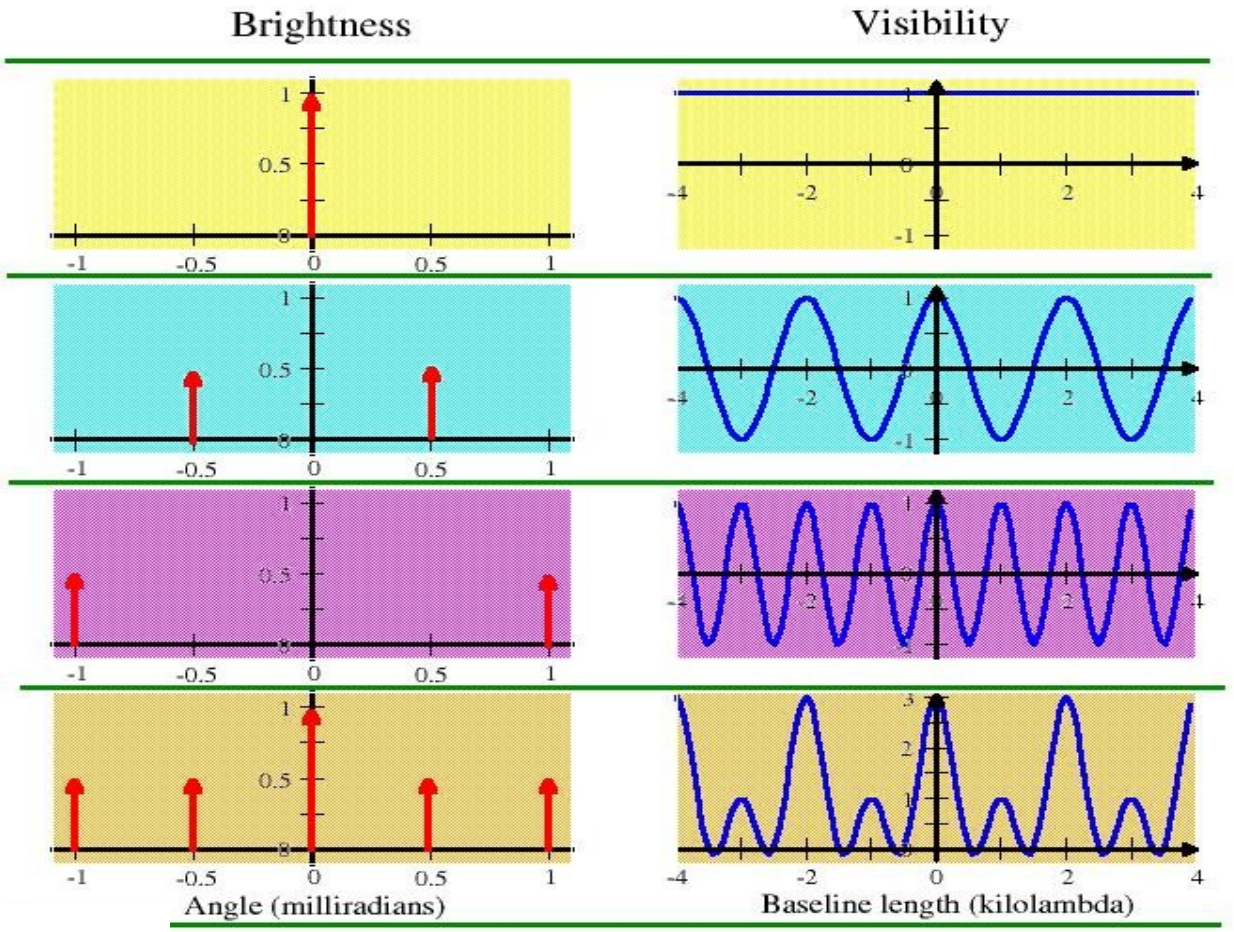
$$h(t) = \int_{-\infty}^{\infty} f(t')g(t-t')dt'$$

$$H(\nu) = F(\nu)G(\nu)$$

Convolution

Simple 1D Fourier Transform Pairs

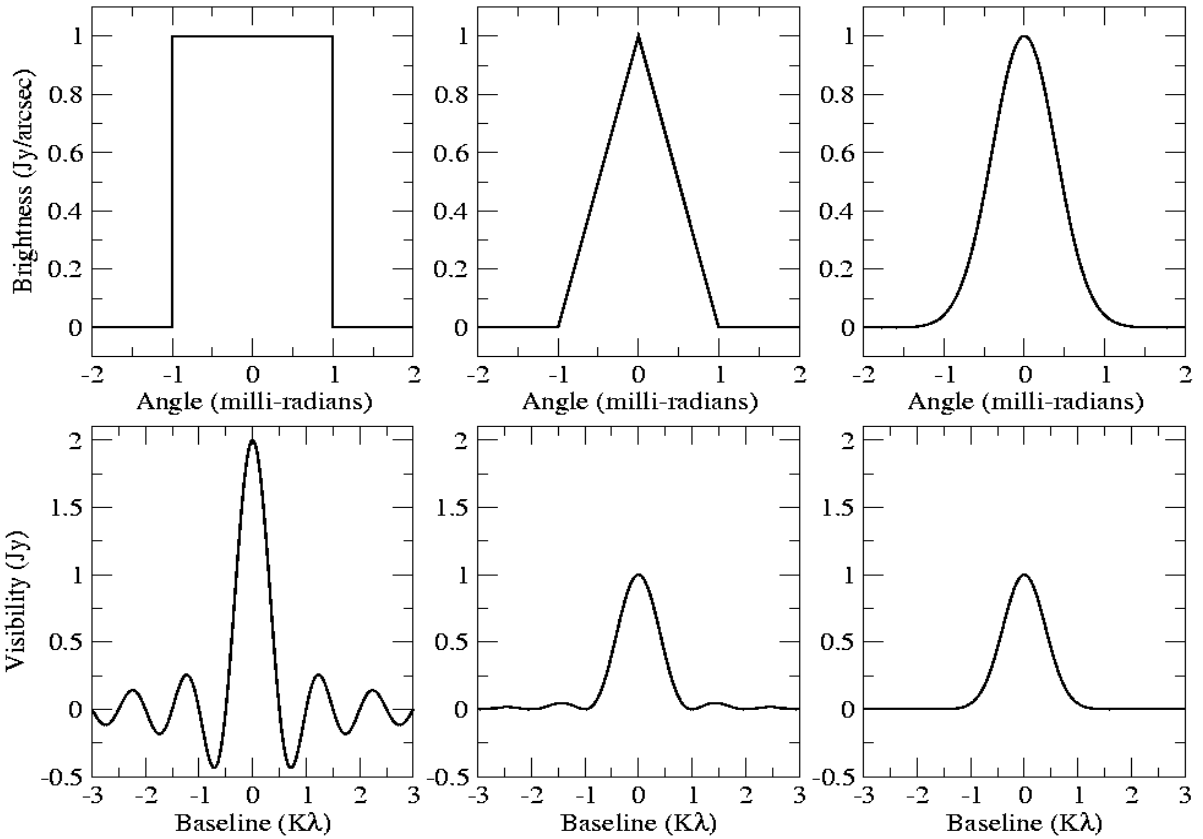
1D Fourier transform pairs



$$F(\nu) = \int_{-\infty}^{\infty} f(t)\exp(-2\pi i\nu)dt$$

$$f(t) = \int_{-\infty}^{\infty} F(s)\exp(2\pi i\nu)d\nu$$

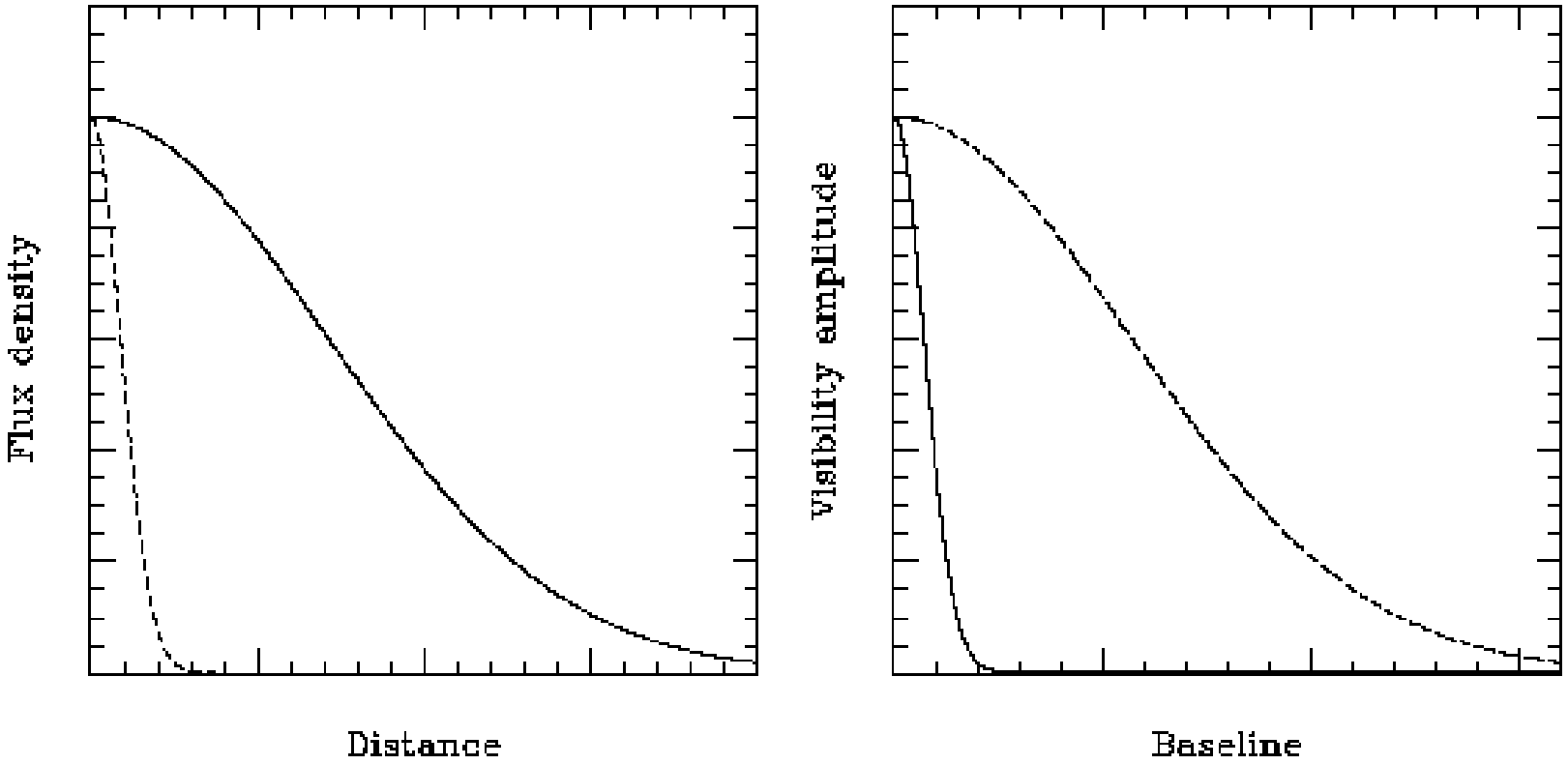
More 1D Fourier Transform Pairs



FT

Note: sharp edges in the image give ripples in the visibilities

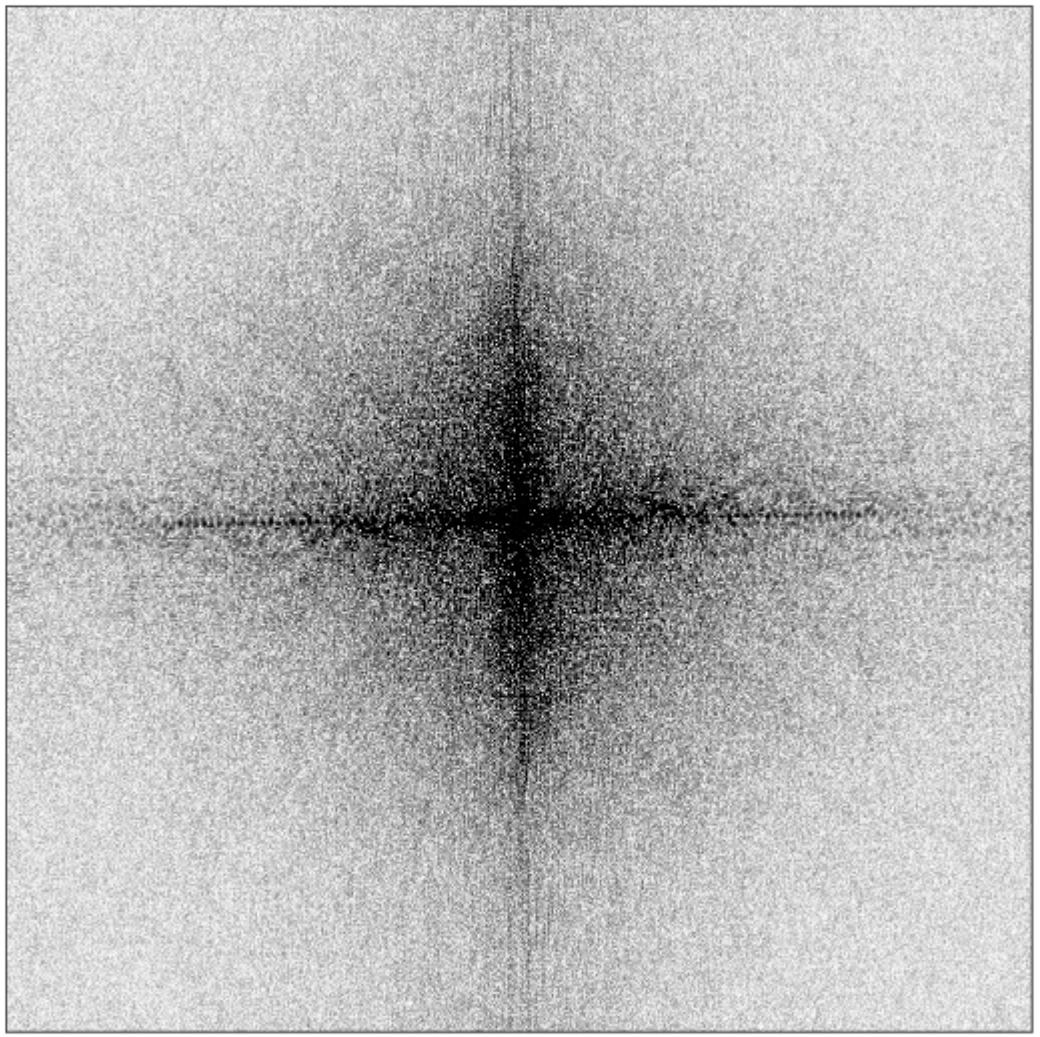
Fourier Transforms (2)



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.

What is this?

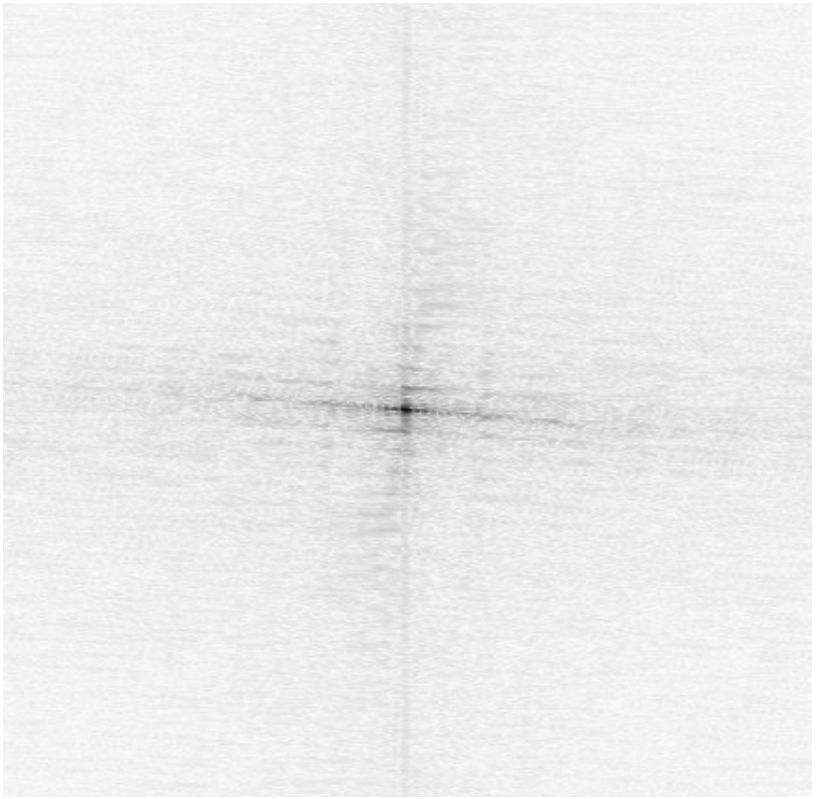


This is the amplitude of the Fourier transform of an image of a well-known local object.

Can you say something about its size, shape and orientation?

The Answer

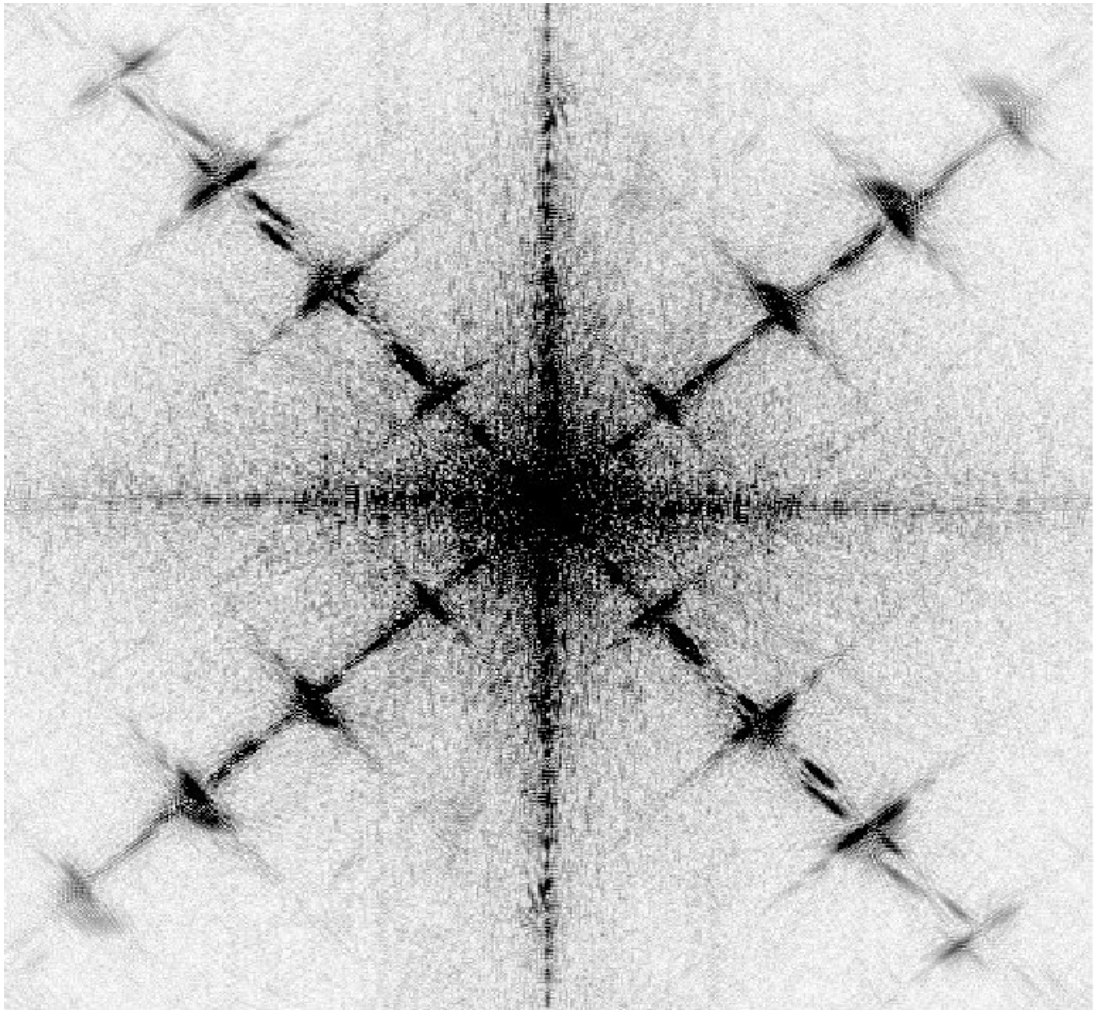
Another example



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

The Answer

Another example

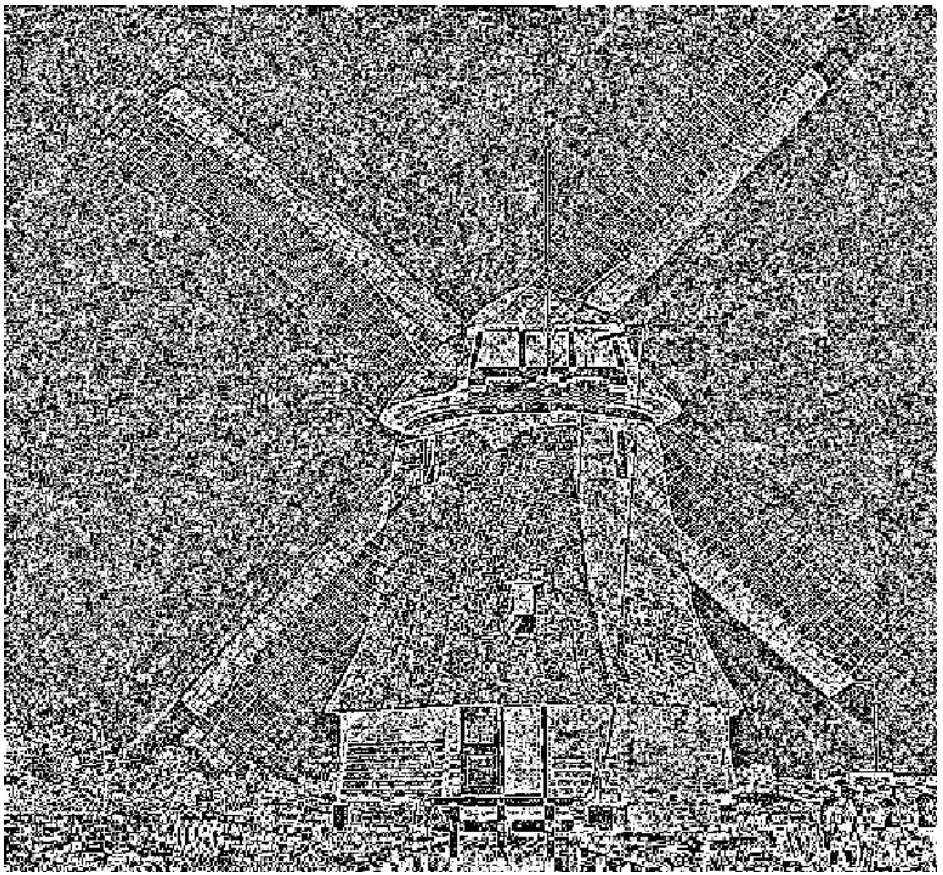


Somewhat more complicated case.

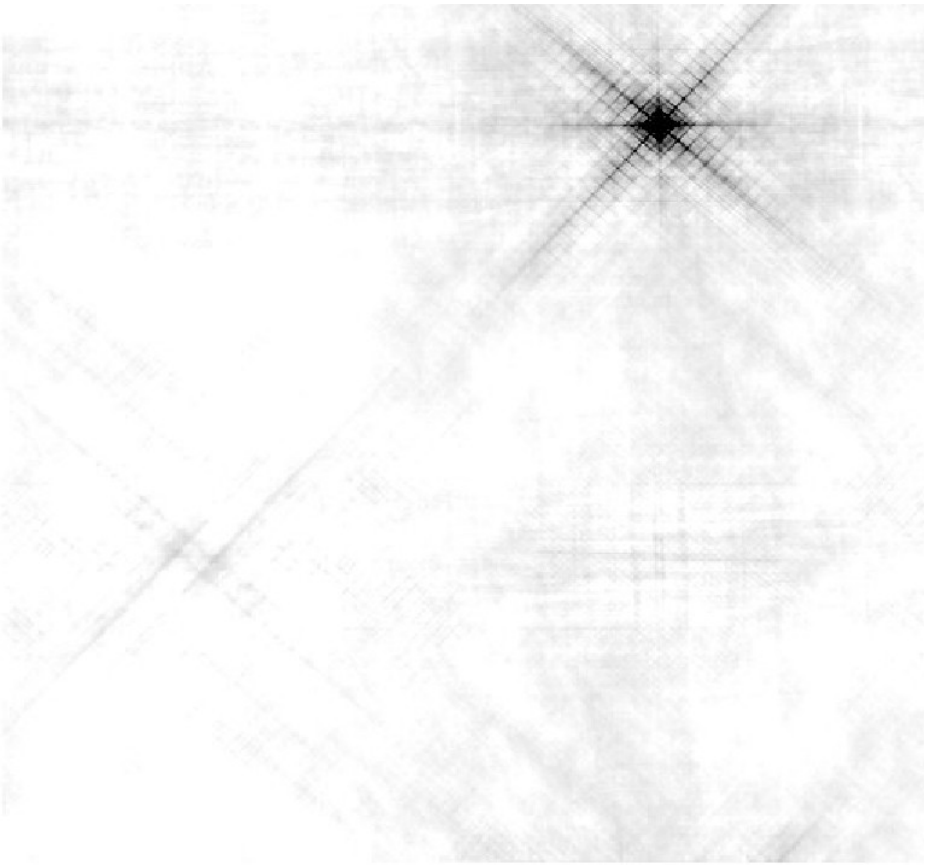
Can you say something about its fine-scale structure as well as size, shape and orientation?

The Answer

Phase and Amplitude



Unit amplitude + correct phase



Zero phase + correct amplitude

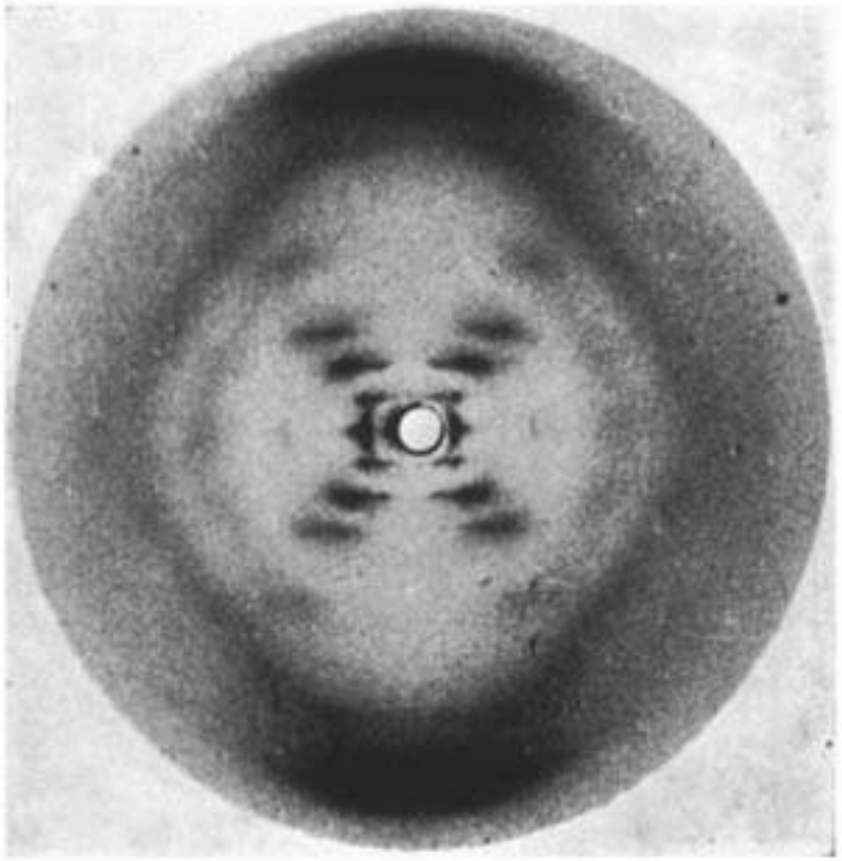
Swapping amplitudes and phases

Chancellor

President

President's amplitudes
Chancellor's phases

And finally ...



The answer

pynterferometer

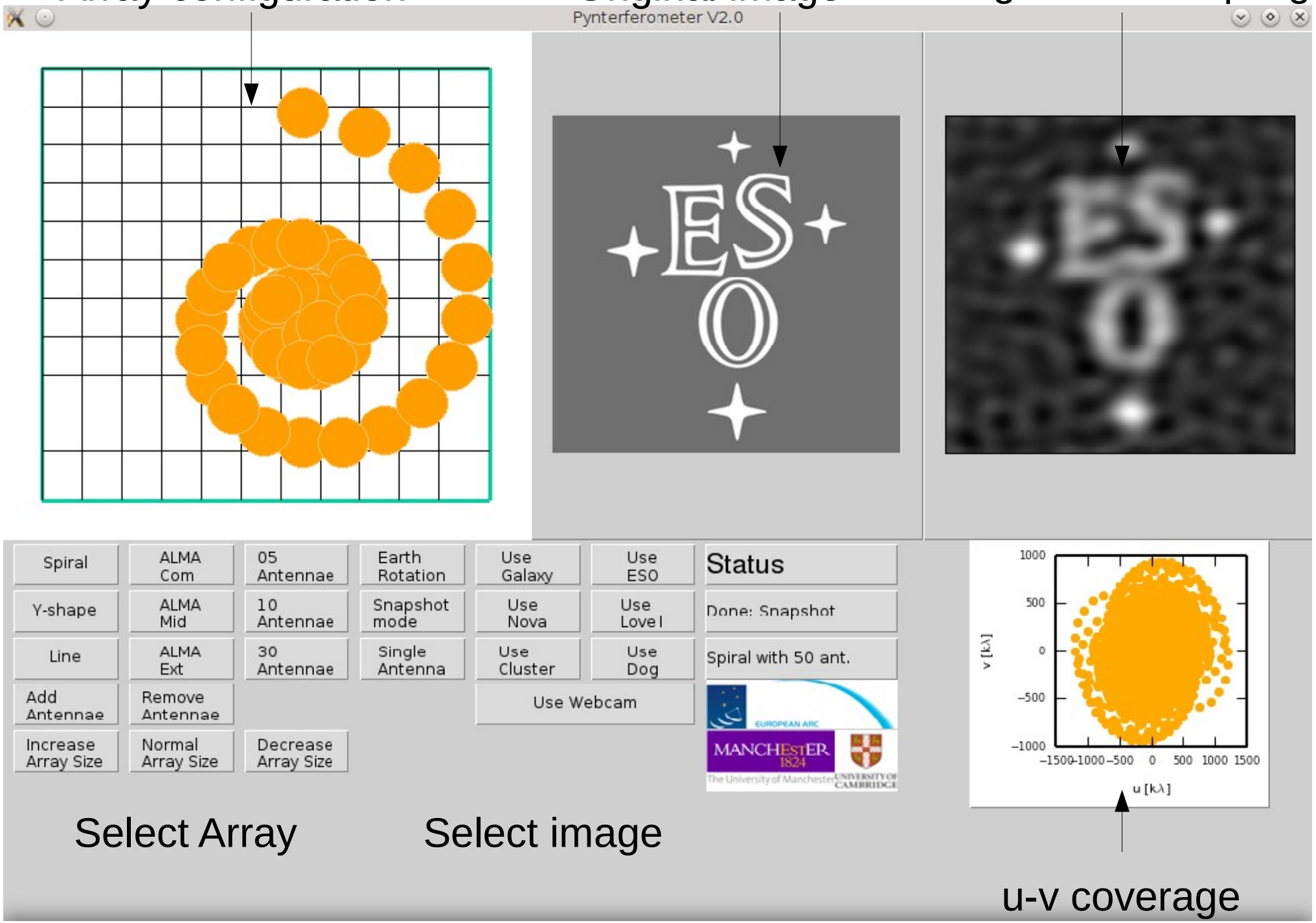
- This program (written by Adam Avison and Sam George) shows you the results of “observing” an object with a variety of array configurations.
- There is no set script to follow: experiment with different configurations to get an intuitive feel for how well they can reproduce the image.
- To start, cd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

python Pyntv2ERIS.py

Array configuration

Original image

Image after sampling



Select Array

Select image

u-v 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?