

An aerial photograph of the SKA (Square Kilometer Array) radio telescope array. The image shows a vast, flat, arid landscape with numerous circular concrete pads arranged in a grid pattern, extending towards the horizon. In the foreground, a single large pad is shown in more detail, with a small white car parked next to it for scale. The sky is clear and blue, and distant mountains are visible on the horizon.

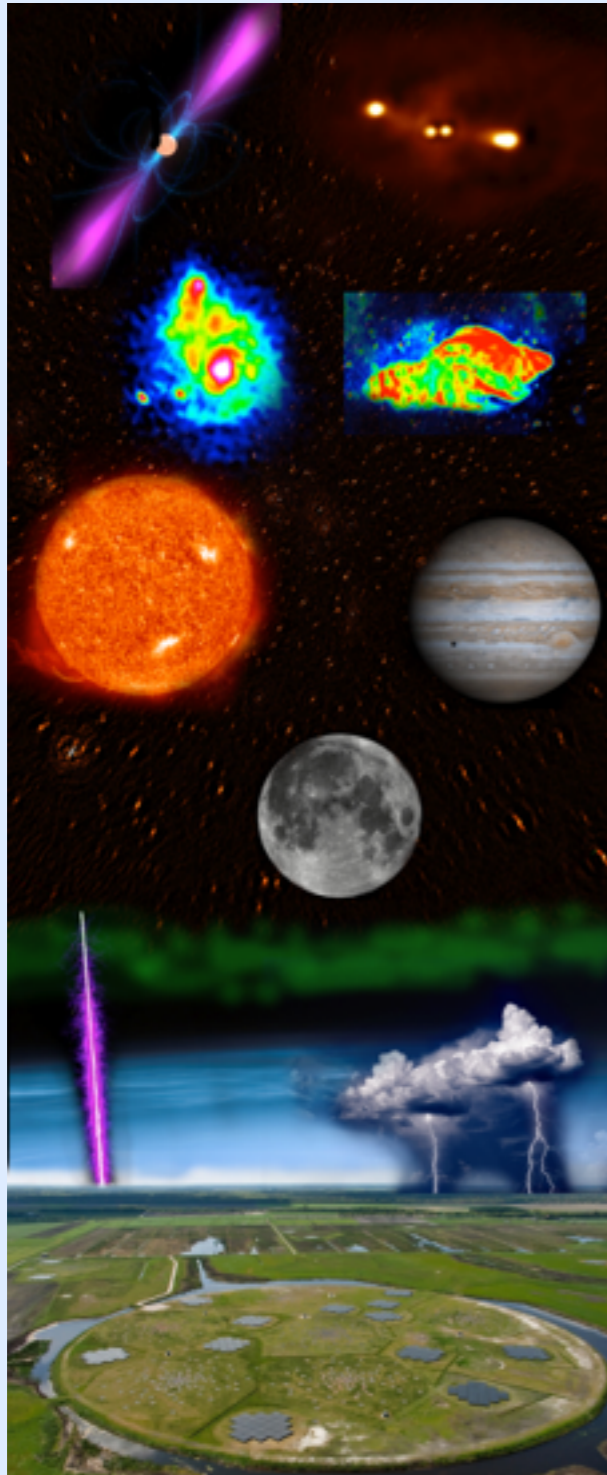
LOFAR, SKA

ASTRON contribution to Obelics

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Obelics F2F, Rome, 26 January 2016

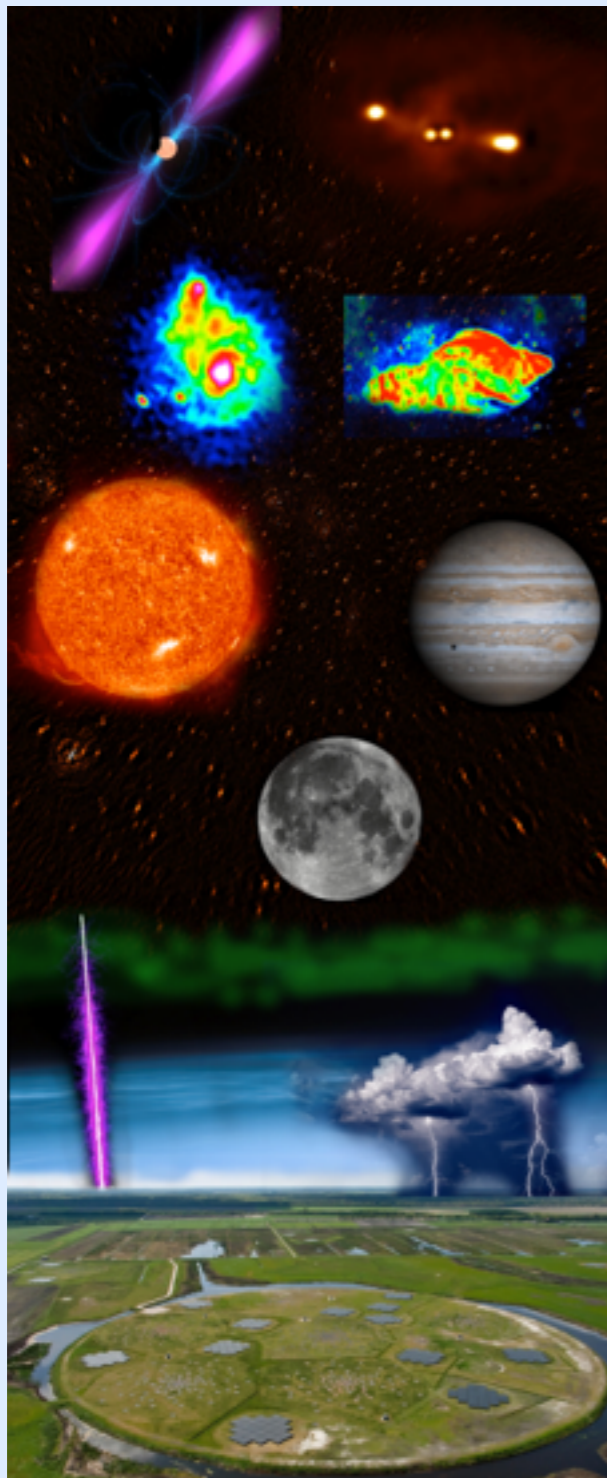
LOFAR introduction



Many types of science

- Epoch of Reionization
- Galaxies, AGNs
- Low frequency sky survey
- Pulsars
- Transients
- Interstellar medium
- The Sun, moon, planets
- Cosmic rays
- Ionosphere
- Lightning
- Earthquakes
- Etc.

LOFAR introduction



Key scientific figures:

- 5th observing cycle
- 5.000 hours observed
- ~ 100 refereed papers (several Science / Nature)
- PI's from >10 countries
- Oversubscription:
 - 2.0 (observe)
 - 1.5 (compute)

Why large radio telescopes

Diameter of telescope should be at least 10× the wavelength of the signal. At 30MHz, wavelength is $c / 30\text{MHz} = 10$ meter.

For sharp pictures, we want a high angular resolution

$$\text{pixel size} \sim \frac{\lambda}{D}$$

λ : wavelength of observed sky

D : diameter of telescope

So to have nicer pictures, we need larger telescopes!

Pictures of large telescopes



Effelsberg (1972)
100 meter

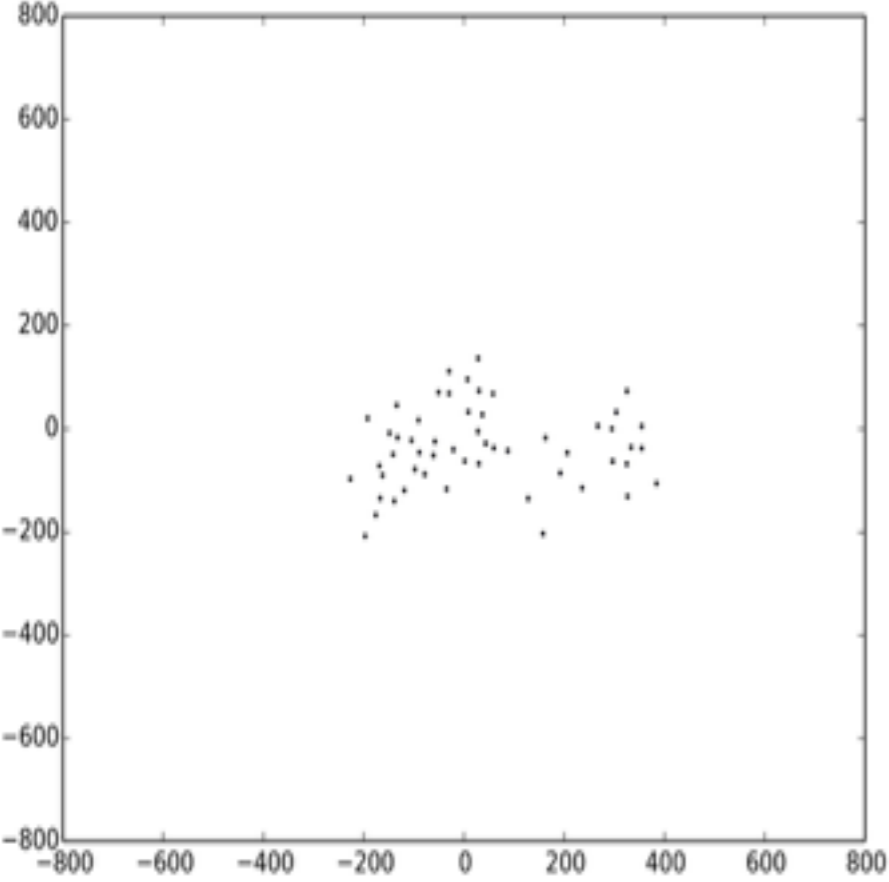


Arecibo (1963)
305 meter

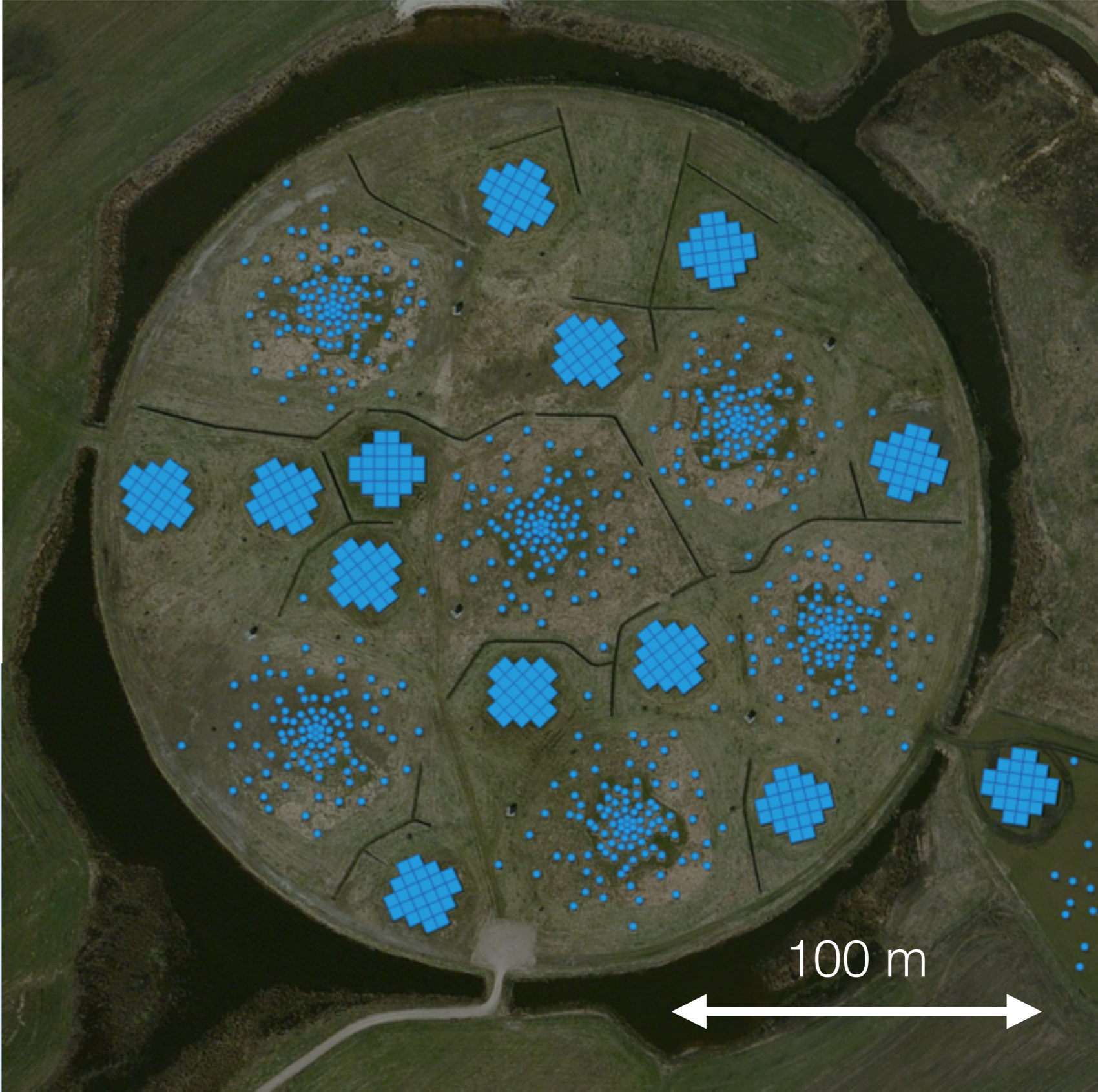


FAST (2016)
500 meter

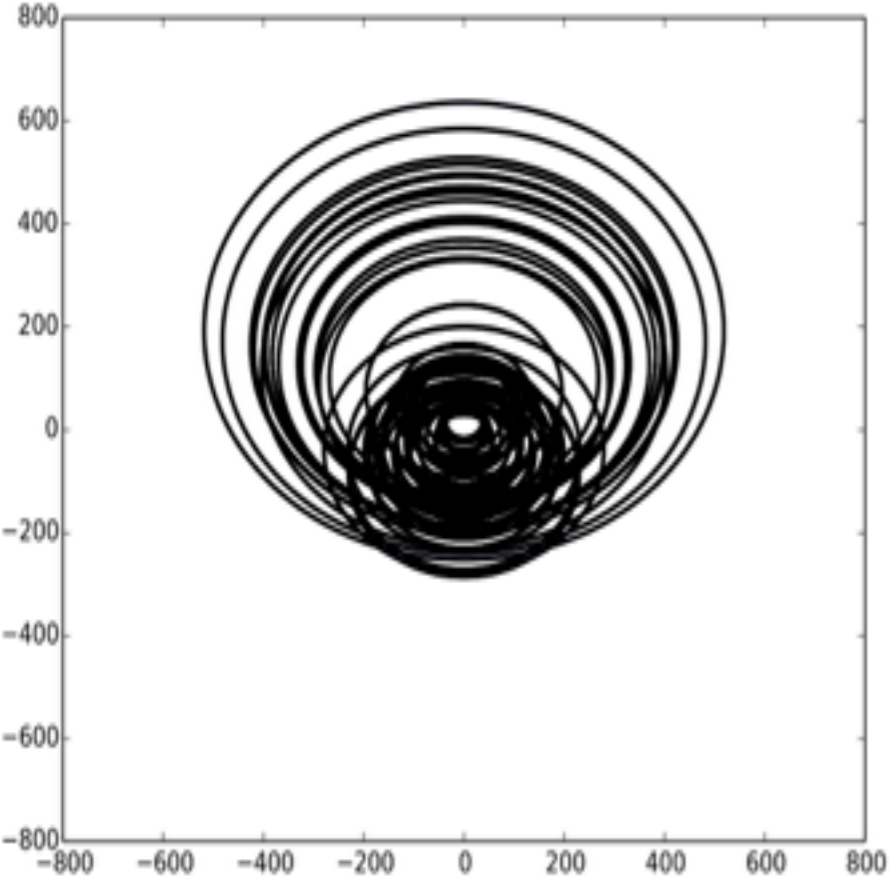
Filling the Fourier plane



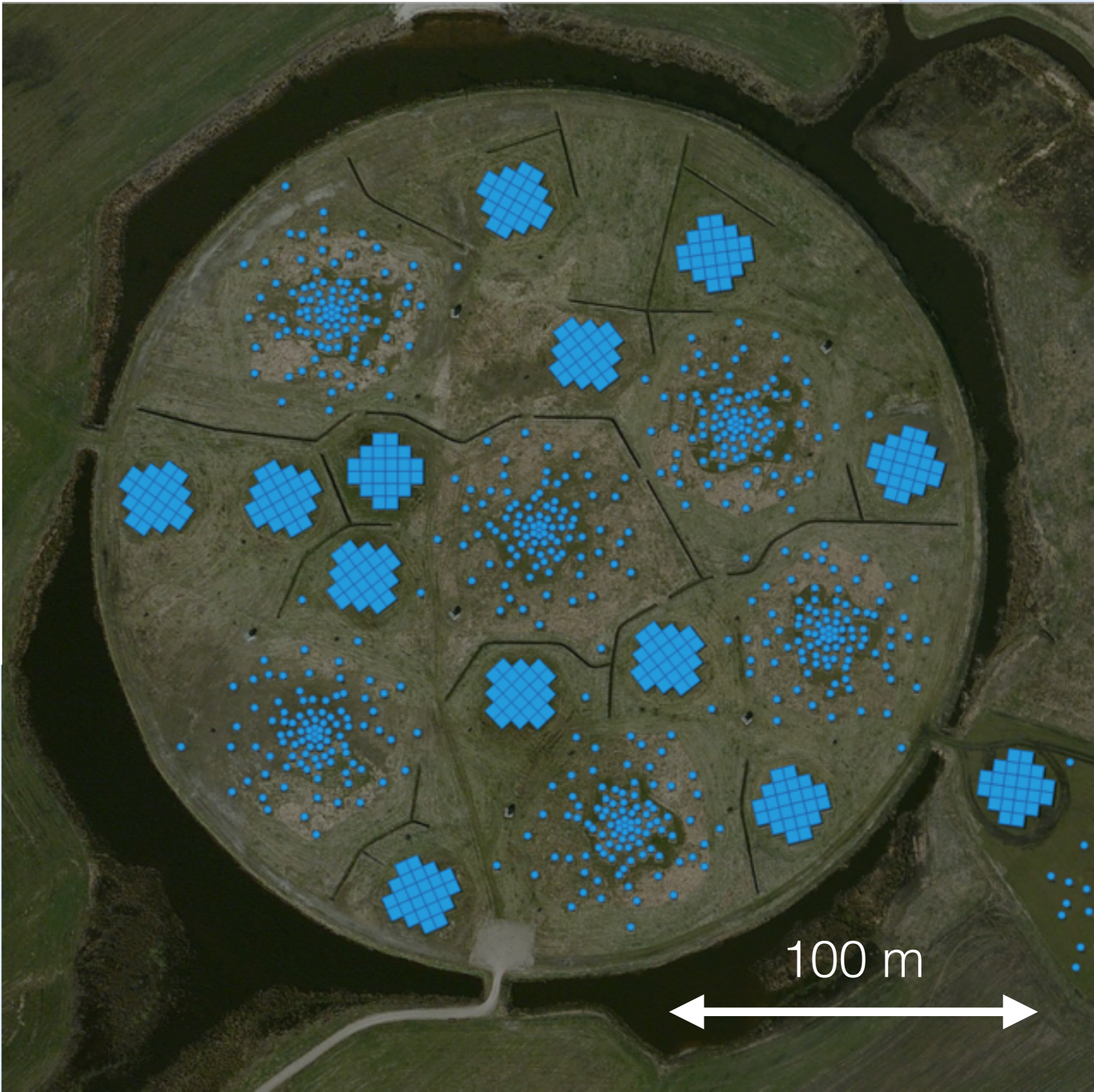
\vec{b} (meter)



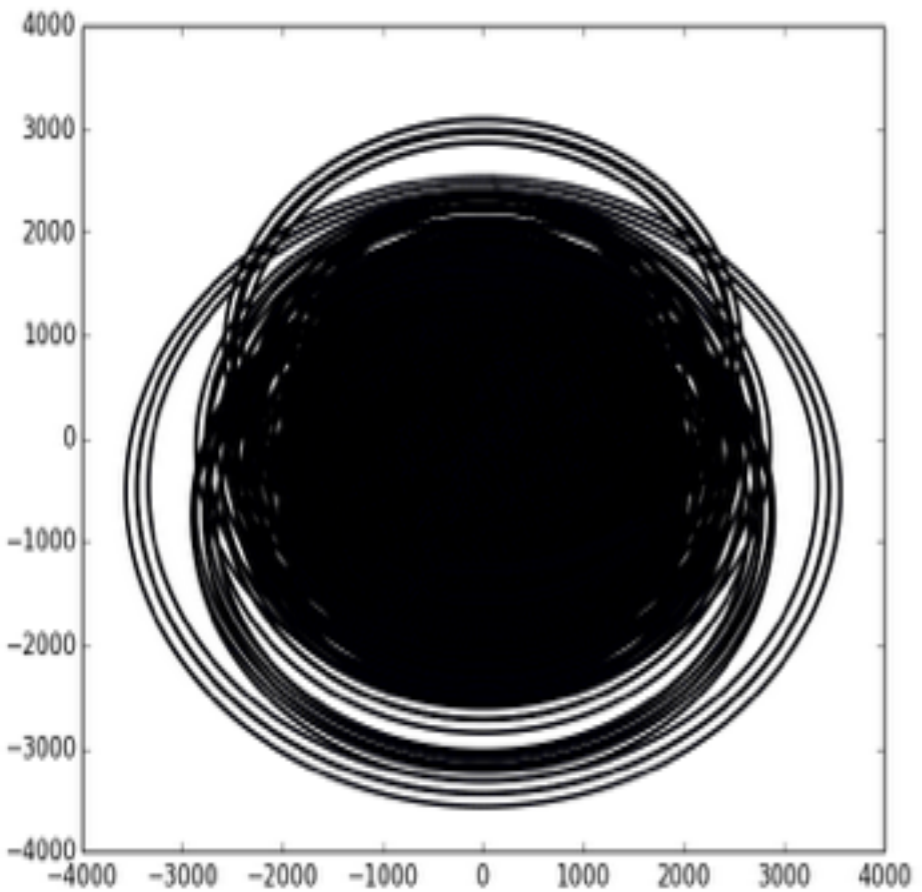
Filling the Fourier plane



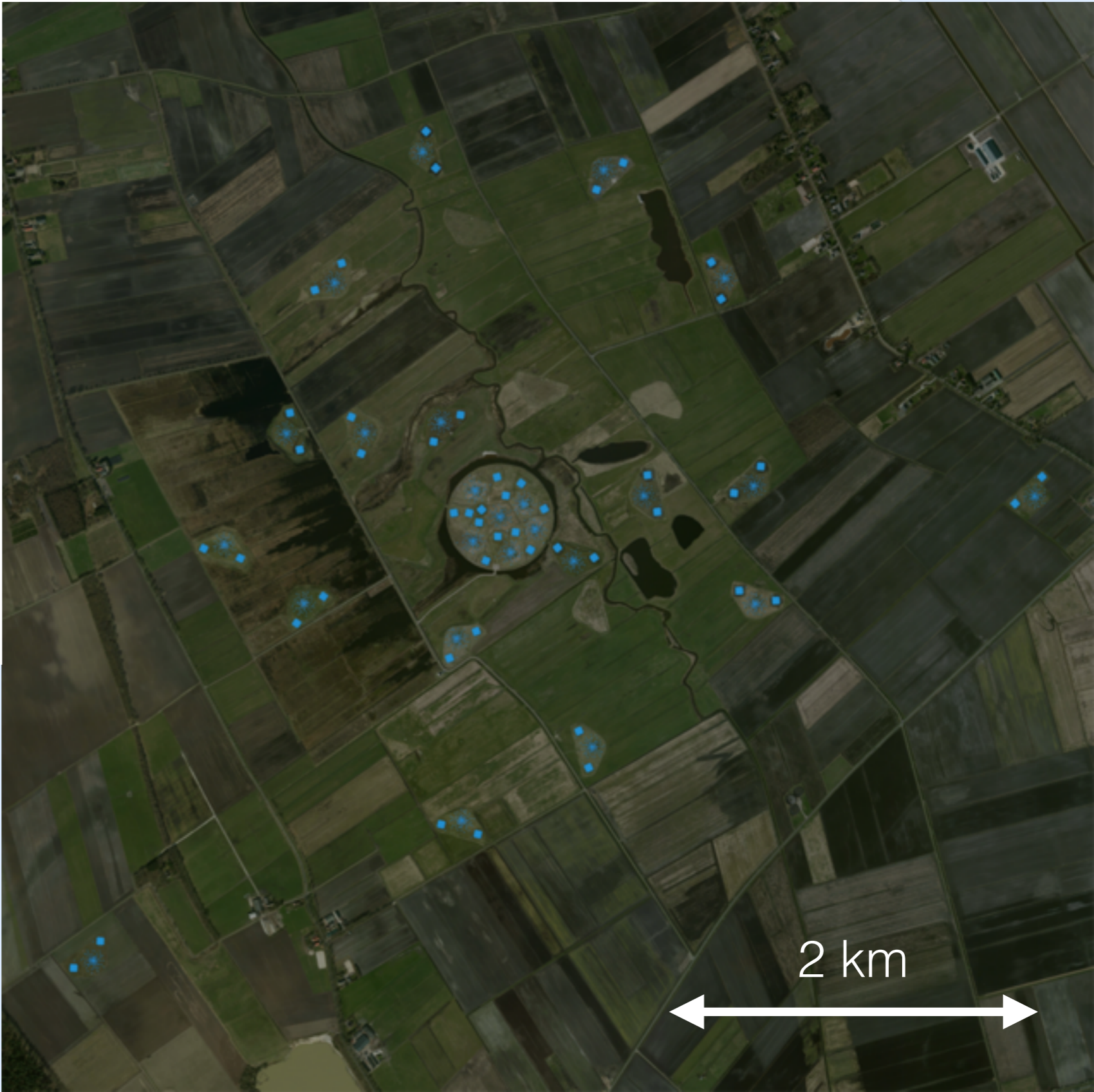
\vec{b} (meter)



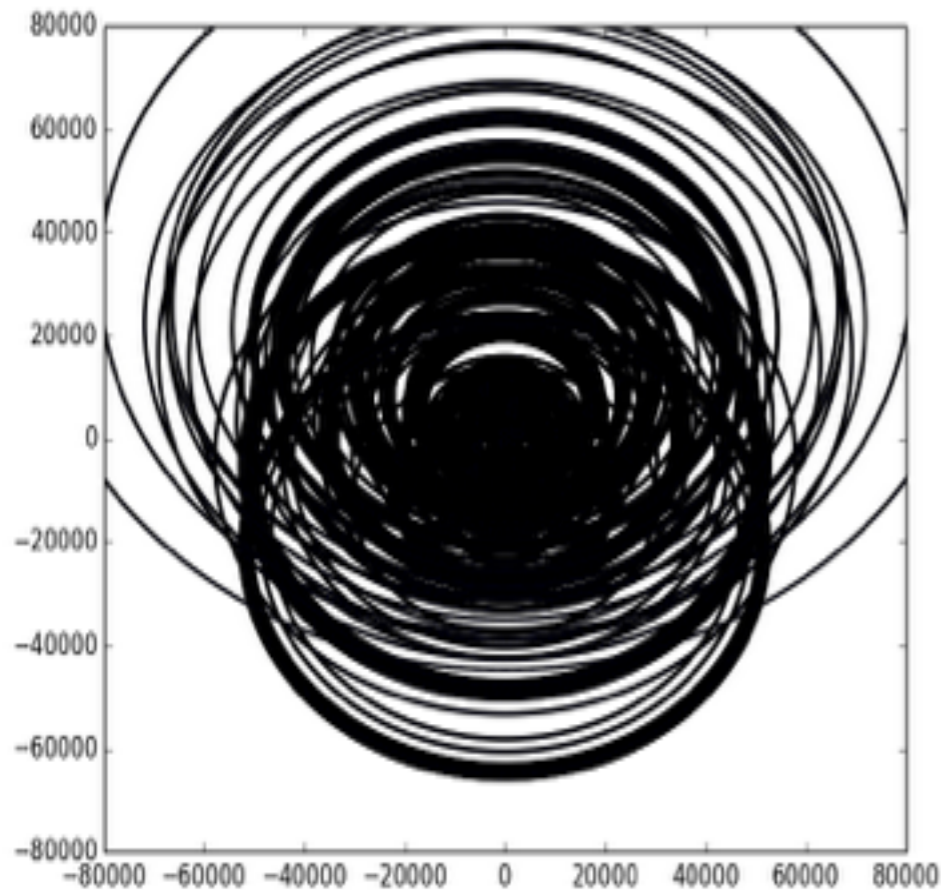
Filling the Fourier plane



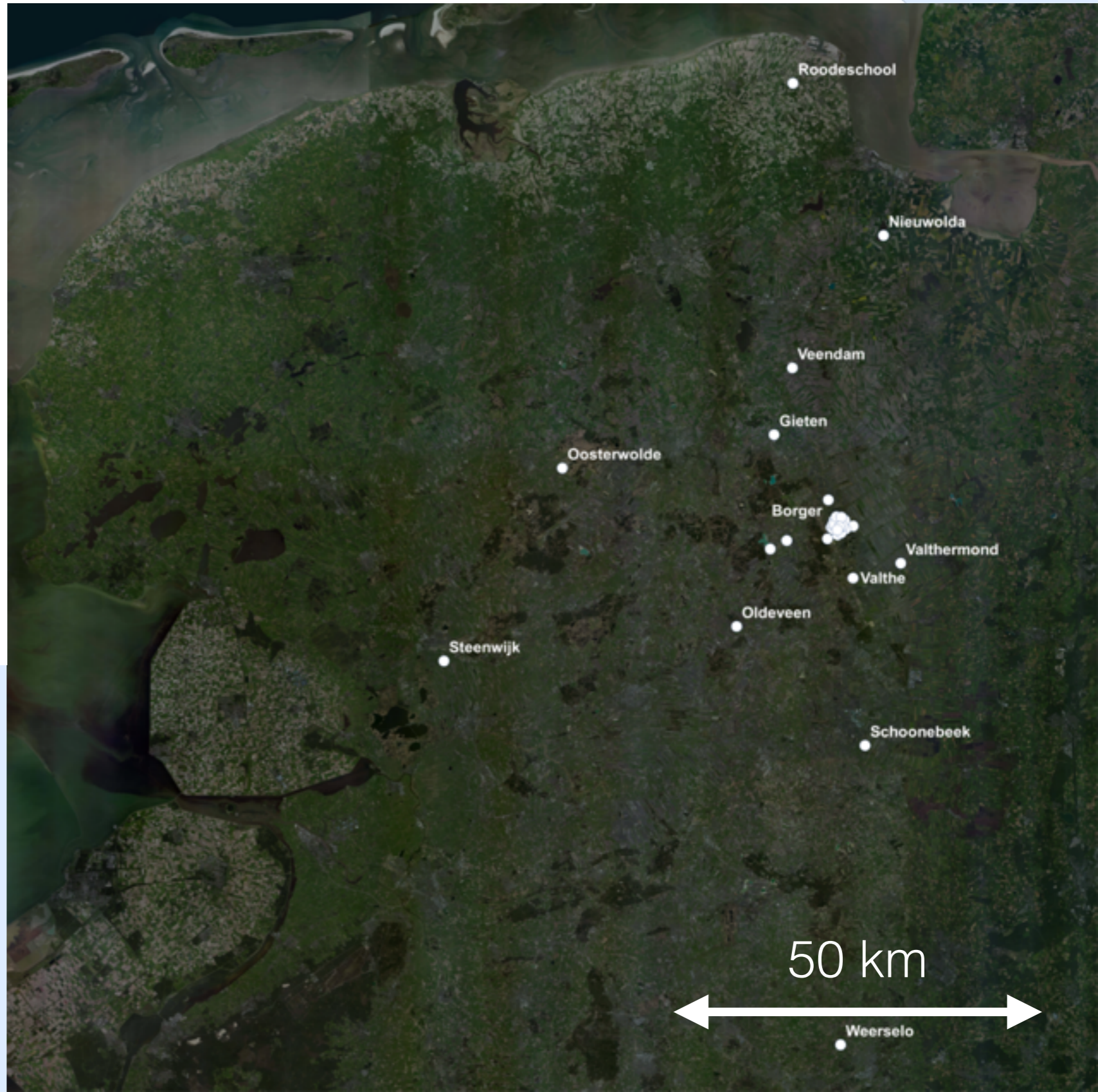
\vec{b} (meter)



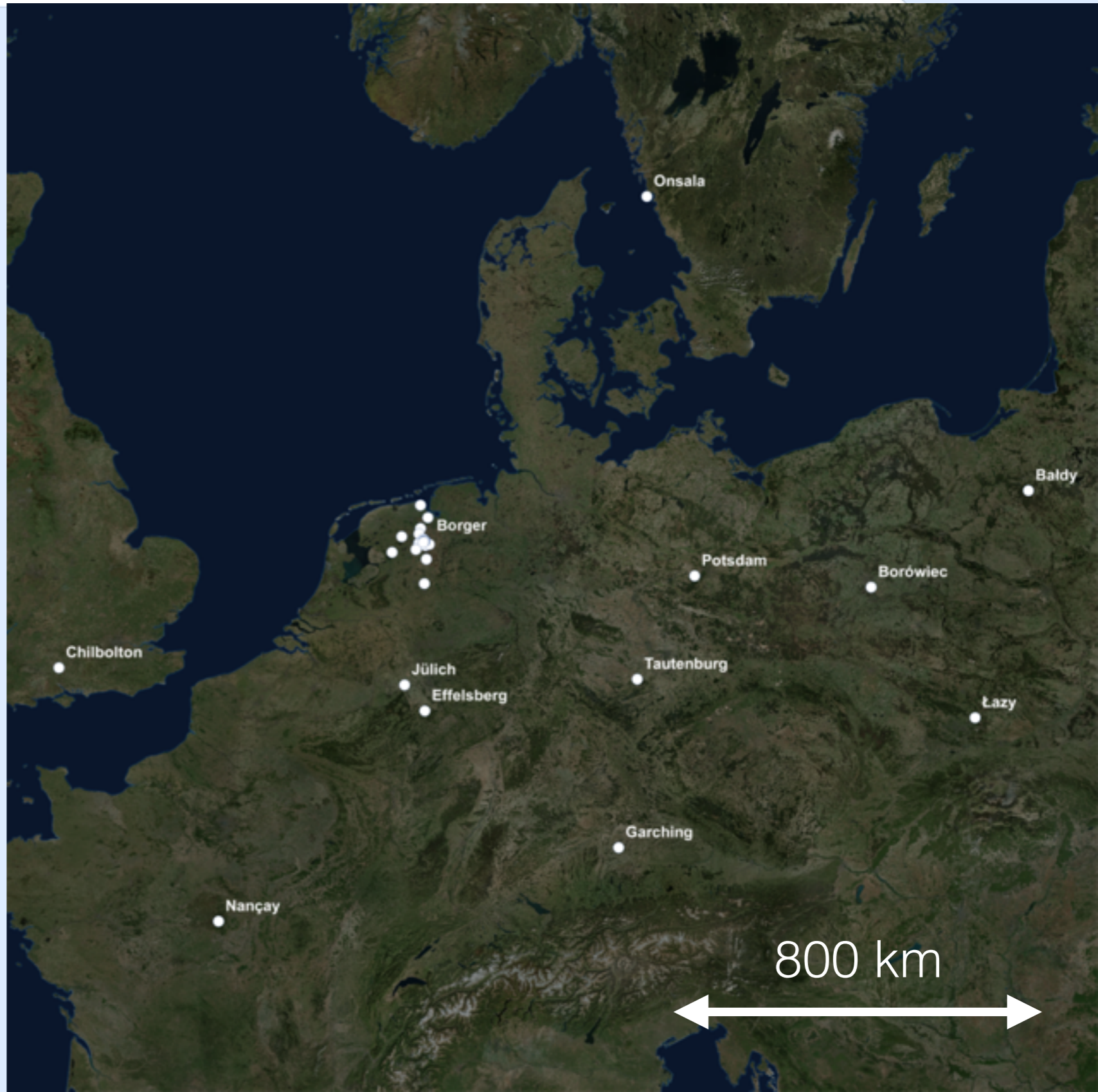
Filling the Fourier plane



\vec{b} (meter)



Filling the Fourier plane



Processing overview

Antennas / Stations

on-site reduction

200 Gbit/s



Realtime System

8 node GPU correlator

80 Gbit/s



Offline Processing

~ 100 node CPU cluster

2 Gbit/s



Long Term Archive

4 grid sites
~20 Petabyte

Offline data reduction challenges

- **Calibrate** the instrument (using model sky)
 - Efficient parameter fitting
 - Algorithms SAGECAL, STEFCAL
 - Program DPPP, streaming framework
- Recover an **image** of the sky:
 - Efficient gridding of UV data on GPUs
 - Fourier Transform
 - Deconvolution algorithm CLEAN
 - Program AWIMAGER, using CASA

SKA1 MID - the SKA's mid-frequency instrument

The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and SKA1 LOW - observing the Universe at different frequencies.



Location: South Africa

Frequency range: **350 MHz** to **14 GHz**

~200 dishes
(including 64 MeerKAT dishes)

Total collecting area: **33,000m²**

or **126 tennis courts**

Maximum distance between dishes: **150km**

Total raw data output:

2 terabytes per second

62 exabytes per year

Enough to fill **340,000** average laptops with content **every day**

x340,000

Compared to the JVLA, the current best similar instrument in the world:

4x the resolution

5x more sensitive

60x the survey speed

LOFAR

52,000m² collecting area
~ 50,000 antennas
Operational now

SKA1 LOW

419,000m² collecting area
~ 130,000 antennas
Based in Australia

SKA1 MID

33,000m² collecting area
~ 200 dishes
Based in South Africa