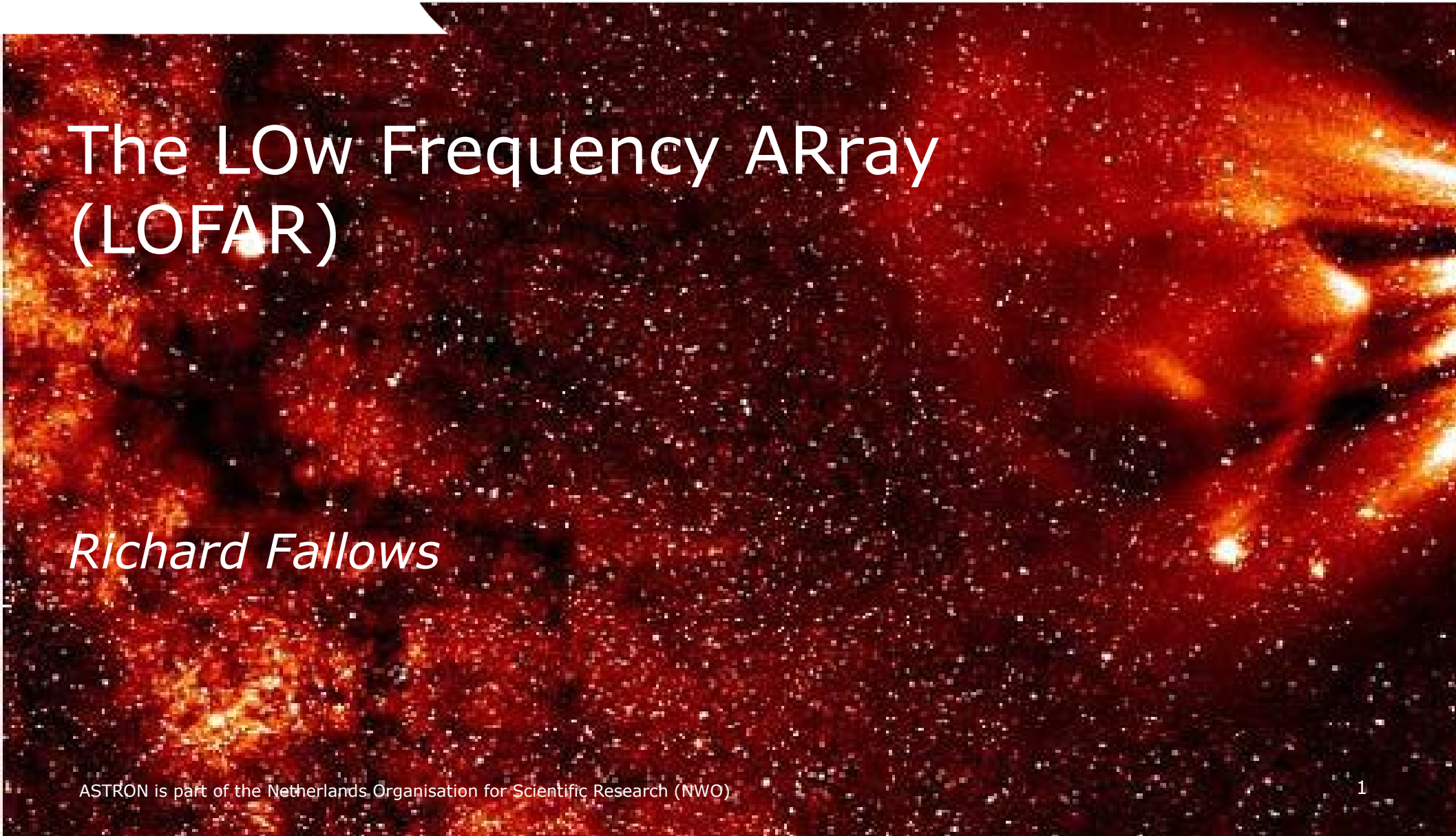
ASTRON

Netherlands Institute for Radio Astronomy

LOFAR

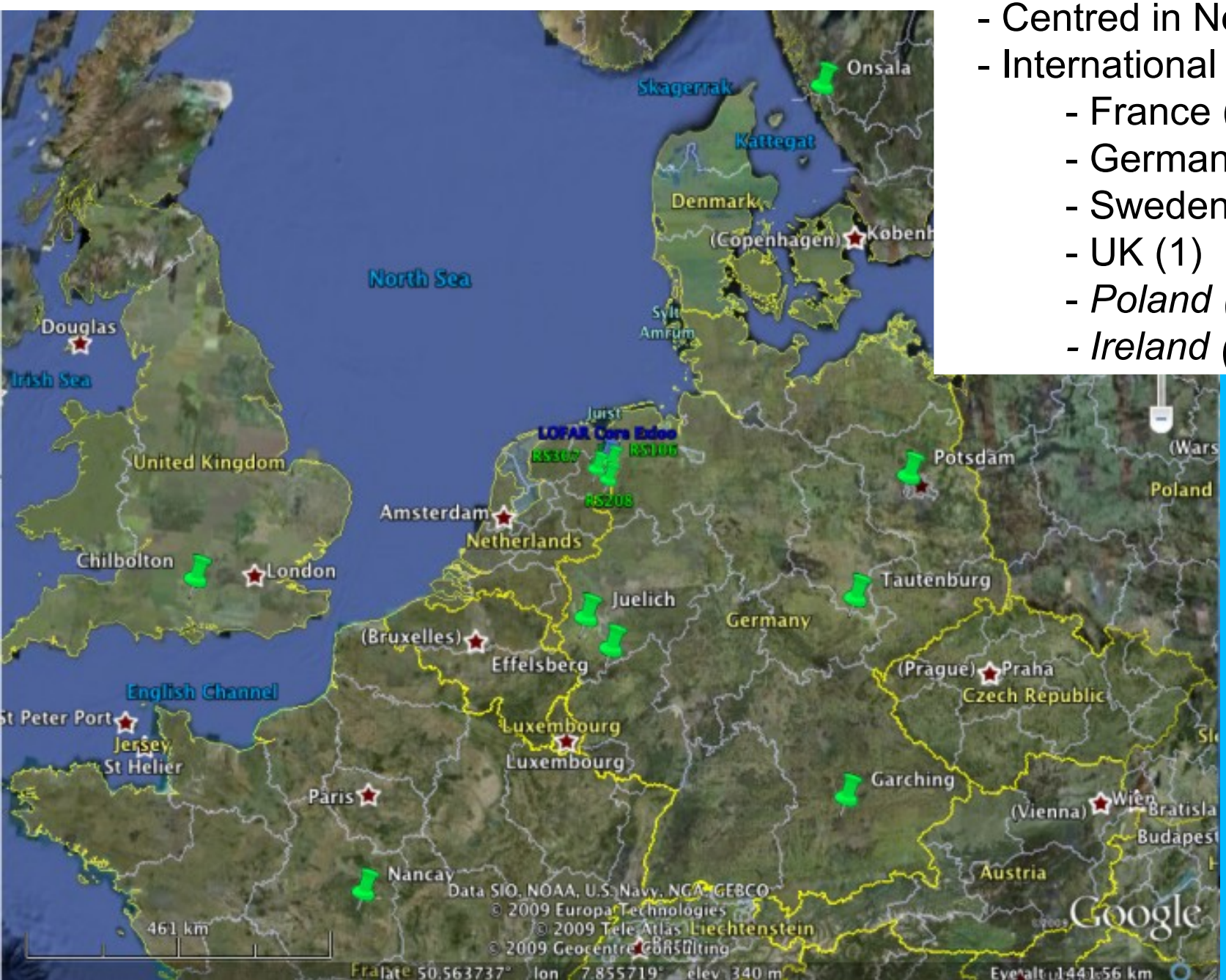
The LOw Frequency ARray (LOFAR)



Richard Fallows

Array Location

- Centred in Netherlands
- International stations:
  - France (1)
  - Germany (5)
  - Sweden (1)
  - UK (1)
  - *Poland (3)*
  - *Ireland (1)*

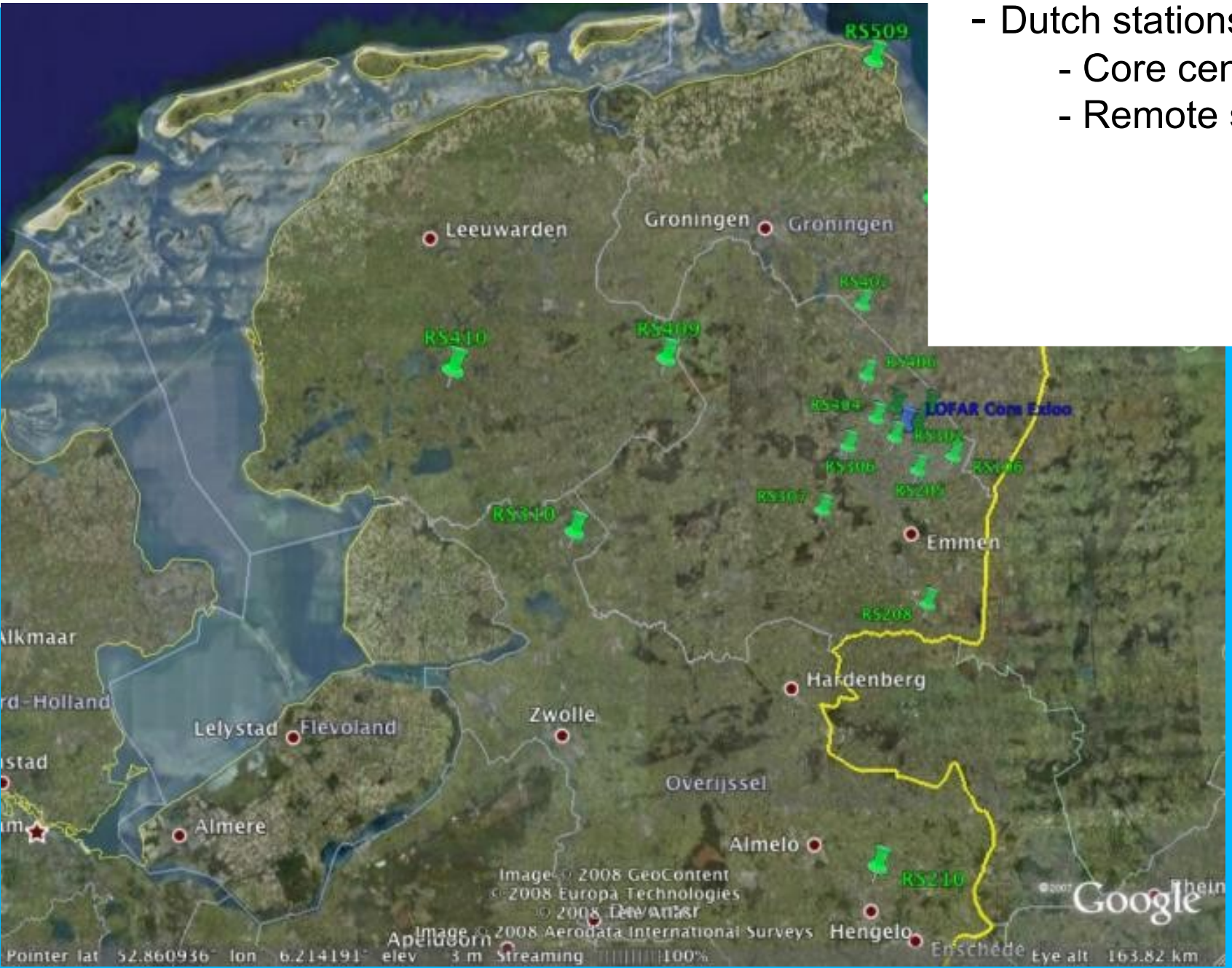


Array Location

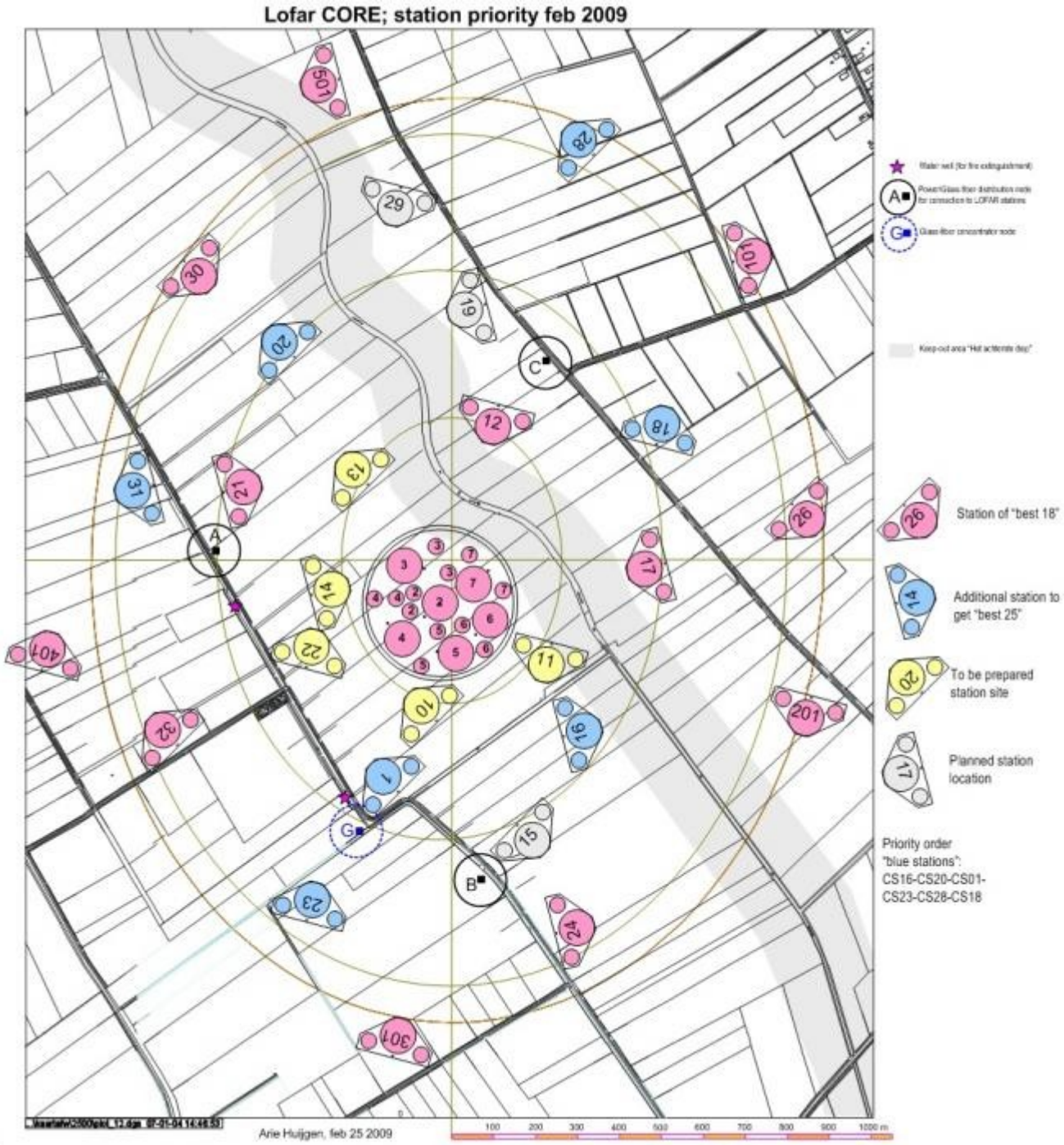
- Centred in Netherlands
- International stations:
  - France (1)
  - Germany (5)
  - Sweden (1)
  - UK (1)
  - *Poland (3)*
  - *Ireland (1)*

Array Location

- Dutch stations:
  - Core centred on Exloo
  - Remote stations



Array Location



- Core stations:
  - Central area of stations with area diameter of 2km.
  - “Superterp” of six stations in centre.

Array Location

LOFAR

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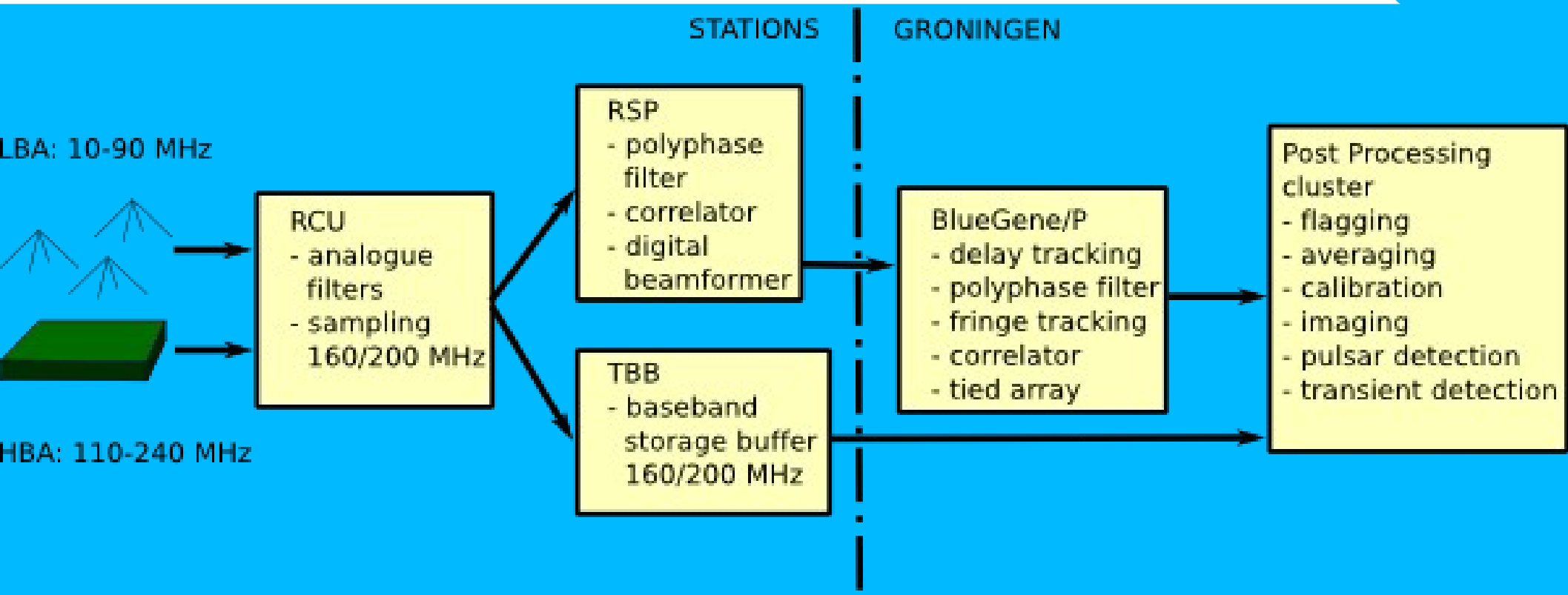
- Superterp

Data Path

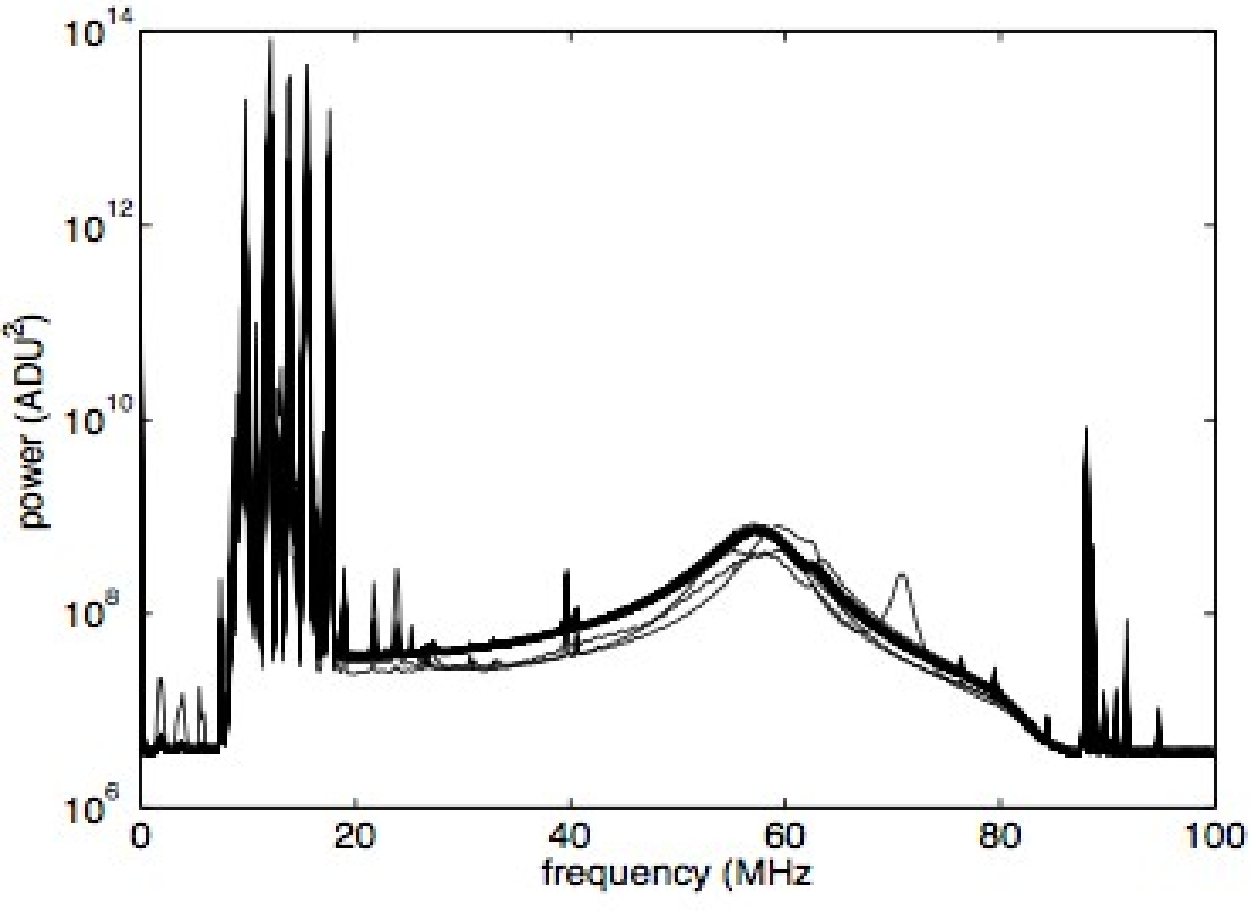

STATIONS
GRONINGEN
LBA: 10-90 MHz
HBA: 110-240 MHz
RCU
- analogue filters
- sampling 160/200 MHz
RSP
- polyphase filter
- correlator
- digital beamformer
TBB
- baseband storage buffer 160/200 MHz
BlueGene/P
- delay tracking
- polyphase filter
- fringe tracking
- correlator
- tied array
Post Processing cluster
- flagging
- averaging
- calibration
- imaging
- pulsar detection
- transient detection

Antennas

- Each site contains two arrays of antennas.
- Low-band (LBA):
  - 10-90MHz
- High-band (HBA):
  - 110-250MHz

Low-Band Antennas

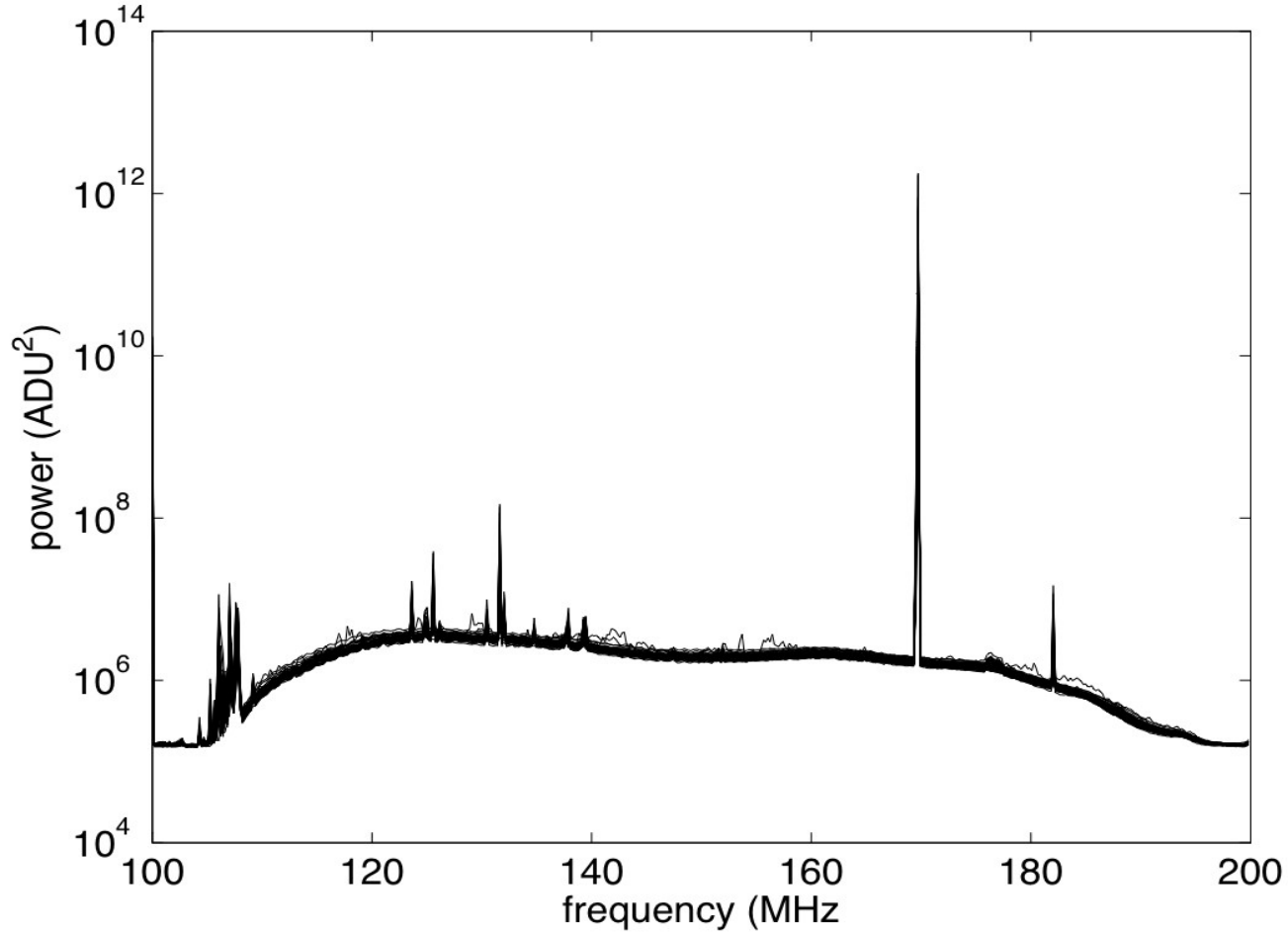
- Wire dual dipoles set at 45 degrees
- Held in place by rubber tensioners
- “Random” distribution within station to reduce sidelobes

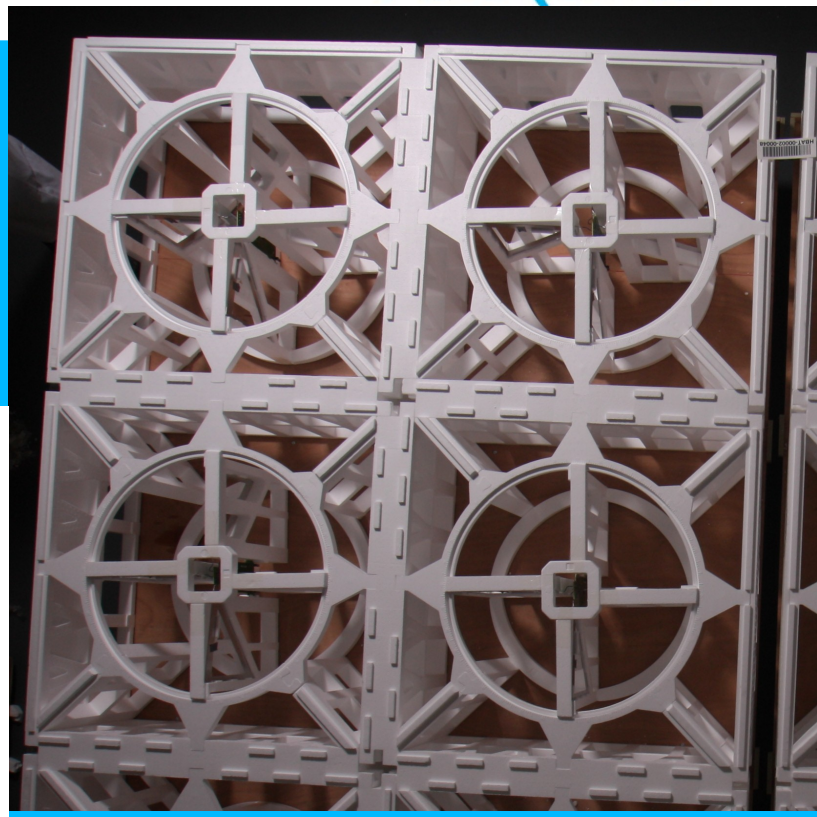


- Usable band:10-90 MHz
- Below 30MHz, ionospheric contamination
- Above 88MHz, FM waveband

High-Band Antennas

- Metal plate “bow-tie” dual dipoles, encased in polystyrene
- Grouped into “tiles” of 4x4 antennas, with tile spacing of 1.25m (1 wavelength at 240MHz).

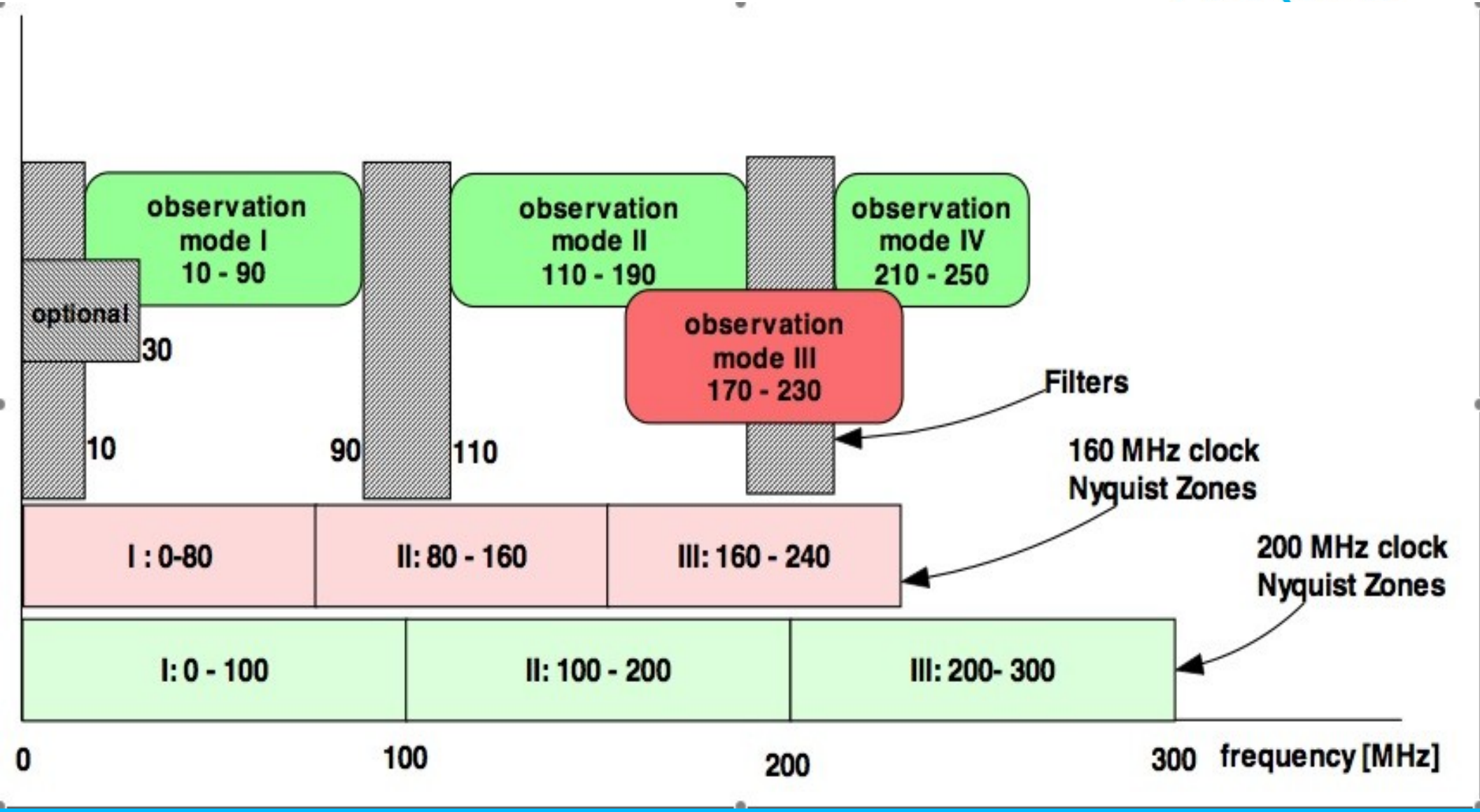




- Usable band:110-250 MHz

- Three filters: 110-190MHz, 170-230MHz, 210-250MHz

Clock and Filter Selections



Frequency and Time Resolutions

- Full bandwidth of the digitised signal (100MHz or 80MHz depending on the clock) split into 512 “subbands”.
- Up to 244 subbands, covering 48/38MHz in total, can be returned to Central Processing (CEP) due to data rate limitations.
  - “8-bit” mode will increase this in the future.
  - Frequency resolution is 0.1953125/0.156250 MHz.
  - Time resolution at this stage is 5.12 μs.
- In CEP, subbands can be split into channels (16 to >256) with a corresponding decrease in time resolution.

Beam Definitions

Dipole/Tile beam:
- Sensitive to whole sky >30 degrees elevation (LBA) or ~30 degrees wide (HBA tile)

Station beam:
- 2 to >8 degrees wide, depending on station size and frequency.

“Tied-array beam”:
- Form array of stations.
- <1 degree wide, depending on frequency and number of stations used.

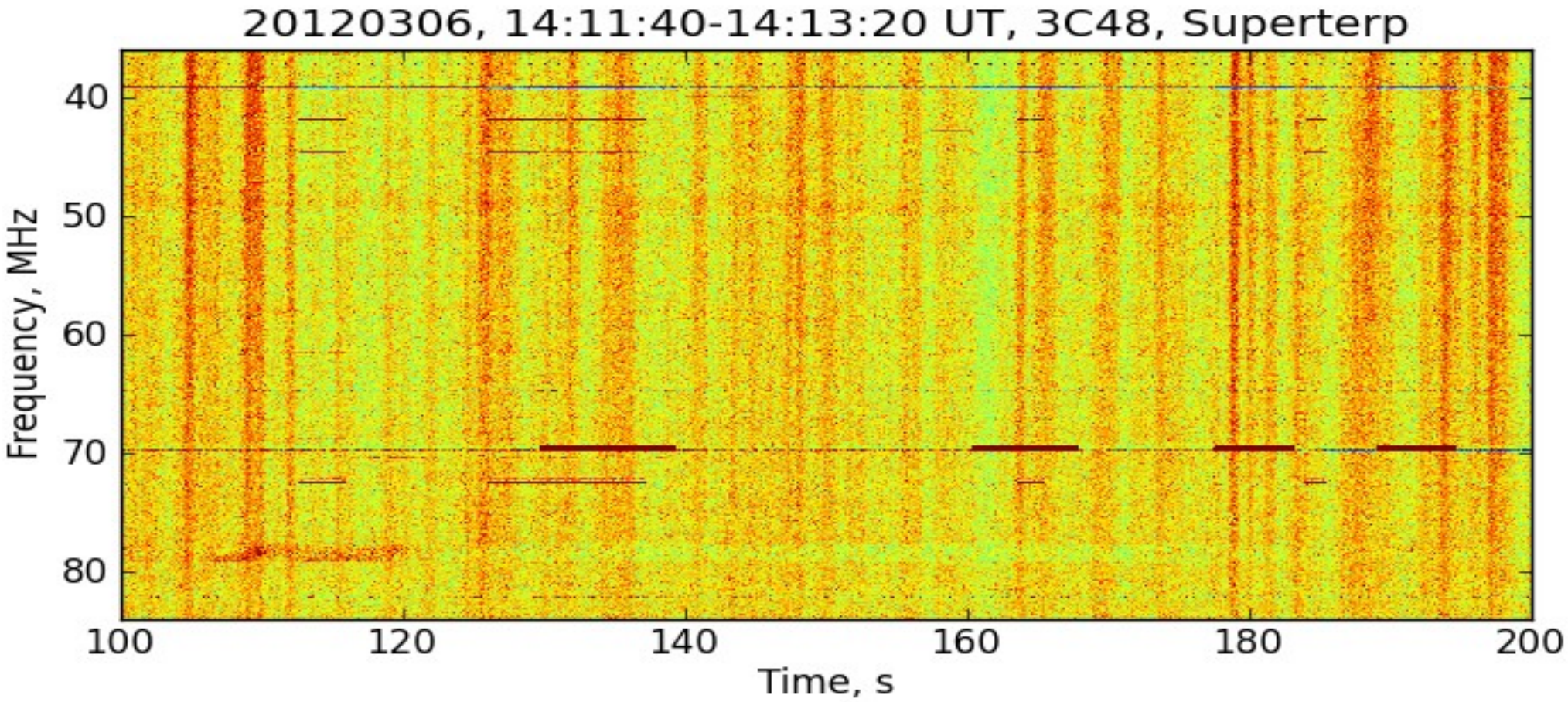
Final Data Products

- Data returned can be combined to return raw visibilities for imaging:
  - Imaging data “pipeline” will return sky images, as specified by the user.
- Or they can be returned as “beam-formed” data:
  - Equivalent to single-dish measurement.
  - Time/Frequency data returned for combined array and/or individual stations.
- Or both simultaneously...

OK, Now for the Science

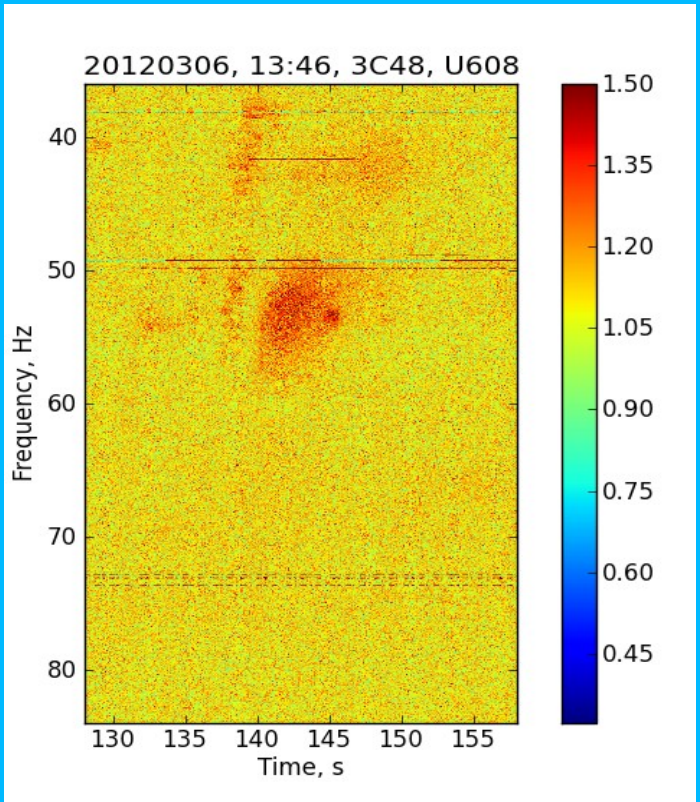
- My particular interest is observing the solar wind using observations of Interplanetary Scintillation:
  - The scintillation of compact radio sources due to density variations in the solar wind.
  - Analogous to the twinkling of stars due to our atmosphere.
- Effectively, observe the same radio sources that astronomers observe, but only care about the noise!

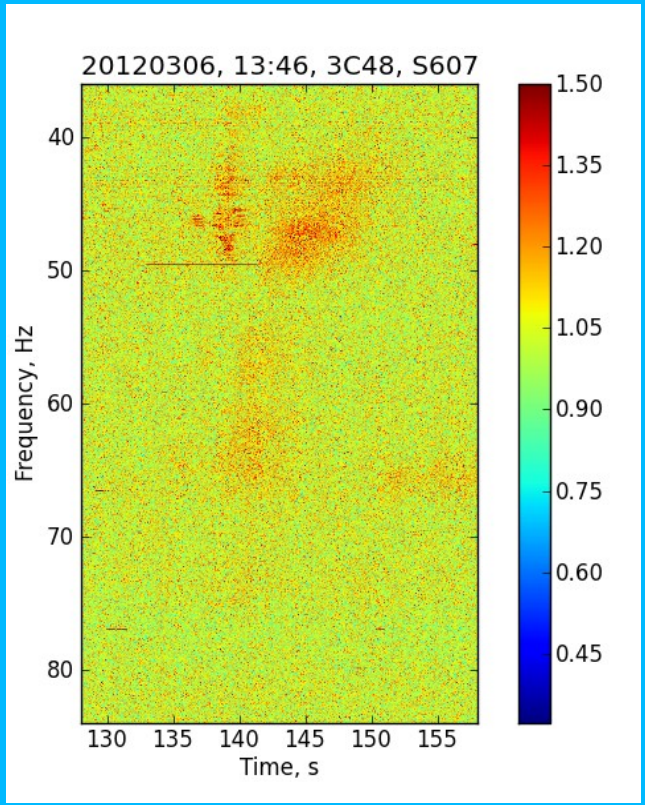
Interplanetary Scintillation

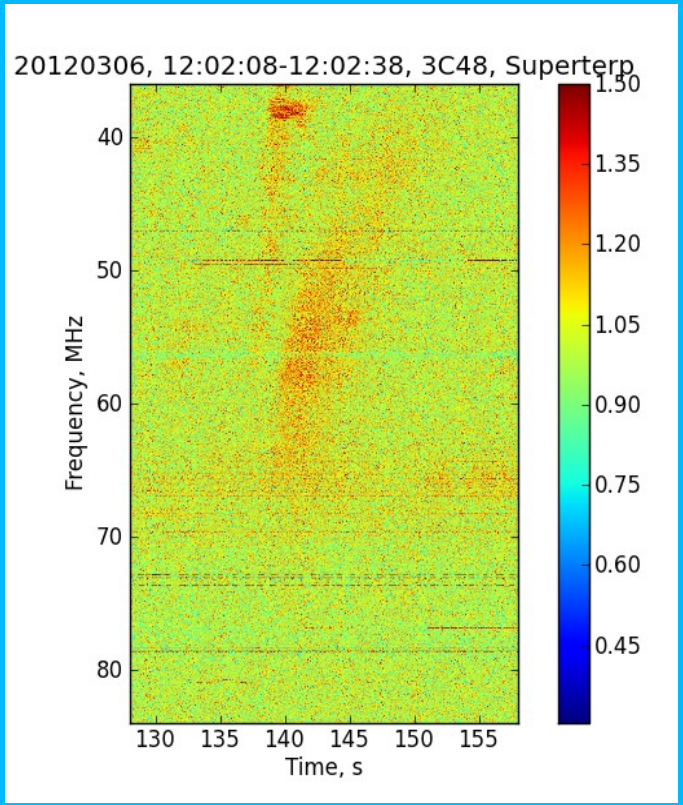


Scintillation seen as stripes in a dynamic spectrum. It is stronger at lower frequencies for a radio source at a given distance from the Sun.

Some Pitfalls...



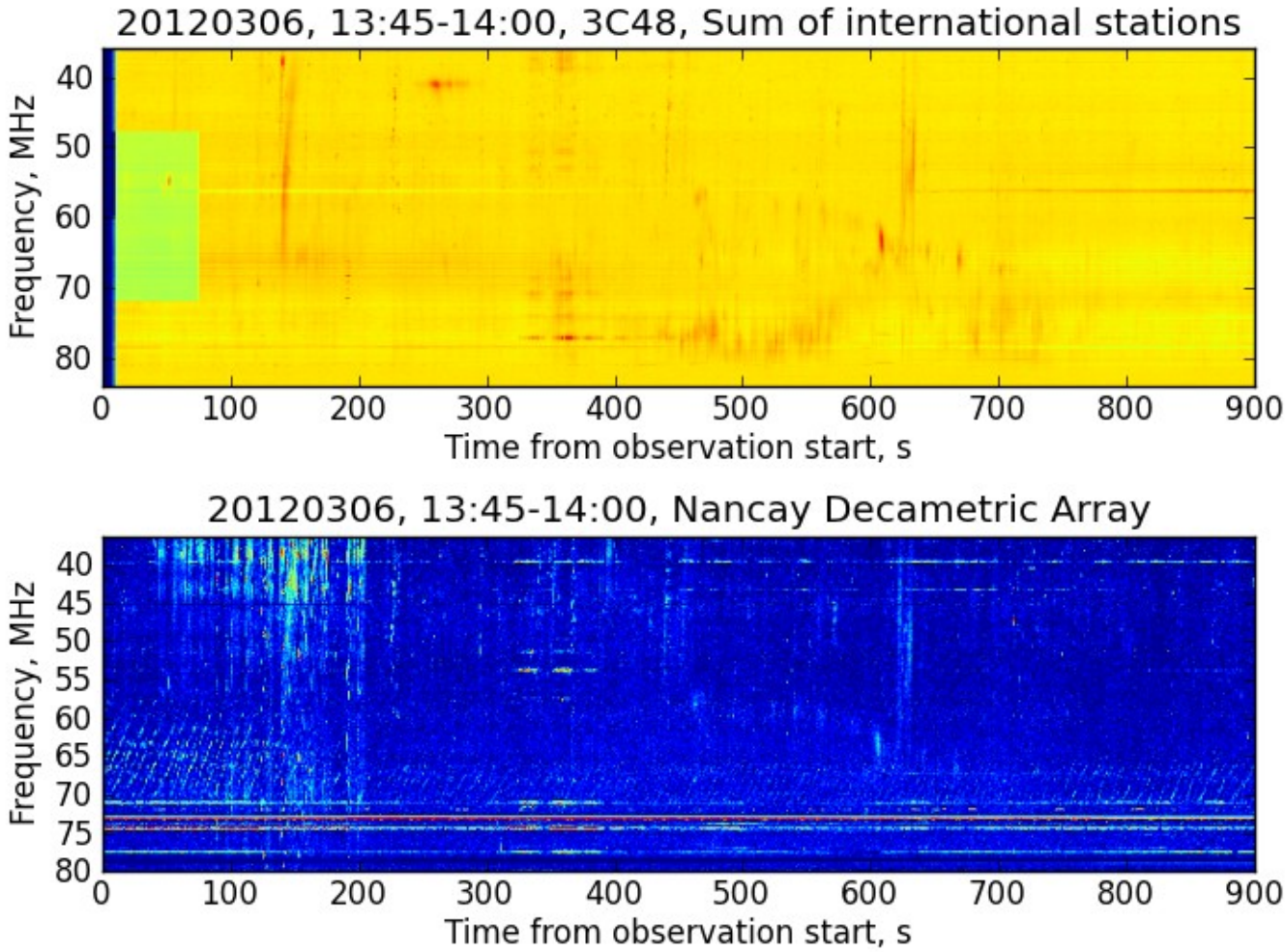




- UK608
- SE607
- Sum of all stations

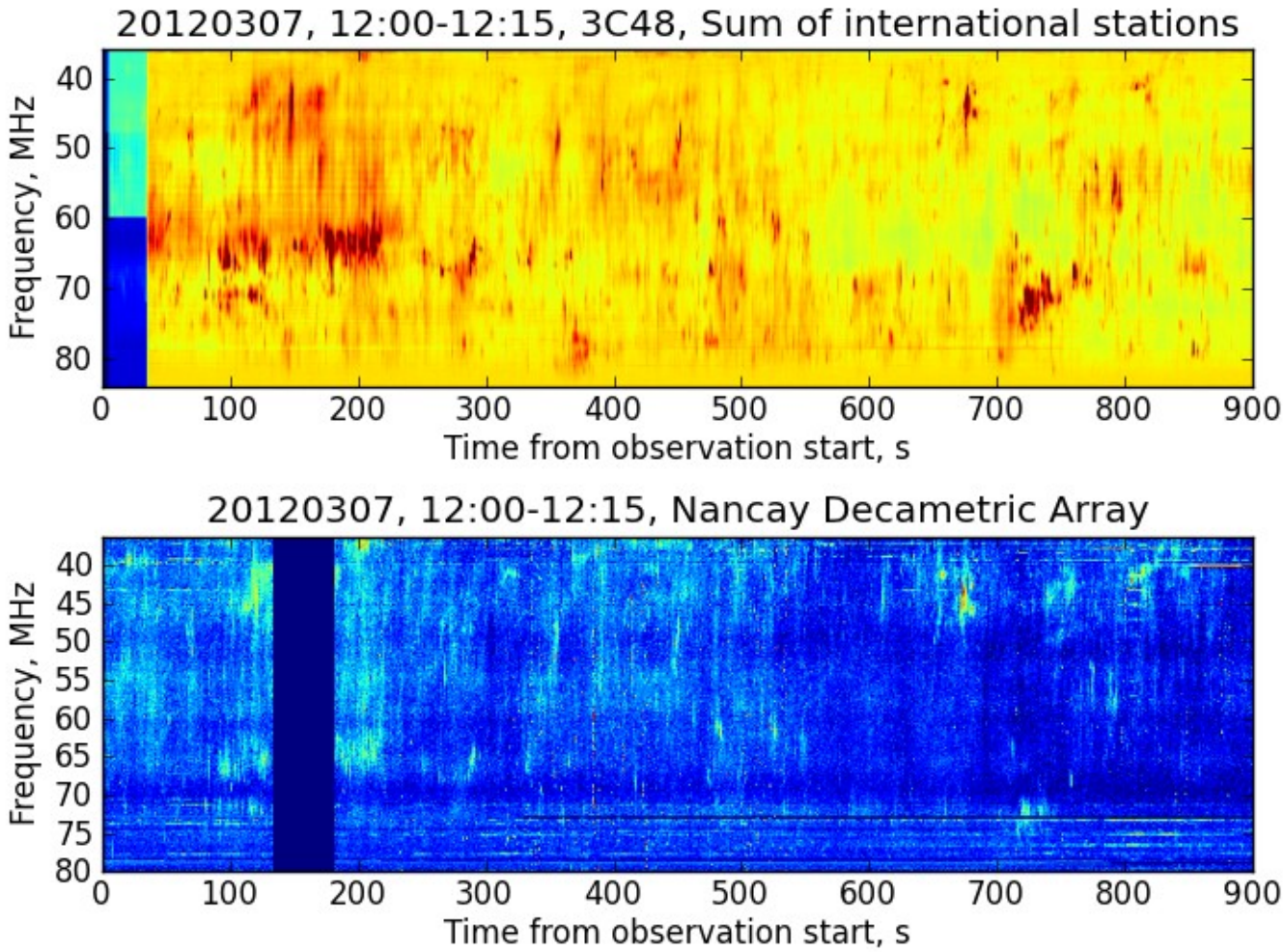
These data are a result of the Sun in a distant station beam sidelobe...
This can be a BIG problem...

Comparison with Full-Resolution Nançay Decametric Array



LOFAR IPS data averaged down to match resolution of Nancay (1.24s).

Another Example



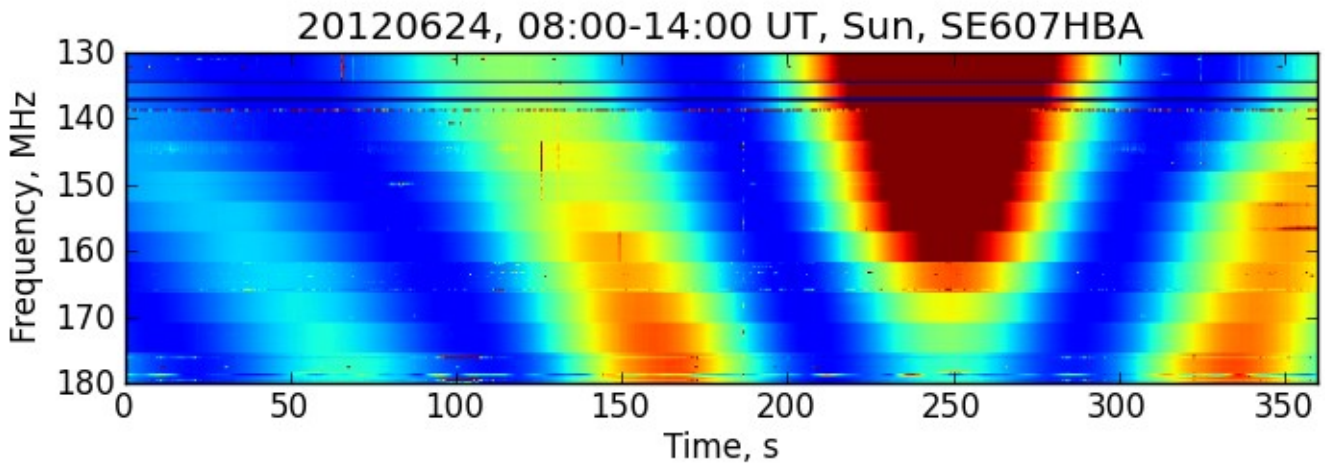
LOFAR IPS data averaged down to match resolution of Nancay (1.24s).

A lot of radio activity seen by both instruments.

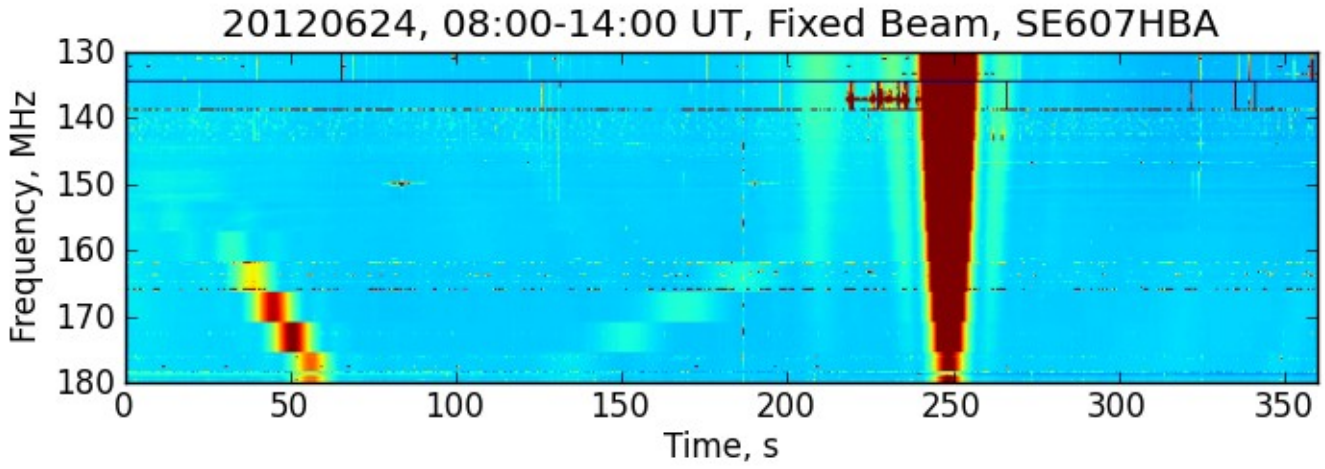
So need to see what the sidelobes might look like...

The Wide-Field HBA Beam: A First Look

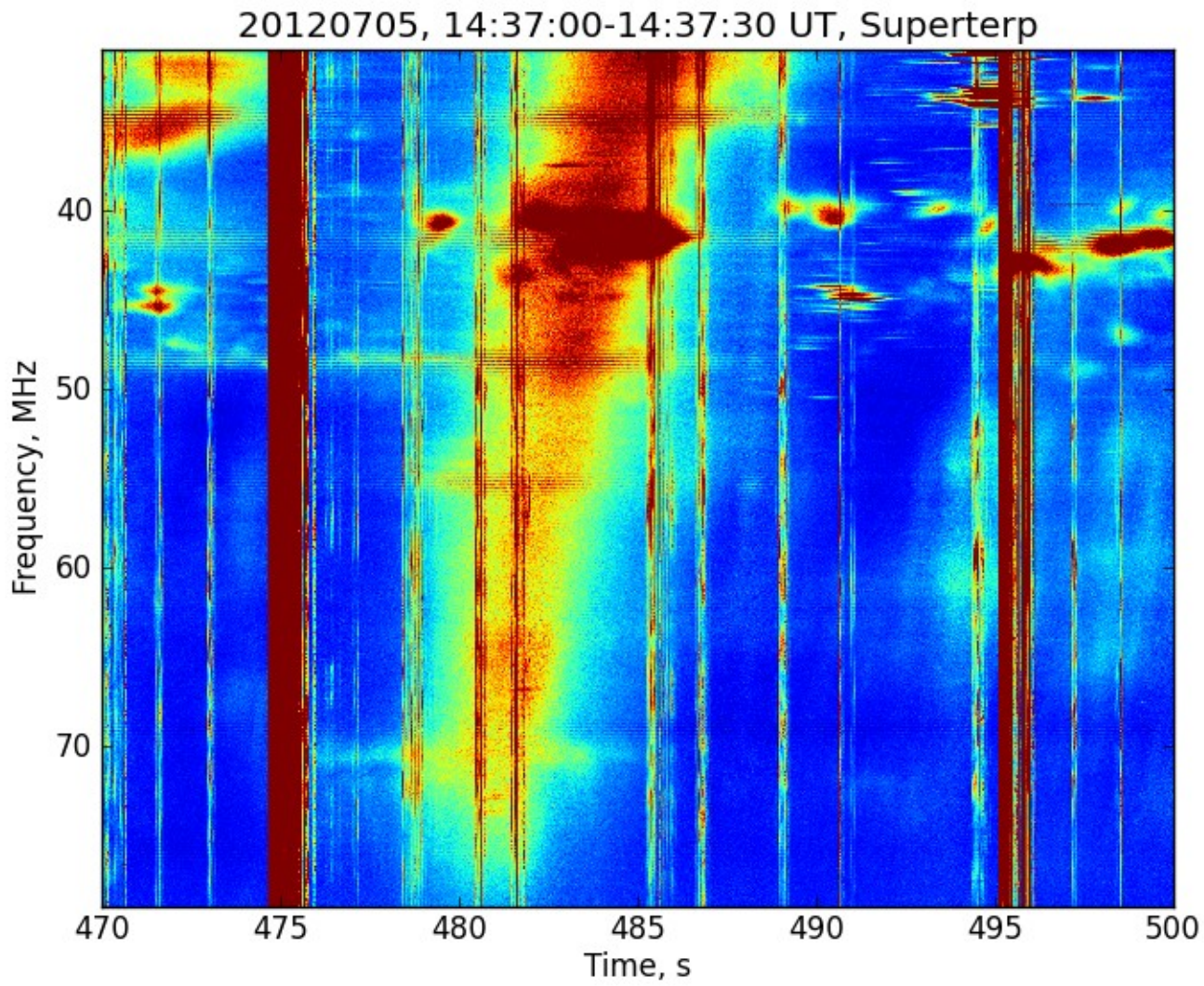
Effectively mapping tile beam



Effectively mapping station beam



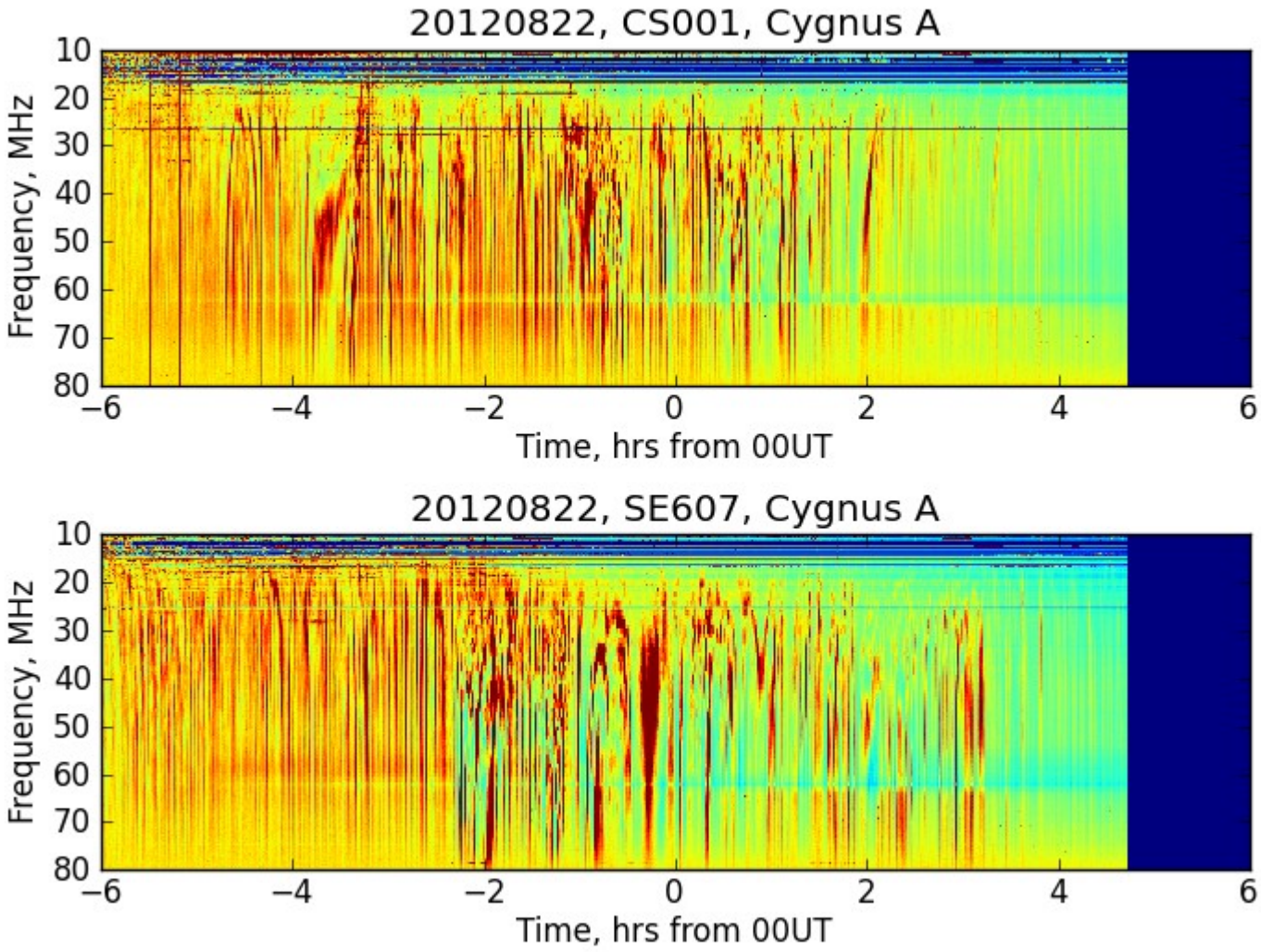
No Problems Observing the Sun!
Even through a thunderstorm...



A Final Puzzle

Overnight observation of Cygnus A appears to show structures which could be ionospheric.

What are they??



Summary

- LOFAR is a powerful and very flexible new radio telescope.
- Capable of observing many things in greater detail than before.
- The ionosphere is a big issue for radio astronomers:
  - Is there anything interesting in the ionosphere at middle latitudes?