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Netherlands Institute for Radio Astronomy

The Low-Frequency Array (LOFAR): A Comprehensive Tool for Space Weather Observation

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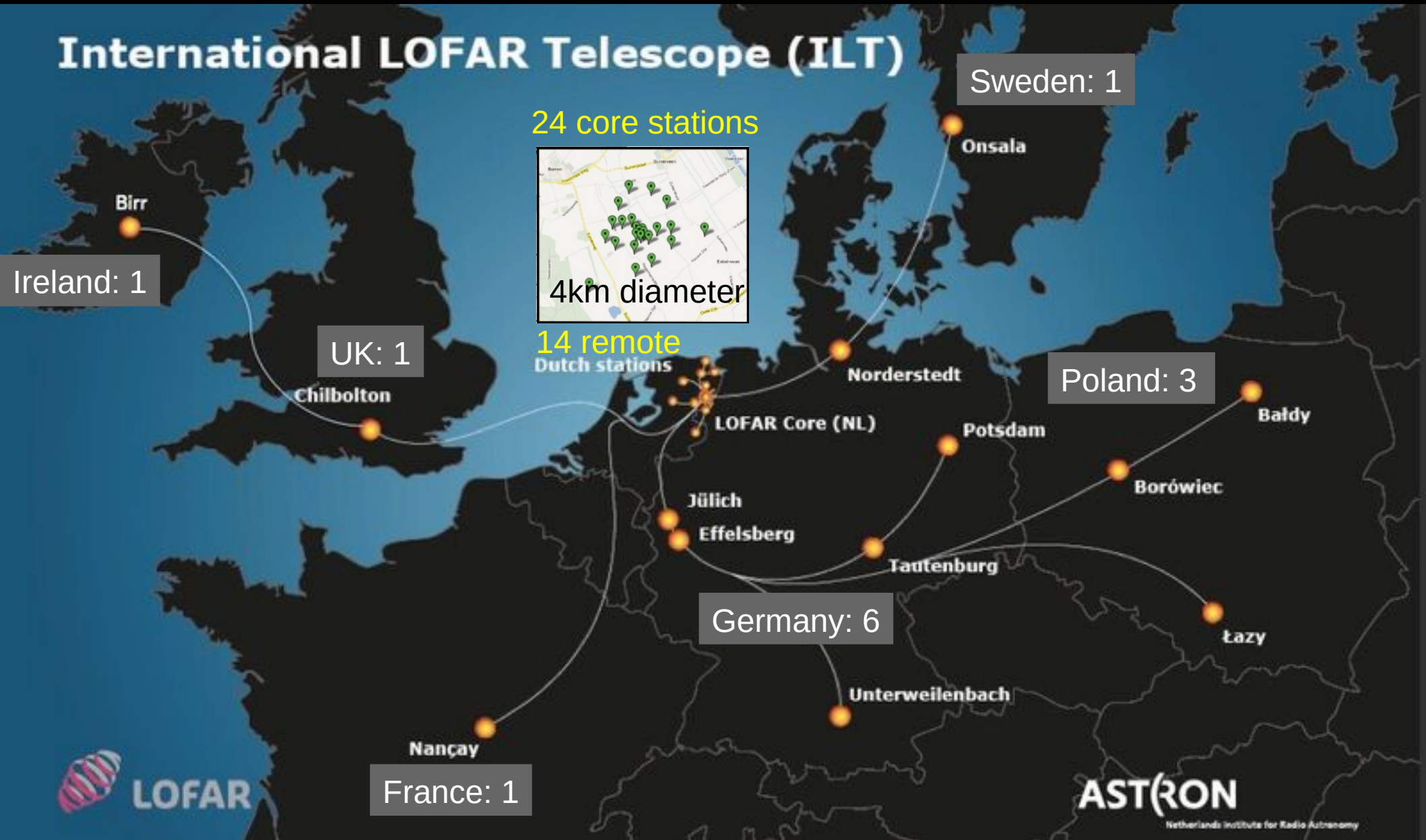
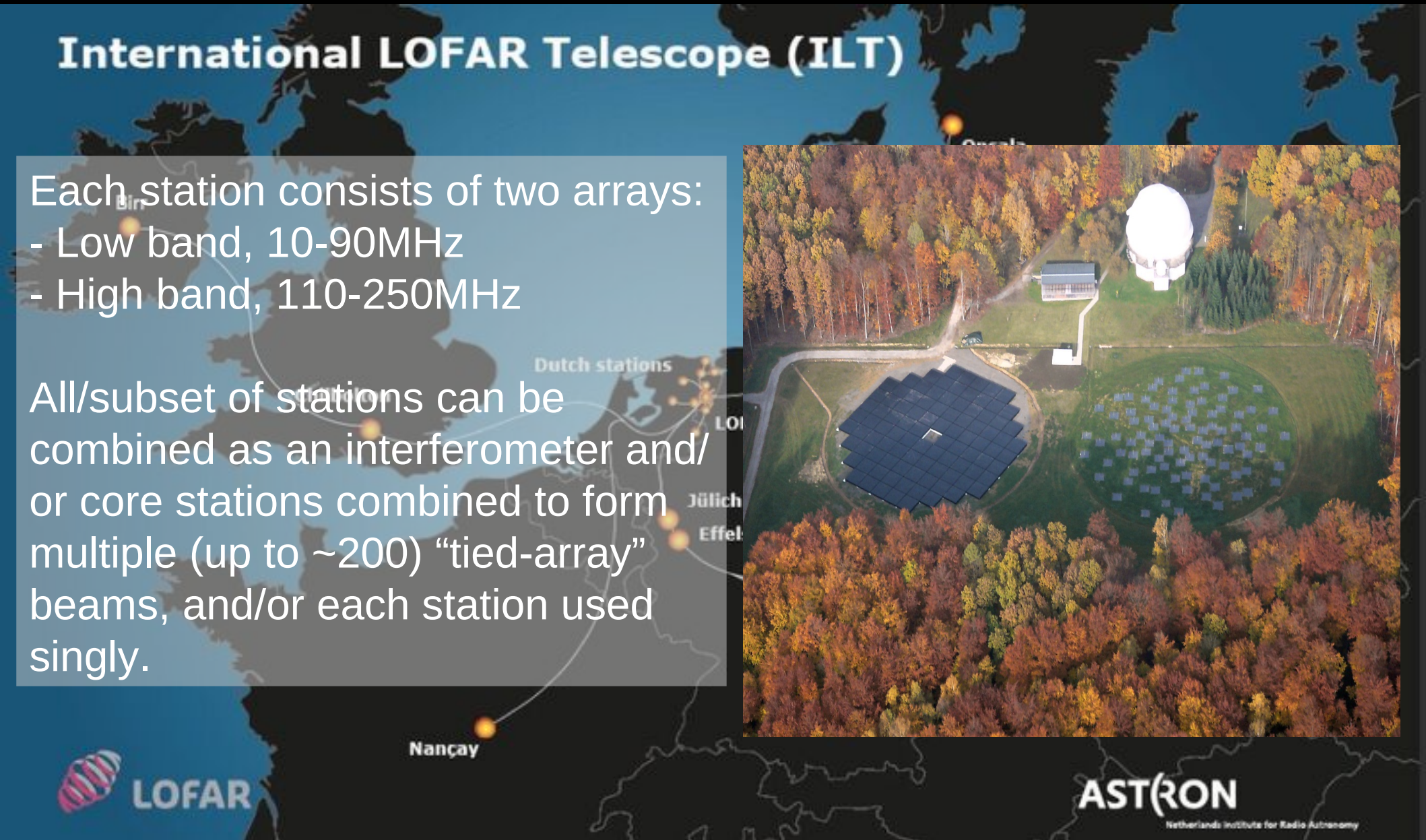
The Low-Frequency Array - LOFAR



The Low-Frequency Array - LOFAR

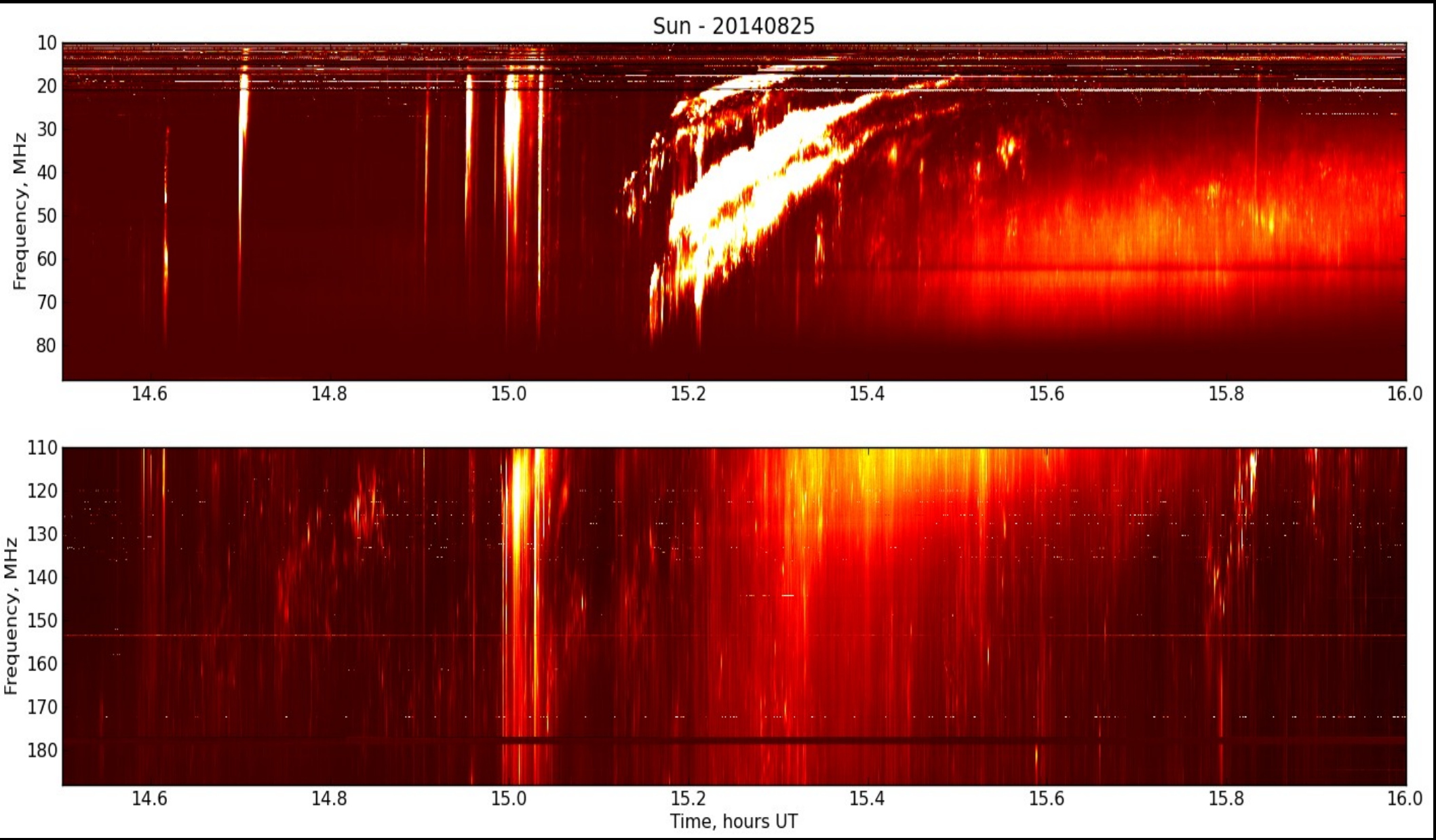


Each station consists of two arrays:
- Low band, 10-90MHz
- High band, 110-250MHz

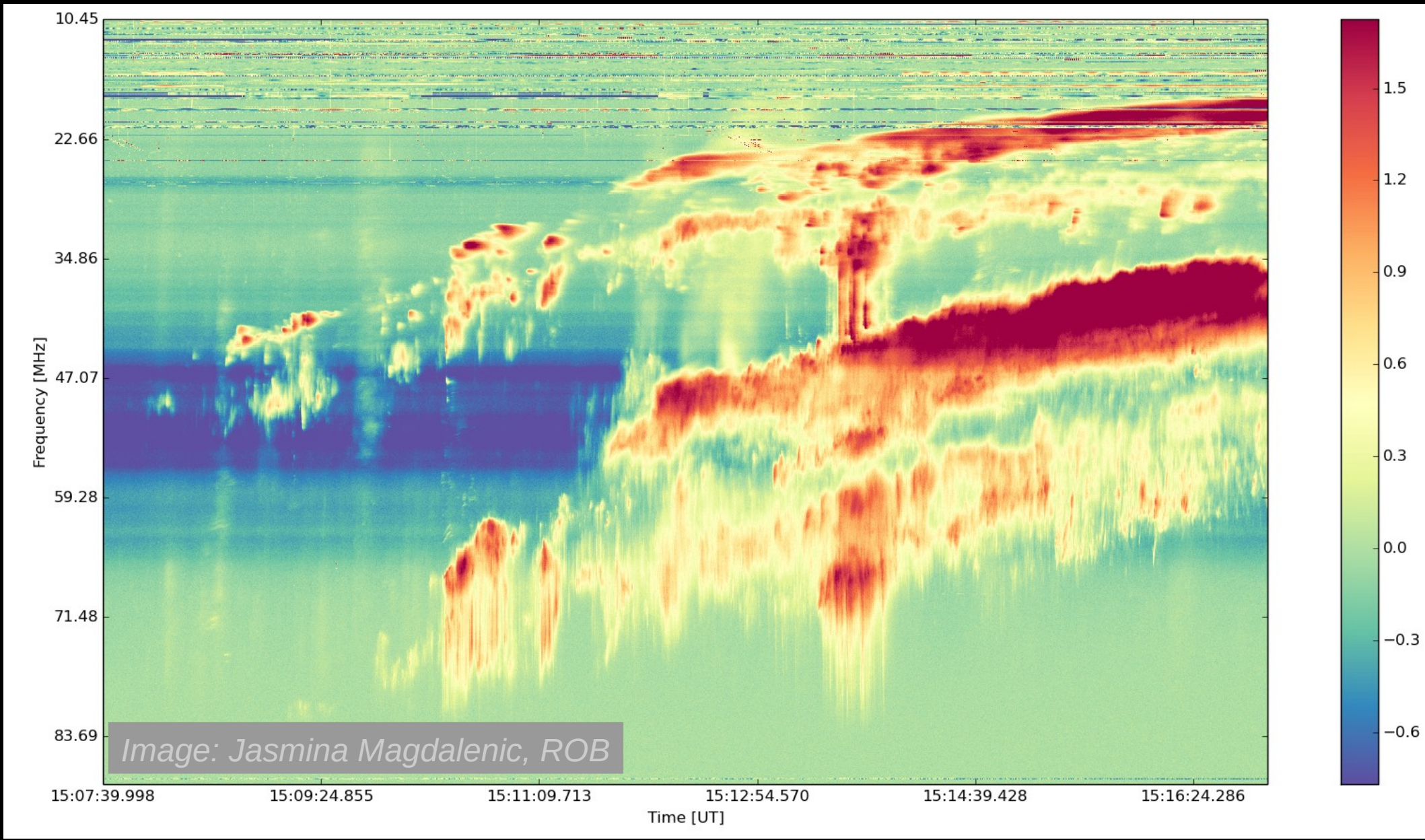
All/subset of stations can be combined as an interferometer and/or core stations combined to form multiple (up to ~200) “tied-array” beams, and/or each station used singly.

Observing the Sun

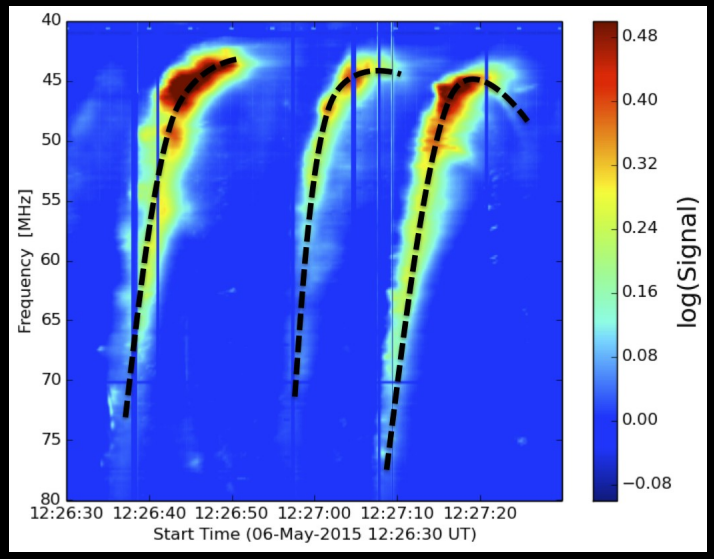
Wide bandwidth dynamic spectrum

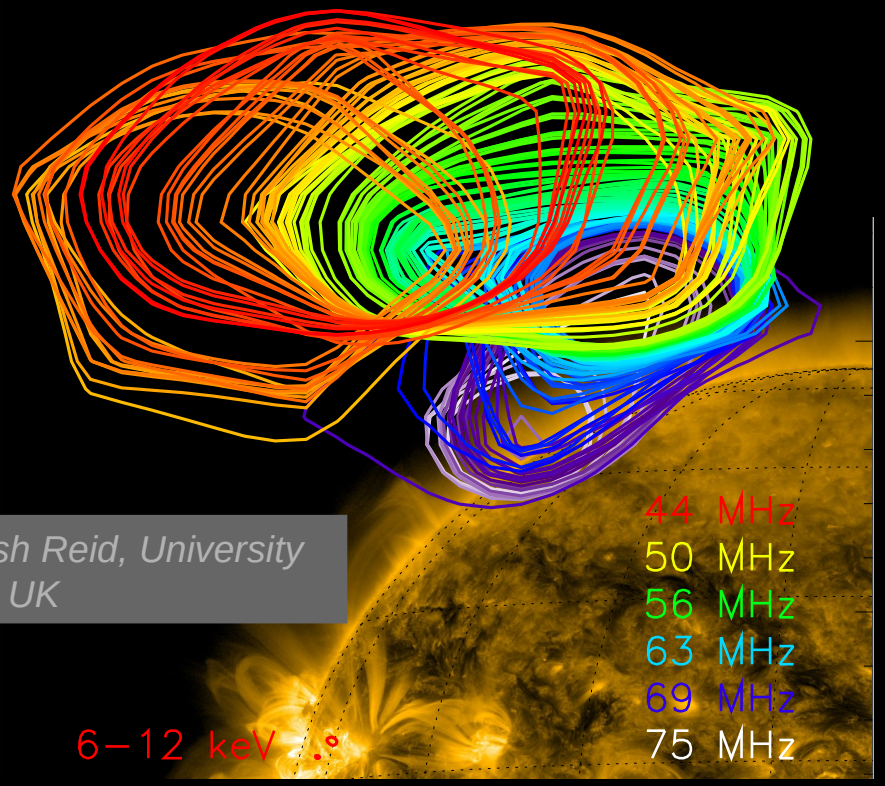


Fine structure inside radio bursts



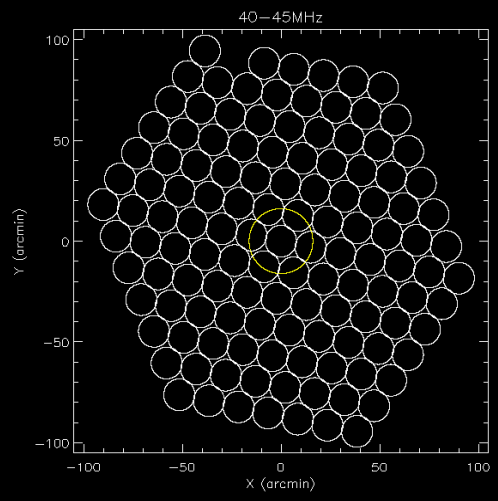
Raster imaging of the Sun with tied-array beams





Plots: Hamish Reid, University of Glasgow, UK

- Use LOFAR core to form ~200 narrow pencil beams covering the Sun and corona.
- Record high time resolution data for each beam:
  - Full dynamic spectrum for each beam;
  - Enables fast imaging.



Probing the Solar Wind

Ground-based Observations: Using Radio-Wave Propagation Effects

LOFAR
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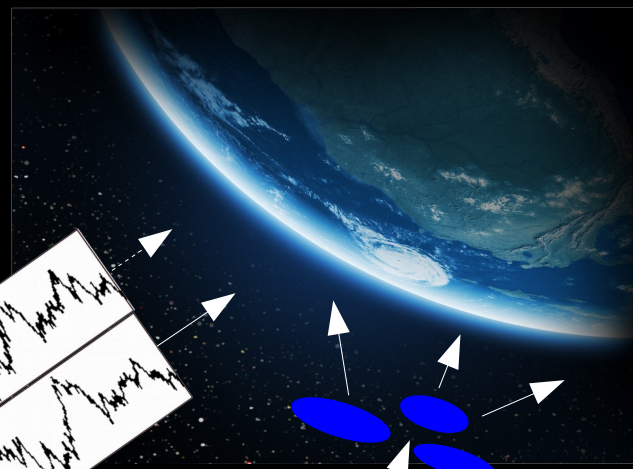
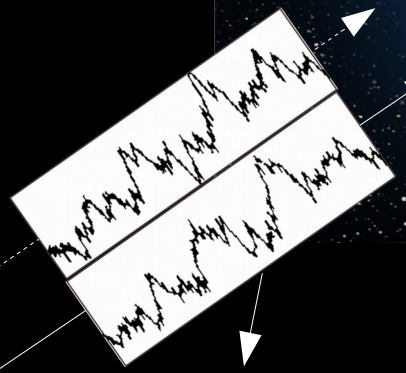
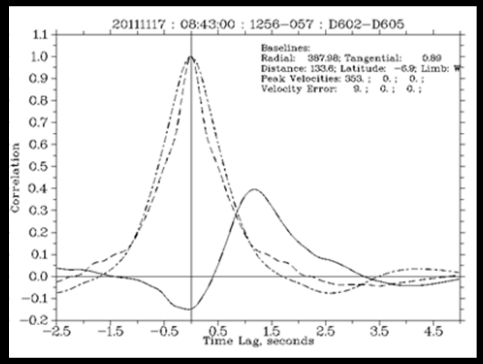




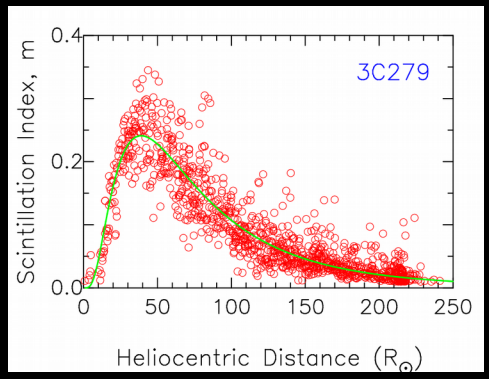
Ionospheric scintillation

Solar wind density and velocity

Interplanetary Scintillation from compact source

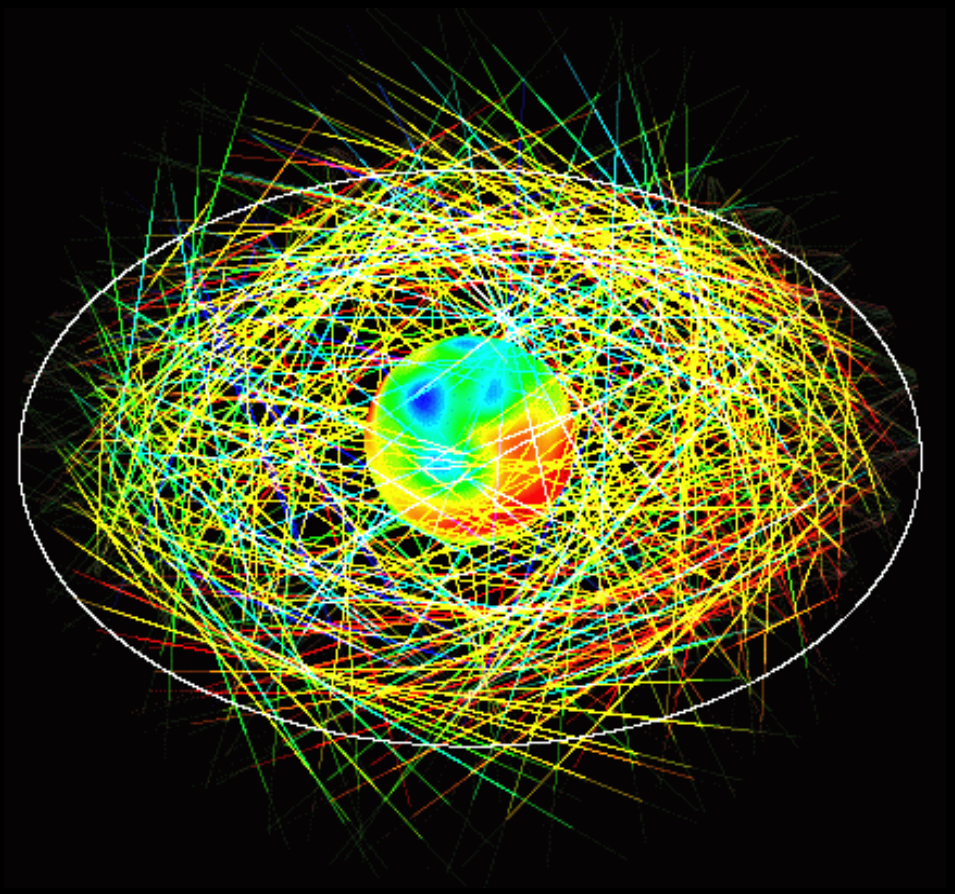


Cross-correlation of time series -> velocity



Variation in amount of scintillation -> density

“Imaging” the Solar Wind with Tomography



- Many observations taken over a whole solar rotation results, in the Sun's frame of reference, in many overlapping lines of sight between antennas and radio sources.
- Tomographic inversion techniques used to create images of the solar wind in both scintillation-level (proxy for density) and solar wind speed.

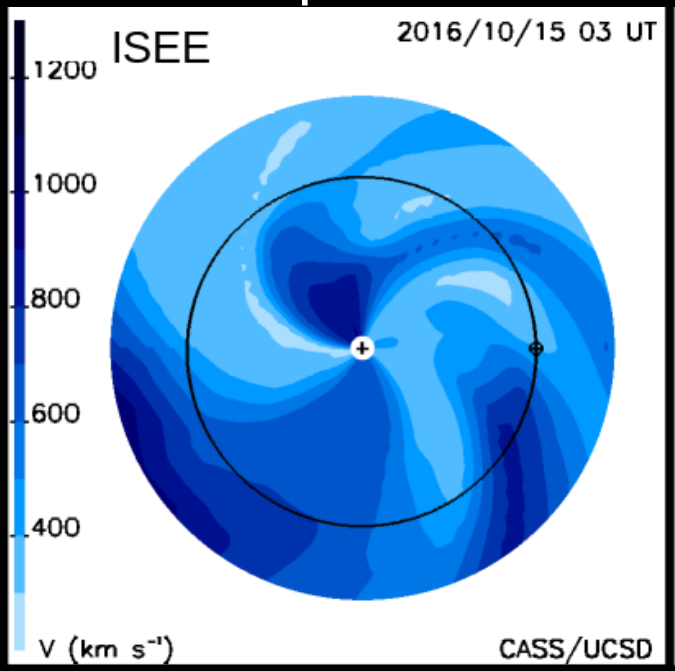
A trial campaign took place in October 2016 involving LOFAR, the MWA, and observatories worldwide to demonstrate the potential for LOFAR and the combination of data from worldwide observatories.

All current dedicated observatories are single-frequency and only Japan is multi-site. This limits the physics which can be studied.

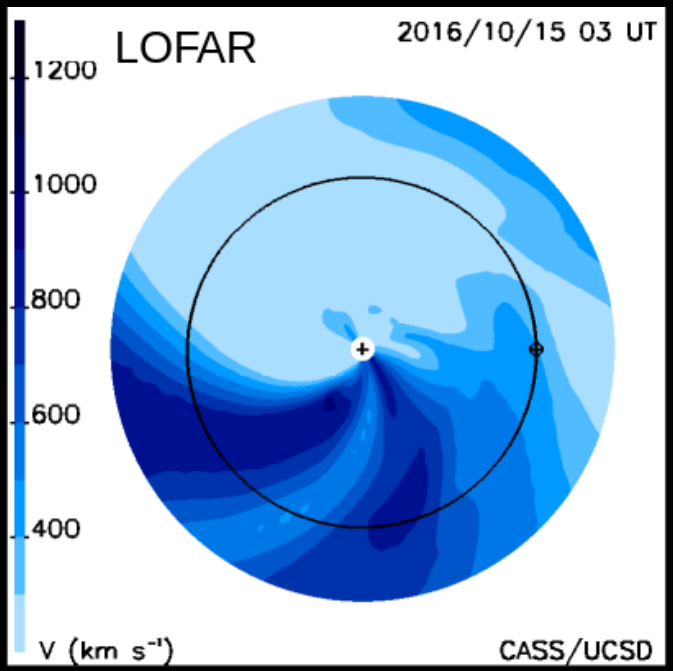
With the wide bandwidth and geographical coverage of LOFAR, we can compare the different methods of analysis currently in use and try analyses which are not possible with any dedicated instruments.

Tomographic Reconstruction of Solar Wind Velocity: October 2016

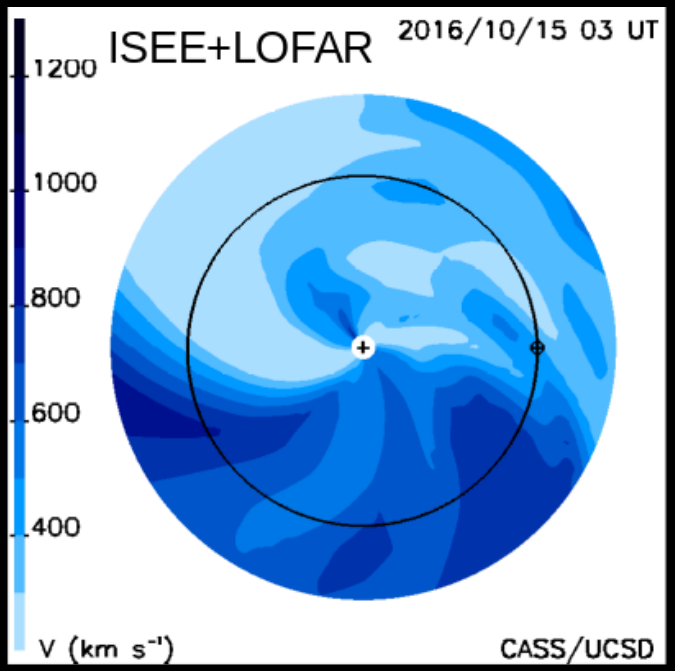
Japan



LOFAR



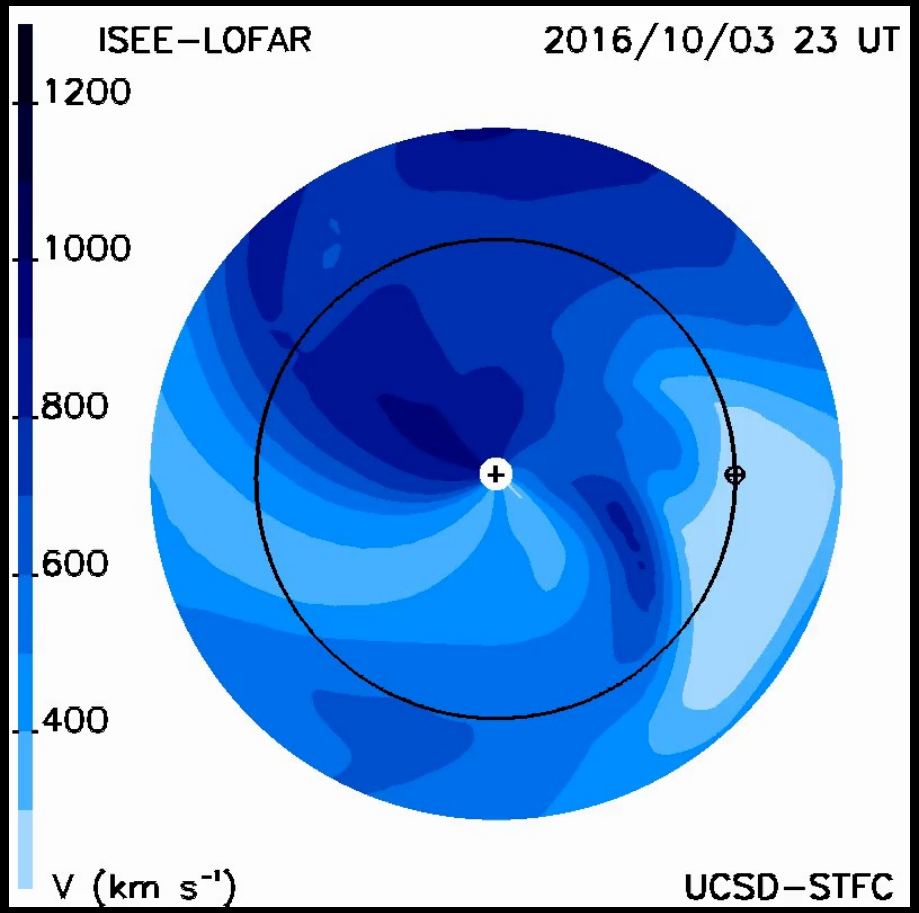
Combined



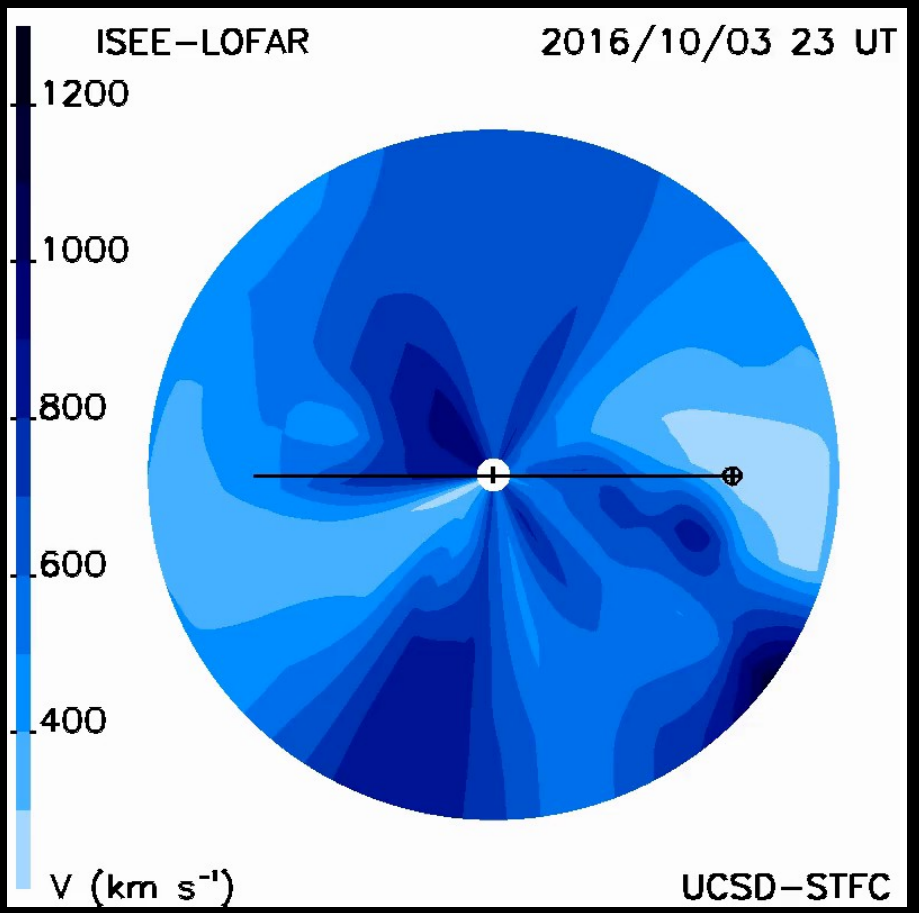
Reconstructions look good, but some key differences between ISEE and LOFAR, most likely due to spatial and temporal coverage of observations of IPS. Combined view most likely dominated by greater number of LOFAR results (~800, compared to ~300 from ISEE). All results **preliminary**.

Reconstructions courtesy Bernie Jackson (UCSD) and Mario Bisi (RAL)

Combined View



Ecliptic plane

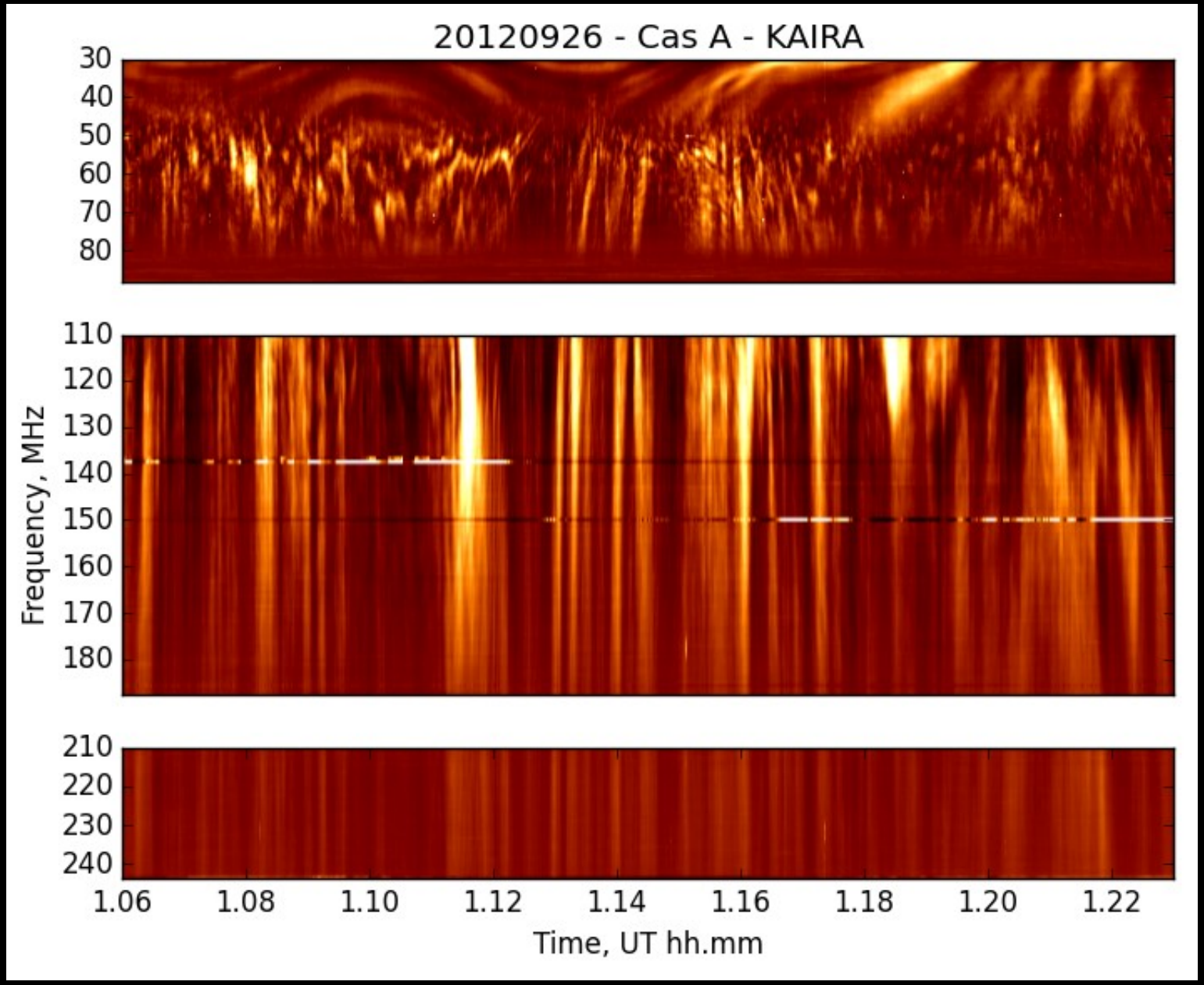


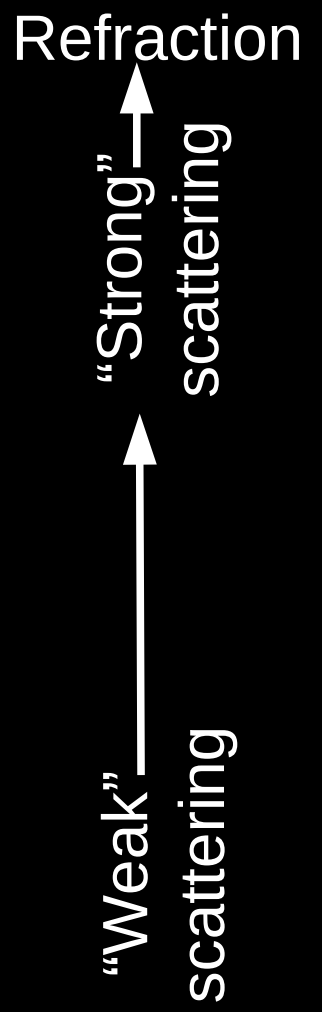
Meridional plane

Scintillation from the mid-latitude ionosphere:

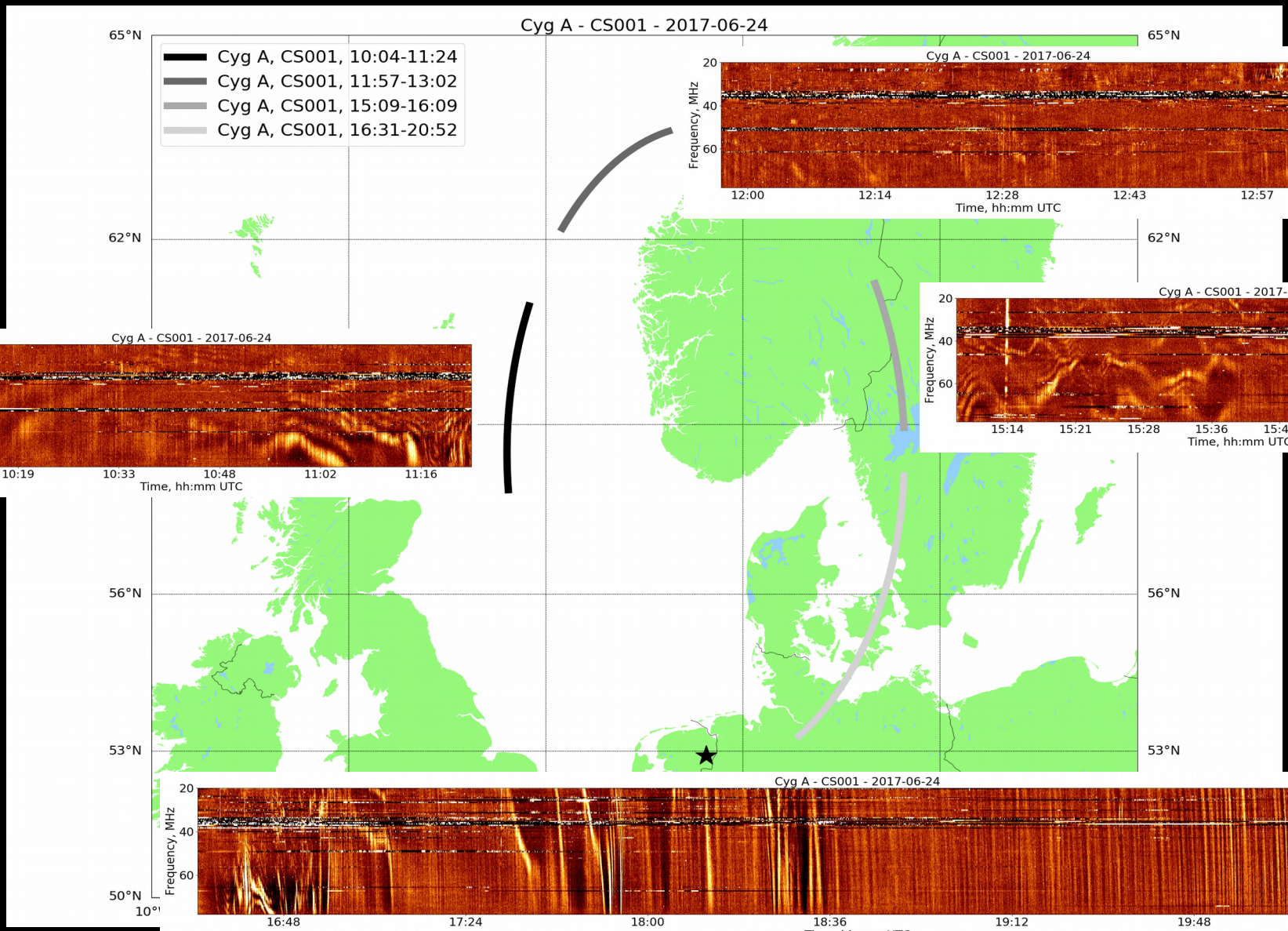
Expanding the view beyond a single-frequency time series.

Wide Bandwidth: a full view of scintillation

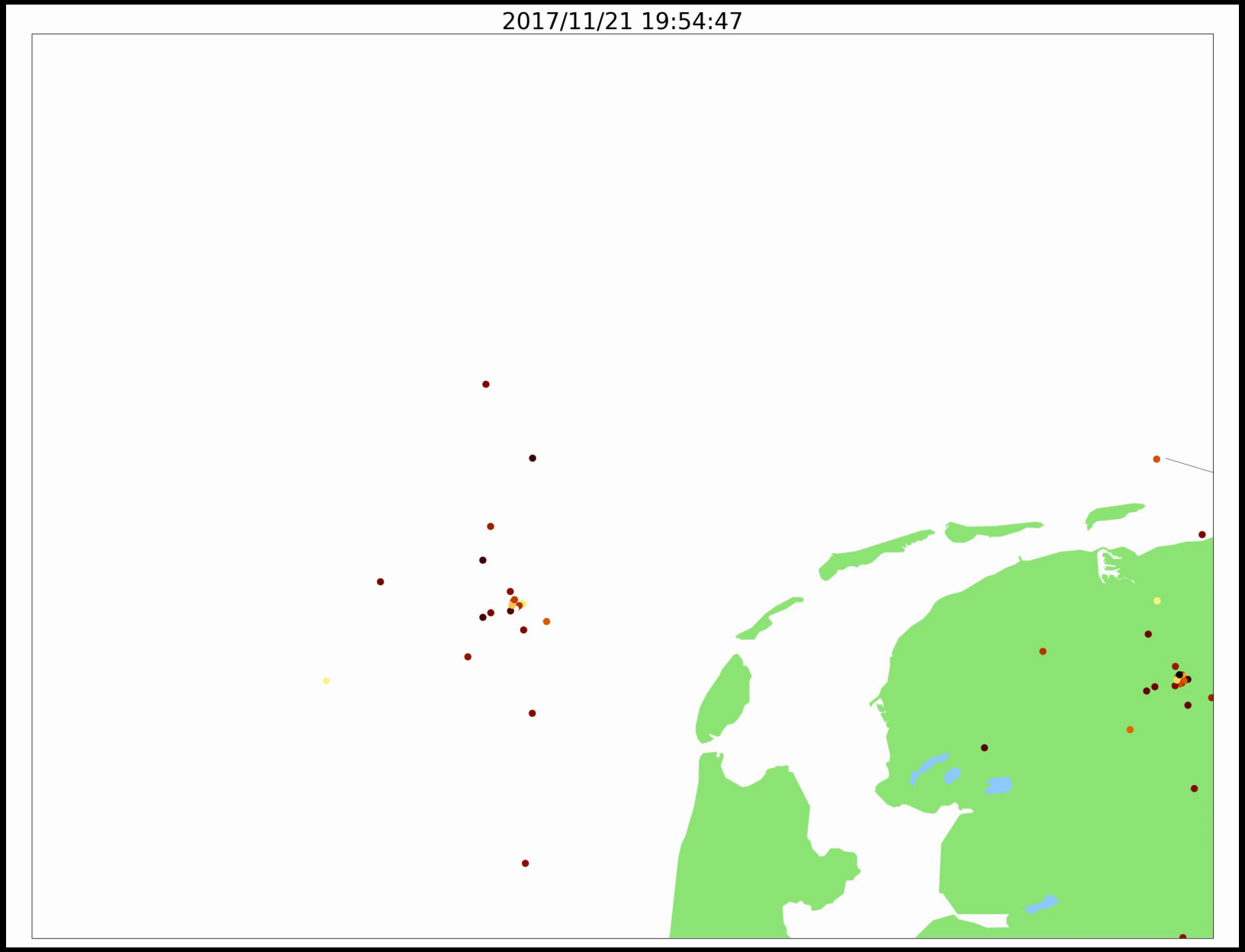




Long-duration Scintillation Structure



Looking Down on LOFAR Through the Ionosphere



This is a brief snapshot of the space weather science being undertaken with LOFAR, and only a tantalising glimpse into the advances that can be made with the new generation of radio telescopes.

LOFAR has the capability to advance space weather science well beyond the current state-of-the-art.