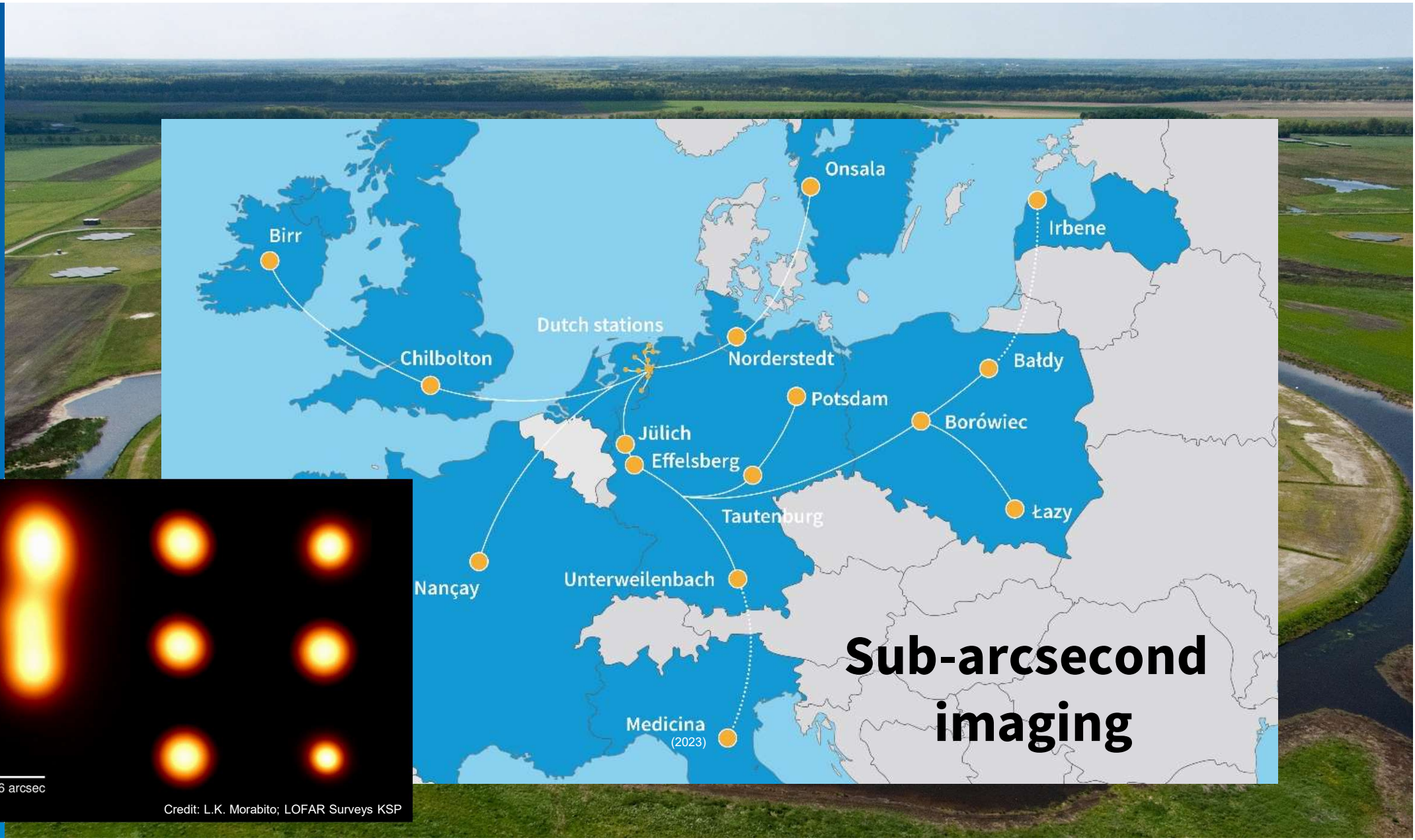
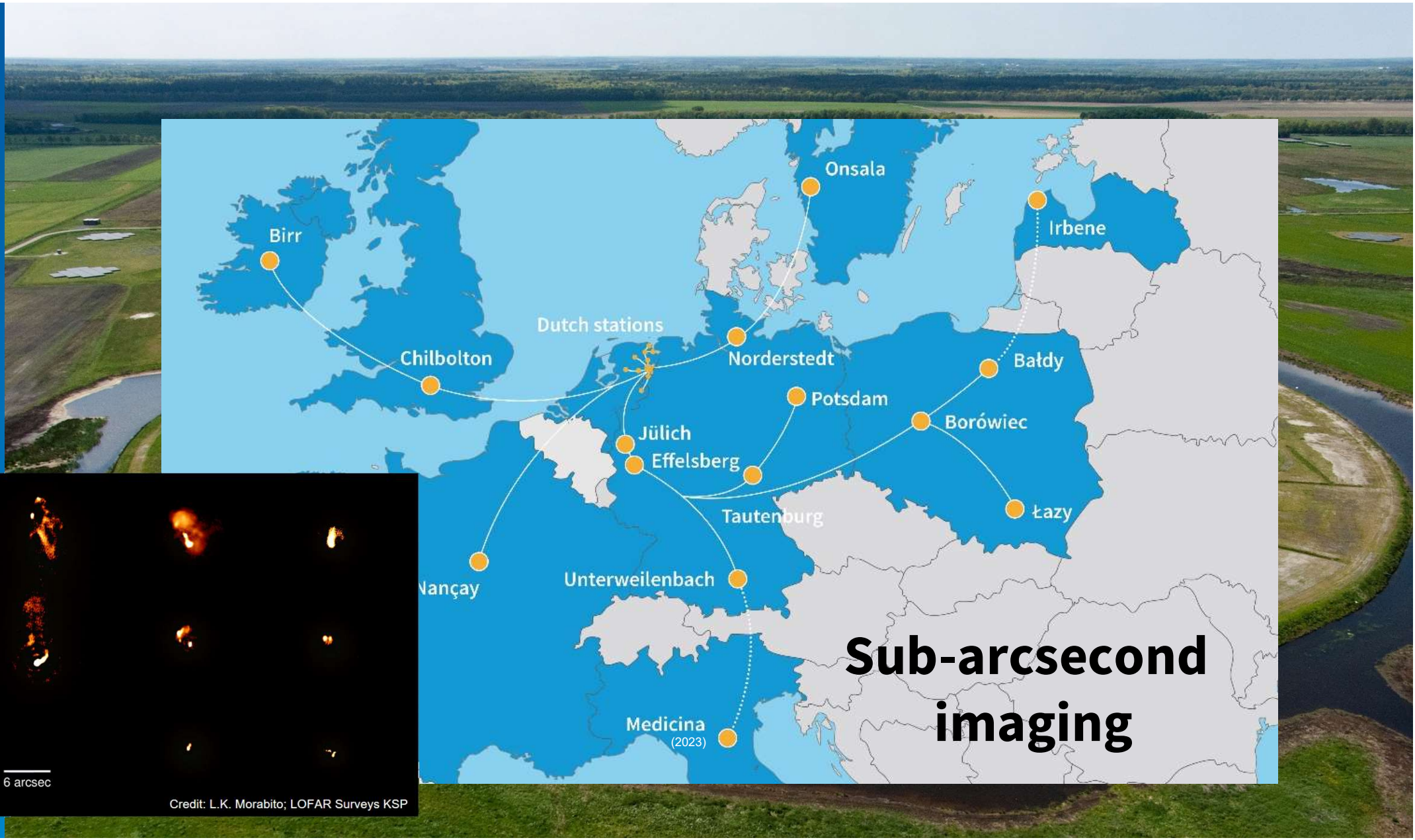
The LOFAR2.0 upgrade

Wim van Cappellen
Carla Baldovin
André Gunst
Boudewijn Hut
Arno Schoenmakers

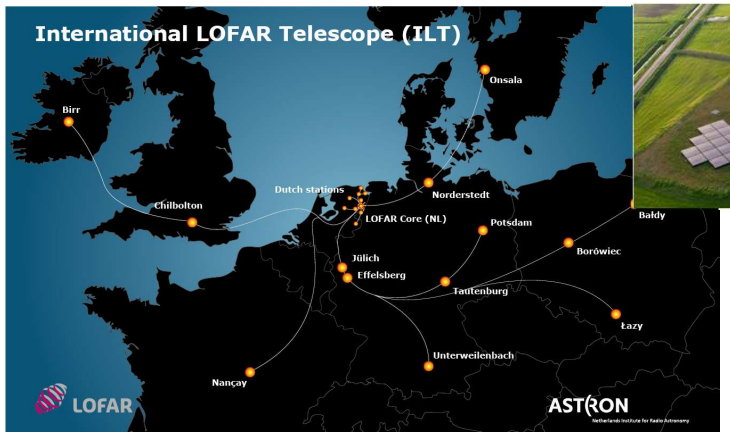
PAFAR 2022, 2022/11/15


Onsala
Irbene
Birr
Dutch stations
Chilbolton
Norderstedt
Bałdy
Potsdam
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Nançay
Unterweilenbach
Medicina
(2023)


Onsala
Irbene
Birr
Dutch stations
Chilbolton
Norderstedt
Bałdy
Potsdam
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Nançay
Unterweilenbach
Medicina
(2023)
Sub-arcsecond imaging
6 arcsec
Credit: L.K. Morabito; LOFAR Surveys KSP


Onsala
Irbene
Birr
Dutch stations
Chilbolton
Norderstedt
Bałdy
Potsdam
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Nançay
Unterweilenbach
Medicina
(2023)
6 arcsec
Credit: L.K. Morabito; LOFAR Surveys KSP
Sub-arcsecond imaging

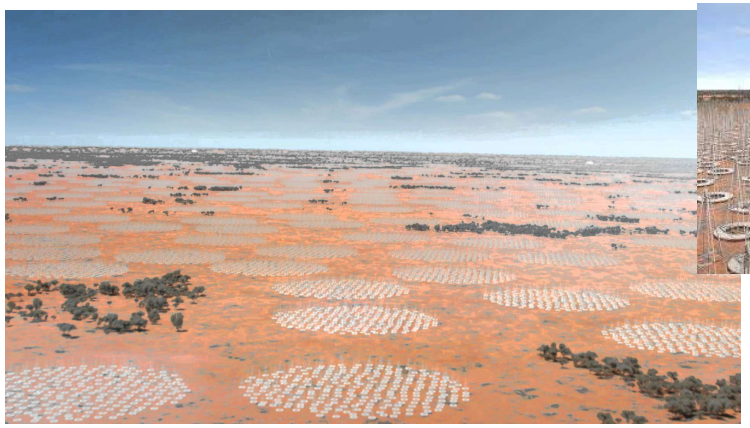
Compared to SKA-Low Phase 1

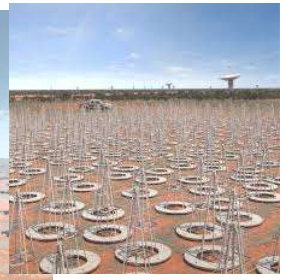


LOFAR + DUPLLO

Reaches 2x lower frequency

>10x higher resolution

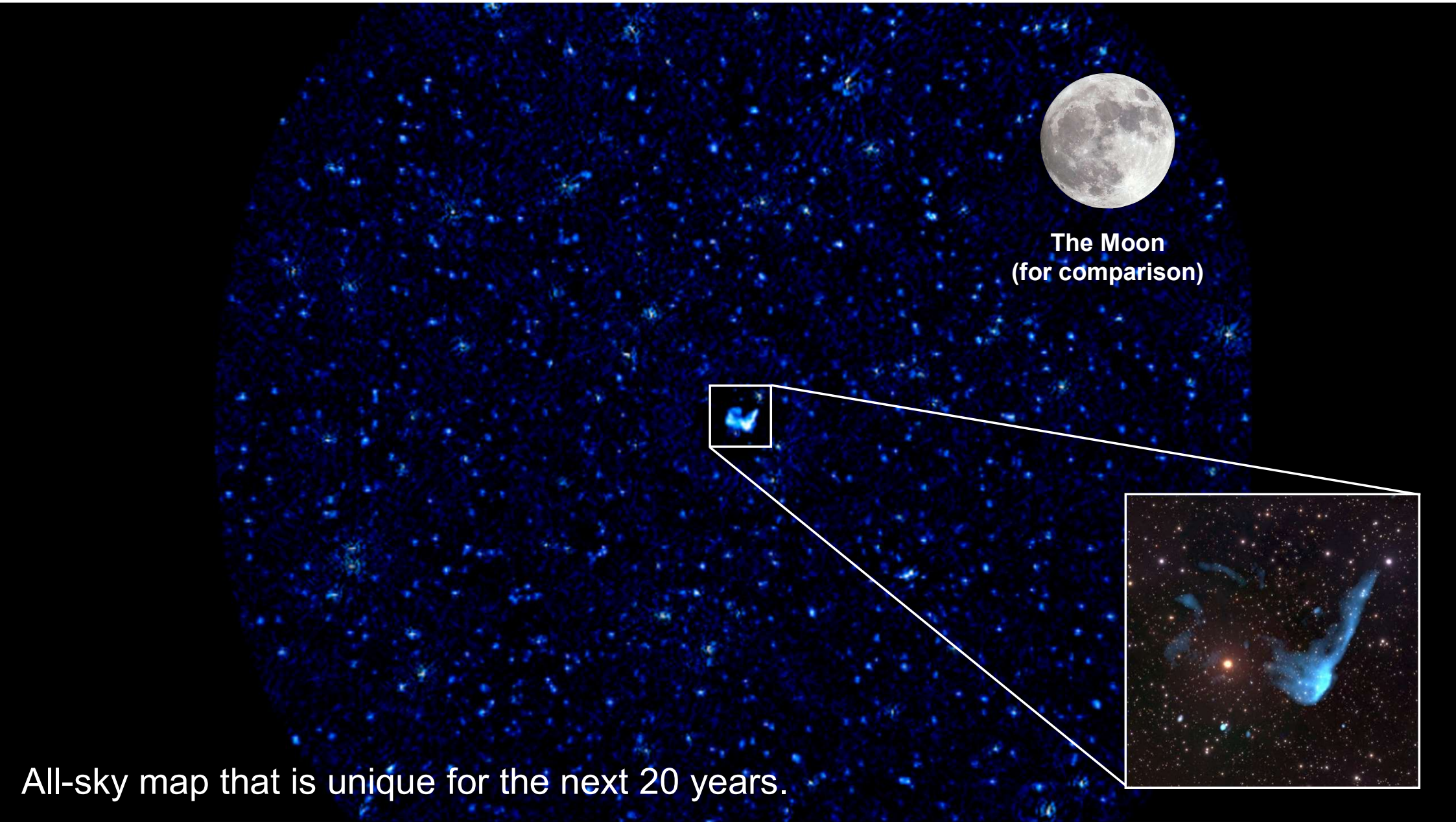




SKA-Low Phase 1

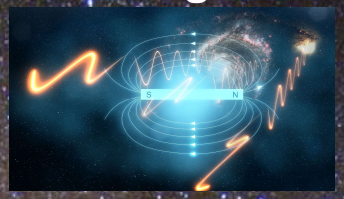
Reaches to 2x higher frequencies

>10x higher collecting area



All-sky map that is unique for the next 20 years.

Cosmic magnetism



Supermassive black holes

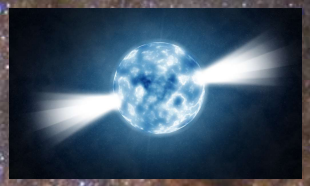
Early Universe

Supernovae

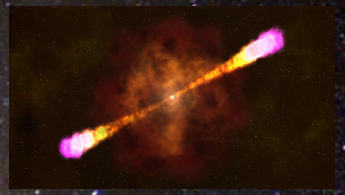
Galaxy clusters

Sun

Pulsars



Gravitational wave events



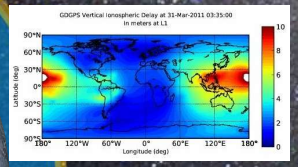
Solar System Planets

Meteors

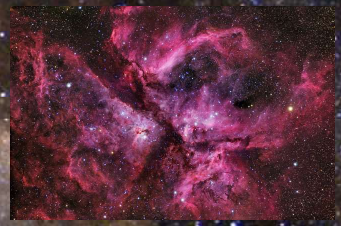
Nearby galaxies

Cosmic rays

Ionosphere

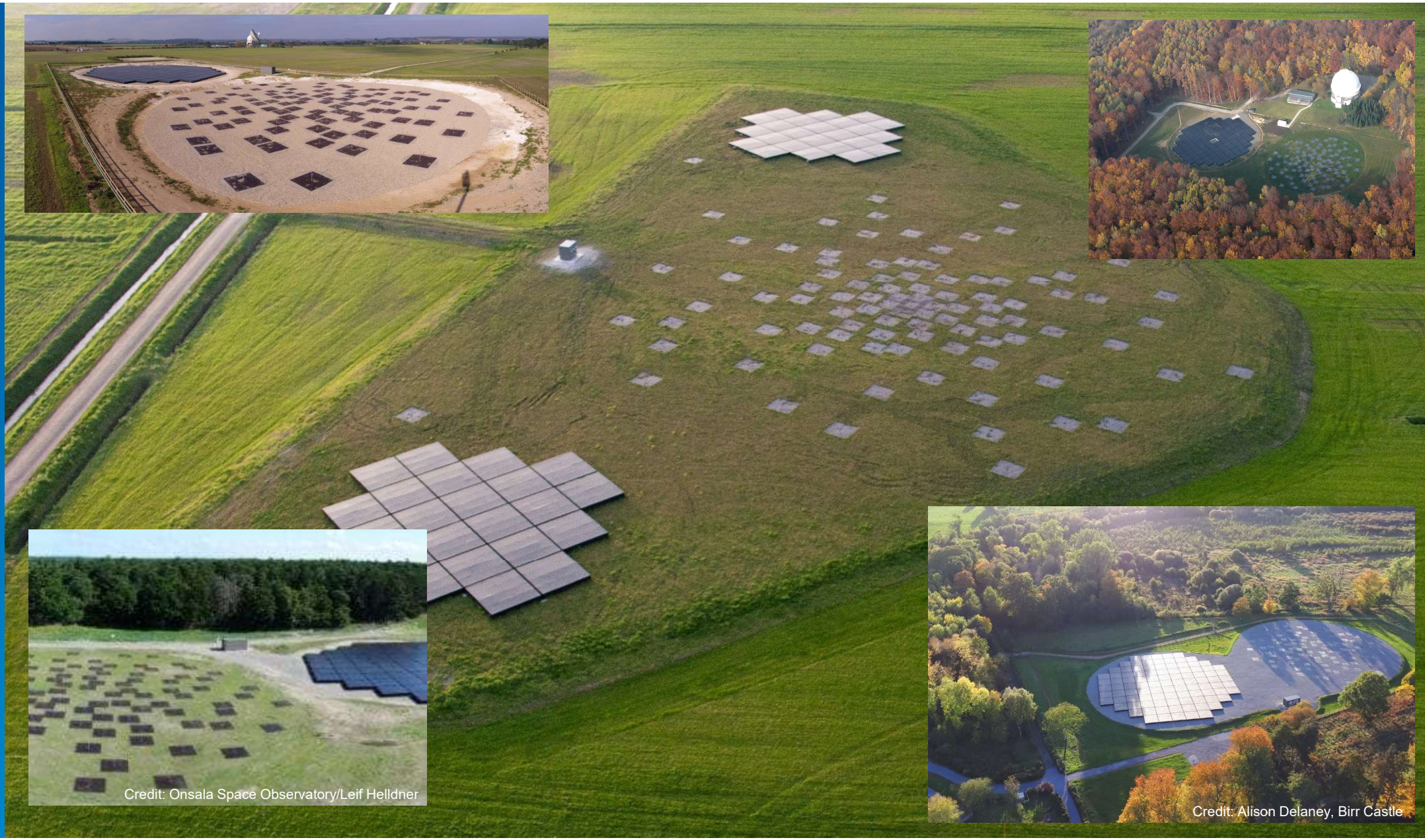


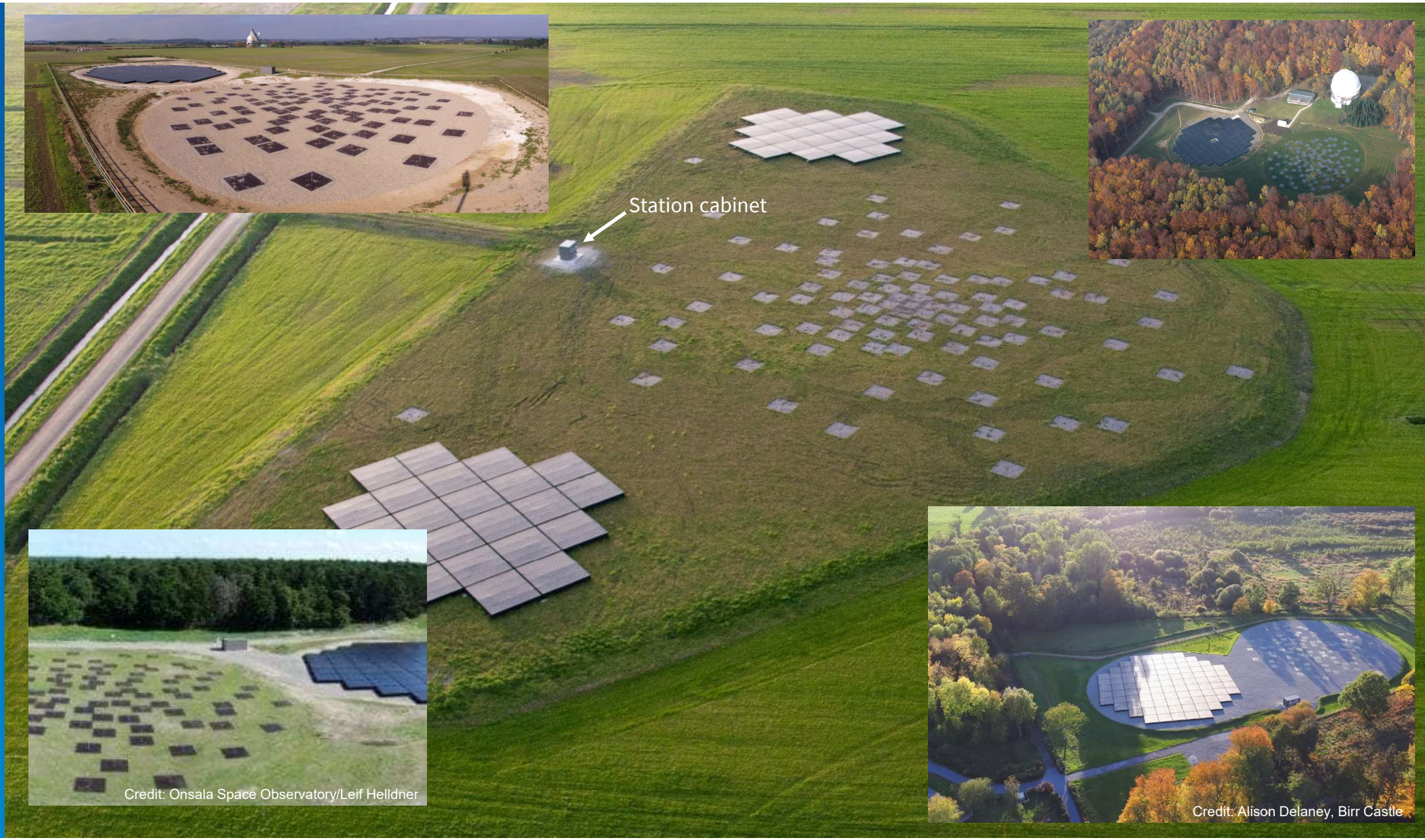
Interstellar medium



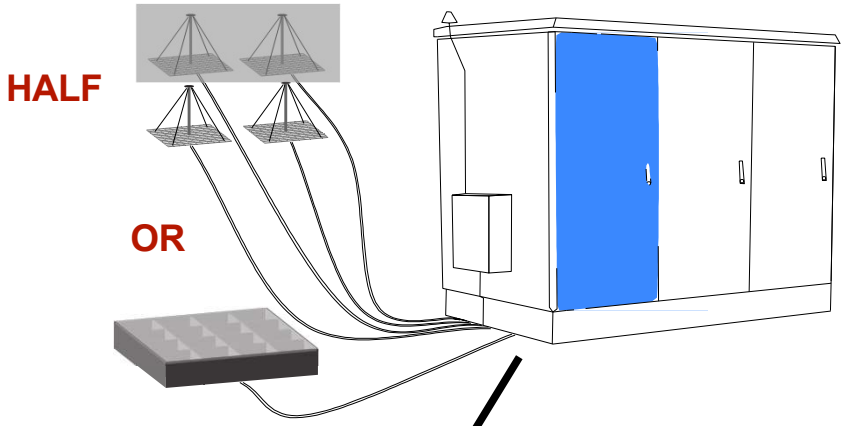
Lightning

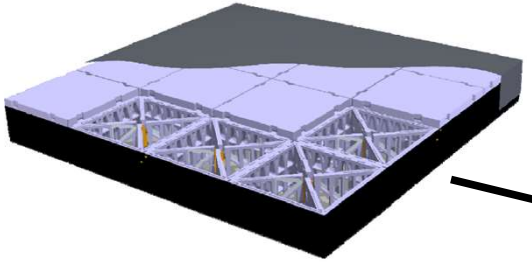
Space weather

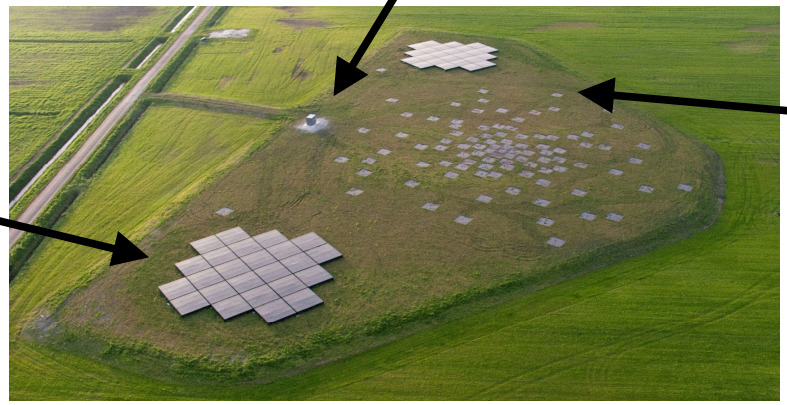

Credit: Onsala Space Observatory/Leif Helldner
Credit: Alison Delaney, Birr Castle

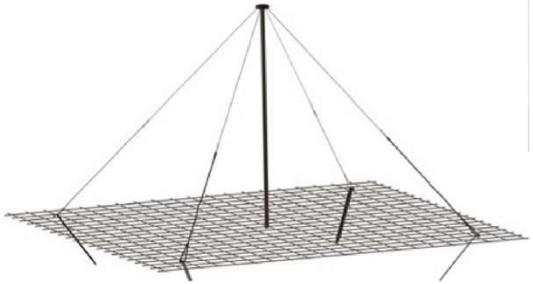

Station cabinet
Credit: Onsala Space Observatory/Leif Helldner
Credit: Alison Delaney, Birr Castle

LOFAR Stations









High-Band Antennas

Frequency = 110-240 MHz

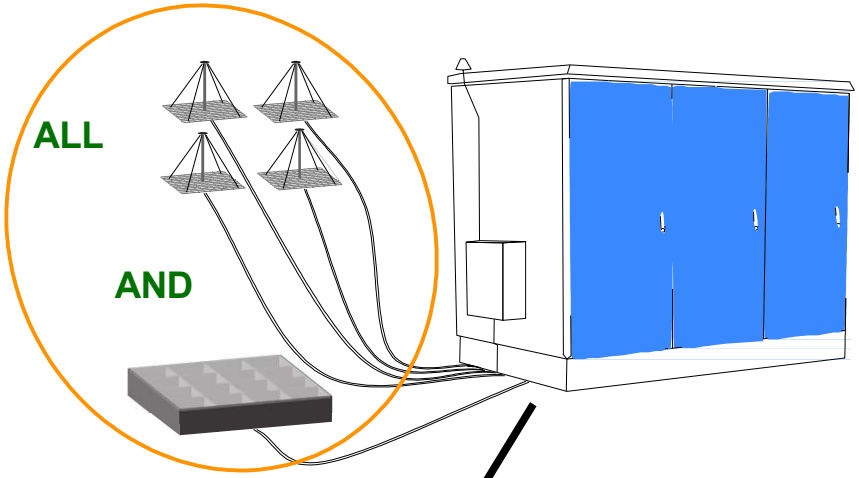
Wavelength = 1-3 metres

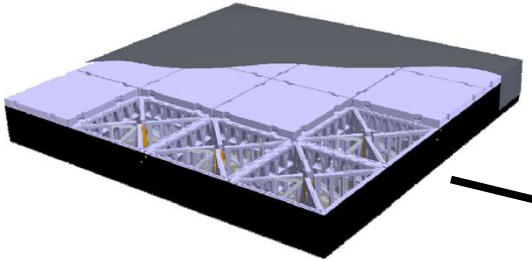
Low-Band Antennas

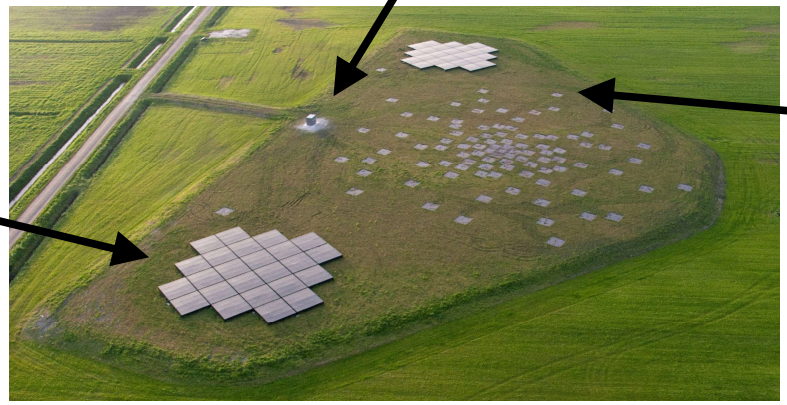
Frequency = 10-90 MHz

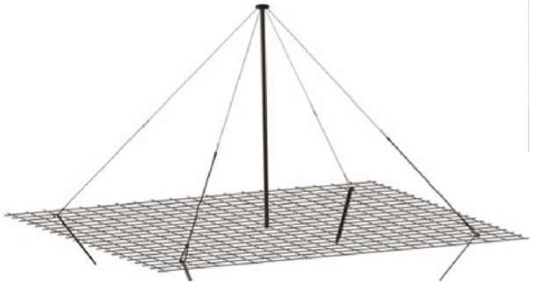
Wavelength = 3-30 metres

LOFAR Stations









High-Band Antennas

Frequency = 110-240 MHz

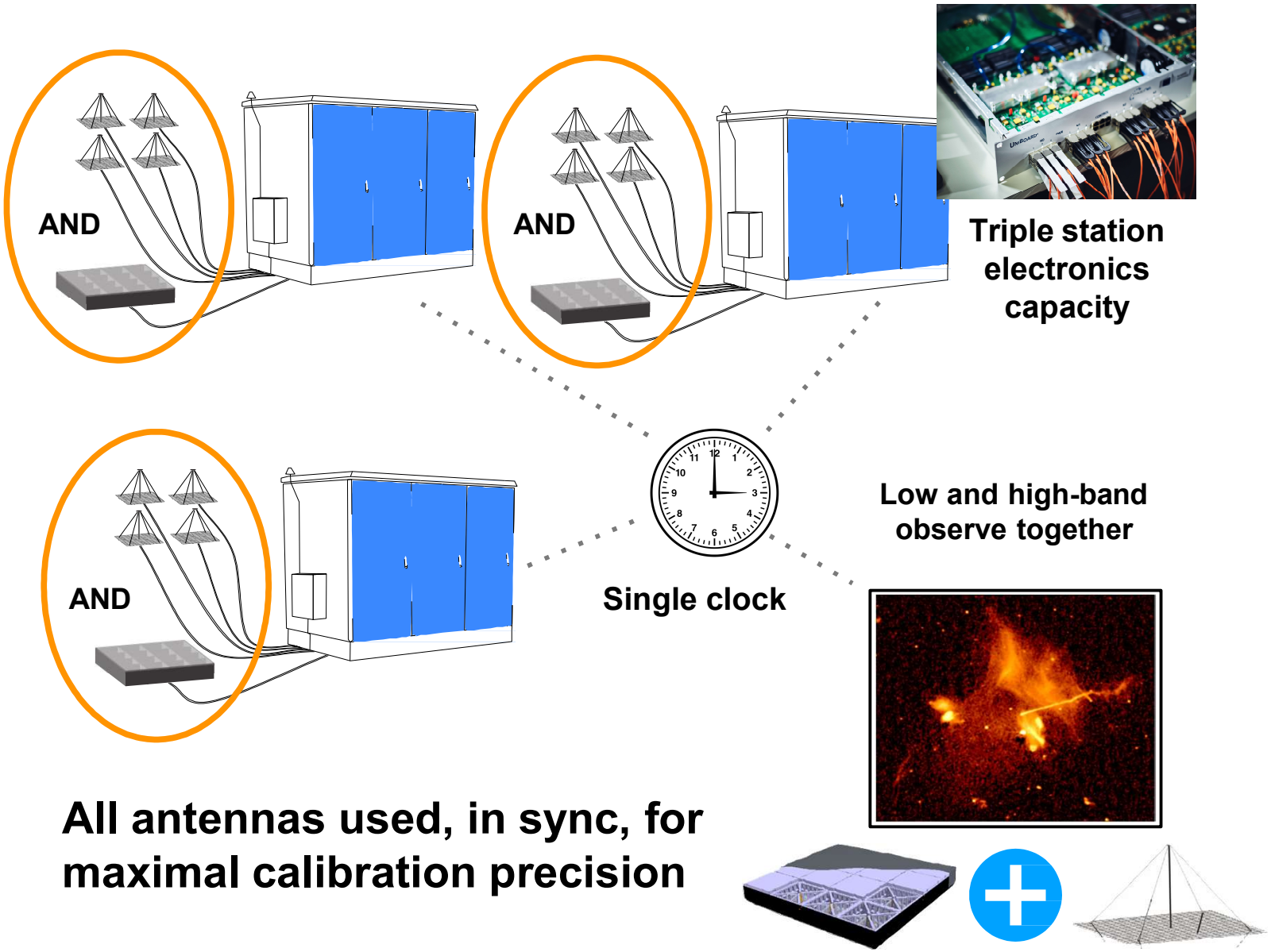
Wavelength = 1-3 metres

Low-Band Antennas

Frequency = 10-90 MHz

Wavelength = 3-30 metres

With LOFAR2.0



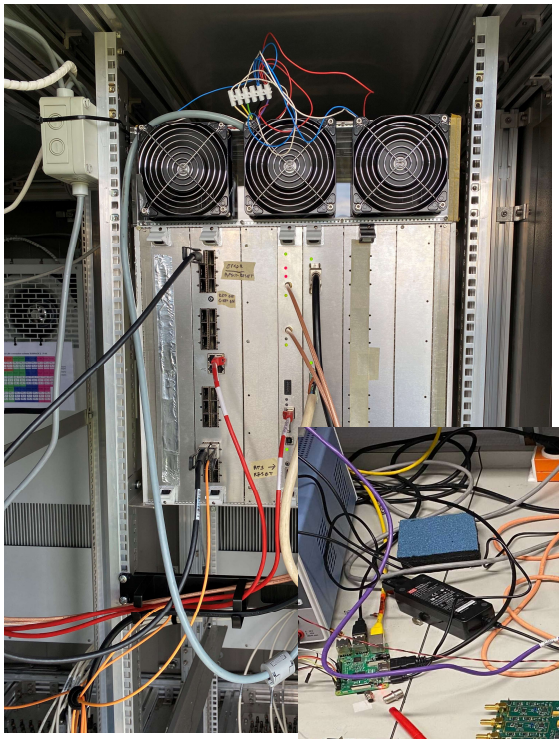
All antennas used, in sync, for maximal calibration precision

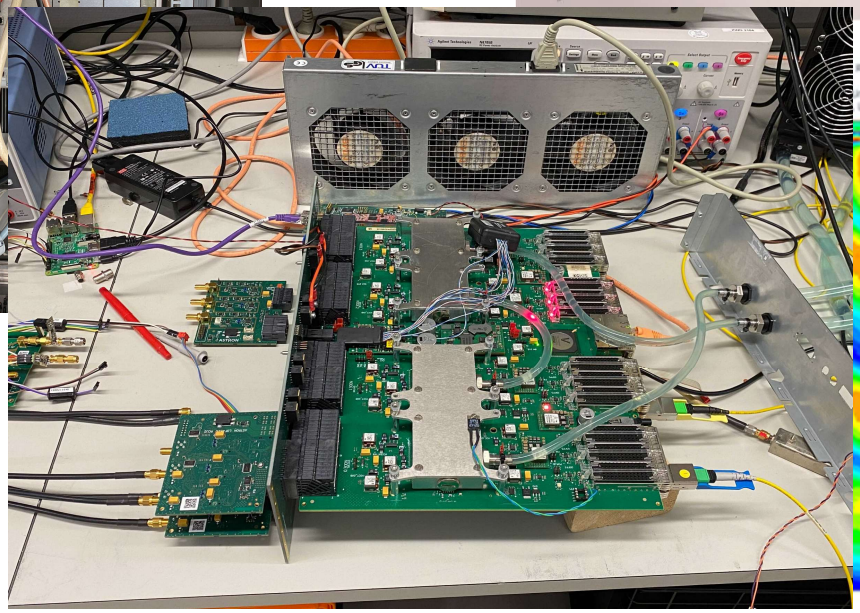
Enabling technologies

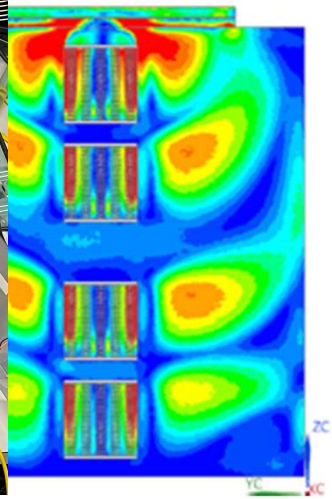
- Higher level of integration (3x more ADC’s in one subrack)
- Higher dynamic range (a.o. from 12 to 14 bits ADC)
- 3-6x more powerful realtime processing in the same cabinets
- Central clock distribution to all NL stations (white rabbit)
- Improved thermal design
- Modernised monitoring and control (TANGO, OPC-UA)
- Dynamic scheduling

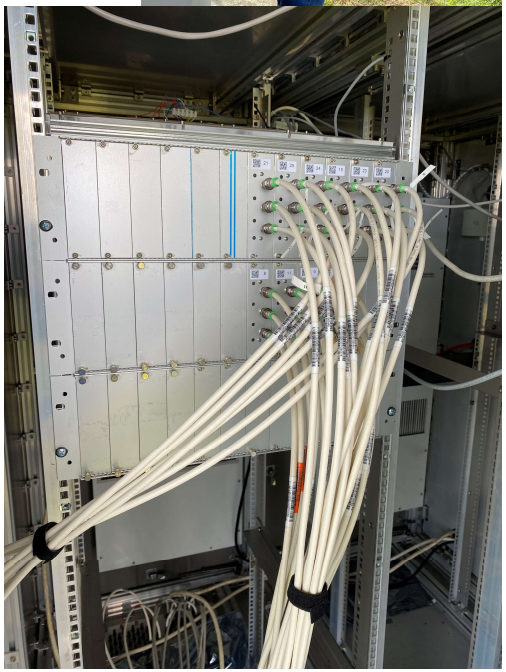
ASTRON
Netherlands Institute for Radio Astronomy

Receivers and processing





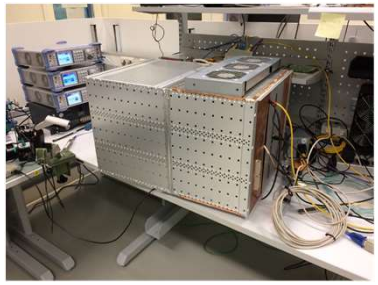




ASTRON
Netherlands Institute for Radio Astronomy

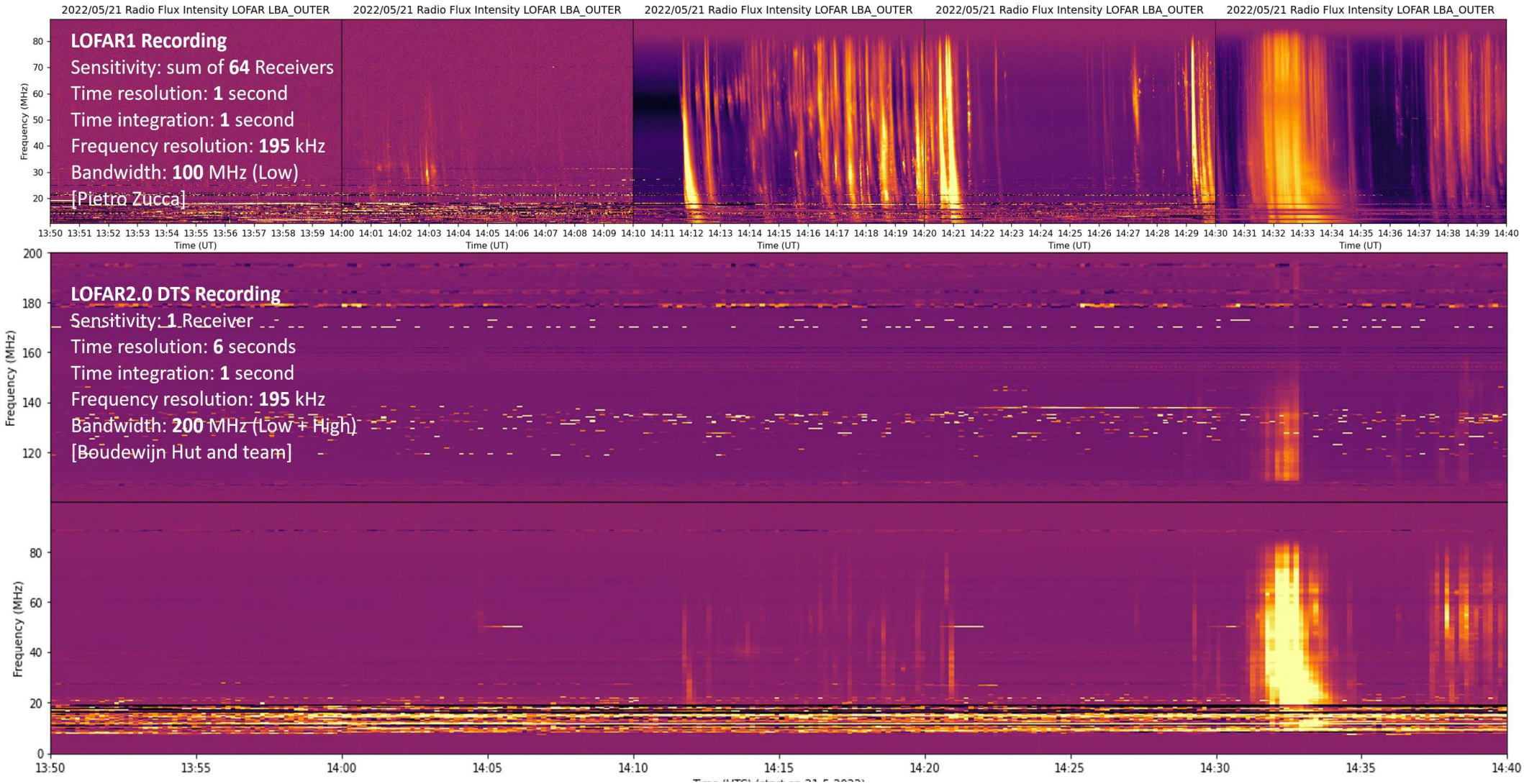
LOFAR2.0 Test Stations

- ✓ **Lab Test station (LTS)**
  - Test pcb's and interfaces
- ✓ **Dwingeloo Test Station (DTS)**
  - ✓ Cabinet thermal tests
  - ✓ Test complete signal chain (antenna to station output)
  - ✓ Monitoring and control
- ✓ **LOFAR2.0 Test Station (L2TS)**
  - ✓ CS001 is used as LOFAR2.0 test station from June 2022 (start of cycle 18)
  - ➢ Start with DTS hardware, upgrade to a fully equipped station
  - Full-scale station verification in operational environment



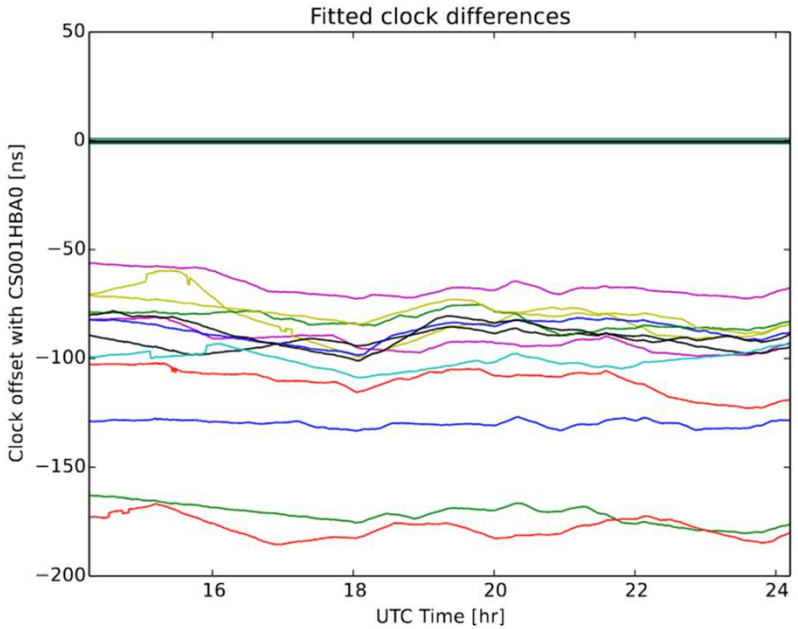
LOFAR

Solar Eruption seen with LOFAR2.0 test station



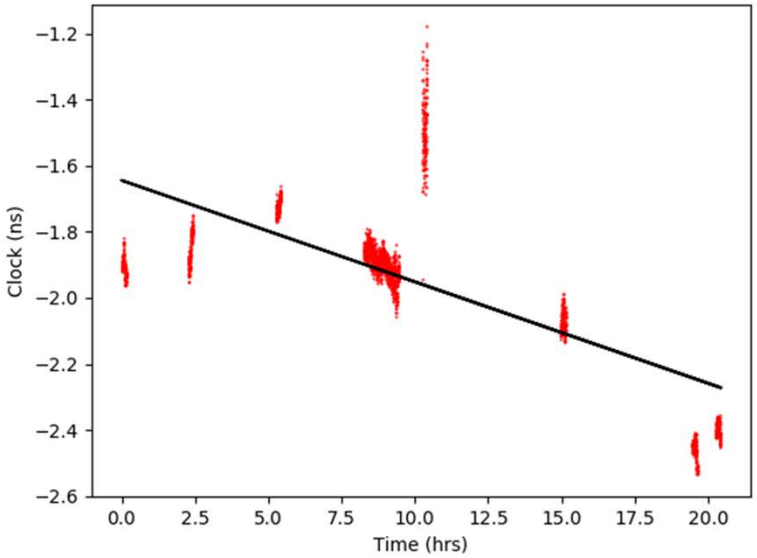
LOFAR2.0 Developments: Timing Distributor

Current LOFAR clock



Van Weeren et al. 2016

With White Rabbit



Tests with WR in RS208HBA and RS307HBA.
Credits: R. Witvers, J. Morawietz, T. Shimwell

✓ Ready to tender!

Timeline

- ✓ 2018 Start of LOFAR2.0 development
- ✓ 2019 Correlator upgrade (COBALT2)
- ✓ 2020 Lab Test Station
- ✓ 2021-2022 Dwingeloo Test Station
- ✓ 2022 LOFAR2.0 Test Station
- 2023 LOFAR2.0 Test Station (full)
- 2024 Start of rollout
- 2025 Operational, with risks (cycle 0)
- 2026+ Full science production

ASTRON
Netherlands Institute for Radio Astronomy