



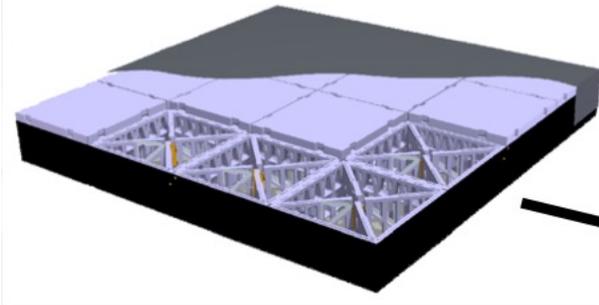
# LOFAR2.0 Science

*Jason Hessels*

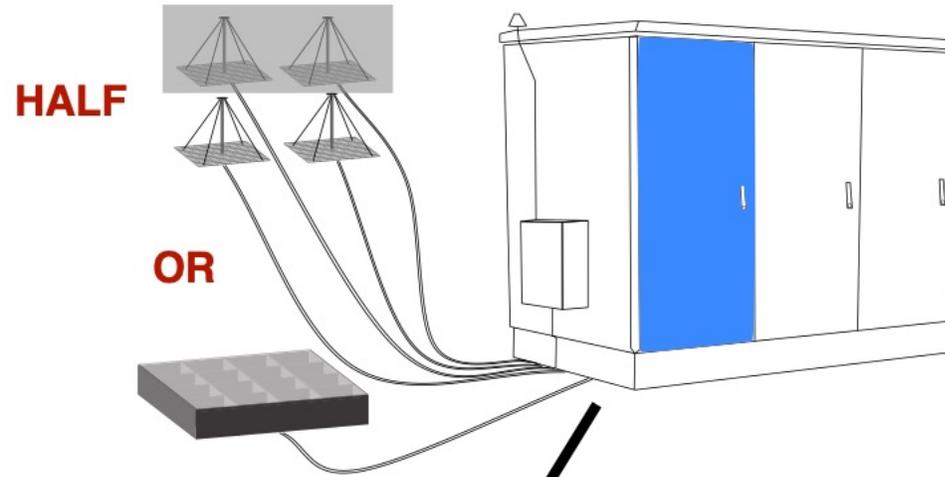
LOFAR2.0 Project Scientist

# LOFAR Stations

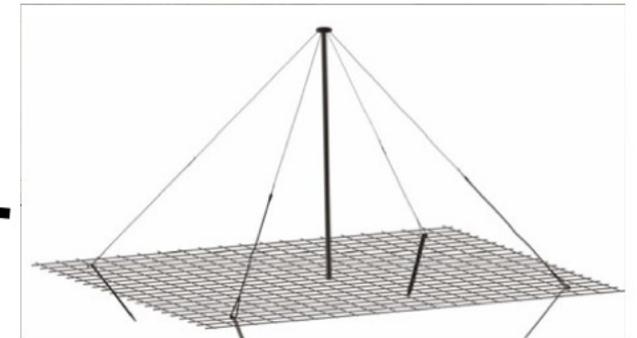
**Robust, full-sensitivity  
imaging**



**High-Band Antennas**  
Frequency = 110-240 MHz  
Wavelength = 1-3 metres



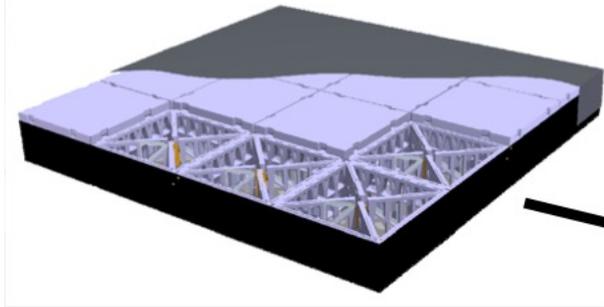
**Sensitivity and  
accuracy limited by  
ionosphere**



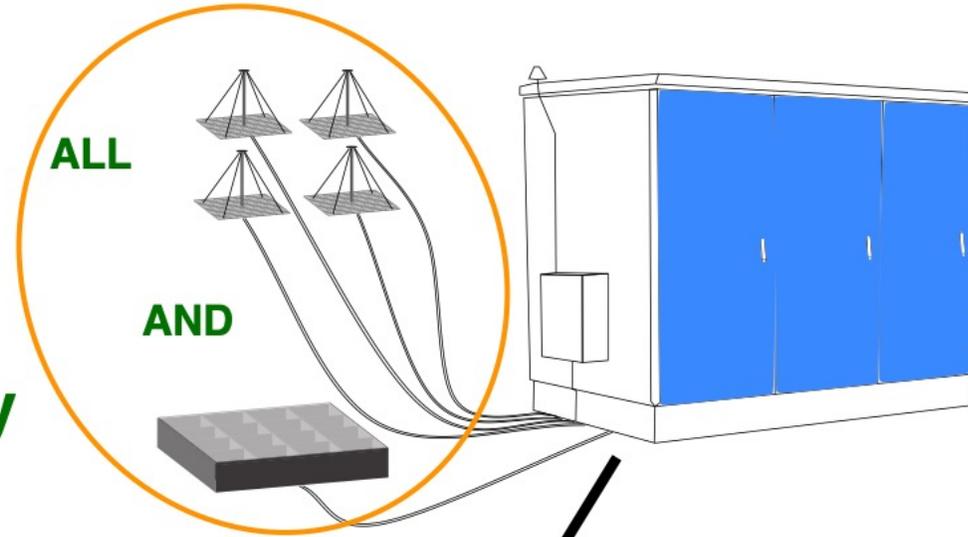
**Low-Band Antennas**  
Frequency = 10-90 MHz  
Wavelength = 3-30 metres

# LOFAR Stations

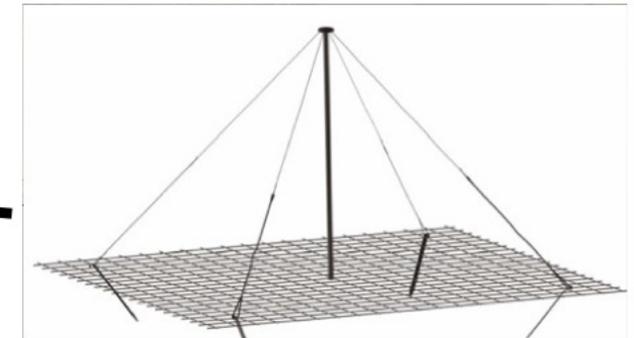
**Robust, full-sensitivity  
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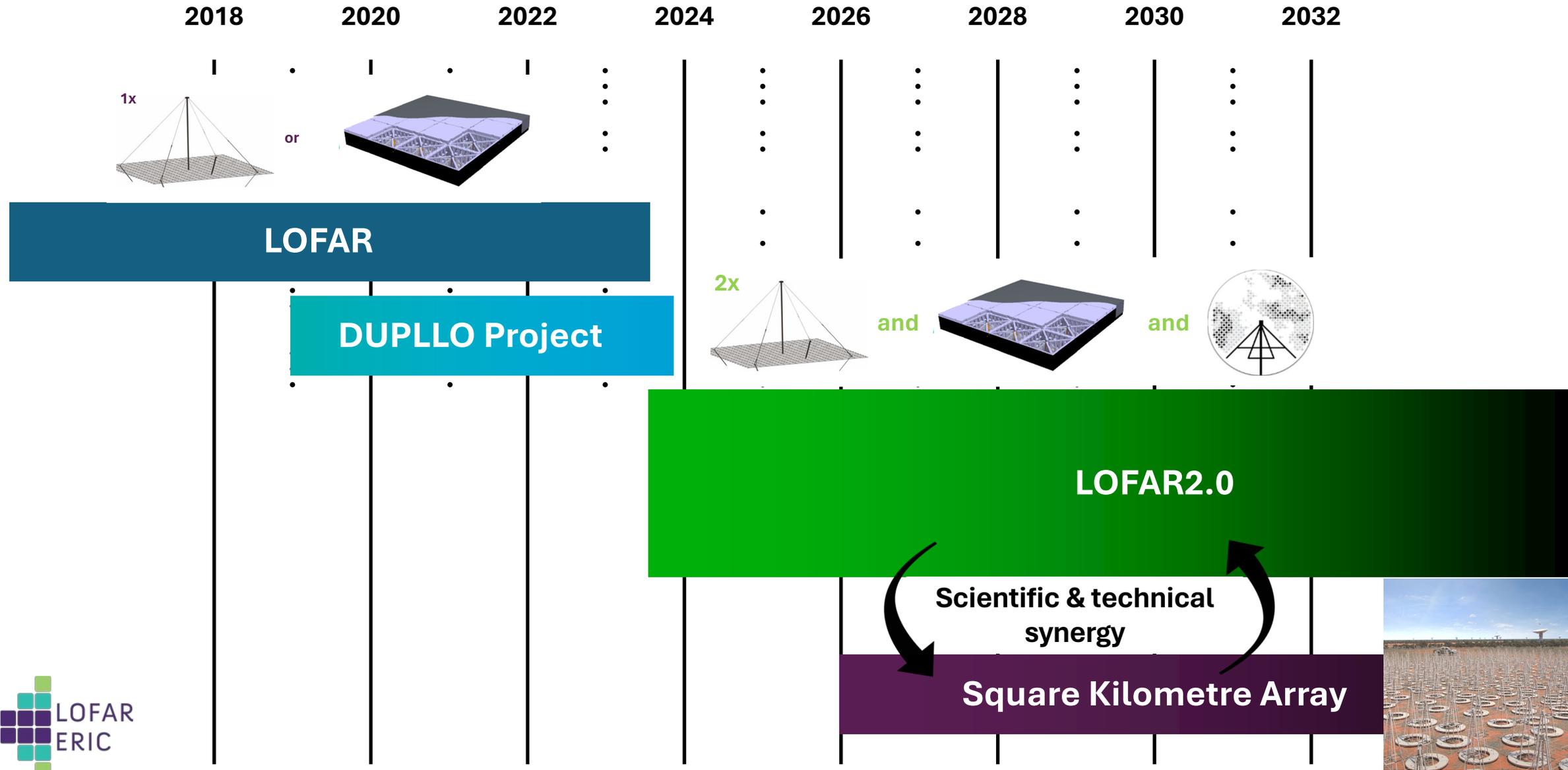


**Robust, full-sensitivity  
imaging**



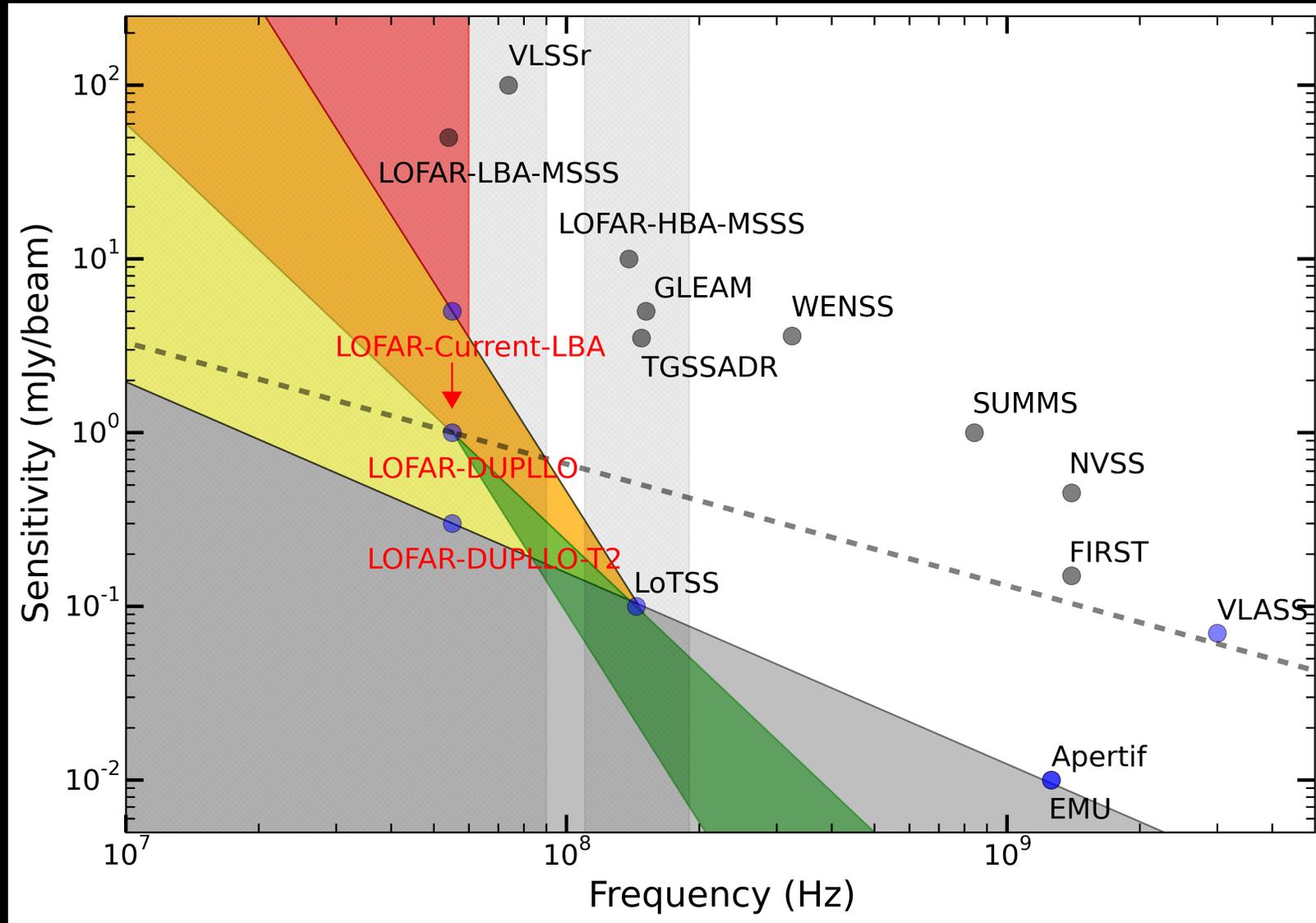
**Low-Band Antennas**  
Frequency = 10-90 MHz  
Wavelength = 3-30 metres

# Timeline





# Parameter space

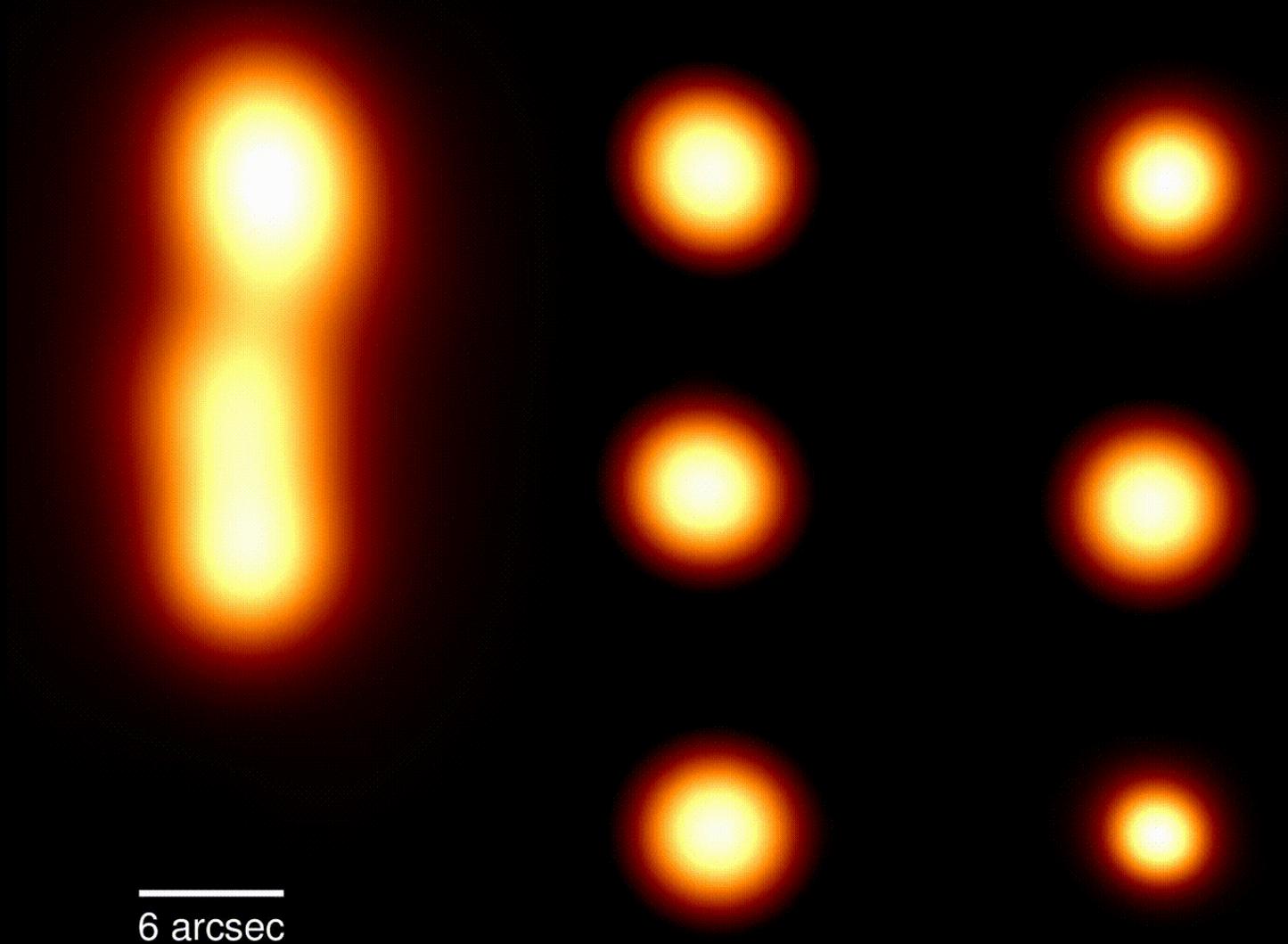


# Observing capabilities

Ultra-low radio frequencies

# Observing capabilities

(sub-)arcsecond angular resolution



6 arcsec

# Observing capabilities

High time resolution





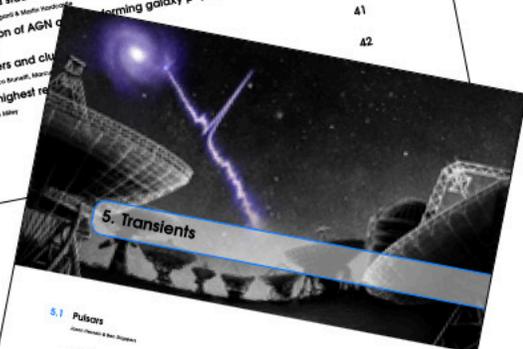
# LOFAR2.0 Science White Paper



## Contents

Science Cases	
1	What is LOFAR2.0? ..... 9
2	Atmospheric & ionospheric science ..... 17
2.1	Lightning ..... 17
2.2	Meteor showers ..... 18
2.3	The ionosphere ..... 19
3	Our Solar System ..... 21
3.1	The Sun ..... 21
3.2	The heliosphere & space weather ..... 22
3.3	Planetary radio emission ..... 23
4	The Milky Way ..... 25
4.1	Stellar, brown dwarf, and star-planet interaction radio emission ..... 25
4.2	Exoplanets ..... 26

4.3	Supernova remnants ..... 26
4.4	Pulsar wind nebulae ..... 27
4.5	The life cycle of the interstellar medium ..... 28
5	Transients ..... 31
5.1	Pulsars ..... 31
5.2	Fast radio bursts ..... 32
5.3	EM counterparts to gravitational wave events ..... 33
5.4	GRB afterglows ..... 33
5.5	Exploring the transient parameter space ..... 35
6	Cosmic rays ..... 35
6.1	Galactic cosmic rays ..... 35
6.2	Ultra-high-energy cosmic rays ..... 37
7	Cosmic Magnetism ..... 37
7.1	The magnetized Milky Way ..... 37
7.2	Magnetic fields in other galaxies ..... 37
7.3	The magnetised cosmic web ..... 39
8	Extragalactic astrophysics & cosmology ..... 39
8.1	Nearby galaxies ..... 40
8.2	Detailed studies of low-redshift AGN and AGN physics ..... 41
8.3	Evolution of AGN ..... 41
8.4	Clusters and clusters ..... 42
8.5	The highest redshift ..... 42



**5.1 Pulsars**  
Pulsars are highly magnetized neutron stars that produce beams of radio waves that sweep across the sky like a cosmic lighthouse. These radio pulsations allow us to study the properties and evolution of massive stars, which are some of the most extreme objects in the Universe. Using the technique of pulsar 'timing', we can detect gravitational waves, constrain the neutron star equation of state and its ability to provide a source of high-frequency waves for the lowest 4 octaves of the radio band, and its ability to provide a source of high-frequency waves for the lowest 4 octaves of the radio band, and its ability to provide a source of high-frequency waves for the lowest 4 octaves of the radio band.

**Highlight 13** LOFAR has discovered both the fastest- and slowest-rotating radio pulsars in the Galactic field.

With LOFAR2.0 we will perform an ultra-deep pulsar survey by targeting compact, highly polarized sources found in LOFAR imaging surveys like LoTSS. We aim to find the most energetic pulsars, and to use them as probes of gravity and dense matter physics. The NL single-dish imaging surveys. The LOFAR stations, especially the large international stations, are sensitive to their own right. By using sub-arrays, we can also monitor dozens of pulsars in parallel and use these pulsar timing data to measure antenna star orbits, probe the interstellar medium, and measure the density and magnetization of the solar wind (see also §1.2).

# LOFAR2.0 Large Programmes



LOFAR ERIC

Low Frequency Array

LOFAR is the largest and most sensitive radio telescope operating at low radio frequencies, between 10 and 240 MHz. It consists of antenna stations geographically distributed across Europe and driven in software by powerful station-level computing to produce a highly flexible and agile observing system. With a sensitivity more than 2

Deadline: October 12th, 2023 at 12:00 UTC

# LOFAR2.0 Large Programmes

- **15 full proposals**

- From dozens of PIs and hundreds of co-Is, spanning the LOFAR partner countries

- **Diverse topics**

- Lightning, star-formation, SNRs, transients, cosmic rays, deep surveys, cosmology, galaxy clusters, Sun & heliosphere, exoplanets, pulsars & FRBs, magnetism

- **All together a (very) ambitious programme**

- Can only come to fruition by working together

Submission: LOFAR2.0 Large Programmes – Full proposal

## LOFAR2.0 Pulsar & Fast Transient Surveys

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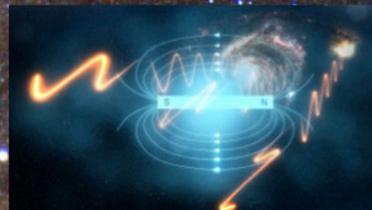
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<sup>22</sup>MIT Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA



# LOFAR

## Cosmic magnetism



## Supermassive black holes



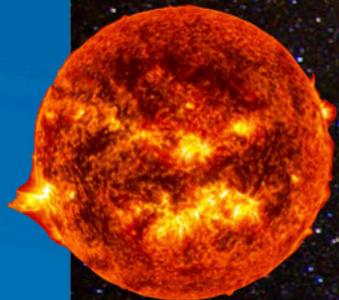
## Early Universe

## Supernovae



## Galaxy clusters

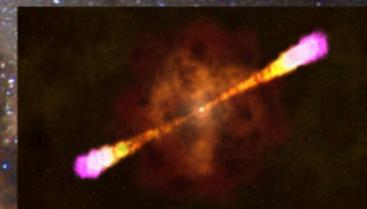
## Sun



## Pulsars



## Gravitational wave events



## Solar System Planets



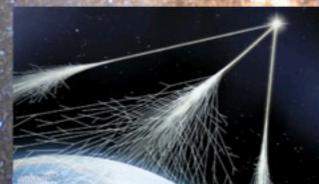
## Meteors



## Nearby galaxies



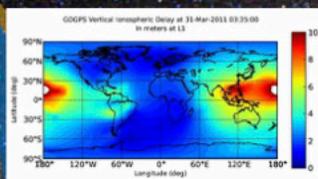
## Cosmic rays



## Interstellar medium



## Ionosphere



## Fast radio bursts



## Lightning



## Space weather



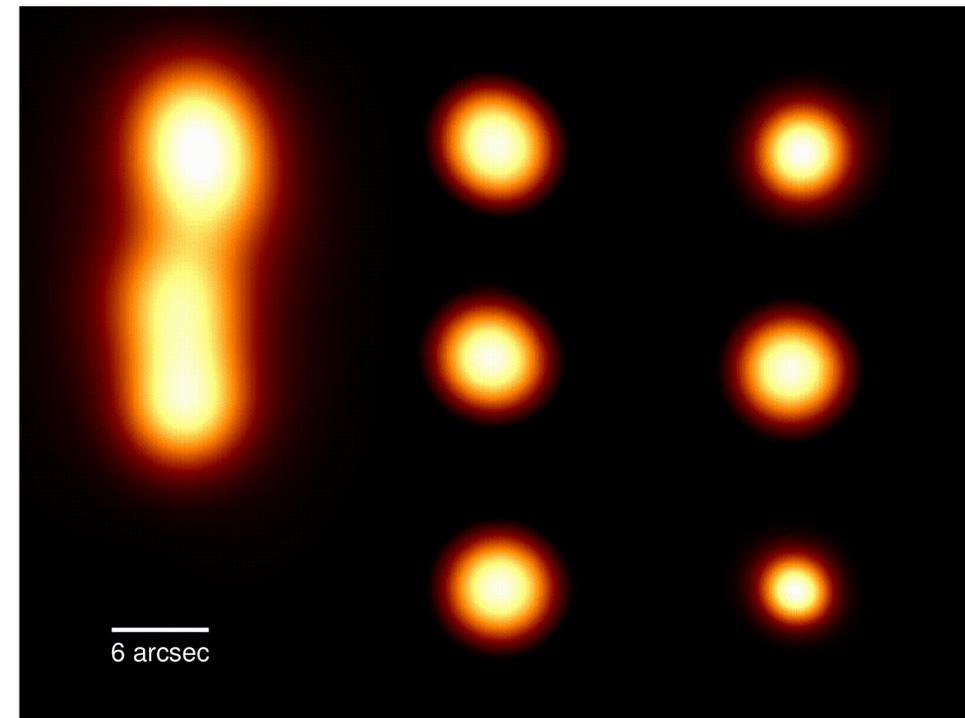
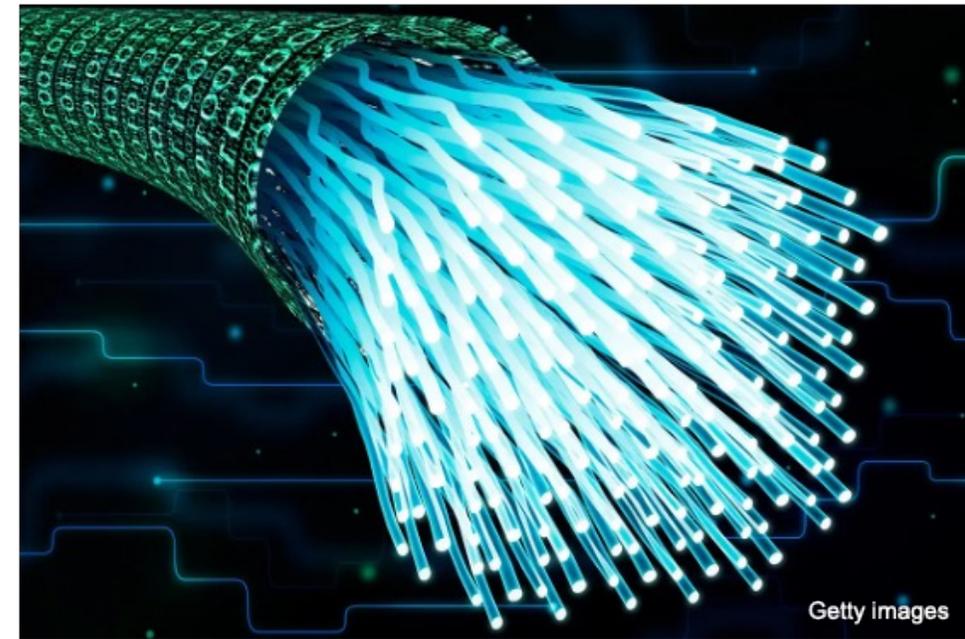
# Firehose rodeo with LOFAR2.0



Inspired by Daniela Huppenkothen

# LENSS - LOFAR Enhanced Network for Sharp Surveys

- Community consultations in NL and with LOFAR partners
- Where can we have a large and unique impact in the coming decade?
- 2024: NWO-RI for upgraded network (10→100Gb/s) and full-FoV, full-res imaging
- 2026: NWO-Roadmap focusing on ultra-low frequencies?



# LOFAR2.0 Large Programmes

## Success Criteria

- **Scientific impact**
  - Publications, citations, theses, prizes, grants
- **Technical impact**
  - Techniques, software
- **Community impact**
  - Partner countries & institutes, support ECRs, develop SKA leadership roles
- **Accessibility & legacy**
  - Data reuse, distilled data products
- **Visibility**
  - Make LOFAR better known to other astronomers, policy makers, the public

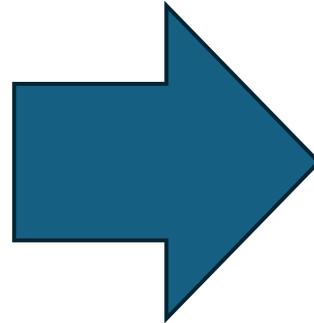


# LOFAR2.0 Commissioning

## Seeds



Hardware   Science ideas   Computing  
Software   Algorithms   Expertise



## Harvest

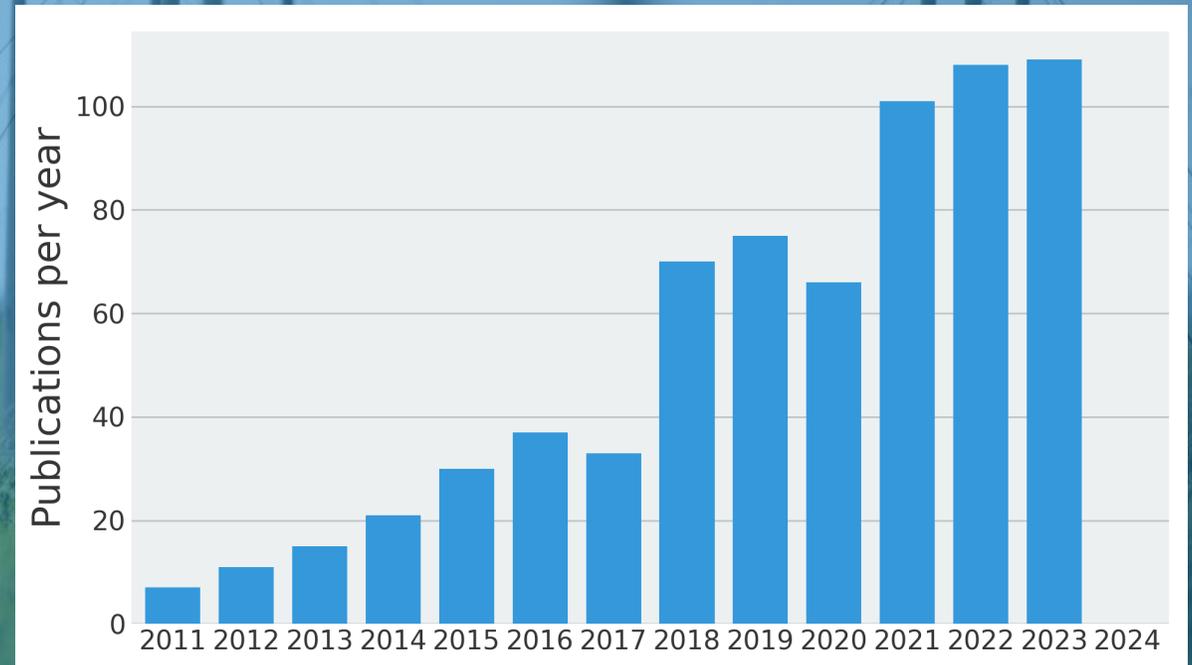
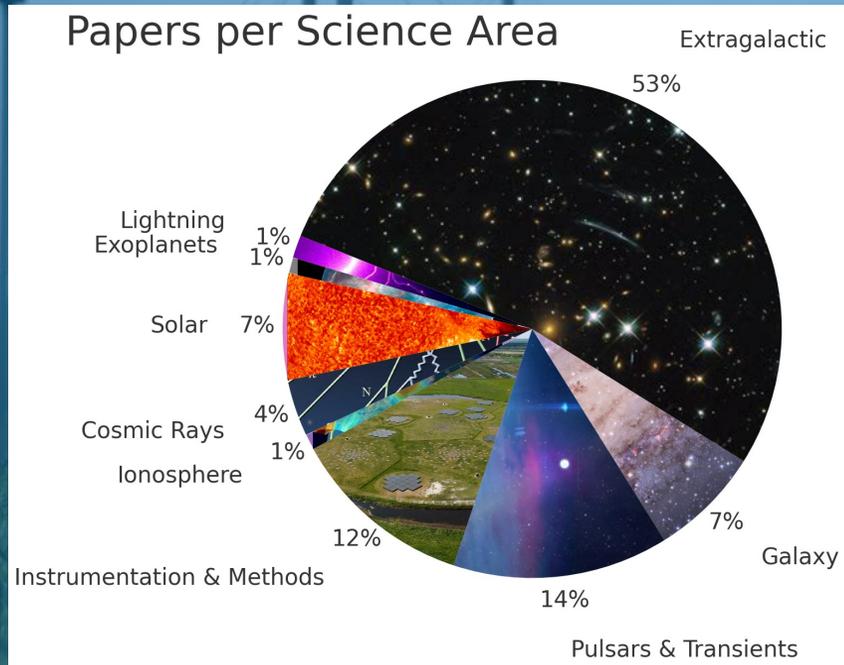


Published papers   New scientific directions  
Press releases   New technical innovations

**ASTRON**

Netherlands Institute for Radio Astronomy

# Impact of LOFAR2.0



**Major new suite of science at a fraction of the original investment in LOFAR**