NenuFAR*:
a giant low-frequency radio telescope in Nançay

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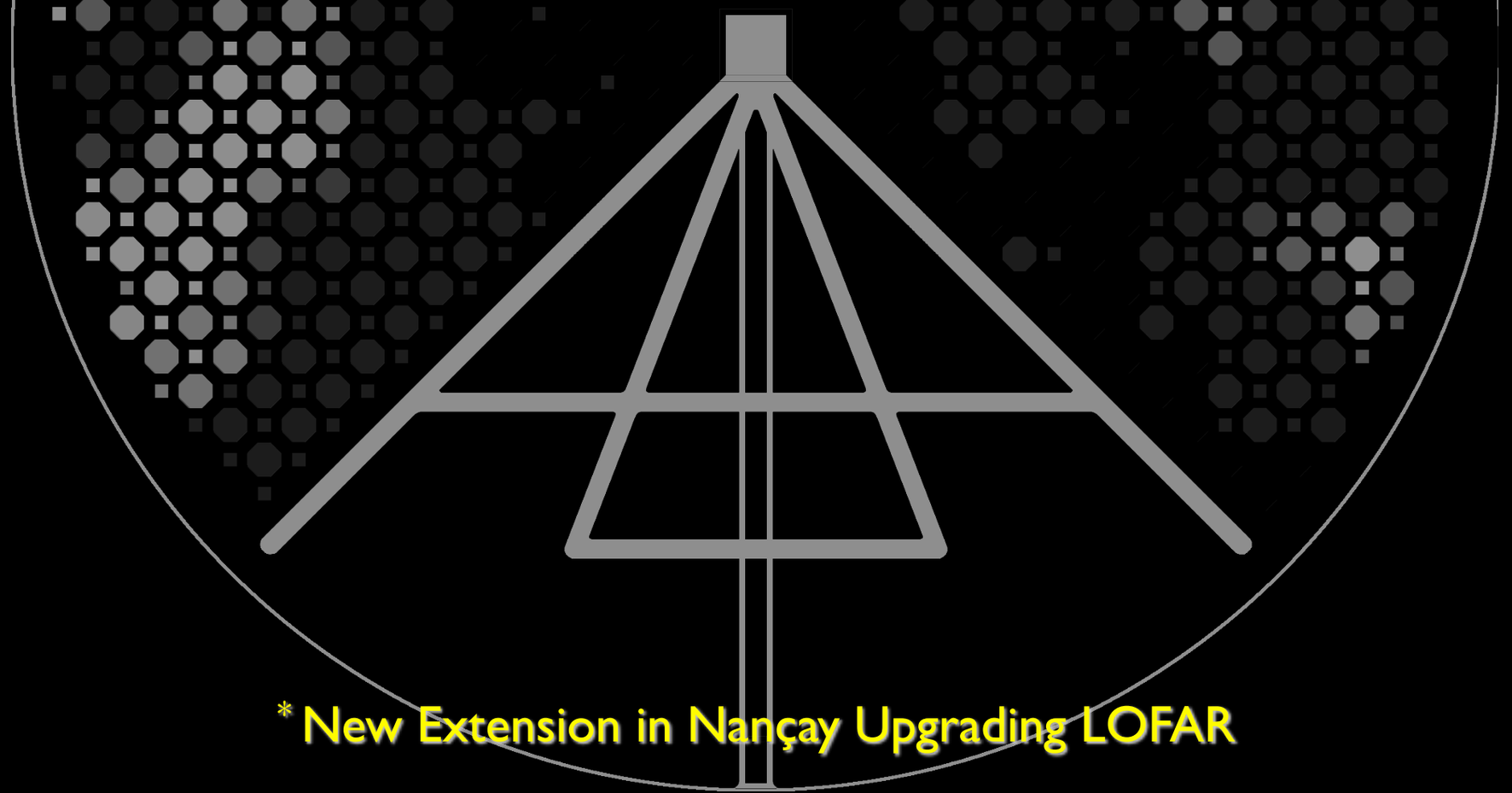
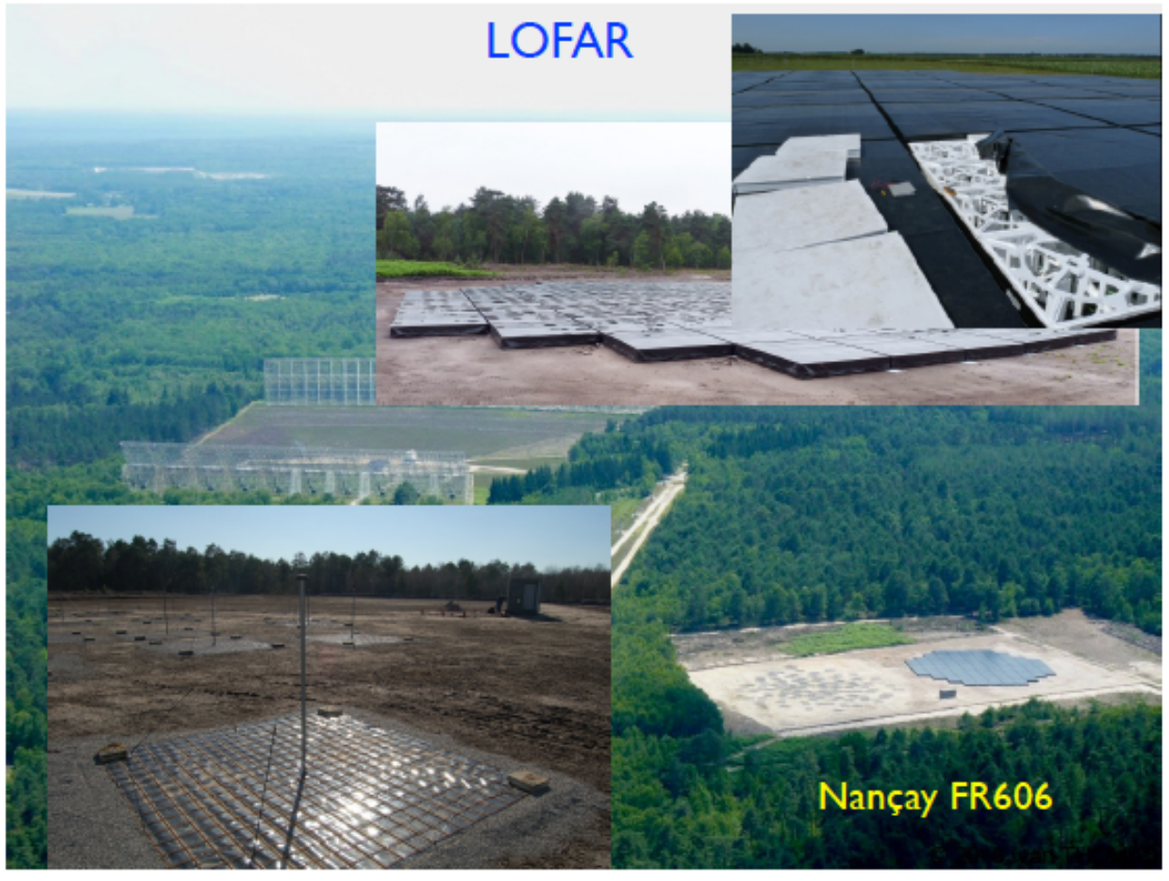
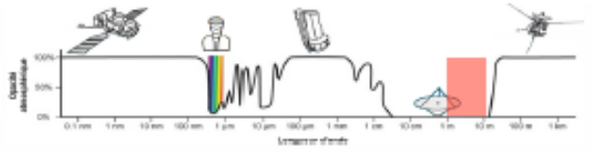
[4]+GEPI, Subatech, CEA/AIM, OCA, ONERA, LERMA, PRISME, APC…



* New Extension in Nançay Upgrading LOFAR

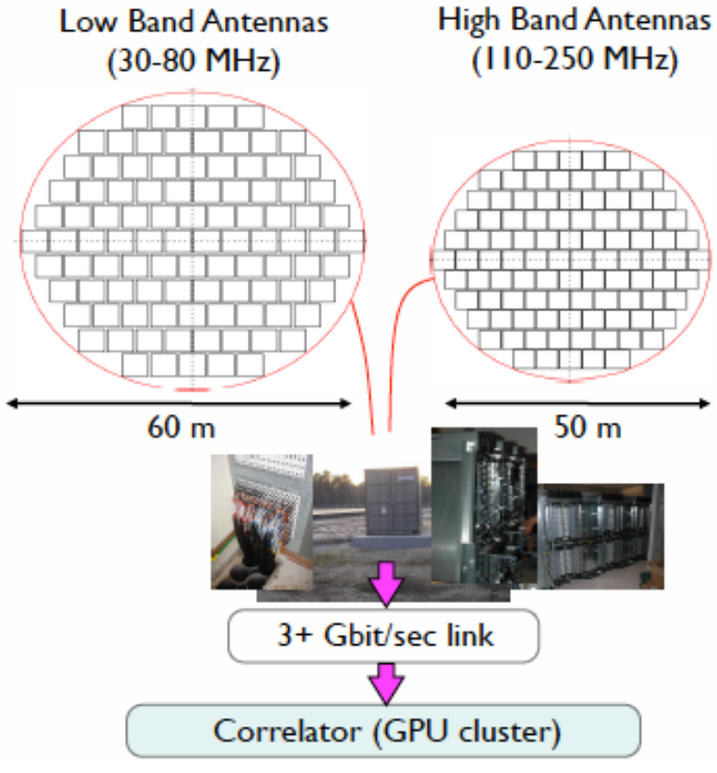


LOFAR
a hierarchical array



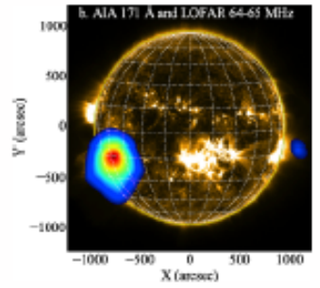
- 1824 Dutch + 1248 International LBA antennas / HBA tiles
- Imaging, Tied-Array Beam, Waveform snapshots

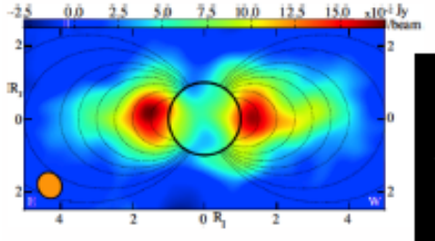
LOFAR station

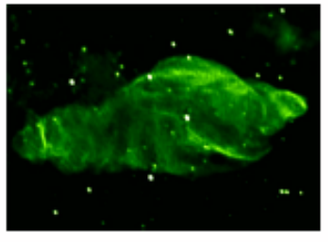


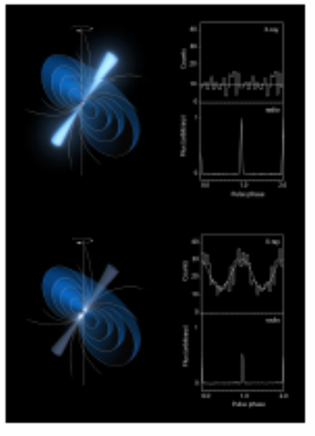
Science with LOFAR

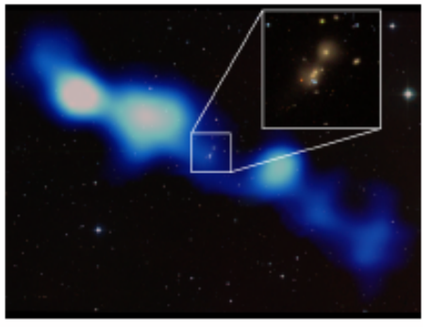
- Cosmology, Reionization
- Surveys, galaxies, clusters, star formation
- Transients (pulsars, stars, planets …)
- Cosmic Rays
- Magnetism
- Solar / space physics

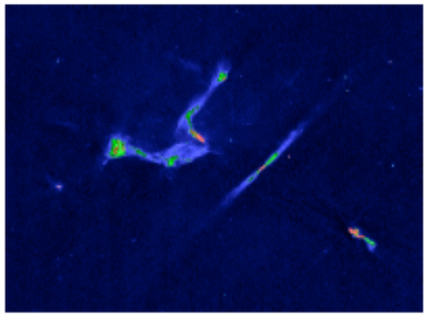












Other modern radio arrays

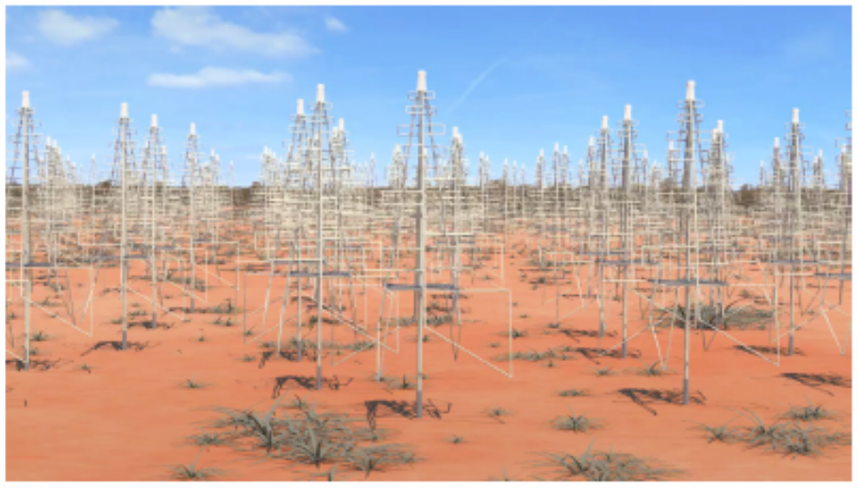
AARTFAAC (NL) : correlation of the 288 individual antennas of the LOFAR superterp, Ø=300 m, all-sky imager

LWA & OLWA (USA) : 256 antennas, Ø=100 m, 10-88 MHz, beam former and imager in 8-16 MHz bandwidth (+ waveform snapshots)

MWA (Australia) : 2048 antennas (128 tiles), Ø=3 km, 80-300 MHz, imager in 30 MHz bandwidth

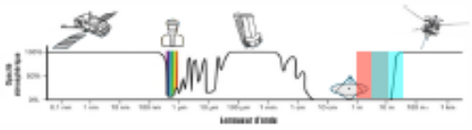
Toward the SKA

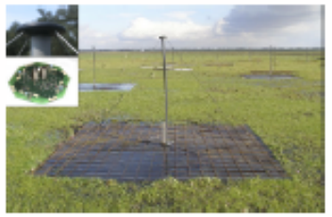
SKA-Low (Australia) : 130000 antennas (in phase 1), Ø=50 km, 50-600 MHz, imager, full bandwidth

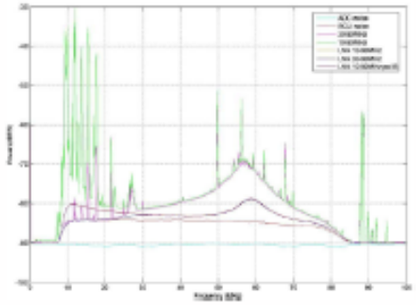


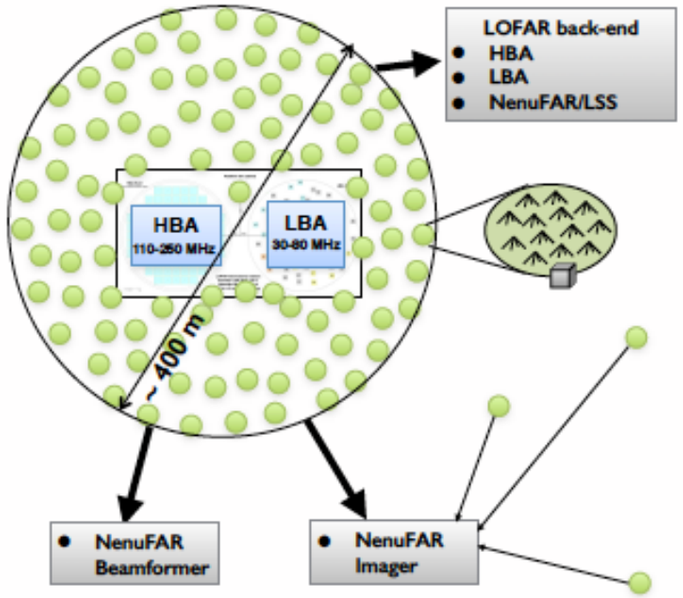
Motivations for NenuFAR

- Improve LBA response
- Sensitivity at low frequencies (→10 MHz)
- Large compact beamformer + extensions (imaging)
- LOFAR compatible
- *Large programs*
- *Training radio community → SKA*
- *Preserve/develop instrumental expertise*

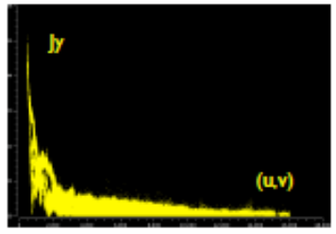


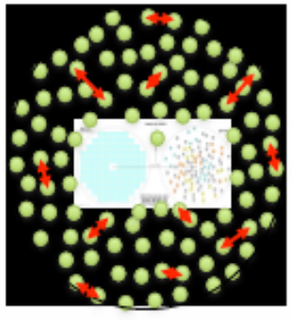






What NenuFAR will bring



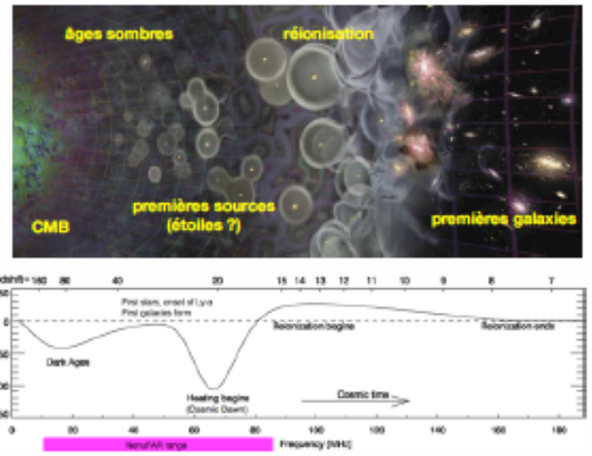


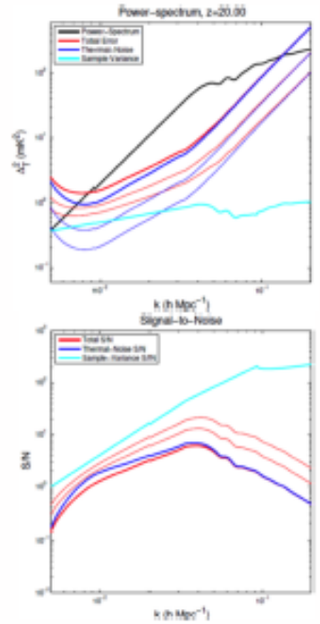
NenuFAR/Lofar Super Station :
- ~4x more sensitive long baselines (2nd LOFAR core)
  → ~10x more calibrators, better high res. imaging
- global LOFAR LBA sensitivity x 2
- short baselines (within LSS)
  → large scale structures (>10°)

NenuFAR/Standalone :
- high sensitivity in LBA range, down to ~10 MHz
- very broad instantaneous bandwidth
- imaging & beam forming
- large duty-cycle

The Science of NenuFAR

- Standalone Imaging (multi-λ rotational synthesis) : *Dark Ages/Cosmic Dawn*

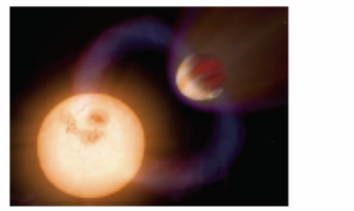


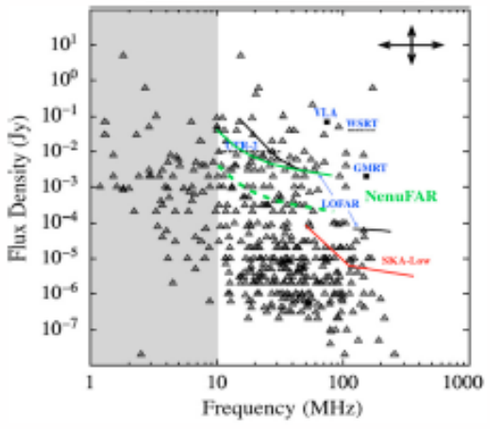


[Koopmans et al.]

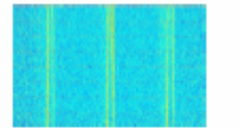
The Science of NenuFAR

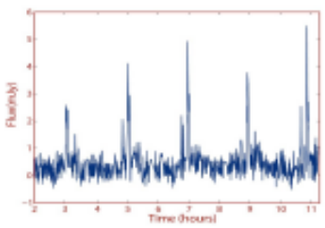
- Standalone Beamformed/Fast imaging : *Exoplanets, Star-Planet plasma interactions, Flaring/Dwarf/Cool stars*



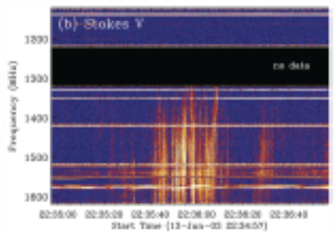


[Zarka et al., 2015]





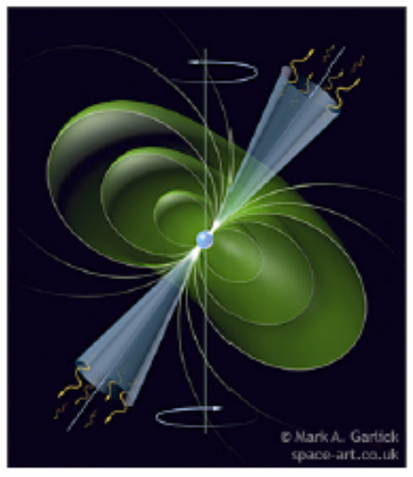
[Hallinan et al., 2007-8]

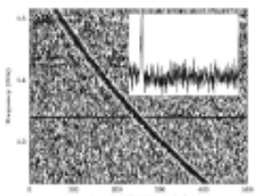


[Osten et al.]

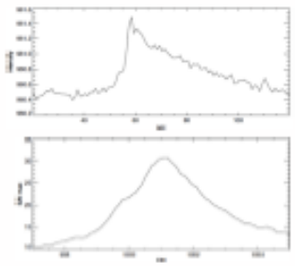
The Science of NenuFAR

- Standalone Beamformed/Fast imaging : *Pulsars searches/studies, fast astrophysical transients (giant pulses, RRATs, FRBs)*

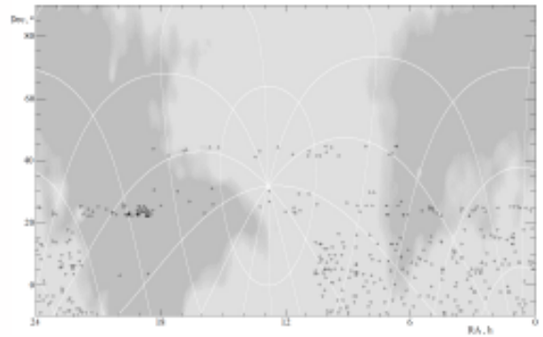




[Lorimer et al., 2007]

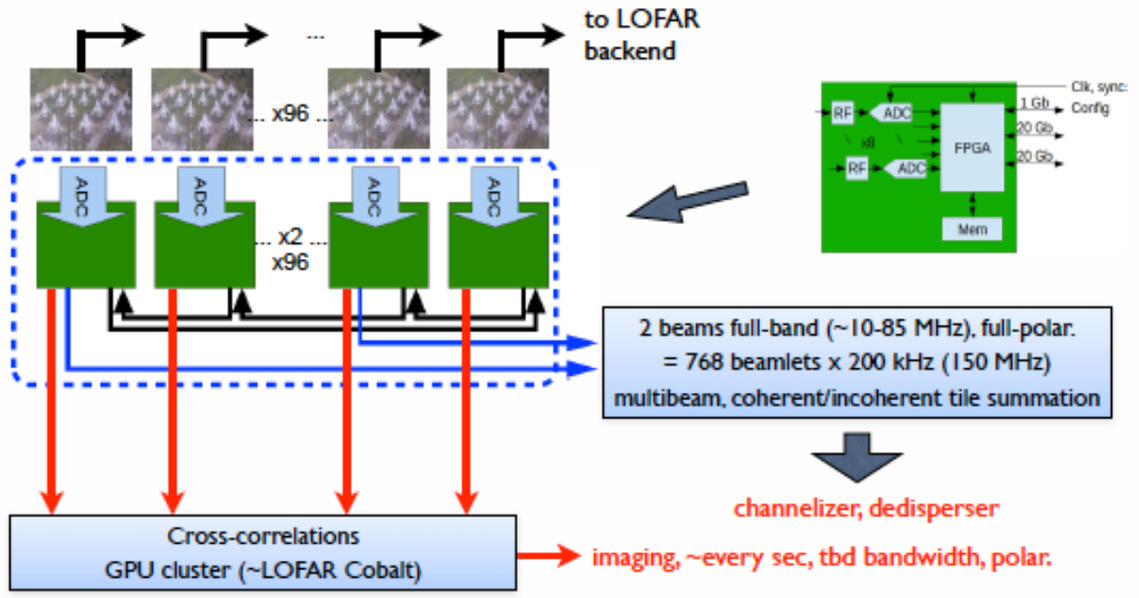


[Zarka, 2016]



Part of UTR-2 transients survey ≤30 MHz [Zakharenko et al., 2015]

The NenuFAR Beamformer + Imager

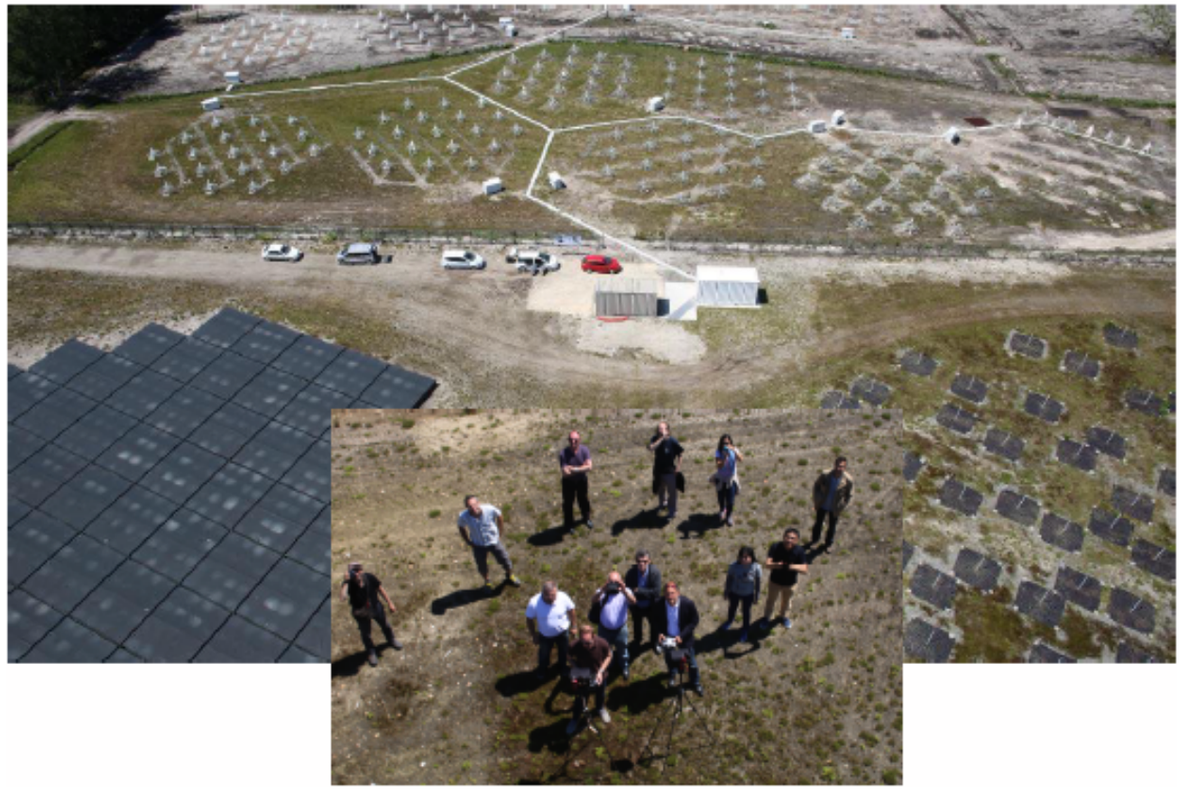


- **NenuFAR** = 3 instruments in 1 { NenuFAR/LSS; NenuFAR/Standalone Beamformer; NenuFAR/Standalone Imager
- Fully parallel use of LSS & Standalone modes ⇒ "duty-cycle" ~100% in the analog mini-array beam

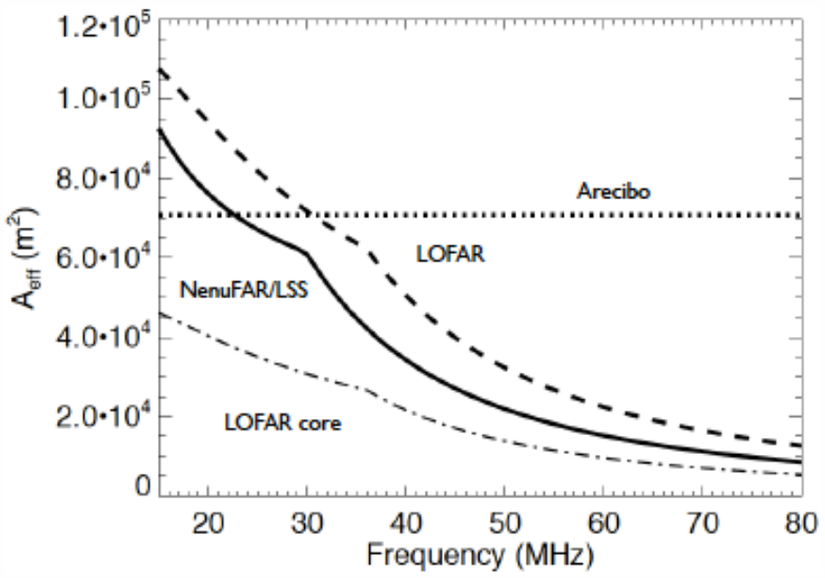
Technical characteristics of NenuFAR

- Large LOFAR-compatible phased array & interferometer
- 1824 antennas : 96 mini-arrays of 19 antennas each (25 m ∅)
- Diameter ~400 m + 6 distant mini-arrays (up to ~3 km)
- ~5000 baselines
- Frequency range = 10-85 MHz (λ=3.5-30m)
- Resolutions: δf = 100 kHz (standalone) → 1 kHz, δt = 5 µsec, TBB @ 5 nsec
- Full polarization (4 Stokes)
- Collective area ~600λ² ≤ 62 000 m²
- FoV = 32° - 8° @ 20-80 MHz ; pointing -23° → +90°
- Angular Resolution 2°-0.5° (Standalone instantaneous),
  5'-40' (Standalone synthesis), 0.1 " (LSS)
- Sensitivity : 2 - 0.5 Jy @ 20-80 MHz (5σ, 1 sec x 10 MHz)
  ~ 31 – 9 mJy " (5σ, 1 h x 10 MHz)

NenuFAR status

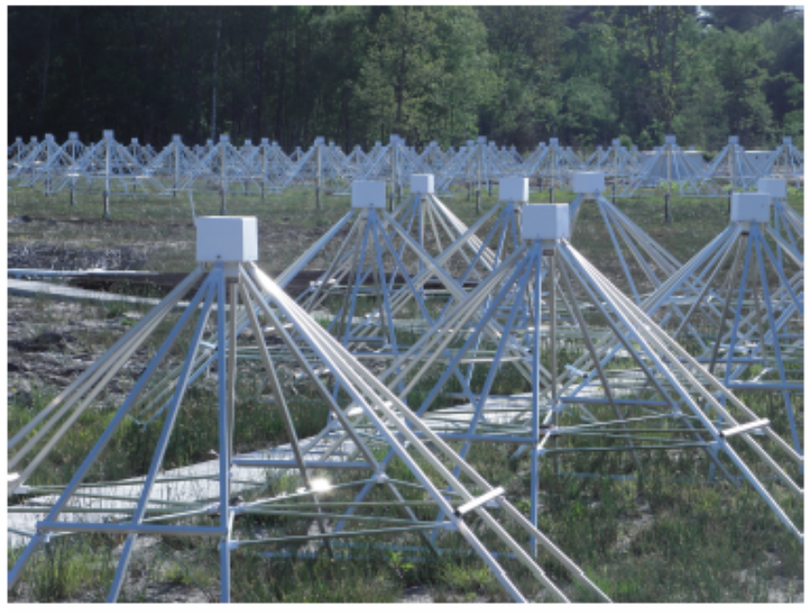


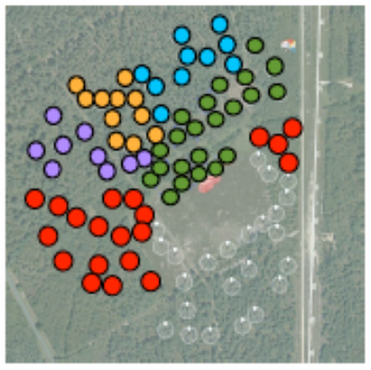
The NenuFAR telescope (standalone)



- ~19x the sensitivity of an international LOFAR station in LBA range
- N antennas = Dutch LOFAR (LBA)
- Access to VLF (10-85 MHz)
- A_{eff} ~ 2 x A_{eff} LOFAR core LBA above 35 MHz, ~ 10 x below 35 MHz
- International LBA stations used <25% of the time ⇒ Strong interest for standalone use

NenuFAR status





Octobre 2015 - 22MR
Juillet 2016 - 32 MR
Novembre 2016 - 41 MR
Juillet 2017 - 52 MR
Novembre 2017 - 72 MR