Data Management and computing services for the NenuFAR telescope

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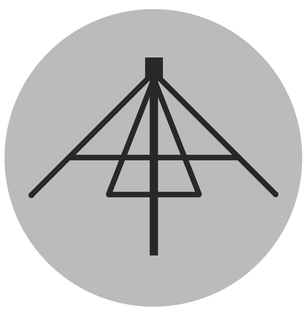
Abstract

NenuFAR is a new radioastronomy instrument located in Nançay (France) operating in the 10–85 MHz frequency band. It is a SKA (Square Kilometre Array) Pathfinder at low frequency at the last stages of its construction, currently in early science phase. The instrument will produce up to 2 PB of data per year in its standalone imager mode. We are now setting up a local data center in order to pre-process the raw data. An e- or physical infrastructure is under development and will allow for, e.g., data transfer/storage/archive, user access and computing time allocation management, scientific analysis platform deployment with preconfigured radio astronomy software suites.

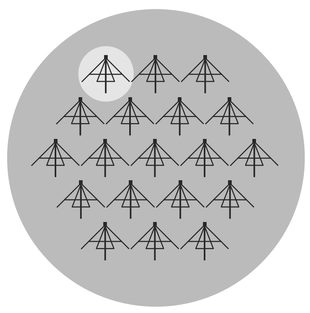
NenuFAR

New extension in Nançay upgrading LOFAR



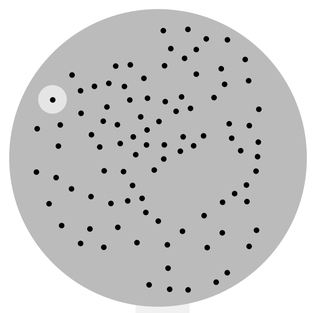
Antenna

1938 LWA-like radiator antennas
Dual-polarizations inverted V shape elements
Low-Noise Amplifier
All-sky field of view
Broadband response at 10–85 MHz



Mini-Array

Hexagon tile of 19 antennas
Analog beamforming with delay lines
16384 pointable directions on the sky
Beam width: 46° at 15 MHz, 8° at 85 MHz

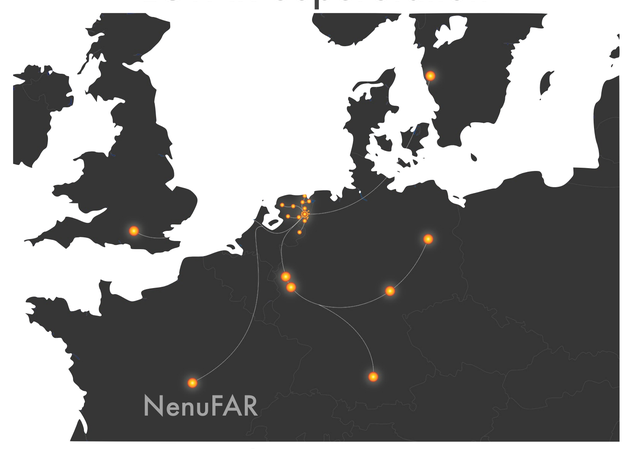


Standalone instrument

NenuFAR Array

96 mini-arrays (400m core) + 6 remote (up to 3km)
Optimal uv plane coverage for snapshots
Relative MA rotations: dampen grating lobes

LOFAR SuperStation



NenuFAR replaces LOFAR FR606 LBA
Connected to LBL inputs
Long-baselines involving NenuFAR:
increased sensitivity

NenuFAR Radio Imager

Correlator NICKEL

NenuFAR Imager Correlation Kluster
Elaborated from LOFAR's

Based on COBALT2.0 (ASTRON's new LOFAR correlator)
96 (+6) antenna fields
Continuous ingestion of 102x2.4Gb/s-streams for several hours from LANewBa
Real-time data crunch by the cluster's V100 Nvidia GPUs
Output 1GB/s stream of covariance matrices (L0 data)

LANewBa

LOFAR-like Advanced New Backend

Pre-processing analog signals received by MAs
Digital backend (based on ADCs + FPGAs)
NenuFAR beamformer
Statistics data (SST, BST, XST)

L0 Data

Raw (or 'Level 0') visibilities: 14 To/h
LOFAR-compatible Measurement Set format
75-MHz total instantaneous bandwidth
384 subbands (64 channels/subband)
Channelization down to 3kHz once per sec

Erased after conversion to L1

UnDySPuTeD

Time-Frequency observations:
down to 3kHz, 1ms resolution
Pulsar backend:
coherent dedispersion and pulse phase folding

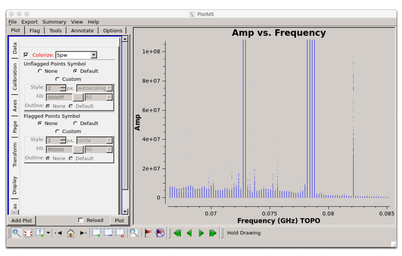
Transient Buffer Board

Stores last 5s of waveform (at 5ns resolution) for each MA and each polarization

Local conversion at Nançay Data Centre

L1 Data

Reduced (or 'Level 1') visibilities: max 5–10 To/day
LOFAR-compatible Measurement Set format
Lower resolution both in frequency and time



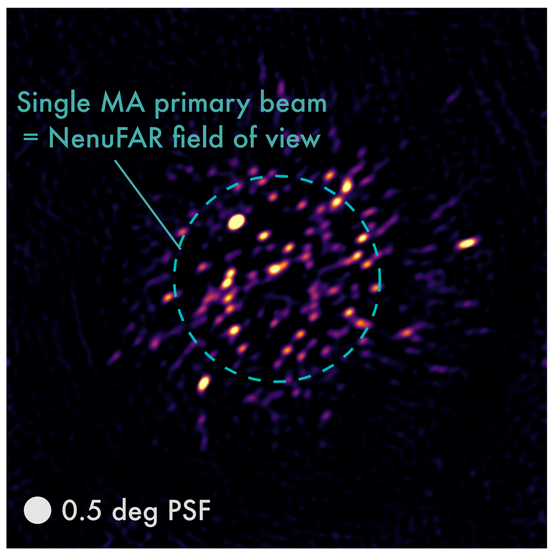
Transfer to NenuFAR Data Center

NenuFAR Data Center

Scalable structure, Open Science,
FAIR principles (*findability, accessibility, interoperability, and reusability*)
Several options are currently under investigation:
- e-infrastructure (EGI)
- physical infrastructure (partnership with BRGM Orléans, France-Grille or GENCI)

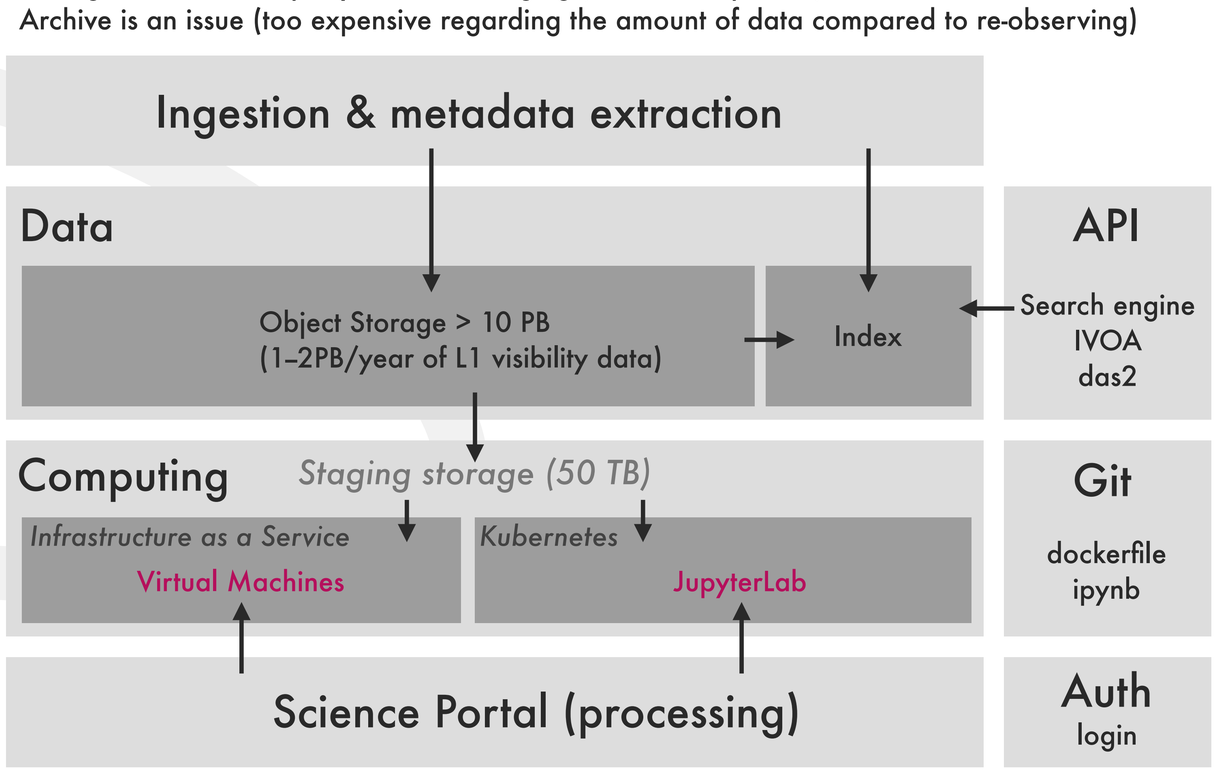
Web services are identified and available (collaboration with MeerKAT/ILIFU, LOFAR/EOSC?)
Storage of several PB per year is challenging (cost and expertise)
Archive is an issue (too expensive regarding the amount of data compared to re-observing)

Images



74 MHz image of the North Celestial Pole made from a 6-h observation with 56 MAs.
The PSF will eventually improve to 4 arcmin at 85 MHz with the full array (core + remote MAs).
Credits: Cosmic Dawn NenuFAR Key Project team (https://www.astron.nl/dailyimage/main.php?date=20190708)

Radioastronomy softwares suites:
Kern
CASA / AIPS
LOFAR DPPP
Prefactor
KillMS / DDFacet
...



References

P. Zarka et al., (http://nenufar.obs-nancay.fr)
Girard, PhD Thesis, *Developement of the LOFAR Super Station & planetary observations with LOFAR*, 2013

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