Fast Radio Burst observations from NenuFAR to GRAND

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FRBs overview

New astrophysical radio transient events :

- Short radio pulses (≈ms)
- Broad frequency band emissions
- Highly dispersed in arrival times

Total delay $\approx DM = \int_0^d n_e \, dl$ can be related to distance

Distinct from giant radio pulses (GP)

More than 75 events now (<u>http://www.frbcat.org</u>) up to 250 unpublished events from CHIME

2 Repeaters events (10 unpublished from CHIME) : 121102 (Arecibo repeater), 180814 (CHIME)

FRB fluencies up to 420 Jy.ms (1 Jy -> 25 nV/m) and steep spectra (ASKAP)

Observations \approx GHz and CHIME -> 400MHz



FRB 010724 - Evan Keane from Duncan R. Lorimer 2018



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Theoretical situation similar to GRB community 50 years ago: lack of observational constraints

Majors unknown :

- Existence at low frequencies (below 400MHz)
- Behaviour at low frequencies (turnover ? cutoff ?)
- Polarisation
- DM and scattering fluctuations (event to event)
- Population rate

Ideally -> observations below 400MHz with polarisation measurements

SKA pathfinder, partly constructed and in commissioning, located in Nançay Radioastronomy Observatory (NRO)

- 1938 dual polarisation antennas, hierarchically distributed in Mini-Arrays
- 10-85 MHz between Earth's ionospheric cut-off and radio broadcast FM band
- Most antennas located in a core of a diameter ≈ 400m and 6 groups of 19 antennas at distances up to 3km

Antennas connected in parallel to several receivers -> operate in 4 distinct modes (simultaneously if needed):

- standalone beam former -> FRB observation
- capturing waveform -> transient buffer
- standalone imager
- Upgraded LOFAR station (low frequency)



Astronomers Page : https://nenufar.obs-nancay.fr/en/astronomer/

Array:

Antennas grouped in hexagonal tiles of 19 crosseddipoles -> Mini-Arrays -MA (5.5m antenna step)

Interferometric measurements:

- In each MA signals are combined through analog phasing + summation system -> beam (restrict FoV but higher sensitivity)
- MA are analog phased with delay lines -> achromatic
- Delay lines are 7-bit systems of switchable cables
 -> 16384 pointable directions (128x128 = EW x NS) in the sky

Signals:

Each MA delivers two linearly polarised signals (NE and NW) to receivers.

NenuFAR configurations allows to reach low intensity signals in the low frequency band

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FRBs are produced at cosmological distances -> signal is heavily scattered during its propagation -> dilution of the intensity toward low frequencies

Typical intensity ≈ from 0.1 to several hundreds of Jy at 1 GHz over times lasting to a few



FRBs with NenuFAR: observation strategy



Dynamic spectra on 45-82.5 MHz = 35.7 MHz bandwidth, 3kHz resolution with a time integration *specified by simulations* (probably 10 to 20 ms)

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FRBs with NenuFAR: observation parameters optimisation

Looking for a FRB with a DM of 190 pc.cm⁻³ in the 40-80MHz



FRBs with NenuFAR: data analysis

Observations



Analysis:

- RFI mitigation (using a pipeline from the Exoplanets Key Program)
- de-dispersion (propagation correction)
- spectral integration

Since the DM is \approx know the processing will be much faster than for a blind research.

For a global survey this doesn't stand anymore -> Increase the analysis time

Data storage and processing:

- Nançay Data Center
- Processing on pipeline mode on the data
- Using 1-2 nodes -> processing time ≈ 2-5 x observation time
- Raw data -> 70GB/h -> 17TB on 240h
- data reduction \approx 16x in frequency (de-dispersion at DM = 190 within 50 kHz channels)

NenuFAR is well suited for FRB observations, doesn't need any sophisticated processing or data storage strategy

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FOV as large as for a single antenna

In the best case scenario GRAND could detect FRBs at the rate of a few thousand per day !

* if several distant hot spots -> allows for localisation through triangulation

GRAND White Paper, GRAND coll. (VD) arXiv:1810.09994v1 Valentin Decoene GRAND CHINA workshop 04/19 http://grand.cnrs.fr

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NenuFAR FRB Pilot Program used as pathfinder for GRAND FRB program: Low frequency FRB existence / benchmark for FRB tools



GRAND data stream and storage challenges



What do you think ?

NenuFAR: Large low-frequency radiotelescope

Crossed dipoles in inverted-V shape at 1.6m above a 3m x 3m ground plane

- Antenna radiator developed for the LWA (USA)
- Coupled to a custom-designed preamplifier -> flat response across the entire observed band with a level of sky background several dB above the preamplifier noise at all frequencies -> sensitivity is sky limited



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Backup

NenuFAR: Large low-frequency radiotelescope



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Backup