Pilot study of FRB at low-frequencies

- Fast Radio Burst (FRB) : what is observed
- FRB detection at low frequencies
- Best candidate to observe
- Observations parameters + processing
- Lessons for GRAND

Fast Radio Burst (FRB) : what is observed

New astrophysical radio transient events

Short radio pulses (≈ms)

Broad frequency band emissions

Highly dispersed in arrival times

Total delay ≈ $\mathrm{DM} = \int_0^d n_\mathrm{e}\, dl$

can be related to distance

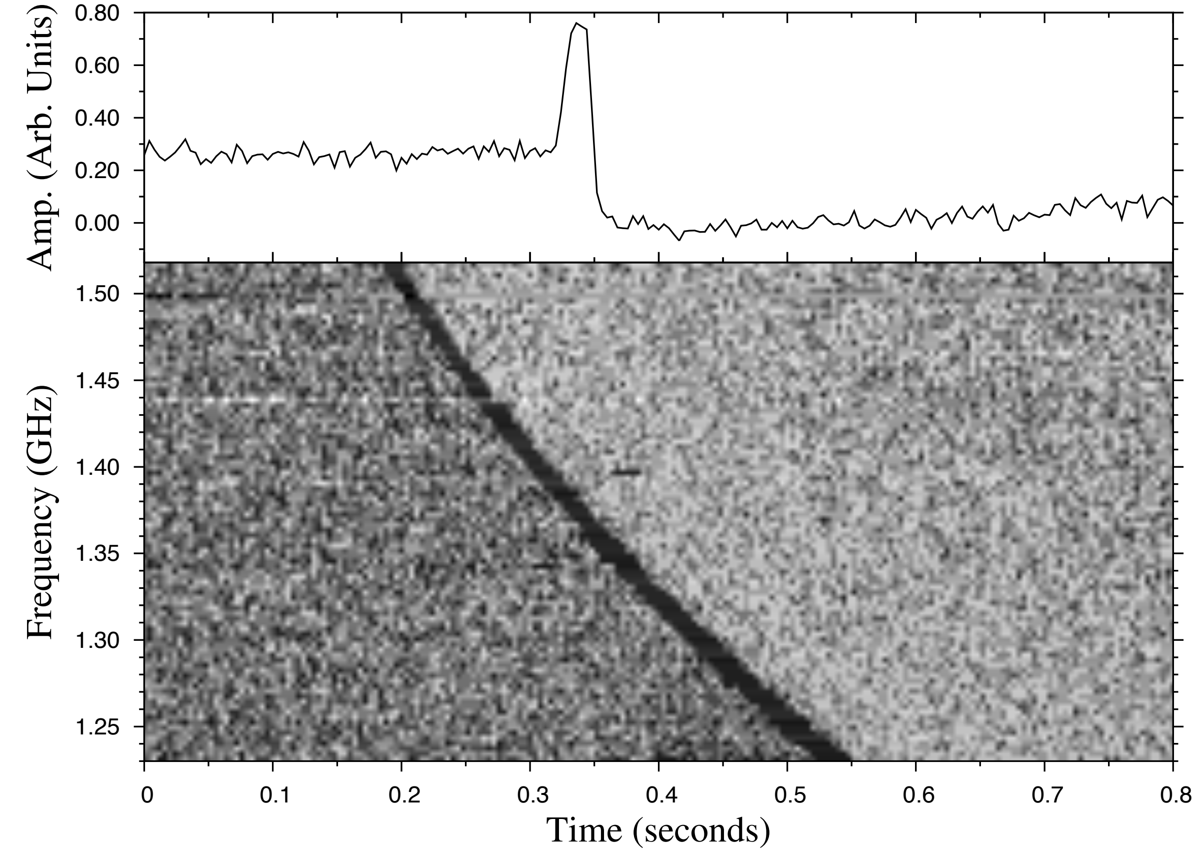
Broader pulse towards lower frequencies

→ turbulent medium (scattering)

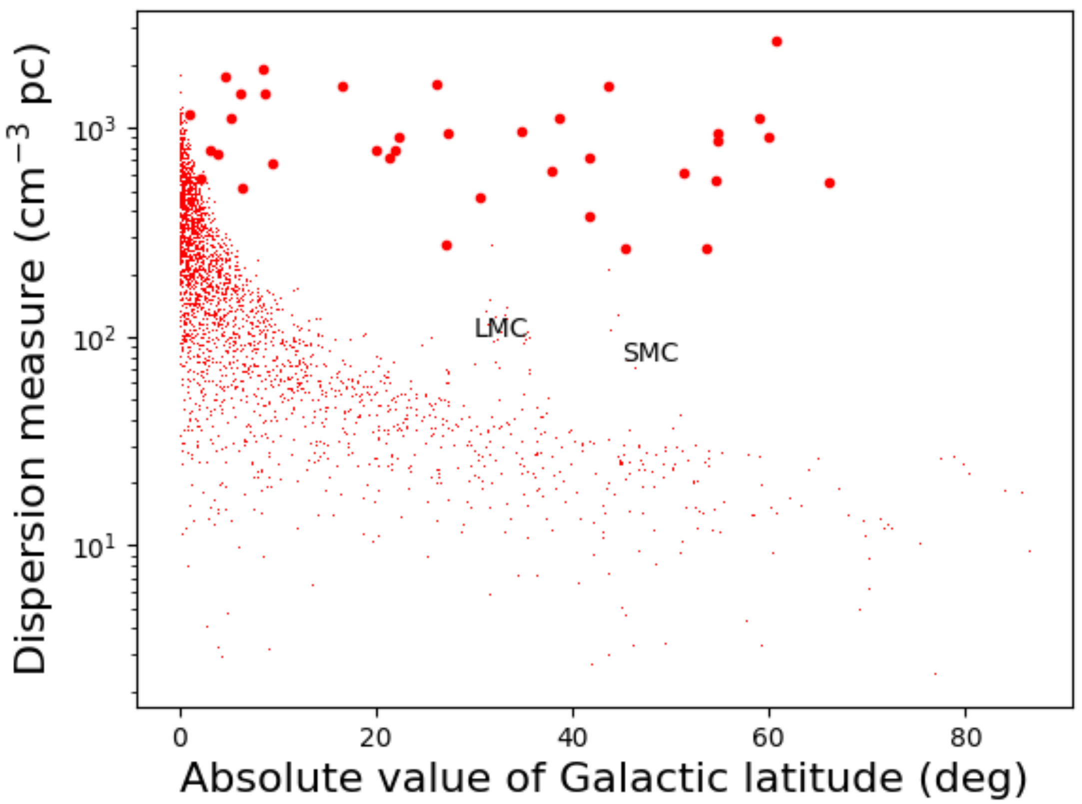
Distinct from giant radio pulses (GP)

More than 60 events now (http://www.frbcat.org)

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



FRB 010724 - Evan Keane from Duncan R. Lorimer 2018



Why going to lower frequencies ?

- **Existence ?**
- **Flux, polarization, LF cutoff ?**

→ strong constraints on theoretical mechanism

What can be achieved ?

- **With DM 190, dispersion delay in 40-80 MHz range ~ 6 min., 10-70 msec within 3 kHz channel**
- **Minimum observed scattering time ~0.1 msec at 1 GHz → 2 sec at 80 MHz, up to 10’s of sec at 40 MHz → limiting factor, but allows for long integration time (short integration useless)**

Best candidate to observe

CHIME repeater 180814

- Observed down to 400 MHz
- Low DM ~190
- Scattering ≤3 msec @ 400 MHz, i.e. ≤2 s @ 80 MHz (≤30s @ 40 MHz)
- Relatively intense : Fluence ~ 10-60 Jy.msec with duration 10-60 msec
- R.A. = 04h22m22s, δ = +73°4' thus circumpolar
- 6 occurrences in 45 days

	FRB	UTC	Telescope	RAJ	DECJ	gl	gb	DM	Width	SNR
i	FRB180814...	2018/09/06 01:17:47.380	CHIME/FRB	04:22	+73:44	136	16	191	3.9	11
i	FRB180814...	2018/09/11 12:59:13.733	CHIME/FRB	04:22	+73:44	136	16	189.8	7.9	12
i	FRB180814...	2018/09/17 00:46:35.359	CHIME/FRB	04:22	+73:44	136	16	189.5	63	22
i	FRB180814...	2018/09/19 12:36:09.141	CHIME/FRB	04:22	+73:44	136	16	190	16	10
i	FRB180814...	2018/10/28 10:12:31.477	CHIME/FRB	04:22	+73:44	136	16	188.9	42	18.7

→ **by far the best candidate for NenuFAR**

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```
IDL> nenufar_calc,56,0,60,decoh=2,dt=0.1,df=30,/verb
Freq(MHz)= 60.0   Wavelength(m)=  5.0   nMAcore,remote=  56   0
dmax(m)=    400   df(MHz),dt(s)= 30.0     0.100   decoh= 2.0
Aeff dipole,MA,NenuFAR(m^2)=   8.3  158.3   8867.
Theta MA(deg),FoV MA(deg^2)=  11.5    103.   Theta NenuFAR(deg)=  0.72
Tsky,Tamp(K)=    3635.     788.   SEFD MA,NenuFAR(Jy)=    77105.     1377.
SminThermal,Confusion(Jy)=    1.5899    2.6404
```

→ by far the best candidate for NenuFAR

Observations parameters + processing

- We propose 30 observations runs of 8 hours each (fractionable in 2h chunks)
- No constraint on day/night observation
- UnDySPuTeD-tf (DynSpec mode) 192 beamlets (1 lane)   45-82.5 MHz
- 20 msec integration time / spectrum

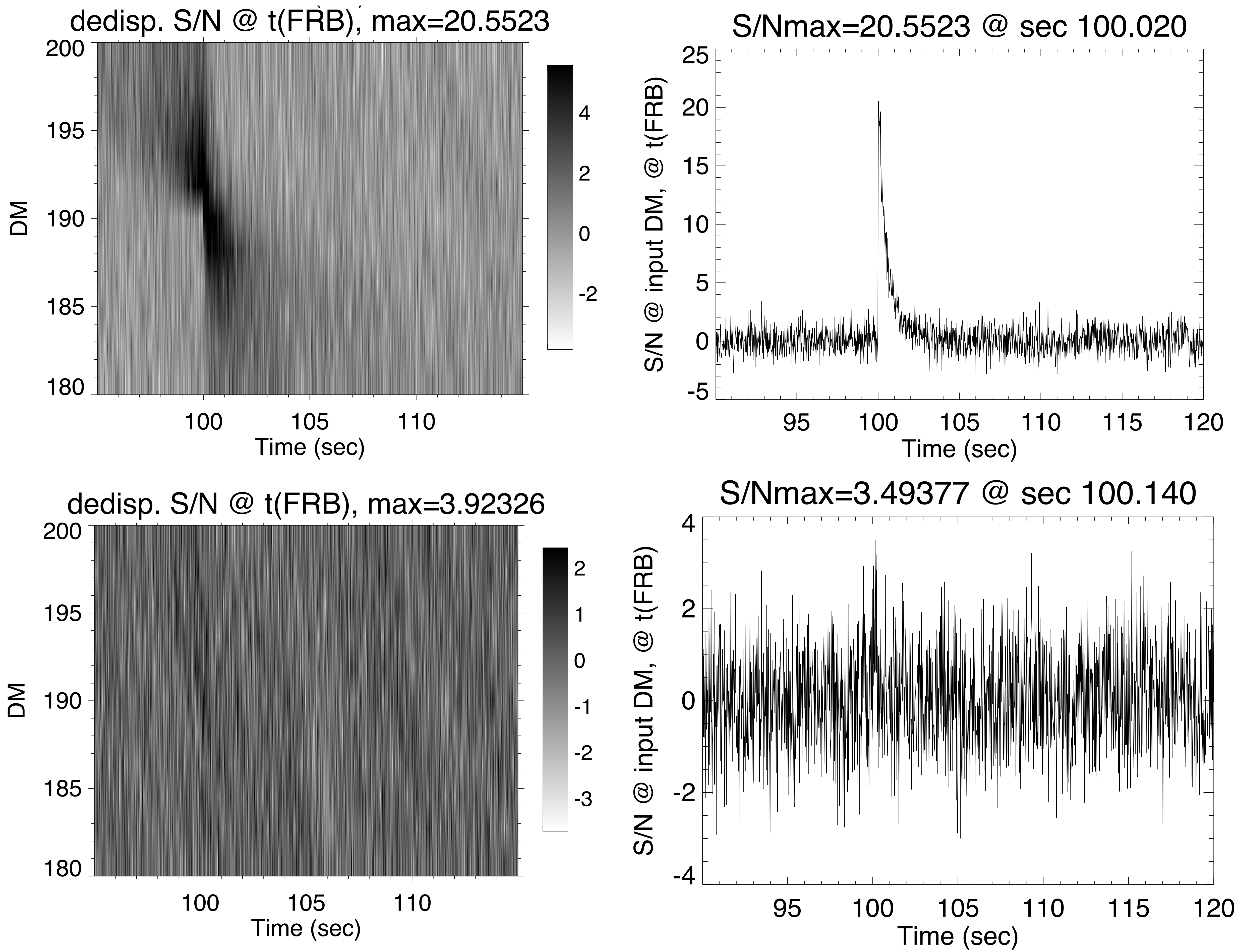
```
IDL> data_rate_vol, 56,64,0.02,37.5,3600,/BF
Rate=      51.0  Kb/s/SB
Rate=      10.0  Mb/s
Volume=    35.5  Gb   in   3600. sec
```

- Fast post-processing:
  - flattening by sky spectrum + RFI mitigation on the fly   read_nu_spec
  - de-dispersion at DM=188-192 (3-5 values)
  - smoothing at expected scattering time
  - integration over frequency (with variable Fmin)
  - testing various time integrations (of resulting time series)
  - If no detection → significant (publishable) constraint
  - If detection → very significant result + motivates systematic blind search (N x 8 h   in ~100°^{2} each).

Few simulations → More refined study needed

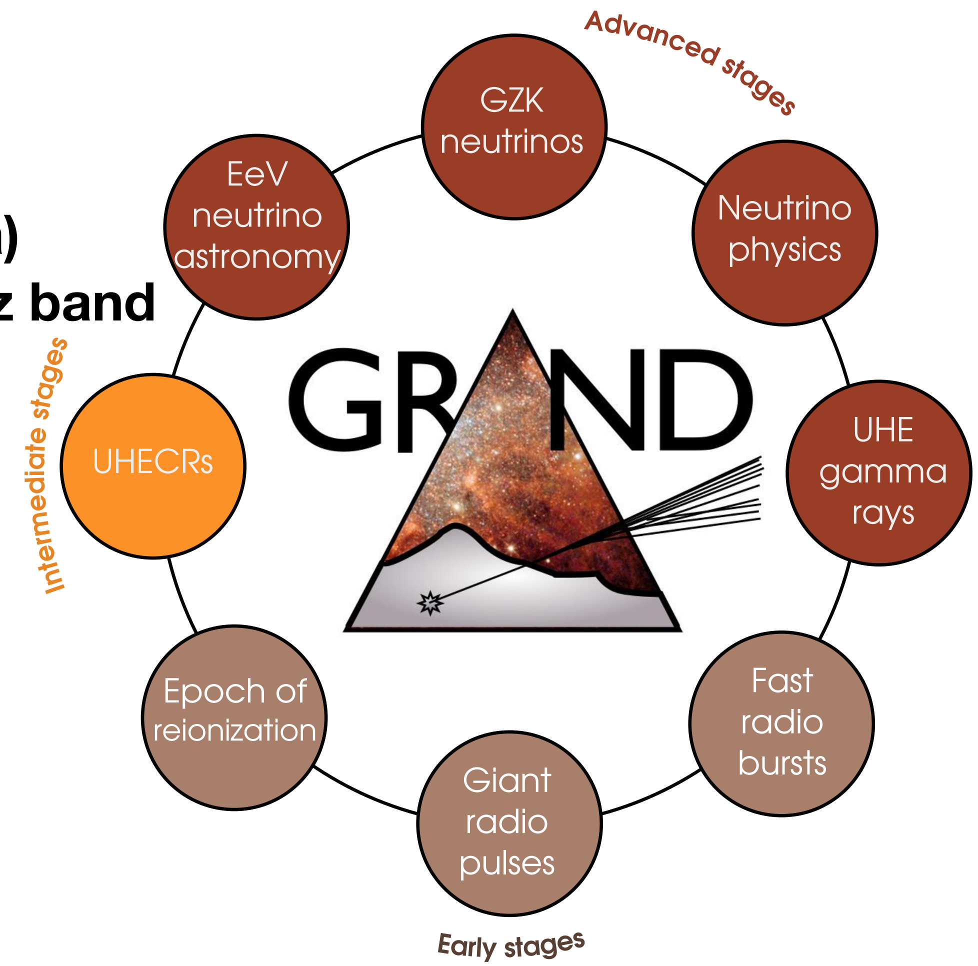
500 μJ peak flux

50 μJ peak flux



Lessons for GRAND

GRAND concept:
- 200,000 antennas over 200,000 km2 = 20 spots of 10,000 km2
- in radio quiet mountainous regions around the world (half in China)
- autonomous radio detection of inclined air-showers in 50-200 MHz band



GRAND could detect FRBs by incoherently adding the signals from individual antennas

→ **Allows to infer the DM but not to locate the source**

→ **Sensitivity** $\propto \sqrt{N_{\text{antennas}}}$

→ **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 !

Questions : is the FRB spectrum extends to low frequencies ?

→ **NenuFAR can :**
- **Answer this question**
- **Provide a benchmark for FRBs detection tools at low frequencies**

GRAND White Paper, GRAND coll. (VD) arXiv:1810.09994v1 http://grand.cnrs.fr

FRB : constraints on models

A study cases : FRB 121102

$$\mathrm{DM} = 557 \pm 2\,\mathrm{cm}^{-3}\,\mathrm{pc}$$
$$z \approx 0.192$$
$$d \approx 972\,\mathrm{Mpc}$$

Each burst released ≈ 10^{37} to 10^{40} erg (isotropic)

Located in a low metallicity star forming dwarf galaxy

Almost entirely linearly polarised

Faraday rotation extremely high : 130 000 - 150 000 radians / m^2

$$T^{121102}_{\mathrm{Black-body}} \approx 10^{33}\,\mathrm{K}$$

! **Repeater can be a distinct class of FRBs, it implies non catastrophic events**

→ **Coherent non thermal emission mechanism**
Produced by compact objects

More theoretical models than observations

Many models could be ruled out if we knew the distances of FRBs

More observations !