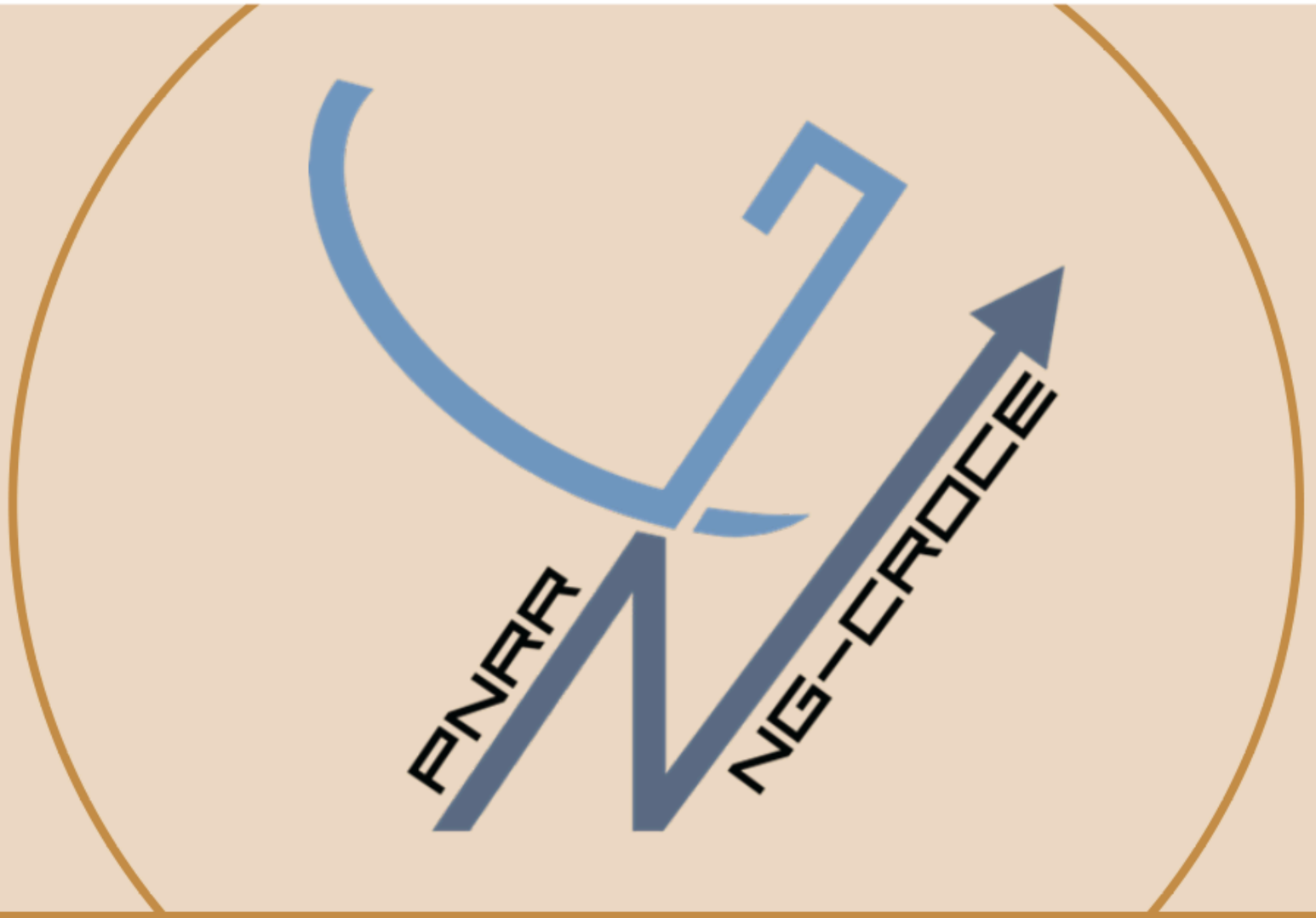
Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INAF ISTITUTO NAZIONALE DI ASTROFISICA

The NC as an FRB search facility

Training Meeting
NG-Croce

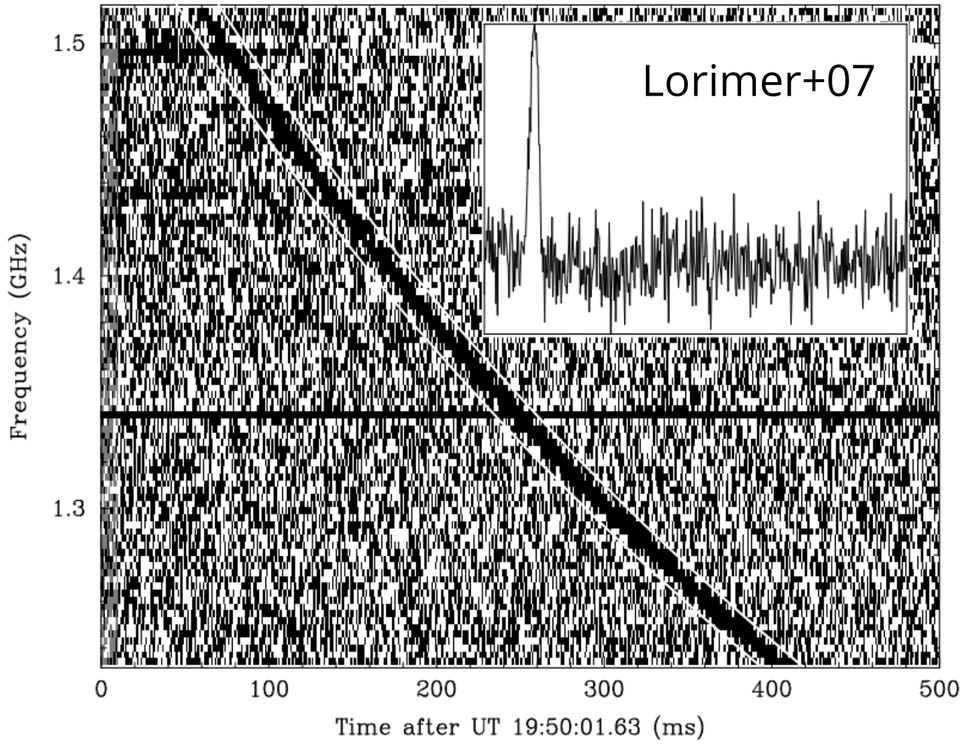
Lunedì 12 Maggio - Giovedì 15 Maggio

Radiotelescopi di Medicina
IRA - Bologna



Davide Pelliciari (IRA-INAF)

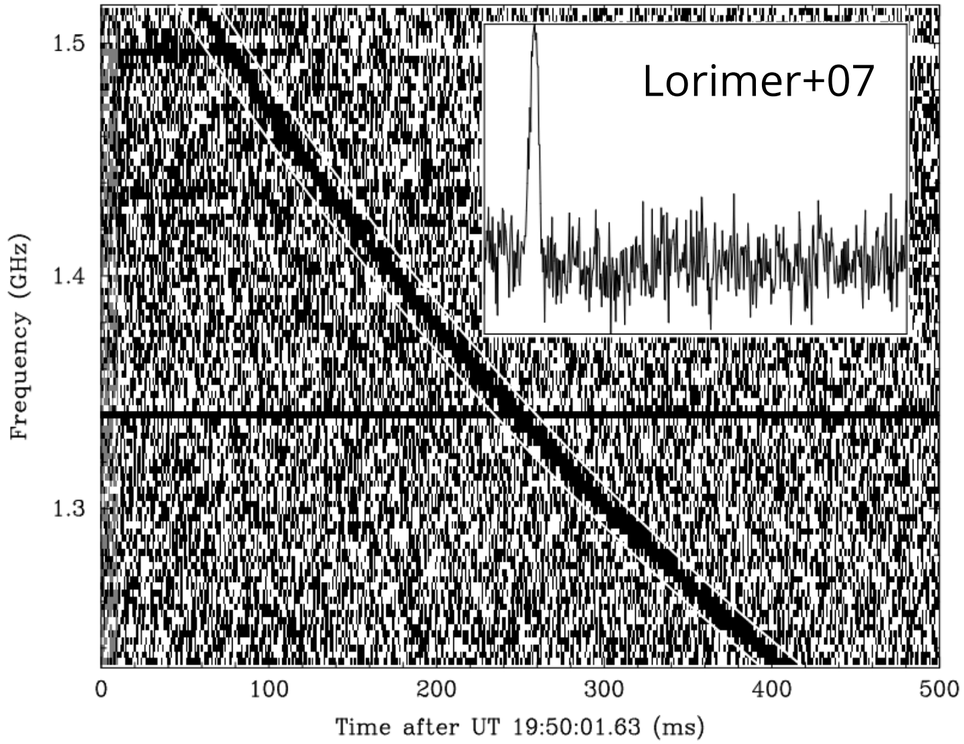
Fast radio bursts (FRBs) in a nutshell

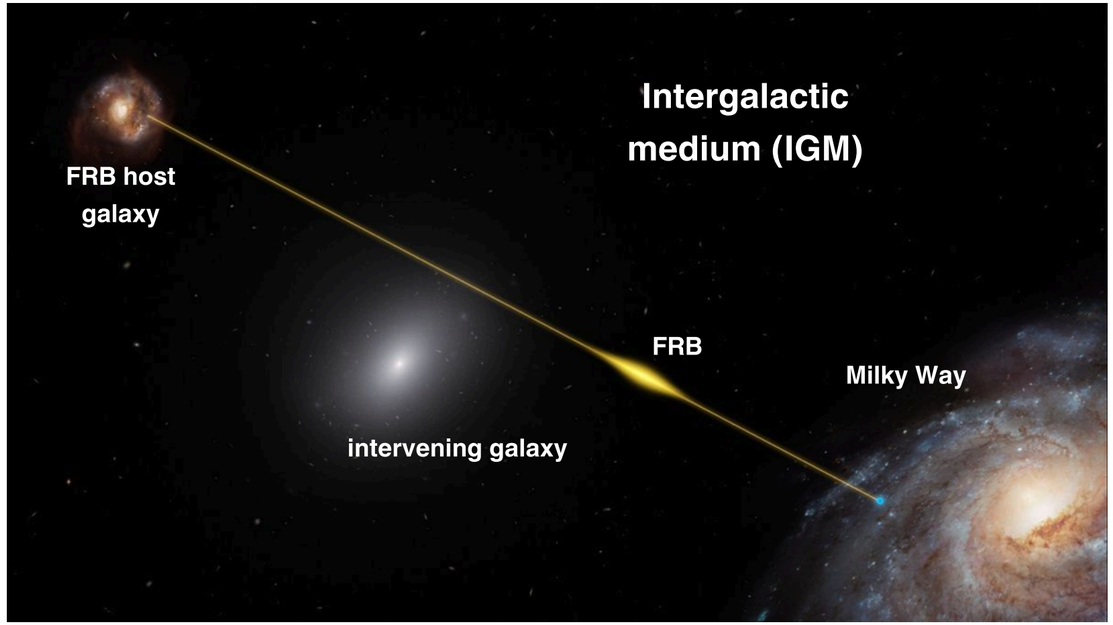


- ~ 900 one-off sources
- repeating (~ 60 sources)

dispersion measure (DM) >> DM by MW

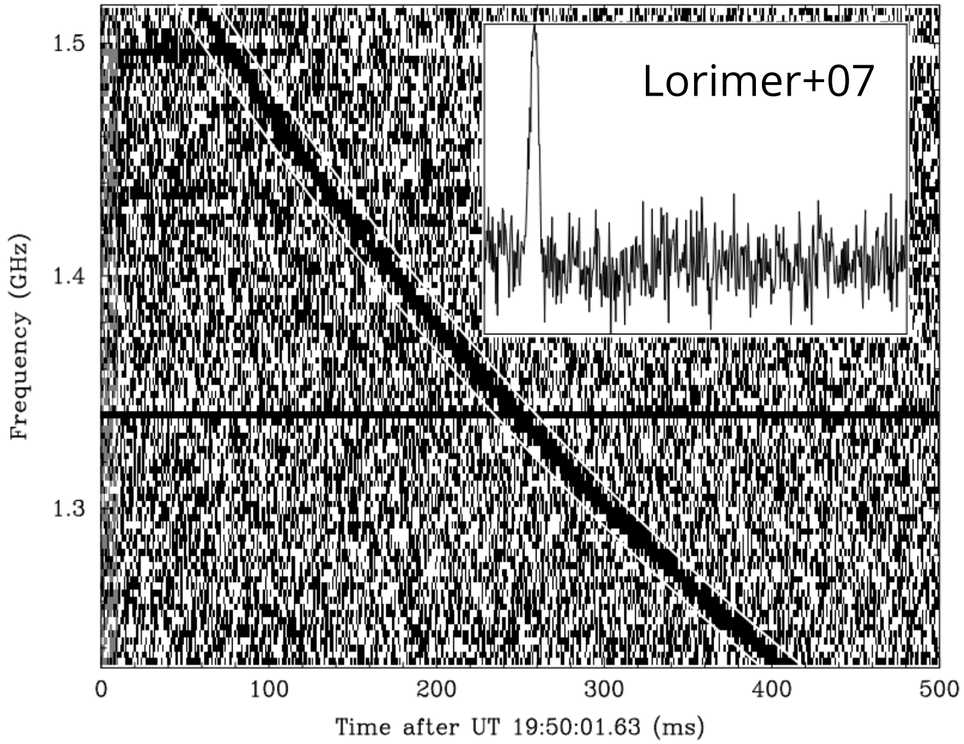
Fast radio bursts (FRBs) in a nutshell

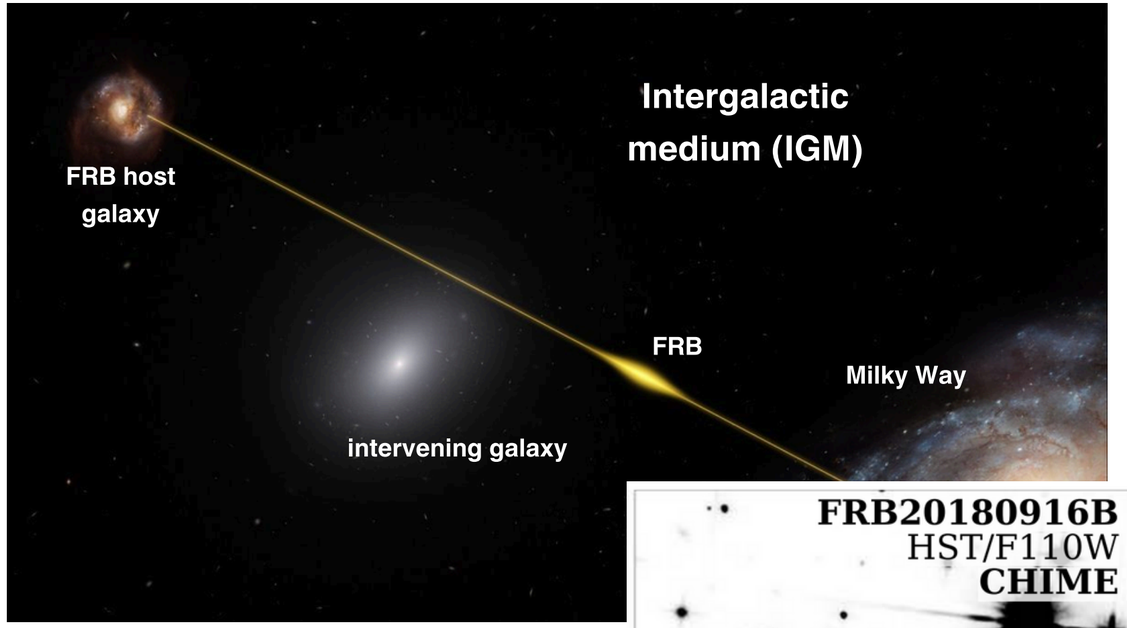


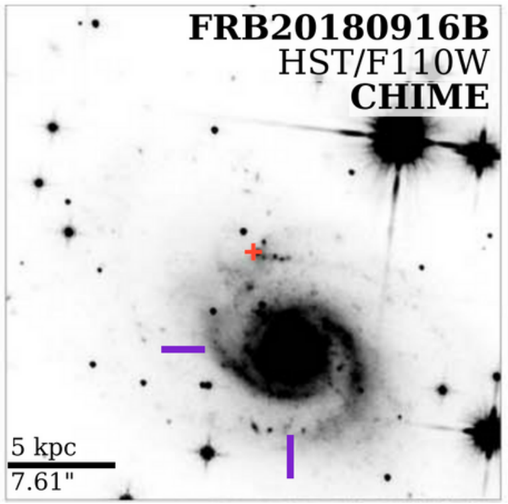


very **energetic** bursts
(up to **kJy ms fluence** and **1e+43 erg**)
about Sun in 100 yr – (Sun 1 yr – 1e+41 erg)

Fast radio bursts (FRBs) in a nutshell

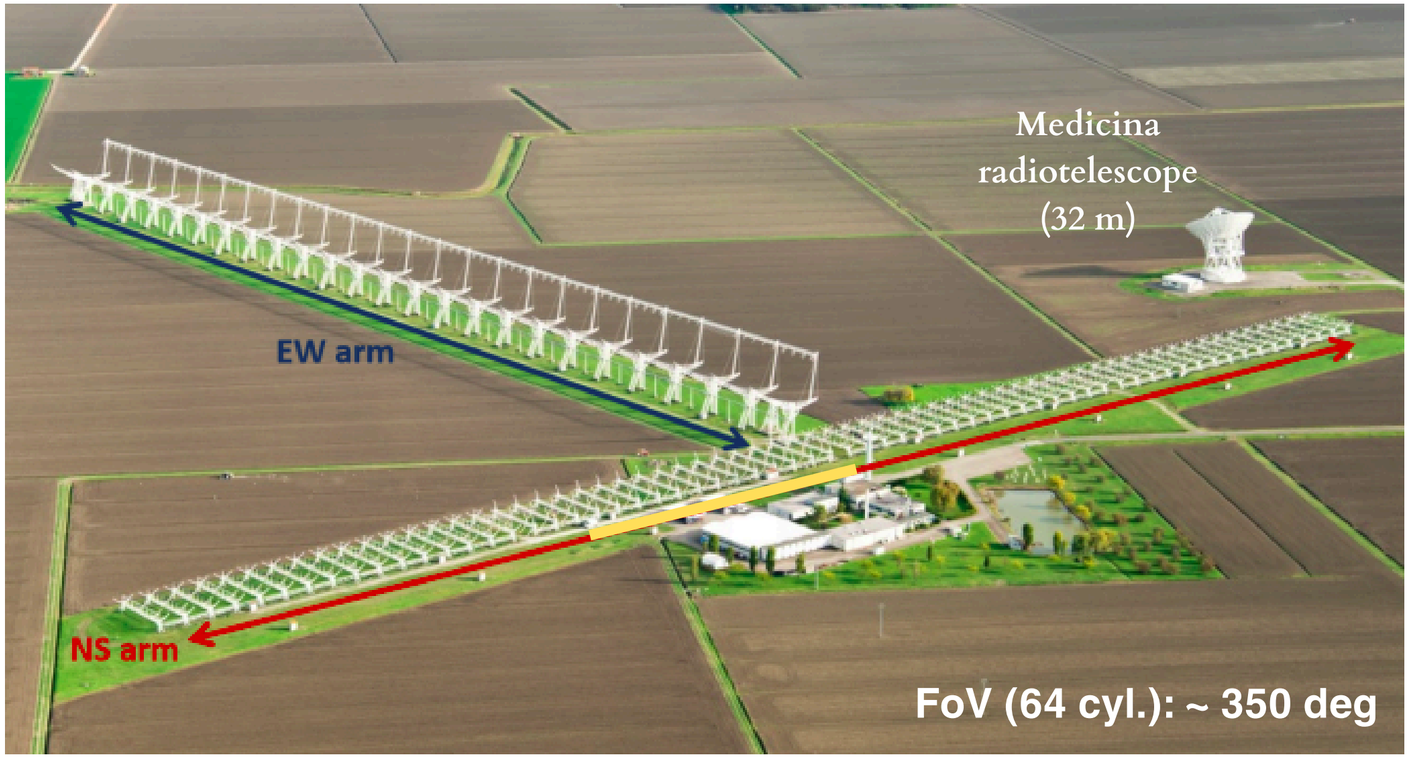






Gordon+23

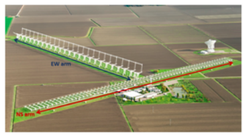
How do we search for FRBs?



Back to 2021

manually:
-- name – ra – dec – t_obs – dt

bestfrb_scheduler.py
+ steering.py



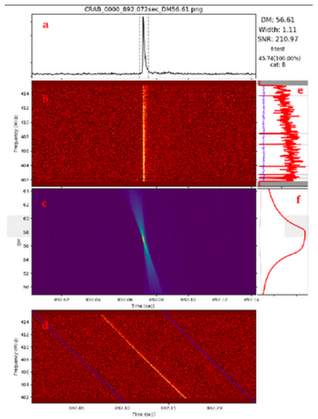
process_obs.py

+ RFI-find

Gajjar et al. 2018

Single pulse search pipeline

FRB (RFI) candidates



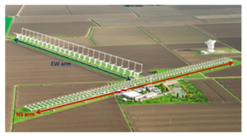
for every observation session

circa 100-200 candidates per observation (human inspection (me))

Back to 2021

manually:
-- name – ra – dec – t_obs – dt

bestfrb_scheduler.py
+ steering.py



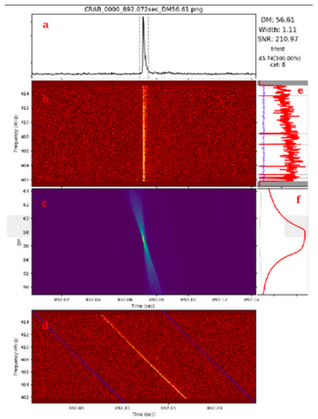
process_obs.py

+ RFI-find

Single pulse search pipeline

Gajjar et al. 2018

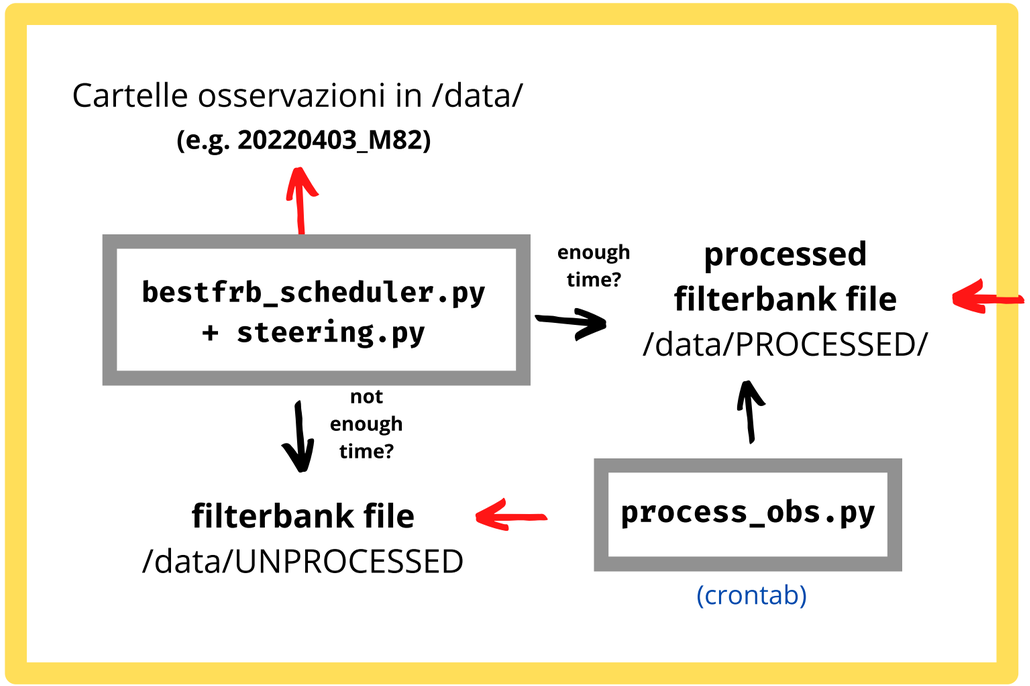
FRB (RFI) candidates

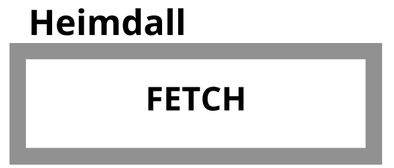


for every observation session

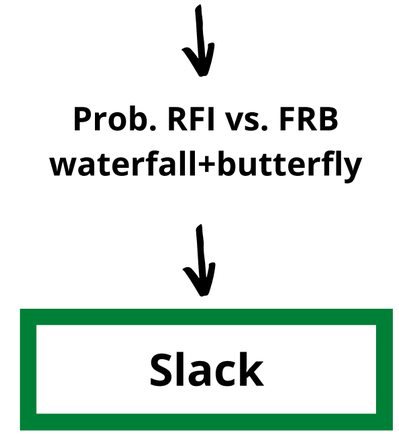
GB: ok now observe 7 galaxies every day
DP: challenge accepted

Nowadays





RFI flag:
- external
- rfifind
- IQRM



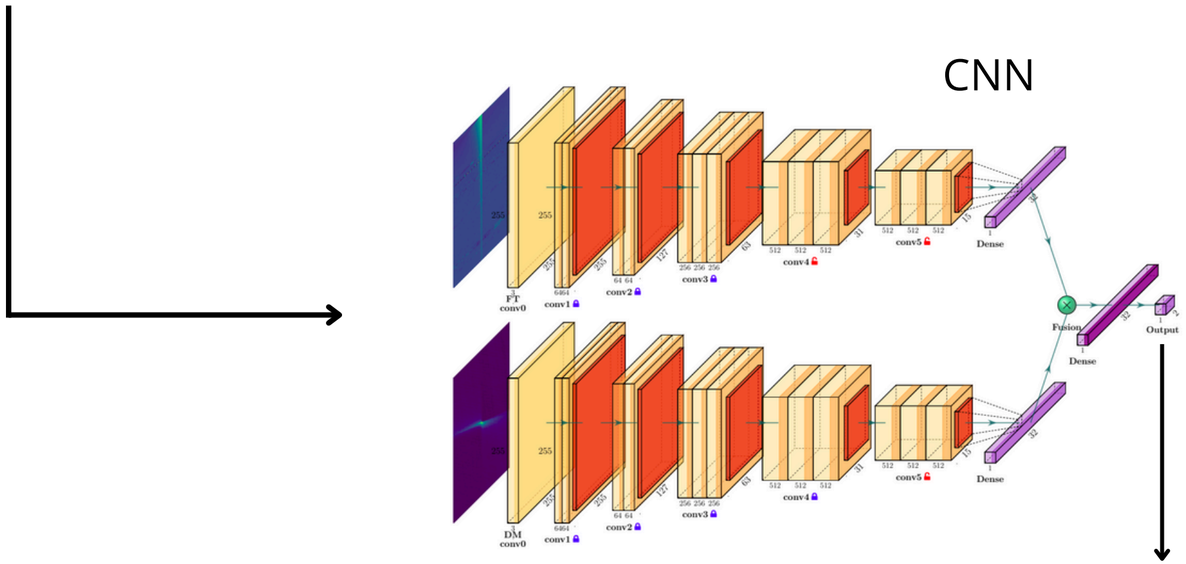
scheduler.py
- multiple observatiations/targets
- multiple dates (e.g. month-long campaign)
- antenna movement + steering

> **1000 hrs scheduled**

Burst classification (FETCH)

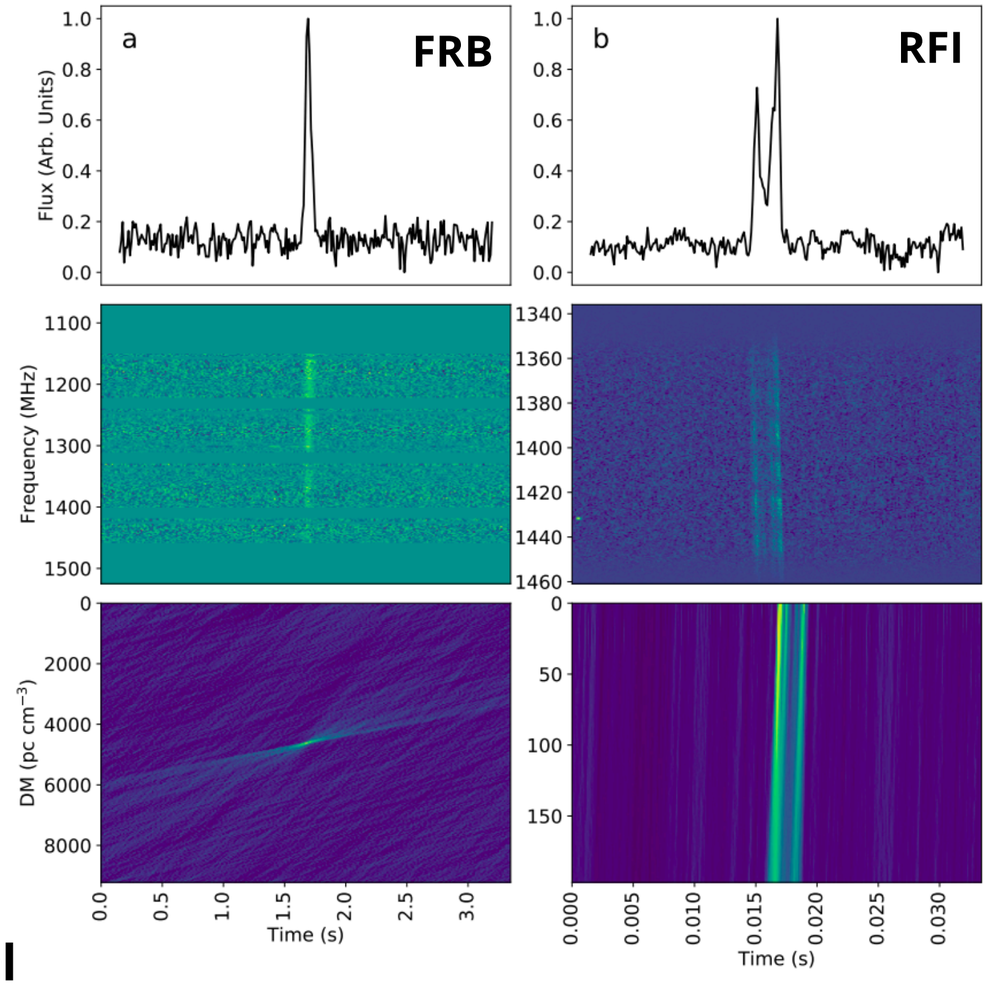
Single pulse search

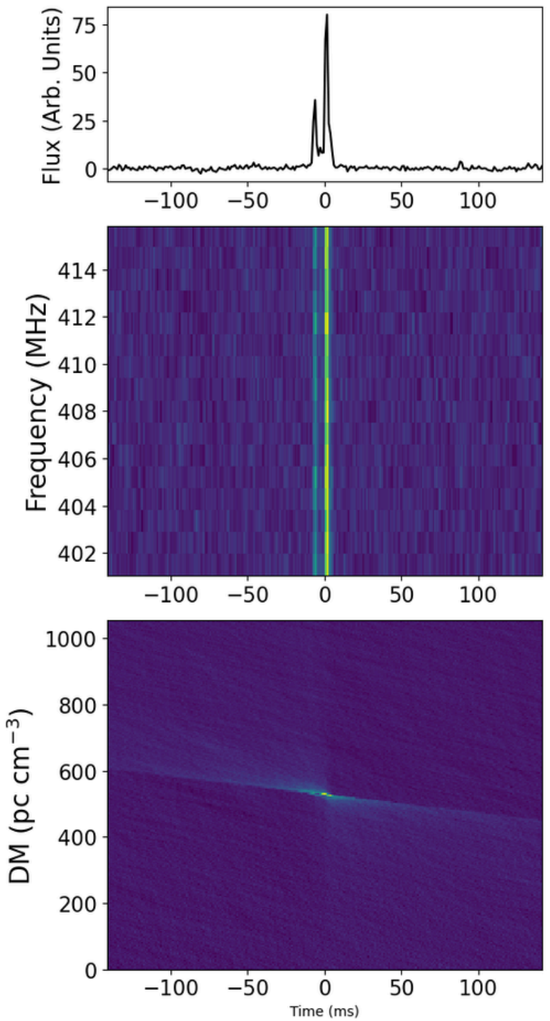
heimdall (DM search + boxcar)



Agarwal *et al.* 2019

slack channel





basename : beam_1710665176.068081_processed
bw : -14.814814814814813
cand_id : cand_tstart_60386.407130417603_tcand_973.6960000_dm_527.88400_snr_73.28440
center_freq : 408.45428240740745
dec_deg : 4.3501
dm : 527.884
dm_opt : -1
dtype : uint16
fch1 : 415.85445601851853
filelist : ['/jbod/PROC_test/20240317T084712_FRB20240114A_1N2N/beam_1710665176.068081_processed.fil']
filename : /jbod/PROC_test/20240317T084712_FRB20240114A_1N2N/beam_1710665176.068081_processed.fil
foff : -0.014467592592592591
format : fil
frequency_decimation_factor : 1
gb : -31.63930342992909
gl : -122.49906367639196
kill_mask : [False]
label : 0
native_foff : -0.014467592592592591
native_nbits : 16
native_nchans : 1024
native_nspectra : 11206656.0
native_tsamp : 0.00013824
nbits : 16
nchans : 1024
npol : 1
nspectra : 11206656
poln_order : I
ra_deg : 321.9162083333334
rfi_mask : [False]
snr : 73.2844
snr_opt : -1
source_name : FRB20240114A
tcand : 973.696
time_decimation_factor : 1
tsamp : 0.00013824
tstart : 60386.4071304176
tstart_utc : 2024-03-17T09:46:16.068
width : 16

from **FRB 20240114A**

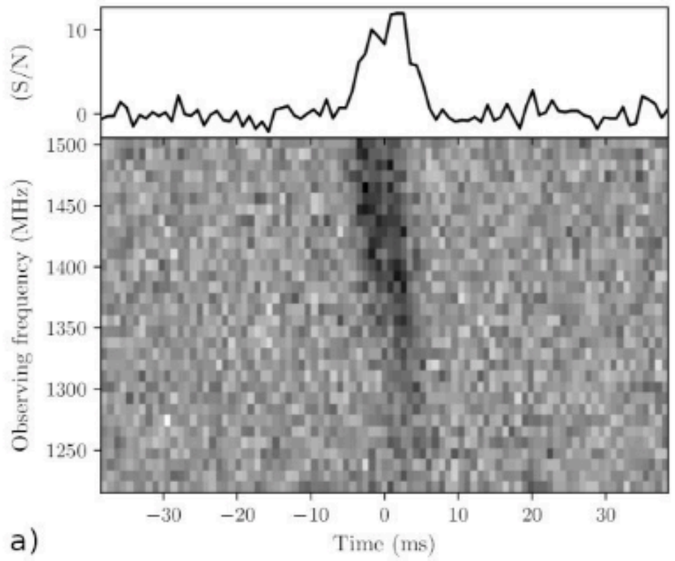
(NC) FRB candidate

NC completeness study

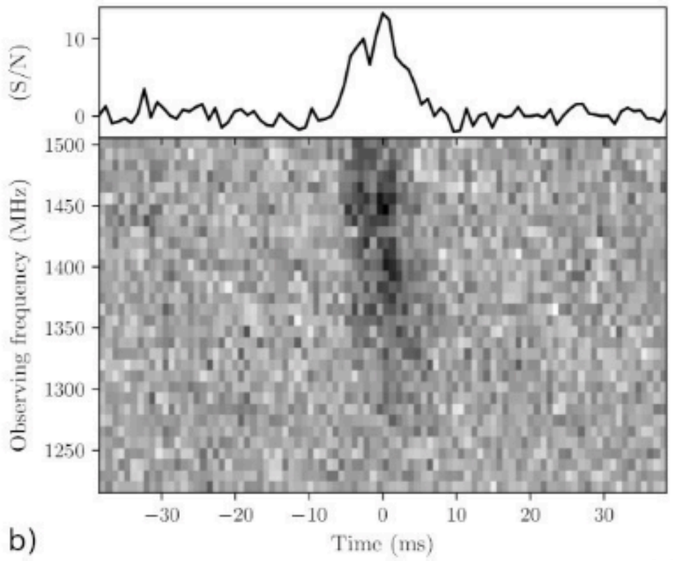
Example

FRB-faker

gitlab-Leon Houben

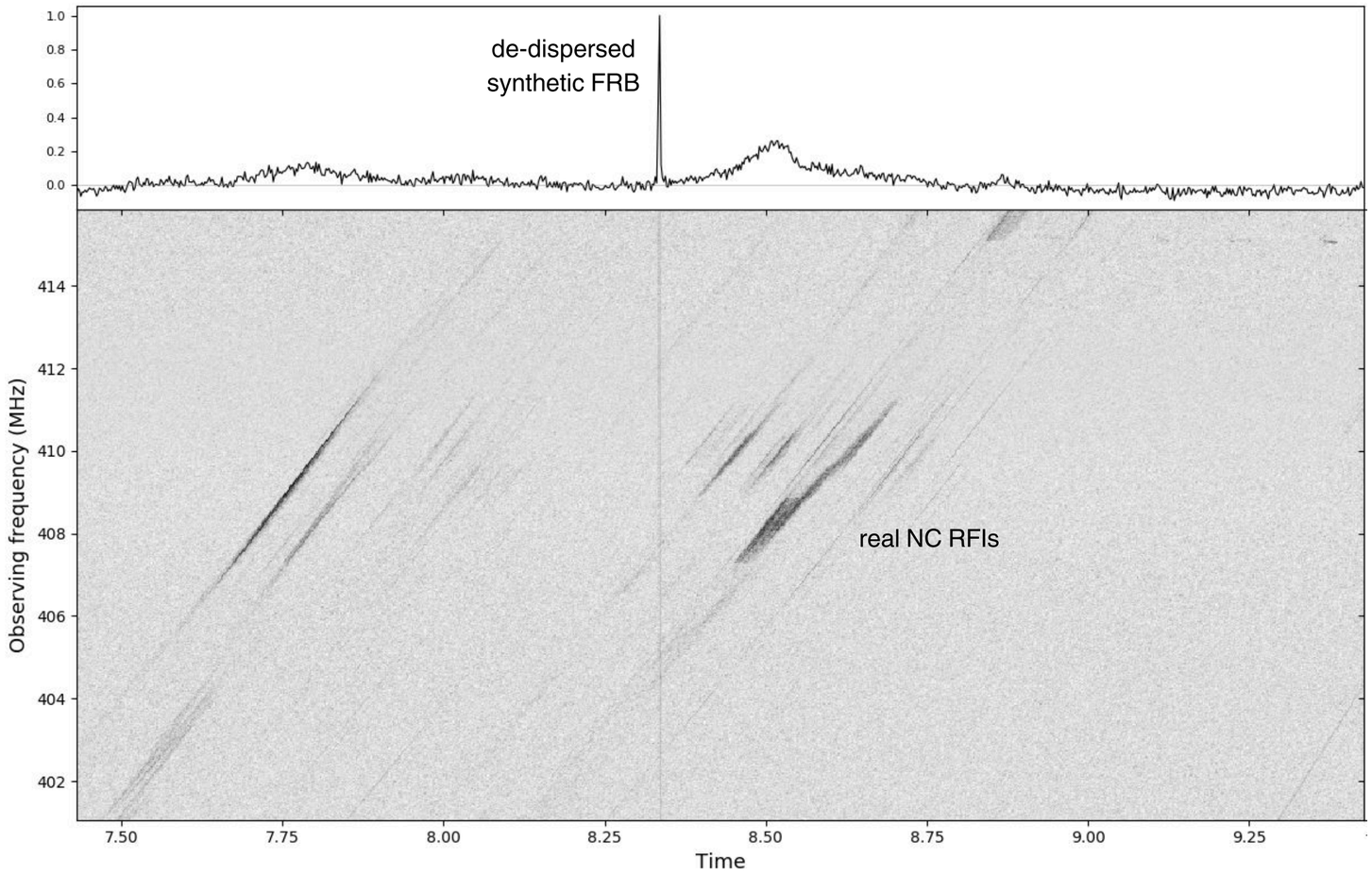


simulated/injected

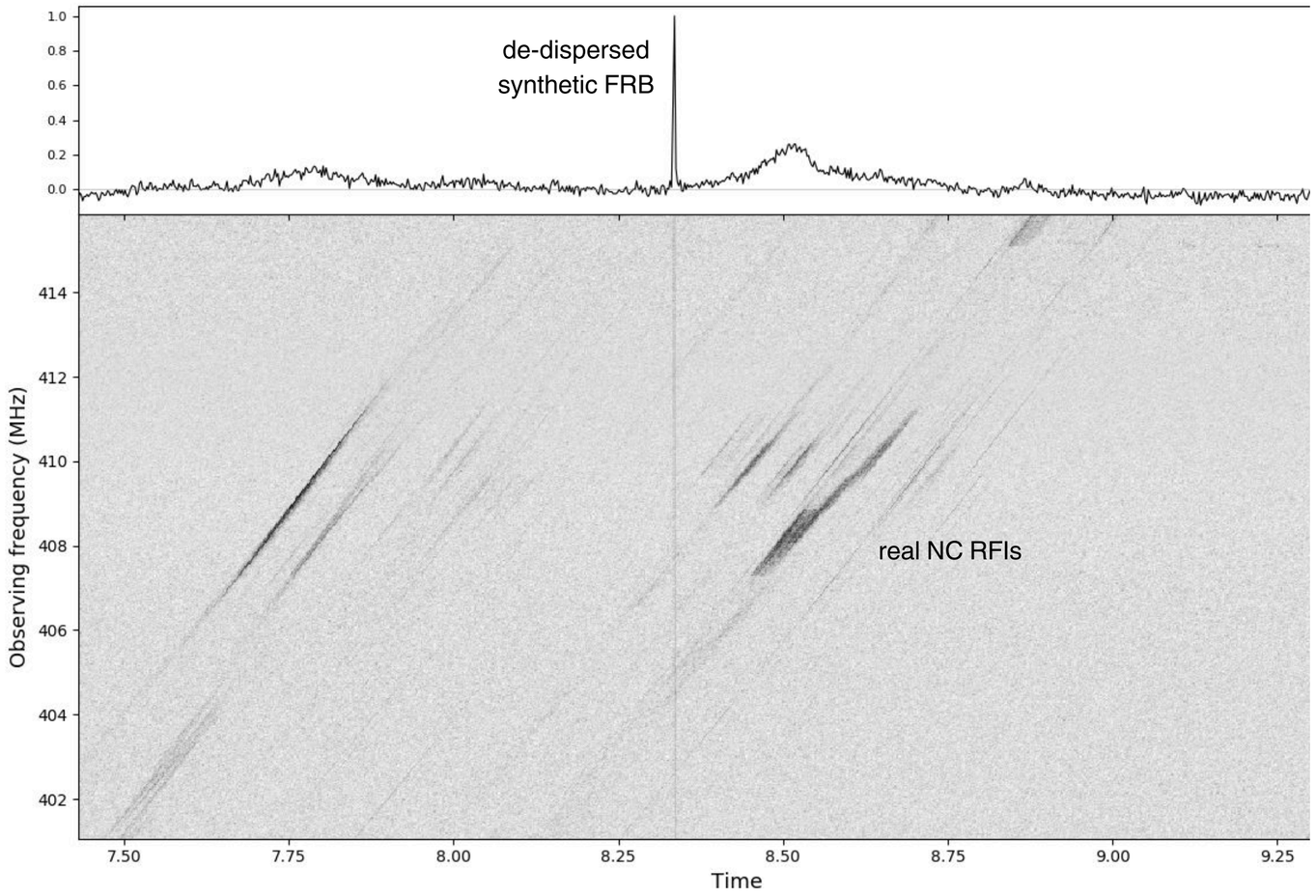


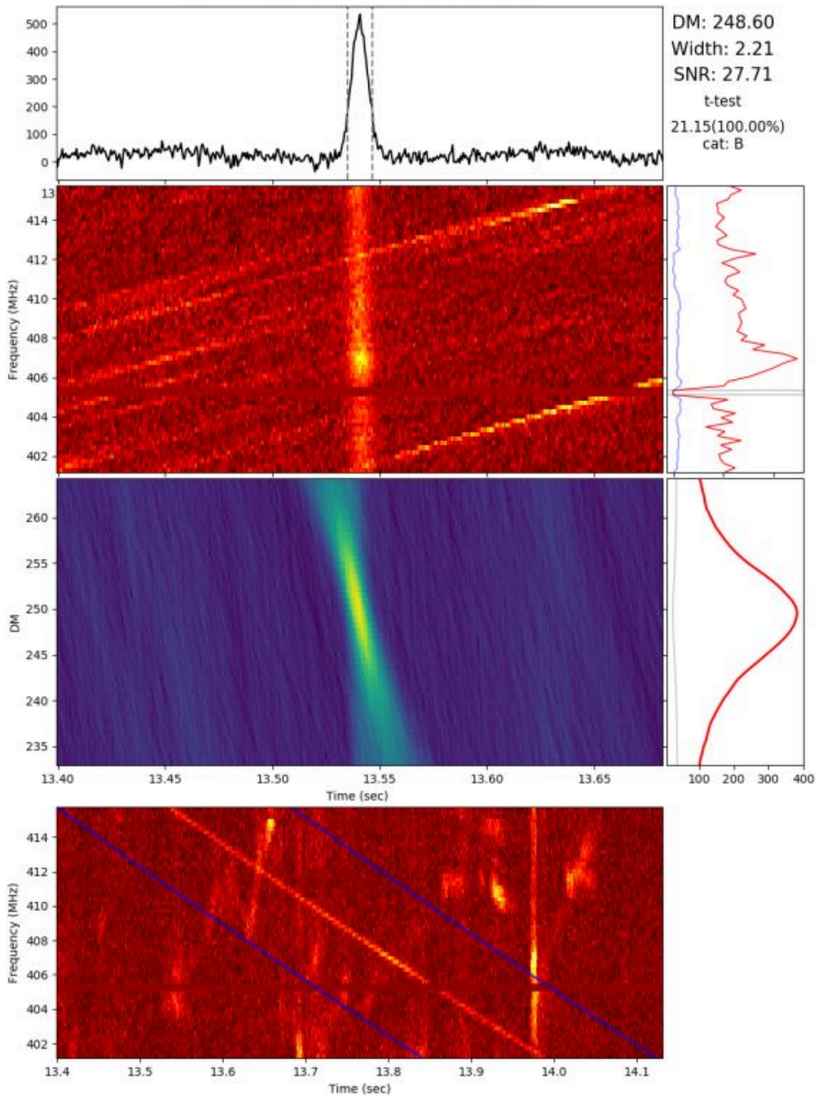
real

Houben et al. 2019



example of injection
on real NC data

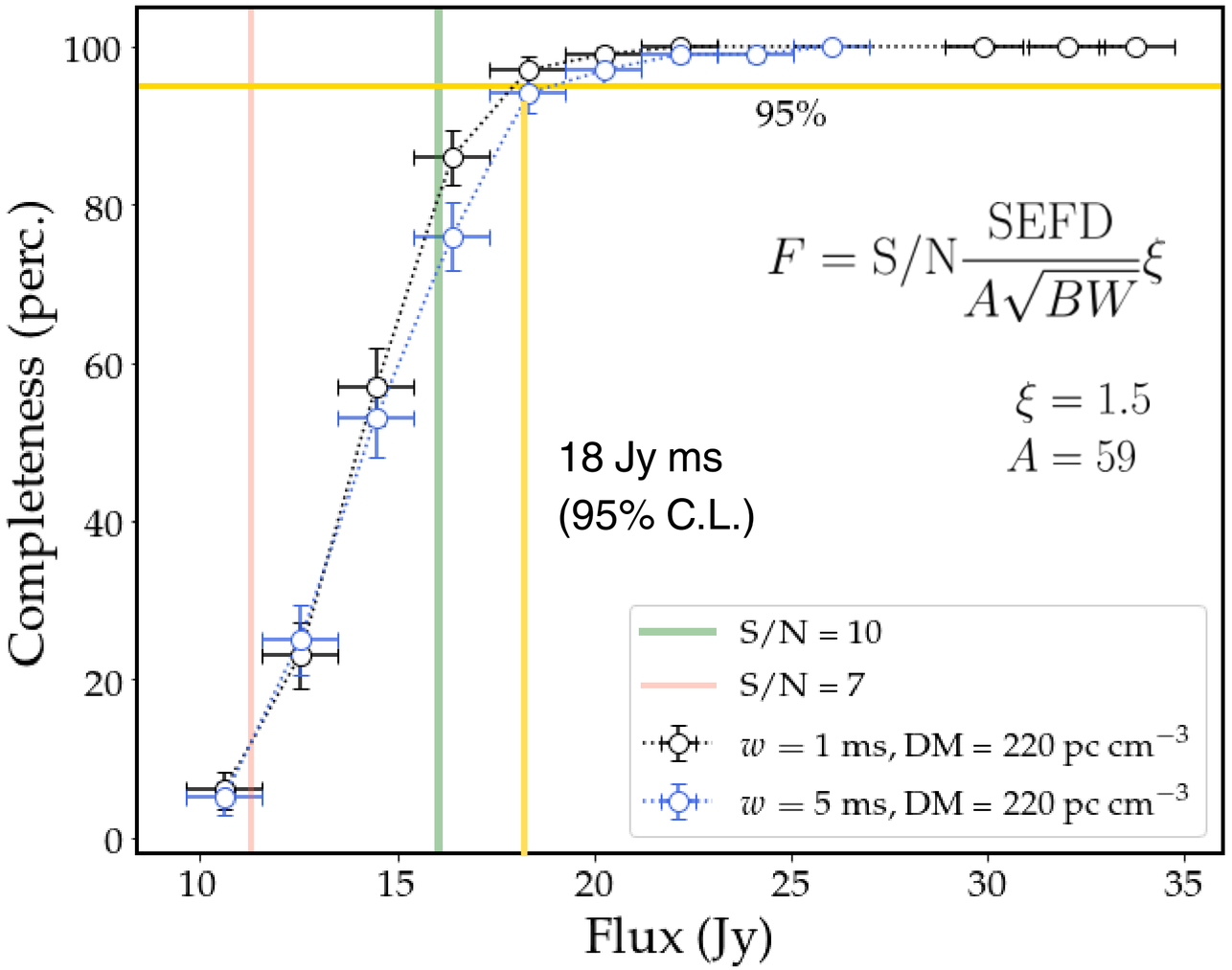

de-dispersed
synthetic FRB
real NC RFIs
Observing frequency (MHz)
Time


DM: 248.60
Width: 2.21
SNR: 27.71
t-test
21.15(100.00%)
cat: B
Frequency (MHz)
DM
Time (sec)

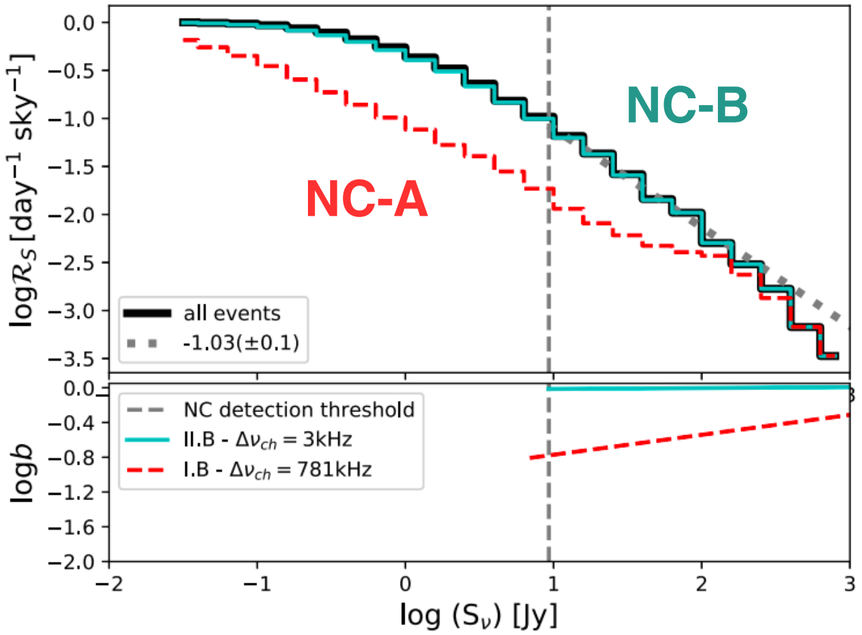
NC completeness (16 cyl. 1N-2N)

We injected N = 100 bursts for every flux/fluence bin (ΔF = 1 Jy) and calculated the completeness as

$$\mathcal{C}(F) = \frac{N_{\rm rec}(F)}{N_{\rm tot}(F)}$$



To be done also for EW arm (& 64-cyl NS)



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **494,** 1229–1236 (2020) doi:10.1093/mnras/staa813
Advance Access publication 2020 April 2

The Northern Cross fast radio burst project – I. Overview and pilot observations at 408 MHz

Nicola T. Locatelli,[1,2★] Gianni Bernardi,[2,3,4] Germano Bianchi,[2] Riccardo Chiello,[5] Alessio Magro,[6] Giovanni Naldi,[2] Maura Pilia,[7] Giuseppe Pupillo,[2] Alessandro Ridolfi,[7,8] Giancarlo Setti[1,2] and Franco Vazza[1,2]

NC-A: blind survey, 8 cyl. 6° apart

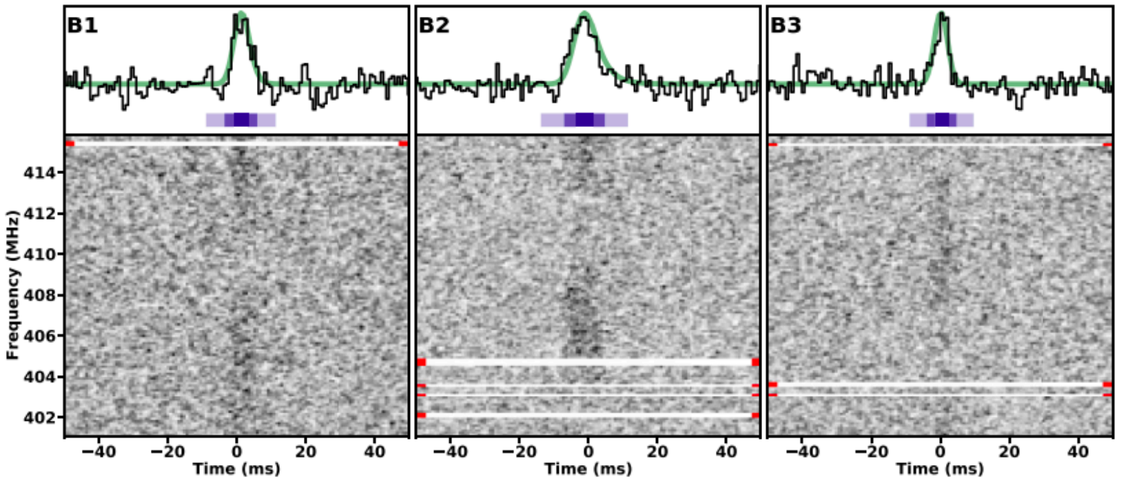
NC-B: blind survey, whole NS ready, covering 0°- 90° dec. range (15 pointings 6° apart)

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **513,** 1858–1866 (2022) https://doi.org/10.1093/mnras/stac1031
Advance Access publication 2022 April 13

The northern cross fast radio burst project – II. Monitoring of repeating FRB 20180916B, 20181030A, 20200120E, and 20201124A

M. Trudu[1,2★] M. Pilia,[2] G. Bernardi,[3,4,5] A. Addis,[6] G. Bianchi,[3] A. Magro[7] G. Naldi,[3] D. Pelliciari,[3,8] G. Pupillo,[3] G. Setti,[3,8] C. Bortolotti,[3] C. Casentini,[9,10] D. Dallacasa,[3,8] V. Gajjar,[11] N. Locatelli,[12] R. Lulli,[3] G. Maccaferri,[3] A. Mattana,[3] D. Michilli[13,14] F. Perini,[3] A. Possenti,[1,2] M. Roma,[3] M. Schiaffino,[3] M. Tavani[9,15] and F. Verrecchia[16,17]

First light!
active repeater FRB 180916B (R3)



+ constraints on the slope of the **energy distribution** of other 3 repeating FRBs

A&A 674, A223 (2023)
https://doi.org/10.1051/0004-6361/202346307

Astronomy & Astrophysics

The Northern Cross Fast Radio Burst project

III. The FRB–magnetar connection in a sample of nearby galaxies

D. Pelliciari[1,2], G. Bernardi[1,3,4], M. Pilia[5], G. Naldi[1], G. Pupillo[1], M. Trudu[5,6], A. Addis[7], G. Bianchi[1], C. Bortolotti[1], D. Dallacasa[1,2], R. Lulli[1], A. Maccaferri[1], A. Magro[8], A. Mattana[1], F. Perini[1], M. Roma[1], M. Schiaffino[1], G. Setti[1,2], M. Tavani[9,10], F. Verrecchia[11,12], and C. Casentini[9]

A&A 674, A223 (2023)
https://doi.org/10.1051/0004-6361/202346307

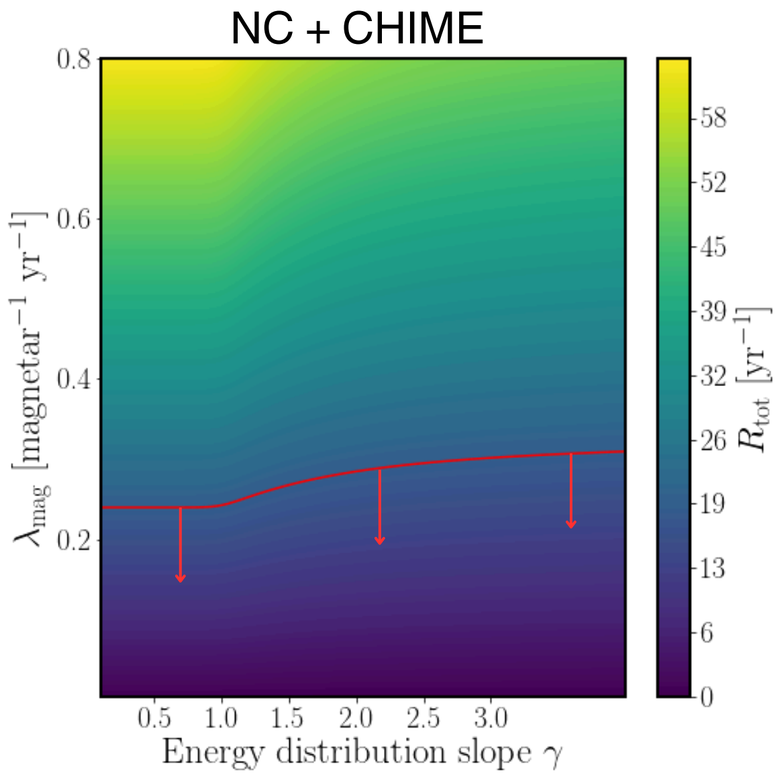
Astronomy & Astrophysics

The Northern Cross Fast Radio Burst project

III. The FRB–magnetar connection in a sample of nearby galaxies

D. Pelliciari[1,2], G. Bernardi[1,3,4], M. Pilia[5], G. Naldi[1], G. Pupillo[1], M. Trudu[5,6], A. Addis[7], G. Bianchi[1], C. Bortolotti[1], D. Dallacasa[1,2], R. Lulli[1], A. Maccaferri[1], A. Magro[8], A. Mattana[1], F. Perini[1], M. Roma[1], M. Schiaffino[1], G. Setti[1,2], M. Tavani[9,10], F. Verrecchia[11,12], and C. Casentini[9]

repetition rate per magnetar
is low → further evidence that a single population of SGR-like magnetars cannot explain the totality of FRBs



$$0.007 \leq \lambda_{\rm mag} \leq 0.25 \ {\rm magnetar}^{-1} \ {\rm yr}^{-1}$$

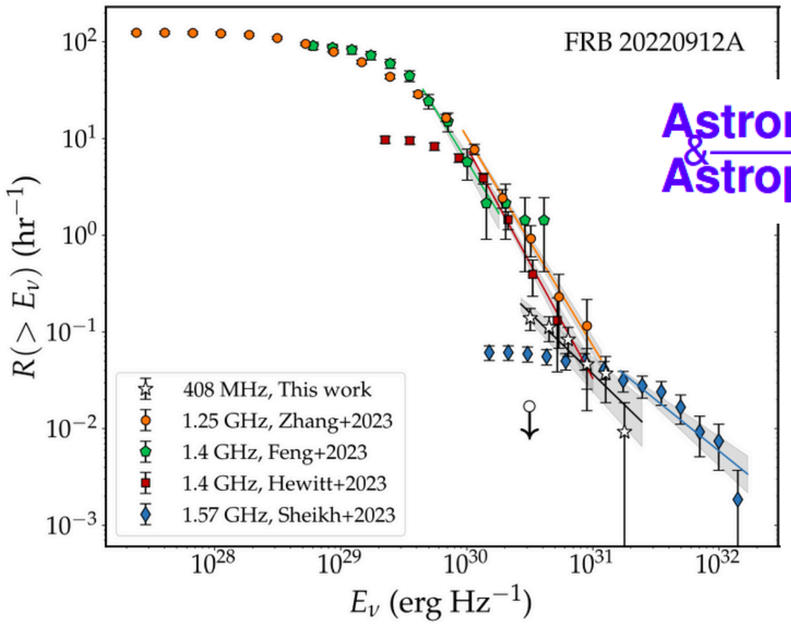
Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INAF ISTITUTO NAZIONALE DI ASTROFISICA

The Northern Cross Fast Radio Burst project

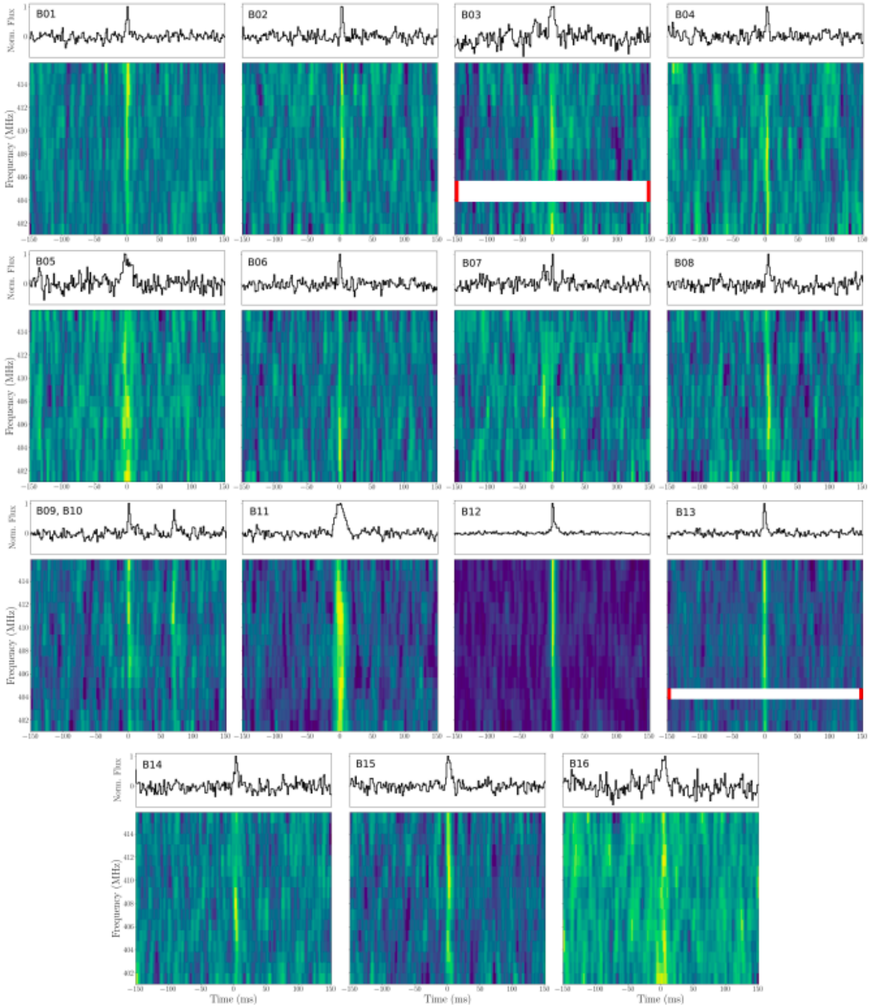
IV. Multi-wavelength study of the actively repeating FRB 20220912A

D. Pelliciari[1,2,*], G. Bernardi[1,3,4], M. Pilia[5], G. Naldi[1], G. Maccaferri[1], F. Verrecchia[13,14], C. Casentini[10], M. Perri[13,14], F. Kirsten[6,7], G. Bianchi[1], C. Bortolotti[1], L. Bruno[1,2], D. Dallacasa[1,2], P. Esposito[9], A. Geminardi[5,8,9], S. Giarratana[1,2], M. Giroletti[1], R. Lulli[1], A. Maccaferri[1], A. Magro[10], A. Mattana[1], F. Perini[1], G. Pupillo[1], M. Roma[1], M. Schiaffino[1], G. Setti[1,2], M. Tavani[11,12], M. Trudu[5], and A. Zanichelli[1]

+ Medicina single dish (1.4 GHz)
+ Swift (X-ray)
+ AGILE (soft-gamma)



Astronomy & Astrophysics



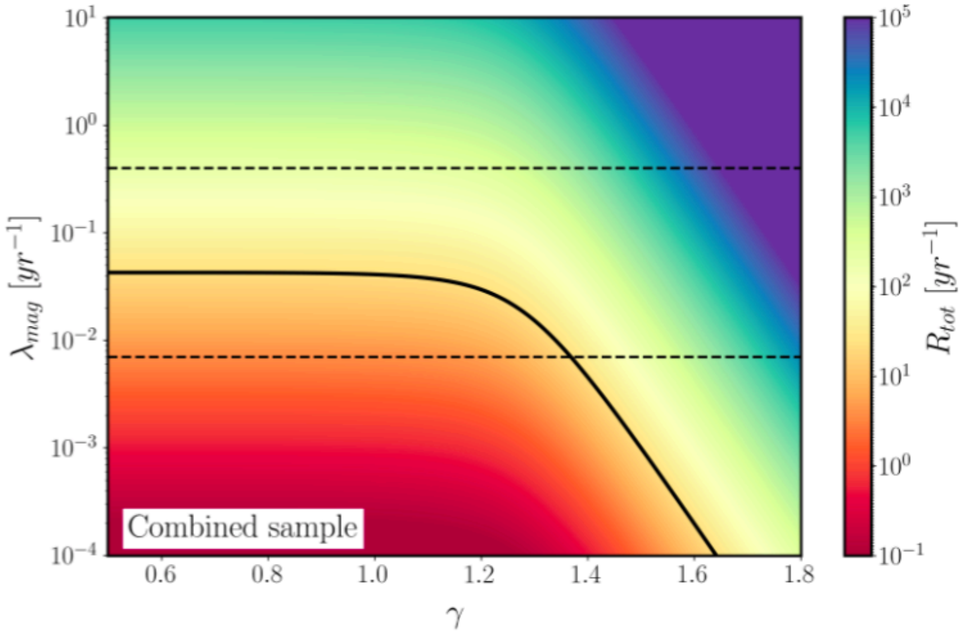
Astronomy & Astrophysics manuscript no. output
May 12, 2025

The Northern Cross Fast Radio Burst project

V. Search for transient radio emission from Galactic magnetars

A. Geminardi[1,2,3], P. Esposito[1,4], G. Bernardi[5,6,7], M. Pilia[3], D. Pelliciari[5], G. Naldi[5], D. Dallacasa[5,8], R. Turolla[9,10], L. Stella[11], F. Perini[5], F. Verrecchia[11,12], C. Casentini[13,14], M. Trudu[3], R. Lulli[5], A. Maccaferri[5], A. Magro[15], A. Mattana[5], G. Bianchi[5], G. Pupillo[5], C. Bortolotti[5], M. Tavani[13,16], M. Roma[5], M. Schiaffino[5], and G. Setti[5,8]

Submitted!



Future NC projects?

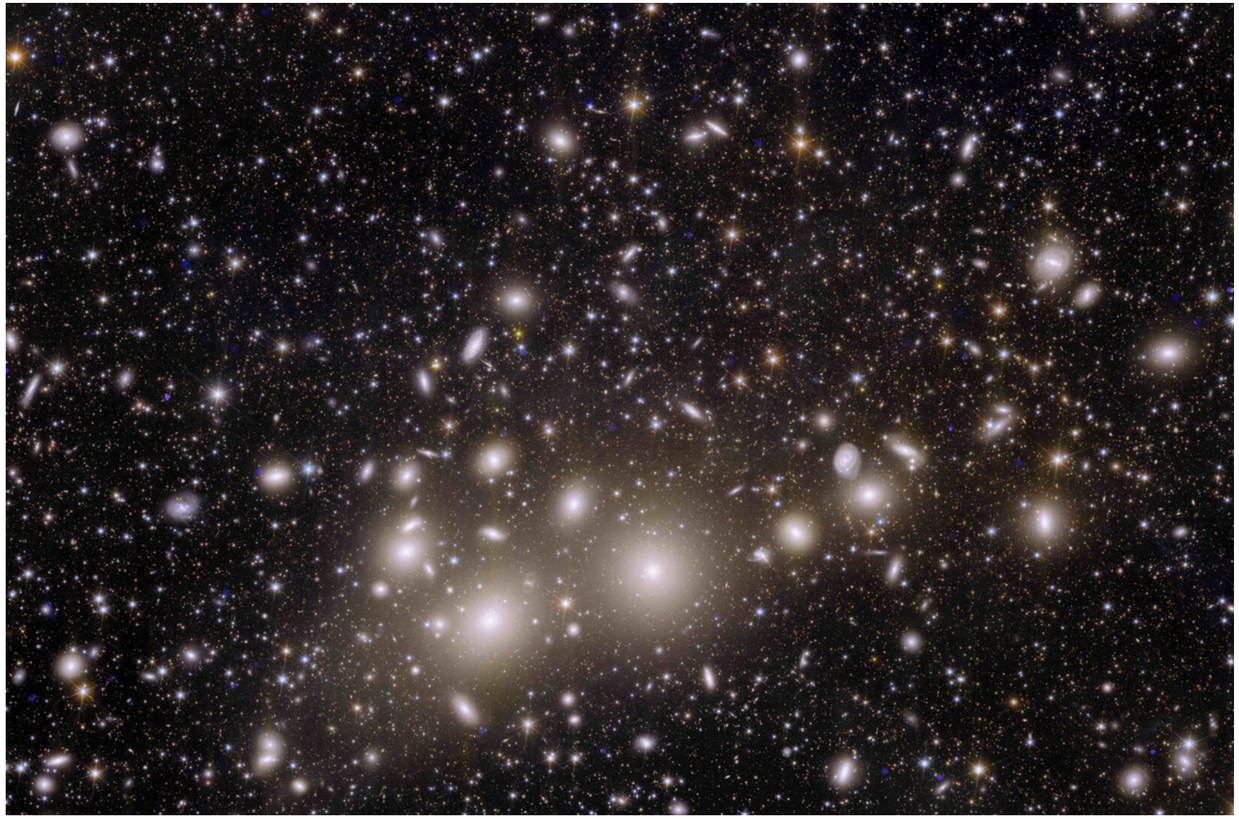
population studies, e.g.:

- dwarf galaxies / massive ellipticals vs. SFGs?
- **galaxy clusters**:
  - enhanced FRB rate (more galaxies more SFR/mass)
  - chances for lensed FRBs?

blind surveys (large FoV from multibeam NS, EW..)

!

Euclid's view of the Perseus GC

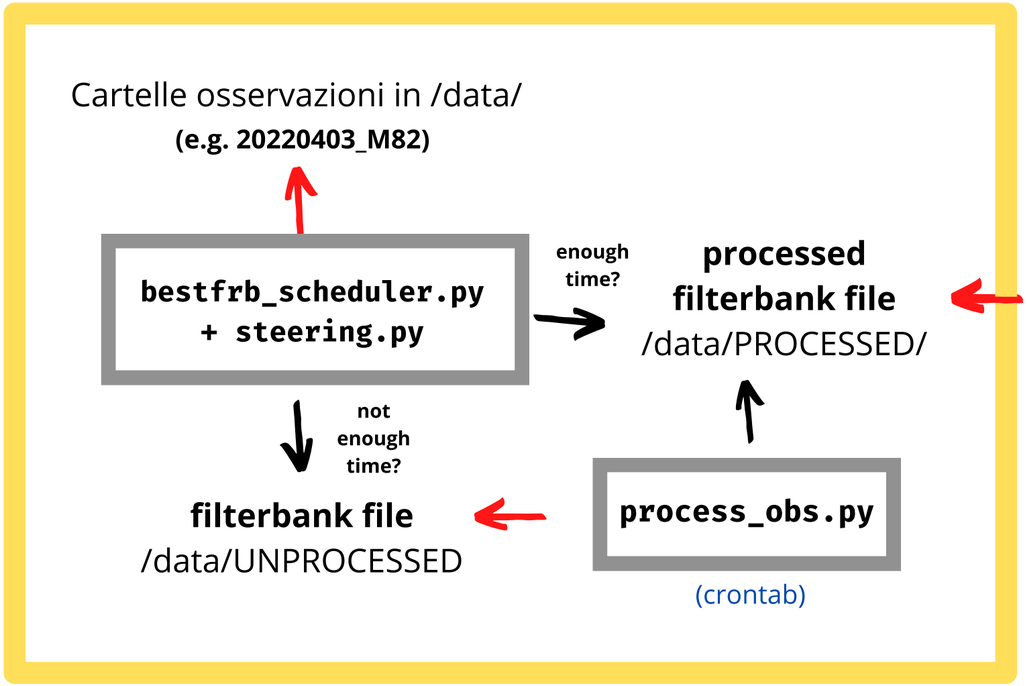


Thank you!

backup slides

A script to schedule them all

(with spandak)



scheduler.py

- multiple observatiations/targets
- multiple dates (e.g. month-long campaign)
- antenna movement + steering

: acts on

: produces

spandak

Heimdall + Spandak

analyse_frbcand.py (crontab)

+ RFI-find

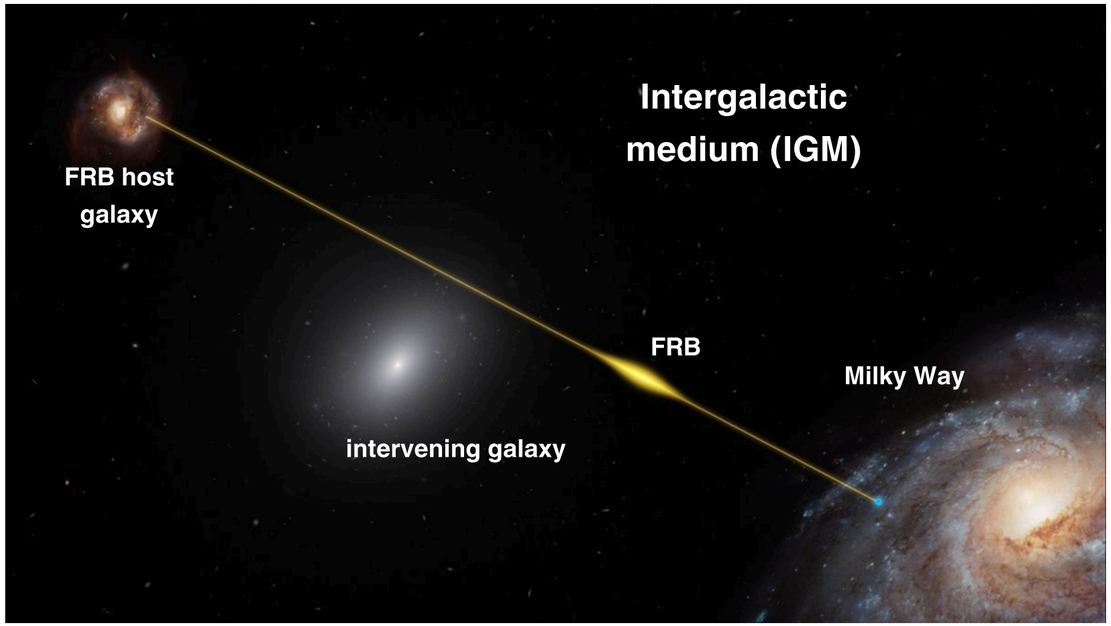
candidates
C candidates
B candidates
SNR vs DM

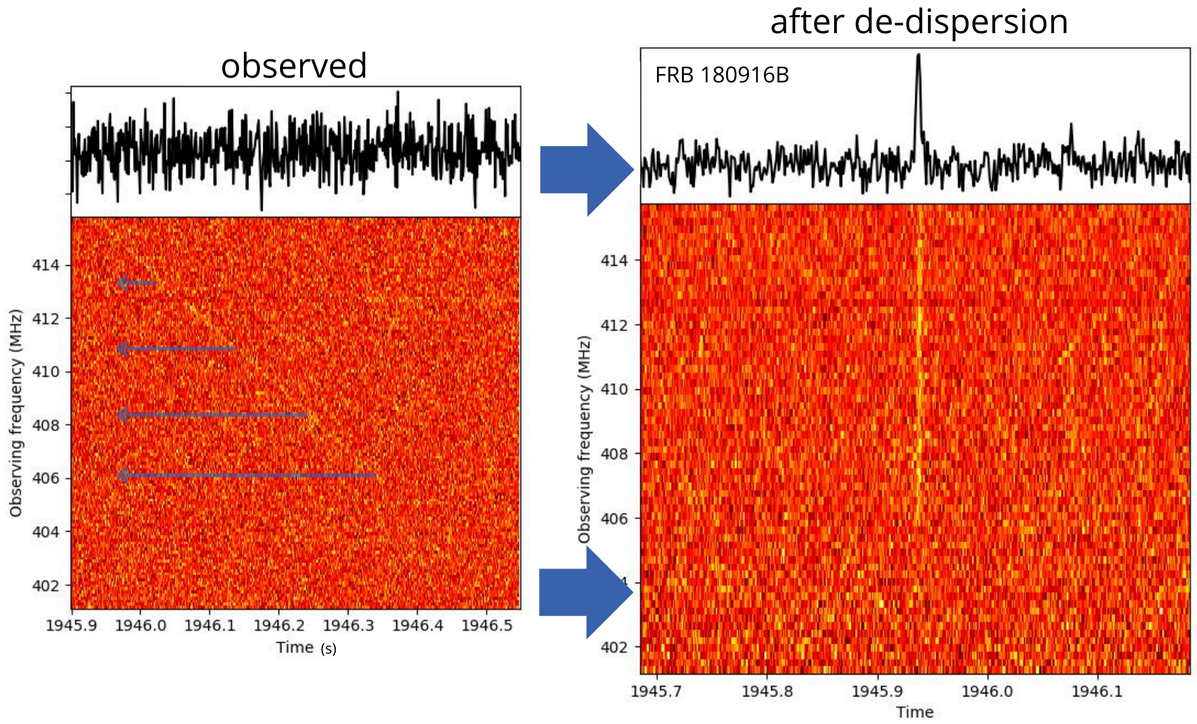
classification based on waterfall plot

email sent

mv /data/PROCESSED/date_frb /data/ANALYSED/

Propagation effects on FRB signals

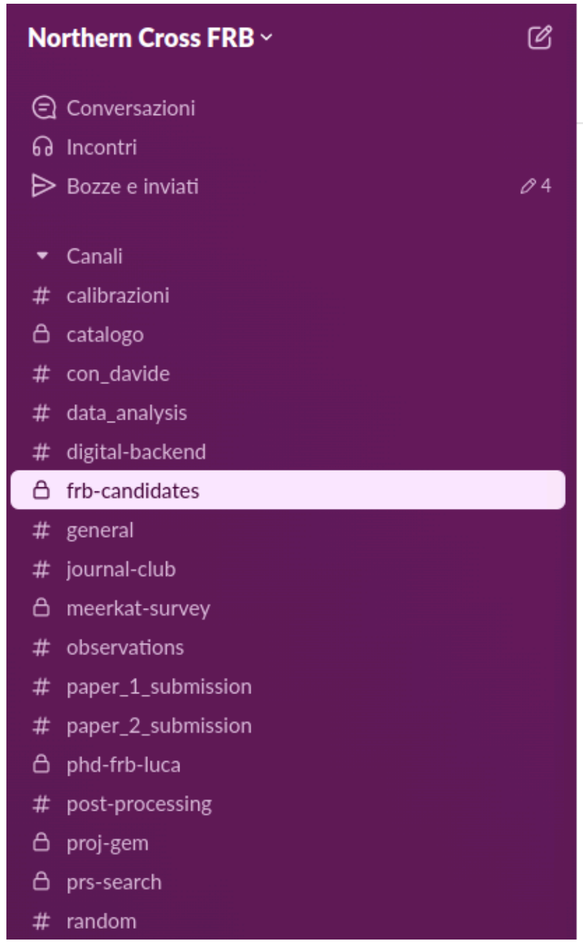




Many contributions have to be taken into account:

$$\mathrm{DM_{obs}} = \mathrm{DM_{MW,ISM}} + \mathrm{DM_{MW,halo}} + \mathrm{DM_{IGM}}(z) + \frac{\mathrm{DM_{host}}}{1+z}$$

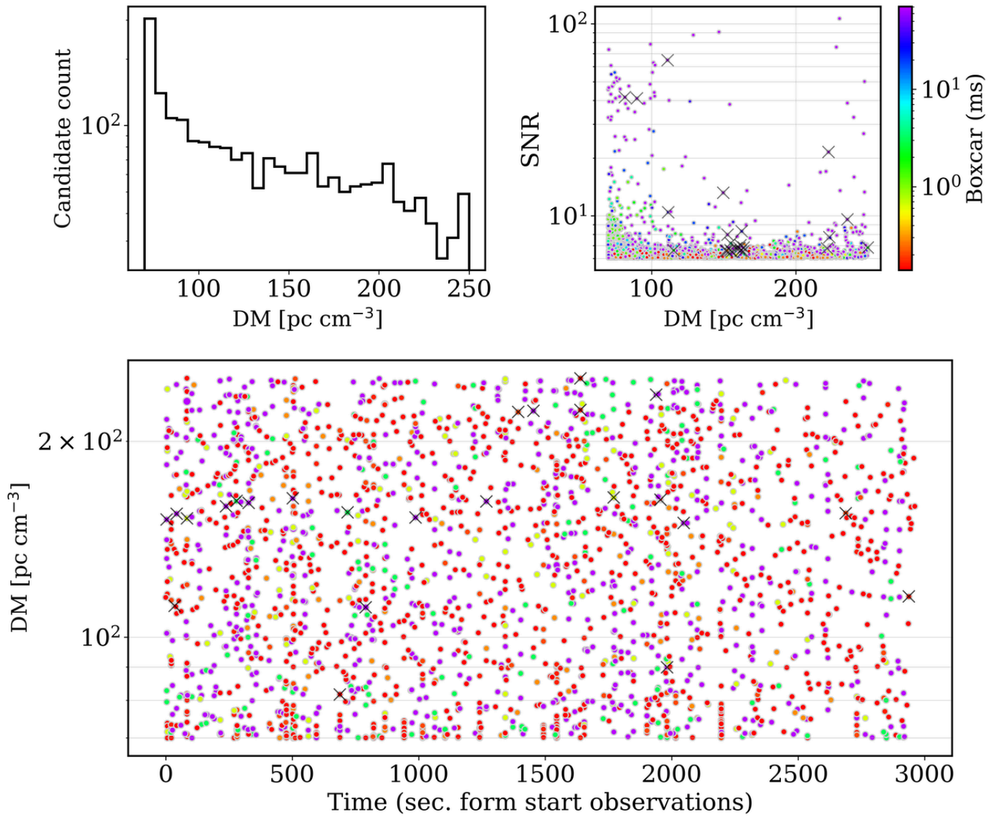
Slack candidates



dropbox → slack bot (NC-FRB)

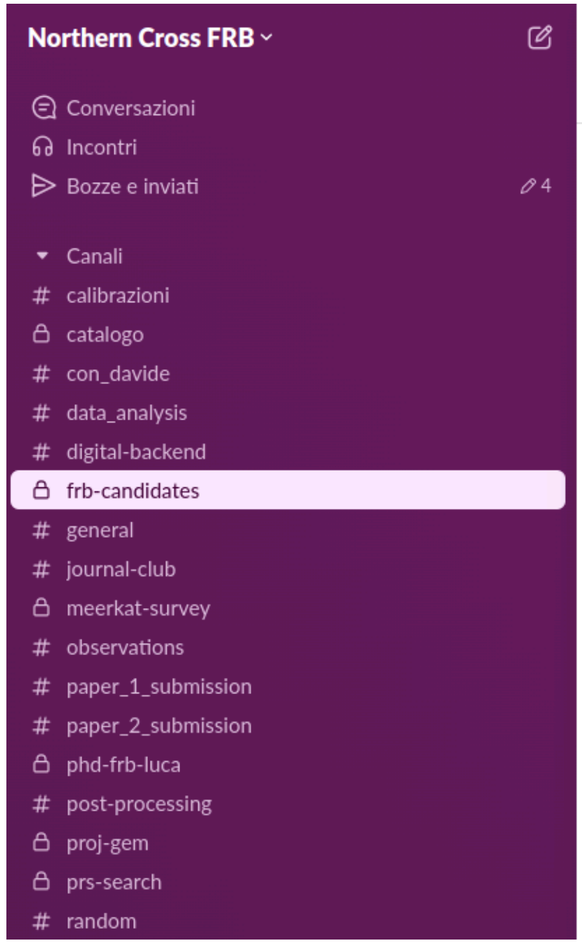
`slack_sender.py` in medfrb

(best candidates from FETCH)



check candidates statistics + RFI environment

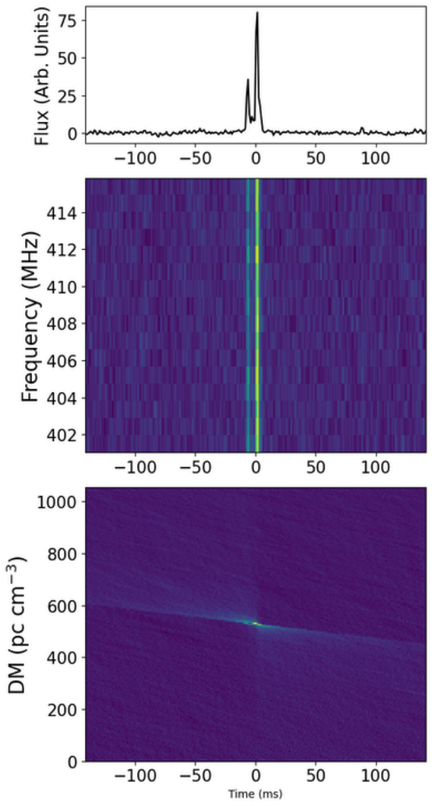
Slack candidates



dropbox → slack bot (NC-FRB)

`slack_sender.py` in medfrb

(best candidates from FETCH)



basename : beam_1710665176.068081_processed
bw : -14.814814814814813
cand_id : cand_tstart_60386.407130417603_tcand_973.6960000_dm_527.88400_snr_73.28440
center_freq : 408.45428240740745
dec_deg : 4.3501
dm : 527.884
dm_opt : -1
dtype : uint16
fch1 : 415.85445601851853
filelist : ['/jbod/PROC_test/20240317T084712_FRB20240114A_1N2N/beam_1710665176.068081_processed.fil']
filename : /jbod/PROC_test/20240317T084712_FRB20240114A_1N2N/beam_1710665176.068081_processed.fil
foff : -0.014467592592592591
format : fil
frequency_decimation_factor : 1
gb : -31.63930342992909
gl : -122.49906367639196
kill_mask : [False]
label : 0
native_foff : -0.014467592592592591
native_nbits : 16
native_nchans : 1024
native_nspectra : 11206656.0
native_tsamp : 0.00013824
nbits : 16
nchans : 1024
npol : 1
nspectra : 11206656
poln_order : I
ra_deg : 321.9162083333334
rfi_mask : [False]
snr : 73.2844
snr_opt : -1
source_name : FRB20240114A
tcand : 973.696
time_decimation_factor : 1
tsamp : 0.00013824
tstart : 60386.4071304176
tstart_utc : 2024-03-17T09:46:16.068
width : 16

NC detection of FRB 20240114A