



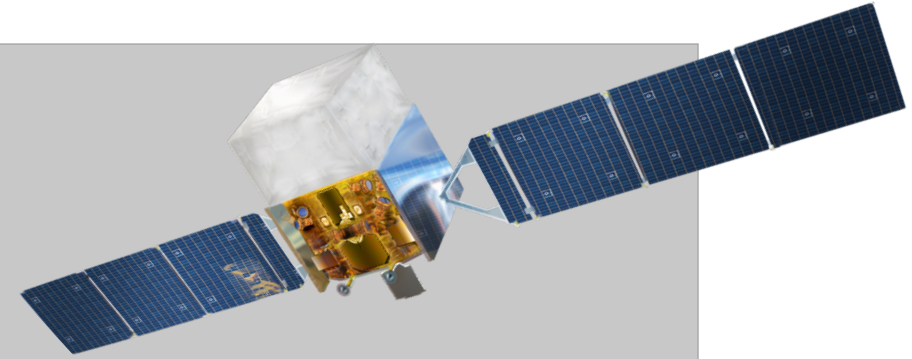
# Hunting the gamma-ray emission from Fast Radio Bursts with Fermi-LAT

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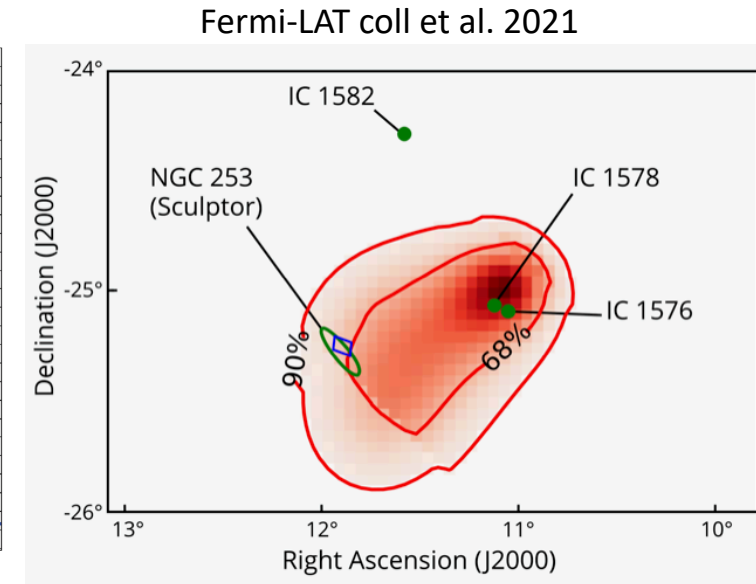
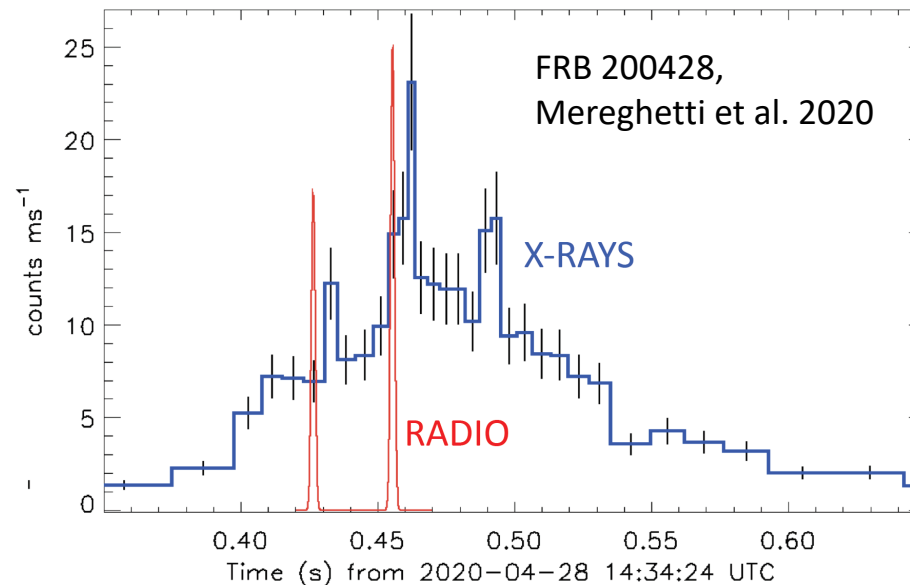
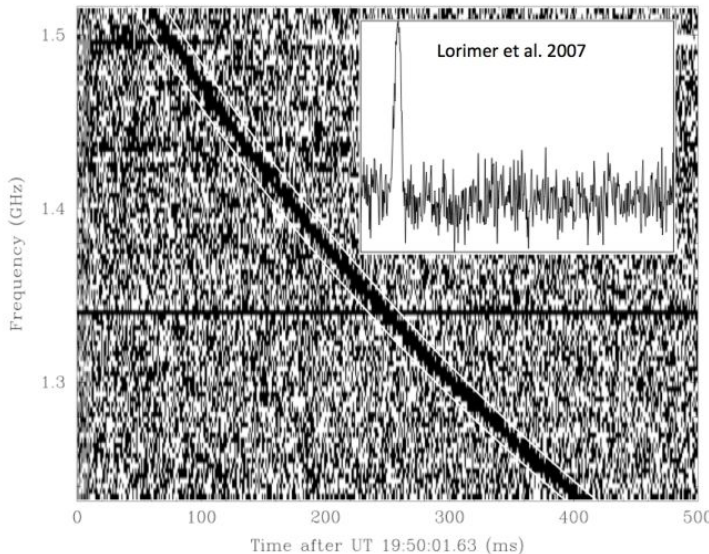
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**Fast radio bursts (FRBs):** are bright (typical fluences of 1-2 Jy) and short-duration (few ms or less) pulses at frequencies of about 1 GHz, caused by some high-energy astrophysical processes not yet understood. Discovered just over a decade ago, FRBs are one of the newest astrophysical enigmas.

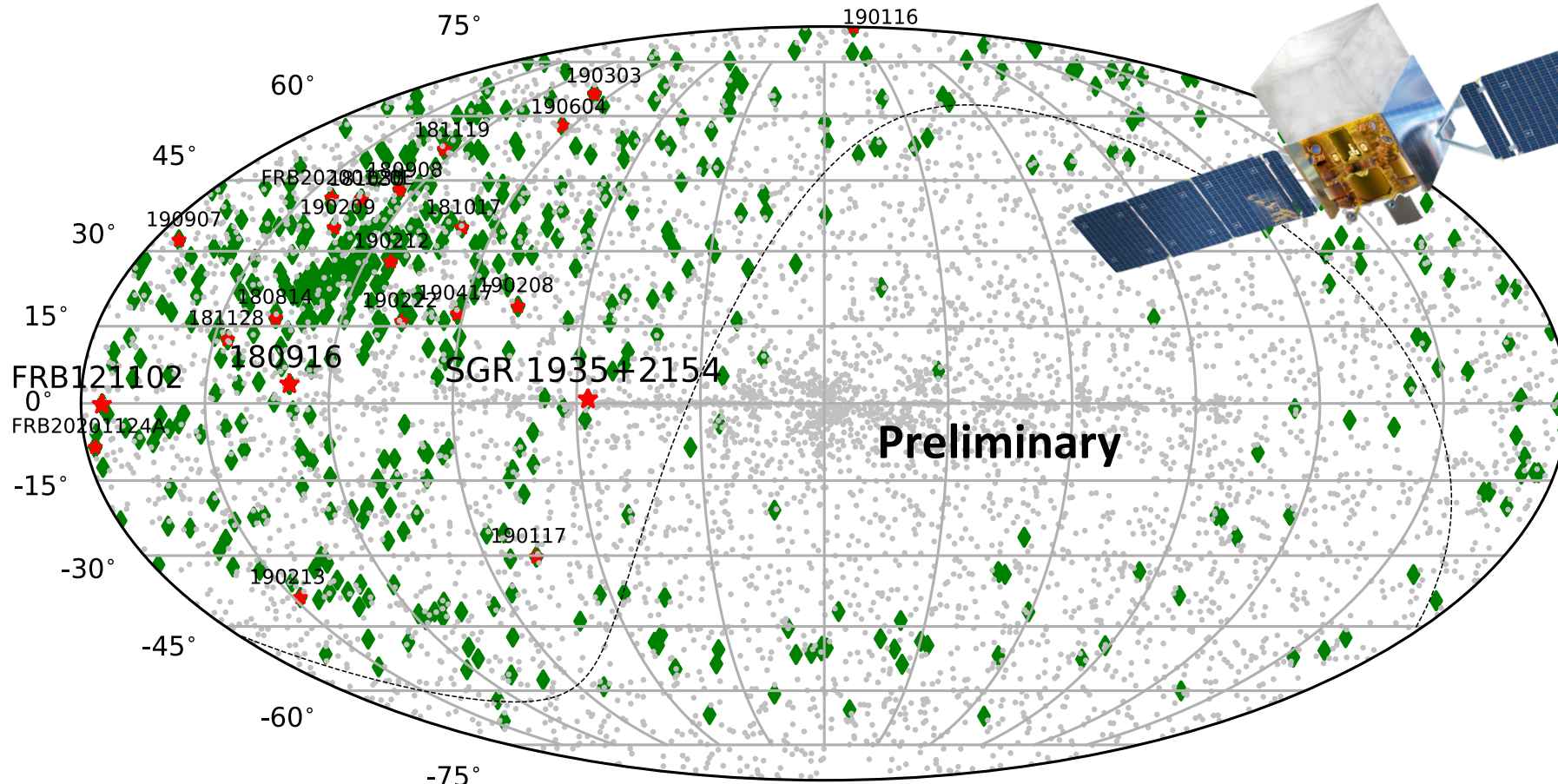
Two years ago, for the first time, an FRB-like event was associated with a Soft Gamma Repeaters (**SGR 1935+2154**) and, in particular, to a Galactic magnetar giant flare (MGF) [FRB 200428].

The recent detection of high energy emission, at GeV energies, from a magnetar giant flare in the *Sculptor* galaxy motivated the search for gamma-ray counterparts to the known FRBs.



# Goal of the project

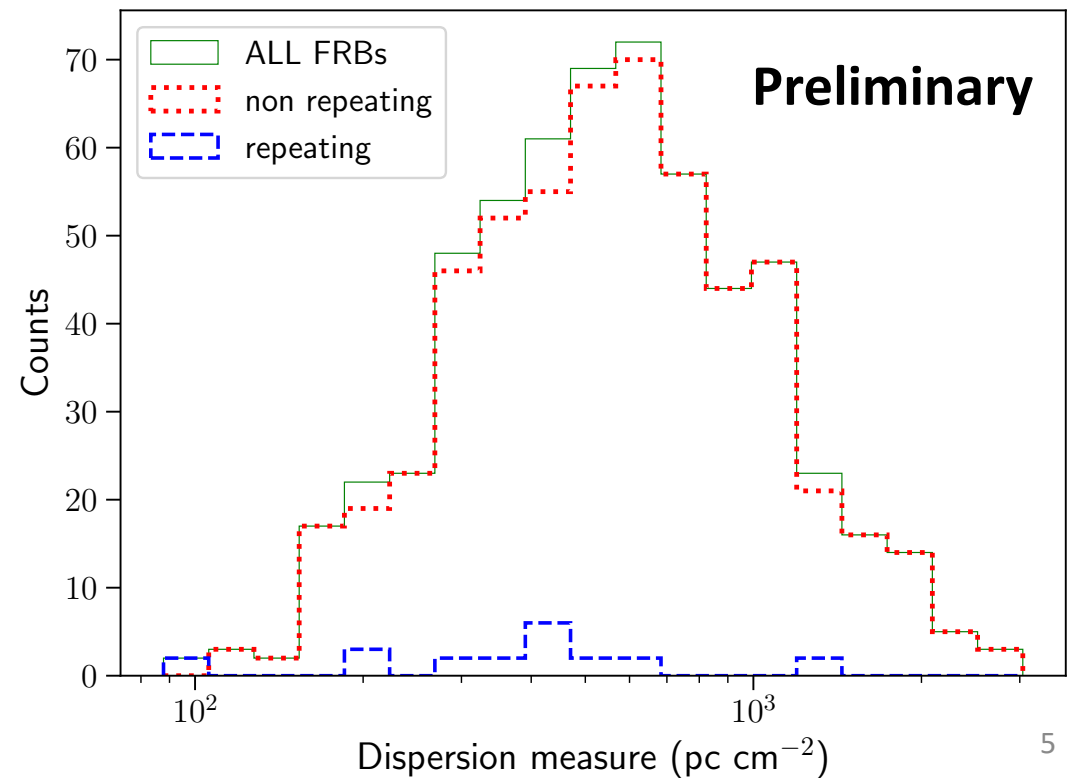
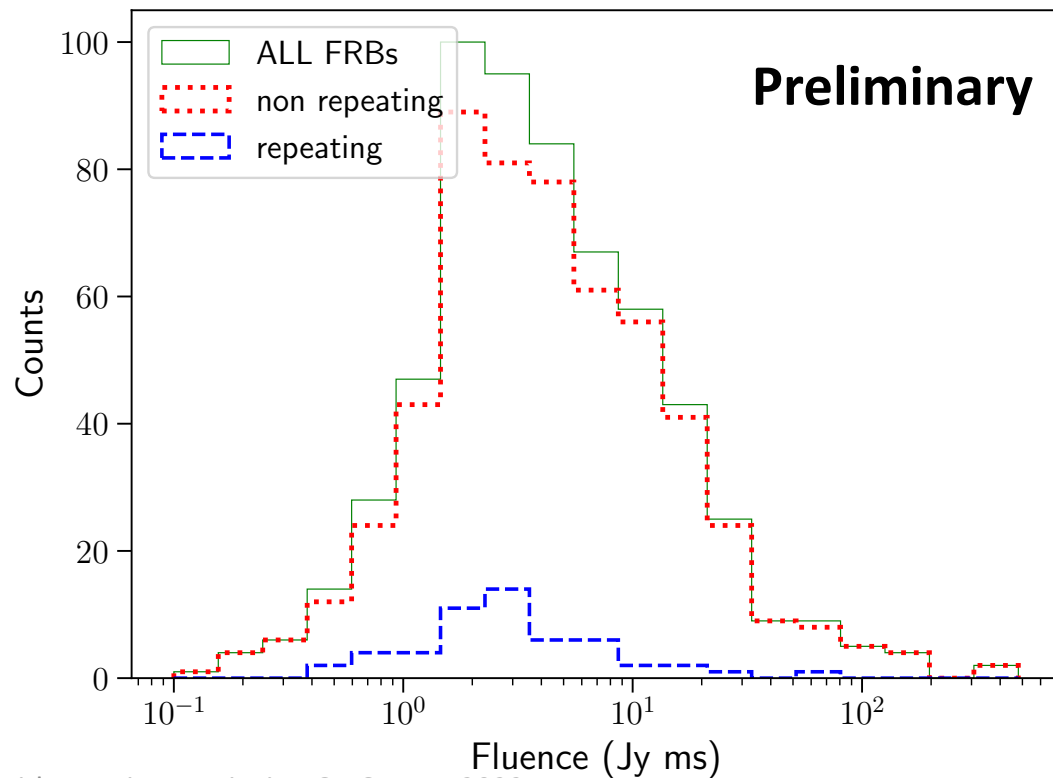
Thanks to over 13 years of Fermi-LAT data, as well as its large FoV and continuous sky survey, and to more than 1000 published FRBs, we aim to perform the largest and deepest systematic search for gamma-ray emission from all the reported repeating and non-repeating bursts.



# FRB Sample

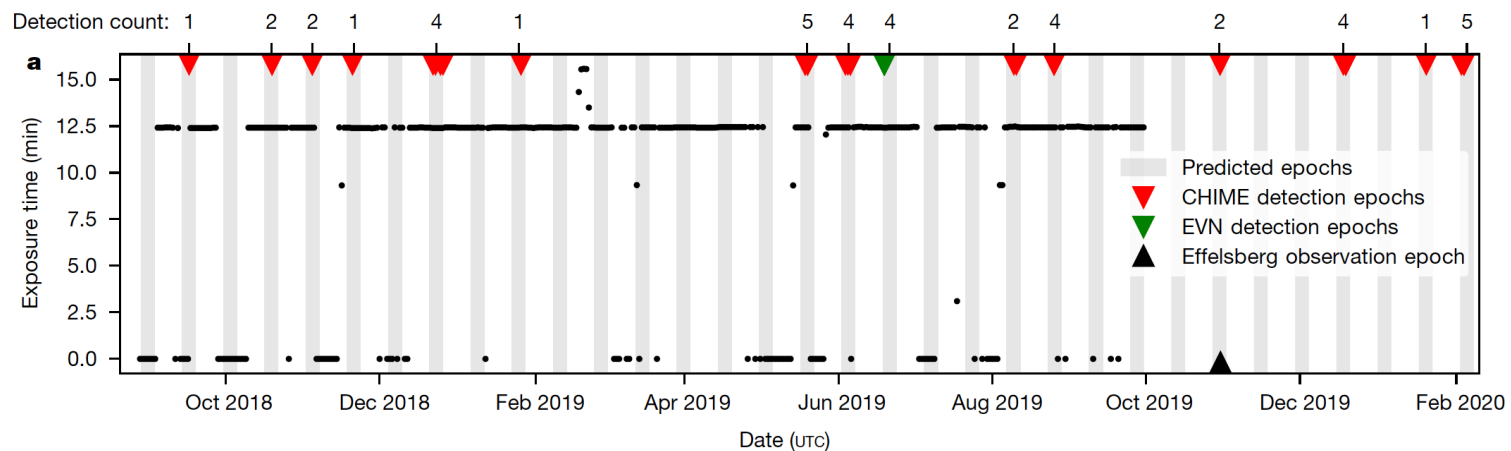
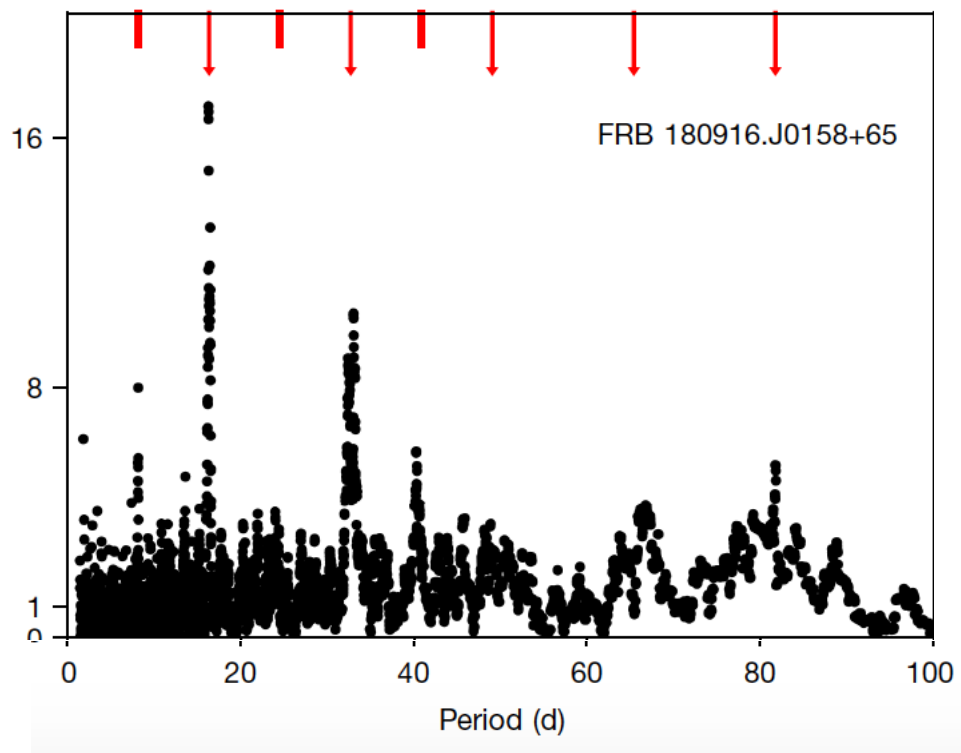
Our sample consists of **1020 FRBs** (560 non repeating and 21 repeating ones presenting 465 events) selected from the following resources:

- 535 repeating and non-repeating FRBs reported in the first CHIME/FRB catalog;
- 230 bursts from 20 repeating FRBs reported by the CHIME/FRB collaboration (<http://www.chime-frb.ca/repeaters>) as of June 15, 2021, including 73 bursts from the periodic FRB 180916;
- 235 burst from FRB 121102 collected by Rajwade et al. 2021.
- 118 events from the FRBCAT (Petroff. et al. 2016);



# A special FRB: the periodic FRB180916

**FRB 180916:** detection of a  $16.35 \pm 0.15$  day periodicity (or possibly higher frequencies). In 38 bursts recorded from September 16th, 2018 through February 4th, 2020, they found that all bursts arrive in a 5.4-day phase window, and 50% of the bursts arrive in a 0.6-day phase window (CHIME Collaboration, Nature; June 2020).



CHIME Collaboration, Nature; June 2020



## Analysis plan:

1. triplets photon counting analysis to study the coincidence of triplet events with the time and position of the FRBs in our sample.
2. Fermipy / Likelihood analysis on each individual FRB:
  - on time intervals ranging from 10 s up to 10000 s
3. Fermipy / Likelihood analysis on the repeating FRBs:
  - stacking analysis on 10s,100s,.. windows
  - analysis on 13 years for a search of possible steady emission
4. Special attention is given to the periodic FRB 180916:
  - folding analysis on the 0.6d (5.4d) phase windows on 13 years
5. Stacking analysis for all the FRBs
6. Analysis verification on background / random events

Data Selection	Values
IRFs	P8R3_SOURCE_v3
PSF Classes	All , [no PSF0 and PSF1, E < 300 MeV] [no PSF0, 300 MeV < E < 1 GeV]
Time Intervals	<b>10 s / 100 s/ 1000 s /... / years</b>
Energy Range	100 MeV (1 GeV) – 1 TeV
Zenith angle	< 105° / [< 85°, E < 300 MeV] / [< 95°, 300 MeV < E < 1 GeV]
Pixel Size	0.1°

**Diffuse models:** galdiff (gll\_iem\_v07.fits), isodiff: ( iso\_P8R3\_SOURCE\_V3\_v1.tx)  
**Model for the Fermi-LAT extend sources:** LAT\_extended\_sources\_10years.fits  
**Catalog:** latest version of the **4FGL-DR2** (gll\_psc\_v27.fit)

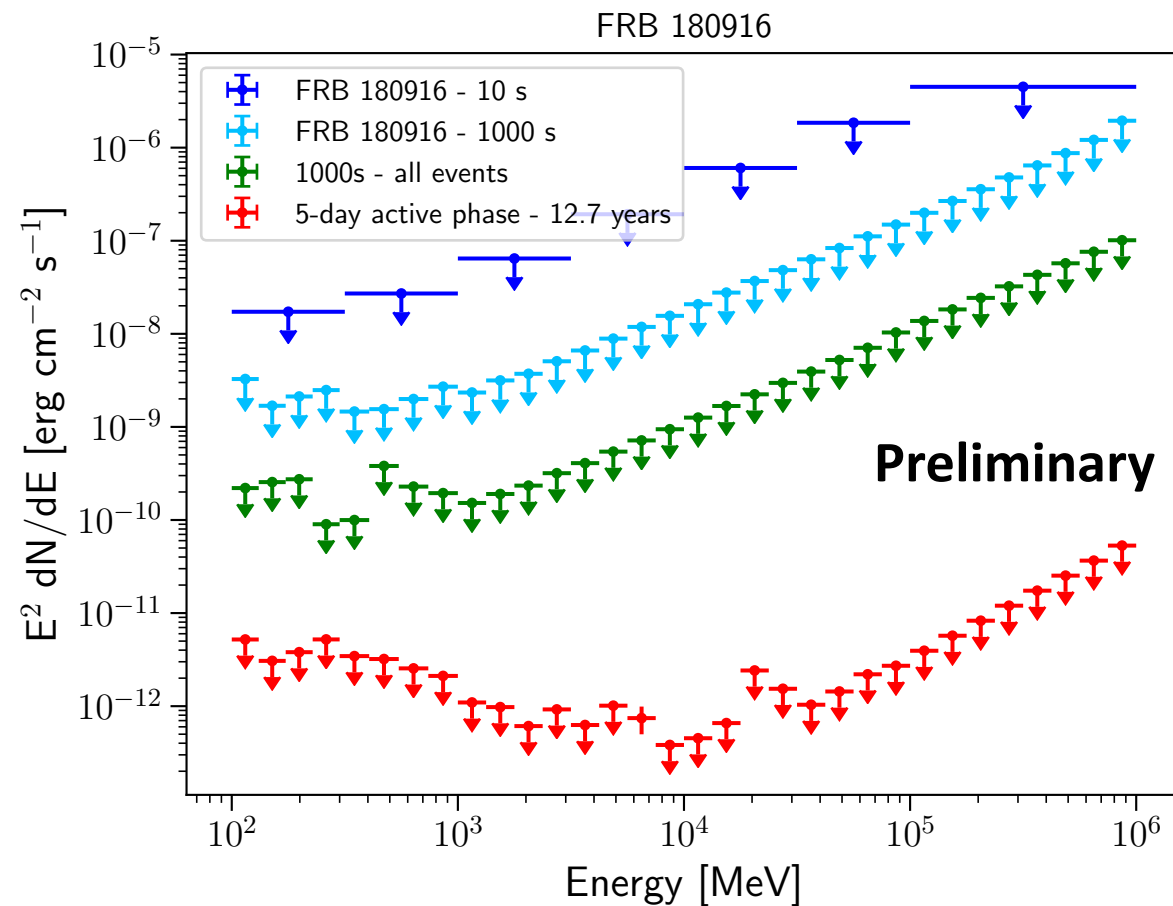
We search for high-energy emission from the periodic FRB 180916 ( $z=0.0337$ ) with Fermi-LAT.

We analysed LAT data:

- 10 s and 1000 s time intervals centred on the first observed burst (MJD=58377.42972096).
- 73 detected bursts using time intervals of 1000 s centred on each event, as well as on the 5.4-day active phase windows of the periodic FRB, using 13 years of available LAT data.

We did not find any significant gamma-ray emission from the periodic FRB 180916. We report 95% upper limits on the FRB energy flux above 100 MeV:

- 10 s:  $F < 7.8 \times 10^{-8} \text{ erg cm}^{-2} \text{ s}^{-1}$
- 1000 s:  $F < 1.4 \times 10^{-9} \text{ erg cm}^{-2} \text{ s}^{-1}$
- folding 1000 s:  $F < 1.7 \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1}$
- 5.4-d active phase:  $F < 2.3 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$





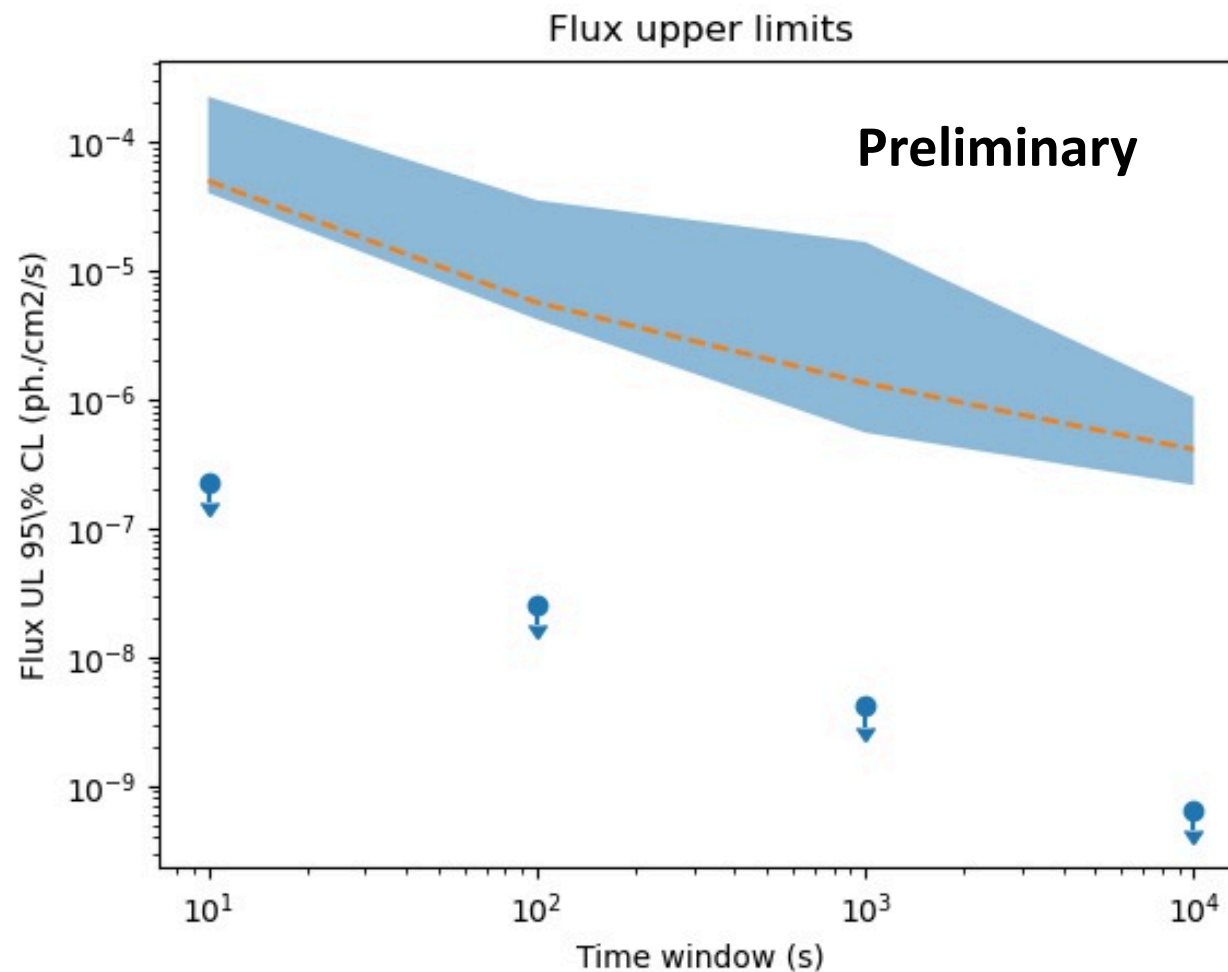
We do not find any significant emission from each individual FRBs.

-> UL provided strongly depends on the exposure to each FRBs events region.

We performed the first stacking analysis on all the analysed FRB events (1020 events).

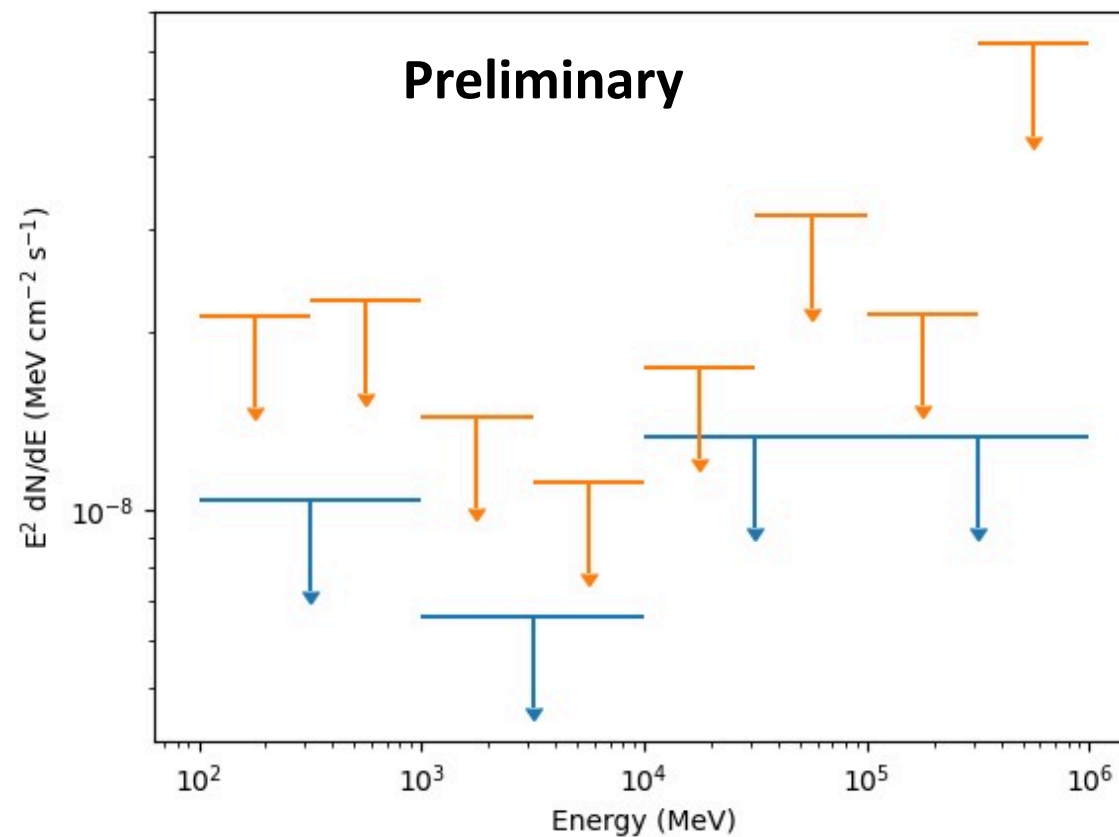
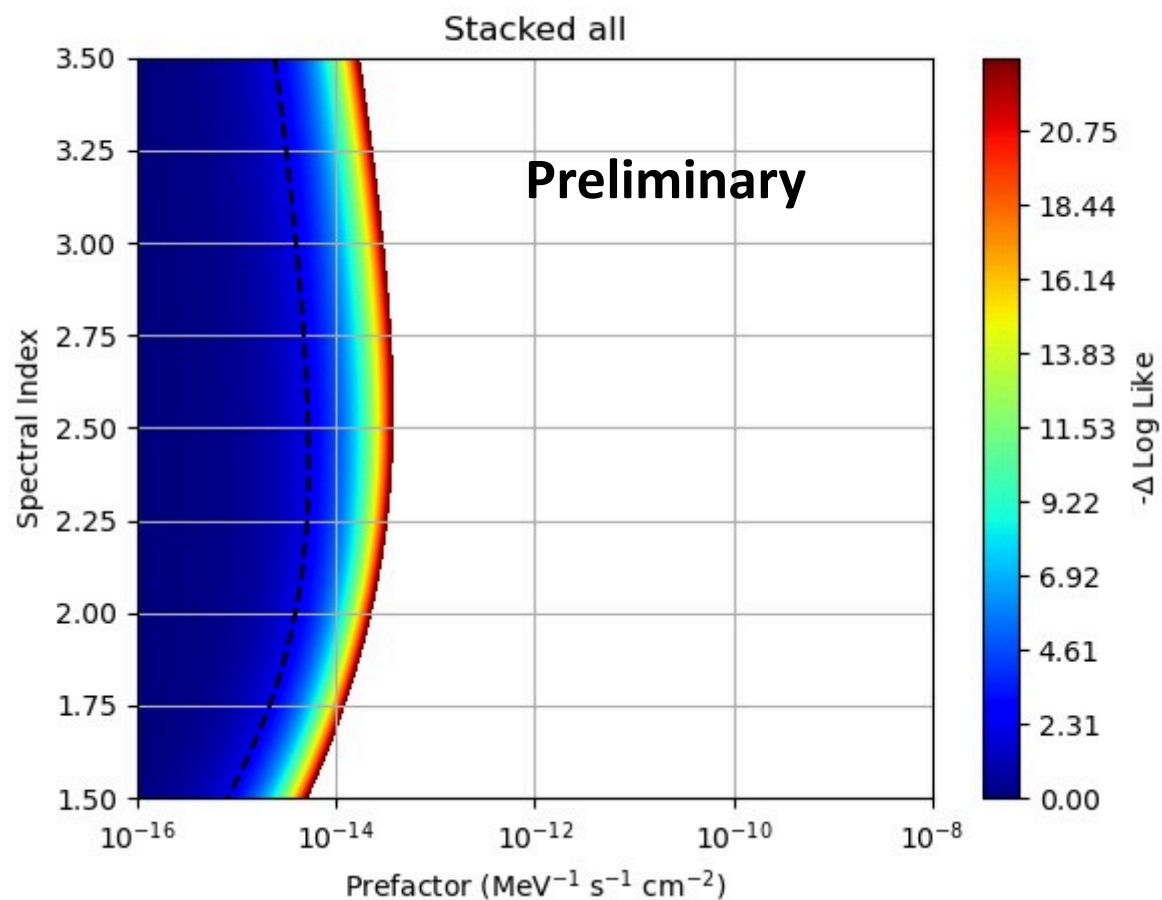
No significant emission has been detected also for the stacking analysis.

This provides the most stringent UL on the gamma-ray emission from a sample of FRBs.



# Preliminary results - Stacking on repeating sources

21 repeating FRBs, analysed over 13 years

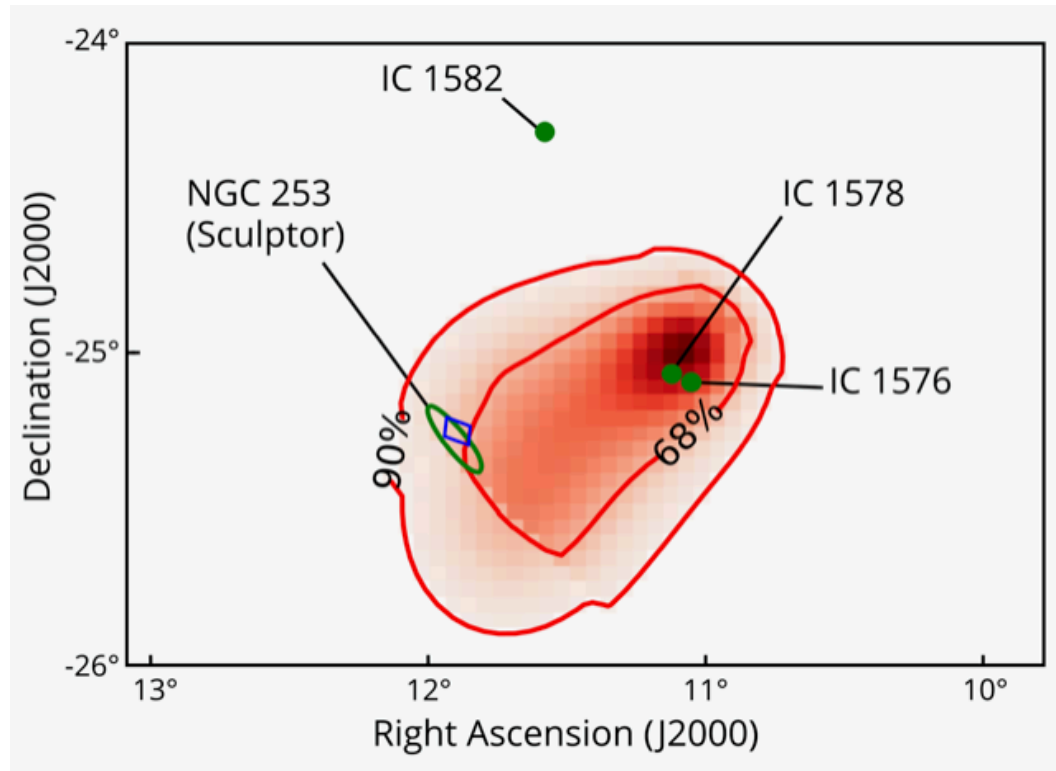


TS = 0.24 Flux (>100 MeV) UL =  $9.3 \times 10^{-11}$  ph/cm<sup>2</sup>/s

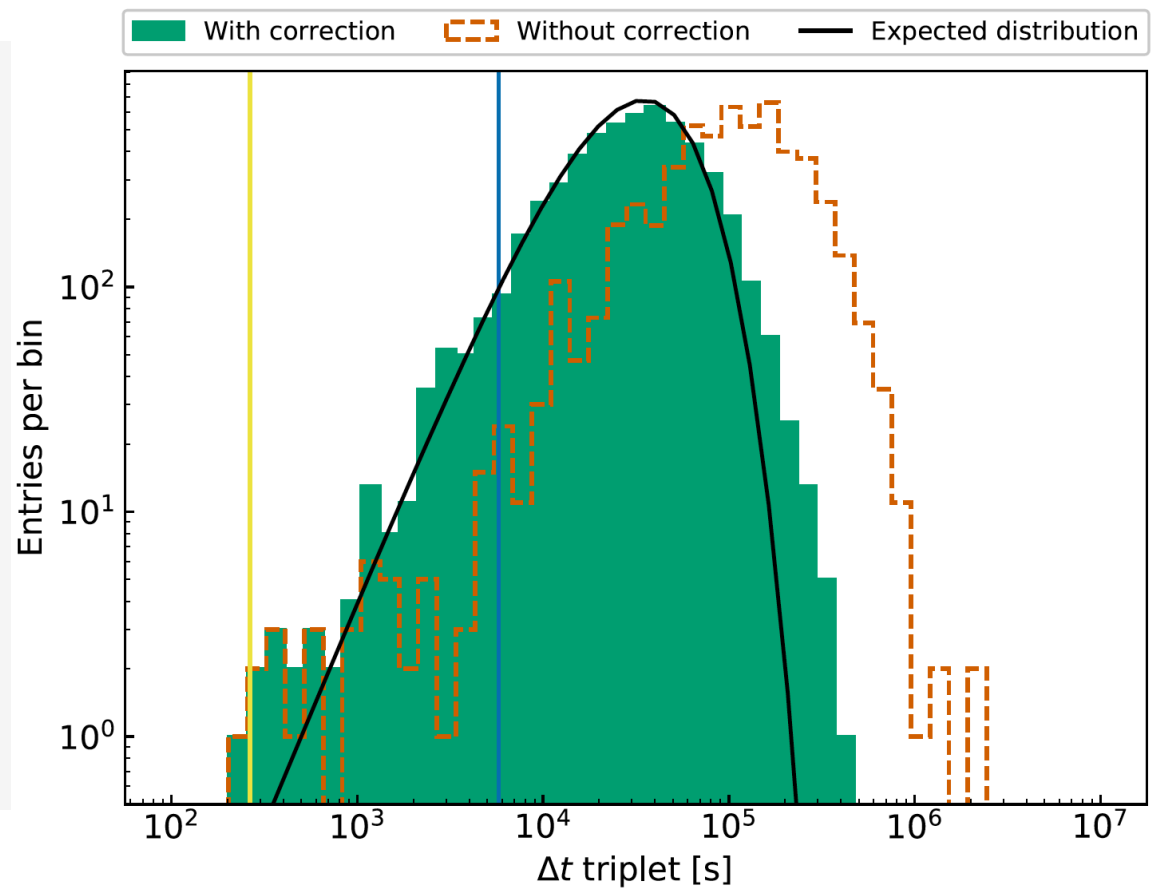
# Triplet photon counting analysis



We search for 'triplets' (three photons close in time) in the vicinity of the FRB event as well as in the past LAT data using the same method applied for the analysis of the magnetar-giant flare in the Sculpture galaxy (Fermi-LAT coll. et al., 2021 )



Fermi-LAT coll et al. 2021



We perform the largest and deepest systematic search of gamma-ray emission from FRBs using a sample of 1020 burst sources and 13 years of Fermi-LAT data.

## Preliminary results

- no significant emission has been found in the 10, 100, 1000 and 10000 s analyses
- we report here the preliminary results on the periodic FRB 180916. We provide the so-far most stringent upper limits on the gamma-ray emission from the FRB 180916 source during its 5.4-day active-phase window ( $F_{\gamma\text{-ray}} < 2.3 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$ ,  $L_{\gamma\text{-ray}} < 7.5 \times 10^{42} \text{ erg s}^{-1}$ ).

We performed for the first time a stacking analysis on a large sample of FRBs

- no significant emission found: resulting ULs are on average more than two orders of magnitude smaller than those on single events.

## Future steps

- ongoing 'triplets' photon counting analysis

Our results provide crucial information on constraining the origin of FRBs and modelling their e

**Thanks for your attention!**

**STAY TUNED!**



# Backup slides

# Analysis verification on background sources

To verify the quality of our results of the (stacking) analysis and see if they could be distinguished from simple background fluctuations, we are performing the same analysis for background sources, using 1020 random events (position / time). For the random events we kept the same number of multiple events as seen in the repeaters contained in our sample.

Background events (random position and time)

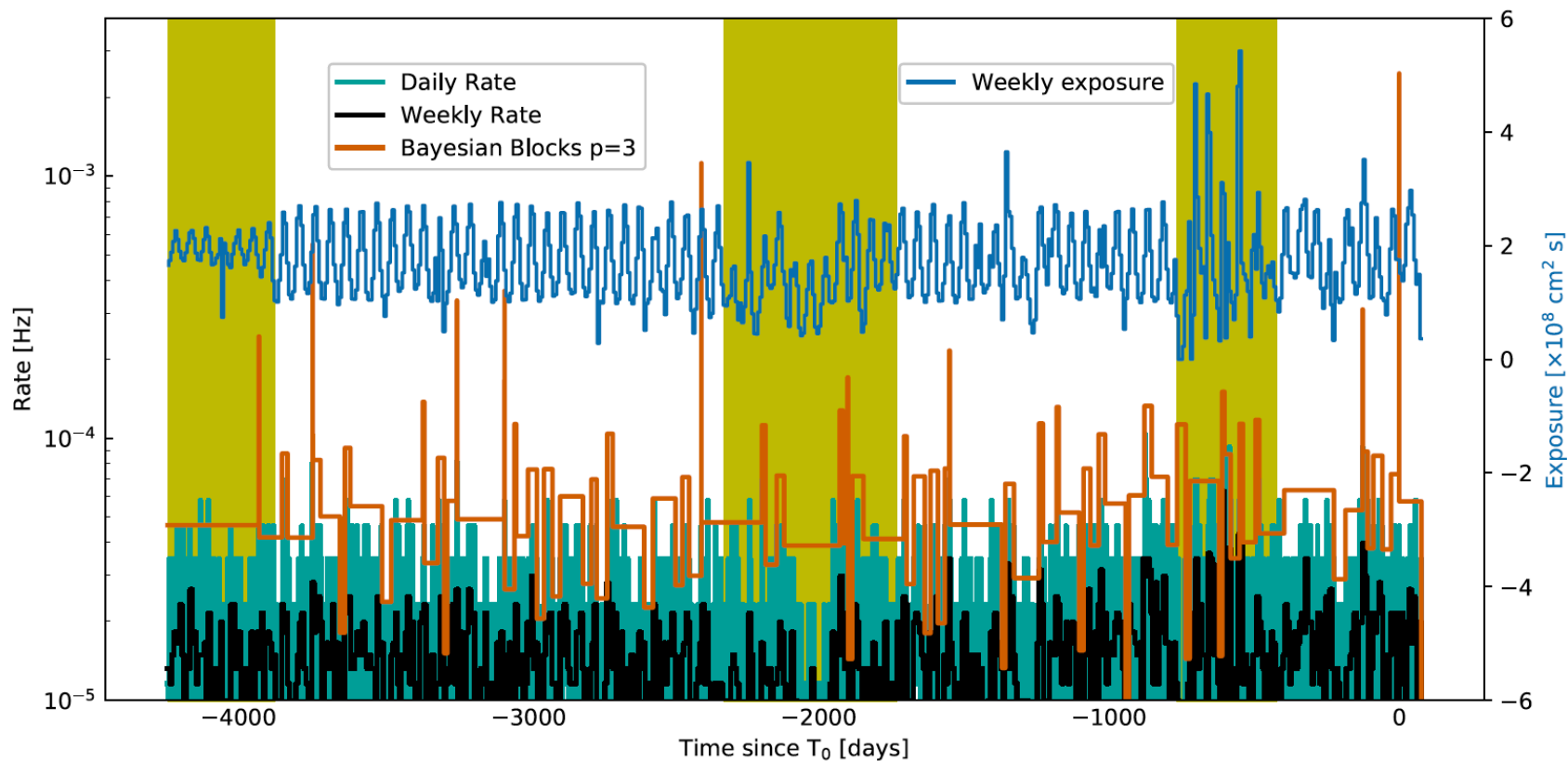
Similarly to the FRB in our sample we generated 1020 events: 561 non repeating and 21 repeating ones presenting 459 events with the following number of events each:

[232, 72, 32, 21, 19, 12, 10, 9, 8, 7, 7, 6, 4, 4, 4, 2, 2, 2, 2, 2, 2]



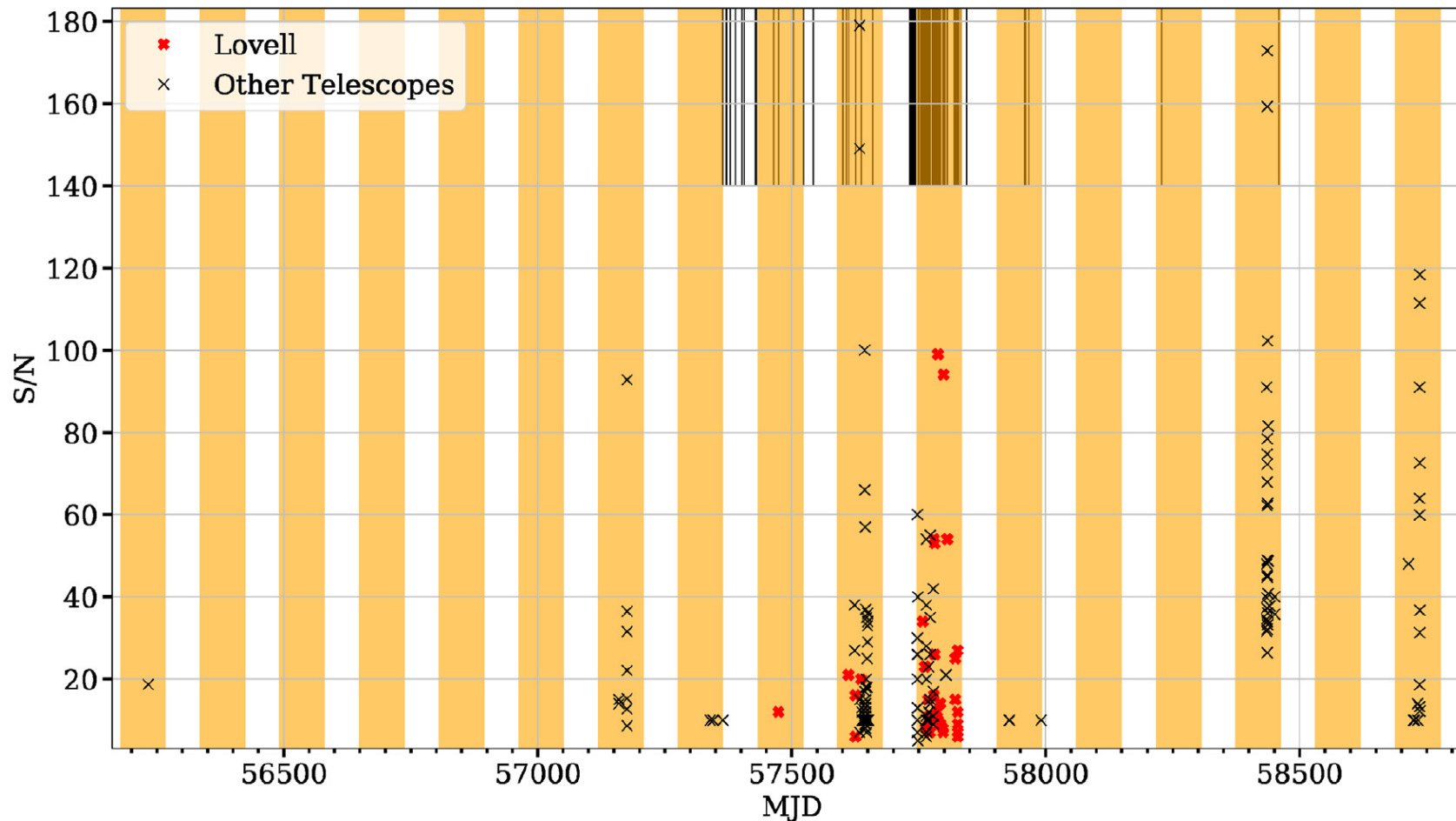


# Triplet photon counting analysis



# Another possible periodicity

**FRB 121102:** 235 burst published so far (Rajawade et al. 2021), hints of a period of about 190 days



Rajawade et al. 2021