Search for Significant Fast Optical Bursts with Aqueye+/EFI/IFI+/Iqueye

Alessia Spolon
Luca Zampieri, Michele Fiori

INAF - OAPd

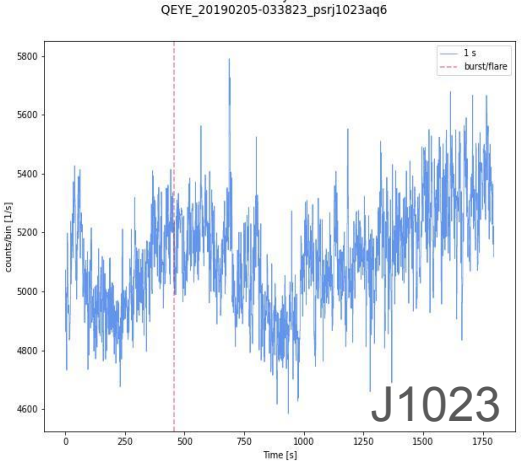
Workshop on Fast Optical Burst
4-7 May 2026 Asiago

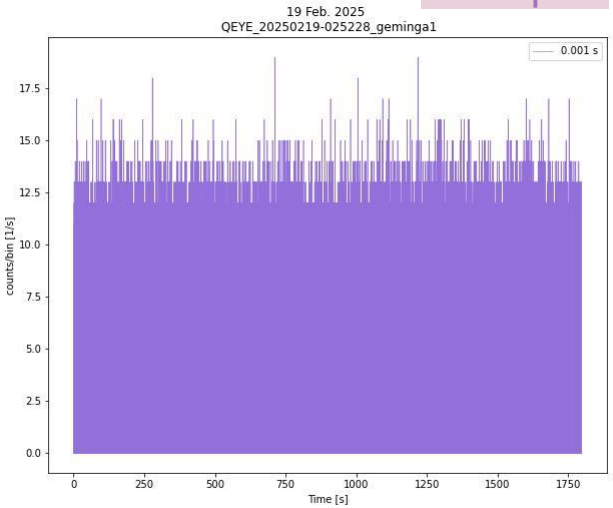
Steps by Steps:

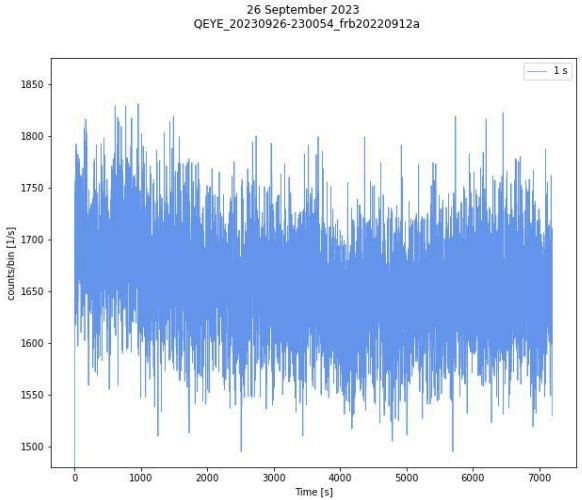
1. Low resolution binning of light curves (1 s) [on-source + on-sky]
2. Sanity check of light curves and selection of 'good time intervals' (check meteo - log!)
Threshold* depends on: night efficiency, count rates of detectors
3. High resolution binning of 'good time intervals'
(1 ms, 10 ms, 100 microsec,...) [on-source + on-sky]
4. Assessing statistical significance of the peaks [on-source + on-sky]
5. Select significant peaks
6. Check if there are coincident peaks: sky vs on-source
7. Look at the structure of the peaks
8. Statistics of the peaks

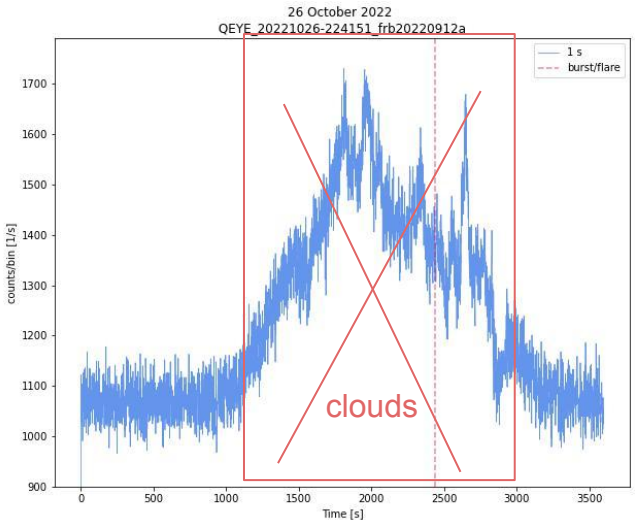
*__Bad sky__ Count rate of on-source detectors
Aqueye+ → > 3600-3700 c/s (J1023: > 6500 c/s)
IFI+Iqueye→ > 2500-2600 c/s

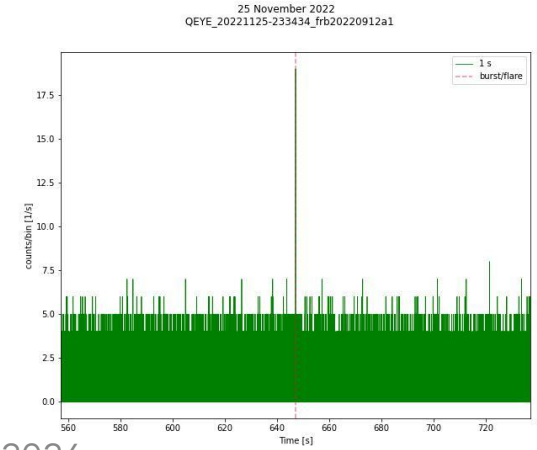
1. Low resolution binning of light curves (1 s)
2. Sanity Check
3. High resolutionion bining of GTI











4. Assessing statistical **significance of the peaks**

The routine follows the approach originally introduced in Zampieri et. al 2022

Magnetar SGR J1935

(application @hands-on)

- search for prompt optical bursts/peaks
- assess their statistical significance

Assumption: **Poisson** distribution

3σ detection threshold corresponding to a chance probability of $0.0027/N_{trials}$ in any of the bins of observations.

total number of bins in the interval (depends on the bin size)

Detection threshold:

Approximate starting/guess threshold (8 Poissonian sigmas):

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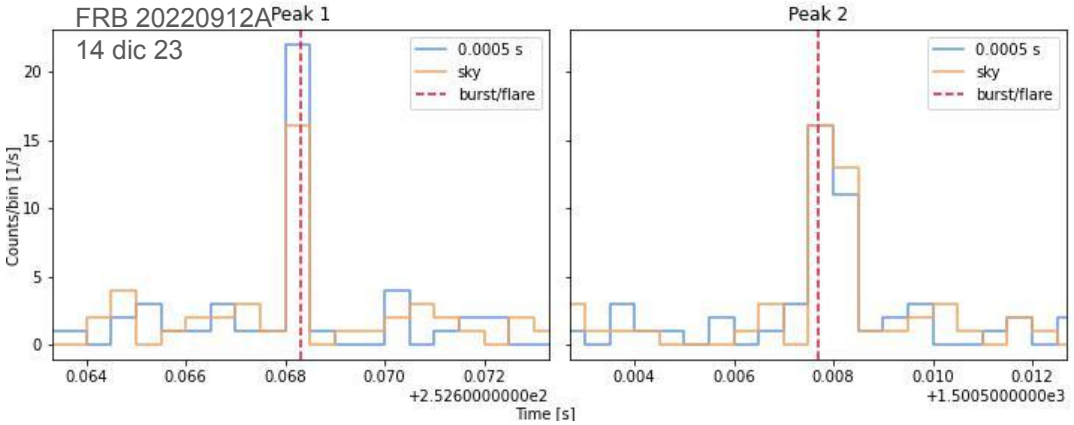
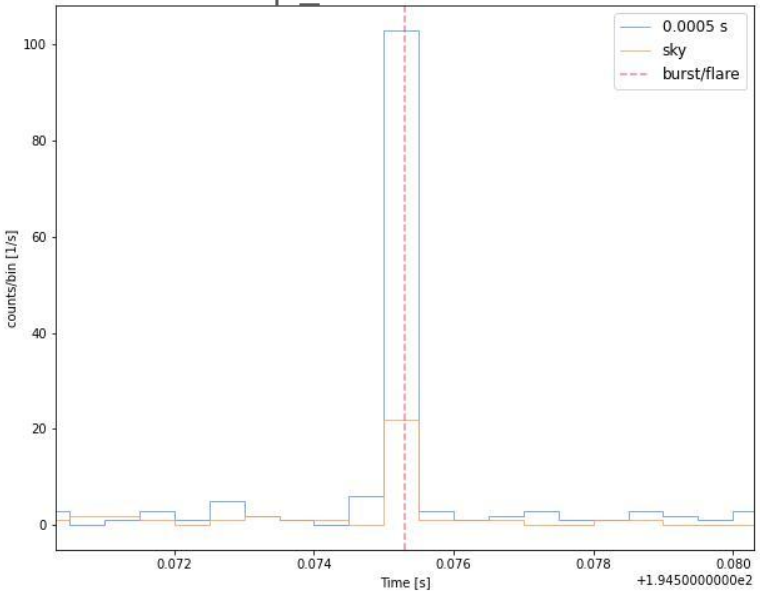
8*np.sqrt(mean)+mean
```

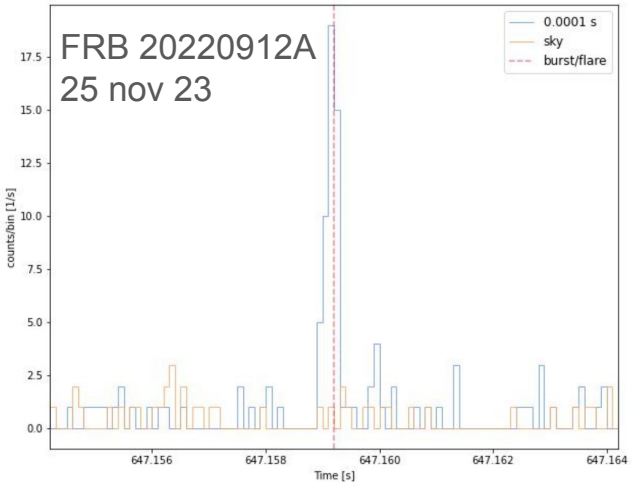
6. Check if there are coincident peaks: sky vs on-source

Examples



PSR J1023
14dic18aq6_0005s

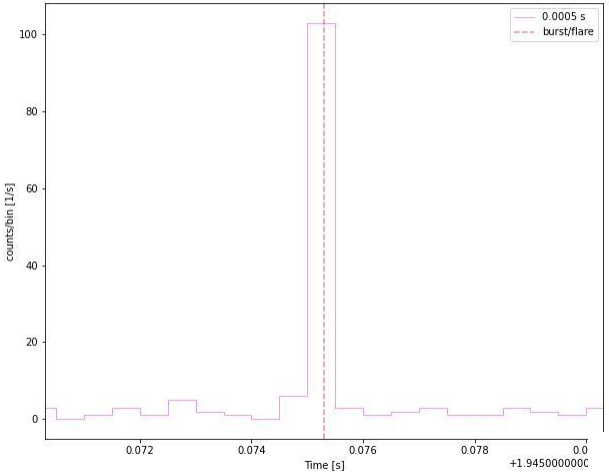




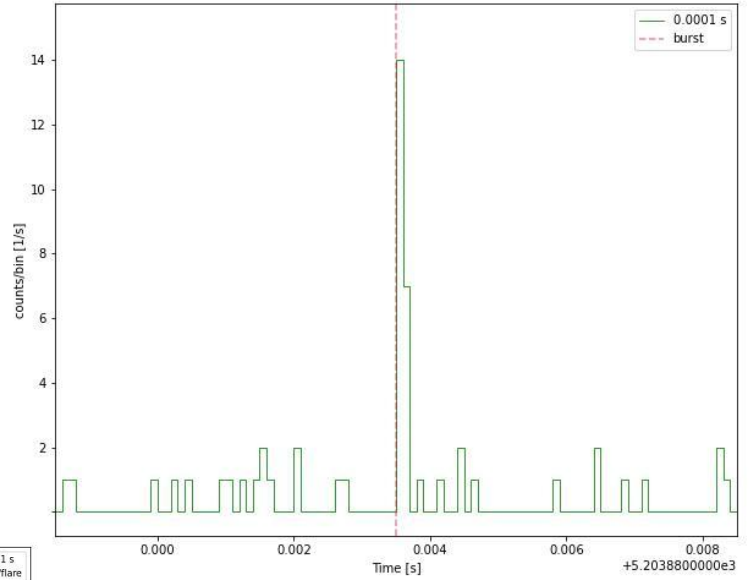
7. Look at the structure of the peaks

Examples

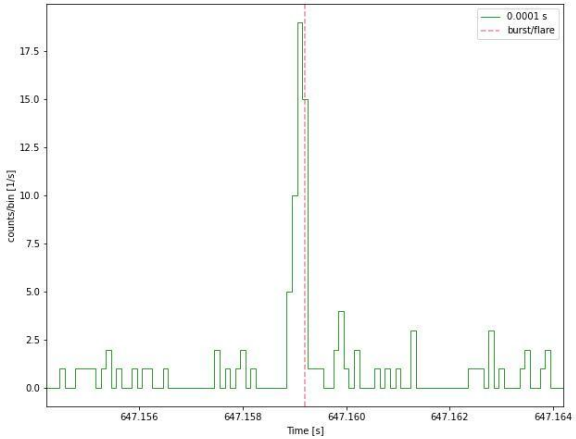
14 December 2018
QEYE_20181214-055002_psrj1023aq6



2 February 20025
QEYE_20250202-233700_frb180916aq2

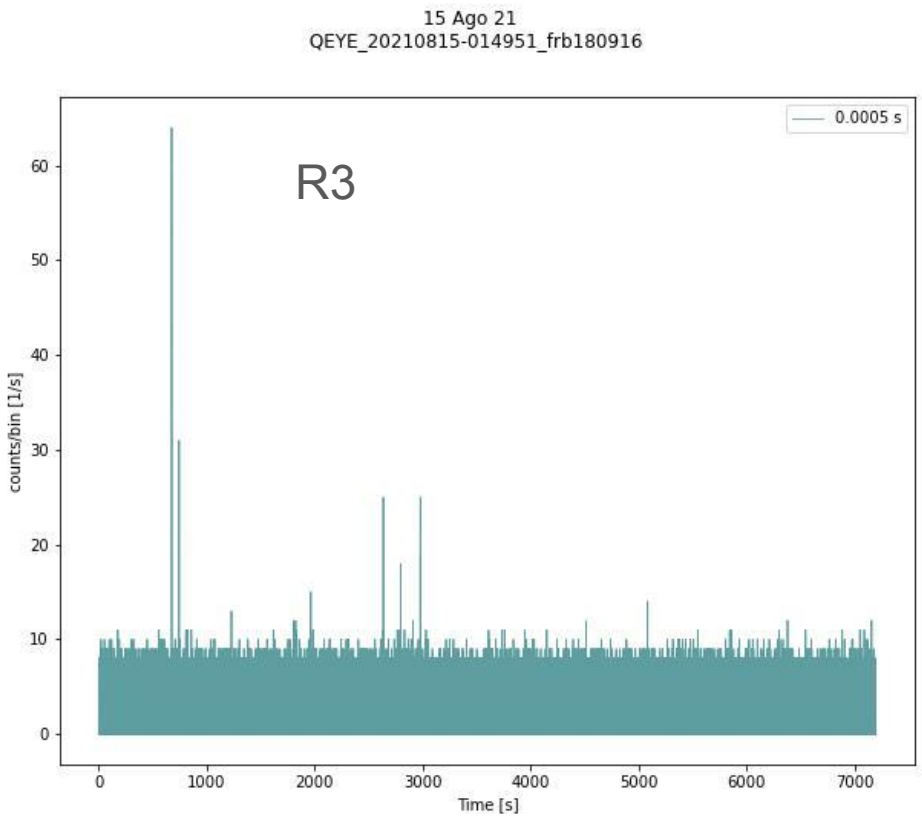


25 November 2022
QEYE_20221125-233434_frb20220912a1

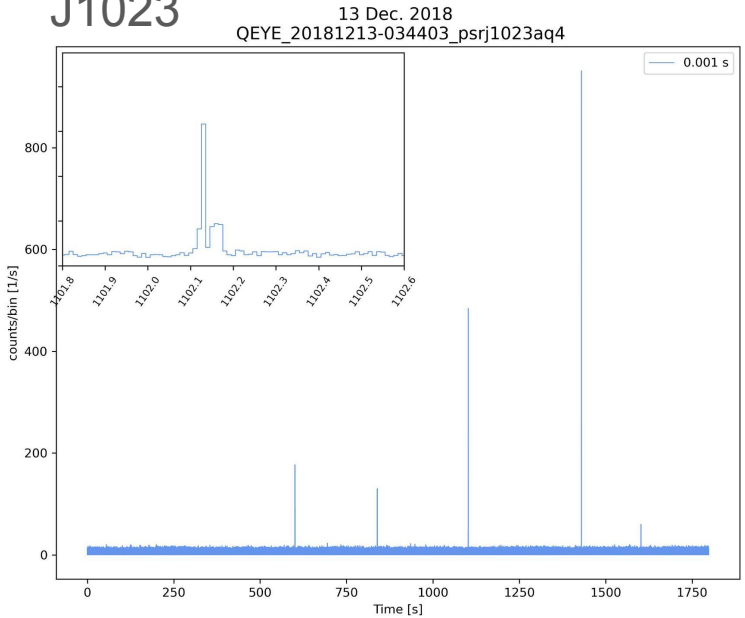


8. Statistics of the peaks

Examples



J1023

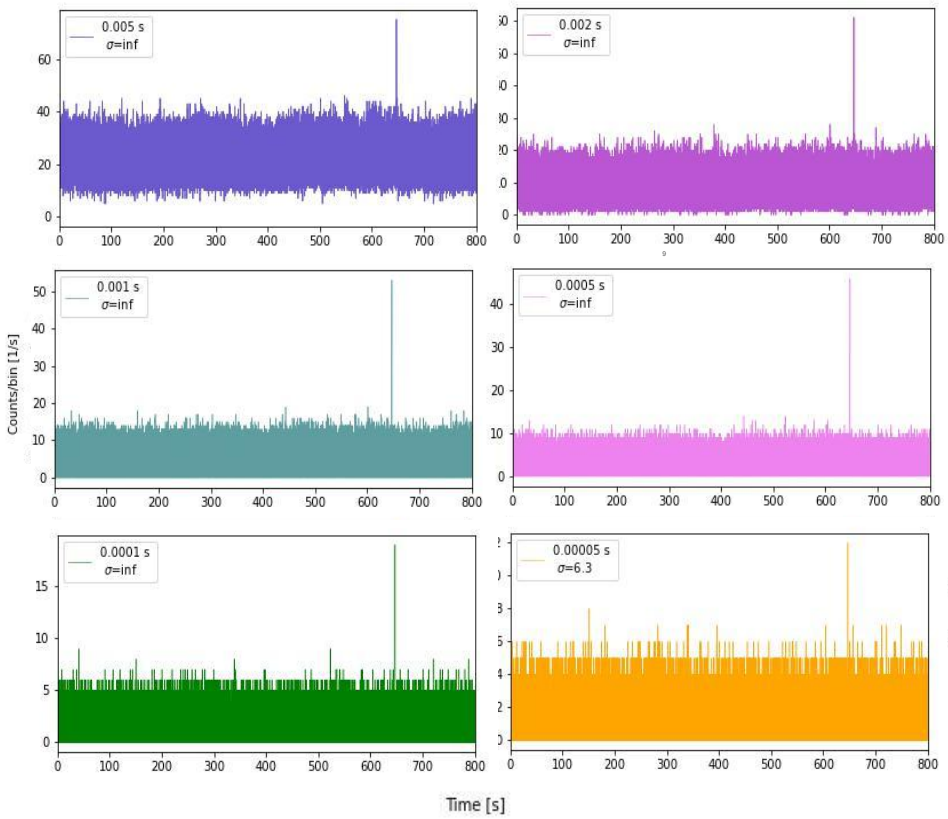


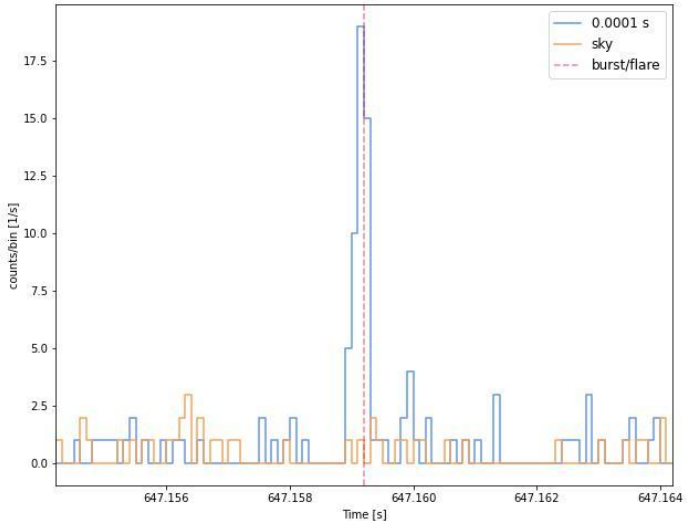
search for some periodicity?

Case:
FRB 20220912A vs J1023

Spolon et al. 2026 (in prep.)

25 Nov. 2022 [Aqueye+] - FRB 20220912A

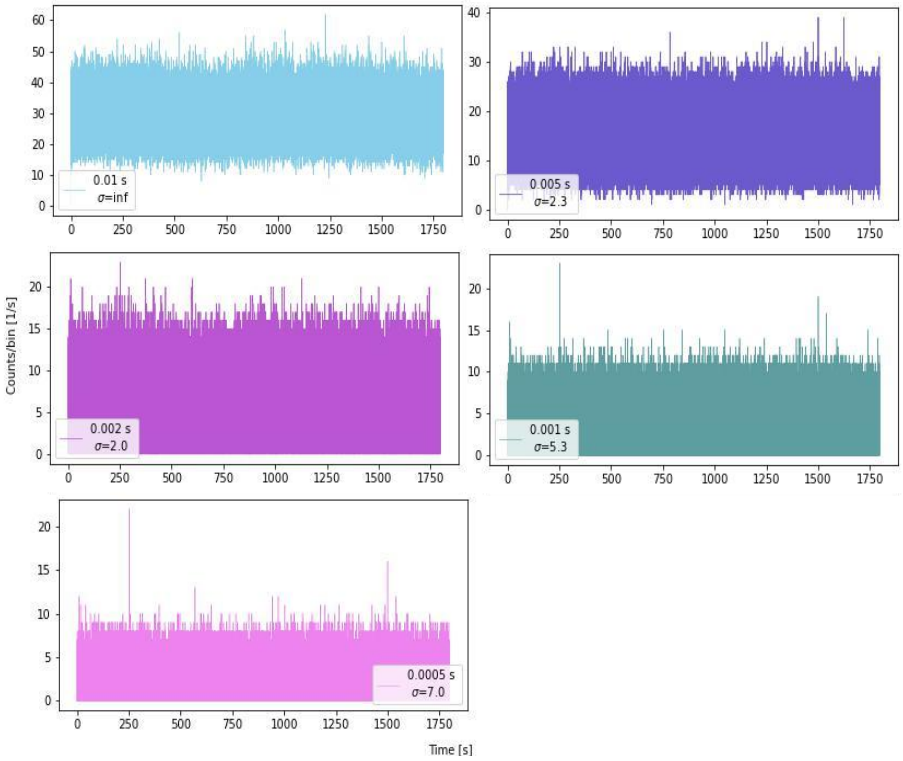


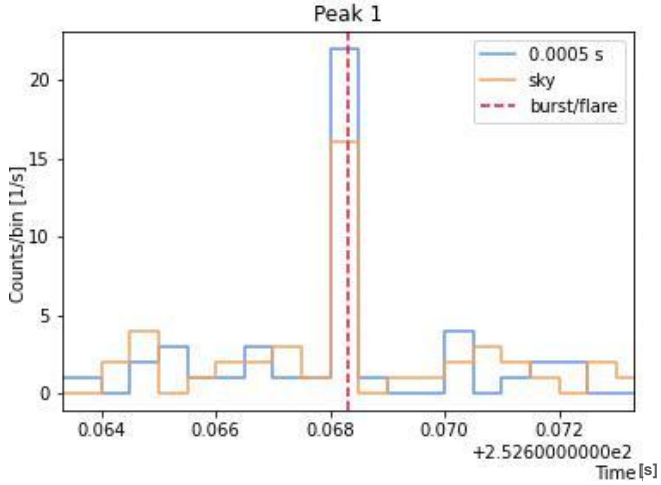


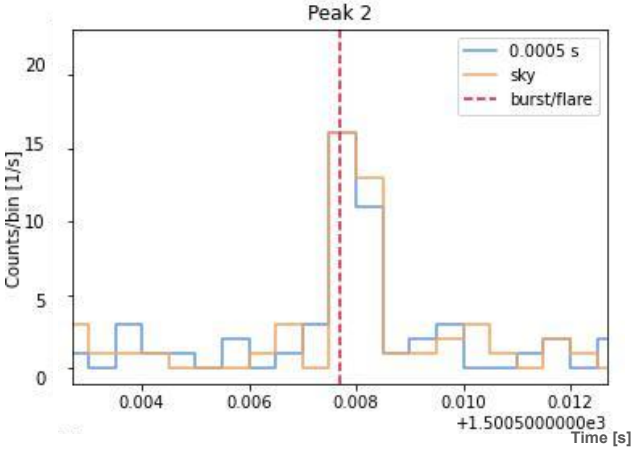
Observation ID	Time bin [s]	Time of peak [s from start]	Time of peak [UT]	on-source SPAD counts/bin	on-source SPAD σ	on-source SPAD FWHM [s]	sky-SPAD counts/bin	sky-SPAD σ	sky-SPAD FWHM [s]
20221125-233434	0.0001	647.1592	22:45:23.1591	19	>10	0.0002	-	-	-

Data not baricetrized

14 Dec. 2023 [Aqueye+] - FRB 20220912A

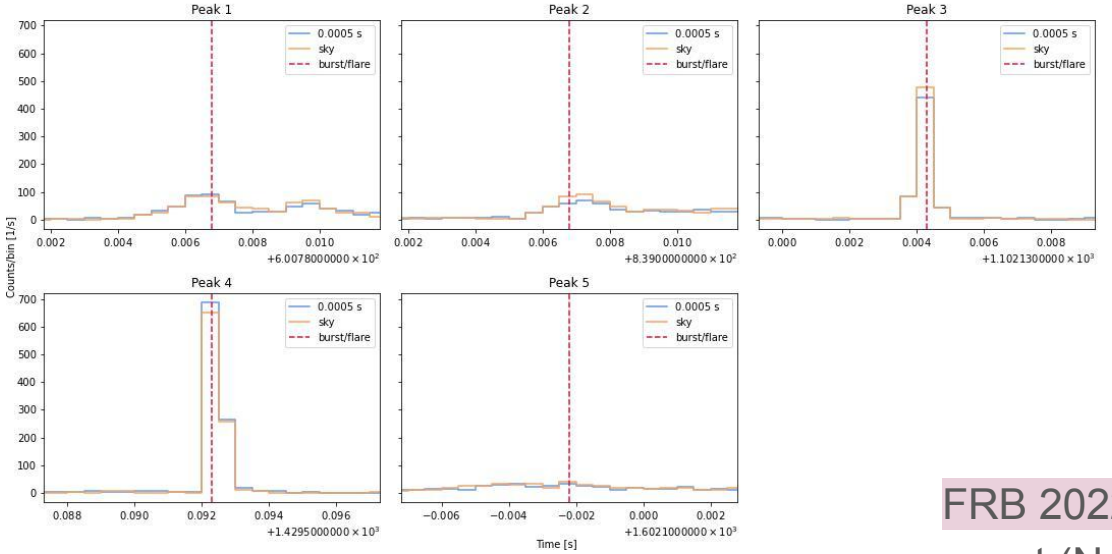






Observation ID	Time bin [s]	Time of peak [s from start]	Time of peak [UT]	on-source SPAD counts/bin	on-source SPAD σ	on-source SPAD FWHM [s]	sky-SPAD counts/bin	sky-SPAD σ	sky-SPAD FWHM [s]
20231214-190534	0.0005	252.6683	18:09:47.6682	22	7	0.0005	16	5.5	0.0057
	0.0005	1500.5077	18:30:35.5077	16	4.3	0.0008	16	5.5	0.0006

13 Dec. 2018 [Aqueye+] - PSR J1023+0038



	On-Source [count/bin]	On-Sky [count/bin]
Threshold	24	22
Events ≥ Threshold	71	70
Separated Peaks	18	20
Coincidents Peaks	12	12
Coincident/Separated	66%	60%
Isolated	6	8

*The separated peaks are considered to be those events whose time difference with adjacent events exceeds 0.005

- 66% of the peaks are detected both on source and on sky, and are likely to be atmospheric events (meteors' glow?)
- 33% of the peaks are detected only on source or on sky

FRB 20220912A: 1 significant on-source-only event (Nov. 25, 2022) vs 2 simultaneous on-source and on-sky events (Dec. 14, 2023)

Distribution of coincident/isolated peaks consistent with that of meteor showers, but statistics too scanty

To Discuss in these days

…From a first comparison between Asiago and TNG

- comparison with other instruments (e.g. SiFAP2, CAHA):
  which time bin use?
  1 ms, 100 microsecs..
- Simultaneous events (sky vs on-source):
  Asiago yes; SiFAP2 no.
- Rate SiFAP2: 1evt/1.5h
  Rate Asiago: 1evt/5-20h
- Structure/morphology of the peaks
- Darks: Poissonian distribution?
  power spectrum
  crosstalk + afterpulse
- Simul. Observations of Meteor shower
- ….

Other suggestions?

BackUp Slides

Probability (p-value)

$$p = 1 - N_{trials} \cdot P_{Poisson}(k \mid \lambda)$$

k counts in the bin (peak)
λ expected value

$$P_{Poisson}(k \mid \lambda) = \frac{\lambda^k e^{-\lambda}}{k!}$$

$$p = erf\left(\frac{\sigma}{\sqrt{2}}\right) \longrightarrow \sigma = \sqrt{2}\, erf^{-1}(p)$$

erf: error function