NAOC 中国科学院国家天文台 NATIONAL ASTRONOMICAL OBSERVATORIES , CAS

Jul 2021

A bimodal burst energy distribution of FRB121102

Pei Wang (王培)

wangpei@nao.cas.cn

D. Li, W. W. Zhu, B. Zhang, X. X. Zhang, R. Duan, Y. K. Zhang, Y. Feng, N. Y. Tang, S. Chatterjee, J. M. Cordes, M. Cruces, V. Gajjar, G. Hobbs, C. Jin, M. Kramer, D. R. Lorimer, C. C. Miao, C. H. Niu, J. R. Niu, Z. C. Pan, L. Qian, S. Dai, L. Spitler, D. Werthimer, G. Q. Zhang, F. Y. Wang, X. Y. Xie, Y. L. Yue, L. Zhang, Q. J. Zhi, Y. Zhu et al.

The work is done by many authors listed above.

FAST Detected Multiple Bursts in Lband from Aug. 2019

Method:

Online (FRB backend)

\+

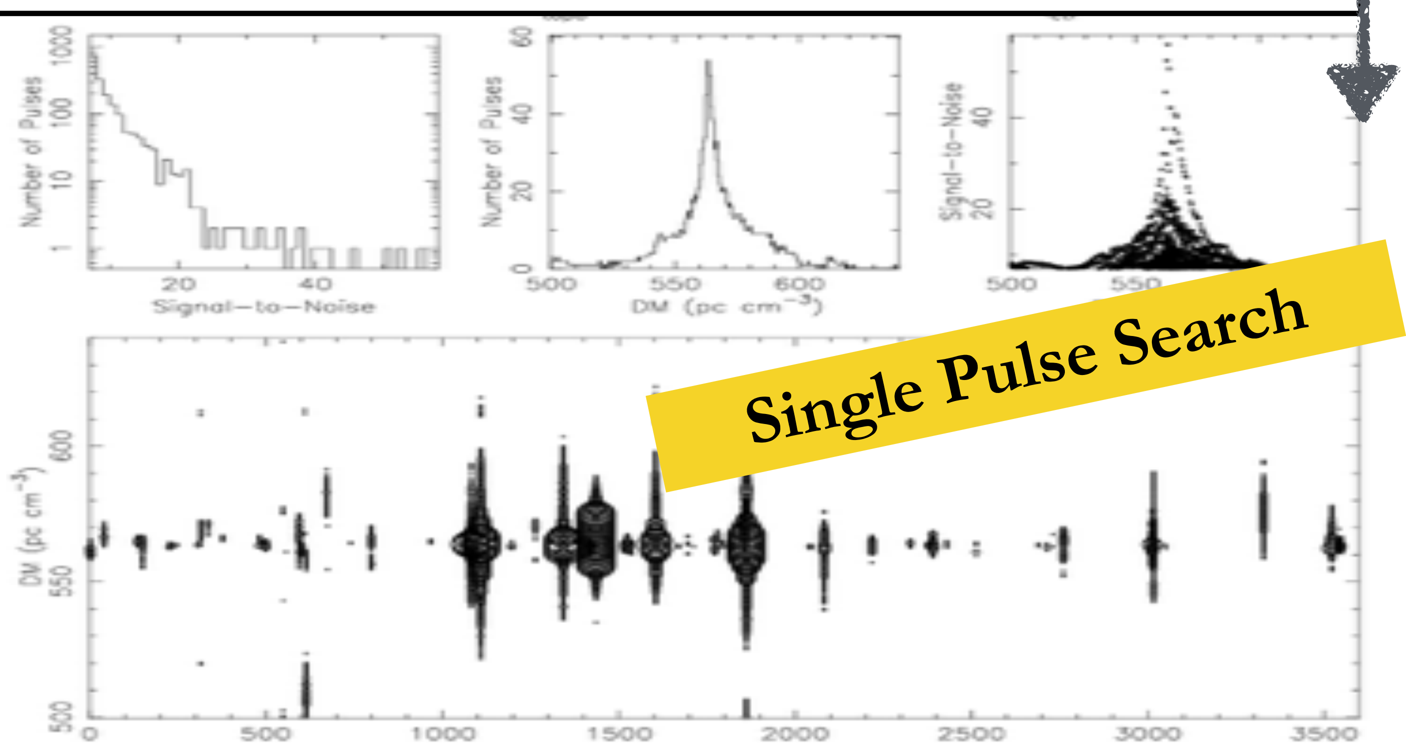
Offline (Presto + Heimdall)

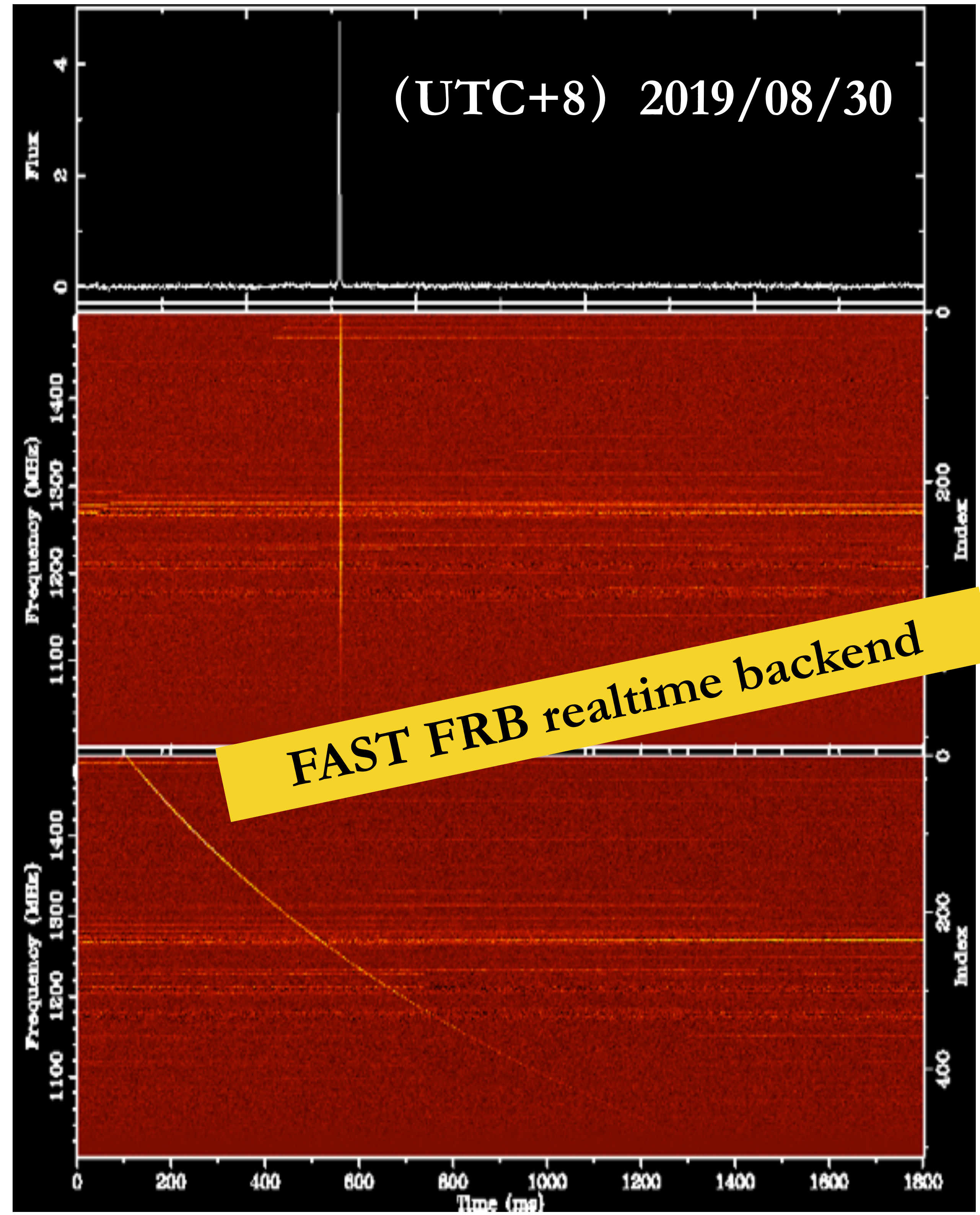
FAST Detects Multiple Bursts in L-band from FRB 121102

ATel #13064; *Di Li (NAOC), Xinxin Zhang (NAOC), Lei Qian (NAOC), Weiwei Zhu (NAOC), Ran Duan (NAOC), Dan Werthimer (Berkeley), Vishal Gajjar (Berkeley), Yan Zhu (NAOC), Jeff Cobb (Berkeley), Youling Yue (NAOC), Chengjin Jin (NAOC), Bing Zhang (UNLV), Christian Gouiff... (CEA), Shen Wang (NAOC), Laura Spitler (MPIfR), Mary Cruces (MPIfR), ... (University of Amsterdam), Andrew Seymour (Arecibo), Eric Korpel... HengQian Gan (NAOC), Peng Jiang (NAOC), Hui Li ... (NAOC), Chenchen Miao (NAOC), Chenhui Niu ... Zhichen Pan (NAOC), Bo Peng (NAOC), JingHai Sun (NAOC) ... QiMing Wang (NAOC), Pei Wang (NAOC), Xin Pei (XAO), Jun Yan (NAO... Yao(NAOC), DongJun Yu (NAOC), Mao Yuan (NAOC), Haiyan Zhang (NAOC), Lei Zhang (NAOC), ShuXin Zhang (NAOC), and and FAST Collaboration (NAOC)*

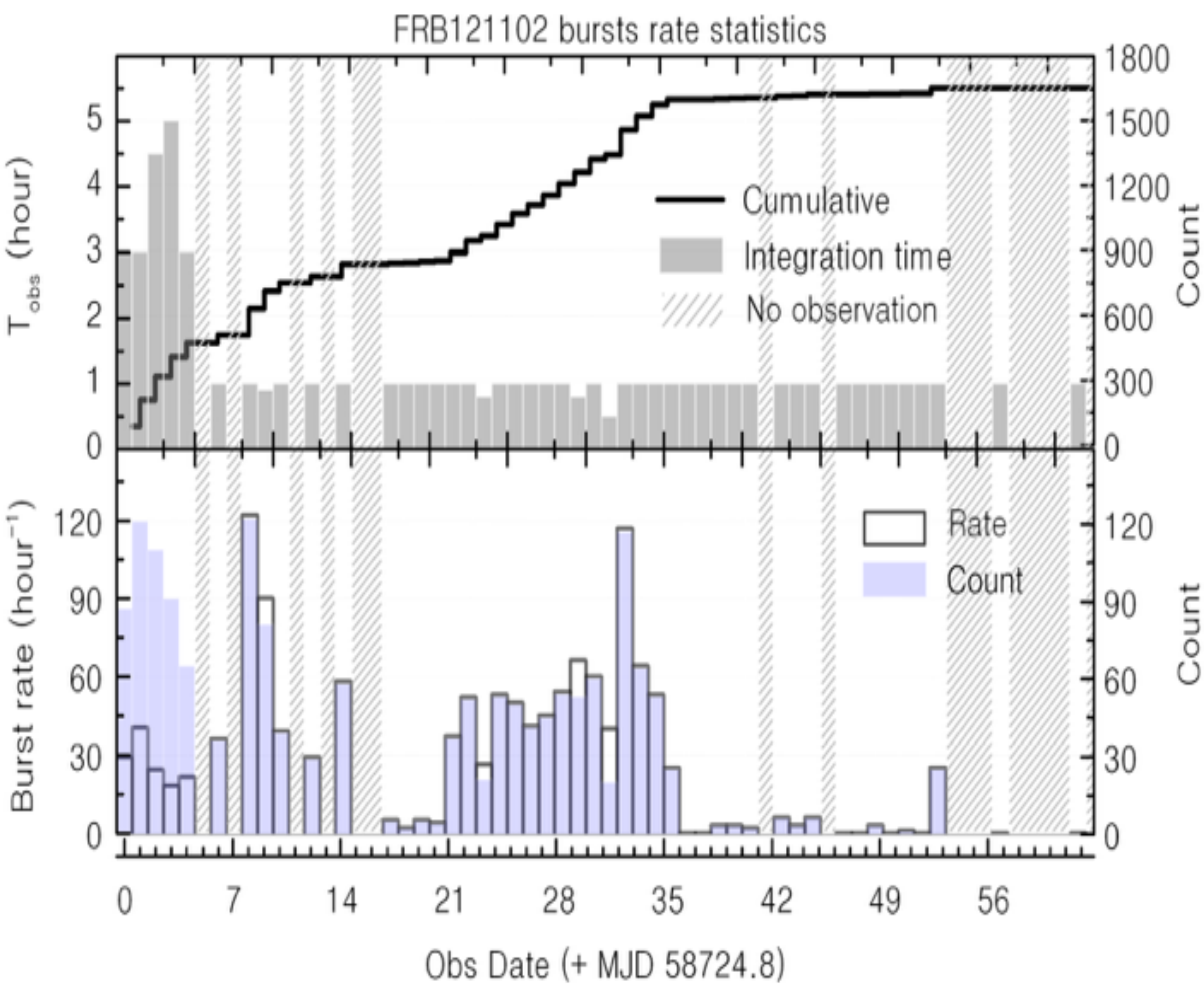
on 2 Sep 2019; 01:32 UT

Credential Certification: Di Li (dili@nao.cas.cn)





A Large Pulse Set from FRB121102 with FAST



47 days, 59.5 hours

RMS = ~2mJy (1ms)

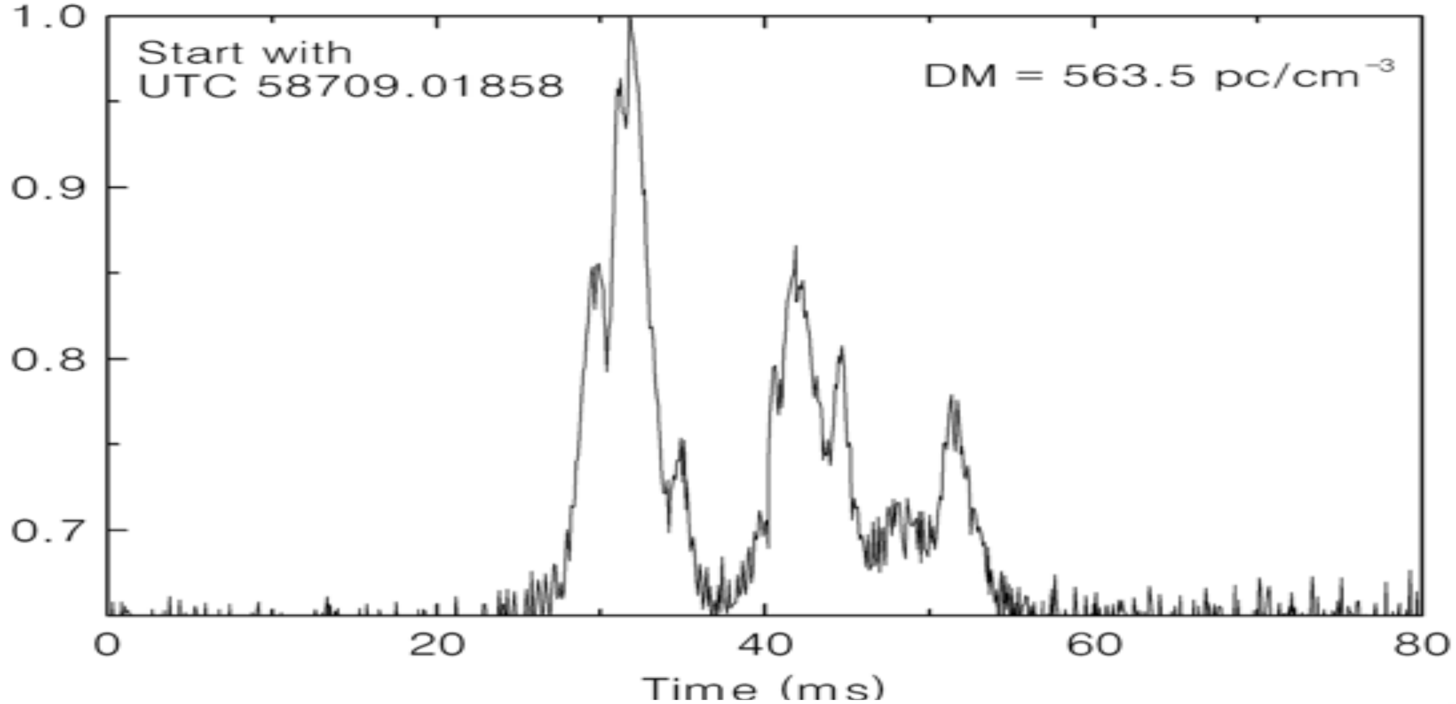
S/N > 7

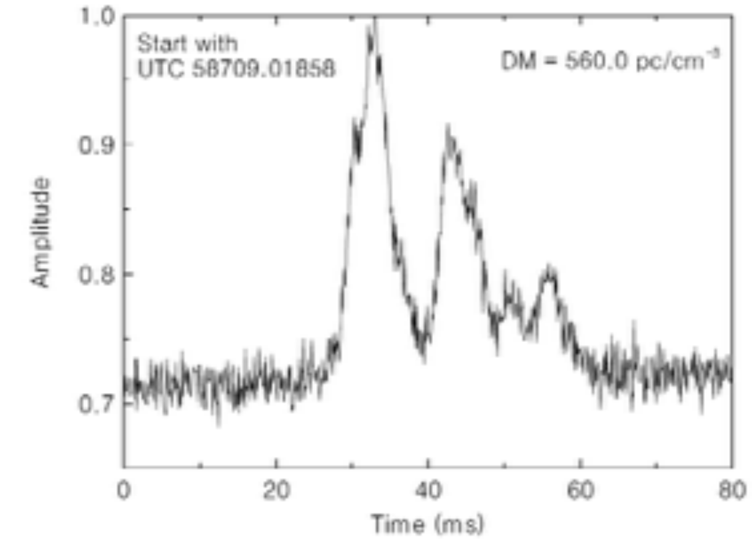
Peak rate > 100/hr

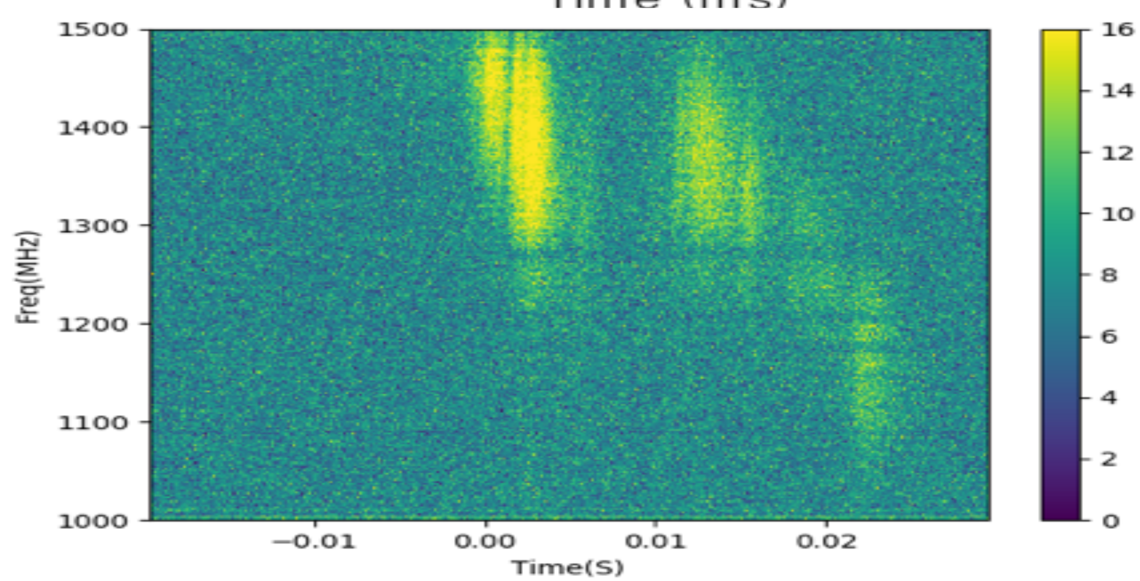
1652 pulses from FRB121102, more than all previous detections combined.

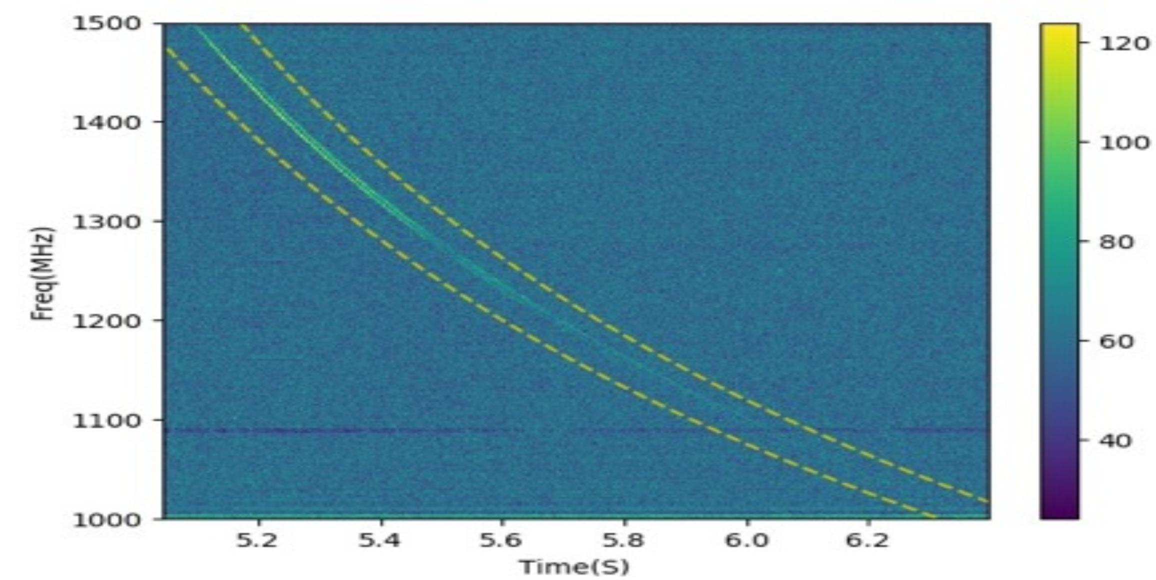
- **E** distribution (log**N**-log**S**)
- **DM** variation
- **Periodicity** search
- Polarization: **RM**
- **Scintillation**

Bursts Show Complex Time–Frequency Structure

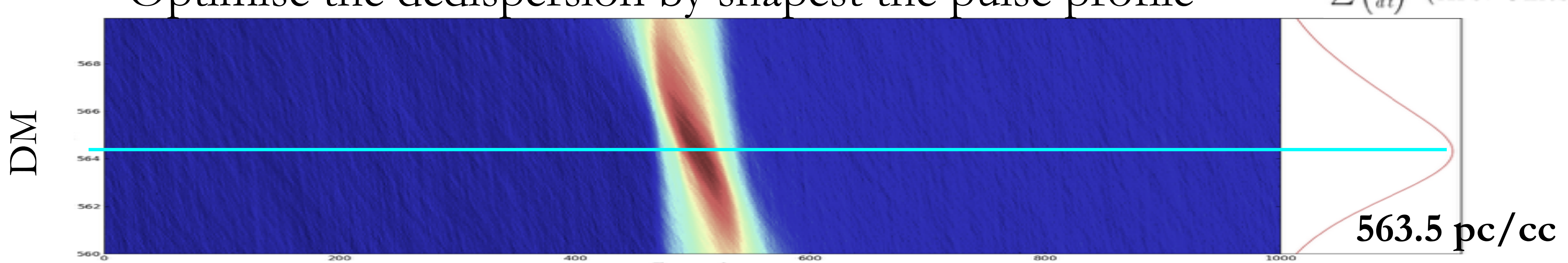




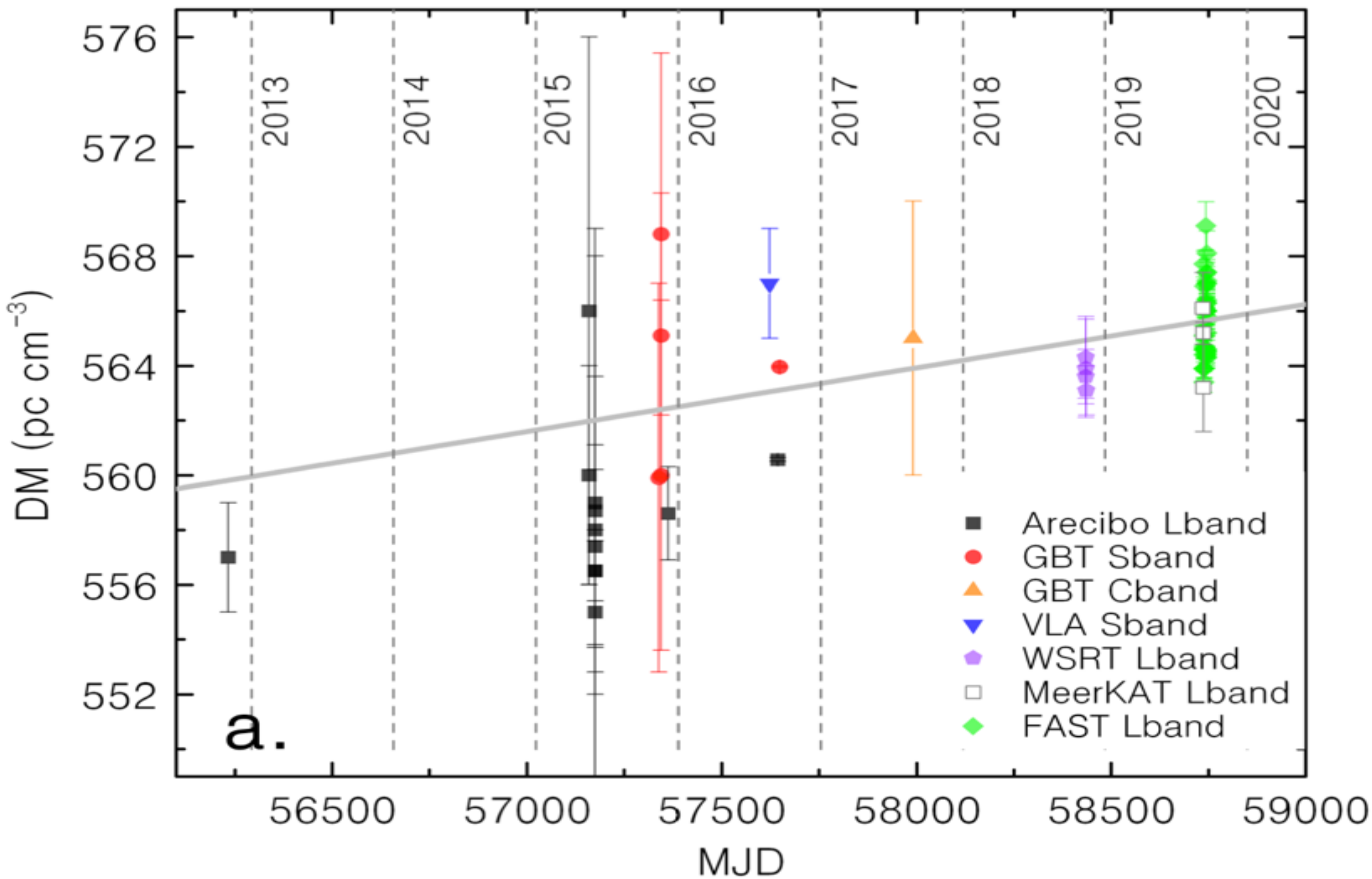




Optimise the dedispersion by shapest the pulse profile



Temporal DM variation for FRB 121102 over the years



$$\frac{d\mathrm{DM}}{dt} = +0.85 \pm 0.10 \text{ pc cm}^{-3} \text{ yr}^{-1}$$

FRB121102 Burst Energy Statistics

$$E \simeq \frac{4\pi D_L^2}{(1+z)} \mathcal{F}_\nu \nu_c$$
$$= (10^{39}\ \mathrm{erg}) \frac{4\pi}{(1+z)} \left(\frac{D_L}{10^{28}\ \mathrm{cm}}\right)^2 \frac{\mathcal{F}_\nu}{\mathrm{Jy}\cdot\mathrm{ms}} \frac{\nu_c}{\mathrm{GHz}}$$

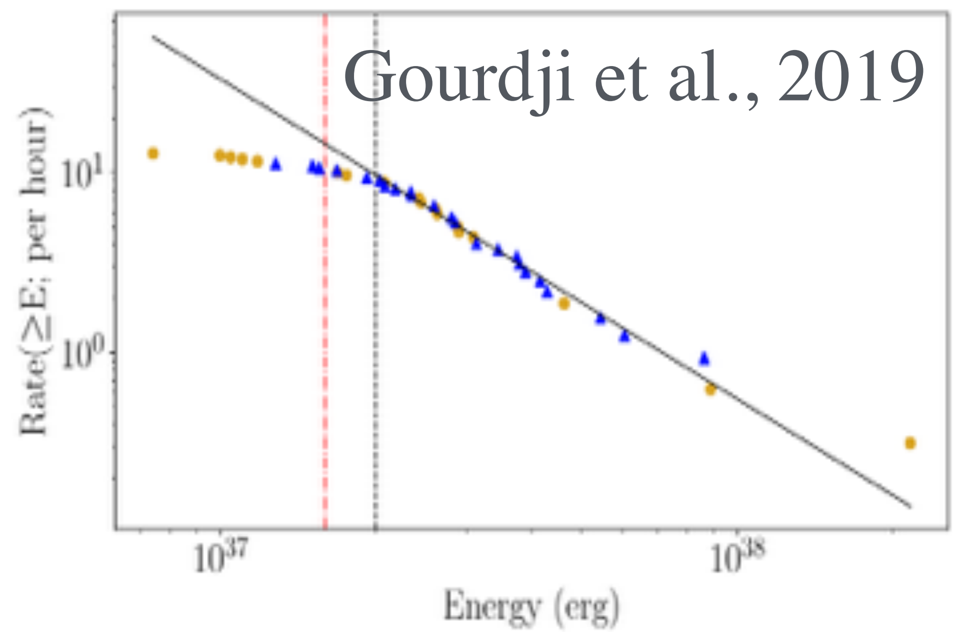
BingZhang et al., 2018

Cumulative burst energy distribution: $R(E > E_{min}) \propto E^\beta$

β= -0.7 JVLA, AO, GBT Law et al., 2017

β= -1.8±0.3 AO Gourdji et al., 2019

β= -1.2±0.2 Effelsberg Cruces et al., 2020



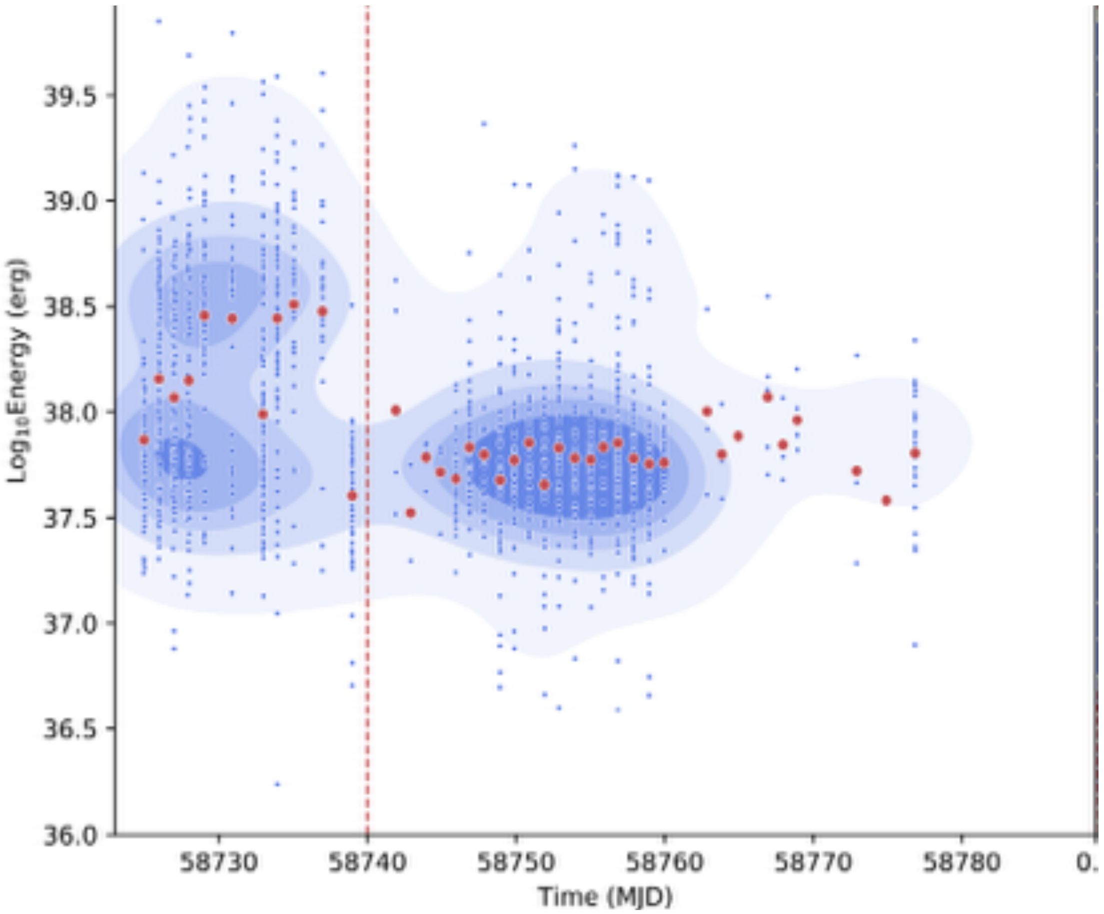
FAST L-band 1.25GHz flux calibration

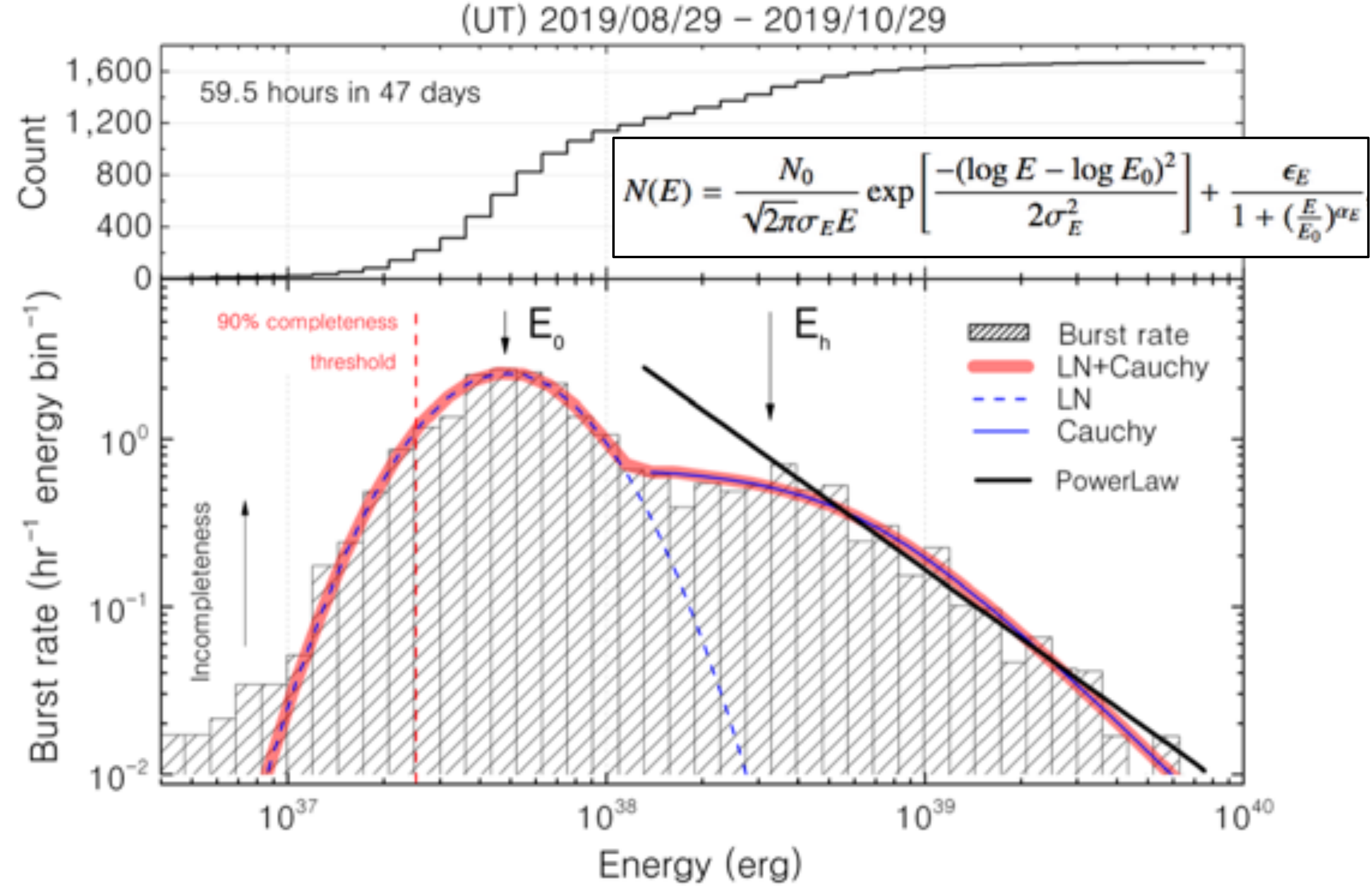
1σ = 2.2 mJy
7σ = 15 mJy

z=0.193， D_L=949Mpc

4.0e+36 erg < Energy < 8.0e+39 erg

FRB121102 Burst Energy Statistics





Function	Fitting parameter	Energy range (erg)	Reduced χ^2 †	R^2 ‡
PowerLaw	γ=-0.61±0.04	$4\times10^{36}\leq E\leq 8\times10^{39}$	0.379(8)	0.105(7)
	γ=-1.76±0.12	$3\times10^{38}\leq E\leq 8\times10^{39}$	0.004(1)	0.999(1)
Lognormal	E_0= 7.3×10^{37} N_0= 1.6×10^{38} σ_E=0.44	$4\times10^{36}\leq E\leq 8\times10^{39}$	0.056(9)	0.86(8)
Cauchy	E_0= 1.06×10^{39} α_E = 3.19±0.1	$4\times10^{36}\leq E\leq 8\times10^{39}$	0.379(8)	0.105(7)
Lognormal+Cauchy	E_0= 5.6×10^{37} N_0= 1.94×10^{38} σ_E=0.52 α_E = 1.65±0.2	$4\times10^{36}\leq E\leq 8\times10^{39}$	0.041(5)	0.929(7)

✗ √ ✗ ✗ √

Lognormal
+
Cauchy

bimodel

FRB simulator —> detection completeness

Single pulse template

▽

DM/Width/Flux/ Bandwidth limit

▽

Combine with FAST real data

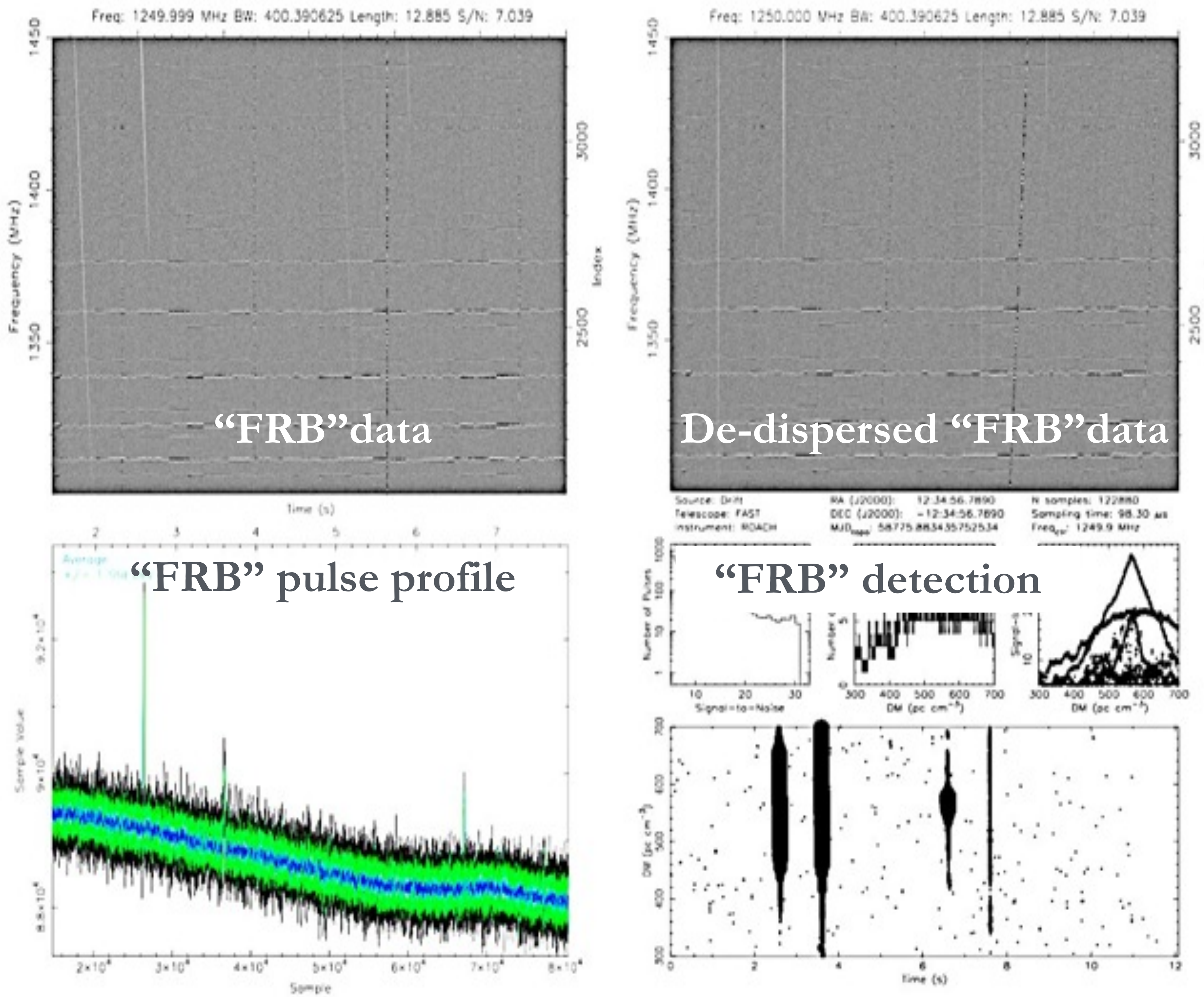
▽

FRB search pipeline

▽

Test recovery rate

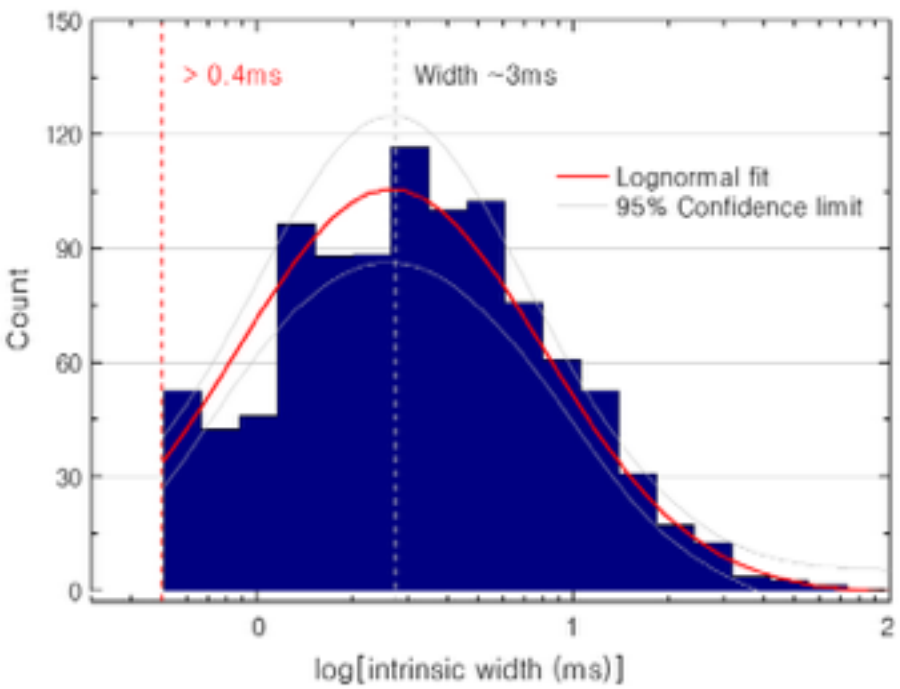
> 1000 “FRB” pulses be injected in real FAST FRB121102 data stream

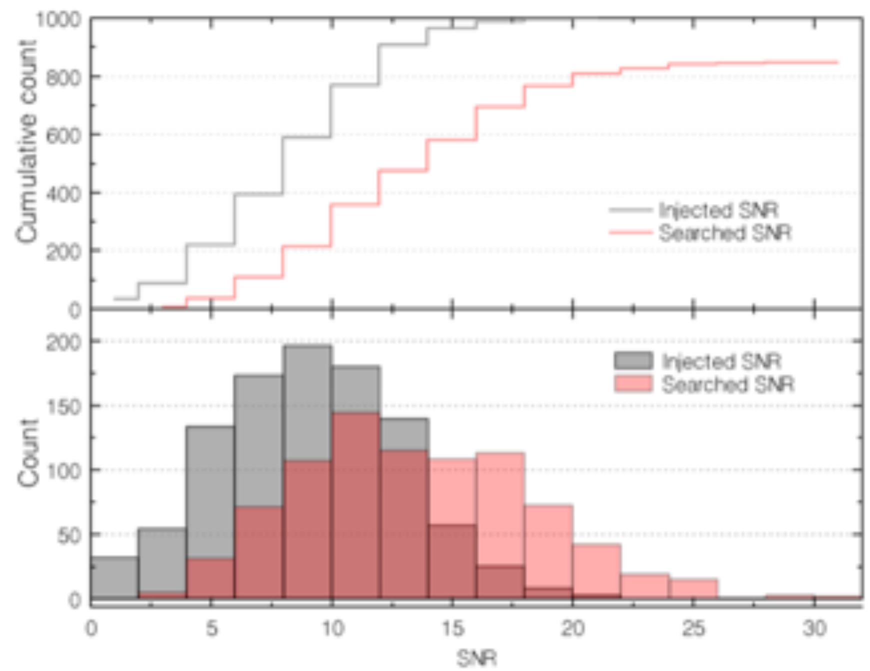


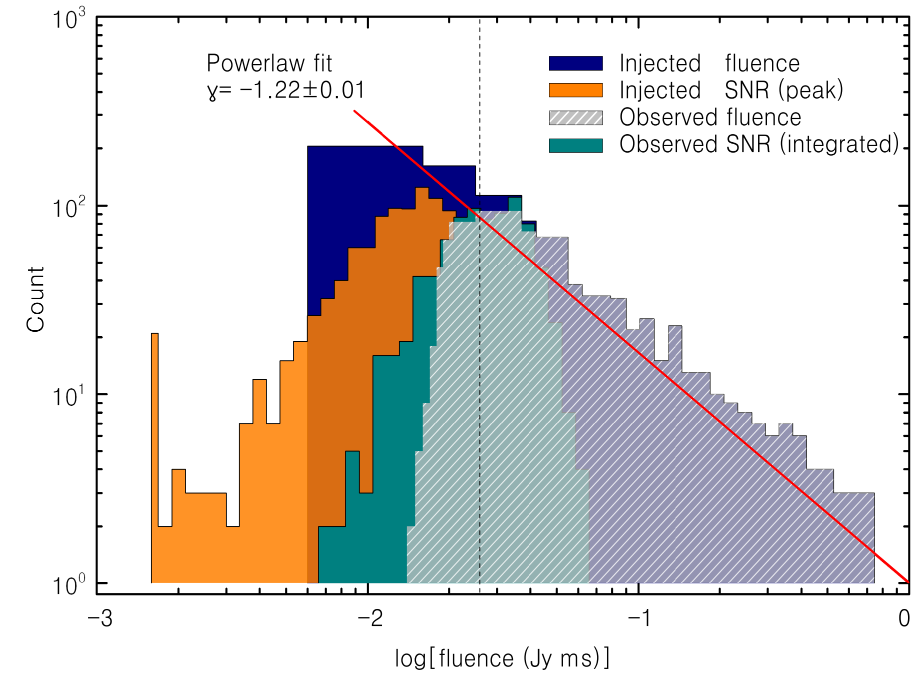
Injected width distribution

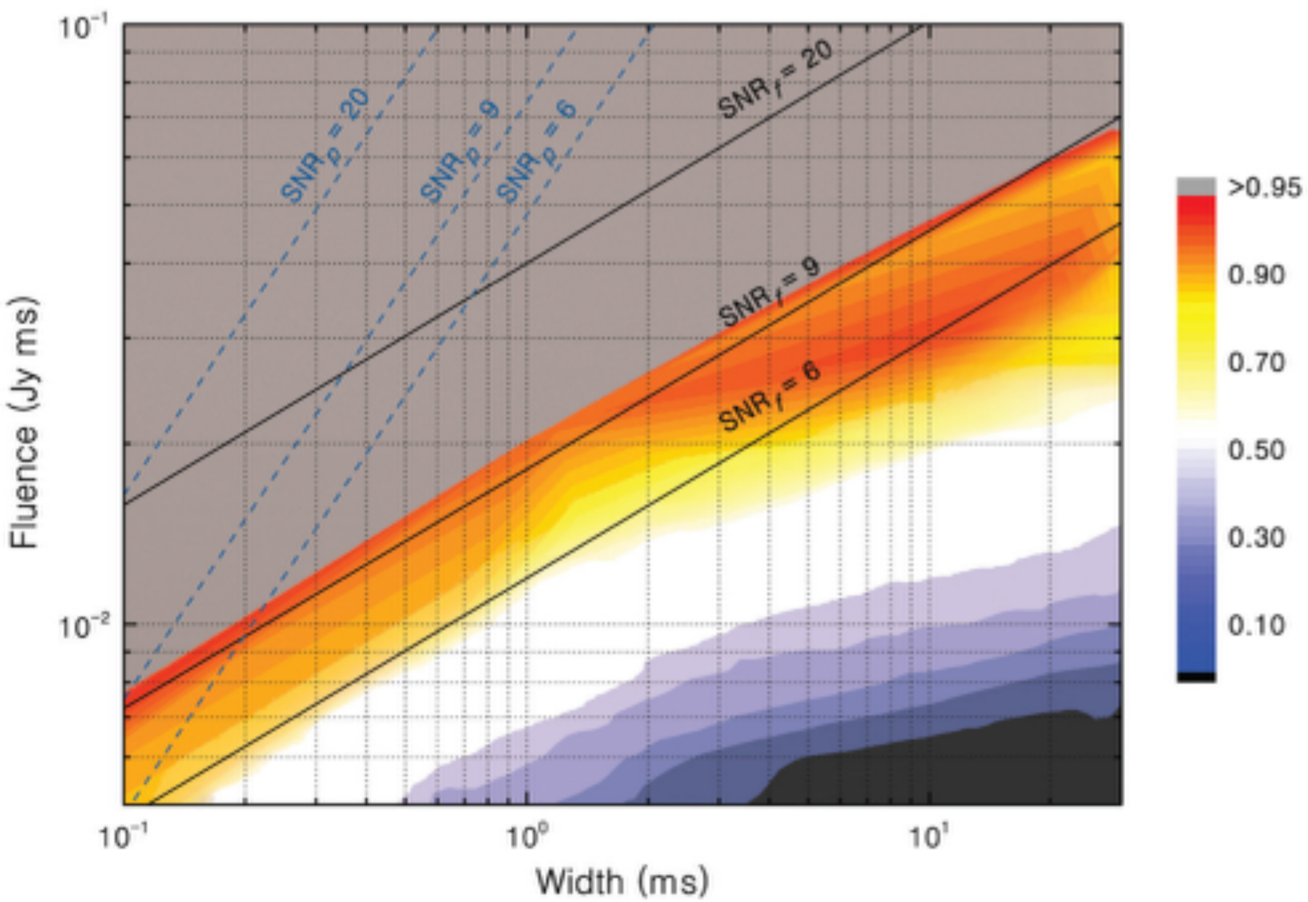
Injected vs. Detected S/N

Flux ~ S/N * width
Fluence ~ S/N / sqrt(width)









- pulse smearing
- fluence completeness
- pulse width completeness

Integrated SNR ∝ Fluence

Assuming pulse width 3 ms:

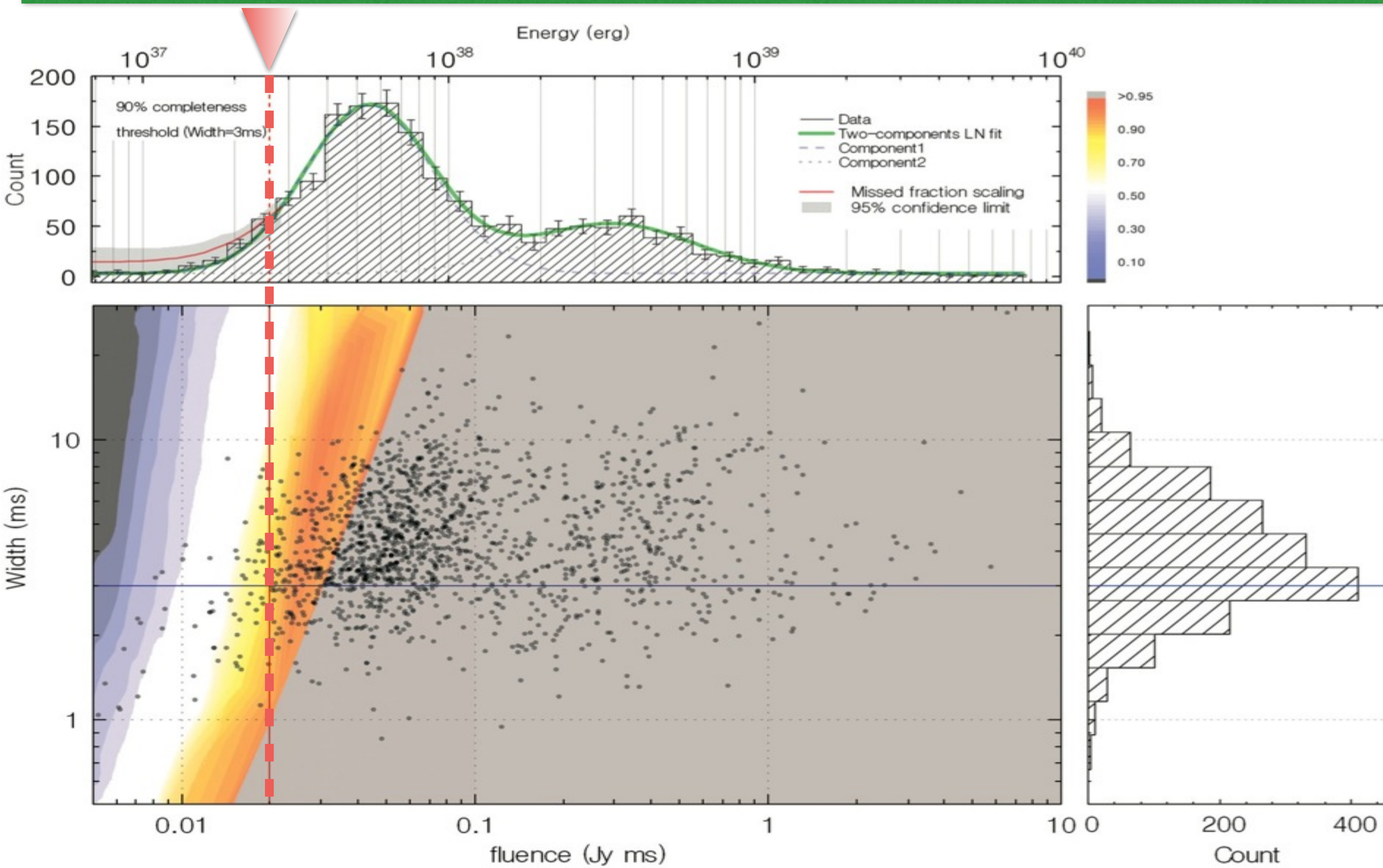
90% completeness:
8 sigma —> E= 2.6e37erg

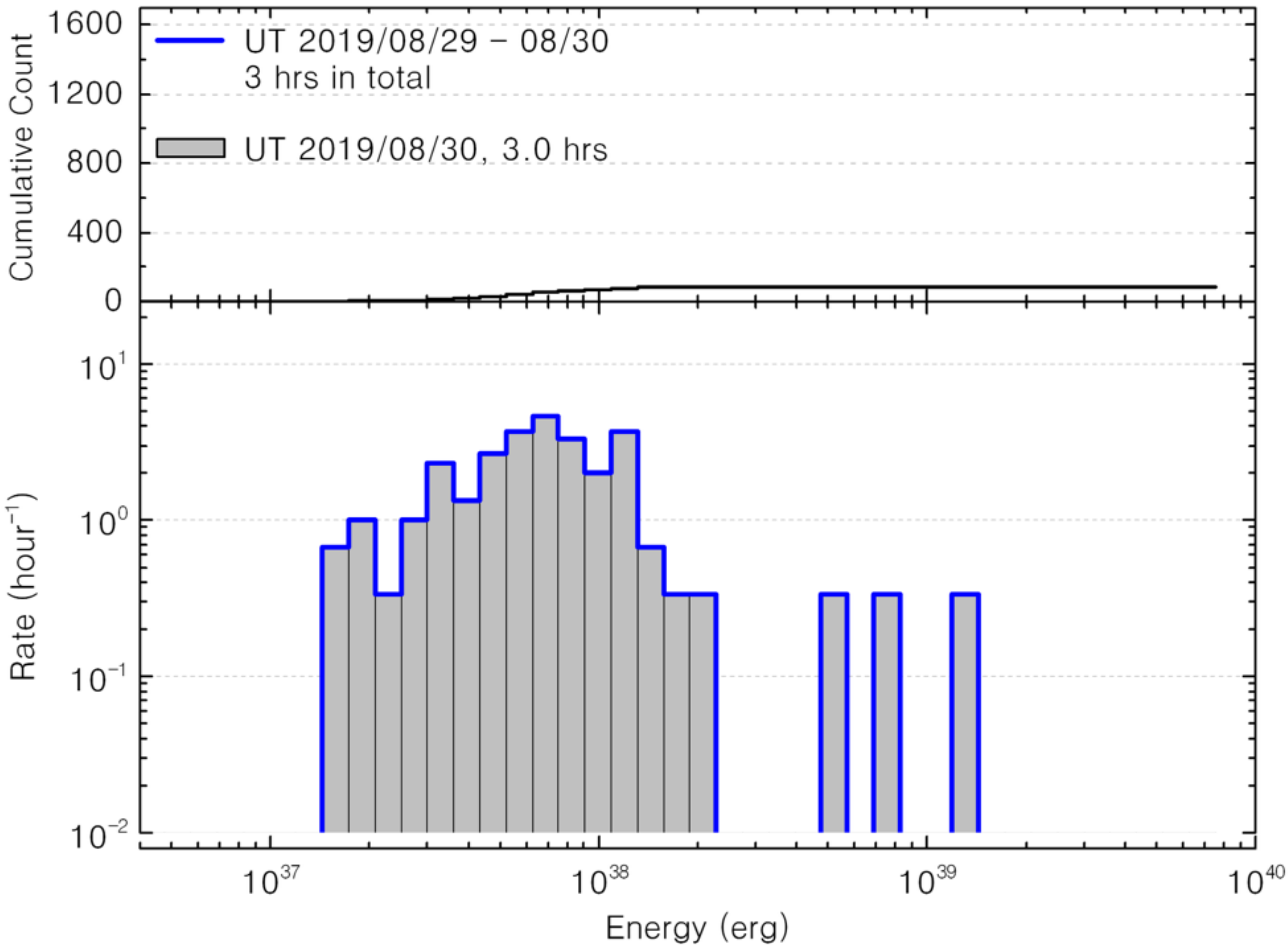
>95% completeness:
>12 sigma —> E= 4e37erg

FRB detection efficiencies at FAST

E = 2.6E37 erg ⇔ 3 ms, 8 sigma, ~90% completeness

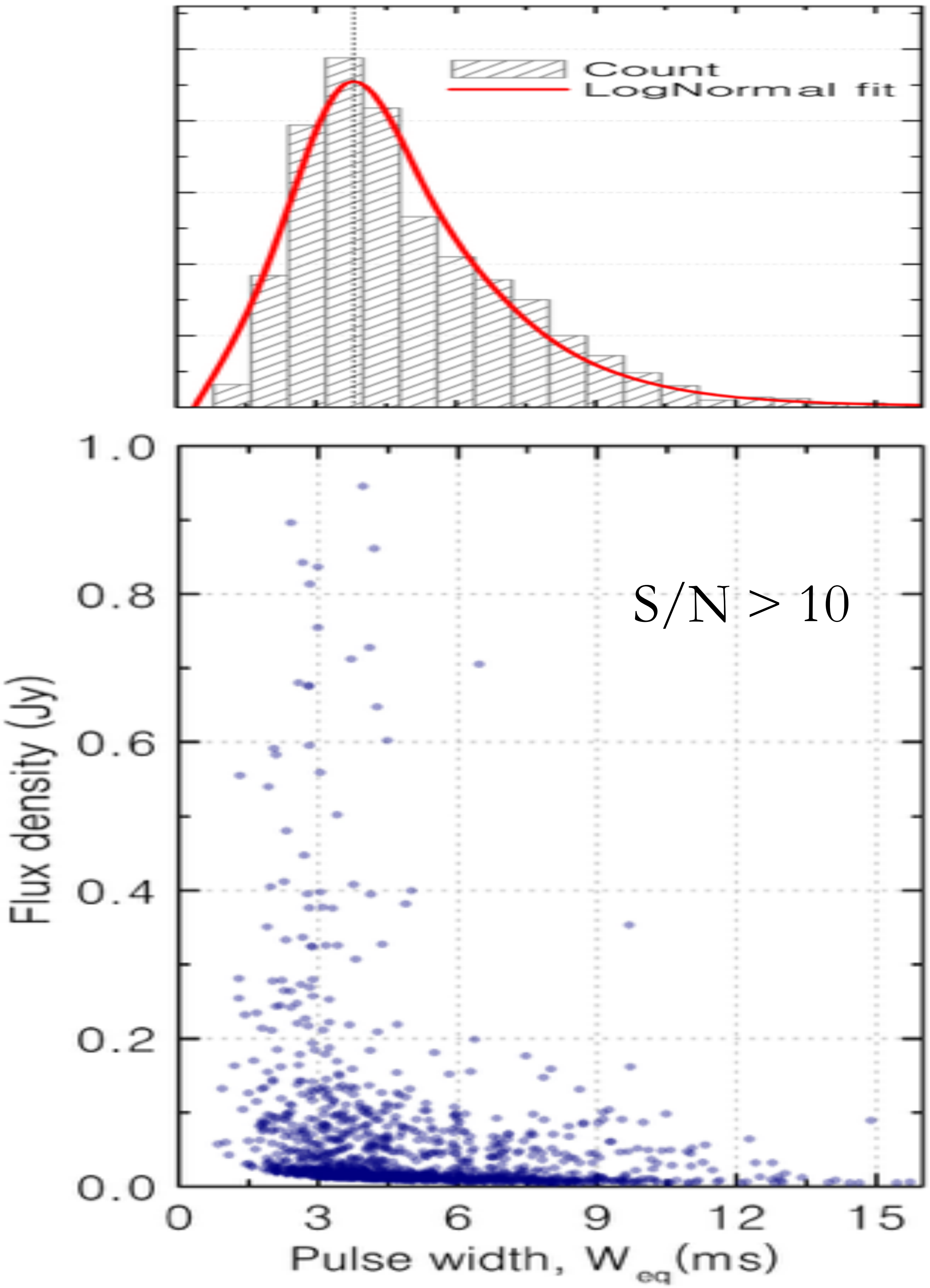
the peaks are still robust !



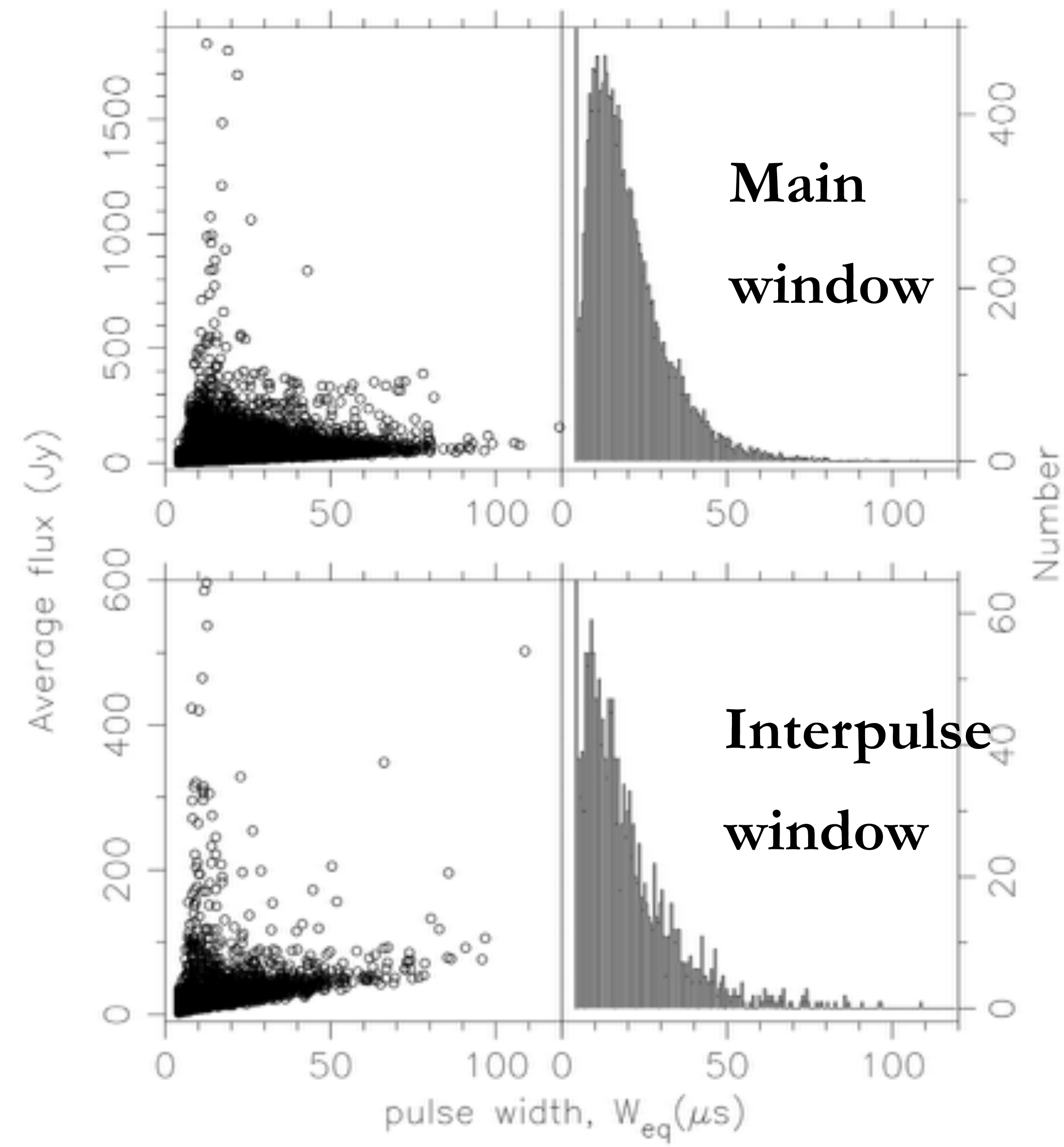


1600
1200
800
400
0
Cumulative Count
UT 2019/08/29 – 08/30
3 hrs in total
UT 2019/08/30, 3.0 hrs
10^1
10^0
10^−1
10^−2
Rate (hour^−1)
10^37
10^38
10^39
10^40
Energy (erg)

Duration Time distribution



Crab pulsar gaint pulses



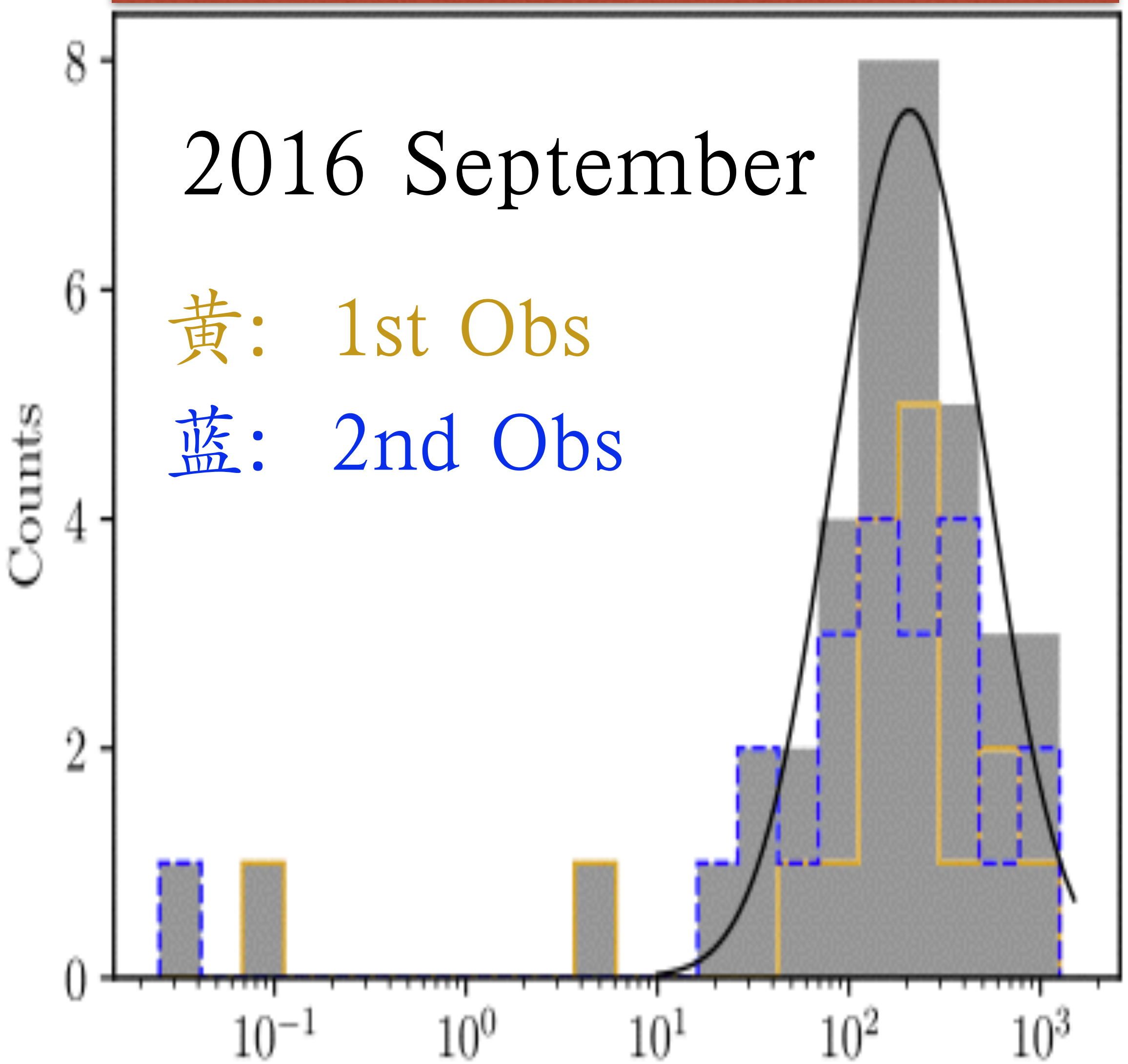
Karuppusamy R. et al., 2010

. Cordes J. M. et al., (2016), MNRAS 457, 232

Waiting Time distribution

Centered at 207 ± 1s

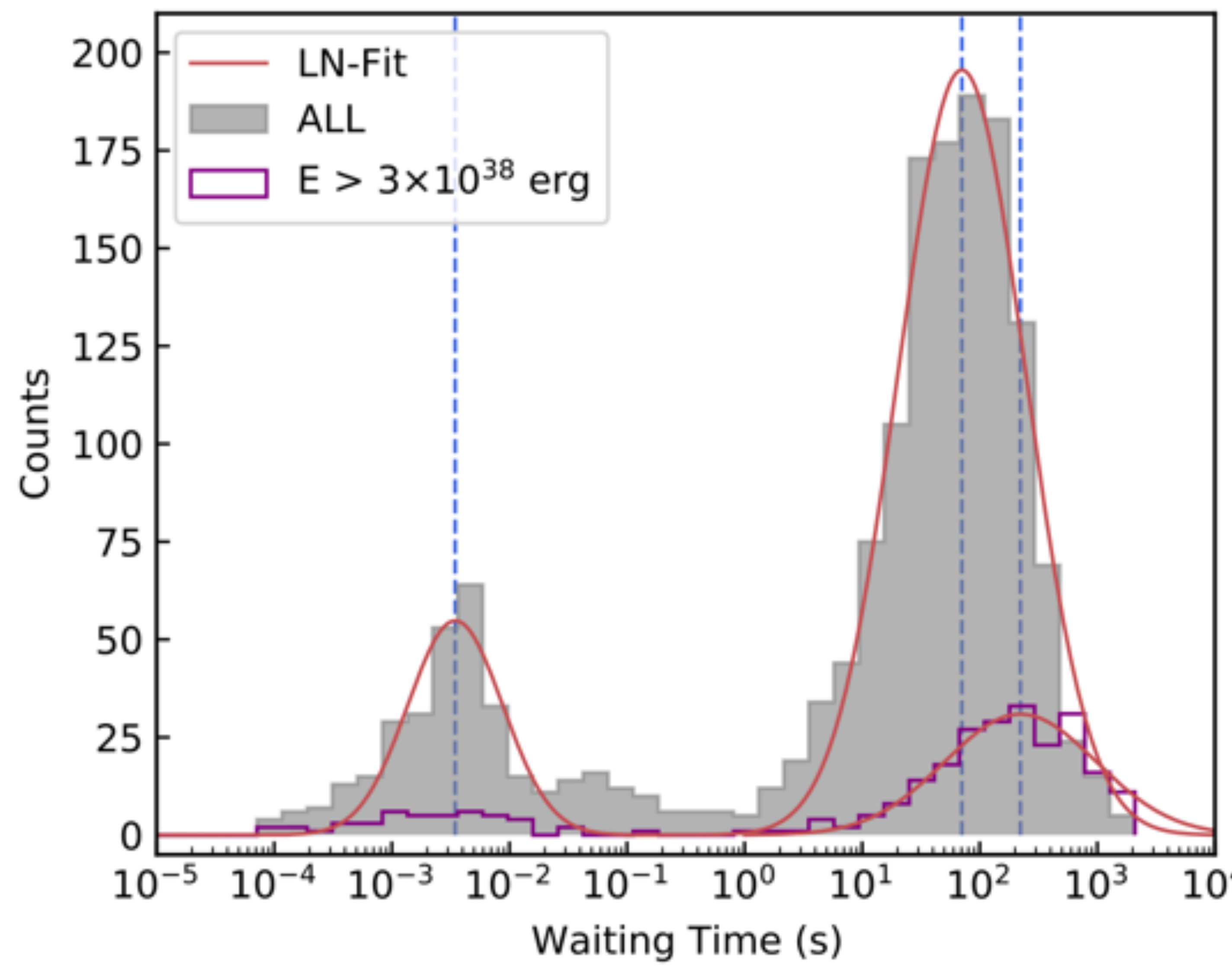
Arecibo 41 bursts @1.4 GHz



Gourdji, K. et al., 2019

Centered at ~70s

FAST 1652 bursts @1.25 GHz



- No obvious correlation with energy and time
- Similar with magnetar bursts

Göğüş et al. 1999, 2000, Wang & Yu, 2017 Cheng et al., 2020

[Previous]

FRB121102 is active again as revealed by FAST

ATel #13959; *Pei Wang(NAOC), Yunpeng Men(PKU), Dejiang Zhou(NAOC), Yongkun Zhang(NAOC), Tao An(SHAO), Yi Feng(NAOC), Jinlin Han(NAOC), Jinchen Jiang(PKU), Kejia Lee(PKU), Di Li(NAOC), Chenhui Niu(NAOC), Chenchen Miao(NAOC), Ningyu Tang(NAOC), Bojun Wang(PKU), Fayin Wang(NJU), Xuefeng Wu(PMO), Heng Xu(PKU), Jiangwei Xu(PKU), Jumei Yao(NAOC), Wenfei Yu(SHAO), Bing Zhang(UNLV), Chunfeng Zhang(PKU), Weiwei Zhu(NAOC)*
on 21 Aug 2020; 16:49 UT
Credential Certification: Di Li (dili@nao.cas.cn)

Subjects: Radio, Request for Observation

Tweet

FAST is monitoring FRB 121102 for two
until now: (UTC) 12-14th Mar., 7th Apr
central beam of the FAST L-band Array
+33d08m52.5s (Chatterjee et al. 2017; M
GHz to 1.45 GHz. The pulsar-searching
4K frequency channels. Following non-
23:55:00 and UTC 2020-07-29 00:55:00)
estimated fluence between 0.03 and 0.2 J
and UTC 2020-08-17 03:35), suggesting
flux density is estimated based on the S
pulse is roughly 44 mJy. Rajwade et al. (
off period of ~156.9 days. Cruces et al. (
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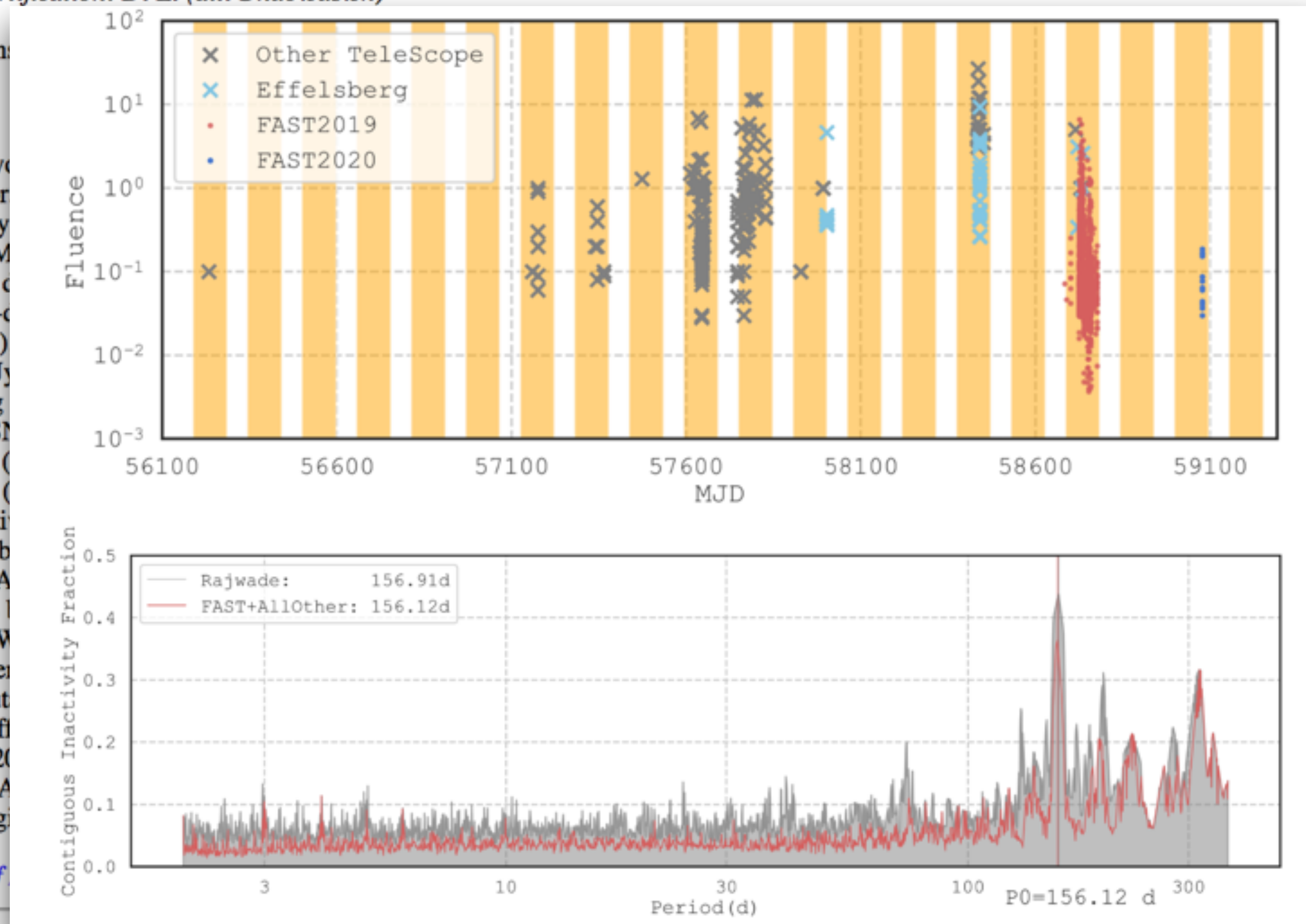
August 31th - September 9th, 2020. Alte
turning-off time, it suggests that the put
encourage more follow-up monitoring ef
S.; Law, C. J.; Wharton, R. S. et al. 2
Stappers, B. W. et al. 2020, MNRA
2020arXiv200803461 Marcote, B.; Parag

Phase-Folding MJDs of

duty cycle (OFF/Period)
44% —> 37%

Yongkun Zhang



[Previous]

FRB121102 is active again as revealed by FAST

ATel #13959; *Pei Wang(NAOC), Yunpeng Men(PKU), Dejiang Zhou(NAOC), Yongkun Zhang(NAOC), Tao An(SHAO), Yi Feng(NAOC), Jinlin Han(NAOC), Jinchen Jiang(PKU), Kejia Lee(PKU), Di Li(NAOC), Chenhui Niu(NAOC), Chenchen Miao(NAOC), Ningyu Tang(NAOC), Bojun Wang(PKU), Fayin Wang(NJU), Xuefeng Wu(PMO), Heng Xu(PKU), Jiangwei Xu(PKU), Jumei Yao(NAOC), Wenfei Yu(SHAO), Bing*
Zhu

on ***21 Aug***
Credential Certificati

Subjects: Radio, Request for Observation

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2020arXiv200803461 Marcote, B.; Parag

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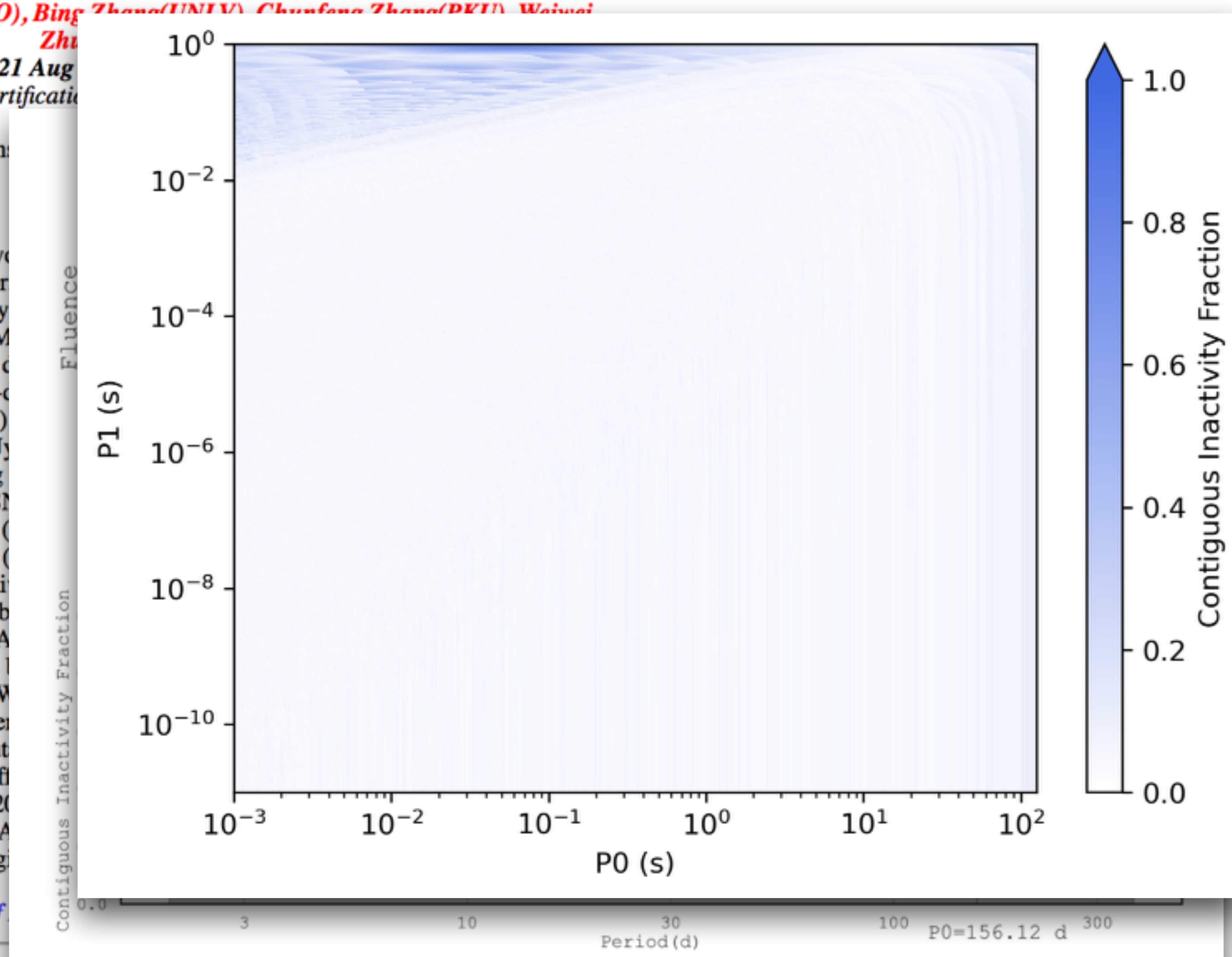


Summary

- ➡ 1652 pulses from FRB121102, more than all previous detections combined.
- ➡ Largely expand low energy detection ability. FRB 121102 has a characteristic peak energy of 4.8×10^{37} erg, which lie just around the detection threshold of Arecibo.
- ➡ FRB 121102 has a complex energy/fluence distribution, which can be best described as a lognormal + Cauchy bimodal function. The power-law logN - log S here seems to be an artifact of detection bias.
- ➡ No periodicity between 10 ms and ~1000 s. Characteristic waiting time of ~70s. Burst period is 156 day, duty cycle is changed to 37% from FAST detection.

Nature accepted

Welcome to test FRB simulator：

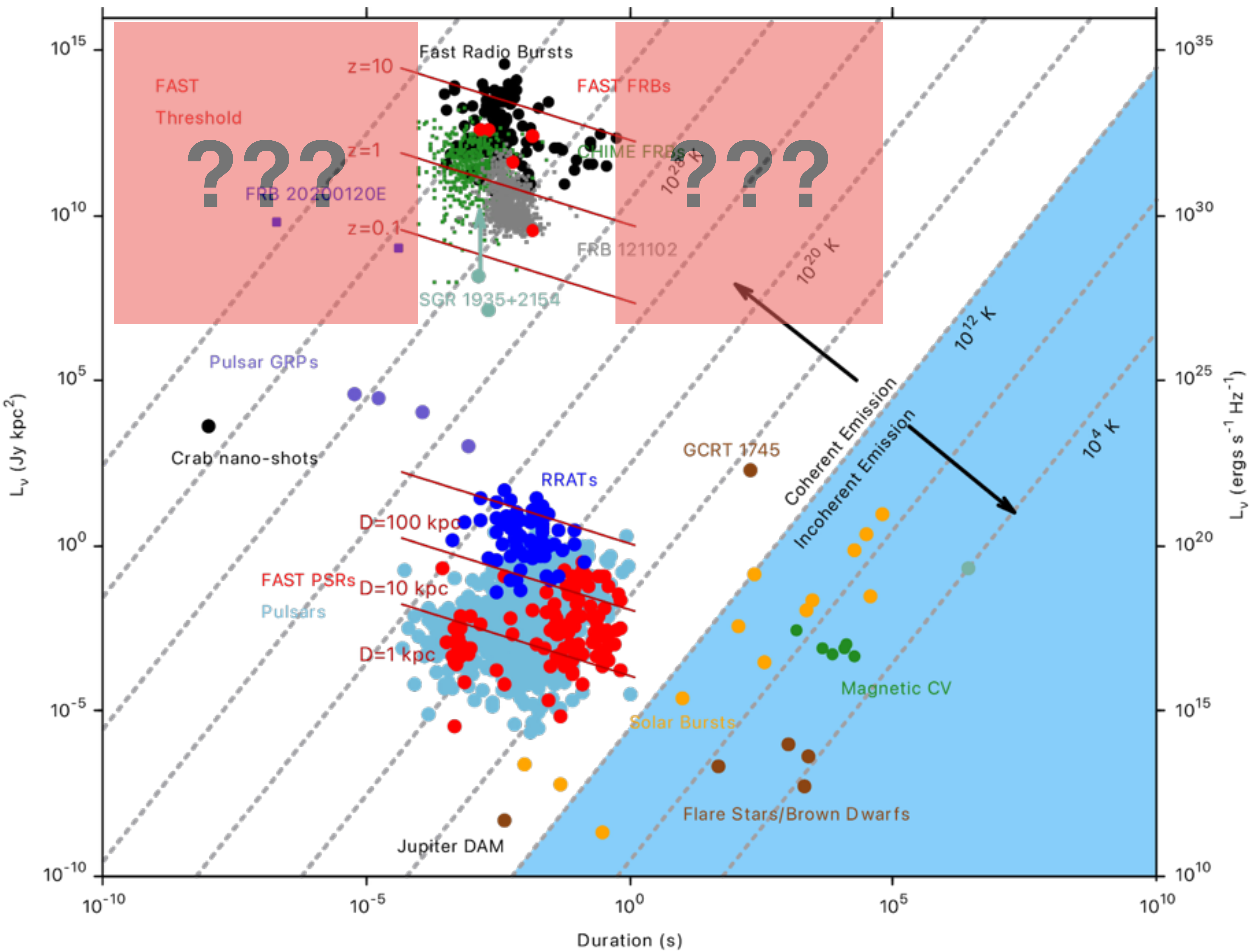
https://github.com/NAOC-pulsar/PeiWang-code

A. Intrinsic physics of sources
(luminosity function, population)

B. Instrumental effects of observations
(resolution, parameter space, pipeline efficiency)

Help to answer open questions:

1. What's the FRB redshift distribution? higher DM -> high z
2. How to detect narrow/wide pulse -> emission population
3. Short time scale DM variation -> local host-Galaxy DM
4. Test pipeline boxcar efficiency



Credit: D. Li、P. Wang、Y. K. Zhang et al.（cf. Keane 2018 “The Future of FRBs”）


FRB 121102
host galaxy
Thanks!
Q & A

Inclusived discussion

- RM from FRB 121102 have not been observed in FAST Lband

Yi Feng

- ISM Scintillation

Jumei Yao

FRB121102:

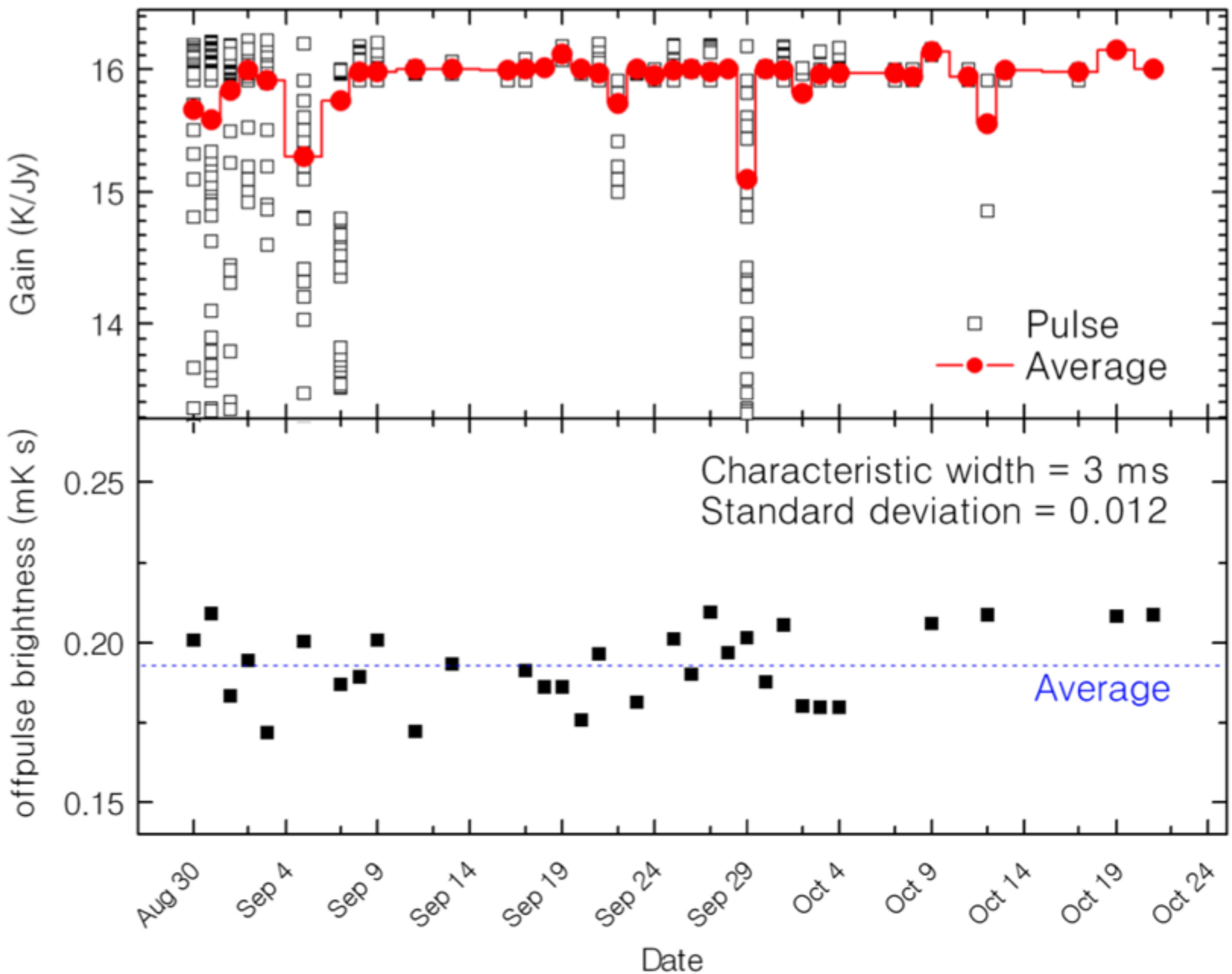
Scattering timescale 1.4 GHz: 9.6*(500/1400)^4= 0.1 ms

Scintillation bandwidth 1.4 GHz: 11*(1400/4900)^4=73 kHz=0.07 MHz

FAST frequency resolution = 500/4096=0.122 MHz

➡Had to study scintillation at L-band. Timescale 0.1ms, bandwidth 0.07MHz.

The distribution of the instrumental gain and off-pulse brightness RMS at 1.25 GHz for observations.



arXiv: 2011.10191v1
The completeness fraction of survey to FRBs

MNRAS **000**, 1–12 (2020) Preprint 23 November 2020 Compiled using MNRAS LaTeX style file v3.0

Estimating fast transient detection pipeline efficiencies at UTMOST via real-time injection of mock FRBs

V. Gupta[1], C. Flynn[1,2], W. Farah[1,8], A. Jameson[1,2], V. Venkatraman Krishnan[1,6], M. Bailes[1,2], T. Bateman[1,3], A. T. Deller[1,2], A. Mandlik[1], A. Sutherland[1,3]

[1]*Centre for Astrophysics and Supercomputing, Swinburne University of Technolo*
[2]*ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav), Australi*
[3]*Sydney Institute for Astronomy, School of Physics A28, University of Sydney, NS*
[4]*CSIRO Astronomy and Space Science, Australia Telescope National Facility, Ep*
[5]*Center for Astrophysics | Harvard & Smithsonian, 60 Garden Street, Cambridge*
[6]*Max-Planck-Institute für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, C*
[8]*SETI Institute 189 Bernardo Ave, Suite 200 Mountain View, CA 94043, United S*