The Stochastic Nature of FRB 121102

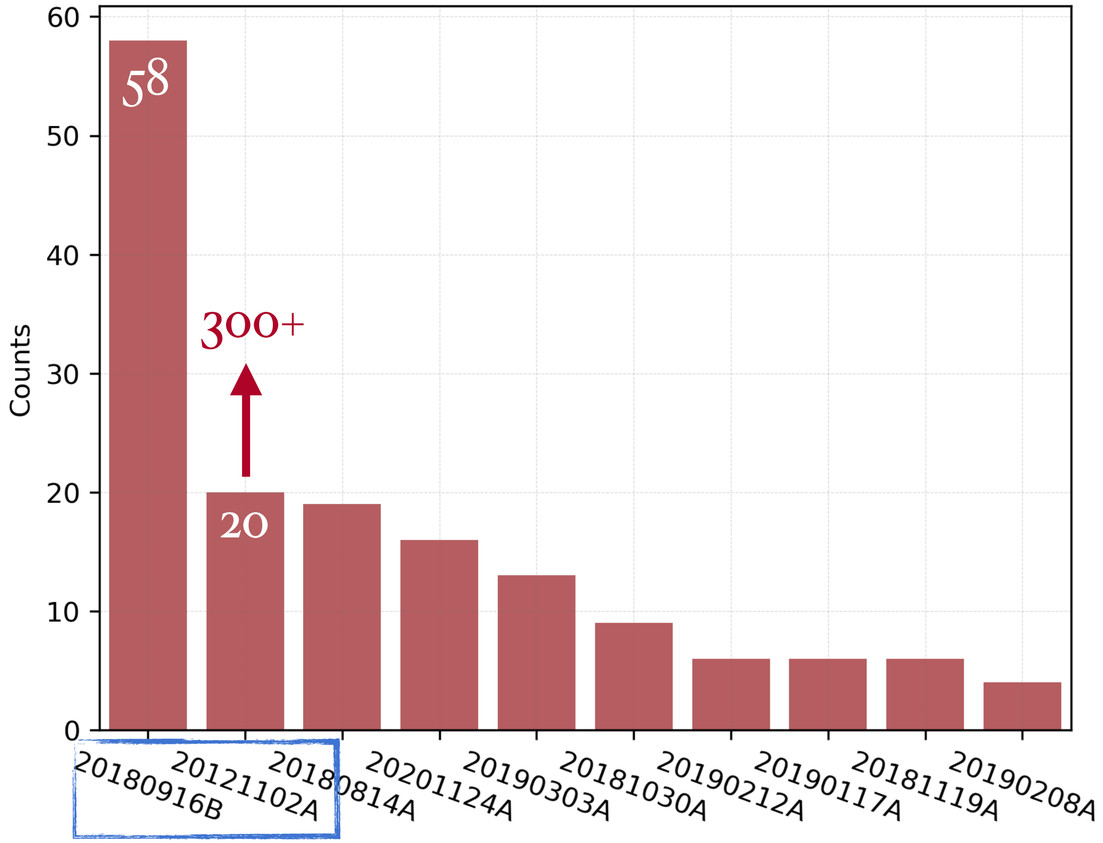
Two Poisson-Like Process

张永坤 / 2021.07.14

快速射电暴

22 重复暴　584 非重复暴 474^{+110}_{-}

起源不同、尚未探测到重复...

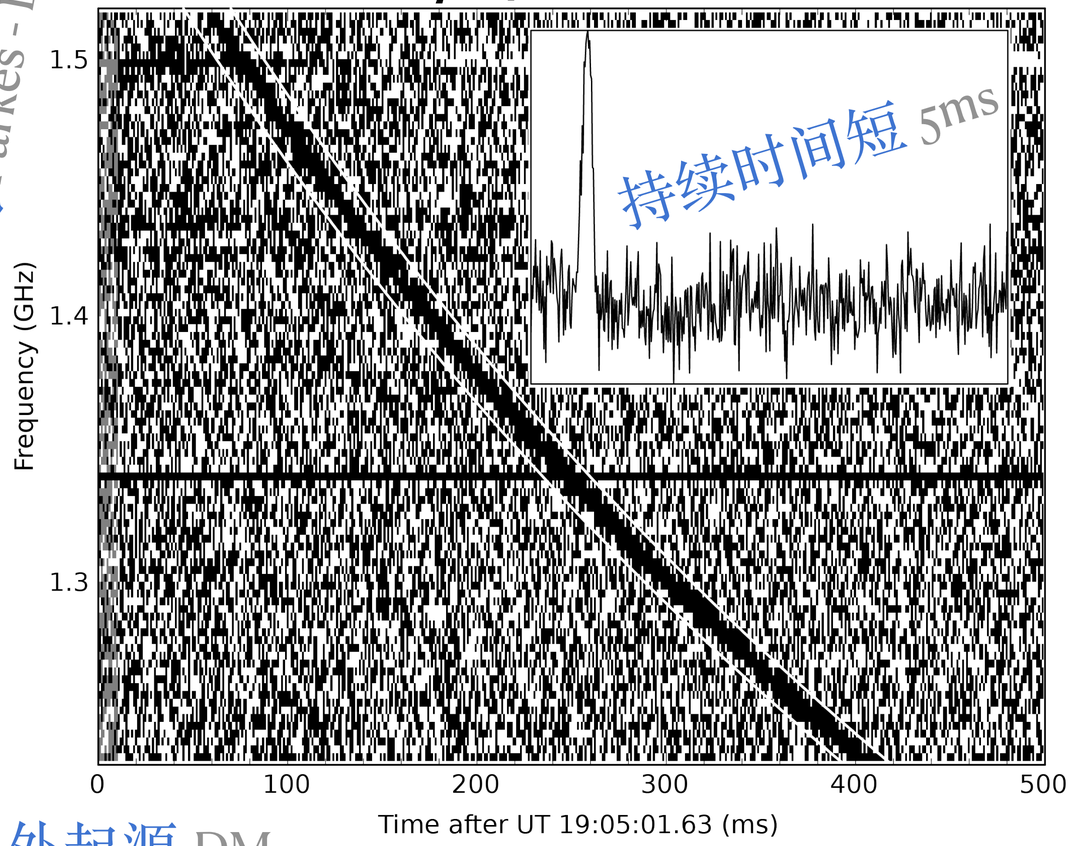


Data from Transient Name Server

射电波段 Parkes - L波段

能量高 30Jy

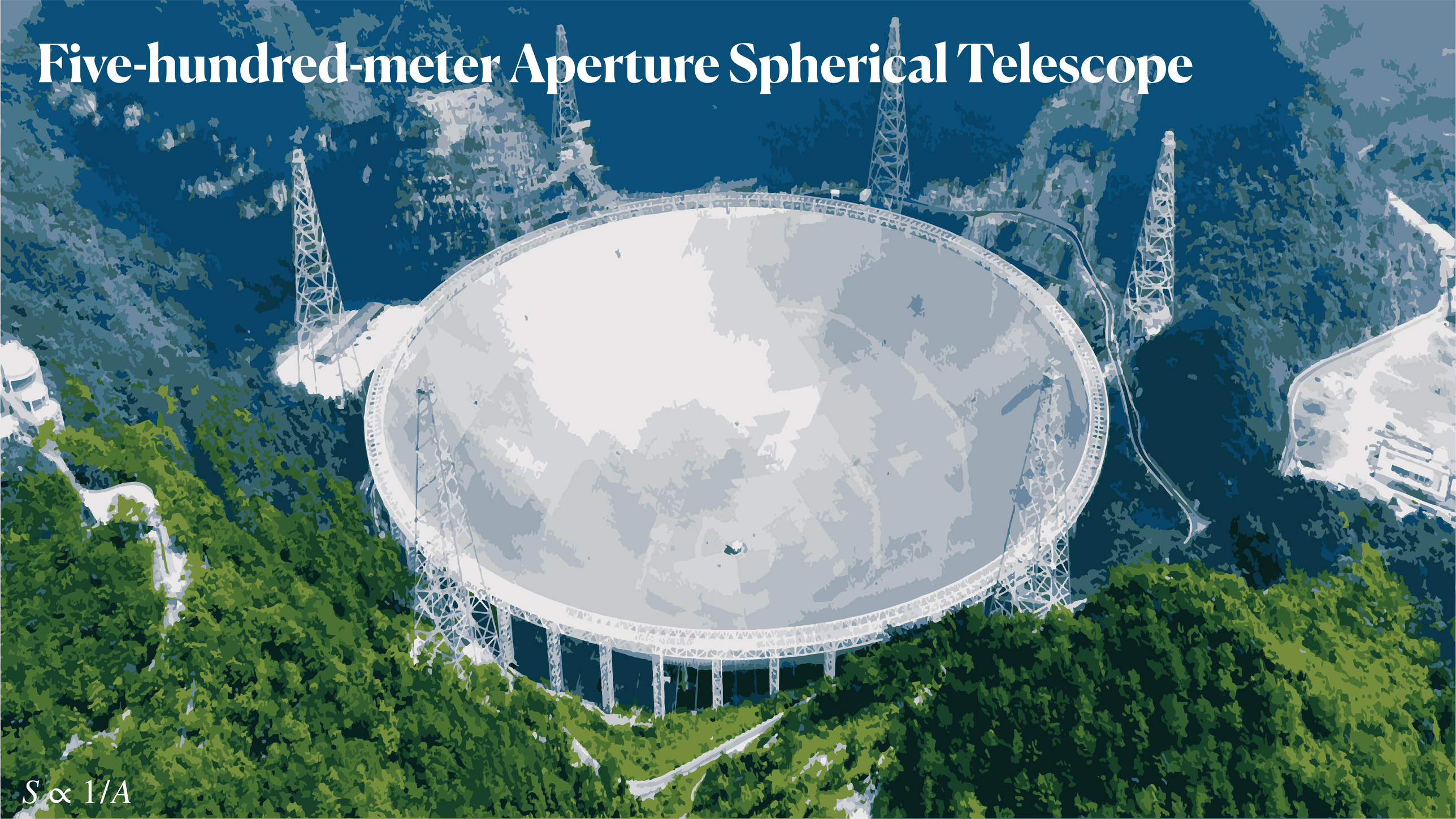
FRB 010724



系外起源 DM

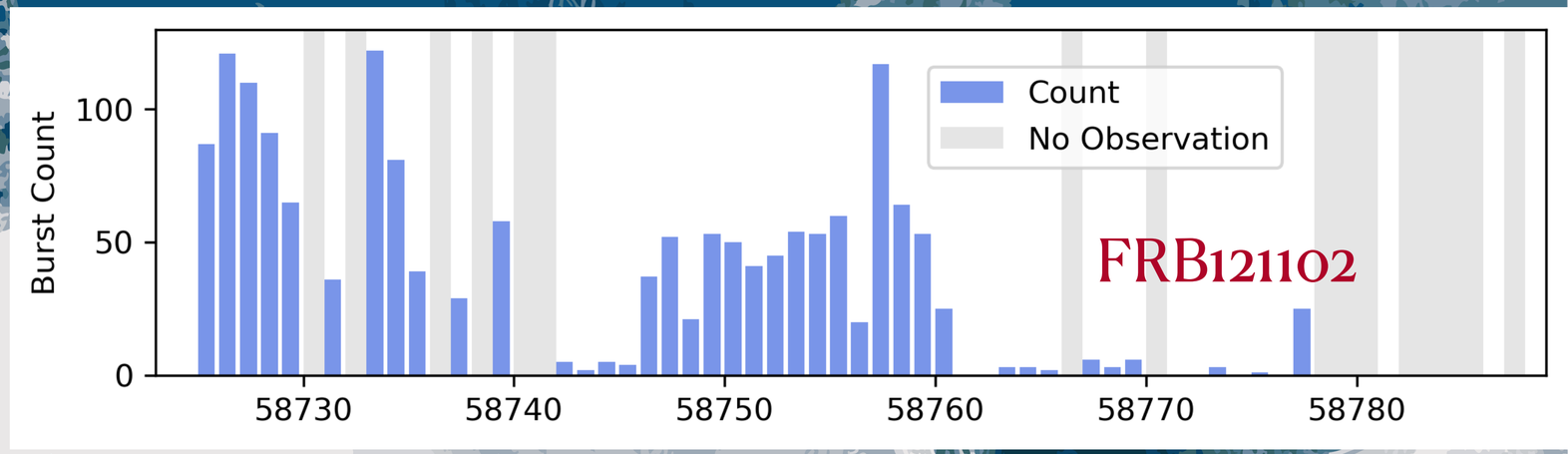
Lorimer et al. 2007

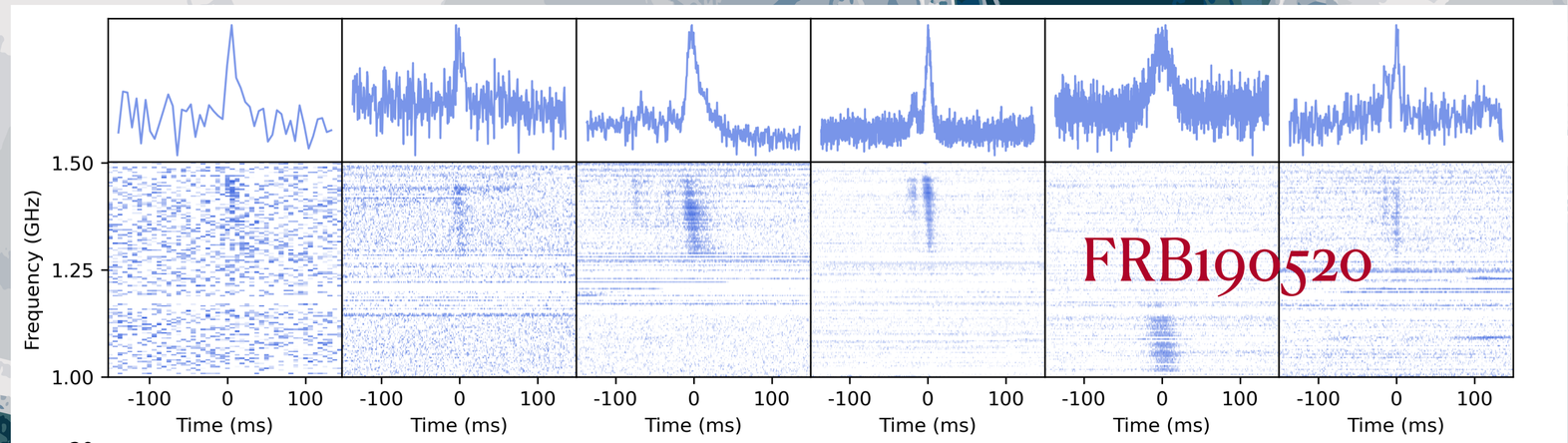
Five-hundred-meter Aperture Spherical Telescope

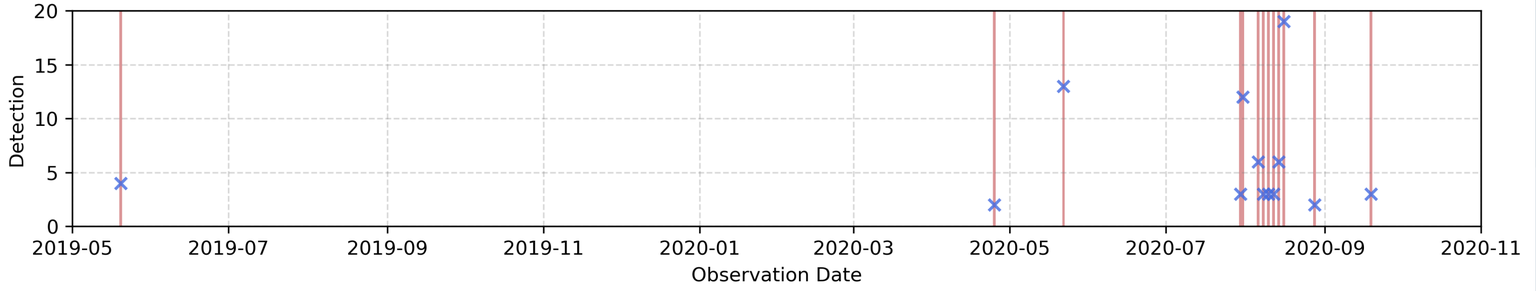


$S \propto 1/A$

Five-hundred-meter Aperture Spherical Telescope







时域分析

中子星、黑洞...

有周期

中子星进动

Zanazzi et al. 2020

轨道周期

Barkov & Giannios 2020

旋转慢的磁星

有自转的源

无周期

星震

Wang et al. 2018

耀斑

Beniamini et al. 2020

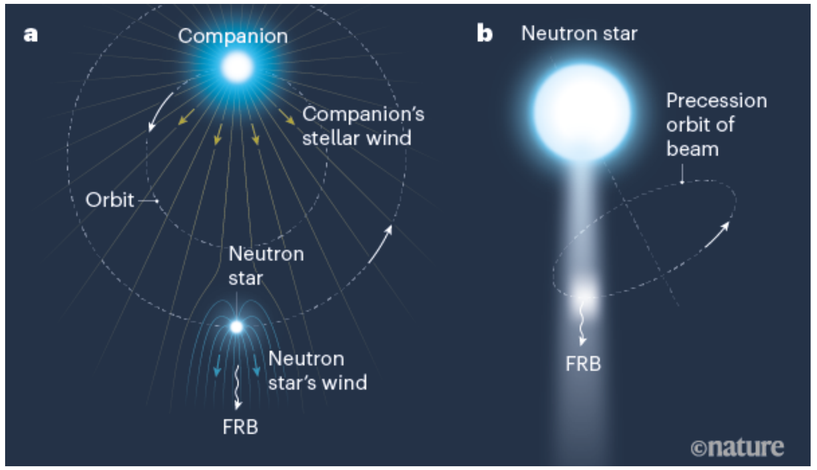
黑洞吸积喷流

Katz et al. 2017

小行星撞击中子星

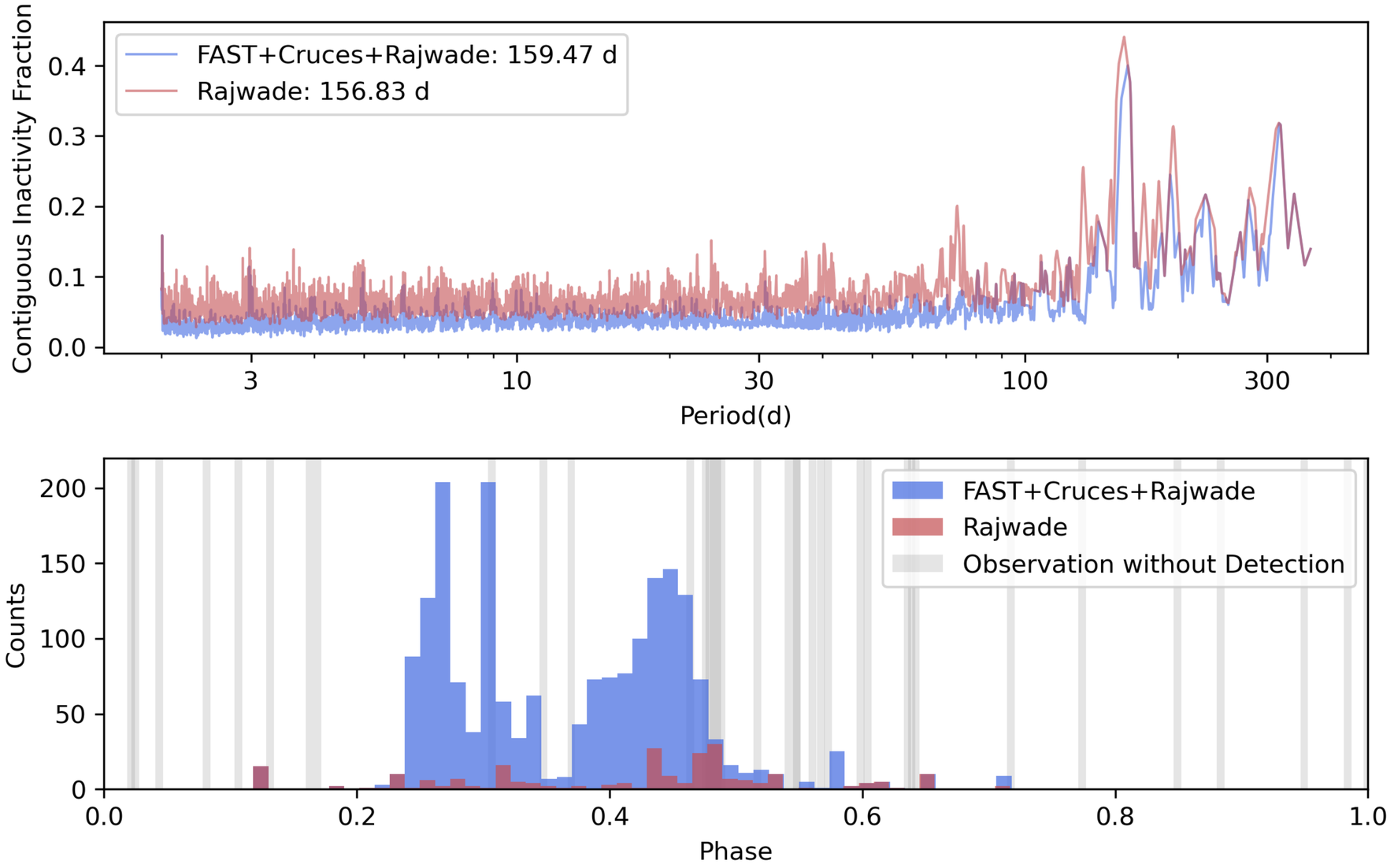
Huang et al. 2016

FRB 180916 16天周期



星风遮蔽

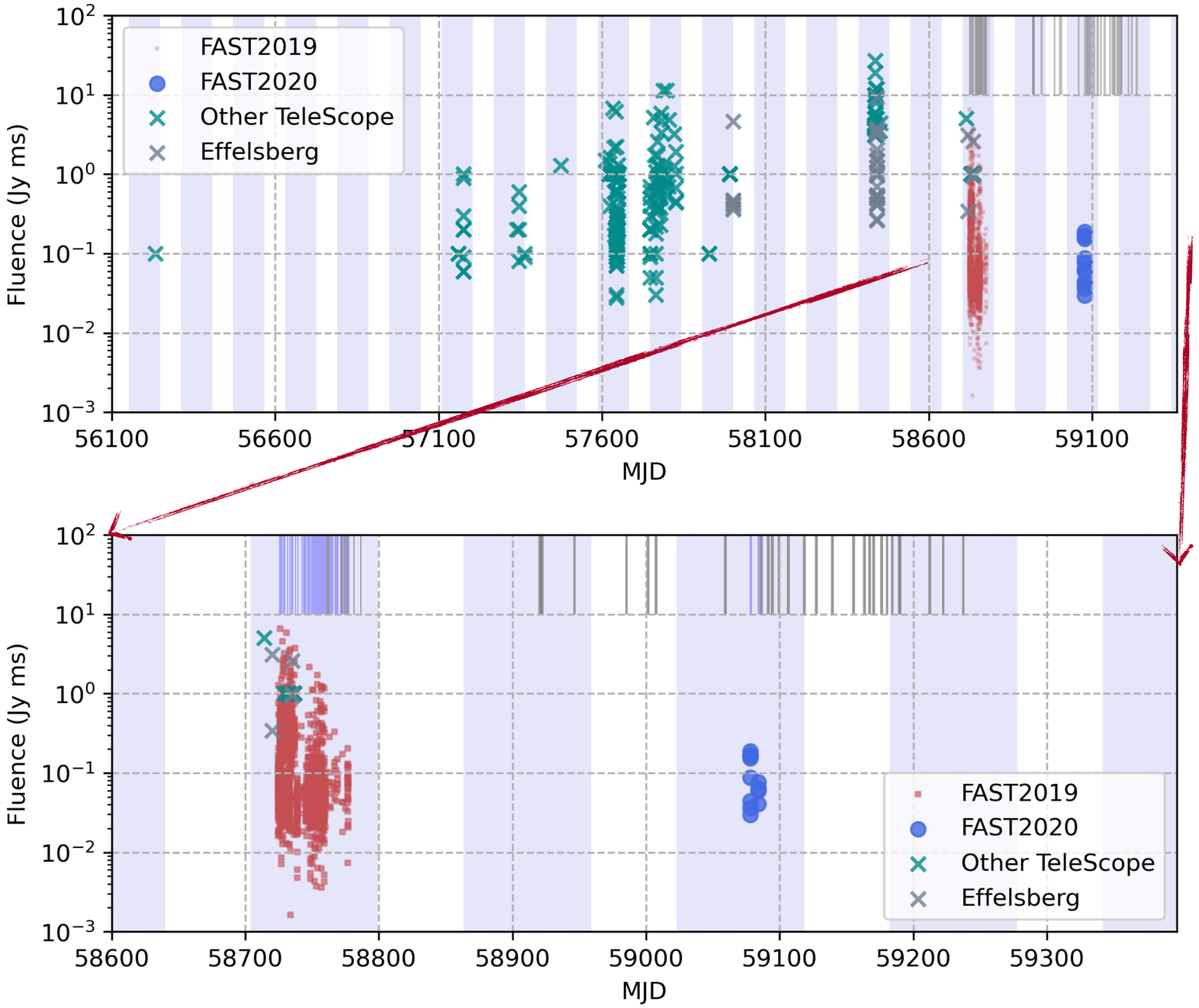
中子星进动



FRB 121102 157d 长周期

灰框 - 观测但没看到脉冲

Duty cycle - 57% to 60%



活跃窗口

蓝框 - 观测且看到脉冲

灰框 - 观测没看到脉冲

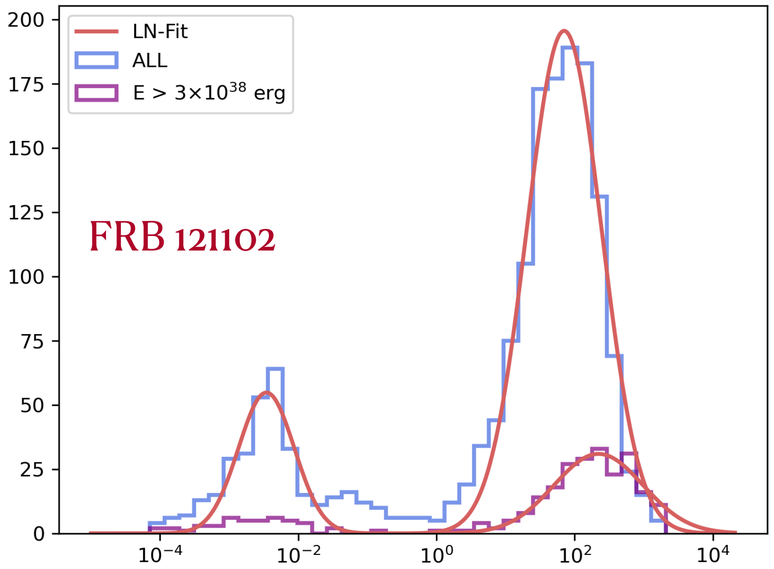
后随未观测到脉冲

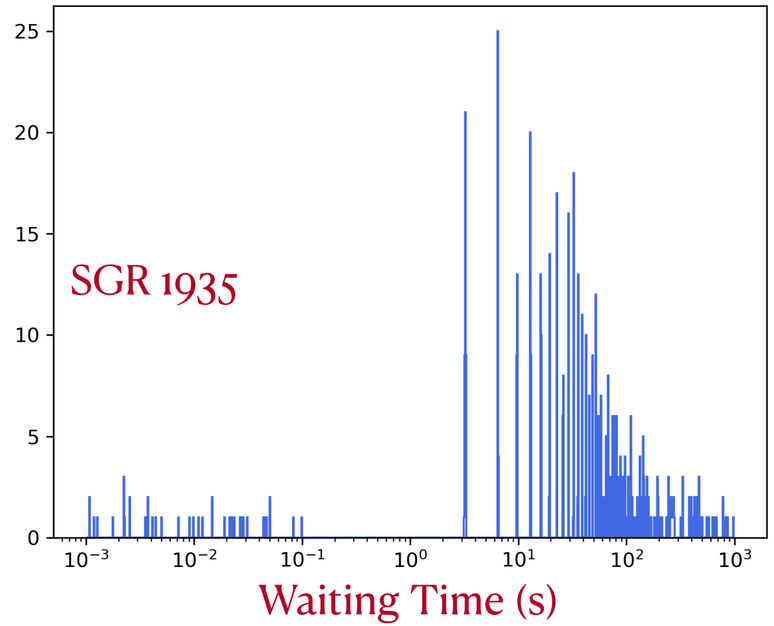
157天的周期可能并不稳定

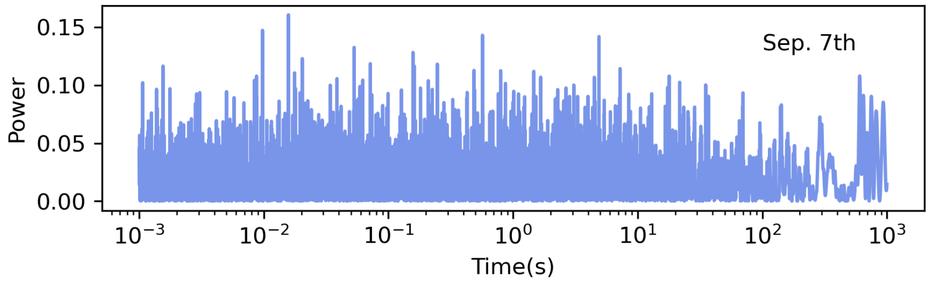
FRB 121102

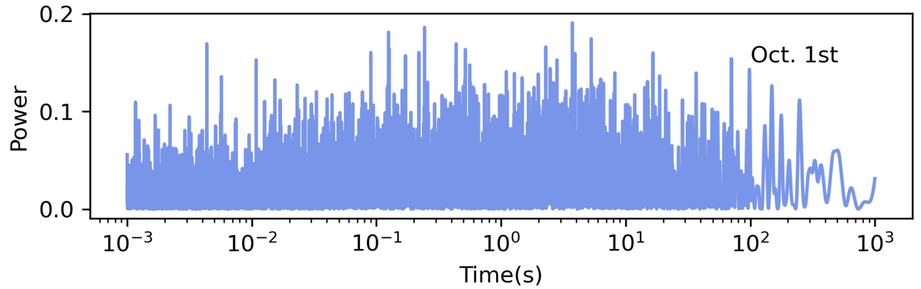
等待时间峰值 3.4 ± 0.1ms

和 70 ± 10 s







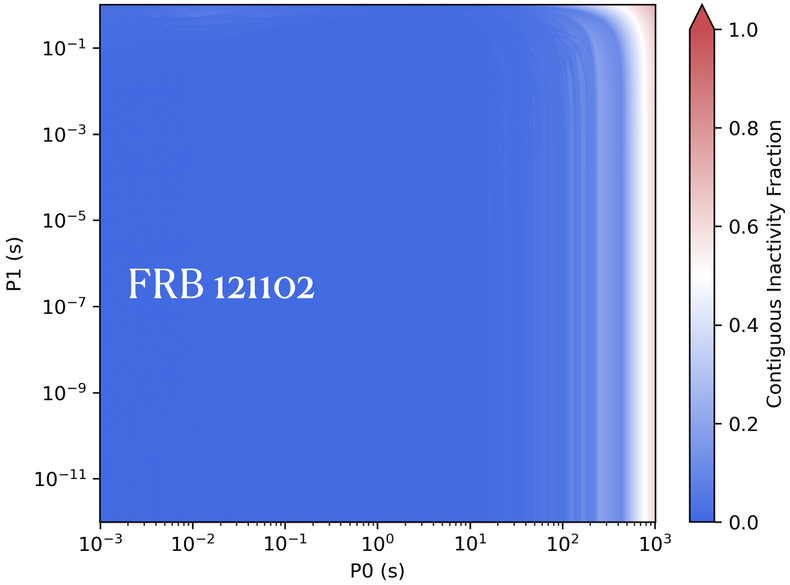


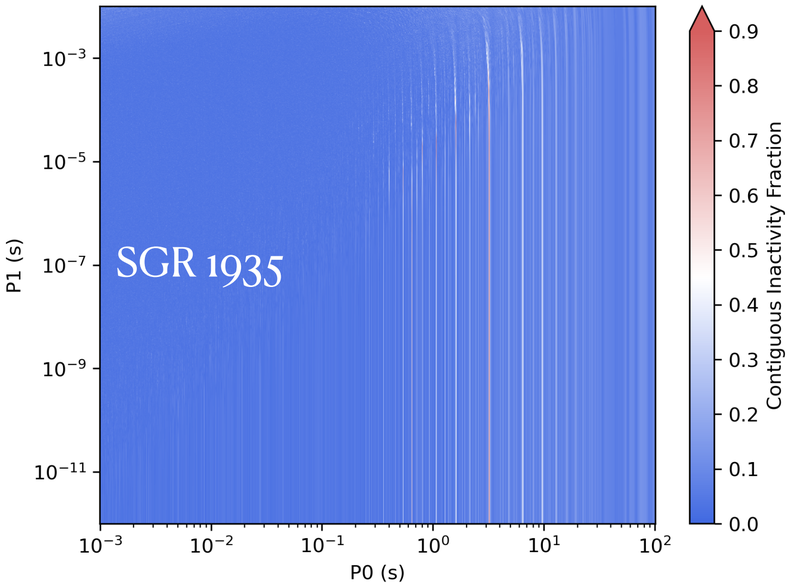
Lomb-Scargle Periodograms

爆发率最高的两天

FRB 121102 没有短周期 → 随机?

Phase-Folding





韦伯分布

“FRB 121102似乎以不规则的方式发射脉冲，但似乎又在某种程度上聚集在一起。”

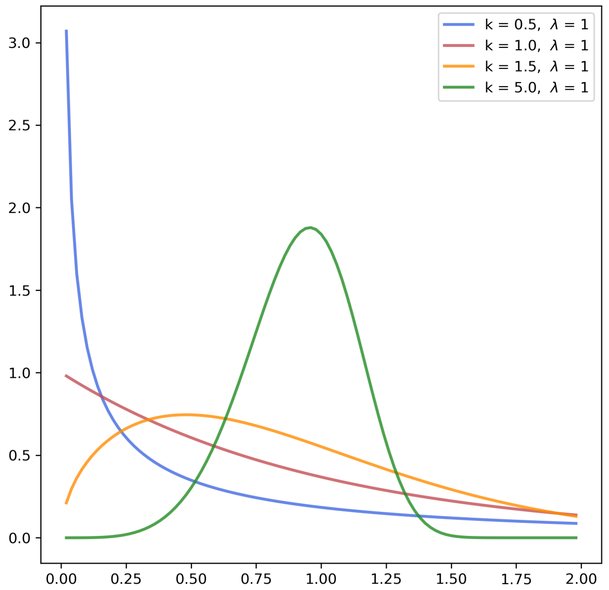
Oppermann et al. 2018中提到用Weibull分布来描述FRB 121102的等待时间的分布

$$\mathscr{W}(\delta\,|\,k,L)=\frac{k}{L}\left(\frac{\delta}{L}\right)^{k}e^{-(\delta/L)^{k}}$$

k是形状因子，当k=1时，Weibull分布退化为指数分布：$\mathscr{W}(\delta\,|\,k=1,\lambda)=\lambda e^{-\lambda\delta}$

k<1时，等待时间显示出更强的成团性

δ是等待时间，$\lambda=1/(L\Gamma(1+1/k))$是事件数期望。



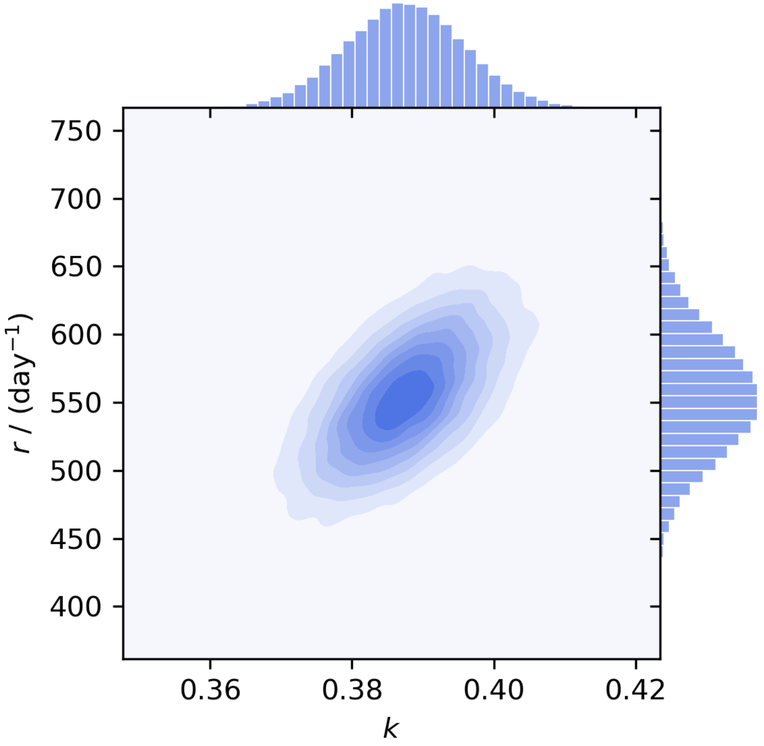
常数先验　$\mathscr{P}(k,\lambda)\propto k^{-1}\lambda^{-1}\Rightarrow\mathscr{P}(\log k,\log\lambda)=const$

概率后验　$\log\mathscr{P}(k,\lambda\,|\,\delta_1,\cdots,\delta_n)\propto\log\left[\mathscr{P}(\delta_1,\cdots,\delta_n\,|\,k,\lambda)\mathscr{P}(k,\lambda)\right]$

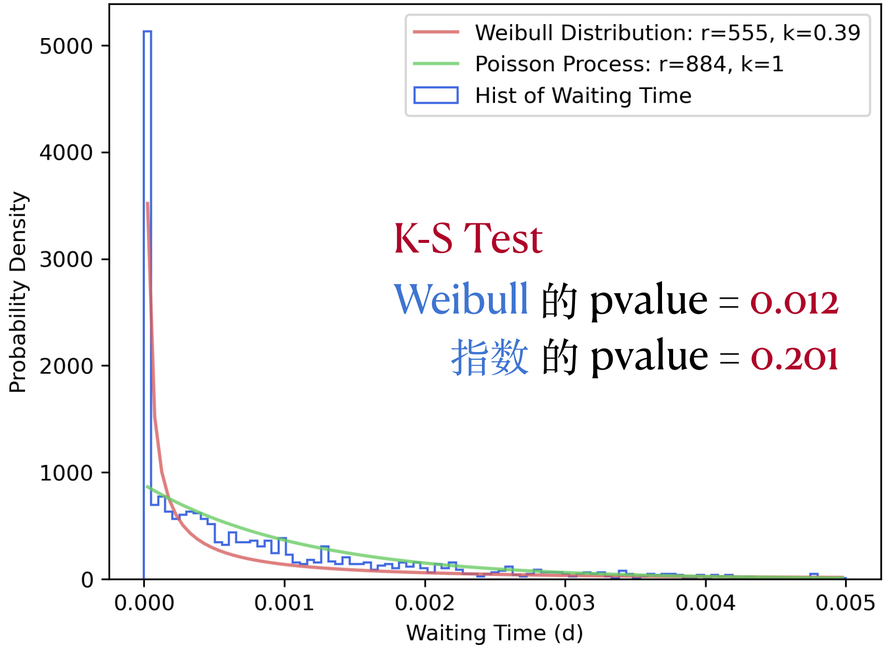
$=\log\mathscr{P}(\delta_1,\cdots,\delta_n\,|\,k,\lambda)+const$

$=\sum\log\mathscr{W}(\delta_i\,|\,k,\lambda)+const$

参数拟合

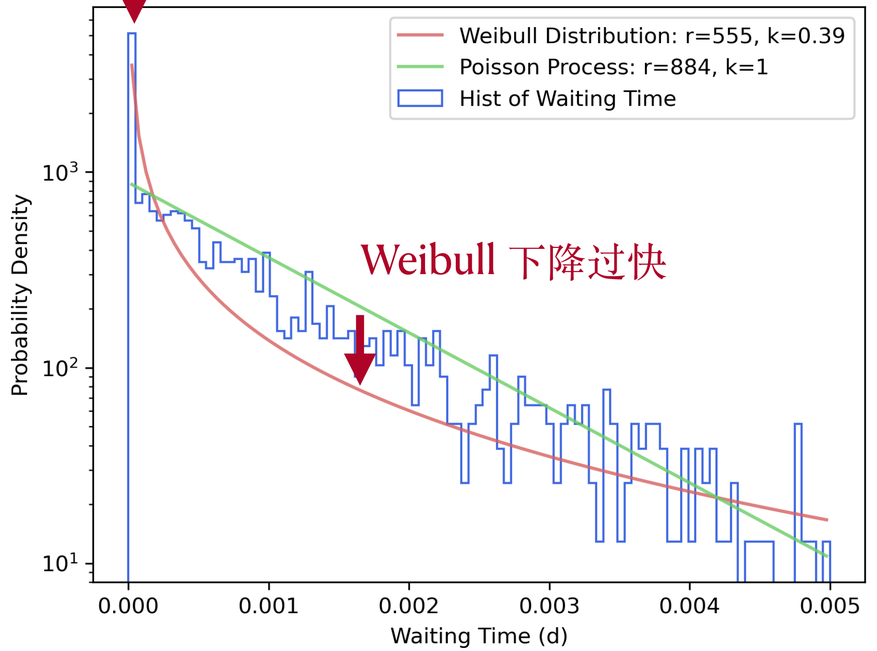


固定$k=1$，$\lambda = 884 \pm 22$



4.3s

左图对纵轴取log



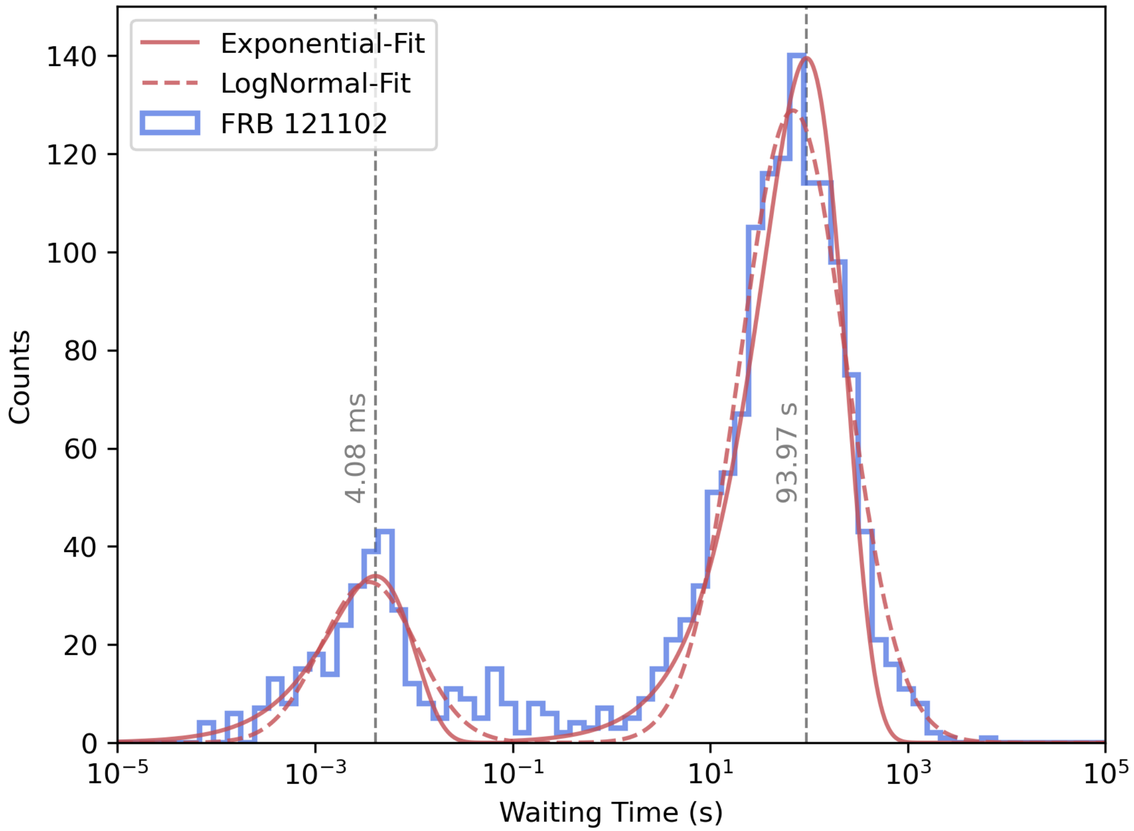
$k = 0.39 \pm 0.01$是形状因子

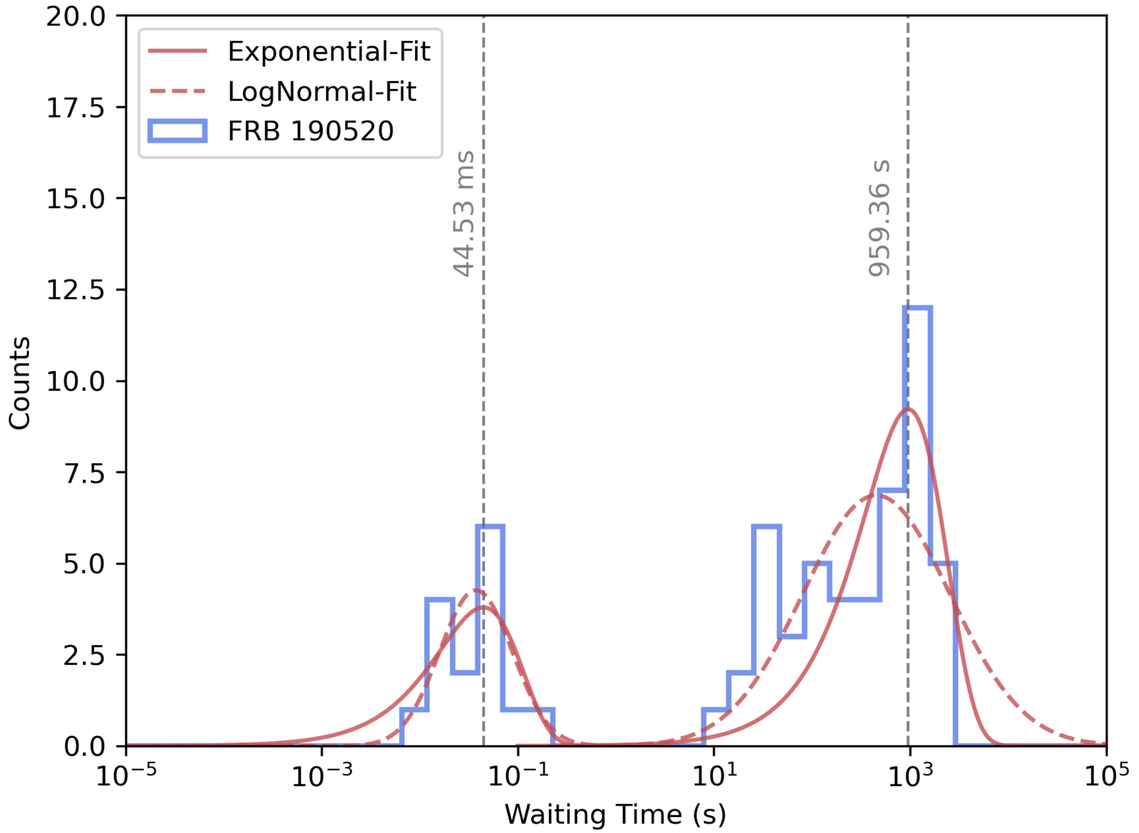
$\lambda = 555 \pm 44$ 是事件期望

单个Weibull分布并不适用于FRB 121102

指数拟合

$$P(x) = \lambda e^{-\lambda x} \qquad d\log x = \frac{dx}{x} \qquad P(x)d\log x \propto xe^{-\lambda x}dx$$





$\lambda = 0.0080/s \approx 1652/59/3600 = 0.0078$

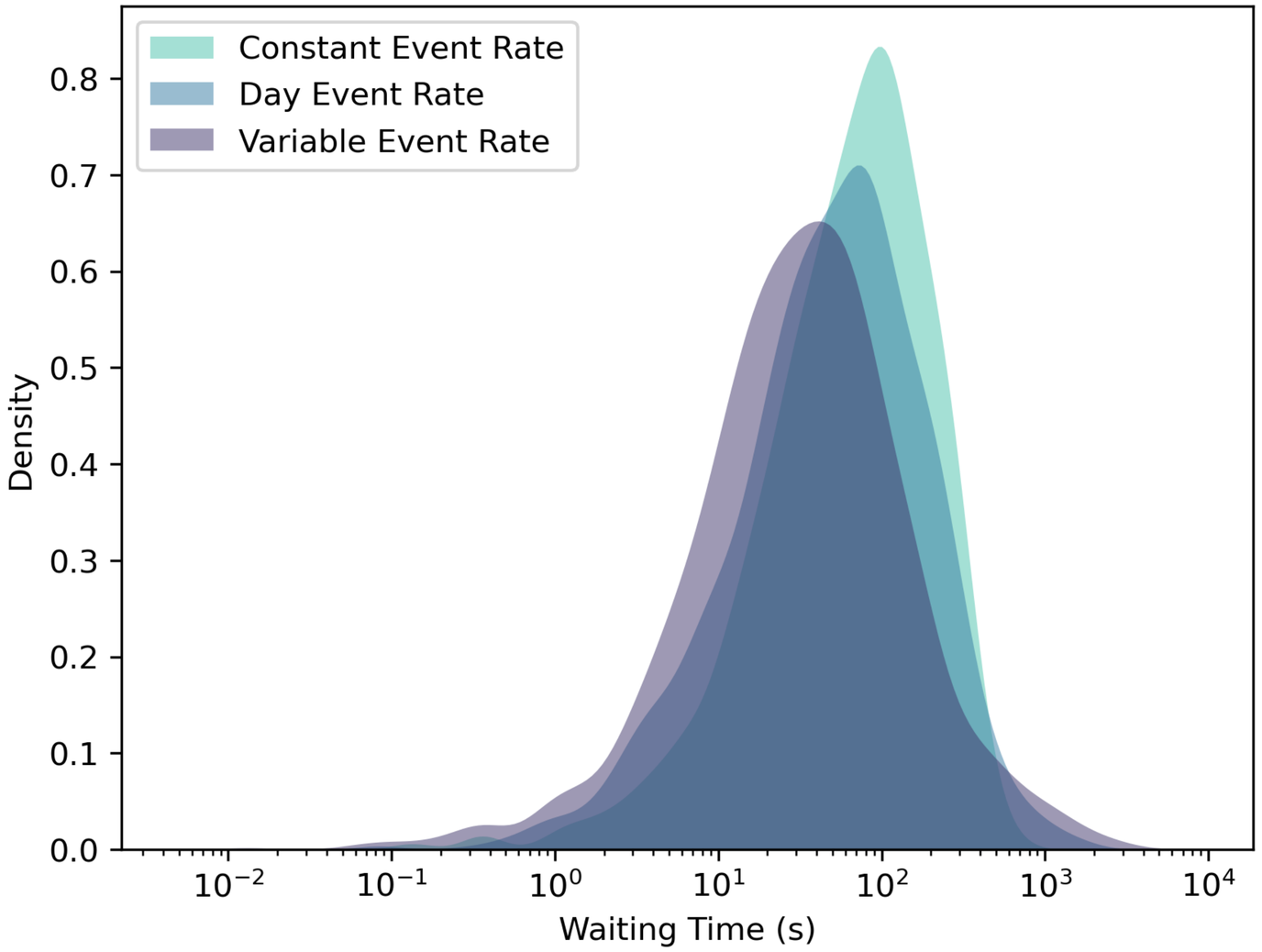
指数（泊松过程）
可能更适合描述FRB

不同的事件率

常数事件率C

事件率大于C
增加短时标等待时间

事件率小于C
增加长时标等待时间



绿色 - 常数事件率 - 泊松过程
指数分布

青色 - FRB 121102的事实事件率
KS-Test检验更接近指数分布

紫色 - 随机事件率
接近对数正态

FRB 121102 相比于随机事件率，少一些事件率高的观测

能量分布

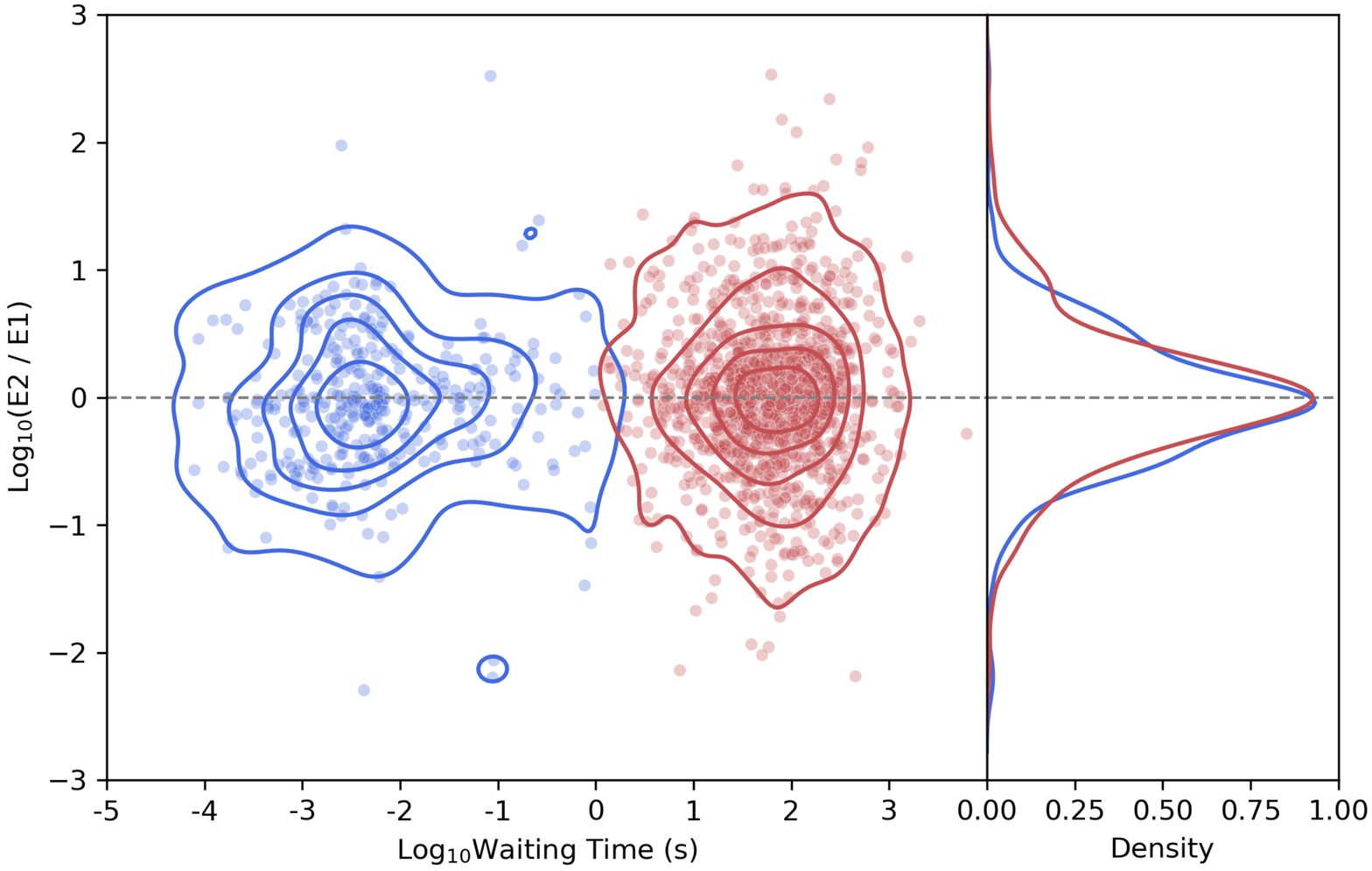
等待时间 → 后序脉冲 / 前序脉冲

沿0对称

前后脉冲能量没有区别

分布一致

两个随机过程能量没有区别

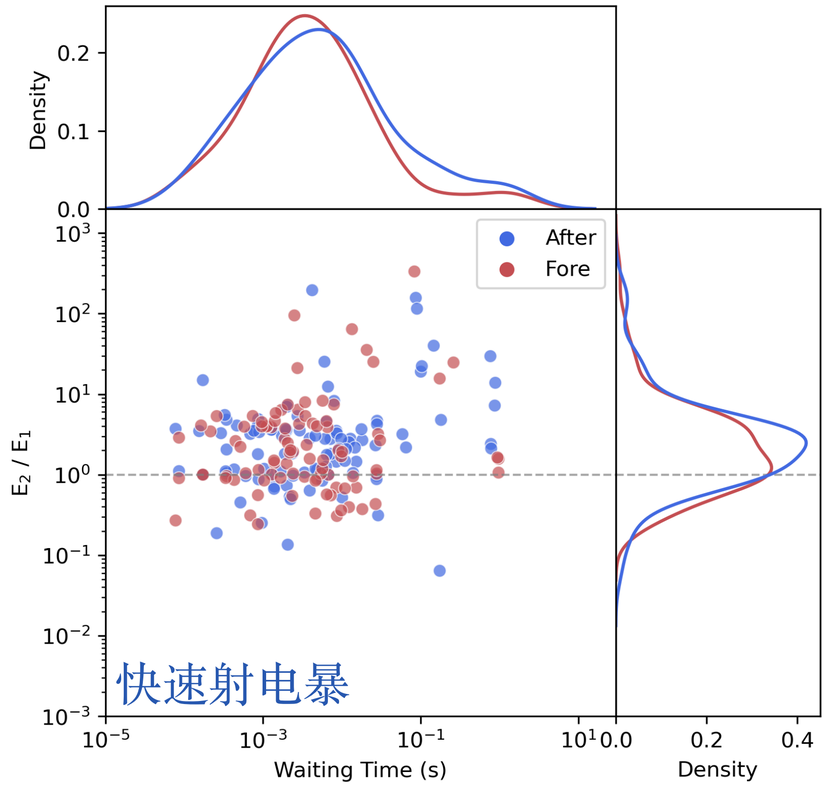


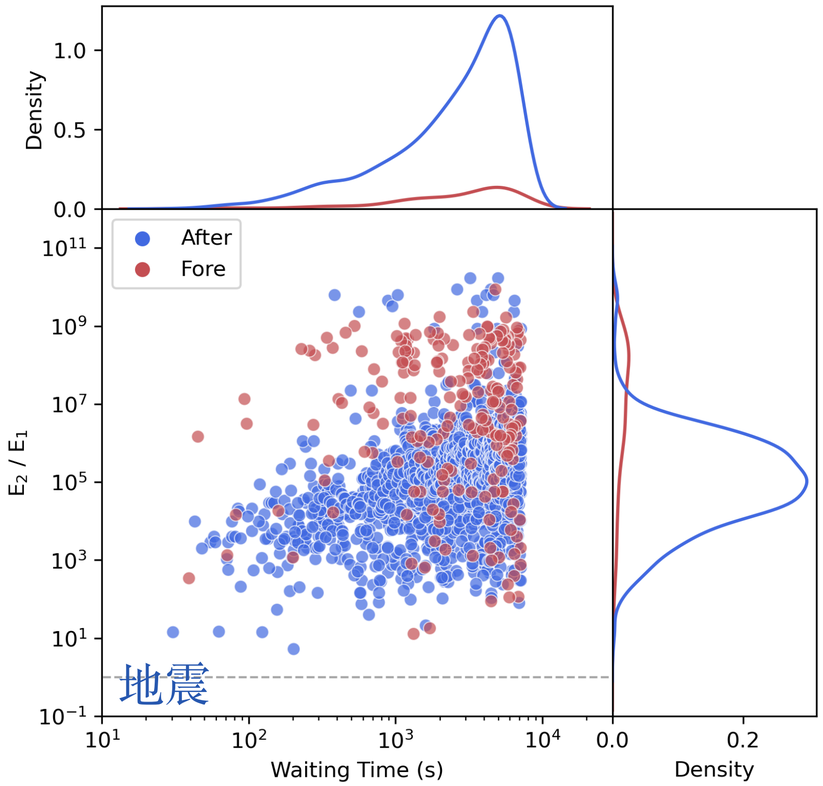
地震

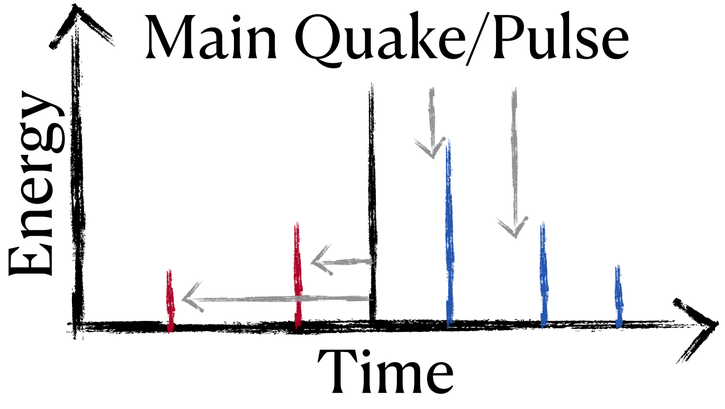
能量指数分布

时域发射随机

主震（脉冲）→ 主震 / 前后







地震

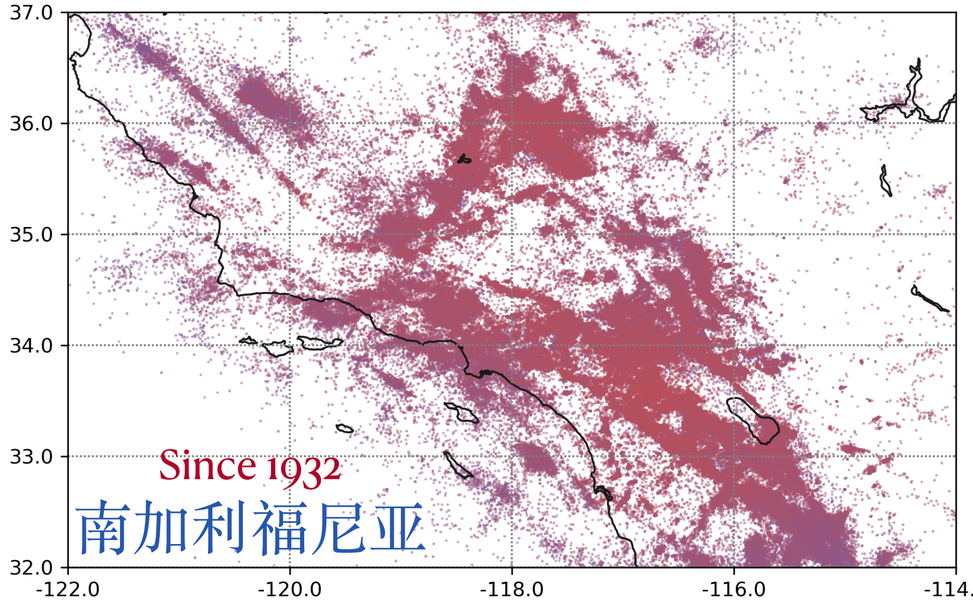
余震更多

前序地震能量更低

余震能量随时间衰减

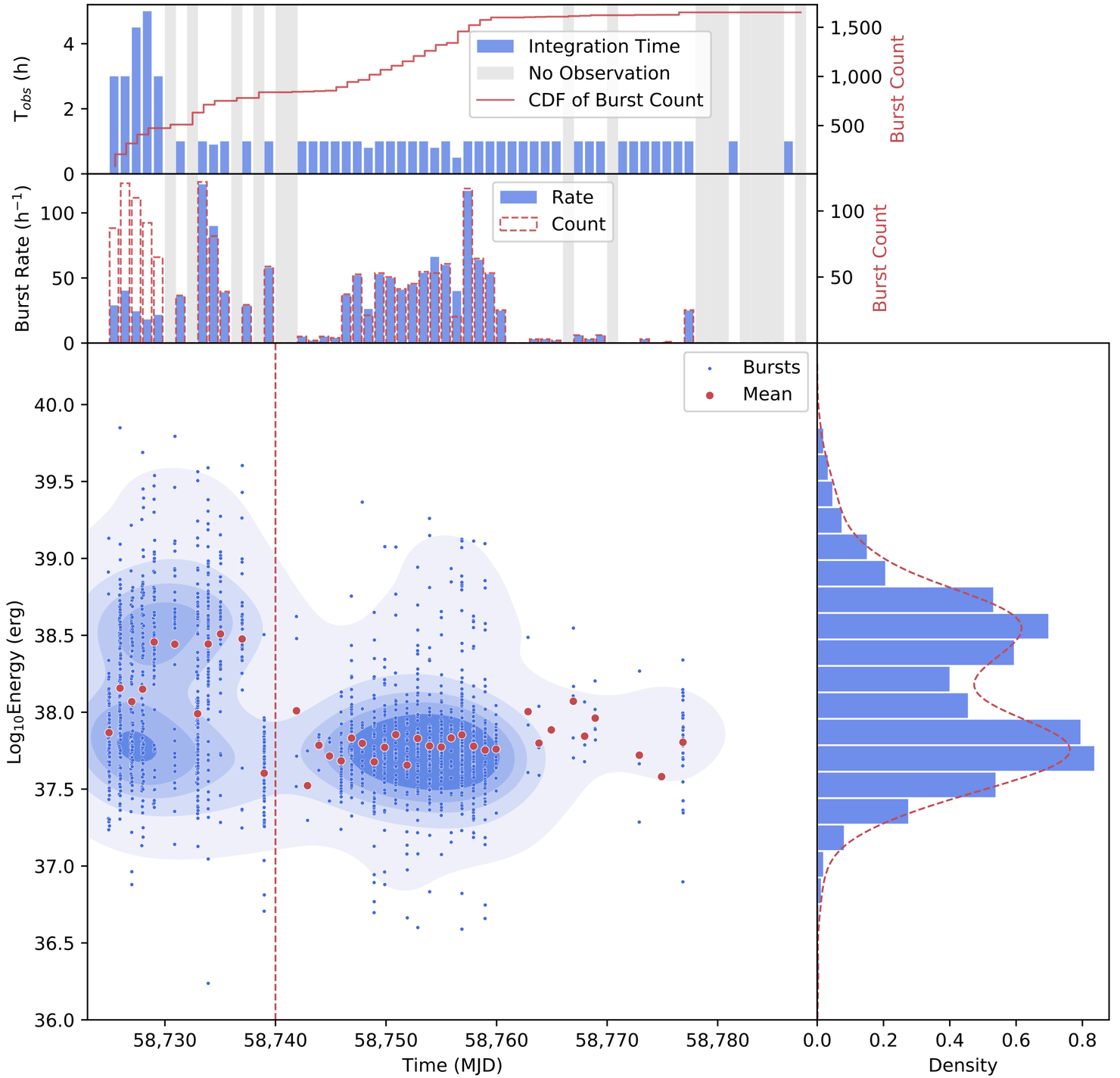
快速射电暴

特征均无



能量分布

FRB121102 能量双峰分布



结

- FRB 121102 没有短周期，长周期可能也不可靠。
- FRB 121102 的脉冲发射是两个随机事件，这两个随机事件在能量上没有显著差异。
- FRB 121102 的脉冲发射行为与地震并不相似。

THANKS!

Q & A