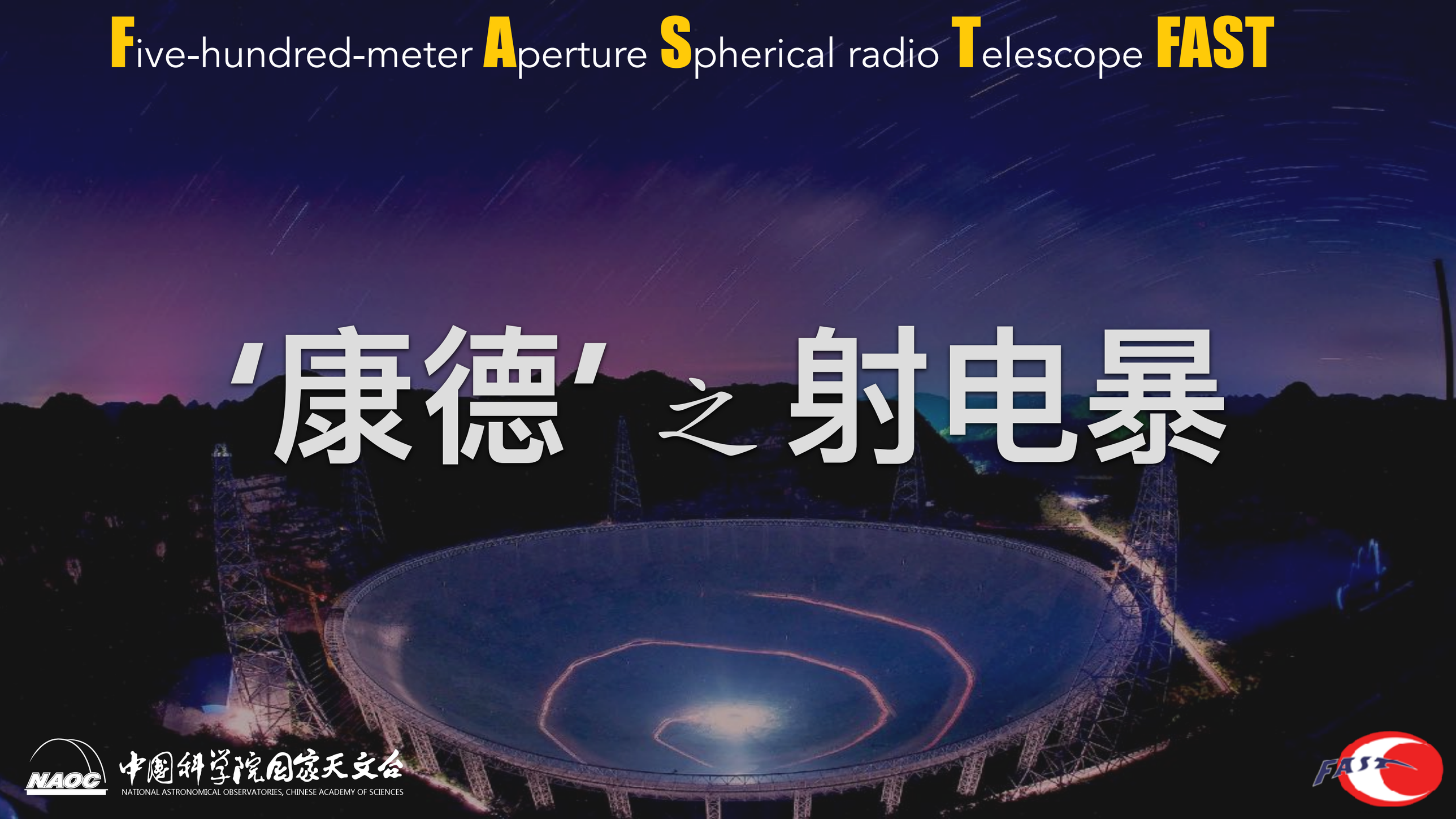
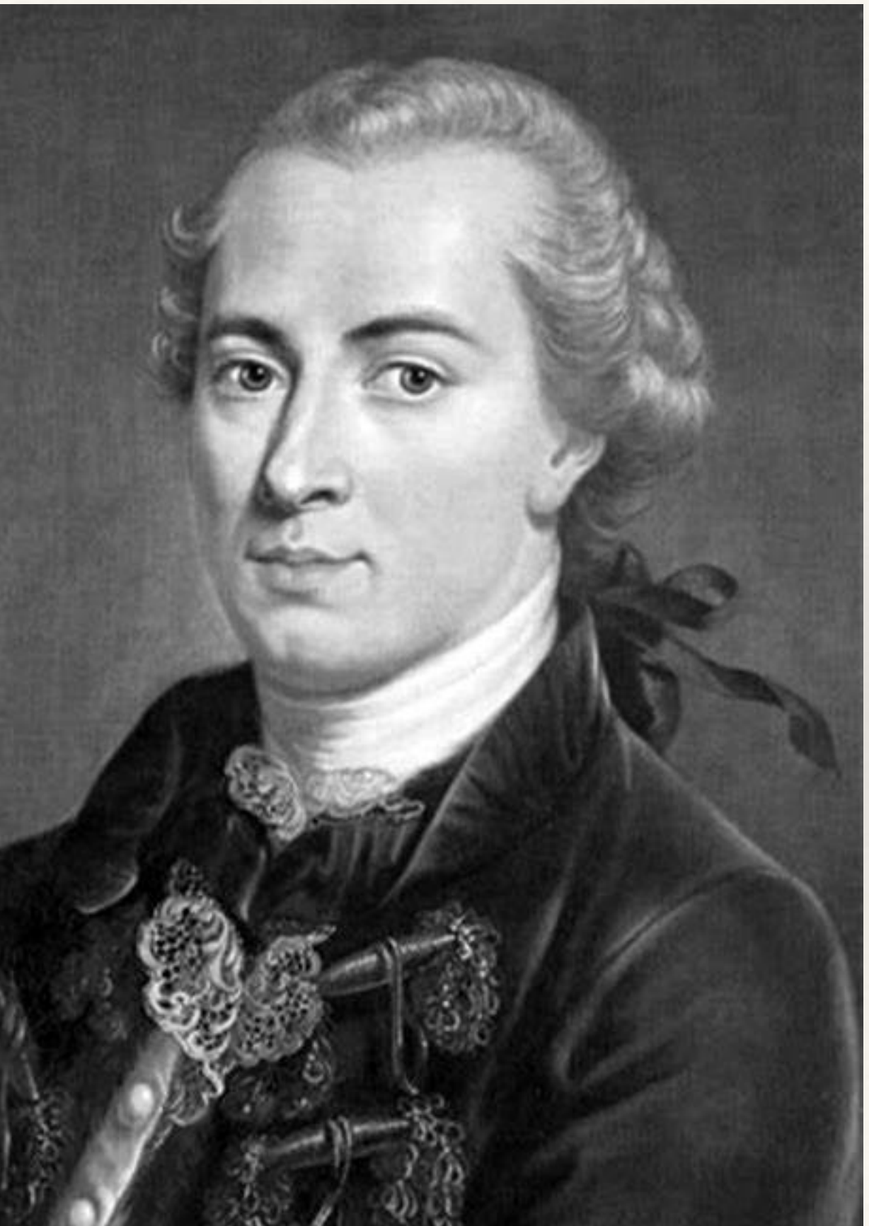

Five-hundred-meter Aperture Spherical radio Telescope FAST
‘康德’之射电暴
NAOC
中国科学院国家天文台
NATIONAL ASTRONOMICAL OBSERVATORIES, CHINESE ACADEMY OF SCIENCES
FAST

Immanuel Kant



«The Critique of Pure Reason»

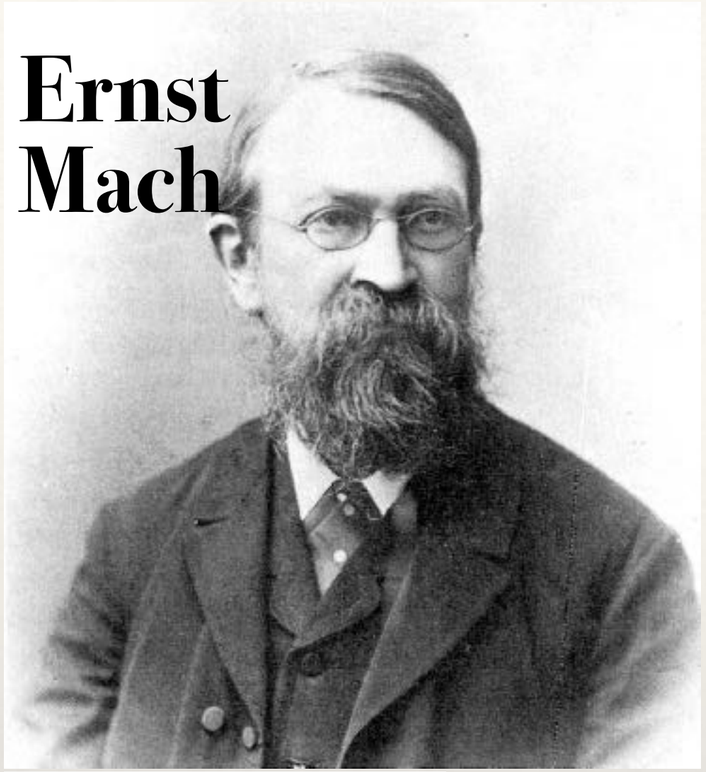
Preface

Human reason, in one sphere of its cognition, is called upon to consider questions, which it cannot decline, as they are presented by its own nature;

but which it cannot answer, as they transcend every faculty of the mind.

“Do all FRB repeat?”

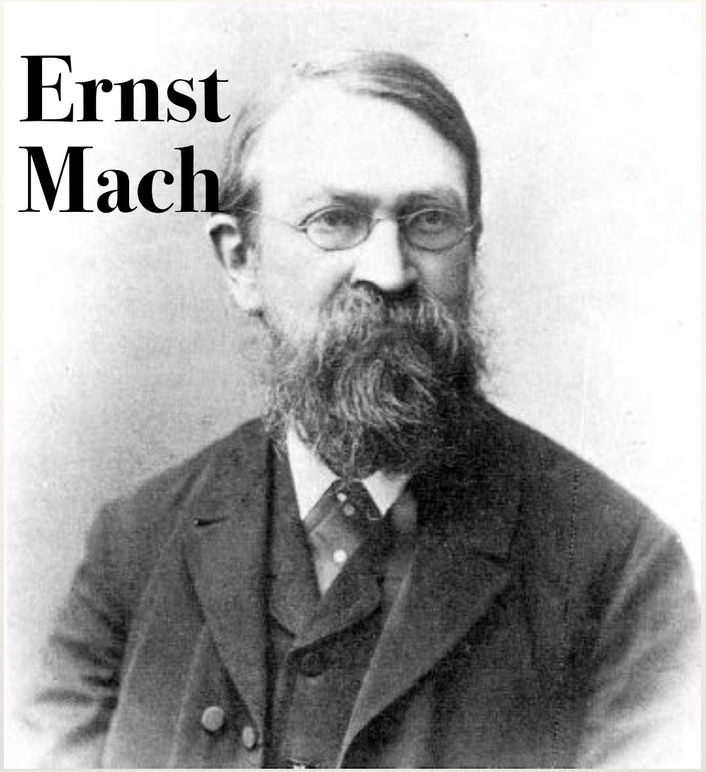
Ernst Mach

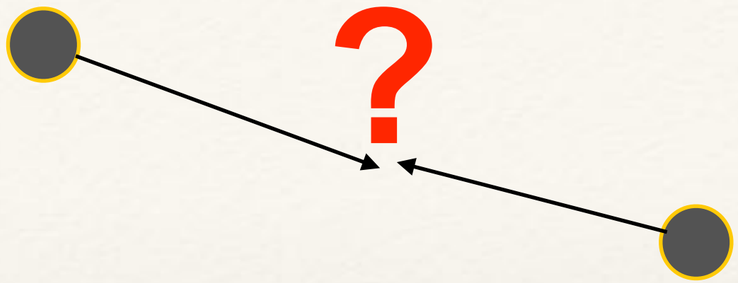


The goal which it (physical science) has set itself is the simplest and most economical abstract expression of facts.

It should be based entirely on directly observable phenomena (in line with his positivistic leanings). It should completely eschew absolute space and time in favor of relative motion. Any phenomena that would seem attributable to absolute space and time (e.g. inertia, and centrifugal force) should instead be seen as emerging from the large scale distribution of matter in the universe.

Ernst Mach



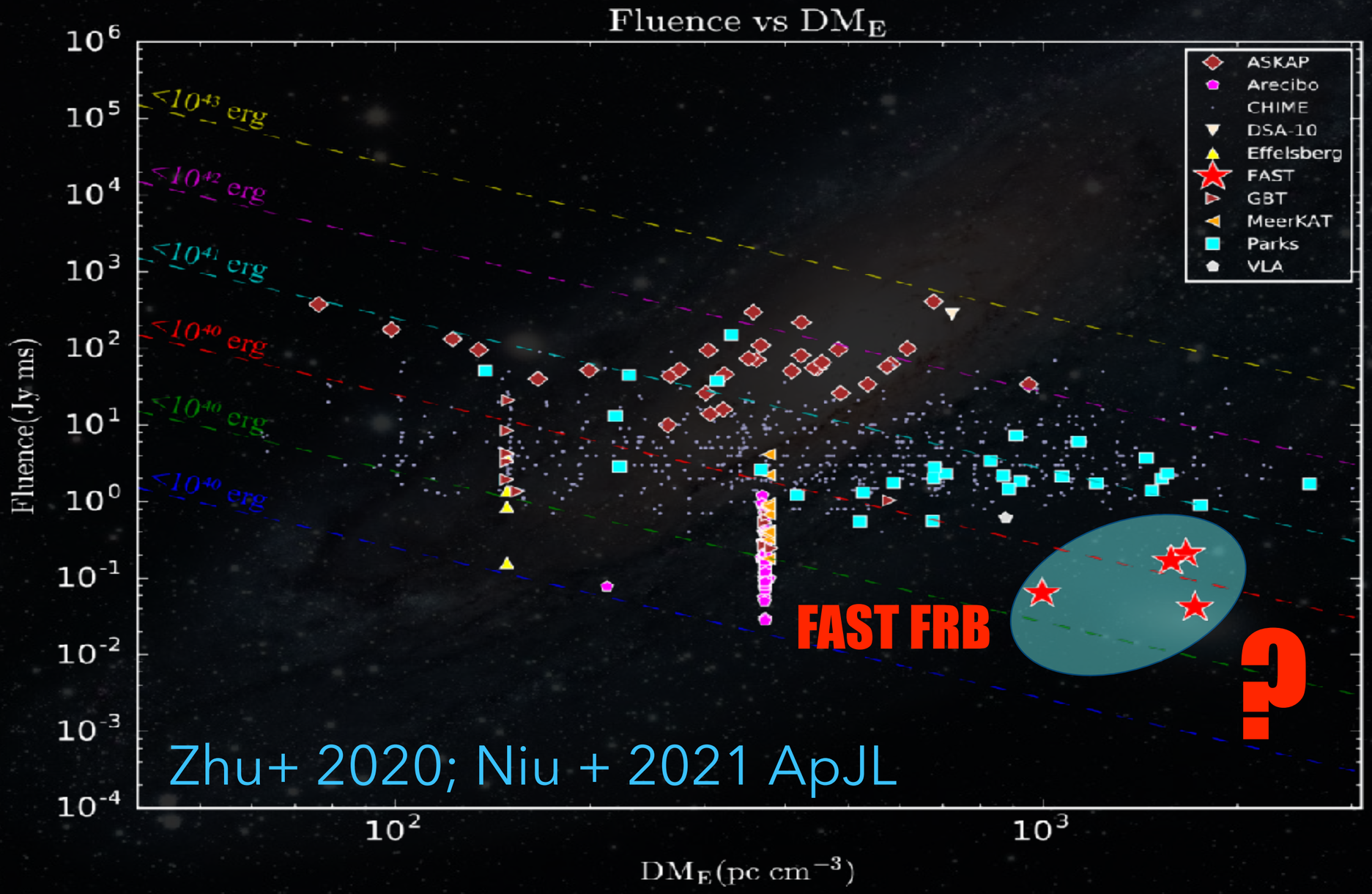


"An empty space, that there is no space field, is non-existent." —**Einstein**

《*Relativity: the special and the general theory*》 1916

(English translation by Robert W. Lawson)

Commensal Radio Astronomy FAST Survey



FAST L-band Array of 19-beams

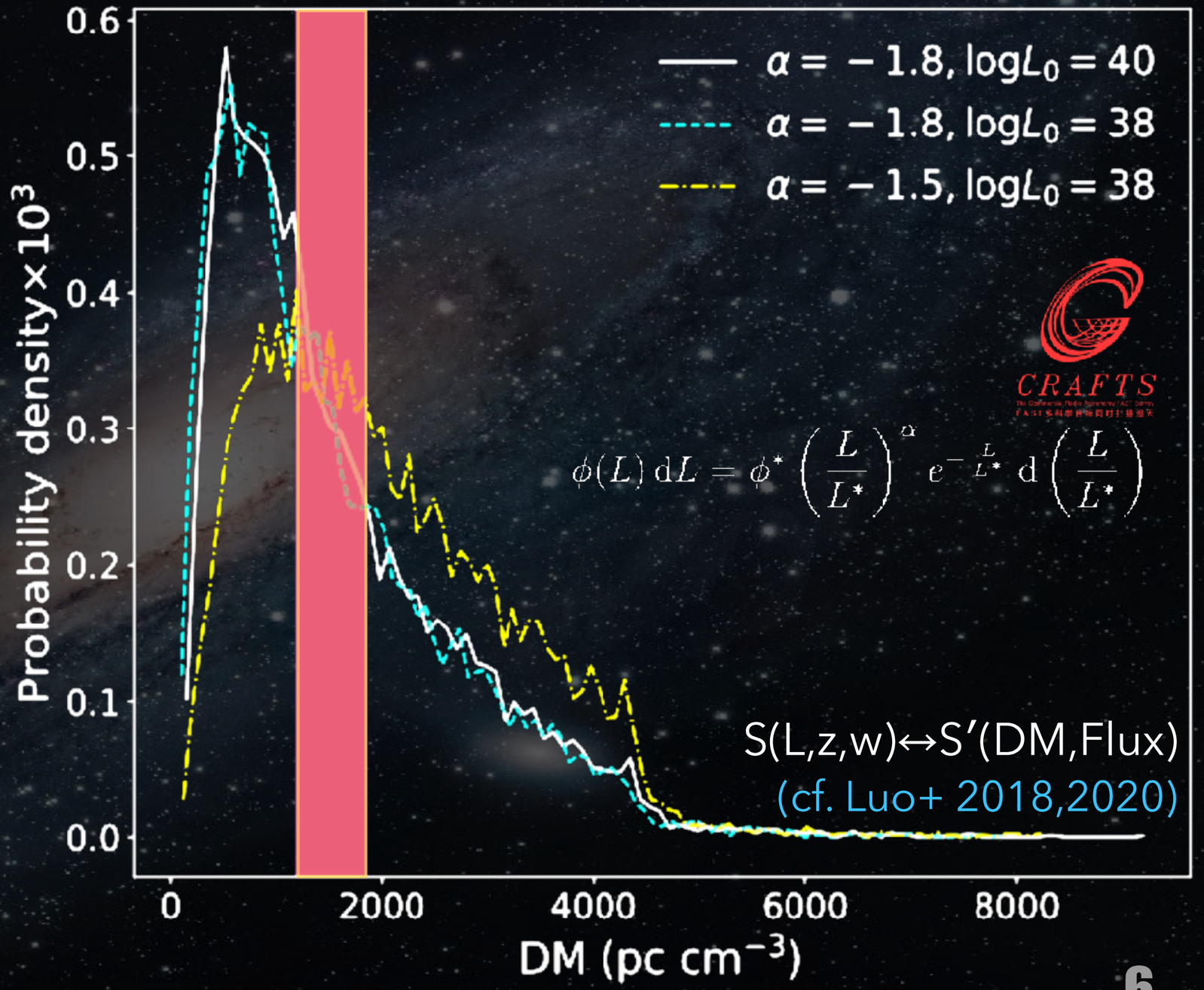
FLAN

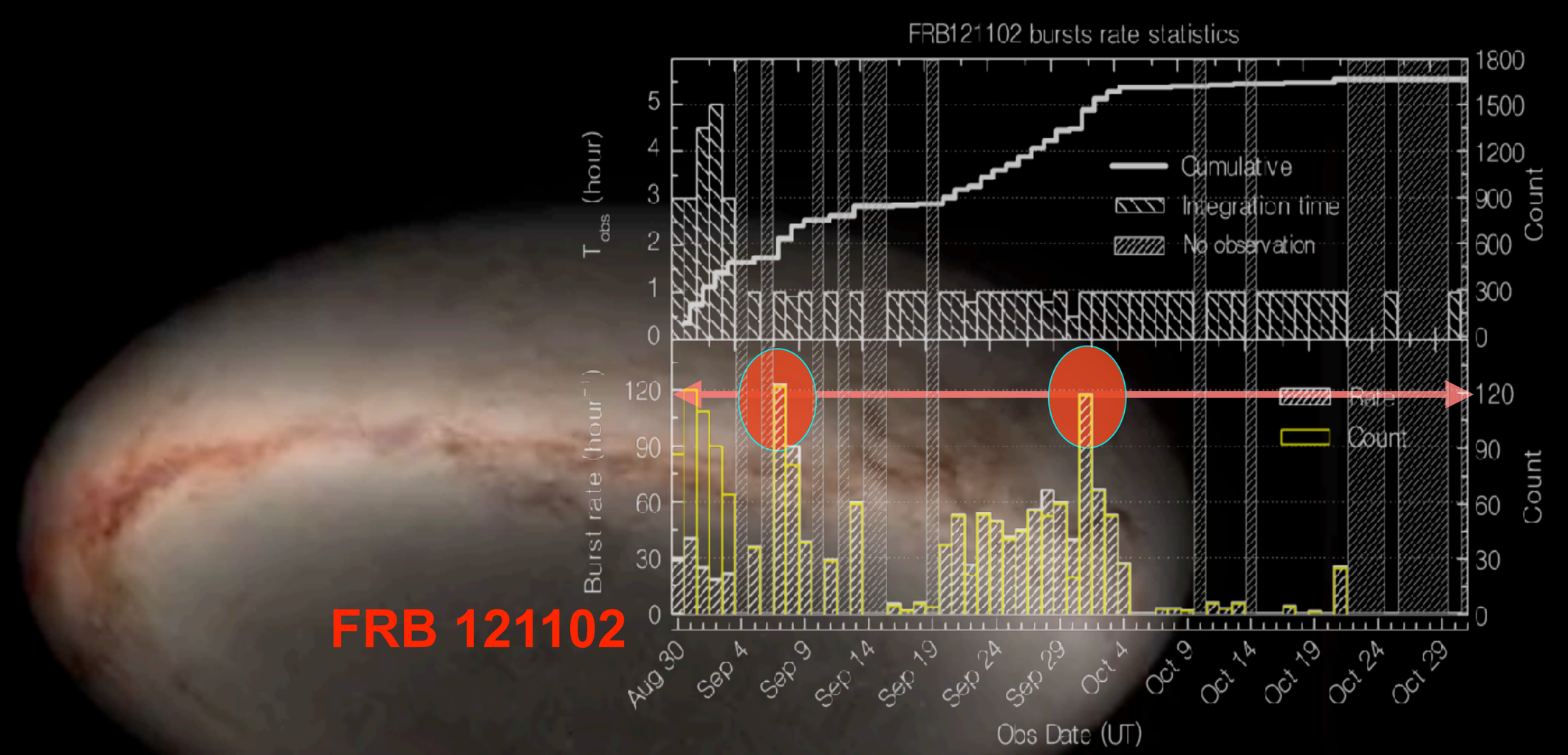
CRAFTS

CRAFTS 2018 FRBs

- **Four** events in a total of **1667 hours** in 2018, corresponds to an all sky rate of **1.2×10^{5} sky^{-1} day^{-1}** at the 95% confidence interval above 0.0146 Jy ms, by far the deepest such estimate.
- ~1 per 400 FLAN hours (cf. Li 2016)

- PDF of FAST-FRB's DM is more sensitive to the slope of the luminosity function than the cutoff brightness L_0.
- FAST will have significant detection probability (>10%) for DM > 3000 pc cm^{-3} (Also Zhang 2018)

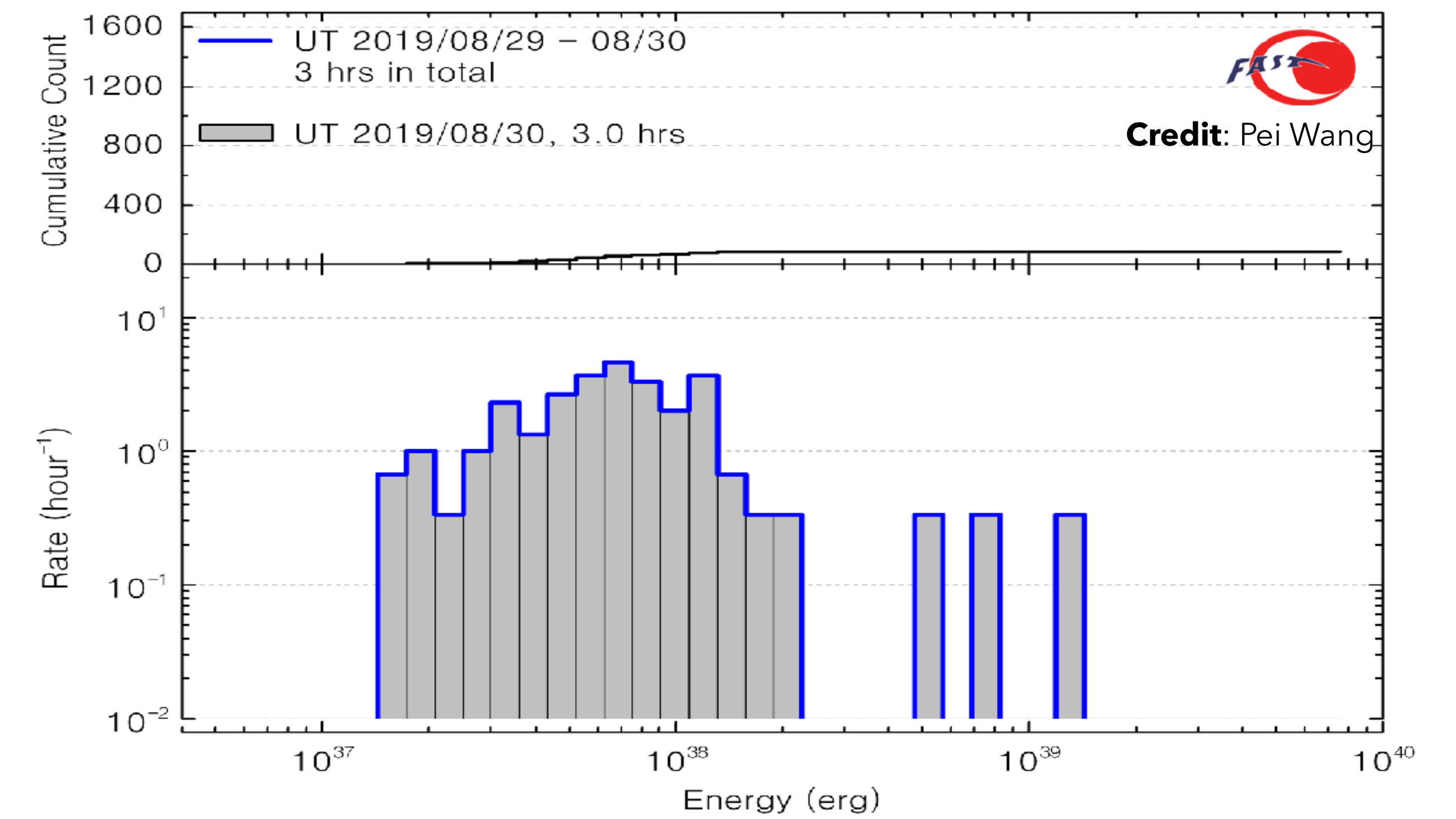




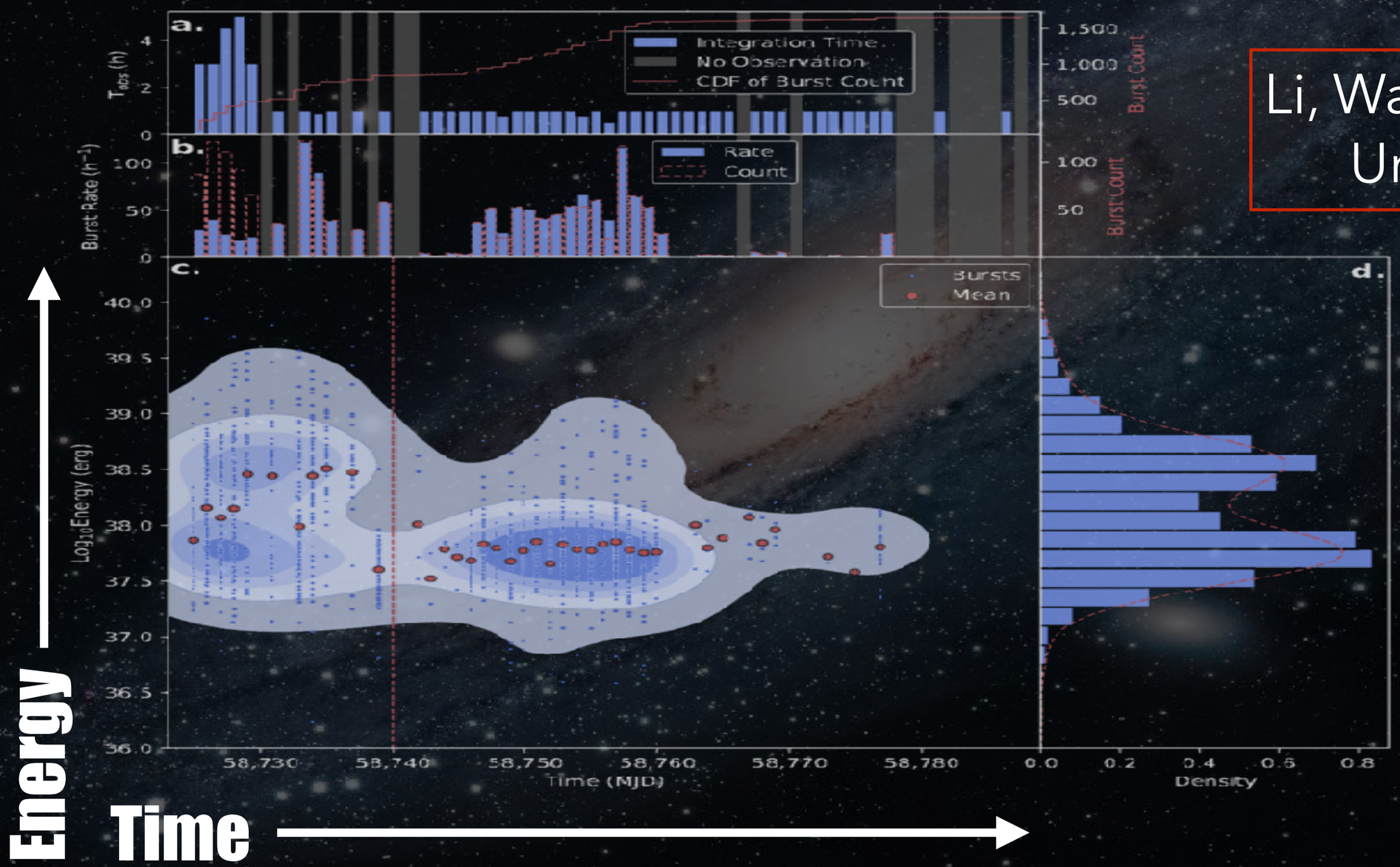
FRB 121102

2021

“1652 pulses in 59 days!” - Li et al. 2021


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

1652 Pulses: Energy and Temporal Distributions



Li, Wang et al. 2021
Under review

FRB121102 Burst Energy Statistics

$$E \simeq \frac{4\pi D_{\rm L}^2}{(1+z)} \mathcal{F}_\nu \nu_c$$

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

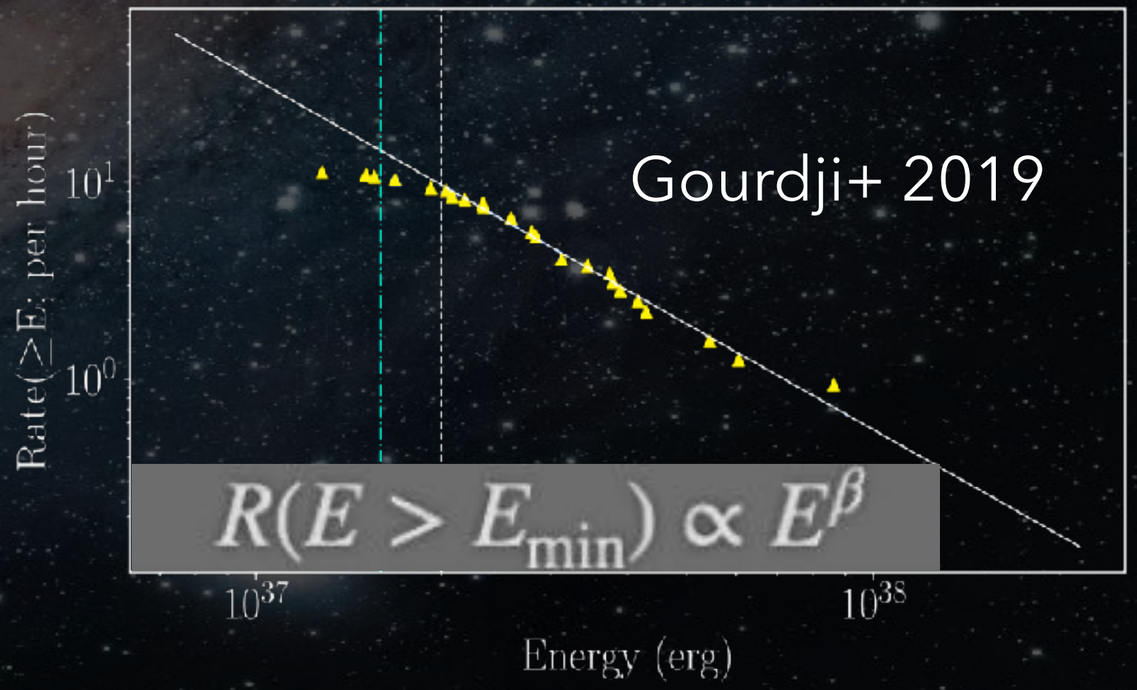
(Zhang 2018)

Cumulative burst energy distribution:

β= -0.7 JVLA, AO, GBT Law+ 2017

β= -1.8±0.3 AO Gourdji+2019

β= -1.2±0.2 Effelsberg Cruces+ 2020



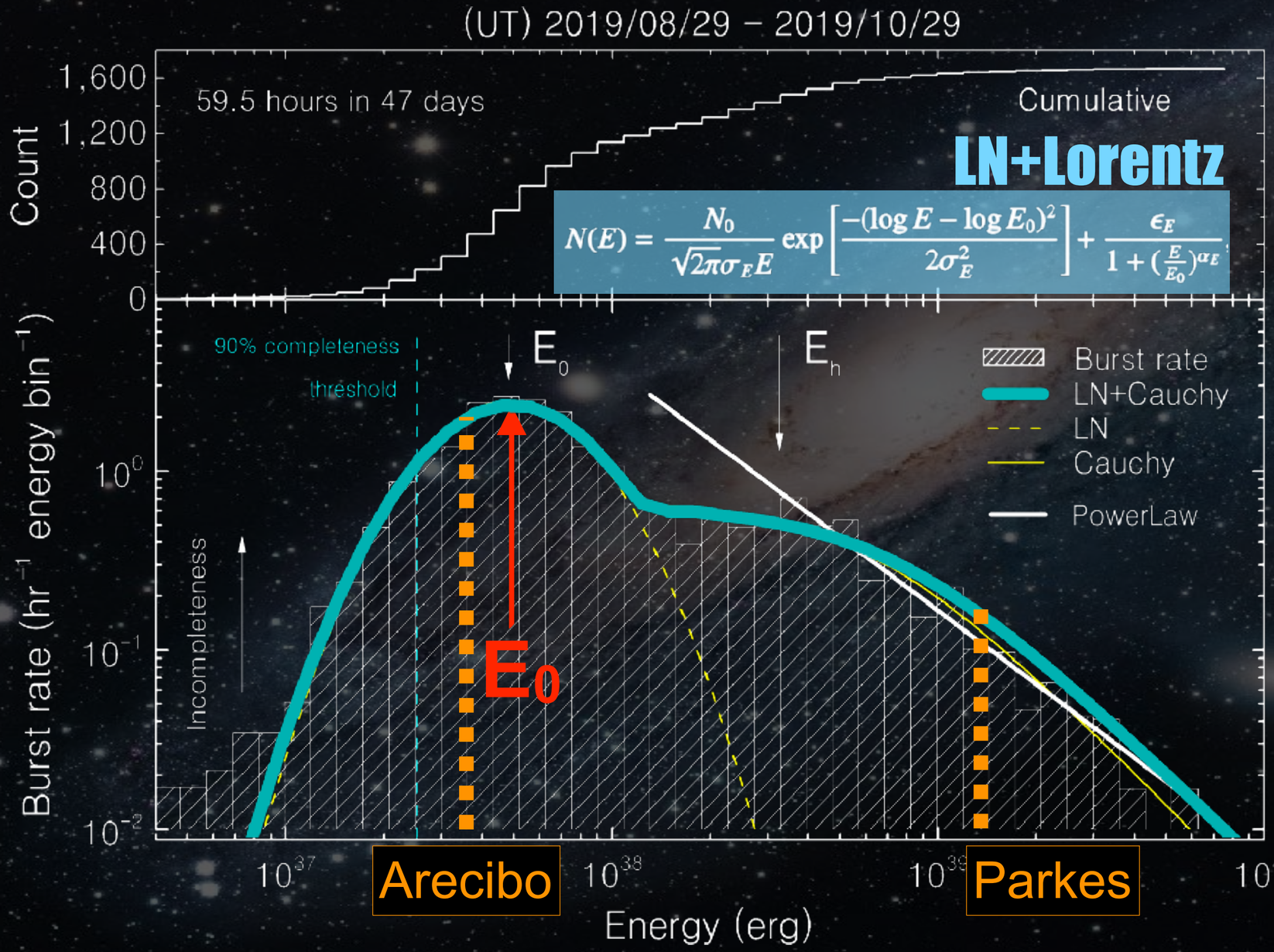
Gourdji+ 2019

FAST L-band 1.25GHz flux calibration

1σ = 2.1 mJy (1ms) z=0.193, D_L=949Mpc, 1Jy ms = 1.07x 10^{39} erg

7σ = 15 mJy **4×10^{36} erg < Energy < 8.0×10^{39} erg**

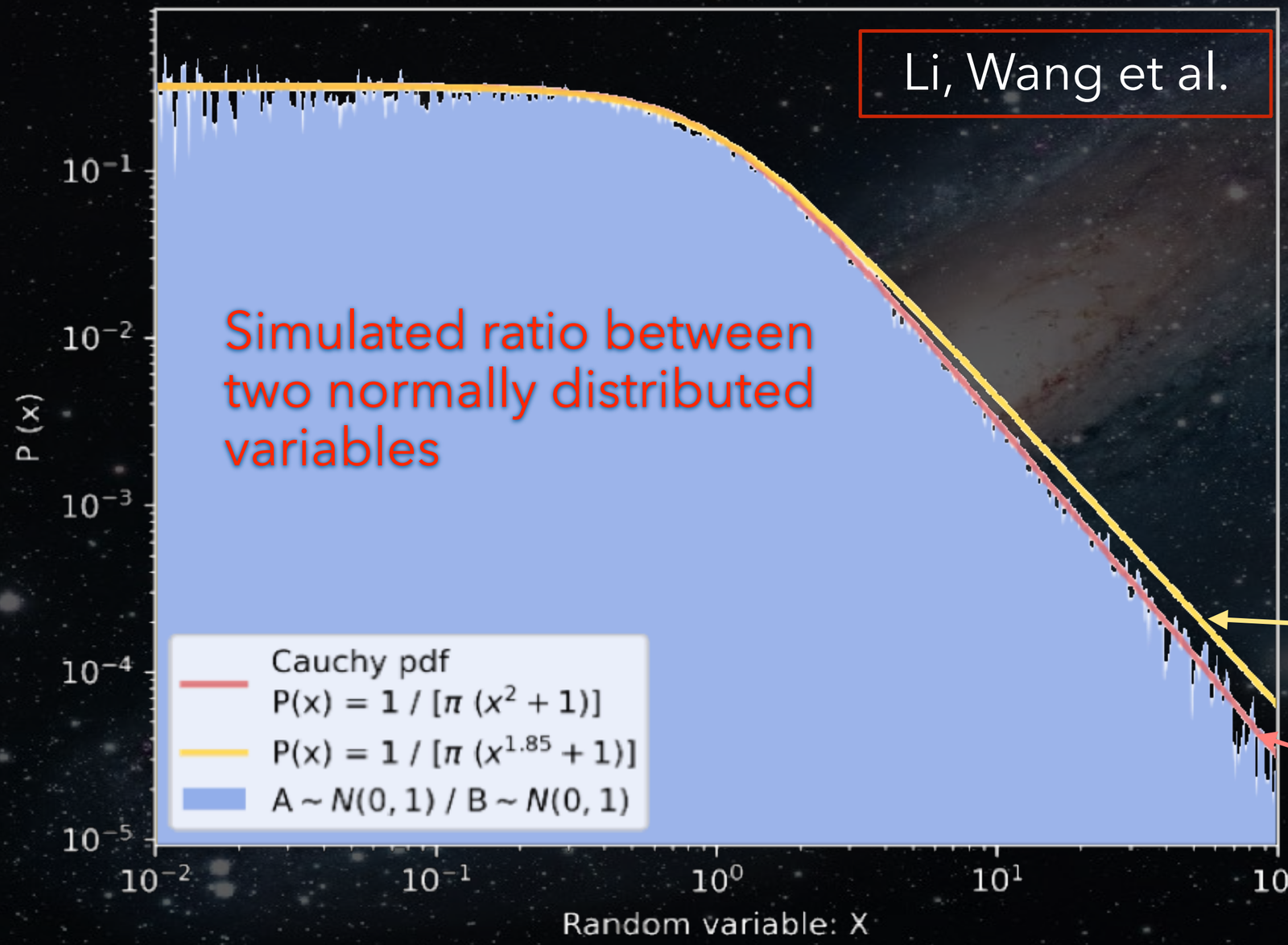
Burst Rate Energy Distribution - bimodel



Function	Energy range	Reduced χ^2	R^2
PowerLaw	F	✗ 0.689(8)	0.104(6)
	H	0.004(1) √	0.999(1)
Lognormal	F	✗ 0.056(9)	0.86(8)
Cauchy	F	✗ 0.438(1)	0.113(1)
Lognormal + Cauchy	F	0.037(4) √	0.931(7)

Li, **Wang** et al. 2021

Burst Rate Energy Distribution - bimodel



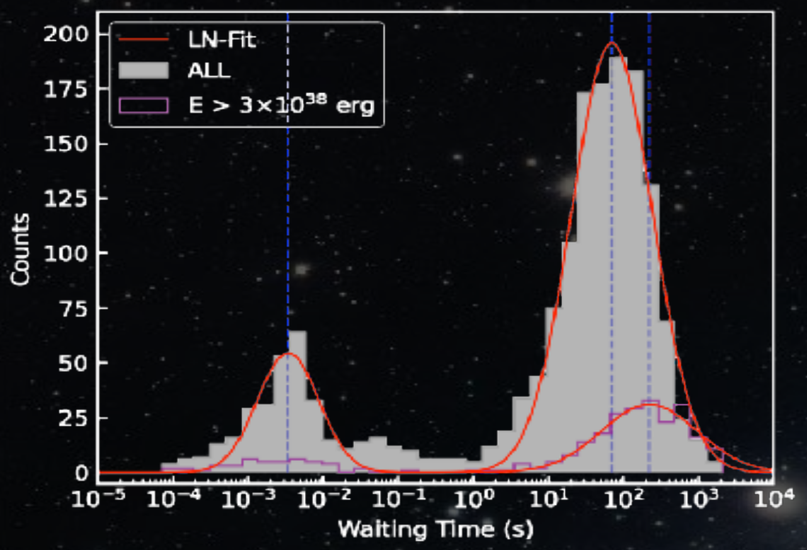
- The Lorentz/Cauchy function describe the ratio between two normally distributed variables
- The best-fit index of 1.85 (generalized Cauchy function) is close to 2 within one σ ~ 0.3

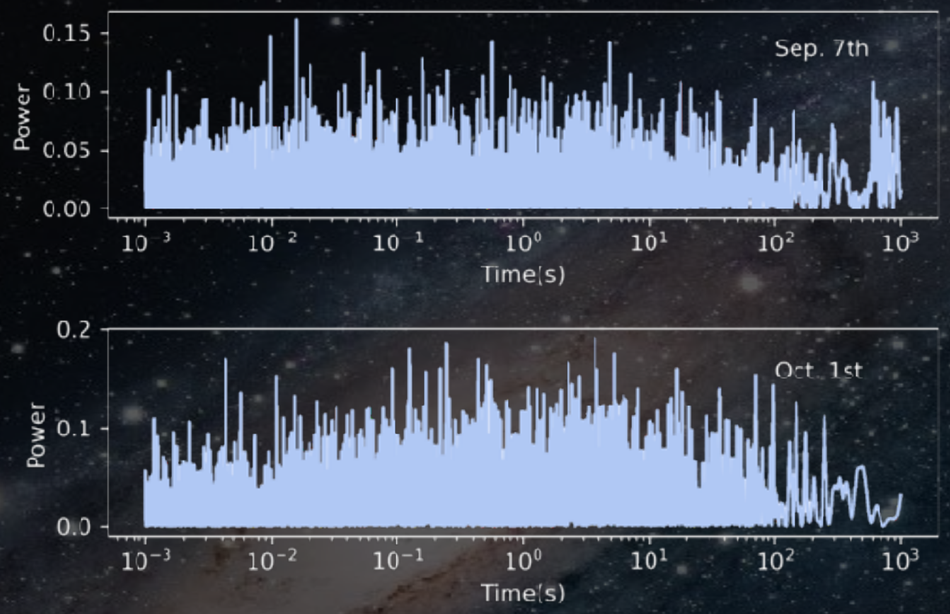
$$p(x) = \frac{1}{\pi\left(x^{\alpha}+1\right)}$$

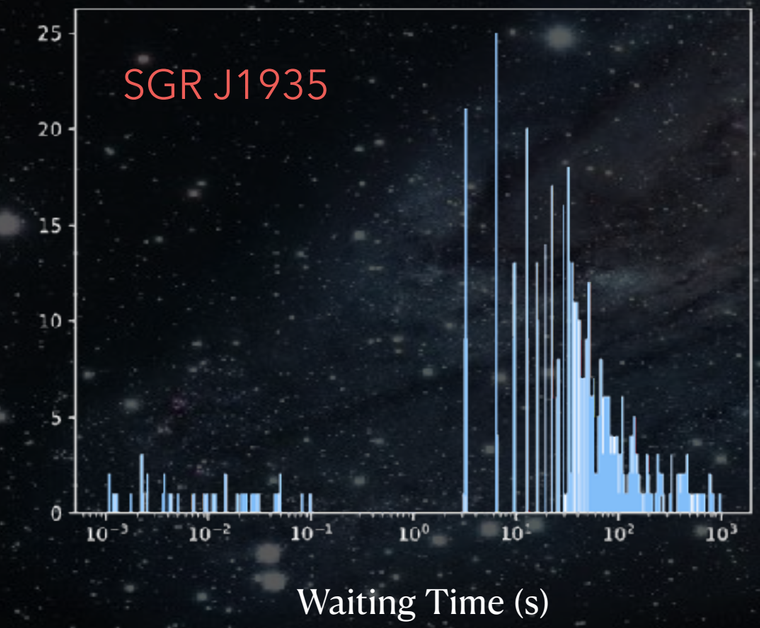
$$p(x) = \frac{1}{\pi\left(x^{2}+1\right)}$$

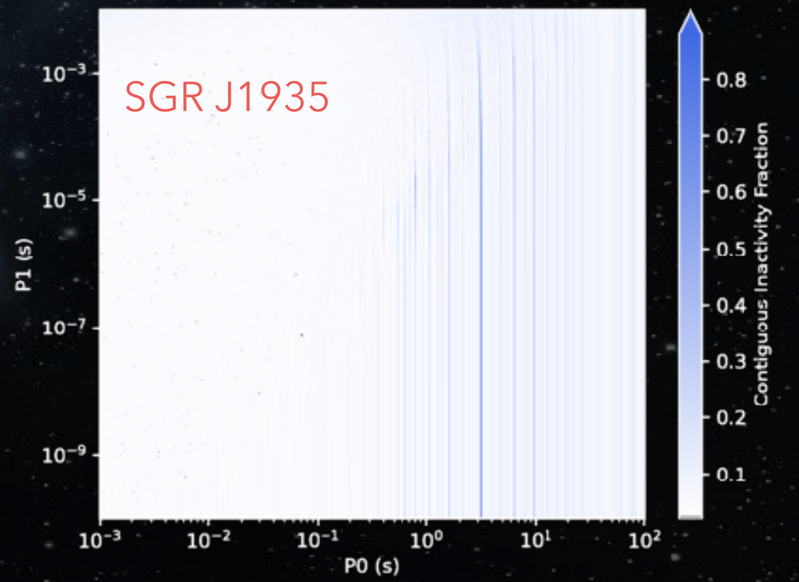
Lomb-Scargle Periodograms

Phase-Folding









FRB 121102 has no discernible short-term periodicity !
(Li et al. 2021 &
Zhang et al. 2021 in prep.)

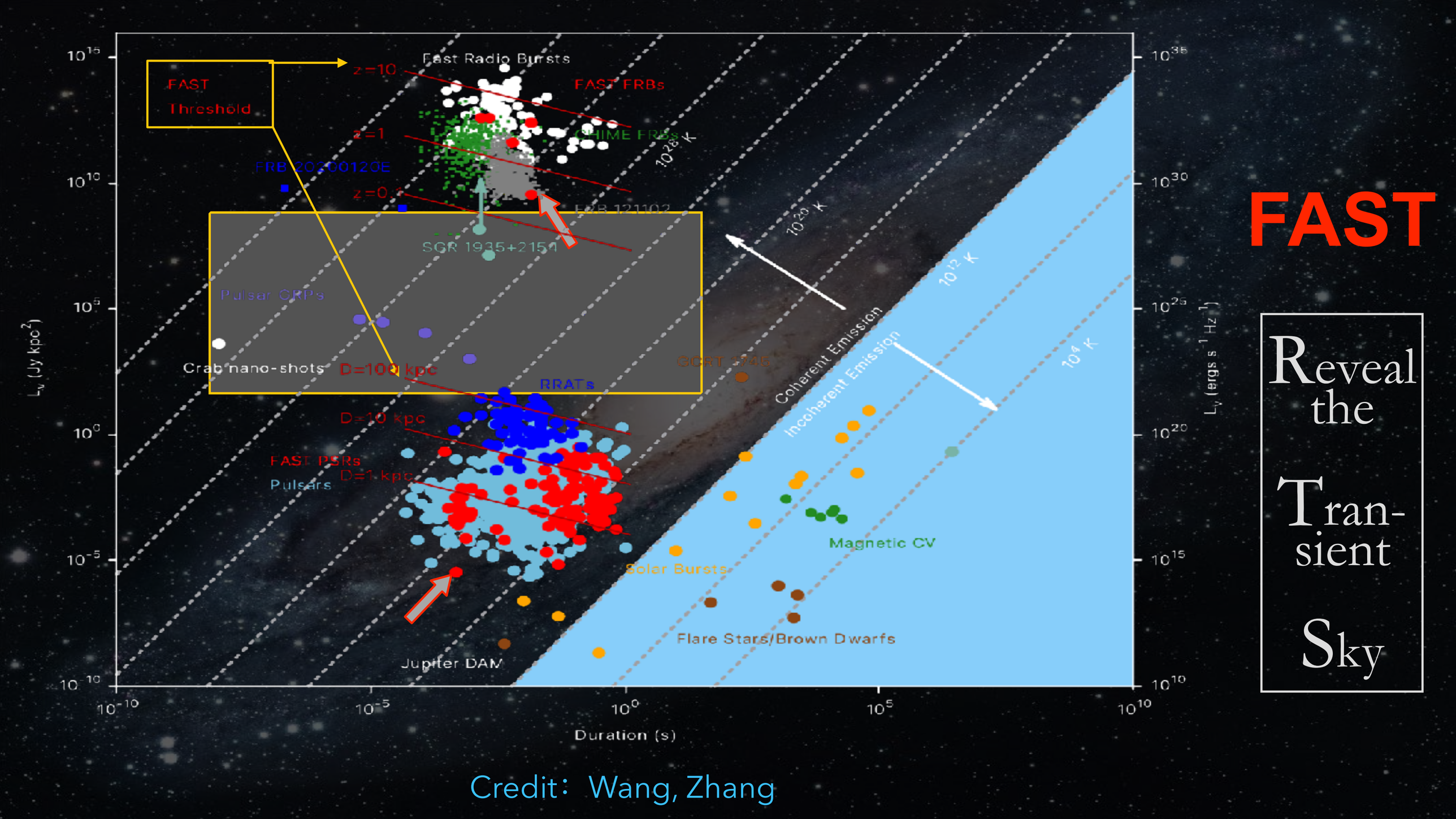
- FRB 121102 has a characteristic peak energy of **4.8×10^{37} erg**, just above the detection threshold of Arecibo, below which the production rate of FRBs starts to drop. In 47 days, **~1%** of the total magnetic energy of a magnetar was released.

- FRB 121102 has a clear bimodal energy distribution which can be adequately described as a **lognormal + Lorentz function**. The power-law logN - log S here seems to be an artifact of detection bias.

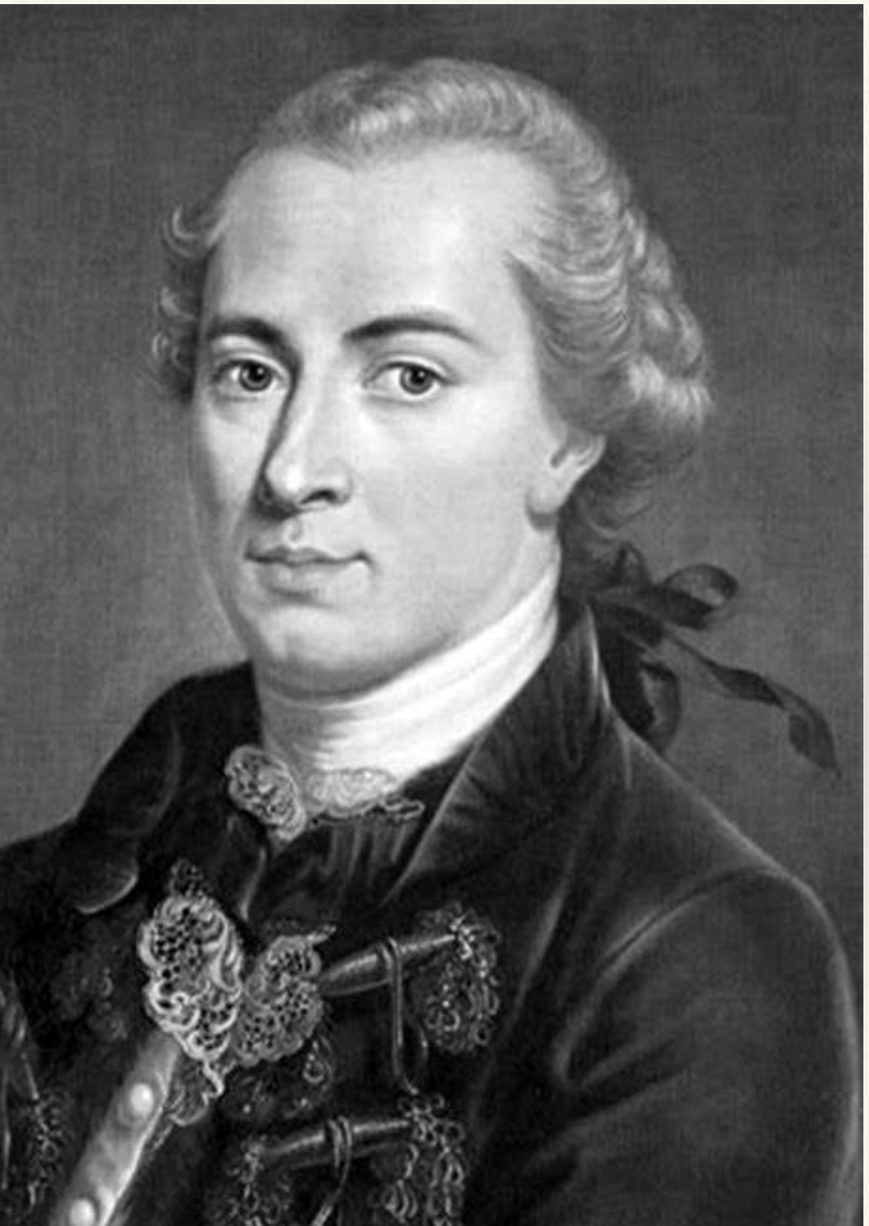
- No periodicity between 1 ms and ~1000 s. Consistent with exponential waiting time (Poisson). A significant clustering of waiting time around **3.5 ms**.

- FRB 121102 bursts unlikely to have originated from **a ~~single compact object~~.**


10000
1000
100
10
1
N
2000
2004
2008
2012
2016
2020
0
0
FRB_ALL
FRB121102


Fast Radio Bursts
FAST FRBs
CHIME FRBs
FAST Threshold
z=10
z=1
z=0.1
FRB 20200120E
FRB 121102
SGR 1935+2154
Pulsar CRPs
Crab nano-shots
D=100 kpc
RRATs
GCRT J1745
D=10 kpc
FAST PSRs
Pulsars
D=1 kpc
Jupiter DAM
Coherent Emission
Incoherent Emission
Magnetic CV
Solar Bursts
Flare Stars/Brown Dwarfs
Duration (s)
FAST
Reveal the Transient Sky
Credit：Wang, Zhang

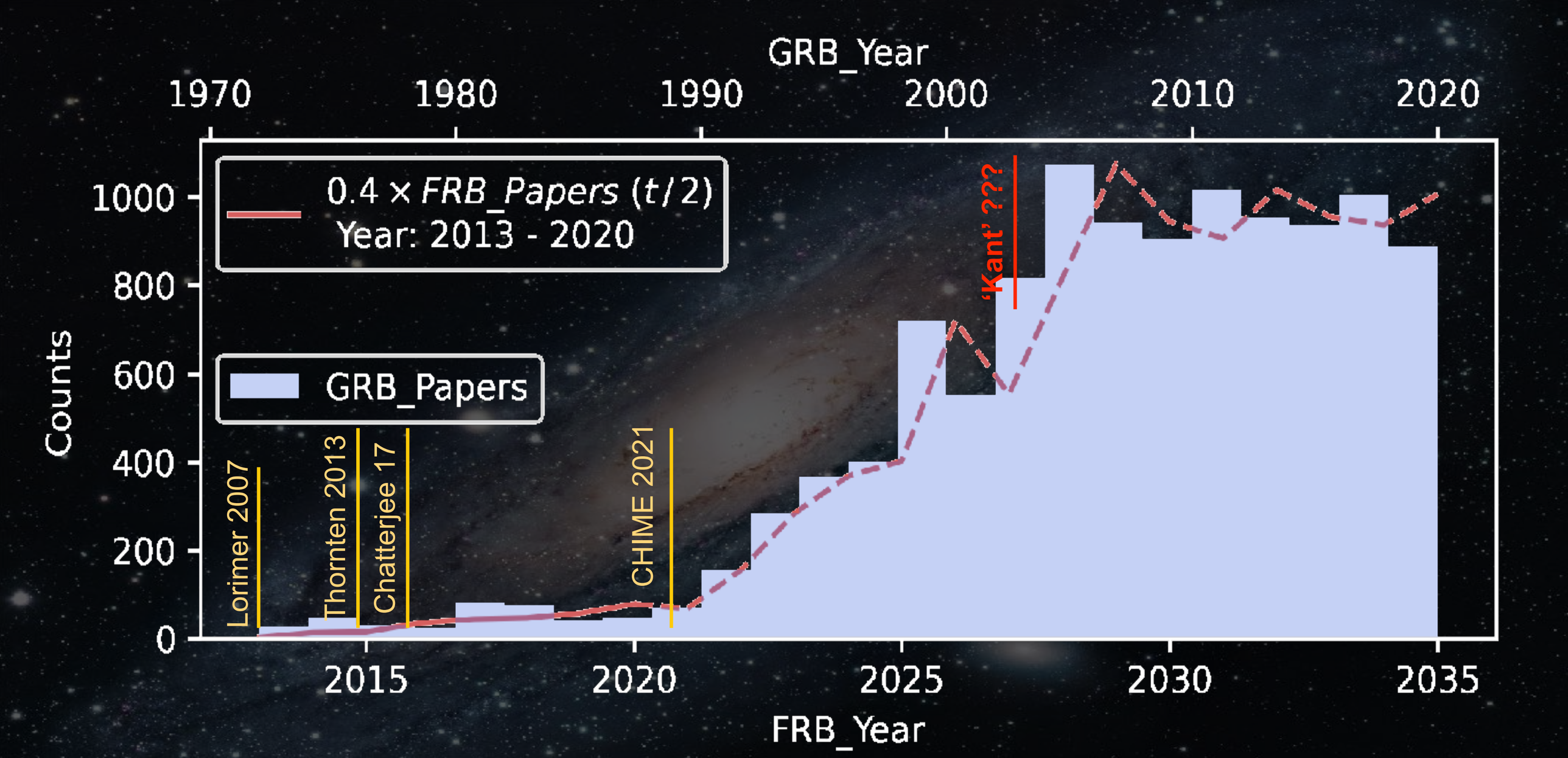
Immanuel Kant



《The Critique of Pure Reason》
A Copernicus revolution: reason within experience

Definitional truth: the agreement of cognition with its object
A priori knowledge: pulsars produces pulses, so do many other processes
Synthetic posteriori judgement: FRB origin?

“Do all FRB repeat?”



Li et al. 2021 《科学通报》

Descartes: *"I think therefore I am."*

Kant: *"Thoughts without content are empty. Intuition without concept are meaningless."*

Mach: *"When the human mind, with its limited powers, attempts to mirror in itself the rich life of the world…it has every reason for proceeding economically. In reality, the law always contains less than the fact itself, because it does not reproduce the fact as a whole but only in that aspect of it, which is important for us, the rest being intentionally or from necessity omitted.*