

An Active Repeating FRB— A Fast Radio Burst Source at A Complex Magnetized site in a barred galaxy

Heng Xu(胥恒), hengxu@bao.ac.cn

Supervisor: Kejia Lee(李柯伽), kjlee@pku.edu.cn

**Kavli institute for Astronomy and Astrophysics, Peking University
National Astronomical Observatories, CAS**

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**Collaborators: Jiarui Niu, Ping Chen, Kejia Lee*, Weiwei Zhu*, Subo Dong*,
Bing Zhang*, Jinchun Jiang, Bojun Wang, Jiangwei Xu, Chunfeng Zhang, Hai Fu,
Alex Filippenko, Eric Peng, et al.,**

arXiv: 2111.11764, accepted by Nature

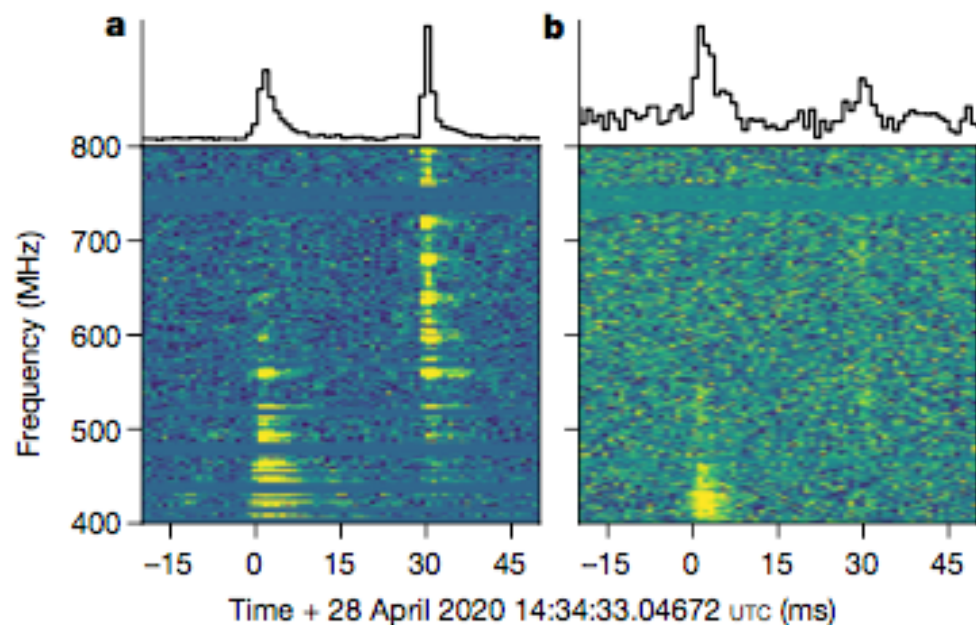
Fast Radio Burst

A Bright Millisecond Radio Burst of Extragalactic Origin

D. R. Lorimer,^{1,2*} M. Bailes,³ M. A. McLaughlin,^{1,2} D. J. Narkevic,¹ F. Crawford⁴

Pulsar surveys offer a rare opportunity to monitor the radio sky for impulsive burst-like events with millisecond durations. We analyzed archival survey data and found a 30-jansky dispersed burst, less than 5 milliseconds in duration, located 3° from the Small Magellanic Cloud. The burst properties argue against a physical association with our Galaxy or the Small Magellanic Cloud. Current models for the free electron content in the universe imply that the burst is less than 1 gigaparsec distant. No further bursts were seen in 90 hours of additional observations, which implies that it was a singular event such as a supernova or coalescence of relativistic objects. Hundreds of similar events could occur every day and, if detected, could serve as cosmological probes.

Lorimer et al., 2007

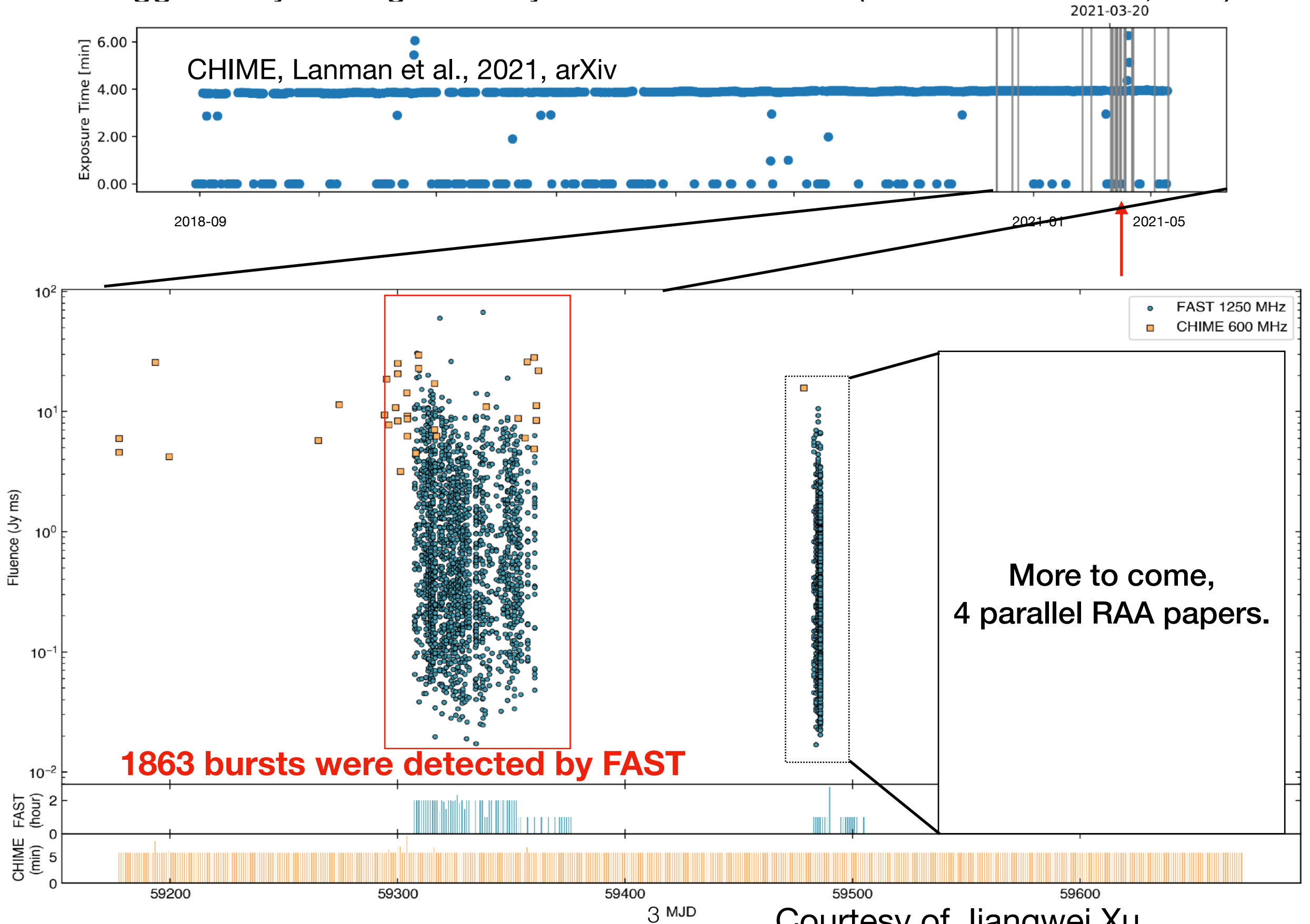


Galactic FRB, CHIME/FRB collaboration, 2020

- Repeating fast radio bursts (Spitler et al., 2012)
- FRB localization / hosts (Chatterjee et al., 2017; Heintz et al., 2020)
- Complex morphology (Hessels et al., 2019)
- Periodic activity (CHIME/FRB 2020; Cruces et al., 2021)
- FRB from Galactic magnetar (CHIME/FRB 2020; STARE2 2020)
- Bimodal distribution in energy (Li et al., 2021)
- High degree of linear polarization, Low degree of circular polarization, Flat polarization angle (PA) (Petroff et al., 2019), PA swing (Luo et al., 2020)
- FRB polarization was inconclusive.

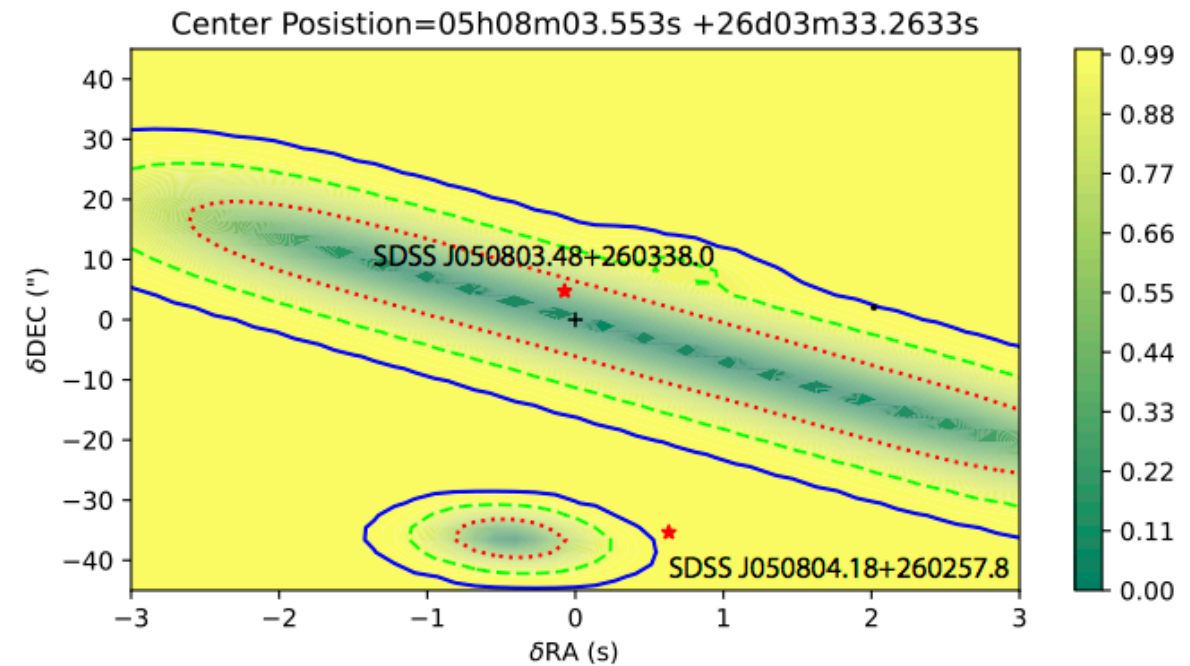
FAST Observations to FRB 20201124A

- Triggered by the high activity alarm from CHIME (CHIME/FRB 2021, Atel)

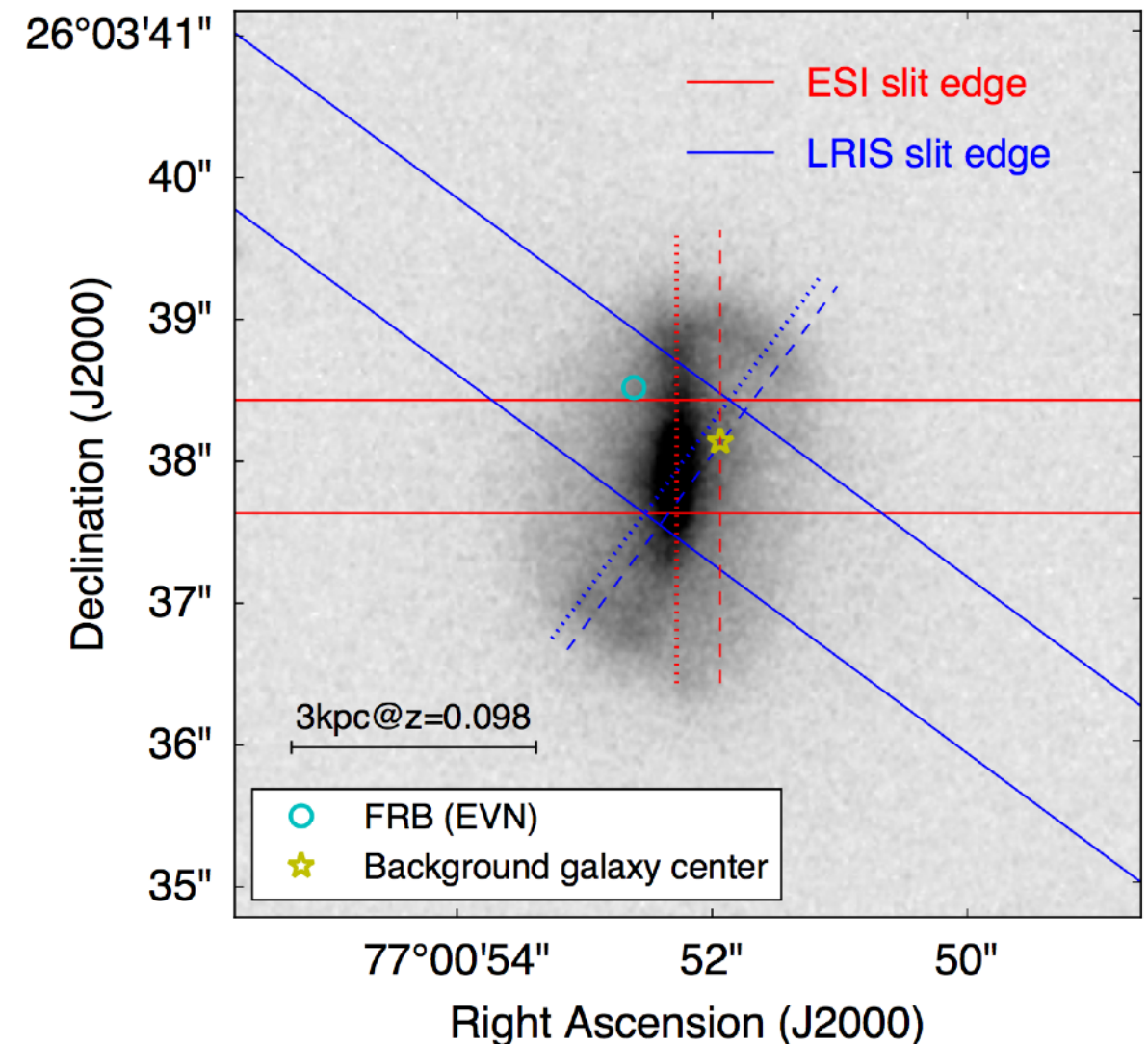


Localization and Host Galaxy Morphology

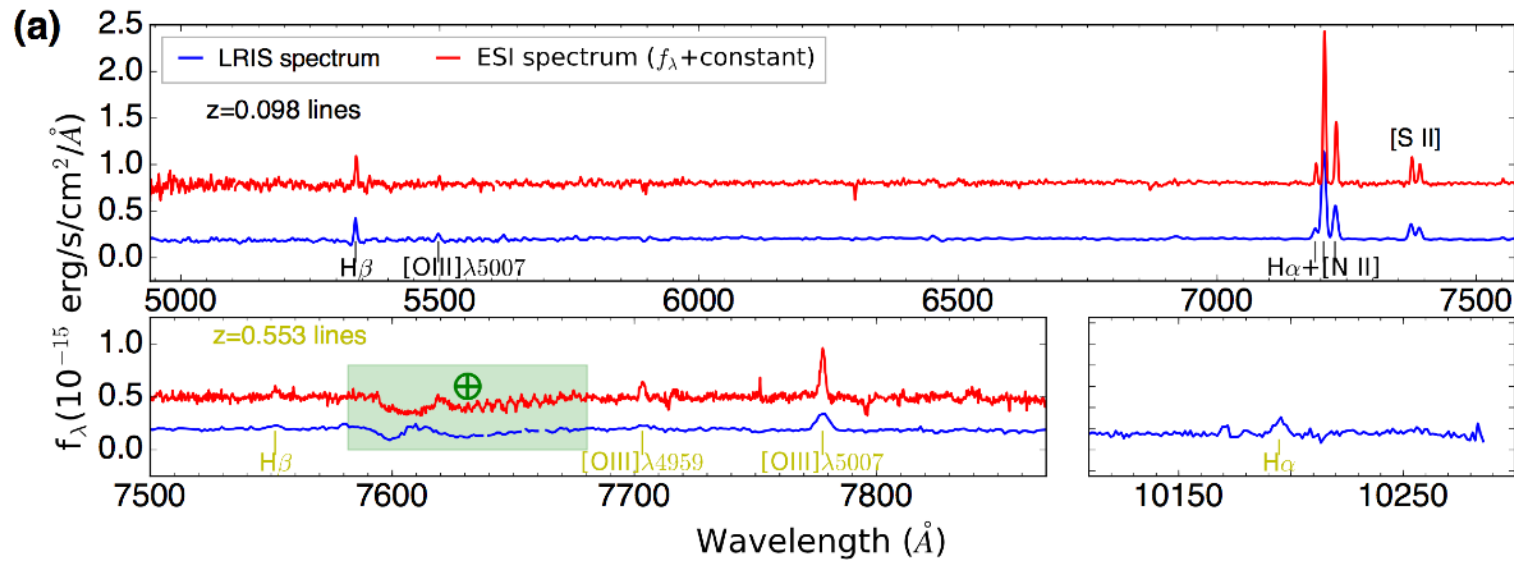
- FAST 19-Beams receiver enable localization, which is consistent with later ENV observations (Nimmo et al., 2022).
- K'-band image with NIRC2 camera using the laser guide-star adaptive-optics (AO) system at the 10m Keck telescopes.
- A barred-spiral galaxy (like the Milky Way, MW)
- FRB source locates at a low stellar density, interarm region.



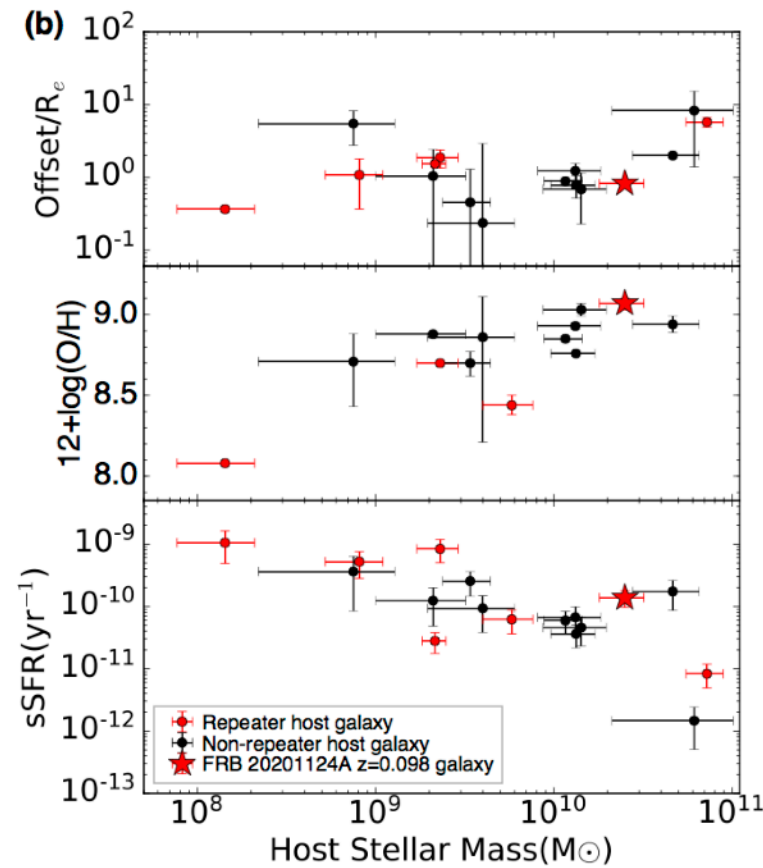
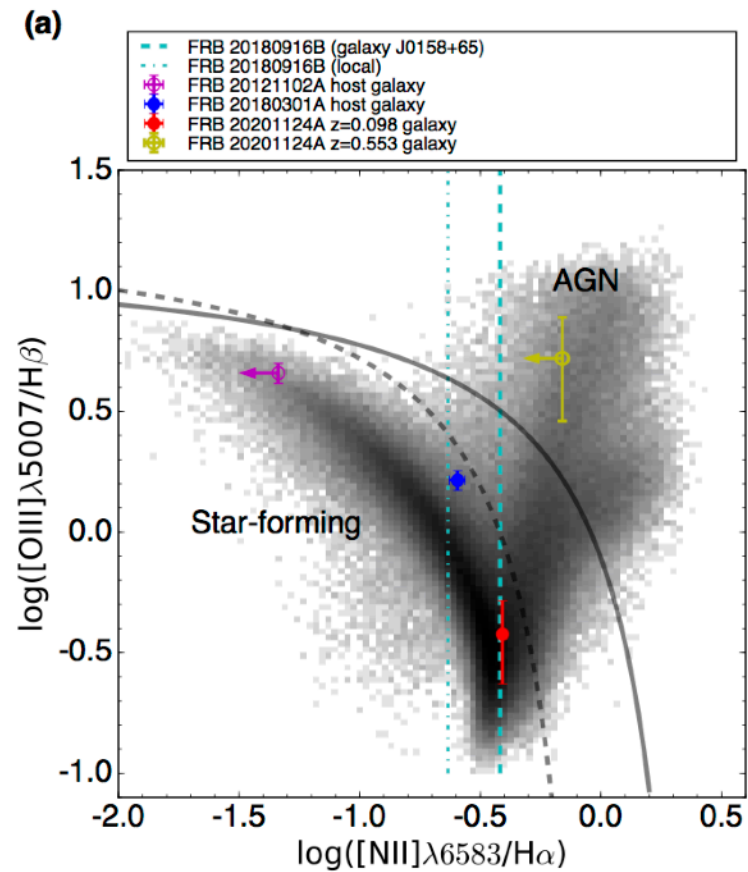
Xu et al., 2021, Atel



Host Galaxy Properties

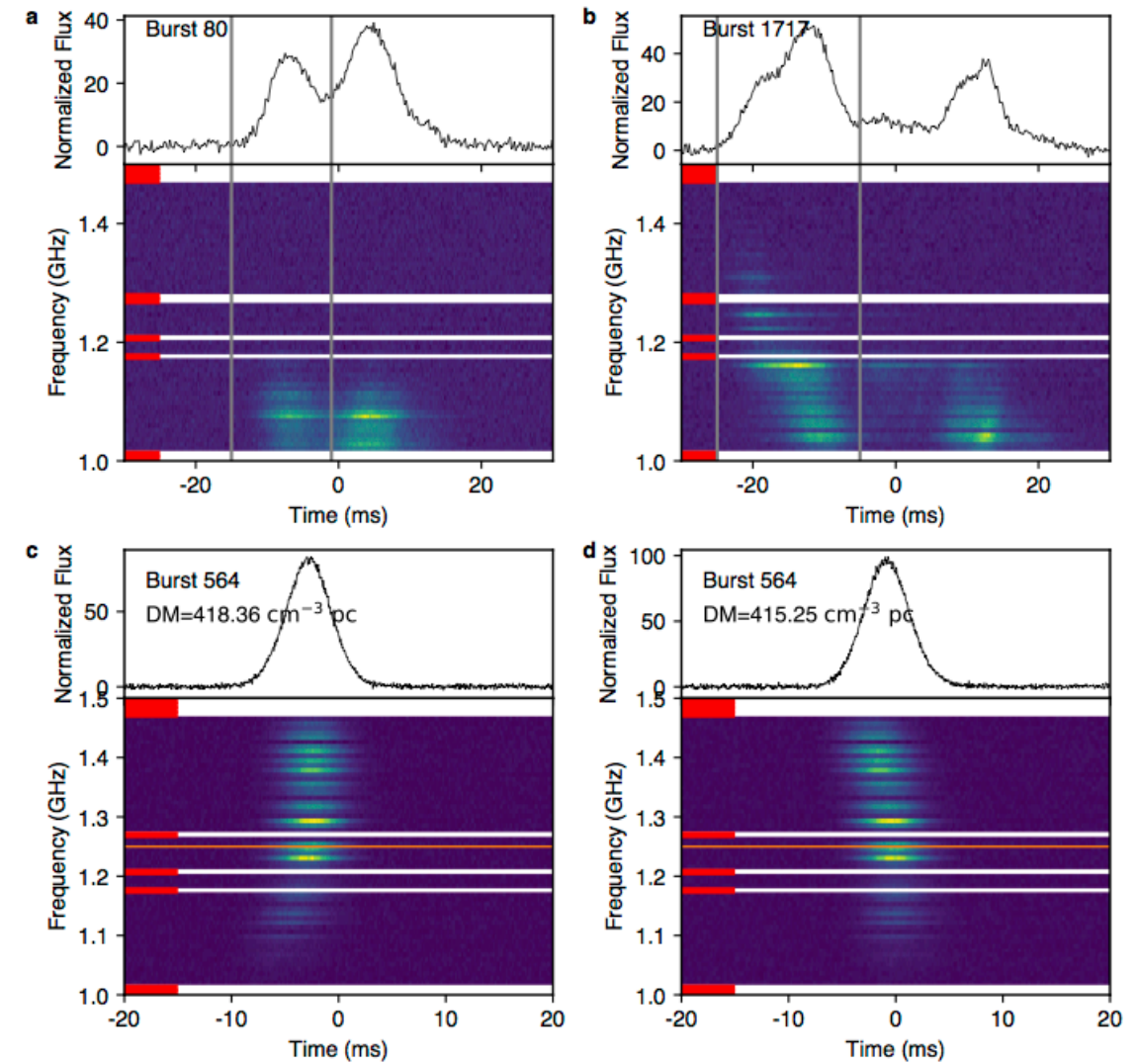
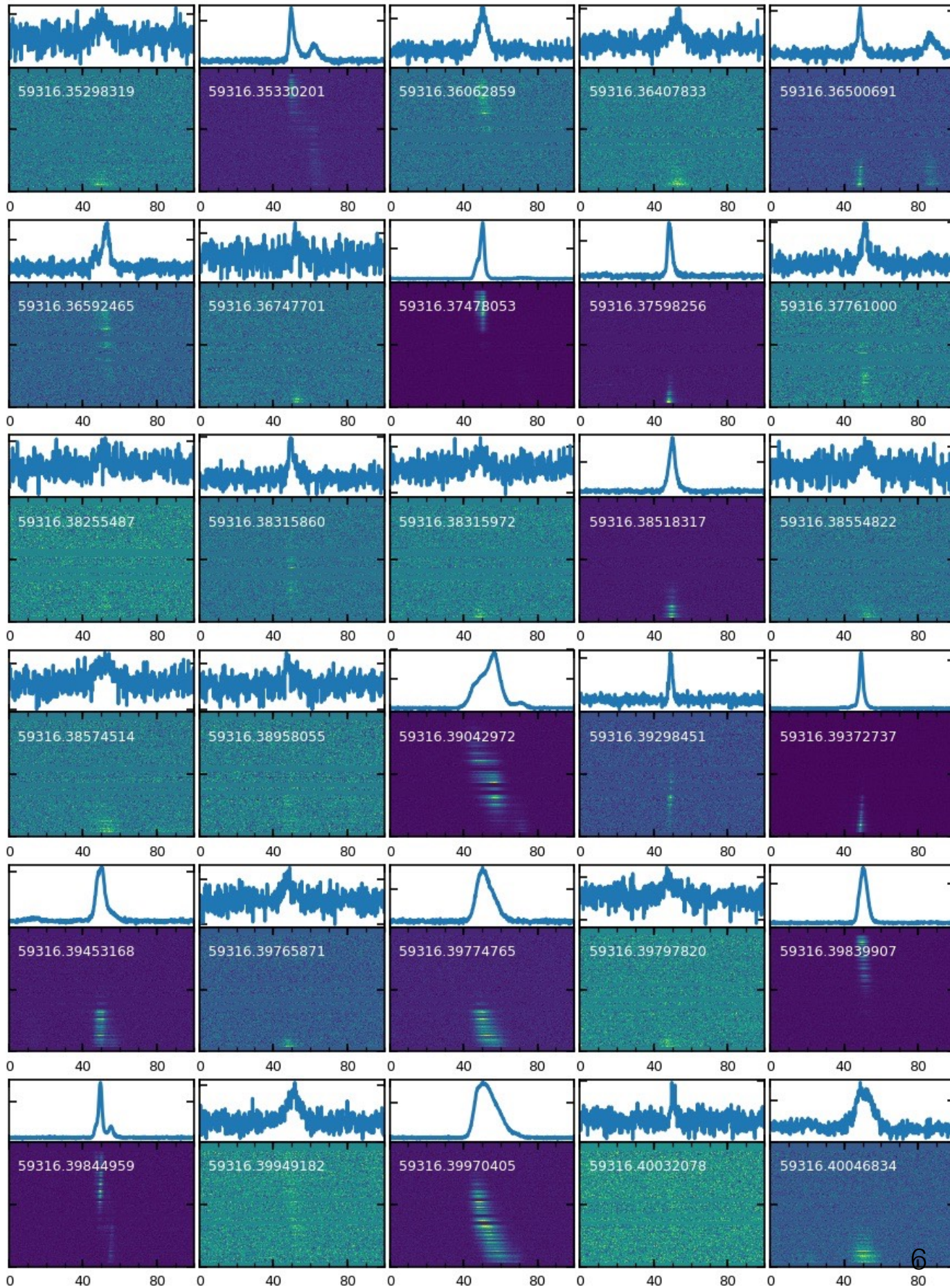


- A metal-rich barred-spiral galaxy
- Galaxy stellar mass is half as massive as the MW
- The star-formation rate is twice of the MW
- Its metallicity is \sim twice solar abundance



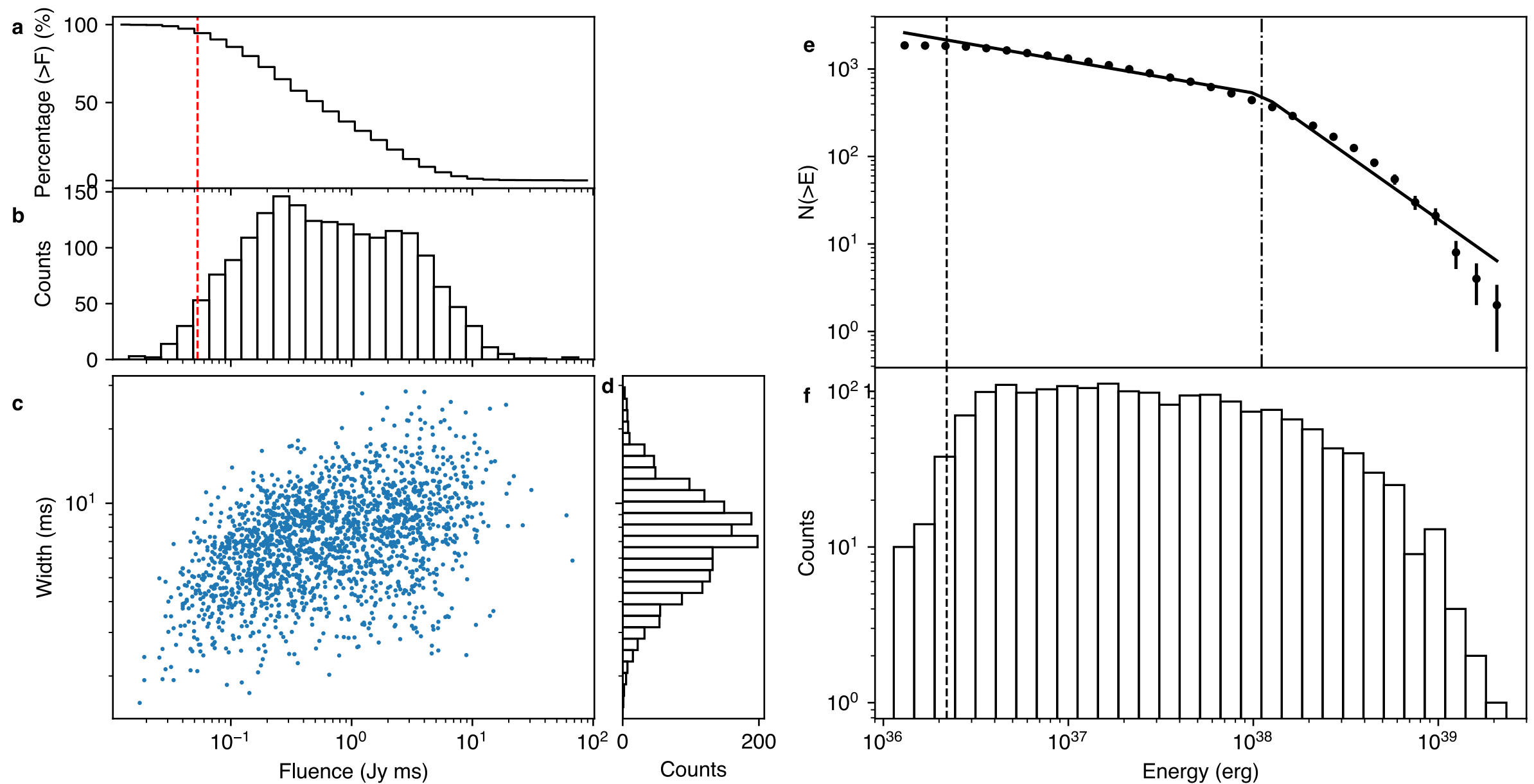
Complex Morphology

- Similar complex morphology seen in other repeating FRBs, (e.g, FRB 121102, FRB 20180301A, FRB 20180916B)



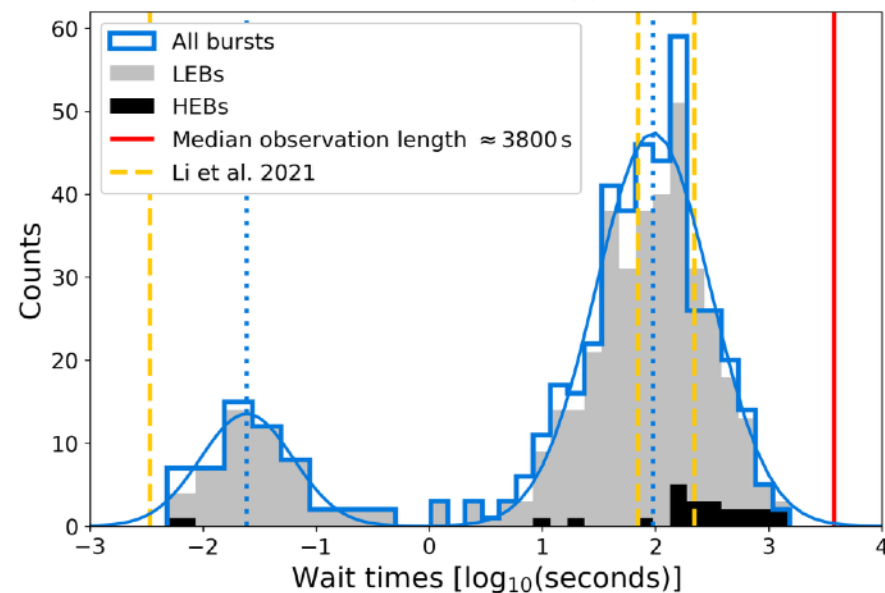
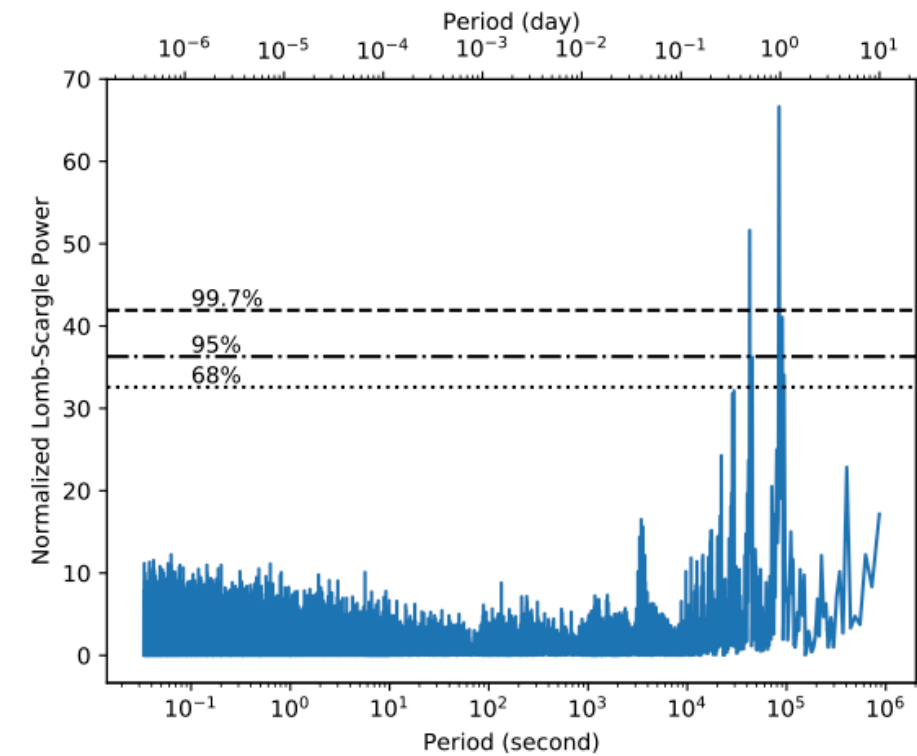
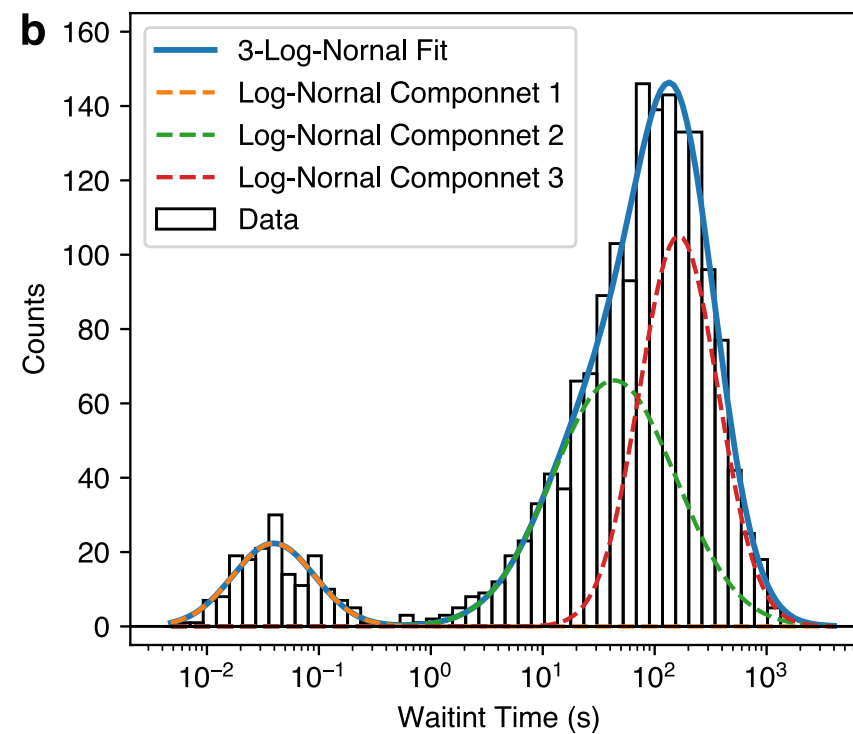
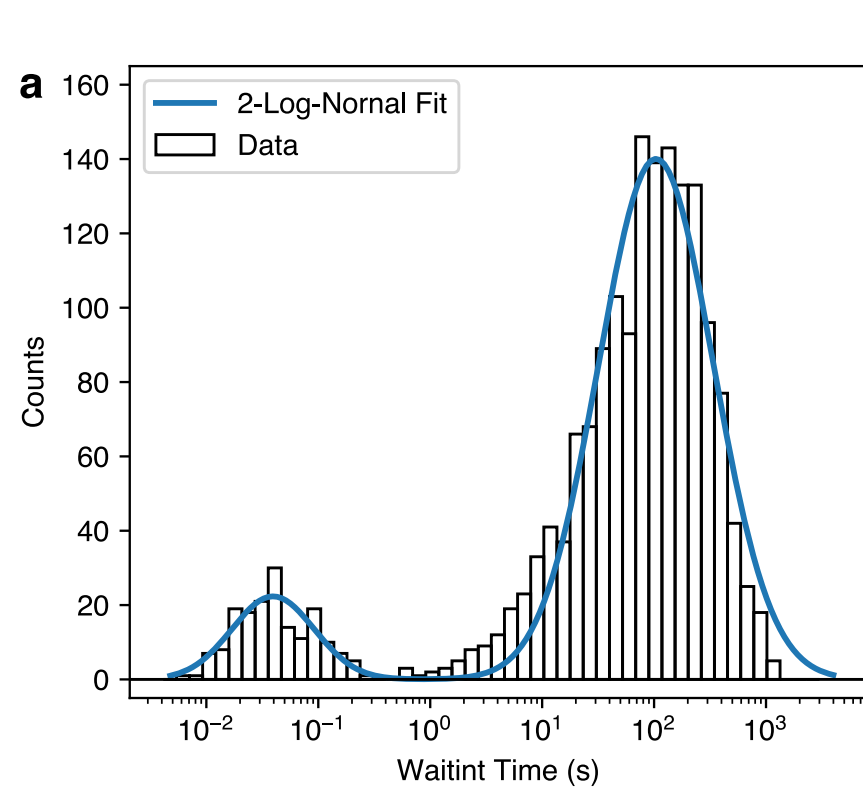
Flux & Energy

- Pulses are wider than other repeating FRBs.
- Energy spans more than 3 magnitudes.
- Energy distribution different from FRB20121102A (Li et al., 2021).



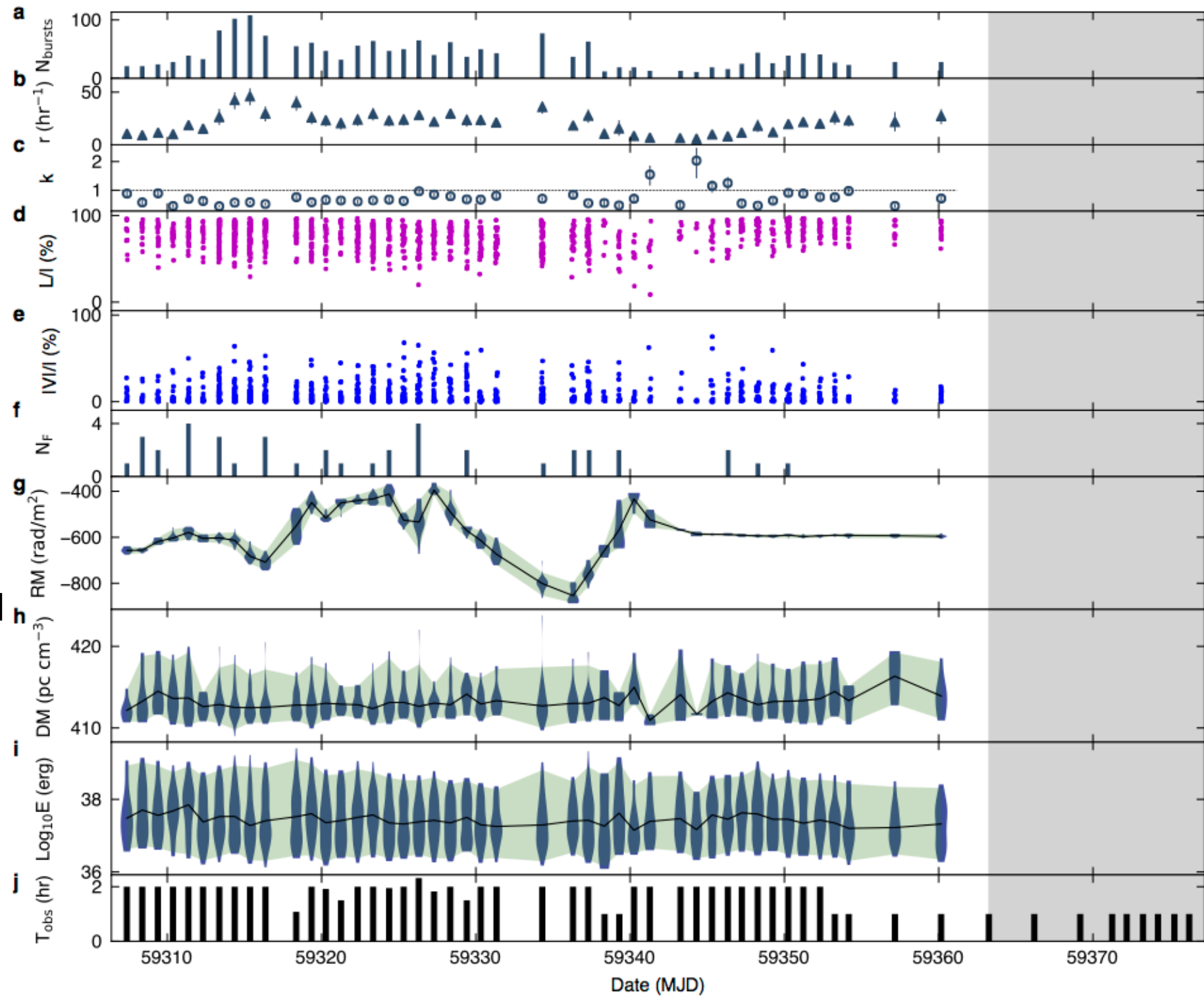
Waiting Time & Periodic Searches

- Striking agreement with FRB20121102A in timescale of microstructures
- No obvious periodicity was found excepts for these artifacts caused by nearly evenly spaced observations.



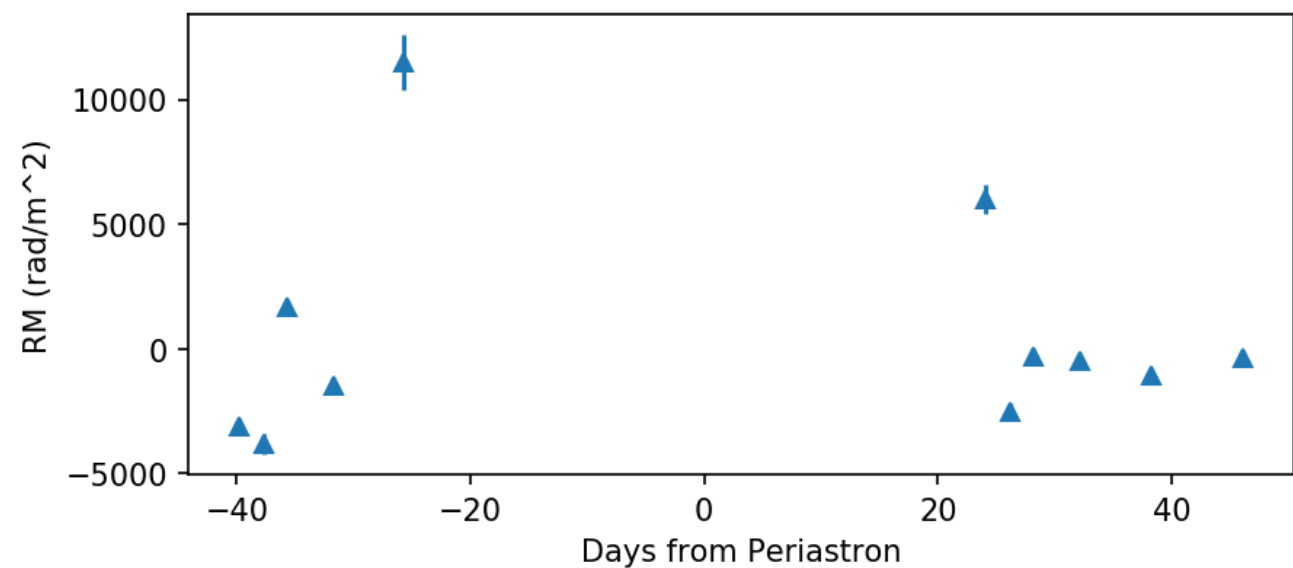
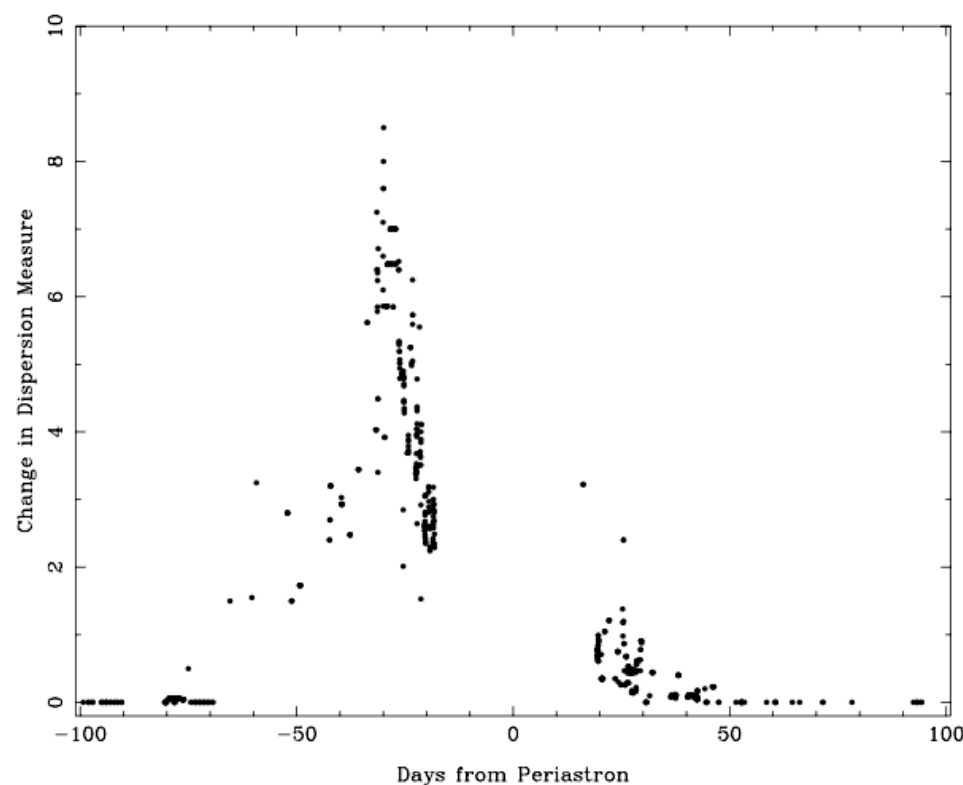
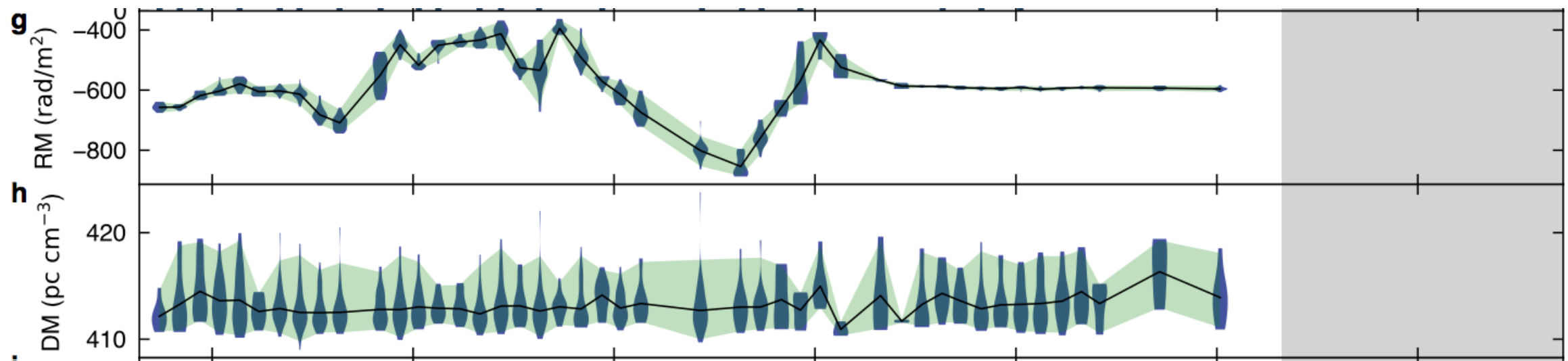
Pulse Properties

- Highly variable activity
- Quenching in 74 hours
- Clustering feature
- Prominent degree of circular polarization (maximum 75%)
- Greatly varying rotational measure (RM) & very stable RM
- No marked DM variation
- Flat energy distribution evolution



Intriguing RM Evolution

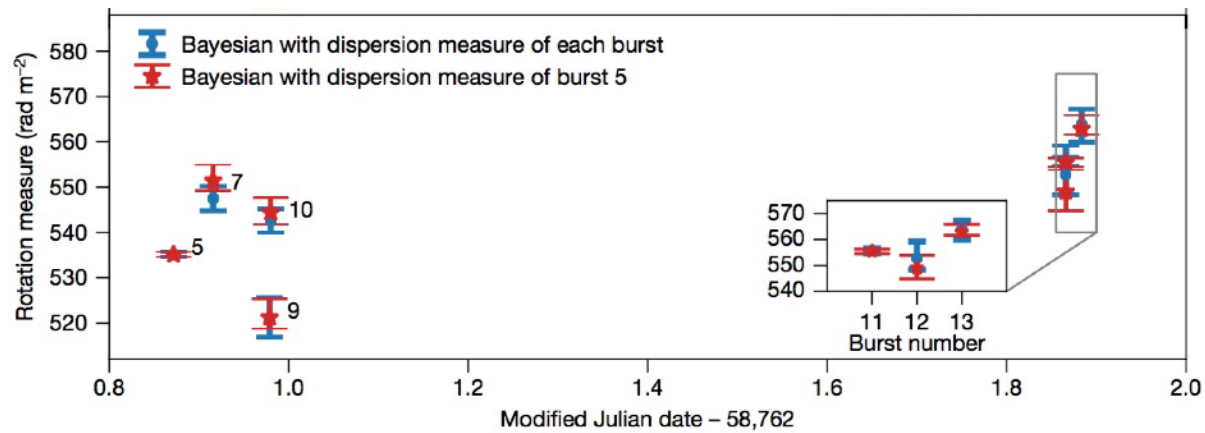
- RM variation: $-889 \sim -365 \text{ rad/m}^2$, on ~ 10 days timescale: environment size $\sim 0.6 \text{ AU}$ ($\tau/10\text{d})(v/100 \text{ km/s})$.
- Stable RM ($d\text{RM} < 9.1 \text{ rad/m}^2$) at the end of the active window (probably coincidence?, or environment origin).
- Such large RM fractional variation was seen in the Galactic Be star binary PSR B1259-63.
- RM doesn't show a secular monotonic decline with time—the central engine is not likely a young magnetar.



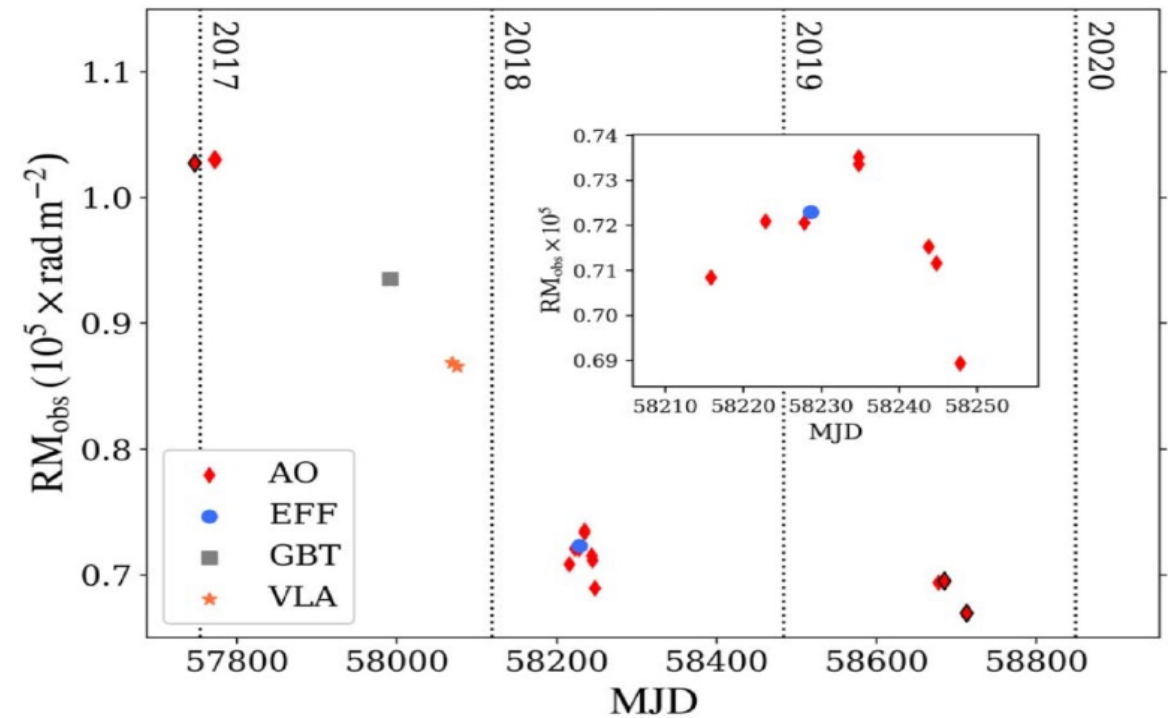
Johnston et al., 2005, MNRAS

RM evolution in Repeating FRBs

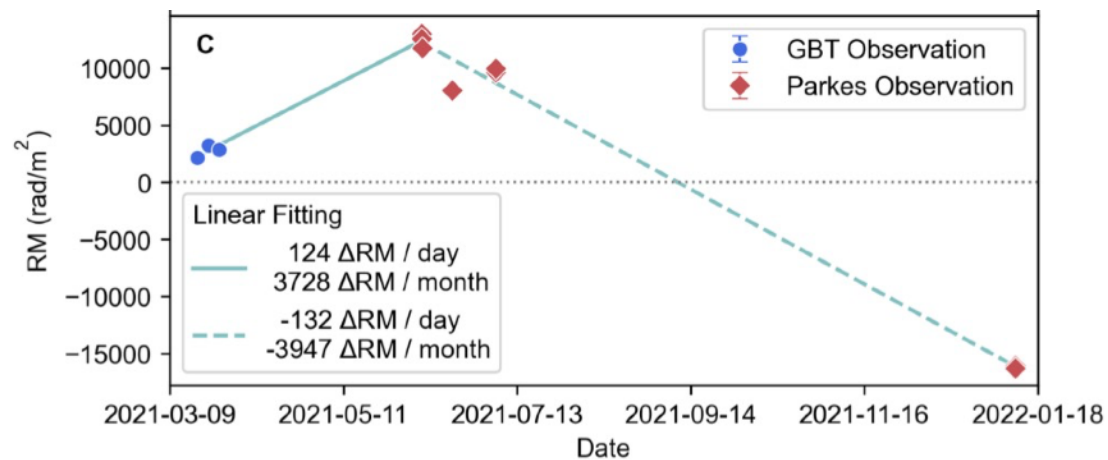
- RM variation is common in repeating FRB sources — evolving magnetized environment around repeating FRBs.
- RM variations are complex, could be different from source to source.



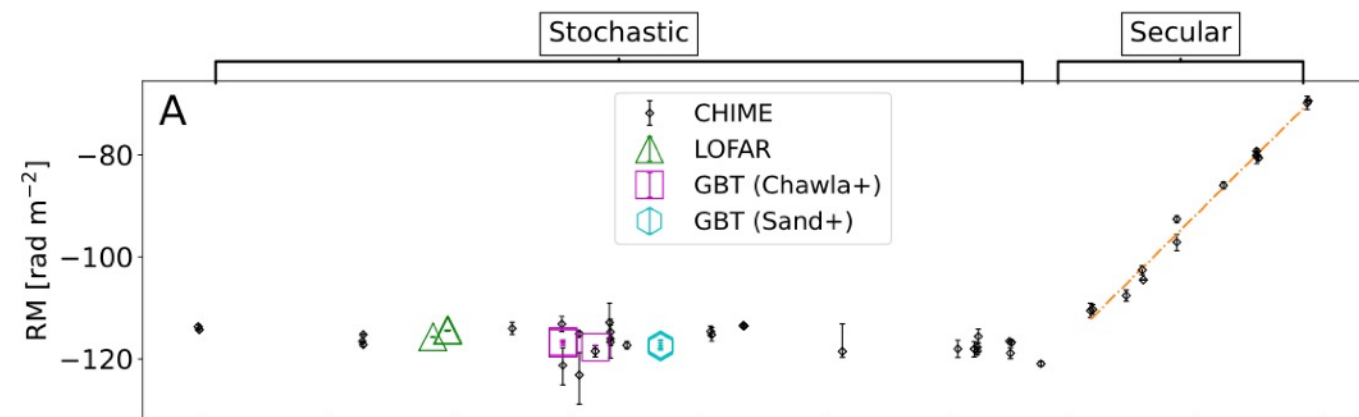
FRB 180301, Luo et al., 2020, nature



FRB 121102, Hilmarsson et al., 2021, ApJL



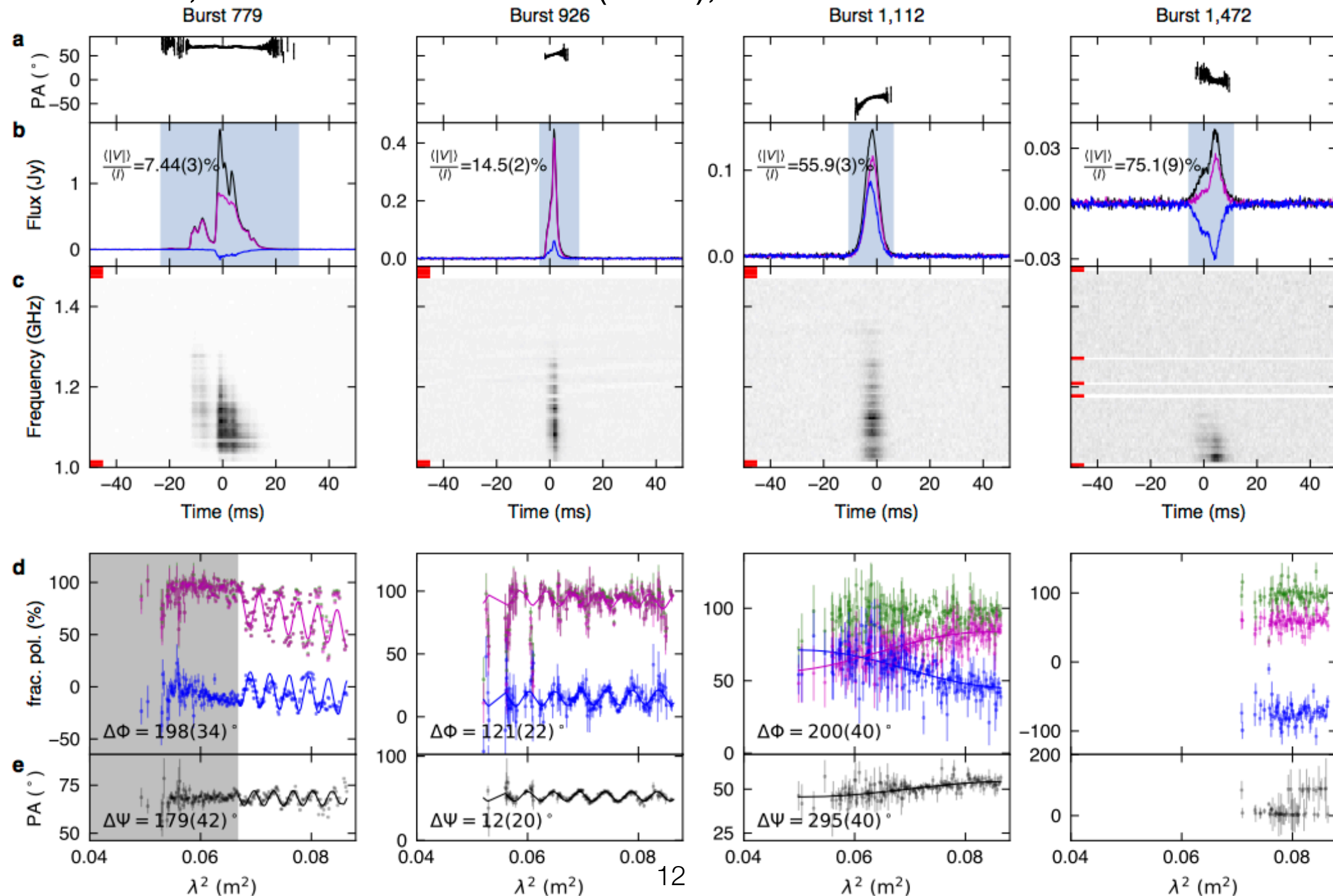
FRB 190520B, Dai et al., 2022, arXiv



FRB 20180916B, Mckinven et al., 2022, arXiv

Oscillations in Polarizations

- PA swings, high degrees of circular polarization
- Oscillation structures of polarization as functions of wavelength: conversion between linear and circular polarization — polarization-dependent absorption or conversion, requires $B > 3(\gamma/10)^{-2}$ Gauss.
- Timescale ~ 1 mins, distance scale $\sim 0.1 \text{ AU}(\tau/\text{min})$, consistent with estimation from RM variation.



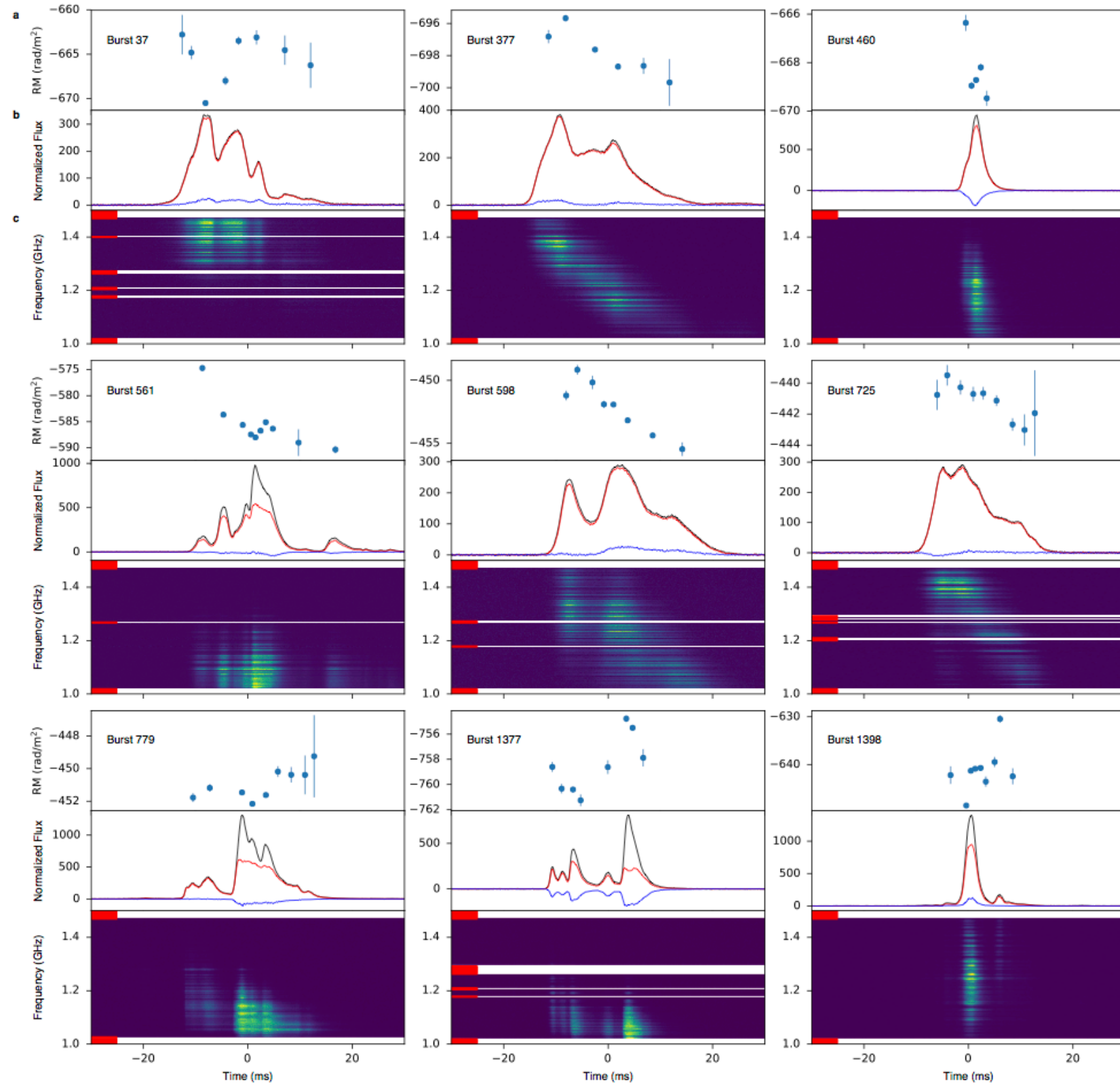
Summary

- FRB 20201124A is one of the most active repeating FRBs; a large sample with polarization information.
- Quasi-random RM variations was observed in our observations.
- Very high degree of circular polarization (up to 75%) was discovered.
- We found oscillation structures in polarization, possibly due to polarization-dependent absorption or conversion.
- A complicated dynamically evolving, magnetized environment around FRB source.

	Polarization Angle	Circular Polarization	RM Evolution	Periodicity at ~ms, ~day	Periodic Activity	Host Galaxy
20121102A	Flat	~0	monotonic decrease	No!	Probably	Irregular dwarf galaxy
20180301A	Flat+Swing	~0	Yes			Irregular?
20180916B	Flat	~0	Yes		Yes	Spiral Galaxy
20190520B	Flat	~10%	Yes			Dwarf Galaxy
20200120E	Flat	~0				M81 Globular
20201124A	Flat+Swing	Could be >70%	Random	No!	?	Barred spiral Galaxy

RM Fluctuations in Bursts

- RM fluctuations of $\sim 10 \text{ rad/m}^2$ is possibly due to intrinsic profile evolution or propagation effects



RM Index

