
Photo: Yu-An Chen

Simultaneous Observations of an Active Repeater FRB 20240114A with LOT & FAST

Tetsuya Hashimoto

NCHU 國立中興大學 NATIONAL CHUNG HSING UNIVERSITY 1919

On behalf of LOT-FAST FRB Team

(c)Shotaro Yamasaki, Tomotsugu Goto, Chow-Choong Ngeow, Chen-hui Niu, Yuhao Zhu, Tsung-Ching Yang, Bjorn Jasper Raquel, Howard Chuang, William Chang, Simon C.-C. Ho, Tzu-Yin Hsu, Mohanraj Madheshwaran, Yuu Niino, Yu-An Chen, Di Li, Pei Wang, Junshuo Zhang

ASROC 2025@NFU, 17 May 2025


Photo: Yu-An Chen

Talk Plan

1. Motivation
2. Strategy/Observation
3. Result & Discussion
4. Conclusion


Photo: Yu-An Chen

Talk Plan

1. **Motivation**
2. Strategy/Observation
3. Result & Discussion
4. Conclusion

Fast Radio Bursts (FRBs)
Since 2007

cf. talks by Chin-Ping/Zi-Jia

Vignesh (next, galactic environments of FRBs)

Shotaro (next next, FRB radiation)

Tomoki (this afternoon, FRB radiation)

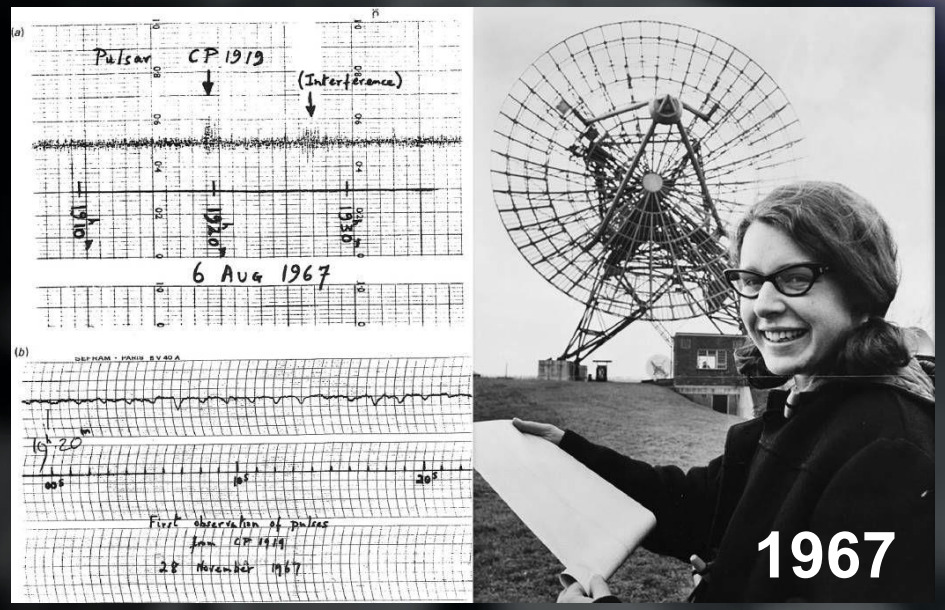
Tsung-Ching (tmr afternoon, FRB cosmology)

Mohan/Che-Cheng (Posters)

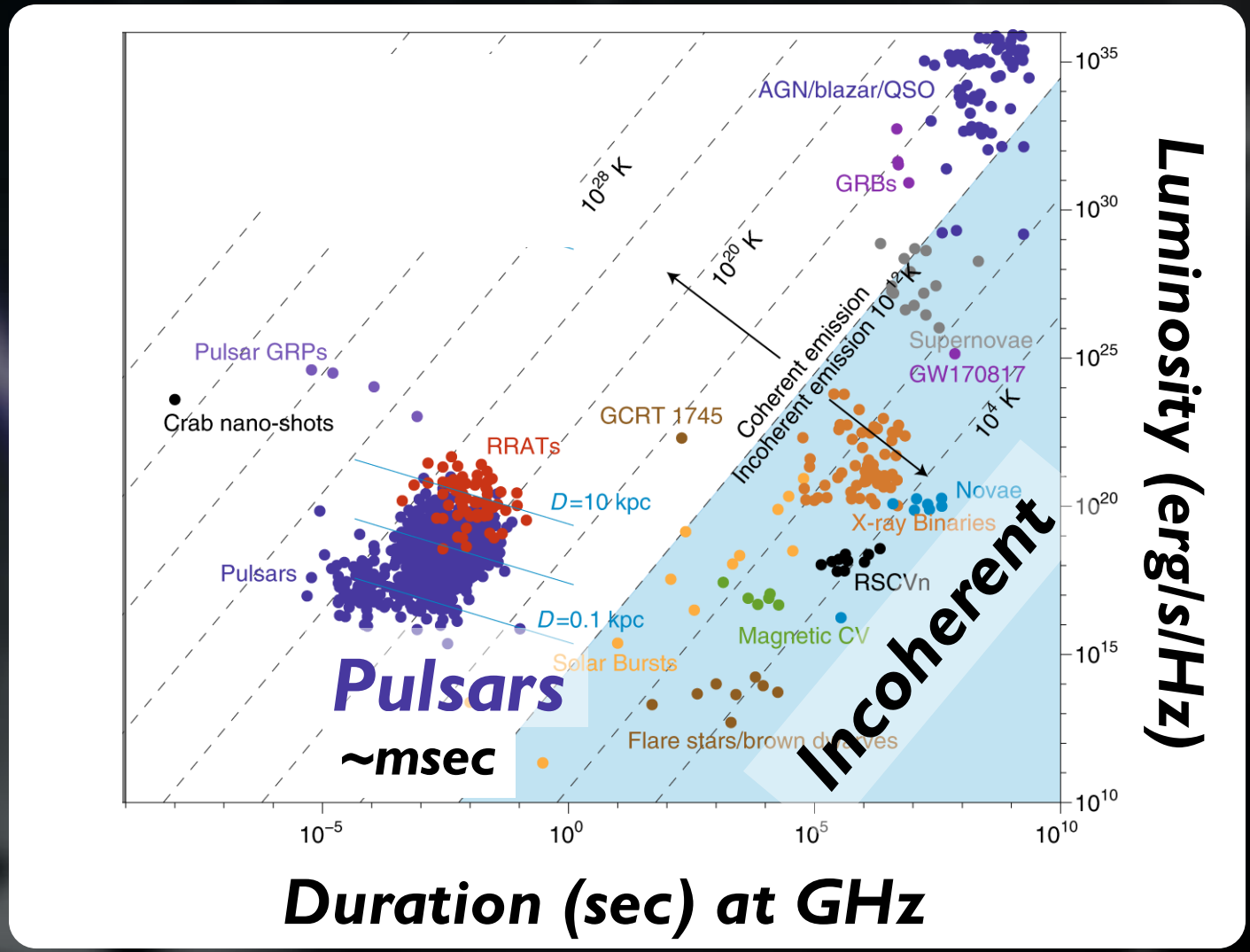
Credit: Danielle Futselaar

Mystery: Coherent Radiation Mechanism(s)

- *Pulsar radio emission mechanisms remain controversial for ~60 years*



Keane 2020, *Nature*



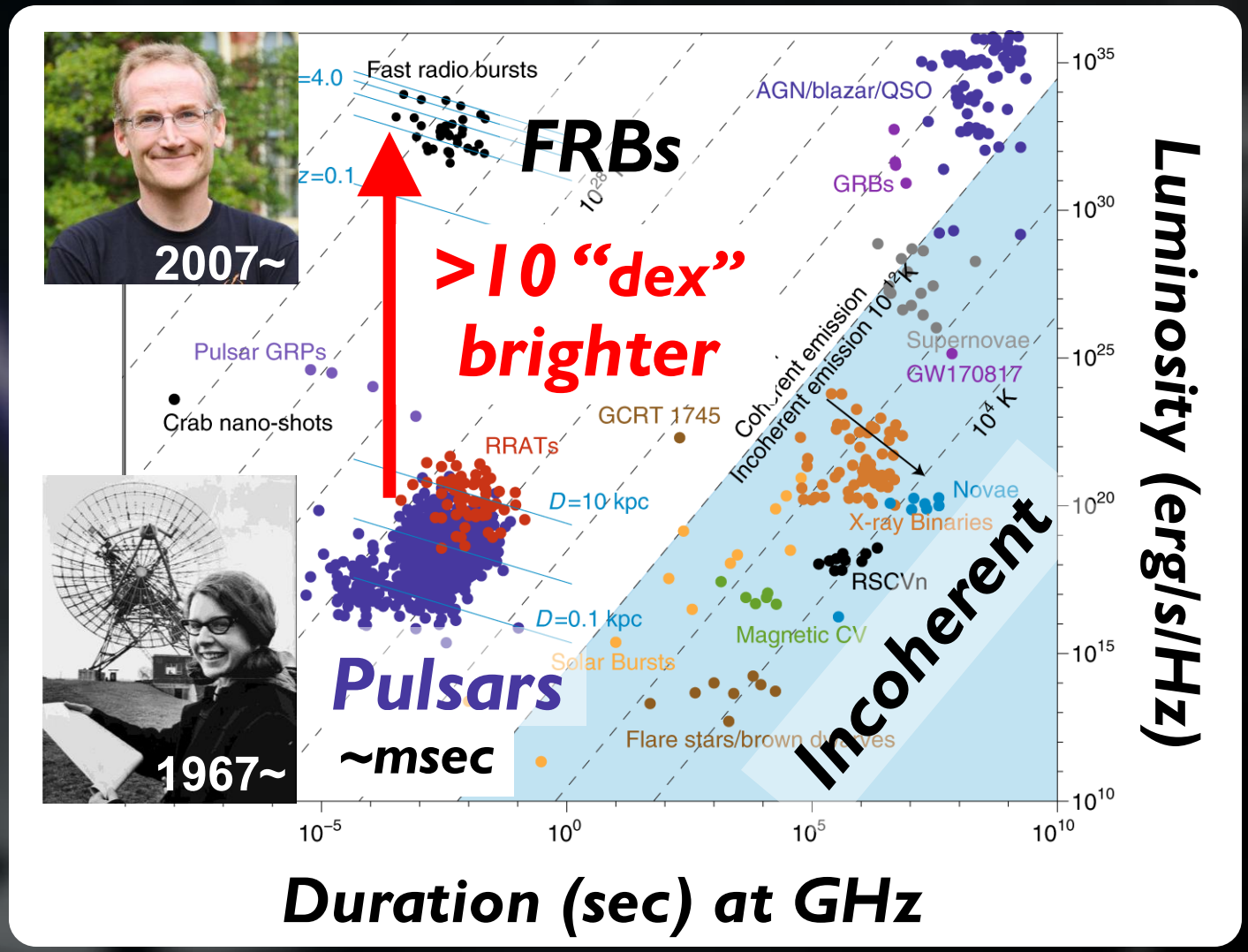
Mystery: Coherent Radiation Mechanism(s)

- *Pulsar:*
  controversial for ~60 years

- *FRBs:*
  10 orders of mag. brighter
  → *Even more extreme*

cf.
Shotaro's talk (next next)
Tomoki's talk (this afternoon)

Keane 2020, *Nature*

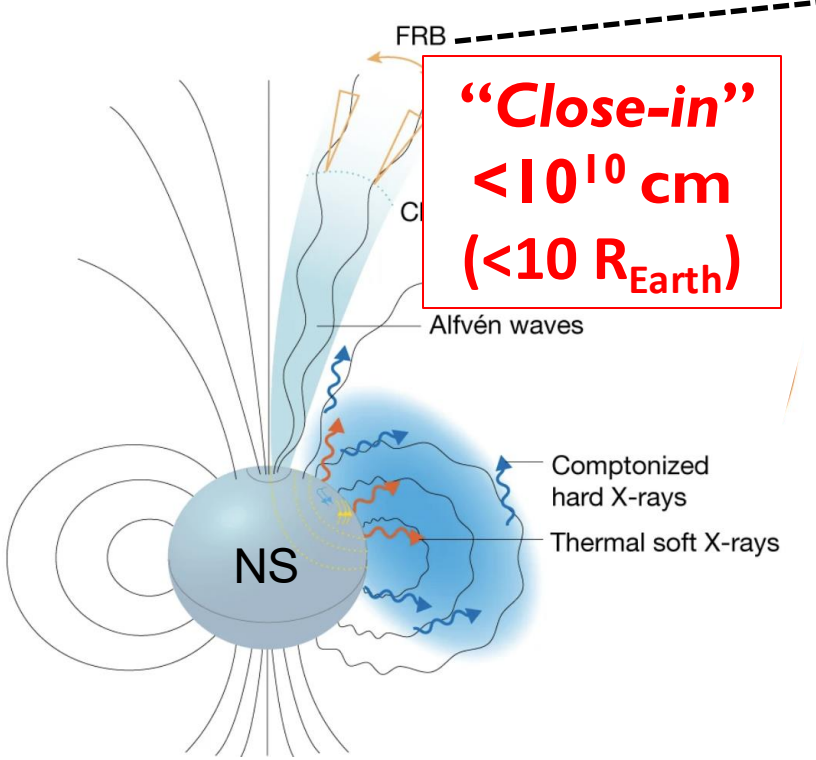


Surviving Theories of FRB Emission?

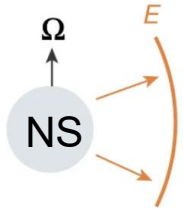
Pulsar-like model

GRB-like model

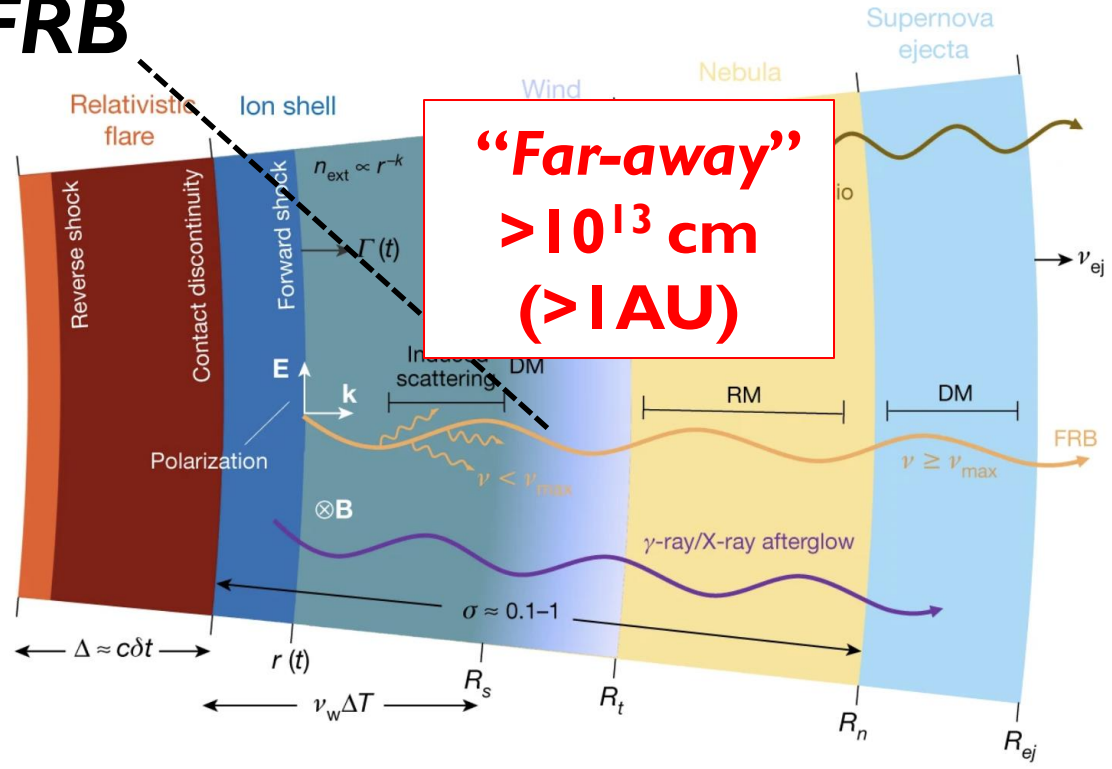
FRB



"Close-in"
$<10^{10}$ cm
($<10\ R_{Earth}$)



"Far-away"
$>10^{13}$ cm
(>1AU)



Lyutikov+16, Kumar+17, Zhang 17, Lyubarsky 20, Kumar & Bošnjak 20, Ioka & Zhang 20, Lu+20, Lyutikov & Popov 20, Katz 20

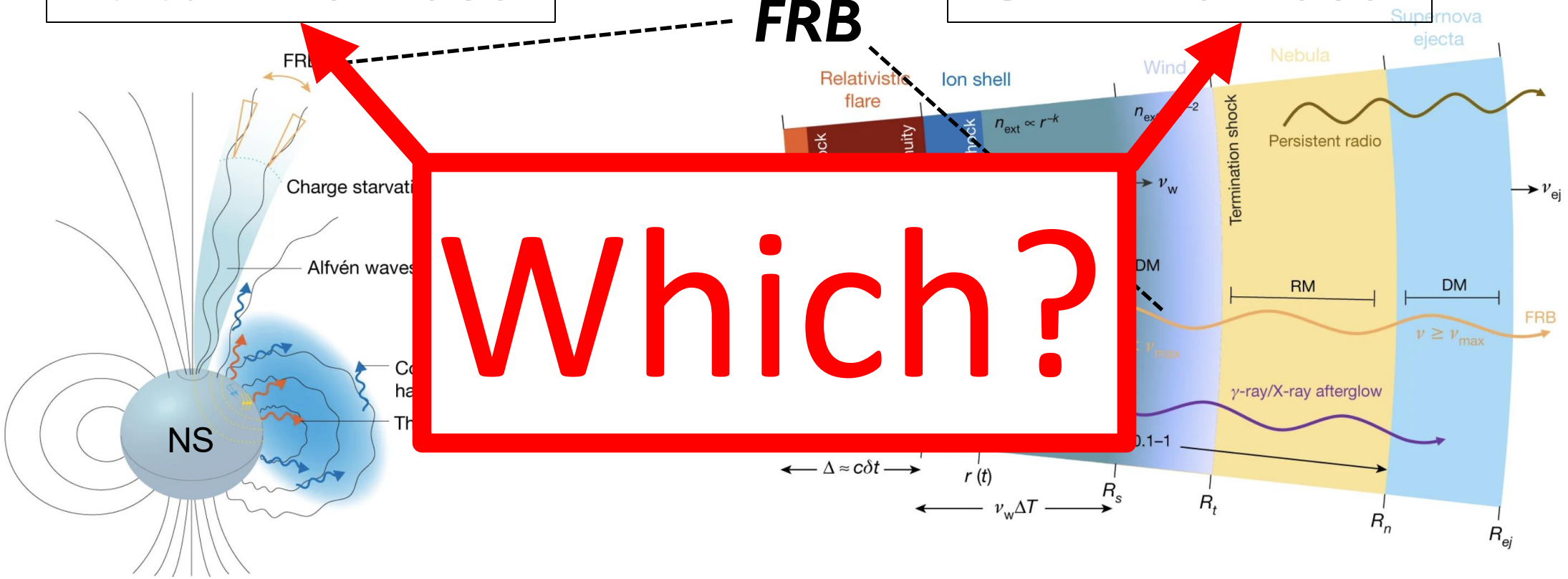
Lyubarsky 14, Murase+16, Waxman 17, Beloborodov 17, Metzger+17, Margalit +20, Yu+20, Yuan+20

Surviving Theories of FRB Emission?

Pulsar-like model

GRB-like model

FRB



Which?

Challenging to distinguish models with radio data alone…

→ Solution lies in multiwavelength properties !

A Big Question: Optical Counterparts?

GRBs

Yes
(Afterglows)

Neutrinos

Yes
(SN1987A)

GWs

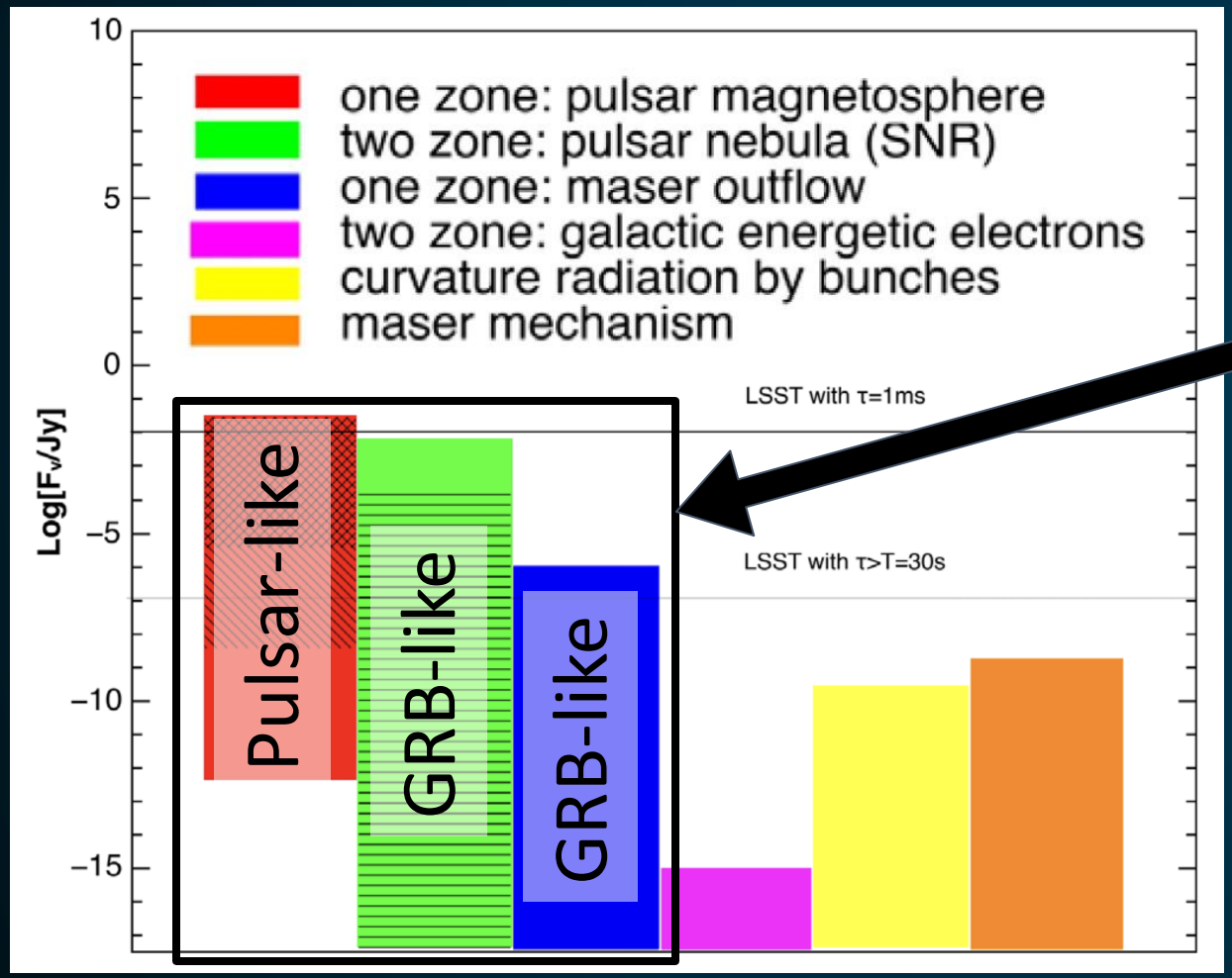
Yes
(Kilonova)

FRBs

??

Distinguishing FRB Models: Optical Predictions

Yang et al. 2019



≈ Log (optical / radio)

To constrain

Optical-bright scenarios w/ inverse-Compton (IC) processes

we need

1. ***Simultaneous*** *radio/optical observations*
2. ***Fast optical camera*** *(~ms time resolution)*


Photo: Yu-An Chen

Talk Plan

1. Motivation
2. **Strategy/Observation**
3. Result & Discussion
4. Conclusion

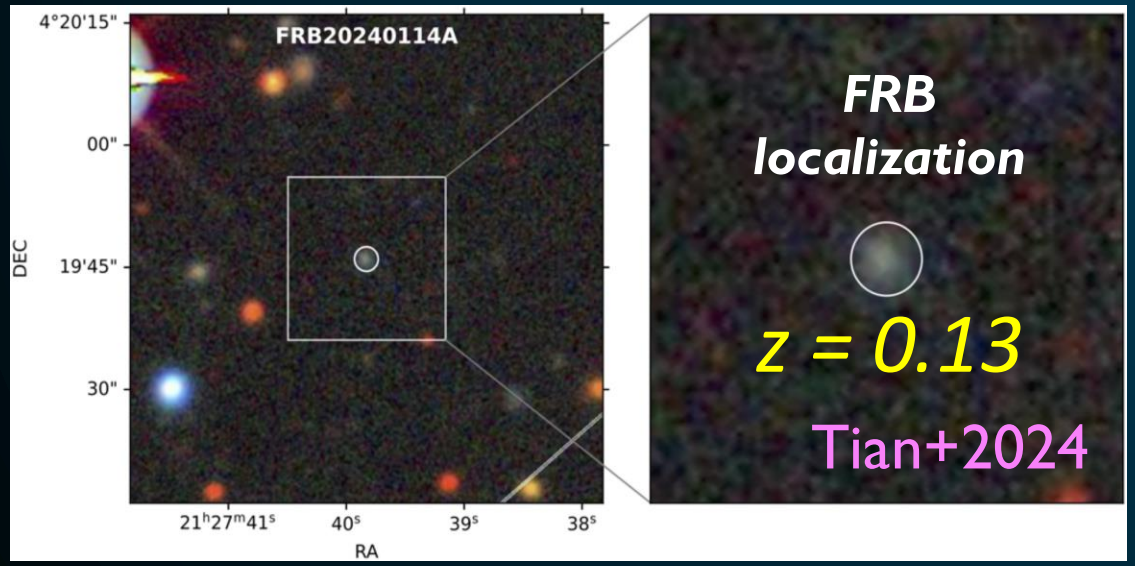
Targeting Hyper-Active Repeater FRB 20240114A

(A new source discovered by CHIME/FRB in January 2024)

✓ ***Hyper active source ever*** :

more than 12,000 bursts detected by FAST as of Nov. (Zhang+ in prep.)

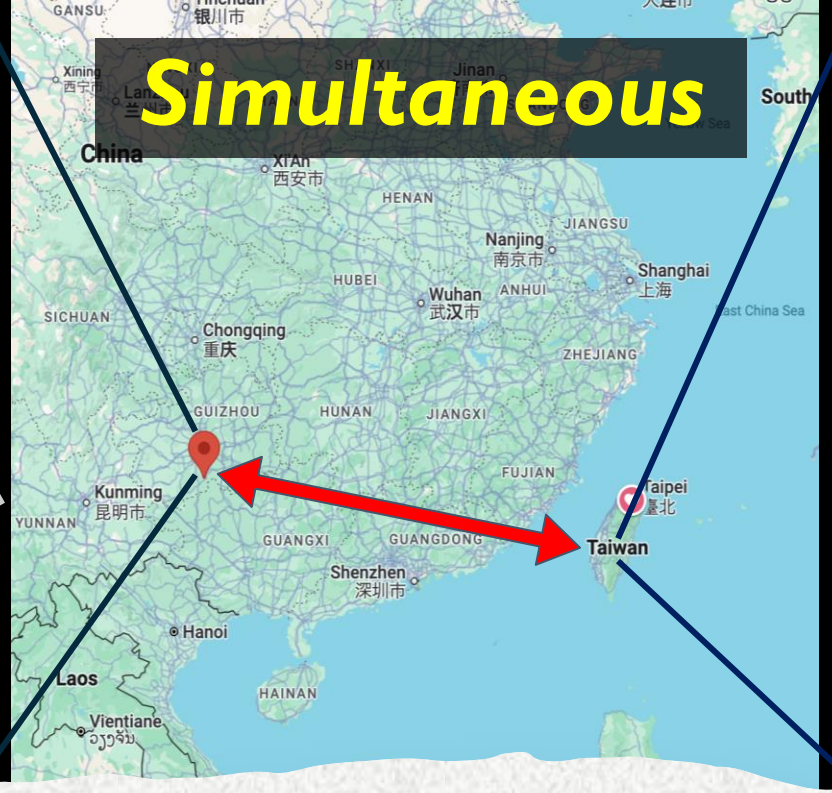
FAST Detections		A slide from *Junshuo Zhang*
FRB	Burst	
FRB 20121102A	>6000	Wang P. et al. In prep. Wang Y.-D. et al. In prep.
FRB 20190520B	444	Niu C.-H. et al. 2022. Zhu Y.-H. et al. 2024.
FRB 20201124A	>5000	Xu H. et al. 2022. Zhang Y.-K. et al. 2022. Xu J.-W. et al. In prep.
FRB 20220529A	>1100	Li Y. et al. Submitted.
FRB 20220912A	~1300	Zhang Y.-K. et al. 2023.
✓ **FRB 20240114A**	**>12000**	Zhang J.-S. et al. In prep

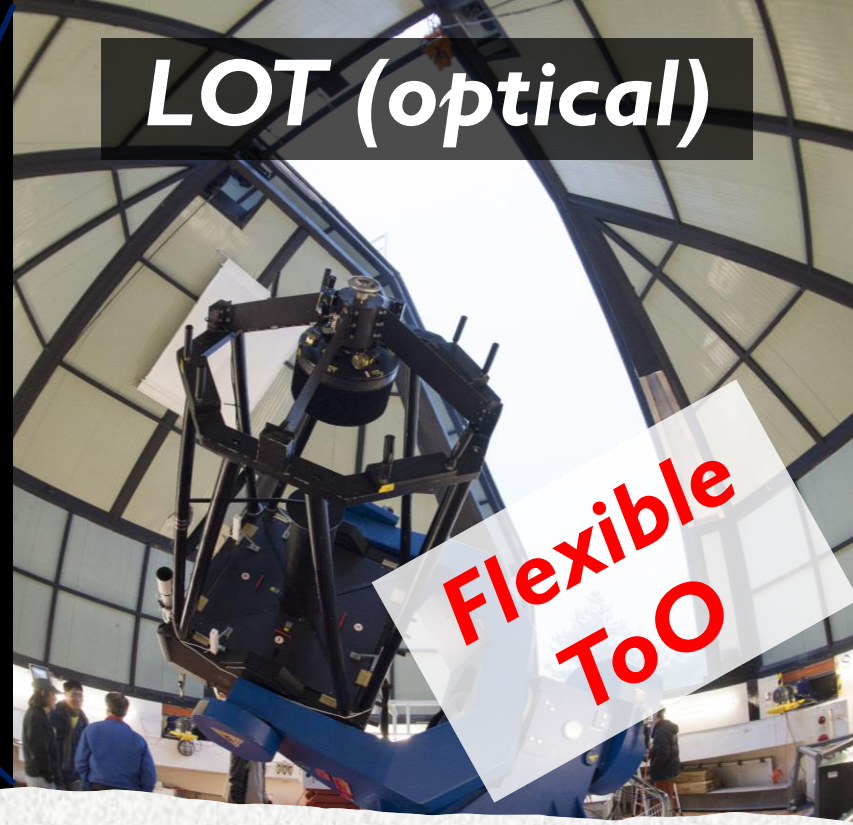


✓ ***Host is known & nereby***:

A dwarf star-forming host galaxy at ***z = 0.13*** (Bhardwaj+2024)

→ ***Most suitable target***





PIs: Di Li, Pei Wang, & Junshuo Zhang

500 m radio single dish

X

Overlapping exp. time of FRB 20240114A :

20 min x 2 = 40 min

(on 7 &14 July 2024)

PI: Tetsuya Hashimoto

thx to Chow-Choong

1m optical CMOS

(17 ms time resolution)

S

We appreciate LOT staff and TEEP/IIPP programs by NSTC and MOE

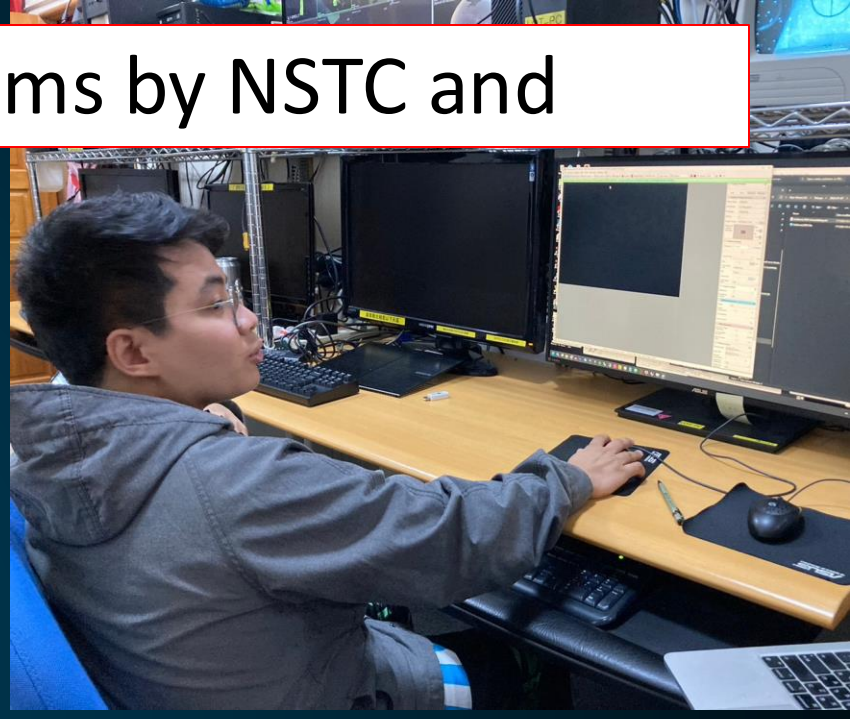



Photo: Yu-An Chen

Talk Plan

1. Motivation
2. Strategy/Observation
3. **Result & Discussion**
4. Conclusion

FAST: >78 FRBs !

Select LOT optical frames

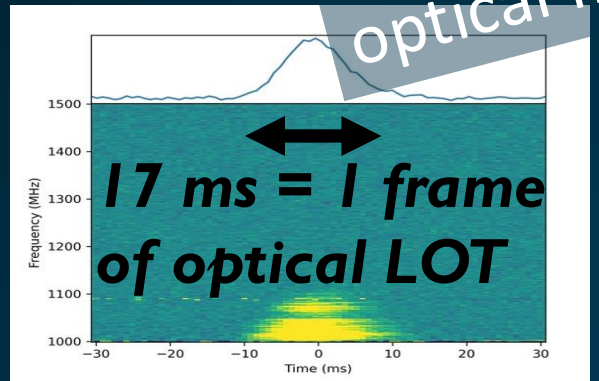
64 FRBs covered by LOT

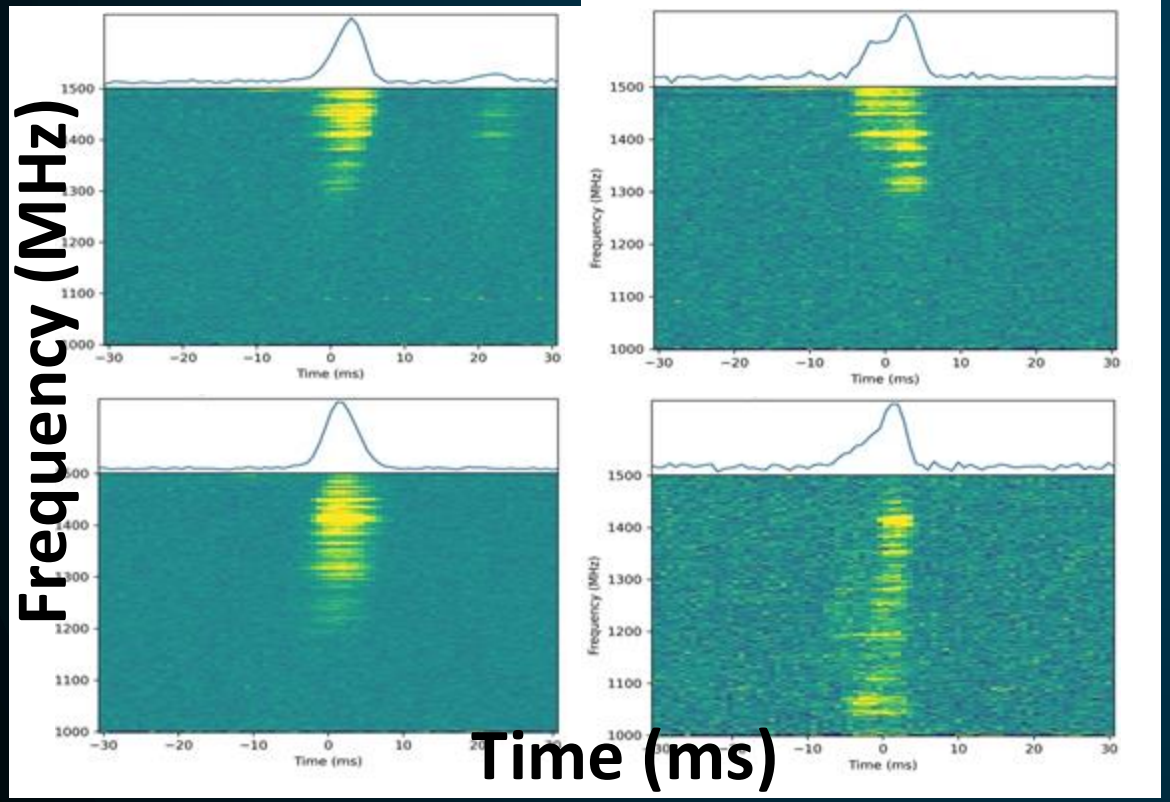
No detection of a point source in individual images

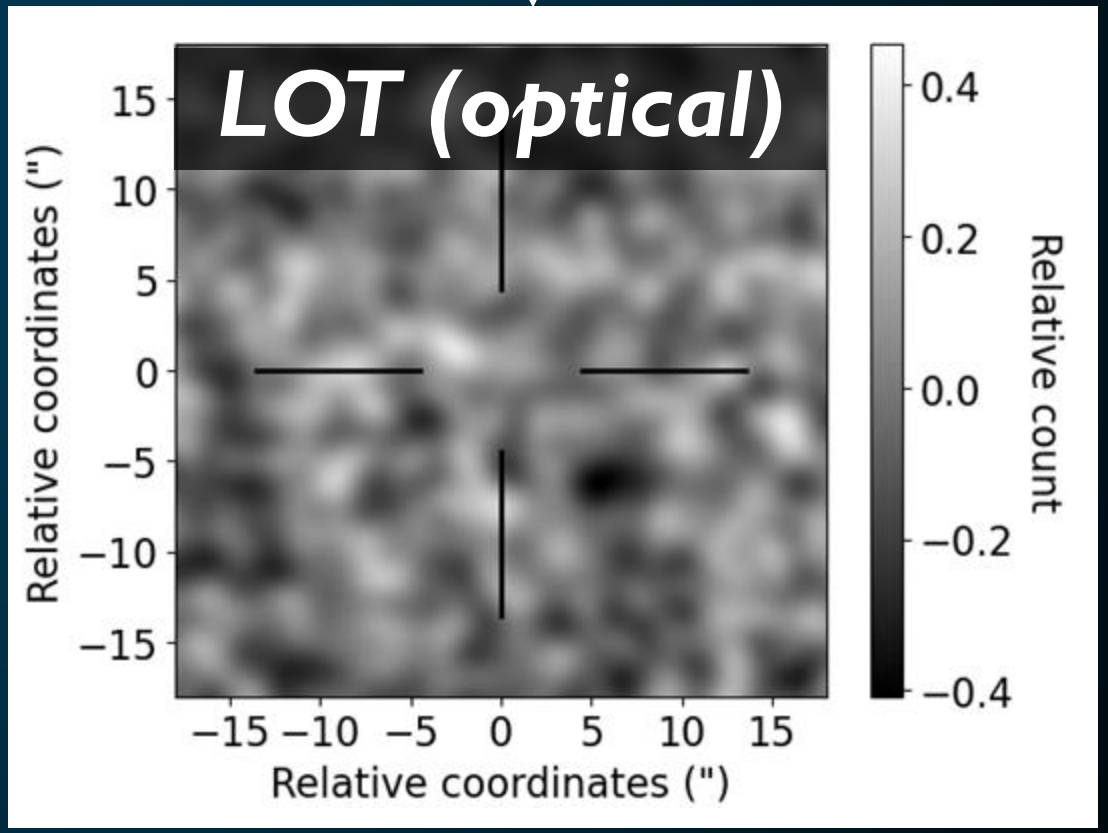
Stack 64 images (factor 8 gain)

FAST (radio)

Credit : Junshuo Zhang



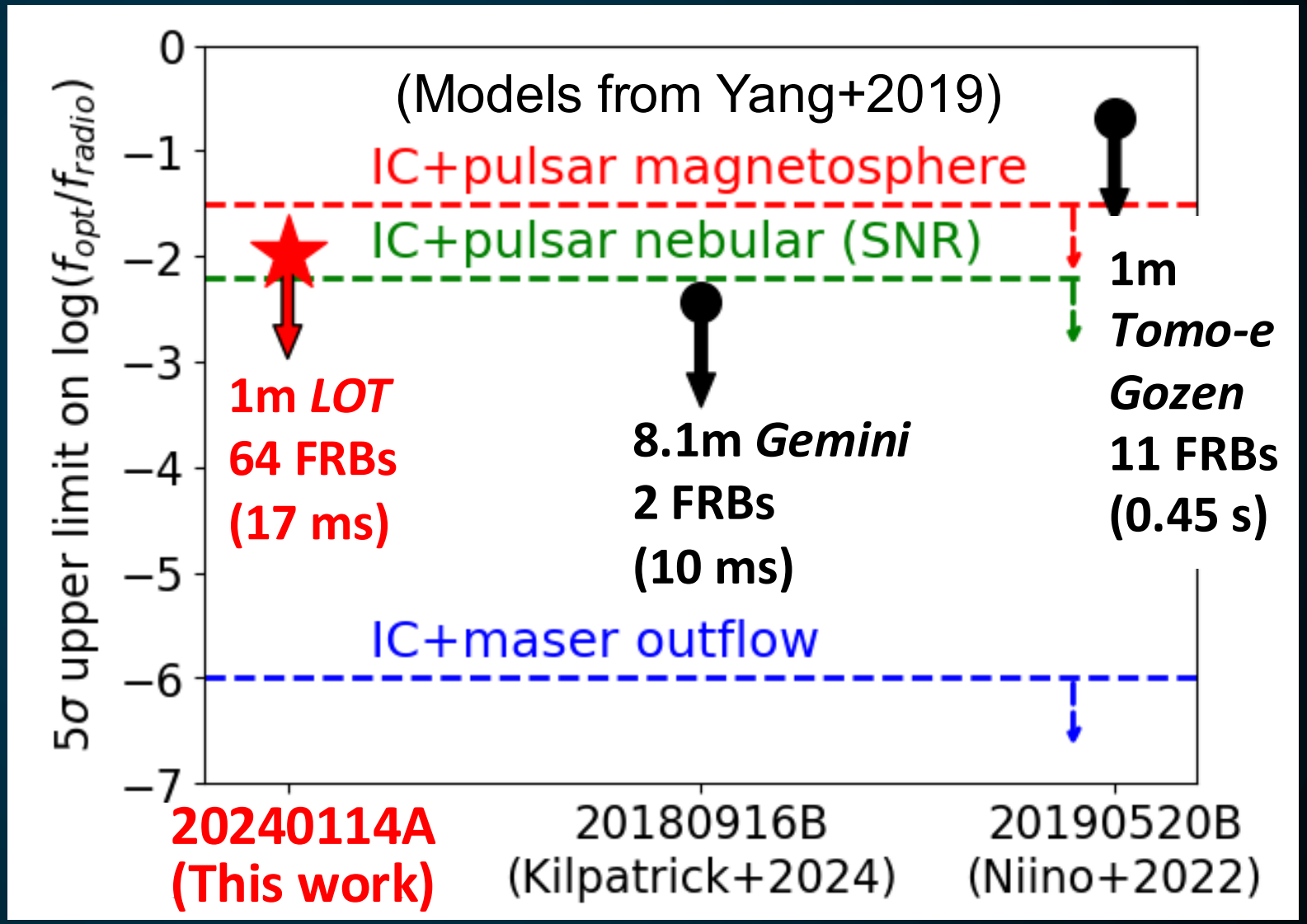




The Brightest Pulsar-Like Scenario Marginally Excluded

- Preliminary 1-m LOT limit ***comparable to that by 8-m optical telescope***
- Thanks to ***many radio-bright*** bursts & ***high-time*** resolution

"Small but BIG"



Conclusions

1. *Optical counterpart = Key to understanding FRBs*
2. *FAST detected 64 FRBs during our LOT observations*
3. *Our strong upper limit marginally excludes the brightest scenario of the optical counterpart*

Can achieve big results using small instruments


Backup Slides


Photo: Yu-An Chen

Talk Plan

1. Motivation
2. **Strategy**
3. Observation
4. Result & Discussion
5. Conclusion

Strategy for Simultaneous Observations?

1. ***Known repeaters***

   Because we need to know their coordinates in advance

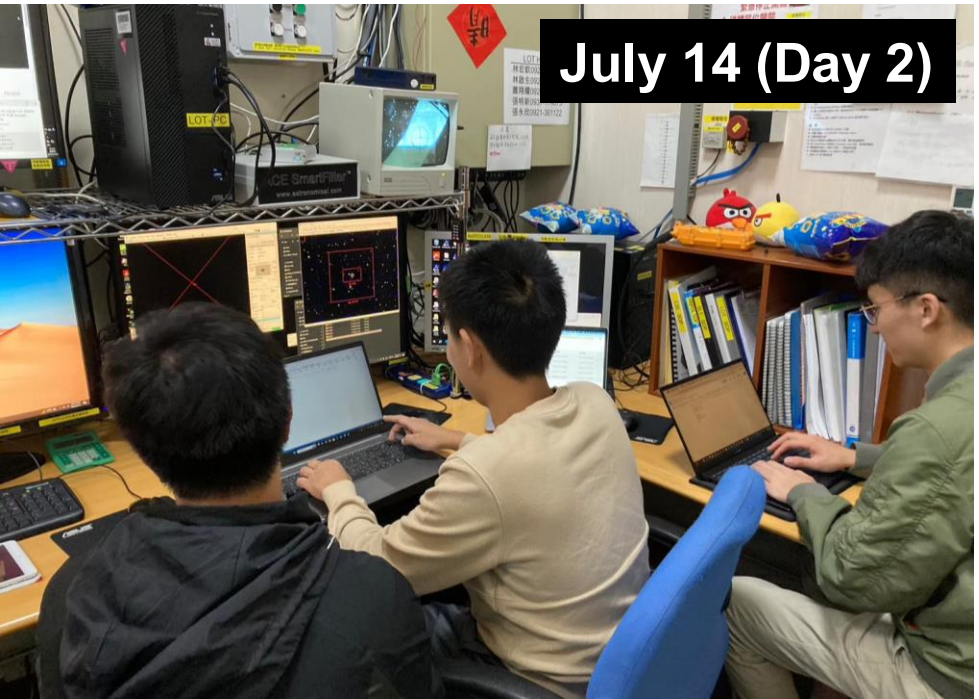
2. ***Repeaters must be active to secure FRB detections***

   Because we constrain the prompt multiwavelength nature of FRBs
   → high-sensitivity in radio → ***FAST! (500m)***

3. ***Flexible optical telescopes with CMOS camera***

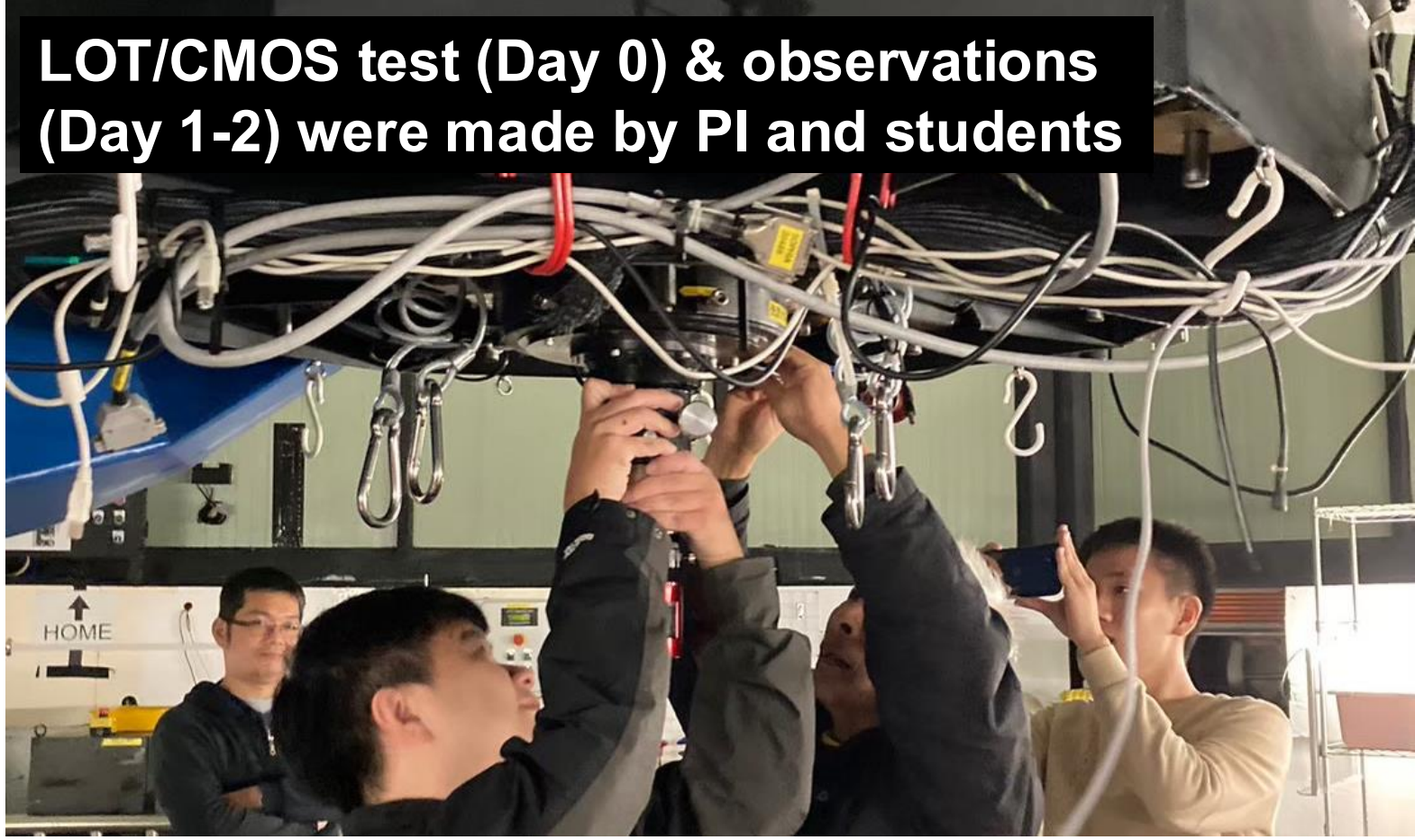
   Because repeaters have time-dependent burst activity
   → ToO → ***Lulin Observatory Telescope! (1m)***

July 7 (Day 1)



July 14 (Day 2)

LOT/CMOS test (Day 0) & observations (Day 1-2) were made by PI and students



Jan 10 (Day 0)

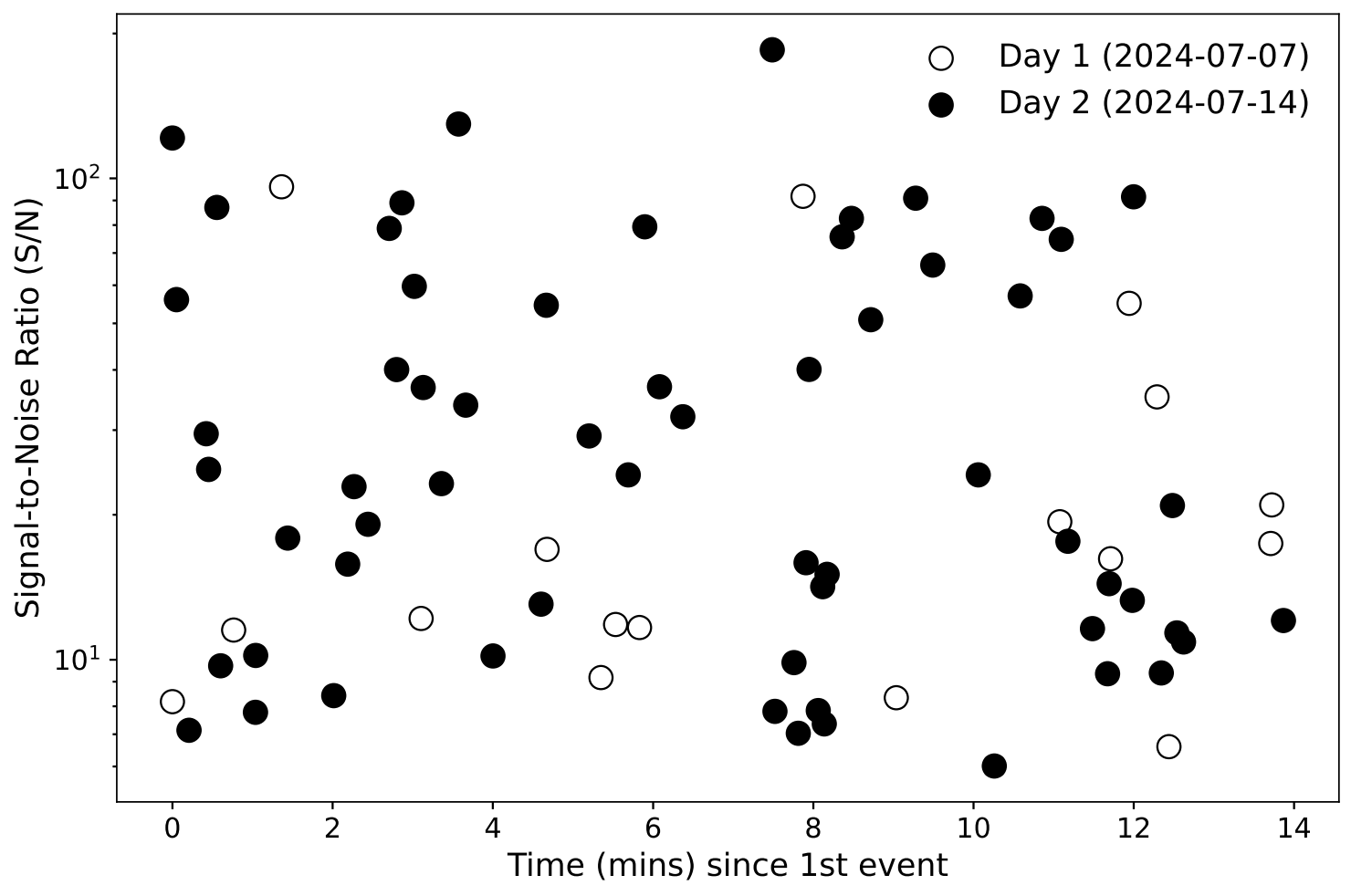

Photo: Yu-An Chen

Talk Plan

1. Motivation
2. Strategy
3. Observation
4. **Result & Discussion**
5. Conclusion

>78 Bursts Detected by FAST !

Credit: SY / Courtesy: Junshuo Zhang



- ***17 bursts within 20 min on 7 July***
- ***61 bursts within 20 min on 14 July***

Very active ~100 hr^{-1} (detection almost guaranteed in radio) but still ***epoch dependent***

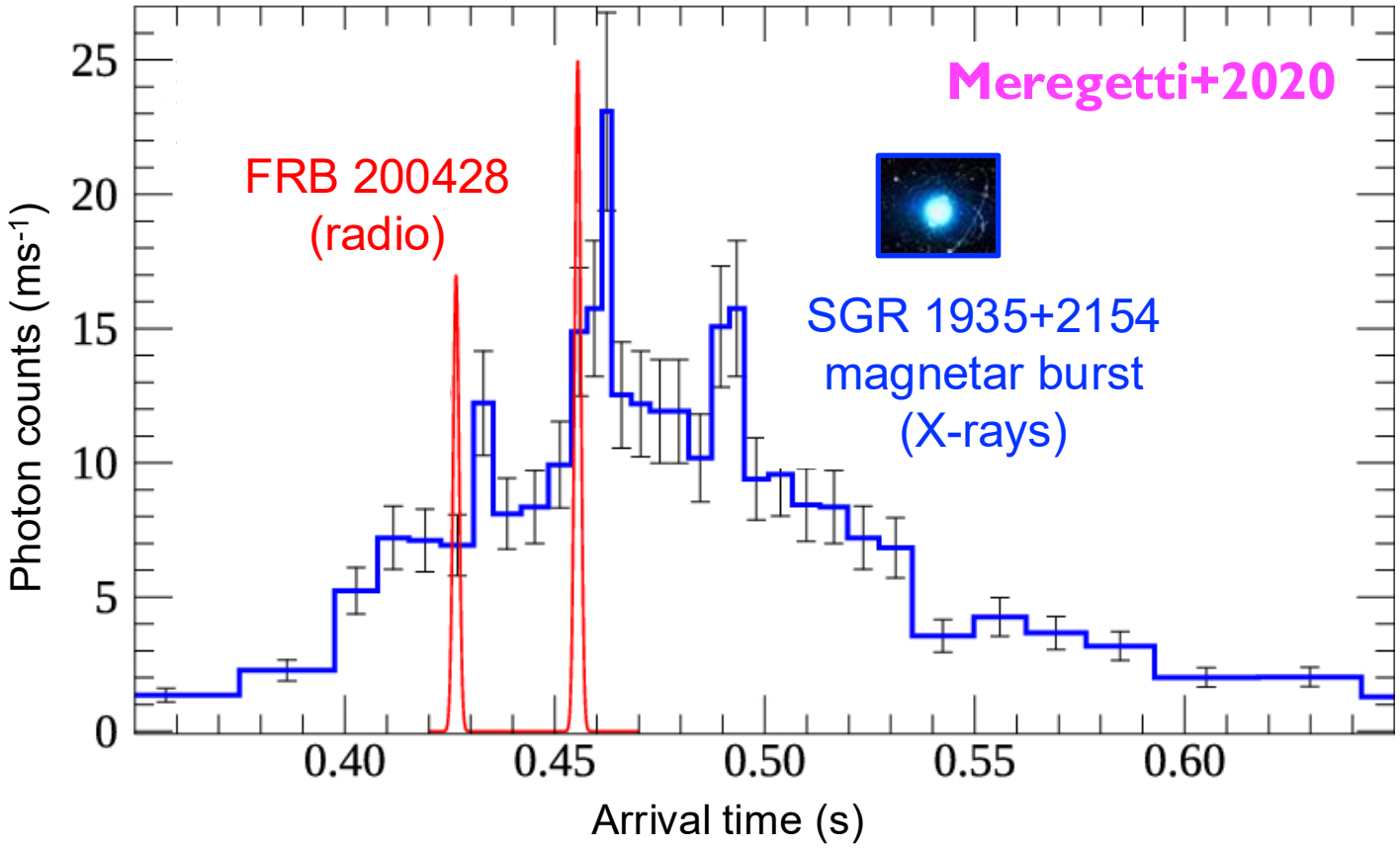

Photo: Yu-An Chen

Talk Plan

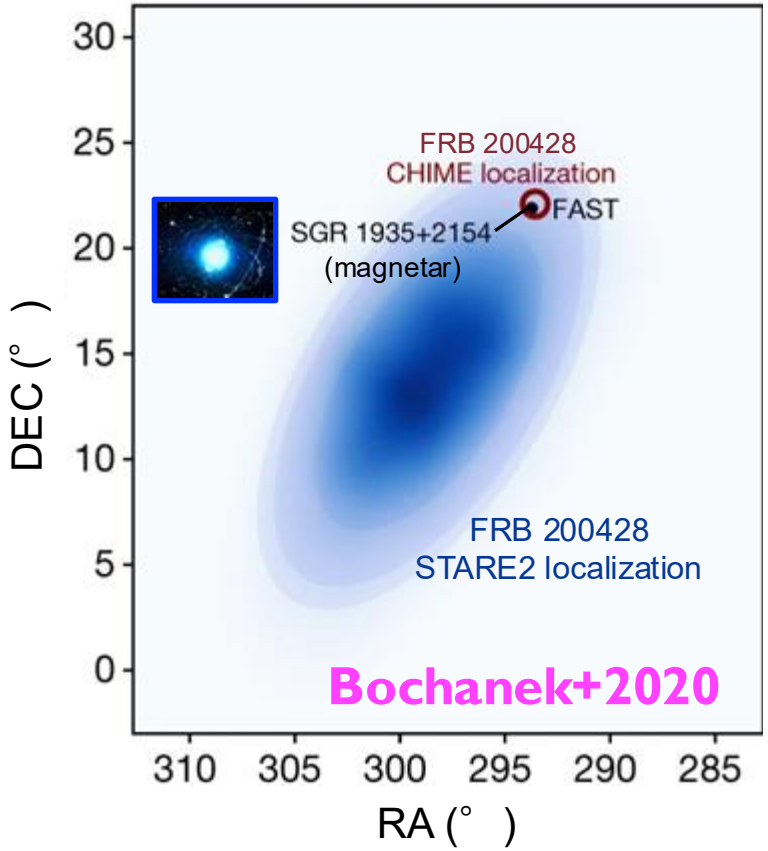
1. Motivation
2. Strategy
3. Observation
4. Result & Discussion
5. Conclusion

A “Galactic” Event on 28 April 2020

Temporal coincidence



Spatial coincidence

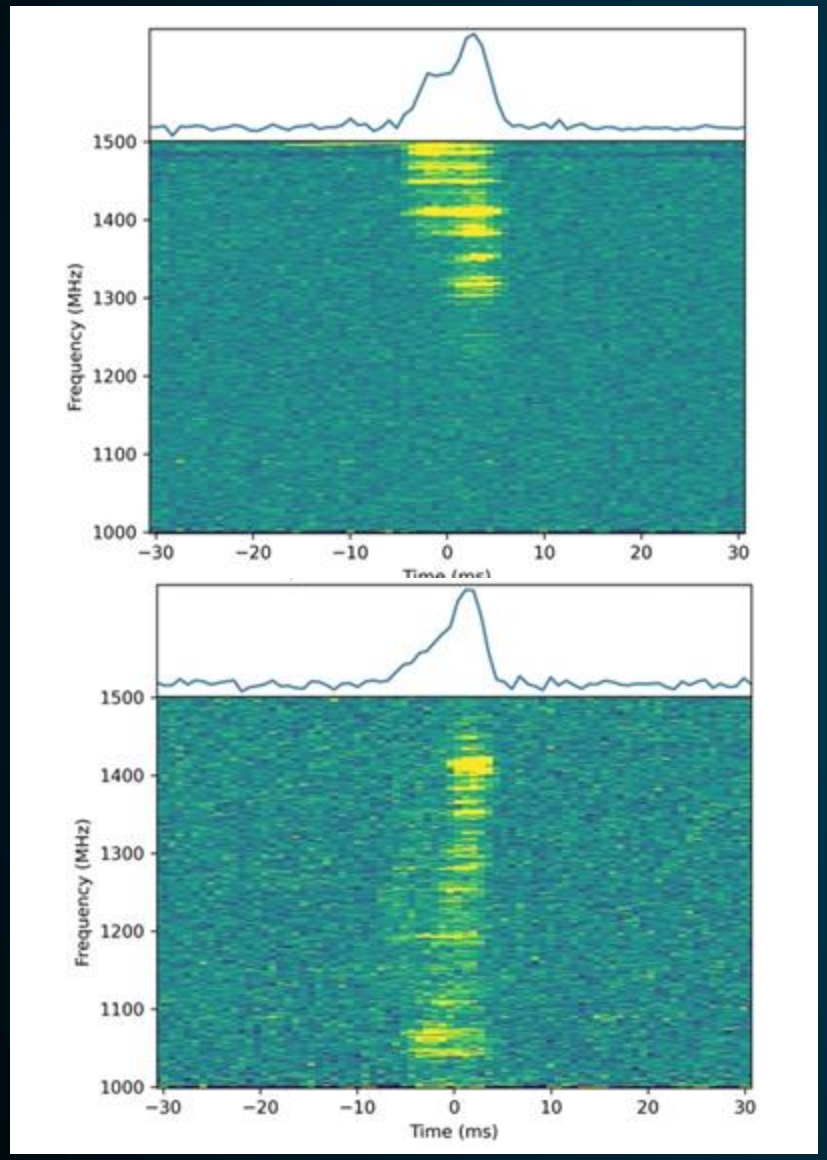


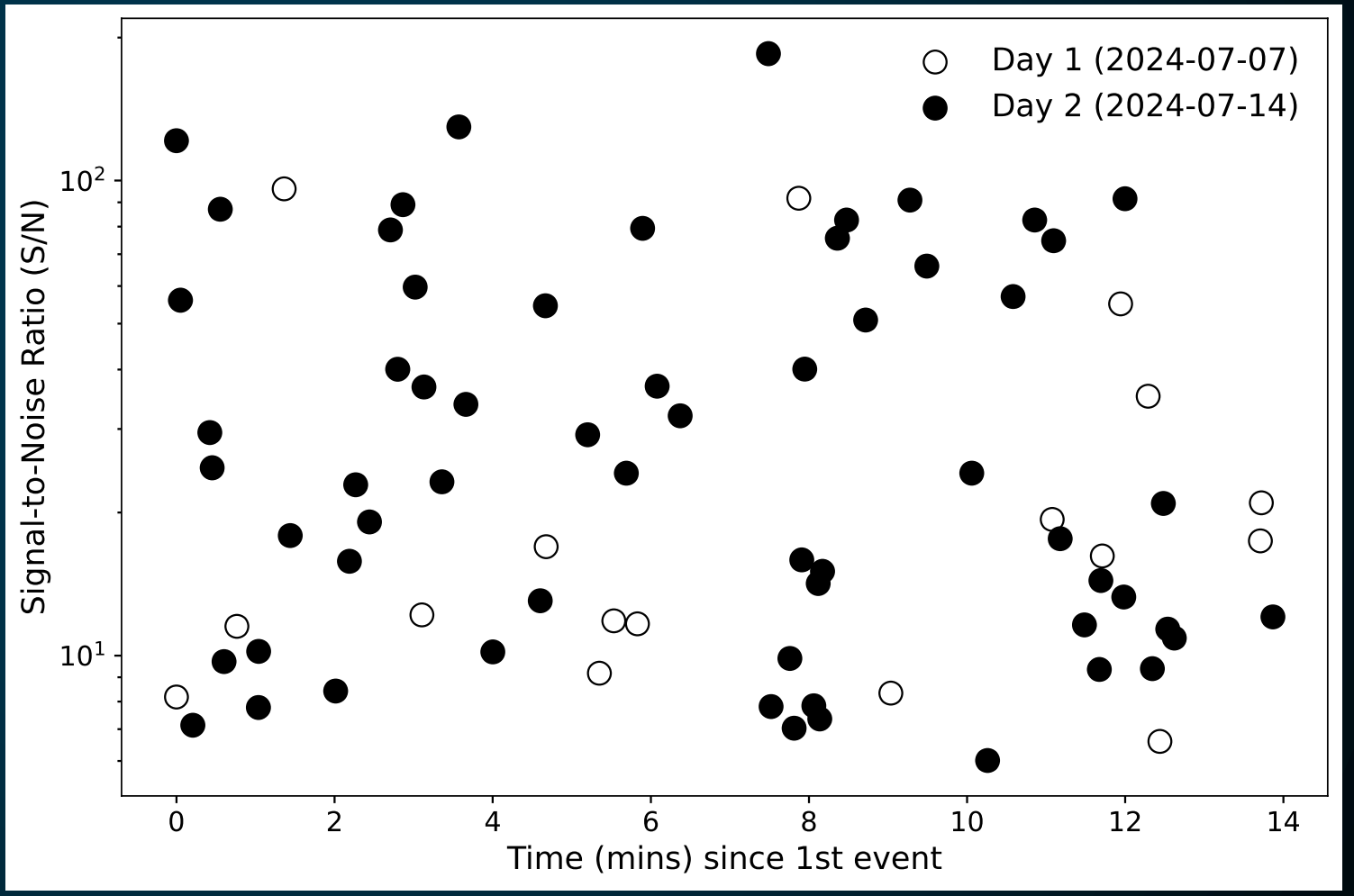
Understanding **FRB-magnetar connection** becoming very important!

>78 Bursts Detected by FAST

17 bursts within 20 min on 7 July

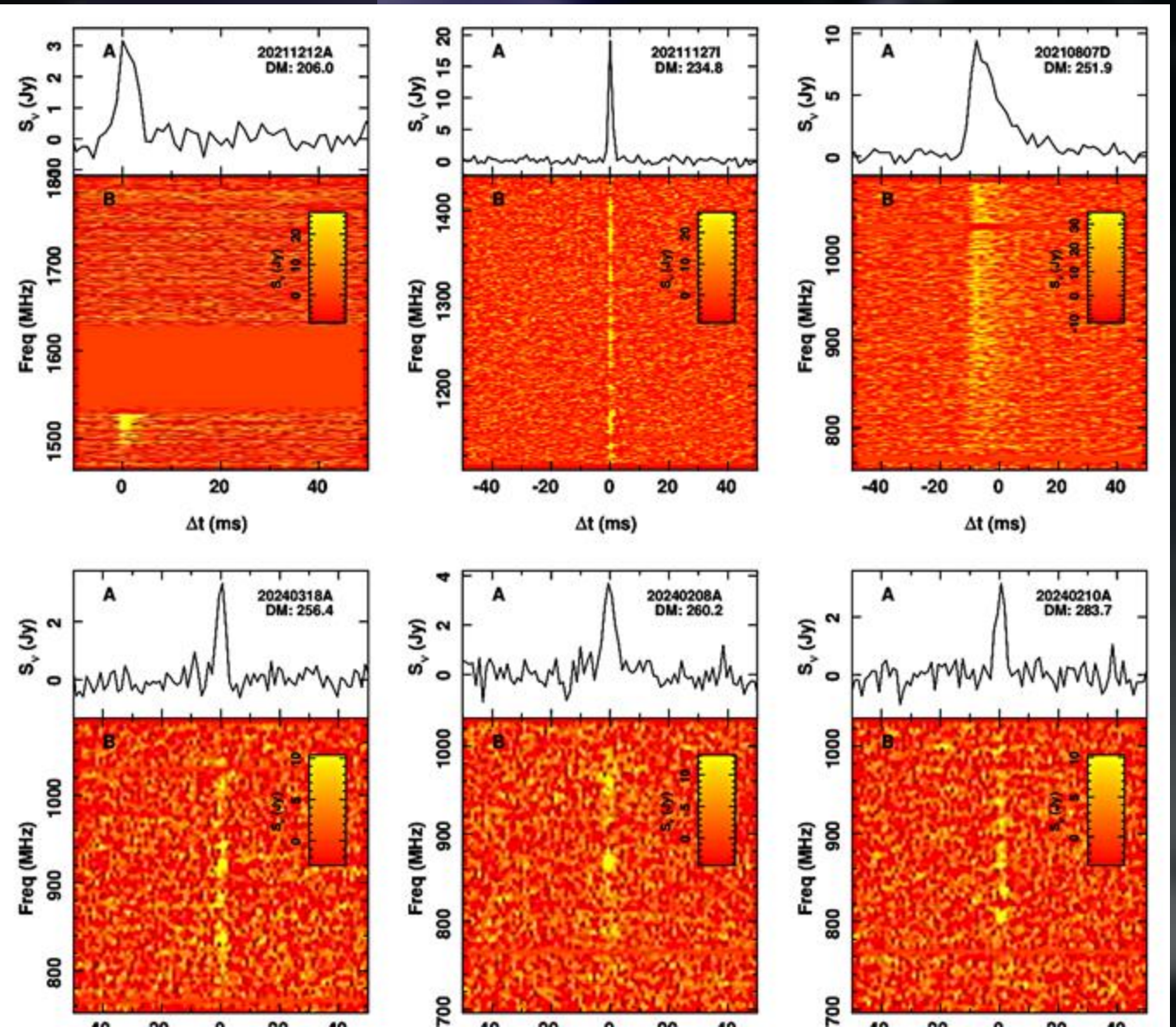
61 bursts within 20 min on 14 July

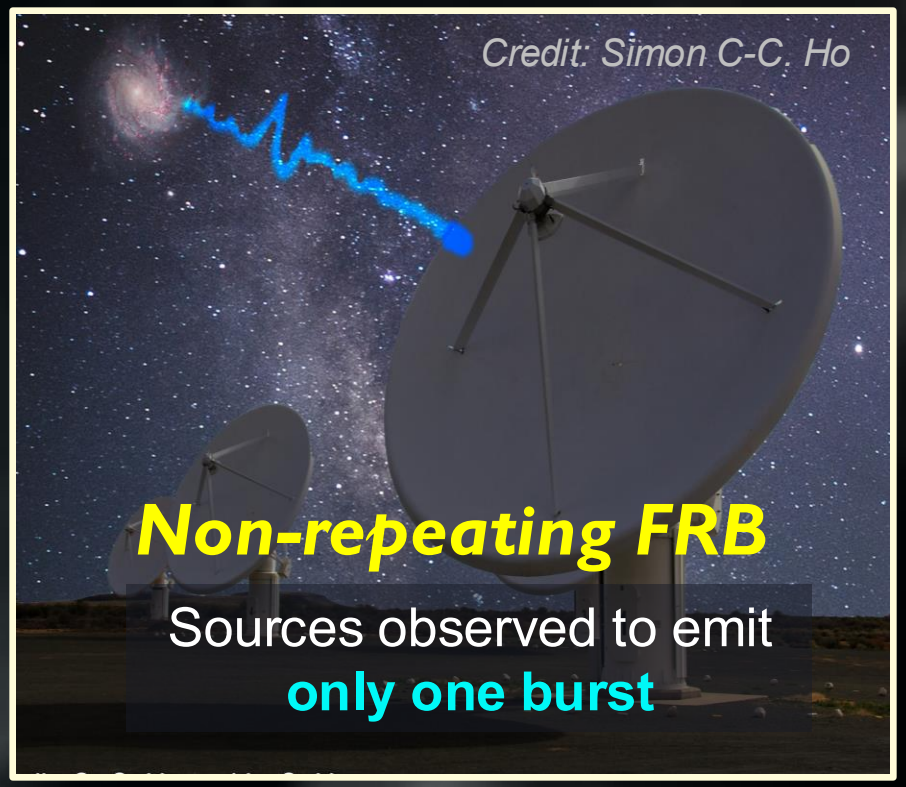




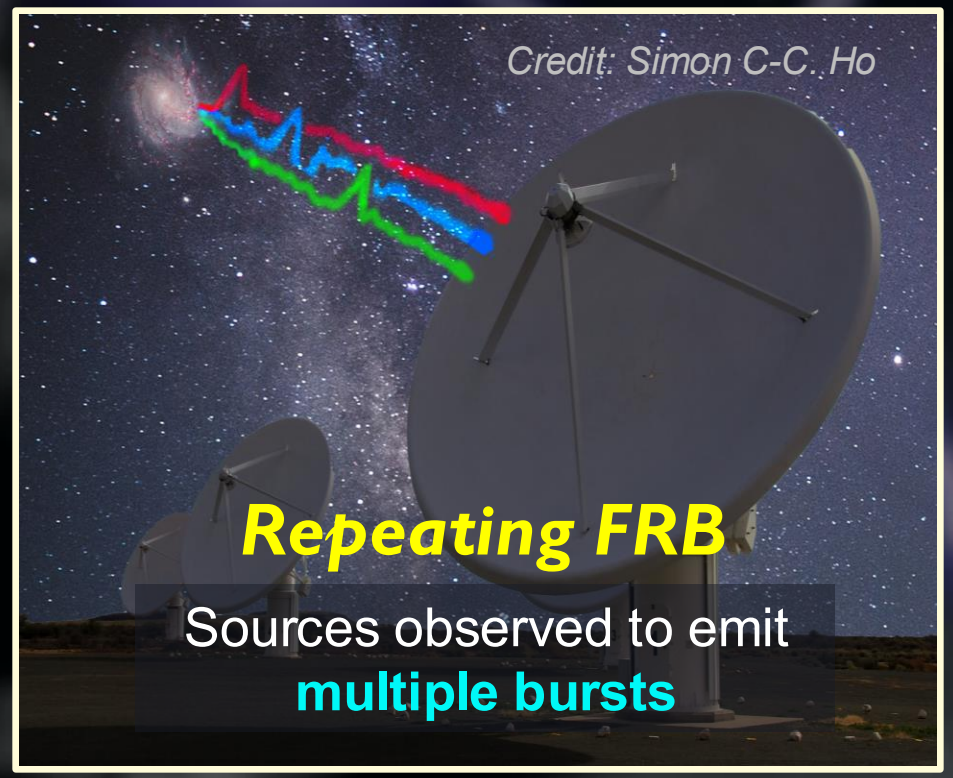
Repeaters vs non-repeaters

Shannon+24

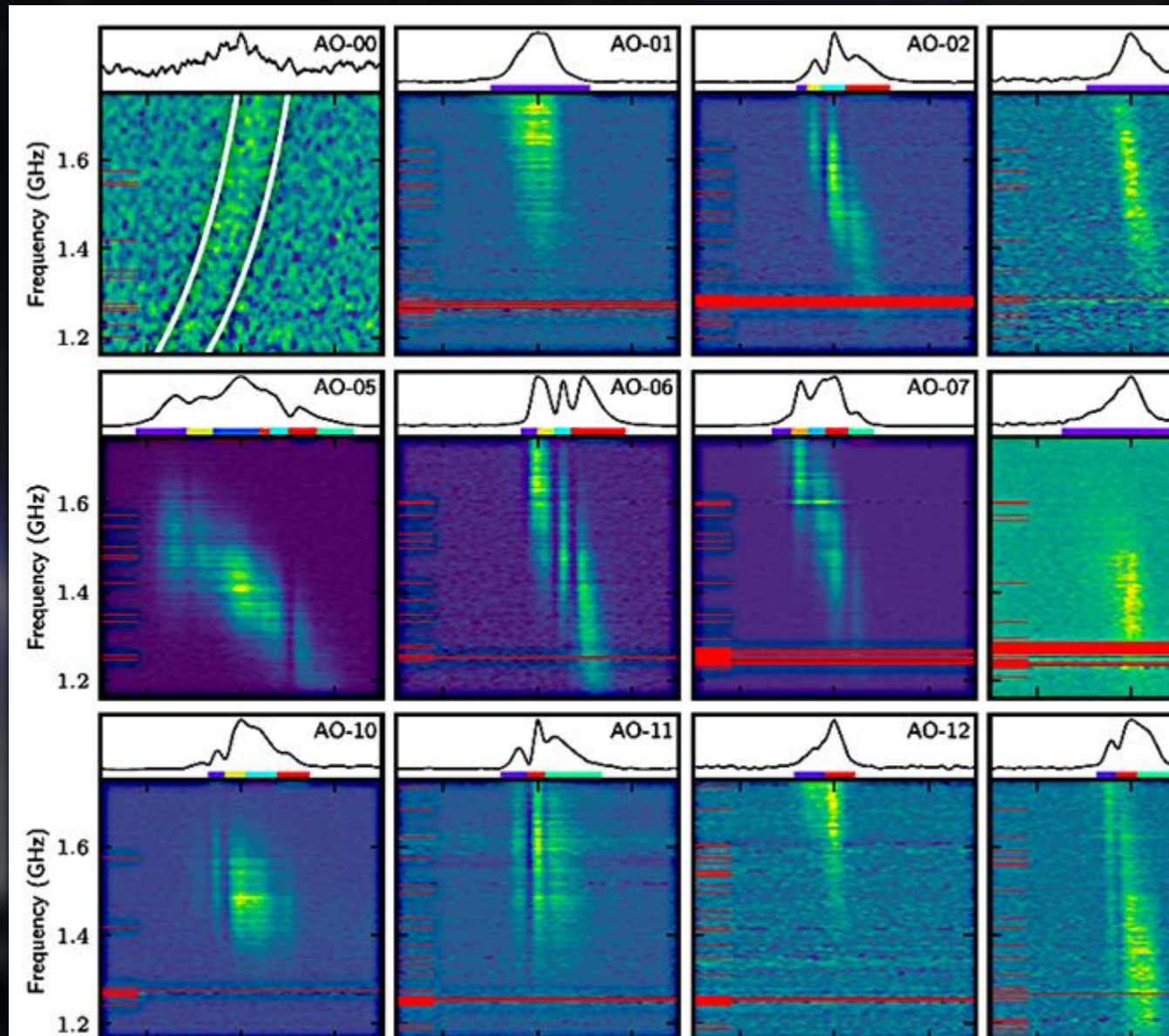




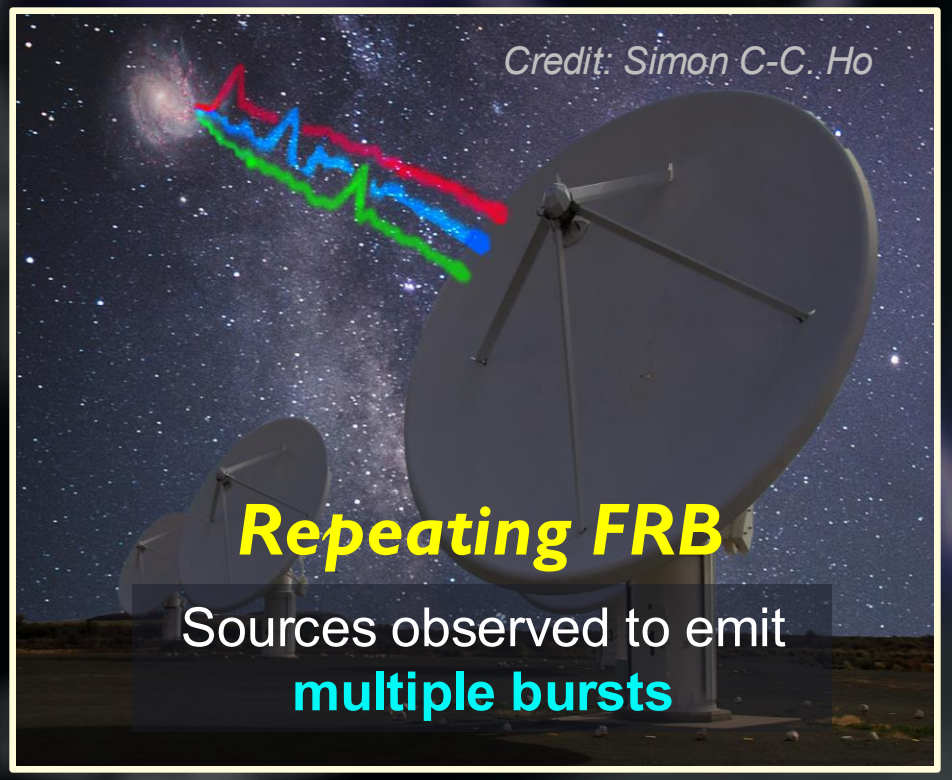
Repeaters vs non-repeaters



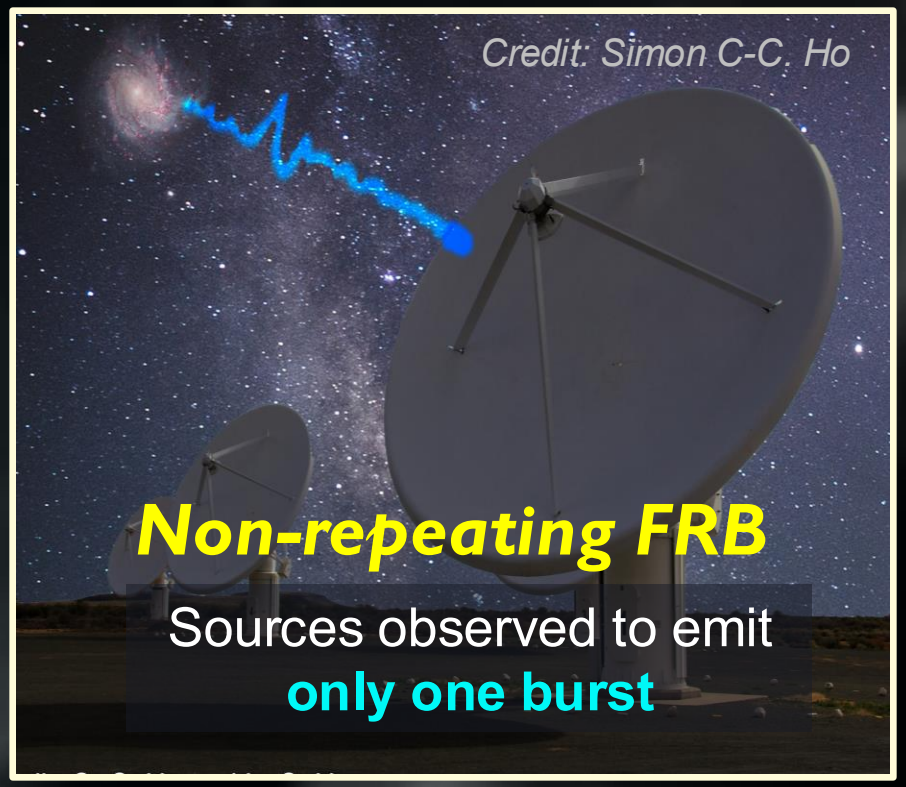
Hessels+19



Repeaters vs non-repeaters



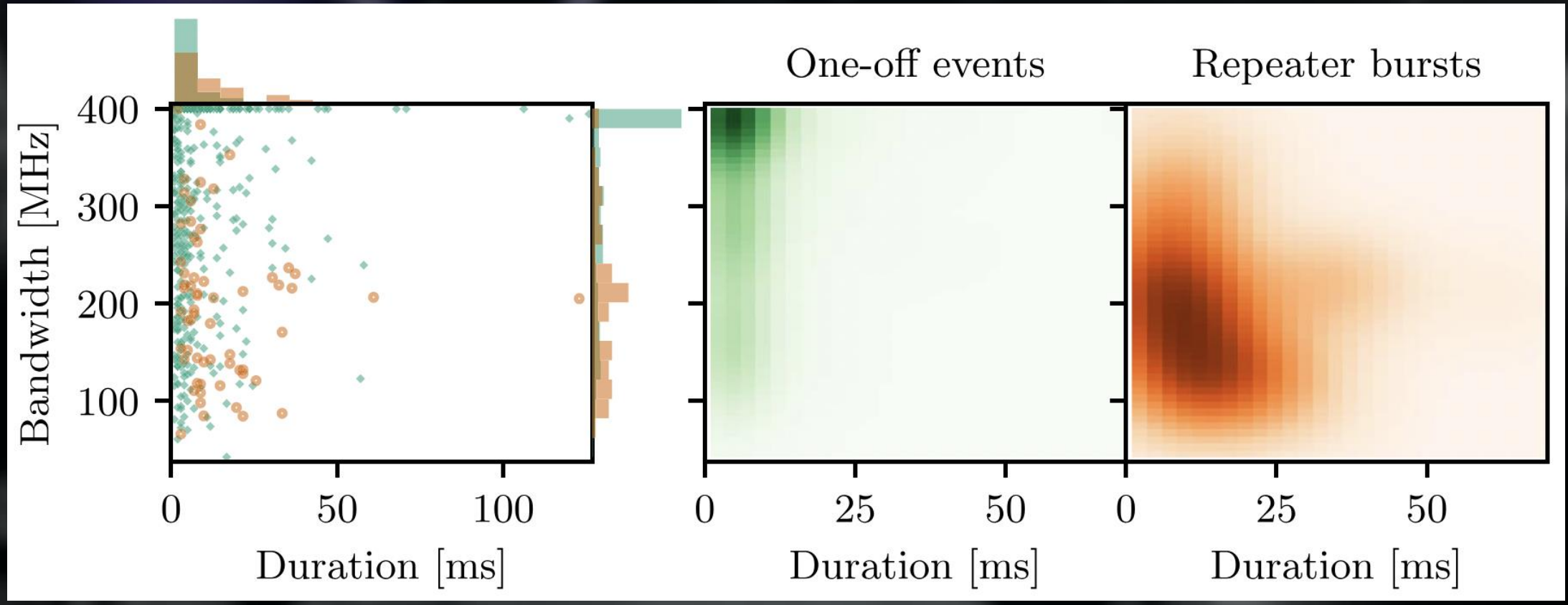
VS



Two types, different origins? Do all FRBs repeat?

Their burst properties look different…

Pleunis et al. 2021 (see also CHIME/FRB C. et al. 2021)



Statistically different properties - intrinsic to the population ?

Statistically-dominant FRB surveys

CHIME

~ 600 "sources"
(will be ~ 3,000 soon)

FAST

~> 6,000 "bursts"
from several repeaters

Arecibo (R.I.P.)

~ 1,500 "bursts"
from 1 repeater

Large-FoV uniform survey of "many unlocalized" sources

→ Population study (PART I)

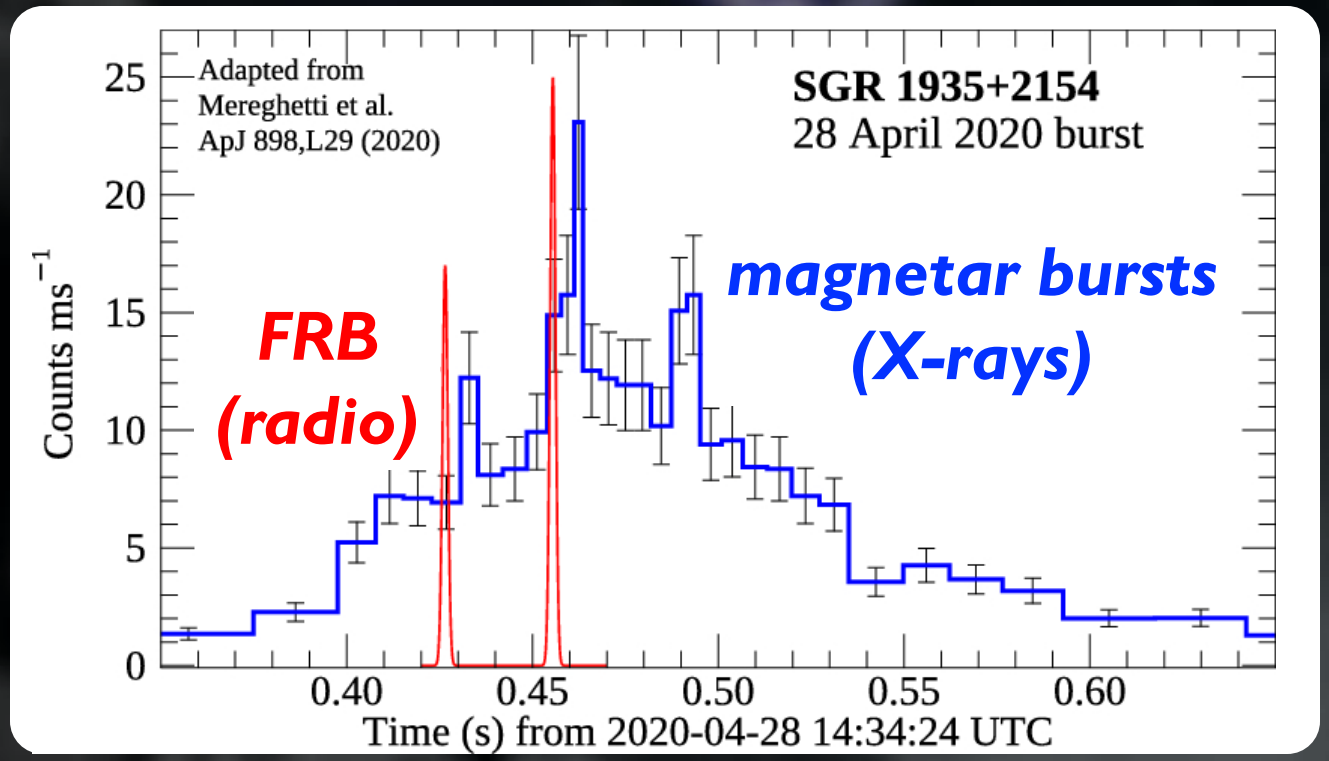
High-sensitivity monitoring of "some localized" active repeating sources

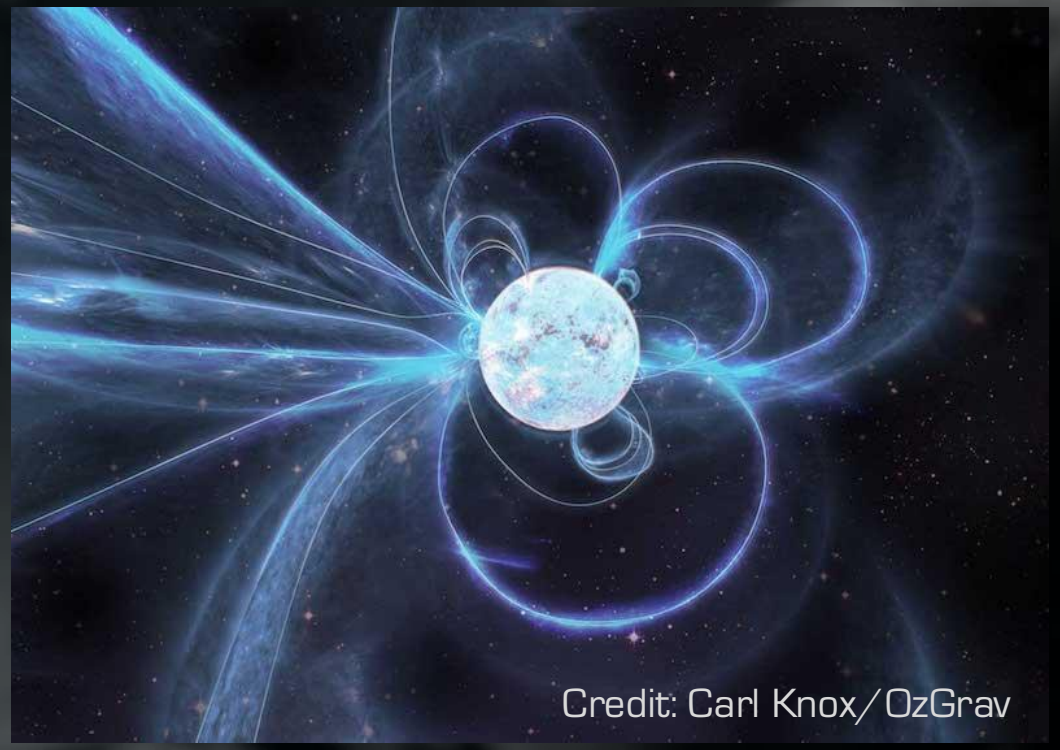
→ Repeating source study (PART II)

A Special Galactic FRB Event from Magnetar Bursts

Magnetars (strongly-magnetized neutron stars): One of the origins

Bochenek+ 20, CHIME/FRB+ 20, Mereghetti+ 20, Li+ 20, Ridnaia+ 20, Tavani+ 20



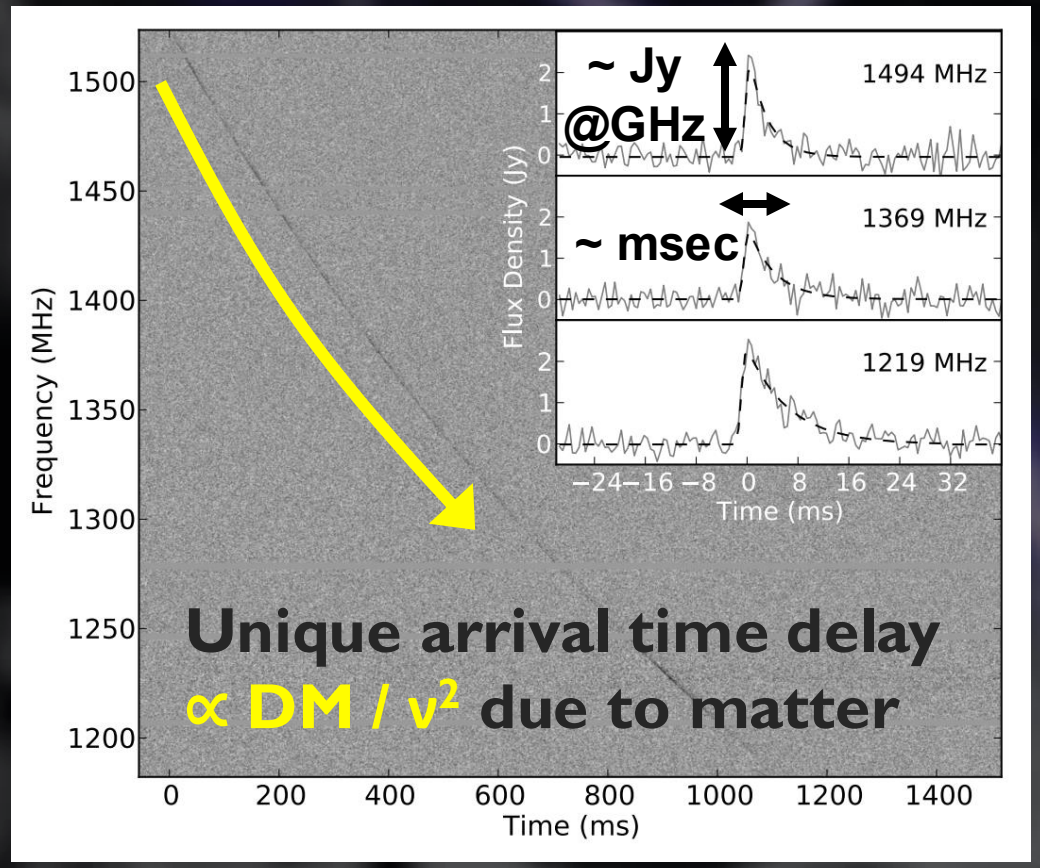


However, origins for extragalactic FRBs remain unknown…

Cosmological Fast Radio Bursts (= FRBs)

Brightest radio flashes!

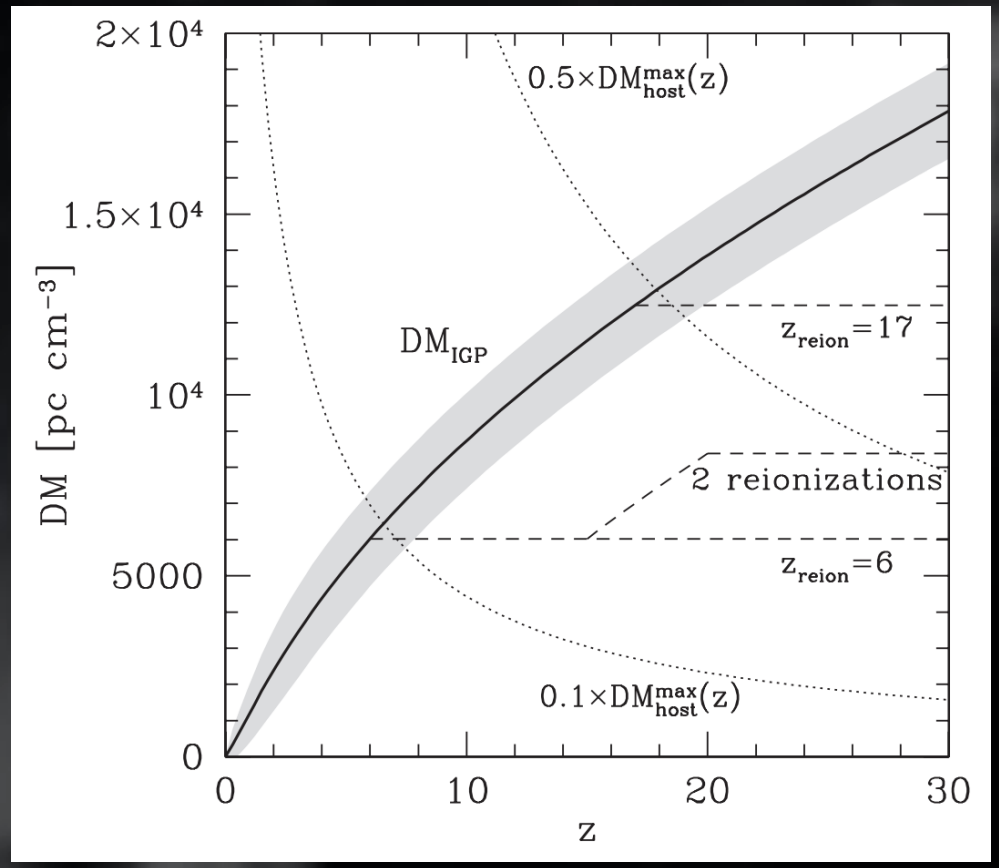
Extremely high $T_B = 10^{32\text{-}36}$ K



Lorimer+07, Thornton+13, and many

FRB Cosmology!

Huge dispersion measure → z



Ioka 03, Inoue 04, Macquart+20, and many