Volumetric rate density of fast radio bursts and its evolution with redshift from CHIME/FRB Catalog 2

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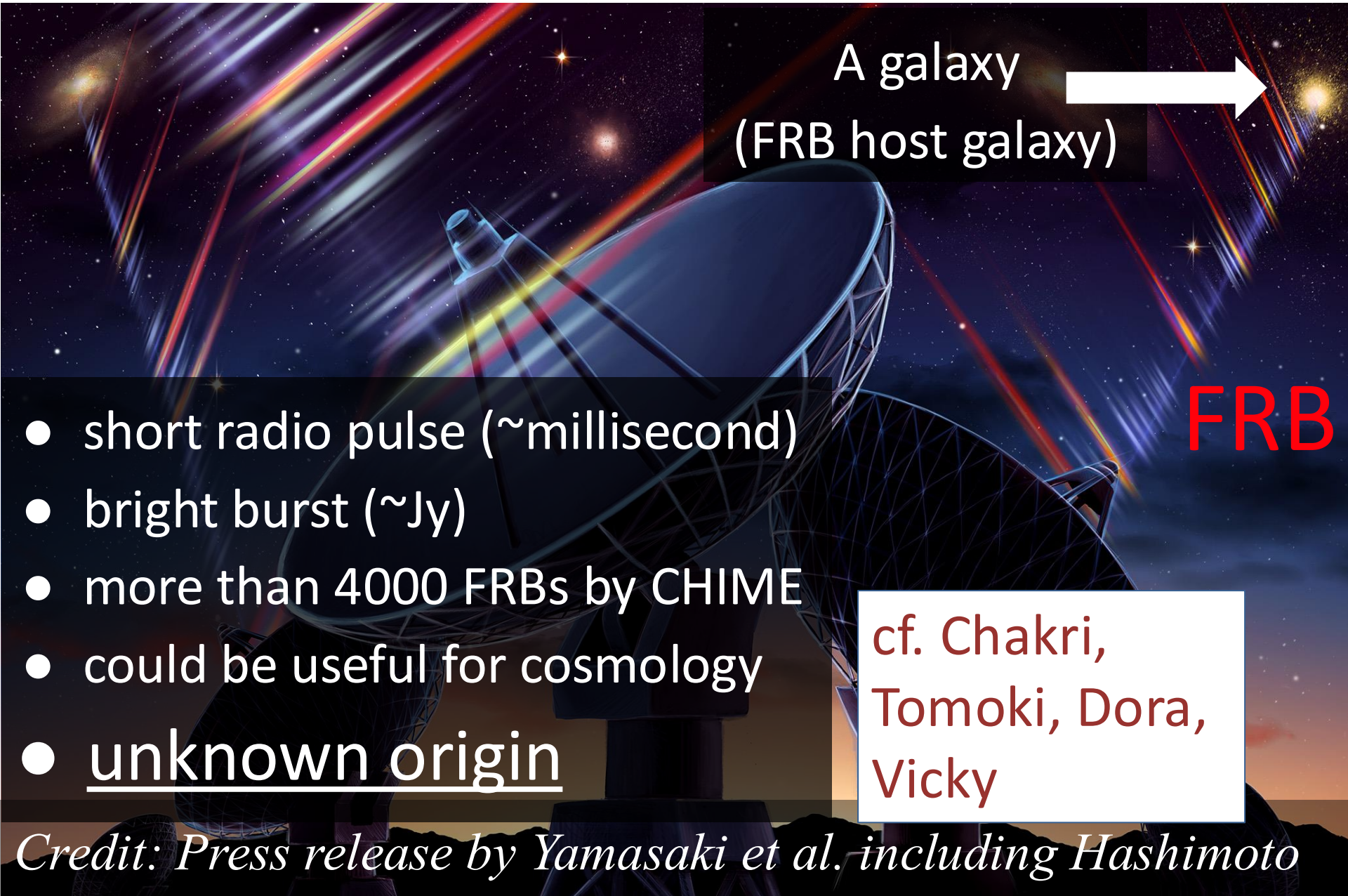
in prep.

16 May 2026@ASROC

Intro: Fast radio burst (FRB)



- short radio pulse (~millisecond)
- bright burst (~Jy)
- more than 4000 FRBs by CHIME
- could be useful for cosmology
- <u>unknown origin</u>

cf. Chakri, Tomoki, Dora, Vicky

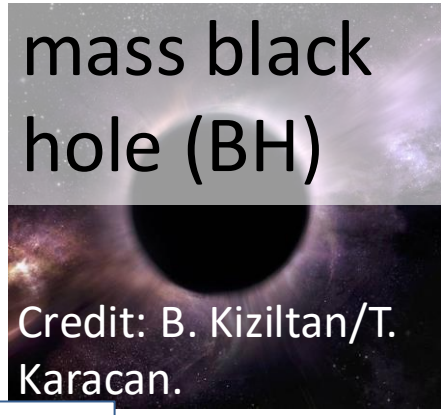
Credit: Press release by Yamasaki et al. including Hashimoto

Introduction: possible FRB progenitors

White dwarf

Neutron-star binary

Old stellar-mass black hole (BH)



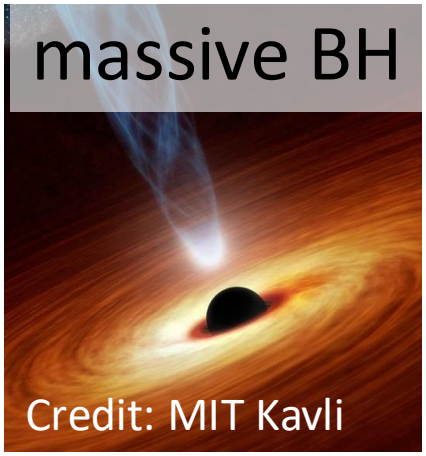
?

cf. Sherry, Ryan

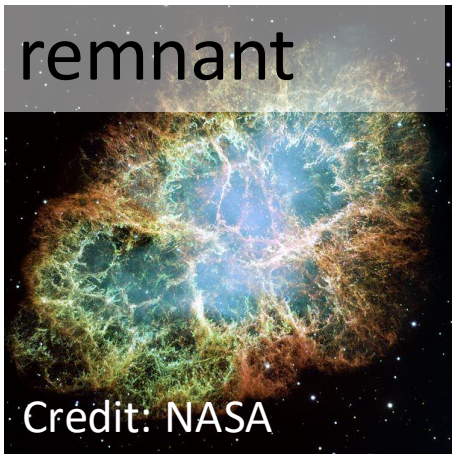
Magnetar

Young pulsar

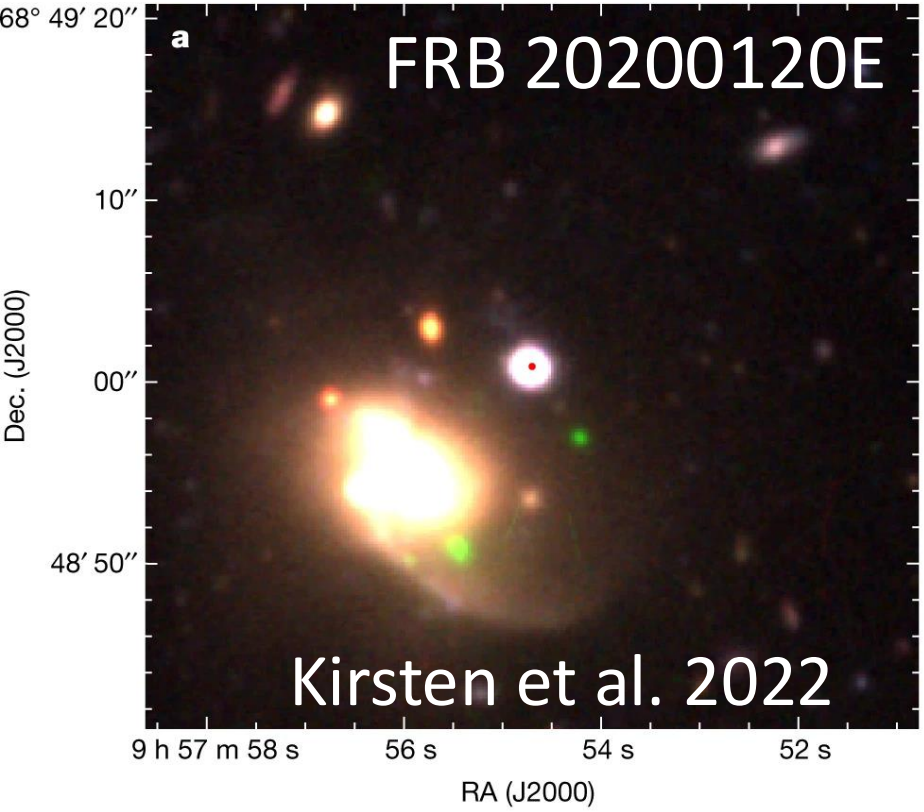
Super massive BH



Supernova remnant

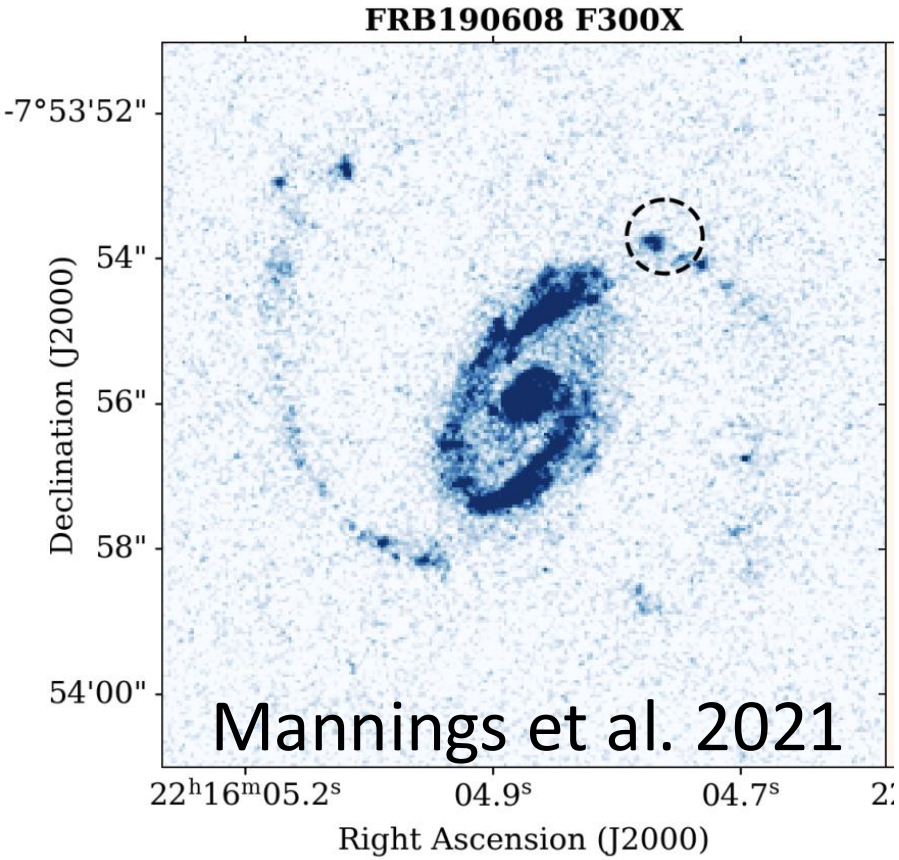


Hosts can constrain the progenitor type



Globular cluster in M81

Old objects?



on a spiral arm

Young objects?

The host studies are powerful. However...

Problem

The number of identified host galaxies is
< 10% of the whole FRB samples,
e.g., ~133 host out of ~4000 FRBs

Solution (this work)

We focus on the history of the FRB rate
(x10 more samples than the host samples)

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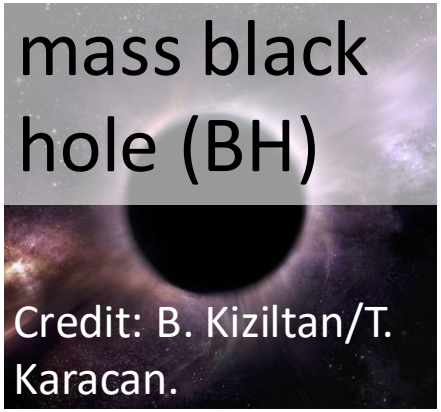
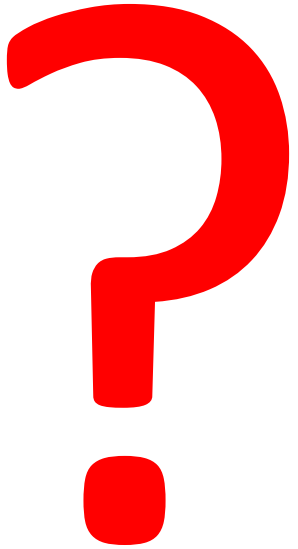
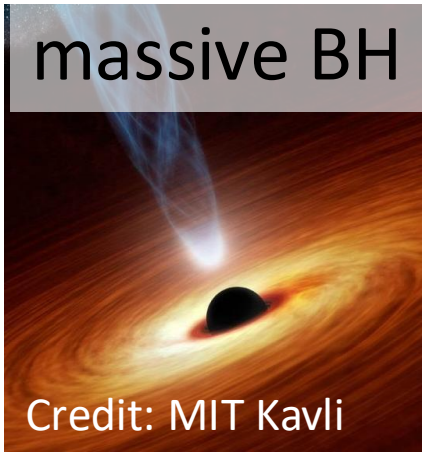




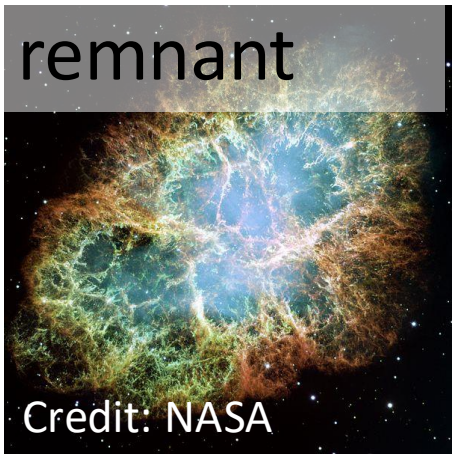
Magnetar

Young pulsar

Super massive BH



Supernova remnant



Introduction: possible FRB progenitors

White dwarf

Credit: Tetsuya Hashimoto

Neutron-star binary

Credit: NSF/LIGO

Old stellar-mass black

Credit: B. Kiziltan/ I. Karacan.

Old objects ∝ stellar mass

?

Magnetar

Young pulsar

Super massive BH

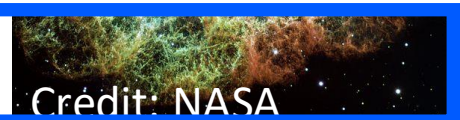
Supernova remnant

Young objects ∝ star formation

Credit: Tetsuya Hashimoto

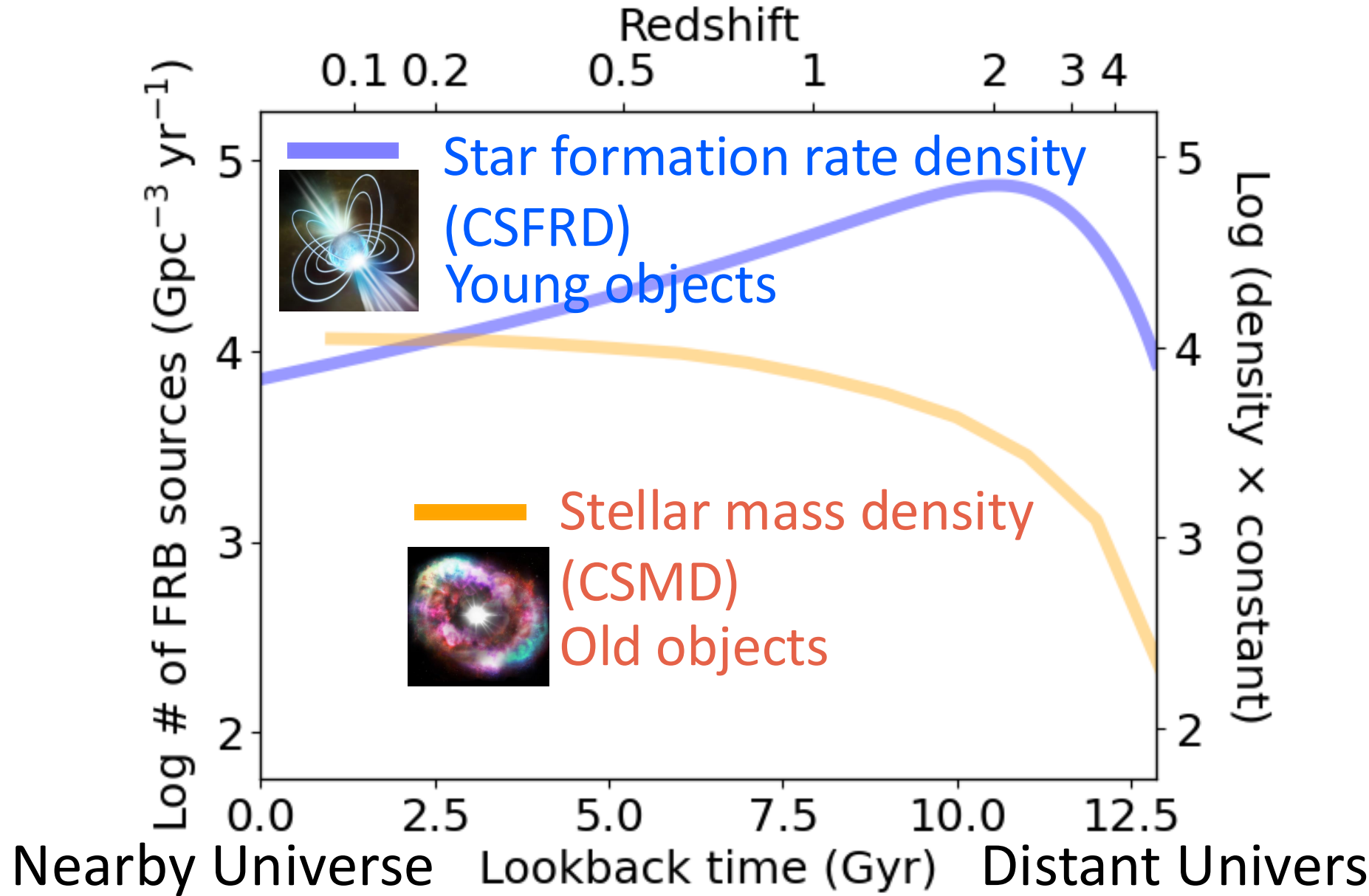
Credit: Nature astronomy

Credit: MIT Kavli



Credit: NASA

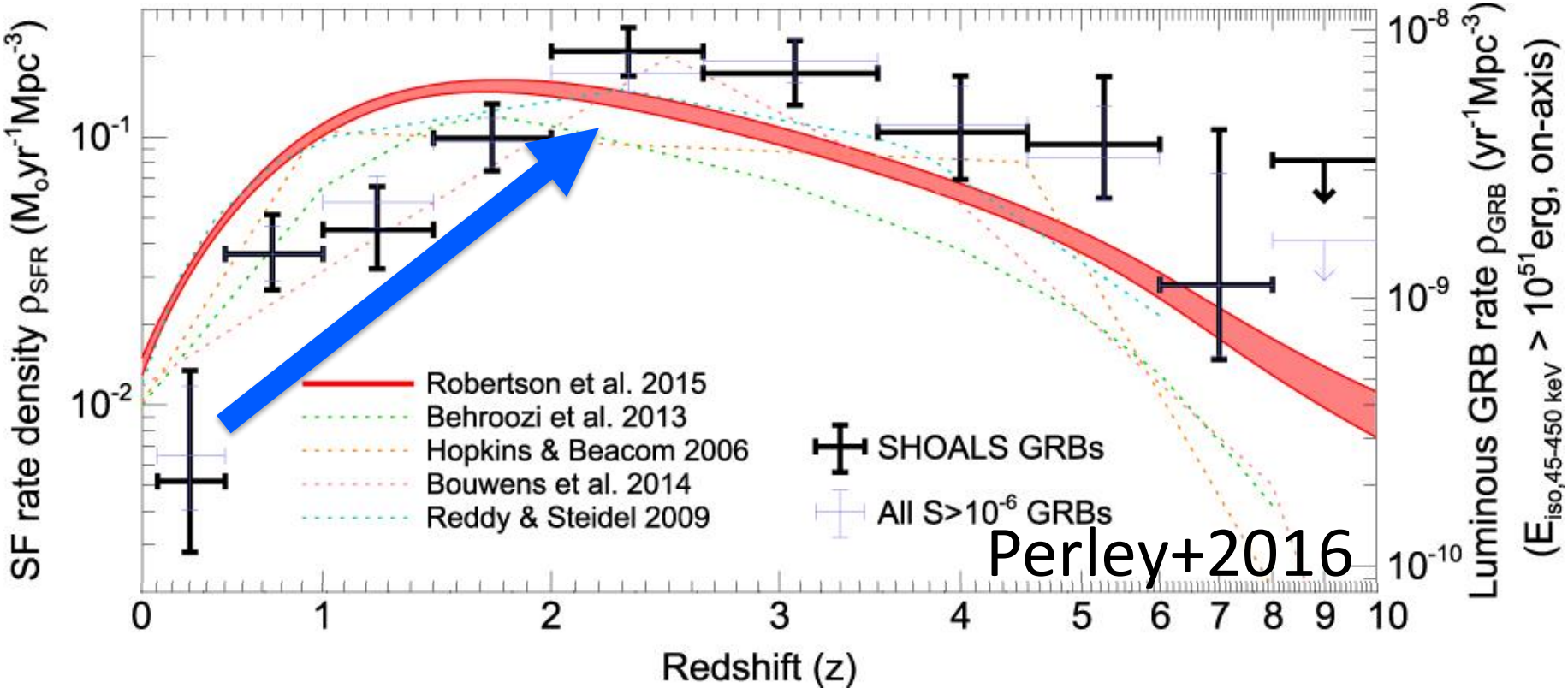
Introduction: Old vs Young



Introduction: Example (LGRBs)

Long Gamma-ray bursts

$\propto$ star formation



Introduction: Example (LGRBs)

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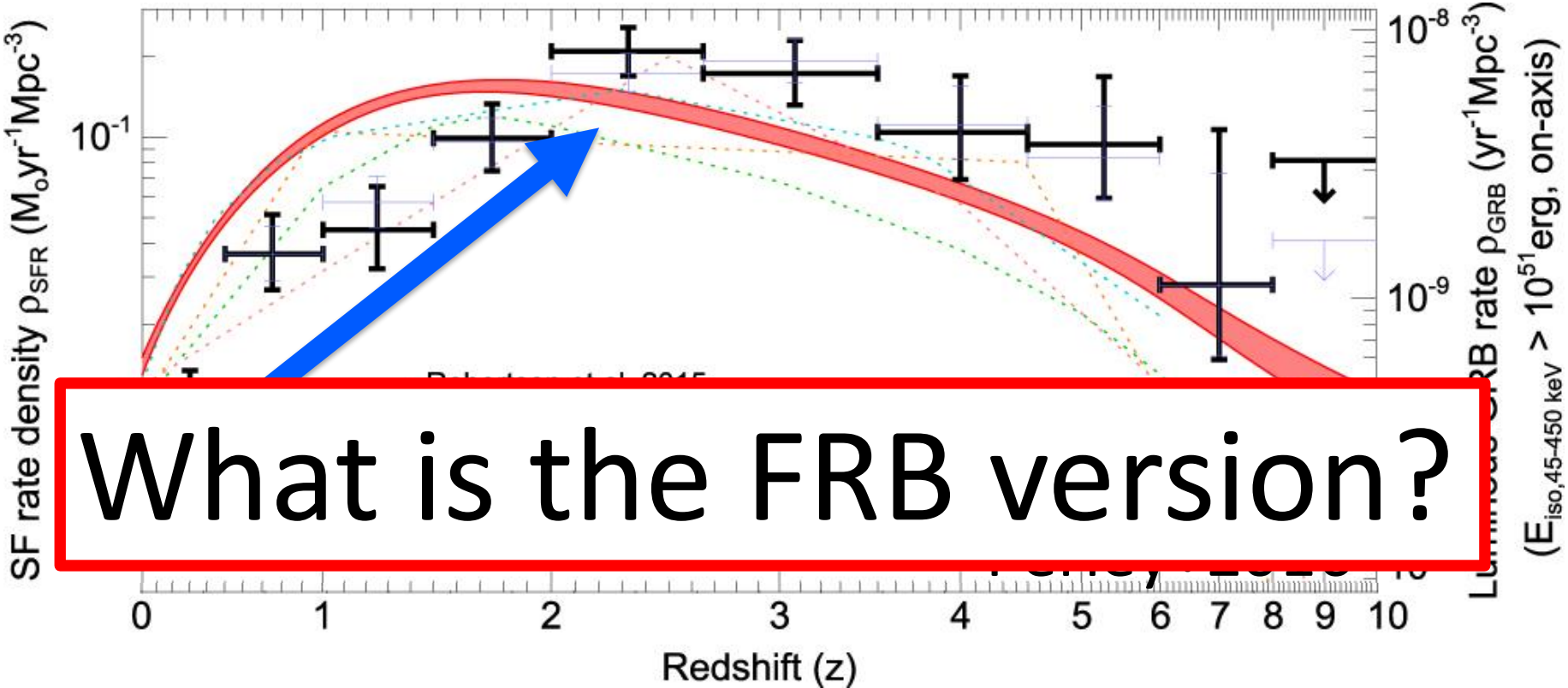


What is the FRB version?

Two approaches to the FRB rate density

- Model-dependent method

assuming FRB rate $\propto$ CSFRD$^{\alpha}$ or CSMD$^{\alpha}$

→ fit the model to DM/fluence distributions

This work

- Model-independent method

Vmax method

→ commonly used for extragalactic sources

→ direct measurements of FRB rate density as a function of redshift

Introduction: previous works

→ no conclusive answer yet

Author	free of the z-evolution assumption?	test an old population scenario?	sample	homogeneous sample?	conclusion
TH+2022	Yes	Yes	CHIME1	Yes	Old pop.
Zhang&Zhang 2022	No	Yes	CHIME1	Yes	Old pop.
James+2022	No	No	ASKAP/ Parkes	No	Young pop.
Arcus+2021	No	Yes	ASKAP/ Parkes	No	Both young and no-evo pops.
Zhang+2021	No	Yes	ASKAP/ Parkes	No	Both pops.
TH+2020c	Yes	Yes	Parkes	Yes	Old. pop.

Let’s use CHIME/FRB cat 2

>4000 FRBs!

Credit: CHIME

Sample selection for non-repeaters

Select FRBs for which
the observational completeness is well estimated

(i) $bonsai\_snr > 10$

(ii) $\mathrm{DMobs} > 1.5 \times \max(\mathrm{DM_{NE2001}}, \mathrm{DN_{YMW16}})$

(iii) not detected in far side-lobes

(iv) $\log \tau_{\mathrm{scat}} < 0.8$ (ms)

(v) $excluded\_flag = 0$

(vi) citizen_science_flag=0

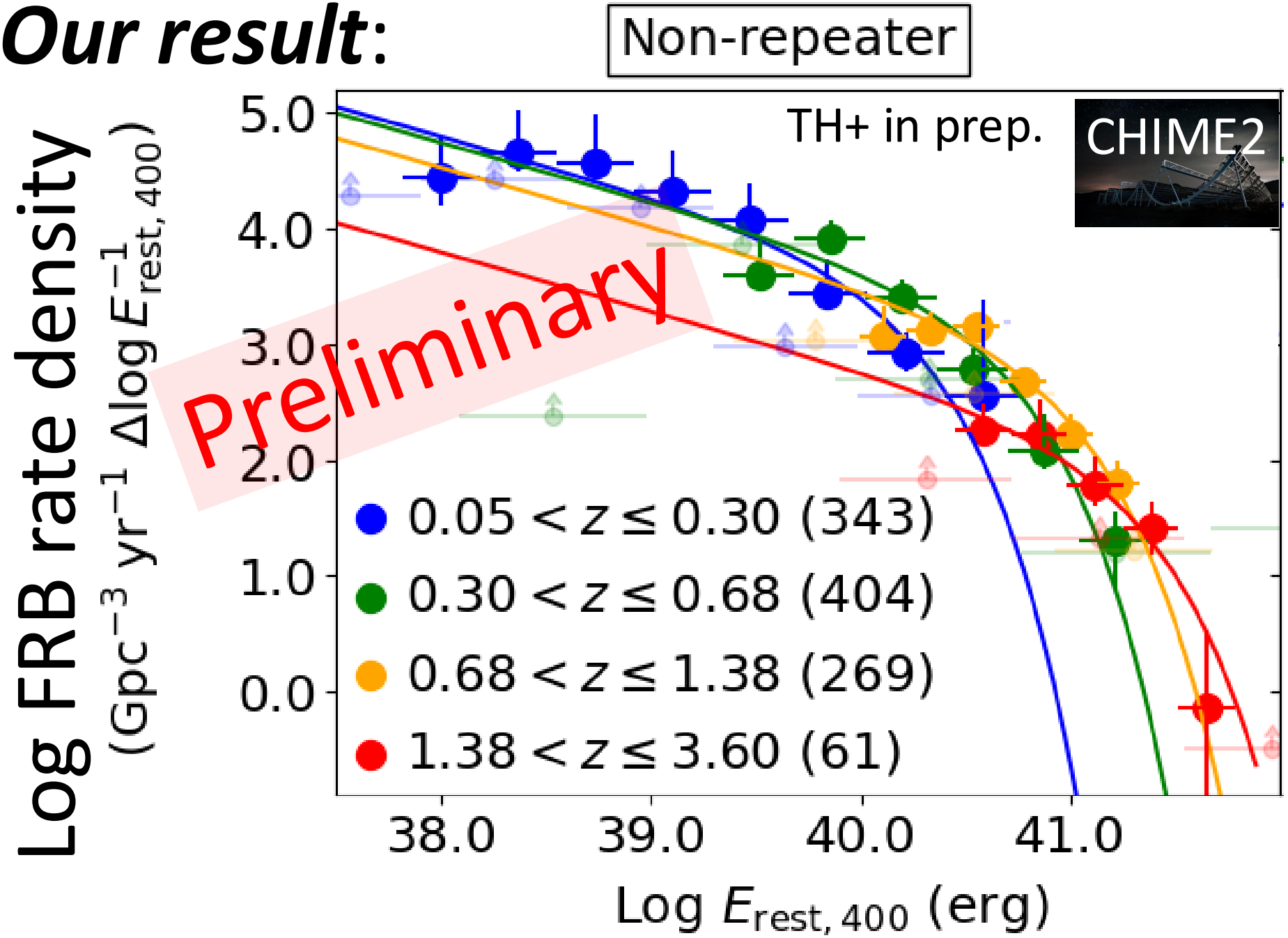
(vii) $\log F_\nu > 0.5$ (Jy ms)

(viii) log (w_{int}/ms) < 1

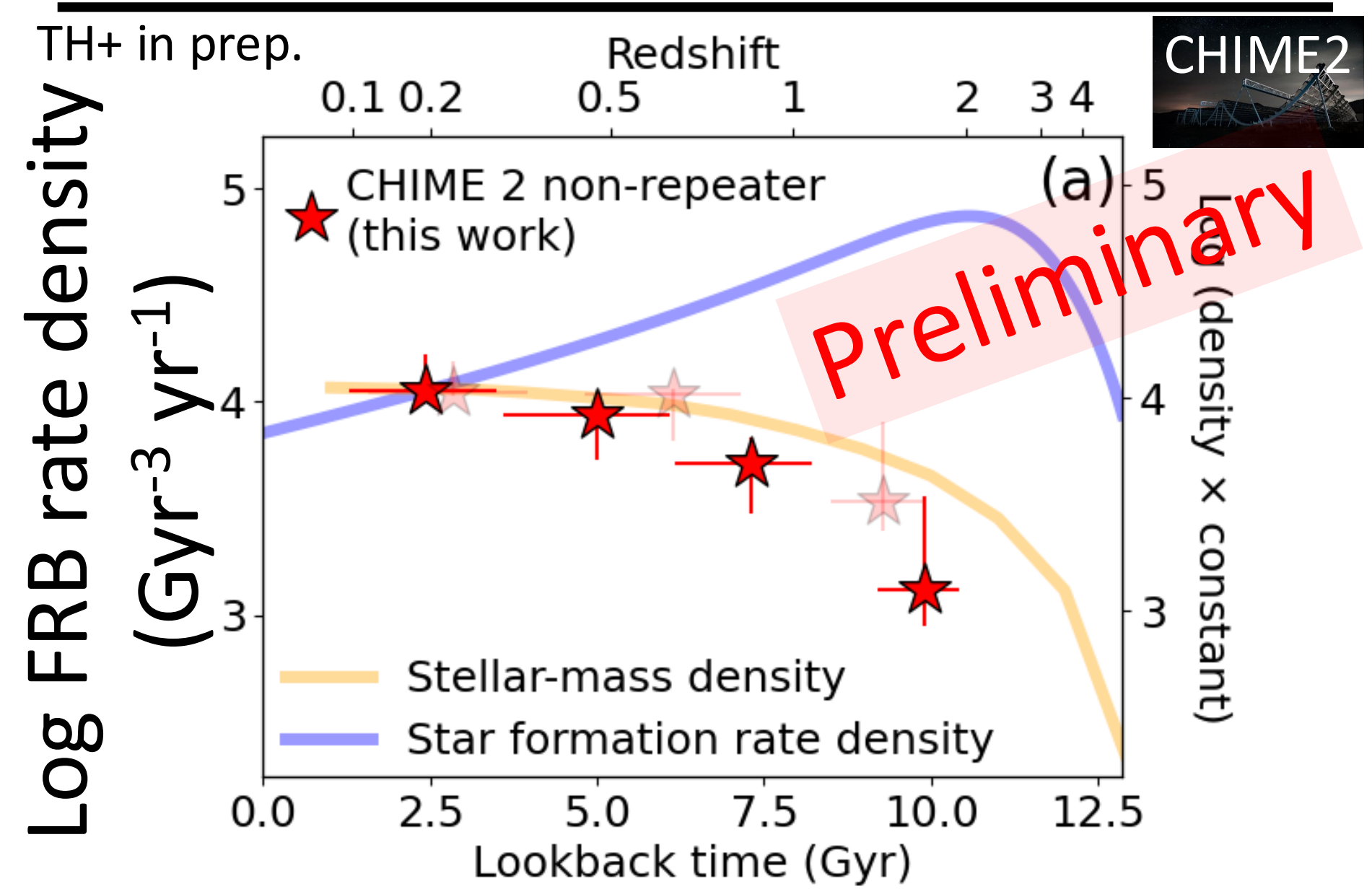
CHIME 1

1077 non-repeaters (x10 more than TH+2022)

***Our result*:**


Non-repeater
TH+ in prep.
CHIME2
Preliminary
Log FRB rate density
(Gpc^{-3} yr^{-1} Δlog $E_{\mathrm{rest,400}}^{-1}$)
5.0
4.0
3.0
2.0
1.0
0.0
$0.05 < z \leq 0.30$ (343)
$0.30 < z \leq 0.68$ (404)
$0.68 < z \leq 1.38$ (269)
$1.38 < z \leq 3.60$ (61)
38.0
39.0
40.0
41.0
Log $E_{\mathrm{rest,400}}$ (erg)

Our result: Non-repeaters → Old?



Conclusion Preliminary

- FRB rate density

→ CHIME 2:

10 times more samples than before

- Vmax method is a model-independent
- Preliminary results:

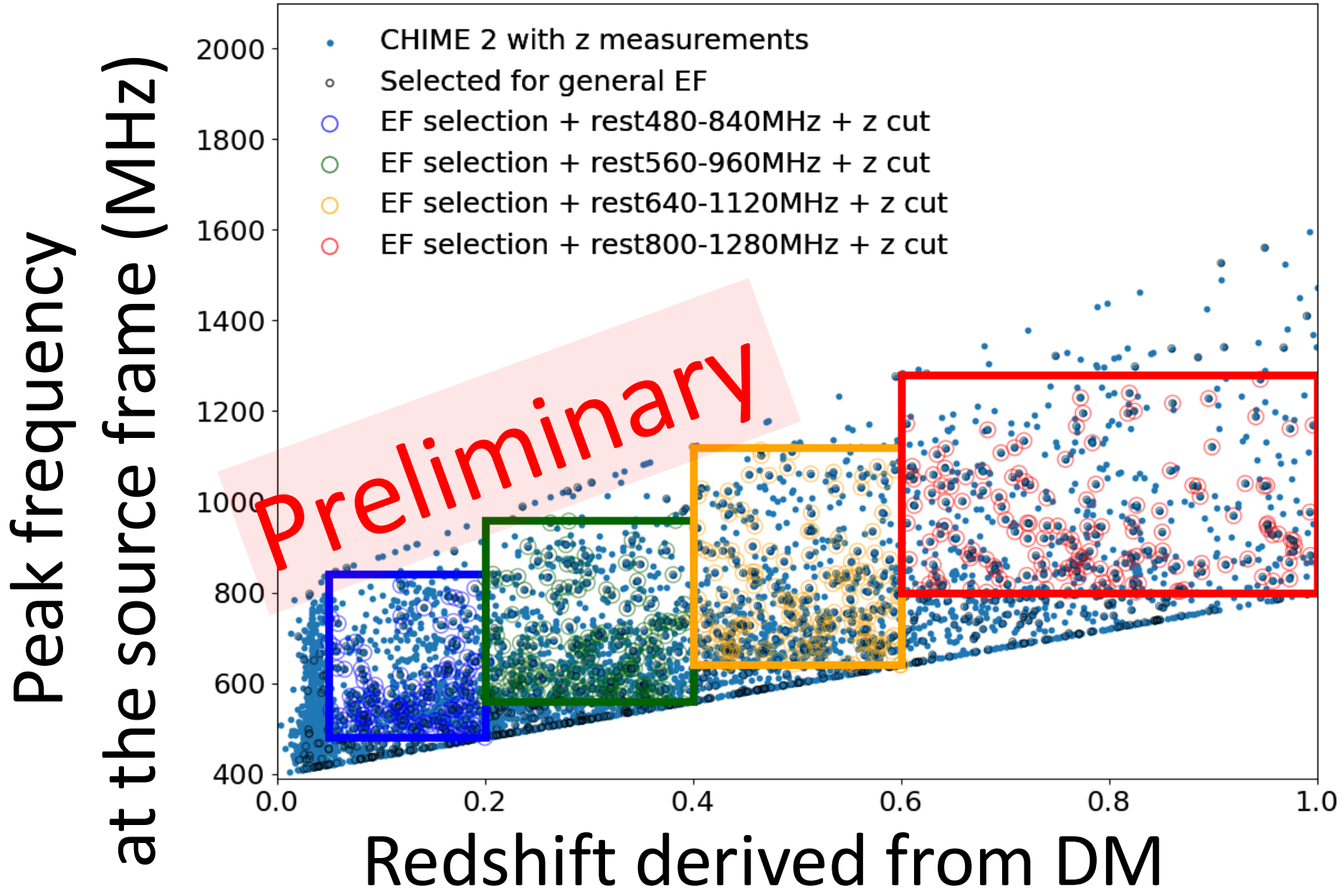
FRB rate density decreases at high-z

→ progenitors = old populations?

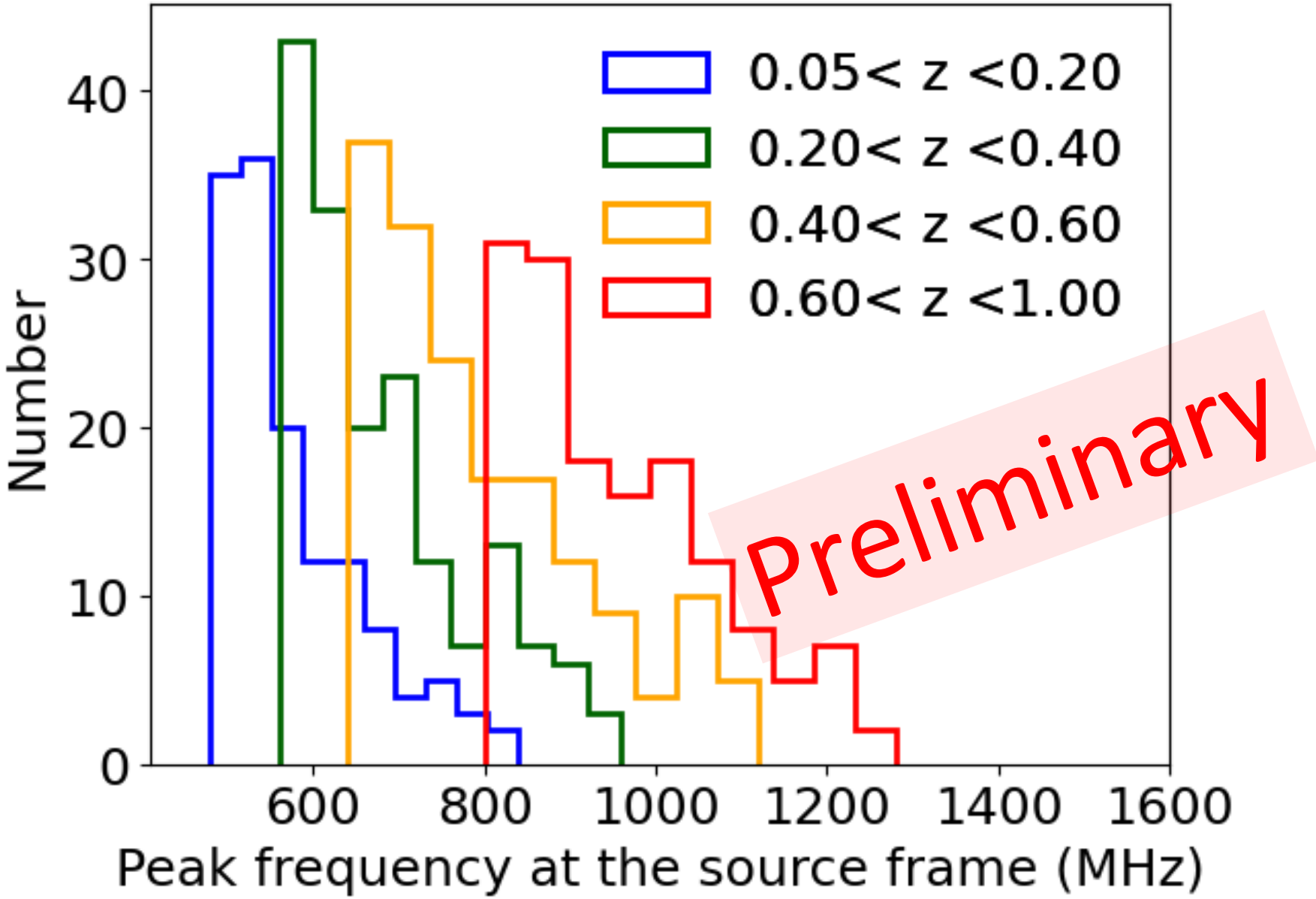
(WD, NS binary, stellar-mass BH?)

Backup slides

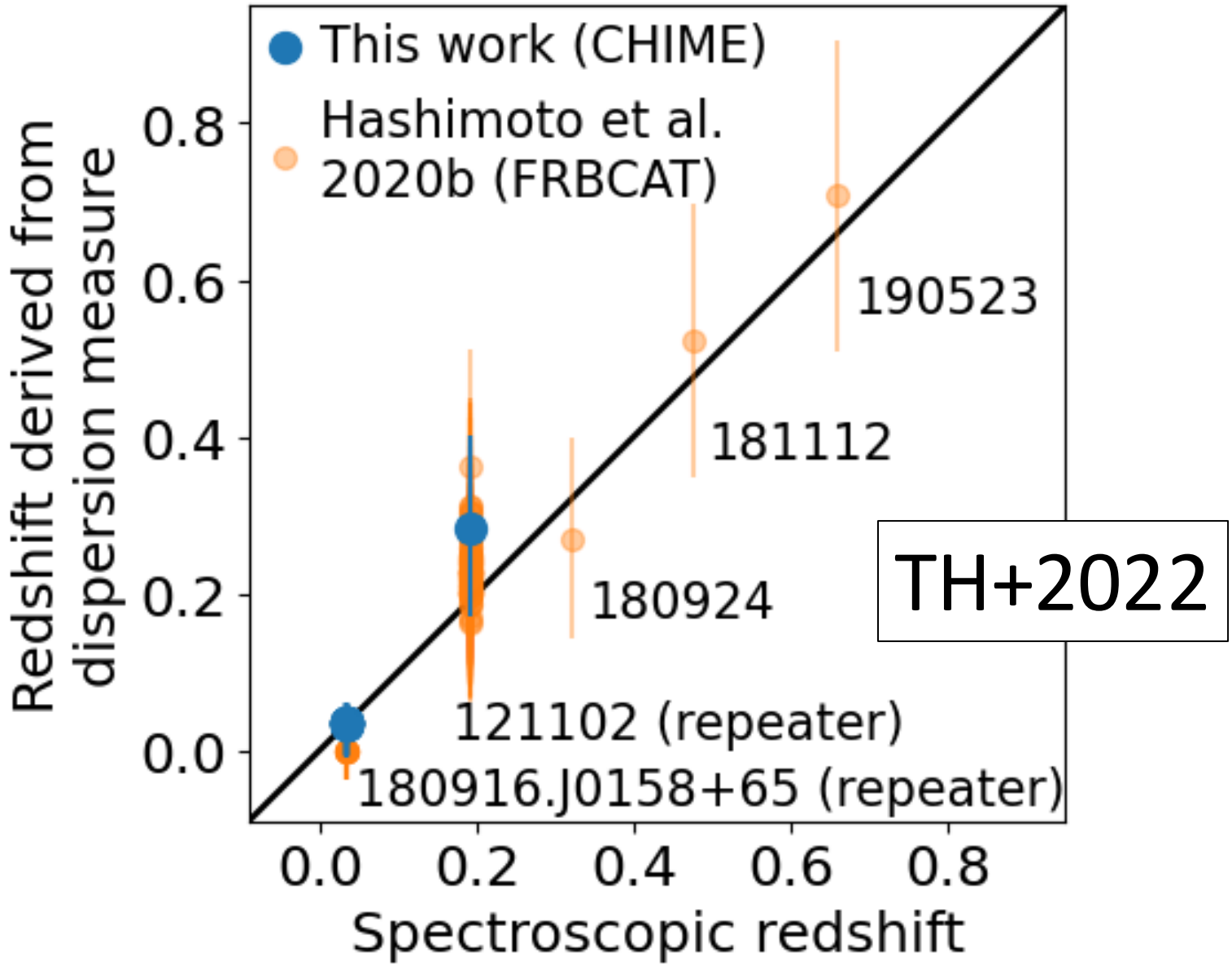
Discussions: low-freq FRBs are missed at high-z

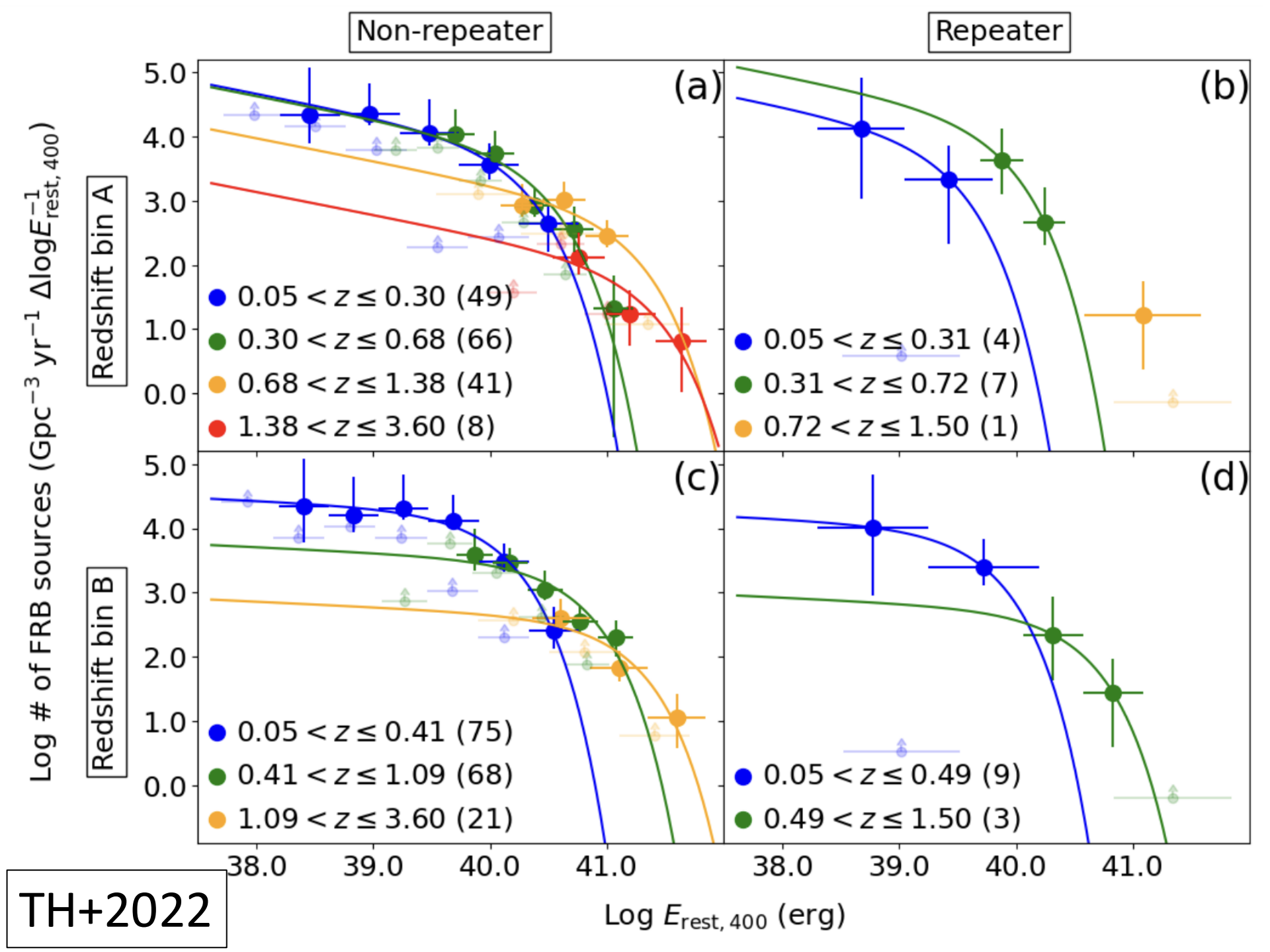


Discussions: low-freq FRBs are missed at high-z



Redshifts derived from dispersion measures




Non-repeater
Repeater
(a)
(b)
(c)
(d)
Redshift bin A
Redshift bin B
Log # of FRB sources (Gpc^{-3} yr^{-1} Δlog$E^{-1}_{\rm rest,\,400}$)
Log $E_{\rm rest,\,400}$ (erg)
0.05 < z ≤ 0.30 (49)
0.30 < z ≤ 0.68 (66)
0.68 < z ≤ 1.38 (41)
1.38 < z ≤ 3.60 (8)
0.05 < z ≤ 0.31 (4)
0.31 < z ≤ 0.72 (7)
0.72 < z ≤ 1.50 (1)
0.05 < z ≤ 0.41 (75)
0.41 < z ≤ 1.09 (68)
1.09 < z ≤ 3.60 (21)
0.05 < z ≤ 0.49 (9)
0.49 < z ≤ 1.50 (3)
5.0
4.0
3.0
2.0
1.0
0.0
38.0
39.0
40.0
41.0
TH+2022

Game changers!

1000

600

20

FRBs per year

Parkes
UTMOST
GBT
Arecibo
ASKAP
61 FRBs in total

Keane 2018

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

Year

CHIME

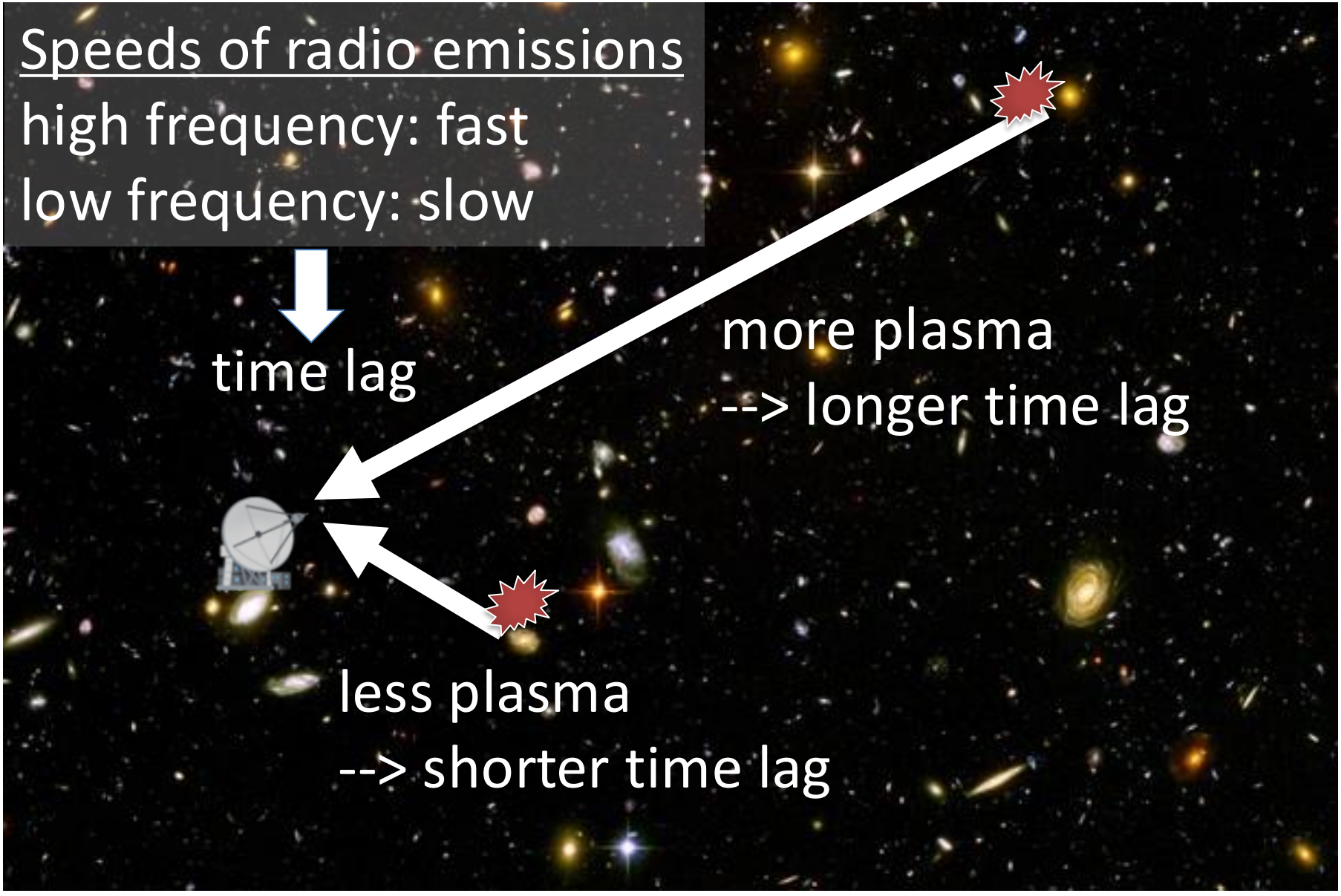
FAST

>1000 repeating FRBs

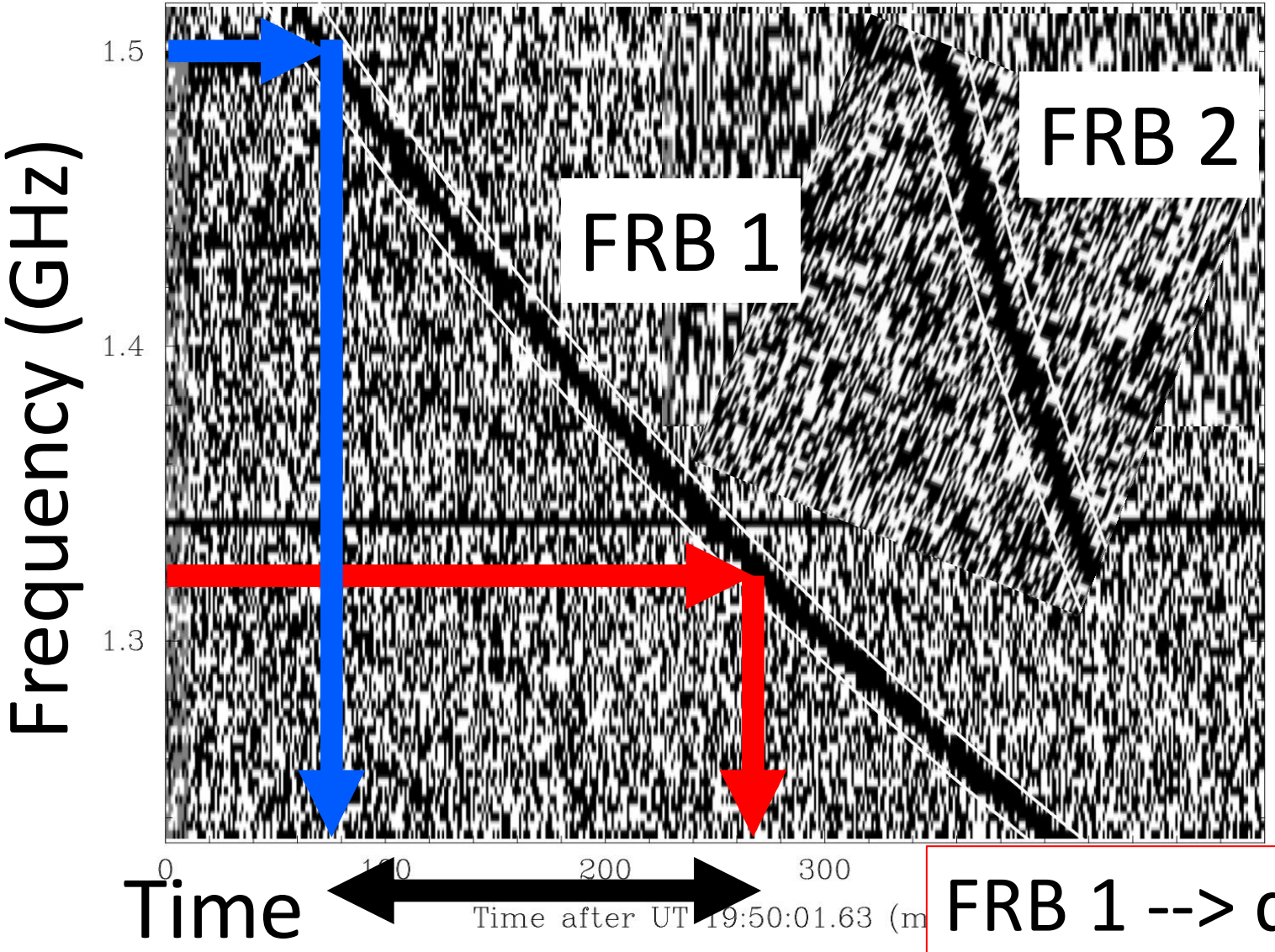
2021

2022

Intro: *dispersion measure <--> distance*

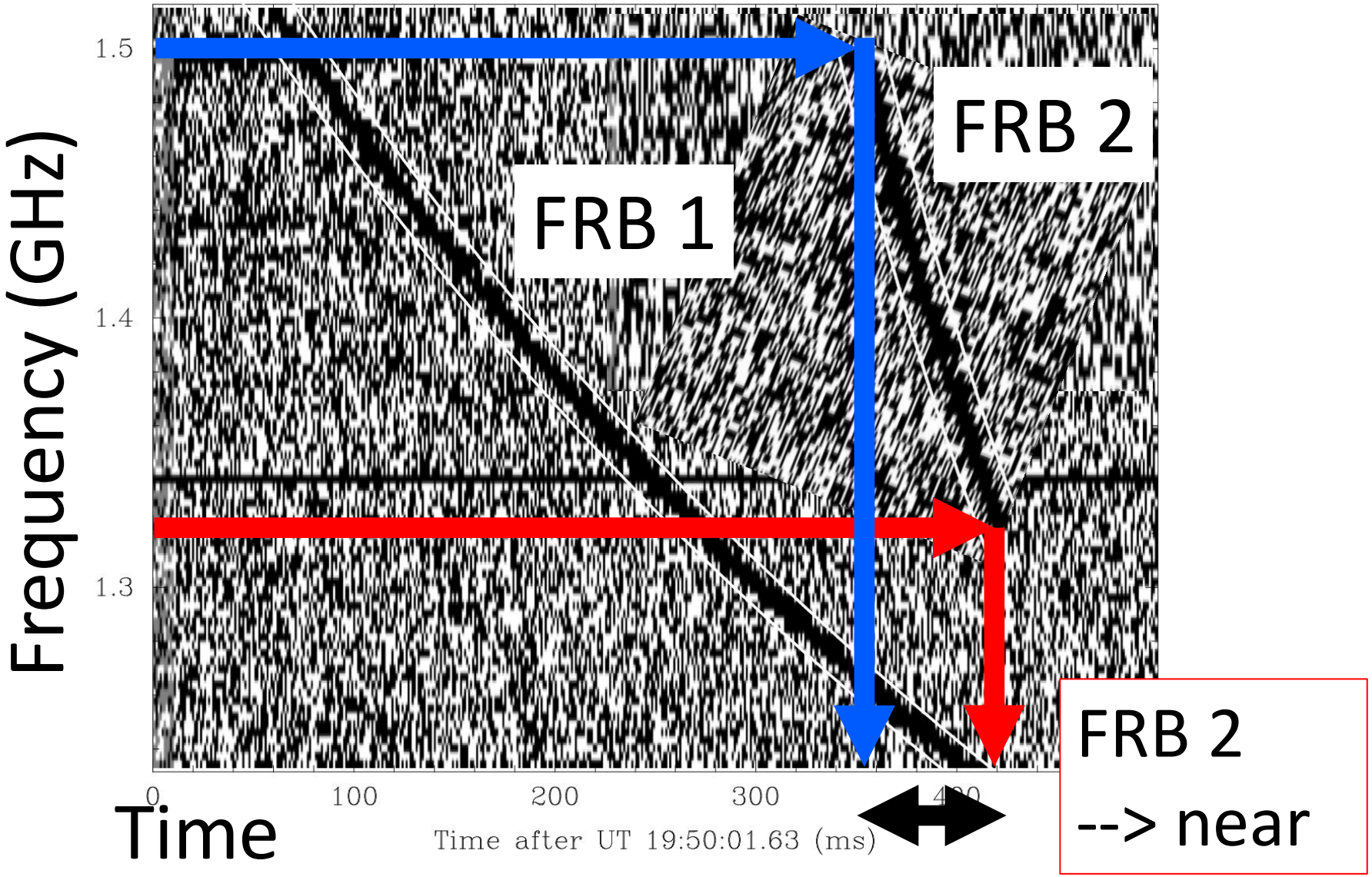


Intro: time lag = dispersion measure = distance indicator



FRB 1 --> distant

Intro: time lag = dispersion measure = distance indicator



using rest-frame 600-800 MHz only