Fast radio bursts in the era of Cherenkov Telescope Array

Tetsuya Hashimoto

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- TH et al. 2020a, MNRAS, 494, 2, p.2886-2904
- TH et al. 2020b, MNRAS, 497, 4, p.4107-4116
- TH et al. 2020c, MNRAS, 498, 3, p.3927-3945

The extreme Universe viewed in very-high-energy gamma rays, 4 Dec. 2020

Outline

1. ***Introduction***

   What is the fast radio burst?

2. ***Our results: origins of FRBs***

   Luminosity-duration relation

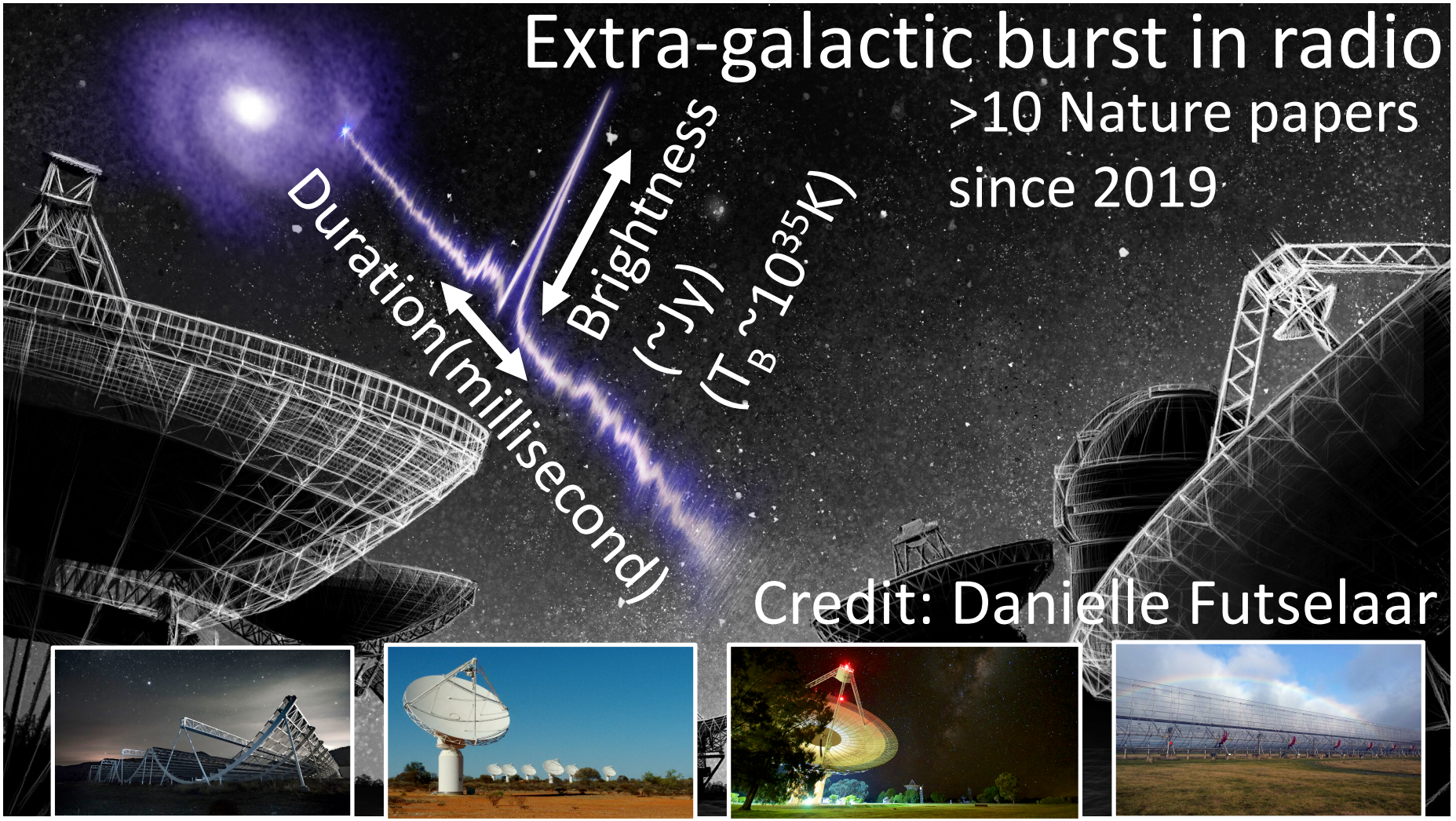
   Luminosity function

3. ***Future: the SKA and CTA***

   The golden age of FRB research

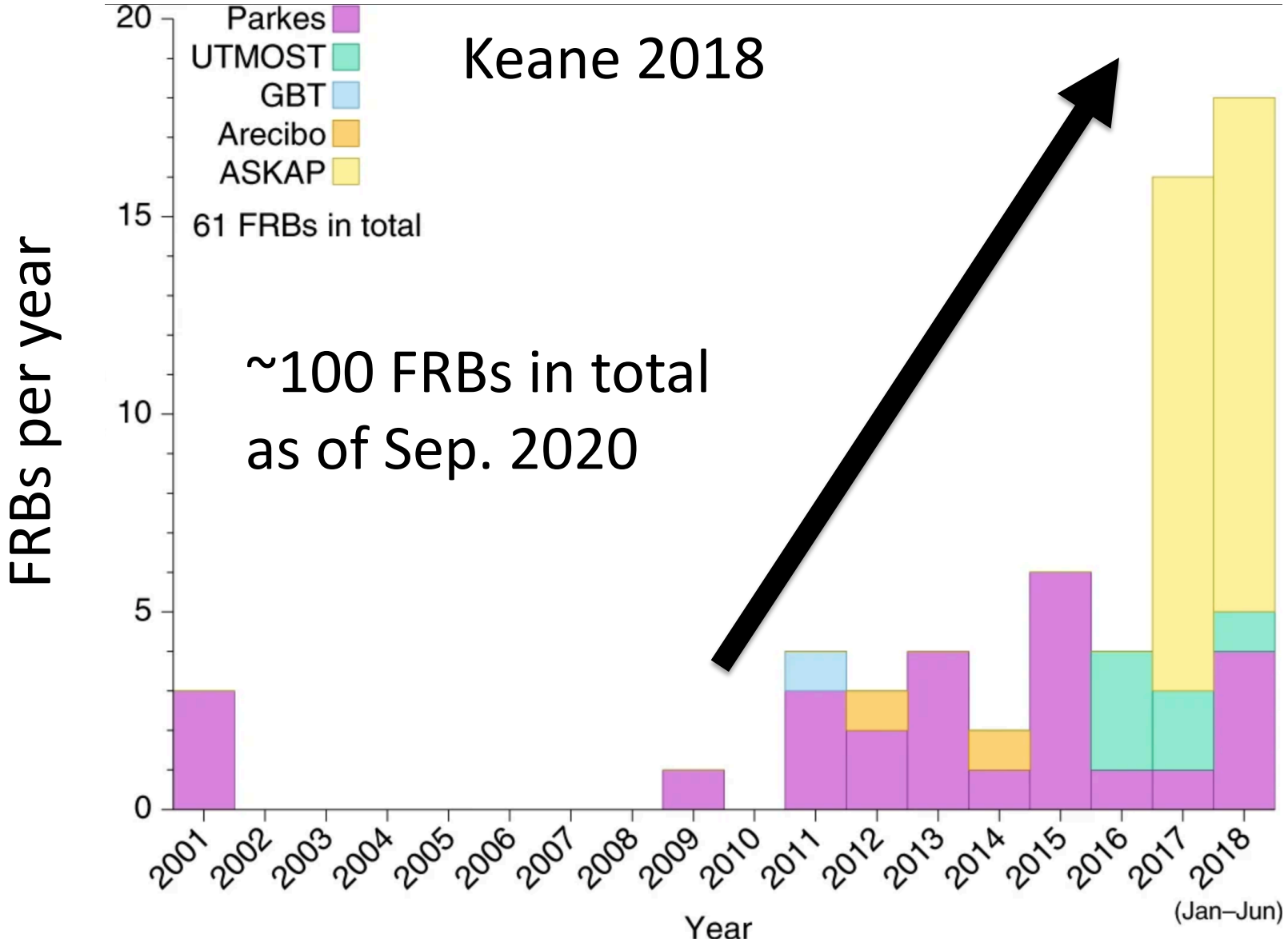
4. ***Conclusion***

Introduction: Fast radio burst (FRB)



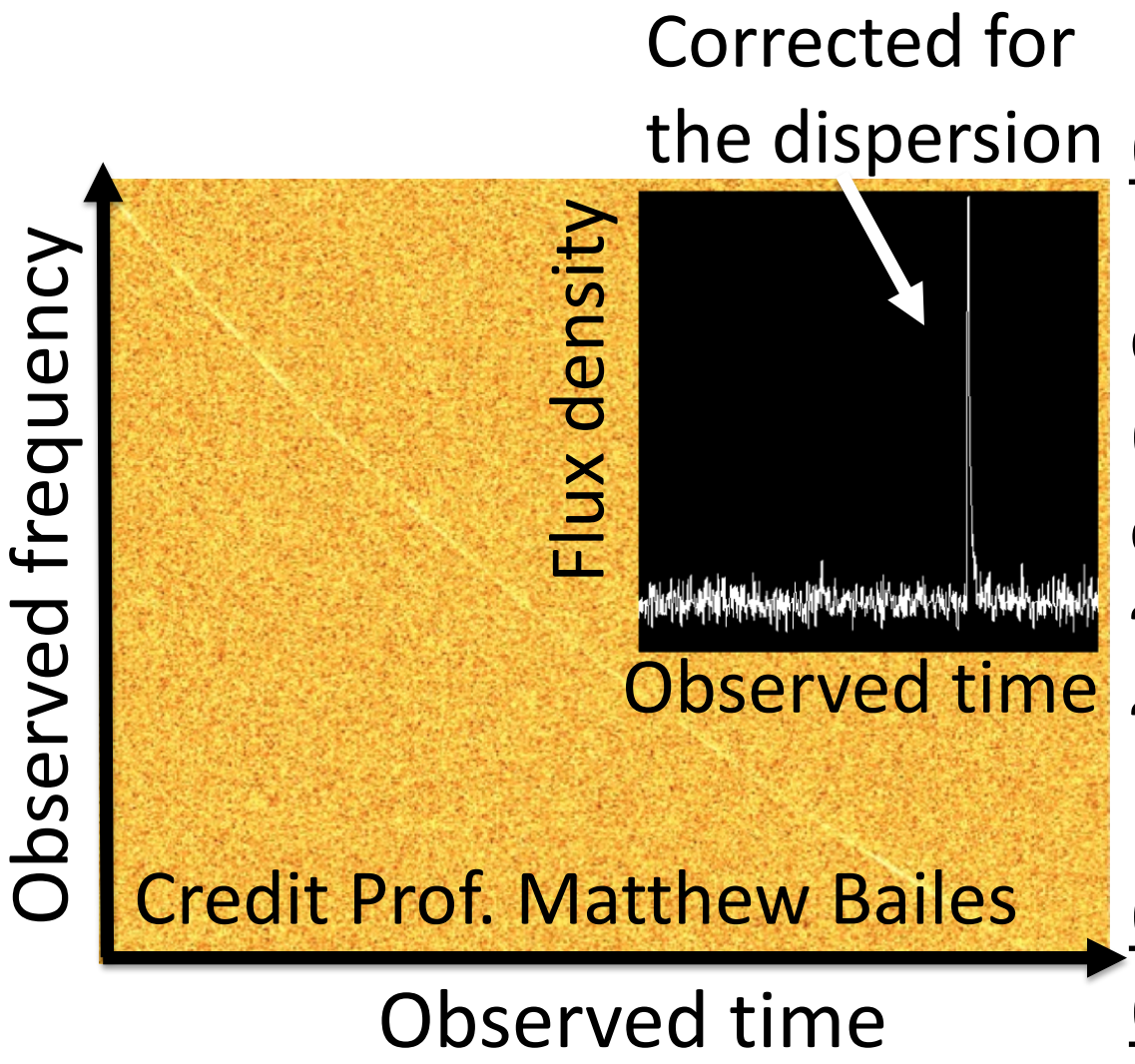
Introduction: Fast radio burst (FRB)

Introduction: Detection per year



>400 FRB detections will be released by CHIME soon 2020-2021

Introduction: Observables



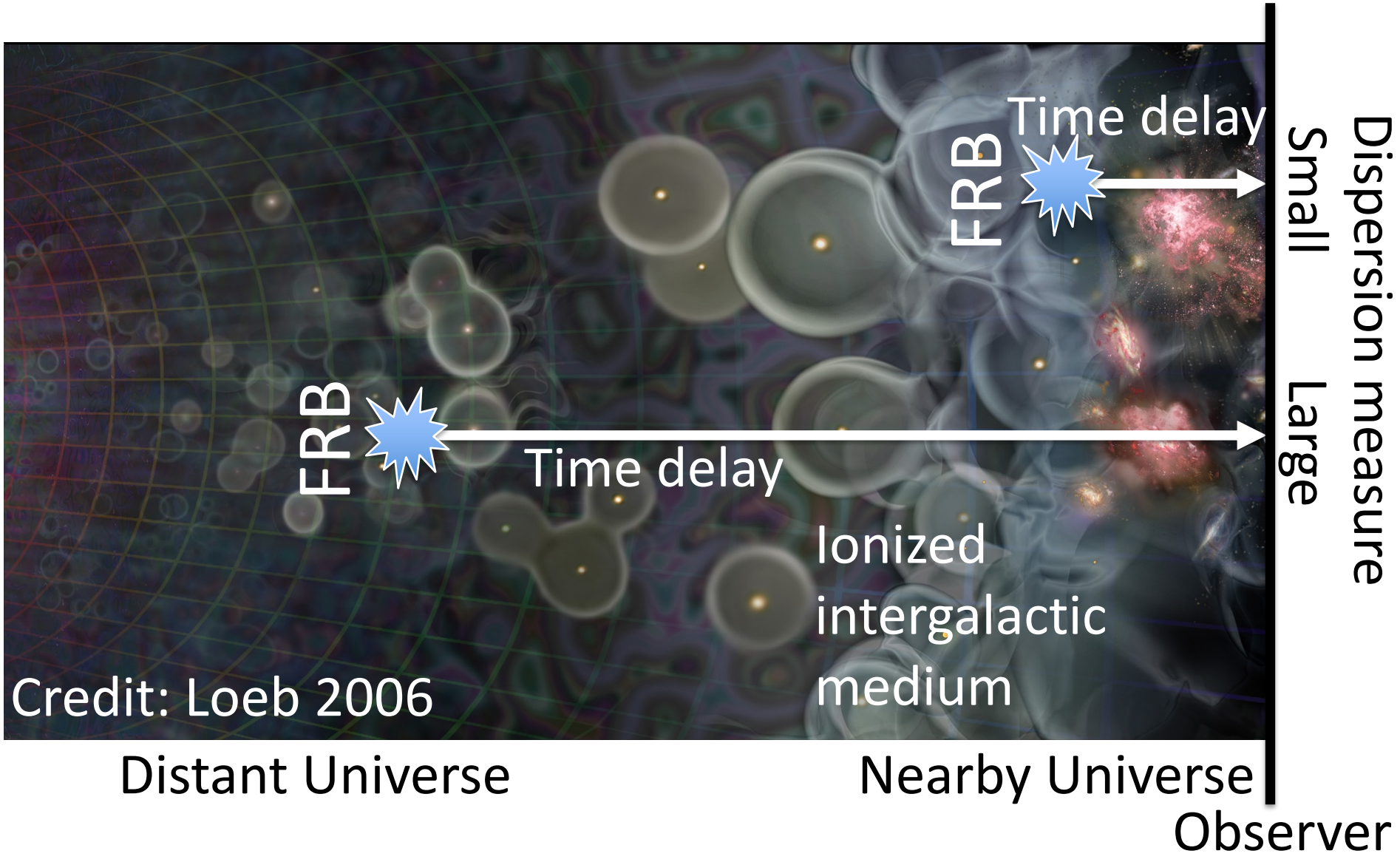
(1) Dispersion measure
→Time delay between different frequencies (materials along a line of sight to a FRB
~distance indicator
~redshift)

(2) Pulse duration

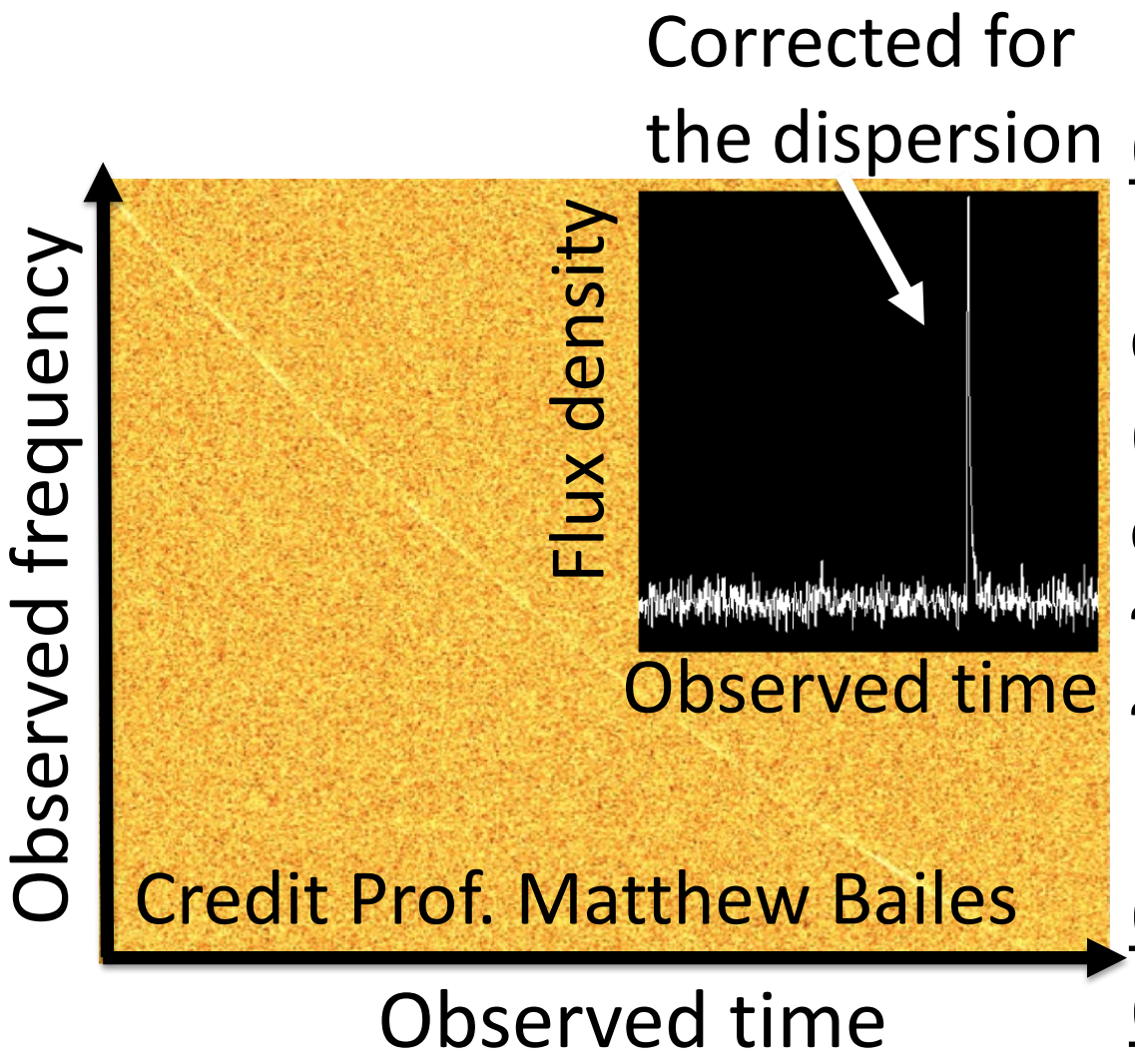
(3) Fluence

(4) Repetition

Introduction: Dispersion measure



Introduction: Observables



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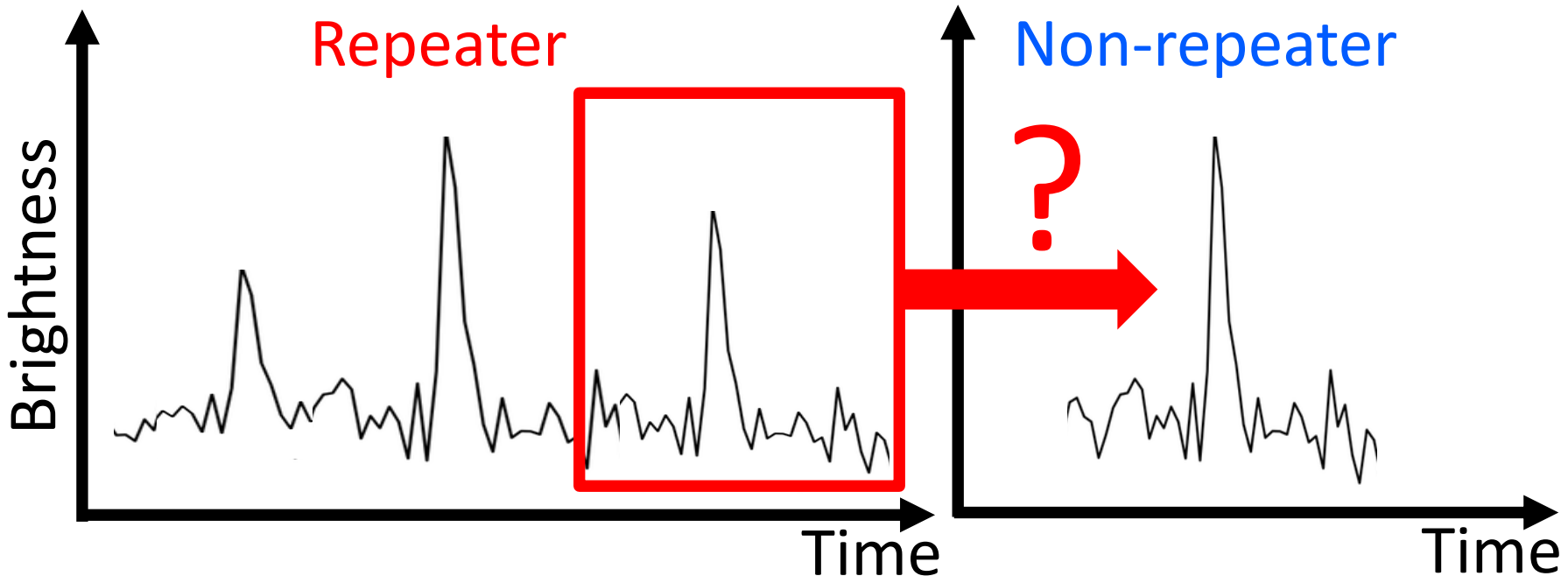
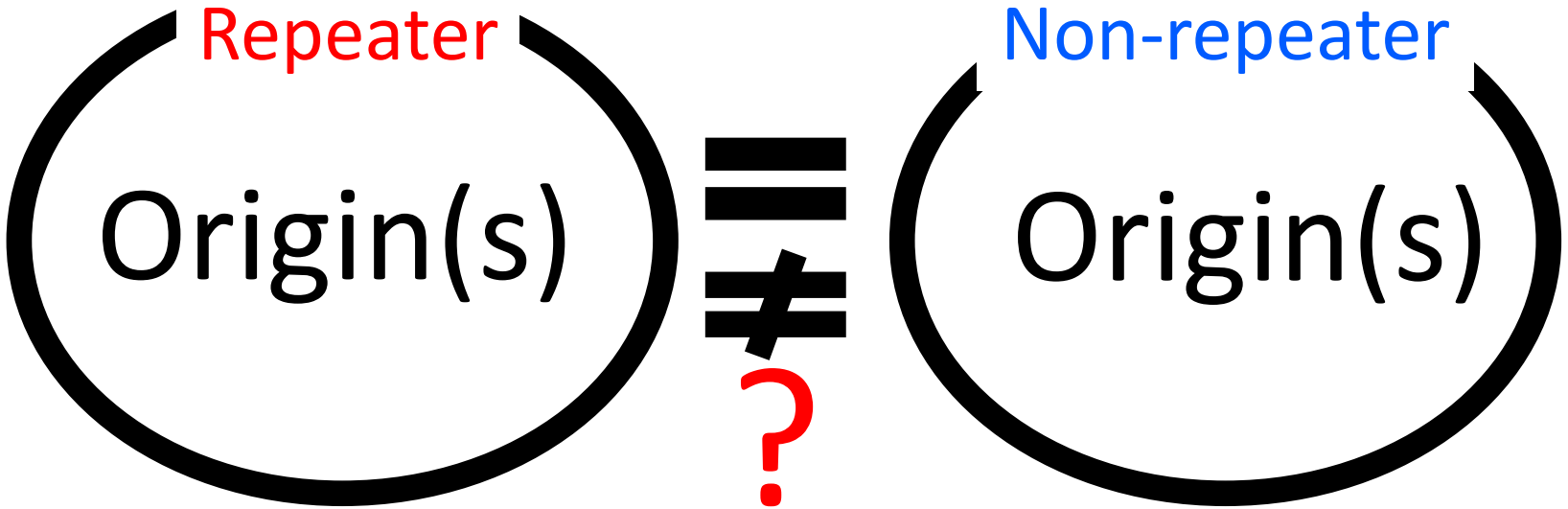
Introduction: Repeater/Non-repeater



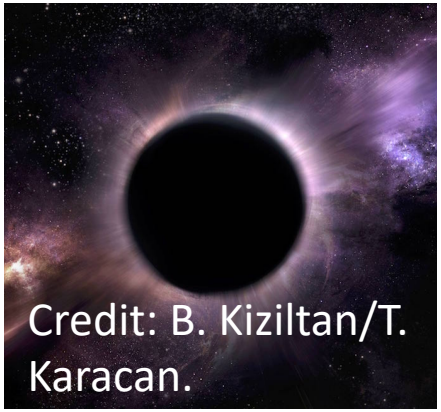


Introduction: >50 theories

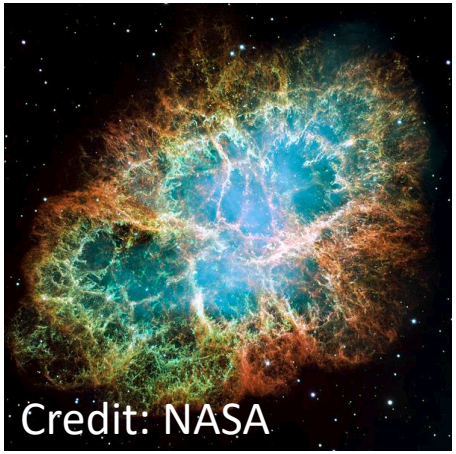
White dwarf

Neutron star

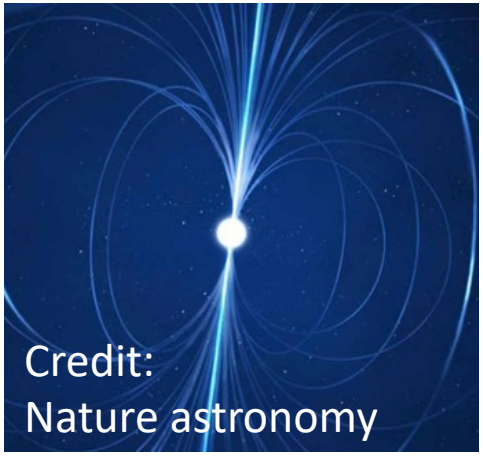
Black hole (BH)



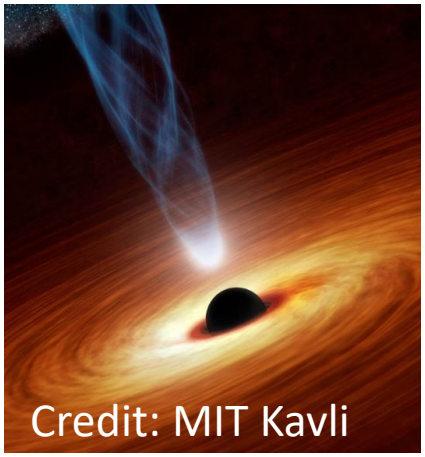
Supernova rem.



Young Pulsar



Active SMBH



Magnetar

Introduction: >50 theories

White dwarf

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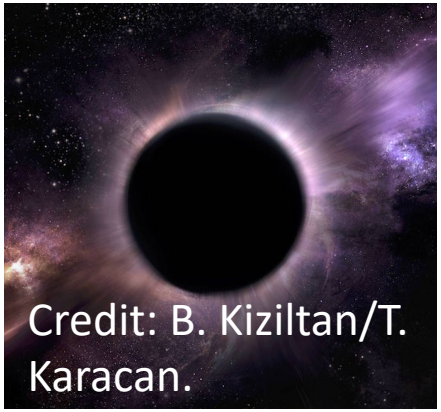
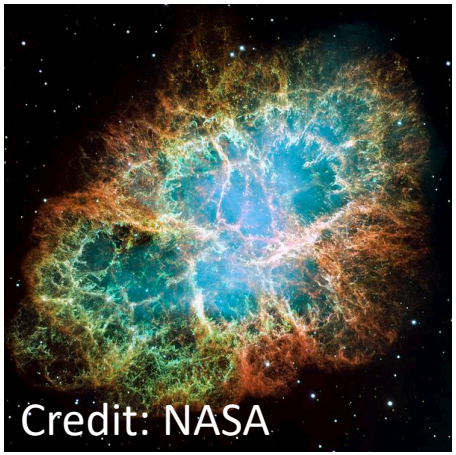
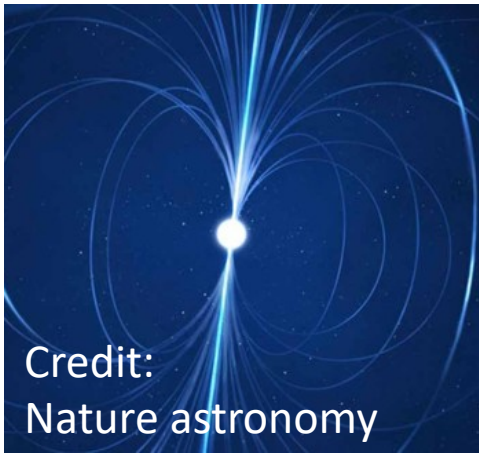
Black hole (BH)



Supernova rem. Young Pulsar Active SMBH Magnetar





One Galactic repeating FRB

e.g., the CHIME/FRB collaboration et al. 2020

Problem

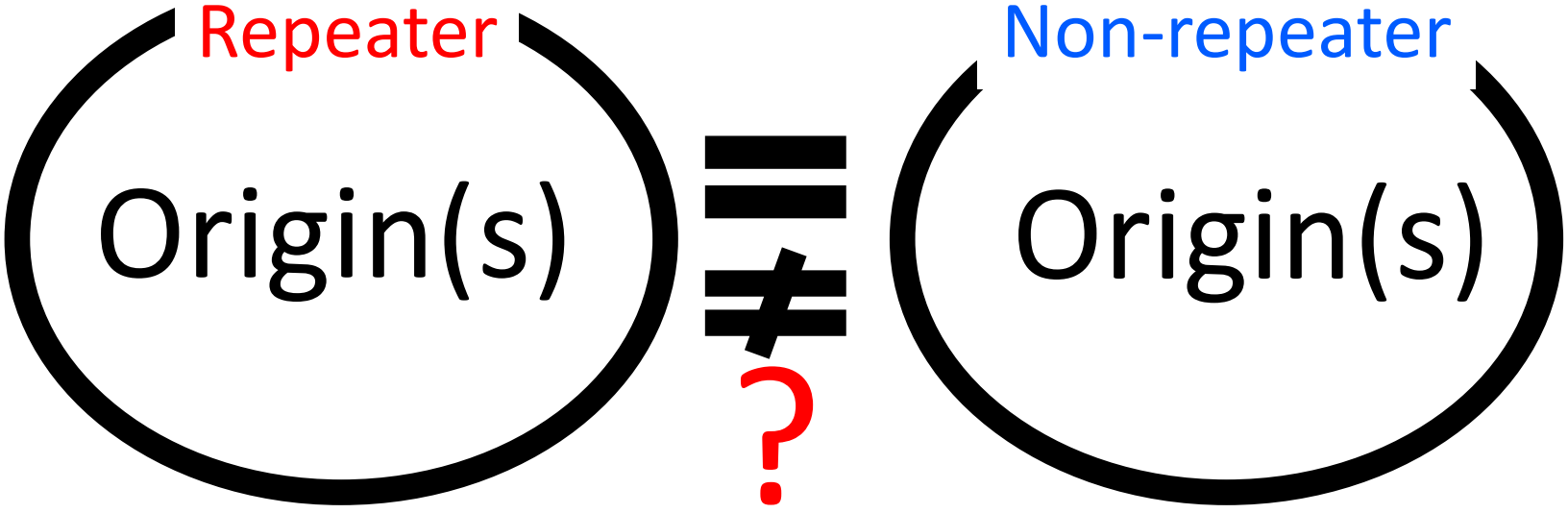
Only one confirmed case out of >100 FRBs

Solution (my talk)

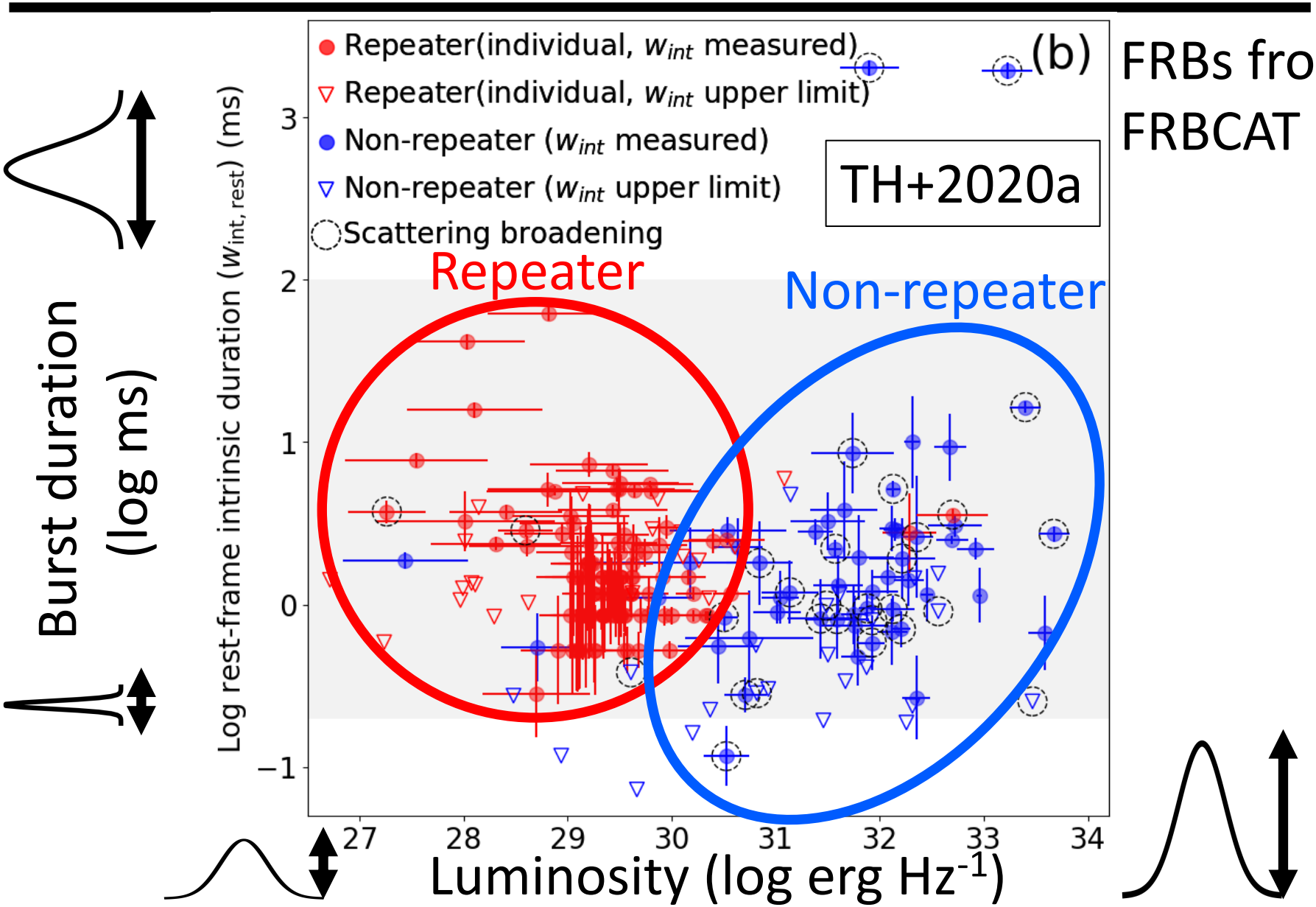
A statistical approach to constrain their origins

2. ***Our results: origins of FRBs***

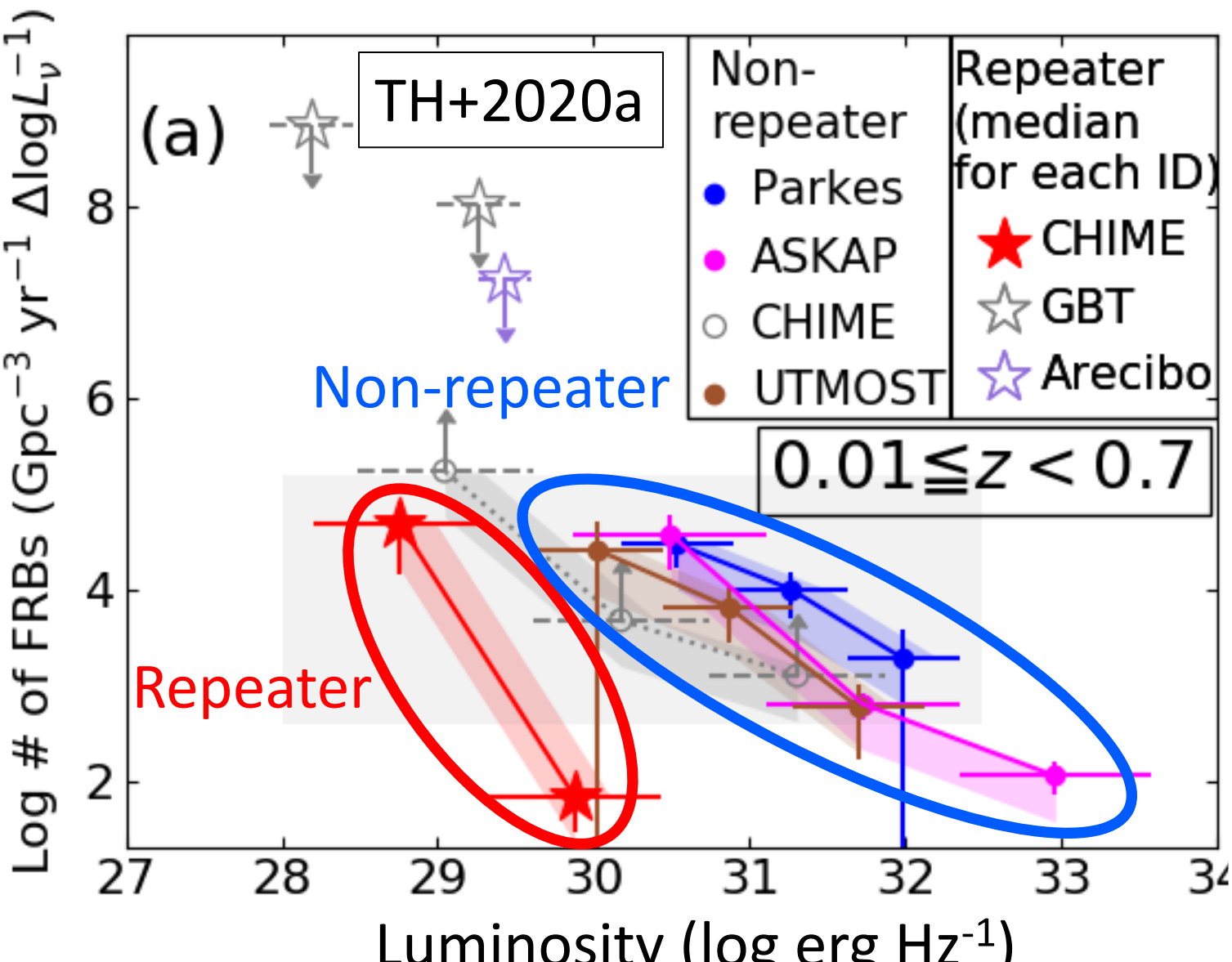
TH et al. 2020a and c



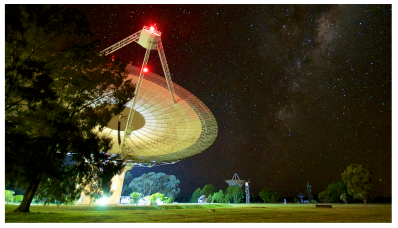
Results: (i)Luminosity and (ii)duration



Results: (iii)Luminosity functions



Parkes

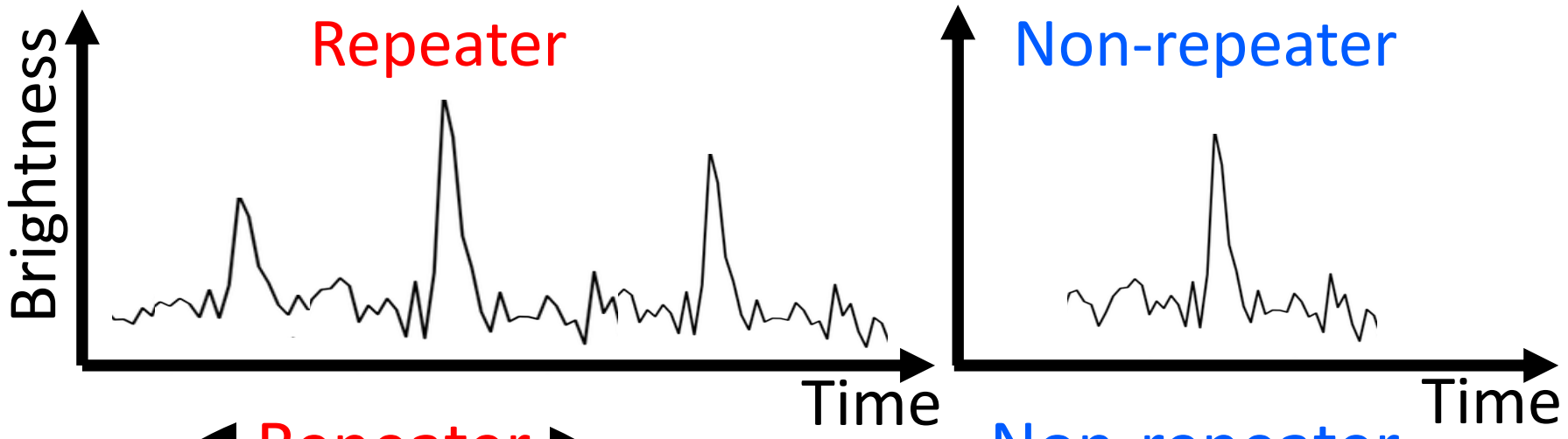


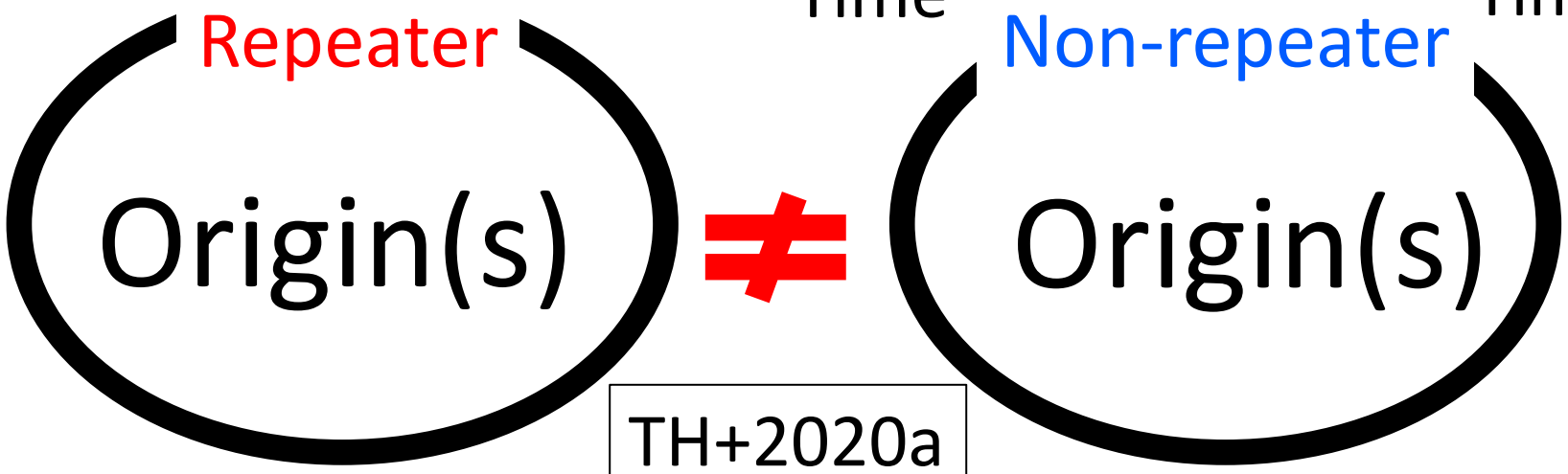
ASKAP

CHIME

UTMOST

Conclusion: Repeater/Non-repeater





TH+2020a

in terms of their

(i)luminosities, (ii)durations, and (iii)luminosity functions

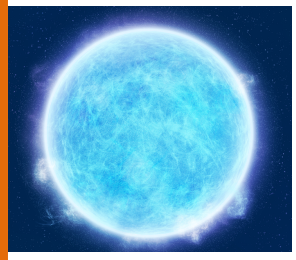
Introduction: Old vs Young

TH+2020c

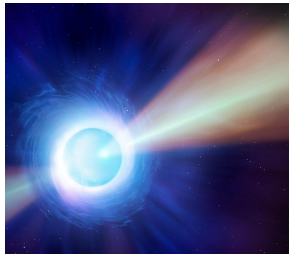
Number density ∝ stellar mass

Old objects

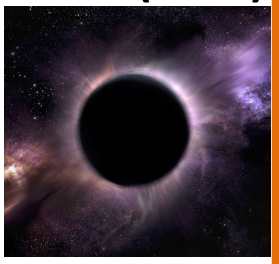
White dwarf



Neutron star



Black hole (BH)

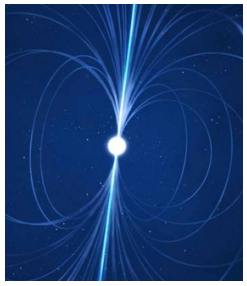


Number density ∝ activity

Young objects

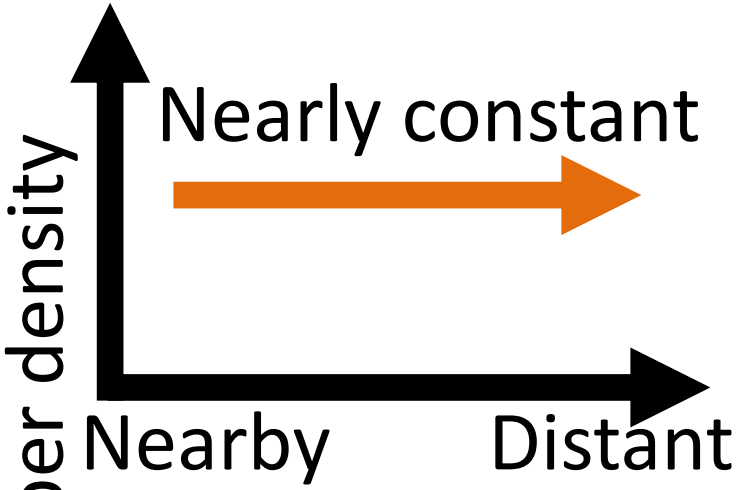
SN rem.

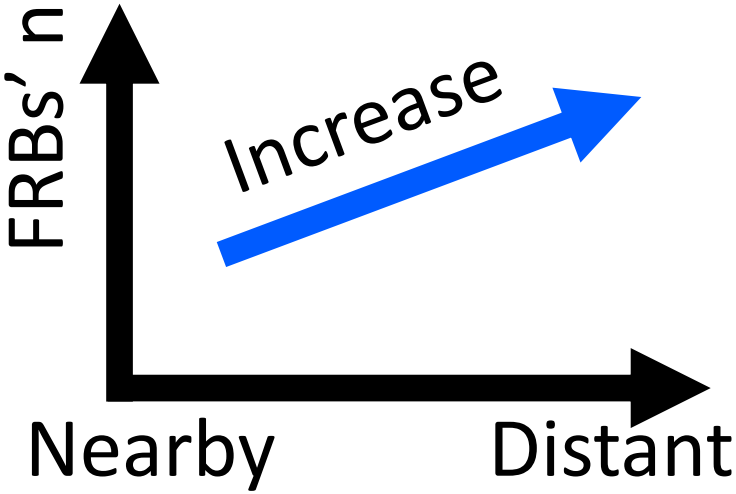
Young Pulsar



Active SMBH

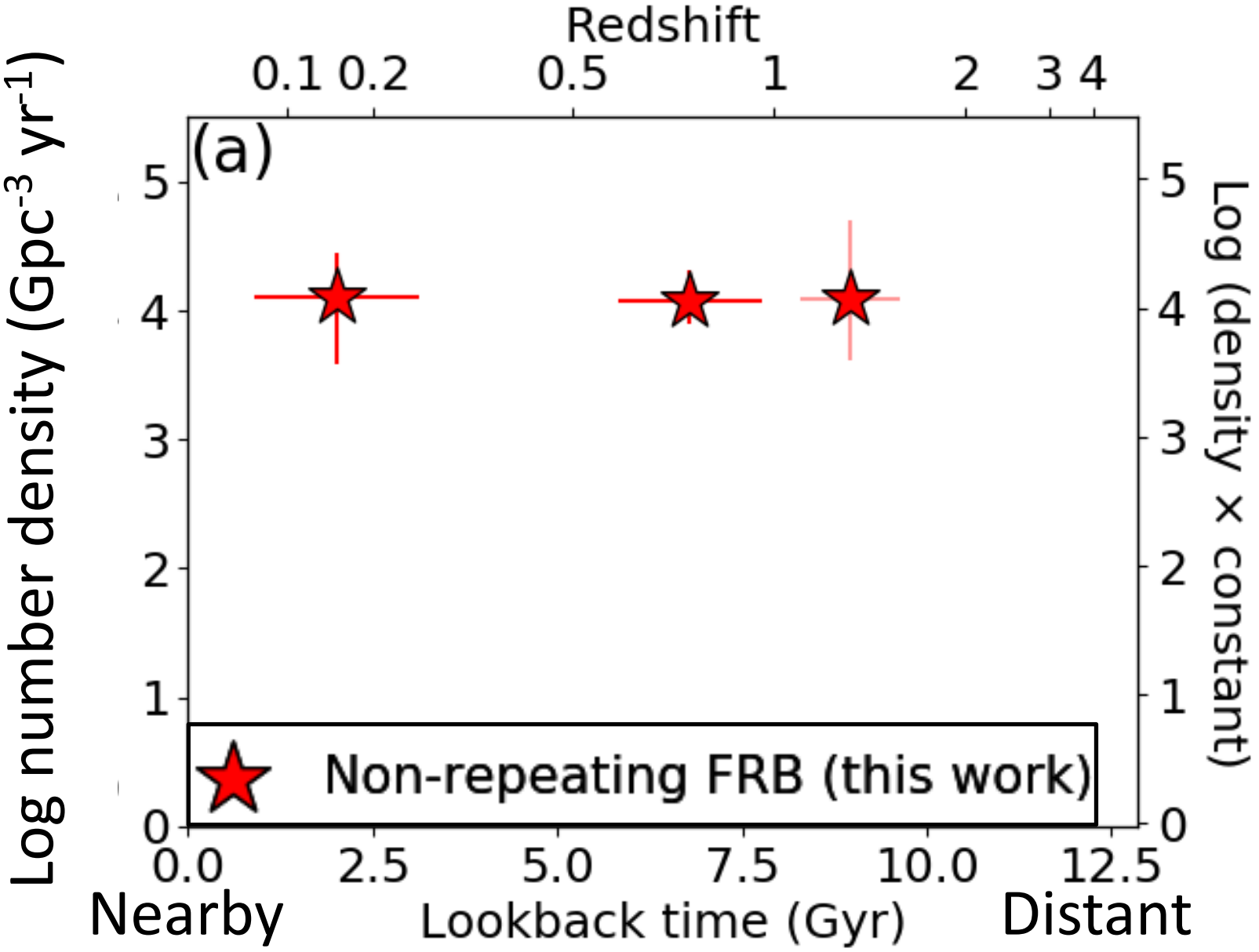
Magne tar





Results: Non-repeaters

TH+2020c



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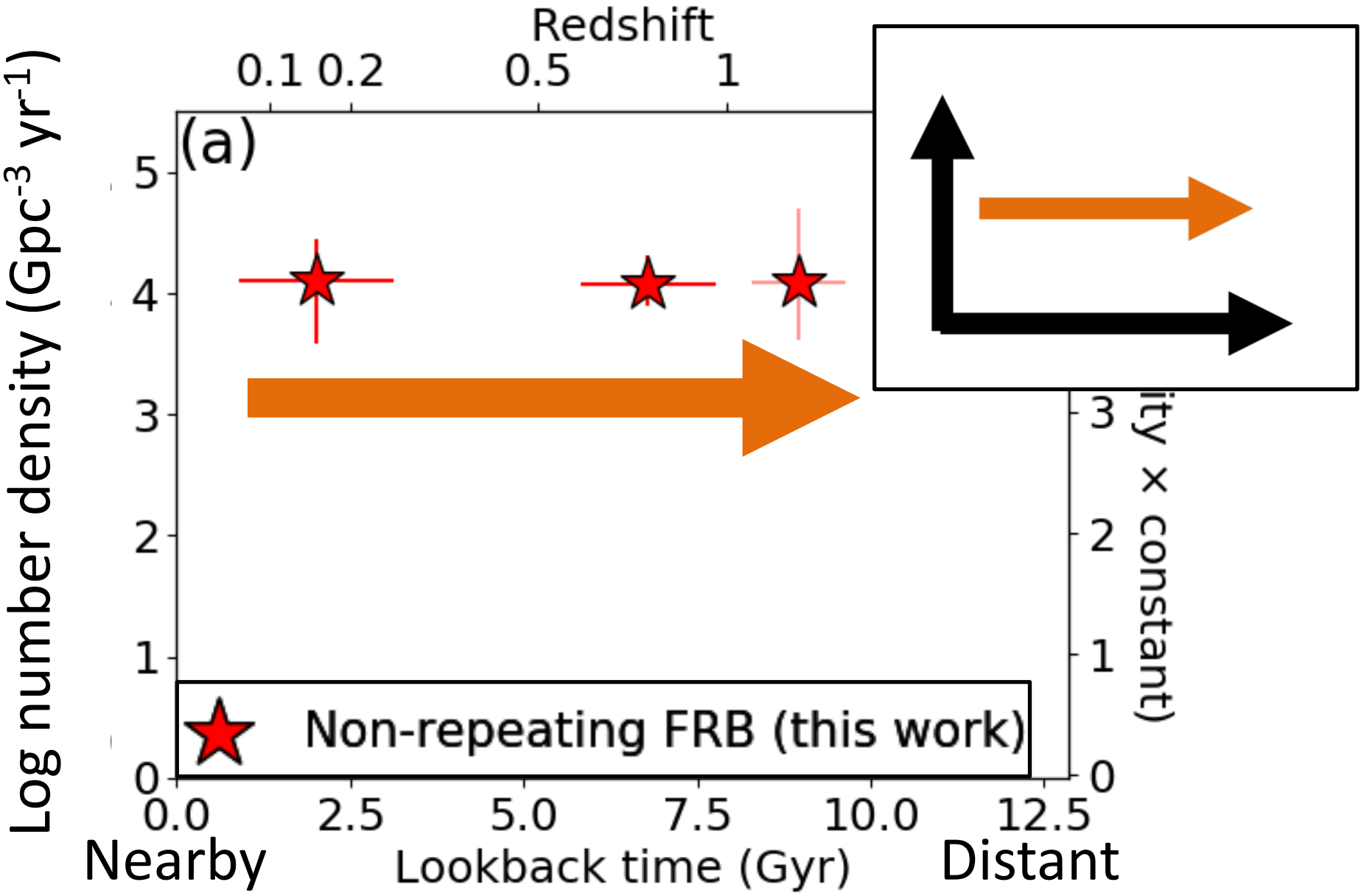

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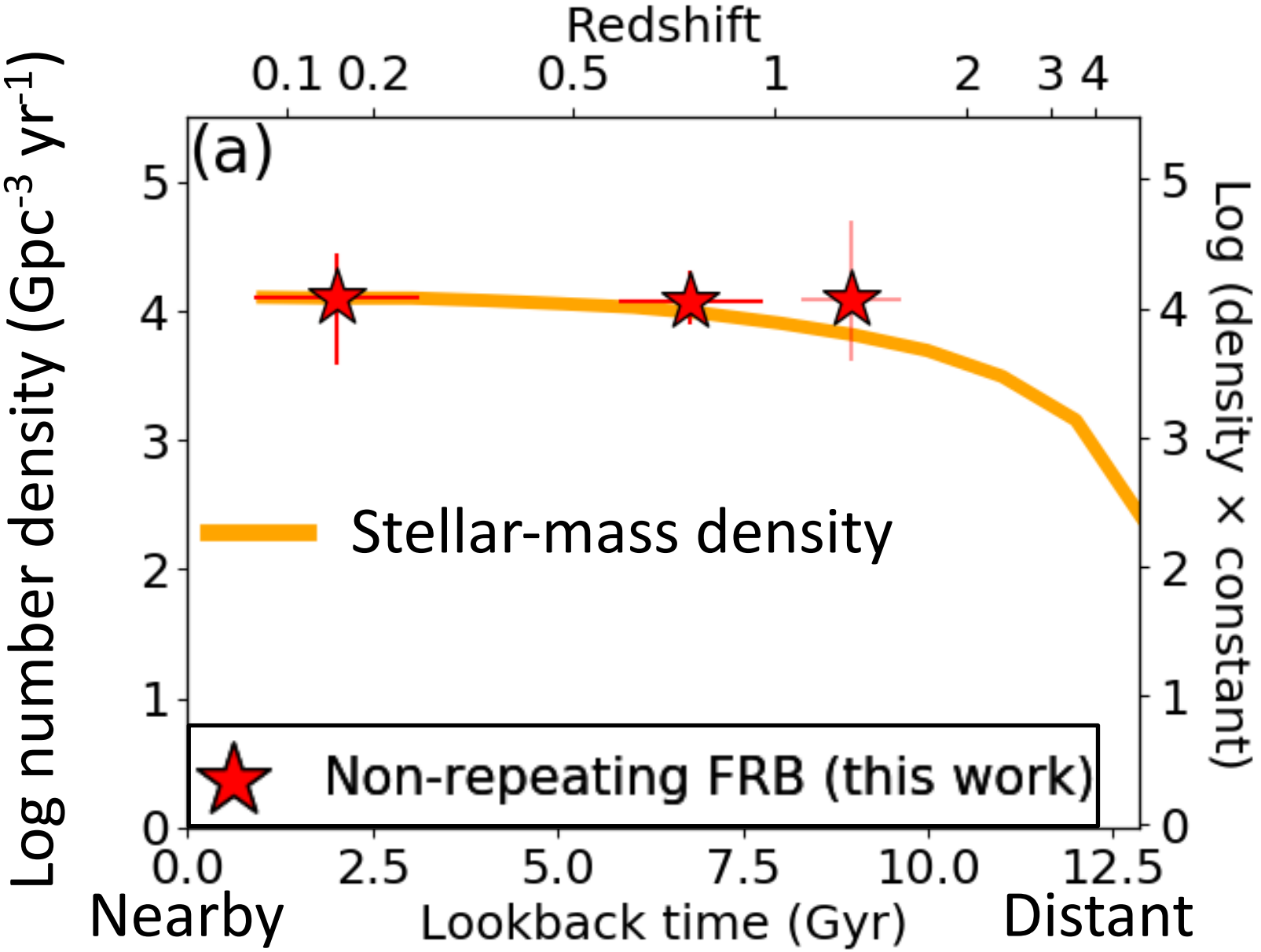

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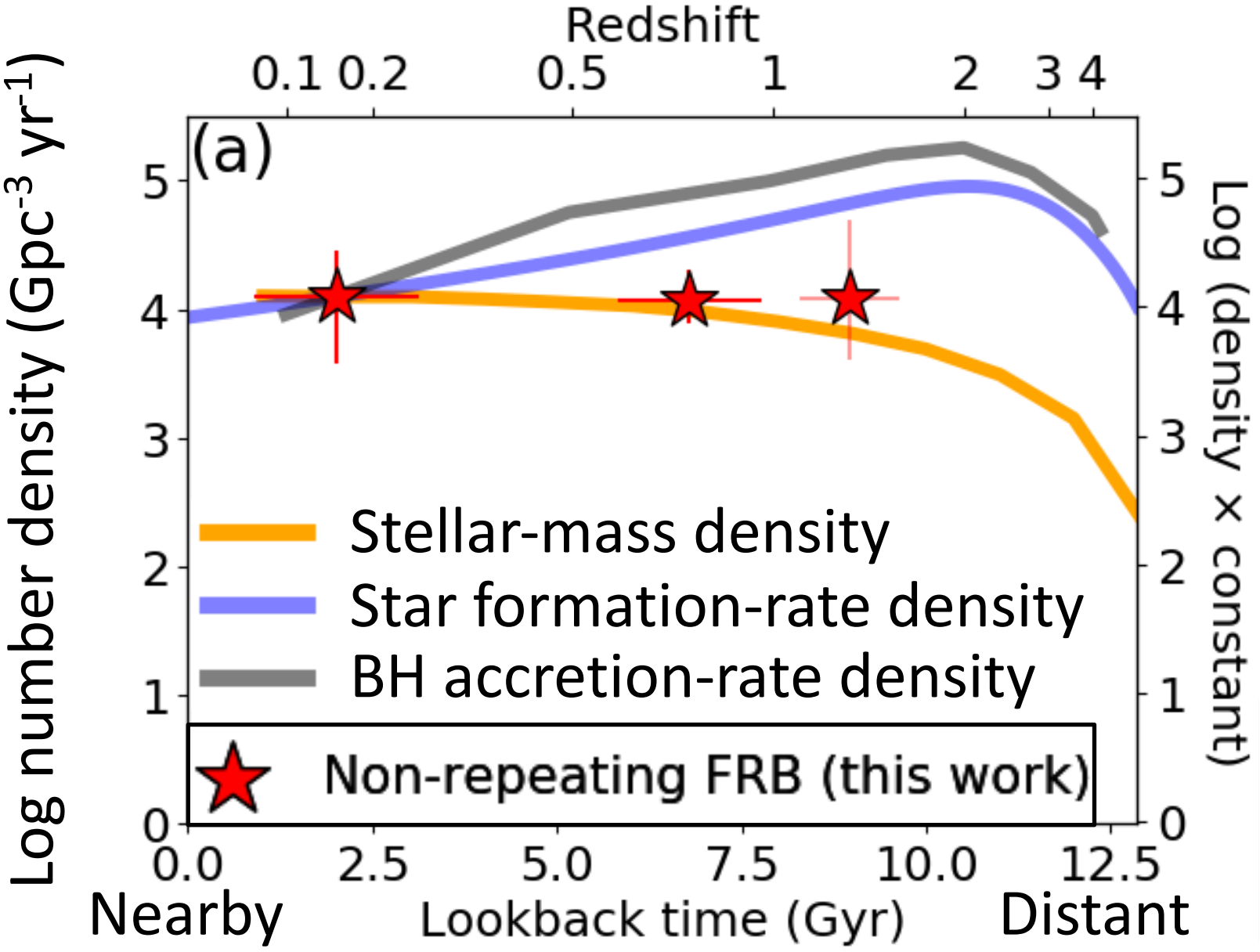

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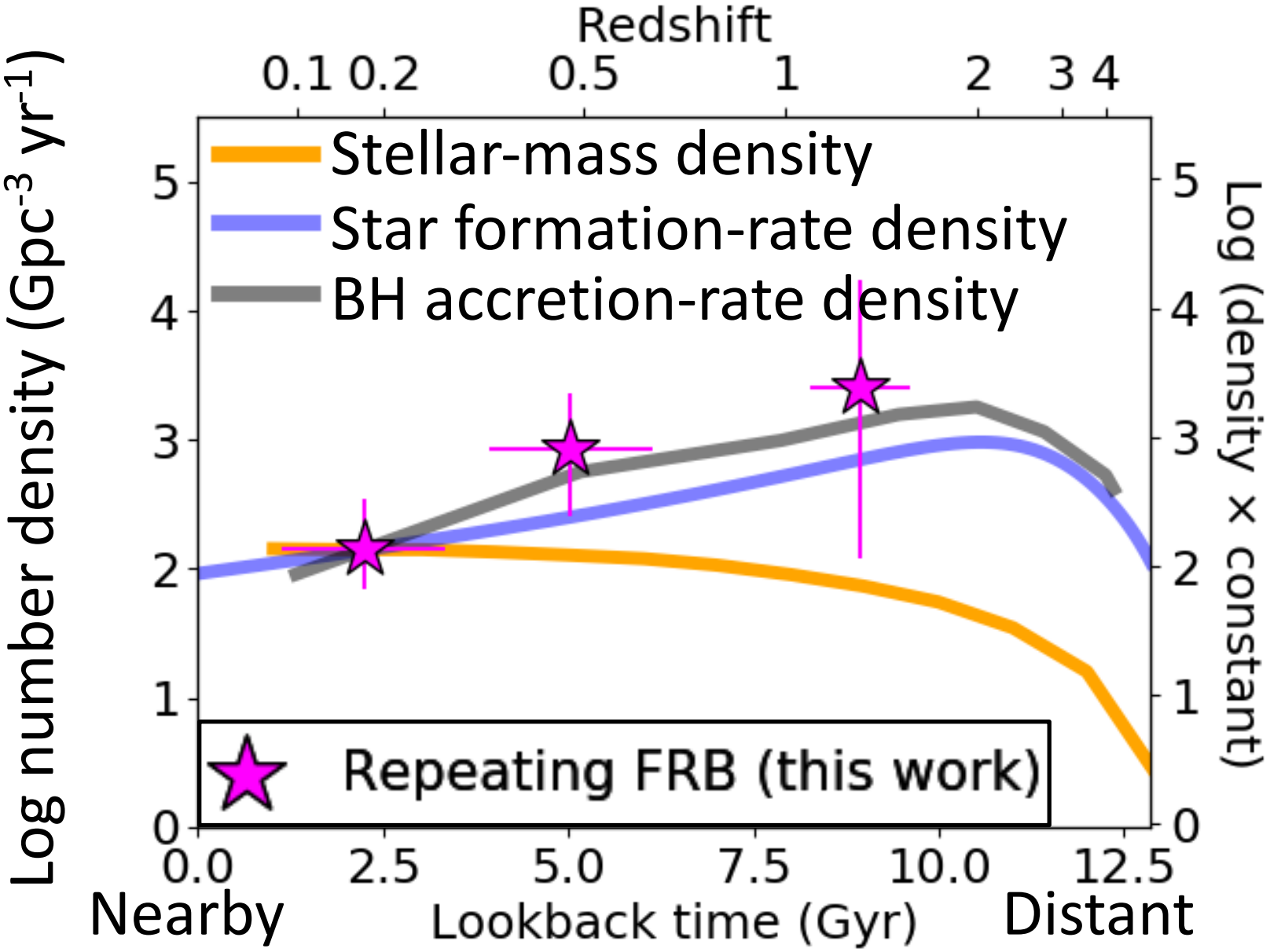
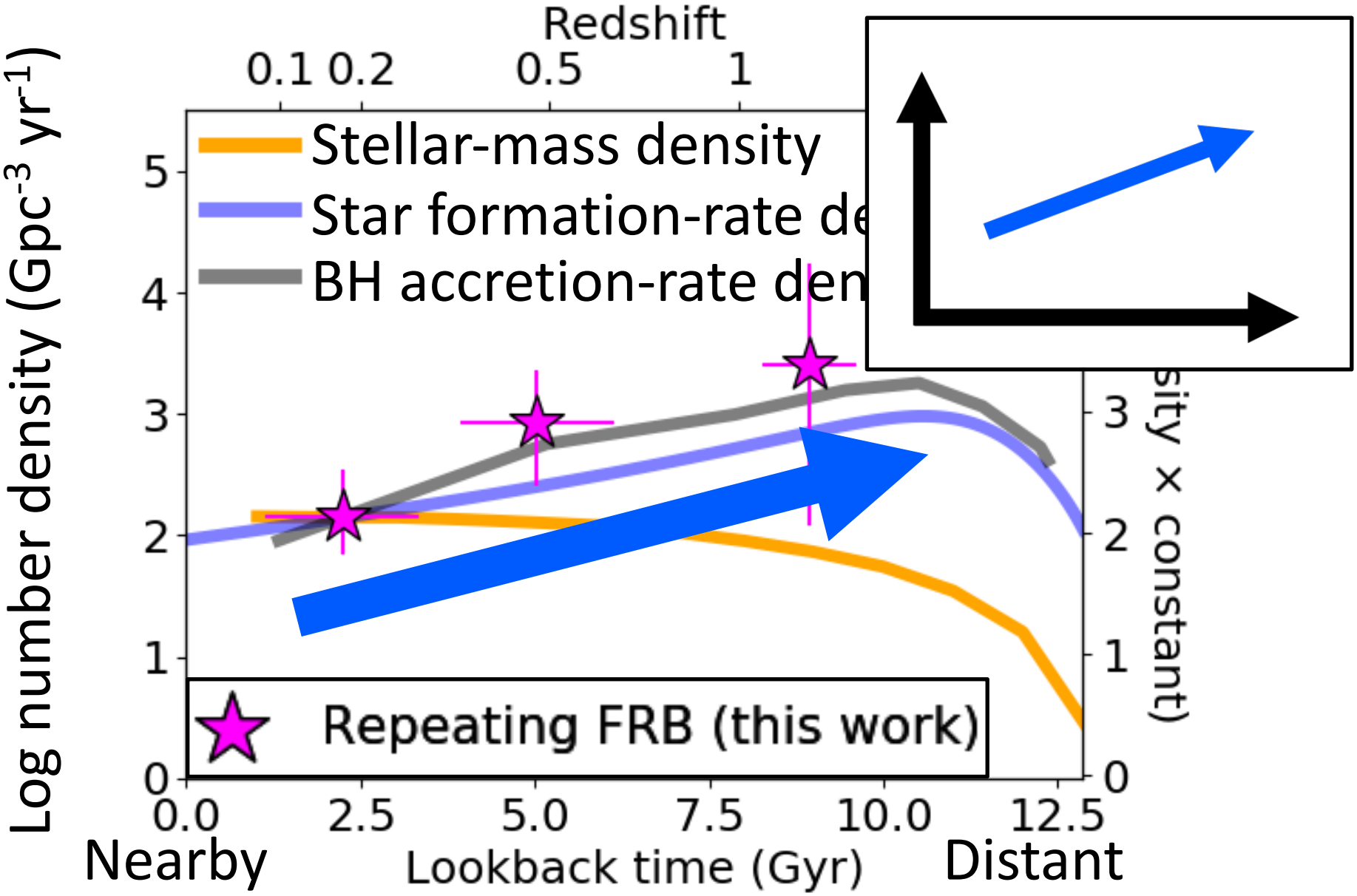


Results: Repeaters

TH+2020c

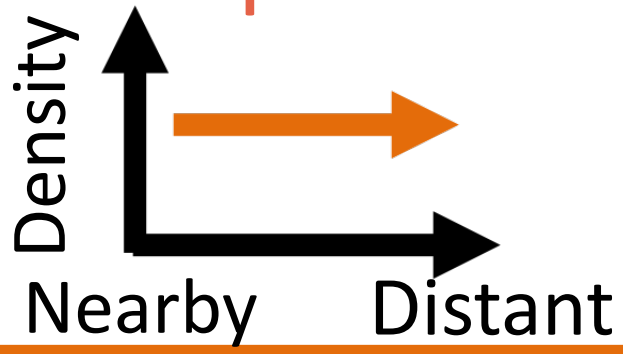


Conclusion: Old vs Young

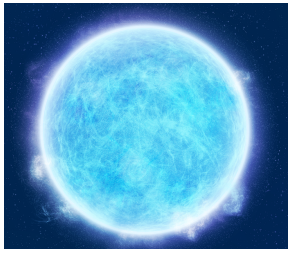
TH+2020c

Number density ∝ stellar mass

Non-repeaters



White dwarf



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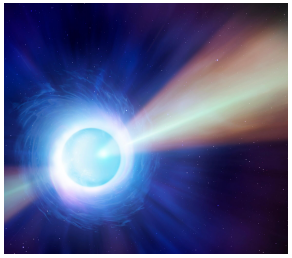

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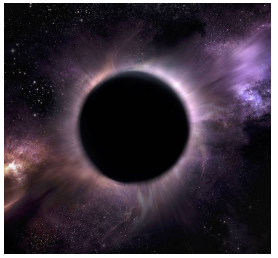
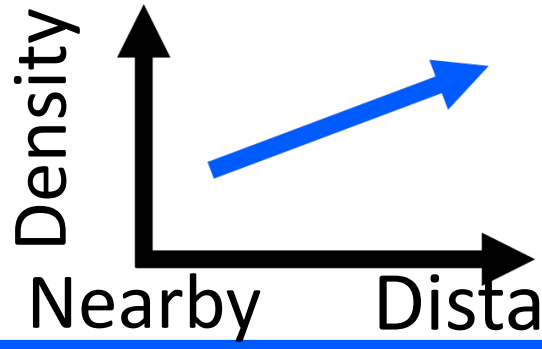


Old objects

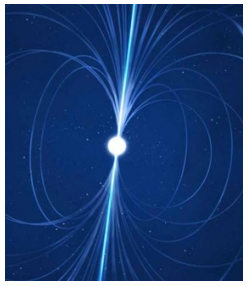
Number density ∝ activity

Repeaters



SN rem.

Young Pulsar



Active SMBH

Magnetar

Young objects

Summary:

(2. ***Our results: origins of FRBs***)

Non-repeaters and repeaters are indeed different in terms of duration, luminosity, and luminosity function, suggesting different origins.

Non-repeaters and repeaters likely originate from old and young objects, respectively.

Our statistical approach is consistent with the confirmed case (Galactic magnetar).

3. *Future prospects: the SKA and CTA*

Future: FRB-related sciences

(0)Origin of FRBs

(e.g., TH et al. 2020a,c)

(1)Dark energy

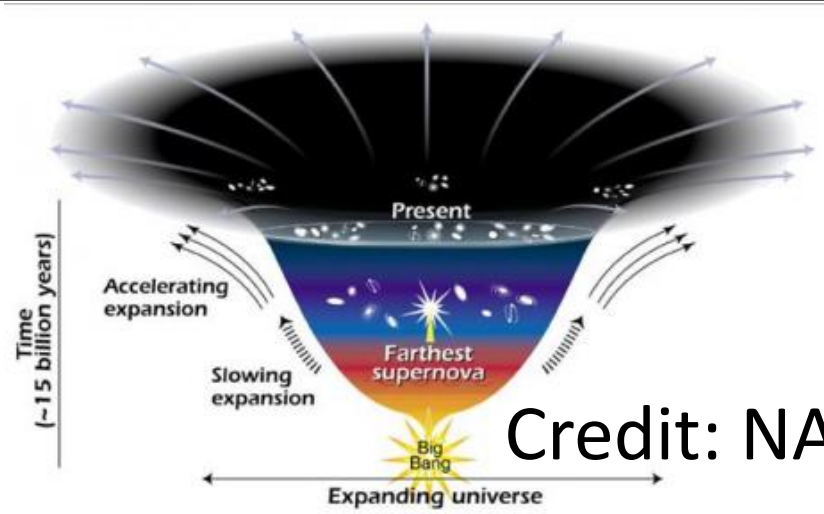
(e.g., TH et al. 2019a)

(2)Cosmic reionization

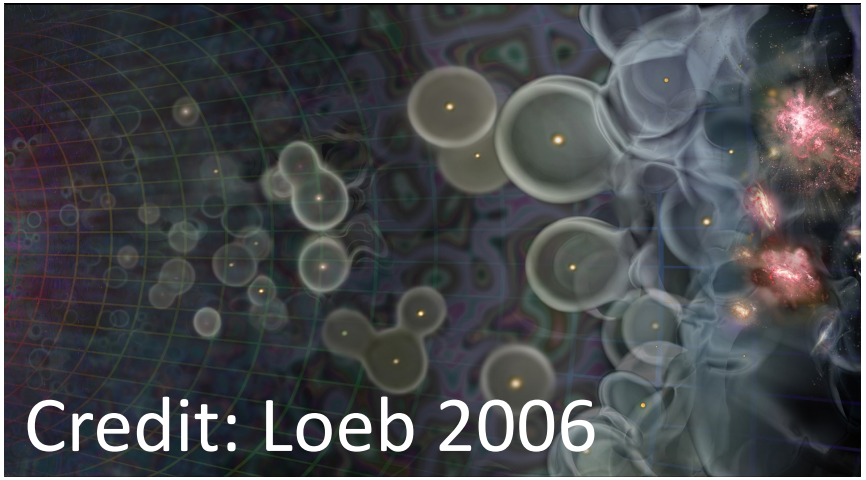
(e.g., TH et al. 2020d)

(3)Missing baryon problem

(e.g., Prochaska et al. 2020)



Credit: NASA



Credit: Loeb 2006

However, only ~100 FRBs to date (FRBCAT)

http://frbcat.org/

TH+2020b:
How many FRBs will the SKA detect?

See also

astrobites

THE ASTRO-PH READER'S DIGEST | SUPPORTED BY THE **AAS**

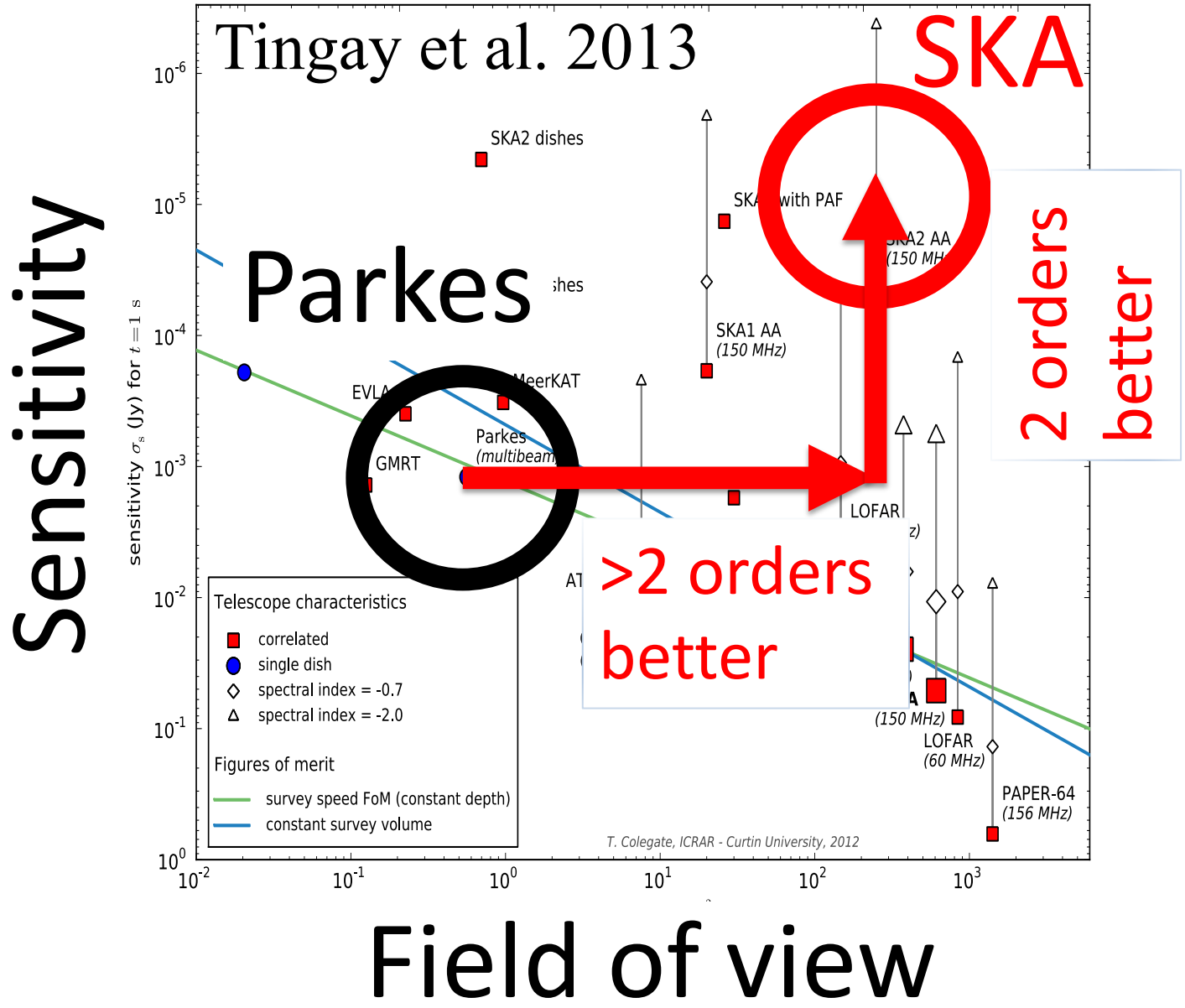
Focusing Squarely on FRBs with
the Square Kilometre Array

https://astrobites.org/2020/08/27/focusing-squarely-on-frbs-with-the-square-kilometre-array/

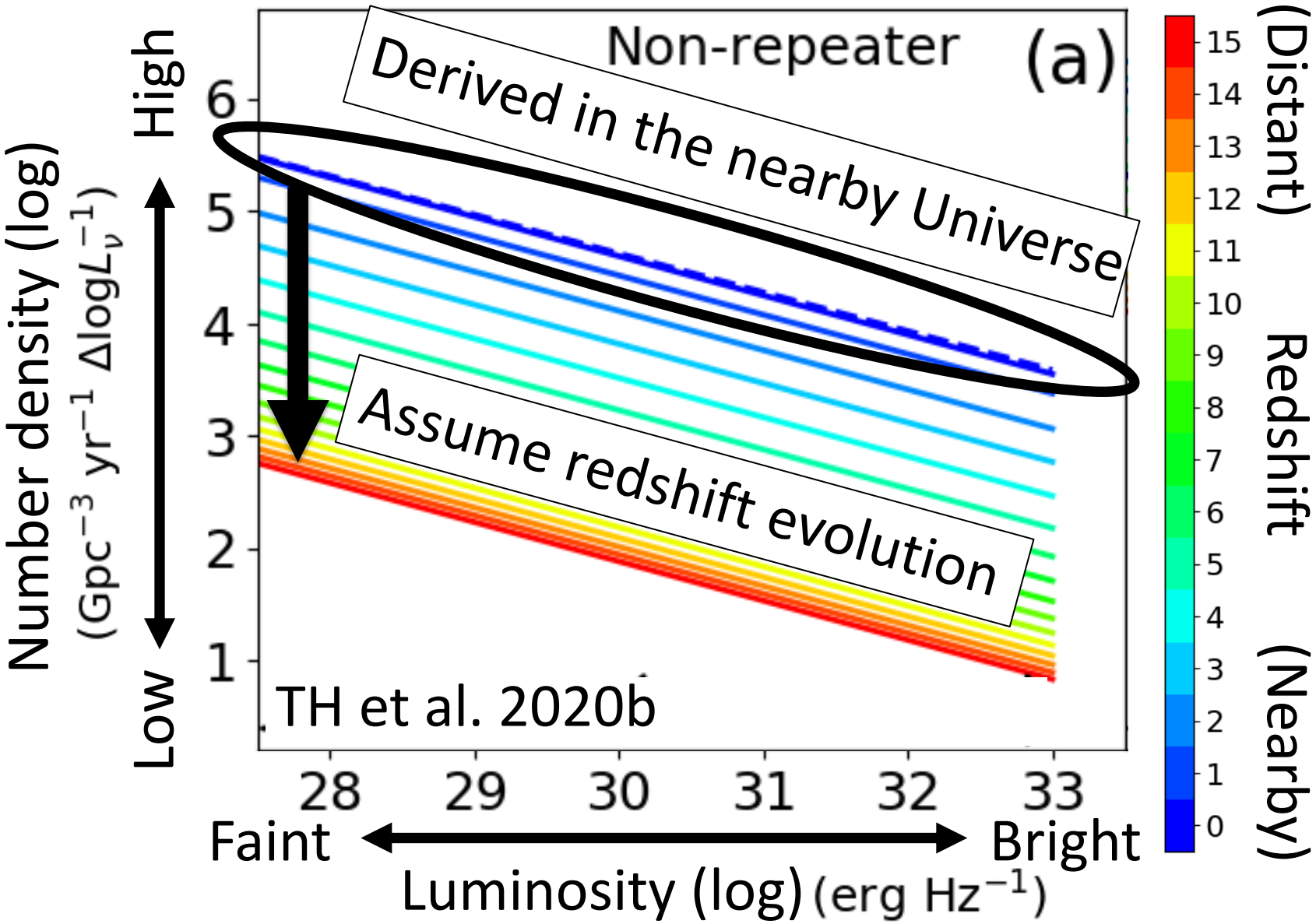
Future: The Square Kilometre Array

The SKA will start science operation in 2020s in South Africa and Australia.

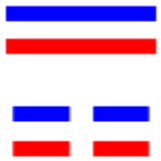
Future: The Square Kilometre Array



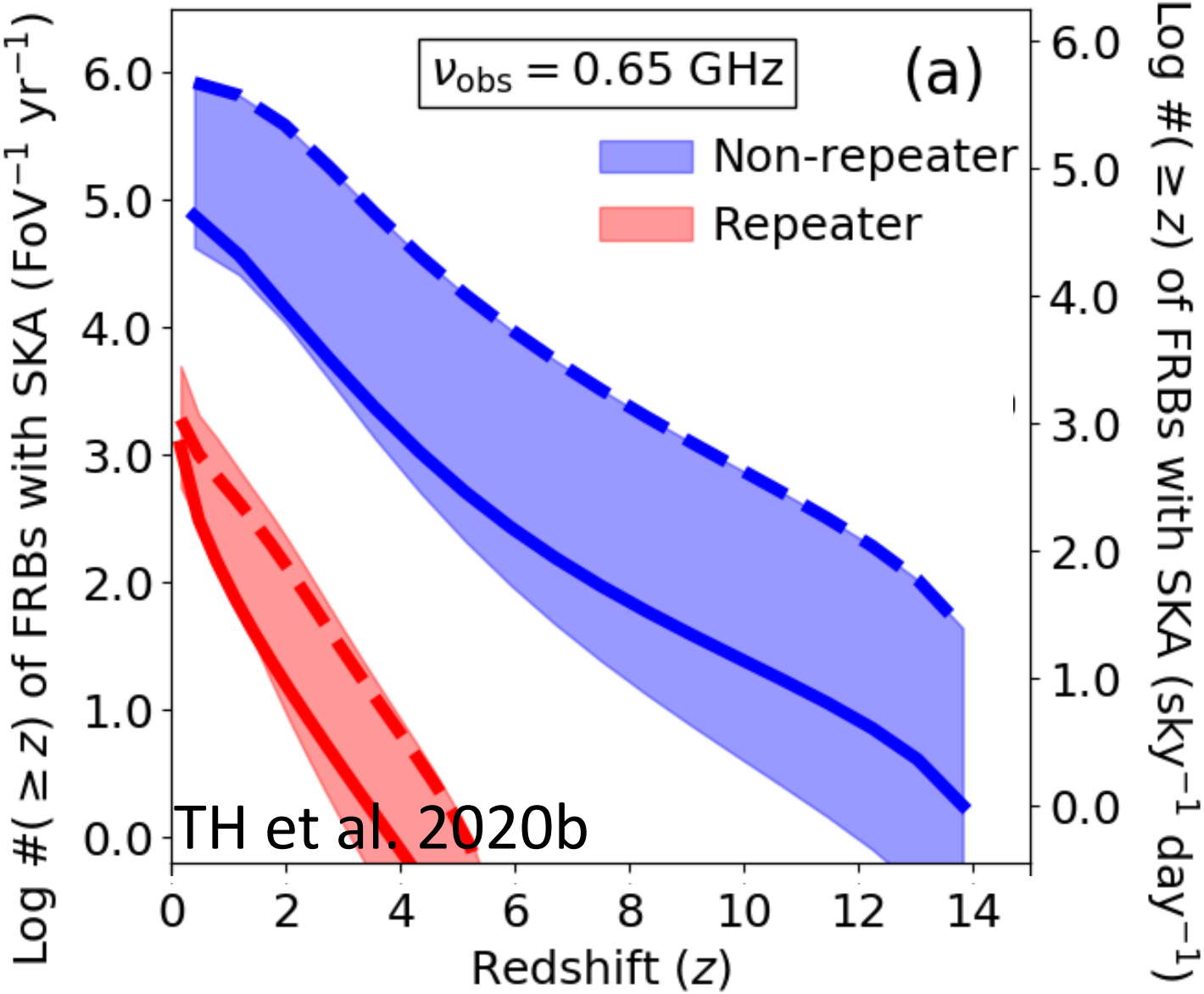
Future: How many FRBs are in the Universe?



Future: How many FRBs with the SKA?



Different assumptions on redshift evolution



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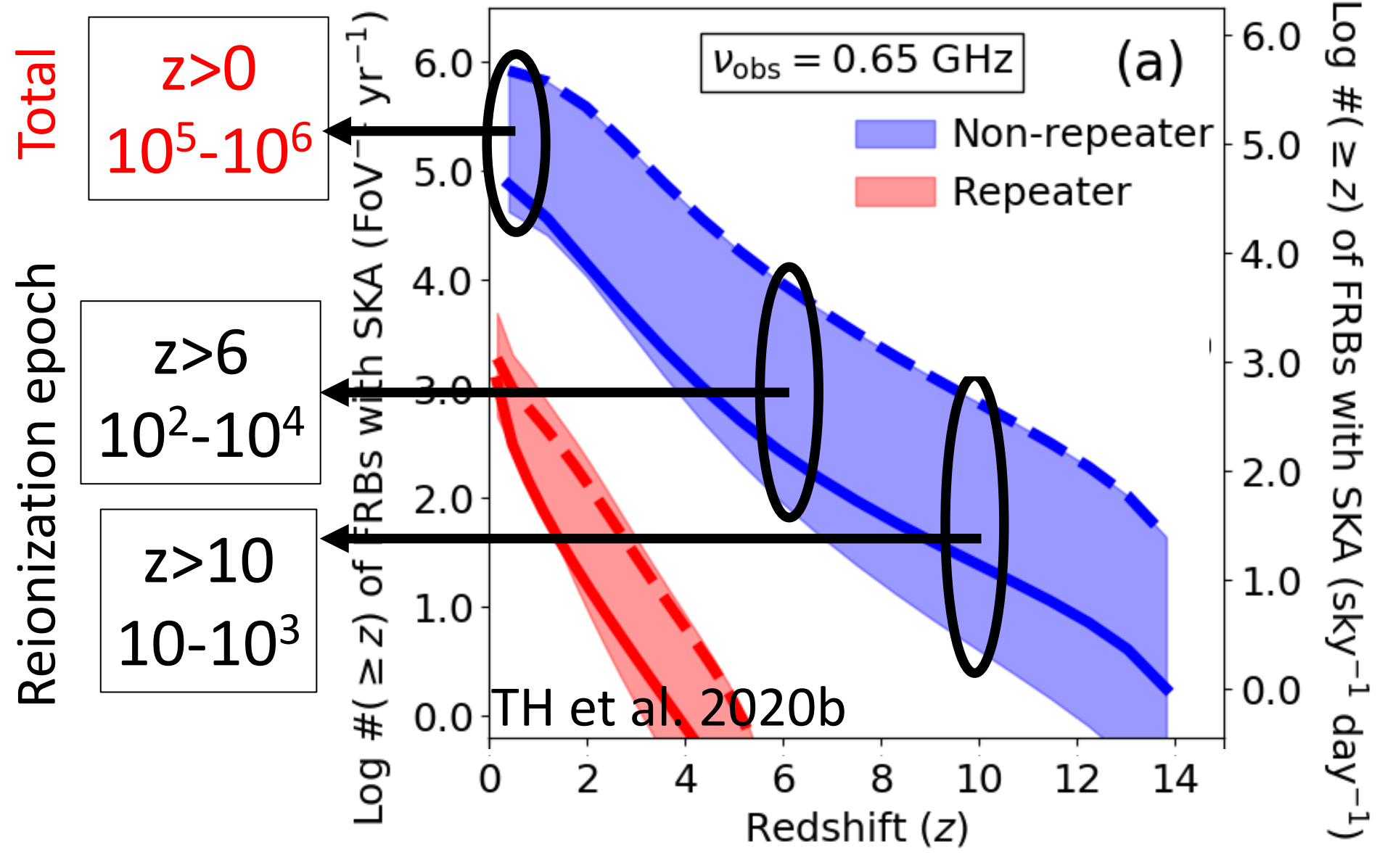
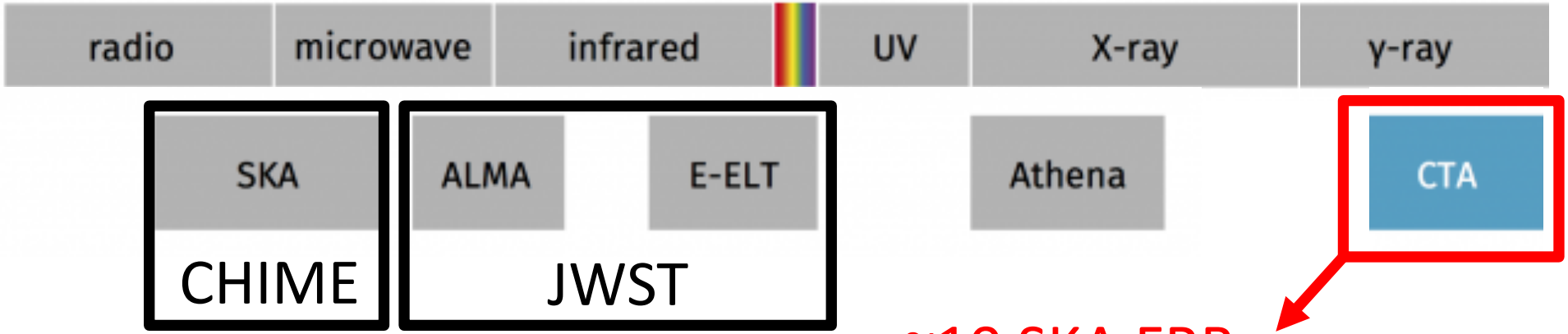


Future: The CTA is definitely important

Credit: https://www.cta-observatory.org/



>~10 SKA FRBs per CTA FoV per day

1. Very high energy (VHE) counterpart
2. $<10^{-3}$ s time resolution optical counterpart

Possible counterparts of FRBs

VHE:

Ultra-relativistic outflows + ambient material

(>~ms, e.g., Lyubarsky 2014; Murase et al 2016)

Relativistic jet from a super massive black hole

(sec-min, e.g., Vieyro et al. 2017)

X-ray to MeV:

Magnetar (~ms, e.g., Lyutikov 2002; SGR1935+2154)

Optical:

Magnetic reconnection (~ms, e.g., Kumar et al. 2017)

NS-NS merger (~day, e.g., Yamasaki+2018)

WD-WD merger (~day, e.g., Kashiyama et al. 2013)

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Benchmark of future FRBs observations

Monthly Notices
of the
ROYAL ASTRONOMICAL SOCIETY

MNRAS **481,** 2479–2486 (2018)
Advance Access publication 2018 September 04

doi:10.1093/mnras/sty2422

Constraining very-high-energy and optical emission from FRB 121102 with the MAGIC telescopes

MAGIC Collaboration: V. A. Acciari,[1] S. Ansoldi,[2,3] L. A. Antonelli,[4] and et al.

Simultaneous observations of repeating FRB 121102 using Arecibo and MAGIC (~9 hours on source).

Five FRBs were detected.

$L_{VHE} < 10^{49}$ erg s^{-1} <-- VHE

$f_{opt} < 8.6$ mJy <-- Optical

Final conclusion

- Our statistical approach: different origins of non-repeating and repeating FRBs, i.e., old and young objects, respectively.
- The SKA: 10^5-10^6 FRBs per year
- The CTA: VHE and optical counterparts of FRBs --> FRB origin(s)