No redshift evolution of non-repeating fast radio burst rates

Tetsuya Hashimoto

(Centre for Informatics and Computation in Astronomy: CICA fellow, NTHU)

- 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
- TH et al. 2020d submitted to MNRAS

高エネルギー宇宙物理学研究会, 14 Dec. 2020

Outline

1. ***Introduction***

   What is the fast radio burst?

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

   Luminosity-duration relation

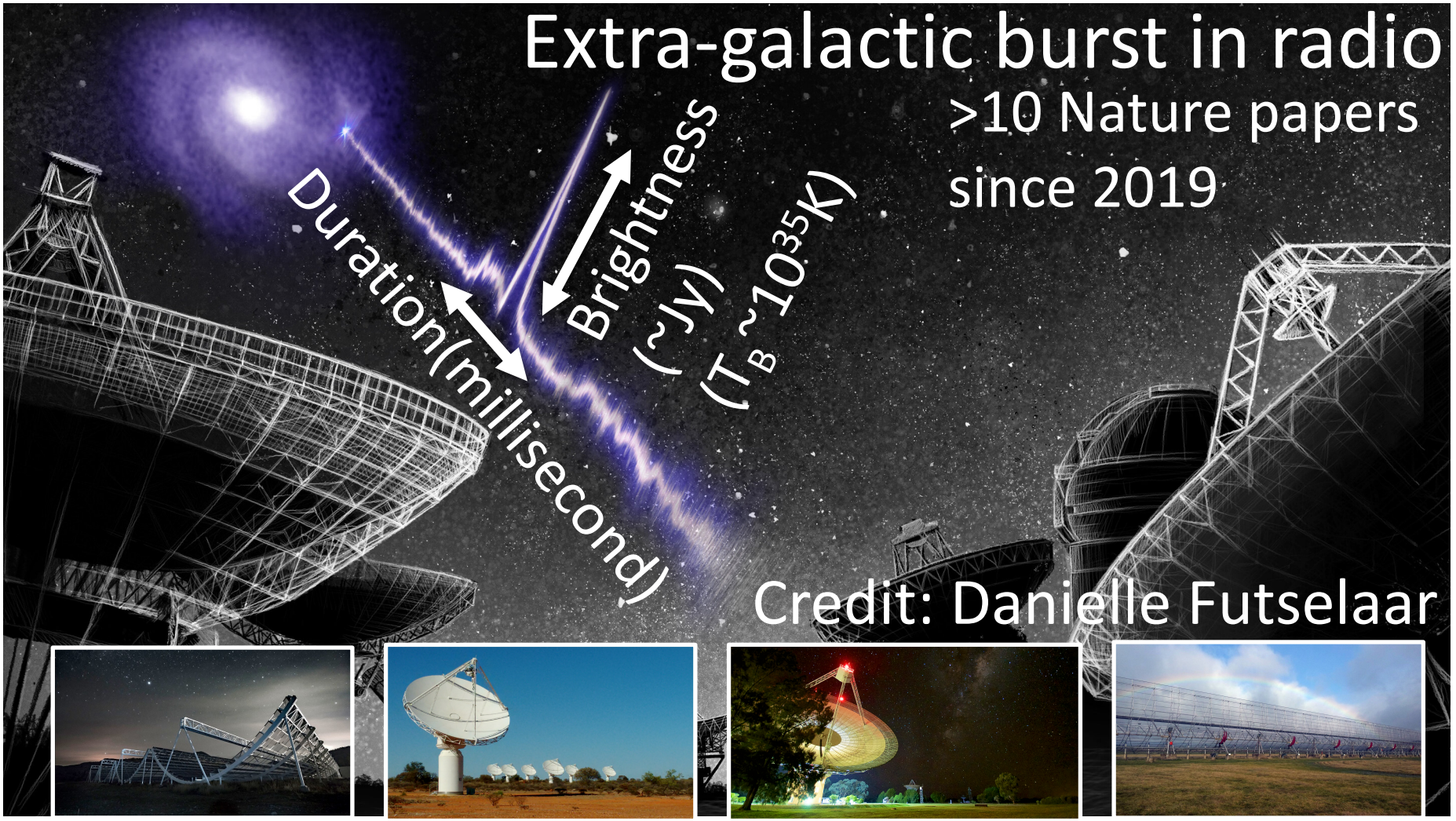
   Luminosity function

3. ***Future prospects of FRBs:***

   The SKA and cosmic reionization history

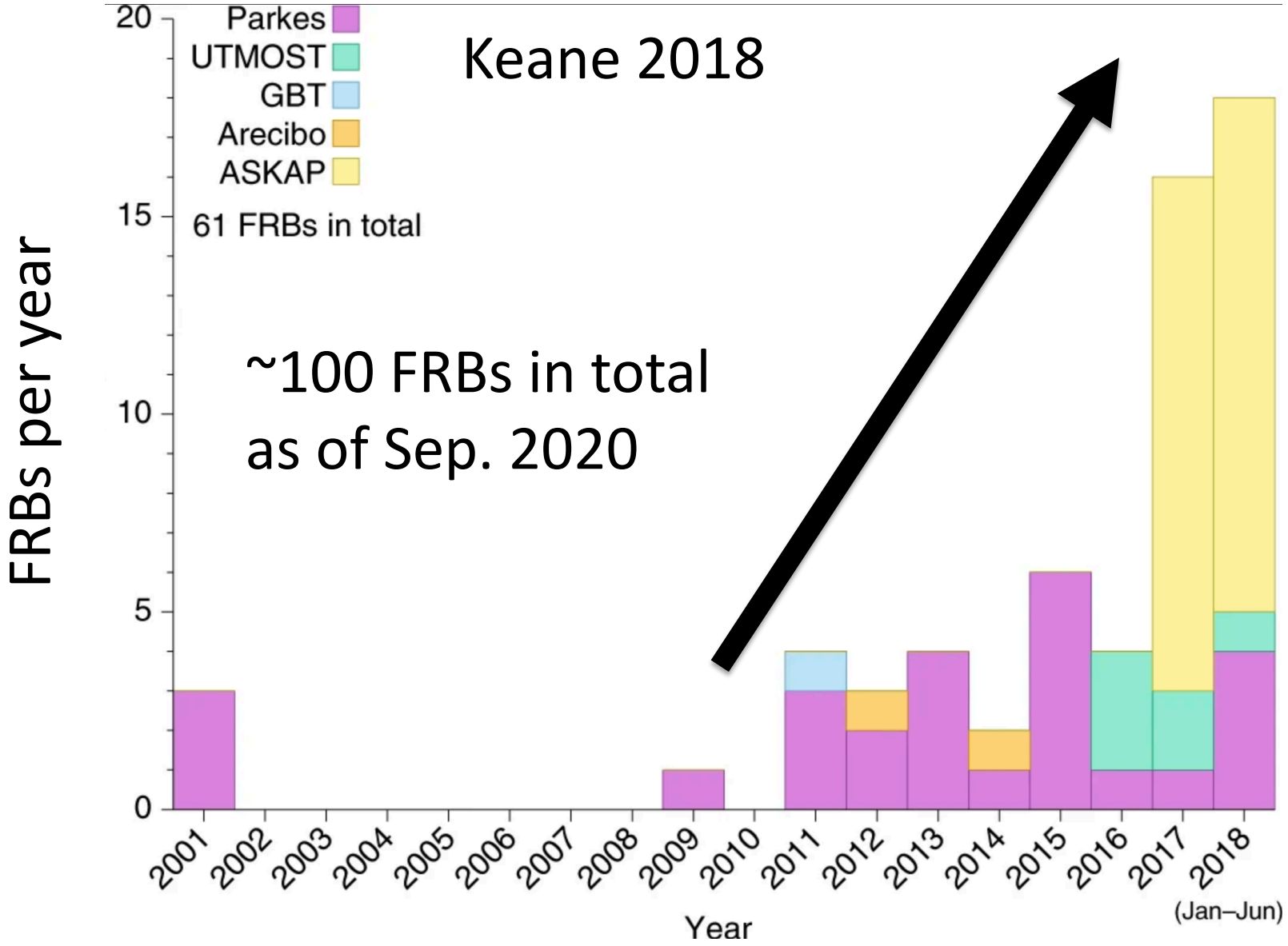
4. ***Conclusion***

Introduction: Fast radio burst (FRB)



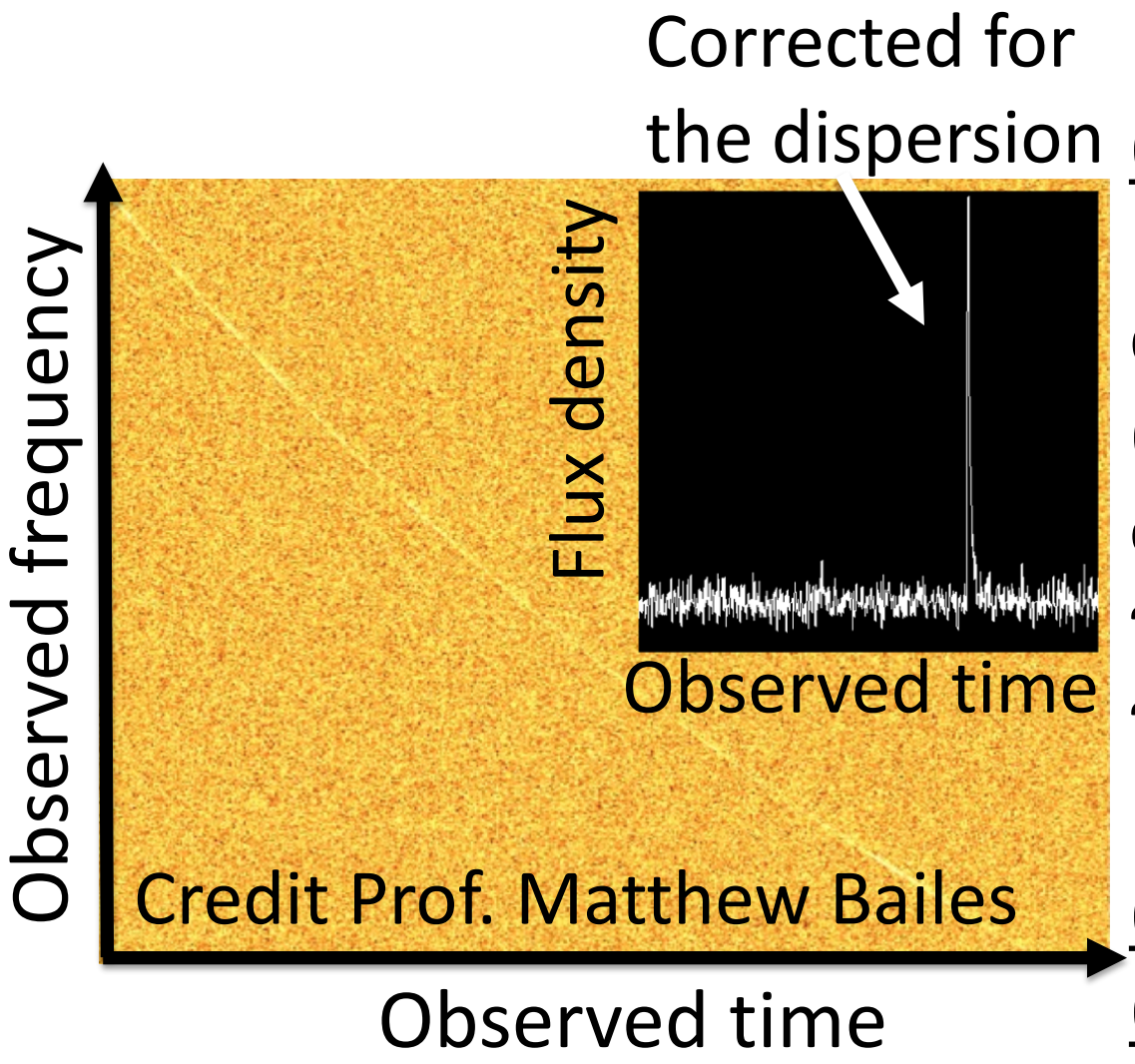
Introduction: Fast radio burst (FRB)

Introduction: Detection per year



>1000 FRB detections will be released by CHIME soon 2020-2021

Introduction: Observables



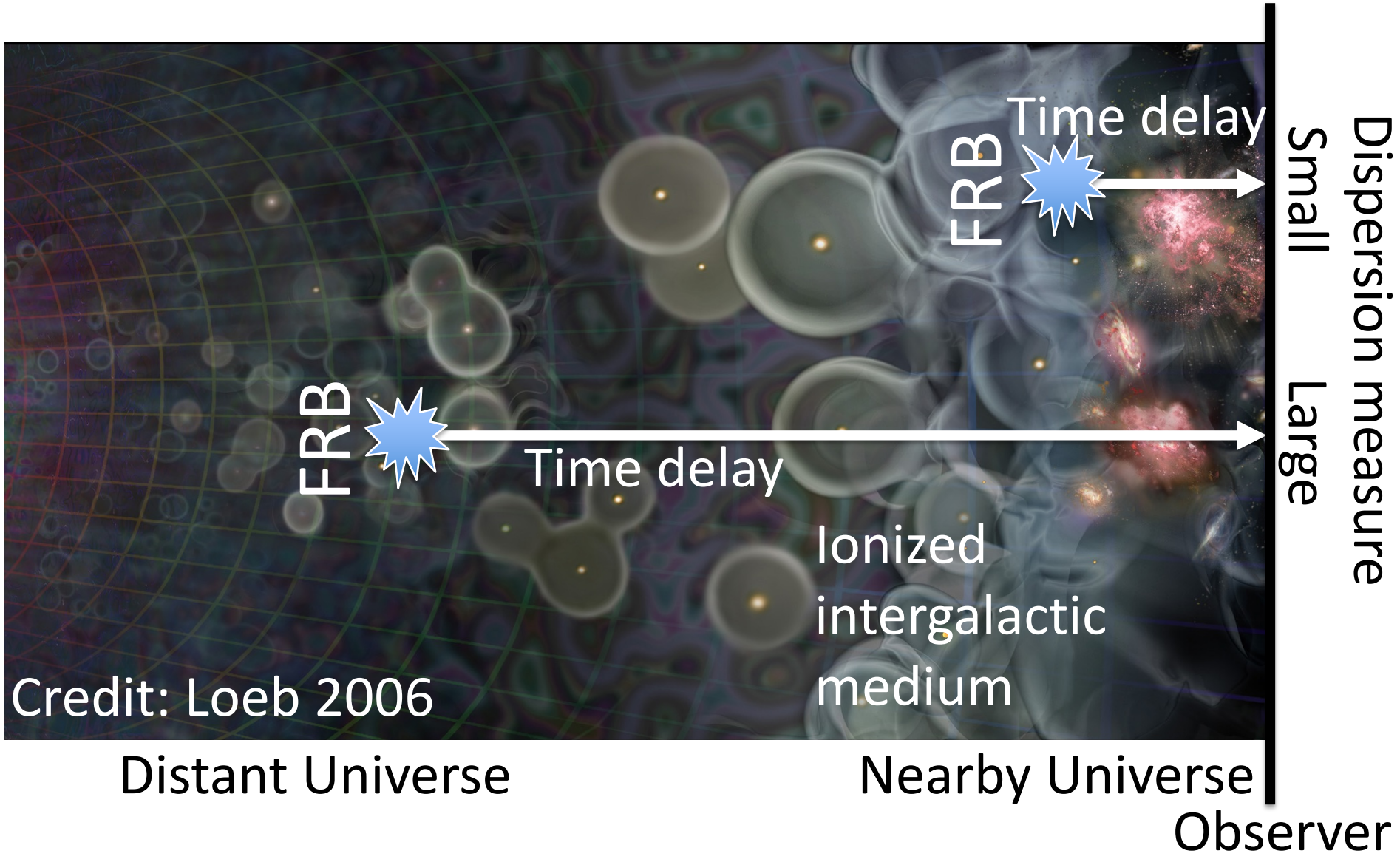
(1) Dispersion measure
→Time delay between different frequencies (materials along a line of sight to a FRB
~distance indicator
~redshift)

(2) Pulse duration

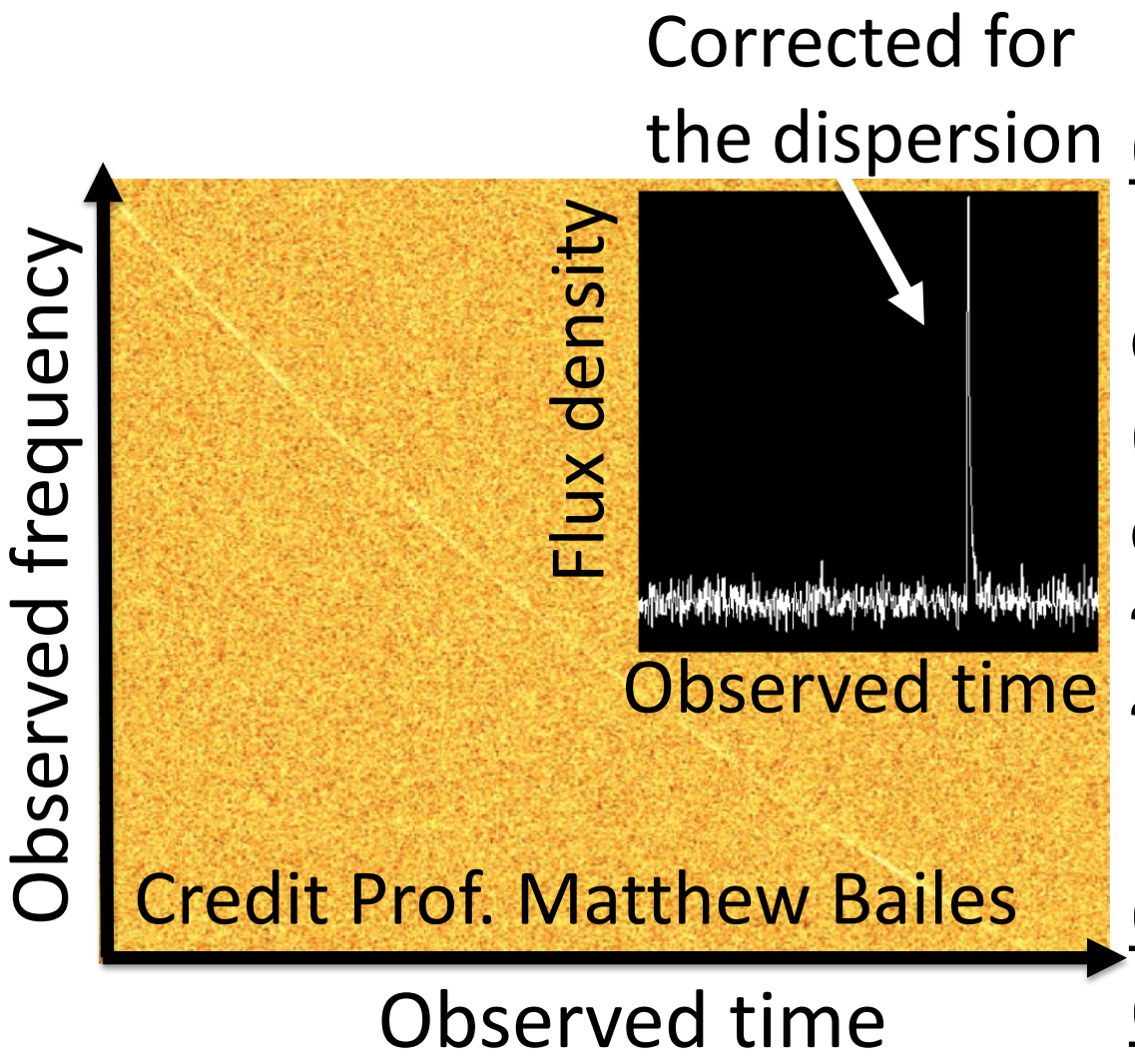
(3) Fluence

(4) Repetition

Introduction: Dispersion measure



Introduction: Observables



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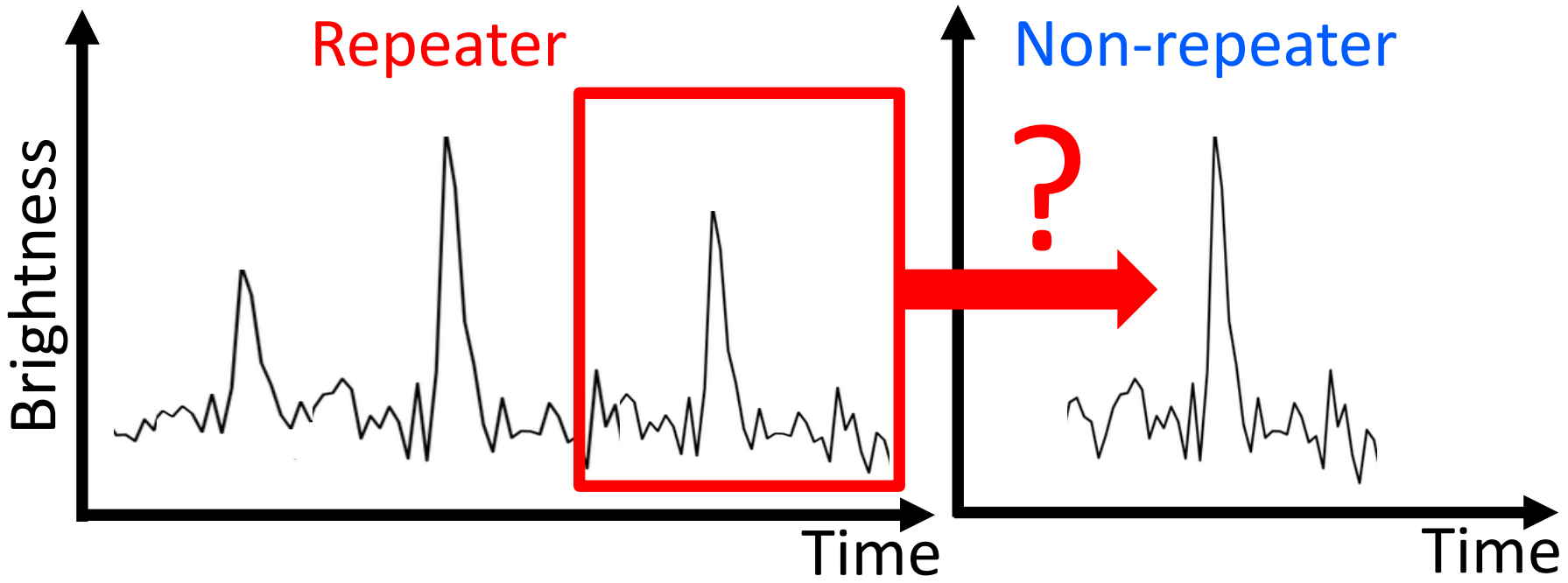
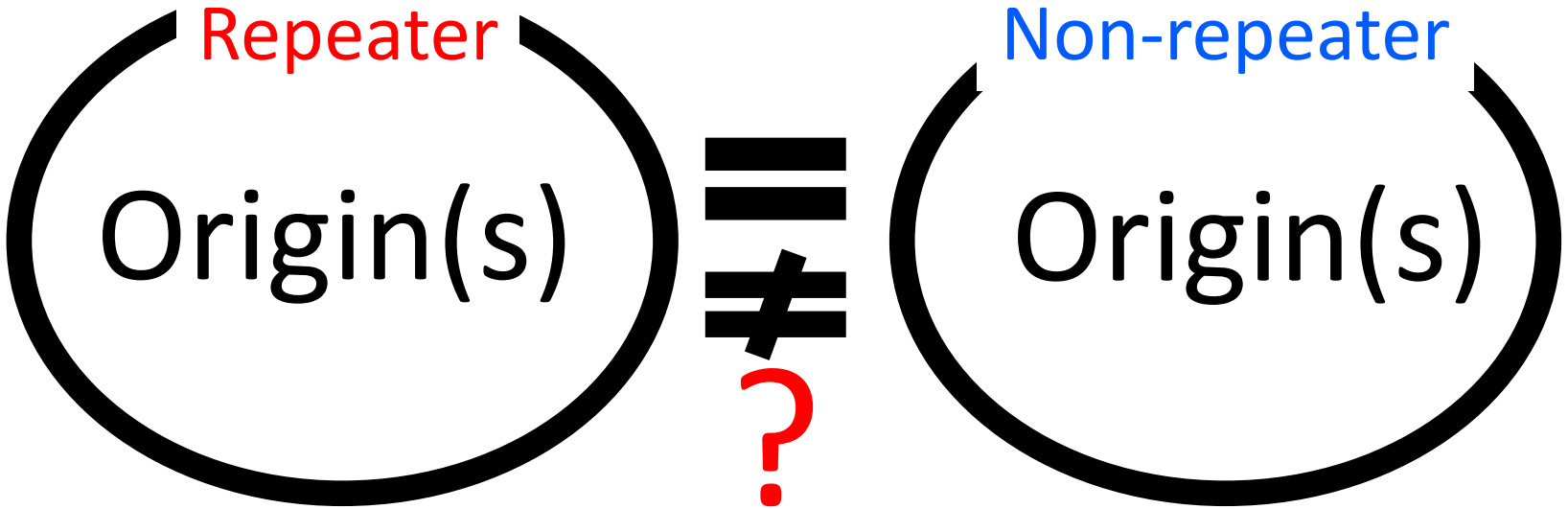
Introduction: Repeater/Non-repeater



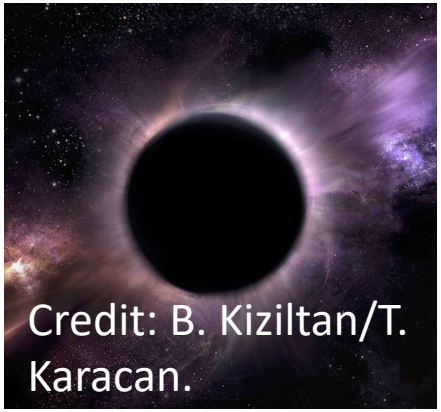


Introduction: >50 theories

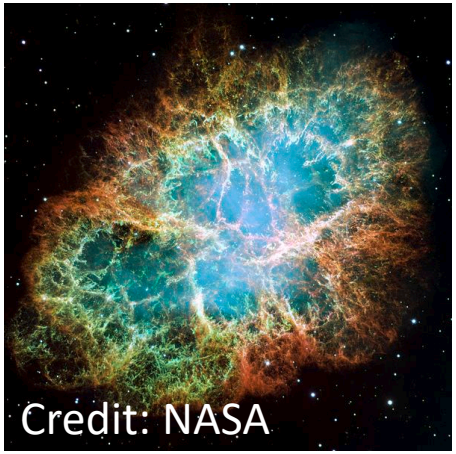
White dwarf

Neutron star

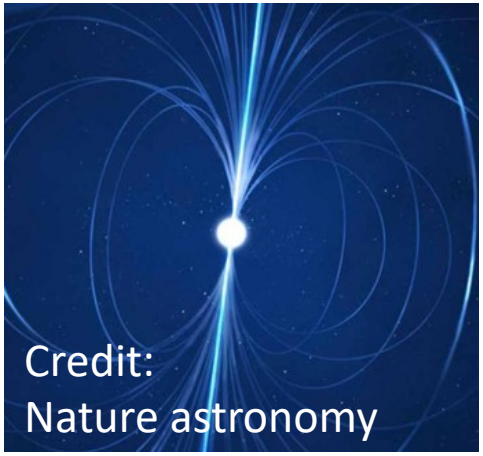
Black hole (BH)



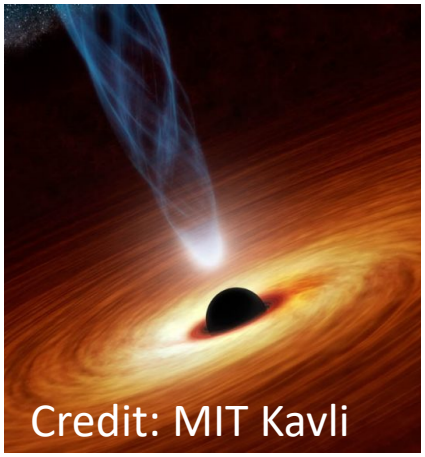
Supernova rem.



Young Pulsar



Active SMBH



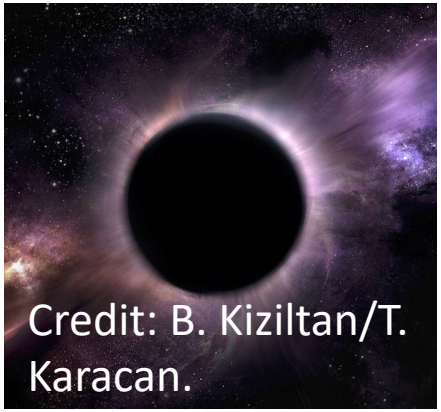
Magnetar

Introduction: >50 theories

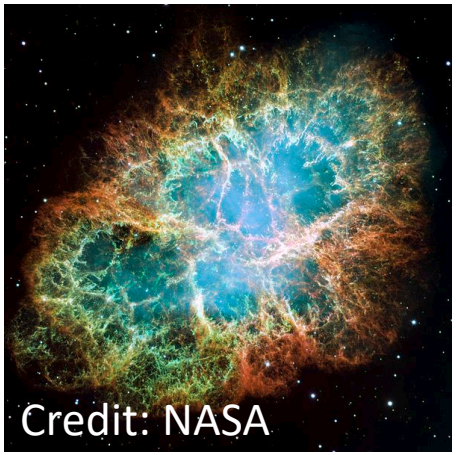
White dwarf

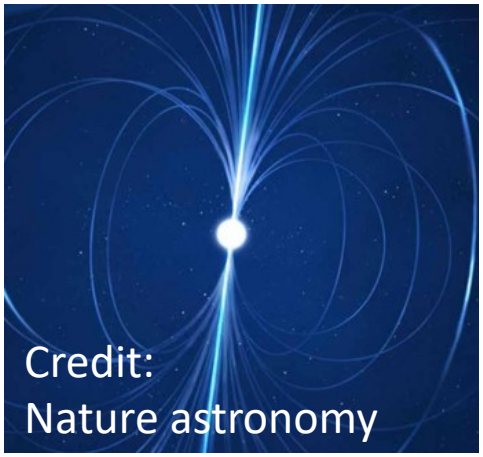
Neutron star

Black hole (BH)



Supernova rem. Young Pulsar Active SMBH Magnetar





One Galactic repeating FRB

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

Problem

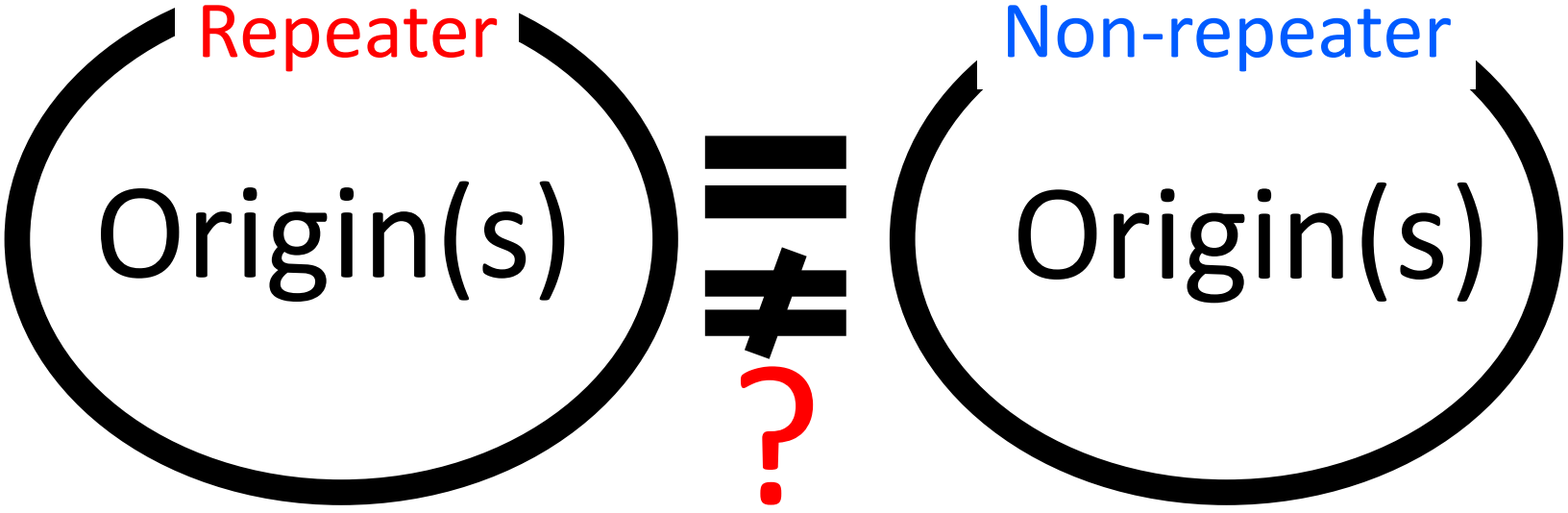
Only one confirmed case out of >100 FRBs

Solution (my talk)

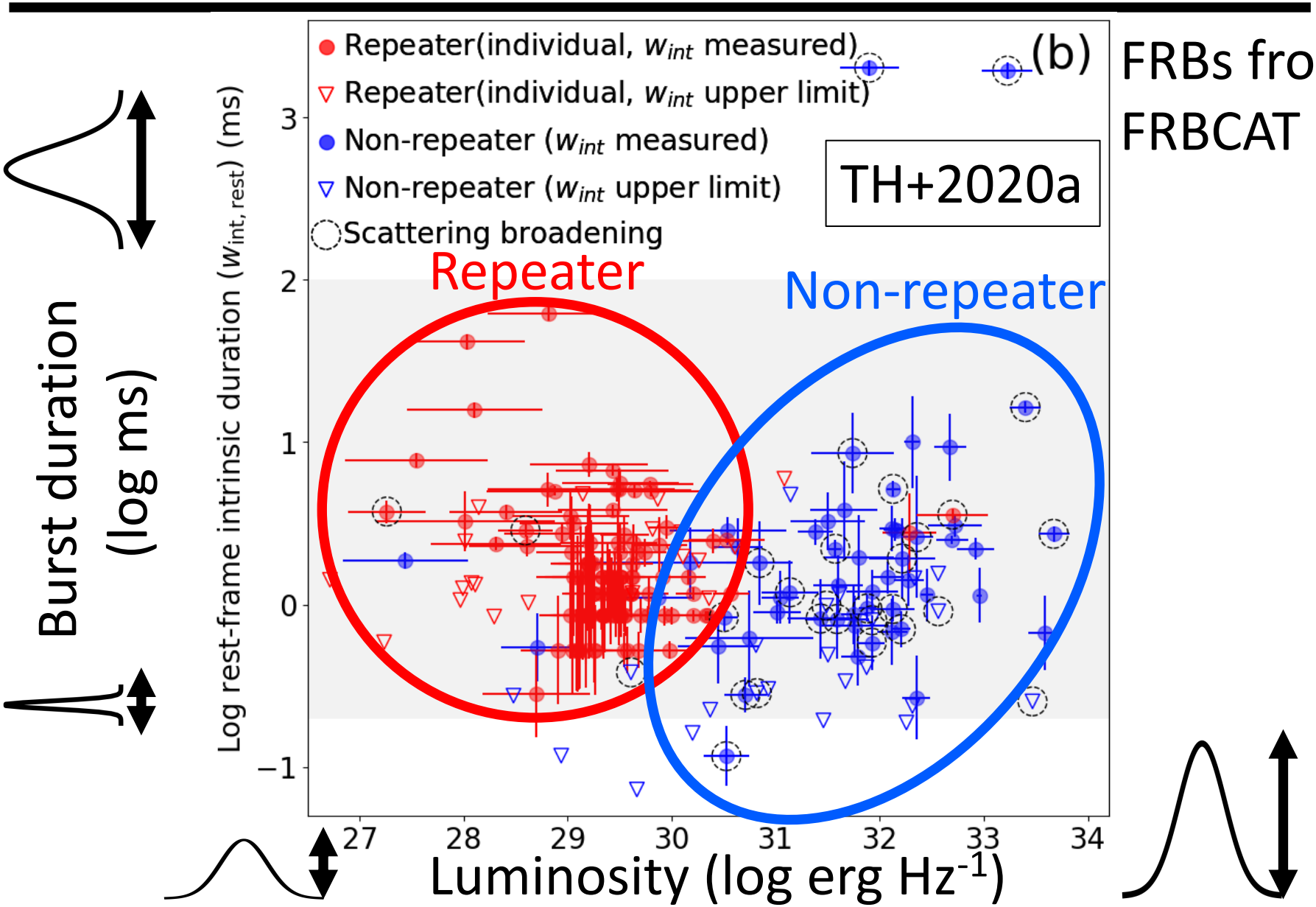
A statistical approach to constrain their origins

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

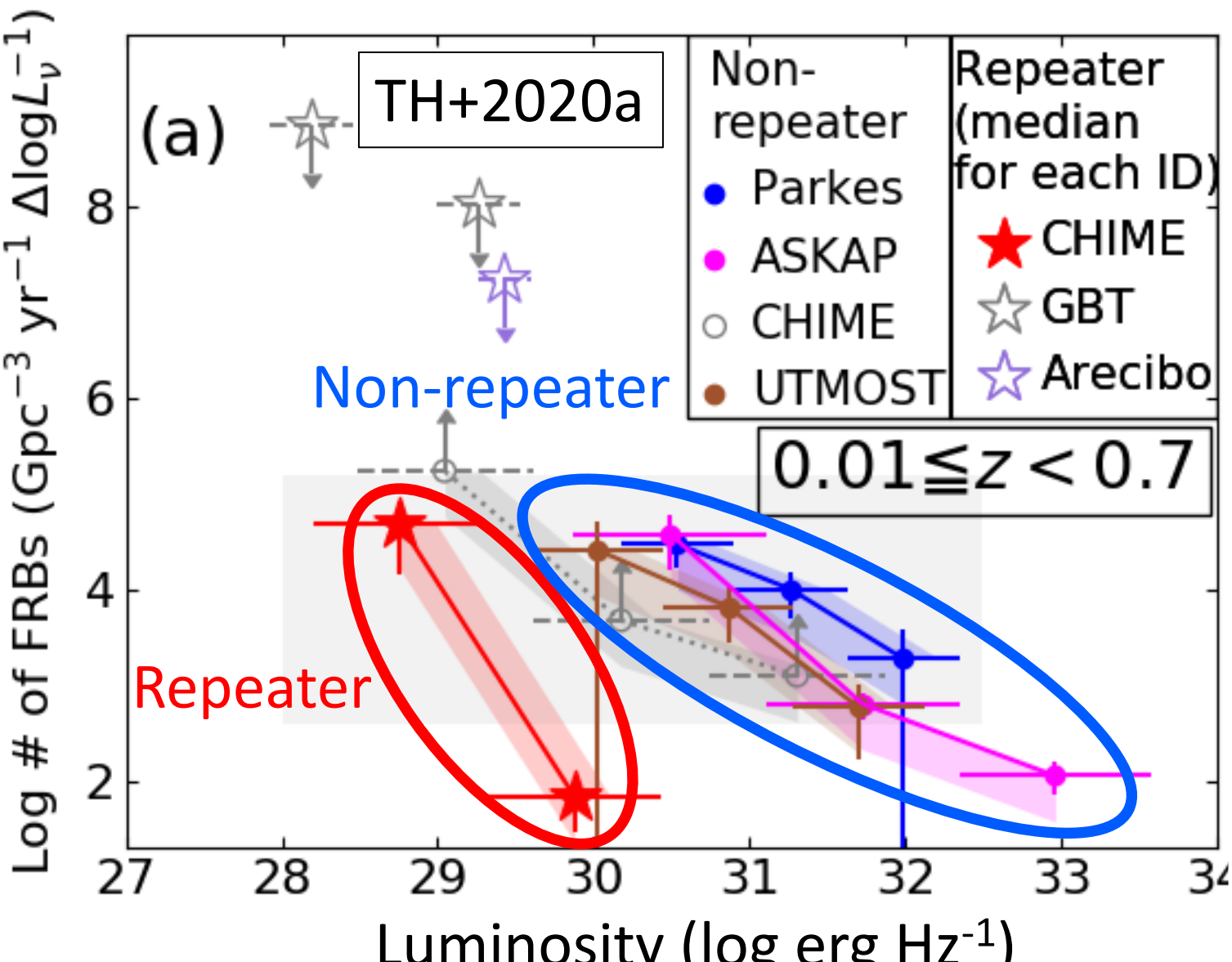
TH et al. 2020a and c



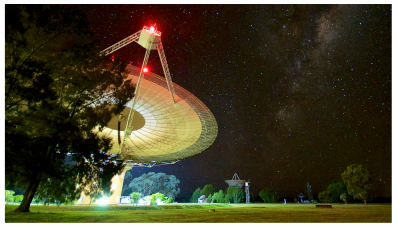
Results: (i)Luminosity and (ii)duration



Results: (iii)Luminosity functions



Parkes

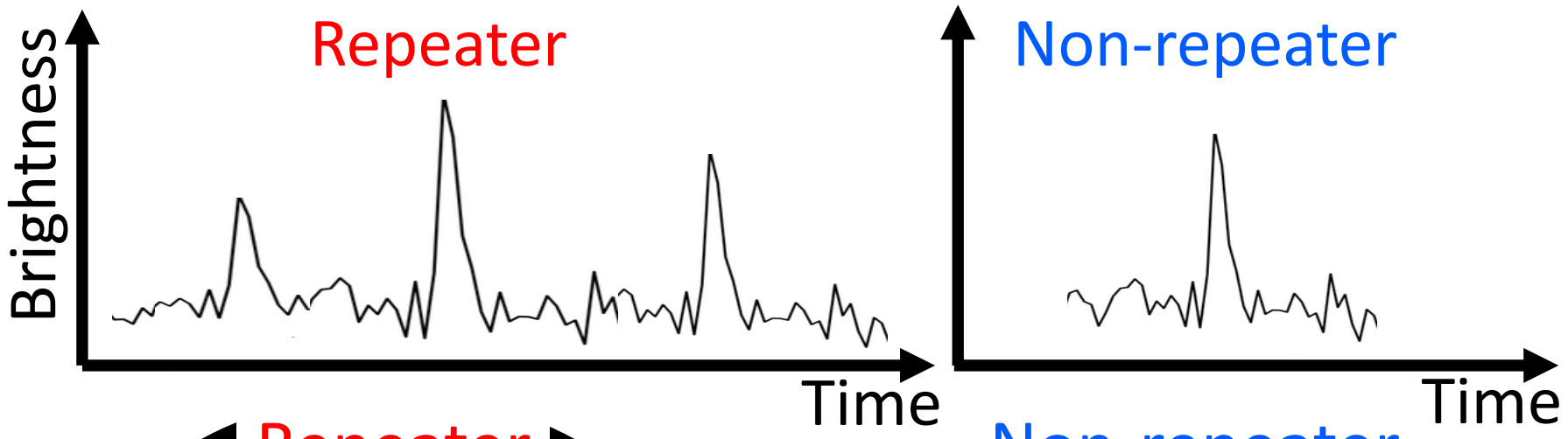


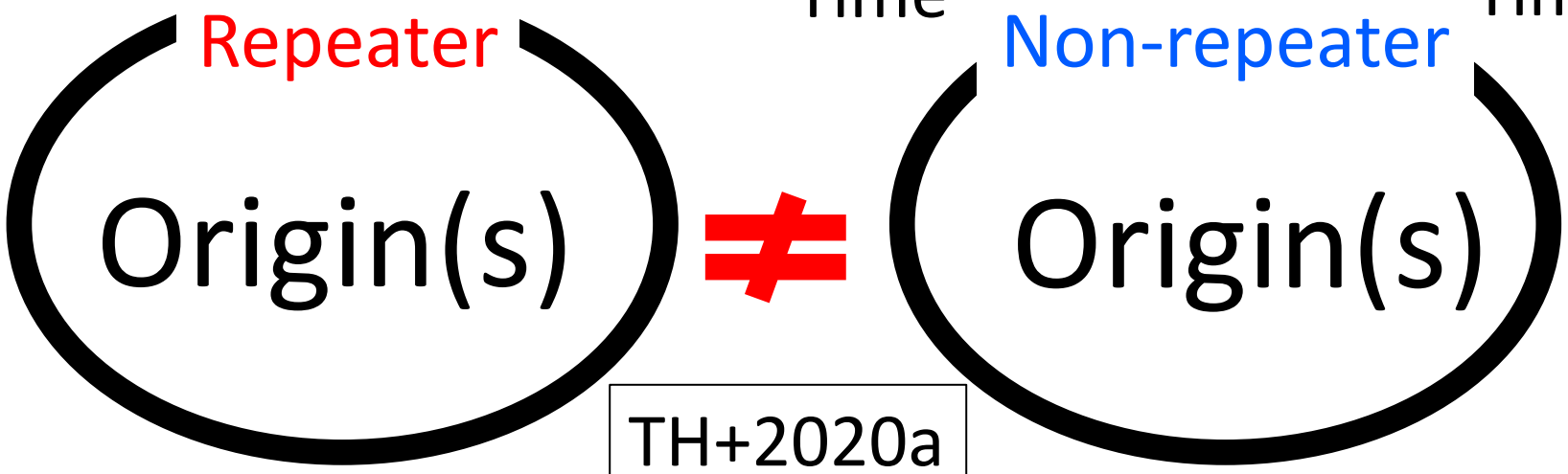
ASKAP

CHIME

UTMOST

Conclusion: Repeater/Non-repeater





TH+2020a

in terms of their

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

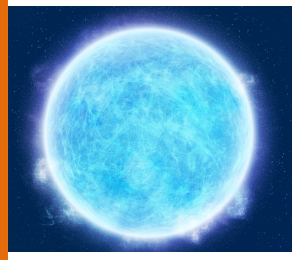
Introduction: Old vs Young

TH+2020c

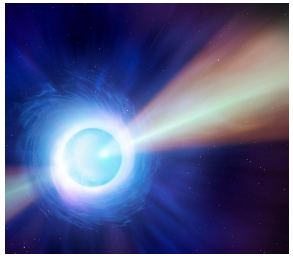
Number density ∝ stellar mass

Old objects

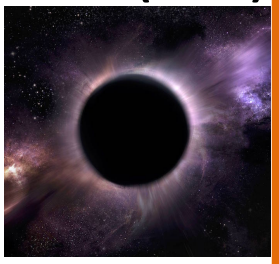
White dwarf



Neutron star



Black hole (BH)

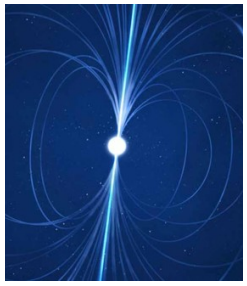


Number density ∝ activity

Young objects

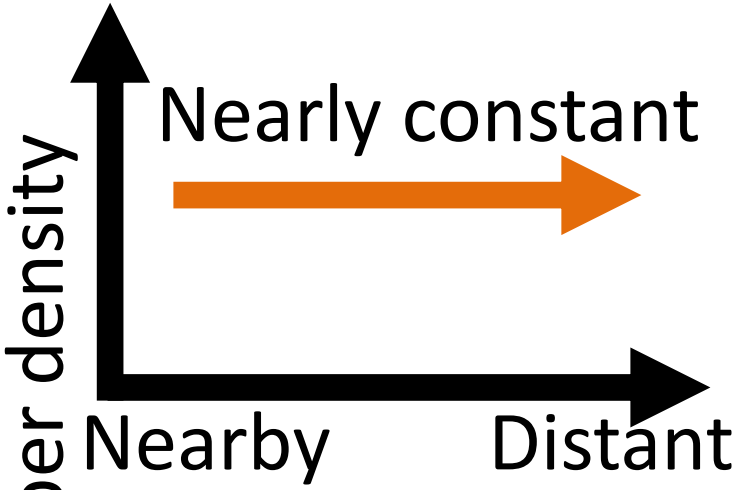
SN rem.

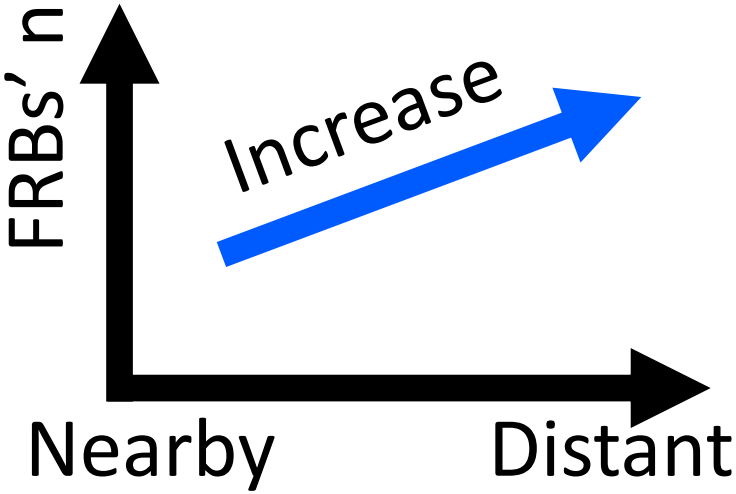
Young Pulsar



Active SMBH

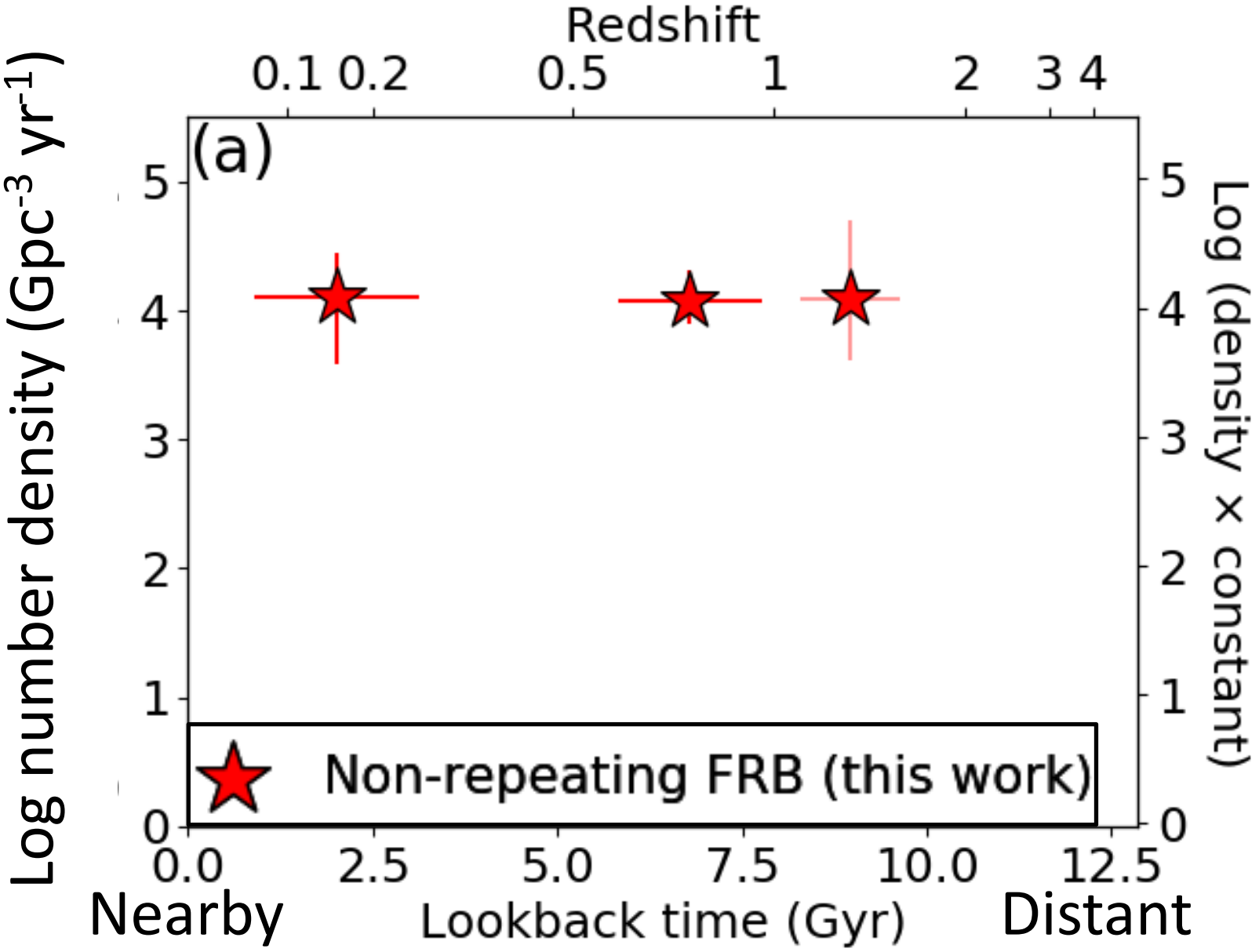
Magne tar





Results: Non-repeaters

TH+2020c



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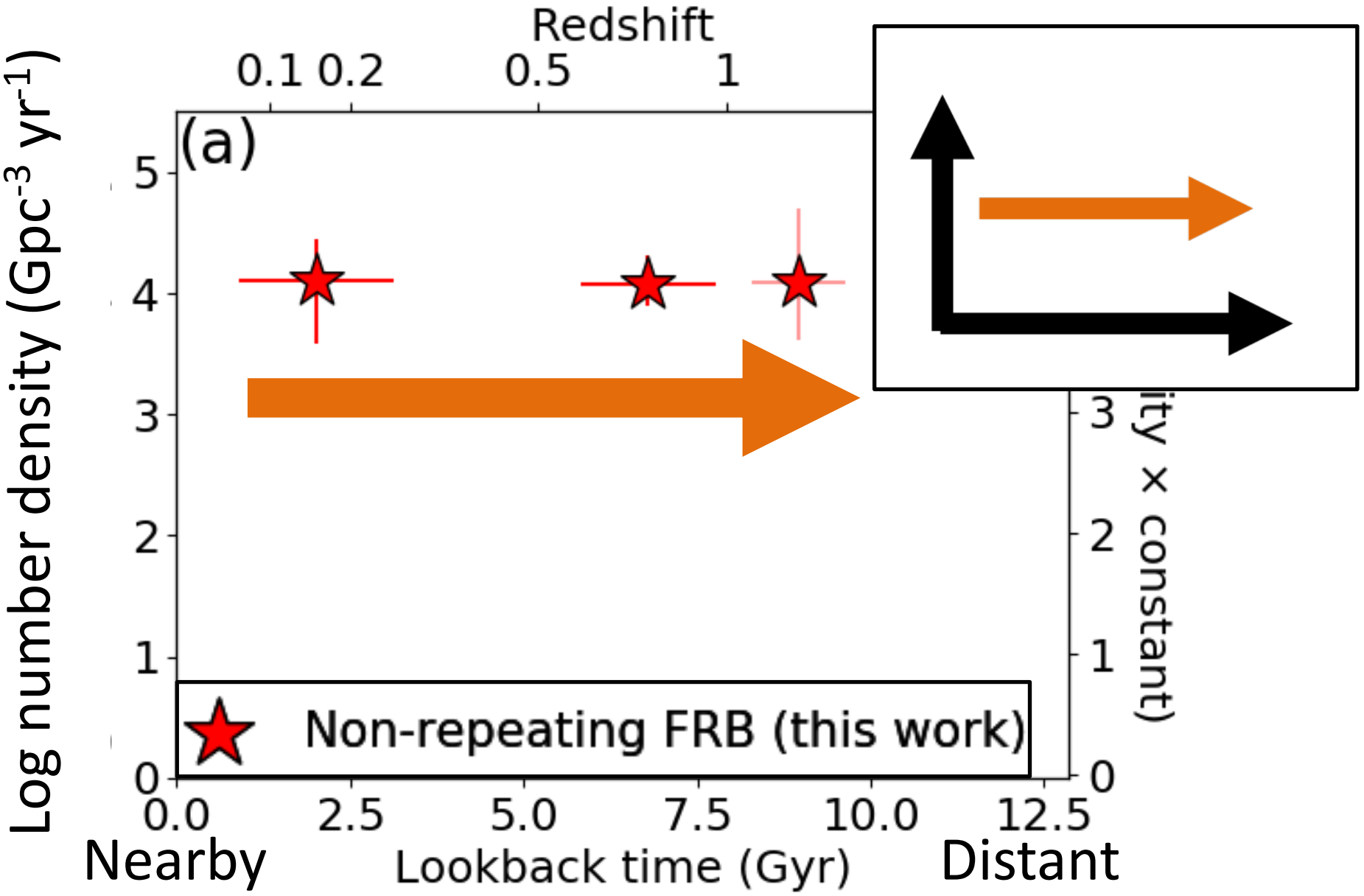

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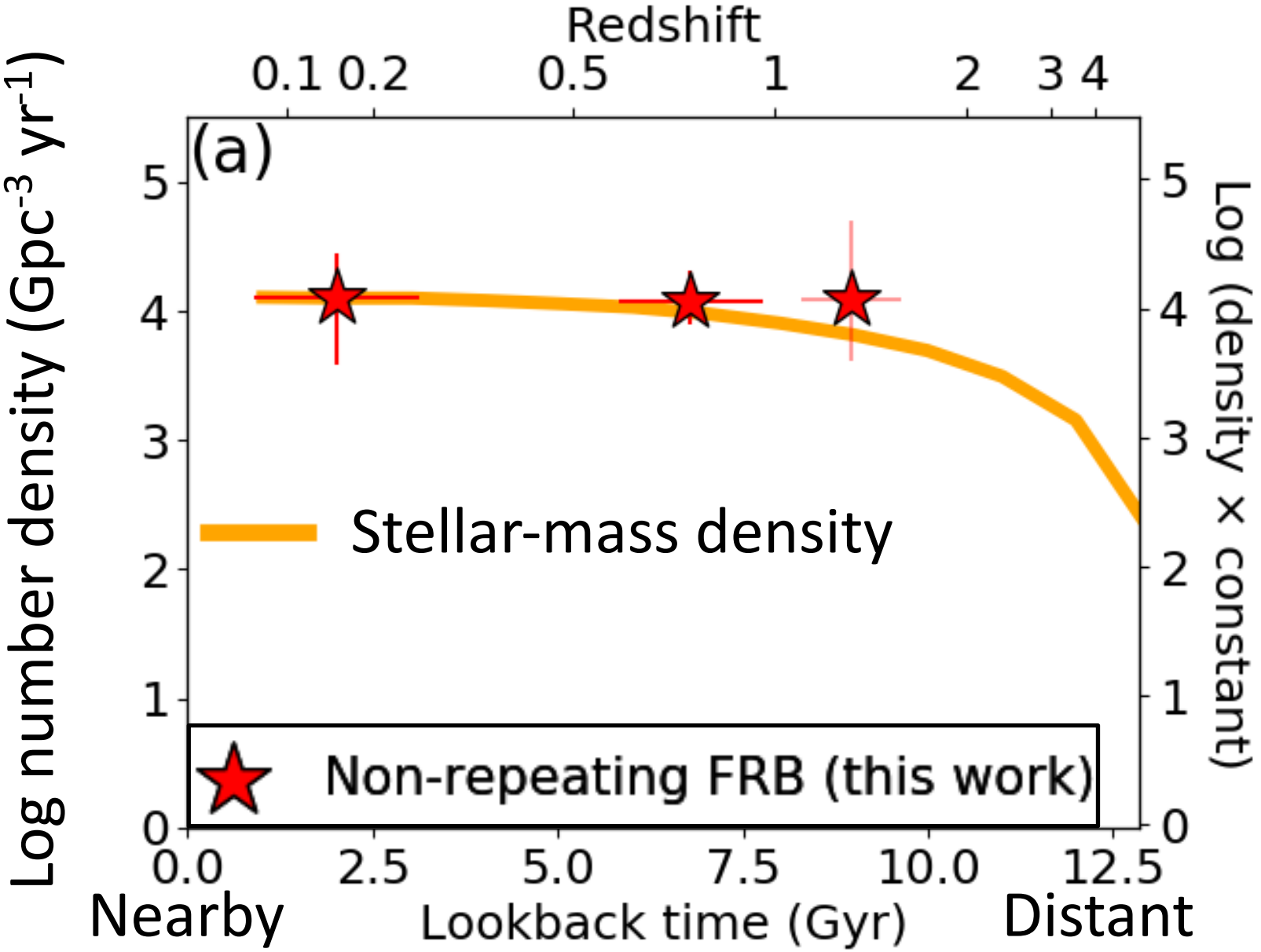

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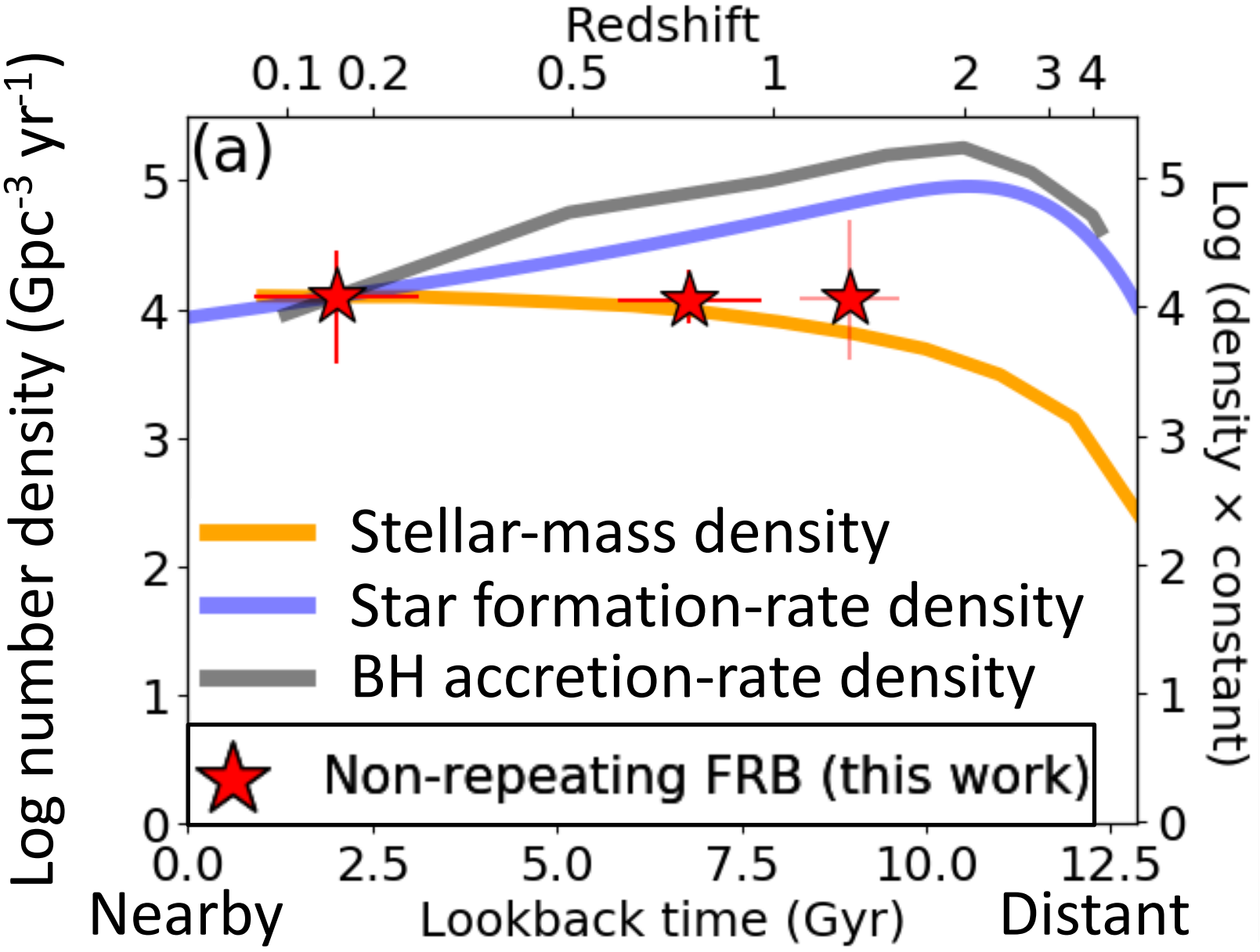

Results: Repeaters

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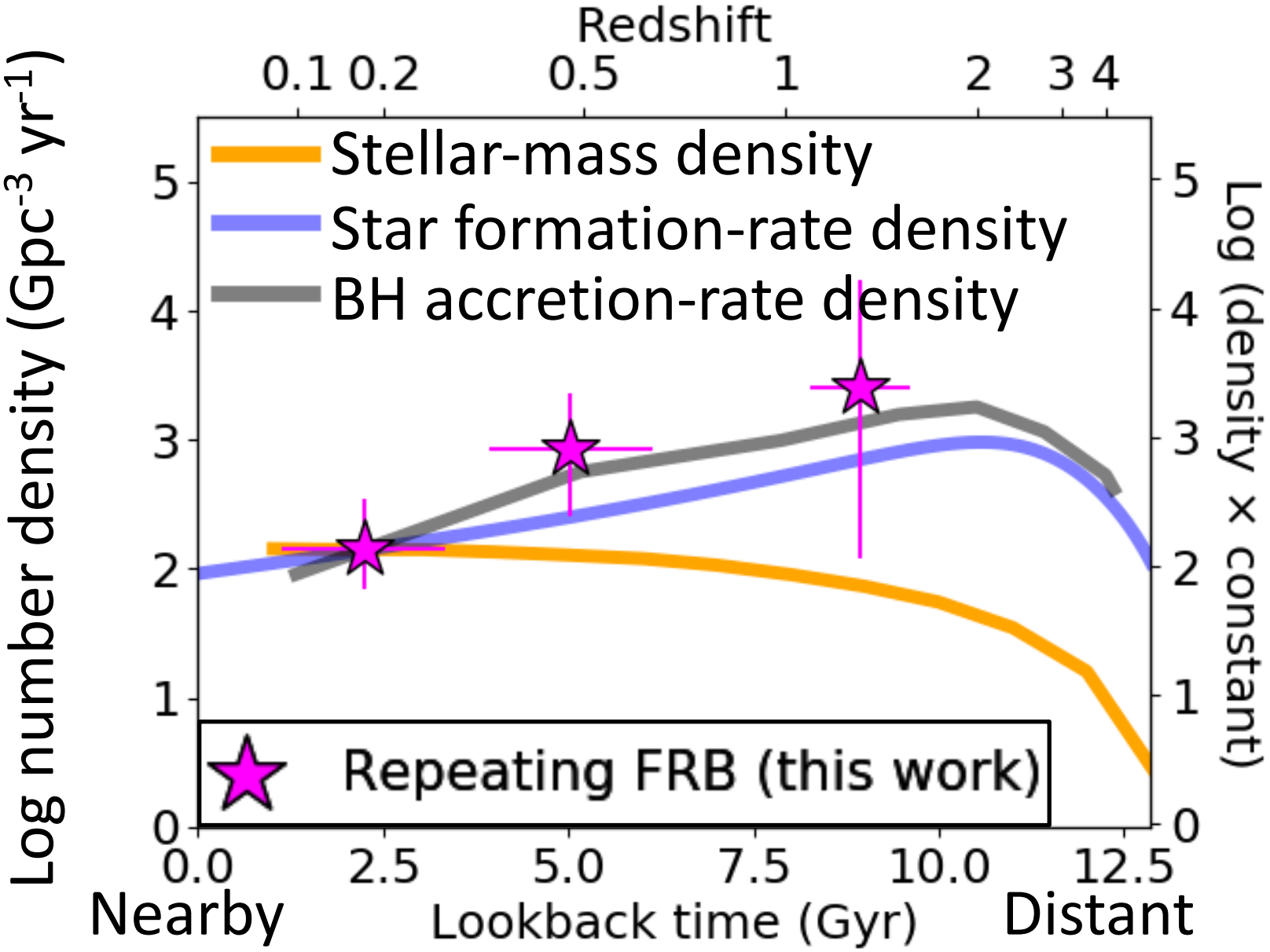
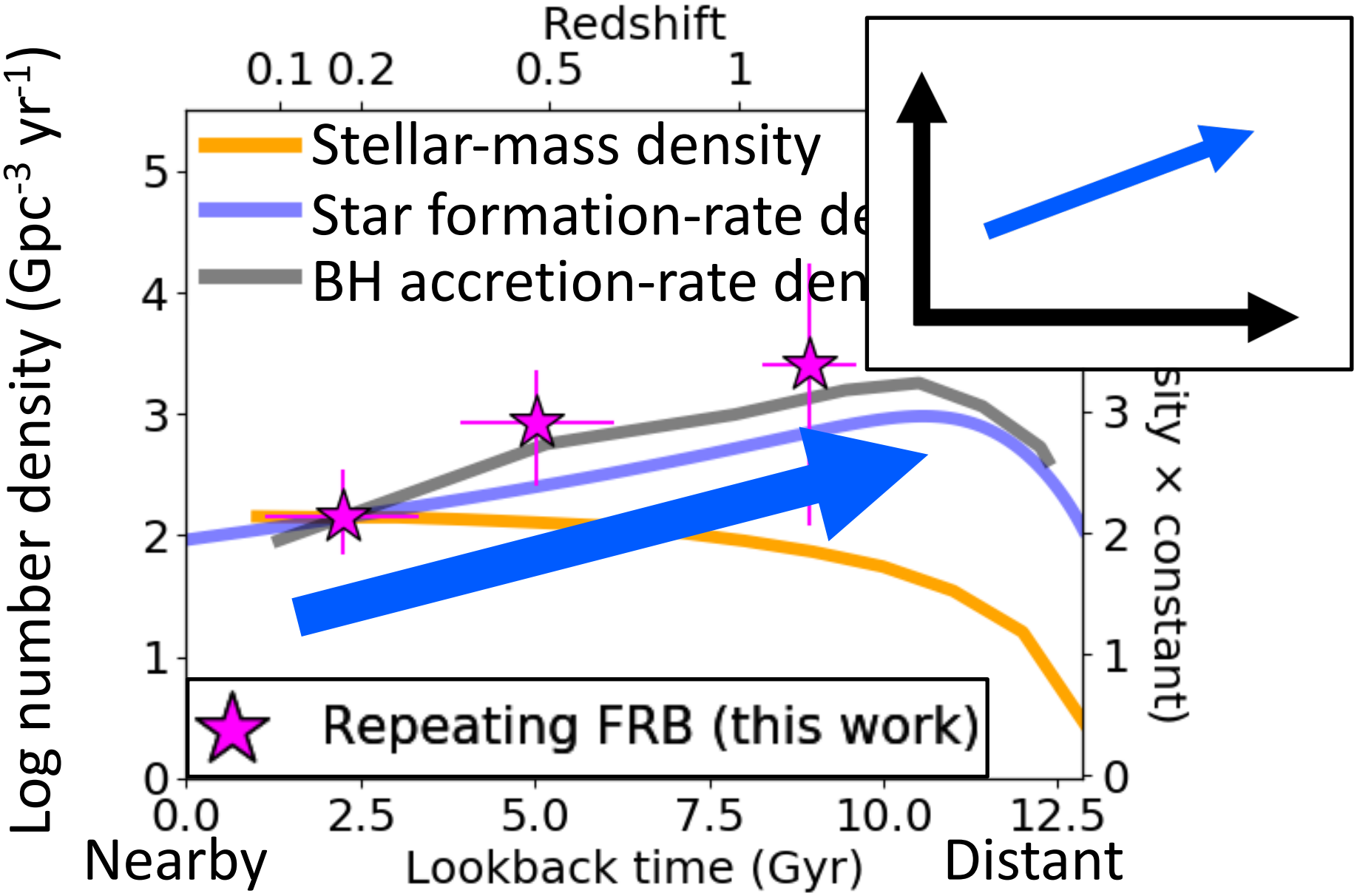


Results: Repeaters

TH+2020c

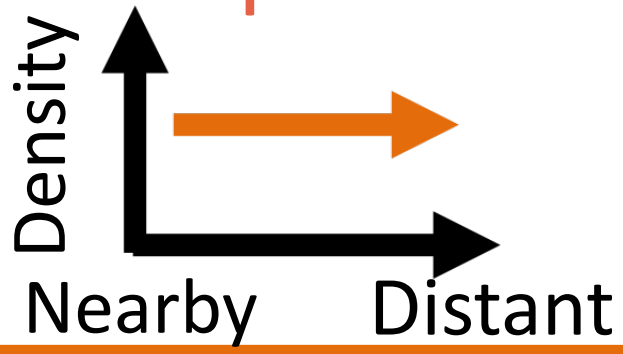


Conclusion: Old vs Young

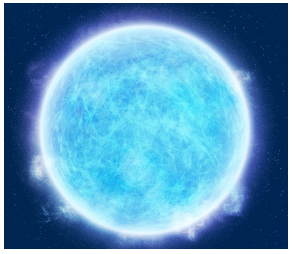
TH+2020c

Number density ∝ stellar mass

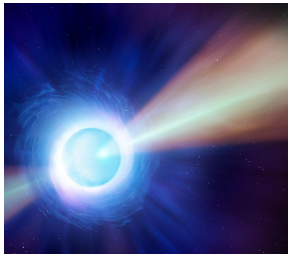
Non-repeaters



White dwarf



Neutron star



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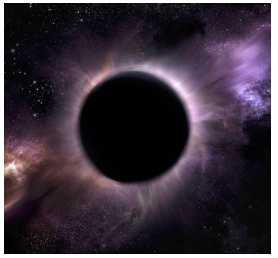
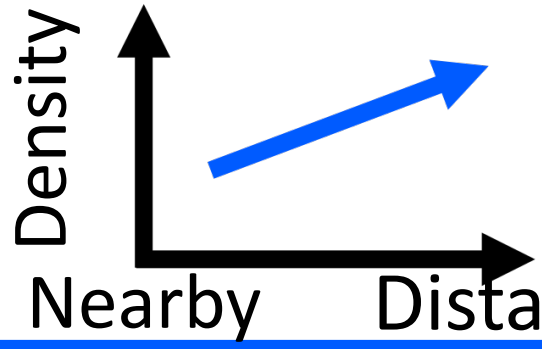


Old objects

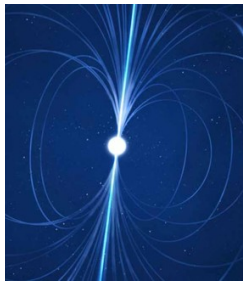
Number density ∝ activity

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 Square Kilometre Array***

TH et al. 2020b

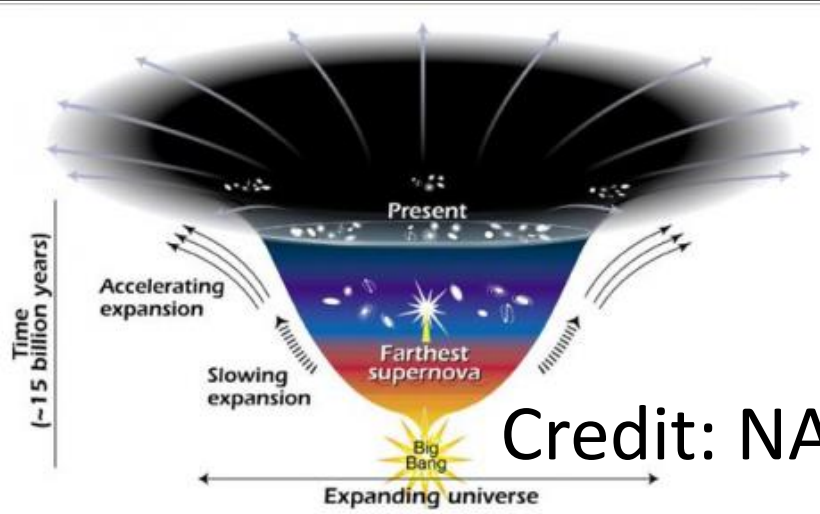
Future: FRB-related key sciences

(0)Origin of FRBs

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

(1)Dark energy

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



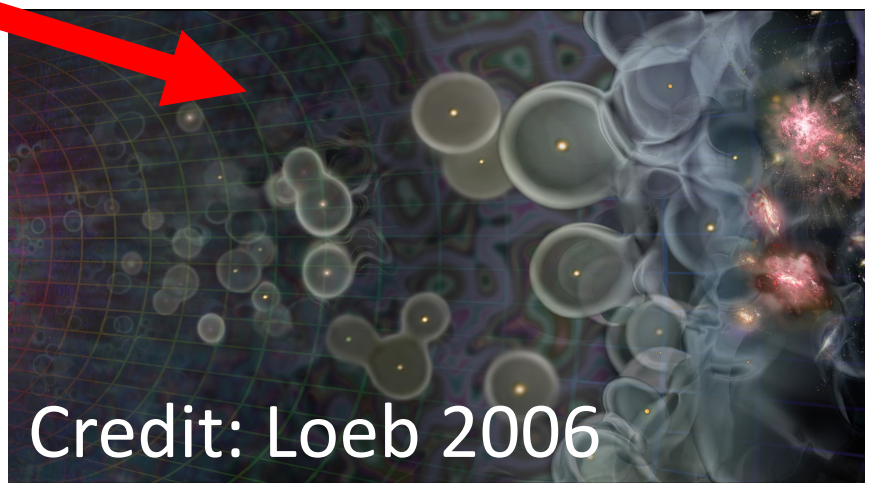
Credit: NASA

(2)Cosmic reionization

(e.g., Ioka 2003, Inoue 2004)

(3)Missing baryon problem

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



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**

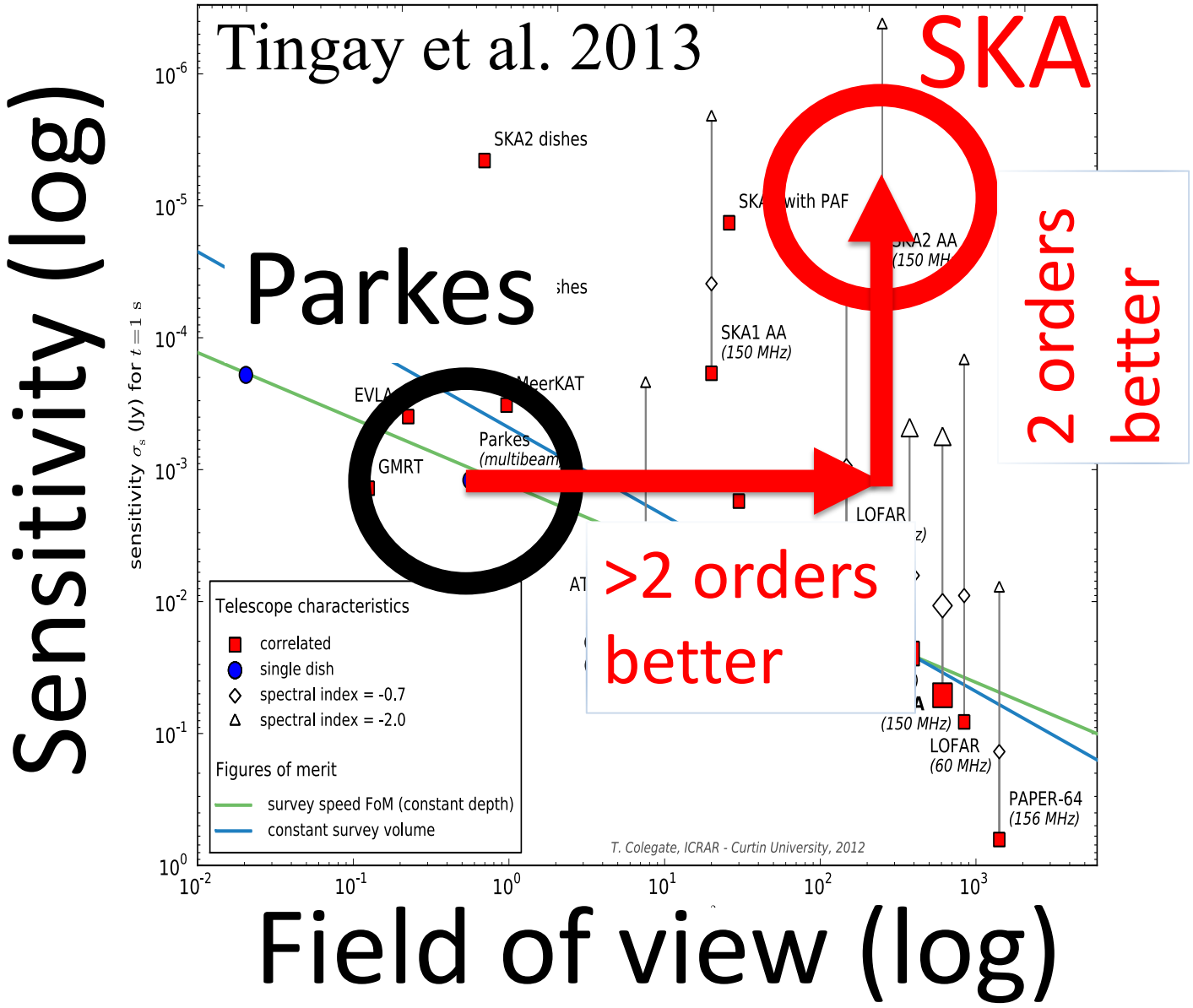
Focusing Squarely on FRBs with
the Square Kilometre Array

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

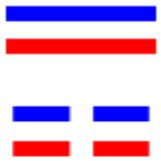
Future: The Square Kilometre Array

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

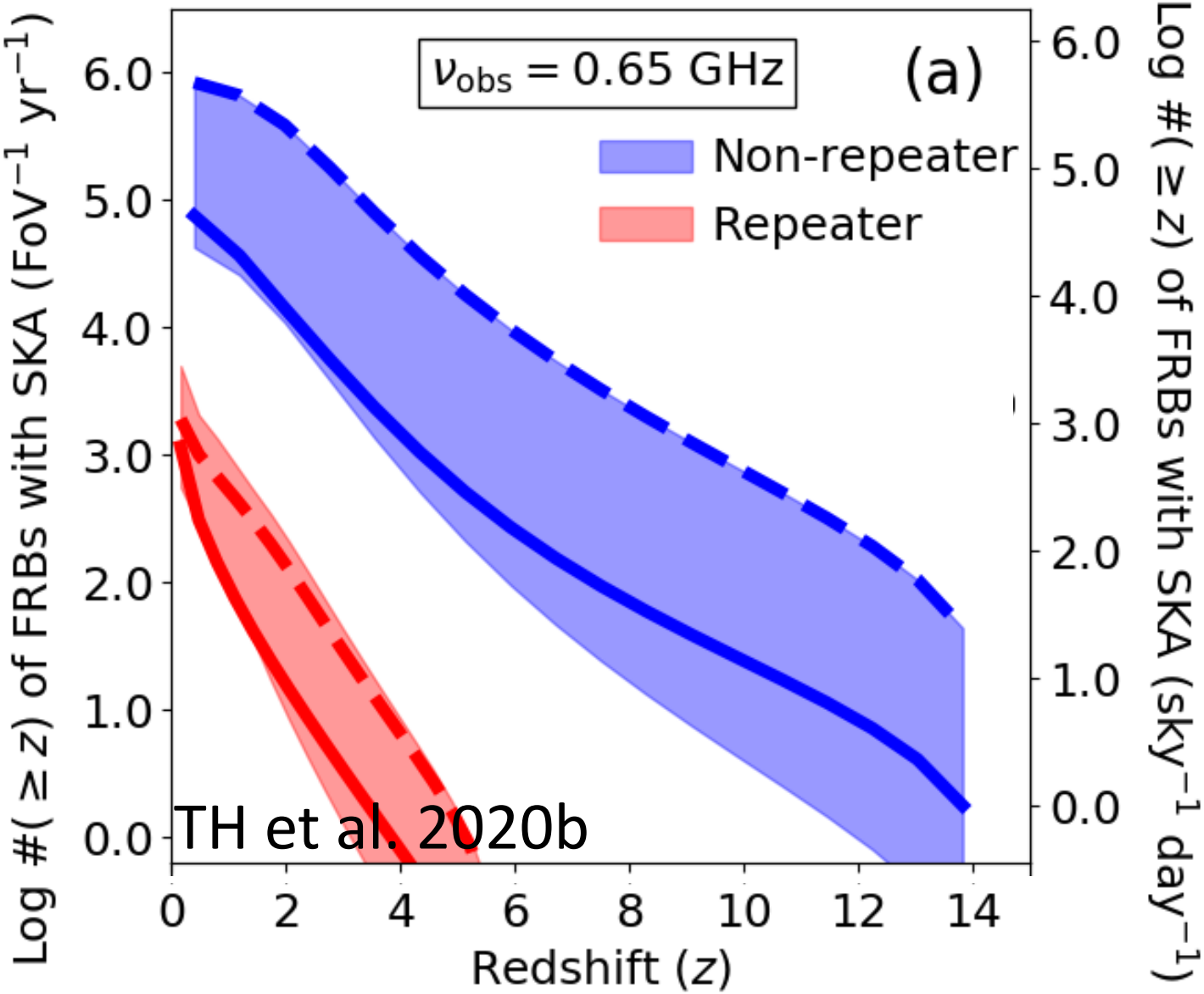
Future: The Square Kilometre Array



Future: How many FRBs with the SKA?



Different assumptions on redshift evolution



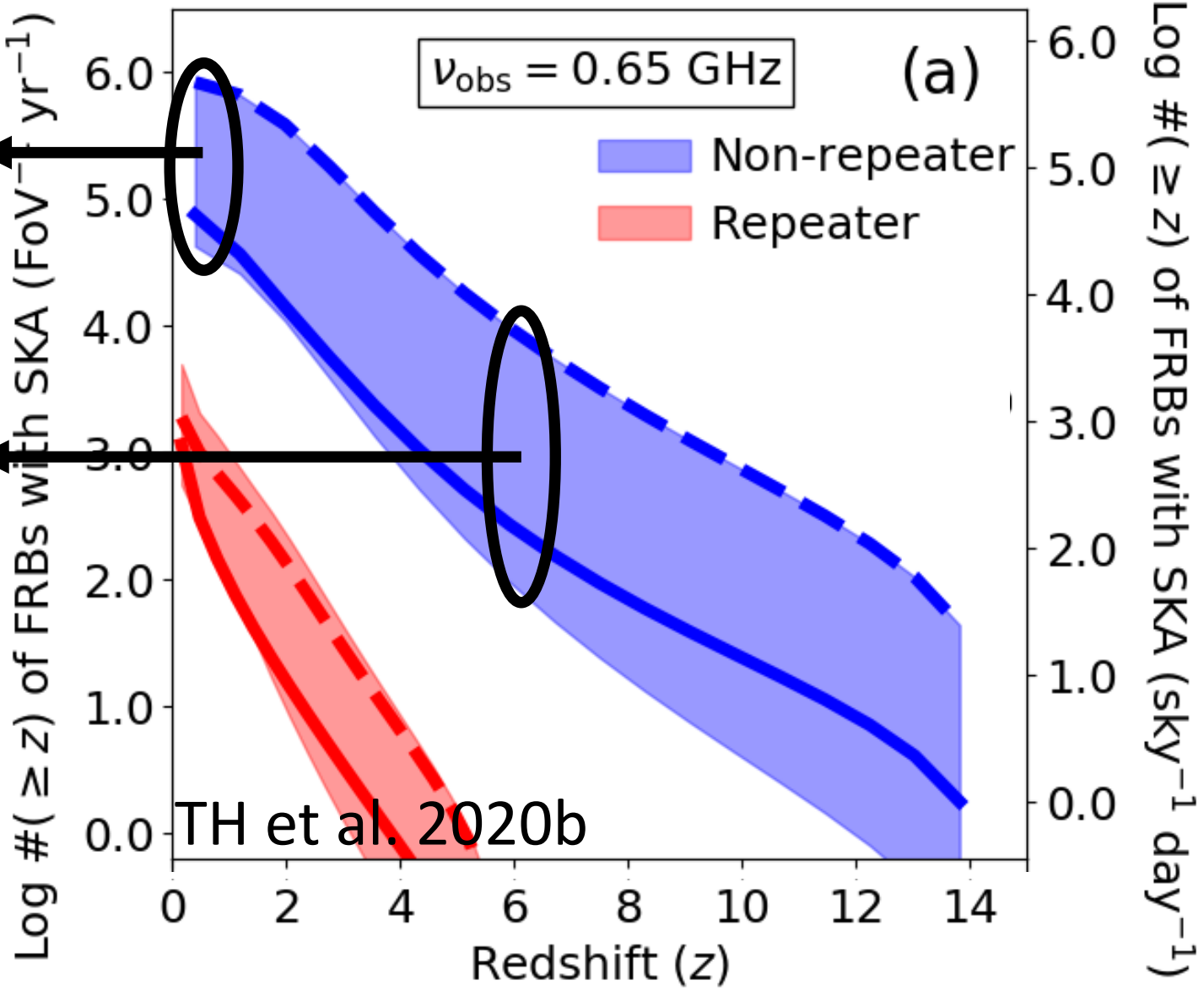
Future: How many FRBs with the SKA?

Total

z>0
10^5-10^6

Reionization epoch

z>6
10^2-10^4

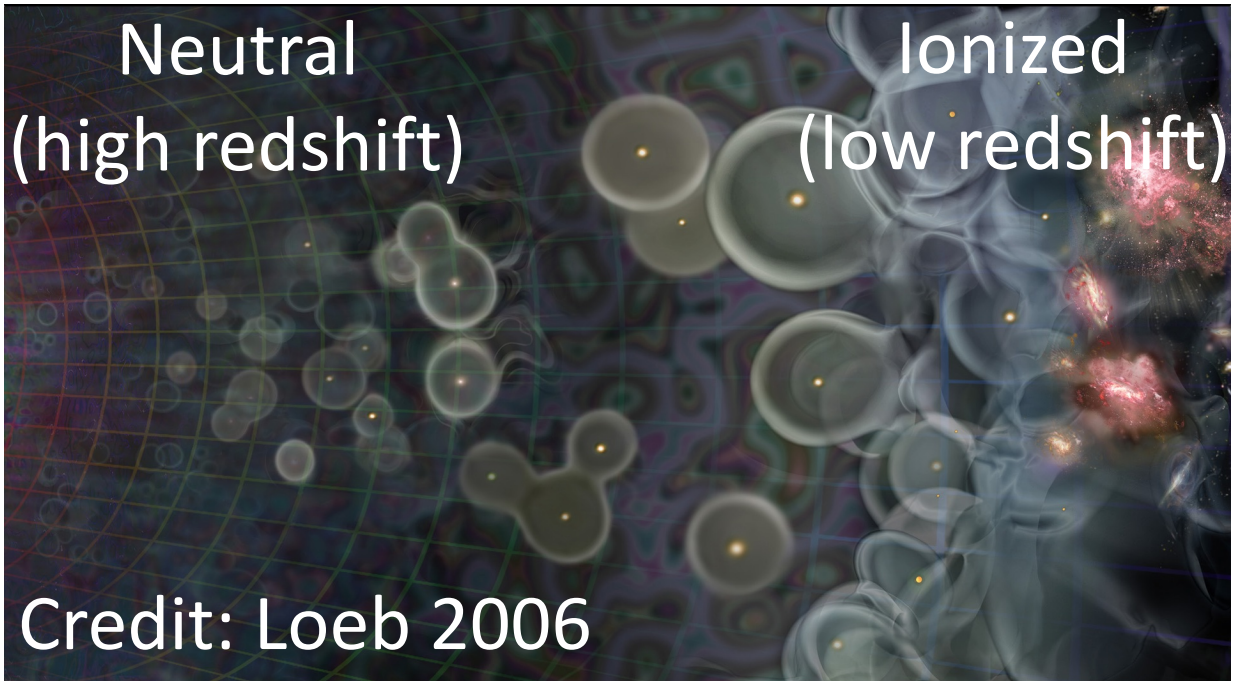


3. ***Future prospects:***

<u>Cosmic reionization</u>

TH et al. 2020d.

Introduction: Cosmic reionization history



Neutral hydrogen

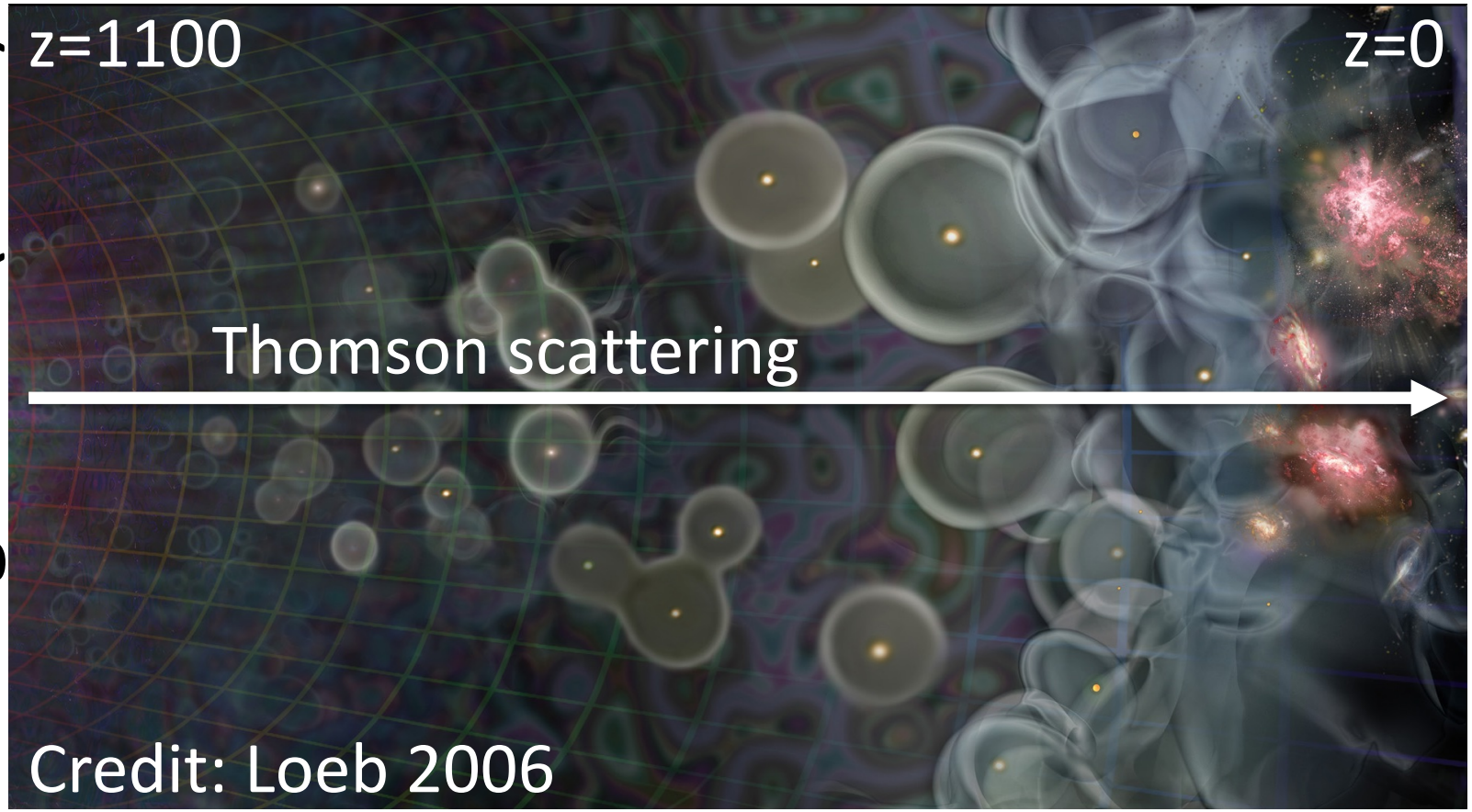
e.g.,

- Quasar spectrum
- 21 cm emi. abs. lines

Ionized material

- Cosmic microwave background (CMB)
- Fast radio bursts (FRBs)

Introduction: Reionization with the CMB



Cosmic microwave background (CMB)

Optical depth

Optical depth (τ_{CMB})

$$\tau_{\mathrm{CMB}} = \int_{z=0}^{1100} \sigma_T \underline{n_{\mathrm{e}}(z)} dl$$

Electron density

Earlier reionization --> Larger τ_{CMB}

Later reionization --> Smaller τ_{CMB}

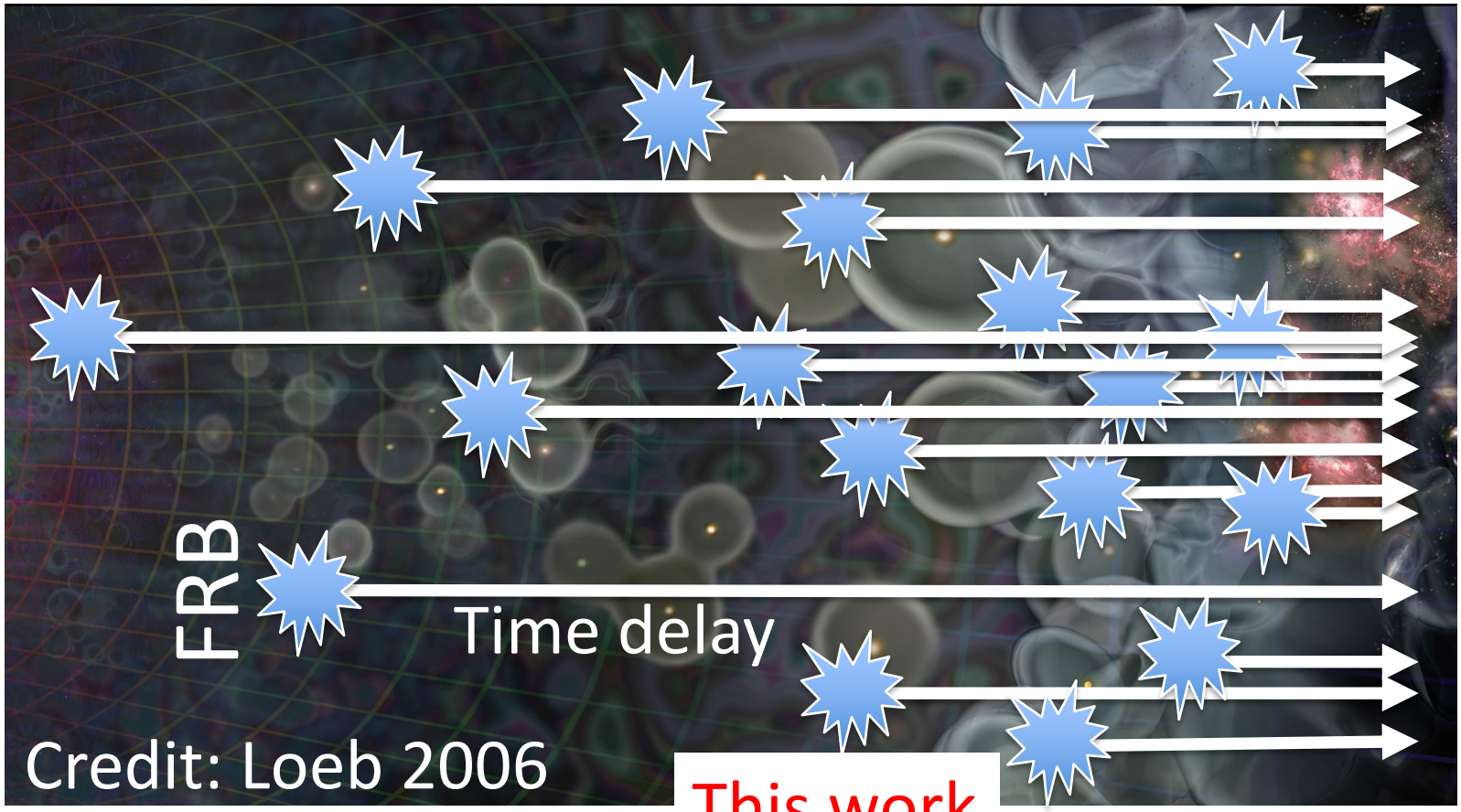
Problem

CMB --> only averaged epoch of reionization

Solution (my talk)

FRBs --> reionization as a function of redshift

Introduction: Reionization with FRBs



Dispersion measures

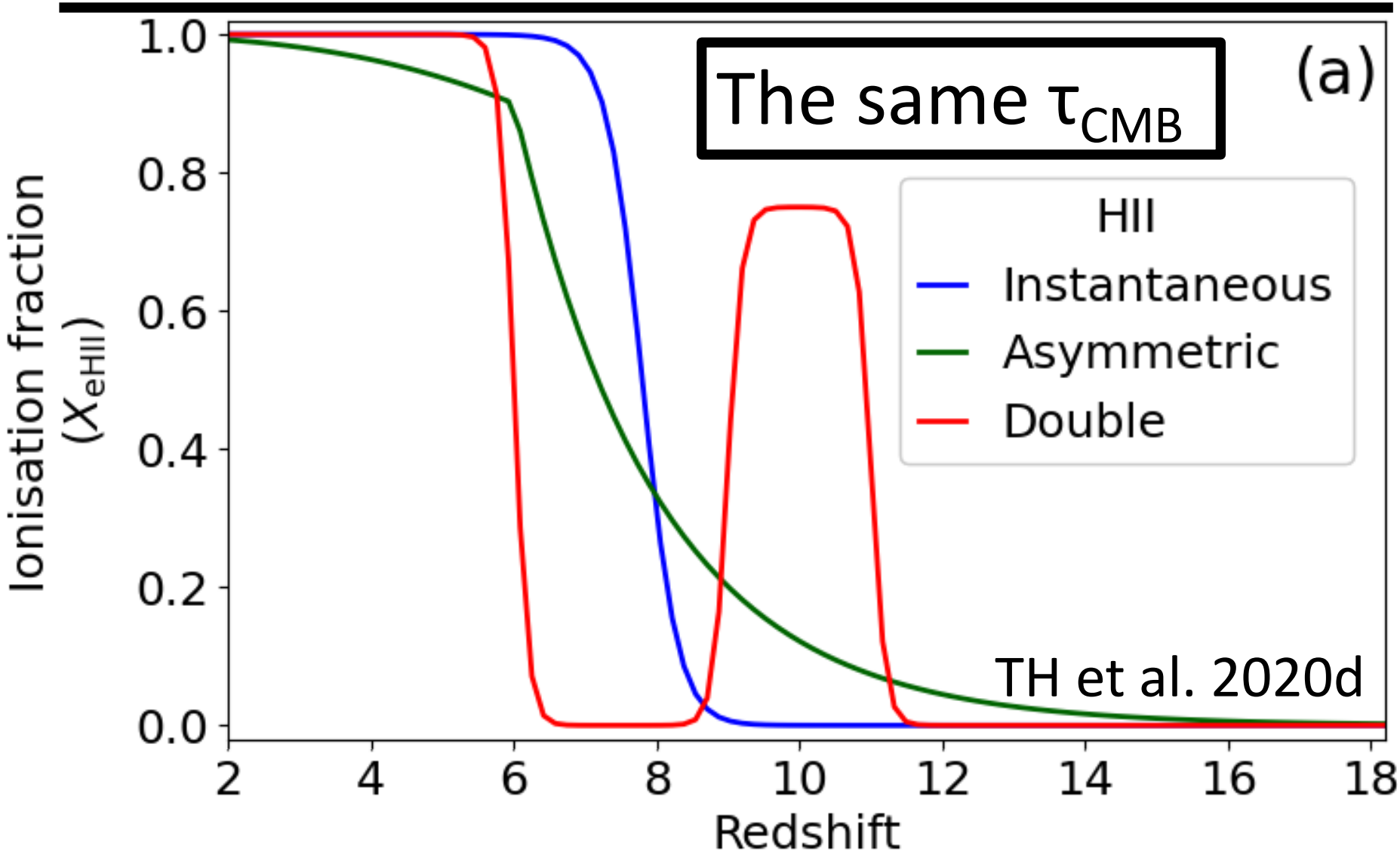
$$\mathrm{DM_{IGM}}(z) = \int_0^z \frac{n_e(z')}{1+z'} dl,$$

This work

$$dDM/dz \propto n_e(z), Xe$$

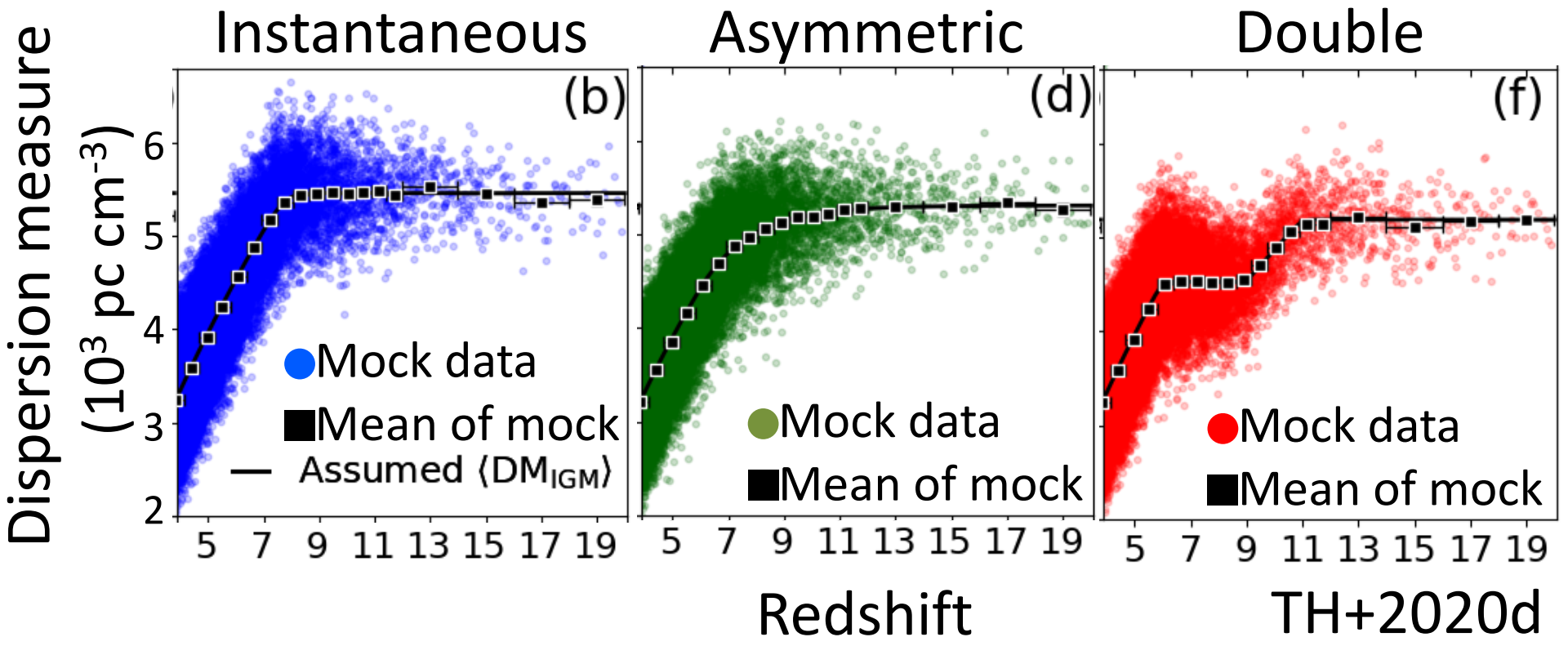
Ionization fraction

This work: The cosmic reionization histories



CMB cannot distinguish between these

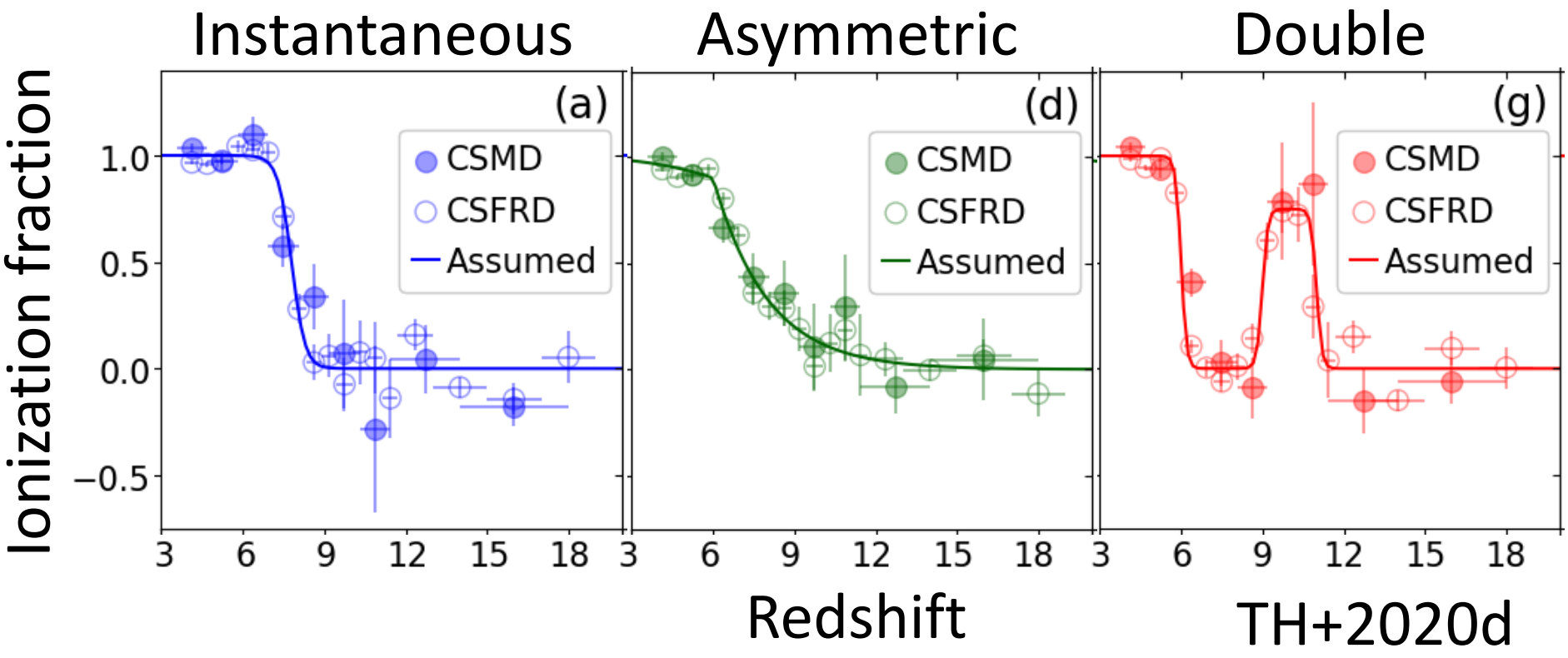
This work: Mock FRBs (CSFRD evolution case)



Data dispersion <-- line-of-sight fluctuation

Slope of mean data (dDM/dz) ∝ ionization fraction

Results: Reconstructed ionization fraction



(i) CMB cannot distinguish between these but FRBs can
(ii) FRBs measure the reionization history as it is

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
- Future FRBs: cosmic reionization history