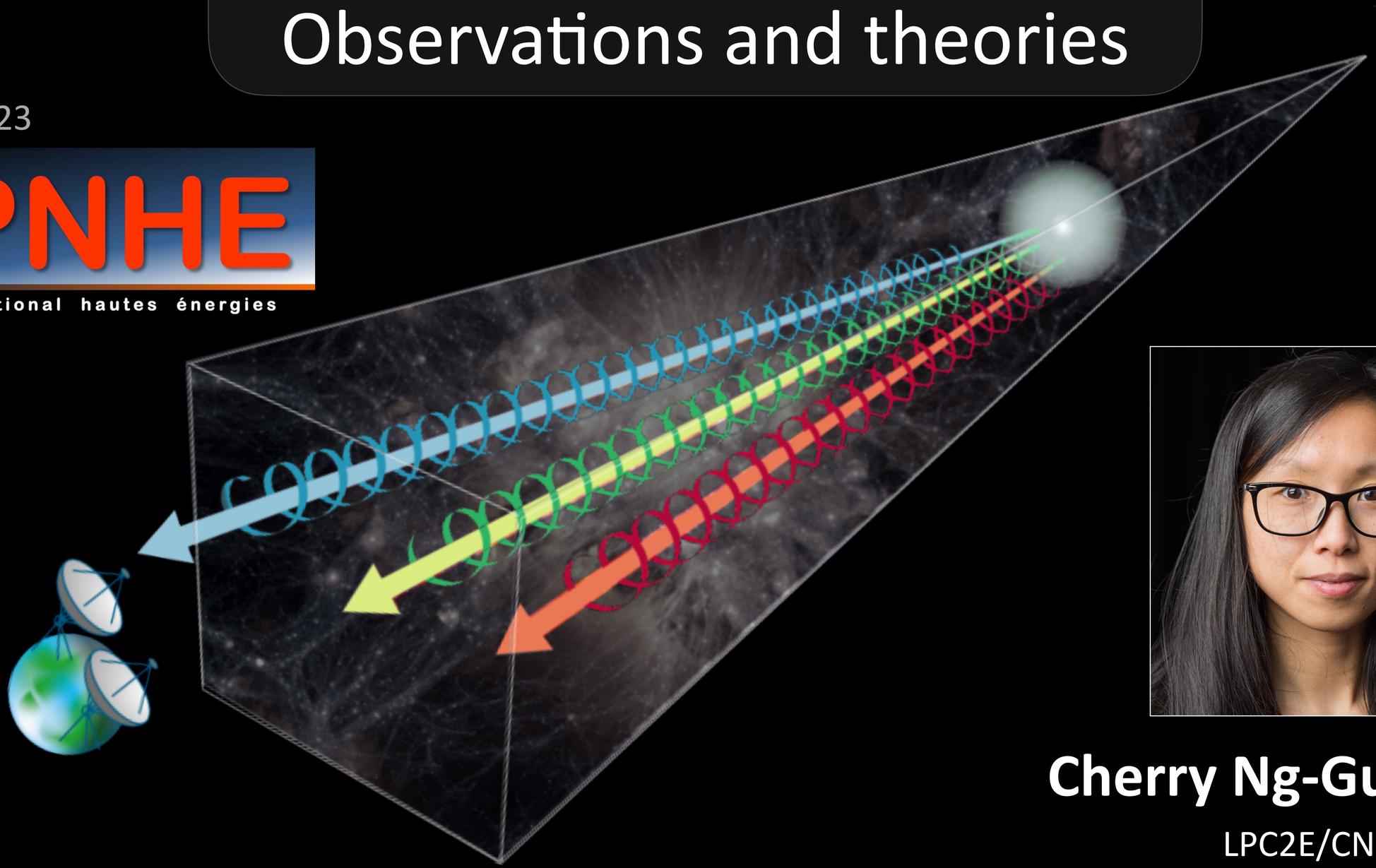
Fast Radio Bursts: Observations and theories

Sept 6-8, 2023

PNHE

Programme national hautes énergies



Cherry Ng-Guihéneuf

LPC2E/CNRS

Fast Radio Bursts (FRB) in a nutshell

- Bright (< 10^{44} erg s-1) and short (~ms)
- High event rate (~5,000/sky/day)
- Extragalactic (~0.03 >z > 1)

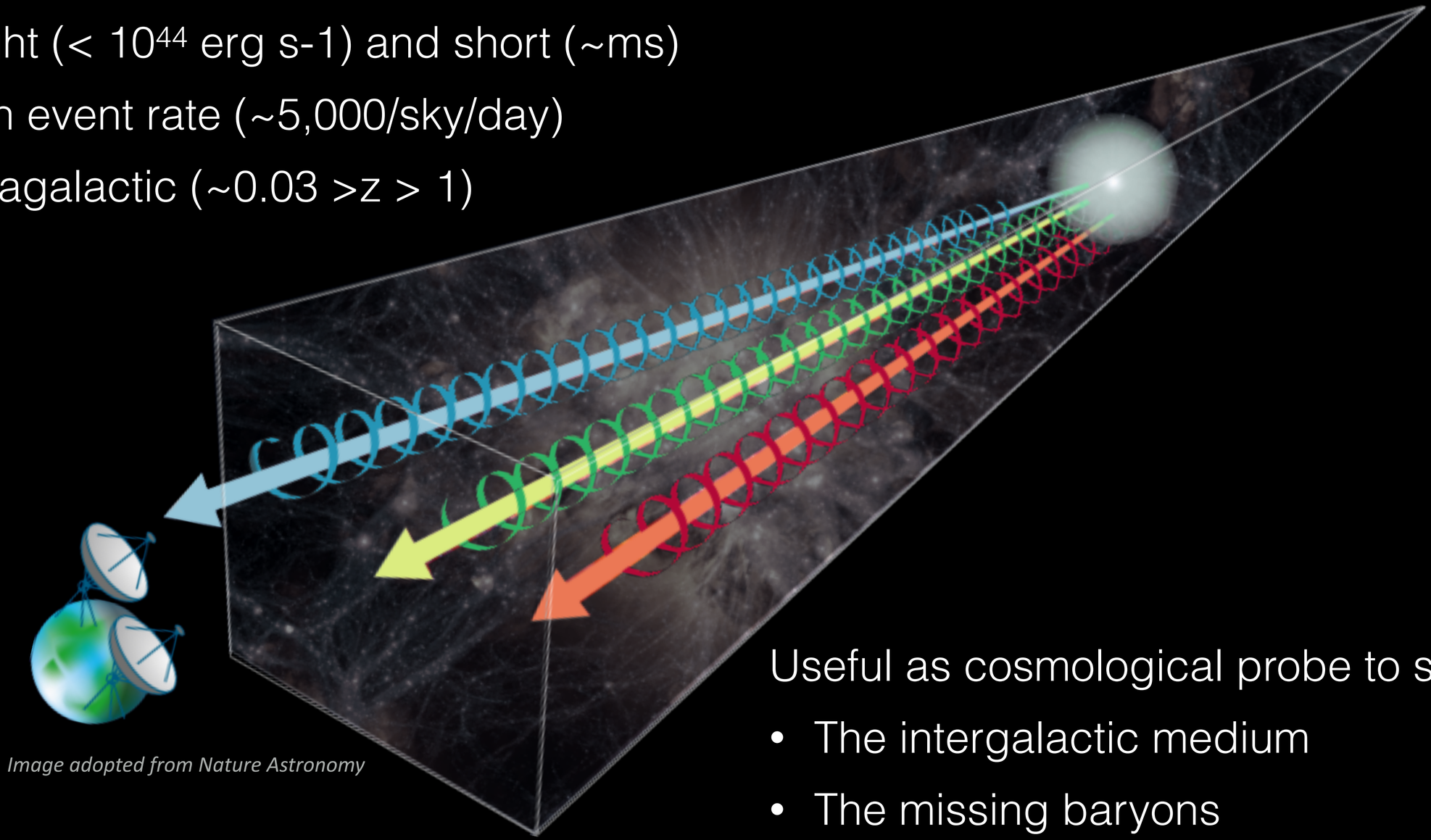


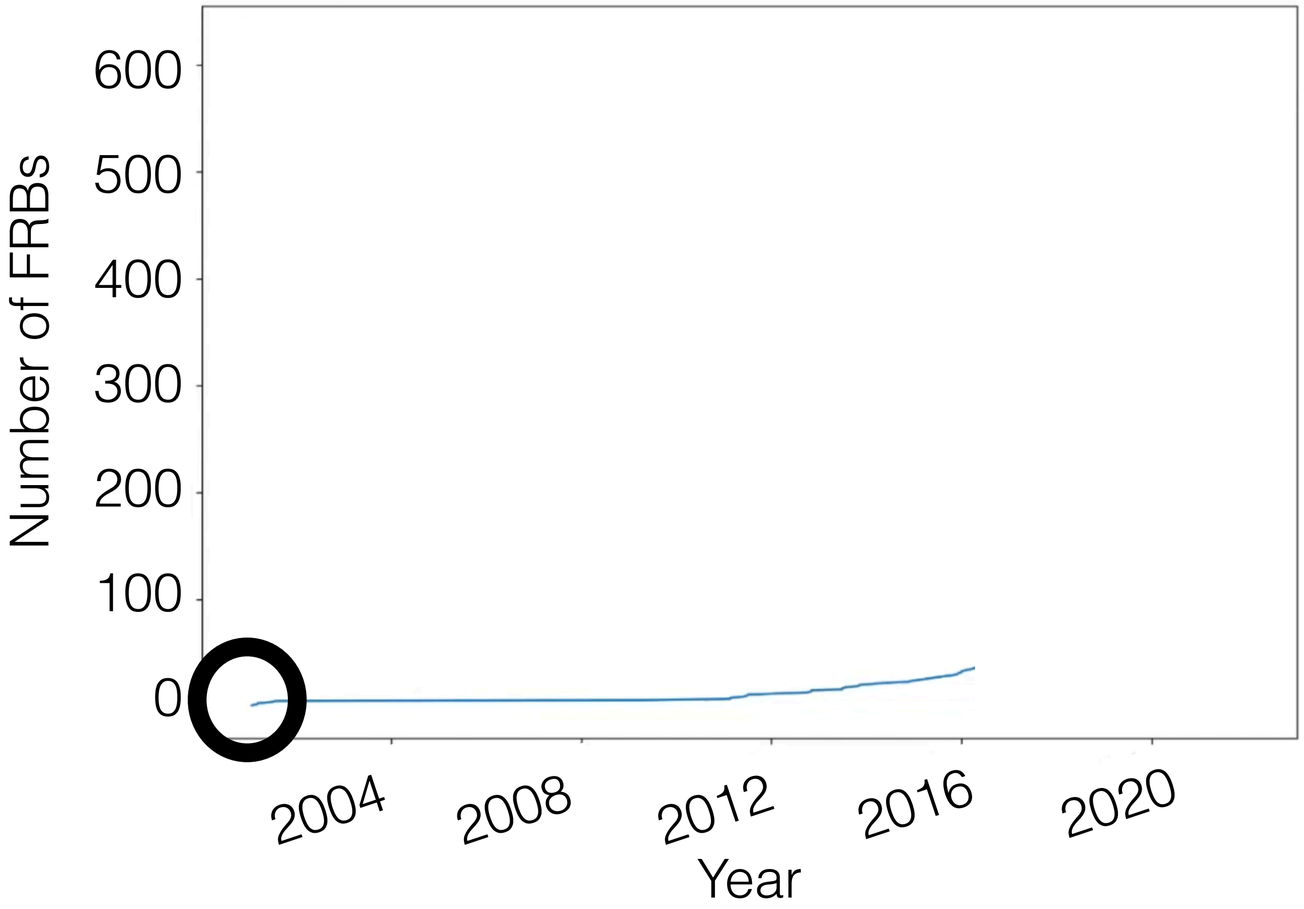
Image adopted from Nature Astronomy

Useful as cosmological probe to study:

- The intergalactic medium
- The missing baryons

Chronology of the FRB discovery

Plot adopted from Xavier Prochaska

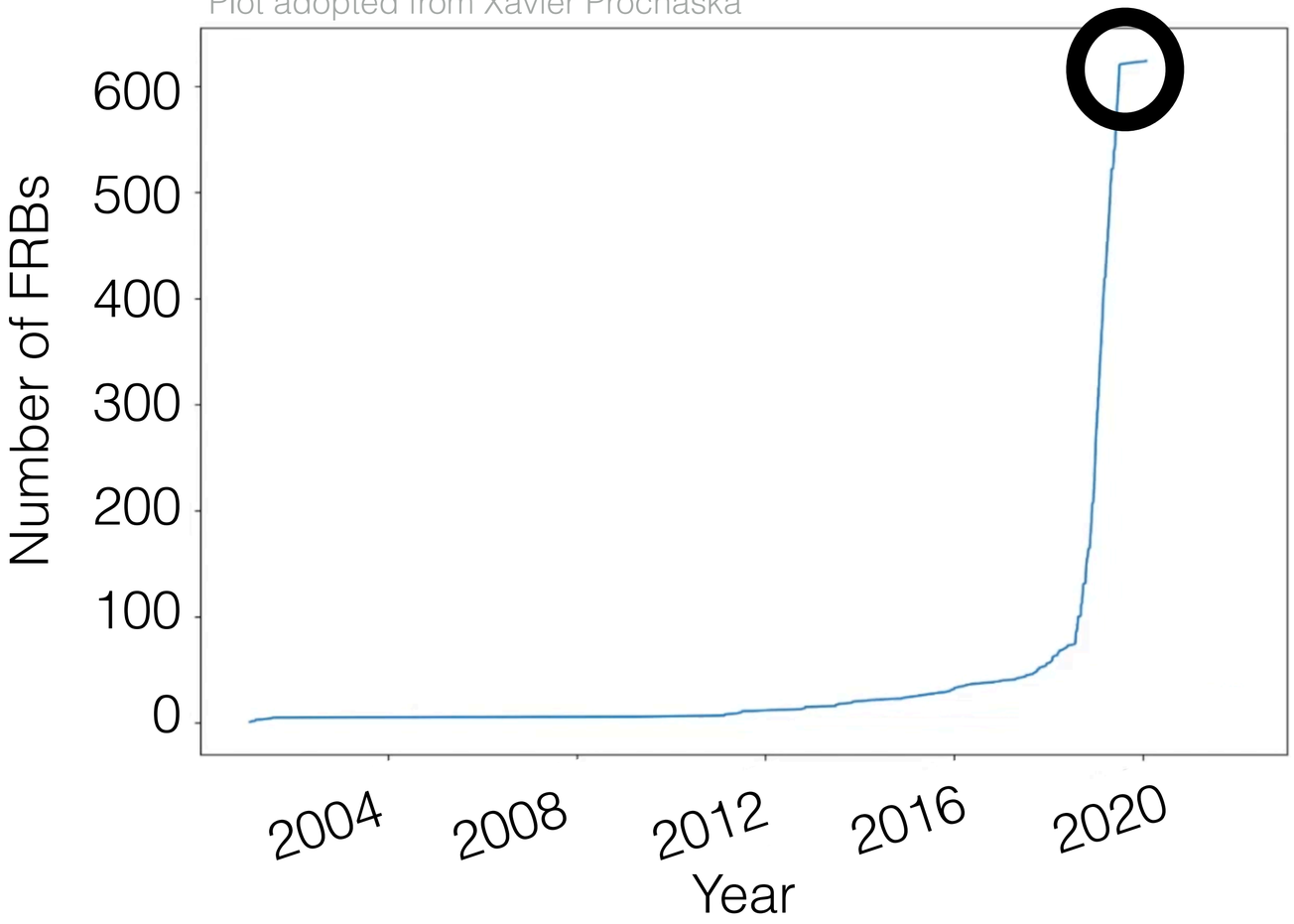


Parkes radio telscope (Australia)

FRB discovered in the archival data of pulsars

Chronology of the FRB discovery

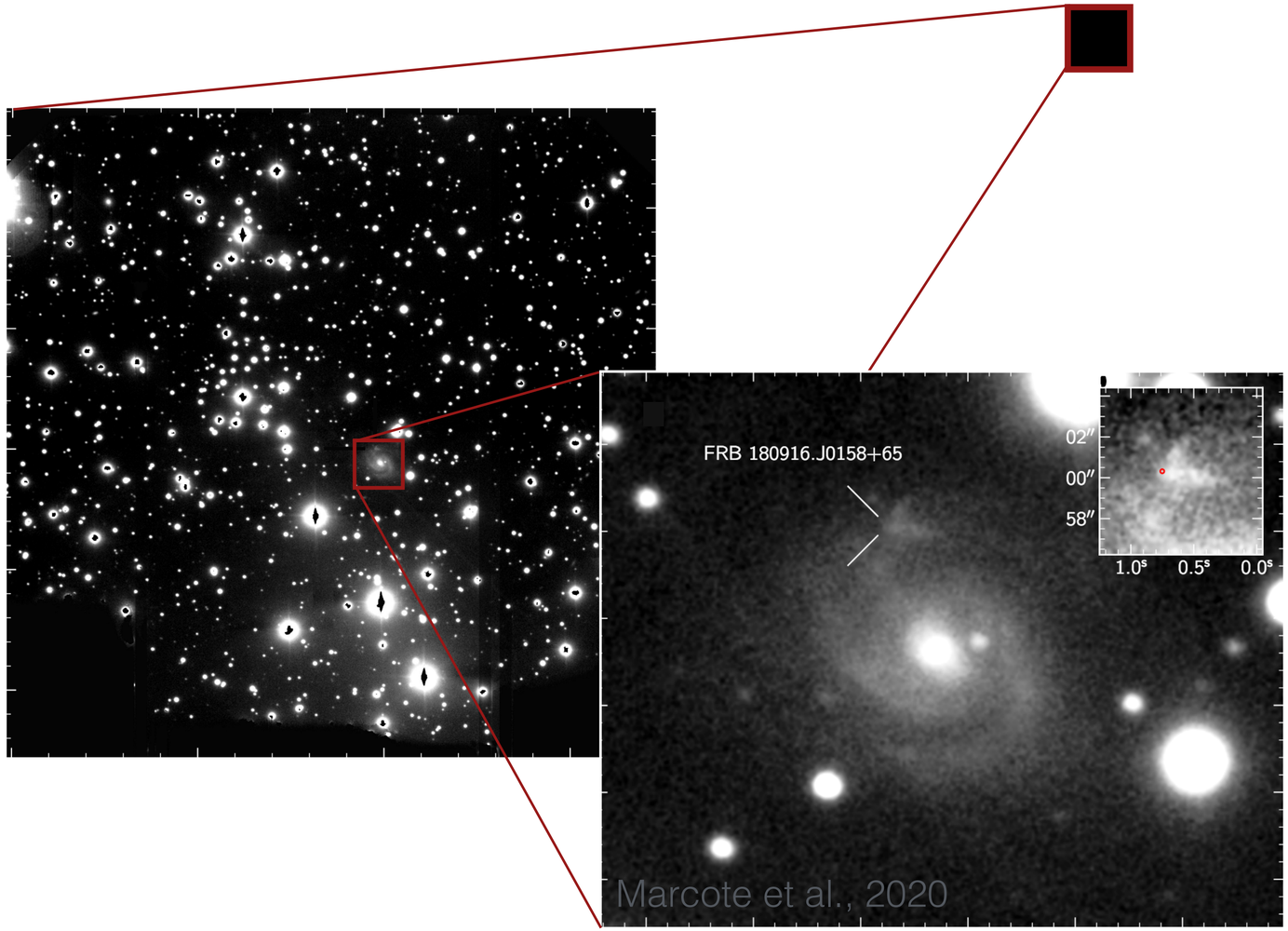
Plot adopted from Xavier Prochaska



CHIME radio telscope (Canada)

Transit telescope = a large field-of-view and a high discovery rate

Chronology of the FRB discovery



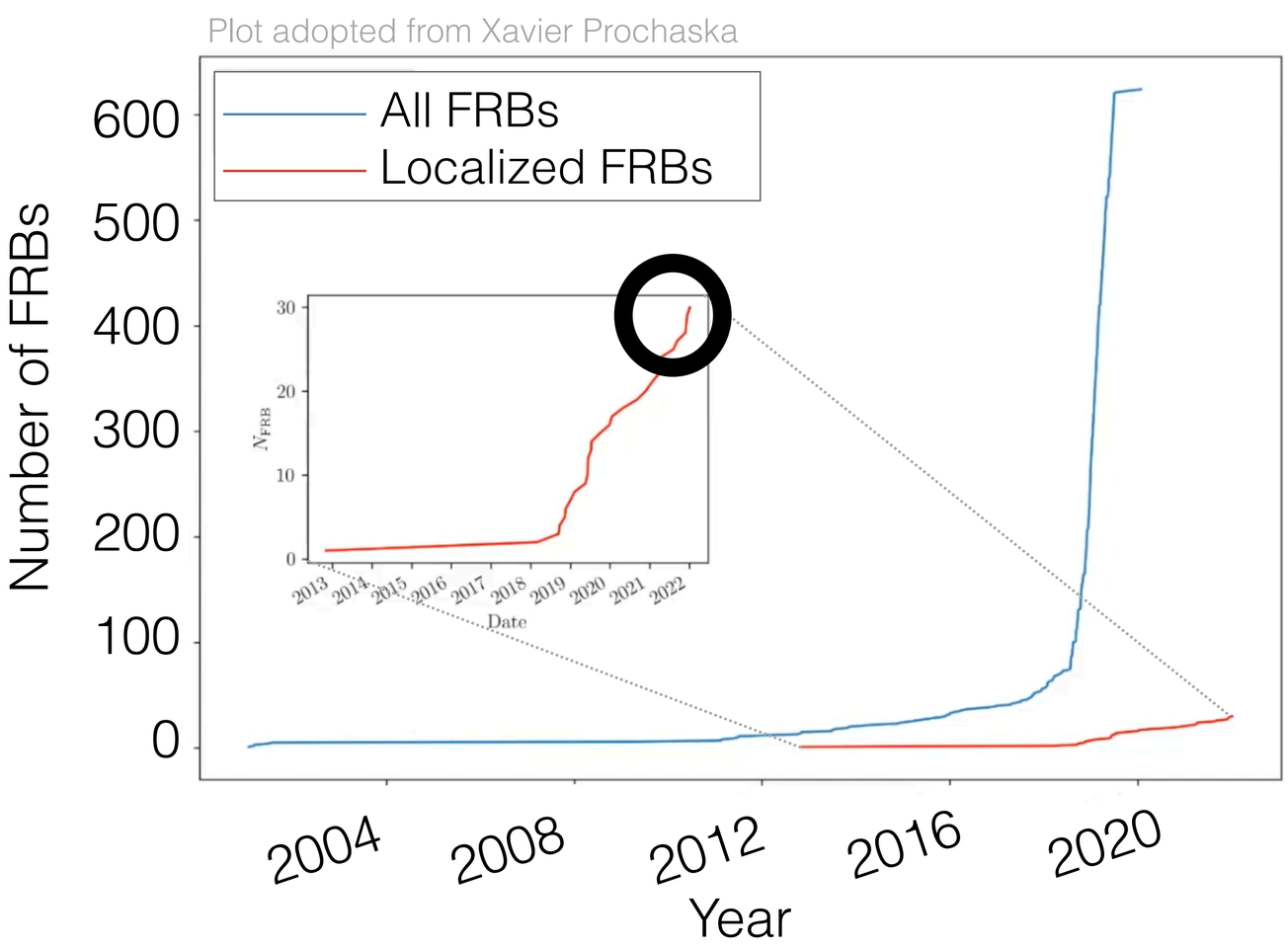
CHIME radio telscope (Canada)

Transit telescope = a large field-of-view and a high discovery rate

Localisation not precise enough for the identification of the host galaxy

Chronology of the FRB discovery

Plot adopted from Xavier Prochaska



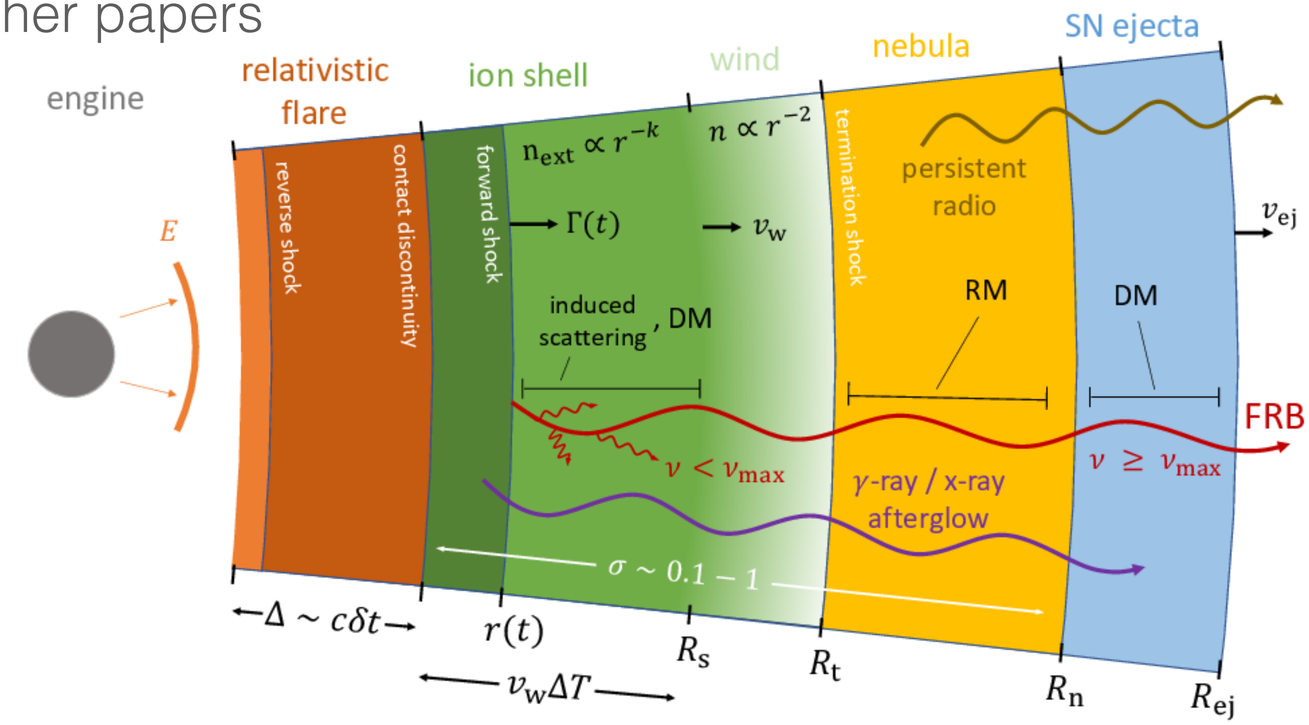
- Published counts: ~700 FRBs, ~40 localized
- Plus a lot more unpublished
- A new astrophysical phenomenon!

Interferometric telescopes = arcseond localizations

What do we know about FRBs so far?

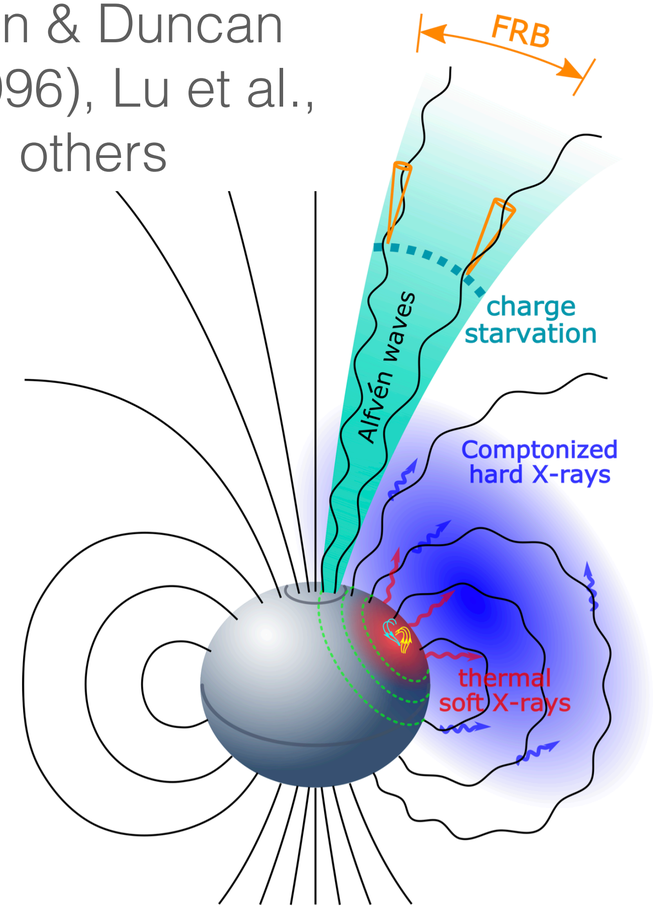
Theoretical models

Metzger et al., 2019 and quite a few other papers



Synchrotron maser emission: relativistic flare collides with an ion shell —> shell decelerates through shock waves —> FRB

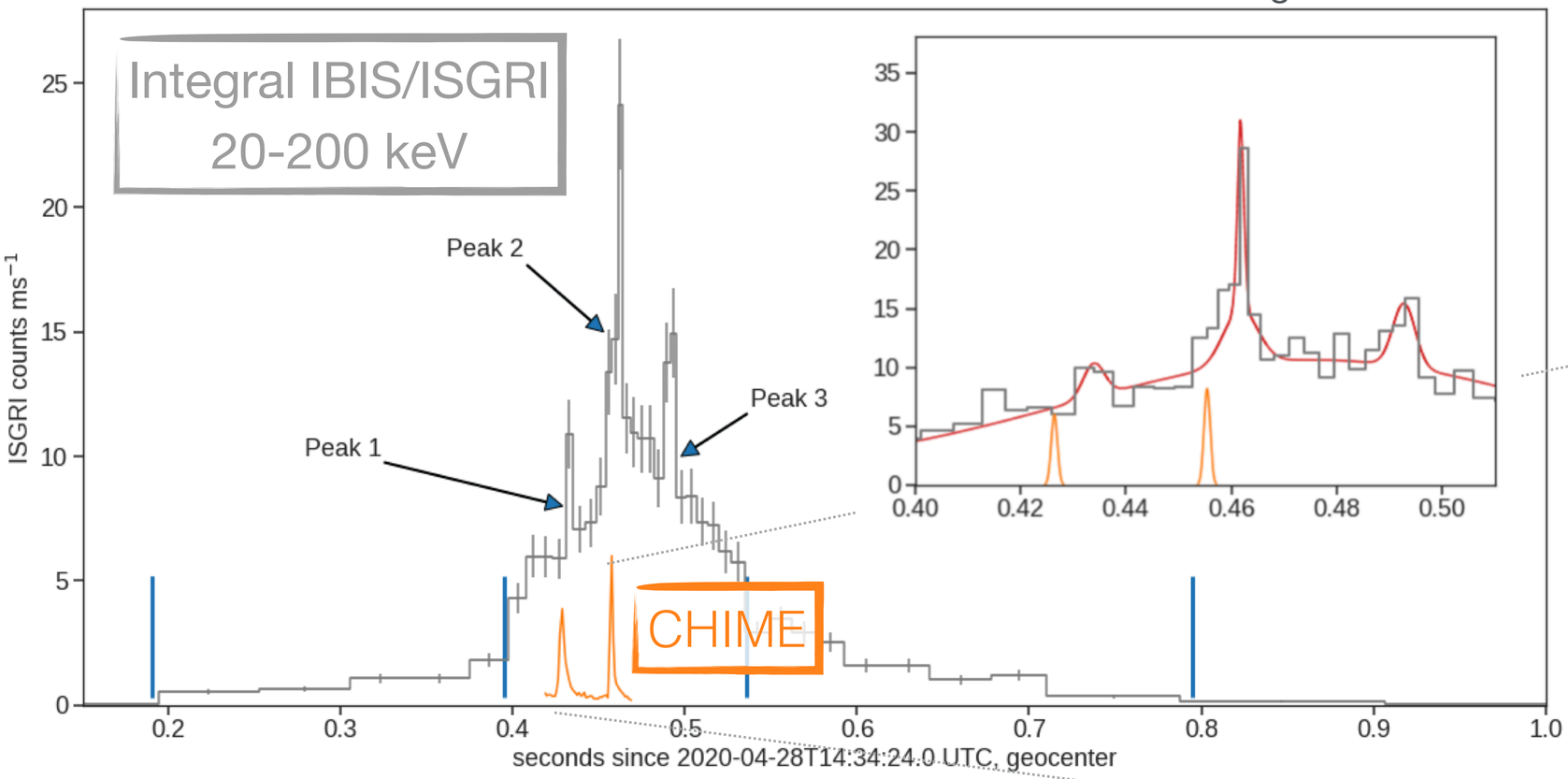
Thompson & Duncan (1995, 1996), Lu et al., 2020 and others



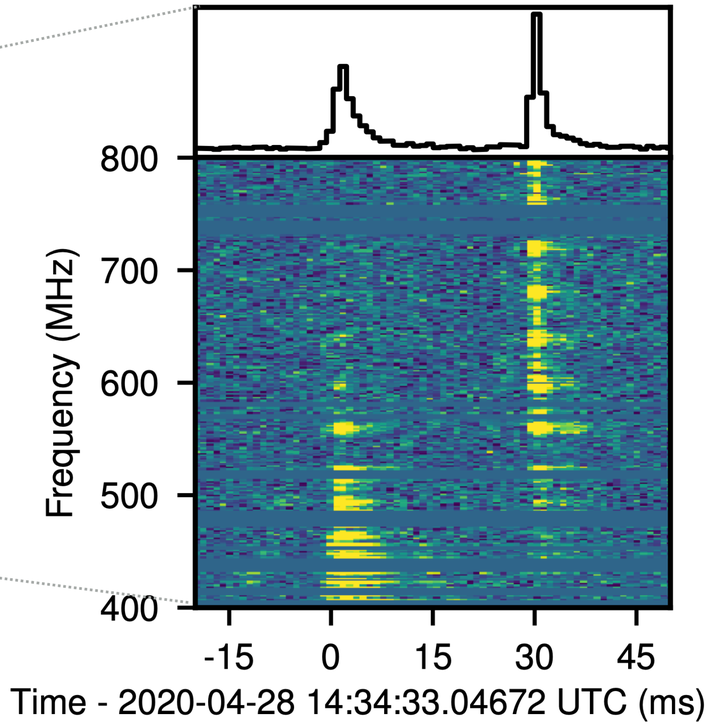
"Classic" Magnetar flare —> trapped fireball —> thermal X-ray and comptonization

Magnetar SGR 1935

Mereghetti et al. 2020



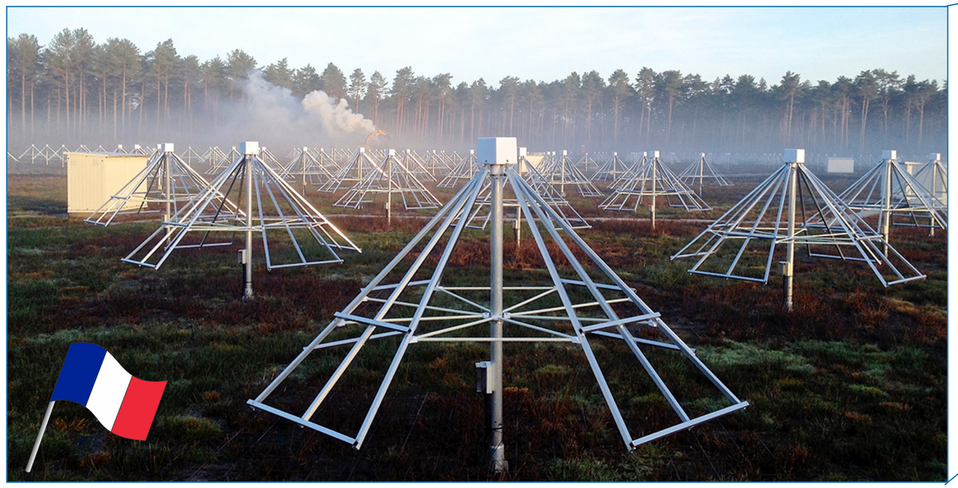
collab. CHIME/FRB, 2020

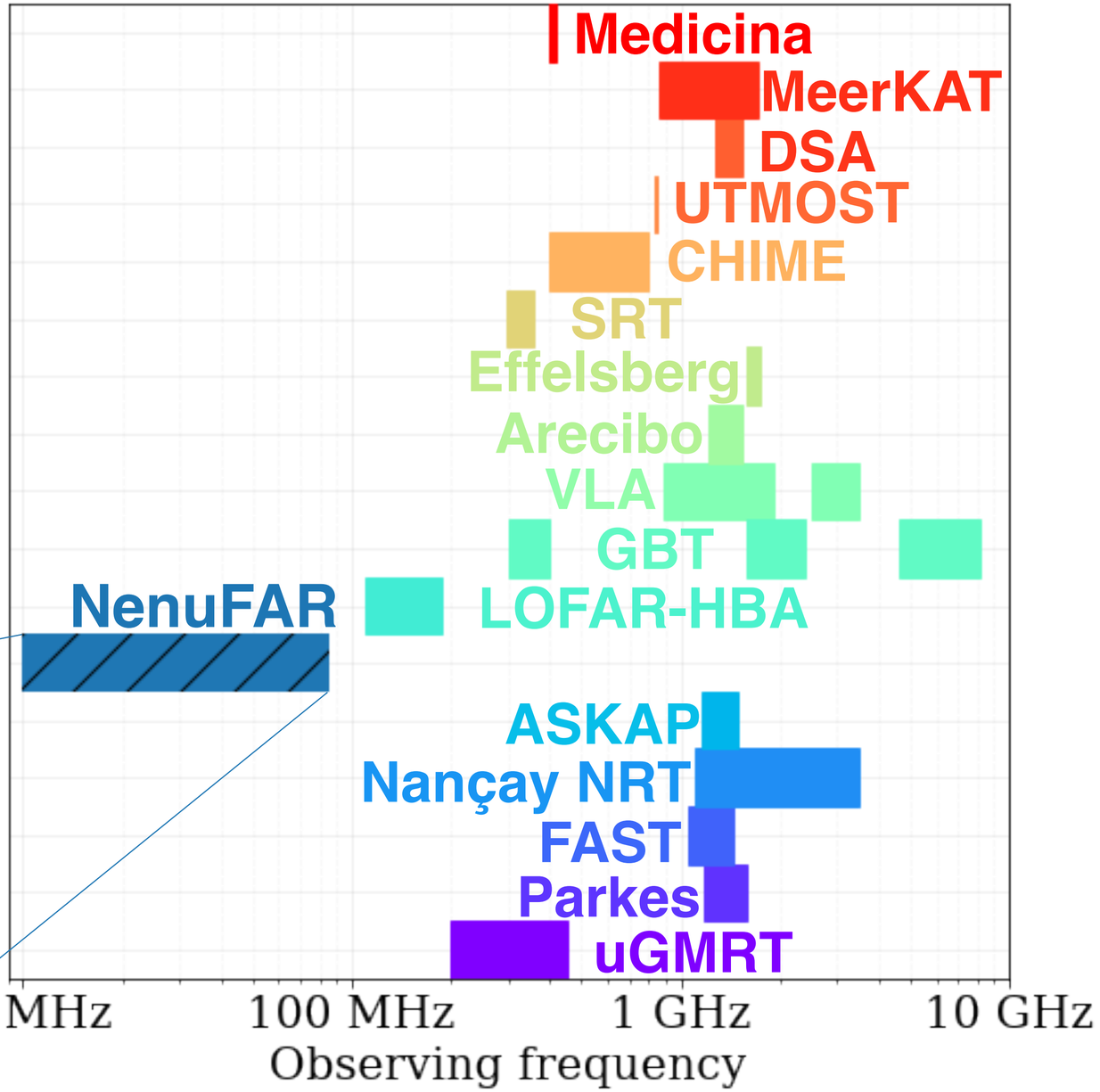


- Detected by CHIME+STARE2 (**radio**) and NICER, Chandra, XMM, Swift XRT (**X-ray**), Swift BAT, Fermi, NuSTAR, Integral (**Gamma ray**)
- Associated to a magnetar in our Milky Way

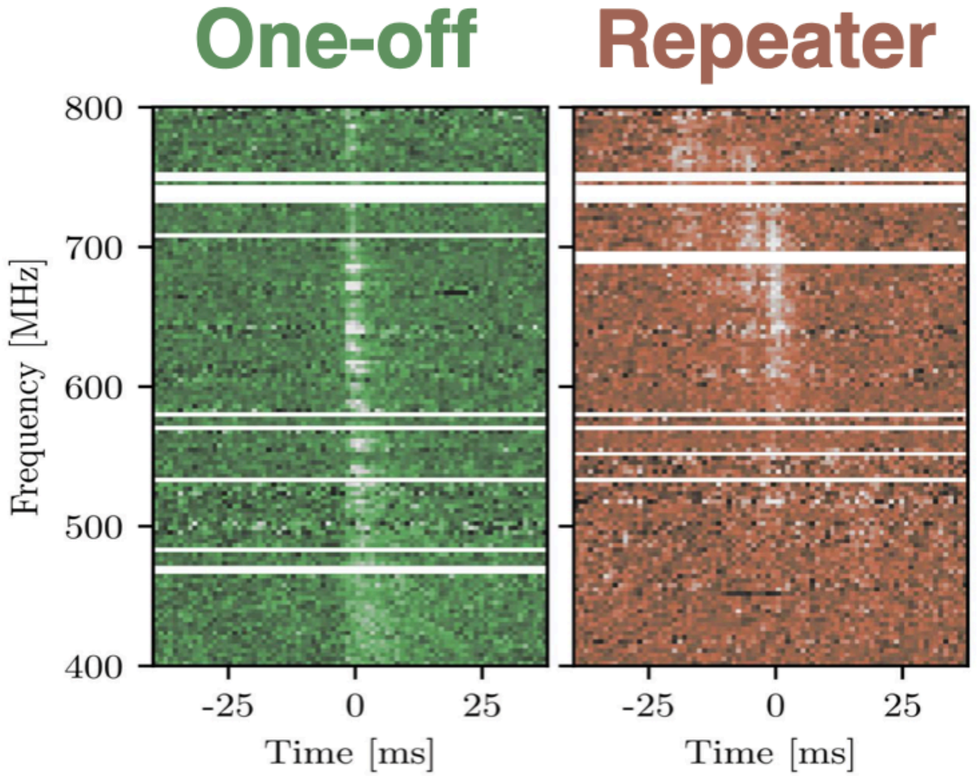
FRB observing frequency

- no conclusive multi-wavelength counterparts yet, except the Galactic magnetar FRB
- So far detected by 16+ radio telescopes between 110 MHz - 8 GHz
- NenuFAR can open a new window at low frequencies — study emission mechanisms

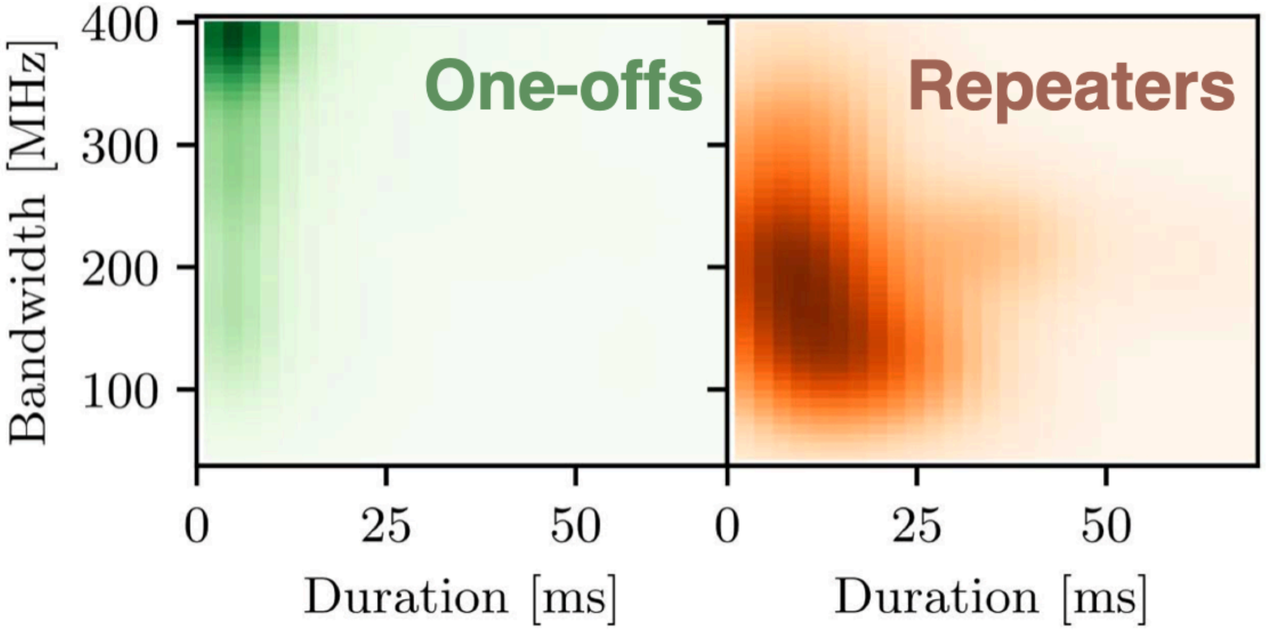




Multiple populations ?

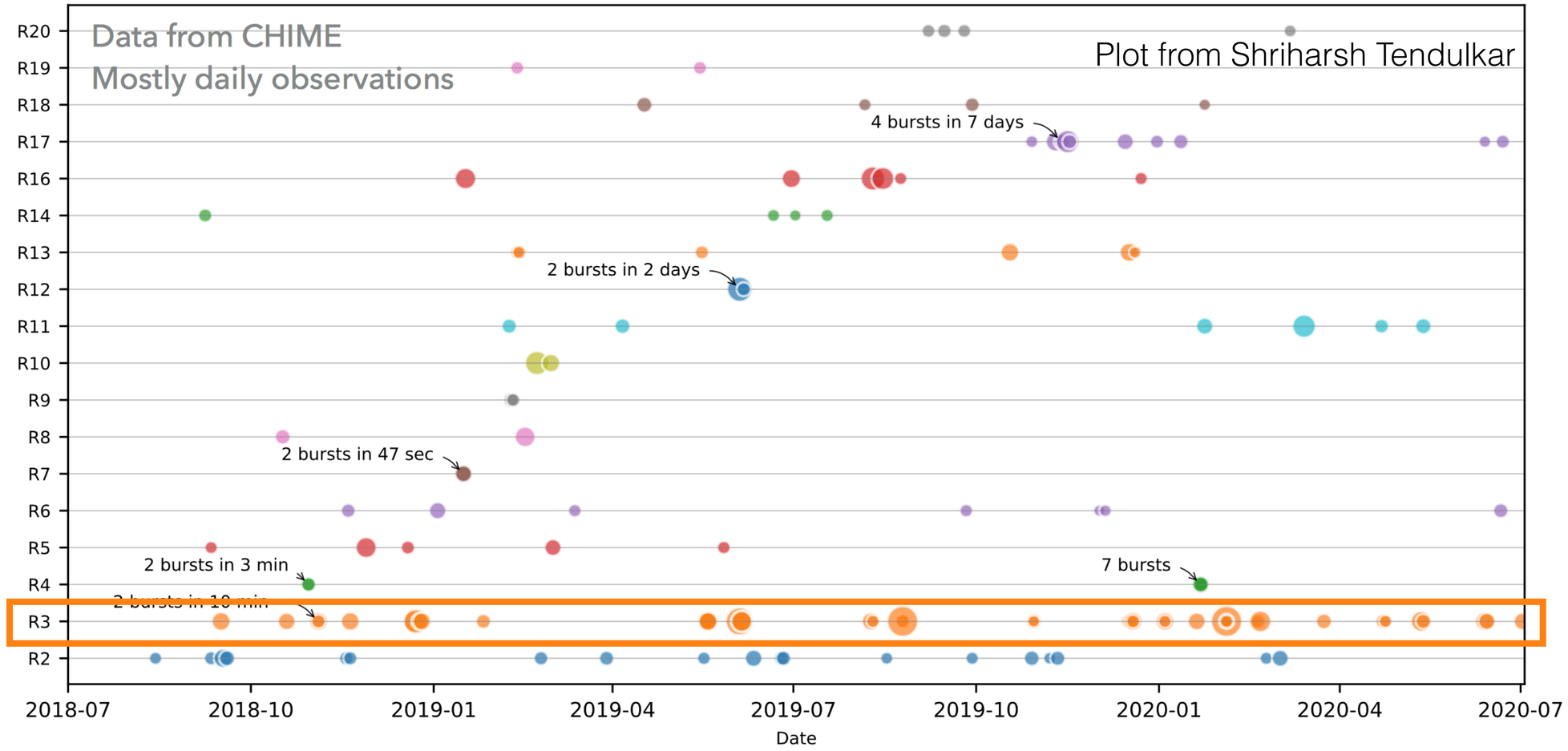


Pleunis+2021 (2106.04356)



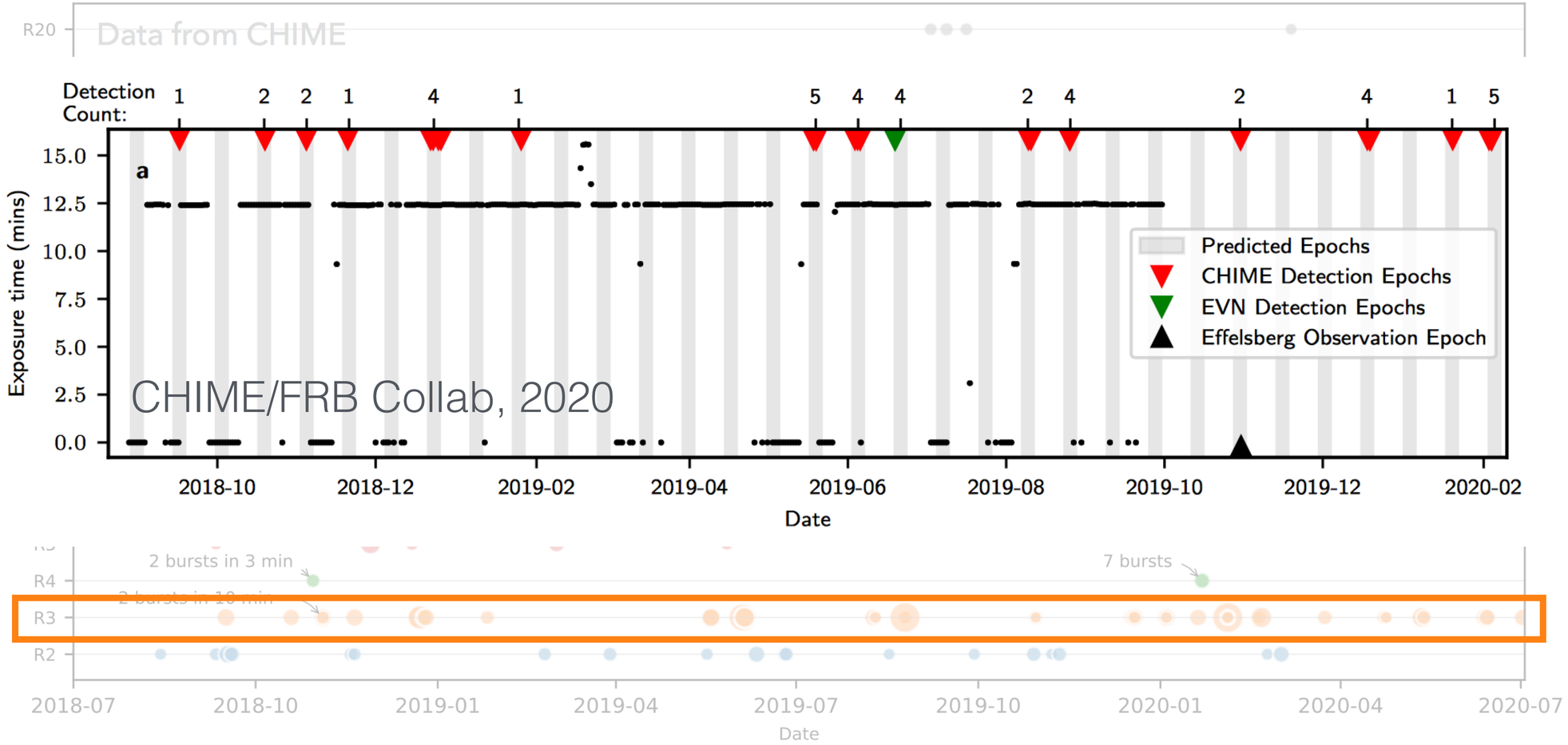
- Only a few % of FRBs seem to repeatedly burst
- The repeaters tend to have wider bursts and a narrow emission band compared to one-off FRBs
- Although, not clear if « one-offs » are truly non-repeating

Repetition



- Clustering in time and energy distribution

Periodicity



- Clustering in time and energy distribution
- 2 FRBs have periodic activity cycles: 16 days (CHIME/FRB Collab, 2020) and ~160 days (Rajwade+2020, Cruces+2020)

FRB host galaxy associations

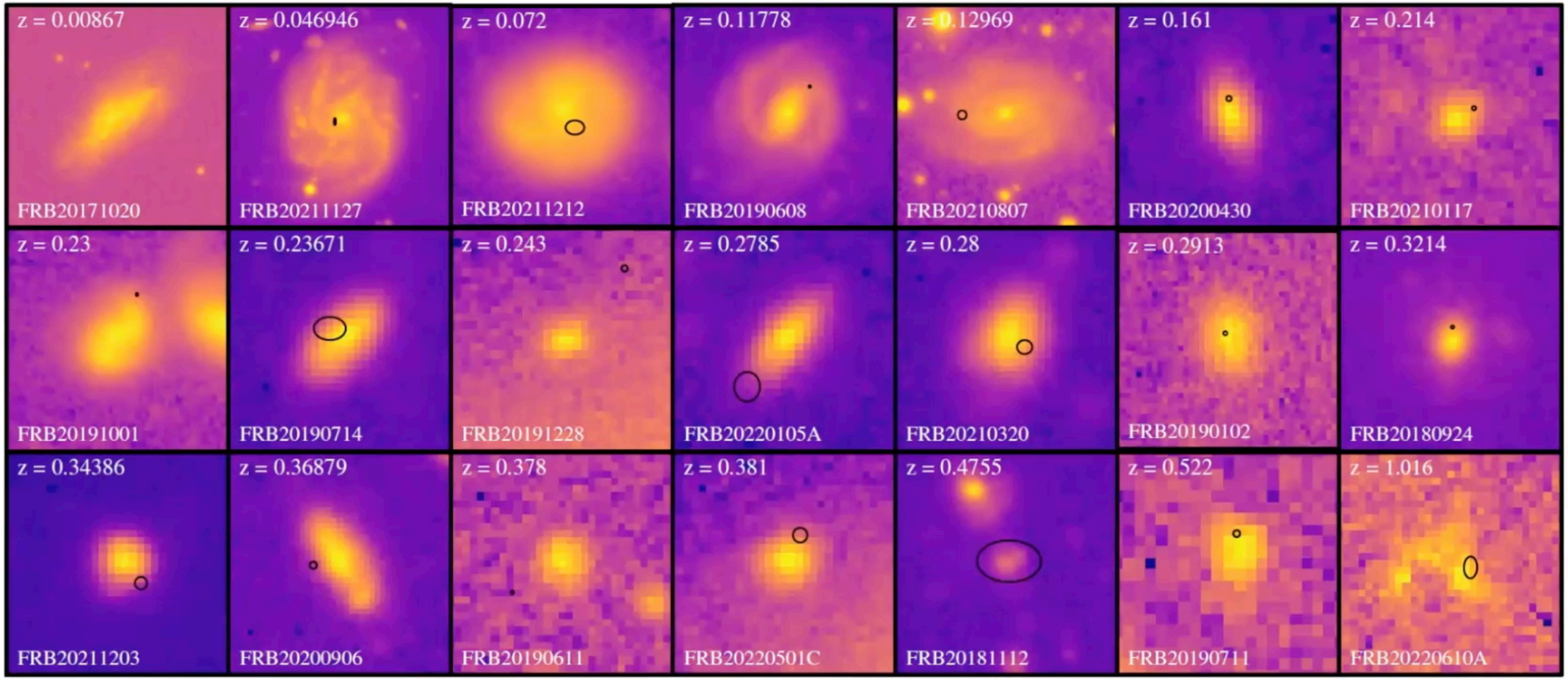
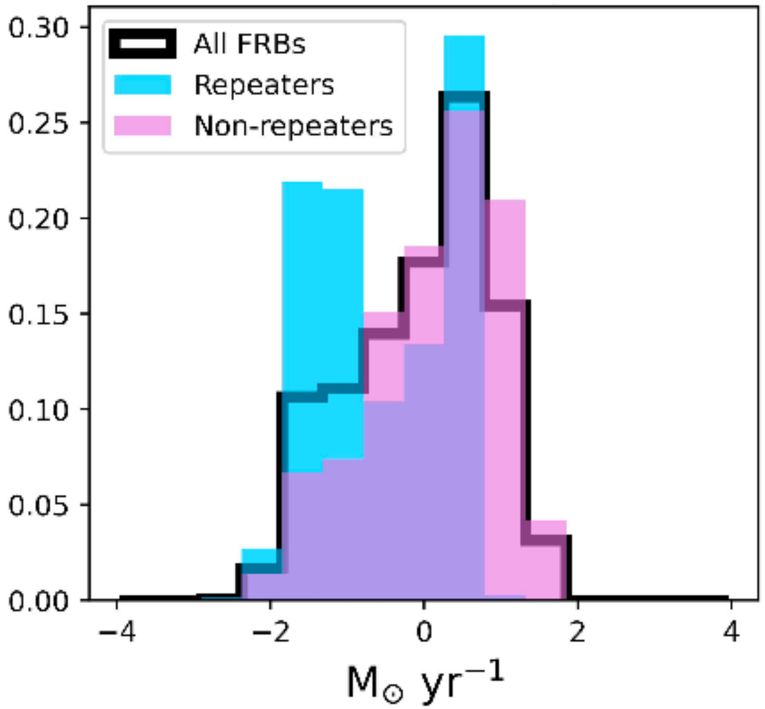


Image from Lachlan Marnoch

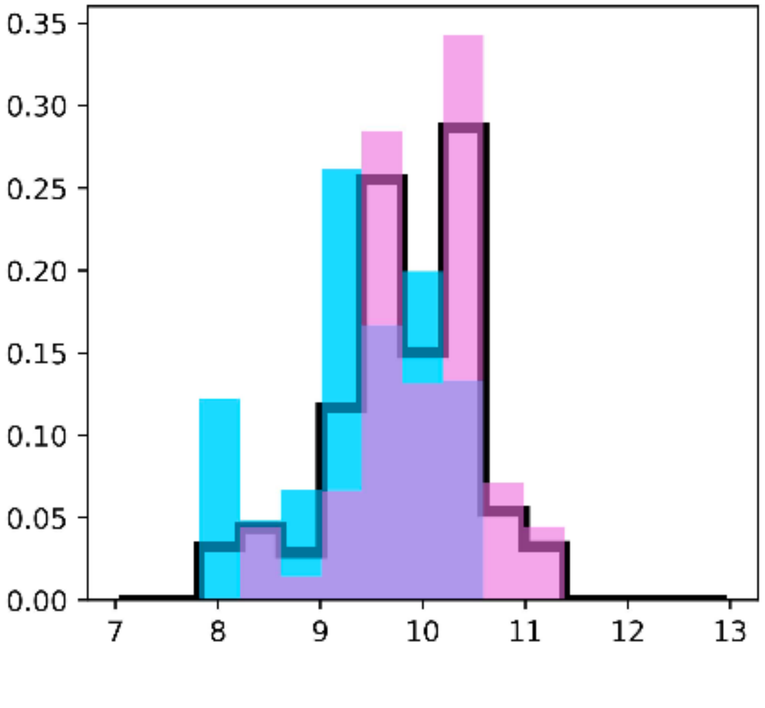
- ~40 localized to host galaxies, with z<=1
- Mostly spiral galaxies (star forming galaxies), but also some lenticular galaxies

Posterior distribution of the host galaxies

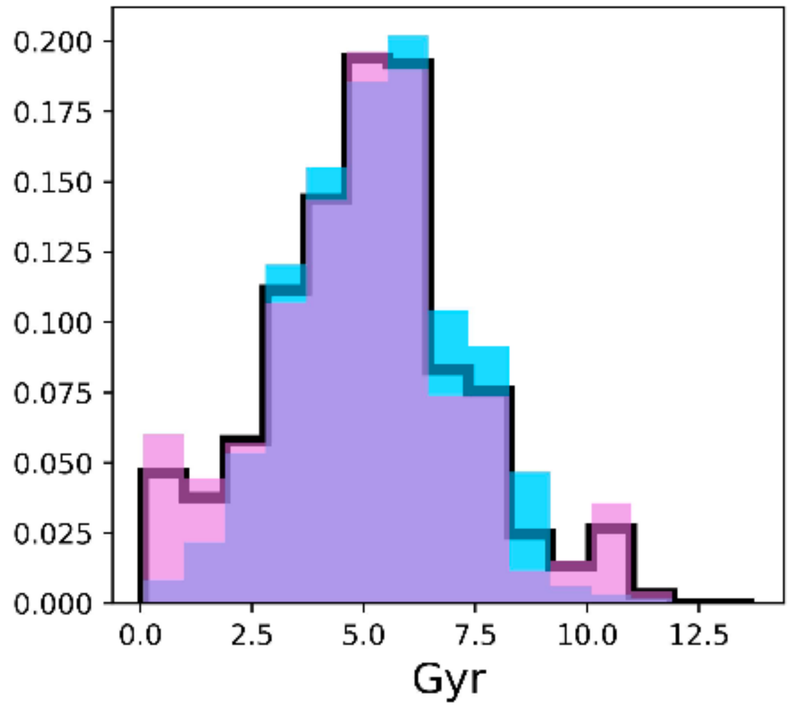
Gordon et al., 2023



Wide range of star formation rate. Median ≈ 1.3 M⊙/yr



Median stellar mass ≈ 10^9.9 M⊙

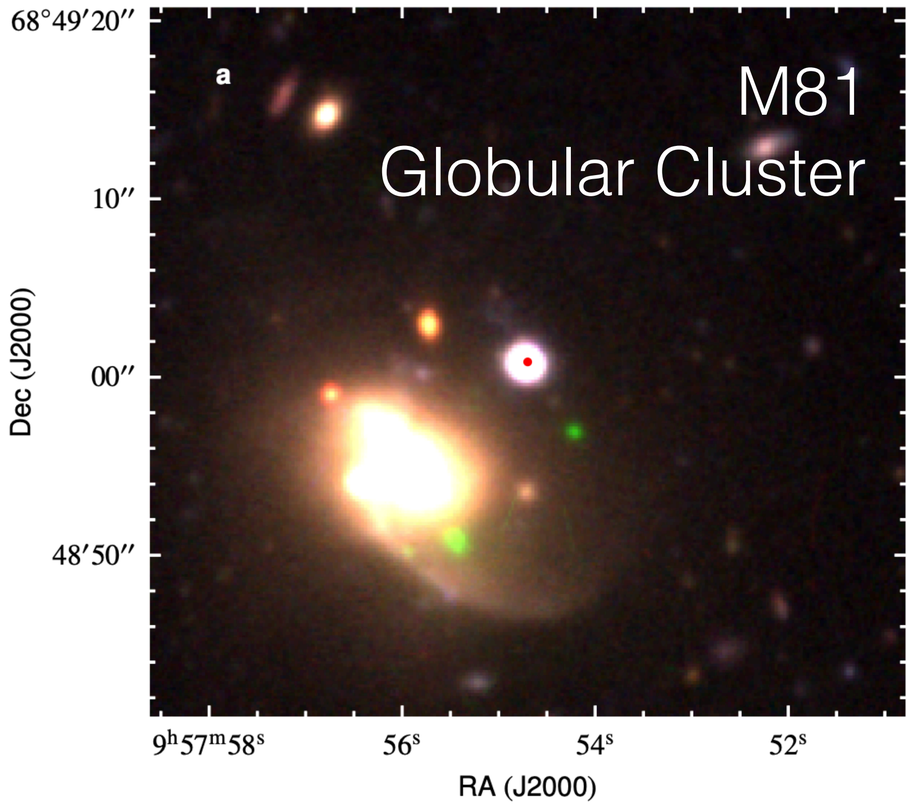


Mass-weighted median age ≈ 5.1 Gyr

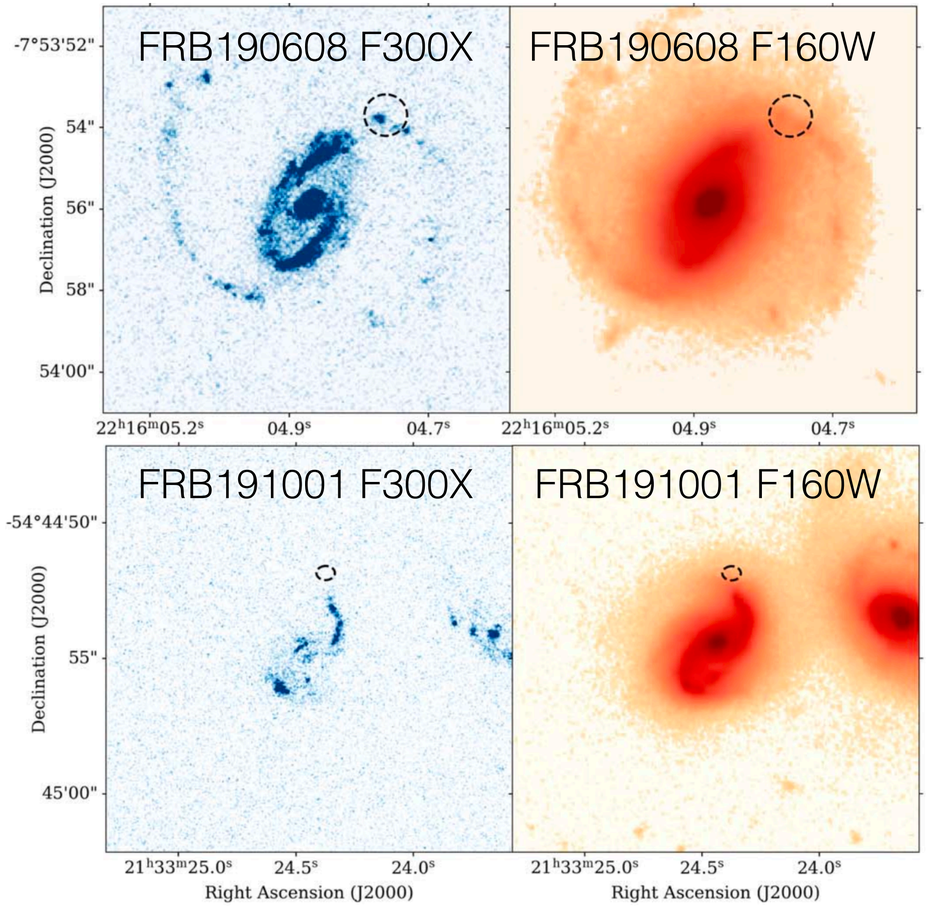
No statistically significant distinction between the hosts of repeaters and non-repeaters

Local host environments

Kirsten et al., 2021



Mannings et al., 2021

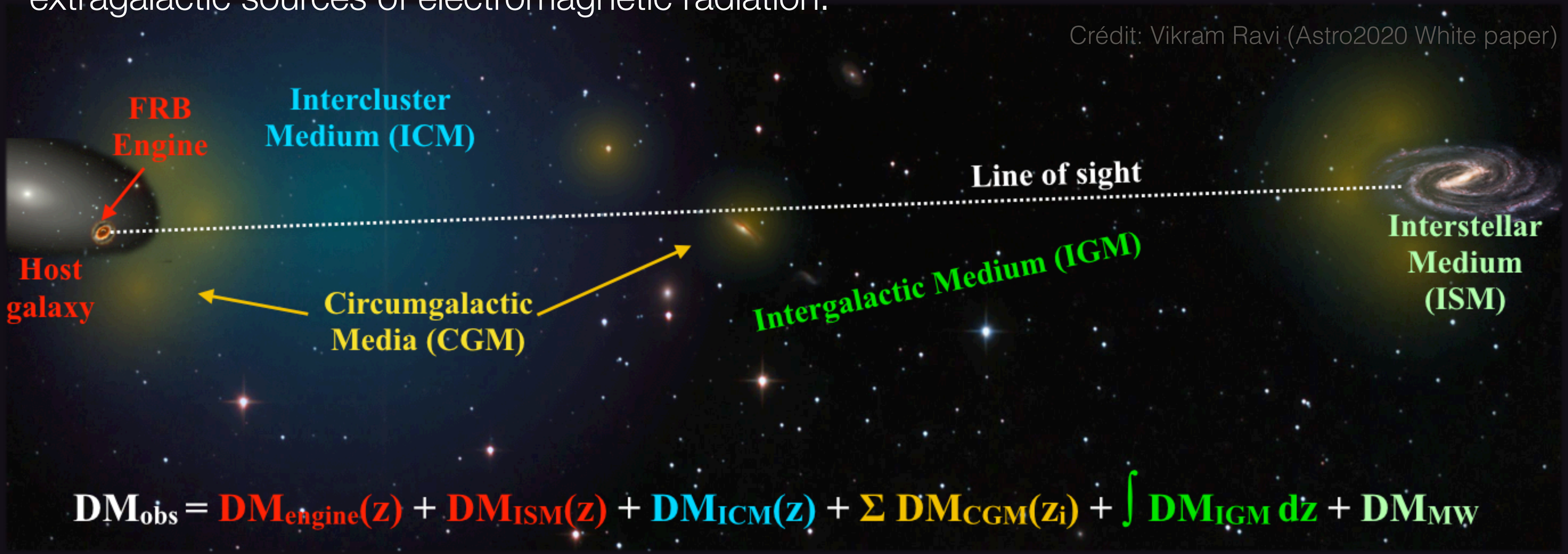


FRBs come from diverse local host environment and various types of host galaxies. Not always in the centre.

Why are FRBs important?

FRB as a probe of the Universe

FRBs are the shortest-duration extragalactic transients, and the most compact known extragalactic sources of electromagnetic radiation.

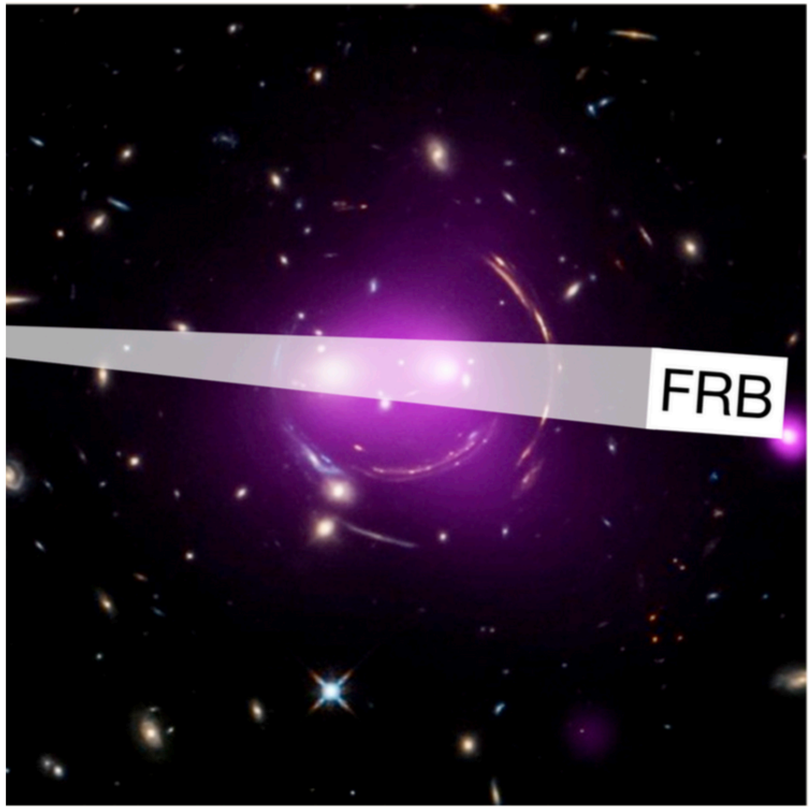


—> FRB provides a clean signal to study these otherwise very hard to probe components

FRBs as a probe of the Universe

10^3 - 10^4 FRBs

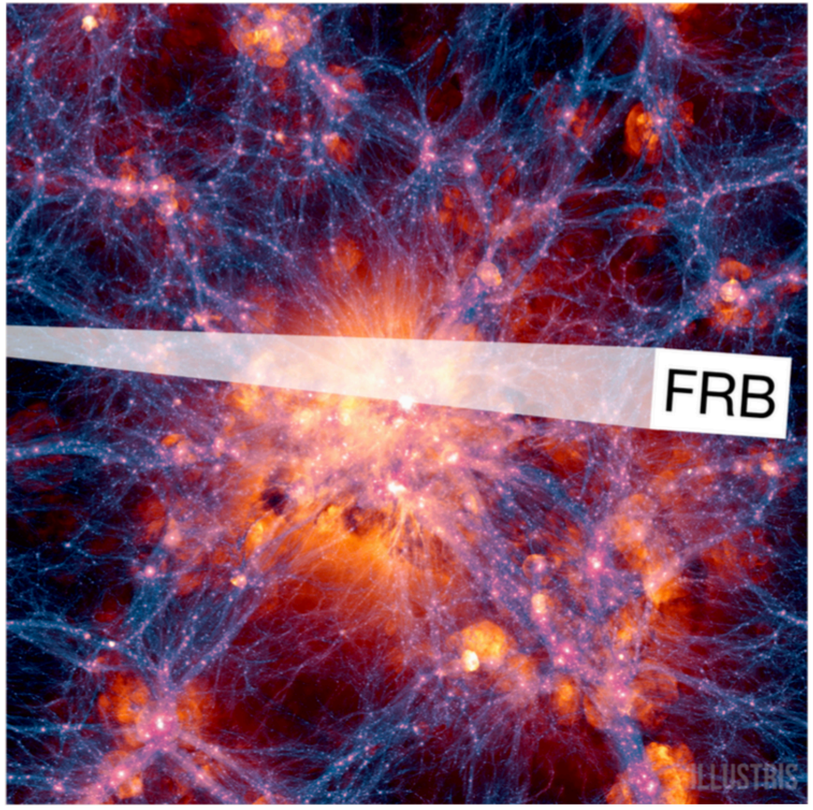
Detection of CGM/IGrM/ICM — CGM cooling — compact-object dark matter



X-ray: NASA/CXC/UA/J.Irwin et al; Optical: NASA/STScI

10^4 - 10^5 FRBs

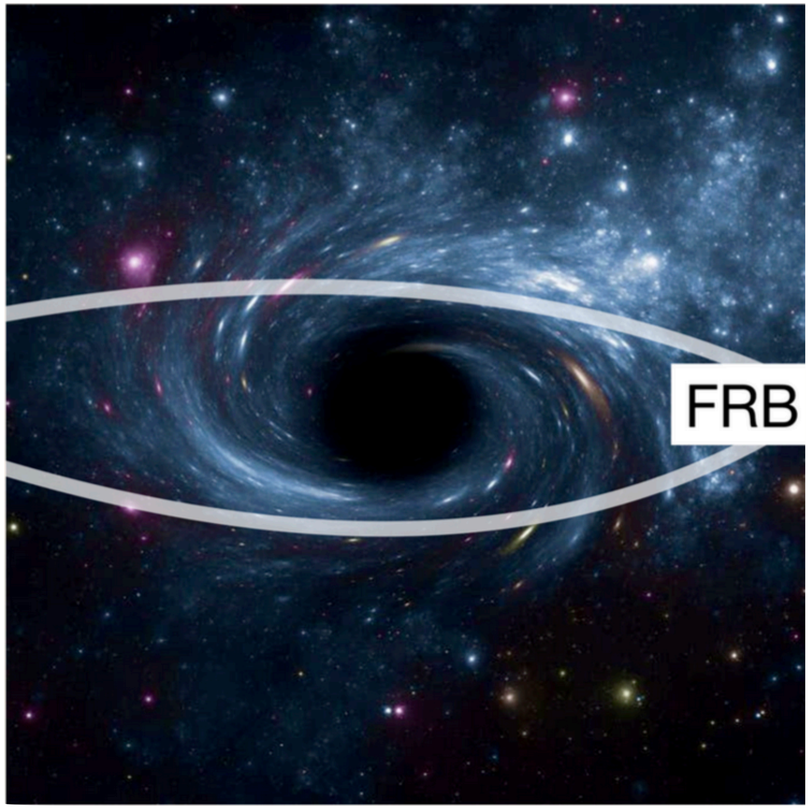
Cosmic web density — Helium reionization — DM-space clustering



Illustris Collaboration / Illustris Simulation

10^5 - 10^6 FRBs

kSZ synergy — extragalactic micro- and nano-lenses



Vikram Ravi (Astro2020 White paper)

Summary and on-look

- Diverse observational properties —> yet unknown origin
- Next breakthroughs will probably come from Multi-wavelength observations and host localizations
- A large, well-localized FRB sample could soon be a reality:
  - CHORD, DSA2000, SKA : >500 mas-localisations per month
  - Challenge: how will the host galaxy identification be able to keep up with this high discovery rate?
- FRB as a probe for our Universe :
  - Localizing missing baryons, galactic halo, constrain H_0, deionization of He-II, lensing, IGM magnetic field…