Measuring H_0 with Fast Radio Bursts

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Steffen Hagstotz
with Robert Reischke & Robert Lilow

November 8 I 2022

Astroparticle Symposium

Fast Radio Bursts

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- Mechanism unknown
- First discovered in archival data 2007
- Short (~ms), bright (~Jy) radio transients
- Frequencies 300 Mhz - 8 Ghz
- Extragalactic
- About 600 known events, soon several 1000s
- Some repeating?

Proposed Mechanisms

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A Living Theory Catalogue for Fast Radio Bursts

E. Platts[a,*], A. Weltman[a], A. Walters[b,c], S. P. Tendulkar[d], J.E.B. Gordin[a], S. Kandhai[a]

arXiv 1810.05836

www.frbtheorycat.org

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2 Contributing to the Wiki
  2.1 Rules and Guidelines
3 Summary Table

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Proposed Mechanisms

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Neutron stars? Mergers? AGN?

Article | Published: 04 November 2020

A bright millisecond-duration radio burst from a Galactic magnetar

The CHIME/FRB Collaboration

Nature **587**, 54–58(2020) | Cite this article

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A repeating fast radio burst source in a globular cluster

F. Kirsten (Chalmers), B. Marcote (JIVE), K. Nimmo (ASTRON, University of Amsterdam), J. W. T. Hessels (U
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Proposed Mechanisms

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1 Welcome to

Fast Radio Bursts from Extragalactic Light Sails

Manasvi Lingam, Abraham Loeb

We examine the possibility that Fast Radio Bursts (FRBs) originate from the activity of extragalactic civilizations. Our analysis shows that beams used for powering large light sails could yield parameters that are consistent with FRBs. The characteristic diameter of the beam emitter is estimated through a combination of energetic and engineering constraints, and both approaches intriguingly yield a similar result which is on the scale of a large rocky planet. Moreover, the optimal frequency for powering the light sail is shown to be similar to the detected FRB frequencies. These `coincidences' lend some credence to the possibility that FRBs might be artificial in origin. Other relevant quantities, such as the characteristic mass of the light sail, and the angular velocity of the beam, are also derived. By using the FRB occurrence rate, we infer upper bounds on the rate of FRBs from extragalactic civilizations in a typical galaxy. The possibility of detecting fainter signals is briefly discussed, and the wait time for an exceptionally bright FRB event in the Milky Way is estimated.

millisecond-duration radio burst from a Galactic magnetar

The CHIME/FRB Collaboration

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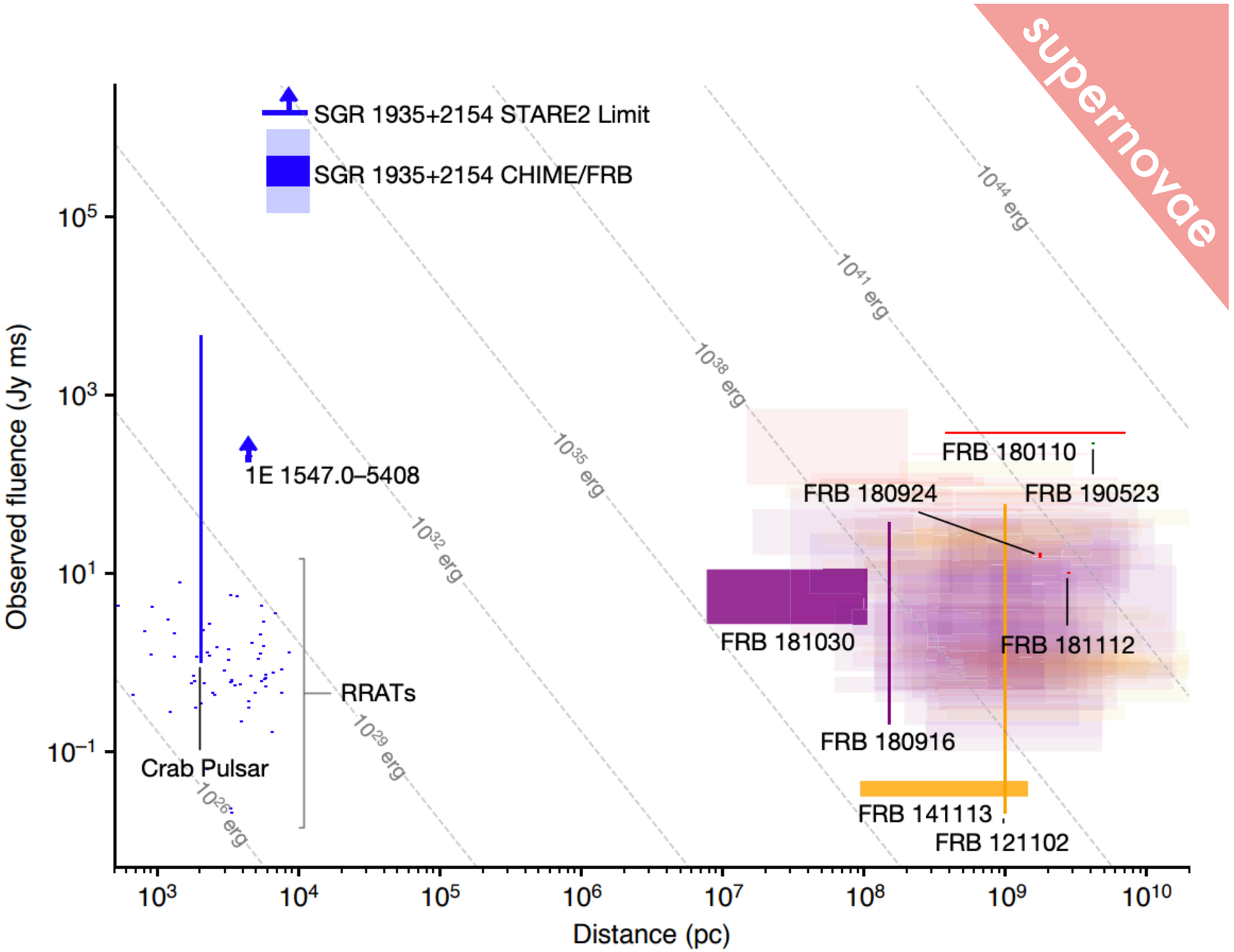
Energy



CHIME/FRB collaboration, Nature 587, 54-58(2020)

Known FRBs

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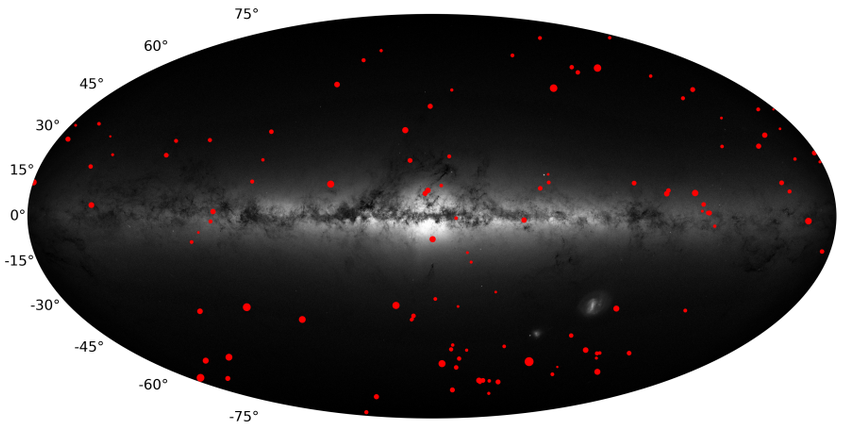

- Until now: detections mostly incidental
- Expect rates of $10^3 - 10^4$ / sky / night

CHIME

- Now: dedicated searches ongoing

ASKAP

Known FRBs

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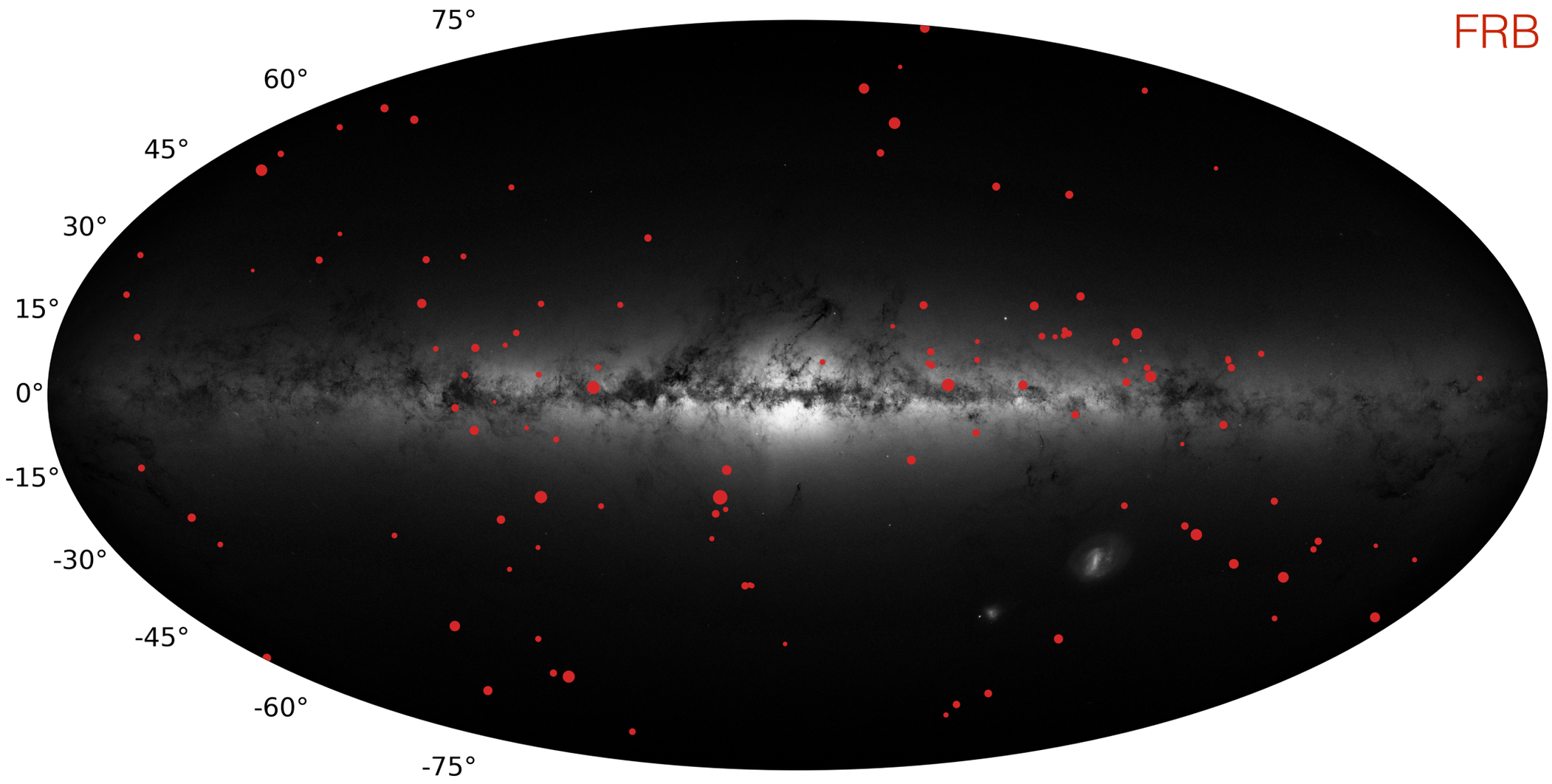

Events uncorrelated with the Milky Way

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Known FRBs

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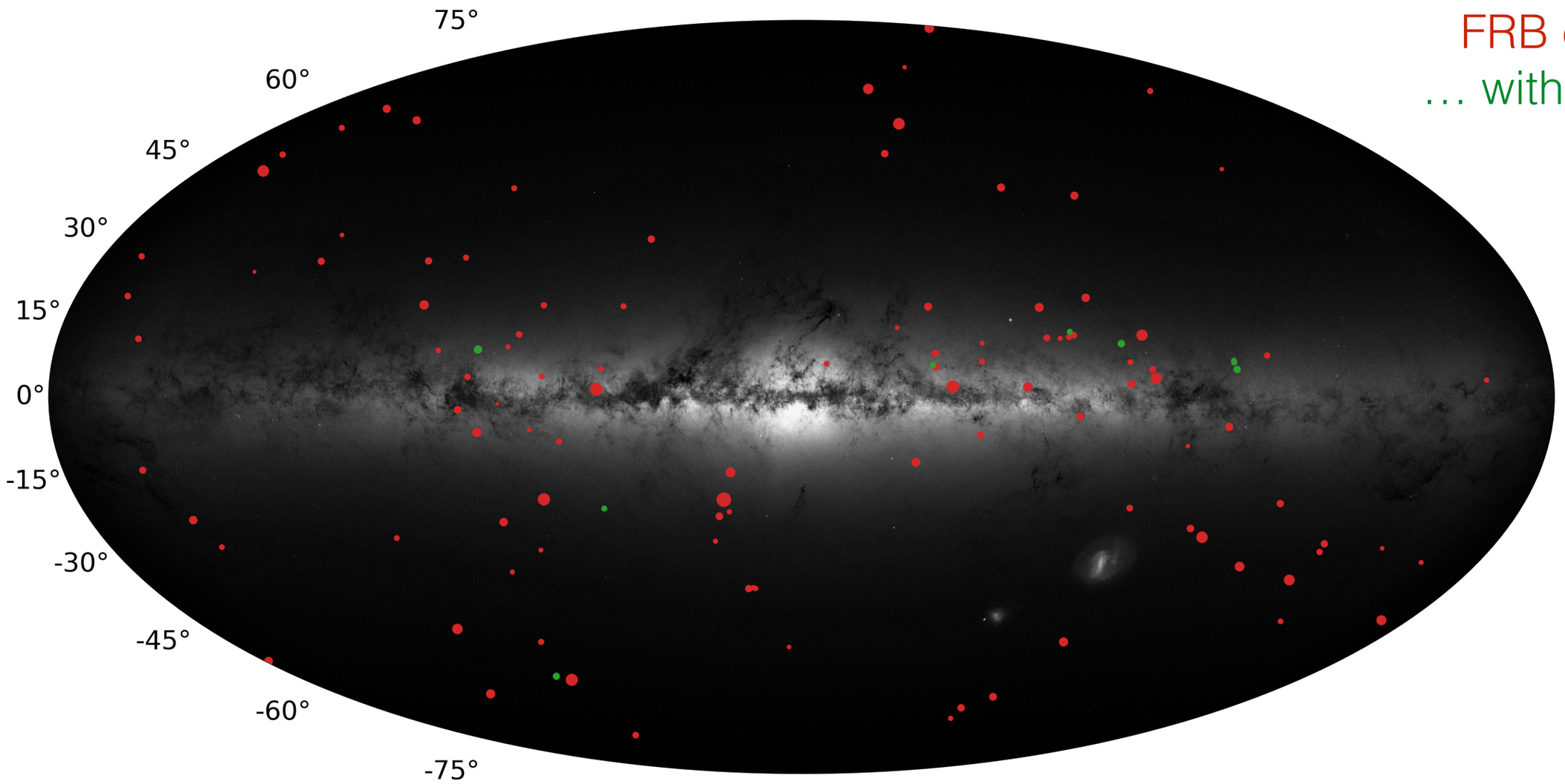

FRB cat
… with host

Events uncorrelated with the Milky Way

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Known FRBs

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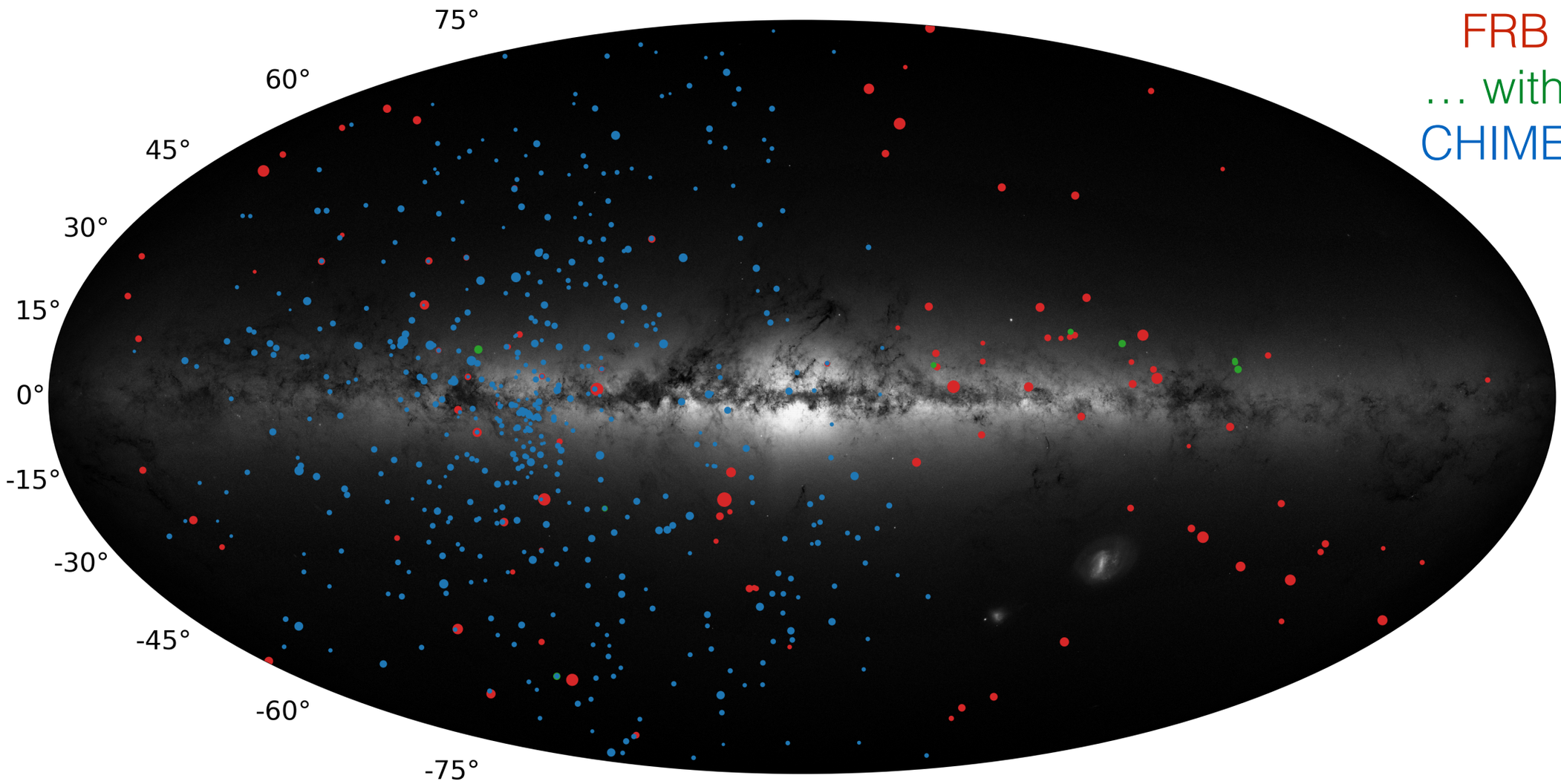

FRB cat
… with host
CHIME/FRB

Events uncorrelated with the Milky Way

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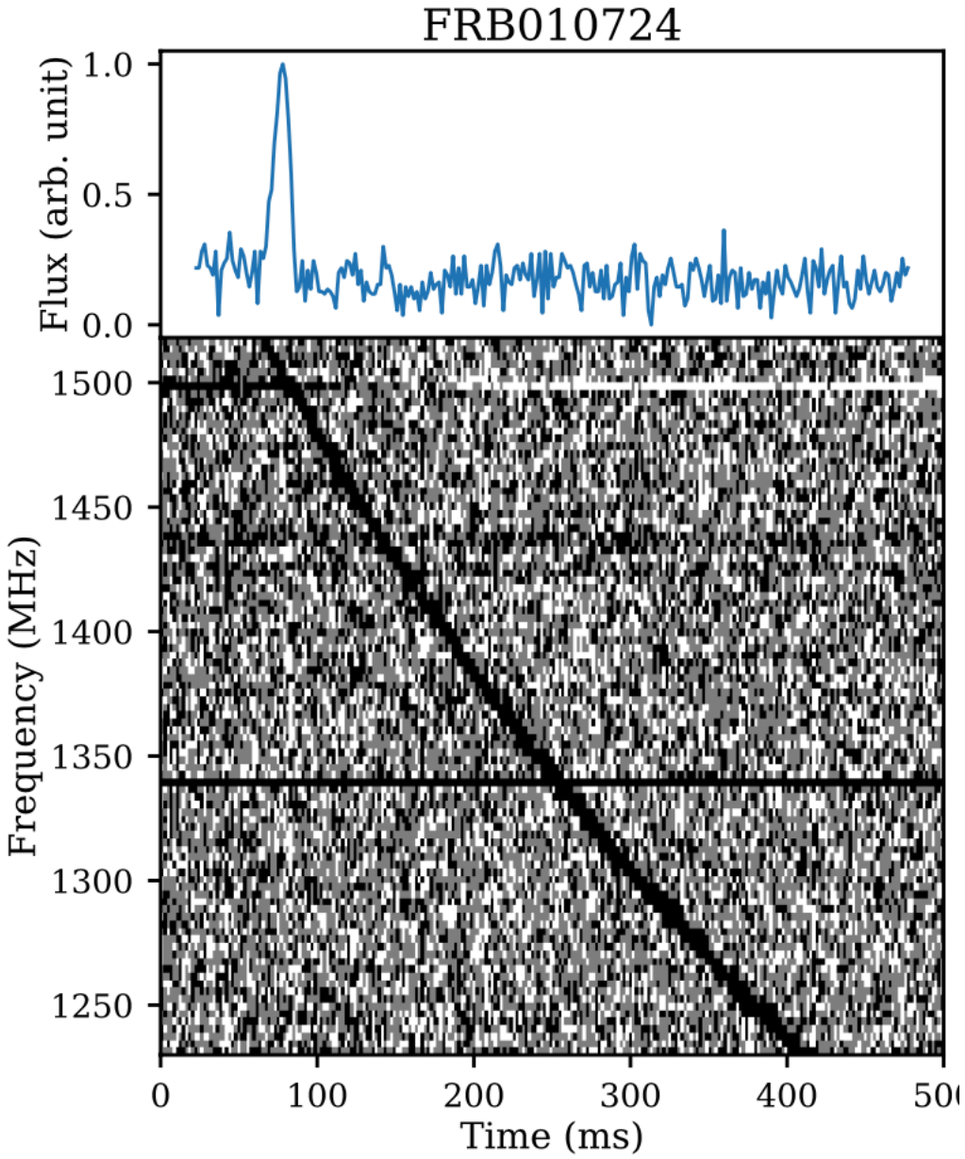
Dispersion measure



Lorimer et al 2007
Cordes & Chatterjee 2019

- Radio signals undergo dispersion
- Pulse delay $\Delta t \sim \nu^{-2}$
- Depends on integrated electrons along LoS

$$\mathrm{DM} = \int \frac{n_e}{1+z} \mathrm{d}l$$

Pulse structure

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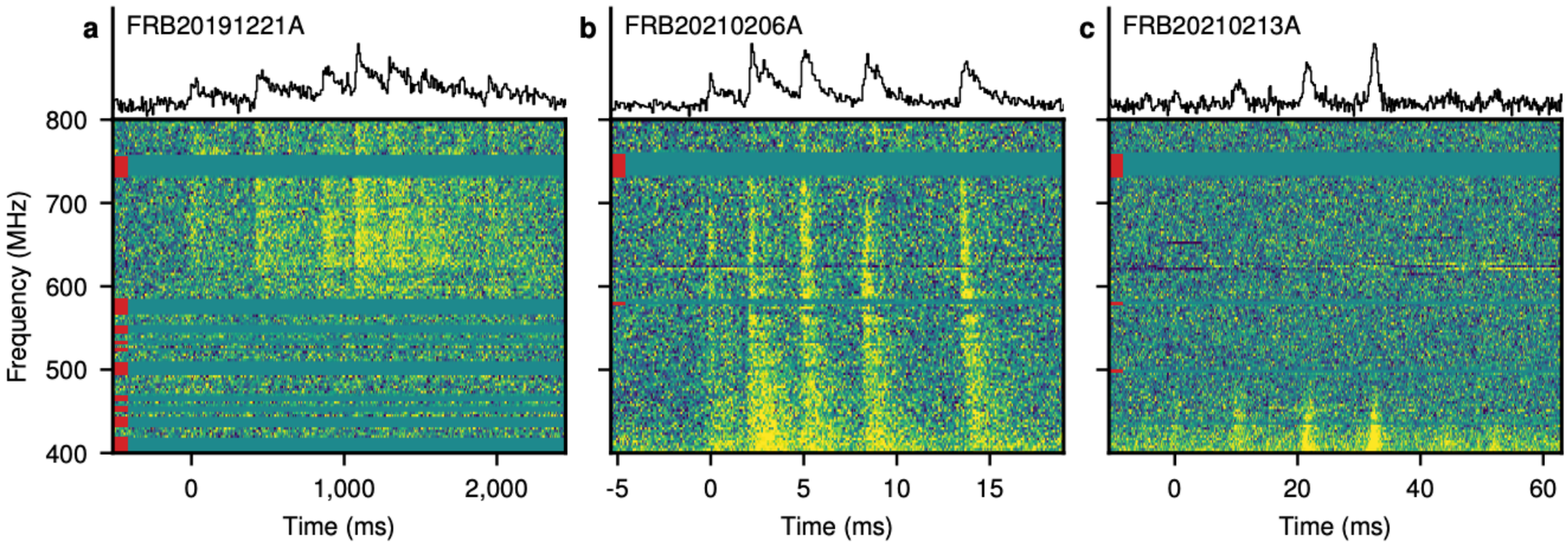

Puls substructure at the ms level -> source not bigger than O(100) km

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Dispersion measure

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$$\mathrm{DM_{tot}}(z) = \mathrm{DM_{MW}} + \mathrm{DM_{LSS}}(z) + \mathrm{DM_{host}}(z)$$

Milky Way models

Can be checked with Pulsars

Quite accurate!

Host halo models

Depends on galaxy types?

Location of FRBs?

Dispersion measure

$$\mathrm{DM_{tot}}(z) = \mathrm{DM_{MW}} + \mathrm{DM_{LSS}}(z) + \mathrm{DM_{host}}(z)$$

LSS

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Location of FRBs?

Redshift scaling:

const.

$$\propto \int^z \frac{1+z'}{E(z')}\mathrm{d}z' \quad \propto \frac{1}{1+z}$$

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Statistics can tell contributions apart

Dispersion measure

Dispersion measure has several contribution:

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Density field

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Ionisation history

Density field

Dispersion measure

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Distance measure

Ionisation history

Density field

Dispersion measure

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Baryon fraction

$$n_e \approx F(z)\frac{\rho_b}{m_p} = F(z)\frac{\bar{\rho}_b}{m_p}\left[1 + b_e\delta_m\right]$$

Distance measure

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Density field

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Distance measure
Need redshifts

Baryon fraction
Need redshifts

Ionisation history
Need redshifts

Density field

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Distance measure
Need redshifts

Ionisation history
Need redshifts

Baryon fraction
Need redshifts

Density field

See next talk by Robert Reischke

Distance scales

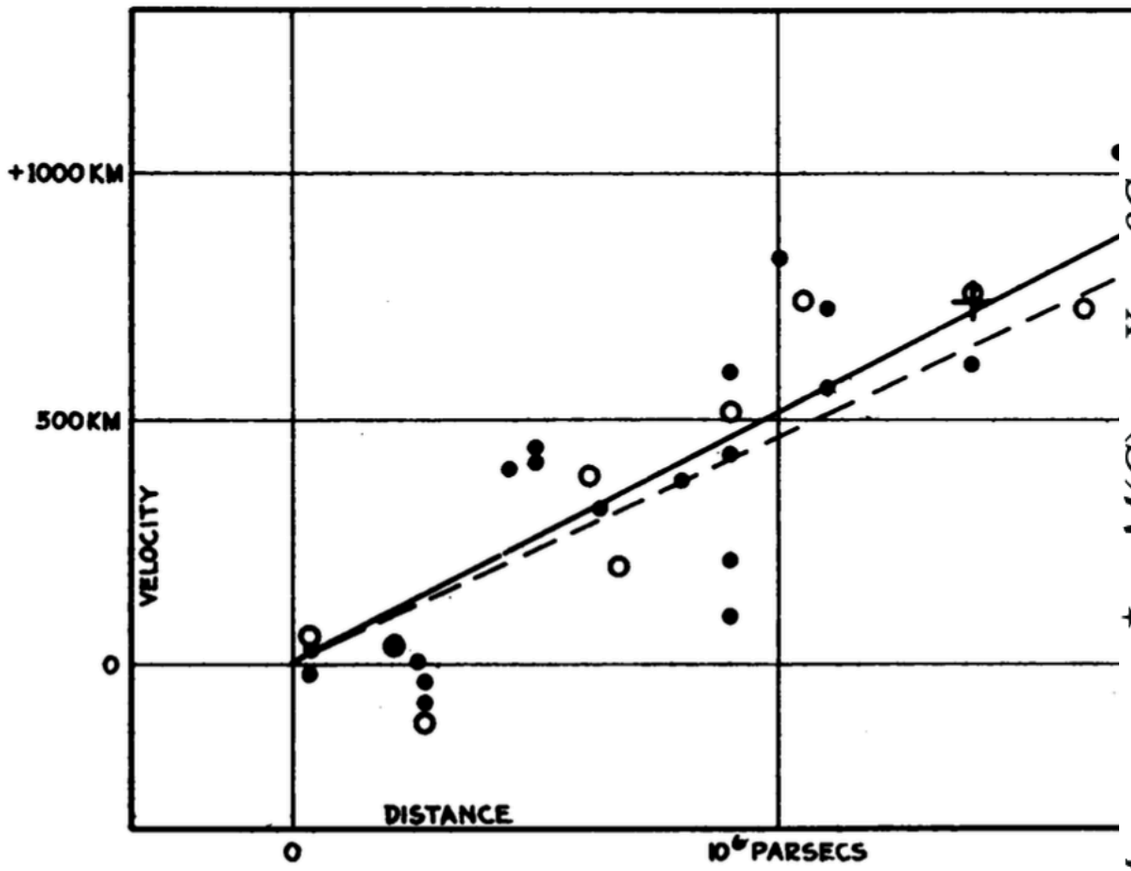
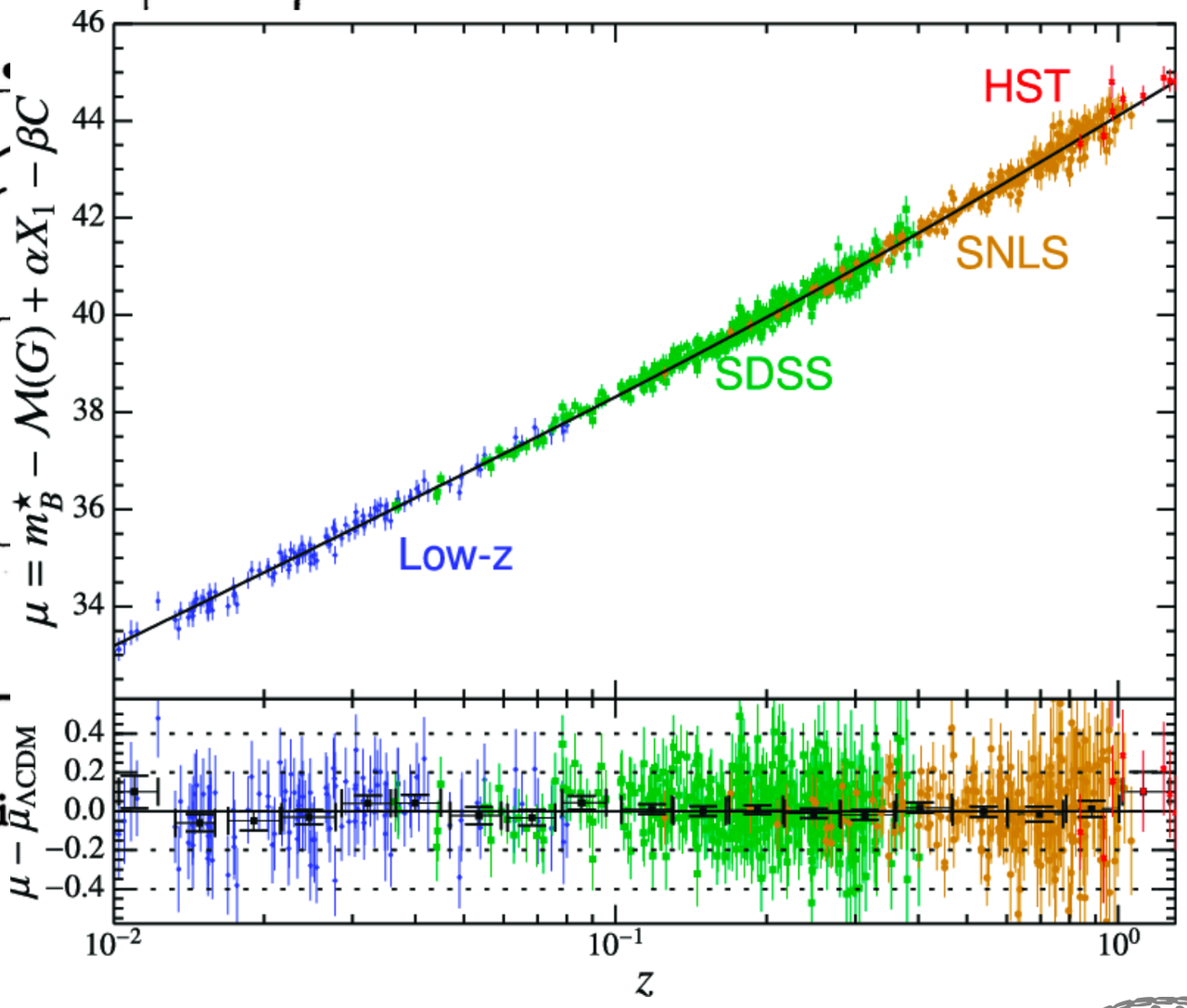


FIGURE 1

Velocity-Distance Relation among Extra-Galacti



Bahcall 2015

FRB distance scale

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Mean LSS dispersion:

$$< \mathrm{DM_{LSS}} > (z) = \int \mathrm{d}l \frac{n_e}{1+z}$$

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FRB distance scale

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FRB distance scale

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$$< \mathrm{DM_{LSS}} > (z) = \int \mathrm{d}l \frac{n_e}{1+z}$$

$$n_e \approx \chi_e \frac{\bar{\rho}_\mathrm{b}}{m_p}$$

$$= \frac{3\Omega_\mathrm{b} H_0}{8\pi G m_\mathrm{P}} \chi_\mathrm{e} f_\mathrm{IGM} \int^z \frac{1+z'}{E(z')} \mathrm{d}z'$$

FRB distance scale

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Mean LSS dispersion:

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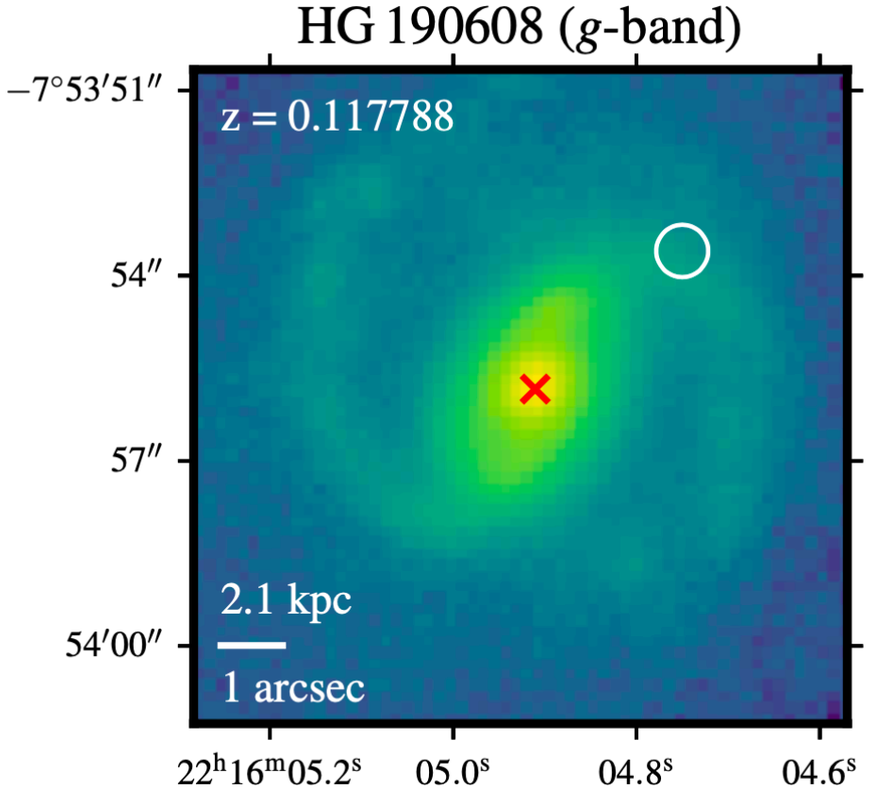
- Perfect degeneracy at the background level
- Combine with prior on baryon density $\Omega_\mathrm{b} h^2$ (from CMB or BBN)

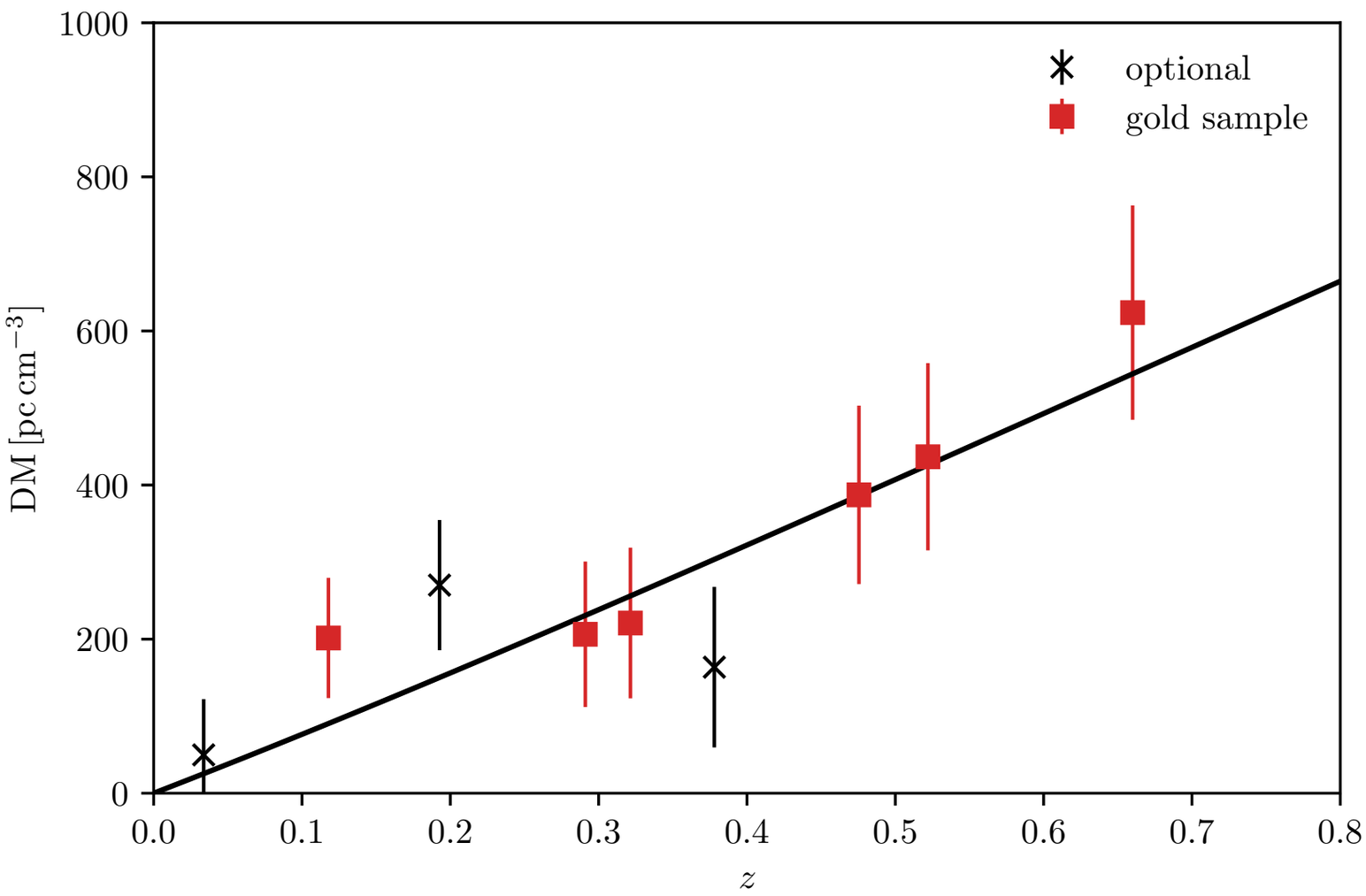
Host ID



VLT + ASKAP (Macquart et al 2020)

- Dedicated FRB searches from radio arrays
- Long baselines, excellent angular resolution
- Optical follow-up allows host ID and redshift

FRB distance scale



- Compile DM-z diagram similar to SNe Ia
- Absolute calibration via subtraction of host & MW DM
- Additional “gold sample” of high quality events

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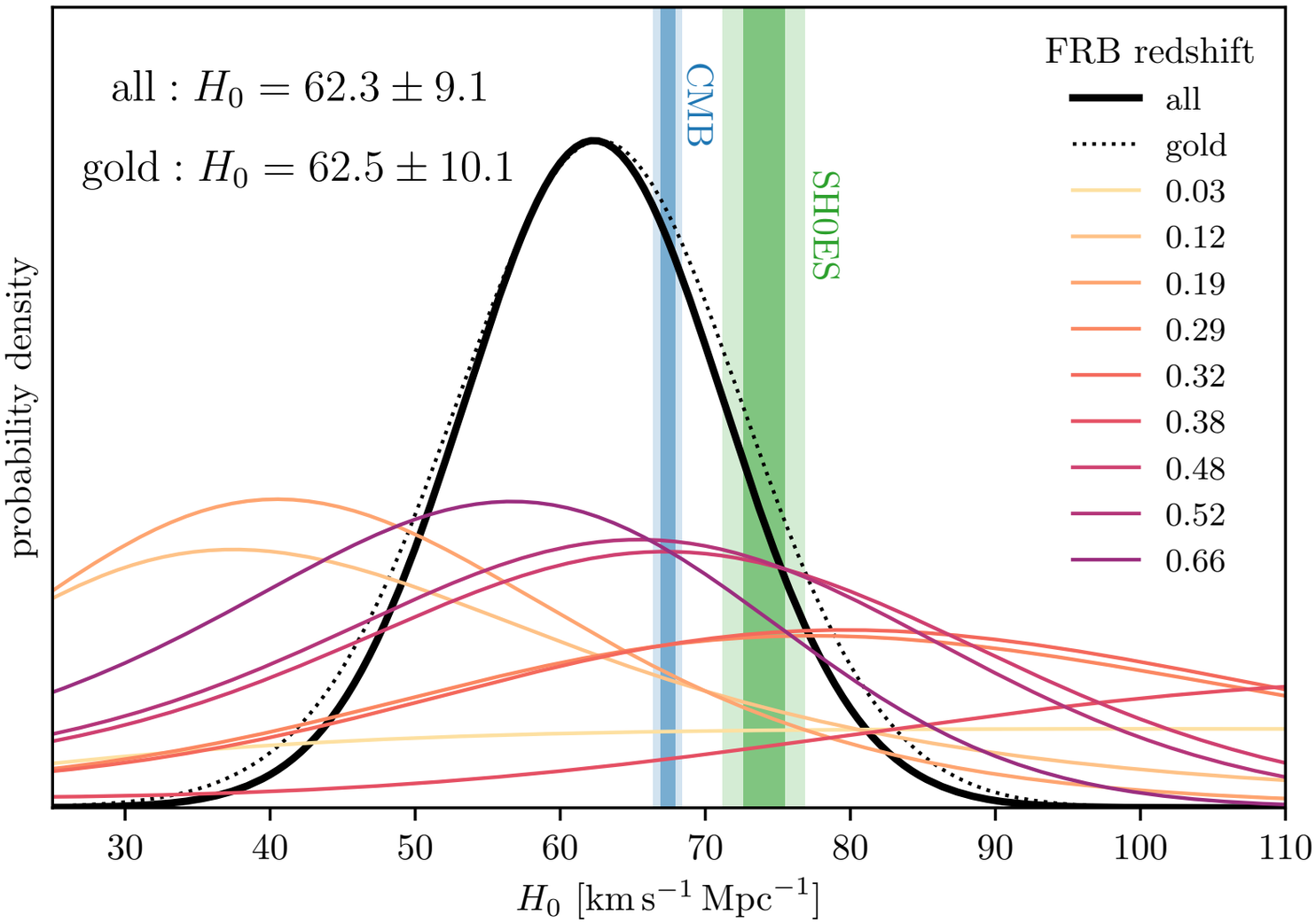
Hubble constant



Events at large z most important

Uncertainty in host DM dominates error

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The Future

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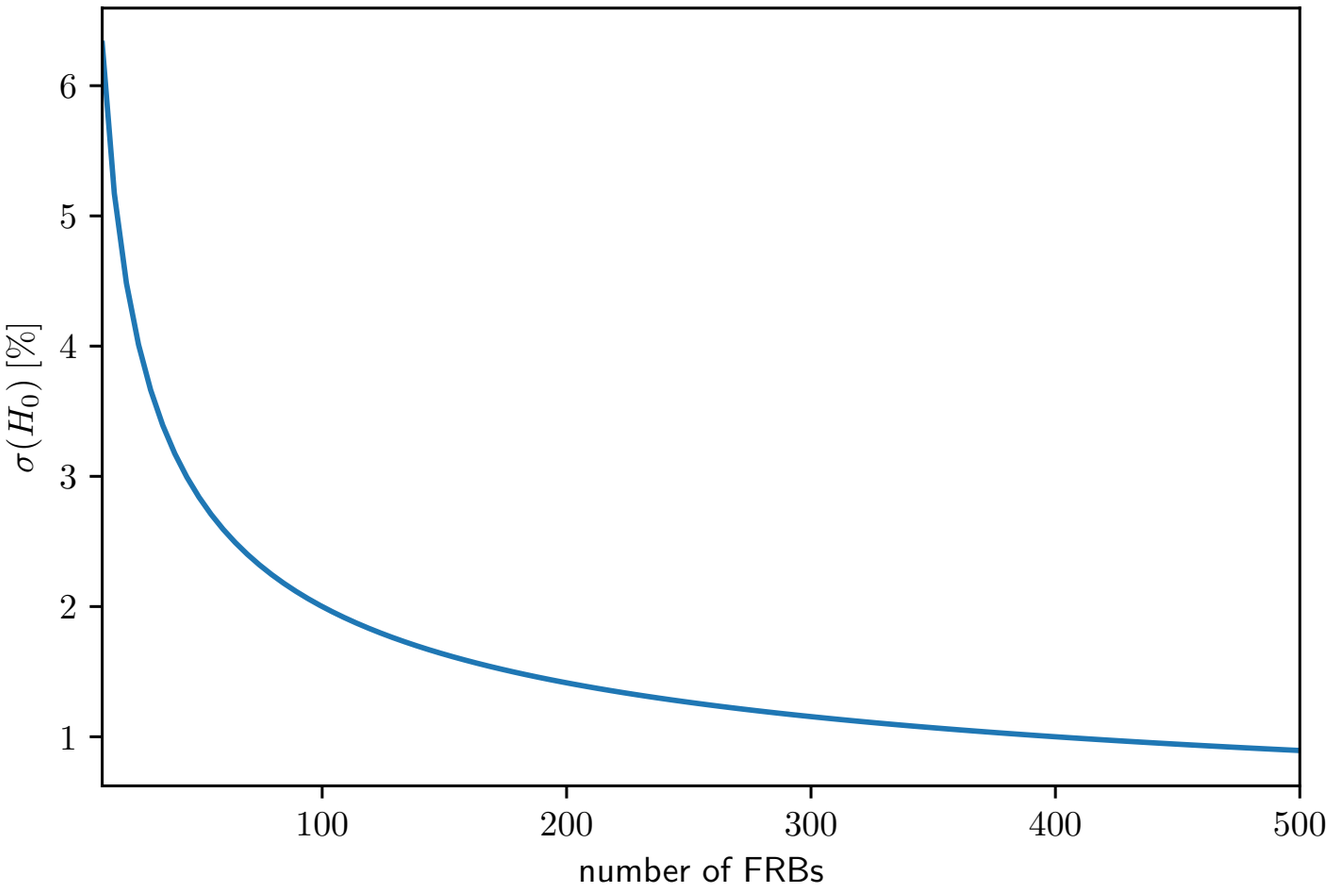
When can FRBs be competitive?



- A few hundred events with host ID get to ~1% precision
- Can we relax some assumptions with larger samples?

Dispersion measure

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LSS

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Can be checked with Pulsars
Quite accurate!

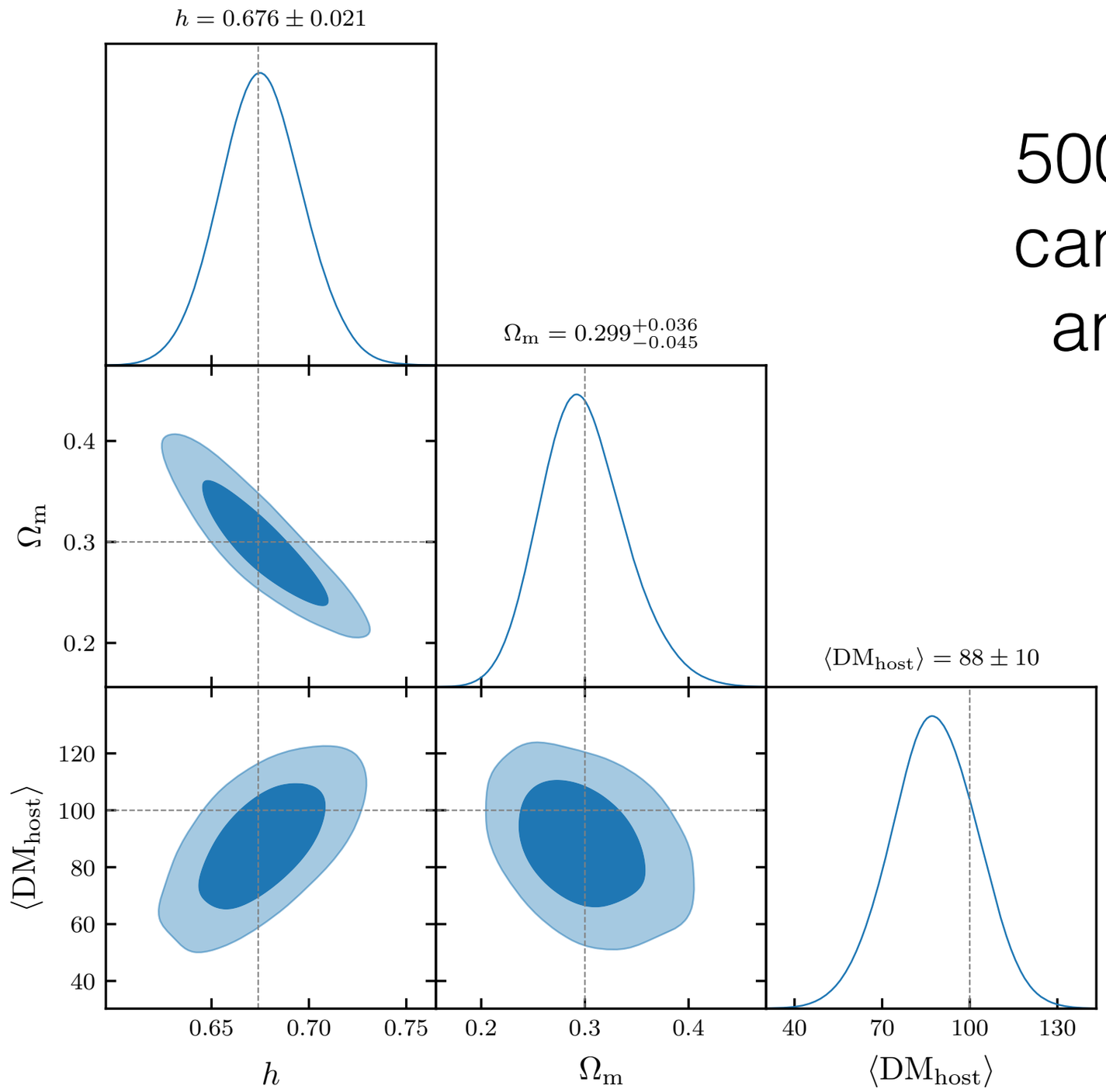
Host halo models
Depends on galaxy types?
Location of FRBs?

Redshift scaling:

const. $\propto \int^z \frac{1+z'}{E(z')}\mathrm{d}z'$ $\propto \frac{1}{1+z}$

Statistics can tell contributions apart

Forecast



500 events with host ID can determine host DM and Hubble constant simultaneously

Available soon!

Summary

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- Mechanism of the bursts unknown

- FRBs can provide independent* measurement of the Hubble constant $H_0 = 62.3 \pm 9.1$

- Currently limited by statistics, many more events are coming from CHIME/ASKAP/HIRAX

- FRBs can do many more things for cosmology!

  Primordial non-Gaussianity (Reischke, SH, Lilow 2020)

  Equivalence principle (Reischke, SH, Lilow 2021)

Backup

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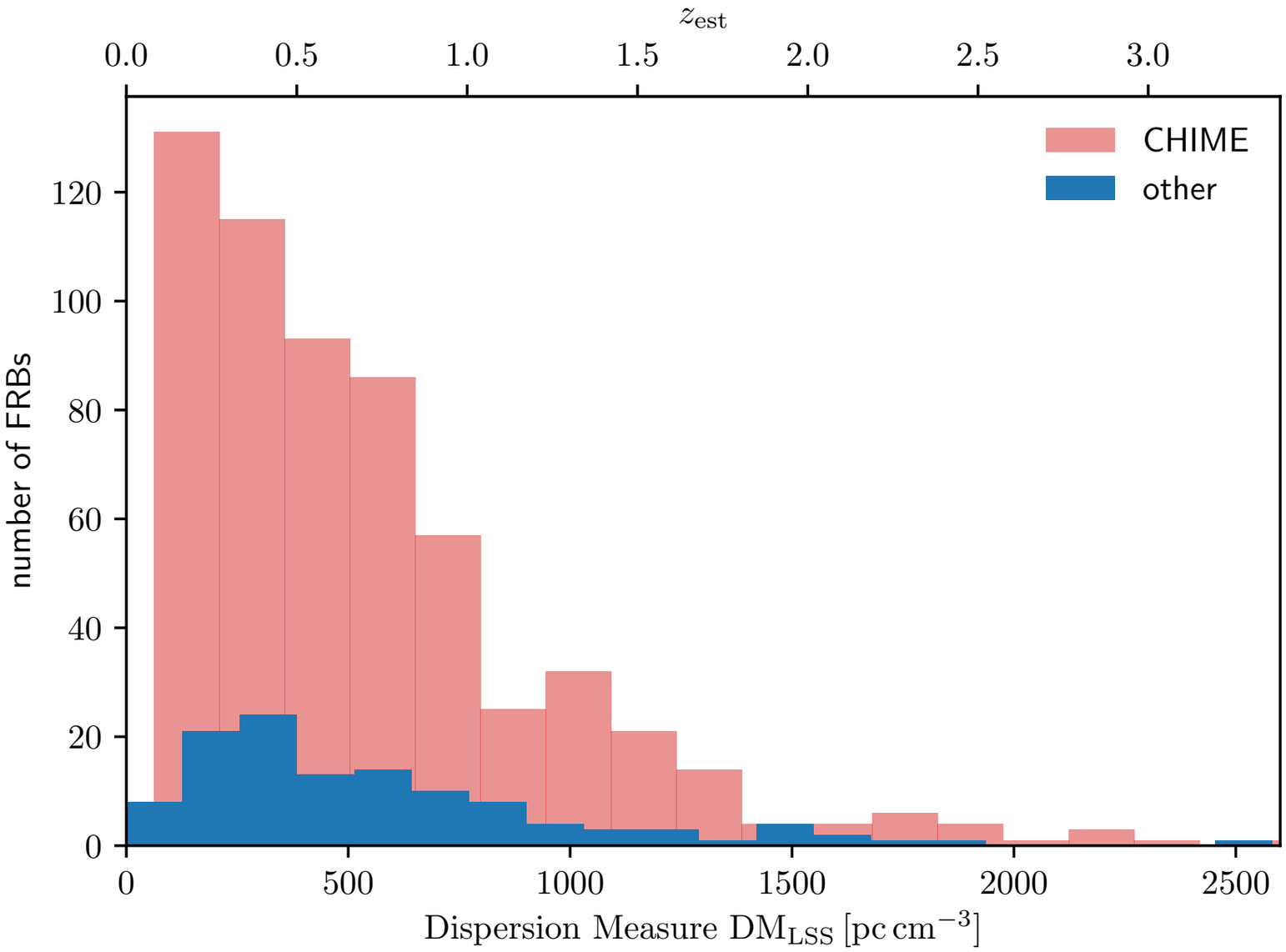
Known FRBs



- True FRB population not well known
- Detections up to z~2 possible
- Maybe beyond? Reionisation studies?

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