

# A new measurement of the Hubble constant with Fast Radio Bursts



Steffen Hagstotz  
with Robert Reischke & Robert Lilow

Cosmology from home  
2021

# Fast Radio Bursts

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

# Proposed Mechanisms

A Living Theory Catalogue for Fast Radio Bursts

*arXiv 1810.05836*

E. Platts<sup>a,\*</sup>, A. Weltman<sup>a</sup>, A. Walters<sup>b,c</sup>, S. P. Tendulkar<sup>d</sup>, J.E.B. Gordin<sup>a</sup>, S. Kandhai<sup>a</sup>

[www.frbtheorycat.org](http://www.frbtheorycat.org)



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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](#)

Steffen Hagstotz

### 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 (University of Amsterdam), S. P. Tendulkar (TIFR, NCRA), A. Keimpema (JIVE), J. Yang (Chalmers), M. P. Snelders (University of Amsterdam), C. J. Law (Caltech), W. M. Peters (NRL), M. Giroletti (INAF), D. M. Hewitt (University of California, Berkeley), S. T. Buttaccio (INAF), J. E. Conway (Chalmers), A. Corongiu (INAF), R. Feiler (NCU), O. Forsberg (MPIfR), M. A. Kharinov (IAA RAS), M. Lindqvist (Chalmers), G. Maccaferri (INAF), A. Melnikov (IAA RAS), O.

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1 Welcome to the catalogue

## 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.

## One millisecond-duration radio burst from a Galactic magnetar

The CHIME/FRB Collaboration

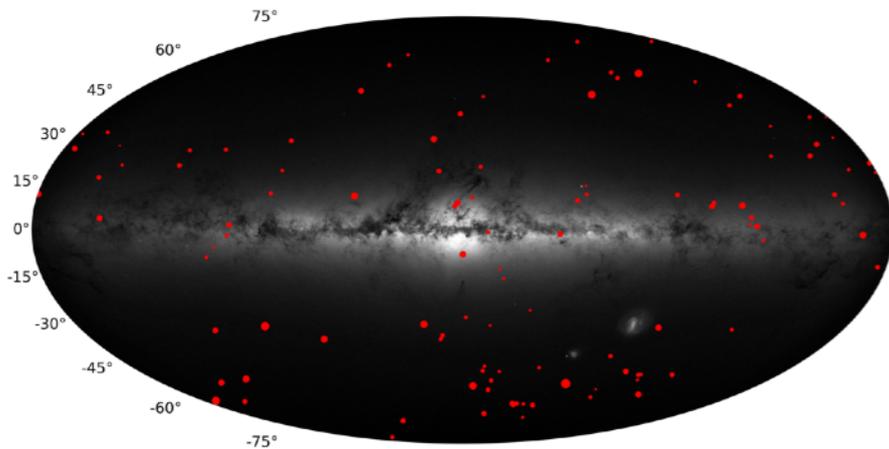
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# Known FRBs

- Until now: detections mostly incidental
- Expect rates of  $10^3$  / sky / night
- Now: dedicated searches ongoing



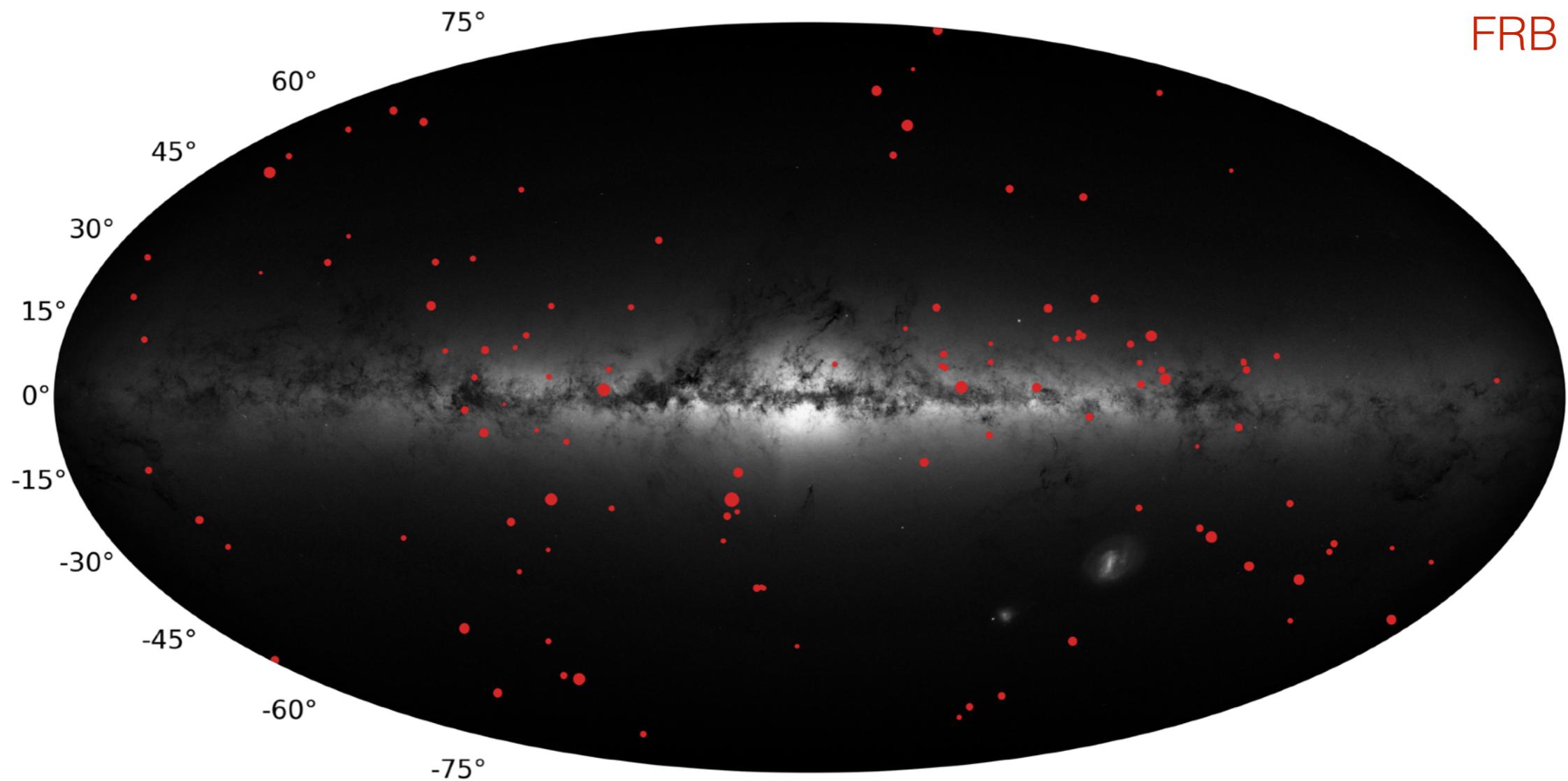
*CHIME*



*ASKAP*

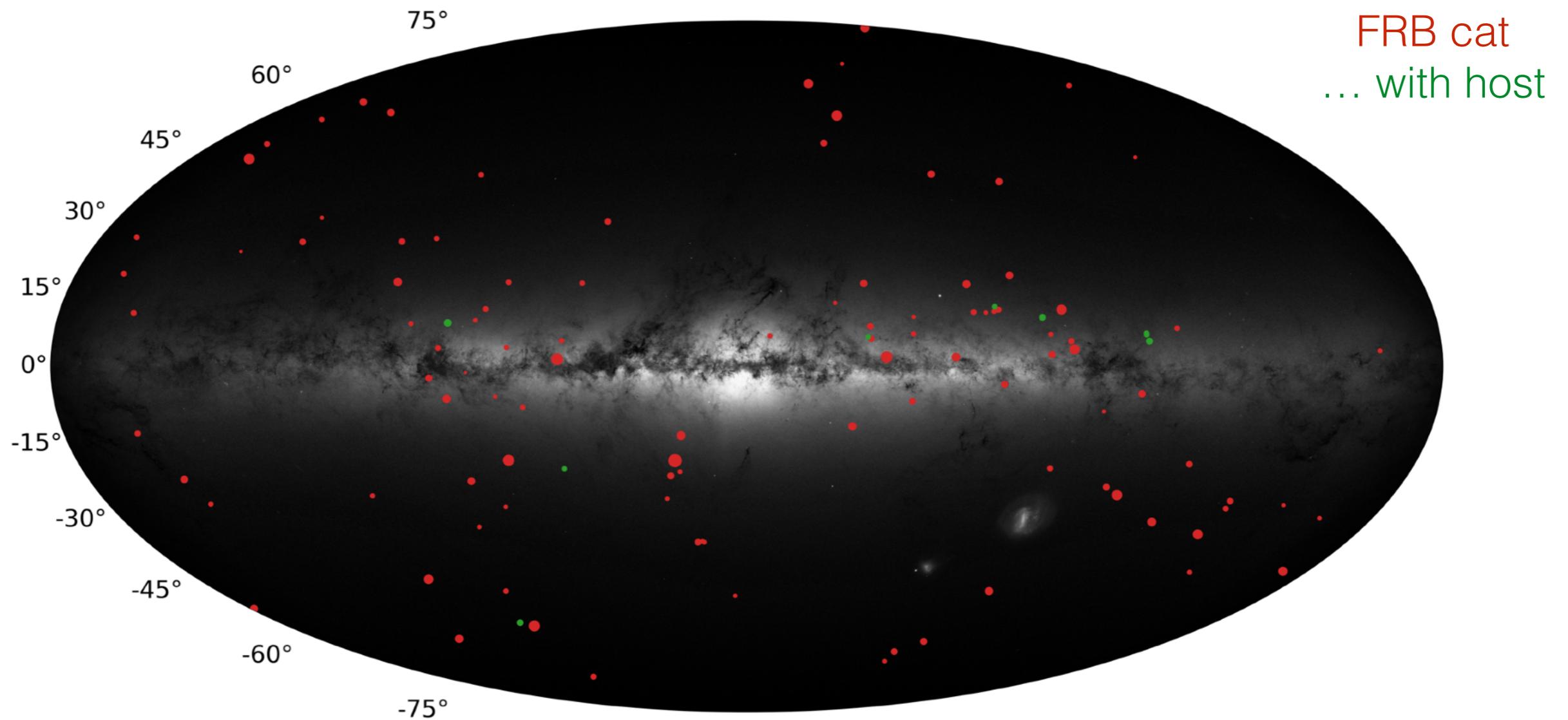
# Known FRBs

FRB cat



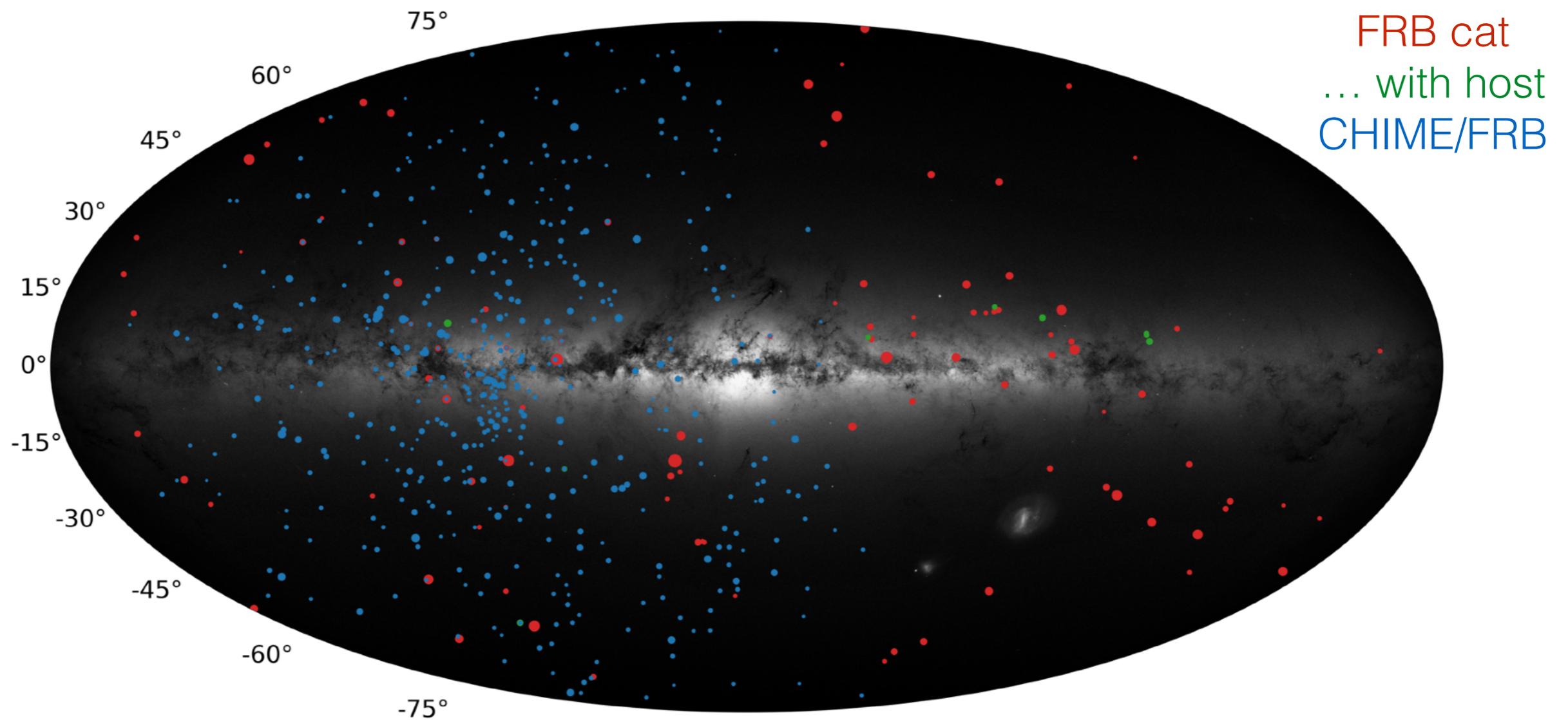
Events uncorrelated with the Milky Way

# Known FRBs



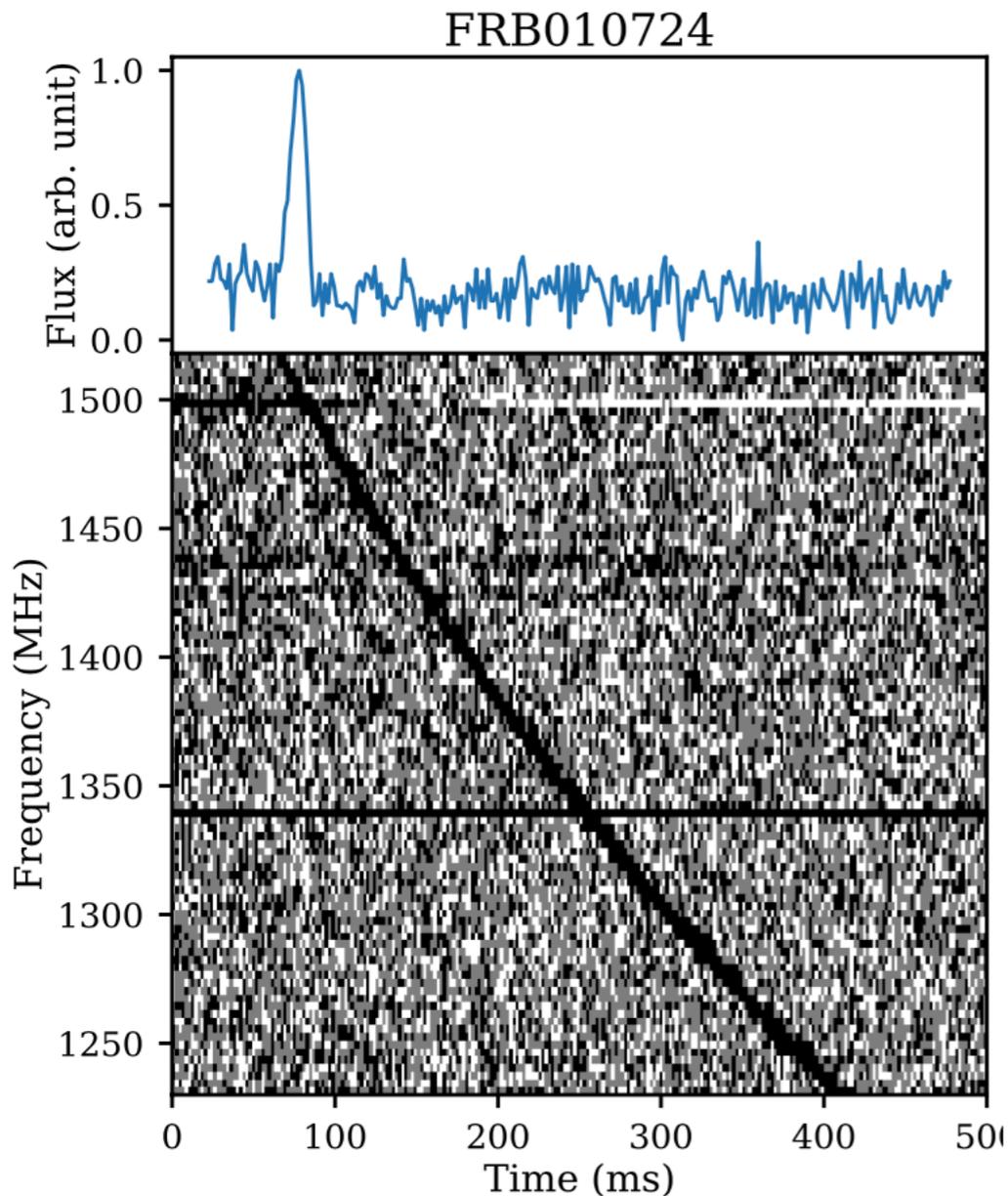
Events uncorrelated with the Milky Way

# Known FRBs



Events uncorrelated with the Milky Way

# Dispersion measure



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

$$DM = \int \frac{n_e}{1+z} dl$$

*Lorimer et al 2007*

*Cordes & Chatterjee 2019*

# Dispersion measure

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



Milky Way models  
Can be checked with Pulsars  
Quite accurate!

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

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Redshift  
scaling:

const.

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

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**Statistics can tell contributions apart**

# Dispersion measure

Dispersion measure has several contribution:

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Ionisation history

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Distance measure

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Density field

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

Baryon fraction

$$DM_{\text{LSS}} = \int dl \frac{n_e}{1+z}$$

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Baryon fraction  
Need redshifts

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**Distance measure**

Need redshifts

Ionisation history  
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Density field

# FRB statistics

Redshifts in general not known: consider angular clustering

## Correlate FRBs

$$C_\ell = \langle \delta_\ell^{\text{FRB}} \delta_{\ell'}^{\text{FRB}} \rangle$$

Sparse, noisy distances, shot-noise dominated

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## Correlate dispersion measure

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signal  $\gg$  noise

Because  $\text{DM}_{\text{LSS}}(z) \gg \text{DM}_{\text{host}}$

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**Super weak lensing\***

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signal  $\gg$  noise

Because  $\text{DM}_{\text{LSS}}(z) \gg \text{DM}_{\text{host}}$

# FRB statistics

## Correlate dispersion measure

$$C_\ell = \langle \text{DM}_\ell \text{DM}_{\ell'} \rangle$$

Great for signals on large scales!

- DM correlations - Masui & Sigurdson (1506.01704)
- Cross-correlations with galaxy surveys - Rafiei-Ravandi, Smith & Masui (1912.09520)
- Primordial non-Gaussianity - Reischke, SH, Lilow (2007.04054)
- Shapiro delay tests of GR - Reischke, SH, Lilow (2102.11554)
- ...

# Distance scales

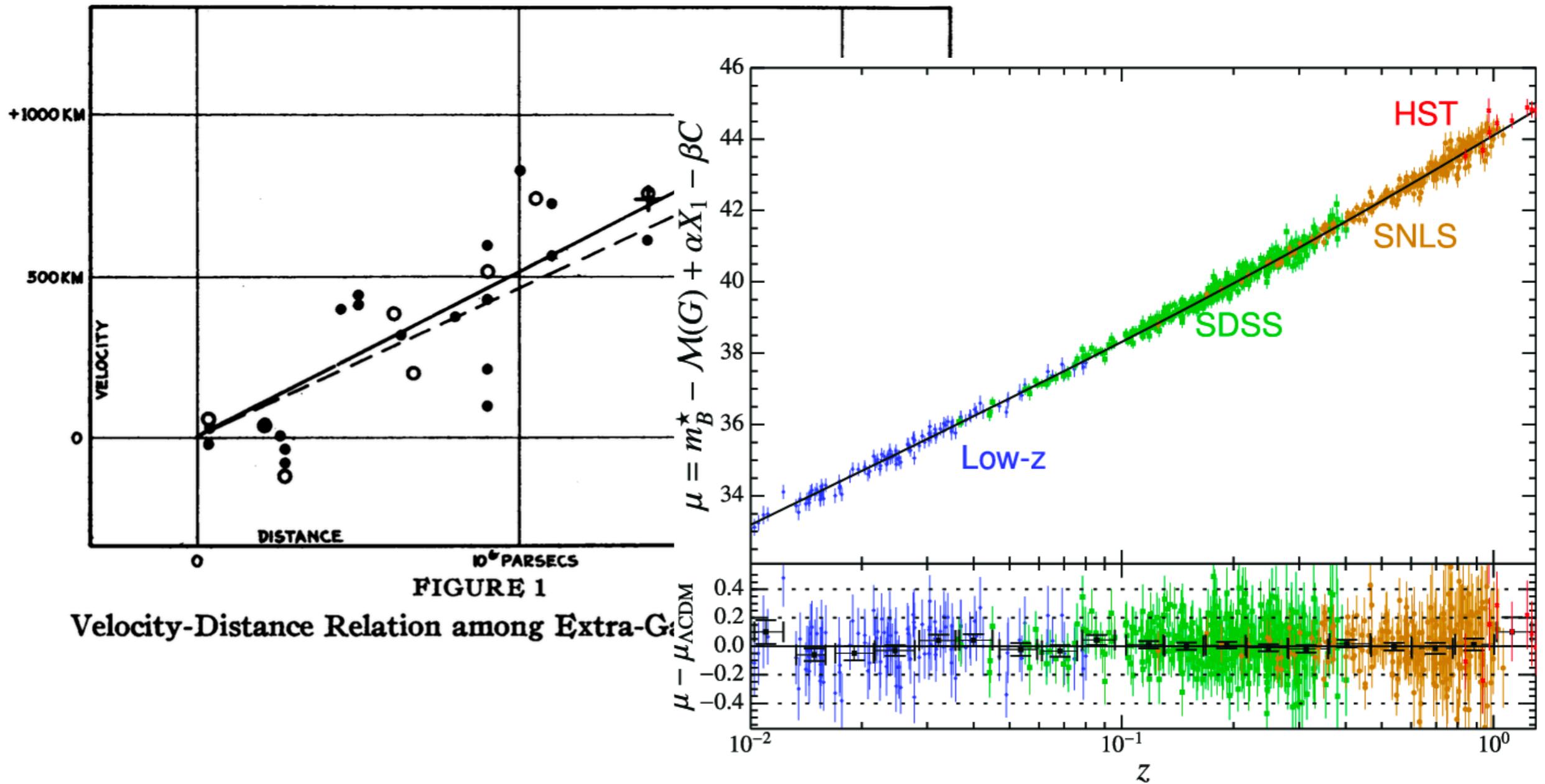


FIGURE 1  
Velocity-Distance Relation among Extra-Galaxies

Bahcall 2015

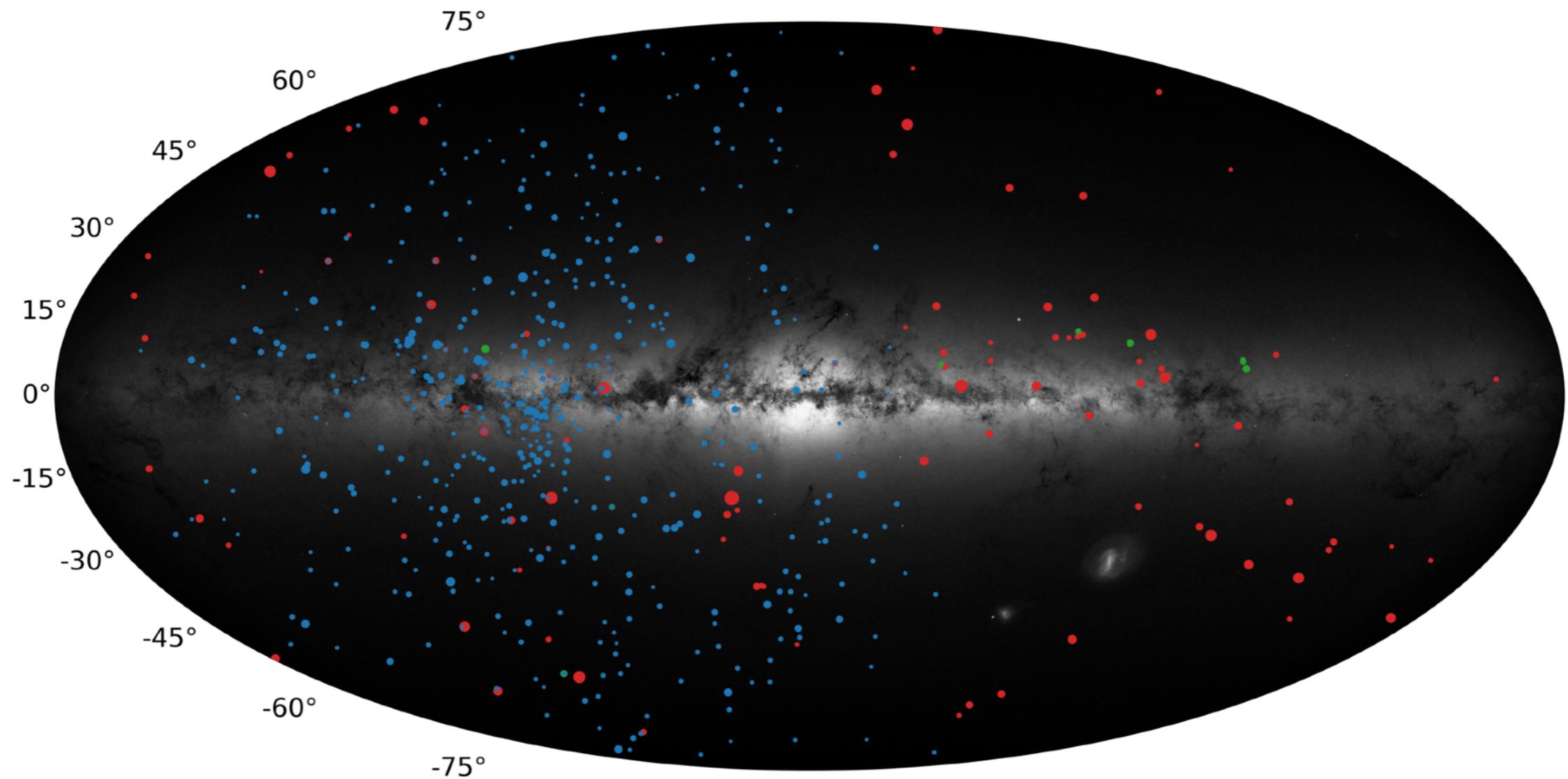
# FRB distance scale

Mean LSS dispersion

$$\langle \text{DM}_{\text{LSS}} \rangle (z) = \frac{3\Omega_b H_0}{8\pi G m_{\text{P}}} \chi_e f_{\text{IGM}} \int^z \frac{1+z'}{E(z')} dz'$$

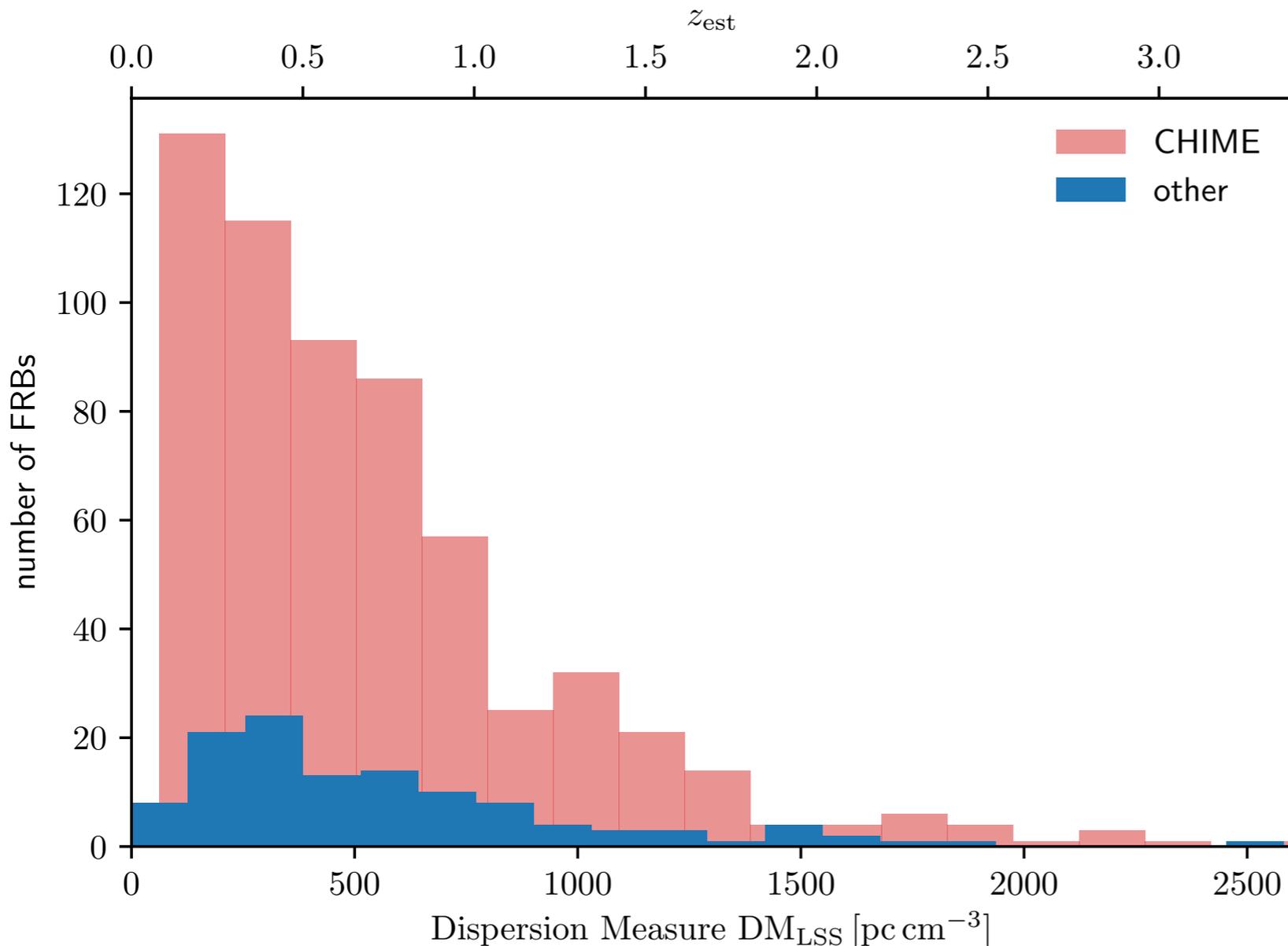
- Slope of relation gives Hubble constant
- Perfect degeneracy at the background level
- Combine with prior on baryon density (CMB, BBN or late times)

# Known FRBs



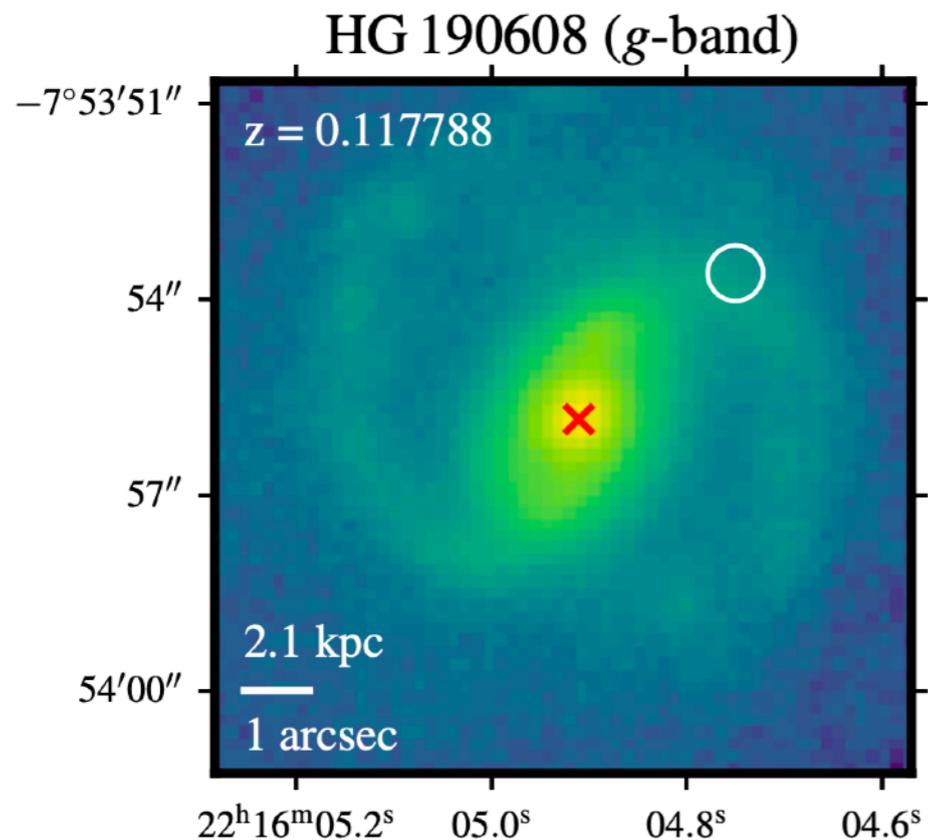
10 events with redshifts known

# Known FRBs



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

# Host ID

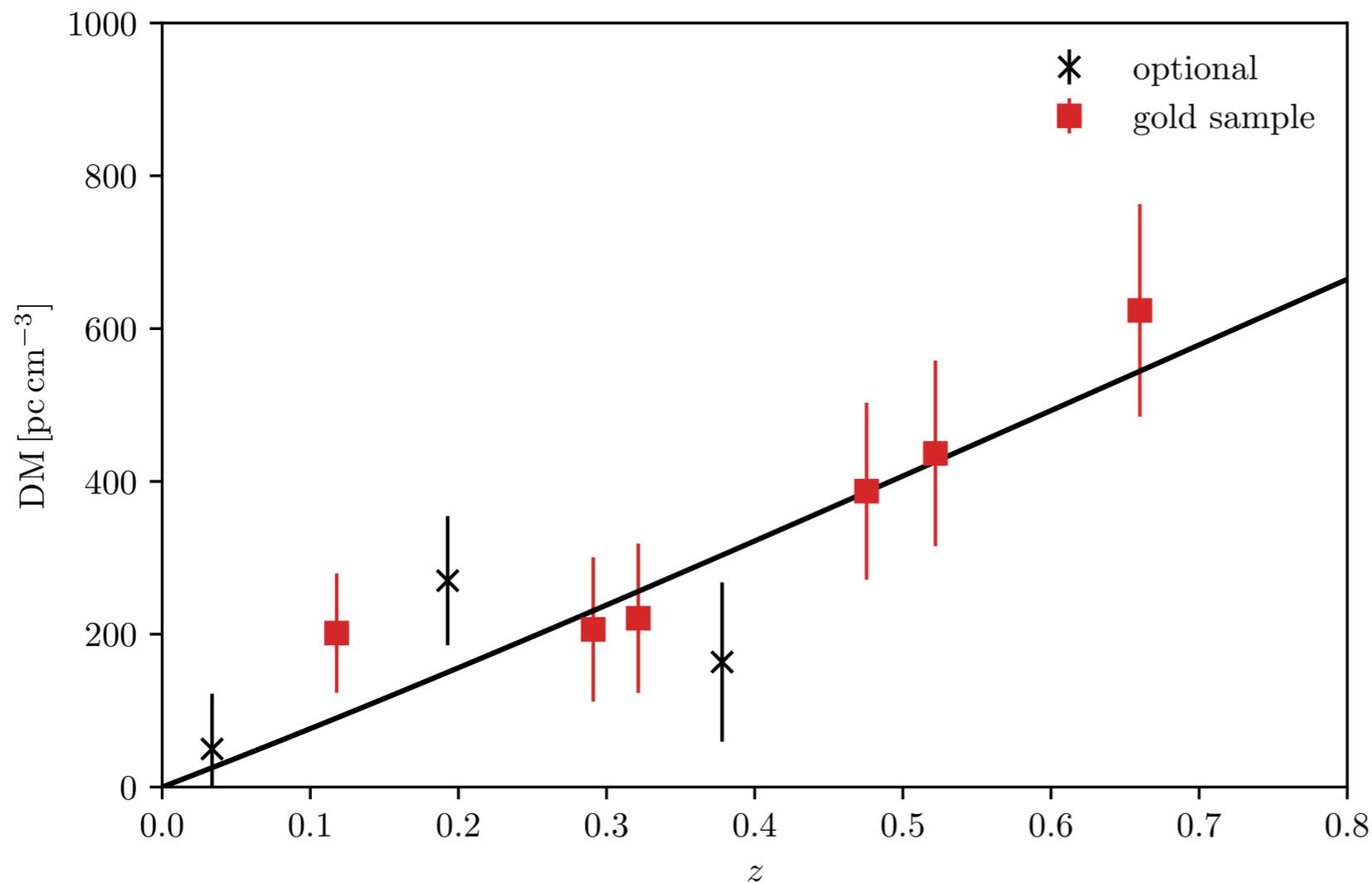


VLT + ASKAP (Macquart et al 2020)



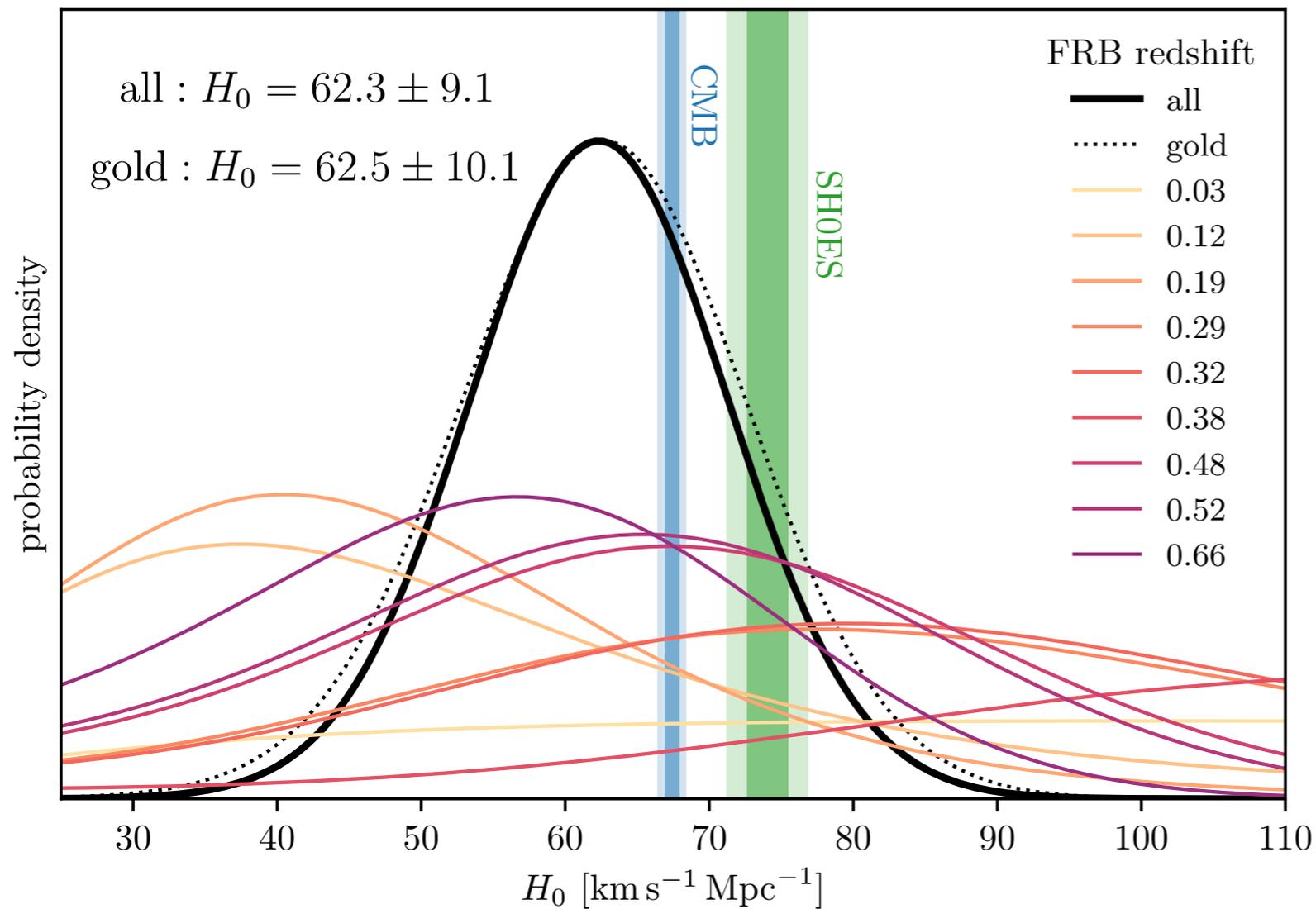
- Dedicated FRB searches from radio arrays
- Long baselines, excellent angular resolution
- Optical follow-up allows host ID and redshift

# 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

# Hubble constant

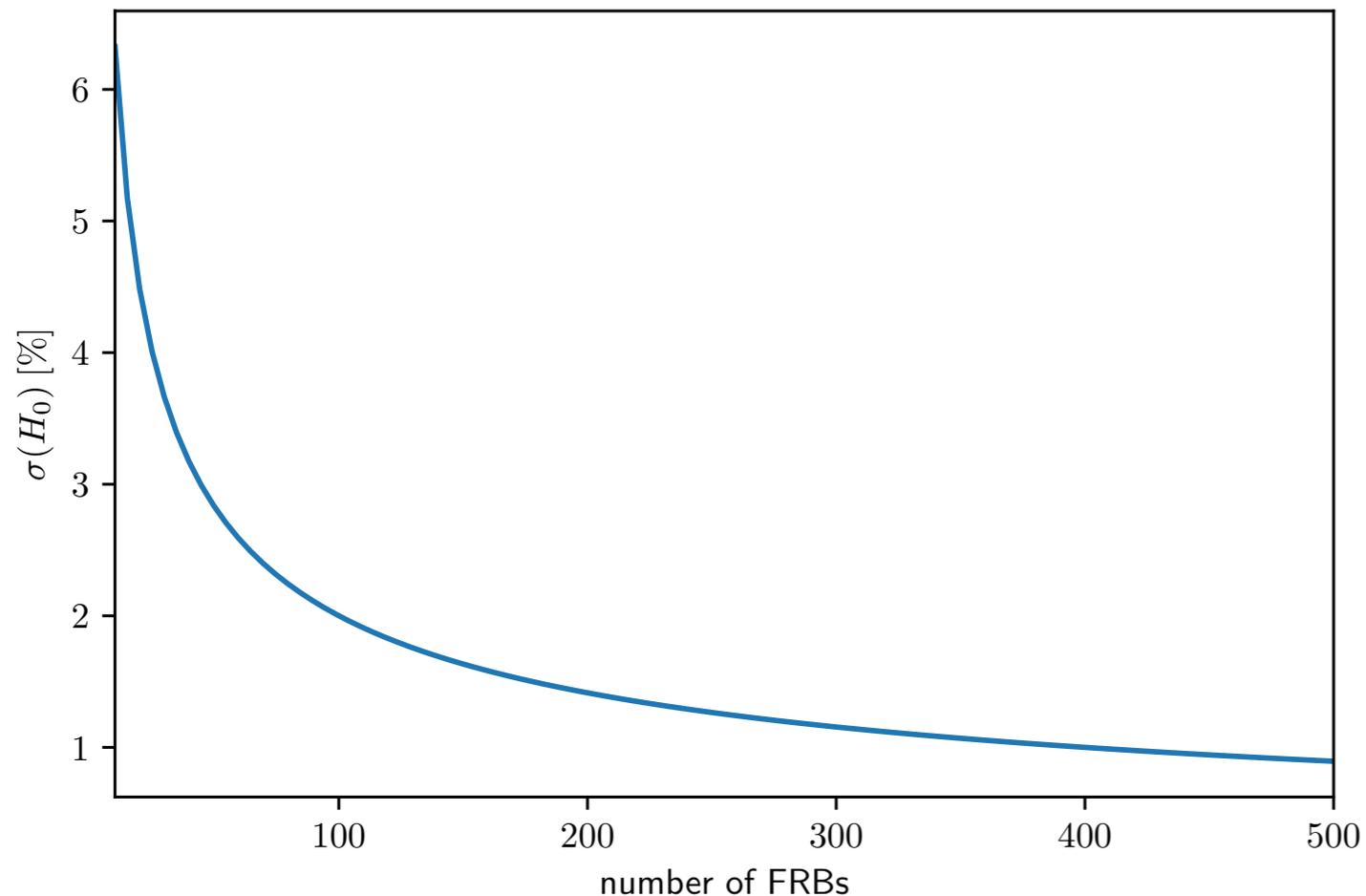


Events at large  $z$  most important

Uncertainty in host DM dominates error

# The Future

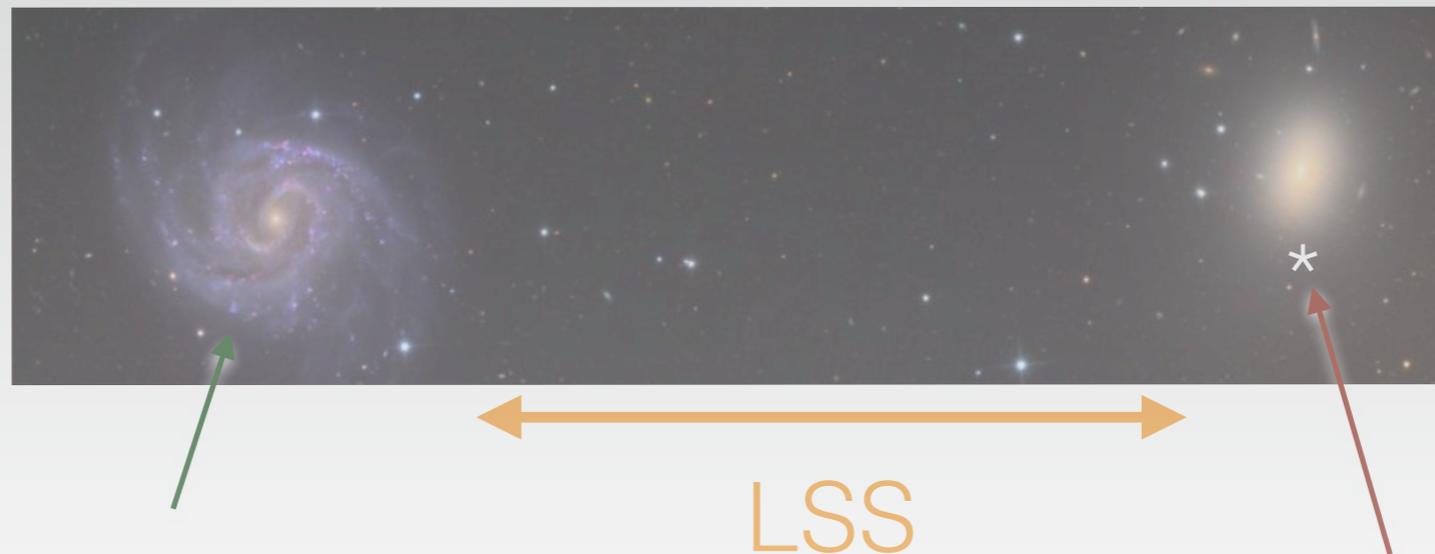
When can FRBs be competitive?



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

# Dispersion measure

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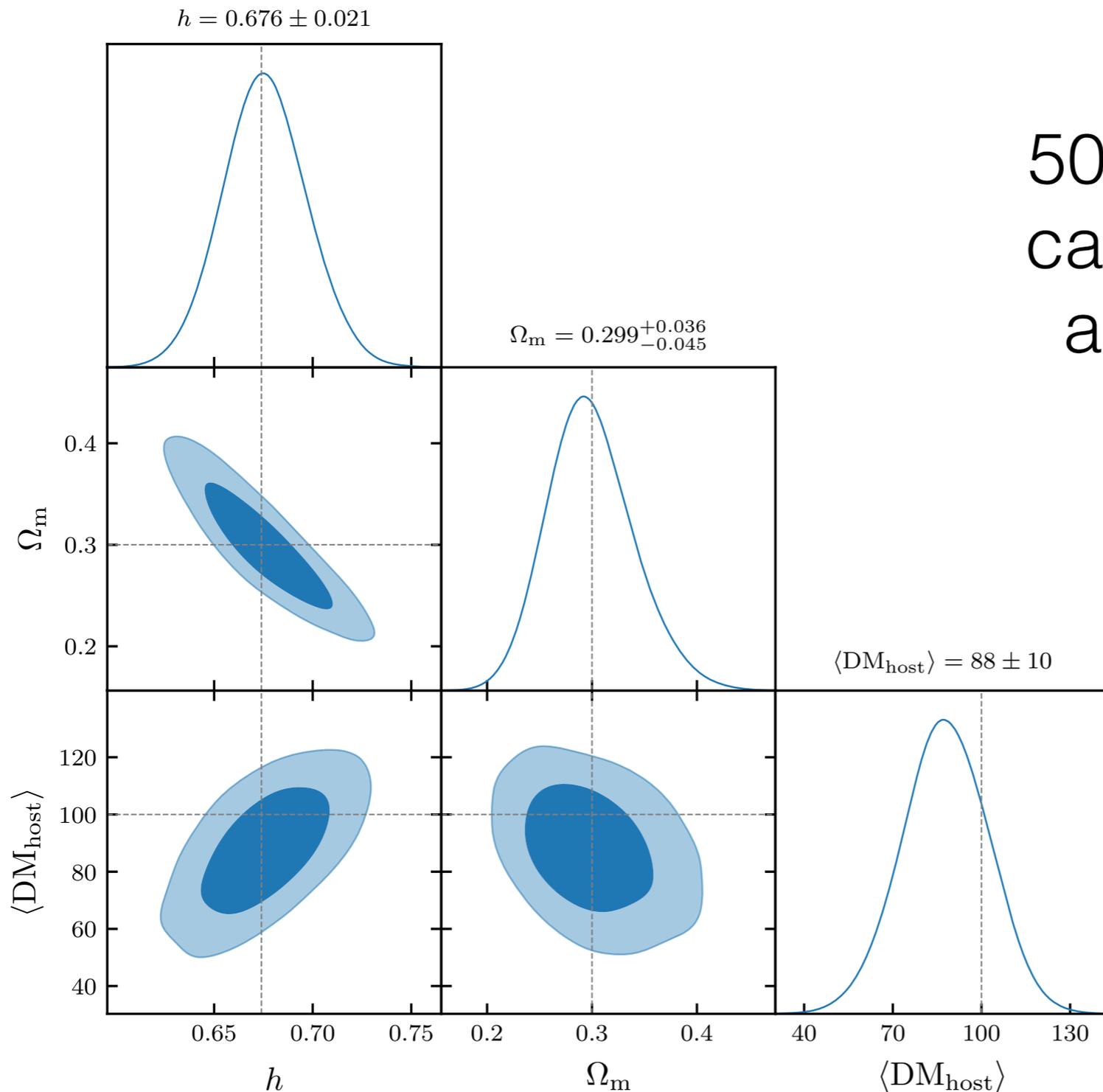
Redshift  
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$$\propto \int^z \frac{1+z'}{E(z')} dz' \quad \propto \frac{1}{1+z}$$

**Statistics can tell contributions apart**

# Forecast



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

Available soon!

# Summary

- 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)