

# PREFRBLE: Predictions of FRBs & Likelihood Estimates

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# Overview

Magnetic Fields in the Universe  
Fast Radio Bursts  
PreFRBLE  
Results

# Outline

Magnetic Fields in the Universe

# The Universe is magnetized!

Earth 0.5 G

Sun 1 G

Planets  $10^{-2} - 10^3$  G

Stars  $10 - 10^4$  G

LHC  $10^5$  G

Neutron Stars  $10^8 - 10^{12}$  G

Magnetars  $10^{12} - 10^{14}$  G

Galaxies  $\sim 5-15 \mu\text{G}$

Galaxy Clusters  $\sim \mu\text{G}$



# Extra-Galactic Magnetic Fields

LSS ( $\approx 20\%$  of volume)

galaxies  $\sim 5 - 15 \mu\text{G}$

clusters  $\sim \mu\text{G}$

filaments  $\lesssim 0.1 \mu\text{G}$

e. g. Beck+ 2016,  
Feretti+ 2012, Brown+ 2017

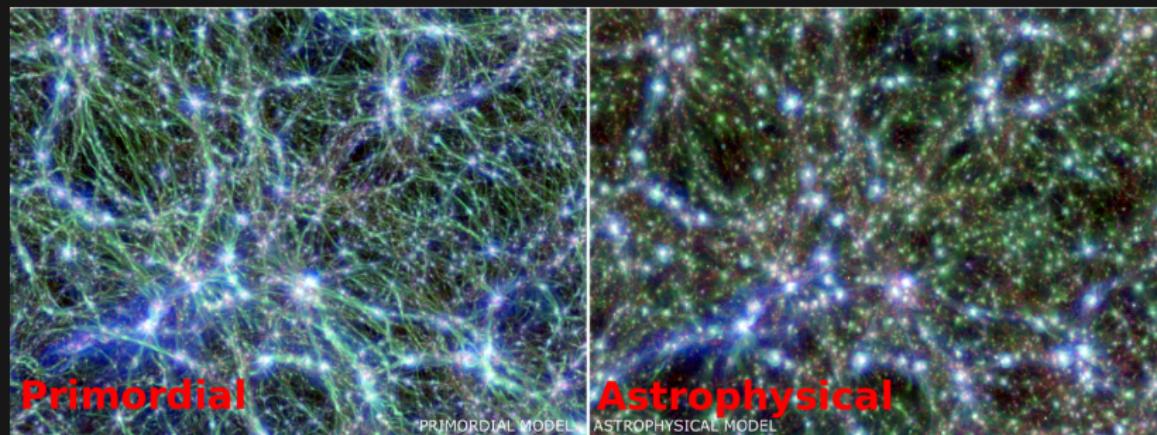
Voids ( $\approx 80\%$  of volume)

$B_0 \lesssim 1 \text{ nG}$  (CMB)

Planck 2015

$B_{\text{void}} \gtrsim 10^{-7} \text{ nG}$  (Blazars)

Neronov & Vovk 2010



PRIMORDIAL MODEL ASTROPHYSICAL MODEL

Vazza et al. 2018

# Motivation

## Intergalactic Magnetic Fields:

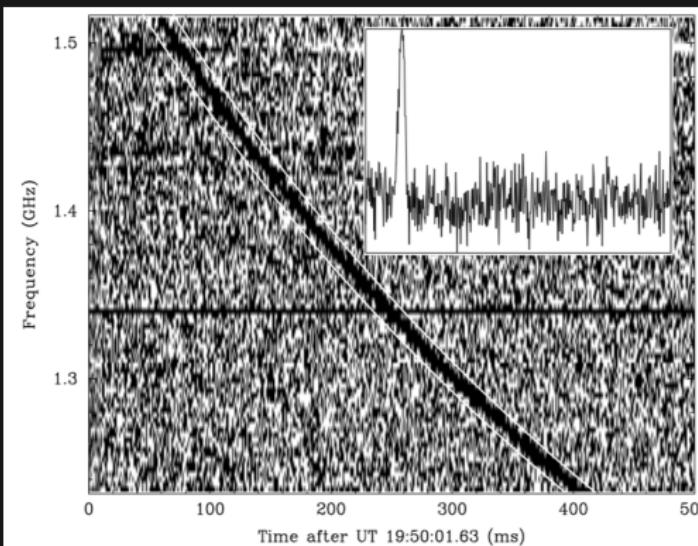
- ▶ how strong are they?
- ▶ what is their origin?

# Outline

## Fast Radio Bursts

# Fast Radio Bursts

- ▶ bright ms bursts
- ▶ short frequency band  
 $\sim 1\text{GHz}$
- ▶ Very short duration  
⇒ small source  $\sim 10\text{ km}$   
⇒ **brilliant probes for traversed medium**
- ▶ dispersion consistent with plasma propagation  
 $v_\gamma \propto \nu^2$
- ▶  $\text{DM}_{\text{FRBs}} > \text{DM}_{\text{MilkyWay}}$   
⇒ **extragalactic**
- ▶ **linear polarized**  
⇒ Faraday rotation  $\propto B_{\parallel}$



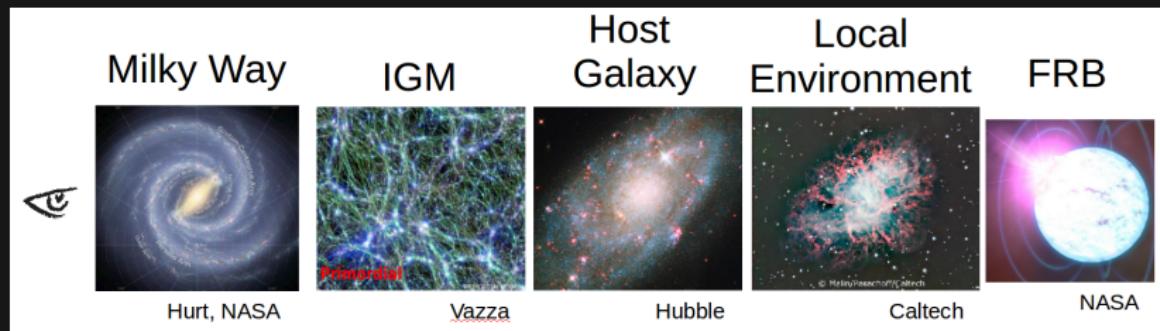
Lorimer'07

$$\begin{aligned} DM &= \int \frac{n_e}{1+z} dl \\ RM &= \int B_{\parallel} \frac{n_e}{1+z} dl \end{aligned}$$

# Key Question

Can Fast Radio Bursts tell us about Intergalactic Magnetic Fields?  
(see also Akahori+ 2016, Vazza+ 2018)

- ▶ Consider **all regions** along line-of-sight
- ▶ Consider different possible **models**
- ▶ Compare **prediction & observation**



# Outline

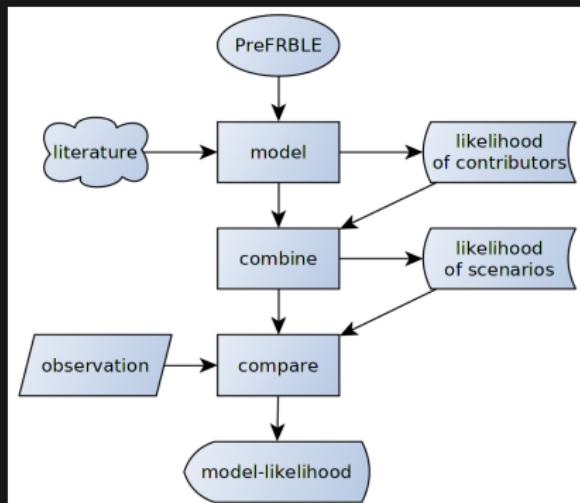
PreFRBLE

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Predict Fast Radio Bursts  
→model-Likelihood Estimates

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Predict Fast Radio Bursts →model-Likelihood Estimates

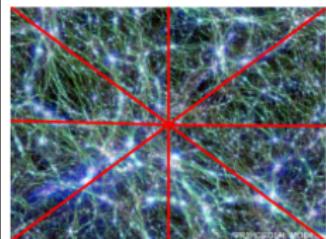


- ▶ models in literature  
→ contribution of regions
- ▶ combine regions  
→ realistic scenarios
- ▶ compare to observations  
→ model likelihood

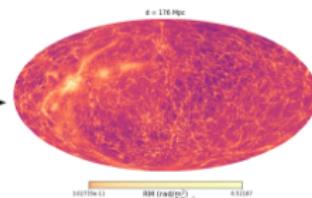
- ▶ **measure Intergalactic Magnetic Fields**
- ▶ find sources of FRBS
- ▶ find host galaxies of FRBs
- ▶ identify FRB populations

# Obtain Likelihood: Monte Carlo method

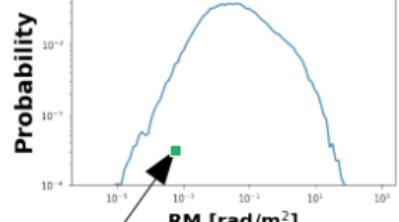
## Simulation



LoS-Path  
Integral



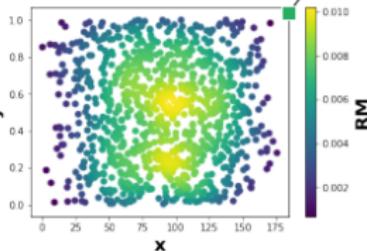
P.D.F



P.D.F

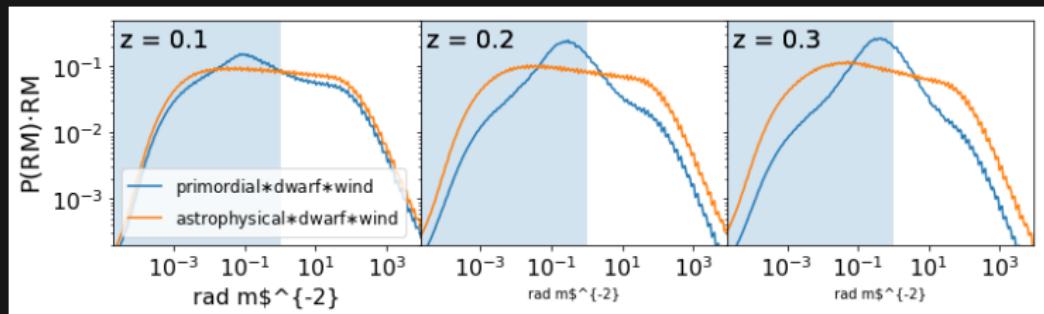
## Analytic Prediction

$RM(x,y)$  Sample



# Combined Likelihood

$$P_{\text{extragalactic}} = P_{\text{IGM}} * P_{\text{Host}} * P_{\text{local}}$$



different distribution of observable RM ( $\gtrsim 1 \text{ rad m}^{-2}$  ionosphere),  
though average  $\langle \text{RM} \rangle$  not distinguishable

⇒ FRBs tell about EGMFs, indeed!

(Walker+'18 and Pol+'19 use similar methods to obtain redshift(DM).  
This is also a byproduct of PREFRBLE. )

# Outline

## Results

How many FRBs do we need?

# Bayesian Inference

model Likelihood ← prediction( measurement ) & prior

$$L(M|v) \propto P(v|M)\pi(M)$$

**Bayes-factor** ( Model<sub>1</sub>  $\xleftarrow{\text{corroboration}}$  Model<sub>2</sub> )

$$b(M_1, M_2|v) = \frac{P(v|M_1)}{P(v|M_2)}$$

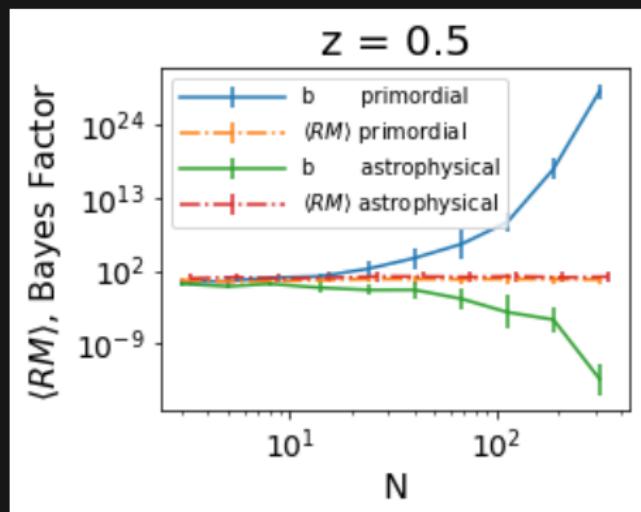
Combine several measurements

$$P(\vec{v}|M) = \prod_{v \in \vec{v}} P(v|M)$$

# fake test-group

- ▶ sample DM & RM for both IGMF models at  $\mathbf{z = 0.5}$
- ▶ compare  $\langle RM \rangle$  and  $b = \frac{P(\vec{v}|\text{primordial})}{P(\vec{v}|\text{astrophysical})}$
- ▶ **⇒ 100 FRBs suffice to identify origin of IGMFs**
- ▶ **if** produced by magnetar in starburst dwarf galaxy

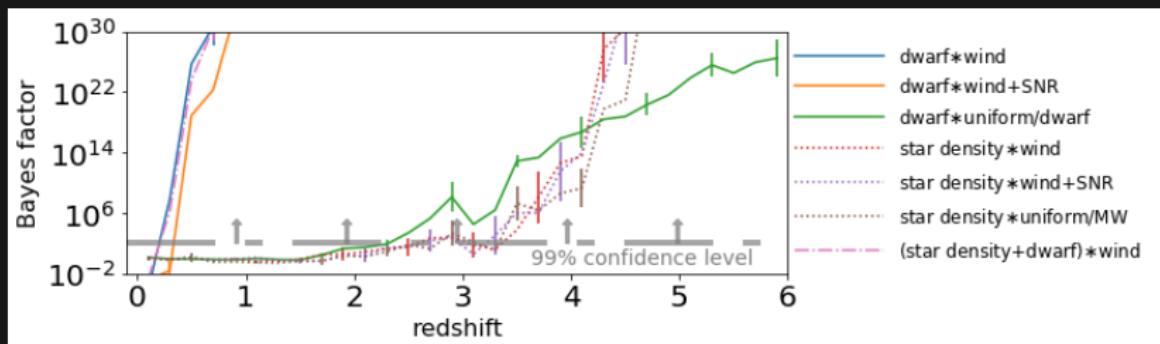
Hackstein+ subm.



How far do we need to look?

# Redshift dependence

Hackstein+ subm.



- ▶ repeat test with 100 FRBs for other redshifts and scenarios
- ▶ **other source environments overshadow signal of IGMF**
  - ⇒ require careful consideration of range of possible models
  - ⇒ benefit from host and source identification
- ▶ (subset of) **FRBs likely tell us about the IGMF**
- ▶ accessible to state-of-the-art telescopes (CHIME, FAST, ...)

# Conclusions

- ▶ Fast Radio Bursts: brilliant new probe to answer long standing astrophysical / cosmological questions
- ▶ **PreFRBLE**: way to **connect observations to theory**
- ▶ 100 RM of FRBs beyond  $z > 0.5$  reveal the origin of intergalactic magnetic fields
- ▶  $\sim 50$  FRBs with RM observed by CHIME (*Mckinven+, in prep*), public this summer
- ▶ find **origin of magnetic fields by end of 2019?**