PREFRBLE: way to interpret FRBs

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FRB2020 online conference

slides at github.com/shackste/publications/talks

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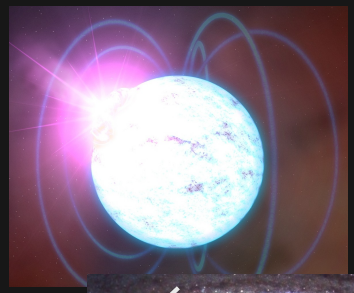
Quest

interpretation of FRB measures to learn about

- population(s)
- progenitors
- host galaxies
- **cosmological questions**:

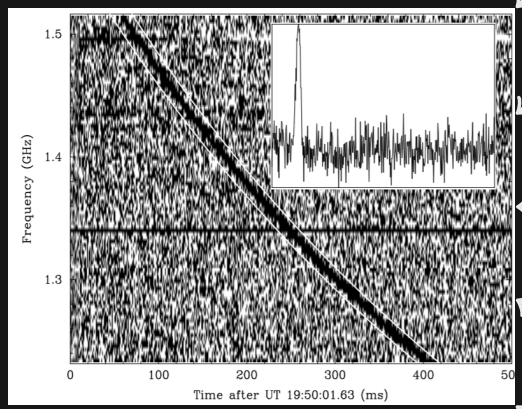
locate missing baryons (Macquart+20, Li+20)
measure intergalactic magnetic field (Akahori+16, Vazza+18)

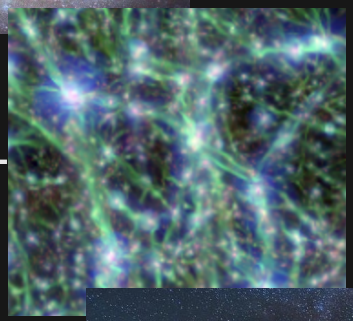
Problem: lots of regions



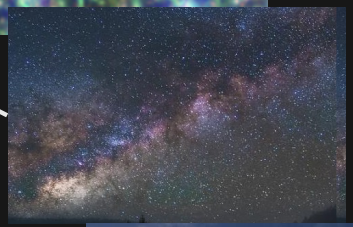
source

host





IGM



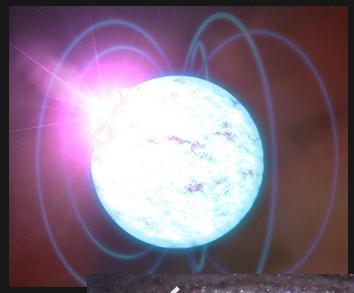
MW

tele

$$\mathrm{DM} = \int n_e \mathrm{d}l$$

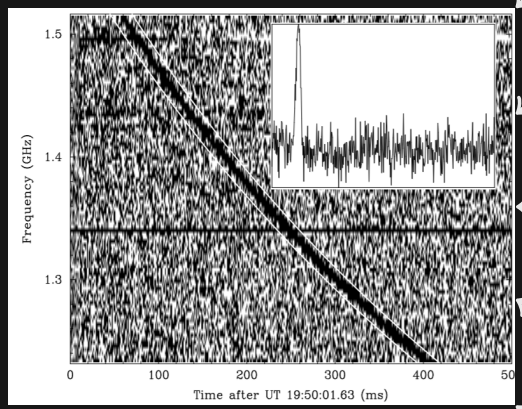
$$\mathrm{RM} \sim \int n_e B_{||} \mathrm{d}l$$

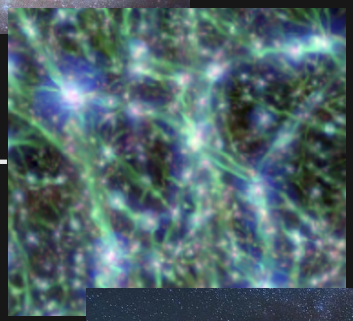
Problem: lots of regions, lots of candidates & models



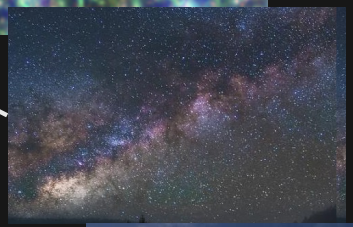
source
- magnetar
- merger

host
- stellar mass
- star formation rate





IGM
- primordial
- astrophysical



MW
- NE2001
- YMW16

$$\mathrm{DM} = \int n_e \mathrm{d}l$$

$$\mathrm{RM} \sim \int n_e B_{||} \mathrm{d}l$$

tele
- CHIME
- ASKAP

Solution

Approximate Bayesian Computation:

- reference table of models / parameters
- marginal likelihood *of A to occur in scenario B*
- compare & find trends

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Compiled in easy-to-use open source python software package

PrEFRBLE

"Probability Estimates for FRBs →model Likelihood Estimates"

github.com/shackste/PreFRBLE

benchmark scenario

Source magnetar (Piro&Gaensler'18, Hackstein+19)

IGM constrained MHD simulation (Hackstein+18,'19)

Host galaxy ensemble, $> 90\%$ of galaxies
(Lacey+16,Rodrigues+18)

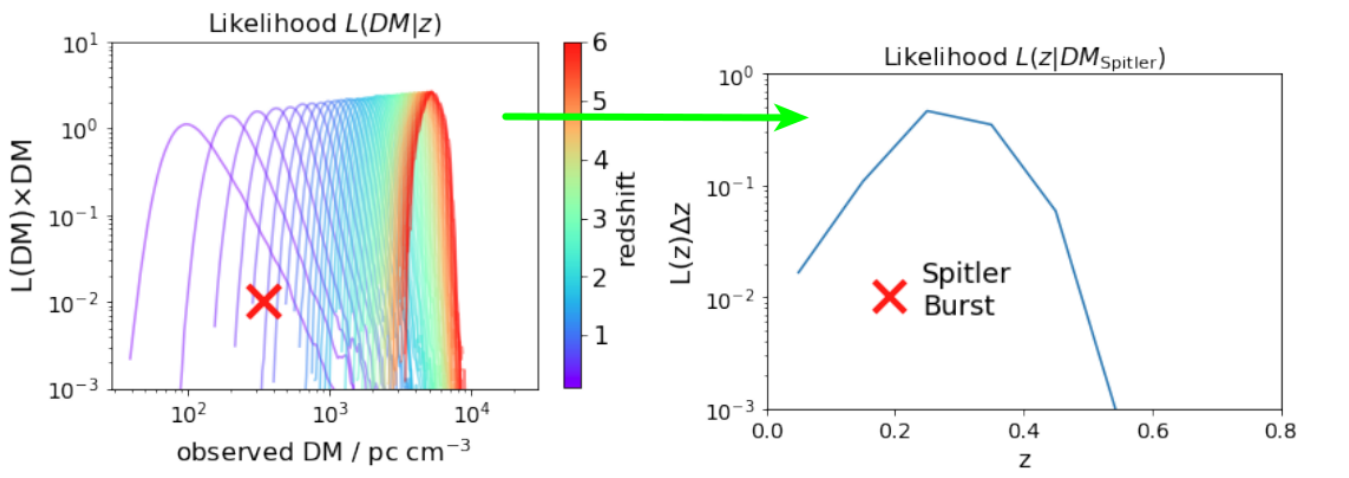
Intervening galaxy ensemble, intersection probability

Redshift distribution $\pi(z)$ (FRBPOPPY, Gardenier+19)

$\rightarrow$ **most realistic estimate** on distribution of
DM, RM and τ
observed by
Parkes, ASKAP, CHIME, ...

Outline

Redshift inference

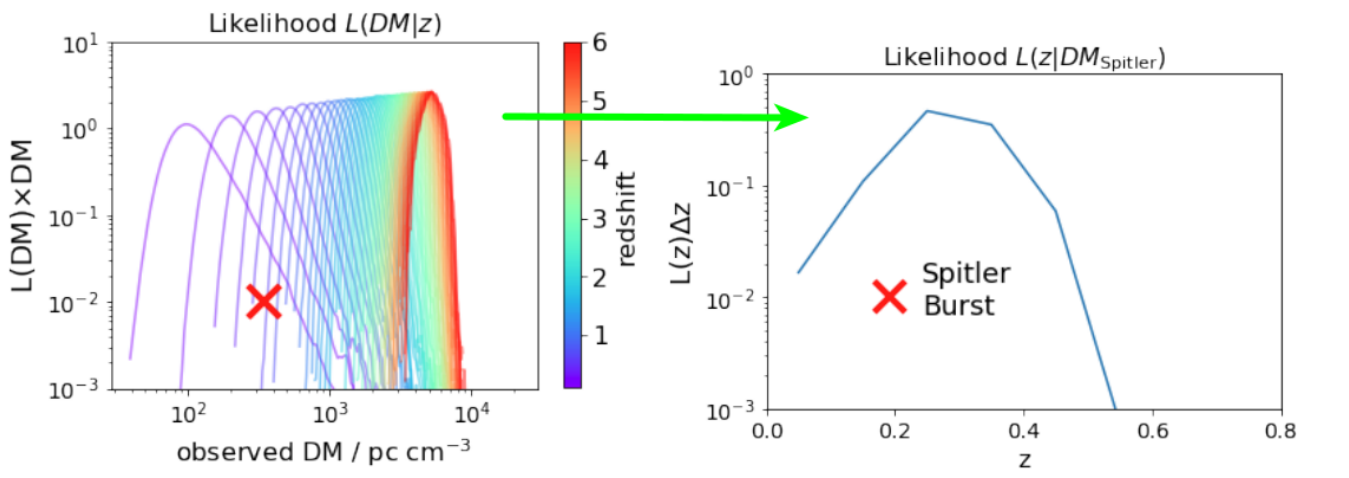


predict DM for host at redshift z: $L(\mathrm{DM}|z)$

observe DM $\rightarrow$likelihood of z to provide DM

$\rightarrow$redshift estimate?

Redshift inference



predict DM for host at redshift z: $L(\mathrm{DM}|z)$

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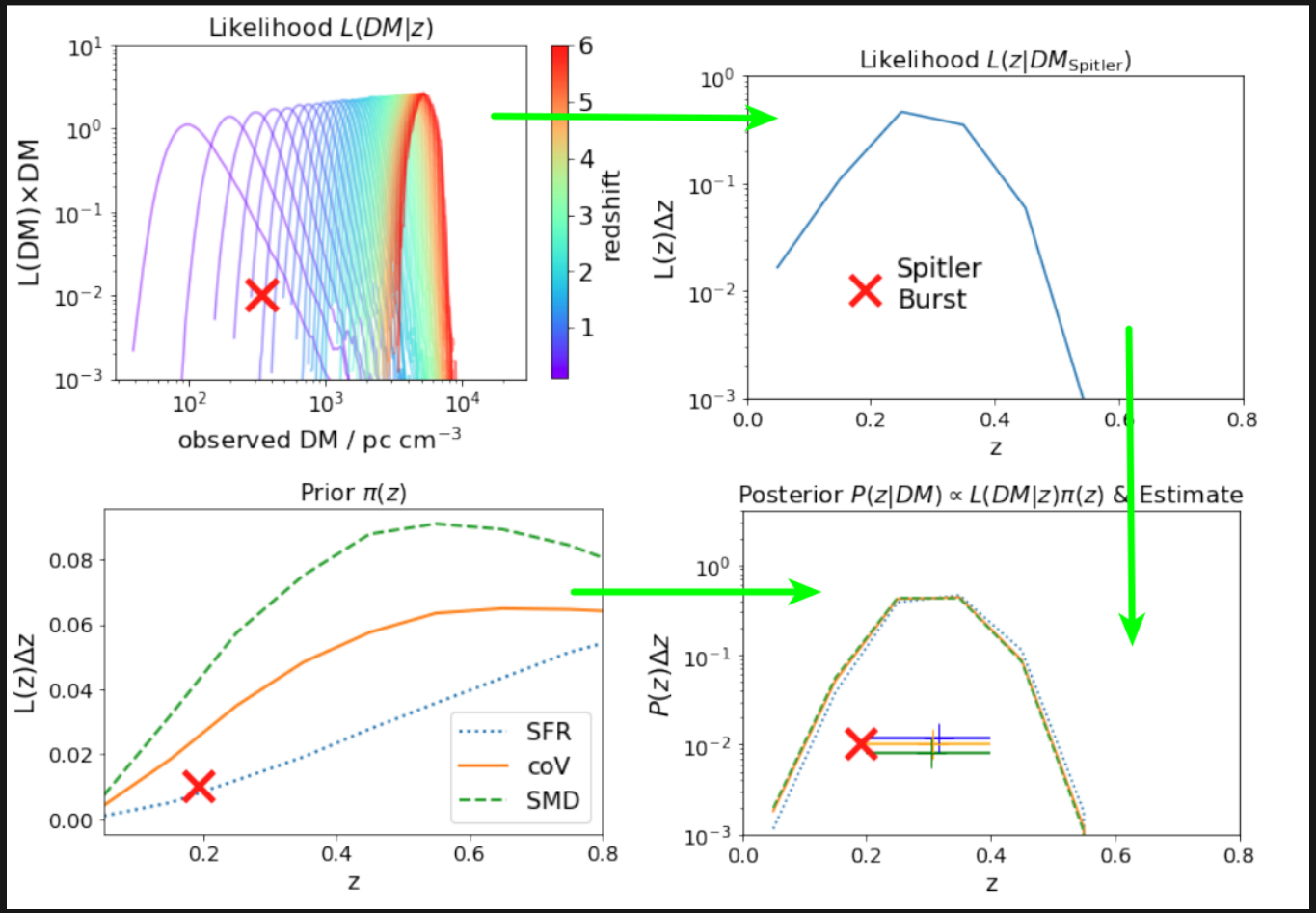
$\rightarrow$redshift estimate?

What about history of sources?
selection effects?
increase of probed volume with z?

Redshift inference



Bayes theorem: $P(z|\mathrm{DM}) \propto L(\mathrm{DM}|z)\ \pi(z)$

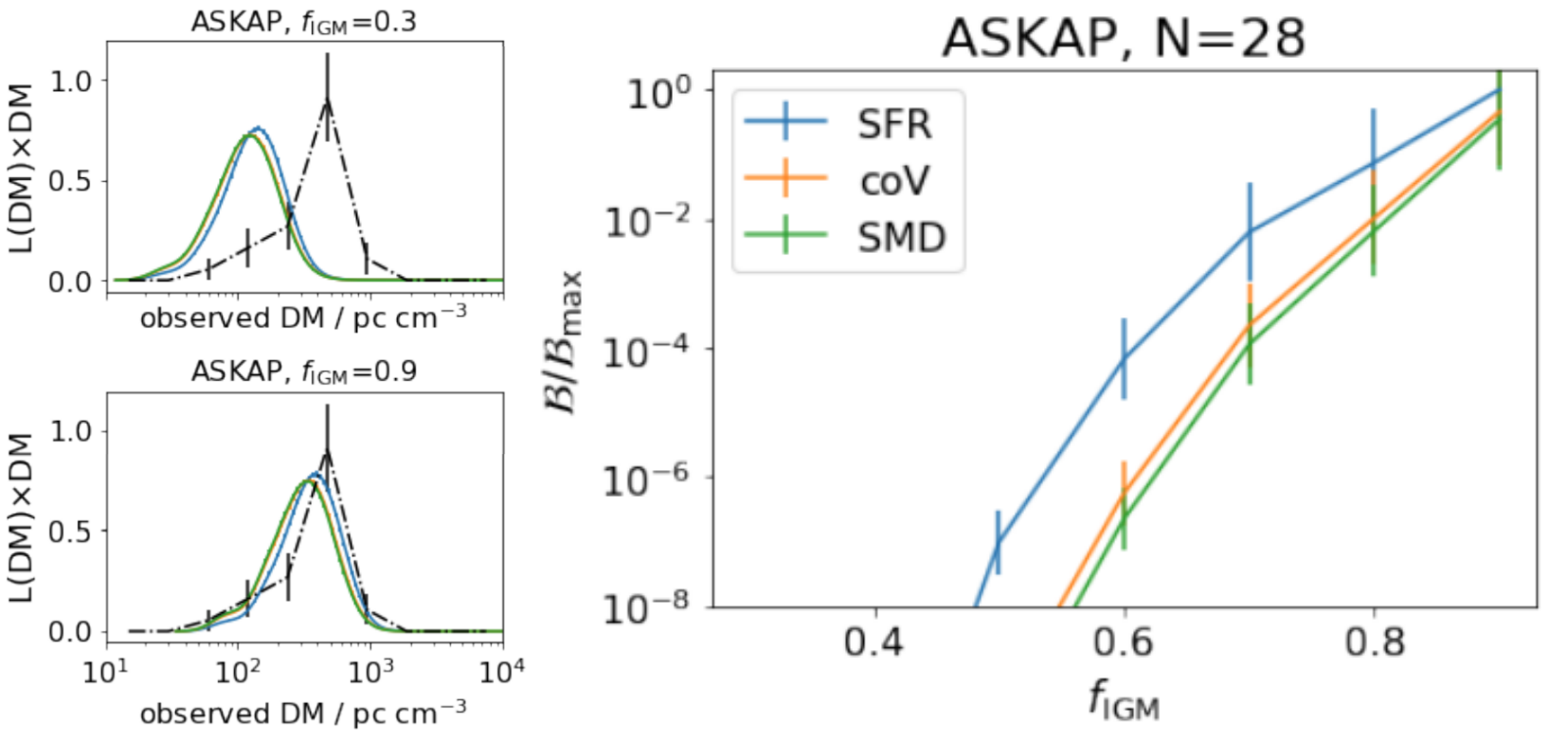
$\Rightarrow z$ lower limits for $>$ 30 FRBs (Hackstein+20a, in subm.)

(see also Walker+18)

Missing Baryons

baryons in ionized IGM? constrain $f_{\rm IGM} = \Omega_{\rm IGM}/\Omega_b$

$L(DM) = \int L(DM|z)\ \pi(z)\ \mathrm{d}z,$ $\qquad$ $\mathrm{DM}(z) \propto f_{\rm IGM} \int \rho\ \mathrm{d}l$



expected $\approx$ observed L(DM) ? $\rightarrow$Bayes factor $\mathcal{B}$

ASKAP prefers **high** $f_{\rm IGM} > 0.8$ (missing baryons in ionized IGM)

Missing Baryons

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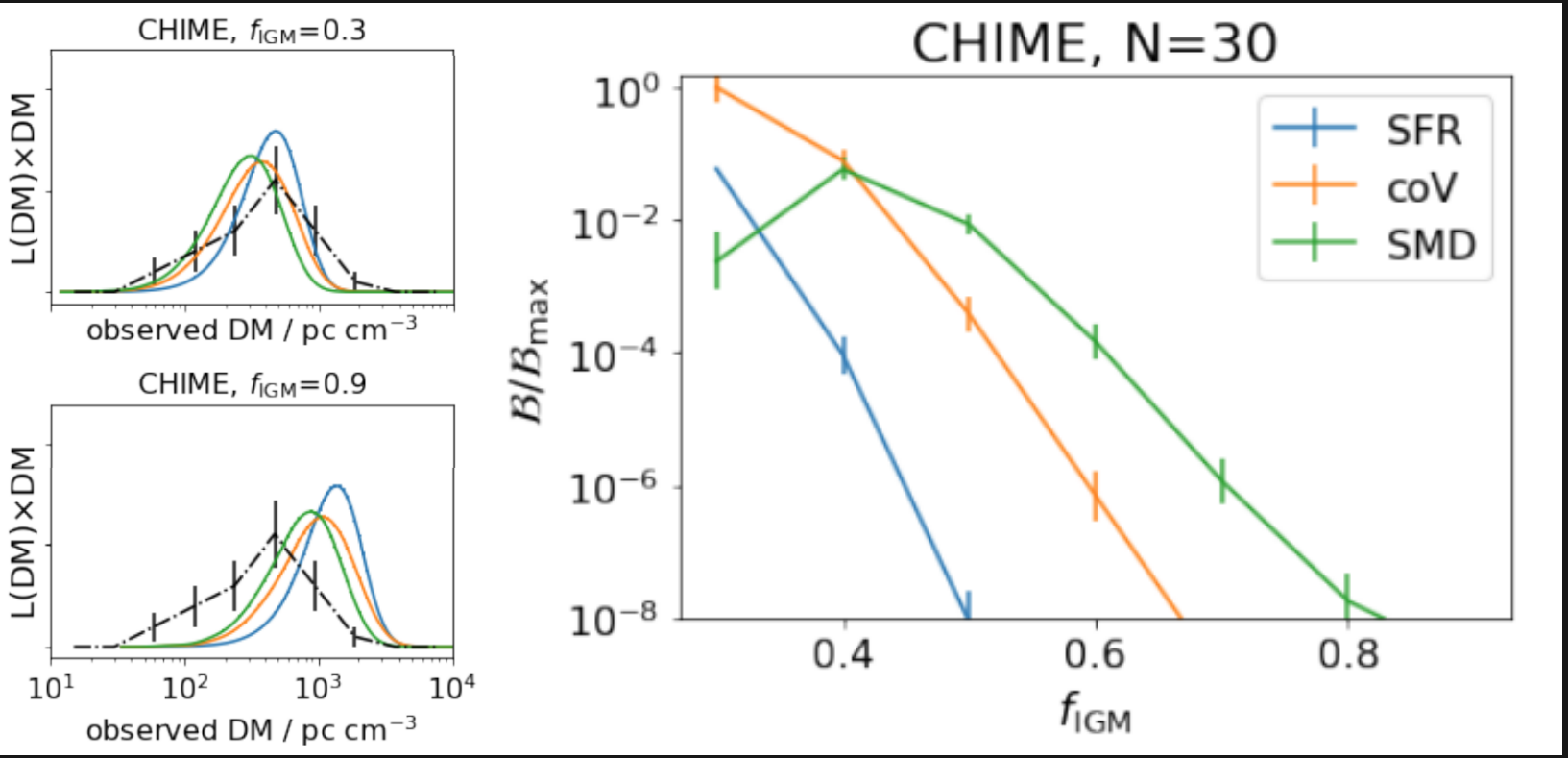
$L(DM) = \int L(DM|z)\ \pi(z)\ \mathrm{d}z,$ $\qquad$ $\mathrm{DM}(z) \propto f_{\rm IGM} \int \rho\ \mathrm{d}l$



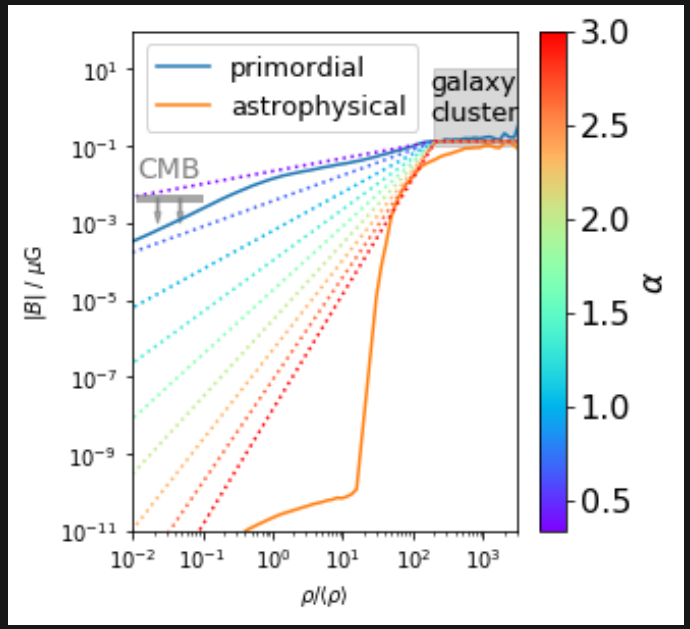
expected $\approx$ observed L(DM) ? $\rightarrow$Bayes factor $\mathcal{B}$

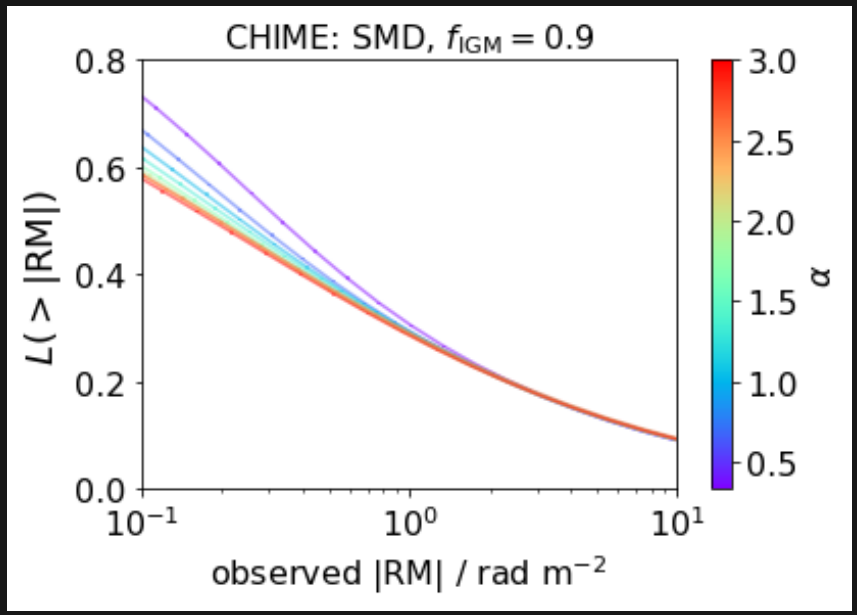
CHIME prefers **low** $f_{\rm IGM} < 0.6$ (missing baryons **not** in IGM)

Do ASKAP and CHIME observe different populations?

Intergalactic Magnetic Field

model IGMF ($B \propto \rho^{\alpha}$)
$\rightarrow$measurable signal in RM





Hackstein+ 20, in subm.
preview:
github.com/shackste/PreFRBLE
in notebooks (no download req.)

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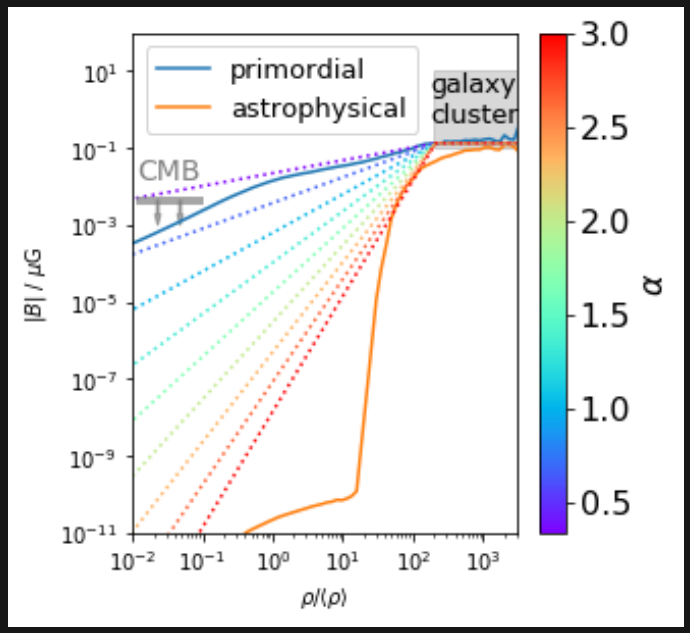

$\rightarrow$**probe IGMF whole range**
Hackstein+ 20, in subm.
preview:
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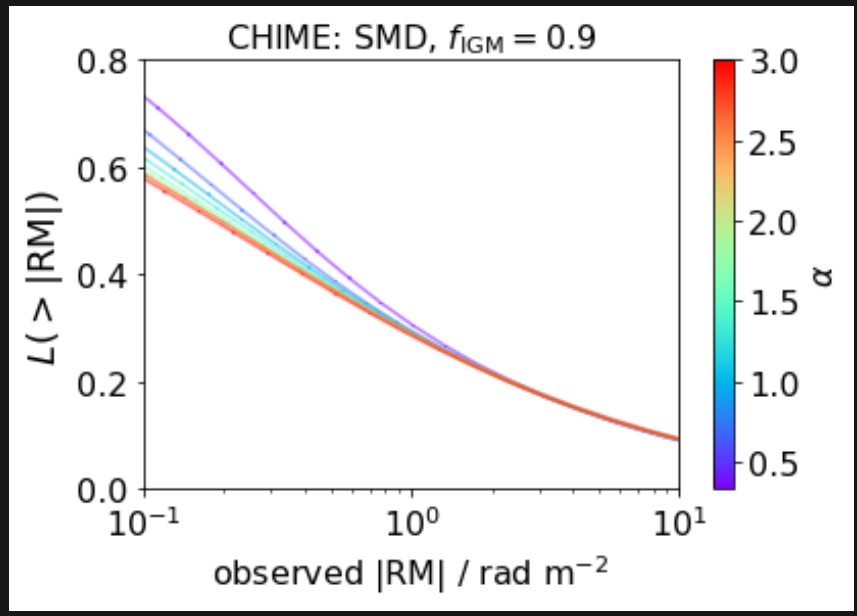
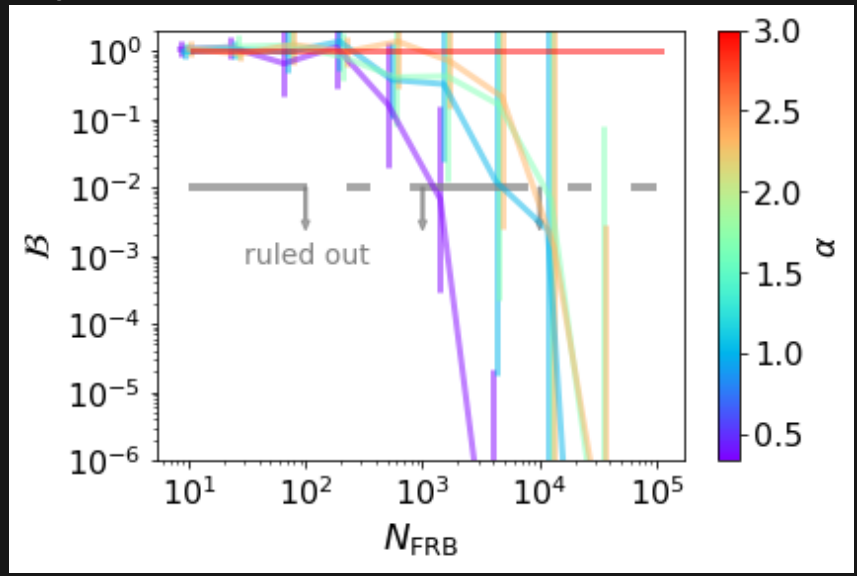


$$\int L(DM|z)\ L(RM|z)\ \pi(z)\ \mathrm{d}z$$



Conclusion

- PREFRBLE:
  interpret FRBs / test models
  for observers & theorists
  github.com/shackste/PreFRBLE

- can answer many pressing questions
  (FRB distribution, missing
  baryons, IGMF strength, . . .)

- more models & measures
  →improved results