

Probing primordial magnetic fields with small-scale structures of dark matter



M. Olalla Olea Romacho (KCL)

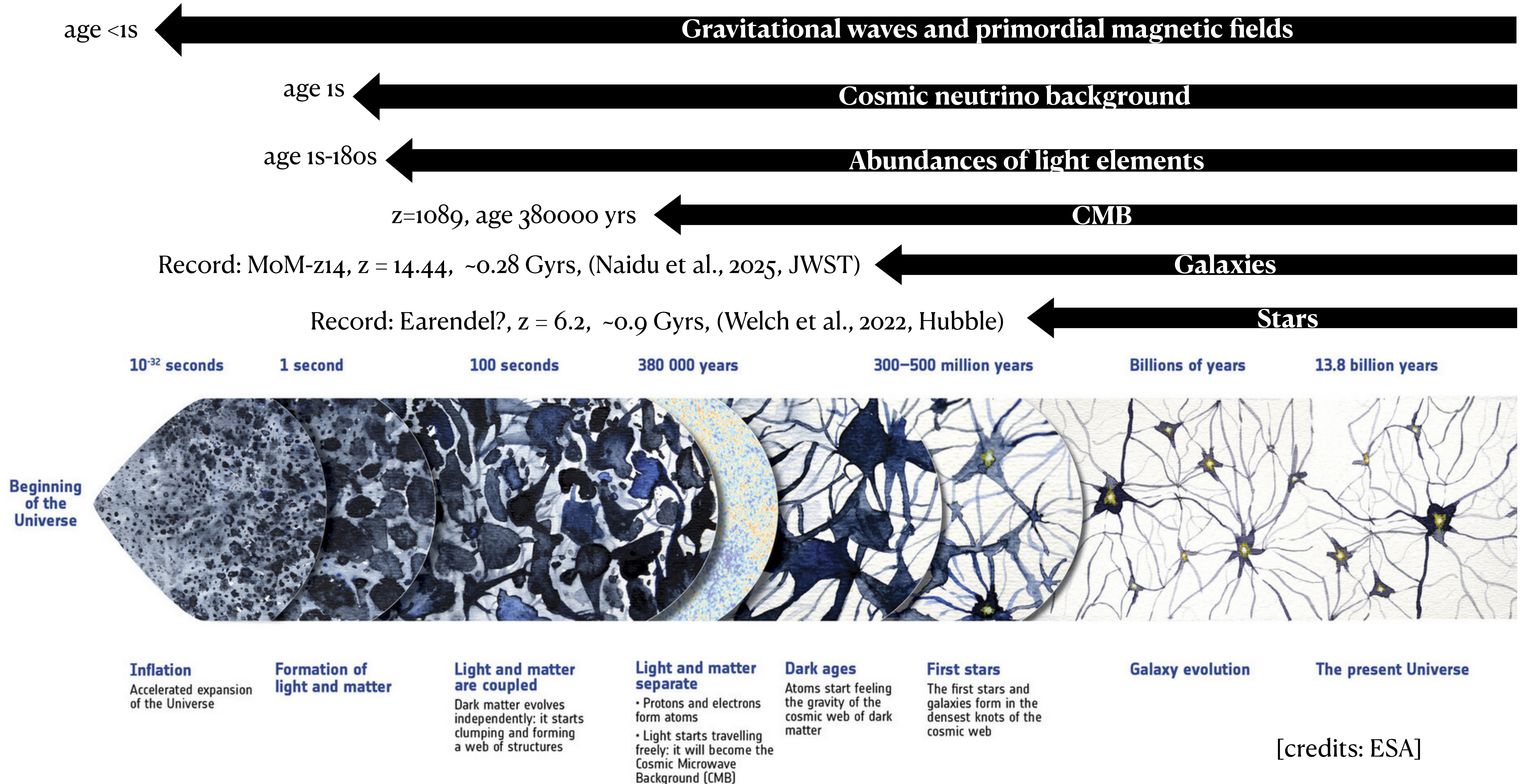
Mildred Thompson, *Magnetic Fields*

News From the Dark 11, 30th September 26, IPhT-Saclay

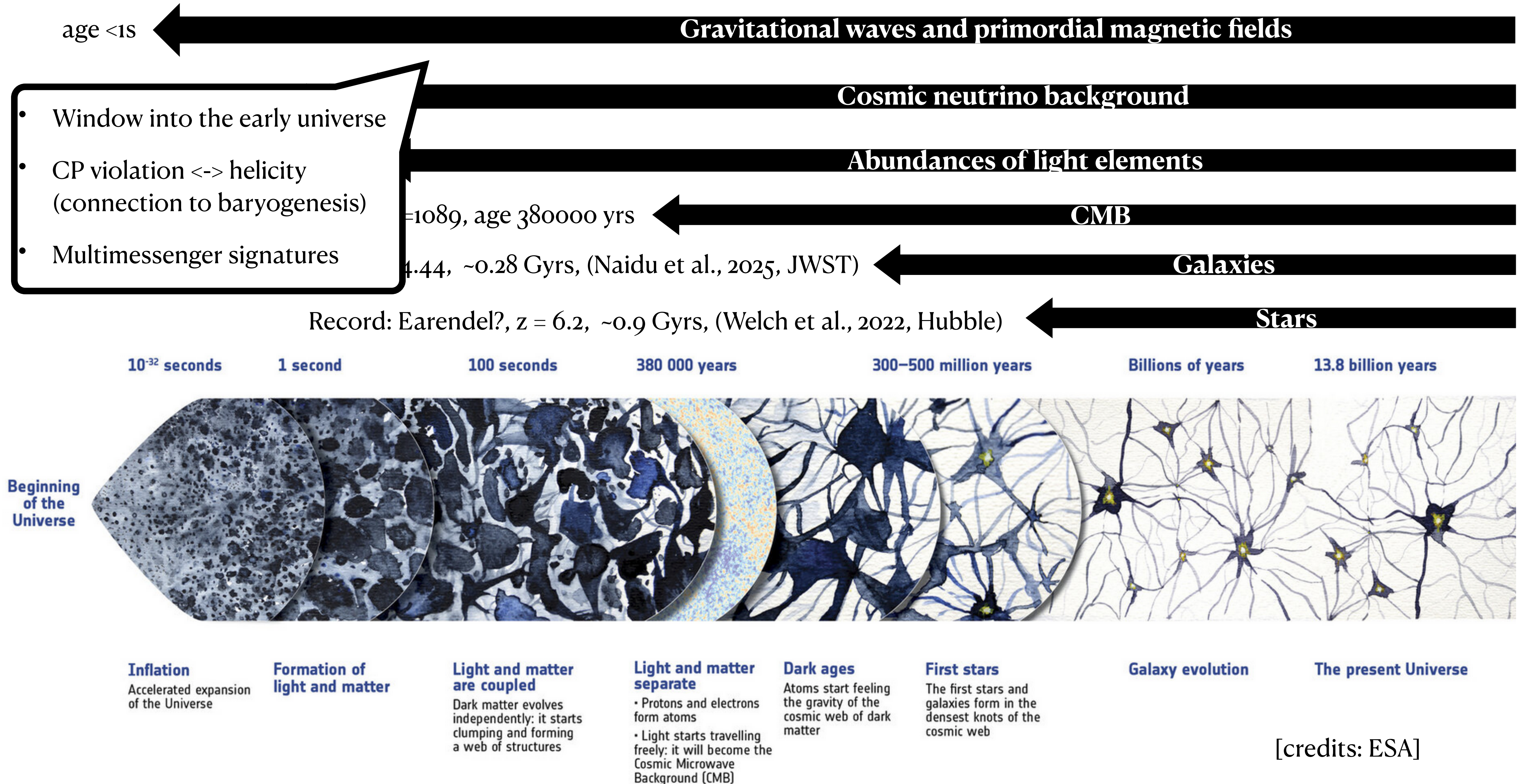
based on 2507.18692 ★, 2604.24835 ☆, 2607.18185

with Malcolm Fairbairn ★, Pranjal Ralegankar ★, Ville Vaskonen ☆ and Juan Urrutia ☆

Cosmology is a search for relics

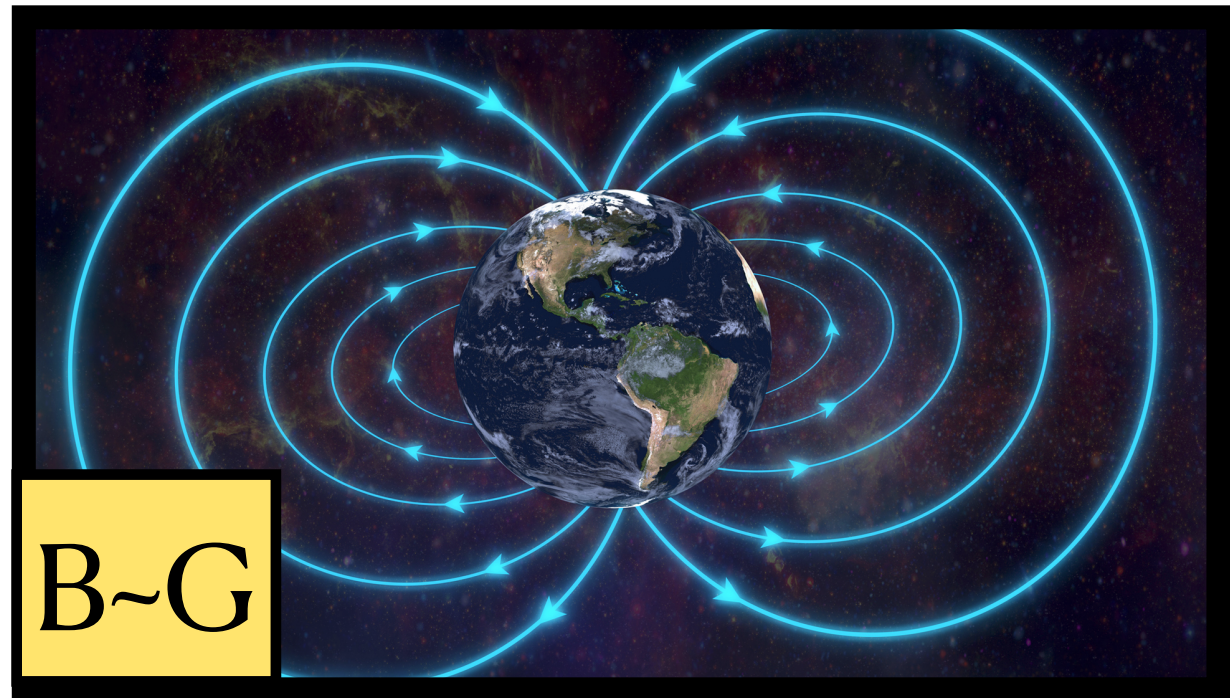


Cosmology is a search for relics



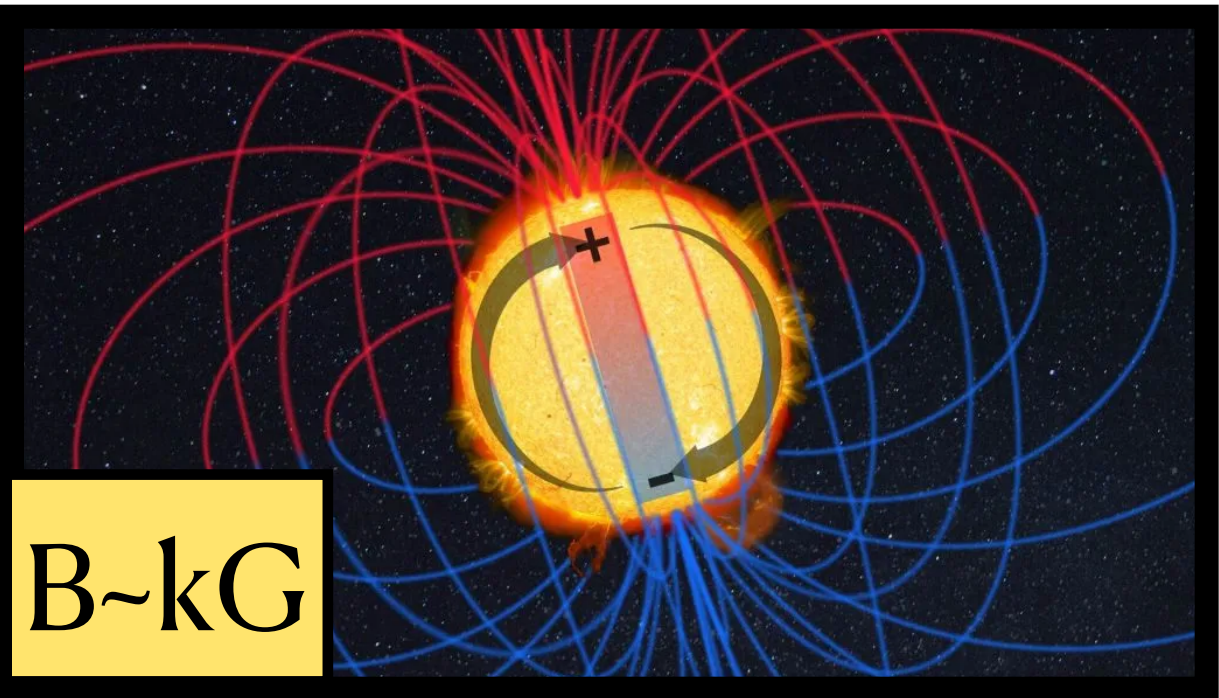
Observed large scale magnetisation

Planets



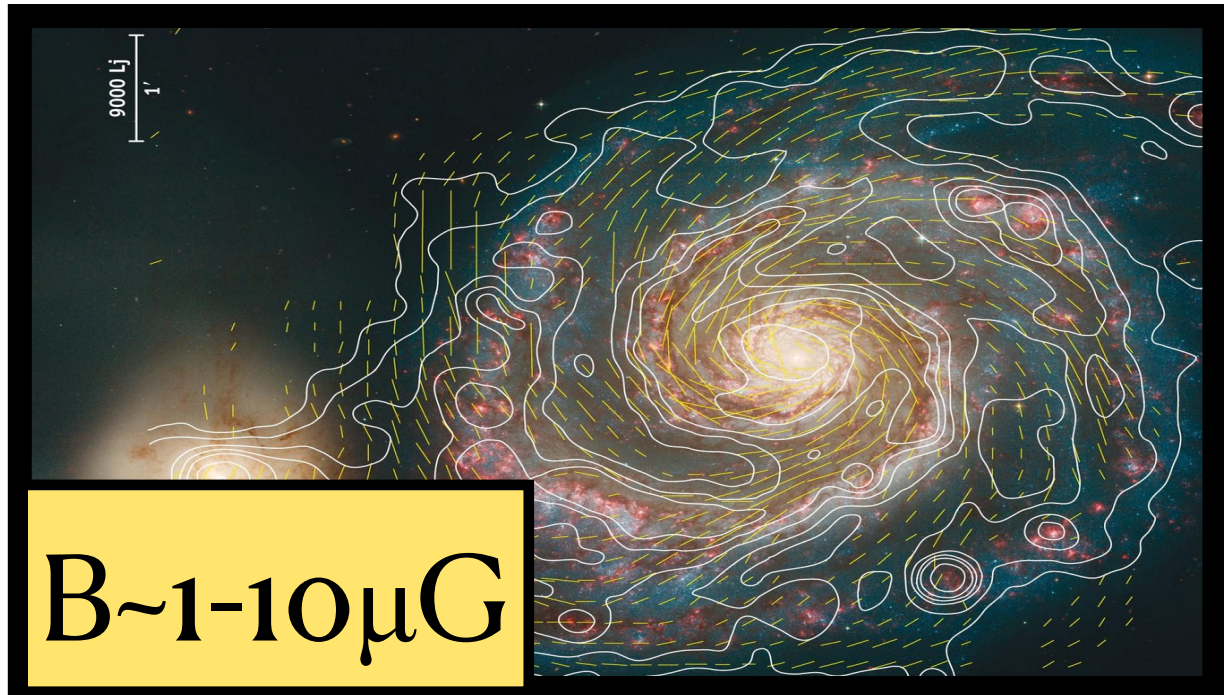
Planetary dynamo

Stars



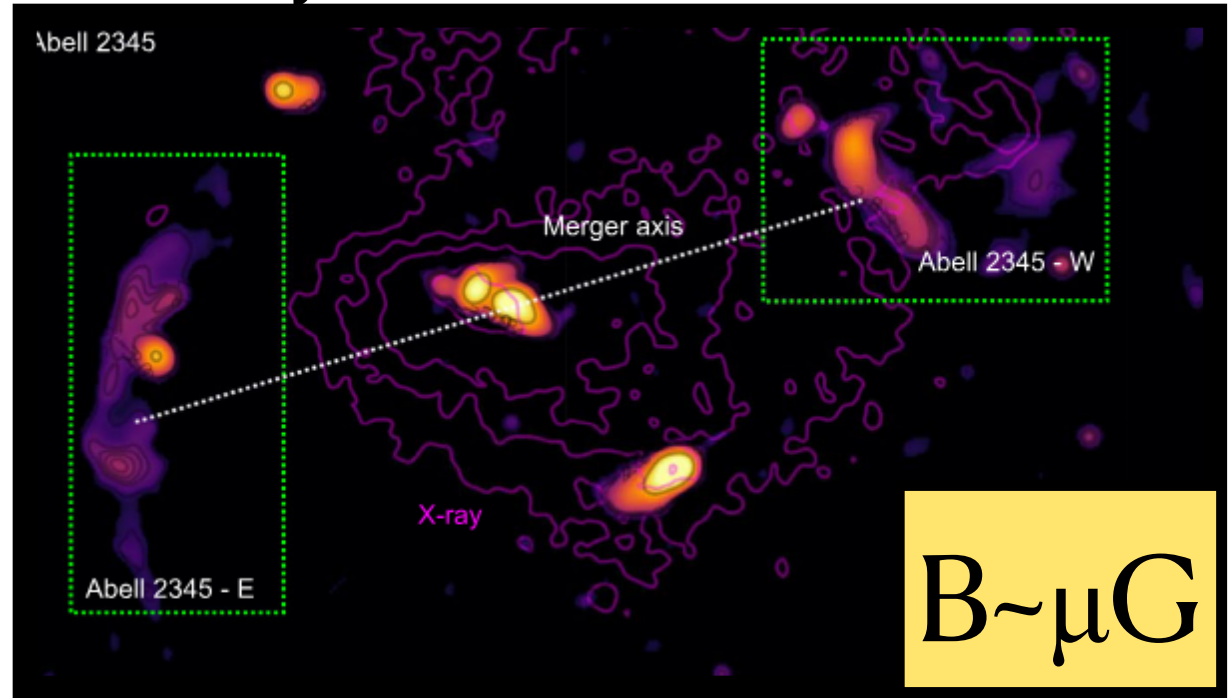
Stellar dynamo

Galaxies



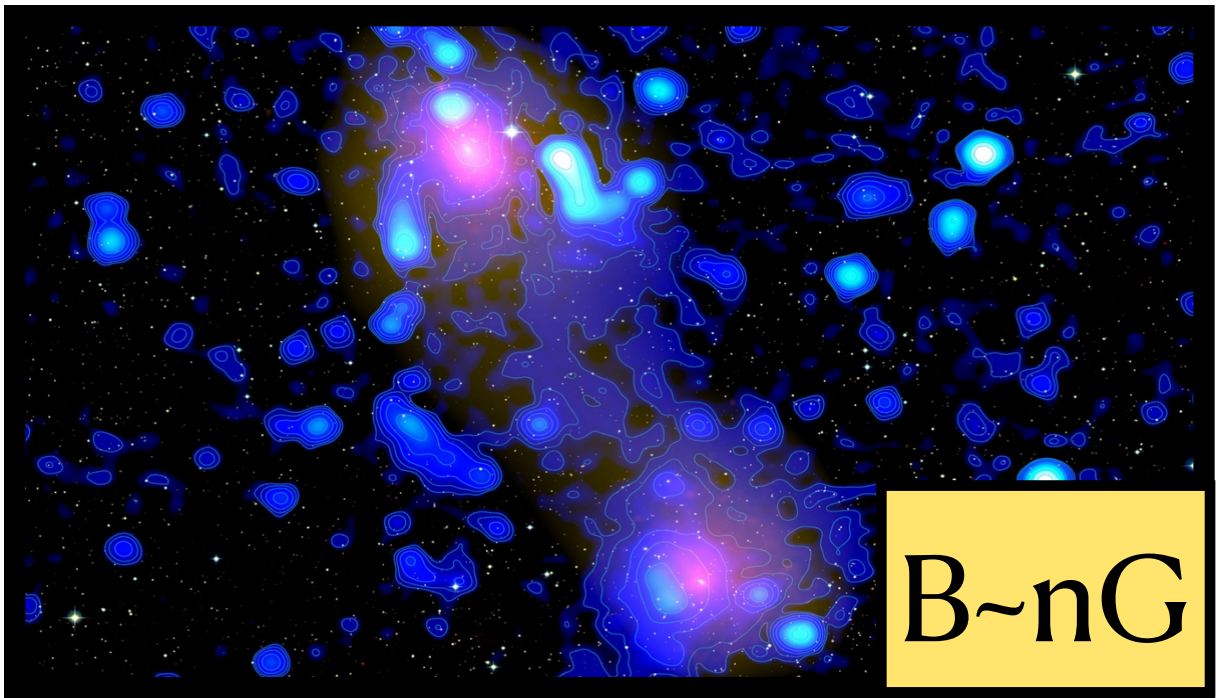
Galactic dynamo + seed (?)

Galaxy clusters



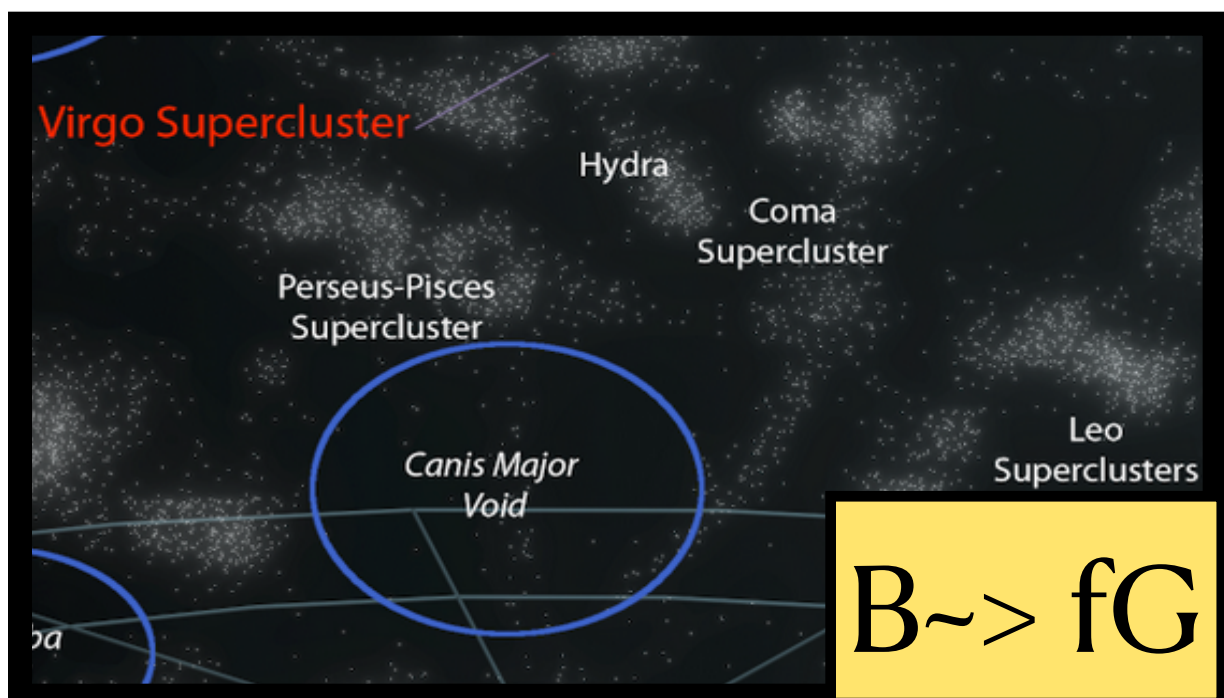
LSS formation+seed (?)

Filaments



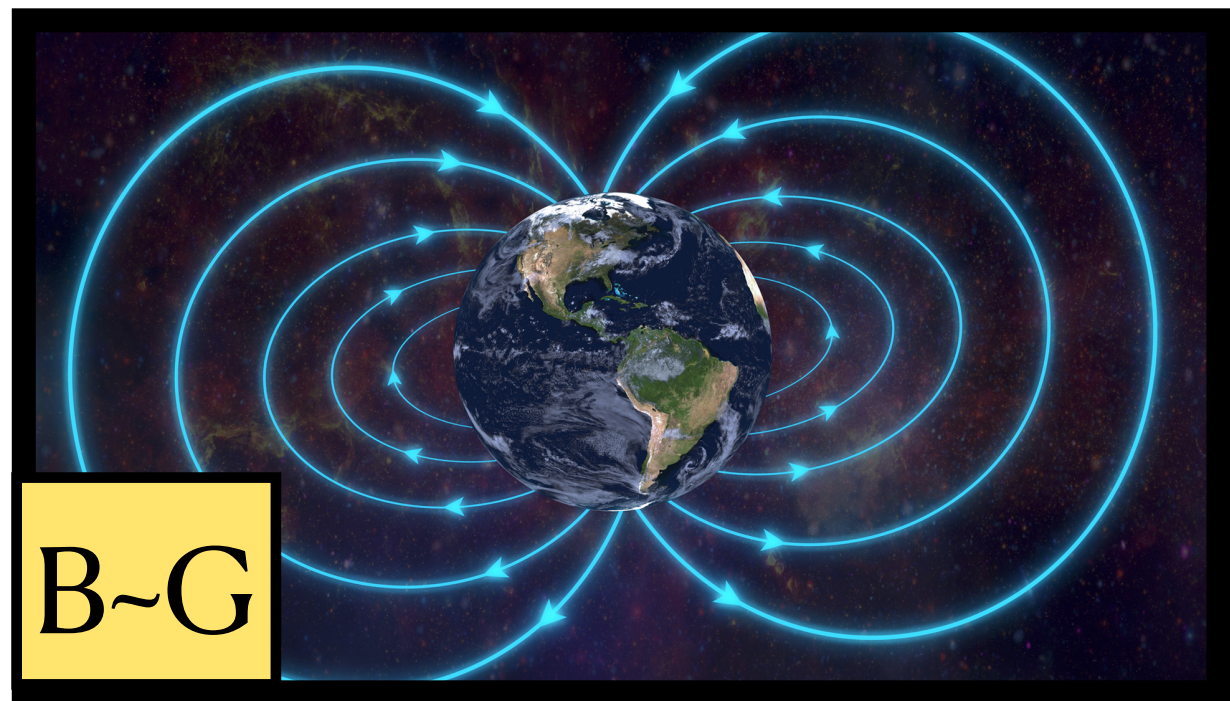
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Voids



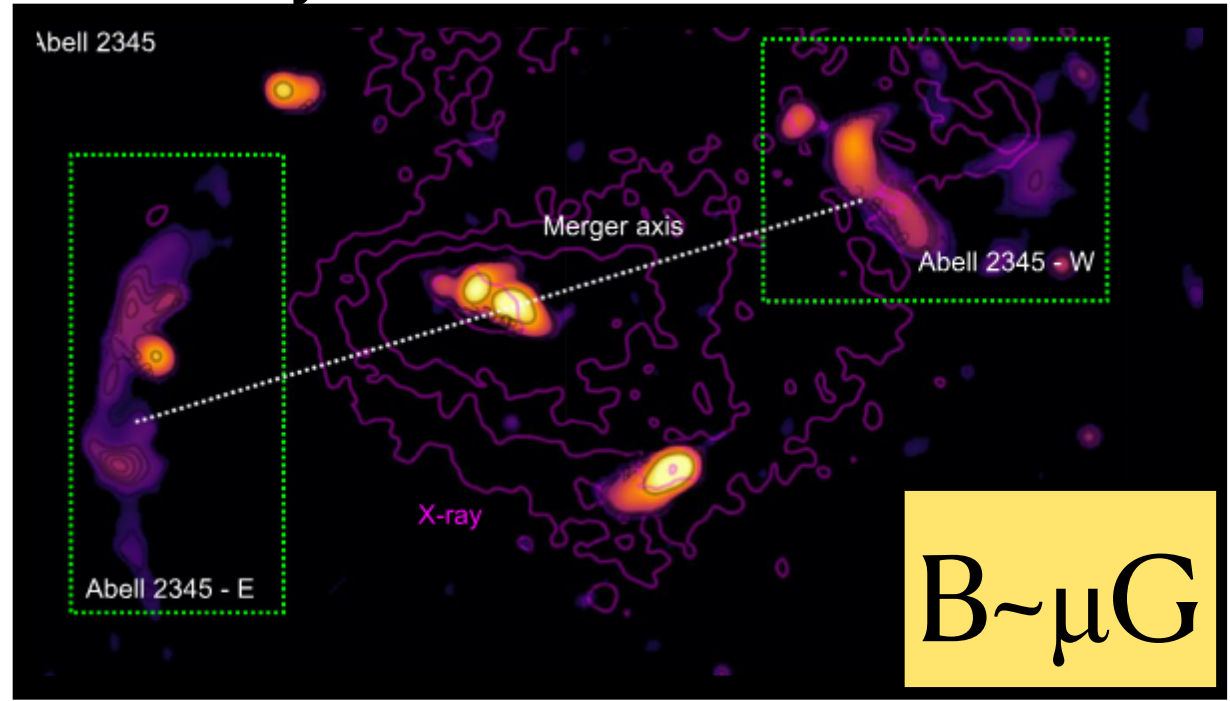
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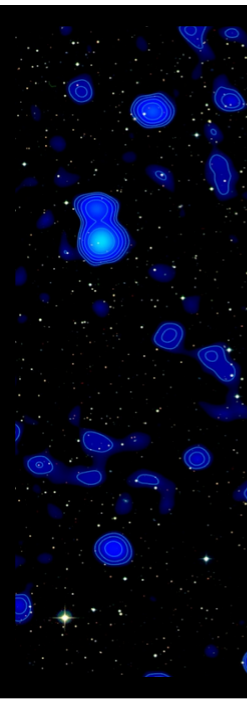
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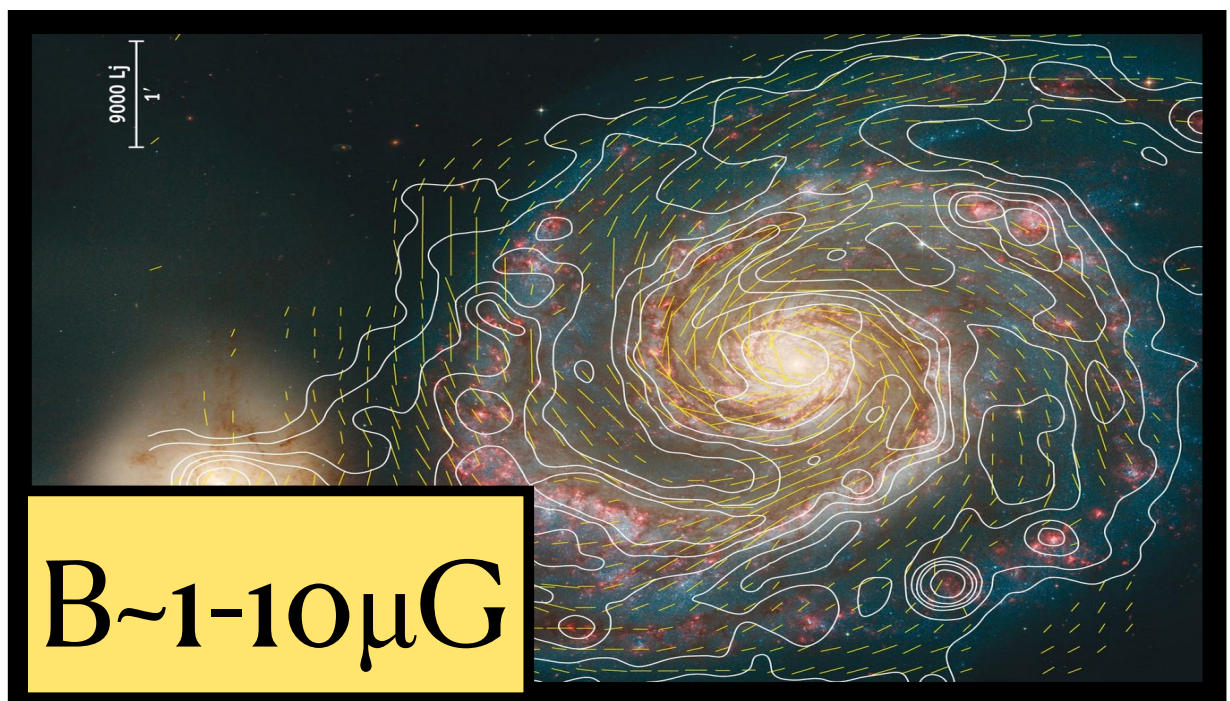
Filaments



Discriminator between primordial and astrophysical origin

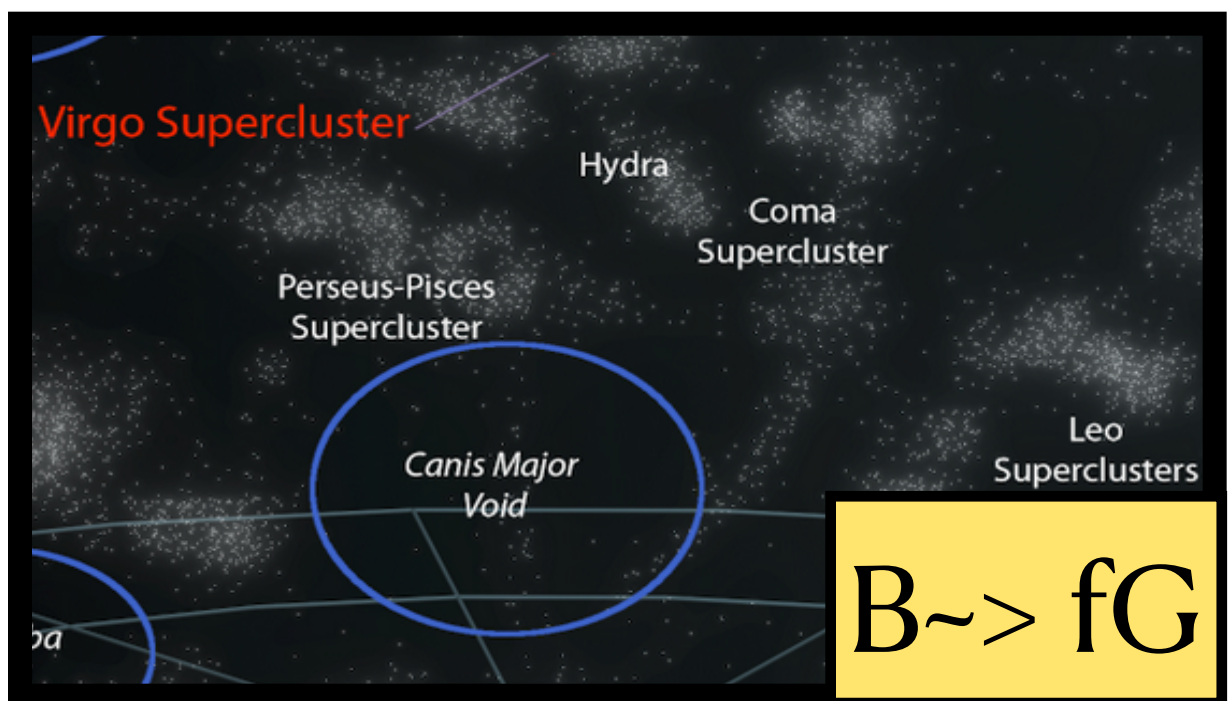
- Minimal astrophysical contamination
- Dynamical evolution - cosmic expansion only
- Probe of magnetic coherence on the largest cosmological scales

Galaxies



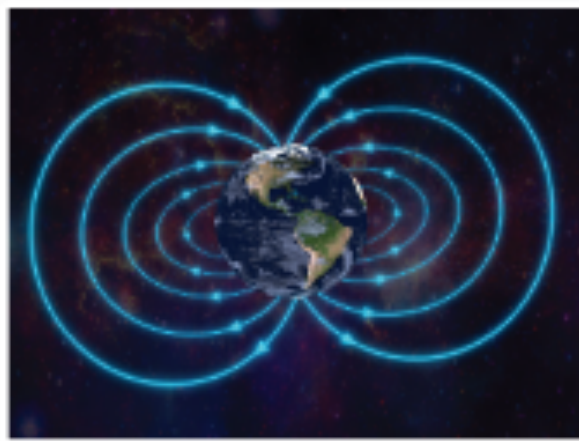
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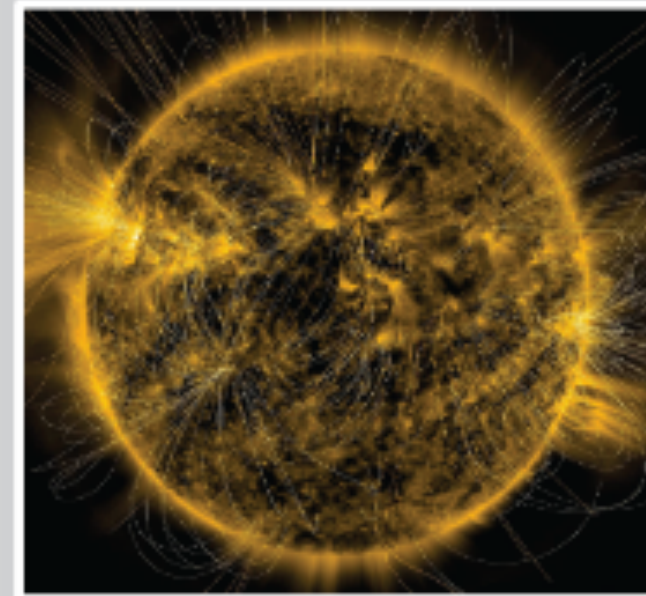
Planets

[here: Earth,
credit: iStock]



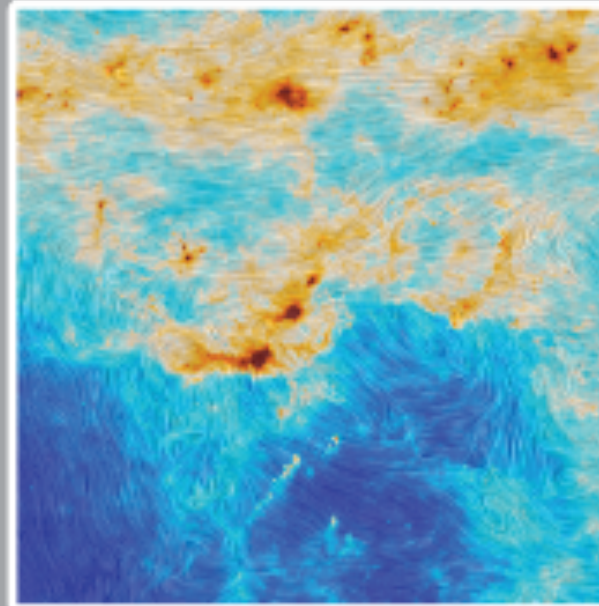
Stars

[here: Sun, credit:
NASA/SDO/AIA/
LMSAL]



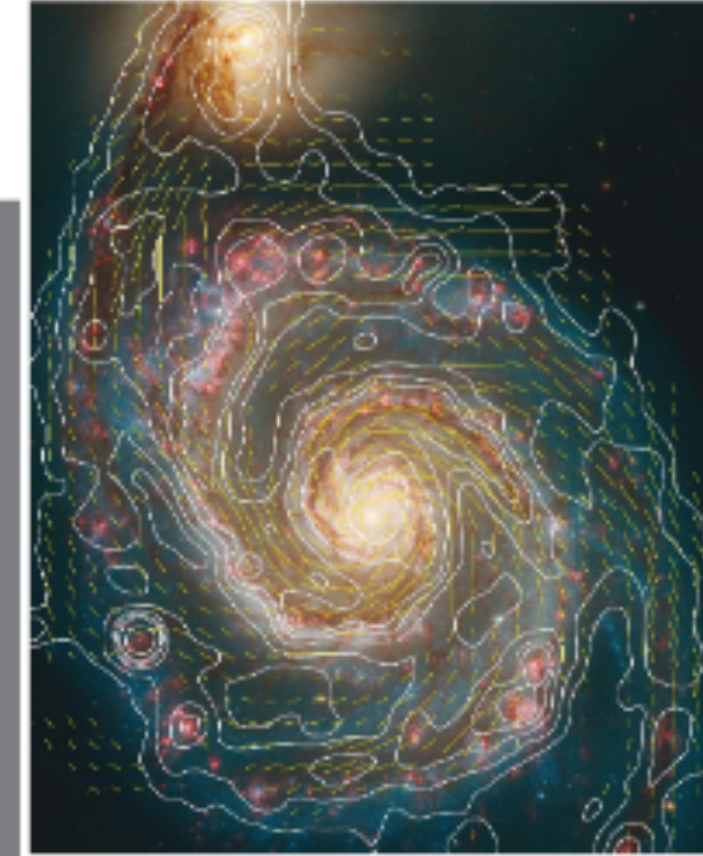
Interstellar medium

[here: Orion molec-
ular cloud, credit:
ESA and Planck
Collaboration]



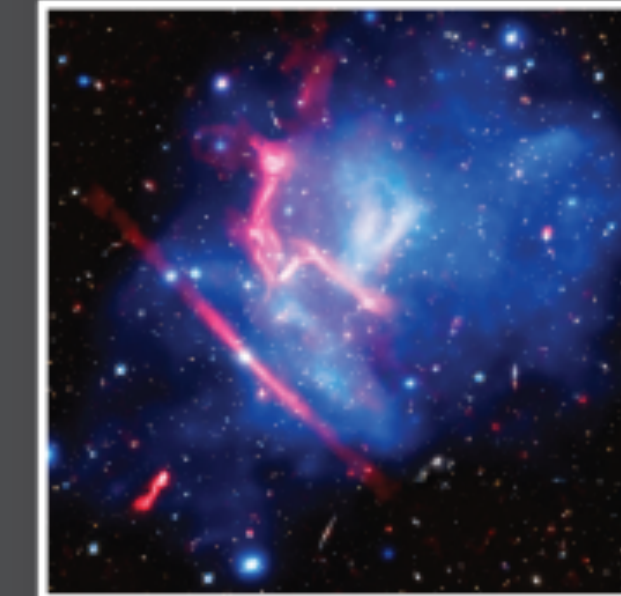
Galaxies

[here: M51, credit:
Beck 2011]

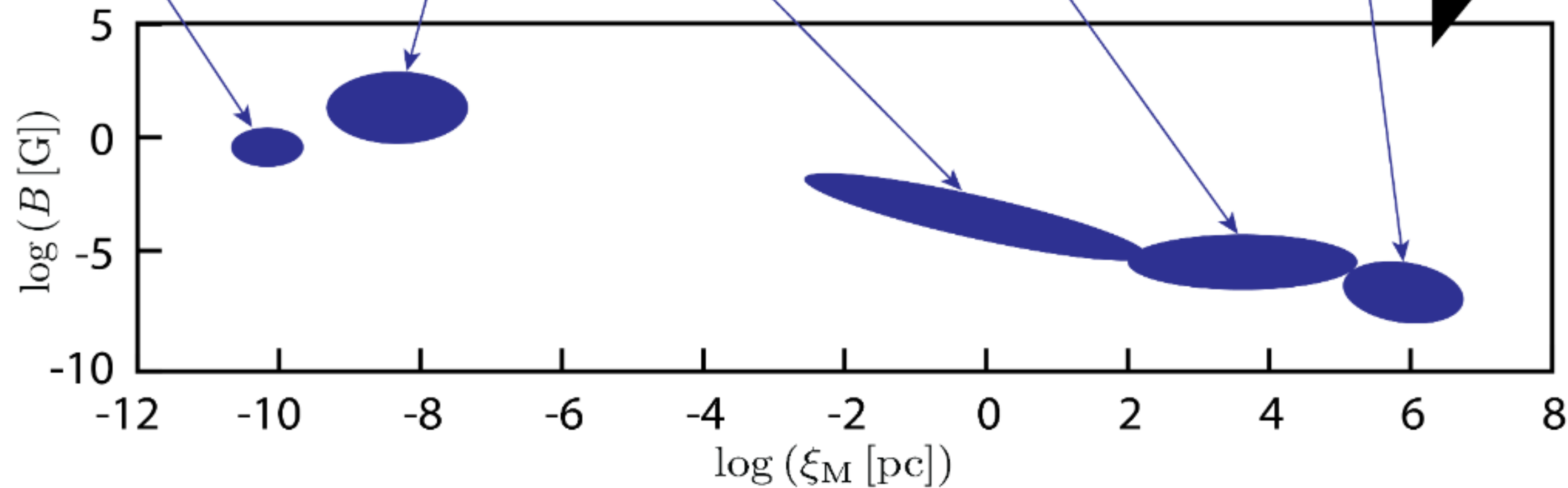


Galaxy clusters

[here: MACS J0717.
5+3745, credit:
NASA, ESA, CXC,
NRAO/AUI/
NSF, STScI]

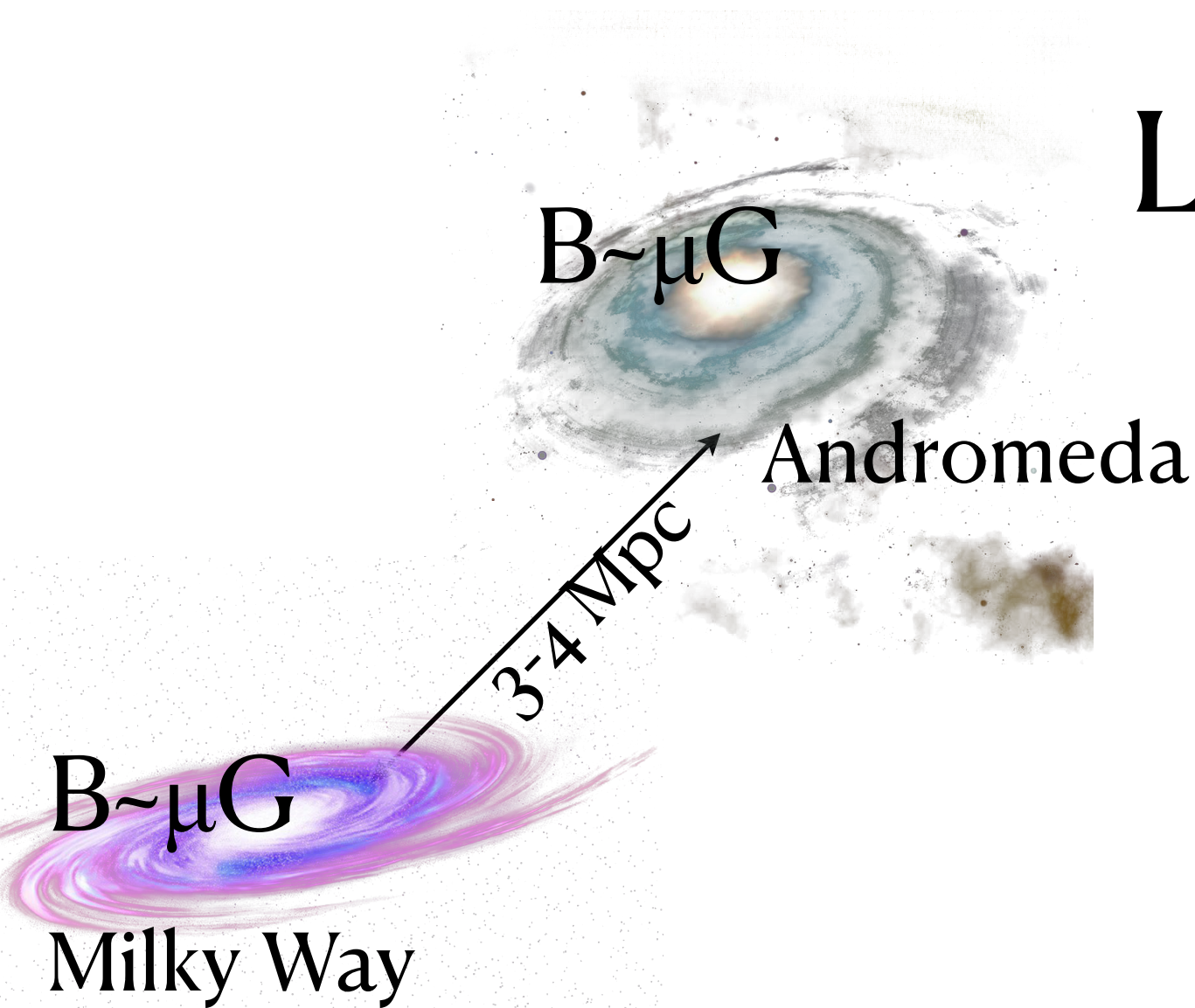


[Credits image: Jennifer Schober]



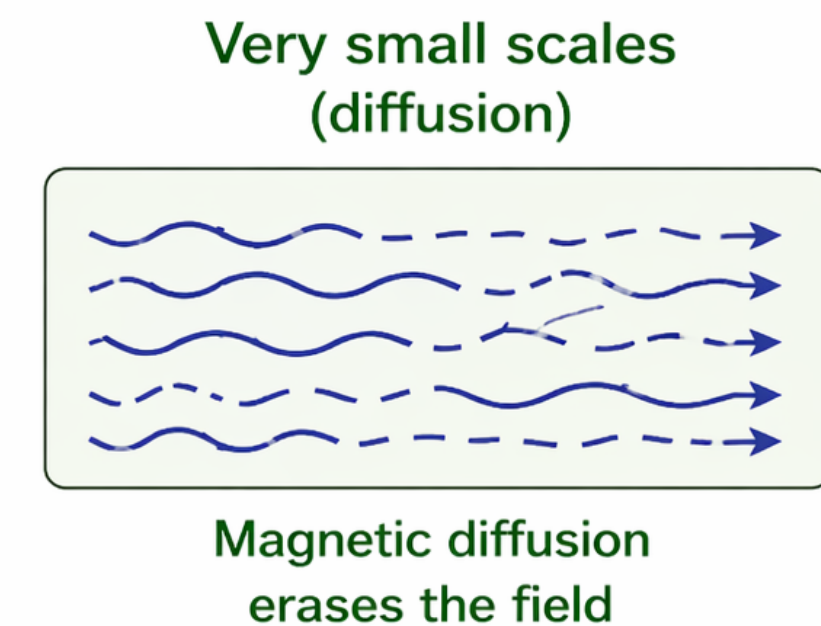
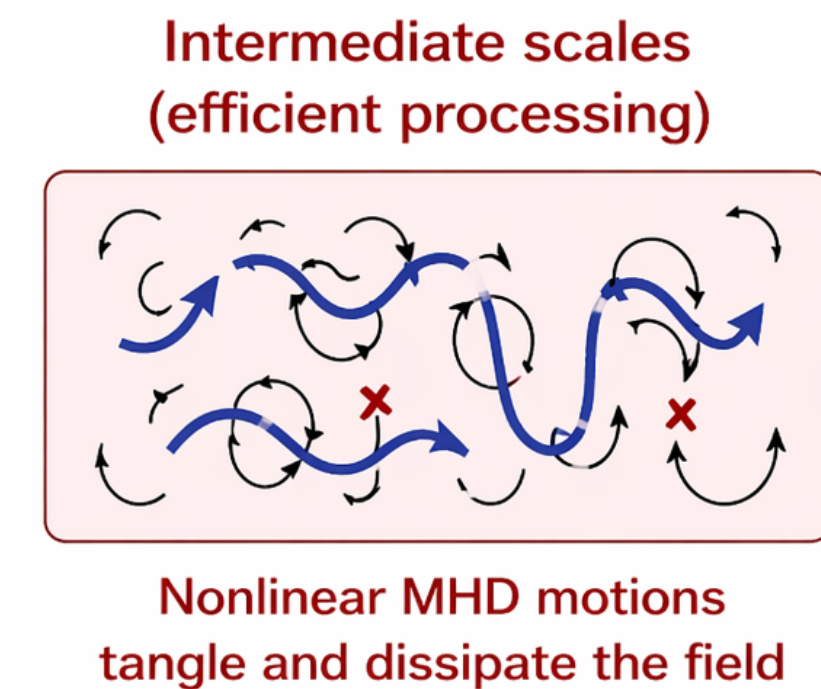
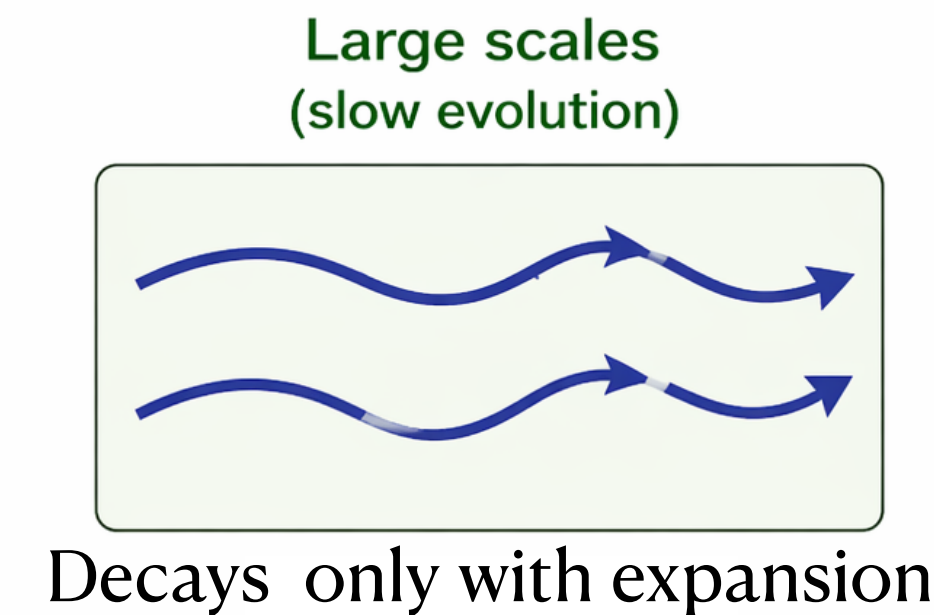
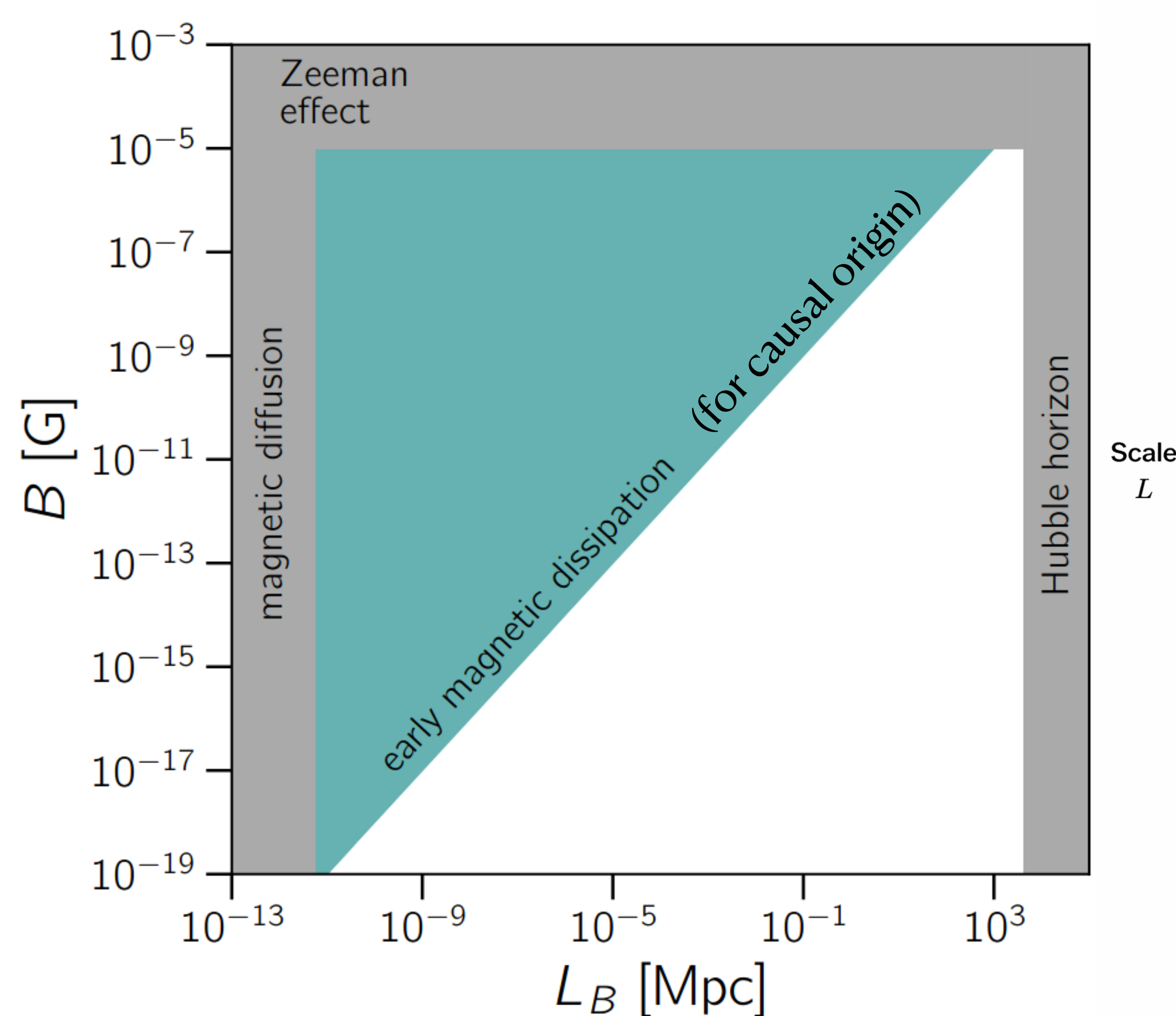
Liasons between magnetism and the architecture of the cosmos?

Limits on primordial magnetic fields

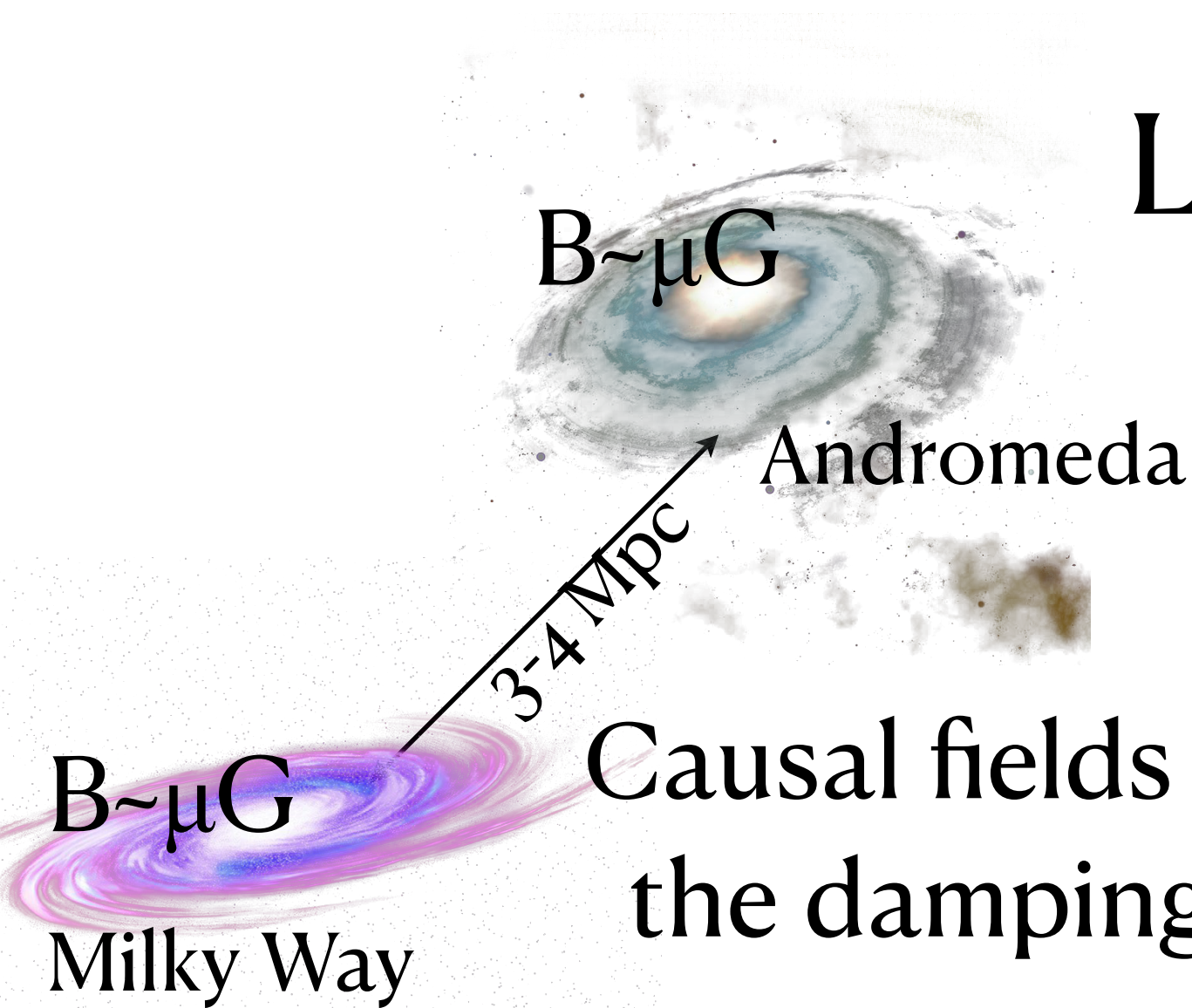


$$\langle B^2 \rangle = \int \frac{d^3 k}{(2\pi)^3} P_B(k)$$

$$\lambda_B = \frac{\int_0^\infty dk k^{-1} P_B(k)}{\int_0^\infty dk P_B(k)}$$



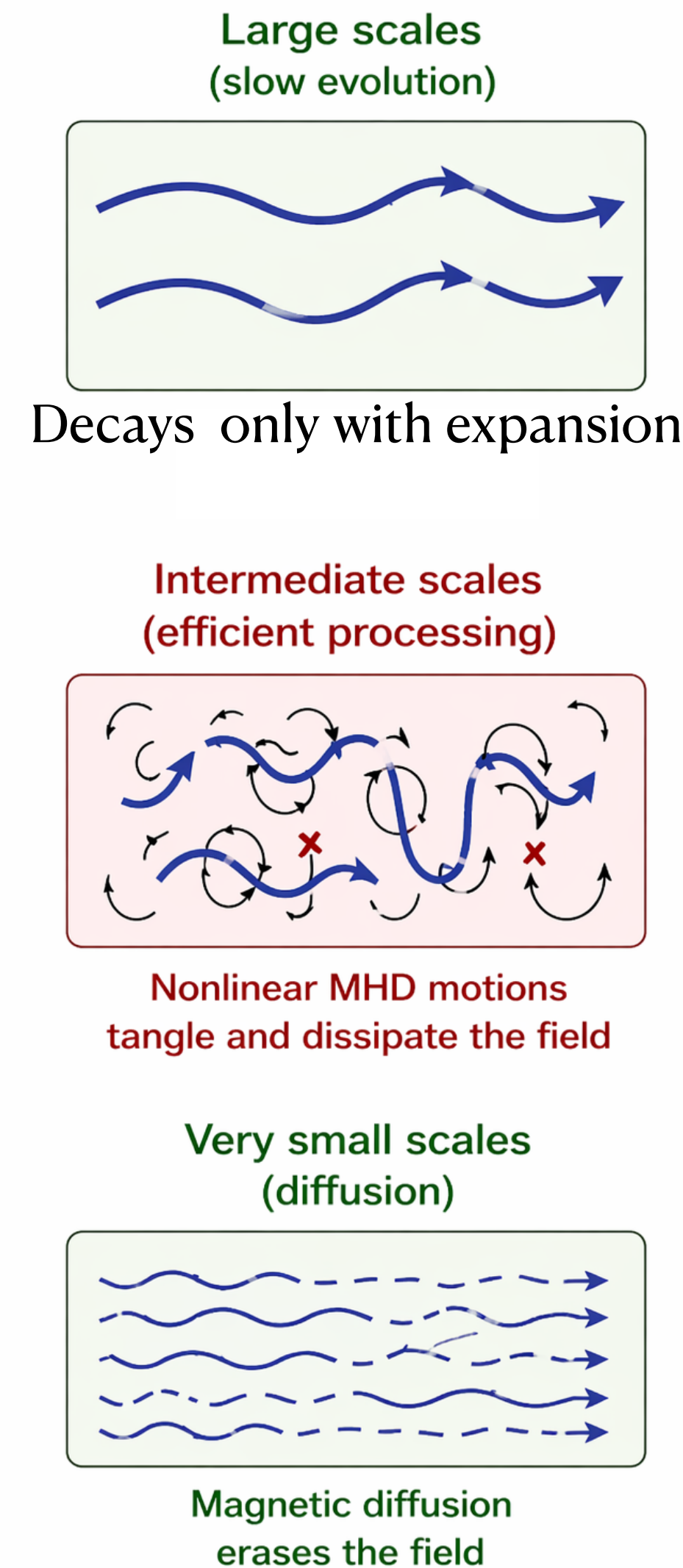
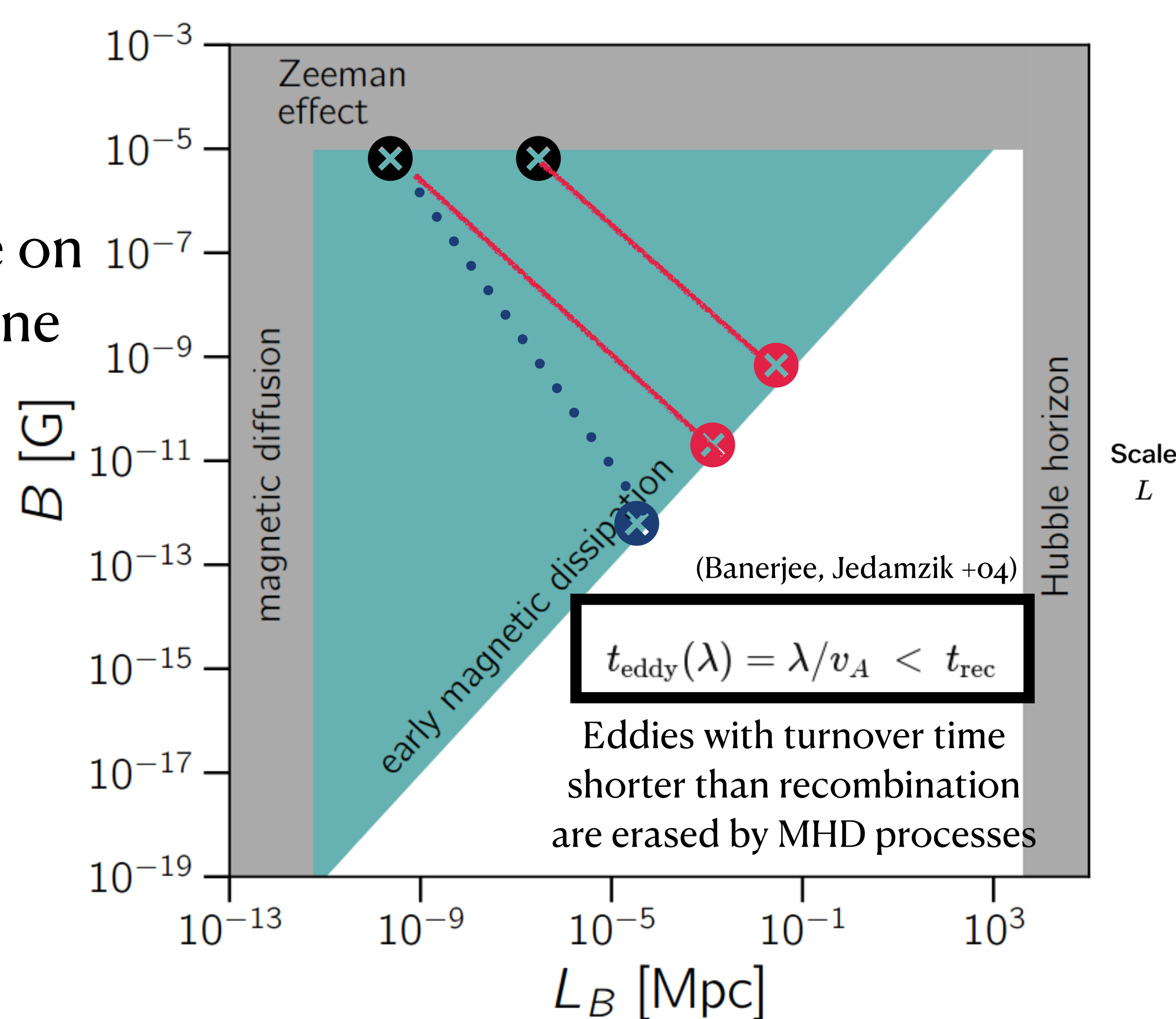
Limits on primordial magnetic fields



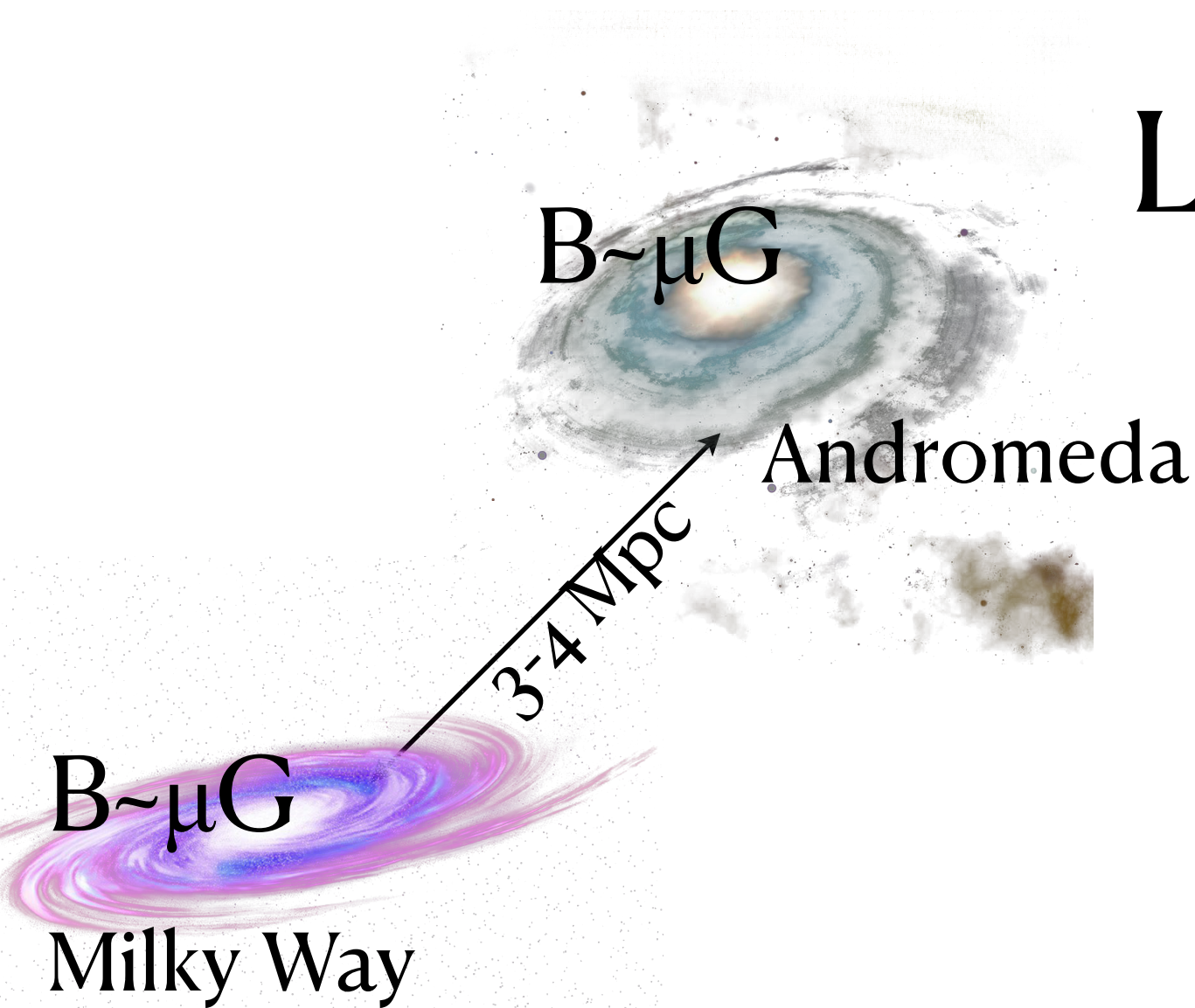
Causal fields lie on the damping line

$$\langle B^2 \rangle = \int \frac{d^3 k}{(2\pi)^3} P_B(k)$$

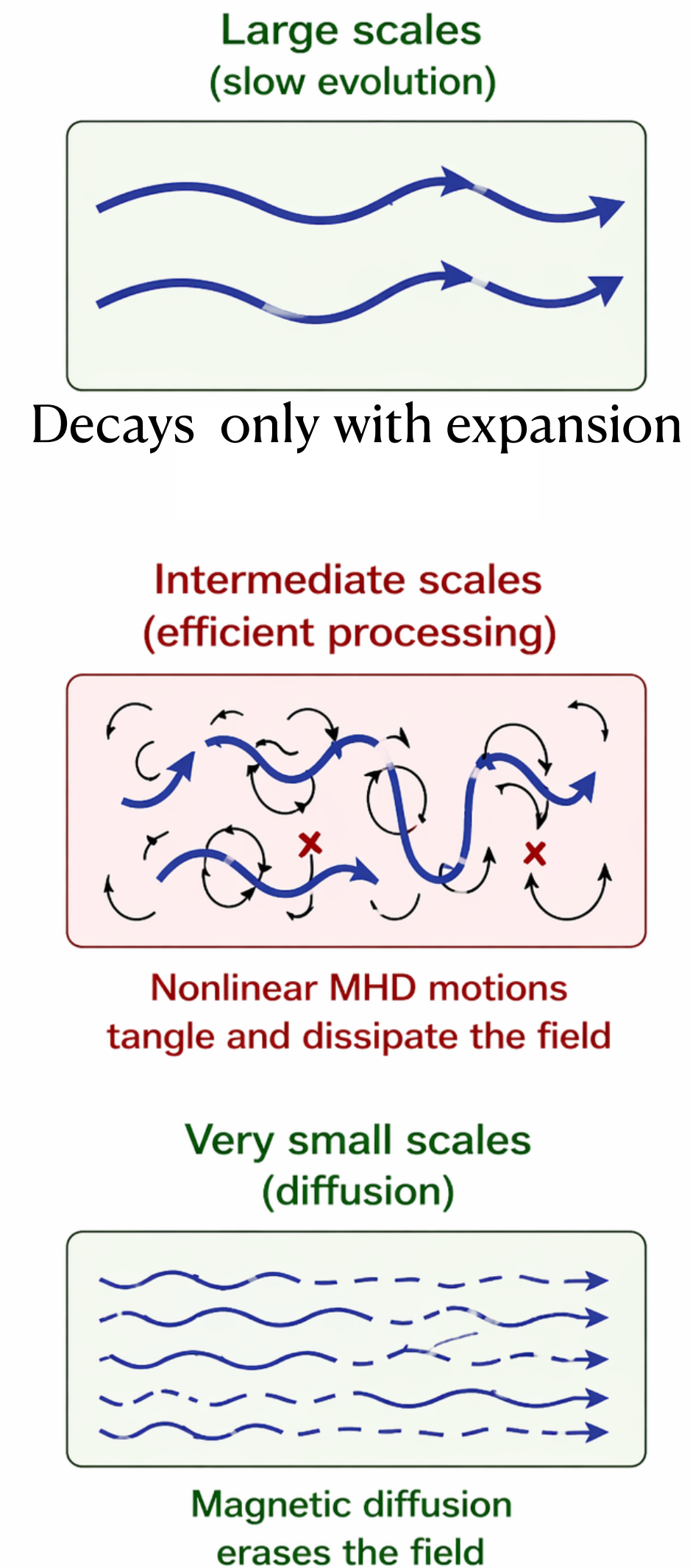
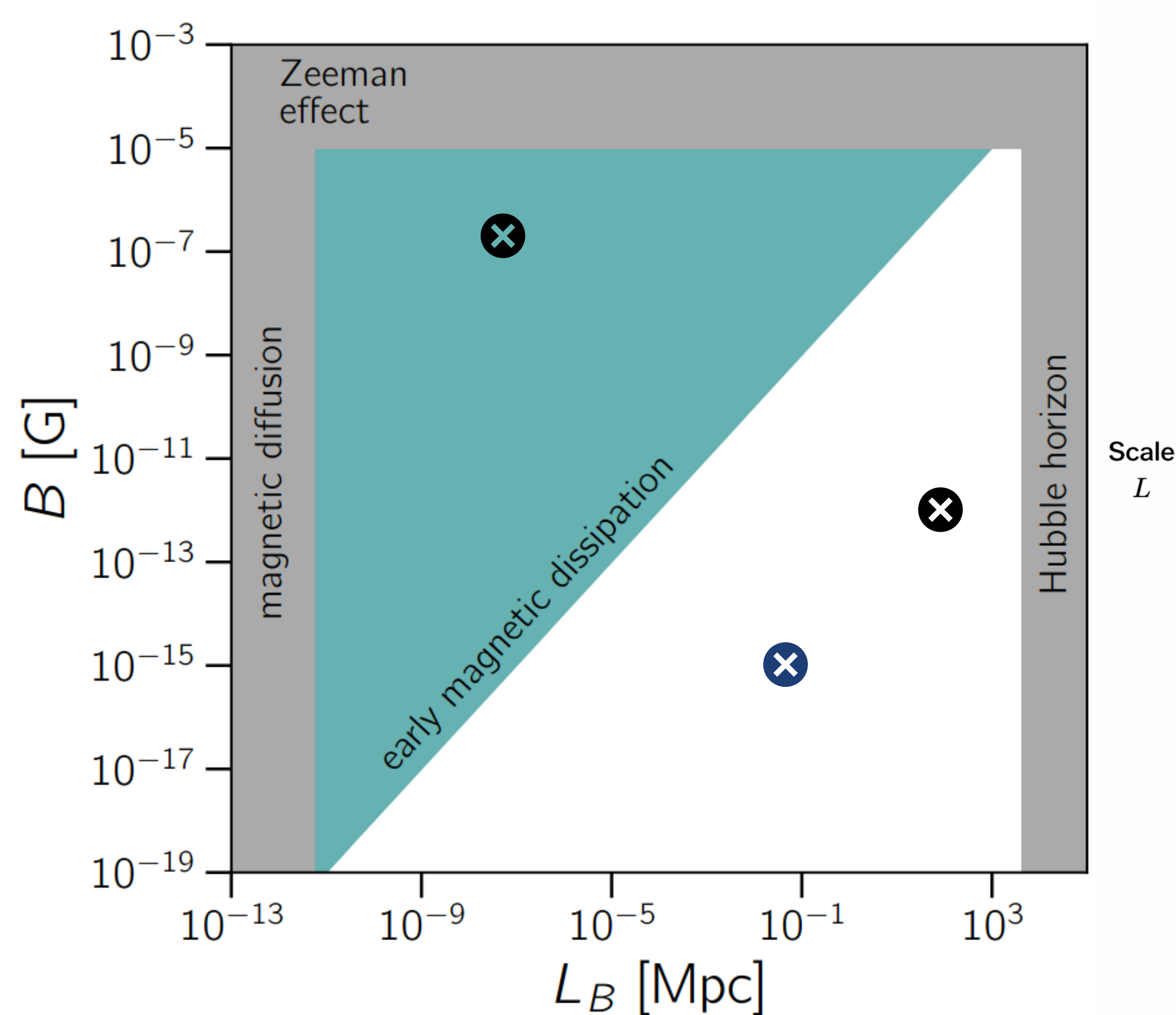
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Limits on primordial magnetic fields

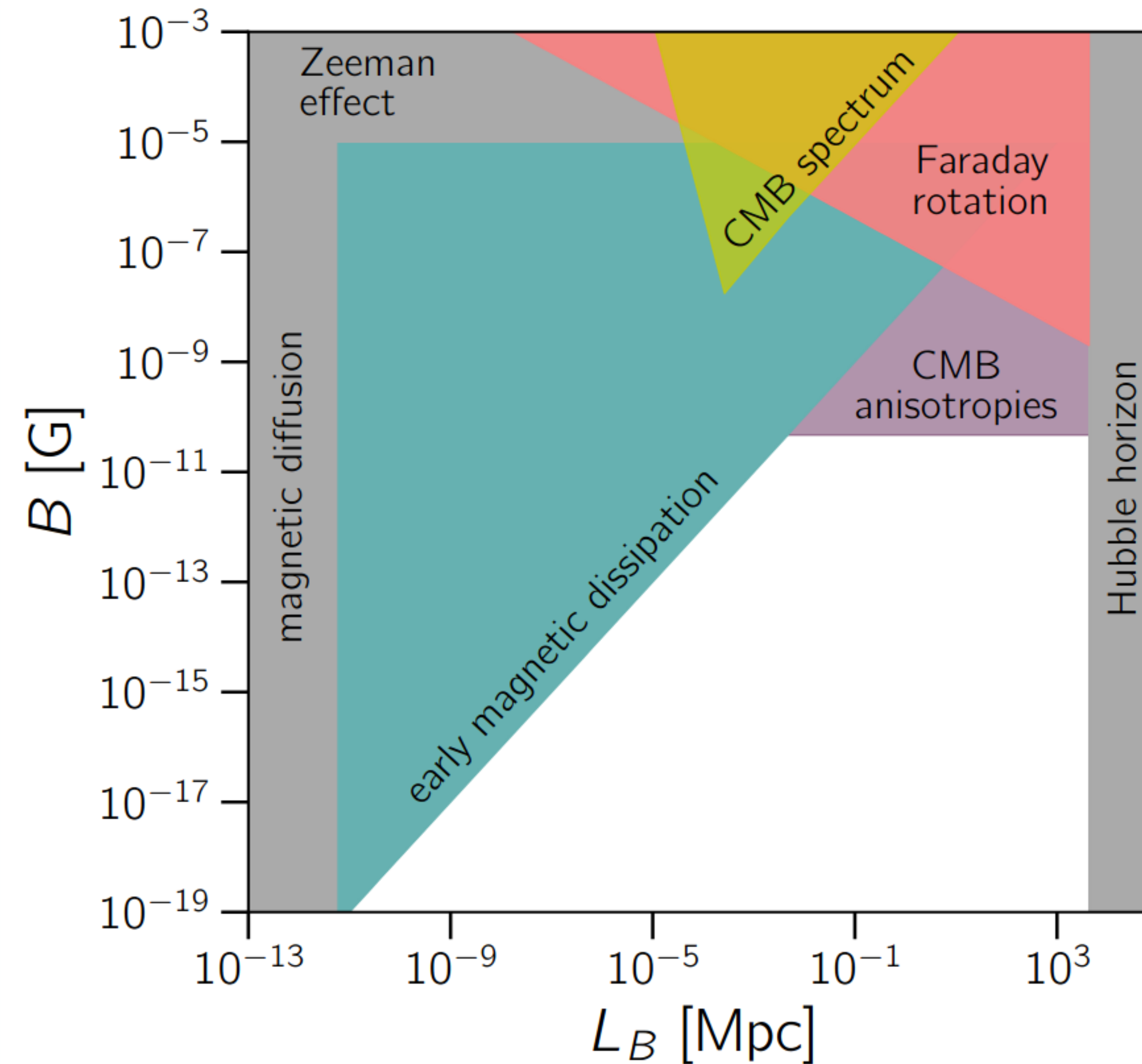
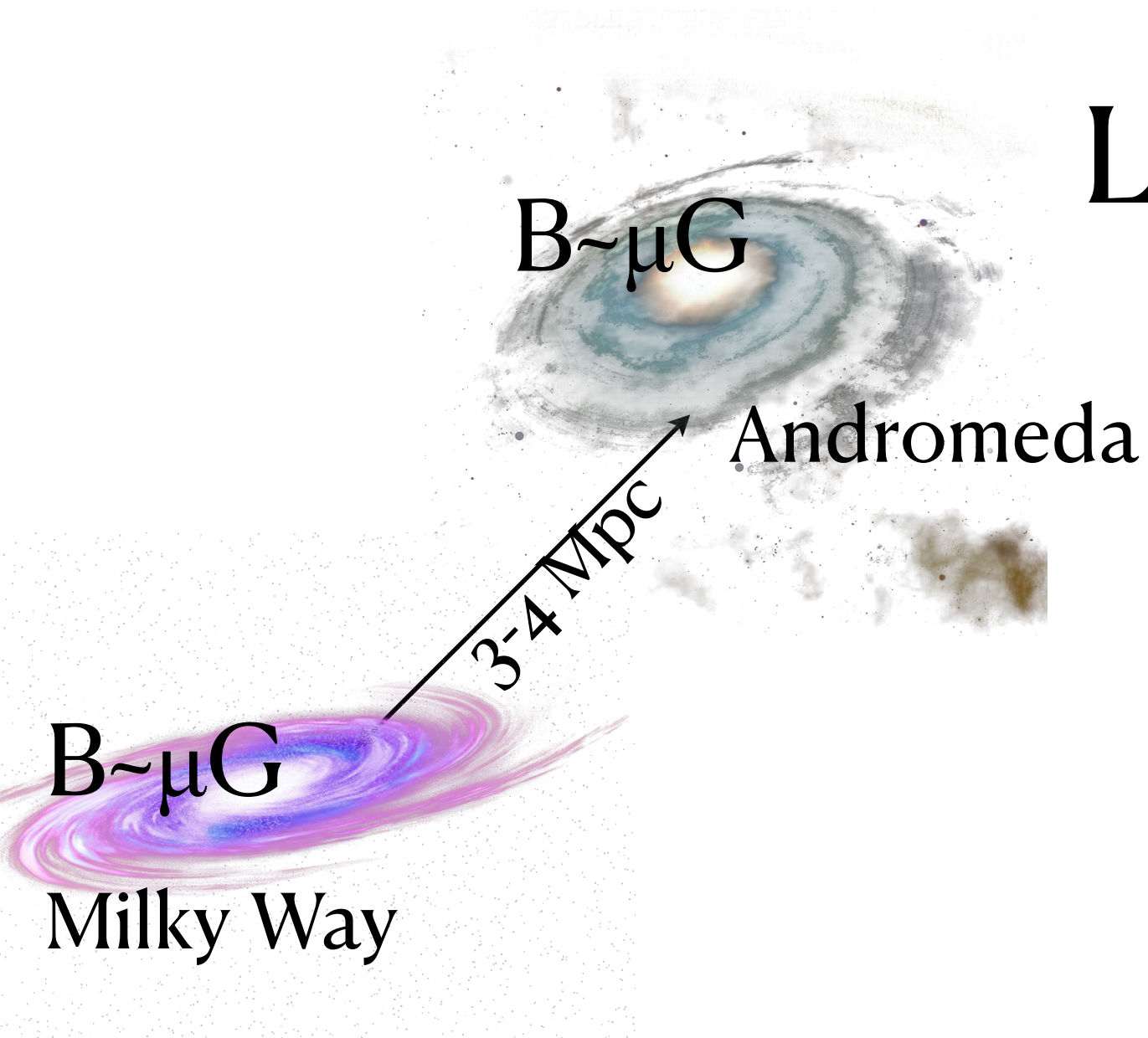


PMFs generated in inflation can lie anywhere to the right side of the damping line



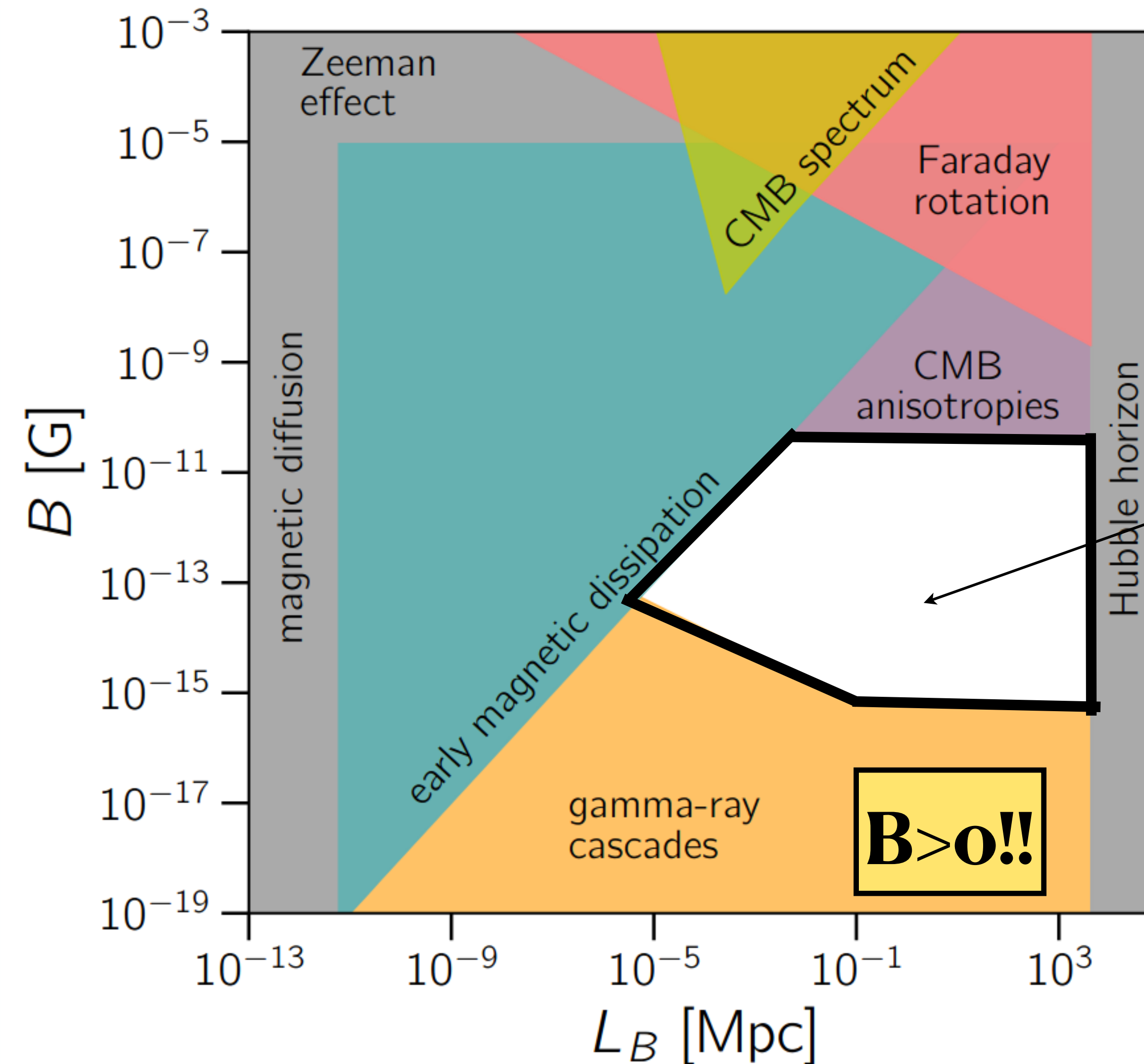
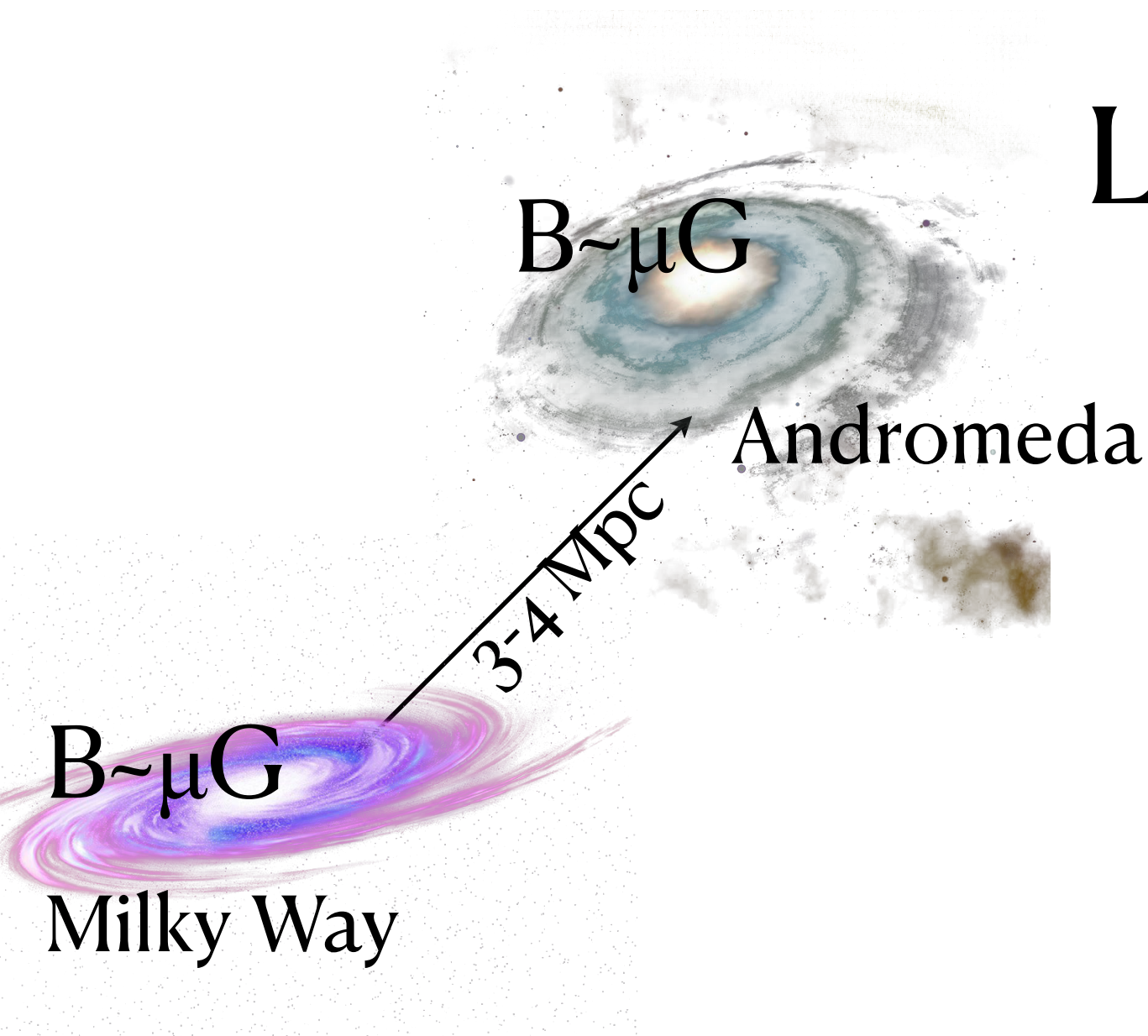
[Alves Batista, Saveliev, *Universe* 7 (2021) 7, 223]

Limits on primordial magnetic fields



[Alves Batista, Saveliev, *Universe* 7 (2021) 7, 223]

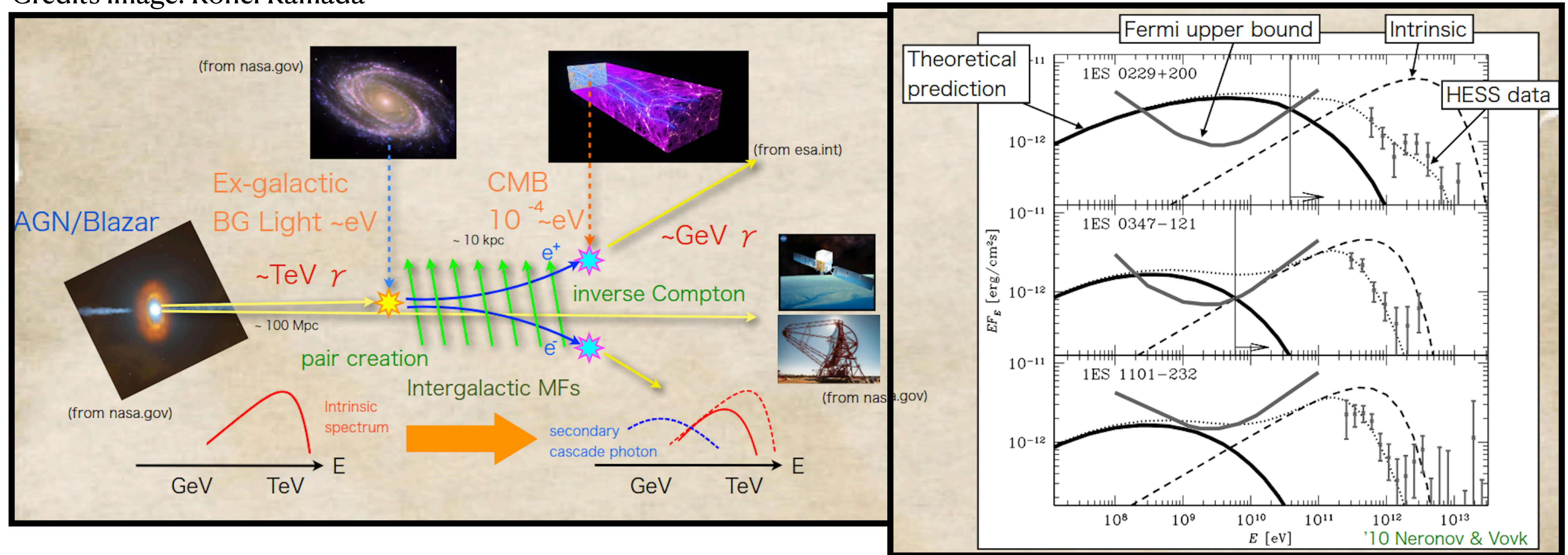
Limits on primordial magnetic fields



Allowed parameter space for void magnetic fields!

Gamma-ray cascades: magnetisation of the voids

Credits image: Kohei Kamada



Non-observation of secondary photon cascades sets a lower limit on the B-field strength

Gamma-ray cascades: magnetisation of the voids?

Could plasma instabilities also explain the non-detection of photons from the secondary cascade?



Astrophysics > High Energy Astrophysical Phenomena

[Submitted on 10 Sep 2025 (v1), last revised 15 Sep 2025 (this version, v2)]

Suppression of pair beam instabilities in a laboratory analogue of blazar pair cascades

Charles D. Arrowsmith, Francesco Miniati, Pablo J. Bilbao, Pascal Simon, Archie F. A. Bott, Stephane Burger, Hui Chen, Filipe D. Cruz, Tristan Davenne, Anthony Dyson, Ilias Efthymiopoulos, Dustin H. Froula, Alice Goillot, Jon T. Gudmundsson, Dan Haberberger, Jack W. D. Halliday, Tom Hodge, Brian T. Huffman, Sam Iaquina, G. Marshall, Brian Reville, Subir Sarkar, Alexander A. Schekochihin, Luis O. Silva, Raspberry Simpson, Vasiliki Stergiou, Raoul M. G. M. Trines, Thibault Vieu, Nikolaos Charitonidis, Robert Bingham, Gianluca Gregori



Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 12 Mar 2025 (v1), last revised 16 Dec 2025 (this version, v2)]

Hints of Primordial Magnetic Fields at Recombination and Implications for the Hubble Tension

Karsten Jedamzik, Levon Pogorian, Tom Abel



Astrophysics > High Energy Astrophysical Phenomena

[Submitted on 12 Dec 2025 (v1), last revised 9 Feb 2026 (this version, v2)]

Intergalactic magnetic field lower limits up to the redshift $z \approx 3$

levgen Vovk

Gamma-ray cascades: magnetisation of the voids?

Could galactic outflows explain the observed gamma-ray emission without invoking a primordial magnetic field?



Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 20 May 2025 (v1), last revised 8 Oct 2025 (this version, v2)]

Are magnetic fields in cosmic voids primordial?

[Deepen Garg](#), [Ruth Durrer](#), [Jennifer Schober](#)



Astrophysics > High Energy Astrophysical Phenomena

[Submitted on 19 Dec 2025 (v1), last revised 5 May 2026 (this version, v5)]

Magnetic field spreading from stellar and galactic dynamos into the exterior

[Axel Brandenburg](#), [Oindrila Ghosh](#), [Franco Vazza](#), [Andrii Neronov](#)



Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 30 Oct 2025]

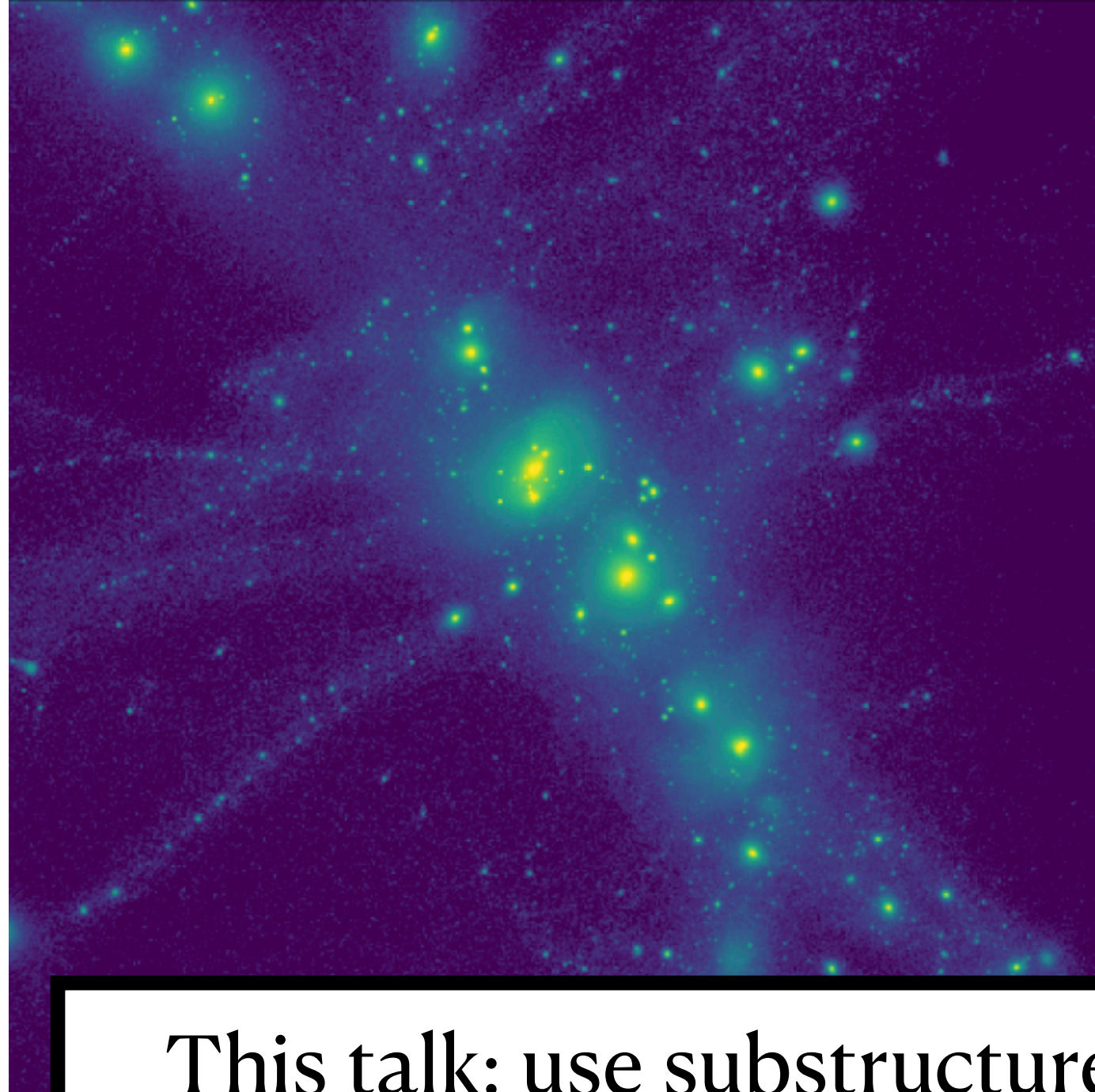
Can galactic magnetic fields diffuse into the voids?

[Oindrila Ghosh](#), [Axel Brandenburg](#), [Chiara Caprini](#), [Andrii Neronov](#), [Franco Vazza](#)

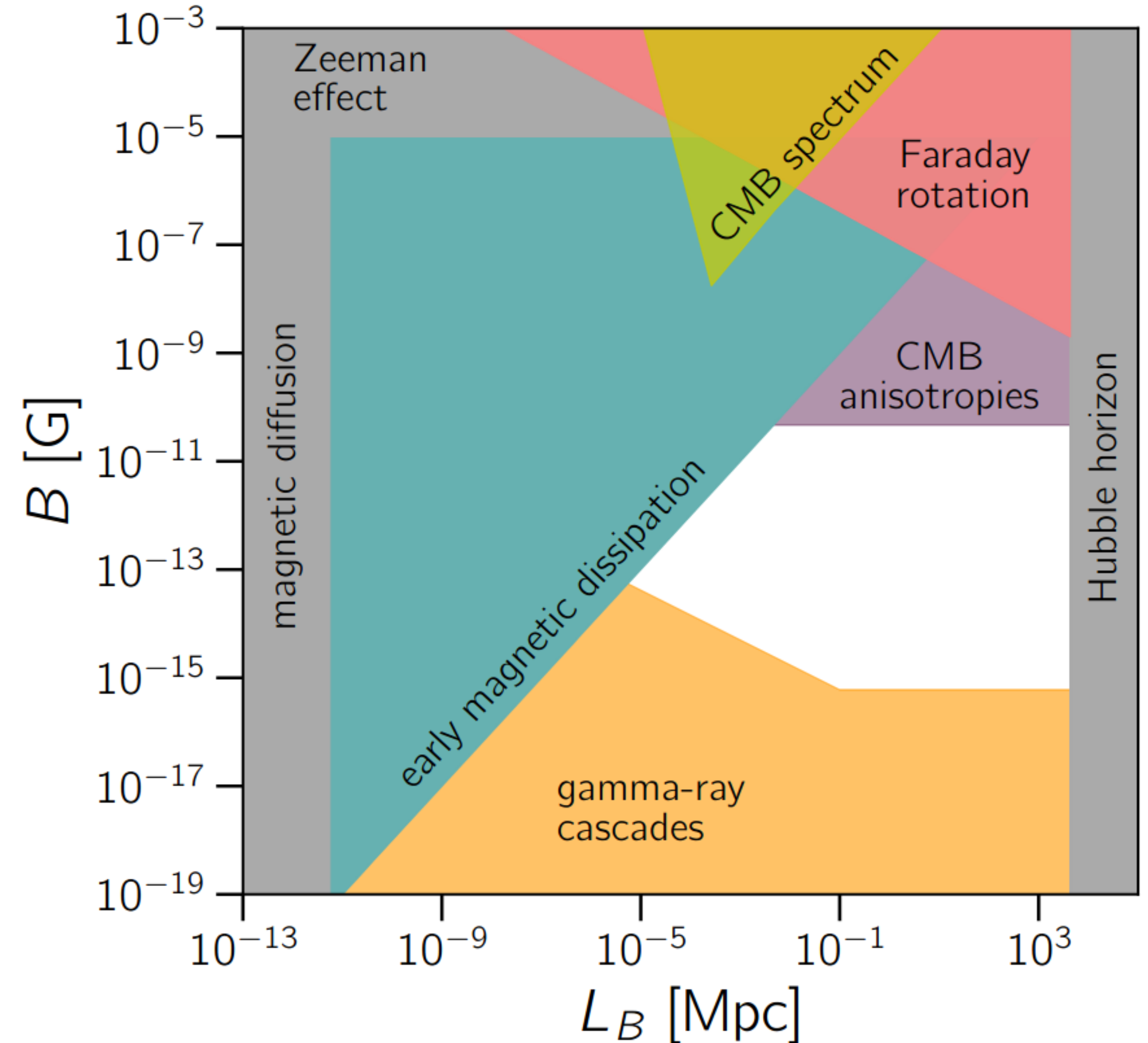


Dark matter substructure as a probe of a primordial origin

[Sten Delos, 26]

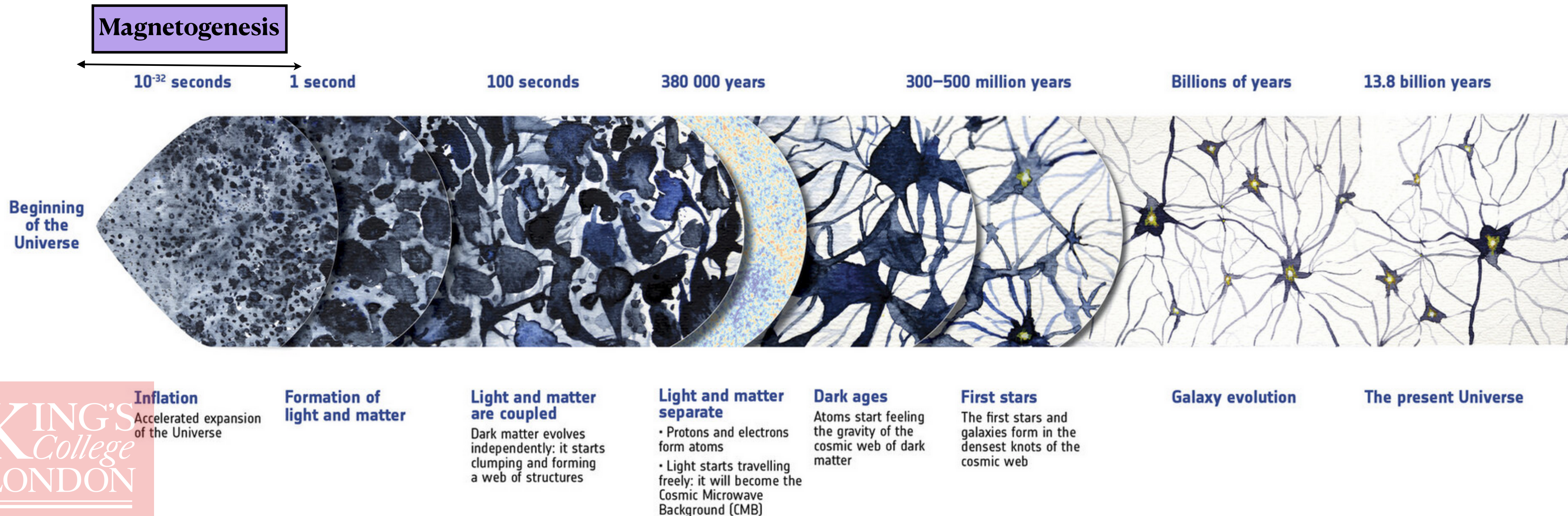


- This talk: use substructure to:
1. Probe the primordial nature of intergalactic magnetic fields
 2. Place new constraints on the parameter space of PMFs



[Alves Batista, Saveliev, *Universe* 7 (2021) 7, 223]

Magnetic history of the Universe



Magnetic history of the Universe

- **LCDM - Second order perturbations.** Ichiki et al., 2007, Maeda et al. 2009, Fenu et al., 2011
- **Inflation.** Turner and Widrow, 1988, Ratra, 1992, etc
- **Other mechanisms:** i.e. Kerr-Newmann black holes (Hooper, Ireland, Krnjaic 2022)
- **Cosmological phase transitions.**
Vachaspati, 1991, Enqvist and Olesen, 1993,
Sigl, Olinto, Jedamzik, 1996, Grasso and Riotto, 1998.

Magnetogenesis

10^{-32} seconds

1 second

100 seconds

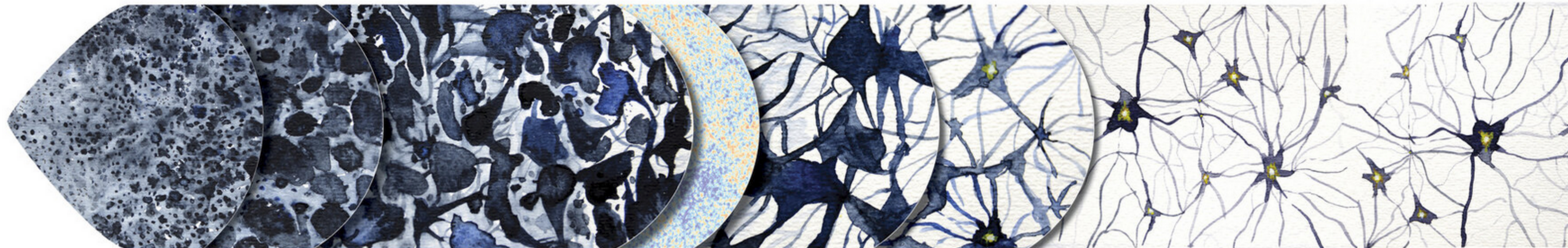
380 000 years

300–500 million years

Billions of years

13.8 billion years

Beginning
of the
Universe



Inflation

Accelerated expansion
of the Universe

**Formation of
light and matter**

**Light and matter
are coupled**

Dark matter evolves
independently: it starts
clumping and forming
a web of structures

**Light and matter
separate**

- Protons and electrons
form atoms
- Light starts travelling
freely: it will become the
Cosmic Microwave
Background (CMB)

Dark ages

Atoms start feeling
the gravity of the
cosmic web of dark
matter

First stars

The first stars and
galaxies form in the
densest knots of the
cosmic web

Galaxy evolution

The present Universe

Magnetic history of the Universe

MagnetoHydroDynamics: continuity equation + Euler equation + induction equation

$$\partial_\eta \mathbf{B}_c = \nabla \times (\mathbf{v}_c \times \mathbf{B}_c) + \frac{1}{\sigma_c} \nabla^2 \mathbf{B}_c$$

Induction equation: dynamo diffusion

Inverse transfer

$$B \searrow \rightarrow \xi \nearrow$$

Non helical fields:

i.e. Hosking invariant
conservation rules evolution

Helical fields:

Conservation of helicity rules evolution

Magnetogenesis **Decaying MHD turbulence**

10⁻³² seconds

1 second

100 seconds

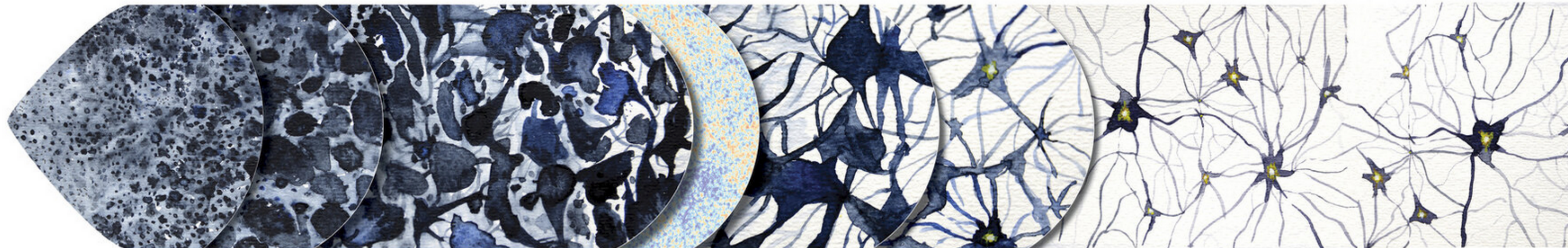
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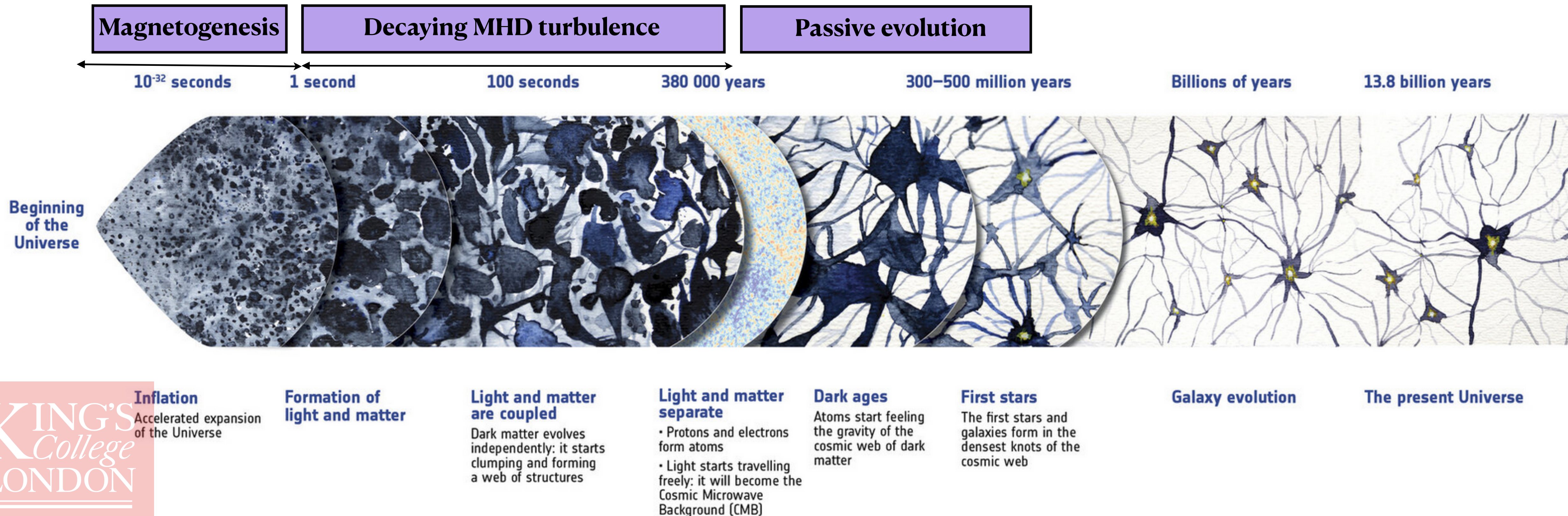
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Induction equation: dynamo diffusion

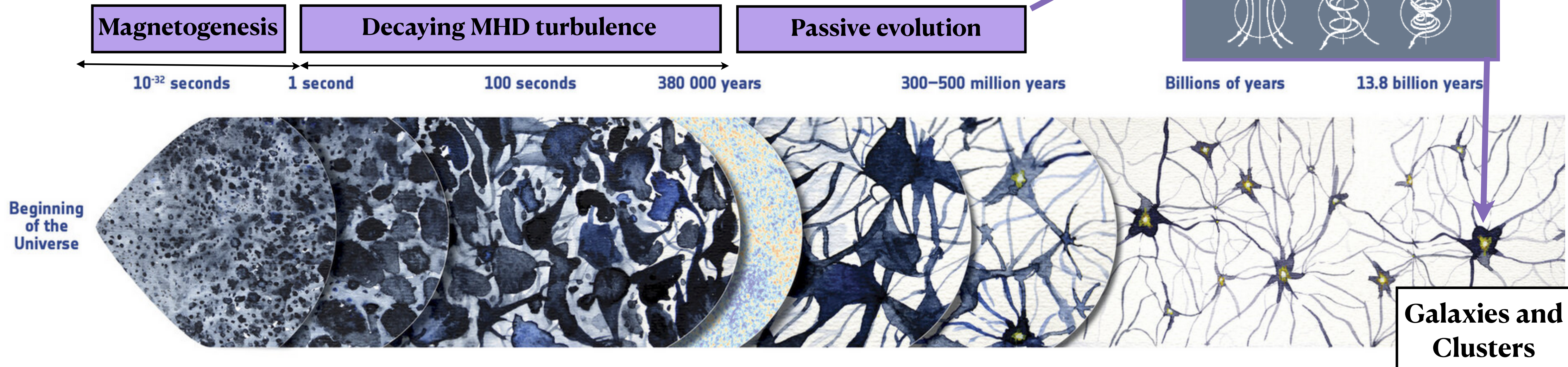
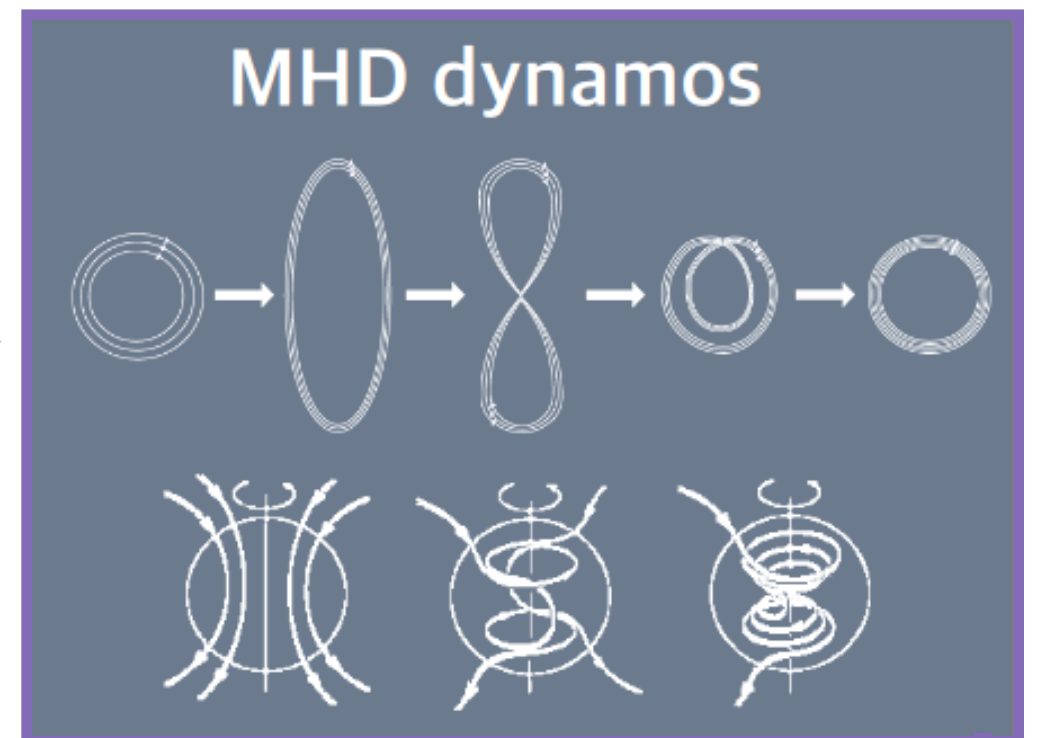


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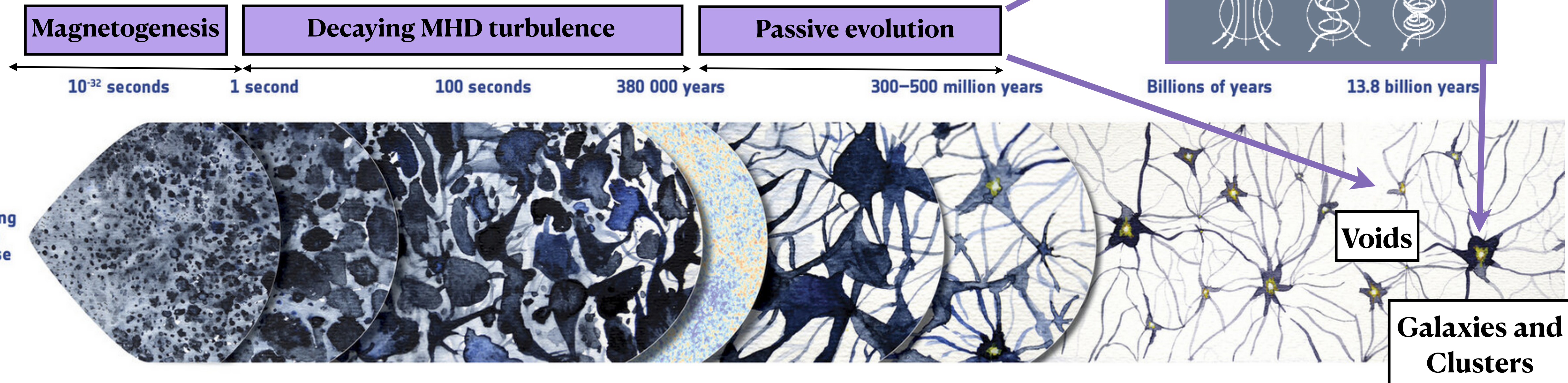
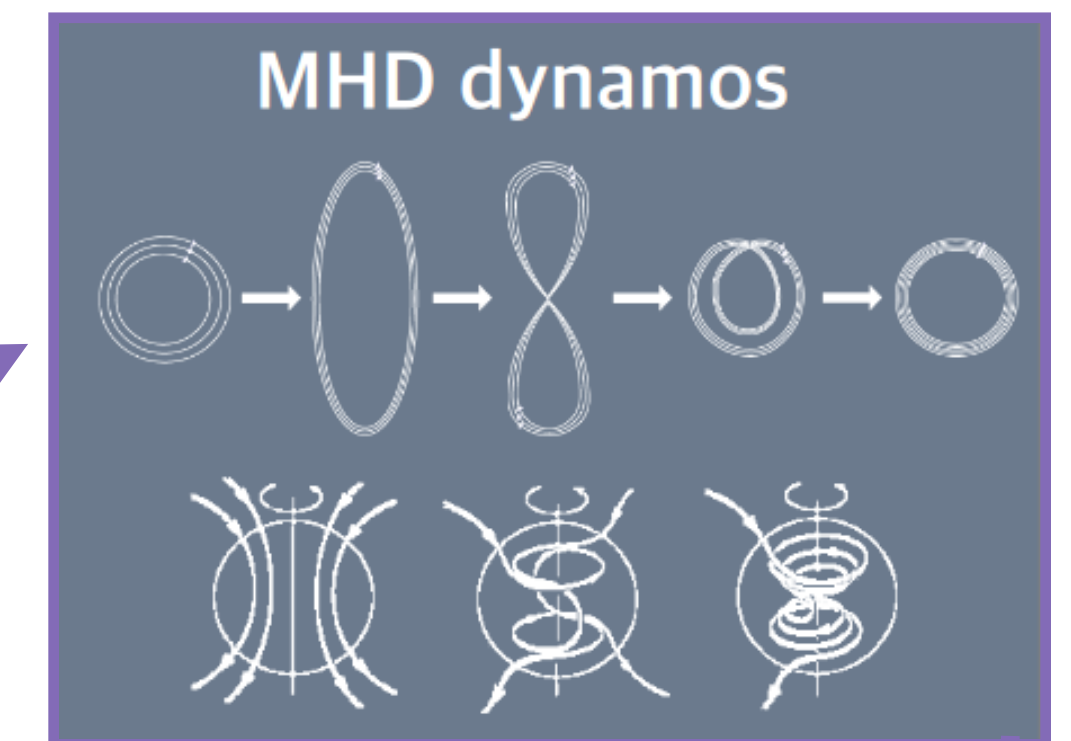
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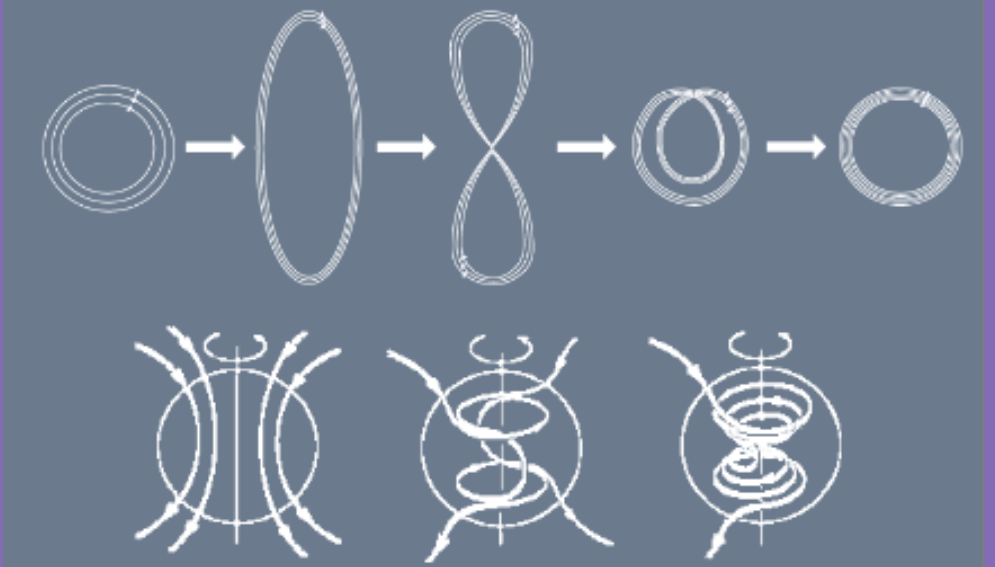
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Induction equation: dynamo diffusion

MHD dynamos



Magnetogenesis

Decaying MHD turbulence

Passive evolution

10^{-32} seconds

1 second

100 seconds

380 000 years

300–500 million years

Billions of years

13.8 billion years

Beginning of the Universe



$z \sim 1100$

$z \sim 100-30$

Impact on structure
("On small scales")

Voids

Galaxies and Clusters

Inflation

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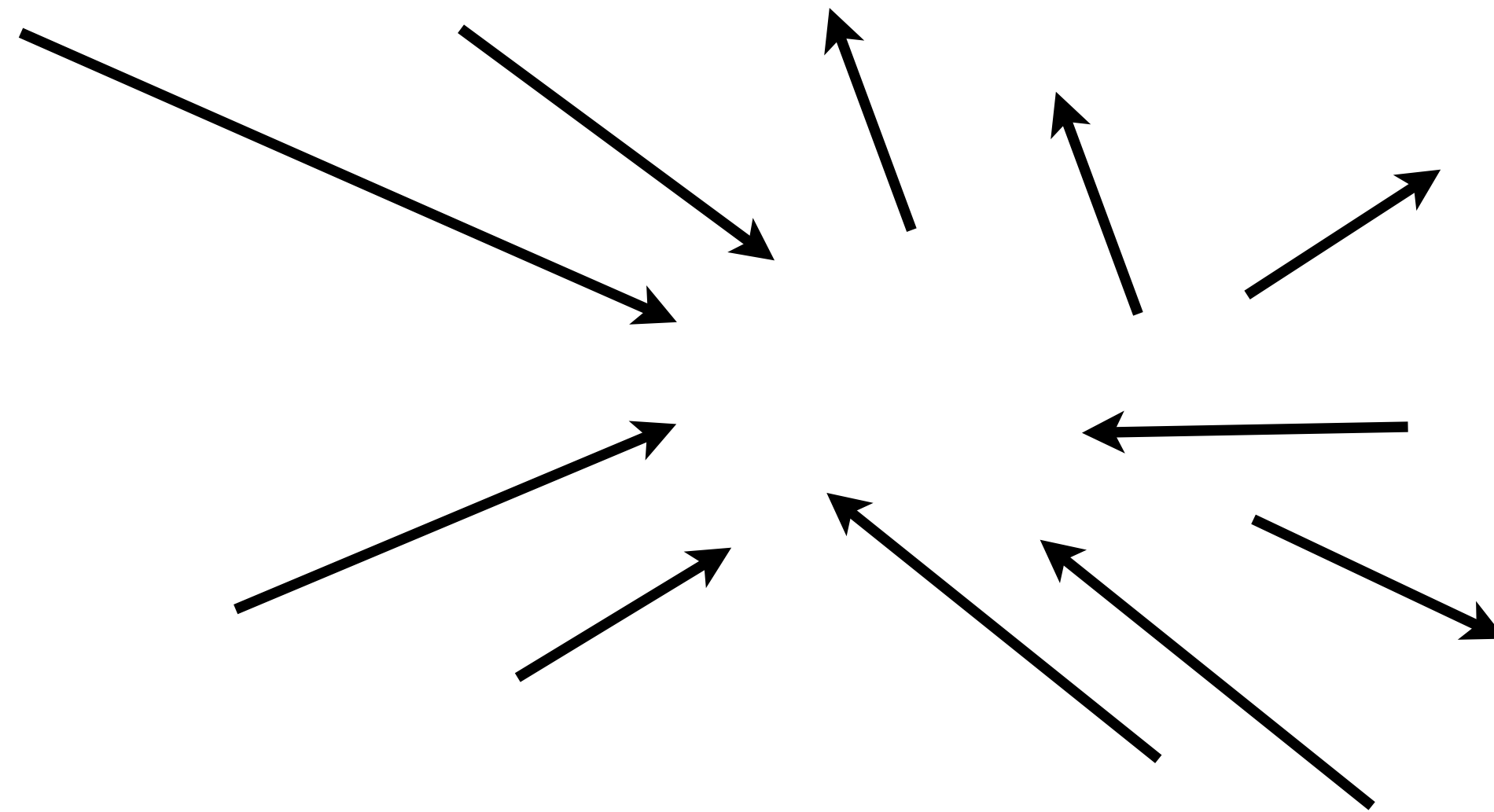
Galaxy evolution

The present Universe

Primordial magnetic fields enhance density perturbations

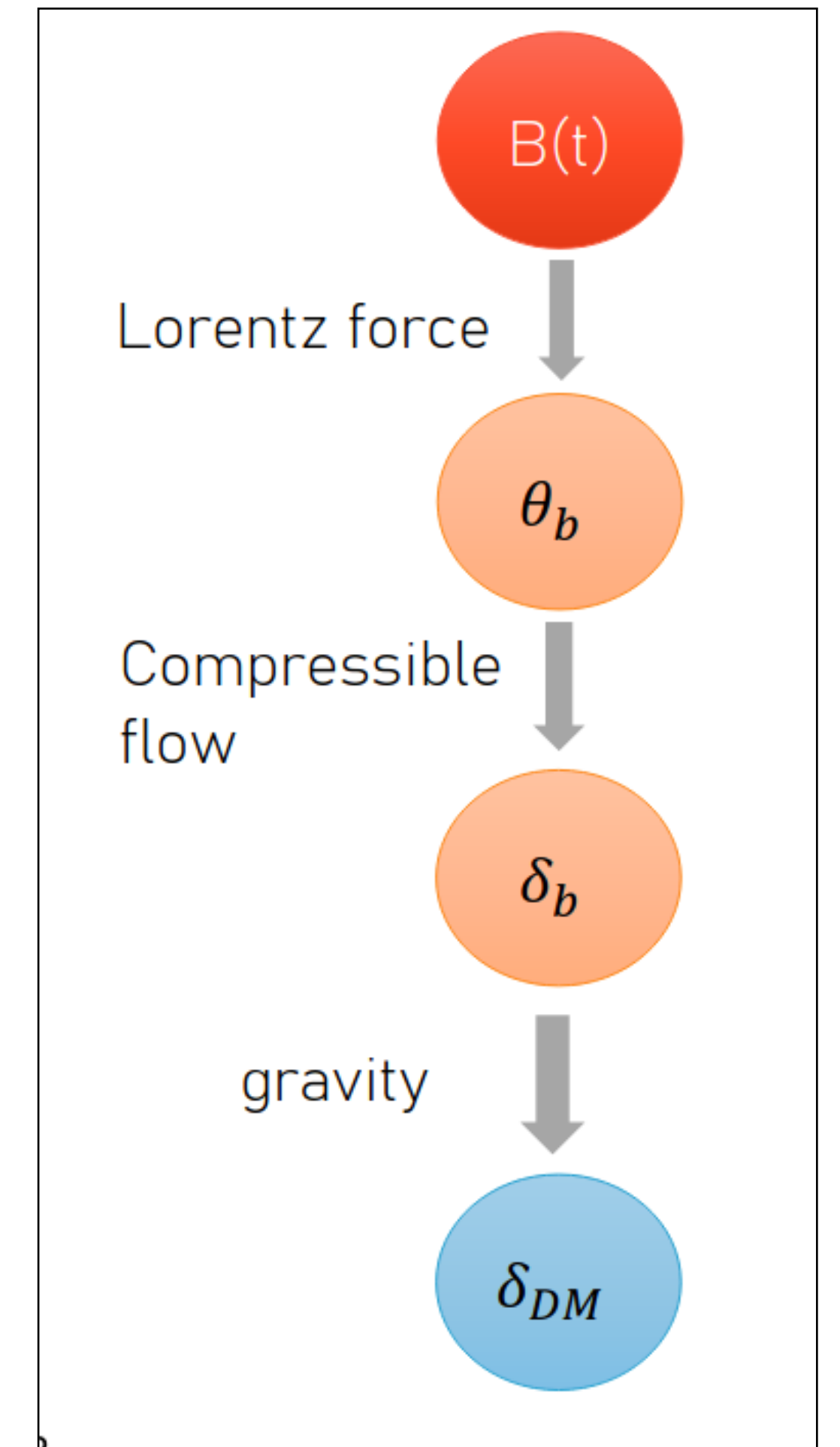
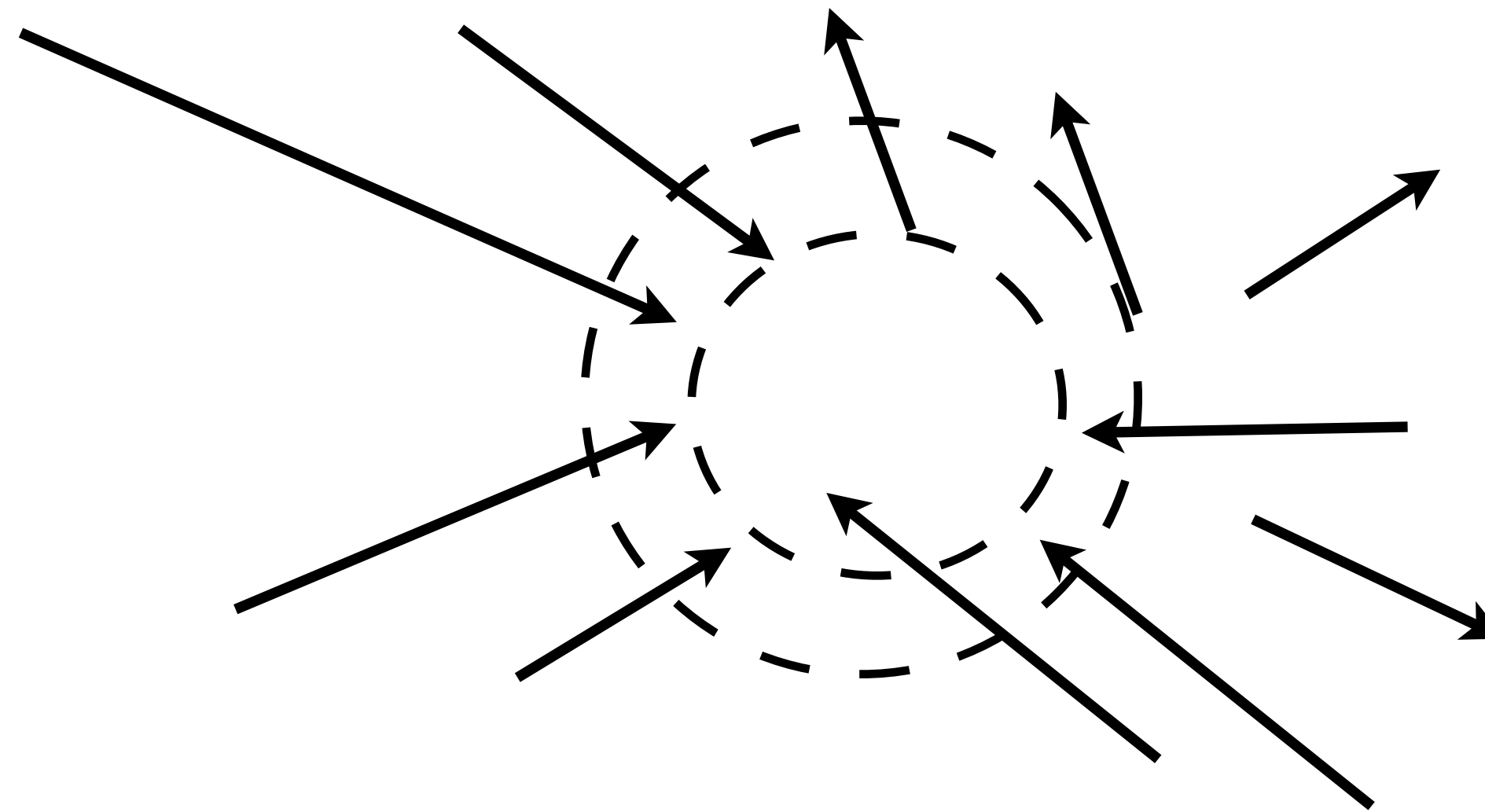
$$\vec{L}_B = \frac{1}{4\pi\rho_b a^4} (\nabla \times \vec{B}) \times \vec{B}$$

Lorentz force acting on a baryon plasma



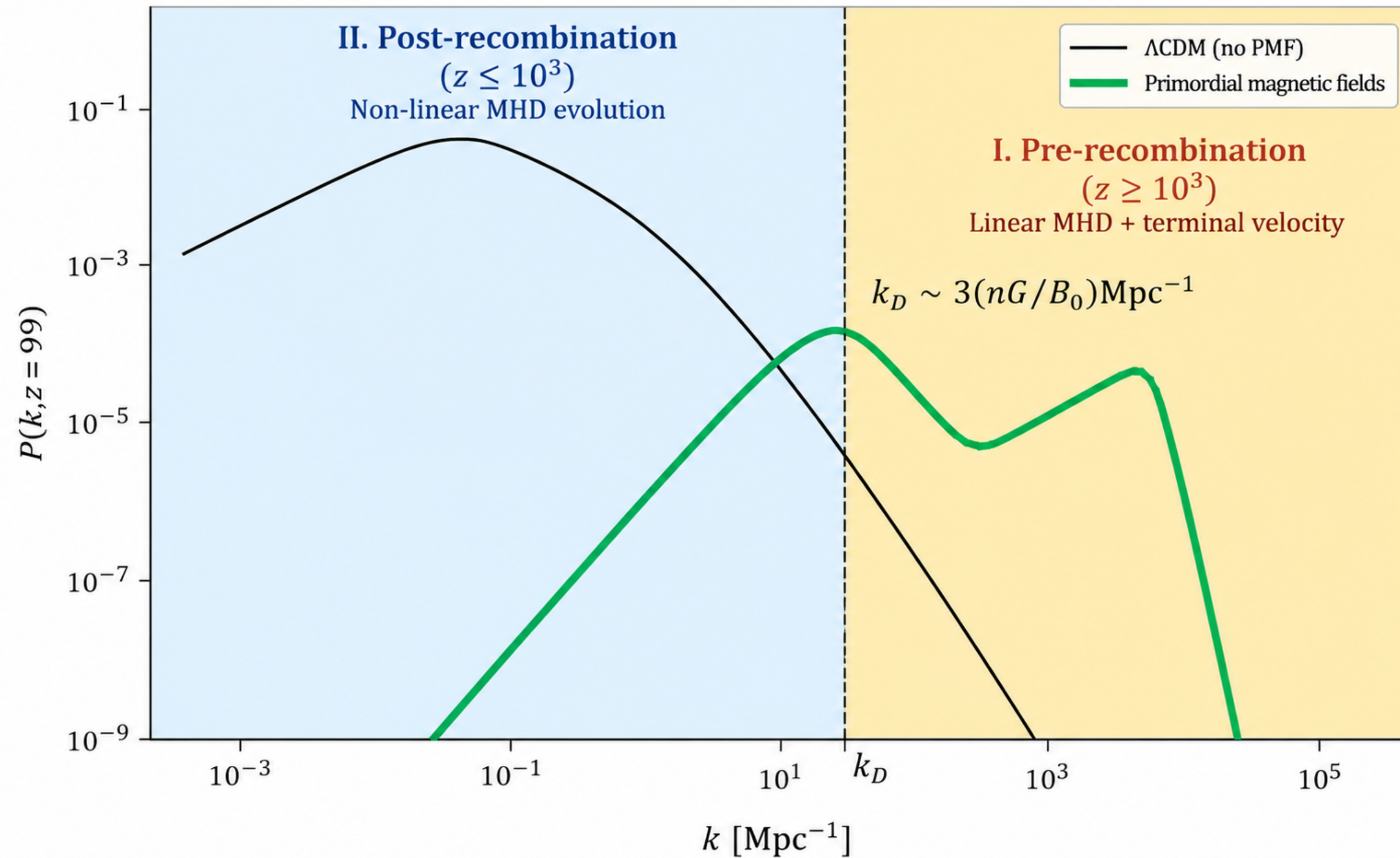
Primordial magnetic fields enhance density perturbations

$$\vec{L}_B = \underbrace{-\frac{1}{4\pi\rho_b a^4} \nabla \left(\frac{B^2}{2} \right)}_{\text{compressible component (magnetic pressure)}} + \underbrace{\frac{1}{4\pi\rho_b a^4} (\vec{B} \cdot \nabla) \vec{B}}_{\text{incompressible component (magnetic tension)}}$$



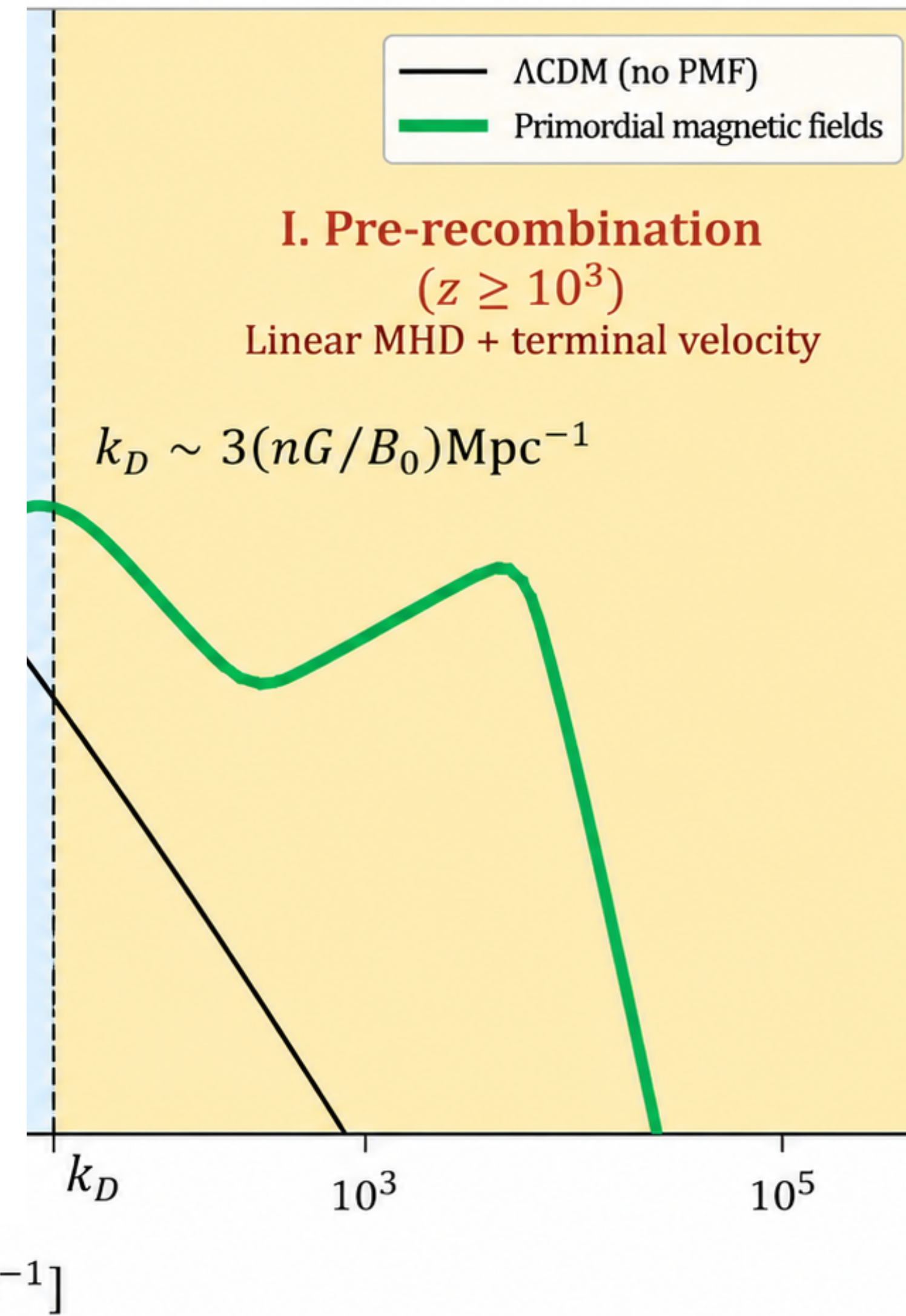
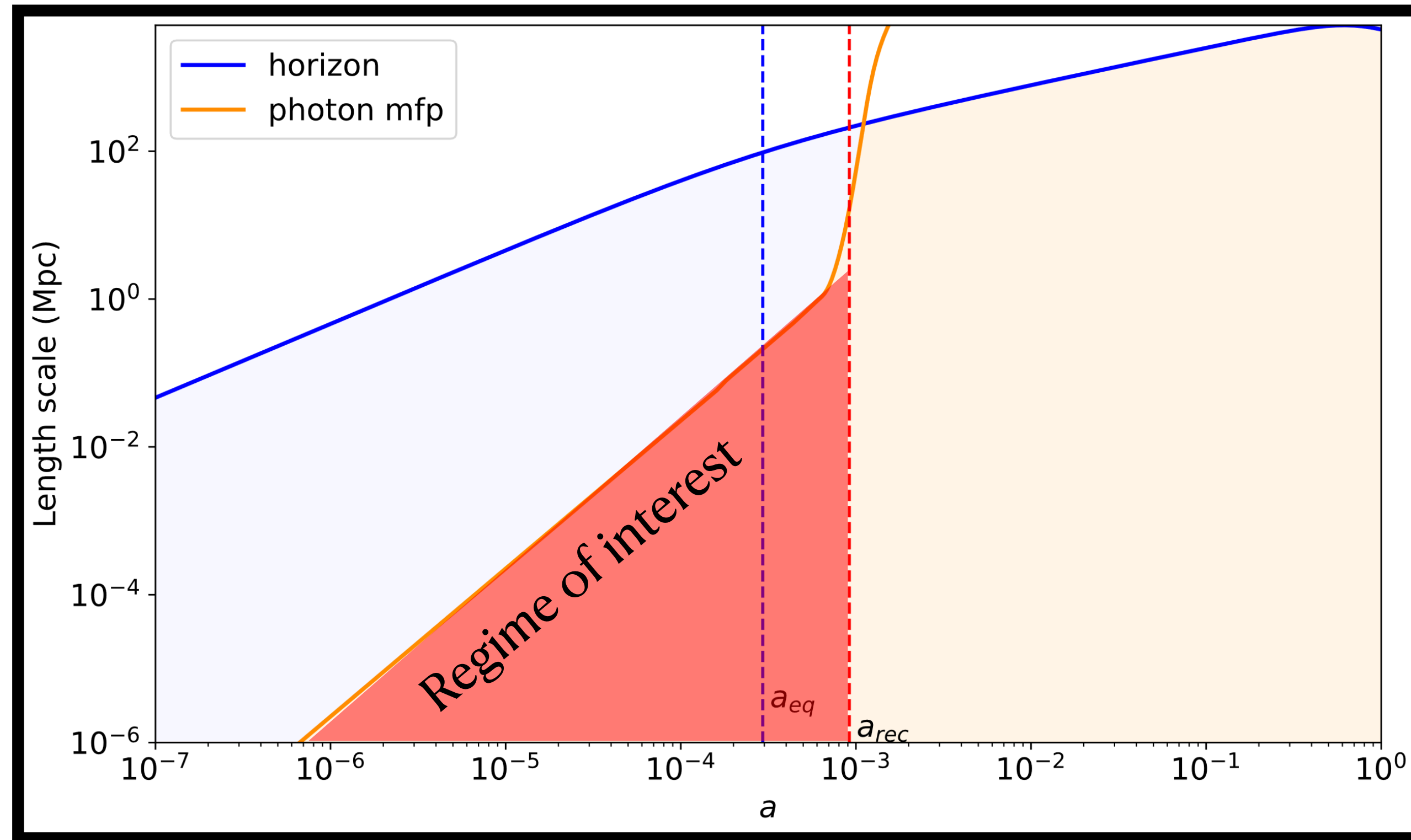
[Credits, illustration: Ralegankar]

Primordial magnetic fields impact structure in two different regimes



Pre-recombination regime

[Ralegankar, *Phys.Rev.Lett.* 131 (2023) 23, 231002]



Pre-recombination: Ideal MHD in the photon drag regime

$$\alpha = \frac{4\rho_\gamma}{3\rho_b\ell_\gamma}, \quad \frac{\alpha}{H} \approx 350 \left(\frac{a_{\text{rec}}}{a} \right)^2$$

Baryons experience a huge photon drag force

$$\frac{\partial v_b}{\partial t} + (H + \alpha)v_b + \cancel{\frac{(v_b \cdot \nabla)v_b}{a}} + \cancel{\frac{c_b^2 \nabla \delta_b}{a}} = \frac{L_B}{a} \implies av_b \approx \frac{L_B}{\alpha + H}$$

which makes flow laminar and dominates the contributions to the Euler equation

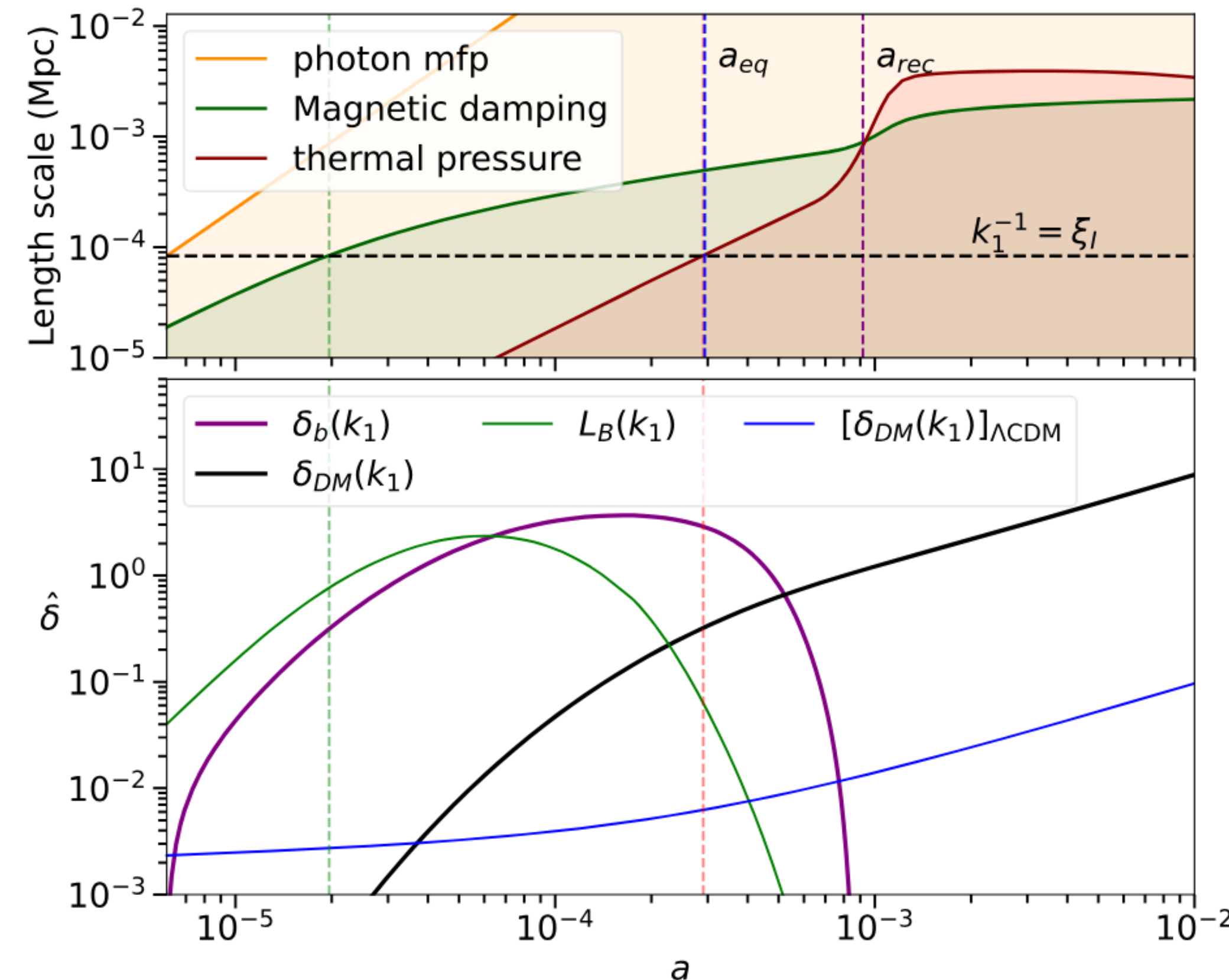
$$\frac{\partial P_B(k)}{\partial t} = -\Gamma(t) k^2 P_B(k)$$

Assuming Gaussianity

$$P_B(k, t) = P_B(k, t_i) e^{-k^2/k_D^2}, \quad a \frac{\partial}{\partial a} \left(\frac{1}{k_D^2} \right) = \frac{4V_A^2/3}{a^2 H(\alpha + H)}$$

[Ralegankar, *Phys.Rev.Lett.* 131 (2023) 23, 231002]

Pre-recombination: Ideal MHD in the photon drag regime

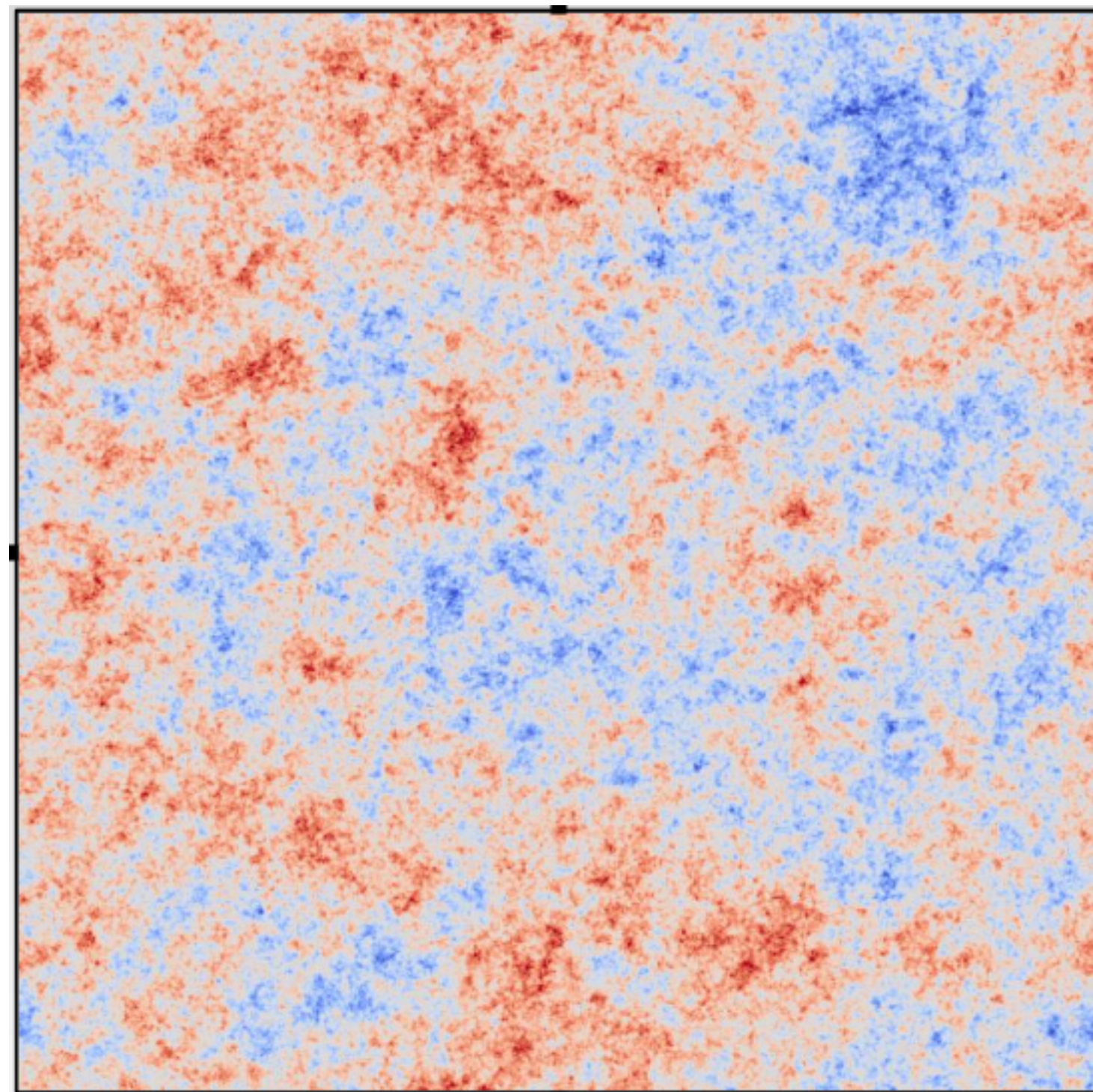


$$\frac{\partial^2 \delta_{DM}}{\partial y^2} + \frac{2+3y}{2y(y+1)} \frac{\partial \delta_{DM}}{\partial y} - \frac{3}{2y(y+1)} \frac{\Omega_{DM}}{\Omega_m} \delta_{DM} = \underbrace{\frac{3}{2y(y+1)} \frac{\Omega_b}{\Omega_m} \delta_b}_{\text{external source}}$$

[Ralegankar, *Phys.Rev.Lett.* 131 (2023) 23, 231002]

Minihalo formation

$$P_{\text{DM}}^{\text{tot}}(k, z) = P_{\text{DM}}^{\Lambda\text{CDM}}(k, z) + P_{\text{DM}}^B(k, z)$$



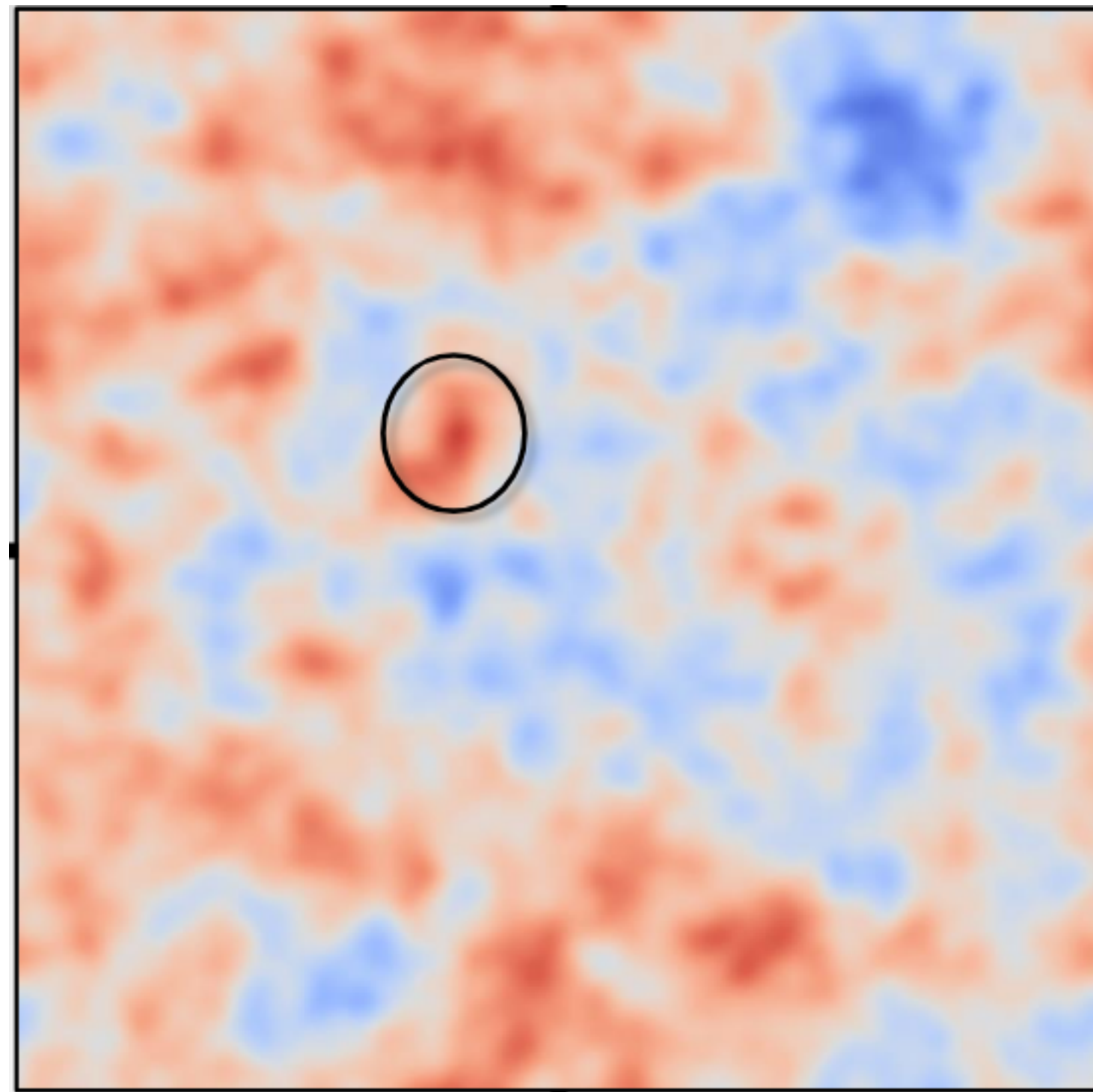
A random density field, expanding over time
and gravitationally amplified over time

The most dense dark matter structures in a LCDM cosmology

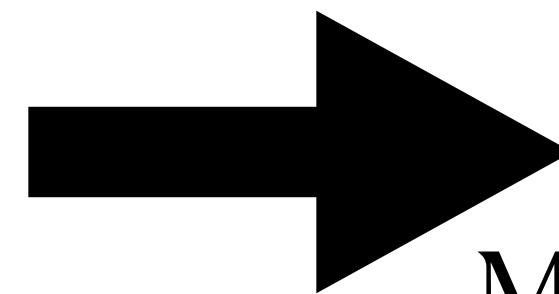
$$P_{\text{DM}}^{\text{tot}}(k, z) = P_{\text{DM}}^{\Lambda\text{CDM}}(k, z) + P_{\text{DM}}^B(k, z)$$

$$\times e^{-k^2/k_{\text{fs}}^2}$$

A random density field, expanding over time
and gravitationally amplified over time
Smooth on sufficiently small scales, e.g.
due to thermal motion of the dark matter



Local maxima in the density field are the first
places to gravitationally collapse



PROMPT CUSPS

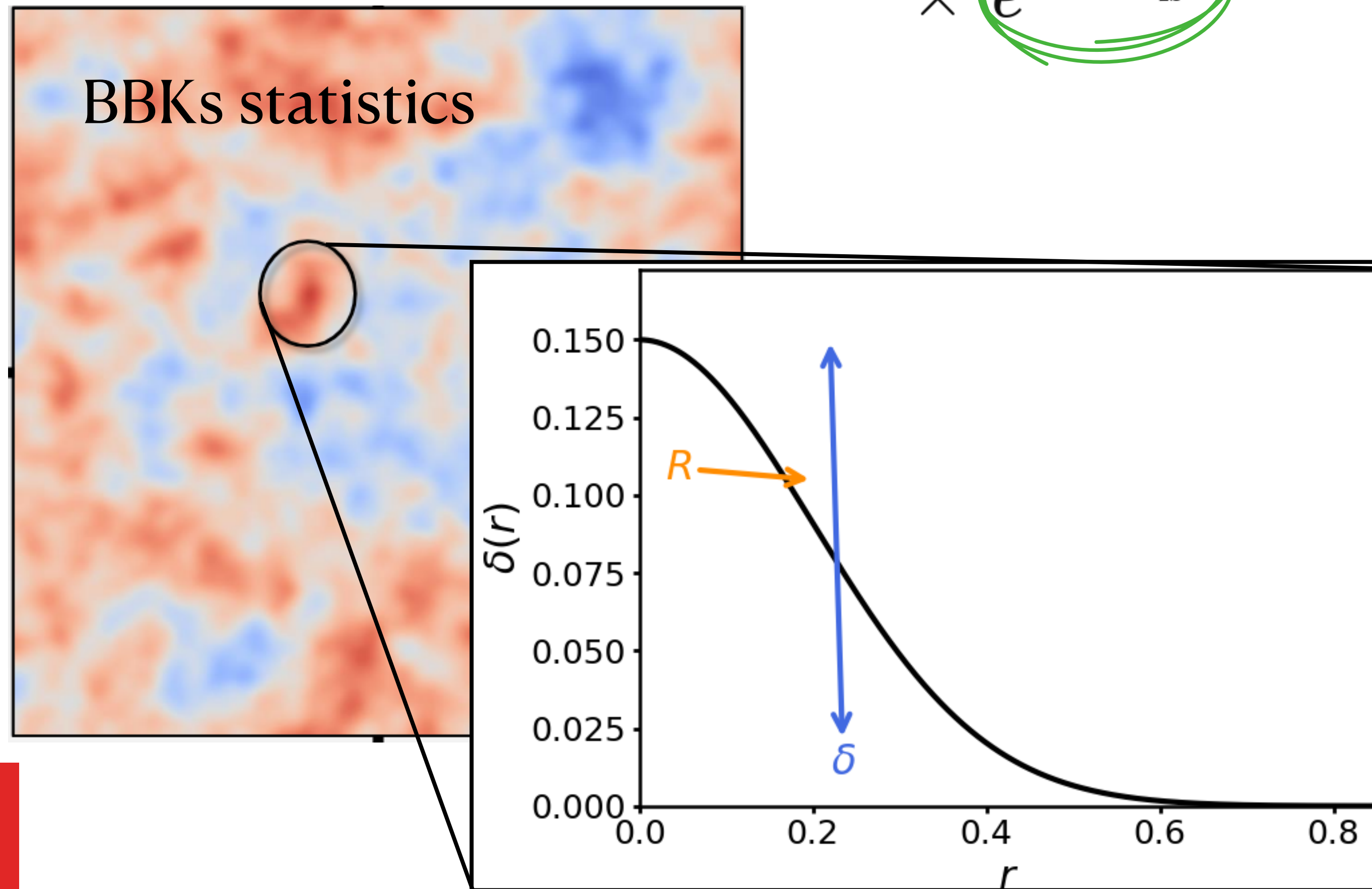
Most dense structures in a CDM cosmology!

The most dense dark matter structures in a LCDM cosmology

$$P_{\text{DM}}^{\text{tot}}(k, z) = P_{\text{DM}}^{\Lambda\text{CDM}}(k, z) + P_{\text{DM}}^B(k, z)$$

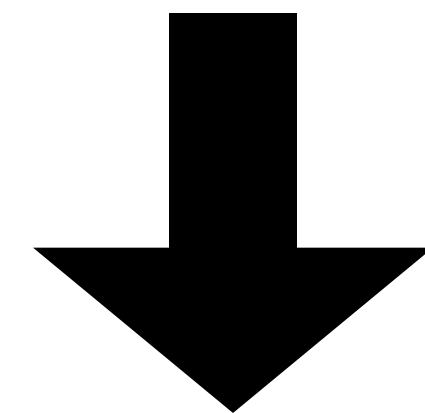
$$\times e^{-k^2/k_{\text{fs}}^2}$$

BBKs statistics



$$D(a_c) = \frac{\delta_c(e, p)}{\delta}$$

$$R \equiv \left| \frac{\delta}{\nabla^2 \delta} \right|^{1/2}$$



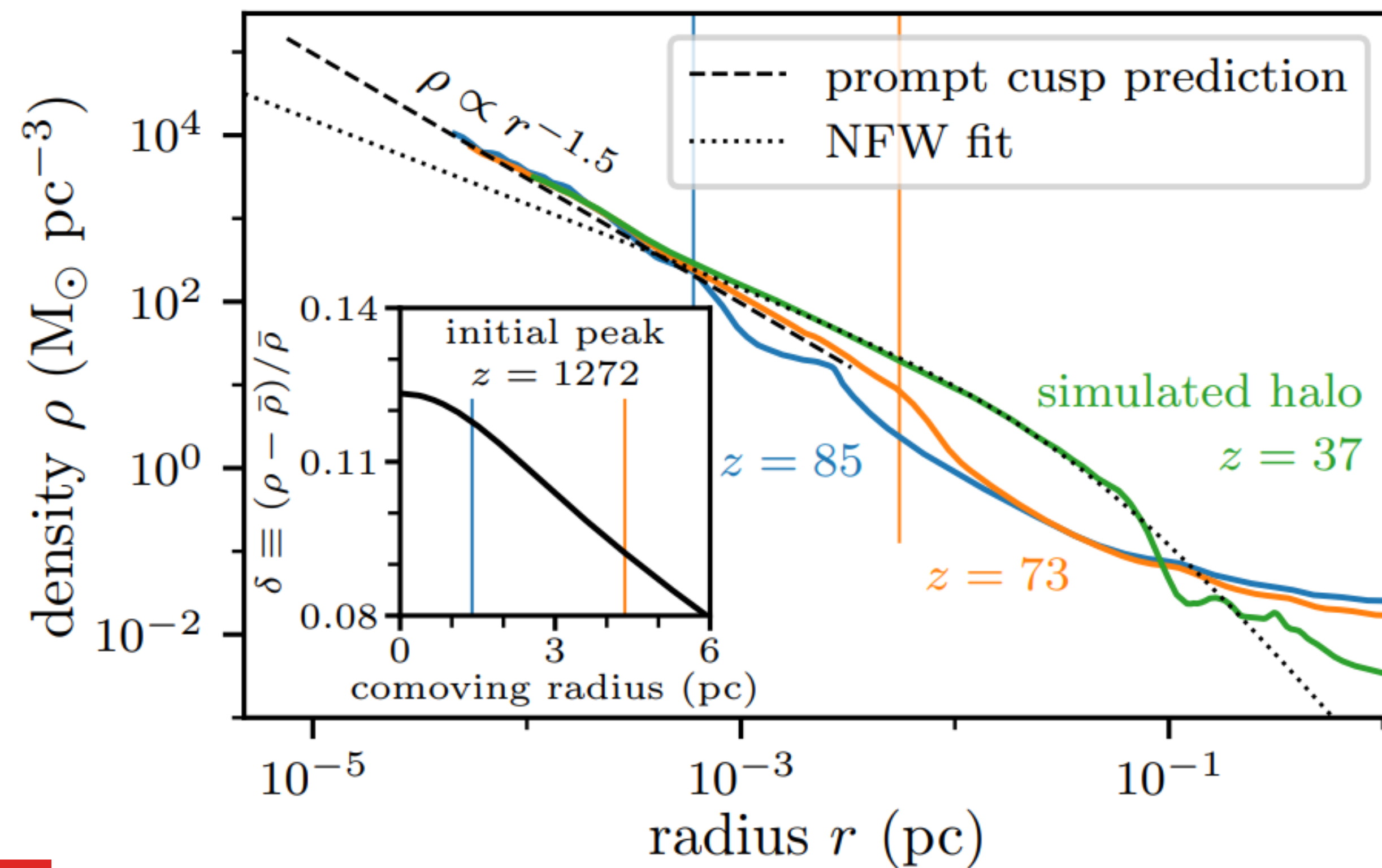
$$A \simeq 24 \bar{\rho}(a_c) (a_c R)^{3/2}$$

$$\rho(r) = A r^{-3/2}$$

The most dense dark matter structures in a LCDM cosmology

$$P_{\text{DM}}^{\text{tot}}(k, z) = P_{\text{DM}}^{\Lambda\text{CDM}}(k, z) \times e^{-k^2/k_{\text{fs}}^2}$$

[Delos, White, *JCAP* 10 (2023) 008]



~85% of the initial
density peaks collapse into cusps

A fraction of 0.4 - 0.6 is expected
to survive tidal disruption

Cusps extend from
 r_{core} to r_{cusp}

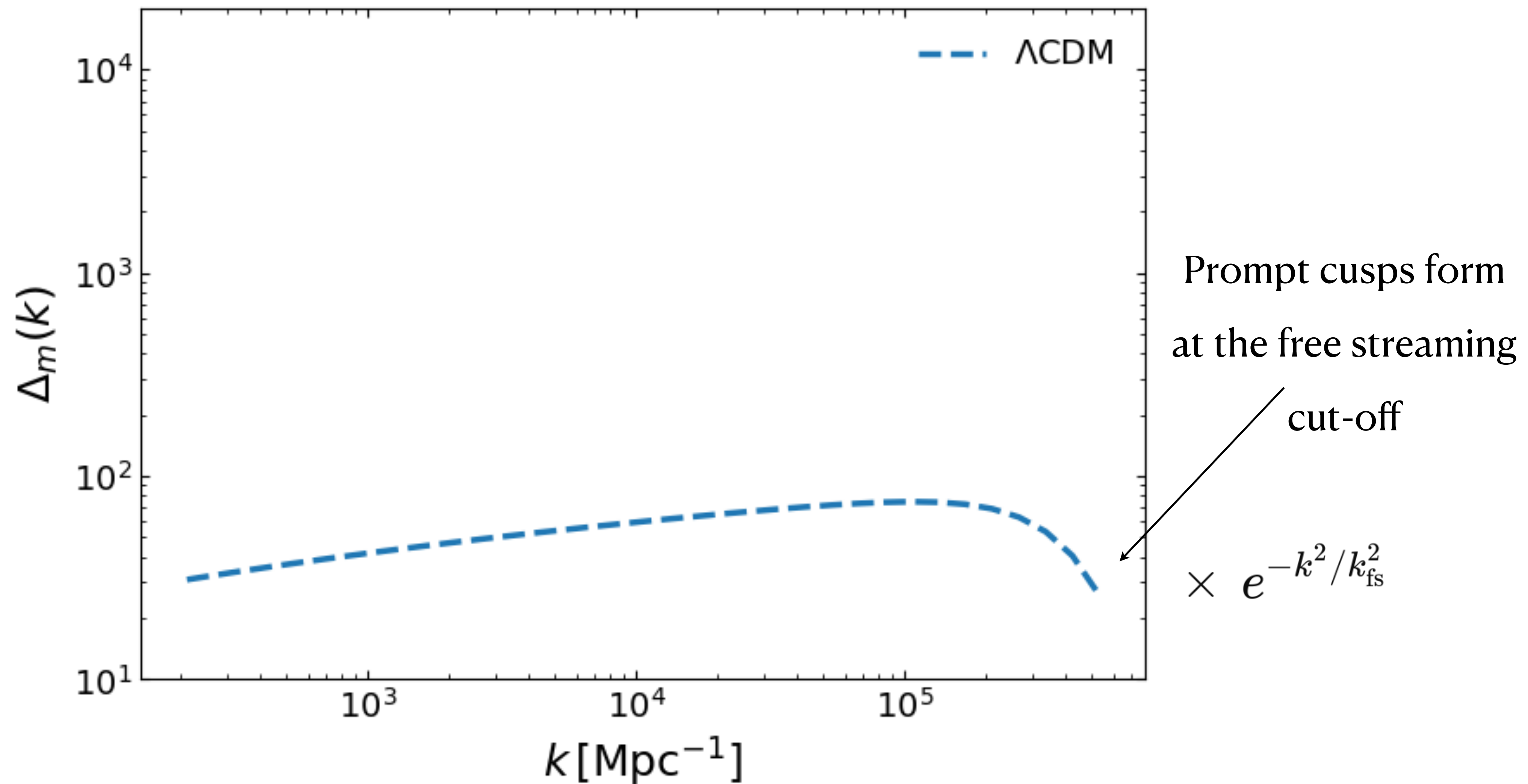
$$r_{\text{core}} \simeq 0.34 G^{-2/3} \left(\frac{m_{\chi}}{T_{\text{kd}}} \right)^{-2/3} \bar{\rho}(a_{\text{kd}})^{-4/9} A^{-2/9}$$

phase space considerations

$$r_{\text{cusp}} \simeq 0.11 a_{\text{coll}} R$$

simulations

The most dense dark matter structures in a LCDM cosmology

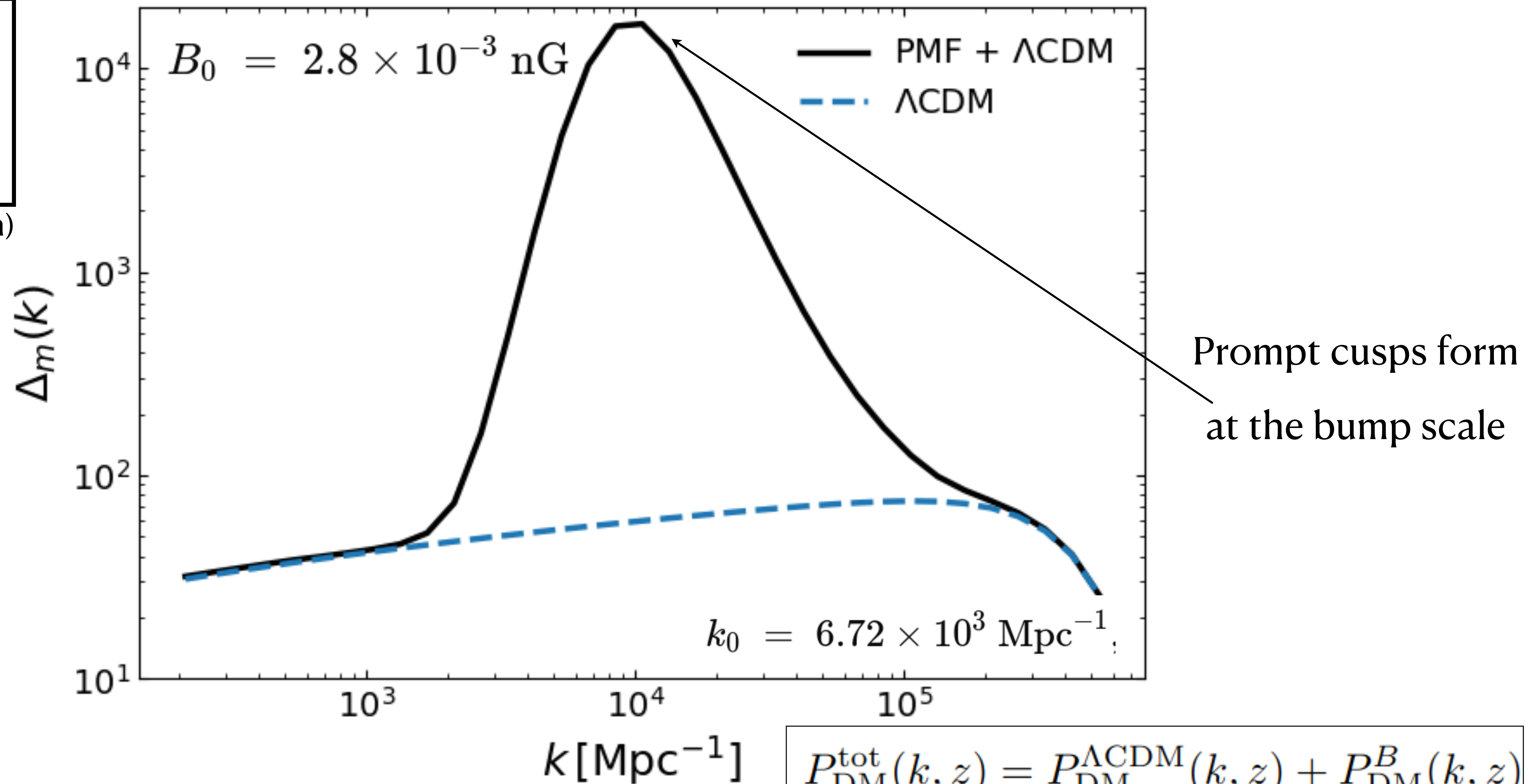


The most dense dark matter structures in a PMF cosmology

Illustrative example:

$$\begin{aligned}\rho_B &= \rho_{\text{SM}} \\ \xi &= (aH)^{-1} \\ T_{\text{PT}} &= 150 \text{ MeV}\end{aligned}$$

(toy model PT-production)

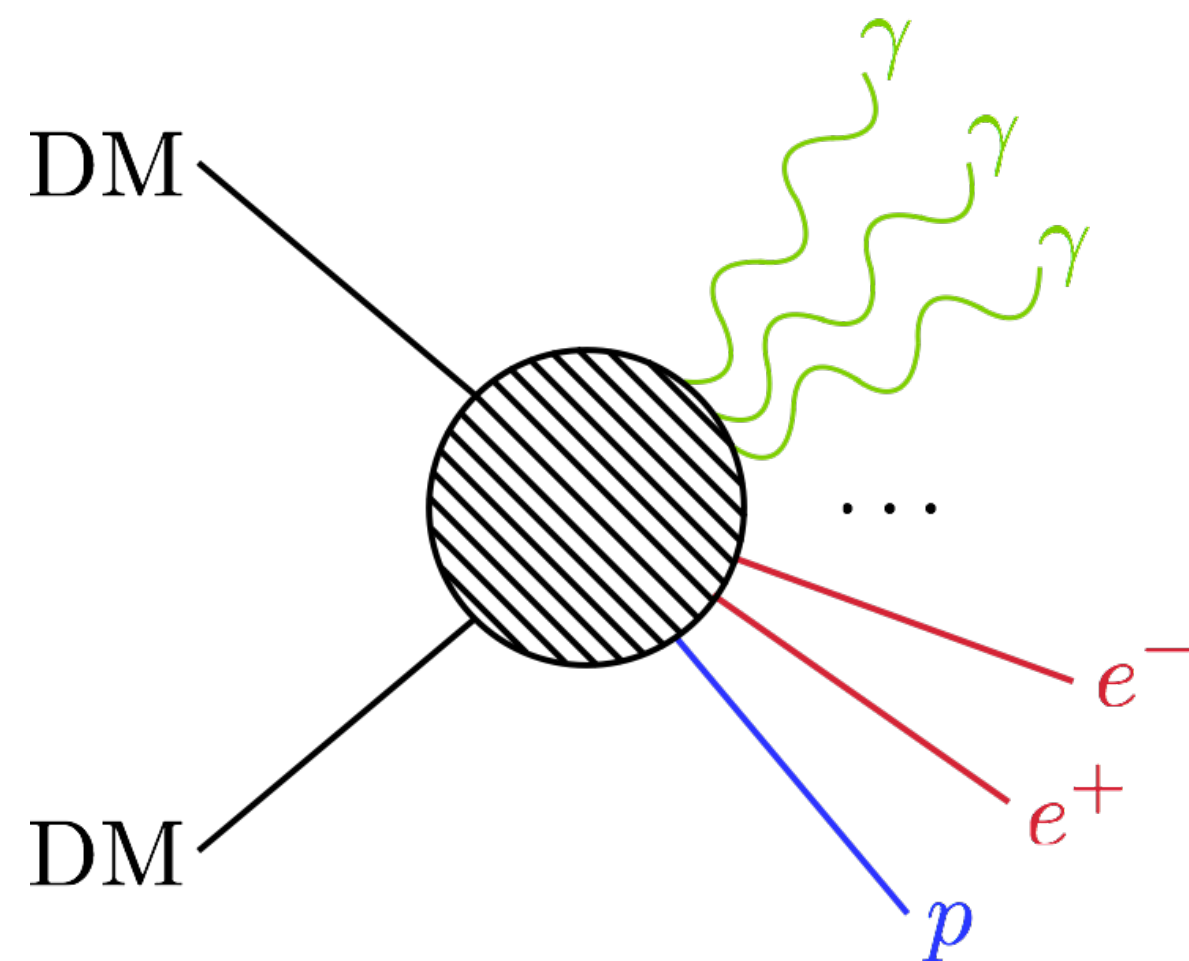


$$P_{\text{DM}}^{\text{tot}}(k, z) = P_{\text{DM}}^{\Lambda\text{CDM}}(k, z) + P_{\text{DM}}^B(k, z)$$

$$\times e^{-k^2/k_{\text{fs}}^2}$$

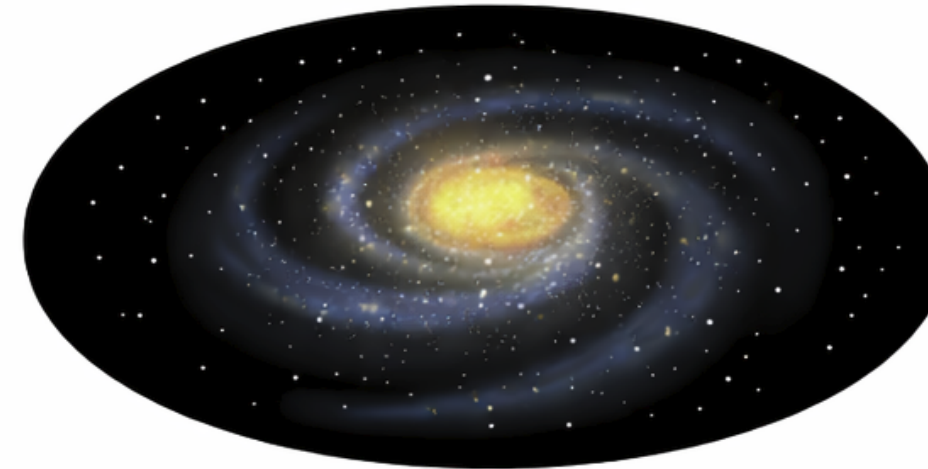
Self-annihilating dark matter

Pair-produced in the early universe



Dark matter annihilation $\propto \rho^2$

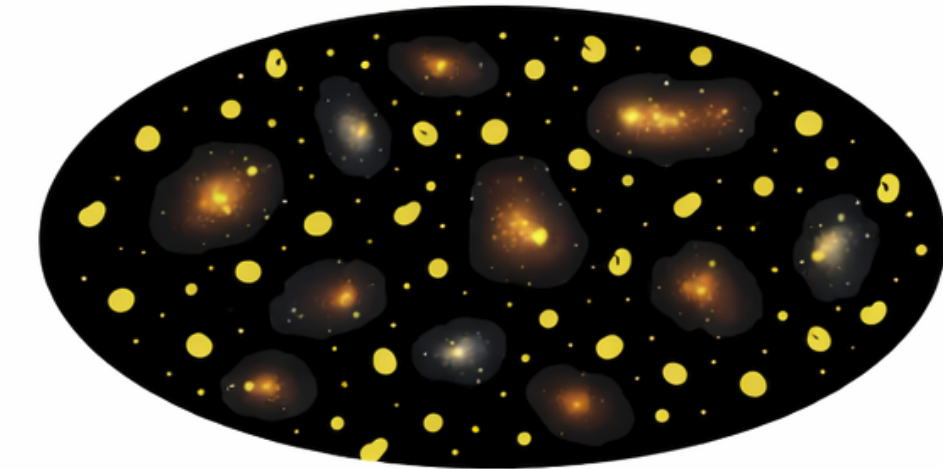
Smooth halo



$$J \propto \int \rho^2 dV \rightarrow \text{dSph}$$

- High central density
- Small total mass
- Optimized for smooth halos

Cusps



$$J \propto M_{\text{tot}} \rightarrow \text{clusters}$$

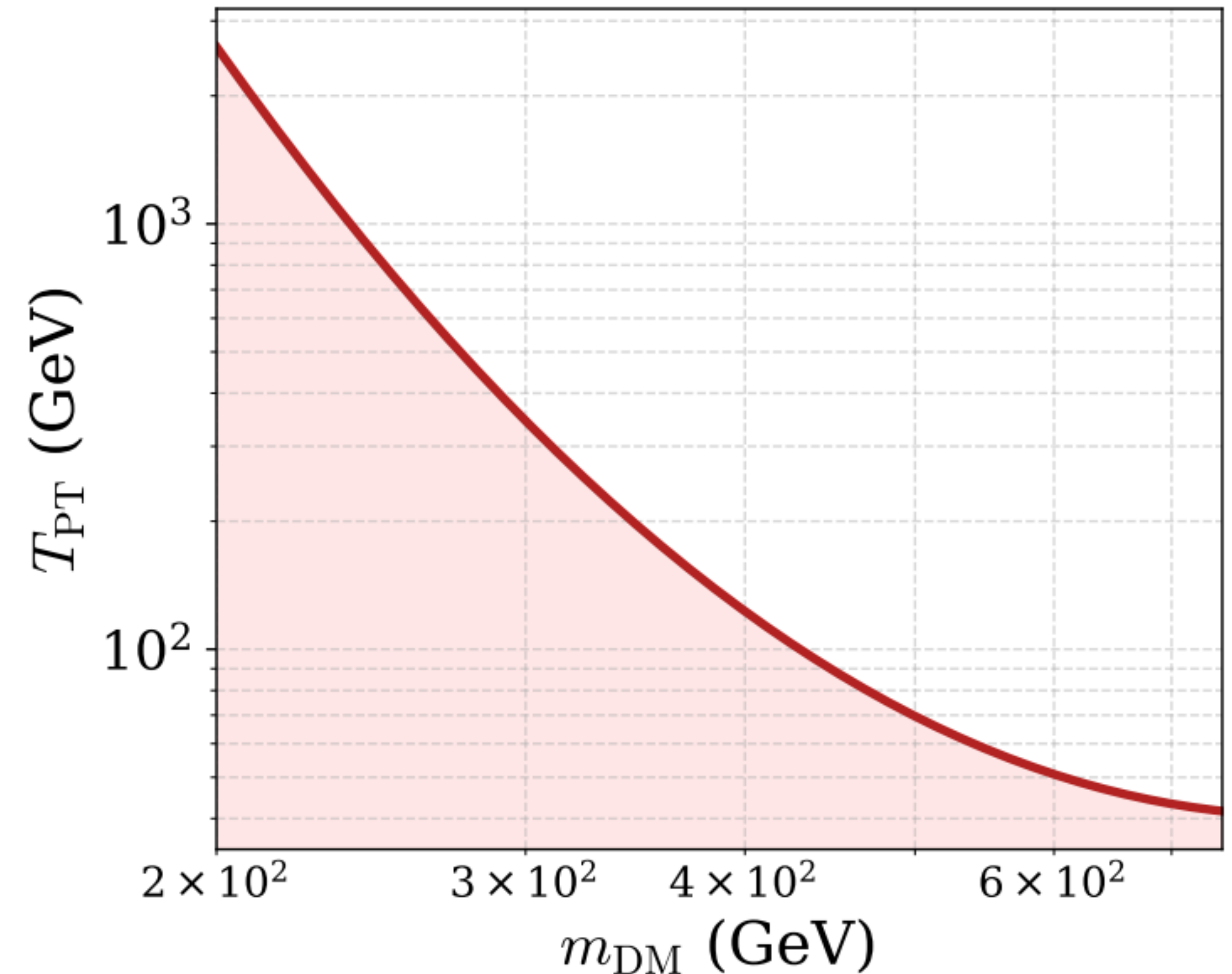
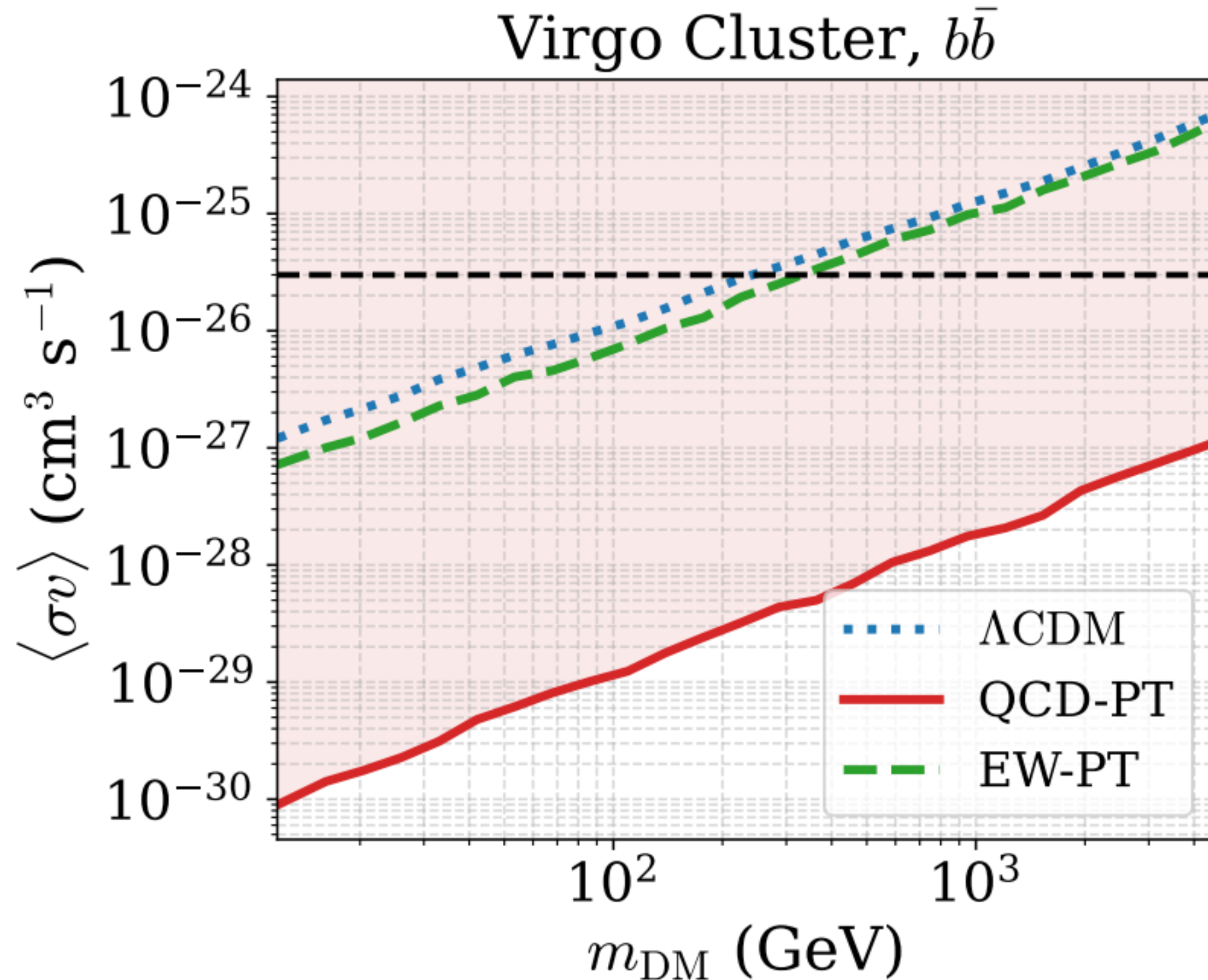
- Many dense cusps
- Each cusp = point source
- Signal $\propto$ total mass

$$\frac{dJ}{d\Omega} = \int d\ell \rho(r) [\rho(r) + f_{\text{surv}} f_{\text{tidal}}(r) \rho_{\text{eff},0}]$$

$$\rho_{\text{eff},0} \equiv \frac{\int_{\text{cusps}} \rho^2 dV}{M} = n_{\text{peaks}} \langle j \rangle / \bar{\rho}_0$$

Results - Toy model for phase transition magnetic fields

[Olea-Romacho, Fairbairn, Ralegankar, *SciPost Phys.* 20 (2026) 044]



Production:

$$\rho_B = \rho_{\text{SM}}$$

$$\xi = (aH)^{-1}$$

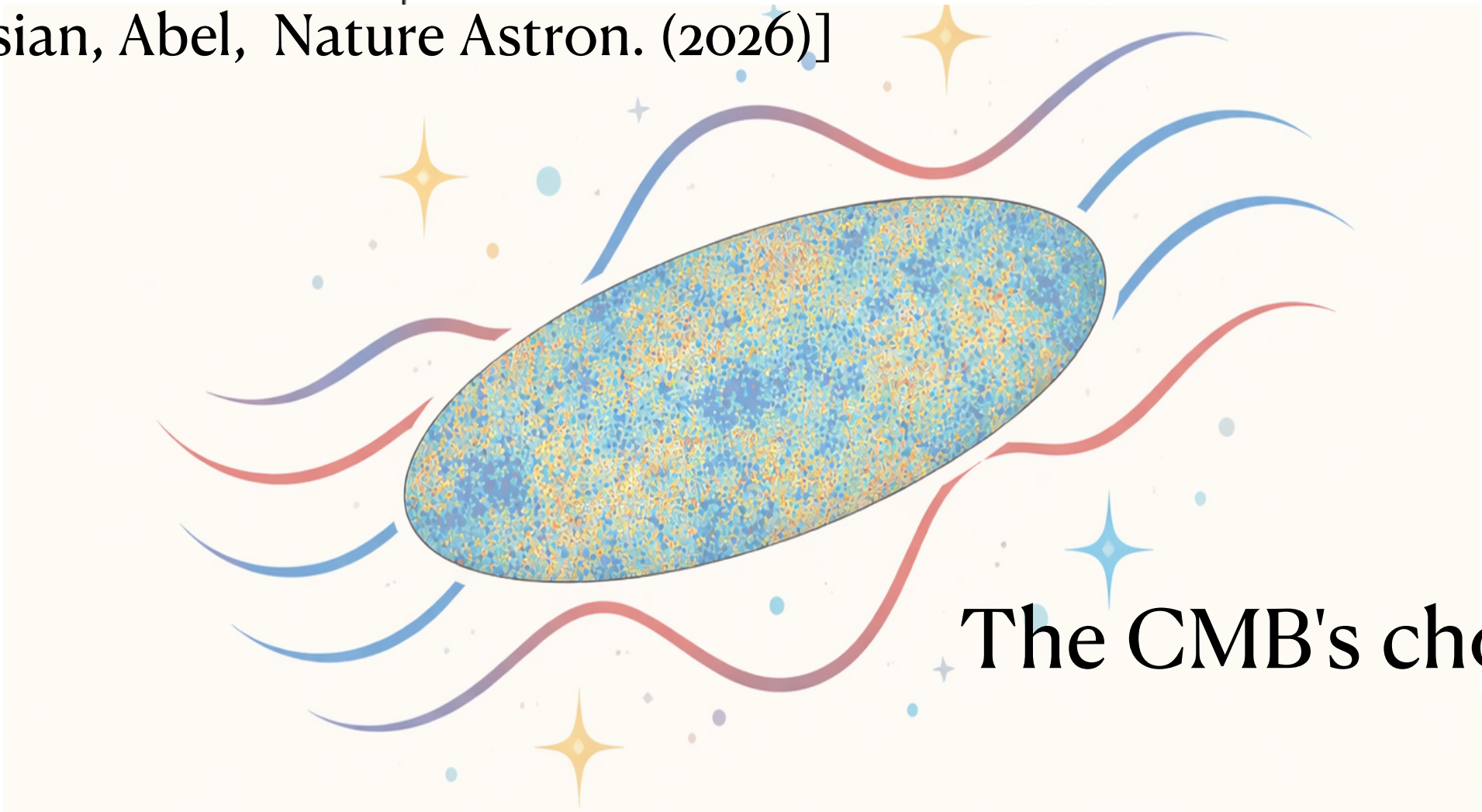
QCD: $B_0 = 2.8 \times 10^{-3} \text{ nG}$
 $k_0 = 6.72 \times 10^3 \text{ Mpc}^{-1}$

EWPT: $B_0 = 3.06 \times 10^{-5} \text{ nG}$
 $k_0 = 1.76 \times 10^6 \text{ Mpc}^{-1}$

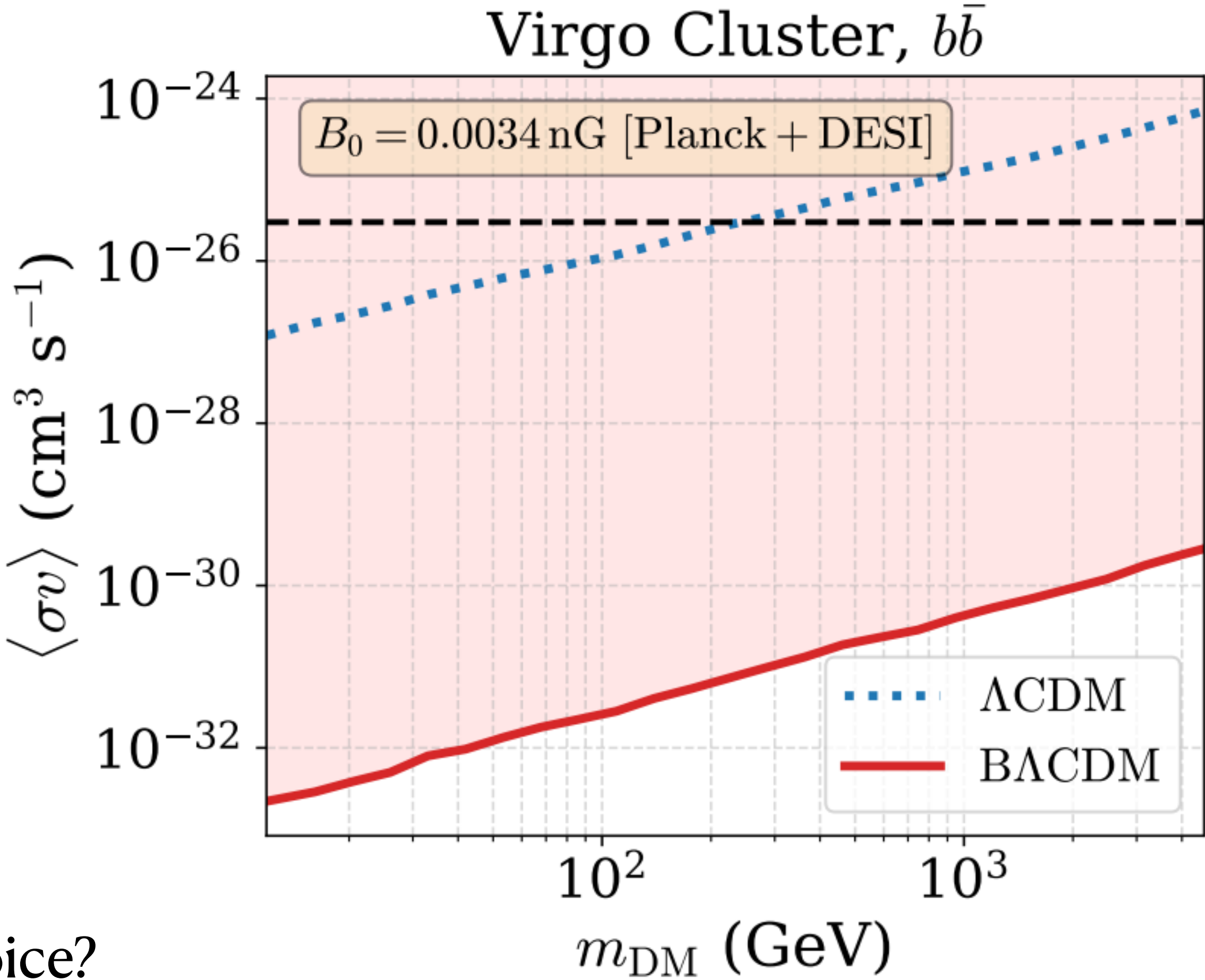
Cosmologically motivated PMFs disfavour standard WIMPS?

	$\chi^2_{b\Lambda\text{CDM}} - \chi^2_{\Lambda\text{CDM}}$	median & 68% CI
PL	-1.7	$0.0023^{+0.0048}_{-0.0022}$
PL+DESI	-4.7	$0.0042^{+0.0021}_{-0.0028}$
PL+DESI+PP	-3.83	$0.0038^{+0.0017}_{-0.0028}$
PL+DESI+ACT	-5.3	$0.0030^{+0.0012}_{-0.0021}$
PL+DESI+SPT	-5.2	$0.0036^{+0.0015}_{-0.0023}$
PL+DESI+PP+ M_b	-15.25	$0.0096^{+0.0029}_{-0.0036}$
PL+DESI+ACT+PP+ M_b	-11.8	0.0064 ± 0.0021
PL+DESI+SPT+PP+ M_b	-17.8	$0.0074^{+0.0018}_{-0.0027}$

[Jedamzik, Pogosian, Abel, Nature Astron. (2026)]



[Olea-Romacho, Fairbairn, Ralegankar, SciPost Phys. 20 (2026) 044]



Reconnection: $\xi_0 \simeq 7.5 \times 10^1 \text{ pc.}$

Independent of microphysics...gravitational probes

Wide binaries in ultra-faint dwarf galaxies as a probe of extended dark matter objects

[Olea-Romacho, 2607.18185]

Why wide stellar binaries

Separations of 10^4 au: barely bound, $v_{\text{orb}} \lesssim 0.3 \text{ km s}^{-1}$.

Every flyby random-walks their internal energy. Enough walks and they unbind.

A survival count is a perturber count.

Why an ultra-faint dwarf

Boötes I: $M_{\star}/M_{\text{DM}} \simeq 10^{-5} - 10^{-4}$

Dark-matter dominated, old stellar population, almost no ordinary baryonic perturbers to confuse the signal.

$\rho_{\text{DM}} = 0.158 M_{\odot} \text{ pc}^{-3}$, $t_{\text{age}} = 13 \text{ Gyr}$

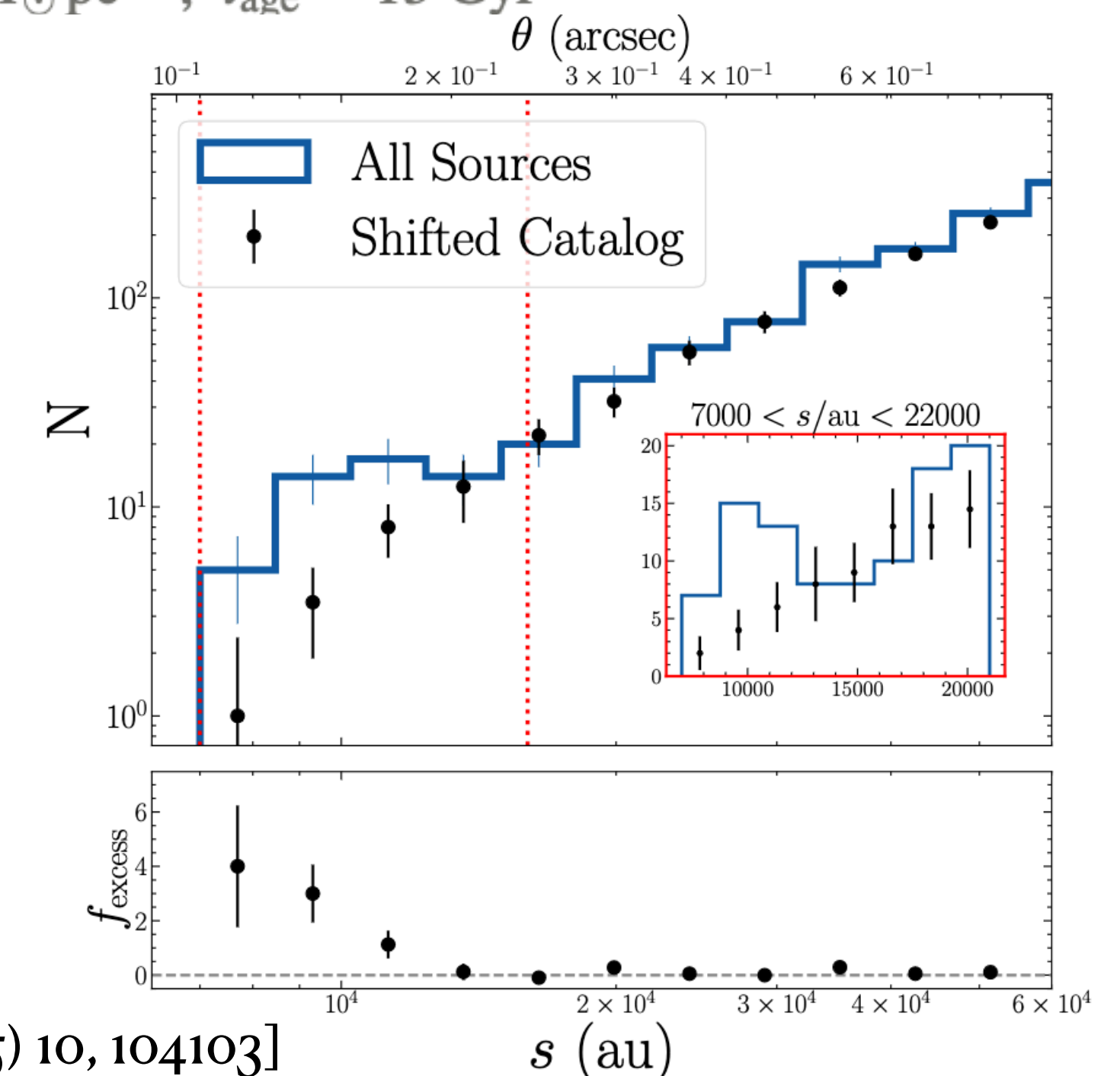
The sample:

52 wide binary candidates
JWST/NIRCam

43 with $s > 9000$ au

Half assumed genuine: 21

Expected 59; stellar flybys
account for observed



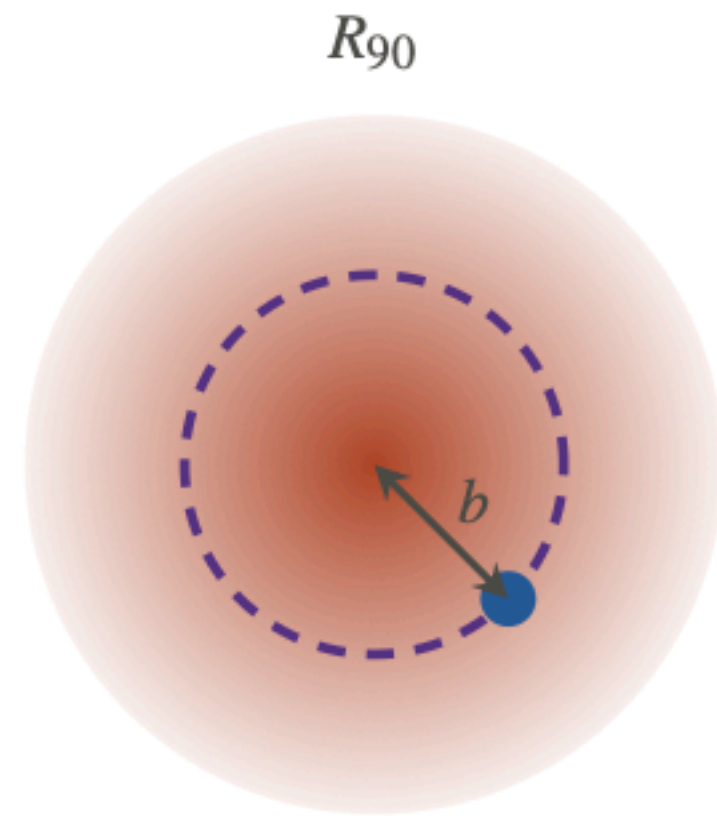
[Shariat et al, Publ.Astron.Soc.Pac. 137 (2025) 10, 104103]

Wide binaries in ultra-faint dwarf galaxies

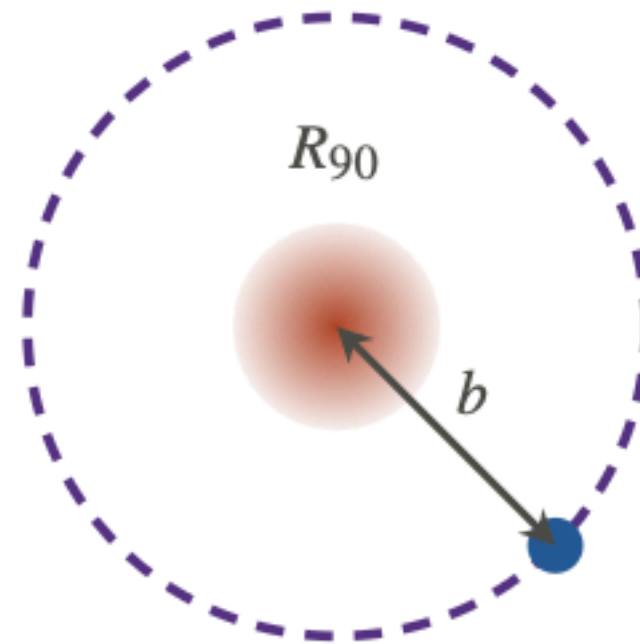
[Olea-Romacho, 2607.18185]

What if the perturber is not a point?

$$\underbrace{\frac{2GM}{bV}}_{\text{point mass}} \longrightarrow \underbrace{\frac{2GM_{2D}(b)}{bV}}_{\text{extended object}}$$



penetrating



distant

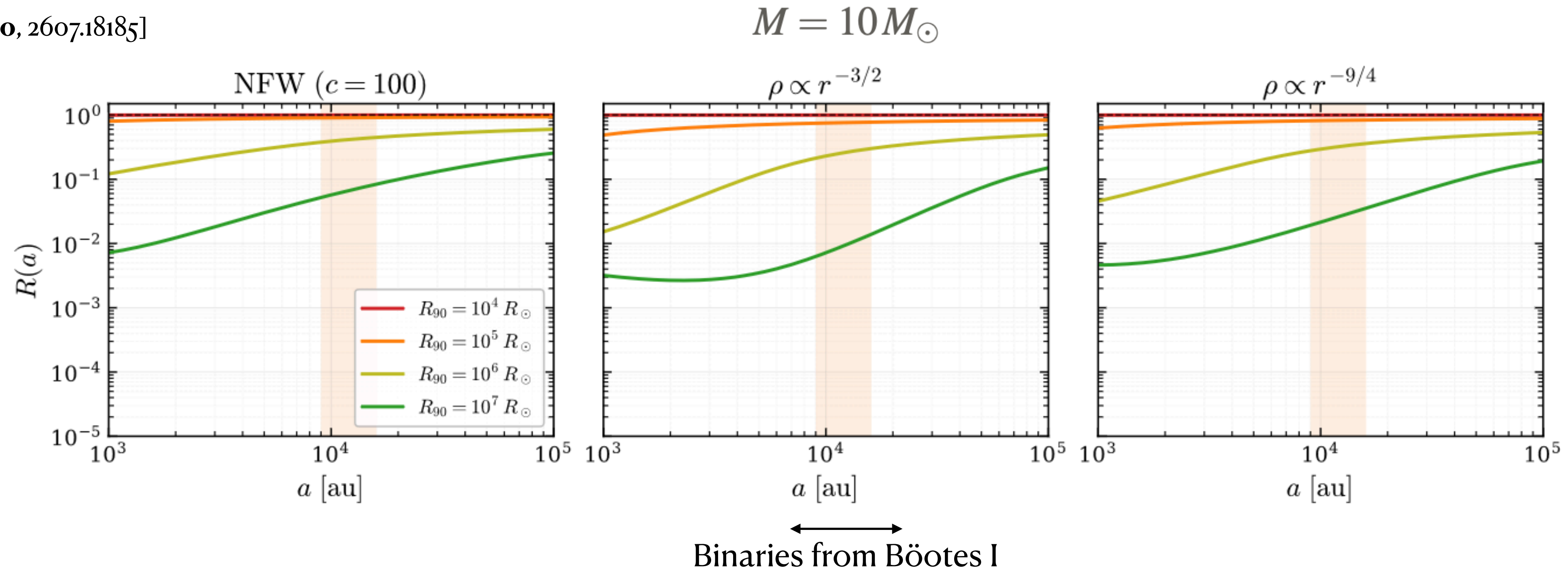
$$M_{2D}(R) = \int_0^R 4\pi r^2 \rho(r) w(r, R) dr$$

$$w(r, R) = \begin{cases} 1, & r \leq R, \\ 1 - \sqrt{1 - R^2/r^2}, & r > R, \end{cases}$$

w = fraction of a shell of radius r inside the cylinder

Wide binaries in ultra-faint dwarf galaxies

[Olea-Romacho, 2007.18185]



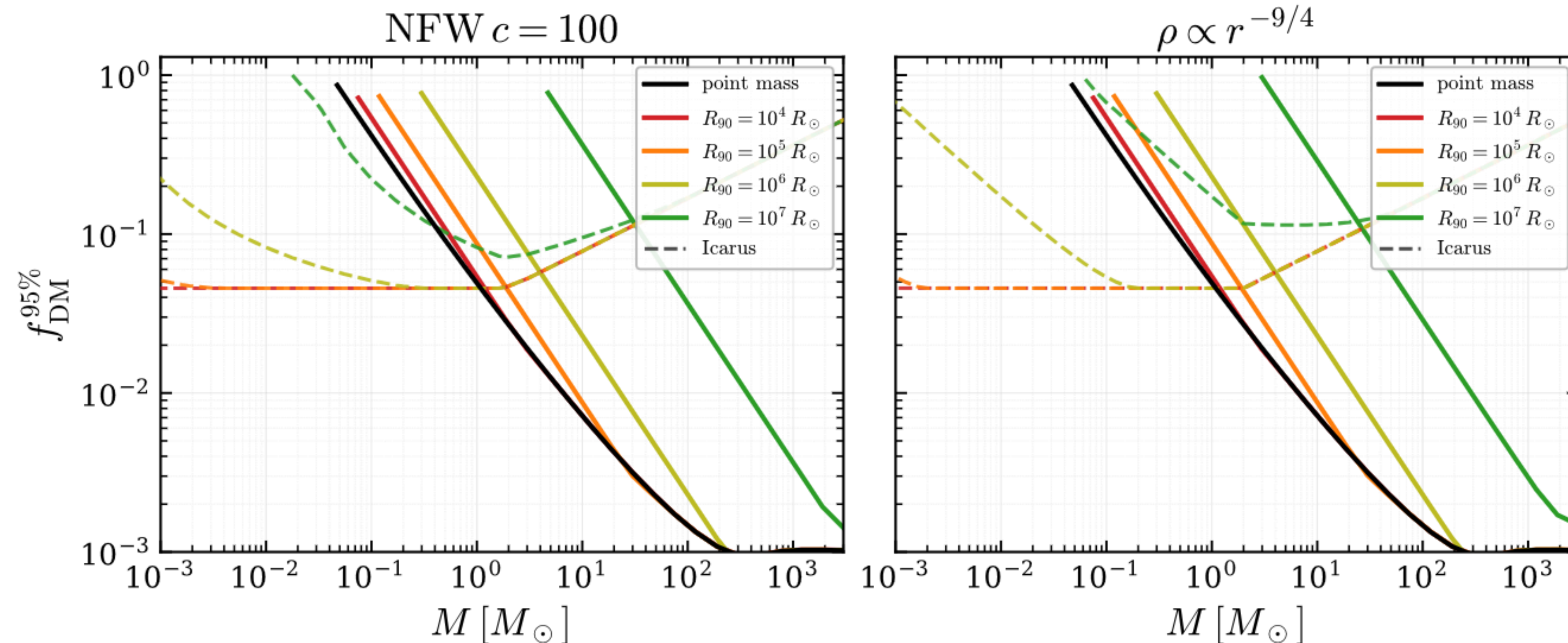
$$\mathcal{R}(a) = \frac{J_{\text{ext}}(a)}{J_{\text{point}}(a)} \quad \text{the fraction of the point-mass heating rate that a binary of separation } a \text{ receives}$$

Red is flat at 1 — $R_{90} < b_{90}$: never resolved, so *exactly* like a black hole

Deeper with size — once resolved, less enclosed mass *and* the two kicks cancel

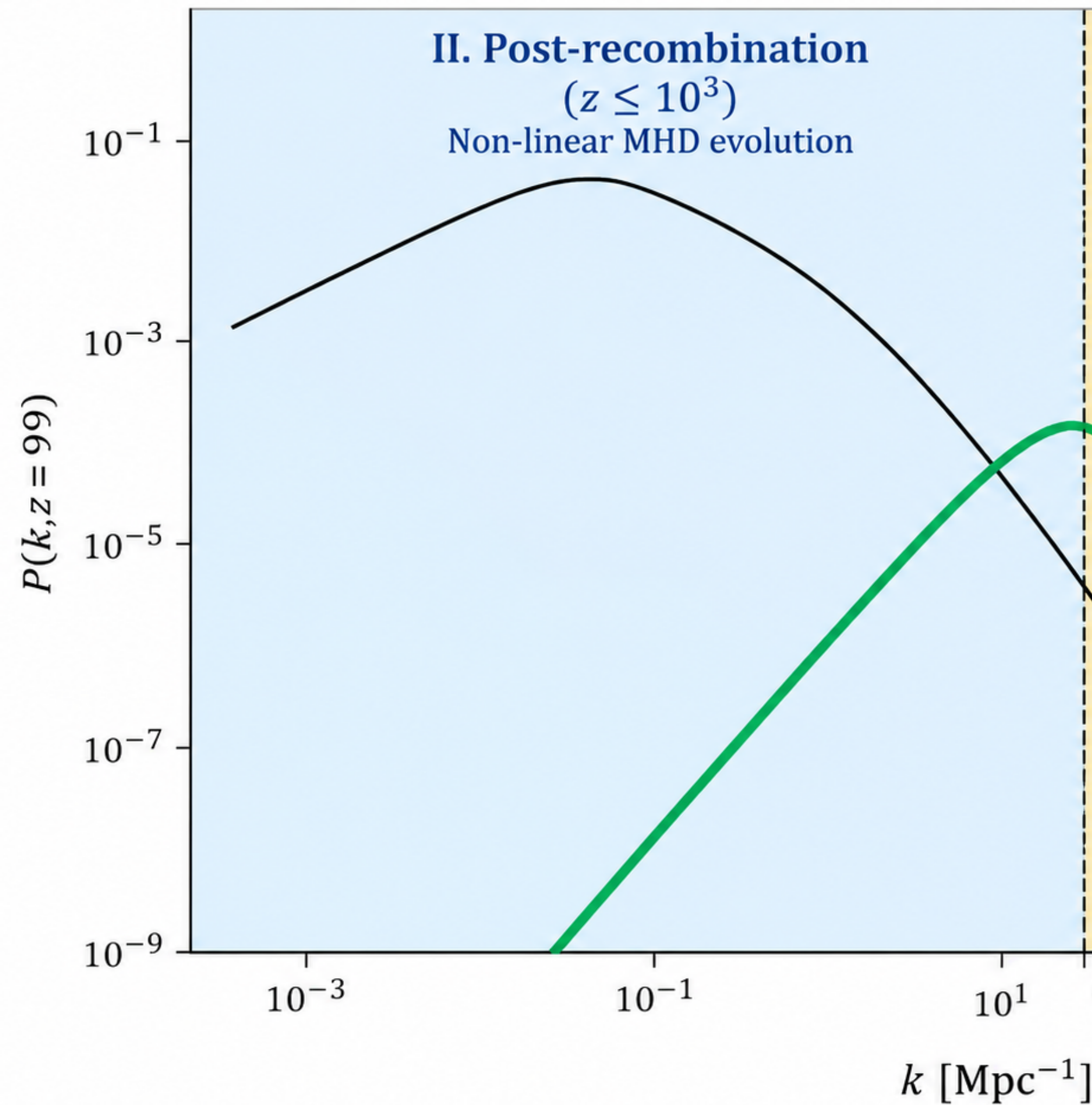
Rising with a — wider binaries reach further out, enclosing more of the mass

Limits on extended objects from wide binaries in UFDs



- Objects modelled with M , R_{90} and type of profile
- Black line: compact objects tend to the point mass limit
- Size weakens the effect

Post-recombination regime



Post-recombination: the photon drag is gone

$$\alpha = \frac{4\rho_\gamma}{3\rho_b \ell_\gamma} \longrightarrow 0 \quad \implies \quad \alpha \ll H \quad \implies \quad \vec{v}_b \text{ no longer slaved to } \vec{L}_B$$

Euler — the fluid goes turbulent

$$\frac{\partial \vec{v}_b}{\partial t} + (H + \cancel{\alpha})\vec{v}_b + \underbrace{\frac{(\vec{v}_b \cdot \nabla)\vec{v}_b}{a}}_{\text{convective: mode mixing}} + \frac{c_b^2 \nabla \delta_b}{a} = \underbrace{\frac{\vec{L}_B}{a}}_{\text{Lorentz force}} - \frac{\nabla \phi}{a}$$

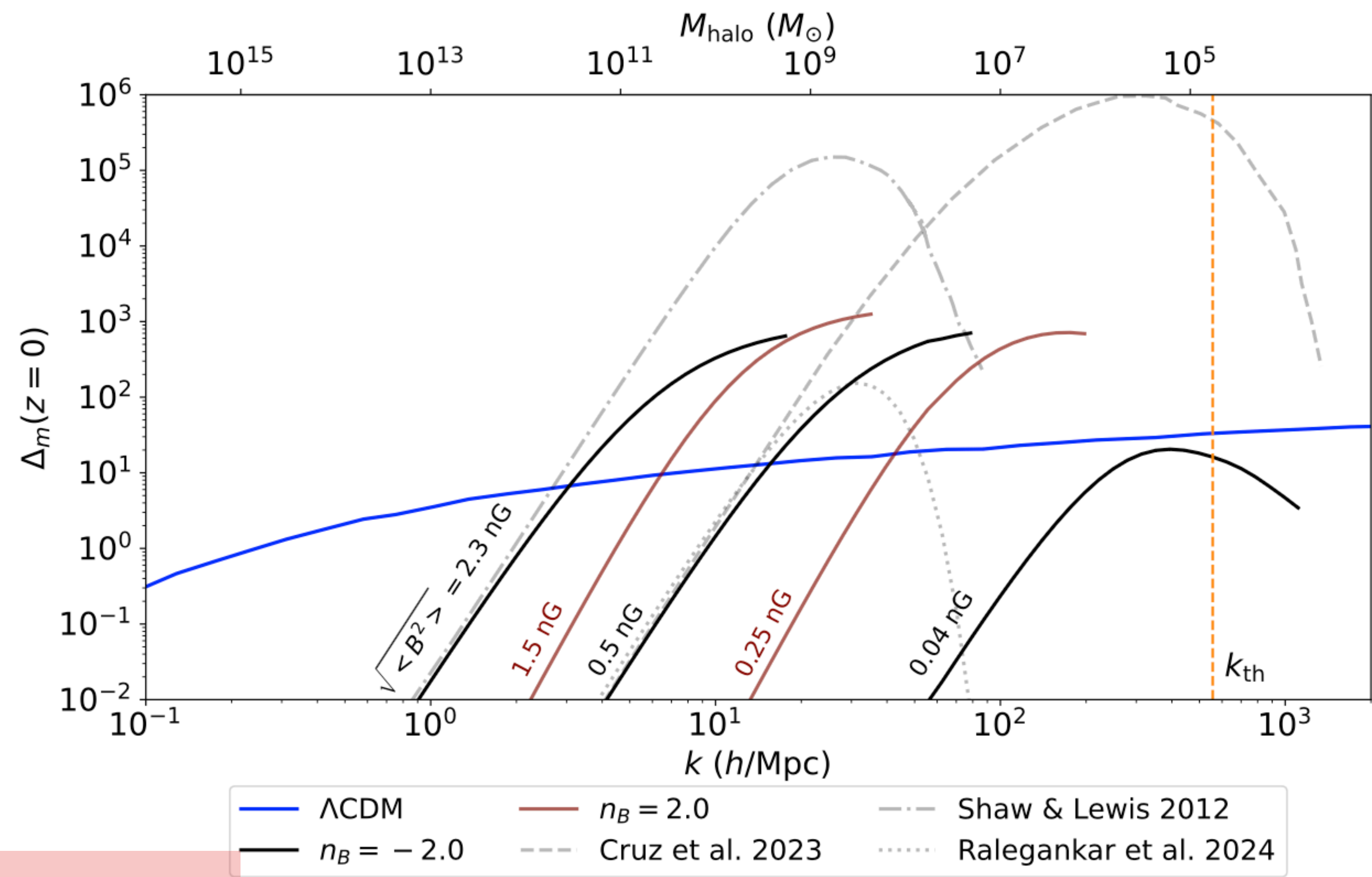
Induction — the baryons push back on the field

$$\frac{\partial \vec{B}}{\partial t} = \frac{1}{a} \nabla \times \underbrace{(\vec{v}_b \times \vec{B})}_{\text{back-reaction on } \vec{B}}$$

$$\frac{\partial P_B(k)}{\partial t} = \int dq K(k, q) P_B(q) \quad \text{instead of} \quad -\Gamma(t) k^2 P_B(k)$$

Power is *transferred* between scales $\Rightarrow$ no longer local in k
MHD simulations required [Ralegankar, Garaldi, Viel 2024]

Post-recombination regime:



$$\Delta_B^2(k, a) = \begin{cases} \frac{\Delta_{\text{lin}}^2(k, a)}{[1 + (\lambda_J k)^p]^{(2n_B+10)/p}}, & n_B = -2, \\ \gamma \frac{(\lambda_J k)^7}{[1 + (\lambda_J k)^p]^{7/p}} \left(\frac{\xi(k, a)}{\xi(k, 0,01)} \right)^2, & n_B = +2. \end{cases}$$

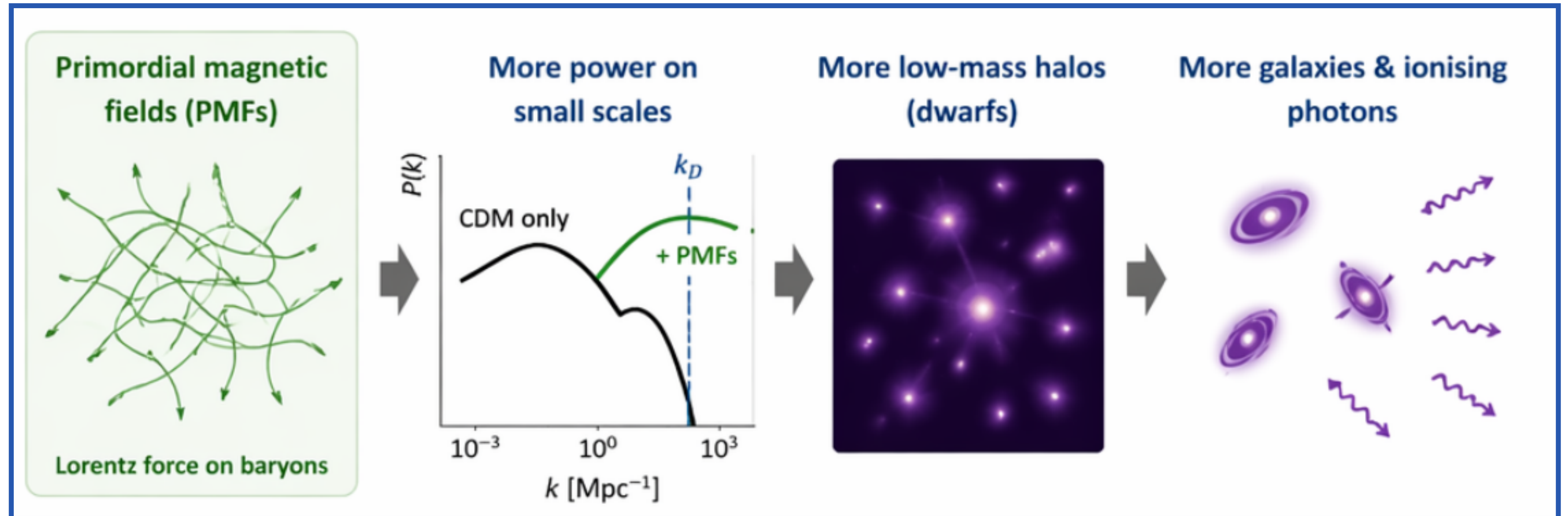
	κ_J	p	γ	κ_D
$n_B = -2$	1,17	1,94	—	0,8
$n_B = +2$	0,593	2,36	0,244	0,9

Fits to simulations

Limits must be recomputed:
Lyman-α, 21-cm signal, etc

[Ralegankar, Garaldi, Viel, *JCAP* 08 (2025) 011]

New limits using JWST data



[Fairbairn, **Olea-Romacho**, Vaskonen, Urrutia, *accepted in PRL*, 2026]

New limits using JWST data: the UV-luminosity function

WHAT IS MEASURED?

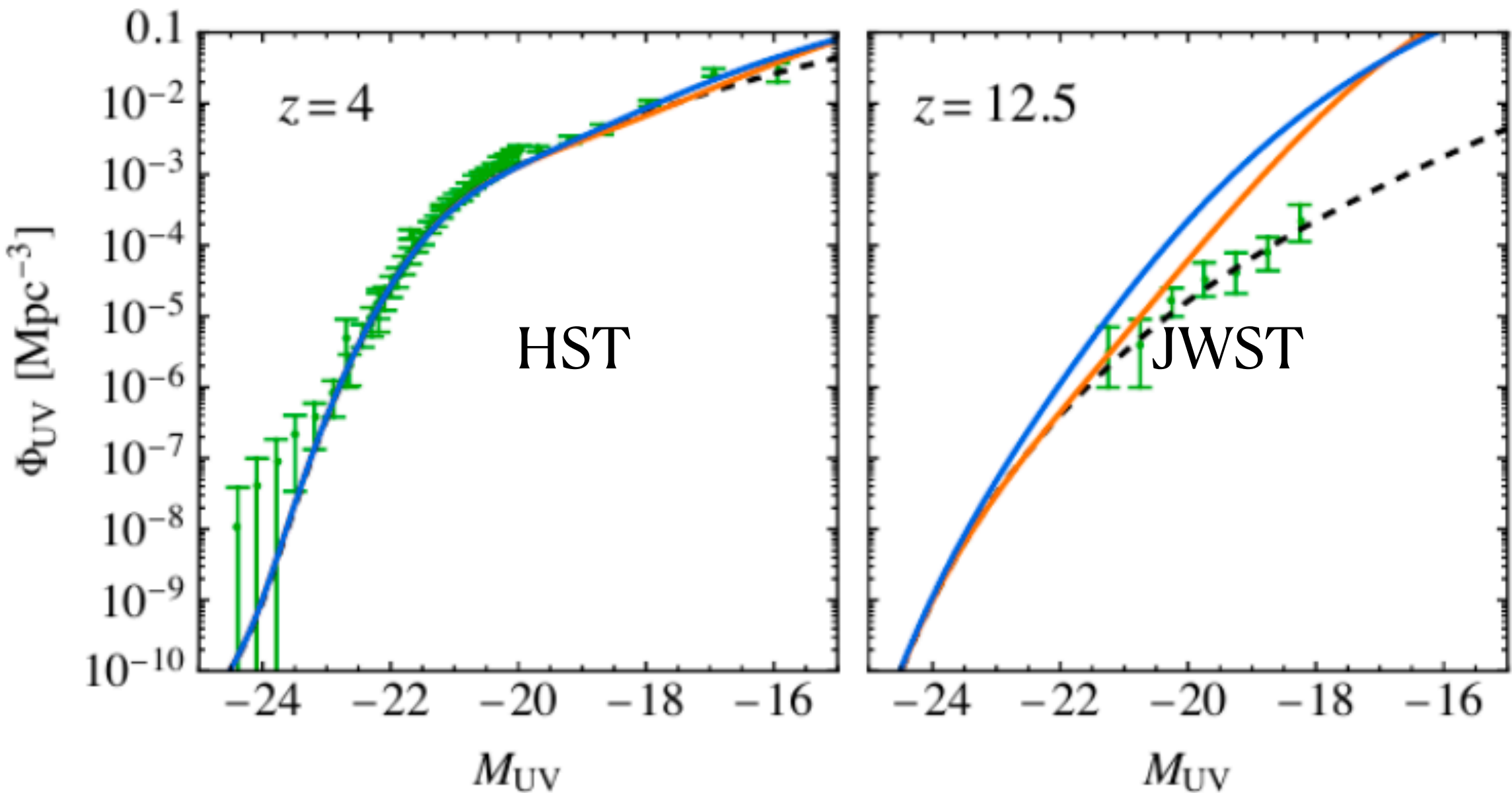
The comoving number density of galaxies as a function of UV magnitude:

$$\Phi_{\text{UV}}(M_{\text{UV}}) = \frac{dn_{\text{gal}}}{dM_{\text{UV}}}$$

Measured by **JWST** at high redshift.

$$\Delta^2(k) = \Delta_{\text{CDM}}^2 + \Delta_B^2 \longrightarrow \frac{dn_h}{d\ln M} \longrightarrow \Phi_{\text{UV}}(L)$$

excursion set with ellipsoidal collapse + SFR as a broken power law



Same field, two redshifts

$z = 4$: indistinguishable from CDM

$z = 12.5$: an order of magnitude, and only at the *faint* end

$$\frac{dn}{d\ln M} \propto \exp\left[-\frac{\delta_c^2}{2\sigma^2(M, z)}\right]$$

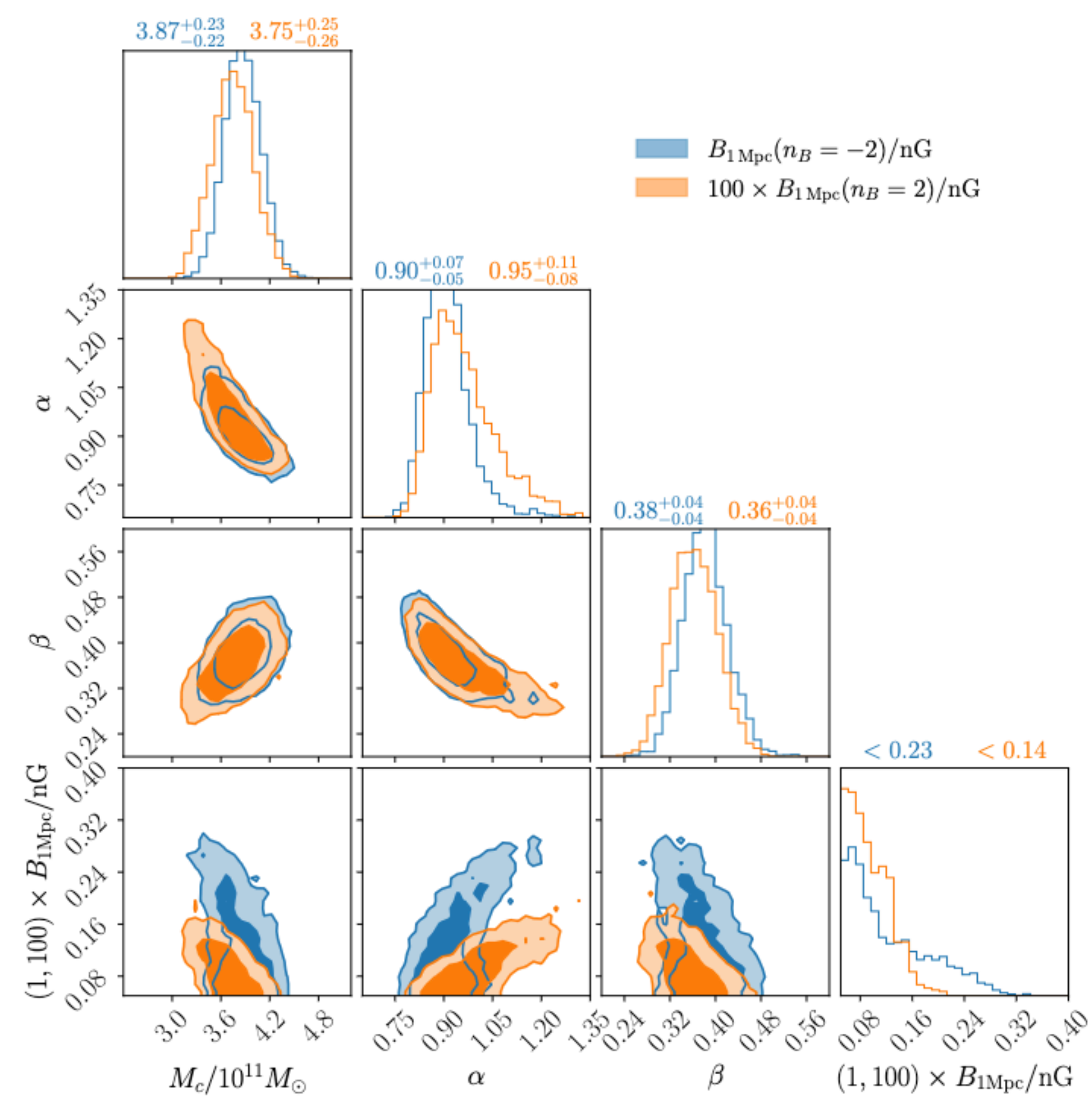
tail, $\propto e^{-\delta_c^2/2\sigma^2}$

A small change in $\sigma \Rightarrow$ orders of magnitude in abundance

$$\sqrt{\langle B^2 \rangle} < 0.87 \text{ nG } (n_B = -2), \quad 0.85 \text{ nG } (n_B = +2) \quad 95\% \text{ CL}$$

Weakened by a degeneracy: the PMF adds faint galaxies, a steeper low-mass SFR slope removes them again

New limits using JWST data: the UV-luminosity function



$$\Phi_{\text{UV}}(L) = \int d\tilde{L} dM \frac{dP(L|\tilde{L})}{dL} \frac{dP(\tilde{L}|M)}{d\tilde{L}} \frac{dn_h}{dM}$$

Dust attenuation & weak-lensing corrections Galaxy luminosity from halo mass (SFR model) Halo mass function

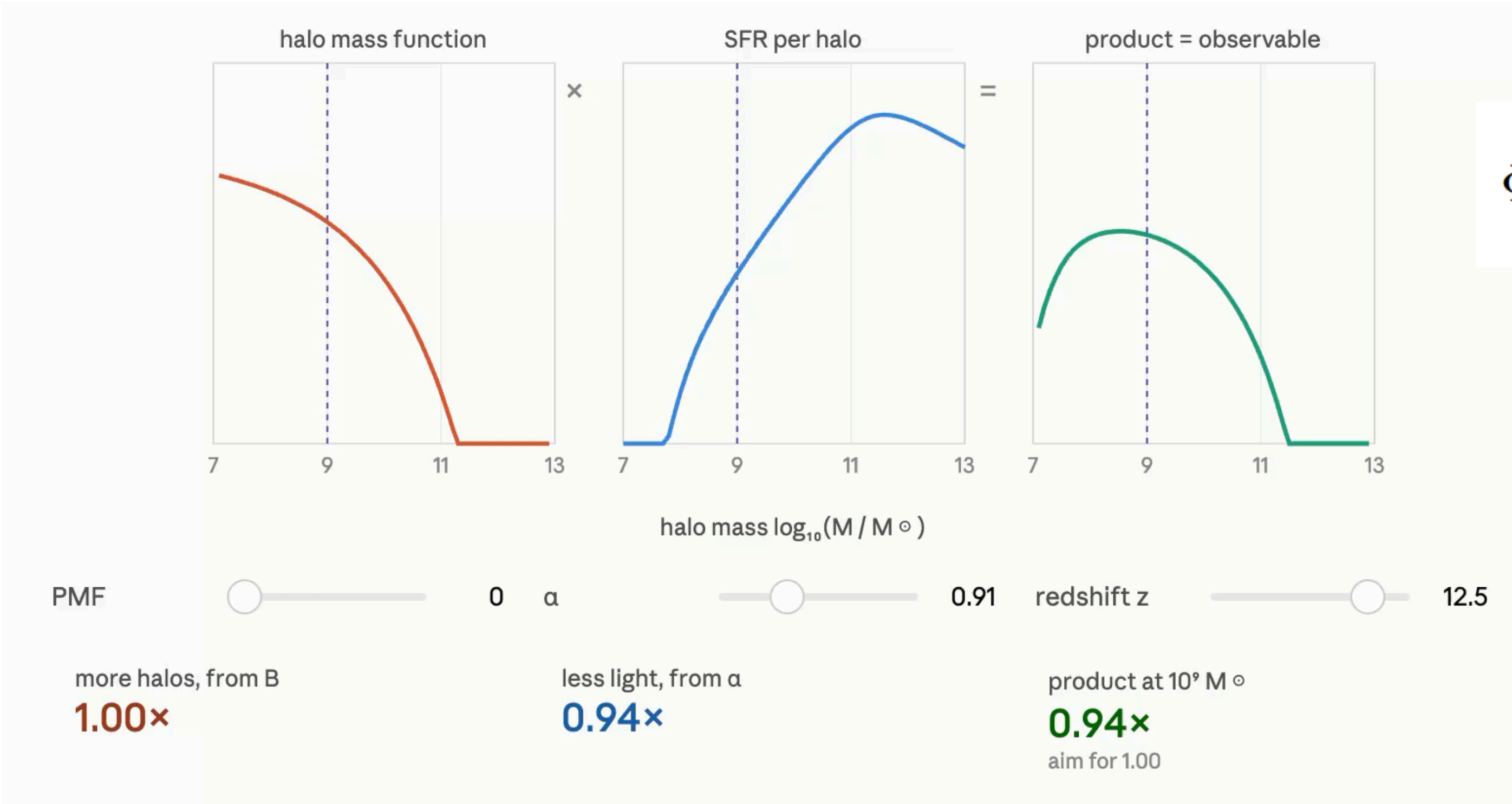
- 1. No detection
- 2. Degeneracies B-SFR

$$\text{SFR} \propto \frac{e^{-M_t/M}}{\beta(M/M_c)^{-\alpha} + \alpha(M/M_c)^\beta}, \quad M_t = M_{\text{cut}} \left[\frac{1+z}{10} \right]^{-3/2}$$

FIG. 2. Posteriors from the UVLF fit. The contours show the 68% and 95% CL regions.



New limits using JWST data: the UV-luminosity function



$$\Phi_{UV}(L) = \int d\tilde{L} dM \frac{dP(L|\tilde{L})}{dL} \frac{dP(\tilde{L}|M)}{d\tilde{L}} \frac{dn_h}{dM}$$

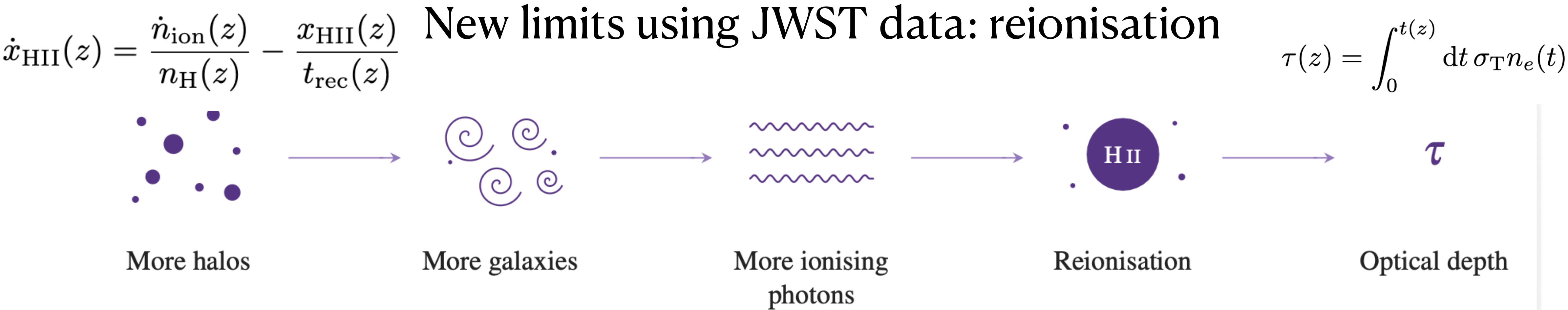
Dust attenuation & weak-lensing corrections

Galaxy luminosity from halo mass (SFR model)

Halo mass function

- 1. No detection
- 2. Degeneracies B-SFR

$$\text{SFR} \propto \frac{e^{-M_t/M}}{\beta(M/M_c)^{-\alpha} + \alpha(M/M_c)^{\beta}}, \quad M_t = M_{\text{cut}} \left[\frac{1+z}{10} \right]^{-3/2}$$



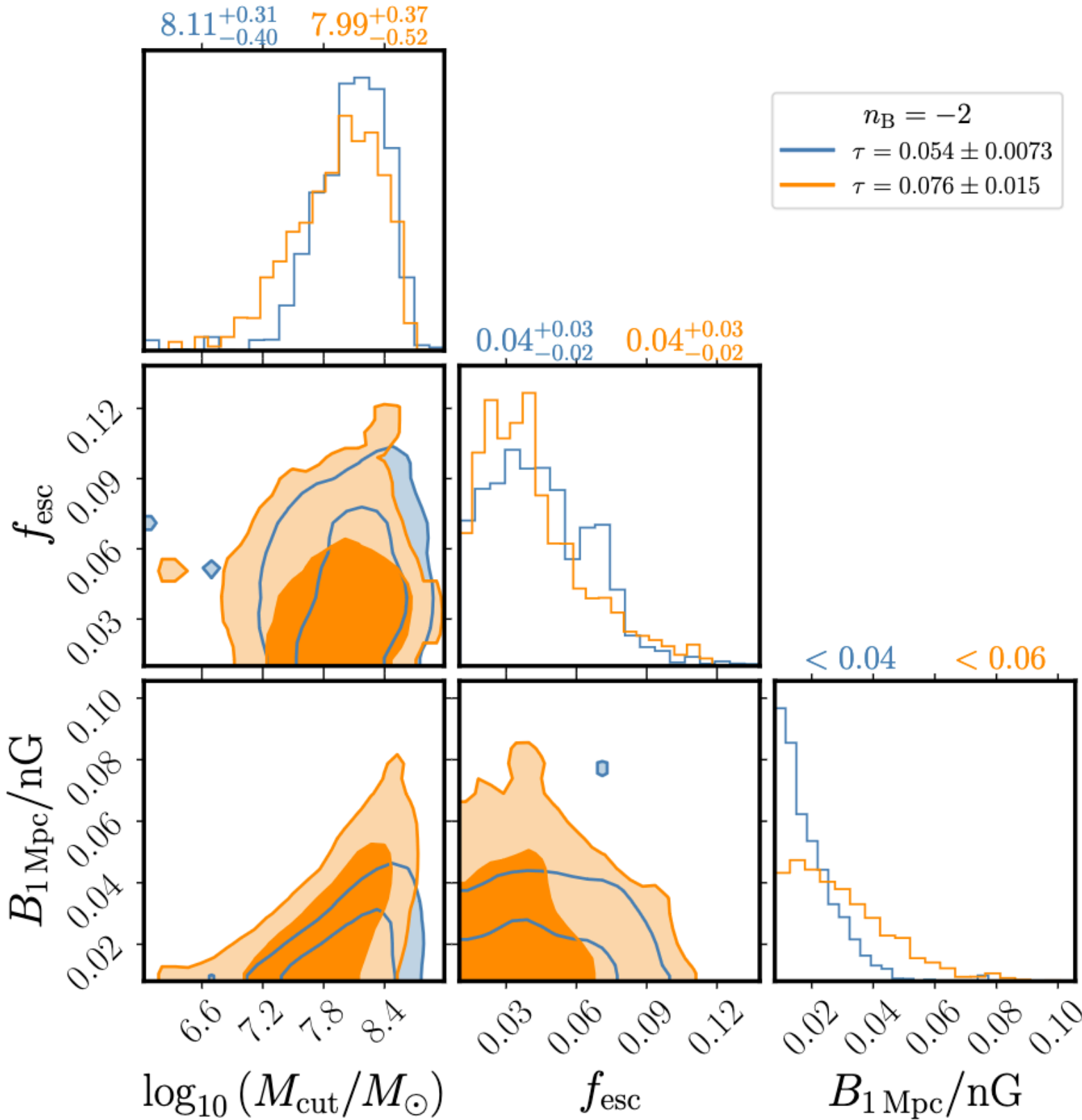
$$\log_{10} \frac{\xi_{\text{ion}}}{\text{Hz erg}^{-1}} = a M_{\text{UV}} + b + dz$$

$$\dot{n}_{\text{ion}} = (1+z)^3 \int dL \Phi_{\text{UV}}(L) \dot{N}_{\text{ion}}(L) f_{\text{esc}}$$

$$\tau = 0.054 \pm 0.0073$$

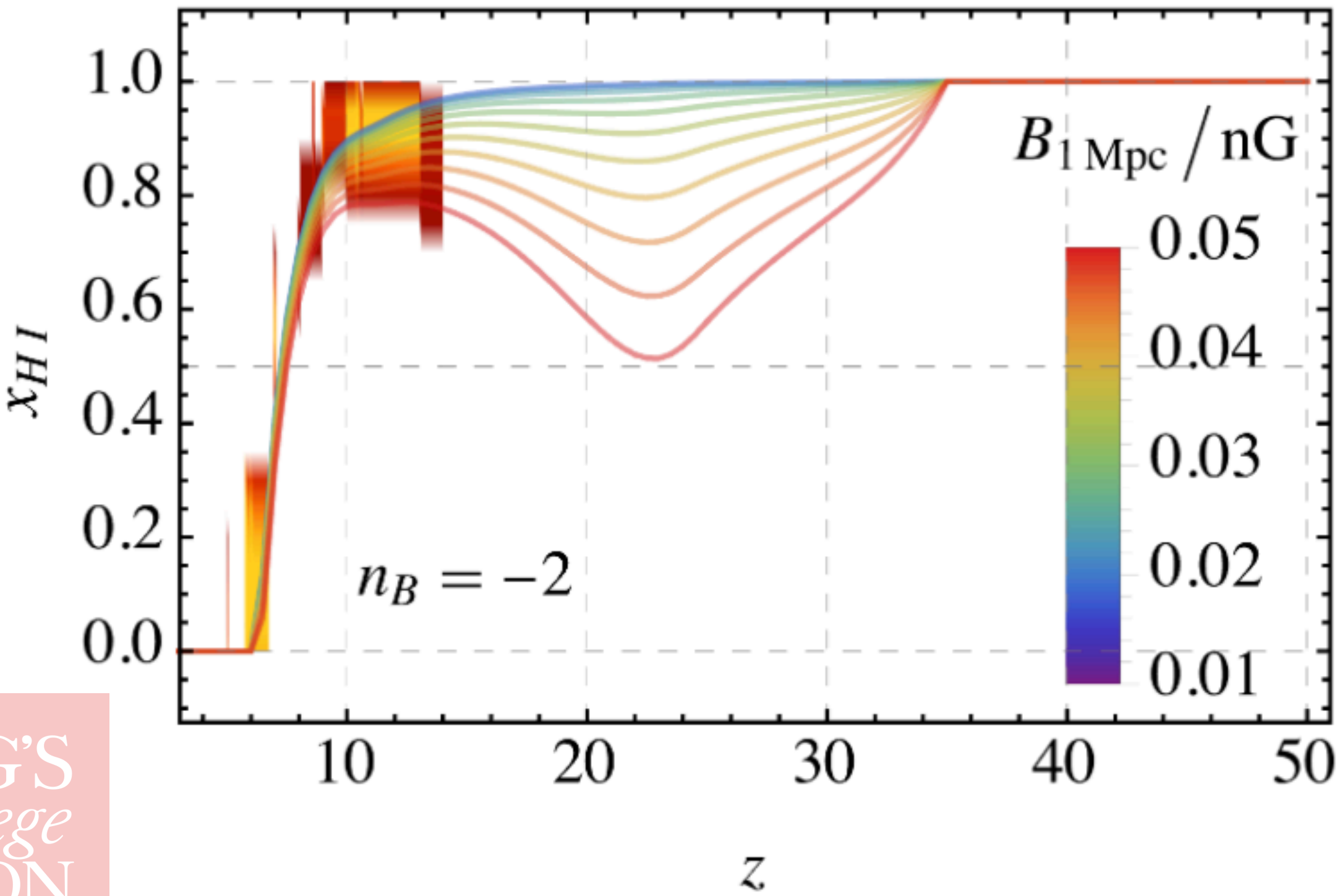
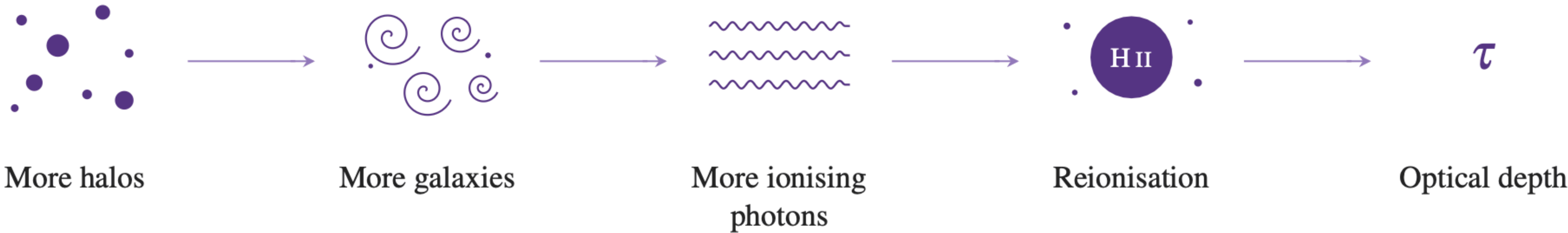
high-*l* polarisation

$$\tau = 0.076 \pm 0.015$$



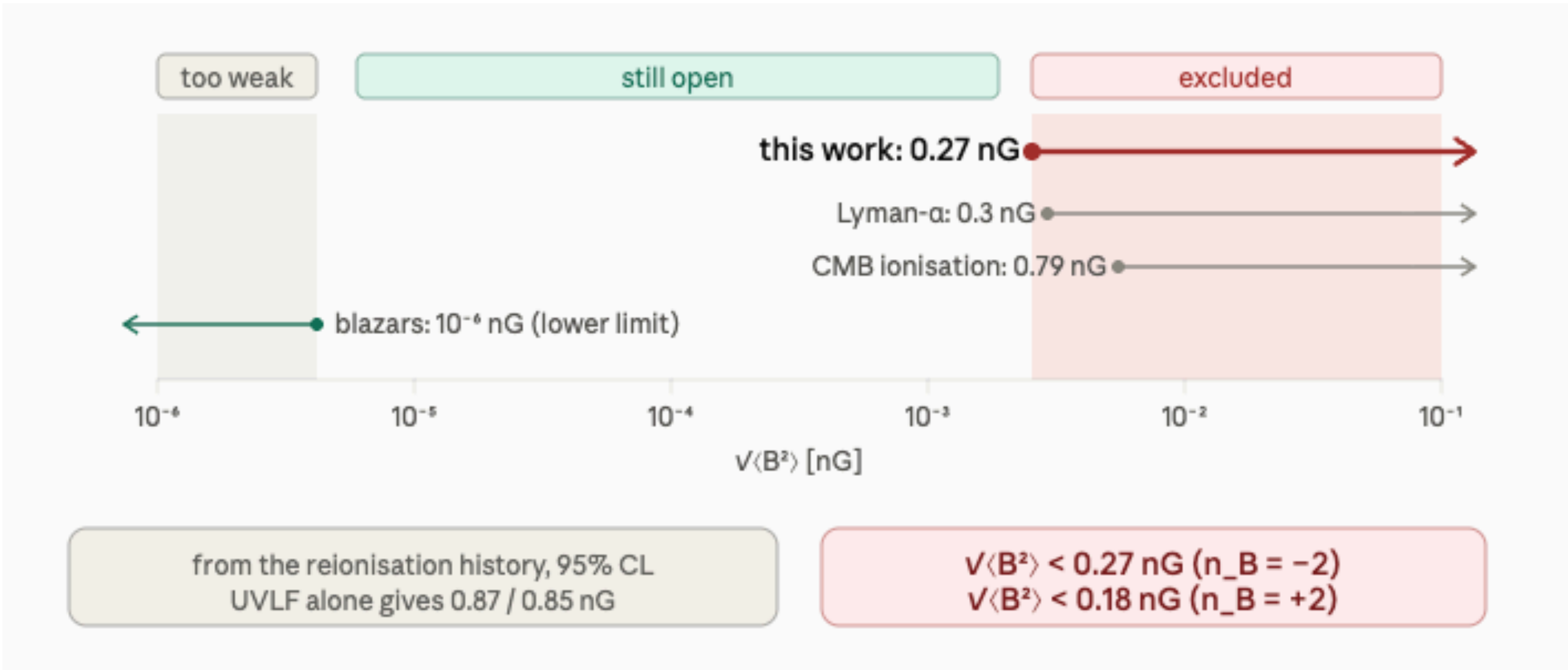
New limits using JWST data: reionisation

$$\tau(z) = \int_0^{t(z)} dt \sigma_T n_e(t)$$



$$\dot{x}_{HII}(z) = \frac{\dot{n}_{\text{ion}}(z)}{n_H(z)} - \frac{x_{HII}(z)}{t_{\text{rec}}(z)}$$

Ionisation Recombination



Conclusions

- ① **Primordial magnetic fields leave a legacy on small scales:** extra power $\rightarrow$ early minihalos with prompt cusps at the bump scale.
- ② **Indirect detection:** a DESI–Planck-level field (3.4 pG) is incompatible with s-wave thermal WIMPs up to beyond the TeV scale.
- ③ **Gravity alone:** wide binaries in Boötes I constrain extended dark objects ($f_{\text{DM}} \sim 10^{-3}$). Next: magnetic minihalos.
- ④ **JWST:** early galaxies as a magnetometer. Reionisation gives $\langle B^2 \rangle^{1/2} < 0.27$ (0.18) nG, and double reionisation is a falsifiable prediction.