CASST 2026 | ASTROPARTICLE PHYSICS

Cosmological Magnetic Fields from Dark Matter

Can ultralight dark matter seed magnetism after recombination?

What looked like a threshold became a clock.

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arXiv:2607.20793

M51 magnetic-field orientation: NASA/SOFIA/HAWC+; NASA/ESA/Hubble

NASA, E

The Universe is magnetized, but what started it?

A dynamo can amplify a field.

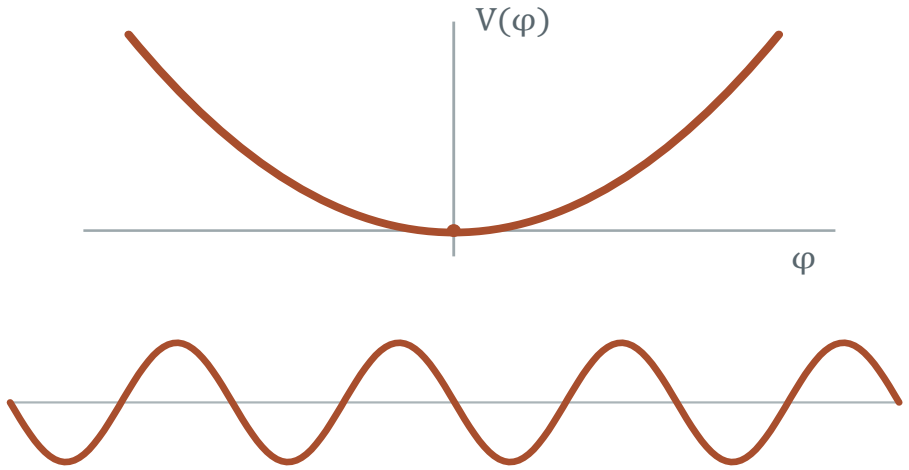
It does not explain the first seed.

Question: can energy in the dark sector create that seed after recombination?

M51 image on title slide: NASA/SOFIA/HAWC+; NASA/ESA/Hubble. Field values are order-of-magnitude orientation.

Ultralight dark matter can act like a cosmic metronome

A coherent classical field



$$\varphi(t) \approx \Phi(t)\cos(mt)$$

the mass sets the beat

One new interaction

$$\Delta\mathcal{L} = -\tfrac{1}{4}\, g_{\varphi\gamma}\, \varphi\, F\, \tilde{F}$$

$$\leftrightarrow\ g_{\varphi\gamma}\, \varphi\, \mathbf{E}\cdot\mathbf{B}$$

E·B is parity odd, so it couples naturally to a pseudoscalar.

$$\alpha_{\mathrm{eff}} = g_{\varphi\gamma}\, \Phi_{\mathrm{rec}}$$

dimensionless pump strength

David & Brandenberger, arXiv:2607.20793, Eqs. (1), (12), and (15).

Recombination opens a window, not a vacuum

BEFORE

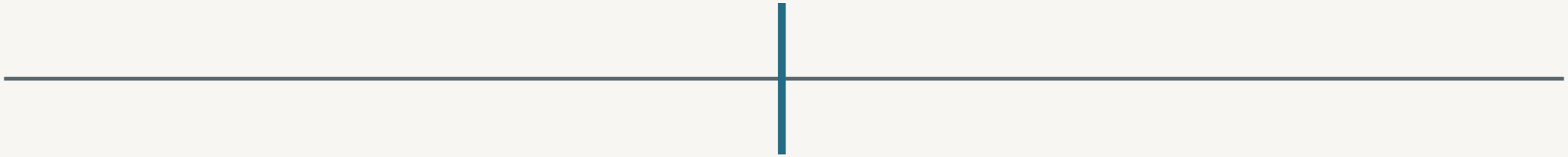
ionized plasma

RECOMBINATION

~380,000 years

AFTER

candidate growth window



High conductivity strongly changes photon propagation.

calculation begins

Neutral atoms form, but a residual electron population remains.

ASSUMPTION

Post-recombination is not a vacuum. The residual-plasma response is the major missing piece.

The published calculation begins at recombination and omits the residual-plasma response.

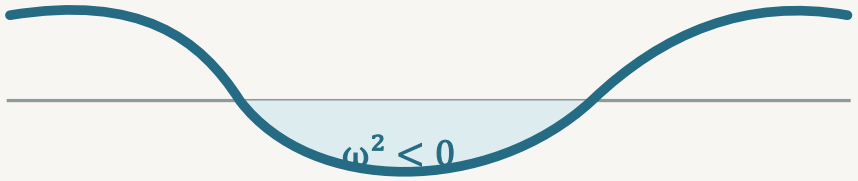
One oscillator, two ways to grow

$$A_\lambda'' + [\, k^2 + \lambda\, k\, g_{\varphi\gamma}\, \varphi' \,]\, A_\lambda = 0 \qquad (\lambda = \pm 1)$$

ordinary oscillator

oscillating dark-field term

Tachyonic burst

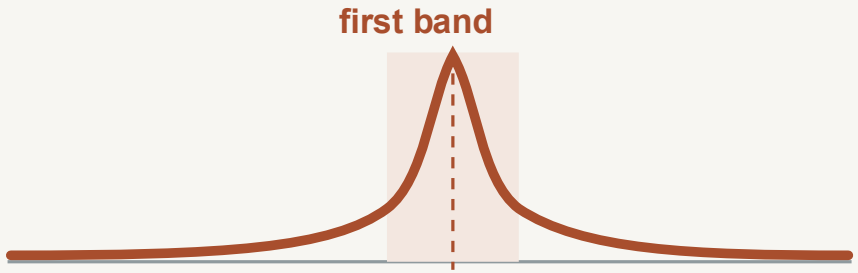


negative effective spring

$$k/a \lesssim g_{\varphi\gamma}\, m\Phi$$

rapid growth during part of each cycle

Narrow resonance



repeated pushes add up

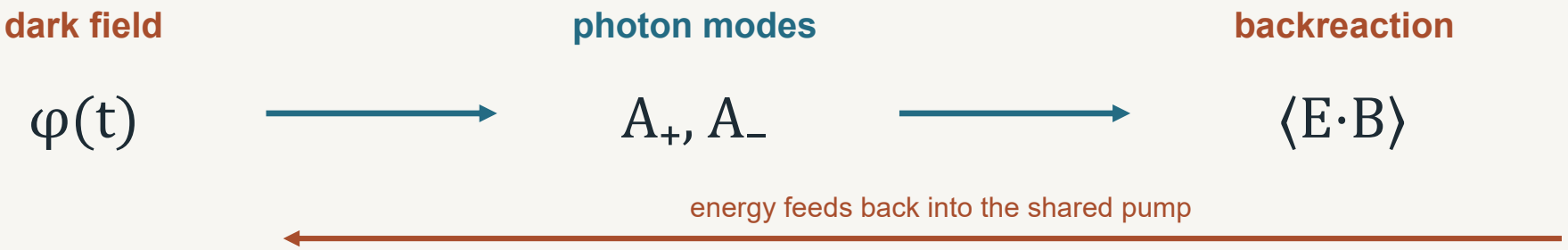
$$k/a \approx m/2 \qquad \mu \approx \alpha_{\mathrm{eff}}/4$$

a swing pushed at the right frequency

The dominant mechanism changes smoothly across the spectrum.

David & Brandenberger, arXiv:2607.20793, Eqs. (3)–(7). Prime denotes conformal-time derivative.

What happens when the produced field pushes back?



How much energy moved?

$$F = \rho_{EM}/(\rho_\varphi + \rho_{EM})$$

electric + magnetic energy

When did it become strong?

$$z_{0.5} = \text{first time } F = 0.5$$

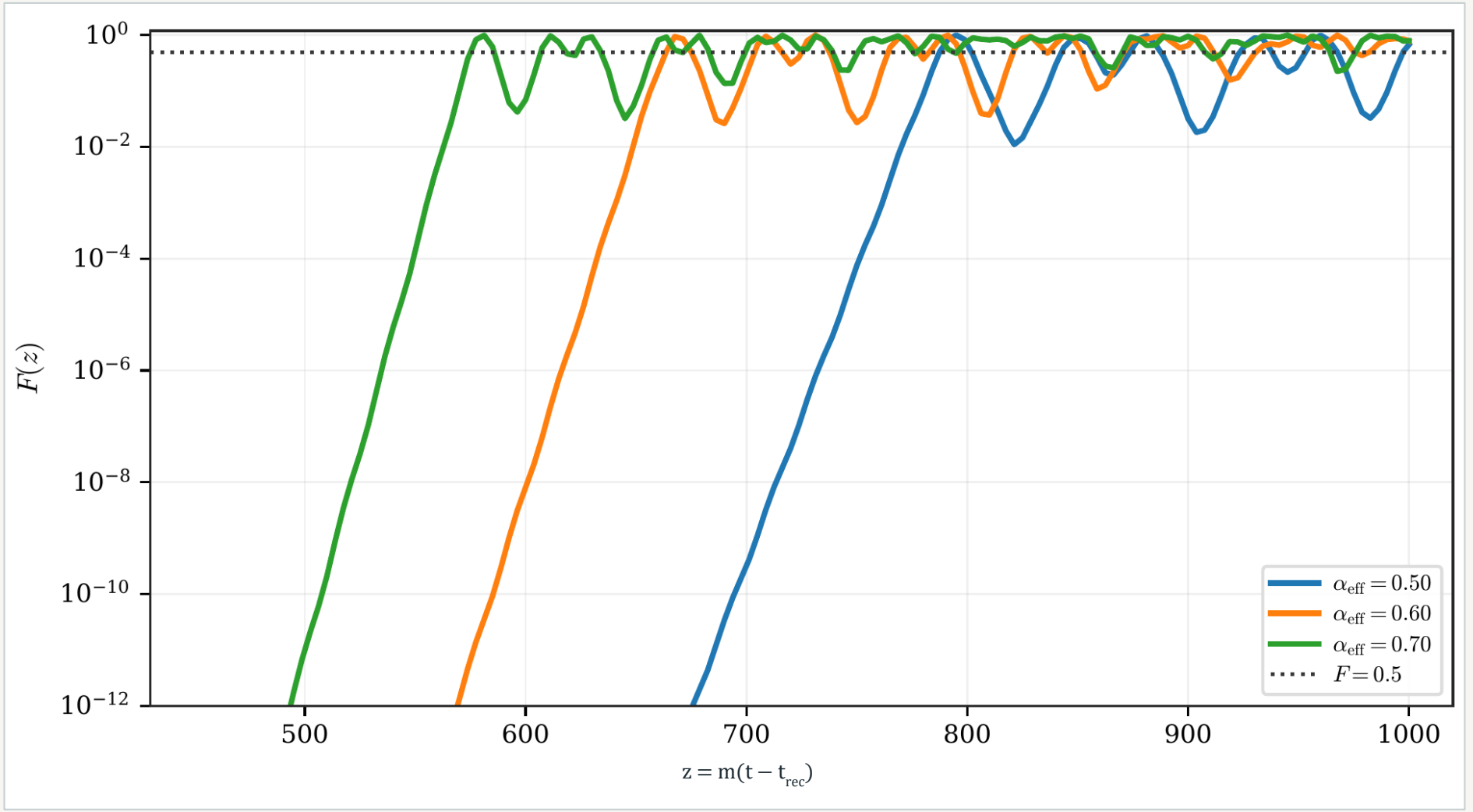
z = m(t − t_rec), not redshift

I evolved these together:

- homogeneous φ
- both helicities
- expansion
- vacuum initial modes

David & Brandenberger, arXiv:2607.20793, Secs. II–IV and Eqs. (26)–(28).

A vacuum ripple grows by twelve orders of magnitude



12

visible orders of growth

vacuum seed begins below the plot

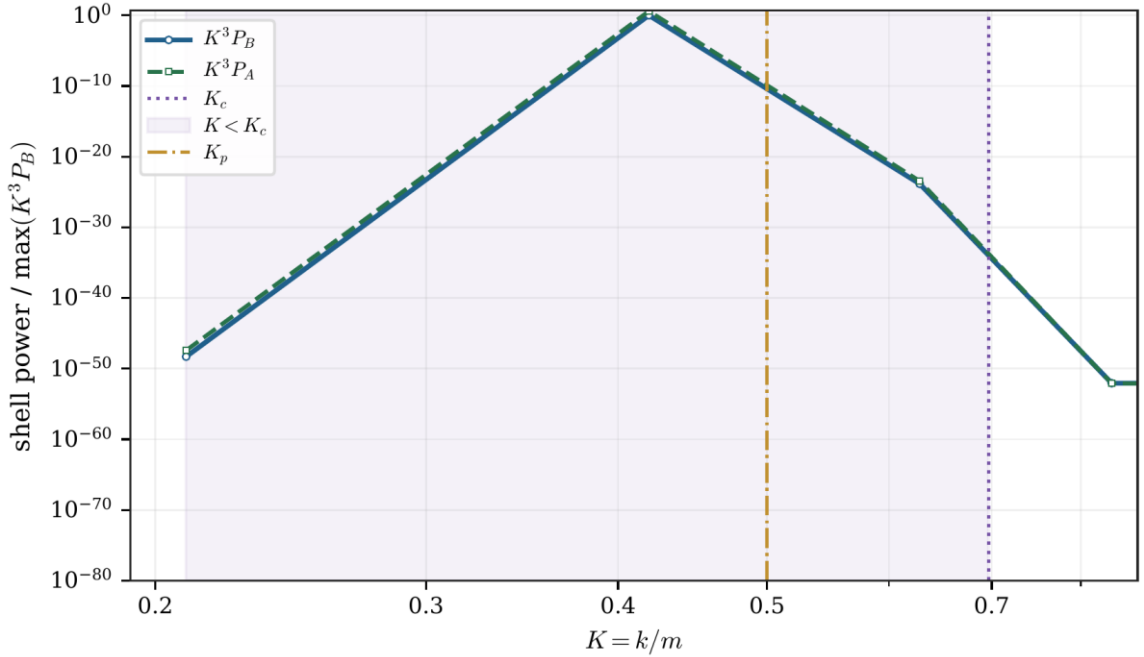
- larger coupling turns up earlier
- first crossing reaches a strong electromagnetic fraction

Later dips = energy returning to φ

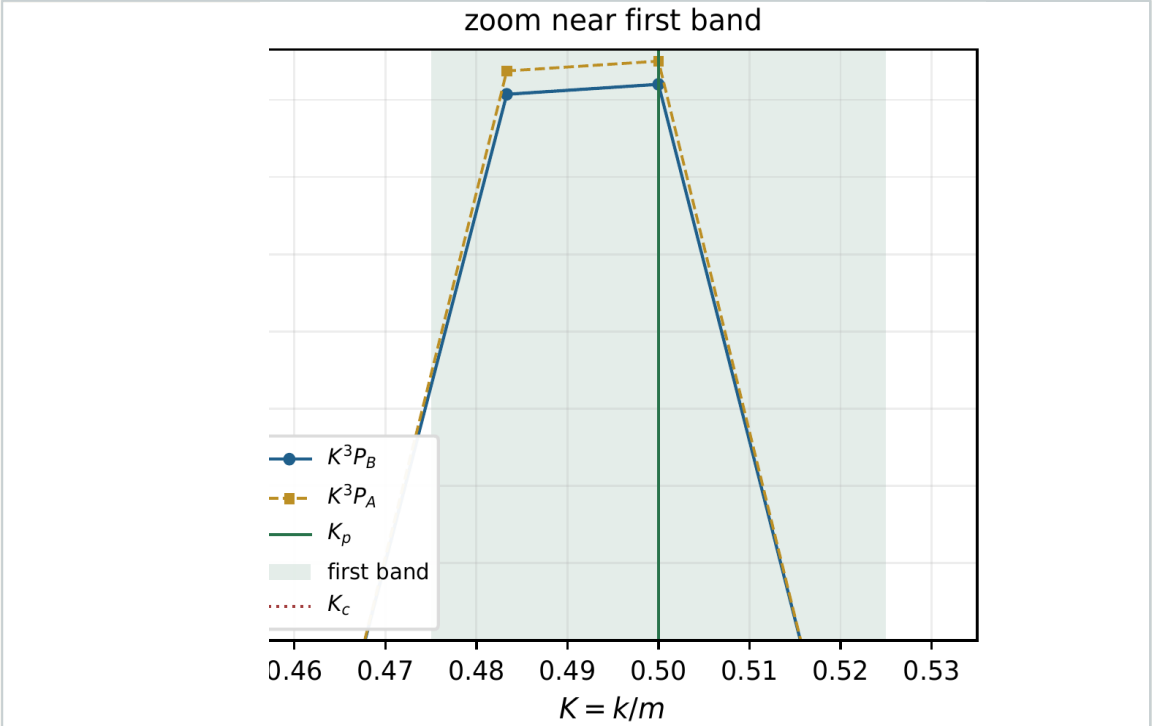
David & Brandenberger, arXiv:2607.20793, Fig. 1. F contains electric and magnetic electromagnetic energy.

The peak location is the fingerprint

tachyonic-dominated



narrow-band dominated



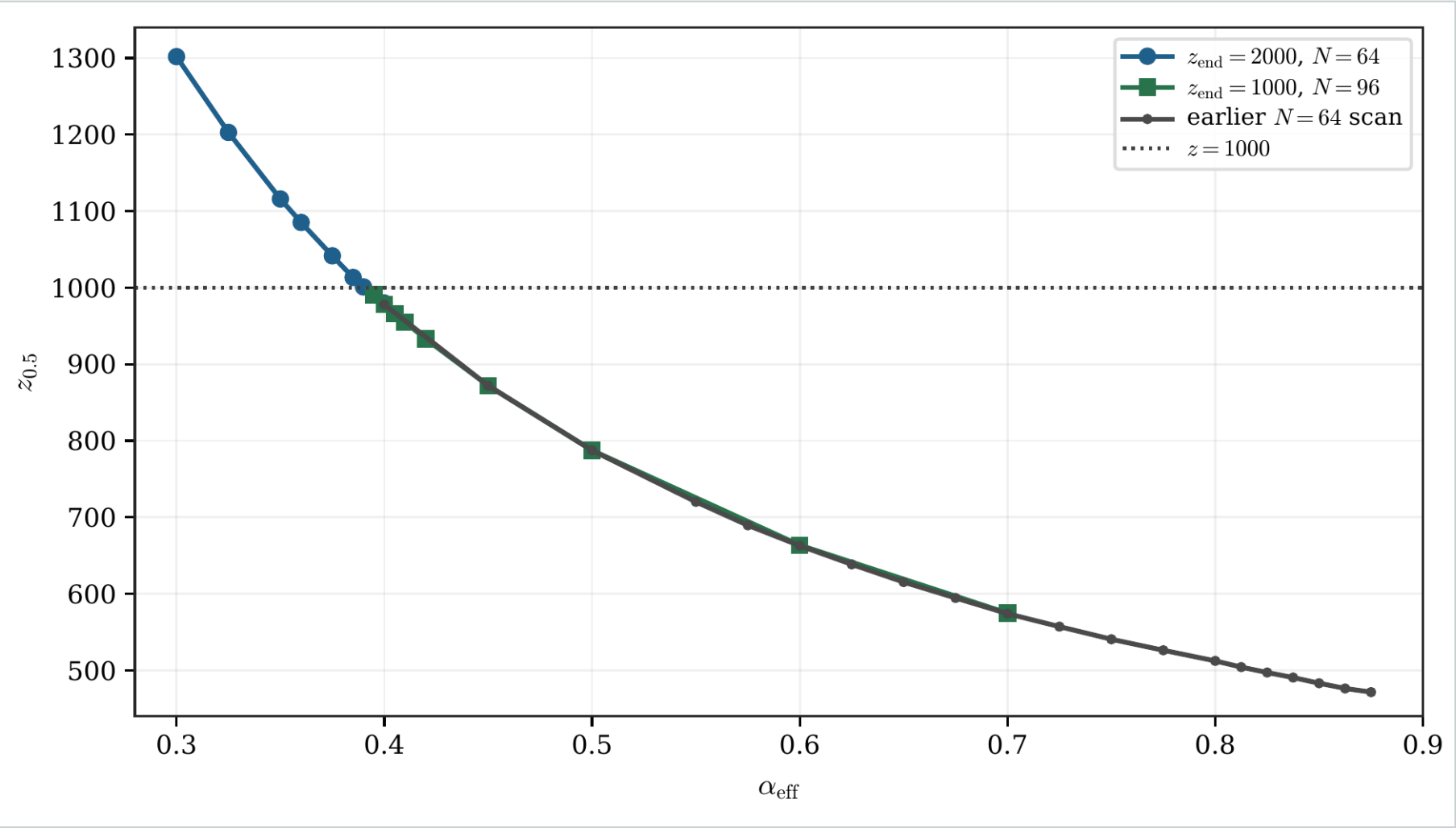
$\alpha_{\text{eff}} = 0.70$ **peak inside tachyonic envelope**

$\alpha_{\text{eff}} = 0.10$ **peak at the first band, K ≈ 0.5**

Compare locations, not heights: the peak is the fingerprint.

David & Brandenberger, arXiv:2607.20793, Figs. 2 and 4. Panels are normalized independently.

What looked like a threshold was really a clock



FIRST STOP

$z = 1000 \rightarrow \alpha_{\rm eff} \approx 0.39$

looked like an on/off threshold

RUN LONGER

$\alpha_{\rm eff} = 0.30 \rightarrow z_{0.5} \approx 1302$

the boundary moves

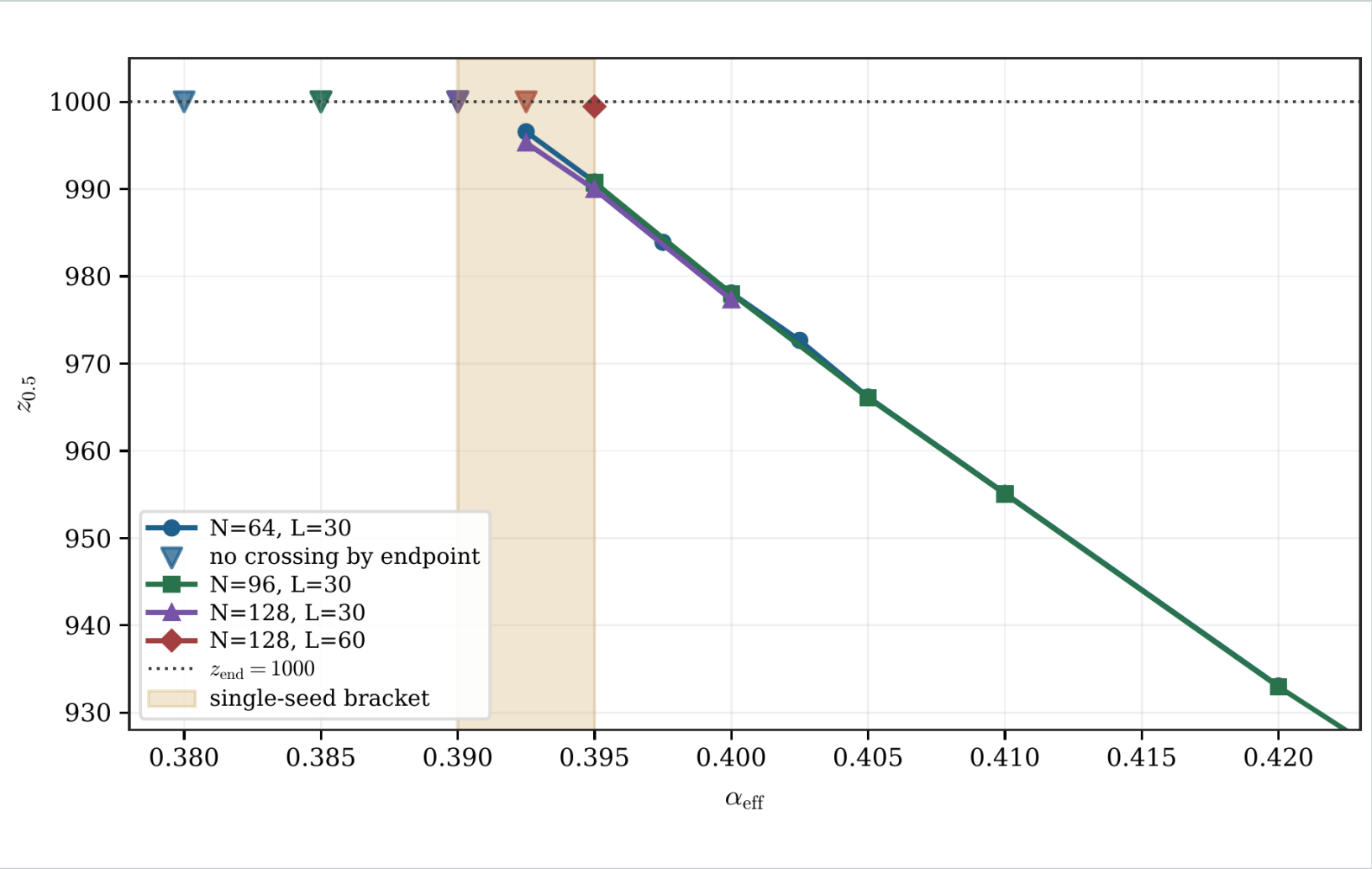
$z_{0.5} \propto \alpha_{\rm eff}^{-1}$

on the measured branch

At very weak coupling, expansion can detune the narrow band.

David & Brandenberger, arXiv:2607.20793, Figs. 3 and 5; Eqs. (30)–(31).

I tried to break the clock



It held.

3 resolutions

same transfer-time curve

10 vacuum seeds

same finite-z bracket

L = 30 → 60

latest crossing ≈1% later

FINITE WINDOW

stable boundary ≠ universal threshold

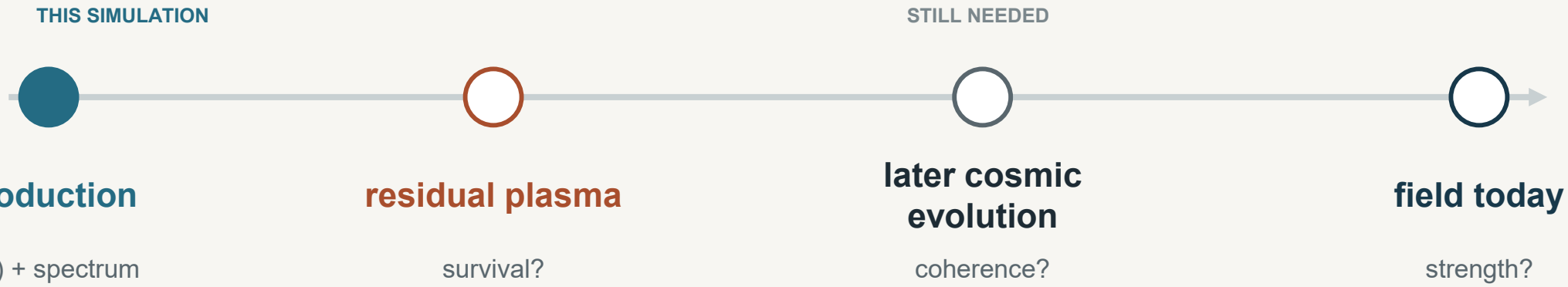
David & Brandenberger, arXiv:2607.20793, Fig. 8 and Table I. All values refer to the finite z = 1000 window.

A fast production event is only the first step

2.1 years

for $z = 1000$, if $m = 10^{-20}$ eV

The production event can be fast.
The rest of the journey is still open.



The simulation gives the first step, not the final field.

The remaining question is survival.

Physical time conversion: arXiv:2607.20793, Sec. IV. The simulation does not directly predict today's field.

Now I'm letting the dark field ripple

PUBLISHED

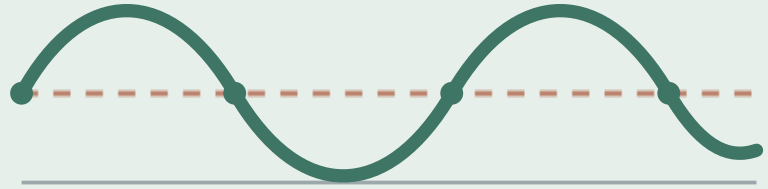
$$\varphi(x,t) = \bar{\varphi}(t)$$

CURRENT 3-D SOLVER

$$\varphi(x,t) = \bar{\varphi}(t) + \delta\varphi(x,t)$$

one value everywhere

perfectly smooth at each time



varies from place to place

3-D gradients + local feedback

PRELIMINARY

In two small-box pilots, electromagnetic energy still leads at first half-transfer.

scalar ripples ≈5–6% of EM energy • phase, volume, and later times are still being tested

Preliminary small-box three-dimensional tests; not included in arXiv:2607.20793.

Can dark matter seed cosmic magnetism?

For the production step: **yes.**

For a field that survives until today: **not yet.**

The coupling behaves like a clock, not a switch.

SHOWN

both instability scales
first strong electromagnetic transfer

STILL OPEN

spatial evolution
residual plasma + later cosmic evolution

Thank you

arXiv:2607.20793

Paper: A. David & R. Brandenberger, arXiv:2607.20793. M51: NASA/SOFIA/HAWC+; NASA/ESA/Hubble.