Searching for Hidden Photons with axion-search technology

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Key Points

"Hidden Photons" (a.k.a. dark photons, paraphotons)

are a possible **5th-force carrier**

and **dark-matter candidate**

Experimental searches are

extremely similar to axion searches

…but are **easier** because:

i) **No static B-field** needed

ii) stellar cooling constraints are weaker

HIDDEN PHOTONS

THEORY:

a **5th force**: a **copy of Electromagnetism**, but with

— **small hidden-photon mass** (= finite range)

— **small coupling ε** (the "kinetic mixing" parameter)

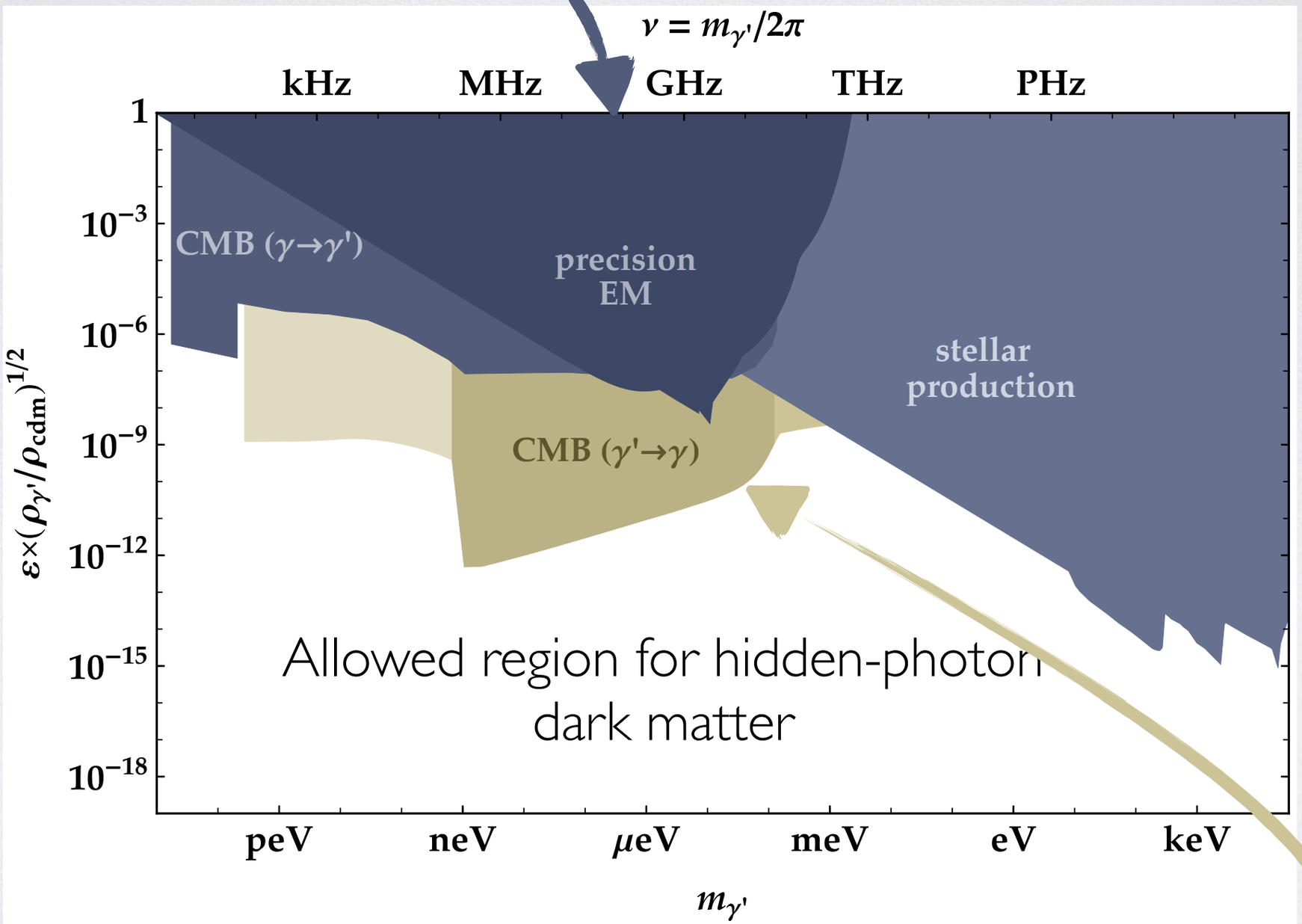
Long-range
Couples to charged particles
⬇
Modification of EM

New light particle
⬇
Cosmo/astro effects

Stores energy in non-relativistic waves/particles
⬇
Dark matter

Hidden Photon Constraints

EXCLUDED
(independent of contribution to dark matter)



EXCLUDED AS DARK MATTER

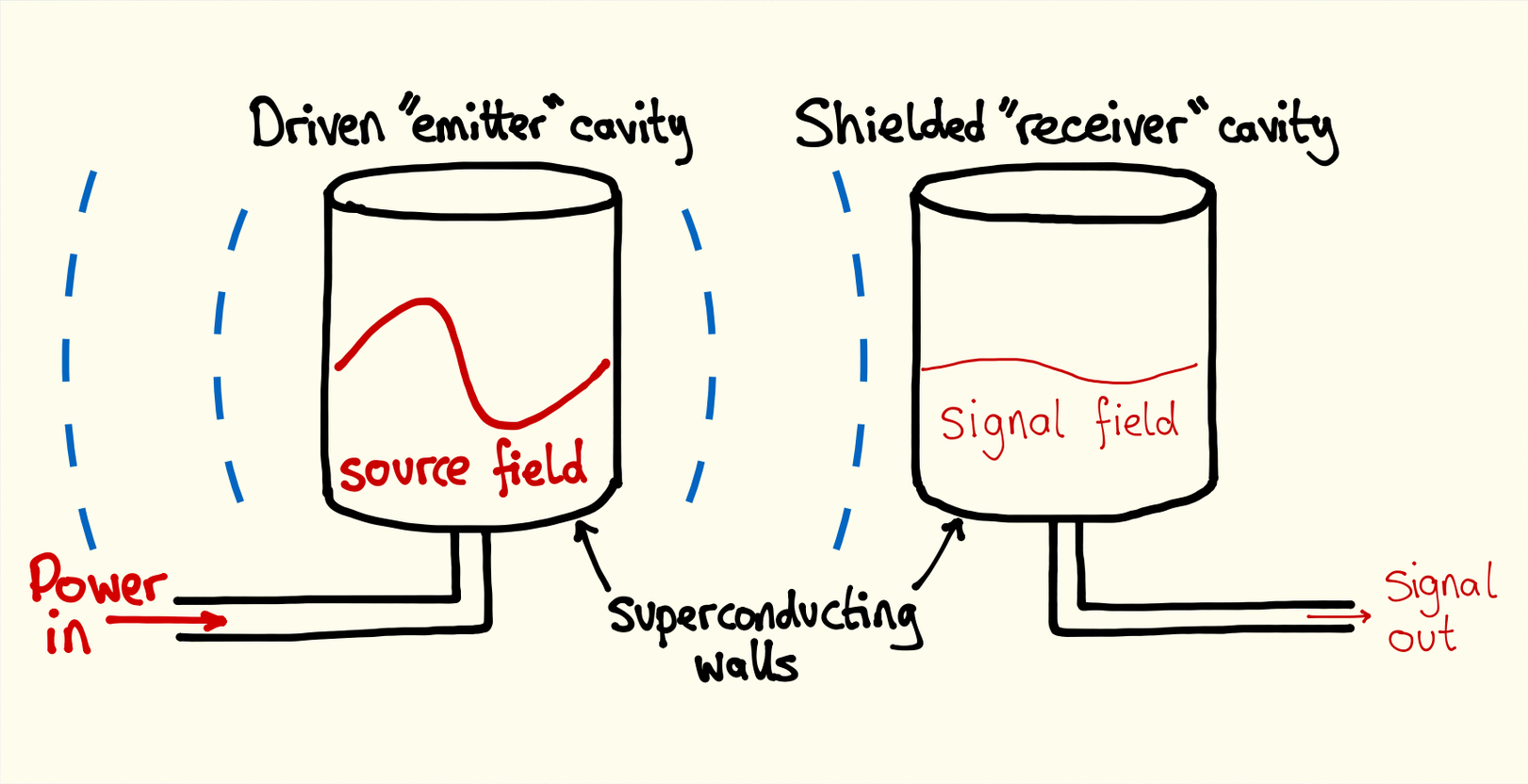
Arias et al 1201.5902

Light-Through-Walls Searches for Hidden Photons

Jeremy Mardon, SITP, Stanford

LIGHT-THROUGH-WALLS CAVITY SEARCH

The hidden photon is an **unshieldable** addition to Electromagnetism



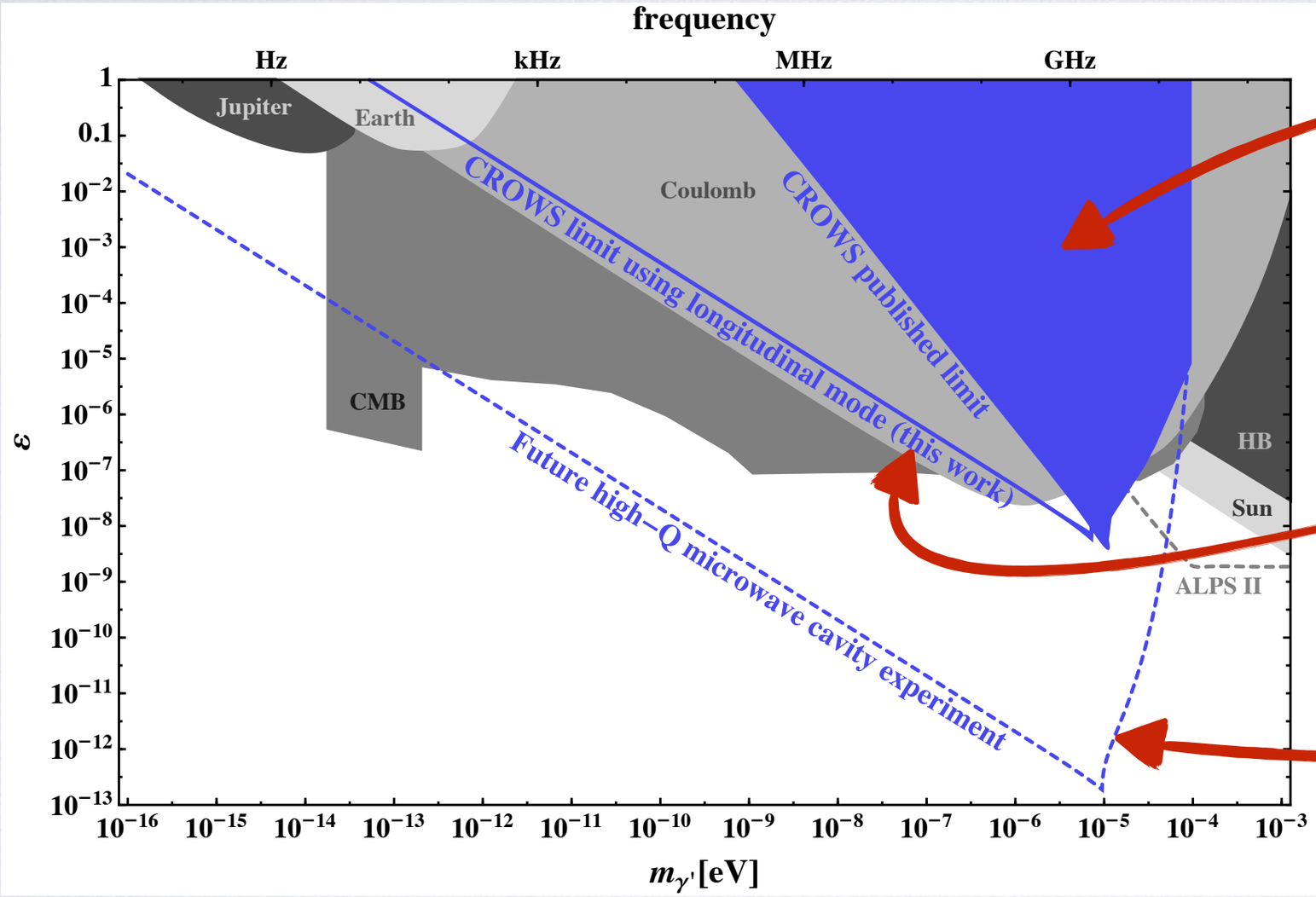
Jaeckel & Ringwald 0707.2063

— tune 2 cavities to same frequency
— drive one cavity, pick up signal in well-shielded 2nd cavity
— large resonant enhancement (up to $Q \sim 10^{10}$?)

Early-stage experiments:

Povey et al 1003.0964 ADMX 1007.3766 CROWS 1310.8098

REACH



Published bound
CROWS collaboration
1310.8098

Reanalysis including longitudinal mode
Graham, J. M., Rajendran & Zhao
1407.4806

Potential reach
proposal with Sami Tantawi & Vinod Bharadwaj

— **large potential reach**

— corresponding **axion search is weak** ($g_{a\gamma\gamma} < 10^{-7}$GeV) 1310.8098

— **longitudinal mode** is important in optimizing setup 1407.4806

Searching for Hidden Photon Dark Matter

Jeremy Mardon, SITP, Stanford

HIDDEN PHOTONS AS DARK MATTER

Light boson as dark matter

— **classical field**
— oscillation frequency $\omega = m_{A'}$
— coherence time $\sim 10^6/\omega$

pseudoscalar → **axion**

— **scalar field**
— **no direction**

vector → **hidden photon**

— **vector field**
— points in **random direction**

Pospelov Ritz & Voloshin 0807.3279
Nelson & Scholtz 1105.2812

HIDDEN PHOTON DM: RESONANT SEARCHES

A "**hidden electric field**" that penetrates shielding

— $E' \approx \sqrt{\rho_{\rm DM}} \approx 2000$ **V/m**

Has **fixed frequency**

— $\omega = m_{\gamma'}$, $\delta\omega/\omega = 10^{-6}$

Can **excite an electromagnetic resonator**

<u>electromagnetic cavities</u>

— ADMX is **automatically sensitive**

Redondo et al 1201.5902

Hidden Photon DM: resonant searches

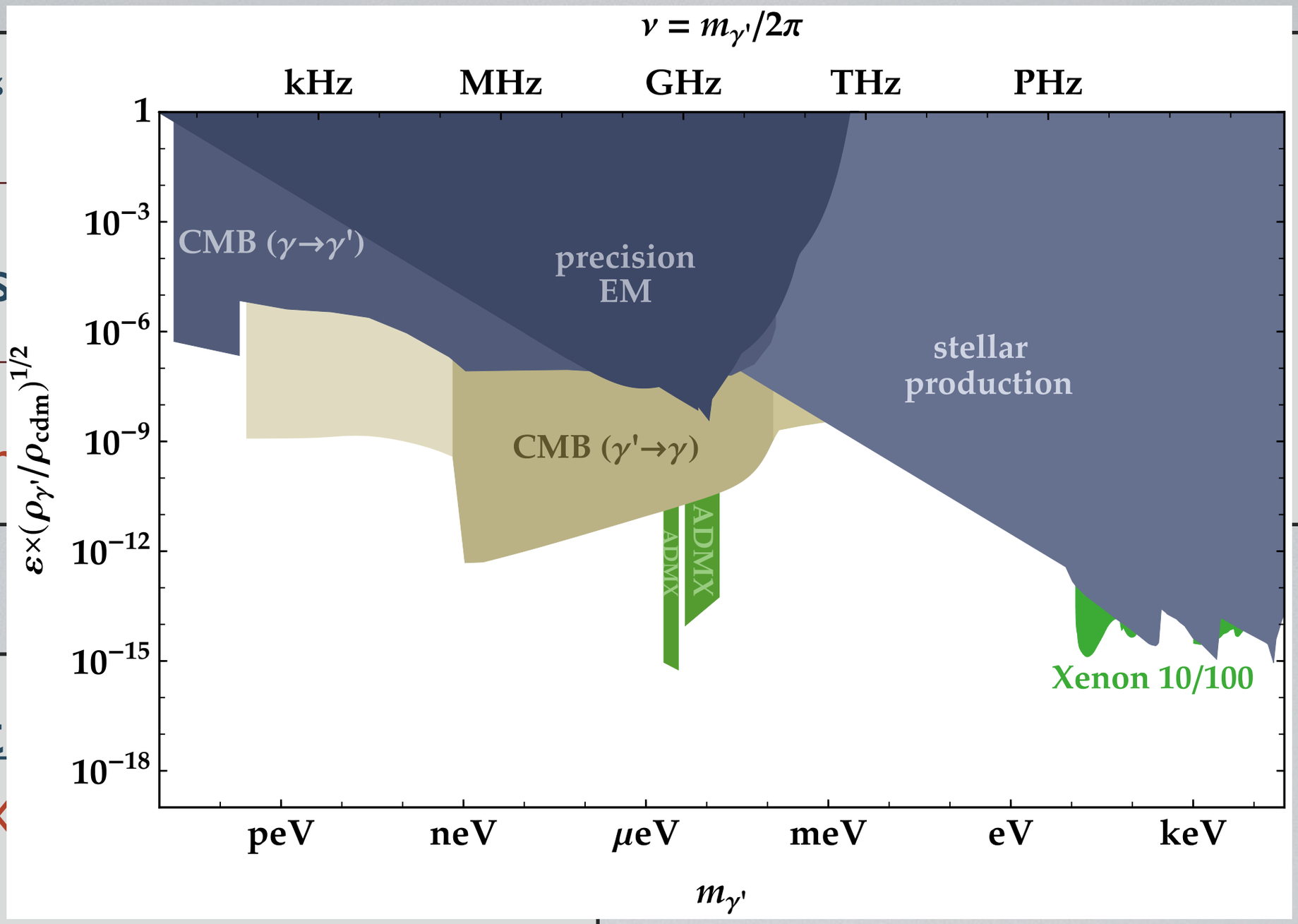
A "

Has

Car

elect

— ADMX



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Redondo et al 1201.5902

<u>**LC circuits**</u>

— **much wider and lower frequency range** than cavities

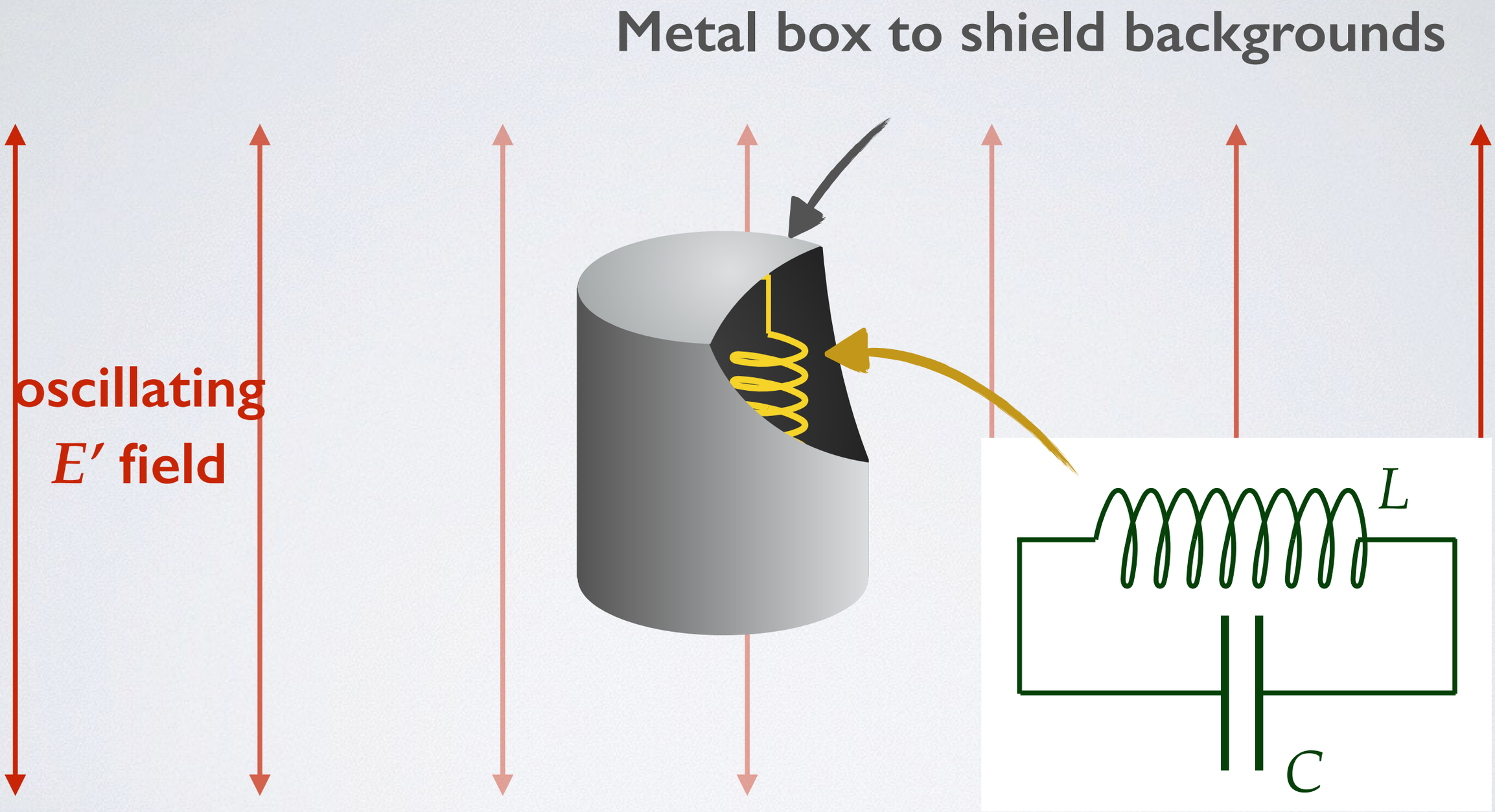
DM Radio:
A tunable LC-circuit for hidden-photon dark matter

"A Radio for Hidden-Photon Dark Matter Detection"

Saptarshi Chaudhuri, Peter Graham, Kent Irwin, J. M., Surjeet Rajendran & Yue Zhao

arXiv:1411.7382

EXPERIMENTAL SETUP

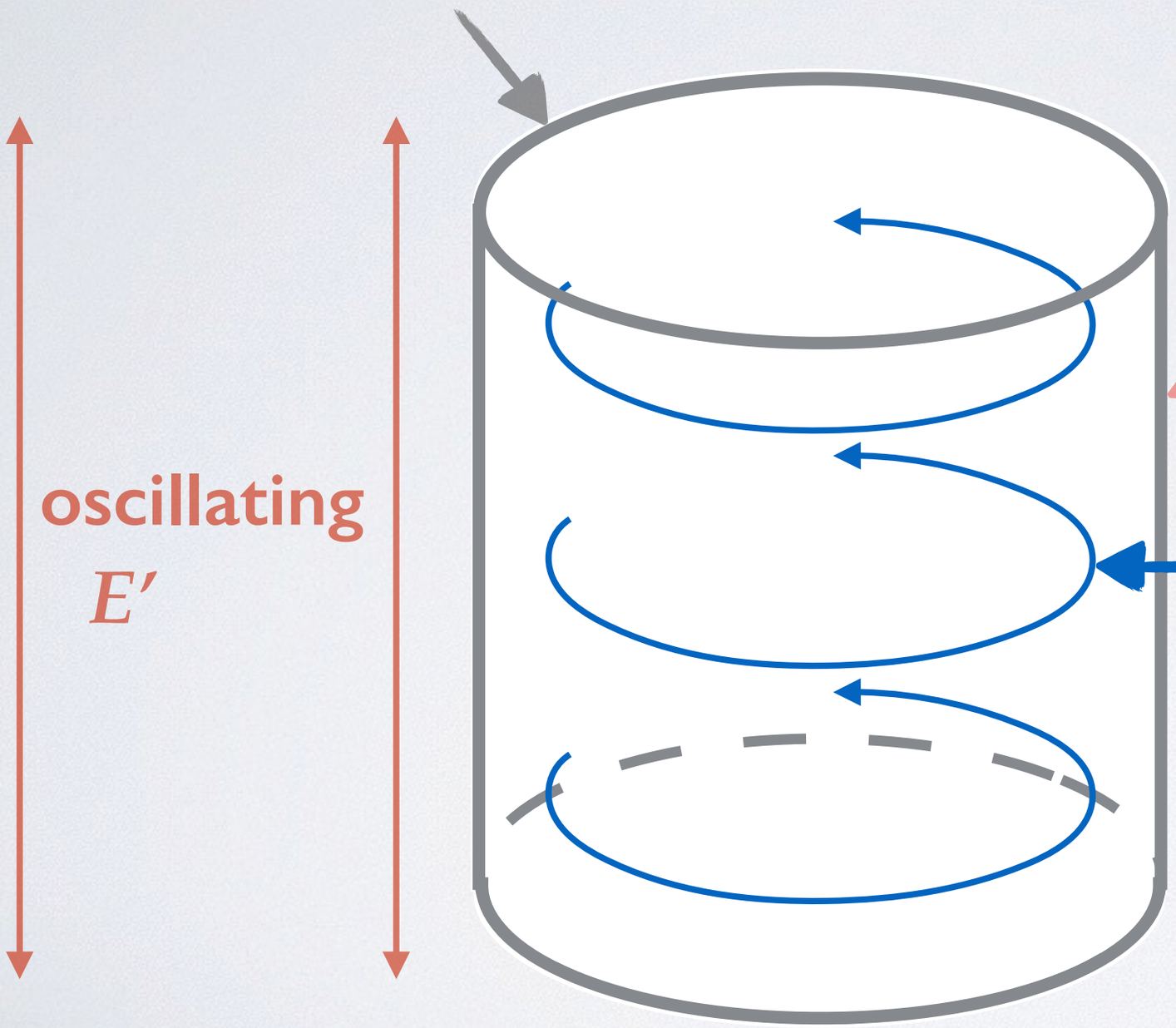


Tunable resonant LC circuit
Read out with SQUID

THE SIGNAL INSIDE A SHIELD

Metal box to shield backgrounds

conduction electrons in wall respond to cancelling observable combination $E+\varepsilon E'$



…but generating real B field inside the shield

$$B \sim \varepsilon\,(m_{\gamma'} R) \times 10^{-5}\ \mathrm{T}$$

oscillates at $\omega = m_{\gamma'}$

THE DM RADIO COLLABORATION

Experiment

Kent Irwin (PI)
Saptarshi Chaudhuri
Dale Li
Christopher Williams
Betty Young
Max Silva-Feaver
Sarah Stokes Kernasovkiy

Theory

Peter Graham
Jeremy Mardon
Surjeet Rajendran
Yue Zhao

SLAC

Stanford University

REACH

PHASES 1&2 (funded)

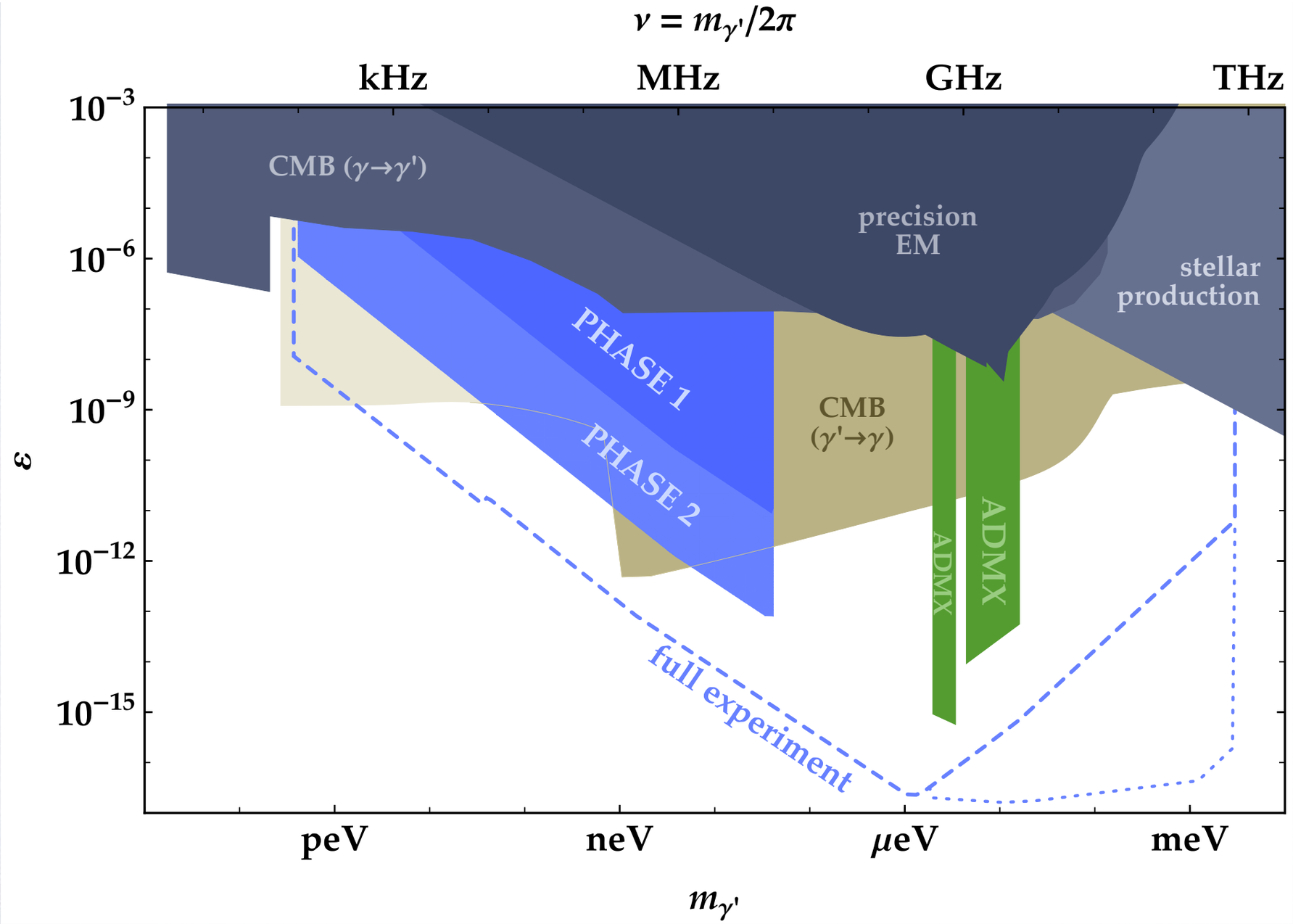
size ~ 350ml — 1m $Q \sim 10^6$

T~4K, thermal noise limited

FULL DESIGN

size ~ 1m $Q \sim 10^6$

T~0.1K, thermal noise limited



CONCLUSIONS

Axion search methods **easily probe hidden photons**

If B-fields are a problem…

a hidden-photon search gives **real science reach without static B-field**

Cavity-to-cavity light-through-walls experiments could be very powerful

Hidden-photon **dark matter search with LC resonator** has huge reach (upcoming at Stanford)

key refs: 1201.5902, 1407.4806, 1411.7382

Extras

Confirming a signal

Excellent **cross-checks** are possible:

— always at same **fixed frequency**

— **orientation dependence** is characteristic of vector

— phase and directional **coherence over ~1000 wavelengths**

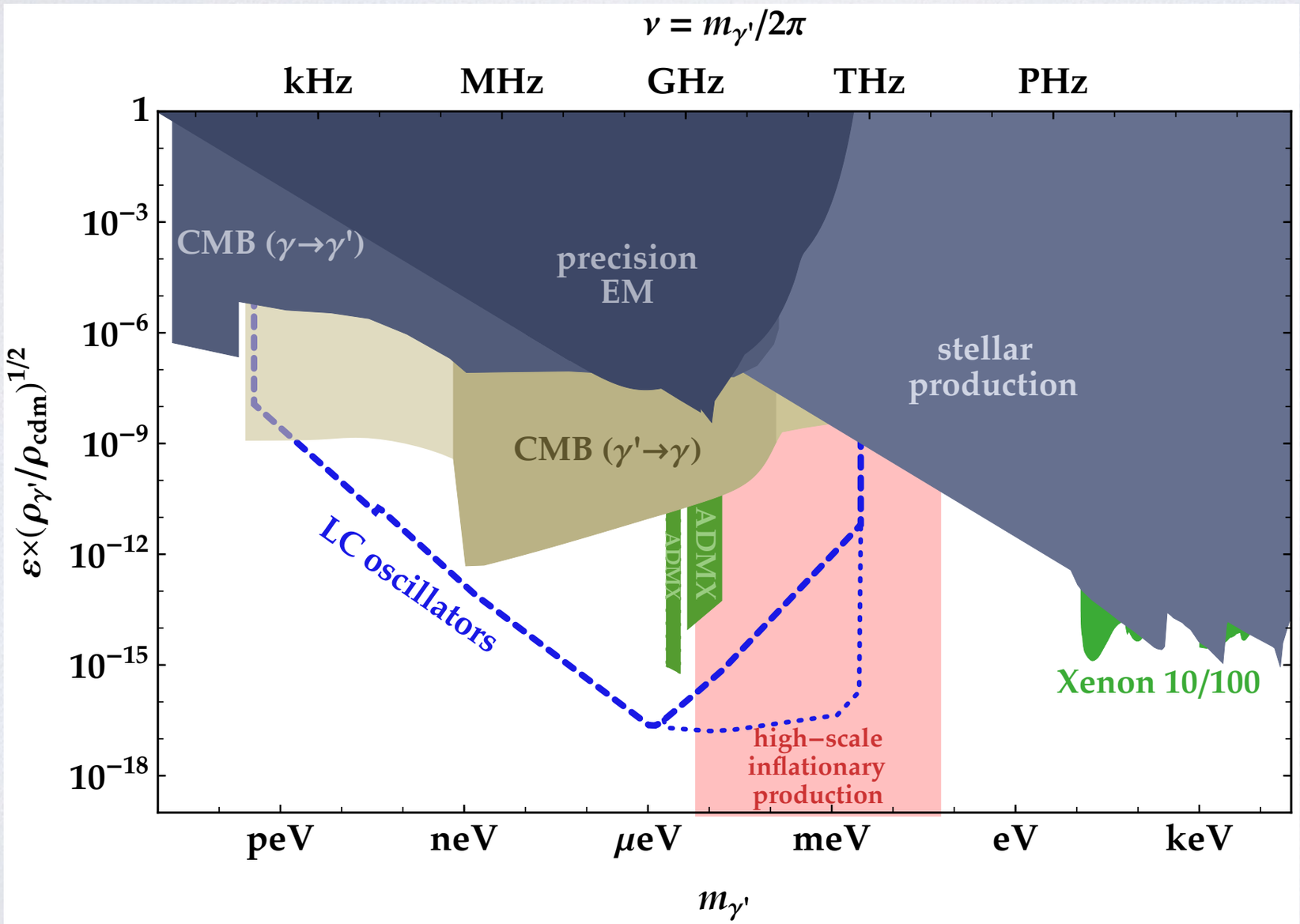
— could **map out phase and direction** over time

PRODUCTION SUMMARY

Inflation produces full DM abundance →

Graham, JM & Rajendran 1504.02102

← **Inflation produces DM subcomponent**



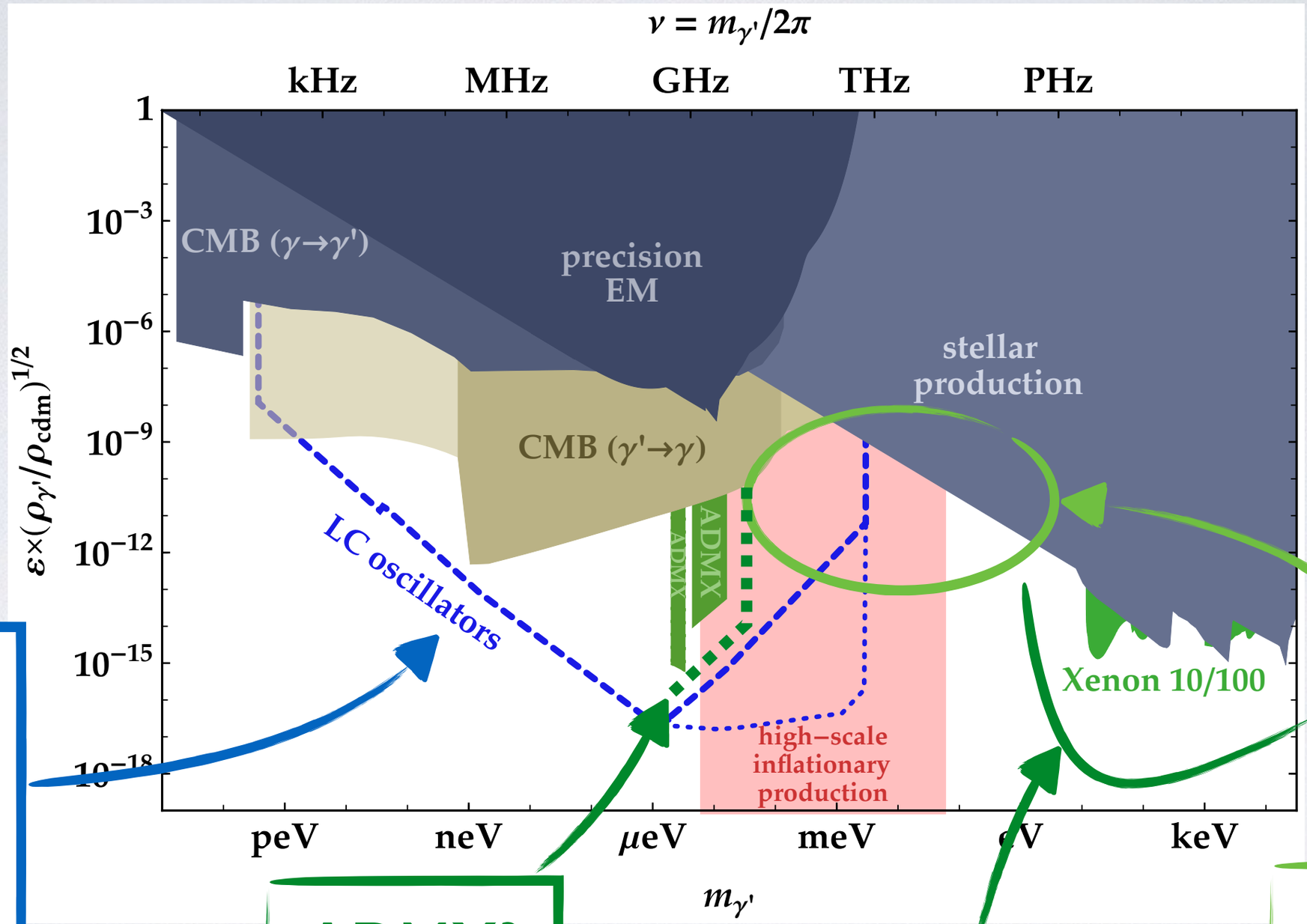
ALSO:

— Misalignment production possible (with special $A_\mu A^\mu \mathcal{R}$ coupling)

Arias et al 1201.5902

— Production not fully explored (work in progress)

Detection Summary



Next few years at SLAC/ Stanford

1411.7382

ADMX?

1201.5902

Direct detection?

1412.8378

?? (dish focussing?)

1212.2970