

HIDDEN PHOTON DARK MATTER SEARCHES AND PRODUCTION

ULTRA-LIGHT HIDDEN PHOTONS

THEORETICALLY

Kinetically-mixed, massive, $U(1)'$ gauge boson

$$\mathcal{L} = \mathcal{L}_{SM} - \frac{1}{4} F'^2 + 2\varepsilon F_{\mu\nu} F'^{\mu\nu} + \frac{1}{2} m_A^2 A'^2$$

kinetic mixing ε

small vector mass

**Dynamically generated
(Higgs mechanism)**
— new light d.o.f.

**Fundamental mass
("Stueckelberg mass")**
— no other d.o.f.

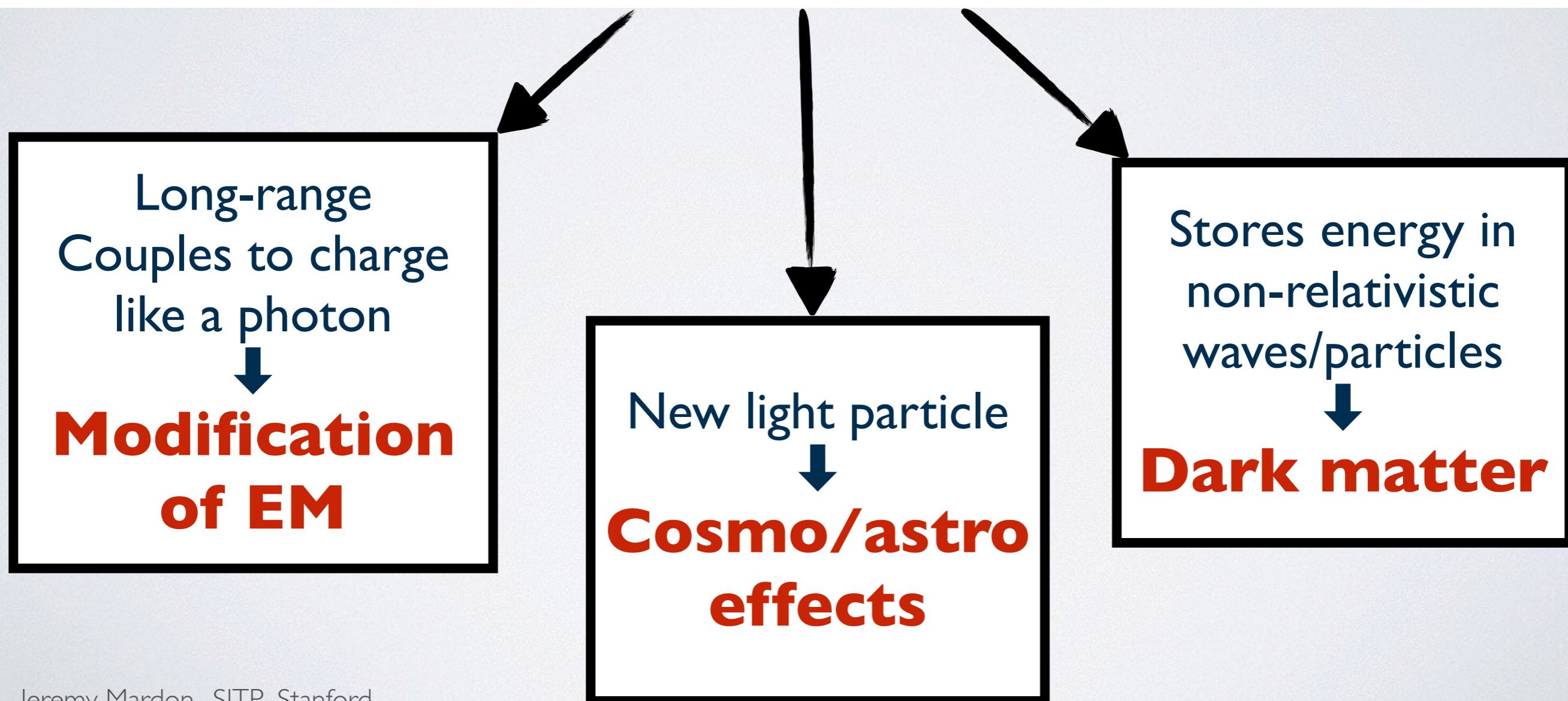
- different cosmology / astrophysics
- same signal in hidden-photon searches

ULTRA-LIGHT HIDDEN PHOTONS

PHENOMENOLOGICALLY

A new force / force carrier:

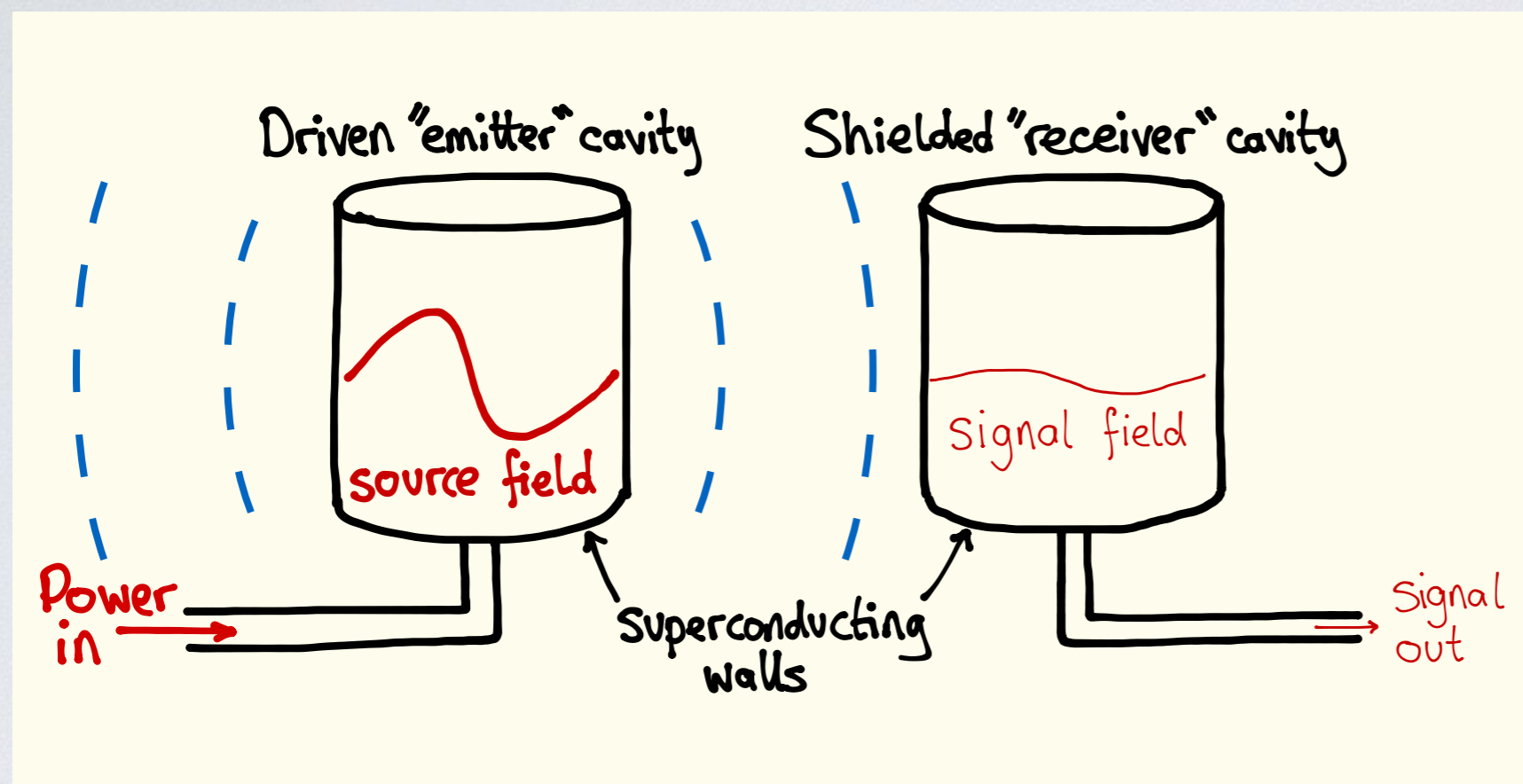
a copy of E&M, with a finite range & very weakly coupled



LIGHT-THROUGH-WALLS SEARCHES FOR HIDDEN PHOTONS

MICROWAVE CAVITY SEARCH

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



Jaeckel & Ringwald
0707.2063

- 2 cavities can be tuned to same frequency
- amazing resonant enhancement: $Q \sim 10^{10}$
- self-shielding from backgrounds

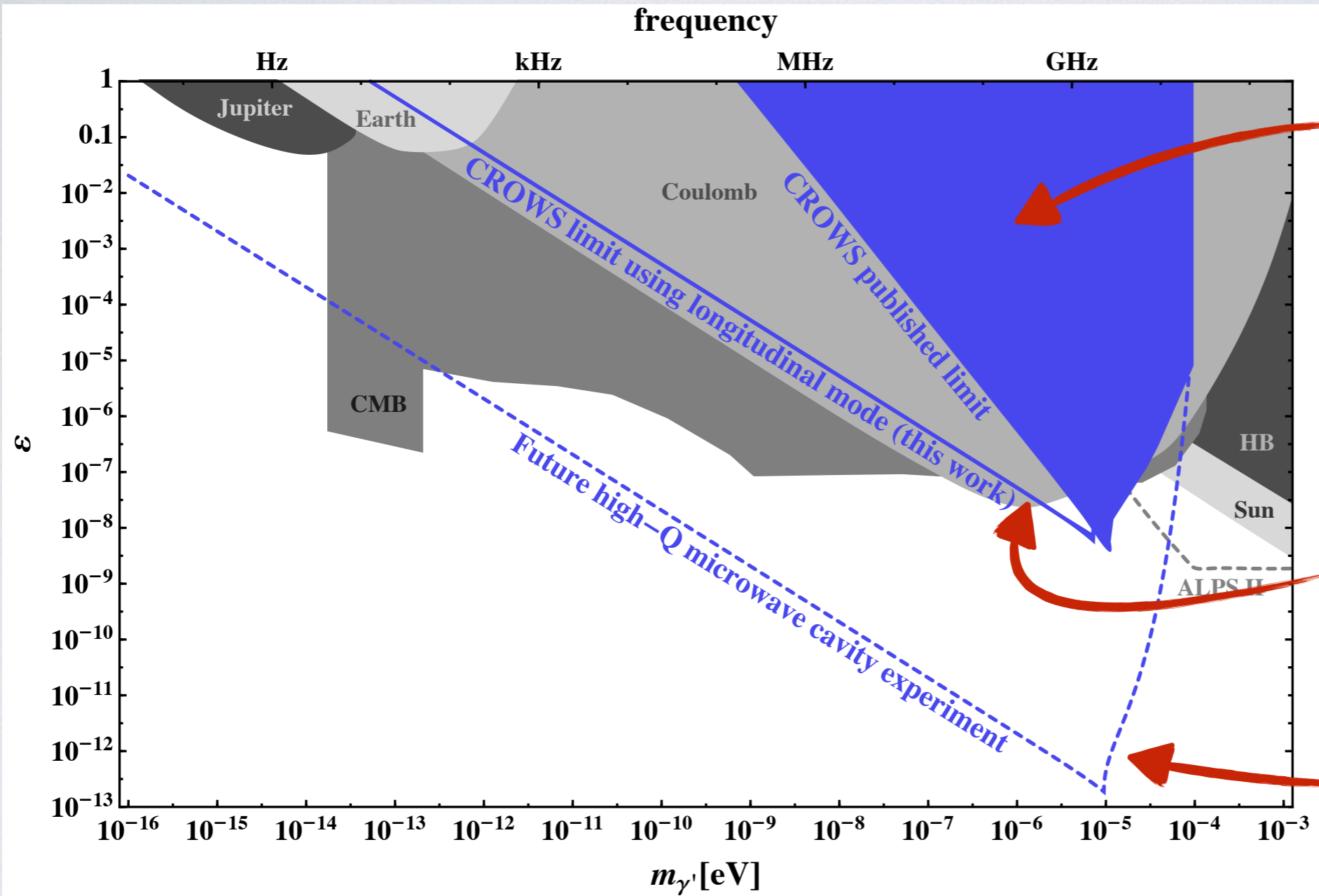
Early-stage experiments already carried out

Povey et al 1003.0964

ADMX 1007.3766

CROWS 1310.8098

REACH



Published bound

CROWS collaboration
|3|0.8098

Reanalyzed bound including longitudinal mode

Graham, J. M., Rajendran & Zhao
|4|07.4806

Potential reach

proposal with Sami Tantawi & Vinod Bharadwaj

SEARCHING FOR HIDDEN PHOTON DARK MATTER

HIDDEN-PHOTONS AS DARK MATTER

Light boson as dark matter?

pseudoscalar

axion

vector

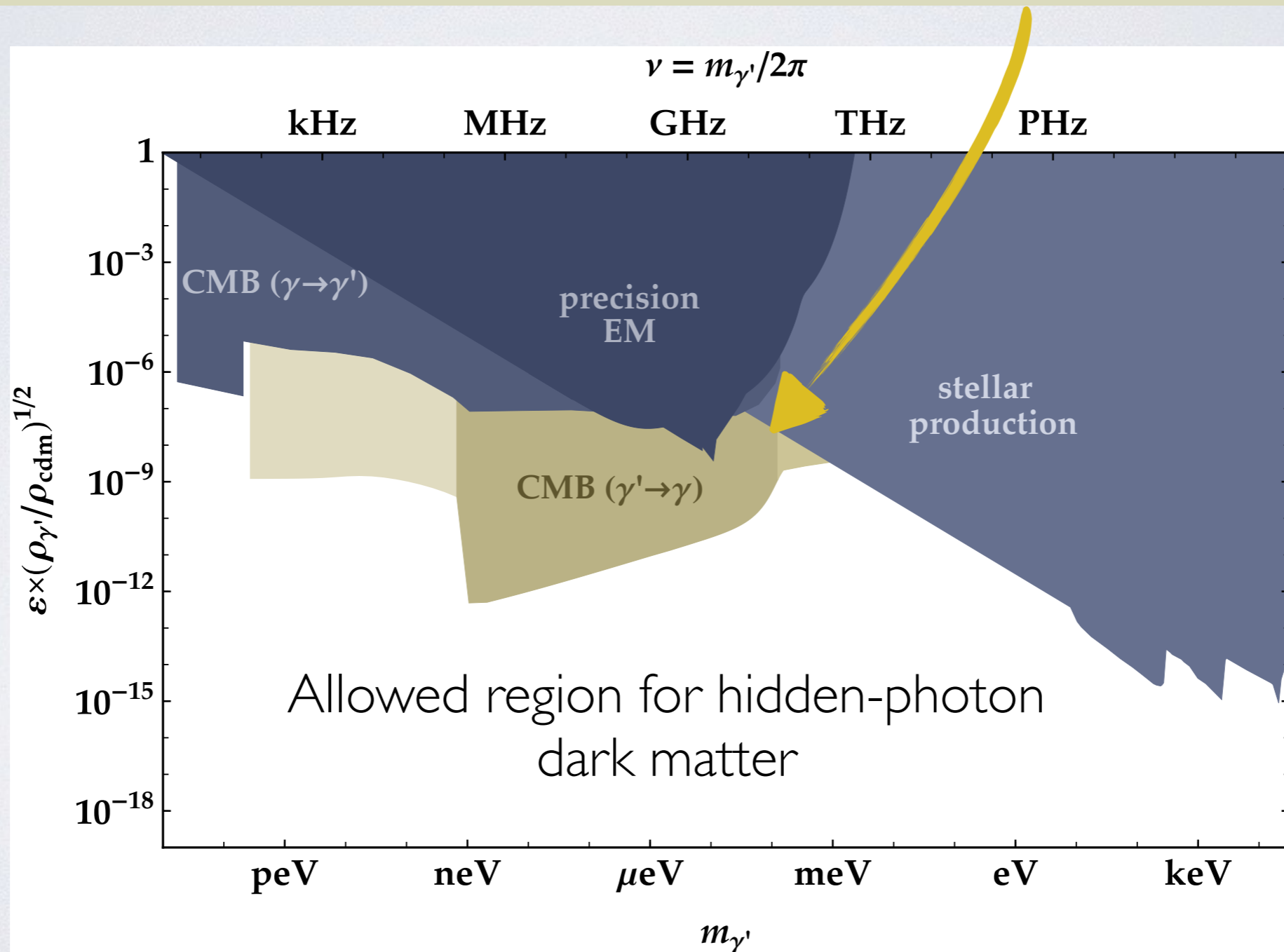
hidden photon

- classical A'_μ field
- oscillation frequency $\omega = m_{A'}$
- random direction

Pospelov Ritz & Voloshin 0807.3279
Nelson & Scholtz 1105.2812

ASTROPHYSICAL CONSTRAINTS

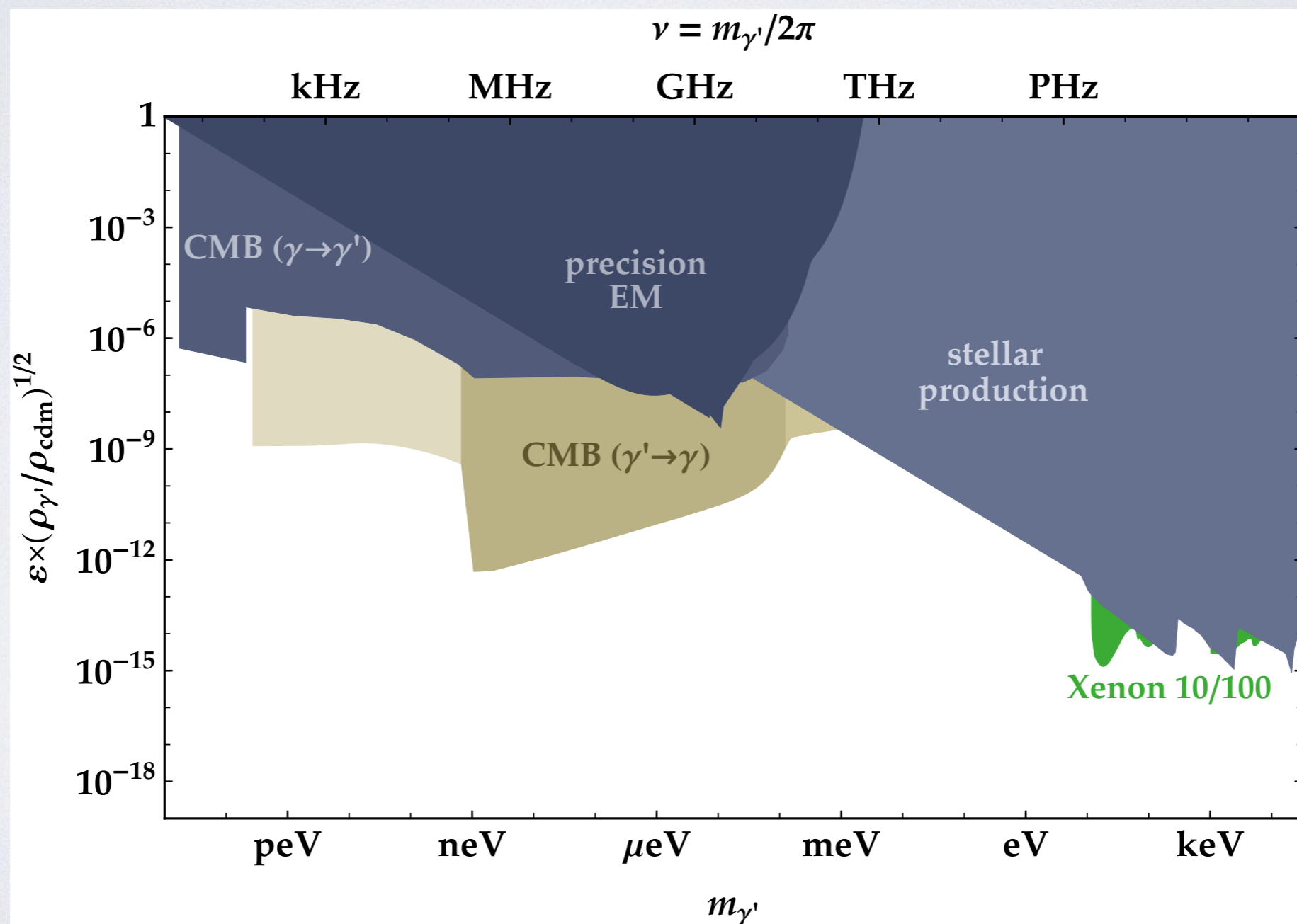
Hidden photon DM:
new constraints from energy deposition into SM plasma
Redondo et al 1201.5902



DETECTING HIDDEN PHOTON DM

I. Absorption of individual hidden photons in detectors

Pospelov, Pradler et al 1412.8378



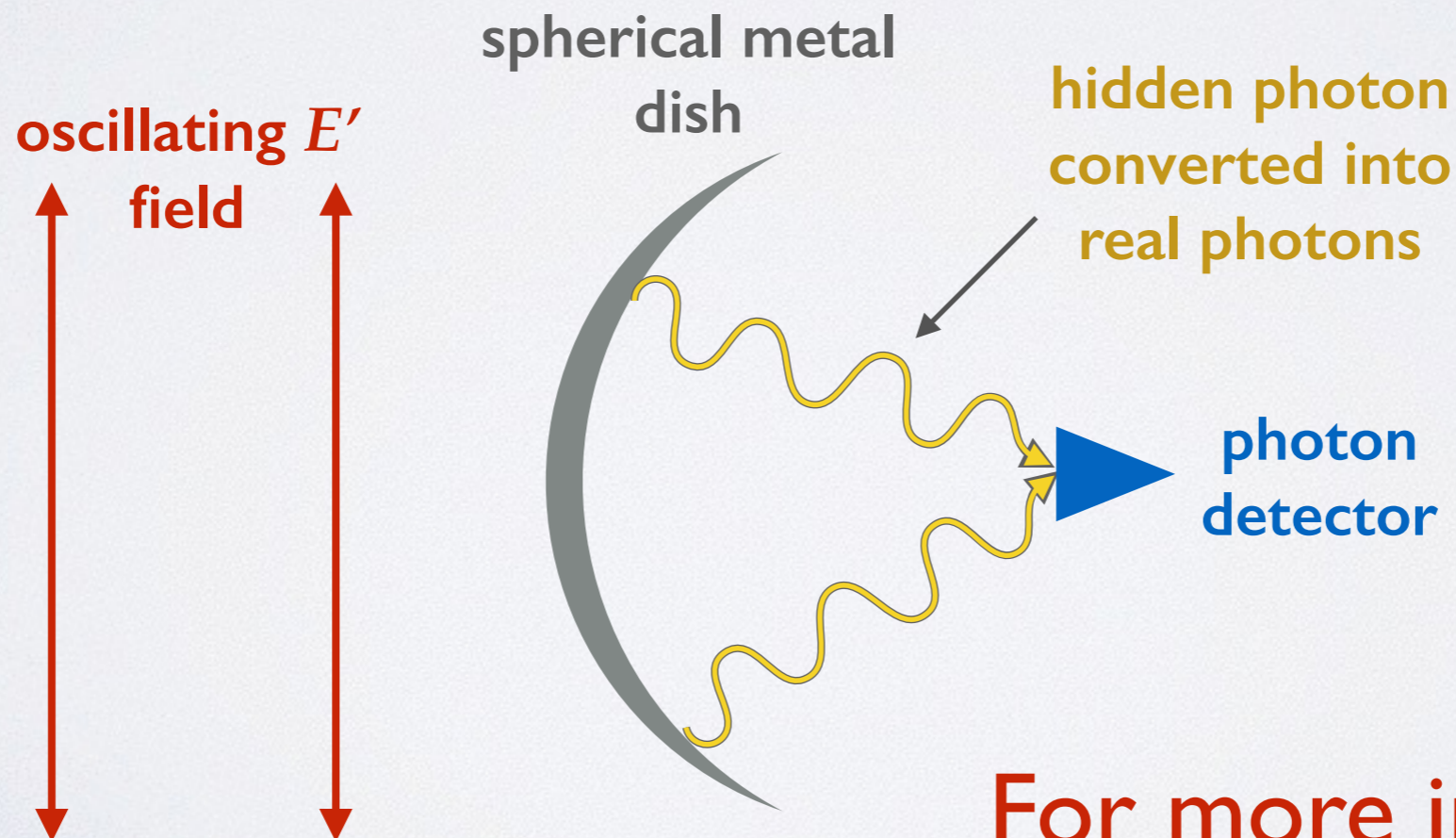
DETECTING HIDDEN PHOTON DM

2. Dish antenna Redondo et al 1212.2970

Hidden photon DM:

A “hidden electric field” that penetrates shielding

Oscillates with fixed frequency $\omega = m_{\gamma'}$



For more info ask Javier!

DETECTING HIDDEN PHOTON DM

3. Resonant searches

A “hidden electric field” that penetrates shielding

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

Has fixed frequency

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

Can excite an electromagnetic resonator

electromagnetic cavities

— ADMX is automatically sensitive!

Redondo et al I201.5902

— cavity size restricts mass range

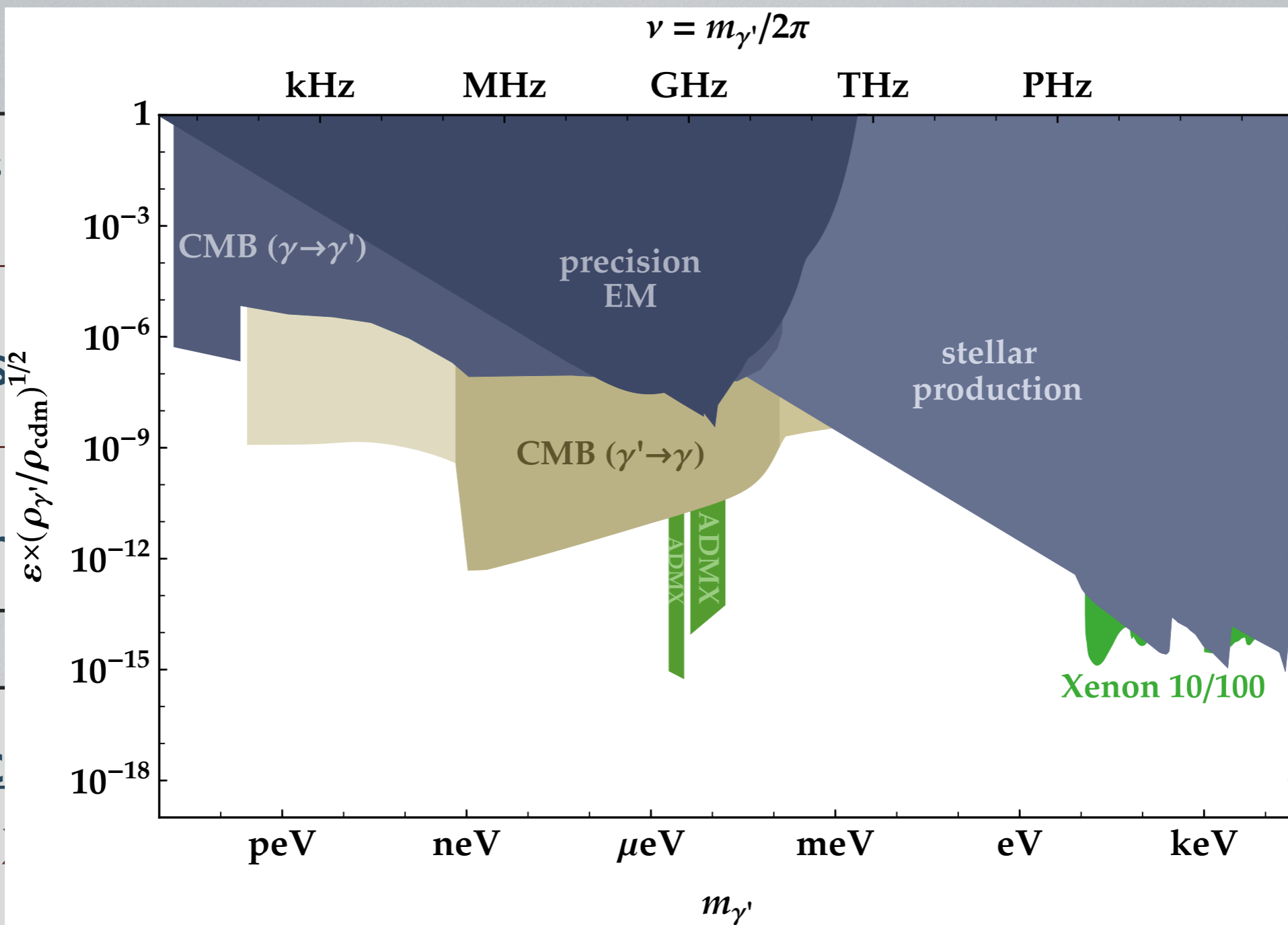
DETECTING HIDDEN PHOTON DM

3. Reso

A “
Has
Car

elec
— ADMX

— cavity size restricts mass range



DETECTING HIDDEN PHOTON DM

3. Resonant searches

A “hidden electric field” that penetrates shielding

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Can excite an electromagnetic resonator

↙ ↘

electromagnetic cavities

- ADMX is automatically sensitive!
Redondo et al I201.5902
- cavity size restricts mass range

LC circuits

- can be high Q
- much wider and lower frequency range than cavities

SCANNING FOR HIDDEN PHOTON DARK MATTER WITH A HIGH-Q RADIO

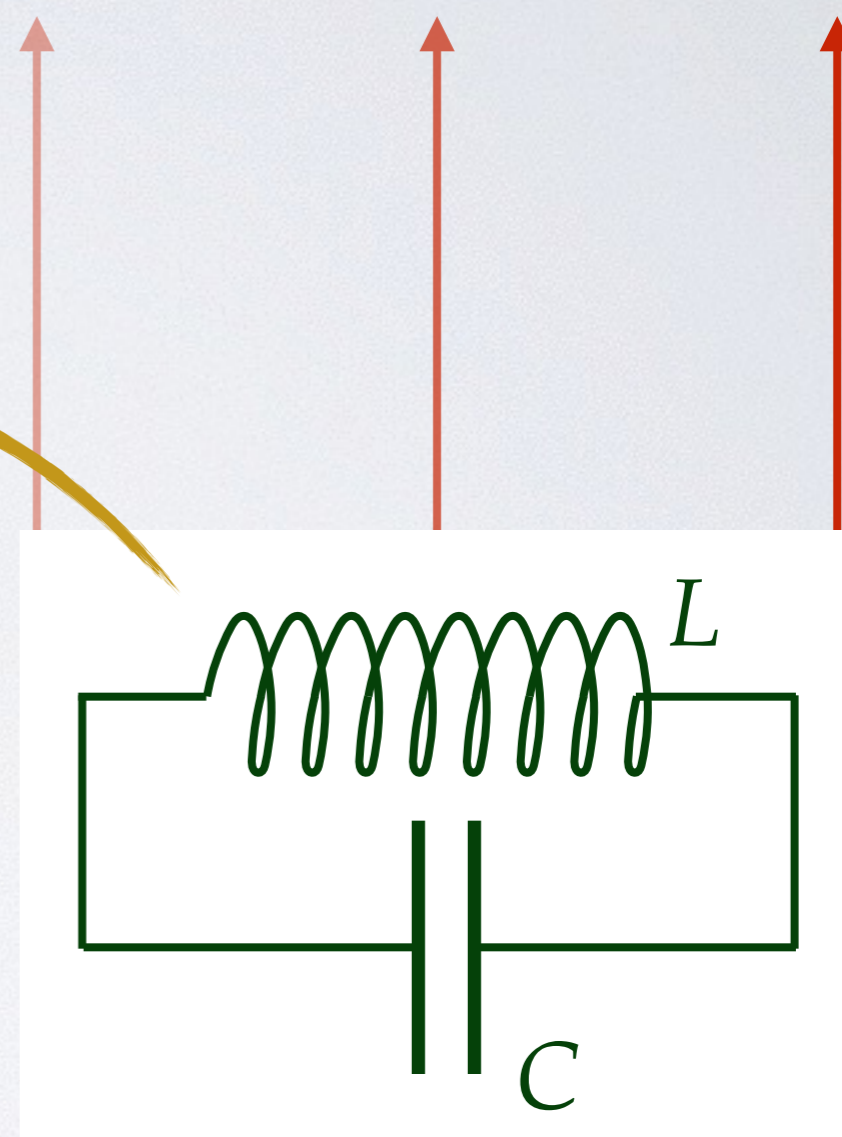
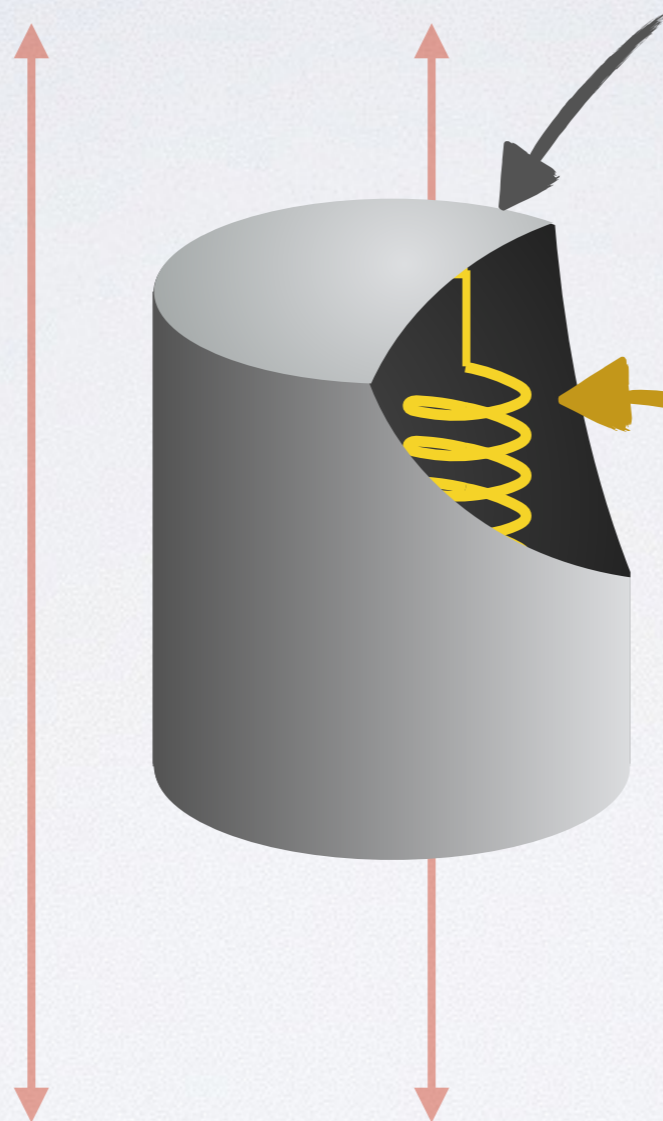
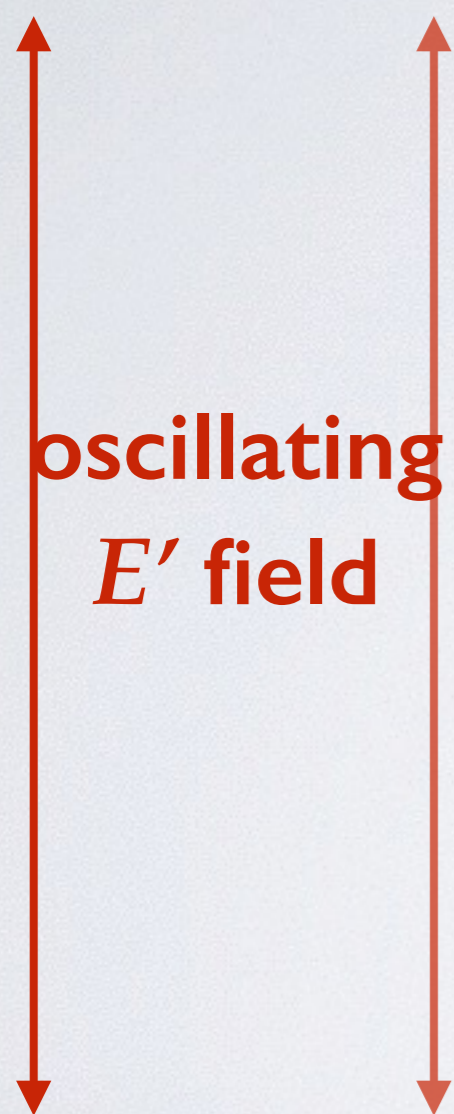
“A Radio for Hidden-Photon Dark Matter Detection”

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

[arXiv:1411.7382](https://arxiv.org/abs/1411.7382)

EXPERIMENTAL SETUP

Metal box to shield backgrounds



Tunable resonant LC circuit
Read out with SQUID

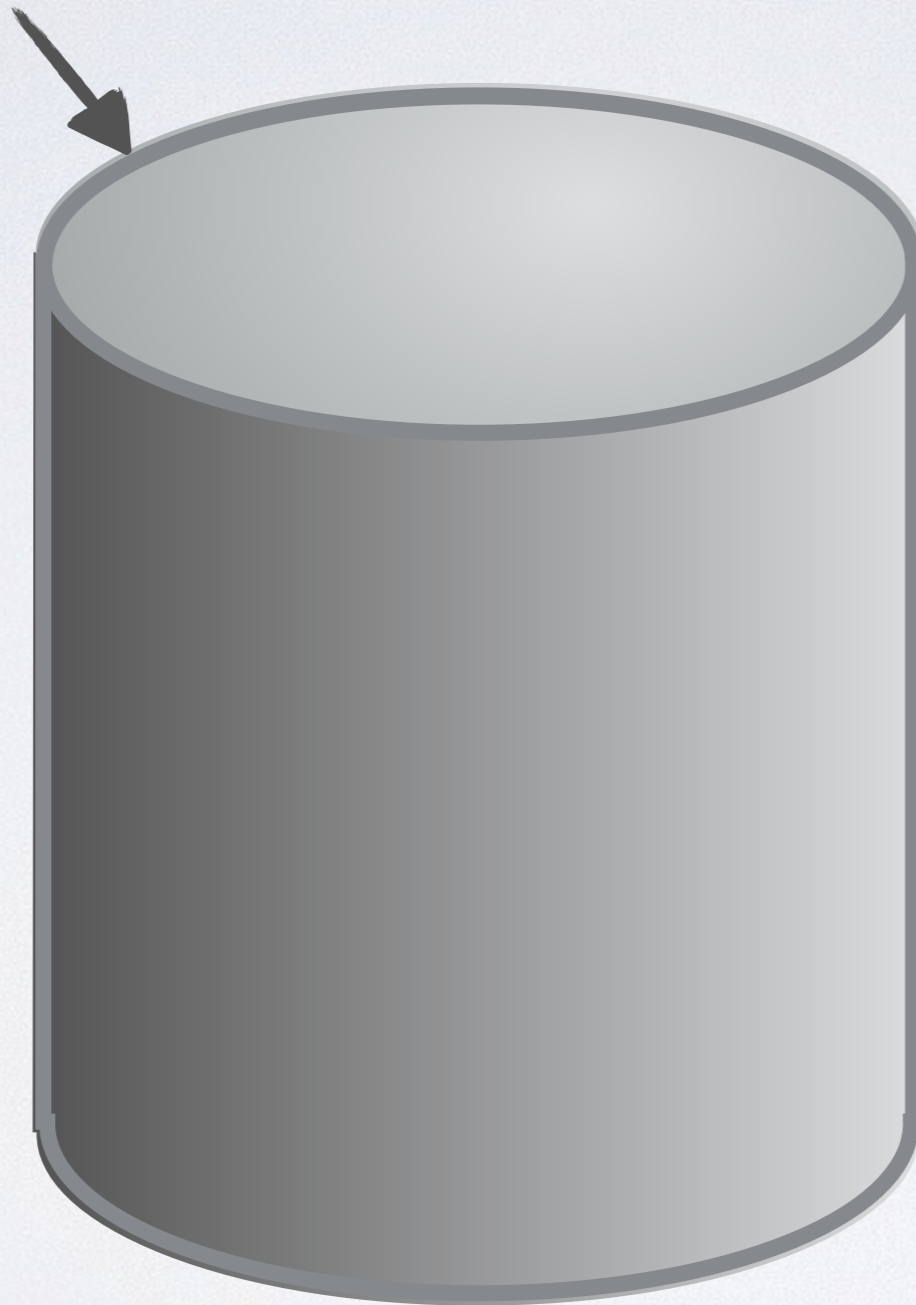
THE SIGNAL INSIDE A SHIELD

Metal box to shield
backgrounds

conduction electrons in wall
respond to E' field,
cancelling observable
combination

$$E + \epsilon E' \dots$$

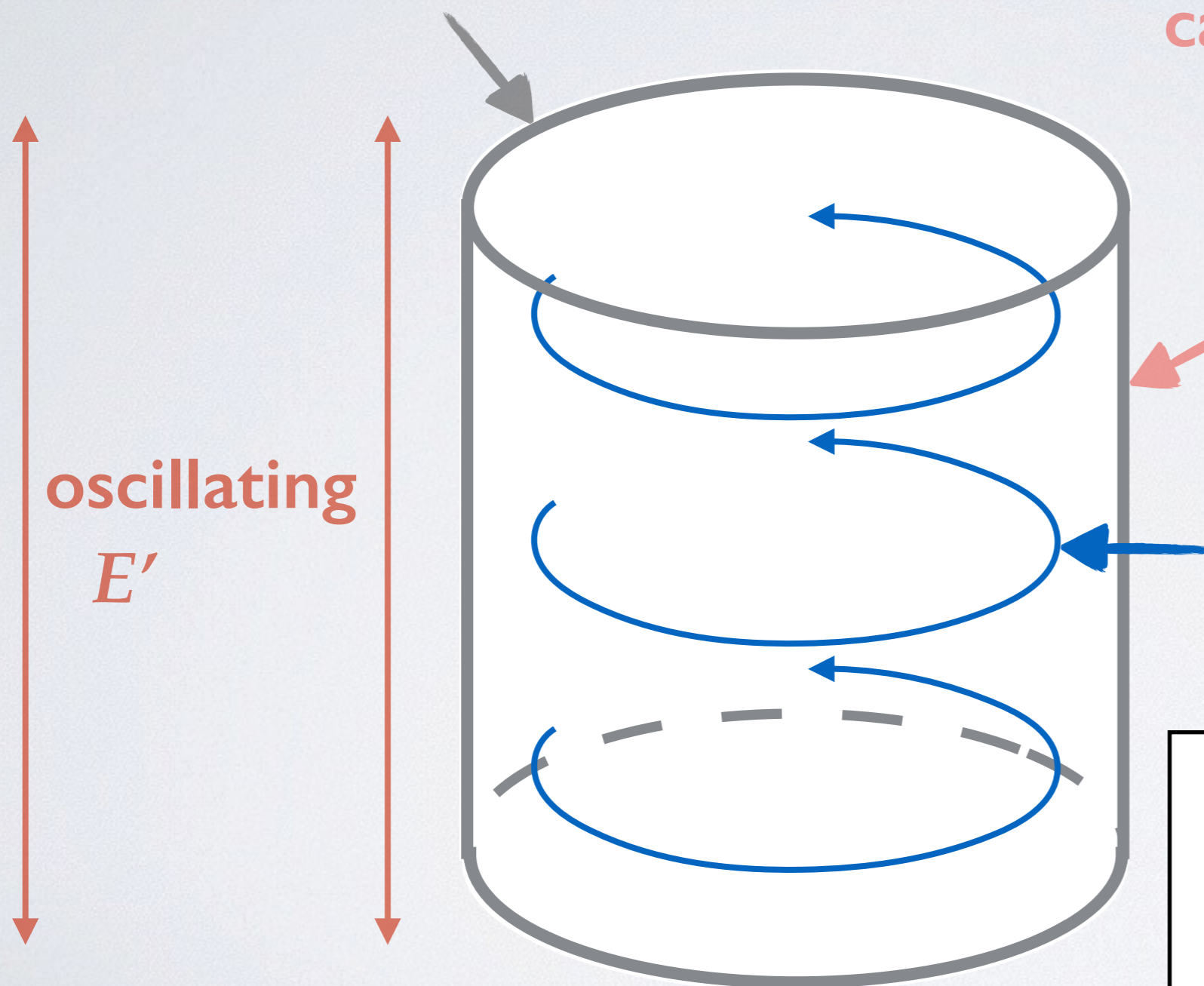
oscillating
 E' field



THE SIGNAL INSIDE A SHIELD

Metal box to shield
backgrounds

conduction electrons in wall
respond to
cancelling observable
combination



$$E + \epsilon E'$$

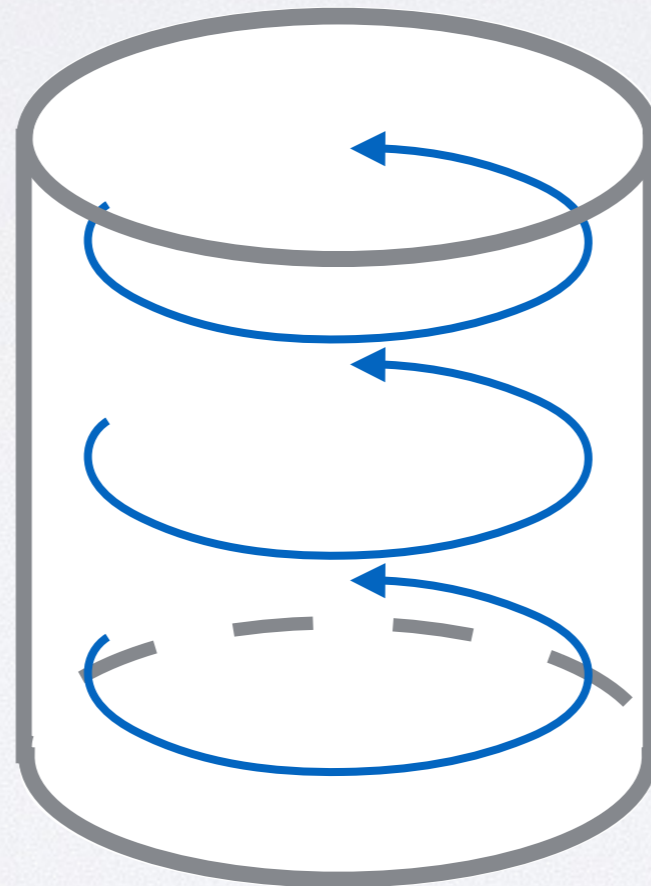
...but generating real
 B field inside the
shield

$$B \sim \epsilon (m_{\gamma'} R) \times 10^{-5} \text{ T}$$

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

DM RADIO CONCEPT

- Inductor designed to pick up induced B-field
- Piezo-adjusted capacitor to tune resonant frequency
- Read out with SQUID
- Scan over frequency looking for signal



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

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



Stanford
University



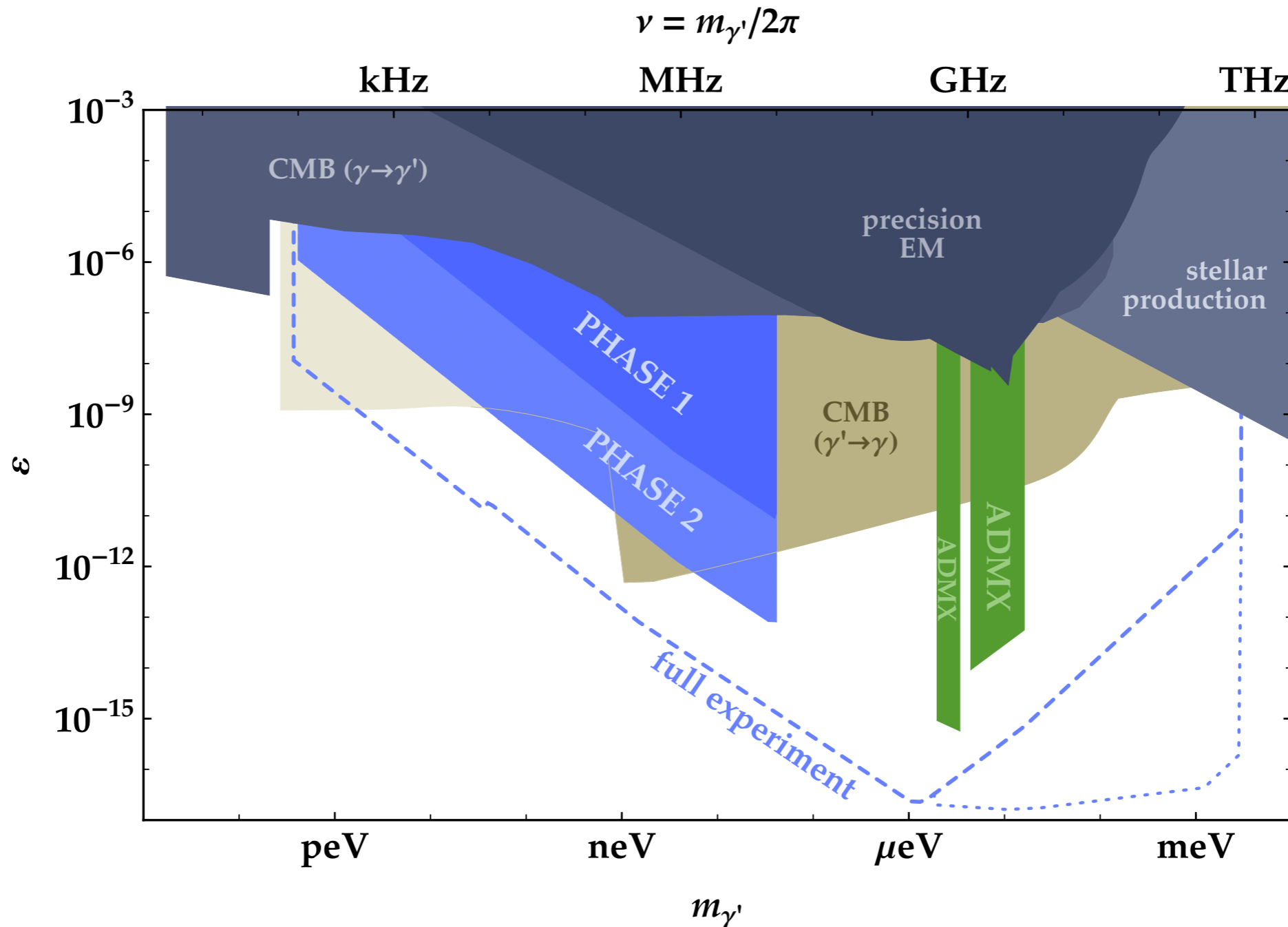
REACH

STAGE I

size ~ 350ml — 1m $Q \sim 10^6$
 $T \sim 4K$, thermal noise limited

FULL DESIGN

size ~ 1m $Q \sim 10^6$
 $T \sim 0.1K$, thermal noise limited



HIDDEN PHOTON DARK MATTER FROM INFLATION

“Vector Dark Matter from Inflationary Fluctuations”

Peter Graham, J. M. & Surjeet Rajendran

[arXiv:1504.02102](https://arxiv.org/abs/1504.02102)

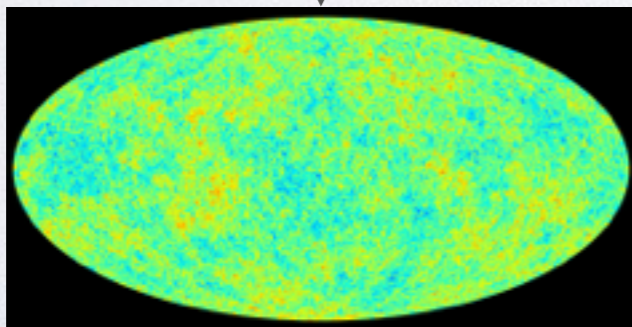
Inflation

⇒ coherent particle production

scalar

inflaton
fluctuations

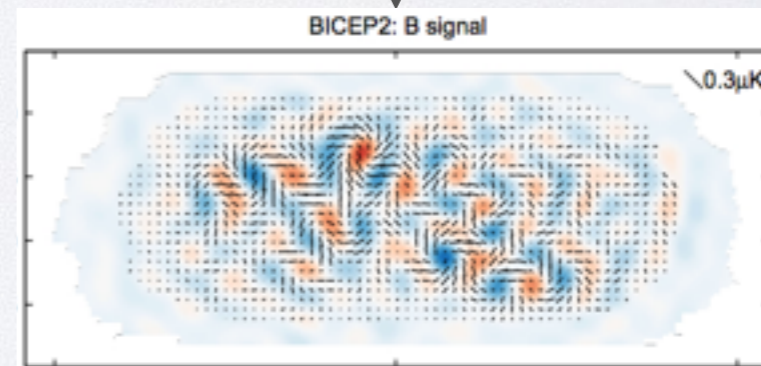
adiabatic
density
perturbations



tensor

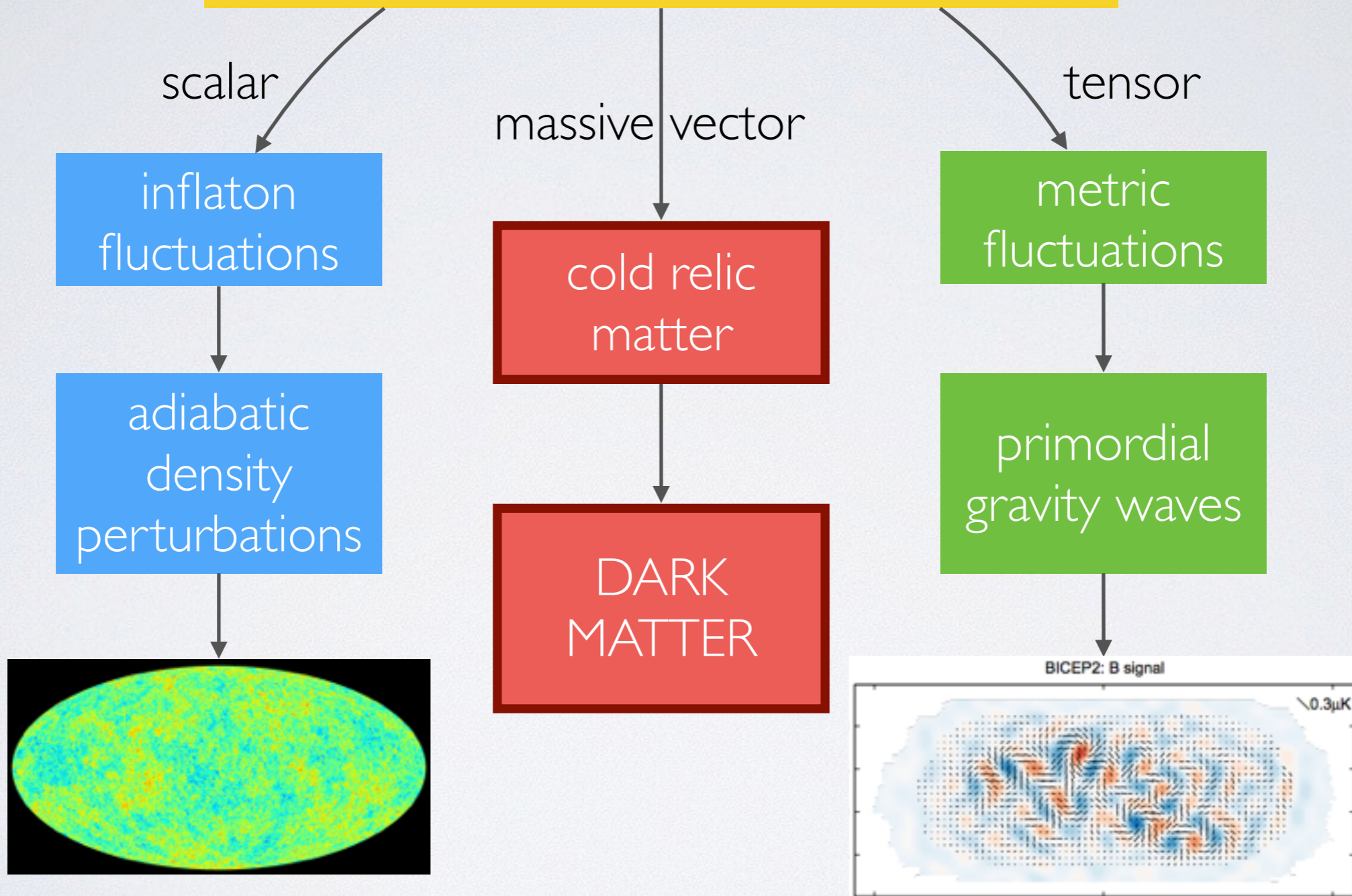
metric
fluctuations

primordial
gravity waves



Inflation

⇒ coherent particle production



COMMENTS

- Requires **Stueckelberg mass** (or Higgs scale above H_I)
- Spectrum peaked at intermediate wavelengths
→ large-scale **isocurvature modes highly suppressed**
- Abundance set by mass and inflationary scale

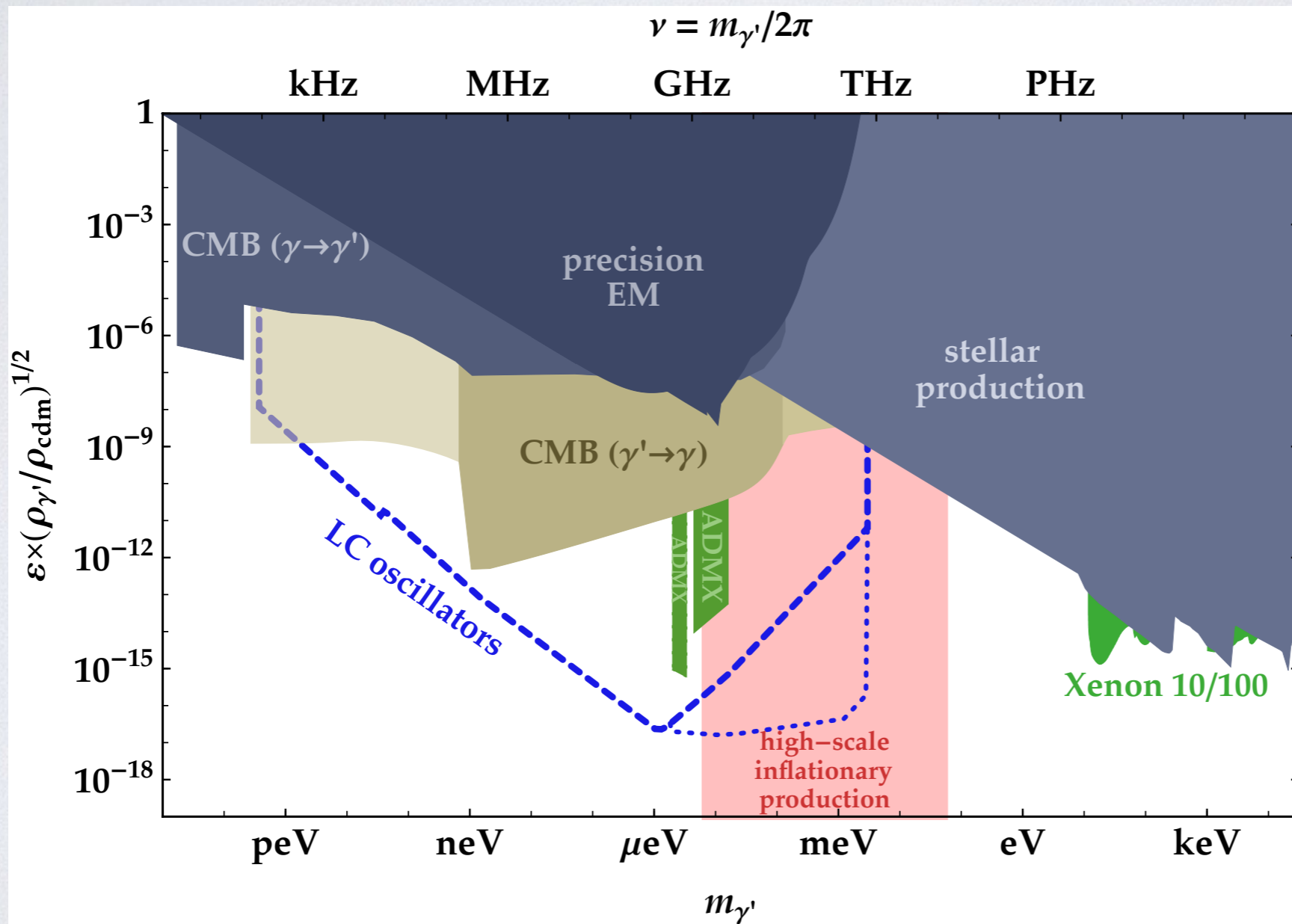
$$\frac{\Omega_A}{\Omega_{\text{cdm}}} \approx \sqrt{\frac{m}{6 \times 10^{-6} \text{ eV}}} \left(\frac{H_I}{10^{14} \text{ GeV}} \right)^2$$

PRODUCTION SUMMARY

Inflation produced full DM abundance



Inflation produced DM subcomponent



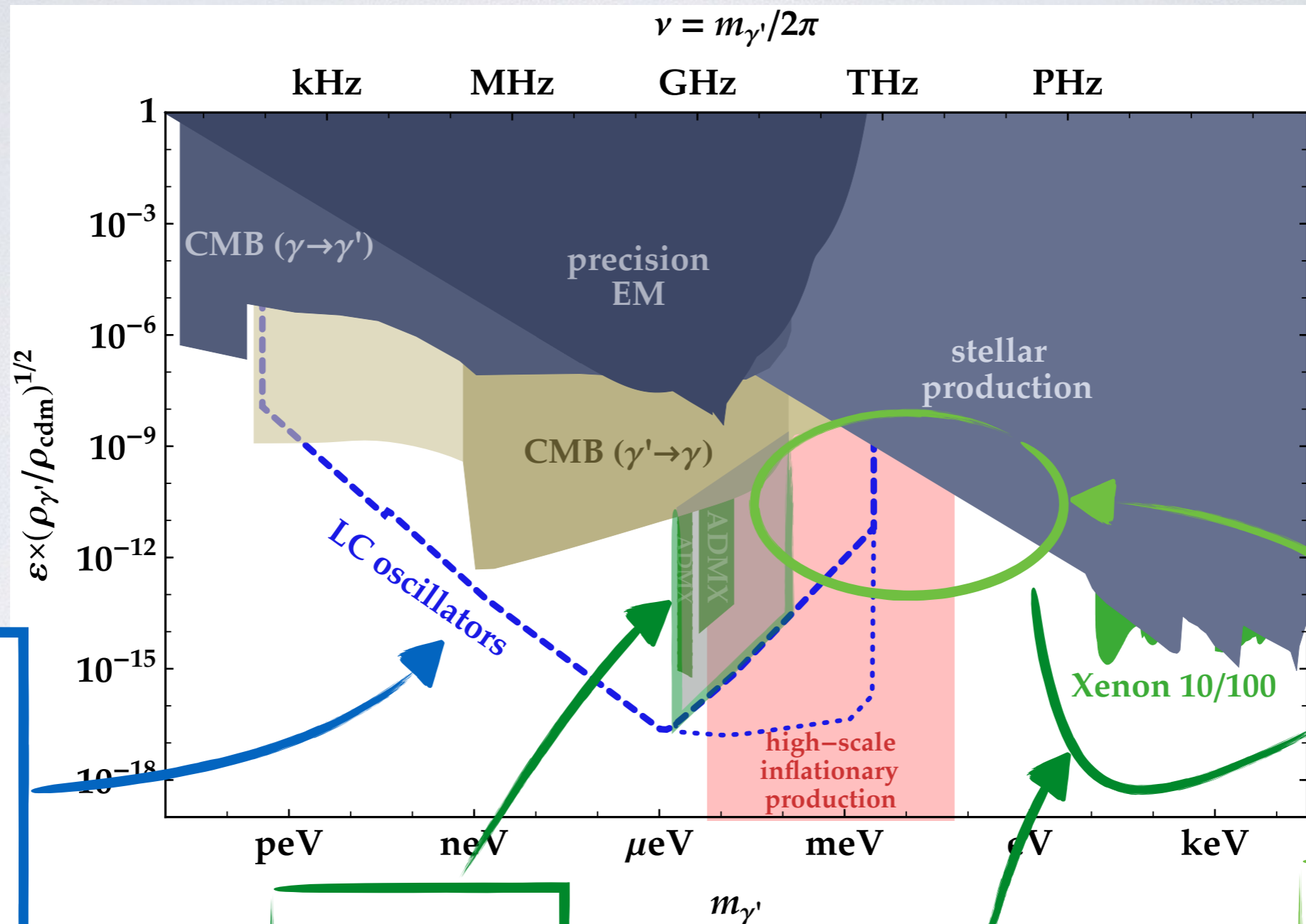
ALSO:

— Misalignment production possible with special A^2R coupling

Redondo et al 1201.5902

— Production not fully explored

DETECTION SUMMARY



Next few years at SLAC/Stanford

ADMX?

Direct detection?

Dish focussing? (???)

STAY TUNED