

# Producing cosmic birefringence through CP-violating axions

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Johns Hopkins University

Based on arXiv/2311.03536  
with Xuheng Luo



$\langle \bar{N} N \rangle$

# Axion-Like Particles: A Primer

- Pseudo-scalars, well-motivated BSM candidates
- Messengers of a variety of UV scenarios

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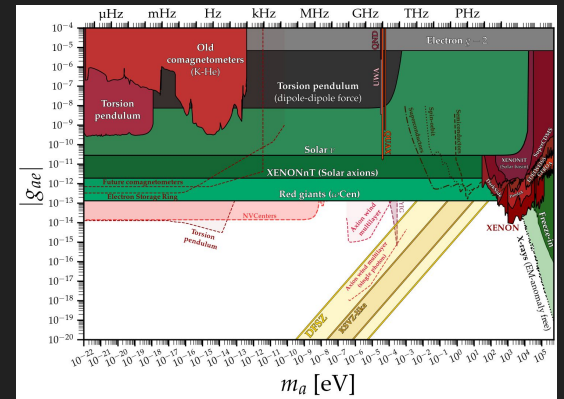
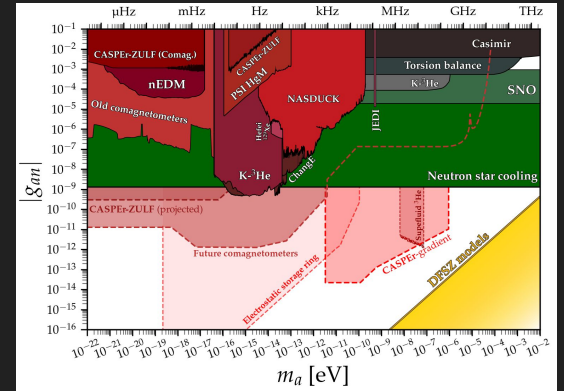
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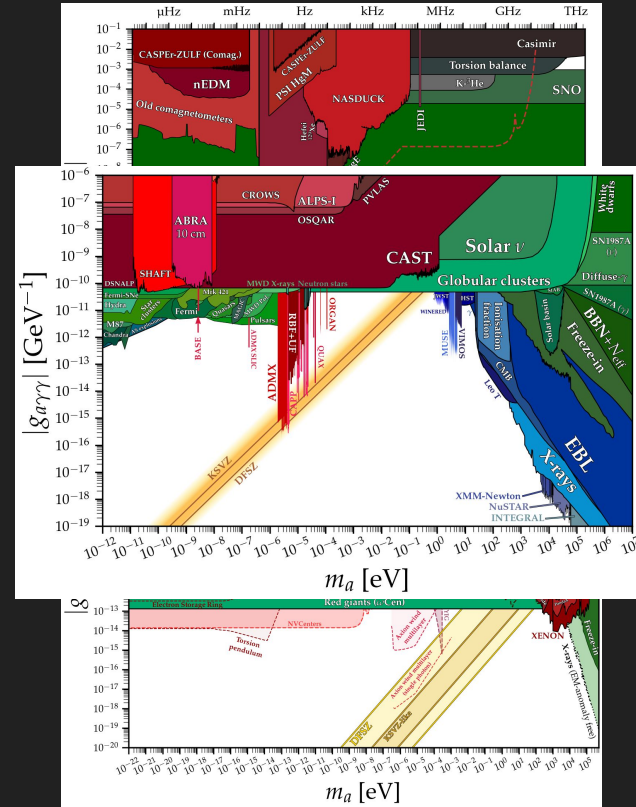


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$$g_{a\gamma} a F \tilde{F}$$



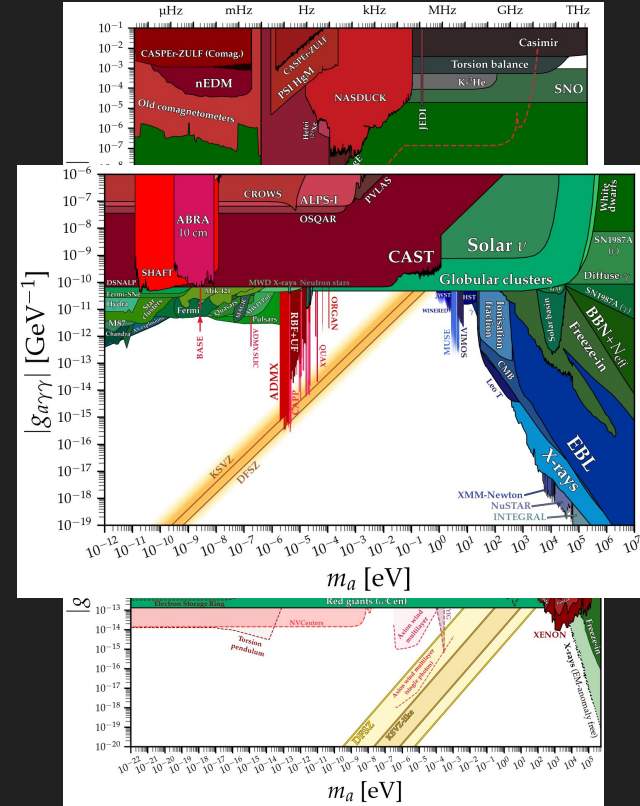
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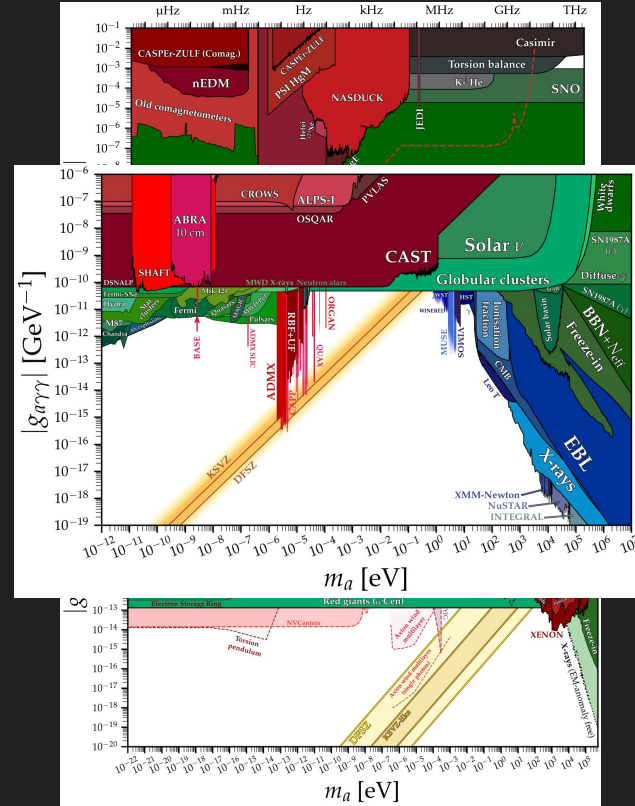
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$g_{aN} a \bar{N} N$   
 CP violating source term!

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# A CP Violating Interaction Term

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- Sources static, coherent monopole field

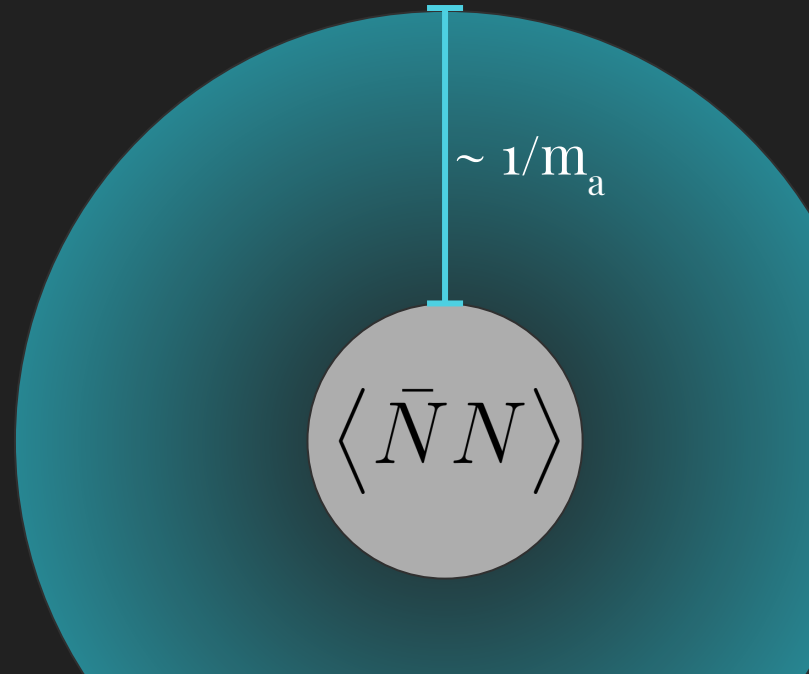
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$$\langle \bar{N} N \rangle$$

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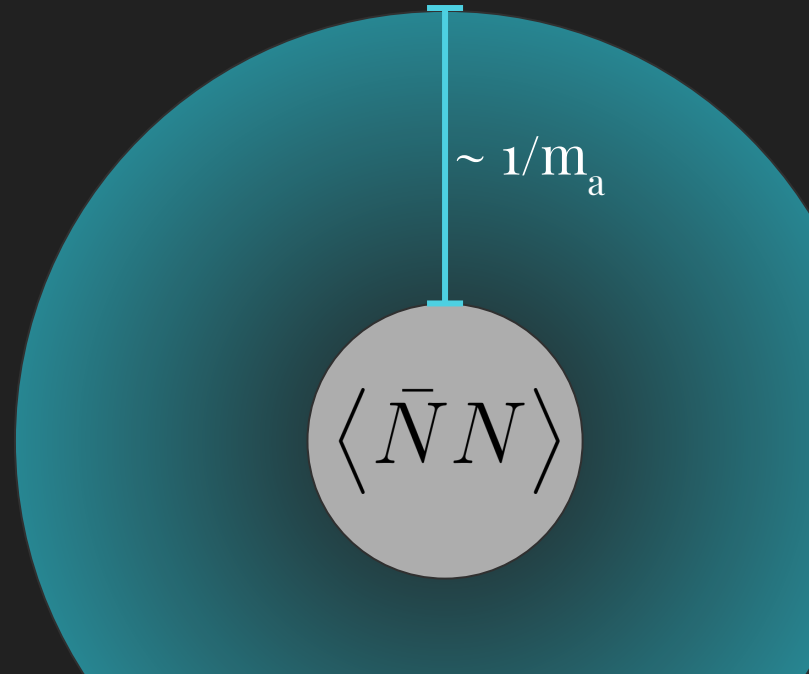


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- Dimension 4 operator:  
probes at what level CP is preserved
- Breaks shift symmetry just like mass term

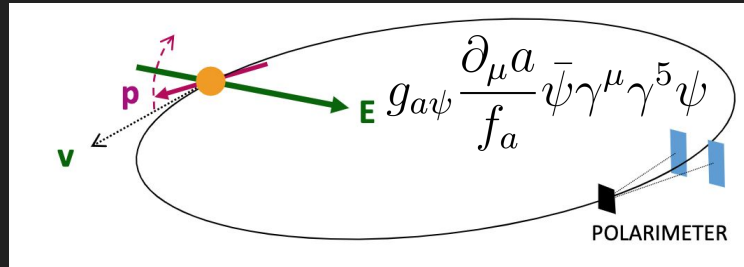


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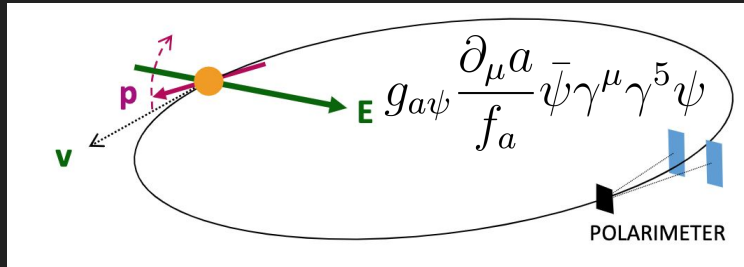
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← Storage rings  
(2210.17547)

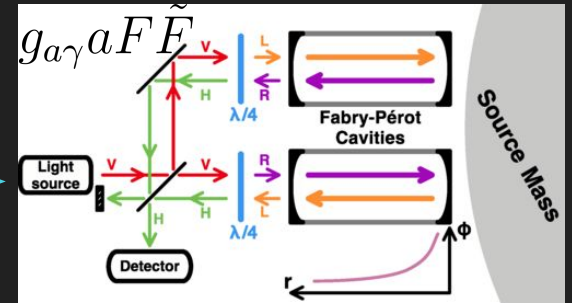
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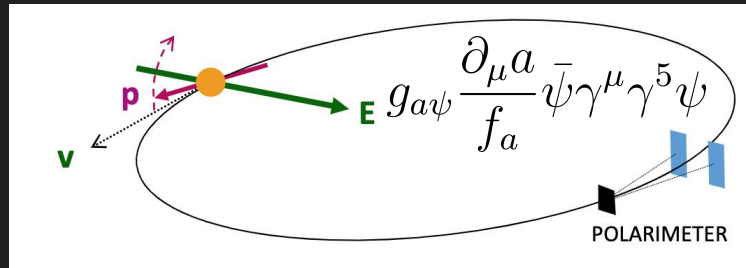
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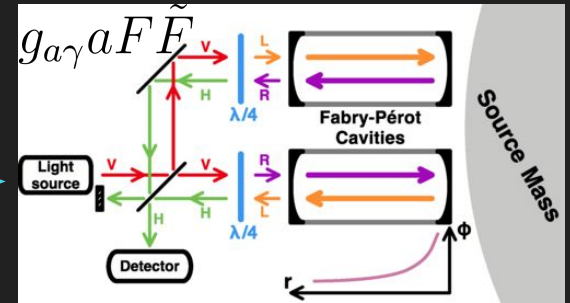
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- New direction: ALP mass  $\sim$  Hubble scale  $\Rightarrow$  background field in cosmology
- Signature: large change in field vev between recombination and today

$$\langle \bar{N} N \rangle = \frac{3\Omega_b H_0^2 M_{\text{Pl}}^2}{8\pi m_N} (1+z)^3$$

# Birefringence

- Propagating left/right circularly polarized photons pick up additional phase

$$\pm \frac{1}{2} g_{a\gamma} (a(t_{\text{final}}, x_{\text{final}}) - a(t_{\text{initial}}, x_{\text{initial}}))$$



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Net rotation of linear polarization angle

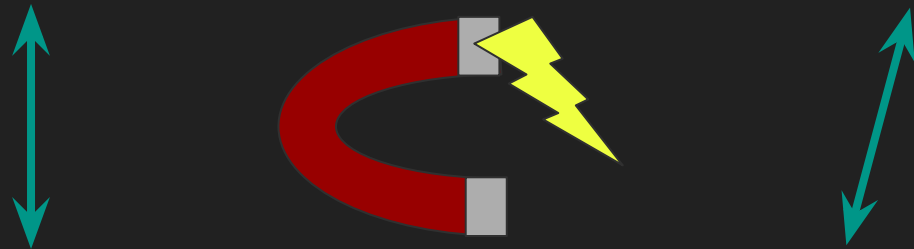
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- Similar to Faraday effect in magnetic field backgrounds

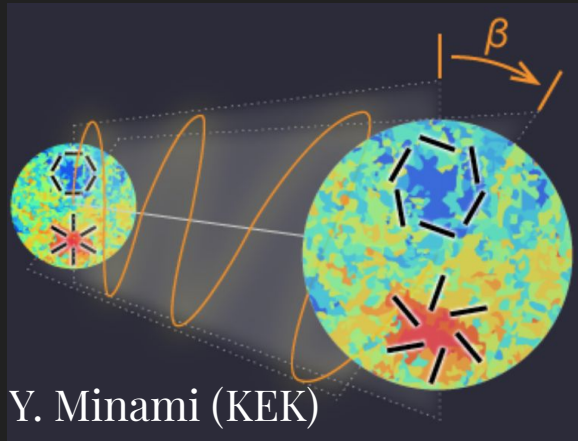


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Y. Minami (KEK)

# Cosmological Evolution

- Homogeneous expectation value, following

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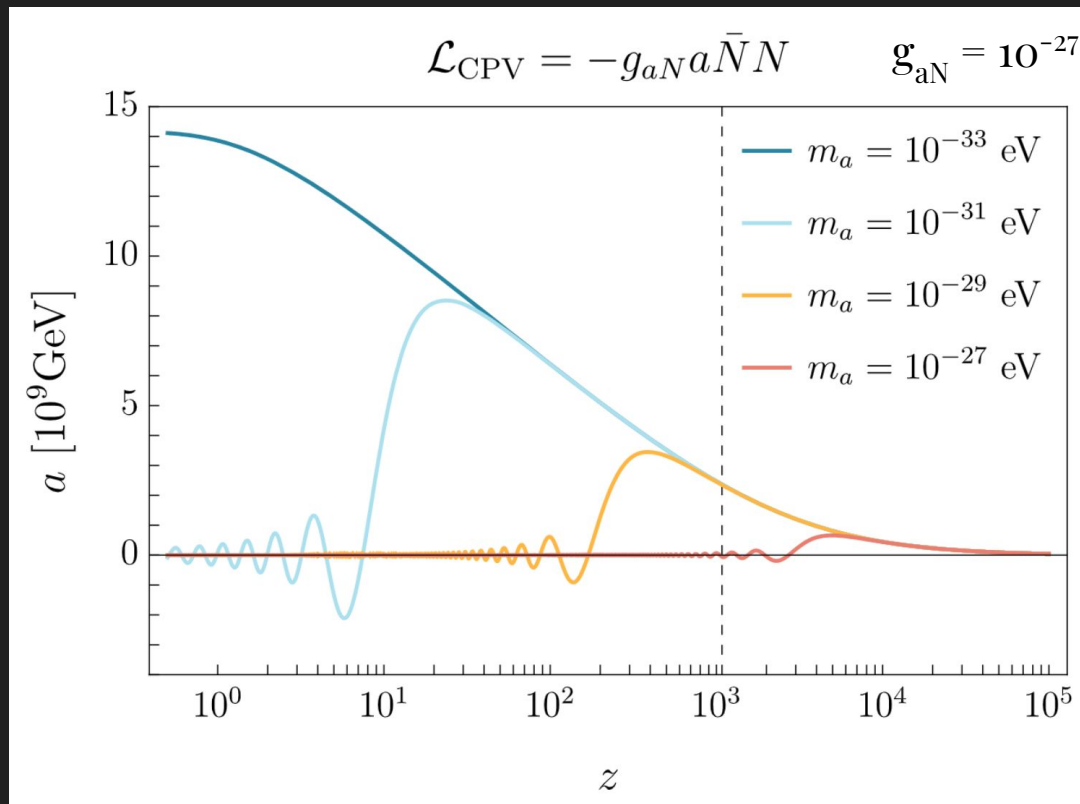
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- Focus on case with small initial condition: robust late-time effect
- Field excursion depends solely on  $m_a, g_{aN}$

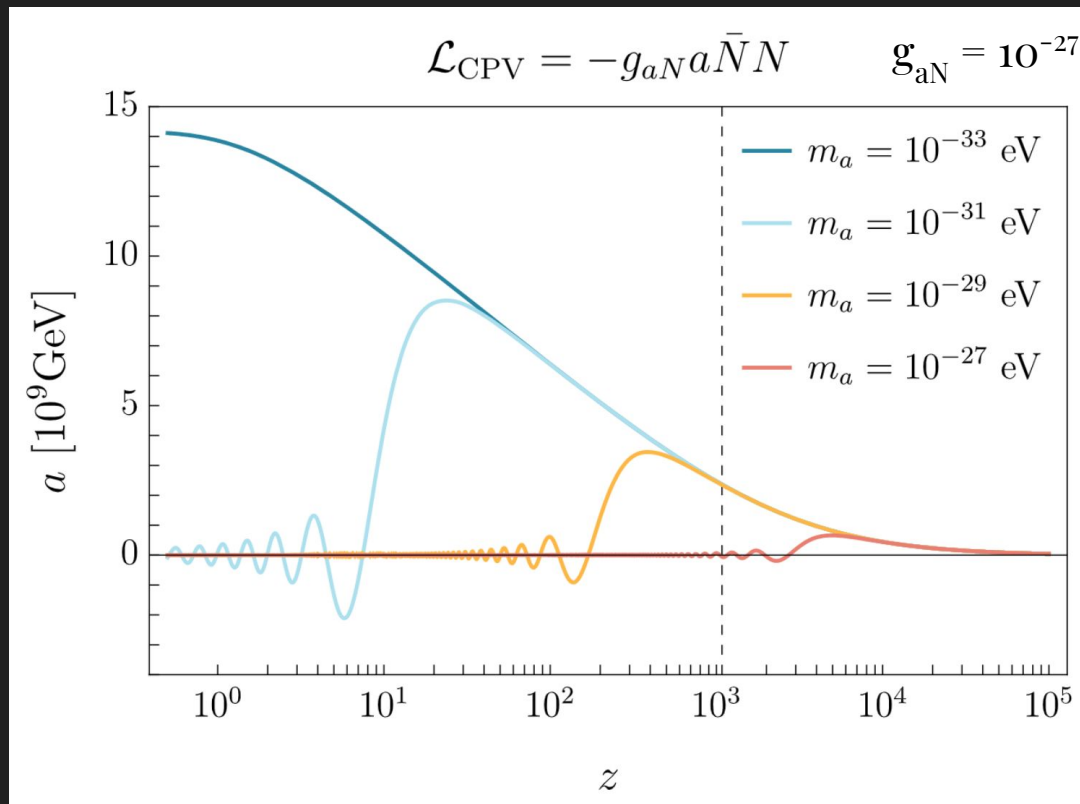
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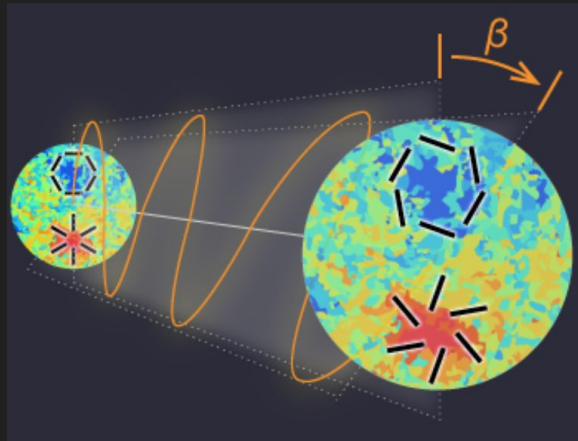
- Field grows  $\propto 1/z$  during radiation domination, then slower
- Peak when enters horizon  $m_a \sim 3H(z)$
- Redshifts like matter subsequently





# Back to Earth

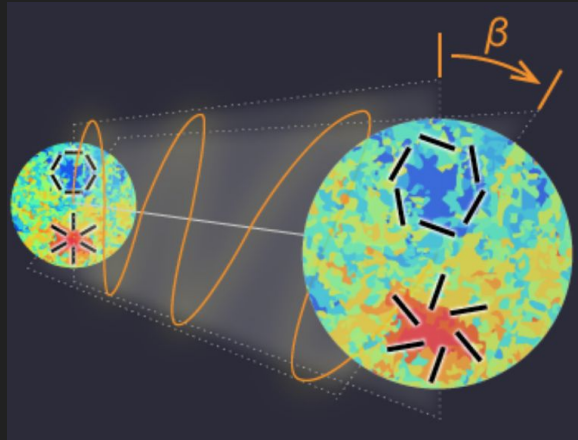
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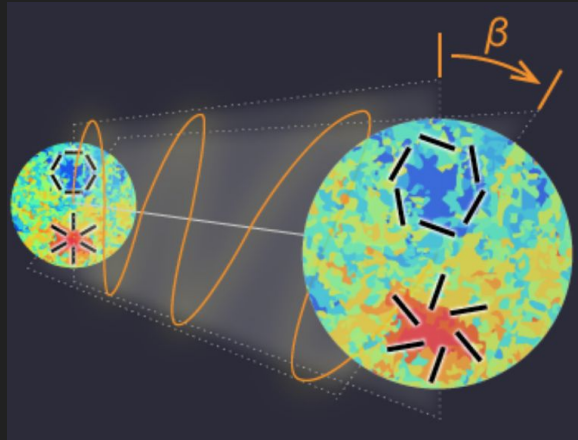
$$C_{\ell}^{EB, \text{ obs.}} = \frac{1}{2} \sin(4\beta) (C_{\ell}^{EE, \text{ CMB}} - C_{\ell}^{BB, \text{ CMB}}) + \cos(4\beta) C_{\ell}^{EB, \text{ CMB}}$$



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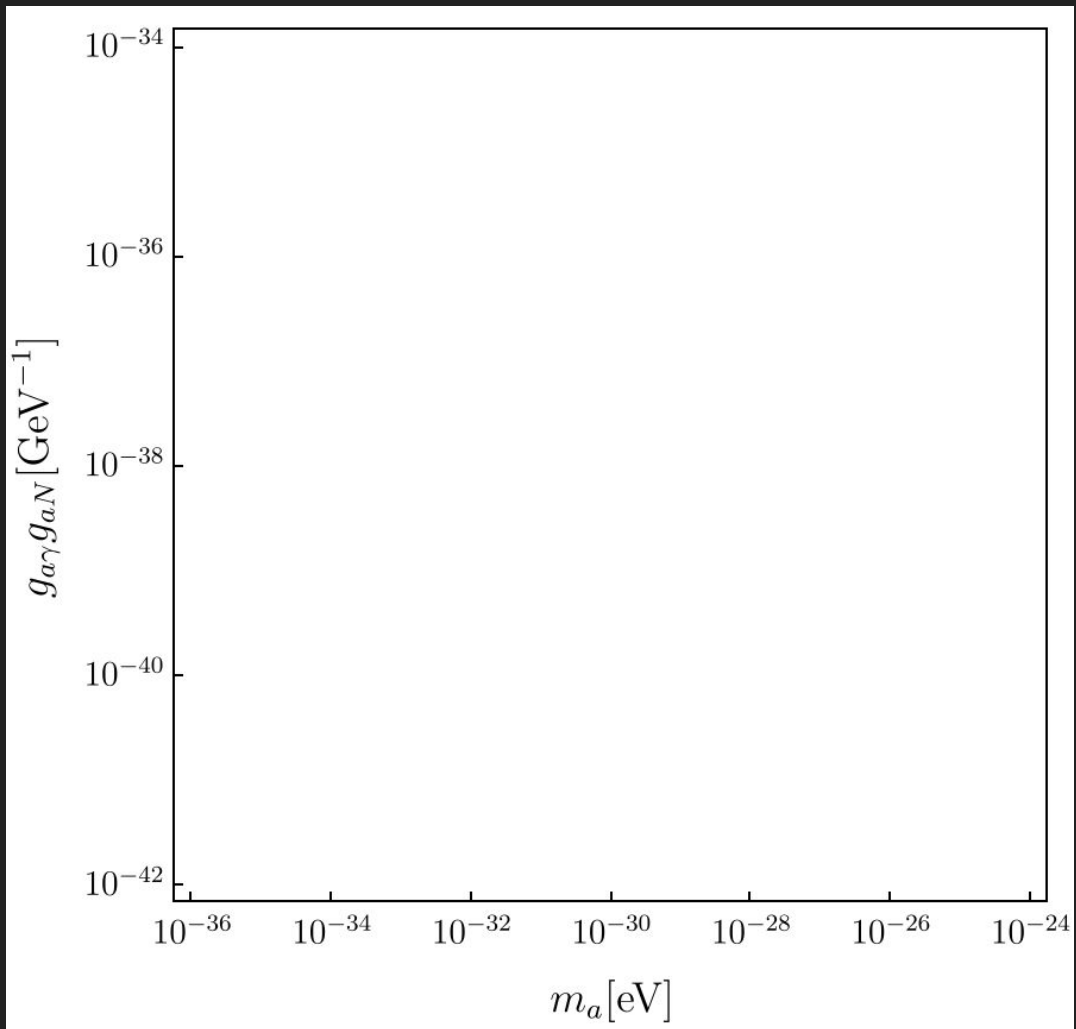
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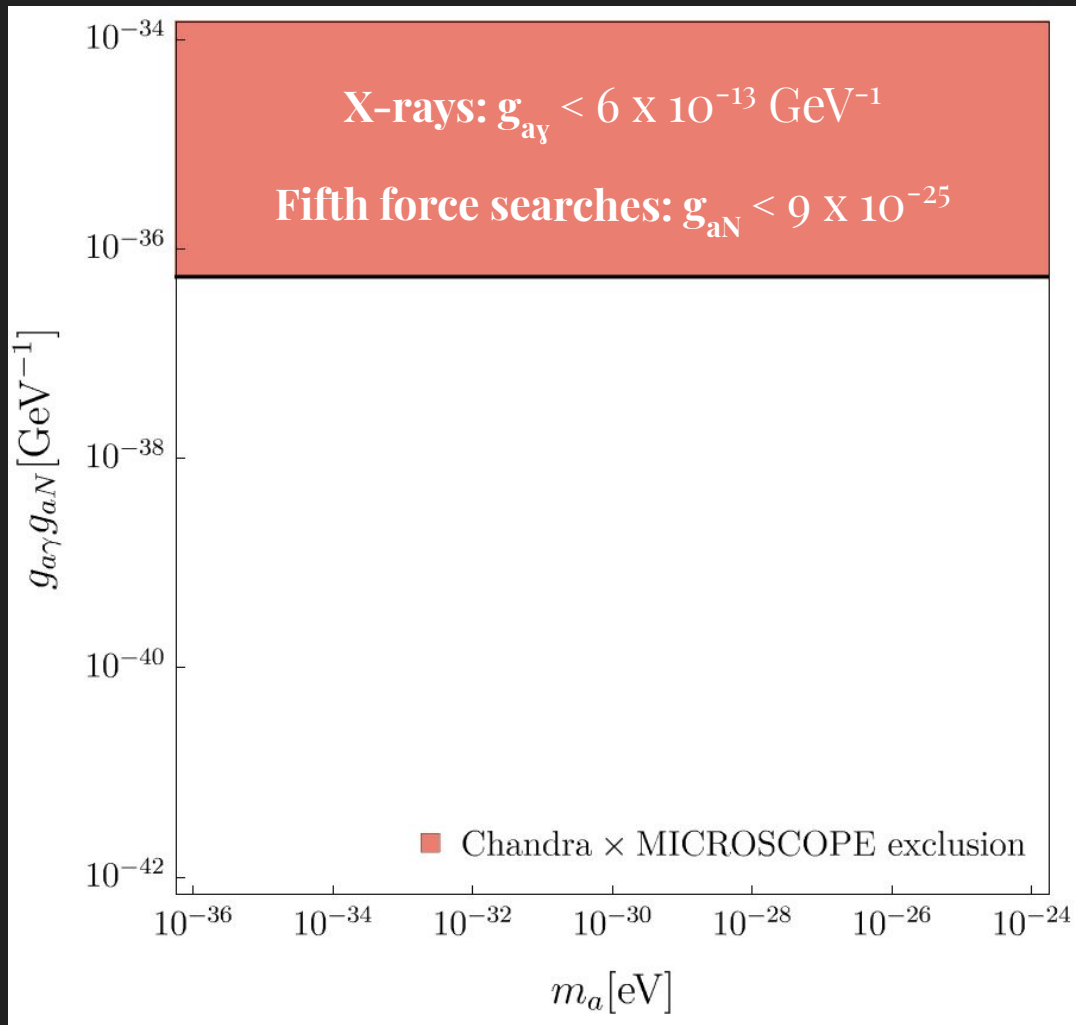
$$\begin{aligned} \cos(4\alpha) C_{\ell}^{EB, \text{obs.}} &= \frac{1}{2} \sin(4\beta) (C_{\ell}^{EE, \text{CMB}} - C_{\ell}^{BB, \text{CMB}}) \\ &+ \frac{1}{2} \sin(4\alpha) (C_{\ell}^{EE, \text{obs.}} - C_{\ell}^{BB, \text{obs.}}) \end{aligned}$$

- Challenge: possible miscalibration  $\alpha$  between polarization-sensitive direction of detector and sky coordinates
- Degeneracy  $\alpha + \beta$  broken by polarized dust emission in MW (only rotated by  $\alpha$ )

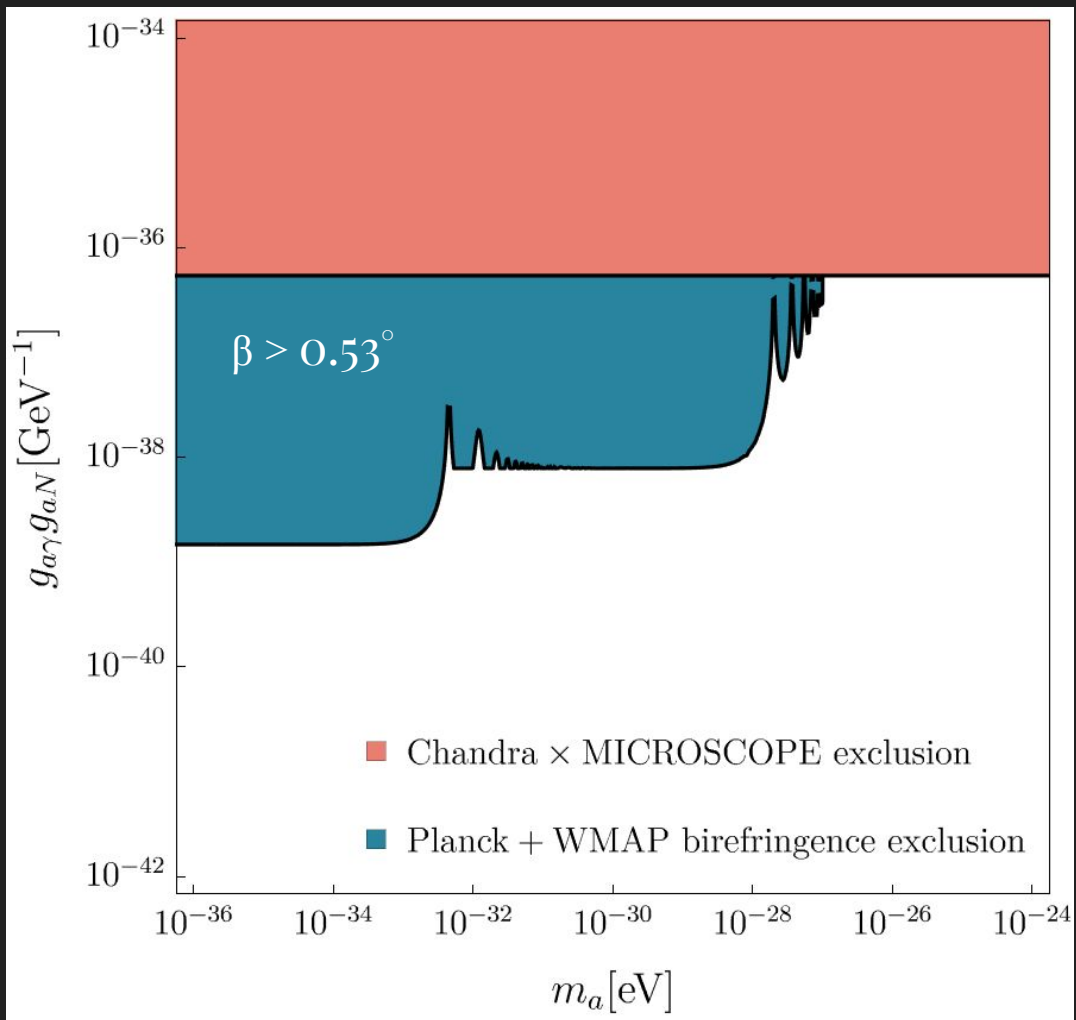
# Parameter Space



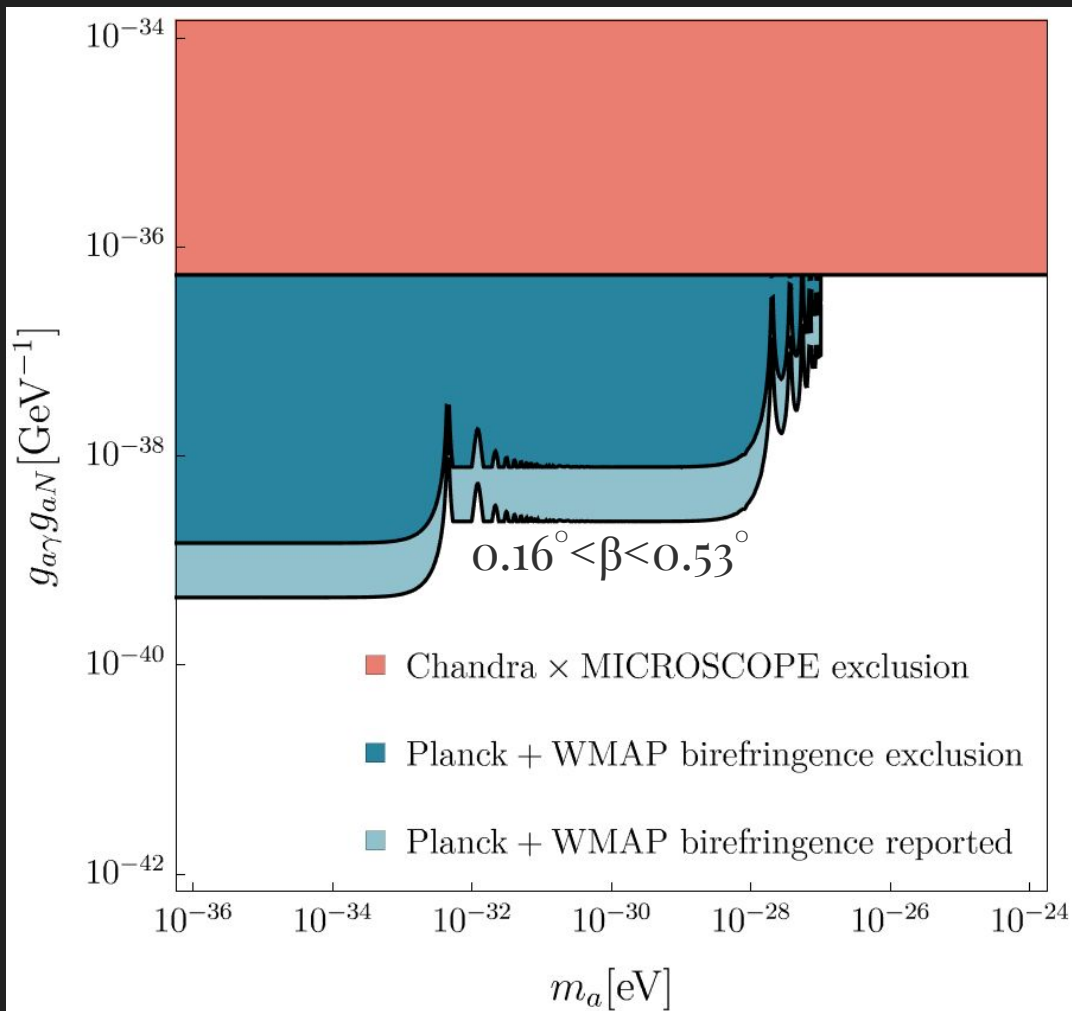
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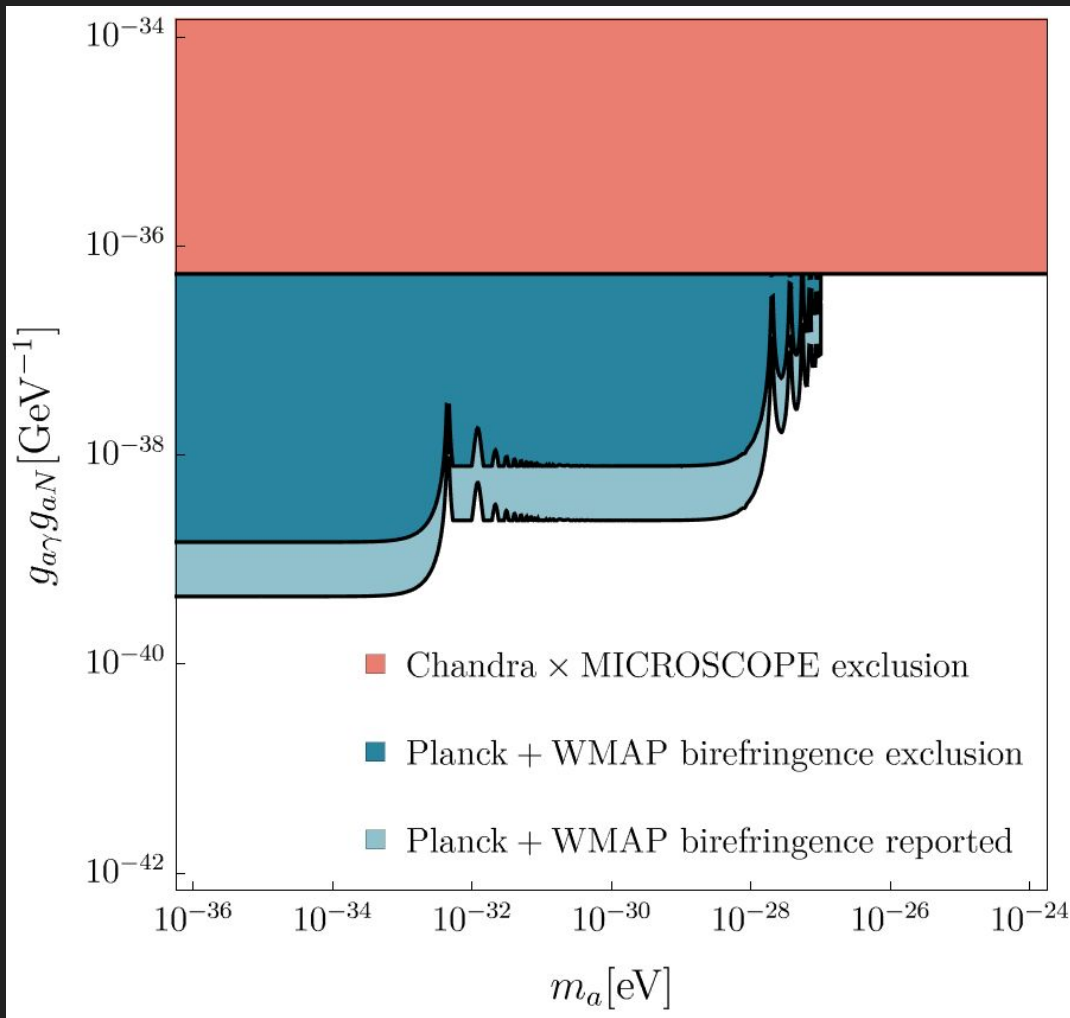
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- $\beta = 0.34^\circ \pm 0.09^\circ$  (68% CL)
- Excludes  $\beta = 0$  at  $3.6\sigma$
  
- Need better understanding/  
characterization of  
polarized foreground  
emission for robust result



# Summary and Outlook

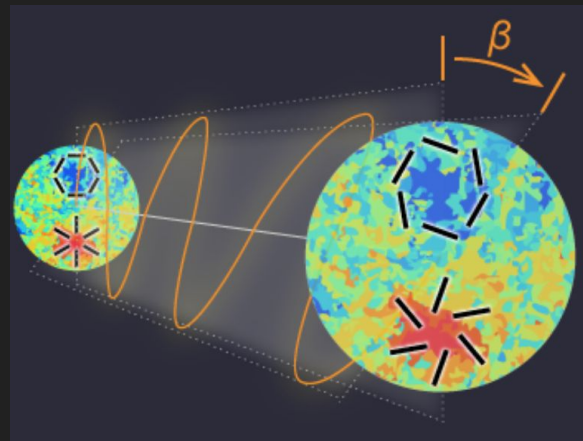
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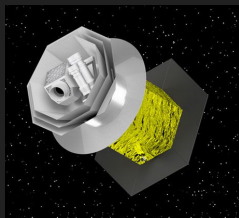
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- Probed by cosmic birefringence, non-zero value currently favoured
- Improve grasp of foregrounds to nail down signal more convincingly



etc.

$$g_{aN} \bar{N} N + g_{a\gamma} F \tilde{F}$$

