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Theoretical motivations for hidden light bosons

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Based on: 2106.12602 and ongoing work

With:

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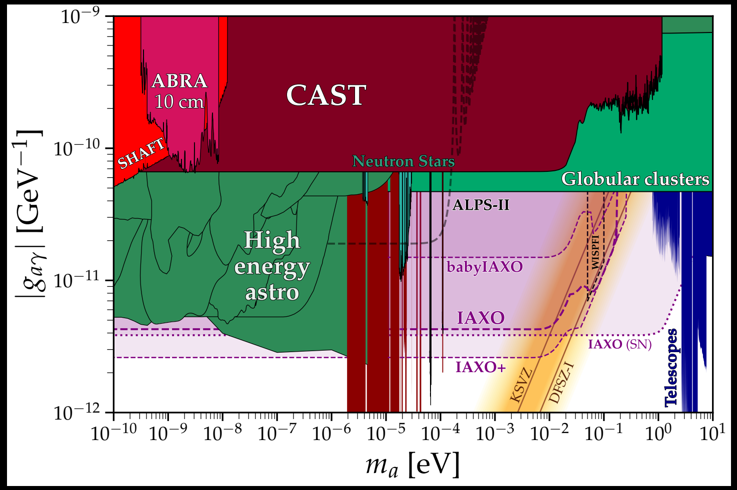
Light bosons searches with EM interactions

If a light axion field exists in Nature, it would inevitably couple with the EM sector, see e.g. Brax+ 1010.4536

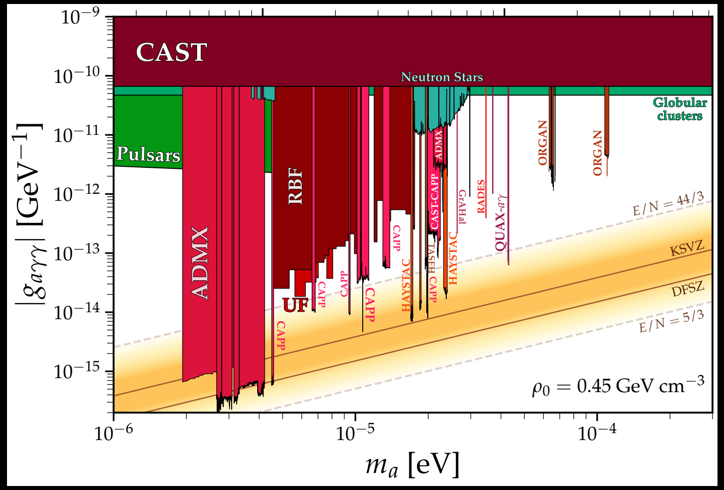
$$\mathcal{L}_{\rm int} \supset g_{\phi\gamma\gamma}\phi\,\tilde{F}^{\mu\nu}F_{\mu\nu}$$

Here, ϕ is the axion field and $F^{\mu\nu}$ is the EM field strength

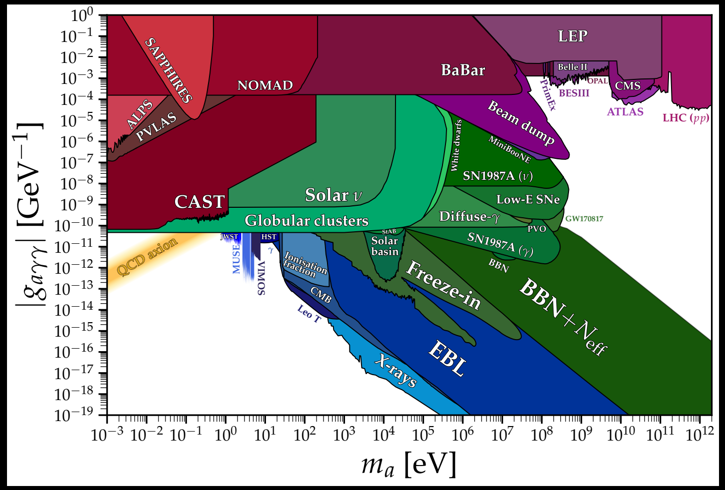
This is vigorously searched with haloscopes, helioscopes and in acceleration production searches



helioscopes



haloscopes



beam dumps

Can we learn something from other hints?

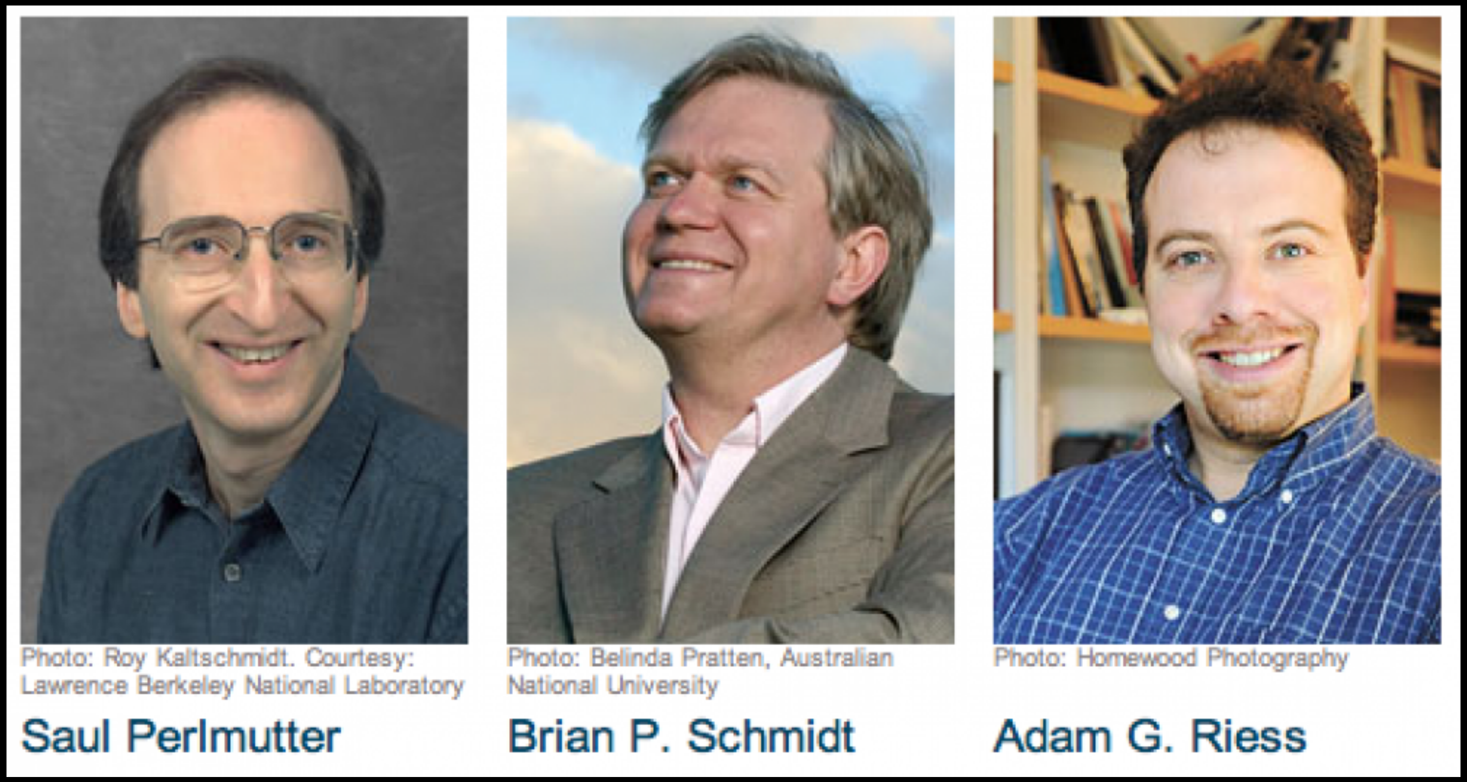
In cosmology, we experience the effects of dark energy

$$\rho_\Lambda = \Lambda^4 \approx (2\,\mathrm{meV})^4 \approx 10^{-120}\, M_{\rm Pl}^4$$

Questions:

- Why is it so small (compared to the naïve estimate)?

- Why is it there in the first place?

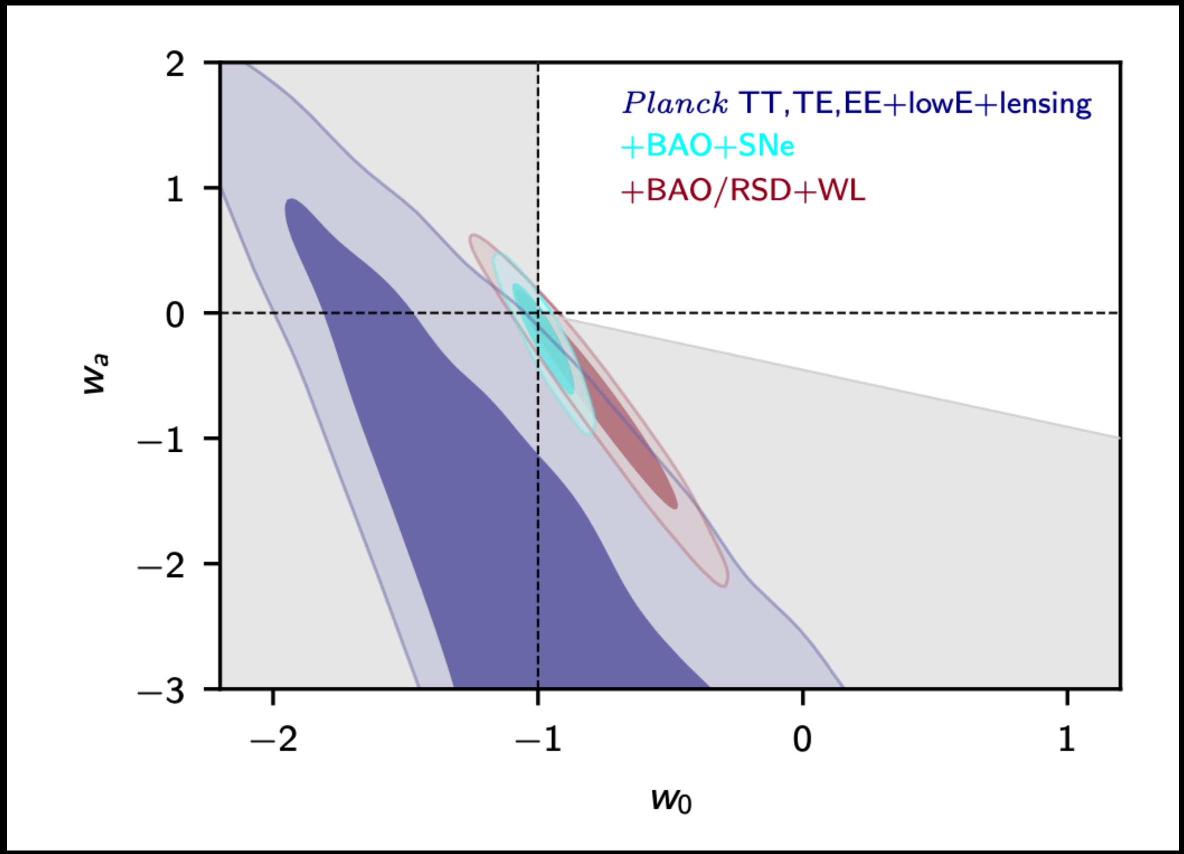


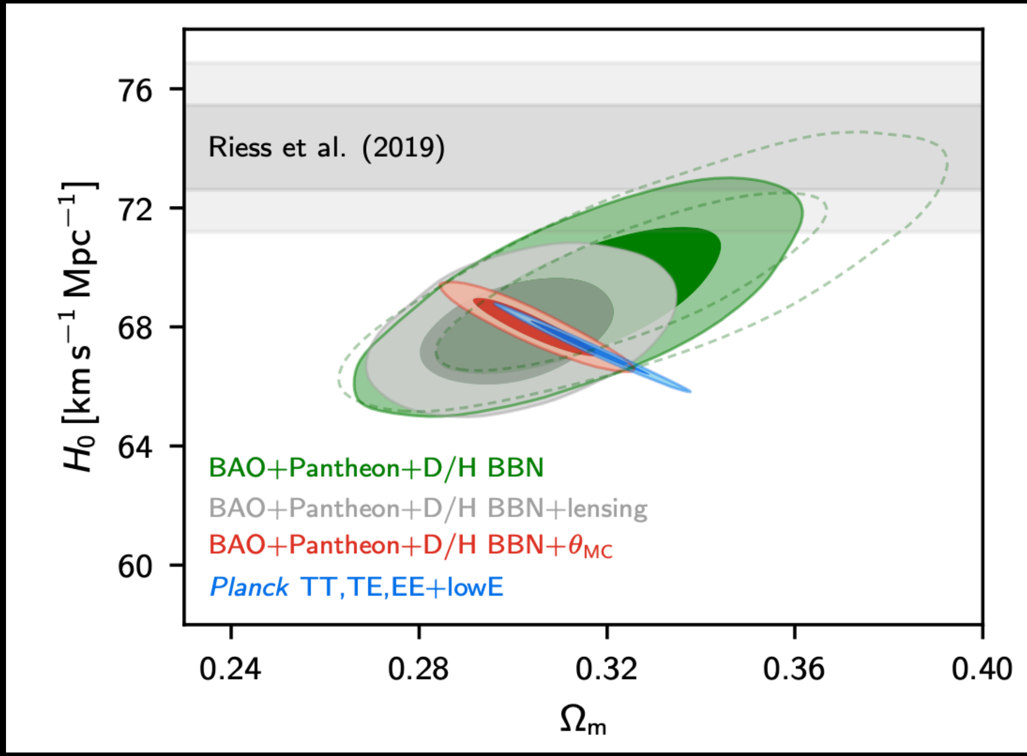
The picture is not as simple as expected

e.g. DE model with e.o.s.

$$w(a) = w_0 + w_a(1-a)$$

Data do not favor a CC





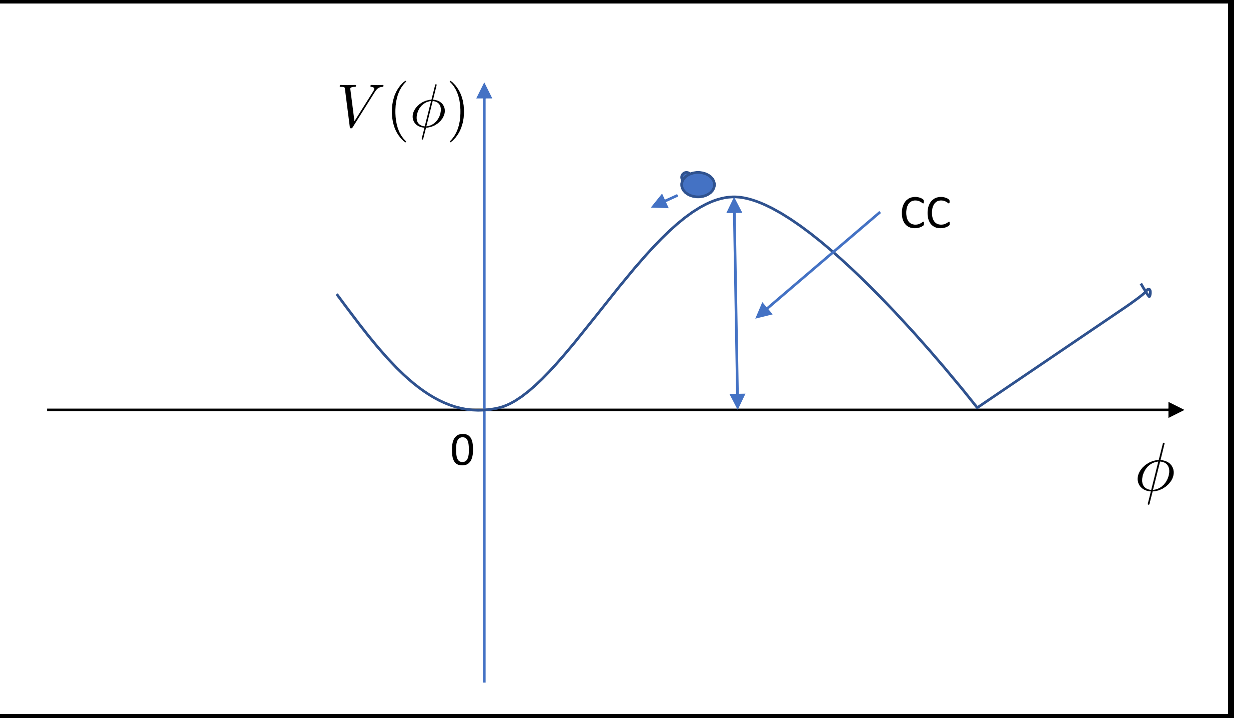
Mismatch between the H_0 coming from early- and late-time measurements

(Planck18: 1807.06211)

Dark energy as a manifestation of a dynamical field

$$\mathcal{L} \supset \frac{1}{2}(\partial^\mu \phi)(\partial_\mu \phi) - V(\phi)$$

The properties of the potential $V(\phi)$ shape the evolution of ϕ



Quintessence with an axion field

One strong requirement is that the field has just started rolling:

$$m_\phi \lesssim H_0 \approx 2 \times 10^{-33}\,\mathrm{eV}$$

How can such a small mass be achieved and protected?

The axion mass is protected by the shift symmetry from correction.

Quintessence axion potential:

$$V(\phi) = \Lambda^4\,\left(1 - \cos(\phi/F)\right)$$

One model: the quintessential axion

One axion superfield Φ_A coupling to a SU(2) field W^a_α

$$\mathcal{L}_{\rm eff} = \int {\rm d}^2\theta \frac{1}{32\pi^2}\frac{\Phi_A}{F_A} W^{a\alpha} W^a_\alpha + {\rm h.c.}$$

(Nomura, Watari, Yanagida 2000)

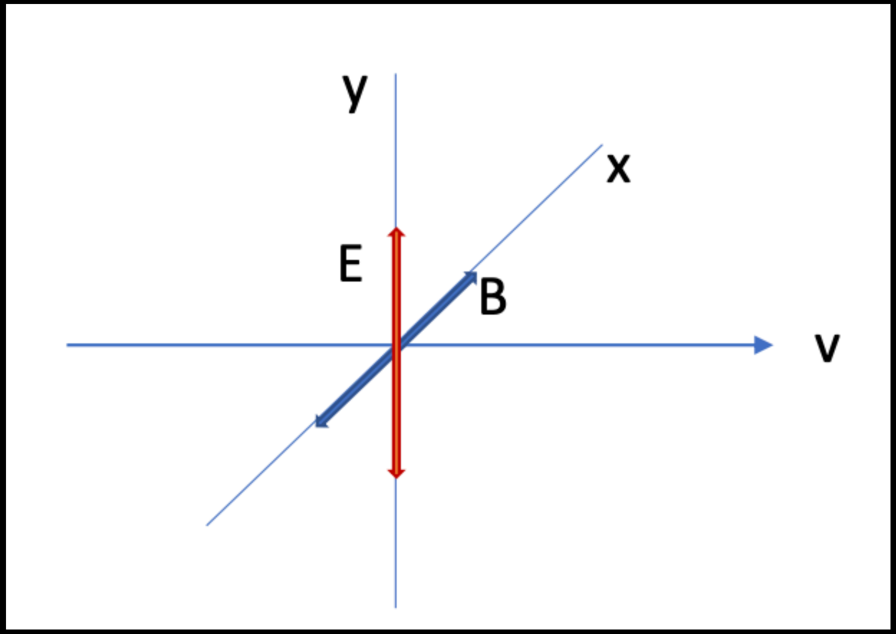
They found the energy scale:

$$\begin{aligned} \Lambda_{\mathcal{A}}^4 &\simeq {\rm e}^{-\frac{2\pi}{\alpha_2(M_{\rm pl})}} c\,\epsilon^{10} m_{\rm SUSY}^3 M_{\rm pl} \\ &\simeq c\left(\frac{\epsilon}{1/17}\right)^{10} (1\times 10^{-3}\ {\rm eV})^4 \end{aligned}$$

The SUSY framework is crucial to attain the result…

One prediction: cosmic birefringence

The CMB photons are polarized by the Thompson scattering at recombination



The electric field oscillates, however polarization is fixed (no rotation in the polarization axis)

One prediction: cosmic birefringence

How does the axion-photon coupling change the picture?

$$\mathcal{L} \propto \phi \mathbf{E} \cdot \mathbf{B}$$

Displacement field: $\mathbf{D} = \mathbf{E} + \phi(t)\mathbf{B}$

The axion field sources Maxwell's equations.

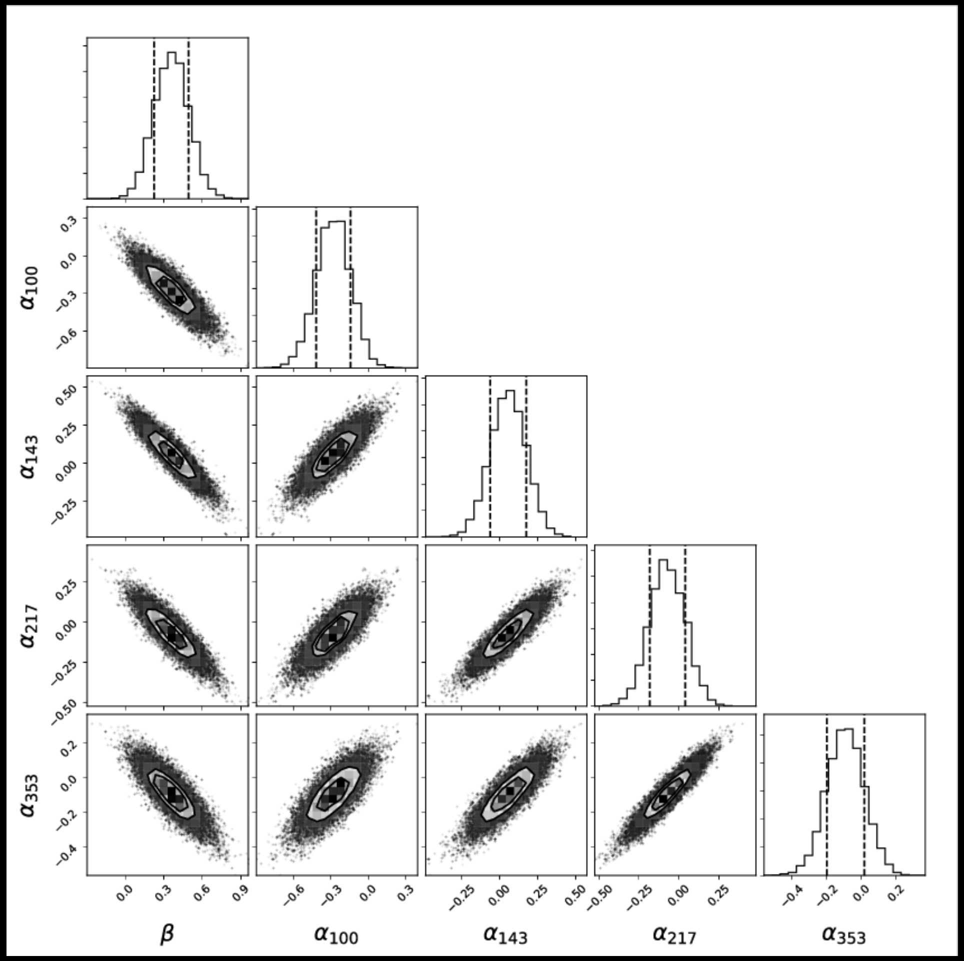
The polarization of the CMB photons is sensitive to a change in the value of the quintessence axion field! $\phi(t)$

The cosmic birefringence angle is given by:

$$\beta = 0.42\,\deg\, c_\gamma\, \frac{\Delta\phi}{2\pi F}$$

Carroll, Field, Jackiw 1990

Induced rotation in CMB photon polarization



$$\beta = 0.35 \pm 0.14\,(68\%)$$

Minami & Komatsu 2011.11254

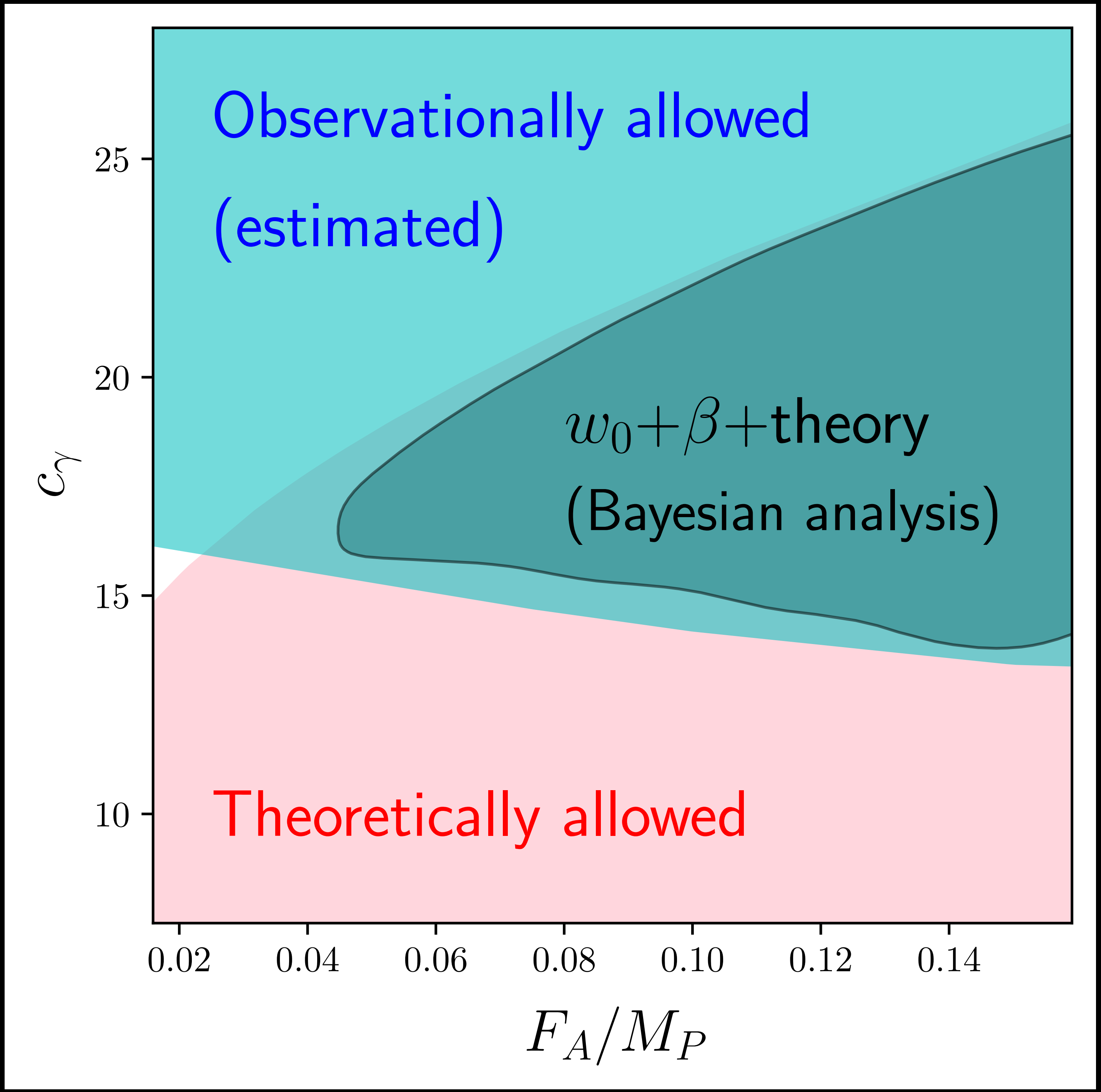
$$\beta = 0.30 \pm 0.11\,(68\%)$$

Diego-Palazuelos+ 2201.07682

We find: $$w_{\rm DE} = -1 + 2\pi^2\xi^2\left(\frac{\beta/c_\gamma}{0.42\,{\rm deg}}\right)^2$$

Choi, Lin, LV, Yanagida 2106.12602

Results



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Summary

A non-zero value of the cosmological constant:

- Can be explained by the vacuum energy of an axion field
- The slow evolution of the axion field causes birefringence rotation of the polarization in the CMB photons
- It can accommodate the results by Minami & Komatsu

$$\beta = 0.35 \pm 0.14\,(68\%)$$

- An electroweak axion predicts the SUSY scale

$$M_{\rm SUSY} \sim 100\,{\rm TeV}$$