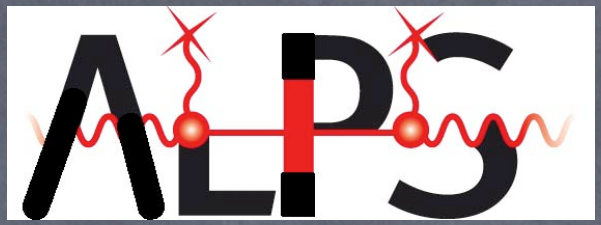
Particle Interpretations of the ALPS experiment



Javier Redondo for the ALPS collaboration

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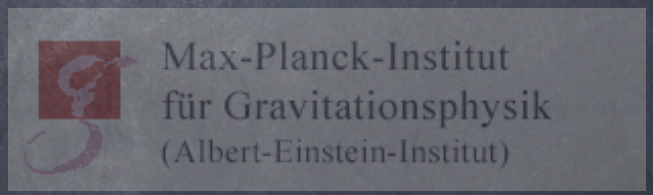


Hidden Sectors

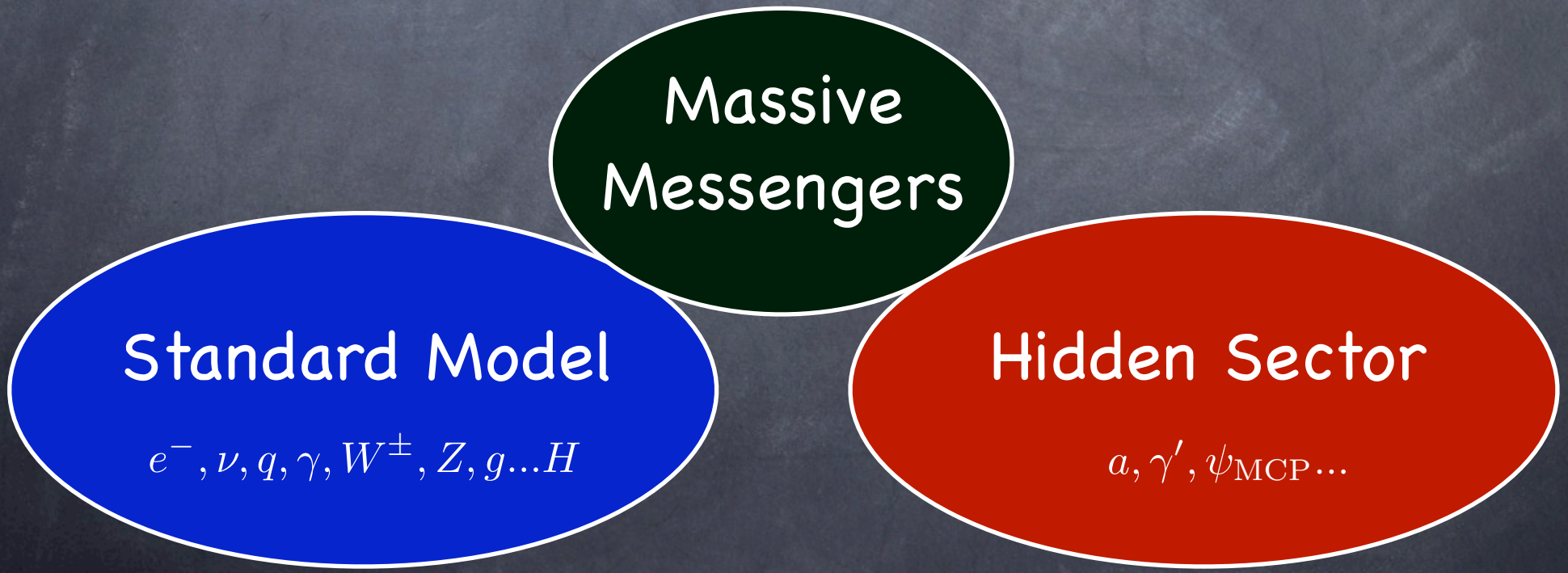
Extensions of SM often include Hidden Sectors

Fields coupled to SM only through gravity or high energy "messenger" fields...

This is the case in string theory (compactifications produce many particles, new gauge symmetries, and KKs)

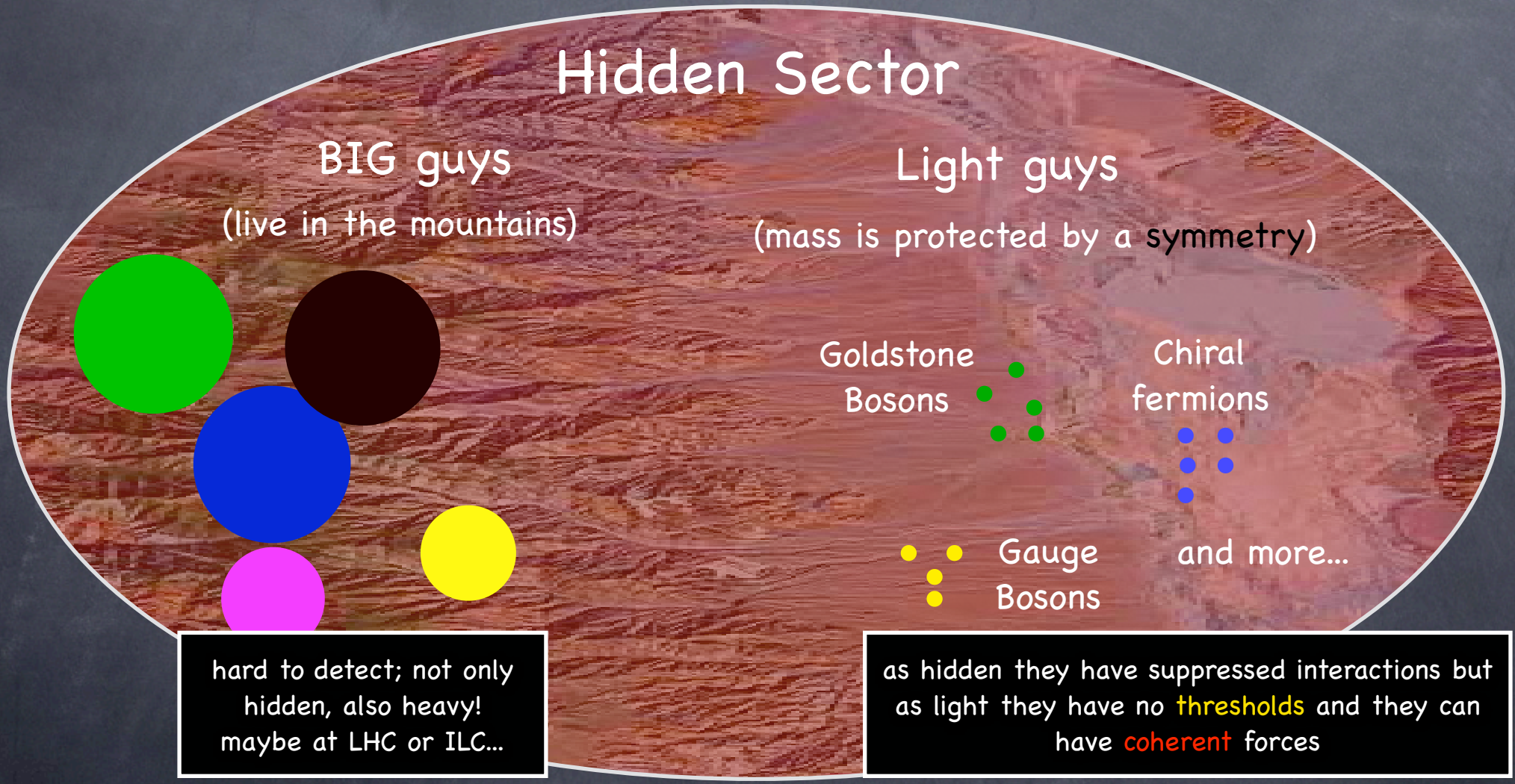
Desirable for ~~SUSY~~

Also in GUT theories...



Hidden Sectors can be quite complicated

we certainly don't know much!



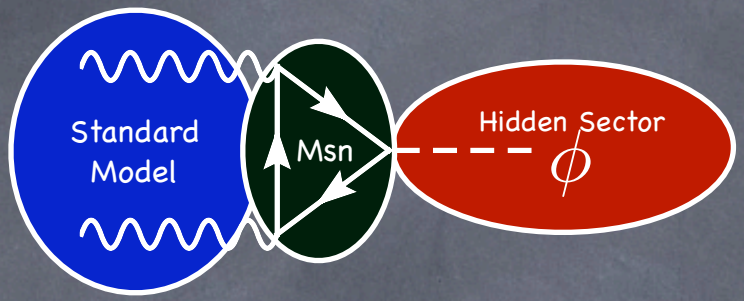
hard to detect; not only hidden, also heavy! maybe at LHC or ILC...

as hidden they have suppressed interactions but as light they have no thresholds and they can have coherent forces

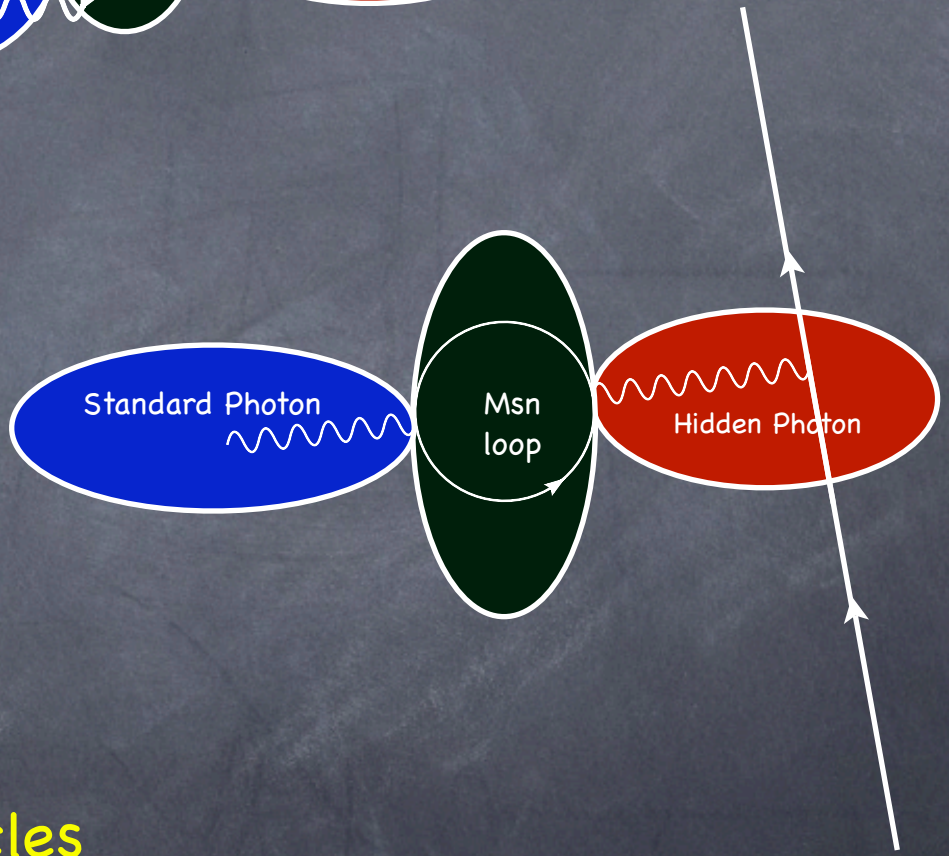
study couplings to photons to exploit coherence

U(1) Symmetries and weakly interacting sub eV particles (WISPs)

1- Global U(1)s and ALPs
(axion-like-particles)



2- Local U(1)s : Hidden Photons

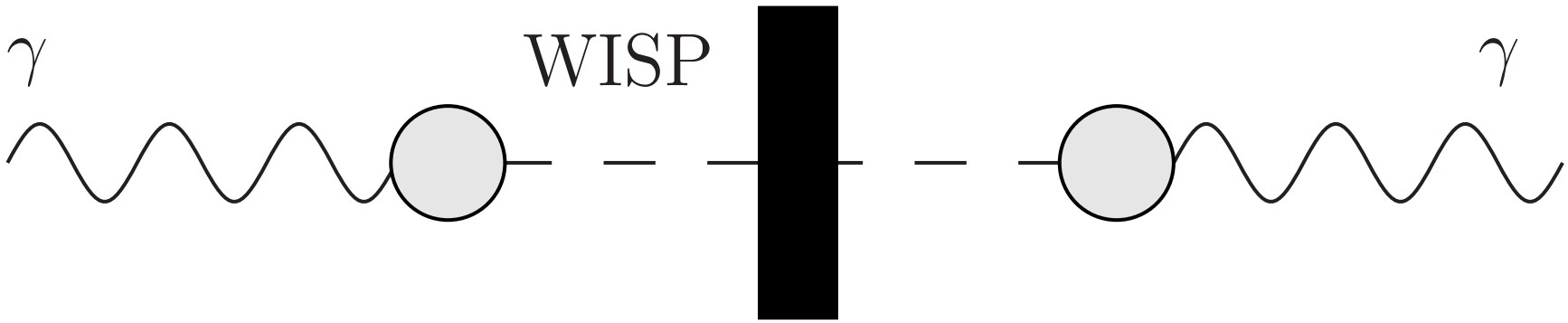


3- Chiral sym : Mini-charged Particles

Particles in a a hidden sector charged under a hidden U(1) that mixes with Photon appear as mini-charged particles

WISPs and Light-shining-through-walls

These WISP candidates can produce LSW through the phenomenon of oscillations via their mixing with photons

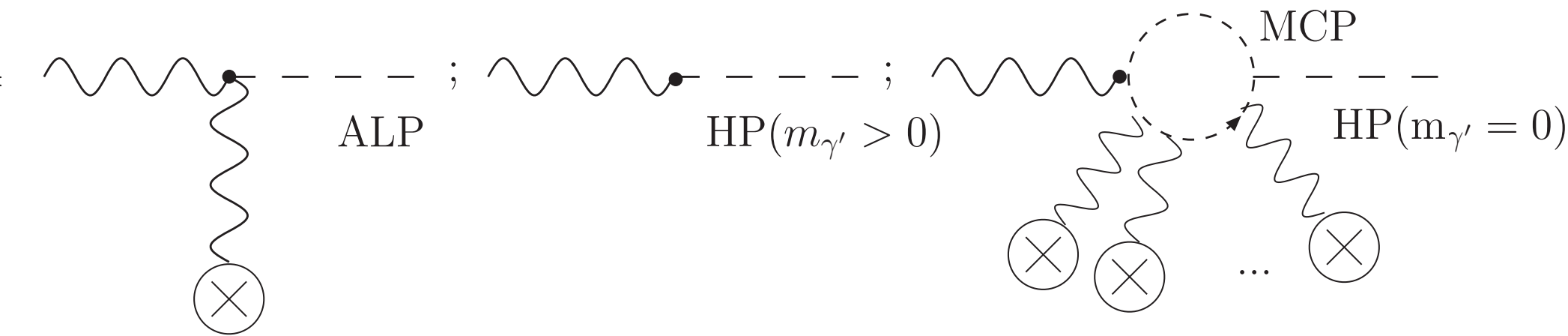


SM Photon coupled to e,p, is an interaction state

$$|\gamma\rangle \simeq |\gamma_p\rangle + \delta|\phi\rangle \rightarrow |\gamma_p\rangle + e^{i\Delta p L}\delta|\phi\rangle$$

combination of two propagation states

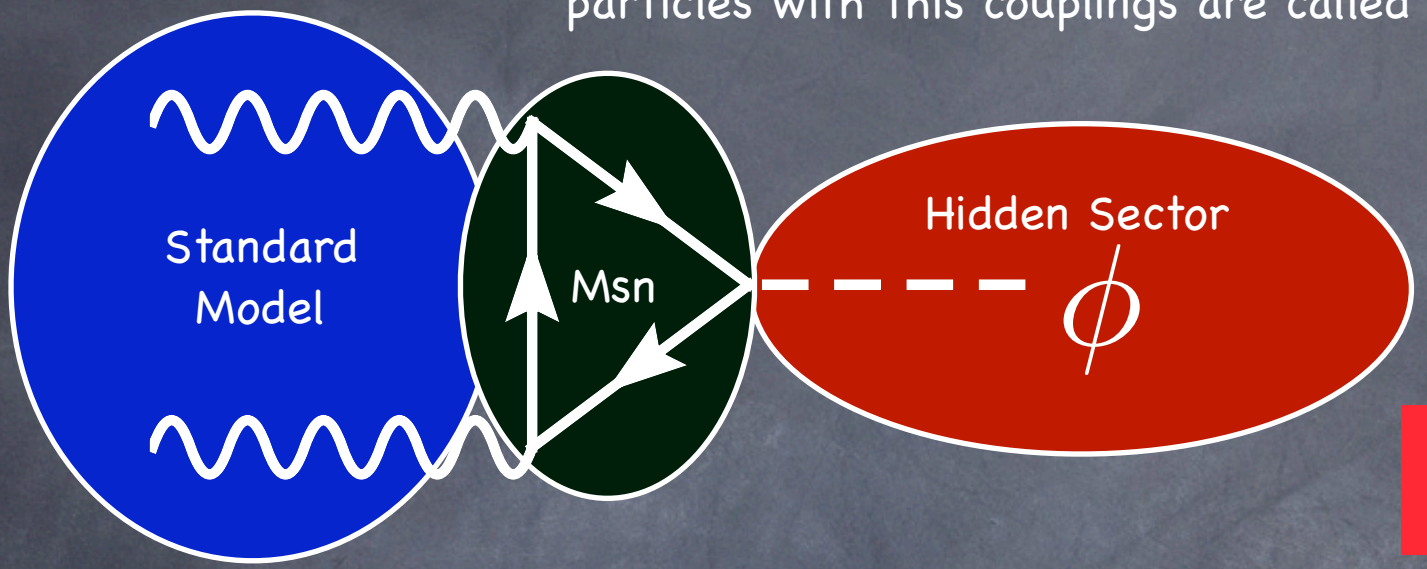
that evolve with different spacetime phases



Axions and PGBs

SSB implies a massless Goldstone boson
(small explicitly breaking implies small mass-> pseudo)

particles with this couplings are called axion-like particles (ALPs)



$$\longrightarrow gF_{\mu\nu}F^{\mu\nu}\phi$$

$$g \sim \alpha/m_{\rm msg}$$

In a background magnetic field, this anomalous term gives rise to a photon-ALP mixing term, a non-diagonal mass between the ALP and the photon's electric field

$$\mathcal{L} \ni gF_{\mu\nu}F^{\mu\nu}\phi \propto gB\cdot E\phi \rightarrow gB^{\rm ext}\cdot E\phi$$

In a convenient gauge, the electric field is just $E = \omega A$

photon frequency

vector potential

Size of the mixing is determined by

$$gB^{\rm ext}\omega$$

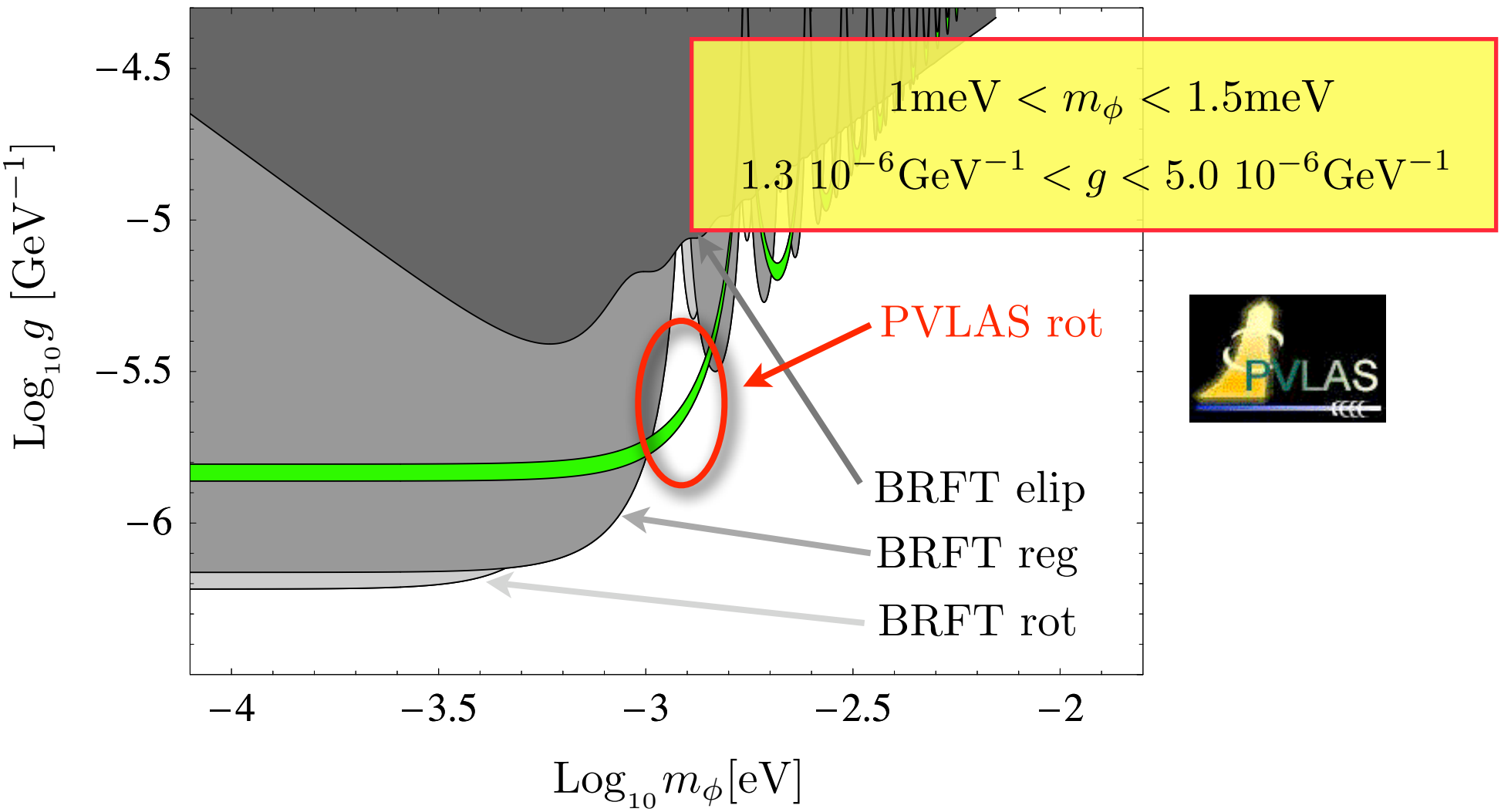
(suppresed by messenger's mass)

dilaton-like coupled scalars have similar phenomenological aspects but generate 5th forces

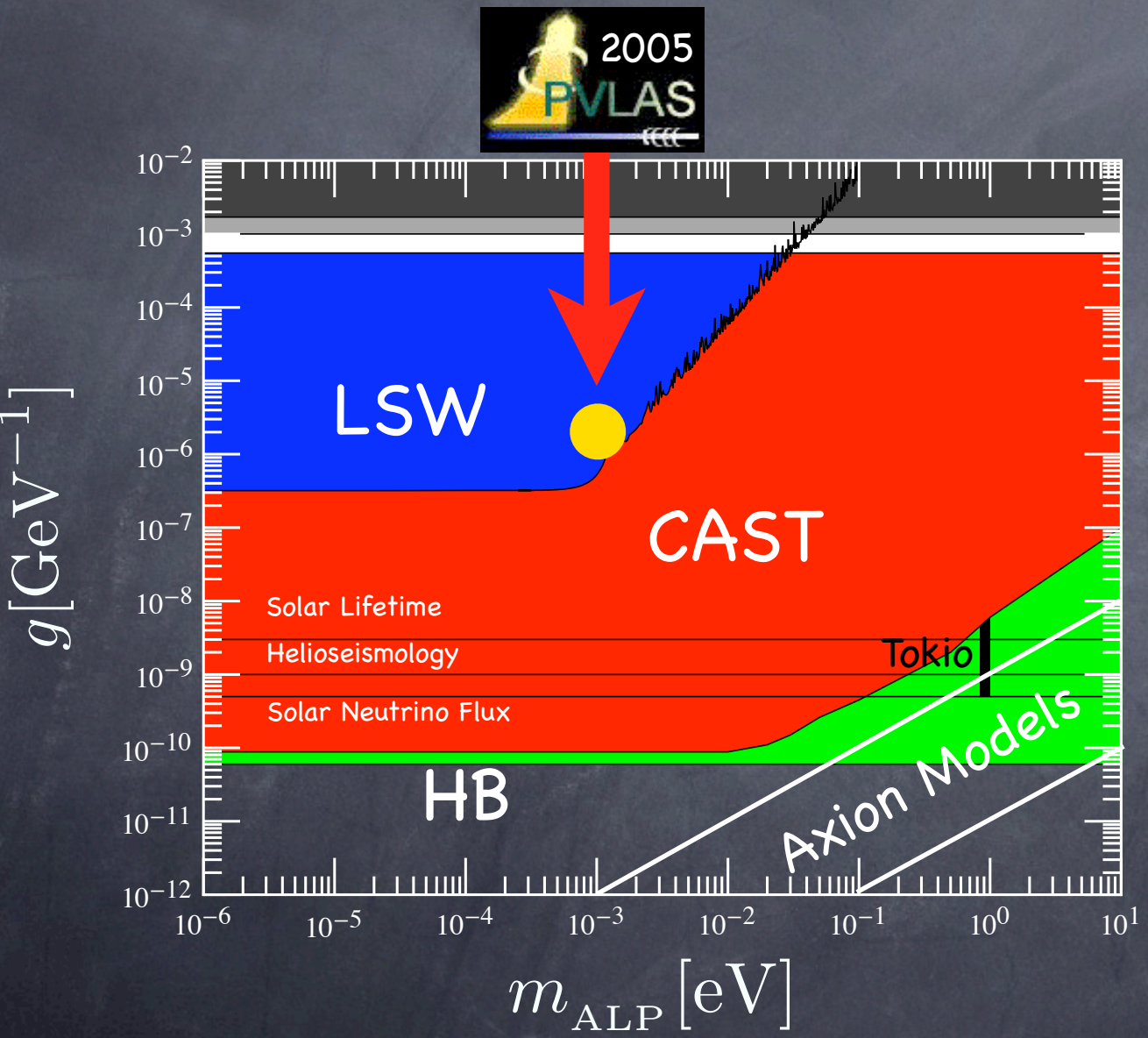
PVLAS

In 2005, PVLAS reported a signal compatible with the existence of an meV mass ALP

(This signal was disclaimed in late 2007)



ALPs, PVLAS and the stars



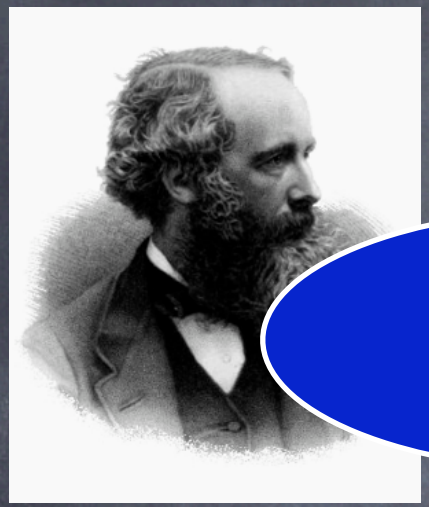
PVLAS ALP was in severe conflict with stellar evolution and direct detection of solar ALPs (CAST)

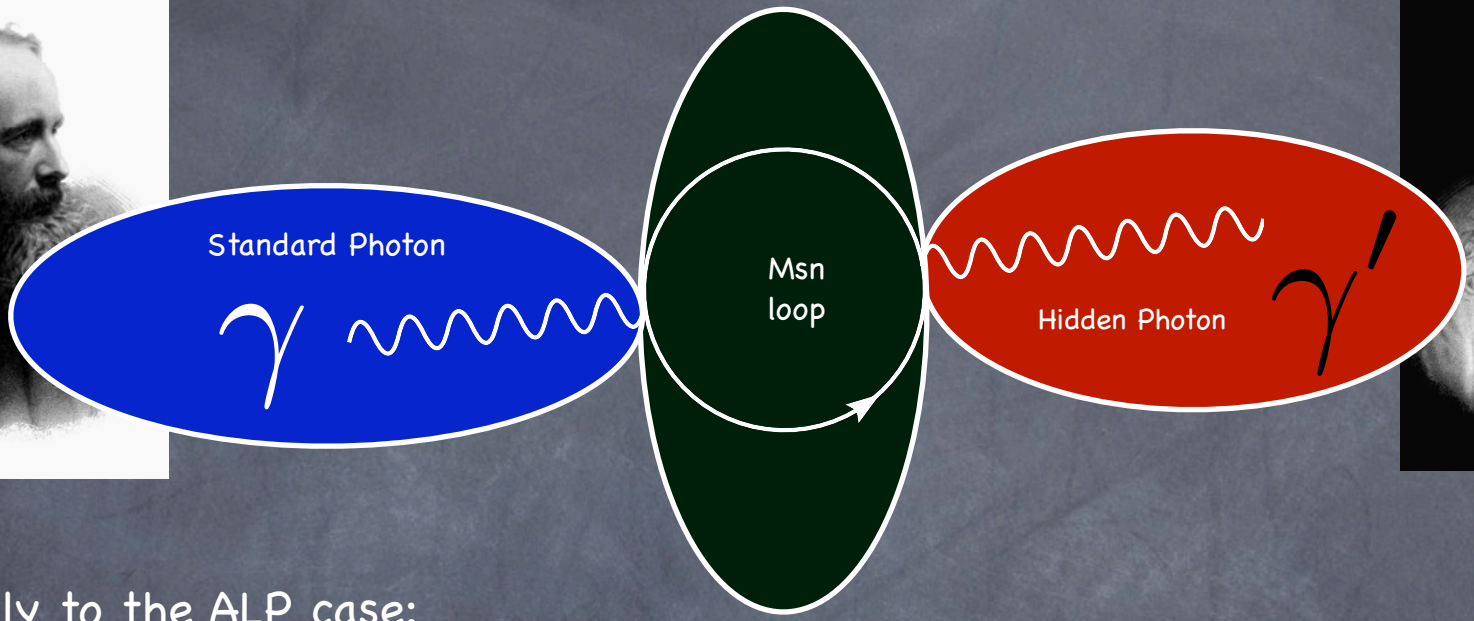
But...

During these days, refined models where proposed that suppress ALP stellar emission and therefore the most severe bounds

All of them required the occurrence of new physics at very low energy scales, new particles, symmetries...

Hidden Photons





Contrarily to the ALP case:
the mixing of photons and hidden photons is NOT suppressed by the messenger mass
(Extremely interesting window to HE physics?)

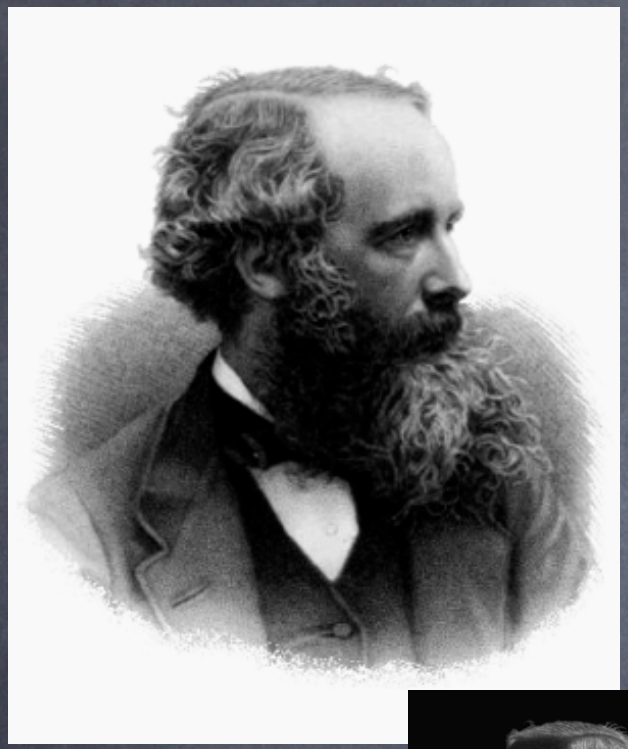
$$\mathcal{L} \ni -\frac{1}{4}\chi F^{\mu\nu} F'_{\mu\nu} \qquad \chi = \frac{e e_h}{16\pi} \sum Q Q' \log m_{\rm msg}$$

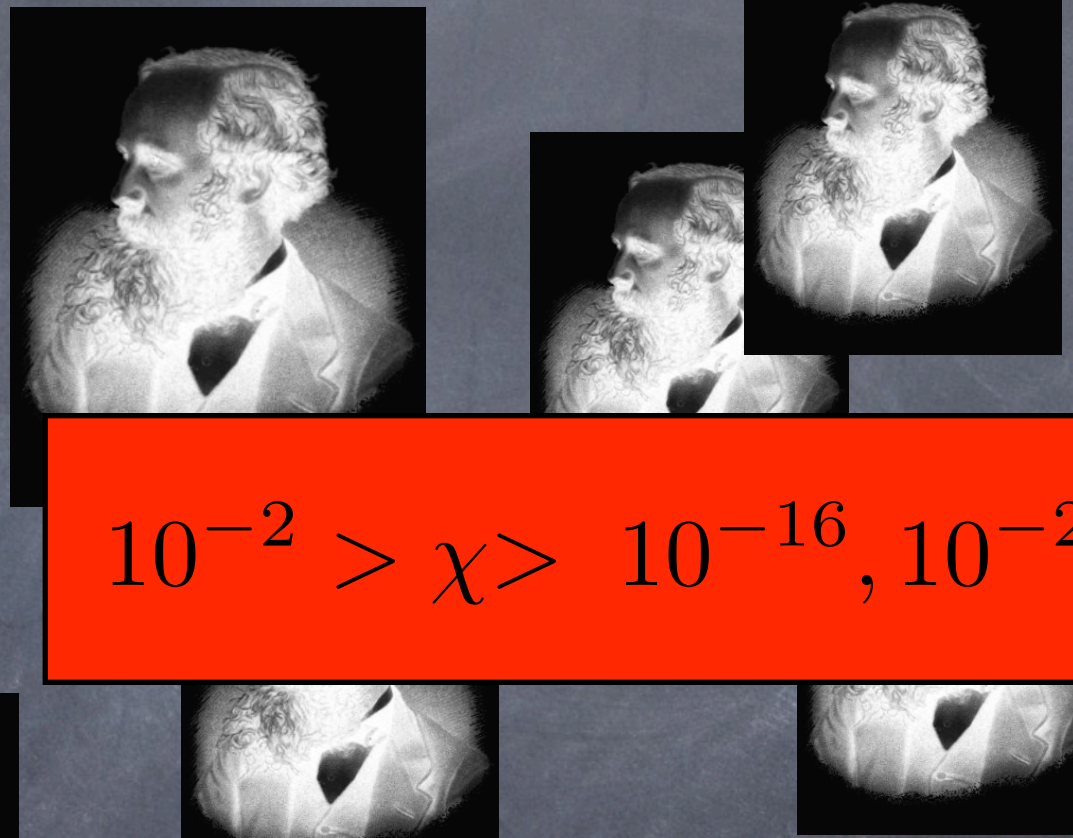
Masses can be given by the Stückelberg mechanism

$$m_\gamma < 10^{-31}\,\mathrm{eV} \qquad m_{\gamma'} < \ldots ?$$

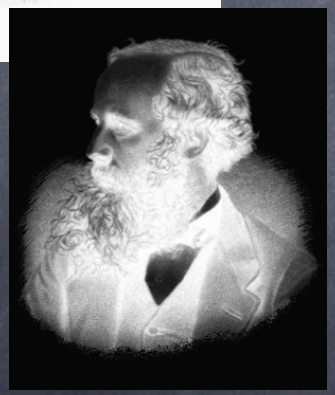
Hidden Photons

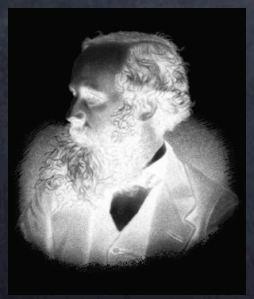
String theory predicts MANY new HPs!!!

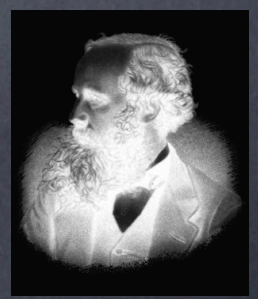




$$10^{-2} > \chi > 10^{-16}, 10^{-23}!$$

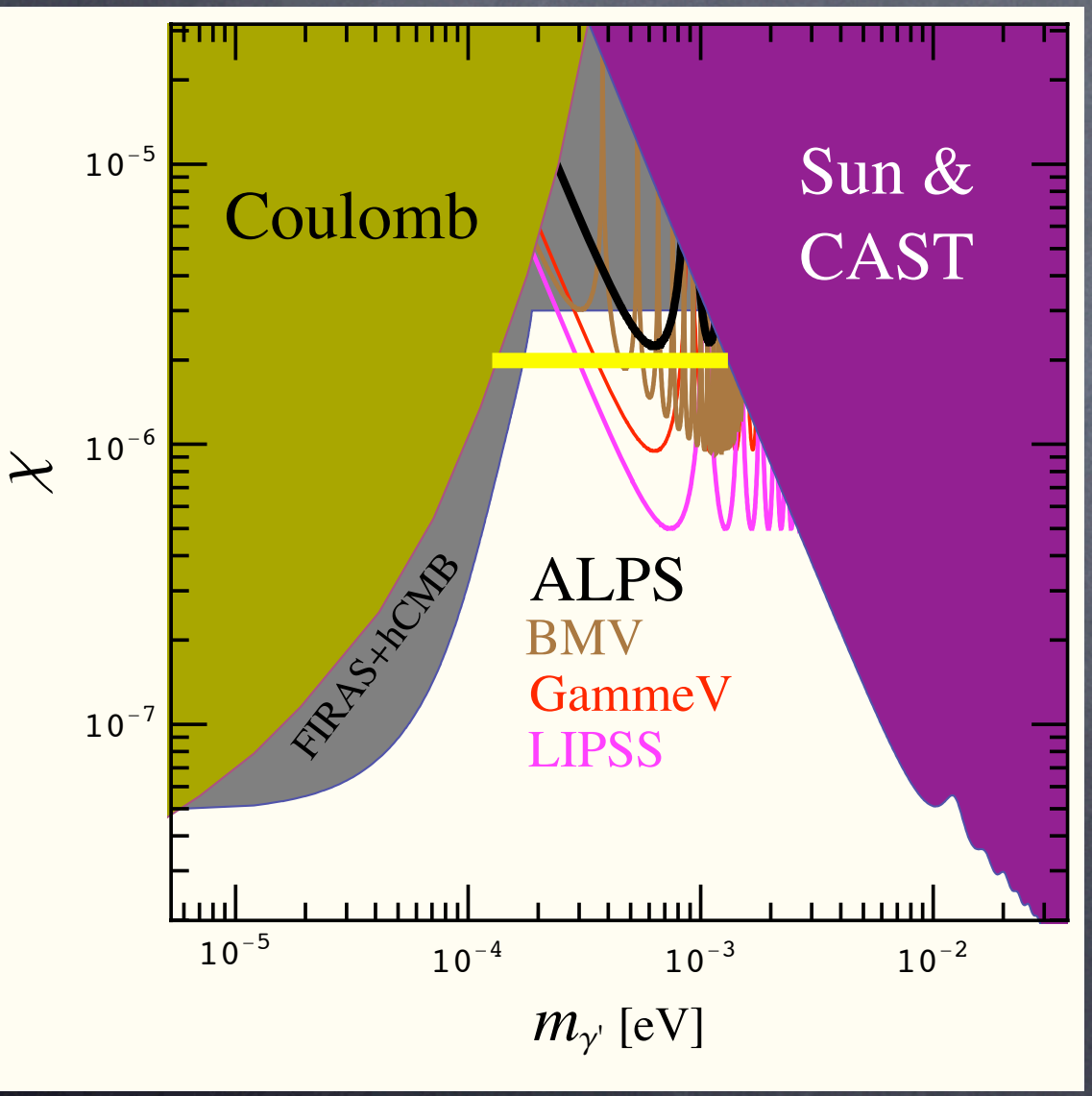






Hidden Photons (in the meV mass valley)

HPs evade naturally astrophysical constraints, since they only couple to SM photons through oscillations and oscillations need a characteristic length, which is forbidden by the opaque stellar interiors



There is increasingly evidence for new physics related to meV mass scales:
-Dark energy
-neutrino masses
-Large extra-dimensions (gravity at the TeV scale)

meV HPs would be relevant for:
-cosmology (dark matter component)

-Technology: long distance communication

-can affect stellar evolution

The massless HP case and Mini-charged particles (MCPs)

$$-\frac{1}{4}A_{\mu\nu}A^{\mu\nu} + ej_\mu A^\mu \qquad -\frac{\chi}{2}A_{\mu\nu}B^{\mu\nu} \qquad -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} + e_h j'_\mu B^\mu$$

Hidden Source, particles charged under the hidden U(1)

$$B^\mu \to \tilde{B}^\mu - \chi A^\mu$$

$$-\frac{1}{4}A_{\mu\nu}A^{\mu\nu} + ej_\mu A^\mu \qquad e_h j'_\mu(\tilde{B}^\mu - \chi A^\mu) \qquad -\frac{1}{4}B_{\mu\nu}B^{\mu\nu}$$

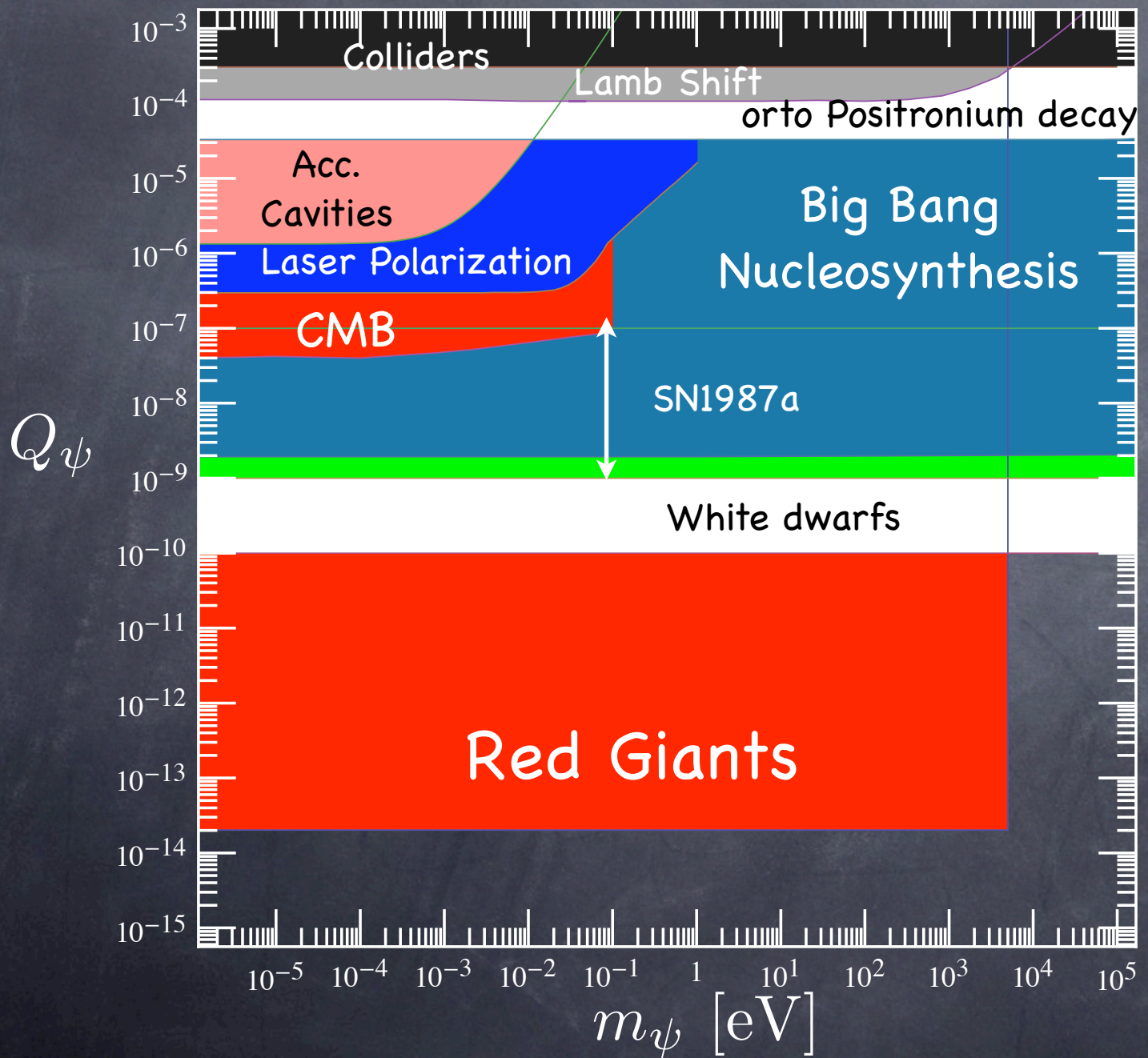
Particles charged under the hidden U(1) get an small electric charge prop to kinetic mixing

$$Q = e_h\chi/e$$

IF no MCPs the hidden photon, decouples after the redefinition, dissappears!

We call them Mini-charged-particles (MCPs)

MiniCharged Particles (MCPs)

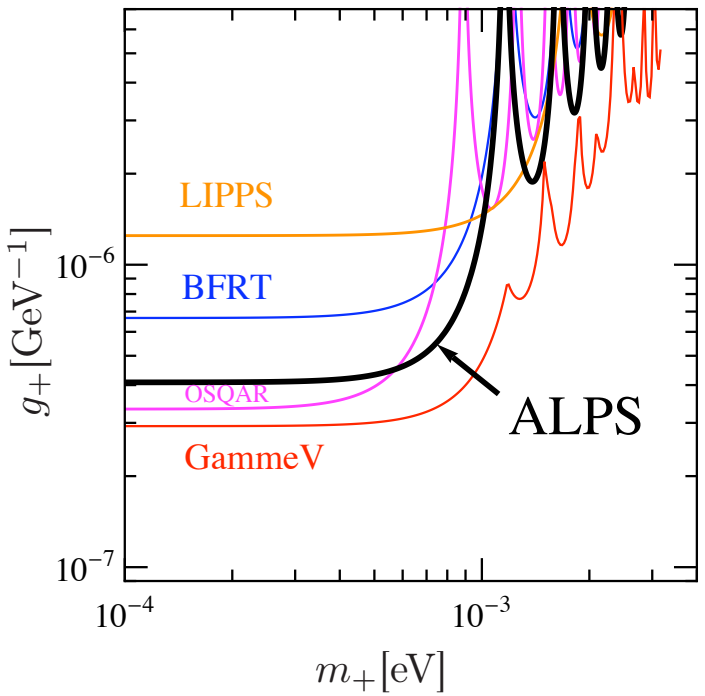


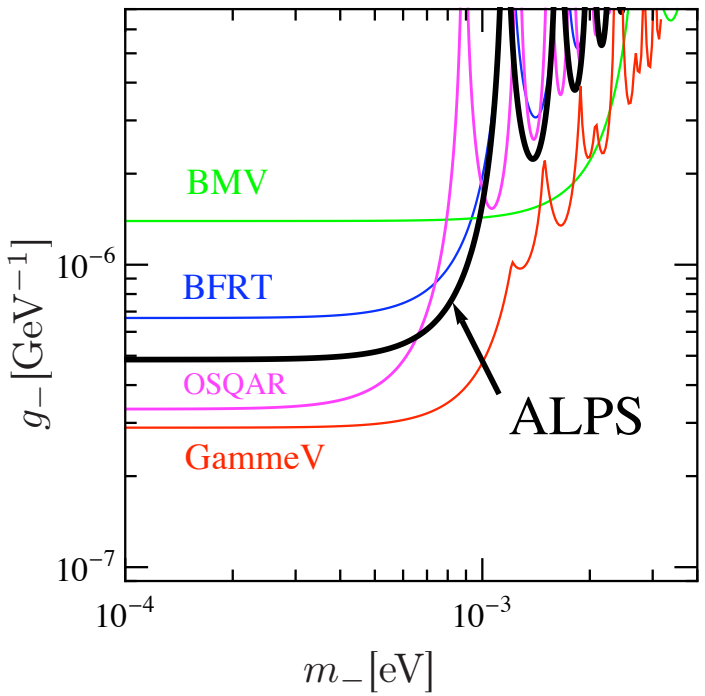
The existence of MCPs is constrained by the same stellar evolution arguments working for ALPs

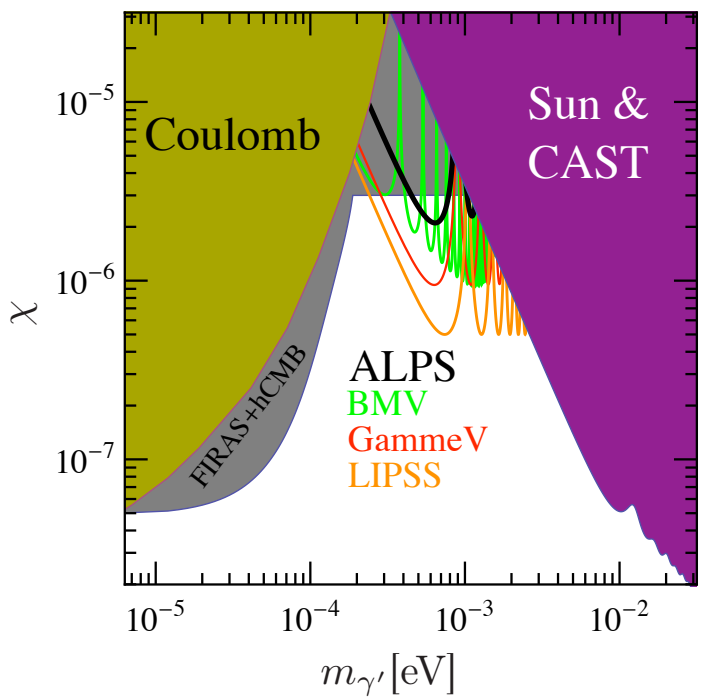
But again...

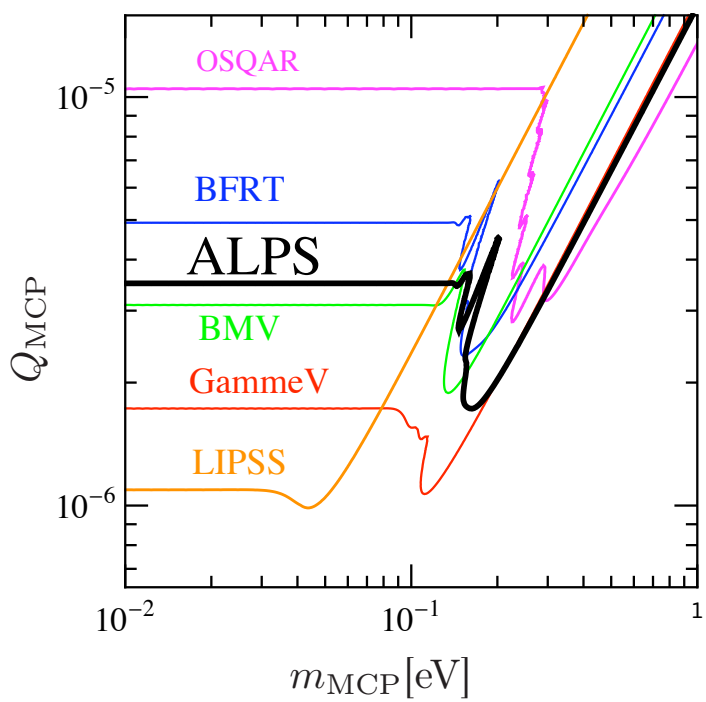
models developed for the PVLAS ALP interpretation work for MCPs, they can evade stellar evolution if more particles and symmetries are considered beyond the simple paradigm outlined before

The Any-Light-Particle-Search is on the way









List of interesting anomalies

Stelar evolution:
White dwarf luminosity function (anomalous cooling detected)

DM:
HPs could be decaying DarkMatter
MCPs could be annihilating DM

Astrophysics:
High transparency of the universe to Gamma rays
UHE cosmic rays
Active Galactic Nuclei emission
Hubble Diagram and MCPs (cosmological constant)