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# Physics case of Weakly Interacting Slim Particles

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**Abstract**

The present investigation is focused on the study of new hypothetical weakly interacting slim particles, motivated from theories beyond the Standard Model. We first introduce these particles from a theoretical point of view, review their interaction with photons and show their main features. Secondly, we compute the oscillation probability between them and photons and point the key parameters to look for them experimentally. Later we study the hypothesis of a hidden cosmic microwave background composed of hidden photons and to conclude we analise the sensitivity of the ALPS experiment at DESY which is looking for these particles with a Light-Shining-Through-a-Wall experiment.

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# Contents

# 1 Introduction

The Standard Model of particle interactions (SM) is incomplete, it does not provide a good dark matter candidate nor solve several sometimes hidden issues as the strong CP problem of QCD or hierarchy problems. So we have to go further: beyond SM. In most extensions of the Standard Model, we usually find the necessity to include hidden sectors, that are only weakly coupled to our visible sector. In this atmosphere, a lot of new exotic particles can arise, some of them with masses below an eV they have dubbed WISPs (weakly interacting slim particles) [1] [2] [3] [4]. A prime example of these particles is the known axion, that solves the strong CP problem of strong interactions [5] and is a very well candidate for cold dark matter[3]. Besides the axion, we want to study axion-like particles (ALPs) that share similar features with the axion, but usually are motivated from string theory scenarios. Another well motivated WISP candidate is the so called hidden U(1), hidden photon or paraphoton [1] [2] [3] that emerges, as its name suggests, from a hidden abelian U(1) weakly coupled to our visible sector through a kinetic term with our visible photons. This gauge vector can be very light depending on the model, and its mass can be provided either from a Higgs-type mechanism or a Stuckelberg mechanism.

An interesting hint has been suggested in [6] about the existence of a hidden CMB of hidden photons in the range of the meV, that could have formed due to resonant oscillations with the CMB after Big Bang Nucleosynthesis but before recombination. Some visible consequences would be an increase in the effective number of neutrinos, and in the baryon to photon ratio.

In order to find these particles their coupling to photons is commonly exploited. There are several experiments looking for these particles, such as laser regeneration experiments, also called Light-Shining-Through-Wall experiments (LSW).

The organization of this rewiev is as follows. In the first part we introduce a new type of particles, known as WISPs; axions, axions-like-particles and hidden photons, we describe the main features. We focus on the interaction between photons and WISPs, and in the second section we can study oscillation probabilities. After, we study the existence of a hidden CMB that has been suggested in [3]and we study the sensitivity of the second phase of the Light Shining through a Wall experiment at DESY, called ALPS. On of them conducted at DESY.

# 2 Introduction to new particles

## 2.1 Axions

In this first section we are going to see how the axion arises in order to solve Strong CP problem. The CP symmetry is the product of two symmetries, namely, C→ charge conjugation which transforms a particle into its antiparticle and P→parity which creates the mirror image of a physical system. Weak interactions violate this combined symmetry. We can see it in the decays of neutral kaons and B mesons. On the other hand, in strong interactions experimentally CP violation has not been observed. Therefore if exists, should be very small. On the other hand, the strong sector of the SM has a $U(1)_A$ anomaly, its Lagrangian gets a topological term:

$$L_{QCD} \supset \frac{g^2}{32\pi^2}\theta G^a_{\mu\nu}\tilde{G}^{a\mu\nu}, \tag{1}$$

where $\theta$ is an arbitrary coefficient, it should be determinated experimentally, and $G^a_{\mu\nu}$ is the field tensor of a non abelian gauge group, and $\tilde{G}^{a\mu\nu}$ is the dual tensor. This term, eq. (1), violates CP. One can see it from its analogous term in QED which is $\theta F_{\mu\nu}\tilde{F}^{\mu\nu} = \theta \mathbf{E}\cdot\mathbf{B}$. So clearly this term is not invariant under CP transformation. A very precise way to determine $\theta$ is by measuring the electric dipole moment of the neutron. Theoretically one finds [3].

$$|d_n| \sim \frac{e}{m_n}\left(\frac{m_q}{m_n}\right)|\tilde{\theta}| \sim 10^{-16}|\tilde{\theta}|e, \tag{2}$$

where $\tilde{\theta}$ is defined by $\theta$ and the quark mass matrix, M, as follows:

$$\tilde{\theta} \equiv \theta + \arg\det M, \tag{3}$$

Now $\tilde{\theta}$ is the physical CP-violating parameter in the Standard Model. However experimentally [13] has been found

$$d < 0.29 \times 10^{-25}, \tag{4}$$

this means that the value of $\tilde{\theta}$ should be

$$|\tilde{\theta}| \leq 10^{-10}. \tag{5}$$

After looking at eq. (3), the main question is why the dimensionless parameter $|\tilde{\theta}|$, a sum of two contribution of very different origins, is so unnaturally small? It is supposed that the solution probably lies outside the Standard Model of elementary particles. The most cogent solution consists of adding a new symmetry, a new U(1) symmetry proposed by Peccei and Quinn [5]. They assume the existence of a global $U_{PQ}(1)$ which is spontaneously broken, and its introduction into the theory replaces the static CP-violating angle $\tilde{\theta}$ with a dynamical CP- conserving field. As always, associated with this spontaneous breakdown there is a new particle: the quasi-Nambu-Goldston boson, called the axion.
As a result, the axion field $a(x)$ has a shift symmetry:

$$a(x) \to a(x) + \alpha f_a \tag{6}$$

where $f_a$ s the scale at which the Peccei-Quinn symmetry is broken and $\alpha$ is an arbitrary parameter. The $\tilde{\theta}$ term can be eliminated from the QCD Lagrangian by absorbing it into the axion field: $a = \tilde{a} - \tilde{\theta} f_a$, and an effective potential for the axion field $\tilde{a}$ arises, which is minimized at zero. Thus, the $\tilde{\theta}$ is wiped out by the axion field, providing a natural explanation of why the electric dipole moment is so small. Due to the effective potential of the axion it acquires a small mass, given by [4]:

$$m_a \simeq 0.6\text{eV}\frac{10^7\text{GeV}}{f_a} \tag{7}$$

One should notice that there is a inverse relation between $m_a$ and $f_a$. We are interested in the strength of the coupling of an axion with two-photons[4], the explicit form of it is:

$$g_{a\gamma\gamma} = \frac{\alpha}{2\pi f_A}\left(\frac{E}{N} - \frac{2}{3}\frac{4+z}{1+z}\right)\frac{1+z}{z^{1/2}}\frac{m_A}{m_\pi f_\pi} \tag{8}$$

where $z = m_u/m_d$, $E$ and $N$ are the electromagnetic and color anomalies of the axial current associated with the axion. In general, a broad range of $E/N$ are possible. In the DFSZ model, $E/N = 8/3$ and in the KSVZ model, $E/N = 0$, therefore axions can live on a band figure 2.3.

To finish this chapter we write the Lagrangian of the axion coupling to two-photons.

$$L = -\frac{1}{4}F^{\mu\nu}\tilde{F}_{\mu\nu} + J_\mu A^\nu + \frac{1}{2}\partial_\mu a \partial^\mu a - \frac{1}{2}m_a^2 a^2 + \frac{1}{4}g_{a\gamma\gamma}F^{\mu\nu}\tilde{F}_{\mu\nu}a \qquad (9)$$

where $F_{\mu\nu}$ is the electromagnetic field strength, $J_\mu$ is the current. In the next section we start form this Lagrangian to obtain motion equations.

## 2.2 Axion-like-particles

There are also particles similar to the axion, scalar bosons, called axion-like particles $\phi$ and they don't solve strong CP problem. Usually they are motivated from fundamental theories, such as string theory scenarios, and there is no relation between its mass and coupling constant, therefore they spawn in the whole parameter space of $g_\phi$ vs. $m_\phi$. Usually the coupling constant is predicted to be very small. We can considerer now the interaction between two-photons and this neutral boson $\phi$. There are two ways for coupling, scalar $g^+$ or pseudoscalar $g^-$. The axion has only the coupling with the last one. For axion like particles we can have both (since they do not solve the strong CP) each one is associated with the opposite parity structure, as we can see:

$$\frac{1}{4}g^+ F^{\mu\nu}F_{\mu\nu}\phi \quad ; \quad \frac{1}{4}g^- F_{\mu\nu}\tilde{F}^{\mu\nu}\phi \qquad (10)$$

In the third section we will show that effectively ALPs (and also axions ) can oscillate with photons in the presence of an external magnetic field.

## 2.3 Hidden photons

We also have another well motivated WISPs candidates: hidden photons which appear in models based on supersymmetry and supergravity. At low energies their only coupling with our visible sector is through a kinetic mixing with the photon. The effective Lagrangian is given by

$$L = -\frac{1}{4}\left(F_{\mu\nu}\right)^2 - \frac{1}{4}\left(B_{\mu\nu}\right)^2 + \frac{\sin\chi}{2} B_{\mu\nu}F^{\mu\nu} + \frac{\cos^2\chi}{2} m_{\gamma'}^2 \left(B_\mu\right)^2, \tag{11}$$

where $\chi$ is a dimensionless parameter that measures the strength of the mixing between them and $A^\nu$ is the photon and $B^\nu$ is the hidden photon field. As we will see further, this kinetic mixing can be removed by a change of basis. However, the mixing will appear in the mass term and this will lead to oscillations between the photon and the hidden photon, as happens with the known neutrino oscillations. In most of the known models [**?**] the parameter $\chi$ is very small,

$$10^{-12} \leq \chi \leq 10^{-3}. \tag{12}$$

As we can see in figure 4 there are hints on the low mass region and in the high mass range. They can be cold dark matter [12] or in the range masses of the meV, the could form the a hidden CMB with a coupling constant $\chi \sim 10^{-6}$. This last region will be analysed by the LSW experiment ALPS at DESY next year.

# 3 Computations of oscillation probabilities

## 3.1 Axions and axion-like particles

We are going to study the coherent $\gamma - \phi$ oscillations in the presence of a long, static and homogeneous magnetic field. We can consider a beam of laser light shining against a region with a strong magnetic field [11]. We choose the beam direction as z-axis and the magnetic field polarization in xz-plane. So all fields are functions of time and z:

$$A^\mu(x^\nu) = A^\mu(t, z) \;;\; \phi(x^\nu) = \phi(t, z) \tag{13}$$

We choose the pseudoscalar coupling, to study axions and ALPs, which obeys $\phi(-x) = -\phi(x)$ and we obtain Lagrangian from eq. (9). Minimizing the action, we can easily find the equations of motion:

$$\partial_\mu F^{\mu\nu} = J^\nu + g\tilde{F}^{\mu\nu}\partial_\mu\phi \tag{14}$$

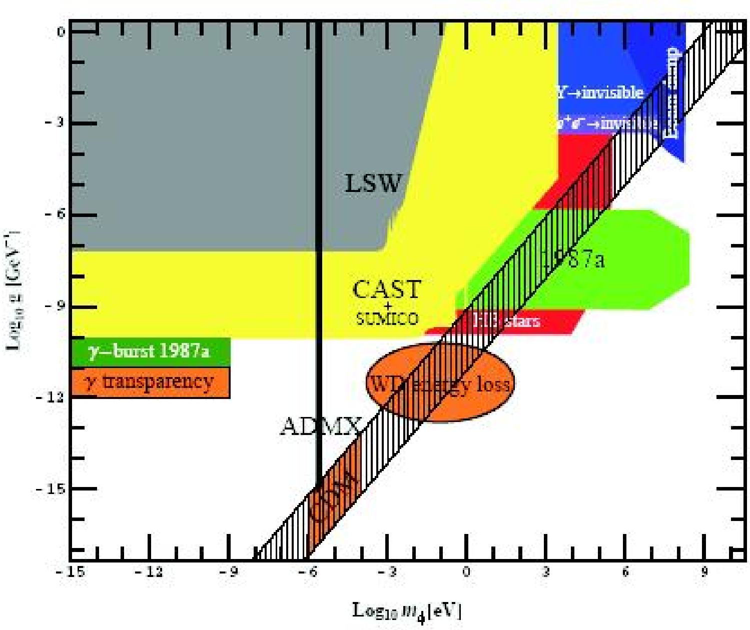


Figure 1: This figure represent the relation between the coupling constant and the mass. At first ALPs can live everywhere, there is not a relation between coupling constant and mass, but some experiments have ruled out some regions. In the opposite way, axions only can live in the hatched band giving by two ways of coupling. There are some hints for the axion showed in orange: the range where it can be cold dark matter and the range where the recently reported anomalous cooling of white dwarf stars. It is show also limits from photon regeneration experiments.

$$\left(\partial^2 + m_\phi^2\right) = -\frac{1}{4} g F_{\mu\nu} \tilde{F}^{\mu\nu} \tag{15}$$

We can divide the electromagnetic field in two parts corresponding to external magnetic field and the laser beam. We must notice that $J^\nu = \partial_\mu F^{\mu\nu}_{ext}$.

$$F^{\mu\nu} = F^{\mu\nu}_{ext} + F^{\mu\nu}_{\gamma}. \tag{16}$$

In order to simplify our equations, we can consider that external magnetic field is much more intense that the laser beam. In this way we can neglect terms involving two fields, such as quadratic terms in $F_\gamma$ or terms such as $F_\gamma g \partial\phi$ which are very small, to find a linear system in terms of $F_\gamma$. So, eq.

(14) and eq.(15) can be written:

$$\partial_\mu F_\gamma^{\mu\nu} = g\tilde{F}_{ext}^{\mu\nu}\partial_\mu\phi \tag{17}$$

$$\left(\partial^2 + m_\phi^2\right) = -\frac{1}{2}gF_{\gamma\mu\nu}\tilde{F}_{ext}^{\mu\nu} \tag{18}$$

Only the component of the photon parallel to the transverse magnetic field interacts with the ALP and the perpendicular component remains unchanged. The equations of motion can be written as follows:

$$\left[\omega - i\partial_z + \begin{pmatrix} 0 & \frac{gB_T}{2} \\ -\frac{gB_T}{2} & -\frac{m_\phi}{2\omega} \end{pmatrix}\right]\begin{pmatrix} A_{||} \\ \phi \end{pmatrix}(z) = 0 \tag{19}$$

where $B_T$ is the transverse part of the external magnetic field. In order to calculate the oscillations we must diagonalize matrix in parenthesis in order to know the states in the propagation basis. The initial conditions $A_{||}(t = 0) = 1$, $\phi(t = 0) = 0$ which means that there is no ALPs in the first part of the experiment and all that we have in $z = 0$ are photons. So, after some algebra, we will see it more explicitly in the hidden photon sector, the probability of $\gamma|| - \phi$ oscillations at distance z and time t is:

$$P(\gamma \to \phi) = |\phi(z) * A_{||}(0)|^2 = \frac{4g^2B_T^2\omega^2}{m_\phi^4}\sin^2\left(\frac{m_\phi^2 z}{4\omega}\right). \tag{20}$$

We have made an aproximation, the mass of ALP is much less than the frequency of of the photon.

## 3.2 Hidden Photons

From the Lagrangian eq. (11) we change basis $\{A, B\} \to \{A_R, S\}$ in order to remove out the kinetic mixing, but this change must leave the photon *sterile*, just thinking in LSW experiments.

$$A_R = A\cos\chi \quad ; \quad S = B - A\sin\chi \tag{21}$$

This is the only possible change because if we do the opposite we would see that hidden photons would interact with matter and this can not occur in experiments such as LSW, on which we must focus later. So, after this transformation we can obtain a new lagrangian, which is diagonal except mass terms.

$$L = -\frac{1}{4}F_R^2 - \frac{1}{4}S^2 + \frac{\cos^2\chi}{2}m_{\gamma'}^2(S_\mu S^\mu + 2\tan\chi S_\mu A_R^\mu + \tan^2\chi A_{R_\mu} A_R^\mu) \quad (22)$$

We can write it in matrix notation with a new basis: $\tilde{A} = \left(\begin{smallmatrix} A_\mu \\ S_\mu \end{smallmatrix}\right)$ and the same with $F := \left(\begin{smallmatrix} F_R \\ S \end{smallmatrix}\right)$. So now:

$$L = -\frac{1}{4}F^T I F + \frac{1}{2}\tilde{A}^T M \tilde{A}, \quad (23)$$

where I stands for the identity matrix and M is:

$$M = \begin{pmatrix} m_{\gamma'}^2 \tan^2\chi & m_{\gamma'}^2 \tan\chi \\ m_{\gamma'}^2 \tan\chi & m_{\gamma'}^2 \end{pmatrix} \quad (24)$$

We diagonalize $M$. Its eigenvalues are $m_{\gamma'}^2(1+\tan^2\chi)$ and 0. We can replace now this new value:

$$L = -\frac{1}{4}\tilde{F}^T I F + \frac{1}{2}\tilde{A}^T P D P^{-1} A \quad (25)$$

In that way, we can see naturally that we have achieved a diagonal basis or propagation basis, we can call it: $A_d(0)$. For example, $P^{-1}\tilde{A}(0) = A_d(0)$ and the same for any time. On the other hand, because it is the basis of propagation we can know the state in every moment: $A_d(t) = EA_d(0)$ where E is the exponential matrix[2].

$$E = \begin{pmatrix} e^{ip_1 t} & 0 \\ 0 & e^{ip_2 t} \end{pmatrix} e^{\mathrm{iet}} \quad (26)$$

where $e$ represent the energy of photon and hidden photon, and it is the same for both. Using this we can write the final state $\tilde{A}(t)$ with $\tilde{A}(0)$ as follows:

$$\tilde{A}(t) = PA_d(t) = PEA_d(0) = PEP^{-1}\tilde{A}(0) \rightarrow \tilde{A}(t) = Q\tilde{A}(0). \quad (27)$$

[2]Photon and hidden photon share the same energy, so you can take it out from the matrix

We know that at $t = 0$ we have $\tilde{A}(0) = \binom{1}{0}$ because there is no hidden photons at first and the photons are 100%. So we can calculate the probability:

$$P(\gamma \to \gamma') = |S_\mu(t) * A_\mu(0)|^2 = 4\chi^2 \sin^2\left(\frac{m_{\gamma'}^2 z}{4\omega}\right) \tag{28}$$

To complete this section, is important to notice what happens with a photon in a gas, which is even more important than in the vacumm. We can calculate the probability of a photon in a gas can oscillate in hidden photon. It easy, we have to add to the last lagrangian a mass of the photon in a gas.

$$L = -\frac{1}{4}(F_{\mu\nu})^2 - \frac{1}{4}(B_{\mu\nu})^2 + \frac{\sin\chi}{2} B_{\mu\nu}F^{\mu\nu} + \frac{\cos^2\chi}{2} m_{\gamma'}^2 (B_\mu)^2 + \frac{\cos^2\chi}{2} m_{\gamma'}^2 (A_\mu)^2, \tag{29}$$

So, let's see how is the M matrix:

$$\begin{pmatrix} m_{\gamma'}^2 \tan^2\chi + m_\gamma^2 & m_{\gamma'}^2 \tan\chi \\ m_{\gamma'}^2 \tan\chi & m_{\gamma'}^2 \end{pmatrix} \tag{30}$$

And if we repeat the same steps in order to calculate the probability of oscillations we get:

$$P(\gamma_m \to \gamma') = |S_\mu(t) * A_\mu(0)|^2 = 4\chi^2 \left(\frac{m_{\gamma'}^2}{m_{\gamma'}^2 - m_\gamma{}^2}\right)^2 \sin^2\left(\frac{\left(m_{\gamma'}^2 - m_\gamma^2\right) z}{4\omega}\right) \tag{31}$$

The result is consistent because if $m_\gamma$ vanishes we can return to probability of eq. (28).

# 4 Hidden CMB and some consequences

Now that we have discovered another kind of particles, and we have studied the oscillation probabilities with photons we are able to speak about the effects of these particles in late cosmology.

First of all, Cosmic microwave background (CMB) was predicted by big bang model, and there the priming universe was a plasma. Photons interacted with this plasma by Thomson dispersion. Electrons couldn't link to protons because of the high energy. So electrons and photons interacted with Compton dispersion. In recombination epoch baryons change ionized states by neutral ones. As baryon recombined the electron density decreased, and photons could not interact with baryons. This epoch is so-called decoupling. Also, as the universe expanded the plasma got cooler until it reached a temperature where stable atoms could form, hydrogen nuclei. The atoms couldn't absorb the thermal radiation and the universe became transparent, photons started to travel without any scattering. CMB is the trace of this period, and the most important: it has the perfect shape of a dark body. The big bang nucleosynthesis was very short, threeminutess after $100s \sim 200s$ the universe started to expand, but it was enough in order to avoid heavy elements.

A thermal population of hidden photons can be created through resonant oscillations after Big Bang nucleosynthesis (BBN) but before cosmic microwave background (CMB). This hidden CMB (hCMB) will contribute to the effective number of additional neutrinos at decoupling and, since some photons dissapear, will increase the baryon to photon ratio respect to BBN value. Even more, we find that the black body spectrum of CMB changes. In principle we can assume that at the time BBN there is no $\gamma'$ thermal bath. Oscillations decrease the photon number and energy density, leaving the total energy unchanged. The key parameter will be the fraction of $\rho_\gamma$ that is converted in $\rho_{\gamma'}$: $x \equiv \frac{\rho_\gamma}{\rho_\gamma}$.

Let's see how affects to the temperature. After hCMB decoupling, the remaining photons will regain a black body distribution, albeit, due to energy loss, at a lower temperature:

$$\rho_\gamma = \sigma T^4_{\text{before}} \quad ; \quad \tilde{\rho} = \sigma T^4_{\text{after}} \tag{32}$$

Before oscillations there are only photons $\rho\gamma$, after oscillations density changes to $\tilde{\rho}$, and as we have just seen the temperatura also changes. The new density is the difference between initial desity of photons and density of photons which h and the hidden photons, where $\tilde{\rho} = \rho_\gamma - \rho_{\gamma'}$, we can write:

$$\frac{\rho_\gamma}{T^4_{\text{before}}} = \frac{\rho_\gamma - \rho_{\gamma'}}{T^4_{\text{after}}} \to T^4_{\text{after}} = (1-x)\, T_{\text{before}} \tag{33}$$

With this we can see how the temperature decreases but without loss the shape of a black body.
We have said that it can change also the effective number of neutrinos that remain unchanged during hCMB formation. The invisible enery density at decoupling can be estimatedd using CMB anisotropies and is often quoted as effective number of standard neutrinos: $\rho_\nu = (7/8)(4/11)^{4/3}\rho\gamma$. The effective number of neutrinos, therefore is defined as:

$$N_\nu^{eff} \equiv \frac{\rho_{\text{tot}} - \rho_\gamma}{\rho_\nu} \tag{34}$$

On the other hand we know that now:

$$\rho_\nu = (7/8)(4/11)^{4/3}\tilde{\rho} = (7/8)(4/11)^{4/3}\left(\rho_\gamma - \rho\gamma'\right) = \rho_\nu^{st}\left(1-x\right) \tag{35}$$

$$\rho_{\text{tot}} = N_\nu^{\text{eff}}\rho_\nu + \rho_\gamma = N_\nu^{st}\rho_\nu + \rho_{\gamma'} + \rho_\gamma \tag{36}$$

We can rewrite the effective number of neutrinos as follows:

$$N_\nu^{\text{eff}}\text{eff}_\nu = \frac{N_\nu^{\text{st}}\rho_\nu^{st} + \rho_{\gamma'} + \rho_\gamma - \rho_\gamma}{\rho_\nu^{\text{st}}\left(1-x\right)} \tag{37}$$

With relation between photons and neutrinos we can write:

$$N\text{eff}_\nu = \frac{N_\nu^{\text{st}}(7/8)(4/11)^{4/3}\rho_\gamma + x\rho_\gamma}{7/8)(4/11)^{4/3}\left(1-x\right)\rho_\gamma} \tag{38}$$

Simplying you can obtain:

$$N_\nu^{\text{eff}} = \frac{N^{\text{st}}}{(1-x)} + \frac{x}{(1-x)}\frac{8}{7}\frac{11}{4}^{4/3} \tag{39}$$

Is the sum of neutrino and hidden photon contributions. A recent analysis of WMAP5 plus other CMB anisotropy probes [7]:

$$N_\nu^{\text{eff}} = 2.9^{+2.0}_{-1.4} \tag{40}$$

which, using standar means: $N_\nu^{\text{st}} = 3.046$, and $x \simeq 0.20$. Planck satellite data could be used to reach sensitivity down to $\Delta N_{eff} = 0.07$, corresponding to $x \sim 0.01$.

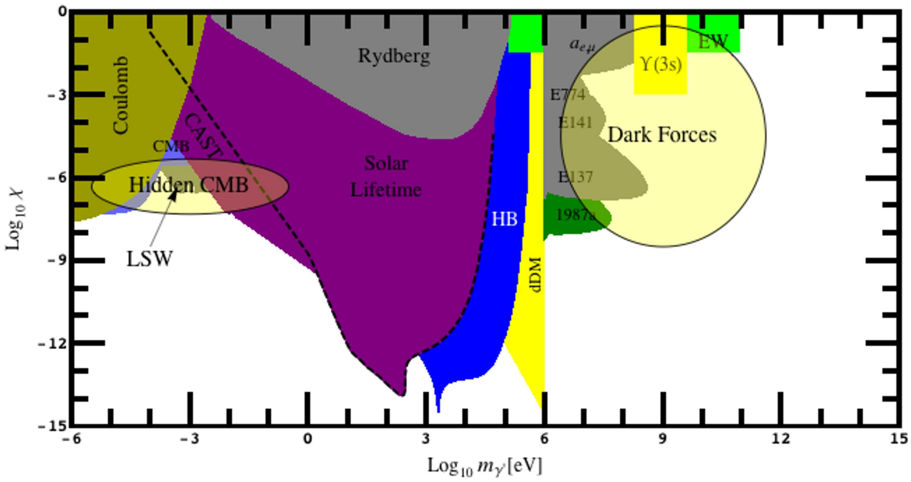


Figure 2: In principle the hidden photon can live in every region, as ALPs. Some regions have been ruled out by several experiments, from the astronomic and comoslogical observations, such as Solar time, white dwarf , or lab experiments like Coulomb, Rydberg, CAST. In yellow circles it is shown the theoretical hints.

The last change is the baryon to photon ratio. Since $\eta_\gamma$ is proportional to $T^3$, the baryon to photon ratio is also modified according to:

$$\eta^{\rm after} = (1-x)^{-(3/4)}\,\eta^{\rm before} \tag{41}$$

This value is inferred from the abundances of the light elements produced at BBN and then obtained by measuring temperature fluctuations in the CMB. It allows us to set the bound $x \lesssim 0.32$

Has been been found that the relation between the parameter $x$ and the kinetic mixing is [6]

$$x \simeq 3.9 \times 10^{10}\chi^2 \tag{42}$$

We can plot, the results, with these constraints in order to see which regions are ruled out, and which are still available to look for them with our current technologies. See figure 4.

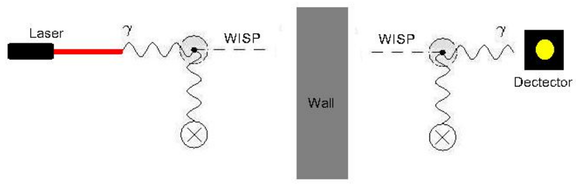


Figure 3: It is shown the main scheme of the experimental work in order to obtain light through a wall. We can see hoy the particle of light, thanks to a transversal magnetic field, changes into a WISP, and after the wall this changes back into a photon.

# 5 Light shining through a wall

A LSW experiment is being carried out at DESY, called ALPS(Any Light Particle Search). The experiment consists on detecting a photon shining through a wall. To achieve it, a laser beam is sent to an opaque wall in a transverse magnet from the HERA ring acceleratoror. In the experiment, if these particle exist, a photon can oscillate into a WISPs. In the middle of the path there is a wall. Photons can not pass throught, but if they oscillate as we said, these WISPs don't interact with matter so they can pass trough it. Once they pass the wall they find another magnetic field which helps to change back into photons, which can be shown up in a photon detector. And so the light can pass trough a wall.

In 2012 ALPS will start its second phase on hidden photon search with an improved set up. Larger facilities and a powerful laser beam. Using that the number of regenerated photons [1] is:

$$N_s = \eta^2 \beta_g \beta_r \frac{P_{prim}}{\omega} P^2_{\gamma \to WISP} \tau \tag{43}$$

we can plot the relation between $\chi$ and the mass with this new values. We can include also the bounds that we have mentioned before.

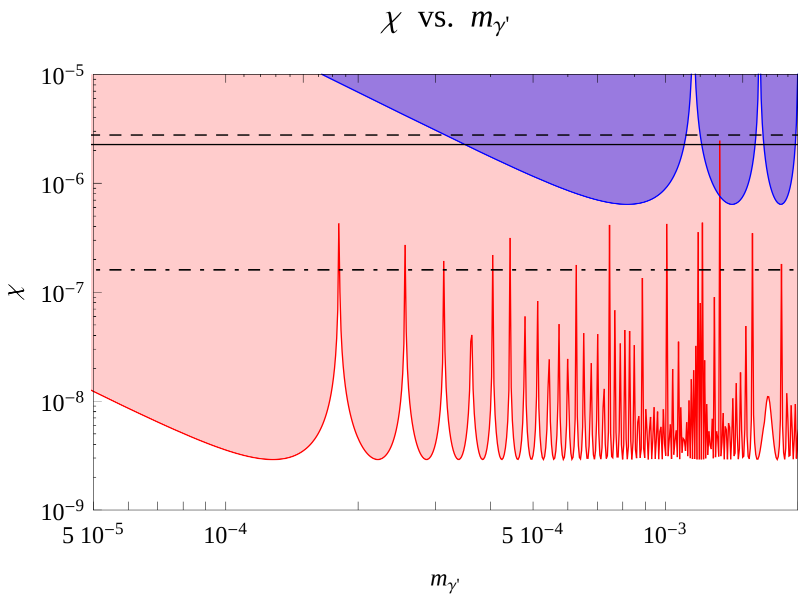


Figure 4: This show the relation between coupling constant of hidden photons and photons with the mass. The region above x=0.32 (dotted line) is excluded by the agreement of baryon to photon ratio. x = 0.2(solid line) is excluded by upper limits on the effective number of neutrinos at CMB epoch. Planck data could provide us in the future a bound $\sim$ 0.01(dotslashed line). The blue zone corresponds to the first phase of ALPS, the second phase appears in red. For ALPS I $\eta = 0.90$, $L = 4.3\text{m}$ $\beta_g = 300$, and $\beta_r = 1$, $\tau = 10h$ and $P_{\text{Prim}} = 3W$, and for ALPS II $\eta = 0.95$, $L = 88\text{m}$ $\beta_g = 10^5$, and $\beta_r = 10^5$, $\tau = 100h$ and $P_{\text{Prim}} = 300W$

# 6 Conclusions

There are several new hypotethical particles that arises from theories beyond the Standard Model of particles. We have studied very weak interactive slim particles, axions, axions like particles, and the oscillations with photons. In the range of meV hidden photons could form hidden cosmic microwave backgroung,. We have explored its consequences, such as the change in to the barion to photon ratio, or change to the temperature universe, and they could change seriusly the effective number of neutrinos. One kind of experiments looking for these particles in the meV range is light shining through a wall experiments. At Desy there is a LSW experiment called ALPS. In its first phase, in 2009 was the most sensitive experiment among the LSW around the world, and in 2012 will take place the second phase, dedicated to HP, which will test a large region as we have seen in Figure 4. If we don't find WISPs in the meV range, we must erase the idea of hCMB, and start to look for them in other region, with powerful tools.


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