Dark Photons

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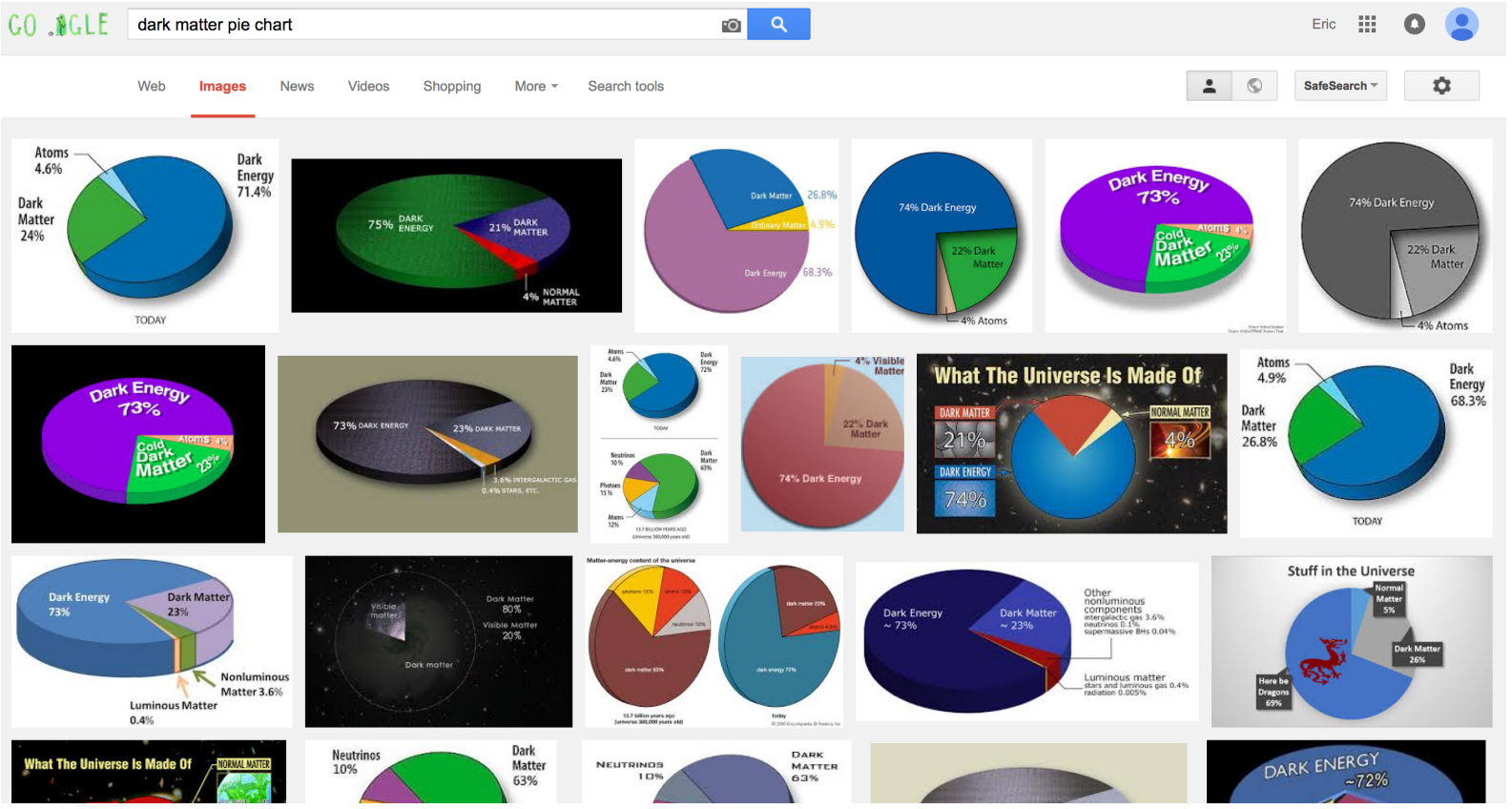


What is a dark photon

- Dark Matter is generally described as a WIMP.
- But it need not be that boring!
- One can consider different types of dark matter particles that interact and coexist.
- The dark photon is the general descriptor for the thingy that mediates this dark matter interaction.

What do we know about DM?

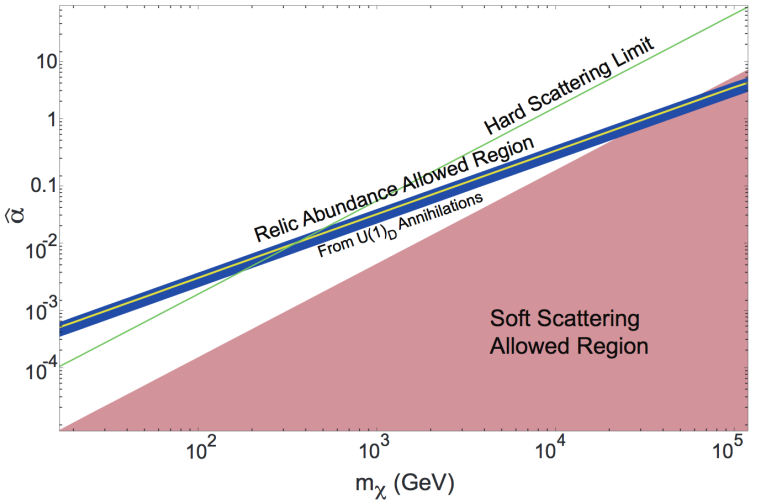
- It's dark
- It's cold
- It's collisionless (mostly)
- It doesn't annihilate (much)
- It's NOT necessarily non-interacting

The EM like Dark Photon

- When originally proposed in (arXiv:0810.5126) the dark photon ($\hat{\gamma}$) was the force carrier for "dark charge"
- It was the gauge boson of a $U(1)_D$ symmetry
- It was massless
- Dark matter could have +1,-1, or 0 dark charge
- The dark matter with dark photons model was characterized by M_X, the mass of a dark matter particle, and $\hat{\alpha}$, the dark fine structure constant.
- The dark photon had no direct SM interactions

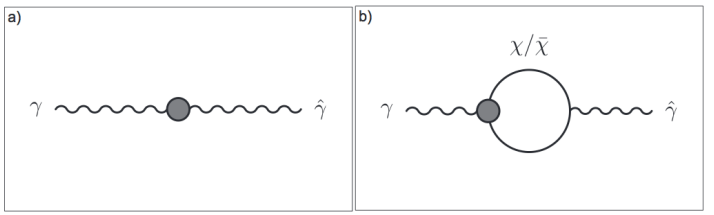
$$SU(3)_C \times SU(2)_L \times U(1)_Y \longrightarrow$$
$$SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_D$$

- Here is the allowed regions as calculated in arXiv:0810.5126 based only upon cosmological observations
- The relic abundance allowed region applies to models in which $U(1)_D$ is the only force coupled to the dark matter; in models where the DM is also weakly interacting, this provides only an upper limit on $\hat{\alpha}$

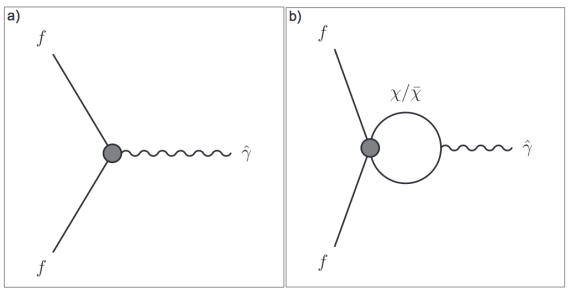


ElectroDarkWeak

- You can have a DM particle that interacts weakly AND through $\hat{\gamma}$

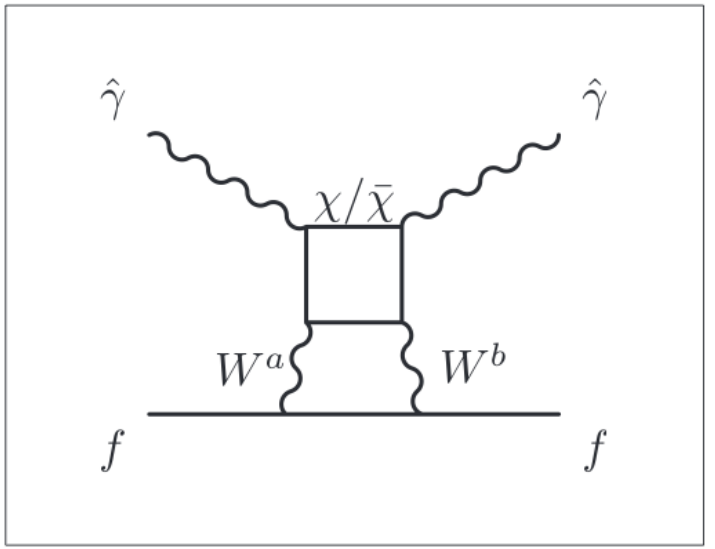


- But if you do almost all mixing ends up cancelling out



ElectroDarkWeak

- The lowest order SM coupling is at order $\lambda_f \alpha^2 \hat{\alpha}$ where λ_f is the coupling of the fermion involved
- In this scenario a signal in a direct detection experiment would be identical to that of normal (non-interacting) dark matter.



Quoth arXiv:0810.5126:

> *Therefore, the presence of a new unbroken $U(1)_D$ in the dark sector could only be probed via its effect on galactic dynamics"*

Moving on to the (more recent) paper du jour

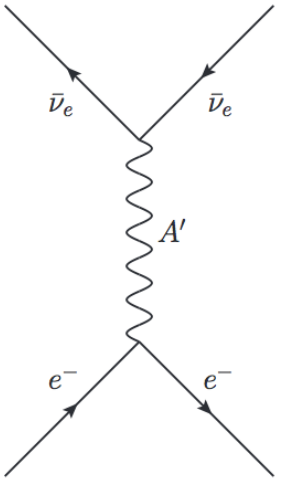
Constraints on Dark Photon from Neutrino-Electron Scattering Experiments

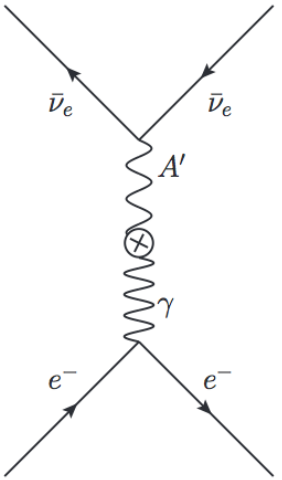
- As the title suggests the authors consider neutrino elastic scattering as the main channel by which dark photons can be observed.
- But wait. Didn't we just hear that terrestrial detection type experiments are hopeless?
- It seems since the original proposition of the dark photon idea has evolved and expanded.

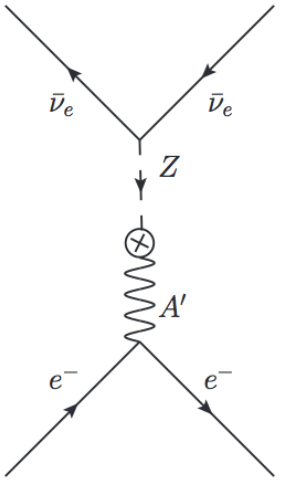
The dark photon according to arxiv:1502.07763

- $\hat{\gamma}$ can have non-zero but tiny mass.
- There are two ideas through which the dark photon can be considered.
  1. The dark photon comes from a $U(1)'$ symmetry that mixes with the SM $U(1)_Y$ symmetry
     - This results in a kinetic mixing between the the photon and the dark photon
     - This has the form $\epsilon B'_{\mu\nu} F^{\mu\nu}$ where ϵ is the strength of the mixing
  2. The other option for getting the dark photon is through a $U(1)_{B-L}$ symmetry
- This paper chooses to consider the $U(1)_{B-L}$ primarily.
- The $U(1)_{B-L}$ model is characterized by dark photon mass $M_{A'}$ and the coupling constant g_{B-L}

$\hat{\gamma}$ Interactions

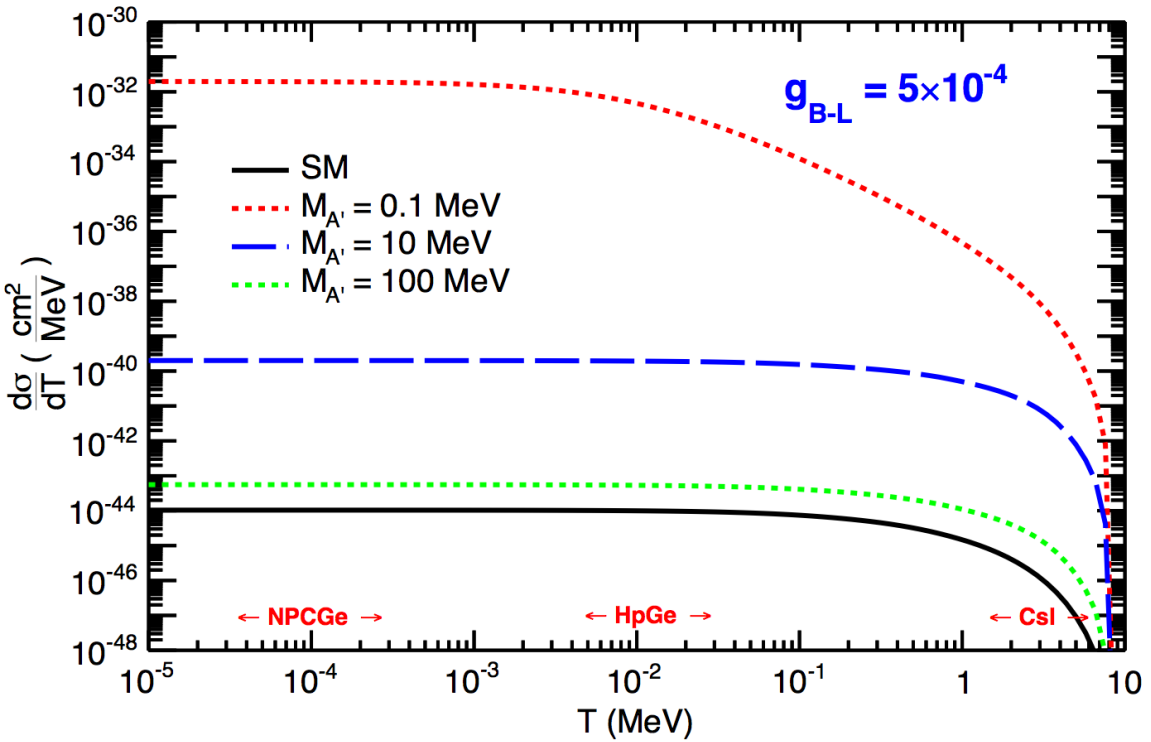






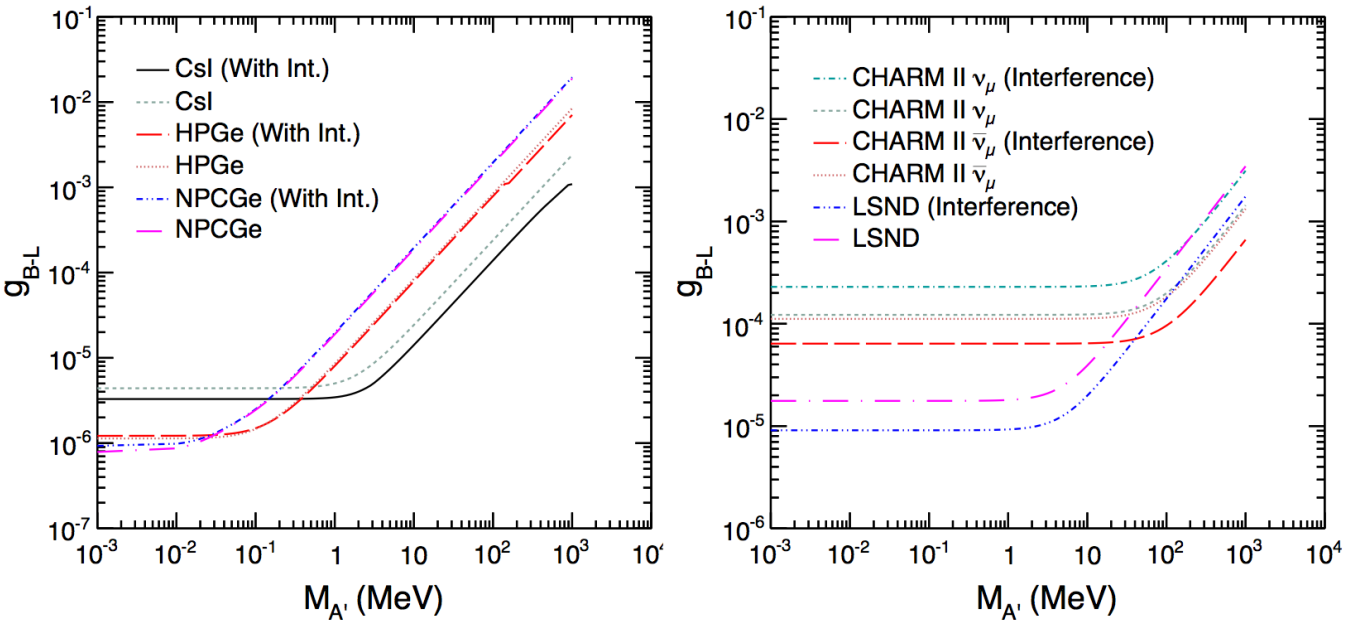
Elastic Scattering Spectrum

Since you now have all these extra diagrams for neutrino-electron elastic scattering you expect the cross section to change.



Interference

- The authors of the paper harped on about the importance of including interference effects
- Apparently there were some people before who hadn't done this



The authors made the world's 2nd most confusing plot to illustrate the error of this neglect

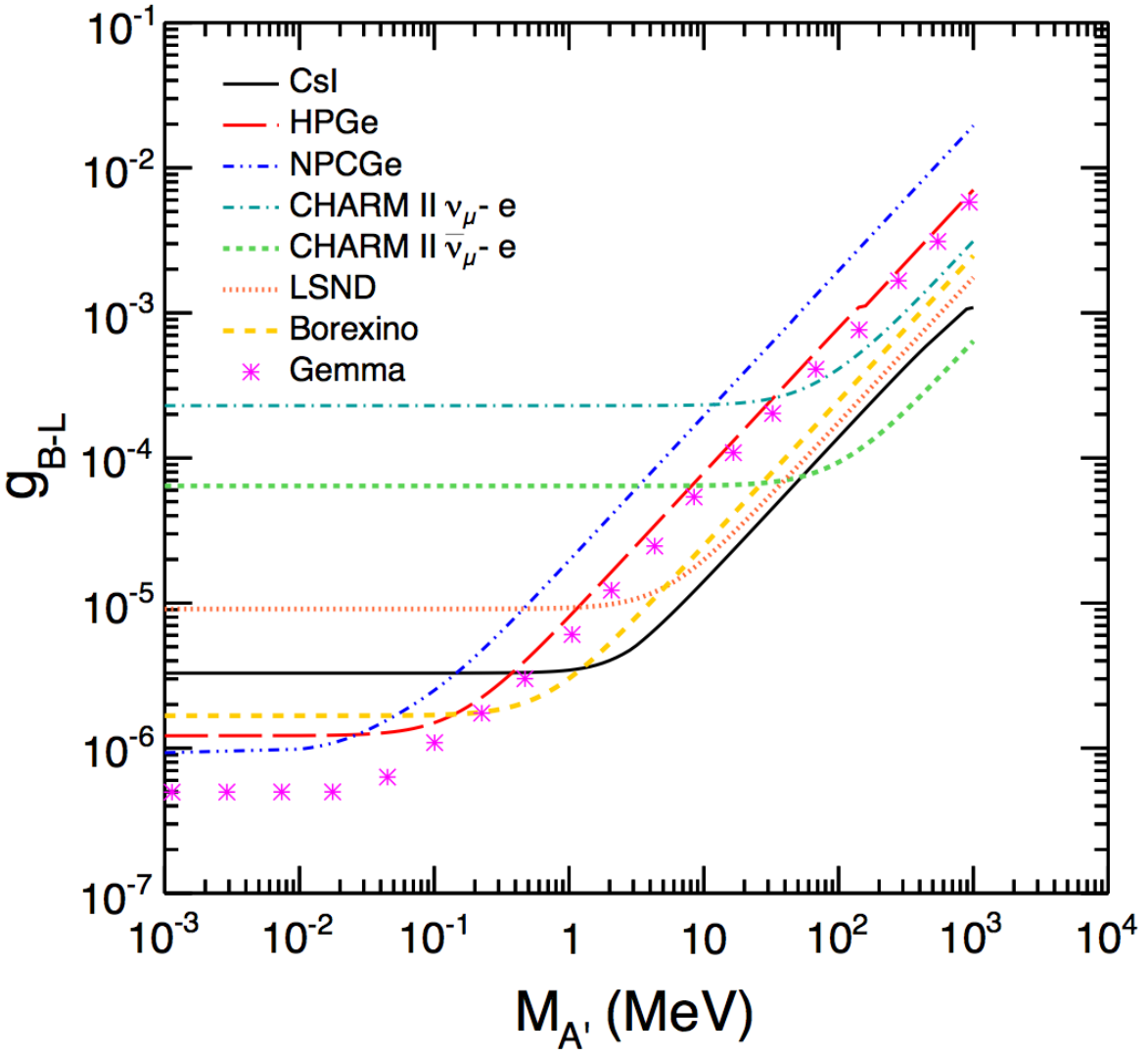
A quick summary of experiments

Several experiments were considered

- TEXONO - Reactor Anti-Neutrinos
- LSND - Accelerator Neutrinos
- BOREXINO - Solar Neutrinos
- GEMMA - Reactor Anti-Neutrinos
- CHARM II - Accelerator Muon Neutrinos

TEXONO comes in 3 different flavors, CsI, HPGe,NPCGe which denote different detector arrays that were swapped in or out. Each different detector had differing physics advantages.

Exclusion Plot



Global Dark Photon Exclusion