Update on Hidden Photon Science Case.

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HELMHOLTZ ASSOCIATION

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Motivation for update

- First thorough investigation of hidden photon production in stellar plasmas: J. Redondo, JCAP 07 (2008) 008
- Revisited recently by H. An, M. Pospelov, J. Pradler, arXiv:1302.3884
  - For small masses, emission rate of the longitudinal modes of the hidden photon dominates over the transversal modes, in contrast to previous finding
  - Stronger bounds at low masses (< 10 eV) from solar and stellar energy loss considerations

    ALPS-I bounds in excluded region
    ALPS-IIa and ALPS-IIb discovery potential diminished
    CAST and SHIPS helioscope bounds/reach in excluded region

Hidden photon production in stellar plasma

- Differential production rate of transversal (T) / longitudinal (L) hidden photons can be resonantly enhanced in a plasma:

$$\frac{d\Gamma^{\mathrm{prod},\gamma'}_{T,L}}{d\omega dV} = \frac{\chi^2}{\left(1-\frac{\mathrm{Re}\,\Pi_{T,L}}{m^2_{\gamma'}}\right)^2+\left(\frac{\mathrm{Im}\,\Pi_{T,L}}{m^2_{\gamma'}}\right)^2}\frac{d\Gamma^{\mathrm{prod}}_{T,L}}{d\omega dV}$$

- At leading order in T/m_e, [An, Pospelov, Pradler, 1302.3884]

$$\mathrm{Re}\,\Pi_T \equiv m_T^2 \simeq \omega_p^2, \qquad \mathrm{Re}\,\Pi_L \equiv m_L^2 \simeq \omega_p^2\left(1-\frac{\mathbf{k}^2}{\omega^2}\right)$$

in terms of plasma frequency, $\omega_p^2 \simeq \frac{4\pi\alpha}{m_e} n_e$

  - [Redondo, JCAP 07 (2008) 008] used $\mathrm{Re}\,\Pi_L \simeq \omega_p^2 - \mathbf{k}^2$; unphysical: $\mathrm{Re}\,\Pi_L$ should vanish at vanishing plasma frequency

Hidden photon production in stellar plasma

- Plasmon production rate as well as electron density (plasma frequency) given by solar / stellar model, for details see [Redondo, JCAP 07 (2008) 008]

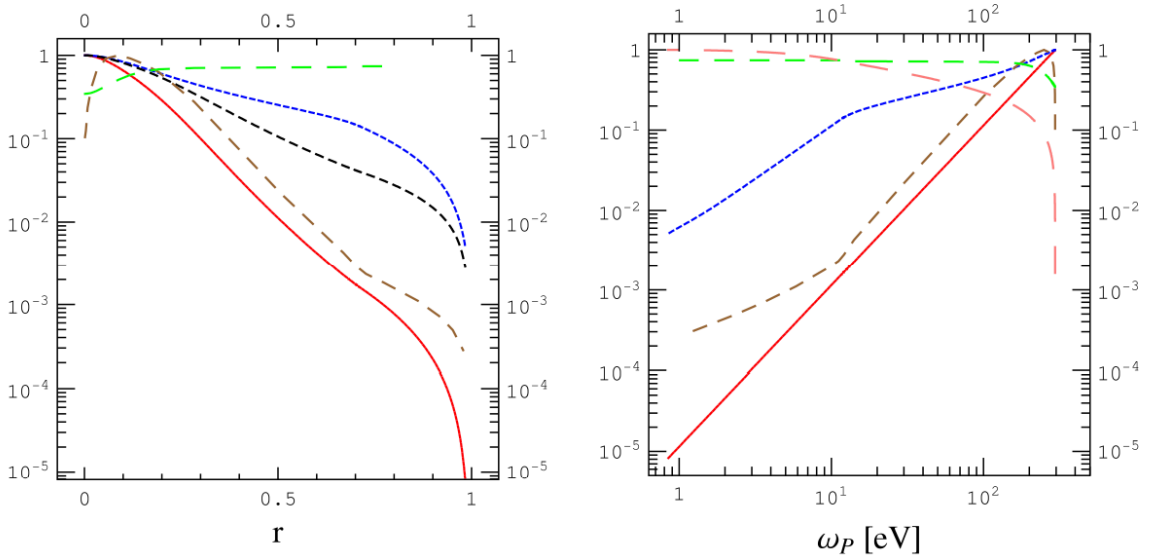
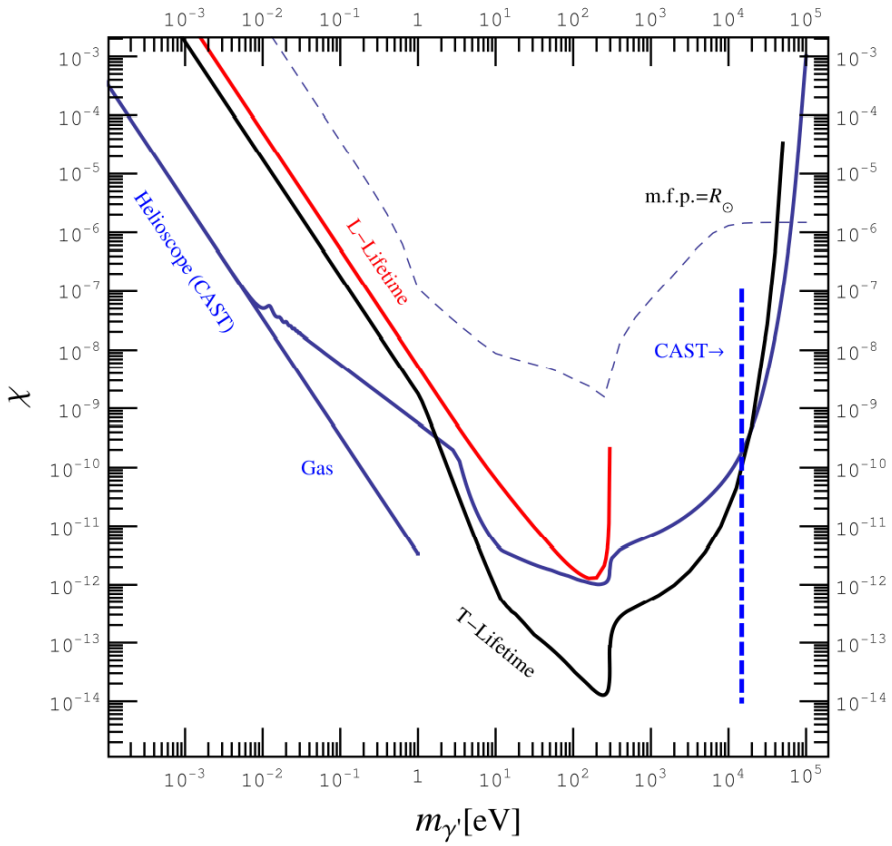


Figure 1. Values of the solar parameters relevant for this work plotted as a function of the normalized solar radial coordinate r (left) and the plasma frequency $\omega_{\rm P}$ (right). From small to large dashed lines these are the electron density $n_{\rm e}$ (red), temperature T (blue), plasma frequency (black), $\mathrm{d}\omega_{\rm P}^2/\mathrm{d}r$ (brown), hydrogen mass fraction X (green) and radial coordinate r (pink). Except for X, they are normalized to their largest values 6.07×10^{25} cm^{-3}, 1350 eV, 295.5 eV, 5.8×10^{-4} eV^2 m^{-1} and $R_\odot = 6.96 \times 10^8$ m, respectively (taken from [44]).

Solar bounds on hidden photons

- Solar bounds derived in [Redondo JCAP 07 (2008) 008]



- Bound from L modes of hidden photons underestimated, cf. [An, Pospelov, Pradler, 1302.3884]

Solar bounds on hidden photons

- Energy loss due to resonant production of L modes of hidden photons, using correct $m_L^2 \simeq \omega_p^2(1 - \mathbf{k}^2/\omega^2)$: [An, Pospelov, Pradler, 1302.3884]

$$P_\odot|_{\rm res} \approx \chi^2 m_{\gamma'}^2 \int_0^{R_\odot} r^2 dr \frac{\omega_p^3(r)}{e^{\omega_p(r)/T} - 1}$$

  - Resonance for L mode occurs at $\omega = \omega_p$
  - Therefore, for $m_{\gamma'} \ll \omega_p$, the L modes of the hidden photon can be produced on resonance at any temperature

- [Redondo JCAP 07 (2008) 008] found instead, using $m_L^2 \simeq \omega_p^2 - \mathbf{k}^2$,

$$P_\odot|_{\rm res} \approx \chi^2 m_{\gamma'}^2 \int_0^{R_\odot} r^2 dr \frac{\omega_p^3(r)}{e^{\omega_p(r)/T} - 1} \frac{2}{\pi} \frac{m_{\gamma'}^2}{\omega_p^2}$$

Production of L modes of hidden photons underestimated at small mass

Solar bounds on hidden photons

- Stronger bounds at small masses from L modes of hidden photons:

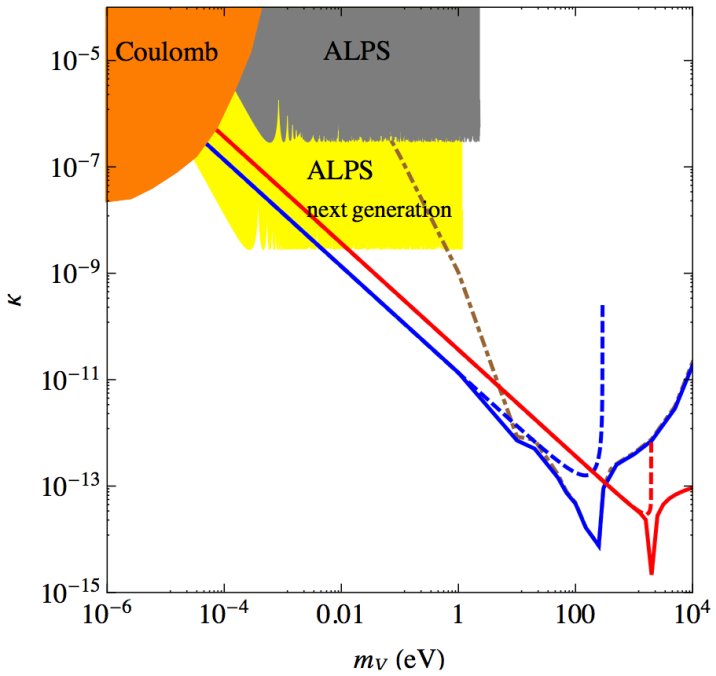


Figure 2: Upper limits on the kinetic mixing parameter κ vs. the mass of the dark photon m_V. The solid blue and red curves are the total constraints on the dark photon parameter space from the sun (blue) and red giants (red). The dashed curves show constraints from retaining only the longitudinal resonance contributions. For comparison, the dot-dashed curve shows the upper limit by considering only the contribution from transverse modes. The current bounds from the latest result of the LSW experiment by the ALPS collaboration [25] is shown in gray, accompanied by the potential reach (yellow region) of the next generation of LSW experiments [26].

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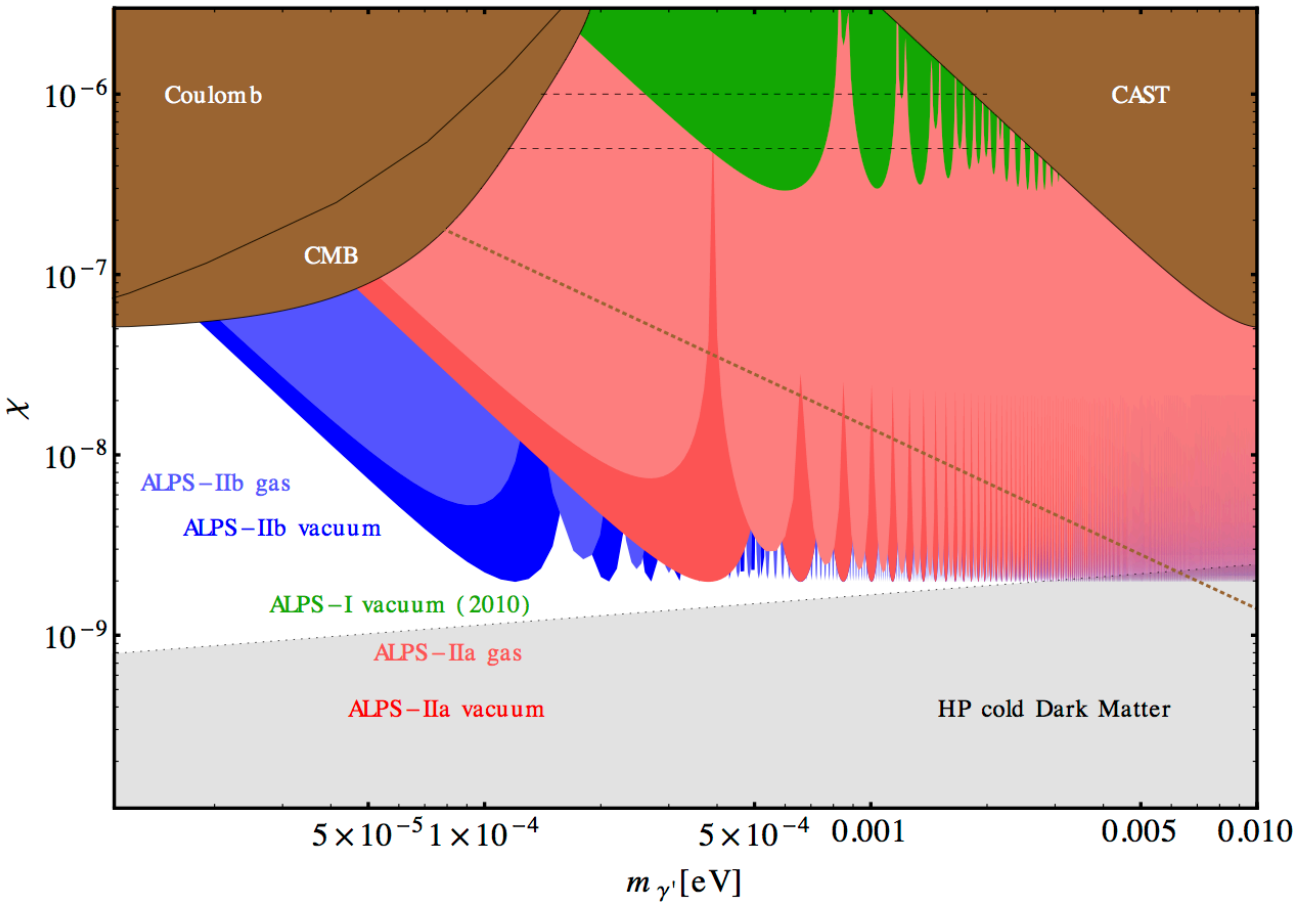
Comparison with ALPS-II

- ALPS-IIa and IIb discovery potential diminished, but still appreciable:



adapted from [ALPS-II TDR, arXiv:1302.5647]