

# Hidden Sector Constraints from Atomic Spectra

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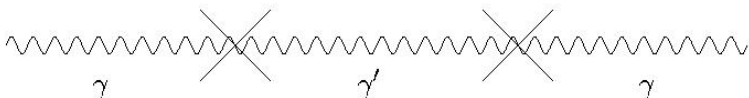
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- LAB based detection/constraints of BSM particles
- Hidden Photon and MCP
- Predict deviations to Coulomb's Law
- Focus on Hidden Photons

- Hidden Photons common in BSM
- Effective Lagrangian

$$L = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}B_{\mu\nu}B^{\mu\nu} + \frac{\sin\chi}{2}B_{\mu\nu}F^{\mu\nu} + \frac{\cos^2\chi}{2}m_{\gamma'}^2 B_\mu B^\mu \quad (2.1)$$

- Insertion to Photon Propagator

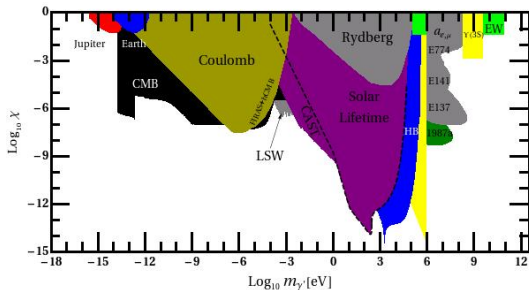


- Modification of Coulomb's Law

$$V(r) = -\frac{Z\alpha}{r}(\cos^2 \chi + e^{-m_{\gamma'} r} \sin^2 \chi) \quad (2.2)$$

- Note limits

- Generic features of  $\chi$  bounds



- Coulomb bounds maximised at  $l_0 \sim 1m \rightarrow 10^{-6} \text{eV}$
- Atomic Spectra  $\rightarrow$  explore  $10^4 \text{eV}$

- Modify MCP method used by Gluck, Rakshit and Reya to HPs  
Use  $2s_{1/2} - 2p_{1/2}$  in Atomic Hydrogen to bound  $\chi$
- Define  $\delta E_{unc}$
- Define perturbation;

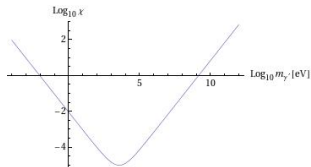
$$V(r) = \frac{Z\alpha}{r} (1 + e^{-m_{\gamma'} r} \chi^2) \quad (3.1)$$

- Calculate energy shift in QM

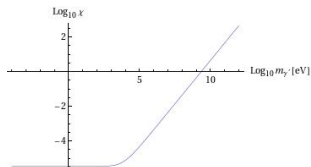
$$\delta E_{\chi} = \langle \psi_n | \delta V | \psi_n \rangle \quad (3.2)$$

- Set  $\delta E_{\chi} < \delta E_{unc} \rightarrow$  upper bound on  $\chi$

- Seems to work for same n transitions  
e.g  $2s_{1/2} - 2p_{1/2}$



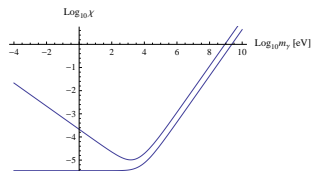
- Breaks down for different n transitions  
e.g  $1s_{1/2} - 2s_{1/2}$



- Examine perturbation;

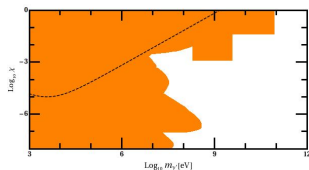
$$\delta V(r) = \frac{Z\alpha}{r} e^{-m_{\gamma'} r} \chi^2 \quad (4.1)$$

- Dies in UV but not IR - renormalise coupling
- Original method  $\alpha = \alpha_0$
- HP  $\therefore \alpha_0 \rightarrow \alpha(\chi, m_{\gamma'})$
- Need 2 measurements to solve for 2 unknowns  $\chi$  and  $\alpha$  in terms of  $m_{\gamma'}$
- Extract  $\chi(m_{\gamma'})$  as function of  $\delta M1, \delta M2$

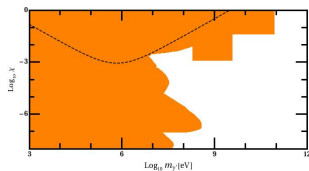




- Try to penetrate new parameter space  
 $2s_{1/2} - 2p_{1/2}$



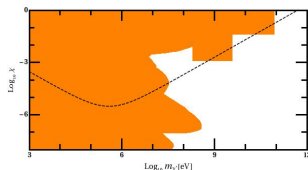
- Tried for range of transitions in Hydrogen and Exotic Atoms
- Current Experimental/Theoretical uncertainties too high
- Promising cases e.g.  $2s_{1/2} - 2p_{1/2}$  in Muonic Hydrogen



- Probes higher mass region

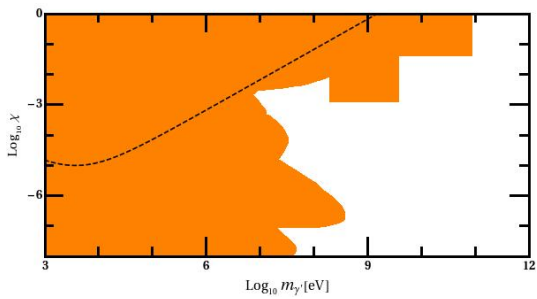
- True Muonium

Pessimistic theoretical calculation produces promising bound



Subject of course to experimental problems (annihilation,  $\mu^-$  lifetime etc.)

- Experimental and Theoretical improvements reduce uncertainty
- Should produce useful bounds



- Developed method
- No new results (so far!)
- Improvements in theoretical/experimental results - new bounds

Questions?