

# Probing Hidden Sectors with Stückelberg $U(1)$ 's

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# Overview

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- Introduction, summary and conclusions
  - Hidden sectors
  - U(1) portals: kinetic and mass mixings
  - The Stückelberg portal

# Hidden Sectors

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- Dark Matter is one of the strongest evidences of physics BSM, but we only know it through its gravitational interactions.
- Such an important topic and so little information leads to speculation
  - 🎤 What is DM? WIMPs, Axion DM, LSP, Vector DM, ...
  - 🎤 How does it interact with us? Higgs- , Axion- , Vector-portals...
- A simple Hidden Sector scenario:

$$\underbrace{SU(3)_c \times SU(2)_L \times U(1)_Y}_{\Psi_v} \times \underbrace{G_h}_{\Psi_h}$$

- 🎤 Also interesting for ~~SUSY~~ mediation, ‘hidden valleys’, etc

# Hidden Sectors: the string perspective

- A simple setup: intersecting D-branes

$$\underbrace{SM'}_{\Psi_v} \times \underbrace{G'_h}_{\Psi_h}$$

- Gauge groups from stack of N-branes

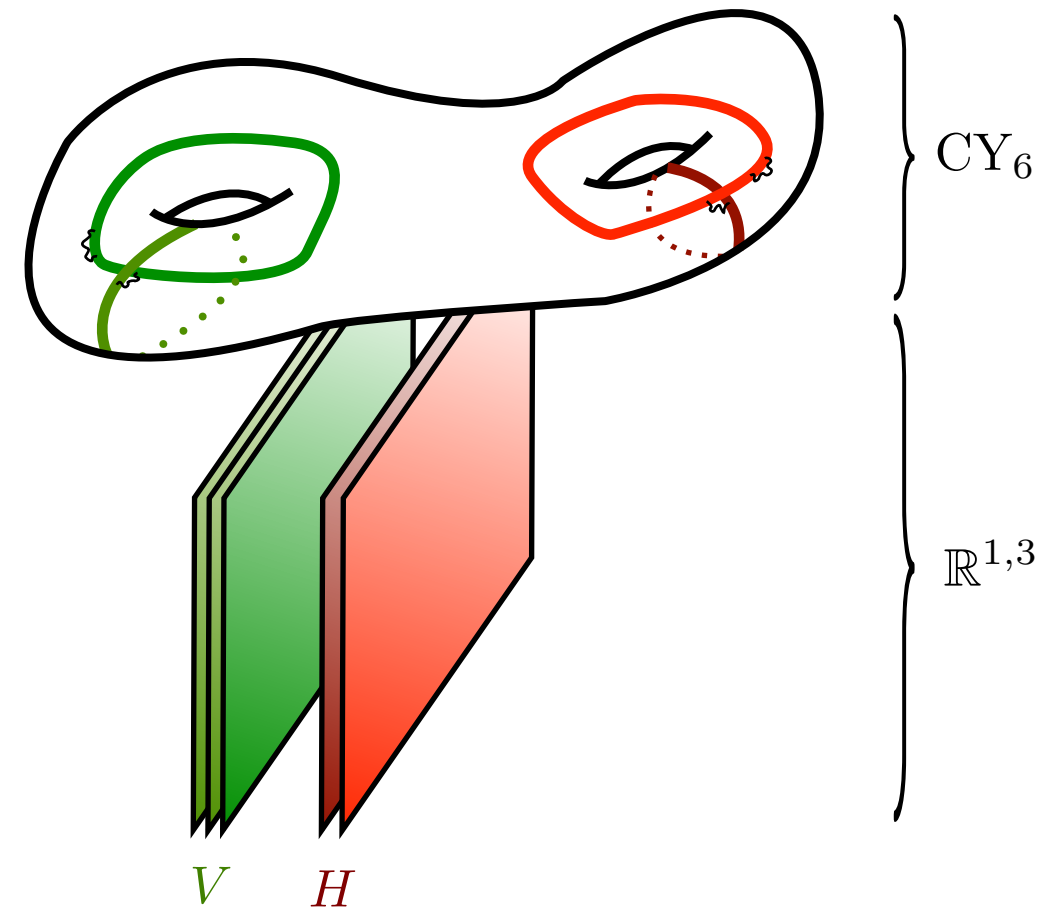
$$U(N) = SU(N) \times U(1)$$

- In (semi)-realistic D-brane models, what we get is

$$\underbrace{SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_v^n}_{\Psi_v} \times \underbrace{U(1)_h^m \times G_h}_{\Psi_h}$$



Distant sectors only communicate via closed strings



# U(1) mixings

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- Our Hidden Sector scenario is

$$\underbrace{SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_V^n}_{\Psi_v} \times \underbrace{U(1)_h^m \times G_h}_{\Psi_h}$$

- Extra U(1) gauge bosons acquire a mass through a Stueckelberg coupling to (closed string RR) axions  $\phi^i$ :

$$\mathcal{L}_{\text{St}} \sim G_{ij} (\partial_\mu \phi^i + k_a^i A_\mu^a) (\partial^\mu \phi^j + k_b^j A^{b\mu})$$

- Distant sectors interact via mixing of U(1) bosons:  $\vec{A} = ( \vec{A}_v \quad \vec{A}_h )$

$$\mathcal{L} = -\frac{1}{4} \vec{F}^T \cdot f \cdot \vec{F} - \frac{1}{2} \vec{A}^T \cdot M^2 \cdot \vec{A} + \vec{A}_v^T \cdot \vec{J}_v + \vec{A}_h^T \cdot \vec{J}_h$$

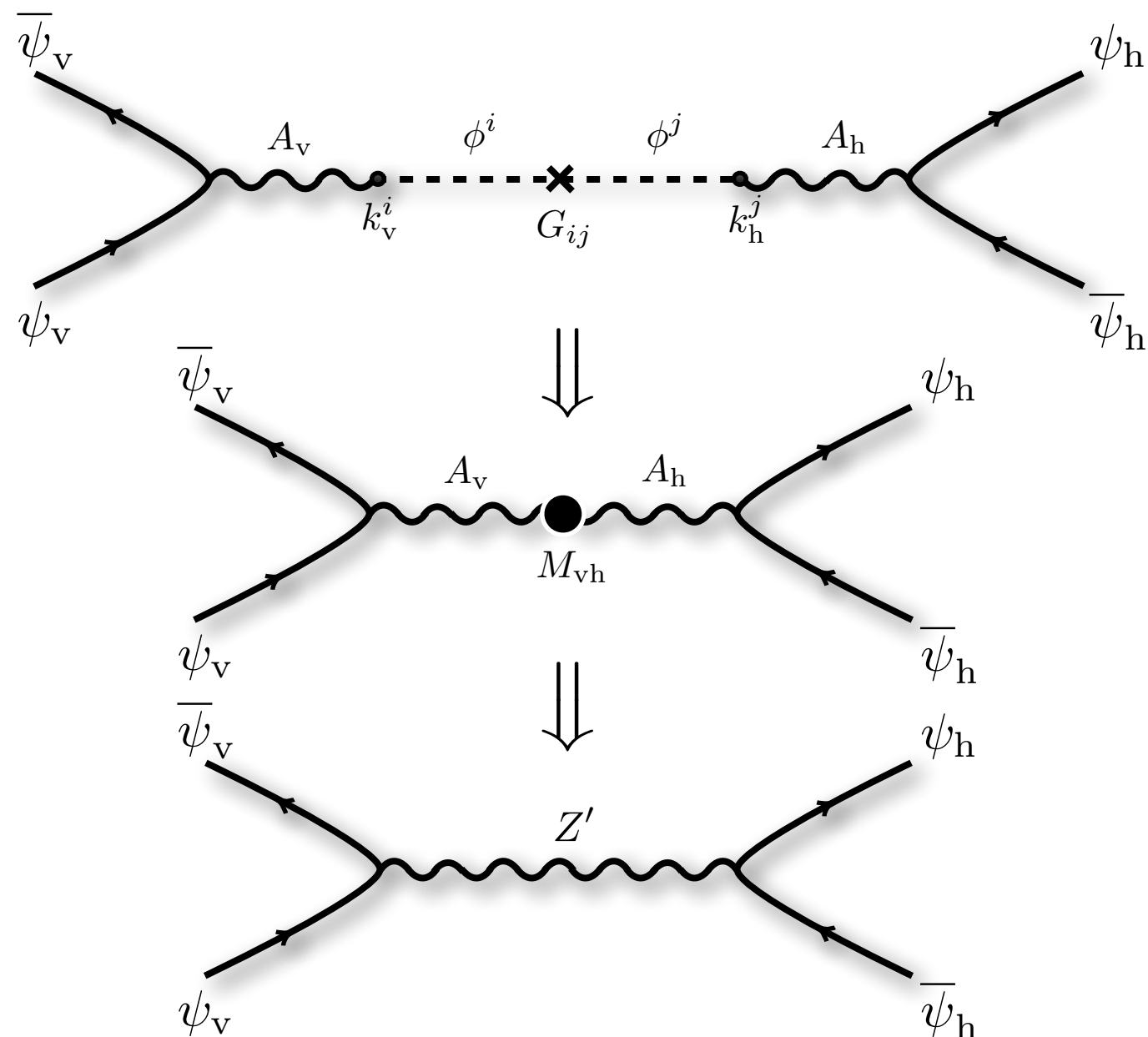
● Kinetic mixing (loop suppressed): millicharged DM  $f = \begin{pmatrix} g_v^{-2} & \delta \\ \delta & g_h^{-2} \end{pmatrix}$

● Mass mixing (tree level): Z' (Stückelberg) portal  $M^2 = \begin{pmatrix} M_v^2 & M_{\text{mix}}^2 \\ M_{\text{mix}}^2 & M_h^2 \end{pmatrix}$

# The Stückelberg portal

- Extra U(1) gauge bosons acquire a mass through a Stueckelberg coupling to (closed string RR) axions  $\phi^i$ :

$$\mathcal{L}_{\text{St}} \sim G_{ij} (\partial_\mu \phi^i + k_a^i A_\mu^a) (\partial^\mu \phi^j + k_b^j A^{b\mu})$$



# Conclusions (some results)

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- The Stückelberg portal combines some of the most popular BSM ingredients: hidden sectors, axions and extra  $U(1)$ 's
- Simple and powerful tool to generate  $Z'$  mediation scenarios
  - Interactions with DM, 'hidden valleys', ~~SUSY~~ mediation, etc
- Massive  $U(1)$ 's remain as (perturbatively) exact global symmetries
  - Extremely useful for proton and DM stability, mu-problem, etc
- The Green-Schwarz mechanism ensures anomaly cancelation
  - General  $Z$ 's can be used without chiral exotics!
- Strongly motivated by string theory:
  - Easily implemented through topological manipulations
  - Features:  $Z$ - $Z'$  mixing, low  $Z'$  masses from random matrices,...

Thank you