The Protophobic Light Vector Boson as a Mediator to the Dark Sector

25 Oct. 2016 @ KIAS workshop

YAMAMOTO Yasuhiro (Yonsei U)

Based on arXiv:1609.01605
in collaboration with T. Kitahara (Karlsruhe Inst. Tech.)
Gone with the anomalies

750GeV diphoton

ATLAS Preliminary

Data
Background-only fit

Spin-0 Selection

√s = 13 TeV, 15.4 fb^{-1}
Gone with the anomalies

Some good insight and ideas are left in your mind.
The Atomki anomaly (→ Talk by Prof. Tait)

1504.01527: A. Krasznahorkay et al.

- $m_X = 16.7 \pm 0.35_{\text{stat}} \pm 0.5_{\text{sys}} \text{ MeV}$
The Atomki anomaly (→ Talk by Prof. Tait)

1504.01527: A. Krasznahorkay et al.

Angular correlation

\[ m_X = 16.7 \pm 0.35_{\text{stat}} \pm 0.5_{\text{sys}} \text{ MeV} \]
Experimental constraints

1604.07411, 1608.03591: J. L. Feng, T. M. P. Tait et al.

\[ 6.1 \times 10^{-5} \leq |g_e| \leq 4.2 \times 10^{-4} \]

\[ 6.1 \times 10^{-4} \leq |g_n| \leq 3.1 \times 10^{-3} \]

- **Protophobic:** \( |g_p| \leq 3.6 \times 10^{-4} \)
- **Prity conservation and exp. bounds → Spin-1.**
Weakly interacting light particle

The protophobic vector + The dark matter

- $U(1)_X$ charged/neutral dark matter models.

兼容性与热 relic 天然重演场景。
Models

\[ \mathcal{L}_X = -\frac{1}{4} X^{\mu\nu} X_{\mu\nu} + |D S|^2 + \mu_S^2 |S|^2 - \frac{\lambda_S}{2} |S|^4 + \mathcal{L}_{\text{DM}} \]

Parameters: \( g_X, m_X, m_s \)

<table>
<thead>
<tr>
<th>( \mathcal{L}_{\text{DM}} )</th>
<th>Scalar</th>
<th>Fermion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charged</td>
<td>( \varphi ) ( \varphi^* )</td>
<td>( \xi ) ( \bar{\xi} )</td>
</tr>
<tr>
<td>Neutral</td>
<td>( \phi )</td>
<td>( \chi ) ( \psi ) ( \bar{\psi} )</td>
</tr>
</tbody>
</table>

(Neglect interactions with Higgs)
U(1)_X charged dark matter

- Direct detection
  Very strong constraint.

- Annihilation
  \[ \varphi \varphi^* \rightarrow XX \rightarrow ss \]
  \[ \xi \bar{\xi} \rightarrow XX \rightarrow sX \]

Large Sommerfeld enhancement with X

Indirect bounds become stronger.
Results of charged models

- Thermal relic scenario is almost excluded.
  (Exception Jia+ 1608.05443)
U(1)\(_X\) neutral dark matter

- Direct detection
  Loop induced process
  Large \(m_s\) dependence

- Annihilation
  \(\phi\phi \rightarrow XX\)
  \(\rightarrow ss\)
  No enhancement

  \(\chi_1\chi_1 \rightarrow XX\)
  \(\rightarrow ss\)
  By p-wave processes
The AMS bound excludes the thermal relic upto 100GeV. The dark Higgs mass dependence is large.
Majorana dark matter

Mass difference is fixed as 100GeV.

- Recent LUX bound excluded broad region.
- Solve the small scale structure problems with $g_X \sim 10^{-3}$
Conclusion

- Weak constraints.
- Large $m_s$ dependence.

The small scale structure problems can be discussed.
Future prospect

\[
\frac{g}{M} \sim \frac{10^{-(4-3)}}{17\text{MeV}} \sim \frac{1}{1.7 \times 10^{1-2}\text{GeV}} \quad \text{(c.f. } \frac{g_2}{\sqrt{2m_W}} \sim \frac{1}{175\text{GeV}}) \]

Mu3e (2018---)  
Associate with $\mu$ decay  
$\mu \rightarrow e\nu\nu X (\rightarrow ee)$

VEPP-3 (if accepted 3--4y)  
Fixed target: $e^+e^- \rightarrow \gamma X$

LHCb (2021--2023)  
D-meson decay  
$D^*(2007)^0 \rightarrow D^0 X (\rightarrow ee)$