Evidence against the decaying dark matter interpretation of the 3.5 keV line

SUSY 2019
Christopher Dessert
1812.06976: CD, Nick Rodd, Ben Safdi, under review Science
The 3.5 keV Emission Line

Bulbul et. al. & Boyarsky et. al.
1402.2301 & 1402.4119
The 3.5 keV Emission Line

XMM-Newton

Perseus Cluster
Dark Matter Decay Signatures

• Sterile Neutrino Decay

\[ \nu_s \rightarrow \nu_a \gamma \]

\[ E_\gamma = \frac{m_s}{2} \]

I will focus only on this minimal decay scenario.

• Decay to axions with conversion in magnetic fields

\[ \phi \rightarrow aa \]

\[ \psi \rightarrow \chi a \]
The 3.5 keV Emission Line

XMM-Newton

Perseus Cluster
The 3.5 keV Emission Line

Detection of An Unidentified Emission Line in the Stacked X-ray spectrum of Galaxy Clusters
Esra Bulbul et. al.
arXiv:1402.2301
The 3.5 keV Emission Line

Sterile neutrinos in cosmology
Kevork N. Abazajian
arXiv:1705.01837
Use Archival XMM-Newton Observations

• XMM is a pointed X-ray telescope, in orbit since 1999
• We want to search for decays in the galactic halo
• All observations look through galactic halo, so we use all observations passing a set of quality cuts—Blank Sky Observations (BSO)
Blank Sky Locations

This work: all XMM-Newton observations in Inner Galaxy

\[ D(\Omega) = \int_{\text{los}} d\Omega \rho_{\text{DM}}(s, \Omega) \]
Expected Sensitivity

• Original detection:
  • $TS \sim 16$
  • 320 ks exposure

• Our analysis:
  • 30 Ms exposure
  • 50x smaller backgrounds
  • Similar or larger signal

\[ TS \sim \sigma^2 \]
\[ TS \sim \frac{S^2}{B} \sim \frac{D^2}{B}t \]
\[ \frac{B_{BSO}}{B_{Pers}} \sim 0.02 \]
\[ \frac{t_{BSO}}{t_{Pers}} \sim 100 \]

\[ TS_{Pers} \sim 16 \implies TS_{BSO} \sim 10^5 \]
Use Archival \textit{XMM-Newton} Observations
Example Data

The figure shows a plot of counts versus energy (E [keV]) with three different models:
- **QPB model**
- **astro model**
- **astro+QPB model**

The graph includes data points for X-ray counts and QPB counts.
Results: Limits
Results: Data

- MOS data
- PN data

- back. model
- back. + signal
- data

$E_{\text{line}}$ [keV]
Conclusion & Further Directions

• We used 30 Ms of XMM-Newton data to search for dark matter decay to 3.5 keV photons
• The 3.5 keV emission line is unlikely to be due to dark matter decay
• We set the strongest limits in the ~7 keV mass range
• Investigate the line’s existence in clusters in future work
Thank you! Questions?
Results: Signal Evidence
Systematics: Injection Test
Systematics: $\delta \chi^2$
Systematics: Varying Quality Cuts
Systematics: Varying Sky Locations
Systematics: Varying Halo Profile
Surface brightness profile of the 3.5 keV line in the Milky Way halo
Alexey Boyarsky et. al.
arXiv:1812.10488 [astro-ph.HE]

Christopher Dessert