HAP Dark Matter 2015

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Dark Matter and Global Symmetries

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Let's start with data analysis

We derive our own model independent limits on the DM lifetime using a large set of data, and then apply to the effective operators listed before

Note: We adopted an Einasto profile with local density of 0.4 GeV/cm^3

1. **CMB data: Planck, WMP9, BAO, HST**

2. **Antiproton: AMS02 and PAMELA**

3. **Neutrino: ICECUBE, Super-K, AMANDA**

   Adapted from: C. E. Aisati, at al [arXiv:1506.02657].
   L. Covi at al, JCAP 1004, 017 (2010) [arXiv:0912.3521]
   S. Palomares-Ruiz, Phys. Lett. B 665, 50 (2008) [arXiv:0712.1937]

4. **Line Searches: Chandra, XMM, HEAO, INTEGRAL, COMPTEL, EGRET, Fermi-LAT**

5. **Gamma-ray: Fermi-LAT (Clusters&Extragalactic)**

   Taken from: S. Ando and K. Ishiwata, JCAP 1505, no. 05, 024 (2015) [arXiv:1502.02007];
   X. Huang, G. Vertongen and C. Weniger, JCAP 1201, 042 (2012) [arXiv:1110.1529]

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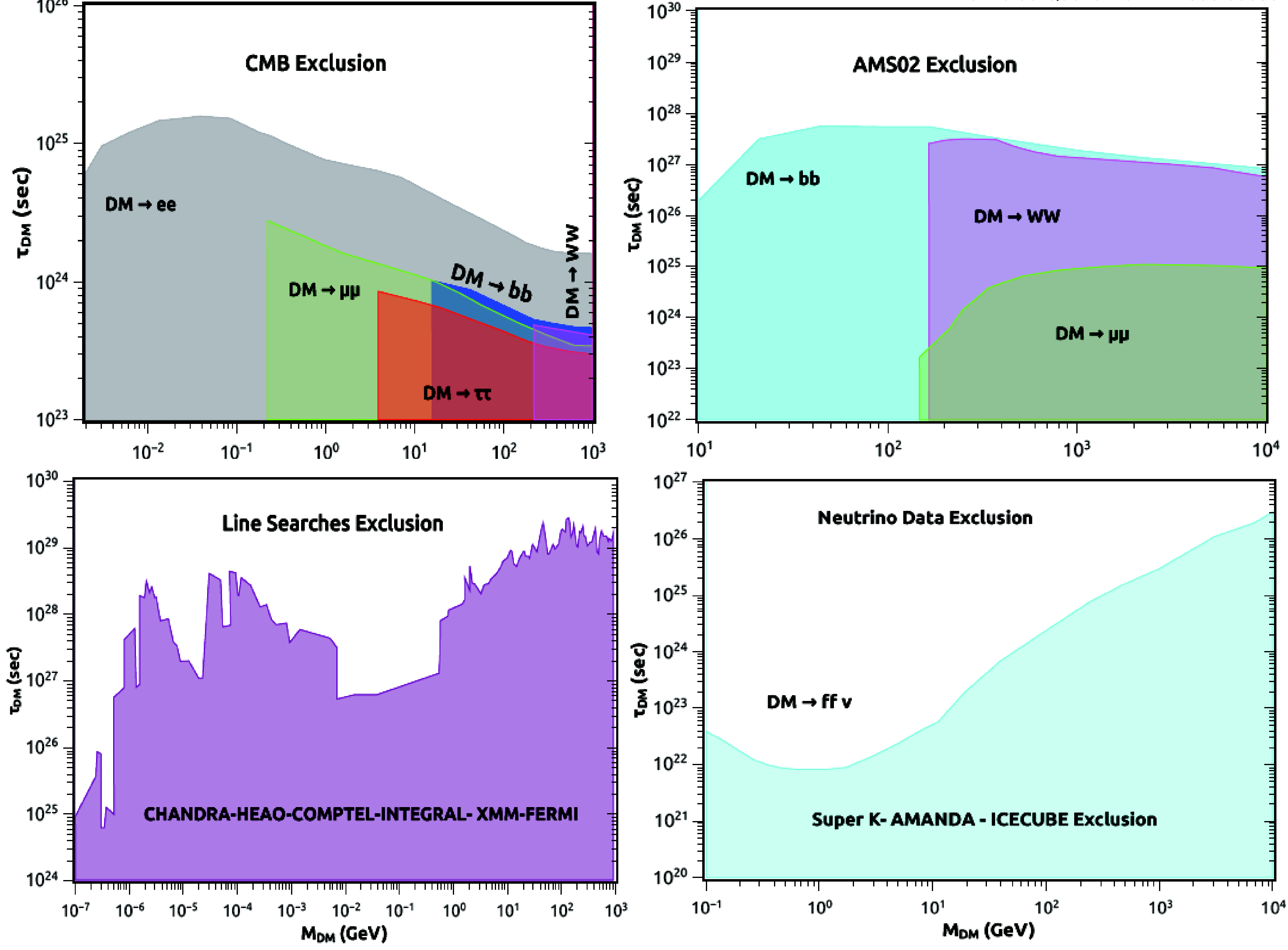

A bit of quantum field theory....

Stabilizing Dark Matter Particles

Are these symmetries good symmetries to stabilize DM particles ?

- Discrete Symmetries ✓
- Gauge Symmetries → Remnant Discrete Symmetries ✓
- Global Symmetries ?

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A bit of Black Hole Physics.....
Known Facts

1. No-hair Theorem: local U(1) symmetries are effectively identical to Gauss's law, any observer outside a Black Hole (BH) horizon can determine the BH charge

2. Hawking Radiation: Since there are no gauge interactions associated with global symmetries, one could throw a large amount of charged particles into a BH and increase its charge (Q) indefinitely.

3. Entropy: Since an external observer cannot infer a global charge, in order to assign an entropy to a given BH one would have to count all micro-states of all charges, finding at least entropy ~ Log[Q]. Taking Q indefinitely large, one would have Bhs violating the Bekenstein-Hawking formula. Thus, such BHs are ruled out along with global symmetries.

Conclusion

Global symmetries are generically violated at the Planck scale

This has profound implications for dark matter: decay!

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Effective Operators that lead to DM decay

Name	Interaction Term
O1	$\frac{\lambda_1}{M_{pl}} \bar{f}\gamma^\mu(1+r_a\gamma_5)f\partial_\mu S$
O2	$\frac{\lambda_2}{M_{pl}} S F_{\mu\nu}F^{\mu\nu}$
O3	$\frac{\lambda_3}{M_{pl}} S\ \epsilon_{\mu\nu\sigma\lambda}F^{\mu\nu}F^{\sigma\lambda}$
O4	$\frac{\lambda_4}{M_{pl}} S\ G^a_{\mu\nu}G^{a,\mu\nu}$
O5	$\frac{\lambda_5}{M_{pl}} S\ \epsilon_{\mu\nu\sigma\lambda}G^{a,\mu\nu}G^{a,\sigma\lambda}$
O6	$\frac{\lambda_6 m_Z^2}{M_{pl}} S\ Z_\mu Z^\mu$
O7	$\frac{\lambda_7}{M_{pl}} S Z_{\mu\nu}Z^{\mu\nu}$
O8	$\frac{\lambda_8}{M_{pl}} S\ \epsilon_{\mu\nu\sigma\lambda}Z^{\mu\nu}Z^{\sigma\lambda}$
O9	$\frac{\lambda_9 m_W^2}{M_{pl}} S\ W^+_\mu W^{-\mu}$
O10	$\frac{\lambda_{10}}{M_{pl}} S\ W^+_{\mu\nu}W^{-\mu\nu}$
O11	$\frac{\lambda_{11}}{M_{pl}} S\ \epsilon_{\mu\nu\sigma\lambda}W^{+\mu\nu}W^{-\sigma\lambda}$
O12	$\frac{\lambda_{12}}{M_{pl}} F^{\mu\nu}Z_\mu\partial_\nu S$
O13	$\frac{\lambda_{13}}{M_{pl}}\ \epsilon_{\mu\nu\sigma\lambda}F^{\mu\nu}Z^\sigma\partial^\lambda S$
O14	$\frac{\lambda_{14}}{M_{pl}} \bar{\psi}\tilde{H}^\dagger(\not{D}L)$
O15	$\frac{\lambda_{15}}{M_{pl}} V^\mu \bar{f}\partial_\mu f$
O16	$\frac{\lambda_{16}}{M_{pl}} V_\mu(H^\dagger D_\nu H)F^{\mu\nu}$

Scalar-DM (O1–O13)

Fermion-DM (O14)

Vector-DM (O15–O16)

Notes

i) List is not complete!

ii) Restricted to a DM field

iii) Dimension five operators only

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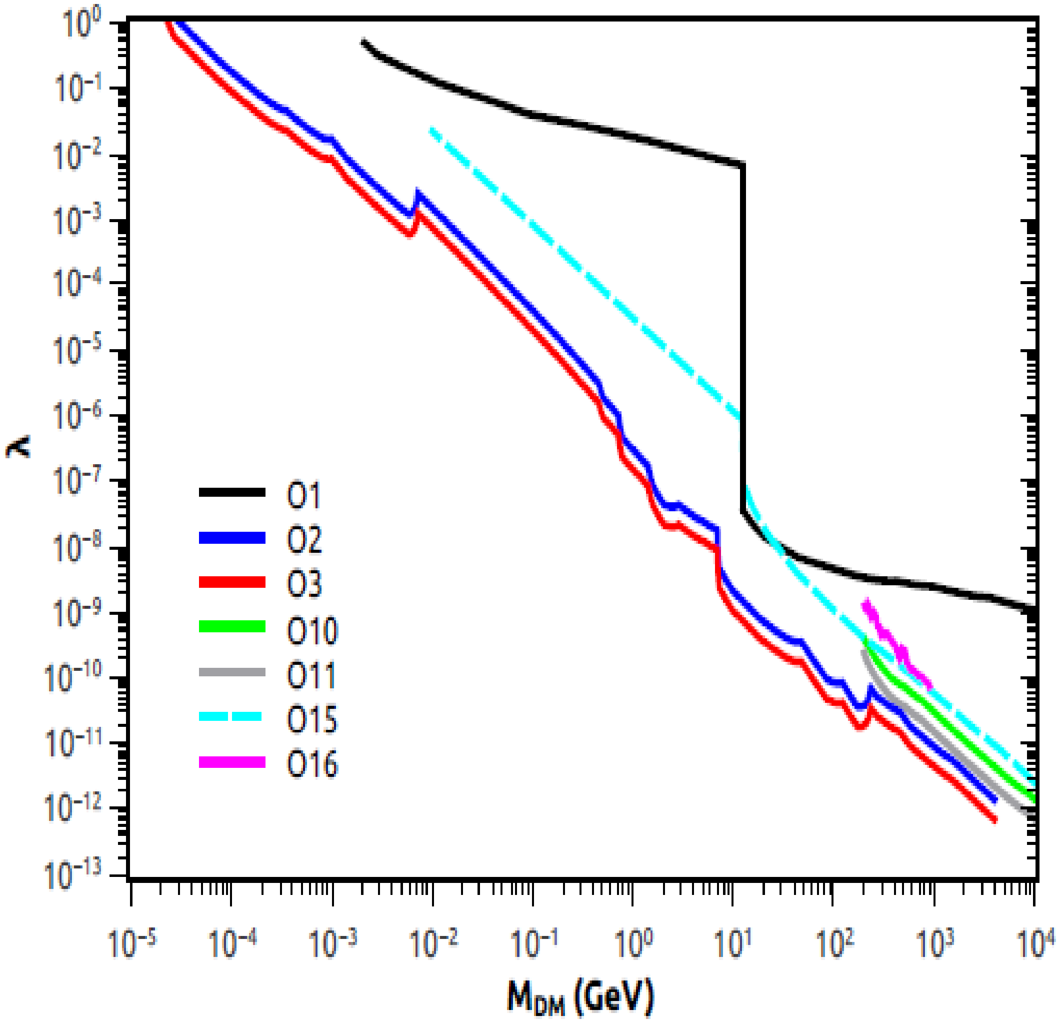
Conclusions I

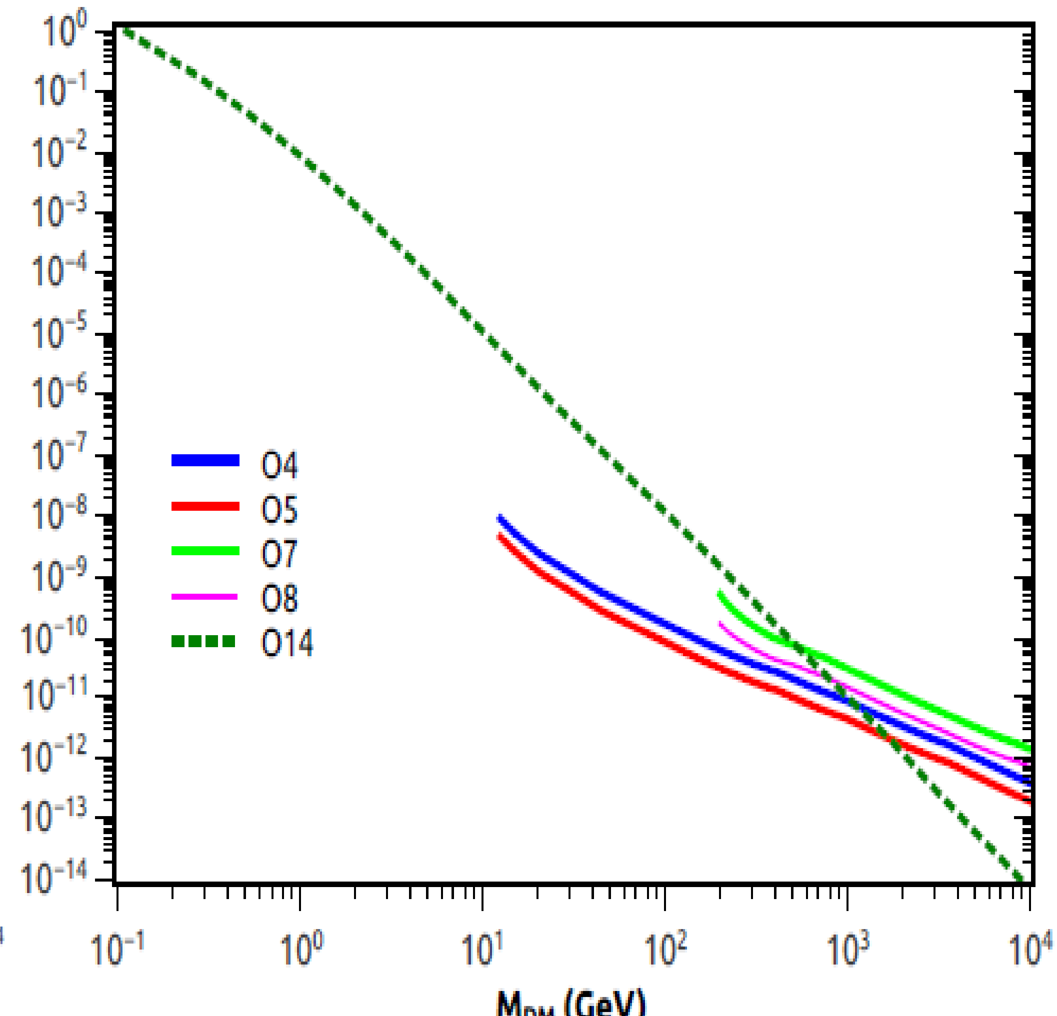
Our bounds:

O1-O13 operators → Scalar DM : Mass < 100 KeV

O14 operator → Fermion DM: Mass < 100 MeV

O15-O16 operator → Vector DM: Mass < 10 MeV





Conclusions II

We also apply our limits to existing models:

Left-Right Model: W. M. Yang, Nucl. Phys. B 885, 505 (2014) [arXiv:1405.0389],W. M. Yang, arXiv:1309.1955 [hep-ph].

Two-Higgs Doublet Model: G. Bhattacharyya, D. Das, P. B. Pal and M. N. Rebelo, JHEP 1310, 081 (2013) [arXiv:1308.4297].

Singlet Fermion Model: S. Baek and H. Okada, Phys. Lett. B 728, 630 (2014) [arXiv:1311.2380]

Radiative See-Saw Model: S. Baek, H. Okada and T. Toma, Phys.Lett. B732 (2014) 85-90 [arXiv:1401.6921]

Zee-Babu Model: M. Lindner, D. Schmidt and T. Schwetz, Phys. Lett. B 705, 324 (2011) [arXiv:1105.4626]

3-3-1 Model: J. K. Mizukoshi, C. A. de S.Pires, F. S. Queiroz and P. S. Rodrigues da Silva, Phys. Rev. D 83, 065024 (2011) [arXiv:1010.4097]

The presence of DM particles in such models is generically problematic!