Discovering dark matter in neutrino telescopes

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Dark matter searches

- In colliders (Tevatron, LHC)
- Directly (XENON10^n, LUX, CRESST...)
- Indirectly (ATIC, PAMELA, FERMI...)
  - Most difficult because of ubiquitous and hard to estimate backgrounds
  - For charged particles more uncertainty due to propagation in our galaxy
  - But also constant flow of new data and more to come (ANTARES,ICECUBE,AMS...)

The cleanest signature of dark matter would be high-energy extended neutrino flux from GC (no propagation effects, small backgrounds). But typical models yield comparable fluxes of neutrino, photons, protons/antiprotons, electron/positrons, and the latter are more readily detected.

`Are there models of dark matter who predict neutrino flux that dominates other indirect detection channels?`

Portals

Low-dimensional gauge singlet operators in the SM == Doors opend for dark sector

- Higgs portal $|H|^2$ (dimension 2)
- Hypercharge portal $B_{\mu\nu}$ (dimension 2)
- Neutrino portal HL (dimension 5/2)

The neutrino portal is the lowest dimension `fermionic` singlet operator in the SM

`If dark matter particle is a fermion and SM singlet, it will come to us via the neutrino portal!`

Idea

- There is a dark (hidden) sector not charged under the SM containing the dark matter particle λ
- The dark matter particle couples to the SM via the neutrino portal

$$\mathcal{L}_{int} = O_{dark}(\lambda)(LH) = vO_{dark}(\lambda)\nu_L + \ldots$$

  where $O_{dark}(\lambda)$ is a fermionic operator constructed from λ and other fields in the hidden sector.
- The dark matter particle is *not* the lightest state in the dark sector. Instead, stability of dark matter is ensured by some discrete symmetry of the hidden sector (for example, it could be the lightest *fermionic* state in the hidden sector)
- The neutrino portal opens the decay channel

$$\lambda \rightarrow (\mathrm{Dark}) + \nu$$

  leading to domination of neutrino flux

Realization

- Dark sector is SU(N) Yang-Mills and adjoint fermion λ (N=1 super Yang-Mill without supersymmetry)
- Dark group confines at the scale $\Lambda \in$ kev-GeV
- Adjoint fermion has mass $m_\lambda \sim 1\,\mathrm{TeV}$
- The lightest states in the dark sector are glueballs of mass $\sim \Lambda$, fermionic dark matter cannot decay to glueballs alone (accidental Z_2 symmetry: $\chi \to -\chi$).
- Dark matter couples to SM via the neutrino portal

$$\frac{c}{\Lambda_N^2}\lambda^a\sigma^{\mu\nu}G^a_{\mu\nu}HL$$

- This breaks $\chi \to -\chi$ and opens up decays to SM final states

Decays

Leading decay is 2-body decay into glueball and neutrino or antineutrino

$$\Gamma(\lambda \to g\nu) = \frac{c^2}{16\pi} \frac{m_\lambda^3 v^2}{\Lambda_N^4}.$$

For $c \sim 1/16\pi^2$ and $\Lambda_N \sim 10^{15}$ GeV the lifetime is $\sim 10^{25}$ sec. Large enough for cosmological stability, and small enough to yield observable indirect signals.

`ANTARES and/or ICECUBE can discover a monoenergetic neutrino line from galactic center!`

Subleading 3-body decays to charged SM particles

$$\lambda \to gZ\nu \qquad \lambda \to gh\nu \qquad \lambda \to gW^\pm e^\pm$$

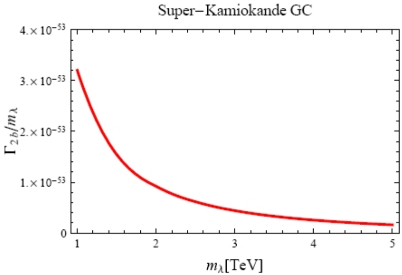
suppressed by 3-body phase space

$$\frac{\Gamma_{3-body}}{\Gamma_{2-body}} \approx \frac{1}{32\pi^2} \frac{m_\lambda^2}{v^2} \approx 0.04 \left(\frac{m_\lambda}{\mathrm{TeV}} \right)^2$$

subleading as long as m_λ not much larger than TeV

Current Bounds

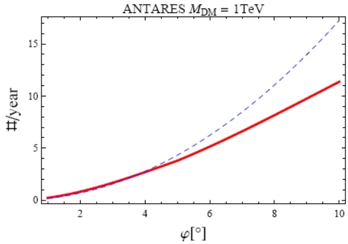
Bounds from upward-going muon flux in Super-Kamiokande



corresponding to the lifetime $\tau \approx 9.9 \times 10^{24} - 1.9 \times 10^{25}$ seconds.

Discovery potential in neutrino telescopes

Best case scenario ANTARES:



Best case scenario IceCube (track-like and cascade-like events):