Spin-Symmetry and Dark Matter Assisted Large Neutrino Magnetic Moment

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Outline

Neutrino magnetic moment (NMM)

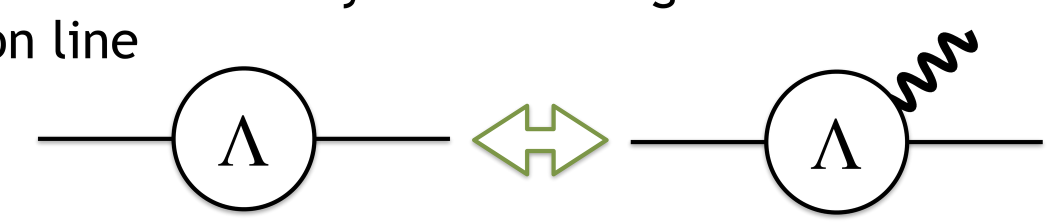
- Standard model predicted NMM: $\mu_\nu = 0$
- NMM through quantum loops in neutrino mass models: $\mu_\nu < 10^{-19}\mu_B$ ("large NMM": when μ_ν is far above this value)
- Current laboratory limit by Borexino: $\mu_\nu < 2.8 \times 10^{-11}\mu_B$
- Astrophysical limit from red giants and horizontal branchstars with plasmon decay: $|\mu_\nu| \leq 1.5 \times 10^{-12}\mu_B$
- Results that could be explained by large NMM: XENON1T and MiniBoone

Implication of new physics

- Large NMM: not (yet) observed
- Neutrino mass: Evidence from neutrino oscillation experiments
- Existence of dark matter: Evidence from astronomy and cosmology

Neutrino magnetic moment - neutrino mass conundrum

NMM operator and neutrino mass operator have the same chirality structure, so large NMM would usually indicate large neutrino mass by removing the photon line



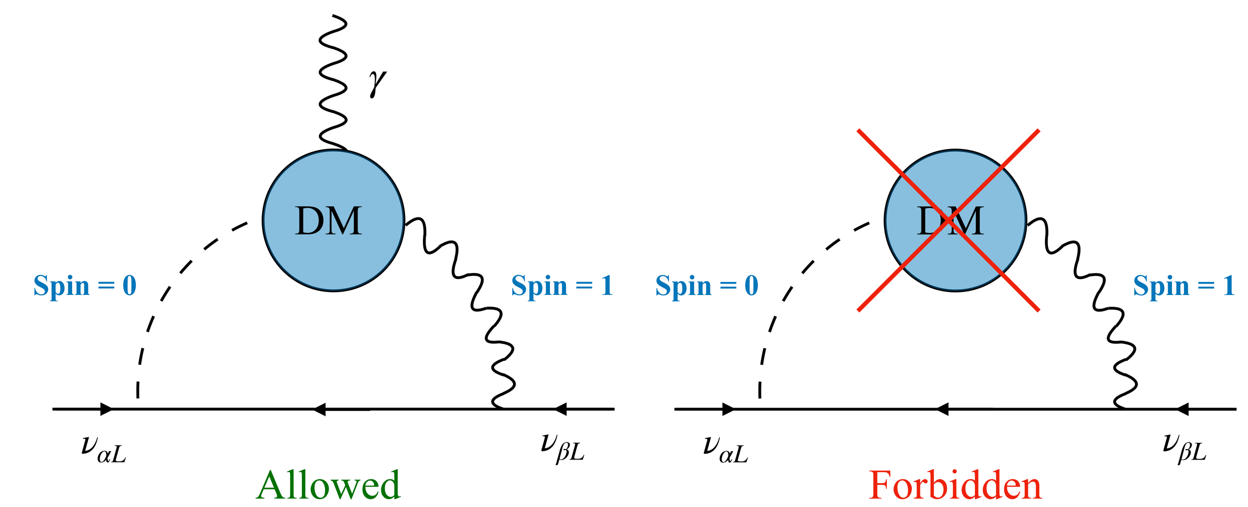
$m_\nu \sim \dfrac{\mu_\nu M^2}{2m_e\mu_B} \sim$ 0.1 MeV for $M = 100$ MeV and $\mu_\nu = 10^{-11}\mu_B$

Purpose of this work

Propose a minimal unified frameworks, based on spin-symmetry to generate mechanism for neutrino mass, to account for both large neutrino magnetic moment as well as the dark matter, by decoupling the mass from the magnetic moment in addition to ensuring the stability of the dark matter particle.

Spin-Symmetry mechanism

- Transition from spin 0 to spin 1 if forbidden for transversely polarised vector bosons
- The contribution to neutrino mass from the longitude polarisation of the vector bosons is suppressed by m_μ^2/m_w^2
- With an additional Z_2 symmetry on top of the spin-symmetry mechanism, some of the BSM particles could be a DM candidate



The Model

Beyond standard model states:

	$SU(2)_L$	$U(1)_Y$	Z_2
Φ_1	2	1/2	+
Φ_2	2	1/2	+
Φ_3	2	1/2	-
$\eta^\pm$	1	1	+

where

$$\Phi_i = \begin{pmatrix} \phi_i^+ \\ \frac{1}{\sqrt{2}}(v_i + \phi_i^{0\,\mathrm{Re}} + i\phi_i^{0\,\mathrm{Im}}) \end{pmatrix}$$

$$v_1^2 + v_2^2 = v_{EW}^2, \quad v_3 = 0$$

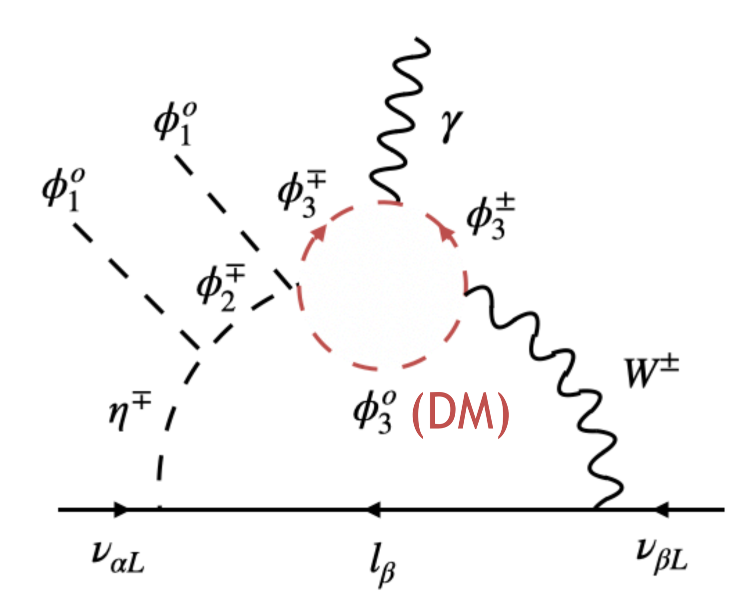
Lightest one of $i = 3$: Dark matter

- A minimal model, in which large NMM can be generated with the aid of dark matter particles via spin symmetry mechanism
- On top of the Zee model [1] for neutrino mass and NMM (including Φ_1, Φ_2 and $\eta^\pm$), we add a Z_2 odd BSM state (Φ_3) as the dark matter candidate which also accounts for NMM

Neutrino Magnetic Moment

- The contributions to NMM in this frame work arise from two loop diagrams including the ones from the Zee model plus the ones where DM runs in the second loop
- Among the possible topologies of the DM induced NMM by a dimension five operator, the figure on the left is the dominant one.
- There would be no NMM if there is no mixing between Φ_1 and Φ_2

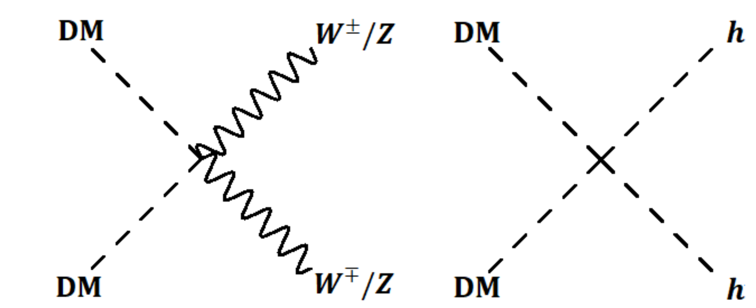
The DM contribution to NMM:



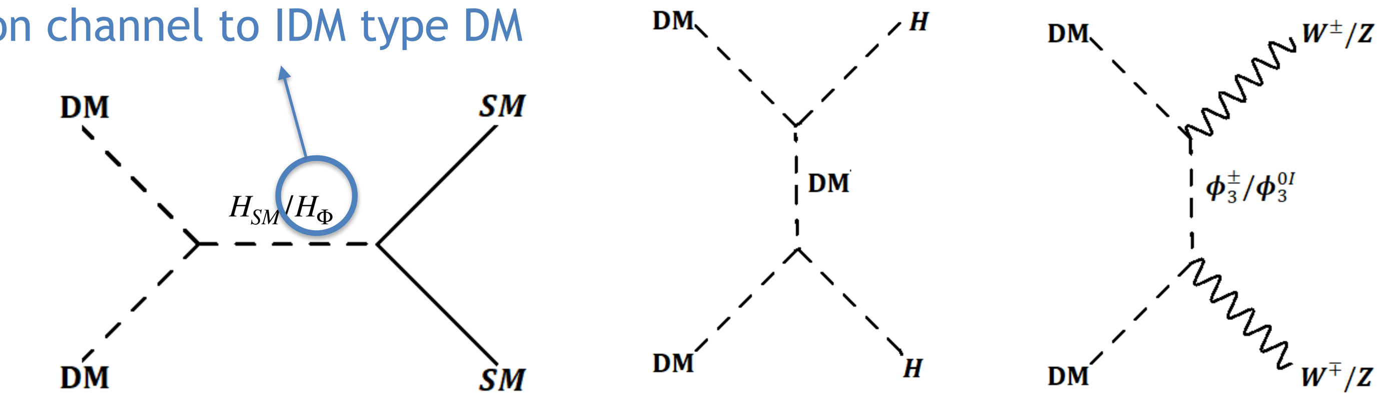
Dark Matter Phynomology

Dark matter (DM) annihilation channels

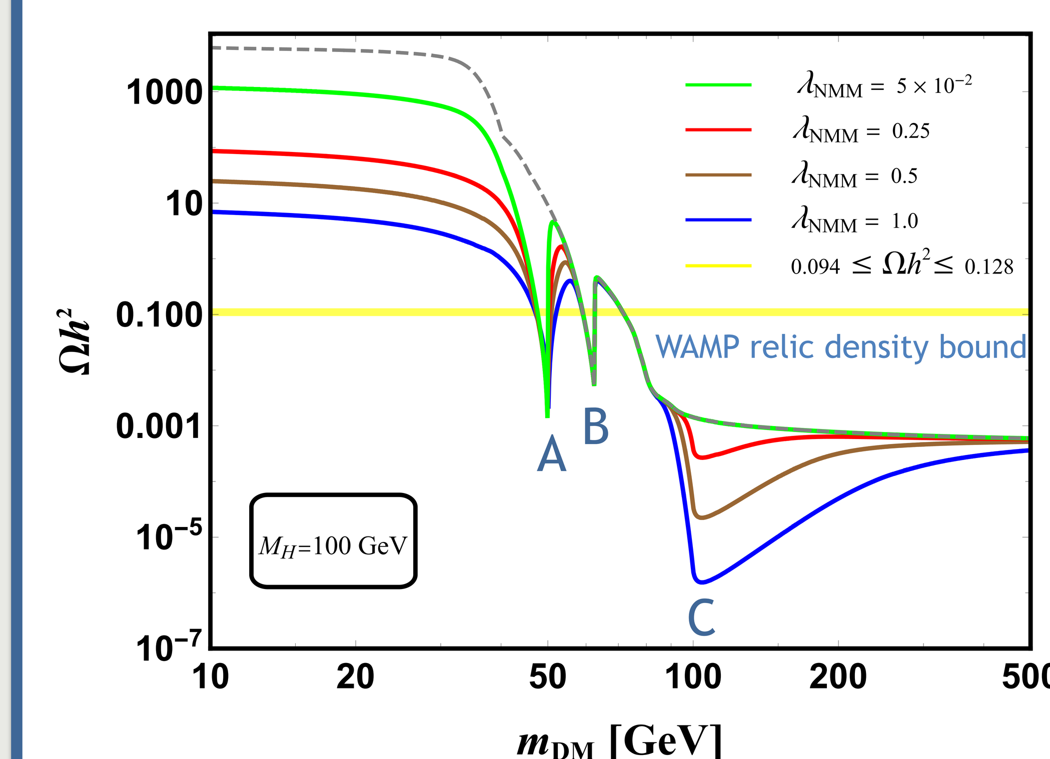
- The DM candidate will be an inert doublet model (IDM) type which are widely discussed in literature
- The presence of the additional scalar multiplet opens up new annihilation modes for DM



Addition channel to IDM type DM

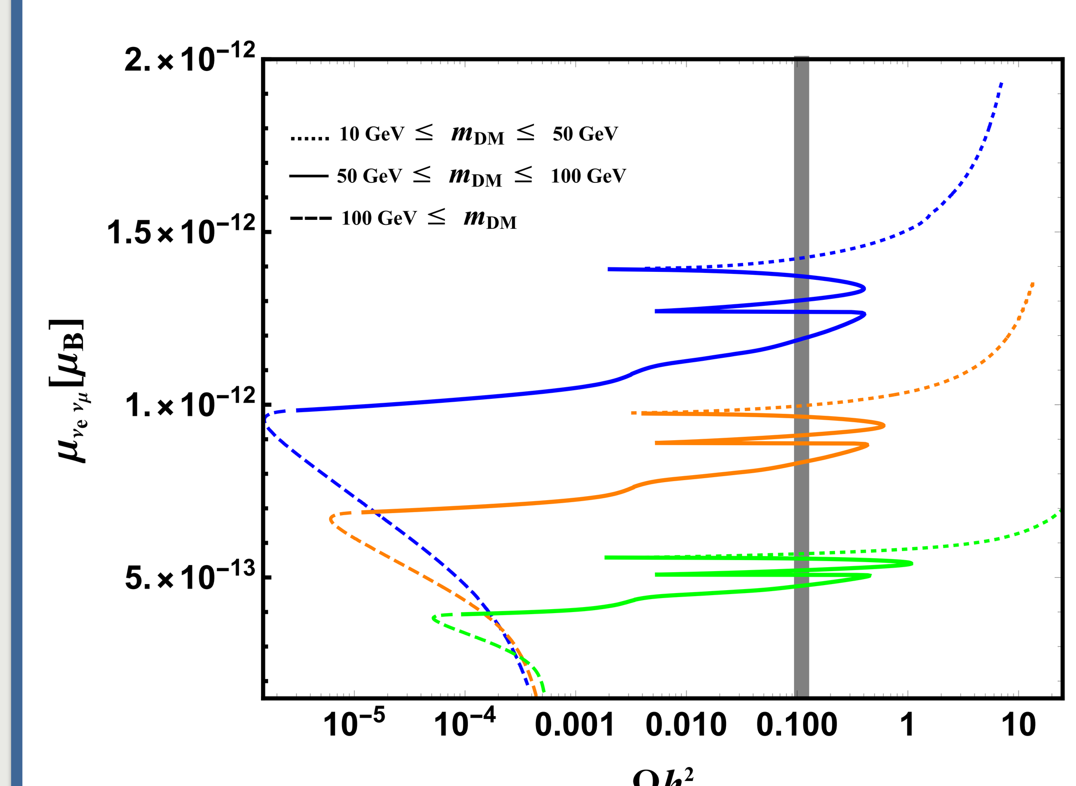


DM relic abundance



- Dashed line : Pure IDM case (no H_Φ mediator)
- Sharp dip at A(B): Resonance effect of the s-channel $H_\Phi(H_{SM})$ mediated process are relevant near half of the mediator mass
- Wide dip at C: Four point annihilation channels merged together

Correlation between DM relic abundance and NMM



- The dark matter relic abundance and NMM are connected through the quadratic coupling between Φ_1, Φ_2 and Φ_3, parameterised as λ_{NMM}
- There is a significant region of parameter space which can accommodate both large NMM as well as the DM relic abundance

Conclusion

- We have presented a minimal unified framework for large NMM, neutrino mass, and dark matter.
- With the consideration of existing evidence from dark matter relic abundance, LHC implications (not presented in this poster), and neutrinos mass, we show a parameter space opened for large NMM under our framework.

Main References

[1] S. M. Barr, E. Freire, and A. Zee, Phys. Rev. Lett. 65 (1990) 2626-2629.

[2] K. S. Babu, S. Jana, and M. Lindner, JHEP 10 (2020) 040

[3] This work: TC, S. Jana, V. P.K, M. Lindner, arXiv: 2107.XXXXX