Probing The Sterile Neutrino Portal To DM With γ − Rays

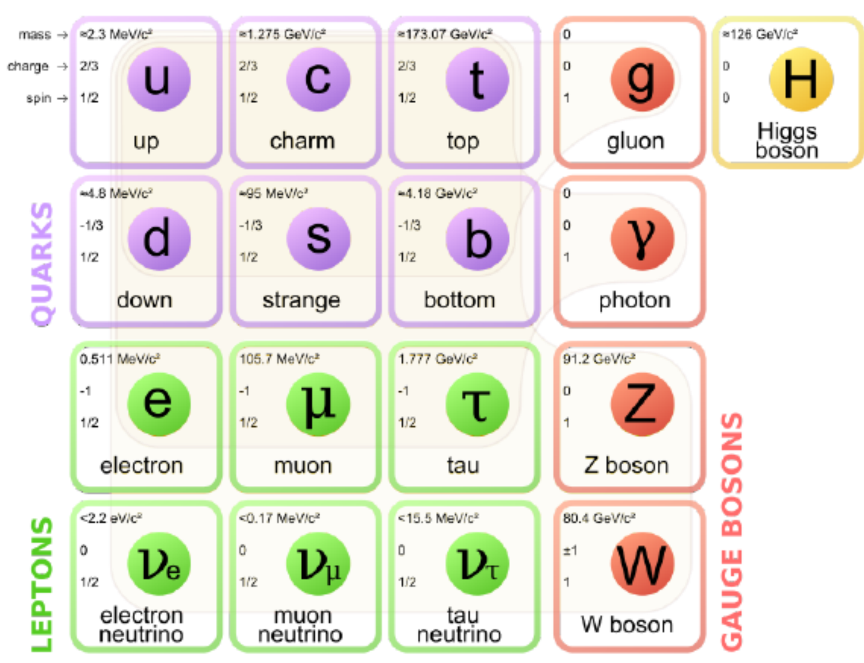
Miguel G. Folgado [1], Germán A. Gómez-Vargas [2], Nuria Rius [3], Roberto Ruiz de Austri [4]

Instituto de Física Corpuscular (IFIC) Universidad de Valencia-CSIC, 46980 Paterna, Spain

Emails: [1]Miguel.Garcia.Folgado@ific.uv.es [2]gggomezv@uc.cl [3]Nuria.Rius@ific.uv.es [4]Roberto.Ruiz@ific.uv.es

1. How invisible is the Dark Matter?

There are many evidences of the existence of dark matter but... what is exactly this new type of matter? which are its main traits? Could this matter interact with us other than gravitationally? If it does, how?



One of many theories is that the Dark Matter decoupled of the rest of the universe at T ≤ 100 GeV, leaving a little remnant known as Relic Abundance. Today we know that the value of this remnant is:

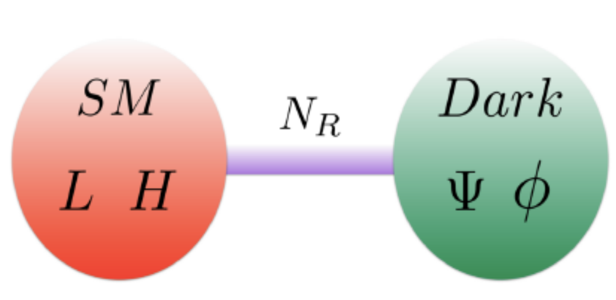
$$\Omega h^2 = 0.1198 \pm 0.0045$$

We analyze a model in which the Dark matter interacts mainly with sterile neutrinos:

2. Sterile neutrino portal

We assume that the observed DM relic abundance is determined by its interactions with sterile neutrinos, which in turn generate light neutrino masses via the type I seesaw mechanism. Besides the sterile neutrinos, the SM is extended by a dark sector that contains a scalar field ϕ and a fermion ψ. These fields are both singlets of the SM gauge group but charged under a dark sector symmetry group, G_{dark} such that the combination of this two fields is a singlet of this hidden symmetry. The lighter of the two dark particles is a good DM candidate. We assume for simplicity that the dark symmetry G_{dark} is a global symmetry at low energies, although our analysis is equally valid whether it is local.

$$\mathcal{L} = \mu_H^2 H^\dagger H - \lambda_H (H^\dagger H)^2 - \mu_\phi^2 \phi^\dagger \phi - \lambda_\phi (\phi^\dagger \phi)^2 - \lambda_{H\phi} (H^\dagger H)(\phi^\dagger \phi)$$
$$- \left(\phi \overline{\Psi}(\lambda_a + \lambda_p \gamma_5) N + Y \overline{L}_L H N_R + \text{h.c.}\right)$$



To generate the light neutrino masses we use a seesaw mechanism of type I.

Escudero, Rius and Sanz 1607.02373

After Electroweak symmetry breaking, the neutrino mass matrix in the basis (υ,N) is given by

$$\mathcal{M}_\nu = \begin{pmatrix} 0 & m_D \\ m_D^T & m_N \end{pmatrix}$$

This mass matrix can be diagonalized by a unitary matrix U:

$$\mathcal{M}_\nu = U^* \, Diag(m_\nu, M) \, U^\dagger \qquad U = \begin{pmatrix} U_{\alpha i} & U_{\alpha h} \\ U_{si} & U_{sh} \end{pmatrix}$$

$$U_{\alpha i} = [U_{PMNS}]_{\alpha i} \qquad U_{sh} = I$$
$$U_{\alpha h} = [m_D m_N^{-1}]^*_{\alpha h}$$
$$U_{si} = -[m_N^{-1} m_D^T U_{PMNS}]_{si} \, .$$

We have 4 free parameters: Sterile neutrino coupling to Dark particles, sterile neutrino mass (M_N), DM mass (M_ψ) and dark scalar mass.

We can reduce this to:

$$(\langle \sigma v \rangle, M_\Psi, M_N)$$

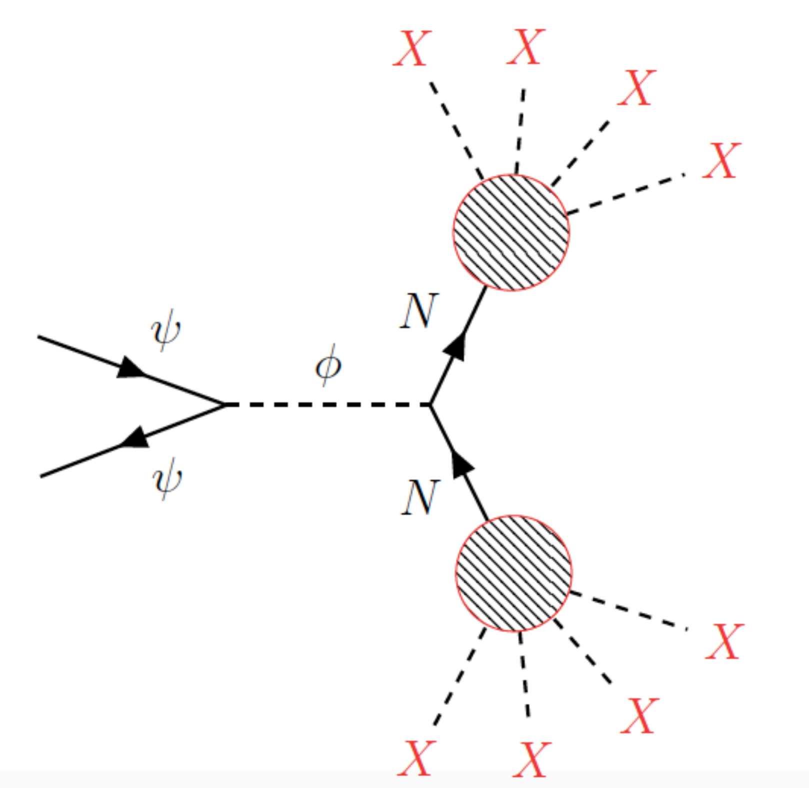
In the cold dark matter scenario the relic abundance only depends on the annihilation cross section:

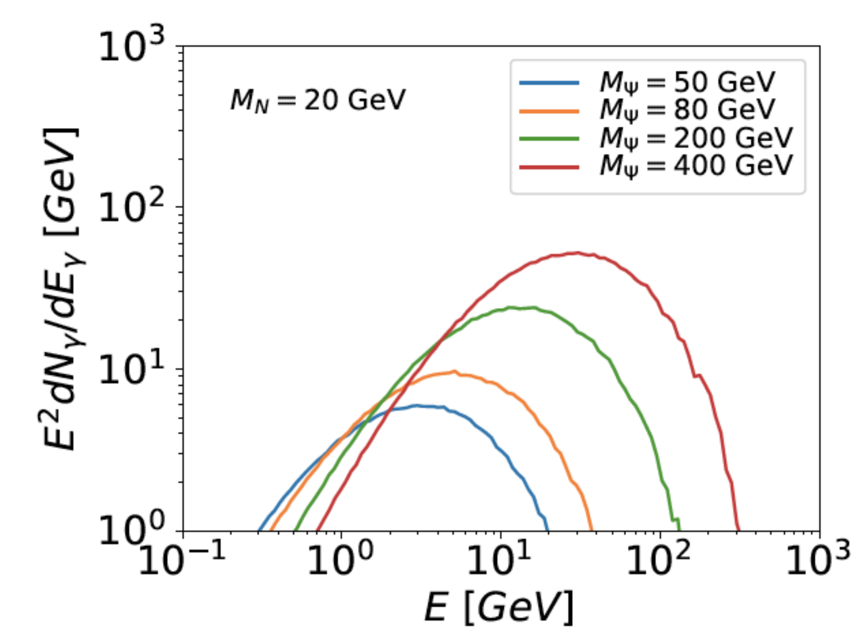
$$\Omega h^2 \simeq \frac{3 \times 10^{-38}\,\text{cm}^2}{\langle \sigma_{\text{ann}} v \rangle} \frac{x_F}{\sqrt{g_*(x_F)}}$$

$$\langle \sigma v \rangle_{Thermal} = 2.2 \cdot 10^{-26} \; cm^3/s$$

3. Neutrino portal indirect signals

Sterile neutrinos are produced in DM annihilations and then decay into SM particles. This process generate a parton shower that in its final states generates extra photons, antiprotons, positrons, etc (X in the figure).



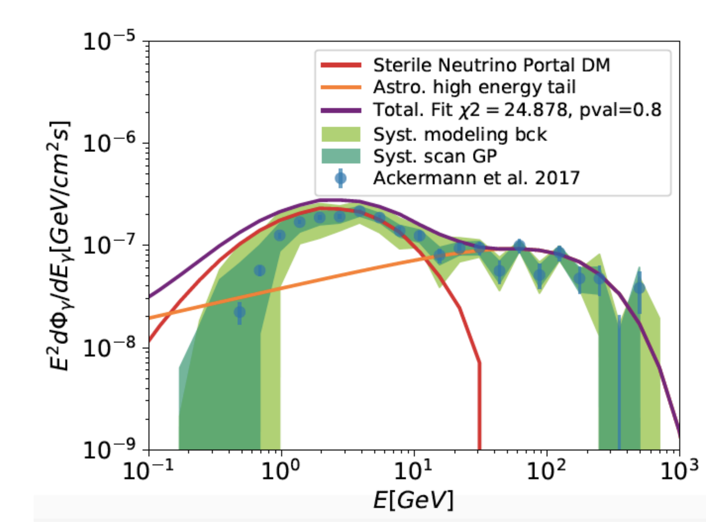


The most interesting and clean signal is that produced by the Photons. Fermi-LAT reports a gamma-ray excess in the galactic center (GCE). Could it be possible to fit this excess with our model?

Two different sources for the fit:

$$\Phi = \Phi_{astro} + \Phi_{DM}$$

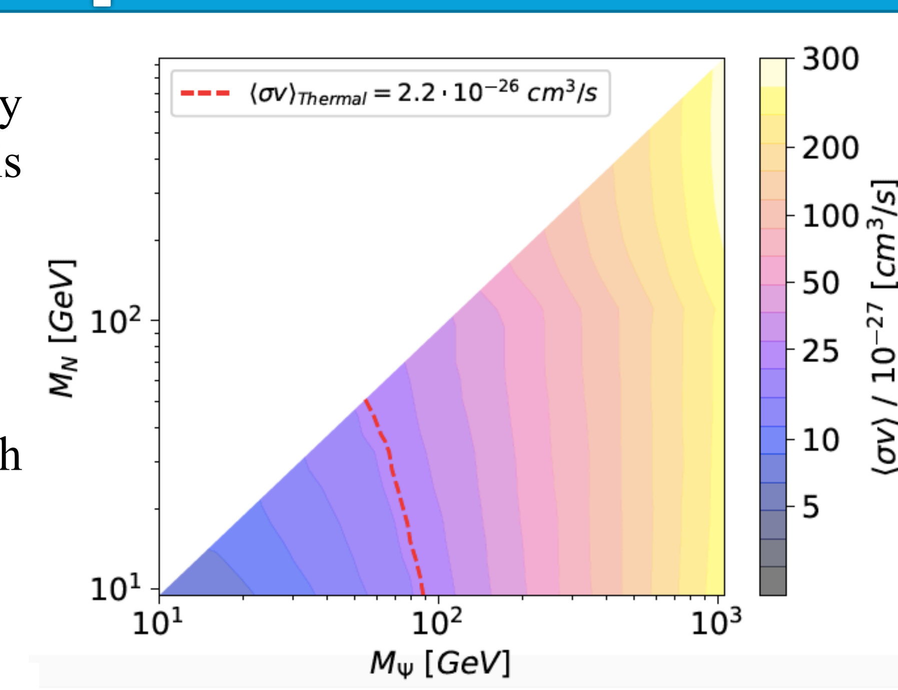
THE MODEL CAN FIT THE GCE WITH A 0.78 P-VALUE!! 😍

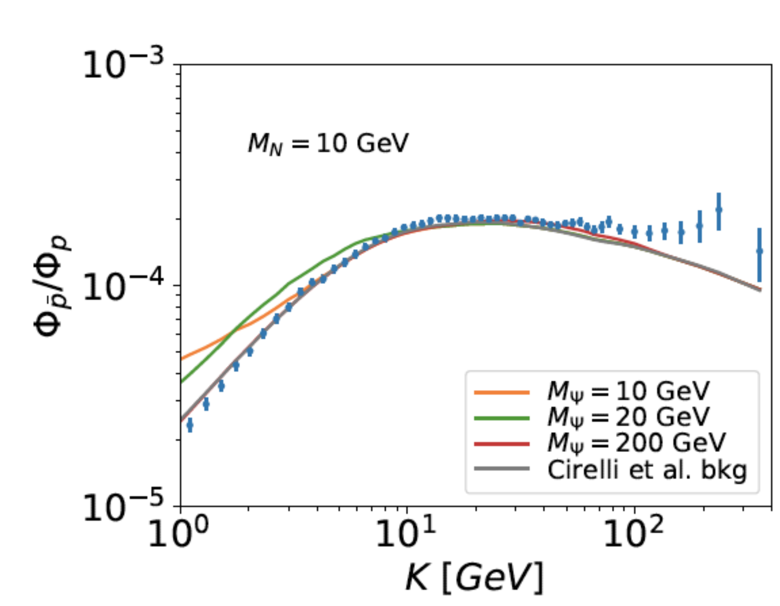


4. Constraints from dSphs and antiprotons

Fermi-LAT has not detected any gamma-ray excess in the dSphs. Is this compatible with the fit of the GCE?

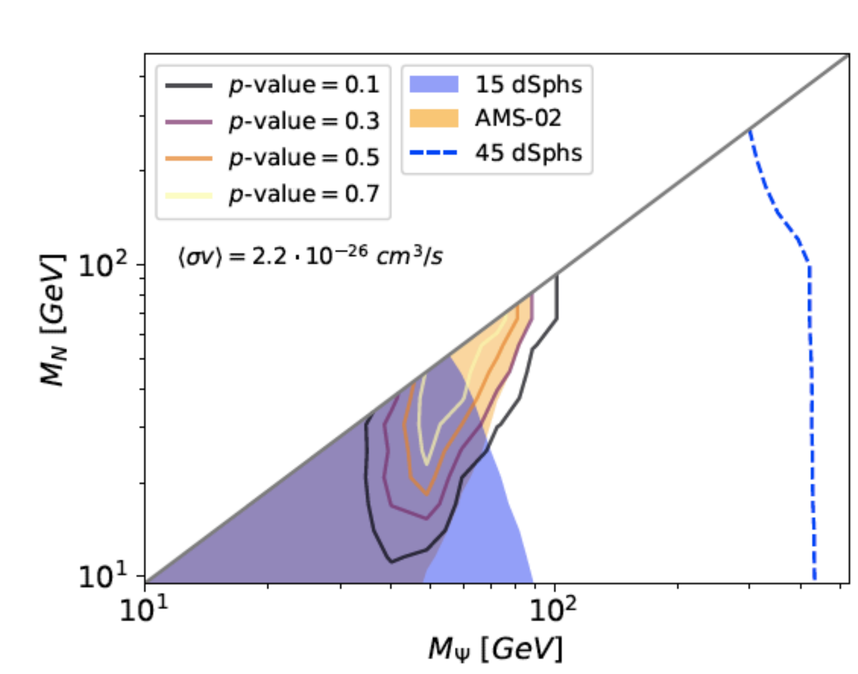
This constrain is strongly related with the annihilation cross section.





But this is not the only possible constrain. AMS-02 has reported the antiproton to proton flux ratio coming from the center of the galaxy

Some tension betwen AMS-02 and fit to the GCE, but be aware of the large uncertennties in the antiproton propagation model used.



5. Conclusions

- We have studied a simple case connecting Dark Matter and the origin of neutrino masses.
- The model can fit the GCE with a very good p-value (0.78).
- Strong constraints from FERMI-LAT (dSphs γ-ray data) and AMS-02 experiment but with large uncertenties.
- The future dSphs data could ruled out the GCE explanation by DM with in this model.

Acknowledgments

Work supported by the European Union grants H2020-MSCA-ITN-2015/674896-Elusives and H2020-MSCA-RISE-2015/690575-InvisiblesPlus, by the Spanish MINECO through grants FPA2014-57816-P, FPA2017-85985-P and SEV-2014-0398 and by Generalitat Valenciana grant PROMETEOII-2014/50.