Light Dark Matter Particle properties with Cosmic Reservoirs

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INTRODUCTION

Can light Dark Matter (DM) particles properties be constrained by using Starburst Nuclei?

Starburst Nuclei (SBNi) are usually referred as cosmic reservoirs, because they are able to confine cosmic-rays (CRs) inside their core for $\sim 10^5\,\mathrm{yr}$ [1]. Therefore, their transport might be strongly affected by scattering with sub-GeV DM. Gamma-ray produced via hadronic collisions can indirectly probe the distortion of the cosmic-ray spectrum. Since the current γ-ray data do not show any hint of distortion, thereby being a very powerful tool to probe the sub-GeV DM parameter space.

CR TIMESCALES

In the standard scenario, CRs lose energy through pp collisions with the interstellar medium (ISM) and escape through either advection or diffusion.

If a DM particle with mass (m_χ) elastically interacts with a CR, the CR will lose a lot of its energy. This provides a timescale strongly energy dependent.

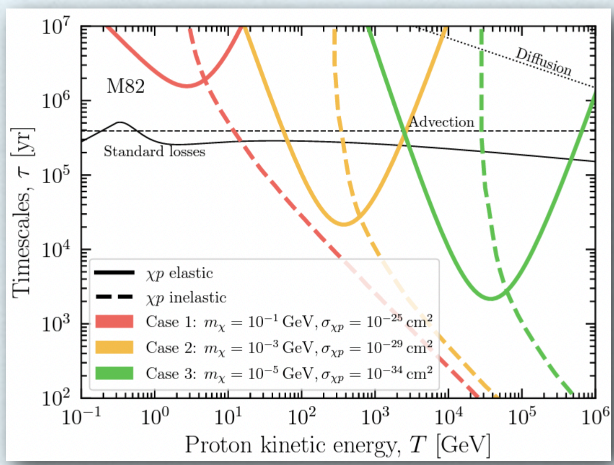


Fig: Comparison between the standard timescales (effective losses, advection and diffusion) in black lines and the effective DM-p timescales for three different cases regarding m_χ and elastic cross section ($\sigma_{\chi p}$)

SIGNATURE ON THE γ-RAY EMISSIONS

In the standard scenario, the γ-ray flux is a simple power-law following the proton injected flux from supernovae remnants (SNRs).

Elastic DM-p interactions induce a dip in the γ-ray spectrum, while the inelastic scatterings replenish the flux at higher energies.

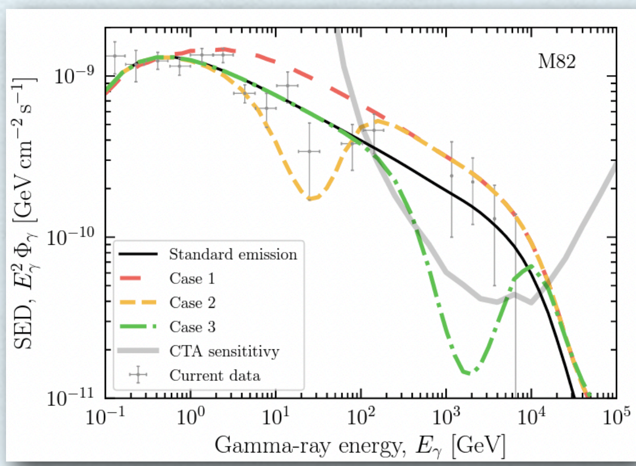


Fig: theoretical expected gamma-ray fluxes for the source compared with the experimental Fermi-LAT and VERITAS data [2,3]. See [4] for details.

BOUNDS ON DM-PROTON CROSS SECTION

Current data are consistent with a power-law, allowing us to impose strong constraints on the elastic cross section between DM and protons.

Likelihood Analysis exploiting GeV-TeV γ-ray observations:

$$\chi^2 = \sum (SED_i - E_i^2 \phi(E_i, m_\chi, \sigma_{\chi p} | \theta))^2 / \sigma_i^2$$

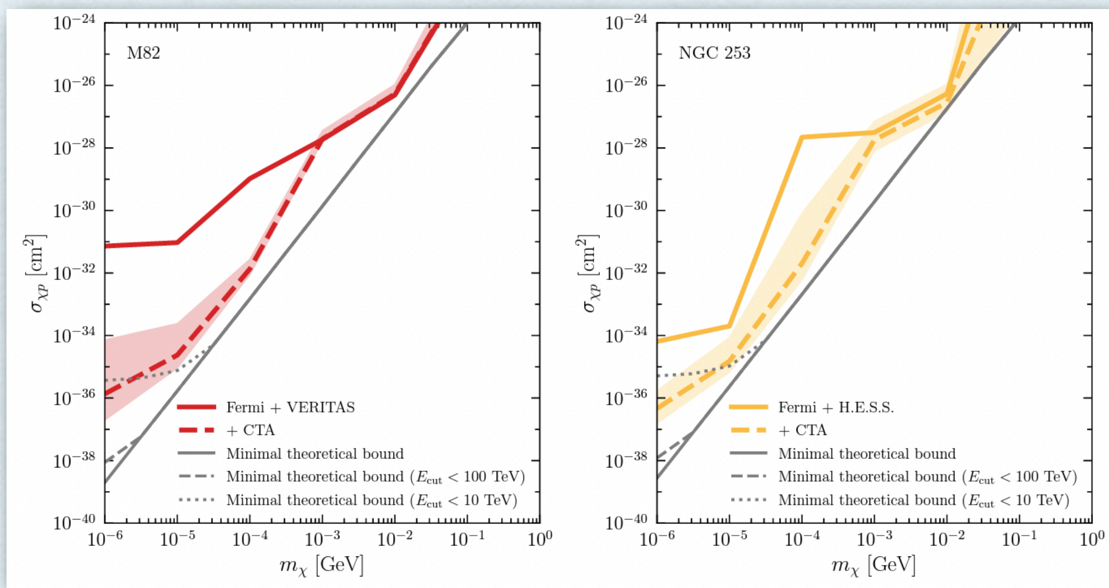
DM-p Interactions constrained according to the test-statistic: $\mathscr{L} = e^{-\frac{\chi^2}{2}}$

$$\Delta\chi^2 = \chi^2(m_\chi, \sigma_{\mathrm{DM-p}}) - \chi^2(m_\chi, 0) = 23.6 \text{ (}5\sigma\text{ level constraints)}$$

The theoretical bounds are obtained through:

$$\min_{E<E_{\mathrm{cut}}} \left[\tau_{\chi p}^{\mathrm{el,eff}} \left(\frac{1}{\tau_{\mathrm{esc}}} + \frac{1}{\tau_{\mathrm{loss}}^{\mathrm{eff}}} \right) \right] = 1 \,.$$

DM-proton collisions should be abundant enough to distort the spectrum



Left: Current data bounds on $\sigma_{\chi p}$ as a function of m_χ (continous red line) for M 82. The red band corresponds to the forecast for the CTA telescope [4]. The black lines show the theoretical minimal bounds. **Right**: Current data bounds on $\sigma_{\chi p}$ as a function of m_χ (continuous yellow line) for NGC 253. The yellow band corresponds to the forecast for the CTA telescope. The black lines show the theoretical minimal bounds. See [3] for details.

TAKE-HOME MESSAGE

SBNi are powerful tools to probe DM particle properties constraint DM-p cross section up to $10^{-34}\,\mathrm{cm}^2$. We have also shown a forecast for the CTA telescope and shown that the future telescope will improve current bounds up to two order of magnitudes.

References

[1] *Mon.Not.Roy.Astron.Soc.* 503 (2021) 3, 4032-4049, [2] *Astrophys.J.* 894 (2020) 2, 88, [3] 2009Natur.462..770V (arxiv:0911.0873), [4] *Phys.Rev.Lett.* 131 (2023) 11, 11, [5] CTA consortium, arxiv:1709.07997, https://doi.org/10.1142/10986