Exotic dark matter searches in dwarf spheroidal galaxies with the MAGIC telescopes: From secluded and branon DM to probing DM annihilation into neutrinos

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Abstract

One of the most pressing questions for modern physics is the nature of dark matter (DM). Several efforts have been made to model this elusive kind of matter, whose presence has been assessed only by gravitational effects so far. The largest fraction of DM cannot be made of any of the known particles of the Standard Model (SM). The ground-based gamma-ray telescope system MAGIC could potentially detect DM indirectly, by observing secondary products of either its annihilation into SM particles or its annihilation into short-lived mediators decaying into SM particles. We present a collection of exotic DM searches in dwarf spheroidal galaxies (dSphs) with the MAGIC telescopes. At first, we focus on brane-world theory as a prospective framework for DM candidates beyond the SM of particle physics. Secondly, we explore secluded DM by introducing short-lived mediators in the annihilation process. Last, we probe the DM annihilation into neutrinos, which produce a non-negligible fraction of gamma-rays and charged leptons in the final state. We present the cross-section limits as a function of the DM particle mass obtained by using a joint binned likelihood analysis, with the inclusion of systematic uncertainties in the residual background intensity and statistical uncertainties in the DM content of the dSphs.

Introduction

Astrophysical and cosmological evidences propose that non-baryonic cold DM accounts for 84% of the matter density of the Universe. Nevertheless, the nature of DM is still an open question for modern physics. In this contribution, we perform exotic DM analyses of dwarf spheroidal galaxies (dSphs) observations with the MAGIC telescopes using *gLike*[a] and *LikelihoodCombiner*[b], open-source analysis tools for multi-target and multi-instrument DM searches. MAGIC recently published in [1] a combined conventional DM search in the dSphs **Segue 1** (158h), **Ursa Major II** (95h), **Draco** (52h), and **Coma Berenices** (49h) with a **total exposure of 354h**.

Branon dark matter

Brane-world theory [2] has been put forward as a prospective framework for DM candidates. The characteristics of the suggested massive brane fluctuations in this theory match the ones of WIMPs, which are one of the most favored candidates of cold DM. This work leads to the **most constraining branon DM limits in the TeV mass range**, superseding previous constraints by CMS, AMS-02 and MAGIC limits for Segue1 alone [3].

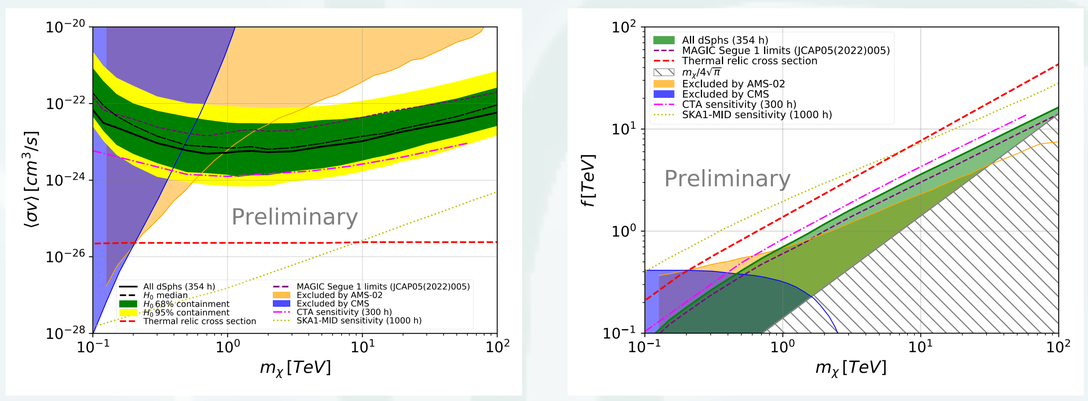

Fig. 1: Observational 95% CL UL on the thermally-averaged cross-section of branon DM (left) and on the brane tension *f* (right).

Secluded dark matter

Secluded DM refers to the DM particle annihilation into short-lived mediators *V* that do not belong to the SM. The mediators then decay in SM particles (see annihilation process in Fig. 2). We explore the annihilation into leptons with a combined analysis of the dSphs data sets of the MAGIC telescopes in Fig. 3.

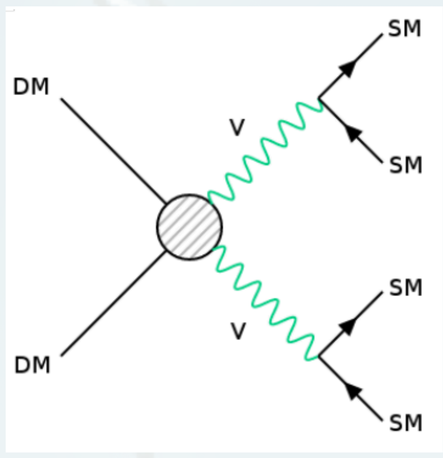

Fig. 2: Feynman diagram for secluded DM [4].

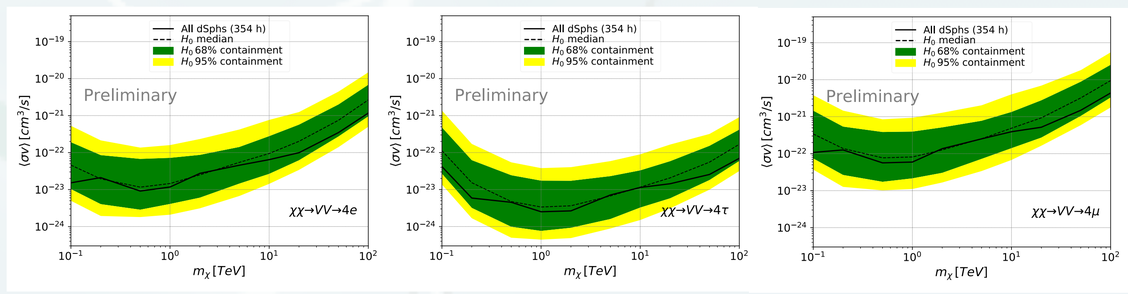

Fig. 3: Observational 95% CL UL on the thermally-averaged cross-section of secluded DM, where the DM particles annihilates into two short-lived mediators V that decay into four leptons (*electron* left, *tau* middle, and *muon* right).

DM annihilation into neutrinos

WIMPs can potentially annihilate into neutrino channels, which produce a non-negligible fraction of gamma-rays in the final state. Primary neutrinos start to radiate gamma rays and charged leptons due to radiative weak corrections when the mass of the DM particle is above the electroweak scale [5]. Fig. 4 shows the constraints to DM annihilation into neutrinos set by dSphs observation of the MAGIC telescopes.

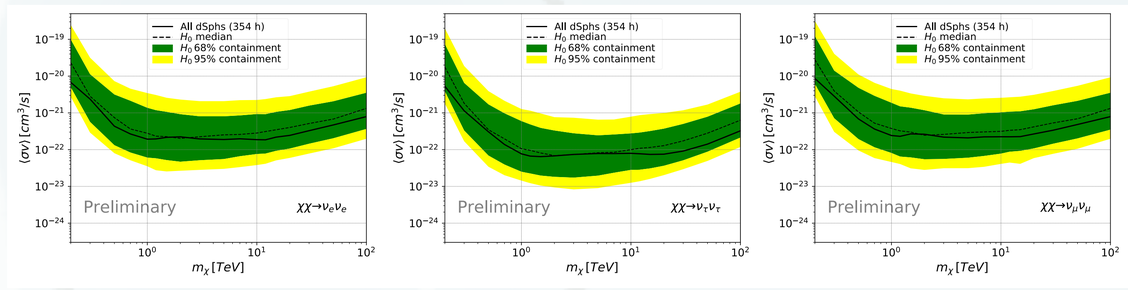

Fig. 4: Observational 95% CL UL on the thermally-averaged cross-section of DM annihilation into neutrinos (*electron-neutrino* left, *tau-neutrino* middle, and *muon-neutrino* right).

Conclusion

We presented in this contribution divers searches for DM and its nature. We can achieve even **more stringent and robust exclusion limits** for those exotic DM searches by adding further dSph observations of the MAGIC telescopes or other gamma-ray [6] or neutrino telescopes to this analysis scheme.

References

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[6] C. Armand et al., *Combined Dark Matter Searches Towards Dwarf Spheroidal Galaxies with Fermi-LAT, HAWC, HESS, MAGIC and VERITAS* [arXiv:2108.13646]

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[a] https://github.com/javierrico/gLike

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[b] https://github.com/TjarkMiener/likelihood_combiner

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