Hunting for dark matter subhalos among the Fermi-LAT sources with VERITAS

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Abstract

The distribution of dark matter (DM) in the Galaxy, according to state-of-the-art simulations, shows not only a smooth halo component but also a rich substructure where a hierarchy of DM subhalos of different masses is found. We present a search for potential DM subhalos in our Galaxy exploiting the high (HE, 100 MeV – 100 GeV) and very-high-energy (VHE, >100 GeV) gamma-ray bands. We assume a scenario where the DM is composed of weakly interacting massive particles of mass over 100 GeV, and is capable of self-annihilation into standard model products. Under such a hypothesis, most of the photons created by the annihilation of DM particles are predicted to lay in the HE gamma-ray band, where the Fermi-Large Area Telescope (LAT) is the most sensitive instrument to date. However, the distinctive spectral cut-off located at the DM particle mass is expected in the VHE gamma-ray band, thus making imaging atmospheric Cherenkov telescopes like VERITAS the best suited instruments for follow-up observations and the characterization of a potential DM signature. We report on the ongoing VERITAS program to hunt for these DM subhalos, particularly focusing on two promising DM subhalo candidates selected among the Fermi-LAT Second Source Catalog unassociated high-energy gamma-ray sources.

INTRODUCTION

Simulations of the DM distribution in Milky Way-like galaxies indicate that it exhibits a wealth of substructure besides the main halo. In the cold dark matter scenario, WIMPs with masses in the GeV-TeV range may self-annihilate and originate γ-rays. DM annihilation in subhalos could be the behind the emission of some unassociated Fermi-LAT objects. We selected DM subhalo candidates from the Fermi-LAT Second Source Catalog (2FGL) aiming to detect the DM spectral cutoff via VERITAS observations.

SELECTION OF CANDIDATES

- Unassociated Fermi-LAT source
- High Galactic latitude: $|b| > 10°$
- No significantly time variable flux
- No counterparts in dedicated search
- Observable from VERITAS with $z < 40°$
- Estimated VERITAS detection time < 50 h

Best DM subhalo candidates: 2FGL J0545.6+6018 & 2FGL J1115.0-0701.

VERITAS

The Very Energetic Radiation Imaging Telescope Array System is located at the Fred Lawrence Whipple Observatory in southern Arizona (31° 40′ N, 110° 37′ W, 1.3 km a.s.l.). It consists of four 12 m diameter imaging atmospheric Cherenkov telescopes. It operates primarily in an all-sky survey mode, covering the entire sky approximately every three hours.

- Energy range: 85 GeV to >30 TeV
- Energy resolution: 15-25%
- Sensitivity: 1% C.U. in 4 h
- Angular resolution: $\theta_{\text{min}}$ = 0.1° at 10 GeV

FERMI-LAT

The Large Area Telescope is a space-based electron-positron pair-conversion instrument on board NASA’s Fermi -Large Area Telescope (LAT). It operates primarily in its regular observation mode, covering the entire sky approximately every three hours.

- Energy range: 20 MeV to >300 GeV
- Energy resolution: 5-25%
- Field of View: 2.4 sr
- Angular resolution: $\theta_{\text{min}}$ = 0.3° at 10 GeV

2FGL J0545.6+6018

- VERITAS observations:
  - No significant VHE detection in 8.5 h (see Fig. 1 and Tab. 1).
  - VHE flux upper limits obtained (see Tab. 2).
- Fermi-LAT 7-years analysis:
  - Spectral description compatible with 3FGL but not with 2FGL (see Tab. 3).
  - No variability detected.
  - Spectral energy distribution fitted to different annihilation models:
    - Single channels considered (100% branching ratio).
    - Best fit results for annihilation into $W$-bosons (see Fig. 3 and Tab. 4).

2FGL J1115.0-0701

- VERITAS observations:
  - No significant VHE detection in 13.8 h (see Fig. 1 and Tab. 1).
  - VHE flux upper limits obtained (see Tab. 2).
- Fermi-LAT 7-years analysis:
  - Spectral description compatible with 2FGL & 3FGL (see Tab. 3).
  - Source is variable, contrary to 2FGL 140° C.U. single flare detected.
  - Source may be a blazar: we encourage HE monitoring to trigger VHE observations during flaring episodes.

References

1. [Reference 1]
2. [Reference 2]
3. [Reference 3]

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