PROCEEDINGS OF SCIENCE

Search for dark matter annihilation with a combined analysis of dwarf spheroidal galaxies from Fermi-LAT, HAWC, H.E.S.S., MAGIC and VERITAS

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Dwarf spheroidal galaxies (dSphs) are among the most dark matter (DM) dominated objects, with negligible expected astrophysical gamma-ray emission. This makes nearby dSphs ideal targets for indirect searches of a DM particle signal. The accurate knowledge of their DM content makes it possible to derive robust constraints on the velocity-weighted cross section of DM annihilation. We report on a joint analysis of 20 dSphs observed by Fermi-LAT, HAWC, H.E.S.S., MAGIC, and VERITAS using a common maximum likelihood approach in order to maximize the sensitivity of DM searches towards these targets. Results for seven annihilation channels and spanning a range of DM masses from 5 GeV to 100 TeV will be presented. Furthermore, the systematic uncertainties coming from the astrophysical J-factor calculated from the dSph dark matter distribution will be discussed by comparing results obtained from two different sets of J-factors.

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1. Introduction

This project consists in the search for dark matter (DM) annihilation with a combined analysis of twenty dwarf spheroidal galaxies (dSphs) observations by five gamma-ray experiments: *Fermi*-LAT [1], HAWC [2], H.E.S.S. [3], MAGIC [4], and VERITAS [5]. The expected differential flux of gamma rays from the self-annihilation of two DM particles is:

$$\frac{\mathrm{d}^2\Phi\left(\langle\sigma v\rangle, J\right)}{\mathrm{d}E\mathrm{d}\Omega} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi^2}\sum_f \mathrm{BR}_f \frac{\mathrm{d}N_f}{\mathrm{d}E} \times \frac{\mathrm{d}J}{\mathrm{d}\Omega}, \tag{1}$$

where m_χ is the DM particle mass, $\langle\sigma v\rangle$ is the velocity-averaged cross-section, and dN_f/dE is the differential spectrum for a given annihilation channel f and BR_f its corresponding branching ratio. $\mathrm{d}J/\mathrm{d}\Omega$, also known as the differential J factor, describes the expected amount of DM within a region of the sky $\mathrm{d}\Omega$ and can be written as:

$$\frac{\mathrm{d}J}{\mathrm{d}\Omega} = \int_{\mathrm{l.o.s.}} \rho_{\mathrm{DM}}^2(l, \Omega)\, dl, \tag{2}$$

where l.o.s. stands for line-of-sight and ρ_{DM} is the DM density distribution.

2. Method

The search for DM is performed via the maximisation of a joint likelihood function $\mathcal{L}$ which is the product over the individual likelihood $\mathcal{L}_{\mathrm{dSph}}$ of the $N_{\mathrm{dSphs}} = 20$ observed targets of our dataset $\mathcal{D}_{\mathrm{dSphs}}$:

$$\mathcal{L}\left(\langle\sigma v\rangle; \boldsymbol{\nu} \mid \mathcal{D}_{\mathrm{dSphs}}\right) = \prod_{l=1}^{N_{\mathrm{dSphs}}} \mathcal{L}_{\mathrm{dSph},l}\left(\langle\sigma v\rangle; J_l, \boldsymbol{\nu_l} \mid \mathcal{D}_{\boldsymbol{l},\mathrm{measured}}\right) \times \mathcal{J}_l\left(J_l \mid J_{l,\mathrm{obs}}, \sigma_{\log J_l}\right), \tag{3}$$

where $\mathcal{D}_{\boldsymbol{l},\mathrm{measured}}$ is the dataset for the l-th dSph; $\boldsymbol{\nu_l}$ is the set of nuisance parameters associated to the l-th dSph excluding J_l; and J_l is the total J factor of the l-th dSph.

3. Results

Two independent public software packages, `gLike` [6] and `LklCom` [7], are used to realize the final likelihood combination. Both software provide the same results. No DM signal was observed [8], hence 95 % CL upper limits on the DM annihilation cross-section $\langle\sigma v\rangle$ were derived for seven annihilation channels: $b\bar{b}$, $t\bar{t}$, e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$, W^+W^-, and ZZ.

4. Conclusion

The combined limits range from 5 GeV to 100 TeV and improve the individual experiment limits by up to a factor 2 to 3. Results obtained from two different sets of J-factors [9–11] allow to assess the systematic uncertainties coming from the astrophysical J-factor: the limits vary from a factor 2 to 6 depending of the DM mass. This is significanly less than individual dSph J-factor uncertainty than can be as high as 2 orders of magnitude.

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