Search for dark matter annihilation signals from unidentified Fermi/LAT objects with H.E.S.S.

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Abstract: Cosmological N-body simulations show that Milky-Way-sized galaxies harbor a population of unmerged dark matter(DM) subhalos. These subhalos could shine in gamma rays and be eventually detected in gamma-ray surveys as unidentified sources. We search for very-high-energy (VHE, E>100 GeV) gamma-ray emission using H.E.S.S. observations carried out from a thorough selection of unidentified Fermi-LAT Objects (UFOs) as dark matter subhalo candidates. Provided that the dark matter mass is higher than a few hundred GeV, the emission of the UFOs can be well described by dark matter annihilation models. No significant VHE gamma-ray emission is detected in any UFO dataset nor in their combination. We, therefore, derive constraints on the product of the velocity-weighted annihilation cross-section $\langle\sigma v\rangle$ by the J-factor on dark matter models describing the UFO emissions. Upper limits at 95% confidence level are derived on $\langle\sigma v\rangle J$ in W^+W^- and $\tau^+\tau^-$ annihilation channels for the TeV dark matter particles. Focusing on thermal WIMPs, strong constraints on the J-factors are obtained from H.E.S.S. observations. Adopting model-dependent predictions from cosmological N-body simulations on the J-factor distribution function for Milky Way (MW)-sized galaxies, only <0.3 TeV mass dark matter models marginally allow to explain observed UFO emission.

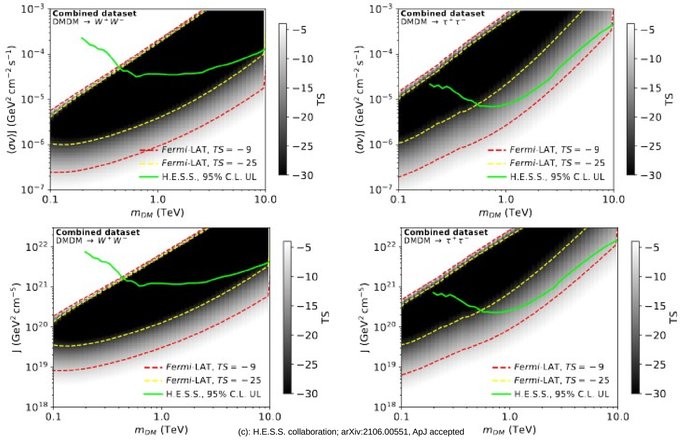
Name	RA [degrees]	Dec. [degrees]	TS for $E \geq 10$ GeV	Position uncertainty [arcmin]	Pivot energy [GeV]	Flux at pivot energy [10^{-13} TeV cm^{-2}s^{-1}]	Power-law index	E_{cut} (95% c.l.) [GeV]
3FHL J0929.2-4110	142.3345	-41.1833	36	2.4	0.39	0.12 ± 0.01	1.37 ± 0.07	> 33
3FHL J1915.2-1323†	288.8182	-13.3916	23	3.0	62.8	2.1 ± 0.9	1.5 ± 0.4	> 35
3FHL J2030.2-5037	307.5901	-50.6344	40	2.6	6.3	1.9 ± 0.3	1.85 ± 0.1	> 67

We searched in the 3FHL Fermi/LAT catalogue of sources detected above 10 GeV and selected sources missing radio-to-X-rays counterparts. We present the result of studies of these sources (see Table) in the TeV band with H.E.S.S. observatory.

- The expected signal from WIMP annihilation is

$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma, \Delta\Omega) = \frac{\langle\sigma v\rangle}{8\pi m_{DM}^2} \sum_f BR_f \frac{dN^f}{dE_\gamma} J(\Delta\Omega)\,, \text{ with } J(\Delta\Omega) = \int_{\Delta\Omega} \int_{l.o.s.} \rho^2(s(r,\theta)) ds d\Omega\,.$$

- For W^+W^- and $\tau^+\tau^-$ annihilation channels the signal is characterised by a cut-off powerlaw-like spectrum with a sharp cutoff at m_{DM}. The strength of the signal is determined by the product of velocity-averaged annihilation cross-section and J-factor of the clump. GeV/TeV observations allow direct measurement or constrainment of this factor as a function of m_{DM}.

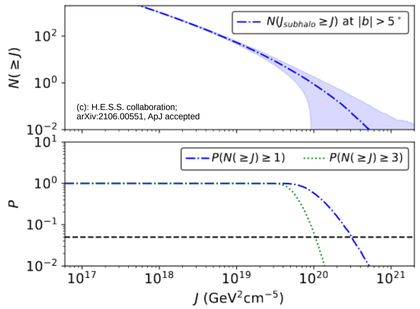


- Non-detection of the signal from UFOs with H.E.S.S. in the TeV band allowed to directly constrain the area on $\langle\sigma v\rangle J$ – m_{DM} plane for which these objects can be DM subhalos.

Introduction and motivation:

- N-body computer simulations predict that MW-type galaxies harbor a population of unmerged DM subhalos. Most massive subhalos can host dwarf spheroidal galaxies, while the rest are dark at all wavelengths. The exact location of DM clumps is not known.
- In case of Weakly Interacting Massive Particles (WIMP) dark matter, WIMPs' self-annihilation in the subhalos can lead to the production of gamma-ray emission.
- Massive WIMPs (m_{DM} > 0.1 TeV) are characterized by a hard gamma-ray spectrum in GeV/TeV band. Without clear multiwavelength counterparts DM subhalos can appear as UnIdentified Objects (UFOs) in all-sky gamma-ray surveys, e.g. with Fermi/LAT.

- Exact values of J-factors for DM subhalos are not not known, but statistics of J-factors distribution is known



- The probability for the MW-type galaxy to host 3 clumps with J>10^{20} GeV^{2}cm^{-5} is less than 5%

Conclusions and Discussion

- UFOs can represent DM subhalos only for a limited range of WIMP masses and $\langle\sigma v\rangle J$ values for W^+W^- and $\tau^+\tau^-$ annihilation channels.
- Assuming that WIMPs are characterised by thermal velocity-averged annihilation cross-section, m_{DM} and average J-factors can be strongly constrained:
  W^+W^- : m_{DM} : [0.2 – 6] TeV; J : [0.6 – 20] 10^{20} GeV^{2}cm^{-5}
  $\tau^+\tau^-$: m_{DM} : [0.2 – 6] TeV; J : [0.7 – 7] 10^{20} GeV^{2}cm^{-5}
- The mean expected upper limits for J-factors seen in N-body simulations barely allow only the lowest mass m_{DM}~0.2 TeV DM UFOs interpretation.
- Given the large uncertainties in the distribution of J-factors in N-body simulations, we argue that the H.E.S.S. model-independent limits are the only relevant ones on the parameters of WIMP DM for which UFOs can represent subhalos of WIMP DM.