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SEARCH FOR CLUMPY DARK MATTER IN THE GALAXY WITH H.E.S.S.

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Abstract. According to N-body simulations, dark matter should be distributed in the Galaxy into structures of various masses. We have modelled the distribution of these sub-structures, so as to produce a map of the expected γ-ray flux. The identification of this signal by H.E.S.S. is a challenge, because it is shadowed by the hadronic and electronic backgrounds. The most massive sub-structures of the galactic halo are the dwarf spheroidal galaxies. We present a preliminary analysis of H.E.S.S. observations on Carina dwarf to put constraints on WIMP models.

1 The H.E.S.S. experiment

The H.E.S.S. experiment, dedicated to the observation of very high energy γ-rays, consists of an array of four telescopes located in Namibia. The system is fully operational since 2004. When a high energy particle enters the atmosphere, it gives birth to an atmospheric shower of particles with velocities higher than the speed of light. Cerenkov light is thus emitted and detected by the H.E.S.S. telescopes.

The main challenge lies in the discrimination between photons and hadrons, and the reconstruction of the energy and the direction of the incoming photons. The energy threshold is around 100 GeV. The success of H.E.S.S. relies on the stereoscopy and the characteristics of the cameras, which combine a good time resolution, high sensitivity, high granularity and a large field of view (5°).

2 Dark matter distribution

Many astrophysical observations as well as cosmological studies converge to the Λ-CDM paradigm (cosmological constant and cold dark matter). Dark matter particles are expected to be stable, massive, neutral and weakly interacting (the so-called WIMPs). They cannot be explained by the standard model of particle physics. Two candidates are often considered: the neutralino which is the lightest stable particle coming from the minimal supersymmetric models (MSSM) and the lightest Kaluza Klein (KK) particle from extra-dimension models.

N-body simulations and analytical frameworks have provided a description of the distribution of cold dark matter. Our Galaxy may be settled in a dark matter halo which contains a large amount of sub-structures. We modelled the distribution of these clumps in the Galaxy with a Monte Carlo approach, with the following main features (see Lavalle et al. 2008): i) the mass of the clumps ranges between 10^{-6} and 10^{12} $M_\odot$; ii) the mass and the spatial distributions are assumed to be not correlated; iii) the normalisation is constrained by astrophysical observations (number of satellite galaxies in the Milky Way and estimation of the total Galactic mass according to the velocity dispersion of stars); iv) the density profile in each clump is identical on all scales.

3 Search for dark matter

WIMPs are expected to self-annihilate and produce a γ-ray flux Φ_γ along the line of sight ψ:

$$\frac{\mathrm{d}\Phi_\gamma}{\mathrm{d}E_\gamma}(E_\gamma, \psi, \Delta\Omega) = \frac{\mathrm{d}\Phi^{\mathrm{PP}}}{\mathrm{d}E_\gamma}(E_\gamma) \times \Phi^{\mathrm{astro}}(\psi, \Delta\Omega) \ . \tag{3.1}$$

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E_γ is the photon energy and $\Delta\Omega$ the angular resolution of the instrument. The first term $\Phi^{\rm PP}$ is related to the particle physics model describing WIMP annihilation, and the second term $\Phi^{\rm astro}$ takes into account the dark matter distribution (clumps of the Galaxy and dwarf spheroidal galaxies).

3.1 Sub-structures of dark matter

Fig. 1 (left panel) presents one realisation of the sky map obtained for $\Phi^{\rm astro}$, considering only sub-structures of the Galaxy. It reveals the presence of spots on top of a diffuse background. With an optimistic model for particle physics (Fornengo et al. 2004), the expected flux from these foreground sub-halos is about $\sim\ 6.1 \cdot 10^{-13}\ \gamma\ {\rm cm}^{-2}\ {\rm s}^{-1}$, below the H.E.S.S. sensitivity. Moreover, the clump position is unknown, the hadronic and electronic diffuse backgrounds are important, and the smooth dark matter contribution should also be added to the sky map.

3.2 Dwarf spheroidal galaxies

Dwarf spheroidal galaxies are dark matter-dominated objects, according to velocity dispersion measurements. They are located off-galactic plane and are expected to be free of astrophysical backgrounds. At present three of them have been observed with H.E.S.S.: Sagittarius and Canis Major (Aharonian et al. 2008, 2009), and we present here a preliminary analysis of Carina. No γ-ray excess has been found, which allows to exclude some WIMP models. Fig. 1 (right panel) presents the exclusion plot in the $\langle \sigma v \rangle\ -\ m_\chi$ plane, for a total observation time of 2.7 h and a standard analysis. No natural MSSM and KK models can be excluded.

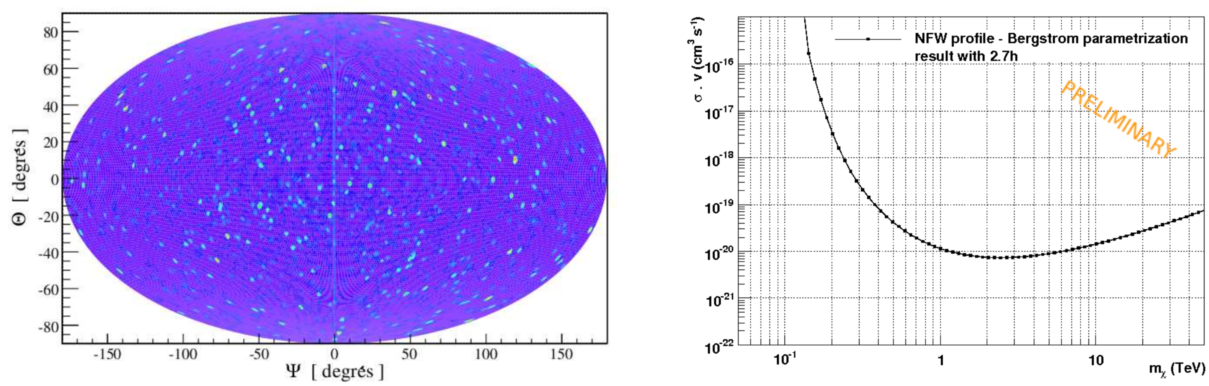

Fig. 1. Left panel: $\Phi^{\rm astro}$ from galactic clumps. **Right panel:** preliminary exclusion plot from Carina observations.

4 Conclusion

The sub-structures studied are not within reach of H.E.S.S. and probably not of H.E.S.S. II, but rather for the next generation of Cerenkov array as CTA (Cerenkov Telescope Array). Stronger constraints from dwarf galaxies could be set with larger observational time. The combination of existing observations on several dwarfs should also be investigated.

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