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DARK MATTER SEARCHES WITH H.E.S.S: NEARBY DWARF GALAXIES AND IMBH MINI-SPIKES

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Abstract. WIMP pair annihilations produce high energy gamma-rays, which can be detected by IACTs such as the H.E.S.S. array of Imaging Atmospheric Cherenkov telescopes. Nearby dwarf galaxies and mini-spikes around intermediate-mass black holes (IMBHs) in the Galactic halo are possible targets for the observation of these annihilations. H.E.S.S. observations on the nearby dwarf galaxy candidate Canis Major is reported. Using a modelling of the unknown dark matter density profile, constraints on the velocity-weighted annihilation cross section of DM particles are derived in the framework of Supersymmetric (pMSSM) and Kaluza-Klein (KK) models. Next, a search for DM mini-spikes around IMBHs is described and constraints on the particle physics parameters in various scenarios are given.

1 Introduction

WIMPS (Weakly Interacting Massive Particles) are among the best motivated particle dark matter candidates. The WIMP annihilation rate is proportional to the square of the DM density integrated along the line of sight. Celestial objects with enhanced DM density are thus primary targets for indirect DM searches. Among these are the Galactic Center, nearby external galaxies and substructures in galactic haloes. In this paper, we report on H.E.S.S. results towards a dwarf galaxy candidate, Canis Major, and on a search for DM mini-spikes around IMBHs.

2 Canis Major overdensity

The nature of the Canis Major (CMa) overdensity (whether it is a Galactic warp or a dwarf galaxy) has been debated since its discovery in 2004. The scenario in which it is presented as a dwarf galaxy makes it a potentially interesting target for DM searches. CMa is located at $\sim$8 kpc from the Sun towards the Galactic anti-center direction. Observations of CMa by H.E.S.S. have been carried out in 2006. After standard quality criteria, the CMa dataset amounts to 9.6 hours (Aharonian et al. (2009)).

The DM mass profile of dwarf galaxies is usually estimated using velocity dispersion measurements of their stellar population as well as their luminosity profile. This modelling was for instance carried out by Aharonian et al. (2008a) for the Sgr dwarf galaxy. In the case of CMa, no such observational data are available. The CMa dark mass distribution was assumed to have a cusped NFW (Navarro-Frank-White) halo profile. The parameters of the NFW profile are determined by solving a three-equation system in a Λ-CDM cosmology with the virial mass, the scale radius and the density profile normalisation taken as unknown quantities (see Aharonian et al. (2009) for details on the procedure). The tidal disruption of CMa by the Galactic gravitational field was taken into account. For a typical CMa mass of 10^8 $M_\odot$, the line-of-sight-integrated squared density is $\sim 10^{25}$ GeV^{2}cm^{-5}.

Halo independent constraints on the annihilation signal have been derived for various neutralino masses. In the center of the field of view, H.E.S.S. reaches a sensitivity of 10^2 GeV^{2}cm^{-2}s^{-1} for 1 TeV higgsino-like neutralino annihilating in W and Z pairs. The right hand side of Fig. 1 shows the constraints on σv. 95% C.L. exclusion limits reach $\sim 5\times 10^{-24}$ cm^{3}s^{-1} in the 500 GeV - 10 TeV DM particle mass range assuming a total halo mass of 3×10^8 $M_\odot$ (Aharonian et al. (2009)).

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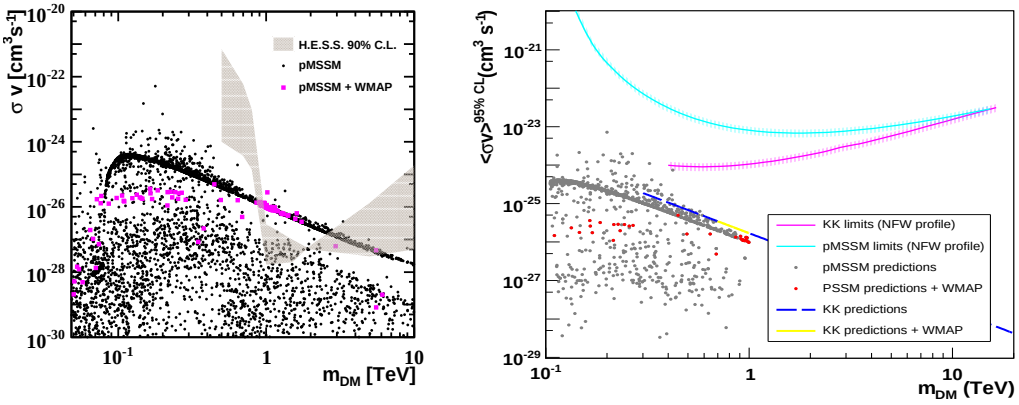

Fig. 1. Left: Constraints on the IMBH γ-ray production scenario for different neutralino parameters, shown as upper limits at 90% C.L. on σv as a function of the mass of the DM particle, in scenario B (grey shaded area). The DM particle is assumed to be a neutralino pair annihilating into $b\bar{b}$ or $\tau^+\tau^-$ pair. SUSY models from the pMSSM (black points) are plotted together with those satisfying the WMAP constraints on the cold DM density (magenta points). Right : Upper limits at 95% C.L. on σv as a function of the DM particle mass in the case of a NFW profile and an assumed CMa total mass of 3×10^8 $M_\odot$. The shaded area correspond to the 1σ error bars on σv for pMSSM and KK DM particles. pMSSM and KK models are also plotted with those satisfying the WMAP+SDSS constraints on the cold DM density.

3 Dark matter mini-spikes in IMBH scenarios

Mini-spikes around IMBHs have been recently proposed as promising targets for indirect DM detection (Bertone et al. (2005)). The growth of massive black holes affects the surrounding distribution of DM. The profile of the final DM overdensity, called mini-spike, depends on the initial distribution of matter, but also on astrophysical processes such as gravitational scattering of stars and mergers. Ignoring astrophysical effects, and assuming adiabatic growth of the black hole, starting from a NFW profile, a spike with a power-law index 7/3 is obtained. In the so-called scenario B of Bertone et al. (2005), the IMBH has a mass of $\sim10^5$ $M_\odot$. The gamma-ray flux from these objects can be calculated, assuming a particle physics model for the WIMP. The scenario B of Bertone et al. (2005) leads to gamma-ray fluxes accessible to H.E.S.S. For a 5 TeV neutralino mass, the mean integrated gamma-ray flux is 4.5×10^{-11}cm^{-2}s^{-1} (Aharonian et al. (2008b)).

H.E.S.S. observations (2004-2006) of the Galactic plane lead to the discovery of more than 20 very high energy gamma-ray sources. Some of them have been identified as counterparts of sources already discovered at other wavelength. However, almost half of the sources have no obvious counterpart and are still considered unidentified. The detailed study of these sources shows that they have intrinsic spatial extensions greater than $\sim$5', while mini-spikes are expected to be point-like sources for H.E.S.S. Their spectra is also inconsistent with a DM spectrum with a WIMP mass $\leq$ 10 TeV. H.E.S.S. has detected so far no IMBH candidate in its Galactic plane survey data.

Constraints are derived on the scenario B for neutralino or LKP annihilations. The left panel of Fig. 1 shows the exclusion limit at the 90% C.L. on σv as a function of the neutralino mass. The neutralino is assumed to annihilate into $b\bar{b}$ and $\tau^+\tau^-$ with 100% BR, respectively. The limits on σv are at the level of 10^{-28} cm^{-3}s^{-1} for the $b\bar{b}$ channel for neutralino masses in the TeV energy range.

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