Update on Dark Matter in the Galactic Centre with H.E.S.S.

Joachim Ripken*, **Jan Conrad***, **Dieter Horns**† **and Hannes Zechlin**†
for the H.E.S.S. collaboration

*Stockholm university, Sweden
†Universität Hamburg, Germany

***Abstract*. Several experiments have measured a strong signal of GeV/TeV-γ-radiation from the direction of the Galactic Centre. A often discussed possibility of the origin of this radiation is the self-annihilation of dark matter particles. Comparing current models with the measurements the hypothesis that the whole radiation has this origin becomes implausible, but the dark matter can still make a contribution to the measured radiation. With results from the H.E.S.S. experiment limits on this contribution were be calculated, which delivered limits on the annihilation cross section or the dark matter density profile. Radiative corrections were neglected in these investigations so far. It emerged, that these corrections can clearly change the energy spectrum of the annihilation radiation. Comparing the new annihilation spectra with the measurements the new limits on dark matter annihilation will be presented.**

***Keywords*: dark matter, Galactic Centre, gamma astronomy**

I. Introduction

The nature of the Dark Matter (DM) is still one of the most challenging problems in particle physics and cosmology. So far it has only shown its existence due to its gravitational interaction. Several experiments and observations were made and are proposed in order to solve the riddle, and many candidates are suggested. One class of candidates are the weakly interacting massive particles (WIMPs) and the mostly discussed member of this class is the neutralino (χ) of the supersymmetric extension of the standard model of elementary particle physics.

Since the neutralino is a majorana particle it would annihilate with itself and if the DM consist of neutralinos it will enrich the universe with its annihilation products. These annihilation products contain neutrinos and photons with an energy up to the neutralino mass as well as electrons, positrons and (anti)protons. Neutrino telescopes, experiments measuring the cosmic radiation and observatories for high energy γ-radiation are looking for these annihilation products and are searching indirectly for dark matter this way. While the detection for neutrinos is still difficult and would need a very nearby DM enhancement (DM accretion in the sun, earth and moon) the detection of photons is easier and the observation of DM accumulations in astrophysical distances is possible. Since the annihilation rate is proportional to ϱ^2, it is suggestive to search for this radiation from a direction with large expected DM density. The Galactic Centre (GC) is one such region.

The High Energy Stereoscopic System (H.E.S.S.) is a stereoscopic system of 4 imaging atmospheric Cherenkov telescopes located at the Khomas highlands in Namibia. It is sensitive for γ-ray photons with an energy larger than $100\,\mathrm{GeV}$.

H.E.S.S. has observed the GC region several times since 2003 and a steady point-like source of very high energy γ-radiation has been found [1], [2], [3], [4]. Within the angular resolution of the γ-radiation the source is compatible to Sagittarius $A^\star$, but the origin is still unclear. The DM interpretation has been investigated several times [2], [5], [6], [7]. The measured energy reaches up to more than $30\,\mathrm{TeV}$. If the radiation originates completely from DM annihilation a DM particle of at least this mass will be needed. To explain the high flux also a very high annihilation cross section will be essential. The measured spectral shape does not fit a typical DM annihilation spectrum well. Due to these facts it is very unplausible that the γ-radiation originates completely from DM annihilation.

However a part of the radiation still may be produced by DM annihilation. Limits on this contribution were be calculated and translated into limits on the annihilation cross section or on the DM density profile [2], [6], [7]. For the calculation of these limits some generic annihilation spectra were used in order to cover all possibilities. Radiative corrections - internal bremsstrahlung (IB) - have been neglected so far, but it was shown, that these processes can deliver a large contribution to the annihilation radiation [8]. This contribution is model dependent and cannot be used in a generic way. Therefore it becomes necessary to test models separately whether they deliver a contribution which is compatible to the measured radiation.

This is an update to the limit calculation where this ansatz is used.

II. Model check

In this work a set of models is used which is taken from a random mSUGRA scan. For each model it was checked whether it is compatible to accelerator constraints and give a WMAP compatible relic density $0.094 \leq \Omega h^2 \leq 0.129$. The scan was performed with

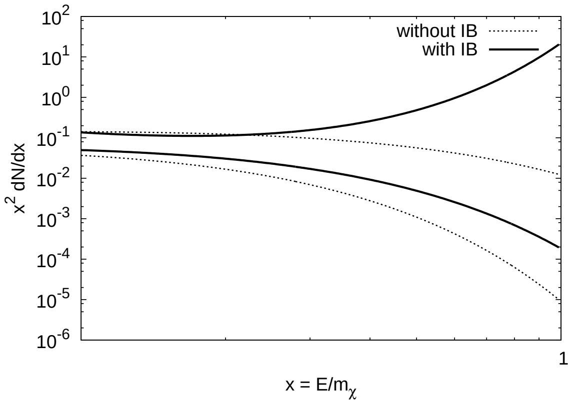

Fig. 1. Possibilities for the spectral energy distribution of the photons per annihilation normalized on the neutralino mass. The dotted lines curtail roughly the possibilities of spectra without IB. The solid lines curtail roughly the possibilities with IB.

DarkSuSY 5.0.4 [9]. A set of models was extracted by this procedure.

The contribution of DM to the measured flux at the GC is given by

$$\Phi_{DM}(E) = 2.8 \cdot 10^{-10}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}\left(\frac{100\,\mathrm{GeV}}{\mathrm{m}_\chi}\right)^2 \quad (1)$$
$$\frac{\langle\sigma v\rangle}{\mathrm{pb\,c}}\frac{dN_\gamma}{dE}(E)J(\Delta\Omega)\Delta\Omega$$

The DM density profile ϱ delivers the scale

$$J(\Delta\Omega)\Delta\Omega = \frac{1}{8.5\,\mathrm{kpc}(0.3\,\mathrm{GeV/cm}^3)^2}\int_{\Delta\Omega} d\Omega \int_{\mathrm{los}} ds\,\varrho^2 \quad (2)$$

The particle physics model delivers the averaged product of velocity and cross-section $\langle\sigma v\rangle$ and the photon spectrum per annihilation dN_γ/dE. The possibilities for this spectrum are shown in figure 1. The effect of IB can increase the spectrum by orders of magnitudes and increase the uncertainty in this variable.

The complete energy spectrum is the sum of the DM annihilation radiation and an astrophysical background $\Phi_{bg}(E)$

$$\Phi(E) = \Phi_{DM}(E) + \Phi_{bg}(E) \quad (3)$$

which is chosen to be a power law, since the measured spectrum is described by one [2].

By choosing the parameters of the background spectrum free, the complete spectrum is fitted to the measured spectrum. The sum of the squared residuals χ^2 of the best fit model delivers a measure of quality. A model is rejected, if χ^2 is larger than the 99% value of the associated χ^2-distribution. The results will be shown at the conference.

III. ACKNOWLEDGMENTS

The support of the Namibian authorities and of the University of Namibia in facilitating the construction and operation of H.E.S.S. is gratefully acknowledged, as is the support by the German Ministry for Education and Research (BMBF), the Max Planck Society, the French Ministry for Research, the CNRS-IN2P3 and the Astroparticle Interdisciplinary Programme of the CNRS, the U.K. Science and Technology Facilities Council (STFC), the IPNP of the Charles University, the Polish Ministry of Science and Higher Education, the South African Department of Science and Technology and National Research Foundation, and by the University of Namibia. We appreciate the excellent work of the technical support staff in Berlin, Durham, Hamburg, Heidelberg, Palaiseau, Paris, Saclay, and in Namibia in the construction and operation of the equipment.

REFERENCES

[1] F.a. Aharonian, et al. (H.E.S.S. collaboration), *A&A* **425**, L13-L17 (2004)
[2] F.A. Aharonian, et al. (H.E.S.S. collaboration), *PRL* **97**, 221102 (2006)
[3] F.A. Aharonian, et al. (H.E.S.S. collaboration), *A&A* **492**, L25-L28 (2008)
[4] F.A. Aharonian, et al. (H.E.S.S. collaboration) in preparation
[5] D. Horns, *PhLB* **607**, 225-232 (2005)
[6] J. Ripken, et al. (H.E.S.S. collaboration), *ICRC 2005* **4**, 151 (2005)
[7] J. Ripken, et al. (H.E.S.S. collaboration), *ICRC 2007* in preparation
[8] T. Bringmann, L. Bergström, J. Edsjö, *JHEP* **01**, 049 (2008)
[9] P. Gondolo, et al., *JCAP* **07**, 008 (2004)