Gamma-ray excess from the galactic center and supergravity models

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Abstract. In the light of recent and forthcoming experiments (EGRET, CANGAROO, HESS, GLAST), we analyse the effect of the compression of the dark matter due to the infall of baryons to the galactic center on the gamma-ray flux in the Supergravity framework.

1. Introduction
It is now well established that luminous matter makes up only a small fraction of the mass observed in Universe. A weakly interacting massive particle (WIMP) is one of the leading candidates for the “dark” component of the Universe. One of the most promising methods for the indirect detection of WIMPs consists of detecting the gamma rays produced by their annihilations in the galactic halo. Concerning the nature of WIMPs, the best motivated candidate is the lightest neutralino, a particle predicted by the supersymmetric (SUSY) extension of the standard model [1].

2. The gamma-ray flux
For the continuum of gamma rays, the observed differential flux at the Earth coming from a direction forming an angle \( \psi \) with respect to the galactic center is

\[
\Phi_{\gamma}(E_\gamma, \psi) = \sum_i \frac{dN_i}{dE_\gamma} \frac{1}{8\pi m_\chi^2} \int_{\text{line of sight}} \rho^2 \, dl ,
\]

where the discrete sum is over all dark matter annihilation channels, \( dN_i/dE_\gamma \) is the differential gamma-ray yield, \( \langle \sigma_i v \rangle \) is the annihilation cross section averaged over its velocity distribution, \( m_\chi \) is the mass of the dark matter particle, and \( \rho \) is the dark matter density.

3. The adiabatic compression model
Recently, SUSY dark matter candidates have been studied in the context of realistic halo models including baryonic matter [2]. Indeed, since the total mass of the inner galaxy is dominated by baryons, the dark matter distribution is likely to have been influenced by the baryonic potential. In particular, its density is increased, and as a consequence typical halo profiles such as Navarro, Frenk and White (NFW) and Moore et al. have a more singular behaviour near the galactic center. The conclusion of the work in Ref. [2] is that the gamma-ray flux produced by the annihilation of neutralinos in the galactic center is increased significantly, and is within the
sensitivity of future experiments, when density profiles with baryonic compression are taken into account. The models and constraints that we used in this work for the Milky Way can be found in Table I of Ref. [2]. As one can see in [3], at small $r$ the dark matter density profile following the adiabatic cooling of the baryonic fraction is a steep power law $\rho \propto r^{-\gamma_c}$ with $\gamma_c \approx 1.45(1.65)$ for a NFW$_c$(Moore$_c$) compressed model.

4. Supersymmetric Models
As discussed in detail in Ref. [4] in the context of indirect detection, $\sigma_t$ can be increased in different ways when the structure of mSUGRA for the soft terms is abandoned. In particular, the most important effects are produced by the non-universality of Higgs and gaugino masses.

5. Confronting experiments
5.1. EGRET
The EGRET telescope on board of the Compton Gamma-Ray Observatory has carried out the first all-sky survey in high-energy gamma-rays ($\approx 30$ MeV – 30 GeV) over a period of 5 years, from April 1991 until September 1996. As a result of this survey, it has detected a signal [5] above about 1 GeV, with a value for the flux of about $10^{-8}$ cm$^{-2}$ s$^{-1}$, that apparently cannot be explained with the usual gamma-ray background.

5.2. CANGAROO-GLAST
Recently, the CANGAROO–II atmospheric Cherenkov telescope has made a significant detection of gamma rays from the Galactic center region [6]. In particular, the collaboration has published the spectrum obtained in six energy bins, from 200 GeV to 3 TeV. Observations taken during 2001 and 2002 have detected a statistically significant excess at energies greater than $\sim 250$ GeV, with an integrated flux of $\sim 2 \times 10^{-10}$ photons cm$^{-2}$ s$^{-1}$. These measurements indicate a very soft spectrum $\propto E^{-4.6\pm0.5}$.

It is interesting to see whether it is possible to obtain such a candidate in SUGRA scenarios imposing the accelerator and WMAP constraints, and within the framework of adiabatically compressed halos. The baryonic cooling effect on the fluxes gives us the order of magnitude needed to fit with both data with a 1 TeV neutralino in the non–universal case e) with $M_3 = 0.5M$.

It is also interesting to see the complementarity of GLAST with EGRET and CANGAROO. GLAST will perform an all-sky survey detection of fluxes with energy from 1 GeV to 300 GeV, exactly filling the actual lack of experimental data in this energy range (see Fig. 1), and checking the CANGAROO results.

5.3. HESS
The HESS Cherenkov telescope experiment has recently published new data on gamma rays, detecting a signal from the Galactic Center [7]. The authors of [7] already pointed out that if we assume that the observed gamma rays represent a continuum annihilation spectrum, we expect $m_\chi \gtrsim 12$ TeV. We analyzed in a quite model-independent way the conditions required on the particle physics field to fit with the HESS data thanks to dark matter annihilation. The results are shown in Fig. 11 of [3]. We point the fact that we do not only compare the spectrum shape of the signal with possible dark matter annihilation explanation. It is worth noticing here that a similar and more complete analysis was done recently by S. Profumo in [8].

6. Conclusion
We have analysed the effect of the compression of the dark matter due to the infall of baryons to the galactic center on the gamma-ray flux. In addition, we have also considered the effect of
\[ \delta = -0.5 \]

\[ 10^{-10} \]

\[ 10^{-14} \]

\[ 10^{-18} \]

\[ \text{Flux (cm}^{-2}\text{s}^{-1}\text{GeV}^{-1}) \]

\[ \tan\beta = 35 \]

\[ \delta' = 0.5 \]

\[ \text{GLAST sensitivity} \]

\[ E_\gamma \text{ (GeV)} \]

**Figure 1.** Gamma-ray spectra from the galactic center as functions of the photon energy for the non–universal case \( e \) with \( M_3 = 0.5M \), compared with data for EGRET and CANGAROO–II experiments and the expected GLAST sensitivity. Here only the average profile defined in Sect. 2.2 of [3] with adiabatic compression, NFW\(_c\), is used.

non-universal soft terms, that arises naturally in string motivated framework [9]. This analysis shows that neutralino dark matter annihilation can give rise to signals largely reachable by future experiments like GLAST. This is a remarkable result if we realize that direct detection experiments will only be able to cover a small region of the parameter space.

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