WIMP Gamma Rays From the Galactic Center with GLAST and Accelerator Comparison

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EGRET data & Susy models

Annihilation channel $W^+W^-$
$M_\chi = 80.3$ GeV

$N_b = 1.82 \times 10^{21}$
$N_\chi = 8.51 \times 10^4$

Typical $N_\chi$ values:
NFW: $N_\chi = 10^4$
Moore: $N_\chi = 9 \times 10^6$
Isotermal: $N_\chi = 3 \times 10^1$

~2 degrees around the galactic center

A.Morselli, A. Lionetto, A. Cesarini, F. Fucito, P. Ullio, astro-ph/0211327
Signal rate from Supersymmetry

gamma-ray flux from neutralino annihilation

\[ \phi(E, \Delta \Omega) \propto \left( \frac{\sigma v}{m^2 \chi} \right) \int_{l.o.s} \int_{\Delta \Omega} \rho^2(l) \, dl \, d\Omega \]

\( \mathcal{J}(\varphi) \): governed by halo distribution

\( \mathcal{J}(\varphi) \): governed by supersymmetric parameters
~2 degrees around the galactic center, 2 years data

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$N_b = 1.82 \times 10^{21} \quad N_\chi = 8.51 \times 10^4$
EGRET, E > 1GeV
Mayer-Hasselwander et al, 1998

Integral data
2° x 2° field IBIS/ISGRI
20–40 keV
Point source location for GLAST ~ 5 arcmin

1 pixel ~ arcmin

2$^\circ$ x 2$^\circ$ field IBIS/ISGRI 20–40 keV
Point source location for GLAST ~ 5 arcmin

1 pixel ~ 5 arcmin

2° x 2° field EGRET, E > 1GeV

2° x 2° field IBIS/ISGRI 20–40 keV
Results of simulations for the mSUGRA point with parameters
\( M_{1/2} = 420, \ M_0 = 380, \ \tan \beta = 53 \ \text{GeV} \)

\( m_\chi \sim 170 \ \text{GeV}, \ \Omega h^2 = 0.114 \)

The dark matter halo used for the GLAST indirect search sensitivity estimate is a truncated Navarro Frank and White (NFW) halo profile.

\( \Phi(E_\gamma > 100 \ \text{MeV}) \sim 3 \times 10^{-7} \ \text{cm}^{-2} \ \text{s}^{-1} \ \text{in} \ 30^\circ \times 30^\circ \ \text{Map (DarkSusy)} \)

30 deg*30 deg count map obtained from GLAST simulations for a NFW profile with mSUGRA parameters after one year GLAST operation. This DM counts map has to be compared with the expected background as computed with the GALPROP code (on the left)
Differential spectra (GC centered)

Resulting differential spectra from LCC4 and Background simulations for two regions (3deg and 0.1deg radius) centered at the Galactic Centre.
Supersymmetry introduces free parameters:

In the MSSM, with Grand Unification assumptions, the masses and couplings of the SUSY particles as well as their production cross sections, are entirely described once 5 parameters are fixed:

• $M_{1/2}$ the common mass of supersymmetric partners of gauge fields (gauginos)

• $m_0$ the common mass for scalar fermions at the GUT scale

• $\mu$ the higgs mixing parameters that appears in the neutralino and chargino mass matrices

• $A$ is the proportionality factor between the supersymmetry breaking trilinear couplings and the Yukawa couplings

• $\tan \beta = \frac{v_2}{v_1} = \frac{<H_2>}{<H_1>}$ the ratio between the two vacuum expectation values of the Higgs fields
Signal and Background are separated?

- Signal
- Background

$\tan(\beta) = 55$, $\text{sign}(\mu) = +1$

No electroweak symmetry breaking

cMSSM

M$_{1/2}$ (GeV)

$M_0$ (GeV)
Signal and Background are separated?

\[ \tan(\beta) = 55, \ \text{sign}(\mu) = +1 \]

cMSSM

[Diagram showing the separation of signal and background in the context of the cMSSM model with specific parameters.]
GLAST limits

WMAP 3
3σ allowed region

no electroweak symmetry breaking

mSUGRA
Sensitivity plot for 5 years observation of mSUGRA for GLAST for tg(b)=55.

GLAST 3σ sensitivity is shown at the blue line and below for truncated NFW halo profile.
Sensitivity plot for 5 years observation of mSUGRA for GLAST for $\tan(\beta)=55$. GLAST 3σ sensitivity is shown at the blue line and below for truncated NFW halo profile.
**mSUGRA**

Sensitivity plot for 5 years observation of mSUGRA for GLAST for tg(b)=55 and for other experiments. GLAST 3σ sensitivity is shown at the blue line and below for truncated NFW halo profile.

accelerator limits @ 100 fb⁻¹ from H.Baer et al., hep-ph/0405210

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**GLAST, PAMELA, LHC, LC Sensitivities to Dark Matter Search**

- **GLAST** limits
- **PAMELA** limits boost factor 10
- **LHC** limits 100 fb⁻¹
- **WMAP 3 3σ allowed region**
- **Region of uncertainties that will be reduced with all the other PAMELA data**
- **LC1000 limits**
- **GLAST limits**
- **LC500**

no electroweak symmetry breaking
Sensitivity plot for observation of mSUGRA for a number of accelerator experiments and GLAST for $\tan(\beta)=10$. GLAST $3\sigma$ sensitivity is shown at the blue line and below a for truncated Navarro Frank and White (NFW) halo profile.
Sensitivity plot for observation of mSUGRA for GLAST for $\tan(\beta)=60$. GLAST $3\sigma$ sensitivity is shown at the blue line and below for truncated NFW halo profile.

WMAP 3 $3\sigma$ allowed region

no electroweak symmetry breaking

GLAST $3\sigma$ limits

5 years of data $\tan(\beta)=60$, sign($\mu$)=+1
large $\tan \beta$ regions favoured in flavour physics:

- suppression of $B \rightarrow \tau \nu$
- sizable enhancement of $(g-2)_\mu$
- small non-standard effects in $\Delta M_{Bs}$ and $B(B \rightarrow X_s \gamma)$
Model independent results for the GC

the background is (as in astro-ph/0305075)

\[
\frac{dN(E_\gamma, l, b)}{dE_\gamma} = N_0(l, b) \left( \frac{E_\gamma}{1 \text{ GeV}} \right)^\alpha \quad 10^{-6} \text{ cm}^{-2} \text{s}^{-1} \text{ GeV}^{-1} \text{sr}^{-1}
\]

\[
N_0(l, b) = \frac{85.5}{\sqrt{1 + (l/35)^2} \sqrt{1 + (b/(1.1 + |l| 0.022))^2}} + 0.5 \quad \text{if } |l| \geq 30^\circ
\]

\[
N_0(l, b) = \frac{85.5}{\sqrt{1 + (l/35)^2} \sqrt{1 + (b/1.8)^2}} + 0.5 \quad \text{if } |l| \leq 30^\circ
\]

the gamma flux from WIMP annihilation is:

\[
\phi_\chi(E, \psi) = 3.74 \cdot 10^{-10} \left( \frac{\sigma v}{10^{-26} \text{ cm}^3\text{s}^{-1}} \right) \left( \frac{50 \text{ GeV}}{M_\chi} \right)^2 \sum_f \frac{dN_f}{dE} B_f \cdot J(\psi) \text{ cm}^{-2} \text{s}^{-1} \text{ GeV}^{-1} \text{sr}^{-1}
\]

and it depends from \( \sigma v \) and \( M_\chi \)
Model independent results for the GC

- Assume a truncated NFW profile
- Assume a dominant annihilation channel
  (good assumption except for $\tau^+ \tau^-$)

**Differential yield for each annihilation channel**

WIMP mass=200GeV

Model independent results for the GC

WIMP contribution higher than the maximum allowed by EGRET

uncertainties:
H column density

$<J(\psi)> = 10^4$

$\Delta \Omega \sim 10^{-5} \text{ sr}$

Effective exposure (per year)
$3.7 \times 10^{10} \text{ cm}^2 \text{ s}^{-1}$

4 years exposure
$3 \sigma$
Model independent results for the GC

Results for different dominant annihilation channel

Model independent GLAST reach (3σ)

NFW profile, $\pi^0$ background, $W^+W^-$ annihilation channel

Excluded by EGRET

Not visible by GLAST

Model independent GLAST reach (3σ)

NFW profile, $\pi^0$ background, $\tau^+\tau^-$ annihilation channel

Excluded by EGRET

Not visible by GLAST
Model independent results for the GC

visible by GLAST (3σ)

excluded by EGRET

4 yr observation of GC (truncated NFW) in a 0.1 deg region with gtobssim (Eth=100 MeV) + Background (GalDiffuse)
**Galactic Center**

**HESS Spectrum**

*Unbroken power-law.*

- **Hard spectrum** $\Gamma = 2.2$.
- **No evidence for variability on a variety of time scales.**

*Consistent with SGR A* to 6” and slightly extended.*

Good agreement between HESS and MAGIC (large zenith angle observation).

astro-ph/0512469
it might still be that a DM component could be singled out, e.g. the EGRET source (?): a DM source can fit the EGRET data; GLAST would detect its spectral and angular signatures and identify without ambiguity such DM source!
Conclusion

Discovery Potential for Supersymmetry

• GLAST will explore a good portion of the supersymmetric parameter space

• Search complementary to antimatter, LHC and Direct Search