GALACTIC DARK MATTER & SUSY PARAMETER SPACE

Dmitri Kazakov

JINR(Dubna) & ITEP(Moscow)

In collaboration with W. de Boer, C. Sander, V. Zhukov (Uni Karlsruhe)
and A. Gladyshev (JINR, Dubna)

Outline

• Diffuse Galactic γ Rays from EGRET
• DM annihilation in the MSSM
• Restriction to SUSY Parameter Space
• SUSY Production at LHC in EGRET Region
• Conclusions

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**DIFFUSE GAMMA RAYS FROM THE SKY**

**Instrumental parameters:**
- Energy range: 0.02–30 GeV
- Energy resolution: ~20%
- Effective area: 1500 cm²
- Angular resol.: <0.5°
- Data taking: 1991–2000

**Main EGRET results:**
- Catalogue of point sources
- Excess in diffuse gamma rays

EGRET All-Sky Gamma-Ray Survey Above 100 MeV
EXCESS OF DIFFUSE GAMMA RAYS ABOVE 1 GEV

A: inner Galaxy (l=±30°, |b|<5°)
B: Galactic plane avoiding A
C: Outer Galaxy
D: low latitude (10-20°)
E: intermediate lat. (20-60°)
F: Galactic poles (60-90°)
PHYSICS PROBLEMS

• What is the origin of excess of diffuse Galactic Gamma Rays?
• What is Cold Dark Matter made of?
• Where are the Supersymmetric Particles?

Solution:

• EGRET excess is due to DM annihilation
• DM is made of WIMPs which are SUSY particles distributed in Halo of our Galaxy
• SUSY Neutralinos have a mass around 60 GeV and should be observable at the LHC
EXCESS OF DIFFUSE GAMMA RAYS WITH AND WITHOUT DM ANNIHILATION

\[ E^2 \times \text{flux [GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}] \]

- tot. background
- Pion decay
- Inverse Compton
- Bremsstrahlung
- \( \chi^2 \) (bg only): 178.8/7

\[ E^2 \times \text{flux [GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}] \]

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\[ \pi^0 \]

IC
Brems

\[ \pi^0 \]

IC
WIMPS
Brems
DM NEUTRALINO ANNHIILATION FINAL STATES

Dominant annihilation $\chi$-section:
$\chi + \chi \Rightarrow A \Rightarrow bb$ quark pair

Sum of diagrams should yield $<\sigma v> = 2 \cdot 10^{-26}$ cm$^3$/s to get correct relic density

B-fragmentation well studied at LEP!
Yield and spectra of positrons, gammas and antiprotons well known!
DM NEUTRALINO ANNIHILATION CROSS-SECTION

Dominant annihilation $\chi$-section:
$\chi + \chi \Rightarrow A \Rightarrow$ bb quark pair
BACKGROUND + SIGNAL DESCRIBE

EGRET DATA

Blue: background uncertainty
Blue: WIMP mass uncertainty
FIT TO WIMP MASS

Heavy neutralino \( M_\chi \sim 50-80 \text{ GeV} \)

Heavy WIMP is excluded
SUSY DARK MATTER

Neutralino = SUSY candidate for the cold Dark Matter
Neutralino = the Lightest Superparticle (LSP) = WIMP

\[ \tilde{\chi}^0 = N_1 \gamma + N_2 \tilde{z} + N_3 \tilde{H}_1 + N_4 \tilde{H}_2 \]

- photino
- zino
- higgsino
- higgsino

\[ M_{\chi}^{\exp} \geq 40 \text{ GeV} \]
\[ M_{\chi}^{\text{theor}} = 40 \div 400 \text{ GeV} \]

\[ R = (-1)^{3(B-L)+2S} \]
\[ R_p = +1, \quad R_p^- = -1 \]

- Superparticles are created in pairs
- The lightest superparticle is stable

SUSY’06, Irvine, 13 June, 2006
The lightest neutralino is almost bino – the superpartner of a photon
DM = superpartner of the CMB

<table>
<thead>
<tr>
<th></th>
<th>\tilde{b}^0</th>
<th>\tilde{w}^0</th>
<th>\tilde{t}_1^0</th>
<th>\tilde{t}_2^0</th>
</tr>
</thead>
<tbody>
<tr>
<td>\chi^0_1</td>
<td>0.833</td>
<td>0.026</td>
<td>0.122</td>
<td>0.018</td>
</tr>
<tr>
<td>\chi^0_2</td>
<td>0.119</td>
<td>0.621</td>
<td>0.187</td>
<td>0.072</td>
</tr>
<tr>
<td>\chi^0_3</td>
<td>0.014</td>
<td>0.030</td>
<td>0.442</td>
<td>0.515</td>
</tr>
<tr>
<td>\chi^0_4</td>
<td>0.033</td>
<td>0.323</td>
<td>0.249</td>
<td>0.395</td>
</tr>
</tbody>
</table>
MSUGRA can fulfill all constraints from WMAP, LEP, b→sγ, g-2 and EGRET simultaneously, if DM is neutralino with mass in range 50-100 GeV and squarks and sleptons are O(1 TeV)

\[ m_0 \text{ common spin 0 mass} \]
\[ m_{1/2} \text{ common spin } \frac{1}{2} \text{ mass} \]
\[ \tan \beta = \frac{v_2}{v_1} \]

**Stau coannihilation**

**\( m_A \) resonance**

**WMAP**

**EGRET**

**High \( \tan \beta \) solution**

\[ \tan \beta = 50 \]
EGRET POINT AND MASS SPECTRUM
FIT TO $\tan \beta$

$\tan \beta \sim 50$
### Fitted SUSY Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tan \beta )</td>
<td>52.2</td>
</tr>
<tr>
<td>( m_0 )</td>
<td>1500 GeV</td>
</tr>
<tr>
<td>( m_{1/2} )</td>
<td>170 GeV</td>
</tr>
<tr>
<td>Sign ( \mu )</td>
<td>+</td>
</tr>
<tr>
<td>( A(0) )</td>
<td>0</td>
</tr>
<tr>
<td>( \alpha_s(M_Z) )</td>
<td>0.122</td>
</tr>
<tr>
<td>( \alpha_{em}(M_Z) )</td>
<td>0.0078153697</td>
</tr>
<tr>
<td>( \sin^2 \theta_W \big</td>
<td>_{\overline{MS}} )</td>
</tr>
<tr>
<td>( m_t )</td>
<td>175 GeV</td>
</tr>
<tr>
<td>( m_b )</td>
<td>4.214 GeV</td>
</tr>
</tbody>
</table>

### SUSY Masses in GeV

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tilde{\chi}^0_{1,2,3,4} )</td>
<td>64, 113, 194, 229 GeV</td>
</tr>
<tr>
<td>( \tilde{\chi}^{\pm}_{1,2} )</td>
<td>110, 130, 516 GeV</td>
</tr>
<tr>
<td>( \tilde{u}<em>{1,2} = \tilde{c}</em>{1,2} )</td>
<td>1519, 1523 GeV</td>
</tr>
<tr>
<td>( \tilde{d}<em>{1,2} = \tilde{s}</em>{1,2} )</td>
<td>1522, 1524 GeV</td>
</tr>
<tr>
<td>( \tilde{t}_{1,2} )</td>
<td>906, 1046 GeV</td>
</tr>
<tr>
<td>( \tilde{b}_{1,2} )</td>
<td>1309, 1152 GeV</td>
</tr>
<tr>
<td>( \tilde{e}<em>{1,2} = \tilde{\mu}</em>{1,2} )</td>
<td>1497, 1499 GeV</td>
</tr>
<tr>
<td>( \tilde{\tau}_{1,2} )</td>
<td>1305, 1288 GeV</td>
</tr>
<tr>
<td>( \tilde{\nu}<em>e, \tilde{\nu}</em>\mu, \tilde{\nu}_\tau )</td>
<td>1495, 1495, 1286 GeV</td>
</tr>
<tr>
<td>( h, H, A, H^\pm )</td>
<td>115, 372, 372, 383 GeV</td>
</tr>
</tbody>
</table>
**SIGNATURE:**
4 b-jets + 4 muons + $E_{t}^{\text{miss}}$

**LARGE!**

**m$_{0}$** = 1400 GeV  
**m$_{1/2}$** = 180 GeV  
A = 0  
$\text{sign}(\mu)$ = +1  
$\tan \beta$ = 50  

**$\sigma \approx 13 \text{ pb}$**
SUSY $gg \rightarrow \tilde{g}\tilde{g}$ IN ATLAS

JINR(Dubna) ATLAS Group
V. Bednyakov, Y. Budagov, G. Khoriauli, J. Khubua

Neutralino $p_T$

$\Delta p_T = 10$ GeV

Pythia within ATHENA, B-vertex tagging

\[ \sum p_T^{B,B_{\mu\nu}} \text{(down)} - \sum p_T^{B,B_{\mu\nu}} \text{(up)} = p_T \approx E_T \]

B mesons

Selection criteria:
* $R(\text{any } B \text{ in the event}) < 0.1$ mm

Efficiency = 94%
DIRECT DM SEARCHES

Spin-independent

Spin-dependent

Predictions from EGRET data assuming Supersymmetry

SUSY’06, Irvine, 13 June, 2006
CONCLUSIONS

If one accepts:
• the interpretation of excess in diffuse galactic gamma rays as a signal of the DM annihilation
• the interpretation of the Cold Dark Matter as SUSY neutralino particles

Then:
• SUSY provides simultaneous consistent description of all observable data including astrophysics
• Parameter space of SUSY is highly restricted
• In the narrow allowed region the SUSY mass spectrum may be predicted
• Light superpartners are observable at the LHC