Enhancement of Line Gamma Ray Signature from Bino-like Dark Matter Annihilation due to Threshold Singularity

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in preparation
Many observations indicate the existence of non-baryonic Dark Matter (DM).

In the MSSM, the lightest neutralino is a candidate for non-baryonic DM.

\[ \tilde{\chi}^0 = N_{\tilde{B}} \tilde{B} + N_{\tilde{W}} \tilde{W} + N_{\tilde{H}_1} \tilde{H}_1 + N_{\tilde{H}_2} \tilde{H}_2 \]

In many SUSY breaking scenarios, Bino-like neutralino is predicted as dark matter.
Motivation

• The viable models with Bino-like DM require “coannihilation” mechanism.

• Bino-like DM need to be nearly degenerate with NLSP, so that coannihilation is effective.

• This situation is realized by several models.

Ex. Bino-stau coannihilation region in MSUGRA, Electroweak Baryogenesis in MSSM, … and so on

\[ m_{\text{SUSY}} \sim a \ m_\chi \]

\[ \Omega h^2 \]

\[ m_\chi(\text{GeV}) \]

Profound and Yaguna

WMAP
Dark Matter (Halo) is associated with the galaxy, and distributes spherically.

The typical velocity of DM

\[ \frac{v}{c} \sim O(10^{-3}) \]

Dark Matter Searches

- Direct detection
- Indirect detection
  - Cosmic gamma rays
  - High energy neutrinos from Sun
  - Positron and anti-proton excess
We consider the case that

- dark matter is Bino-like neutralino,
- Bino is nearly degenerate with sfermion in mass,
- CP violating phase is in the sfermion mass matrix.

We found that the line gamma ray signature from Bino-like dark matter pair annihilation will be detectable by future Air Cherenkov Telescopes.
DM pair annihilation for indirect detection

- DM pair annihilation to two gammas is radiative process. 

  one-loop calculation by Bergstroem and Ullio

- When CP is violated, the transition between Bino two-body state in an S-wave and sfermion-antisfermion state in an S-wave can take place.

We consider the case that the CP violating phase is only in $A_T$ (or $A_t$).
Threshold Singularity

The higher-order contributions are enhanced due to threshold singularity.
Line Gamma Ray flux from the Galactic Center

parameters: $m_{\tilde{B}}$, $\delta m = m_{\tilde{f}} - m_{\tilde{B}}$, $\theta = \frac{\pi}{4}$, $\gamma = \frac{\pi}{2}$

NFW profile $\Delta \Omega = 10^{-3}$

\textbf{stau case}

\textbf{stop case}

Flux at one-loop of CP conserved case $< 10^{-14} \text{cm}^{-2} \text{sec}^{-1}$


Summary

• Line gamma ray flux from Bino-like DM pair annihilation may be enhanced due to threshold singularity.

• To realize this enhancement, in stau case, high degeneracy between Bino and stau is needed, while in stop case a few percent of degeneracy between Bino and stop is needed.

• Line gamma ray signature from Bino-like DM pair annihilation will be detectable by future experiments when CP is violated.
Back Up Side
**CP Violating Phase in the Sfermion Mass Term**

- **Sfermion mass matrix**

  \[
  \begin{pmatrix}
  M_L^2 + m_\tau^2 + \cos 2\beta (T_{3L} - Q \sin^2 \theta_W) m_Z^2 & m_Z^2 f_{LR}^2 \\
  m_Z^2 f_{LR}^* & M_R^2 + m_\tau^2 - \cos 2\beta Q \sin^2 \theta_W m_Z^2
  \end{pmatrix}
  \]

- **CP violating phase cannot be** in $\mu$, but **can still be** in $A_\tau$

- **We consider the case that the CP violating phase is only** in the $A_\tau$
Line Gamma Ray Flux from Galactic Center

\[ F_{\text{line}} = 1.9 \times 10^{-11} \text{ cm}^{-2}\text{s}^{-1} \Delta \Omega \left(\frac{100\text{GeV}}{m_{\tilde{\nu}}}\right)^2 \left(\frac{<\sigma v>}{10^{-27}\text{ cm}^3\text{ s}^{-1}}\right) \bar{J} \]

where
\[
\bar{J} \equiv \int_{\Delta \Omega} \frac{d\Omega}{\Delta \Omega} \int_{\text{line of site}} \frac{dl}{8.5 \text{ kpc}} \left(\frac{\rho}{0.3 \text{ GeV cm}^{-3}}\right)^2
\]

\[ \Delta \Omega = 10^{-3} \]

\[ \bar{J} = 500 \ (\text{NFW profile}) \]

\[ F_{\text{line}} = 9.5 \times 10^{-12} \text{ cm}^{-2}\text{s}^{-1} \left(\frac{100\text{GeV}}{m_{\tilde{\nu}}}\right)^2 \left(\frac{<\sigma v>}{10^{-27}\text{ cm}^3\text{ s}^{-1}}\right) \]