Neutrinos From WIMP Annihilations

Mattias Blennow
Royal Institute of Technology

(in collaboration with J. Edsjo and T. Ohlsson)

SUSY 07 Parallel Talk
Lehmann-Auditorium
Karlsruhe University
Outline

- WIMP capture
- Neutrino interactions
- Neutrino oscillations
- Conclusions
WIMP capture

- WIMPs from the halo scatter in the Sun and become gravitationally bound
- Sink to the solar core following subsequent scatterings

Neutrino production

- Neutrinos can be a byproduct of several WIMP annihilation channels
- We simulate the fluxes of neutrinos per annihilation into a specific channel
- The fluxes for a specific DM candidate can then be deduced from the branching ratios
Simulation details

- Simulations are performed for the following WIMP masses (in GeV):
  10, 25, 50, 80.3, 91.2, 100, 150, 176, 200, 250, 350, 500, 750, 1000, 1500, 2000, 3000, 5000, and 10000
- 2.5 million annihilations simulated per mass and annihilation channel
Neutrino production results

Generic example: $\tau^+ \tau^-$ annihilation channel, WIMP mass 250 GeV
Neutrino Interactions

- Neutral- and charged-currents
- NC degrade neutrino energy
- CC transforms neutrino to charged lepton
Neutrino interaction results

Neutrino fluxes at 1 AU
Mass: 250
Channel: 4

$\frac{dN_{\nu}}{dz}$ (ann$^{-1}$)

$z = \frac{E_{\nu}}{m_\chi}$
Oscillations of “ordinary” solar neutrinos

- Third mass eigenstate decouples
- Insignificant amount of neutrino interactions
- Low energy
- Loss of coherence
- Only $\nu_e$
WIMP neutrino oscillations

- Energy is above the high MSW resonance at production (third state does not decouple)
- No certain coherence loss
- Sizable interactions
**Neutrino oscillation results**

**At $R_{\text{SUN}}$:**

Best-fit $\nu$-osc param: $\theta_{13} = 10^\circ$:

(Neutrinos, normal hierarchy)
Propagation to 1 AU

- Obviously no interactions after $R_{\text{SUN}}$
- Straightforward vacuum neutrino oscillations
Neutrino oscillation results

At 1 AU:

Best-fit $\nu$-osc param:

$\theta_{13} = 10^\circ$:

(Neutrinos, normal hierarchy)
Propagation to detector

- Experiments will not be located at exactly 1 AU distance from the Sun
- Evolve to detector
Propagation to detector

- Example detector at the south pole averaged over the detection location over one year (any similarity to location of real detector is not accidental)
- The main effect is to smoothen the oscillatory pattern
- This is due to the eccentricity of the Earth orbit
Detector flux results

Best-fit parameters:

![Graph showing neutrino fluxes at detector.](image)
Detector flux results

- In principle, the oscillatory pattern will remain if statistics for parts of the year is large enough or $L/E$ behavior is observed, however ...
- ... energy resolution becomes an issue
- With a WIMP candidate providing monochromatic neutrinos, energy resolution is irrelevant
Comparison to previous results

• Similar study provided by Cirelli et al., NPB 727 (2005) 99

• Differences:
  – Their study focuses on the neutrino energy spectra while our study is event-based
  – Our study is fully implemented as a MC usable with DarkSUSY and experimental MCs (code already in use by IceCUBE)
  – Minor discrepancies
Summary and conclusions

- Neutrino oscillations can result in significant changes in the neutrino spectra.
- $\nu_\mu$ and $\nu_\tau$ mix already during propagation out of the Sun.
- $\nu_e$ is mainly mixed during the vacuum propagation to the Earth.
Summary and conclusions

• Results are not very sensitive to exact neutrino oscillation parameters

• For neutralino DM
  – Usually less $\nu_\tau$ is produced
  – $\nu_\mu$ flux reduced
Summary and conclusions

- For KKDM
  - Annihilates into charged leptons (20% each)
  - Only $\tau$ decay before interacting
  - Results in significant increase of $\nu_\mu$ compared to the non-oscillation case (about a factor of four)
Summary and conclusions

• Code written in a general format easily implementable by neutrino telescope Monte Carlos
Technicalities

- Annihilations and interactions simulated using Pythia 6.400
- Interaction uses CTEQ6 parton distribution functions
Neutrino oscillations

- Occur since neutrino flavor eigenstates are not equivalent to the neutrino mass eigenstates
- Six extra free parameters
- Two mass squared differences $\Delta m_{21}^2$ and $\Delta m_{31}^2$
- Three mixing angles $\theta_{12}$, $\theta_{23}$, $\theta_{13}$
- One complex phase $\delta$
Neutrino oscillation parameters

- Neutrino mixing status (2σ bound):
  
  \[ \sin^2(2\theta_{12}) \sim 0.3 \ (0.25-0.34) \]
  
  \[ \sin^2(2\theta_{23}) \sim 0.5 \ (0.38-0.64) \]
  
  \[ \sin^2(2\theta_{13}) \sim 0.0 \ (< 0.028) \]
  
  \[ \delta \sim ?? \]

- Neutrino mass squared differences
  
  \[ \Delta m_{21}^2 \sim 8.1 \cdot 10^{-5} \text{ eV}^2 \ (7.5-8.7) \]
  
  \[ |\Delta m_{31}^2| \sim 2.2 \cdot 10^{-3} \text{ eV}^2 \ (1.7-2.9) \]