Neutrino Signals from Gravitino Dark Matter Decays [1]

Michael Grefe

DESY Hamburg

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[1] Based on work in progress together with L. Covi, A. Ibarra & D. Tran

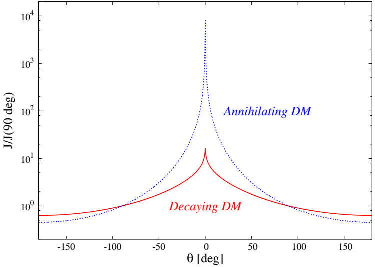
Outline

Decaying Gravitino DM vs Annihilating Neutralino DM

Annihilation

- Neutralinos accumulate inside the sun and the earth due to capturing via weak interactions.
- Flux $\propto \varrho^2 \longrightarrow$ Signal from 'point sources'.

$\Rightarrow$ Look at neutrinos from annihilations in the center of the sun or the earth!



[Bertone, Buchmüller, Covi & Ibarra (2007)]

Decay

- Gravitinos interact only gravitationally and do not accumulate inside stars or planets.
- Flux $\propto \varrho \longrightarrow$ 'Almost isotropic' signal.

$\Rightarrow$ Look for diffuse neutrino flux.

Signals from the galactic Center are not favored because of not well understood large galactic neutrino backgrounds.

Totally different strategies to observe the scenarios!

Outline

Gravitino Decays and Neutrino Spectra

The primary decay channels of the gravitino are:

$$\psi_{3/2} \to \gamma + \nu_\tau$$
$$\psi_{3/2} \to W^\pm + \tau^\mp$$
$$\psi_{3/2} \to Z^0 + \nu_\tau$$

Above we assumed that the gravitino decays dominantly into the tau lepton generation.

The branching ratios depend only on the gravitino mass.
Decay rates additionally depend on the gravitino lifetime.

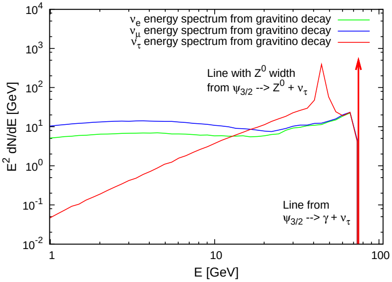
We consider gravitino parameters that can accommodate the EGRET excess.

$$m_{3/2} = 150\ \text{GeV} \qquad \tau_{3/2} = 1.6 \times 10^{26}\ \text{s}$$

Energy spectrum for neutrinos from gravitino decay:

$$\frac{dN_\nu}{dE} = \text{BR}(\gamma + \nu_\tau)\,\delta\left(E - \frac{m_{3/2}}{2}\right) + \text{BR}(W + \tau)\,\frac{dN_\nu^W}{dE} + \text{BR}(Z^0 + \nu_\tau)\,\frac{dN_\nu^Z}{dE}$$

Neutrino spectra from W and Z channels were produced with `PYTHIA`.



Galactic Flux

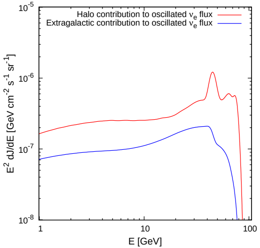
$$\frac{dJ_{halo}}{dE} = \frac{1}{4\pi\tau_{3/2}m_{3/2}} \int_{l.o.s.} \varrho_{halo}(\vec{l})d\vec{l} \cdot \frac{dN_\nu}{dE}$$

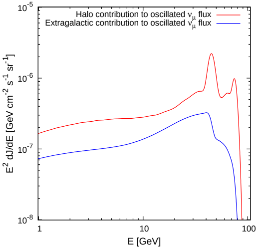
- We use a NFW halo density profile.
- We exclude the galactic disk to avoid the galactic neutrino background.
- We average over the galactic flux.

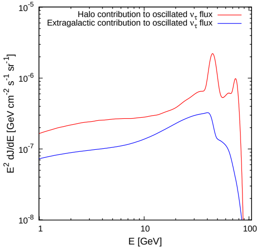
Extragalactic Flux

$$\frac{dJ_{eg}}{dE} = \frac{\Omega_{3/2}\varrho_c}{8\pi\tau_{3/2}H_0\Omega_M^{1/2}} \int_1^\infty dy \frac{dN_\nu}{d(yE)} \frac{y^{-3/2}}{\sqrt{1+\Omega_\Lambda/\Omega_M y^{-3}}}$$

- Redshifted spectrum from decays at extragalactic distances.
- Extragalactic contribution dominated by halo contribution.







We included neutrino propagation and averaged over neutrino oscillations.

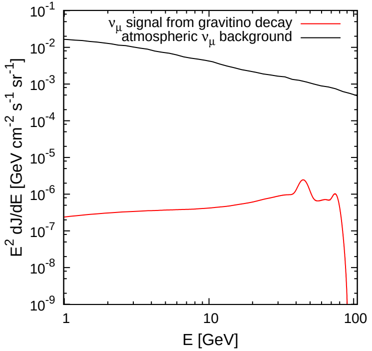
$\Rightarrow$ Signals for ν_μ and ν_τ are equivalent.

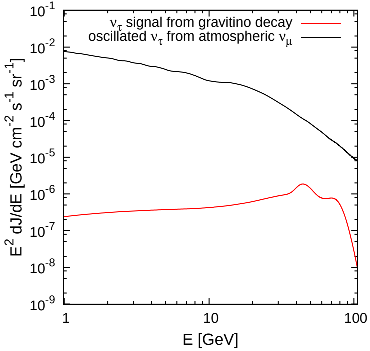
Neutrino signal does not crucially depend on dominant decay to tau generation!

Outline

Neutrino Background

- Main neutrino background comes from atmospheric electron and muon neutrinos.
- We used the fluxes generated with FLUKA [Battistoni et al. (2001)]
- Atmospheric tau neutrino flux is several orders of magnitude below the other flavors.
- Main contribution to tau neutrino background comes from oscillations between muon and tau neutrinos.

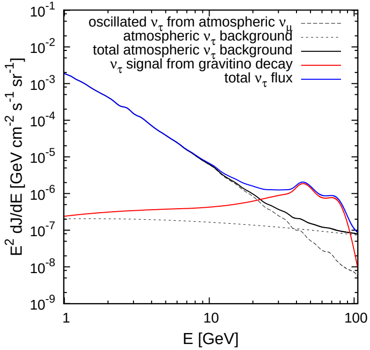




Diffuse neutrino signal from gravitino decays lies far below the atmospheric neutrino background for all neutrino flavors!

Reduction of the Neutrino Background

- For tau neutrinos the background can be reduced dramatically if we only look at the upper hemisphere.
- Then also the background from tau neutrinos produced in the atmosphere has to be included.
- We used the tau neutrino flux from atmospheric charm decays calculated with `PYTHIA` [Pasquali & Reno (1998)] and extrapolated to energies below $100\ \mathrm{GeV}$.



For the upper hemisphere the signal lies above the background for $E \gtrsim 20\ \mathrm{GeV}$.

The tau neutrino signal from decaying gravitino dark matter could in principle be observable at neutrino observatories!

Signals at Neutrino Observatories

SuperKamiokande can detect and identify tau neutrinos [Kato (2007)].

Unfortunately our flux is so low that it results in roughly one event per one hundred years in the fiducial volume of SK (22.5 kton).

Still the flux should be observable in a km^3 detector like IceCube. Then the same flux would result in several hundred events per year.

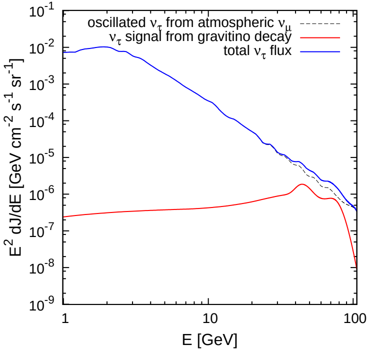
Problem:

- IceCube looks downward!

Look for a signal near the horizon! For example in the region $-0.1 < \cos\theta < 0$ the signal is comparable to the averaged background.

Caution:

- The ratio of signal to background is strongly dependent on the observed solid angle!



Other problems:

- Energy threshold for IceCube will be about 100 GeV.
- With Amanda reduction to 30 GeV possible.
- By now no strategy to identify ν_τ below several TeV known.

Outline

Conclusions and Outlook

- Neutrinos from decaying gravitino dark matter are most likely observable in the tau sector!
- Background is most effectively reduced looking in the upward direction for high energies.
- Future neutrino experiments like HyperKamiokande (~ 0.5 Mton) can improve the sensitivity for the signal.
- Observability of the signal increases if the gravitino has a larger mass since the background decreases for higher energies.
- Detailed searches for this signal should be made if specific gravitino parameters are favored or fixed by observations in other channels. A signal in γ-rays observed with GLAST could provide this in the near future.

- The same strategy to reduce the background could also be applied to tau neutrinos from neutralino annihilations in the sun!