Neutrinos From Solar WIMPs

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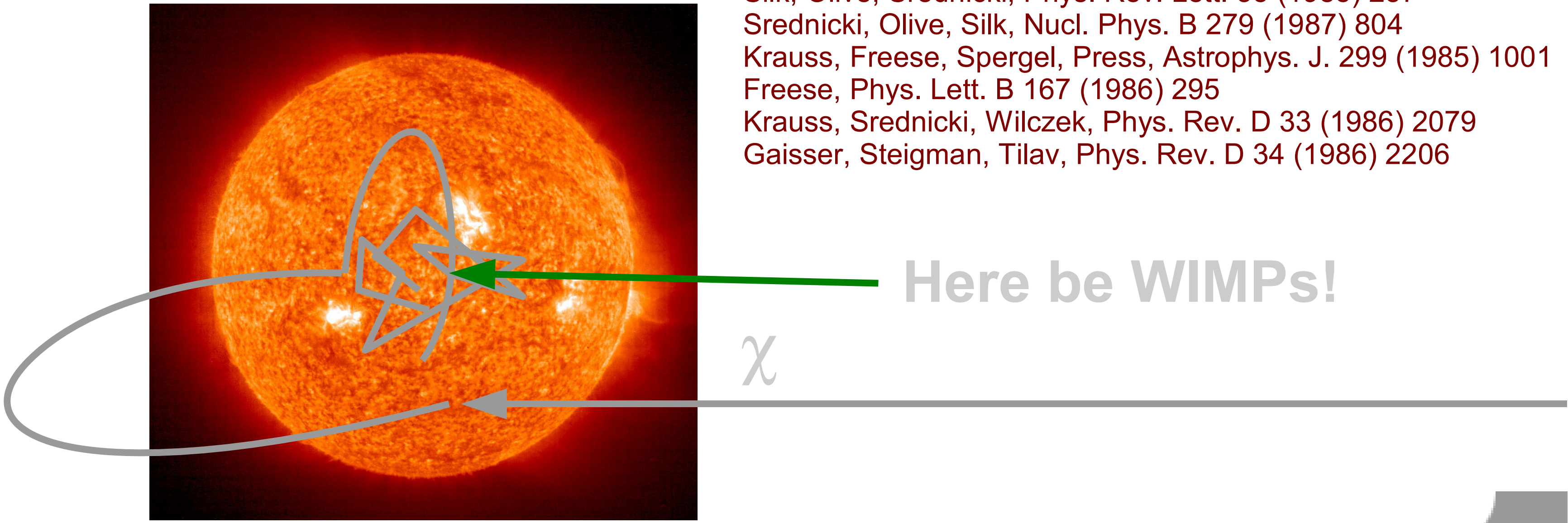
Outline

- WIMP capture
- Neutrino propagation
  - 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

Silk, Olive, Srednicki, Phys. Rev. Lett. 55 (1985) 257
Srednicki, Olive, Silk, Nucl. Phys. B 279 (1987) 804
Krauss, Freese, Spergel, Press, Astrophys. J. 299 (1985) 1001
Freese, Phys. Lett. B 167 (1986) 295
Krauss, Srednicki, Wilczek, Phys. Rev. D 33 (1986) 2079
Gaisser, Steigman, Tilav, Phys. Rev. D 34 (1986) 2206



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 specifc DM candidate can then be deduced from the branching ratios and annihilation rates

Simulation details

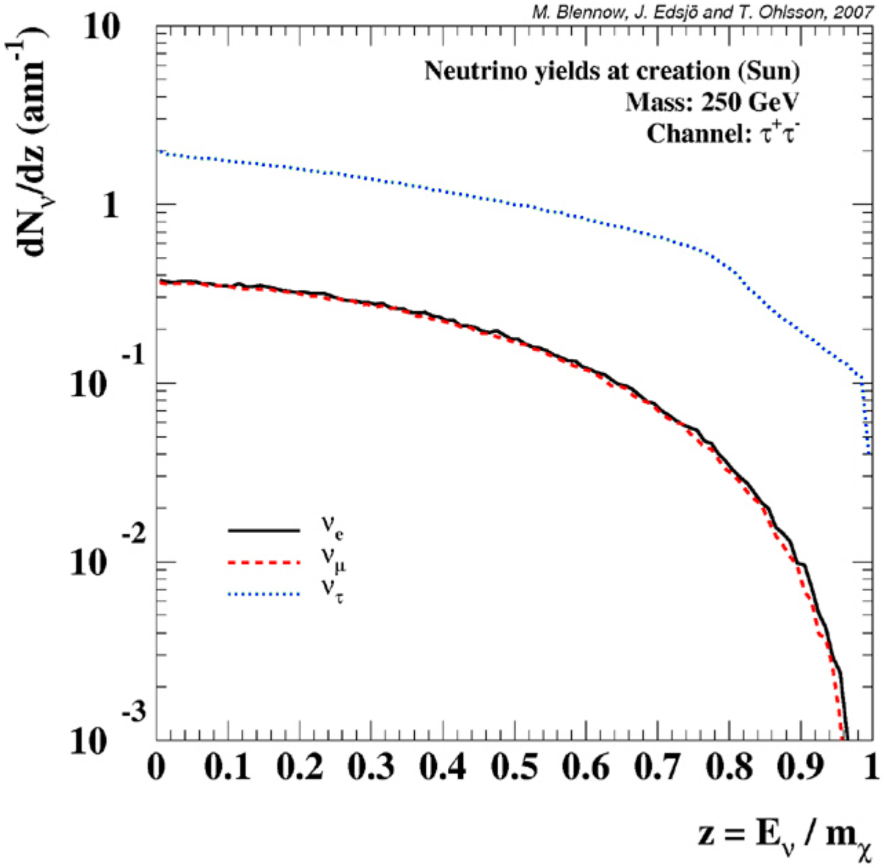
- Simulations are performed for the following WIMP masses (in GeV):

  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

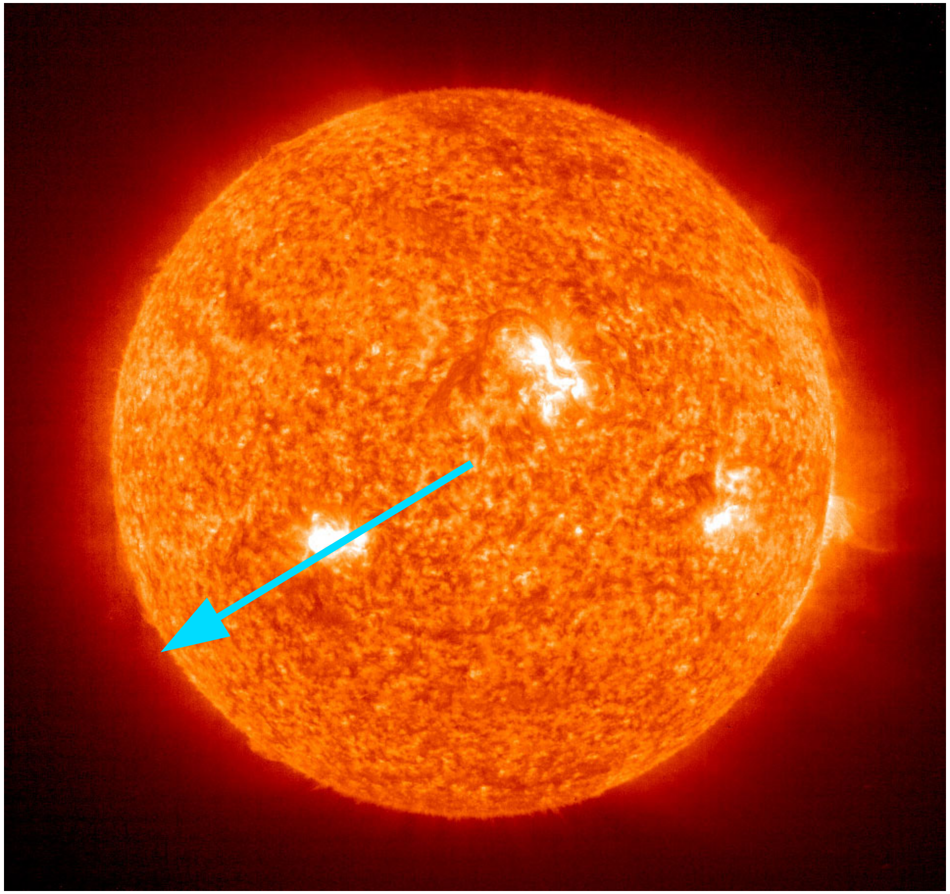
Neutrino production results

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


M. Blennow, J. Edsjö and T. Ohlsson, 2007

Neutrino Interactions

- Neutral- and charged-currents
- NC degrade neutrino energy
- NC does not affect flavor composition

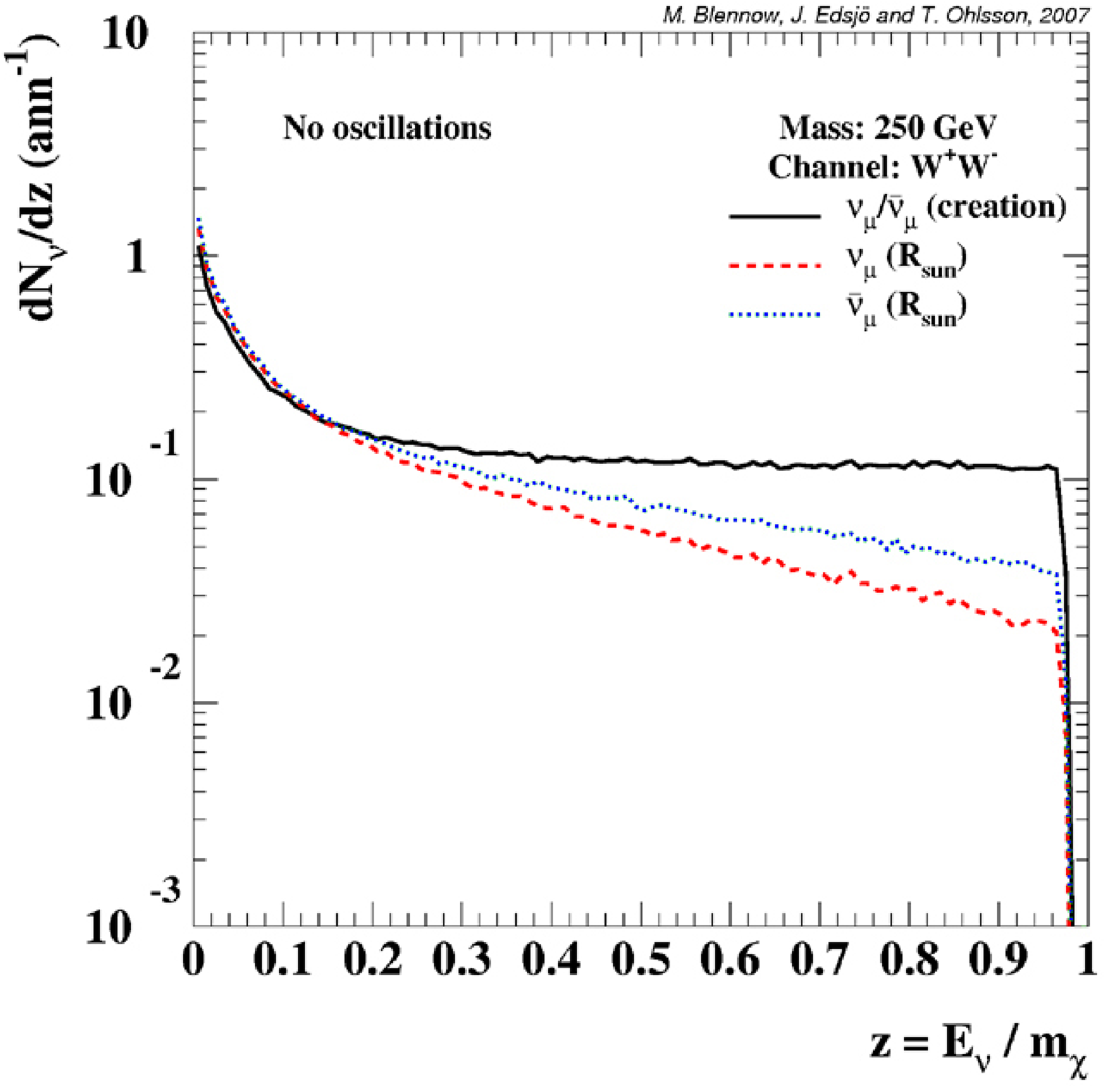


Neutrino Interactions

- CC interaction cross-sections are flavor dependent due to the τ mass
- Accounted for in interaction routines
- Among the CC interactions, only ν_τ interactions provide a secondary flux

Neutrino interaction results

M. Blennow, J. Edsjö and T. Ohlsson, 2007



Neutrino oscillations

- Occur since neutrino flavor eigenstates are not equivalent to the neutrino mass eigenstates
- Six extra free parameters
- Two mass squared differences Δm_{21}^2 and Δm_{31}^2
- Three mixing angles θ_{12}, θ_{23}, θ_{13}
- One complex phase δ

Neutrino oscillation parameters

- Neutrino mixing status (2σ bound):

Maltoni, Schwetz, Tórtola, Valle, New J. Phys. 6 (2004) 122

$\sin^2(\theta_{12}) \sim 0.3$ (0.25-0.34)

$\sin^2(\theta_{23}) \sim 0.5$ (0.38-0.64)

$\sin^2(\theta_{13}) \sim 0.0$ (< 0.028)

$\delta \sim$??

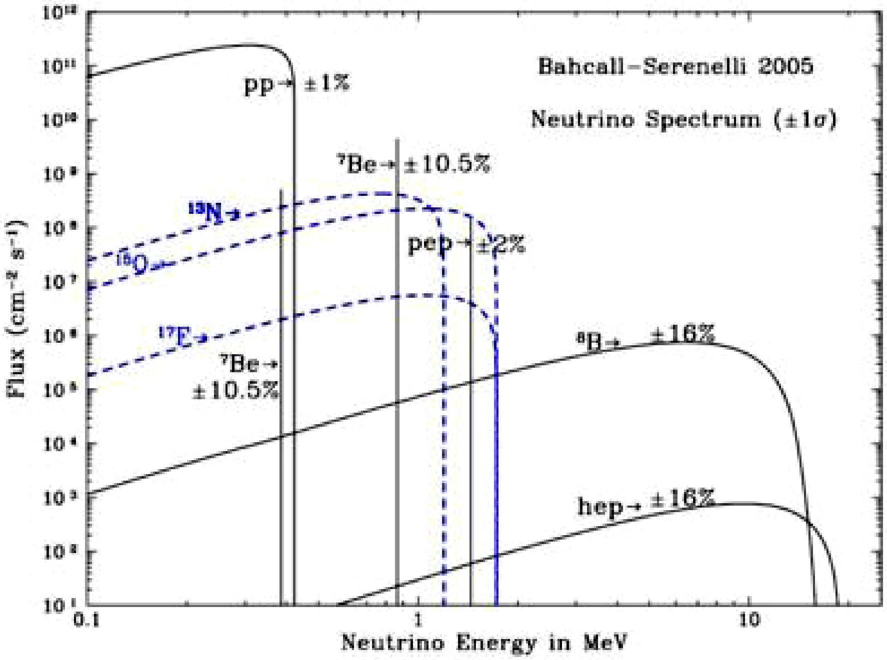
- Neutrino mass squared differences

$\Delta m_{21}^2 \sim 8.1 \cdot 10^{-5}$ eV^2 (7.5-8.7)

$|\Delta m_{31}^2| \sim 2.2 \cdot 10^{-3}$ eV^2 (1.7-2.9)

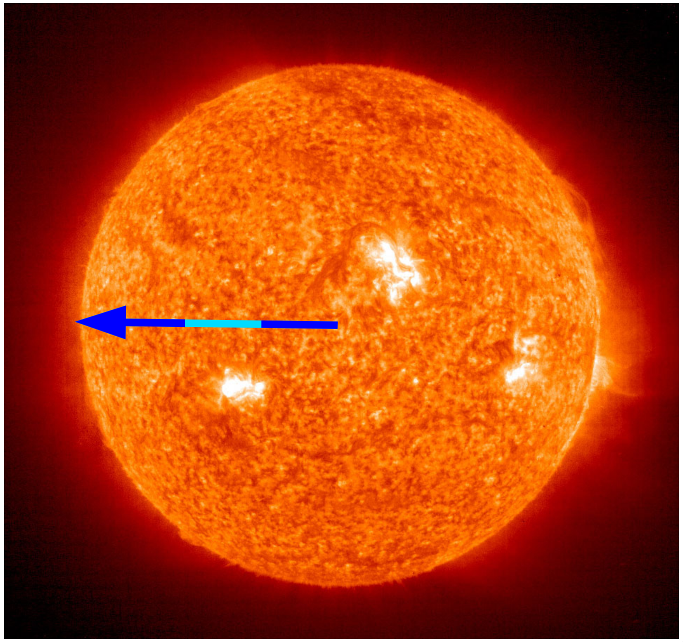
Oscillations of “ordinary” solar neutrinos

- Third mass eigenstate decouples
- Insignificant amount of neutrino interactions
- Low energy
- Loss of coherence
- Only ν_e



WIMP neutrino oscillations

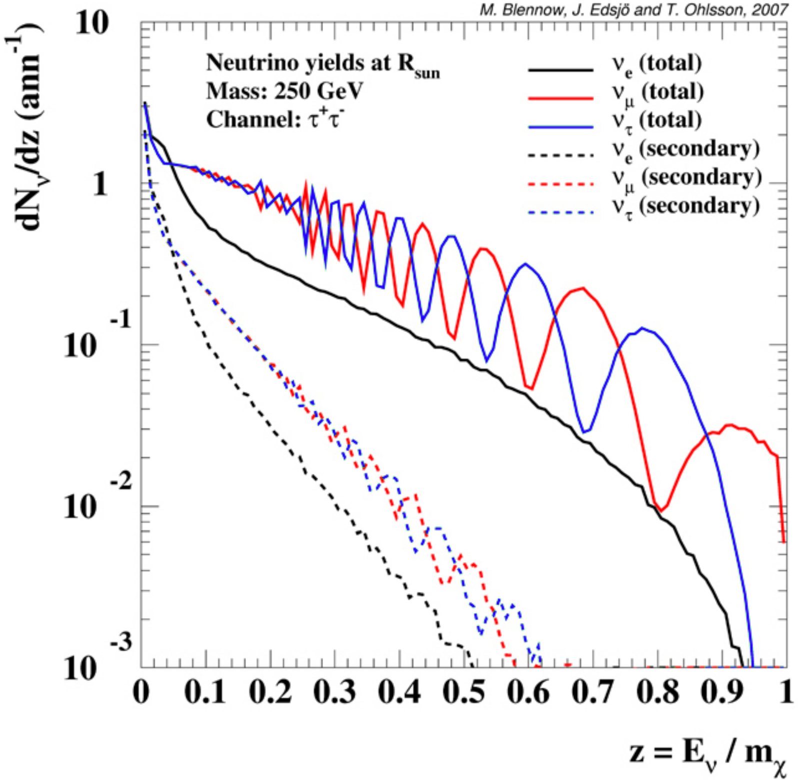
- Energy is above the high MSW resonance at production (third state does not decouple)
- No certain coherence loss
- Sizable interactions



Neutrino oscillation results

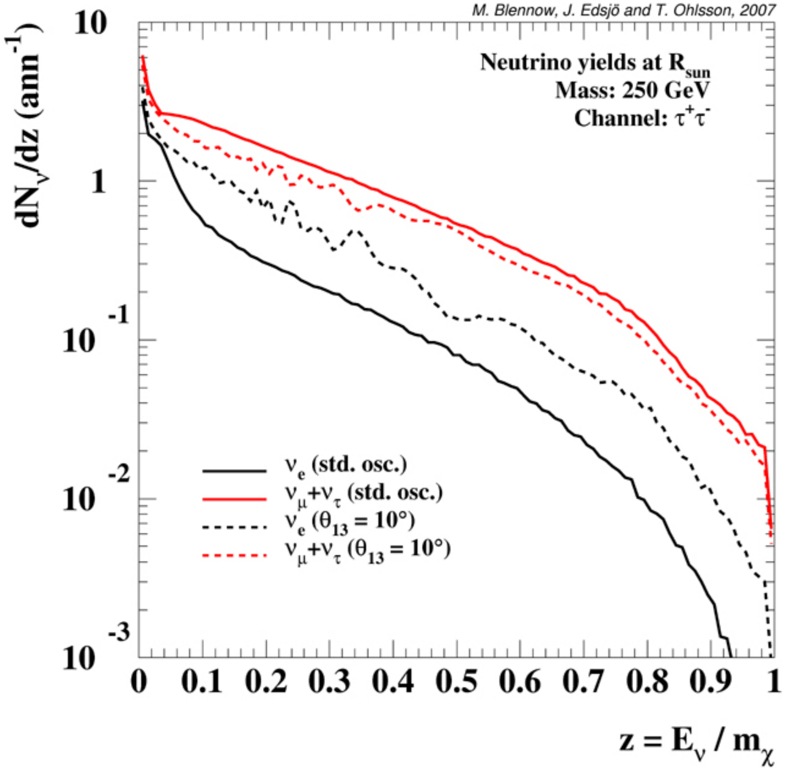
At R_{SUN}:

Best-fit ν-osc param:



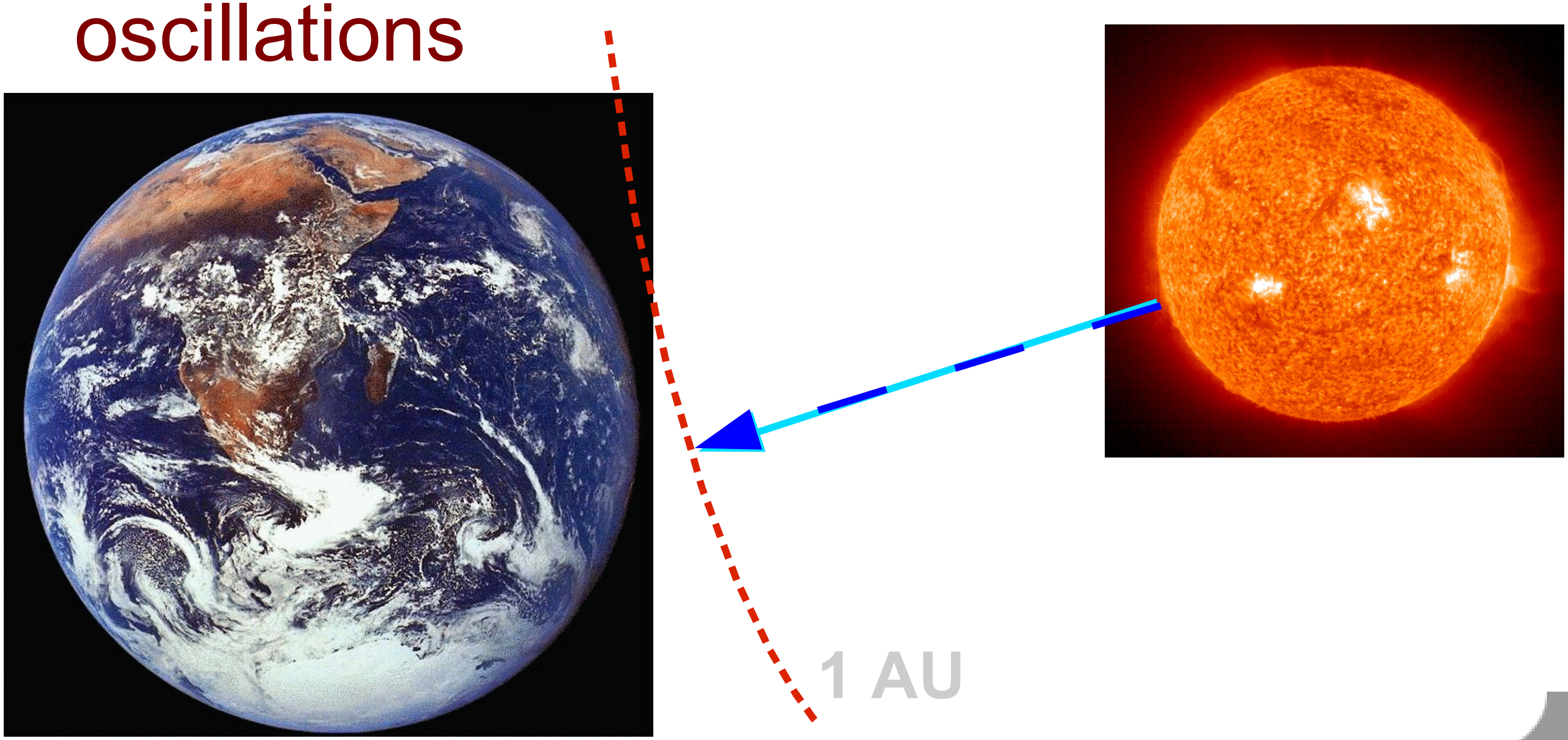
θ_{13} = 10º:

(Neutrinos, normal hierarchy)



Propagation to 1 AU

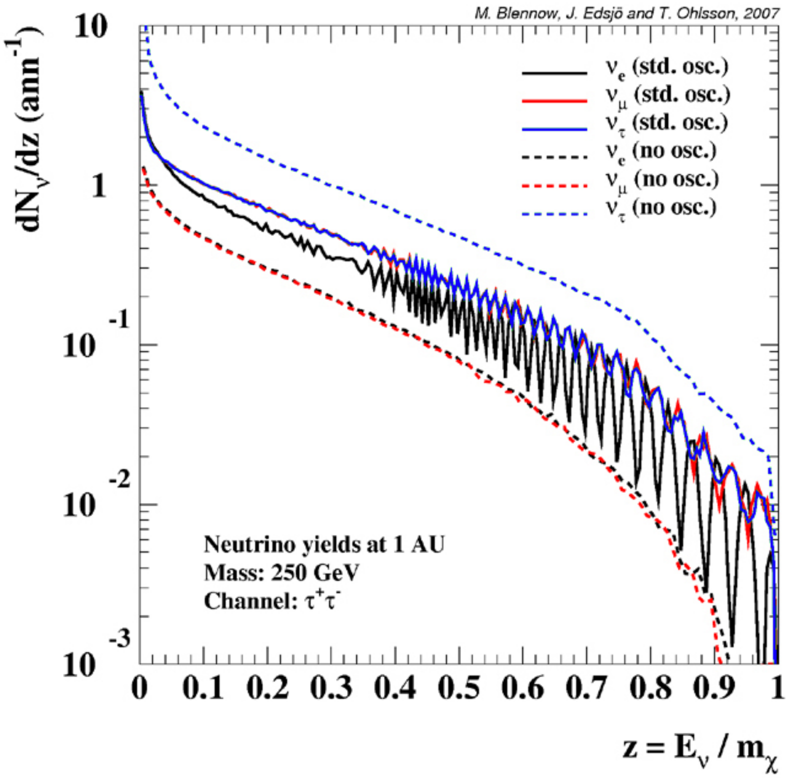
- Obviously no interactions after R_{SUN}
- Straightforward vacuum neutrino oscillations



Neutrino oscillation results

At 1 AU:

Best-fit ν-osc param:



θ_{13} = 10º:

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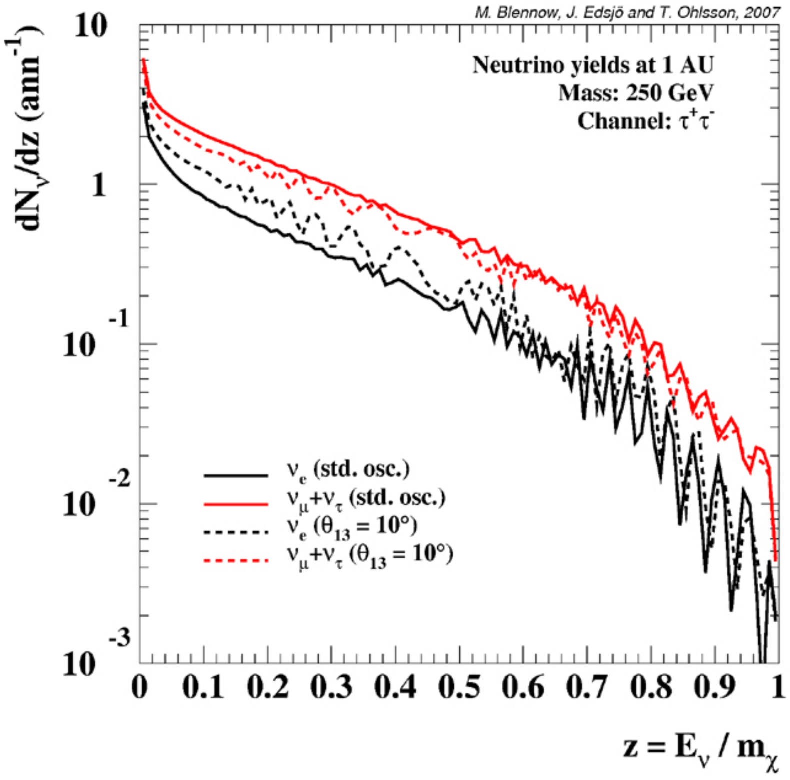
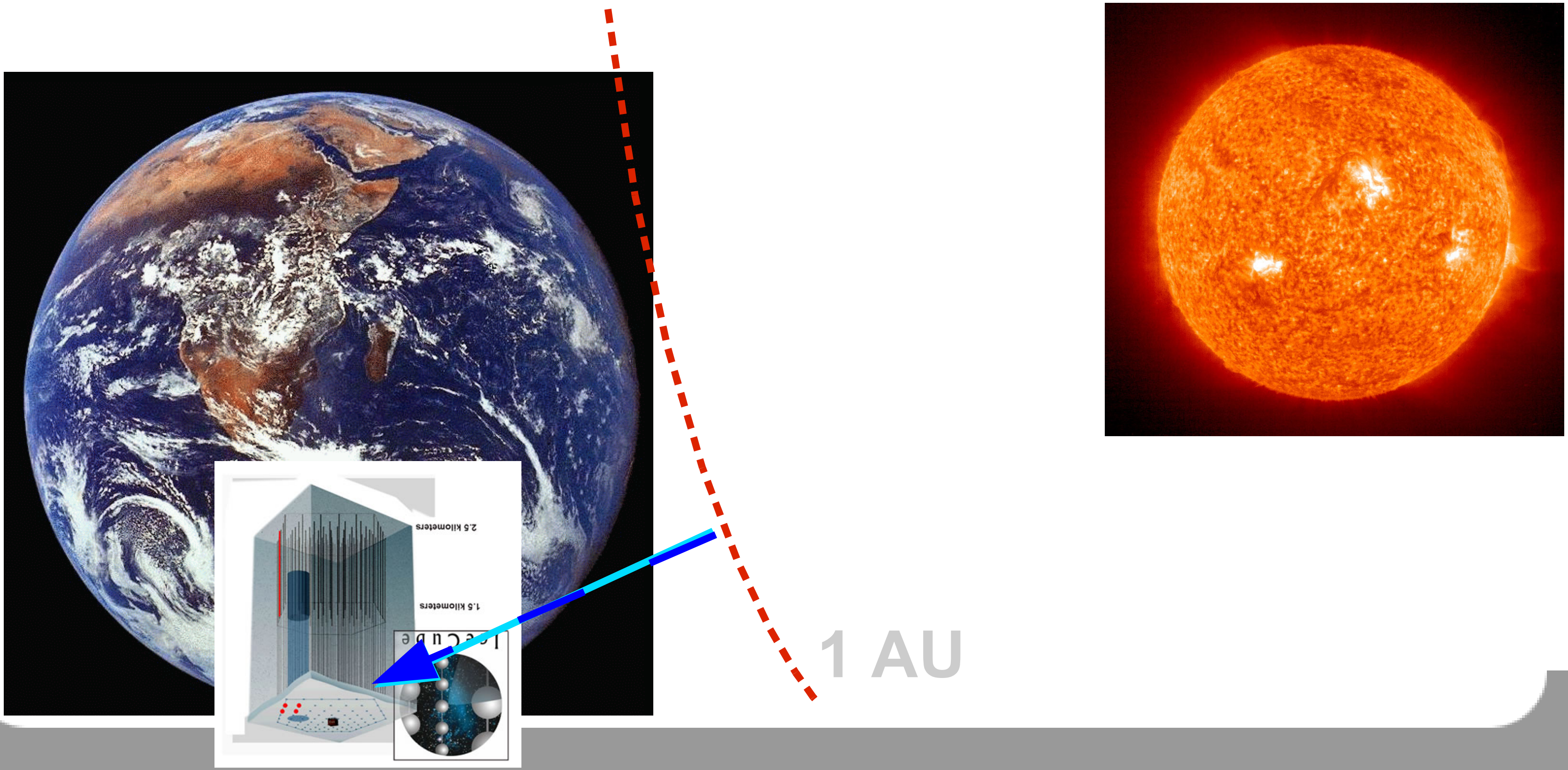


Propagation to detector

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

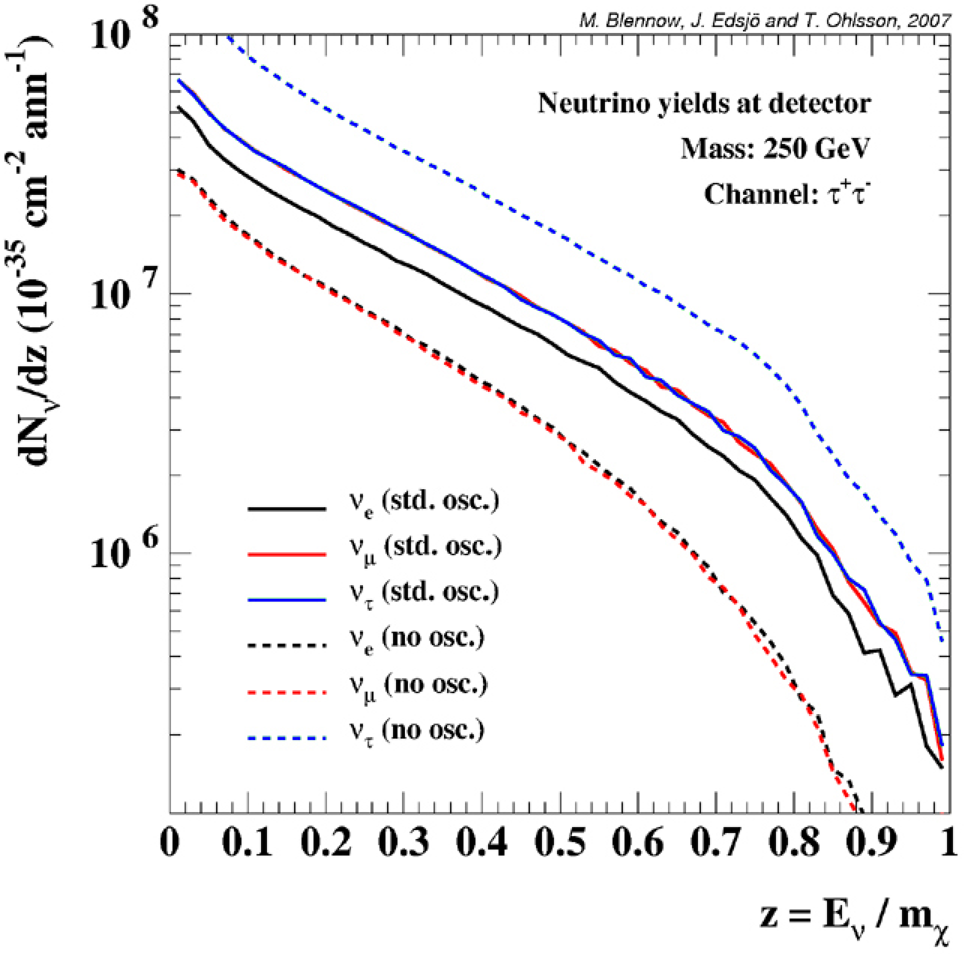


Propagation to detector

- Example detector at the south pole averaged over the detection location over one year
- 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:



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 enegry spectra while our study is event based
  - Our study is fully implemented as a MC usable with DarkSUSY and experimental MCs
  - Minor discrepancies

Technicalities

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

Summary and conclusions

- Neutrino oscillations can result in significant changes in the neutrino spectra
- ν_μ and ν_τ mix already during propagation out of the Sun
- ν_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 ν_τ is produced
  - ν_μ flux reduced

Summary and conclusions

- For KKDM
  - Annihilates into charged leptons (20 % each)
  - Only τ decay before interacting
  - Results in significant increase of ν_μ 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