Neutrino flavor conversion

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Overview

Motivation

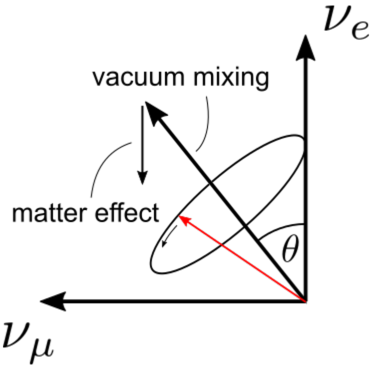
- flavor conversion changes measurements
- neutrino oscillation influenced by surrounding medium
  $\rightarrow$ MSW effect
- high neutrino density leads to collective effects
- might affect SN mechanism and nucleosynthesis

MSW effect

resonance phenomenon for slowly changing densities

mixing maximized from vacuum and matter

vector length related to electron density



Slow flavor conversion

caused by $\nu\nu$-interaction

same mechanism as the MSW effect
can occur in supernovae

important: coupling $>$ energy spread

can lead to a spectral swap in the energy distribution of ν_e and ν_μ

Fast flavor conversion

fast conversions based on completely different principle

fast because $\lambda_{\text{fast}} \sim$ m whereas $\lambda_{\text{vac}} \sim$ km

consider supernova environment with a high density of neutrinos

common oscillation suppressed

conversion possible, when correlation function blows up $\rightarrow$ instability

Correlation function

correlation function $\hat{=}$ mixing of neutrino states

Wigner transformed correlation function

$$S(\mathbf{x},\,\mathbf{k},\,t) = \int \mathrm{d}^3 y\, \mathrm{e}^{-i\mathbf{k}\cdot\mathbf{y}} \nu_e \left(\mathbf{x} - \tfrac{\mathbf{y}}{2}\right) \nu_\mu^\dagger \left(\mathbf{x} + \tfrac{\mathbf{y}}{2}\right)$$

linearized equation of motion $\hat{=}$ first order wave equation

$$i\left(\partial_t + \mathbf{v}\cdot\partial_{\mathbf{x}}\right) S_{\mathbf{v}} = \tfrac{\mu}{4\pi} \int \mathrm{d}\mathbf{v}' \,\left(1 - \mathbf{v}\cdot\mathbf{v}'\right) G_{\mathbf{v}'} S_{\mathbf{v}'}$$

with $G_{\mathbf{v}} \sim$ lepton number distribution

Izzaguirre et al. arXiv:1610.01312

Dispersion relation

plane wave ansatz $S \sim \exp\left[-i\left(\omega t - \mathbf{k}\cdot\mathbf{x}\right)\right]$

derive dispersion relation $\omega(\mathbf{k})$

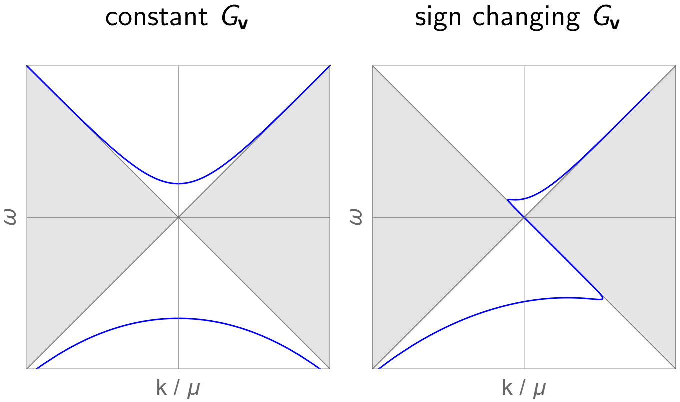
instable branch if $\omega(\mathbf{k}) \in \mathbb{C}$

$\rightarrow$ correlation function blows up

$\rightarrow$ ν_e and ν_μ become strongly mixed

looking for instability criterion

Examples



Duan et al. arXiv:1001.2799

Instability criterion

$G_{\mathbf{v}}$ axially symmetric around $\mathbf{k}$

- sign change in $G_{\mathbf{v}}$ necessary, but not sufficient
- single crossing $\Leftrightarrow$ instability
- several crossings: no simple rule

Capozzi et al. arXiv:1906.08794

non symmetric configuration:

- instabilities directional dependent

Summary

several effects influence neutrino behaviour

fast conversions arise on the shortest scales

criteria for occurence and importance for e.g. supernova explosion mechanism still unclear