Dispersion Relation and Neutrino Flavor Instabilities in Fast Modes*

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ABSTRACT PLACEHOLDER

I. INTRODUCTION

Neutrino flavor conversions in vacuum are linear effects in Schrodinger equation. In dense neutrino media, neutrinos demonstrate highly nonlinear flavor transformations due to forward scattering interactions of neutrinos. Such interactions lead to flavor conversions of different category from vacuum oscillations. The technique used to investigate the nonlinear effect is linear stability analysis.[1, 2] Recent studies by I. Izaguirre, G. Raffelt, and I. Tamborra show that neutrino flavor conversion instabilities is related to gaps in dispersion relation.[3] They showed that dispersion relation can be defined and calculated in linear regime of neutrino flavor conversions. In this work we argue that neutrino flavor conversion instabilities are not exactly mapped to gaps in dispersion relation.

II. DISPERSION RELATION OF NEUTRINO FLAVOR CONVERSION

We consider two-flavor scenario of neutrino oscillations. In principle, neutrino oscillations depend on three different contributions from vacuum oscillations, interactions with matter, and interactions with neutrinos themselves. The concentration of this work is on fast neutrino oscillations, which would occur even without neutrino mass differences. For completeness we keep the vacuum oscillations term in the calculations.

Another ingredient is the spectrum of neutrino distributions.

which is defined by the equation of motion

$$\mathrm{i}(\partial_t + \mathbf{v}\cdot\boldsymbol{\nabla})\rho = [H, \rho]\,, \tag{1}$$

where ρ is the traceless density matrix and H is the Hamiltonian. The density matrix is explicitly defined as

$$\rho = \frac{1}{2}\begin{pmatrix} 1 & \epsilon \\ \epsilon^* & -1 \end{pmatrix}. \tag{2}$$

Hamiltonian is composed of three contributions from vacuum oscillations H_{v}, interactions with matter H_{m}, as well as neutrino forward scattering potential $H_{\nu\nu}$. Vacuum oscillations term is defined

$$H_{\mathrm{v}} = -\frac{\omega_{\mathrm{v}}}{2}\sigma_3, \tag{3}$$

where $\omega = \frac{\delta m^2}{2}$ with δm^2 being the mass squared difference in this two flavor scenario. Interactions with matter is described by matter potential

$$H_{\mathrm{m}} = \frac{1}{2}\lambda\sigma_3. \tag{4}$$

where $\lambda = \sqrt{2}G_{\mathrm{F}} n_\nu$. G_{F} is the Fermi constant and n_ν is the number density of neutrinos. Neutrino forward scattering potential is

$$H_{\nu\nu} = . \tag{5}$$

III. PLAN OF THE PAPER

- ~~Review fast mode oscillations~~
- State what has been done in Raffelt's paper.
- The conclusion is not true.
- Two beams examples to prove that the number of solutions is the key.
- Show that the continuous case is not related to gap at all. Box spectrum?
- Continuous spectrum or Garching group, data to show that we can prove the location of the instability.

But I have a question. Is it really reliable? Should I use principal value integral for box spectrum DR?

We are still not crystal clear about the relation between gap and lsa.

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* A footnote to the article title

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[3] I. Izaguirre, G. Raffelt, and I. Tamborra, Physical Review Letters **118**, 021101 (2017), arXiv:1610.01612.