Neutrino oscillation and matter-antimatter asymmetry of universe

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I show that matter-antimatter asymmetry can be generated through the neutrino oscillation at the very beginning of the Universe. The neutrino oscillation happens due to the matter effect despite the tiny vacuum mass of the neutrino in the presence of the dimension-five term contributing to the ordinary Majorana neutrino mass. This talk is mainly based on Ref. [1]. See also the subsequent study [2, 3] appeared after this talk.

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1. Introduction

The origin of the matter-antimatter (baryon) asymmetry is a long-standing puzzle in the Standard Model (SM) in inflationary cosmology. The successful generation of the baryon asymmetry requires the process satisfying the Sakharov's conditions: **1.** the interaction violating the baryon number, **2.** the breaking of the C and CP symmetry, and **3.** the out of equilibrium of the interaction **1**. It was known that it is difficult to generate the baryon asymmetry within the SM and standard cosmology. So we need new physics to explain the baryon asymmetry.

A clear new physics is the neutrino oscillation, which means neutrinos have masses. To explain the neutrino oscillation, one of the simplest way is that the SM is an effective theory whose Lagrangian is with various higher dimensional operators. Then the total Lagrangian is in general given by

$$\mathcal{L} = \mathcal{L}_{\rm SM} - \frac{\kappa_{ij}}{2}(\bar{L}_i^c P_L L_j)HH + \text{h.c.} + ... \tag{1}$$

where $\mathcal{L}_{\rm SM}$ is the SM Lagrangian, H, L are SM Higgs and left-handed lepton fields, and ... denotes the $d > 5$ operators. Through the $LLHH$ term, the neutrinos get masses and can oscillate. The $LLHH$ term could arise, for example, by integrating out right-handed neutrinos [4, 5]. (See also Refs. [6].) It was also shown that one of the neutrino oscillation scales can be obtained in the supersymmetry broken at the Planck-scale if wino is anomaly induced [7]. In the scenario the charge assignment of the SM particle contents are predicted from anomaly-cancellation since the Higgs boson is identified as a slepton. It may also just exist and becomes strong at a high energy scale. We do not specify the UV model and we neglect the terms of ... in the following discussion.

The $LLHH$ term obviously breaks the lepton number. Within the SM there is a sphaleron effect which violates the baryon number, but conserves the baryon minus lepton (B-L) number. The effect is in equilibrium and can not sufficiently generate the baryon asymmetry, but can transfer the lepton number to baryon number. The baryogenesis via the this kind of asymmetry transferring is called leptogenesis [8]. Therefore, due to the interaction of the $LLHH$ we could have leptogenesis if **2** and **3** are satisfied.