# Curriculum Vitae

## Personal data


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## Education

4/2003 – 3/2007 College of Science and Engineering, Ritsumeikan University, Japan
-Awarded the degree of Bachelor of Science

4/2007 – 3/2009 Graduate School of Science and Technology, Niigata University, Japan
-Awarded the degree of Master of Science

4/2009 – 3/2012 Graduate School of Science and Technology, Niigata University, Japan
-Awarded the degree of Doctor of Science

## Research Experience

4/2012 – present Postdoc
(Maskawa Institute , Japan)

# List of Publications

## Publications

[1] "Baryogenesis via sterile neutrino oscillation and neutrino parameters,"
T. Asaka and H. Ishida, Prog. Part. Nucl. Phys. **64** (2010) 390.

[2] "Flavour Mixing of Neutrinos and Baryon Asymmetry of the Universe,"
T. Asaka and H. Ishida, Phys. Lett. B **692** (2010) 105

[3] "Mixing of Active and Sterile Neutrinos,"
T. Asaka, S. Eijima and H. Ishida, JHEP **1104** (2011) 011

[4] "Kinetic Equations for Baryogenesis via Sterile Neutrino Oscillation,"
T. Asaka, S. Eijima and H. Ishida, JCAP **1202** (2012) 021

[5] "Partial mass-degeneracy and spontaneous CP violation in the lepton sector,"
T. Araki and H. Ishida, arXiv:1211.4452 [hep-ph].

## Talks in the Conference of the Physical Society of Japan

[1] "Baryogenesis via right-handed neutrino oscillation"
Tokyo, Japan, 2009.

[2] "Baryogenesis via Sterile Neutrino Oscillation and Active Neutrino Parameters"
Okayama, Japan, 2010.

[3] "Flavour Mixing of Neutrinos and Baryon Asymmetry of the Universe"
Fukuoka, Japan, 2010.

[4] "Enhancement of CP violation in Neutrino Sector and Baryon Asymmetry of the Universe"
Niigata, Japan, 2011.

[5] "Momentum Dependence of Density Matrices in Baryogenesis via Neutrino Oscillation"
Hyogo, Japan, 2012

[6] "CP Violation in Neutrino Sector and Leptogenesis"
Kyoto, Japan, 2012

## Talks in the International Conference

[1] "Low energy CP violation in neutrino sector and baryogenesis via sterile neutrino oscillation",
in the "Summer Institute 2009", Fuji-Yoshida, Japan, 2009.

[2] "Low energy CP violation in neutrino sector and baryogenesis via sterile neutrino oscillation",
in the International Conference "Cosmo International Conference on Particle Physics and Cosmology 2009", Geneva, Switzerland, 2009.

[3] "Flavour Mixing of Neutrinos and Baryon Asymmetry of the Universe",
in the "Summer Institute 2010", Fuji-Yoshida, Japan, 2010.

[4] “Flavour Mixing of Neutrinos and Baryon Asymmetry of the Universe”,
in the International Conference
“Cosmo International Conference on Particle Physics and Cosmology 2010”
“Symposium on Cosmology and Particle Astrophysics 2010”, Tokyo, Japan, 2010.

[5] “Possibility of 1-2 Degenerate Model for Fermion Flavour Structure”,
in the “Japanese-German Symposium”, Kanazawa, Japan, 2012(invited).

# RESEARCH INTERESTS

The minimal standard model (MSM) is considered as the very successful model because its predictions have been confirmed by various experimental observations. Recently, however, there have been several phenomena which are inconsistent with the MSM, *e.g.* neutrino masses confirmed by Super Kamiokande and the cosmological dark matter and the baryon asymmetry of the universe (BAU) measured precisely by WMAP satellite. The MSM can not answer the origins of such phenomena. Then, we have to look for the "new Standard Model" instead of the MSM. From these reasons, I have been investigating with considering "What is the new physics?" and "How to confirm such a new physics?".

Currently, my research topics are the origin of flavour structure of fermions and phenomenological aspect of family gauge symmetry. And also, I have investigated the origins of neutrino masses and BAU in my PhD student days. Here, I would like to explain the later two problems. It can be solved simultaneously by introducing right-handed neutrinos. The extensively discussed possibility is to introduce superheavy right-handed neutrinos. However, I would like to take into account the observability of new particles, therefore I assume that the mass scale of right-handed neutrinos are below than electroweak scale ($\sim$ 100GeV). In such model, the BAU can be explained by baryogenesis via right-handed neutrino oscillation proposed by Akhmedov, Rubakov and Smirnov. Notice that even in this case tiny neutrino masses can be also explained by the seesaw mechanism taking Yukawa couplings small.

Specifically, I have investigated in the model called the $\nu$MSM, which is the MSM extended by three right-handed neutrinos with masses lighter than electroweak scale. This model is very attractive model phenomenologically. In this model, neutrinos are divided into two mass eigenstates, that is, the lighter one called 'active neutrinos' and the other heavier one called 'sterile neutrinos'.

Three sterile neutrinos have very important roles for particle / astroparticle physics. The lightest one is a candidate of cosmological dark matter. The rest two are responsible to generate not only the tiny neutrino masses by seesaw mechanism but also BAU through the mechanism below. The generated lepton asymmetries are stored to left-handed and right-handed sector separately due to CP asymmetry in the productions, destructions and flavor oscillation of right-handed neutrinos. Then, the stored asymmetry in the left-handed sector is partially converted into baryon asymmetry through the electroweak sphaleron processes. The notable thing about this mechanism is this mechanism can work even if right-handed neutrinos have the masses lighter than electroweak scale. These two right-handed neutrinos connect low energy parameters *i.e.* active neutrino masses, the mixing angles of neutrinos and CP phases and very high energy physics *i.e.* BAU.

In Refs.[1, 2], I have neglected CP violation in the right-handed neutrino sector, and investigated the case when BAU is solely originated from CP violation in the mixing matrix of active neutrinos, PMNS matrix. In particular, I have estimated how the amount of BAU is changed by neutrino masses, mixing angles and CP phases. At first, I have shown that the produced asymmetry in the inverted hierarchy for neutrino masses is suppressed to 4% compare with normal hierarchy case. Secondary, when the atmospheric neutrino angle, $\theta_{23}$, has maximal value $\theta_{23} = \pi/4$, and the solar neutrino angle, $\theta_{13}$, is close to zero, the generation of BAU only in normal hierarchy case is suppressed very much, and so, the observable BAU can't be realized. From these consequences, I have emphasized the importance of the dependence on

$\theta_{23}$ and $\theta_{13}$ for BAU. We should focus on the deviations $\theta_{23}$ from maximal angle and $\theta_{13}$ from zero on the future experiments. Finally, I showed the correlation between BAU and active CP phases (Dirac phase $\delta$ and Majorana phase $\eta$). It has been found that BAU depend on $\sin(\delta+\eta)$ in the normal hierarchy case, on the other hand on $\sin\eta$ in the inverted hierarchy case.

In Ref.[3], I have investigated the direct detectability of right-handed neutrinos with masses lighter than pions. In previous work, the existence of such a light neutrinos was forbidden because the upper bound of interactions from direct searched is not consist with the lower bound of interactions constrained from lifetime of right-handed neutrinos to keep the successful of big bang nucleosynthesis.

But from my work, Yukawa couplings can be bigger exponentially due to CP violation in the right-handed neutrino sector. The lifetime of right-handed neutrinos can become short enough to avoid the constraints from big bang nucleosynthesis. On the other hand, when Yukawa couplings become bigger, the constraints from direct detection become stringent. Especially, the electron type is the most stringent one in the current bounds. However, I have found that Yukawa couplings of the electron type can be received strong suppression in the normal hierarchy case. Such suppression mechanism can be applied in all mass region of the model.

Furthermore, I have discussed about the effective decay channels of the mesons to detect right-handed neutrinos. In the normal hierarchy case, the decays into electrons or positrons might be missed because of the suppression mechanism of the electron type interaction. Then the muonic decay is very important signal to verify right-handed neutrinos.

In Ref.[3], I have also investigated about neutrinoless double beta ($0\nu\beta\beta$) decay. The decay rate of $0\nu\beta\beta$ decay is characterized by the effective mass of electron neutrino which denoted by neutrino masses and the elements in the PMNS matrix. In the $\nu$MSM, right-handed neutrino can have light masses closed to typical energy scale for $0\nu\beta\beta$ decay ($\sim$ 100MeV). Therefore, the effective mass would be changed by light right-handed neutrinos in the $\nu$MSM.

In the case all right-handed neutrinos are much smaller than 100MeV, I have been able to show the effective mass becomes negligibly small than the MSM case using seesaw mechanism. On the other hand, in the case right-handed neutrinos have masses comparable to 100MeV, the contribution from right-handed neutrinos are destructive contributions to the effective mass. Then, the decay rate of $0\nu\beta\beta$ decay is smaller in the $\nu$MSM than the MSM generally. From these conclusion, the observation of $0\nu\beta\beta$ decay can not give any constraints to light right-handed neutrinos in the $\nu$MSM.

In Ref.[4], I have presented the kinetic equations for the matrix of densities of leptons which describe the generation of asymmetries with the momentum dependence of the matrix of densities. The reason of this work is to verify the effect of the modes with low momenta. We show the most important mode for the yields of sterile neutrinos as well as the baryon asymmetry is $k \simeq 2T$. This momentum is smaller than the thermal averaged one. Further, we have investigated the differences of the momentum dependence with the different right-handed neutrino masses. When right-handed neutrinos have comparatively small masses, *e.g.* 100MeV, the contributions from low momenta become important and the amount of asymmetry grow about 40%. But the amount of asymmetry does not change so much when right-handed neutrinos have heavy masses, *e.g.* 10GeV, because the modes with low momenta also become thermal equilibrium.

From now on, I would like to explain my current research and plan. I would like to clear up the problems which can not be solved by the MSM and verify the origins from the ground experiments or cosmological observation. For these purpose, my current research topic is the origin of the structure of fermions and phenomenological aspect of family gauge symmetry.

For the origin of the structure of the fermions, there is no guiding principle. In my work, I investigate partially degenerate model. Such a model can be induced naturally when the small parameter in the theory set to zero. In the neutrino sector, the atmospheric mass squared difference is much larger than the solar one. Then we assume the solar mass squared difference is zero limit, that is, $m_1^\nu = m_2^\nu$. In this limit, $O(2)$ symmetry appears in the neutrino sector. For the charged fermion sector, their masses are more hierarchical so that we consider the masses for the first and second generation are zero at leading order. This model can derive the mixing pattern of quarks and leptons without tuning of dimensionless couplings.

At present, I have no prediction in my model. Therefore, I will apply the phenomenological problems, *e.g.* lepton flavour and number violation and so on. With comparing with such phenomena, I can constrain my model and reveal the origin of the structure of fermions from current and near future experiments.

Secondary, I investigate the phenomenological aspect of family gauge symmetry. In experimental data, there might be several conflicts competing with universality of family. This conflicts might be solved by the contributions of family gauge boson.

Furthermore, I discuss the detectability of these gauge boson. In many of previous works, such gauge bosons are considered too heavy to produce at the collider. But Koide and Yamashita have proposed inverted hierarchy mass spectra for family gauge boson. If family gauge boson have inverted mass spectra, the third generation of family gauge boson is smallest. Then, this family gauge boson can be produced at the LHC. I will investigate these aspects and search beyond the SM.

At last, my continuing research topic is baryogenesis via neutrino oscillation which can work with the light right-handed neutrinos. Further, another remarkable feature is that this mechanism can connect BAU and neutrino parameters.

Additionally, I will research about the detectability of right-handed neutrinos. In particular, when right-handed neutrinos are lighter than pions, these right-handed neutrinos could be produced by near future experiments, for example J-PARC. I will contribute to the experimental fields through my research.

In my previous works, I have showed CP violating phase in right-handed neutrino sector has very important role for the existence of right-handed neutrinos having masses lighter than pions. Then it is the most necessary work for me to investigate BAU taking into account this CP violating phase. From these works, I will estimate BAU more accuracy and show the correlation between neutrino parameters. In addition to these, I will find out the CP violating pattern in the neutrino sector from the key component BAU.

I will extend the mass region of right-handed neutrinos to electroweak scale. If right-handed are heavier than pions, BAU tend to increase and lifetime becomes shorter so the parameter region open more. But the signals of right-handed neutrinos from the heavier meson decays will not distinguish well because there are many signals from the meson decays. Therefore, I will show the effective signals and parameter region to detect right-handed neutrinos directly. I will research these points inclusively and solve neutrino masses and BAU.

On the other hand, I will research about the detectability in the collider experiments *e.g.* LHC. To do this, I will investigate the production processes of right-handed neutrinos an its signature. Further, I will think about the contribution to the lepton flavor changing neutral currents measuring in MEG experiment etc. In these research, I will aim to show the possible parameter regions to discover right-handed neutrinos.

I will also research about the effect to big bang nucleosynthesis from right-handed neutrinos. If there are long-lived light right-handed neutrinos, expansion of the universe is accelerated and then the conversion rates between proton and neutron might be changed. In this case, it can not be consistent with current observation of the light elements. Then I will estimate such modifications and develop big bang nucleosynthesis.

Finally, the $\nu$MSM is also low energy effective theory I think. Therefore, I will construct the new unified model which can solve the origins of neutrino masses and BAU taking into account the conclusions from LHC and other experiments.

## REFERENCES

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