## Activity Report of the NAOJ Visiting Scholar Program

Host Project/Division: <u>Division of Theoretical Astronomy</u> Name of Host Scientist: <u>Toshitaka Kajino</u> \_\_\_\_\_\_ Name of Visiting Scholar: Yamac Deliduman

Title: Visiting Professor

Period: from 2017/04/01 to 2017/07/31

I. Report from the visiting scholar

[ i ] Achievement during the period of stay (in comparison with the initial plan)

(Collaborative Research)

1) We worked on the so called nu-p process of nucleosynthesis which happens in the hot bubble region of a core collapse supernova if the conditions are proton rich. In particular we worked on the effect of neutrino collective oscillations on the resulting abundances. We showed that collective neutrino oscillations always enhance the relevant neutrino reaction rates and increase the abundances of nu-p process nuclei. Since nu-p process syntheses very rare proton rich nuclei in the universe such as 130Ba whose origin is still not fully explained, our findings are very important for nuclear origins. This work was published in Physical Review D.

2) We also worked on the collective neutrino oscillation in an exact many-body formalism. Our study is strongly connected to the long standing mystery of the origin of r-process nuclei. R-process nucleosynthesis is believed to happen either at neutron star mergers or core collapse supernova but both theories have some problems and it is believed that the emerging many-body effects in collective neutrino oscillations play an important role in solving this mystery. Recently some groups started to work on these effects beyond the mean field approximation which is usually employed in the study of collective oscillations. The idea is that the mean field approximation may break down at some point and give rise to important consequences. We worked on the exact many-body system without adopting the mean field approximation and have found that the results are not very much different from the mean field prediction. This was an important result because we are the first group to calculate neutrino collective oscillations without using the mean field approximation but by directly attacking the exact many-body system. We are now in the process of submitting this work to Physical Review D.

3) We worked on the nu-process nucleosynthesis of some elements in the outer layers of the core collapse supernova. This process synthesizes some of the rarest elements in the universe. Since nu-process elements are known to be produced in the core collapse supernova with direct neutrino-nucleus reactions, their observation (for example with 30m telescope on NAOJ) is important for several issues pertaining to the supernovae and neutrinos. For example 92Nb is a very important nu-process nucleus which is used as a cosmic chronometer. Our work involved the combined effect of the collective neutrino oscillations and the propagation of shock wave in the supernova on the abundances of nu-process nuclei. Most of the previous studies have considered these effects separately, but we have shown that there is an interplay between them which cannot be captured by analyzing the collective oscillations and the shock wave separately. This is an extended international collaboration among me and several scientists in Japan, Korea and US. This work is now being prepared for publication.

(Education)

1) I gave intensive lectures on "Neutrino Physics and Astrophysics" in the Astronomy Department, Graduate School of Science, The University of Tokyo. In addition to the students from this department, several others from NAOJ, and Meiji University also attended at my lectures.

(Others)

1) Colloquium in The Tokyo University Department of Astronomy: "Neutrino Oscillations in Supernovae," June 4<sup>th</sup>, 2017.

2) DTA Colloquium at NAOJ: "Stars as extreme laboratories for neutrino physics" June 12<sup>th</sup>, 2017

3) Presentation for the NAOJ Theoretical Astronomy Group: "Astronomy and astrophysics with neutrinos" April, 2017.

4) Presentation for high school students in Turkey: "The particle at the edge of existence: the neutrino – from my research stay at NAOJ, Tokyo in Japan" August 27<sup>th</sup>, 2017.

## [ ii ] Any comments on this program

I think that NAOJ visiting professor program is very successful in the sense that it greatly helps the scientists from Japan and other countries establish valuable scientific collaborations and stay connected. During my stay here I worked very closely not only with my host, Prof. Kajino and his students, but also with several other Japanese scientists such as Prof. Takiwaki from NAOJ, Prof. Hayakawa from Tsukuba University, Prof. Maruyama from Nihon University, and Prof. Hideka from Meisei University. I was also able to work with other short term visitors such as Prof. Balantekin from University of Wisconsin, Prof. Mathews from University of Notre Dame, Prof. Famiano of Western Michigan University, and Prof. Cheoun from Soongsil University.

Large international collaborations such as the one we established during my stay in NAOJ are particularly useful for students to establish useful connections. For example, during my stay here we worked closely with Mr. Sasaki who is a student of Prof. Kajino. Together with Mr. Sasaki we applied to an international program of JSPS for him to visit me in Turkey. Our application was accepted and Mr. Sasaki is now scheduled to visit me for four months in Istanbul starting from June 2018. I think that this will establish a life long collaboration between us.

[ iii ] List of publications and presentations by the visiting scholar in collaboration with NAOJ staff or graduate students

(Publications)

- H. Sasaki, T. Kajino, T. Takiwaki, T. Hayakawa, A. B. Balantekin, and Y. Pehlivan-Deliduman, Phys. Rev. D 96, 043013 (2017), Possible effects of collective neutrino oscillations in three-flavor multi-angle simulations of supernova vp processes.
- Y. Pehlivan-Deliduman, A. L. Subaşı, N. Ghazanfari, S. Birol, and H. Yüksel, Phys. Rev. D 95, 063022 (2017), Spectral splits of neutrinos as a BCS-BEC crossover type phenomenon.
- S. Birol, Y. Pehlivan-Deliduman, A.B. Balantekin, T. Kajino, Phys. Rev. D (2018), to be submitted, A Neutrino Spectral Split in the Exact Many-Body Formalism.

## (Presentations)

3) Y. Pehlivan-Deliduman,
Colloquium in Tokyo University, Department of Astronomy,
"Neutrino Oscillations in Supernovae," June 4<sup>th</sup>, 2017.

4) Y. Pehlivan-Deliduman, DTA Colloquium at NAOJ, "Stars as extreme laboratories for neutrino physics," June 12th, 2017.

- 5) Y. Pehlivan-Deliduman, Seminar at the NAOJ Theoretical Astronomy Group, "Astronomy and astrophysics with neutrinos," April, 2017.
- Ⅱ. 以下の項目について、受入教員が記入してください。

Report from the host scientist

[iv]本制度に対する意見、要望など Any comments on this program

This was a fruitful time for research and discussions with Prof. Yamac Deliduman and many other scholars. We completed several ongoing projects and started new ones during his stay at NAOJ Mitaka. The opportunity for our graduate students and post docs to interact with him was inspiring for their development as researchers. I sincerely believe that this provides substantial enrichment for all scientists.