

Activity Report of the NAOJ Visiting Scholar Program

Host Project/Division: Division of Theoretical Astronomy Name of Host Scientist: Kajino, Toshitaka

Name of Visiting Scholar: Kusakabe, Motohiko

Title: Visiting Associate Professor

(Choose the appropriate one)

Period: from 18/04/17 to 18/06/29

I. Report from the visiting scholar

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

(Collaborative Research)

1. The s-process in metal-poor environment

Based upon the current understanding of stellar evolution in binary systems, I went forward development of a reasonable model calculation code for the s-process for a prediction of heavy nuclear abundances in metal-poor stars in binary system. Also, Mr. Kanji Mori (graduate student) is interested in deriving a constraint on coupling constants from theoretical consideration of the s-process. Here, coupling constants are in general related to the fine structure constant, strong coupling constant, and the Fermi constant. He started a study to reproduce the $^{151}\text{Eu}/^{153}\text{Eu}$ isotopic ratio inferred from observations of metal-poor stars, since the beta decay rate of ^{151}Sm is especially sensitive to a change in the fine structure constant. Related to his investigation, I provided two kinds of numerical codes which are modified versions of my previously developed code for relatively massive AGB stars.

2. The neutrino process in supernovae

Second, I analyzed effects of different neutrino mass hierarchy as well as different initial nuclear abundances on the neutrino process in core-collapse supernovae in detail. Especially, time evolution of not only abundances but also nuclear production and destruction rates through all important reactions are checked. Summarizing all products of a large collaboration including Beihang University, Soongsil University, Kyushu University, and others, we submitted a paper to Astrophysical Journal.

From June 9 to 11, I visited Kyushu University and attended a workshop on supernova neutrino nucleosynthesis. We shared our knowledge on various aspects of supernova nucleosynthesis. Especially, we got to know information of stellar nucleosynthesis of light to intermediate nuclei relevant to the weak s-process from the Kyushu university group, i.e., Prof. Hashimoto, Masaaki in Kyushu University and Dr. Ono, Masaomi in RIKEN. We strengthened our relation with Kyushu group that would help driving this supernova neutrino project.

3. Nuclear reaction rates under Tsallis statistics

I have worked on corrected nuclear reaction rates in the case that nuclear velocity distributions follow the Tsallis statistics, with Prof. Kajino and Mr. Luo, Yudong, a graduate student, in NAOJ, and Prof. Mathews in University of Notre Dame. This work is for a correction for an erroneous formulation in previous investigations. I calculated the freeze-out temperatures of respective nuclei during the big bang nucleosynthesis, and showed typical differences in important reaction rates between the exact and previously adopted formulations for the Tsallis distribution. After including this analysis, a paper was submitted to Physical Review D.

4. Effects of spatial inhomogeneity of primordial magnetic field on big bang nucleosynthesis

I discussed effects of an inhomogeneous magnetic field on big bang nucleosynthesis with Mr. Luo, Yudong (principal investigator), Prof. Kajino, and Prof. Mathews. Mr. Luo submitted a paper to Astrophysical Journal. This study will become a main part of his master thesis. This investigation is certainly a more extensive study than previous studies including my papers on magnetic field effects. This is because there should be an inhomogeneity in magnetic fields, but it has not yet been treated in previous studies.

In addition, I discussed supernova grain formation with Prof. Nozawa, an expert of dust formation theory, and a possible future study was found.

From April 24 to May 1, I attended the Korean Physics Society meeting in Daejeon, Korea, and gave an invited talk. Also, during and after the meeting, I discussed effects of Tsallis distribution for photon energy spectrum on big bang nucleosynthesis with Prof. Cheoun, Myung-Ki, Dr. Kwon, Youngshin, and Mr. Jang, Dukjae in Soongsil University. In addition, I discussed supernova neutrino process in Soongsil University with Prof. Cheoun and Ms. Ko, Heamin.

(Education)

In COSNAP seminar where Prof. Kajino in Division of Theoretical Astronomy, his graduate students and visiting researchers join, I had a talk on effects of nonequilibrium nuclear energy distribution and resonant reactions in big bang nucleosynthesis. I had meetings with Mr. Sasaki, Hirokazu (graduated student) about numerical calculation of nucleosynthesis and production of heavy p-rich nuclei in deep inside of core-collapse supernovae via the nu-p process.

(Others)

When we had a meeting on supernova neutrino process in Kyushu University, additionally I gave a seminar talk on June 11 to graduate students in the astrophysics group in Kyushu University.

During my stay in NAOJ, Mr. Yao, Xingqun, an undergraduate student in Beihang University, also visited NAOJ from April 16 to May 31. I mentored him about basics of supernova nucleosynthesis and numerical techniques. He performed a graduation report on sensitivity of supernova nucleosynthesis to

nuclear and neutrino reaction rates, which successfully passed a screening after he returned to Beijing.

[ii] Any comments on this program

I appreciate the hospitality of NAOJ during my stay in this program. This is a very fruitful and multidisciplinary international collaboration program because during my stay I could carry out many collaborations with visiting scholars, graduate students, and post docs in Prof. Kajino's group. We made valuable discussions concerning new projects as well as on-going projects. I applaud the NAOJ for supporting such an excellent exchange program under the leadership of many outstanding scholars.

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

I. Presentation

1. Effects of non-Maxwellian distribution and nuclear resonances on big bang nucleosynthesis, COSNAP seminar in Prof. Kajino's group, NAOJ, Japan, April 18, 2018
2. Production of Nuclei in Type II Supernova via Neutrino-process, 2018 Spring Meeting of the Korean Physical Society (KPS), Daejeon, Korea, April 24 to 28, 2018
3. Distribution function of relative velocity in Tsallis statistics and effects of non-Maxwellian distribution on BBN, Seminar, Soongsil University, Seoul, Korea, April 30, 2018
4. Effects of presupernova abundances on supernova neutrino-process Li & B ~details on numerical code, 超新星ニュートリノ元素合成ワークショップ, 九州大学, 日本, June 11, 2018
5. 初期宇宙の軽元素組成の進化と銀河系初期のリチウム組成, 九州大学大学院理学研究院講演会, 九州大学, 日本, June 11, 2018

II. Planned publication

1. Journal paper on reaction rates under the Tsallis statistics, Kusakabe, Kajino, Mathews, Luo, submitted to Physical Review D
2. Journal paper on supernova neutrino process, Kusakabe, Cheoun, Kim, et al., submitted to Astrophysical Journal
3. Journal paper on effects of magnetic field inhomogeneity on big bang nucleosynthesis, Luo, Kajino, Kusakabe, Mathews, submitted to Astrophysical Journal

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. Kusakabe and many other scholars who visited our group at NAOJ Mitaka. We completed several ongoing projects and started new ones during his stay. This opportunity for our graduate students and post docs to interact with him was also inspiring for their maturity as scientists who keep international competitiveness. I sincerely believe that this provides substantial opportunity to promote international collaboration for all scientists, and therefore I strongly recommend NAOJ to keep and even enrich this program in the future, too.

* If it is necessary, two extra pages can be used. The page limit of the entire document is five pages.

* This report will be posted on the website of the Research Coordination Committee, NAOJ except [v].

【Request】

For three years following the completion of the research, we will send you a request to submit a list of papers and other results that have been produced by this research collaboration. We appreciate your cooperation.