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: Michael A. Famiano

Title: Visiting Professor

Period: from 2018/04/28 to 2018/05/31

I. Report from the visiting scholar

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

(Collaborative Research)

During the project period, we have made significant progress on all of the topics relevant to our proposed work.

(1) Type Ia SN Nucleosynthesis:

We have published papers on the role of resonances in the C+C reaction rates and how these affect the nucleosynthesis and observed abundances. Type Ia supernovae (SNe Ia) are thought to be thermonuclear explosion of white dwarfs (WDs). Their progenitors are not well understood. One popular scenario is the double-degenerate (DD) scenario which attributes SNe Ia to WD-WD binary mergers. The fates of the WD mergers depend on the rate of 12C + 12C reaction. Recently, the 12C + 12C cross-sections have been measured and the analysis of the data using the Trojan Horse Method suggested that the astrophysical reaction rate is larger than conventional rates at astrophysical temperatures due to possible resonances. The resonance contribution results in a decrease of the carbon burning ignition temperature. Therefore, accretion-induced collapse occurs more easily and increases the birth rate of Galactic neutron stars with the contribution of the DD scenario to the SNe Ia rate becoming even smaller.

(2) Astrobiology:

We have developed computational tools to not only predict formation of amino acid chirality in meteorites, but we've also predicted isotopic abundance anomalies associated with these. Measurements of the isotopic abundances in meteoritic amino acids have found enhancements of D/H and 15N/14N, and 13C/12C, in the meteorites studied and in corresponding amino acids in those meteorites. We show that they are consistent with the processing of the previously formed amino acids by electron anti-neutrinos that would be expected from a core-collapse supernova or neutron-star merger. Using theoretical electron antineutrino cross sections we are able to predict these isotopic anomalies depending on the time-integrated neutrino flux at the site where the amino acids were processed. In addition, 7Li/6Li and 10B/11B ratios have been studied using the same model and compared to existing measurements.

DD scenario to the SNe Ia rate becoming even smaller.

(3) Electron Screening in Astrophysical Plasma:

We have enhanced our reaction screening model by including effects from magnetic fields, and we are preparing results now. For work in the field of relativistic plasmas, we have continued to develop our model. In particular, we have incorporated two things. We have first begun examining the effects of relativistic screening on electron capture. We have also begun to examine the effects of screening in strong magnetic fields. In astrophysical plasmas, nuclear reaction rates are enhanced by the presence of the background electronic and nuclear charges. These charges reduce the Coulomb repulsion between interacting nuclei by reducing the effective charge between them or creating correlations. This "screening" has been known for a long time.

However, the standard for over 40 years has been to assume a classical model of electron screening which ignores the relativistic effects of the plasma. As hot, magnetized environments do exist in the universe, relativistic plasma effects must be accounted for. Electrons and positrons may be created in the plasma via pair production, changing the charge density and subsequent screening of nuclear reactions. Also, magnetic fields will alter the electron-positron energy distribution. Because of this, the screening lengths (Thomas-Fermi) change – in some cases dramatically. We have begun preliminary calculations on the effects of these in astrophysical site.

(Education)

I gave intensive lectures entitled "From the Origin of Elements to the Creation of Life" in the graduate course of The University of Tokyo as a Lecturer. I also gave special lectures entitled "Element Genesis and Origin of Life" in the Graduate Program on Physics for the Universe, Tohoku University. At Tohoku University I gave another seminar in Physics Department on "Precise Measurements of Nuclear Masses of Astrophysical Interest".

I discussed many subjects on nuclear astrophysics with Prof. Kajino's graduate students of the University of Tokyo, Mr. Yuta Yamazaki, Mr. Yudong Luo, Mr. Kanji Mori and Mr. Hirokazu Sasaki, and those of Beihang University, Mr. Shinquin Yao and Mr. Zhenyu He. Some of research results with them were published in journal papers as reported below. I also joined in regular Theoretical Astronomy Seminar and COSNAP (COSmology and Nuclear AstroPhysics) Seminar which are organized by Prof. Kajino's group in Division of Theoretical Astronomy. I had several talks in these seminars on the research subjects as mentioned above. I also made many valuable discussions with post docs, too.

(Others)

I and Prof. Kajino organized an NAOJ Workshop on astrobiology entitled "Connecting Fundamental Physics, Chemistry and the Origin of Biomolecular Homochirality". We worked with international collaborations of scientists from US (Prof. A. B. Balantekin, Prof. G. J. Mathews), Germany (Prof. R. Diehl), Korea (Prof. M.-K. Cheoun), and China (Prof. W. Wang, Prof. S. Zhang) and their graduate students.

[ii] Any comments on this program

I appreciate the hospitality of NAOJ during my stay as a Visiting Professor. This program is indeed a very fruitful and multidisciplinary international collaboration program because we can make intensive and extensive discussions with many experts in various research fields. During my stay several senior collaborators inside Japan and from foreign countries visited Prof. Kajino and we could carry out valuable discussions concerning our on-going and new projects. I strongly support this NAOJ program that is an excellent exchange program under the leadership of outstanding scholar like Prof. Kajino.

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

(Publications)

(1) K. Mori, M. Famiano, T. Kajino, T. Suzuki, P. Garnavich, G. Mathews, R. Diehl, S. Leung, & K. Nomoto,
ApJ **863** (2018), Issue 2, article id. 176, 10 pp,
Nucleosynthesis Constraints on the Explosion Mechanism for Type Ia Supernovae.

(2) M. A. Famiano, R. N. Boyd, T. Kajino, T. Onaka,
Astrobiology **18** (2018), 190-206,
Selection of Amino Acid Chirality via Weak Interactions with ^{14}N in Crossed Electric and Magnetic Fields.

(3) M. A. Famiano, R. N. Boyd, T. Kajino, T. Onaka, and Y. Mo,
Sci. Rep. **8** (2018), 8833,
Amino Acid Chiral Selection Via Weak Interactions in Stellar Environments: Implications for the Origin of Life.

(4) R. N. Boyd, M. A. Famiano, T. Kajino, T. Onaka, and Y. Mo,
Astrophys. J. **856** (2018), article id. 26, 5 pp,
Sites that can produce left-handed amino acids in the supernova neutrino amino acid processing model.

(5) K. Mori, M. A. Famiano, T. Kajino, M. Kusakabe, and X.-D. Tang,
MNRAS, Lett. **482** (2019), L70-L74,
Impacts of the New Carbon Fusion Cross Sections on Type Ia Supernovae.

(6) T. Kajino, W. Aoki, A. B. Balantekin, R. Diehl, M.A. Famiano, G.J. Mathews,
Prog. Part. Nucl. Phys. **107** (2019), 109-166.
Current Status of r-Process Nucleosynthesis.

(Presentations)

(1) M. A. Famiano,
Course lectures in Graduate School of Science, The University of Tokyo,
From the Origin of Elements to the Creation of Life.

(2) M. A. Famiano,
Special lectures in the Graduate Program on Physics for the Universe, Tohoku University,
Element Genesis and Origin of Life.

(3) M. A. Famiano,
Seminar at Department of Physics, Tohoku University
Precise Measurements of Nuclear Masses of Astrophysical Interest.

(4) Many seminar talks at NAOJ.

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. Michael Famiano and many other scholars. Although Prof. Famiano had planned to make the second visit from January 2019, he resigned this NAOJ visiting professorship because he started staying here as a Fulbright Fellow. His extended stay was longer, and the scientific products and performance were even more rich. We completed several ongoing projects and also started new projects 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 opportunity to promote international collaboration for all scientists, and therefore I strongly recommend NAOJ to keep and even enrich this program in the future.

* 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.