

# Activity Report of the NAOJ Visiting Scholar Program

Host Project/Division: Div. Theor. Astronomy Name of Host Scientist: Toshitaka Kajino

Name of Visiting Scholar: Myung-Ki Cheoun

Title: Visiting Professor

Period: from 2015/12/26 to 2016/02/24

## I. Report from the visiting scholar

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

(Collaborative Research)

### 1. Roles of active and sterile neutrinos in nuclear astrophysics

Neutrinos are the key elementary particles for understanding the supernova (SN) explosion. But their properties are not known exactly. For example, are they Dirac or Majorana particles? How are the mass and the magnetic moment? How is the mass hierarchy of the neutrinos? In particular, I focused on the mass hierarchy problem, which can be studied by the investigation of light elements abundances produced in the SN explosion though the MSW effects (flavor oscillation of neutrinos in matter). During my stay we succeeded in obtaining the interesting results for the neutrino process simulation. In addition, we also studied effects of neutrino-neutrino interactions and sterile neutrinos in the SN explosion in the strong magnetic field presumed to reside inside neutron stars.

### 2. Neutrino-nucleus interactions and coherent neutrino scattering

Neutrino interactions with nuclei turn out to be important in the neutrino related processes in the cosmos. But their interactions are very sensitive on nuclear structure problems. During my stay, I applied our recent nuclear structure model, which includes the deformation explicitly, to various neutrino interactions with exotic nuclei through precise understanding of the Gamow-Teller experimental data which are recently available in the nuclear physics facilities in Japan and US. With the increase of great interest in the dark matter physics, coherent scattering off dark matter including neutrino is also of great importance in the nuclear astrophysics. Much advanced and sophisticated calculations for this coherent scattering were carried out during the visit.

### 3. Strong magnetic field (SMaF) physics in the neutron stars

The SMaF becomes an inevitable ingredient in understanding exotic phenomena in the cosmos. We have developed a formalism regarding the particle behavior in the SMaF in the quantum field theory. One of interesting results is that high-energy neutrinos can be produced by the charged particle propagation through the interstellar medium with SMaF. Detailed study was performed in order to find observational evidence for cosmological high-energy neutrinos that are produced in our proposed mechanism. Also the MSW effect in the SMaF was discussed and the result was published in an international journal which is the scientific product from our collaborators in Japan and US.

### 4. New accelerator neutrino simulation

During my stay we discussed extensively a possibility of making a new neutrino source by using a proton

accelerator. It has more merits than the other accelerator neutrino beams for the application to the neutrino astrophysics. For example, lower neutrino energy around a few MeV from the source enables to test neutrino interactions with matter in the supernovae explosion, whose experiments were never performed in laboratory systems. Moreover, since we use a simple proton accelerator, it would be much cheaper than the beta beam usually considered in this field.

(Education)

1. I discussed neutrino collective oscillations with Mr. Sasaki, r-process nucleosynthesis with Mr. Shibagaki, Galactic chemo-dynamical evolution with Mr. Hirai, electron-capture effects on SN Ia with Mr. Mori who are Prof. Kajino's PhD students at the University of Tokyo. I made informal lectures for them, too. I also made many valuable discussions with post docs.

(Others)

1. NAOJ Colloquium talk

"Compact Stars, Human Beings, and Accelerator", at the No.932 NAOJ Colloquium, Myung-Ki Cheoun.

2. Extensive discussions about the recent progress in the nuclear astrophysics with the guest scientists at NAOJ, Profs. Baha Ballantekin (Univ. Wisconsin), Grant Mathews (Univ. Notre Dame), M. Famiano (West Michigan Univ.), K. Hagino (Tohoku Univ.), T. Maruyama (Nihon Univ.), T. Hayakawa (JAEA), T. Suzuki (Nihon Univ.) and others.

[ ii ] Any comments on this program

I really appreciate the hospitality of NAOJ through this program. This could be a really fruitful and multidisciplinary international collaboration program because we need more intensive and extensive discussions with many experts in various research fields. During my stay many of my graduate student, post docs and senior collaborators in Korea visited Prof. Kajino and carried out valuable discussions on our on-going and new projects. They are Prof. Kyujin Kwak at Ulsan National Institute of Science and Technology, Prof. W.-Y. So at Kangwon National University, Dr. Eunja Ha, Dr. Ghil-Seok Yang and Mr. Ki-Seok Choi at Soongsil University. Some of them used NAOJ Visiting Fellow Program. I applaud the NAOJ for supporting such excellent exchange programs 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

1. Pion Production from Proton Synchrotron Radiation under Strong Magnetic Field in Relativistic Quantum Approach,  
Tomoyuki Maruyama (Nihon Univ.), Myung-Ki Cheoun (Soongsil Univ. & Natl. Astron. Observ. of Japan), Toshitaka Kajino (Natl. Astron. Observ. of Japan & Univ. of Tokyo), Grant J. Mathews (Univ. of Notre Dame), Published in EPJ Web Conf. 109 (2016) 05006.

2. Neutrino-induced Reactions and Neutrino Scattering with Nuclear Targets,  
Myung-Ki Cheoun, Eunja Ha, Ghil-Seok Yang (Soongsil Univ. & Natl. Astron. Observ. of Japan), Kyungsik Kim (Korea Aerospace Univ.), Toshitaka Kajino (Natl. Astron. Observ. of Japan & Univ. of Tokyo), Published in EPJ Web Conf. 109 (2016) 05002.

3. New neutrino source for the study of the solar neutrino physics in the vacuum-matter transition region,  
Jae Won Shin, Myung-Ki Cheoun (Soongsil Univ. & Natl. Astron. Observ. of Japan), Toshitaka Kajino (Natl. Astron. Observ. of Japan & Univ. of Tokyo), Phys. Rev. (2016), submitted (e-Print: arXiv:1601.00377 [astro-ph.]).

4. Production via Proton Synchrotron Radiation in Strong Magnetic Fields in Relativistic Field Theory: Scaling Relations and Angular Distributions,  
Tomoyuki Maruyama (Nihon Univ.), Myung-Ki Cheoun (Soongsil Univ. & Natl. Astron. Observ. of Japan), Toshitaka Kajino (Natl. Astron. Observ. of Japan & Univ. of Tokyo), Grant J. Mathews (Univ. of Notre Dame), Physics Letter (2016), in the press.

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. Cheoun 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.