Title of Project : Nuclear Matter in Neutron Stars Investigated by Experiments and Astronomical Observations

Hirokazu Tamura
(Tohoku University, Department of Physics, Graduate School of Science, Professor)

【Purpose of the Research Project】

Neutron stars are extremely dense stellar objects whose core part is made only of baryons (neutrons and other particles) without electrons. Our project aims at revealing this unknown matter by combining experiments on the earth and astronomical observations from the space through theoretical studies.

As illustrated in Fig. 1, we experimentally study strangeness nuclear physics at J-PARC, neutron-rich nuclei at RIBF in RIKEN, ultra-cold atomic gas, and also observe neutron stars using X-ray satellites such as ASTRO-H. Then we combine those results through theoretical studies to uniquely determine the equation of state (EOS) of nuclear matter. Then various types of matter in the neutron stars and the structure of the neutron stars will be revealed.

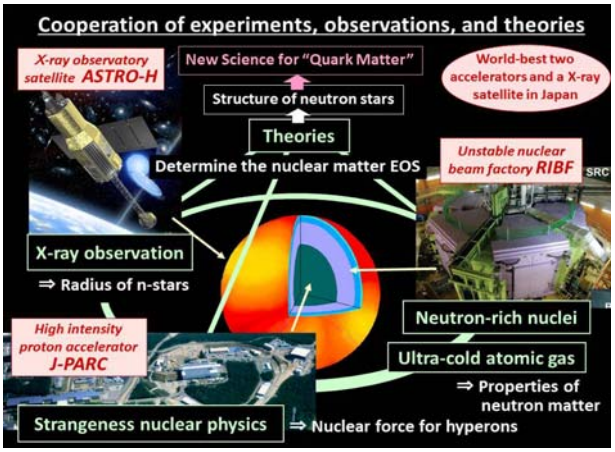

Figure 1: Image of the project.

【Content of the Research Project】

(A) In order to investigate the high density region in the central part of the neutron stars, where strange quarks are expected to appear, we study strangeness nuclear systems (hyper-nuclei) and determine the hyperon-nucleon interactions to be used as an input for the EOS.
(B) In order to understand low/medium density neutron matter in the outer region of the neutron stars, we investigate properties of neutron-rich nuclear matter and thin neutron matter through various studies of neutron-rich unstable nuclei. We also investigate laser-cooled ultra-cold Fermi gas systems, of which properties are similar to thin neutron matter in the crust of the neutron stars.
(C) Both of the mass and the radius of the neutron star would strongly restrict and/or confirm the EOS. However, direct measurement of the radius has not been achieved yet. Using X-ray observatory satellites such as ASTRO-H with new X-ray detectors, we will obtain direct data on the radius for several samples.
(D) The theory group studies related subjects on nuclear/hadron physics, cold atomic systems, and astronomical physics to analyze/interpret results of (A), (B), (C). The best EOS will be constructed from (A) and (B), and then confirmed by the radius data (C). Exotic neutron-star matter such as various baryonic superfluid and pasta- like matter will be also investigated.

【Expected Research Achievements and Scientific Significance】

As mentioned above, we will be able to uniquely establish the EOS of nuclear matter, which has been one of the dreams in nuclear physics. Then the structure of the neutron stars and various types of matter inside them will be understood, and the long-standing questions such as existence of strange hadronic matter and superfluid neutron matter will be answered. The mechanism of production and cooling of neutron stars will be also elucidated.

Furthermore, this project will lead to a creation of a new type of science for matter beyond atomic/molecular physics, condensed matter physics, chemistry, and plasma physics.

【Key Words】

Neutron star: Extremely dense stellar object which remains after supernova explosion.
Nuclear Matter: Matter in a nucleus consisting of baryons (such as neutrons) without electrons.

【Term of Project】 FY2012-2016

【Budget Allocation】 1,079,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://lambda.phys.tohoku.ac.jp/nstar/
tamura@lambda.phys.tohoku.ac.jp