【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project : From Quarks to Neutron Stars: Challenges in QCD

Tetsuo Hatsuda
(RIKEN, Interdisciplinary Theoretical and Mathematical Sciences, Program Director)

Research Project Number : 18H05236 Researcher Number : 20192700
Keyword : Neutron star, Lattice QCD, Baryon force, Quantum many-body problem, Equation of state

【Purpose and Background of the Research】

Structure of dense matter is one of the most important unsolved problems in nuclear physics. The coalescence of binary neutron stars (GW 170817) was recently observed by the gravitational wave and electromagnetic waves simultaneously. Understandings of high-density matter inside the neutron star and the origin of heavy elements will be further accelerated by such observations in the future.

The purpose of the present project is to derive the equation of state of dense matter through the precision quantum many-body calculations combined with the baryon-baryon interactions extracted from quantum chromodynamics (QCD) simulations on the lattice.

【Research Methods】

Reseachers participating in this project have pioneered the HAL QCD method for deriving the nuclear force from lattice QCD and also have developed the cluster variation method for quantum many-body systems. We will carry out systematic calculations of the baryon-baryon interactions as well as detailed studies of the three-body interactions by using lattice QCD simulations. This will provide basic data necessary to formulate the equation of state relevant to outer and inner cores of neutron stars. Also, we construct the equation of state at finite temperature with arbitrary proton fraction by the cluster variational method.

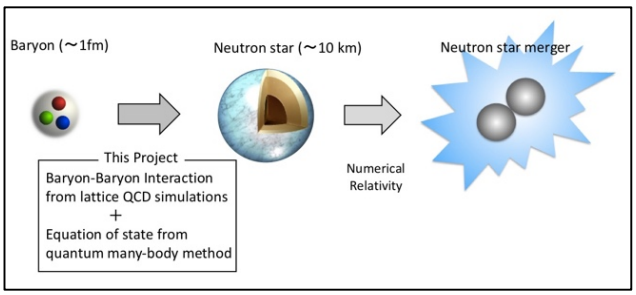

Figure 1 From quarks to neutron star mergers

【Expected Research Achievements and Scientific Significance】

Combining lattice QCD and quantum many-body method to construct a microscopic equation of state is crucial for analyzing gravitational wave from neutron star mergers. In addition, the present project is closely related to condensed matter physics for strongly correlated quantum systems such as cold atomic gases and liquid helium. The present project is also related directly to the experimental studies of dense matter using the collisions of heavy nuclei.

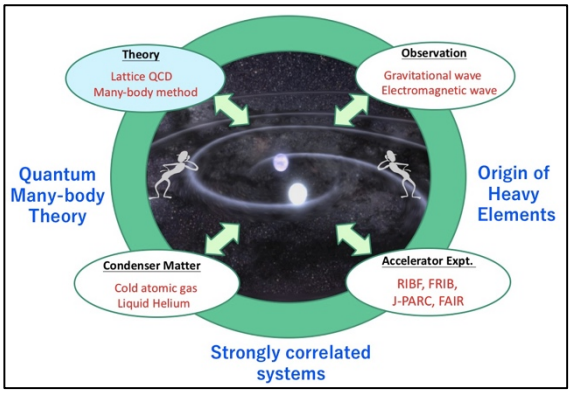

Figure 2 Interdisciplinary connections

【Publications Relevant to the Project】

・G. Baym, T. Hatsuda, T. Kojo, et. al, "From Hadrons to Quarks in Neutron Stars", Rept. Prog. Phys. vol.81, 056902 (2018).
・H. Togashi, E. Hiyama, Y. Yamamoto, M. Takano, "Equation of State for Neutron Stars with Hyperons by the Variational method", Phys. Rev. C93, 035808 (2016)

【Term of Project】 FY2018-2022

【Budget Allocation】 91,600 Thousand Yen

【Homepage Address and Other Contact Information】

https://ithems.riken.jp/
thatsuda@riken.jp