【Grant - in - Aid for Scientific Research on Innovative Areas(Research in a proposed research area)】
Science and Engineering

Title of Project : Clustering as a window on the hierarchical structure of quantum systems

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Research Project Number : 18H05400　Researcher Number : 50272456

【Purpose of the Research Project】

We aim to understand the formation mechanism of the hierarchical structure of quantum particles, from quarks to molecules (Fig.1). For this purpose, we integrate our research activities on hadron, nuclear, atomic physics, and molecular science, where Japan has played leading roles, and establish a research consortium to fill the large gaps among the conventional research fields. A variety of novel clustering phenomena will be primary targets of the research, which will clarify not only universal phenomena and physical laws, but also characteristic features of each hierarchy. We thus open a new research field to investigate the origin of hierarchies of matter.

【Content of the Research Project】

The quantum world has a hierarchical structure, from quarks to molecules (Fig.1). Each hierarchy is characterized by its unit particles and interactions between them. The unit particle, composed of lighter particles, is called a cluster. Recently, as shown in Fig.1, "Semi-hierarchy" lying between the conventional hierarchies, and its constituents, novel clusters, have drawn much attention. Such clusters may have universality across different hierarchies, and thus can provide a key to understand the hierarchical structure. As shown in Fig.2, Groups A,B,C will investigate clusters and interactions between them in each hierarchy. Group C, in addition, will explore quantum simulators to understand the clustering phenomena more generally. Group D will develop relevant theories. With this combined expertise, we expect to understand the underlying mechanism of the hierarchical structure.

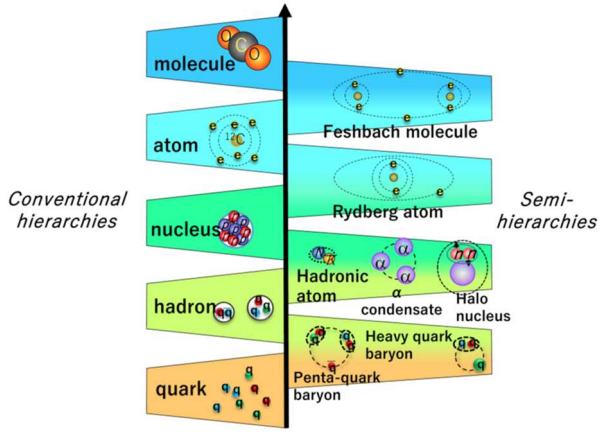

Fig.1 Hierarchical structure of matter

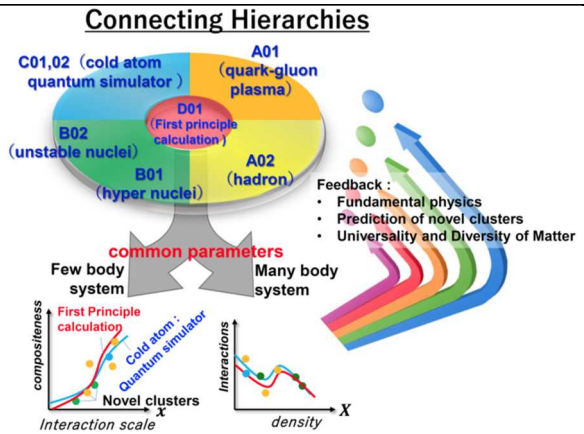

Fig.2 Scheme of this project

【Expected Research Achievements and Scientific Significance】

Novel clusters in semi-hierarchies will be observed and established. In addition, the interactions between the novel clusters will be investigated. Theories will play important roles in understanding the interactions from first principles. Quantum simulators using ultra-cold atom experiments will be one of the significant achievements. A semi-hierarchy with mixed configurations can be analyzed by quantum simulators, which will allow us to understand the phenomena in a more unified way. We thus expect to find physics phenomena and laws universally applicable to multiple hierarchies. In this way, we will open a new research field connecting the multiple hierarchies, from quarks to molecules, through the study of clustering phenomena.

【Key Words】

Cluster: A unit particle of the respective hierarchy, composed of lighter particles.

Semi-hierarchy: A hierarchy between two conventional hierarchies, often characterized by weakly (un)bound systems, strong pairing, mixed configurations, showing some universal features.

Quantum simulator: Simulators of quantum clusters to be realized by ultra-cold atom experiments.

【Term of Project】　FY2018-2022
【Budget Allocation】　1,169,700 Thousand Yen

【Homepage Address and Other Contact Information】

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