【Grant-in-Aid for Transformative Research Areas（A）】

Section Ⅱ

# Title of Project： Next Generation Astrochemistry: Reconstruction of the Science Based on Fundamental Molecular Processes

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Number of Research Area：20A202　Researcher Number：70533553

## 【Purpose of the Research Project】

Planet formation is a natural consequence of the star formation process, and there is an incredible variety of planetary systems, which are significantly different from the Solar System. Recent ALMA observations have revealed chemistry in planet-forming regions. Various complex organic molecules are found in protoplanetary-disk forming regions, and their abundances vary significantly among objects. This indicates that the Solar System may not have been common in terms of its initial chemistry, which invokes the discussion on the rarity of our existence. Progress of the Solar System exploration, including the recent successful return of the Hayabusa2 spacecraft, makes it possible to analyze pristine Solar System materials directly. The combination of such analysis with high-sensitivity observations of planet-forming regions will tell us the chemical origin of our Solar System and how common or rare it is in the universe. However, to tackle these questions, we have to revisit fundamental astrochemical processes. In the past decades, the astrochemical studies focused on chemistry under extremely low temperature and density conditions, where only barrierless exothermic reactions proceed efficiently. During the planetary system formation, on the other hand, the physical condition changes dynamically resulting in dynamic interactions of molecules between gas and dust(ice) surface. Investigation of such physical and chemical processes is crucial to understand the formation of complex organic molecules and the chemical variety of planet-forming regions. This transformative research area aims at the re-establishment of "astrochemistry" by investigation of the microscopic chemical processes with the close collaboration of astronomy, planetary science, and molecular science, and also aims at understanding the origin of the Solar System from the view of chemistry.

## 【Content of the Research Project】

Following studies are planned in our research area.

1) High resolution/sensitivity observations and laboratory spectroscopy to explore the entire view of chemical evolution and its diversity.

2) Analysis of extraterrestrial organics, including the returned Ryugu samples, along with laboratory experiments to reproduce the Solar System organics.

3) Experimental study on gas-phase reactions based on advanced beam technologies. Reaction pathways and rate coefficients are investigated as a function of temperature.

4) Experimental study on dust surface reactions, which aims at the molecular-scale elucidation of the reaction elementary processes by the single-molecule surface spectroscopy.

5) Theoretical astrochemistry based on microscopic processes in the gas and solid phases. Construct the model of chemical evolution model during the star and planet formation by the combination of hydrodynamic calculations, reaction parameters obtained by the laboratory experiments and quantum chemical calculations.

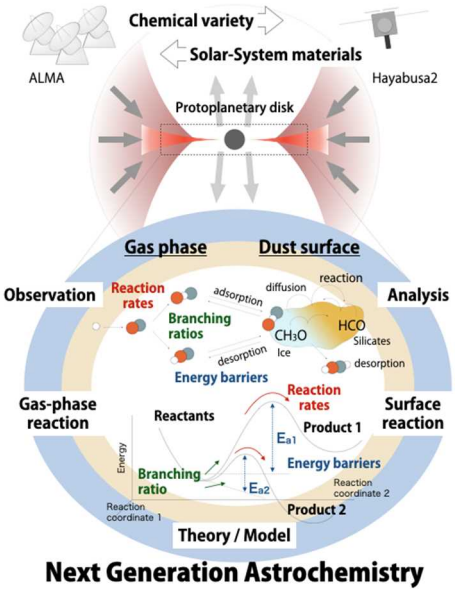


Fig 1. Next generation astrochemistry to reveal the chemical evolution along with the star/planet formation based on microscopic chemical processes.

## 【Expected Research Achievements and Scientific Significance】

The next generation astrochemistry will reveal the chemical evolution in the star/planet formation and the commonness/uniqueness of the origin of the Solar System. It is also applicable to various physical conditions in space, i.e., the material evolution in the Universe in general, and enable us to use chemistry as a diagnostic tool for the structure formation. Our research area is also beneficial to various fields such as astrobiology, exoplanet research, material science, molecular chemistry, and surface science.

【Key Words】 Astrochemistry : Chemistry taken place in space, which includes the Solar system and interstellar clouds.

【Term of Project】 FY2020-2024

【Budget Allocation】 931,200 Thousand Yen

## 【Homepage Address and Other Contact Information】

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