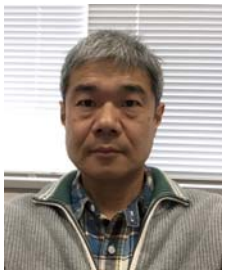
【Grant-in-Aid for Specially Promoted Research】

Science and Engineering (Mathematics/Physics)



Title of Project : Chemical evolution on cosmic dust: approach from elementary processes

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Research Project Number : 17H06087 Researcher Number : 50271531
Research Area : Earth and Planetary Science
Keyword : Chemistry of extraterrestrial materials, Dust surface processes

【Purpose and Background of the Research】

Chemical evolution in interstellar molecular clouds (MCs) is a key to understand the entire evolution of matter toward planetary system. Various species including organic molecules were found in MCs, indicating that chemical processes occur actively even under extreme conditions: e.g. low temperatures as low as 10 K. Surface reactions on interstellar dust are crucial in producing primordial species like H_2, H_2O and organic molecules.

We have demonstrated that quantum phenomena, tunneling reaction and nuclear spin conversion (NSC) of molecules on dust, at the cryogenic temperatures play an important role in chemical evolution. In the present project, we will extend our research for better understanding chemical evolution, in which key elemental processes will be clarified quantitatively by experimental approach.

【Research Methods】

We target (1) molecular formation, (2) deuterium enrichment, and (3) nuclear spin conversion of molecules on the surfaces of various types of dust as shown in Figure 1.

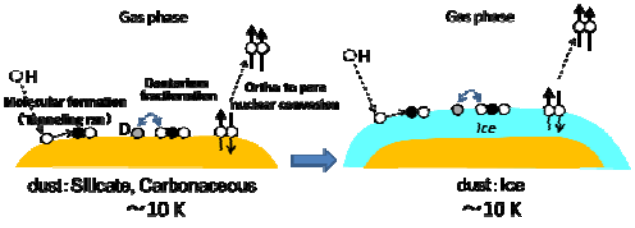

Figure 1. Illustration for chemical evolution on dust. The dust materials and key processes are described.

In ultra-high vacuum chambers, the dust surface analogues are produced, which are analyzed and evaluated by electron microscopes and an atomic force microscope. For the subjects on (1) and (2), infrared absorption spectroscopy, a resonance-enhanced multiphoton ionization method (REMPI), and high-resolution mass spectrometry will be adopted. For the subject on (3), a sum-frequency generation spectroscopy and the REMPI methods will be used. From the experiments, we will determine diffusion rates of atoms and radicals, surface reaction rates, and mechanism and rates for NSC of molecules on the various surfaces at low temperatures.

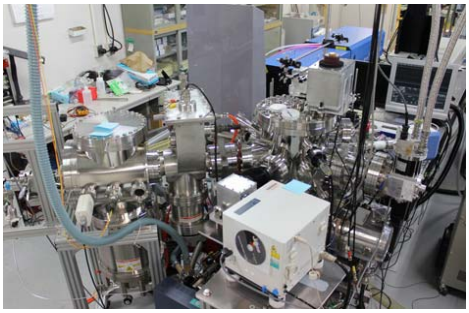

Figure 2. One of our experimental apparatus for the present project.

【Expected Research Achievements and Scientific Significance】

The results of experiments can greatly improve understanding chemical evolution. Especially, the information of silicate and carbonaceous surfaces is still highly desirable.

Recent progress in astronomical observation enables us to know the existence of various species including complex organic molecules toward astronomical objects. Our project is timely and has a great impact on astronomy. The elementary processes on various solids, targeted in this project, also fascinate pure chemists and physicists.

【Publications Relevant to the Project】

・ T. Hama, N. Watanabe, “Surface Processes on Interstellar Amorphous Solid Water: Adsorption, Diffusion, Tunneling Reactions, and Nuclear Spin Conversion”, Chem. Rev. 113, 8783 (2013)

【Term of Project】 FY2017-2021

【Budget Allocation】 433,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.lowtem.hokudai.ac.jp/astro/