【International Leading Research】

Heavy Elements in the Early Universe Elucidated by Superconducting Nanoelectronics, Large-Scale Numerical Simulations, and Data Science

Principal Investigator	The University of Tokyo, Graduate School of Science, Professor **KOHNO Kotaro** Researcher Number : 80321587
Project Information	Project Number : 23K20035 Project Period (FY) : 2023-2029 Keywords : Line intensity mapping, integrated superconducting spectroscopy, sparse modeling, deep learning, submillimeter-wave

Purpose and Significance of the Research

●Background: obscured star-formation activities in the Universe

It is important to understand how star formation in the Universe has evolved and the physical processes behind it, because it helps us comprehend the origin of the heavy elements and materials that were produced in stars and came to constitute our world and life, as well as to understand the behavior of dark matter. Now galaxy candidates with redshifts of more than 10 (i.e., less than 1 billion years since the beginning of the Universe) have been discovered by the James Webb Space Telescopes in the visible to mid-infrared wavelengths. Sub/millimeter-wave observations are key to detecting star formation hidden in heavy-element solid particles, i.e., “dust”. So far, dramatic progress has been made in observing individually detectable bright galaxies using ALMA. However, the detection of dust-enshrouded star formation in fainter, more numerous, ergo more common galaxies remains extremely challenging (i.e., time-consuming) even with ALMA.

●Objectives and significance: submillimeter-wave line intensity mapping

We propose to conduct the “line intensity mapping” (LIM) observations targeting the ionized carbon emission [CII] 158μm line. LIM measures the integral amount of energy emitted by the spectral lines of galaxies averaged in the spatial and depth (redshift) directions, rather than resolving individual galaxies separately, and thus can obtain information from faint (and therefore numerous) galaxies that are difficult to detect individually (Fig.1, left). The large-format superconducting imaging spectrograph TIFUUN (Fig.1, top right) will be developed and deployed on the Atacama Submillimeter-wave Telescope Experiment (ASTE). Further, data-scientific methods will be developed to remove atmospheric emission (Fig.1 bottom right) and contaminating foreground lines. We will quantify the dust-obscured star formation and clarify the formation and accumulation of heavy elements in the first 2 billion years of the Universe’s history.

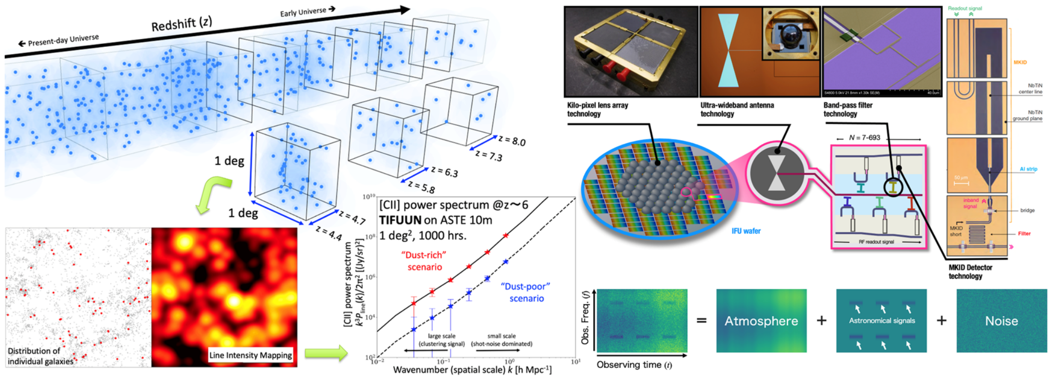

Fig.1 The [CII] line intensity mapping (left); imaging spectrograph TIFUUN (top right); removal of atmospheric emission using sparse modeling (bottom right)

Organization of the Project Team

●International collaborative research encompassing superconducting nanoelectronics, data science, astrophysics, and observational astronomy

The team consists of experts in observational and theoretical studies of spectral lines from ionized carbon and oxygen. The team also includes an expert in data science who plays leading roles in cross-disciplinary projects with observational astronomy, and a researcher in engineering who has rich expertise in submillimeter-wave instrumentation. We will strengthen our longstanding collaboration with TU Delft and SRON, which successfully demonstrates the integrated superconducting spectroscopy technology. Experts in line intensity mapping (U. Penn) and galaxy SED modeling (LAM) will also participate. The framework of the joint research is shown in Fig. 2 (right).

●Japan-Netherlands joint development by consolidating respective budgets

ERC consolidator grant (PI: Prof. Endo) has been awarded for the development of TIFUUN. Young researchers and graduate students will have a unique opportunity to participate in such a large-scale development from the beginning of the project.

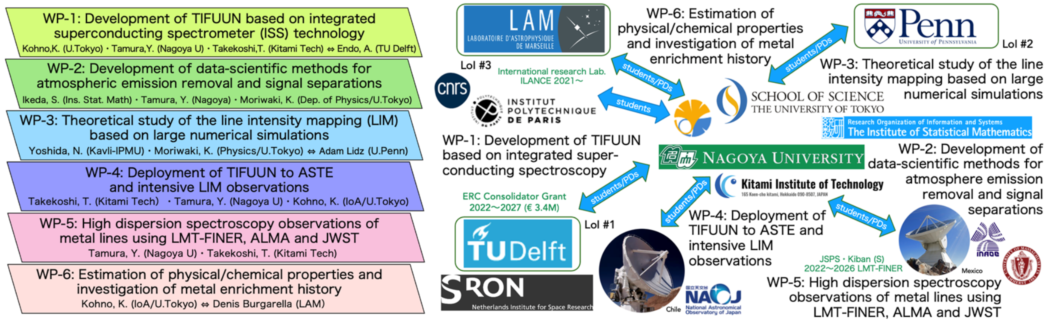

Fig.2 Work packages (left) and framework of international joint research (right)

Plan for Fostering Early-career Researchers

Approximately 20 graduate students and young researchers will participate in this project at the start. We will accept several international students and young researchers every year from e.g., CNRS. The characteristics of the talent development plan and the appeal to students and young researchers can be summarized as follows.

●Acquisition of a broad perspective and challenge to the border areas

Participation in international collaborative research, which brings together experts from various fields allows for not only the formation of a wide network but also the acquisition of interdisciplinary perspectives and opportunities to challenge the border areas.

●Fostering an environment for open-minded research

We will provide specially-appointed assistant professor positions, allowing for up to 6 years to work with experts from various fields. It facilitates open-minded research by gaining new skills. For instance, ultra-low temperature experimental facilities would be available for use by students and young researchers at their discretion.

●Career seminars to promote international success

We will hold career seminars to share valuable for students to thrive overseas. Seminars will also be conducted on how to write effective recommendation letters for international institutions, thereby supporting the international success of young talents.

●Tutorials on superconductivity and data science

Tutorials will foster talent development in quantum and data sciences and encourage interdisciplinary collaboration among emerging experts.

Homepage Address, etc.	https://sites.google.com/view/sublime-tifuun/