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

Evolution of the Universe revealed with transients observed by next-generation large surveys

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Purpose and Background of the Research

● Outline of the Research

Transients, such as supernovae, are the main origin of elements heavier than helium (metals) in the Universe and drive the evolution of the Universe. This study aims to elucidate how the transients drive the evolution of the Universe by utilizing next-generation large surveys, simultaneous observations with the Subaru Telescope, theoretical studies, and the construction of a system to integrate them.

In this five years, an optical survey by Rubin/Legacy Survey of Space and Time (LSST) and near-infrared surveys by European Euclid satellite and the U.S. Roman satellite will start. We are now at the stage to reveal the evolution of the Universe.

In the nearby Universe, we use the Subaru/Prime Focus Spectrograph (PFS) for immediate spectroscopic follow-ups of nearby transients discovered by Rubin/LSST and compare them with radiation hydrodynamics simulations to clarify their nucleosynthesis and explosion energy. In the distant Universe, we perform an optical simultaneous survey using the Subaru/Hyper Suprime-Cam (HSC) along with the near-infrared surveys by Euclid and Roman to search for distant transients. This allows us to determine their occurrence rates and properties. Based on these results, we perform cosmological simulations and compare them with observations of distant galaxies. We understand the evolution of the Universe by using transients.

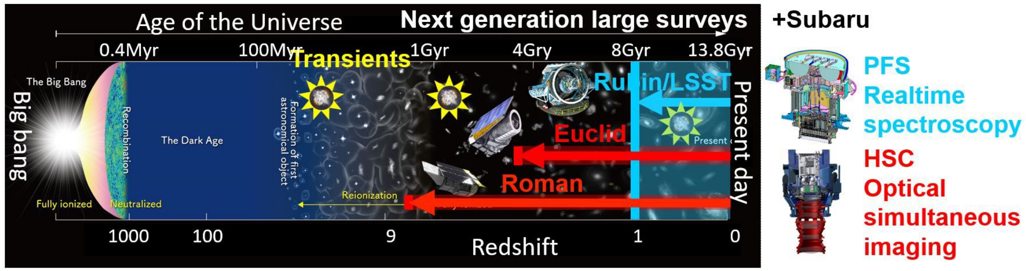

Figure 1. The evolution of the Universe revealed by utilizing the next-generation large surveys and the simultaneous observations with Subaru. ©NAOJ

● Questions

Utilizing the next-generation large surveys by Rubin/LSST, Euclid, and Roman and the simultaneous observations using the Subaru/HSC and PFS, this research answers following questions:

(1) What are the population and properties of transiens in the Universe?

(2) How have the transients contributed to the evolution of the Universe?

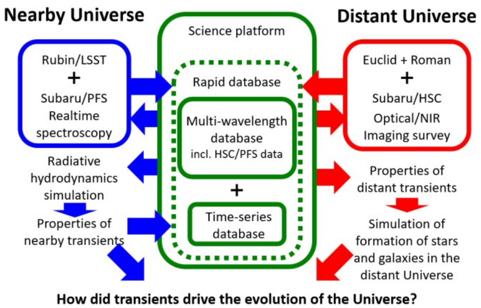

Figure 2. Schematic structure of this research.

Expected Research Achievements

● Census of nearby transients

Transiens discovered by the Rubin/LSST are reported to the world by transient brokers (e.g., ALeRCE). We perform immediate spectroscopic follow-ups using PFS for ~10,000 transients. From the spectra obtained by the PFS, we determine the species of ejected metals and the ejecta velocity and classify the transients. We perform radiative hydrodynamics simulations to determine the mass of ejected metals and explosion energies and reveal how transients have contributed to the evolution of the nearby Universe. We also establish a method to estimate the properties of transients only with imaging observations with the large sample of transients.

● Contributions of distant transients

We conduct deep simultaneous optical survey using HSC for the areas surveyed by Euclid and Roman and perform a dedicated search for distant transients; transients with long duration at redshift < 4 for Euclid and transients at redshift < 7 for Roman. Based on theoretical predictions we expect detection of ~50 distant transients for Euclid and ~100 distant transients for Roman. This determines the occurrence rates of distant transients. Based on the results, we perform numerical simulations of formation of next-generation stars and the formation and evolution of galaxies and compare them with observations of distant galaxies, e.g., recently obtained by the James Webb Space Telescope (JWST). We elucidate the contribution of distant transients to the evolution of the early Universe.

We comprehensively understand the evolution of the Universe using the next-generation large surveys and theoretical studies.

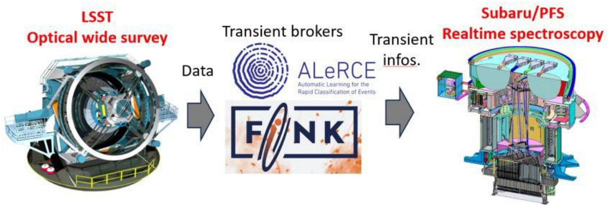

Figure 3. Study of nearby transients. We establish an ultimate spectra library of transients and make census of transients. © Rubin/LSST, ALeRCE, Fink, NAOJ

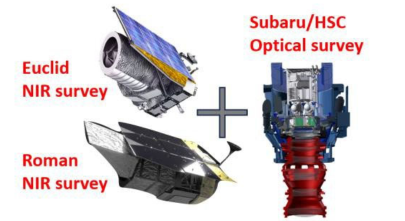

Figure 4. Study of distant transients. We perform a dedicated survey for distant transients. © Euclid, Roman, NAOJ

● Basis of big data astronomy

Since the huge data are obtained by these observations, the traditional framework is no longer applicable. To realize this research, it is essential to construct an efficient system (science platform) with large file server and rapid database. We construct them with referring a framework developed by Rubin/LSST.

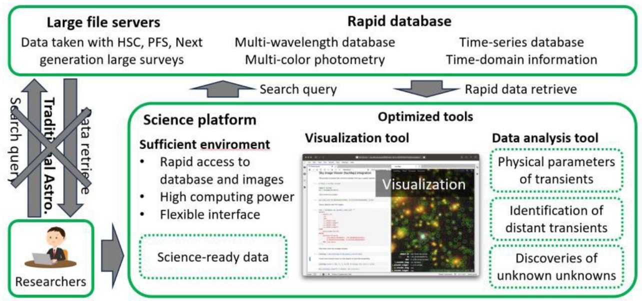

Figure 5. Basis of big data astronomy.

This system generates science-ready data by individual researchers and enables them to easily achieve scientific outcomes. Furthermore, we build a basis of big data astronomy in Japan. We also put effort into fostering young researchers who will lead the next generation of big data astronomy.

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