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

Multi-messenger Astrophysics : From a static universe to a dynamic universe

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Research Area Information	Number of Research Area : 23A205　Project Period (FY) : 2023-2027 Keywords : Multimessenger Astronomy, Neutrinos, Gravitational Waves

Purpose and Background of the Research

●Outline of the Research

Since the era of Galileo Galilei in the early 17th century, human understanding of the universe has been advanced by observations of electromagnetic waves such as visible light, radio waves, and X-rays. On the other hand, as physics has progressed, it has become clear that electromagnetic waves are only part of the messengers of information from the universe to us. The new messengers are neutrinos, which are weakly interacting elementary particles, and gravitational waves, which are oscillations of space-time due to gravity. The origin of cosmic ray radiation, the origin of matter, and the origin of black hole formation are extreme phenomena in the universe, but electromagnetic waves such as visible light cannot emerge directly from these sites. High-energy neutrinos, on the other hand, are elementary particles produced directly from collisions of matter accelerated to very high energies. Space-time distortions produced in ultra-high-density space are gravitational waves. These are messengers produced directly in strong gravitational field/high energy particle collisions. The mission of this research area is to combine these new observational tools with conventional electromagnetic waves (radio waves, visible and near-infrared light, X-rays, and gamma rays), which have superior resolution, to elucidate extreme cosmic phenomena in regions of the universe that were previously unobservable.

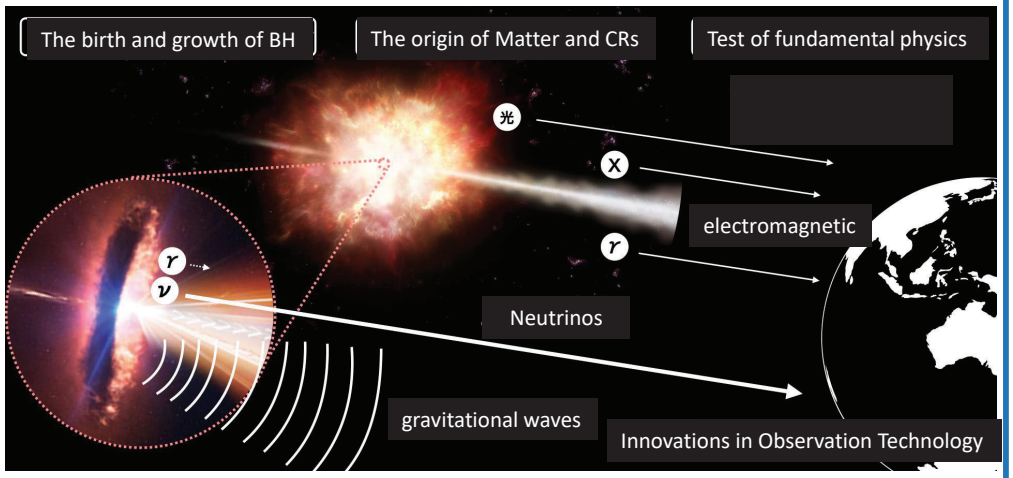

Figure 1. Concepts of multimessenger astronomy

● Main Research Subjects

Understanding the ultimate fate of gravitational energy, the following three subjects are addressed **I.** The birth and growth of black holes **II.** Origin of Matter and Cosmic-Rays **III.** High-precision test of fundamental physical laws.

●Structure of the Domain

Each research project is composed of observational research groups covering various messenger observations, technological development for future observatories, and theoretical research to deepen observational research.

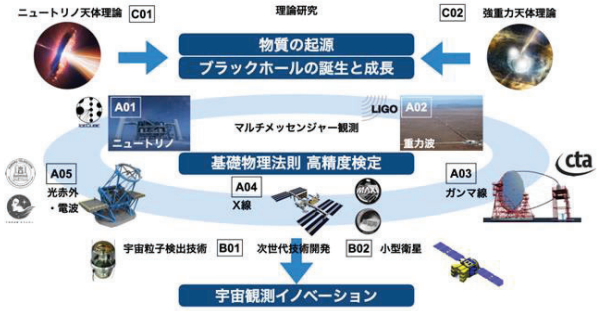

Figure 2. Structure of the Research Areas

Expected Research Achievements

●The Joint Research Programs

In order to advance joint researches using neutrinos and gravitational waves, which are non-electromagnetic signals, together with electromagnetic observations at various wavelengths, we conduct the five specific joint research projects. These are the observation of black hole-driven flares, observation of low-luminosity black hole ejecta, observation of element synthesis driven by neutrino star mergers, search for unknown transient objects, and search for binary neutron star merger jet emissions (Figure 3). Although the energy and time scales of the target objects, neutrinos, and electromagnetic radiation are different in each of the five missions, they all share the agendas, which are 1) understanding of the birth and growth of ultra-strong gravitational field objects such as black holes (birth and growth of black holes), 2) how the powerful gravitational energy is converted to form the elements that form us, and 3) to accelerate the proton and nuclear plasma to enormous energies to produce cosmic rays (the origin of matter). Observational data will be provided to the theoretical studies to reveal the ultimate fate of gravitational energy. Furthermore, gravitational waves, which are a general relativistic phenomenon, and cosmic neutrino beams, which are the product of high-energy particle reactions, themselves depend on fundamental physical laws such as the principle of relativity, the Standard Model of elementary particles, and Big Bang cosmology. We provide a "space laboratory" for high-precision testing of fundamental physical laws.

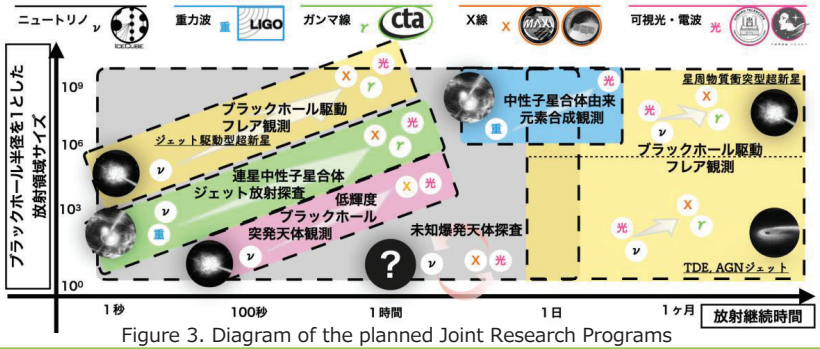

Figure 3. Diagram of the planned Joint Research Programs

Homepage Address, etc.	multimessenger.jp