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

Section Ⅱ

Title of Project： What is dark matter? - Comprehensive study of the huge discovery space in dark matter

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【Purpose of the Research Project】

"Dark matter" certainly exists and plays a critical role in formation of all cosmic structures such as stars and galaxies. However, the nature of dark matter has yet to be known. As guided by particle physics, most efforts have focused on WIMP dark matter candidates in the mass range of two order magnitudes, but observations and experiments in 2010's did not find any clue of WIMP. There is now growing interest in non-WIMP dark matter candidates. In this program, to comprehensively cover the vast discovery space of dark matter search spanning 90 orders of magnitudes in the mass scale, we aim at opening up research areas using theoretical approaches, observations of the Universe, and terrestrial experiments.

【Content of the Research Project】

To perform a comprehensive study of dark matter that is a dominant component of matter in the Universe today, we focus on three categories of dark matter candidates, "light dark matter", "heavy dark matter", and "macroscopic dark matter".

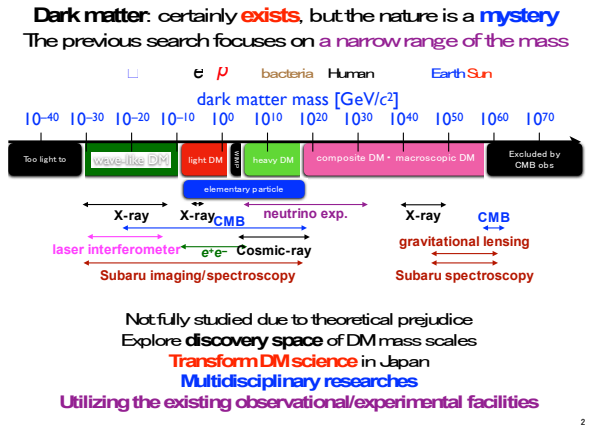

Fig 1. The mass range of dark matter candidates, and the purpose of this research program

Theory groups under this program (A01 – A03) will study generation mechanism of dark matter in the early universe and dark matter physics, and explore observation and experiment methods for dark matter search. Observation and experiment groups (B01 – B06) will explore the nature of dark matter using new methods based on the unique idea/consideration from this group and/or taking advantage of the cutting-edge observational data of the Universe. More exactly, we will use laser interferometer experiment (B01), spectroscopic data of Subaru telescope (B02), the innovative technical method/data in X-ray energy range (B03), high-cadence, wide-field-of-view imaging data in optical wavelengths (B04), electron-position accelerator experiment (B05), and cosmic microwave background (B06). Moreover, the research group (C01) will take a top-down approach such as quantum gravity to explore ultimate theory explaining the existence and physics of dark matter. The group (C02) will use numerical simulations to study how different dark matter models lead to characteristic features in cosmic structure formation. These C01 and C02 groups help and stimulate synergetic research between different research groups for dark matter physics. Thus we form a comprehensive research group covering both theory and observations/experiments and aim at unveiling the nature of dark matter during the period of this program.

【Expected Research Achievements and Scientific Significance】

We can obtain more stringent constraints on the nature of dark matter than previously obtained during the period of this research program. We will achieve realization of new table-top experiment, led by junior researchers in our group, and explore axion and gauge-boson dark matter candidates from the experiment data. We will explore X-ray emission originating from annihilation of dark matter from the cutting-edge data of the new-generation X-ray satellite XRISM that will be launched in 2022. We will use the cutting-edge imaging data from the already-running HSC camera at the 8.2m Subaru Telescope to obtain the unprecedented large three-dimensional map of dark matter in the Universe, and search for macroscopic dark matter candidates such as primordial black holes. Furthermore, using the data from wide-field, multi-object spectrograph, PFS, at the Subaru telescope, which is under construction and will be operated from 2023, we will obtain constraints on self-interaction strength and/or de Broglie wavelength of dark matter from the observations of dwarf galaxies in the Milky Way. In addition, we use the PFS data to obtain improved constraints on gamma-ray signals of dark matter annihilation from dwarf galaxies. We will also use the cosmic microwave background data to constrain axion dark matter or dark matter annihilation signal at the recombination epoch. Furthermore, we will install a new trigger into the Super-K Belle II accelerator that just started to be operated, and use the data to explore dark photon and SIMP dark matter. We aim to obtain these exciting new results during the period of this research program.

【Key Words】

Dark Matter: a form of matter thought to account for most of the matter in the Universe. Its presence is implied in a variety of astrophysical observations, and dark matter is believed to play a critical role in formation of cosmic structures. However, its nature is still a mystery.

【Term of Project】 FY2020-2024

【Budget Allocation】 1,130,500 Thousand Yen

【Homepage Address and Other Contact Information】
http://member.ipmu.jp/DarkMatter/