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

Broad Section B

Title of Project： Inclusive study on gravitational-wave astrophysics

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Keyword：Gravitational waves, data analysis, black holes, binary neutron star, kilonova, origin of heavy elements

【Purpose and Background of the Research】

Direct detection of gravitational waves from black holes and neutron stars by LIGO and Virgo has brought about a new era of gravitational wave astrophysics. The Japanese KAGRA detector is also joining the world-wide network of gravitational wave observations with its sensitivity to be improved. In this situation, this research project aims at the following scientific goals. (1) To achieve the detection of gravitational waves by KAGRA applying the independent component analysis of both gravitational-wave channel and environmental channels. (2) Using the observed data of black holes by gravitational waves and timing residuals of pulsars, we deduce the nature of these black holes to clarify if they are of primordial origin or not. (3) With regards to the binary neutron star coalescence, we clarify the dynamics and radiation processes of the kilonova phase and calculate the abundance of heavy elements produced by the r-process nucleosynthesis. We thereby advance gravitational-wave astrophysics inclusively.

【Research Methods】

First we perform joint analysis of the environmental data of KAGRA with its strain channel including the gravitational-wave signals to remove non-Gaussian noises in terms of the independent component analysis (ICA). Then we apply the GstLAL pipeline to detect gravitational wave signals from KAGRA. These analyses heavily use the computer cluster we will install with this grant.

As for the origin of black holes, we first make a volume-limited sample to extract the proper mass function of the holes. Then assuming that they are of primordial origin, we calculate the power spectrum of curvature perturbations and associated spectrum of long-wave stochastic gravitational wave background. This is compared with the pulsar timing data to constrain the mass range of primordial black holes.

The study on kilonova and nucleosynthesis will be done in the following procedure. First we calculate the initial configuration after the binary neutron star coalescence in terms of numerical relativity. Then we calculate nuclear contents and radiation processes in nonequilibrium situation to yield the abundance of heavy elements produced by the r-process nucleosynthesis using the computer cluster we will install. The results will be compared with various observations including those of Tomo-e camera.

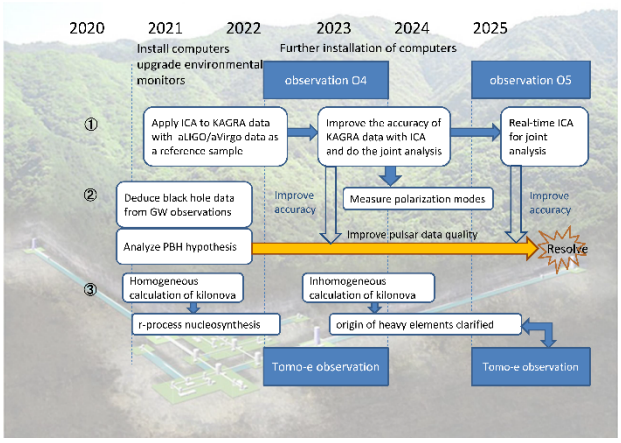

Figure 1. KAGRA and proposed timeline (without Covid-19's impact)

【Expected Research Achievements and Scientific Significance】

First KAGRA will accomplish detection of gravitational waves hopefully with the help of our analysis and the computer cluster we will install. Then simultaneous operation of four detectors in the world will improve the directional accuracy of the sources and the data quality. With increased observational data we should be able to constrain mass range of primordial black holes to judge whether these black holes are of primordial origin or from first generation of stars. Furthermore numerical analysis of kilonova and associated nucleosynthesis will uncover what fraction of heavy elements such as gold and platinum was produced in these events with the help of the observations of dwarf galaxies. This will also yield important information on elementary processes of nuclear interactions.

【Publications Relevant to the Project】

・ KAGRA collaboration "Application of the independent component analysis to the iKAGRA data" PTEP 2020(2020)053F01

【Term of Project】 FY2020- 2024

【Budget Allocation】 155,700 Thousand Yen

【Homepage Address and Other Contact Information】

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