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

Broad Section B

Title of Project : Study of r-process nucleosynthesis of gravitational wave sources by means of high sensitivity wide-band near infrared spectroscopy

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Keyword : optical near-infrared astronomy, gravitational wave, neutron-star merger, adoptive optics, spectroscopy

【Purpose and Background of the Research】

The cosmic origin of elements heavier than iron (heavy elements) such as gold, platinum, and uranium is not known well. Mergers of neutron stars have been considered as the most promising sites that produce heavy elements. When neutron stars merge, some materials are ejected, and rapid neutron capture nuclear reactions that produce heavy elements can occur in the ejecta. However, it was difficult to observationally confirm that neutron-star mergers produce heavy elements until recently.

In 2017, the gravitational wave observatories LIGO and Virgo observed the gravitational wave event GW170817 from a neutron-star merger for the first time. In addition, the electromagnetic counterpart of GW170817 was identified and observed by many telescopes including the Subaru Telescope. The electromagnetic signatures that are expected to appear when heavy elements are synthesized were found in it, and it was confirmed that heavy elements were produced in the neutron-star merger. However, electromagnetic signatures from only one neutron-star merger have been observed so far. Neutron-star mergers are expected to have diversity, and a typical amount of heavy elements produced by neutron-star mergers is still unknown. In this research, we observe many neutron-star mergers and investigate the diversity in the heavy-element production in neutron-star mergers.

【Research Methods】

In order to estimate the amount of heavy elements synthesized in neutron-star mergers, it is required to conduct their spectroscopic observations in near-infrared for one week after the merger. The current largest telescopes like the Subaru Telescope can observe neutron-star mergers for one week if they appear within 400 million light years. However, only two neutron-star mergers that can be reached by Subaru Telescope appear within 400 million light years in a year. If we can increase the sensitivity to reach up to 600 million light years, we will be able to observe about 10 neutron-star mergers per year. Then, we can uncover the diversity in the heavy element production in neutron-star mergers immediately.

The current sensitivity of the Subaru Telescope is set by image degradation by atmospheric turbulence (we call it “seeing”). Light from space is distorted by atmosphere before it reaches the telescope. If we can correct for the seeing, we can achieve a better sensitivity. A Laser Tomographic Adaptive Optics system (LTAO) which utilizes tomography technique using multiple artificial laser guide stars is currently under development for the Subaru Telescope. LTAO can correct the atmospheric turbulence effect very accurately. However, there is no near-infrared spectrograph fully optimized for LTAO in the world. In this research, we develop a brand-new near-infrared spectrograph that is fully optimized for LTAO. The new spectrograph will be sensitive enough to observe neutron-star mergers up to 600 million light years for one week after the merger. This will allow us to observe many neutron-star mergers for one week and, therefore, to uncover how much heavy elements are typically produced in neutron-star mergers (Figure 1).

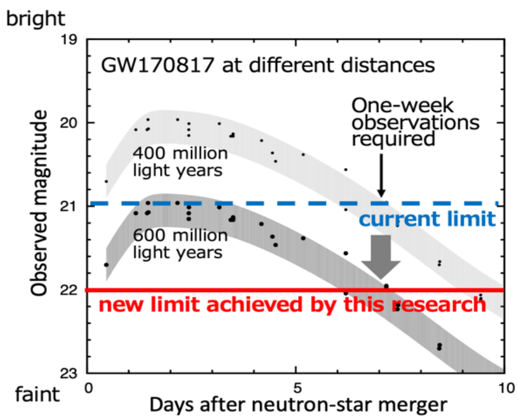

Figure 1: Near-infrared brightness of neutron-star mergers.

【Expected Research Achievements and Scientific Significance】

By observing many neutron-star mergers, we will know how much heavy elements are generally synthesized in neutron-star mergers. Then, we can tell if neutron-star mergers are really the major production site of heavy elements in the Universe. The new near-infrared spectrograph can also be used for other studies such as supernovae and supermassive black holes.

【Publications Relevant to the Project】

- “J-GEM observations of an electromagnetic counterpart to the neutron star merger GW170817,” Utsumi, Y., Tanaka, M., Tominaga, N., et al. 2017, PASJ, 69, 101
- “Kilonova from post-merger ejecta as an optical and near-infrared counterpart of GW170817,” Tanaka, M., Utsumi, Y., Mazzali, P.A., et al. 2017, PASJ, 69, 102

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