

## 変革を駆動する先端物理・数学プログラム (FoPM)

## 国外連携機関長期研修 報告書

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With the financial support of FoPM, I visited the Gravitational Wave groups at Institut de Physique des 2 Infinis de Lyon at Université Claude Bernard Lyon 1, France. The group contributes to data collection of the gravitational wave detector, data analysis, and mirror production. I spent two months there, doing research work on gravitational wave data analysis.

The research project during the stay is to start a joint inference of population parameters and cosmological parameters in gravitational wave astrophysics. As the number of detections of gravitational waves increases, the study of the statistical aspects of compact binary coalescence is beginning to gain significance. The source parameter of compact binary coalescence, which is the major source of the gravitational waves, can be tracked from theoretical waveform from General relativity, and this imprints the mechanism to form such a binary system. A number of astrophysical scenarios have been proposed as mechanisms for the formation of compact binary stars that merge within the age of the universe, but no consensus has been reached to date. To investigate such a population property of compact binary coalescence, some cosmology is assumed to calculate source-frame masses, since masses that can be directly measured from gravitational wave observation are redshifted. On the other hand, the inference of cosmological parameters using gravitational wave observations is another science that has become more realistic with the recent increase in the number of events. The observation of sources that emit not only gravitational waves but also electromagnetic waves will greatly improve cosmological inference, as their redshift will be measured by optical measurement. However, most of the detected objects to date do not have an optical counterpart. The measure of distance that can be directly determined from observations of gravitational waves is the luminosity distance, and the redshift appears in the form of an effect on the mass. Therefore, some mass distribution of compact binary is often assumed to infer the cosmology parameter. For this reason, methods for simultaneously estimating cosmological and astrophysical parameters (such as mass distribution of black holes) have recently begun to be developed.



During my stay, I worked on developing a code for fitting gravitational wave observations with parametric functions on source/cosmology parameters. Before the stay, My work had a specific astrophysical scenario in mind, but there I learned the method of fitting by parametric functions on source parameters. The fourth observing run of gravitational waves by the International Gravitational Wave Observatory Network began in May 2023, and the first

period of observing run ended in January 2024. I visited during the commissioning period before the second period of observing run starting April 2024. During the visit, there was an internal conference within Virgo collaboration, the gravitational wave detector in Europe. Also, a global collaboration meeting consisting of LIGO in the U.S., Virgo in Europe, and KAGRA in Japan. I attended both conferences, which are hard to attend in Japan because of the difference in time zones. I participated in a session whose agenda included the sensitivity status of the current observing run and interesting events obtained from observations within the year 2023. Since Virgo was not observing during the first period of the fourth observing run, it was a good opportunity to learn about the Virgo situation. Of course, discussions on the cosmology subgroup and population subgroup in LVK collaboration are meaningful.

Life in Lyon was comfortable. Having been to Paris before, I imagined that the city would be as unsafe as Paris, but I never felt unsafe when commuting to school by bus or tram. The public transportation system in the city is very well developed, and I never felt inconvenienced by public transportation when commuting to the university or going out on weekends. Wandering around the city of Lyon is a lot of fun, as there is so much to explore. The view of the city from Fourvière Hill left me speechless. Lyon is also famous for its food. A staff who roomed with me gave me a list of his recommendations for food during my stay. Many of the dishes were memorable, such as cervelle de canut and crème aux œufs. It is a pity that I did not get to enjoy all of them, but I will try again in the future when I have more money and time to spare.

I used flat-share accommodations that were rented out to students by a private landlord during the stay. My roommates there were students from Gabon, majoring in political science in Africa. Since I could not speak French and they could not speak English, the discussion took place over a translator. Let alone the fun of everyday conversation, their perspectives on the situation in their home countries and international circumstances were new to me. Also, my opinions seemed to be interesting to them, and sometimes they took notes of what I said (this is when talking through a translator comes in handy) for his doctoral thesis. I think we had a valuable discussion and gained valuable experience.

Finally, I would like to thank FoPM administration office for giving me this opportunity, the secretaries for facilitating the procedures during my stay in Lyon, and the IP2I gravitational group, including Viola Sordini, for accepting my stay.