（別紙様式５）

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

氏　　名	直川史寛
所属部局	理学系 研究科　　物理学 専攻
受入先	マックスプランク宇宙物理学研究所・ケンブリッジ大学・ライデン大学等
日程	西暦　2025　年　4　月　14　日　～　西暦　2025　年　7　月　20　日

-Research

I have been working on “cosmic birefringence” for several years. Cosmic birefringence is currently reported interesting signal from the Cosmic Microwave background (CMB), the oldest photons in the universe. Cosmic birefringence refers to the rotation of polarizations planes of photons during their propagations through the universe. This signal, if confirmed, should play a key role to explore new physics including new particles, dark matter and dark energy, beyond the current understandings. I work on the theoretical calculations of the signal imprinted in the CMB data. I also work on the establishment for the method of independent tests of the signal using astrophysical objects such as radio galaxies. In this travel, I visited and stayed multiple universities and institutes related to both the works of the CMB and the astrophysical objects.

-Places to visit

I mainly stayed at the Max-Planck Institute for Astrophysics (MPA) near Munich, Germany and the University of Cambridge in the Unite Kingdom. During the period, I also visited institutes related to my work, including DESY, Hamburg Observatory, the headquarter of the SKA Observatory, Leiden University, and ASTRON, staying at each for several days each.

-Germany

I stayed at the MPA for two months, hosted by Dr. E. Komatsu, who reported the signal of cosmic birefringence in 2020 and is also one of my collaborators. During the stay, I improved my current analysis of radio galaxies detected by LOFAR (the name of telescope) for studying cosmic birefringence. There are many researchers who were interested in such topics, and I regularly reported my progress in meetings with colleagues who shared the interests and received feedback through the discussion.

At MPA, there were a lot of people from a wide range of fields of astrophysics and cosmology, and we could interact with each other. For example, there is a coffee time in the morning every day, where many MPA researchers and visitors get together. There were sometimes also events for students and postdocs. I actively joined these events, which were great opportunities to get along with collogues and interact with new people. These interactions with researchers from different fields indeed resulted in new ideas of integrating different specialties and doing new things. Especially, I could interact with a group measuring the expansion of the universe. I joined their meetings several times and gave of my project related to their works. Through these intensive interactions with diverse researchers, I also came up with some new ideas for my research.

During the two months in Germany, I temporarily stayed in Hamburg for a week to visit DESY and the Hamburg Observatory. I gave a talk and could discuss my work with related researchers. I also learned several other things from this small trip: When visiting a place, learning about local history and culture plays an important role in communicating people there. I also learned that different cities and regions show quite different sceneries even within the same country.

-the United Kingdom

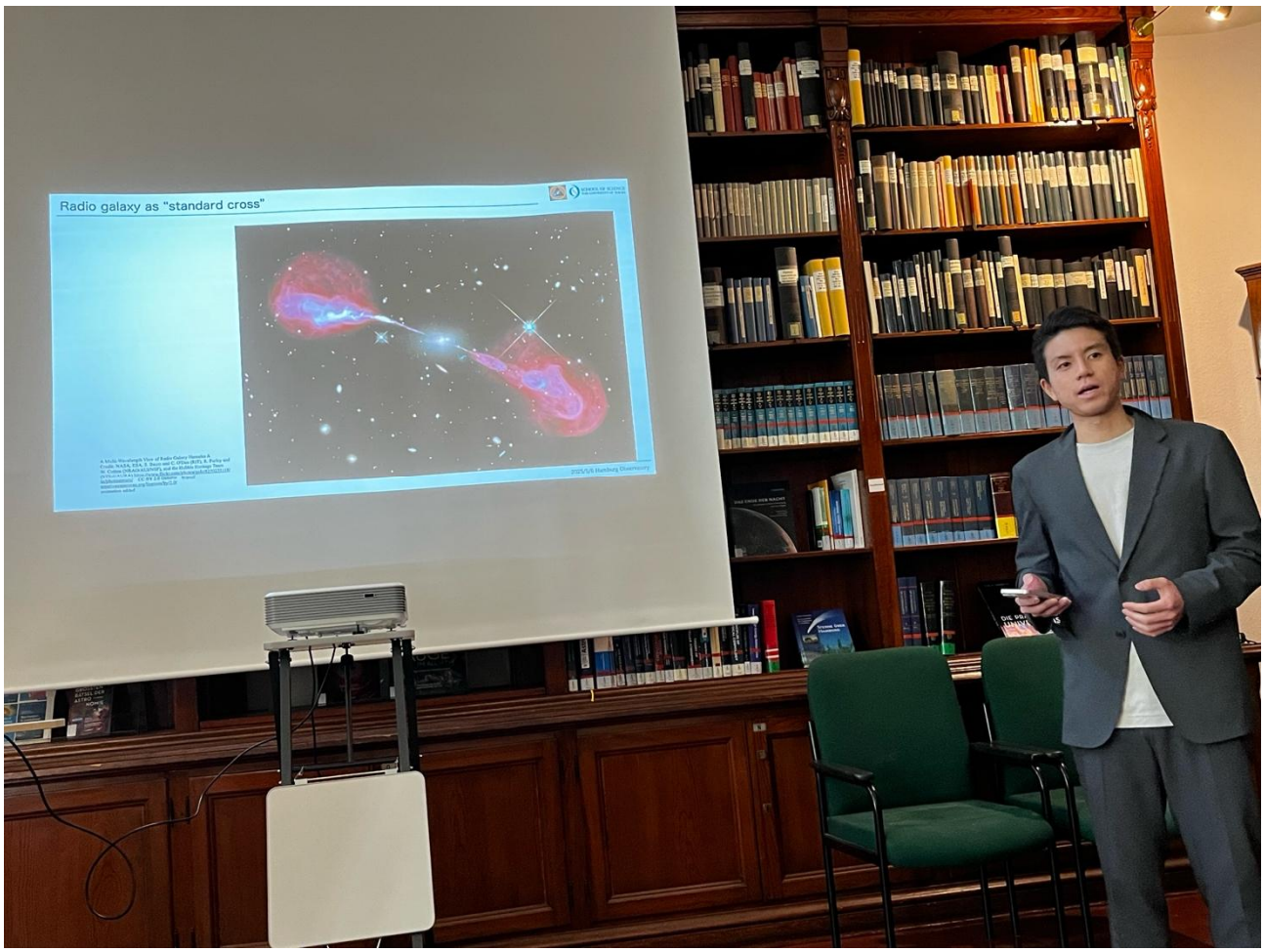
I mainly stayed in Cambridge for one month in the U.K. I was hosted by Dr. T. Namikawa and his research group led by Dr. B. Sherwin. I worked on analyses of the latest CMB data to explore the cosmic birefringence and possible signals of axion-like particles underlying it. This is mainly the collaboration with Dr. Namikawa, but there were so many experts in CMB data analysis and experiments in Cambridge. There were also many researchers and students who were interested in party violations in the universe, from both theoretical and observational perspectives. Therefore, I could get deep discussion with them on topics. Cambridge has a long and distinctive academic history with the city itself. It was fun to visit and explore its various stores, restaurants and colleges.

In the final several days in the U.K., I visited to SKA Observatory at Jodrell Bank near Manchester. This is because my work using radio galaxies ultimately requires the powerful data to be obtained by the SKA in the near future. It was a valuable opportunity to discuss my research with scientists there.

-Netherlands

In the last part of this trip, I stayed in the Netherlands for about a week to visit Leiden University and ASTRON. Both are places where studies using LOFAR are actively conducted. I had the opportunities to give talks about my work at each place. I could get several useful feedback from the viewpoints of radio astronomical researchers. It was very meaningful for me to give a talk in the Netherlands, since this country is one of the birthplaces of radio astronomy. Leiden University is where Oort and van de Hulst proposed observing the 21cm emission line at the dawn of radio astronomy.

In addition to the progress of my research, what I have obtained in this trip is professional connections and a research network across Europe. I gave 7 talks at different institutes and universities across the three countries. Also, this was my first time living outside Japan for longer than a month. Living in different countries and cultures is always a beautiful experience, but I simultaneously felt some difficulties in living in such circumstances. I also realized how the kindness of the people living and working there was helpful. I thought I should help them and be generous to them in the future as well, and also to those who visit or live in my place.



At the Humburg Observatoy (The picture on the slide in the photo is A Multi-Wavelength View of Radio Galaxy Hercules A Credit: NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team (STScI/AURA) https://www.flickr.com/photos/gsfc/8230235118/in/photostream/ CC BY 2.0 Generic https://creativecommons.org/licenses/by/2.0/)