（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	木戸大三郎
所属部局	理学系研究科　　物理学専攻
受入先	Max Planck Institute for Gravitational Physics/ Max Planck Institute for Astronomy/Institute of Science and Technology Austria
日程	西暦 2025 年　9 月　24 日　～　西暦 2025 年 11 月 8 日

From the end of September to the beginning of November, I visited the Max Planck Institute for Gravitational Physics (AEI), the Max Planck Institute for Astronomy (MPIA), and the Institute of Science and Technology Austria (ISTA). The overall goal was to strengthen both the theoretical and observational aspects of my work on the growth of supermassive black holes (SMBHs) and on the nature of “Little Red Dots” (LRDs) discovered by the James Webb Space Telescope (JWST). LRDs are recently identified compact objects characterized by very compact morphologies, red colors, and broad hydrogen Balmer emission lines, which resemble those seen in many active galactic nuclei (AGN). At the same time, they show low variability and striking weakness in X-ray, radio, and mid– to far–infrared emission, challenging the standard AGN picture. Earlier this year, our group published a paper proposing a theoretical model for LRDs. One aim of my visit was to present this published work to experts in different subfields, receive feedback on the underlying assumptions, and learn how observers interpret LRDs. Across the three institutes, I was able to deepen my understanding of relevant theory, simulations, and observations, and to identify future directions. At AEI, I interacted with researchers who work on state-of-the-art numerical relativity and high-energy astrophysics. In addition to discussing the LRD project, I focused on understanding how relativistic jets propagate through the ejecta produced by neutron star–black hole mergers. Through conversations and informal whiteboard sessions, I learned how such systems are modeled using numerical relativity codes, and how one connects simulation outputs with potential electromagnetic counterparts. We discussed which aspects of jet–ejecta interaction are particularly important for interpreting observations, and clarified which questions would be most interesting to address. I attended regular group meetings, seminars, and journal clubs, which exposed me to current topics in gravitational wave astronomy, numerical relativity, and high-energy transient astronomy. AEI hosts many theorists who carefully consider general relativistic effects around black holes, and I had the opportunity to ask how the innermost region near the SMBH might influence the global configuration and spectra in simplified envelope models such as the one we proposed. These discussions helped to refine the treatment of the inner boundary in future theoretical work. Another important outcome of the AEI stay was the opportunity to start a new collaboration, which I plan to develop further after returning to Tokyo.



Figure 1 AEI の正面玄関

My visit to the MPIA focused mainly on the observational side of galaxy evolution and AGN physics, particularly in the context of JWST. I gave a talk and joined group meetings, which led to constructive discussions. The MPIA galaxy group has many subgroups that treat several different topics from both theoretical and observational side.

Seminars and group discussions covered a wide range of topics, from theoretical galaxy formation to AGN activity in the epoch of reionization. One of the key consequences of here is to meet and discuss with Raphael Hviding on LRDs, which may expand our model and impact current understanding of LRDs.

At ISTA, I interacted with both theorists and observers who investigate SMBH growth at high redshift and the properties of JWST-selected galaxies, including LRDs. Several groups there work on theoretical considerations of SMBH formation and on interpreting JWST observations of early galaxies. I gave a seminar on our envelope model and received feedback. It was particularly fruitful to discuss with Jorryt Matthee, one of the leading researchers on LRDs, who generously spent time explaining recent results and observational trends. These conversations helped me understand which properties of LRDs appear robust across different samples and analyses, and which remain uncertain. Motivated by these discussions, we outlined possible future studies, which I will not go into details here. Although I could not meet Zoltan Haiman due to his business trip, I had many opportunities to talk with other theorists about high-energy astrophysics, accretion physics, and stellar evolution, which broadened my scientific perspective beyond my immediate thesis topic.

Across all three institutes, the visits provided valuable experience in international research environments. Working in different groups taught me how collaboration styles, expectations, and communication practices can vary, and how to present my work to researchers with diverse specialties, from gravitational wave physics to observational cosmology and theoretical astrophysics. I improved my ability to give concise talks, respond to questions, and participate actively in discussions. Living and working in Germany and Austria also enhanced my practical skills in planning, time management, and maintaining productivity while adapting to new surroundings. In summary, the training period at AEI, MPIA, and ISTA was highly beneficial for my development as a researcher. I deepened my theoretical understanding of SMBH growth and accretion physics and built an international network of collaborators and mentors. These experiences will directly support the progress of my PhD research on LRDs and SMBH evolution, and they have also given me a clearer picture of how I would like to shape my future career in astrophysics.