（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	持田隼
所属部局	理学系研究科　物理学専攻
受入先	ライス大学
日程	西暦 2025 年　1 月　15 日　～　西暦 2025 年 3 月 3 日

I had an opportunity to stay at Rice University with the support of FoPM for international experience. Rice is located in Houston, Texas, which is the fourth largest city in the US. Although Rice is quite a small university, it has a good reputation for education and research in the US. I visited Professor Qimiao Si's group to discuss the possibility of cavity control of heavy fermion materials. Qimiao is known for his research on the theory of quantum criticality in the heavy fermion and his group is vigorously studying strongly correlated electron system including the Weyl-Kondo semimetal and the strange metal.

My research focused on the theory of cavity quantum electrodynamics (cavity QED) applied to materials. The focus is on the control of correlated matter, particularly systems related to Kondo physics, via strong vacuum fluctuations in the quantum electromagnetic field.　The state-of-the-art technique of cavity QED provides a novel way to control quantum material by coupling ultra-strongly with photons. As mentioned above, Qimiao's group is the expert in Kondo physics.　Study of cavity QED in heavy fermion systems (or Kondo physics) is a brand new idea, and it is also a new project in Qimiao's group. On the other hand, Professor Junichiro Kono's group has done a lot of great work on ultra-strong cavity QED experiments at Rice. Prof. Kono graduated from the Department of Applied Physics at the University of Tokyo decades ago and is now the director of the Smalley-Curl Institute, which is the host institution for my project. My cavity QED materials project had the potential to provide an intersection of cutting-edge quantum physics research at Rice.

One of the salient predictions of cavity QED is a superradiant phase and its transition. In the superradiant phase, strong light-matter interaction induces macroscopic photon condensation. The relationship between strongly correlated electron systems and superradiant phases in the context of cavity QED material is less well understood. I discussed the superradiant phase in the electron systems with the group members, especially Yiming, Shouvik, and Mounica. We also discussed with members of the Kono group about recent experiment of their group, which opens a possibility of the new platform of Dicke physics, typical model of the cavity QED, in gadolinium gallium garnet that forms the Zeeman polaritons in the ultra-strong coupling regime. Also, I heard about a seminar by Subir Sachdev, Professor of Havard university, on strange metals in the Suchdev-Ye-Kitaev model, which is the celebrated model named after him. This was a valuable opportunity as it was relevant to what I am studying at Rice.

I was impressed by the active collaboration, including between experiments and theorists inside Rice. Qimiao's group is one of the larger theory groups, but I could see that the members were actively discussing with each other every day. Group meetings are also held frequently to facilitate research efficiently. I hope to learn from this approach when I return to Japan. I met a lot of people at Rice and learned a lot during my stay. I will keep in touch with the group members and continue our research.

Fig.1. Squirrel living in the campus

Life in Houston

This was literally my first time in the US. Therefore, it was a very exciting and nervous time before I left from Japan. It turned out to be a truly unforgettable and valuable experience. Houston is a practical and

multicultural city with friendly people. I was supported by many people during my stay. Also, many of people I met were interested in Japanese culture and I was happy about that.

The university and my accommodation were in an area lined with museums and facing a huge park, so I was able to spend a comfortable time there. I was also impressed to see many lovely (and big) squirrels on the streets and on the campus, surrounded by nature (Fig. 1). My favorite thing is that even in February there were many warm days with plenty of sunshine. (By the way, when I first arrived, an enormous winter storm caused the most intense snowfall in several years; Fig 2.)

Fig.2. Beautiful building of Brockman Hall for Physics (left), where my office was. Shortly after the winter storm in January.

I suppose I have to mention it to be fair, but Houston is probably one of the most car-based cities in the US, even if it is generally considered that US cities are largely car-based. (I am reminded of the old saying "What's good for General Motors is good for America") There are tons of parking and only poor public transportation in Houston. The pavements are narrow and suddenly they disappear, very few people are on the streets. I was surprised that Houston is such an unwalkable city, I'm used to Tokyo, a walkable and extremely convenient transportation city, and feels like the opposite city of Houston. Interestingly, Houston is designed without any land zoning for city planning, with free and large-scale development led by the private sector. The result is a large city with sparse urban functions. Anyway, living in Houston was definitely an interesting experience.

Houston is famous for the NASA space center. (J. F. Kenedy gave a historic speech to declare that they were going to the Moon in 1962 at Rice!). I visited the Johnson space center with Japanese scholars I met at Rice. (Fig. 3) The Space Centre in Houston houses astronaut training facilities and flight control and many historic achievements were achieved here, including the Apollo program. At the center, I could feel the history of strong US and international joint space exploration.

Conclusion

The stay was a valuable opportunity not only to meet excellent collaborators, but also to experience life and research abroad. I would like to thank everyone involved for their support and the wonderful people I met in Houston.

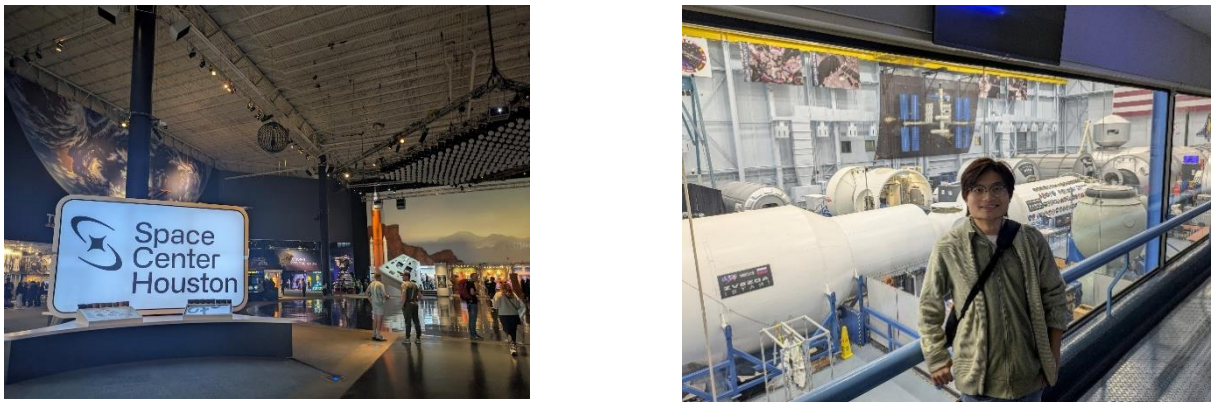

Fig.3. (left) Space Center Houston opens to the public. (right) Me at Astronaut Training Facility