I have been fascinated by the infinite stars since childhood. In my childhood memory, my grandfather had a small telescope in the attic of his house. Every night after the rain, when the stars came out, my grandfather would take me to see those twinkling stars, Milky Way, Albireo, Saturn, the brightest Jupiter, North Star, Cassiopeia … even lucky enough to see satellite and meteor at some special timing. At that time, I spent a lot of time with atroscience picture books, and often look at those colorful, large or small planet imagination pictures in a daze. Among them, the most attractive chapters for me are always those about black holes. Because black holes are not like other celestial with gorgeous colors, they are just pure black, floating in space, constantly gobbling up everything around them, frightening but desirable.

Gradually growing up, I have never expected to meet with black hole in my undergraduate graduation thesis again, even though learning applied mathematics in my undergraduate.

Everything begins in year 2019, encouragingly, the Event Horizon Telescope (EHT) has showcased the first image of the supermassive black hole M87* using very-long-baseline-interferometric (VLBI) technology. The outcome of EHT reveals a fine structure near the black hole horizon.

After this exciting news came out, our university's physics mathematics professors jointly gave an introduction lecture on what behind the VLBI and black holes. At that lecture I had the good fortune to meet my current mentor who is now supervising my graduation study. When I learned that he had just transferred from the department of Mathematics of The University of Tokyo to teach in our school and had profound research experience in gravitational lensing, I decided to contact him immediately and requested for a deeper discussion on black holes and theorems behind it.

Fortunately, the professor was extremely friendly and willing to spare his spare time to show me the most basic knowledge of differential geometry and topology to gradually

understand the existence principle and behavior of black holes. This made me super excited, and I chose to continue the study and exploration of black holes without hesitation as my graduation project which aims to simulate the shadow silhouettes of different types of black holes under different light sources illuminating the black hole.

Starting from first principles by professor's support, I have developed basics of metric differential geometry. Then we go through Einstein's special and general theory of relativity, which describe the kinematics and dynamics of spacetime, and discuss aspects of black holes. Then, by learning basic differential geometry and typology, more about Schwarzschild matrix, and tensors, starting with the numerical analysis of geodesic equation, I have then split it into one ordinary differential equation system by an implicit Runge-Kutta method. Hence, I succeed in generating Python code to plot photon ring trajectory passing through a black hole at an extreme deviated angle only according to two different variables, which are the distance that observer from the black hole and the radius of the black hole. Which is the basis of describing the shadow of black hole for the spherically symmetric, non-rotating Schwarzschild case.

While, the professor and I agreed that I could continue to explore and research on it. So, the next goal will be to extend the code to simulate the same situation for more general types of black hole solutions, such as the rotating Kerr black hole, binary black holes and perhaps more exotic cases as well. Even more, as a third goal, the code will be refined from isotropic illumination to different types of accretion disks in order to exhibit the effect of different light sources and also to make the results more compatible with the observational data.

Finally, I am probably going to investigate the relative effect of different black hole parameters. It is hoped that through the above research process, I can learn more about the differences between stellar and supermassive black holes on the one hand, and intermediate-mass black holes on the other, whose existence is surprising and a subject of current research in the field.

So far, I have been ecstatic and feel very lucky to meet the black hole again. It feels like my childhood dream is unfolding before my eyes. Of course, it also drives me to explore and pursue new things around me and dreams in my heart and it makes me more curious and competitive. I hope that under the guidance of the professor, I can finish my graduation thesis well and publish it, so as to realize my childhood dream.