Academic Statement

In graduate study, **(magneto)hydrodynamics simulation for high energy astrophysics** is one of my most interesting directions. MHD simulation has a wide range of applications, through accretion, Magnetars to Tidal Disruption Event(TDE), which help us find the role played by the magnetic field in these transients. Yet we still know less about the formation of TDE. The relatively low rate of TDE has been pushing us to concentrate on simulation and theory study. **Prof. Enrico Ramirez-Ruiz** is a recognized pioneer. As early as 2009, Prof. Enrico studied the influence of the stellar structure on the accretion rate after TDE. In 2013, using an adaptive-mesh hydrodynamics code FLASH, he made a thorough investigation on how the penetration parameter impacts accretion rate and challenged the previous "freezing model". This work has inspired scholars for years to follow this type of pattern and perform the simulation. In recent years, Prof. Enrico Ramirez-Ruiz has collaborated closely with scholars to explain the driven mechanism of repeated TDE. Working with Prof. Smadar Naoz at UCLA, he has been testifying about the combined effects of two-body relaxation processes and the eccentric Kozai–Lidov mechanism. These historical achievements clearly demonstrate that Prof. Enrico possesses exceptional scientific insight, accurately identifying and pioneering cutting-edge research topics in the field of TDEs. He has provided powerful tools for theoretical validation, accumulating extensive experience in simulations throughout this process. Therefore, I am eager to develop high-performance MHD codes and apply them to the study of TDEs or accretion disks under his guidance. My coding experience in BH accretion is very helpful. My story is below.

My journey into astrophysics began during a visit to the Fuxian Lake Solar Observatory in Kunming, where I was introduced to MHD for studying the Sun's interior by Prof. Chun Xia. There, I witnessed how the activity of the Sun influence on Earth. Exploring the application of fluid dynamics in astrophysics during my undergraduate ignited my passion for astrophysics. My excellent academic performance in my freshman year earned me a place in the Fudan University Joint-Cultivated Undergraduate Program. At Fudan, I strengthened my understanding of theoretical physics. Although this program was interrupted by the *2022 spring Shanghai Lockdown.* I continued pursuing study opportunities at the University of Notre Dame and UC Santa Barbara. These study and research experiences aroused my interest in astrophysics and laid a foundation for my future academic career.

In my junior year, I initiated a research project on extremely super-Eddington BH accretion in AGN, under the supervision of Prof. Luo Yang. It is well known that the accreting material piled at the surface of a neutron star(or white dwarf) is likely to go through thermonuclear fusion and shine in X-ray band. Why is then the accreting black hole cannot induce such a burst? What is the difference between a black hole accretion and a neutron star? On the other hand, a kind of fast accretion stellar mass black hole is thought to exist in the disk of AGN(named as accretion-modified star, AMS[1]). Small BH mass with a fast accretion will bring an extremer ambient (hotter and denser). Based on these questions and analysis, we started from the basic advection-dominated accretion flow(ADAF) model and explored the effect of thermonuclear fusion on the fast accretion of BH. In the energy equation, we considered the heat released by two types of hydrogen burning(p-p chain and CNO-cycle) and Helium burning(triple alpha). In order to learn more about nuclear reactions, I studied courses such as Stellar Structure and Evolution at UCSB as an exchange student in 2024. There, I was also introduced to the Modules for Experiments in Stellar Astrophysics (MESA), a module for stellar evolution developed mainly by UCSB. Then, with my supervisor's help, I developed a 4th-order Runge-Kutta method using Python to solve the disk structure for AMS. We found that the heat released by fusion is still negligible, mainly due to the low density and the high advection cooling rate. After our discussions, my answer to the previous question is that BH has no clear physical surface to deposit the material, therefore, cannot make it as dense as those in neutron stars or white dwarfs. Then, we employed an open-source FORTRAN code(the workhorse of MESA) to compute the nuclear reaction network. Significant metal enrichment has been reproduced, such as ^{3}He and ^{12}C. The mass ratio of N/C and O/C are also lifted. If these elements are carried by the outflow of the disk, we may explain the supersolar metallicity observed in the broad line region. During this research, I also greatly enhanced my skills in parallel computing on a Linux server and the application of FORTRAN. This work culminated in a paper accepted by *MNRAS* (See the link).

In this fall quarter, I finished two graduate courses with satisfactory grades in UCSB; one was High Energy Astrophysics conducted by Prof. Omer Blase. I also finished a course project entitled Repeated Tidal Disruption Event(see the link). I surveyed the observational and theoretical progress in explaining repeated TDEs and concentrated on the promising models. Hills Mechanism and Kozai-Lidov Mechanism are two promising directions, both trying to introduce a third body's perturbation to drag the star near the disruptor. This course has not only pushed me to the most cutting-edge and active research directions in the field but also deepened my understanding of radiation mechanisms in high energy astrophysics.

In addition to astrophysics, I am also interested in **condensed matter theory**. I conducted a project entitled Phase Transitions in the 2D Ising Model with Prof. Bo Zheng. Using Monte Carlo method, I simulated the Paramagnetism-Ferromagnetism transition of the system using Python. I analyzed the order parameters of the system and compared the convergence and robustness of two strategies. The Wolff Algorithm displayed enhanced accuracy and speed as the system expanded, owing to its multi-particle flipping strategy. I also made an animation that shows the transition of the symmetry breaking of the lattice. Later, I also conducted some surveys on the application of artificial neural networks in phase transitions. I believe that my solid theoretical foundation and multidisciplinary research experience will greatly benefit me in my future study. A good example of interdisciplinary research is the *crystallization of a white dwarf*. Electrostatic interactions between ions can be substantial at sufficiently low temperatures and high densities. During this process, the white dwarf goes through a first-order phase transition, releases latent heat, and forms a lattice, which was observed by the Gaia in 2019.

Overall, the Department of Physics at UCSC offers a broad range of research topics pursued by various scholars. This interdisciplinary environment fosters intellectual stimulation and encourages collaboration across different fields, enabling us to tackle scientific challenges in unexpected and innovative ways. For these reasons, I am deeply enthusiastic about starting my graduate studies at UCSC. In the long run, I am going to be a theoretical astrophysicist aspiring to build models that better align with observational data and adhere more closely to physical intuition.

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