Academic Statement

In graduate study, I am interested in **simulation and theoretical study of accretion phenomena**. Prof. **Charles F. Gammie** is a highly prolific scholar. His early research in the 1990s began with observations and numerical studies on molecular clouds and star formation. In 1996, He proposed a layered accreting model for T Tauri star, which predicts a slower fall-off in effective temperature with radius and meets the observed spectral energy distribution very well. After the magnetic instability was discovered in 1991, He started exploring Magnetic Arrested Disks and MHD turbulence. Using the shearing box approximation, he is one of the first scholars to study numerically in 3D the behavior of the MRI instability in disks(1995). Then, working closely with James Stone et al., he found that an initially vertically stratified accretion disk also demonstrated similar anisotropic turbulence(1996). In 1998, He provided a detailed theoretical and successive numerical study of ADAFs in Kerr metric, based on which he developed a two-temperature ADAF model for Sgr A. Following the development of the 3D MHD simulation code —Zeus, he evaluated the dissipation rate of supersonic, sub-Alfvenic turbulence to be rapid, challenging the previous notions (1998). Based on previous work results, in 2001, he used the performed simulations of giant molecular clouds with varying initial magnetic field strengths. In the same year, he also employed a shearing-sheet model to investigate gravitational instabilities in thin, Keplerian accretion disks. In 2003, a numerical scheme was designed by him to solve the equations of General Relativistic MHD. In recent years, he has collaborated with scientists in the Event Horizon Telescope(EHT) to push the boundary of black hole observations. After reading through a substantial number of his papers, I can see **his remarkable ability to focus on a specific topic for years, steadily building a series of accomplishments that ultimately culminate in significant breakthroughs**. Therefore, I am eager to become one of his students, learning to cultivate this ability and contributing to pushing the boundaries of accretion physics. My research experience in BH simulation perfectly aligns with Prof. Gammie's, and I am confident in becoming one of his best students. 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 grade *A* 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.

Overall, the Department of Astronomy and the Department of Physics at UIUC offer 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 UIUC. 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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