

Statement of Purpose

Xihe Liu

My name is Xihe Liu, an undergraduate student in the Physics Department at Shandong University, class of 2025. Currently, I'm working in ATOMS(ALMA Three-millimeter Observations of Massive Star-forming regions) group with Prof. Guido Garay at Department of Astronomy, University of Chile. I'm interested in studying Interstellar Medium (ISM) and star formation using continuum and molecular lines, mainly analyzing the data from the (sub)millimeter observations with interferometers (SMA and ALMA).

After reading "*An Introduction to Star Formation*" by Derek Ward-Thompson, I believe that ISM and molecular clouds are the most beautiful celestial objects in the universe. They possess extended structures, filaments, bubbles, outflows and more—expand across the sky like an impressionist painting—not only as scientific goal but also as art work. These clouds also serve as cradles for star formation; by studying the “embryo” and “baby” of star within them, we can unveil the birth of stars! However, many mysteries remain in the field of ISM and Star formation today: How do stars form under extreme conditions at the center of Milky Way? What is the impact of turbulence within molecular clouds on star formation? In search of answers to these questions, I proactively contacted professors to conduct research on star formation using ALMA since my sophomore year. I aspire to apply for PhD focusing on ISM and Star formation so that I can continue my exciting journey on star formation and get prepared for my research career with the excellent academic training at University of Chile.

Project 1 In my sophomore year, I joined the ATOMS group under Dr. Tie Liu at Shanghai Astronomical Observatory (SHAO), and followed Dr. Xing Lv to study proto-cluster formation in the Central Molecular Zone (CMZ). This region, being close to a supermassive black hole at the Milky Way center, is characterized by high temperatures, elevated densities, and strong magnetic fields, rendering it an ideal laboratory for studying star formation in extreme environments, and we can utilize ALMA to conduct extremely high-resolution radio observations.

Currently, star formation in the CMZ is not as well-explored as other, more nearby star forming regions (e.g., the Orion nebula), so I hope to enhance our understanding of star formation in these extreme environments. The star formation rate (SFR) in this region is observed to be 10 times lower than expected from the dense gas star formation relation extrapolated from the nearby molecular clouds, which raise the question of what makes the SFR lower! Utilizing Astrodendro, I identified dense cores within CMZ Cloud ‘e’ region and calculated their spectral indices through Band 3 & Band 6 continuum data. For data processing details, to analyze the two continuum images in a synergistic way, I smooth them to a common beam size and convolved them together, then added the residual map to get the image. Subsequently, I analyzed potential filament fragmentation processes, clustering and mass segregation among these dense cores.

Project 2 During the second semester of sophomore year, I conducted research on numerical simulations within filamentary molecular clouds under the guidance of Prof. Pakshing Li at SHAO in the ATOMS group. Due to the difficulty and time-consuming nature of directly measuring ISM magnetic field strengths using Zeeman effect, the Davis-Chandrasekhar-Fermi (DCF) method provides a more convenient approach by assuming isotropic media and that changes in magnetic field direction are caused by Alfvén waves or possess isotropic magnetic pressure. However, this results has errors in estimating POS field strength, with DCF correction factors ranging from 0.25 to 0.87. I tested the validity of DCF method by conducting a new calibration, using high-resolution large-scale data of forming filamentary dark cloud from simulation and comparing it with the estimated results.

However, after deeper study into numerical simulations, I found that observations is more interesting as I prefer getting in touch with telescope data to study real molecular clouds, so I am pursuing observational astronomy in your PHD.

Project 3 In the second semester of my junior year, I become the first student in my univeristy to traveled to Chile. On the opposite side of earth, I collaborate with Prof. Guido Garay at the University of Chile on research in massive star formation in the ATOMS group. I adjusted my undergraduate coursework so that I could dedicate an entire semester exclusively to scientific research. The

ATOMS have over 28 hours of observation time using ALMA, during which we observed 146 active star-forming regions. I analyzed several luminous SFRs regions among these targets (including IRAS13484, IRAS16272, IRAS18182, and IRAS18264) and investigated their hub-filament system structures. Additionally, we studied outflows from these regions by examining molecular lines such as SiO and SO – even tracing jets. Thanks to ALMA’s exceptionally high resolution, we gained new insights into massive star formation in these areas. During this time, I also traveled to USA for AAS 244th where I presented our findings through a poster session to astronomers in USA. It was gratifying that they showed considerable interest in our work.

Outreach I also engaged in some ambitious ventures—emulating Astrobites, I established Chinese first academic exchange community specifically for undergraduates majoring in astrophysics. Due to the fact that only a minority of Chinese universities offer astronomy major and most professors are working in observatories and other research institutions, most undergraduates aspiring to engage in astronomical research lack professional guidance. Within physics departments, we are also a minority group and it’s challenging to find peers interested in astronomical research together. Under the voice of the physics student, many students have gradually abandoned their dreams of pursuing astronomy research. To change this situation, I determine to gather undergraduates who are passionate about astronomy into a community.

We discuss the latest papers on arXiv every week, supporting each other and solving academic problems together. Every Saturday night, I invite Chinese astronomers from different institutions to present their work to help undergraduates gain understanding of research in different topic. Initially, it took significant courage for me to reach out and invite unfamiliar professors; however, their friendly attitudes soon gave me confidence to continue this endeavor. Through my efforts, scattered Chinese astrophysics undergraduates have transformed into a tightly-knit community. Today, there are over 400 members including undergraduates as well as PhD candidates and faculty members participating in this community. My hope is we can continue expanding its scale in the future as well.

Additionally, I also participated in numerous astronomy outreach, writing my teaching plans and delivering astronomy popularization courses about star formation and evolution at elementary schools. These efforts were well-received by children.

Conclusion I had an enjoyable time at the University of Chile over the past half year. Prof. Guido Garay’s passion for astronomy greatly inspired me, and my learning experience within the ATOMS group gave me profound insights into the early stages of massive star formation. This solidified my determination to apply for a PhD in Astronomy at the University of Chile and to continue studying star formation under Prof. Guido Garay’s guidance. Additionally, thanks to the collaboration between the University of Chile and the Chinese Academy of Science South America Center for Astronomy(CASSACA), I also established close connections with Chinese professors. There are still numerous unsolved mysteries in star formation, with extreme interest in these questions, I plan to remain dedicated to this field throughout my PhD journey.

Additionally, due to the differences in university systems between China and Chile, I will be getting my undergraduate diploma in June, 2025. Therefore, I wish to apply for a PhD program starting in 2025 with the hope of submitting my undergraduate diploma in August 2025 and directly enrolling at the University of Chile. Then by March 2026, I plan to officially transfer to a PhD student. I’m looking forward to collaborate further with Prof. Guido Garay on illuminating star formation in ATOMS group.