

Zhuoya Cao

Tsinghua University, China

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Research Interest

- Planetary Dynamics, Solar and Planetary System Evolution
- Protoplanetary Disk Dynamics and Disk-planet Interaction

Education

B.S., Tsinghua University

Beijing, China

Tsien Excellence in Engineering Program (28/3800+)

Sep, 2021 – Jun, 2025

Major: Mechanics (GPA: 3.7/4.0)

Minor: Astronomy (GPA: 4.0/4.0) (rank: 1/13)

Core Courses:

Observational Astronomy (rank A)

Statistical Methods in Astrophysics (A-)

Galaxies and the Universe (A-)

Black holes and Compact Objects (A-)

Galactic Physics (A-)

Advanced Algebra and Geometry 1 (A)

Physics core courses:

Physics (1) and (2)

Fundamentals of Dynamics & Control (Classical mechanics)

Quantum Mechanics

Thermodynamics and Statistical Physics

Electrical Engineering and Applied Electronics

Kyoto University (Undergraduate Exchange Program)

Kyoto, Japan

Oct, 2023 – Feb, 2024

Major: Astronomy

Core Courses:

Thermodynamics and Statistical Physics (rank A+)

Quantum Mechanics

Scientific Work Experience

Westlake University

Hangzhou, China

Student Intern (Astrophysics)

Jun, 2025 – Present

Advisor: Prof. Shude Mao, Prof. Douglas N.C. Lin

Harvard University

Cambridge, United States

Student Intern (Astrophysics)

Sep, 2024 – Feb, 2025

Advisor: Prof. Abraham Loeb

University of Tokyo

Tokyo, Japan

Student Intern (Thermophysics)

Jun, 2024 – Aug, 2024

Advisor: Prof. Shiomi Junichiro

Publications

Journal articles

1. **Zhuoya Cao**, Morgan MacLeod, Abraham Loeb, A Comet Shower at the Pliocene-Pleistocene Transition Triggered by the Close Approach of HD7977, under review by *Scientific Reports*, [[link](#)].
2. **Zhuoya Cao**, Yaping Li, Douglas N.C. Lin, Planet Migration Driven by a Dead Zone in Protoplanetary Disks, in preparation.
3. **Zhuoya Cao**, Fujiang Yu, Mingyu Li, Zheng Cai, HST to JWST Super-Resolution Imaging by ControlNet, in preparation.
4. Xiaochen Zheng, **Zhuoya Cao**, Shigeru Ida, Douglas N.C. Lin, Shude Mao, A Robust Launching Mechanism for Freely-Floating Planets from Host Stars with Close-in Planets, submitted to *the Astrophysical Journal*.

Conference posters

1. **Zhuoya Cao**, Morgan MacLeod, Abraham Loeb, A Comet Shower at the Pliocene-Pleistocene Transition Triggered by the Close Approach of HD7977. *The Annual Meeting of the Earth 2.0 Space Mission*, Aug 2025, Shanghai, China.
2. **Zhuoya Cao**, Yaping Li, Douglas N.C. Lin, Shude Mao, Convergent and Divergent Planet Migration Driven by a Dead Zone in Protoplanetary Disks. *The International Conference on Exoplanets and Planet Formation*, Dec 2025, Shanghai, China.

Project Reports

1. **Zhuoya Cao**, Shude Mao, Stability of the Solar System by Impacts from Free Floating Planets to Stellar Flybys, [[link](#)].
2. **Zhuoya Cao**, Shiomi Junichiro, Observation of the Flow Field of the IPC Process with PIV, [[link](#)].
3. **Zhuoya Cao**, Danxu Zhang, Cunjing Lv, Guided movement of Oil Film on the Water Surface, [[link](#)].

Research Experience

1. Main projects

➤ Planet Migration Driven by a Dead Zone in Protoplanetary Disks

Apr, 2025 – Present

Adviser: Prof. Douglas N.C. Lin, University of California, Santa Cruz (UCSC), Prof. Shude Mao, Westlake University

- Conducted simulations on migration of planets on a protoplanetary disk with ring-shaped dead zone by Athena++.
- Theoretically analyzed the migration mechanism as the competition between two kinds of torque in planet-disk interaction — the Lindblad torque and the corotation torque.
- Proposed and explained the different migration behavior of hot Jupiters and super-Earths from the torque-competition aspect.

➤ A Robust Launching Mechanism for Freely-Floating Planets from Host Stars with Close-in Planets

Apr, 2025 – Oct. 2025

Adviser: Prof. Douglas N.C. Lin, UCSC, Prof. Shude Mao, Westlake University

- Conducted REBOUND/REBOUNDx simulation to test the influence of tides on the production of FFPs from the host stars with cometary companions and close-in planets.
- Deduced a theoretical model to explain the tide influence on general two-body systems.
- Proposed a launching mechanism for producing planets with highly eccentric retrograde orbits.
- Submitted to *the Astrophysical Journal*.

➤ **Comet Shower at the Pliocene-Pleistocene Transition Triggered by a Stellar Fly-by**

Sep, 2024 – Feb, 2025

Adviser: Prof. Abraham Loeb, Harvard University

- Conducted numerous simulations on Oort cloud and stellar flyby by REBOUND package, revealed and explained the Oort cloud behaviors during single and binary star invasions.
- Theoretically explained a possible comet shower caused by HD 7977's flyby 3 Myr ago, analyzed comet duration, intensity, and its impact on the ancient Earth.
- Collected geographic evidence of craters and comet components, revealing that this comet shower could be the cause of the Pliocene-Pleistocene Transition.
- Under review by *Scientific Reports*, [[link](#)].

2. Other Previous Lead Projects

➤ **HST to JWST Super-Resolution Based on ControlNet**

Feb, 2025 – July, 2025

Adviser: Prof. Zheng Cai, Tsinghua University

- Using convolution techniques to down-resolve the JWST images to HST resolution, using stable-diffusion-based ControlNet to train the dataset, achieving reliable super-resolution for HST images.

➤ **Solar System Stability under Impacts from Planetary to Stellar Flybys**

Oct, 2023 – Jun, 2024

Adviser: Prof. Shude Mao, Tsinghua University

- Explored flybys' impact on planetary systems with REBOUND simulations and theoretical model, revealed the effect of intrusion perihelion distance on system collapse probability. [[Report link](#)].

➤ **Astronomical Image Reduction using Data from Seimei Telescope**

Nov, 2023 – Jan, 2024

Adviser: Prof. Fumihide Iwamuro, Kyoto University

- Post-processed the images from TriCCS (TriColor CMOS Camera and Spectrograph) and KOOLS (Kyoto Okayama Optical Low-dispersion Spectrograph) on SEIMEI telescope. [[Report link](#)]

➤ **Observation of the Flow Field of the IPC Process with PIV**

Jun, 2024 – Aug, 2024

Adviser: Prof. Shiomi Junichiro, University of Tokyo

- Analyzed the inner flow of IPC (Interfacial Polyelectrolyte Complexation) process with PIV (Particle Image Velocimetry) technique for producing high quality nano-fibers. [[Report link](#)]

➤ **Particle-guided Movement of Oil Film on the Water Surface**

Jun, 2022 – Aug, 2023

Adviser: Cunjing Lv, Tsinghua University

- Experimentally linked the distance from the particle to the leading edge of the oil film and the Weber number, proposed a theory of surface tension gradient for explanation. [[Link](#)]

Skills

- **REBOUND and REBOUNDx (N-body dynamics simulation)**
 - Simulate impact of a stellar flyby on the stability of planetary systems, analyzed the planet ejection probability and distribution.
 - Simulate the Oort cloud's evolution after invaded by a perturber, and the behavior of subsequent comet showers in the solar system.
 - Test the influence of tides on the production of FFPs from the host stars with cometary companions and close-in planets, analyzing Kozai mechanism on a high-eccentricity planetary system.
- **Athena++ (Magnetohydrodynamic simulation)**
 - Simulate planet migration on a viscous protoplanetary disk with dead zone, analyzing torque and understanding planet-disk interactions.
 - Analyze migration of high-eccentricity gas giant on a protoplanetary disk.
- **Others**
 - C/C++ (incl. Athena++), Python (incl. REBOUND, REBOUNDx, KozaiPy, GalSim, SciPy), MATLAB
 - Mathematica, ImageJ (AstroImageJ), ANSYS Fluent, SolidWorks

Awards and Honors

- 2024 Scholarship for Comprehensive Development (4 out of 200+ in the department)
- 2023 Aeon Scholarship (20/3800 in Tsinghua University)
- 2023 Tsinghua Xuetang Scholarship
- 2022 Scholarship for Comprehensive Excellence of Tsinghua University
- 2022 Tsinghua Xuetang Scholarship
- 2021 Tsinghua Xuetang Scholarship

Grants and Programs

- 2024 10000 USD Senior Undergraduate Research Fellowship
- 2024 5000 CNY Academic Promotion Program of Tsinghua University
- 2024 10000 CNY Open Research for Innovative Challenges Program
- 2024 15000 CNY Tsinghua TopOpen Program for Overseas Research Internship
- 2024 160000 JPY UTokyo Engineering Summer Education Program
- 2023 5000 CNY Student Research Training Program
- 2022 5000 CNY Student Research Training Program