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
- Hydrodynamics in Black Hole and Galaxy Evolution

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**, Yaping Li*, Douglas N.C. Lin, Shude Mao, Planet Migration in Protoplanetary Disks with Rims, submitted to *the Astrophysical Journal*, [link].
2. **Zhuoya Cao***, Abraham Loeb, Morgan MacLeod, On the coincidence between the close passage of HD7977 and the Pliocene-Pleistocene transition, accepted by *Scientific Reports*, [link].
3. 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*, [link].
4. **Zhuoya Cao**, Fujiang Yu, Mingyu Li, Zheng Cai*, HST to JWST Super-Resolution Imaging by ControlNet, in preparation, [link].

Conference posters

1. **Zhuoya Cao**, Abraham Loeb, Morgan MacLeod, 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, [link].
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.
3. **Zhuoya Cao**, Yaping Li, Douglas N.C. Lin, Shude Mao, Convergent and Divergent Planet Migration Driven by a Dead Zone in Protoplanetary Disks. The 247th *AAS Annual Meeting*, Jan 2026, Phoenix, United States.

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 in Protoplanetary Disks with Rims**

Apr, 2025 – Nov, 2025

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 distinct migration behaviors of hot Jupiters and super-Earths from the perspective of torque competition, predicting that Jupiters tend to reside in bright rings while super-Earths are more likely found in dark rings.
- Submitted to *the Astrophysical Journal*, [link].

➢ **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*, [link].

➢ **Prolific Nitrogen Production and Metallicity Gradient in AGN Accretion Disk**

Nov, 2025 – Present

Adviser: Prof. Douglas N.C. Lin, UCSC

- Constructing an idealized diffusion model to show that multiple generation of stars leads to fast N-enrichment with an abundance gradient in the AGN disks.

➢ **On the Coincidence Between the Close Passage of HD7977 and the Pliocene-Pleistocene Transition**

Sep, 2024 – Feb, 2025

Adviser: Prof. Abraham Loeb, Harvard University, Prof. Morgan MacLeod, 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.
- Accepted 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++** (Hydrodynamic 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