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 (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

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 on a Protoplanetary Disk with Ring-shaped Dead Zone, 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, A Robust Launching Mechanism for Freely-Floating Planets and Interstellar Asteroids from Host Stars with Cometary Companions and Close-in Planets, submitted to *the Astrophysical Journal*.

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 on a Protoplanetary Disk with Ring-shaped Dead Zone**

  Apr, 2025 – Present

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

  - 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 FFPs from Host Stars with Cometary Companions and Close-in Planets** *Apr, 2025 – Oct. 2025*

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

  - 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

- **N-body dynamics simulation with REBOUND and REBOUNDx**

- 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.

- **Hydrodynamic simulation with Athena++**
  - 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.
- **Software**
  - C/C++ (incl. Athena++), Python (incl. REBOUND, REBOUNDx, Kozaipy, GalSim), 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