Zhuoya Cao

Tsinghua University, China

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Research Interest

- Planetary Dynamics, Protoplanetary Disk and Planetary System Evolution
- Super-resolution for Galactic Images

Education

B.S., Tsinghua University

Beijing, China

Tsien Excellence in Engineering Program (TEEP)

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)

Students Research Training (rank A+)

Introduction to Machine Learning (rank A)

Advanced Algebra and Geometry 1 (rank A)

Galaxies and the Universe (rank A-)

Black holes and Compact Objects (rank A-)

Statistical Methods in Astrophysics (rank A-)

Kyoto University (Exchange Program)

Kyoto, Japan

Oct, 2023 – Feb, 2024

Major: Astronomy

Core Courses:

Statistical Physics (rank A+)

Thermodynamic (rank A+)

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 (Avi) 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, submitted, [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, in preparation.

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

➢ **Migration of High-eccentricity Gas Giants on a Protoplanetary Disk** *Jul, 2025 – Present*

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

- Conducting hydrodynamic simulations on gas giant migration on a protoplanetary disk by Athena++.
- Integrating migration laws from hydro simulations into REBOUNDx framework for effective dynamic simulation on complex planetary systems.

➢ **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++.
- Reveal density changes caused by ring-shaped dead zone as a possible mechanism to stop gas giant migration.

➢ **A Robust Launching Mechanism for FFPs from Host Stars with Cometary Companions and Close-in Planets** *Apr, 2025 – Present*

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

- Conducted 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 such systems.
- Proposed a mechanism for producing planets in highly eccentric retrograde orbits.

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

Sep, 2024 – Feb, 2025

Adviser: Prof. Abraham (Avi) 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.
- Submitted, [link].

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

Feb, 2025 – July, 2025

Adviser: Prof. Zheng Cai, Tsinghua University

- Realized auto-adjusting process of raw images like auto-aligning and normalization.
- Using convolution techniques to down-resolve the JWST images to HST resolution within an error of 10^{-4} compared to real HST images.
- Trained the mock dataset with the real dataset using stable diffusion based ControlNet, achieved reliable super-resolution for HST images.

2. Other Participated Projects

➢ **Stability of the Solar System by Impacts from Free Floating Planets 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, understanding planet-disk interactions.
  - Analyze migration of high-eccentricity gas giant on a protoplanetary disk.
- **Software**
  - C/C++ Language ((incl. Athena++), Python (incl. REBOUND, REBOUNDx, 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