Kai Wu

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Research Profile

Computational astrophysicist specializing in collisional stellar dynamics and direct N-body simulations of dense stellar systems. Research spans massive star clusters, compact-object populations, Population III clusters, and the dynamical evolution of planetary systems in cluster environments. Developer and code administrator of NBODY6++GPU, with experience in million-body simulations, heterogeneous GPU supercomputing, and large-scale simulation-data analysis.

Academic Appointments

Postdoctoral Researcher 2024–present

Astronomisches Rechen-Institut (ARI-ZAH), Heidelberg University, Germany

- Lead and analyse direct N-body simulations of globular, nuclear, and Population III star clusters within the DRAGON-III programme.
- Develop coupled methods for planetary-system evolution in dense stellar environments using NBODY6++GPU and REBOUND.
- Maintain scientific software and simulation workflows across heterogeneous CPU/GPU supercomputing systems.

Education

PhD in Mathematical Sciences 2019–2024

University of Liverpool, UK

- *Thesis:* Dynamical stability of debris discs with planets in star clusters
- Supervisor: Prof. M. B. N. Kouwenhoven; research conducted off-site at Xi'an Jiaotong-Liverpool University (XJTLU).
- Full scholarship covering tuition and stipend.

BSc in Physics 2015–2019

Nankai University, China

- *Thesis:* Dynamical evolution of young open clusters in the solar neighbourhood
- Supervisor: Prof. Fang Bo; cumulative GPA: 85.3/100.
- Graduation thesis awarded Excellent Thesis (top 3%).

Research and Software Contributions

DRAGON-III and dense stellar systems: million-body simulations of globular and nuclear star clusters over cosmic time; rotating and extremely massive Population III clusters; compact objects and multi-messenger observables.
Planetary systems in clusters: dynamical stability of debris discs and planets, survival of planetary architectures along stellar orbits, and long-term evolution of free-floating minor bodies.
NBODY6++GPU developer and lead maintainer: code developer since 2022; introduced Git-based development and CI testing; manage pull requests, issues, documentation, and user support.
Numerical-method development: implemented a Fortran routine in NBODY6++GPU that records stellar perturbers at high cadence, and a C program on the REBOUND C API that integrates the perturbed planetary systems (LPS+).
HPC and data: management of large-scale runs, failure diagnosis, restart validation, and reproducibility of long-running MPI/GPU simulations; cross-code validation with NBODY6++GPU and PeTar. Simulation and benchmarking experience on JUPITER, JUWELS, LUMI, Dongfang, Silkroad, and Kepler; CUDA/HIP platforms; analysis of more than 100 TB of DRAGON simulation data.
Numerical verification and simulation reliability: develop independent reference calculations, finite-difference and convergence tests, end-to-end validation workflows, and guarded run-time checks for direct N-body simulations and Galactic-potential implementations.

Publications

Peer-reviewed journal articles

[1] **Kai Wu**, Ataru Tanikawa, Francesco Flammini Dotti, Marcelo C. Vergara, Boyuan Liu, Albrecht W. H. Kamlah, Manuel Arca Sedda, Nadine Neumayer, and Rainer Spurzem. *Direct N-body simulations of rotating and extremely massive Population III star clusters*. Astronomy & Astrophysics, 709, A142 (2026). doi:10.1051/0004-6361/202558659.

[2] Francesco Flammini Dotti, M. B. N. Kouwenhoven, **Kai Wu**, Abbas Askar, Peter Berczik, Mirek Giersz, Rainer Spurzem, and Ian Dobbs-Dixon. *Dynamical evolution of massless particles in star clusters with NBODY6++GPU-MASSLESS: II. The long-term evolution of free-floating comets*. Astronomy & Astrophysics, 706, A219 (2026). doi:10.1051/0004-6361/202557334.

[3] Guimei Liu, Yu Zhang, Jing Zhong, Li Chen, Xiangcun Meng, and **Kai Wu**. *Formation and evolution of new primordial open cluster groups: Feedback-driven star formation*. Astronomy & Astrophysics, 696, A117 (2025). doi:10.1051/0004-6361/202452774.

[4] Songmei Qin, Jing Zhong, Tong Tang, Yueyue Jiang, Long Wang, **Kai Wu**, Friedrich Anders, Lola Balaguer-Núñez, Guimei Liu, Chunyan Li, Jinliang Hou, and Li Chen. *Unveiling the binary nature of NGC 2323*. Astronomy & Astrophysics, 693, A317 (2025). doi:10.1051/0004-6361/202452962.

[5] **Kai Wu**, M. B. N. Kouwenhoven, Francesco Flammini Dotti, and Rainer Spurzem. *Influence of planets on debris discs in star clusters - II. The impact of stellar density*. Monthly Notices of the Royal Astronomical Society, 533(4), 4485–4499 (2024). doi:10.1093/mnras/stae2067.

[6] **Kai Wu**, M. B. N. Kouwenhoven, Rainer Spurzem, and Xiaoying Pang. *Influence of planets on debris discs in star clusters - I. The 50 au Jupiter*. Monthly Notices of the Royal Astronomical Society, 523(4), 4801–4817 (2023). doi:10.1093/mnras/stad1673.

Submitted manuscripts

[7] Philip Cho, **Kai Wu**, Francesco Flammini Dotti, Taras Panamarev, Shuo Li, Shiyan Zhong, Klaus Reuter, and Rainer Spurzem. *Simulating tidal disruption events in nuclear star clusters*. Submitted to Astronomy & Astrophysics, arXiv:2609.31083 (2026).

[8] Francesco Flammini Dotti, M. B. N. Kouwenhoven, **Kai Wu**, Abbas Askar, Dominik Schleicher, and Ian Dobbs-Dixon. *Dynamical evolution of free-floating brown dwarfs in star clusters*. Submitted to Astronomy & Astrophysics (2026).

Conference proceedings

[9] M. B. N. Kouwenhoven et al. (including **Kai Wu**). *Planetary systems in dense stellar environments*. Journal of Physics: Conference Series, 1523, 012011 (2020). doi:10.1088/1742-6596/1523/1/012011.

[10] **Kai Wu**, Philip Cho, Rainer Spurzem, Long Wang, Francesco Flammini Dotti, and Vahid Amiri. *DRAGON-III simulations: modelling million-body globular and nuclear star clusters over cosmic time*. Proceedings of the International Astronomical Union, 21(S398), 184–188 (2025). doi:10.1017/S1743921325103980.

[11] Philip Cho, **Kai Wu**, Francesco Flammini Dotti, Taras Panamarev, and Rainer Spurzem. *Modeling Tidal Disruption Events and Compact Object Plunges in Nuclear Star Clusters*. Proceedings of the International Astronomical Union, 21(S398), 279–283 (2025). doi:10.1017/S1743921325104067.

[12] Yuzhe Song, Debatri Chattopadhyay, Jarrod Hurley, Rainer Spurzem, Francesco Flammini Dotti, and **Kai Wu**. *Modeling Millisecond Pulsar Populations in Globular Clusters with NBODY6++GPU*. Proceedings of the International Astronomical Union, 21(S398), 255–259 (2025). doi:10.1017/S174392132510464X.

[13] Guimei Liu, Yu Zhang, Jing Zhong, Li Chen, Xiangcun Meng, and **Kai Wu**. *Supernova-Triggered Formation of Primordial Star Cluster Groups in the Milky Way*. Proceedings of the International Astronomical Union, 21(S398), 110–113 (2025). doi:10.1017/S1743921325104602.

Manuscripts in preparation

[14] **Kai Wu**, Francesco Flammini Dotti, Marcelo C. Vergara, Vahid Amiri, and Rainer Spurzem. *DRAGON-III simulation - I. Multi-messenger observations in the computer and comparison with observed astrophysical objects*. In preparation.

[15] **Kai Wu**, M. B. N. Kouwenhoven, Rainer Spurzem, and Francesco Flammini Dotti. *Linking the survivability of planets in star clusters with the orbits of their host stars*. In preparation.

Honours and Awards

$360 equivalent, ICISE, accommodation support for conference Modelling and Observing Dense Star Clusters. 2026

Selected participant (40 places), Astro-CC Pilot Virtual Observatory school, Madrid. Travel and accommodation covered by the organisers. 2025

€1,500, Young Researcher and Innovator Conference Grant, COST Action CA22133. Awarded to present at the European Astronomical Society Annual Meeting. 2025

€450, Travel Grant, Astronomische Gesellschaft. Support to present two talks at the Annual Meeting of AG. 2025

Excellent Teaching Assistant Award (top 2%), XJTLU 2023

Best Oral Presentation Award (top 5%), XJTLU Postgraduate Research Symposium 2022

Best Poster Award (top 5%), XJTLU Postgraduate Research Symposium 2021

Full-scholarship PhD, tuition waiver and stipend, XJTLU 2019–2023

Excellent Graduation Thesis (top 3%), Nankai University 2019

Boling Scholarship (top 10%, three times) and Second-class Scholarship (top 8%), Nankai University 2015–2017

Second Prize (top 10%), Nankai Physicists' Tournament 2016

Invited Courses and Seminars

Courses and tutorials

Shanghai Astronomical Observatory: 30-hour doctoral course on N-body simulations with NBODY6++GPU Aug. 2023

Spurzem's International Seminar: four-hour tutorial on Git and GitHub for NBODY6++GPU development and collaboration Apr. 2022

Seminars

Max Planck Institute for Astrophysics, Garching (colloquium): Multi-scale Stellar Dynamics in Dense Clusters: From Planetary Debris to Black Hole Seeds Apr. 2026

ARI-ZAH, Heidelberg University: From Debris Disks to Million-Body Clusters: Planetary Perturbations, Stellar Interactions, and DRAGON-III Jul. 2025

Zhejiang University: Dynamics of debris discs with planets in star clusters Oct. 2024

KIAA-Peking University: Dynamics of debris discs in star clusters Jul. 2023

Shanghai Astronomical Observatory: An in-depth introduction to numerical star-cluster simulations Jul. 2023

Selected Conference Presentations

Annual Meeting of the German Astronomical Society (AG2026), Garching – From million-body star clusters over cosmic time to black-hole growth in primordial systems Sep. 2026

Bridging It: Connecting Observations and Models of (Exo)planets and their Formation, MPIA, Heidelberg – SCULPT: star-cluster and planetary-system dynamics as physically motivated prescriptions for planet population synthesis Sep. 2026

MODEST-26: Modelling and Observing Dense Star Clusters, Quy Nhon – Rotation-driven collapse and black-hole growth in primordial star clusters Aug. 2026

14th Silk Road Meeting, Tashkent – From million-body star clusters over cosmic time to black-hole growth in primordial systems May 2026

Annual Meeting of the German Astronomical Society (AG2025), Goerlitz – two contributed talks on DRAGON-III and planetary systems in star clusters Sep. 2025

European Astronomical Society Annual Meeting, Cork – Dynamical stability of debris discs with planets in star clusters Jun. 2025

IAU Symposium 398 / MODEST-25, Seoul – DRAGON-III million-body globular and nuclear star clusters Jun. 2025

Gas Accretion in Planet Formation, MPIA – Star clusters, protoplanetary discs, and debris-disc evolution Mar. 2025

SPP 1992 Final Colloquium, Berlin – Dynamical evolution of planetary systems in star clusters Mar. 2024

Teaching and Academic Training

Associate Fellow of the Higher Education Academy (AFHEA), Advance HE 2024

- Teaching qualification aligned with the UK Professional Standards Framework.

Part-time Lecturer – IB Calculus, Suzhou Research Institute of Xi'an Jiaotong University Jan.–Jul. 2022

- Designed and delivered 105 hours of calculus instruction for an international high-school preparatory programme.

Teaching Assistant / Tutor, Xi'an Jiaotong-Liverpool University 2019–2023

- Delivered approximately 30 hours of English-language teaching in physics experiments, calculus, advanced linear algebra, and statistical methods.
- Received the School of Mathematics and Physics Excellent Teaching Assistant Award (top 2%).

Invited Instructor – Doctoral N-body Course, Shanghai Astronomical Observatory Aug. 2023

- Delivered a 30-hour practical course on simulating star clusters with NBODY6++GPU.

Invited Tutorial Instructor, Spurzem's International Seminar Apr. 2022

- Delivered a four-hour tutorial on Git, GitHub, and collaborative scientific-software development.

Academic Service and Memberships

Referee, Research in Astronomy and Astrophysics 2026–present

Referee, The Astrophysical Journal 2026–present

Referee, Astronomy & Astrophysics 2026–present

Referee, Planetary and Space Science 2025–present

Member, Roman Science Collaboration: Exoplanets and Solar System; Milky Way and Stellar Astrophysics science groups 2026–present

Member, Einstein Telescope (ET) Collaboration 2026–present

Member, European Cooperation in Science and Technology Action *CA22133* "The Birth of Solar Systems" 2023–present

Member, Silk Road Collaboration for stellar dynamics and computational astrophysics 2019–present

Selected Academic Visits

National Astronomical Observatories of China and KIAA-Peking University – visitor of Dr. Shuo Li Dec. 2024; Jun. 2025

Frankfurt Institute for Advanced Studies – visitor of Prof. Volker Lindenstruth Jan. 2025

Heidelberg University – guest researcher funded by DFG SPP 1992 Mar.–Apr. 2024

National Astronomical Observatories of China – visiting scholar funded by XJTLU Dec. 2019

CITA, University of Toronto – visiting student of Prof. Yanqin Wu Jul.–Oct. 2018

Space Telescope Science Institute / Johns Hopkins University – visiting student of Prof. Christine Chen Jun.–Sep. 2017

Earlier visits: Purple Mountain Observatory; National University of Singapore; Nanyang Technological University 2016

Technical Expertise

Scientific programming: Python, Fortran, C/C++, Bash; NumPy, SciPy, pandas, multiprocessing
Parallel and GPU computing: MPI, OpenMP, CUDA, HIP; heterogeneous CPU/GPU systems
AI-assisted research: tool-enabled LLM coding/research agents for scientific software, numerical verification, HPC debugging, and research automation, with test- and physics-based validation. Multi-agent orchestration.
Scientific software: NBODY6++GPU, PeTar, REBOUND, MERCURY
Data and visualisation: HDF5, Matplotlib, Plotly; large-scale simulation-data processing
Development workflows: Git, GitHub, CI/CD, Docker, documentation, issue and release management
Typesetting and reproducibility: LaTeX, Linux-based research workflows