Ben Zhu

Research Interests

My research interests focus on theoretical and computational plasma physics, with a particular emphasis on magnetic fusion energy (MFE), including multi-spatiotemporal scale nonlinear dynamics in magnetized plasmas (e.g., instabilities and turbulence, transport barrier, bifurcation, particle and heat exhaust, etc.) and numerical methods and models for boundary plasma in tokamaks and stellarators. Additionally, I explore the applications of machine learning and artificial intelligence (ML/AI) in plasma physics and MFE research, including NN-based kinetic closures and surrogate model for tokamak control.

Professional Experience

Columbia University in the City of New York — New York, NY
Assistant Professor of Applied Physics and Applied Mathematics — 2026 –

Lawrence Livermore National Laboratory, Research Scientist — Livermore, CA
Physics Division, Physical and Life Sciences Directorate — 2020 – 2025

Lawrence Livermore National Laboratory, Postdoctoral Staff Researcher — Livermore, CA
Advisor: Xue-qiao Xu and Alex Friedman — 2018 – 2020

Dartmouth College, Postdoctoral Associate — Hanover, NH
Advisor: Barrett N. Rogers — 2017 – 2018

Dartmouth College, Graduate Research Assistant — Hanover, NH
Advisor: Barrett N. Rogers — 2011 – 2017

University of California, Davis, Graduate Research Assistant — Livermore, CA
Advisor: David Q. Hwang — 2008 – 2010

Institute of Plasma Physics, Chinese Academic of Science (ASIPP), Undergraduate Research Intern — Hefei, China
Advisor: Youwen Sun and Xiang Gao — 2007 – 2008

Education

Ph.D. in Physics, **Dartmouth College** — 2010 – 2017

- Dissertation: Global 3D Two-fluid Simulations of Turbulent Transport at Tokamak Edge Region
- Advisor: Barrett N. Rogers

M.S. in Applied Science, **University of California, Davis** — 2008 – 2010

B.S. in Applied Physics, **University of Science and Technology of China** — 2004 – 2008

- Thesis: Density Limit and Operation Regime on EAST Tokamak
- Advisor: Xiang Gao (ASIPP)

Awards and Honors

Physics Divsion SPOT Award, LLNL — 2025
Early Career Research Program (ECRP) Award, US Department of Energy — 2024
17th Institutional Unclassified Computing Grand Challenge Award, LLNL — 2022
PLS FY20 Summer Directorate Award of Excellence in Publication, LLNL — 2020
Physics and Astronomy Graduate Research Award, Dartmouth College — 2017

Graduate Student Poster Award, International Sherwood Fusion Theory Conference	2016
Gordon F. Hull Fellowship, Dartmouth College	2016
Selamawit Tsehaya Teaching Award, Dartmouth College	2016

Grants and Project Leaderships

- **ECRP: Advancing Edge Physics and Modeling towards Fusion Pilot Plants**, sole PI, $2.75M, FY2025-2029
- **SciDAC-5: High-fidelity Simulations for Stellarators (*Hifi*Stell)**, institutional PI for LLNL (led by Princeton University), $1.2M (LLNL portion), FY2024-2027
- **INFUSE: Machine Learning Accelerated Predictions of Power and Particle Exhaust in Fusion Pilot Plant**, institutional PI for LLNL (led by General Atomics), $200k (LLNL portion), FY2024-2025
- **Integrated 3D-edge Long-pulse Tokamak Scenarios - Extended with Core Instability and Transport Control**, institutional PI for LLNL (led by PPPL), $500k (LLNL portion), FY2023-2025

Publications

First-authored

1. **B. Zhu**, M. Zhao, X. Xu, A. Gupta, K. Kwon, X. Ma and D. Eldon, “Latent space mapping: revolutionizing predictive models for divertor plasma detachment control”, *Physics of Plasmas* **32**, 062508 (2025)
2. **B. Zhu**, X. Xu and X. Tang, “Electromagnetic turbulence simulation of tokamak edge plasma dynamics and divertor heat load during thermal quench”, *Nuclear Fusion* **63**, 086027 (2023)
3. **B. Zhu**, M. Zhao, H. Bhatia, N. Li, T. Bremer, X. Xu, W. Meyer and T. Rognlien, “Data-driven model for divertor plasma detachment prediction”, *Journal of Plasma Physics* **88**, 895880504 (2022)
4. **B. Zhu**, H. Seto, M. Yagi and X. Xu, “Drift reduced Landau fluid model for magnetized plasma turbulence simulations in BOUT++ framework”, *Computer Physics Communication* **267**, 108079 (2021)
5. **B. Zhu**, M. Francisquez, B. Rogers and X. Xu,“Generalized slab universal instability and its appearance in pair plasma”, *Physics of Plasmas* **27**, 102104 (2020)
6. **B. Zhu**, M. Francisquez and B. Rogers, “Up-down symmetry breaking in global tokamak edge simulations”, *Nuclear Fusion* **58**, 106039 (2018)
7. **B. Zhu**, M. Francisquez and B. Rogers, “GDB: a global 3D two-fluid code for plasma turbulence and transport at tokamak edge region”, *Computer Physics Communications* **232**, 46 (2018)
8. **B. Zhu**, M. Francisquez and B. Rogers, “Global 3D two-fluid simulation of tokamak edge region: turbulence, transport, profile evolution and spontaneous $E\times B$ rotation", *Physics of Plasmas* **24**, 055903 (2017)

Co-authored

9. M. Zhao, **B. Zhu**, X. Xu, T. Rognlien, X. Ma, W.H. Meyer, K. Kwon, D. Eldon, N. Li, H. Lee and J. Hwang, “Physics insights from a large-scale 2D UEDGE simulation database for detachment control in KSTAR”, submitted to *Nuclear Fusion* (2025)
10. A. Gupta, D. Eldon, E. Bang, K. Kwon, H. Lee, A. Leonard, J. Hwang, X. Xu, M. Zhao and **B. Zhu**, “Detachment control in KSTAR with Tungsten divertor”, submitted to *Plasma Physics and Controlled Fusion* (2025)
11. X. Xu, N. Li, M. Zhao, X. Liu, P. Diamond, **B. Zhu**, T. Rognlien and G. Xu, “Fluctuation entrainment and SOL width broadening in small/grassy ELM regime”, *Nuclear Materials and Energy* **42**, 101866 (2025)
12. K. Fan, X. Xu, **B. Zhu**, C. Dong, T. Xia and Z. Li, “Theoretical and global simulation analysis of collisional microtearing modes”, *Physics of Plasmas* **31**, 052102 (2024)
13. M. Holec, **B. Zhu**, C. Vogl, B. Southworth, A. Campos, A. Dimits, W. Pazner and I. Joseph, “High-order energy and enstrophy conserving finite element method for 2D incompressible fluid dynamics”, submitted to *Journal of Computational Physics* (2022)

14. Z. Li, X. Chen, C. Muscatello, K. Burrell, X. Xu, **B. Zhu**, R. Hong, T. Osborne, B. Grierson, T. Rhodes, T. Xia, G. McKee and Z. Yan, "Numerical Modeling of Pedestal Stability and Broadband Turbulence of Wide-Pedestal QH-mode Plasmas on DIII-D", *Nuclear Fusion* **62**, 076033 (2022)
15. M. E. Fenstermacher, J. Abbate, S. Abe, T. Abrams, M. Adams, B. Adamson, ..., **B. Zhu**, etc, "DIII-D research advancing the physics basis for optimizing the tokamak approach to fusion energy", *Nuclear Fusion* **62**, 042024 (2022)
16. K. Fan, X. Xu, **B. Zhu** and P. Li, "Kinetic Landau-Fluid closures of non-Maxwellian distributions", *Physics of Plasmas* **29**, 042116 (2022)
17. X. He, X. Xu, Z. Li, **B. Zhu** and Y, Liu, "Prediction of divertor heat flux width for ITER Pre-Fusion Power Operation using BOUT++ transport code", *Nuclear Fusion* **62**, 056003 (2022)
18. A. Mathews, M. Francisquez, J. Hughes, D. Hatch, **B. Zhu** and B. Rogers, "Uncovering turbulent plasma dynamics via deep learning from partial observations", *Physical Review E* **104**, 025205 (2021)
19. W. Zholobenko, T. Body, P. Manz, A. Stegmeir, **B. Zhu**, G. D. Conway, M. Griener, D. Coster, F. Jenko and the ASDEX Upgrade Team, "Electric field and turbulence in global Braginskii simulations across ASDEX Upgrade edge and scrape-off-layer", *Plasma Physics and Controlled Fusion* **63**, 034001 (2021)
20. M. Pueschel, R. Sydora, P. Terry, B. Tyburska-Pueschel, M. Francisquez, F. Jenko, and **B. Zhu**, "Pair plasma instability in homogeneous magnetic guide fields", *Physics of Plasmas* **27**, 102111 (2020)
21. M. Francisquez, T. Bernard, **B. Zhu**, A. Hakim, B. N. Rogers, and G. W. Hammett, "Fluid and gyrokinetic turbulence in open field-line, helical plasmas", *Physics of Plasmas* **27**, 082301 (2020)
22. L. Wang, X. Xu, **B. Zhu**, C. Ma and Y. Lei, "Deep Learning surrogate model for kinetic Landau-fluid closure with collisional effects", *AIP Advances* **10**, 075108 (2020)
23. C. Ma, **B. Zhu**, X. Xu and W. Wang, "Machine learning surrogate models for Landau fluid closure", *Physics of Plasmas* **27**, 042502 (2020)
24. W. Zholobenko, A. Stegmeir, T. Body, A. Ross, P. Manz, D. Coster, O. Maj, F. Jenko, M. Francisquez, **B. Zhu**, B. Rogers, "Thermal dynamics in the FCI turbulence code GRILLIX", *Contribution to Plasma Physics* e201900131 (2019)
25. X. Xu, N. Li, Z. Li, B. Chen, T. Xia, T. Tang, **B. Zhu** and V. Chan, "Simulations of tokamak boundary plasma turbulence transport in setting the divertor heat flux width", *Nuclear Fusion* **59**, 126039 (2019)
26. M. Francisquez, **B. Zhu** and B. Rogers, "Multigrid treatment of implicit continuum diffusion", *Computer Physics Communications* **236**, 104 (2019)
27. L. Wang, **B. Zhu**, X. Xu and B. Li, "A Landau-fluid closure for arbitrary frequency response", *AIP Advances* **9**, 015217 (2019)
28. B. Rogers, **B. Zhu** and M. Francisquez, "Gyrokinetic theory of slab universal modes and the non-existence of the gradient drift coupling (GDC) instability", *Physics of Plasmas* **25**, 052115 (2018)
29. M. Francisquez, **B. Zhu** and B. Rogers, "Global 3D Braginskii simulations of the tokamak edge region of IWL discharges", *Nuclear Fusion* **57**, 116049 (2017)

Selected Invited Talks

- *Bifurcation and hysteresis in global and local edge turbulence simulations*, 2025 Sherwood Fusion Theory Conference, New York City, NY April 7-9, 2025
- *Latent space mapping: revolutionizing predictive models for divertor plasma detachment control*, 66th Annual Meeting of the APS Division of Plasma Physics, Atlanta, GA October 7-11, 2024 & SIAM Conference on Computational Science and Engineering (CSE25), Fort Worth, TX March 3-7, 2025
- *Modeling boundary plasma in complicated magnetic geometries*, 11th International Workshop on "Stochasticity in Fusion Plasmas (FPP)", Bad Honnef, Germany April 15-17, 2024

- *Overcoming challenges: leveraging machines for efficient modeling of divertor plasmas*, IAEA Workshop on Artificial Intelligence for Accelerating Fusion and Plasma Science, Vienna, Austria November 28 - December 1, 2023
- *Data-driven divertor plasma detachment prediction with applications to integrated tokamak design and control*, 4th International Conference on Data-Driven Plasma Science, Okinawa, Japan April 16-21, 2023
- *BOUT++ simulations of edge plasma dynamics during thermal quench*, 2022 US-EU Joint Transport Task Force Workshop, Santa Rosa, CA April 5-8, 2022 & 6th Asia-Pacific Conference on Plasma Physics, October 9-14, 2022
- *Particle pinch in the tokamak edge*, 63rd Annual Meeting of the APS Division of Plasma Physics, Pittsburgh, PA November 8-12, 2021 & 40th ITPA Pedestal and Edge Physics Topical Group Meeting, October 24-28, 2022
- *Fusion Science*, LLNL Teacher Research Academy, June 10, 2020 & June 17, 2021 & June 14, 2022
- *Numerical study of DIII-D wide pedestal quiescent H-mode: instabilities and broadband turbulence*, 2019 US-EU Joint Transport Task Force meeting, Austin, TX March 18-21, 2019
- *Up-down symmetry breaking and the density pinch in global tokamak edge simulations*, 2018 US Transport Task Force Workshop, San Diego, CA May 8-11, 2018
- *Global 3D two-fluid simulation of tokamak edge region: turbulence, transport, profile evolution and spontaneous $E\times B$ rotation*, 58th Annual Meeting of the APS Division of Plasma Physics, San Jose, CA October 31 - November 4, 2016

Community Service

- 67th Annual Meeting of the APS Division of Plasma Physics, Program Committee (2025)
- APS Career Mentoring Fellow (2023 - present)
- LLNL PLS ML/AI Strategic Planning Committee (2023 - 2024)
- APS FIAP Career Lectureship Award, Selection Committee (2022-2023, Chair 2023)
- American Physical Society (APS), Committee on Careers and Professional Development (2022-2024, Chair 2023)
- Guest editor of *Physics of Plasmas* (2022)
- International Sherwood Fusion Theory Conference, Executive Committee (2020-2024, Chair 2023), Program Committee (2021, 2022), Organizing Committee (2021, 2022, 2025)
- BOUT++ Workshop, Organizing Committee (2018, 2023, 2024)
- Session chair, student poster/presentation judge, domain expert for various conferences, meetings, workshops, and round-tables
- Reviewer for various scientific journals, funding agencies, and research institutions