Kunhao Zhong

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Education

- **University of Pennsylvania** — Philadelphia, PA, USA
  Ph.D. - Physics — *Aug 2023 - May 2027 (expected)*
  Research Focuses: *Cosmology, theory and statistics.*
- **Stony Brook University** — Stony Brook, NY, USA
  Master of Art - Physics; GPA: 3.96 — *Aug 2021 - May 2023*
  Courses: *String Theory, Particle Physics, Advanced Particle Physics, Computing Physics*
- **University of Texas at Austin** — Austin, TX, USA
  Bachelor of Science - Physics; GPA: 3.91; Major GPA: 3.96 — *Aug 2018 - May 2021*
  Graduate Level Courses: *Quantum Field Theory (I&II), Electrodynamics, Statistical Mechanics, Cosmology, General Relativity, Quantum Mechanics, Astrophysics*

Main Author Publication

- J. Rebouças, J. Gordon, D. Souza, **K. Zhong**, V. Miranda, R. Rosenfeld, "Investigating Late-Time Dark Energy and Massive Neutrinos in Light of DESI Y1 BAO",*arXiv*: 2408.14628.
- E. Saraivanov, **K. Zhong**, V. Miranda, S. S. Boruah, T. Eifler, Elisabeth Krause, "Attention-Based Neural Network Emulators for Multi-Probe Data Vectors Part II: Assessing Tension Metrics",*arXiv*: 2403.12337.
- **K. Zhong**, M. Gatti, B. Jain, "Improving Convolutional Neural Networks for Cosmological Fields with Random Permutation", *arXiv*: 2403.01368.
- **K. Zhong**, E. Saraivanov, J. Caputi, V. Miranda, S. S. Boruah, T. Eifler, Elisabeth Krause, "Attention-based Neural Network Emulators for Multi-Probe Data Vectors Part I: Forecasting the Growth-Geometry split", *arXiv*: 2402.17716.
- J. Rebouças, J. Gordon, D. Souza, **K. Zhong**, V. Miranda, R. Rosenfeld, T. Eifler, "Early dark energy constraints with late-time expansion marginalization", *arXiv*: 2302.07333. .
- **K. Zhong**, E. Saraivanov, V. Miranda, J. Xu, T. Eifler, "Growth and Geometry Split in light of the DES-Y3 survey", *arXiv*: 2301.03694.

Supporting Author Publication

- J. Xu, et.al , "Constraining Baryonic Physics with DES Y1 and Planck data – Combining Galaxy Clustering, Weak Lensing, and CMB Lensing", *arXiv*: 2311.08047.

Research Experience

- **Ph.D Thesis Research** — Philadelphia, PA
  Advisor: Bhuvnesh Jain — *Aug 2023 - present*
  - **Machine Learning in Cosmology**: Machine learning techniques, together with the Simulation-Based Inference framework, offer a promising avenue for extracting cosmological insights not captured by conventional perturbation theory. My research focuses on exploring the potential of machine learning in cosmology, which encompasses developing improved neural network architectures, addressing model misspecification, and enhancing interpretability to demystify the "black box" nature of neural networks.
- **Master Thesis Research** — Stony Brook, NY
  Advisor: Vivian Miranda — *Aug 2021 - present*
  - **Geometry and Growth Split**: Splitting Geometry and Growth information to study the consistency between the expansion and structure growth of the universe. One publication with Dark Energy Survey Year 3 data, and one paper to be published LSST forecast.
  - **EDE with marginalized late expansion(Collaborative)**: Marginalizing the late time expansion rate and testing with different data sets to see if a late time modification can save the Early Dark Energy(EDE) model, which is now the most promising way to solve the Hubble tension.
  - **Anisotropic Stress of Dark Energy (Collaborative)**: Study the Anisotropic Stress of Dark Energy using Parameterized Post-Friedmann prescription.
  - **Non-canonical Scalar Field of Dark Energy**: Generalisation of canonical Scalar Field(*Quintessence*) description of scalar field to non-canonical case.
  - **Emulator for Weak Lensing Analysis**: Designing Neural Network architecture for weak lensing likelihood inference. An emulator accelerates the MCMC process by a factor of 100, making many additional tests possible. Based on previous work, our goal is to design an emulator that is robust against cosmology shifts, easy to generalize to extension models, and applicable for real data of DES-Y6.
- **UT Cosmology Group & Weinberg Theory Group** — Austin, TX
  Advisor: Kimberly Boddy — *Aug 2020 - Aug 2021*
  - **Early Dark Energy with ACT**: Using Atacama Cosmology Telescope(ACT) likelihood to test the discrepancy of primordial amplitude A_s between CMB and EFT of LSS.
  - **Migdal Effect around Recombination**: Study the secondary contribution of Dark Matter(DM)-baryon scattering from Migdal Effect, and its correction to CMB

- **Independent Study Program** — Austin, TX
  Advisor: Richard Matzner — *Aug 2018 - Aug 2020*
  - **Glory Scattering of Scalar Field wave to Balck Hole**: Generalized the cross section of scalar wave on a Schwarzschild black hole from flat space to conformal flat space, i.e, in an expanding universe.
  - **Independent study**: General Relativity and Cosmology: reading of *General Relativity* by Wald, and *Modern Cosmology* by Scott Dodelson.

Honors and Awards

- Stony Brook University's Gerald Brown Prize for Outstanding Research - May, 2023

Survey Membership

- **Dark Energy Survey(DES)**: Theory and Combined Probe working group, DES-Year6 extension models team.
- **Rubin Observatory Legacy Survey of Space and Time(LSST)**: Dark Energy Science Collaboration
- **Nancy Grace Roman Space Telescope** : Cosmological Parameters Inference Pipeline

Presentations

- **Stony Brook University–YITP seminar**: Simulation-based inference
- **University of Arizona Weekly Meeting**: Results of growth geometry split with DES-Y3
- **DES 2022 Collaboration Meeting**: Growth and geometry split in light of DES data
- **Stony Brook Graduate Seminar Fall 2021**: Neutrino Cosmology

Teaching & Mentering

- **Teaching Assistant** — Philadelphia, PA
  Instructor: Adam Lidz and Mariangela Bernardi — *Aug 2023 - May 2024*
  - **ASTRO 0001 and ASTO 3392)**: Grading.
- **Mentor in Miranda Group** — Stony Brook, NY
  Mentee: James Caputi and Alexa Draper — *May 2022 - present*
  - **Summer Research Program**: Dark Energy with general equation of state, and growth history of the universe.
- **Teaching Assistant** — Stony Brook, NY
  Instructor: Thomas Hemmick — *Aug 2021 - May 2022*
  - **PHY 134: Laboratory for Classical Physics (I & II)**: Grading reports and help students finish their lab.
- **Undergrad Teaching Assistant** — Austin, TX
  Instructor: Sonia Paban, John Yeazell — *Aug 2019 - May 2020*
  - **PHY 362K: Quantum Mechanics 2** : Grading part of the homework and holding problem-solving sessions.
  - **PHY302L: General Physics 2**: Attending normal Class session as a learning assistant and holding office hours.

Outreach

- **Scientific Article Writing**: I wrote Chinese scientific articles targeting high school students. The official account is on WeChat. I did not continue writing after graduate school, but due to the popularity of those articles, especially the one memorizing Stephen Hawking, I was invited to edit for other accounts and platforms in China, like zhihu.com.
- **Astronomy and Astrophysics Outlist**: I joined the ally list for LGBTQIA+ members in the astronomy and astrophysics community.

Programming Skills

- **CLASS-GSF in C**: A modified version of CLASS with a non-canonical scalar field where users can enter Lagrangians and initial conditions as needed, with several examples provided. Unlike *hi-class* that uses Effective Field Theory(EFT), the code uses full perturbation equations for generalized scalar fields. The code can be used to study dark energy clustering models like k-essence, as well as other components like generalized dark matter(GDM).
- **CAMB-AS in FORTRAN**: CAMB with anisotropic stress of dark energy, in Parameterized Post-Friedmann(PPF) prescription.
- **C++/CosmoLike**: Implemented the Growth-Geometry splitting and dark energy anisotropic stress analysis routine into CosmoLike. The modification enables the Modified Gravity study and other extensions to be done in the Boltzmann code and thus makes cross-analysis with CMB available.
- **Parallel Computing**: MPI implementations on scripts that generate multiple cosmological observables from chains. The true posteriors of observable like power spectrum and distances are lacking in most phenomenological studies due to many chains. With Message-Passing Interface(MPI), this can be done within a reasonable time(1 hour for LCDM).
- **Mathematica**: Wrote a set of notebooks in calculating general relativity exercises. Experience in using the cosmological perturbation package xPand to check the equations used in CLASS-gsf.
- **Machine Learning**: ML applications in cosmology, with a focus on Normalizing Flow and Neural Networks. ResBlock architecture in training emulators for week lensing observables
- **Bash/Unix Environment**: Extensive experience in working on High-Performance Computing Clusters. At UT-Austin, I wrote a sample for future students on how to use MontePython with Planck Likelihood. At Stony Brook University, I helped other students doing cosmological computing on clusters.

References

- **Vivian Miranda** — Stony Brook, NY, USA
  C. N. Yang Institute for Theoretical Physics — *vivian.miranda@stonybrook.edu*
- **Tim Eifler** — Tuscon, AZ, USA
  University of Arizona — *timeifler@arizona.edu*
- **Rogerio Rosenfeld** — São Paulo, Brazil
  ICTP-SAIFR — *rosenfel@ift.unesp.br*
- **Kimberly Boddy** — Austin, TX, USA
  The University of Texas at Austin — *kboddy@physics.utexas.edu*
- **Richard Matzner** — Austin, TX, USA
  The University of Texas at Austin — *matzner2@physics.utexas.edu*