Akhil Premkumar

Machine Learning Researcher | Probabilistic Modeling & Rare-Event Statistics

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Summary

Machine learning scientist (Ph.D.) specializing in probabilistic generative modeling, information theory, and the statistics of rare events. Sole-authored papers at ICML 2026, NeurIPS 2025 (Spotlight), and Physical Review D, plus peer-reviewed work on computing the probabilities of rare, extreme fluctuations in stochastic systems. Three years of industry software engineering at Hewlett-Packard, including sole ownership of the software for a prototype high-speed imaging instrument (multithreaded C++, GPU processing).

Technical Skills

Machine learning: Deep generative models (diffusion models, VAEs), density and likelihood estimation, probabilistic modeling, representation learning, model evaluation and diagnostics

Statistics & math: Large deviation theory and rare-event statistics, information theory (entropy, KL divergence, mutual information), stochastic processes, numerical optimization, stochastic optimal control

Programming: Python (JAX, NumPy, SciPy; familiar with PyTorch), C++11, C, C#, Qt; multithreaded and GPU-accelerated applications; Git, Linux, Jenkins; cloud GPUs (Modal)

Experience

Machine Learning Researcher (Postdoctoral) 2022 – Present

San Diego, CA / New Haven, CT / Chicago, IL

Postdoctoral Scholar, Department of Physics, University of California San Diego (2026 – Present)
Postdoctoral Associate, Department of Applied Physics, Yale University (2025 – 2026)
Associate Fellow, Kavli Institute for Cosmological Physics, University of Chicago (2022 – 2025)

- **Measuring what a model has learned.** Introduced *neural entropy*, a measure of how much information a diffusion model stores in its weights and a diagnostic of what it has absorbed from its training data. Measurements on image models showed they are highly efficient at compressing structured datasets: the information stored grows only logarithmically with the size of the training set. Sole author, **NeurIPS 2025 Spotlight**.
- **Where a diffusion model spends its information.** Showed that a diffusion model allocates a significant chunk of its information budget to fine perceptual detail, which explains why latent diffusion models are more efficient. Used the same analysis to explain why classifier-free guidance works. Sole author, **ICML 2026**.
- **Data statistics from trained diffusion models.** Developing a method that extracts the cumulants of a data distribution directly from a trained diffusion model, with higher sample efficiency and lower variance than estimating them from generated samples, and with no retraining. On solvable lattice field theories, its precision advantage over direct sampling grows rapidly with pixel separation (ongoing work).
- **Rare events in cosmology.** Used large deviation theory, the mathematics of rare events, to compute the probabilities of rare fluctuations in stochastic systems, from random walks to cosmic inflation. Showed that a distribution's tail retains an imprint of microscopic dynamics that typical fluctuations wash out, and used the large deviation principle to diagnose when an effective model can no longer predict the rate of rare events. Showed that the dominant rare fluctuations of open quantum systems minimize a relative entropy (Phys. Rev. D, SciPost Physics, 2026 preprint).
- **Communication.** Invited talks at MIT, Caltech, Yale, University of Michigan, the Aspen Center for Physics, Perimeter Institute, and Jump Trading (Chicago and New York).

Systems Engineer, Hewlett-Packard 2011 – 2014

Bangalore, India / San Diego, CA

- **Sole software developer** for a prototype high-speed, high-resolution print-quality scanner built in-house around a line-scan camera. Wrote the multithreaded C++11/Qt application that orchestrated the hardware, acquired scans, and streamed images to GPUs for processing.
- Designed and implemented the calibration routines for the new instrument.
- Extended the image-analysis software (C/C++, performance-critical paths in x86 assembly) of two established print-quality instruments, a high-resolution scanner and a tile-scanning microscope, measuring line edges and dot sizes to characterize inkjet pen performance.
- Built a C# tool that engineers used to design test-print layouts, with targeted artifacts that stress different aspects of pen performance.
- Set up a Jenkins continuous-integration framework serving about 40 engineers across teams working in Java, C#, and C++.
- Worked with HP's San Diego print-quality engineering team, first remotely from Bangalore and then on site.

Selected Publications

- *On the Separability of Information in Diffusion Models*. **A. Premkumar**. **ICML 2026**.
- *Neural Entropy*. **A. Premkumar**. **NeurIPS 2025 (Spotlight)**.
- †*The Quantum Mechanics of Rare Events: From Quantum Walks to Stochastic Inflation*. D. Green, K. Gupta, **A. Premkumar**. arXiv:2608.06319 (2026).
- *Regulating Loops in de Sitter Spacetime*. **A. Premkumar**. Physical Review D 109, 045003 (2024).
- †*Large Deviations in the Early Universe*. T. Cohen, D. Green, **A. Premkumar**. Physical Review D 107, 083501 (2023).
- †*A Tail of Eternal Inflation*. T. Cohen, D. Green, **A. Premkumar**. SciPost Physics 14, 109 (2023).
- †*Stochastic Inflation at NNLO*. T. Cohen, D. Green, **A. Premkumar**, A. Ridgway. JHEP 09, 159 (2021).

†Authors listed in alphabetical order of last name. Full list of papers on akhilprem.me.

Education

Ph.D., Physics, University of California San Diego 2017 – 2022

Chancellor's Dissertation Medal, School of Physical Sciences (2023). Lecturer for an undergraduate physics course (Summer 2020); teaching assistant for undergraduate and graduate courses.

M.Sc., Physics, Indian Institute of Technology Bombay 2015 – 2017

Institute Silver Medal (equivalent to graduating summa cum laude); R.P. Singh Memorial Award for academic performance.

B.Tech., Applied Electronics and Instrumentation, College of Engineering, Trivandrum 2007 – 2011