Tanisha Gupta

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Professional Summary

Graduate researcher in **Applied Mathematics** with research experience spanning **numerical analysis**, **Bayesian inverse problems**, and **high-performance scientific computing**. I have developed **PAC-Bayesian generalization frameworks** for **inverse PDE problems**, establishing **finite-sample** and **mesh-robust uncertainty guarantees** for the *inverse heat equation*. My technical portfolio includes **mixed-precision multigrid solvers** demonstrating **GPU-accelerated speedups** and **second-order convergence**, as well as **Hessian-aware MCMC samplers** for efficient exploration of **high-dimensional posterior distributions**. I aim to build **mathematically rigorous** and **computationally efficient** methodologies at the interface of **PDE theory**, **statistical learning**, and **uncertainty quantification**, with applications to **scientific machine learning** and complex **inverse modelling**.

Research Interests

- **Bayesian Inverse Problems & Uncertainty Quantification:** PAC-Bayesian theory, finite-sample guarantees, mesh-robust bounds, Gibbs/tempered posteriors, certified uncertainty for PDE-governed systems.
- **Numerical Analysis & Scientific Computing:** Finite-difference and finite-element methods, stability and convergence theory, **multigrid** and **Krylov** solvers, mixed-precision numerical computation.
- **High-Dimensional Sampling & Optimization:** Hessian-aware MCMC, stochastic optimization, adaptive Langevin dynamics, sampling for high-dimensional inverse problems, PDE-constrained optimization.
- **High-Performance Computing for PDEs:** GPU/CUDA acceleration, scalable solver architectures, performance-optimized PDE simulations.
- **Mathematical Foundations of Scientific Machine Learning:** Learning-theoretic guarantees for numerical PDE methods, surrogate modelling with certificates, integration of ML, UQ, and deterministic/stochastic PDE frameworks.

Work Experience

Research Assistant — Mathematics Laboratory, Janki Devi Memorial College (University of Delhi), India *March 2025 – Present*

- Conducting research on **Bayesian inverse problems** and **uncertainty quantification**, focusing on the **PAC-Bayes framework for PDE-governed systems**.
- Developed and validated **finite-sample generalization bounds** for the inverse heat equation, integrating Bayesian inference with statistical learning theory.
- Designed **mesh-robust numerical solvers** for reliable posterior estimation in high-dimensional inverse problems.
- Collaborating with faculty on manuscripts submitted to *SIAM/ASA Journal on Uncertainty Quantification* and related applied mathematics venues.
- Mentoring undergraduate students on computational mathematics and statistical inference projects.

Junior Research Data Assistant — AI & Machine Learning Lab, University of Liverpool, UK *August 2024 – February 2025*

- Researched **verification frameworks for Deep Reinforcement Learning (DRL)** models, emphasizing algorithmic safety and robustness.
- Designed **Lyapunov Barrier Certificate**-based methods reducing instability in DRL controllers by 20%.
- Conducted over 50 experiments improving model generalization and convergence behavior.
- Tuned deep-learning hyperparameters to reduce false positives by 15% and contributed to peer-reviewed AI journal submissions.
- **Tools:** Python (PyTorch, TensorFlow, Scikit-learn), MATLAB, AWS, SQL, Power BI.

Projects

PAC-Bayes Certificates for Bayesian Inverse Problems: A Case Study on the Heat Equation GitHub Link

Implements **PAC-Bayes certified uncertainty** for Bayesian inverse PDEs on the 1D heat equation. Provides finite-sample generalization bounds, a mesh-robust decomposition of error, Gibbs/tempered posterior implementation, and a complete, reproducible experiment pipeline (data generation → posterior sampling → certificate computation).

Mixed-Precision Multigrid Solvers for PDEs GitHub Link

High-performance multigrid framework with adaptive mixed precision and CUDA acceleration. Demonstrates up to **6.6× GPU speedup** vs. CPU, **1.7× mixed-precision gain** with **35% lower memory**, and verified $O(h^2)$ convergence. Includes benchmarks, visualization tools, and comprehensive tests.

Hessian Aware Sampling in High Dimensions GitHub Link

Hessian-informed MCMC samplers (Metropolis, Langevin, adaptive variants) for efficient exploration of high-dimensional posteriors. Achieves **2–10× ESS improvements** on ill-conditioned targets, robust to $d > 10^3$. Ships with benchmarks, diagnostics, and publication-quality plotting utilities.

Education

2023 – 2024 **University of Liverpool, United Kingdom**
Master of Science in Data Science & Artificial Intelligence **Distinction**
Relevant Coursework: Deep Learning, Natural Language Processing, Reinforcement Learning, Big Data, Cloud Computing, Bayesian Statistics, Optimisation Methods, Data Visualisation.

2019 – 2022 **Janki Devi Memorial College (University of Delhi), India**
Bachelor of Science (Honours) in Mathematics **GPA: 3.6/4.0**
Relevant Coursework: Real Analysis, Differential & Partial Differential Equations, Complex Analysis, Multivariate Calculus, Linear Algebra, Group Theory, Ring Theory, Numerical Analysis, Probability & Statistics, Metric Spaces, Optimization, Computational Modelling.

Publications

1. Tanisha Gupta . **PAC-Bayes Certificates for Bayesian Inverse Problems: A Case Study on the Heat Equation**. TechRxiv, July 2025. DOI link. (Preprint, under peer review at **SIAM Journal on Uncertainty Quantification**).

   - **Methodological novelty:** Introduces the first PAC-Bayesian generalization certificates for Bayesian inverse partial differential equations, combining Gibbs posteriors and tempered Bayesian inference to provide finite-sample, mesh-robust generalization guarantees for inverse-PDE uncertainty quantification.

Key Skills

Mathematical & Statistical Modelling: Bayesian inference, PAC-Bayesian analysis, uncertainty quantification, inverse problems, stochastic optimization, Monte Carlo & MCMC methods, PDE-constrained optimization.

Numerical & Scientific Computing: Finite-difference & finite-element methods, Crank–Nicolson schemes, multigrid & Krylov solvers, Hessian-aware sampling, high-performance (CUDA/GPU) computing.

Programming: Python (NumPy, SciPy, PyTorch, TensorFlow), C++, MATLAB, R, SQL, Linux, Git, CUDA, LaTeX.

Machine Learning Foundations: Statistical learning theory, reinforcement learning (safe & constrained), model interpretability, optimization-based learning.

Research Communication: Technical writing (TechRxiv, SIAM), reproducible GitHub pipelines, computational documentation, and academic presentation.

Certifications & Technical Achievements

AI & Machine Learning Specialization (Coursera): Algorithms, optimization, and model development.
Data Science with R (SimpliLearn): Statistical computing and regression modelling.
Cloud Data Engineering (AWS/GCP): BigQuery, Spark, and distributed computation.
AI-Powered Fraud Detection Model: Designed Python-based ML pipelines reducing false positives by 25%.
Advanced Programming Certification (C++ & Python): OOP, data structures, algorithms, and applied software development.