

# SONIA REILLY

Courant Institute of Mathematical Sciences, New York University

soniareilly.github.io  $\diamond$  sonia.reilly@nyu.edu

## EDUCATION

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**Courant Institute of Mathematical Sciences, New York University**

New York, NY

Ph.D. in Mathematics

*Expected 2027*

Thesis Advisor: Georg Stadler

Supported by Department of Energy Computational Science Graduate Fellowship

**Massachusetts Institute of Technology**

Cambridge, MA

S.B. in Mathematics with Computer Science

*2021*

## RESEARCH INTERESTS

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Bayesian inverse problems, PDE-governed inverse problems, uncertainty quantification

## RESEARCH EXPERIENCE

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**Courant Institute of Mathematical Sciences**

New York, NY

*Graduate Researcher, advised by Georg Stadler*

*2022 – present*

*Low-Rank Approximations for Hierarchical Bayesian Inverse Problems*

- Developing accurate and scalable deterministic methods of approximating posterior distributions of linear Bayesian PDE inverse problems with Gaussian priors and low-dimensional hyperparameters.
- Exploiting low-rank structures in the posterior covariance to avoid repeated PDE solves.
- Demonstrating the speed and accuracy of the algorithms on a time-dependent advection-diffusion benchmark problem.

*Ensemble MCMC Sampling for Infinite-Dimensional Bayesian Inverse Problems*

- Implemented a novel MCMC sampler designed for posterior distributions that emerge from infinite-dimensional Bayesian PDE inverse problems.
- Combined elements of affine invariant methods and the preconditioned Crank Nicolson method to form a gradient-free ensemble sampler that targets high-dimensional, concentrated posteriors.
- Tested the method against existing MCMC samplers on Gaussian regression problems of varying complexity, using NYU's Greene supercomputer to compute MCMC chains in parallel.

**Lawrence Berkeley National Laboratory**

Berkeley, CA

*Graduate Research Intern, advised by Jeff Donatelli in James Sethian's group*

*Summer 2023*

- Designed a method to incorporate measurement uncertainty into the Multi-Tiered Iterative Phasing (M-TIP) algorithm for recovering the density of a molecule imaged using fluctuation X-ray scattering.
- Successfully retrieved densities from images with added constant and variable Gaussian noise, and made progress towards adapting the algorithm to allow for Poisson-distributed data.

**Johns Hopkins University Applied Physics Laboratory**

Laurel, MD

*Postgraduate Researcher, advised by Sam Yee*

*Summer 2021*

- Tackled the tomographic inversion problem of recovering a map of atmospheric brightness from satellite data which records integrated brightness values.
- Developed and implemented a numerical method using 2D piecewise linear basis functions and a regularized matrix solve, which is more generalizable to 2D and 3D than classical 1D methods.

*Undergraduate Researcher, advised by William Swartz*

*Sep 2016 - Aug 2017, Summer 2018*

- Designed and implemented a method of extracting high-resolution maps of Earth's outgoing radiation from low-resolution satellite data using spherical harmonics approximation and compressive sensing.
- Applied the method to extract spatial data from RAVAN, NASA's first earth science CubeSat mission, and co-authored a resulting publication in *Remote Sensing* in April 2019.

**Massachusetts Institute of Technology**

Cambridge, MA

*Undergraduate Researcher, advised by Jörn Dunkel*

*Feb 2020 – Dec 2020*

- Developed network topologies optimized to cancel out fluctuations in coupled oscillator systems governed by the swing equation, such as power grid models.
- Categorized the effect of the noise spectrum of the fluctuations on the optimal network structure.
- Quantified the resistance of these optimized networks to cascades of line failures in a power grid model.

*Undergraduate Researcher, advised by Sai Ravela*

*Summer 2019*

- Investigated the mathematics of deep learning by modeling information flow in neural networks as a dynamical system.
- Derived the Fokker-Planck equation for the evolution of stochastic gradient descent as a drift-diffusion system, with the aim of applying the model to the evolution of the weights of neural networks.

## PRESENTATIONS AND POSTERS

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6. SIAM Annual Meeting 2026, Cleveland, OH, July 2026 (upcoming, invited minisymposium talk)  
Session: From Theory to Computation: Modern Methods for PDE Inverse Problems  
Title: "Bayesian Inference for Latent Gaussian Models Governed by PDEs"
5. ICERM Workshop on Bayesian Inverse Problems and UQ, Providence, RI, March 2026 (poster)  
Title: "Bayesian Inference for Latent Gaussian Models Governed by PDEs"
4. IMSI Workshop on Data Assimilation and Inverse Problems for Digital Twins, Chicago, IL, October 2025 (poster)  
Title: "Bayesian Inference for Latent Gaussian Models Governed by PDEs"
3. DOE CSGF Annual Program Review Outgoing Fellow Presentation, Washington D.C., July 2025  
Title: "Bayesian Inversion of Hierarchical PDE-Governed Problems Using INLA"
2. SIAM Conference on Computational Science and Engineering, Fort Worth TX, March 2025 (invited minisymposium talk)  
Session: Investigating Inverse Problems using Bayesian Inference: Challenges and Advances  
Title: "Bayesian Inversion of PDE-Governed Problems Using Integrated Nested Laplace Approximations"
1. Mid-Atlantic Numerical Analysis Day, Temple University, Philadelphia, PA, November 2024  
Title: "Bayesian Inversion of PDE-Governed Problems Using Integrated Nested Laplace Approximations"

## PUBLICATIONS

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2. (in preparation) **S. Reilly**, G. Stadler. Efficient Low-Rank Approximation for Hierarchical PDE-Governed Bayesian Inverse Problems.
1. W. Swartz, S. Lorentz, S. Papadakis, P. Huang, A. Smith, D. Deglau, Y. Yu, **S. Reilly**, N. Reilly, and D. Anderson. "RAVAN: CubeSat Demonstration for Multi-Point Earth Radiation Budget Measurements". *Remote Sensing* 11.7 (Apr. 2019), 796. DOI: 10.3390/rs11070796.

## TEACHING EXPERIENCE

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### Graduate Teaching Assistant, Courant Institute of Mathematical Sciences

MATH-UA 334: Mathematical Statistics

*Spring 2025, 2026 and Fall 2024, 2025*

- Led two weekly 75 minute recitation sections per semester, each for 40 undergraduate juniors and seniors, and held weekly office hours.
- Wrote example problems and solutions for recitation worksheets, prepared and posted reviews of lecture material, led exam review sessions, and engaged with students on the class discussion board.
- Student evaluations: 4.88/5 Fall 2025, 5.00/5 Spring 2025, 4.50/5 Fall 2024

MATH-UA 253: Linear and Nonlinear Optimization

*Spring 2024*

- Led weekly 75 minute recitation sections and held office hours for a class of 45 undergraduate seniors.
- Developed Julia coding tutorials, wrote example problems and solutions for weekly worksheets, and prepared reviews of lecture material. Graded exams and responded to discussion board questions.
- Delivered a 90-minute lecture as a substitute for the course instructor.
- Student evaluations: 4.75/5

## AWARDS

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SIAM Student Travel Award

2025

- \$650 in travel funding to SIAM's Computational Science and Engineering conference

Department of Energy Computational Science Graduate Fellowship

2021-2025

- 4 years of \$45,000 per year in stipend, plus tuition and fees

NSF Graduate Research Fellowship

2021

- 3 years of stipend, tuition, and fees. (Awarded, but declined in favor of DOE CSGF.)

Henry M. MacCracken Fellowship, New York University

2021

- 5 years of PhD support, with no teaching requirement.

Johns Hopkins University Applied Physics Laboratory ASPIRE Scholarship

2017

- \$2,000 in college tuition scholarship, awarded for the best presentations by high school interns.

Research Science Institute, Massachusetts Institute of Technology

2016

- Competitive, tuition-free summer research program for high school seniors.

## SERVICE AND OUTREACH

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CAS-GSAS Student Network Mentoring Program, Graduate Mentor

2026

- Mentored an NYU rising senior applying to graduate programs in math.

Courant Student Organization, President

2023–2024

- Co-led the mathematics PhD student organization, including interfacing with the department, raising funds, and organizing visiting students' day.
- Oversaw a revamp of the student-organized website that hosts qualifying exam prep resources for incoming PhD students.

Diversity, Equity, and Inclusion Reading and Outreach Group, Member

2021–2024

- Led and participated in discussions on diversity and equity in mathematics and graduate education.
- Volunteered at a local high school, assisting in evaluating student math projects.

- Association for Women in Math, Courant Organizing Committee Member 2021–2023
- Organized social events for women in the Courant math department, and led an effort to invite more women speakers to department colloquia.
- Courant Graduate Student/Postdoc Seminar, Co-organizer 2021–2022
- Invited speakers and organized logistics for a seminar intended to connect first-year students with potential advisors.
- MIT Undergraduate Society of Women in Math, Peer Mentor 2020–2021
- Mentored a younger undergraduate woman in navigating the math department at MIT.
- North American Computational Linguistics Open Competition, Organizing Committee Member and Problem Writer 2017–2021
- Helped organize, contributed problems, served on the jury, and hosted the MIT location of this contest for high school students.

## SKILLS

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**Software** Python, Julia, MATLAB, C/C++, CUDA, OpenMP

**Languages** Spanish (fluent); German, Italian, French (proficient in reading)