

ALEJANDRO JOSÉ SOTO FRANCO

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RESEARCH INTERESTS

Mimetic discretization of partial differential equations on manifolds. Performance-portable code generation for the resulting operators, targeting GPUs. Discrete exterior calculus, bundle-valued forms and connection Laplacians; finite element exterior calculus; geometric numerical integration. Formal verification of mathematical analysis in Lean 4. Active matter and complex fluids.

EDUCATION

Johns Hopkins University, Baltimore, Maryland 2021–2025

Master of Science in Engineering, Biomedical Engineering. Conferred 22 May 2025.

Graduate coursework grade point average 3.66. Coursework in Introduction to Differential Geometry, Calculus on Manifolds, Mathematical and Computational Foundations of Data Science, and Condensed Matter Physics II.

Bachelor of Science, Biomedical Engineering. Conferred 22 May 2025.

Graduated with General Honors and with Departmental Honors in Biomedical Engineering. Cumulative grade point average 3.58. Coursework in Computational Modeling of Soft and Biological Materials, Biomedical Data Science, and Computational Medicine.

PUBLICATIONS

B. Klein, **A. J. Soto Franco**, M. Sabbir, J. Deutsch, S. Kliegman, R. Selinger, K. Mitchell and D. Beller. *Chaos-generating periodic orbits of topological defects in confined active nematics*. Proceedings of the National Academy of Sciences **123**(28), e2516670123, 2026. doi:10.1073/pnas.2516670123.

A. J. Soto Franco. *Configuration-space curvature and the Navier–Stokes singular set*. Zenodo, 2026. doi:10.5281/zenodo.20600978.

A. J. Soto Franco. *Surgery in membrane fusion*. Zenodo, 2026. doi:10.5281/zenodo.22063174.

TALKS AND PRESENTATIONS

Talk. “Periodic dynamics of topological defects in active fluids on Riemannian 2-manifolds.” Johns Hopkins Soft Matter Talks, 17 April 2025.

Poster. “Sequence variations in pathogenic and commensal bacterial flagellin binding domains account for differential Toll-like receptor 5-mediated gut-associated immune responses.” Leadership Alliance National Symposium, Connecticut Convention Center, Hartford, July 2023; and summer capstone presentation, University of Chicago, 2023.

Poster. “Synthesis and *in vitro* characterization of interleukin-2 polymeric micelles for local solid tumor immunotherapy.” DREAMS Hopkins Undergraduate Research Symposium, and Institute for NanoBioTechnology symposium, Johns Hopkins University, 2023.

Talk, with J. Choy. “Biomaterial niches for *in vivo* metabolic engineering of CD8+ T cells.” Johns Hopkins Translational Tissue Engineering Center, 13 October 2022.

Poster and talk. “A novel peptide nanodelivery system for sustained release of semaglutide to treat type-2 diabetes.” BMES Mid-Atlantic Undergraduate Research Competition, 29 April 2022; DREAMS Hopkins Undergraduate Research Symposium and Institute for NanoBioTechnology symposium, 2022; and PULSE Student Research Presentations, Johns Hopkins Biomedical Engineering, March 2022.

Abstract. B. Klein, **A. J. Soto Franco**, M. M. H. Sabbir, K. A. Mitchell and D. A. Beller. “Boundary-guided topological entropy production in confined active nematics.” American Physical Society Global Physics Summit, 2025; and University of Delaware Soft Matter Symposium, 2025.

RESEARCH SOFTWARE

Author and maintainer unless stated. Rust unless stated.

cartan (*crates.io*, *PyPI*). Discrete exterior calculus with bundle-valued operators: rotors in the even subalgebra, discrete fiber-bundle connections, frame transport along mesh edges, and a covariant Laplacian on bundle sections. GPU kernels are generated through **cuda-oxide**. A sixteen-crate workspace, 9,112 cumulative downloads across its published crates as of 23 August 2026.

volterra. Covariant Beris–Edwards dynamics on simplicial meshes, with a discrete energy law and a machine-checked index law for defect charge. The solver behind the confined active-nematic results above.

vonkarman. Multi-precision pseudospectral direct numerical simulation of the incompressible three-dimensional Navier–Stokes equations on the periodic torus. ETD-RK4 integration, dealiasing by three-halves zero padding, adaptive CFL stepping, with energy spectra and conservation-law diagnostics.

EllipticPDE (*Lean 4*). Formalization of second-order linear elliptic theory, from existence and uniqueness through the Fredholm alternative to higher interior regularity and interior smoothness. No **sorry** in the development; every headline statement is pinned by an axiom audit.

Meridian (*Lean 4*, *VS Code*). A metaprogramming toolkit for mathematical formalization, with a Visual Studio Code extension giving a live dependency graph, a **sorry** inventory and a Mathlib coverage view for any Lean 4 project. Runs entirely locally, with no network calls and no telemetry.

proofsense (*Rust and Lean 4*). A proof linter. Lean answers whether a declaration typechecks; **proofsense** answers whether it matches what the cited source states, targeting the hypothesis quietly strengthened, the step citing a lemma the source never gives, and the inequality pointing the wrong way.

multiscale-geometry. Diffusion wavelets and geometric multi-resolution analysis, neither of which has a maintained implementation in any major ecosystem. Validated to machine precision against the reference implementations.

elworthy. A just-in-time compiler specializing Bismut–Elworthy–Li formulas into SIMD kernels.

kloeden (*Rust and C++*). Hand-written SIMD C++ benchmark companion to **elworthy**, for measuring generated kernels against tuned reference code.

ferrum-gpu (*PyPI*). A pure-Rust GPU compute substrate with Python bindings. FFT kernels run on NVIDIA hardware through **cuda-oxide**, compiling Rust to PTX with no CUDA C in the path.

gpufft (*crates.io*, *PyPI*). Cross-vendor GPU fast Fourier transforms behind one typed interface, over Vulkan and CUDA backends, with Python bindings. Buffers and plans are typed at backend and scalar level, so mixing a Vulkan buffer with a CUDA plan fails to compile.

tikhonov (*crates.io*, *PyPI*). Harmony2 in Rust for single-cell RNA sequencing batch correction, with Python bindings and a command-line interface.

mermin (*crates.io*, *PyPI*). *k*-atic alignment analysis of multi-channel fluorescence microscopy. Written for orientational-order studies of connective tissue with the Moalli laboratory, University of Pittsburgh School of Medicine.

CONTRIBUTIONS TO OTHER PROJECTS

NVIDIA cuda-oxide, a Rust compiler for NVIDIA GPUs. Forty merged pull requests and maintenance of the **cuda-oxide-codegen** crate, which was extracted from the compiler as a standalone backend from the dialect intermediate representation to PTX.

infinity-cosmos, the formalization of ∞ -cosmoi in Lean 4. Six merged pull requests.

mathlib4. One merged contribution, commit [2ff8885](#), *feat(Topology/Algebra/Support): compact multiplicative support under product operations* (#38022).

Eventual Daft, a distributed query engine. Two merged pull requests.

open-Qmin, the lattice Landau–de Gennes solver. Three open pull requests on the CUDA build path.

Fifty-two crates published to crates.io.

RESEARCH EXPERIENCE

Research Assistant, Department of Physics and Astronomy, Johns Hopkins University Dec. 2023 – May 2025

Confined two-dimensional active nematics, supervised by Daniel Beller. Defect dynamics, periodic orbits and their braid representation. `volterra`, the covariant solver listed above, grew out of this work.

Leadership Alliance Research Fellow, Pritzker School of Molecular Engineering, University of Chicago Summer 2023

Nagler Laboratory, supervised by Cathryn Nagler. Receptor desensitization by commensal bacteria in gnotobiotic mouse models, including the cecal extractions and the single-cell sequencing that followed them.

Research Assistant, Institute for NanoBioTechnology and Department of Materials Science and Engineering, Johns Hopkins University Jan. 2022 – Feb. 2024

Mao-Schneck Laboratory. Micromixing fabrication of interleukin-2 polymeric nanoparticles for solid-tumor immunotherapy, with sustained release characterized over two weeks.

TEACHING

Learning Assistant, General Physics II, Department of Physics and Astronomy, Johns Hopkins University Spring 2023

Learning Assistant, General Physics I, Department of Physics and Astronomy, Johns Hopkins University Fall 2022

Grader, Immunoengineering, Engineering for Professionals, Johns Hopkins University Spring 2023

State Exams Director, Maryland Science Olympiad May 2022 – June 2023

Supervised the testing sites and the event supervisors under them, and directed the writing, editing and formatting of every official exam used at the Johns Hopkins tournaments.

Exam Author, Johns Hopkins Mathematics Tournament Spring 2025

Wrote, proctored and graded the middle-school proof round for ninety students in thirty teams, and analyzed the score distribution for the coaches.

PROFESSIONAL EXPERIENCE

HPC and Machine Learning Associate, Ishaya & Associates June 2026 – present
Probabilistic and geostatistical prediction of subsurface properties, with GPU machine-learning pipelines in Rust and PyTorch and a three-dimensional Darcy-flow reservoir model.

Consulting Computational Fluid Dynamics Engineer, LOTTECH June 2026 – present
Simulation campaign for compressible high-speed multiphase flow, designing the boundary conditions and refining component geometry in CAD to improve gas-liquid mixing.

Founding Principal, Holonomy Securities Dec. 2025 – present
Three-person team building systematic trading engines for prediction markets and equity options on one Rust platform, with a multi-asset backtesting and execution stack under them.

Rust Trading Strategies Developer, Anti Capital, New York Aug. – Oct. 2025
Spot automated market making on crypto tokens in a Rust engine. Implemented the pre-debit balance check that removed insufficient-balance order rejections across a multi-exchange execution stack.

HONORS AND AWARDS

Kam Leong Research Fellowship, Whiting School of Engineering, Johns Hopkins University, 2022. John and Marion Kreutzberg Scholar. Dean's List, most terms.

PROFESSIONAL MEMBERSHIPS

The Leadership Alliance. Society for Industrial and Applied Mathematics. Biomedical Engineering Society.

LANGUAGES AND TOOLS

English and Spanish, both native. Rust, Lean 4, Python, Julia, C++, CUDA, $\text{\LaTeX}$.