Amirhossein Samandar

Ph.D. Candidate in Physics — Cosmology, Statistical Inference & Machine Learning

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Research Interests

Cosmologist working at the intersection of cosmological data analysis, statistical inference, probabilistic machine learning, and computational methods. My research covers Bayesian inference, information-theoretic model comparison, simulation-based (likelihood-free) inference with deep generative models, CMB statistics, and work on calibrated Bayesian evaluation of LLMs. My work combines analytic derivation, GPU/HPC implementation, and validation of learned inference.

Education

Case Western Reserve University — **Cleveland, OH, USA**
Ph.D. in Physics — *Aug 2023–16 Jan 2027 (expected)*
Direct Ph.D. from the B.Sc., to be completed in 3.5 years.
Advisor: Glenn D. Starkman • GPA 3.7/4.0

Sharif University of Technology — **Tehran, Iran**
B.Sc. in Physics — *2018–2023*
GPA 18.85/20 — **Rank 4 of 56**

Selected Research

Information Theory and Statistical Model Comparison — *2025–present*

COMPACT Collaboration — CWRU • ***First author, project lead***

- Derived **log-likelihood-ratio sampling distributions for Gaussian data** to connect information-theoretic distinguishability with detection probabilities and parameter recovery.
- Calibrated parameter searches with simulations to quantify false-positive rates, detection probabilities, and the effect of the detection criterion on recovered parameters. Applied the framework to cosmic topology, primordial tensor modes, and supernova-based dark-energy analyses; first-author preprint, arXiv:2610.17186.

Theoretical Cosmology and CMB Data Analysis — *2023–present*

COMPACT Collaboration — CWRU • ***Project lead***

- Derived spin-2 eigenmodes and CMB covariance models for compact Euclidean spaces, connecting cosmological perturbations with temperature and polarization observables.
- Developed **CMBtopology**, a GPU-parallelized Python/HPC package used across the collaboration for tensor-mode likelihood analysis.
- Developing an end-to-end analysis pipeline to constrain cosmic topology with **Planck PR4 data**.

Simulation-Based Inference and Neural Emulation — *2026–present*

COMPACT Collaboration — CWRU • ***Project lead***

- Developing variational-autoencoder **likelihood emulators** and **amortized inference** methods for cosmological parameter estimation from simulated CMB data.
- Combining probabilistic modelling with uncertainty calibration and validation against established Bayesian inference methods.

Machine Learning for CMB Classification — *Dec 2023–Mar 2024*

COMPACT Collaboration — CWRU / IFT Madrid

- Contributed to classification of simulated CMB maps, benchmarking learned discrimination between topologies against a computable likelihood. Published in JCAP 09 (2024) 057.

Calibrated Evaluation and Inference-Time Methods for Language Models — *2025–present*

Case Western Reserve University

- Co-developed a Bayesian alternative to Pass@k using posterior estimates and credible intervals for uncertainty-aware evaluation; published at **ICLR 2026** and released through the open-source **Scorio** toolkit.
- Co-authored a paper **accepted at TMLR** on test-time scaling in reasoning models, examining inference regimes, evaluation, and reproducibility.

Scalar-Field Models and Cosmological Perturbation Theory *Jan 2022–Feb 2023*
Institute for Research in Fundamental Sciences (IPM), Tehran

- Investigated complex scalar-field dark matter in the non-relativistic limit, effective field theory, canonical transformations, and multi-field axion models.
- Studied inflation and primordial non-Gaussianity using cosmological perturbation theory and `xAct`.

Methods and Computational Skills

Theoretical physics: Cosmological perturbation theory; primordial gravitational waves; CMB temperature and polarization; cosmic topology; scalar-field models and effective field theory.

Statistical inference: Bayesian inference and sampling; simulation-based and likelihood-free inference; likelihood emulation; information-theoretic model comparison; uncertainty quantification and calibration.

Probabilistic ML: Variational autoencoders; diffusion and score-based generative models; Gaussian processes. Research and extensive study of probabilistic modelling for scientific inference and emulation.

Deep learning: Transformer architectures, representation learning, and language-model evaluation; inference-time scaling and reproducibility.

Scientific computing: **GPU acceleration**, HPC and parallel computing, numerical linear algebra, and scientific-software development. Python, Julia, Mathematica, PyTorch, JAX, and scikit-learn.

Agentic AI: **AI-assisted research and programming**; tailored agent instructions and reusable skills; verification of generated reasoning and code.

Languages: Persian (native); English (fluent).

Research Mentorship

Case Western Reserve University **Cleveland, OH, USA**
Undergraduate Research Mentor *May 2026–present*
Have mentored **several undergraduate researchers**, working one-on-one on the **underlying physics**, **computational methods**, and the **interpretation and validation of numerical results**.

Software

CMBtopology: GPU-parallelized Python/HPC package computing CMB covariance matrices for compact Euclidean topologies; adopted collaboration-wide for tensor-mode likelihood analysis.

Scorio: Open-source Bayesian evaluation toolkit for LLMs (Python/Julia). `https://github.com/mohsenhariri/scorio`

Collaborations

COMPACT: Cosmic topology collaboration — CWRU, Pittsburgh, Imperial College London, IFT Madrid, INFN Padova.

LiteBIRD: Adjoint member; developing a forecasting pipeline to constrain cosmic topology using high-fidelity E-mode polarization data alongside temperature data.

Teaching

CWRU: Computational Methods in Physics (Spring 2025); General Physics Lab (Fall 2023–Fall 2024).

Sharif Univ.: Cosmology; Special Relativity; Electrodynamics I & II (2020–2021).

Selected Talks and Conferences

2026: **COSMO-26**, International Conference on Particle Physics and Cosmology.

2025: **COSMO-25**, International Conference on Particle Physics and Cosmology (contributed talk).

2025: "LLM Evaluation and Test-Time Scaling," invited CERCA Weekly Seminar, CWRU.

2024–2025: Parity Violation from Home Conference; 6th and 7th Neighborhood Workshops, Institute for Gravitation and the Cosmos, Penn State.

Awards

- **Art Walker Award for Outstanding Service**, Department of Physics, Case Western Reserve University (2026)
- Full graduate funding (Ph.D. in Physics), Case Western Reserve University
- Ranked **20th of 20,000** candidates, Iran National University Entrance Exam for M.Sc. studies
- Top 0.5% (**420th of 150,000**), Iran National University Entrance Exam for undergraduate studies

References

Glenn D. Starkman — Case Western Reserve University — glenn.starkman@case.edu

Andrew H. Jaffe — Imperial College London — a.jaffe@imperial.ac.uk

Yashar Akrami — IFT UAM-CSIC, Madrid — yashar.akrami@csic.es