

Sandro Martinelli Reia, PhD

Urban Scientist | Complex Systems Researcher | Computational Physicist

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Summary

Computational Physicist and Research Scientist with experience of applying statistical physics, machine learning, high-performance computing, and data science to model complex, real-world systems. Developed high-performance simulations of human activity and mobility for 20M+ individuals for the IARPA HAYSTAC program, engineering scalable geospatial pipelines and optimizing MPI workflows to cut runtimes from days to minutes. Author of 35+ peer-reviewed publications, including 25+ as first author and articles in *Nature Communications*, *Nature Cities*, and *Physics of Life Reviews* (450+ citations; h-index: 13). Proven track record of translating complex problems into scalable analytical and computational solutions, dexterity collaborating with a range of stakeholders across multidisciplinary initiatives, and commitment to providing timely deliverables in a fast-paced workplace to meet evolving project needs.

Experience

Postdoctoral Researcher, Geography & Geoinformation Science

2023 – Present

George Mason University

Fairfax, VA

- Developed a large-scale agent-based model simulating mobility for 20M+ agents using `repast4py`/MPI; optimized high-performance computing (HPC) workflows to reduce simulation runtime from days to minutes.
- Architected end-to-end geospatial pipelines using GeoPandas and OSMnx to integrate social, infrastructure, and behavioral data for deployment in the HAYSTAC/IARPA program.
- Led research lifecycles for high-stakes deliverables, translating complex technical findings into actionable insights for L3Harris and ensuring on-time delivery of mission-critical outcomes.

Postdoctoral Researcher, Civil Engineering

2021 – 2023

Purdue University (ranked [66th worldwide](#))

West Lafayette, IN

- Developed multi-scale stochastic systems models to characterize urban evolution, disaggregating domestic migration into inter-city and intra-city flows for 3,100+ U.S. counties.
- Engineered analytical workflows to synthesize 15 years of American Community Survey (ACS) data, utilizing Lévy stable distributions to identify "migration shocks" and quantify their impact on city rank volatility.
- Authored high-impact research (e.g., *Nature Communications*, *Nature Cities*) demonstrating how negative population density gradients drive urban sprawl and how spill-over effects temper local demographic shocks.

Postdoctoral Researcher, Institute of Physics

2016 – 2021

University of São Paulo - USP (ranked [118th worldwide](#) and [1st in Latin America](#))

São Paulo, Brazil

- Developed and analyzed parsimonious agent-based models in Fortran across 10^5 simulation runs, demonstrating that constrained information sharing optimizes search efficiency in complex collective systems.
- Used the SIR epidemic model to describe 15 years of empirical APS data, showing that state-of-the-art models for forecasting nonstationary time series are very likely to fail to predict the long-term citation counts of highly-cited papers.
- Evaluated the "wisdom of crowds" phenomenon by applying nonparametric statistical analysis to nearly 10,000 empirical forecast experiments from the FRBP database, demonstrating that collective predictions outperform the majority of individual experts less than 70% of the time and exposing the phenomenon as a selective attention fallacy.

Education

PhD in Physics (Statistical and Computational Physics)

2015

University of São Paulo - USP (ranked [118th worldwide](#) and [1st in Latin America](#))

São Paulo, Brazil

Dissertation: [Activity, Phase Transitions, and Media Effects in a Sociocultural Model](#)

MSc in Physics (Statistical and Computational Physics)

2011

University of São Paulo - USP

São Paulo, Brazil

Thesis: [Phase Transitions and Nucleation Processes in Cellular Automata Rule Space](#)

BSc in Physics (Theoretical Physics)

2008

University of São Paulo - USP

São Paulo, Brazil

Important Accomplishments

- First author of more than 25 scientific publications, demonstrating the ability to lead research projects from inception to publication.
- *Persistent Agents in Axelrod's Social Dynamics Model* was recognized among the *2016 Better Biophysical Works in the World* by **Biophysical Reviews and Letters**.
- Experience writing **NSF** proposals. Awarded multiple research grants, including a postdoctoral fellowship from **FAPESP** (São Paulo Research Foundation).
- Academic Editor for **PLOS ONE** in Urban Studies, Complexity, and Networks.

Selected Projects

IARPA HAYSTAC – Large-scale Urban Mobility Simulation

- Established models of “normal” human movement across times, locations, and people in order to characterize what makes an activity detectable as anomalous within the expanding corpus of global human trajectory data.
- Led the development of a high-performance urban microsimulator in Repast4Py/MPI to generate realistic trajectories for 20M+ agents, enabling the detection of subtle anomalous behaviors within massive mobility datasets.

NSF CRISP Type 2 – Critical Transitions in the Resilience and Recovery of Interdependent Social and Physical Networks

- Investigated post-disaster recovery in interdependent social and physical networks, focusing on how network structure, household decision-making, and cascading failures influence resilience, tipping points, and community re-entry.
- Simulated recovery dynamics and evaluated policy scenarios; highlighted heterogeneous recovery pathways relevant to climate adaptation and community resilience.

FAPESP – Diffusion of Innovations: a computational approach based on Axelrod's model

- Investigated how innovations spread in culturally heterogeneous populations using variants of Axelrod's model, with emphasis on social influence, homophily, media effects, demographic mobility, and phase transitions in collective behavior.
- Developed and analyzed computational extensions of Axelrod-type agent-based models, using large-scale simulations and statistical-physics methods to characterize how mobility, long-range interactions, and network structure affect innovation diffusion and cultural dynamics.

Selected Publications

- Reia, S. M., et al. [*Domestic migration and city rank dynamics*](#). **Nature Cities**, 2025.
- Reia, S. M., et al. [*Spatial structure of city population growth*](#). **Nature Communications**, 2022.
- Reia, S. M., et al. [*Modeling the dynamics and spatial heterogeneity of city growth*](#). **npj Urban Sustainability**, 2022.
- Reia, S. M., et al. [*Function and form of U.S. cities*](#). **Computers, Environment and Urban Systems**, 2025.
- Reia, S. M., et al. [*Towards universal urban patterns-of-life simulation*](#). **npj Complexity**, 2026.
- Reia, S. M., et al. [*Agent-based models of collective intelligence*](#). **Physics of Life Reviews**, 2019.
- Reia, S. M., et al. [*Opportunities and challenges of LLMs in urban science*](#). **Physics of Life Reviews**, 2025.

Teaching Experience

Mathematical Physics

University of São Paulo (USP)
Teaching Assistant

2014
São Paulo, Brazil

Mathematical Physics

University of São Paulo (USP)
Teaching Assistant

2012
São Paulo, Brazil

Basic Physics

University of São Paulo (USP)
Teaching Assistant

2010
São Paulo, Brazil

Academic service

- Academic Editor, [PLOS ONE](#) (Complexity and Networks; Urban Studies).
- Frontiers Topic Editor for the Research Topic [“Science of Science: A Complex Network Perspective”](#).
- Reviewer for a broad range of journals in complex systems, urban science, geospatial analysis, and computational modeling, including: *Nature Communications*, *Computers, Environment and Urban Systems*, *Communications Physics*, *International Journal of Geographical Information Science*, *International Journal of Disaster Risk Reduction*, *Scientific Reports*, *PeerJ Computer Science*, *PLOS ONE*, *Physica A: Statistical Mechanics and its Applications*, *Frontiers in Ecology and Evolution*, *Physics Letters A*, *Frontiers in Physics*, and *Complexity*.

Funding & Fellowships

Postdoctoral Fellowship Coordination for the Improvement of Higher Education Personnel (CAPES)	2019–2021 Brazil
Postdoctoral Fellowship São Paulo Research Foundation (FAPESP) Grant 16/20874-3	2017–2018 Indiana, US
Postdoctoral Fellowship São Paulo Research Foundation (FAPESP) Grant 15/17277-0	2016–2019 Brazil
PhD Fellowship Coordination for the Improvement of Higher Education Personnel (CAPES)	2011–2015 Brazil
Master's Fellowship Coordination for the Improvement of Higher Education Personnel (CAPES)	2009–2011 Brazil

Certificates

- **Statistics for Data Science: Theory and Practice with Python** (2021), Institute of Mathematics and Computer Science (ICMC), University of São Paulo (USP).
- **Machine Learning** (2021), online course offered by Stanford Online through Coursera.
- **DAT210x: Programming with Python for Data Science** (2017), online course offered by Microsoft through edX.
- **Introduction to Artificial Intelligence** (2011), online course offered by Sebastian Thrun and Peter Norvig.

Core Skills

HPC	Fortran, OpenMP, MPI, Repast4Py.
Data Science & Machine Learning	Python (Pandas, SciPy, Scikit-learn, MySQL), data analysis, data visualization (Seaborn), supervised and unsupervised learning, classification, regression, k-means clustering, random forests, multilinear regression, feature engineering (embedding).
Geospatial & GIS	GeoPandas, Shapely, PyProj; geospatial data processing, spatial analysis.
Data Sources	OpenStreetMap (building footprints and road network), NHTS/AADT (mobility data), Safe-graph/Veraset (POI foot-traffic volume), Census/ACS (demographic datasets), Web of Science/APS (citation network).
Leadership & Mgmt	Supervised PhD students and led day-to-day laboratory activities. Expert in project lifecycle management, interdisciplinary team coordination, and technical mentorship.
Communication	Scientific writing with 35+ publications and 450+ citations. Skilled at translating complex data insights for non-technical audiences.

Languages

Portuguese (native) | English (Cambridge CPE)

Publications

Urban Systems, Mobility, and the Built Environment

- *Towards Universal Urban Patterns-of-Life Simulation.*
npj Complexity, 2026.
Sandro M. Reia, Henrique F. de Arruda, Shiyang Ruan, Taylor Anderson, Hamdi Kavak, and Dieter Pfoser.
- *UrbanLLMind: Scalable LLM-Powered Urban Mobility Simulation with Open-Weight Models.*
Third Conference on Language Modeling (COLM), 2026.
Prabin Bhandari, **Sandro M. Reia**, Dieter Pfoser, Antonios Anastasopoulos.
- *Opportunities and challenges of LLMs in urban science.*
Physics of Life Reviews, 2025.
Sandro M. Reia, Dieter Pfoser, and Henrique F. de Arruda.
- *Function and form of US cities.*
Computers, Environment and Urban Systems, 2025.
Sandro M. Reia, Taylor Anderson, Henrique F. de Arruda, Shiyang Ruan, Kudip S. Atwal, Hamdi Kavak, and Dieter Pfoser.
- *Domestic migration and city rank dynamics.*
Nature Cities, 2025.
Sandro M. Reia, P. Suresh C. Rao, Marc Barthélemy, and Satish V. Ukkusuri.
- *An OpenStreetMap derived building classification dataset for the United States.*
Scientific Data, 2024.
Henrique F. de Arruda, **Sandro M. Reia**, Shiyang Ruan, Kudip S. Atwal, Hamdi Kavak, Taylor Anderson, and Dieter Pfoser.
- *An agent-based model of post-disaster recovery in multilayer socio-physical networks.*
Sustainable Cities and Society, 2024.
Jiawei Xue, Sangung Park, Washim U. Mondal, **Sandro M. Reia**, Tong Yao, and Satish V. Ukkusuri.
- *Modeling the dynamics and spatial heterogeneity of city growth.*
npj Urban Sustainability, 2022.
Sandro M. Reia, P. Suresh C. Rao, and Satish V. Ukkusuri.
- *Spatial structure of city population growth.*
Nature Communications, 2022.
Sandro M. Reia, P. Suresh C. Rao, Marc Barthélemy, and Satish V. Ukkusuri.

Computational Social Science and Collective Dynamics

- *Agent mobility and hotspot adaptability drive group aggregation.*
Physica A: Statistical Mechanics and its Applications, 2025.
Sandro M. Reia, Dieter Pfoser, and Paulo R. A. Campos.
- *Communication patterns affect the collective performance of social agents.*
The European Physical Journal B, 2025.
Sandro M. Reia, Dieter Pfoser, and Paulo R. A. Campos.
- *Group size matters: Synergistic effects and reduced inequality in performance rankings.*
Physica A: Statistical Mechanics and its Applications, 2025.
Sandro M. Reia, Dieter Pfoser, and Paulo R. A. Campos.
- *Science of Science: A Complex Network Perspective.*
Frontiers in Research Metrics and Analytics, 2025.
Sandro M. Reia, Filipi N. Silva, and Henrique F. de Arruda.
- *Cultural heterogeneity constrains diffusion of innovations.*
EPL (Europhysics Letters), 2023.
Aruane M. Pineda, **Sandro M. Reia**, José F. Fontanari, and Francisco R. Rodrigues.
- *Long-term scientific impact revisited.*
The European Physical Journal Plus, 2022.
Sandro M. Reia and José F. Fontanari.

- *A SIR epidemic model for citation dynamics.*
The European Physical Journal Plus, 2021.
Sandro M. Reia and José F. Fontanari.
- *Wisdom of crowds: much ado about nothing.*
Journal of Statistical Mechanics: Theory and Experiment, 2021.
Sandro M. Reia and José F. Fontanari.
- *The surprising little effectiveness of cooperative algorithms in parallel problem solving.*
The European Physical Journal B, 2020.
Sandro M. Reia, Larissa F. Aquino, and José F. Fontanari.
- *Policies for allocation of information in task-oriented groups: elitism and egalitarianism outperform welfarism.*
The European Physical Journal B, 2019.
Sandro M. Reia, Paulo F. Gomes, and José F. Fontanari.
- *Individual decision making in task-oriented groups.*
The European Physical Journal B, 2019.
Sandro M. Reia, Paulo F. Gomes, and José F. Fontanari.
- *Mobility helps problem-solving systems to avoid Groupthink.*
Physical Review E, 2019.
Paulo F. Gomes, Sandro M. Reia, Francisco A. Rodrigues, and José F. Fontanari.
- *Agent-based models of collective intelligence.*
Physics of Life Reviews, 2019.
Sandro M. Reia, André C. Amado, and José F. Fontanari.
- *Impact of centrality on cooperative processes.*
Physical Review E, 2017.
Sandro M. Reia, Sebastian Herrmann, and José F. Fontanari.
- *Effect of group organization on the performance of cooperative processes.*
Ecological Complexity, 2017.
Sandro M. Reia and José F. Fontanari.

Complex Systems and Statistical Physics

- *Nonequilibrium phase transition and cultural drift in the continuous-trait Axelrod model.*
Physical Review E, 2025.
Paulo R. A. Campos, Sandro M. Reia, and José F. Fontanari.
- *Diffusion of innovations in Axelrod's model on small-world networks.*
International Journal of Modern Physics C, 2020.
Sandro M. Reia.
- *Comfort-driven mobility produces spatial fragmentation in Axelrod's model.*
Journal of Statistical Mechanics: Theory and Experiment, 2020.
Sandro M. Reia, Paulo F. Gomes, and José F. Fontanari.
- *Species differentiation in Axelrod's model.*
International Journal of Modern Physics C, 2019.
Sandro M. Reia, Gustavo D. M. Madeira, João P. Fiorelli, and Ubiraci P. C. Neves.
- *Effect of long-range interactions on the phase transition of Axelrod's model.*
Physical Review E, 2016.
Sandro M. Reia and José F. Fontanari.
- *Persistent agents in Axelrod's social dynamics model.*
EPL (Europhysics Letters), 2016.
Sandro M. Reia and Ubiraci P. C. Neves.
- *Activity of a social dynamics model.*
Physica A: Statistical Mechanics and its Applications, 2015.
Sandro M. Reia and Ubiraci P. C. Neves.

Scientific Computing and Mathematical Methods

- *Finding contrasting patterns in rhythmic properties between prose and poetry.*
Physica A: Statistical Mechanics and its Applications, 2022.
 Henrique F. de Arruda, **Sandro M. Reia**, Filipi N. Silva, Diego R. Amancio, and Luciano da F. Costa.
- *Analysis of statistical correlations between properties of adaptive walks in fitness landscapes.*
Royal Society Open Science, 2020.
Sandro M. Reia and Paulo A. C. Campos.
- *Nonsynchronous updating in the multiverse of cellular automata.*
Physical Review E, 2015.
Sandro M. Reia and Osame Kinouchi.
- *Conway's game of life is a near-critical metastable state in the multiverse of cellular automata.*
Physical Review E, 2014.
Sandro M. Reia and Osame Kinouchi.