

Matheus Rolim Sales

Postdoctoral Researcher in Physics

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Research interests

Nonlinear dynamics and chaos; Hamiltonian systems; mechanism of transport and diffusion; classical and quantum billiards; synchronization and chimera states in complex networks; adaptive dynamical networks; neuronal models.

Education

Ph.D. in Physics

Mar 2020 – Oct 2023

State University of Ponta Grossa (UEPG), Brazil

Thesis: *Dynamical aspects of Hamiltonian systems: chaos, stickiness, and recurrence plots*

Advisor: Prof. Dr. José Danilo Szezech Jr. (CAPES)

M.Sc. in Physics

Mar 2018 – Feb 2020

Federal University of Paraná (UFPR), Brazil

Dissertation: *Dinâmica dos níveis de energia do Biliar de Sinai dessimetrizado e sua relação com bilhares triangulares*

Advisor: Prof. Dr. Marcos Gomes Eleutério da Luz (CNPq)

B.Sc. in Physics

Aug 2017

Federal University of Paraná (UFPR), Brazil

Appointments

Postdoctoral Researcher

Nov 2023 – present

Department of Physics, São Paulo State University (UNESP), Rio Claro, Brazil

Supervisor: Prof. Dr. Edson Denis Leonel (FAPESP)

Research visits

Visiting Fellow

Feb 2025 – Jan 2026

School of Mathematics, Statistics and Actuarial Science, University of Essex, UK

Host: Dr. Chris G. Antonopoulos (FAPESP/BEPE)

Doctoral exchange (PDSE)

Oct 2022 – Mar 2023

Humboldt University of Berlin and Potsdam Institute for Climate Impact Research (PIK), Germany

Hosts: Dr. Serhiy Yanchuk and Prof. Dr. Jürgen Kurths (CAPES/PDSE)

Fellowships and funding

FAPESP Postdoctoral Fellowship (UNESP)

2023 – present

FAPESP Research Internship Abroad, BEPE (University of Essex)

2025 – 2026

CAPES/PDSE Doctoral Exchange (HU Berlin / PIK)

2022 – 2023

CAPES Doctoral Scholarship (UEPG)

2020 – 2023

CNPq Master's Scholarship (UFPR)

2018 – 2020

Software

[dynamicalsys](#), an open-source Python toolkit for the analysis of dynamical systems (NumPy/Numba).

Documentation: dynamicalsys.readthedocs.io.

Talks

On the dynamical and statistical properties of a quartic mean-field Hamiltonian model. I Encontro Campos Gerais de Sistemas Complexos, Ponta Grossa, PR, Brazil (2026).

Characterization of weakly chaotic dynamics using recurrence time entropy. XLV Dynamics Days Europe, Thessaloniki, Greece (2025).

Directed transport and scaling laws in a nontwist Hamiltonian mapping. Dynamics Days Latin America and the Caribbean, Buenos Aires, Argentina (2024).

Directed transport and scaling laws in the $E \times B$ drift motion. IV Encontro Nacional de Física Estatística, Curitiba, PR, Brazil (2024).

Transporte direcionado e leis de escala em um mapeamento Hamiltoniano não-twist. VI Workshop on Nonlinear Dynamics, Rio Claro, SP, Brazil (2024).

Characterizing stickiness using recurrence time entropy. V Workshop on Nonlinear Dynamics, Rio Claro, SP, Brazil (2024).

Characterizing stickiness using recurrence time entropy. XXII Conference on Non-equilibrium Statistical Mechanics and Nonlinear Physics (MEDYFINOL 2024), Caraguatatuba, SP, Brazil (2024).

Publications

Peer-reviewed articles (26), most recent first:

26. M. Mugnaine, **M. R. Sales**, E. D. Leonel, I. L. Caldas, J. D. Szezech Jr., *Role of manifolds in the transport of chaotic trajectories in the standard nontwist map*, [Phys. Rev. E 114, 014222 \(2026\)](#).
25. **M. R. Sales**, E. D. Leonel, C. G. Antonopoulos, *On the dynamical and statistical properties of a quartic mean-field Hamiltonian model*, [Chaos, Solitons & Fractals 211, 118787 \(2026\)](#).
24. **M. R. Sales**, M. Mugnaine, L. C. Souza, I. L. Caldas, E. D. Leonel, J. D. Szezech Jr., *Hierarchical fragmentation of regular islands in a discontinuous nontwist map*, [Chaos 36, 063129 \(2026\)](#).
23. D. Borin, **M. R. Sales**, E. D. Leonel, and D. F. M. de Oliveira, *On the dynamics of the q -Tsallis Gauss Iterated Map*, [Physica A 686, 131352 \(2026\)](#).
22. **M. R. Sales**, E. D. Leonel, and C. G. Antonopoulos, *On the behavior of Linear Dependence, Smaller, and Generalized Alignment Indices in discrete and continuous chaotic systems*, [Chaos, Solitons and Fractals 205, 117884 \(2026\)](#).
21. **M. R. Sales**, L. C. de Souza, D. Borin, M. Mugnaine, J. D. Szezech, R. L. Viana, I. L. Caldas, E. D. Leonel, and C. G. Antonopoulos, *ynamicalsys: A Python toolkit for the analysis of dynamical systems*, [Chaos Solitons and Fractal 201 117269 \(2025\)](#).
20. D. Borin, J. D. Szezech Jr., and **M. R. Sales**, *Characterizing and quantifying weak chaos in fractional dynamics*, [Chaos, Solitons and Fractals 200 117137 \(2025\)](#).
19. L. C. de Souza, **M. R. Sales**, J. D. Szezech Jr., R. L. Viana, I. L. Caldas, and M. S. Baptista, *Pattern formation in symplectic coupled map lattices*, [Chaos, Solitons and Fractals 200 117057 \(2025\)](#).
18. **M. R. Sales**, M. Mugnaine, A. L. R. de Moraes, E. D. Leonel, C. G. Antonopoulos, I. L. Caldas, and J. D. Szezech Jr., *Transport mechanisms associated with non-integer wavenumbers in a discontinuous nontwist map*, [Chaos, Solitons and Fractals 200, 116966 \(2025\)](#).
17. P. G. Buiar, J. D. Szezech Jr., **M. R. Sales**, and G. M. Favero, *Time to focus again on matrix metalloproteinases? Results of complex network analysis involving the pathophysiology of HER2-positive breast cancer*, [ecancer 19, 1850 \(2025\)](#).
16. V. dos Santos, **M. R. Sales**, I. L. Caldas, R. L. Viana, and J. D. Szezech Jr., *Extended networks as a route of stabilization of divergent dynamics*, [Chaos, Solitons and Fractals 193, 116115 \(2025\)](#).
15. **M. R. Sales**, M. Mugnaine, E. D. Leonel, I. L. Caldas, and J. D. Szezech Jr., *Shrinking shrimp-shaped domains and multistability in the dissipative asymmetric kicked rotor map*, [Chaos: An Interdisciplinary Journal of Nonlinear Science 34, 113129 \(2024\)](#).
14. **M. R. Sales**, D. Borin, D. R. da Costa, J. D. Szezech Jr., and E. D. Leonel, *An investigation of escape and scaling properties of a billiard system*, [Chaos: An Interdisciplinary Journal of Nonlinear Science 34, 113122 \(2024\)](#).
13. **M. R. Sales**, D. Borin, L. C. de Souza, J. D. Szezech Jr., R. L. Viana, I. L. Caldas, and E. D. Leonel, *Ratchet current and scaling properties in a nontwist mapping*, [Chaos, Solitons & Fractals 189, 115614 \(2024\)](#).

12. **M. R. Sales**, S. Yanchuk, and J. Kurths, *Recurrent chaotic clustering and slow chaos in adaptive networks*, [Chaos: An Interdisciplinary Journal of Nonlinear Science](#) **34**, 063144 (2024).
11. A. L. Azevedo, A. C. Maioli, F. Teston, **M. R. Sales**, F. M. Zanetti, and M. G. E. da Luz, *Wave amplitude gain within wedge waveguides through scattering by simple obstacles*, [Phys. Rev. E](#) **109**, 025303 (2024).
10. L. C. Souza, **M. R. Sales**, M. Mugnaine, J. D. Szezech, I. L. Caldas, and R. L. Viana, *Chaotic escape of impurities and sticky orbits in toroidal plasmas*, [Phys. Rev. E](#) **109**, 015202 (2024).
9. E. C. Gabrick, **M. R. Sales**, E. Sayari, J. Trobia, E. K. Lenzi, F. S. Borges, J. D. Szezech Jr., K. C. Iarosz, R. L. Viana, I. L. Caldas, and A. M. Batista, *Fractional dynamics and recurrence analysis in cancer model*, [Brazilian Journal of Physics](#) **53**, 145 (2023).
8. V. dos Santos, **M. R. Sales**, S. S. Muni, J. D. Szezech, A. M. Batista, S. Yanchuk, and J. Kurths, *Identification of single- and double-well coherence/coherence patterns by the binary distance matrix*, [Communications in Nonlinear Science and Numerical Simulation](#) **125**, 107390 (2023).
7. **M. R. Sales**, M. Mugnaine, J. Szezech, José D., R. L. Viana, I. L. Caldas, N. Marwan, and J. Kurths, *Stickiness and recurrence plots: An entropy-based approach*, [Chaos: An Interdisciplinary Journal of Nonlinear Science](#) **33**, 033140 (2023).
6. M. Mugnaine, **M. R. Sales**, J. D. Szezech, and R. L. Viana, *Dynamics, multistability, and crisis analysis of a sine-circle nontwist map*, [Phys. Rev. E](#) **106**, 034203 (2022).
5. D. R. da Costa, A. Fujita, **M. R. Sales**, J. D. Szezech, and A. M. Batista, *Dynamical properties for a tunable circular to polygonal billiard*, [Brazilian Journal of Physics](#) **52**, 75 (2022).
4. F. Teston, A. L. Azevedo, **M. R. Sales**, F. M. Zanetti, and M. G. E. da Luz, *The flexibility in choosing distinct Greens functions for the boundary wall method: Waveguides and billiards*, [Journal of Physics A: Mathematical and Theoretical](#) **55**, 175201 (2022).
3. **M. R. Sales**, M. Mugnaine, R. L. Viana, I. L. Caldas, and J. D. Szezech, *Unpredictability in Hamiltonian systems with a hierarchical phase space*, [Physics Letters A](#) **431**, 127991 (2022).
2. D. R. da Costa, A. Fujita, A. M. Batista, **M. R. Sales**, and J. D. Szezech Jr, *Conservative generalized bifurcation diagrams and phase space properties for oval-like billiards*, [Chaos, Solitons & Fractals](#) **155**, 111707 (2022).
1. **M. R. Sales**, A. L. Azevedo, F. Teston, M. G. E. da Luz, and F. M. Zanetti, *Soliton-like structures in the spectrum and the corresponding eigenstates morphology for the quantum desymmetrized Sinai billiard*, [Chaos: An Interdisciplinary Journal of Nonlinear Science](#) **31**, 113122 (2021).

Book chapter:

- R. L. Viana, L. C. Souza, **M. R. Sales**, M. Mugnaine, J. D. Szezech Jr., I. L. Caldas, N. Marwan, and J. Kurths, *Recurrence-Based Characterization of Stickiness in Hamiltonian Systems*. In: [Recurrence Plots and Their Quantifications: Methodological Breakthroughs and Interdisciplinary Discoveries](#). Springer Proceedings in Complexity, Springer, Cham, 2025.

References

Prof. Dr. Edson Denis Leonel (Postdoctoral supervisor)

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Prof. Dr. José Danilo Szezech Jr. (Ph.D. advisor)

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