Raphaël Sarfati

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ACADEMIC APPOINTMENTS

RESEARCH ASSOCIATE | Earls Group | Jul 2023 - present
Cornell University | Civil and Environmental Engineering Department & SciAI Center
Emergent properties of Large Language Models

POSTDOCTORAL ASSOCIATE | Peleg Lab | Apr 2019 - Jul 2023
University of Colorado Boulder | BioFrontiers Institute & Computer Science Department
Physics of animal collective behavior, including:

- social interactions, collective dynamics, and information transfer in firefly swarms
- mechanics of dense animal aggregates

POSTDOCTORAL ASSOCIATE | Schwartz Lab | Aug 2017 - Apr 2019
University of Colorado Boulder | Department of Biological and Chemical Engineering
Transport in interface-rich media, including:

- transport in fluctuating porous materials
- molecular diffusion in extreme confinement

EDUCATION

Ph.D. APPLIED PHYSICS | Yale University, New Haven, CT, USA
2013 - 2017 | Advisor: Eric R. Dufresne
Thesis: Lipid membrane-mediated interactions between bound particles

M.S. APPLIED PHYSICS | Yale University, New Haven, CT, USA
2010 - 2013 | Advisor: Eric R. Dufresne

B.S. PHYSICS | Ecole Polytechnique, Paris, France
2007 – 2010 | Major: Mesoscopic Physics & Physics of Atmosphere and Oceans

TEACHING

Teaching Assistant at Yale University
2016, 2017 | University Physics for the Life Sciences II
2012, 2013, 2014, 2015, 2016 | University Physics for the Life Sciences I
2015 | Introduction to Engineering, Innovation and Design
2014 | General Physics Lab
2013 | Modern Physical Measurements Lab

AWARDS & ACHIEVEMENTS

2022 | Two-time winner, Divide 100 ultratrail race (100mi/29,000ft vert+)
2020 | First Unsupported & Fastest Known Time, New England National Scenic Trail (~225mi/360km)
2020 | Outstanding Postdoc Nominee, University of Colorado Boulder
2017 | Yale Digital Education Innovation Grant
2015 | Yale Prize Teaching Fellow

RESPONSIBILITIES & OUTREACH

MENTORING

- Kiersten Johnson | CU Boulder undergraduate
- Julie Hayes | CU Boulder undergrad
- Srishti Rawal | CU Boulder graduate student, Computer Science Department
- Emma Rusconi Clerici | Vrije Universiteit Amsterdam & OIST graduate student
- Aubrey Kroger | CU Boulder graduate student, Computer Science Department

PEER REVIEW CONTRIBUTIONS

- Journal of Physics Communications (IOP Publishing)
- Advances in Complex Systems (World Scientific)
- Bioinspiration & Biomimetics (IOP Publishing)
- Physical Biology (IOP Publishing)
- Entomologia Experimentalis et Applicata (Wiley)
- Science Advances (AAAS, contributed)
- Journal of Insect Science (Oxford University Press)
- Communications Physics (Nature Portfolio)
- Entomologia Experimentalis et Applicata (Wiley)
- Physical Biology topical review (IOP Publishing)
- Physical Biology (IOP Publishing)
- Scientific Reports (Nature Portfolio)
- Journal of Physics: Complexity (IOP Publishing)
- SN Applied Science (Springer Nature)

GRANT CONTRIBUTIONS

- "High-throughput Automatic Monitoring Tools for Firefly Conservation" | National Geographic Society's Committee for Research and Exploration | PI: Orit Peleg | 2020 | funded
- "Center for Harnessing Energy-Water Interface Environments" | Department of Energy, Energy Frontiers Research Center | PI: Daniel Schwartz et al. | 2018 | not funded

WRITINGS

- Contours of Curiosity | Living Futures (Medium)
- Synchrony with chaos – firefly flashes embody what mathematics predicted | The Conversation
- republished notably in: Phys.org ; Popular Science ; Big Think

WEBSITES

- `lucidluminescence.org` – the science of firefly swarms
- `blinkorsync.app` – firefly synchrony app
- `fonoflies.org` – sonification of firefly collective flashing patterns

GITHUB

- `oorb` – 3D reconstruction from 360-degree cameras
- `firefl-eye-net` – database and neural nets for firefly flash classification
- `tiny-ghosts` – vision models for flash identification in trail cameras pictures

SELECTED PRESS COVERAGE

- Harper's Magazine | Bright Flight
- New York Times | How Swarms of Fireflies Sync Their Flashes
- NPR, All Things Considered | Firefly Light Shows Don't Just Dazzle. Swarms Can Also Synchronize Their Flashes
- Quanta Magazine | How Do Fireflies Flash in Sync? Studies Suggest a New Answer.
- Wired | A New Explanation for How Fireflies Flash in Sync
- EcoWatch | How Do These Fireflies Sync Their Iconic Flashes? New Research Has Answers
- Science Advances 2021 paper also discussed in leblob.fr (France), Voz Populi (Spain), To Vima (Greece), News-O-Matic (USA), and more.
- Smithsonian Magazine | How Fireflies' Dramatic Light Show Might Spark Advances in Robot Communication
- National Geographic | A rare look at fireflies that blink in unison, in a forest without tourists
- Washington Post | Firefly festivals are canceled due to coronavirus, lightning bugs might be pleased about it
- Interface 2020 paper discussed on Phys.org, Aljazeera, BBC Russia, and more.
- BPoD - Biomedical Picture of the Day (London Institute of Medical Sciences)
- Outside Science (inside parks) | National Park Service channel @naturenps | March 14, 2022

DOCUMENTARY CONSULTING

- One Planet
- National Geographic

CONFERENCES & SEMINARS

POSTER PRESENTATION □ | ORAL PRESENTATION ○ | INVITED CONTRIBUTION ★

□ ICLR | Singapore | 2025 (upcoming)
○ APS March Meeting | Anaheim, CA | 2025
★ APS March Meeting | Minneapolis, MN | 2024 (unable to attend)
○ APS March Meeting | Las Vegas, NV | 2023
★ Yale Physics and Qbio Seminar | New Haven, CT | 2023
★ Soft, Living, Active, and Adaptive Matter (SLAAM) seminar series | virtual | 2023
★ Theo-Bio Physics Podcast | virtual | 2023
★ NPS Science Interpretation Community of Practice | virtual | 2023
★ Central Colorado Humanists' Sunday Science | Salida, CO | 2022
○ Aspen Winter Conference: The Dynamics of Social Interactions | Aspen, CO | 2022
○ APS March Meeting | Chicago, IL | 2022
★ Inaugural Western Firefly Meeting | virtual | 2022
□ Conference on Computer Vision and Pattern Recognition | virtual | 2021
○ APS March Meeting | virtual | 2021
★ Great Smoky Mountains National Park Science Colloquium | virtual | 2021
○ APS March Meeting | Denver, CO | 2020 [cancelled]
□ Liquids At Interfaces International Conference | Bordeaux, France | 2018
□ 4th International Soft Matter Conference | Grenoble, France | 2016
○ ACS Colloids and Surface Science | 2012, 2014, 2016
□ GRC Colloidal, Macromolecular and Polyelectrolyte Solutions | Ventura, CA | 2016
□ Boulder Summer School: Soft Matter In and Out of Equilibrium | Boulder, CO | 2015
○ APS March Meeting | San Antonio, TX | 2015
□ OIST Dynamics at Interfaces Workshop | Okinawa, Japan | 2014
□ GRC Soft Condensed Matter Physics | New London, NH | 2013
○ New England Complex Fluid Workshop | 2012 - 2016
□ IUPAP International Conference of Biological Physics | San Diego, CA | 2011
○ Physics of Living Systems Network | San Diego, CA | 2011

PUBLICATIONS

OPEN ACCESS | OPEN REVIEW | ARXIV

[1] R. Sarfati, T. J. Liu, N. Boulle, and C. Earls, "Lines of Thought in Large Language Models," in The Thirteenth International Conference on Learning Representations, 2025.

[2] T. J. Liu, N. Boulle, R. Sarfati, and C. Earls, "Density estimation with LLMs: a geometric investigation of in-context learning trajectories," in The Thirteenth International Conference on Learning Representations, 2025.

[3] R. Sarfati, "Firefly swarms: What models for what physics?," arXiv, Nov 2024.

[4] R. Sarfati, "Tracking and triangulating firefly flashes in field recordings," arXiv, Oct 2024.

[5] T. J. Liu, N. Boulle, R. Sarfati, and C. Earls, "LLMs learn governing principles of dynamical systems, revealing an in-context neural scaling law," in Proceedings of the 2024 Conference on Empirical Methods in Natural Language Processing (Y. Al-Onaizan, M. Bansal, and Y.-N. Chen, eds.), (Miami, Florida, USA), pp. 15097–15117, Association for Computational Linguistics, Nov. 2024. Also accepted at ICML 2024 Workshop on In-Context Learning, https://openreview.net/forum?id=ANeHJIoF54.

[6] O. Martin, C. Nguyen, R. Sarfati, M. Chowdhury, M. L. Iuzzolino, D. M. T. Nguyen, R. M. Layer, and O. Peleg, "Embracing firefly flash pattern variability with data-driven species classification," Scientific Reports, vol. 14, p. 3432, Feb 2024.

[7] R. Sarfati and et al., "Crowdsourced dataset of firefly trajectories obtained by automated stereo calibration of 360-degree cameras," Dryad Dataset, Jun 2023.

[8] R. Sarfati*, K. Joshi*, O. Martin*, J. C. Hayes, S. Iyer-Biswas, and O. Peleg, "Emergent periodicity in the collective synchronous flashing of fireflies," eLife, vol. 12, p. e78908, Mar 2023.

[9] R. Sarfati, J. Hayes, and O. Peleg, "Three-dimensional time-resolved flash occurrences of swarming Photinus carolinus fireflies in their natural habitat," Dryad Dataset, Jan 2023.

[10] R. Sarfati and O. Peleg, "Chimera States among Synchronous Fireflies," Science Advances, vol. 8, p. eadd6690, Sep 2022.

[11] R. Sarfati and O. Peleg, "Video recording of the collective display of Photuris frontalis fireflies," Dryad Dataset, Oct 2022.

[12] O. Vilk, E. Aghion, T. Avgar, C. Beta, O. Nagel, A. Sabri, R. Sarfati, D. K. Schwartz, M. Weiss, D. Krapf, R. Nathan, R. Metzler, and M. Assaf, "Unravelling the origins of anomalous diffusion: From molecules to migrating storks," Phys. Rev. Research, vol. 4, p. 033055, Jul 2022.

[13] R. Sarfati, L. Gaudette, J. Cicero, and O. Peleg, "Statistical analysis reveals the onset of synchrony in sparse swarms of Photinus knulli fireflies," J. R. Soc. Interface, vol. 19, Mar 2022.

[14] R. Sarfati, J. Hayes, and O. Peleg, "Self-organization in natural swarms of Photinus carolinus synchronous fireflies," Science Advances, vol. 7, Jul 2021. [cover to the July 2021 issue].

[15] R. Sarfati, C. Calderon, and D. Schwartz, "Enhanced Diffusive Transport in Fluctuating Porous Media," ACS Nano, vol. 15, p. 7392–7398, Apr 2021.

[16] R. Sarfati, J. Hayes, E. Sarfati, and O. Peleg, "Spatiotemporal reconstruction of emergent flash synchronization in firefly swarms via stereoscopic 360-degree cameras," J. R. Soc. Interface, vol. 17, Sep 2020. [cover to the October 2020 issue].

[17] H. Wu, R. Sarfati, D. Wang, and D. K. Schwartz, "Electrostatic Barriers to Nanoparticle Accessibility of a Porous Matrix," Journal of the American Chemical Society, vol. 142, pp. 4696–4704, Mar 2020.

[18] M. de Marcken and R. Sarfati, "Hydrodynamics of a dense herd of sheep," arXiv, Feb 2020.

[19] R. Sarfati and D. K. Schwartz, "Temporally Anticorrelated Subdiffusion in Water Nanofilms on Silica Suggests Near-Surface Viscoelasticity," ACS Nano, Jan 2020.

[20] G. Kaufman, W. Liu, D. M. Williams, Y. Choo, M. Gopinadhan, N. Samudrala, R. Sarfati, E. C. Y. Yan, L. Regan, and C. O. Osuji, "Flat Drops, Elastic Sheets, and Microcapsules by Interfacial Assembly of a Bacterial Biofilm Protein, BslA," Langmuir, vol. 33, pp. 13590–13597, Nov 2017.

[21] Q. Xu, K. E. Jensen, R. Boltyanskiy, R. Sarfati, R. W. Style, and E. R. Dufresne, "Direct measurement of strain-dependent solid surface stress," Nature Communications, vol. 8, no. 1, p. 555, 2017.

[22] R. Sarfati, J. Bławzdziewicz, and E. R. Dufresne, "Maximum likelihood estimations of force and mobility from single short Brownian trajectories," Soft Matter, vol. 13, pp. 2174–2180, 2017.

[23] N. Samudrala, J. Nam, R. Sarfati, R. W. Style, and E. R. Dufresne, "Mechanical stability of particle-stabilized droplets under micropipette aspiration," Phys. Rev. E, vol. 95, p. 012805, Jan 2017.

[24] R. Sarfati and E. R. Dufresne, "Long-range attraction of particles adhered to lipid vesicles," Phys. Rev. E, vol. 94, p. 012604, Jul 2016. [also reproduced in: Current Opinion in Colloid & Interface Science, 40, 58-69 (2019) & Computational Nanotoxicology: Challenges and Perspectives, Chapter 5 (2019)].

[25] K. E. Jensen, R. Sarfati, R. W. Style, R. Boltyanskiy, A. Chakrabarti, M. K. Chaudhury, and E. R. Dufresne, "Wetting and phase separation in soft adhesion," Proceedings of the National Academy of Sciences, vol. 112, no. 47, pp. 14490–14494, 2015.

[26] G. Kaufman, S. Nejati, R. Sarfati, R. Boltyanskiy, M. Loewenberg, E. R. Dufresne, and C. O. Osuji, "Soft microcapsules with highly plastic shells formed by interfacial polyelectrolyte–nanoparticle complexation," Soft Matter, vol. 11, pp. 7478–7482, 2015.