Alexandre Champagne-Ruel

NASA Postdoctoral Program Fellow

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Origins of Life • Astrobiology • Complex Systems

RESEARCH PROFILE

NASA Postdoctoral Fellow and Physicist investigating the physical principles underlying the origin of life. My research integrates statistical mechanics, information theory, and evolutionary dynamics to understand how spatial environments drive the emergence of complexity. Currently developing quantitative frameworks for agnostic life detection and biosignature assessment.

ACADEMIC POSITIONS

NASA Postdoctoral Program Fellow — **Current**
Arizona State University, Mathis Group — *Tempe, AZ*

EDUCATION

Ph.D. Physics — **2025**
Université de Montréal — *Montréal, QC*

- Thesis: *Spatiality in Prebiotic Evolution: Toward a Physics of the Emergence of Complexity*
- Advisor: Paul Charbonneau

M.Sc. Physics — **2020**
Université de Montréal — *Montréal, QC*

- Thesis: *From Game Theory to Exobiology: The Emergence of Cooperation as a Critical Phenomenon*
- Advisor: Paul Charbonneau

B.Sc. Physics — **2018**
Université de Montréal — *Montréal, QC*

B.Sc. Philosophy — **2012**
Université de Montréal — *Montréal, QC*

GRANTS & AWARDS

NASA Postdoctoral Fellowship	146,496 USD	**2025**
Project: Mapping Molecular Complexity for Agnostic Life Detection		
J. Armand Bombardier Scholarship	10,000 CAD	**2024**
Globalink Research Award (Mitacs Canada)	6,000 CAD	**2024**
J. Armand Bombardier Scholarship	10,000 CAD	**2023**
J. Armand Bombardier Scholarship	10,000 CAD	**2022**
Doctoral Scholarship (FRQNT)	70,000 CAD	**2022**
Excellence Award (UdeM)	10,000 CAD	**2018**
Various Travel & Research Grants (15 awards)	∼30,000 CAD	**2011 – 2025**

PUBLICATIONS & PRESENTATIONS

Articles under Review

A. **Champagne-Ruel** and C. Mathis, "Spatial Patterning and Selection: How the Environment Shapes Molecular Complexity", 10.48550/arXiv.2509.04547 (2025), (Submitted to PNAS Nexus).

OoLEN, S. Asche, C. Bautista, D. Boulesteix, A. **Champagne-Ruel**, C. Mathis, et al., "What it takes to solve the Origin(s) of Life: An integrated review of techniques", 10.48550/arXiv.2308.11665 (2023), (Submitted to Cell Reports Physical Science).

Published Articles

A. **Champagne-Ruel**, S. Zakaib-Bernier, and P. Charbonneau, "Diffusion and pattern formation in spatial games", Physical Review E **110**, 014301 (2024).

A. **Champagne-Ruel** and P. Charbonneau, "A Mutation Threshold for Cooperative Takeover", Life **12**, 254 (2022).

S. Gelin, A. **Champagne-Ruel**, and N. Mousseau, "Enthalpy-entropy compensation of atomic diffusion originates from softening of low frequency phonons", Nature Communications **11**, 3977 (2020).

Invited Talks

A. **Champagne-Ruel**, "Physics of Complexity And Agnostic Life Detection", Trottier Institute for Research on Exoplanets (Canada), 2025.

A. **Champagne-Ruel**, "Spatial Patterning and Selection: How the Environment Shapes Molecular Complexity", Max Planck Institute for Terrestrial Microbiology (Germany), 2025.

A. **Champagne-Ruel**, "From Emergent Complexity to Reliable Life Detection", Arizona State University, 2024.

A. **Champagne-Ruel**, "Coopération, émergence et transitions : comment la physique statistique peut nous éclairer sur la question des origines", Qu'est-ce qu'expliquer une origine en science ? (CIRST, UQAM), 2022.

Contributed Talks

A. **Champagne-Ruel** and C. Mathis, "From Emergent Complexity to Reliable Life Detection", BEACON (Iceland), 2025.

A. **Champagne-Ruel**, "Diffusion: an Overlooked Driver of Prebiotic Complexity", AbSciCon (Providence), 2024.

A. **Champagne-Ruel**, "Théorie de l'information et origine de la vie", 90e Congrès de l'ACFAS, 2023.

A. **Champagne-Ruel**, "A Mutation Threshold for Cooperative Takeover", AbSciCon (Atlanta), 2022.

A. **Champagne-Ruel**, "Cooperation: an emergent universal feature at the dawn of life", Interdisciplinary Origin of Life Meeting for Early Career Researchers (Montréal), 2022.

A. **Champagne-Ruel**, "Mutation favors the emergence of cooperation", Life and Space Poland, 2021.

A. **Champagne-Ruel**, "La criticalité dans un système évolutif artificiel", Centre de recherche en astrophysique du Québec (CRAQ) - Rencontre annuelle, 2019.

Posters

A. **Champagne-Ruel**, C. P. Kempes, and C. Mathis, "Mapping molecular complexity for agnostic life detection", NASA Postdoctoral Program Virtual Symposium, 2025.

A. **Champagne-Ruel**, A. Demers-Bergeron, and P. Charbonneau, "L'émergence de la coopération via l'évolution de réseaux informationnels", 90e Congrès de l'ACFAS, 2023.

A. **Champagne-Ruel**, S. Zakaib-Bernier, and P. Charbonneau, “Diffusion, structures spatiales et origine de la vie”, 90e Congrès de l’ACFAS, 2023.

S. Asche, A. **Champagne-Ruel**, S. F. Jordan, M. Preiner, A. d. N. Vieira, J. C. Xavier, et al., “OoLEN - The Origin of Life Early-career Network: Building the community needed to solve the problem”, AbSciCon Atlanta, 2022.

A. **Champagne-Ruel**, “A Mutation Threshold for Cooperative Takeover”, Gordon Research Conference: Environments for the Origins of Life and Habitability (Oxnard), 2022.

A. **Champagne-Ruel**, “A Mutation Threshold for Cooperative Takeover”, Gordon Research Seminar: Challenging Paradigms in Prebiotic Chemistry (Oxnard), 2022.

A. **Champagne-Ruel** and P. Charbonneau, “Les mutations favorisent la coopération en contexte évolutif”, Centenaire, Département de Physique, Université de Montréal, 2021.

A. **Champagne-Ruel** and P. Charbonneau, “Mutation favors the emergence of cooperative behavior”, Molecular Origins of Life Munich, 2021.

A. **Champagne-Ruel** and P. Charbonneau, “Mutations promote cooperation in an evolutionary setting”, XIXth ISSOL Conference, 2021.

A. **Champagne-Ruel** and P. Charbonneau, “Self-organized criticality : a prelude to avalanche models of solar flares”, Space Climate 7 Symposium, 2019.

Media & Public Engagement

É. Beaudoin-Paul, “Entrevue avec Alexandre Champagne-Ruel, récipiendaire de la prestigieuse bourse en astrobiologie de la NASA”, Quartier Libre (2025).

A. Riopel, “Comment reconnaître la vie sur d’autres planètes”, Le Devoir (2023).

C. Tamura, “Cooperation and the Origin of Life”, Quantum Photonics Clubhouse Podcast (2022).

SCHOOLS & SELECTIVE WORKSHOPS

Assembly Theory for Folded Matter — **2025**
Santa Fe Institute — *Santa Fe, NM*

Information Driven States of Matter — **2024**
University of Rochester — *Rochester, NY*

TEACHING EXPERIENCE

Mentor – Biocomputing Scholars program — **2025 – 2026**
Arizona State University — *Tempe, AZ*

- Guiding 3 undergraduate students in developing computational chemistry simulations.

Undergraduate Internship Supervision — **2022**
Université de Montréal — *Montréal, QC*

- Supervised a summer research project on diffusion; resulted in journal publication and poster presentation.

Teaching Assistant – Introduction to Astrobiology — **2021 – 2022**
Université de Montréal — *Montréal, QC*

Tutoring – Undergraduate Level — **2018 – 2022**
Université de Montréal — *Montréal, QC*

SERVICE & OUTREACH

Scientific Leadership

Positions

Member of the Executive Board **2022 – Present**
Origin of Life Early-career Network (OoLEN)

Origin of Life Digest (link) **2021 – Present**
Editor

Conference Organization

- **Interdisciplinary Origin of Life Meeting (Japan, 2026)** (Organizing Committee)
- **Frontiers in Astrobiology and Origins of Life Conference (Iceland, 2025)** (Organizing Committee)
- **Origine de la vie : de l'astrophysique à la philosophie (Canada, 2023)** (Lead Organizer)
- **Interdisciplinary Origin of Life Meeting for Early Career Researchers (Canada, 2022)** (Lead Organizer)
- **Space Climate 7 (Canada, 2019)** (Local Organizing Committee)

Session Convener

- **AbSciCon (Madison, 2026)**: *Assembly Theory Across Scales: From Molecules to Planetary Systems*
- **AbSciCon (Madison, 2026)**: *Exploring Self-Assembly and Self-Organization in Prebiotic Complexity*

Reviewing Activities

- Royal Society Open Science

Memberships

- International Society for Artificial Life
- Center for Research in Astrophysics of Québec
- Canadian Association of Physicists
- Canadian Astronomical Society
- Origin of Life Early-career Network
- International Society for the Study of the Origin of Life
- Complex Systems Society
- Scientific Society for Astrobiology (Founding Member)

SKILLS

Languages: Fluent in Spoken/Written French, English

Programming: Python, C++, Fortran, Julia, R, LaTeX, MatLab, Assembly, Bash

Modeling: Agent-based, Evolutionary Algorithms, Machine Learning, Network Theory, Game Theory

Development Workflow: Linux, High Performance Computing (HPC)/SLURM, Git, Jekyll, Hugo, HTML5/CSS3