Dr Rahil N Valani

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RESEARCH INTERESTS

Active matter, Fluid mechanics, Dynamical systems, Chaos, Inertial microfluidics, Mechanobiology, Microswimmer motion, Synchronization, Time delay systems

RESEARCH SUMMARY

My research lies at the intersection of active matter, fluid mechanics, and nonlinear dynamical systems. I develop theoretical and computational models to understand how nonequilibrium interactions give rise to emergent structure and dynamics in physical and biological systems, with a particular focus on active nematics, mechanobiological flows, and active particles with memory such as walking droplets. My work combines tools from dynamical systems theory, hydrodynamics, and applied mathematics to uncover collective behaviour, instabilities, and chaos across scales.

PROFESSIONAL RESEARCH EXPERIENCE

- **Leverhulme-Peierls Fellow** — *Apr 2024 to date*
  Rudolf Peierls Centre for Theoretical Physics, University of Oxford — United Kingdom
- **ARC Grant Funded Postdoctoral Researcher** — *Feb 2021 to Apr 2024*
  School of Computer and Mathematical Sciences, The University of Adelaide — Australia
- **Research Assistant** — *Jun 2015 to Feb 2017*
  School of Mathematical Sciences, Monash University — Australia

EDUCATION

- **Doctor of Philosophy** — *2017 - 2020*
  School of Physics and Astronomy, Monash University — Melbourne, Australia
  - Thesis title: Superwalking Droplets and Generalised Pilot-Wave Dynamics
  - Supervisors: Assoc. Prof. Anja Slim, Assoc. Prof. Tapio Simula, Prof. Kristian Helmerson
- **Dual Degree: Bachelor of Aerospace Engineering (Honours) and Bachelor of Science** — *2012 - 2016*
  Monash University — Melbourne, Australia
  - Majors: Mathematics, Physics, Aerospace Engineering
  - GPA/WAM=3.861/86.879
  - Graduated with **first-class honours** and received **Dean's List for Outstanding Academic Achievement** for 4 consecutive years, awarded to students achieving an average of 85% or above in that year

AWARDS & PRIZES

- **2024 Edward N. Lorenz Early Career Award** — *2025*
  Awarded by the American Institute of Physics (AIP) journal Chaos to recognize outstanding research in nonlinear science.
- **QJMAM Travel Fund** — *2025*
  Awarded £1500 to attend the Applied Mathematics MATRIX workshop in Creswick, Australia
- **The CASS Foundation Travel Award** — *2023*
  Awarded $3000 (AUD) to present at SIAMDS23 conference in Portland, USA
- **Mathematics Outreach Award** — *2022, 2023*
  Awarded for my Maths Outreach poster and Maths Art at the CARMA-Matrix Maths Art/Poster Competition, Australia
- **Best Presentation Award** — *2022*
  Awarded at the Nonlinear Science & Complexity 2022 conference (online)
- **Research Communication Award** — *2022*
  Awarded for my poster presentation at the Australasian Fluid Mechanics Society Retreat, University of Melbourne
- **T.M. Cherry Prize** — *2021*
  Jointly awarded for best student presentation at the 2021 ANZIAM conference
- **Robert Street Doctoral Prize** — *2021*
  Jointly awarded for the best PhD thesis in 2020 by the School of Physics and Astronomy at Monash University
- **2020 Norris Family Award for Outstanding Research Output** — *2020*
  Awarded by the Faculty of Science, Monash University for my PhD paper on Superwalking droplets
- **Postgraduate Publication Award** — *2020*
  Awarded by the Faculty of Science, Monash University - awarded $5000 (AUD) for preparation and publication of PhD research
- **Best Student Presentation Award** — *2018*
  Awarded at the 8th Meeting on Hydrodynamics Quantum Analogs, Brown University, Rhodes Island, USA
- **J L William Postgraduate Top Up Scholarship** — *2017*
  $5000 (AUD) per year, awarded to high achieving PhD students
- **Best in School Award** — *2016*
  Awarded by School of Physics at Monash University for achieving highest score in 3rd year Physics undergraduate subjects
- **Australian Mathematical Science Institute (AMSI) Summer Research Scholarship** — *2015*
  Awarded $500 (AUD) per week for 6 weeks to undertake an undergraduate summer research project in Mathematics

GRANTS & FUNDING

- **Leverhulme-Peierls Fellowship** *2024-2027*
  Awarded prestigious three-year Fellowship to pursue independent research at the Rudolf Peierls Centre for Theoretical Physics.
- **[Declined] Australian Research Council Discovery Early Career Research Award (DECRA)** *2025-2028*
  Awarded $465,331 AUD by the Australian Research Council. Project title: Attractor-driven matter (DP250100435).
- **Partner Investigator on Australian Research Council Discovery Project (DP)** *2024-2027*
  Awarded $454,573 AUD. Project title: Mathematics to underpin and drive novel inertial microfluidic technologies (DP240101089).

PUBLICATIONS

P=PUBLISHED, U=UNDER REVIEW, I= IN PREPARATION, *=TOP 7

[P.1] **R. Valani** and D. M. Paganin, Active wave-particle clusters, *Physical Review E*, **112**, 065103 (2025).

[P.2] D. Müller-Bender and **R. Valani**, Laminar chaos in systems with random and chaotically time-varying delay, *Physical Review E*, **112**, 064203 (2025).

[P.3] D. Jaganathan and **R. Valani**, Markovian embedding of nonlocal equations using spectral representation, *Communications in Nonlinear Science and Numerical Simulation*, 109540 (2025).

[P.4] B. Harding, **R. Valani** and Y. M. Stokes, Hamiltonian formulation for the motion of an active spheroidal particle suspended in laminar straight duct flow, *Physical Review E*, **112**, 054125 (2025).

[P.5] J. Kabarowski, A. S. Khair and **R. Valani**, Hydrodynamic memory and Quincke rotation, *Physical Review Fluids*, **10**, 093701 (2025).

[P.6] I. Hadjifrangiskou, S. P. Thampi and **R. Valani**, Nematic order from phase synchronization of shape oscillations, *Physical Review Letters*, **135**, 068101 (2025). Student supervision

[P.7] A. G. López and **R. Valani**, Driven transitions between megastable quantized orbits, *Chaos, Solitons & Fractals*, **198**, 116549 (2025).

[P.8] R. Xu and **R. Valani**, Tunneling in a Lorenz-like model for an active wave-particle entity, *Physical Review E*, **111**, 034218 (2025). Student supervision

[P.9] A. G. López and **R. Valani**, Megastable quantization in generalized pilot-wave hydrodynamics, *Physical Review E (Letter)*, **111**, L022201 (2025).

[P.10] **R. Valani** and B. Dandogbessi, Asymmetric limit cycles within Lorenz chaos induce anomalous mobility for a memory-driven active particle, *Physical Review E (Letter)*, **110**, L052203 (2024).

[P.11] **R. Valani**, B. Harding and Y. M. Stokes, Active particle motion in Poiseuille flow through rectangular channels, *Physical Review E*, **110**, 034603 (2024).

[P.12] **R. Valani**, B. Harding and Y. M. Stokes, Inertial particle focusing in fluid flow through spiral ducts: dynamics, tipping phenomena and particle separation, *Journal of Fluid Mechanics*, **990**, A13 (2024).

[P.13] **R. Valani** and A. G. López, Quantum-like behavior of an active particle in a double-well potential, *Chaos, Solitons & Fractals*, **186**, 115253 (2024).

[P.14] B. Harding, Y. M. Stokes and **R. Valani**, Inertial focusing dynamics of spherical particles in curved microfluidic ducts with a trapezoidal cross-section, *SIADS*, **23**, 1805–1835 (2024).

[P.15] **R. Valani**, B. Harding and Y. M. Stokes, Bifurcations in inertial focusing of a particle suspended in flow through curved rectangular ducts, in *Perspectives in Dynamical Systems II — Numerical and Analytical Approaches*, Springer Proceedings in Mathematics & Statistics, vol. 454. Springer, Cham. (2024).

[P.16] A. G. López and **R. Valani**, Unpredictable tunneling in a retarded bistable potential, *Chaos*, **34**, 043117 (2024).

[P.17] **R. Valani**, Infinite-memory classical wave-particle entities, attractor-driven active particles and the diffusionless Lorenz equations, *Chaos*, **34**, 013133 (2024).
This paper was awarded Edward Lorenz Early Career Award 2024. Solo publication.

[P.18] J. Perks and **R. Valani**, Dynamics, interference effects and multistability in a Lorenz-like system of a classical wave-particle entity in a periodic potential, *Chaos*, **33**, 033147 (2023). Student supervision

[P.19] **R. Valani** and D. M. Paganin, Attractor-driven matter, *Chaos*, **33**, 023125 (2023).

[P.20] D. Müller-Bender, **R. Valani** and G. Radons, Pseudo-laminar chaos from on-off intermittency, *Physical Review E*, **107**, 014208 (2023).

[P.21] **R. Valani**, B. Harding and Y. M. Stokes, Utilizing bifurcations to separate particles in spiral inertial microfluidics, *Physics of Fluids (Letter)*, **35**, 011703 (2023).

[P.22] **R. Valani**, B. Harding and Y. M. Stokes, Bifurcations and dynamics in inertial focusing of particles in curved rectangular ducts, *SIADS*, **21**, 2371–2392 (2022).

[P.23] **R. Valani**, Lorenz-like systems emerging from an integro-differential trajectory equation of a one-dimensional wave-particle entity, *Chaos*, **32**, 023129 (2022). Solo publication

[P.24] **R. Valani**, Anomalous transport of a classical wave-particle entity in a tilted potential, *Physical Review E (Letter)*, **105**, L012101 (2022). Solo publication

[P.25] **R. Valani**, D. M. Paganin, A. C. Slim, T. Simula and T. Vo, Unsteady dynamics of a classical particle-wave entity, *Physical Review E*, **104**, 015106 (2021).

[P.26] **R. Valani**, A. C. Slim and T. Simula, Stop-and-go locomotion of superwalking droplets, *Physical Review E*, **103**, 043102 (2021).

[P.27] **R. Valani**, J. Dring, A. C. Slim and T. Simula, Emergence of superwalking droplets, *Journal of Fluid Mechanics*, **906**, A3 (2021).

[P.28] **R. Valani**, A. C. Slim and T. Simula, Superwalking droplets, *Physical Review Letters*, **123**, 024503 (2019). High impact publication

[P.29] **R. Valani** and A. C. Slim, Pilot-wave dynamics of two identical, in-phase bouncing droplets, *Chaos*, **28**(9), 096114 (2018) – Editor's pick.

[P.30] **R. Valani**, A. C. Slim and T. Simula, Hong-Ou-Mandel-like two-droplet correlations, *Chaos*, **28**(9), 096104 (2018).

[P.31] **R. Valani**, A. J. Groszek and T. Simula, Einstein–Bose condensation of Onsager vortices, *New Journal of Physics*, **20**, 053038 (2018).

[U.1] **R. Valani**, S. Thampi and J. Yeomans, From Equilibrium Multistability to Spatiotemporal Chaos in Channel Flows of Nematic Fluids, arXiv:2511.14747.

[U.2] R. Sekhri, **R. Valani** and T. Simula, Intermittent Motility of a Synthetic Active Particle in Changing Environments, arXiv:2512.16135.

[U.3] **R. Valani**, Emergence of Friedel-like oscillations from Lorenz dynamics in walking droplets, arXiv:2512.21049.

[I.1] M. Stower, F. Zhou, **R. Valani**, J. Rozman, H. Hathrell, J. Godwin, X. Lu, J. Rittscher, J. Yeomans, and S. Srinivas. *Quantitative multi-scale morphodynamic analysis reveals ratchetlike collective DVE migration and epiblast retrograde cell flow during anterior patterning in the mouse embryo*. Experimental collaboration

[I.2] T. Mukherjee, **R. Valani**, S. Banerjee. *Active Soft-Impact Oscillator: Dynamics of a Walking Droplet in a Non-Smooth Potential*.

SELECTED TALKS & SEMINARS

- **4th London workshop on Active Matter**, Imperial College London, UK, Jan 2026
- **Euromech Colloquium on Recent Advances in Non-Smooth Dynamics**, University of Exeter, UK, Dec 2025
- **Slender and Active conference, Institute of Physics**, University of Edinburgh, UK, Dec 2025
- **3rd London workshop on Active Matter**, Kings College London, UK, Nov 2025
- **Oxford-Japan Symposium on Cell Behaviors**, Mathematical Institute, University of Oxford, UK, Sep 2025
- **Melbourne Mathematical Biology Seminar [Invited]** , University of Melbourne, Australia, Jul 2025
- **MATRIX workshop on slow viscous flows with interfaces [Invited]** , Creswick, Australia, Jul 2025
- **NODYCON 2025** , Online, Jul 2025
- **Mathematical Biology and Ecology Seminar Series [Invited]** , Mathematical Institute, Oxford, UK, Jun 2025
- **SIAMDS25**, Denver, USA, May 2025
- **2nd London Workshop on Active Matter**, London, UK, Apr 2025
- **IOP Physics of Life**, Harrogate, UK, Mar 2025
- **APS Global Physics Summit**, Anaheim, USA, Mar 2025
- **Mathematical Modelling for Biology, Health, and Environment Seminar Series [Invited]**, Queens Mary University of London, UK, Feb 2025
- **Nonlinear dynamics in Electronic Systems (NDES) 2024**, Graechen, Switzerland, Sep 2024
- **Metastability & Tipping conference 2024**, Leicester, UK, Sep 2024
- **Nonlinear Science & Complexity (NSC) conference 2024**, Online, Aug 2024
- **EUROMECH Colloquium on Nonlinear Dynamics at Zero Reynolds Number**, Imperial College London, UK, May 2024
- **ANZIAM 2024**, Adelaide Hills, Australia, Feb 2024
- **Physics of Fluid Cassyni Seminar Series [Invited]**, Online, Jul 2023
- **SIAMDS23**, Portland, USA, May 2023
- **ANZIAM 2023**, Cairns, Australia, Feb 2023
- **75th Annual Meeting of the APS's Division of Fluid Dynamics**, Indianapolis, USA, Nov 2022

- **Statistics and Mathematical Modelling in Combination Conference** , Melbourne, Australia, Nov 2022
- **SA ANZIAM Meeting 2022** , Adelaide, Australia, Nov 2022
- **Nonlinear Science & Complexity (NSC) conference** (Best presentation award in symposium), Online, Sep 2022
- **Australasian Fluid Mechanics Society (AFMS) Retreat** , University of Melbourne, Melbourne, Australia, Jul 2022

- **8th Statistical Mechanics of Soft Matter Conference** , Monash University, Melbourne, Australia, Jul 2022
- **Australasian Fluid Mechanics Society Conversations in Fluids Seminar Series [Invited]** , Online, May 2022
- **ANZIAM 2022** , Online, Feb 2022
- **16th International Conference on Dynamical Systems Theory and Applications** , Online, Dec 2021
- **ANZIAM 2021** , Online, Feb 2021
- **Statistical Mechanics of Soft Matter Meeting** , Online, Dec 2020
- **73rd Annual Meeting of the APS's Division of Fluid Dynamics** , Online, Nov 2020
- **Statistical Mechanics of Soft Matter Meeting** , University of Adelaide, Adelaide, Australia, Dec 2019
- **Australian Institute of Physics Summer Meeting** , RMIT, Melbourne, Australia, Dec 2019
- **72nd Annual Meeting of the APS's Division of Fluid Dynamics** , Seattle, USA, Nov 2019
- **Fluids Seminar Series [Invited]** ,Monash University, Melbourne, Australia, May 2019
- **8th Meeting on Hydrodynamic Quantum Analogs** ,Brown University, USA, Jul 2018

TEACHING EXPERIENCE

- **Tutoring for B1 Fluids (third-year course)** *2025-2026*
  St Hilda College, Queen's College, University of Oxford, UK
- **Course coordinator at the University of Adelaide, Australia** *2023*
  Developed and delivered a Masters/Honours level course on chaotic dynamical systems with applications.
- **Lecturing and tutoring at Monash College, Melbourne, Australia** *2019-2020*
  Physics and Engineering lecturing and tutoring for foundational year students entering university.
- **Teacing Assistant at Monash University, Melbourne, Australia** *2017-2020*
  Tutoring across Mathematics, Engineering and Physics for second and third year undergraduate courses.

SUPERVISION

- **Oliver Preest** , Summer research undergraduate student, University of Oxford, 2024-2025
- **Simranjeet Dahia** , Summer research undergraduate student, University of Adelaide, 2023-2024
- **Runze Xu** , Summer research undergraduate student, University of Adelaide, 2023-2024
- **Joshua Perks** , Summer research undergraduate student, University of Adelaide, 2021-2023
- **James Day** , Summer research undergraduate student, University of Adelaide, 2020-2021
- **Jack Dring** , Summer research undergraduate student, Monash University, 2019

OUTREACH

- **Oxford Physics Society talk -** Delivered a general Physics talk on Nonlinear dynamics of active matter along with an interactive experiment to undergraduate Physics students at the University of Oxford - Oct 2025
- **Biophysics impact day -** Interactive activity showing active matter with superwalking droplets and Boids flocking algorithm for Grade 10 students during Biophysics impact day 2025 at the University of Oxford - Jun 2025
- **Saturday morning of theoretical physics talk -** Delivered a general Physics talk on to Alumni of the Physics department at the University of Oxford - Apr 2025
- **Mathscraft Workshops -** Assisted as a Mathematician at the workshop to provide school maths teachers an experience of doing maths like a research mathematician in Adelaide, Australia - Nov 2021
- **Gallery of fluid motion posters & videos -** I created videos and posters about my research that are accessible to the general public and visually aesthetic.
- **Youtube outreach video** I was interviewed by Dr. Tom Crawford (University of Oxford) for my PhD work on superwalking droplets. The video is uploaded on his Maths outreach channel 'Tom Rocks Maths'.