P.G. Ledda

Researcher in fluid mechanics

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In short I am interested in any problem that involves **fluid mechanics**, trying to apply the elegance of mathematics in capturing the essence of complex physical phenomena. My research activity spans from small to large scales, although mostly focused on small scales, and combines **theoretical** approaches, **numerical** simulations, and **experiments**. My goal is to understand the **underlying physical mechanisms** and the key parameters governing fluid flows to formulate general laws capable of describing their behavior. These results can be applied to the prediction, interpretation, and optimization of fluid dynamics phenomena of both engineering and environmental relevance.

Research Activities and Interests **Flows around and through porous bodies**. Numerical and theoretical studies with applications in flow control, optimization of filtration processes, and seed dispersion. Derivation of homogenized models for transport across thin membranes, stability analysis of flow-porous interactions, study of falling objects. T**hin fluid films and capillary flows**. Theoretical, experimental and numerical work on capillary flows, film instabilities and gravity currents. I enjoy deriving closed-form solutions for draining flows. Applications include geophysical flows and chemical engineering. **Biofluid mechanics**. flows generated during or after surgical procedures in cardiovascular and ophthalmic contexts, in collaboration with medical doctors, using both numerical and experimental approaches. **Low-Reynolds-number fluid–structure interactions**: study of bio-inspired flexible valves (passive flow selector via buckling and a snapping-instability based valve), combining analytical solutions with numerical simulations and experiments. I enjoy deriving analytical solutions capturing the essential physics. **High-Reynolds-number fluid mechanics**: heat transfer and dispersion in indoor environments, atmospheric flows around canopies; numerical simulations exploit OpenFOAM while laboratory experiments employ Particle Image Velocimetry (PIV).

Education

08/2018 – 06/2022: PhD in Mechanics, EPFL (Switzerland). Thesis: "From coating flow patterns to porous body wake dynamics via multiscale models". Supervisor: Prof. F. Gallaire.

09/2015 – 05/2018: MSc in Aerospace Engineering (Aeronautical Engineering curriculum), University of Pisa (Italy). Thesis supervisors: F. Gallaire, S. Camarri, L. Siconolfi

09/2012 – 09/2015: BSc in Aerospace Engineering, University of Pisa (Italy).

Experience

01/03/2023 – present: Assistant Professor (RTDA), University of Cagliari (Italy).
22/09/2022 – 15/01/2023: Collaborator, University of Cagliari (Italy).
01/08/2018 – 30/06/2022: Doctoral Assistant, LFMI, EPFL (Switzerland).
13/09/2017 – 28/03/2018: Exchange Student for Master thesis, EPFL (Switzerland).

Research collaborations

Prof. Alice Marcotte (Sorbonne Université) &– bubble blockage in capillaries, thin films.
Dr. L. Keiser (Université Côte d'Azur), bubble blockage in capillaries, surface tension
Prof. G.Querzoli (University of Cagliari) – project *eINS*, flow between photovoltaic panels (PIV experiments, simulations).
Prof. G.Querzoli (University of Cagliari) & M.D. T. Rossi (Fondazione Bietti) – ophthalmic surgery flows.
Prof. G.Querzoli (University of Cagliari) & M.D. G. Matta (AOU Brotzu) – cardiovascular flows.
Prof. G. Querzoli (University of Cagliari) & Prof. P. Monti (La Sapienza) – project *BRIC-INAIL*, indoor flows and dispersion.
Prof. A. De Simone (Sant'Anna Pisa) – project *I-Seed* (H2020), fluid–structure interaction in free-falling bodies.
Prof. M. Pezzulla (Aarhus University) – project *Villum Foundation*, FSI.
Dr. G.A. Zampogna (EPFL) – project *SNSF PZ00P2_193180*, flow through permeable membranes.
Prof. F. Gallaire (EPFL) & Prof. P.-T. Brun (Princeton) – surface tension & thin-film flows.
Prof. F. Gallaire (EPFL), Prof. B. Scheid (ULB), Prof. M. Wyart (EPFL) – thin films & karst formations.
Prof. F. Gallaire & Prof. F. Sorin (EPFL) – dewetting and contact-line instabilities.
Prof. F. Gallaire (EPFL) & Prof. Stefano Camarri (Univ. Pisa) – porous bluff-body wakes.
Prof. F. Gallaire (EPFL) – project *SNSF 200021_178971*, thin-film instabilities.

Journal articles

*=corresponding
†=equal contribution with first author

1) **P.G. Ledda**, L. Siconolfi, F. Viola, F. Gallaire, S. Camarri
Suppression of von Karman vortex streets past porous rectangular cylinders.
Physical Review Fluids, 3, 103901 (2018) (doi:10.1103/PhysRevFluids.3.103901).

2) **P.G. Ledda**, L. Siconolfi, F. Viola, S. Camarri, F. Gallaire
Flow dynamics of a dandelion pappus: a linear stability approach.
Physical Review Fluids, 4, 071901(R) (2019) (doi:10.1103/PhysRevFluids.4.071901).

3) G. Lerisson, **P.G. Ledda**, G. Balestra, F. Gallaire
Instability of a thin viscous film flowing under an inclined substrate: steady patterns.
Journal of Fluid Mechanics, 898, A6 (2020) (doi:10.1017/jfm.2020.396)

4) **P.G. Ledda***, G. Lerisson, G. Balestra, F. Gallaire
Instability of a thin viscous film flowing under an inclined substrate: the emergence and stability of rivulets.
Journal of Fluid Mechanics, 904, A23 (2020) (doi:10.1017/jfm.2020.673)

5) **P.G. Ledda***, G. Balestra, G. Lerisson, B. Scheid, M. Wyart, F. Gallaire
Hydrodynamic-driven morphogenesis of karst draperies: Spatio-temporal analysis of the two-dimensional impulse response.
Journal of Fluid Mechanics, 910, A53 (2021) (doi:10.1017/jfm.2020.1010)

6) E. Jambon-Puillet, **P.G. Ledda**, F. Gallaire, P-T Brun
Drops on the Underside of a Slightly Inclined Wet Substrate Move Too Fast to Grow.
Physical Review Letters 127, 044503 (2021) (doi:10.1103/PhysRevLett.127.044503)

7) **P.G. Ledda***, E. Boujo, S. Camarri, F. Gallaire, G.A. Zampogna
Homogenization based design of microstructured membranes: wake flows past permeable shells.
Journal of Fluid Mechanics 927, A31 (2021) (doi:10.1017/jfm.2021.756)

8) M. Ciuti, G.A. Zampogna, F. Gallaire, S. Camarri, **P.G. Ledda***
On the effect of a penetrating recirculation region on the bifurcations of the flow past a permeable sphere.
Physics of Fluids 33, 124103 (2021) (doi:10.1063/5.0075244)

9) **P.G. Ledda***, M. Pezzulla, E. Jambon-Puillet, P-T Brun, F.Gallaire
Gravity-driven coatings on curved substrates: a differential geometry approach.
Journal of Fluid Mechanics , 949, A38 (2022) (doi:10.1017/jfm.2022.758)

10) G. Vagnoli, G.A. Zampogna, S. Camarri, F. Gallaire, **P.G. Ledda***
Permeability sets the linear path instability of buoyancy-driven disks.
Journal of Fluid Mechanics, 955, A29 (2023) (doi:10.1017/jfm.2022.989)

11) **P.G. Ledda**, M.G. Badas, G. Matta, G. Querzoli
Flow dynamics in a model of dilated thoracic aorta prior to and following prosthetic replacement.
Theoretical and Computational Fluid Dynamics 37, 375–396 (2023) (doi:10.1007/s00162-023-00651-4)

12) H. Garg, **P.G. Ledda**, J.S. Pedersen, M. Pezzulla
Passive Viscous Flow Selection via Fluid-Induced Buckling.
Physical Review Letters 133, 084001 (2024) (doi:10.1103/PhysRevLett.133.084001)

13) G. Lerisson, **P.G. Ledda**, G. Balestra, F. Gallaire
Dripping down the rivulet. Paper associated with a video winner of the 2018 APS/DFD Milton van Dyke Award,
Physical Review Fluids 4, 100504 (2019) (doi:10.1103/PhysRevFluids.4.100504)

14) **P.G. Ledda***, F. Gallaire
Secondary instability in thin film flows under an inclined plane: growth of lenses on spatially developing rivulets.
Proceedings of the Royal Society A 477:20210291 (2021) (doi:10.1098/rspa.2021.0291)

15) L. Martin-Monier, **P.G. Ledda**†, P.L. Piveteau, F. Gallaire, F. Sorin
Prediction of Self-Assembled Dewetted Nanostructures for Photonics Applications via a Continuum-Mechanics Framework.
Physical Review Applied 16, 034025 (2021) (doi:10.1103/PhysRevApplied.16.034025)

16) G.A. Zampogna, **P.G. Ledda**, F. Gallaire
Transport across thin membranes: effective solute flux jump.
Physics of Fluids 34, 083113 (2022) (doi:10.1063/5.0101621)

17) G.A. Zampogna, **P.G. Ledda**, K. Wittkowski, F. Gallaire.
Homogenization theory captures macroscopic flow discontinuities across Janus membranes.
Journal of Fluid Mechanics 970, A39 (2023) (doi:10.1017/jfm.2023.659)

18) F. Caruso Lombardi, A. Bongarzone, G.A. Zampogna, S. Camarri, F. Gallaire, **P.G. Ledda***
Von Karman vortex street past a permeable circular cylinder: two-dimensional flow and dynamic mode decomposition-based secondary stability analysis.
Physical Review Fluids 8, 083901 (2023) (doi:10.1103/PhysRevFluids.8.083901)

19) **P.G. Ledda**, T. Rossi, M.G. Badas, G. Querzoli.
Can wall shear-stress topology predict proliferative vitreoretinopathy localization following pars plana vitrectomy?
Journal of Biomechanics 162, 111914 (2024) (doi:10.1016/j.jbiomech.2023.111914)

20) G. Corsi, **P. G. Ledda†***, G. Vagnoli, F. Gallaire, A. De Simone
Instability and trajectories of buoyancy-driven annular disks: A numerical study.
Physical Review Fluids 9, 043907 (2024) (doi:10.1103/PhysRevFluids.9.043907).

21) A. Marcotte, **P. G. Ledda**, V. Buriasco, P. Dené, F. Gallaire, L. Keiser.
Releasing long bubbles trapped in thin capillaries via tube centrifugation and inclination.
Journal of Fluid Mechanics 999, A9 (2024) (doi:10.1017/jfm.2024.746)

22) K. Wittkowski, A. Ponte, **P.G. Ledda**, G.A. Zampogna.
Quasi-linear homogenization for large-inertia laminar transport across permeable membranes.
Journal of Fluid Mechanics 1000, A46 (2024) (doi:10.1017/jfm.2024.987)

23) **P.G. Ledda**, M.G. Badas, T. Rossi, G. Querzoli.
Fluid dynamics in the vitreous chamber during infusion in ophthalmic surgery: a numerical study
Flow, 5, E30 (2025) (doi:10.1017/flo.2025.10021)

Preprints

1) P.G. Ledda, H. Garg, V. Østergaard-Clausen, L.K. Rudzki, A. Madary, M. Pezzulla.
Fluid-induced snap-through instability of spherical shells
arXiv preprint arXiv:2506.12247

2) K. Wittkowski, P.G. Ledda, E.C. Giordano, F. Gallaire, G.A. Zampogna.
Effective flows across diffusio-phoretic membranes
arXiv preprint arXiv:2505.22197

Presenter at conferences

P.G. Ledda, M.G. Badas, T. Rossi, G. Querzoli
Assessing Mixing and Transport in the Vitreous Chamber During Infusion in Ophthalmic Surgery.
2nd European Fluid Dynamics Conference, 26th - 29th August 2025
Dublin, Ireland

P.G. Ledda, G. Corsi, G. Vagnoli, F. Gallaire, A. De Simone
Linear stability analysis of freely-falling annular disks.
16th ERCOFTAC SIG 33 Workshop, Progress in Flow Instability, Transition and Control. June 30-July 2, 2025, Cagliari, Sardinia, Italy

P.G. Ledda, M.G. Badas, G. Querzoli.
Experimental assessment of fluid dynamics around scale models of an array of photovoltaic panels.
XXXIX Convegno Nazionale di Idraulica e Costruzioni Idrauliche, 15-18 Settembre 2024, Parma, Italia.
Ente organizzatore: Gruppo Italiano di Idraulica (GII).

P.G. Ledda, A. Seoni, M.G. Badas, G. Querzoli.
Toward A Micrometeorological Assessment Of Agrivoltaic Farms: A Feature Tracking Velocimetry-Based Analysis.
21st International Symposium on Applications of Laser and Imaging Techniques to Fluid Mechanics, 8-11 Luglio 2024, Lisbona, Portogallo.
Ente organizzatore: IN+ Center for Innovation Technology and Policy Research, Instituto Superior Técnico e ADAI, University of Coimbra.

P.G. Ledda.
Low Reynolds number hydraulics: from everyday observations to biomedical and technological applications.
PhD Days and Marchi Lecture, 27-28 Giugno 2024, Trieste, Italia. (Young Marchi Lecture)
Ente organizzatore: Gruppo Italiano di Idraulica (GII).

P.G. Ledda, F. Angius, M.G. Badas, G. Querzoli.
Microclimate impact of renewable energy integration: a numerical study of atmospheric flow around models of agrivoltaic farms.
22nd International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, 10-13 Giugno 2024, Parnu, Estonia.
Ente organizzatore: Initiative on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes.

P.G. Ledda, F. Angius, M.G. Badas, T. Rossi, G. Querzoli.
Flow dynamics of silicone oil tamponade in steady and unsteady conditions.
Engineering Mechanics Institute 2023 International Conference, 27-30 Agosto 2023, Palermo, Italia.
Ente organizzatore: Engineering Mechanics Institute, gruppo dell'American Society of Civil Engineers (ASCE).

P.G. Ledda, F. Angius, M.G. Badas, T. Rossi, G. Querzoli
Silicone oil tamponade flow dynamics following everyday movements.
Convegno congiunto dei Gruppi AIMETA GIMC, GMA e GBMA, 12-14 Luglio 2023, Reggio Calabria, Italia.
Ente organizzatore: Gruppi AIMETA GIMC, GMA e GBMA.

P.G. Ledda, G. Vagnoli, G.A. Zampogna, S. Camarri, F. Gallaire.
Linear path instability of buoyancy-driven permeable disks.
15th ERCOFTAC SIG 33 Workshop - Progress in Flow Instability, Transition and Control, 28-30 Giugno 2023, Alghero, Italia.
Ente organizzatore: ERCOFTAC.

P.G. Ledda, M. Pezzulla, E. Jambon-Puillet, P-T Brun, F.Gallaire.
Gravity-driven coatings on three-dimensional substrates.
14th European Fluid Mechanics Conference (EFMC14), 13-16 Settembre 2022, Atene, Grecia.
Ente organizzatore: European Mechanics Society (EuroMech).

P.G. Ledda, E. Boujo, S. Camarri, F. Gallaire, G.A. Zampogna.
Homogenization-based optimization and design of microstructured membranes: flow past a circular cylindrical shell.
74th Annual Meeting of the APS Division of Fluid Dynamics, 21-23 Novembre 2021, Phoenix, USA.
Ente organizzatore: American Physical Society (APS).

P.G. Ledda, G. Lerisson, G.Balestra, F. Gallaire.
To drip or not to drip: pattern formation of a thin film flowing under an inclined plane.
European Coating Symposium 2021, 6-9 Settembre 2021, Bruxelles, Belgio.
Enti organizzatori: Von Karman Institute for Fluid Dynamics e Université Libre de Bruxelles.

P.G. Ledda, G. Lerisson, G.Balestra, F. Gallaire.
Instability of a thin film flowing under an inclined plane.
25th International Congress of Theoretical and Applied Mechanics (ICTAM 2020+1), 22-27 Agosto 2021, Milano, Italia.
Ente organizzatore: International Union of Theoretical and Applied Mechanics (IUTAM).

P.G. Ledda, G.Balestra, G. Lerisson, B. Scheid, M. Wyart, F. Gallaire.
On the origin of draperies structures in limestone caves: two-dimensional analysis of the impulse response.
73rd Annual Meeting of the APS Division of Fluid Dynamics , 22-24 Novembre 2020, Virtual, Chicago Time.
Ente organizzatore: American Physical Society (APS).

P.G. Ledda, G. Lerisson, G.Balestra, F. Gallaire.
Pattern formation of a thin film flowing under an inclined plane.
72nd Annual Meeting of the APS Division of Fluid Dynamics , 23-26 Novembre 2019, Seattle, USA.
Ente organizzatore: American Physical Society (APS).

Awards and prizes

2022: EDME Award – Best PhD thesis in the "doctoral program in mechanics" at EPFL.

2018: APS/DFD Milton van Dyke Award – Dripping down the rivulet, Gallery of Fluid Motion, American Physical Society.

2023: SWICCOMAS Prize – PhD dissertation at EPFL: From coating flow patterns to porous body wake dynamics via multiscale models.

2024: Junior Marchi Lecture – Invited lecture by Gruppo Italiano di Idraulica (GII) titled "Low Reynolds number hydraulics: from everyday observations to biomedical and technological applications".

2023: Editors' Suggestion, Physical Review Fluids – Article F. Caruso Lombardi et al., Phys. Rev. Fluids 8, 083901.

2019: Featured in Physics Magazine, APS – Article P.G. Ledda et al., Phys. Rev. Fluids 4, 071901(R).

Teaching activities

2024: Lecturer – La Computational Fluid Dynamics (CFD) con OpenFOAM, University of Cagliari, 10 hours.
2024: Lecturer – Modelling Camp, University of Cagliari, supervision of PhD students in fluid mechanics, 20 hours.
2018: Teaching Assistant – Two-phase flows and heat transfer (ME-446), EPFL, Prof. F. Gallaire, 9 hours.
2019: Teaching Assistant – ICC-Information, Calcul, Communication (CS-119(a)), EPFL, Prof. M. Rajman, 9 hours.
2019: Teaching Assistant – Hydrodynamics (ME-444), EPFL, Prof. F. Gallaire, 16 hours.
2019: Teaching Assistant – Two-phase flows and heat transfer (ME-446), EPFL, Prof. F. Gallaire, 27 hours.
2020: Teaching Assistant – Hydrodynamics (ME-444), EPFL, Prof. F. Gallaire, 20 hours.
2020: Teaching Assistant – Two-phase flows and heat transfer (ME-446), EPFL, Prof. F. Gallaire, 25 hours.
2021: Teaching Assistant – Hydrodynamics (ME-444), EPFL, Prof. F. Gallaire, 26 hours.
2021: Teaching Assistant – Two-phase flows and heat transfer (ME-446), EPFL, Prof. F. Gallaire, 10 hours.

Thesis supervision (selected)

1) Three-dimensional instability of the von Karman vortex street past a porous cylinder (Filippo Caruso Lombardi. Master, EPFL e Università di Pisa 2022)

2) Wakes and paths of buoyancy-driven permeable disks: a linear stability approach (Giovanni Vagnoli. Master , EPFL e Università di Pisa 2022)

3) Wake flow past a permeable sphere: characterization, stability and design (Matteo Ciuti. Master, EPFL e Università di Pisa 2021)

1) Analisi sperimentale del flusso attorno ad un impianto agrivoltaico (Omar Pittau. Bachelor, Università degli studi Cagliari, 2024)

2) Analisi sperimentale del flusso attorno ad ali bio-mimetiche (Maria L. Schirru. Bachelor, Università degli studi Cagliari, 2024)

Seminars

2025: Wake instabilities and trajectories of porous bluff bodies – Ladhyx, École Polytechnique, Palaiseau, France.
2024: Junior Marchi Lecture – Low Reynolds number hydraulics: from everyday observations to biomedical and technological applications, Gruppo Italiano di Idraulica, PhD Days, Trieste, Italy.
2024: MechE Seminar Series – Canopy flows of the built environment: Numerical and experimental assessment of flow dynamics around photovoltaic farms, EPFL, Lausanne, Switzerland.
2024: Invited Seminar – From coating flow patterns to porous body wake dynamics via multiscale models, University of Genoa, Italy.
2023: IBIM Seminar Series – What can we learn from flying seeds and deep-sea sponges? Flow around and through permeable bluff bodies, Online.
2023: Complex Fluids Group, Princeton University, USA – Non-uniform spreading on curved substrates: from sphere to ellipsoid through a spheroid.