

Programme

The programme of the *EUROMECH Colloquium 666: Beyond the Free Surface: Liquid Film Flows from Theory to Applications* is outlined below. Each day is structured around thematic sessions dedicated to specific physical phenomena. The final session of each day will include a presentation by an industry expert, followed by a dedicated problem-solving discussion to foster the exchange of ideas on real-world industrial challenges.

The colloquium will conclude with a roundtable discussion on the final day, during which invited speakers will explore synergies between academia and industry, and discuss ways to promote cross-fertilisation across different approaches and application areas. All the presentations will take place in room MS.02 in the Zeeman Building in the Mathematics and Statistics Departments of the University of Warwick. **To access the abstracts of the presentations, simply click on the titles in the programme or see the abstracts section below.**

Wednesday 22: Capillary Flow and Thermal Effects

08:45-08:50 – *Welcome Address* —

08:50-09:00 *Some reflections on the 1999 and 2009 meetings on thin-film flows from Prof. Stephen Wilson*

Session 1: Reduced Order Modelling & Capillary Regime

09:00-09:40 **Adjustable formulations for modelling falling liquid film flows**
Prof. Christian Ruyer-Quil (Université Savoie Mont Blanc)

09:40-10:20 **Evaporation and deposition of colloidal droplets on an inclined substrate**
Dr. Anna Kalogirou (University of Nottingham)

10:20-11:00 **Liquid film flows with surface-active agents**
Prof. Vasilis Bontozoglou (University of Thessaly)

11:00-11:30 ————— *Coffee Break* —————

11:30-12:10 **Three-Dimensional Dynamics of Falling Films in the Presence of Surfactants** Dr. Lyes Kahouadji (Imperial College London)

12:10-12:50 **Surfactants and liquid-infused surfaces: From ideal to real interfaces**
Prof. Shervin Bagheri (FLOW Center - KTH, Royal Institute of Technology)

12:50-13:30 **Instabilities in soap films**
Prof. Isabelle Cantat (Institut de Physique de Rennes)

13:30-14:30 ————— *Lunch Break* —————

Session 2: Thermal Instabilities & Pattern Formation

14:30-15:10 **Linear stability analysis of nonisothermal glass fiber drawing**
Prof. Benoit Scheid (Université Libre de Bruxelles)

15:10-15:50 **Evaporating Droplets on Soft Substrates: Interactions and Instabilities**
Prof. George Karapetsas (Aristotle University of Thessaloniki)

15:50-16:20 ————— *Coffee Break* —————

16:20-17:00 **Evaporation-driven dynamics in thin liquid films and droplets** Prof. Luca Biancofiore (University of L'Aquila)

Session 3: Industrial Perspectives & Challenges 1

17:00-17:30 **Challenges in coalescence modelling for dense food emulsions**
Dr. Jo Janssen (Unilever R&D)

17:30-18:00 **Wing runback ice dynamics**
Dr. Ian Roberts (AeroTex UK)

18:00-18:30 **Industry-Focused Problem Discussions**

18:30 – *Welcome Reception & Poster Session* –

Thursday 23: Multiphysics Coupling and Complex Fluids

Session 4: Interfacial Transport Phenomena & Evaporation-Driven Flow

09:00-09:40 **Detailed measurements in film and other interfacial flows with heat transfer, phase change and reaction – challenges and opportunities**
Dr. Nathan Blanc (Imperial College London)

09:40-10:20 **Evaporation-driven solutocapillary flows in thin liquid films**
Dr. Mariana Rodriguez-Hakim (Universidad Nacional de Educación a Distancia)

10:20-11:00 **Capillary Jumps and Wave Blocking in Thin-Film Flows**
Dr. Rajesh Kumar Bhagat (University of Cambridge)

11:00-11:30 ————— *Coffee Break* —————

11:30-12:10 **Liquid mixing, sculpting and stability using light-actuated photosurfactants**
Prof. Demetrios Papageorgiou (Imperial College London)

12:10-12:50 **Interfacial dripping faucet: generating monodisperse liquid lenses**
Prof. Javier Rodriguez-Rodriguez (Universidad Carlos III de Madrid)

12:50-13:30 **Optical phase mask fabrication by light-actuated closed-loop control of thermocapillary flow in liquid photopolymer films** Prof. Moran Bercovici (Technion - Israel Institute of Technology)

13:30-14:30 ————— *Lunch Break* —————

Session 5: External Forcing, Complex Fluids and Coupled Interfacial Phenomena

14:30-15:10 **A leaky-dielectric fluid pump**
Dr. Toby L. Kirk (University of Southampton)

15:10-15:50 **Mixing with magnetic field – the case of magnetic micro-convection**
Prof. Guntars Kitenbergs (University of Latvia)

15:50-16:20 ————— *Coffee Break* —————

16:20-17:00 **Coating dynamics of acoustowetting oil films**
Prof. Linda J. Cummings (New Jersey Institute of Technology)

17:00-17:40 **Air-driven dynamics of viscoplastic liquid layers: mucus clearance by coughing**
Prof. Duncan Robin Hewitt (University of Cambridge)

Session 6: Industrial Perspectives & Challenges 2

17:40-18:10 **Rethinking Flow Batteries: Replacing Membranes with Liquid-Liquid Interfaces**
Dr. Federico Paratore (Unbound Potential)

18:10-18:40 **A breath of fresh air for cryogenic distillation: how more perforations led to better performance**
Dr. Lionel Vincent (Air Liquide)

18:40-19:00 **Industry-Focused Problem Discussions**

19:00- ————— *Conference Dinner* —————
————— (*Radcliffe Conference Centre*) —————

Friday 24: Topological Modifications and Control Strategies

Session 7: Film Dynamics Across Scales & Substrate Effects

09:00-09:40 **Dynamics of thin liquid films: Mapping out the interplay between forces.** Prof. Jan Vermant (ETH Zürich)

09:40-10:20 **Evaporating rivulets and thin-film flow of nematics**
Prof. Stephen Wilson (University of Bath)

10:20-11:00 **Stability and Dynamics of Fluctuating Nanofilms**
Prof. James Sprittles (University of Warwick)

11:00-11:30 ————— *Coffee Break* —————

11:30-12:10 **Surrogate Modelling and optimisation of droplet motion on chemically patterned surfaces via automatic differentiation**
Prof. Nikos Savva (University of Cyprus)

12:10-12:50 **Thin films flows on soft, poroelastic substrates**
Prof. Camille Duprat (Ladhyx -École Polytechnique)

Session 8: Control, Design & Applications

12:50-13:30 **Controlling the dewetting morphologies of thin liquid films on patterned and switchable substrates: insights from mesoscopic numerical simulations**

Dr. Andrea Scagliarini (CNR Institute for applied mathematics "Mauro Picone" (IAC))

13:30-14:30 ————— *Lunch Break* —————

14:30-15:10 **Control to unravel dynamic complexity for confined bubbles**

Dr. Alice Thompson (University of Manchester)

15:10-15:50 **Controlling the Navier-Stokes equations** Dr. Alexander Wray (University of Strathclyde)

15:50-16:20 ————— *Coffee Break* —————

16:20-17:00 *Closing Panel: Industry and Research Synergies*

Abstracts

Opening

Some reflections on the 1999 and 2009 meetings on thin-film flows

Prof. Stephen Wilson

EUROMECH 666 builds on the legacy of the previous meetings “The Dynamics of Thin Fluid Films” and “EUROMECH 497 Recent Developments and New Directions in Thin-Film Flow” both chaired by me and organised in conjunction with the ICMS that were held in Edinburgh in 1999 and 2009, respectively. In this short talk I will reflect on these meetings and consider what the future might hold.

Session 1: Capillary Regime & Reduced Order Modelling

Adjustable formulations for modelling falling liquid film flows.

Sanghasri Mukhopadhyay, Ranganathan Usha and Prof. Christian Ruyer-Quil
(**Université Savoie Mont Blanc**)

We consider a gravity driven falling liquid film on an inclined plane. We extend the parabolic-ellipse velocity profile proposed initially in Mukhopadhyay et al. JFM 952, R3 (2022) by adding a second parameter. We show that this parameter enables to adjust the velocity of the marginal linear kinematic waves in the limit of the an infinite wave number. We show that this formulation improves the accuracy of the prediction of the linear stability analysis with respect to the Orr-Sommerfeld equations. We also discuss the improvement of the prediction of the solitary wave characteristics (speed, amplitude and velocity profile) offered by this two-parameter formulation.

Instabilities in soap films

Prof. Isabelle Cantat ✉, Corentin Tregouet
(**Institut de Physique de Rennes**)

Even though liquid foams and bubble suspensions are ubiquitous in everyday life and industrial processes, their ageing and eventual destruction remain a puzzling problem. In the presence of surfactants, thin liquid films are known to drain through marginal regeneration, which involves periodic patterns of film thickness along the rim of the film. The origin of these patterns in horizontal films (i.e. neglecting gravity) still resists theoretical modelling. In this work, we theoretically address the case of a flat horizontal film with a thickness perturbation, either positive (a bump) or negative (a groove), which is initially invariant under translation along one direction. This pattern relaxes towards a flat film by capillarity. By performing a linear stability analysis on this evolving pattern, we demonstrate that the invariance is spontaneously broken, causing the elongated thickness perturbation pattern to destabilise into a necklace of circular spots. The unstable and stable modes are derived analytically in well-defined limits, and the full evolution of the thickness profile is characterised. The original destabilisation process we identify may be relevant to explain the appearance of the marginal regeneration patterns near a meniscus and thus shed new light on thin films drainage.

Liquid film flows with surface-active agents

Prof. Vasilis Bontozoglou

**Emeritus Professor of Transport Phenomena Mechanical Engineering
(University of Thessaly)**

A brief introduction to the dynamic interfacial characteristics of aqueous mixtures with surface-active / surfactant molecules is followed by the consideration of three case studies of liquid film flow. The first involves aqueous solutions of isopropanol, which behave like simple fluids with reduced surface tension. Experimental data for this system confirm the role of reduced Reynolds number and indicate modification of stability characteristics by side-walls. The second case study involves aqueous mixtures with sodium dodecyl sulfate (SDS), which attributes elasticity to the interface. The primary instability of such liquid films is studied experimentally and predicted theoretically, leading to an interesting discrepancy in the zero-wavenumber limit for momentum and for mass transfer across the film. The third case study involves the dynamics of the thin watery layer with pulmonary surfactant that covers the interior of alveoli. Analysis of small-amplitude oscillations indicates that Marangoni stresses dominate the interfacial dynamics but capillary stresses affect interior parameters like volumetric flow rate and epithelial shear stress. Modeling of strong oscillations, which lead to collapse of the monolayer during compression and its replenishment during re-expansion, reveal phenomena of potential physiological significance.

Three-Dimensional Dynamics of Falling Films in the Presence of Surfactants

Dr. Lyes Kahouadji

(Imperial College London)

We investigate how insoluble surfactants influence the dynamics of waves in vertically falling liquid films. Using three-dimensional numerical simulations, we adopt a hybrid interface-tracking/level-set framework that incorporates Marangoni effect stresses arising from gradients in interfacial surfactant concentration. Our approach is first validated against the experimental observations of Park & Nosoko (AIChE J., 2003), demonstrating accurate predictions of surfactant-free, three-dimensional wave structures. We then show that the presence of surfactants markedly alters the evolution of characteristic horseshoe-shaped waves. At low Marangoni numbers, wave fronts develop pronounced spanwise oscillations before transitioning toward a quasi-two-dimensional configuration. Marangoni stresses also dampen both the amplitude of the primary travelling waves and the smaller capillary ripples that precede them. At higher Marangoni numbers, the interface undergoes near-complete rigidification, fundamentally changing the flow dynamics.

A brief outlook will be given on falling-film flows in more complex settings, particularly when the interface is influenced by interfacial viscosity, soluble surfactants, and micellar aggregation. These considerations open new directions for understanding and controlling interfacial dynamics, with potential applications illustrated through examples in carbon capture processes.

Surfactants and liquid-infused surfaces: From ideal to real interfaces

Théo Lenavetier, Julien Cerutti, Zhuxuan Cui, Prof. Shervin Bagheri ✉
(FLOW Center, KTH, Royal Institute of Technology)

Textured surfaces impregnated with a viscous lubricant exhibit important functionalities—e.g. antifouling, drag reduction, and heat-transfer enhancement—when submerged and exposed to flow. We investigate the interplay between interface mobility, surfactant distribution, texture geometry, and lubricant drainage. Optical coherence tomography (OCT) is used to measure interface curvature and mobility, while simulations provide detailed insight into surfactant transport, including

three-dimensional recirculation patterns. Combined with theory, we analyze the design of classical liquid-infused surfaces, showing that mobile interfaces necessarily undergo drainage, whereas stable interfaces exhibit limited mobility. Finally, we propose LIS designs based on strategies for removing contaminated interfaces and restoring interfacial mobility.

Capillary Jumps and Wave Blocking in Thin-Film Flows

Dr. Rajesh Kumar Bhagat^{1*} ✉, Arnab Kumar Malik¹

¹ Department of Applied Mathematics and Theoretical Physics (DAMTP),
University of Cambridge, UK, CB3 0WA

Surface tension is the dominant restoring force for gravito-capillary waves in thin films whose thickness falls below the capillary length-scale. We study wave propagation in a slowly varying thin film and derive a criterion for wave blocking – the dispersive analogue of hydraulic choking. We show that blocking disrupts depth-averaged communication across the film, giving rise to a capillary jump. These results are verified with OpenFOAM simulations of viscous planar thin-film flow under zero-gravity. We then revisit the kitchen-sink hydraulic jump and argue that surface tension is not a secondary correction but the primary driving mechanism for the observed flow transition.

Session 2: Thermal Instabilities & Pattern Formation

Linear stability analysis of nonisothermal glass fiber drawing

Prof. Benoit Scheid
(Université Libre de Bruxelles)

The draw resonance effect appears in fiber drawing processes when the draw ratio, defined as the ratio between the take-up and the inlet velocities, exceeds a critical value. In many cases, inertia, gravity, and surface tension cannot be neglected, and a model combining all these effects is necessary in order to correctly describe the physics of the phenomenon. Additionally, it is also known that cooling can have a highly stabilizing effect on the draw resonance instability. However, a detailed analysis encompassing the effect of inertia, gravity, surface tension, and temperature is still lacking. Due to a destabilizing effect induced by geometry in the heat equation, we first show that the maximum critical draw ratio for fiber drawing can be two orders of magnitude lower than the one for the film casting problem when the heat transfer coefficient is assumed constant. By introducing a scaling making the fiber aspect ratio an independent parameter, we next show that the high value of the critical draw ratio encountered in industrial applications could be rationalized only if we consider that the heat transfer coefficient is not constant but depends on both the velocity and the cross-section area of the fiber. Within this framework, we show how the practical stability window is affected by the five control parameters: the draw ratio, the fiber aspect ratio, the inlet temperature, the convective heat transfer coefficient, and the stiffness of the non-homogeneous ambient temperature. We finally discuss the influence of radiative heat transfer on the stability.

Reference: Philippi J., Bechert M., Chouffart Q., Waucquez C. & Scheid B., Linear stability analysis of nonisothermal glass fiber drawing, *Physical Review Fluids* 7, 043901 (2022)

Evaporating Droplets on Soft Substrates: Interactions and Instabilities

Prof. George Karapetsas
(Aristotle University of Thessaloniki)

We present a theoretical study of thin volatile droplets evaporating on soft viscoelastic substrates, addressing both droplet–droplet interactions and particle-laden evaporation. Using lubrication theory coupled with vapour diffusion in the gas phase and substrate elasticity, we account for evaporative cooling, Marangoni stresses, and contact-line dynamics. For droplet pairs, interactions arise through both the deformable substrate and the vapour field, leading to attraction, repulsion, or symmetry breaking depending on substrate stiffness and thermocapillarity. For particle-laden droplets, substrate compliance and particle transport promote secondary wetting ridges and can trigger symmetry-breaking oscillatory instabilities. The results reveal how elastocapillary, thermocapillary, and osmotic effects jointly shape evaporation dynamics on soft solids.

Evaporation-driven dynamics in thin liquid films and droplets

Prof. Luca Biancofiore
(University of L'Aquila)

Thin liquid films are widely used for thermal management and energy applications, where interfacial dynamics strongly couple with heat transfer. In evaporating films, thermal effects such as latent heat removal, vapor recoil and thermocapillary stresses can profoundly modify interfacial stability, leading to complex instability mechanisms that remain only partially understood. In this talk, I first present recent results on evaporation-driven instabilities in falling and sheared thin films. Our recent work goes beyond classical one-sided formulations by introducing a two-phase model that explicitly accounts for vapor diffusion and its coupling with interfacial dynamics. In particular, we extend kinetic–diffusion evaporation models by consistently incorporating evaporative mass loss and film thinning, leading to reduced evolution equations derived via long-wave theory. This framework captures the competition between thermodynamic nonequilibrium at the interface and vapor diffusion in the gas phase, which naturally defines different evaporation regimes. The resulting reduced models reveal how evaporation alters classical instability thresholds and nonlinear wave dynamics through the interplay between Marangoni stresses, phase change and interfacial deformation, and highlight the emergence of distinct instability mechanisms depending on whether evaporation is transfer-rate-limited or diffusion-limited. In the final part, I discuss ongoing work aimed at extending these reduced descriptions beyond evaporation by incorporating radiative effects motivated by solar-driven applications. Radiation introduces new couplings through spatially varying heat fluxes and optical interactions at the liquid interface, opening new perspectives for the control and optimization of thermally driven thin-film flows.

Session 3: Industrial Perspectives & Challenges 1

Challenges in coalescence modelling for dense food emulsions

Dr. Jo Janssen
(Unilever R&D)

Wing runback ice dynamics

Dr. Ian Roberts
(AeroTex UK LLP)

When aircraft fly through clouds containing supercooled large droplets, large ice formation can form on the lifting surfaces and other components, presenting a significant hazard to safe flight. To prevent the formation of large ice shape, modern commercial aircraft wings have heating systems integrated into the leading edges. On the lower surface of the wing, anti-ice systems are designed to be running wet as whilst the formation on the main wing may increase drag, they do not pose a risk to the aircraft. The upper surface is where the lift is generated, and therefore the systems are designed to be fully-evaporative across most common conditions. Under the most severe or Supercooled Large Droplet conditions, full evaporation cannot be achieved resulting in the formation of runback ice accretions which may be in the form of roughness, ridges or frozen rivulets. These shapes compromise the performance of the aircraft and therefore their formation needs to be better understood. The goal of this presentation is to present some challenges to the academic community related to film and droplet dynamics. The aim being to develop models that can improve our understanding of these formations and how they may be mitigated, through the use of coatings or other methods to remove the water from the surface.

Session 4: Interfacial Transport Phenomena & Evaporation-Driven Flow

Detailed measurements in film and other interfacial flows with heat transfer, phase change and reaction – challenges and opportunities

Dr. Nathan Blanc ✉ and Prof. Christos N. Markides ✉
(Clean Energy Processes (CEP) Laboratory, Department of Chemical Engineering,
Imperial College London)

Clean Energy Processes (CEP) Laboratory, Department of Chemical Engineering, Imperial College London, London SW7 2AZ, U.K. The availability of spatiotemporally-resolved information in multiphase flows remains limited due to the challenges in performing such measurements. Interfacial flows, specifically, present unique challenges, such as restricted fluid domains, moving and complex interfaces, and large refractive index changes. Experimental techniques based on optical principles can provide information with high spatiotemporal resolution on important scalar and vector fields of interest. We will present efforts to develop and apply a variety of optical techniques to a range of interfacial flows, with a focus on simultaneous deployment for the provision of multiphysics information, and discuss the challenges faced when attempting such measurements in selected flows.

Evaporation-driven solutocapillary flows in thin liquid films

Dr. Mariana Rodriguez-Hakim ✉, Joseph M. Barakat, Xingyi Shi,
Gerald G. Fuller, Eric S. G. Shaqfeh

(Department of Fundamental Physics, Universidad Nacional de Educación a Distancia
- Department of Chemical Engineering, Stanford University)

Solutocapillary Marangoni flows arise when a nonuniform distribution of chemical species creates gradients in surface tension. These flows are important in coating applications, where evaporation in a multicomponent liquid induces concentration gradients, leading to defects in the final product. Our experiments reveal solutocapillary flows in thin films with solute fractions as low as 0.01%. Disjoining pressure gradients supply a mechanism to stabilize ultrathin films (10 nm), which can thus sustain solutocapillary flow at such low volume fractions. Our experiments and theory reveal the synergistic action of evaporation and disjoining pressure in creating and sustaining solutocapillary flows in thin films.

Evaporation and deposition of colloidal droplets on an inclined substrate

Dr. Anna Kalogirou
(University of Nottingham)

Evaporation of colloidal droplets on horizontal substrates is well studied, but far less is known about how substrate inclination alters internal flows and particle deposition. Recent laboratory experiments have shown that inclination can be used to control deposition patterns and have revealed the emergence of terraces near the contact lines. In this talk, I present a lubrication-based theoretical framework for evaporating colloidal droplets on inclined substrates, extending one-sided evaporation theory to incorporate structural oscillatory disjoining pressure. The latter is an essential component for reproducing terrace formation in the thin-film region. Numerical simulations based on this model reveal how gravity and capillary-driven flow interact to generate asymmetric internal flow structures and directional deposition patterns. These predictions are then compared with experimental observations across a range of inclination angles, validating the model and highlighting its ability to capture the number, size, and spatial distribution of particle terraces.

Liquid mixing, sculpting and stability using light-actuated photosurfactants

Prof. Demetrios Papageorgiou
(Imperial College London)

A theoretical model is developed and used to study the utilisation of photo-surfactants and light illumination in the generation of Marangoni interfacial forces that can be useful in microfluidic applications. We begin with a brief overview of surfactants and their effect on flows (in many cases detrimental), and then introduce two-species systems that contain so-called trans and cis molecules. These can be switched from one state to another using different wavelength light (the effect is essentially isothermal). The physics opens the possibility of light-actuation as a control mechanism. After describing the models and studying their basic properties, we present two applications motivated by experiments: (i) the use of a “laser pointer” to create a converging or diverging flow for particle trapping/motion – the so-called Marangoni tweezer experiment, and (ii) the use of non-uniform light gradients to generate mixing on the microscale. An inverse problem will also be described and solved that calculated the light gradient needed to produce a desired interfacial shape (analogously a desired bulk flow). Finally (and time permitting) the effect of light actuation on the classical capillary instability of a liquid thread and falling film flows will be described.

Interfacial dripping faucet: generating monodisperse liquid lenses.

Prof. Javier Rodríguez Rodríguez
(Universidad Carlos III de Madrid)

The dripping faucet is familiar to many liquid matter scientists, both because of its practical use as a tool to generate monodisperse droplets, and its rich behaviour as a dynamical system. In this work, we present a surface analogue to a dripping faucet, where a viscous liquid slides down an immiscible liquid meniscus. Periodic pinch-off of the dripping filament is observed, generating a succession of monodisperse floating droplets – also called liquid lenses. We show that this interfacial dripping faucet can be described analogously to its single-phase counterpart, replacing surface tension by the spreading coefficient, and even undergoes a transition to a jetting regime.

Optical phase mask fabrication by light-actuated closed-loop control of thermocapillary flow in liquid photopolymer films

Jonathan Ericson, Boaz Gavriel, Prof. Moran Bercovici
(Technion - Israel Institute of Technology)

I will present our approach for fabrication of optical phase masks by shaping photopolymer films using light-induced thermocapillary flow. We project spatially patterned light onto absorbing metal pads beneath the film, generate controlled temperature gradients, and create surface-tension-driven flows that deform the liquid–air interface into a prescribed topography. By solving an inverse problem, we compute the illumination pattern required to produce a desired topography, enabling rapid fabrication of optical elements. I will further present our ongoing work to integrate real-time topography measurements and closed-loop control to dynamically update the projected light pattern, improving both shape accuracy and convergence speed.

Session 5: External Forcing, Complex Fluids and Coupled Interfacial Phenomena

A leaky-dielectric fluid pump

Dr. Toby L. Kirk
(University of Southampton)

In this talk I will introduce a new architecture for pumping leaky-dielectric fluids arbitrary distances down microchannels. For two such fluids layered in a channel, the pumping mechanism utilizes Maxwell stresses on fluid interfaces (referred to as menisci) induced by a periodic array of electrode pairs inserted between the two fluids and separated by the menisci. The electrode pairs are asymmetrically spaced and held at different potentials, generating an electric field with variation along the menisci. To induce surface charge accumulation, an electric field (and thus current flow) is also imposed in the direction normal to the menisci. The existence of both a normal and tangential electric field gives rise to Maxwell stresses on each meniscus, driving the flow in opposite directions on adjacent menisci. But the asymmetric nature of the electrodes leads to one meniscus dominating, causing a net pumping in one direction. The pumping speed and direction can be controlled by the (four) potentials of the electrodes. In the analysis, matched asymptotic expansions are employed, together with complex conformal mapping methods to produce closed-form solutions (rare for a non-trivial multiphase flow) for the pumping speed.

Mixing with magnetic field – the case of magnetic micro-convection

Prof. Guntars Kitenbergs
(University of Latvia)

External magnetic field can induce an instability driven flows across a miscible magnetic fluid and water interface, forming peculiar finger like patterns. This phenomenon - magnetic micro-convection – not only allows to tune microfluidic mixing with an external field but also provides an interesting multiphysics problem with an interplay between diffusion, magnetism and gravity. I will show how careful experimental work and extended simulations allow to unravel the peculiarities of this complex phenomenon.

Coating dynamics of acoustowetting oil films

Prof. Linda J. Cummings
(New Jersey Institute of Technology)

It has long been known that surface acoustic waves (SAWs) - small-amplitude displacements that propagate along a solid substrate - can impart their energy to an overlying viscous fluid and drive flow. Motivated by experiments with silicone oil droplets driven by SAWs, on both flat substrates and in the presence of obstacles, we present a simplified thin-film theory of such fluid motion, based on asymptotic analysis in the small acoustic Mach number. Our analysis leads to a new variant in the family of such thin-film models, with an acoustic driving term. Simulations of the model, in both 2D and 3D, show qualitative agreement with experimental results. We discuss possible applications and extensions of the work.

Air-driven dynamics of viscoplastic liquid layers: mucus clearance by coughing

Prof. Duncan Robin Hewitt
(University of Cambridge)

Airway clearance by coughing is a key mechanism for mucus transport, particularly in obstructive lung diseases associated with altered mucus rheology. Here I investigate the dynamics of a viscoplastic liquid film driven by flow in a turbulent air layer, as a model for air-driven mucus transport incorporating yield-stress effects. The theoretical analysis is based on a long-wave model, and this is complemented with experiments in which layers of Newtonian and yield-stress liquids are exposed to air flow in a rectangular duct. Perturbations to the layer depth can lead to localised yielding and wave generation. Rapid wave growth occurs when the fluid ahead of the oncoming wave is unyielded, so that as the wave propagates it consumes static fluid while depositing a much thinner film behind. This mechanism causes dramatic “blow-out” events in experiments, where liquid hits the roof of the tank. Ongoing work on how the interplay of elasticity and plasticity in a thin film of ‘elasto-viscoplastic’ fluid affects its stability will also be discussed.

Session 6: Industrial Perspectives & Challenges 2

Rethinking Flow Batteries: Replacing Membranes with Liquid–Liquid Interfaces

Dr. Federico Paratore
(Unbound Potential)

Since their introduction by NASA in the 1970s, the architecture of redox flow batteries (RFBs) has remained largely unchanged, relying on ion-selective membranes to separate electrolytes while enabling ionic transport. However, membranes remain a key barrier to the widespread adoption of RFBs: they constrain design and manufacturing, account for over 30% of system cost, and add operational complexity.

Here, we present a membrane-less RFB that replaces the membrane with the liquid–liquid interface between two immiscible electrolytes (negolyte and posolyte). We demonstrate operation from a single cell to a multi-cell stack, evaluate its performance, and discuss the challenges of scaling from a centimeter-scale benchtop prototype to an industrial-scale energy storage system. At a fundamental level, we examine how the formation, stability, and dynamics of liquid films at immiscible interfaces govern ionic transport and battery performance, and identify key knowledge gaps that must be addressed to fully harness membrane-less architectures.

A breath of fresh air for cryogenic distillation: how more perforations led to better performance

Dr. Lionel Vincent
(Air Liquide)

At Air Liquide, R&D initiatives drive the evolution of small molecule production and application. Our specialized team of 20 focuses on the field of cryogenics, specifically air distillation—a foundational, century-old technology that continues to push the boundaries of modern engineering. At the core of these distillation systems are structured packings: thin, corrugated aluminum sheets designed to optimize contact between the downflowing condensate and the upflowing vapor. This presentation highlights a successful collaboration between academia and industry, tracing the journey from a fundamental scientific study to an industrial application that secured substantial performance gains for our distillation plants.

Session 7: Film Dynamics Across Scales & Substrate Effects

Dynamics of thin liquid films: Mapping out the interplay between forces

Prof. Jan Vermant
(ETH Zürich)

Thin-film stability governs macroscopic behaviour in foams, emulsions, and lung surfactants, yet the coupling between hydrodynamics, Marangoni stresses, and disjoining pressure remains unresolved. Using a dynamic thin-film balance with fluorescent lipid imaging and tunable electro-osmotic forcing, we independently control interfacial mobility and visualise surfactant concentration fields during drainage. We observe strong interfacial asymmetries and localized convective flows, revealing a dynamic coupling in which surfactant depletion both generates lateral stresses and weakens local disjoining pressure. Surprisingly, sufficiently high interfacial mobility induces spatial hydrodynamic instabilities that prolong film lifetime. The transition is governed by the competition between

tangential transport and drainage timescales. We will also present some results on how the stress boundary condition leads to variations of the flow field inside the film.

Evaporating rivulets and thin-film flow of nematics

Prof. Stephen Wilson
(University of Bath)

In this talk I will discuss recent developments in new aspects of two rather different thin-film flows that we have been interested in for a long time (going back at least as far as EUROMECH 497 in 2009!). In particular, I will discuss the evaporation of a rivulet flowing down an inclined plane and the manipulation of thin-film flow of a nematic both with and without a free surface. For problems I hope to show that taking a thin-film approach allows us to obtain considerable insight without the need for extensive numerical calculations.

Stability and Dynamics of Fluctuating Nanofilms

Prof. James Sprittles
(University of Warwick)

Thin liquid films at the nanoscale are strongly influenced by thermal fluctuations, which can fundamentally alter their surface dynamics and routes to rupture. I will first briefly discuss how stochastic descriptions of capillary waves can be used to capture the transient roughening of initially smooth films, going beyond classical equilibrium capillary wave theory and providing guidance at nanometre scales. The main focus of the talk will then be on how thermal fluctuations can destabilise thin films well outside the classical spinodal regime, leading to rupture via rare, extreme 'rogue nanowaves' even when linear theory predicts stability. Using a combination of molecular dynamics, fluctuating hydrodynamics, and rare-event theory, I will outline a framework that captures thermally driven film evolution and rupture with both physical fidelity and computational efficiency.

Surrogate Modelling and Optimisation of droplet motion on chemically patterned surfaces via automatic differentiation

Prof. Nikos Savva
(University of Cyprus)

We present a framework for modelling and controlling the transport of thin viscous droplets on chemically heterogeneous substrates. The framework integrates two complementary components, both enhanced by automatic differentiation: (i) the development of accurate, reduced-order models for forward modelling droplet dynamics, and (ii) a gradient-based inverse design strategy that establishes a proof-of-concept computational pipeline for designing surface features that guide droplets along predetermined trajectories. Our key findings are highlighted through a few representative numerical experiments.

Thin films flows on soft, poroelastic substrates

Prof. Camille Duprat
(Ladhyx -École Polytechnique)

Session 8: Control, Design & Applications

Controlling the dewetting morphologies of thin liquid films on patterned and switchable substrates: insights from mesoscopic numerical simulations

Dr. Andrea Scagliarini
(Istituto per le Applicazioni del Calcolo - CNR)

Patterned, switchable and adaptive substrates emerged as valuable tools for controlling wetting and actuation of droplet motion. I will present results from recent computational studies on the dynamics of an unstable thin liquid film deposited on a switchable substrate, modeled with a space- and time-varying contact angle. For a sufficiently large rate of wettability variation, a morphological transition appears, whereby the film breaks into metastable rivulets. A criterion discriminating whether droplets or rivulets appear is identified in terms of a single dimensionless parameter. I will provide a theoretical derivation of the dependence of film rupture times, droplet shape, and rivulet lifetime on the pattern wavelength and speed. Finally, the effect of thermal fluctuations in the dewetting of ultra-thin films and the fate of a ring-shaped rivulets on patterned substrates will be also discussed.

Control to unravel dynamic complexity for confined bubbles

Dr. Alice Thompson
(University of Manchester)

Feedback control is often used to drive a system towards some predefined target state, with the aim to do this as quickly, efficiently or robustly as possible. However, an alternative use of feedback control, via control-based continuation, is to detect and explore dynamical states of the underlying system, whether stable or not. In this case, the observations of the system dynamics are the key scientific output. In this talk, I will explain the mathematical structure and experimental difficulties of implementing control for stationary or propagating bubbles. I will discuss how our experimental observations highlight shortcomings of typical depth-averaged models.

This is joint work with Sammy Ayoubi, Joao Fontana and Anne Juel.

Controlling the Navier-Stokes equations

Dr. Alexander Wray
(University of Strathclyde)

Multiphase flows are ubiquitous in nature and industry, and controlling them has applications everywhere from carbon sequestration to medical diagnostics. As a consequence, control has seen an ever-increasing focus in the field of fluid dynamics. Unfortunately, due to computational cost, multiphase studies have typically confined their focus to lubrication-type equations, which have limited applicability.