ACADEMIC YEAR 2026
The George M. Homsy Session

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

FLUID MIXING: FUNDAMENTALS AND PRACTICES

CISM-EUROMECH Advanced course
coordinated by

Teodor Burghelea
CNRS - Lab. de Thermique et Energie de Nantes
Nantes, France

Emmanuel Villermaux
IRPHE - Aix-Marseille Université
Marseille, France

EUROPEAN MECHANICS SOCIETY

Udine *May 11 -15* 2026

ADMISSION AND ACCOMMODATION

The course is offered in a hybrid format, allowing participants the flexibility to attend either in person or remotely via the Microsoft Teams platform. Admission to on-site attendance is granted on a first-come, first-served basis to comply with the capacity of the lecture room.

Registration fees:

- **Early Bird On-Site Participation: € 650.00 + VAT***
  Deadline: March 11, 2026
- **Late On-Site Participation: € 800.00 + VAT***
  Deadline: April 29, 2026
- **Live Streaming Online Participation: € 250.00 + VAT***
  Deadline: April 29, 2026

On-site participation includes a complimentary bag, five fixed menu buffet lunches, hot beverages, downloadable lecture notes.
Online participation includes downloadable lecture notes.

Application forms should be submitted online through the website: http://www.cism.it. A confirmation message will be sent to participants whose applications are accepted.
Upon request, and subject to availability, a limited number of on-site participants can be accommodated at the CISM Guest House for € 35 per person per night. To request accommodation, please contact: foresteria@cism.it.

** where applicable; bank charges are not included - Italian VAT is 22%.*

CANCELLATION POLICY

Applicants may cancel their registration and receive a full refund by notifying the CISM Secretariat in writing (via email) no later than:
- March 11, 2026, for early bird on-site participation;
- April 11, 2026, for late on-site participation;
- April 29, 2026, for online participation.

No refunds after the deadlines. Cancellation requests received before these deadlines and incorrect payments will be subject to a € 50.00 handling fee.

CISM GRANTS

A limited number of participants from universities and research centers who do not receive support from their institutions can request a waiver of the registration fee and/or free lodging.
Requests should be submitted by email to the CISM Secretariat at: info@cism.it by **March 11, 2026**. Submissions must include the applicant's curriculum vitae and a letter of recommendation from the head of the department or a supervisor, confirming that the institute is unable to provide funding. Preference will be given to applicants from countries that sponsor CISM.

For further information please contact:

CISM (Seat of the course)
Palazzo del Torso - Piazza Garibaldi 18 - 33100 Udine (Italy)
tel. +39 0432 248511 (6 lines)
e-mail: info@cism.it | www.cism.it

TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	May 11	May 12	May 13	May 14	May 15
09.00 - 09.45	Registration	Lester	Dentz	Villermaux	Burghelea
09.45 - 10.30	Burghelea	Lester	Dentz	Villermaux	Student presentations
11.00 - 11.45	Lester	Dentz	Lester	Le Borgne / Heyman	Student presentations
11.45 - 12.30	Lester	Dentz	Heyman / Le Borgne	Lacorata	Round Table, Closing Words
14.00 - 14.45	Villermaux	Heyman / Le Borgne	Le Borgne / Heyman	Lacorata	
14.45 - 15.30	Villermaux	Heyman / Le Borgne	Lacorata	Lacorata	
16.00 - 16.45	Dentz	Villermaux	Lacorata	Burghelea	
16.45 - 17.30	Dentz	Villermaux	Burghelea	Burghelea	
18.00	Welcome aperitif				

FLUID MIXING: FUNDAMENTALS AND PRACTICES

Fluid mixing or the process of homogenization of gradients of scalar fields such as concentration or temperature is ubiquitous in nature and may be observed over a broad range of spatial scales starting from the microscopic scale (e.g. in porous media or bio-physical flows) up to geophysical flows (e.g. mixing of bio-mass by ocean currents). The relevance of fluid mixing across the disciplines is twofold.

From a practical standpoint, understanding the physics of mixing is of paramount importance in optimizing industrial processes that rely on the efficient transport of mass and/or heat related to a variety of modern industrial settings such polymer processing, food engineering, bio-chemical engineering. The control and optimization of practically relevant mixing processes may be achieved various approaches including by either special design of the flow geometry, optimized flow forcing schemes or fine tuning of the rheological properties of the fluids to be mixed. Regardless the approach that is undertaken, a deep physical understanding of the interplay between diffusion and advection in each particular context is needed in order to achieve this goal.

From a fundamental standpoint, a systematic understanding of the fluid mixing requires an interdisciplinary effort at the intersection of several disciplines: fluid mechanics, applied mathematics, chaos and nonlinear dynamics, chemical and biological engineering.

The central aim of this course is to provide a thorough overview of mixing in various flows based on the most recent research results and most up to date methods used in either experiments or analytical predictions and/or their numerical validation.

The course is organized along three blocks. Within the first block, fundamental theoretical aspects on flow kinematics, advection, diffusion, mixing, rheology will be introduced. Through the second block, modern approaches to characterize mixing in chaotic flows including nonlinear dynamics tools, braiding theory, finite size Lyapunov exponents, finite time Lyapunov and quanta. will be detailed. Within the third block, mixing will be discussed in several specific contexts: porous media, geophysical flows, industrial flows and rheologically complex fluids.

PRELIMINARY SUGGESTED READINGS

Burghelea, T., Segre, E., & Steinberg, V., Mixing by polymers: experimental test of decay regime of mixing, Phys. Rev. Lett. 92, 164501 (2004).

Burghelea, T., Segre, E., & Steinberg, V., Statistics of particle pair separations in the elastic turbulent flow of a dilute polymer solution, Europhys. Lett. 68, 529 (2004).

Le Borgne, T. & Heyman, J. (2025). Fluid Deformation and Mixing in Porous Media as Drivers for Chemical and Biological Processes. Annual Review of Fluid Mechanics, in press.

Le Borgne, T., Huck, P., Dentz, M. and Villermaux, E. 2017, Scalar gradients in stirred mixtures: deconstruction of random fields. J. Fluid Mech., 812, 578-610.

Crisanti, A., M. Falcioni, G. Paladin and A. Vulpiani. Lagrangian chaos: Transport, mixing and diffusion in fluids. Riv. Nuovo Cim. 14, 1–80 (1991). https://doi.org/10.1007/BF02811193

Dentz, M., Hidalgo, J. J., & Lester, D. (2023). Mixing in porous media: concepts and approaches across scales. Transport in Porous Media, 146(1), 5-53.

Dentz, M., Kang, P. K., Comolli, A., Le Borgne, T., & Lester, D. R. (2016). Continuous time random walks for the evolution of Lagrangian velocities. Physical Review Fluids, 1(7), 074004.

Heyman, J., Lester, D. R., Turuban, R., Méheust, Y., & Le Borgne, T. (2020). Stretching and folding sustain microscale chemical gradients in porous media. Proceedings of the National Academy of Sciences, 117(24), 13359-13365.

Lester, D., G. Metcalfe, and M. Rudman, 2007, "Complete parametric scalar dispersion," in Proceedings of SPIE, Microelectronics, MEMS, and Nanotechnology, Complex Systems II, Vol. 6802.

Lacorata G. and A. Vulpiani. Chaotic Lagrangian models for turbulent relative dispersion. Phys. Rev. E 95, 043106 (2017).

Lester, D., G. Metcalfe, and M. Rudman, 2014a, "Control mechanisms for the global structure of scalar dispersion in chaotic flows," Phys. Rev. E 90, 022908.

Kamal El Omari, Eliane Younes, T. Burghelea, Yann Moguen, Cathy Castelain and Yves Le Guer, Active chaotic mixing in a channel with rotating arc-walls, Phys. Rev. Fluids, 2021, 6(2), 024502.

Taylor, G. I. (1953). Dispersion of soluble matter in solvent flowing slowly through a tube. Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences, 219(1137), 186-203.

Villermaux, E. 2026 The Quantum Mechanics of Mixing, Parts 1 & 2. In press, J. Fluid Mech.

Villermaux, E. and Duplat, J., Mixing as an aggregation process. Phys. Rev. Lett. 91, (18), 184501, 2003.

Villermaux, E. 2019 Mixing versus stirring. Annu. Rev. Fluid Mech. 51, 245–73.

INVITED LECTURERS

Teodor Burghelea - CNRS, Lab. de Thermique et Energie de Nantes, France
5 lectures on: Introduction to mixing/overview of the course, introduction to complex fluids (from micro-structure to macroscopic flow behavior), active mixing in shear thinning fluids and yield stress fluids, mixing and heat transport by Elastic Turbulence.

Marco Dentz - IDAEA, Spanish National Research Council Barcelona, Spain
6 lectures on: Fundamentals of diffusion and stochastic processes, flow in heterogeneous media (Navier-Stokes equation, Stokes equation, Darcy equation, Darcy-Weisbach equation, power-law fluids, Darcy and network scales), dispersion and mixing from pore to regional scales.

Guglielmo Lacorata - Institute of Marine Sciences (CNR-ISMAR), Roma, Italy
5 lectures on: Lagrangian chaos in geophysical flows (from data analysis to trajectory modeling), including diffusion models, theory of conservative dynamical systems, applications in atmospheric physics, applications in physical oceanography and laboratory experiments.

Tanguy Le Borgne and Joris Heyman - University of Rennes, France
5 lectures on: Fluid deformation, mixing and reactions in porous materials, control of mixing on chemical reactions in porous media, the interplay between mixing, interfacial processes and biological activity.

Daniel Lester - University Melbourne, Australia
5 lectures on: Fundamentals of fluid stirring (basic concepts, advanced concepts), mixing applications in porous media (pore-scale and Darcy-scale flows), engineering applications of mixing in pipe flows and interactions with chemical and biological processes.

Emmanuel Villermaux - IRPHE, Aix-Marseille Université, France
5 lectures on: The quantum mechanics picture of fluid mixing including the definition of a quantum and interaction rules between quanta, the coarsening scale, the quantum construction of concentration distributions, the quantum picture of a turbulent jet and the analogy with the blackbody radiation problem.

LECTURES

All lectures will be given in English.
Lecture notes can be downloaded from the CISM web site.
Instructions will be sent to accepted participants.