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Recueil des contributions

26^e RENCONTRE DU NON-LINÉAIRE PARIS 2023

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**Résumés de la 26^e
Rencontre du Non-Linéaire
Paris 2023**

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Focus Point on Nonlinear Physics Advances

S. Chibbaro, M.-C. Firpo, G. Napoli and S. Randoux (Guest editors)

Division Physique Non Linéaire

Société Française de Physique

Créée **début 2021**, la toute nouvelle Division de Physique Non Linéaire (DPNL) de la SFP a pour but de **structurer la communauté du non-linéaire** au sein d'une division transverse de la SFP qui a vocation à être **interdisciplinaire**.

Exemples : dynamique des fluides, mécanique, matière molle, optique, plasmas, biophysique, physique des interfaces...



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- Pour un laboratoire adhérent à la SFP:

Chaque **doctorant.e** d'un laboratoire adhérent bénéficie d'une adhésion **gratuite** individuelle à la SFP

⇒ être informé des actualités de la division, rejoindre le réseau des doctorants, accéder au forum emploi de la SFP,

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- **Pour tous: réductions/gratuité pour les événements organisés par les partenaires de la SFP** tels que l'American Physical Society (**DFD, March Meeting**), l'Institut of Physics (IOP), l'European Physical Society (EPS).

Comment rejoindre la nouvelle Division Physique Non Linéaire de la SFP ?

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Cas 1 : Je suis membre de la SFP

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- Dans « S'informer », sélectionner : *Division Physique Non Linéaire*, valider

Cas 2 : Je ne suis pas membre de la SFP

- Renseigner le formulaire d'adhésion <https://www.sfpnet.fr/inscription-adherent>
- Cocher : *Physique Non Linéaire* au moment du choix des divisions thématiques

Cas 3 : Adhésion gratuite d'un doctorant.e d'un laboratoire adhérent

- remplir le formulaire en ligne <https://www.sfpnet.fr/inscription-doctorant>

Cas 4 : Pour devenir un laboratoire adhérent

<https://www.sfpnet.fr/adhesions-laboratoires-et-autres-organisations>



Programme du mini-colloque

Programme de la 26^e Rencontre du Non-Linéaire

Turbulence intégrable, gaz de solitons et hydrodynamique généralisée

Université Paris Cité, **28 mars 2023** – Amphithéâtre Buffon, 15 rue Hélène Brion, Paris 13^e

Le concept de turbulence intégrable a été introduit en 2009 par V. Zakharov pour désigner l'ensemble des phénomènes complexes émergents lors de la propagation d'ondes non-linéaires aléatoires dans un système décrit par une équation intégrable (telle que Korteweg-De Vries ou Schrödinger non-linéaire à une dimension). Les gaz de solitons sont un cas particulier de turbulence intégrable dans lequel interagissent uniquement des solitons (dont les paramètres sont aléatoires). Ce concept, également introduit par V. Zakharov en 1971, a fait l'objet d'intenses recherches théoriques et expérimentales ces dernières années. Quant à l'hydrodynamique généralisée, il s'agit d'une approche statistique permettant la description à grandes échelles de systèmes intégrables en considérant l'équilibre thermodynamique local (à l'échelle d'une « cellule de fluide ») et en introduisant un ensemble de Gibbs généralisé. L'objectif de ce mini-colloque est de stimuler des discussions entre ces trois thématiques dans une approche à la fois théorique et expérimentale.

09h15 – 10h00 : Gennady EL (Northumbria University, UK)

[Spectral theory of soliton gas in integrable dispersive hydrodynamics](#)

10h00 – 10h25 : Stéphane RANDOUX (Phlam, Université de Lille)

[Turbulence intégrable et gaz de solitons : expériences en optique et en hydrodynamique](#)

10h25 – 11h00 : Pause-café et discussions

11h00 – 11h45 : Benjamin DOYON (King's College London, UK)

[Hydrodynamique émergente dans les systèmes intégrables hors équilibre](#)

11h45 – 12h10 : Filip NOVOKOSKI (Matière et Systèmes Complexes, Université Paris Cité, Paris)

[Experimental Nonlinear Waves along a Torus of Fluid](#)

12h10 – 14h00 : Pause déjeuner

14h00 – 14h25 : Thibault BONNEMAIN (King's College London, UK)

[Generalized hydrodynamics of the KdV soliton gas](#)

14h25 – 14h50 : Isabelle BOUCHOULE (Laboratoire Charles Fabry, Palaiseau)

[Experimental test of Generalized Hydrodynamics in 1D Bose gases and extension of the notion of rapidity distribution to the framework of classical non-linear physics](#)

14h50 – 15h15 : Eric BARTHELEMY (LEGI, Université Grenoble-Alpes, Grenoble)

[Soliton gas in shallow water: Experiments in 1D and 2D.](#)

15h15 – 15h40 : Thibault CONGY (Northumbria University, UK)

[Statistique des événements extrêmes en turbulence intégrable](#)

15h40 – 16h15 : Pause-café et discussions

16h15 – 16h40 : Romain DUBESSY (Université Sorbonne Paris Nord, Villetaneuse)

[États hors équilibre d'un gaz de Bose unidimensionnel](#)

16h40 – 17h05 : Maurizio FAGOTTI (LPTMS, Orsay)

[Light-cone dynamics escaping generalized hydrodynamics](#)

17h05 – 17h30 : Andrey GELASH (ICB, Université Bourgogne Franche-Comté)

[Bi-solitons on the surface of a deep fluid: IST perturbation theory approach](#)

17h30 – 17h45 : Loïc FACHE (Phlam, Université de Lille)

[Génération contrôlée et propagation d'un gaz de solitons dans une chaîne électrique d'oscillateurs non-linéaires modélisée par l'équation de Korteweg-de-Vries](#)

17h45 – 18h00 : Dmitry AGAFONTSEV (Northumbria University, UK)

[Integrable turbulence in the adiabatic pumping regime: from small noise to bound-state soliton gas](#)

18h00 – 18h15 : Pierre SURET (Phlam, Université de Lille)

[Turbulence intégrable et turbulence d'ondes](#)

18h15 : Clôture

Le mini-colloque satellite de la RNL 2023 est organisé par Pierre Suret et François Copie (Phlam, Univ. Lille).

26^e Rencontre du Non-Linéaire

Université Paris Cité, 28 – 30 mars 2023

Bienvenue à la 26^e Rencontre du Non-Linéaire 2023 qui aura lieu à l'Université Paris Cité, amphithéâtre Buffon, 15 rue Hélène Brion, Paris 13^e.

Nous aurons 134 contributions se répartissant en 4 conférences invitées, 12 communications longues et 118 communications courtes.

Mercredi 29 mars 2023

08h30 - 08h50 : Enregistrement

09h00 : **Introduction**

09h05 - 09h50 : **Conférence invitée 1 (40 + 5 min.)**

09h50 - 10h25 : **Présentation des posters (2 min.) - 17 communications courtes**

10h25 - 11h15 : **Pause café Posters (50 min.)**

11h15 - 11h55 : **Présentation des posters (2 min.) - 20 communications courtes**

11h55 - 12h40 : **Exposés longs (20 + 2 min.) - 2 communications longues**

12h40 - 14h00 : Déjeuner

14h00 - 14h45 : **Exposés longs (20 + 2 min.) - 2 communications longues**

14h45 - 15h50 : **Présentation des posters (2 min.) - 32 communications courtes**

15h50 - 17h00 : **Pause café Posters (1h10)**

17h00 - 17h45 : **Exposés longs (20 + 2 min.) - 2 communications longues**

17h45 - 18h30 : **Conférence invitée 2 (40 + 5 min.)**

18h30 - 20h30 : Cocktail

Jeudi 30 mars 2023

09h00 - 09h45 : **Conférence invitée 3 (40 + 5 min.)**

09h45 - 10h45 : **Présentation des posters (2 min.) - 29 communications courtes**

10h45 - 11h45 : **Pause café Posters (1h00)**

11h45 - 12h30 : **Exposés longs (20 + 2 min.) - 2 communications longues**

12h30 - 14h00 : Déjeuner

14h00 - 14h45 : **Conférence invitée 4 (40 + 5 min.)**

14h45 - 15h25 : **Présentation des posters (2 min.) - 20 communications courtes**

15h25 - 15h50 : **Exposés longs (20 + 2 min.) - 1 communication longue**

15h50 - 16h55 : **Pause café Posters (1h05)**

16h55 - 18h00 : **Exposés longs (20 + 2 min.) - 3 communications longues**

Nous remercions l'Université Paris Cité de mettre à notre disposition les locaux de la RNL2023. Nous remercions également la Division de Physique Non Linéaire de la SFP, le laboratoire de Physique de l'ENS, le laboratoire Matière et Systèmes Complexes (MSC), le laboratoire Physique et Mécanique des Milieux Hétérogènes (PMMH), le Centre de Physique Théorique (CPT), le laboratoire de Physique de ENS de Lyon, l'Institut Jean Le Rond d'Alembert, les laboratoires Phlam, LiPhy, LiSN, et le CNRS. Cette année, nous sommes 193 inscrits au 9 mars 2023.

Le Comité d'Organisation de la RNL 2023 : Eric Falcon, Marc Lefranc, François Pétrélis et Chi-Tuong Pham.



Mercredi 29 mars 2023

09h05 - 09h50 : Conférence invitée par Bérengère DUBRULLE (40 + 5 min.)

How many modes does it take to describe the hydrosphere in climate simulations?

09h50 - 10h25 : Présentation des posters (2 min.) - 17 communications courtes

[Pourquoi est-il si difficile de définir un seuil pour le régime de filamentation laser ?](#)

A. Gomel, G. Gaulier, D. Eeltink, M. Brunetti, J. Kasparian, présenté par Jérôme Kasparian

[Dynamique bistable des lacs sous-glaciaires](#)

L.-A. Couston, J. Nandaha, B. Favier, présenté par Louis Couston

[Epidemic model with four compartments and retarded transition rates](#)

T. Granger, T. Michelitsch, M. Bestehorn, A. Riascos, B. Collet, présenté par Thomas Michelitsch

[Finger revival and reconnections near breakthrough in unstable growth processes](#)

S. Żukowski, A. J. M. Cornelissen, S. Douady, P. Szymczak, présenté par Stanisław Żukowski

[Efficacité de la propulsion intermittente](#)

T. Aurégan, S. Courrech du Pont, B. Thiria, présenté par Tristan Auregan

[Recent progress on smooth self-similar solutions to the compressible Euler equations](#)

A. Biasi, présenté par Anxo Farina-Biasi

[Reversible Navier-Stokes equation on logarithmic lattices](#)

G. Costa, A. Barral, B. Dubrulle, présenté par Guillaume Costa

[Nonlinear stimulated Raman scattering in fusion plasmas](#)

D. Benisti, O. Morice, L. Gremillet, M. Tacu, C. Rousseaux, A. Debayle, présenté par Didier Benisti

[The mixing dynamics of the blast-driven instability](#)

B. Musci, S. Petter, B. Olson, G. Pathikonda, D. Ranjan, présenté par Benjamin Musci

[Spontaneous suppression of inverse energy cascade in instability-driven 2D turbulence](#)

B. Favier, A. van Kan, K. Julien, E. Knobloch, présenté par Benjamin Favier

[Some key ingredients for observing an internal gravity waves turbulence regime](#)

V. Labarre, P. Augier, G. Krstulovic, S. Nazarenko, présenté par Vincent Labarre

[Three-dimensional structure of turbulent transport by ocean mesoscale turbulence](#)

J. Meunier, B. Miquel, B. Gallet, présenté par Julie Meunier

[Minimizing the elastic energy by conformal growth: the case of *Monstera deliciosa*](#)

Anna Dai, Martine Ben Amar, présenté par Anna DAI

[Experimental study of the penetrative convection in gases](#)

V. Dorel, M. Le Bars, P. Le Gal, présenté par Valentin Dorel

[Soft violation of Bell's inequality](#)

M. Labousse, présenté par Matthieu Labousse

[Statistical mechanics of fracture phenomena and brittle-to-ductile transitions](#)

A. Cannizzo, G. Florio, G. Puglisi, S. Giordano, présenté par Andrea Cannizzo

[Dynamic study and some exact compact solutions in a Nonlinear Electrical Transmission line](#)

D. Ndjanfang, W. Kamgaing Mabou, A. Mulu Fombu, D. Yemèlè, présenté par Désiré Ndjanfang

10h25 - 11h15 : Pause café Posters (50 min.)

11h15 - 11h55 : Présentation des posters (2 min.) - 20 communications courtes

[Le vol des Odonates : une étude mécanique des ailes](#)

C. Aracheloff, B. Thiria, R. Godoy-Diana, A. Nel, R. Garrouste, présenté par Camille Aracheloff

[Dynamiques bistables markoviennes d'écoulements sur une aile](#)

I. Kharsansky Atallah, L. Pastur, L. Zimmer, R. Monchaux, présenté par Ivan Kharsansky

[Quelles sont les structures aérodynamiques à l'origine du bruit de décrochage des pales d'éoliennes](#)
L. Sicard, M. Monchaux, B. Cotté, E. Jondeau, présenté par Lisa Sicard

[Decomposing weather maps into interpretable patterns using Latent Dirichlet Allocation](#)
L. Fery, B. Dubrulle, B. Podvin, F. Pons, D. Faranda, présenté par Lucas Fery

[Nonlinear networks and the formation of dissipative solitons in problems of dynamic holography](#)
S. Bugaychuk, présenté par Svitlana Bugaychuk

[Wave scattering and irreversible wave capturing by two-dimensional turbulent flow](#)
S. Boury, O. Bühler, J. Shatah, présenté par Samuel Boury

[Probabilistic study of the formation of extreme waves](#)
M. Garrido, R. Grande, K. Kurianski, G. Staffilani, présenté par Ricardo Grande

[Fluctuating hydrodynamics for dilute active gases](#)
O. Feliachi, M. Besse, C. Nardini, J. Barré, présenté par Ouassim Feliachi

[Oscillations du ressaut hydraulique circulaire](#)
A. Goerlinger, M. Baudoin, F. Zouesthiagh, A. Duchesne, présenté par Aurélien Goerlinger

[Competition between vertical and Rayleigh-Benard convection in a thin cylinder](#)
F. Rein, L. Carénini, F. Fichot, B. Favier, M. Le Bars, présenté par Florian Rein

[Patterning at the upper transitional range of plane Couette flow](#)
P. Manneville, M. Shimizu, présenté par Paul Manneville

[Efficient training method for a shell model of turbulence](#)
D. Noto, S. Chibbaro, A. Allauzen, présenté par Daniele Noto

[Dynamo action sustaining turbulence: a subcritical transition](#)
F. Daniel, C. Gissinger, L. Petitdemange, présenté par Florentin Daniel

[Améliorer les capacités prédictives des outils de simulation numérique pour les plasmas de fusion magnétique grâce à des modèles réduits pour la turbulence](#)
G. Ciraolo, H. Bufferand, Ph. Ghendrih, S. Baschetti, N. Fedorczak, P. Tamain, E. Serre, présenté par Guido Ciraolo

[Differential diffusion of bouncing grains](#)
O. Devauchelle, P. Popović, P. Szymczak, A. Abramian, A. Lazarus, S. Protière, présenté par Olivier Devauchelle

[Bouchage par formation d'arches dans les écoulements confinés de suspensions : du silo au tuyau](#)
N. Vani, S. Escudier, DH. Jeong, A. Sauret, présenté par Nathan Vani

[Exploring single-particle diffraction with a pilot-wave model](#)
G. Pucci, A. Bellaigue, A. U. Oza., présenté par Giuseppe Pucci

[Memory-based localisation of a classical wave-particle object in a disordered and periodic medium](#)
Z. Herson, S. Hidalgo Caballero, Y. Couder, E. Fort, présenté par Emmanuel Fort

[Elastic snap-through instabilities are governed by geometric symmetries](#)
B. Radisson, E. Kanso, présenté par Basile Radisson

[Topological mechanical metamaterials and nonlinearity](#)
Georgios Theocharis, Rajesh Chaunsali, présenté par Georgios Theocharis

11h55 - 12h40 : Exposés longs (20 + 2 min.) - 2 communications longues

[Suspensions granulaires et dissipation près d'une ligne de contact mobile](#)
A. Pelosse, E. Guazzelli, M. Roché, présenté par Alice Pelosse

[Human-Scale Brownian Ratchet: A Historical Thought Experiment](#)
M. Lagoin, C. Crauste-Thibierge, A. Naert, présenté par Antoine Naert

12h40 - 14h00 : DEJEUNER

14h00 - 14h45 : Exposés longs (20 + 2 min.) - 2 communications longues

Impact on a breath figure

L. Betti, C. Cohen, X. Noblin, présenté par Xavier Noblin

Vortex clustering, polarisation and intermittency of velocity circulation in quantum turbulence

Nicolás P. Müller, Juan Ignacio Polanco, Giorgio Krstulovic, présenté par Nicolás Müller

14h45 - 15h50 : Présentation des posters (2 min.) – 32 communications courtes

Are vortex interactions the source of time-irreversibility and singularities in turbulent flows?

A. Cheminet, D. Geneste, A. Barlet, Y. Ostovan, T. Chaabo, V. Valori, P. Debue, C. Cuvier, F. Daviaud, J.-M. Foucaut, J.-P. Laval, B. Dubrulle, présenté par Adam Cheminet

Tracking complex singularities of fluids on Logarithmic Lattices

Q. Pikeroen, A. Barral, B. Dubrulle, présenté par Amaury Barral

Probability density function for particle accelerations in turbulence and the structure of vortices

G. Ruiz Chavarria, présenté par Gerardo Ruiz Chavarria

Multi-scale turbulent synthesis

P. Lesaffre, présenté par Pierre Lesaffre

1D Chain of Coupled Pendulum in a Turbulent Flow

J. Zhang, S. Perrard, présenté par Jishen Zhang

Reactive front propagation in turbulence

N. Tawdi, C. Almarcha, M. Le Bars, présenté par Nihal Tawdi

Bubble collapse regimes in the presence of a wall

D. Fuster, M. Saini, E. Tanne, S.Zaleski, et M. Arrigoni, présenté par Daniel Fuster

Dissolution de bulles dans un fluide à seuil

B. Saint-Michel, présenté par Brice Saint-Michel

Dissipation rate in turbulent bubbly von Karman flow

V. Mouet, F. Pétrélis, S. Fauve, présenté par Valentin Mouet

Asymmetric Rayleigh streaming induced by large amplitude vibrations around a sharp obstacle

G. Zhong, L. Yingwen, X. Guo, L. Royon, et P. Brunet, présenté par Philippe Brunet

Can an acoustic dipole surf on its self-generated radiation force? Toward a 3D macroscopic wave-particle coupling

J.-P. Martischang, M. Baudoin, présenté par Jean-Paul Martischang

Influence de la gravité dans le drainage de films mobiles

A. Monier, F-X. Gauci, C. Claudet, F. Celestini, C. Brouzet, C. Raufaste, présenté par Antoine Monier

Spiraling of a confined elastic sheet after buckling

S. Deboeuf, S. Protière, E. Katzav, présenté par Stéphanie Deboeuf

Dancing Rivulets in a Hele-Shaw Cell

G. Le Lay et A. Daerr, présenté par Grégoire Le Lay

Artificial ice sheet at the laboratory scale: experimental model

Baptiste Auvity, Antonin Eddi, Laurent Duchemin, Stéphane Perrard, présenté par Baptiste Auvity

Formation de film continu et homogène par coalescence de gouttes

A. Bouvier, E. Reyssat, J. Bico, B. Bouteille, présenté par Antoine Bouvier

Solving the turbulent jet puzzle in the scale-relativity framework

T. Lehner, L. Nottale, présenté par Thierry Lehner

Analyse résolvente d'un jet turbulent tournant

Q. Chevalier, L. Lesshafft, présenté par Quentin Chevalier

Unsteady propulsion: Application to windsurfing

G. Bertrand, R. Godoy-Diana, B. Thiria et M. Fermigier, présenté par Bertrand Gauthier

[From wave turbulence to a shock-wave regime: intermittency and Burgers turbulence](#)

Guillaume Ricard, Eric Falcon, présenté par Guillaume Ricard

[Generation of water waves by the impulsive motion of a vertical plate](#)

W. Sarlin, Z. Niu, A. Sauret, P. Gondret, C. Morize, présenté par Wladimir Sarlin

[Breaking waves in a fully non-linear potential flow model](#)

S. Mohanlal, J.C. Harris, M.L. Yates, L. Pastur, C. Peyrard and S.T. Grilli, présenté par Sunil Mohanlal

[Drag force tuning through passive adaptive Origami structure](#)

R. Nain, T. Marzin, E. de Langre, S. Ramananarivo, présenté par Tom Marzin

[Auto-organisation des mottureaux](#)

G. Rousseaux, A. Beaudoin, L. Cordier, F. Hubert, P. de Bouët du Portal, F. Robin, présenté par Germain Rousseaux

[When the dynamical writing of coupled memories with reinforcement learning meets physical bounds](#)

L. Michel, T. Jules, A. Douin, F. Lechenault, présenté par Laura Michel

[Dynamique 2D d'un gaz granulaire forcé magnétiquement](#)

Jean-Baptiste Gorce, Eric Falcon, présenté par Jean-Baptiste Gorce

[Friction and fracture propagation in a granular media](#)

Y. Faure, présenté par Yohann Faure

[Fragmentation of a granular raft by surface waves](#)

M. Berhanu, L. Saddier, A. Palotai, M. Aksil, M. Tsamados, présenté par Michael Berhanu

[Asymptotic models of rotating flows in stress-free ellipsoids](#)

J. Vidal, D. Cébron, présenté par Jérémie Vidal

[On the wanderings of a ludion in a corral: in search of a quantum analogy](#)

P. Le Gal, B. Castillo Morales, S. Hernandez-Zapata, G. Ruiz Chavarria, présenté par Patrice Le Gal

[Écoulement induit par la rupture d'un film de savon](#)

A. Guillemot, J. Pierre, A. Bussonnière, présenté par Alexandre Guillemot

[Dynamique d'un front de collage visqueux](#)

M. Dobler, J. Bico, É. Reyssat, L. Duchemin, présenté par Maud Dobler

15h50 - 17h00 : Pause café Posters (1h10)

17h00 - 17h45 : Exposés longs (20 + 2 min.) - 2 communications longues

[Dynamique des tourbillons chauffés \(ou refroidis\) radiativement dans la stratosphère](#)

B. Legras, A. Podglajen, C. Duchamp, P. Sellitto, A. Limare, Z. Niu, P. Billant, V. Zeitlin, présenté par B. Legras

[Bubble break-up is always sub-critical](#)

A. Rivière, L. Duchemin, C. Josserand, S. Perrard, présenté par Aliénor Rivière

17h45 - 18h30 : Conférence invitée par Anne-Laure DALIBARD (40 + 5 min.)

Nonlinear forward-backward parabolic equations

18h30 – 20h30 : Cocktail (présentation du badge obligatoire)

Jeudi 30 mars 2023

09h00 - 09h45 : Conférence invitée par François GALLAIRE (40 + 5 min.)
Weak non-linearity for strong non-normality

09h45 - 10h45 : Présentation des posters (2 min.) – 29 communications courtes

[Oscillation à basse fréquence derrière une sphère et un cube](#)

B. Semin, G.-J. Michon, J.E. Wesfreid, présenté par Benoît Semin

[Kirigami pour créer des structures déployables](#)

J. Hong, M. Tani, J. Bico, E. Reyssat, B. Roman, présenté par Joo Won Hong

[Shedding light on how illumination shapes fish collective dynamics](#)

B. Lafoux, R. Godoy-Diana, B. Thiria, présenté par Baptiste Lafoux

[Statistical properties of energy transport in a set of bending waves](#)

M. Muralidhar, A. Naert, S. Aumaître, présenté par Murukesh Muralidhar

[One-dimensional Optical Turbulence](#)

C. Colléaux, S. Nazarenko, J. Laurie, J. Skipp, présenté par Clément Colléaux

[Fiber aggregation in flows](#)

L. Gey, G. Verhille, P. Le Gal, présenté par Lucas Gey

[Pincement au voisinage d'un ménisque dans un film liquide mince](#)

A. Etienne-Simonetti, I. Cantat, F. Restagno, E. Rio, présenté par Alice Etienne-Simonetti

[Coherence of velocity fluctuations in a turbulent jet flow](#)

T. Singla, G. Prabhudesai, F. Pétrélis, S. Fauve, présenté par Tanu Singla

[Etude expérimentale de la création d'un jet par une membrane élastique submergée forcée par des vagues](#)

G. Polly, A. Mérigaud, B. Thiria, R. Godoy-Diana, présenté par Gatien Polly

[Lagrangian tracer transport in surface ocean turbulence with ageostrophic dynamics](#)

M. Maalouly, G. Mompean, S. Berti, présenté par Michael Maalouly

[Comparative assessment of non-linear deterministic models for coastal wave propagation and run-up on a vertical wall](#)

G. Coulaud, M. Benoit, M. Teles, présenté par Guillaume Coulaud

[Modélisation stock-flux d'une économie multi-sectorielle auto-organisée](#)

P. Valcke G. Giraud, présenté par Paul Valcke

[Synchronous Motion of Active Particles in a Trap](#)

N. Vanesse, E. Opsomer, N. Vandewalle, présenté par Nathan Vanesse

[Ultimate regime of rapidly rotating convection: experimental and numerical assessment of the "geostrophic turbulence" scaling predictions](#)

G. Hadjerici, B. Miquel, V. Bouillaut, S. Aumaître, B. Gallet, présenté par Gabriel Hadjerici

[Instabilities around a differentially rotating ellipsoid embedded in a rotating stratified fluid](#)

A. Chauchat P. Meunier M. Le Bars, présenté par Antoine Chauchat

[Interplay between turbulence and large-scale flows in the presence of two competing instabilities at the edge of tokamak plasmas](#)

O. Panico, Y. Sarazin, G. Dif-Pradalier, Ö. Gürçan, P. Hennequin, présenté par Yanick Sarazin

[Laminar-turbulent intermittency in pipe flow for a non-Newtonian fluid: Receptivity and thermo-rheology](#)

A. Charles, C. Blervacq, F. Romanò, T. Ribeiro, V. Rocher, S. Azimi, J.-C. Baudez, S. A. Bahrani, présenté par Antoine Charles

[Comparison of PIV and visualisation in Couette-Poiseuille flow](#)

V. Nicolazo-Crach, T. Liu, R. Godoy-Diana, J.E. Wesfried, B. Semin, présenté par Victoria Nicolazo-Crach

[Instabilité élasto-inertielle de suspensions viscoélastiques en écoulement de Taylor-Couette](#)

C. Carré, M. Moazzen, T. Lacassagne, V. Thomy, S. Amir Bahrani, présenté par Charles Carré

[Experiments on the impact and fragmentation of a liquid onto a lighter immiscible liquid](#)

A. Maller, M. Landeau, S. Charnoz, présenté par Augustin Maller

[Geo-inspired thin film model flows](#)

W.-E. Khatla, A. Eddi, E. Reyssat, L. Duchemin, présenté par Wissem-Eddine Khatla

[Idealized modeling of diabatically-forced anticyclonic plumes from wildfires and volcanic eruptions in the stratosphere](#)

A. Podglajen, B. Legras, G. Lapeyre, R. Plougonven, V. Zeitlin, présenté par Aurélien Podglajen

[Experimental investigation of 2D plumes of soluble particles](#)

Y. Cui, B. Semin, P. Claudin, présenté par Yutong Cui

[Sedimentation of a single soluble particle](#)

N. He, Y. Cui, T. Darnige, B. Semin, P. Claudin, présenté par Nan He

[The spinorial ball: a macroscopic object of spin-1/2](#)

S. Bernard-Bernardet, D. Dumas, B. Apffel, présenté par Benjamin Apffel

[Nouvelles solutions de l'équation de Ginzburg-Landau complexe](#)

R. Conte, M. Musette, T. W. Ng, C. F. Wu, présenté par Robert Conte

[Topography-induced hydrodynamic roughness](#)

P. Jia, P. Claudin, B. Andreotti, présenté par Philippe Claudin

[Réfraction d'un soliton par un gaz de solitons](#)

M. Dufour, P. Suret, F. Copie, G. Roberti, G. El, S. Randoux, présenté par Martin Dufour

[Manipulation of solitons in optical fiber experiments](#)

A. Mucci, A. Gelash, S. Randoux, F. Copie, P. Suret, présenté par Alexandre Mucci

10h45 - 11h45 : Pause café Posters (1h00)

11h45 - 12h30 : Exposés longs (20 + 2 min.) - 2 communications longues

[Ultimate regime of transport of angular momentum in Keplerian turbulence](#)

M. Vernet, S. Fauve, C. Gissinger, présenté par Marlene Vernet

[Rheology, tribology, and acoustic lubrication of dense non-Brownian suspensions](#)

A. Izzet, X. Jia, A. Tourin, G. Ovarlez, A. Colin, présenté par Adrien Izzet

12h30 - 14h00 : DEJEUNER

14h00 - 14h45 : Conférence invitée par Silvia VIGNOLINI (40 + 5 min.)

Biomimetic colour engineering from nature to applications

14h45 - 15h25 : Présentation des posters (2 min.) – 20 communications courtes

[Thin flexible disc trapped in a vortical flow: reconstruction and analysis](#)

E. Ibarra, A. Bartoli, F. Candelier, G. Verhille, présenté par Eric Ibarra

[Elastic instabilities in soft structures](#)

E. Duval, J. Asnacios, S. Fauve, V. Tournat, F. Pétrélis, M. Lanoy, présenté par Éléonore Duval

[Shape of the cavity formed by an oblique capillary jet](#)

T. Gaichies, A. Salonen, A. Antkowiak, E. Rio, présenté par Théophile Gaichies

[Dynamique d'une mare de fonte](#)

L. Hasbroucq, S. Courrech du Pont, présenté par Loup Hasbroucq

[Formation of spikes, crests and scallops in erosion by dissolution](#)

M. Chaigne, S. Carpy, M. Massé, J. Derr, S. Courrech du Pont, M. Berhanu, présenté par Martin Chaigne

[Acoustic ring solitons in a periodic network](#)

I. Ioannou Sougleridis, O. Richoux, V. Achilleos, G. Theocharis, C. Desjouis, D. J. Frantzeskakis, présenté par Ioannis Ioannou Sougleridis

[Subcritical dynamics of axisymmetric rotor-stator flow](#)

A. Gesla, L. Martin Witkowski, Y. Duguet, P. Le Quéré, présenté par Artur Gesla

[Perversions dans les hélices: transition de phase et cristallisation de solitons](#)

É. Dilly, J. Derr, S. Neukirch, D. Zanchi, présenté par Émilien Dilly

[Transport de fibres souples en écoulement turbulent homogène et isotrope.](#)

H. Poncelet, G. Verhille, présenté par Hugo Poncelet

[Water wave implementation of a coherent source based on time-varying medium](#)

B. Apffel, Q. Louis, E. Fort, présenté par Quentin Louis

[Wave-packet spreading in the disordered and nonlinear Su-Schrieffer-Heeger chain](#)

B. Many Manda, V. Achilleos, O. Richoux, C. Skokos, G. Theocharis, présenté par Bertin Many Manda

[Entraînement retardé d'un film de liquide sur substrat mou en condition de mouillage partiel](#)

A. Varlet, P. Brunet, L. Limat, J. Dervaux, M. Roché, présenté par Anthony Varlet

[Wave field of capillary surfers](#)

W. Reino, A. Eddi, R. Barberi, G. Pucci, présenté par Wilson Reino

[Dynamics of a leaf central vein](#)

C. Le Scao, J. Derr, S. Douady, présenté par Camille Le Scao

[Modeling and numerical simulations of elastic turbulence in polymer solutions](#)

S. Reddy Yerasi, J. R. Picardo, A. Gupta, D. Vincenzi, présenté par Sumithra Reddy Yerasi

[Morphogénèse de craquelure dans l'argile en dessiccation](#)

S. Jeammet, J. Derr, P. Bonnin, S. Douady, présenté par Paul Jeammet

[Small-scale model of liquid plugs rupture in human lungs](#)

R. Hao, T. Lacassagne, A. Bahrani, F. Romano, présenté par Renjie Hao

[Solidification de mousse de savon](#)

K. Bumma, A. Huerre, J. Pierre, T. Séon, présenté par Krishan Bumma

[Génération de bulles de savon dans un écoulement d'air](#)

O. Zepeda-Arceo, A. Cros, présenté par Anne Cros

[Coated microbubbles exploit shell buckling to swim](#)

G. Chabouh, M. Mokbel, B. van Elburg, M. Versluis, T. Segers, S. Aland, C. Quilliet, G. Couplier, présenté par Catherine Quilliet

15h25 - 15h50 : Exposés longs (20 + 2 min.) - 1 communication longue

[Embolism growth in biomimetic leaves: from veins to networks](#)

L. Keiser, F.-X. Gauci, C. Cohen, X. Noblin, P. Marmottant, B. Dollet, présenté par Philippe Marmottant

15h50 - 16h55 : Pause café Posters (1h05)

16h55 - 18h00 : Exposés longs (20 + 2 min.) - 3 communications longues

[Distribution des gouttes de pluie créée par une cascade inverse contrôlée par la gravité](#)

F. Poydenot, B. Andreotti, présenté par Florian Poydenot

[Sedimenting flexible fibers against obstacles in a viscous fluid](#)

U. Makanga, M. Sepahi, C. Duprat, B. Delmotte, présenté par Ursy Makanga

[Comment s'orientent un flotteur allongé dérivant dans une onde ?](#)

F. Moisy, L. Danion, B. Dhote, J. Andriamapianina, W. Herreman, L. Martin-Witkowski, présenté par F. Moisy

18h00 : FIN



**Exposés invités de la 26^e Rencontre
du Non-Linéaire**

Nonlinear forward-backward parabolic equation

Anne-Laure Dalibard

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This talk will be devoted to the study of solutions of the 2d equation

$$uu_x - u_{yy} = f \tag{1}$$

which acts as a “toy model” for the stationary Prandtl equation. The goal is to construct solutions that change sign (and thus include a recirculation bubble), in the neighborhood of explicit profiles, by perturbing the source term and/or the data on the boundary. This equation can be seen as a parabolic (heat-like) forward equation in the area where u is positive, and as a backward equation in the area where u is negative. These two areas are separated by the line where $u = 0$, which is a free boundary.

One would expect that for regular data (i.e. for regular source term and boundary conditions), one could construct a regular solution. However, it can be shown that this is not the case: generically, even for very regular data, the solutions have singularities in the neighborhood of the cancellation points of u on the lateral edges. The solution is regular if and only if the data verify some orthogonality conditions. This phenomenon is already present for linear variants of the above equation, but persists in the nonlinear case.

In this talk, I will explain the necessity of the orthogonality conditions, and I will present the singular profiles associated with the equation. I will also give some elements on the construction of solutions when the orthogonality conditions are verified.

This is a joint work with Frédéric Marbach and Jean Rax.

How many modes does it take to describe the hydrosphere in climate simulations?

Béregère Dubrulle, François Daviaud, Arnaud Chiffaudel, Brice Saint-Michel, Florent Ravelet, Pierre-Philippe Cortet, Éric Herbert

SPEC, CNRS, CEA Saclay, 91191 Gif sur Yvette Cedex, France

berengere.dubrulle@cea.fr Work done with F. Daviaud, A. Chiffaudel, B. Saint-Michel, F. Ravelet,

P.-P. Cortet, E. Herbert, S. Thalabard, D. Faranda, D. Paillard, A. Barral, Q. Pikeroen, G. Costa, A. Mailybaev, C. Campolina

According to everyone's experience, predicting the weather reliably for more than 8 days seems an impossible task for our best weather agencies. At the same time, politicians and citizens are asking scientists for decades of climate predictions to help them make decisions, especially on CO₂ emissions. To what extent is this request scientifically admissible?

In this presentation, I will investigate this question, focusing on the topic of predictions of bifurcations of the atmospheric or oceanic circulations. In such case, the issue is whether present climate models, that have necessarily a finite resolution and a smaller number of degrees of freedom than the actual terrestrial systems, are able to reproduce spontaneous or forced bifurcations. For this, I will use results obtained at SPEC in a laboratory analog of such systems, so called von Kármán flow, in which spontaneous bifurcations of the circulation take place. I will detail the analogy, and discuss what is the effect of reducing the number of degrees of freedom in such system. I will highlight the importance of fluctuations and discuss a new type of models that would be suitable to capture them, based on computations on a logarithmic lattice.

Weak non-linearities for strong non-normality

François Gallaire

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In this work with Y.-M. Ducimetière and E. Boujo, we propose a theoretical approach to derive amplitude equations governing the weakly nonlinear evolution of nonnormal dynamical systems when they experience transient growth or respond to harmonic forcing. This approach reconciles the nonmodal nature of these growth mechanisms and the need for a center manifold to project the leading-order dynamics. Under the hypothesis of strong nonnormality, we take advantage of the fact that small operator perturbations suffice to make the inverse resolvent and the inverse propagator singular, which we encompass in a multiple-scale asymptotic expansion. The methodology is outlined for a generic nonlinear dynamical system, and several application cases which highlight common nonnormal mechanisms in hydrodynamics: the streamwise convective nonnormal amplification in the flow past a backward-facing step, and the Orr and lift-up mechanisms in the plane Poiseuille flow.

Biomimetic colour engineering from Nature to applications

Silvia Vignolini

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The most brilliant colours in nature are obtained by structuring transparent materials on the scale of the wavelength of visible light. By designing the dimensions of such nanostructures, it is possible to achieve extremely intense colourations over the entire visible spectrum without using pigments or colorants. Colour obtained through structure, namely structural colour, is widespread in the animal and plant kingdom [1]. Such natural photonic nanostructures are generally synthesised in ambient conditions using a limited range of biopolymers. Given these limitations, an amazing range of optical structures exists: from very ordered photonic structures [2], to partially disordered [3], to completely random ones [4].

In this seminar, I will introduce some striking example of natural photonic structures [2–4] and share some insight on their development. Then I will review our recent advances to fabricate bio-mimetic photonic structures using the same material as nature. Developing biomimetic structures with cellulose enables us to fabricate novel photonic materials using low cost polymers in ambient conditions [5, 6]. Importantly, it also allows us to understand the biological processes at work during the growth of these structures in plants.



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Exposés du Mini-colloque
**« Turbulence intégrable, gaz de solitons
et hydrodynamique généralisée »**

Hydrodynamique émergente dans les systèmes intégrables hors équilibre

Benjamin Doyon

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L'approximation hydrodynamique est un outil extrêmement puissant pour décrire le comportement des systèmes à plusieurs corps. A l'échelle d'Euler (c'est-à-dire lorsque les variations de densités et de courants ne se produisent que sur de grandes échelles d'espace-temps), l'approximation repose sur l'idée d'équilibre thermodynamique local : localement, au sein des cellules fluides, le système est dans une transformée galiléenne ou relativiste d'un état d'équilibre de Gibbs. On s'attend à ce que cela se produise dans les gaz conventionnels grâce à l'ergodicité et à la thermalisation de Gibbs, qui dans le cas quantique est incarnée par l'hypothèse de thermalisation de l'état propre ("eigenstate thermalisation hypothesis"). Cependant, les systèmes intégrables sont bien connus pour ne pas se thermaliser de façon standard. La présence d'un nombre infini de lois de conservation empêche la thermalisation de Gibbs, et à la place des ensembles de Gibbs généralisés émergent. Dans cet exposé, je présenterai la théorie associée de l'hydrodynamique généralisée (GHD) [1, 2], qui applique les idées hydrodynamiques à des systèmes avec une infinité de lois de conservation. Elle décrit la dynamique des états inhomogènes et dans des champs de force inhomogènes, et est valable à la fois pour les systèmes quantiques tels que les gaz de Bose et les chaînes quantiques de Heisenberg réalisés expérimentalement, et pour les systèmes classiques tels que les gaz de solitons et la théorie classique des champs. Je donnerai un aperçu de ce qu'est le GHD, de la manière dont ses principales équations sont dérivées et de sa relation avec les systèmes intégrables quantiques et les gaz des solitons classiques. Si le temps le permet, je présenterai quelques sujets supplémentaires tels que : la géométrie qui se trouve à son noyau et qui donne une solution exacte au problème de valeur initiale sous la forme d'équations intégrales, des résultats exacts dans les problèmes de transport, y compris les poids de Drude et les courants hors d'équilibre, et des résultats exacts pour les corrélations en espace-temps à grande échelle.

Références

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Experimental test of generalized hydrodynamics in 1D Bose gases and extension of the notion of rapidity distribution to the framework of classical nonlinear physics

Isabelle Bouchoule

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Long time behavior of isolated chaotic quantum many-body system is now well established: as long as local observable are concerned, the system relaxes towards a thermal equilibrium which is parameterized by a few quantities. A key recent theoretical advance is the understanding of relaxation in quantum integrable systems solvable by Bethe ansatz: one also expects relaxation; the relaxed state, however, is characterized by a full function, the rapidity distribution. This notion of relaxation is at the heart of the generalized hydrodynamic theory, which describes the slow and long wave-length dynamics in integrable systems, assuming local relaxation of the gas. It amounts to an equation giving the time evolution of the spatially-dependent rapidity distribution. In this seminar we will present the experimental test of the generalized hydrodynamic theory [1], which has been realized in 1D Bose gases well described by the Lieb-Liniger model.

At the heart of GHD is the notion of rapidity distribution. Extending this notion to the classical field framework is very interesting since it permits to apply results obtained for quantum system to the classical field domain. We propose to do so using the definition of the rapidity distribution as the asymptotic momentum distribution after a very large expansion. Focusing on the Non-Linear Schrödinger Equation model, which is the classical limit of the Lieb-Liniger model, we use this definition to derive the relation between the rapidity distribution and inverse scattering constant of motions, obtained as the trace of the monodromy matrix, parameterized by the spectral parameter [2].

References

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Turbulence intégrable et turbulence d'onde

Pierre Suret, Stéphane Randoux

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La théorie de la turbulence d'onde (théorie cinétique des ondes) permet de décrire le spectre (de Fourier) à l'équilibre ou hors d'équilibre d'un système d'ondes dispersives, aléatoires et non linéaires [1]. L'approche standard de la théorie cinétique consiste à ne conserver que les interactions résonnantes dans un régime faiblement non linéaire (les résonances sont l'équivalent de la conservation de l'impulsion et de l'énergie totale au cours d'une collision).

Dans un tout autre contexte, la turbulence intégrable peut être définie comme la propagation d'ondes non linéaires aléatoires dans un système intégrable (décrit par exemple par l'équation de Schrödinger non linéaire à une dimension) [2]. La turbulence intégrable ne peut être décrite dans le cadre de la théorie cinétique des ondes standard car les interactions qui jouent un rôle dans un système intégrable ne sont pas résonnantes.

Il est néanmoins possible de dériver des équations « quasi-cinétiques » décrivant l'évolution du spectre de Fourier dans un système intégrable en conservant les termes non résonnants [3, 4].

Dans cet exposé, nous ferons une mini revue de résultats obtenus dans cette direction dans les années 2000–2010. L'objectif est de croiser les regards entre turbulence d'onde et gaz de solitons (régime non linéaire de la turbulence intégrable) et de stimuler la recherche d'une théorie complète (décrivant à la fois les régimes faiblement et fortement non linéaires de la turbulence intégrable).

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Soliton gas in shallow water: Experiments in 1D and 2D

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We will present the results of experimental realizations of soliton gas for propagation in 1D and 2D. The 1D soliton gas is observed in a 35 m long waveflume. Several practical concerns impact the generation of solitons. The waves are generated by a piston wavemaker. Shallow water solitons are KdV type of solitons. They require a fast forward motion of the piston to put water in the soliton followed by a slow receding phase so that no waves are generated in this phase. This restricts strongly the rate of generation of soliton. We rather use an alternative generation scheme that is inspired by the fission of a soliton from a sine wave as in the historical work of Zabusky & Kruskal [1]. A second concern is that we use a reflective condition at the end of the flume so that solitons move back and forth in the flume. Thus the theoretical framework is rather the Kaup-Bousisnesq equations [2] rather than KdV. We measure the water elevation resolved in space and time using a set of synchronized cameras over 14 m. We will present the statistical properties of such a soliton gas [3–5].

2D soliton gas were investigated in an experimental campaign in the Artelia LHF shallow water wave tank of in Pont de Claix (30 m × 27 m, 35 cm deep). Wave are generated by a set of 60 piston wavemakers disposed along one of the side walls. The theoretical framework of such 2D configuration is that of Kadomtsev–Petviashvili (KP) solitons [6]. Individual KP solitons are infinite line solitons which profile is similar to KdV solitons. However realization of such solitons in practice has to face several practical concerns when inclined with respect to the wall axes. First, space is limited so that the waves interact with walls. This results in very specific structures (Mach stems) along the walls. Second the extension of the wave maker is also finite so that some sort of nonlinear diffraction is observed at the end of the finite extension line soliton. Ideal KP line soliton do not exist in experiments. Surface elevation is measured using a stereoscopic reconstruction using 2 cameras (space and time resolved) as well as with a set of 30 localized wave gauges. We will present the statistical properties of shallow water wave turbulence when varying the forcing parameters resulting in either weak turbulence of dispersive waves or solitonic regimes. We will show the conditions for the observation of either regimes.

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États hors équilibre d'un gaz de Bose unidimensionnel

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Les gaz d'atomes ultra-froids pi eg es permettent de r ealiser des syst emes bien contr ol es et particuli erement adapt es   l' tude des ph enomenes de transport dans les superfluides. Il est notamment possible de cr eer des circuits   atomes qui imitent les fonctionnalit es des circuits  lectroniques, avec des applications potentielles aux mesures de pr ecision. Dans ce contexte, il est int eressant de consid erer la limite unidimensionnelle o u la dynamique du transport est fortement contrainte. En particulier, ce syst eme est d ecrit dans la limite de champ moyen par une  quation de Schr odinger non-lin eaire qui supporte la propagation d'ondes de chocs et de solitons gris.

Nous nous sommes int eress es   la mani ere dont une petite barri ere localis ee perturbe l' coulement et induit une dissipation, due   la r eflexion de solitons gris sur l'obstacle [1]. Lorsque l'amplitude de la barri ere est tr es grande, la dissipation se fait via des ondes de choc dispersives bien d ecrites par la th eorie de modulation de Whitham, dans le r egime de champ moyen. Nous avons montr e que le formalisme d'hydrodynamique g en eralis ee permettait d' tendre cette description au r egime d'interaction fortes et que le m ecanisme d'onde de choc dispersive  tait universel en ce sens [2].

Dans ce contexte je pr esenterai des r esultats r ecents obtenus dans le r egime de champ moyen visant   caract eriser un  tat hors  quilibre d'un syst eme unidimensionnel [3]. L'approche suivie repose sur les outils de la transform ee de diffusion inverse et notamment l' tude des valeurs propres de la matrice de diffusion, que nous appliquons   un  tat tr es hors  quilibre. Nous montrons que le spectre obtenu peut  tre « dense », sans valeur propre isol ee. Cependant il est possible de quantifier la localisation des valeurs propres et d'identifier ainsi le nombre de solitons pr esents dans le syst eme. Cette approche offre donc une mani ere quantitative et simple   mettre en  uvre pour caract eriser les  tats hors  quilibre de l' quation de Schr odinger non lin eaire avec des interactions r epulsives.

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Statistique des événements extrêmes en turbulence intégrable

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La turbulence intégrable est le cadre idéal pour décrire les ondes non linéaires aléatoires gouvernées par des dynamiques dites intégrables, telle que l'équation de Schrödinger non linéaire dans le régime d'interaction attractive :

$$i\frac{\partial\psi}{\partial t} + \frac{\partial^2\psi}{\partial x^2} + 2|\psi|^2\psi = 0. \quad (1)$$

Le gaz de solitons, correspondant à un ensemble stochastique de solitons en interaction (Figure 1), constitue une des réalisations fondamentales de la turbulence intégrable [1]. Nous examinons dans ce travail la probabilité d'événements extrêmes dans un gaz de solitons pour l'équation (1) en calculant analytiquement le kurtosis du champ d'onde $\psi(x, t)$.

La théorie est illustrée par deux exemples physiques de gaz de solitons dense. Nous calculons premièrement le kurtosis pour le développement asymptotique de l'instabilité modulationnelle de l'équation (1) induite par du bruit, qui peut être modélisée par un gaz de solitons "états liés" [2]. Nous généralisons ensuite ce résultat au problème de l'évolution des ondes partiellement cohérentes, correspondant à des conditions initiales aléatoires où l'amplitude $|\psi|$ varie lentement. Pour chaque exemple, l'accord entre le calcul analytique de la kurtosis et la valeur obtenue avec l'implémentation numérique du problème [2, 3] est très bon.

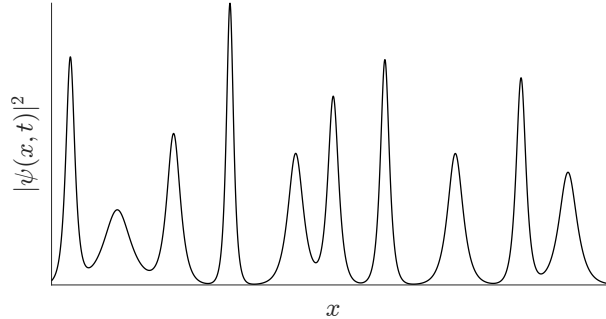


Figure 1. Réalisation typique d'un gaz de solitons pour l'équation (1).

Références

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Spectral theory of soliton gas in integrable dispersive hydrodynamics

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Multi-scale dispersive hydrodynamic flows can exhibit complex spatiotemporal behaviours that require a statistical description even though the underlying physical model can be, in principle, amenable to the well-established mathematical techniques of integrable systems such as the inverse scattering transform and finite-gap theory. At a microscopic scale associated with the system's coherence length, integrable dispersive hydrodynamics feature solitons—the localised nonlinear waves that exhibit particle-like properties such as elastic, pairwise interactions. *Soliton gas* then can be introduced phenomenologically, as an infinite random ensemble of interacting solitons that display a nontrivial collective, hydrodynamic or kinetic behaviour. The theory of soliton gas was initiated by V. Zakharov in 1971 [1], where an approximate kinetic equation for solitons of the Korteweg-de Vries equation was constructed by evaluating the effective adjustment to the tracer soliton velocity in a *rarefied gas* due to its interactions with other solitons, accompanied by the well-defined phase shifts. The generalisation of Zakharov's equation to the case of dense soliton gas has required the development of a new theoretical framework based on the thermodynamic limit of spectral finite-gap solutions to integrable equations and their modulations described by multiphase Whitham theory [2–4]. Along with novel mathematical aspects related to integrability of the spectral kinetic equation, it has transpired recently that statistics of soliton gas provides important insights in the long-time behaviour of modulationally unstable systems [5]. Additionally, the recently revealed intriguing parallels between kinetic theory of soliton gas and generalised hydrodynamics of integrable many-body systems [6] open an avenue to the construction of soliton gas thermodynamics.

In my talk I will present general ideas of the spectral kinetic theory of soliton gas and outline its perspectives.

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Turbulence intégrable et gaz de solitons : expériences en optique et en hydrodynamique

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La turbulence intégrable désigne le champ de recherches où l'on s'intéresse aux propriétés statistiques d'ondes non linéaires aléatoires dont la dynamique spatio-temporelle est régie par des équations intégrables telles que l'équation de Korteweg-de Vries ou l'équation de Schrödinger non linéaire à une dimension (1D-NLSE) [1]. Dans ce cadre général, les gaz de solitons représentent des objets particuliers composés d'un grand nombre de solitons paramétrés par des valeurs propres discrètes apparaissant dans le problème spectral (décrit dans le cadre de la méthode appelée inverse scattering transform (IST)) associé à l'équation intégrable considérée.

Dans cet exposé, je présenterai des simulations numériques et des expériences d'optique et d'hydrodynamique portant sur certains développements récents de la turbulence intégrable et des gaz de solitons. En particulier, je présenterai une expérience d'hydrodynamique dans laquelle nous avons réalisé la première synthèse non linéaire d'un train d'ondes constitué de 128 solitons densément répartis dans l'espace. Cette expérience a été réalisée à l'Ecole Centrale de Nantes dans un canal long de 140 mètres, large de 5 mètres et profond de 3 mètres. L'ensemble de solitons complètement paramétré par 128 valeurs propres dans l'espace spectral IST est synthétisé dans le monde physique grâce à des méthodes numériques développées récemment [2]. Le champ non linéaire généré dans le canal à une dimension représente un gaz de solitons dont les propriétés peuvent être examinées dans le cadre de la théorie cinétique des gaz de solitons introduite par Zakharov en 1971 [3]. En particulier le nombre de solitons généré est suffisamment large pour que nous puissions effectuer la première mesure de la densité d'états du gaz de solitons (i.e. la distribution de probabilité des valeurs propres caractérisant le gaz de solitons dans l'espace IST) [4].

Je présenterai également des expériences récentes réalisées dans une boucle de fibre optique à recirculation [5] dans laquelle nous avons pu observer la dynamique spatio-temporelle résultant de l'interaction entre un soliton et un gaz de solitons.

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Experimental nonlinear waves along a torus of fluid

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Curved interfaces such as toroidal drops are ubiquitous in nature, but are unstable, making them difficult to control and study. Using an original technique we create a stable and stationary torus of liquid, deposited on a superhydrophobic substrate allowing for a systematic study of waves along its inner and outer border under curved and periodic conditions [1,2]. By exciting the torus border and recording the displacements of the two borders, we study the dispersion relation of the torus, yielding a rich spectral structure: gravity-capillary waves, sloshing modes and a center-of-mass mode [1]. We will first show that nonlinear waves in form of solitons can propagate along the torus borders for sufficiently strong forcing. We will then stress the observation of subsonic elevation solitons which are due to a strong influence of periodic boundary conditions through a Korteweg–de Vries equation, giving a non-trivial dependence of the soliton velocity on its amplitude and torus curvature. Finally, we will discuss the observation of a triadic resonance instability between two different dispersion branches, namely the sloshing and gravity-capillary modes [3]. Such nonlinear interactions thus lead to a transfer of energy between the two branches which is fully characterized. For a stronger forcing, additional waves are generated by a cascade of three-wave interactions populating the wave spectrum. Such a three-wave two-branch interaction mechanism is probably not restricted to hydrodynamics and could be of interest in other systems involving several propagation modes.



Figure 1. A stable torus of fluid of outer radius $R_o = 4.8$ cm on a superhydrophobic substrate.

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Generalised hydrodynamics of the KdV soliton gas

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We establish the explicit correspondence between the theory of soliton gases in classical integrable dispersive hydrodynamics [1], and generalized hydrodynamics (GHD), the hydrodynamic theory for many-body quantum and classical integrable systems [2, 3]. To that end we heuristically construct the GHD description of the soliton gas for the Korteweg-de Vries (KdV) equation and re-contextualise the tools of GHD in the terms of soliton gas theory [4]. In particular we predict the exact form of the entropy and free energy for the soliton gas, as well as the static correlation matrices of conserved charges and currents. For this purpose, we identify the solitons' statistics with that of classical particles, and confirm the resulting GHD static correlation matrices by numerical simulations.

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Numerical spectral synthesis of soliton and breather gas

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Soliton gas was introduced by Zakharov [1] as an infinite ensemble of interacting KdV solitons randomly distributed in velocity and positions. This concept has been extended by El and Tovbis [2], in their development of the spectral theory of soliton and breather gases, in the framework of the focusing Nonlinear Schrödinger (fNLS) equation. Moreover, it has been shown in a recent work by Gelash et al. [3] how the spectral soliton gas formalism could lead to a new understanding of the evolution of random processes in integrable systems, the so-called integrable turbulence. In this context, the ability to numerically build the soliton and breather gas solutions from the nonlinear spectral plane is a key element for testing the mathematical model and investigating its physical applications. In this work, we present the algorithms for the synthesis of soliton and breather gases in the KdV and fNLS framework and we discuss the theoretical and numerical challenges that arise in the implementation.

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Génération contrôlée et propagation d'un gaz de solitons dans une chaîne électrique d'oscillateurs non linéaires modélisée par l'équation de Korteweg–de Vries

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Nous étudions expérimentalement la propagation d'ondes non-linéaires dans une ligne de transmission électrique. Il s'agit d'un système non-linéaire discret, composé d'oscillateurs électriques de type LC, où la capacité est fonction de la tension (voir Fig. 1 (b)). Dans la limite continue et dans l'approximation des ondes de faibles amplitudes, la propagation d'ondes dans ce système est régie par l'équation de Korteweg–de Vries (KdV) [1], décrivant aussi la propagation d'ondes hydrodynamiques unidimensionnelles en eau peu profonde.

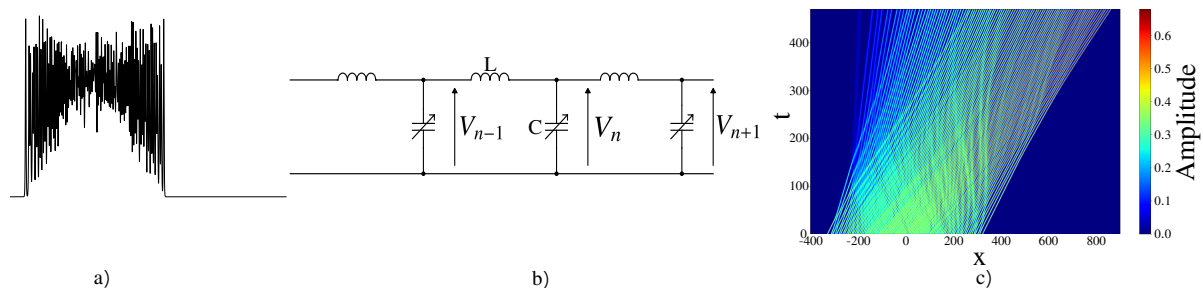


Figure 1. Représentation de la ligne électrique expérimentale et diagramme spatio-temporel issu d'une simulation de propagation d'un gaz de solitons KdV

Un générateur de fonction arbitraire produit au niveau du premier oscillateur une onde (distribution temporelle de tension) qui va se propager dans la ligne électrique composée de 160 oscillateurs LC identiques. Nous présentons ici une démonstration expérimentale de dynamique KdV dans cette ligne. L'équation KdV est dite intégrable et peut être résolue dans le formalisme de la méthode IST (*Inverse Scattering Transform*). Dans ce formalisme, un soliton est représenté par une valeur propre discrète, caractérisant à la fois son amplitude et sa vitesse. Plusieurs solitons distribués de manière aléatoire dans cet espace constituent ce que l'on appelle un gaz de solitons dont les propriétés statistiques sont caractérisées dans le cadre d'une théorie cinétique (analogue à la théorie cinétique des gaz) que nous cherchons à vérifier expérimentalement. Des méthodes numériques [2] nous permettent de générer ce gaz de solitons et de l'implémenter dans notre chaîne. Nous observons ainsi sa dynamique spatio-temporelle et l'évolution de sa densité d'états, c'est-à-dire la distribution de probabilité des valeurs propres caractérisant le gaz de solitons dans l'espace IST [3].

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Light-cone dynamics escaping generalised hydrodynamics

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The nonequilibrium dynamics of 1D integrable and quasi-integrable systems with inhomogeneities are nowadays investigated in the framework of “generalised hydrodynamics” [1,2]. Under some assumptions (always satisfied in free systems), the expectation values of local observables can be computed exactly by solving a system of nonlinear equations representing the infinitely many conservation laws underlying integrability. In this talk I present various situations in which nonequilibrium time evolution produces lightcone dynamics that seem to escape generalised-hydrodynamic descriptions. Our ideal setting is time evolution under a translationally invariant Hamiltonian after that a localised perturbation has broken translational invariance in the initial state. I describe the following scenarios:

1. the Hamiltonian has jammed excited states, i.e., states that can be interpreted as a collection of particles stuck together; before the perturbation, the initial state is jammed [3,4];
2. there are semi-local conservation laws, which are integrals of motion that allow the system to retain memory of string order [5];
3. the state before the perturbation is a quantum scar [6].

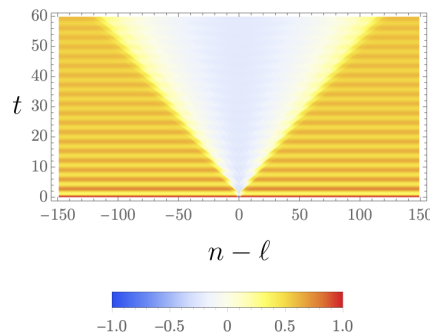


Figure 1. Example of an unexpected ballistic profile of a local observable emerging from a product state with all but one (at site ℓ) spins aligned in the same direction [5].

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Bi-solitons on the surface of a deep fluid: IST perturbation theory approach

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We apply the Inverse Scattering Transform (IST) to analyze the bound state coherent structures (bi-solitons) discovered previously in the free surface deep water models, see [1, 2]. We consider the Dyachenko–Zakharov equation together with fully nonlinear equations, and present them as the one-dimensional focusing nonlinear Schrödinger equation (NLSE) plus a right-hand side. When the impact of the right-hand side is small compared to the NLSE part, one can use the IST perturbative approach to analyze the scattering data of the wavefield. We compute the right-hand side numerically for the bi-solitons and ensure that the perturbation theory is valid in this case. Then we compute trajectories of the soliton eigenvalues during the bi-soliton evolution and find that they are in good agreement with predictions of the IST perturbation theory. Based on the obtained results, we conclude that the IST perturbation theory can justify the existence of the bound state coherent structures on the surface of deep fluid. Finally we discuss the general perspectives of applications of the IST perturbations theory in combination with efficient numerical IST tools [3, 4] in various studies of coherent structures, soliton gases and integrable turbulence.

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Integrable turbulence in the adiabatic pumping regime: from small noise to bound-state soliton gas

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Within the framework of the focusing one-dimensional nonlinear Schrodinger equation (1D-NLSE) supplemented by a small linear pumping term,

$$i\psi_t + \psi_{xx} + |\psi|^2\psi = ip_0\psi, \quad (1)$$

we study numerically the turbulence that develops from statistically homogeneous Gaussian noise of small amplitude. For sufficiently small initial noise and pumping coefficient, and also for not very wide simulation box (basin length), we observe that such turbulence grows in a universal adiabatic regime, moving successively through the statistically stationary states of the integrable 1D-NLSE: as soon as the pumping is turned off, the resulting integrable turbulence [1] turns out to be stationary and does not depend on the pumping coefficient, amplitude of the initial noise or basing length. Focusing on this adiabatic pumping regime, we study how the integrable turbulence grows from small (linear) noise, goes through states of intermediate nonlinearity and reaches strongly nonlinear states characterized by a high frequency of rogue waves. Monitoring this evolution with the IST method, we observe that the solitonic part of the wavefield becomes dominant even when the (linear) dispersion effects are still leading in the dynamics and with increasing average intensity the wavefield approaches a dense bound-state soliton gas, whose properties are defined by the Fourier spectrum of initial noise [2].

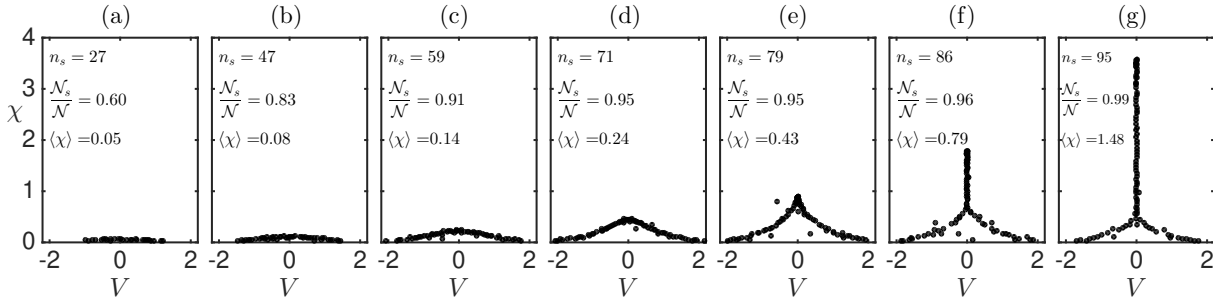


Figure 1. Soliton amplitudes χ and velocities V at different stages of the pumping: (a) $\langle |\psi|^2 \rangle^{1/2} = 0.125$, (b) 0.177, (c) 0.25, (d) 0.35, (e) 0.5, (f) 0.71 and (g) 1.0. In the panels, $\mathcal{N}_s/\mathcal{N}$ represents the ratio between the wave action of the solitonic part of the wavefield $\mathcal{N}_s = \langle |\psi_s|^2 \rangle$ and the total wave action $\mathcal{N} = \langle |\psi|^2 \rangle$.

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**Exposés longs de la 26^e Rencontre
du Non-Linéaire**

Sedimenting flexible fibers against obstacles in a viscous fluid

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The motion of flexible fibers often happens in complex media that are structured by obstacles. Examples range from the transport of biofilm streamers through porous media to the design of sorting devices for DNA molecules. For large number of such problems, the fiber dynamics result from the complex interplay between internal elastic stresses, contact forces and hydrodynamic interactions with the walls and obstacles. By means of numerical simulations, experiments and analytical predictions, we investigate the dynamics of flexible fibers settling in a viscous fluid embedded with obstacles of arbitrary shapes [1]. We identify and characterize two types of events: gliding (Fig. 1 (a)) and trapping (Fig. 1 (b)), for which we detail the mechanisms at play. We observe nontrivial trapping conformations on sharp obstacles that result from a subtle balance between elasticity, gravity and friction (Fig. 1 (c, d)). In the gliding case, a flexible fiber reorients and drifts sideways after sliding along the obstacle. The subsequent lateral displacement is large compared to the fiber length and strongly depends on its mechanical and geometrical properties. We show how these effects can be leveraged to propose a new strategy to sort particles based on their size and/or elasticity (Fig.1 (e)). This approach has the major advantage of being simple to implement and fully passive, since no energy is needed.

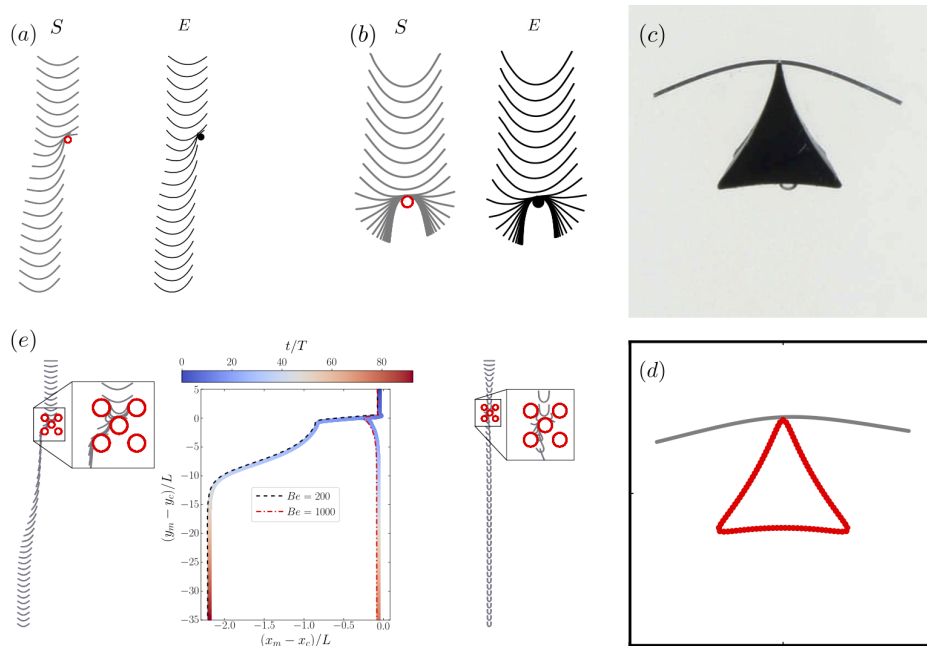


Figure 1. (a–b) Numerical (S) and experimental (E) chronophotographies of a flexible fiber settling against an obstacle in a viscous fluid. (c–d) Trapping events from experimental (c) and numerical (d) results. (e) The central panel shows the trajectories of the center of mass of two fibers with the same length and different flexibilities ($Be = 200$ and $Be = 1000$). The side to side panels show the corresponding chronophotographies of the fiber centerline settling through a unit cell.

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Bubble break-up is always sub-critical

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Bubble fragmentation in turbulent flows controls gas transfers at the ocean-atmosphere interface [1]. Nevertheless, characterizing the flow–interface coupling that leads to break-up remains challenging both experimentally and numerically, even in simpler geometries. Inspired by Masuk and co-authors [2], we identify the uni-axial straining flow as the main geometry leading to break-up at high Reynolds number, Re (ratio between kinetic and viscous forces). Since the original work of Miksis [4], the stationary bubble shapes in this flow have been studied extensively as a function of the Weber number, We , ratio of kinetic forces and surface tension forces. They lead to the identification of a critical Weber, We_c^S , separating stable, $We < We_c^S$, from unstable bubbles, $We > We_c^S$.

Through direct numerical simulations starting from a sphere, we show that the dynamical break-up threshold, We_c , is always significantly smaller than We_c^S . Indeed, bubble break-up is in reality sub-critical and the transition must be described dynamically. We describe the whole interface dynamics by a one dimensional non-linear oscillator on the amplitude x of the second Rayleigh mode of oscillations [3]:

$$\ddot{x} + \lambda \dot{x} = -\nabla V(x) \quad (1)$$

where λ is the damping factor, and V a nonlinear potential with non trivial dependency on the initial shapes. We show that this one-dimensional model perfectly captures the dynamics, both far from We_c (see black dotted line in figure 1 (b)) and close to We_c (same in figure 1 (c)). This model can then be applied to predict bubble deformations and lifetime in more complex turbulent flows.

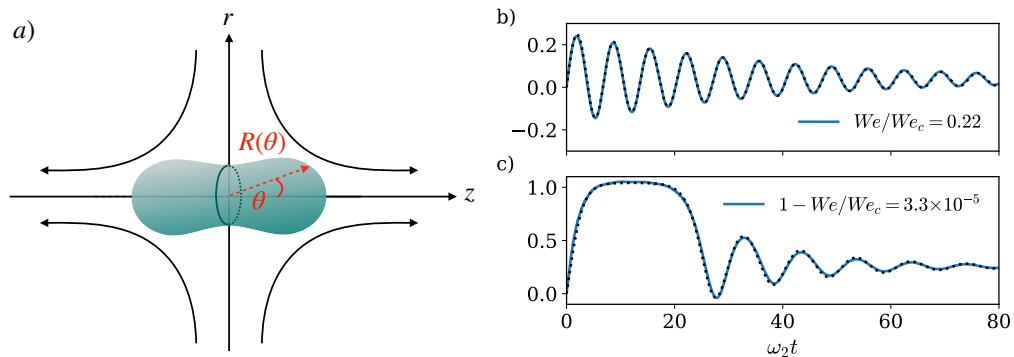


Figure 1. (a) Bubble in a uni-axial extensional flow. Arrows are typical streamlines in the absence of bubble. (b-c) Amplitude of the second Rayleigh mode, far from We_c : (b), and close to We_c ; (c), at $Re = 400$. ω_2 is the mode pulsation. The model (1) is superimposed (black dotted line) and perfectly reproduces the dynamics.

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Comment s'oriente un flotteur allongé dérivant dans une onde ?

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Il est bien connu qu'un corps flottant dans un champ d'onde propagative dérive avec l'onde. Dans une approche faiblement non linéaire et pour un corps de petite taille complètement immergé, ce comportement résulte des phénomènes classiques de dérive de Stokes et d'écoulement moyen redressé. Mais la situation plus réaliste d'un corps de taille finie et partiellement immergé peut faire apparaître des comportements beaucoup plus subtils et difficiles à modéliser.

Parmi ces comportements, celui de l'orientation préférentielle d'un flotteur allongé par rapport à la direction de propagation de l'onde est particulièrement intrigant : on observe que les flotteurs courts ont tendance à s'aligner selon le vecteur d'onde (alignement *longitudinal*), tandis que les flotteurs longs s'alignent plutôt perpendiculairement (alignement *transverse*). Cette tendance à l'alignement longitudinal est d'autant plus prononcée que le corps est dense, et donc fortement immergé. La raison de ce comportement surprenant n'a pas été élucidée à notre connaissance.

Afin de comprendre ce phénomène, nous avons mené une étude expérimentale, théorique et numérique. Les expériences ont été effectuées dans une petite cuve à houle (longueur 3 m) remplie de 10 cm d'eau, permettant d'émettre des ondes de fréquence 1 à 4 Hz (soit $\lambda = 0.1 - 0.8$ m). Les flotteurs sont des parallélépipèdes homogènes, de largeur $L_y = 10$ mm, épaisseur $L_z = 5$ mm, et longueur L_x comprise entre 20 et 140 mm, construits dans des matériaux de densité $d = \rho/\rho_w$ comprise entre 0.1 et 0.9. Les expériences sont réalisées avec des ondes de pente modérée ($ak < 0.2$), de sorte que le flotteur reste toujours partiellement immergé, sans démouillage sur la face inférieure ni submersion sur la face supérieure. Pour chaque combinaison de λ , L_x et d , nous suivons l'évolution de l'angle de lacet ψ entre l'axe du flotteur et le vecteur d'onde.

Nos observations montrent que (a) l'orientation à temps long du flotteur est indépendante de l'amplitude de l'onde ; (b) le temps caractéristique d'évolution de l'orientation varie en $(\omega ak)^{-1}$, signature d'une dynamique faiblement non linéaire ; (c) la transition entre orientation longitudinale ($\psi = 0^\circ$) et transverse ($\psi = 90^\circ$) s'observe pour un flotteur de longueur $L_x \sim \sqrt{e\lambda}$, où e est l'enfoncement (ici $e = dL_z$ pour un solide homogène).

Notre analyse théorique et numérique a permis d'identifier les contributions principales à l'origine de cette transition. Il s'agit d'une compétition entre deux phénomènes faiblement non linéaires : en plus du couple oscillant issu des forces de flottaison (forces de Froude–Krylov), responsable de l'oscillation « rapide » de l'angle ψ d'ordre ak , il existe deux corrections d'ordre $(ak)^2$ conduisant à une évolution « lente » de l'angle. La première est caractéristique d'un oscillateur paramétrique : de manière analogue au pendule de Kapitza, un oscillateur excité tend à s'aligner selon la direction de vibration, ce qui favorise l'orientation longitudinale. Mais lorsque le flotteur devient suffisamment allongé, une seconde correction entre en jeu, liée à la variation de la ligne de flottaison le long du flotteur. Cette seconde correction tend au contraire à aligner le flotteur en position transverse, et ce d'autant plus que l'enfoncement est faible (corps léger). De la compétition entre ces deux tendances résulte la transition observée.

Suspensions granulaires et dissipation près d'une ligne de contact mobile

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Le sang, la peinture, le ciment, les coulées de boue et les avalanches sont des suspensions, c'est-à-dire des mélanges de particules suspendues dans un fluide. Quand le mouvement brownien des particules est négligeable, on parle plus spécifiquement de suspensions granulaires, des fluides complexes qui présentent des propriétés de volumes étonnément simples avec une approche milieu continu. À titre d'exemple, pour une suspension monodisperse concentrée dont la fraction solide ϕ est de 40 %, le mélange reste newtonien et sa viscosité effective est 10 fois celle du fluide suspendant, quelle que soit la taille des particules.

Nous étudions des suspensions granulaires concentrées avec interfaces libres et plus particulièrement l'étalement d'une goutte [1]. Les propriétés en volume de l'approche milieu continu sont ici mises à l'épreuve avec une interface mobile qui doit composer avec un écoulement biphasique. Aux abords de la ligne de contact, les particules ne peuvent pas approcher du fait de leur taille. La taille de la zone de fluide pur croît avec le diamètre des particules comme illustré avec des suspensions bidisperses sur la figure 1. Quand l'épaisseur est suffisante, une monocouche fortement ordonnée est observée, conséquence du confinement extrême des particules. Plus loin suit une région désordonnée lorsque le confinement par l'interface devient moins important. Par une approche expérimentale et théorique, l'influence des particules sur le mouillage dynamique est étudiée. Les modèles classiques (Cox-Voinov, Tanner) restent valables avec des viscosités effectives. Mais contrairement aux propriétés du volume, la viscosité effective d'une suspension en mouillage est fortement affectée par la taille des particules. En particulier, pour des particules de plus de 100 microns, la viscosité mesurée est celle du fluide pur. Cette taille caractéristique de « cut-off » visqueux est retrouvée grâce à une analyse des équations et confirmée expérimentalement. L'étude de systèmes bidisperses confirme les effets de taille et d'ordre des particules à proximité d'une ligne de contact en avancée. Enfin la dynamique globale d'étalement est étudiée et reliée aux observations locales près de la ligne de contact.

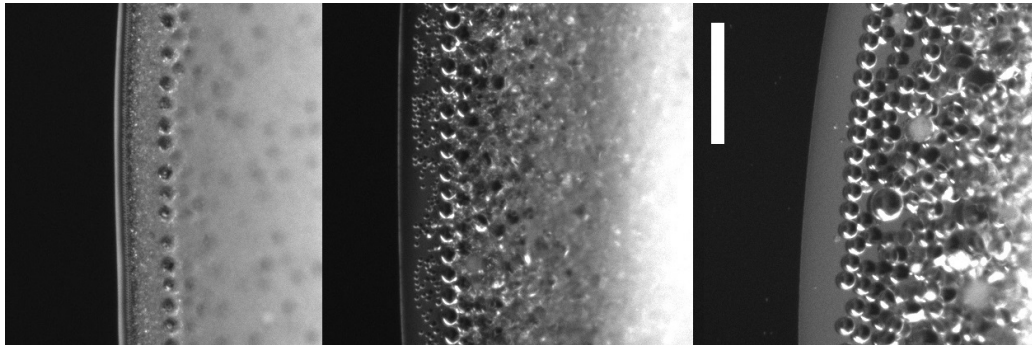


Figure 1. Abords de la ligne de contact en avancée pour des suspensions de particules de (10-80), (20-80) et (80-250) microns. Vues du dessus, échelle : 500 microns.

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Ultimate regime of transport of angular momentum in Keplerian turbulence

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We report an experimental analogue to astrophysical accretion disks in liquid metal. Accretion disks are turbulent gas in Keplerian rotation around massive central bodies like protostars or black holes. They exhibit large values of accretion: transport of matter toward the center of the disk. By conservation, this matter flow implies an important outward transport of angular momentum. The molecular viscosity is of course far too small to be responsible for this transport. Although several mechanisms have been proposed to answer this issue (Magnetorotational instability, sub-critical transition to turbulence), there is still no clear agreement to explain this transport [1].

Here, the fluid is driven by an electromagnetic force which enables the flow to reach a turbulent state where the mean azimuthal velocity scales as $\overline{u_\theta} \sim r^{-1/2}$ [2], known in Astrophysics as 'Keplerian rotation'. The presence in this regime of fully developed turbulence leads to an Ultimate transport of the angular momentum, as predicted by Kraichnan for the transport of heat in Rayleigh-Bénard. This transport is therefore independent of the molecular viscosity since it is only due to turbulent structures. The Ultimate regime is characterised by a prediction for the Nussult number $Nu_\Omega \propto \sqrt{Ta}$ which is well verified experimentally [3].

This experiment thus offers a configuration analogous to accretion disks. An effective "accretion rate" can be computed for both accretion disks and Kepler experiment. The good agreement between Kepler accretion rate and values measured for accretion disks around T-Tauri stars supports the idea that turbulence is able to transport efficiently the angular momentum in accretion disks.

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Distribution des gouttes de pluie créée par une cascade inverse contrôlée par la gravité

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La distribution de la taille des gouttes de pluie suit une forme particulièrement simple, mesurée au siècle dernier [1]. Elle est exponentielle, et le diamètre moyen des gouttes de pluie augmente avec l'intensité de la pluie. Pourtant, cette relation reste encore mal expliquée. La dépendance du diamètre moyen avec l'intensité implique un contrôle de la polydispersité des gouttes de pluie par des effets collectifs, et non par l'instabilité ou l'évolution stochastique des gouttes individuelles. Nous montrons ici, à partir des premiers principes de l'hydrodynamique, que la coalescence des gouttes par gravité contrôle la distribution de la taille des gouttes de pluie. Notre théorie adapte le concept de cascade d'énergie à travers les échelles de la turbulence à la distribution de la masse des gouttes. Nous dérivons la distribution de l'état d'équilibre atteint lorsque les gouttes nucléent à un taux constant en résolvant la condition d'un flux de masse d'eau constant à travers les échelles, et nous la comparons aux données expérimentales existantes.

Un aspect clé du modèle est la section efficace de collision des gouttes qui sédimentent : les grosses gouttes tombent plus vite que les petites et coalescent avec elles sur leur chemin. Paradoxalement, la pression de lubrification due au film d'air piégé entre les gouttes diverge rapidement comme l'inverse de la séparation, empêchant toute collision. Nous améliorons ici la description hydrodynamique des collisions en considérant à la fois l'interaction hydrodynamique à longue distance et le film de lubrification qui se forme entre les gouttes immédiatement avant la collision. Deux mécanismes différents régularisent la divergence de la pression au contact : la transition vers un régime de gaz dilué dans le film de lubrification, lorsque l'écart est comparable au libre parcours moyen de l'air, et la formation d'un écoulement à l'intérieur des gouttes par le cisaillement à leur surface. Nous calculons l'efficacité de collision, et la décomposons en la somme d'une contribution suramortie et d'une contribution inertielle, analysées séparément. Les principales caractéristiques du régime inertiel sont interprétées en utilisant des collisions frontales, dans lesquelles la lubrification crée un seuil de vitesse pour la collision. Nous montrons que la lubrification est responsable d'une diminution de l'efficacité de collision à l'échelle pour laquelle l'inertie et la dissipation visqueuse sont de magnitude comparable. La lubrification explique ainsi la stabilité relative des brouillards et des nuages ne produisant pas de précipitations, formés de gouttelettes micrométriques. Cela ouvre la possibilité d'améliorer la description de la microphysique des nuages dans les simulations atmosphériques.

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Human-scale Brownian ratchet: A historical thought experiment

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We present an experimental realization at macroscopic scale of the storied Brownian ratchet, which is an illustration of the Maxwell's demon. In our mechanism, the rotation of a centimeter-scale 1D Brownian object in a granular gas is detected by an electromechanical converter (dynamo), generating a voltage proportional to its angular velocity. The current generated by this random rotation is rectified by an electronic device (demon), such that only positive current passes. Eventually, work can be produced. The advantage of such a macroscopic setup is to allow measurement of all the observables with time: useful power (work), heat taken from the bath, and finally the efficiency of the equivalent heat engine. The feedback allowing the conversion from heat into work expresses as a bias on the Brownian motion.

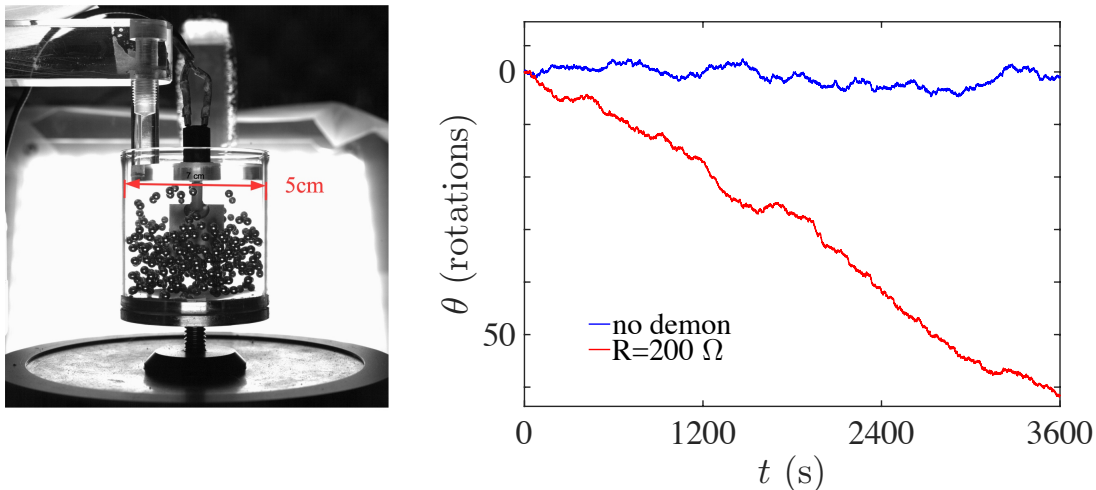


Figure 1. Left: Picture of the experimental system. The beads are vibrated vertically in a vessel by an electromagnetic shaker. A 2 cm-diameter rotor is immersed in the grains, fastened on the shaft of a small dc motor. Right: realizations of Brownian trajectories, with and without the demon.

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Embolism growth in biomimetic leaves: from veins to networks

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In case of drought, the water in the xylem hydraulic circuits of trees falls down to very negative pressures. Cavitation bubbles can nucleate, initiating an air embolism that propagates, a process called air-seeding, leading to the failure of the water circulation. Observations on real leaves showed that the embolism advances by a succession of long stops and sudden jumps. To understand the nature of jumps, we propose an experimental model using biomimetic leaves in silicone (PDMS), made of a thin water-permeable membrane [1,2]. The veins of these artificial leaves are channels filled with water, and here we have introduced constrictions to mimic the pits in between real leaf channels. We observed that the jumps after each constriction are due to the sudden release of an elastic deformation of the channels, occurring when the meniscus is pinned and evaporation continues. The jumps of the meniscus can reach directly the next constriction (when it is nearby) or can reach the inside of the next channel and are followed by a slow progression of the evaporation. A simple model enables to capture this peculiar stop-and-go dynamics, and is successfully applied to quantitative data extracted from experiments realized with real *Adiantum* leaves (Fig. 1 (a)).

The geometry of our biomimetic leaves can be made more complex by using branched vein networks similar to those of oak trees (Fig. 1 (b)). In this case, the embolism exhibits complex propagation fronts, which we aim to control by modifying the spatial distribution of the pit-like constrictions.

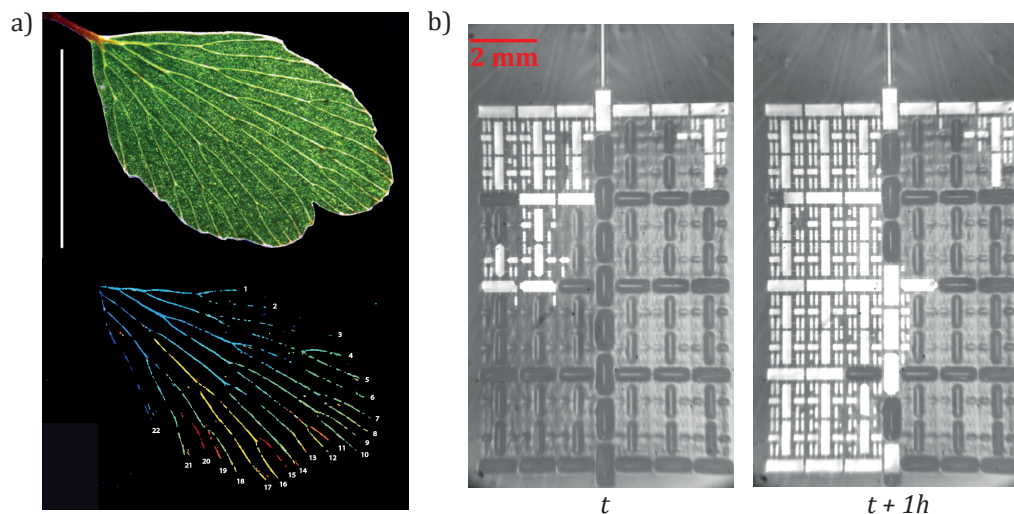


Figure 1. (a) Picture of a drying *Adiantum* leaf (top) and reconstruction of the embolism propagation path (bottom) in each of the 22 veins. The color represents time, from early (blue) to late embolism (red). (b) Biomimetic branched network of veins. Air embolism (light) propagates by jumps, from pits to pits as water (dark) evaporates.

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Rheology, tribology, and acoustic lubrication of dense non-Brownian suspensions

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Suspensions are dispersions of solid particles in a fluid. Their rheology [1] implies a linear dependence of the shear stress σ on the shear rate, as a function of the microscopic friction μ_p between the particles. The coupling between the flow, the normal forces, and μ_p , induces a strong dependence of the rheology on σ . While the theoretical framework is well-established, measurements of the microscopic properties are missing.

In this presentation, I will show how one can use Tuning-Fork Microscopy (TFM) to measure μ_p between solid polystyrene (PS) particles immersed in a solvent, and how our results compare with the numerical simulations found in the literature [2,3], and moreover, provide novel insights on the origin of the rheological behaviors of suspensions [4]. This study focuses on three typical solvents: I will show that both PEG and water lead to constant values for μ_p (resp. 0 and 0.13), while Silicon (Si) oil leads to a decrease of μ_p with increasing load σ . The TFM results are consistent with the rheology: for Si oil, μ_p depends on the contact elasticity and thus on the applied load; PS-water exhibits a constant viscosity up to a critical shear stress from which a shear-thickening behavior is observed. Because the applied stress is less than the critical value at which electrostatic repulsive forces are overcome in the inter-particle contacts, the observed transition in the rheology is not due to a change in the nature of particle contacts (from frictionless to frictional) but instead finds its origin in a change of regime from viscous to inertial, as suggested by Fall et al. [5]. PS-PEG has a Newtonian behavior but exhibits shear-thinning when the volume fraction ϕ gets close to Random Loose Packing: the swelling of the beads induces a repulsive force preventing particle contact, except at high ϕ .

Following these experiments, I will also present recent results from a new experiment in which ultrasounds activate a PS-Si oil suspension. While in this suspension μ_p can decrease with increasing shear stress, I will show that it is also possible to tune it down by propagating ultrasounds into the suspension: in the presence of ultrasound, at constant stress, the microscopic friction coefficient is replaced by a lower effective microscopic coefficient. This leads to a decrease in the viscosity of the system at fixed imposed stress and solid fraction.

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Vortex clustering, polarisation and intermittency of velocity circulation in quantum turbulence

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The velocity circulation, a measure of the rotation of a fluid within a closed path, is a fundamental observable in classical and quantum flows. In quantum flows, circulation is quantized, taking discrete values that are directly related to the number and the orientation of thin vortex filaments enclosed by the path. By varying the size of such closed loops, the circulation provides a measure of the dependence of the flow structure on the considered scale. Here, we consider the scale dependence of circulation statistics in quantum turbulence, using high-resolution direct numerical simulations of a generalized Gross–Pitaevskii model. Results are compared to simulations of the incompressible Navier–Stokes equations. When the integration path is smaller than the mean intervortex distance, the statistics of circulation in quantum turbulence displays extreme intermittent behavior due to the quantization of circulation, in stark contrast with the viscous scales of classical flows. In contrast, at larger scales, circulation moments display striking similarities with the statistics probed in the inertial range of classical turbulence, including intermittency deviations from Kolmogorov’s theory [1–3]. Our results strongly reinforce the resemblance between classical and quantum turbulence, highlighting the universality of inertial-range dynamics, including intermittency.

We also propose quantum turbulence as a composition of two effects: the polarisation of vortices that leads to the formation of vortex bundles and self-similar Kolmogorov scaling properties, and the clustering of vortices that leads to multifractality and intermittent deviations. We test this idea by taking a quantum turbulent vortex configuration and randomizing their signs, keeping their positions fixed.

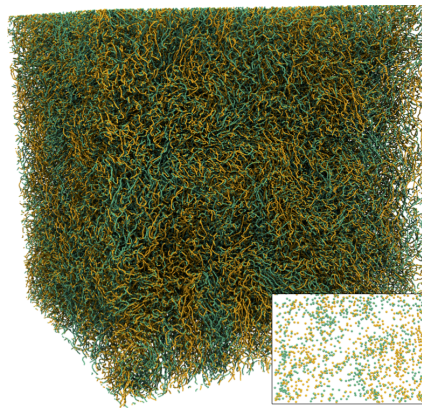


Figure 1. Visualisation of a quantum turbulent vortex tangle. Instantaneous state obtained from GP simulations using 2048^3 collocation points. Green and yellow colours correspond to opposite orientations of the vortex lines with respect to the vertical direction. The inset shows a horizontal two-dimensional cut of the system.

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Dynamique des tourbillons chauffés (ou refroidis) radiativement dans la stratosphère

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Le panache stratosphérique des grands feux de forêts australiens en 2019–2020 a permis la découverte d'un phénomène nouveau et surprenant pour l'hydrodynamique des fluides tournants stratifiés : l'auto-organisation du panache sous forme de tourbillons anticycloniques persistants sous l'effet du chauffage radiatif des fumées. L'un de ces tourbillons a persisté trois mois, parcouru 66 000 km et est monté de 16 à 36 km [1]. De tels tourbillons ont été détecté depuis dans des feux antérieurs [2]. L'éruption récente de Tonga en janvier 2022 a montré un cas similaire de structures vorticales formées cette fois par un refroidissement intense [3]. De tels phénomènes n'ont à ce jour pas d'analogie connue dans la nature et n'ont jamais été décrits dans la littérature. Cette présentation décrira d'abord brièvement les phénomènes observés et présentera ensuite les éléments de théorie qui expliquent la formation d'un front ascendant de traceur chauffant et de vorticit e potentielle proche de z ero,   la limite de l'instabilit e inertielle, maintenant et propulsant le tourbillon. Les r esultats de simulations num eriques dans une simplification axisym etrique, montrant la structure radiale inattendue du tourbillon, seront pr esent es et discut es. Nous esp erons pouvoir aussi montrer les premiers r esultats des exp eriences de laboratoire en cuve tournante.

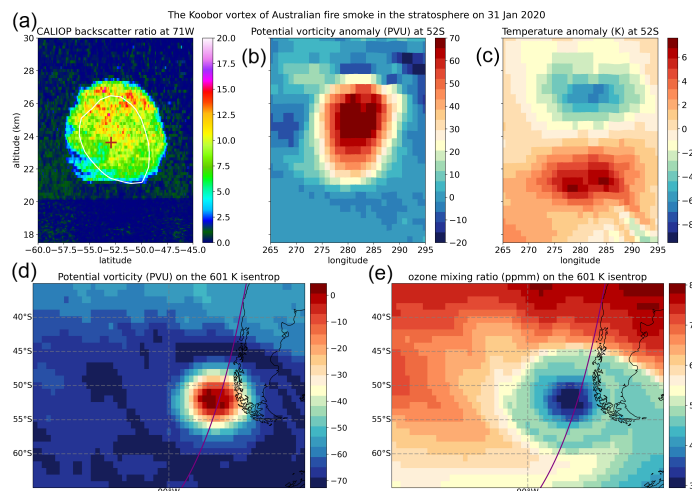


Figure 1. Description de l'observation qui a motiv e cette  tude. (a) Boule de fum e vue par le lidar spatial CALIOP. La quantit e montr ee est le rapport de la r etro-diffusion observ ee   la r etro-diffusion mol eculaire. La croix indique le centre du tourbillon. (b) Distribution d'anomalie de vorticit e potentielle (en PVU) restitu ee par l'analyse m et eorologique en section selon la latitude 52 S. (c) Distribution de l'anomalie de temp erature (en K) selon la m eme section. (d) Coupe horizontale de la vorticit e potentielle (en PVU) sur le niveau de temp erature potentielle 601 K. (e) Coupe horizontale de l'anomalie d'ozone associ ee (en ppmv). 1 PVU = 10⁶ m² K kg⁻¹ s⁻¹)

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A breath figure describes the droplet pattern formed when a vapor condenses onto a surface. First, nanometric droplets of spherical cap shape are created by heterogeneous nucleation. When vapor is constantly provided (supersaturated atmosphere, cold enough surface...), this breath figure evolves with time, the average droplets radii increase. This evolution has been actively studied in the last decades, motivated by understanding nucleation effects [1], thin film vapor deposition, development of anti-dew surfaces and dew recovery system [2, 3].

We present here the effect of a mechanical impact on a solid substrate supporting a breath figure. A falling spherical metallic ball impacts the top of the plate, the droplets being on its bottom part. We changed the drop height of the projectile and we observed at different locations the evolution of the breath figure with time. We compared the droplets size distributions before and after impact using the droplet number reduction (%DNR). We show that, for a given mean radius of the droplets, when the acceleration of the substrate exceeds a threshold, the final number of droplets starts to decrease and keeps on decreasing as acceleration is increased. We interpret this result knowing that droplets vibrate, their contact line unpin above a threshold in acceleration [4], presenting oscillations of their radius. This makes them contacting and coalescing with neighbours giving birth eventually to liquids networks. The impact accelerates the natural aging of a breath figure. This could provide a new solution to increase the efficiency of dew recovery processes [5].

For a better understanding, we then focused on the coalescence dynamics between two water droplets partially wetting under vibrations. We show that several behaviours can then be expressed as function of the contact line speed and the substrate wetting properties.

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**Exposés courts de la 26^e Rencontre
du Non-Linéaire**

Finger revival and reconnections near breakthrough in unstable growth processes

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Transport networks, such as vasculature or river networks, provide key functions in organisms and the environment. They often emerge as a result of unstable growth processes, in which growing branches compete for the available flux. This leads to effective repulsion between the branches and screening of the shorter ones. We show that a striking transition in growth dynamics takes place as the leading branch reaches the boundary of the system. The shorter branches revive then and grow toward the leading one forming loops. These effects are found in a large variety of systems (Fig. 1 (b–d)): dissolving fractures, viscous fingering, discharge patterns, and even growth of a gastrovascular canal network of the jellyfish *Aurelia* (Fig. 1 (e)). The ubiquity of this process suggests the existence of a shared underlying mechanism, which we elucidate.

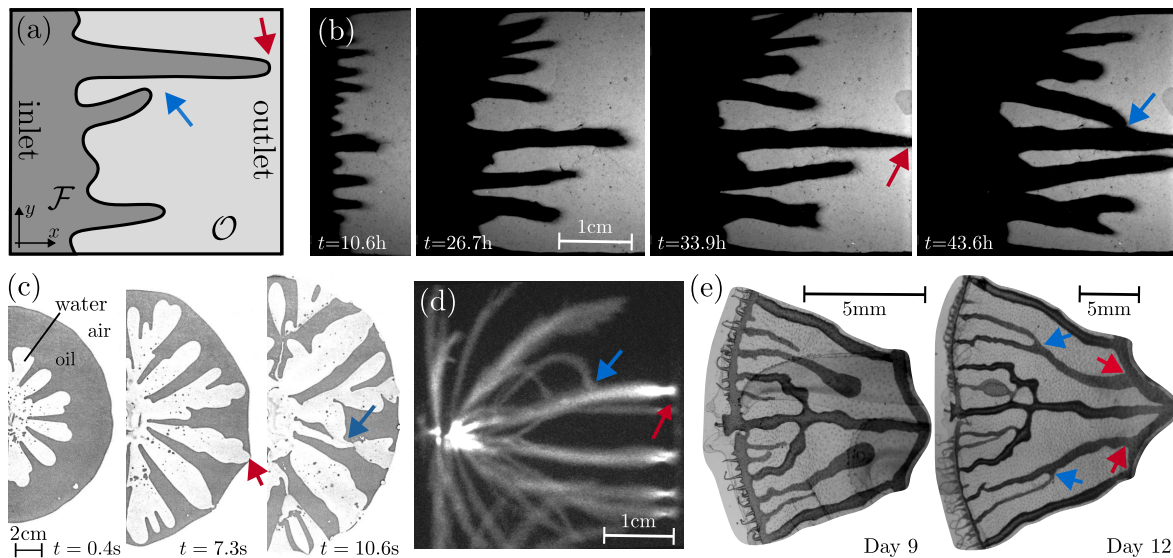


Figure 1. Systems near breakthrough in nature. (a) Each system consists of two phases: an invading phase with mobility λ_1 (\mathcal{F}), and a displaced phase with mobility λ_2 (\mathcal{O}), separated by an interface. Growth direction is from left to right. Red arrows mark places where the fingers are near breakthrough or already broke through, and blue arrows mark associated breakthrough reconnections. (b–e) Examples of breakthrough reconnection in various systems: (b) a fracture dissolution experiment in a Hele-Shaw cell, (c) viscous fingers in the Saffman–Taylor experiment, (d) streamer channels in air (photo: Sander Nijdam, Eindhoven University of Technology, by permission), (e) an octant of the jellyfish *Aurelia*, showing the gastrovascular canal network in dark gray.)

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Pourquoi est-il si difficile de définir un seuil pour le régime de filamentation laser ?

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La filamentation est un régime de propagation non linéaire et autoguidé typique des lasers de haute intensité. Ses propriétés spectaculaires, dont la propagation sur de longues distances, l'émission intense de lumière blanche émise par le plasma sur les côtés ainsi que par l'automodulation de phase vers l'avant, et le bruit caractéristique de l'onde de choc dans l'air donnent l'intuition d'un régime qualitativement distinct de la propagation linéaire. Cependant, il s'avère difficile de définir un seuil univoque définissant la filamentation [1], en particulier dans les faisceaux focalisés où la propagation linéaire est suffisante pour atteindre le seuil d'ionisation. De la même manière, dans le domaine spatial, définir le début et la fin de la filamentation nécessite un choix partiellement arbitraire.

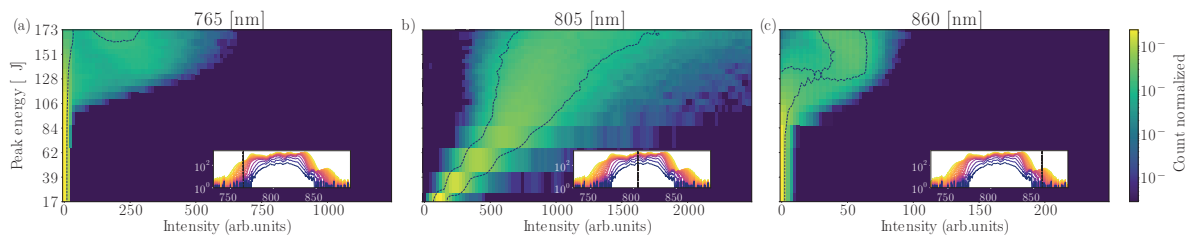


Figure 1. Évolution de l'histogramme de l'intensité spectrale à (a) 765 nm (transition via une distribution bimodale), (b) 805 nm (décalage progressif du pic de la distribution) et (c) 860 nm (transition bimodale) pour des intensités incidentes croissantes. Chaque histogramme est normalisé à 1. Les médaillons montrent la position de la longueur d'onde considérée dans le spectre.

Nous étudions d'un point de vue statistique la transition vers la filamentation. Nous caractérisons l'élargissement spectral, et plus précisément la distribution de probabilité des intensités spectrales. L'évolution en fonction de l'intensité incidente des distributions de probabilité est contrastée selon la longueur d'onde, faisant apparaître deux régimes. Au centre du spectre, le mode de la distribution se décale progressivement vers les hautes intensités (Figure 1 (b)), tandis que sur les bords du spectre de la lumière blanche, la transition se produit par l'apparition d'un nouveau mode de haute intensité au détriment du mode initial de faible intensité, avec une étape bimodale pour des intensités incidentes intermédiaires (Figure 1 (a,c)). Ces comportements contrastés pourraient être à l'origine de la difficulté de définir de manière univoque un seuil de filamentation et offrir une explication à l'absence jusqu'à ce jour de définition claire de la limite du régime de filamentation [2].

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Dynamique bi-stable des lacs sous-glaciaires

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Les inlandsis de l'Antarctique et du Groënland cachent de nombreux lacs sous leur épaisse couche de glace. Ces lacs sous-glaciaires sont le siège de deux types d'écoulements que nous avons étudiés numériquement afin d'améliorer notre compréhension des conditions physiques de ces environnements d'intérêt pour le paléoclimat et la vie en milieu extrême. Tout d'abord ils peuvent être le siège d'une circulation verticale s'apparentant à la convection de Rayleigh–Bénard, forcée par le flux géothermique. Puis ils peuvent également être le siège d'une circulation principalement horizontale, forcée par la pente de l'interface eau–glace, qui tend à générer des écoulements thermiques gravitaires accolés à la paroi de glace. La question posée est alors : laquelle de ces circulations domine dans les lacs sous-glaciaires ? Dans cette présentation nous discuterons les résultats de simulations numériques qui nous ont permis de déterminer les paramètres clés contrôlant la dynamique de ces systèmes, l'existence d'une gamme de paramètres pour lesquelles une bi-stabilité est obtenue et notre prédiction actuelle (et provisoire) sur la dynamique attendue des lacs sous-glaciaires de l'Antarctique et du Groënland.

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Spontaneous suppression of inverse energy cascade in instability-driven 2D turbulence

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Instabilities of fluid flows often generate turbulence. Using extensive direct numerical simulations, we study homogeneous two-dimensional turbulence driven by a wavenumber-localised instability superposed on stochastic forcing, in contrast to previous studies generally focusing on a purely stochastic and state-independent forcing [1].

As the contribution of the instability forcing increases, the system undergoes at least two transitions. Below a first threshold, a regular large-scale vortex condensate forms. Above this threshold, shielded vortices (SVs) emerge within the condensate. These vortices are tripolar and are characterised by an outer ring and a core having opposite vorticity sign. At the instability strength increases, the condensate breaks down, and a gas of weakly interacting vortices with broken symmetry spontaneously emerges, characterised by preponderance of vortices of one sign only and quasi-suppressed inverse energy cascade. The latter transition is shown to depend on the damping mechanism necessary to reach a steady state in such a system. Bistability is observed between the condensate and mixed SV-condensate states.

The number density of SVs in the broken symmetry state slowly increases via a random nucleation process. After a very long transient, yet another transition towards a perfect hexagonal lattice of vortices is observed, reminiscent of solutions obtained in active matter models such as the Toner–Tu model [2]. Our findings provide new evidence for a strong dependence of two-dimensional turbulence phenomenology on the forcing [3].

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Epidemic model with four compartments and retarded transition rates

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The first modern approach of epidemic dynamics appeared almost a century ago in the seminal work of Kermack and Mc Kendrick who introduced the ‘SIR - model’ considering three states (‘compartments’) of health (susceptible, infected, recovered) [1]. This presentation is devoted to an epidemic model for a constant population by taking into account four compartments of individuals characterizing their states of health. Each individual is in one of the compartments susceptible (S); incubated – infected yet not infectious (C), infected and infectious (I), and recovered – immune (R). An infection is ‘visible’ only when an individual is in state I. Upon infection, an individual performs the transition pathway $S \rightarrow C \rightarrow I \rightarrow R \rightarrow S$ remaining in each compartments C, I, and R for certain random waiting time t_C, t_I, t_R , respectively. The waiting times for each compartment are independent and drawn from specific probability density functions (PDFs) introducing memory effects into the model [2] generalizing our previous model [3].

In the first part we introduce the macroscopic SCIRS model. We derive memory evolution equations involving convolutions (time derivatives of general fractional type). We consider several cases. The memoryless case is represented by exponentially distributed waiting times. Cases of long waiting times with fat-tailed (power-law) waiting time distributions are considered as well where the SCIRS evolution equations take the form of time-fractional ODEs. We obtain formulae for the endemic equilibrium and a condition of its existence for cases when the waiting time PDFs have existing means. We analyze the stability of healthy and endemic equilibria and derive conditions for which the endemic state becomes oscillatory (Hopf) unstable.

In the second part we present computer simulations of a simple multiple random walker’s approach (microscopic model of Brownian motion of Z independent walkers) with above random SCIRS waiting times where Python programming language is used. Infections occur with a certain probability by collisions of infectious with susceptible walkers. We compare the endemic states predicted in the macroscopic model with the numerical results of the simulations and find accordance of high accuracy. We conclude that a simple random walker’s approach offers an appropriate microscopic description for the macroscopic SCIRS model.

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Recent progress on smooth self-similar solutions to the compressible Euler equations

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I am going to discuss recent developments in singularity formation in the compressible Euler equations. In particular, I will focus on implosions, a phenomenon where a fluid concentrates at a point, resulting in the breakdown of the Euler equations. This process is modeled by self-similar solutions, whose generic mechanisms are known since the pioneering work done by Guderley in 1942 [1]. Despite this fact, we have recently lived a revival of the problem with the discovery and study of an unknown class of self-similar solutions (smooth profiles) [2–4] among the generic ones (non-smooth profiles) uncovered by Guderley 80 years ago. In this talk, I will discuss the differences between self-similar solutions in the 20th century [1,5] and the 21st century [2–4], as well as the differences in their stability analysis performed in [5] and [3], respectively.

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Reversible Navier–Stokes equation on logarithmic lattices

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We study the three-dimensional Reversible Navier–Stokes equations first introduced by [1,2], in which the energy is kept constant by adjusting the viscosity over time. We perform numerical simulations of these equations using a new framework called log-lattices, to reach extremely large resolutions at a moderate numerical cost. This technique allows us to explore regimes of parameters that were out of reach of the previous direct numerical simulations of [2]. Using the non-dimensionalized forcing as a control parameter, and the square root of enstrophy as the order parameter, we confirm the existence of a second order phase transition well described by a mean field Landau theory. The log-lattices framework allows us to probe the impact of the resolution, highlighting an imperfect transition at small resolutions with exponents differing from the mean field predictions. Our findings are in qualitative agreement with predictions of a 1D nonlinear diffusive model, the reversible Leith model of turbulence.

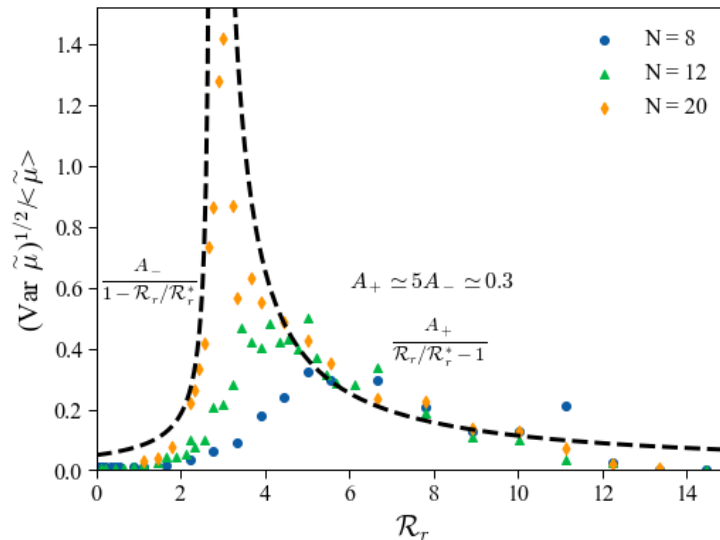


Figure 1. Second order transition for Reversible Navier–Stokes on log-lattices. Figure shows the variation of the square-root of the enstrophy as a function of a dimensionless control parameter $\mathcal{R}_r = f_0/(E_0 k_f)$.

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Efficacité de la propulsion intermittente

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De nombreuses espèces de poissons utilisent un mode de locomotion intermittent lors de la nage au lieu de se propulser continûment. Ce type de nage, appelé *Burst and Coast* est supposé être plus énergétiquement avantageux pour les poissons [1, 2]. Nous étudions un système nouveau : un bateau à hélice qui utilise cette stratégie bioinspirée pour réduire sa consommation. L'expérience consiste en un bateau libre de se déplacer dans un écoulement à surface libre (Fig. 1). L'hélice est actionnée durant un temps $\Delta \times T$ puis le bateau utilise l'inertie accumulée pour glisser vers l'avant pendant le reste de la période $(1 - \Delta) \times T$. Nous mesurons directement la consommation énergétique du système à l'aide d'un dynamomètre et d'un capteur de vitesse angulaire. En comparant la consommation énergétique à celle du bateau propulsé continûment à la même vitesse moyenne, nous mettons évidence un paramètre crucial de la locomotion intermittente : le contraste de traînée entre les phases actives et passives. Dans le cas des poissons, la traînée dans la phase active est environ 4 fois plus importante que dans la phase passive. Pour reproduire ce phénomène nous utilisons une hélice pliable capable de s'ouvrir et de se fermer passivement au rythme des activations du moteur.

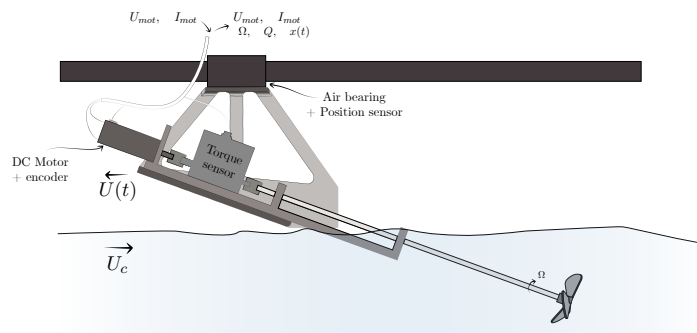


Figure 1. Schema du dispositif expérimental

En utilisant ce type d'hélice nous montrons que la propulsion intermittente par hélice peut être plus efficace que la propulsion continue. Dans le cas optimal, à vitesse égale, la consommation est réduite de 27 % en utilisant la propulsion intermittente. Nous détaillons un modèle avec une approche quasi-statique qui permet de prédire la consommation en fonction des paramètres de la propulsion (période, rapport cyclique, vitesse, etc.). Ce modèle permet en particulier de montrer qu'il existe une réduction de traînée minimale pour que la propulsion intermittente soit favorable. Si la traînée dans la phase passive est plus grande que 0,4 fois la traînée dans la phase active, la propulsion continue est la plus efficace.

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The mixing dynamics of the blast-driven instability

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The fluid mixing caused by variable-density instabilities is important in a wide variety of scenarios from ocean mixing and astrophysical phenomena to nuclear fusion techniques and atomic weapons. This work explores the mixing resulting from a specific instability known as the Blast-Driven Instability (BDI). Using high speed experimental techniques, the first fully time-resolved observations of the BDI are made [1]. These observations have been used to test common mixing models (RANS and LES) in a "digital-twin" simulation [2]. The experimental data is used in conjunction with the simulation results to explore the BDI's sensitivity to two key governing parameters: the blast Mach number, M , and normalized density ratio, A . How changes in these governing parameters create qualitative and quantitative changes in the BDI's behavior is explored extensively. Finally, various scaling attempts are investigated in an attempt to decipher how the mixing induced by the BDI can be explicitly linked to these parameters.

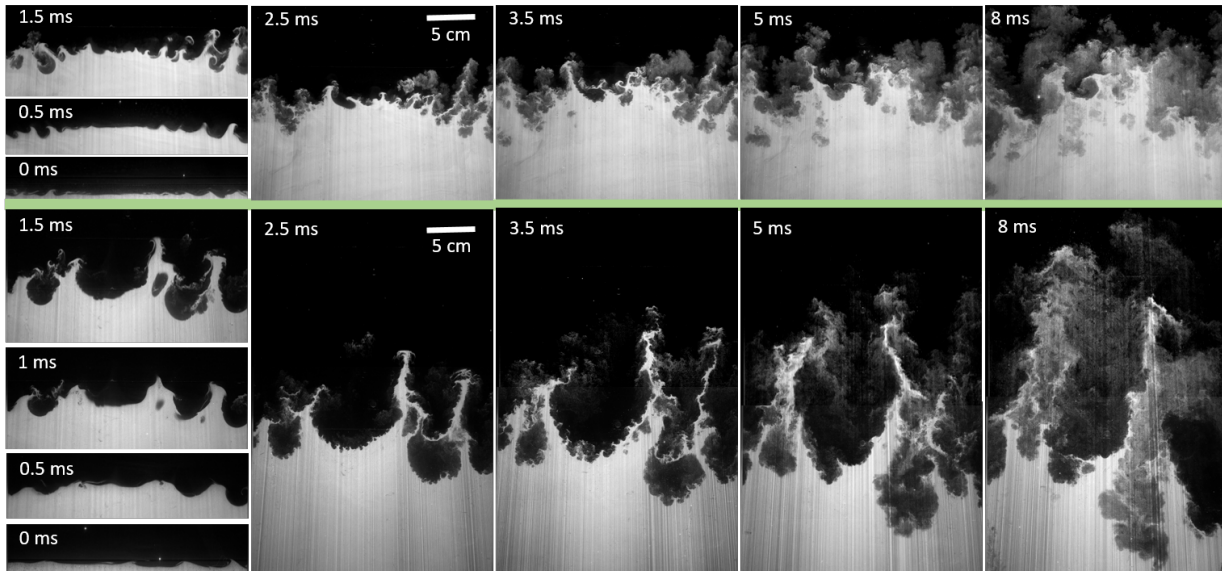


Figure 1. Experiments with $M = 1.55$ and different A , with the two cases separated by the green bars. Top row: $A = 0.68$ and bottom row: $A = 0.95$. In all cases the IC prior to blast impact is shown at $t = 0$ ms. The different morphological development in each highlights some of the effects caused by varying the driving parameters.

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Some key ingredients for observing an internal gravity waves turbulence regime

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Stratified flows support the propagation of internal gravity waves that interact nonlinearly. The Wave Turbulence Theory (WWT) aims to describe the collective behavior of such waves systems, when the interactions are weakly nonlinear [1–4]. Yet, the presence of shear modes, vortical modes [5], and wave-breaking [6] makes the observation of an internal gravity-waves turbulence regime in a realistic flow delicate, if not impossible.

We performed Direct Numerical Simulations of linearly stratified flows in a periodic domain, with and without vortical modes, using a pseudo-spectral solver [7]. We varied the values of the control parameters, namely the Froude and Reynolds numbers, in order to assess the existence of a wave turbulence regime.

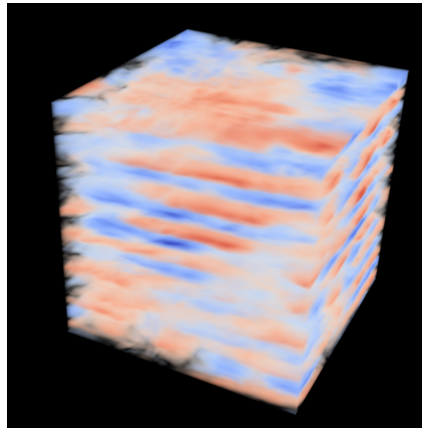


Figure 1. Buoyancy field of a strongly stratified flow without vortical modes.

We report that not only a strong stratification matters for observing internal gravity waves turbulence. (i) Keeping the aspect-ratio of the domain close to unity, (ii) having a scale separation between the eddy turnover time and the wave-period [8], and (iii) forcing at high frequency and small spatial scales are important as well. For more, vortical mode energy is never negligible when they are not removed from the dynamics. These results motivate the removing of the hydrostatic hypothesis when considering the problem of interactions between internal gravity waves.

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Three-dimensional structure of turbulent transport by Ocean mesoscale turbulence

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Ocean mesoscale eddies are vortices of typical scale tens of kilometers that enhance the transport of heat, salt and other flow tracers across latitudes. This process is especially crucial in the Antarctic Circumpolar Current, where it contributes to setting the deep stratification of the neighboring ocean basins. Despite this significant impact on ocean transport properties, mesoscale vortices remain unresolved in global climate models and the associated transport needs to be parameterized.

Leveraging the scale separation between the small mesoscale eddies and the large ocean basins, the parameterization takes the form of a diffusion tensor relating the turbulent fluxes to the background gradients. The most common choice for this diffusion tensor is the Gent–McWilliams/Redi parameterization scheme, which was designed based on the intuition that rapidly rotating density-stratified fluids flow along density surfaces [1, 2].

We propose a direct derivation of the Gent–McWilliams/Redi parameterization from the dynamics of a rapidly rotating strongly stratified patch of ocean, that hinges on the identification of a new material invariant of the dynamics. The derivation provides new relations between the two unknown coefficients of the parameterization that constrain the vertical profiles of the turbulent fluxes within the water column.

We validate these findings by comparison to numerical simulations of idealized patches of ocean [3].

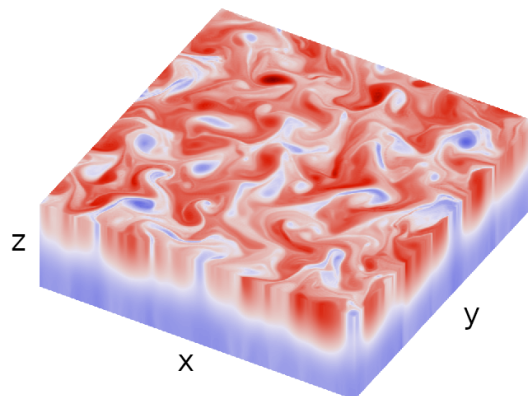


Figure 1. Visualisation of mesoscale eddies in a simulation of an idealized patch of ocean using the departure temperature field.

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Experimental study of the penetrative convection in gases

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Long-time evolution of stars is only accessible through parameterised models that rely on correct physical modelling of small-scale, rapid processes. In particular, their lifetimes depend on the mixing of their nuclear fuel that can happen at the interface between a convective and a stratified radiative zone. Stellar convection zones are strongly turbulent and their interaction with a stratified layer, called penetrative convection, is still hard to model properly. Experimental investigation of this interaction is thus needed. Most experimental studies used liquids, specifically heated (resp. salty) water [1–3], where the Prandtl (resp. Schmidt) number Pr is equal to 7 (resp. 700), when in stars $Pr \ll 1$. On the contrary, our setup takes the advantage of using gases and reaches $Pr = 0.7$.

A heavy gas (SF_6) fills the bottom of a rectangular tank with dimensions $85 \times 85 \times 150$ cm. Diffusion of SF_6 in air quickly establishes a stratified region in the upper part (Fig. 1 (a)). Electric resistors heat the bottom plate of the tank up to a chosen temperature while water circulation fixes the top one at room temperature. The SF_6 lower layer rapidly convects. Mist-makers placed at the top and at the bottom produce droplets used for PIV measurements (Fig. 1 (b)). A density and temperature probe regularly moves up and down during a run (Fig. 1 (a)).

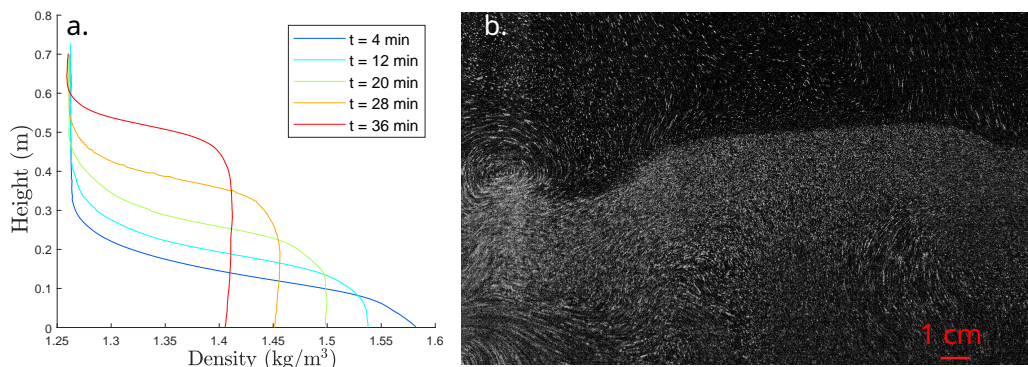


Figure 1. (a) Density profiles measured during an experiment. (b) Superimposition of 5 images from a movie of an experiment, performed at 25 fps. The interface between the lower convective region and the upper stratified one is clear.

When most models use eddy diffusivity mechanisms for the interface growth, we found that it is parabolic in time, which contradicts a turbulent diffusive process. The analysis of the spectra in the stratified domain confirms the presence of propagating internal gravity waves. Running PIV in both layers simultaneously allows us to compute the energy transfer from the convective zone to the radiative one, as well as to investigate scaling laws for the erosion rate.

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Soft violation of Bell's inequality

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Walking drops on Faraday waves are one of the rare examples of non-quantum wave-particle duality. A series of striking experiments with one walking drop has led to behaviors that were thought to be peculiar to the quantum scale. I will present a recent numerical and experimental investigation involving the coupling of two walking drops. To our great surprise, we have found that the statistical behavior of this system shares some non-expected features of collective emission of photons in quantum optics, including superradiance [1] and violation of Bell's inequality [2]. This result is very intriguing as the quantum counterpart is the signature of non-separable states which in our case, is the result of a collective wave self-organisation.

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Statistical mechanics of fracture phenomena and brittle-to-ductile transitions

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The fracture behavior of brittle and ductile materials can be strongly influenced by thermal fluctuations, especially in micro- and nano-devices as well as in rubberlike and biological materials. However, temperature effects, in particular on the brittle thermo-activated fracture and on the brittle-to-ductile transition, still require a deeper theoretical investigation. As a step in this direction we propose a theory, based on equilibrium statistical mechanics, able to describe the temperature dependent brittle fracture and brittle-to-ductile transition in prototypical discrete systems consisting in a lattice with breakable non-linear elements. Concerning the brittle behavior, we obtain closed form expressions for the temperature-dependent fracture stress and strain, representing a generalized Griffith criterion [1], ultimately describing the fracture as a genuine phase transition. With regard to the brittle-to-ductile transition [2–4], we obtain a complex critical *scenario* characterized by a threshold temperature between the two fracture regimes, an upper and a lower yield strength, and a critical temperature corresponding to the complete breakdown. The proposed fracture models are implemented by means of the spin variable approach, useful to deal with arbitrarily non-convex potential energies [5]. This method has been largely applied to several situations including the physics of muscles [6], the folding of macromolecules [7–9], the adhesion or peeling processes [10, 11], and the phase transformations in solids [12]. In the context of fracture, it allows to distinguish between the intact, softened and broken states of the discrete elements and therefore to directly follow the propagation of cracks in given materials and structures.

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Dynamiques bistables markoviennes d'écoulements sur une aile

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Nous étudions expérimentalement la dynamique de l'écoulement autour d'un profil symétrique mince (NACA0012) et un profil asymétrique épais (NACA 63418) pour des nombres de Reynolds Re allant de 50 000 à 110 000. Pour le profil mince nous confirmons que des oscillations à basse fréquence peuvent être observées dans la gamme la plus basse des nombres de Reynolds et autour du décrochage, comme cela a été décrit dans plusieurs études numériques et expérimentales [1–3]. Nous avons découvert qu'au-delà d'une valeur critique du nombre de Reynolds et d'angle d'attaque α , toujours autour du décrochage, la dynamique de l'aile devient bi-stable intermittente et remplace les oscillations à basse fréquence. Dans ce nouveau régime, la boucle d'hystérésis attendue n'est pas observée en raison de la dynamique intermittente, qui relie les deux branches de solutions pour un α fixe. Le profil asymétrique ne présente pas d'oscillations aux basses fréquences ; en revanche, une dynamique bi-stable intermittente est observée dans la gamme des petits nombres de Reynolds, bien avant le décrochage, en coïncidence avec la formation d'une bulle de recirculation sur l'extrados du profil. À notre connaissance, cette dynamique bi-stable intermittente n'a encore jamais été décrite dans la dynamique d'une aile. Elle est caractérisée par des transitions aléatoires sans mémoire entre les états d'écoulements complètement attaché et complètement détaché ; elle peut être décrite par la théorie des chaînes de Markov continues et des événements rares.

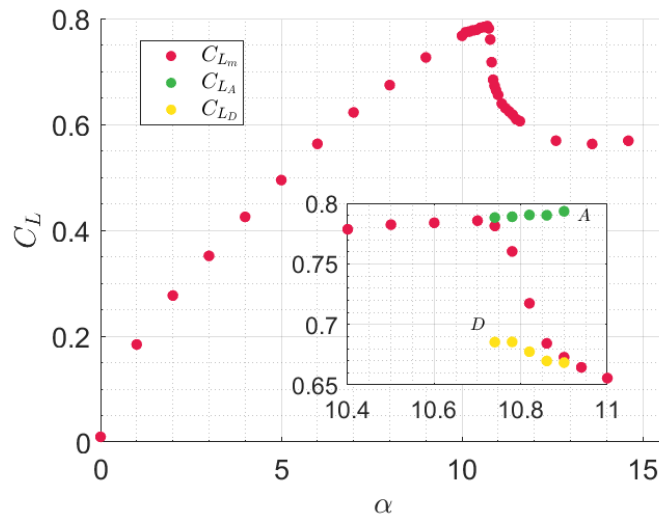


Figure 1. Évolution du coefficient de portance du profil mince en fonction de l'angle d'attaque. Sur une plage finie d'angle critique, le système subit une bifurcation sous-critique qui donne lieu à une dynamique de transitions intermittentes entre les deux branches stables A et D

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Decomposing weather maps into interpretable patterns using Latent Dirichlet Allocation

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The chaotic dynamics of mid-latitude atmospheric circulation is often described with a few number of weather regimes. These are typical field configurations featuring a combination of several synoptic objects (cyclones and anticyclones). Such intrication makes it arduous to quantify recurrence and intensity of climate extremes and to get insight into their genesis and dynamical properties, as extreme events are often associated with specific synoptic structures. Here we apply Latent Dirichlet Allocation (LDA) [1], which has been used for topic modeling in natural language processing (NLP), to build a weather dictionary: we define daily maps of a gridded target observable as documents, and the grid-points composing the map as semantic words. LDA then provides a representation of weather maps in terms of a combination of spatial patterns named motifs, which are latent variables inferred from the set of snapshots. For atmospheric data (daily sea-level pressure anomalies), we find that motifs correspond to pure synoptic objects (cyclones and anticyclones), that can be seen as building blocks of weather regimes. We show that LDA weights provide a natural way to characterize the impact of climate change on the recurrence of patterns associated with extreme events.

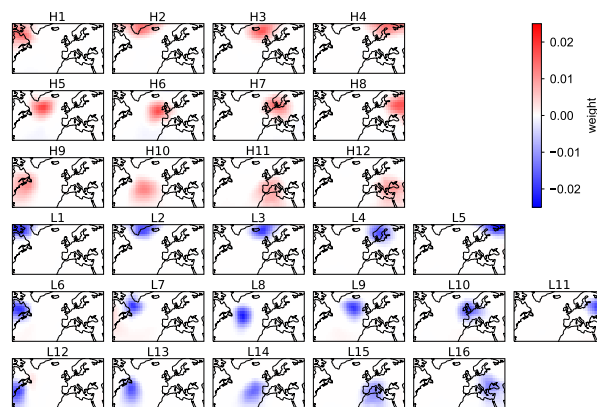


Figure 1. The 28 motifs identified by LDA by using as documents the daily sea-level pressure anomaly maps over North-Atlantic from 1948 to 2018 from NCEP reanalysis. Positive anomalies and negative anomalies are respectively represented in red and blue and are grouped accordingly in high pressure motifs (H) and low pressure motifs (L). The motifs are then roughly ordered by their geographic location from West to East and North to South. LDA outputs normalized weights, so the color intensity should be interpreted as a normalized anomaly amplitude.

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Nonlinear networks and the formation of dissipative solitons in problems of dynamic holography

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Dynamic holographic systems can be considered as a nonlinear network that describes the effects arising due to the coupling of laser beams in a nonlinear medium. A feature of this network is the presence of a coupling function, for which an additional equation can be written. The physical meaning of this function is to describe the evolution of the amplitude of the dynamic grating excited by interacting laser beams, and it obviously includes a temporal relaxation term.

Multiscale analysis has proven to be a powerful technique for considering nonlinear phenomena in various fields including nonlinear mechanics, fluid dynamics, nonlinear optics. It is well known that such a technique has been successfully applied to transform the nonlinear evolutionary sine-Gordon equation into the nonlinear Schrodinger equation (NLS) [1]. We report on the application of the multiscale perturbation method to an entire nonlinear system describing a network. This approach makes it possible to obtain a unified evolutionary equation of the complex Ginzburg-Landau type (CGLE) [2, 3]. It is known that equations of NLS and CGLE types are considered as an universal mathematical approach that gives rise a multiplicity of dissipative soliton (DS) solutions. In this respect, for our system, each DS solution can predict a new effect, which can be achieved by means of dynamic holographic set-ups. A single DS solution describes the formation of a spatially localized profile for the envelope of the amplitude of the dynamic grating. The whole evolutionary process is considered as a nonlinear interaction of two lattices: a light lattice (an interference intensity pattern) and a dynamic grating (a periodic pattern of matter changes photoinduced in a nonlinear medium).

The proposed approach seems to be very promising for practical applications of dynamic holographic systems, which are now experiencing a new leap in development [4]. Their applications occupy manipulations of laser pulses for optical communication technologies, image processing, holographic optical memory, both dynamic and permanent, and even solar energy conversion. Especially it reveals a new look at the development of a holographic artificial intelligence machine (AIM).

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Wave scattering and irreversible wave capturing by two-dimensional turbulent flow

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Coupled wave-flow systems are prone to a wide variety of phenomena. Recently, several studies (e.g. [2] and [5]) have shown that, in the presence of a weak and stationary random mean flow, dispersive waves whose dispersion relation $\omega(k)$ is a power law in k , may exhibit a “scattering” behaviour. In agreement with theoretical surveys [3], said scattering lies on the dispersion relation map in the phase space: the wave vector \mathbf{k} is rotating while its magnitude remains constant (and, consequently, so does the frequency). This process has been proposed for internal waves as well [4] but, due to the particular nature of their dispersion relation, such result does not reflect the capability of the group velocity to evolve without changing the frequency, potentially breaking the fundamental assumption of a weak mean flow compared to the group velocity. In this work, we explore the elementary set of conditions that allows to obtain a scattering only in wave number orientation or both in wave number orientation and magnitude. We show that two regimes coexist with a non-trivial transition from one to the other.

Starting from a set of PDEs describing dispersive waves in presence of a turbulent mean flow, we first present a procedure using the Wigner transform to reduce the system to the following set, constituted of a Liouville equation on the energy density A with a Hamiltonian Ω involving a Doppler shifting term

$$\partial_t A + \{\Omega, A\} = 0, \quad (1)$$

$$\Omega = \omega + \epsilon_0 \mathbf{U} \cdot \mathbf{k}, \quad \epsilon_0 \in \mathbb{R}^+, \quad (2)$$

$$\omega = |k|^\alpha, \quad \alpha \in \mathbb{R}. \quad (3)$$

We identify two relevant parameters for our study: α , controlling the power law of the dispersion relation; and ϵ_0 , indicating the initial ratio between the average value of the stationary mean flow and the initial group velocity. We then investigate this phase diagram thanks to a 2D ray tracing scheme in order to identify the different asymptotic regimes. This scheme is derived from the Hamiltonian system

$$\partial_t \mathbf{x} = \epsilon_0 \mathbf{U}(\mathbf{x}) + \mathbf{c}_g(\mathbf{x}, \mathbf{k}), \quad (4)$$

$$\partial_t \mathbf{k} = -\epsilon_0 \mathbf{k} \cdot \nabla_{\mathbf{x}} \mathbf{U}(\mathbf{x}). \quad (5)$$

We demonstrate that there is a range of dispersive systems for which the frequency stays constant with a scattering only observed in wave number angle. However, for other systems the assumption that the group velocity is larger than the mean flow can break, yielding to a drift in frequency. This scattering is associated to an irreversible wave capturing process by the turbulent flow, the rays being trapped in large scale features. We also show that the existence of these regimes is robust by testing different turbulent flows and that the transition between them is modified when the mean flow becomes time-dependent.

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Le vol des Odonates : une étude mécanique des ailes

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Les Odonates sont l'ordre comprenant les libellules et les demoiselles. Réputées pour leurs capacités de vol exceptionnelles, elles peuvent tout aussi bien voler en zigzag que vers l'avant, l'arrière, faire du sur place, planer, faire des virages serrés ou encore faire de brusques accélérations [1]. Toutes ces trajectoires sont le résultat d'interactions fluide-structure complexes où les propriétés morphologiques des ailes jouent un rôle important [2]. Les ailes d'insectes sont des structures hétérogènes flexibles composées d'une membrane et d'un réseau de nervures qui influence localement la rigidité de l'aile. Les caractéristiques des ailes (taille, géométrie, réseau de nervures, présence de structures spécifiques...) présentent une grande diversité du fait du nombre d'espèces d'Odonates et de leur répartition géographique extrêmement large. L'objectif de notre étude est de comprendre le rôle de différents paramètres impliqués dans la production de force aérodynamique. Ainsi que le lien entre les caractéristiques des ailes, les environnements et les modes de vie de différentes Odonates actuelles. Ces résultats pourront être extrapolés aux formes passées des Odonatopteras, dont les plus anciens fossiles datent du Carbonifère (325-324Ma) [3], afin d'avoir une meilleure compréhension de leur vol, de leur environnement et de leur évolution.

Le vol des Odonates est un vol battu où les ailes subissent de grand déplacement et ainsi que d'importantes déformations. La forme prise au cours du vol a un impact sur la production de force aérodynamique, or cette forme est liée aux propriétés mécaniques de l'aile. Une première étude de caractérisation mécanique d'ailes, provenant de 27 spécimens venant de 9 genres différents, a été réalisée via des tests de vibrations en faible amplitude qui permet notamment de connaître la fréquence de résonance des ailes (Fig. 1).

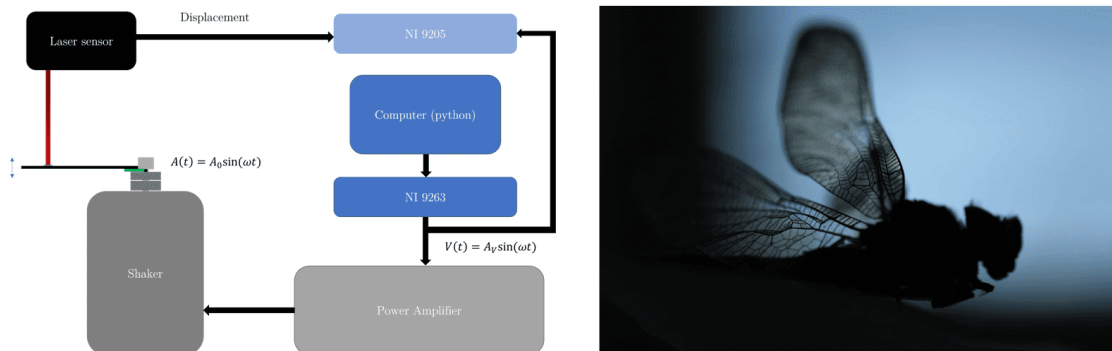


Figure 1. Dispositif expérimental de mise en vibration où un pot vibrant impose un mouvement à la base d'une aile. Le déplacement de l'aile est mesuré avec un capteur laser (a). Détail d'une aile de libellule (b).

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Oscillations du ressaut hydraulique circulaire

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Le ressaut hydraulique circulaire est un phénomène facilement observable lorsqu'un jet vertical impacte une surface horizontale. Une grande partie de la littérature [1–3] s'est concentrée sur l'état stationnaire du ressaut hydraulique circulaire en cherchant à prédire le rayon du ressaut, cependant il existe aussi d'autres travaux qui étudient des ressauts non circulaires [4] et/ou non stationnaires [5, 6].

Nous reportons ici l'observation d'un ressaut hydraulique circulaire oscillant (*i.e.* qui se ferme et se réouvre périodiquement). Nous utilisons un réservoir d'eau à niveau constant en hauteur afin de créer par gravité (donc sans bruit mécanique) un jet d'eau sub-millimétrique impactant un disque de Plexiglas horizontal. Nous construisons alors un diagramme de phase décrivant le comportement de ces oscillations en fonction du débit et du rayon du disque. Nous démontrons ainsi que les fréquences de ces oscillations dépendent du rayon de la plaque mais pas du débit. À l'aide d'un modèle construit à partir des équations de Saint-Venant, nous montrons que ces oscillations peuvent être interprétées comme des modes de résonance de cavité décrits par des fonctions de Bessel de première espèce. Nous excitons enfin d'autres ordres des modes de cavité en déplaçant le jet et observons le couplage de mode lors l'impact simultané de 2 jets. L'accord entre modèle et données expérimentales valide entièrement notre approche.

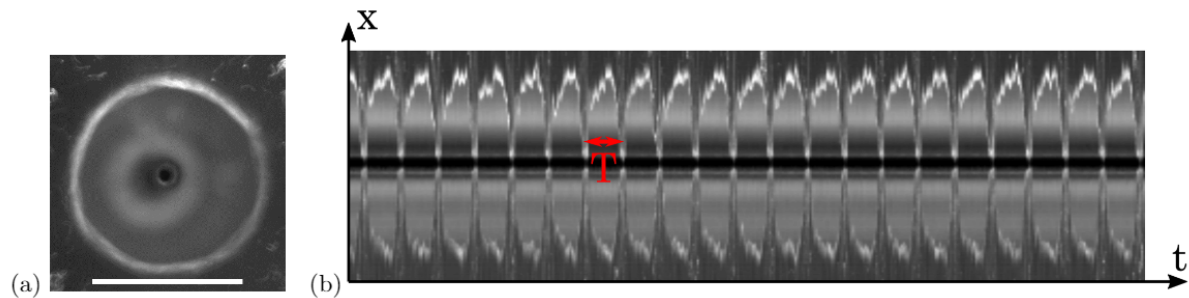


Figure 1. (a) Photographie d'un ressaut circulaire vu de dessous (barre d'échelle : 10 mm). (b) Évolution spatio-temporelle du diamètre d'un ressaut circulaire oscillant sur une durée de 8,15 s sur laquelle les oscillations du ressaut sont clairement visibles. La largeur verticale de l'image correspond à 15,8 mm.

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Efficient training method for a shell model of turbulence

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Learning a complex system is a challenging task. In the turbulence field, it is rarely possible to have access to direct simulations and large datasets. That is one of the main reasons which ask for the development of simplified models of the Navier–Stokes (NS) equations. We focus here on the shell models of turbulence, which have a tractable dimension, and they share with NS fundamental aspects from the Kolmogorov scaling to intermittency. Our goal is to develop a suitable Machine Learning strategy to develop a robust model from data. We have chosen to analyse Recurrent Neural Networks. The standard approach to the training of a Recurrent Neural Network consists in giving the network each time the points in training data and minimising the loss between the training data and the generated ones. We have found that this approach is not able to provide a correct model. This training approach creates a discrepancy between what the model learns and what the model has to be able to do. Indeed the model should be able to generate new points starting from an initial condition. We propose then a new training method. During the new training process, each time we give as input h training points and after we use as inputs f points generated by the model itself. Then we minimise the loss between the generated points and the training ones. We show through extensive statistical analysis that this method shows an important increase in performance, and we can train a model giving excellent agreement with the bare truth, even using a few training data.

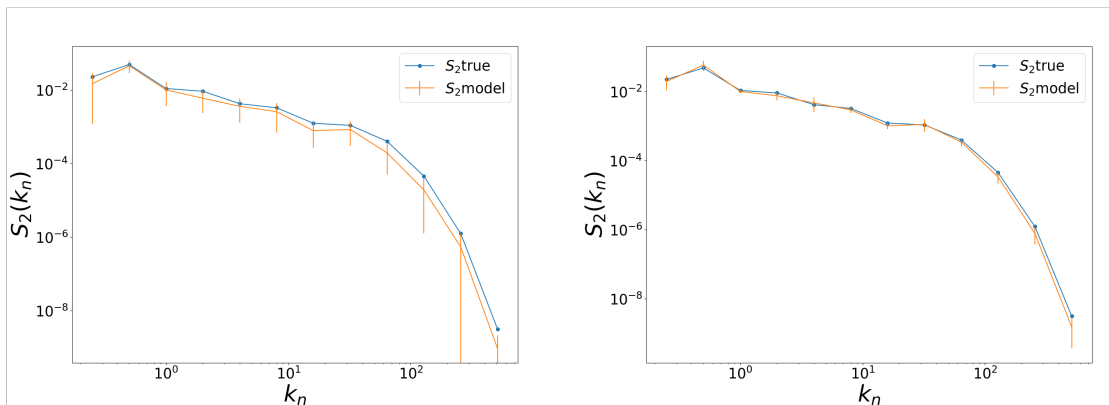


Figure 1. The left figure is the structure function evaluated with the model trained with the standard training, the right one is the forecast one. The structure function is computed by let the model generate on its own 10000 points, and then it is evaluated with the following formula $\langle |u_n(t)|^2 \rangle_t$. Where $u_n(t)$ is the n -th shell velocity of the SABRA Model.

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Competition between vertical and Rayleigh–Bénard convection in a thin cylinder

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When an accident occurs in a nuclear power plant, a fluid called “corium” composed of the radioactive fuel and the reactor metallic components is formed. To deal with this event, one of the strategies consists in submerging the reactor in water in order to cool the wall reactor and try to keep the corium inside. However, few minutes after the accident, the corium splits in two phases: an oxide layer, highly radioactive, which heats from below a thin liquid metal layer at the surface. It has been shown [1] that the heat flux across the thin metal layer can lead to the complete melting of the side wall, hence to the failure of this retention strategy.

Motivated by those nuclear safety issues, we study heat flux exchanges in the liquid metal layer, modeled by a thin cylinder with an imposed flux at the bottom and top (not necessarily equal) and a fixed temperature on the side. We combine Direct Numerical Simulations and a theoretical approach to derive scaling laws for the temperature difference between top and bottom and for the mean temperature of the system. We find two scaling laws depending on the heat flux ratio. The first one is controlled by heat exchanges on the side, for which we recover classical laws of vertical convection [2]. The second one is driven by top-bottom heat transfers analogous to Rayleigh–Bénard convection [3]. Furthermore, we show that the system is inherently inhomogeneous, with a superposition of both mechanisms identified. In addition to averaged quantities, we show that heat flux fluctuations at the side wall are large and highly intermittent, which might impact safety protocols.

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Probabilistic study of the formation of extreme waves

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Oceanographers generally define extreme waves to be water waves whose amplitude exceeds twice the characteristic wave height expected for the given surface conditions. There are several open questions regarding their formation:

- *Formation mechanism*: What is the most likely way in which such waves form?
- *Profile*: What is the typical shape of such waves?
- *Forecast*: what are the most likely initial conditions that will produce an extreme wave in the future?

Some of these questions are very difficult to answer in the deterministic setting due to unusual, pathological solutions which might not be relevant in most practical situations. The statistical approach we propose allows us to avoid such issues.

In [1], we use the cubic NLS equation as a toy model for the propagation and interaction of waves in a large one-dimensional box of sufficiently large size with periodic boundary conditions. We consider random initial data, and we set out to study the set of waves that reach an amplitude of at least $z > 0$ at time $t > 0$, namely

$$\mathcal{A}(t, z) = \left\{ \sup_{x \in \mathbb{T}} \eta(t, x) \geq z \right\}, \quad (1)$$

where $\eta(t, x) = |u(t, x)|$, and u solves the focusing cubic NLS equation on a large periodic box. Our goal in this setting is to give a simplified, statistical description of this set as $z \rightarrow \infty$, which is supported by numerical and experimental evidence in a series of works by Dematteis, Grafke, Onorato and Vanden-Eijnden [2, 3].

We set ourselves in a simplified setting where the initial data are statistically small ($\mathbb{E}|\eta_0(x)|^2)^{1/2} \approx \varepsilon$, which is mathematically equivalent to a weakly nonlinear problem.

Our main result in [1] is a large deviations principle for the set $\mathcal{A}(t, z)$ as $z \rightarrow \infty$. This result is obtained by identifying a small subset of $\mathcal{A}(t, z)$ that concentrates all the probability of $\mathcal{A}(t, z)$ as $z \rightarrow \infty$.

This subset is a small neighborhood around the most typical profile of such extreme waves, which is the nonlinear evolution of an explicit choice of initial data. This yields a statistical characterization of the most typical profile of these waves as well as the initial datum that created them.

In an upcoming work [4], we extend our techniques to tackle the case where η in (1) solves the (periodic) Water Wave system.

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Differential diffusion of bouncing grains

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More than two centuries ago, Chladni noticed that salt grains, when deposited on a vibrated metal plate, spontaneously gather into remarkable geometric figures [1]. We now understand that these figures show the eigenmodes of the vibrating plate—the grains accumulate along nodal lines. The mechanism by which the grains accumulate, however, remains debated. As they move erratically over the plate, one is tempted to see their individual trajectories as random walks, and their collective motion as diffusion. We suggest the grains gather where diffusivity is low, thus forming Chladni figures by differential diffusion.

To test this hypothesis, we design a series of experiments in which the amplitude of the plate's vibration is heterogeneous (figure 1). We observe that the places of lower diffusivity indeed collect more grains. At equilibrium, the surface density of grains, ρ , is inversely proportional to the local diffusivity, D :

$$\rho \propto 1/D. \quad (1)$$

In a diffusivity gradient, random walkers usually generate a macroscopic flux \mathbf{q} , whose expression depends on the details of the microscopic dynamics [2]. For jumping grains, we propose

$$\mathbf{q} = -\nabla(D\rho) \quad (2)$$

which, in equilibrium, yields equation (1). Particles that diffuse according to this law can also produce non-equilibrium steady states, wherein macroscopic currents stir the grains around the box that contains them [3, 4]. We pursue these elusive configurations in our experiments.

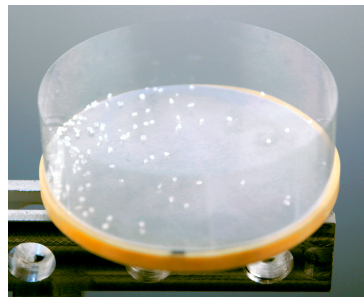


Figure 1. Salt grains bouncing over a vibrated rigid disk (radius 9 cm). The vibration amplitude increases from left to right.

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Dynamo action sustaining turbulence: a subcritical transition

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Dynamo action in a stably stratified environment has been observed for the first time in global numerical simulations quite recently [1]. The so-called Tayler–Spruit dynamo interestingly exhibits a strong level of turbulent fluctuations, turbulence which can be maintained up to very low levels of differential rotation. By varying the magnetic Prandtl number, we show that the relevant criterion for this dynamo is a constant magnetic Reynolds number, compatible with previous predictions [2]. Beside this very general result, the simulations seem to suggest that the mechanism at hand is a subcritical transition to turbulence, transition which can be described by a dynamical system involving only three modes. In very good agreement with the direct numerical simulations, this dynamical system offers a more general scenario for a subcritical transition to turbulence, which could also apply to other types of instabilities, such as magneto-rotational instability.

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Bouchage par formation d'arches dans les écoulements confinés de suspensions : du silo au tuyau

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Une rivière dans une gorge, les connectiques d'une puce microfluidique, les canalisations d'une salle de bain : les systèmes où un fluide transporte des particules ont une fâcheuse tendance à boucher. Une variété de mécanismes plus ou moins interconnectés peuvent causer un bouchon [1], mais un en particulier attire l'œil du physicien des milieux granulaires. On observe ainsi dans les suspensions de particules des phénomènes de *bridging* où plusieurs particules entrent en contact et trouvent un équilibre statique en formant une arche obstruant une constriction comme illustré par la figure 1. Les similarités à la situation classique du blocage d'un silo granulaire sont ainsi nombreuses, mais les suspensions complexifient le problème : conditions d'écoulement, lubrification, interactions colloïdales, nature du fluide...

Dans un premier temps, nous quantifions expérimentalement le rôle de la fraction volumique de particules sur la formation d'arches dans un système millifluidique modèle en deux dimensions [2]. Alors que les suspensions denses ont un comportement similaire à un milieu granulaire sec, celles diluées présentent des discontinuités dans la dépendance de la probabilité de bouchage par rapport aux dimensions de la constriction. Grâce à un modèle statistique statique, nous mettons en évidence que diluer la suspension ne peut que réduire, et non annuler, la probabilité d'obstruction, ne faisant que retarder l'inévitable.

Par la suite, nous nous intéressons à l'influence de l'angle de constriction. Augmenter cet angle augmente la probabilité d'obstruction jusqu'à un seuil au-delà duquel un plateau est observé de manière similaire au cas du silo granulaire, malgré l'influence de la dilution et de la dépendance à la section de la vitesse particulière dans le cas des suspensions. L'analyse des configurations d'arches stables montre ainsi les effets conjoints de la fraction volumique et de la géométrie de constriction. Dans une certaine mesure, la dilution et la réduction de l'angle de constriction auront surprenamment un effet similaire sur la dynamique de bouchage d'une suspension.

La prédiction statistique de la formation d'arches peut ainsi permettre un meilleur dimensionnement des systèmes fluidiques. On s'interrogera néanmoins : peut-on utiliser d'autres mécanismes pour enfin concevoir un système imbouchable ?

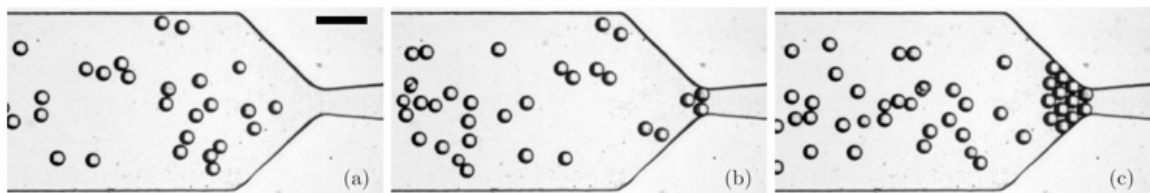


Figure 1. Images successives montrant un exemple de formation d'une arche pour une suspension diluée de fraction surfacique 9% et un rapport de taille de constriction sur le diamètre d'une particule de 1,8. La barre d'échelle est longue de 2 mm.

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Exploring single-particle diffraction with a pilot-wave model

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Millimetric liquid droplets can bounce indefinitely on the surface of a vertically vibrating bath of the same liquid [1]. In some regimes, these droplets self-propel on the liquid surface by bouncing on the wave field created by their previous impacts [2]. A series of experiments with these walking droplets have shown a number of quantum-like behaviors [3]. One of the seminal experiments suggested that single-particle diffraction and interference may be obtained when a droplet crosses a single- or double-aperture between submerged barriers [4]. Later experiments with finer control of experimental parameters yielded different conclusions with respect to the seminal experiments [5–7], thus reopening the question of the extent of the analogy between walking droplets and quantum particles. Here we use the pilot-wave model developed by Oza et al. [8] to describe walking droplets and explore the diffraction of a two-dimensional, wave-piloted particle by one-dimensional barriers. The statistical distribution of deflection angles is wavelike and generally exhibits multiple peaks (Fig. 1), the number of which depends on the obstacle geometry.

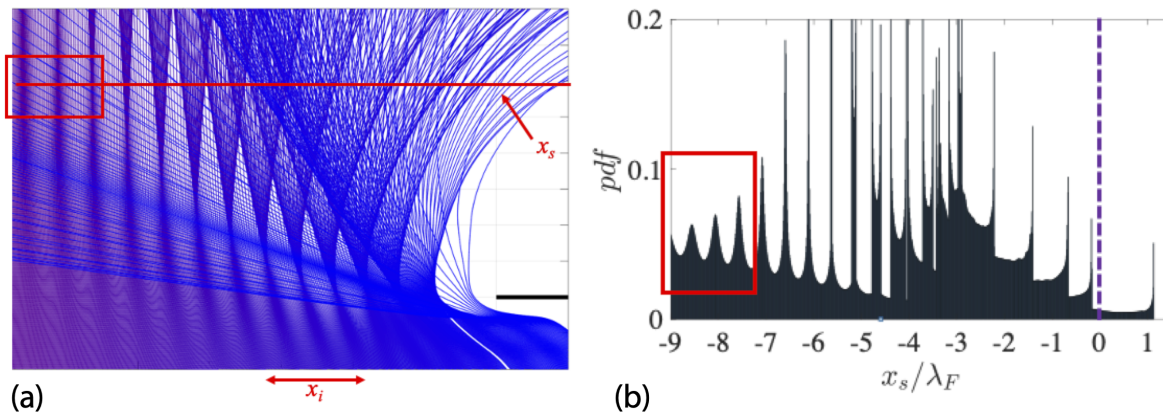


Figure 1. Interaction of an ensemble of wave-piloted particles with an edge (black line in panel (a)). (a) Multiple trajectories of a single droplet with varying impact parameter x_i , with the droplet moving from the bottom of the panel toward the top. (b) Probability distribution function of the droplet impacts on a horizontal screen placed at a distance $3\lambda_F$ above the edge (red line on panel (a)). The wavelength of Faraday waves is denoted by λ_F .

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Patterning at the upper transitional range of plane Couette flow

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The transition to/from turbulence in wall-bounded flows is a long-standing problem, aspects of which remain open [1]. On general grounds, laminar flow is known to experience a subcritical bifurcation towards nontrivial flow resulting from some “self-sustaining process” and a wide transitional range of Reynolds numbers R exists where quasi-laminar flow competes with turbulence in physical space. At the low- R end of this range R_g (“g” for “global stability”), the consensus is that the decay of turbulence takes place according to a directed-percolation scenario. In contrast, a regime of uniform (“featureless”) turbulence is recovered at very large R , possibly beyond a well-characterised upper threshold usually called R_t . Between these two thresholds, turbulence develops in the form of domains of quasi-laminar flow coexisting with the chaotic flow, often organised in regular laminar-turbulent patterns somewhat above R_g , as in plane simple shear flow (Couette, PCF), and similarly in cylindrical geometry [2], or channel flow (Poiseuille, PPF) [3]. Up to now, the mechanism responsible for this patterning is subject to conjectures, and the exact nature –continuous or discontinuous– of the pattern’s emergence, is still controversial [4, 5].

Here, paralleling our study of PPF [3], we present the result of fully resolved numerical simulations of PCF in a wide periodically-continued domain $(L_x \times L_z) = (500 \times 250)$ performed by MS in Osaka. Patterning is studied using Fourier spectra of the crossflow-energy field $E_{cf}(x, z; t) = v^2 + w^2$ cleared from the dominant but confusing contribution of streamwise streaks u . Focussing on the regime around and above R_t , we observe that a weak long-wavelength modulation of the turbulence intensity is already present at large R in the form of wide bumps centred at wavevectors already similar to those corresponding to the peaks that develop when the pattern is present below R_t . The spectra fulfil the expected spanwise symmetry of PCF all along the featureless regime, which helps us improve the statistics by considering appropriately symmetrised spectra. This symmetry is broken for $R \sim 410$, and sharp peaks associated with the emerging pattern rapidly grow. The transition is abrupt but continuous, with no trace of hysteresis. Our results reproduce those of Prigent [2], who estimated $R_t \simeq 415$, more closely than simulations where the flow is modelled using the quasi-1D Barkley–Tuckerman oblique domain framework [4], or at reduced resolution [5], limitations of which are both raised in our wide-domain fully-resolved simulations. Our better agreement is perhaps because the latter approaches over-emphasise the flow coherence in the upper transitional range, giving the temporal “turbulence reentrance” they describe too much significance.

The mechanism responsible for the instability of the uniformly turbulent regime, similar to that described in [6] for PPF, the pre-patterning above R_t , and the focusing that turns it into a bona fide pattern amenable to the noisy Ginzburg–Landau-like formalism discussed in [2], remains a challenging problem, with the generation of large-scale flows by the phase dynamics of small-scale chaos in perspective [7, 8].

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Topological mechanical metamaterials and nonlinearity

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Following the recent discovery of topological insulators in condensed matter physics, a new notion of topology has emerged in association with the intrinsic wave dispersion of a structure. This has led to a plethora of mechanical designs with non-trivial and robust energy localization - potentially offering new applications in energy harvesting, vibration isolation, and phononic wave guidance. In this talk, after a review of the different classes of topological mechanical metamaterials, we will present a new family of finite-frequency mechanical metamaterials that we have recently introduced [1]. Here, topological properties appear in deformation coordinates and topological edge waves appear for free boundaries. In the second part, we will focus our attention on the effect of nonlinearity. In particular, we will discuss our recent efforts to understand the interplay between nonlinearity and topology in mechanical systems. By choosing simple topological systems and including different types of nonlinearities, we will present various phenomena that we have observed, such as the amplitude-dependent topological transition [2], the formation of solitons [3] and the chaotic transition to thermalization [4].

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Are vortex interactions the source of time-irreversibility and singularities in turbulent flows?

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Turbulence is a dissipative phenomenon, thus subject to irreversible events. Indeed, the time-reversal symmetry is explicitly broken by viscosity, and yet it is spontaneously broken in the inviscid limit. We term this the dissipative anomaly. Recently, Theodore D. Drivas [1] formally proved the equivalence of two different local indicators of time-irreversibility: i) an Eulerian one, based on regularity properties of the velocity field [3] and local energy transfers ; ii) a Lagrangian one, based on symmetry properties of the trajectories under time reversal [2]. Theodore D. Drivas [1], rigorously proved that under suitable limits, the Eulerian and Lagrangian indicators converge to the same quantity $\epsilon(x, t)$, the local energy dissipation. This result is crucial because it provides two different indicators that discriminate between regions where the fluid is or is not time-irreversible. By tracking dynamically in time and space such regions, one may then get hints of the physical processes that are responsible for the symmetry breaking.

In this talk, I will first test the equivalence of the two indicators in an experimental turbulent von Kármán flow at a resolution of the order of the Kolmogorov scale using a high resolution 4D-PTV technique. I will then use the equivalence to perform the first joined Eulerian–Lagrangian exploration of the dynamics leading to time irreversibility, and find that it is linked with vortex interaction, suggesting a link between irreversibility and singularity (Figure 1).

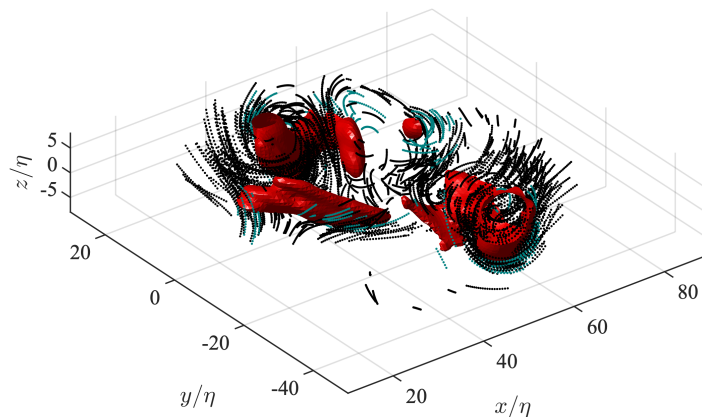


Figure 1. 3D visualization of Eulerian irreversibility iso-surfaces (in red) and highly irreversible trajectories selected from the Lagrangian criterion in black (positive) and blue (negative).

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Solving the turbulent jet puzzle in the scale-relativity framework

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We apply the scale-relativity theory of turbulence to the turbulent round jet problem. In this theory, the time derivative of the Navier–Stokes equations can be integrated under the form of a macroscopic Schrödinger equation acting in v -space, in which the potential is that of harmonic oscillators. This equation is solved in terms of a wave function whose square yields the velocity PDF, from which the Reynolds stresses can be derived, thus solving the closure problem in this case. This allows us to obtain a theoretical prediction for the turbulent intensity radial profiles which agrees with the experimental data, and for the various purely numerical invariants characterizing the turbulent jet, such as its opening angle $\approx 1/5$, the ratio of turbulent intensities over the centerline axial velocity $\approx 1/4$ and the velocity correlation coefficient ≈ 0.4 (which is common to all free shear flows).

Tracking complex singularities of fluids on Logarithmic Lattices

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En 1981, Frisch et Morf [1] ont postulé l'existence de singularités complexes dans les solutions des équations de Navier–Stokes. Les progrès actuels sur cette conjecture sont entravés par la charge de calcul impliquée dans la simulation des équations d'Euler ou de Navier–Stokes à un nombre de Reynolds élevé. Nous étudions cette conjecture dans le cas de la dynamique des fluides sur des log-lattices [2], un framework numérique récent qui réduit drastiquement la complexité numérique de telles simulations. Nous analysons les propriétés des potentielles singularités complexes à la fois en 1D et en 3D pour différents pas de grilles. Les singularités complexes dominantes sont suivies à l'aide de la méthode de la singularity strip, afin d'obtenir une nouvelle loi d'échelle concernant leur distance à l'axe réel, ainsi que l'influence de la dissipation (normale, hypo, hyper).

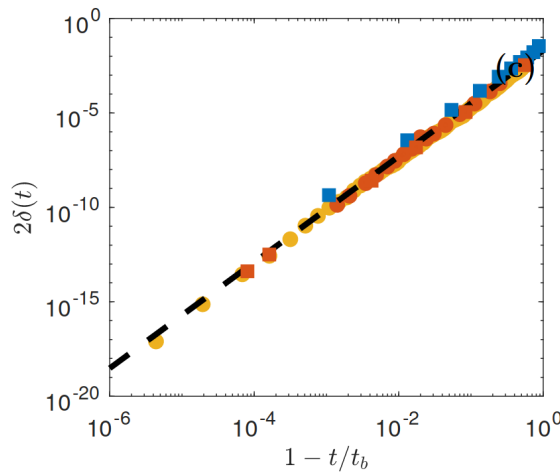


Figure 1. Largeur de la bande d'analyticité δ en fonction du temps ajusté $\tau = 1 - t/t_b$ dans le blowup inviscide pour le cas Euler (3D) en utilisant $\lambda = 2$ (jaune), $\lambda = \phi$ (rouge) et $\lambda = \sigma$ (bleu). La ligne pointillée noire représente une pente de 2,805.

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Multi-scale turbulent synthesis

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Give a gentle push to a puff of smoke: it soon develops convoluted motions, diverging trajectories blur the initial impulse, but nevertheless some distinctive features remain. In this apparent chaos, the human eye is expert at recognising waves, spiraling structures, vortices, shocks, eddies... Also, hierarchical order emerges from this apparent randomness: small structures are embedded in bigger ones, which manifest in the celebrated Kolmogorov (1941) spectral power law. Turbulence studies look for a number of generic statistical properties shared by flows after they have lost the imprint of their initial conditions: structure functions, statistics of increments, multifractal spectra, etc...

Today, simulations can predict the evolution of fluid motions from random initial conditions and we can try to assess what statistical laws control them, but simulations are rather costly to run, especially in 3D, and this limits the number of possible independent realisations of these experiments. Recently, L. Chevillard, J.-B. Durrive and myself have been developing new models of synthetic turbulence [2, 3]: we can produce a realisation of our synthetic random flows at a computational cost no more than the equivalent of a few time-steps of a simulation. These synthetic flows bear the classical signatures of intermittency (power spectra and non-Gaussian statistics of increments) and reproduce other known correlations. However, these early models fail at reproducing coherent structures seen in DNS [4, 5]. This is a hint that the increment statistics (or equivalently the structure functions and multifractal spectrum) do not constrain sufficiently the coherent structures.

Here, I will present a set of new ideas for synthetic models which allow to generate some coherent features. These ideas are a set of approximations which are directly applied to the filtered Navier–Stokes equations. As such, they are straightforward to generalise to many types of turbulent flows (2D/3D, MHD, compressible or not, gravitating...). The purpose of the present work is to quantitatively assess their validity in the most simple framework: 2D decaying incompressible hydrodynamical turbulence. To this aim, we will compare results of 2D decaying simulations to snapshots of synthetic turbulence generated with our method (MUSCAT, for MUlti-Scale Turbulent Synthesis). We will first assess quantitatively the difference by using the standard tools of increments statistics and show that they can be fairly well recovered. Then, we will use the metrics provided by scattering transforms [1], which are a more stringent tool to constrain non-Gaussian features.

We hope such generative methods for turbulence can be used for a number of applications. They can simply serve as better initial conditions for developed turbulence. 3D synthetic fields could be adjusted to observed projections with the hope to recover the underlying structure in astrophysical images. Similar methods may be used to guess a turbulent field outside regions where it is measured, such as in weather forecast. Finally, they can also serve as simplified statistical models to theoretically understand measured statistical laws.

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Breaking waves in a fully non-linear potential flow model

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Once generated by wind, ocean waves evolve, with complex kinematics and dynamics, as a result of nonlinear and dispersive effects, the effects of bathymetry, and dissipation from wave breaking and bottom friction, to name a few. Accurate simulations of this evolution are crucial for predicting phase-resolved surface wave properties in complex sea states, which govern wave interactions with fixed and floating objects, including offshore renewable energy systems, and surf zone parameters that drive nearshore currents and sediment processes, whose understanding and prediction are key to coastal management decisions.

Due to the computational complexity of modeling these phenomena over large domains in Navier–Stokes models, researchers rely on using simpler models and explicitly introduce the desired effects, e.g., the addition of a dissipative term in the Euler equations. Our work is concentrated on using the existing knowledge of breaking waves to mimic its effects in simpler models such as potential flow.

Extensive research has been done on understanding the many aspects of wave breaking (e.g., Duncan [1], Stive [2], Banner and Peregrine [3], Barthelemy *et al.* [4], Derakhti *et al.* [5]). This knowledge is used extensively to model breaking waves in 2D, in specific conditions (e.g, Simon *et al.* [7], Papoutsellis *et al.* [6], Grilli *et al.* [8]). We propose a unified method for modeling 2D depth-limited breaking waves, which is also being currently extended to 3D waves.

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1D chain of coupled pendulum in a turbulent flow

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Ned Kahn is an American artist who has implemented numerous exhibits inspired by the ephemeral nature. Amongst his works is the kinetic facade, which is composed of a matrix of small aluminium plates that cover facades of buildings. As the wind blows over the wall, the plates oscillate freely creating some wave-like large scale patterns (Fig. 1 (left)), that could be either wind generated waves [1], or the signature of turbulent pressure fluctuations [2].

To unravel the physical origin of these deformations, we designed in a wind tunnel a one-dimensional chain of coupled pendulum in a reduced version (Fig. 1 (right)), composed of rectangular 3d printed thin plates. Inspired by the works of Brouzet *et al.* [3], we use nylon fishing wires to achieve a precise coupling with an elastic coupling constant controlled by the wire diameter. In the absence of external wind, the dispersion relation of the chain oscillatory motions follows the theoretical prediction (discrete sine-Gordon equation):

$$\omega_0^2 = \omega_p^2 + 4\omega_w^2 \sin^2 \left(\frac{kW}{2} \right), \quad (1)$$

Where ω_p denotes the angular frequency of a single pendulum under gravity, ω_w the elastic coupling frequency and W the distance between two plates. For a wind velocity ranging from 0 to $8 \text{ m} \cdot \text{s}^{-1}$, we observe long trains of linear waves and local gusts propagating downstream. We equally report on a wind-induced modification of the dispersion relation, as a result of an interaction between turbulence, pendulum and the pendulum coupling, and we discuss the physical mechanism of these wave generations.

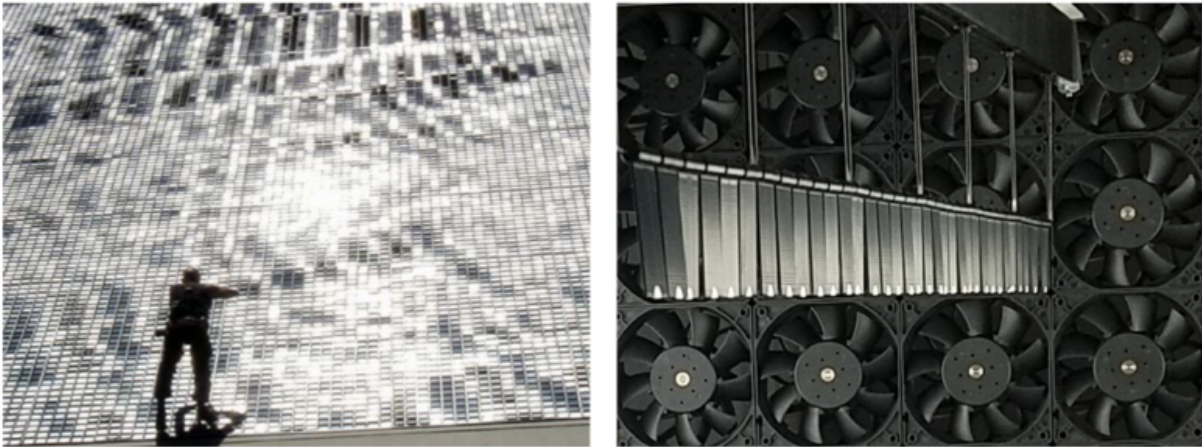


Figure 1. (left) One of Ned Kahn's kinetic facade exhibits, wave like patterns can be seen. Human worker for scale. (right) Photography of our 1-dimensional chain of coupled pendulum located at the center of the wind tunnel's test section, each plate is 3 cm wide and 5 cm high.

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Asymmetric Rayleigh streaming induced by large amplitude vibrations around a sharp obstacle

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The steady streaming generated near solid walls by the periodic forcing of a viscous fluid, is known to be strongly enhanced near sharp structures, owing to centrifugal effects that lead to the generation of an intense jet from the sharp tip [1, 2]. This flow has been shown to provide efficient active mixing in microchannels, due to strong transverse velocity. The forcing is often prescribed by acoustic transducers, but it can also be generated by low-frequency time-periodic flow ensured by mechanical vibrations. In this paper, we study the flow structure generated by low-frequency forcing (typically 10 Hz) around a sharp tip. Using Direct Numerical Simulations, we extract both the time-periodic and steady responses within a large span of amplitude of vibrations. When the amplitude is smaller than the tip radius of curvature, we recover the flow structure observed at higher frequencies (> 1 kHz) in previous studies, namely an intense symmetric central jet and a quadratic dependence for the characteristic streaming velocity with the oscillating velocity $v_s \sim v_a^2$. At higher amplitudes, such a scaling no longer holds and the streaming flow pattern loses its left-right symmetry. We then analyse the mechanisms of the instability from the careful examination of the instationary flow fields, and we propose possible mechanisms for such a flow transition involving the coupling between the streaming jet and instationary vorticity [3].

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Unsteady propulsion: Application to windsurfing

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The competitive practice of sailing and windsurfing is evolving. It may be assigned to the willingness to break the records increasing the performances of the sailing boats. Thus, the development of new platforms using hydrofoils, capable of providing lift, is replacing the use of the so-called “classic” windsurf that relies only on buoyancy. Among these innovations are the new “iQFoil” class of windsurf which will be used in the next Olympic Games.

The interest of using a foil, and the passage from an Archimedean boat to a dynamically supported boat, is to obtain a considerable increase of speed during sail races. An unsteady maneuver called “pumping” is essential [1]. For windsurfers, pumping consists in a periodic pitching of the sail with a certain kinematics and seems to be an efficient contribution to the propulsive force under certain wind conditions. It is used a lot in the beginning of the race to accelerate and after tack changes to stabilize the boat in flight mode. Understanding the details of the functioning of boats is complex like on a sailing yacht [2] and requires some measurements even more so difficult to do during navigation in a windsurf boat because of its size. It is a complex mechanical structure with deformation associating the mast, the sail and the battens that stiffen it, but also geometrically complex by the camber and the helical torsion of the sail. It has a fairly clear analogy with insect wings [3]. Here we investigate a simplified model of a pumping sail in a wind-wall open aerodynamic tunnel.

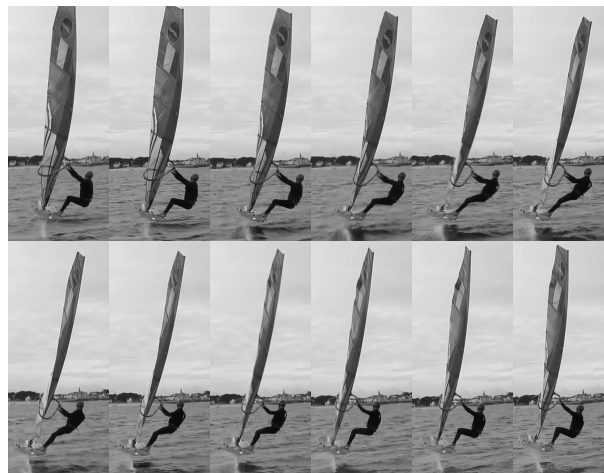


Figure 1. Chronophotography from top-left to bottom-right of a windsurfer during one oscillation period of a pumping phase.

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Influence de la gravité dans le drainage de films mobiles

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Prédire la durée de vie d'une mousse est primordiale dans l'industrie de l'eau et de l'alimentaire. Leur stabilité est liée à celle des films qui connectent leurs bulles. Ceux-ci peuvent s'évaporer [1] ou drainer sous l'action de la gravité, ce qui est visible dans le cas de films uniques supportés par un cadre. Dans cette géométrie, Mysels *et al.* [2] ont montré l'existence d'une instabilité le long des bords du cadre : la régénération marginale. Des patches fins remontent alors dans le film avec une vitesse V^+ s'opposant au drainage global du reste du film, visible avec les franges de Newton, avec une vitesse V^- , observables sur la figure 1 (a) [3]. Ces échanges gouvernent le drainage et nécessitent d'être mieux compris.

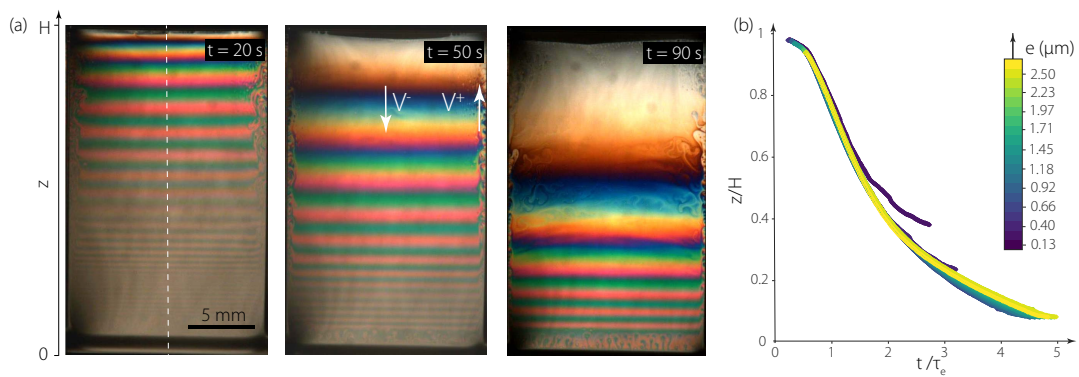


Figure 1. (a) Photos d'une expérience pour différents temps, les couleurs correspondent à l'épaisseur locale du film. (b) Profils adimensionnés des franges illustrant l'auto-affinité. Les couleurs codent pour l'épaisseur du film.

Nous étudions le drainage de films mobiles supportés par un cadre en les filmant avec une caméra couleur. La Figure 1 (a) montrent trois photos d'une expérience à différents temps. Nous quantifions le drainage en suivant, au cours du temps, des franges d'iso-épaisseur ($\lambda = 660$ nm) au centre du film. Ces franges suivent une tendance similaire à une variable temporelle près τ_e , nous permettant d'agréger les profils z/H sur la figure 1 (b). τ_e dépend de l'épaisseur de la frange : plus la frange est fine plus τ_e est grand. Ces résultats confirment l'auto-affinité pour le drainage de films mobiles. En changeant les paramètres de contrôle (gravité effective, géométrie du cadre et propriété de la solution), nous montrons que le drainage est limité par la friction des patches qui remontent le long des bords. Ces résultats permettent de mieux comprendre le drainage des films mobiles et donc de la durée de vie des mousses.

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Probability density function for particle accelerations in turbulence and the structure of vortices

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In the last decades many investigations about the motion of particles in a turbulent flow have been conducted. The use of high speed cameras and the Doppler sonar has allowed to measure the velocity and the acceleration of particles inside the fluid. From the experimental data the probability density function (pdf) of the particle acceleration has been computed. The pdf is strongly non gaussian with accelerations as high as $200g$ [1]. The existence of strong accelerations has been related to the trapping of particles into the vortex cores. To support this assertion we need to recover a classic picture of a vortex. In a first approximation the particles inside the vortex core (after subtracting its translation velocity) move as in a rigid body rotation. Then, the fluid particles move along circular paths. We have investigated the structure of the annular vortices for different values of the Reynolds number (Re), but always in a laminar regime. The vortices are produced by expelling the fluid contained in a box through a circular hole. The velocity has been measured using both Particle Image Velocimetry (PIV) and Hot Wire Anemometry, the latter has a better spatial resolution (we have used a probe with a diameter of $5\ \mu\text{m}$ and $0.5\ \text{mm}$ long). In the vortex core the tangential velocity is proportional to the distance to its center. For an experiment corresponding to a Reynolds number $Re = 1\ 200$ we have observed that tangential velocity changes from $-1\ \text{m/s}$ to $3\ \text{m/s}$ through a distance of $4\ \text{mm}$. In this case the acceleration of particles in the outer limit of the core attains the value $a = 2^2/2 \times 10^{-3} = 2\ 000\ \text{m/s}^2$. In this work we investigate the size of the vortex core and the acceleration of fluid particles for vortices having different values of Reynolds number. We discuss the trend observed when the Reynolds number increases and the role of the vortex stretching to produce strong accelerations in a turbulent flow.

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Can an acoustic dipole surf on its self-generated radiation force? Toward a 3D macroscopic wave-particle coupling

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Since the seminal work by Couder et al. [1] on “walking” droplets, many studies have investigated the ability of this system exhibiting wave-particle duality to reproduce quantum like behaviours, within a two-dimensional space [2–4]. In this work, we aim to open perspectives for extending such quantum analogs to 3D by the mean of acoustics. For this purpose, we study the possibility for an acoustic source to surf on its self-generated wave through a nonlinear force called the acoustic radiation force. We introduce a small translation perturbation to the source, and look whether the asymmetric radiation force resulting from Doppler effect is able to propel the source. Our results show that a monopolar source is stable since the force is opposite to the motion of the source [5] while for a dipolar source, the perturbation is amplified by the self-generated acoustic radiation force.

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Spiraling of a confined elastic sheet after buckling

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Plant leaves in buds, insect wings in cocoons or DNA in viral capsids are examples in nature of tightly packed flexible structures. One might wonder whether mechanics and physics of flexible sheets can help to understand geological folds [1]. However, the general equations describing deformations of tightly packed rods or sheets are challenging to solve. Here, we apply experimental and theoretical approaches to model the compression of a confined elastic sheet. Our experimental set-up consists of a sheet, whose ends are quasi-statically moved closer to each-other, while confined in the orthogonal direction by two walls separated by a given gap. Upon buckling and post-buckling of the sheet, as already observed by Roman and Pocheau [2], quasi-periodic wavy folded patterns appear. However, when pushed from the sides, as in the current configuration, a spontaneous instability occurs, leading to a single spiral pattern not reported before, but common to other confined configurations [3]. Experimentally, we measure simultaneously mechanical and geometrical properties of the system, using image analysis and force measurements. From a theoretical perspective, we compute predictions from the Euler-Bernoulli theory of elastic rods, both linearized and non-linear, inspired by the work of Chai [4]. A systematic comparison allows to investigate whether some regimes observed experimentally are well described by the linear theory and to identify the mechanisms that are necessary for the emergence of the spiral. Surprisingly, the appearance of the elastic spiral does not require friction, although the precise location of the transition is strongly affected when friction exists.

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Dancing rivulets in a Hele-Shaw cell

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We study a wetting rivulet acoustically excited when falling in a Hele-Shaw cell. At leading order, it behaves like a 1-dimensional membrane and follows the motion imposed by the speaker. Under certain conditions on the frequency and the strength of the excitation, the sinuosity of the rivulet pattern and the inhomogeneities in width become non-linearly coupled and amplify one another. This instability mechanism gives birth to the sinuous-variquous pattern one can see in Fig. 1.

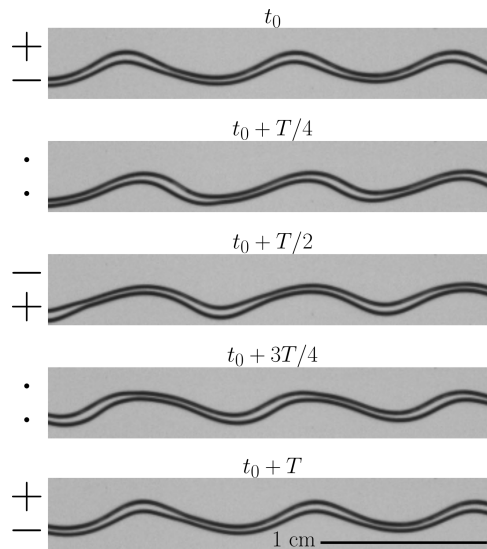


Figure 1. Modification of the rivulet geometry in response to an acoustic perturbation of period $T = 40$ ms (the $+/-$ signs indicate the sign of the differential pressure).

This instability is particularly surprising because it presents variquous oscillations which are normally damped in this set-up, and a sinuous pattern even in the flow rate range where only a straight rivulet is stable.

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Friction and fracture propagation in a granular media

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The simplest description of a tectonic fault is that of two solid blocks sliding on top of each other in a stick-slip motion. The instant just before the 'slip' part of the motion, the onset of sliding, has been shown to be caused by a propagating fracture front, which is well described by the theory of linear elastic fracture mechanics [1].

However, this theory does not take into account the shape of the asperities at the interface, as these asperities are hidden in a dissipative non-linear zone surrounding the fracture tip. The main objective of my research is to develop a more comprehensive description of this frictional phenomenon by performing experiments on a homogeneous solid–solid frictional interface locally perturbed by a granular heterogeneity.

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Dissolution de bulles dans un fluide à seuil

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La tension de surface induit une différence positive de pression (de Laplace) entre une bulle de rayon initial R_0 et le fluide dans lequel elle est plongée. La sur-pression associée permet à la bulle de dissoudre localement plus de gaz dans le fluide – suivant la Loi de Henry – ce qui entraîne la dissolution progressive de la bulle. Dans un fluide Newtonien, la dynamique de dissolution de petites bulles peut être utilisée pour mesurer la tension de surface Γ [1, 2]. Des transferts de gaz peuvent également s’effectuer entre bulles : ce processus appelé le mûrissement d’Ostwald régit la stabilité de milieux bulleux et aérés.

La dissolution de micro-bulles dans des fluides à seuil permettrait *a priori* de mesurer également la tension de surface de ces matériaux, tout en présentant l’avantage de piéger les bulles dans le volume du fluide, ainsi que de supprimer les effets convectifs qui peuvent amener des éventuels contaminants de surface. Dans le cas où le seuil en contrainte τ_Y est faible devant la pression de Laplace $2\Gamma/R_0$, le seuil n’intervient pas dans la dissolution, dont la dynamique peut être alors utilisée comme banc d’essai pour la mesure de tension de surface du fluide à seuil Γ . Quand ce seuil devient plus important, et que le nombre plasto-capillaire $\tau_Y R_0/2\Gamma$ devient de l’ordre de 1, ce dernier peut ralentir, voire arrêter le processus de dissolution [3, 4], ce qui pourrait définir une méthode simple de mesure du seuil dans ces fluides.

Dans ce poster, je compare ces arguments théoriques avec des données expérimentales de dissolution de bulles effectuées dans un fluide à seuil modèle (du Carbopol 980), dont le seuil $\tau_Y = 1$ Pa correspond au cas limite où seuls les effets capillaires comptent. L’ajustement des données au modèle souligne l’importance de la saturation en gaz f dans le fluide [5]. Il suggère en outre que la tension de surface de ces milieux est bien plus faible que les mesures indépendantes obtenues dans la littérature [6]. Je tenterai d’expliquer cette différence et conclurai quant à la pertinence de mesurer une tension de surface et les propriétés rhéologiques de fluides à seuil à l’aide de petites bulles.

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Artificial ice sheet at the laboratory scale: Experimental model

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The North Pole is covered by an ice sheet of about 1m in thickness, generated by sea ice freezing during the winter. At the edges of the polar ice region, ocean waves can break this ice sheet, over 500km, creating a mixed area of ice fragments and open water, called the Marginal Ice Zone (MIZ) [1]. The ocean waves can propagate through the MIZ, which enhances mixing, melting and affects the dynamics of the whole arctic [2]. What determines the breaking of ice sheet by waves and how does it depend on wavelength and ice thickness?

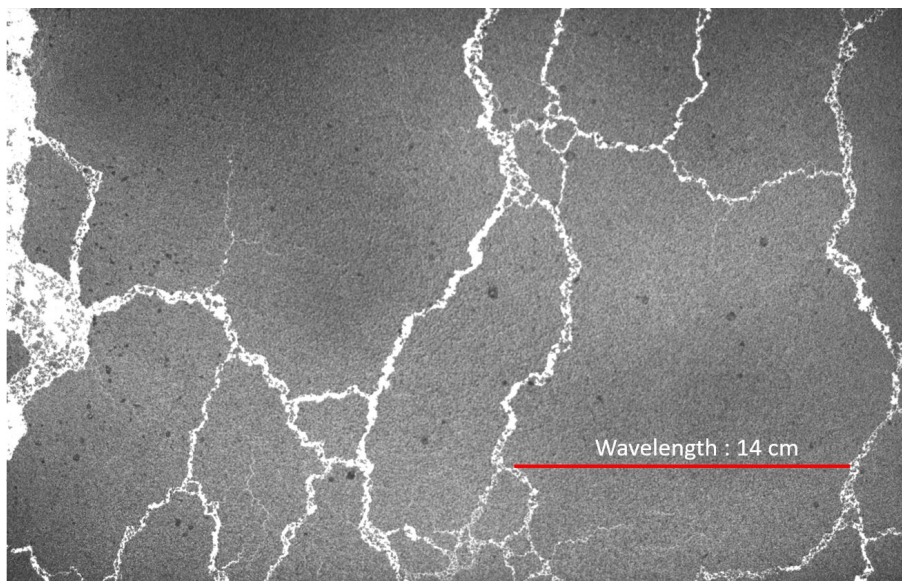


Figure 1. Picture of a thin elastic brittle membrane broken by surface waves generated in the laboratory. Tentative of scaling down ice breaking by ocean swell.

In the lab, we design a model experiment to study at a smaller scale the fracture of a thin, brittle, elastic sheet under surface wave mechanical loading. We use a varnish that forms a thin ($100\ \mu\text{m}$), cohesive, granular material which is brittle enough to be broken by waves of millimetric amplitude (cf. Fig. 1). We first show that this material mimics the wave elastic response of an ice sheet and we measure the effective Young's modulus of our heterogeneous material. Using various wave geometries (propagative and stationary sloshing modes), we study the breaking threshold as a function of the amplitude and the wavelength of the incident wave.

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Dissipation rate in turbulent bubbly von Kármán flow

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Bubbly flows are ubiquitous in nature and have been shown to control gas fluxes between the atmosphere and the ocean [1]. Understanding the coupling between turbulent energy, energy dissipation and bubble size distribution therefore is of prime interest. We present an experimental study of these processes in a von Kármán flow. A turbulent von Karman flow is generated by two counter-rotating disks fitted with blades. This flow has been investigated extensively as a model for turbulence because of its high shear rate in the middle plane, creating a strongly turbulent mixing zone. Energy dissipation ε in single phase turbulent von Karman flow follows the asymptotic behaviour in the high Re limit :

$$\varepsilon \propto \rho R^5 \Omega^3 \quad (1)$$

where R and Ω respectively are the radius and the rotation rate of the disks, ρ is the fluid density [2]. The proportionality constant depends on geometrical parameters (distance between the disks, height of the blades, radius of the tank...). We show experimentally that in the presence of air bubbles in water, this relation is not valid anymore as soon as the air volume fraction is above $\alpha \simeq 5\%$. We report a drastic reduction of energy input in the system (and therefore energy dissipation), depending on void fraction : up to 30% compared with a single phase flow at the same effective density.

Laser Doppler Velocimetry measurements (LDV) using particles or bubbles as trackers allow us to investigate the effects of bubbles both on the forcing efficiency and on the mixing zone.

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Formation de film continu et homogène par coalescence de gouttes

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L'état de surface d'un matériau a une grande influence sur ses propriétés. C'est pourquoi, dans le monde industriel, des revêtements sont très souvent utilisés pour protéger ou fonctionnaliser leur surface. Une manière de créer ces revêtements est de déposer un film liquide mince sur la surface et l'utilisation d'un spray ou d'une impression jet d'encre sont deux méthodes possibles pour cela. Le liquide y est déposé sous forme de gouttes suivi d'une étape de coalescence qui entraîne la formation d'un film continu. Dans le cas du spray le liquide est déposé suivant une distribution statistique en taille et position [1] tandis que l'impression jet d'encre permet un dépôt contrôlé au niveau de chaque goutte [2]. L'utilisation de ces techniques repose sur le phénomène de coalescence de goutte qui est déjà bien connu [3] mais devient beaucoup plus complexe dès que l'on considère plus de deux gouttes. Nous étudions l'influence du nombre et de la position des gouttes sur la coalescence à l'échelle millimétrique. L'expérience modèle consiste à déposer des gouttes de manière précise à certaines positions et sans inertie. Pour cela des gouttes de glycérol sont maintenues à l'extrémité de tubes, ce qui permet de contrôler les positions, puis déposées sur une plaque en verre (cf. Fig. 1).

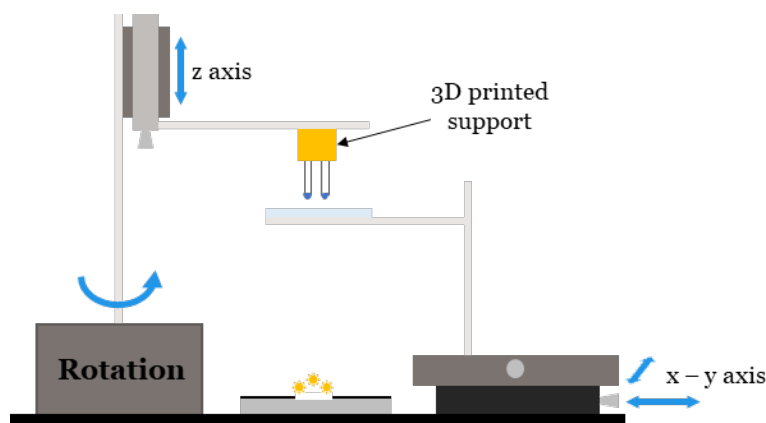


Figure 1. Schéma du montage expérimental

Nous mesurons les dynamiques de coalescence pour chaque événement ainsi que la forme et les dimensions du liquide après coalescence. En comparant ces mesures entre les expériences nous observons une grande influence de la position respective des gouttes et de leur nombre sur le résultat. La chronologie des événements est également un facteur important qui amène à des dynamiques et résultats différents selon l'ordre suivant lequel les gouttes se touchent.

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Analyse résolvente d'un jet turbulent tournant

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L'observation de filaments de vitesse (*streaks*) dans des jets ronds est une découverte relativement récente [1]. Comme des structures cohérentes similaires se sont révélées critiques dans la transition vers la turbulence dans le cas de plaques planes [3], on peut s'interroger sur le rôle de ces mêmes structures dans le cas des jets. Plusieurs travaux d'analyse des instabilités comme [2] ont progressivement amené à une meilleure caractérisation du comportement linéaire de jets turbulents, et mis en évidence certains mécanismes favorisant leur génération.

Dans la même logique, on s'intéresse maintenant aux jets tournants par le prisme de l'analyse linéaire. A partir des équations de Navier-Stokes linéarisées dans un régime à haut nombre de Reynolds, le formalisme résolvente nous permet d'exhiber les forçages les plus amplifiés par l'opérateur linéaire à une fréquence donnée, ainsi que la réponse associée.

Pour obtenir un jet pleinement turbulent, on utilise une viscosité turbulente obtenue par le modèle de Spalart–Allmaras via le logiciel OpenFOAM. Nos paramètres finaux sont : le nombre de Reynolds, fixé à $Re = 400\,000$ pour garantir un écoulement turbulent, le nombre de Strouhal St , l'intensité de la rotation S et l'indice de décomposition azimutale m .

Parmi nos résultats, on peut voir sur la figure 1 une séparation claire entre les m positifs et négatifs dans le cas tournant ainsi qu'une forte amplification des basses fréquences pour $|m| > 0$.

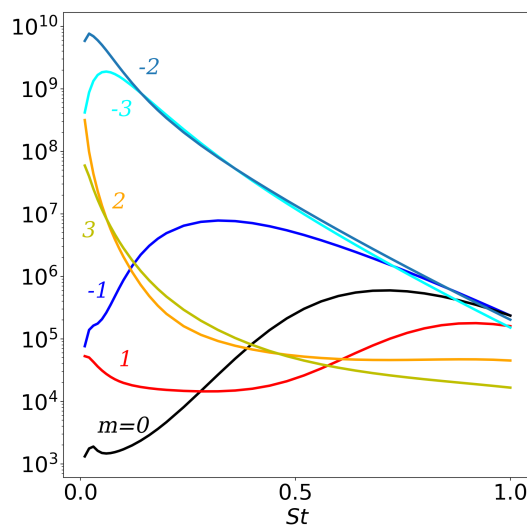


Figure 1. Graphe des gains obtenus à $Re = 400\,000$ et $S = 1$.

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Fragmentation of a granular raft by surface waves

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When particles of a few tens of microns are spread on the surface of water, they aggregate under the action of capillary forces and form a thin floating membrane, a granular raft [1]. In an experimental tank with a raft made of graphite powder, we generate gravity surface waves, whose wavelength is very large compared to the thickness of the raft. For a sufficiently strong wave amplitude, the raft breaks up progressively by producing fragments whose sizes decrease on a time scale long compared to the period of the wave. For this two-dimensional fragmentation process, we study the size, shape and drift of the fragments as a function of time. Since the fragments are randomly distributed, we perform a statistical analysis. The visual appearance of the fragments surrounded by open water bears a striking resemblance to the floes produced by the fracturing of sea-ice by waves in the polar oceans. Fragmentation concepts and morphological tools built for sea-ice floes [2] can be applied to our macroscopic analog, on which the entire dynamic evolution is accessible.

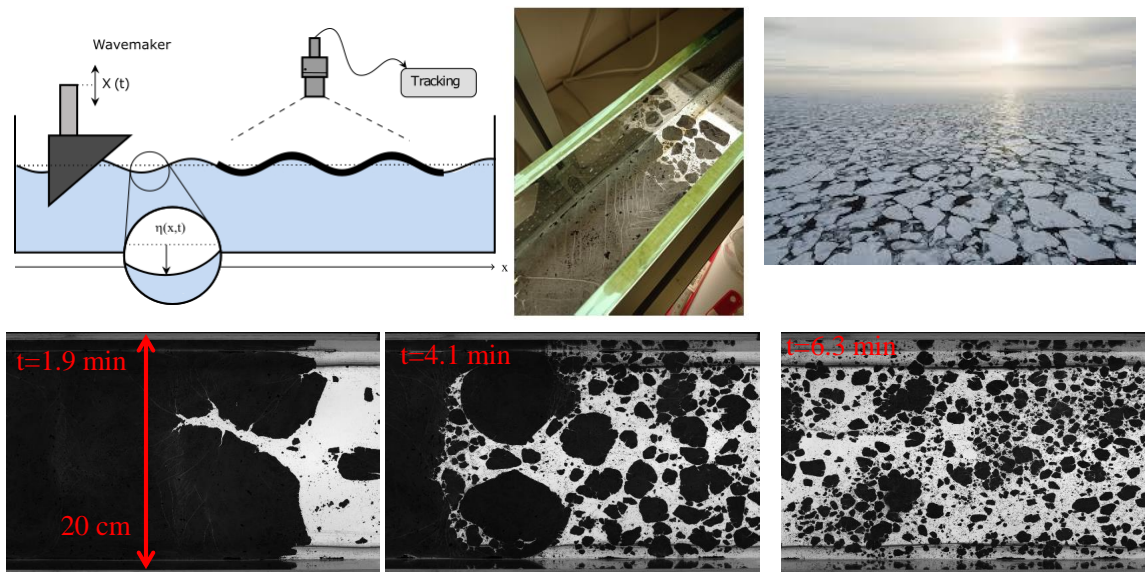


Figure 1. Top left: Schematics of the experimental setup. A thin granular raft floats at the water surface and is broken under the action of gravity waves generated by a wavemaker. The transparent tank is lighted from below. The fragments are then tracked during the fragmentation process. Top middle: Fragments on one side and oblique cracks. Top right: Floes in the arctic ocean (Credits: Daniel Beltrá / Greenpeace). Bottom: Progressive fragmentation at three different time steps for incoming waves of frequency 3.0 Hz and amplitude 1.48 mm.

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Generation of water waves by the impulsive motion of a vertical plate

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Recently, the generation of impulse surface waves by the collapse of a rectangular granular column into water was investigated experimentally [1–3]. These laboratory experiments aiming at modeling the generation of tsunami waves by subaerial landslides [4] have shown different regimes of waves depending on the Froude number Fr_g based on the velocity of the advancing granular front relative to the linear gravity wave velocity in shallow water [5]: linear Cauchy–Poisson waves at low enough Fr_g , solitary waves at moderate Fr_g , and transient bores leading to breaking waves at large enough Fr_g . For the two last regimes where the grains push the shallow water like a piston, the amplitude of the generated wave can be predicted from the initial characteristic of the granular column [6]. In these gravity-driven flows, the run-out distance of the granular collapse is linked to its time scale and thus to the typical velocity of the granular front [7].

Here, we investigate the more general case of surface gravity waves generated by the impulsive motion of a vertical plate in a rectangular channel partially filled with water. The water surface dynamics is tracked from the images taken by a camera from the side of the channel. By independently varying the stroke L and the velocity V of the piston, as well as the water depth h_0 , we observe a large variety of waves including the three wave regimes described before but also other regimes such as a jet splash regime where a tongue of fluid is ejected at high piston acceleration. The different wave regimes are shown to depend on both the relative Stroke L/h_0 and the Froude number $Fr_p = V/(gh_0)^{1/2}$ of the motion of the piston, which have been varied in a large range. Interestingly, all kind of waves exhibit a common transient bore shape during the first stage of formation, suggesting the short-time hydrodynamics belongs to an unsteady shock structure problem.

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Drag force tuning through passive adaptive Origami structure

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Origami-like geometries occur in a lot of natural settings like in leaves or foldable insect wings. While the main apparent purpose of such folding is to assist deployment, structures after that retain pleated morphologies that may affect the operation of wings in flight or the wind resistance of tree leaves. Thus, it becomes important to understand the impact of folds on fluid-elastic processes. In our study, we incorporate a network of creases into the structure. The addition of folds enables the programming of the structure's response to fluid loading, leading to greater levels of deformation.

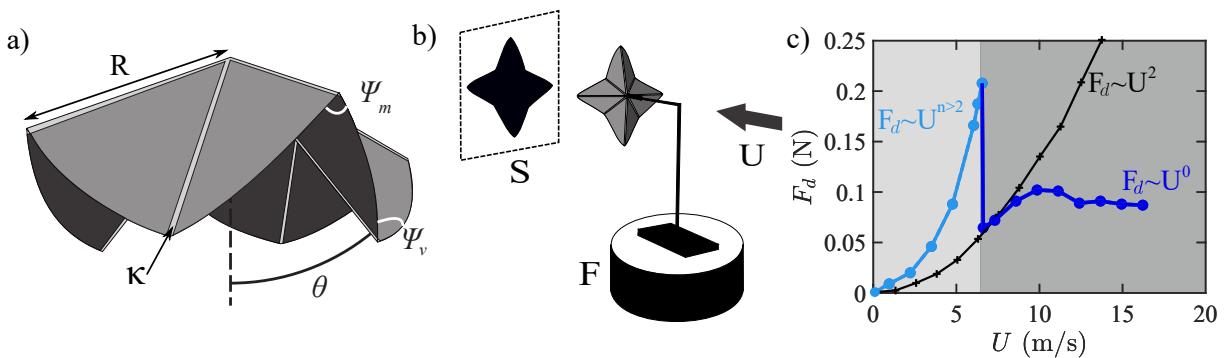


Figure 1. (a) Folded state characterized by the opening angle θ between a valley fold and the central axis passing through the vertex. The angles of mountain and valley folds, ψ_m and ψ_v , respectively. (b) An experimental system with the origami cell held in an incoming uniform airflow with speed U . The drag force F_d is measured by a force balance, while simultaneously extracting the frontal area S to quantify shape changes. (c) Evolution of the drag force with U at two deformation phases (shaded area). It is compared to a rigid origami (in black line) with the same cell parameters

By mixing experiments on the aerodynamics of an elementary origami waterbomb cell and simplified theoretical models we probe the response of a folded structure in a controlled fluid flow environment. The waterbomb folding, as shown in Figure 1a, is an origami unit featuring an even number of uniformly spaced folds that radiate from a single vertex. This crease pattern can be reduced kinematically to a single degree of freedom, represented by the opening angle θ . The unit is bistable and can transition between its two stable states by snapping around the unstable flat configuration i.e., $\theta = 90^\circ$. This non-trivial folding pathway enables a large change in shapes and allows the emergence of a new drag law. The opening phase of the cell results in a stronger drag evolution (light grey area of the Fig. 1) than that of a bluff body ($F_d \approx U^2$), while the closing phase witnesses a significant drag reduction (dark grey area of the Fig. 1 (c) and [1]) after a large drag drop around the unstable snapping. By varying the parameters of the origami cell, the drag law can be programmed, and adding folds to the structure highlights its relevance as a passive drag control method.

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Auto-organisation des mottureaux

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Nous étudions l'auto-organisation de mottes gazonnées sur les eaux ou mottureaux, microstructures pédologiques que le promeneur rencontre typiquement dans les marais de l'Ouest de la France. Selon le géographe Fernand Verger [1–4], « le mécanisme de la formation et les raisons qui commandent la distribution géométrique des mottureaux ne sont pas encore complètement élucidés » et nécessitent « de nombreuses mesures de terrain ». Ce patrimoine géomorphologique a disparu progressivement dans le siècle dernier à cause de la mécanisation de l'agriculture par la mise en culture des prairies et leur aplatissement. Nous présenterons les premiers résultats [5,6] d'un programme de recherche interdisciplinaire, dans une optique de préservation, autour des motifs de mottureaux (ingénieurs putatifs de l'écosystème humide similaires aux cercles de fées des zones arides) combinant pédologie des sols argileux, hydrologie, mesures par drones, botanique, apprentissage automatique et systèmes dynamiques. Cette « espèce en voie de disparition » est l'objet d'un suivi dans une réserve naturelle du marais poitevin.



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When the dynamical writing of coupled memories with reinforcement learning meets physical bounds

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Traditionnellement, les opérations d'écriture de mémoire se déroulent un bit à la fois, limitant la capacité de stockage des matériaux. Une façon de surmonter cette limitation serait d'écrire plusieurs bits à la fois. Bien que les opérations quasi-statiques sont typiquement utilisées pour la manipulation de bits, elles sont connues pour réduire la capacité de mémoire d'un système. Pour adresser ce problème, nous introduisons un cadre de modélisation pour la manipulation dynamique de la mémoire basée sur une chaîne multi-stable de systèmes à deux états couplés par ressorts-masses (voir Fig. 1). Nous montrons que, en utilisant un agent d'apprentissage par renforcement, nous pouvons contrôler ce système hautement non linéaire en force, le faisant passer de n'importe quelle configuration stable ou aléatoire à n'importe quelle autre. Notamment, en tirant parti de la physique sous-jacente, l'agent partage des connaissances précieuses en pointant vers une conception optimale du système.

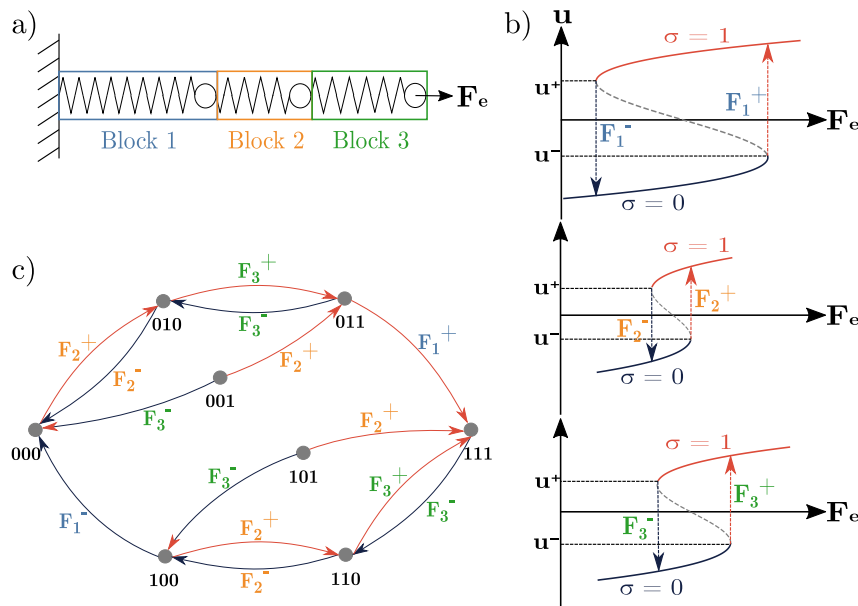


Figure 1. Model for a chain of three coupled bi-stable spring-mass units. (a) Schematics view of the model. The first unit is attached to a fixed wall and an external force F_e is applied to the last one. (b) Deformation u of all three bi-stable springs under external load F_e . (c) Transition graph where the nodes represent the stable configurations and the arrows the quasi-statically achievable transitions between them. The states 001 and 101 are inaccessible from any other equilibrium state through quasi-static operations.

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Dynamique 2D d'un gaz granulaire forcé magnétiquement

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Nous présentons une étude expérimentale de la dynamique 2D d'un ensemble d'aimants immergé dans un fluide et soumis à un champ magnétique oscillant vertical. Grâce à cette technique, l'injection d'énergie se fait de manière homogène et diffère des études expérimentales de gaz granulaires où l'énergie est injectée en faisant vibrer les parois du réservoir. Ici, nous n'observons ni formation d'amas, ni d'équipartition de l'énergie. Les distributions de vitesse linéaire des aimants sont des exponentielles étirées, dont les exposants sont indépendants du nombre d'aimants et sont proches de la valeur $3/2$ théorique [1]. Nos résultats illustrent que le taux de conversion du moment angulaire en moment linéaire contrôle la dynamique de ce gaz granulaire. Nous montrons également les différences entre cet ensemble d'aimants forcé de manière homogène, le modèle de gaz idéal, et les gaz granulaires forcés en paroi. Ce travail étend les mesures effectuées sur la paroi supérieure dans le système tridimensionnel [2].

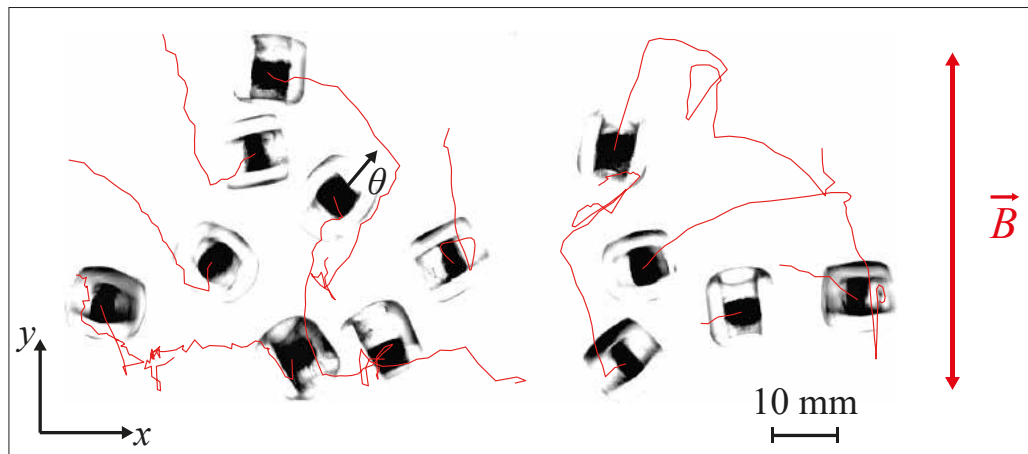


Figure 1. Trajectoires 2D (rouge) de 13 aimants immergés dans l'eau et qui reçoivent un moment angulaire par le champ magnétique oscillant vertical. Les noyaux noirs sont des aimants en néodyme entourés de coques en plexiglas transparent.

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From wave turbulence to shock-wave regime: Intermittency and Burgers turbulence

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Wave turbulence is a statistical state in which numerous random weakly nonlinear waves interact with each other. It leads to an energy cascade (generally, from large scales down to small scales) driven by resonant interactions between waves [1]. This state has been recently evidenced experimentally in a one-dimensional canal for dispersive capillary waves on the surface of mercury [2].

Here, using a ferrofluid and a high external magnetic field, we report experimentally a transition from dispersive wave turbulence to a nondispersive regime involving coherent structures which are found to be shock-waves [3]. Such acousticlike structures are characterized by a significant steepening with a discontinuity close to shock-waves obtained from the Burgers equation. Because of their discontinuities, these shock-waves are rich in the frequency domain, and carry energy over the canal. They thus become the main mechanism building the wave energy spectrum. Finally, we have also found experimentally that this shock-wave regime generates a strong intermittency [4]. That is well described by the prediction from the Burgers turbulence [5].

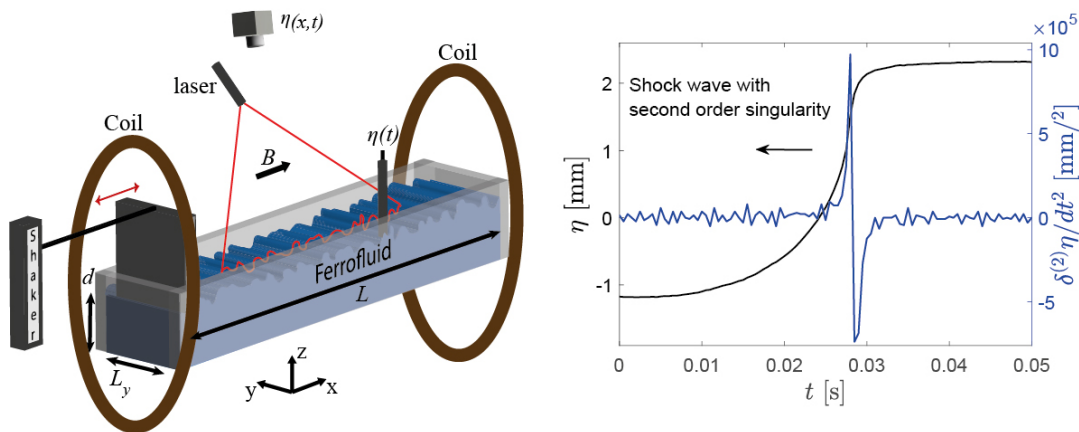


Figure 1. Left: Experimental setup used to obtain the shock-wave regime. Right: Temporal evolution of the surface elevation at a shock-wave, the strong steepening is evidenced by a δ -Dirac on the second-order difference of the signal.

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Asymptotic models of rotating flows in stress-free ellipsoids

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As a canonical model of turbulence in planetary liquid cores, we study precession-driven flows in ellipsoids with stress-free boundary conditions (SF-BC). SF-BC could indeed unlock numerical constraints imposed by no-slip boundary conditions (NS-BC) for planetary applications. Although SF-BC have been employed in the pioneering work of Lorenzani & Tilgner [1], they have scarcely been used because of mathematical issues associated with angular momentum conservation [2]. We revisit the problem using numerical simulations and asymptotic analysis in the low-viscosity regime [3]. First, we extend the reduced model of uniform-vorticity flows in ellipsoids [4] to account for SF-BC. Contrary to previous expectations [2], we show that the long-term evolution of angular momentum is damped by viscosity in axisymmetric SF-BC ellipsoids when the mean rotation axis of the fluid is not the symmetry axis (but also in any triaxial ellipsoids). In the asymptotic regime of planets, we analytically obtain the primary forced flow in triaxial geometries, which exhibits a second inviscid resonance. Then, we investigate the transition towards turbulence (via bulk instabilities) in precessing ellipsoids. We show that the non-viscous inertial instabilities [5], relevant for planetary applications, can be studied using SF-BC. This is of great interest as they are often hampered in experiments or simulations with NS-BC [6, 7].

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On the wanderings of a ludion in a corral: In search of a quantum analogy

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We have recently described the resonance of the vertical oscillations of a ludion (or Descartes diver) in a stably stratified fluid together with the internal gravity waves it emits and its bifurcation to horizontal swimming [1]. Now, in search of a quantum hydrodynamic analogy and possible associated pilot wave dynamics [2, 3], we analyze the motions of a ludion in a cylindrical container (a corral) in the hope of revealing an interaction between its swimming and its own internal gravity wave field. According to the ratio of the forcing frequency to the Brunt-Väisälä frequency, the ludion can chaotically explore the horizontal cylindrical section where it is constrained on average. Although the statistical study would have required recordings over days, the analysis of the trajectories recorded during several hours seems to show that certain radii of curvature are well privileged, a phenomenon reminiscent of Couder walkers. For a particularly long record (16 hours) of the ludion dynamics in a corral of 30 cm in diameter, the color coding of the chaotic trajectory proportional to the instantaneous horizontal speed of the diver reveals as expected a faint but real target pattern (see Figure 1) with a slightly lower speed along a first yellowish rings at the periphery of the corral and another one at a radius ≈ 5 cm. This pattern may indeed be the ghost of one of the eigenmodes of the corral. In line with these results, a Proper Orthogonal Decomposition (POD) of the synthetic Schlieren images of the waves emitted by the ludion during its chaotic excursion shows large-scale gravity eigenmodes of the cylindrical corral. Without drawing any definitive conclusions from this study, we are hopeful that a wave-driven or a wave-influenced particle dynamics exists also in our system and hence opens the way to a new hydrodynamic quantum analogy.

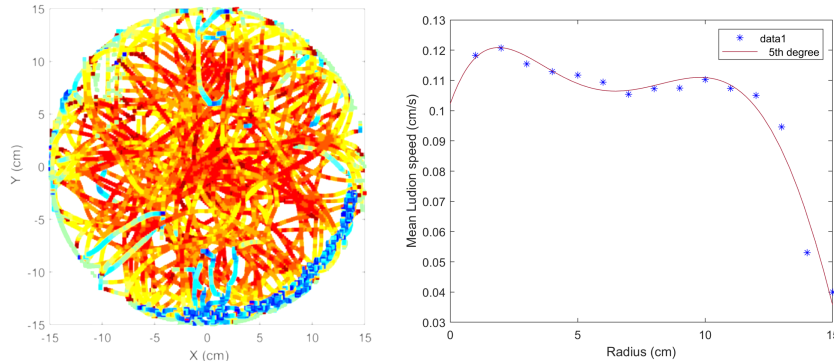


Figure 1. Left: Trajectory of the ludion in a corral 30 cm in diameter, where the color coding is proportional to the instantaneous horizontal speed. A faint target pattern which may be the ghost of one of the eigenmodes of the corral, can be detected. Right: Mean speed of the ludion averaged along the azimuth direction.

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Écoulement induit par la rupture d'un film de savon

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Un film de savon est une couche d'eau mince allant de quelques microns d'épaisseurs à une dizaine de nanomètres, maintenue en équilibre par les tensioactifs présents à ses surfaces. Lorsque celui-ci est percé, un trou apparaît et croît à une vitesse bien définie dite de Taylor–Culick, résultante de l'équilibre entre la tension de surface et l'inertie [1]. Pendant l'éclatement, le bord du trou, que l'on appelle bourrelet, se met à battre tel un drapeau au vent et se fractionne en une multitude de gouttelettes [2].

Ce qui déclenche cette instabilité drapée est encore mal compris. Elle est associée dans la littérature à une instabilité de type Kelvin–Helmholtz [2,3]. Or, la vitesse de rétractation du bourrelet est inférieure au seuil permettant de déclencher une telle instabilité. Cependant, dans les films savonneux, le bourrelet est précédé par un écoulement de Marangoni issu de la compression rapide des tensioactifs aux interfaces [4,5]. La surface du film se réduit et disparaît en quelques millisecondes ce qui est de l'ordre du temps de désorption des tensioactifs. Cet écoulement se situe dans une région nommée auréole où la tension de surface diminue et le film s'épaissit ; elle serait à l'origine des oscillations du bord du film. Afin de vérifier cette hypothèse, nous avons réalisé un dispositif expérimental dédié à l'étude de l'auréole.

Nous produisons des films de savons fluorescents verticaux d'environ vingt centimètres de hauteur que nous perçons ensuite. L'intensité lumineuse émise par fluorescence dépend de l'épaisseur du film ce qui nous permet, avec l'aide d'une caméra rapide, de mesurer le champ d'épaisseur pendant l'éclatement. Avec les équations de conservation de quantité de mouvement et de masse nous pouvons alors estimer la tension de surface et l'écoulement dans l'auréole.

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Dynamique d'un front de collage visqueux

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Le collage de deux surfaces enduites d'une couche d'adhésif est une opération courante dans la vie de tous les jours, par exemple lorsqu'on dépose un autocollant sur un substrat. Cette opération conduit souvent au piégeage de bulles d'air dans la zone d'adhésion, ce qui est néfaste à la qualité du collage. Cet important problème d'ingénierie soulève la question fondamentale de la dynamique d'un front d'adhésion. Nous présentons des expériences modèles autour de cette question.

La mise en contact de deux plaques de verre toutes deux enduites d'un film liquide visqueux donne lieu à une surprenante instabilité de digitation [1]. Cette instabilité se distingue du mécanisme classique de digitation visqueuse : le front visqueux chassant de l'air de faible viscosité devrait être stable selon le critère de Saffman–Taylor [2]. Ici un front d'adhésion instable forme des doigts qui s'allongent au cours du temps. (cf Figure 1. (a)).

Dans de nombreuses situations pratiques, seule l'une des surfaces est recouverte d'adhésif. Dans cette configuration, le front d'adhésion est fortement modifié par rapport au cas précédent : des doigts se forment, mais ils sont orientés dans la direction transverse à la propagation du front d'adhésion (cf. Fig. 1 (b)). Ce nouveau mode d'instabilité semble être la signature d'une dissipation singulière exercée au voisinage de la ligne de contact.

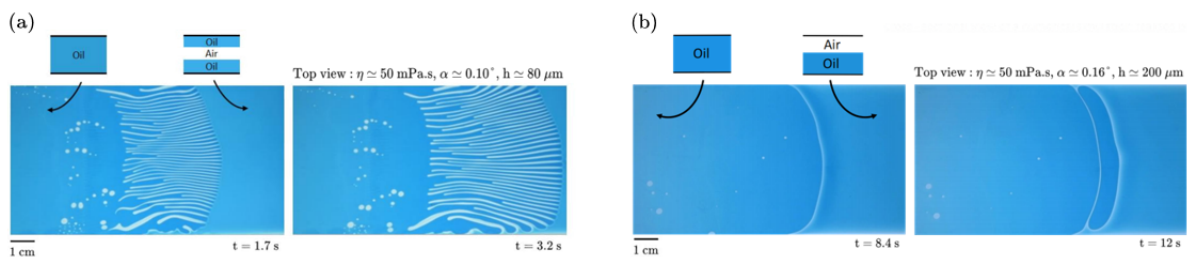


Figure 1. (a) Vue du dessus d'une expérience réalisée avec deux plaques de verre toutes deux enduites d'huile de silicone coloré en bleu conduisant à des doigts longitudinaux. (b) Même expérience mais avec une seule plaque recouverte d'un film d'huile de silicone conduisant à des doigts transverses.

Nous cherchons à démontrer que les motifs de cette instabilité sont déterminés par la géométrie du système. Nous portons notamment notre attention sur la dynamique globale de l'interface en nous appuyant sur les résultats obtenus avec la configuration doublement enduite.

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Reactive front propagation in turbulence

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The relation between the propagation velocity of a thin flame and the turbulence intensity of the ambient flow is largely debated in the literature, giving rise to various parametrisations (e.g. [1–5]).

According to Damköhler’s analysis [1], based on the Huygens propagation model, a flame front propagates with a constant normal velocity even when wrinkled by turbulence. However, experiments using exothermic combustion reactions deviate from this model. The analysis of these experiments is complicated by the intermingling of turbulent and thermal effects, limiting potential improvement of the flame propagation parameterisation.

To test and improve Damköhler’s original theory, an autocatalytic chemical reaction is extensively studied experimentally and numerically. Analogous to a combustion reaction, it produces a thin reactive front separating the reactants from the products in an aqueous medium. Accordingly, it allows to quantify the specific influence of turbulence on the speed and shape of the front in the absence of thermal effects.

In our experimental set-up, turbulence is generated by a system of oscillating grids allowing to establish a homogeneous and isotropic turbulence in a closed water tank. Coupled measurements of PIV and LIF allow to follow, simultaneously, the velocity field and the propagation of the front.

Our experimental approach is complemented by numerical simulations solving the propagation of a reaction front in various imposed flows, using the Dedalus solver [6].

In this poster, the characterizations of the grid turbulence as well as the laminar propagation of the chemical reaction are discussed. First results of the reactive front’s turbulent propagation are analyzed together with systematic numerical studies on a progressively complexified flow in 2D and 3D domains.

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Oscillation à basse fréquence derrière une sphère et un cube

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La transition à la turbulence derrière un objet 3D comme une sphère ou un cube est liée à plusieurs instabilités. Nous étudions expérimentalement la seconde instabilité oscillante.

Nous considérons l'écoulement derrière une sphère ou un cube, de dimension typique $D = 24$ mm, placé dans un canal hydraulique de côté $h = 100$ mm (voir Fig. 1 (a)). En amont de l'objet, la vitesse U est uniforme et stationnaire. Le nombre de Reynolds est $Re = DU/\nu$, où ν est la viscosité cinématique.

Derrière une sphère, deux tourbillons longitudinaux contrarotatifs se forment à un nombre de Reynolds d'environ 210. La première instabilité oscillante consiste en l'oscillation et l'émission de ces tourbillons, et elle commence à un nombre de Reynolds d'environ 270 [1]. Une instabilité similaire existe derrière un cube, à un nombre de Reynolds de 284 [2].

Nous étudions la seconde instabilité oscillante, qui est caractérisée par une fréquence plus basse que la fréquence liée à la première instabilité. Cette seconde instabilité a été étudiée numériquement [3,4], mais peu expérimentalement. Nous mesurons le champ de vitesse par vélocimétrie par images de particules (PIV) dans un plan yz situé à une distance x du centre de l'objet. Pour mesurer la basse fréquence, nous effectuons des acquisitions longues. La puissance associée à la basse fréquence est obtenue en calculant un périodogramme dans chaque fenêtre d'interrogation.

Nous avons montré que la bifurcation associée à la basse fréquence est supercritique (voir Fig. 1 (b)). Nous avons aussi montré que les deux fréquences sont en général incommensurables, mais qu'il existe une plage où les deux fréquences sont commensurables derrière un cube.

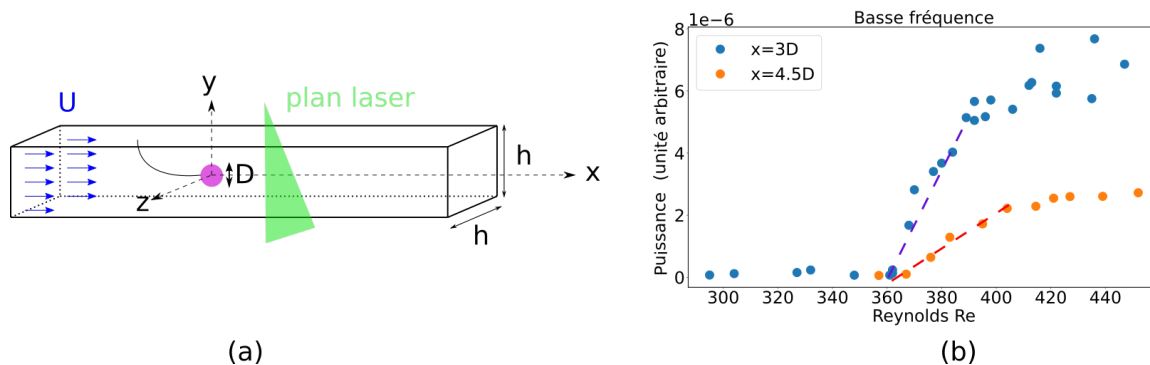


Figure 1. (a) Schéma du dispositif expérimental. (b) Puissance spectrale associée à la basse fréquence en fonction du nombre de Reynolds, dans le cas de la sphère, pour deux positions de mesure.

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Kirigami pour créer des structures déployables

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Le kirigami, l'art de créer des formes en découpant du papier, est une méthode ingénieuse pour étirer des films minces [1]. Cette méthode est utilisée dans différents domaines tels que la robotique [2], l'électronique [3] ou encore le biomédical [4]. On peut contrôler la forme 3D obtenue lorsque l'on déploie la structure à l'aide d'une force appliquée perpendiculairement au plan du film. On cherche à savoir s'il est possible de générer un motif de découpe spécifique correspondant à une forme 3D souhaitée lorsque la feuille est déployée.

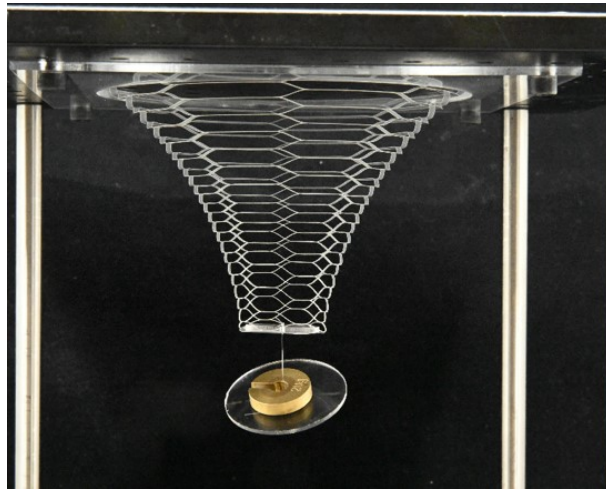


Figure 1. Kirigami en forme de pavillon de trompette déployé à l'aide d'un poids de 20g

Nos premières études des formes simples ont montré théoriquement et expérimentalement que cela était possible. De plus, la déflexion observée est perpendiculaire au plan, c'est-à-dire parallèle à la force appliquée lorsque cette dernière est faible [5]. Nous avons étendu cette étude sur des formes asymétriques.

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Shedding light on how illumination shapes fish collective dynamics

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In this experimental study, we investigate how illumination affects the collective motion of a large school of approximately 50 fish (rummy-nose tetras, *Hemigrammus rhodostomus*). We use two order parameters to quantify the structure of the group as we systematically alter the fish's visual range by gradually varying ambient light intensity. Our results indicate that at low light levels, the fish are unable to form a cohesive group, but as light intensity increases, the degree of alignment of the school increases. As we further increase the illuminance, the school structure transitions from a polarized state to a highly regular and stable rotational configuration (milling). Our findings highlight the importance of vision for cohesive collective motion in free-swimming fish schools, as opposed to the short-range hydrodynamic sensing via the lateral line, which is insufficient in this context. Overall, this experiment provides new insights into the interaction mechanisms that govern the emergence and intensity of collective motion in biological systems.

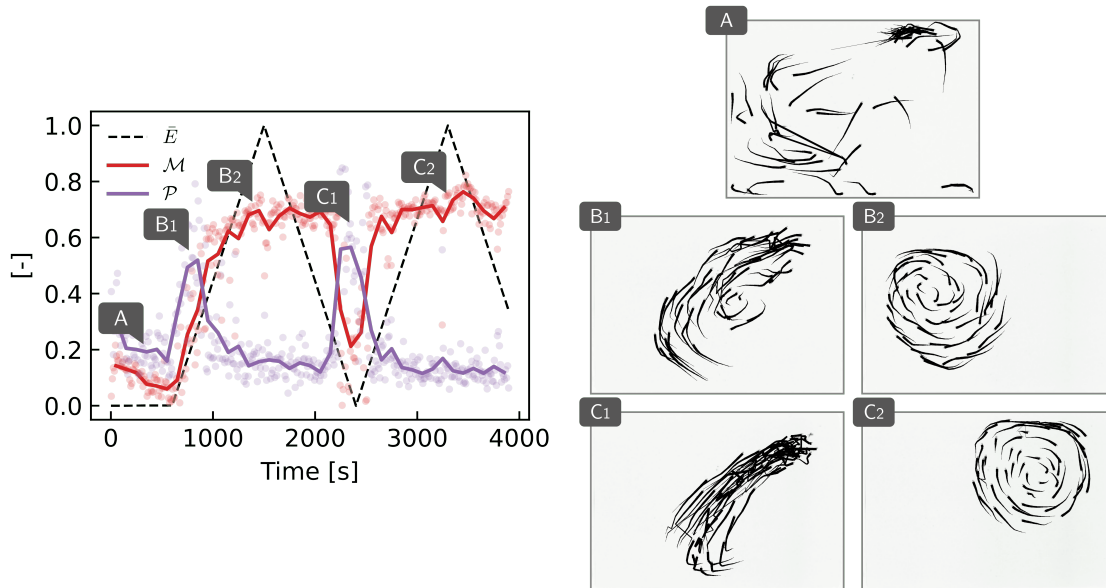


Figure 1. (Left) Experimental time signal of the milling \mathcal{M} and polarization \mathcal{P} parameters for a group of 53 fish experiencing variations of the illuminance (\bar{E} , normalized) over a 1h time period. (Right) Trajectories snapshots showing the different phases of the school, exhibiting the strong correlation between organization level and available visual cues.

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Statistical properties of energy transport in a set of bending waves

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Energy per mode or per degrees of freedom is a key quantity at equilibrium where it defines unambiguously the temperature of the systems and has well-known properties. Out-of-equilibrium the definition and pertinence of such quantity is still an open question. The aim of this work is to propose two ways of measuring it in a given out-of-equilibrium system: a set of bending waves generated in a thin elastic plate.

The first method relies on the fluctuation theorem. A large electromagnetic shaker sustains a random set of bending waves in thin stainless steel plate. Another small shaker, attached to the moving plate, exchanges a very small amount of energy to the plate seen as an out-of-equilibrium thermostat. From the study of the fluctuations of power provided by the small shaker, smoothed over long time, we deduce an energy per degrees of freedom in plate. We show that the energy is linear with the rms velocity of the plate [1].

The second approach relies on the wave turbulence (WT) theory applied to a set of bending waves. The WT theory does not predict an inverse cascade in such system. Therefore, an equipartition of energy per modes can be expected for wavelength larger than the forcing wavelength. We confirm experimentally this expectation and deduce the properties of the energy per modes as a function of the forcing parameters [2].

At equilibrium both methods converge to the temperature of the system but the benchmark in our system drives to qualitative and quantitative differences of both characteristic energy. They do not have the same dependency with forcing parameters and orders of magnitude different. This result needs to be confirmed by simultaneous measurements with both methods to insure similar experimental conditions although this would imply experimental difficulties. Further work would involve a systematic study of the thermodynamical properties of both characteristic energy determined by these two methods.

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Pincement au voisinage d'un ménisque dans un film liquide mince

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Dans un film liquide mince relié à un ménisque, le ménisque crée une aspiration capillaire qui engendre une zone de plus faible épaisseur là où le ménisque se connecte au film. Cette zone fine appelée pincement est à l'origine du phénomène de régénération marginale (cf. Fig. 1 (a)) observé dans les années 60 par Mysels dans les films de savon [1]. Il a été montré récemment [2] que la régénération marginale est d'une importance majeure pour décrire l'amincissement du film au cours du temps c'est-à-dire son drainage. Le drainage est à son tour central pour prédire la durée de vie du film et donc par extension la stabilité des mousses quand il s'agit de films de savon.

Nous étudions la dynamique d'apparition du pincement dans un film d'huile silicone horizontal, déposé sur une surface solide au *spin-coater*. Le ménisque est créé en déposant une tige verticalement sur le film [3]. Nous mesurons l'épaisseur du film dans la région du pincement, perpendiculairement à la tige, à l'aide d'une caméra hyperspectrale. Nous obtenons des profils d'épaisseur en différents instants, desquels on peut extraire la position (cf. Fig. 1 (b)) et l'épaisseur du pincement qui sont à mettre en regard avec le modèle théorique de la dynamique de ce pincement établi par Aradian *et al.* [4].

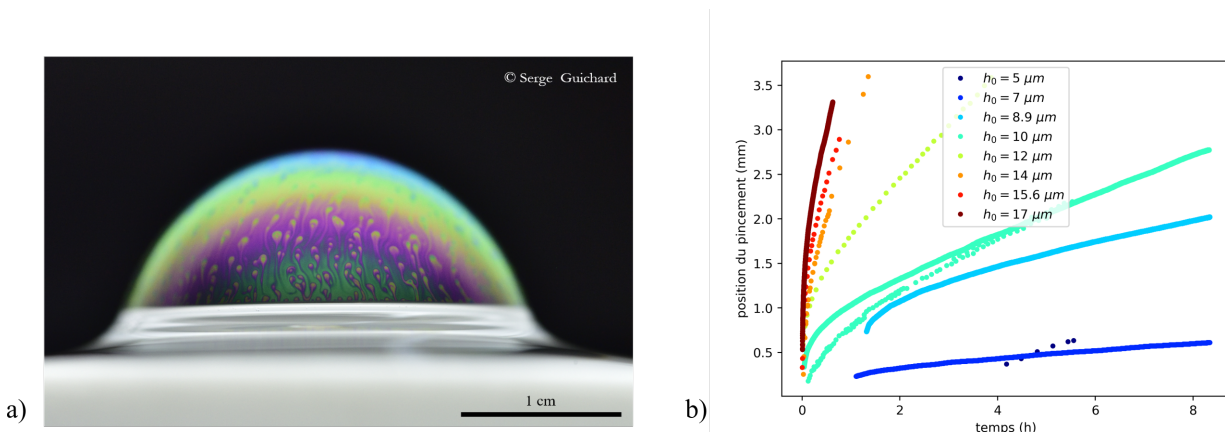


Figure 1. (a) Photographie d'une bulle de surface illustrant la régénération marginale : des patches circulaires fins montent alors que le reste du film, plus épais, descend. (b) Position du pincement pour des films d'épaisseur initiale allant de 5 micromètres à 14 micromètres et de viscosité dynamique $\eta = 30 \text{ mPa} \cdot \text{s}$.

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Coherence of velocity fluctuations in a turbulent jet flow

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Coherence between the velocity fluctuations measured at two points is investigated in a turbulent jet flow. Different regions of the flow are observed by changing the separation between the points, distance of the points from the exit of the jet and from its central axis, and the injection velocity of the jet. It is observed that the functional form of the coherence depends on regions where it is measured. Coherence is also observed to be self-similar in different regions of the flow.

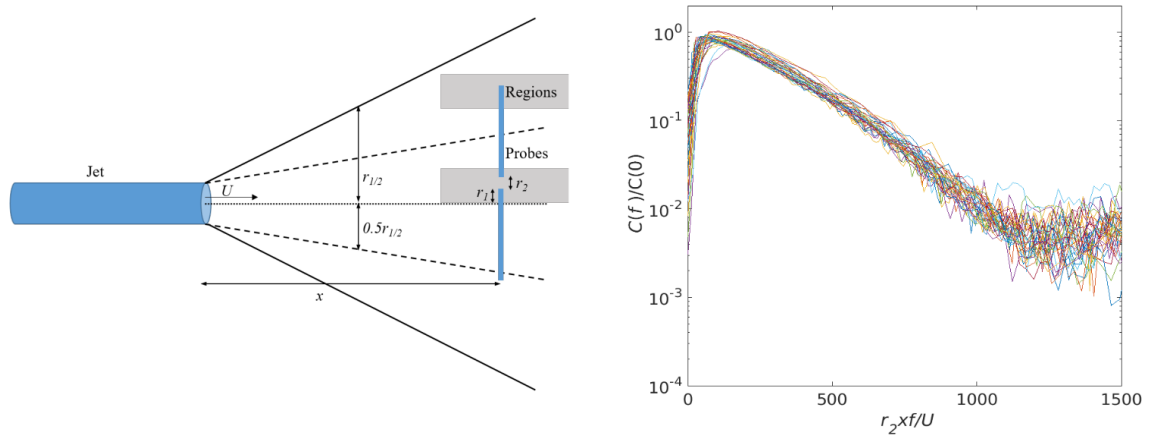


Figure 1. Schematic diagram of the experimental setup (left) and rescaled coherence curves for different values of parameters (right).

Comparative assessment of nonlinear deterministic models for coastal wave propagation and run-up on a vertical wall

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When propagating over variable seabed, ocean surface waves experience transformations due to various physical processes, including shoaling, refraction, diffraction, reflection or depth-induced breaking. Dispersive and non-linear effects can also be of importance, depending on the relative water depth kh (k being the characteristic wavenumber and h the local water depth) and the wave steepness ka (with a the characteristic wave amplitude) respectively. Among the deterministic (or phase-resolving) class of wave models, depth-averaged models are commonly used as a cheaper alternative to the fully dispersive fully non-linear Euler equations. However, due to the simplifying assumptions made in their derivation regarding dispersion and/or non-linearity, their ranges of applicability in terms of kh and ka vary significantly and remain limited.

In this work, we compare various deterministic wave models, ranging from the non-dispersive non-linear shallow water equations to a fully non-linear potential-flow model [1]. Several depth-averaged weakly dispersive Boussinesq-type models (from Peregrine [2], Nwogu [3] and Wei *et al.* [4]), or Serre-Green-Naghdi equations (e.g. Cienfuegos *et al.* [5] and Clamond *et al.* [6]) are also considered.

The capabilities and limitations of the various models regarding dispersion and non-linearity are assessed on cases of propagation of non-breaking waves in one horizontal dimension with uniform or variable water depth. Extreme wave run-up on a vertical wall due to a dispersive shock-wave wave train is also investigated based on the test-case introduced by Benoit *et al.* [7]. This case allows a quantitative assessment of the performances of the various approximate models and highlight the importance of both dispersion and non-linearity.

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Modélisation stock–flux d’une économie multi-sectorielle auto-organisée

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Les modèles macroéconomiques sont souvent construits sur une base d’optimisation intertemporelle d’utilité et d’équilibre général, dans un formalisme profondément éloigné des systèmes physiques qu’ils animent, et sont par leur nature omniscientes, incapables de comprendre leurs crises inhérentes [1]. De plus, leur formalisme en agrégats rendent difficile l’accès aux propriétés physiques des processus industriels qui animent l’économie, limitant les possibilités d’endogénéisation à la fois en entrée et en sortie avec leur environnement.

Dans cette présentation, on développera une approche alternative de modélisation, via des approches en systèmes dissipatifs complexes sur une structure stock–flux cohérente [2], avec comportements heuristiques antagonistes au sein-même de sa structure. On fera le lien avec des systèmes proies–prédateurs [3] et l’on montrera comment on peut étudier le couplage économie–climat comme la déformation d’un bassin de stabilité [4]. Finalement, on montrera comment on peut désagréger la production et s’approcher des flux matériels qui structurent l’économie, ainsi que la propagation de dynamiques intersectorielles via l’inflation ou des tensions logistiques.

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Synchronous motion of active particles in a trap

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We propose a numerical model to study active particles which can be trapped in a well. We consider attractive dipolar interactions to define the trap but also some short-range repulsive interactions between active particles. Depending on the competition between particle motion and trap characteristics, a number of particles can be trapped. Orbital motion, as expected in a well, is obtained in dilute cases. But for dense situations, due to their relative motions and short-range interactions, some synchronous motion is observed within the trap. This particular regime is illustrated in the figure below. The conditions for trapping as well as the occurrence of various collective dynamics are emphasized.

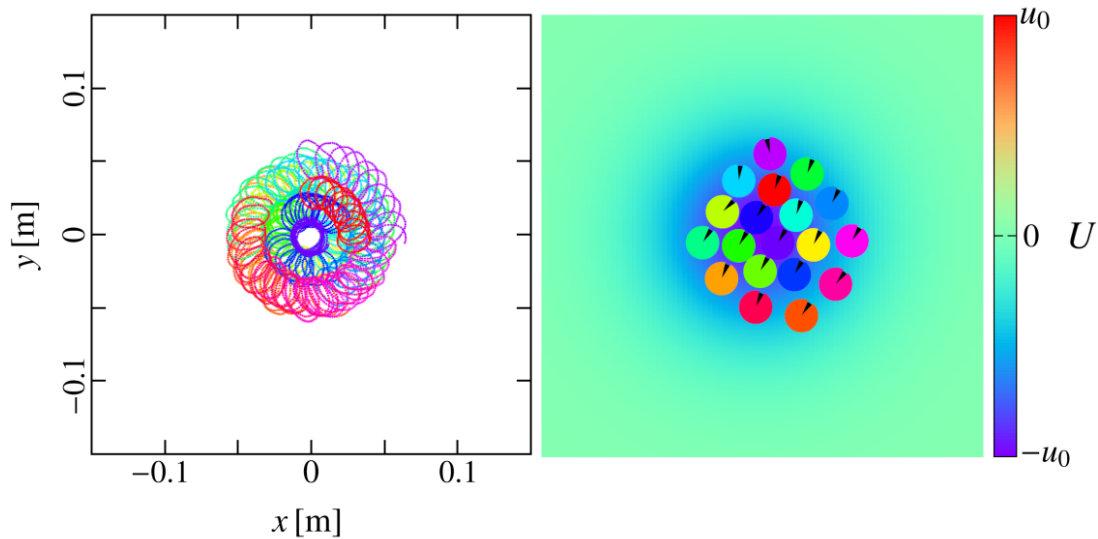


Figure 1. (Left) Typical trajectories followed by the trapped particles in a numerical simulation exhibiting synchronized movement. (Right) Snapshot of that numerical simulation showing particles moving collectively as a unique entity in the synchronous regime, where all angular velocities and directions are similar. The center of the trap is located in the center of the image.

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Ultimate regime of rapidly rotating convection: Experimental and numerical assessment of the "geostrophic turbulence" scaling predictions

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Several regimes of rotating convection arise depending on the background rotation rate and the strength of the thermal forcing. Of particular interest is the ‘geostrophic turbulence’ scaling regime, an ‘ultimate’ or diffusivity-free scaling regime that is believed to govern the transport of heat and tracers in planetary and stellar interiors. This regime has remained undetected in laboratory experiments for a long while, despite an effort of the community to build ever-taller rotating Rayleigh-Bénard convection cells. We recently introduced an alternate rotating convection setup where the fluid is heated radiatively through the absorption of visible light. This approach led to the first experimental observation of the ‘geostrophic turbulence’ regime [1], based on measurements of the heat transport efficiency. Beyond this characterization of the Nusselt-versus-Rayleigh scaling behaviour, the geostrophic turbulence regime is associated with scaling predictions for the turbulent kinetic energy, the temperature fluctuations and the typical scales of the convective flow [2, 3]. Based on recent experimental and numerical data of rapidly rotating radiatively driven convection, we assess the validity of these additional scaling predictions and discuss the range of validity of each prediction independently.

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Étude expérimentale de la création d'un jet par une membrane élastique submergée forcée par des vagues.

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Les membranes submergées forcées par des vagues offrent des applications prometteuses pour la conception de convertisseurs d'énergie des vagues, comme l'illustrent les concepts du « *wave carpet* » ou du « *Bombora Wave concepts* ». Cependant, alors que la dynamique des membranes dans un fluide a été largement documentée lorsque le forçage provient d'un courant constant (« effet de drapeau ») ou d'oscillations imposées, le forçage par des vagues a été peu étudié. Jusqu'à présent, la plupart des travaux qui se sont intéressés à ce système sont analytiques et numériques et mettent l'accent sur les applications à la production d'électricité. Seuls quelques travaux expérimentaux ont été réalisés mais également avec une priorité donnée aux aspects appliqués. L'objectif de cette étude est d'apporter un éclairage expérimental sur l'interaction entre une membrane submergée et un champ de vague tout en se focalisant sur les aspects physiques de l'interaction.

Pour ce faire, une membrane flexible, encastrée à une extrémité, est placée horizontalement dans un champ de vague comme schématisé en figure 1. L'effet de la membrane sur les vagues est obtenu en filmant par le haut et en utilisant une reconstruction complète du champ de vagues. La déformation de la membrane est obtenue en utilisant un enregistrement vidéo de la vue de côté. Un bilan d'énergie du point de vue des vagues montre que, lorsque le forçage, est suffisant, la membrane ponctionne de l'énergie aux vagues. Le procédé par lequel l'énergie est enlevée aux vagues est examiné par *Particle Image Velocimetry* (PIV). Cette étude montre que la membrane crée un jet ce qui fournit une explication partielle à la diminution d'énergie des vagues.

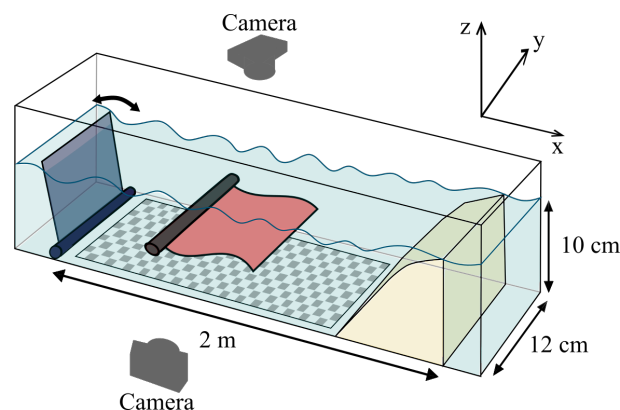


Figure 1. Schéma du dispositif expérimental. Les vagues sont générées en utilisant un *wavemaker* à rabat représenté à gauche. La membrane en rouge sur le schéma est encastrée à l'avant. Une plage (en beige) est placée au bout du bassin afin d'empêcher la réflexion des vagues sur le mur. Deux caméras (au dessus et sur le côté du bassin) sont utilisées pour effectuer les mesures.

Laminar-turbulent intermittency in pipe flow for a non-Newtonian fluid: Receptivity and thermo-rheology

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Turbulence being an ubiquitous flow behavior, the transition to this state is one of the most studied fields in fluid mechanics, yet it is not entirely understood. Turbulence, in addition to its academics appeal, is also a key element for the fluid transport optimization in many industrial processes. Among them, wastewater treatment processes require to control the transition to turbulence in the pipe with the added complexity of an Herschel–Bulkley fluid [1]. The transition to turbulence is realised through non linear amplifications of finite-size amplitudes perturbations [2]. The practical interest of modelling the intermittency is to optimize the sludge transport in pipe. For this reason the present work investigates the non-linear physics in the momentum equation that are essential to explain the intermittency and the non-linear interaction between turbulent and laminar regions leading to transition.

A one-dimensional model characterizing the transition to turbulence in Newtonian fluid has been developed by Barkley [3]. We generalized this model [4] to include power-law fluids, a particular case of an Herschel–Bulkley fluid without yield-stress, in a heated pipe. Recently, the model has further been extended [5] to study the radial receptivity to finite-size perturbations for an Herschel–Bulkley fluid. The objective of this work is to integrate the interaction between temperature and rheology to the model developed in previous works. We aim here to be capable to describe the receptivity to perturbations in pipe flow for different thermo-rheological properties and different heating conditions.

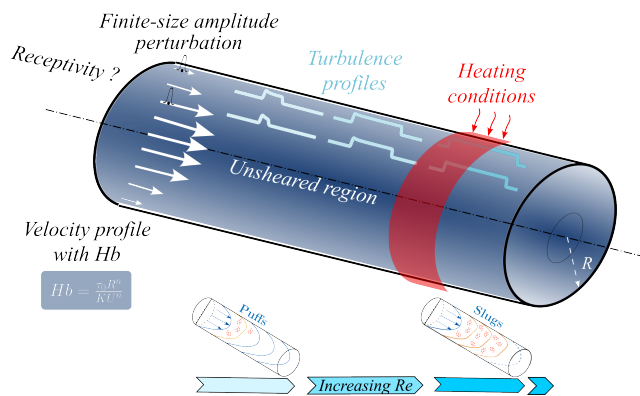


Figure 1. Illustration of the 1D model of the transition to turbulence due to non-linear amplification of finite-size amplitude perturbations for an Herschel–Bulkley fluid under thermal conditions

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Comparison of PIV and visualisation in Couette–Poiseuille flow

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In a linearly stable Couette–Poiseuille flow, the sub-critical transition to turbulence is linked to the appearance of coherent turbulent structures which take the form of streamwise vortices (or rolls) and modulations of the streamwise velocity (or streaks). Streaks, streaks break-up and vorticity are subjected to the self-sustaining process (SSP) of turbulence. When the turbulence decays, a Reynolds number dependent time-scale has been measured using visualisation [1], and two time-scales using PIV [2]. The goal of this study is to determine which time-scale and which structure is measured by visualisation by the means of a comparison between visualisation and PIV on the same experimental set-up.

The experiment is carried out in a plane Couette–Poiseuille channel in which the flow is driven by a moving belt, two tanks at the ends of the channel ensure a zero mean flux (Fig. 1 (A)). The moving belt direction defines the streamwise direction x , while z is the spanwise direction and y the wall-normal direction. The streaks and rolls are quantified respectively by the streamwise velocity fluctuations u_x and u_z , measured using PIV (Fig. 1 (B)). To study the decay of turbulence, we perform a "quench", an abrupt decrease of the Reynolds number Re , from a fully turbulent state to a laminar regime.

During this transition to a laminar regime, the coherent structures can be observed, either by visualisation or PIV. We implement the visualisation method by introducing in the flow anisotropic aluminium particles (30–80 μm) which reflect light directed in the spanwise direction. The fluid is then rheoscopic, making water movements visible to the naked eye (Fig. 1 (C)). Until now no measurement of visualisation and PIV has been made on a linearly stable plane Couette–Poiseuille flow using the exact same set-up.

The experiment showed that light intensity from visualisation seems to have the same characteristic time of decay as streaks during quench (Fig. 1 (D)). This allows us to conclude that such visualisation method appears to represent streamwise velocity fluctuations.

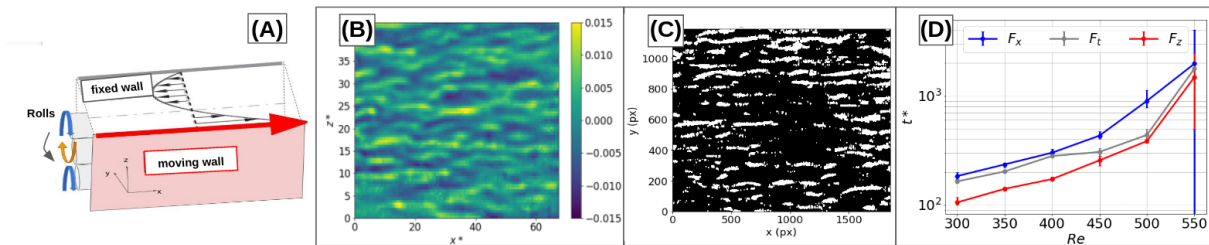


Figure 1. (A) Sketch of the experiment. (B) Dimensionless streamwise fluctuation velocity u_x^* . (C) Processed binary visualisation image of streaks. (D) Characteristic times of decay for turbulent fractions from visualisation (F_t) and PIV (F_x , F_z in the streamwise and spanwise direction respectively).

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Instabilité élasto-inertielle de suspensions viscoélastiques en écoulement de Taylor–Couette

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Dans de nombreuses applications industrielles, biologiques ou environnementales, une complexité non-linéaire peut-être introduite par la présence d’éléments mésoscopiques dans une matrice de fluide. La présence d’un ou plusieurs de ces comportements induit une complexité dynamique de l’écoulement, rendant difficile la prédiction des performances des procédés et le contrôle en termes de mélange, transferts thermiques, et stabilité. Malgré de récentes études [1–3] des données expérimentales sont encore nécessaires pour mieux comprendre le comportement hydrodynamique de ces suspensions. Dans une géométrie de Taylor–Couette, écoulement fondamental également appliqué dans les réacteurs, nous avons montré à travers une récente étude que pour un fluide viscoélastique (Boger), le Reynolds critique (\mathcal{R}) auquel apparaissent les instabilités diminue [5]. On observe alors une transition vers une turbulence élasto-inertielle, car pilotée par les forces viscoélastiques, qui sont sources de non-linéarités. De même, il a été montré que l’ajout de particules sphériques non-colloïdales en régime dilué ou semi-dilué dans une matrice Newtonienne diminue également le Reynolds critique de la bifurcation primaire (instabilité inertielle) [4]. Ainsi, augmenter la concentration de particules revient à accélérer l’apparition de l’instabilité et donc des non-linéarités. De rares études ont exploré la combinaison entre viscoélasticité du fluide et présence de particules [6]. Nous avons montré qu’un faible apport en particules dans une matrice viscoélastique tend à déstabiliser l’écoulement, mais qu’une concentration plus élevée retarde la transition vers la turbulence élasto-inertielle.

La présente étude permettra de confronter les non-linéarités liées aux lois de comportement du fluide ainsi que celles liées à la présence de particules. En particulier, elle apportera des informations sur la dynamique de frottement de tels régimes elasto-intertiels en présence de particules, ce qui n’a jamais été abordé jusqu’ici, et de mettre en perspectives les aspects chaotiques de l’écoulement et l’énergie dissipée par frottement.

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Lagrangian tracer transport in surface ocean turbulence with ageostrophic dynamics

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Ocean submesoscales, which have length scales of $\mathcal{O}(1-10)$ km, are notoriously difficult to measure due to their small size and rapid temporal evolution. However, recent studies have shown that these small scales can have a relevant impact on the advection of Lagrangian tracer particles, as well as on phenomena such as aquatic life migration, and pollutant dispersion and accumulation. Despite their importance, the present understanding of submesoscale ocean dynamics remains limited, with a key open question concerning the role of the non-geostrophic components of the surface velocity field. To address this question, we conducted numerical simulations using a model that includes non-geostrophic motions related to fronts, and that is derived as a small, but finite, Rossby number approximation of the fundamental equations of motion. In the limit of vanishing Rossby number, this model describes surface quasi-geostrophic (SQG) dynamics, and is known as SQG⁺¹ [1].

Our study focuses on the effect of the ageostrophic flow component on Lagrangian transport properties, specifically particle clustering. We used different statistical indicators to examine the characteristics of the turbulent flow, and to assess the impact of the latter on the spatial distribution of particles. Our results show that the ageostrophic flow components are responsible for the (temporary) formation of particle clusters, and that the intensity of this phenomenon increases with the Rossby number. Moreover, we provide evidence that Lagrangian tracers preferentially accumulate in frontal regions characterized by intense strain and positive (i.e. cyclonic) vorticity, as suggested by previous observations and modeling studies [2].

This study demonstrates that the relatively simple model we adopted captures some of the main features characterizing ocean turbulence at submesoscales, and can help shedding light on the mechanisms underlying particle clustering in this range of scales.

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Instabilities around a differentially rotating ellipsoid embedded in a rotating stratified fluid

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To better predict Earth's climate evolution, the CO_2 and heat fluxes between the oceans and the atmosphere must be taken into account. These fluxes are governed by the vertical mixing in the ocean. But the measured mixing rate is 10 times smaller than necessary to balance the energy budget of the oceans: this calls for new, local mechanisms of mixing. At the edge of meso-scale eddies, a horizontal layering is observed, corresponding to density steps [1]. This is a local signature of an increased vertical mixing. To quantify its influence we need to determine the origin of the underlying instability/ies.

To model this geophysical flow, a heated solid ellipsoid differentially rotates anticyclonically in a rotating stratified medium. We numerically and experimentally study this setup to assess the intensity and the structures of instabilities around the ellipsoid in the different regions of the Rossby, Froude, Eckman, Prandtl and Schmidt numbers space.

The numerical analysis is conducted using the pseudo-spectral eigenvalue problem solver Dedalus [2]. The experimental apparatus uses a rotating cylindrical tank of 1 m in diameter. The base flow is analytically computed for any aspect ratio from 0 to infinity. Various types of instabilities are observed, including baroclinic, double diffusive, convective and centrifugal ones, see e.g. Fig. 1. Their efficiency and relevance to explain the observed mixing are systematically assessed.

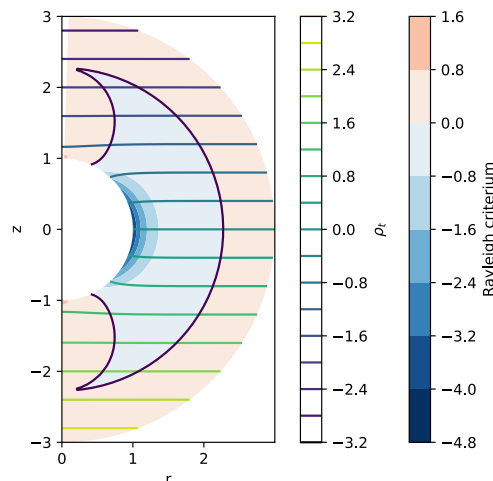


Figure 1. Rayleigh criterium map around a rotating sphere for $\text{Ro} = -10$, $\text{Fr} = 0.32$.

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Experiments on the impact and fragmentation of a liquid onto a lighter immiscible liquid

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The Earth formed by high-energy collisions between planetary embryos [1]. These impacts set the composition of our planet. We present laboratory experiments on the fluid dynamics of these giant impacts.

We investigate the impact of a centimeter-sized liquid volume onto a pool of a lighter immiscible liquid at large Weber numbers, which measures the relative importance of inertia to surface tension effects (Fig. 1). Our impactors are larger than in previous drop impact experiments to minimize the effect of surface tension during impact cratering [2,3]. We find that the impacting liquid fragments into drops when the Froude number, which measures the relative importance of inertia to gravity, is large enough, regardless of the value of the Weber number. This result contrasts with previous studies on drop impacts [2]. In our experiments, when inertia is comparable to gravity, i.e. $Fr < 10$, the impactor remains coherent. In contrast, when $Fr > 40$, the impactor fragments into millimeter-sized droplets. This fragmentation results from the growth of a turbulent Rayleigh–Taylor instability at the interface between the impacting liquid and the target pool. We obtain a scaling law for the mean drop size as a function of the Weber number that characterizes the turbulent Rayleigh–Taylor instability.

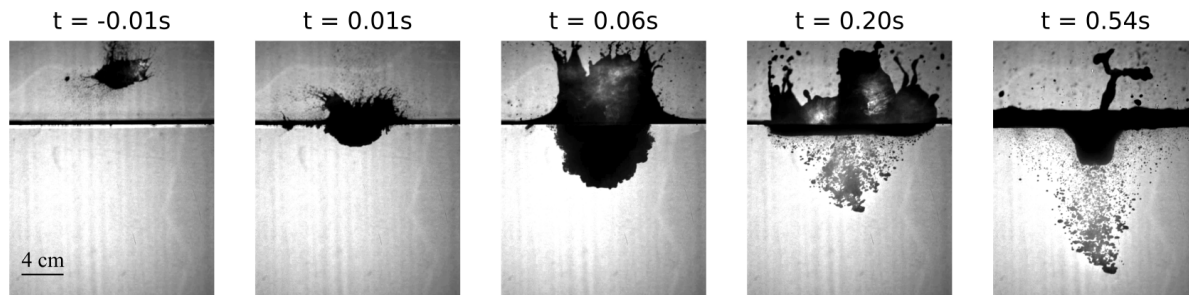


Figure 1. Experiment on the impact of a liquid volume onto a pool of a lighter immiscible liquid.

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Réfraction d'un soliton par un gaz de solitons

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Le soliton est une onde non linéaire conservant sa forme, sa vitesse et son spectre au cours de l'évolution, propriété issue de l'équilibre entre la non-linéarité de l'onde et la dispersion du système. Dans un système physique décrit par l'équation de Schrödinger non linéaire à une dimension (1DNLSE) deux solitons de vitesses différentes collisionnent élastiquement : à l'issue du processus d'interaction ils se retrouvent inchangés et un décalage dans leurs trajectoires apparaît.

Nous proposons une expérience d'optique fibrée dans laquelle nous faisons entrer en collision un soliton avec un gaz de solitons (un ensemble aléatoire de solitons) [1]. Dans un tel système, le décalage total de la trajectoire du soliton est égal aux décalages cumulés induits par chaque collision élémentaire. En utilisant une boucle de recirculation fibrée [2], nous pouvons capturer en mono-coup la dynamique spatio-temporelle du paquet d'onde et la représenter dans un diagramme (Fig. 1).

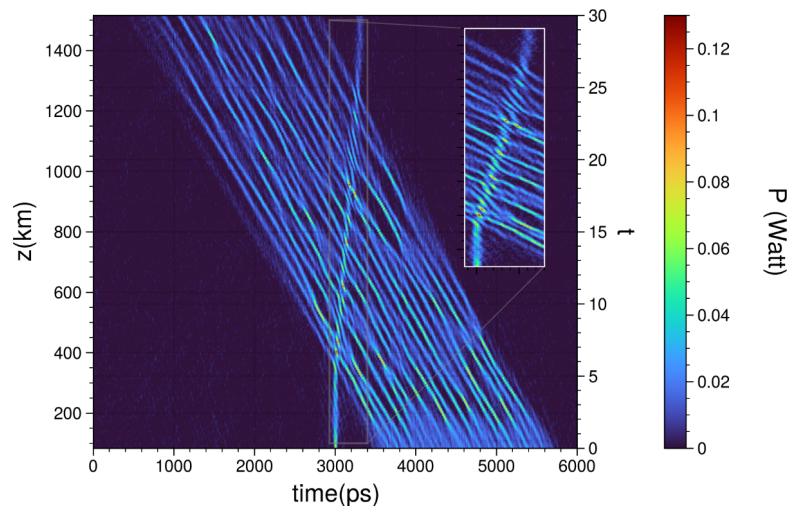


Figure 1. Diagramme spatio-temporel de la réfraction d'un soliton par un gaz de soliton monochromatique

Le diagramme présenté décrit la réfraction d'un soliton par un gaz de soliton. La trajectoire initiale du soliton est rectiligne (temps constant dans son référentiel). Lors de la traversée du gaz, le soliton est comme réfracté, sa vitesse change et sa trajectoire s'en retrouve décalée à la sortie.

Dans ma présentation je vous détaillerai le dispositif mis en place, la mesure du délai pour plusieurs gaz de tailles différentes et la théorie sur laquelle est appuyée notre étude.

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Geo-inspired thin film model flows

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We develop a serie of laboratory-scale model experiments to explore the dynamics and instabilities of liquid thin films inspired by geophysics [1, 2]. Laccoliths are pockets of magma whose growth is accompanied by deformations of neighbouring rock layers. Within certain limits, these dynamic formations can be compared to liquid drops covered with a thin elastic membrane. We revisit the classical experiments of free surface drop dynamics, by modifying the boundary condition at the interface.

We have built an experimental setup to observe the spreading and to characterize the typical lengths involved in the problem using the fast checkerboard demodulation technique (FCD) [3]. We inject a fluid of viscosity μ and density ρ through a glass plate on which we deposit a thin millimetric elastic membrane (cf. Fig. 1). This is performed at a constant flow rate Q . Thus, the evolution of the height profile $h(r, t)$ is described by the thin film equation in the lubrication approximation where D and T are respectively the bending stiffness and the tension of the membrane:

$$\frac{\partial h}{\partial t} = \frac{1}{12\mu r} \frac{\partial}{\partial r} \left[rh^3 \left(\rho g \frac{\partial h}{\partial r} + D \frac{\partial}{\partial r} (\Delta_r^2 h) - T \frac{\partial}{\partial r} (\Delta_r h) \right) \right] + w(r, t) \quad (1)$$

What is the shape and the dynamics of a fluid pocket trapped under an elastic membrane? How does the coalescence of two neighbouring pockets take place in this configuration? How are dynamic regimes then changed? We first reconstruct the general shape of the elastic drop and exhibit several spreading regimes that evolve following scaling laws (cf. Fig. 1 (right)). We then try to match the shape of each regime to an associated self similar behavior. A numerical analysis is also in progress for a comparison with the experimental dataset obtained.

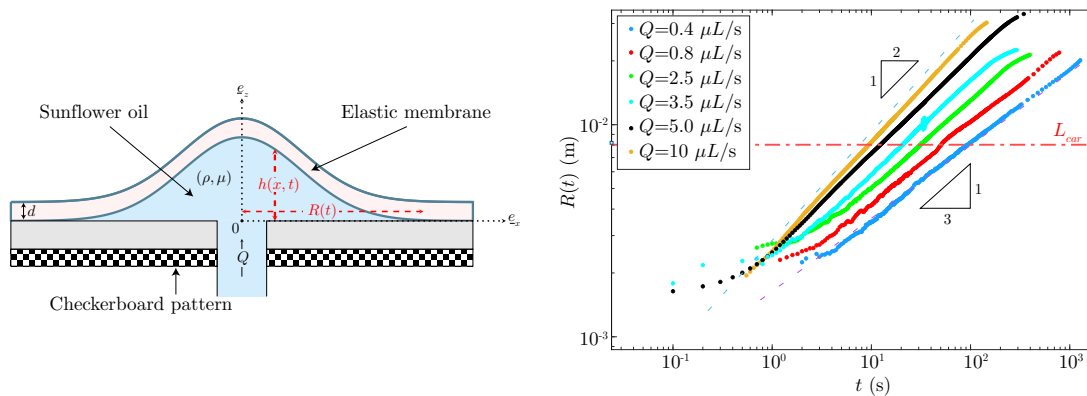


Figure 1. Experimental setup and temporal evolution of the radius $R(t)$ of a droplet for different values of the flow rate Q .

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Dynamique d'une mare de fonte

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Lorsque la banquise ou une calotte glacière fond au soleil, des étendues d'eau liquide se forment à sa surface, appelées « mares de fonte », dont l'évolution impacte significativement la stabilité de la couche de glace. L'objectif de notre travail est d'étudier expérimentalement et théoriquement les mécanismes physiques responsables de la dynamique de ces mares.



Figure 1. À gauche : Mares de fonte sur la banquise. À droite : Photo du dispositif expérimental. L'échantillon, du polyéthylène glycol ou de la paraffine initialement solide, est placé dans une cuve en verre, isolée par de la laine de verre. Une lampe halogène éclaire l'échantillon par le haut afin de le faire fondre. La température est contrôlée à la base du dispositif par des modules à effet Peltier asservis à une sonde thermocouple.

L'albédo est défini comme la fraction de flux de rayonnement réfléchi à l'interface entre deux milieux. Ainsi, une instabilité possible serait due au couplage entre l'albédo effectif de la mare de fonte et sa profondeur : plus une mare est profonde, plus elle absorbe de rayonnement. Nous avons alors établi un modèle théorique, le plus simple possible, afin de rendre compte de cette instabilité. Celui-ci prédit deux comportements pour la profondeur d'équilibre en fonction du flux radiatif, l'un supercritique, l'autre sous-critique, matérialisé expérimentalement par une hystérèse, qui dépend notamment du rapport entre l'épaisseur de glace et la longueur d'absorption de la lumière. Nous avons ensuite établi un dispositif expérimental simple afin d'observer ces deux régimes, où l'on mesure l'évolution de la profondeur de la mare en fonction du flux de rayonnement incident.

Idealized modeling of diabatically-forced anticyclonic plumes from wildfires and volcanic eruptions in the stratosphere

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Anticyclonically-trapped plumes were first discovered following the 2020 Australian fires. Since then, they have been reported after several extreme wildfires and volcanic eruptions, including the 2017 Canadian wildfires, the 2019 Raikoke and the 2022 Hunga Tonga-Hunga Ha'apai eruptions. They appear as coherent plumes of aerosols and combustion/volcanic compounds confined within mesoscale anticyclones (100s to 1000 km diameter), which for several months resist dispersion and dilution by the large-scale stratospheric flow. Due to their unusual composition, large radiative forcing is prevailing inside the plumes, generating significant diabatic responses in terms of vertical motions (ascent or descent) and potential vorticity.

This presentation will be focused on the analysis of idealized numerical simulations of the ascending vortices. The mechanisms governing their formation, maintenance and evolution will be discussed and the simulations confronted to theoretical investigations. In particular, after an appropriate coordinate transformation, the dynamics of the diabatically-forced flow can be to a good approximation reduced to a 1 dimensional Burgers' equation for the tracer, to which potential vorticity responds, resulting in anticyclonic PV formation at the location of the tracer front.

The spinorial ball: A macroscopic object of spin-1/2

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The existence of spin-1/2 particles is one of the most striking features of quantum mechanics and is often described as 'an object that does not come back to its initial state after one turn but that does after two turns'. Such feature has no straightforward equivalent in our macroscopic world and is therefore often considered as puzzling for the intuition. To provide better understanding, several macroscopic demonstrations have been proposed, the most famous one being the 'Dirac belt trick'. Alternatively, half integer spin can also be mapped on coupled pendulums in some specific parameter space [1]. However, a direct physical implementation of a half-integer spin in three dimensions without constraints is still missing.

We propose here to fill this gap by introducing the spinorial ball. It consists of a translucent plastic ball with internal gyroscope and LED illumination that behaves as a free-to-move macroscopic spin-1/2 object. It provides a new pedagogical tool to introduce spin-1/2 but also to the covering group homomorphism from $SU(2)$ (the rotation group of spinors) to $SO(3)$ (the rotation group in physical space). This device offers in particular a clear visualization of the different homotopy classes of $SO(3)$. The embedded electronics also allow the ball to mimic quantum measurement and wave function collapse. The entire system is open source hardware, with build details, models, 3d printing files, etc., provided under an open source license [2], and a virtual version of the ball can be manipulated online [3].

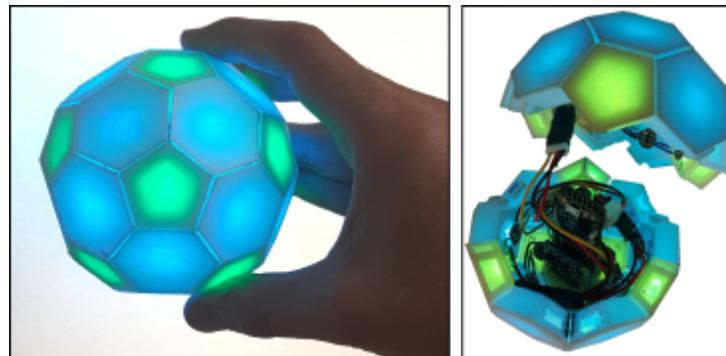


Figure 1. Pictures of the spinorial ball: the two color displayed on the LED panel encode the two complex component of a spinor. An embedded gyroscope detects the physical rotations of the ball and an Arduino changes the colors displayed in order to simulate spin-1/2 evolution under such rotation.

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Nouvelles solutions de l'équation de Ginzburg–Landau complexe

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L'équation de CGL unidimensionnelle

$$iA_t + pA_{xx} + q|A|^2A + r|A|^4A - i\gamma A = 0, \quad (1)$$

(p, q, r constantes complexes, γ constante réelle) présente un tout petit nombre de textures élémentaires connues analytiquement (fronts, impulsions, chocs, trous, puits, etc.). Nous ajoutons ici [1] trois nouvelles textures du type onde propagative $A = \sqrt{M(\xi)} e^{i[-\omega t + \varphi(\xi)]}$, $\xi = x - ct$ (c et ω réels) : un défaut (observé par Popp *et al.*, *Phys. Rev. Lett.*, **70**, 2880 (1993) et deux états liés de deux solitons sombres (observés par Afanasyev *et al.*, *Phys. Rev. E*, **57**, 1088 (1998)). De plus, nous prouvons [2, 3] qu'il n'existe pas d'autre onde propagative bornée, ni pour CGL3 ($r = 0$) ni pour CGL5, dont le module au carré $M(\xi)$ a pour seules singularités des pôles dans le plan complexe.

Exemple : le défaut de CGL5 (figure ci-dessous) a pour module au carré

$$M = -20 \frac{\Im(q/p)}{\Im(r/p)} \frac{\sinh^2 \frac{k\xi}{2}}{8 \sinh^4 \frac{k\xi}{2} + 36 \sinh^2 \frac{k\xi}{2} + 3}, \quad (2)$$

correspondant aux valeurs des paramètres

$$cp_i = 0, \quad \frac{p_r r_r + p_i r_i}{p_r r_i - p_i r_r} = \frac{3}{2}, \quad \frac{p_r q_r + p_i q_i}{p_r q_i - p_i q_r} = \frac{29}{15}, \quad \gamma = \frac{(p_r q_i - p_i q_r)^2}{|p|^2 (p_r r_i - p_i r_r)} \left(-\frac{7}{12} p_i - \frac{1}{5} p_r \right), \quad (3)$$

$$\omega = \frac{(p_r q_i - p_i q_r)^2}{|p|^2 (p_r r_i - p_i r_r)} \left(\frac{7}{12} p_r - \frac{1}{5} p_i \right) - \frac{p_r^3}{4|p|^4} c^2. \quad (4)$$

Sa vitesse c est arbitraire si p est réel, sinon elle est nulle (défaut stationnaire). Les deux états liés ont des expressions analytiques similaires, cf. [1] pour leurs figures.

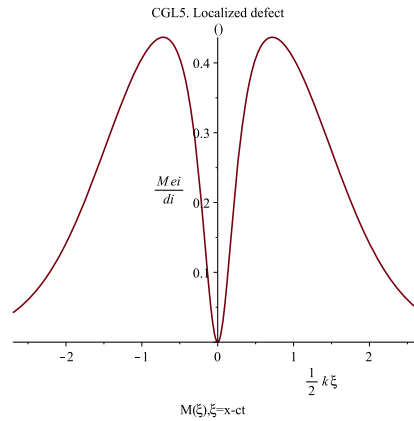


Figure 1. Défaut homocline en unités sans dimension.

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Experimental investigation of 2D plumes of soluble particles

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In this study, several mixtures of particle and water are injected with constant injection rates at the top of a 2D water tank. We compared two types of particle plumes with similar densities: plastic beads (which are not soluble) with water, and butyramide particles (which are highly soluble in water) with its saturated solution. We chose butyramide particles because they do not change the density of the aqueous solution when they dissolve, meaning that buoyancy effects only occur due to solid particles. The injection of particles leads to the formation of a plume in the tank since the density of particles are slightly larger than the one of water.

We used light absorption to quantify particle concentration and particle image velocimetry (PIV) to measure velocity fields. As showed in Fig. 1, the average plume shape for butyramide plume is much narrower than the plastic bead plume due to dissolution. The velocity on the side, called the entrainment velocity, is almost constant for plastic bead plume, but decreases along the vertical direction for butyramide. From these measurements, we also derived the entrainment velocity as a function of the particle injection rate and analyzed the plume shape.

Our research is relevant to understand the behavior of localized rain, where water droplets evaporate while falling through the air. This process can be mimic by the dissolving of soluble chemicals in water.

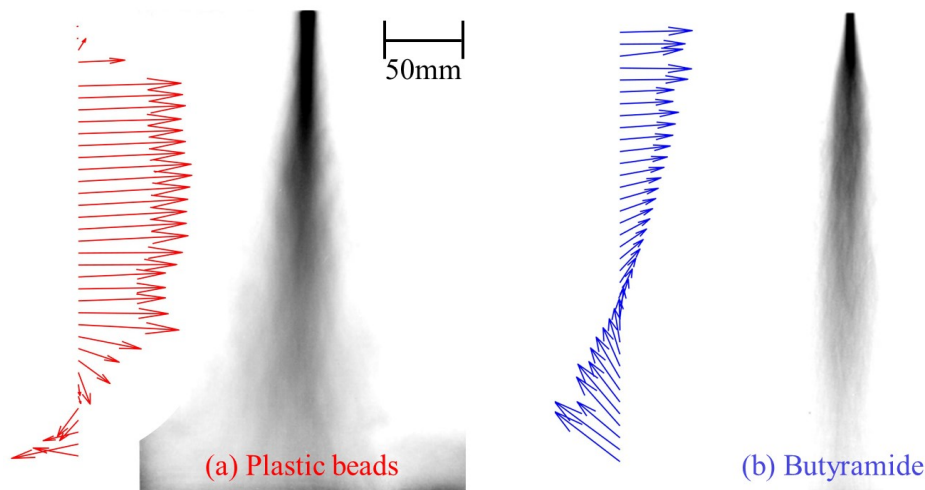


Figure 1. Comparison between plastic bead plume (red) and butyramide plume (blue) with similar injection rate, including the average image of concentration in grey level and the time-averaged velocity profile in color on the side of the plume (150 mm away from the plume middle line). (a) Plastic bead plume, injection rate 0.59 g/s; (b) Butyramide plume, injection rate 0.53 g/s.

Topography-induced hydrodynamic roughness

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Turbulent flows above a solid surface are characterised by a hydrodynamic roughness that represents, for the far velocity field, the typical length scale at which momentum mixing occurs close to the surface. Here, we are theoretically interested in the hydrodynamic roughness induced by a sinusoidal bed of given wavelength and amplitude. We describe the flow with RANS equations closed by means of a mixing-length approach that takes into account a possible bed geometrical roughness as well as the presence of a viscous sublayer. It also incorporates transient effects at the laminar-turbulent transition. Performing of a weekly nonlinear expansion in the bedform aspect ratio, we predict the effective hydrodynamic roughness when the bed wavelength is varied and show that it presents a non-monotonic behaviour at the laminar-turbulent transition when the surface is geometrically smooth. With a further self-consistent looped calculation, we are able to recover the smooth-rough transition of a flat bed, for which the hydrodynamic roughness changes from a regime where it is dominated by the viscous length to another one where it scales with the bed corrugation (Fig. 1). We finally apply the results to natural patterns resulting from hydrodynamic instabilities such as those associated with dissolution or sediment transport. We discuss in particular the aspect ratio selection of dissolution bedforms and roughness hierarchy in superimposed ripples and dunes.

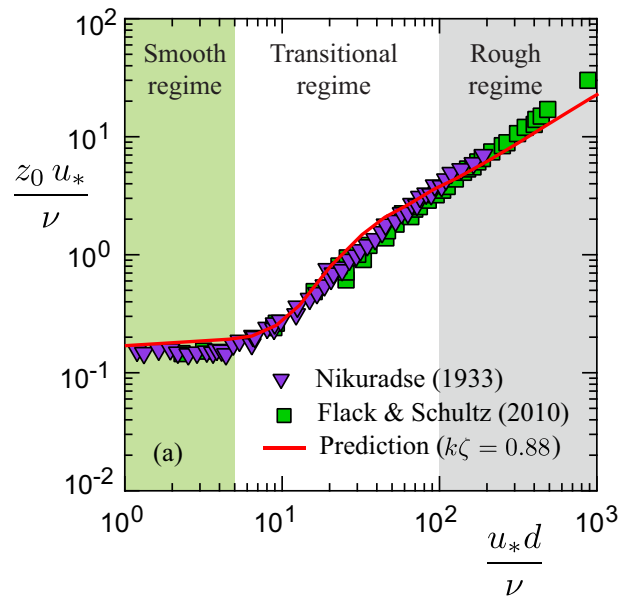


Figure 1. Hydrodynamic roughness z_0 as a function of the bed equivalent sand grain d . These quantities are made dimensionless by the viscous length ν/u_* , where ν is the kinematic viscosity of the fluid and u_* the shear velocity of the flow. Symbols: measurement data (see legend). Solid line: self-consistent prediction of the model.

Manipulation of solitons in optical fiber experiments

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In nonlinear physics, more precisely in integrable system like sine–Gordon (SG), Korteweg–de Vries (KdV) and the one dimensional nonlinear Schrödinger equation (1D-NLSE), the concept of fundamental soliton plays a key role in understanding the dynamics due to its main property : the preservation of its shape during the evolution and of its parameters when interacting with other solitons. In 1D-NLSE, a spatially localized wavefield contain a high-order soliton solution known as a bound state of solitons, they form when two or more fundamental solitons coexist spatially with no relative velocity [1]. In this work, we use optical fibers to study the spatio-temporal dynamics associated with a localised phase modulation of a bound state of solitons in order to manipulate the velocity of a selected soliton. Finally we compare the results with a perturbed Inverse Scattering Transform spectrum theory (IST) in which the signal is decomposed into solitons characterized by their amplitudes and velocities.

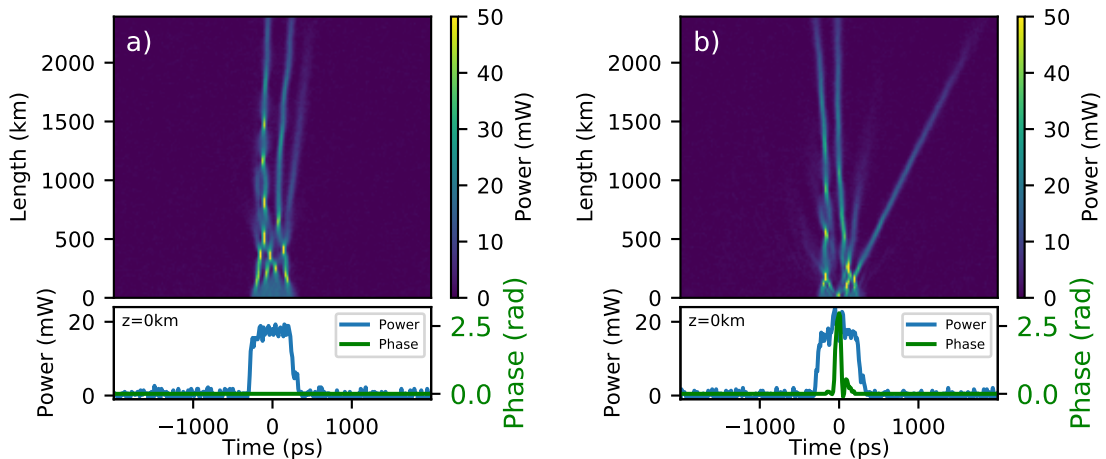


Figure 1. Comparison of experimental spatio-temporal evolution of an unperturbed square-shaped light pulse (a) and localised phase modulated square-shaped light pulse (b) with the respective initial conditions.

Experimentally, we generate a square-shaped light pulse composed of several solitons that is launched into a recirculating optical fiber loop. Each loop, a portion of the light is collected allowing us to record the spatio-temporal dynamic in single shot [2]. Figure 1 shows the propagation of a square-shaped light pulses composed initially of 5 solitons over 2,400 km. In the first panel (a) no phase modulation is applied exhibiting the spatio-temporal dynamic of a bound state of solitons. In the second panel (b) a phase modulation is applied initially, changing the velocity of one of the soliton [2].

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Fiber aggregation in flows

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When fibers are suspended in flows, they can collide and sometimes create balls. This aggregation process has been observed in natural system [1]. We are now running some experiments to reproduce this phenomenon in the lab in order to model the fiber aggregation. Recently, we observe the formation of nearly spherical aggregates in a turbulent von Kármán flow (cf. Fig. 1).

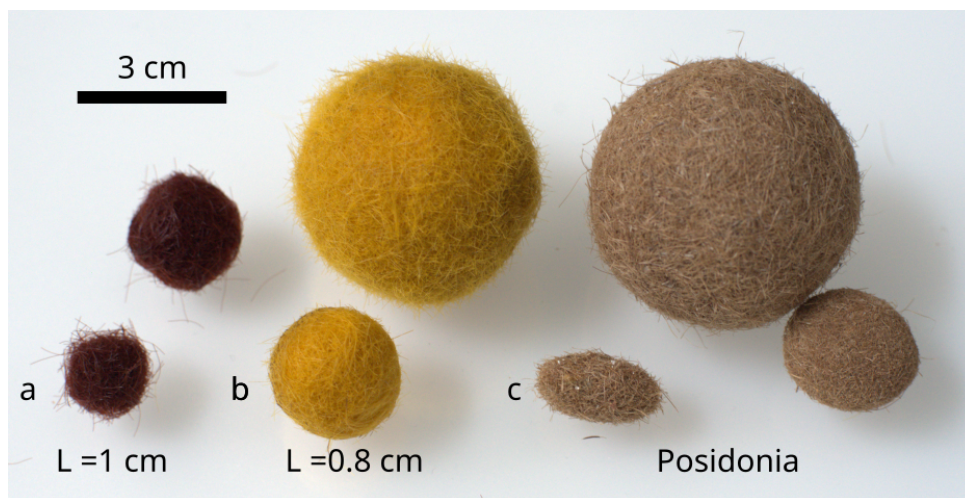


Figure 1. Images of fiber aggregates. (a) and (b) Aggregates of nylon fiber produced in our set up. (c) Natural posidonia balls found on the beach.

We are investigating the impact of the different parameters on the number and size of the aggregate, such as the forcing frequency of the flow or the mechanical properties of the fibers and their concentration. We then characterize the aggregate with tomographic images. We are able to reconstruct each fibers and the network of entangled fibers. The formation of the aggregates is expected to be a dynamical process with a balance between aggregation and fragmentation. Therefore we are also studying the fragmentation of balls independently by immersing a single aggregate within a turbulent flow and looking at its destruction.

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One-dimensional optical turbulence

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One dimensional Nonlinear Schrödinger Equation (1D NLSE), which governs different nonlinear systems (optical fibers, liquid crystals, Bose–Einstein condensation), was proven to be integrable by Zakharov and Shabat in 1971 [1]. They used the Direct Scattering Transform (DST) method, a computation of the nonlinear spectrum, equivalent of Fourier Transform. 1D NLSE is however just a model for most systems, the real equations contain high-order corrections. These new terms often break its integrability, allowing these systems to have a turbulent behaviour. The system studied here is the propagation of a laser beam into a liquid-crystals medium, governed by an non-integrable equation corresponding to a modified 1D NLSE. This system is thus turbulent and present interactions between linear waves and solitons. The main idea of our work is that we can apply DST to characterize solitons and thus study this turbulent system.

To understand these interactions, we run Direct Numerical Simulations and process the data obtained by using different methods to characterize the solitons, including the DST. We compare the results given by DST to the $x-t$ plot of the simulation and to $k-\omega$ plots. Doing this, we have three ways to identify solitons and to obtain their speeds and amplitudes. It appeared that the information given by DST is consistent with $x-t$ and $k-\omega$ plots which makes it a useful tool to study a non-integrable system. With these tools, we observed different sets of sech-profile solitons evolving with modified 1D NLSE and obtained interesting results, (*i*) these solitons move with an oscillating amplitude, (*ii*) some new solitons can be created and some annihilated, (*iii*) we saw evidences of soliton turbulence [2], a series of non-elastic collisions that leads to a big single soliton.

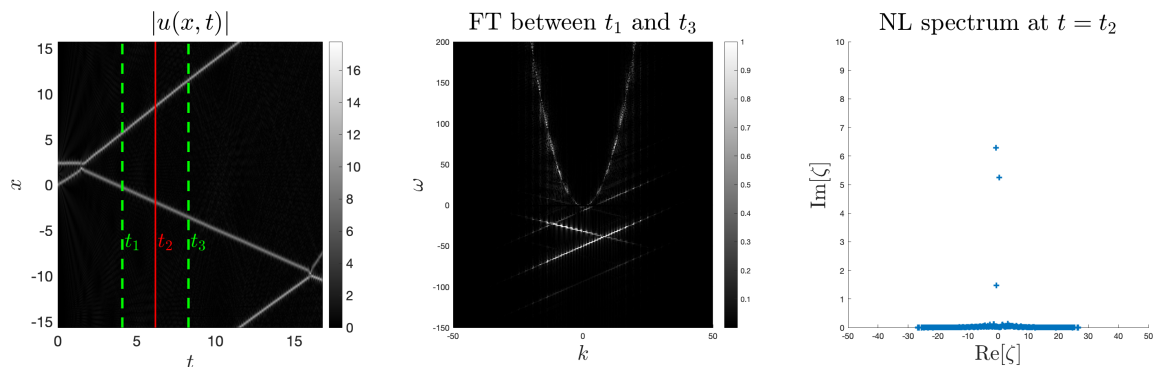


Figure 1. Study of a 2-solitons collision with appearance of a new soliton

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Sedimentation of a single soluble particle

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In this study, we investigate the dissolution and sedimentation process of individual soluble particles. We chose butyramide as the solute because it does not change the density of the surrounding water when it dissolves [1]. The particles sediment in a small tank with a two-layer fluid, where the upper layer is a saturated butyramide solution and the lower layer is a low concentration NaCl solution, as shown in Fig. 1 (a). To ensure optimal resolution in detecting particles during the dissolution process, we designed a particle tracking system that moves the camera vertically using a stepper motor with real-time feedback to maintain camera aligned with the particle position. This setup allows for high magnification of particles and detailed observation of the dissolution process, as shown in Fig. 1 (b). Our experiments were conducted under the conditions of small particle Reynolds number and large Péclet number.

Through theoretical derivation, we found that the radius reduction rate of a particle during dissolution depends only on the characteristics of the salt and the solution, and is thus constant over time. From experiments, we obtained the reduction rate of a particle directly from the shrinking of its radius (Fig. 1 (b)) and from its sedimentation dynamics. Both estimates of the reduction rate give consistent results, similar to the theoretical prediction.

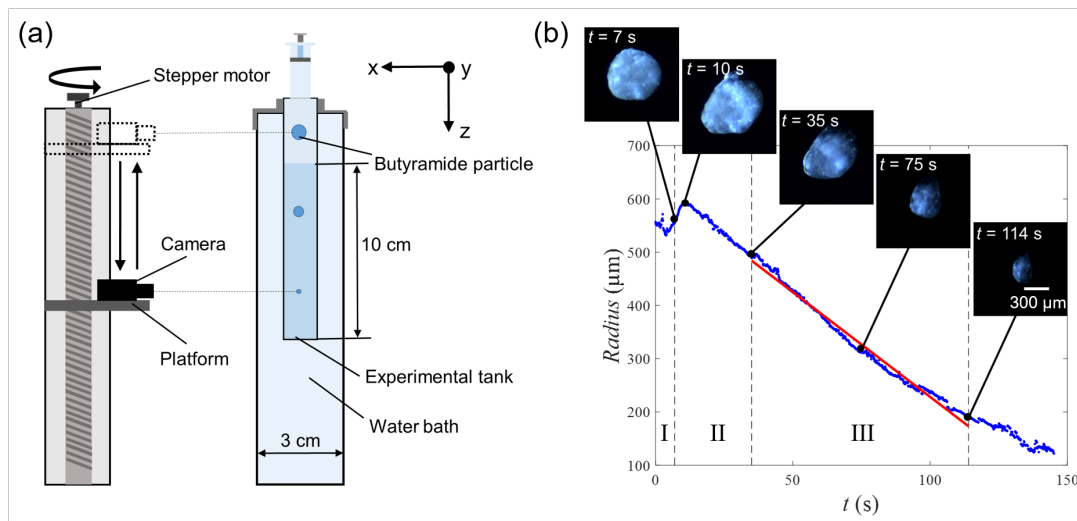


Figure 1. (a) Schematic diagram of the experimental setup; (b) Radius of the particle versus time. The blue points represent the equivalent radius from the projection of the particle, and the red line is a linear fit. Regime I corresponds to the saturated butyramide solution. Regime II corresponds to the intermediate transition of two layers. Regime III corresponds to the low concentration NaCl solution.

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Thin flexible disc trapped in a vortical flow: Reconstruction and analysis

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A thin flexible disc is observed repeatedly “trapped” near the vicinity of a vortex. Work will be presented on the 3D reconstruction and tracking of the disc using shape-from-silhouette and Thin-Plate Splines (TPS). The reconstruction process uses shape-from-silhouette to define an initial 3D reconstruction, which is subsequently refined by minimizing a cost function based on physical and visual criteria. Approaches to understand the mechanism behind the “trapping” event will also be reviewed.

Subcritical dynamics of axisymmetric rotor–stator flow

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Rotor–stator flows have been studied extensively in the past. There have been many experimental observations of coexistence of both circular rolls and spiral arms [1]. The origin of the latter is well understood [2] while that of the former is not. Such rolls display chaotic and sometimes transient dynamics [3]. Linear stability analysis performed by [4] for the height/radius ratio of 0.1 revealed a Hopf bifurcation around $Re = 3,000$, value much higher than found experimentally, and the existence of the subcritical branch. We revisit this transitional flow using numerical simulation and dynamical systems tools. New results concerning the first axisymmetric Hopf bifurcation will be presented. For lower values of Re , at least three flow regimes are identified: base flow, turbulent state and an edge state separating the two. This edge state features several incommensurate frequencies, involves inertial waves and, contrary to the expectations, does not originate directly from the Hopf bifurcation point.

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Shape of the cavity formed by an oblique capillary jet

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When a liquid enters another liquid with enough velocity, air can be entrained. This phenomenon is widely studied, as it is found in multiple practical situations [1], from waves breaking in the ocean to the pouring of a beer in a pint.

Here, we study the case of an oblique capillary jet of water with or without surfactants entering a bath of the same liquid. Most of the literature indeed focuses on the vertical case, which appears to be very different concerning the air entrainment process. This behavior also differs from the case where an inclined jet impacts a thin soap film [2].

We show that when the jet impacts the bath, a stationary cavity and meniscus are formed. When the speed of the jet increases, an instability appears, which can grow enough to pinch bubbles at the tip of the cavity. The size and shape of the cavity is then primordial to understand air entrainment in this situation.

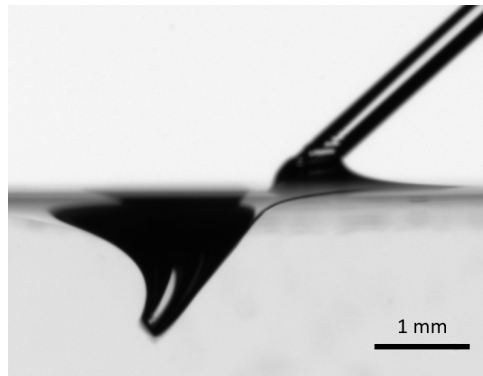


Figure 1. Image of a jet of radius $190\ \mu\text{m}$ entering a bath of water at $2.1\ \text{m/s}$.

We find that the shape of the cavity and the meniscus can partly be described by an hydrostatic balance between gravity and Laplace pressure at the interface. We observe that the size of the cavity is weakly dependent on the speed of the jet, but very sensitive to the angle between the jet and the bath. Adding surfactants to the solution will change the size of the cavity. The smallest cavity is observed for a minute amount of surfactant. The cavity then grows with the concentration of surfactant, but remains smaller than in the case of pure water.

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Elastic instabilities in soft structures

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A parametric oscillator is a system whose natural frequency is periodically modulated, via the time variation of one of its physical parameters. When this parameter is modulated to about twice the natural frequency, the amplitude of the oscillation increases exponentially: this is known as parametric resonance¹.

Here, we study the behaviour of a system in which the natural frequency varies both temporally and spatially. We use a flexible pre-stressed strip undergoing longitudinal excitation. This induces parametric changes in the tension of the strip. We first study the linear domain by characterising the different compression and bending modes. Then, by exciting this system in the vicinity of the natural frequencies of the bending modes, we observe and study the growth of elastic instabilities.

If at first sight the system seems to be close to a classical case of parametric oscillator (similar to Melde's experiment [1]), it turns out that the dynamics of instability growth is very different from what is usually observed. We propose a model to explain this atypical phenomenon by taking into account a spatio-temporal modulation of the strip tension and a mode-dependent dissipation.

The study and understanding of these unstable behaviours in soft materials is particularly motivated by applications in energy recovery or soft robotics [2].

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¹ Other modulation frequencies can also lead to resonance but are usually less efficient.

Formation of spikes, crests and scallops in erosion by dissolution

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Chemical erosion occurs when a soluble rock like salt, gypsum or limestone is dissolved in contact with a water flow. The coupling between the topography of the rocks, the mass transfer and the flow can lead to the formation of remarkable patterns, like rillenkarrens (parallel channels), tsingys (sharp pinnacles) or scallops (cups-like shapes) [1]. All these patterns display very sharp spikes or crests, despite the diversity of hydrodynamic conditions and nature of the soluble materials. By comparing field measurements, numerical models and experiments, we explain the generic occurrence of these spikes by a geometric approach: singularities at the interface are a direct consequence of the fact that the erosion velocity is directed in the normal direction.

First, we demonstrate the presence of singular structures on the limestone walls, shaped by dissolution, of the Saint-Marcel cave (Ardèche). Then, we propose interface evolution models of increasing complexity allowing us to explain the emergence of spikes and crests as well as the long-term formation of cellular structures. Finally, we perform experiments in which dissolution patterns are carved on the surface of an immersed salt block by a solutal convection instability [2]. We report the emergence of a cellular pattern of concavities surrounded by sharp crests reminiscent of natural scallops, in accordance with our model (cf. Fig. 1).

Although the precise prediction of dissolution shapes requires a complete hydrodynamic study, our results show that the characteristic spikes reported ultimately are explained by geometric arguments. These findings can be applied to other ablation patterns, reported for example on melting or sublimating ice and on the surface of meteorites.

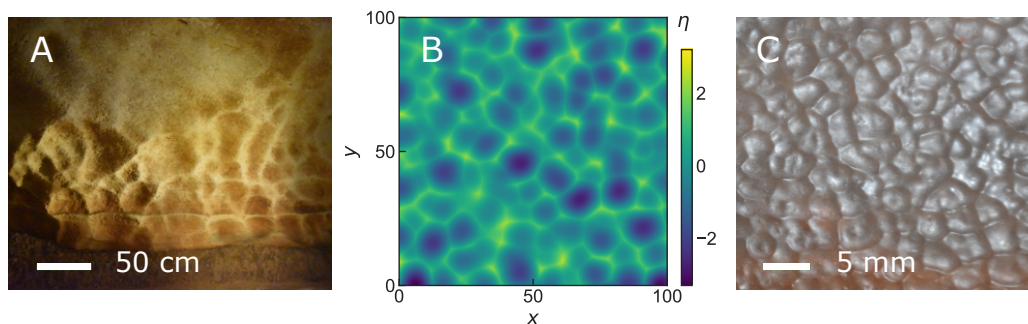


Figure 1. A: Scallops on a wall of the Saint-Marcel cave. B: Scallops obtained numerically with an interface evolution model. C: Scallops obtained experimentally on the bottom surface of an immersed pink salt block.

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Perversions dans les hélices : transition de phase et cristallisation de solitons

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En tournant l'extrémité d'une hélice élastique, à partir d'un certain nombre de tours, une instabilité fait apparaître une hélice de chiralité opposée. Cette nouvelle hélice est reliée à l'hélice de chiralité naturelle par ce qu'on appelle une perversion. En continuant de tourner, la perversion se propage le long de la tige. Pendant cette propagation, le moment axial est fixé par le système, à l'instar d'un plateau de Maxwell. Nous montrons que ce phénomène peut être rationalisé en terme de coexistence de deux phases : l'hélice de chiralité naturelle et l'hélice de chiralité inversée, avec pour interface entre les deux phases, la perversion. La perversion, comme un soliton, peut se propager le long de la tige sans se déformer. Nous avons analysé l'interaction entre deux perversions. Elles agissent comme deux particules présentant une distance inter-particulaire d'équilibre. Il est alors possible d'appareiller une perversion avec sa voisine. En répétant l'opération, il est alors possible de créer un chapelet de perversions, correspondant à l'agrégation des solitons.

J'exposerai les résultats numériques et expérimentaux en rapport avec cette transition de phase faisant apparaître coexistence entre hélice et antihélice, l'interaction entre deux perversions et cette cristallisation des solitons en un chapelet de perversions.

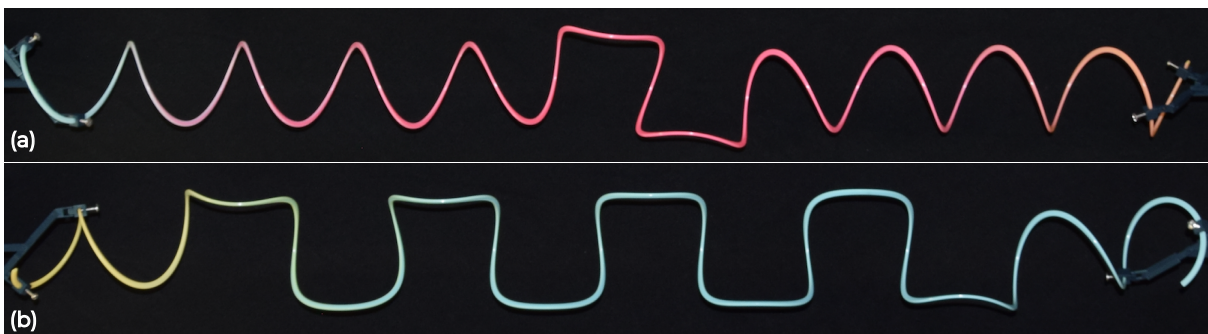


Figure 1. (a) Deux perversions appareillées le long d'une tige hélicoïdale. (b) Chapelet de perversions.

Transport de fibres souples en écoulement turbulent homogène et isotrope

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Le transport de fibres souples en turbulence suscite un grand intérêt depuis quelques années : c'est un problème que l'on retrouve dans l'industrie, dans le cadre des fibres de cellulose utilisées pour la fabrication du papier, mais aussi en océanographie, concernant le transport des microplastiques. Des études expérimentales ont déjà été menées concernant des fibres rigides en écoulement turbulent [1], mais concernant les fibres flexibles, la majorité des études sont, à ce jour, numériques [2]. L'étude expérimentale présentée a pour objectif de caractériser l'impact de la déformation des fibres souples sur leur déplacement. De telles observations nécessitent de calculer les coordonnées 3D des fibres grâce aux images de trois caméras rapides, à partir desquelles, il est possible de calculer les coordonnées des voxels en projetant les coordonnées des pixels contenant une fibre de chaque image. Ce premier calcul est très limité par la résolution de la calibration. Il faut donc passer par une étape d'optimisation des coordonnées, étape primordiale qui représente actuellement la majorité du travail mené sur ce sujet, car elle dépend beaucoup des propriétés mécaniques des fibres, ainsi que de l'intensité de la turbulence.

Afin de valider le processus de reconstruction 3D, les premiers résultats sont comparés à ceux de précédentes études sur les fibres souples (cf. Fig. 1, résultats d'une étude numérique [3]) ou rigides [1].

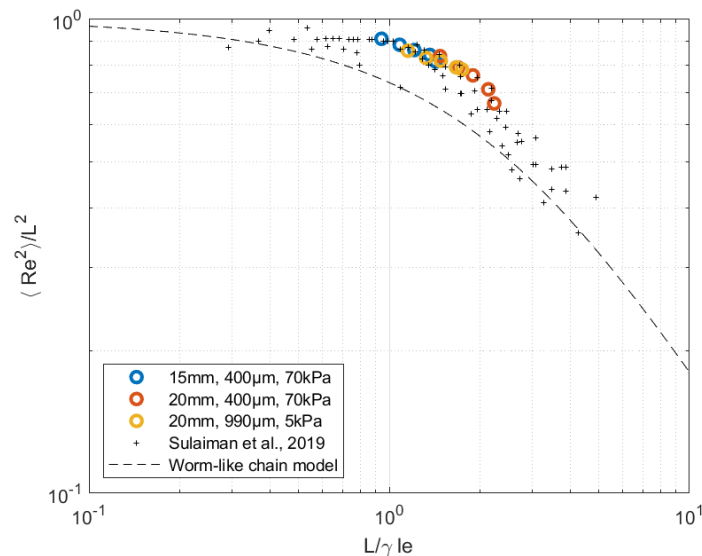


Figure 1. Évolution de la norme du vecteur bout-à-bout \mathbf{R}_e en fonction du nombre de Sperm $Sp^{1/8} = L/l_p = L/(\gamma l_e)$, où l_e est la longueur élastique de la fibre dans un écoulement donné.

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Water wave implementation of a coherent source based on time-varying medium

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Time crystals [1] and time-varying media [2] are a promising playground for new physics and for novel manipulation of wave propagation. Recently, the time analog of a laser has been proposed theoretically based on a time modulation of the medium properties [3,4]. The experimental realization of this concept is most challenging and currently out of reach in optics. Here, we show the first experimental realization of a time-modulated source with water waves. A vertical shaking of the bath can be used with a bathymetric confinement to modulate the medium over arbitrary spatial geometries at fast timescales relative to the wave speed (Fig. 1). Alternatively, we also use electrostriction to reach higher modulation amplitudes and to reduce the spatial boundary effects [5–7]. We characterize our system and discuss the relation with the Faraday instability, the parametric amplification, the phase-conjugate mirrors, and the analogy with the optical counterpart [8].

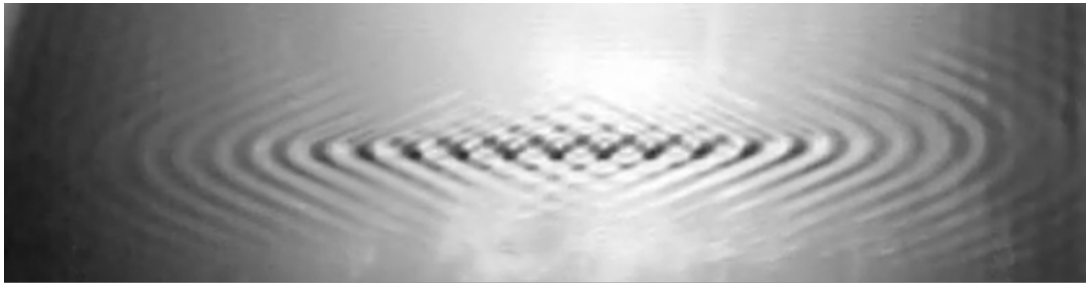


Figure 1. A time-modulated source emitting coherent waves under vertical vibration (Photo credit: Sander Wildeman).

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Wave-packet spreading in the disordered and nonlinear Su–Schrieffer–Heeger chain

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We discuss the connection between topological phases and long-time dynamics of initially localized wave-packets in one-dimensional disordered and nonlinear topological systems. Our model is a dimerized tight-binding lattice referred to as Su–Schrieffer–Heeger (SSH) chain [1]. This model is relevant in a variety of systems like optical waveguides [2], Bose–Einstein condensates (BECs) trapped in optical potentials [3] and synthetic momentum lattices [4]. We show that in the linear regime, as the parameters controlling the topology of the lattice are varied, the transition between two different topological phases is preceded by an anomalous diffusion of the wave-packet, in contrast to Anderson localization within these topological phases. In the presence of nonlinearity this feature is lost due to chaos and mode-mode interactions. We find that at weak and moderate strengths of nonlinearity a delocalization of the wave-packet takes place across the whole studied parameter space of the linearized model. Consequently, we underline the importance of the chaos and mode-mode interactions in nonlinear topological systems, which must be studied in order to define reliable nonlinear topological markers [5].

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Entraînement retardé d'un film de liquide sur substrat mou en condition de mouillage partiel

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La technique du « *dip-coating* » est un procédé couramment utilisé dans l'industrie pour, par exemple, enduire de liquide de grandes surfaces de tissus ou encore du matériel médical. En laboratoire, ce système est utilisé pour étudier des problèmes de mouillage dynamique : il permet d'obtenir une ligne de contact assez rectiligne et d'imposer une vitesse de mouillage ou de démouillage de manière bien contrôlée. Le principe de ce dispositif est d'extraire un solide d'un bain liquide, à vitesse constante, afin d'y déposer une couche fine de liquide. Les résultats d'expériences de *dip-coating* avec un solide rigide sont assez bien décrits. En mouillage total, le liquide recouvre systématiquement la surface du solide sous forme d'un film fin de liquide, d'épaisseur uniforme au dessus du ménisque relié au bain. Cette épaisseur est décrite par la relation de Landau–Levich–Derjaguin (LLD) et varie proportionnellement au nombre capillaire à la puissance $2/3$ [1] (nombre adimensionné de la vitesse du système comparant les forces visqueuses aux forces capillaires tel que $Ca = \eta V / \gamma$, avec η la viscosité dynamique du fluide et γ la tension de surface de l'ordre de $0,07 \text{ J/m}^2$). En mouillage partiel, un film au contour trapézoïdal est observé car la ligne de contact sur les côtés recède lors de l'extraction [2] (il devient triangulaire aux temps longs [3]). Cette couche de liquide est déposée lorsque le nombre capillaire atteint une valeur seuil.

En revanche, l'enduisage de surfaces déformables est peu exploré [4]. Nous utilisons ici des substrats avec un module d'Young Y de l'ordre du kPa. Lorsqu'un liquide s'étale sur un tel substrat, une déformation (« *ridge* ») apparaît au niveau de la ligne triple, résultant de la compétition entre force capillaire et l'élasticité du substrat. La taille du ridge est défini par la longueur élastocapillaire $l_s \sim \gamma / Y$ [5,6]. Si pour un substrat rigide ($Y \sim \text{GPa}$) cette longueur est inférieure au nanomètre, considérée comme négligeable, pour nos substrats mous, elle est de l'ordre de la dizaine de micromètres, assez significative pour pouvoir intervenir sur l'écoulement : sa présence et sa propagation conduisent à une dissipation d'énergie dans le solide.

Nos expériences ont mis en évidence le résultat suivant : contrairement au cas du solide rigide, où l'entraînement du liquide se fait instantanément, avec un substrat suffisamment déformable, et dans une plage de nombre capillaire intermédiaire, l'entraînement n'est pas instantané, mais plutôt retardé. On assiste donc ici à l'émergence d'une nouvelle plage de solutions, dans laquelle le liquide est entraîné après un transitoire allant de la seconde à plusieurs dizaines de secondes, durée entre le début de l'extraction du solide et le moment où le liquide fini par être entraîné. Ce retard, que l'on nomme temps d'entraînement, semble décroître avec le nombre capillaire et présente une divergence en-deçà d'une valeur seuil Ca_1 .

L'origine de ce retard reste encore à expliquer. Néanmoins, nous étudions la piste suivante : les substrats que nous utilisons contiennent des chaînes libres, et lorsqu'on les retire, ce retard semble « disparaître », ou du moins ne subsiste que dans une gamme de capillaire très petite. Ainsi, on pourrait expliquer ce retard à l'entraînement par une possible réorganisation lente de ces chaînes libres près de la ligne triple durant l'extraction.

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Acoustic ring solitons in a periodic network

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We model nonlinear and dispersive effects in air-filled acoustic networks composed of simply connected waveguides, such as the square network depicted in Figure 1 (a). In the longwavelength regime the dispersion of the square network varies along the azimuthal angle θ and vanishes on the diagonal direction.

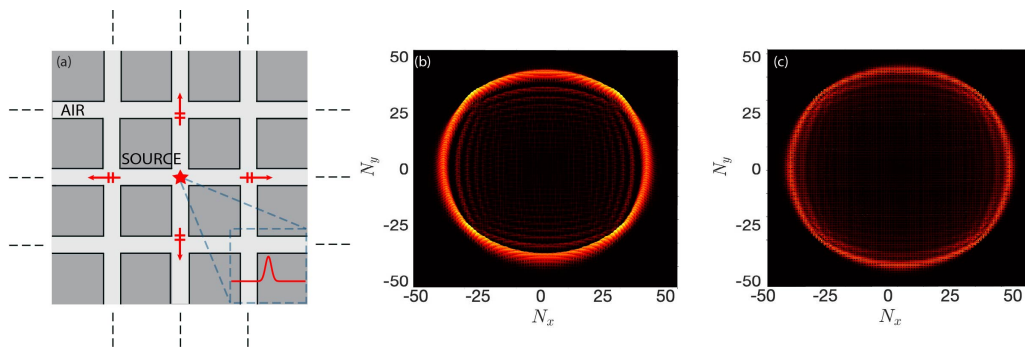


Figure 1. (a) Sketch of the acoustic network composed of air-filled waveguides. The red star indicates the gaussian source. (b) Linear propagation of a radial pulse in the network. (c) Nonlinear propagation of a radial pulse in the network.

In this work we focus on the propagation of cylindrical shaped pressure pulses, which we find that can be effectively modeled by a cylindrical Korteweg–de Vries equation (CKdV),

$$p_R + \underline{p}p_T + \beta(\theta)p_{TTT} + \frac{1}{2R}p = 0 \quad (1)$$

where the coefficient of the dispersive term $\beta(\theta)$ varies with θ . To validate our analytical findings we study numerically pulse propagation in the square network using the longwavelength numerical scheme proposed in [1]. We use a time dependent source condition in the form of a gaussian pulse (illustrated in Fig. 1 (a)) at the center of a $N_x \times N_y = 101 \times 101$ lattice. In Figure 1 (b, c) we demonstrate the results in the linear and nonlinear regime respectively. In the linear regime we confirm that the amplitude decay of longwavelength radial pulses can be approximated by the Airy self-similar solutions of the CKdV equation. Finally, in the nonlinear regime we find that the amplitude decay of longwavelength nonlinear pulses is captured by the amplitude decay of the CKdV soliton solutions provided by Ku and Kuehl [2].

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Wave field of capillary surfers

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Ho *et al.* [1] have recently introduced capillary surfers: wave-driven particles at a vibrating fluid interface (Fig. 1 (a)). These active particles are characterized by high tunability and have the potential to fill the gap between overdamped and inertial active systems. In addition, they exhibit multistability since their interaction forces are long-range and spatially oscillatory.

Capillary surfers are asymmetric solid objects. It has been suggested that their propulsion is due to asymmetric wave generation on the liquid surface, which would result in an asymmetric transfer of momentum from the surfer to the liquid and net radiation stress [1].

Here we check this propulsion mechanism by measuring the wave field of capillary surfers using a surface reconstruction technique [2, 3] (Fig. 1 (b)). Wave field measurements are performed by varying forcing frequency and amplitude and with surfers with different shapes. Indeed, in all cases, the wave field asymmetry is compatible with the direction of the surfer propulsion. A comparison with an existing theoretical model for the surfer wave field is also attempted [4].

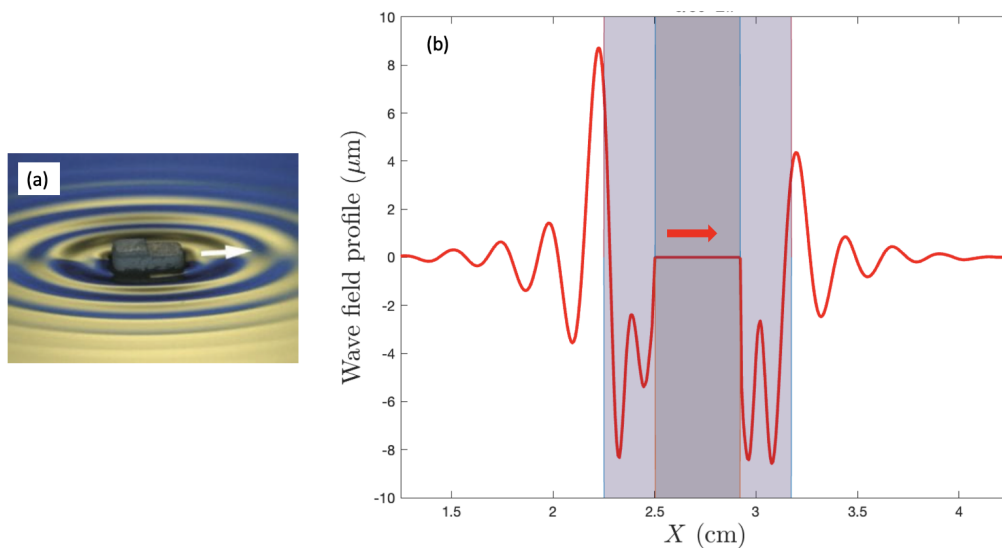


Figure 1. (a) Oblique view of a capillary surfer, from [1]. (b) Profile of the wave field of a capillary surfer along his long axis. The red arrow shows the direction of motion of the surfer. The central shaded zone corresponds to the surfer and the external shaded regions span one capillary length.

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Dynamics of a leaf central vein

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Leaves are photosynthetic organs with a diversity of shapes and complex vascular networks, often featuring a central vein with very stable oscillations (Fig. 1(a)). In order to explain the development of this central vein, we propose a numerical model of growth by interface propagation describing the dynamics of the vascular network as a function of the initial shape of the front and the spacing of the veins.

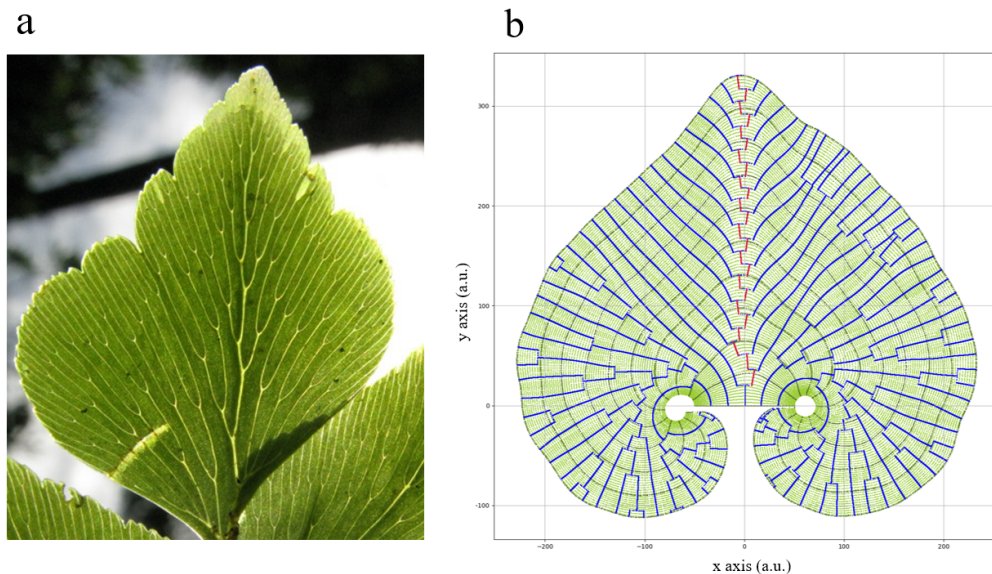


Figure 1. (a) *Adiantum* leaf showing a central vein. (b) Proposed numerical model of peripheral growth, with interdependence between front and vein growth. Successive growth fronts are emphasized every 50 time steps. The central vein is highlighted in red.

We make the assumptions that veins can be used as a marker of previous growth zones, as they develop around morphogen auxin flux [1], and include regular vein spacing and symmetrical bifurcations as they correspond to the more primitive leaves [2]. During morphogenesis, two modes of growth are distinguished, peripheral and global [3]. A front propagation model corresponds to a peripheral mode of growth. We find a leaf-like object with a stable central vein, with two lobes by edge effect (Fig. 1(b)). We base our growth function on gaussians centered on the position of veins, and introduce an initial pre-factor on the vein closest to the center, making the central vein stable. In the absence of this pre-factor, the dynamic of the central vein can be modelled by an iterated function whose geometry explains its instability.

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Memory-based localisation of a classical wave–particle object in a disordered and periodic medium

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La localisation d'Anderson est une transition conducteur-isolateur dans les matériaux désordonnés. Lorsque la température diminue, la dynamique des électrons passe du régime brownien classique, satisfaisant la loi d'Ohm, à celui d'un état localisé. L'effet trouve son origine dans l'augmentation de la longueur de cohérence de l'électron qui passe d'un comportement de type particule à un comportement de type onde. Pour un désordre suffisamment fort, les interférences dominent le transport de l'électron qui perd sa mobilité. Le même comportement est observé pour les ondes classiques telles que les ondes acoustiques ou électromagnétiques.

Ici, nous voulons étudier le comportement de localisation sur des entités classiques présentant une forme de dualité non-quantique. Pour cela nous utilisons des "marcheurs" qui sont des gouttelettes autpropulsées rebondissant sur un bain vibré verticalement, guidées par l'onde qu'elles produisent à la surface du liquide [1]. Leur dynamique dépend des ondes émises lors des rebonds précédents qui interfèrent pour former une onde pilote. La rémanence des ondes émises successivement constitue une sorte de mémoire de la trajectoire du marcheur. Celle-ci peut être réglée en modifiant l'amplitude de l'excitation verticale. Elle détermine l'extension du paquet d'onde qui est joue un rôle analogue de la cohérence du paquet d'onde et détermine un comportement particulière ou ondulatoire pour le marcheur.

Nous présentons des expériences montrant le comportement de marcheurs dans des milieux au désordre contrôlé. Lorsqu'ils sont placés dans un environnement désordonné composé d'épingles immergées, les marcheurs ont une dynamique brownienne à faible mémoire mais ont tendance à ce localiser à mémoire plus élevée en formant des sortes d'auto-orbités observées dans d'autres expériences avec les marcheurs [2–4]. Les simulations confirment ce comportement expérimental de localisation à haute mémoire. Le coefficient de diffusion diminue régulièrement avec la mémoire. Ce comportement trouve des analogies intéressantes avec le phénomène de localisation pour les ondes classiques dans les milieux désordonnés mais également des spécificités inattendues induites par la dualité basée sur la mémoire.

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Modeling and numerical simulations of elastic turbulence in polymer solutions

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Elastic turbulence is a phenomenon characterized by the emergence of a chaotic flow in viscoelastic fluids such as solutions of long-chain polymer molecules. In contrast to Newtonian turbulence, which requires large Reynolds number (Re) to drive the fluid motion into a chaotic regime, the Re number in elastic turbulence is arbitrarily low, i.e., the flow is purely driven by the amplification of elastic instabilities. As a consequence, elastic turbulence is a useful tool for enhancing mixing in microfluidics [1].

Simulating elastic turbulence by using the continuum-level differential constitutive equations coupled with the Navier–Stokes equation has been a great challenge in terms of properly resolving the steep gradients that emerge in the polymer stress field [2]. The lack of accuracy in calculating the numerical solution generates large-scale errors in the flow fields, thereby modifying the spatial flow structures. In the literature, to overcome the numerical instabilities, various reformulations of the conformation tensor field, which describes the average extension and orientation of the polymer chains at each point in the fluid, have been proposed, such as the symmetric square root and the Cholesky decompositions. We introduce a necessary criterion that must be satisfied for a numerical simulation of elastic turbulence to be accurate. This consists of a lower bound on the trace of the conformation tensor. We show that the violation of this bound is associated with a misrepresentation of the large-scale flow structures. We also show that numerical methods that involve a logarithmic transformation of the conformation tensor resolve its steep gradients more accurately, and therefore are more effective in preserving the lower bound on its trace.

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Morphogénèse de craquelure dans l'argile en dessiccation

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Le système expérimental est le suivant : on incorpore de l'argile dans de l'eau puis on le dépose sur une plaque de verre en couche mince (de quelques millimètres à quelques centimètres), en contrôlant la température et l'humidité de l'air en contact avec sa surface. On suit l'évolution de ce système jusqu'à dessiccation complète avec un appareil photo (de quelques heures à quelques jours).

La dessiccation de l'argile à la surface avec des conditions aux limites contraintes (argile toujours humide au fond qui adhère au substrat) induit une augmentation de la déformation, et donc une augmentation des contraintes. Passé un certain seuil, ce matériau ductile bifurque vers un comportement instable, menant à l'apparition de craquelures. Le modèle phénoménologique développé ici, décrivant les variations d'humidité, de déformation et de contrainte, permet de comprendre la propagation de ces craquelures. Via ce modèle, on se propose d'expliquer le comportement local des craquelures dans le champ de contraintes et depuis cette croissance, la structure globale du réseau spatial ainsi formé.

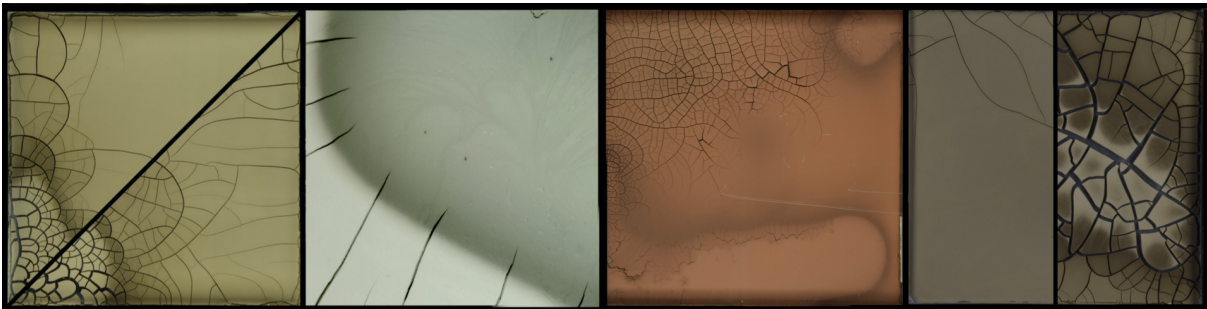


Figure 1. Différentes expériences en cours de dessiccation. De gauche à droite : Montmorillonite beige, Montmorillonite-Illite verte, Montmorillonite rouge à faible épaisseur, Montmorillonite beige / Maizena

En fonction des conditions expérimentales (type d'argile, épaisseur, température, humidité), l'apparition de phénomènes instables (craquelures, front de séchage, ...) permet à ce système d'aller vers des structures très variées (Fig. 1). Certaines de ces structures émergentes sont retrouvées dans d'autres systèmes de réseaux spatiaux physique ou biologiques [1], comme les rues des villes [2] ou les veines de feuilles d'arbres [3], car la croissance y est régie par la même classe de mécanismes.

Ainsi, les craquelures sont un bon système modèle pour l'exploration de la morphogénèse de réseaux spatiaux, tant par la variété de motifs obtenus que par la simplicité de l'expérimentation.

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Solidification de mousse de savon

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La fabrication d'une mousse solide, ensuite exploitable pour ses propriétés mécaniques, thermiques ou acoustiques, commence par la formation d'une mousse à l'état liquide avant une étape de solidification.

Nous nous intéressons ici à la solidification d'une mousse d'eau savonneuse au contact d'une surface froide. On observe dans nos expériences que la mousse subit un changement de volume lors de la solidification, ainsi qu'un assèchement de la zone encore liquide.

Des observations directes par caméra rapide, et indirectes par mesure acoustique révèle que ce changement de volume est dû à l'éclatement de bulles au niveau du front de solidification. Nous montrons une dépendance du taux d'éclatement de bulles en fonction de la taille des films liquide et la température du substrat, et proposons des mécanismes expliquant l'assèchement zone liquide.

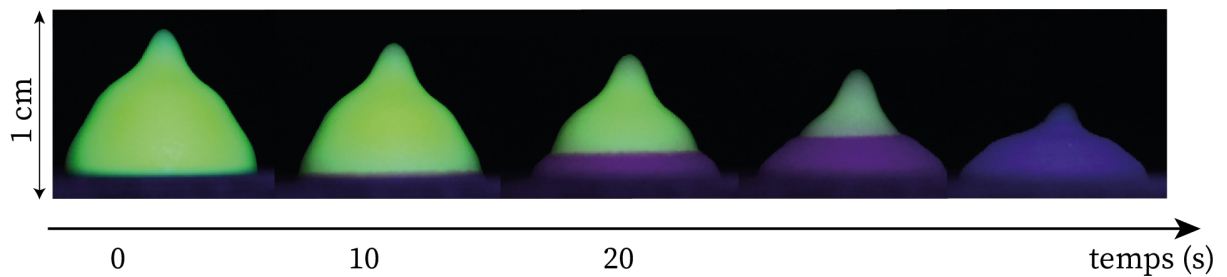


Figure 1. Série temporelle d'une mousse se solidifiant sur une surface de cuivre à -50°C , avec un rayon de bulle moyen de $38\ \mu\text{m}$ et une fraction de liquide de 0,10. On voit, en vert, la phase liquide et en bleu, la phase solide.

Small-scale model of liquid plugs rupture in human lungs

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Lung airways are coated with a liquid film made of mucus and serous layers. Owing to capillary instability, surface tension forces can form liquid plugs (especially under pathological conditions) that occlude the distal respiratory tract [1]. Thereafter, within a breathing cycle, such liquid plugs can be broken by propagation [2, 3] and splitting in the airways [4]. Upon their breakup, a pressure wave forms and can be acoustically detected in form of crackling sounds (Fig. 1, [5]). The dynamics of the liquid plug is here studied in detail by deriving and solving an asymptotic small-scale model of the mucus plug right prior to its rupture.

Before the rupture of the liquid plug, the front and back air fingers gradually approach each other. Our study will therefore be employed in future investigations that will focus on the coupling between the large-scale liquid plug propagation and the small-scale dynamics of its rupture.

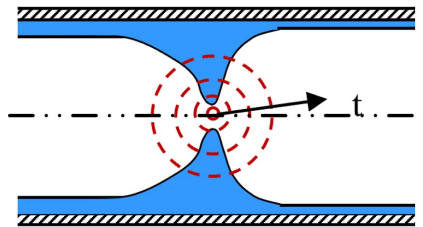


Figure 1. Schematic diagram of a liquid plug breaking. The red circles represent the propagation of a pressure wave.

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Génération de bulles de savon dans un écoulement d'air

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Dans ce travail expérimental, des bulles de savon sont générées dans un écoulement d'air. Pour cela, un anneau délimitant une pellicule de savon est fixé à l'entrée de la section d'essai de la soufflerie. À partir d'une vitesse seuil, des bulles se détachent de manière périodique. Lorsqu'on augmente la vitesse de l'air, une poche de savon reste attachée à l'anneau et grandit jusqu'à une longueur maximale qui dépend de la vitesse de l'air et du diamètre D de l'anneau. La figure 1 montre une photographie de cette poche et des bulles qui se détachent.

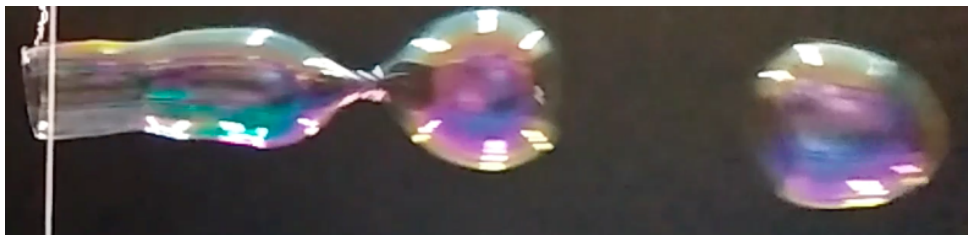


Figure 1. Photographie de la poche de savon à l'aval de laquelle des bulles se détachent de manière périodique.

Dans notre configuration, les bulles sont générées pour des vitesses seuils inférieures à celles prédites par Salkin *et al.*(2016) [1] à cause du déficit de pression derrière la bulle. Des expériences sont réalisées pour trois différentes valeurs de D et différentes vitesses. À partir des films enregistrés, on en déduit la longueur de la poche et la fréquence des bulles. Nos résultats présentent certaines similitudes avec ceux de Suñol et González-Cinca (2015) [2].

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