Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

Rectors:

E. Guazzelli (Marseille) - A. Soldati (Vienna) - W. A. Wall (Munich)

CISM PROGRAMME 2023

" ...The purpose of the Centre is to promote, on a non-profit basis, research in the Mechanical Sciences and related multidisciplinary sciences, favour the exchange, diffusion, and application of the most advanced knowledge in this field, establish active relations with similar national, or international institutions, enlist the cooperation of the most qualified scientists and researchers throughout the world, set up research laboratories and libraries, organize courses and seminars of a high scientific level ..."

from the Statute of the "International Centre for Mechanical Sciences".
CISM, Chap. I, Art. 1.

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PROGRAMME 2023

Udine, Italy

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The Alfred Kluwick Session

Fluid Mechanics of Planets and Stars

April 17 - 21, 2023

Understanding the dynamics of planetary and stellar fluid layers - including the atmosphere of the Earth and other planets, iron cores, and stellar convective and radiative zones - remains a tremendous interdisciplinary challenge, relying on common knowledge in fundamental fluid mechanics. A few of the numerous open questions include:

• What are the basic physical mechanisms responsible for climate circulation, and how can they be parameterised to reliably predict global climate change?

• What are the prevalent force balances and physical mechanisms behind natural large-scale features such as Jupiter's Great Red Spot and bands?

• What are the relevant driving forces and flow regimes in conducting planetary cores for explaining the generation of large-scale magnetic fields by dynamo action?

• How are the various types of waves propagating in the stellar interiors generated, what influence do they have on stellar evolution, and how can they be used to probe interiors via asteroseismology?

Interdisciplinary research in geo- and astrophysical fluid dynamics is also intrinsically multi-method. Indeed, the main obstacle to quantitative modeling and understanding of planetary and stellar flows stands in the extreme character of the involved dimensionless parameters. Relevant studies thus rely on the principle of dynamical similitude and scaling laws, sustained by theory, experiments and numerical simulations.

Much research effort has been devoted to understanding planetary and stellar flows within the various communities of Mechanics, Applied Mathematics, Engineering, Physics, Planetary, Atmospheric and Earth Sciences, and Astrophysics. But progress has mostly been confined to each separate domain, with only marginal cross-fertilisation. The objective of this school is to go beyond this state, by providing participants with a global introduction and an up-to-date overview of all relevant studies, fully addressing the wide range of involved disciplines and methods.

The course will be organized in three parts. The first will focus on fundamental aspects of fluid mechanics in geo- and astrophysical flows, including introductory material as well as current cutting-edge research, with a focus on instabilities, turbulence, and waves. The second part will focus on concrete applications to topical geo- and astrophysical problems, with lectures focusing on planetary interiors, atmospheres, and stars. Finally, the third part will involve practical numerical sessions using the open-source solver Dedalus (http://dedalus-project.org). Participants will learn to set up and run numerical simulations on their laptops related to the research problems discussed in the lectures.

The targeted audience for this school is PhD students, postdocs, and young researchers, working in departments of Mechanics, Applied Mathematics, Engineering, Physics, Planetary, Atmospheric and Earth Sciences, and Astrophysics. A background in fluid dynamics will be assumed for each participant, but no specific knowledge in any of the application domains or in computational methods will be requested. Each participant will be given the opportunity to present her/his work during a flash talk presentation, followed by a poster session.

Invited Lecturers:
Isabelle Baraffe (Exeter, UK), Keaton J. Burns (Cambridge, MA, USA), Michael Le Bars (Marseille, France), Daniel Lecoanet (Evanston, IL, USA), Juan Pedro Mellado (Hamburg, Germany), Jérõme A. R. Noir (Zurich, Switzerland).

Coordinators: M. Le Bars, D. Lecoanet

Plastic Anisotropy and Damage from Single Crystal to Engineering Scale

May 22 - 26, 2023

Advances in the theory of plasticity of metallic materials have been driven by the demand to improve performance and safety of structures and machine parts.
The central goal of this series of lectures is to provide an overview of the current knowledge and recent developments in the field with applications spanning multiple length scales and strain-rate regimes. Emphasis is placed on providing a rigorous framework for description of dissipative phenomena, a clear understanding of the hypotheses and simplifying assumptions for each of the constitutive models and computational methods presented. Specifically, for each model, the range of applicability, and limitations are provided along with examples of their predictive capabilities through applications from various engineering fields. Furthermore, open questions related to modeling of plastic deformation mechanisms at the single crystal scale, role of the material's symmetries, how plastic anisotropy affects damage are pointed out and possible future directions of research and applications are provided. Attention is also paid to the interplay between plasticity and the evolution of ductile damage, which triggers the formation instabilities that eventually lead to material fracture. Finally, the importance of material microstructure at various length scales is discussed along with the impact of microstructure and its evolution on overall material behavior.
Following this course, the attendees will have (1) the basic concepts necessary to design experiments that would reveal key features of the mechanical response of a material under given loading conditions, (2) understanding of the deformation mechanisms at lower length scales that induce the observed macroscopic response, (3) the ability to determine the most appropriate model to be used along with an appropriate parametrization, (4) concepts necessary to formulate constitutive models for fully-dense and porous metals which display anisotropy and tension-compression asymmetry, (5) the basics necessary for implementation of the models into FE codes, (6) analytical modeling of instabilities, (7) basic understanding of the differences between mean-field and full-field polycrystal formulations, enabling the selection of the appropriate model for prediction of the mechanical behavior and microstructure evolution of a polycrystal; (8) basics of the mechanics of interfaces, with focus on microstructure evolution, phase transformations, and the respective computational approaches.
The course will combine theoretical classes with hands on lectures in which the attendees will run codes and perform simulations putting into practice the concepts introduced, developing critical understanding of the mechanisms which control plastic deformation

at different scales. In addition, slots for the participants to present their research will be allocated.

Invited Lecturers:
Oana Cazacu (Shalimar, FL, USA), Odd Sture Hopperstad (Trondheim, Norway), Ricardo Lebensohn (Los Alamos, MN, USA), José A. Rodríguez Martínez (Madrid, Spain), Javier Segurado (Madrid, Spain), Stanisław Stupkiewicz (Warsaw, Poland).

Coordinators: O. Cazacu, J. A. Rodriguez-Martinez

Interfacial Flows - The Power and Beauty of Asymptotic Methods

June 5 - 9, 2023

Interfacial flow phenomena are observed in everyday life on nanoscopic to geophysically large scales (wetting, Leidenfrost phenomenon, Lotus effect, teapot effect, sheet formation and breakup, free-surface waves, etc.) and are vital for many biological and industrial processes. Despite the demand for their thorough understanding and control, their rigorous description still poses a major challenge, given the various disparate spatial and temporal scales involved. Deep insight into their beauty and formidable, rich complexity is gained by pushing the governing dimensionless key parameters to their limits and applying asymptotic techniques. These allow for the systematic approximative examination of self-similar phenomena and singularities and their regularisation. The appropriate scaling of the physical problem and identification of the relevant scales enables its formal reduction to a simpler canonical one that already captures the essential effects; higher-order corrections account rationally for less important ones. The required mastery of advanced analytical/numerical tools is rewarded by a conclusive comprehension of the multi-scale physics at play, far beyond that pure full-scale simulations provide. Asymptotic methods have proven their strengths in more traditional areas of fluid mechanics for long, but applying them to interfacial flows is a relatively new thrust of research, which has already led to exciting recent advances.
The course addresses doctoral students, post-docs and early-career researchers interested in theoretical fluid mechanics and its mathematical foundations. It focusses on the state of the art of perturbation and related mathematical methods and how to apply them to a representative variety of interfacial flows – and to almost any physical or engineering problem. The following building blocks of interfacial-flow phenomena are covered:
1. Drop dynamics.
• Sessile drops: large/small Bond numbers, hydrophobic limit.
• Quasi-spherical drops: on an inclined plane, contact-line hysteresis, sticking, sliding, rolling.
• Drop–vapour interaction (levitated drops, Leidenfrost phenomenon).
2. Free-surface instabilities and singularities.
• Rayleigh–Plateau (long-wave limit), Saffman–Taylor and other instabilities, geometrical

influence of bounding solid phase.
• Instability series might trigger highly nonlinear singular phenomena, due to the vanishing of a length scale described by
• Local similarity solutions (exactly solvable problems upon rescaling)
• Examples: droplet pinching, in non-Newtonian flows, soft-/condensed-matter physics, interplay liquid sheets/elasticity of wetted substrates
3. Free-surface potential flows, gravity waves, sloshing problems. Playing a significant role in geophysical/maritime sciences and applications, their complex nonlinear dynamics is analysed through.
• Advanced conformal-mapping methods.
• Multi-modal analysis.
• Near-resonance asymptotics.
4. Slender viscous sheets. The emerging multiple length and time scales render them ideally suited for an asymptotic analysis:
• Lubrication approximation.
• Coating flows (Landau–Levich problem) .
• Droplet coalescence, defragmentation (Savart sheets), film-on-film spreading, soap films.
• Thin films on rotating cylinders, on textured/superhydrophobic surfaces, rivulet flows.

Invited Lecturers:
Jens Eggers (Bristol, UK), Bernhard Scheichl (Vienna, Austria), Ory Schnitzer (London, UK), Jacco Snoeijer (Twente, The Netherlands), Howard A. Stone (Princeton, NJ, USA), Alexander N. Timokha (Kiev, Ukraine), Stephen Wilson (Glasgow, UK).

Coordinator: B. Scheichl

Nonlinear Electro- and Magneto-Mechanics: Theory, Computations, and Experiments

June 12 - 16, 2023

Recent decades have seen an exponential increase in the interest in highly deformable smart materials that use multi-field interactions for actuation. Magneto-rheological elastomers (MREs) are smart materials in which the mechanical and the magnetic properties are strongly coupled with each other. Externally applied magnetic fields lead to effects such as reversible magnetostriction and tuneable material stiffness. Dielectric elastomers or Electroactive polymers (EAPs) typically consist of a soft polymer sandwiched between two compliant electrodes. On the application of a potential difference, the electrostatic forces cause the polymer to deform thereby creating mechanical actuation. Alternatively keeping the charge constant, mechanical deformation of the polymer can be used to change the potential difference thereby making them useful for energy generation mechanisms. Both MREs and EAPs have found uses in a variety of engineering applications, such as variable stiffness actuators, vibration suppression by energy absorption, nonlinear diaphragms, wave energy generators, artificial muscles,

haptic interfaces, compliant robotic components, and lenses with tuneable focal-lengths. Modelling such complex materials with coupled field interactions is one of the fundamental issues in further development and large-scale industry adoption of these smart materials. Mathematical and computational methods coupled with novel experimentation techniques are employed in the research, development, testing, and evaluation of these systems. The mathematical, computational, and experimental techniques introduced in this course will be rooted within the framework of Continuum Mechanics. As such the lectures will start with an overview of nonlinear Continuum Mechanics specialised for solids. Balance equations of mechanics, electromagnetism, and thermodynamics will be used to construct rational theories of nonlinear electro-mechanics and magneto-mechanics. A parallel but equivalent development using the variational formulation will also be done as it is necessary to analyse stability and to perform numerical computations. Computational techniques to solve this complex coupled and nonlinear electro-mechanical / magneto-mechanics set of equations for fields in the body as well as in the surrounding space will be discussed in detail. The course will also discuss the challenges and methods to efficiently manufacture particle filled MREs and capacitor type EAPs. Performing mechanical experiments on these composites is rather challenging and requires custom made equipment and innovative procedures.
The course is addressed to doctoral students and postdoctoral researchers in mechanical, civil and aerospace engineering, material science, applied physics and applied mathematics; academic and industrial researchers, and practicing engineers.

Invited Lecturers:
Kostas Danas (Palaiseau, France), Luis Dorfmann (Medford, MA, USA), Daniel Garcia-Gonzales (Madrid, Spain), Marc-André Keip (Stuttgart, Germany), Prashant Saxena (Glasgow, UK), Paul Steinman (Erlangen-Nuremberg, Germany).

Coordinators: P. Saxena, P. Steinmann

Wave Motion in Heterogenous Media: Analysis, Modeling and Design

June 19 - 23, 2023

A deep understanding of wave motion through heterogeneous solids and structures is critical to predict their dynamic behavior, or to tailor them for the purposes of e.g. cloaking, vibration control, seismic protection, information transport, and sub-wavelength sensing. In this vein, we aim to provide a review of recent developments on the subject by elucidating:
1. Wave propagation through periodic and non-periodic media and structures governed by either linear or non-linear field equations;
2. Homogenization of wave motion through “micro-structured” media; importance and utilization of the spectral singularities characterizing the dispersion map;
3. Boundary effects that are critical for understanding the dynamics of finite structures and phenomena such as topologically protected states;

4. Design and optimization of the heterogeneous (micro-) structure to achieve the sought wave phenomena.

The subjects will be covered from diverse viewpoints, including continuum mechanics, experimental mechanics, physics, and applied mathematics. The course will be structured as follows.

Introductory lectures will focus on the fundamentals of elastic wave motion in periodic media such as Bloch-Floquet theory, band-gaps, and spectral degeneracies. Essential mathematical tools will be recalled, including the (classical) low-frequency homogenization, high frequency homogenization, and Willis' approach. Higher-order extensions of low-frequency homogenization will be introduced to facilitate topological optimization. Analogies will be drawn between the homogenization results and enriched continuum theories. Generalizations catering for the asymptotic treatment of aperiodic systems and arbitrary spectral neighborhoods will be included.

The above fundamentals, introduced in the linear regime, will be partly extended to investigate the nonlinear dynamics of systems triggered e.g. by large deformations or multistable architectures. Effective description via non-local temporal operators will be included. Besides theoretical issues, experimental realizations will demonstrate the rich phenomenology of nonlinear metamaterials, including solitons and transition waves. Overall, it will be shown how a carefully designed architecture of engineering structures can be leveraged to control their dynamic performance.

Lastly the role of boundaries will be examined. The germane evanescent waves and underpinning eigenvalue problem will be highlighted. Boundary and interface correctors will be introduced to capture the effective transmission conditions. Recent developments on the asymmetric transport and topological insulators will be included. The robustness of interface states to disorder will be examined through the prism of topology. The analysis will focus on the class of partial differential Hamiltonians to which a topological charge can be assigned.

With this lecture series, we aim to attract doctoral students and researchers interested in the dynamics of micro-structured media and the design of next-generation of modern ("meta") materials. The objective is to provide the audience with a theoretical framework, computational tools, and experimental evidence to better understand the most recent developments on the subject and so facilitate the technology transfer from research to applications.

Invited Lecturers:

Guillaume Bal (Chicago, IL, USA), Rémi Cornaggia (Paris, France), Richard Craster (London, UK), Bojan Guzina (Twin Cities, MN, USA), Dennis Kochmann (Zürich, Switzerland), Bruno Lombard (Marseille, France).

Coordinators: B. Guzina, B. Lombard

Liquid Interfaces, Drops and Sprays (LIDESP)

June 26 - 30, 2023

The knowledge of the physics of liquid drops and sprays is essential for many applications, from aeronautics (icing) to oil extraction (effervescent sprays, drop collisions in pipes), from electronics (spray cooling) to agriculture (distribution of agrochemicals), from microfluidics (droplet management) to painting processes (spray coating), from biology (blood droplets, sterilization) to thermal transfer (condensation in heat exchangers), from chemical and process engineering (drying tower) to medical applications.

The course objective is to provide the participants with a thorough overview of the state-of-the-art knowledge on the physics of drops and sprays and its applications in industrial processes as well as in everyday life, based on recent research results and on the most updated methods for the prediction of dynamic outcomes, heat transfer, wettability effects, their measurement, and their numerical simulation. Specific attention will be paid to the applications in life sciences, such as microdroplet management. Application to chemical processes will be dealt with special care in view of the industrial interest towards this component, while the very recent application of drop management in microscale, including microstructured surfaces will be treated in detail.

Lectures will cover several topics, including: an introduction of the basic Thermodynamics and Fluid Mechanics of interfaces; Experimental techniques to measure interfacial properties; Drop impact phenomena on solid and liquid surfaces; Heat and mass transfer in drops; Superhydrophobicity; Physics of sprays and spray characterization techniques; Non-Newtonian drops; Advanced numerical methods for interfacial flows.

The course is addressed to postgraduate students and young researchers in the fields of Engineering, Chemistry, Biology, Medicine, Applied and Fundamental Sciences, as well as to professionals and R&D staff from industry. The course is especially of interest to researchers dealing with phenomena involving drops and sprays. In terms of mathematics and physics, lectures are delivered at the level of a good Postgraduate or Ph.D. degree. The pre-requisites are a background in Mathematics and Physics equivalent to a Master's Degree in Engineering or Physics, and a good university-level understanding of Fluid Dynamics and Heat Transfer.

Invited Lecturers:
Alidad Amirfazli (Toronto, Canada), Volfango Bertola (Liverpool, UK), Marco Marengo (Brighton, UK), Alfredo Soldati (Vienna, Austria), Cameron Tropea (Darmstadt, Germany), Stéphane Zaleski (Paris, France).

Coordinators: A. Amirfazli, V. Bertola, M. Marengo

Physics of Granular Suspensions: Micromechanics of Geophysical Flow
8th CISM-AIMETA Advanced School

July 3 - 7, 2023

The course is an exploration of the recent theoretical, experimental and numerical advancements in the modelling of non-Brownian granular suspensions. The quest is mainly motivated by the growing scientific and engineering interest in geophysical flows as a consequence of the climate change and the severe impact of hydro-geological catastrophic events on socio-economic activities. Among geophysical phenomena, the course focuses on water-saturated sub-aerial and sub-aqueous debris flows, hyper-concentrated flows, underwater turbidity currents, creeping and fluid-like movements of soil in landslides as well as on the sediment transport in rivers and along ocean shores, both at the bed and in suspension. Indeed, the presence of a liquid, which saturates the interstices between grains, formidably expands the parameter space of granular flows, the mixture exhibiting behaviours typical of either viscous shear-thinning fluids or dense granular flows depending essentially on the average distance between solid particles (i.e. the particle concentration), the relative velocity of particles and the electro-chemo-mechanical properties of the mixture components.
The scope of the course is the investigation of the purely hydraulic problem, thus the liquid is water while particles are in general coarse and inert (non-colloidal and non-adhesive) and, therefore, only their mechanical properties are considered.
The opening of the course is devoted to highlighting the striking differences between (dry) granular flows and granular suspensions. Granular suspensions are first classified on the basis of the relative velocity of particles, namely of the particle Reynolds number, into "viscous" and "inertial", which determines the nature of dominant fluid-solid interactions. Then, "dilute", "semi-dilute" and "dense viscous suspensions" are distinguished, which differ in the number concentration of particles and, consequently, in the role of inter-particle contacts. The dynamics of the granular suspensions under different boundary/initial conditions as well as different driving forces are investigated and modelled highlighting the most recent advancements in the subject. Continuum and discrete approaches are considered. The continuum approach comprises a single-phase, also referred to as "single effective fluid", or two-phases which indicates that the "theory of mixture" is adopted. As for the discrete approach, it necessarily requires the use of numerical methods to solve the fluid-particle-coupled continuity and momentum equations. The coupling and the inter-particle contacts can be obtained with a point-particle approach or, for "large particles", by fully resolving the flow field around the particles. The effects due to the presence of turbulent vortices or to phase transition, when solid particles are in quasi-static conditions, are also considered. Finally, models are described and applied to the aforementioned geophysical flows.

Invited Lecturers:
Pascale Aussillous (Marseille, France), Sivaramakrishnan Balachandar (Gainesville, FL, USA), Julien Chauchat (Grenoble, France), Claudio di Prisco (Milan, Italy), Elisabeth Guazzelli (Paris, France), Laurent Lacaze (Toulouse, France), Marco Mazzuoli (Genoa, Italy), Dalila Vescovi (Milan, Italy).

Coordinators: L. Lacaze, M. Mazzuoli

Machine Learning for Fluid Mechanics

July 10 - 14, 2023

Machine learning / artificial intelligence accelerates the progress in all research fields, fuels the fourth industrial revolution and transforms our daily lifes. Increasing computer power, rapidly improving methods of machine learning and the availability of ever increasing amounts of high quality data facilitate a paradigm shift from first-principle based deductions to data-driven discoveries and modeling. Fluid mechanics, historically a field of big data, is no exception. In addition, machine learning provides increasingly powerful methods for the challenging optimization problems faced in aerodynamic engineering. This course will outline established state-of-the-art methods of machine learning and demonstrate their application in high-challenge applications of fluid mechanics, like analyses, discovery of equations, dynamic modeling, control, turbulence closures and shape optimization. This course is aimed at Ph.D. students and Master students in all fields of fluid mechanics. Researchers interested in the potential of machine learning are also welcome to attend this course.

The literature of fluid mechanics contains myriad of machine learning applications. The curriculum aims to pair methods with problems, i.e. present machine learning methods in a natural application environment. Thus the power of each method can immediately be assessed. The applications belong to 6 fields.

1. Analysis of coherent structures. Low-dimensional flow representations have been at the core of theoretical fluid dynamics, starting with vortex models in the 1870s. Machine learning allows to distill low-dimensional Galerkin expansions and nonlinear manifolds from data. A low-dimensional state space is a critical enabler for understanding, full-state estimation, prediction and optimization.
2. Nonlinear dynamics. Hitherto, new equations have typically been derived from first principles. Machine learning enables to distill predictive human interpretable ordinary/partial differential equations from data.
3. Sparse data/rare events. Most engineering problems, e.g. for many involved parameters or for rare events, will never have enough data for a purely empirical characterization. A probabilistic framework is presented to compensate for lack of data.
4. Turbulence closures. Practically every engineering simulation is based on eddy viscosity, wall models and related closure simplifications. Machine learning harnesses rich data sets to develop more accurate closures.
5. Turbulence control. Modern computer and hardware developments provide an eldorado of unprecedented control opportunities with dramatic aerodynamic performance improvements, e.g. powerful actuators and sensors and smart skins. Machine learning facilitates an automated learning of nonlinear control laws.
6. Shape optimization. Over hundred years, the shape of every high-speed transport vehicle and flow machine has been systematically improved for aerodynamic performance based on first principles and experience. Machine learning offers new automated approaches for these high-dimensional optimization problems.

This course aims to synergize machine learning methods with first principle knowledge of fuid mechanics.

Invited Lecturers:
Steven L. Brunton (Seattle WA, USA), Andrea Ianiro (Madrid, Spain), Bernd R. Noack (Shenzhen, P.R. China), Themistokles Sapsis (Cambridge, MA, USA), Ricardo Vinuesa (Stockholm, Sweden), Xiaojing Wu (Xi'an, P.R. China).

Coordinators: S. L. Brunton, B. R. Noack

Variational Methods for Complex Materials and Processes

July 17 - 21, 2023

In the past decades, a better understanding of engineering materials and processes has emerged, leading to numerous technological applications as the design of tailor-made materials having specific properties or optimal solutions of engineering problems. This evolution would not have been possible without fundamental contributions from the theoretical sciences, in particular solid mechanics and mathematics, which offer both analytical and numerical tools for the solution of complex problems. Within this general framework, mathematical concepts from the broad context of variational analysis have proven to be successful. This spectrum of methods includes, but is not limited too, the theories of homogenization and scale transition, relaxation, Gamma convergence and variational time evolution. Classical application areas involve models in the framework of nonlinear elasticity, finite plasticity, diffusion and phase transformations in general and the analysis of fracture, damage, motion of dislocations, formation of microstructure and the impact of these effects on material behavior in particular. The proposed course will approach the aforementioned topics from different perspectives and not only from one point of view. The different perspectives refer to continuum modeling techniques and the associated algorithmic treatments as well as to the different types of applications.
Mathematics and especially the calculus of variations are essential in the understanding of multiscale problems, micro structured materials and localization phenomena. New solution concepts have to be introduced in order to treat the associated models. Solutions to macroscopic boundary value problems become infimizing sequences whose limits are probability measures. This is a rapidly developing area of research with essential progress made only over the last two decades, which is why this is still a relatively young field of research with many unsolved problems. Professors Manuel Friedrich and Dorothee Knees will give lectures to lay the foundation.
The mechanics side of this course aims to exploit the above mathematical concepts towards formulating and validating constitutive theories and associated numerical tools for the prediction of the behavior of complex materials and processes. Professors Laura De Lorenzis, Sanjay Govindjee, Laurent Stainier, and Klaus Hackl will contribute lectures to survey the theoretical and numerical fundamentals as well as problem classes of interest.

Invited Lecturers:
Laura De Lorenzis (Zurich, CH), Manuel Friedrich (Erlangen, Germany), Sanjay Govindjee (Berkeley, CA, USA), Klaus Hackl (Bochum, Germany), Dorothee Knees (Kassel, Germany), Laurent Stainier (Nantes, France).

Coordinators: K. Hackl, D. Knees

Microphysics of Atmospheric Clouds

July 24 - 28, 2023

Clouds determine precipitation and constitute the main component of the hydrological cycle. They can be very beautiful, but also emphemeral in the eyes of people, artists, but also of scientists, thereby creating a fascinating enigma.

The scientific study of clouds began with Luke Howard's classification in 1803. Throughout the 19th century, the boundary between the arts and sciences, particularly with regard to natural sciences, including meteorology, was much less rigid than it is today. For instance, the great German poet Goethe took particular interest in the scientific classification of clouds. The most original sea-and-sky scape painter of the 19th century, JWM Turner, annotated his copy of Goethe's 'Theory of Colors', and referred to it directly in the title of one of his paintings (Light and color (Goethe's theory)—The Morning After the Deluge—Moses writing the book of Genesis (The Tate Gallery, London)). And one the finest of all cloud painters, John Constable, was also well aware of the work of Luke Howard, and performed detailed cloud studies in the 1820s over Hampstead Heath.

It is now understood that, paradoxically, the global dynamics of the atmosphere and climate are very much dependent upon the microscale-level processes of clouds. In fact, in addition to convective heating due to the latent heat release associated with the condensation of water vapor, clouds control, to a large extent, the solar and thermal radiation balances of the atmosphere.

The present course mainly focuses on a few of the fundamental aspects concerning clouds:

- Latent heat release, which leads to convective or stratiform heating/cooling, that is, one of the main energy sources of atmospheric motions at spatial scales, ranging from local turbulence and single
clouds to global circulation.
- The condensation of water vapor and the subsequent precipitation within clouds through microphysical processes that take place at cloud particle size scales, ranging from several micrometers to a few centimeters.
- The effects of clouds on radiation caused by cloud coverage, the altitude of the cloud top, the size of the cloud particles, the size distributions, and the phase.
- The effects associated with atmospheric aerosols, which play a key role in determining the properties of clouds and give rise to the formation of water droplets and ice crystals.
- The development of improved observational techniques to study microphysical processes and bulk cloud properties and to measure the physical and optical properties of atmospheric aerosols.
- The interplay between the continuously increasing resolution of large-scale and mesoscale atmospheric models and the treatment of the intrinsic unsteady evolution of individual clouds.

The design of this PhD course in part stems from activities associated with the Marie Sklodowska Curie Action Innovative Training Network, COMPLETE, which was a Cloud-MicroPhysics-Turbulence-Telemetry shared inter-multidisciplinary research training environment for enhancing the understanding and modeling of atmospheric clouds.

The network was financed under the Horizon 2020 Framework Program (2016-2021, GA 675675) and coordinated by Daniela Tordella, www.complete-h2020network.eu.

Invited Lecturers:
Annica Ekman (Stockholm, Sweden), Kalli Furtado (Exeter, UK), Wojciech W. Grabowski (Boulder, CO, USA), Fabian Hoffmann (Munich, Germany), Szymon Malinowski (Warsaw, Poland), Annette Miltenberge (Mainz, Germany), Annika Oertel (Karlsruhe, Germany), Daniela Tordella (Torino, Italy).

Coordinator: D. Tordella

The Morton Gurtin Session

Vehicle Dynamics, Control and Design
9th CISM-AIMETA Advanced School

September 4 - 8, 2023

and more automated vehicles, vehicle dynamics remains a key aspect in the vehicle development. Vehicle engineers need to be able to ensure safe and robust performance of vehicles through classical and novel modelling and control approaches, requiring an ever broadening set of skills.
The design of a vehicle is now more challenging than ever, including the need to meet new driver-oriented requirements. At the same time, the role of the driver is shifting through steady advancements in vehicle automation. Progressive vehicle electrification allows control techniques that were not imaginable before, such as those harnessing independently actuated drivetrains. Meanwhile, innovative vehicle control techniques often require reliable estimates of relevant vehicle motion parameters (e.g. sideslip angle) which are not trivial to achieve. Engineers and researchers should not only to be able to perform theoretical studies and simulations, but also be proficient vehicle test engineers. Conducting vehicle testing or state-of-the-art research on actual vehicle prototypes requires familiarity with vehicle instrumentation techniques and experimental platforms for real-time vehicle control.
With that in mind, this course aims to benefit vehicle dynamics engineers at any level of their career, working in academia and/or industry. At the beginning of the course, the main vehicle dynamics fundamentals will be briefly revisited, including e.g. tire and vehicle modelling. The subsequent module will refresh and strengthen the control theoretic background of the participants, along with discussing specific vehicle dynamics applications. The course will then move onto torque vectoring control, explaining how to exploit the possibility of independent actuation as the vehicle corners, supported through a Matlab-Simulink tutorial. Then, the framework of autonomous vehicles will be explored, covering key topics like levels of vehicle automation, path planning etc. Having in mind how to control a human-driven or autonomous vehicle, the participants

will have the chance to learn and apply vehicle state-estimators based on Kalman filters and/or machine learning techniques, again with the support of Matlab-based tutorials. Then, a module on vehicle instrumentation and testing will cover key practical insights related to what sensors should be installed on the vehicle depending on the specific needs, how to install them and coordinate with all the car sensory equipment, how to read and analyze data. The final part of the course will deal with the importance of a driver-oriented approach in chassis design, including the analysis of the external demands on the chassis, and the investigation of the combination of the vehicle's properties, such as driving pleasure, driving safety, driving comfort, ride comfort, noise comfort

Invited Lecturers:
Ricardo De Castro (Merced, CA, USA), Basilio Lenzo (Padua, Italy), Mathias Lidberg (Gothenburg, Sweden), Frank Naets (Leuven, Belgium), Gabor Orosz (Ann Arbor, MI, USA), Carlo Rottenbacher (Pavia, Italy).

Coordinators: B. Lenzo, F. Naets

Lagrangian Approaches to Multiphysics Two-Phase Flows

September 11 - 15, 2023

Two-phase flows are common in environmental and industrial applications. To name a few examples, dispersion of solid & liquid matter in atmospheric flows (dust, sand, droplets or ice crystals) or marine systems populated by a number of organic & inorganic objects (e.g., plankton, sediments, or microplastics). Two-phase flows are also a matter of concern in industrial systems (e.g., spray dryers, bubble columns, combustion engines) which can involve complex fluids (e.g., containing polymers or colloids) as well as interfacial and free-surface flows.

To address the complexity of these phenomena, models require to combine a range of disciplines such as fluid dynamics (including turbulence or microfluidics), transport of a dispersed phase, surface science, thermodynamics & chemistry (including phase changes), soft matter physics (e.g. predicting materials properties or transport coefficients) or even biology. A specific challenge is that these processes span a wide range of spatial and temporal scales (from nanometers/nanoseconds to kilometers/days).

The aim of this course is to explore multiphysics and multiscale aspects of two-phase flows through particle tracking methods. Whereas handling fields is natural in areas pertaining to continuum mechanics, Lagrangian approaches have been gaining increased attention in past decades. In fact, for dispersed two-phase flows, they allow to treat without approximation key phenomena (like transport or polydispersity) and are flexible enough to include specific models (like thermal noise for fluctuating hydrodynamics). Moreover, they constitute an adequate framework in which models at the mesoscopic and macroscopic levels of description can be naturally coupled, providing a consistent methodology throughout these scales.

The course is organized so as to cover a range of available Lagrangian techniques. This will include lectures on particle tracking measurement principles and methods (e.g., PIV & PTV). On the micro- and mesoscopic levels, lectures on modeling approaches encompass methods used in statistical physics (typically below the hydrodynamic level, such as Dissipative Particle Dynamics (DPD) or Smoothed Dissipative Particle Dynamics (SDPD))for the dynamics of molecules/super-molecules). On the macroscopic level, meshfree and particle methods used in computational fluid dynamics for single- and multi-phase flows will be presented (like Smoothed Particle Hydrodynamics (SPH)). Concerning turbulent particle-laden flows, lectures will cover Direct Numerical Simulations of turbulent flows coupled to detailed DEM tracking approaches, alongside spatially-filtered approaches (Large-Eddy Simulations with sub-scale models for particle dynamics) and all the way up to macroscopic stochastic PDF approaches based on mean-field theories.

Through these various examples, similarities and differences between particle-based descriptions will be highlighted. The lectures will shed light on experimental issues (e.g., uncertainties), modeling issues (how to select key factors in a physical description of a system, how to model unresolved scales), and computational issues (like consistency and compatibility in hybrid approaches).

Invited Lecturers:
Pep Español (Madrid, Spain), Jochen Fröhlich (Dresden, Germany), Christophe Henry (Valbonne, France), David Le Touzé (Nantes, France), Alex Liberzon (Tel Aviv, Israel), Jacek Pozorski (Gdansk, Poland).

Coordinators: C. Henry, J. Pozorski

Scientific Machine Learning in Design Optimization
8th CISM-ECCOMAS Advanced School

September 18 - 22, 2023

When browsing the news, one perceives a rather widespread fear of “artificial intelligence forcing humans into unemployment”. As a counterpoint to this fear, within the proposed course, we will demonstrate that daring more intelligence can aid human engineers to excel by relieving them from repetitive tasks and allowing future pioneers to better exploit their creativeness for the benefit of both the engineer and the end-user of the product. Just like “classic” numerical analysis, artificial intelligence can play an integral role in finding reliable and reproducible answers to mechanical design questions without depending on costly experiments or on decades of engineering experience. In this spirit, the course will discuss recent advances in artificial intelligence and their application to engineering design / computational mechanics. Topics will span the entire design and analysis process from geometry representation via numerical analysis to design optimization, including data-enhanced, knowledge-enabled (i) geometric design, (ii) predictive analysis, and (iii) optimization of complex mechanical systems.

The course sets out to provide a basic understanding of the classic engineering design process and identify potential usage of artificial intelligence in this context. We will proceed by detailing basic theory of machine learning concepts suitable for (i) geometry representation, (ii) model order reduction, (iii) optimization, and (iv) uncertainty quantification.
- We will demonstrate how Variational Autoencoders (VAE) can be employed to learn low-dimensional, yet feature-rich shape representations;
- We will build the foundations of Reduced Order Modelling and its application to digital twins;
- We will employ Gaussian process regression to create a non-parametric scalar regression model of objective functions based on probability distributions;
- We will introduce the concept of physics-informed neural networks that aim to connect the world of data-driven and knowledge-based modelling and extend this approach to spline-based approaches using IgAnets;
- We will demonstrate several operator learning techniques like DeepONets
- We will perform design optimization based on reinforcement learning, an experience-driven, autonomous way of learning.
The course participants will not only be introduced to the basic concepts, but will also be pointed to open-source implementations of the presented concepts that will allow them to directly include the newly studied methods into their everyday research. To further facilitate this transfer, the course will discuss examples from mechanics, where these approaches have been successful.
The course is addressed to anyone new to machine learning in the mechanics community, be it a doctoral student, a young researcher, or even a senior researcher, who would like to try out something new.

Invited Lecturers:
Stefanie Elgeti (Vienna, Austria), Elie Hachem (Sophia Antipolis, France), Matthias Möller (Delft, The Netherlands), Paris Perdikaris (Philadelphia, PA, USA), Gianluigi Rozza (Trieste, Italy), Sebastian Schöps (Darmstadt, Germany).

Coordinators: S. Elgeti, M. Möller

Batteries - Basic Principles, Experimental Investigations and Modeling across Scales

September 25 - 29, 2023

Batteries are considered to be a key technology in a future energy and mobility system based on renewable and fluctuating energy sources. Depending on the application, the specifications for energy density, power density, safety, and lifetime of batteries can vary considerably. Therefore, the need for optimization tools to balance application-specific conflicting constraints on batteries is obvious. In addition, the demand for rapid developments of new energy storage materials and battery designs requires the transition

to a rational, knowledge-based battery development strategy based on validated models and sophisticated simulation tools. The challenge is to describe mathematically all electrochemical, physical, and mechanical processes necessary for an efficient and safe operation of batteries, which, for such highly complex electrochemical storage devices, means modeling and coupling processes on a large range of scales.
The course will cover theoretical methods as well as experimental insights on these different scales. Predictive modeling starting from Density Functional Theory calculations allow investigating thermodynamic, mechanical, and electrochemical stability of materials and combination of materials. They provide fundamental electrode material parameters to be used in the continuum modeling and give insights into the kinetics of electrochemical reactions. A crucial factor for the stability and power density of batteries is the choice of electrolyte. Finding the right compromise between electrochemical stability, excellent transport properties, and forming interfaces that support the reaction kinetics at positive and negative electrodes is a challenging task. The method of choice to investigate the behavior of electrolytes is molecular dynamics simulation (MD), either ab initio MD or classical MD, with fine-tuned force fields for the electrolyte under investigation. For optimizing the structural design of the electrodes and the cell design from nanometer to cm scale continuum theories are necessary to describe the complex interplay of transport, reactions, and mechanical processes during battery operation. To allow for a systematic coupling of continuum theories and underlying atomistic theories, it is important to derive continuum models within rigorous theoretical concepts. The course will give an introduction to state-of-the-art continuum modeling and simulation techniques for electrochemical as well as mechanical processes on electrode and device scales. This part will be complemented by an overview of experimental techniques for investigating battery behavior and validating continuum theories of batteries. On the largest scale, the system scale, simulation tools are required which maintain the essential features of the underlying detailed models but are systematically simplified to allow for real-time control of the battery operation in order to guarantee safety and preserve the lifetime of the battery. The description of the art of model reduction and real-time simulations of battery responses on system requests rounds up this CISM course.
The course aims at doctoral students as well as (junior) researchers, from different backgrounds, both from academia and industry. In the afternoon of the first day, a poster/slide flash will be held to give participants the opportunity to briefly present their interests or working area. This will enable fostering a collegial discussion during the course.

Invited Lecturers:
Oleg Borodin (Adelphi, MD, USA), David Howey (Oxford, UK), Jürgen Janek (Gießen, Germany), Arnulf Latz (Ulm, Germany), Yue Qi (Providence, RI, USA), Wolfgang A. Wall (Munich, Germany).

Guest Lecturers:
Long-Qing Chen (State College, PA, USA), Edwin Knobbe (Munich, Germany).

Coordinators: A. Latz, W. A. Wall

Landslides Mechanics: from Complex Granular Behaviour to Field-Scale Flows

October 2 - 6, 2023

Gravitational instabilities such as debris flows and landslides play a key role in erosion processes and represent one of the major natural hazards threatening population and infrastructures all over the world. They are also closely related to volcanic, seismic, and climatic activity and thus represent potential precursors or proxies for the time change of these activities.

One of the ultimate goals of research on gravitational mass flows is to produce tools for detection of landslides and for prediction of their velocity and runout extent. The theoretical description and physical understanding of these processes are extremely challenging problems. In recent years, significant progress in the mathematical, physical, and numerical modelling of gravitational flows, as well as advances of monitoring techniques, have made it possible to develop and use numerical models to investigate process dynamics and assess associated risks. However, key questions still remain unanswered, for instance concerning the reason for the high mobility of natural landslides. Two severe limitations prevent a full understanding of landslide dynamics. First, the mechanical behavior (rheology) of these flows is still an open issue and the resulting mathematical and numerical models are oversimplified and not always well-posed. In particular they do not take into account complex natural phenomena such as interaction of fluid and solid phases, cohesion or fragmentation. Secondly, field measurements relevant to the dynamics of natural landslides are scarce due to the unpredictability and destructive power of such events, making it nearly impossible to validate the description of the physical processes in the models. In this context, the analysis of the seismic signal generated by these instabilities provides a unique tool to recover information on flow dynamics.

The Advanced School provides an overview of the state-of-the-art in these different fields going from the behavior of granular material involving cohesion, fragmentation, presence of a fluid-phase up to the behavior of landslides at the field-scale and their interaction with climatic, seismic, volcanic, and human forcing. The courses will span from theoretical work on granular flow models, experimental work on granular flows, discrete and continuum simulations up to field measurements as well as inversion of the generated seismic waves. A focus will be made in each field on the limitations and complementarity of the different approaches and on the open issues.

Two poster and brainstorming sessions dedicated to:

1) physics and rheology of lab-scale granular flows;

2) measurements and simulation of field-scale landslides.

The brainstorming sessions will more particularly address the two challenging issues, which play a key role in the description of natural gravitational flows:

1) What are the limits of the current rheological laws such
as $\mu(I)$ when applied to describe transient flows?

2) Which processes can be at the origin of the unexplained high mobility of natural landslides?

We expect that confronting the different and possibly contradictory points of view of the

speakers and assembly on these issues will make it possible to identify original research directions in physics, mechanics, modelling and field measurements.
The Vajont field trip will focus on the biggest landslide-related disaster in Italian modern history. On October 9th, 1963, a devastating landslide occurred in the valley of Vajont, Italy. After filling the reservoir behind a recently built dam, around 250-300 Mm^3 of rock and debris detached and slit into the reservoir. The resulting flood wave overtopped the dam and destroyed settlements and infrastructure along the way, causing more than 2,000 casualties. During the field trip we will visit the dam and the landslide as well as the Museo Longarone Vajont.

Invited Lecturers:
Nico Gray (Manchester, UK), Elisabeth Guazzelli (Paris, France), Roland Kaitna (Vienna, Austria), Anne Mangeney (Paris, France), Prabhu Nott (Bangalore, India), Dave Petley (Sheffield, UK), Olivier Pouliquen (Marseille, France), Fahrang Radjai (Montpellier, F)**.**

Coordinators: R. Kaitna, A. Mangeney

Model Order Reduction for Design, Analysis and Control of Nonlinear Vibratory Systems

October 9 - 13, 2023

This CISM course is devoted to the analysis of realistic engineering nonlinear vibratory systems with the tools provided by the dynamical systems theory. The cornerstone of the courses will be the use of model order reduction methods defined in the framework of the invariant manifold theory for nonlinear systems, which allows definitions of efficient methods generating the most parsimonious nonlinear models having minimal dimension, and reproducing the dynamics of the full system under generic assumptions. Emphasis will be put on the development of direct computational methods for finite element (FE) structures, allowing one to go from the physical coordinates to an invariant-based span of the system. Reduction methods have witnessed major improvements in the recent years. In particular, direct calculations of reduced dynamics for large FE structures using invariant manifold theory, allow one to reduce a problem from millions of dofs to the few essential ones. Besides, the reduced models are known to be minimal, representative, and convergent thanks to arbitrary order expansion. Open source codes are available for geometric nonlinearity and the course will introduce them.
Once the reduced order model obtained, numerical and analytical methods will be detailed in order to get a complete picture of the dynamical solutions of the system in terms of stability and bifurcation. The numerical continuation methods will be specifically addressed to obtain fast and accurate solutions of reduced dynamics. Applications from the MEMS industry (Micro Electro Mechanical Systems) and from the aerospace industry (vibrations of blades, bolted structures, vibration mitigation), will be covered and analyzed, in the light of proposing fast computations for more efficient designs and control of nonlinear vibrations of engineering structures. Geometric nonlinearity, friction

nonlinearity in contact and jointed structures, detection and use of internal resonance, piezoelectric coupling and passive control, parametric driving will be surveyed as key applications. The course will also address the links with experiments, and the connection between invariant manifold theory and methods obtained with data-driven techniques will be illustrated, opening the door to efficient use of digital twins in nonlinear analysis of engineering structures.
The course is structured along three main didactic themes: (i) Reduction methods - Basic notions about reduced order models for nonlinear systems, emphasis on nonlinear normal modes and the parametrisation method for invariant manifold, direct computational methods for FE structures; (ii) Numerical tools for analysis and design – continuation methods, stability and bifurcation, control; and, (iii) Applications – practical and industrial problems where reduction methods combined with analysis are used at the design stage or for controlling nonlinear systems, applications in MEMS and aerospace industry. The course is addressed to doctoral students and postdoctoral researchers in nonlinear vibrations, mechanics, applied physics and applied mathematics, academic and industrial researchers and practicing engineers.

Invited Lecturers:
Attilio Frangi (Milan, Italy), Malte Krack (Stuttgart, Germany), Walter Lacarbonara (Rome, Italy), Olivier Thomas (Lille, France), Cyril Touzé (Palaiseau, France), David Wagg (Sheffield, UK).

Coordinators: A. Frangi, C. Touzé

Virtual Elements for Problems in Mechanics

October 16 - 20, 2023

Batteries are considered to be a key technology in a future energy and mobility system based on renewable and fluctuating energy sources. Depending on the application, the specifications for energy density, power density, safety and lifetime of batteries can vary considerably. Therefore, the need for optimization tools to balance application specific conflicting constraints on batteries is obvious. In addition, the demand for rapid developments of new energy storage materials and battery designs requires the transition to a rational, knowledge-based battery development strategy based on validated models and sophisticated simulation tools. The challenge is to describe mathematically all electrochemical, physical and mechanical processes necessary for an efficient and safe operation of batteries, which, for such highly complex electrochemical storage devices means to model and couple processes on a large range of scales.
The course will cover theoretical methods as well as experimental insights on these different scales. Atomistic theories allow investigating thermodynamic and electrochemical stability of materials and combination of materials. They provide fundamental electrode material parameters and transport mechanisms and give insights in the reaction kinetics of chemical reactions. A very crucial factor for stability and power density of batteries

is the choice of the electrolyte. Finding the right compromise between electrochemical stability, excellent transport properties and forming interfaces which support the reaction kinetics at positive and negative electrodes is a challenging task. The method of choice to investigate the behavior of electrolytes is molecular dynamics simulation (MD), either ab initio MD or classical MD with fine-tuned force fields for the electrolyte under investigation. For optimizing the structural design of the electrodes and the cell design from nanometer to cm scale continuum theories are necessary to describe the complex interplay of transport, reactions and mechanical processes during operation of the battery. To allow for a systematic coupling of continuum theories and underlying atomistic theories it is important to derive continuum models within rigorous theoretical concepts. The course will give an introduction in state-of-the-art continuum modeling and simulation techniques for electrochemical as well as mechanical processes on electrode and device scale. This part will be complemented by an overview over experimental techniques for investigating battery behavior and validating continuum theories of batteries. On the largest scale, the system scale, simulation tools are required which maintain the essential features of the underlying detailed models but are systematically simplified to allow for a real time control of the battery operation in order to guarantee safety and preserve lifetime of the battery.

Invited Lecturers:
Edoardo Artioli (Rome, Italy), Lourenco Beirao da Veiga (Milan, Italy), Jože Korelc (Ljubljana, Slovenia), Alessandro Russo (Milan, Italy), Sukumar Natarajan (Davis, CA, USA), Peter Wriggers (Hannover, Germany).

Coordinators: L. Beirao da Veiga, P. Wriggers

Delays and Structures in Dynamical Systems: Modeling, Analysis and Numerical Methods

November 20 - 24, 2023

Delays and structures pervade the realistic modeling of populations and their investigation under the paradigm of dynamical systems. They prove to be essential also in control and related fields, where modeling through delay functional or partial differential equations has become increasingly fundamental. The inclusion of past history in the time evolution and the introduction of structuring variables add nontrivial complexities with respect to ordinary systems, balancing the undoubted advantage of dealing with more realistic models. Equations involving time delays and structures both generate dynamical systems of infinite dimension, asking for advanced methods in the mathematical analysis and the numerical treatment. Finally, understanding stability of equilibria and other invariants is crucial and often requires sophisticated numerical and computational approaches.
The school brings together strong and up-to-date contributions in population dynamics and related fields as far as delays and structures give fundamental tools for the realistic modeling of, e.g., the transmission of an infectious disease, the evolution of a resource-consumer scenario or the competition in a predator-prey system. Numerical and

computational expertise is also offered, providing reliable approaches towards a practical and accessible analysis. The course aims at discussing the most recent advances in the different contexts of the relevant mathematical analysis (functional aspects of semigroup theory); the concerned modeling approaches (delay differential, renewal and partial differential equations of evolution type, including multi-structured, neutral and state-dependent equations); the numerical and computational techniques to operate with infinite-dimensional dynamical systems (simulation, stability, bifurcation). This knowledge will be employed to discuss applications from ecology, epidemiology and life sciences in general. Laboratory sessions will allow the participants to learn both theoretical considerations and the practical application of modern software and packages (MATLAB/Octave, Python, MatCont, DDE-Biftool). Analysis, modeling, methods and applications will be illustrated focusing also on their interdisciplinary connections, starting from rapid introductions of the basics and reaching a state-of-the-art level by evolving classic approaches into modern perspectives.
The school is primarily addressed to PhD students and post-docs in the fields connected to structured population dynamics and dynamical systems involving time delays and their numerical analysis, ranging from mathematics to engineering and physics. Young and senior researchers in the above or neighboring fields, interested in gaining a compact yet comprehensive overview of population dynamics with delays and structures, are also welcome from academia or private R&D centers. The school also offers the possibility to learn and apply relevant software and computational tools through the investigation of case studies in the planned laboratory sessions.

Invited Lecturers:
Odo Diekmann (Utrecht, The Netherlands), Tony Humphries (West Montreal, Canada), Davide Liessi (Udine, Italy), Zachary McCarthy (Toronto, Canada), Stefano Maset (Trieste, Italy), Shigui Ruan (Coral Gables, FL, USA), Francesca Scarabel (Leeds, UK), Rossana Vermiglio (Udine, Italy).

Coordinators: Dimitri Breda (Udine, I), Jianhong Wu (Toronto, Canada)

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