TIME TABLE

TIME	Monday April 19	Tuesday April 20	Wednesday April 21	Thursday April 22	Friday April 23
9.00 - 9.45	Registration	Le Bars	Le Bars	Lecoanet	Baraffe
9.45 - 10.30	Le Bars	Le Bars	Le Bars	Lecoanet	Mellado
11.00 - 11.45	Lecoanet	Baraffe	Lecoanet	Baraffe	Noir
11.45 - 12.30	Lecoanet	Mellado	Lecoanet	Baraffe	Noir
14.00 - 14.45	Burns	Noir	Baraffe	Mellado	
14.45 - 15.30	Burns	Burns	Mellado	Mellado	
16.00 - 16.45	flash talk presentations	.... from the participants	Noir	Noir	
16.45 - 17.30	Poster Session	Poster Session	Burns	Burns	
18.00	Welcome Aperitif				

ADMISSION AND ACCOMMODATION

The registration fees are:
- Participation in presence, 600.00 Euro + VAT*

This fee includes a complimentary bag, four fixed menu buffet lunches (on Friday upon request), hot beverages, downloadable lecture notes.
- Participation online, 250.00 Euro + VAT*

This fee includes downloadable lecture note.

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through the following web site: http://www.cism.it. A message of confirmation will be sent to accepted participants. Applicants requiring assistance with the registration should contact the secretariat at the following email address: cism@cism.it.

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email to cism@cism.it) no later than two weeks prior to the start of the course.

Cancellation requests received during the two weeks prior to the start of the course will be charged a 50.00 Euro handling fee. Incorrect payments are also subject to a 50.00 Euro handling fee.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered lodging and/or board, if available, in a reasonably priced hotel or student guest house.

Requests should be sent to CISM Secretariat by **February 19, 2021** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

Information about travel and accommodation is available on the web site www.cism.it, or can be mailed upon request.

* where applicable (bank charges are not included)
Italian VAT is 22%.

For further information please contact:
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ACADEMIC YEAR 2021

The Erwin Stein Session

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

FLUID MECHANICS OF PLANETS AND STARS

Advanced School
coordinated by

Daniel Lecoanet
Northwestern University
Evanston, Illinois, USA

Michael Le Bars
CNRS, Aix Marseille Université
France

Udine *April 19 - 23* 2021

FLUID MECHANICS OF PLANETS AND STARS

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.

PRELIMINARY SUGGESTED READINGS

Le Bars, Michael, and Daniel Lecoanet (eds). “Fluid Mechanics of Planets and Stars." Publisher: Springer (2020).

Vallis, Geoffrey K. "Atmospheric and Oceanic Fluid Dynamics." Publisher: Cambridge University Press (2006).

Sutherland, Bruce R. "Internal Gravity Waves." Publisher: Cambridge University Press (2010).

Mellado, Juan Pedro. "Cloud-top entrainment in stratocumulus clouds." Annual Review of Fluid Mechanics 49: 145-169 (2017).

Ogilvie, Gordon I. "Astrophysical fluid dynamics." Journal of Plasma Physics 82.3 (2016).

Davidson, Peter A. "Turbulence in rotating, stratified and electrically conducting fluids." Publisher: Cambridge University Press (2013).

Olson, Peter (ed). "Core Dynamics: Treatise on Geophysics." Publisher: Elsevier (2010).

LECTURES

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

INVITED LECTURERS

Isabelle Baraffe - University of Exeter, United Kingdom
5 lectures on:
Stellar fluid dynamics, including: basics of stellar structure & evolution; stellar convection; the radiative-convective interface: overshoot, waves; angular momentum and chemical transport; asteroseismology.

Keaton J. Burns - Massachusetts Institute of Technology, Cambridge, MA, USA
5 practical work sessions:
Participants will learn to set up and run numerical simulations using the Dedalus spectral solver on their laptops. Example simulations include: Rayleigh-Bénard convection; wave generation and propagation; wave mixing; solidification; moist convection.

Michael Le Bars - CNRS, Aix Marseille Université, France
5 lectures on:
Fundamental fluid mechanics in rotating and/or stratified fluids relevant for geophysical and astrophysical flows, focusing on the most common instabilities (3 lectures) and on the basic properties of turbulence (2 lectures), including: barotropic and baroclinic instabilities; convection; geostrophic & wave turbulence; mixing.

Daniel Lecoanet - Northwestern University, Evanston, IL, USA
6 lectures on:
Fundamental fluid mechanics in rotating, stratified, and magnetized fluids, focusing on the generic properties of waves in geophysics and astrophysics (5 lectures), and on the basics of magneto-hydrodynamics (1 lecture), including: internal gravity waves; inertial waves; MHD waves; non-linear interactions; wave breaking; wave-mean-flow interactions; dynamo action.

Juan Pedro Mellado - Universitat Politecnica de Catalunya, Barcelona, Spain
5 lectures on:
Atmospheric fluid dynamics, including: basic structure of the Earth’s atmosphere; planetary boundary layer; moist convection and clouds; inversion layer dynamics; wave-driven flows and instabilities.

Jérõme A. R. Noir - EPM, ETH Zurich, Switzerland
5 lectures on:
Internal planetary fluid dynamics, including: basics of planetary interior structure; convection and mixing in planetary cores and mantles; solidification in subsurface oceans; turbulence and dynamo action in planetary cores.