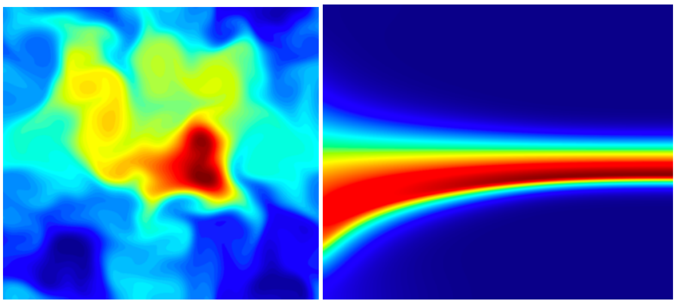
Title :**Numerical methods and simulation codes**	
Acronym : TC5	
EU Coordinators : Andrea CIARDI et Aymeric VIE, Laboratoire d'Etudes du Rayonnement et de la Matière en Astrophysique et Atmosphères (LERMA) et Laboratoire Énergétique Moléculaire et Macroscopique, Combustion (EM2C)	
Teaching staff : Anne BOURDON, Andrea CIARDI, Antoine TAVANT, AymericVIE	
Pre-requisites :First year of MSc in Physics or Engineering Schools.	
Credits : 3 ECTS	
Language : French/English	
Keywords :Introduction to algorithms - Solving differential equations - Discretization methods - Explicit and implicit schemes - Stability and efficiency - Numerical simulations in fluid mechanics - Numerical simulations in plasma physics: fluid models (MHD codes, ...) , kinetic models (Particle-In-Cell, gyro-kinetic codes, ...) , hybrids.	

The objective of this course, both theoretical and applied, is twofold: (i) to train students in the methods and algorithms of numerical simulation by introducing them to the different mathematical models used in fluid dynamics and plasma physics, and (ii) to initiate them to numerical simulation by using specific computational codes, in order to study complex phenomena in plasma physics, which are described by fluid and/or kinetic models and which are dealt with in the different teaching units of the Master.

Numerical simulations in fluid mechanics

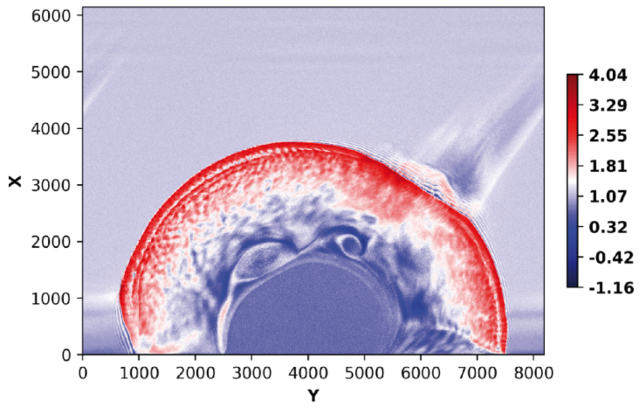
The objective is to present a set of numerical methods necessary to solve equations governing the dynamics of a fluid, and to put the students in the situation to build themselves a solver allowing to solve these equations in the framework of a given physical problem.On completion of the course, students will be able to solve a simple problem with a small script to implement a numerical resolution; to formalize a physical problem into equations and identify their mathematical nature; to discretize a set of differential equations; to derive an adapted numerical method in terms of accuracy and efficiency to solve the problem ; to analyze the accuracy and the stability of a numerical method; to ensure the validity of the results through hypotheses' checking and numerical errors' characterization; to have a critical interpretation of the physical results; to solve problems found in fundamental physics and in engineering applications.



Scalar diffusion in turbulence (left) and temperature field in a countercurrent flame (right).

Numerical simulations in plasma physics

This part is devoted to the modeling of plasmas and the physical phenomena that take place in such media. After a theoretical presentation of the main approaches used (fluid, kinetic, hybrid descriptions,…) to describe various physical processes at work in different types of plasmas (cold or hot, dense or diluted, magnetized or not, collisional or not, ...) and taking place on different scales (microscopic, mesoscopic, macroscopic), students are introduced, with the help of numerical practical work, to the study of a few examples: magnetohydrodynamic description of a plasma, discharges in a gas at atmospheric pressure, beam-plasma interaction in theframe of a kinetic code.



Simulation of the Earth's bow shock using a two-dimensional kinetic code (PIC code)