Title : **Magnetohydrodynamics**

Acronym : TC2

EU Coordinator : Catherine KRAFFT, Laboratoire de Physique des Plasmas (LPP)

Teaching staff : Sébastien GALTIER, Catherine KRAFFT

Pre-requisites : First year of MSc in Physics or Engineering Schools.

Credits : 3 ECTS

Language : French/English

Keywords : Theory of Magnetohydrodynamics (MHD) - MHD invariants - Cylindrical, toroidal, force-free equilibria - MHD instabilities - Magnetic containment - MHD waves - MHD turbulence - Magnetic reconnection - Kolmogorov spectrum

The objective is to present the fluid approach of the generalized Magnetohydrodynamics (MHD) theory in which the corpuscular aspect (electrons, ions) is no longer essential to describe the linear and nonlinear physical processes in magnetized plasmas. Four main parts will be discussed: (I) Theoretical foundations of MHD; (II) Invariants and equilibria; (III) Instabilities and magnetic containment; (IV) MHD turbulence. The articulation between these parts will be facilitated by examples from astrophysical plasmas and magnetic thermonuclear fusion.

The content of the teaching unit is the following :

General introduction - Moments of the Boltzmann equation - Multi-fluid model - Bi-fluid model - Single-fluid model - MHD equations - Generalized Ohm's law - Resistivity - Conductivity - Limits of validity of the theory - Ideal and resistive MHD - Magnetic tension - Lorentz force - Pressure tensor - Resistive diffusion - Convection.

Conservation laws of mass, energy and momentum density - Alfven flow and freeze theorems - Magnetic helicity - Crossed helicity - Magnetic topology.

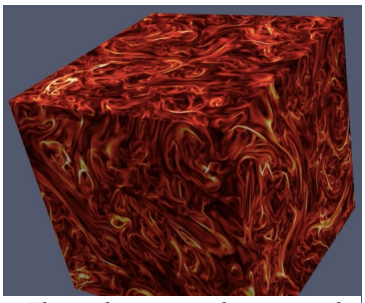
Wave propagation - Equations and dispersion characteristics of Alfven and magnetosonic waves - Radiation diagrams - Field, pressure and mass density perturbations.

Equilibria and magnetic containment - Cylindrical equilibria (theta and z pinches) - Toric equilibrium (Grad-Shafranov equation) - Force-free equilibrium.

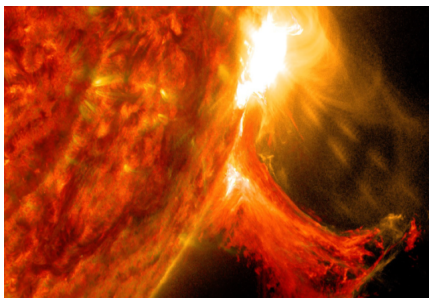
Instabilities: Linear perturbation theory and limits of validity - Rayleigh-Taylor and Kruskal-Schwarzschild - z and theta pinches - Magneto-rotational instability in accretion disks - Resistive tearing instability.

Magnetic reconnection: Solar flares - Reconnection rates - Sweet-Parker model - Fast reconnection with Hall effect.

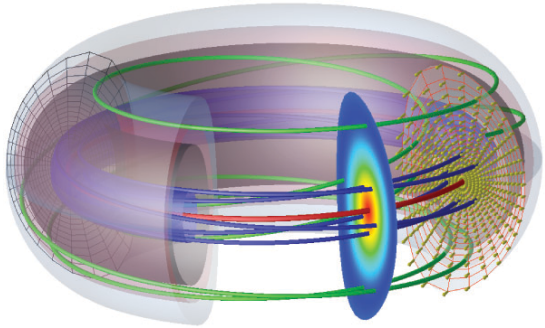
MHD Turbulence : Solar wind and tokamak - Statistical concepts and tools - Hydrodynamic turbulence with exact law and Kolmogorov spectrum - MHD turbulence with exact law and anisotropic spectrum - Intermittence and fractal.



Three-dimensional numerical simulation of MHD



Solar burst observed by the Solar Dynamics Observatory (NASA/SDO)



Toroidal equilibrium in a Tokamak : solution of the Grad Shafranov equation