Title: **High energy density astrophysical plasmas**

Acronym : O4

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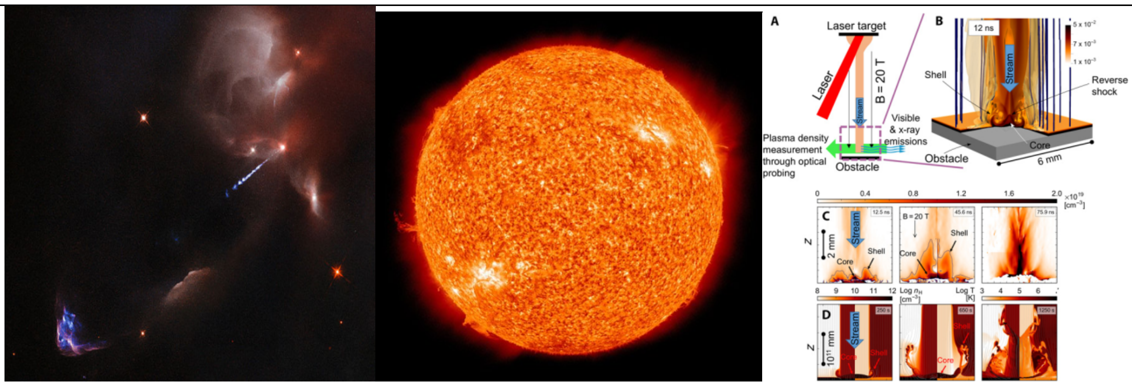
Pre-requisites : First year of MSc in Physics or Engineering Schools.

Credits : 3 ECTS

Language : French/English

Keywords : Astrophysics, natural plasmas, high-energy density plasma, thermonuclear fusion, radiation, Magnetohydrodynamics.



Left : Astrophysical jet from a young star: object HH34 [ESA/Hubble, CC BY 4.0]
Middle : The Sun [NASA/SDO (AIA), Public domain]
Right : Laboratory astrophysics with high power lasers (Revet et al "Laboratory unraveling of matter accretion in young stars" Science Advances 2017)

Stars concentrate the overwhelming majority of visible matter in the universe in the form of hot plasmas. In this course, we focus on the high energy density plasmas that are involved in the formation and evolution of stars.

The objective of this module is to explain the macroscopic physical phenomena that structure stellar plasmas and dictate their thermodynamic conditions, as well as the microscopic physics that locally determine their properties.

After an introduction, we qualitatively address the star formation process. We study the dynamics of the accretion disks and astrophysical jets that occur at the beginning of the star's existence. We study their internal functioning during the main sequence, the longest phase of their existence. We look at the heat production within the star and the transport of this heat to its surface, leading to the equations of the stellar structure. We also discuss some modeling elements that allow us to calculate properties useful for modeling stars: the equations of state and opacities. We also discuss the evolution and end of life of stars, supernovae and cosmic ray acceleration. Finally, we discuss recent works that aim at reproducing some astrophysical phenomena in the laboratory, using high power lasers or magnetic pinch machines (z-pinch).

Course outline

1. Introduction, astrophysical context
2. Phenomena involved in star formation
3. Thermonuclear fusion in stars, stellar nucleosynthesis
4. Radiative transfer in stellar interiors
5. Convective transfer in stellar interiors
6. Equations of the stellar structure
5. Thermodynamic and radiative properties
6. Stellar evolution, supernovae and cosmic rays
7. Laboratory astrophysics