M2 IRT
MC "Radiation"
2024-2025

Group projects

The projects described below are designed to be undertaken by groups of two or three students over the course of the semester. Most of the work is to be done collaboratively, outside class hours. Two class sessions (October 23 and November 20) will be devoted entirely to monitoring the progress of the projects. The descriptions of the various projects below are deliberately succinct, to enable each group to develop its own ideas. A number of possible developments are nevertheless given, to enable each student to explore the project according to his or her aptitudes and tastes. Assessment of project work will take the form of an oral presentation (30-minute presentation, 30-minute question period) on December 11, and may be individualized within each group, depending on the amount of work involved. It will count for 60% of the final grade.

1 Spectral line diagnostics

[Suggested group size : two students]

The goal of this project is to develop a numerical tool to perform the automated identification of lines in a given spectrum, measure their equivalent widths taking into account the underlying continuum, and use theoretical curves of growth to estimate the physical properties (redshifts, column densities and velocity dispersions) of the gas species that are causing the line formation.

Possible developments : Queries of databases of observational spectra - Continuum fitting - Queries of spectral line databases - Estimation of equivalent widths - Computation of theoretical line profiles - Computation of theoretical curves of growth - Interactive visualization of the spectrum and the fitted lines - Estimation of the uncertainties on the derived physical properties - Applicability to a wide range of spectra, from the UV to the radio domain.

2 Absorption spectra of transiting exoplanets

[Suggested group size : two or three students]

The goal of this project is to develop a model of the transmission spectra of transiting exoplanets, such as those now observed by JWST, due to the presence of an exoplanetary atmosphere containing specific chemical species in possibly various excitation states.

Possible developments : Transit light curves for an exoplanet without an atmosphere - Effect of the planet's temperature - Telescope beam effects - Stellar limb darkening - Atmospheric pressure profile - Atmospheric composition profiles - Excitation conditions - Instrumental noise - Comparison to actual observational data.

3 Atmospheric scattering

[Suggested group size : three students]

The goal of this project is to develop a model to compute the diffusion of the light emitted by a nearby star by the atmosphere of an orbiting planet using a Monte Carlo method, provide an image of the sky as seen by an observer on the planet's surface or spectra along lines of sight selected by the user.

Possible developments : Image and spectra of a star as seen from the planet surface without scattering - Atmospheric model with a simple geometry - Implementation of scattering processes using photon packets and a Monte Carlo Method - Application to various atmospheric compositions, densities and diffusion processes - Application to different positions of the star, types of stars, binary systems - Time evolution

4 Spectra across MHD simulations

[Suggested group size : two or three students]

The goal of this project is to develop a numerical tool to compute the emission and absorption of light across MHD simulations of the multiphase turbulent interstellar medium in different tracers, such as those observed by Planck, JWST, and SKA, and provide images and spectra. Simulated data, including the 3D chemical composition of the gas are provided by the teachers.

Possible developments : Emission and absorption by dust grains without scattering processes - Study of stellar reddening - Excitation conditions of atoms or molecule - Emission and absorption by atoms or molecules without scattering processes - Emission maps or spectra with or without a background radiation source - Diffusion by dust grains - Instrumental noise - Comparison to actual observational data.

5 Thermal dust emission

[Suggested group size : two students]

The goal of this project is to develop a pipeline to model the infrared emission of dust grains heated by the UV and visible light from stars, taking into account for instance the optical properties of materials constituting the grains and their size distributions, all the way to the measurements that are made of this emission by broadband instruments such as Planck/HFI, to gain an understanding of how physical properties of the dust may be constrained by these measurements.

Possible developments : Equilibrium temperature of large grains - Stochastic heating of small grains - Realistic optical constants - Dust grain size distributions - Impact of irradiation sources such as nearby stars or the interstellar standard radiation field - Variations of dust properties along the line of sight - Dust emission characterization with broadband instruments - Temperature and spectral index degeneracy.