
# GISM2 2023 SUMMER SCHOOL

## List of Hands-on Projects

### Contents

## Project 1 Numerical Simulations of Shocks and Instabilities Using the RAMSES Code

**Supervisors:** Evangelia NTORMOUSI & Pierre LESAFFRE

**Objectives:**

1. Learn to use an MHD code with simple initial conditions.
2. Perform analysis of the results and compare to analytical models.

**Description.** In this exercise we will learn how to use an MHD code to run numerical simulations and perform a preliminary analysis of the results. We will first test the different hydrodynamic solvers to see their effect on a simple solution, and then proceed to study two situations often encountered in the interstellar medium: a spherical shock and the Kelvin-Helmholtz instability.

1. First, you will have to download and install the code on your laptop or a server you can access remotely. Ideally, this should be done before arrival at the school. Detailed instructions and assistance will be provided.
2. The first exercise will be a simple wave advection, computed with different solvers. We will plot and compare the solutions to decide which solver we prefer for our problem.
3. The second exercise will be a Sedov blast wave in three dimensions. Once we calculate the numerical solution, we will compare it to the analytical one.
4. Finally, we will try slightly more complex initial conditions by simulating the Kelvin-Helmholtz instability in two or three dimensions, and observe its evolution over time. If there is enough time, we will study the transition from the linear to the nonlinear regime.

We will use python for post-processing the simulations. Details on how to install specific packages will also be provided before your arrival at the school.

## Project 2 Cloudy Hands-On: Emission Lines

**Supervisors:** Patrice THEULÉ

**Objective:** Playing with the Cloudy model on several scientific cases.

**Description.** In the Cloudy hands-on part of the workshop you will be running your version of Cloudy to do some simple examples related to the physics and chemistry of the ISM. The goal is to start interacting with a few other participants, students or teachers, with similar research interests on the basis of practical material. You will receive few weeks before instructions to install Cloudy and you should get started by doing simple homework. You will work in a small group on projects (structure of a PDR, BPT diagrams, AGN emission, *etc.*) using Cloudy.

## Project 3 Cloudy Hands-On: Absorption Lines

**Supervisors:** Hsiao-Wen CHEN

**Objective:** Exploring the ionisation conditions of the diffuse circumgalactic gas.

**Description.** A key objective in CGM research is to characterize the physical and chemical properties of the gas. A common approach to determine gas density, temperature, and metallicity is to compare the observed relative abundance ratios between different ions with expectations from different ionization models. However, the conclusions may differ due to different assumed model priors, such as the adopted ionizing spectrum, relative elemental abundance ratios, and the dynamic state of the gas. The goal of this hands-on session is to learn in depth the physics of ionized gas, and gain institution for the effects of different systematics by running a suite of Cloudy models. Sample exercises can be found in two papers:

- Chen et al., 2017, ApJL, 842, L19; and

- Gnat & Sternberg, 2007, ApJS, 168, 213.

---

## Project 4 Spectrophotometric Modeling of Galaxies and AGNs

**Supervisors:** Yannick ROEHLLY, Patrice THEULÉ & Daniel DALE

**Objective:** Testing the imprint of stellar, dust, gas (lines and continuum) on the spectral energy distribution of a sample of nearby galaxies.

**Description.** During this project the student will use the Sings/KINGFISH sample of nearby galaxies (Dale et al. ApJ 2017) and fit their spectral energy distribution (SED) using the CIGALE SED fitting code. The students will learn to use the different CIGALE modules to simulate physical inputs (star formation history, dust attenuation, *etc.*) to generate photometric ans spectroscopic data to fit against the observational sample to retrieve the physical parameters governing galaxy evolution (gas mass, stellar mass, age, *etc.*). In addition, the students will build a BPT diagram using strong emission line ratios to discriminate between star forming galaxies and active galaxies nuclei.

---

## Project 5 The Spatially-Resolved Dust Properties of Nearby Galaxies

**Supervisors:** Frédéric GALLIANO & Lara PANTONI

**Objective:**

1. Learn to homogenize multi-wavelength images of galaxies.
2. Perform SED modeling in order to infer maps of the dust properties.

**Description.** In this hands-on session, we will learn the different steps required to go from an heterogeneous sample of multi-wavelength images of a galaxy to producing maps of the dust properties. This type of analysis is necessary whenever one needs to estimate dust-to-gas mass ratio distributions in an object, understand better the heating sources or simply study dust evolution.

We will use the public database of the DustPedia project (http://dustpedia.astro.noa.gr/). It contains UV-to-mm photometry and images of 800 nearby galaxies, with ancillary data (gas masses, SFR, stellar mass, metallicity). We will choose a few objects to work on.

1. The first goal is to learn to homogenize multi-wavelength data sets: degradation of the angular resolution, reprojection, subtraction of external contributions and artifacts, and propagation of the uncertainties.
2. Second, we will model the spectral energy distribution (both globally and spatially resolved) of these galaxies using the hierarchical Bayesian model HerBIE (Galliano, 2018).
3. If there is enough time, we will discuss the physical interpretation of these maps and their comparison to other tracers, such as the gas and stellar masses, the SFR, *etc.*

We will work in Python.

---

## Project 6 Millimeter Rotational Lines as Powerful Diagnostics of the Physical Conditions Inside a Giant Molecular Cloud – The Orion B Case

**Supervisors:** Jérôme PETY & Antoine ZAKARDJIAN

**Objective:** An analysis of the (mm-)molecular emission spectrum of a GMC, of its variation with the physical conditions, and of its link with the total column density of interstellar matter.

**Description.** In this hand-ons activity, we will use part of the ORION-B data to learn how to deal with tens of data cubes of different lines, and use the molecular emission lines to estimate the total mass of the molecular cloud, in comparison to the mass derived from dust emission. We will also characterize the typical spectra of regions with different physical conditions and compare with extragalactic observations. Finally, we will study the relationships between molecular emission and the underlying physical parameters using Principal Component Analysis, and in particular, we will attempt to find the relation between molecular emission and the total column density of interstellar matter using Random Forests, a machine learning algorithm.

---

## Project 7 Combining 1D Models with MULTIGRIS

**Supervisors:** Vianney LEBOUTEILLER

**Description.** In this hand-on, the students will use the code MULTIGRIS (https://gitlab.com/multigris/) together with a public grid of photoionization 1D Cloudy models in order to recover internal variations of physical conditions in spatially-unresolved galaxies. The main objective is to appreciate the complexity of interstellar medium models in order to interpret integrated galaxy spectra while understanding how to adapt the level of complexity depending on the motivating question. Time permitting we will apply the method to public JWST spectra of very high-z galaxies.

**Prerequisites.**

- Python 3.8 (if possible 3.9) installation.
- Specific packages and virtual environment can be installed on-the-spot.

---

## Project 8 Star-Formation Efficiency & Timescales: Globally to 100 pc Scales

**Supervisors:** Brent GROVES & Mélanie CHEVANCE

**Objective:**

- Understand the concept of Star-formation efficiency and what this means.
- Understand the variation of this at small scales and the connection with feedback.

**Description.** In this project the student will take data (CO and H$\alpha$) from the PHANGS survey of nearby galaxies to understand the connection between recent star-formation and the interstellar gas it forms from. They will learn about convolving data to different scales, how to measure star formation rates and gas-mass surface densities, and what the standard relations are and how they vary at small scales. At the smallest scales they will explore how this breakdown of the expected relation is linked to the rapid cycling between gas clouds and young stars. They will investigate how the feedback of massive stars limits the lifetime of molecular clouds and the efficiency of the conversion of gas to stars.

**Software & Prerequisites.** This project will use python and the `numpy`, `scipy`, `matplotlib`, `astropy`, and `FITS_Tools` packages. Experience with python will be useful. Project can be carried out via `GoogleColab` or on own machine.

---

## Project 9 Using JWST NIRCAM and MIRI Photometry to Probe the Physical State of PAHs in the ISM of Nearby Galaxies

**Supervisors:** Karin SANDSTROM & Jessica SUTTER

**Objective:**

1. Understand how JWST photometry can be used to assess PAH properties
2. Be able to interpret and use the Draine+2021 PAH emission models

**Description.** Data from JWST provides exciting opportunities to study the smallest dust grains that fill the ISM, polycyclic aromatic hydrocarbons, or PAHs. As PAHs are one of the major sources for photo-ejected electrons, they play an important role in heating the ISM. Given that photoelectric heating efficiency depends on the size, charge, and abundance of PAHs, their properties therefore have key impacts on ISM energy balance. PAHs are primarily traced by broad emission features in the mid-infrared, many of which are covered by the MIRI and NIRCam photometric bands. While spectroscopy is ideal for studying the variation of the features, the small field of view of the JWST IFU instruments make it extremely costly to map PAH emission across large regions of nearby galaxies spectroscopically. Instead, using photometric bands, PAH emission features can be mapped across entire galaxies, providing insight into how PAHs are distributed and how their properties change across a multi-phase ISM.

In this session, we will focus on how we can use multi-band MIRI and NIRCam photometry along with Draine+2021 dust emission models to study the properties of PAHs in nearby galaxies. We will focus on interpreting the observed NIRCam and MIRI filter ratios using PAH emission models, extracting synthetic photometry from these models, and comparing the extracted photometry to JWST data from the PHANGS survey. Participants will then be tasked with creating their own scientific question to ask about how PAHs are changing with ISM environment, potentially making use of publicly available ancillary data for these galaxies from PHANGS.

# GUIDELINES TO THE STUDENTS

## 1 Goals

Making people work together on a given project is usually very fruitful. The goals are the following.

- To teach you a particular set of skills related to the school science.
  - You could pick a project that you are interested in, because it is relevant to your current work.
  - You could alternatively pick a project far from your current field, as a refreshing experience.
- By inciting you to work together, we hope to create links between students, and potentially with the advisers. It is also possible that some of these hands-on sessions will kick-start projects or collaborations.

## 2 Working on the Project

- The first session will likely be devoted to introducing everyone, and adapting the project more precisely to the skills and interests of the group.
- Meeting with the advisors is only a part of the session. You are then supposed to work by yourselves. There are no particular rules. You invest the amount of time you can in these projects.
- The projects have been designed so that they can be conducted on a personal laptop.
- Each team is self-organized. You decide how to split the tasks, and how to efficiently work together.

## 3 Presentation

Each team will present their achievements to the audience, on the last school day (Wednesday, August 2, from 2:15pm to 4:15pm).

- The order of the presentations will follow the project numbers in this document.
- Each team will have 12 minutes in total (including questions). You must therefore prepare a $\simeq 10$ minute talk maximum.
- Different team members can take turns to present different slides.