

Workshop material on Galaxy Clusters

Florian Pacaud

Within the few hours available for this workshop, we will brainstorm together on a few topics relevant to the cosmological analysis of galaxy clusters and observational astronomy in general.

The goal will be for the students to place themselves in the shoes of researchers working with observations, as they are trying to grasp the whereabouts of a research topic and determine in which direction to focus their efforts. Therefore, the students will first attempt to answer the questions by themselves in an open discussion, guided by the tutor who will then add content and material to broaden the topic and point out key missing aspects.

A summary of the reflections developed collectively, as well as the material prepared in advance to support our discussions will be provided to the participants after the workshop.

Discussion topic 1: Observational astronomy

Observations of the electromagnetic signal is the main source of information in cosmology (although gravitational waves and astro-particles are set to take a more important role in the future). This is actually the only source of information (so far) on galaxy clusters.

- a. Can we define together the main observation regimes and types ?
- b. What does each regime tell us about ?
- c. What are the different technologies and methods, required and / or available to observe in these different regimes ?

Discussion topic 2: Selecting galaxy cluster in survey data

Based on the census of topic 1 and the first lectures, we will then think about the best ways to define a galaxy cluster sample for cosmological applications.

- a. Which wavebands and methods would seem appropriate ?
- b. What could be the challenges of detecting and identifying galaxy clusters ? Think about the nature of the signal and what could alter the detectability of galaxy clusters.
- c. What could be the sources of contamination in the sample ? Think about methods that could allow to mitigate them, and to estimate the residual contaminants.
- d. How would one go about assessing the selection effects of a specific sample ?

Discussion topic 3: Cosmological modeling of cluster samples

Once a sample has been defined (and understood). One needs to set up inference methods which could be used to learn about underlying cosmological models.

- a. How would one go about defining a frequentist or Bayesian model to perform inference on such a sample ?
- b. Consider possible cluster mass calibration strategies.
- c. Try and write down a description of the full population, to be used in the modeling.
- d. How could one possibly incorporate modern deep learning methods in the analysis ?

Discussion topic 4: Designing your satellite mission

In march 2025, ESA will open a new call for two astrophysics space missions: a medium class one (M8) and a fast one (F3).

- a. What sets a satellite mission apart from ground based ones ? Why are they useful ?
- b. What would be the main constraints and aspects to consider in defining a possible satellite mission ?
- c. Which type of satellite mission could you think of, which would shed light on some interesting aspect of galaxy clusters ? (either cosmology or physics)
- d. How would one justify choosing them over comparable ground based experiments ?