Galaxy clusters as multiwavelength astrophysical laboratories

SUMMARY.
Galaxy clusters are the largest gravitationally collapsed objects in the Universe, giving them a two-fold advantage in being both valuable cosmological probes as well as astrophysical laboratories. With current state-of-the-art surveys such as the Euclid mission, we are now able to detect and characterise more galaxy clusters than ever before. As the building blocks of the Universe, studying clusters allows us to understand how large scale structure has formed and evolved over cosmic time. One key advantage of clusters is their emission in multiple wavelengths, allowing us to understand their properties and how best to constrain them for cosmology. This METEOR will focus on extracting properties of known clusters to study the interplay between different wavelength observations, which is critical to use them for both cosmology and understanding the environments in which they grow and evolve.

OBJECTIVES

- The student will gain a comprehensive theoretical and observational perspective on how clusters form based on our understanding of large scale structure. This will involve the necessary cosmological background. From the observational point of view, the student will learn the key observables from clusters, notably in optical, X-ray, milimetre, radio and gamma-ray wavelengths. They will also learn about observational inference, surveys, selection functions, statistical methods.
- The student will learn how to analyse observational datasets, such as cluster catalogues from different surveys. They will learn to run and write characterisation pipelines based on optical and SZ datasets.

PREREQUISITES

- ✗ S1. General Astrophysics
- ✗ S2. Large-scale Universe
- ✗ S2. Gravity & relativity

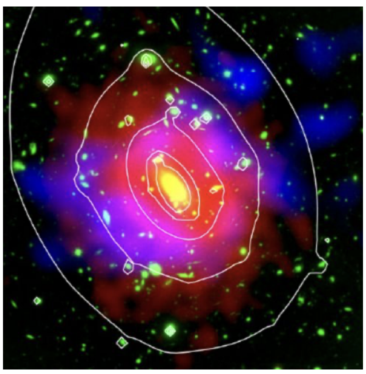
THEORY

by Sunayana Bhargava & Rémi Adam

The theory component of this course will consist of two subsections. The first will introduce the cosmological framework to understand the context of galaxy cluster formation and evolution, such as understanding the Friedmann equations, spherical top hat collapse model, structure formation and perturbation theory. The second part will focus on the composition of clusters and their observables in multiple wavelengths, as well as survey selection and statistics. We focus on the complementary views offered by optical observations of the galaxies and milimetre observations of the hot gas to study clusters.

APPLICATIONS

Practical studies on cluster characterisation based on available public data. The main topics covered will be: (i) Analysis of nearby galaxy cluster catalogues and SZ datasets to study clusters ii) Plotting cluster galaxy density and SZ maps (ii) Comparison of cluster mass proxies and properties such as optical richness, red sequence, centring distributions and gas properties.



Multiwavelength view of a cluster showing SZ (blue), X-ray (red) and lensing mass contours (white).

MAIN PROGRESSION STEPS

- Tier 1: courses A/B and exercices
- Tier 2: course C and project
- Tier 3: project

EVALUATION

- Theory grade [30%]
  - Written exam (70%): theoretical question, base calculus from lectures
  - Presentation of an article (30%): critical spirit
- Practice grade [30%]
  - Exercices (30%): thought-process and results
  - Project (70%): initiative, progress, analysis
- Defense grade [40%]
  - Oral and slides quality
  - Context
  - Project / Personal work
  - Answers to questions

BIBLIOGRAPHY & RESOURCES

- G. W. Pratt et al. (2019), Space Sci Rev (2019) 215:25, https://arxiv.org/abs/1902.10837
- Cosmology, Nicola Vittorio (2018)

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