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An overview of the CHANCES: Chilean Cluster Galaxy Evolution Survey project

Argudo-Fernández, M.[1,2], Haines, C.[3], Jaffé, Y.[4], Tejos, N.[5], Sifón, C.[5], and the CHANCES Collaboration

[1] Departamento de Física Teórica y del Cosmos, Edificio Mecenas, Campus Fuentenueva, Universidad de Granada, 18071 Granada, Spain.
[2] Instituto Carlos I de Física Teórica y Computacional, Facultad de Ciencias, Universidad de Granada, 18071 Granada, Spain.
[3] Instituto de Astronomía y Ciencias Planetarias (INCT), Universidad de Atacama, Copayapu 485, Copiapó, Chile.
[4] Departamento de Física, Universidad Técnica Federico Santa María, Avenida España 1680, Valparaíso, Chile.
[5] Instituto de Física, Pontificia Universidad Católica de Valparaíso, Casilla 4059, Valparaíso, Chile.

Abstract

CHANCES, the CHileAN Cluster galaxy Evolution Survey, is one of the nine Extragalactic Surveys of the 4-metre Multi-Object Spectroscopic Telescope (4MOST) consortium. CHANCES is designed to study the evolution of galaxies in and around 100 of the most massive galaxy clusters in the local Universe and out to z $\sim$ 0.45, and 2 superclusters (containing dozens of clusters each). In alignment with 4MOST science goals, CHANCES will provide legacy spectroscopic support for the eROSITA X-ray mission, by obtaining spectroscopic redshifts confirming membership for more than 1000 galaxies per cluster. In this context, CHANCES will cover cluster galaxies both within and well beyond the virial radius, covering the surrounding infall regions out to $5r_{200}$ from the cluster. This will allow mapping the hierarchical assembly of the clusters in detail, and measure the importance of pre-processing, where galaxies are transformed within groups and filaments prior to their arrival into the clusters.

1 Introduction

At cosmological timescales, galaxies evolve from star-forming gas-rich spirals to quiescent early-type galaxies. However, while most field galaxies remain as gas-rich star-forming spi-

rals to the present day, the bulk of galaxies within massive clusters have lost their gas and have been transformed into quiescent early-type galaxies [11]. Both internal (secular) energetic mechanisms (like active galactic nucleus feedback or stellar winds) and external (environmental) processes are expected to play major roles in transforming galaxies. Still, understanding what drives their evolution remains a fundamental task within astrophysics.

There are some physical mechanisms that are able to transform galaxies as they fall into the clusters that have been proposed to contribute to this transformation of galaxies from star-forming gas-rich spirals to quiescent early-types. These mechanisms include gas stripping by the intracluster medium (e. g., ram-pressure stripping and starvation), and gravitational interactions among galaxies or between the galaxies and the cluster ([2, 4]). In addition, there is observational evidence of transformation of galaxies prior to their fall into clusters. Galaxies in the vicinity of clusters are more likely to be quiescent than counterparts in typical field regions, at fixed stellar mass and redshift, even at large distances from the cluster, up to $\sim 3r_{200}$ [1] ([6, 1, 8]). The suppression of star formation at these distances cannot be reproduced by models of infalling field galaxies (only once they pass within r_{200} of the cluster), but is consistent with some of them being first pre-processed within galaxy groups.

Galaxies may be pre-processed within galaxy groups that are later accreted onto the cluster. Therefore, we need to understand the physical mechanisms that can transform field galaxies prior to their arrival into the cluster. In this context, the CHileAN Cluster galaxy Evolution Survey (CHANCES[2], [7]) aims to study galaxy pre-processing and the role of the evolving environment on galaxies. CHANCES is one of the nine Extragalactic Community Surveys of the 4-metre Multi-Object Spectroscopic Telescope (4MOST[3]) consortium.

CHANCES will spectroscopically cover 100 of the most massive galaxy clusters in the local Universe and out to $z \sim 0.45$, and 2 superclusters (containing dozens of clusters each), with a field radius aperture out to $5r_{200}$, to cover infalling galaxy groups detected by the eROSITA all-sky X-ray survey. Here we present an overview of CHANCES and its scientific goals in the context of the sub-surveys composing the project.

2 CHANCES in the context of 4MOST

4MOST is a unique wide-field, high-multiplex, optical spectrograph survey facility developed by the 4MOST Consortium that is being installed (2024) on ESO's 4-m VISTA telescope at Cerro Paranal (Chile) as the sole instrument on the telescope. 4MOST obtain spectra for 25 million objects across the entire Southern hemisphere over its first five years of operations. In this context, 4MOST will not only have a major impact on several key areas of contemporary astrophysics, but it will be also of great strategic importance to the European astronomical community. Several key European all-sky, space-based facilities, such as Gaia, eROSITA and Euclid, will only unfold their full potential if complemented by optical spectroscopy of suffi-

[1] r_{200} is the radius containing matter at 200 times the ambient density, so it can be considered the virial radius of the cluster.

[2] `https://chances.uda.cl/`

[3] `https://www.4most.eu/cms/home/`

cient depth and density. 4MOST will also complement existing and upcoming ground-based facilities (which includes the Vera Rubin Observatory, as well as SKA and its pathfinders).

CHANCES is designed to study the evolution of galaxies in and around 100 of the most massive galaxy clusters in the local Universe and out to z $\sim$ 0.45, and 2 superclusters (containing dozens of clusters each). CHANCES will provide comprehensive spectroscopic coverage of cluster galaxies both within and well beyond the virial radius (up to $5r_{200}$), covering the surrounding infall regions of the clusters. In this context, CHANCES will provide an important legacy value as spectroscopic support for the eROSITA X-ray mission, complementing that from the 4MOST Galaxy Clusters Survey ([5]), by obtaining spectroscopic redshifts and confirming membership for more than 1000 galaxies per cluster. CHANCES will also complement future radio observations by the Square Kilometre Array and the Australian SKA Pathfinder (ASKAP), as well as current and planned large optical surveys such as the DESI Legacy Survey DR10 (LSDR10), the Southern Photometric Local Universe Survey (S-PLUS) and the Legacy Survey of Space and Time (LSST). This will allow mapping the hierarchical assembly of the clusters in detail, and measure the importance of pre-processing, where galaxies are transformed within X-ray groups and filaments prior to their arrival into the clusters [7].

3 CHANCES sub-surveys and scientific motivation

CHANCES is originally composed by three sub-surveys with different scientific objectives: CHANCES low-z, CHANCES evolution, and CHANCES CGM.

The CHANCES low-z will target 50 z<0.07 clusters ($M_{200} > 10^{14}\,M_{\odot}$), in addition to large regions covering the Shapley and Horologium-Reticulum superclusters, each containing a large number of clusters within a rich cosmic web, and near systems (20-40 Mpc) including the Fornax, Antlia, and Hydra clusters, targeting galaxies out to $5r_{200}$. CHANCES low-z will push cluster galaxy evolution studies well into the dwarf galaxy regime (10^8-10^9 $M_{\odot}$) where the environment is expected to play a dominant role in their evolution.

The CHANCES Evolution will target 50 of the most massive clusters over 0.07<z<0.45 (see Fig. 1) to track evolution of cluster galaxies over the last 4 Gyr, to trace cosmic filaments and infalling groups. CHANCES Evolution aims to continuously track the evolution of cluster galaxies over the last four billion years, and measure when, where and how quickly spiral galaxies are being transformed in and around clusters.

The CHANCES CGM will observe $\sim$10 000 background quasi-stellar objects (QSOs) within 6 Mpc of optically selected clusters at 0.35<z<0.7, together with $\sim$60 000 galaxies within 1 arcmin around these QSOs. With CHANCES CGM, CHANCES will probe the effect of clusters and their surrounding overdense environments on the cool circumgalactic medium (CGM) traced by MgII absorption.

We refer to [10] for a detailed description of the cluster selection of CHANCES.

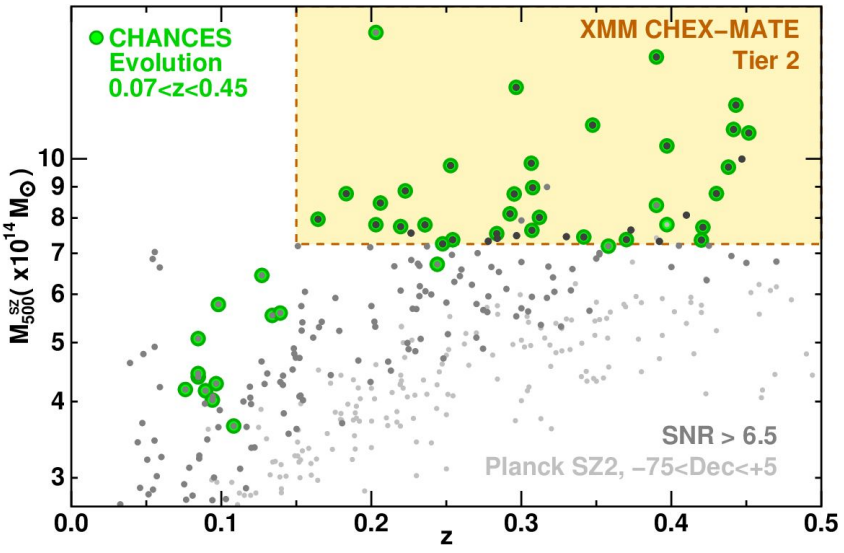

Figure 1: CHANCES Evolution clusters (green circles) compared with southern clusters in Planck SZ2 survey (grey circles). The CHANCES evolution cluster selection is based on the second Planck catalogue of Sunyaev–Zel'dovich (SZ) sources (PSZ2, [9]) all-sky catalogue over 0.07<z<0.45 while maintaining an even redshift distribution, and good DECam griz coverage. At z>0.15 mass-limit of $M_{500} > 7.25\times10^{14}\,M_\odot$ matches selection used for the CHEX-MATE XMM survey [3]. Figure adapted from [10].

4 Summary

4MOST will be ESO's flagship spectroscopic survey facility that will obtain spectra for 25 million objects across the entire Southern hemisphere over its first five years of operations. For that, 4MOST will carry out 18 public spectroscopic surveys, where CHANCES is one of them, over 5 years starting February 2025.

CHANCES will attempt to provide highly complete spectroscopic coverage for 100 of the most massive galaxy clusters in the local Universe and out to $z \sim 0.45$, and the Shapley and Horologium-Reticulum superclusters (containing dozens of clusters each), targeting 300,000 galaxies. In this context, CHANCES will extend spectroscopic coverage of clusters out to $5r_{200}$ enabling a study of pre-processing in infalling galaxy groups detected by the eROSITA all-sky X-ray survey.

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