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Morphological characterization of galaxies in the Abell 1644 and Abell 1631 clusters

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Abstract. This project aims to contribute to the understanding of the formation and evolution of the Universe through the study of galaxy clusters, whose formation process involves complex phenomena such as massive structure mergers, accretion of galaxy groups, and galactic interactions with both the interstellar medium and with each other. In this context, a study of the morphological and non-parametric parameters of galaxies in the Abell 1644 and Abell 1631 clusters is carried out using the photometric fitting software ASTROMORPHLIB and GALFITM. Estimates were obtained for a total of 640 galaxies, enabling an analysis of how the morphological properties of galaxies vary as a function of distance from the cluster center up to $5R_{200}$, contributing to the understanding of the environmental influence on the morphological evolution of galaxies in different regions of the systems. Furthermore, we identified a sample of 14 galaxies that are ram-pressure stripping candidates.

Resumo. Este projeto visa contribuir para a compreensão da formação e evolução do Universo através do estudo de aglomerados de galáxias, cujo processo de formação envolve fenômenos complexos como fusões de estruturas massivas, acreção de grupos de galáxias e interações galácticas com o meio interestelar e entre si. Nesse contexto, um estudo dos parâmetros morfológicos e não paramétricos de galáxias dos aglomerados Abell 1644 e Abell 1631 é realizado utilizando os softwares de ajuste fotométrico ASTROMORPHLIB e GALFITM. Estimativas foram obtidas para um total de 640 galáxias, permitindo uma análise de como as propriedades morfológicas das galáxias variam em função da distância do centro do aglomerado até $5R_{200}$, contribuindo para a compreensão da influência do ambiente na evolução morfológica das galáxias em diferentes regiões. Além disso, identificamos uma amostra de 14 galáxias candidatas à sofrerem o efeito de pressão de arraste.

Keywords. Galaxies: clusters: general – Galaxies: fundamental parameters – Galaxies: photometry

1. Introduction

Galaxy clusters are the largest gravitationally bound systems that have reached, at least marginally, a state of dynamical equilibrium. Its process of formation involves complex phenomena, such as massive mergers, the accretion of galaxy groups, and interactions of galaxies with the interstellar medium as well as with other galaxies. Therefore, they play a central role in understanding the evolution of the Universe. Thus, it is important to highlight the study of the so-called Jellyfish (or Ram-Pressure Stripped) galaxies, which present a unidirectional tail as a result of its interaction with the intracluster medium. This mechanism is responsible for driving the rapid evolution of galaxies in dense environments, such as clusters. Therefore, the aim of this work is to contribute to such study through the analysis of structural and morphological properties of galaxies, correlating its parametric and non-parametric parameters with their respective positions within these clusters.

2. Materials and Methods

The sample studied is composed of 2 galaxy clusters: Abell 1644 (z = 0.047 and 278 galaxies) and Abell 1631 (z = 0.046 and 362 galaxies), which were selected for being nonrelaxed clusters and for presenting a significant number of spectroscopy measurements in the literature. The selection of galaxies in each cluster was carried out using data from the Southern Photometric Local Universe Survey (SPLUS DR4,Herpich et al. (2024)), while the analysis was performed with images in the g band from the Legacy DESI Survey. As for the measurements, two softwares were used. The first one is called Astromorphlib and can automatically download the images, providing routines to perform photometric analysis. This program also calculates a 2D sky background model and generates accurate segmentation maps of the galaxies in the image field. The second software is called GALFITM Häußler et al. (2013) and it's a multi-wavelength extension of GALFIT Peng et al. (2002), which allows simultaneous adjustment of images of a galaxy in multiple bands, making it possible to study the evolution of structural parameters (such as the Sersic index and the effective radius).

3. Results

Through the use of the Astromorphlib software (Hernandez-Jimenez & Krabbe (2022)), it was possible to obtain parameters such as asymmetry (A), concentration (C), Sérsic index (n), and bulge strength parameters F(G,M20), which, according to Krabbe et al. (2024), present a high correlation with the JClass classification. Based on these indices, three graphics were constructed for each cluster. According to Krabbe et al. (2024), morphologically disturbed galaxies — which include interacting galaxies and Jellyfish galaxies — occupy a region distant from undisturbed field galaxies. In Figure 1, this separation is highlighted by the black line in both panels, to the right of which lie the morphologically disturbed galaxies.

Subsequently, in order to select candidate Jellyfish galaxies, a visual and individual analysis of the galaxies located in the region defined as the morphological disturbance zone was performed. For this inspection, two main criteria were adopted: (i) the presence of a unidirectional tail, a distinctive feature of Jellyfish galaxies, and (ii) the absence of companion galaxies, to exclude those whose morphological disturbances could be caused by the gravitational influence of neighbors. As a result, 49 galax-

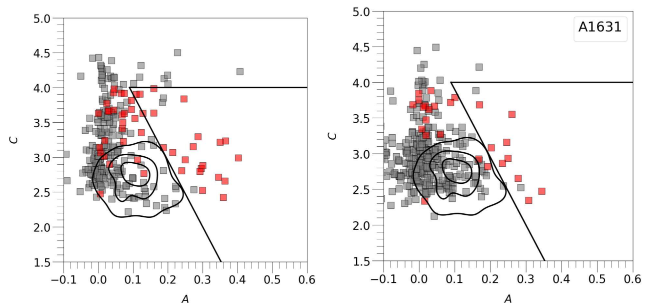

Figure 1. The distribution of galaxies in the Abell 1644 (right panel) and Abell 1631 (left panel) clusters is shown in the A versus C graph. The solid black lines delineate the boundaries of the morphological transition zone. In red are the galaxies that are within the morphological transition zones in all three graphs: A versus C, A versus F(G, M20) and A versus n, (not shown here).

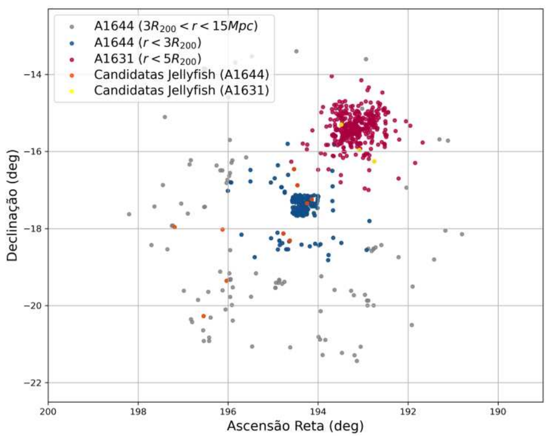

Figure 2. Spatial distribution of galaxies in the Abell 1644 and Abell 1631 clusters, highlighting the Jellyfish candidates (in orange for A1644 and in yellow for A1631)

ies from the Abell 1644 cluster were found in the morphologically perturbed zone, of which 11 were identified as Jellyfish candidates, representing more than 20% of the perturbed galaxies. In Abell 1631, 26 galaxies were classified as morphologically perturbed, among which 3 are Jellyfish candidates.

In this way, a map of all 640 galaxies was obtained (Figure 2), in order to visualize the distance of the candidate galaxies (in orange and yellow) from the center of the clusters. Figure 2 reveals that the galaxies are well distributed along the radii of the clusters. The presence of two galaxies in the contact region between Abell 1631 and Abell 1644 stands out, which is characterized by the heating of the gas, increasing the probability of occurrence of galaxies of this type.

The GALFITM software was used to fit images in the g, r, i, and z bands of the 75 morphologically disturbed galaxies from both clusters. The input parameters for the Sérsic profile were obtained in different ways: using (i) the DESI Legacy Survey database, (ii) data from the literature, and (iii) the output parameters from ASTROMORPHLIB. The software output consists of parametric parameters, models of the galaxies in each band, and their respective residual images, which reveal substructures such as star-forming regions, non-homogeneities, and asymmetries.

The software used in this work represents complementary methods for morphological analysis of galaxies, so that their combined use results in obtaining parametric and non-parametric parameters. Furthermore, while ASTROMORPHLIB performs adjustments in a single band at a time, GALFITM is a multi-band tool, allowing the adjustment of several bands simultaneously. This enables the analysis of different substructures and components of galaxies, which exhibit distinct peaks of spectral emission.

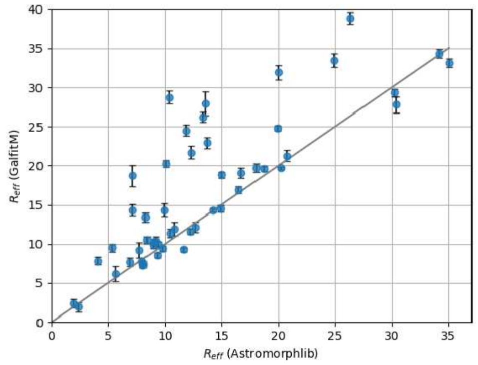

Figure 3. Comparison between values of the effective radius in the g band of the ASTROMORPHLIB and GALFITM software.

Among the output parameters common to both software packages, the Sersic index and the effective radius (Reff) are particularly significant, as they describe the morphology of galaxies. To evaluate the consistency of these results, a qualitative comparison was performed between the values obtained via ASTROMORPHLIB and GALFITM. Figure 3 presents this comparison for the effective radius, where a strong agreement between both methods is observed, following a linear trend of the type y = x.

4. Conclusion

This work presents a study of galaxies in two clusters, Abell 1644 and Abell 1631. A morphological analysis was carried out using two independent techniques, ASTROMORPHLIB and GALFITM, providing a robust framework to investigate cluster dynamics, galaxy morphology, and galaxy–environment interactions. Such interactions were explored through the identification of morphologically disturbed galaxies, from which candidates for Jellyfish galaxies were selected.

In Abell 1644, 278 galaxies were analyzed, 49 of which were classified as morphologically disturbed, and 11 were identified as jellyfish candidates based on the presence of a unidirectional tail and the absence of close companions; two of these are located in the interaction region between the two clusters. In Abell 1631, 26 disturbed galaxies were identified out of 362, with 3 selected as Jellyfish candidates. All 75 disturbed galaxies were modeled with GALFITM. A qualitative comparison between ASTROMORPHLIB and GALFITM showed a high agreement for the effective radius, which exhibited a clear linear trend, indicating a higher level of consistency between the two methods.

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