UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

DEPARTAMENTO DE FÍSICA

Defensa Proyecto Investigación para optar al grado de Licenciado en Astrofísica.

Tema: ***Characterizing Galaxies Using Non-Parametric Methods within the IllustrisTNG Cosmological Simulations Framework.***

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Abstract: Galaxies, composed of gas, dust, stars, and dark matter, are fundamental for understanding the cosmos. Their varied morphologies and physical properties reflect billions of years of evolutionary processes influenced by internal mechanisms and environmental effects. Morphological classification, far from a descriptive task, is vital for studying these processes. However, no single classification system fully captures the complexity of galactic morphology, and the lack of consensus among methods adds uncertainty.

This study compares two non-parametric classification methods: CAS (Concentration, Asymmetry, and Smoothness) and Deep Learning (DL), using the IllustrisTNG simulation (TNG100). CAS classifies galaxies within specific parameter ranges, while DL relies on probabilistic models with high-confidence thresholds for morphological types. The aim is to examine differences and complementarities between these methods and analyze their effectiveness in classifying galaxies based on key physical property planes such as color vs. stellar mass, sSFR vs. stellar mass, and gas fraction vs. stellar mass.

Both methods effectively separate early- and late-type galaxies, with clear thresholds at color (g-r) = 0.6 and $\mathrm{sSFR} = 10^{-11}[\mathrm{Yr}^{-1}]$, consistent with literature. However, DL struggles with low-mass galaxies ($M_{\star} \leq 10^{10.5}[M_{\odot}]$), likely due to TNG100's resolution limitations. CAS provides greater structural detail but excludes galaxies outside strict parameter ranges, affecting representativeness. The methods are complementary: CAS addresses DL's limitations for dwarf ellipticals, while DL performs better for broader classifications but struggles with intermediate morphologies.

Notably, the CAS 'early spiral' category overlaps with the DL 'late spiral' category, highlighting the possibility of combining classifications of late-type galaxies. The CAS 'early spiral' category also groups together transient morphologies, such as lenticulars, suggesting that it should be renamed to improve accuracy. Late Spiral CAS complements the Early Spiral CAS category to form what is known as a 'blue cloud'. CAS could serve as a complementary tool to DL for robust classifications, in particular for intermediate morphologies.

Future work should incorporate additional parameters (e.g., Gini, M20, Sérsic index, ellipticity, and specific angular momentum) and extend analyzes to higher-resolution simulations like TNG50. Unified synthetic images for both methods and human visual classifications are also recommended, pending future collaborations. By identifying differences and complementarities, this study underscores the value of combining techniques to advance the understanding of galactic morphological diversity

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Jueves 9 de enero 2025 a las 10:00 hrs. - Sala Conferencias Dr. Luciano Laroze, E300