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Author: Ms. Neha Upadhyay
India

LEVERAGING AI TO EXPLORE GALAXY MORPHOLOGY AND EVOLUTION ACROSS THE AGES

Abstract

In the quest to decode the cosmic ballet of galaxy evolution, leveraging Artificial Intelligence (AI) to analyze galaxy morphology represents a frontier in astrophysical research. This study outlines a comprehensive methodology framework aimed at harnessing large datasets from pivotal astronomical surveys such as the Dark Energy Survey (DES), Sloan Digital Sky Survey (SDSS), and the Dark Energy Camera Legacy Survey (DECaLS) to study the morphology and evolution of galaxies over time. The methodology emphasizes the critical stages of data acquisition and preprocessing, including data cleaning and the strategic pruning of datasets to enhance the fidelity of morphological classifications for machine learning models. Central to our approach is the development and deployment of Convolutional Neural Networks (CNNs) and unsupervised learning techniques, including deep contrastive learning, tailored to distinguish and classify galaxies into fundamental morphological categories. These AI models are trained across multi-survey datasets to ensure robustness and generalizability, addressing the challenge of varying image qualities and the vast temporal scope represented in the data. This cross-dataset training strategy is instrumental in achieving high classification accuracy and understanding galaxy morphology's nuanced features that span billions of years of cosmic history. Furthermore, the study proposes the integration of morphological classifications with additional astrophysical parameters—such as chemical composition, stellar age, star formation rate, mass, and distance—to construct a multi-dimensional view of galaxy evolution. This integrative analysis is designed to uncover the intricate relationships between galaxy morphology and the underlying formation and evolution processes, offering insights into the role of dark matter and dark energy in shaping the cosmos. The culmination of this research is the creation of extensive catalogs of galaxy morphologies, providing a valuable resource for the astrophysical community. These catalogs, enriched with detailed classifications and combined astrophysical measurements, serve as a foundation for theoretical modeling and evolutionary studies of galaxies. By bridging the gap between large-scale astronomical data and advanced AI methodologies, this study aims to advance our understanding of the universe's structure and evolution, highlighting the transformative impact of AI on the exploration of the cosmos.