Curriculum Learning-Based Detection and Analysis of Dark Matter via Strong Gravitational Lensing

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Dark matter constitutes approximately 85% of the matter in the universe and is inferred through gravitational lensing, in which both baryonic and dark matter bend light from distant galaxies. Real astronomical images of this phenomenon, however, contain baryonic structure and observational noise that may obscure lensing features. This raises the critical question of whether increasing realism fundamentally limits our ability to detect dark matter signals in these gravitational lensing events, which my project investigates. Using DeepLenstronomy, thousands of simulated lens and non-lens images were generated across progressive realism stages. Each stage systematically incorporated baryonic structure, instrumental noise, and observational effects, while preserving cosmological parameters. A Convolutional Neural Network (CNN) was then trained on those simulations using a curriculum learning approach, where image complexity increased incrementally. Model performance was evaluated thoroughly to assess the model’s classification metrics. As realism increased, performance initially exhibited transient degradation, followed by rapid reconvergence to consistently high metrics (accuracy Approaching 100% and loss approaching zero). Diagnostic metrics confirmed strong class separability with no sustained failure modes, despite a temporary plateau. Observational complexity did not fundamentally prevent identification of strong lensing events, indicating that strong gravitational lensing signatures remain detectable under realistic imaging conditions. These findings enhance automated detection pipelines in large-scale surveys like the LSST, and also provide insight toward improved reconstruction of dark matter distributions in mapping, advancing our understanding of dark matter.

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