Updating the DeepLense Pipeline

Tests done - 1&3

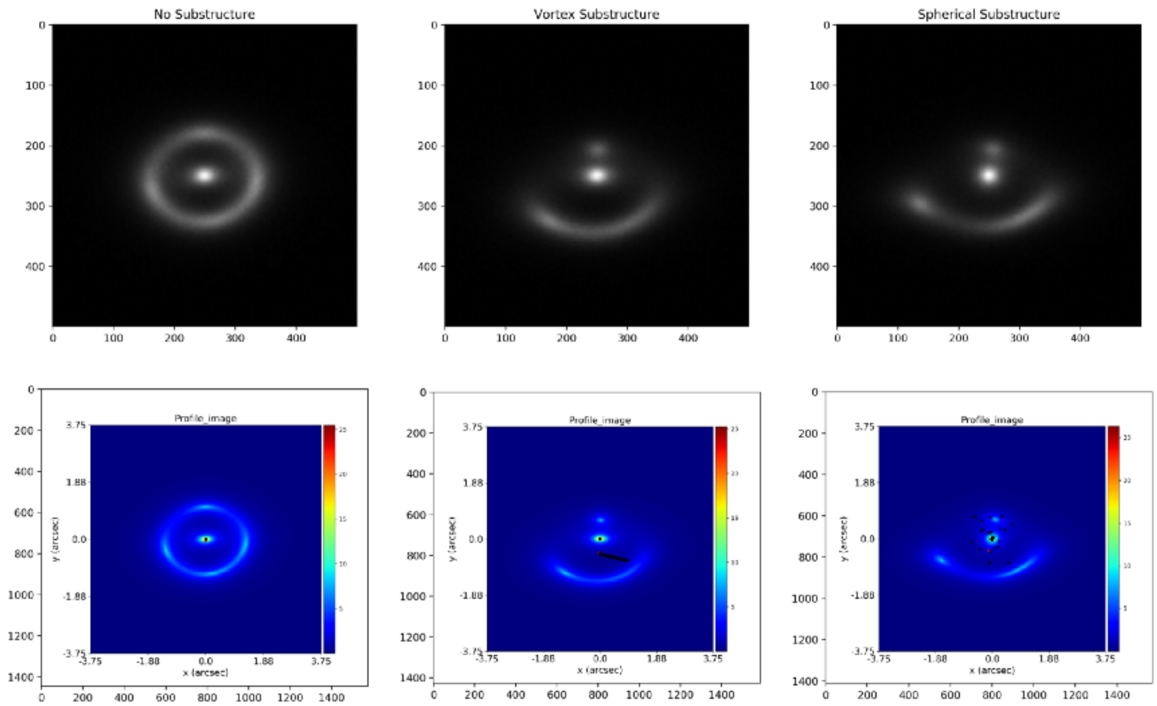
Link-Tasks

Abstract

Deep learning has been successful in identifying substructures of dark matter and even differentiating images of WIMP particle dark matter from other models. Continuing on the work done on the unsupervised learning done for the identification of substructure, the plan is to update the results using the new simulations based on lenstronomy. Using new simulations on WDM, evaluate old models to see possibilities of substructures and build new models specific to data from WDM.

1. Motivation

Deep learning has been shown to solve problems in various domains with almost unparalleled results. Gravitational lensing is a phenomenon that can occur when a huge amount of matter creates a gravitational field that distorts and magnifies the light from distant galaxies that are behind it but in the same line of sight. Such lenses can be produced due to the presence of dark matter. Using this information, the properties of dark matter can be found. To study this we use Unsupervised learning, which is extremely useful in finding underlying patterns in the data where there is not much information about the structure of the data. On this idea, "Decoding Dark Matter Substructure without Supervision" has attempted to understand the nature of dark matter by studying the substructures found through gravitational lensing. They used 2 types of dark matter - subhalos of CDM and vortices of superfluid dark matter, made using the PyAutoLens package. Built on this they considered various supervised and unsupervised techniques to classify them into ones with substructures and ones without. The dataset consists of three classes, strong lensing images with no substructure, vortex substructure, and spherical substructure. These gave very promising results, including results for unsupervised learning. As the aim is to build substructure agnostic models, the supervised methods are not considered initially. Based on this we will work on Warm Dark matter to produce similar results for the classification of the substructures and regression for mass densities as done in the previous projects. Starting with the models used in the paper- DCAE, VAE, RBM, and AAE. Considering the performance, as given in the paper, using only AAE and VAE seems like a viable option.



Source - [GSoC 2020 with CERN-HSF | Dark Matter and Deep Learning | by Pranath Reddy | Towards Data Science]()

2. Proposal

Use AAE and VAE to identify the substructures in the WDM simulation data from lenstronomy to find substructures. Then based on the results move to supervised learning methods to implement Resnet and AlexNet. Then compare these with the results obtained from the models built on CDM data. If the existing models do prove to give promising results, then the task only involves using the models in the DeepLense pipeline to classify the new image data. Along with the models given in the paper, we can also use the models built during last year's Gsoc and train on those. If the results are comparable to the previously obtained results, then it is possible to first update the results for both substructure classification and mass-density regression tasks and then look into improving those models.

3. Project Timeline

Week	Task
1	Obtain & prepare data
2-5	Build the unsupervised models
6	Compare results and optimize
Phase 1 Submission	
6-8	Supervised Learning
9-10	Optimize
11	Semi-Supervised
12	Patch up and push
Submission	

Data Preparation
Get the simulated data from lenstronomy and get statistics about the distribution of the data. Discuss the effects of using WDM instead of CDM.

Unsupervised Models [Paper 1 and 3]
Use the available models and see their performance on the new lensing images. Use the AAE and VAE and get the results. Then use the UDA models in the domain adaptation project to get the results.

Result Comparison
Compare the results with the results for the previous lensing images. Scores from the pre-trained models and transfer learning models can also be considered for comparison.
If the results are not satisfactory, building new models will be necessary.

Supervised Models [Paper 1]
Use the ResNet and AlexNet models on the new data. Then use the ResNet used as an Anomaly detector. After this, test the Equivariant neural network built last year. After the classification tasks use the Regression models to get mass densities.

Semi-Supervised [Paper 1]

Implement the semi-supervised method mentioned in the paper. Use AAE to get the feature space and then use ResNet to implement a binary classifier.

Patching up

Compile all the results, add relevant documentation, if missing. Look for bugs and get feedback then upload to Github.

4. References

Paper-1

Stephon Alexander, Sergei Gleyzer, Hanna Parul, Pranath Reddy, Michael W. Toomey, Emanuele Usai, Ryker Von Klar "Decoding Dark Matter Substructure without Supervision," [2008.12731] Decoding Dark Matter Substructure without Supervision, 2021.

Paper-3

Stephon Alexander, Sergei Gleyzer, Pranath Reddy, Marcos Tidball, Michael W. Toomey, "Domain Adaptation for Simulation-Based Dark Matter Searches Using Strong Gravitational Lensing," [2112.12121] Domain Adaptation for Simulation-Based Dark Matter Searches Using Strong Gravitational Lensing, 2021.

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