Honors in Astronomy Project Outline

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Project Title

Applying Machine Learning to Gravitational Lens Modeling

Project Introduction

Gravitational lensing, or the bending of light due to the gravity of cosmological objects, can make images appear distorted in space. Strong gravitational lensing in particular is responsible for producing multiple images from a lens system due to a small impact parameter. In terms of galaxy-scale lenses, strong lensing allows for properties of the lens galaxy to be measured, such as the mass of the galaxy. It provides a viable method for probing dark matter and also for determining the Hubble Constant, which is the rate of expansion of the Universe. Known gravitational lens systems exhibit a range of parameters that characterize their properties. These include the shear (γ) and the convergence (κ) or amount of distortion, and the Einstein radius (θ_E) or radius of the ring of light that is produced by strong lensing [1]. However, the process of manually identifying these parameters for newly discovered lens systems can be labor-intensive and cumbersome. As such, Machine Learning may offer a more efficient and automated approach for determining gravitational lens parameters.

We will develop a neural network in order to identify the aforementioned parameters for a general lens system. To this end, we will use standard gravitational lens models, such as the Singular Isothermal Sphere with external shear (SIS+shear), Singular Isothermal Ellipsoid (SIE), and Singular Isothermal Ellipsoid with external shear (SIE+shear) to generate a multitude of mock lenses that will serve as training data for our neural network. Using this, we would like to know the accuracy of the results when working with the same system on which the network was trained and when testing out the network on different systems (such as using the network trained on SIS+shear training data and applying it to both the SIS+shear and SIE test data). This could then be generalized to more unknown gravitational lens systems. My project seeks to increase efficiency and accuracy of finding the lens parameters for an arbitrary lens system using the family of isothermal models.

Project Objectives and Milestones

1. Generate large sets of training data (of magnitude 10^5 or higher training samples) of mock lenses by week of 12/16/2024 (around finals)
2. Use machine learning techniques and the family of isothermal models (isothermal sphere with external shear, isothermal ellipsoid, and isothermal ellipsoid with external shear) to extract the parameters from the mock lenses by week of 3/10/2025 (a couple weeks before presentations).
3. Generalize to other lensing systems in order to analyze accuracy of machine learning in determining relations between the lensing systems and parameters by week of 3/10/2025.
4. Produce the output Hubble Constant from the lenses in order to check accuracy of lenses with respect to the known value for the Hubble Constant by week of 3/10/2025.

References

[1] C. Keeton, *Principles of Astrophysics: Using Gravity and Stellar Physics to Explore the Cosmos.* Springer, 2014.