Final Year Project

Gravitational Lens Modelling of an IllustrisTNG Mock Multiply Lensed Supernova

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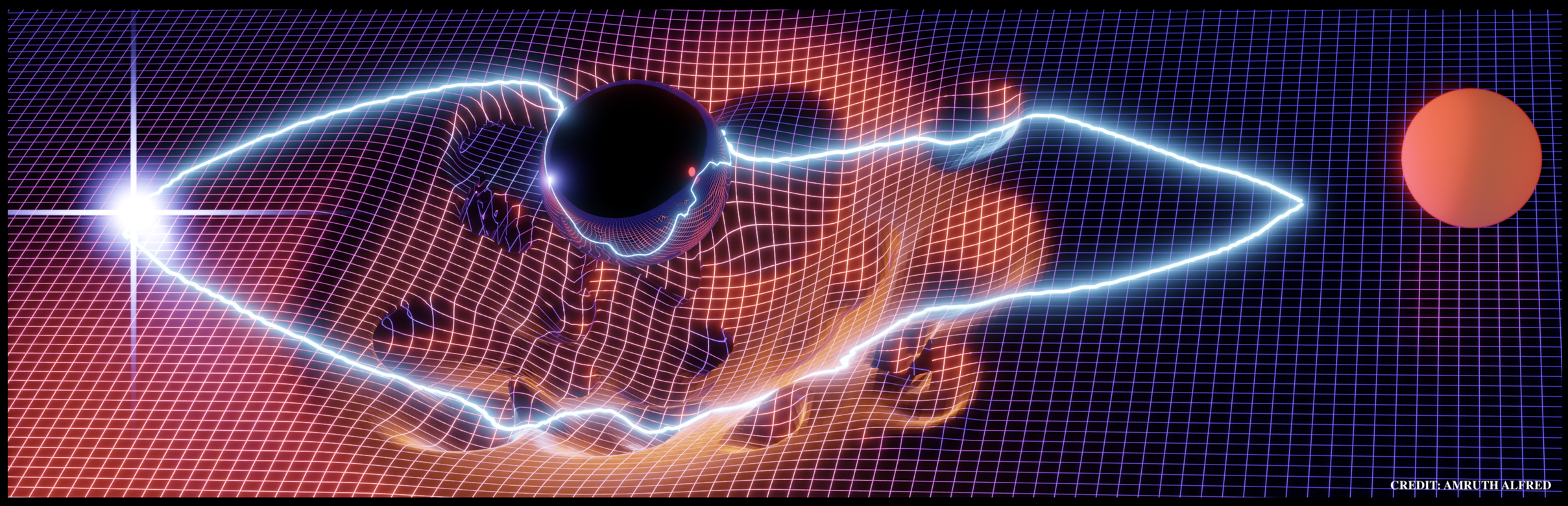

ABSTRACT

We present a novel approach to test if lens modelling can determine the underlying lensing galaxy dark matter profile by using mock strong lenses of a Type Ia supernova (SNIa) using the IllustrisTNG suite of simulations.

INTRODUCTION

Strong gravitational lensing is the phenomenon by which massive bodies, such as galaxies, curve spacetime, bending light from a background object, creating multiple images of the object [1]. Gravitational lens modelling is one way we can probe the dark matter profile of the lensing galaxy [2]. No previous work has modelled a perfect lens, leaving either position or magnification anomalies.

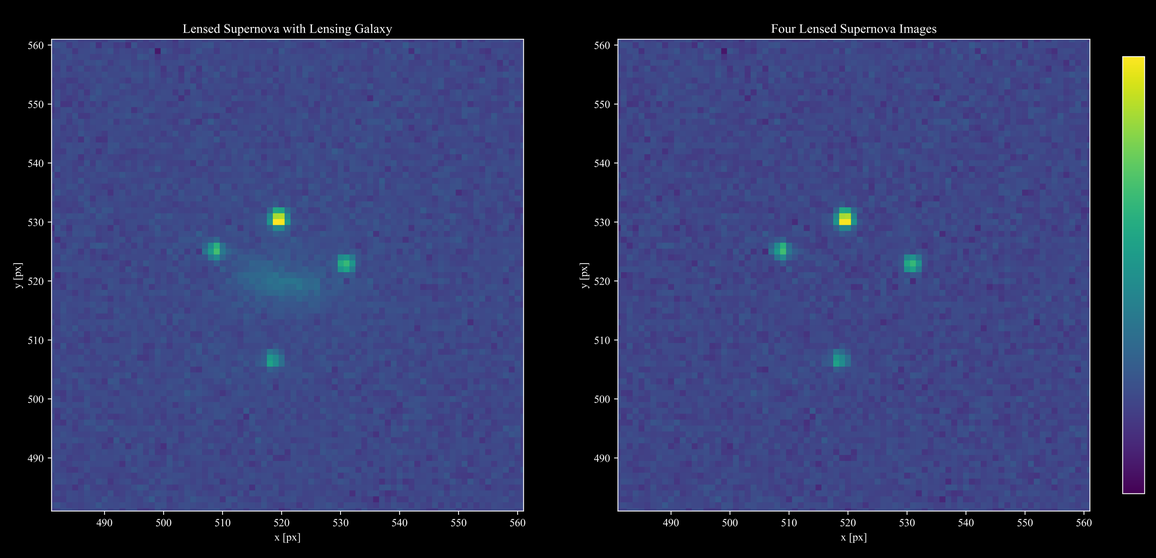

Figure 1. Mock Lensed Supernova

What is Lens Modelling?

Model the mass profile of the lensing galaxy to match observations.

Model Input:

1. Observed Positions
2. Observed Magnifications

Constraints Used:

1. Only Positions
2. Positions and Magnifications

We model using 5 mass profiles:

1. Single Isothermal Ellipsoid (SIE)
2. Power Law (POW)
3. Navarro-Frenk-White (NFW)
4. Einasto (EIN)
5. Cored Single Isothermal Ellipsoid (SIE)

METHODOLOGY

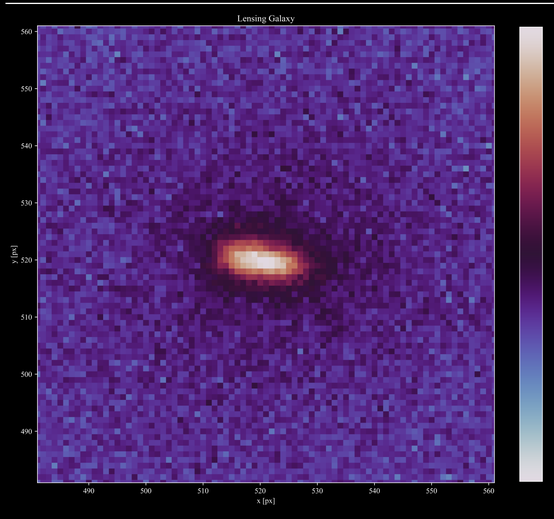

Figure 2. Lensing Galaxy (Post-SN Observation)

The methodology involves the following steps:

- Extract the predicted positions and magnifications of the lensed images.
- Model the light of the lensing galaxy from post-SN observation.
- Make lens models using observed positions and magnifications.
- Add in baryonic matter and a shear component to account for mass along the line of sight.

LENS MODELS

The best singular lens model:

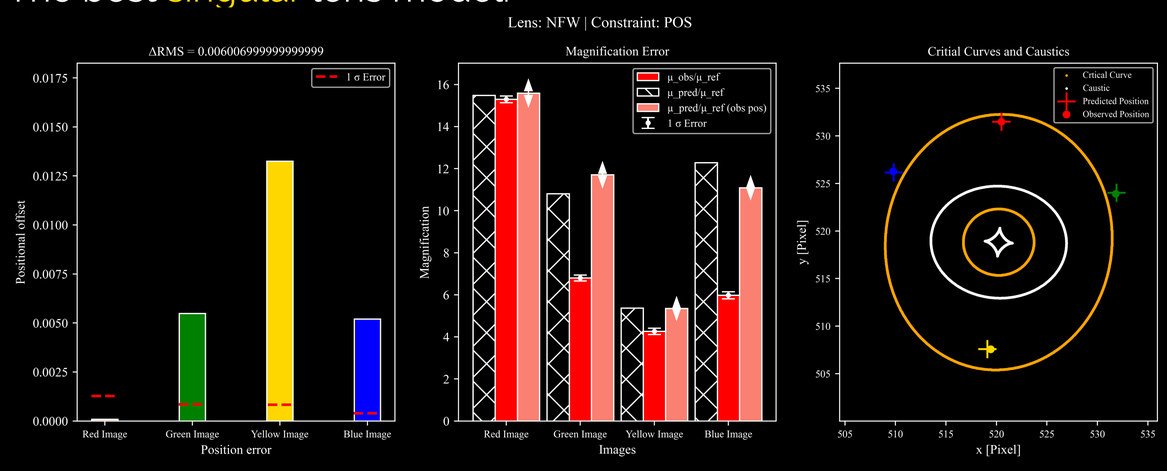

Figure 3. NFW Position Constrained Model Results

The best lens model with an external shear:

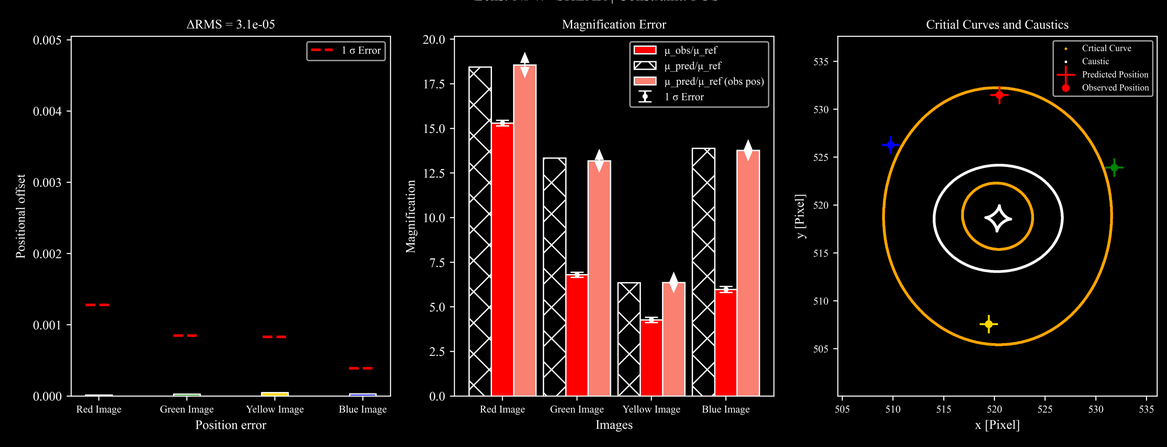

Figure 4. NFW+SHEAR Position Constrained Model Results

The surface mass density contour plot shows how the lensing potential changes when we add shear:

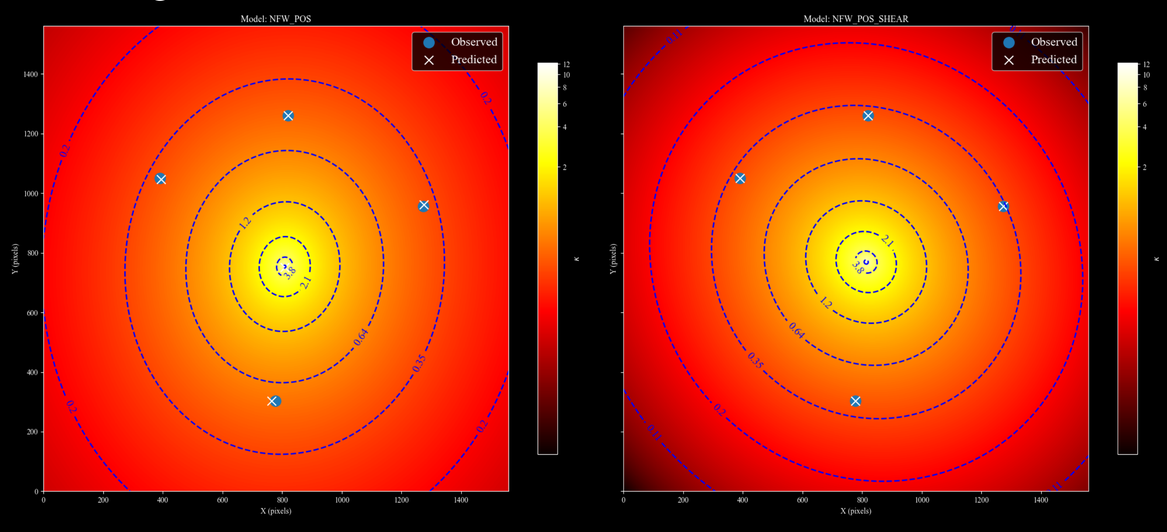

Figure 5. Surface Mass Density Contour Plot (NFW & NFW+SHEAR)

RESULTS

- None of the lens models can match the observed positions and magnifications of all images within 1σ.
- Adding a shear profile improves both the position and magnification anomalies but is unphysical.

REFERENCES

[1] N. Arendse, E. M¨ortsell, L. Weisenbach, E. Hayes, S. Thorp, S. Dhawan, A. Goobar, S. Guerrini, J. O. Hjortlund, J. Johansson, and C. Lemon. Microlensing of lensed supernovae zwicky iptf16geu: constraints on the lens galaxy mass slope and dark compact object fraction, 2025. URL https://arxiv.org/abs/2501.01578.

[2] D. A. Torres-Ballesteros and L. Casta¨neda. iscp¿relensingi/scp¿: Reconstructing the mass profile of galaxy clusters from gravitational lensing. Monthly Notices of the Royal Astronomical Society, 518(3):4494–4516, Nov. 2022. ISSN 1365-2966. doi:10.1093/mnras/stac3253. URL http://dx.doi.org/10.1093/mnras/stac3253.