Gravitational Lensing Research through The Indonesia Network for Astrophysical Gravitational Lensing EducatioN and reSearch (INAGLENS)

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Abstract

We present a student-led strong lensing analysis of 60 galaxy-scale lenses from the SuGOHI sample. Using lenstronomy, students in the Indonesia Network for Astrophysical Gravitational Lensing Education and Research (INAGLENS) modeled the mass and light distributions of the lens galaxies. The mass models include an elliptical power-law profile and external shear, while the deflector-galaxy light is described by a Sérsic profile. We measure the Einstein radii and estimate stellar masses from multi-band photometry provided by the Hyper Suprime-Cam Subaru Strategic Program survey. We then use the sample to model the population distributions of the initial mass function (IMF) mismatch parameter and dark matter halo mass. The population analysis incorporates a weak-lensing-based prior on halo mass and accounts for strong lensing selection effects. This work combines lens-by-lens modeling with a population-level framework to investigate the stellar and dark matter properties of strong lens galaxies, while providing students with hands-on experience in gravitational lens modeling and statistical analysis.

Keyword: strong lensing, IMF, INAGLENS (https://www.astrobridge.org/projects/inaglens)

Introduction

Strong gravitational lensing occurs when a foreground galaxy bends and magnifies light from a more distant source, often producing multiple images or an Einstein ring. Modeling these systems provides a direct measure of the projected mass within the Einstein radius. When combined with multi-band photometry, which helps estimate the lens galaxy's stellar mass, lensing can be used to investigate how its mass is divided between stars and dark matter.

This comparison also provides a way to study the stellar initial mass function (IMF), which describes the distribution of stellar masses at birth. The IMF mismatch parameter quantifies the difference between the stellar mass inferred using a reference IMF and the mass required by lensing-based models. Studying its distribution across a lens sample can reveal how the IMF and dark matter content vary among galaxies.

Research Method

We modeled 60 galaxy-scale strong lenses from the SuGOHI sample using multi-band imaging from the Hyper Suprime-Cam Subaru Strategic Program. The *g,r,i,z,* and *y* band images were fitted simultaneously with *lenstronomy* (Birrer & Amara, 2018). For each system, the mass distribution of the foreground deflector was represented by an elliptical power-law (EPL) profile, with external shear included to account for perturbations from the surrounding environment. The deflector's light distribution was described by a Sérsic profile. The lens and light models shared a common centroid, ellipticity, and position angle, so that the adopted geometry of the mass distribution followed that of the observed light.

The model was evaluated against the observed image data within the fitting region. The instrumental point-spread function was handled using PSF from stars, and the lensed source light was represented by source model.

Model parameters were optimized and their uncertainties estimated using MCMC. The Einstein radius was derived from the best-fitting mass model for each lens.

Stellar masses for the deflector galaxies were estimated from their HSC multi-band photometry using stellar-mass estimation. We then modeled the sample-level distributions of the IMF mismatch parameter and dark matter halo mass, accounting for measurement uncertainties from the individual lens models. The halo-mass analysis incorporated a prior informed by weak-lensing measurements. We also included the strong-lensing selection function in the population model to account for the fact that the observed lens sample is not a random subset of all galaxies.

Result

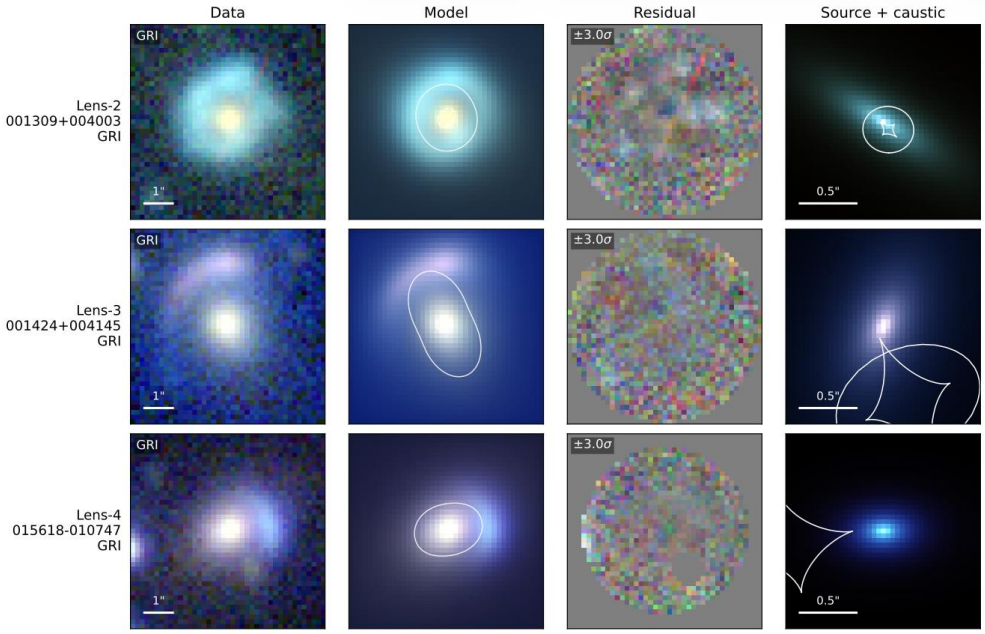


Figure 1. *Composite gri-band image of an example lens-modeling result.* ***From left to right:*** *observed data, best-fitting model, residuals, and reconstructed source with the caustic curve.*

Summary

We have successfully modeled 60 galaxy-scale lens systems from the SuGOHI sample using multi-band Hyper Suprime-Cam imaging. The models reproduce the observed lens systems well, with residual maps and reduced \(\chi^2\) values close to unity indicating satisfactory fits. The composite *gri*-band image provides a representative example of the modeling results (see Figure 1). This work establishes a consistent set of lens models and measurements of Einstein radii and stellar masses for the sample.

We are now analyzing the population distributions of the IMF mismatch parameter and dark matter halo mass using the framework of Sonnenfeld et al. (2019). This analysis incorporates a weak-lensing-based prior on halo mass and accounts for strong-lensing selection effects. Once complete, it will allow us to investigate the stellar and dark matter properties of the lens galaxies across the sample. The modeling has also provided INAGLENS students with practical experience in strong-lens analysis using *lenstronomy*.

References

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