A Weak Lensing Analysis of Moderate-redshift Strong Lenses

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The radial mass profile of the SLACS sample of strong gravitational lenses exhibits isothermal behavior out to distances of ~300 h⁻¹ kpc (~100 effective radii) (Gavazzi et al., 2007). This is thought to be due primarily to the “Bulge-Halo Conspiracy” whereby a steep luminous matter component and a shallow dark matter component combine to form a total mass profile that appears isothermal.

We are investigating whether the deviations from an isothermal profile can be explained by evolution in the galaxy population. To do so, we plan to conduct further comparative studies by splitting the full sample based on other physical parameters, such as color, velocity dispersion, and morphology.

OVERVIEW

The radial mass profile of the SLACS sample of strong gravitational lenses exhibits isothermal behavior out to distances of ~300 h⁻¹ kpc (~100 effective radii) (Gavazzi et al., 2007). This is thought to be due primarily to the “Bulge-Halo Conspiracy” whereby a steep luminous matter component and a shallow dark matter component combine to form a total mass profile that appears isothermal.

We are performing a similar analysis on a higher redshift sample of lenses in order to

1.) Look for evidence of the Bulge-Halo Conspiracy at earlier epochs
2.) Investigate correlations of mass profile characteristics with redshift and other galaxy properties.

Because strong lenses have been shown at low redshifts to be identical to isolated early-type galaxies, once they have been matched by stellar velocity dispersion (Treu et al. 2006, 2008; Gavazzi et al. 2007), we will use our investigation to gain insight into the evolutionary behavior of early-type galaxies.

LENS SAMPLE

Our sample consists of a total of 42 strong lenses, observed as part of the CASTLES program, the COSMOS survey (Faure et al., 2008), and the AEGIS program (Moustakas et al., 2007), as well as deep observations of individual lens systems (B0218+357 - PI. Jackson; B1608+656- PI. Fassnacht). Additionally, we perform a similar analysis on the full 44 lenses of the SLACS deep sample (Bolton, et al., 2008) as a baseline comparison, for a grand total of 86 lenses. The median redshift of the non-SLACS sample is z = 0.599, the SLACS median is z = 0.225. The sample was chosen based on the availability of deep (t_exposure~2000 sec) imaging in the F814W filter band from the Hubble Space Telescope’s Advanced Camera for Surveys (ACS). This provided an average source density of ~70 gal/arcmin² in each field, giving us enough of a statistical sample to attempt the weak lensing analysis. As was the case for the SLACS sample, the weak lensing signal around a single lens is too small to be detected. Thus, we combine the data from all fields in catalog space and determine the average mass profile of all lenses instead.

RESULTS AND FUTURE WORK

After multiplying the PSF-corrected tangential shear profile by the mean critical density of the lens stacks, we obtain a significant detection of the excess surface mass density surrounding the strong lenses. We have performed this operation both for a set of SLACS lenses (left figure) and for our moderate-redshift sample (right figure). Our SLACS profile is consistent with that obtained by Gavazzi et al. for their smaller sample of SLACS lenses. Both the SLACS and moderate-redshift results are broadly consistent with an isothermal (SIS) profile, indicating that the bulge-halo conspiracy may continue to higher redshifts.

From our preliminary analysis, there is also some indication of evolution in the best-fit SIS velocity dispersion.

The lack of significant B-mode signal (red points in bottom plots) is a good indication of freedom from systematics. We are carrying out additional tests for systematic errors; any quantification of evolution in galaxy parameters (e.g., velocity dispersion) will be conducted once these further tests have been completed.

We are investigating whether the deviations from a single power law at small and large radii are due to real physical effects or are produced by the nature of the data. For example, the small number of galaxies per bin at the smallest radii lead to small-number statistics effects, while the outermost bins may be showing edge effects due to the field of view of the ACS camera.

After completing this proof of concept study involving the separation of our lens samples based on redshift, we plan to conduct further comparative studies by splitting the full sample based on other physical parameters, such as color, velocity dispersion, and morphology.

Reduction and Analysis

The data were reduced using the automated pipeline developed by the HST Archive Galaxy Gravitational Lens Survey (HAGGLES) team (Marshall et al., in prep). This pipeline aligns the individual input exposures to higher accuracy than the standard ACS processing, producing final images that can be used in weak lensing analyses.

We use standard software for object detection (SExtractor) and shape estimation (IMCAT) to create galaxy catalogs. The full weak lensing analysis is then carried out in catalog space, using a python-based code that we designed in order to implement the most up-to-date KSB+ correction routines.

To correct galaxy shapes for systematic effects, we first implement a correction for Charge Transfer Efficiency (CTE), using a technique described in Gavazzi et al., (2007). We then correct effects of the Point Spread Function (PSF), by applying the algorithm described in Schrabback et al. (2007), using a series of well-sampled stellar fields to create smooth PSF models. The best-fit model for a science exposure is determined using χ² minimization between the model and real field stars. The models for each exposure in a given lens field are then averaged together to create a master PSF model.

Additionally, since the “wings” of the PSF are important in space-based weak lensing analyses, we create a series of PSF models at various KSB+ filter scales. This is done to match the filter size of a galaxy to the PSF model, ensuring a more accurate correction.

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