Mass Estimates of 36 Galaxy Clusters From The SDSS Giant Arcs Survey

Carlos A. García Diaz[1], Keren Sharon[2], Juan D. Remolina González[2], Guillaume Mahler[2], And Anna Niemiec[2]
[1]Delaware State University | [2]University of Michigan

Abstract

General Relativity claims the degree of spacetime curvature around an object correlates with the object's mass. An extremely massive galaxy cluster can curve spacetime to a high enough degree to bend the path of light rays resulting in a lensing effect. This strong gravitational lensing provides a way of studying a galaxy cluster's shape and mass, specifically dark matter halos. Currently creating a detailed lens model is the best way of examining these masses, however the process of producing a lens model is time consuming. For large surveys an automated process for measuring the core mass is critical. The mass within the inner most few hundred parsec can be estimated from the observed Einstein Radius assuming spherical symmetry. The accuracy of this method has not been compared with lens model results, therefore we applied this method to 36 strong lensing clusters from the SDSS Giant Arcs Survey, SGAS. We fitted Einstein Radii with fixed and free centers using SGAS positional coordinates of arcs and applied an empirical correction to measure mass estimates at the cores of the galaxy clusters. We expect our estimates to have a scatter of 20% and bias to be eliminated, thus showing the degree of uncertainty this method has compared to lens models. Applying this correction to observational data for the first time, establishes this method as an effective way of estimating the masses at the cores of galaxy clusters, making it a testbed for large astronomical surveys.

Objectives and Background

Goals

1. Measure Einstein radii of 36 SGAS galaxy clusters.
2. Compare results with Detailed Lens Models, DLM.

Strong Gravitational Lensing

★ Strong gravitational lensing is a unique opportunity to analyze the masses of galaxy clusters.

★ Galaxy Cluster Masses teach us about dark matter properties.

Figure 1 Example of SGAS Strong Lensing cluster SDSS J0146–0929: Composite image from *HST* using F105W, F606W , and F390W.

Methods

Fitting Circle to SGAS Positional Coordinates

1. We first located the position of the fixed centers of each cluster and calculated the radii by averaging the distance from the center to the arc family coordinates (Sharon et al. 2019). We used the coordinates of the arcs to find the free center and its corresponding radius.
2. Using a MATLAB library by Ofek et al.(2014), we calculated the mass enclosed by the Einstein Radius by multiplying together the critical surface density of the universe and the area of within the Einstein Radius.

$$M(<\theta_E) = \Sigma_{cr}(z_L,z_S)\, \pi\, [D_L(z_L)\theta_E]^2.$$

3. Using specific fixed and free center parameters we applied an empirical correction to the masses (Remolina Gonzalez et al. in prep.)
4. Lastly, we measured the masses within the fixed and free center Einstein Radii of the detailed lens model and compared our results.

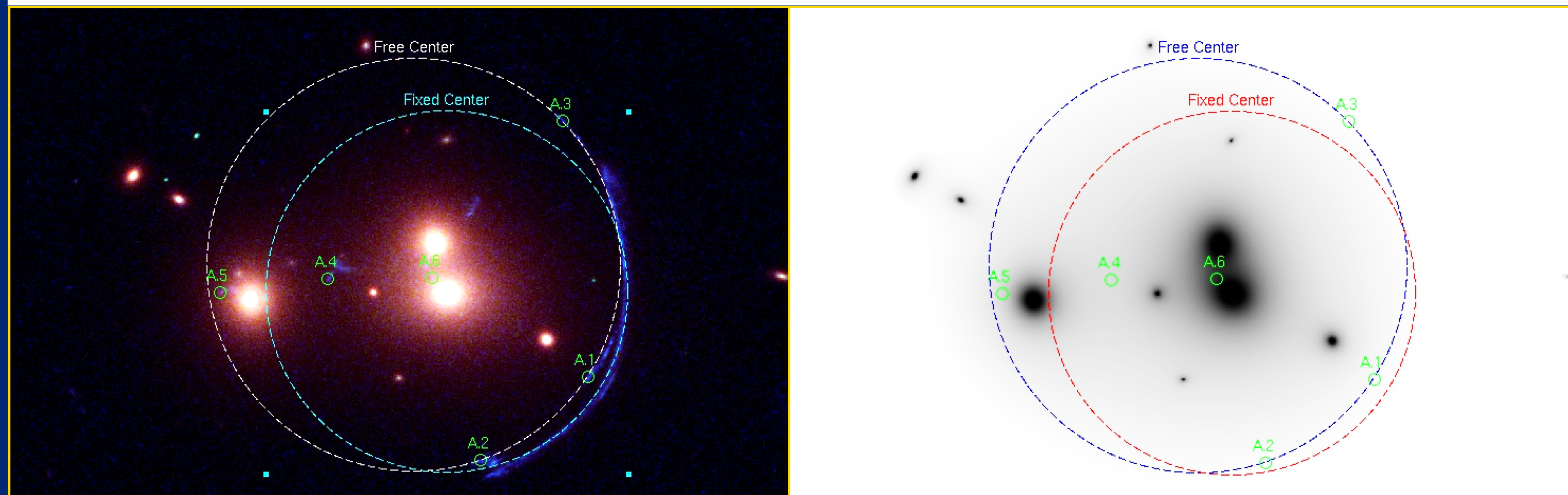

Figure 2: RGB Image and DLM: Left – Composite image from *HST* using F105W (red), F606W (green), and F390W (blue) of cluster SDSS J1152+3313. The green points indicate the arcs of source A. The dashed circles represent the Einstein Circle for a free and fixed center. Right – Projected Mass distribution from the Detailed Lens Model of the same cluster where the greyscale represents the mass.

Comparing: Mass Estimates and Detailed Lens Model

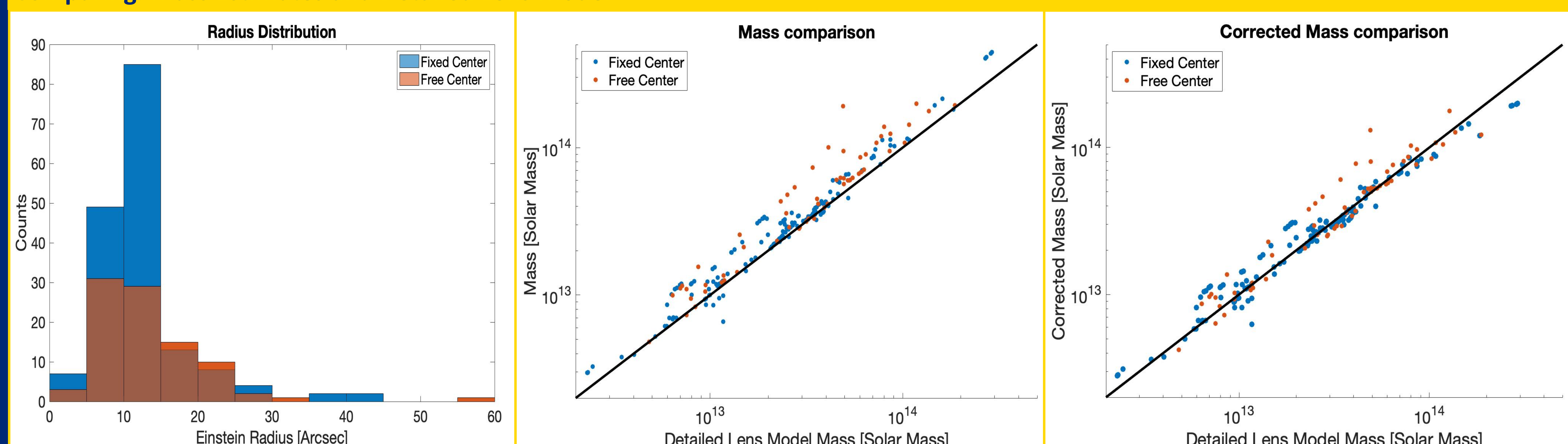

Figure 3 Measurements and Results: Left – distribution of Einstein Radii. Middle – comparison of measured mass estimates and DLM; this estimate method tends to over-estimate the mass. Right – comparison of corrected mass estimates and DLM shows an un-biased measurement compared to the measured mass.

References

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2. Sharon, K., Bayliss, M. B., Dahle, H., Dunham, S. J., et al. 2019, arXiv e-prints, arXiv:1904.05940
3. Remolina Gonzalez, J. D. In preparation