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STRONG LENSING, WEAK LENSING, AND DYNAMICS IN SL2S J02140-0535

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RESUMEN

Presentamos un análisis en el que se combinan el modelado de lente fuerte con restricciones dinámicas con el fin de estudiar la distribución de masa en SL2S J02140-0535. Este grupo de galaxias a $z = 0.44$ pertenece al Strong Lensing Legacy Survey (SL2S), una exploración que ha descubierto una nueva población de lentes a escala de grupos de galaxias. Nuestro análisis de lente fuerte está basado en imágenes multibanda del HST/ACS en las cuales se pueden observar los arcos gravitatorios presentes en SL2S J02140-0535; arcos que hemos estudiado espectroscópicamente con datos del VLT/FORS2. Para restringir el radio de escala de un perfil de masa NFW, proponemos un metódo que usa la información dinámica a gran escala del grupo, obtenida a través de la espectroscopía (VLT/FORS2 and KECK/LRIS) de los miembros del grupo. Este trabajo muestra un método potencialmente útil para restringir parámetros no accesibles usando únicamente modelos de lente fuerte, como el radio de escala del perfil NFW.

ABSTRACT

We combine strong lensing modeling and dynamical constraints in order to probe the mass of SL2S J02140-0535, a galaxy group at $z = 0.44$ from the Strong Lensing Legacy Survey (SL2S) which has uncovered a new population of group-scale strong lenses. The strong lensing analysis is based on multi-band HST/ACS observations which display strong lensing features that we have followed up spectroscopically with VLT/FORS2. To constrain the scale radius of an NFW mass profile, we propose a new method taking advantage of the large scale dynamical information provided by VLT/FORS2 and KECK/LRIS spectroscopy of group members. This work shows a potentially useful method for constraining large-scale properties inaccessible to strong lensing, such as the scale radius of the NFW profile.

Key Words: gravitational lensing: strong — galaxies: clusters: individual (SL2S J02140-0535)

1. INTRODUCTION

In the context of structure formation and evolution, galaxy groups play a key role, spanning the regime between individual galaxies and galaxy clusters. Therefore, detailed studies of this intermediate regime of the mass spectrum are relevant. Only a few years ago there was a small number of well-known galaxy groups associated with strong lenses (see Limousin et al. 2009, and references therein).

2. SL2S J02140-0535

SLS2S J02140-0535 is a group of galaxies that belongs to the Canada France Hawaii Telescope (CFHT) Strong Lensing Legacy Survey sample (Cabanac et al. 2007). This group at $z = 0.44$, have three lens galaxies acting as strong lensing deflector with at least two of them bound gravitationally. The source images consist of three arcs surrounding the deflectors: one in the north (arc A) composed by two merging images with substructure (see top panel of Figure 1), one in the east (arc B), and one in the south (arc C).

3. DYNAMICAL CONSTRAINTS IN THE LENSING MODEL

In order to reproduce the arcs observed in SL2SJ02140-0535, we use the parametric method implemented in the LENSTOOL ray-tracing code (Jullo et al. 2007). The group component was modeled using an NFW profile (Navarro et al. 1997). We add the three central galaxies modeled like PIEMD (Elíasdóttir et al. 2007), as perturbations to the group potential. Our fit was done using the substructures showed in the top panel of Figure 1. Being the systems A-B ($z_{\rm phot} = 1.7 \pm 0.1$) and C ($z_{\rm spec} = 1.023 \pm 0.001$) produced by two different sources.

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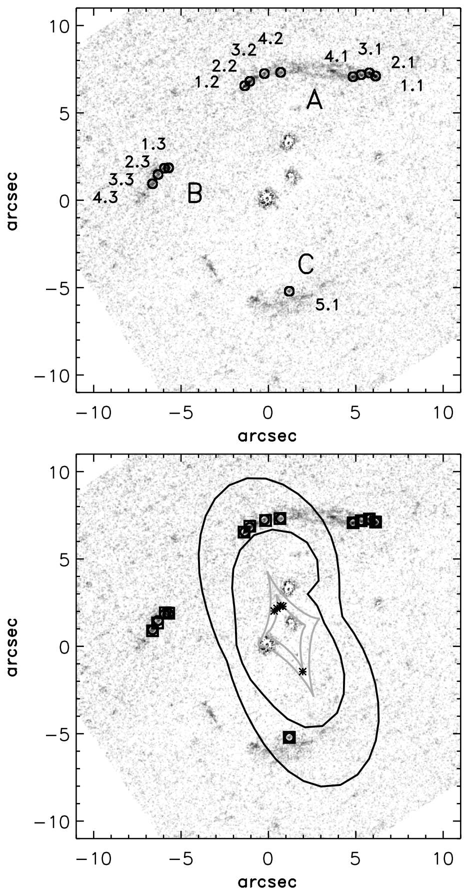

Fig. 1. Top panel. HST/ACS image (F475W) after the subtraction of the central galaxies of the group. The circles shows the positions of the conjugated images that constitutes the arc system AB and the location of arc C. Bottom panel. Tangential critical lines (black) and caustic lines (gray) for two different sources located at $z = 1.0$ and $z = 1.7$. The circles shows the measured positions of the images (input data for the model). The squares are the model-predicted image positions after optimization and the asterisks the positions in the source plane.

We use the dynamical information of the group in order to constrain the scale radius of the NFW profile (see the discussion in Verdugo et al. 2010). In the bottom panel of Figure 1 we show the model-predicted image positions after optimization as well as the observed positions. The remarkable agreement between both positions is quantified by a mean scatter in the image plane smaller than $0.04''$ and a $\chi^2_{\rm DOF} = 1.2$

4. COMPARING MASSES

The weak lensing analysis of this group was presented in the work of Limousin et al. (2009) and the dynamical analysis was done using spectroscopic data form VLT/FORS2 and KECK/LRIS (see Verdugo et al. 2010). In Figure 2 we compare the masses obtained with different methods: strong lensing, weak lensing, $M_{\rm 2D}$ derived analytically from the profile, and the virial mass calculated from the dynamics. As we place limits on the possible values of the scale radius, the strong lensing mass is still reliable up to this radius ($r_s = 170 \pm 18$ kpc). From Figure 2 we can note that the masses are in agreement within the errors

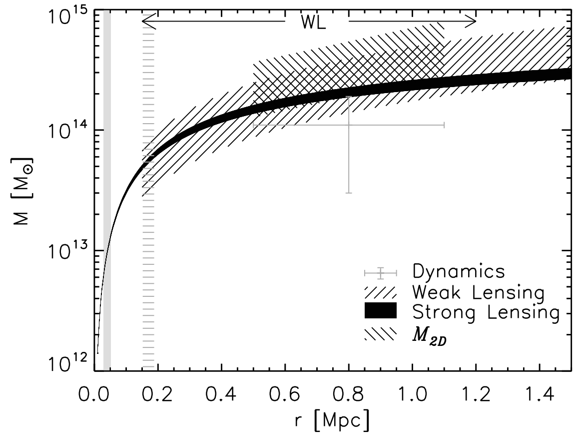

Fig. 2. The 2D projected mass as a function of the aperture radius measured from the center of the group. The $M_{\rm 2D}$ depict the mass of the profile calculated analytically. The point with error bars is the mass estimate from dynamics. The gray-shaded region shows the area where the arc systems lie and the gray region filled with horizontal lines shows the model-predicted scale radius.

5. CONCLUSIONS

We have probed the mass of SL2S J02140-0535 on a large radial range using complementary techniques: strong lensing, weak lensing, and dynamics. Our model reproduces the observed features in this system and we shows the possibility of constraining large scale properties that could not be measured by strong lensing, such as the scale radius in the NFW profile.

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