Application of Gravitational Lensing Models to the Brightest Strongly Lensed Lyman Break Galaxy – the 8 o'clock arc

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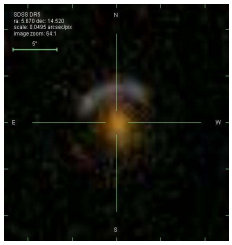
ABSTRACT

We report on modeling of the recently discovered brightest strongly lensed Lyman Break Galaxy (LBG), the so called "8 o'clock arc". This galaxy is at redshift 2.73 and is lensed by a luminous red galaxy (LRG, z=0.38) in the Sloan Digital Sky Survey (SDSS) DR4 imaging data. We observe four images, three in the arc plus a counterimage. The three lensed images in the arc subtend an angle of 160 degrees around the LRG and extend over more than 9.6 arcsec in length. For the modeling we are using information from all four images extracted from SPICAM images taken on the 3.5m telescope at APO. Using the GRAVLENS package with an Singular Isothermal Ellipse (SIE) mass profile we obtain a velocity dispersion of 392 km/sec for the LRG and a total magnification of about 12.

Discovery

The 8 o'clock arc was discovered while performing a visual scan of an interacting/merging galaxy pair catalog extracted from the SDSS DR4. The central Luminous Red Galaxy (LRG) has an SDSS spectrum which indicates that it is at a redshift of 0.38. The associated arc is a very blue extended object which does not have an SDSS spectrum. There are 3 images in the arc and a 4th counter image below the LRG which is not visible in the SDSS image.

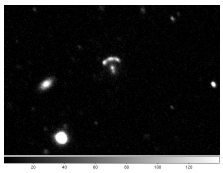


SDSS DR5 image

Follow-up observations

Follow-up observations were carried out using the 3.5m at Apache Point Observatory on 24 August 2006. Three 300 sec exposures were taken using the SPIcam CCD imager in each of the SDSS gri filters under seeing conditions of 1.0-1.2" (FWHM).

Spectroscopy was taken using the DISIII spectrograph. The resulting spectrum indicated that the arc was a Lyman Break Galaxy at a redshift of 2.73. (See Poster #256.03 S. Allam et al. and astro-ph/0611138)



SPIcam g-band co-added image

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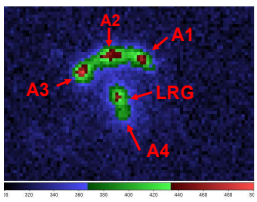
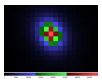
Modeling the LRG

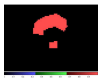
We used the GALFIT program (Peng et al. 2002, AJ, 124: 266) to model the LRG and subtract it fr om the image prior to modeling the lens. We chose to work with the g-band co-added image as the counter image A4 is clearly visible. A PSF im age was generated from one of the stars in the SPIcam image using IRAF's mkobject. We chose to mask out the pixels in the arc and counter image t o avoid biasing the galaxy modeling.



Input image

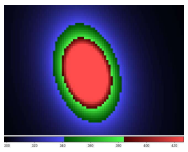


PSF Image



Pixel mask

We generated a galaxy model based on a de Vaucouleurs profile.



Galaxy model

$$\Sigma(r) = \Sigma_e \exp\left[-k\left(\left(\frac{r}{r_e}\right)^{1/n} - 1\right)\right]$$

n = 4 k = 7.67

Σ(r) = surface brightness at radius r

Σ_e = surface brightness at radius r_e

Fitted parameters

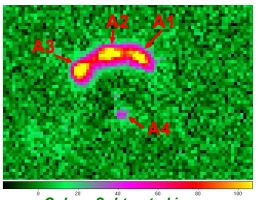
Magnitude = 20.41 ± 0.03

r_e = 3.66 ± 0.18"

Ellipticity = 0.37 ± 0.02

PA = 14.72 ± 2.78 deg

χ^2/dof = 1.33



Galaxy Subtracted image

A Sérsic profile yields a very similar fit with a slightly smaller r_e of 2.88 ± 0.2"

Modeling the Lens

We used the gravlens/lensmodel software (C. Keeton astro-ph/0102340) to model the lens. We used the four image positions obtained by running SExtractor (Bertin & Arnout, 1996 A&AS, 117, 393) on the g-band galaxy subtracted image. The LRG position was taken from th e GALFIT subtraction. We assumed a singular isothermal ellipse (SIE) for the mass profile of the le ns. We assume a flat cosmology, Ω_m=0.3, Ω_Λ=0.7 H_0=100h km s^{-1} Mpc^{-1}.

$$\kappa(\xi) = \frac{b'}{2\left(\xi^2\right)^{1/2}}$$

κ = surface mass density

$\xi = x^2 + y^2/q^2$ where q = ellipse axis ratio

b' is related to the Einstein radius b_{SIE} such that $b_{SIE} = b'\sqrt{\frac{(1+q^2)}{2q}}$

The velocity dispersion is given by $\sigma = \left[\frac{b_{SIE} c^2 D_s}{4\pi D_{LS}}\right]^{1/2}$

D_s = 1141 h^{-1} Mpc angular diameter distance to source

D_L = 752 h^{-1} Mpc angular diameter distance to lens

D_{LS} = 863 h^{-1} Mpc angular diameter distance between lens and source

Fitted parameters

b' = 2.94 ± 0.14"

Ellipticity = 0.53 ± 0.05

PA = $12.76^{+1.74}_{-1.56}$ deg

χ^2/dof = 1.04

Calculated parameters

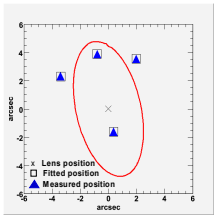
b_{SIE} = 3.35 ± 0.16"

σ = 392 ± 9 km s^{-1}

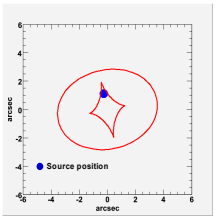
R_{EIN} = 12.2 ± 0.6 h^{-1} kpc

M_{EIN} = 1.37 ± 0.13 x10^{12} h^{-1} $M_\odot$

Mass-to light ratio = 17.7 h $M_\odot$/ $L_\odot$



The image plane



The source plane

Image magnifications

A1 = $4.01^{+4.42}_{-1.11}$ A2 = $-4.44^{+5.59}_{-1.59}$

A3 = $3.79^{+1.17}_{-0.69}$ A4 = -0.52 ± 0.04

Total magnification = $12.76^{+11.6}_{-3.4}$