

How should we study the light distribution of lensing galaxies ?

Analysis of luminosity profiles and shape parameters of strong gravitational lensing galaxies

Based on J. Biernaix, P. Magain, D. Sluse, and V. Chantry, 2015, A&A 585, A84 (arXiv:1510.09118)

I am not around ? Scan the QR code for a video presentation of this poster !



Why bother ?

Strong gravitational lensing galaxies usually appear surrounded by point-like and diffuse lensed components (Fig 1). The study of their luminosity profile is thus restricted to small, inner areas. In those conditions, usual fitting methods perform poorly; previous studies measuring their half-light radii (r_{eff}) using software such as GALFIT or IMFITFITS and various PSF-determining methods have resulted in somewhat discrepant results (1). Yet, their luminosity profiles are crucial, for example, in computing their mass-to-light ratios and detecting or locating dark matter within early-type galaxies.

More robust techniques for studying the morphology of early-type lensing galaxies are needed, with the ability to subtract the lensed signal from their luminosity profiles. We are designing such a method, based on an innovative scheme for computing isophotes. It independently measures each shape parameter, namely, the **position angle (PA)**, **ellipticity**, and **r_{eff}** of the galaxy.

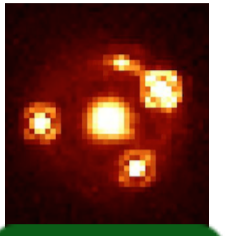


Fig 1 - SDSS0924+0219 (HST - NICMOS)

The sample

- 7 systems from the CASTLES database (2), amongst a larger sample previously processed in (3) and (4), in the near infrared H band.
- NIC2 camera of the NICMOS instrument onboard the HST. Angular scale : 0.075 arcseconds per pixel.

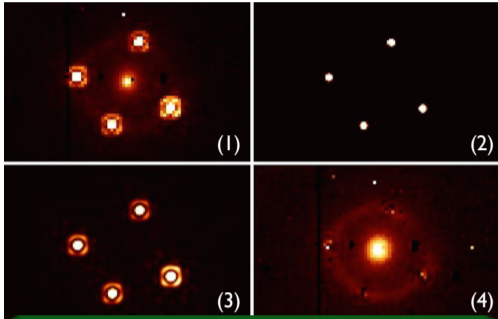


Fig. 2 - Point sources subtraction on HE0435-1223. (1) original image, (2) synthesised image of the deconvolved sources, (3) of the reconvolved sources (4) result of (1) - (3).

The PSF, the PA and the ellipticity

Previous processing of these data in (3) and (4) includes a thorough determination of the PSF for each data frame, using the MCS (5, 6) algorithm. It finds the best PSF by iteratively subtracting any non-point-like object until convergence to an image of the point sources. These very detailed PSFs have given access to accurate astrometry. It makes it easier to distinguish the deflected images from the galaxy, and to subtract their signal from the original image, as shown in Fig 2. The PA and ellipticity are determined independently with custom-made routines detailed in (7).

The half-light radius

The light distribution of a circular galaxy is usually represented by the de Vaucouleurs profile (8), in its logarithmic form :

$$\ln I = \ln I_{\text{eff}} - k \left(\frac{r}{r_{\text{eff}}} \right)^{1/4} - k$$

$$s = -\frac{k}{r_{\text{eff}}^{1/4}}$$

With k a normalisation constant. The r_{eff} measurement procedure is based on determining the slope s of this linear relationship in the $(r^{1/4}, \ln(I))$ plane. We therefore call it the **linear regression method (LRM)**. For an elliptical luminosity profile, $r = \sqrt{ab}$, with a and b the semi-major and semi-minor axes of the isophotes.

Note: The luminosity profile is still affected, at that point, by the PSF. To correct that, a 2D-image of an elliptical de Vaucouleurs profile is produced for each lens, and convolved by the PSF. Its ellipticity, PA, and r_{eff} are measured the same way as on the data frame. Its parameters are tuned until the values measured on the convolved model match those measured on the actual data frame.

Testing the LRM

To compare the LRM to GALFIT, we perform the r_{eff} measurement with both methods on sets of simulations. We examine their dependency on various processing parameters. 2D-mock galaxies are built using a circular symmetric Sérsic luminosity profile and convolved by a typical NIC2 PSF. Some noise is added, with various signal-to-noise ratios (SNR). GALFIT's algorithm consists in fitting a convolved model directly on a data frame, and is similar to many galaxy shape measurement softwares, such as IMFITFITS, setting this comparison in the context of our investigation of the discrepancies noted by (1).

Sensitivity of GALFIT and of the LRM to various parameters

meas. method	GALFIT	LRM
Parameter		
Value of n (stars in Fig 3)	When using a too large n : r_{eff} overestimated by 40% to 70%, depending on the fitting region	When using a too large n : r_{eff} overestimated by 0.5% to 45%, depending on the fitting region
SNR (crosses in Fig 3)	For large fitting regions : r_{eff} overestimated by 3% to 7% for SNR from 50 to 800. At a data SNR: 6% to 9%, depending on fitting region (*)	No change larger than 2% for SNR from 50 to 800. At a data SNR: error <0.5% regardless of the fitting region
Size of the galaxy compared to the PSF (Fig 4)	Input r_{eff} from 2 to 7 PSF widths : r_{eff} overestimated by 6% to 18%, depending on the fitting region	Input r_{eff} from 2 to 7 PSF widths : r_{eff} error <0.5% regardless of the fitting region

Notes:

- (*) The fact that GALFIT converges to a too high value for r_{eff} may come from the processing of the PSF. Indeed, when the measurement is performed directly on the deconvolved mock galaxy, it reaches the right value.
- Those simulations have a domain of validity. In particular, the PSF we use here is perfectly known and free of any noise. Neither the behaviour of GALFIT nor that of the LRM with uncertain PSFs has been investigated in this work.

➔ **More robust results are obtained with the LRM. It behaves better than GALFIT regarding critical aspects of image processing, such as the SNR or the fitting region, handles small galaxies much better, and depends less on the knowledge of n .**

When studying gravitational lensing galaxies, close attention should be paid to;

- **the PSF** - Point sources subtraction helps disentangling relevant galaxy light from other components. It relies on a good PSF. The MCS algorithm is better-suited to gravitational lensing images, because it subtracts diffuse components. It also has the advantage of not violating the sampling theorem. TinyTim PSFs, for example, proved not to be accurate enough to model the point sources and subtract their contribution (3, 6). The PSF also affects the determination of the luminosity profile parameters.
- **the fitting method** - Our simulations show that classical fitting methods like GALFIT have some instabilities, especially regarding the fitting region or n . The LRM depends less on such crucial parameters. Moreover, the shape parameters are measured individually, freeing the fitting from the existence of local minima.

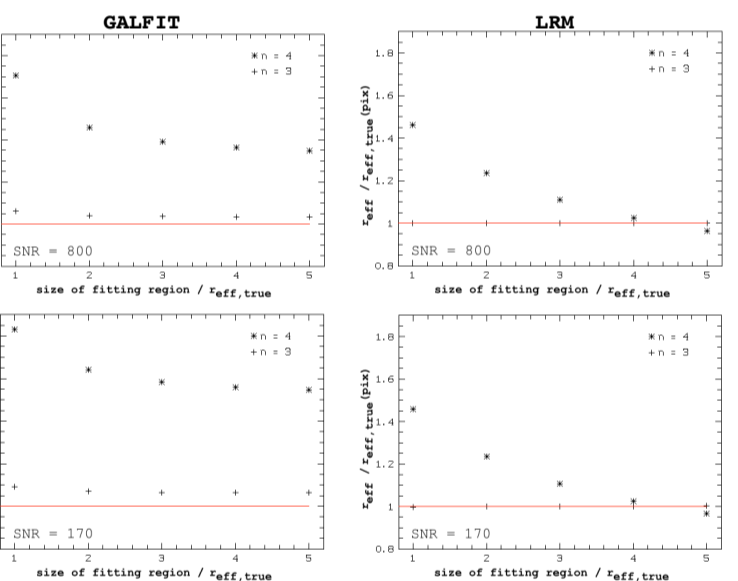


Fig 3 - r_{eff} measurement by GALFIT and the LRM on a $n=3$ mock galaxy with a 10-pix half-light radius. Because they are smaller than the symbol size, the error bars are not shown.

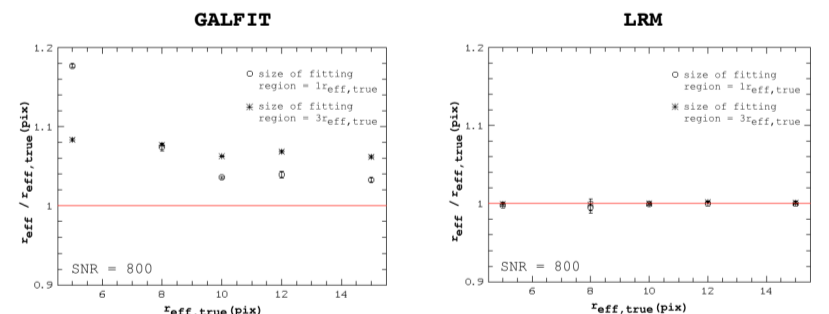


Fig 4 - r_{eff} measurement by GALFIT and the LRM on a $n=3$ mock galaxy with SNR=800. The results are shown with error bars.

What is next ?

- Even though the shape parameters were measured quite independently from n , the latter should be measured too for a complete characterisation of the lensing galaxies. The method should therefore be expanded to the computing of n .
- The signal from the point sources can be subtracted, and the same should be done for diffuse lensed components, a.k.a the arc. A pre-processing that achieves that is currently being implemented.

References and acknowledgements

(1) Schechter et al., 2014 - (2) Muñoz et al., 1998b - (3) Chantry et al., 2010 - (4) Sluse et al., 2012 - (5) Magain et al., 1998 (6) Chantry & Magain, 2007 - (7) Biernaix et al., 2015 (8) Prugniel & Simien, 1997 - (8) Kormendy et al., 2009 - (9) Bolton et al., 2012

J. Biernaix acknowledges the support of the F.R.I.A. fund of the F.N.R.S. Thanks to Pierre Magain for his help, to Clémentine Hauret for her inspiration, and to Tristan Van Egroo for his video skills !

Contact

Judith Biernaix
FRIA PhD Student
STAR-OrCA
University of Liège
jbiernaix@ulg.ac.be

Scan the QR
code to
access my
webpage !

