An example of Galaxy cluster mass determination based on Weak-lensing studies using an NFW profile*

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Abstract

During few weeks, we learned the theoretical basis of Weak lensing to measure the mass of a galaxy cluster. We have taken as an example the Abell3926 galaxy cluster, computations where performed from scratch in Python. We found a total mass of order 10^{+15} $M_\odot$*. We summarize here the intermediate followed step's to obtain this result. This work have to be improved to reduce the errors and many other things can be done after that.*

Keywords: cosmology – observations – galaxies clusters – dark matter halo – Weak gravitational lensing

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1. Introduction:

It is well known that in general relativity (GR), space and time are strogly related such that massive objects locally distort space-time itself, and in the same way: thoses massive objects are also affected. An interesting consequence is that light travelling througt space in a proximity of a massive object are deflected. This is the so-called *gravitational-lensing*, a general representation is given in fig.1.

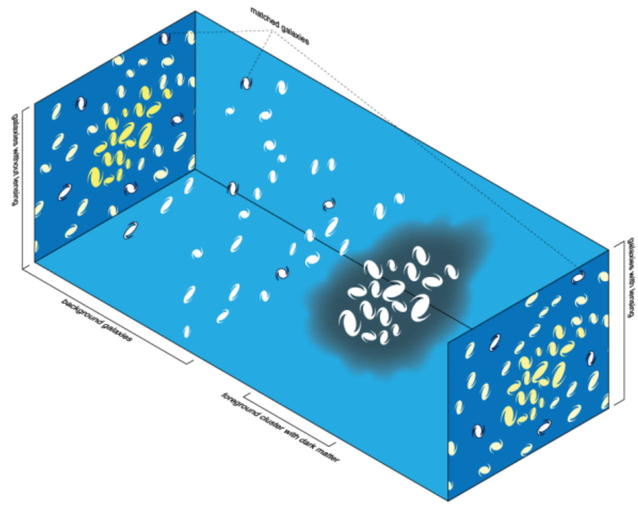

Figure 1: Artistical description of gravitational lensing, Image by Michael Sachs [CC BY-SA 3.0 or GFDL], via Wikimedia Commons.

Let's consider this massive object to be a calaxy cluster from now, every beam of light from a background object (galaxy) will be named a source, the light comping from this source is deflected in a different way depending on its angular position with respect to the galaxy cluster that will act as a lens. The final image as seen by the observer will be distorted.

We are attached in this short repport to give the necessary conceptual tools to understand gravitational lensing, interested reader may consult [1, 2, 3, 4] for a more detailed description.

Surely, we haven't the pretentious to say that we were able to compute accurately the mass of our galaxy cluster, but at least it is a starting point and we will present here a summary of first step's we have to pass throught these kind of studies.

2. Characterization of studied galaxy cluster:

Firstly, we have just observed naively the galaxy gluster and make different visual plots of how it looks like in fig.2. The red point in the middle represent the galaxy cluster center, we have restricted next computation between 0.2 and 3.0 Mpc.

As the distances in GR is given by redshift, we have plotted an historgam of redshifts of cluster and background galaxies, the cut between them have firsly been taken to 0.25 as shown in fig.3,

It is also interessting to average the redshift of background galaxies in radial bins as shown in fig.4,

*We will focus on the poorly known galaxy cluster A3926 situated in the southern hemisphere covered by the *kilo Degree Survey*.

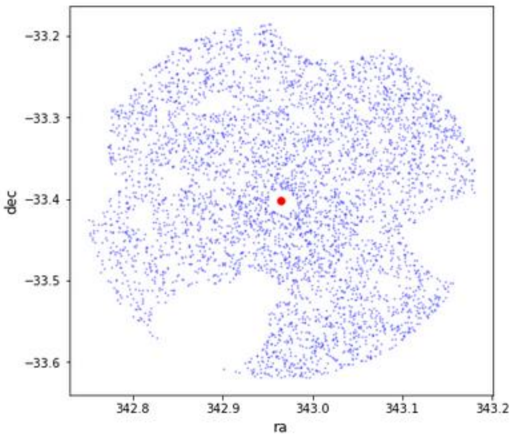

Figure 2: Visual representation of the galaxy cluster A3926.

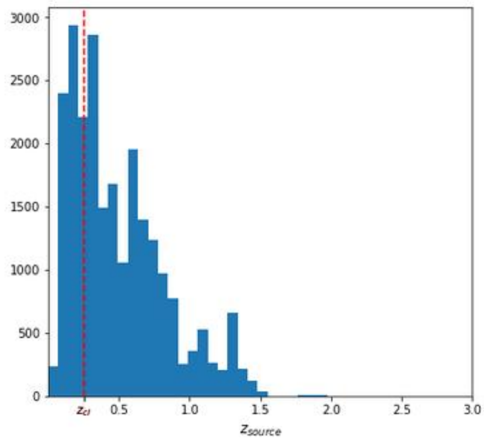

Figure 3: Histogram of galaxies redshift.

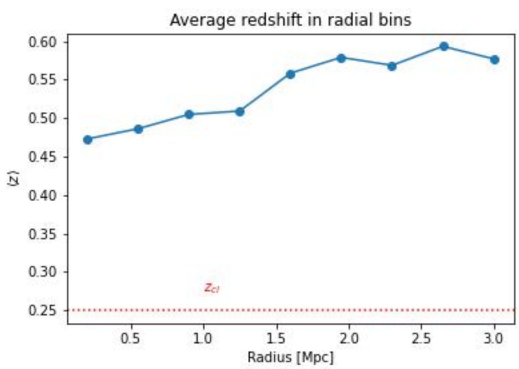

Figure 4: Averaging redshift in radial bins.

3. Tangential & Cross Ellipticities:

In order to measure the mass of the cluster, we need a measure on how it affect the background galaxies, a good indicator of that is the measure of cross and tangential shear, and in order to do, we need the ellipticities of each galaxies and a scatter plot of them is given in fig.5,

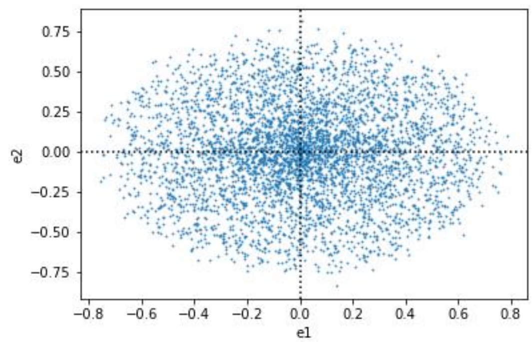

Figure 5: Ellipticities scatter plot.

Both of the cross and tangential shear have been computed and their histogram is represented in fig.6 and fig.7 respectively,

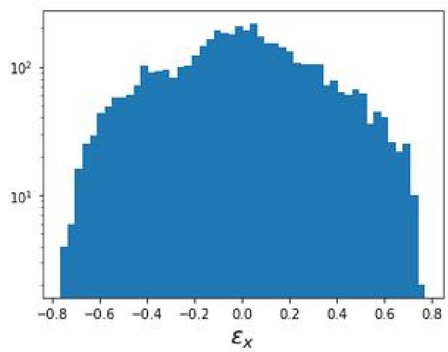

Figure 6: Cross shear histogram.

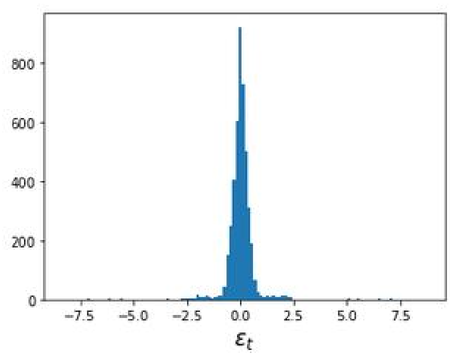

Figure 7: (bias corrected) Tangential shear histogram.

4. NFW Profile

Finally, we have binned the last cross and tangential shear's in radial bins, where we clearly observe that the cross shear is consistent with zero as it should be (it is generally used to suppress statistical errors) and the Tangential shear is of order 0.1 to 0.7 as in litterature,

And performed an NFW profile fit using the celebrated *Wright & Brainerd 2000* on the Tangential shear in fig.9,

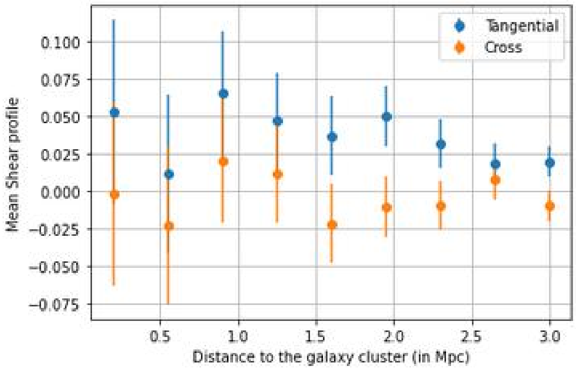

Figure 8: Cross and Tangential shear profiles.

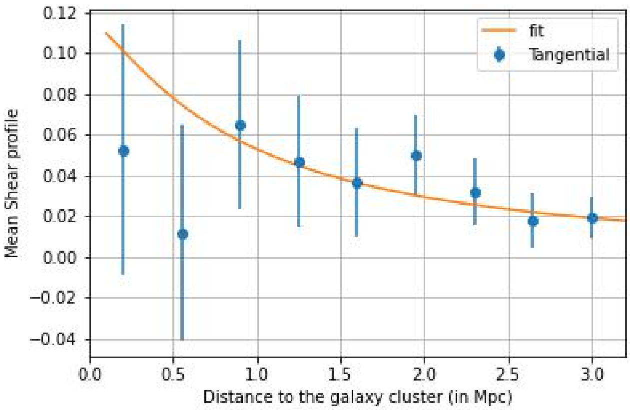

Figure 9: *Wright & Brainerd 2000* fit for the Tangential shear profile.

5. Results & conclusions

The last fit is based on two free parameters, knwon as c_{200} and r_s which represent the density and the radial scale of the cluster respectively, where we found $c_{200} = 1.801 \pm 0.886$ and $r_s = 1.585 \pm 0.907$Mpc, the induced mass is then found to be $M_{200} = 3.608 \pm 8.0165$ $M_\odot$ which is consistent with litterature.

As there is a degeneracy between c_{200} and r_s, we have fixed c_{200} to 3.5 as it is suggested to be an universal value which gives a mass of $M_{200} = 2.617 \pm 0.589$ $M_\odot$, the error bars are much smaller.

So in conclusion, we have learned a lot of things all along this work and here we summarize the most importants:

- The mass estimation of galaxy clusters depend on a multiple parameters but still can be estimated with some good accuracy (see 5.1).
- General relativity (and Cosmology) offers the needed theoretical hint to go more deeper throught the understanding of our universe, the weak lensing effect is just a small part of it and there is much more to do.
- Collecting more accurate astronomical data is of a great importance, their analysis may be reveal for discovering new fundamental phenomena.
- The NFW profile is largely used as an universal profile to descibe the Halo of dark matter surrounding cluster of galaxies.

5.1. *Future directions*

For sure, our work is not complete and there is still a lot of things to do, don't forget that it is an entire field of study by itself, there is a lot of variables that we can play with in order to refine the measurements. Here is some ideas on what can be performed :

- Optimize our NFW profile fit in order to obtain better parameters (r_s, c_{200}), this will conduct directly to a better estimation of the mass M_{200} of our cluster.
- Try different cluster centers and investigate the effect on the mass estimation M_{200}.
- Select more appropriately the background source galaxies using different cuts redshift than the one we used in .

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