



LEIDEN UNIVERSITY

Study of BCG-Subtracted Images of Nearby Clusters

by

Juan Manuel Espejo Salcedo

Advisor:

Dr. Henk Hoekstra

Natural Sciences Faculty
Sterrenwacht

March 2017

“Not only is the Universe stranger than we think, it is stranger than we can think..”

Werner Heisenberg

Abstract

Natural Sciences Faculty
Sterrenwacht

T.

Acknowledgements

I would like to thank ...

Contents

Abstract	ii
Acknowledgements	iii
List of Figures	v
List of Tables	vi
1 Introduction	1
2 Theoretical Framework	2
2.1 Galaxy Clusters	2
2.2 Gravitational Lensing	4
2.3 IMF in BCGs	4
3 Observational Procedures	7
3.1 SExtractor	7
3.2 Galfit	7
3.3 Color images	7
4 Study of images	8
5 Conclusions	9
Bibliography	10

List of Figures

2.1	M	3
2.2	M	5

List of Tables

*Dedicated to my parents, whose love and support are my biggest
motivation. . .*

Chapter 1

Introduction

Science case

Galaxy Clusters

IMF is a very fundamental and important quantity in the study of stellar systems because it constraints the physics of star formation but also because it allows us to infer stellar masses through observed luminosities.

the correct use of an IMF in the context of gravitational lensing on massive objects like early type galaxies in galaxy clusters can help us constraint the amount of stellar mass and thus also infer the amount of dark matter in these systems.

Studying the amount of dark matter contribution, one could in principle make a good estimation of the stellar mass-to-light ratio.

For galaxies that are far away, it is impossible to make star counts, for this reason, the mass to light ratio of the stellar population provides a simple constraint on the IMF (Russell J. Smith and John R. Lucey)

Strong gravitational lensing of background galaxies provides a useful method to determine masses in elliptical galaxies, since it is difficult to constraint the IMF via M/L

massive galaxies - salpeter is a good IMF

A Kroupa IMF finds a value of gamma of around 4 for the mass to light ratio. (R. J. Smith 2014)

DM fraction in comparison with the IMF

Studying the matter distribution given by strong gravitational lensing can give us information about the IMF of the BCGs

Old stuff

mass to light ratio of 4

percentage of dark matter will allow me to define the IMF more precisely. I want to see what fraction of the mass, what fraction of the surface density is stars

make a plot of the mass as a function of the radius of the cluster

strong lensing at different radii is usefull.

if I got to certein radius I will have more dark matter, becaue light drops quickly.

given my scicne case, am I maybe too pesimistic? shjould I look inside the Eeinstin radius? we want to know what radius we should be looking at, for that we can make a plot for a cluster with typical parameters,

basically find how much dark matter and hoy many stars are there in the profile

first step, find the luminosity of the cluster

Chapter 2

Theoretical Framework

Tyter.

2.1 Galaxy Clusters

Glas.

dwarf stars contribute very little to the integrated light from an old stellar population (Smith 2015)

Galaxy clusters contain a population of stars gravitationally unbound to individual galaxies, yet still bound to the clusters overall gravitational potential, created by the stripping of stars from galaxies during interactions and mergers



FIGURE 2.1: G

The image of galaxy cluster MACS J1206.2-0847 (or MACS 1206) is part of a broad survey with NASA Hubble Space Telescope. The distorted shapes in the cluster are distant galaxies from which the light is bent by the gravitational pull of an invisible material called dark matter within the cluster of galaxies. This cluster is an early target in a survey that will allow astronomers to construct the most detailed dark matter maps of more galaxy clusters than ever before. These maps are being used to test previous, but surprising, results that suggest that dark matter is more densely packed inside clusters than some models predict. This might mean that galaxy cluster assembly began earlier than commonly thought.

Scientists are planning to observe a total of 25 galaxy clusters under a project called CLASH (Cluster Lensing and Supernova survey with Hubble). One of the first objects observed for the new census is the galaxy cluster MACS J1206.2-0847. This conglomeration of galaxies is one of the most massive structures in the universe, and its gigantic gravitational pull causes stunning gravitational lensing. MACS 1206 lies 4 billion light-years from Earth. In addition to curving of light, gravitational lensing often produces double images of the same galaxy. In the new observation of cluster MACS J1206.2-0847, astronomers counted 47 multiple images of 12 newly identified galaxies. The era when the first clusters formed is not precisely known, but is estimated to be at least 9

billion years ago and possibly as far back as 12 billion years ago. If most of the clusters in the CLASH survey are found to have excessively high accumulations of dark matter in their central cores, then it may yield new clues to the early stages in the origin of structure in the universe.

$$I(R)\sigma_p^2(R) = \frac{2}{\Gamma} \int_R^\infty \left(1 - \beta \frac{R^2}{r^2}\right) \frac{\nu \bar{v}_r^2 r dr}{\sqrt{r^2 - R^2}} \quad (2.1)$$

Whuster.

2.2 Gravitational Lensing

At small radii, stars dominate the lensing mass, so that lensing provides a direct probe of the stellar mass to light ratio, with only small corrections needed for dark matter.

In the paper of Russell Smith (a giant elliptical galaxy with a lightweight initial mass function) they find a stellar mass to light ratio of 3.01 plus minus 0.25

Modelling the lensing configuration provides the total projection mass within an aperture.

bulges have heavier IMFs than disks

Several recent studies have presented evidence for "heavyweight" IMFs in giant ellipticals, with a mass-to-light-ratio twice that of a Milky Way like IMF.

NFW profile for dark matter that is basically the dynamical mass of the cluster

2.3 IMF in BCGs

let's take the case of ABELL1068, it's magnitude in U is 21.94, in I is 18.46, in g is 20.09, in r is 19.5

the distance to the galaxy is 591.42857 Mpc

(but using the apparent magnitude and the distance, we get $L=2.9631e+9$

from the NASA webpage: $1.41e+45$)

salpeter mass function is $n(M) \propto M^{-2.3}$

the NFW density profile is

$$\rho(r) = \frac{\delta_c \rho_c}{(r/r_s)(1 + r/r_s)^2} \quad (2.2)$$

where the characteristic overdensity is:

$$\delta_c = \frac{200}{3} \frac{c^3}{\ln(1+c) - c/(1+c)} \quad (2.3)$$

from Munoz cuartas et. al. we see that the concentration parameter depends on the mass and the redshift as we see in the following plot:

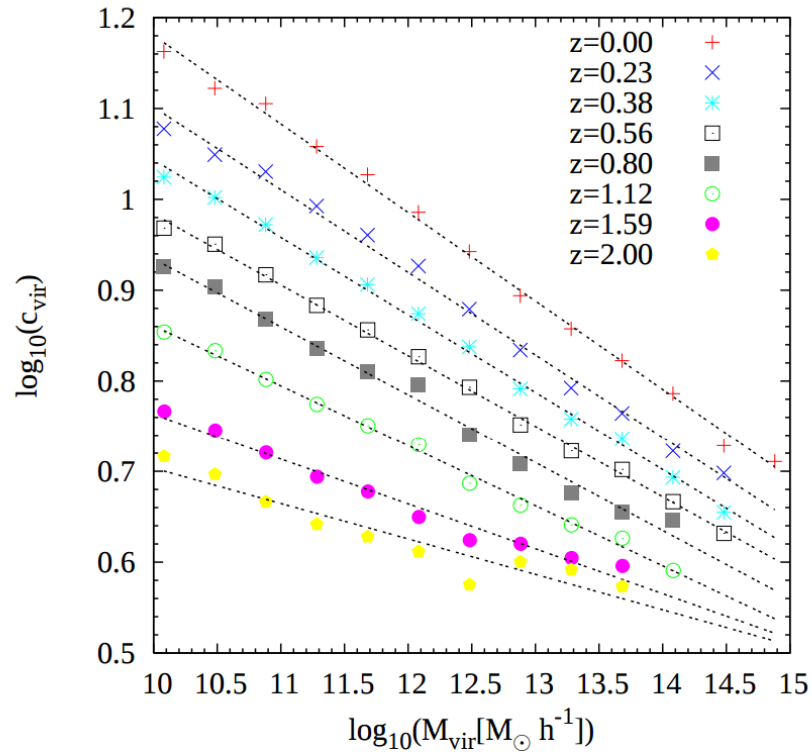


FIGURE 2.2: G

juank.png

(grafica de Juank)

then the concentration parameter for ABELL1068 is about 4.46

so from the critical density:

$$\rho_c = \frac{3H^2(z)}{8\pi G} \quad (2.4)$$

the critical density would be: $2\text{e-}26$ in SI units so in Msol/pc^3 it is 2.9×10^{-7}

$$H(z) = H_0(1 + \Omega z)^{3/2}$$

the hubble parameter at $z=0.138$ is $H(z)=85.6$

let's take a value of 40 kpc for the concentration parameter given by $r_s = r_{200}/c$

delta c is 6716.38 (dimensionless)

Chapter 3

Observational Procedures

the full description of the survey is in: D. J. Sand et. al. 2011

MegaCam wide field imager on the CFHT (Canada-France-Hawaii Telescope). The cluster sample consisted of 101 clusters within the range of redshifts from $0.05 < z < 0.55$

58 clusters from the MENEACs (Multi-Epoch nearby cluster survey)

The meneacs clusters represent all clusters in the BAX X-ray cluster database that are observable for the CFHT

the redshifts of the clusters as given by C. Bildfell et. al. 2012

g and r images

3.1 Sextractor

Stars and selection of galaxies

3.2 Galfit

3.3 Color images

In er.

Chapter 4

Study of images

We ter.

Chapter 5

Conclusions

Thes.

Bibliography

- [1] Treu, Tommaso. 2010 *Strong Lensing by Galaxies*. Annu. Rev. Astron. Astrophysics. 2010. 48:87-125.
- [2] R. F. J. Van der Burg et. al. 2015 *Evidence for the inside-out growth of the stellar mass distribution in galaxy clusters since $z\tilde{1}$* . preprint arXiv:1412.2137v2.
- [3] Binney J., Tremaine S. *Galactic Dynamics*. Princeton University Press, 1994.
- [4] C. O. Wright & Teresa G. Brainerd, Teresa. 1999 *Gravitational Lensing by NFW halos*. preprint arXiv:astro-ph/9908213v1.
- [5] Smith, Russell. 2014 *Variations in the initial mass function in early-type galaxies: a critical comparison between dynamical and spectroscopic results*. MNRASL 443, L69-L73 (2014).
- [6] C. Bildfell et. al. 2012 *Evolution of the red sequence giant to dwarf ratio in galaxy clusters out to $z\tilde{0.5}$* . MNRAS 425, 204-221 (2012).
- [7] Smith, Russell & Lucey, John. 2013 *A giant elliptical galaxy with a lightweight initial mass function*. MNRAS 000, 1-14 (2013).
- [8] R. J. Smith et. al. 2015 *The IMF-sensitive $1.14\text{-}\mu\text{m}$ Na I doublet in early-type galaxies*. MNRAS 000, 1-14 (2013).
- [9] C. Sifon et. al. 2015 *Constraints on the alignment of galaxies in galaxy clusters from $\tilde{14000}$ spectroscopic members*. A&A 575, A48 (2015).
- [10] S. M. Adams et. al. 2012 *The environmental dependence of the incidence of galactic tidal features*. The Astrophysical Journal, 144:128(11pp) (2012).
- [11] D. J. Sand et. al. 2011 *Intracuster supernovae in the multi-epoch nearby cluster survey*. The Astrophysical Journal, 729:142 (13pp) (2011).
- [12] J. C. Muñoz Cuartas et. al. 2010 *The redshift evolution of ΛCDM halo parameters: concentration, spin and shape*. MNRAS, 000,1-11 (2010).