# The Larger sample of Strong Lensing in Galaxy Cluster of RCS2

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## Abstract

***We are obtaining spectroscopy for a new large sample of strong gravitational lenses and lensed sources from the Red-Sequence Cluster Survey II (RCS2). We have obtained spectroscopy of 9 lensing clusters from a total sample of 33. For these 9 clusters, we obtained their total masses through their velocity dispersion. We have also obtained their masses using strong lensing models for 3 of these clusters. With these two masses we will study some inherent features of galaxy clusters in the early Universe. In future works we will obtain a better gravitational lensing model, with a more realistic potential of a galaxy cluster.***

## Introduction

Because galaxy clusters are the more massive and virialized structures in the universe, it is believed that their mass fraction (dark-luminous) is representative of the mass of the universe and for this reason they have played a central role in studies of cosmological parameters (Wu & Chiueh 2006) and large scale structure (Puchwein et al. 2006). The galaxy clusters are real laboratories for study galaxy evolution, due to their high galaxy density and the complexity of the observed phenomena, as the red sequence (Gladders et al. 1998).

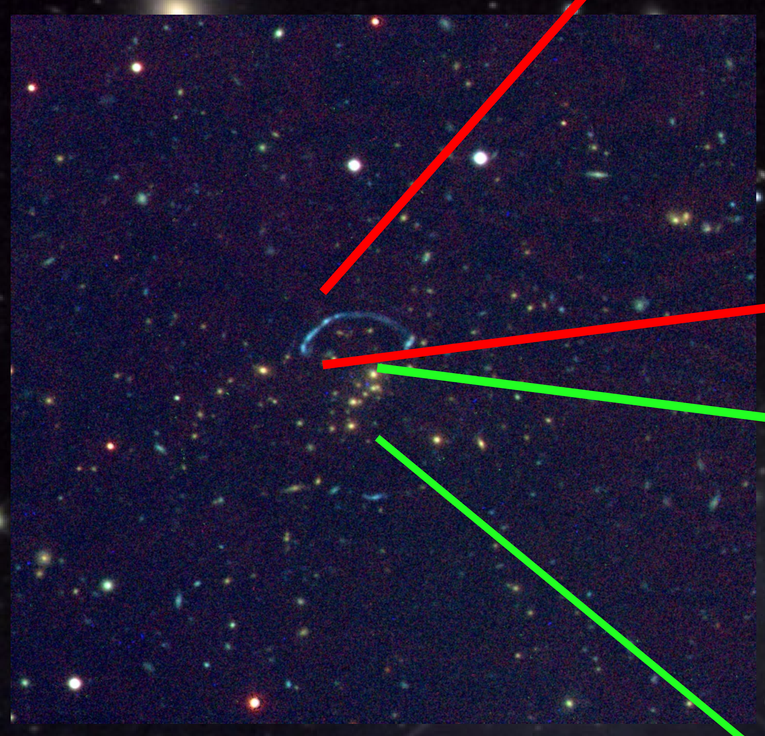
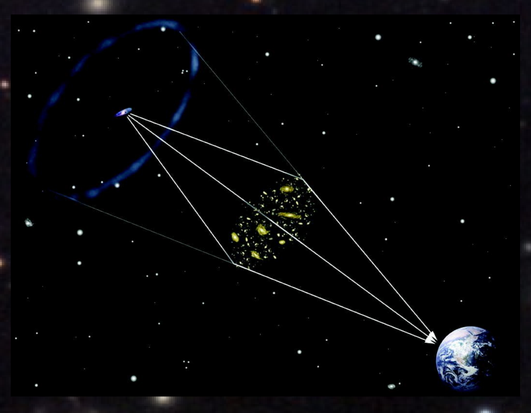


*Figure 1: Cluster RCS03101_1502 that is at a redshift of 0.561 ± 0.004. This cluster presents a bright large arc around of your center. This lensed galaxy is at a redshift of 1.7009 ± 0.0008!*

In this work we study the clusters of the Red Sequence Cluster SurveyII (RCS2), a survey of 1000 square degree with 3-band (grz) imaging, which is a subsample of the RCS I. This survey was created with the goal of studying high redshift clusters that act as strong lenses (SL) . When clusters behave this way, they are much more interesting objects, because they allow us to estimate the total mass of the cluster (dark and luminous) using strong lensing models (Schneider, Kochanek & Wambsganss, 2006, hereafter SKW06). Besides, the SL phenomena magnifies the light of the lensed galaxy and it is possible to study with more detail the characteristics of galaxies in the early universe.



## Sub-sample of RCS2

We have spectroscopic data MXU of 9 clusters of the RCS2 from a sub-sample of 50. These images MXU were taken in the 8 m VLT telescope, with the instrument FORS2 in the R filter, in Paranal Observatory, Chile. The main goal is to obtain the lensed galaxy spectra to calculate their redshift and try to characterize in the best way these lensed galaxies to construct a good lensing model and estimte the total mass of the cluster. This model is constructed assuming that the core of the clusters are isothermal spheres and the arcs are a projection of the Einstein's ring (SKW06). On the other hand, with these data we can have nearly 30 velocities of the individual galaxies in the cluster, which allows us to calculate the dynamical mass of the cluster using their velocity dispersion.

We also have spectroscopic data of 4 of these clusters that were observed in the 6 m Baade Telescope, with the instrument GISMO in IMACS f2, at Las Campanas Observatory, Chile (LCO). The main objective with these data is obtaining a significant higher number of velocities for each cluster (nearly 120 velocities per cluster) to obtain a better velocity dispersion and as a consequence a more realistic dynamical mass. Besides, with a higher number of velocities we can make a better statistical study of the galaxies in each cluster and obtain valuable information of galaxy clusters at high redshift.

## Results

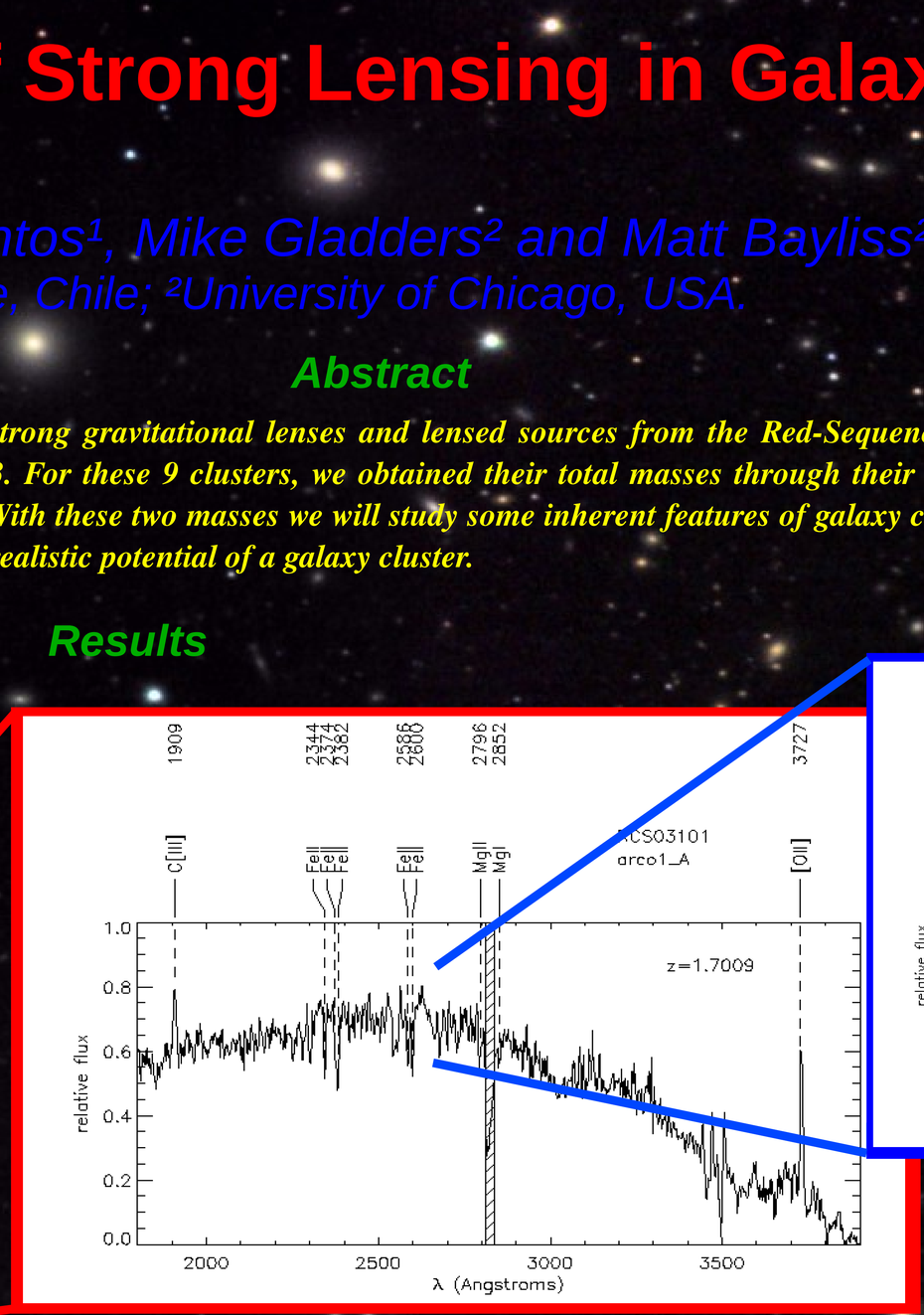



*Figure 2: Spectrum of the lensed galaxy in the cluster RCS03101_1502. This galaxy lies at a redshift of 1.7009 ± 0.0008.*

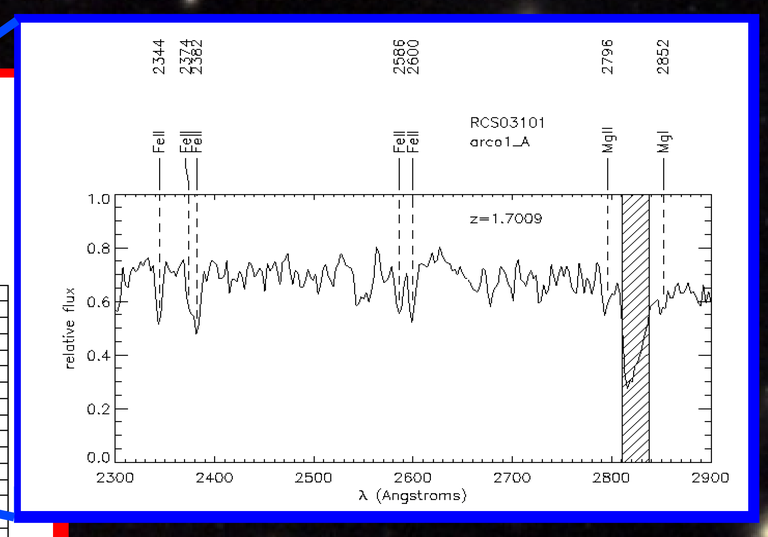



*Figure 3: Zoom of spectrum of the lensed galaxy in the cluster RCS03101_1502. This galaxy lies at a redshift of 1.7009 ± 0.0008.*

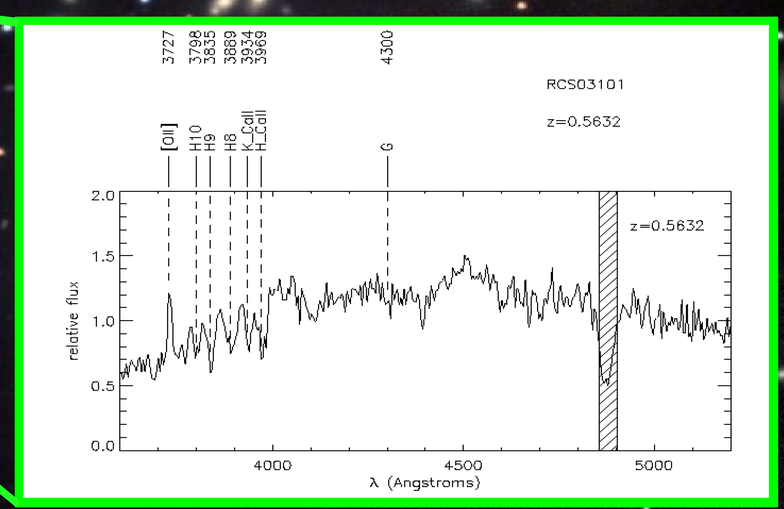



*Figure 4: Spectrum of a galaxy of cluster RCS03101_1502. The cluster is at a redshift of 0.561 ± 0.004.*

## Discussion

The masses that we found for the cluster's core are in agreement with the literature. The same is true for the virial masses obtained with the VLT. However, the lensing model that we used was to simple. The assumed potential is the one of an isothermal sphere and it is evident that a cluster potential is different from this.

The velocity dispersion obtained with the data of GISMO and a more sophisticated lensing model will help us to understand more about the early universe.

We have a lot of work to do!

*Current Basic Data For the Cluster Sample*

| Cluster | $z_{cum}$ | $z_{arc}$ | $\theta_{arc}$ ['] | Member | $M_{core}$ $[M_\odot]$ | $\sigma$ $[kms^{-1}]$ | $M_{dyn}$ $[M_\odot]$ |
|---|---|---|---|---|---|---|---|
| $RCS0310\_1502$ | 0.561 ± 0.004 | 1.7009 ± 0.0008 | 14.9 | 6 | $6.55\times10^{13}$ | 448 | $1.75\times10^{14}$ |
| $RCS0310\_2399$ | 0.270 ± 0.007 | 1.515 ± 0.005 | 7.2 | 19 | $0.72\times10^{13}$ | 946 | $7.80\times10^{14}$ |
| $RCS2329\_5295$ | 0.531 ± 0.007 | 1.5703 ± 0.0002 | 2.0 | 9 | $0.12\times10^{13}$ | 749 | $4.90\times10^{14}$ |
| $RCS0047\_1879$ | 0.723 ± 0.005 | 1.542 ± 0.003 | Pending | 4 | Pending | 858 | $6.41\times10^{14}$ |
| $RCS0047\_2527$ | 0.429 ± 0.005 | 0.7279 ± 0.0003 | Pending | 11 | Pending | 982 | $8.40\times10^{14}$ |
| $RCS0047\_4381$ | 0.385 ± 0.003 | 2.373 ± 0.004 | Pending | 21 | Pending | 745 | $4.84\times10^{14}$ |
| $RCS1515\_1020$ | 0.302 ± 0.005 | 0.7321 ± 0.0004 | Pending | 17 | Pending | 1142 | $11.4\times10^{14}$ |
| $RCS2143\_3766$ | 0.329 ± 0.005 | 3.074 ± 0.003 | Pending | 37 | Pending | 1215 | $12.9\times10^{14}$ |
| $RCS2329\_7418$ | 0.529 ± 0.004 | 1.4697 ± 0.0005 | Pending | 12 | Pending | 699 | $4.26\times10^{14}$ |
| $RCS2J21350102(*)$ | 0.3279 | 2.313 | 41.1 | 32 | Pending | 1258 ± 189 | $13.8\times10^{14}$ |
| $SDSSJ1531+3414(*)$ | 0.3342 | 1.096 | 10.2 | 21 | $66 \pm 27\times10^{13}$ | 1001 ± 255 | $8.73\times10^{14}$ |
| $SDSSJ1209+2640(*)$ | 0.5607 | 1.018 | 32.3 | 25 | Pending | 1193 ± 200 | $12.4\times10^{14}$ |
| $RCS2J03271325(*)$ | 0.5637 | 1.703 | 19.1 | 16 | $165 \pm 70\times10^{13}$ | 982 ± 88 | $8.4\times10^{14}$ |

*Table 1: This table presents the data of VLT for 9 cluster. In this work the cluster's core mass was calculated assumption that the center of the clusters are isothermal spheres and that the arcs are a projection of the Einstein's ring. On the other hand, the total mass of clusters was calculated with the virial theorem, assuming that cluster are virialized and that all they have a radii equal to 0.5 Mpc. Moreover, we also present data from LCO (*) for 4 clusters studied. The calculation of total mass was performed assuming the same as before. The lensing mass calculation was performed with a more complex model.*

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### Reference

Gladders, M., Lopez-Cruz, O., Yee, H., Kodama, T.,1998, ApJ,501,571.

Puchwein, E., Bartelmann, M., Dolag, K., & Meneghetti, M. 2005, A&A, 442, 405.

Schneider, P., Kochanek, C., Wambsganss, J., "Gravitational Lensing: Strong, Weak and Micro", Springer-Verlag (2006)

Wu, J. M., & Chiueh, T. 2006, ApJ, 639, 695