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# Lensing Survey of a Sample of X-ray Luminous Galaxy Clusters

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**Abstract**

We present a lensing survey of a sample of the most X-ray luminous galaxy clusters selected from the ROSAT Bright Survey (RBS). All clusters are located in the medium redshift regime and hence the probability for finding strongly lensed objects of background sources (gravitational arcs) very high. In these conference proceedings we present several lensing features in three clusters of this survey.

*Key words:* Galaxy clusters; X-ray luminous sample; lensing survey;

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## 1 Introduction

Since the first double imaged quasar was discovered in 1979 (Walsh et al. [1979]) gravitational lensing has become a very blooming branch of astrophysics. Nowadays there are diverse possibilities for application of lensing, e.g. detection of even planet sized objects via microlensing, mass determinations of the lenses themselves (in the weak/strong lensing regime) and even cosmology.
Our project is based on a unique, well defined sample of galaxy clusters which is necessary for the latter purposes. The clusters are the most X-ray luminous systems in the ROSAT Bright Survey (Schwope et al. [2000]). According to the $L_x$-$M$ cluster scaling relations (Reiprich et al.[1999], Schindler [1999]) all systems in our sample are assumed to be very massive. In addition, the medium redshift range was chosen, hence the probability for these clusters to contain lensing features like arclets or arcs is very high. Based on a similar large sample (selected from the EMSS) in a similar redshift range, Luppino et al. [1999] found lensing features in $\sim 42\%$ of all objects under study. Since our luminosity cutoff is even higher than this comparison sample, we expect an even higher fraction of lensing features in our samples.
The main goals of our project are: (a) determination of the mass distribution of the lensing clusters and comparison to X-ray observations, and (b) arc statistics (for example Bartelmann et al. [1998], Wambsganss et al. [2004]), which is a powerful tool to determine the inner slope of cluster profiles, which is still quite controversial (see Sand et al [2004] and references therein).

## 2 The Sample

All clusters were chosen from the ROSAT Bright Survey (henceforth RBS, Schwope et al. [2000]) with the following criteria: (a) classified as clusters, (b) no member of the Abell catalogue, (c) bolometric X-ray luminosity $L_x \geq 0.5 \times 10^{45}$ erg/sec in the 0.5-2keV band, (d) redshift range $0.1 \leq z \leq 0.52$ and, finally, (e) observability from La Silla/Paranal ($\delta \leq 20°$). The resulting 22 galaxy clusters were observed under good seeing conditions ($\leq 1$") in the R and V band either with the Wide Field Imager (WFI@ESO2.2m) or with the SUperb Seeing Imager 2 (SUSI2@ESONTT). One cluster (RBS1316 / RXJ 1347-1145) was observed in the U, B, V, R and I band at the ESO-VLT. All observations were done in Service Mode between August 2001 and April 2004. The data reduction was performed with the GaBoDS pipeline (Schirmer et al. [2003], Schirmer et al. [2004]), a software package, especially designed for mosaic imaging. The final image was used to extract object catalogues using SExtractor 2.3.2 at a $2\sigma$-detection level.
In these proceedings we present arc candidates of the clusters RBS325, RBS653

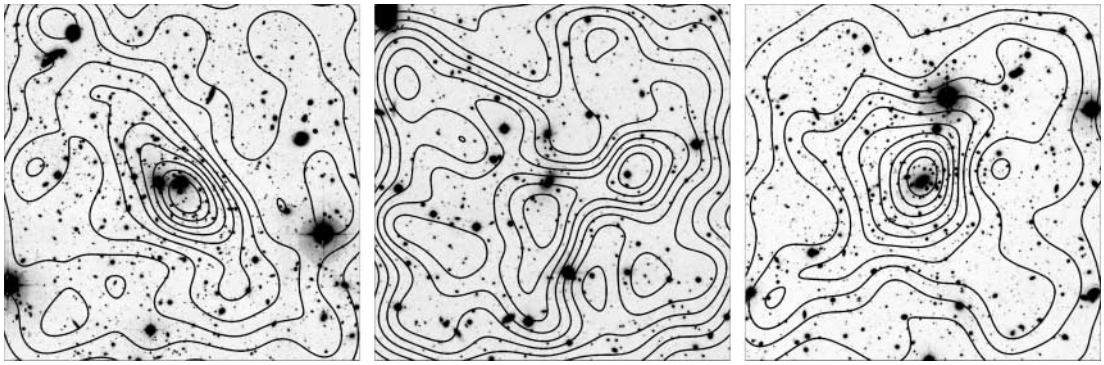

Fig. 1. R-band images of RBS325 (left), RBS653 (middle) and RBS864 (right). The Field of View is $\sim 6' \times 6'$ ($\sim 2 \times 2$Mpc) in all images. The contours show the galaxy number densities of the Red Sequence galaxies.

and RBS864, which were observed with the WFI@ESO2.2m. The used filters were BB#Rc/162_ESO844 and BB#V/89_ESO843 with twice the exposure time in R (4.46h) than in V. RBS653 was observed in both bands for 2.26h (see Tab. 1 for more details on the clusters).

## 3 Methods

For establishing catalogues of the objects we used SExtractor 2.3.2. Galaxies are all objects with CLASS_STAR parameter $< 0.95$ and a seeing dependent FLUX_RADIUS $> 2.8/2.7$, $3.5/2.9$ and $3/3$ pixels for RBS325 (R/V), RBS653 (R/V) and RBS864 (R/V), respectively. The galaxy density plots in Fig. 1 are derived by creating a blank image of $1500 \times 1500$ pixel image (corresponding to a FOV of $\sim 6 \times 6$ arcmin), allocating pixel value "1" to all positions of Red Sequence galaxies and a subsequent smoothing with a gaussian of 300 pixels. The Red Sequence galaxies are derived from color-magnitude ((V-R) vs. R) diagrams, the magnitudes are obtained using MAG_AUTO. The length of an arc given in Tab. 1 is the chord between the pixels with largest distance.

## 4 Preliminary Results

RBS325 and RBS653 seem to undergo a current merging process. This is indicated by the galaxy density plots shown in Fig. 1, which are extracted from the Red Sequence galaxies. In these plots several substructures, which indicate infalling subclusters can be seen. In addition, the optical and X-ray center of RBS653 differ by $\sim$ 40 arcsec (Schwope et al. [2000]), which is a further indication for such a merging process.
RBS864 is the cluster with a very massive massive cooling flow (Edge et al.

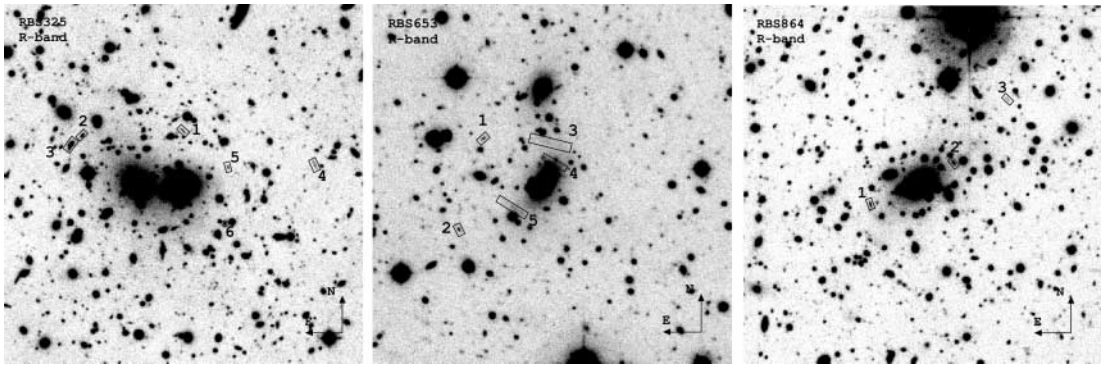


Fig. 2. R-band images of the three clusters. The Field of View is $\sim$ 3×3 arcmin ($\sim$1×1Mpc, assuming $H_0$ = 75km/s/Mps), North is up, East to left. The arc candidates are numbered (see table 2 for more details).

| cluster | $\alpha$ | $\delta$ | z | log($L_x$) [erg/sec] | $R_{lim}$ | $V_{lim}$ |
|---|---|---|---|---|---|---|
| RBS325 | 02 32 16.4 | –44 20 48 | 0.282 | 44.8 | 25 | 25 |
| RBS653 | 05 28 52.7 | –39 28 18 | 0.286 | 44.9 | 25 | 24.5 |
| RBS864 | 10 23 39.6 | +04 11 10 | 0.2906 | 45.3 | 25 | 25 |

Table 1
Summary of the cluster properties. All data are taken from Schwope et al. [2000], $R_{lim}$ and $V_{lim}$ denote the limiting magnitudes of the final images.

[1994]), hence the galaxy density plot in Fig. 1 shows no major fluctuations. All three clusters show distinct lensing features (see table 2 for more details). RBS325 contains five arc candidates and one very red object (#6), which might be a highly magnified very distant object. RBS864 shows three such candidates, two on opposite sides of the elliptical central galaxy (#1 and #2) and one far outside in a distance of the cluster center given in the ROSAT Bright Survey of about $\sim$ 62 arcsec (#3).
The most remarkable cluster of this sample is RBS653. Apart from two arclets in a distance of 40 arcsec (#1) and 50 arcsec (#2) it shows three giant arcs, denoted with #3, #4 and #5. Object #3 is located in a distance $D$ of roughly $\sim$21 arcsec with a length $L$ of $\sim$16 arcsec, #4 has a distance from the cluster center of about $\sim$10" arcsec and a length of roughly 7 arcsec and #5 has a $D$ $\sim$20 arcsec with $L$ $\sim$9 arcsec.

## 5 Summary

We presented the first three clusters of a sample of 22 members. All clusters show distinct lensing features which are now to be confirmed by either spectroscopic or photometric redshift determination. These are very promising first results of our project.

| cluster number | # of object in Fig.2 | Dist. to cc [arcsec] | Dist. to cc [kpc] | length [arcsec] | R [mag] | V [mag] |
|---|---|---|---|---|---|---|
| RBS325 | 1 | 27 | 14.7 | 4 | 23.6 | 23.7 |
| | 2 | 55 | 30.1 | 2.5 | 22.9 | 23.6 |
| | 3 | 60 | 32.8 | 5 | 21.7 | 21.8 |
| | 4 | 65 | 35.5 | 5 | 23.5 | 24.4 |
| | 5 | 24 | 13.1 | 2.5 | 24.3 | 24.8 |
| | 6 | 28 | 15.3 | – | 24.3 | 24.3 |
| RBS653 | 1 | 40 | 22.2 | 3 | 23.4 | 23.4 |
| | 2 | 50 | 27.7 | 3 | 23.0 | 23.3 |
| RBS864 | 1 | 27 | 15.2 | 3.5 | 22.6 | 24.8 |
| | 2 | 20 | 11.3 | 4 | 21.5 | 21.4 |
| | 3 | 62 | 35 | 3.5 | 24.6 | – |

Table 2
summary of the arc properties. "cc" denotes the optical cluster center, given in Schwope et al. [2000], usually the position of the central galaxy.

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