

# THE GALAXY CLUSTER RBS380: X-RAY AND OPTICAL ANALYSIS

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**Abstract** We present X-ray and optical observations of the  $z=0.52$  galaxy cluster RBS380. This is the most distant cluster in the ROSAT Bright Source catalog. The cluster was observed with the CHANDRA satellite in September 2000. The optical observations were carried out with the NTT-SUSI2 camera in filters V and R in August and September 2001. The preliminary conclusions are that we see a very rich optical galaxy cluster but with a relative low X-ray luminosity. We also compare our results to other clusters with similar properties.

## 1. Introduction

The galaxy cluster RBS380 was observed with NTT-SUSI2 as part of a programme to search for gravitational arcs in X-ray bright clusters of galaxies. We selected the most X-ray luminous clusters from the ROSAT Bright Survey (Schwope et al. 2000), which have a predicted probability for arcs of 60%. RBS380 is the most distant cluster of this sample and is therefore the first one that we analyse. In a parallel programme several of these clusters are observed in X-rays with CHANDRA. The aims of the project are threefold. One aim is to compare mass determinations by the gravitational lensing method and the X-ray method. A second aim is to perform arc statistics to constrain cosmological models. A third aim is to study in detail the distant background galaxies that are magnified by the gravitational lensing effect.

## 2. Observations and Data Reduction

### 2.1 Optical Data

The galaxy cluster RBS380 was observed with the New Technology Telescope (NTT) in service mode during the Summer 2001. The Superb Seeing Imager-2 (SUSI2) camera was used in bands V and R. The SUSI2 detector is a 2 CCDs array, each with  $1024 \times 1024$  pixels, subtending an area on the sky of  $5'.5 \times 5'.5$ .

The data reduction was performed with the IRAF package. A total number of 6 images with very good seeing conditions ( $\leq 1''$ ) were used in the analysis, with an exposure time of 760 sec each. After bias subtracting, the flatfielding cannot be done in a standard way. A hyper-flat (Hainaut et al. 1998) was built using both the twilights flats set and the night-sky (scientific) images set. The twilights correct very well the high spatial frequencies in the field, whereas from the scientific images one obtains the low spatial frequencies correction. We found that a simple linear combination of the two final flats (one from the twilight flats and the other from the scientific images) was enough for producing a high quality final one. Of course, the procedure has to be done for each filter.

Once the images were flatfielded, they were co-added, obtaining a deep image of the field and free of gaps between the chips (this was possible due to the dithering between the exposures).

### 2.2 X-ray Data

The RBS380 cluster was observed in October 17, 2000 by the CHANDRA X-ray Observatory (CXO). A single exposure of 10.3 ksec (3 hrs) was taken with the Advance CCD Imaging Spectrometer (ACIS). Only the  $2 \times 2$  arrays ACIS-I chipset was active. Each CCD is a  $1024 \times 1024$  pixels array. The pixel resolution is  $0''.5$ , covering a total area on the sky of  $17' \times 17'$ .

The data were processed with the CIAO suite toolkit provided by the CXC. We upgraded the gainmaps, checked the correction for the aspects offsets and removed bad pixels from the field (using the files provided by the CXC). Then we built the lightcurve for the observing period, looking for short high backgrounds intervals, but finding none.

Since we are interested in diffuse emission, the first step is removing the point sources present. We used the *wavdetect* subroutine to detect them. We applied it to a broadband (0.3-10 keV) image. We found 29 sources, expecting none to be spurious. After removing the sources, we filled the holes using the same counts distribution of background pixels for that

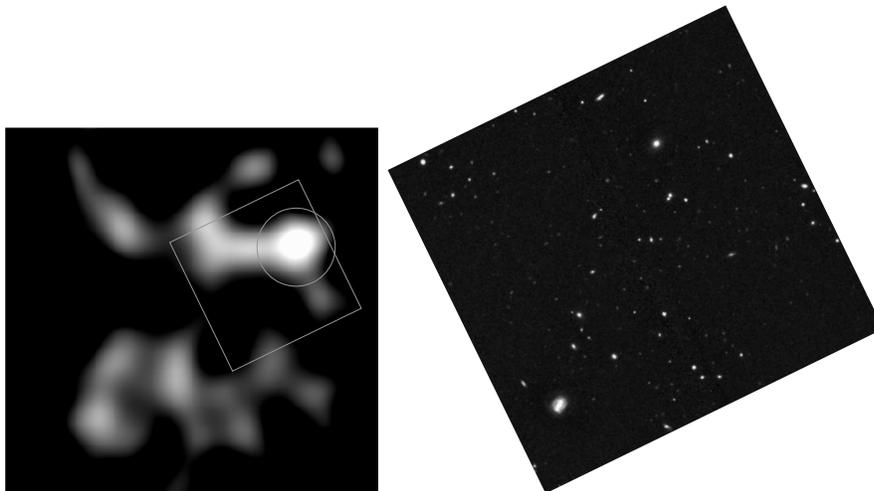
region.

The correction for telescope vignetting and variations in the spatial efficiency of the CCDs was done by means of an exposure map. The exposure map was generated for a integrated energy distribution peak of 0.7 keV. Background correction was also applied by using the sets provided by the CXC.

### 3. Results

The preliminary results show optical R and V images with a high number density of galaxies. The right side of Fig. 1 shows the final R band image. So far no gravitational arcs have been detected. On the left side of Fig. 1 we present the results in X-ray. We selected a circular region of radius  $1'.5$  centred at the peak of the emission. We obtain a count rate of 0.05 counts/s in the encircled region, where most of the cluster emission is supposed to be. The derived X-ray luminosity is  $L_X = 1.06 \cdot 10^{44}$  erg/s. This is a relatively low X-ray luminosity for a massive cluster of galaxies.

Furthermore, the structure found in the X-ray emission is not perfectly



*Figure 1.* *Leftside:* X-ray image of the cluster. The total area is  $14' \times 14'$ . The rotated square shows the region that was observed in the optical band. The circle has a radius of  $1'.5$ , the area where we computed the count rate. *Rightside:* The optical counterpart of the selected region. The total area is  $5' \times 5'$ . Although the number density of galaxies seems to be high, no gravitational arcs were detected. In both panels North is up and East is left.

symmetrical, but presents extended emission to both sides of the main region. This could mean that the cluster is not relaxed, but rather

Name	Redshift	Luminosity [erg/s]	band
Cl0500–24	0.32	$5.6 \cdot 10^{44}$	bolometric
Cl0939+4713	0.41	$7.9 \cdot 10^{44}$	bolometric
RBS380	0.52	$1.06 \cdot 10^{44}$	[0.3-10] keV

*Table 1.* We compare the X-ray luminosity of RBS380 with two more clusters of galaxies which are also optically rich, but have relatively low X-ray luminosity.

interacting with surrounding material or another close cluster. This is point that merits more attention indeed.

#### 4. Conclusions

A clear correlation between optical richness and X-ray luminosity is not yet well established. Although it is in general assumed that a high number density of galaxies should imply a great amount of intergalactic hot gas, there are few cases in the literature that show little correlation between these two facts. In particular, Cl0500–24 and Cl039+4713 are two interesting cases (Schindler & Wambsganss 1996, 1997; Schindler et al. 1998). In Table 1 we show the X-ray luminosities of the three clusters.

Since we are presenting preliminary results, we have not fully analysed the optical images of RBS380. In a forthcoming paper we will build a catalogue of objects in the field. With such a catalogue we will be able to establish what are the galaxies that belong to the cluster and get a precise number density map.

#### Acknowledgments

This work has been partly supported by a predoctoral Marie Curie Fellowship to RGM at the Liverpool John Moores Astrophysics Institute (HPMT-CT-2000-00136). We specially thank Betty De Filippis and Africa Castillo for many useful discussions and time-sharing. We also thank Olivier Hainaut for detailed explanations on hyper-flatfielding.

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