The ROSAT-ESO flux limited X-ray galaxy cluster survey (REFLEX II)[★]

I. Newly identified X-ray luminous clusters at $z \geq 0.2$

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ABSTRACT

We report 19 intermediate redshift clusters newly detected in the ROSAT All-Sky survey that are spectroscopically confirmed. They form a part of 911 objects in the REFLEX II cluster catalogue with a limiting flux of 1.8×10^{-12} erg/s/cm² in the 0.1–2.4 keV ROSAT band at redshift $z \geq 0.2$. In addition we report three clusters from the REFLEX III supplementary catalogue, which contains objects below the REFLEX II flux limit but satisfies the redshift constraint above. These clusters are spectroscopically followed-up by our ESO NTT-EFOSC2 campaigns for the redshift measurement. We describe our observing and data reduction methods. We show how X-ray properties such as spectral hardness ratio and source extent can be used as important diagnostics in selecting galaxy cluster candidates. Physical properties of the clusters are subsequently calculated from the X-ray observations. This sample contains the high mass and intermediate-redshift galaxy clusters for astrophysical and cosmological applications.

Key words. X-rays: galaxies: clusters – galaxies: clusters: general – galaxies: distances and redshifts

1. Introduction

Galaxy clusters are the largest well-defined objects in our Universe characterized by a dynamical equilibrium configuration (e.g. Navarro et al. 1995). They form an integral part of the cosmic large-scale structure and are ideal probes for the testing of cosmological models (e.g. Allen et al. 2011). However, they are also astrophysical superlatives in many respects causing the largest deflections as gravitational lenses (e.g. Schneider et al. 1992), major mergers of galaxy clusters during the large-scale formation constituting the most energetic events in the Universe apart from the big bang (Sarazin 2002), and imprinting a distinct frequency-dependent feature onto the cosmic microwave background by means of the Sunyaev-Zel'dovich effect (Sunyaev & Zel'dovich 1970). Therefore, they are extremely interesting astrophysical laboratories to study various important processes on very large scales.

With technological advances in the past few decades, the detection of an increasing number of galaxy clusters has enabled us to study their properties in detail, and to apply the statistics of the cluster population to a number of cosmological studies.

One of the most efficient methods for detecting galaxy clusters as truly gravitationally bound objects in a close to mass-selected way is the use of X-ray surveys (Böhringer 2008). In these surveys galaxy clusters are observed as extended X-ray sources owing to the thermal X-ray emission of the very hot intracluster medium (ICM).

The largest sample of X-ray luminous galaxy clusters to date is the one that has been identified in the ROSAT all-sky Survey (RASS), the only all-sky X-ray survey yet conducted

with an imaging X-ray telescope (Trümper 1993). The southern REFLEX I (Böhringer et al. 2004) and northern NORAS I (Böhringer et al. 2000) cluster samples identified in the RASS representing a total of 996 X-ray detected galaxy clusters provide the largest X-ray catalogue compiled, where the REFLEX survey has the most well-understood three-dimensional survey selection function.

With the completion of two recent spectroscopic observing campaigns, we have almost completed the REFLEX II survey by adding 50–60 newly determined redshifts. The REFLEX II survey effectively doubles the number of galaxy clusters from 447 to 911 objects.

The most massive galaxy clusters provide the tightest constraining power for cosmological model testing and are also the most interesting astrophysical laboratories. We therefore communicate here the detailed properties of 22 of the most massive and highest redshift clusters ($z \geq 0.2$) among the sample of 50–60 X-ray detected clusters with newly determined redshifts from our recent observing campaigns. Our major aim in this paper is to communicate the data of newly discovered X-ray luminous clusters and most importantly to provide the redshift information for all the cluster galaxies with new redshift measurements, so that they can enter public data bases (e.g. NED, SIMBAD) and be used by the community.

In this paper, we provide a brief description of REFLEX II and the present cluster sample in Sect. 2. Our optical observations and data reduction is outlined in Sect. 3 and in Sect. 4 the X-ray properties and their use as the diagnostics of the nature of the sources are described. In the latter section we also provide some comments on individual clusters. Section 5 then provides a summary and some conclusions about the application of these findings.

[★] Based on the data obtained at the European Southern Observatory, La Silla, Chile.

Fig. 1. Luminosity-redshift plot of the REFLEX II cluster catalogue. The limiting flux is 1.8×10^{-12} erg/s/cm² in the 0.1–2.4 keV ROSAT band. The blue filled circles are the 19 clusters in the REFLEX II catalogue, and the 3 open circles below the flux limit are the clusters in the REFLEX III supplementary catalogue with $z > 0.2$.

2. Description of the cluster sample

The galaxy clusters of the present sample are the last galaxy cluster candidates of the REFLEX II catalogue for which a final confirmation and redshift measurement was obtained in the last year. The REFLEX II sample as a whole extends the flux limit of REFLEX I from 3×10^{-12} erg/s/cm² to 1.8×10^{-12} erg/s/cm² in the 0.1–2.4 keV ROSAT band. This flux limit was imposed on a fiducial flux calculation assuming cluster parameters of 5 keV for the ICM temperature, a metallicity of $0.3 Z_{\odot}$, a redshift of $z = 0$, and an interstellar hydrogen column-density according to the 21cm measurements of Dickey and Lockman (1990). This fiducial flux was calculated independent of (prior to) any redshift information and is therefore somewhat analogous to an extinction-corrected magnitude limit without K-correction in optical astronomy. We then calculated the true fluxes and luminosities by taking an estimated ICM temperature from the X-ray luminosity-temperature scaling relation (Pratt et al. 2009) and redshifted spectra into account.

Fluxes were measured by adopting a growth curve analysis in an aperture maximising the signal. The flux values were then corrected to an aperture of r_{500}^1 by estimating mass based on the luminosity-mass relation of Pratt et al. (2009) in an iterative way.

The total count rates, from which fluxes and luminosities were determined, were derived with the growth curve analysis (GCA) as described in Böhringer et al. (2000). The cluster candidates were compiled from a flux-limited sample of all sources in the RASS analysed by the GCA method, combining all information on the X-ray detection parameters, visual inspection of available digital sky survey images, properties in the NASA extragalactic database², and other available images at optical or X-ray wavelength. In addition, we cross-correlated our data with publicly available SZ catalogues from large surveys such as *Planck*, SPT, and ACT. For a detailed description

of the construction of the REFLEX II galaxy cluster catalogue, we refer to Böhringer et al. (in prep.).

The current cluster sample, comprising 19 objects, was selected from among the clusters of the REFLEX II sample confirmed by means of follow-up in 2010–2011 at redshifts above $z \geq 0.2$, and the remaining three objects were confirmed from the data taken in 2004. These clusters have luminosities in the range $L_X = 1.6\text{--}13 \times 10^{44}$ erg/s and estimated masses (based on Pratt et al. 2009) of $M_{500} = 2.3\text{--}7.8 \times 10^{14} M_{\odot}$, and cover the redshift range $z = 0.2\text{--}0.33$. Figure 1 shows the X-ray luminosity and redshift distribution of the REFLEX II cluster sample and the newly confirmed 19 clusters and 3 supplementary clusters in comparison. The newly added cluster which has an exceptionally high luminosity is RXCJ1914.5–5928. Table 1 lists optical properties, and the essential X-ray properties of the galaxy clusters are found in Table 2. For the derivation of distance-dependent parameters, we use a flat cosmology with $\Omega_m = 0.3$, $h_{70} = H_0/70$ km/s/Mpc.

3. Optical spectroscopic data

3.1. Observations

A more accurate determination of physical parameters is possible for spectroscopically confirmed clusters than for those with photometric redshifts, which usually have larger errors. In addition, a well-observed redshift sample of cluster members probes the dynamical state of a cluster that can be studied with the galaxy velocity dispersion within the system.

With this in mind, REFLEX and some NORAS clusters have been spectroscopically followed-up since 1992 with the EFOSC1/2 instruments. The 19 cluster data presented in this paper is based on two spectroscopic observing campaigns, 085.A-0730(A) and 086.A-0055(A), during five nights each in September 2010 and March 2011 with the EFOSC2 instrument at the New Technology Telescope (NTT) in La Silla. The additional three clusters are from observations in 2004 with the EFOSC2 instrument at the ESO 3.6 m telescope in La Silla.

Where possible, the multi-object spectroscopy (MOS) mode of EFOSC2 was used, and in some cases if a visual inspection of the pre-imaging data identified a clear BCG, we used a single long-slit (LS) observation on the BCG with at least one other member of the cluster. The different observing modes are marked in Table 1, which also lists the redshifts from the spectroscopic observations.

Each field of our candidate clusters was optically imaged in Gunn r band around the X-ray centre for the target selection and the mask making. The imaging resolution is 0.12×0.12 arcsec², and the field of view is 4.1×4.1 arcmin² for both imaging and spectroscopic observations. When necessary, the field was rotated to help optimise target selection. We used the grism that covers the wavelength range between 4085 Å and 7520 Å with 1.68 Å per pixel at resolution 13.65 Å per arcsec. We used slitlets with a fixed width of 1.5 arcsec for the MOS and of 2.0 arcsec for the long-slit observations.

Including at least three bright objects, preferably stars, to orient the field, the slitlets were allocated to the candidate member galaxies. Typically ten slitlets per field were punched onto one mask. Owing to the instrumental set-up, a maximum of five MOS plates can be loaded per night. The typical exposure time for the clusters in this paper ranges from 1500 to 2000 s per exposure, whose variation also reflects the observing conditions. The seeing was on average around one arcsec for most of the observations.

¹ Defined as the radius where the mean cluster mass density is 500 times the critical density of the Universe at the epoch at which the cluster is observed.

² The NASA/IPAC Extragalactic Database (NED) is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Table 1. Optical properties of all clusters studied.

Cluster (1)	Alt. name (2)	RA (3)	Dec (4)	z (5)	Δz (6)	N_{gals} (7)	Observing mode (8)
RXCJ0052.4-5746		13.1093	-57.7806	0.2559	2.37	3	MOS
RXCJ0129.4-6432		22.3730	-64.5409	0.3264	1.98	6	MOS
RXCJ0139.5-2629		24.8888	-26.4886	0.2445	1.56	4 B	LS
RXCJ0343.5-7152		55.8775	-71.8764	0.2136	1.61	3	MOS
RXCJ0347.4-2149	A3168	56.8724	-21.8224	0.2399	1.77	5	MOS
RXCJ0425.5-0045	ZwCl0423.2-0053	66.3798	-0.7577	0.2240	1.75	6	MOS
RXCJ0521.4-2754		80.3581	-27.9065	0.3175	2.79	2 B	LS
RXCJ1253.8-2622	A1633	193.4682	-26.3828	0.2179	1.65	9 B	MOS
RXCJ1617.6-0714		244.4099	-7.2446	0.2523	2.36	3 B	MOS
RXCJ1914.5-5928	PLCKG337.1-26.0	288.6333	-59.4767	0.2636	1.74	4	MOS
RXCJ2006.4-1912		301.6046	-19.2106	0.2769	1.83	4	MOS
RXCJ2041.2-1324		310.3188	-13.4149	0.3311	2.11	5 B	MOS
RXCJ2049.9-3029	A3715	312.4885	-30.4926	0.2088	1.55	3	MOS
RXCJ2126.1-3202	AS0946	321.5441	-32.0338	0.2797	1.66	2 B	MOS
RXCJ2149.0-3228		327.2524	-32.4744	0.2326	1.94	4	MOS
RXCJ2149.9-1859		327.4500	-19.0050	0.2836	3.64	2 B	LS
RXCJ2308.3-0155		347.0873	-1.9210	0.3047	2.07	4	MOS
RXCJ2317.9-3534	A3989	349.4828	-35.5794	0.2041	2.04	3	MOS
RXCJ2351.0-1954		357.7703	-19.9132	0.2477	1.90	2	MOS
RXCJ1013.1-1641		153.2794	-16.6884	0.2240	2.00	3	LS
RXCJ1023.2-0636	A1001	155.8268	-6.6046	0.2544	1.06	3	LS
RXCJ1355.6-2623	A1816	208.9334	-26.3833	0.2035	1.43	5	MOS

Notes. (1) RA and Dec for J2000 in degrees. (2) The centre of RXCJ1914.5-5928 is 4.3 arcmin away from that of PLCKG337.1-26.0. There are three different redshifts associated with this *Planck* cluster (Planck collaboration 2011a, 2011b). We take the redshift of the component with the largest contribution to the Fe line at 0.26 in the Table 2 of Planck Collaboration (2011b). (6) Errors in units of 10^{-4} (7) Number of galaxies with concurrent redshifts, B indicates when the BCG redshift is available. LS marks the redshift obtained from a single long-slit observation. The last three entries are based on the observation in March 2004 with the EFOSC2 instrument, which forms part of the REFLEX III supplementary catalogue.

Table 2. X-ray properties of the sample clusters.

Cluster (1)	Count rate (2)	F_X (3)	L_X (4)	$L_{X,r500}$ (5)	Error (6)	r_{500} (7)	Ext (8)	N_H (9)	HR (10)	KS prob (11)
RXCJ0052.4-5746	0.090	1.86	3.33	3.26	28.9	0.988	6.5	3.40	0.96	1.4
RXCJ0129.4-6432	0.090	1.80	5.46	5.14	42.1	1.043	8.0	2.24	0.50	3.7
RXCJ0139.5-2629	0.069	1.96	3.19	3.02	30.4	0.985	8.5	1.49	0.24	2.0
RXCJ0343.5-7152	0.108	2.34	2.82	2.66	20.4	0.980	9.5	5.31	0.76	3.3
RXCJ0347.4-2149	0.153	3.11	4.80	4.41	20.3	1.070	13.0	2.83	0.59	5.0
RXCJ0425.5-0045	0.087	1.94	2.60	2.53	24.1	0.959	7.0	6.38	0.32	3.6
RXCJ0521.4-2754	0.100	1.98	5.62	5.45	29.5	1.055	6.5	1.77	0.66	1.9
RXCJ1253.8-2622	0.100	2.25	2.84	2.73	58.8	0.979	8.0	6.80	1.00	1.9
RXCJ1617.6-0714	0.073	1.89	3.28	3.32	26.0	0.987	5.5	12.45	0.63	2.2
RXCJ1914.5-5928	0.320	7.07	13.16	12.60	20.0	1.285	9.0	5.82	0.68	4.2
RXCJ2006.4-1912	0.076	1.73	3.68	3.58	52.6	0.995	6.5	7.22	1.00	0.6
RXCJ2041.2-1324	0.093	1.94	6.05	5.66	18.3	1.061	8.5	3.65	0.86	1.4
RXCJ2049.9-3029	0.087	1.92	2.23	2.21	38.0	0.939	6.5	6.16	0.80	2.1
RXCJ2126.1-3202	0.099	2.11	4.56	5.49	25.0	1.036	3.5	4.54	1.00	0.1
RXCJ2149.0-3228	0.075	1.49	2.19	2.14	36.0	0.922	6.5	2.09	0.28	0.5
RXCJ2149.9-1859	0.151	3.12	6.94	6.74	22.0	1.121	7.0	3.35	-0.04	2.1
RXCJ2308.3-0155	0.089	1.88	4.91	4.72	22.5	1.035	7.0	4.29	1.00	5.2
RXCJ2317.9-3534	0.101	1.98	2.19	2.17	59.4	0.938	6.5	1.69	0.18	0.6
RXCJ2351.0-1954	0.133	2.61	4.33	4.09	19.5	1.045	9.0	1.50	0.50	3.2
RXCJ1013.1-1641	0.071	1.54	2.07	1.95	18.3	0.917	9.0	5.36	0.90	0.1
RXCJ1023.2-0636	0.067	1.43	2.53	2.84	19.4	0.938	4.0	4.65	0.94	1.5
RXCJ1355.6-2623	0.071	1.53	1.67	1.63	43.7	0.890	7.0	5.02	0.69	1.2

Notes. (2) In s^{-1} . (3) In units of $10^{-12} \text{ erg/s/cm}^2$ in [0.1–2.4] keV band measured in the aperture. Column (4) L_X in 10^{44} erg/s in [0.1–2.4] keV band in the aperture. (5) L_X in 10^{44} erg/s in [0.1–2.4] keV band measured in r_{500} . (6) Error in percentage. (7) r_{500} in Mpc. (8) Source extent in arcmin. (9) N_H in units of 10^{-20} cm^{-2} . (10) Hardness ratio defined as $\text{HR} = (\text{H-S})/(\text{H+S})$ where H is the count rate in the hard band (0.5–2 keV) and S in the Soft band (0.1–0.4 keV). (11) -log probability of the Kolmogorov-Smirnov test.

3.2. Data reduction

We reduced the data using the standard reduction pipeline of IRAF. The reduction scheme is briefly summarised below, which applies equally to MOS and single-slit data.

Bias correction. The CCD frames were visually inspected and trimmed at all edges of the images. All bias frames of a similar mean in each run were combined to reduce the rms fluctuations in the master bias, which was then subtracted from the science images.

Flatfielding. Unlike the bias that is an additive correction, the flatfielding corrects the multiplicative spatial variations. The correction includes the varying quantum efficiency manifested as the structural variations in the CCD, and vignetting. We combined all dome flats for the combination of our slit, grism, and filter as described in the previous subsection. The spectrum of the quartz lamp was then fitted with a cubic spline function, and normalised. All spectroscopic exposures were then divided by the resulting response frame.

Extracting the spectra. After the bias and flatfield corrections, the two science spectra were combined and weighted using IMCOMBINE, which also removes the cosmic-ray events. We used APALL in IRAF to extract the spectra. The one-dimensional collapsed spectra were sky-background subtracted by using the sky region on both sides of an object spectrum as a background estimate. The calibration spectra, which are two He-Ar frames were also extracted from the same spatial position as the science spectra.

Wavelength calibration. We identified at least 4–5 known lines in the He-Ar lamp spectrum to fit the wavelength as a function of pixel number with an rms of far smaller than $1 \text{ \AA}$ where the corresponding rms of the long-slit observation is larger owing to the larger slit width. The procedure was performed with the IDENTIFY and REIDENTIFY packages.

Astrometric correction. The optical image taken during the spectral observation does not contain sky coordinates. The first guess was taken from the pointing directions used for the telescope, and the image was then astrometrically corrected for based on the accurate location of a number of identified objects in a public optical catalogue.

3.3. Redshift determination

The calibrated spectra undergo several corrections such as sky-line removals, a heliocentric correction, and emission line removals before the redshift determination. The redshifts from the emission lines are determined separately after the correlation with the passive galaxy templates, hence we removed them for this step. We then use the RVSAO package, which applies the cross-correlation technique to the input templates of galaxy spectra to measure the object redshift. The REFLEX I templates were used for this analysis, which include 17 galaxy and stellar templates (Guzzo et al. 2009). In essence, the method uses the fast fourier transform to construct the correlation function of the input spectrum together with the template, after filtering to remove the spurious components and binning noise. The significance of the correlation is reflected in the amplitude of the correlation peaks, and the shift in the correlation function corresponds to the velocity of the measured object. Among all correlation functions, we selected the one with the highest R -value as the most closely matching spectrum, and quoted accordingly its redshift measurement. We confirmed a spectroscopic cluster detection if at least three galaxies have their R value greater than 5, and lie within $\pm 3000 \text{ km s}^{-1}$ of the mean velocity of the cluster

Fig. 2. The optical image (*top*), cleaned MOS frame (*middle*), and an example spectrum (*bottom*) of RXCJ1253.8-2622. The *bottom panel* shows the extracted spectrum with the identified absorption lines from the 6th object from the left of the middle panel.

members. We then took the median of those galaxy redshifts as the cluster redshift.

Fig. 3. RXCJ2149.9-1859: (*upper panel*) photon distribution in the hard band (*left*) and soft band (*right*). Most of the emission in the soft band is identified as the Seyfert galaxy occupying a region in the north-east of the cluster centre. (*lower panel*) Contour plots of the significance in flux in the hard (*left*) and soft band (*right*) at 1.5, 2, 3, 4, 5, 6, 7 σ per Gaussian beam of 1 arcmin width. Contours are marked with two alternating types of lines for clarity. After deblending, the centre of the cluster moves to where the cross is. Note that the location of the Seyfert galaxy is marked by an asterisk.

For the long slit observations, a cluster was confirmed if the redshift of the BCG was known and at least another galaxy has a similar redshift within the aforementioned criteria.

A small fraction of our cluster galaxy sample exhibit emission lines, which are identified with EMSAO in the RVSAO package. These are marked by *E* in Table A.1. The resulting individual galaxy redshifts for the clusters in the REFLEX II sample are listed in the Table A.1 in the appendix.

4. Properties of the cluster sample

In Table 2, we list the X-ray properties of our cluster sample. The X-ray flux and luminosity in the 0.1–2.4 keV band are calculated iteratively from the count rate using an estimated temperature and the measured redshift and N_H for the count rate to flux conversion and the luminosity K-correction to yield the rest-frame luminosity. We use the luminosity-temperature relation from Pratt et al. (2009), $T_X = 3.306 L_X^{1/3} h_{70}^{2/3}$, for the temperature estimate, where T_X is in units of keV and L_X in units of 10^{44} erg/s. This flux and luminosity were measured for the largest aperture used by the GCA method. The size of this aperture is also given in Table 2 in units of arcmin. The uncertainties in the flux and luminosity measurements were calculated from the contributions of the Poisson statistics of the source counts and the variance in the background determined in a total area of 4009 arcmin². The growth curve result was carefully checked for blending of the target source with neighbouring sources and a manual deblending was performed when necessary. The additional flux error introduced by the deblending was estimated and added to the above statistical error. A complex case of deblending is discussed below and shown in Fig. 3.

We also corrected the aperture luminosity to the luminosity inside r_{500} for which we used the $L_X - M_Y$ relation of Pratt et al. (2009), which translates to $r_{500} = 0.895 \text{ Mpc } L_X^{0.195} E(z)^{-1.056}$, with L_X in units of 10^{44} erg/s for the 0.1 to 2.4 keV band. Further details of these calculations will be described in a forthcoming paper on the REFLEX II sample construction by Böhringer et al.

4.1. Detection at other wavelengths

Some of the clusters in our list are sufficiently prominent that seven were previously detected by Abell (1958, 1989) and one was noted by Zwicky, as indicated in Table 1. One of the clusters, RXCJ1914.5-5928, has been detected by the *Planck* survey (Planck Collaboration 2011a).

4.2. Additional diagnostic X-ray properties

Given the low count rates (19–65 counts and two cases with 10 and 16 counts), the low angular resolution of the RASS (90 arcsec half power radius), and the low spectral resolution, the data do not permit a detailed spectral and morphological analysis to be made for these sources. However, it allows us to derive two simple and robust parameters.

One parameter, the spectral hardness ratio, is determined from the count rates in the soft (channel 11–40, ~ 0.1 –0.4 keV) and hard (channel 52–201, ~ 0.5 –2 keV) bands by the formula $HR = (H-S)/(H+S)$. Since for a given temperature, redshift, and assumed metal abundance of 0.3 solar the expected X-ray spectrum of a cluster is known, the hardness ratio for a given interstellar absorption can be calculated. In Fig. 4, we show the distribution of the deviations of the detected from the estimated values of the hardness ratio in units of significance for the total REFLEX II catalogue, the present cluster sample, and we compare these properties to those of a sample of non-cluster sources.³ Fewer than one third of the non-cluster sources overlap with the cluster distribution. Therefore, the inspection of the hardness ratios is a powerful diagnostic of the possible AGN (or other non-cluster X-ray sources) contamination of our sample. Indeed all clusters of the present sample deviate by less than 3 σ from expectations, except for the cluster RXCJ2149.9-1859, where the contamination is obvious and has been deblended as described below.

The second diagnostic is used to discriminate extended sources from either point or unresolved sources. The most robust test we have applied in the REFLEX project is a Kolmogorov-Smirnov test to check if the source photon distribution was consistent with a point source and the estimated background. The test was conducted in a radial region of 6 arcmin radius around the cluster centre (Böhringer et al. 2000). We assumed a probability threshold of <1% for a reliable designation of a source as extended. We found a significant extent for 11/22 of the clusters in our sample, which is again a very good confirmation given that the clusters have a high redshift and are not always expected to display a significant extent. In comparison, the REFLEX I sample at higher flux levels show a significant extent for 81% of the clusters with unresolved sources mostly at higher redshifts (Fig. 26 in Böhringer et al. 2001). Figure 5 shows the distribution of the extent parameter, $-\log(KS \text{ probability})$ for the REFLEX II catalogue, the present sample, and the 1542 non-cluster sources.

³ These non-cluster sources comprise 1524 of the RASS X-ray sources in the REFLEX sky region with fluxes above the REFLEX II cut that were described as cluster candidates in the REFLEX II sample construction (Böhringer et al. 2001).

Fig. 4. Distribution of the measured hardness ratio deviations from the expectation in units of the significance for the REFLEX II clusters is marked with the slanted lines in the histogram. The filled bars show the distribution of the cluster sample in this paper. The blank bars mark 1542 non-cluster sources identified during the construction of the REFLEX II catalogue. It is clear that the hardness deviation of the clusters has an approximate Gaussian distribution with a mean close to zero, while the non-cluster sources have a significant excess towards the negative deviations.

Fig. 5. Fractional histograms of the $-\log$ Kolmogorov-Smirnov probability for three categories of objects. The solid line represents the REFLEX II clusters as in Fig. 4. We truncate the values so that the last bin contains the remaining counts for the whole sample, which amounts to 5%. The dotted lines mark 1542 non-cluster sources, and the red dashed lines are for the 22 clusters. The non-cluster sources are strongly concentrated at small extents.

Only a few percent of the non-cluster sources have an extent parameter larger than 2. They are mostly nearby galaxies, very bright stars with an artificial extent signal, and some sources with spurious extents. Fig. 6 shows the hardness ratio - extent parameter distribution for all REFLEX II clusters and the present sample. Most of the present clusters with an extent parameter smaller than 2, which is used as a conservative threshold, still have parameter values corresponding to a low probability of being a point source.

Fig. 6. Hardness ratio vs. $-\log$ probability of the Kolmogorov-Smirnov test for the same clusters in the Fig. 2. The larger blue circles indicate the 22 clusters presented in this paper. The lower left sector enclosed by dashed lines is the zone where there is a high chance that a source is not a cluster. We note that this is a conservative limit, and any source that falls into this category must be scrutinised in detail to be confirmed. One cluster indicated by a blue circle that has an exceptionally soft emission among all of the 22 (the large blue circle nearest to the vertical dashed line) is RXCJ2149.9-1859. See Sect. 4.3 for detailed remarks about this source. Two clusters of small extent are clearly compact clusters where there is a central dominant galaxy close to the X-ray centres.

4.3. Remarks on individual clusters

RXCJ0347.4-2129 has a complex emission region with two major components.

RXCJ0521.4-2754 is deblended from a nearby source.

RXCJ1253.8-26 has a complex, diffuse emission region. The structure of this source will be inspected in greater detail using an allocated 7 ks *Chandra* observation.

The centre of RXCJ1914.5-5928 coincides with that of PLCKG337.1-26.0 to within a distance of 4.3 arcmin from the SZ cluster center (Planck Collaboration 2011a). In terms of the flux limit this cluster should have been included in the REFLEX I catalogue. However, the REFLEX I catalogue was strictly based on the detection of X-ray sources, as well as significant galaxy overdensities, in the COSMOS database, which is a relatively shallow with a non-uniform coverage across the sky (Böhringer et al. 2001). Hence, this cluster was identified as a supplementary cluster on the basis of its X-ray extent. With a more comprehensive identification procedure for the REFLEX II catalogue, it is identified as a part of the new sample.

The cluster, RXCJ2149.9-1859, contains an X-ray point source that is offset by about 2.4 arcmin from the X-ray centre of the cluster. The point source is significantly softer than the cluster emission and originates from a Seyfert galaxy at $z = 0.157$. It is located at 21:49:58 in RA and -18:59:24 in Dec and is denoted by an asterisk in the lower panels of Fig. 3. The flux from this source was deblended from the cluster emission. The X-ray surface brightness distribution of this source in the soft (0.1–0.4 keV) and hard band (0.5–2 keV) is shown in Fig. 3. The contribution of the Seyfert galaxy to the cluster X-ray emission is clearly noticeable as a much softer source than the cluster emission north-east of the cluster centre. It was deblended by cutting off the contaminated sector of the cluster emission and filling it with the remaining azimuthal average. After deblending, the new centre is then found to be 1.5 arcmin south of its initial location.

RXCJ2149.0-3228 has been deblended from a source in the south-west of the cluster.

5. Summary and conclusions

We have presented a sample of 22 nearby spectroscopically confirmed clusters selected from the REFLEX II catalogue. These clusters all have redshifts above $z = 0.2$ and therefore for the given flux limit of the sample they are very X-ray luminous and have high estimated masses. This implies that these objects are interesting for follow-up studies, in particular for Sunyaev-Zel'dovich effect observations, gravitational lensing measurements, studies of the dark matter and baryon mass fraction, and cosmological studies. For this reason, we wish to make these findings public in advance of the publication of the main catalogue. For the two most prominent clusters of the sample, RXCJ1914.5-5928 and RXCJ2149.9-1859 we have obtained mass estimates, M_{500} , of $7.8 \times 10^{14} M_{\odot}$ and $5.3 \times 10^{14} M_{\odot}$ using the scaling relation of Pratt et al. (2009), $M_{500} = 2.02 L_x^{0.585} E(z)^{-1.17}$. The most luminous cluster, RXCJ1914.5-5928, was detected among the high significance sample in the *Planck* survey. These two most massive clusters are the most interesting objects, e.g. for lensing studies and with estimated Y_X parameters of $8.6 \times 10^{14} M_{\odot} \text{ keV}$ and $4.4 \times 10^{14} M_{\odot} \text{ keV}$ (using the Y_X scaling from Arnaud et al. 2007, $Y_x = 0.1934 M_{500}^{1.825} E(z)^{0.73}$),

they should be detectable by on-going Sunyaev-Zel'dovich experiments.

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Appendix A: List of spectroscopic redshifts of the identified cluster galaxies**Table A.1.** List of the cluster galaxies.

Cluster (1)	RA (2)	Dec (3)	z (4)	remark (5)
RXCJ0052.4-5746	13.133868	-57.775865	0.2493	E
	13.147719	-57.776764	0.2559	
	13.170916	-57.794	0.2582	
RXCJ0129.4-6432	22.435034	-64.597408	0.3204	
	22.437597	-64.577611	0.3264	
	22.430907	-64.570233	0.3290	
	22.438965	-64.554441	0.3246	
	22.459002	-64.549708	0.3287	
	22.429443	-64.545141	0.3243	
RXCJ0139.5-2629	24.868537	-26.495456	0.2451	
	24.894092	-26.486702	0.2433	
	24.901974	-26.48409	0.2447	
	24.901285	-26.49041	0.2451	
	24.8275	-25.4239	0.2440	
	24.8508	26.3783	0.2462	
RXCJ0343.5-7152	24.7742	26.5789	0.2506	2dFGRS S151Z172(C)
				2dFGRS S151Z165(C)
				2dFGRS S220Z172(C)
RXCJ0347.4-2149	55.945821	-71.849902	0.2147	
	55.959294	-71.856585	0.2128	
	56.041557	-71.889731	0.2133	
RXCJ0425.5-0045	56.93468	-21.827332	0.2440	
	56.9313	-21.8214	0.2399	
	56.923154	-21.807932	0.2391	
	56.92696	-21.803433	0.2413	
	56.914577	-21.794706	0.2397	
RXCJ0521.4-2754	66.367106	-0.77938041	0.2239	
	66.371827	-0.77442204	0.2239	
	66.387509	-0.75881324	0.2178	
	66.385977	-0.75223203	0.2200	
	66.40343	-0.7513067	0.2278	
RXCJ1253.8-2622	66.405553	-0.74196309	0.2242	
	80.344202	-27.90332	0.3163	
	80.356403	-27.898519	0.3187	
	193.43474	-26.41951	0.2178	
	193.43792	-26.396884	0.2159	
RXCJ1617.6-0714	193.43035	-26.40101	0.2147	6dF J1253475-262452(J)
	193.4442	-26.404795	0.2124	
	193.44809	-26.420722	0.2234	
	193.45253	-26.424123	0.2208	
	193.4567	-26.409775	0.2116	
	193.46578	-26.41682	0.2234	
	193.46967	-26.421824	0.2259	
	193.448	-25.5856	0.2252	
	244.40231	-7.2400582	0.2522	
	244.41683	-7.2274564	0.2487	
RXCJ1914.5-5928	244.39301	-7.2549254	0.2545	
	288.59075	-59.468145	0.2624	
	288.64634	-59.46307	0.2662	
	288.65983	-59.463317	0.2627	
	288.65554	-59.472132	0.2635	
	288.67541	-59.491637	0.2680	

Table A.1. continued.

Cluster (1)	RA (2)	Dec (3)	z (4)	remark (5)
RXCJ2006.4-1912	301.57594	−19.19882	0.2798	
	301.59097	−19.207681	0.2772	
	301.60487	−19.204003	0.2694	
	301.61177	−19.205136	0.2769	
	301.63241	−19.210241	0.2759	
RXCJ2041.2-1324	310.30095	−13.406979	0.3328	
	310.30239	−13.407497	0.3311	
	310.2907	−13.389369	0.3302	
	310.32768	−13.423979	0.3295	
	310.31764	−13.412583	0.3172	
RXCJ2049.9-3029	312.45369	−30.504551	0.2088	
	312.44101	−30.498744	0.1998	
	312.45211	−30.495267	0.2064	
	312.45157	−30.474272	0.2143	
RXCJ2126.1-3202	321.53756	−32.038193	0.2805	E(0.2807)
	321.54668	−32.032845	0.2788	
RXCJ2149.0-3228	327.21805	−32.472663	0.2285	
	327.23078	−32.477076	0.2304	
	327.25531	−32.485818	0.2326	
	327.27583	−32.476373	0.2333	
RXCJ2149.9-1859	327.36016	−19.031057	0.2852	
	327.36666	−19.021321	0.2820	
RXCJ2308.3-0155	347.05782	−1.9312007	0.3101	
	347.06292	−1.9292463	0.3046	
	347.06925	−1.9297486	0.3030	
	347.10146	−1.9380196	0.2971	
RXCJ2317.9-3534	349.52696	−35.624088	0.2041	
	349.49957	−35.608131	0.1949	
	349.53337	−35.60149	0.2048	
	349.49667	−35.585751	0.1939	
	349.65900	−34.3772	0.1965	2dFGRS S600Z062(C)
RXCJ2351.0-1954	357.76166	−19.948692	0.2483	
	357.77012	−19.940193	0.2471	

Notes. E in (5) denotes a galaxy with emission lines. The first galaxy of RXCJ2126.1-3202 also has emission lines whose redshift is provided adjacent to E in brackets. We take also the literature galaxy redshift in the vicinity of the cluster centres, available in the NED search, which are marked by its object identifiers in the catalogues. (C) refers to the galaxies found in Colless et al. (2003), and (J) in Jones et al. (2009).