The 2XMMi/SDSS Galaxy Cluster Survey

III. Clusters associated with spectroscopically targeted luminous red galaxies in SDSS-DR10^{*}

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ABSTRACT

We present a sample of 383 X-ray selected galaxy groups and clusters with spectroscopic redshift measurements (up to $z \sim 0.79$) from the 2XMMi/SDSS Galaxy Cluster Survey. The X-ray cluster candidates were selected as serendipitously detected sources from the 2XMMi-DR3 catalogue that were located in the footprint of the Sloan Digital Sky Survey (SDSS-DR7). The cluster galaxies with available spectroscopic redshifts were selected from the SDSS-DR10. We developed an algorithm for identifying the cluster candidates that are associated with spectroscopically targeted luminous red galaxies and for constraining the cluster spectroscopic redshift. A cross-correlation of the constructed cluster sample with published optically selected cluster catalogues yielded 264 systems with available redshifts. The present redshift measurements are consistent with the published values. The current cluster sample extends the optically confirmed cluster sample from our cluster survey by 67 objects. Moreover, it provides spectroscopic confirmation for 78 clusters among our published cluster sample, which previously had only photometric redshifts. Of the new cluster sample that comprises 67 systems, 55 objects are newly X-ray discovered clusters and 52 systems are sources newly discovered as galaxy clusters in optical and X-ray wavelengths. Based on the measured redshifts and the fluxes given in the 2XMMi-DR3 catalogue, we estimated the X-ray luminosities and masses of the cluster sample.

Key words. X-rays: galaxies: clusters – galaxies: clusters: general – surveys – catalogs – techniques: spectroscopic

1. Introduction

Galaxy clusters are the largest gravitationally bound objects in the Universe. They have been formed from the densest regions in the large-scale matter distribution of the Universe and have collapsed to form their own proper equilibrium structure. Their form can be well assessed by observations and well described by theoretical modelling (e.g. Sarazin 1988; Bahcall 1988; Voit 2005; Böhringer 2008; Ota 2012). X-ray and optical observations show that galaxy clusters are clearly defined connected structural entities, where the diffuse X-ray emission from the hot intracluster medium (ICM) trace the whole structure of the cluster. They are excellent giant laboratory sites for several astrophysical studies, for example, investigating galaxy evolution in their dense environments (e.g. Dressler 1980; Goto et al. 2003), evolution of the dynamical and thermal structure (e.g. Balestra et al. 2007; Maughan et al. 2008; Anderson et al. 2009), chemical enrichment of the ICM (e.g. Cora 2006; Heath et al. 2007), studying lensed high-redshift background galaxies (e.g. Metcalfe et al. 2003; Santos et al. 2004; Bartelmann 2010), and investigating the evolution of the Universe to test the cosmological models (e.g. Rosati et al. 2002; Reiprich & Böhringer 2002; Voit 2005; Vikhlinin et al. 2009; Allen et al. 2011).

Owing to the multi-component nature of galaxy clusters, they can be observed and identified through multiple observable signals across the electromagnetic spectrum. Tens of thousands of galaxy clusters have been identified by detecting their galaxies in the optical and near-infrared (NIR) bands (e.g. Abell 1958; Abell et al. 1989; Zwicky et al. 1961; Gladders & Yee 2005; Merchán & Zandivarez 2005; Koester et al. 2007; Wen et al. 2009, 2012; Hao et al. 2010; Szabo et al. 2011; Geach et al. 2011; Durret et al. 2011; Gettings et al. 2012; Rykoff et al. 2013). Recently, several galaxy cluster surveys have been conducted at mm wavelengths using the Sunyaev-Zeldovich (SZ) effect based on observations made by several instruments, for example, the Atacama Cosmology Telescope (ACT, Hasselfield et al. 2013), the South Pole Telescope (SPT, Reichardt et al. 2013), and the Planck Satellite (Planck Collaboration 2014). These surveys have provided cluster samples that contain several hundreds of SZ-selected clusters.

X-ray cluster surveys provide pure and complete cluster catalogues, in addition, their X-ray observables correlate tightly with masses of clusters (e.g. Allen et al. 2011). Several hundreds of galaxy clusters were detected in X-rays based on previous X-ray missions mainly from ROSAT data (e.g. Ebeling et al. 1998, 2010; Böhringer et al. 2004; Reiprich & Böhringer 2002; Rosati et al. 1998; Burenin et al. 2007). The current X-ray telescopes (*XMM-Newton*, *Chandra*, *Swift*/X-ray) provide contiguous cluster surveys for small areas (e.g. Finoguenov et al. 2007, 2010; Adami et al. 2011; Šuhada et al. 2012), in addition

* The cluster catalog is only available at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via <http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/564/A54>

to serendipitous cluster surveys (e.g. Barkhouse et al. 2006; Kolokotronis et al. 2006; Lamer et al. 2008; Fassbender et al. 2011; Takey et al. 2011; Mehrrens et al. 2012; Clerc et al. 2012; Tundo et al. 2012; de Hoon et al. 2013; Takey et al. 2013). So far, these surveys have provided a substantial cluster sample of several hundreds up to a redshift of 1.57.

We have conducted a systematic search for X-ray detected galaxy clusters based on *XMM-Newton* fields that are located in the footprint of the SDSS-DR7. The catalogue of serendipitously detected sources (extended) in *XMM-Newton* EPIC images was the basic database from which we selected a list of X-ray cluster candidates, comprising 1180 objects. The main goal of the survey is to construct a large catalogue of newly discovered X-ray emitting groups and clusters. Due to the higher sensitivity of *XMM-Newton* the compiled cluster sample extends ROSAT cluster samples to fainter X-ray fluxes. The sample, which comprised galaxy groups and clusters, allows us to investigate the evolution of X-ray scaling relations as well as the correlation between the X-ray and optical properties. Other long-term goals of the survey are the selection of distant clusters beyond the SDSS detection limit and, in general terms, the preparation for the eROSITA mission, which will uncover a similar cluster population as in our survey.

The main way to obtain the cluster redshifts is based on the optical data. This can be achieved by either cross-matching the X-ray cluster candidates with the available optically selected galaxy cluster catalogues in the literature or by measuring the cluster photometric redshifts based on galaxy redshifts given in the SDSS catalogues. Using these two methods, we were able to establish an optically confirmed cluster sample comprising 530 groups/clusters with redshift measurements. From these optically confirmed groups/clusters with redshift measurements, we derived their X-ray luminosities and temperatures and investigated the X-ray luminosity-temperature relation. The selection criteria of the X-ray cluster candidates and redshift measurements as well as the X-ray properties of the optically confirmed sample were described in more detail by Takey et al. (2011, 2013, Paper I, Paper II, hereafter).

In this work, we compile a sample of X-ray detected galaxy clusters among the X-ray cluster candidate list that are associated with luminous red galaxies (LRGs), which have spectroscopic redshift measurements out to 0.8 in the SDSS-DR10. We present the procedure we used for constructing this cluster sample that is spectroscopically confirmed and for measuring their redshifts. We also present estimates of X-ray bolometric luminosity and luminosity-based mass at R_{500} (the radius at which the cluster mean density is 500 times the critical density of the Universe at the cluster redshift) of the cluster sample.

The compiled cluster sample can be used to investigate various relations among the cluster physical properties, for example, the correlations between the properties of the BCG and its hosting cluster. By measuring the X-ray temperature of the cluster sample, one can extend the $L_X - T$ relation in Paper II to slightly higher redshifts. Moreover, the cluster sample is expected to permit studies of the relations between the cluster optical properties (richness and luminosity) and the cluster X-ray properties (X-ray temperature, luminosity, and mass). These correlations will be discussed in an upcoming paper.

The article is organized as follows: Sect. 2 gives a short overview on the selection procedure of the X-ray cluster candidates. In Sect. 3, we describe the construction of the cluster sample associated with LRGs and their redshift measurements. The X-ray parameters of the cluster sample are presented in Sect. 4. The summary of the paper is presented in Sect. 5. Throughout

this paper, we used the cosmological parameters $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$ and $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

2. Description of the X-ray cluster candidates

Galaxy clusters are simply identified among the X-ray sources as X-ray luminous, spatially extended, extragalactic sources (Allen et al. 2011). The largest X-ray source catalogue so far is the *XMM-Newton* serendipitous source catalogue, which has been created by the *XMM-Newton* Survey Science Centre (SSC). The latest edition of this catalogue is the 3XMM-DR4¹, which contains 372 728 unique X-ray sources drawn from 7427 *XMM-Newton* EPIC observations made between 2000 February 3 and 2012 December 8. Our survey was based on the previous edition of the *XMM-Newton* serendipitous source catalogue (2XMMi-DR3², Watson et al. 2009) that was compiled based on 4953 *XMM-Newton* observations made between 2000 February 3 and 2009 October 8. The 2XMMi-DR3 catalogue comprises 353191 detections corresponding to 262 902 unique sources. Of these detections, 30 470 are extended detections, which include both real and spurious extended sources as well as multiple detections of the same sources.

We selected the X-ray cluster candidates from reliable extended sources (with no warning about being spurious) in the 2XMMi-DR3 catalogue at high galactic latitudes, $|b| > 20^\circ$. The survey was constrained to the *XMM-Newton* fields that were located in the footprint of the SDSS-DR7 to be able to measure the optical redshifts of the possible optical counterparts. The overlap area of *XMM-Newton* fields and the imaging area of the SDSS-DR7 is 210 deg^2 . After excluding possible spurious X-ray extended detections and low-redshift galaxies that appear resolved at X-ray wavelengths through visual inspections of the X-ray images and the X-ray-optical overlays, the X-ray cluster candidate list comprised 1180 objects. The selection procedure was described in more detail in Papers I and II.

In this paper, we identify a subsample of these X-ray cluster candidates associated with LRGs that have spectroscopic redshifts in the SDSS-DR10 to construct a sample with spectroscopic confirmations. As an example, Fig. 1 shows a galaxy cluster, 2XMMi J143742.9+340810, at a redshift of 0.5446, associated with two LRGs as cluster member galaxies with available spectroscopic redshifts. We use this cluster to show the procedure of measuring the redshift in the next section.

3. Clusters associated with spectroscopically targeted LRGs in SDSS-DR10

Generally, the brightest cluster galaxies (BCGs) are elliptical massive galaxies and reside near the cluster centre of mass. The BCGs tend to be very luminous and red galaxies (e.g. Postman & Lauer 1995; Eisenstein et al. 2001; Wen et al. 2012), therefore they have a good chance to be selected for BOSS spectroscopy in SDSS-III as members of the LRG sample, which in turn allows a straightforward spectroscopic confirmation of associated galaxy clusters (e.g. Goto et al. 2002; Mehrrens et al. 2012).

We identified the LRGs from the SDSS-DR10 data that are cluster member galaxies of the X-ray cluster candidates. The spectroscopic redshifts of these cluster members were used to measure the cluster redshift. In the next subsections, we describe

¹ http://xmmssc-www.star.le.ac.uk/Catalogue/xcat_public_3XMM-DR4.html

² http://xmmssc-www.star.le.ac.uk/Catalogue/xcat_public_2XMMi-DR3.html

Fig. 1. SDSS image of the cluster 2XMMi J143742.9+340810 at a redshift of 0.5446, with X-ray surface brightness contours (0.2–4.5 keV) overlaid in yellow. The plotted cyan circle has a radius of one arcmin around the X-ray position. The field of view is $4' \times 4'$ centred on the X-ray emission peak.

how we selected the LRGs from the recent data of the SDSS and the procedure we followed to measure the cluster redshift. We also present some statistical properties of the constructed cluster sample, such as the redshift distribution and the projected offsets of the BCGs from the X-ray positions. Then a comparison of the current redshift measurements with the published ones is presented. Finally, we give a general overview of the total optically confirmed cluster sample from our survey.

3.1. Luminous red galaxy sample

The Sloan Digital Sky Survey (SDSS) has been in continuous operation since 2000. The latest data release so far from the SDSS is Data Release 10 (SDSS-DR10, [Ahn et al. 2013](#)), which provides the spectroscopic data from the SDSS-III's Baryon Oscillation Spectroscopic Survey (BOSS) as well as imaging and spectroscopic data from the previous SDSS data releases. SDSS-DR10 provides optical spectra for 1 880 584 galaxies. BOSS is an ongoing project and its current data release includes 927 844 galaxy spectra, in addition to thousands of quasar and stellar spectra, which were selected over 6373.2 deg^2 . One aim of BOSS is to obtain spectra of 1.5 million galaxies in the redshift range of $0.15 < z < 0.8$ distributed over $10\,000 \text{ deg}^2$. Therefore, it is a valuable resource to obtain spectroscopic redshifts for luminous cluster galaxies.

Luminous red galaxies are among the most luminous red galaxies that can be observed up to redshift 0.8 with SDSS equipment. As a starting point for identifying LRGs that are expected to be cluster galaxies, we selected all galaxies within 10 arcmin of the X-ray position, which is the maximum angular scale at the low-redshift end (500 kpc at $z = 0.04$) to be considered for our cluster candidate sample. In a second iteration step, we refined this search radius according to the initial cluster

redshift estimate based on the redshift of the BCG candidate. The galaxies were selected from the galaxy view table in the SDSS-DR10, which contains the photometric parameters measured for resolved primary objects, classified as galaxies.

The photometric redshifts (z_p) and, where available, the spectroscopic redshifts (z_s) of the galaxy sample were also selected from the Photoz and SpecObj tables, respectively. The SpecObj table includes spectroscopic redshifts that were measured from clean galaxy spectra taken by the new and old spectrographs in the SDSS projects. The extracted parameters of the galaxy sample included the coordinates, the (model and composite model) magnitudes in r - and i -bands, the photometric redshifts, and, where available, the spectroscopic redshifts. We used the magnitudes in the galaxy table that are corrected for Galactic extinction following [Schlegel et al. \(1998\)](#). To clean the galaxy sample from faint objects beyond the completeness limits of SDSS or from galaxies with large uncertainty in z_p , we only considered galaxies that have a model magnitude of $m_r \leq 22.2 \text{ mag}$ and $\Delta m_r < 0.5 \text{ mag}$ and a relative error of photometric redshift of $\Delta z_p/z_p < 0.5$.

The BOSS data include two main target galaxy samples; first the BOSS LOWZ galaxy sample with $z \leq 0.4$; second the BOSS constant-mass CMASS galaxy sample with $0.4 < z < 0.8$. The target selection algorithms for galaxies in BOSS are significantly different from those used in the previous SDSS projects because of the different scientific goals ([Ahn et al. 2012](#)). BOSS galaxy targets are significantly fainter than those in the previous SDSS projects with the aim of measuring large-scale clustering of galaxies at higher redshifts.

To select a homogeneous luminous red galaxy sample from BOSS and previous SDSS data releases, we applied the same selection criteria on both data. We selected LRGs with available spectroscopic redshifts from the constructed galaxy sample within 10 arcmin from the X-ray positions. The applied selection criteria of LRGs were based on the colour and magnitude cuts that are described by Padmanabhan et al. (in prep.) and given on the SDSS website³ as well as in Appendix A. We also ensured that the selected objects are confirmed galaxies using the spectroscopic class parameter given in the SpecObj table to exclude objects targeted as galaxies that were stars or quasars. The selected LRG sample was used to identify the BCGs of the X-ray cluster candidates as described in the following subsection.

3.2. Optical identifications and redshift measurements

To measure the redshifts of cluster candidates, we firstly identified the BCG candidates, then we selected cluster member candidates with available similar z_s of the BCG's spectroscopic redshift. The procedure works as follows:

1. We identified a BCG candidate as an LRG within 200 kpc (computed based on z_s of the LRG) from the X-ray position of the cluster candidate. If there was only one LRG, we considered it as the BCG candidate. If there were several LRGs, we divided them into groups with similar redshifts that are within a redshift interval of $\Delta z_s = 0.01$. When there was only one group, we chose the brightest LRG as the BCG candidate. If there was more than one group, the priority was given to the group with more members and the BCG candidate was selected as the brightest galaxy from this group. If the groups have the same count of LRGs, we initially

³ http://www.sdss3.org/dr10/algorithms/boos_galaxy_ts.php

Fig. 2. Histogram of the spectroscopic (z_s , red solid) and photometric (z_p , blue dashed) redshifts of the cluster member candidates (N_{z_s} and N_{z_p}) within 500 kpc of the example cluster, 2XMMi J143742.9+340810. The green dotted histogram represents the distribution of z_p of field galaxies within the same region. The cluster spectroscopic $\bar{z}_s$ and photometric $\bar{z}_p$ redshifts are represented by red solid and blue dashed vertical lines, respectively, and are listed in the upper corner.

selected the brightest galaxy in each group. Then the next-brightest LRG to the X-ray emission peak was regarded as the BCG candidate. The maximum number of LRGs within 200 kpc from the X-ray centre was four.

At low redshifts, the search radius of 200 kpc subtends a large angle on the sky and might cause an incorrect association of LRGs with the X-ray cluster candidates. Therefore, we set a maximum angular separation limit on the BCGs offset from the X-ray emission peak of 90 arcsec. The search radius of 200 kpc was used since we found that 90 percent of the BCGs in Paper II had an offset lower than 200 kpc. The search radius (200 kpc) used here is slightly larger than the search radius (175 kpc) used by [Mehrtens et al. \(2012\)](#) to identify LRGs that are part of the cluster. These authors assigned the spectroscopic redshift of an LRG or a group of LRGs within 175 kpc from the X-ray position as the cluster redshift.

2. We identified the cluster member candidates (not necessarily LRGs) within 500 kpc from the X-ray peak based on the spectroscopic redshift of the identified BCG candidate, $z_{s,BCG}$. The cluster galaxies with available z_s were selected within a small redshift interval of $z_{s,BCG} \pm 0.01$. While the cluster member candidates with only z_p were selected within a slightly larger redshift interval of $z_{s,BCG} \pm 0.04(1 + z_{s,BCG})$. The distribution of the redshifts of the cluster member candidates and field galaxies for the example cluster is shown in Fig. 2. The redshift interval we used to identify the cluster members with z_p gives 80 percent of the cluster members ([Wen et al. 2009](#)). These authors also showed that a radius of 500 kpc gives a high overdensity level and a low false-detection rate. The identified BCG candidate could be a cluster galaxy fainter than the first BCG, thus we re-identified the likely BCG as the brightest galaxy among the cluster member candidates within 500 kpc.
3. We computed the spectroscopic, $\bar{z}_s$, and photometric, $\bar{z}_p$, redshift of a cluster as a weighted average of the spectroscopic and photometric redshifts of the cluster member candidates within 500 kpc, respectively. The weights are given

Fig. 3. Distribution on the sky of the cluster member candidates (red dots) and field galaxies (blue dots) within 500 kpc (~ 1.3 arcmin) from the X-ray position (marked by a black cross) of the example cluster, 2XMMi J143742.9+340810. Note the different scale in Fig. 4. The cluster galaxies with available z_s are marked by stars. The BCG candidate is marked by a black plus that has a projected separation from the X-ray position of ~ 11 kpc. We only present galaxies with $m_r \leq 22.2$ mag, $\Delta m_r < 0.5$ mag, and $\Delta z_p/z_p < 0.5$.

as $w_i = 1/(\Delta z_{s,i})^2$ in computing $\bar{z}_s$ and as $w_i = 1/(\Delta z_{p,i})^2$ in determining $\bar{z}_p$. If there was only one cluster galaxy (LRG) with available spectroscopic redshift z_s , we considered its z_s as the cluster redshift.

4. We accepted the optical counterpart and the redshift measurement of an X-ray cluster candidate if the optical detection passed the quality assessment performed through a visual inspection process. We compared the identified BCG and cluster member candidates with the corresponding SDSS colour image of the same field. The sky distribution of cluster members of the example cluster is shown in Fig. 3, while Fig. 4 shows the corresponding SDSS colour image. From both images, it was obvious that the algorithm picked the correct associated LRGs (and thus the BCG too) and the luminous cluster member candidates. The fainter cluster galaxies were not considered in Fig. 3 because of the magnitude limit we used to create the galaxy sample or they were not detected at all in Fig. 4 because of the detection limit of the SDSS imaging.

The current procedure yielded an initial list of optical counterparts that comprised 415 candidates. We regard about 8 percent of the initial candidates as doubtful for two main reasons, overlapping clusters and unrelated nearby galaxies. We found cases of most likely overlapping clusters where the algorithm probably picked an incorrect cluster since an LRG of this not-so-distant cluster happened to lie closer to the X-ray position. Another reason for an incorrect redshift estimate is the identification of a bright foreground galaxy as BCG candidate for a distant cluster candidate, where no detected cluster galaxies are found around the X-ray emission peak. We excluded such systems from the initial cluster candidate sample. Therefore, the estimated misidentification fraction of the resulting optical counterpart list using the current cluster identification procedure is about 8 percent. These systems were removed from the sample without additional attempts to correct for or quantify their effect. The final list of the optically validated cluster sample included 383 systems with spectroscopic confirmation based on at least one spectrum of an LRG.

Fig. 4. SDSS colour image of the cluster 2XMMi J143742.9+340810 with 4 arcmin a side centred on the X-ray position, which is marked by the cross-hair. Two cluster galaxies (LRGs) with spectra are marked by red squares. The measured spectroscopic redshift for this system is 0.5446, which is computed as the weighted average, $\bar{z}_s$, of the spectroscopic redshifts of the two LRGs.

3.3. Optically validated cluster sample

The redshifts of the optically confirmed cluster sample (383 systems) span a wide range from 0.05 to 0.79 with a median of 0.34. Among this sample, 147 clusters are spectroscopically confirmed based only on the SDSS-III BOSS data. The redshift distribution of the current cluster sample (383 systems), the subsample based only on BOSS survey (147 objects), and the optically confirmed cluster sample (530 systems) in Paper II are shown in Fig. 5. The redshift distribution of the current cluster sample is dependent on the selection of LRG targets in SDSS projects and the selection of X-ray cluster candidates from the 2XMMi-DR3 catalogue as well as the cluster identification procedure we used here to construct the cluster sample. The drop of the redshift histogram at $z = 0.60\text{--}0.65$ might be a result of a combination of these effects or possibly the low-statistics regime of the survey.

The objects in common between the two samples (Paper II sample and the current one) are 316 systems, see the next subsection for the redshift comparison. The current cluster sample includes 40 more distant clusters beyond $z = 0.5$ than the distant sample in Paper II. As shown in Fig. 5, these distant clusters were detected based on BOSS data, thanks to the data release of BOSS in the SDSS-DR10. Additionally, the current cluster sample extends the confirmed cluster sample in Paper II by 67 systems, of these 52 systems are newly discovered galaxy clusters. Therefore, the current cluster sample is complementary to that presented in Paper II in terms of size and redshift range. Both samples can be combined for future investigations of X-ray scaling relations as well as X-ray-to-optical relations.

The majority of the clusters in the sample have one or two cluster member galaxies with z_s , while few clusters have three member galaxies or more with available z_s . The distribution of

Fig. 5. Distribution of measured spectroscopic redshifts of the cluster sample associated with LRGs that have spectra is presented by the red dashed line, and a subsample of it based only on BOSS data is indicated by the green solid line, while the redshift distribution of the optically confirmed cluster sample in Paper II is presented by the blue dotted line.

Fig. 6. Distribution of the number of identified spectroscopic cluster galaxies per system within 500 kpc from the X-ray positions for the optically validated cluster sample. The bin size of the histogram is one.

the cluster galaxies with z_s per cluster of the cluster sample is shown in Fig. 6. The cluster member galaxies are not complete for the distant systems in our cluster sample. Faint cluster galaxies were not considered or detected because of the magnitude limit (SDSS completeness or limit) used in the current procedure or the limited data depth of the SDSS imaging, respectively. For instance, only the BCG (LRG) was identified for the most distant cluster in the sample at a redshift of 0.79.

Figure 7 shows the scatter plot between the count of identified cluster member candidates per system with z_p and within 500 kpc from the X-ray position and the cluster redshift. It is shown that distant clusters have only a few identified luminous cluster galaxies, mainly because of the sensitivity limits of the SDSS. We kept these objects in our cluster candidate list, even with only two member galaxies, for the summed evidence of extended X-ray emission positioning that coincides with an LRG with spectra. To determine a complete cluster richness, one needs to follow-up these systems to obtain deep imaging data.

Based on the cluster redshift and the angular separation of the BCGs to the X-ray peaks, we computed their projected offsets. The distribution of the projected separations between the

Fig. 7. Cluster member galaxies plotted against the cluster spectroscopic redshifts. These cluster member candidates were selected based on their z_p within 500 kpc from the X-ray emission peak

Fig. 8. Histogram of the projected separations between the probable BCGs and the X-ray emission peaks of the cluster sample.

probable BCGs and the X-ray emission peaks is shown in Fig. 8. We found that the majority of the BCGs (about 90 percent) have offsets smaller than 200 kpc, which agree with the offsets of BCGs sample in Paper II. By using the current selection procedure of the BCG as a cluster member galaxy within 500 kpc from the X-ray centers, the maximum offset is about 500 kpc. The large offset of the BCGs from the X-ray centroids might appear in systems with an ongoing merger or in dynamically active clusters (Rykoff et al. 2008).

The distribution of positional offsets of the BCGs from the X-ray positions might be biased by the initial LRG (BCG candidate) selection, which was required to lie within a projected distance of 200 kpc. Since we excluded apparent doubtful systems from the initial cluster sample, the distribution is less affected by identifying incorrectly associated BCGs. The median offset of the BCG for the cluster sample is 33 kpc. We investigated a possible evolution of the BCG offset with the cluster redshift. The cluster sample was divided into three subsamples with redshift bins of $0.05 \leq z < 0.30$, $0.30 \leq z < 0.55$, and $0.55 \leq z < 0.80$ and number of clusters 156, 184, and 43, respectively. The median BCG offsets for the low, intermediate, and distant redshift subsamples were 23 kpc, 42 kpc, and 45, respectively. These numbers indicate a trend of increasing positional offset of the BCG with increasing redshift.

We compared the BCGs properties of the cluster sample (383 systems) with the selection criteria of the spectroscopically targeted LRGs in BOSS survey, see Appendix A. We found that 92 percent of the BCGs fulfil the colour and magnitude cuts of the LRGs in BOSS. This high percentage is affected by our strategy of the cluster identification, which selected a cluster galaxy as an LRG within 200 kpc from the X-ray emission peak.

3.4. Comparison with published redshifts

The largest optically selected galaxy cluster sample so far was compiled by Wen et al. (2012, WHL12 hereafter), based on overdensities of galaxies in photometric redshift space from the SDSS-DR8 data. It comprises 132684 clusters with photometric redshift measurements in the range of $0.05 \leq z < 0.8$. The catalogue also provides spectroscopic redshifts for about 30 percent of the BCGs. Cross-matching our sample with the WHL12 catalogue yielded 188 common clusters, of these, 131 systems have spectra for the BCGs in their catalogue. We also queried

Fig. 9. Comparison of the present spectroscopic redshift measurements with the published BCG spectroscopic (green dots) and cluster photometric (blue dots) redshifts by Wen et al. (2012) and the available (either spectroscopic or photometric) redshifts from the NED (red triangle).

the NASA Extragalactic Database (NED) for available redshift measurements for the remainder of the cluster sample. As a result, 76 clusters with redshift estimates from different projects were found. In total, 264 clusters are previously known in the literature mostly as optically selected galaxy clusters.

Figure 9 shows the comparison between the present redshift measurements and the WHL12 ones as well as the available redshifts from the NED. The good agreement between the current redshift measurements and the published values is clear. The differences between the two measurements, $\Delta z = z_{\text{present}} - z_{\text{published}}$, have a mean and standard deviation of 0.0009 and 0.0170, respectively.

We also compared the current redshift measurements with the published ones of the optically confirmed cluster sample from our ongoing survey (Paper II). There are 316 clusters in common between the two samples, of these, 238 have spectroscopic redshifts for at least one cluster galaxy in Paper II. The current procedure spectroscopically confirmed the remainder of the common sample with only photometric redshifts (78 systems). We noted that the current procedure did not identify the whole sample in Paper II with spectroscopic confirmations (310 clusters). This is because we used the criterion of having an LRG with z_s within 200 kpc. In addition, in Paper II we used the spectroscopic data from the SDSS/II projects, which provides a

Fig. 10. Comparison of the present spectroscopic redshift measurements with the measured spectroscopic redshifts (green dots) and photometric ones (red squares) from Paper II.

galaxy sample with z_s including LRGs as well as a magnitude-limited galaxy sample that are not necessarily LRGs.

Figure 10 shows the comparison of the present redshift measurements with the values from Paper II of the common sample. The two measurements agree well. The mean and standard deviation of the differences between the measured values, $\Delta z = z_{\text{present}} - z_{\text{Paper II}}$, are 0.0039 and 0.0150, respectively. Only 4 percent of the common sample have redshift differences of $2\sigma < |\Delta z| \leq 4\sigma$, where $\sigma = 0.02$ is the uncertainty of the measured photometric redshifts in Paper II. Systems with such redshift differences had only photometric redshifts in our previous work.

We also noted that the present spectroscopic redshifts are not identical with the spectroscopic redshifts in Paper II for a few cases. There are eleven clusters with redshift differences of $0.01 < |\Delta z| < 0.04$. This is because cluster galaxies in Paper II were selected within a redshift interval of $z_{p,\text{BCG}} \pm 0.04(1 + z_{p,\text{BCG}})$, then the cluster spectroscopic redshift was measured as the weighted average of the available spectroscopic redshifts of these identified cluster galaxies. This led to selecting galaxies with available z_s that have redshifts outside the redshift interval we used in this work ($z_{s,\text{BCG}} \pm 0.01$, see Sect. 3.2).

3.5. Combined optically confirmed cluster sample from the 2XMMi/SDSS cluster survey

Based on the photometric redshifts of galaxies in the SDSS-DR8, we have optically identified the counterparts of 530 galaxy groups/clusters in Paper II including the cluster sample in Paper I. In the present work, we constructed a cluster sample of 383 systems based on the spectroscopic redshifts of galaxies in the SDSS-DR10. The spectroscopically confirmed cluster sample extends the optically confirmed cluster sample in Paper II by 67 objects. Therefore, out of 1180 X-ray cluster candidates we optically confirmed 597 galaxy groups/clusters (51 percent) and measured their redshifts.

This is the largest X-ray selected galaxy cluster catalogue so far based on the archival *XMM-Newton* observations. The *XMM-Newton* sensitivity and the available deep *XMM-Newton* fields allowed us to detect clusters down to X-ray flux of $\sim 10^{-15} \text{ erg cm}^{-2} \text{ s}^{-1}$ in $[0.5-2.0] \text{ keV}$. However, this is not a flux-limited cluster sample since we included *XMM-Newton* observations with different exposure times in our survey. The redshifts

of the full cluster sample span a wide range from 0.03 to 0.79 with a median of 0.34. Concerning spectroscopic redshifts, out of 597 confirmed clusters 455 systems (76 percent) have a spectroscopic confirmation based on at least one member galaxy with a spectrum.

Overall, we are left with 583 unconfirmed X-ray cluster candidates (49 percent). These remaining candidates are either distant clusters beyond the SDSS detection limit, systems with low richness that are groups with few members, or possibly spurious detections.

4. X-ray parameters

In Paper II, we provided two subsamples of clusters: (i) a cluster subsample comprising 345 objects with their X-ray spectroscopic temperature and flux from the spectral fitting; and (ii) a cluster subsample consisting of 185 systems with their X-ray flux obtained from the 2XMMi-DR3 catalogue, because their X-ray data are insufficient for spectral fitting. For both subsamples, we also estimated the X-ray bolometric luminosity L_{500} using an iterative method based on scaling relations. This iterative procedure was the same for the two subsamples but with different inputs, see Sect. 4 in Paper II for more detail about this procedure. We found a good agreement between the derived L_{500} for the clusters in common between the two subsamples.

In the current work, we estimate the X-ray parameters (L_{500} and M_{500}) for the present optically validated cluster sample (383 systems) based on the integrated β model fluxes that were given in the 2XMMi-DR3 catalogue. Firstly, we compute the X-ray luminosities using the catalogue fluxes and the measured redshifts. Secondly, we convert the computed luminosity to bolometric luminosities L_{500} . Finally, the estimated L_{500} are used to compute the cluster masses M_{500} .

4.1. X-ray luminosity and mass

For each system in the current cluster sample, we obtained its X-ray aperture-corrected, β -model, flux that was calculated by the SAS tasks *emldetect* from the 2XMMi-DR3 catalogue (Watson et al. 2009). Here we used the combined EPIC (MOS1, MOS2, PN) flux in $(0.5-2.0 \text{ keV})$, $F_{\text{cat},0.5-2}$, and its propagated error. Then we computed the X-ray luminosity in $(0.5-2.0 \text{ keV})$, $L_{\text{cat},0.5-2}$.

To convert $L_{\text{cat},0.5-2}$ into bolometric luminosity L_{500} , we used the properties of the cluster sample with reliable X-ray spectroscopic parameters in Paper II. Among the current optically validated cluster sample, there are 218 clusters with X-ray spectroscopic parameters from the spectral fitting were already published in Paper II. We compared bolometric L_{500} from Paper II and $L_{\text{cat},0.5-2}$ from the current procedure of these common systems, as shown in Fig. 11. It shows a linear relation between the two luminosity measurements with a few outliers (about 4 percent), which are contaminated by point sources. The best-fit linear relation after excluding these outliers derived using the BCES orthogonal regression method (Akritas & Bershady 1996) is represented by the solid line in Fig. 11 and is given by

$$\log(L_{500}) = (0.51 \pm 0.02) + (0.91 \pm 0.02) \log(L_{\text{cat},0.5-2}). \quad (1)$$

The error in L_{500} was calculated by including the error measurement of $L_{\text{cat},0.5-2}$, the intrinsic scatter in this relation (Eq. (1)), and the propagated errors caused by the uncertainty in the slope and the intercept. The intrinsic scatter value of the relation (Eq. (1)) is 0.15 ± 0.01 , which was estimated following the method used by Pratt et al. (2009).

Fig. 11. X-ray bolometric luminosity L_{500} from Paper II plotted against the present luminosity $L_{\text{cat}, 0.5-2}$ of 218 clusters in common between the current cluster sample and the sample in Paper II with reliable X-ray parameters. The solid line represents the best fit derived using the BCES orthogonal regression method after excluding eight outliers that are represented by blue dots. The intercept (a) and the slope (b) of the linear relation are written in the lower left corner.

Equation (1) provides a quick method to derive bolometric L_{500} based on the measured $L_{\text{cat}, 0.5-2}$. This scaling relation implicitly includes the bolometric correction (with scatter introduced by the X-ray temperature and luminosity in the energy band [0.5–2.0] keV) as well as aperture flux extrapolation to R_{500} (with scatter introduced by different surface brightness profile parameters).

The estimated bolometric L_{500} was used to compute the X-ray luminosity-based mass using the $L_{500} - M_{500}$ relation published by Pratt et al. (2009) of the form

$$M_{500} = 2 \times 10^{14} M_{\odot} \left(\frac{h(z)^{-7/3} L_{500}}{1.38 \times 10^{44} \text{ erg s}^{-1}} \right)^{1/2.08}, \quad (2)$$

where $h(z)$ is the Hubble constant normalised to its present-day value, $h(z) = \sqrt{\Omega_M(1+z)^3 + \Omega_{\Lambda}}$. We calculated the error in M_{500} that has contribution from the error in L_{500} , the intrinsic scatter in Eq. (2), and the propagated errors for the uncertainty in relation's slope and intercept. Finally, M_{500} was used to compute R_{500} as

$$R_{500} = \sqrt[3]{3M_{500}/4\pi 500\rho_c(z)}, \quad (3)$$

where $\rho_c(z)$ is the critical density, $\rho_c(z) = h(z)^2 3H_0^2/8\pi G$.

For the whole current cluster sample (383 systems), we derived $L_{\text{cat}, 0.5-2}$, R_{500} , L_{500} and M_{500} , as described above. Among this sample, there are 316 clusters in common with the whole sample (530 objects) in Paper II. The current sample extended the optically confirmed cluster sample from our survey by 67 objects and added several clusters at higher redshift up to $z = 0.79$. Since we provided the measurements of L_{500} and M_{500} for the common sample in Paper II, we only present the catalogue of the extended cluster sample (67 systems) listing their optical and X-ray parameters. In addition to this new sample, we also provide the spectroscopic redshifts and the X-ray properties for 78 clusters among the common sample in Paper II that previously had only photometric redshifts. These two subsamples are compiled in Table 1 with a note referring to each subsample.

Table 1, available in full form at the CDS, lists the new cluster sample (67 objects) from the current work in addition to a subsample (78 systems) that has only photometric redshifts in

Paper II. The X-ray parameters are estimated based on the flux given in the 2XMMi-DR3 catalogue. Columns [1] and [2] report the cluster identification number (detection Id, detid) and its name (IAUNAME), Cols. [3] and [4] provide the coordinates of X-ray emission in equinox J2000.0. The remaining columns are Col. [5] the *XMM-Newton* observation Id (obsid), Col. [6] the cluster spectroscopic redshift, Col. [7] the scale at the cluster redshift in kpc'', Col. [8] the R_{500} in kpc, Cols. [9] and [10] the 2XMMi-DR3 X-ray flux F_{cat} [0.5–2.0] keV and its error in units of $10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}$, Cols. [11] and [12] the estimated X-ray luminosity L_{cat} [0.5–2.0] keV and its error in units of $10^{42} \text{ erg s}^{-1}$, Cols. [13] and [14] the cluster bolometric luminosity L_{500} and its error in units of $10^{42} \text{ erg s}^{-1}$, Cols. [15] and [16] the cluster mass M_{500} and its error in units of $10^{13} M_{\odot}$, Col. [17] the objid of the probable BCG in SDSS-DR10, Cols. [18] and [19] the BCG coordinates in equinox J2000.0, Col. [20] the apparent model magnitude m_r of the BCG, Cols. [21] and [22] the weighted average spectroscopic redshift $\bar{z}_s$ and the number of cluster members N_{z_s} within 500 kpc with available spectroscopic redshifts that were used to compute the average redshift, Cols. [23] and [24] the weighted average photometric redshift $\bar{z}_p$ and the number of identified cluster member candidates N_{z_p} within 500 kpc based on their photometric redshifts, Col. [25] the projected separation between the cluster X-ray position and the BCG position, Cols. [26] the NED name of previously known clusters in the literature, and Col. [27] a note indicating the object status, “Paper III” refers to a new system confirmed using the current procedure, and “Paper II” refers to a previously published system in Paper II with only photometric redshift and it is spectroscopically confirmed in the current work.

4.2. Comparison of the derived X-ray parameters

Among the clusters (316 systems) in common between the current cluster sample and that in Paper II, there were 98 clusters published in Paper II with their X-ray properties based on the flux given in the 2XMMi-DR3 catalogue. Since we here used a different method to determine the X-ray bolometric L_{500} from that used in Paper II, we present a comparison of the derived luminosities from the two methods. As shown in Fig. 12, both methods give consistent values of L_{500} . The only two outliers are at the lowest redshifts (0.05 and 0.11) of the common sample. The median value of the ratios between the present L_{500} estimates and the values from Paper II is 1.1. This offset of the current estimates of L_{500} (10 percent) might arise from using two different procedures, the slight difference in the measured redshifts of the common systems, in addition to the two outliers mentioned above.

Figure 13 shows the good agreement between the current L_{500} estimates and the corresponding values from the XCS project for 107 common objects. The ratio between the present L_{500} to the corresponding values in the XCS project has a median of 0.95. Of the common sample, 33/107 have only photometric redshifts in the XCS sample, therefore our cluster sample provides spectroscopic confirmation for these systems. In general, there is consistency between the redshift measurements of the common sample apart from ten systems with $|z_{\text{present}} - z_{\text{XCS}}| > 0.05$, which have only photometric redshifts in the XCS sample. The mean and standard deviation of the redshift differences ($z_{\text{present}} - z_{\text{XCS}}$) are 0.01 and 0.03, respectively.

The mass range of the cluster sample is $M_{500} \sim 2\text{--}28 \times 10^{13} M_{\odot}$ and the bolometric luminosity range is $L_{500} \sim 1\text{--}600 \times 10^{42} \text{ erg s}^{-1}$. Figure 14 shows the distributions of L_{500} as a function of redshift for the new cluster sample (67 systems) and

Fig. 12. Present measurements of L_{500} plotted against the corresponding values from Paper II for 98 common clusters with fluxes obtained from the 2XMMi-DR3 catalogue. The solid line represents the one-to-one relationship.

Fig. 13. Comparison of the present estimates of L_{500} and the values from the XCS project for 107 clusters in common. The solid line shows the one-to-one relationship.

the objects in common with Paper II (316 objects) as well as for 1730 clusters ($z < 0.8$) from the MCXC catalogue, which was compiled from published X-ray selected cluster catalogues from ROSAT data (Piffaretti et al. 2011). Owing to the sensitivity of *XMM-Newton* and deeper exposures for some fields, the current cluster sample mostly includes low-luminosity groups and clusters at each redshift, as shown in Fig. 14. Cross-matching our cluster sample with the MCXC catalogue within a radius of 30 arcsec yielded 17 clusters. The current estimates of M_{500} agree well with the corresponding values in the MCXC catalogue of the common systems, as shown in Fig. 15. The small overlap between the two samples is caused by the relatively small survey area in our project and by constraining our survey to include only systems identified as serendipitously detected sources and not targets in *XMM-Newton* observations.

In the new sample that comprises 67 X-ray selected clusters, only 12 systems were previously known as X-ray detected clusters. They were published by Mehrrens et al. (2012), Clerc et al. (2012), Piffaretti et al. (2011), or Finoguenov et al. (2007). In total, about 25 percent of this new sample were previously known either in optical or X-ray band, the remainder of this sample are new systems.

Fig. 14. Distribution of the X-ray bolometric luminosities, L_{500} , with redshift of the new cluster sample (red dots) from the current procedure, the cluster sample in common with Paper II (green dots), and a sample of 1730 clusters (black stars) below redshift 0.8 detected from ROSAT data (Piffaretti et al. 2011).

Fig. 15. Measurements of M_{500} from our survey plotted against values from the MCXC catalogue for 17 clusters in common with ours. The solid line shows the one-to-one relationship.

In Paper II, we presented the $L_X - T$ relation based on a cluster sample comprising 345 systems in the redshift range $0.03 < z < 0.67$. In the future, we plan to extend the $L_X - T$ relation to include distant clusters up to slightly higher redshifts from the newly constructed cluster sample in this work. Since the current cluster sample provides spectroscopic confirmation for 78 clusters of the cluster sample published in Paper II, we can re-measure their X-ray parameters with a better accuracy, which might help in reducing the scatter in the $L_X - T$ relation. We also plan to investigate the correlations between the X-ray and optical properties of the full cluster sample from our cluster survey that are optically confirmed so far.

5. Summary

We presented a sample of 383 X-ray selected galaxy groups and clusters associated with at least one LRG, which has a spectroscopic redshift in the SDSS-DR10. The redshifts of the associated LRGs were used to identify BCGs and other cluster galaxies with spectroscopic redshifts. The cluster spectroscopic redshift was computed as the weighted average of the available spectroscopic redshifts of the cluster galaxies within 500 kpc from the

X-ray emission peak. The cluster sample spans a wide redshift range of $0.05 \leq z \leq 0.79$ with a median of $z = 0.34$. Of the cluster sample, 264 are previously known as optically selected galaxy clusters. In addition to re-identifying and confirming the redshift estimates of 316 clusters in common with the published cluster sample from our survey, we extended the optically confirmed cluster sample by 67 objects. Of this new sample that comprises 67 systems, about 75 percent are newly discovered groups and clusters, and about 80 percent are new X-ray detected clusters. Comparing the BCGs of the cluster sample with the colour and magnitude cuts of LRGs in the BOSS survey yielded that 92 percent of the BCGs are considered LRGs. However, this percentage is dependent on the selection of the spectroscopically targeted LRGs in SDSS as well as on the current cluster identification procedure.

The measured redshift and the X-ray flux in 0.5–2.0 keV given in the 2XMMi-DR3 catalogue were used to determine the X-ray luminosity in 0.5–2.0 keV of the cluster sample. We converted the X-ray luminosity in 0.5–2.0 keV into bolometric luminosity L_{500} based on the available properties of the published cluster sample with X-ray spectroscopic parameters from our survey. This conversion yielded a scaling relation, which could be used to derive bolometric L_{500} from the luminosity (0.5–2.0 keV) that is computed based on the β model flux (0.5–2.0 keV) given in the 2XMMi-DR3 catalogue.

We also derived X-ray-luminosity-based masses of the cluster sample based on published scaling relation in the literature. Comparing the current estimates of the X-ray bolometric luminosity, L_{500} , with the available values from the XCS project, we found a good agreement between the two measurements. The distribution of X-ray luminosities of our cluster sample and ROSAT clusters with redshifts showed that we detected less-luminous groups and clusters at each redshift interval, and added a few tens of clusters at high redshifts.

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Appendix A: Selection criteria of LRGs

We used the colour and magnitude cuts that were used to select spectroscopic targets to construct the BOSS galaxy sample in the SDSS-III project. The selection criteria of galaxies targeted in BOSS were given in Padmanabhan et al. (in prep.) and

were provided on the BOSS homepage⁴. The BOSS includes two samples of galaxies, one is the BOSS “LOWZ” galaxy sample, $z \leq 0.4$. The selection cuts are as follows:

1. $|c_{\perp}| < 0.2$, to define the colour boundaries of the sample around a passive stellar population, where $c_{\perp} = (r - i) - (g - r)/4.0 - 0.18$.
2. $r < 13.5 + c_{\parallel}/0.3$, to select the brightest galaxies at each redshift, where $c_{\parallel} = 0.7(g - r) + 1.2[(r - i) - 0.18]$.
3. $16 < r < 19.6$, to define the faint and bright limits.

The other is the BOSS “CMASS” galaxy sample, $0.4 < z < 0.8$. The colour and magnitude cuts are as follows:

1. $d_{\perp} > 0.55$, to isolate high-redshift objects, where $d_{\perp} = (r - i) - (g - r)/8.0$.
2. $i < 19.86 + 1.6(d_{\perp} - 0.8)$, to select the brightest or more massive galaxies with redshift.
3. $17.5 < i < 19.9$, to define the faint and bright limits.
4. $r - i < 2$, to protect from some outliers.

Note that we did not apply the criteria that were used to perform a star-galaxy separation since we only considered objects that were classified as galaxies indicated by spectroscopic class parameters given in the SpecObj table. Note also that all colours were computed using model magnitudes while the magnitude cuts were applied on composite model (cmmodel) magnitudes. All magnitudes were corrected for Galactic extinction following Schlegel et al. (1998).

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⁴ http://www.sdss3.org/dr10/algorithms/boss_galaxy_ts.php

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Table 1. New cluster sample (67 objects) from the current work in addition to a subsample (78 systems) that has only photometric redshifts in common with Paper II.

Detid ^a	Name ^a IAUNAME	RA ^a (deg)	Dec ^a (deg)	Obsid ^a	z^b	Scale kpc''	R_{500} (kpc)	$F_{\text{cat}}^{a,c}$	$\pm eF_{\text{cat}}$	L_{cat}^d	$\pm eL_{\text{cat}}$	L_{500}^e	$\pm eL_{500}$	M_{500}^f	$\pm eM_{500}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
005735	2XMM J003840.4+004746	9.66841	0.79636	0203690101	0.5553	6.44	542.28	1.44	0.18	17.86	2.20	44.88	5.02	8.31	1.69
007554	2XMM J004304.2+092801	10.76751	-9.46695	0065140201	0.1866	3.12	585.47	6.84	1.06	6.74	1.05	18.50	2.61	6.87	1.45
010986	2XMM J005556.9+003806	13.98720	0.63507	0303110401	0.2047	3.36	570.81	5.01	0.95	6.06	1.15	16.81	2.91	6.49	1.41
016221	2XMM J012341.3+072323	20.92215	7.38985	0300000301	0.3418	4.86	640.75	5.90	0.85	23.02	3.33	56.53	7.43	10.68	2.17
021043	2XMM J015558.5+053159	28.99394	5.53329	0153030701	0.4499	5.76	658.59	5.82	0.85	43.43	6.37	100.68	13.43	13.14	2.64
021597	2XMM J020019.2+001931	30.08012	0.32553	0101640201	0.6825	7.07	629.03	4.17	0.52	85.10	10.59	185.57	20.98	15.09	2.98
030746	2XMM J023346.9+085054	38.44543	-8.84844	0150470601	0.2653	4.08	615.99	5.95	1.09	12.93	2.36	33.47	5.55	8.71	1.84
030889	2XMM J023458.7+085055	38.74463	-8.84868	0150470601	0.2590	4.01	581.98	4.15	0.53	8.54	1.09	22.96	2.67	7.29	1.51
089821	2XMM J083114.4+523447	127.81014	52.57993	0092800201	0.6107	6.74	495.95	0.79	0.11	12.25	1.64	31.86	3.88	6.79	1.42
089885	2XMM J083146.1+525056	127.94516	52.84719	0092800201	0.5190	6.23	616.14	3.50	0.21	36.78	2.24	86.56	4.80	11.67	2.26
091280	2XMM J083926.4+193658	129.86017	19.61622	0101440401	0.3742	5.16	495.43	0.93	0.13	4.50	0.62	12.81	1.60	5.12	1.10
091629	2XMM J084124.2+004640	130.35101	0.77799	0202940201	0.4075	5.43	624.47	4.28	0.29	25.27	1.69	61.53	3.75	10.66	2.08
092718	2XMM J084847.8+445611	132.19968	44.93637	0085150101	0.5697	6.52	633.94	4.22	0.21	55.46	2.75	125.74	5.66	13.50	2.59
093338	2XMM J084957.4+445945	132.49091	44.99510	0085150101	0.5400	6.35	566.06	1.94	0.18	22.47	2.05	55.29	4.58	9.28	1.85
097216	2XMM J092137.5+372003	140.40631	37.33440	0149010201	0.5958	6.66	503.31	0.87	0.21	12.72	3.09	32.96	7.29	6.97	1.58
099426	2XMM J094034.6+355945	145.14429	35.99594	0021740101	0.3011	4.47	570.00	3.01	0.41	8.75	1.19	23.47	2.91	7.18	1.49
099550	2XMM J094107.7+032912	145.28229	3.48674	0306050201	0.2490	3.90	451.87	0.77	0.14	1.45	0.27	4.57	0.77	3.38	0.79
099864	2XMM J094314.6+481003	145.81122	48.16796	0201470101	0.2724	4.16	551.86	2.71	0.25	6.25	0.59	17.29	1.47	6.31	1.30
101697	2XMM J095603.5+410709	149.01476	41.11923	0111290201	0.5893	6.63	784.27	18.20	2.13	259.75	30.39	511.77	54.43	26.17	5.14
103306	2XMM J095945.4+023634	149.93957	2.60961	0302351601	0.3445	4.89	481.20	0.82	0.16	3.26	0.65	9.56	1.73	4.54	1.03
103892	2XMM J100026.2+022143	150.10926	2.36217	0302351201	0.2204	3.56	429.63	0.64	0.21	0.92	0.30	3.01	0.89	2.81	0.75
104390	2XMM J100056.7+023343	150.23611	2.56332	0203360601	0.2194	3.54	487.07	1.53	0.26	2.16	0.37	6.57	1.03	4.09	0.93
105537	2XMM J100217.2+015625	150.57174	1.94037	0203360401	0.3082	4.54	512.31	1.41	0.39	4.33	1.19	12.38	3.10	5.25	1.26
106241	2XMM J100423.5+410008	151.09813	41.00230	0207130201	0.3583	5.01	499.56	1.02	0.28	4.46	1.24	12.71	3.20	5.16	1.24
106447	2XMM J100634.9+124944	151.64547	12.82893	0140550601	0.6525	6.94	616.30	3.56	0.44	65.05	8.11	145.35	16.47	13.70	2.71
106515	2XMM J100713.3+124718	151.80582	12.78839	0140550601	0.2481	3.89	422.81	0.49	0.12	0.91	0.22	3.01	0.66	2.76	0.69
106609	2XMM J100744.0+123943	151.93360	12.66200	0140550601	0.6545	6.95	530.15	1.27	0.19	23.34	3.43	57.25	7.64	8.74	1.80
108152	2XMM J102137.2+125653	155.40526	12.94810	0146990101	0.3246	4.70	530.98	1.71	0.29	5.91	1.00	16.43	2.53	5.96	1.29
108311	2XMM J102235.7+131045	155.64891	13.17929	0146990101	0.7053	7.17	561.39	1.94	0.42	42.96	9.35	99.69	19.73	11.03	2.37
109295	2XMM J102748.7+000336	156.95333	0.06013	0305980401	0.7060	7.17	687.95	7.85	0.62	173.96	13.79	355.47	25.62	20.31	3.90
109850	2XMM J103003.5+052023	157.51499	5.33982	0148560501	0.3081	4.54	516.27	1.49	0.14	4.56	0.42	12.98	1.08	5.38	1.13
109997	2XMM J103027.8+310802	157.61623	31.13392	0102040301	0.4622	5.85	541.99	1.51	0.22	12.00	1.71	31.28	4.06	7.43	1.55

Notes. The X-ray parameters are determined based on the flux given in the 2XMMi-DR3 catalogue. The entire cluster catalogue is available online at CDS. ^(a) Parameters extracted from the 2XMMi-DR3 catalogue. ^(b) Spectroscopic redshift as given in col. (21). ^(c) 2XMMi-DR3 flux, F_{cat} [0.5–2.0] keV, and its errors in units of 10^{-14} erg cm⁻² s⁻¹. ^(d) X-ray luminosity, L_{cat} [0.5–2.0] keV, and its errors in units of 10^{42} erg s⁻¹. ^(e) X-ray bolometric luminosity at R_{500} , L_{500} and its error in units of 10^{42} erg s⁻¹. ^(f) X-ray–luminosity-based mass at R_{500} , M_{500} and its error in units of $10^{13} M_{\odot}$. ^(g) Parameters obtained from the current detection algorithm in the optical band. ^(h) A note about each system as “Paper III”: new cluster from the current work and “Paper-II”: a cluster in Paper II and confirmed spectroscopically with the present procedure.

Table 1. continued.

Detid ^a	Name ^a IAUNAME	RA ^a (deg)	Dec ^a (deg)	Obsid ^a	z^b	Scale kpc''	R_{500} (kpc)	$F_{\text{cat}}^{a,c}$	$\pm eF_{\text{cat}}^d$	L_{cat}^d	$\pm eL_{\text{cat}}^e$	L_{500}^e	$\pm eL_{500}$	M_{500}^f	$\pm eM_{500}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
110111	2XMM J103046.8+052751	157.69516	5.46432	0148560501	0.3772	5.18	491.44	0.88	0.07	4.31	0.35	12.31	0.90	5.02	1.06
112052	2XMM J104104.0+060130	160.26679	6.02522	0151390101	0.5056	6.14	500.47	0.85	0.11	8.34	1.12	22.46	2.74	6.16	1.30
113642	2XMM J104421.8+213029	161.09102	21.50839	0128531601	0.5174	6.22	679.68	6.87	0.18	71.66	1.84	158.72	3.70	15.64	2.97
118189	2XMM J105215.5+441759	163.06461	44.29999	0146990201	0.4982	6.09	523.96	1.16	0.22	11.07	2.05	29.06	4.89	7.00	1.51
118353	2XMM J105226.8+441859	163.11217	44.31609	0146990201	0.4983	6.09	615.28	3.50	0.44	33.38	4.20	79.25	9.07	11.34	2.27
121351	2XMM J110344.0+360513	165.93374	36.08715	0205370101	0.4972	6.09	499.37	0.84	0.13	7.93	1.24	21.45	3.06	6.06	1.30
121575	2XMM J110355.9+360025	165.98326	36.00699	0205370101	0.3328	4.78	444.60	0.49	0.08	1.81	0.31	5.59	0.87	3.53	0.81
125233	2XMM J111659.0+174953	169.24600	17.83141	0099030101	0.4390	5.68	573.30	2.28	0.41	16.01	2.89	40.65	6.68	8.56	1.81
125384	2XMM J111736.7+074245	169.40361	7.71341	0203560201	0.4796	5.97	439.45	0.35	0.07	3.06	0.58	9.03	1.54	4.04	0.93
125448	2XMM J111745.2+074824	169.43852	7.80691	0082340101	0.5370	6.33	412.88	0.22	0.15	2.54	1.71	7.63	4.65	3.59	1.31
125812	2XMM J111824.3+074727	169.60165	7.79099	0203560201	0.4854	6.01	431.91	0.31	0.07	2.79	0.58	8.29	1.58	3.86	0.90
125888	2XMM J111834.6+074434	169.64317	7.74298	0082340101	0.4831	5.99	501.95	0.88	0.08	7.74	0.68	20.99	1.68	6.05	1.25
127013	2XMM J112349.4+052952	170.95623	5.49793	0083000301	0.6571	6.96	653.22	5.32	0.34	98.90	6.29	212.73	12.29	16.40	3.14
128668	2XMM J113804.0+031525	174.51687	3.25708	0111970701	0.4491	5.75	613.68	3.59	0.52	26.66	3.84	64.61	8.46	10.62	2.16
129017	2XMM J113913.0+165446	174.80457	16.91278	0066950201	0.5738	6.55	684.71	7.16	1.18	95.76	15.82	206.59	31.03	17.10	3.46
132492	2XMM J120544.4+352307	181.43514	35.38554	0148742401	0.6530	6.94	562.10	1.89	0.41	34.65	7.50	82.00	16.13	10.40	2.24
133193	2XMM J120933.9+392234	182.39078	39.37648	0112830201	0.5547	6.44	594.58	2.72	0.20	33.52	2.48	79.55	5.34	10.94	2.14
134697	2XMM J121205.3+131739	183.02238	13.29430	0112550501	0.4491	5.75	594.47	2.88	0.31	21.43	2.34	52.98	5.26	9.65	1.93
135421	2XMM J121658.3+065826	184.24317	6.97416	0204650201	0.4842	6.00	607.93	3.26	0.70	28.96	6.24	69.65	13.64	10.76	2.31
135555	2XMM J121733.6+071035	184.39023	7.17641	0204650201	0.5777	6.57	573.81	2.13	0.38	28.96	5.11	69.65	11.18	10.11	2.11
137397	2XMM J122112.7+143937	185.30332	14.66042	0306060101	0.2971	4.42	468.10	0.79	0.09	2.23	0.26	6.77	0.71	3.96	0.87
137446	2XMM J122121.3+143317	185.33911	14.55496	0306060101	0.5041	6.13	447.11	0.39	0.07	3.82	0.64	11.05	1.69	4.38	0.98
137700	2XMM J122200.0+144203	185.50012	14.70104	0306060101	0.3709	5.13	442.57	0.43	0.08	2.04	0.37	6.26	1.03	3.64	0.84
137863	2XMM J122235.6+143542	185.64867	14.59508	0306060101	0.5041	6.13	563.12	1.90	0.26	18.62	2.56	46.62	5.82	8.75	1.79
138077	2XMM J122354.5+071937	185.97729	7.32710	0205090101	0.4397	5.68	472.77	0.61	0.15	4.28	1.07	12.24	2.80	4.80	1.13
139177	2XMM J122643.5+334555	186.68155	33.76528	0200340101	0.7665	7.40	498.23	0.91	0.09	24.59	2.36	60.03	5.24	8.29	1.67
140028	2XMM J122903.6+015012	187.26514	1.83680	0159960101	0.3139	4.59	505.26	1.26	0.35	4.03	1.12	11.59	2.93	5.07	1.22
141388	2XMM J123033.7+105717	187.64171	10.95541	0145800101	0.4407	5.69	521.04	1.18	0.14	8.37	1.00	22.54	2.44	6.44	1.34
141650	2XMM J123046.7+105658	187.69556	10.95013	0306630201	0.7519	7.34	462.55	0.54	0.08	13.87	2.02	35.67	4.72	6.52	1.38
141670	2XMM J123047.5+105423	187.69827	10.90645	0306630201	0.4134	5.48	459.42	0.52	0.13	3.15	0.79	9.27	2.10	4.27	1.02
142659	2XMM J123139.1+205518	187.91324	20.92180	0112650101	0.6543	6.95	499.89	0.85	0.21	15.58	3.86	39.64	8.94	7.32	1.66
142993	2XMM J123232.4+200350	188.13529	20.06410	0301450201	0.0635	1.22	370.12	1.91	0.39	0.19	0.04	0.71	0.13	1.53	0.40
143008	2XMM J123235.9+000233	188.14990	0.04251	0203170301	0.6832	7.08	500.09	0.86	0.07	17.68	1.44	44.48	3.30	7.59	1.53
146549	2XMM J124312.0+131310	190.80005	13.21968	0112551001	0.7896	7.47	610.35	3.75	0.37	109.26	10.86	232.91	21.05	15.67	3.05
147020	2XMM J124425.3+164759	191.10564	16.79993	0302581501	0.2351	3.74	499.97	1.66	0.17	2.74	0.29	8.18	0.77	4.50	0.97
147115	2XMM J124448.8+001949	191.20335	-0.33035	0110980201	0.4693	5.90	527.41	1.24	0.12	10.26	0.96	27.11	2.32	6.90	1.41
149238	2XMM J125313.4+155612	193.30610	15.93687	0082990101	0.2754	4.19	688.29	12.17	1.19	28.83	2.82	69.37	6.18	12.28	2.41
149472	2XMM J125345.0+101144	193.43755	10.19567	0001930301	0.6544	6.95	626.59	3.99	0.30	73.49	5.60	162.40	11.24	14.43	2.78

Table 1. continued.

Detid ^a	Name ^a IAUNAME	RA ^a (deg)	Dec ^a (deg)	Obsid ^a	z^b	Scale kpc/''	R_{500} (kpc)	$F_{\text{cat}}^{a,c}$	$\pm eF_{\text{cat}}$	L_{cat}^d	$\pm eL_{\text{cat}}$	L_{500}^e	$\pm eL_{500}$	M_{500}^f	$\pm eM_{500}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
153943	2XMM J130534.9+175650	196.39577	17.94736	0017940101	0.5445	6.38	682.66	7.03	0.33	82.84	3.94	181.08	7.83	16.36	3.12
154013	2XMM J130544.8+175329	196.43684	17.89153	0017940101	0.5412	6.36	529.07	1.22	0.12	14.20	1.35	36.44	3.14	7.59	1.54
155237	2XMM J130902.5+081734	197.26052	8.29289	0110950401	0.4643	5.86	617.98	3.71	0.66	29.80	5.27	71.49	11.50	11.04	2.29
155752	2XMM J131022.5+081952	197.59390	8.33137	0110950401	0.7059	7.17	550.09	1.69	0.30	37.47	6.55	88.04	14.00	10.38	2.16
158679	2XMM J132505.0+302445	201.27118	30.41268	0025740201	0.4348	5.65	627.12	4.24	0.60	29.14	4.15	70.05	9.07	11.14	2.25
159400	2XMM J132631.5+074503	201.63141	7.75093	0200730201	0.5343	6.32	502.94	0.86	0.12	9.74	1.40	25.86	3.37	6.46	1.36
160695	2XMM J133046.2+334620	202.69291	33.77228	0305361601	0.4485	5.75	561.14	1.94	0.29	14.39	2.11	36.87	4.92	8.11	1.68
162382	2XMM J133458.4+375019	203.74351	37.83850	0109661001	0.3834	5.23	525.87	1.38	0.11	7.03	0.56	19.23	1.40	6.19	1.27
162545	2XMM J133514.1+374908	203.80896	37.81876	0109661001	0.6964	7.13	567.32	2.07	0.12	44.47	2.67	102.86	5.62	11.26	2.18
163417	2XMM J133712.0+241438	204.30040	24.24406	0096010101	0.5056	6.14	501.60	0.86	0.17	8.47	1.69	22.78	4.13	6.20	1.37
163928	2XMM J133852.5+044309	204.71904	4.71926	0152940101	0.7264	7.25	596.43	3.00	0.35	71.25	8.29	157.90	16.69	13.56	2.67
164535	2XMM J134138.7+001721	205.41160	0.28936	0111281001	0.5054	6.14	711.85	9.49	1.17	93.56	11.54	202.26	22.67	17.71	3.48
164909	2XMM J134304.9+000053	205.77057	-0.01498	0202460101	0.7151	7.21	735.43	12.50	0.44	285.97	10.01	558.52	17.78	25.08	4.76
165043	2XMM J134330.3+403051	205.87636	40.51441	0070340701	0.7083	7.18	503.36	0.92	0.11	20.58	2.46	51.05	5.54	7.98	1.63
165602	2XMM J134656.7+173218	206.73647	17.53844	0144570101	0.4736	5.93	514.02	1.04	0.10	8.75	0.81	23.47	1.97	6.42	1.32
168090	2XMM J135540.9+182544	208.92067	18.42914	0094401201	0.3554	4.99	516.10	1.29	0.16	5.51	0.69	15.41	1.76	5.67	1.20
170597	2XMM J140615.5+283051	211.56477	28.51444	0140960101	0.5457	6.39	658.94	5.51	0.43	65.32	5.12	145.90	10.40	14.74	2.84
170668	2XMM J140700.1+282140	211.75055	28.36122	0140960101	0.5042	6.13	559.55	1.82	0.23	17.83	2.26	44.82	5.17	8.59	1.75
171595	2XMM J141256.9+030918	213.23753	-3.15574	0013140101	0.6697	7.02	548.75	1.62	0.27	31.56	5.30	75.31	11.50	9.87	2.05
171668	2XMM J141313.0+031732	213.30419	-3.29242	0013140101	0.3088	4.54	518.90	1.54	0.31	4.74	0.96	13.43	2.47	5.46	1.22
171714	2XMM J141319.2+440454	213.33022	44.08177	0103660101	0.5615	6.48	528.41	1.21	0.14	15.34	1.74	39.10	4.03	7.74	1.58
173756	2XMM J142305.5+382807	215.77325	38.46869	0147570601	0.4508	5.77	554.51	1.79	0.27	13.39	2.03	34.54	4.77	7.85	1.64
174080	2XMM J142731.1+262904	216.87978	26.48452	0111290601	0.3693	5.11	540.45	1.71	0.15	8.01	0.68	21.64	1.68	6.61	1.35
175129	2XMM J143038.8+421035	217.66170	42.17661	0212480701	0.4275	5.59	550.04	1.74	0.32	11.49	2.12	30.05	5.03	7.46	1.60
178050	2XMM J145317.4+033446	223.32278	3.57946	0150350101	0.3709	5.13	641.40	5.52	0.28	26.11	1.33	63.39	2.94	11.07	2.14
178120	2XMM J145351.0+032319	223.46267	3.38865	0150350101	0.3685	5.11	536.76	1.64	0.26	7.61	1.23	20.68	3.03	6.47	1.38
180311	2XMM J150918.8+001424	227.32855	-0.24013	0305750201	0.2625	4.05	608.87	5.56	0.93	11.81	1.97	30.81	4.66	8.38	1.76
184398	2XMM J154931.9+213259	237.38303	21.54999	0136040101	0.6358	6.86	649.90	5.08	0.31	87.21	5.29	189.74	10.47	15.74	3.01
185578	2XMM J155930.6+350441	239.87761	35.07807	0112600801	0.4895	6.03	578.38	2.30	0.44	21.03	3.98	52.08	8.95	9.32	1.97
187930	2XMM J161713.8+123805	244.30779	12.63495	0103461001	0.1987	3.28	464.33	1.27	0.25	1.44	0.29	4.54	0.83	3.47	0.82
190632	2XMM J163056.7+374227	247.73659	37.70770	0033540901	0.5598	6.47	616.25	3.47	0.60	43.79	7.59	101.42	15.98	12.26	2.52
190800	2XMM J163133.5+374908	247.88995	37.81891	0033540901	0.4143	5.49	524.12	1.27	0.32	7.81	1.98	21.15	4.87	6.35	1.46
191450	2XMM J163251.9+374042	248.21664	37.67856	0033540901	0.2032	3.34	406.83	0.50	0.26	0.59	0.30	2.02	0.95	2.35	0.76
193467	2XMM J164142.2+390736	250.42616	39.12683	0204340101	0.5922	6.64	677.83	6.69	0.41	96.64	5.93	208.32	11.61	16.95	3.24
200392	2XMM J172335.5+341155	260.89826	34.19881	0102040101	0.4428	5.71	728.94	11.78	1.79	84.63	12.89	184.63	25.56	17.67	3.54
262357	2XMM J081129.1+481011	122.87145	48.17000	0402780701	0.6074	6.72	546.52	1.53	0.31	23.52	4.75	57.65	10.58	9.05	1.94
262423	2XMM J082135.2+010231	125.39651	1.04223	0404911201	0.0994	1.83	558.36	14.13	0.71	3.54	0.18	10.30	0.47	5.45	1.13

Table 1. continued.

Detid ^a	Name ^a IAUNAME	RA ^a (deg)	Dec ^a (deg)	Obsid ^a	z^b	Scale kpc''	R_{500} (kpc)	$F_{\text{cat}}^{a,c}$	$\pm eF_{\text{cat}}$	L_{cat}^d	$\pm eL_{\text{cat}}$	L_{500}^e	$\pm eL_{500}$	M_{500}^f	$\pm eM_{500}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
263066	2XMMi J084011.4+5111330	130.04768	51.22505	0301340101	0.5798	6.58	471.47	0.55	0.12	7.59	1.68	20.61	4.15	5.62	1.27
263705	2XMMi J085930.8+170856	134.87851	17.14896	0303561101	0.3257	4.71	617.94	4.82	0.63	16.81	2.19	42.49	5.03	9.40	1.91
264469	2XMMi J092623.1+362132	141.59634	36.35902	0402370101	0.6558	6.96	558.49	1.81	0.17	33.56	3.19	79.65	6.88	10.23	2.02
264943	2XMMi J095610.3-002151	149.04328	-0.36440	0206430101	0.5828	6.59	619.41	3.60	0.32	50.02	4.45	114.47	9.25	12.79	2.49
265123	2XMMi J095801.8+020147	149.50756	2.02998	0302352401	0.6740	7.04	480.73	0.65	0.65	12.96	6.48	33.54	15.25	6.67	1.98
274756	2XMMi J134549.4+074440	206.45601	7.74465	0405950501	0.6539	6.95	542.12	1.48	0.27	27.14	4.89	65.66	10.76	9.34	1.96
275328	2XMMi J143713.9+341519	219.30818	34.25553	0405200101	0.5427	6.37	681.19	6.93	0.77	81.01	9.06	177.43	18.03	16.22	3.17
275341	2XMMi J143742.9+340810	219.42892	34.13626	0405200101	0.5446	6.38	615.20	3.44	0.44	40.58	5.21	94.64	11.04	11.98	2.39
278534	2XMMi J164729.3+271241	251.87220	27.21165	0304071801	0.4937	6.06	472.38	0.57	0.22	5.33	2.09	14.96	5.32	5.10	1.37
287820	2XMMi J220605.5-001110	331.52310	-0.18635	0401180101	0.3878	5.27	494.29	0.89	0.18	4.68	0.94	13.28	2.42	5.17	1.16
309027	2XMMi J080348.7+234957	120.95316	23.83268	0504102101	0.5780	6.57	530.95	1.25	0.15	17.01	2.07	42.95	4.75	8.01	1.64
309493	2XMMi J081058.2+500529	122.74276	50.09156	0401270401	0.4029	5.40	656.49	6.08	0.45	34.94	2.57	82.61	5.52	12.32	2.39
309859	2XMMi J082432.7+294757	126.13630	29.79925	0504102001	0.2094	3.42	457.63	1.06	0.18	1.35	0.23	4.30	0.65	3.36	0.78
310654	2XMMi J084004.3+294544	130.01817	29.76230	0504120101	0.5708	6.53	543.62	1.47	0.20	19.40	2.61	48.39	5.91	8.52	1.75
310685	2XMMi J084013.0+295305	130.05434	29.88497	0504120101	0.5082	6.16	562.18	1.88	0.22	18.73	2.24	46.86	5.09	8.75	1.77
310772	2XMMi J084052.6+383847	130.21920	38.64663	0502060201	0.1171	2.12	425.29	1.64	0.15	0.58	0.05	2.00	0.16	2.45	0.57
311197	2XMMi J085253.3+175718	133.22230	17.95522	0305480301	0.2075	3.40	454.09	1.02	0.09	1.27	0.12	4.07	0.34	3.28	0.73
312824	2XMMi J092209.5+063230	140.53973	6.54177	0502920101	0.1733	2.94	420.04	0.79	0.21	0.66	0.17	2.23	0.53	2.50	0.64
315216	2XMMi J103007.0-030638	157.52957	-3.11081	0404840201	0.4392	5.68	589.50	2.75	0.18	19.41	1.26	48.41	2.86	9.30	1.83
316779	2XMMi J111206.6+061236	168.02788	6.21024	0200080201	0.3472	4.91	420.24	0.32	0.04	1.30	0.17	4.15	0.51	3.03	0.70
317214	2XMMi J111357.8+061047	168.49103	6.17995	0200080701	0.5400	6.35	557.29	1.75	0.13	20.18	1.47	50.16	3.31	8.85	1.75
317419	2XMMi J111947.3+153302	169.94720	15.55074	0505880301	0.4789	5.96	508.44	0.96	0.23	8.31	1.96	22.38	4.80	6.25	1.42
318253	2XMMi J114541.4+025415	176.42267	2.90425	0551022701	0.2799	4.24	482.89	1.05	0.16	2.58	0.40	7.72	1.09	4.26	0.95
318315	2XMMi J114619.2+025609	176.58015	2.93602	0551022701	0.1584	2.74	426.39	1.00	0.27	0.69	0.18	2.32	0.56	2.58	0.66
319555	2XMMi J114619.2+025609	180.18887	34.41505	0551630301	0.2627	4.05	488.43	1.22	0.15	2.60	0.32	7.79	0.88	4.33	0.95
320719	2XMMi J121921.0+060134	184.83777	6.02628	0502120101	0.3535	4.97	474.26	0.72	0.17	3.06	0.71	9.03	1.90	4.39	1.03
321022	2XMMi J122905.8+102930	187.27432	10.49173	0414980101	0.6563	6.96	505.62	0.92	0.21	17.00	3.86	42.91	8.85	7.60	1.68
321239	2XMMi J123040.1+115706	187.66711	11.95190	0551870501	0.2480	3.89	530.70	2.33	0.51	4.35	0.95	12.42	2.48	5.46	1.24
321268	2XMMi J123050.8+413415	187.71095	41.57120	0556300101	0.7454	7.32	515.00	1.11	0.15	28.22	3.68	68.02	8.06	8.93	1.82
321464	2XMMi J123242.9+123421	188.17917	12.57256	0551870301	0.5361	6.33	503.65	0.87	0.31	9.91	3.48	26.28	8.39	6.51	1.65
322726	2XMMi J124919.4+051837	192.33104	5.31033	0503610101	0.4198	5.53	518.84	1.18	0.16	7.45	1.00	20.28	2.48	6.20	1.31
322873	2XMMi J125003.9+052118	192.51654	5.35501	0503610101	0.3849	5.25	488.67	0.83	0.11	4.28	0.58	12.24	1.51	4.98	1.08
325696	2XMMi J133805.9-013501	204.52478	-1.58373	0502060101	0.3481	4.92	590.92	3.33	0.44	13.55	1.79	34.91	4.19	8.44	1.73
327024	2XMMi J142114.9+030745	215.31213	3.12938	0502480701	0.3122	4.58	646.92	6.90	0.61	21.81	1.92	53.83	4.31	10.63	2.09
327387	2XMMi J143113.8-000618	217.80765	-0.10501	0501540201	0.7122	7.19	550.55	1.71	0.31	38.70	7.09	90.66	15.09	10.49	2.19
327608	2XMMi J143927.3+001249	219.86378	0.21364	0551200101	0.3000	4.45	482.31	0.96	0.15	2.77	0.44	8.24	1.18	4.34	0.97
329022	2XMMi J145709.1-010057	224.28792	-1.01585	0502780601	0.2742	4.18	560.30	2.98	0.30	6.99	0.71	19.13	1.76	6.62	1.36
331167	2XMMi J151529.5+003943	228.87305	0.66205	0556210501	0.2645	4.07	569.25	3.47	0.39	7.50	0.85	20.40	2.11	6.87	1.42

Table 1. continued.

Detid ^a	Objid ^b (BCG)	RA ^c (deg)	Dec ^d (deg)	m_i^g (BCG)	$\bar{z}_s^g$ (21)	$N_{s,g}$ (22)	$\bar{z}_p^g$ (23)	$N_{p,g}$ (24)	Offset ^e (kpc)	NED-name (26)	Note ^f (27)
(1)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
005735	1237663204918428144	9.68054	0.78241	20.047	0.5553	3	0.5127	7	429.63	–	Paper-III
007554	1237652630713860232	10.80832	–9.47863	17.213	0.1866	2	0.1794	18	473.45	–	Paper-III
010986	1237663784740388918	14.02537	0.62659	17.537	0.2047	3	0.1951	20	473.61	–	Paper-III
016221	1237669767089357103	20.92160	7.39115	18.557	0.3418	1	0.3327	14	24.64	–	Paper-II
021043	1237678663047250389	28.98754	5.53072	19.553	0.4499	1	0.4258	12	142.32	–	Paper-II
021597	1237657071160263439	30.08100	0.32491	20.448	0.6825	1	0.6555	3	27.36	SEXCLAS 03	Paper-III
030746	1237653500970139807	38.44673	–8.84925	17.540	0.2653	1	0.2547	17	22.30	WHL J023347.2-085057	Paper-II
030889	1237653500970270877	38.74547	–8.84926	17.762	0.2590	2	0.2528	17	14.70	–	Paper-II
089821	1237651701914141241	127.80965	52.57912	20.467	0.6107	1	0.6465	4	20.97	–	Paper-III
089885	1237651272960967114	127.94343	52.84937	19.251	0.5190	2	0.5165	13	54.28	WHL J083146.4+525057	Paper-II
091280	1237667107965108712	129.86275	19.61566	18.114	0.3742	3	0.3542	15	46.34	–	Paper-II
091629	1237648722282742639	130.35096	0.77637	19.415	0.4075	1	0.3774	16	31.66	–	Paper-II
092718	1237654651492696344	132.20540	44.93004	20.000	0.5697	2	0.5367	11	176.30	WARP J0848.8+4456	Paper-II
093338	1237657609112846711	132.48110	45.00498	20.247	0.5400	1	0.5383	9	275.93	–	Paper-II
097216	1237660634915537365	140.40148	37.33249	19.816	0.5958	1	0.6058	2	102.86	RCS J092135+3720.0	Paper-III
099426	1237661139030638763	145.14560	35.99356	17.982	0.3011	1	0.2795	7	41.85	–	Paper-II
099550	1237654601024471324	145.28619	3.50159	18.009	0.2490	1	0.2231	13	215.50	–	Paper-II
099864	1237657590849339531	145.79662	48.17485	17.936	0.2724	1	0.2953	9	178.57	GMBCG J145.79666+48.17485	Paper-II
101697	1237660343401054372	149.01197	41.12232	20.670	0.5893	1	0.5947	10	89.40	400d J0956+4107	Paper-II
103306	1237651754534044209	149.93796	2.60627	19.098	0.3445	1	0.3452	10	65.24	[KLJ2009] 018	Paper-II
103892	1237653665258864851	150.09090	2.39125	17.174	0.2204	2	0.2178	26	439.97	[KLJ2009] 008	Paper-III
104390	1237651754534175091	150.23989	2.56276	17.632	0.2194	1	0.2132	9	48.74	[KLJ2009] 011	Paper-III
105537	1237653664722256181	150.56128	1.94206	18.564	0.3082	1	0.3201	8	173.06	–	Paper-II
106241	1237661852532277722	151.10591	41.01332	19.300	0.3583	1	0.3419	16	225.39	GMBCG J151.08861+40.99730	Paper-II
106447	1237664106316235399	151.64462	12.82811	19.455	0.6525	1	0.6062	5	29.11	–	Paper-III
106515	1237661069785956568	151.80525	12.78700	17.503	0.2481	1	0.2362	13	20.95	–	Paper-III
106609	1237661069786022936	151.93352	12.66245	20.088	0.6545	1	0.6049	4	11.44	–	Paper-III
108152	1237664105780937527	155.40648	12.94890	18.425	0.3246	1	0.3202	19	24.29	–	Paper-II
108311	1237661069787595439	155.64725	13.18128	19.956	0.7053	1	0.6729	5	66.03	–	Paper-III
109295	1237654670275511096	156.95279	0.06054	20.848	0.7060	1	0.7141	4	17.56	–	Paper-III
109850	1237654602640457895	157.51425	5.33829	18.500	0.3081	1	0.3056	10	27.78	–	Paper-II
109997	1237665127460045508	157.61411	31.13688	19.109	0.4622	1	0.4610	7	73.14	–	Paper-III
110111	1237658297923076324	157.69698	5.46371	18.764	0.3772	1	0.3607	12	35.55	SDSSCG 39821	Paper-II
112052	1237658298461061646	160.26775	6.02345	19.502	0.5056	1	0.4980	10	44.34	–	Paper-II
113642	1237667736109777445	161.09192	21.50878	20.693	0.5174	1	0.5044	11	20.58	WHL J104422.2+213035	Paper-II
118189	1237660634386727421	163.08740	44.29841	19.524	0.4982	1	0.4835	8	359.37	WHL J105219.6+441732	Paper-II
118353	1237660634386792717	163.11172	44.31504	19.925	0.4983	3	0.5078	11	24.13	GMBCG J163.11171+44.31503	Paper-III
121351	1237664338249187791	165.93781	36.08689	19.650	0.4972	1	0.4977	13	72.41	2XMM J110344.0+360513	Paper-II

Table 1. continued.

Detid ^a	Objid ^b (BCG)	RA ^c (deg)	Dec ^d (deg)	m_i^g (BCG)	$\bar{z}_s^g$ (21)	$N_{s,g}$ (22)	$\bar{z}_p^g$ (23)	$N_{p,g}$ (24)	Offset ^e (kpc)	NED-name	Note ^h
(1)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
121575	1237664338249187846	165.98502	36.00626	18.686	0.3328	1	0.3167	11	27.64	–	Paper-II
125233	1237668496852844963	169.24231	17.83243	19.318	0.4390	2	0.4189	8	74.85	–	Paper-III
125384	1237661972252525308	169.41169	7.70112	20.196	0.4796	1	0.4765	12	315.03	[BGV2006] 029	Paper-II
125448	1237661972252525407	169.44442	7.80882	20.099	0.5370	1	0.5612	5	140.29	–	Paper-III
125812	1237661972252590293	169.59836	7.78262	19.553	0.4854	1	0.4750	6	194.27	BLOX J1118.3+0747.0	Paper-III
125888	1237661972252565966	169.63897	7.74007	20.167	0.4831	1	0.4876	5	109.43	BLOX J1118.5+0744.5	Paper-III
127013	1237654606404256168	170.95872	5.49313	21.222	0.6571	2	0.6371	7	135.80	–	Paper-III
128668	1237654030866776457	174.51838	3.25657	18.134	0.4491	2	0.4363	12	32.92	BLOX J1138.0+0315.3	Paper-II
129017	1237668495244525616	174.80358	16.90980	19.765	0.5738	2	0.5737	8	73.80	–	Paper-II
132492	1237665129079570844	181.43720	35.38470	20.295	0.6530	1	0.6295	3	46.82	–	Paper-III
133193	1237664667907850801	182.38888	39.37339	19.409	0.5547	1	0.5436	13	79.41	WHL J120933.3+392224	Paper-II
134697	1237661950790599069	183.03074	13.28715	19.177	0.4491	3	0.4606	10	224.23	2XMM J121205.3+131739	Paper-III
135421	1237661974936223829	184.23923	6.97396	18.743	0.4842	1	0.4826	18	84.67	WHL J121657.7+065825	Paper-II
135555	1237661971185271488	184.38379	7.16889	20.754	0.5777	3	0.5722	7	233.17	–	Paper-III
137397	1237661069263372471	185.30358	14.66065	18.115	0.2971	1	0.2850	12	5.36	–	Paper-II
137446	1237664289928577798	185.33821	14.55440	19.676	0.5041	1	0.4927	12	22.98	–	Paper-II
137700	1237661069263438328	185.50058	14.69882	19.284	0.3709	1	0.3532	9	41.93	SDSSCG 07578	Paper-II
137863	1237664289928708314	185.65661	14.57371	19.421	0.5041	2	0.5012	14	499.35	–	Paper-II
138077	1237661975473881551	185.97452	7.32436	19.505	0.4397	1	0.4418	12	79.31	–	Paper-II
139177	1237665126933922648	186.68128	33.76685	20.275	0.7665	1	0.6427	2	42.03	–	Paper-III
140028	1237651752939749568	187.26808	1.83400	18.417	0.3139	1	0.3003	18	67.11	GMBCG J187.26136+01.84321	Paper-II
141388	1237658493893280628	187.64330	10.95252	20.030	0.4407	2	0.4716	8	67.26	–	Paper-III
141650	1237658493893280722	187.69326	10.94824	20.940	0.7519	1	0.6886	2	78.00	–	Paper-III
141670	1237658493893280303	187.69396	10.90162	19.391	0.4134	1	0.3833	20	126.62	–	Paper-II
142659	1237668299279040873	187.91414	20.92443	20.238	0.6543	1	0.5702	3	68.98	–	Paper-III
142993	1237668298205364430	188.13313	20.06167	16.077	0.0635	2	0.0614	11	13.94	–	Paper-III
143008	1237648704579175014	188.14958	0.04373	21.039	0.6832	1	0.7176	2	32.14	–	Paper-III
146549	1237661950793941297	190.80023	13.21965	19.968	0.7896	1	0.7116	1	4.64	–	Paper-III
147020	1237668623551889555	191.10600	16.79916	17.357	0.2351	2	0.2167	22	11.38	WHL J124425.4+164756	Paper-II
147115	1237671764249543261	191.22085	−0.32448	19.986	0.4693	1	0.4536	7	391.95	BLOX J1244.8-0019.8	Paper-III
149238	1237664292079403190	193.30398	15.93415	18.095	0.2754	1	0.2673	18	51.39	WHL J125313.0+155602	Paper-III
149472	1237662238006969117	193.43795	10.19564	19.742	0.6544	1	0.6044	5	9.75	–	Paper-III
153943	1237668625164665758	196.41292	17.93772	20.241	0.5445	2	0.5109	14	436.08	WHL J130534.9+175649	Paper-II
154013	1237668625164730643	196.43635	17.89166	19.442	0.5412	1	0.5208	8	11.29	–	Paper-III
155237	1237661972801454697	197.26012	8.29365	19.238	0.4643	1	0.4348	15	18.26	–	Paper-II
155752	1237661972801651791	197.59477	8.33155	20.077	0.7059	1	0.6671	3	22.83	–	Paper-III
158679	1237665225700934189	201.27591	30.41477	18.416	0.4348	1	0.4170	10	93.27	RCS J132506+3024.8	Paper-III
159400	1237671956442120782	201.63075	7.75169	20.070	0.5343	2	0.5208	9	22.80	2XMM J132631.5+074503	Paper-II

Table 1. continued.

Detid ^a	Objid ^b (BCG)	RA ^g (deg)	Dec ^g (deg)	m_r^g (BCG)	z_s^g (21)	N_{cs}^g (22)	z_p^g (23)	N_{sp}^g (24)	Offset ^g (kpc)	NED-name	Note ^h
(1)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
160695	1237665128550367803	202.69388	33.76724	19.998	0.4485	2	0.4485	15	105.69	SDSSCGB 63162	Paper-II
162382	1237664294223085804	203.76069	37.83613	18.949	0.3834	1	0.3735	25	259.46	WHL J133457.6+375029	Paper-II
162545	1237664294223086790	203.81047	37.81983	20.737	0.6964	1	0.7021	2	41.24	[MJM98] 034	Paper-III
163417	1237667912211562931	204.29989	24.24573	20.045	0.5056	1	0.5011	10	38.21	–	Paper-III
163928	1237671992413782929	204.71949	4.72021	21.535	0.7264	1	0.7145	4	27.58	–	Paper-III
164535	1237651504881140622	205.41102	0.28245	19.338	0.5054	2	0.4906	16	153.82	2XMM J134138.7+001721	Paper-III
164909	1237651504344400779	205.76896	−0.01547	19.692	0.7151	1	0.6751	6	43.58	[BPG2004] J134304.8-000056.3	Paper-II
165043	1237662194533401363	205.87815	40.51334	20.387	0.7083	1	0.6737	2	44.70	–	Paper-III
165602	1237668316456222887	206.73146	17.53798	19.607	0.4736	1	0.4419	4	102.37	–	Paper-III
168090	1237668298214015138	208.89436	18.41726	17.899	0.3554	1	0.3416	19	496.37	GMBCG J208.92465+18.43231	Paper-II
170597	1237665430243705255	211.56488	28.51455	19.649	0.5457	1	0.5208	12	3.41	NSCS J140614+282911	Paper-II
170668	1237665430243705255	211.75041	28.36103	19.802	0.5042	1	0.4965	12	4.98	–	Paper-II
171595	1237655497594897279	213.23824	−3.15516	20.370	0.6697	1	0.7371	2	23.07	–	Paper-III
171668	1237655493299536387	213.30337	−3.29271	18.403	0.3088	1	0.3229	18	14.34	–	Paper-II
171714	1237661434853982771	213.33018	44.08188	20.301	0.5615	1	0.5402	8	2.75	–	Paper-III
173756	1237662195073745343	215.76928	38.46832	19.469	0.4508	1	0.4292	12	64.95	WHL J142304.6+382805	Paper-II
174080	1237665429172126097	216.88109	26.48409	18.722	0.3693	1	0.3508	17	22.92	GMBCG J216.88110+26.48409	Paper-II
175129	1237661361303126731	217.66426	42.17847	19.048	0.4275	1	0.4381	9	53.57	–	Paper-II
178050	1237651822175715561	223.32185	3.57965	18.760	0.3709	2	0.3531	18	17.57	GMBCG J223.32185+03.57965	Paper-II
178120	1237654879667028594	223.46466	3.39233	19.004	0.3685	2	0.3576	19	77.10	–	Paper-II
180311	1237648704059474189	227.32956	−0.23877	17.821	0.2625	1	0.2517	29	24.73	SDSS CE J227.319229-00.249662	Paper-II
184398	1237665536540279868	237.38329	21.55053	20.089	0.6358	1	0.6584	2	14.54	CXO J154932.0+213301	Paper-II
185578	1237662474765992736	239.87379	35.07410	19.752	0.4895	2	0.4835	8	109.72	WHL J155926.1+350456	Paper-II
187930	1237668367463481778	244.31101	12.62973	17.493	0.1987	1	0.1889	14	72.10	SDSSCGB 06910	Paper-III
190632	1237659324956345286	247.73853	37.71158	20.110	0.5598	1	0.5019	3	97.34	–	Paper-III
190800	1237659329779204630	247.88892	37.81662	19.358	0.4143	2	0.3917	14	47.87	WHL J163133.3+374859	Paper-II
191450	1237659325493346719	248.21061	37.68201	17.869	0.2032	1	0.1939	4	70.80	–	Paper-III
193467	1237655374647984970	250.42645	39.12752	20.634	0.5922	1	0.5798	4	17.25	–	Paper-III
200392	1237662701873267520	260.90067	34.19946	18.321	0.4428	2	0.4313	14	42.98	WHL J172336.2+341158	Paper-II
262357	1237651495759315826	122.87630	48.16215	21.000	0.6074	2	0.5786	2	205.31	–	Paper-III
262423	1237653621761769513	125.39666	1.04216	15.743	0.0994	1	0.0873	50	1.05	–	Paper-II
263066	1237651191357571426	130.04640	51.22396	19.980	0.5798	1	0.5944	5	32.20	–	Paper-III
263705	1237667291576729942	134.87965	17.14886	18.851	0.3257	1	0.3183	16	18.56	–	Paper-II
264469	1237660962404172624	141.58913	36.35895	19.799	0.6558	1	0.6501	4	145.52	RCS J092622+3621.8	Paper-III
264943	1237654669735166950	149.04432	−0.36284	20.462	0.5828	1	0.5651	10	44.43	–	Paper-II
265123	1237653664721797488	149.50358	2.02399	20.780	0.6740	1	0.5520	3	182.09	–	Paper-III
274756	1237662247131349450	206.46481	7.75003	20.539	0.6539	2	0.6696	5	256.85	–	Paper-III
275328	1237662662134661959	219.31932	34.25158	20.046	0.5427	4	0.5322	19	229.84	WHL J143713.7+341530	Paper-II

Table 1. continued.

Detid ^a	Objid ^b (BCG)	RA ^g (deg)	Dec ^g (deg)	m_r^g (BCG)	z_s^g	$N_{s,g}$	z_p^g	$N_{p,g}$	Offset ^g (kpc)	NED-name	Note ^h
(1)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
275341	1237662662134727278	219.42946	34.13609	19.954	0.5446	2	0.5386	8	10.82	–	Paper-III
278534	1237662500012425472	251.86614	27.21090	20.408	0.4937	1	0.5004	6	118.76	–	Paper-III
287820	1237663543146644275	331.52062	−0.17853	19.208	0.3878	1	0.3632	8	155.73	–	Paper-II
309027	1237660764833317399	120.95424	23.83309	19.318	0.5780	1	0.5791	5	25.44	–	Paper-III
309493	1237651274032874098	122.74182	50.09320	18.559	0.4029	1	0.4049	16	34.04	GMBCG J122.74182+50.09326	Paper-II
309859	1237660635983118556	126.13809	29.79794	16.667	0.2094	1	0.2021	14	25.08	–	Paper-III
310654	1237660961862189496	130.01495	29.76319	20.549	0.5708	1	0.5874	5	69.10	2XMMi J084004.3+294544	Paper-II
310685	1237660764837708479	130.05775	29.87904	20.209	0.5082	1	0.5021	7	147.05	GMBCG J130.06007+29.88694	Paper-II
310772	1237657400804966579	130.21947	38.64636	15.502	0.1171	2	0.1154	16	2.67	–	Paper-II
311197	1237667293186883997	133.22122	17.95514	16.979	0.2075	3	0.2016	21	12.72	GMBCG J133.22120+17.95514	Paper-III
312824	1237658425155977363	140.55332	6.53523	17.140	0.1733	3	0.1884	9	157.99	–	Paper-III
315216	1237650369398375098	157.53108	−3.10994	18.820	0.4392	2	0.4442	14	35.39	WHL J103007.5-030635	Paper-II
316779	1237658422483550621	168.02887	6.21016	19.144	0.3472	1	0.3503	14	17.43	–	Paper-II
317214	1237658422483747584	168.49093	6.18121	20.184	0.5400	1	0.5210	9	28.85	–	Paper-II
317419	1237661070867497545	169.94669	15.55053	19.976	0.4789	1	0.4727	4	11.39	–	Paper-III
318253	123765403030691620	176.41303	2.88182	18.177	0.2799	3	0.2631	17	372.99	WHL J114541.1+025409	Paper-II
318315	123767114255975817	176.58184	2.93817	16.675	0.1584	1	0.1564	17	26.90	–	Paper-III
319555	1237665024366477463	180.18868	34.41193	18.037	0.2627	2	0.2580	17	45.66	GMBCG J180.18869+34.41193	Paper-II
320719	1237655126620045679	184.83849	6.02894	18.724	0.3535	1	0.3507	10	49.29	–	Paper-III
321022	1237658493356212842	187.27738	10.49481	20.745	0.6563	1	0.6364	4	107.98	–	Paper-III
321239	1237658629158732021	187.66631	11.95001	17.931	0.2480	1	0.2393	21	28.61	WHL J123039.9+115700	Paper-II
321268	1237662193453695521	187.71084	41.57208	20.261	0.7454	1	0.7264	2	23.31	–	Paper-III
321464	1237661812813070980	188.18885	12.55483	20.301	0.5361	2	0.5539	3	456.54	–	Paper-III
322726	1237654880727139062	192.33753	5.30017	19.905	0.4198	1	0.3916	11	239.86	WHL J124918.6+051848	Paper-II
322873	1237671264962150728	192.50153	5.34915	18.727	0.3849	2	0.3757	16	303.29	WHL J125000.4+052056	Paper-II
325696	1237655499738579243	204.52444	−1.58302	18.794	0.3481	1	0.3663	11	13.86	–	Paper-II
327024	1237651821098500609	215.30550	3.13251	18.623	0.3122	1	0.3260	10	120.69	–	Paper-III
327387	1237648721247273154	217.80191	−0.10467	21.057	0.7122	1	0.6585	5	148.88	–	Paper-III
327608	1237648704593068052	219.84926	0.21340	18.493	0.3000	2	0.2831	9	233.23	–	Paper-II
329022	1237655693551796667	224.28785	−1.01563	18.441	0.2742	1	0.2813	9	3.40	SDSS CE J224.294342-01.012142	Paper-II
331167	1237655467525407096	228.87274	0.66177	18.122	0.2645	1	0.2516	24	6.16	WHL J151529.5+003942	Paper-II