

THE FRACTION OF COOL-CORE CLUSTERS IN X-RAY VS. SZ SAMPLES USING *CHANDRA* OBSERVATIONS

FELIPE ANDRADE-SANTOS¹, CHRISTINE JONES¹, WILLIAM R. FORMAN¹, LORENZO LOVISARI¹, ALEXEY VIKHLININ¹,
REINOUT J. VAN WEEREN¹, STEPHEN S. MURRAY¹, MONIQUE ARNAUD², GABRIEL W. PRATT², JESSICA DÉMOCLÈS², RALPH
KRAFT¹, PASQUALE MAZZOTTA^{1,3}, HANS BÖHRINGER⁴, GAYOUNG CHON⁴, SIMONA GIACINTUCCI⁵, TRACY E. CLARKE⁶,
STEFANO BORGANI^{7,8}, LARRY DAVID¹, MARIAN DOUSPIS⁹, ETIENNE POINTECOUTEAU^{10,11}, HÅKON DAHLE¹², SHEA
BROWN¹³, NABILA AGHANIM¹⁴, ELENA RASIA⁸

¹Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

²Laboratoire AIM, CEA/IRFU, CNRS/INSU, Université Paris Diderot, CEA-Saclay, 91191 Gif-Sur-Yvette, France

³Dipartimento di Fisica, Università di Roma Tor Vergata, via della Ricerca Scientifica 1, 00133 Roma, Italy

⁴Max Planck Institute for Extraterrestrial Physics, Giessenbachstrasse, 85748 Garching, Germany

⁵Naval Research Laboratory, 4555 Overlook Avenue SW, Code 7213, Washington, DC 20375, USA

⁶U.S. Naval Research Laboratory, Code 7213, 4555 Overlook Ave. SW., Washington, DC 20375

⁷Dipartimento di Fisica dell'Università di Trieste, Sezione di Astronomia, via Tiepolo 11, I-34131 Trieste, Italy

⁸INAF, Osservatorio Astronomico di Trieste, via Tiepolo 11, I-34131, Trieste, Italy

⁹Institut d'Astrophysique Spatiale, CNRS (UMR8617) Université Paris-Sud 11, Bâtiment 121, Orsay, France

¹⁰CNRS; IRAP; 9 Av. colonel Roche, BP 44346, F-31028 Toulouse cedex 4, France

¹¹Université de Toulouse; UPS-OMP; IRAP; Toulouse, France

¹²Institute of Theoretical Astrophysics, University of Oslo, P.O. Box 1029, Blindern, NO-0315 Oslo, Norway

¹³Department of Physics & Astronomy, The University of Iowa, Iowa City, IA, 52245

¹⁴Institut d'Astrophysique Spatiale, CNRS, Univ. Paris-Sud, Université Paris-Saclay, Bât. 121, 91405 Orsay Cedex, France

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ABSTRACT

We derive and compare the fractions of cool-core clusters in the *Planck* Early Sunyaev-Zel'dovich sample of 164 clusters with $z \leq 0.35$ and in a flux-limited X-ray sample of 100 clusters with $z \leq 0.30$, using *Chandra* observations. We use four metrics to identify cool-core clusters: 1) the concentration parameter: the ratio of the integrated emissivity profile within $0.15 r_{500}$ to that within r_{500} , and 2) the ratio of the integrated emissivity profile within 40 kpc to that within 400 kpc, 3) the cuspliness of the gas density profile: the negative of the logarithmic derivative of the gas density with respect to the radius, measured at $0.04 r_{500}$, and 4) the central gas density, measured at $0.01 r_{500}$. We find that the sample of X-ray selected clusters, as characterized by each of these metrics, contains a significantly larger fraction of cool-core clusters compared to the sample of SZ selected clusters ($44 \pm 7\%$ vs. $28 \pm 4\%$ using the concentration parameter in the $0.15\text{--}1.0 r_{500}$ range, $61 \pm 8\%$ vs. $36 \pm 5\%$ using the concentration parameter in the $40\text{--}400$ kpc range, $64 \pm 8\%$ vs. $38 \pm 5\%$ using the cuspliness, and $53 \pm 7\%$ vs. $39 \pm 5\%$ using the central gas density). Qualitatively, cool-core clusters are more X-ray luminous at fixed mass. Hence, our X-ray flux-limited sample, compared to the approximately mass-limited SZ sample, is over-represented with cool-core clusters. We describe a simple quantitative model that uses the excess luminosity of cool-core clusters compared to non-cool-core clusters at fixed mass to successfully predict the observed fraction of cool-core clusters in X-ray selected samples.

Subject headings: galaxy clusters: general — cosmology: large-structure of universe

1. INTRODUCTION

Clusters of galaxies are the largest gravitationally bound structures in the Universe. In the standard Λ CDM cosmology, massive halos dominated by dark matter assemble by the accretion of smaller groups and clusters (e.g., Forman & Jones 1982; Allen et al. 2011; Kravtsov & Borgani 2012). Under the influence of gravity, diffuse matter and smaller collapsed halos fall into larger halos and, occasionally, halos of comparable mass merge with one another. X-ray observations of substructures in clusters of galaxies (see, for instance, Jones & Forman 1984; Jones et al. 1979; Jones & Forman 1999; Mohr et al. 1995; Buote & Tsai 1996; Jeltema et al. 2005; Böhringer et al. 2010; Laganá et al. 2010; Andrade-Santos et al. 2012, 2013) and measurements of the growth of structure (Vikhlinin et al. 2009b; Mantz et al. 2010; Allen et al. 2011; Benson et al. 2013; Planck Collaboration et al. 2014, 2016) demonstrate that clusters are still in the

process of formation.

Early X-ray observations of galaxy clusters revealed that a significant fraction present a bright and dense core, whose central cooling time is much shorter than the Hubble time. These observations led to the development of the cooling flow model (Fabian & Nulsen 1977; Fabian et al. 1984; Fabian 1994, 2012). Analyzing deep *Chandra* observations of Hydra-A, David et al. (2001) showed that the spectral fits yielded significantly smaller mass deposition rates than expected. Using XMM-Newton, Peterson et al. (2003) presented high-resolution X-ray spectra of 14 putative cooling-flow clusters that exhibit a severe deficit of very cool emission relative to the predictions of the isobaric cooling-flow model. However, as predicted by the cooling-flow model, a temperature drop in the center of many clusters is observed, typically reaching one third of the peak temperature (e.g., Peterson et al. 2003; Vikhlinin et al. 2005). Clusters presenting such a temperature drop in their cores are re-

ferred to as cool-core (CC) clusters (Molendi & Pizzolato 2001).

Using a very large, high-resolution cosmological N-body simulation (Millennium-XXL), Angulo et al. (2012) showed that cosmological conclusions based on galaxy cluster surveys depend critically on the selection biases, which include the wavelength used for identification of clusters of galaxies. Planck Collaboration et al. (2011, 2013) presented the first observational evidence of different morphological properties in X-ray vs. SZ selected samples: SZ selected clusters have a less peaked density distribution and are less X-ray luminous at a given mass than X-ray selected clusters. Wen & Han (2013) presented a method to diagnose substructure and dynamical state for 2092 optical galaxy clusters. They found that the fraction of relaxed clusters is 28% in the full sample, while the fraction increases to 46% for the subsample matched with ROSAT detections, indicating that the wavelength used for detecting clusters plays a significant role in the dynamical state of the population that is selected. McDonald et al. (2013) showed that CC clusters in his SZ sample represent $40 \pm 10\%$ of the cluster population at low redshift. Sommer & Basu (2014) constructed near-complete samples based on X-ray and SZ catalogs. They found that roughly $70 \pm 10\%$ of the clusters in the X-ray selection have no radio halos (indicating they are relaxed), whereas the fraction in the *Planck* selection is only $30 \pm 10\%$, in agreement with findings from Wen & Han (2013); McDonald et al. (2013).

More recently, Rossetti et al. (2016) compared the dynamical state of the 132 clusters with the highest signal to noise ratio from the *Planck* Sunyaev-Zel'dovich (SZ) catalogue, to that of three X-ray-selected samples (HIFLUGCS¹, MACS², and REXCESS³). They showed that the fractions of relaxed clusters in the X-ray samples are significantly larger than that in the *Planck* sample, and interpreted this result as an indication of a cool core bias (Eckert et al. 2011) affecting X-ray selection.

Recently, Rossetti et al. (2017) compared the fraction of cool core clusters in a *Planck* cosmology SZ sample (PSZ1, Planck Collaboration et al. 2014) to that in the MACS X-ray sample. Using the concentration parameter which measures the ratio of the integrated surface brightness in two fixed physical apertures, as defined by Santos et al. (2008), they showed that the cool core fraction is significantly higher in the MACS X-ray selected sample than in the *Planck* cosmology SZ sample ($59 \pm 5\%$ in their X-ray sample vs. $29 \pm 4\%$ in their SZ sample). This result agrees with that presented by Andrade-Santos et al. (2017), which is fully described in this paper. The X-ray sample presented in this paper spans a higher mass range compared to the mass range in the X-ray sample presented by Rossetti et al. (2017). Therefore, we also make use of three parameters which are computed at radii that scale with total mass. We note that the work presented by Rossetti et al. (2017) and the work presented here were developed in parallel (Jones et al. 2016; Andrade-Santos et al. 2017).

¹ HIFLUGCS – The Highest X-ray FLUX Galaxy Cluster Sample (Reiprich & Böhringer 2002)

² MACS – The MAAssive Cluster Survey (Ebeling et al. 2001)

³ REXCESS – The REpresentative XMM-Newton ClustEr Structure Survey (Böhringer et al. 2007)

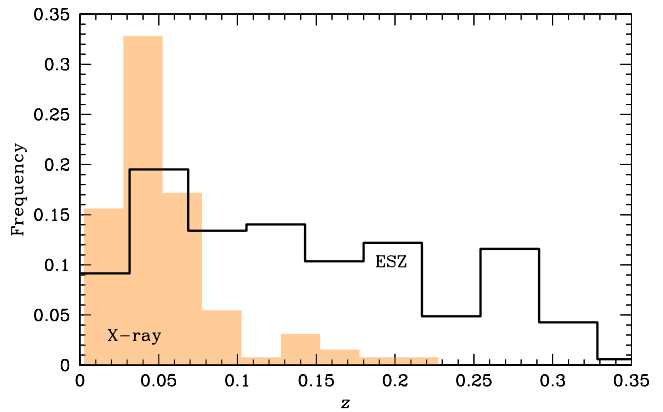


FIG. 1.— Distribution of cluster redshifts in the ESZ and X-ray selected samples. The ESZ sample extends to higher redshifts. The solid histogram shows the X-ray flux limited sample while the solid line corresponds to the ESZ cluster sample.

In this paper we compare the nature of the cores for 164 *Planck* ESZ clusters at $z < 0.35$ to the 100 highest flux X-ray clusters at Galactic latitudes $|b| > 20^\circ$ and $0.025 < z < 0.30$. The X-ray sample is extended to 100 clusters from the sample of 52 clusters presented by Voevodkin & Vikhlinin (2004), by lowering the flux limit to $f_X > 7.5 \times 10^{-12}$ erg s⁻¹ cm⁻² in the 0.5 – 2.0 keV band.

Throughout this paper, we assume a standard Λ CDM cosmology with $H_0 = 70$ km s⁻¹ Mpc⁻¹, $\Omega_M = 0.3$, and $\Omega_\Lambda = 0.7$. All uncertainties are quoted at the 1σ level.

2. SZ AND X-RAY SELECTED CLUSTERS

The main goal of this work is to compare the fraction of CC clusters in X-ray and SZ selected samples. In this section, we describe the two samples.

2.1. SZ sample

The first catalog of 189 SZ clusters detected by the *Planck* mission was released in early 2011 (Planck Collaboration et al. 2011). A *Chandra* XVP (X-ray Visionary Program – PI: Jones) and HRC Guaranteed Time Observations (PI: Murray) combined to form the *Chandra-Planck* Legacy Program for Massive Clusters of Galaxies⁴. For each of the 164 ESZ *Planck* clusters at $z \leq 0.35$, we obtained *Chandra* exposures sufficient to collect at least 10,000 source counts.

2.2. X-ray sample

Voevodkin & Vikhlinin (2004) compiled a sample of the X-ray brightest clusters in the local universe by selecting the highest flux clusters detected in the ROSAT All-Sky survey at $|b| > 20^\circ$ and $z > 0.025$ – using the HIFLUGCS catalog (Reiprich & Böhringer 2002) as reference. The sample used here is an extension of the Voevodkin & Vikhlinin (2004) sample, where the flux limit in the 0.5 – 2.0 keV band was lowered to $f_X > 7.5 \times 10^{-12}$ erg s⁻¹ cm⁻². This sample contains 100 clusters and has an effective redshift depth of $z < 0.3$. All have *Chandra* observations. Of the 100 X-ray selected clusters, 49 are also in the ESZ sample, and 47 are in the HIFLUGCS catalog.

⁴ hea-www.cfa.harvard.edu/CHANDRA.PLANCK.CLUSTERS/

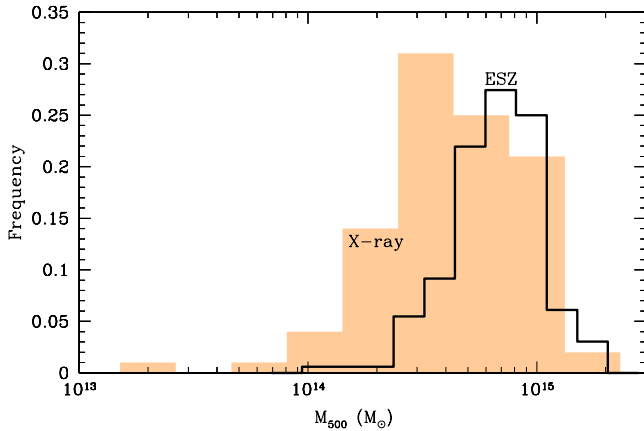


FIG. 2.— Distribution of cluster masses within r_{500} for the ESZ and X-ray selected samples (see Sections 2.1 and 2.2). The X-ray sample extends to lower masses than does the ESZ sample. The solid histogram shows the X-ray flux limited sample, while the solid line corresponds to the ESZ cluster sample.

2.3. Comparisons between the X-ray and ESZ selected clusters

Figure 1 presents the redshift distribution in both samples. The *Planck* detected clusters are clearly more broadly distributed in redshift than are the X-ray clusters. This is due to the nature of the selection: for resolved clusters the Sunyaev-Zel’dovich signal is independent of the redshift of the cluster because it is the CMB that is distorted (the CMB photons originated at the epoch of recombination – from a constant redshift of $z \sim 1000$), while the X-ray selected clusters constitute a flux-limited sample, which strongly favors the X-ray brighter, lower redshift clusters. Figure 2 presents the mass distribution of both samples. The X-ray sample spans a much larger mass range, extending to lower masses than the *Planck* ESZ sample. The difference between the lowest observed mass in the X-ray and ESZ samples is caused by different detection thresholds. Note that the highest observed mass is the same for both samples (see Figure 2).

2.4. Subclusters

A small fraction ($\sim 10 - 20\%$) of the clusters in both the X-ray and SZ samples present X-ray bright subclusters. In our analyses we exclude the secondary subclusters. Only the principal cluster component is used in the comparisons between the X-ray and SZ samples. However, we present the metrics for all cluster components in Tables A1 and A2.

3. DATA REDUCTION

Our *Chandra* data reduction followed the process described in Vikhlinin et al. (2005). We applied the calibration files CALDB 4.7.2. The data reduction included corrections for the time dependence of the charge transfer inefficiency and gain, and also a check for periods of high background, which were then omitted. Standard blank sky background files and readout artifacts were subtracted. We also detected compact X-ray sources in the 0.7–2.0 keV and 2.0–7.0 keV bands using CIAO wavdetect and then masked these sources before performing the spectral and spatial analyses of the cluster

emission. For each cluster, we used all available *Chandra* observations within 2 Mpc of the cluster center with all CCDs (ACIS-I and ACIS-S).

4. EMISSION MEASURE PROFILES

We refer to Vikhlinin et al. (2006) for a detailed description of the procedures we used to compute the emission measure profile for each cluster. We outline here only the main aspects of the method.

We measured the surface brightness profiles in the 0.7–2.0 keV energy band, which maximizes the signal to noise ratio in *Chandra* observations for typical cluster gas temperatures. We used the X-ray halo peak as the cluster center. The readout artifacts and blank-field background (see section 2.3.3 of Vikhlinin et al. 2006) were subtracted from the X-ray images, and the results were then exposure-corrected, using exposure maps computed assuming an absorbed optically-thin thermal plasma with $kT = 5.0$ keV, abundance = 0.3 solar, with the Galactic column density and including corrections for bad pixels and CCD gaps, which do not take into account spatial variations of the effective area. We subtracted any small uniform component corresponding to soft X-ray foreground adjustments, if required (determined by fitting a thermal model in a region of the detector field distant from the cluster center, taking into account the expected thermal contribution from the cluster).

Following these steps, we extracted the surface brightness in narrow concentric annuli ($r_{\text{out}}/r_{\text{in}} = 1.05$) centered on the X-ray halo peak and computed the *Chandra* area-averaged effective area for each annulus (see Vikhlinin et al. (2005), for details on calculating the effective area). To compute the emission measure and temperature profiles, we assumed spherical symmetry. The spherical assumption is expected to introduce only small deviations in the emission measure profile (Piffaretti et al. 2003). Using the modeled de-projected temperature (see Section 7), effective area, and metallicity as a function of radius, we converted the *Chandra* count rate in the 0.7–2.0 keV band into the emission integral, $EI = \int n_e n_p dV$, within each cylindrical shell. Tables A1 and A2 list the maximum cluster radius where the emission integral is computed (r_{max}) for each cluster. Seven clusters in the ESZ sample have $r_{\text{max}} < r_{500}$, and in the X-ray sample, nine clusters have this condition (four of them are also in the ESZ sample). These numbers represent only 4% and 9% of the clusters in the ESZ and X-ray samples, respectively.

We fit the emission measure profile assuming the gas density profile follows that given by Vikhlinin et al. (2006):

$$n_e n_p = n_0^2 \frac{(r/r_c)^{-\alpha}}{(1 + r^2/r_c^2)^{3\beta - \alpha/2}} \frac{1}{(1 + r^\gamma/r_s^\gamma)^{\epsilon/\gamma}} + \frac{n_{02}^2}{(1 + r^2/r_{c2}^2)^{3\beta_2}}, \quad (1)$$

where the parameters n_0 and n_{02} determine the normalizations of both additive components. α , β , β_2 , and ϵ are indexes controlling the slope of the curve at characteristic radii given by the parameters r_c , r_{c2} , and r_s . γ controls the width of the transition region given by r_s . Although the relation given by Equation 1 is based on a classic

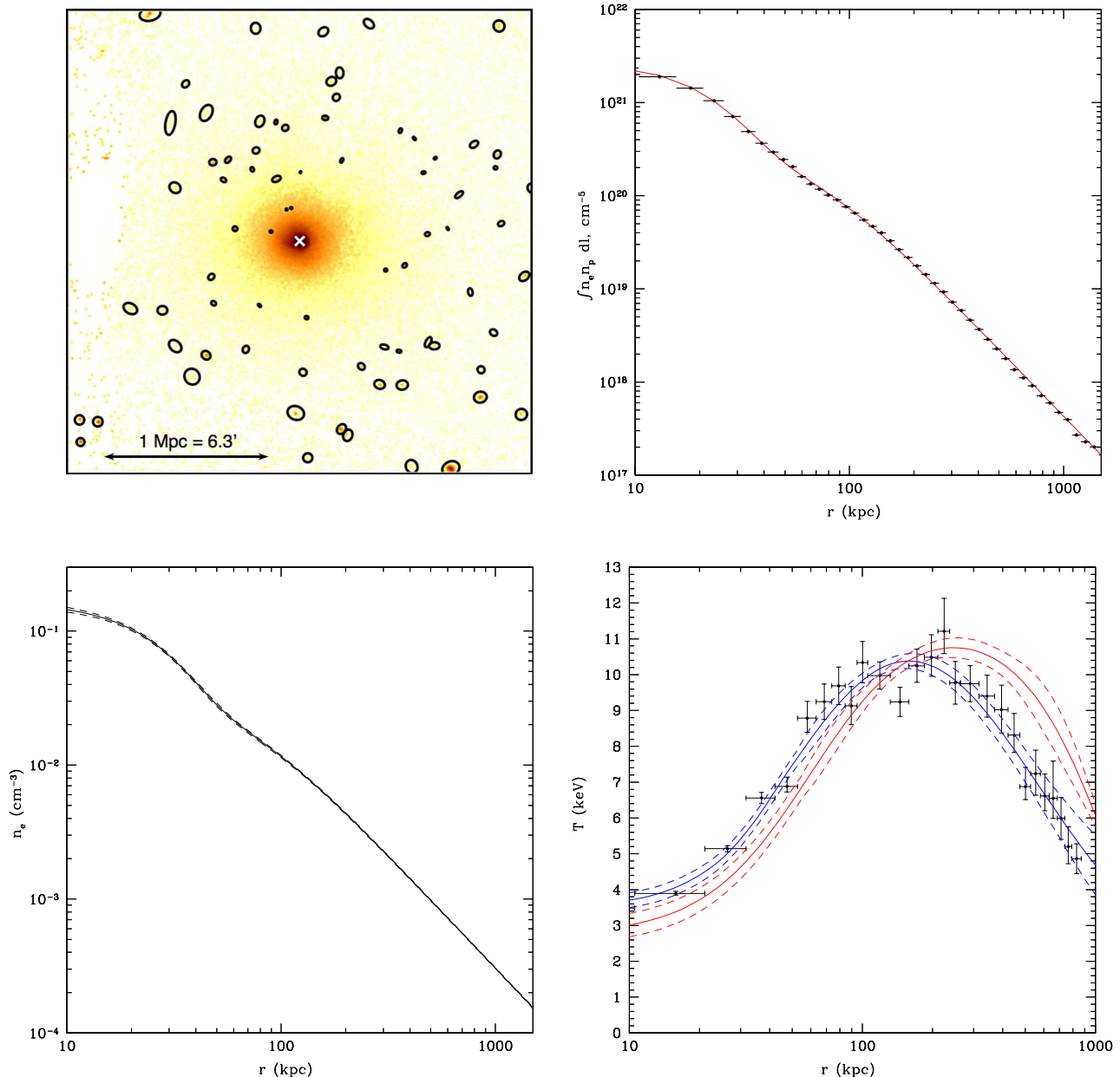


FIG. 3.— Example of the X-ray image and the projected emissivity, gas density, and temperature profiles for a cool-core cluster (A2204). Top left panel shows the 0.5-2.0 keV, background-subtracted, exposure map corrected ACIS-I image. The total filtered *Chandra* exposure is 117 ks. Black ellipses correspond to the masked X-ray point sources and the cross corresponds to the cluster center. Top right panel shows the projected emissivity profile. The solid line shows the emission measure integral of the best fit to the emissivity profile given by Equation (1). Bottom left panel shows the gas density profile. The solid line shows the density profile obtained from the emissivity profile given by Equation (1). Bottom right panel shows the gas temperature profile. The red and blue lines show the de-projected and projected temperature profiles, respectively (Equations 7 and 8). The dashed lines in the gas and temperature profiles show the 68% confidence range. This is an example of a cluster with deep *Chandra* exposure, which allow us to extract the temperature profile in many radial bins.

β -model (Cavaliere & Fusco-Femiano 1976), it is modified to account for a central power-law type cusp and a steeper emission measure slope at large radii. In addition, a second β -model is included, to better characterize the cluster core. For further details on this equation, we refer the reader to Vikhlinin et al. (2006). In the fit to the emissivity profile, all parameters are free to vary. For a typical metallicity of $0.3 Z_{\odot}$, the reference values from Anders & Grevesse (1989) yield $n_e/n_p = 1.1995$. Exam-

ples of projected emissivity and gas density profiles are presented in Figures 3 and 4.

5. TOTAL CLUSTER MASS ESTIMATES

Using the gas mass and temperature, we estimated the total cluster mass from the Y_X - M scaling relation

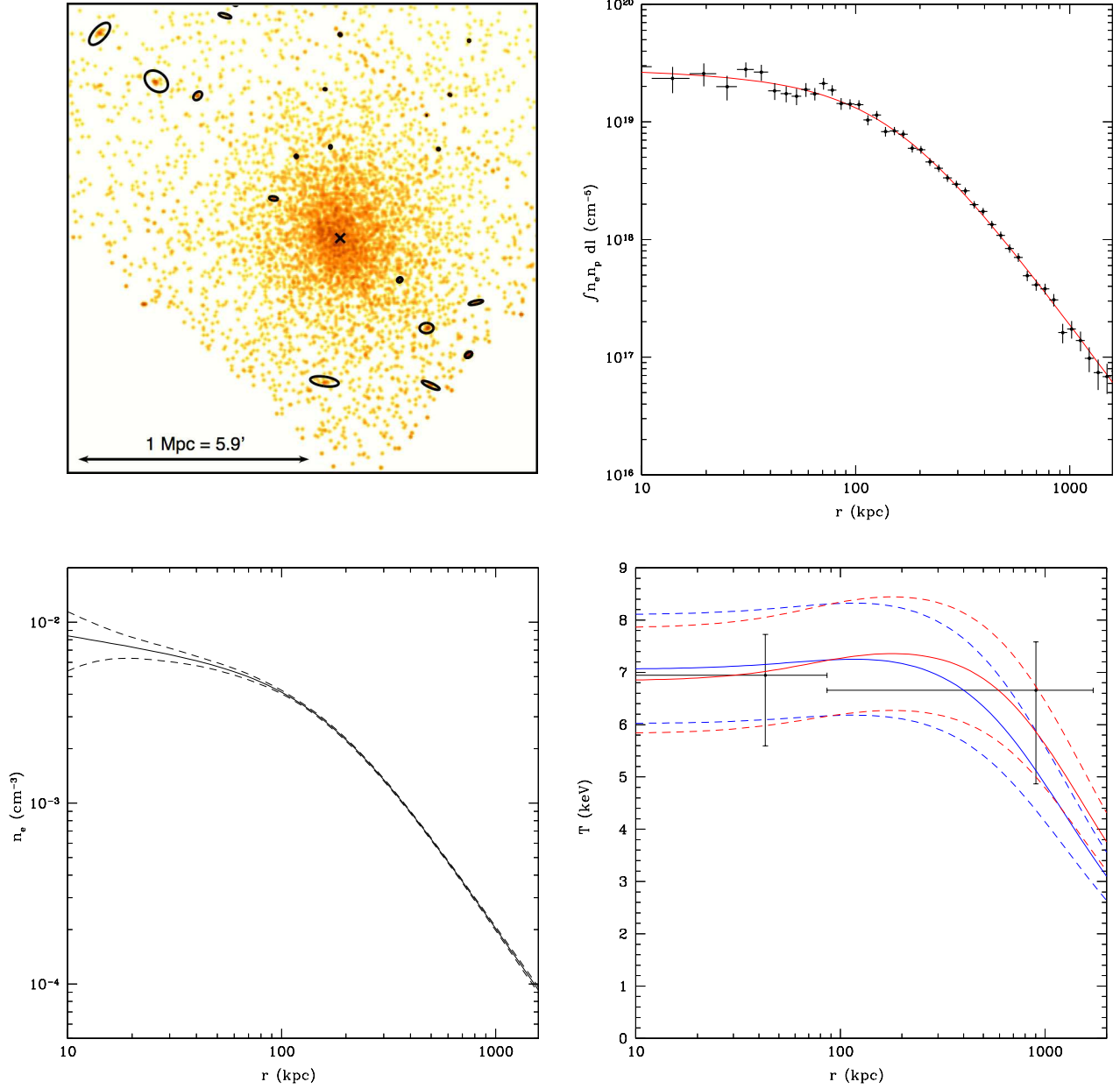


FIG. 4.— Similar panels as in Figure 3, for the non-cool-core cluster PLCKESZ G000.44-41.83. This is an example of a cluster with moderate data quality, which illustrates the necessity of metrics to determine the nature of the cluster core in the absence of a detailed temperature profile, like that shown in Figure 3. The total filtered *Chandra* exposure is 14 ks.

of Vikhlinin et al. (2009a),

$$M_{500, Y_X} = E^{-2/5}(z) A_{YM} \left(\frac{Y_X}{3 \times 10^{14} M_\odot \text{keV}} \right)^{B_{YM}}, \quad (2)$$

where $Y_X = M_{\text{gas},500} \times kT_X$, $M_{\text{gas},500}$ is computed using the best fit parameters of Equation (1), and T_X is the measured temperature in the $(0.15-1) \times r_{500}$ range. $A_{YM} = 5.77 \times 10^{14} h^{1/2} M_\odot$ and $B_{YM} = 0.57$ (Maughan et al. 2012). Here, $M_{Y_X,500}$ is the total mass within r_{500} , and $E(z) = [\Omega_M(1+z)^3 + (1-\Omega_M-\Omega_\Lambda)(1+z)^2 + \Omega_\Lambda]^{1/2}$ is the function describing the evolution of the Hubble parameter.

Using Equation (2), r_{500} is computed by solving

$$M_{500, Y_X} \equiv 500 \rho_c (4\pi/3) r_{500}^3, \quad (3)$$

where ρ_c is the critical density of the Universe at the cluster redshift. In practice, Equation (2) is evaluated at a given radius, whose result is compared to the evaluation of Equation (3) at the same radius. This process is repeated in an iterative procedure, until the fractional mass difference is less than 1%.

6. COOL-CORE METRICS

It is not possible to measure the temperature profile to determine the presence of a cool-core for all clusters in our SZ and X-ray samples because of the X-ray data

quality. Figures 3 and 4 illustrate the difference in data quality in the sample. Instead, we apply a more robust approach of using four metrics described below, to characterize the presence of cool cores.

6.1. Concentration parameter in the 40–400 kpc range

The presence of cooler gas in the cores of clusters usually implies a larger gas density in the core, compared to the gas density outside the core, to maintain the pressure balance. This increased gas density produces an X-ray bright core, since the X-ray emissivity is roughly proportional to the square of the gas density. Evaluating the X-ray brightness in the cluster core compared to the brightness within a given larger radius is a powerful method to determine if the cluster contains a cool-core. This metric is referred to as the concentration parameter and was originally introduced by Santos et al. (2008):

$$C_{\text{SB4}} = \frac{\Sigma(< 40\text{kpc})}{\Sigma(< 400\text{kpc})}, \quad (4)$$

where $\Sigma(< r)$ is the integrated projected emissivity within a circle of radius r .

6.2. Concentration parameter in the 0.15–1.0 r_{500} range

Here we also use a modification of the original definition (Santos et al. 2008), which is scaled by the characteristic radius r_{500} as (Maughan et al. 2012):

$$C_{\text{SB}} = \frac{\Sigma(< 0.15r_{500})}{\Sigma(< r_{500})}. \quad (5)$$

6.3. Cuspidity of the gas density profile

A third related metric is the cuspidity of the gas density profile computed at a fixed scaled radius of $0.04r_{500}$ (Vikhlinin et al. 2007):

$$\delta = -\left. \frac{d \log n(r)}{d \log r} \right|_{r=0.04r_{500}}, \quad (6)$$

where $n(r)$ is the gas density at a distance r from the cluster center.

6.4. Central gas density

A fourth useful quantity that indicates if a cluster presents a cool core is the central gas density (Hudson et al. 2010). Here we calculate the central density at $0.01 r_{500}$ from the core (which will be called n_{core}), since the equation used to fit the density profile may diverge at $r = 0$ (if $\alpha > 0$ in Equation (1)).

7. TEMPERATURE PROFILES

In this paper, we present the temperature profiles for only two clusters, although we have temperature profiles for all clusters in our samples, which vary in the number of fitted parameters according to the quality of the data. We provide the fitted parameters for all clusters in Andrade-Santos et al. (2017). The two temperature profiles presented in this paper are examples of CC and NCC clusters as well as clusters with very different data quality (see Figures 3 and 4). In this Section, we present the analytic equations used to obtain the profiles, referring the reader to papers where the full description of

the calculations are presented (see Vikhlinin et al. 2006; Andrade-Santos et al. 2015, 2016).

Vikhlinin et al. (2006) give a 3D temperature profile that describes the general features of the temperature profile of clusters:

$$T_{3\text{D}}(r) = T_0 \times \frac{x + T_{\text{min}}/T_0}{x + 1} \times \frac{(r/r_t)^{-a}}{(1 + (r/r_t)^b)^{c/b}}, \quad (7)$$

where $x = (r/r_{\text{cool}})^{a_{\text{cool}}}$. r_t and r_{cool} are the transition and cool core radii, respectively. T_{min} is the central temperature, and a , b , c , and a_{cool} are indexes that determine the slopes of the temperature profile in different radial ranges.

We derive the deprojected 3D temperature by projecting a model to compare to the projected measured temperature. The 3D temperature model, $T_{3\text{D}}$, is weighted by the density squared according to the spectroscopic-like temperature (Mazzotta et al. 2004, presented a formula to project the temperature which matches the spectroscopically measured temperature within a few percent):

$$T_{2\text{D}} = T_{\text{spec}} \equiv \frac{\int n_e^2 T_{3\text{D}}^{1/4} dz}{\int n_e^2 T_{3\text{D}}^{-3/4} dz}, \quad (8)$$

to give values of $T_{2\text{D}}$ for comparison with the measured values. n_e is the electron density, given by Equation 1, and $T_{3\text{D}}$ is the deprojected 3D temperature, given by Equation 7.

8. RESULTS

With the cluster gas density and emission measure profiles, we are able to compute the cuspidity of the gas density profile, concentration, and central gas density for the X-ray and *Planck* ESZ cluster samples. The uncertainties on the metrics for each cluster were computed using 100 Monte Carlo realizations of the density profile, including also a Gaussian distribution for r_{500} ($r_{500} \pm \sigma_{r_{500}}$). The top left panel of Figure 5 presents the distribution of concentration parameters in the 0.15–1.0 r_{500} range for both cluster samples. We used a Kolmogorov–Smirnov (K-S) test for the SZ and X-ray samples to evaluate the probability that the two samples were drawn from the same distribution. We obtained p -values that are smaller than 3.1×10^{-2} for all metrics, which suggests that the fraction of cool cores in the sample of X-ray selected clusters is different from that in the SZ sample. Defining a cool-core cluster as one that presents a concentration parameter in the 0.15–1.0 r_{500} range, $C_{\text{SB}} > 0.4$, the fraction of cool-cores in the X-ray sample is $44 \pm 7\%$, whereas in the SZ sample, the fraction is $28 \pm 4\%$. The uncertainties on the fraction of cool-core clusters were computed using a Bootstrap re-sampling method, including Poisson statistics on the number of clusters satisfying the cool-core criterion: a metric value greater than the break value used to segregate clusters into CC and NCC. With a break value of 0.075 (Santos et al. 2008) for the concentration parameter in the 40–400 kpc range (Figure 5, top right panel), we have a CC fraction of $61 \pm 8\%$ in the X-ray sample and $36 \pm 5\%$ in the SZ sample. The high fraction of CC clusters in the X-ray selected sample compared to that in the SZ sample agrees quite well with the recent results presented by Rossetti et al. (2017) ($59 \pm 5\%$ in their X-ray sample vs. $29 \pm 4\%$ in their SZ sample).

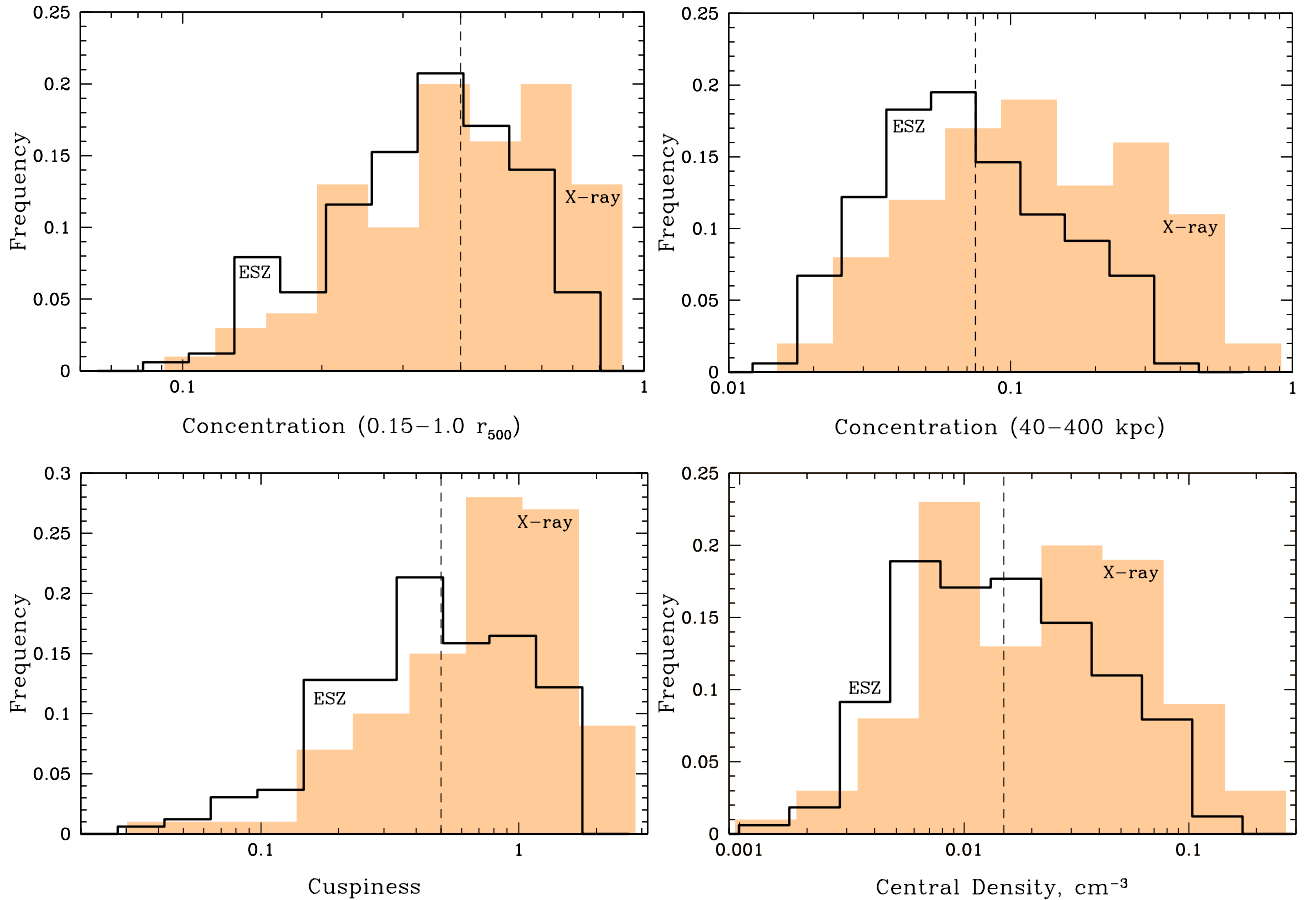


FIG. 5.— Top Left: Distribution of the concentration parameter in the 0.15–1.0 r_{500} range (C_{SB} – see Equation 5) for the 164 *Planck* ESZ (solid line) and the 100 X-ray selected clusters (orange shaded). Top Right: Distribution of the concentration parameter in the 40–400 kpc range (C_{SB4} – see Equation 4) for both samples. Bottom left: Distribution of the cuspiness (δ – see Equation 6) for both samples. Bottom right: Distribution of the central density (n_{core}) for both samples. The dashed vertical line in each panel corresponds to the break value used to segregate clusters into CC and NCC subsamples (0.4 for the concentration parameter in the 0.15–1.0 r_{500} range, 0.075 for the concentration parameter in the 40–400 kpc range, 0.5 for the cuspiness, and $1.5 \times 10^{-2} \text{ cm}^{-3}$ for the central gas density).

TABLE 1
COOL-CORE METRICS
Systematic uncertainty is computed by varying the break value by $\pm 10\%$.

Metric	K-S p -value	Break Value	CC fraction X-ray (%)	CC fraction ESZ (%)
C_{SB} : Concentration (0.15–1.0 r_{500})	3.1×10^{-2}	0.4	44 ± 7 (sys $^{+6}_{-6}$)	28 ± 4 (sys $^{+10}_{-6}$)
C_{SB4} : Concentration (40–400 kpc)	2.9×10^{-4}	0.075	61 ± 8 (sys $^{+3}_{-5}$)	36 ± 5 (sys $^{+4}_{-4}$)
δ : Cuspiness	1.1×10^{-4}	0.5	64 ± 8 (sys $^{+3}_{-4}$)	38 ± 5 (sys $^{+4}_{-4}$)
n_{core} : Central Density	1.9×10^{-2}	$1.5 \times 10^{-2} \text{ cm}^{-3}$	53 ± 7 (sys $^{+3}_{-2}$)	39 ± 5 (sys $^{+3}_{-3}$)

With a break value of 0.5 (Vikhlinin et al. 2007) for the cuspiness of the gas density profile (Figure 5, bottom left panel), we have a CC fraction of $64 \pm 8\%$ in the X-ray sample and $38 \pm 5\%$ in the SZ sample. Maughan et al. (2012) used a value of 0.8, more appropriate for moderate to strong CC clusters. They also use a break value of 0.5 for the concentration parameter in the 0.15–1.0 r_{500} range, which we chose to be 0.4 to also include weak CC clusters. Finally, using a break value of $1.5 \times 10^{-2} \text{ cm}^{-3}$ (Hudson et al. 2010) for the central gas density to distinguish cool and non-cool core clusters (Figure 5, bottom right panel), we find that $53 \pm 7\%$ of the clusters in the X-ray sample have cool cores, whereas the SZ sample shows

a fraction of $39 \pm 5\%$. The fraction of CC clusters and K-S test results are listed in Table 1. We also include in Table 1 a systematic uncertainty on the fraction of CC clusters by varying the break value by $\pm 10\%$. The magnitude of this systematic uncertainty is comparable to the statistical uncertainty.

Using all four comparisons of the X-ray and SZ cluster samples, we find that CC clusters are significantly more common in X-ray selected cluster samples than in SZ selected samples.

Figure 6 shows the correlations between all metrics. Visually, we observe a strong correlation between all metrics, which we verified numerically using a Spearman

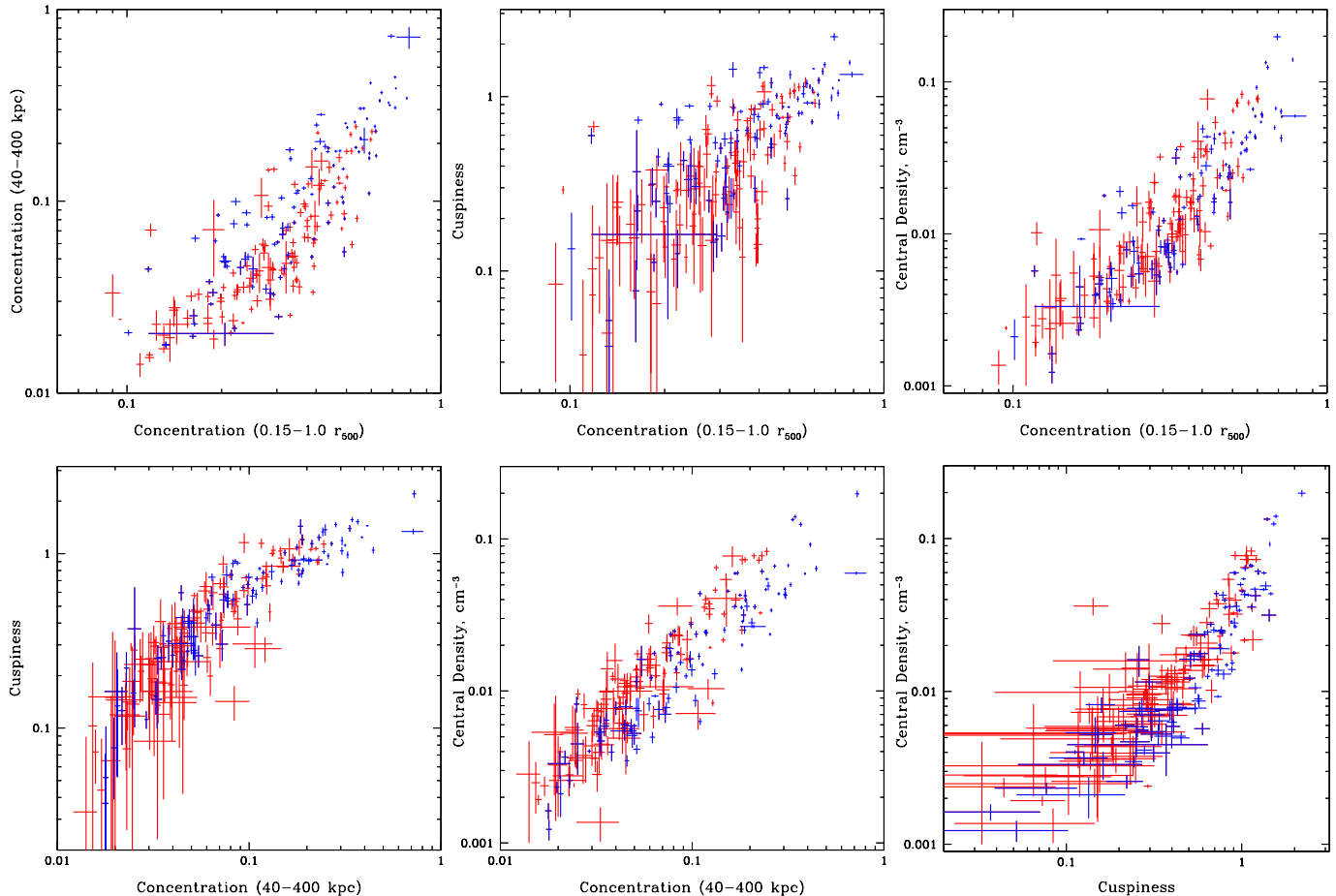


FIG. 6.— Top Left: Concentration parameter in the 40–400 kpc range (C_{SB4}) vs. Concentration parameter in the 0.15–1.0 r_{500} range (C_{SB}). Top Center: Cuspiness (δ) vs. Concentration parameter in the 0.15–1.0 r_{500} range (C_{SB}). Top Right: Central density (n_{core}) vs. Concentration parameter in the 0.15–1.0 r_{500} range (C_{SB}). Bottom Left: Cuspiness (δ) vs. Concentration parameter in the 40–400 kpc range (C_{SB4}). Bottom Center: Central density (n_{core}) vs. Concentration parameter in the 40–400 kpc range (C_{SB4}). Bottom Right: Central density (n_{core}) vs. Cuspiness (δ). In red, the ESZ sample, in blue, the X-ray sample. This figure shows the strong correlation between different metrics, whose correlations are quantified in Table 2.

test. This provides a correlation coefficient ranging between 0 (no correlation) and (-)+1, in the case of perfect (anti)correlation. Results for our metrics are listed in Table 2.

Using a set of cosmological hydrodynamic simulations of galaxy clusters, [Rasia et al. \(2015\)](#) found that 38% (11/29) of their simulated clusters at $z = 0$ are classified as CC using the central entropy ([Cavagnolo et al. 2009](#)) and pseudo-entropy ratio ([Leccardi et al. 2010](#)) as metrics. This result agrees very well with our observed fraction of CC clusters in the SZ sample (28 – 39% according to the metric used, suggesting that the fraction of CC clusters in SZ samples is representative of the fraction of CC clusters in the universe). [Lin et al. \(2015\)](#) showed that constraints on the fraction of CC clusters in SZ selected datasets are only subject to a systematic bias of order one percent, a significant reduction compared to X-ray selected samples, supporting that SZ selected samples of galaxy clusters are robust cosmological probes.

8.1. Numerical Simulations

In this section, we apply the four metrics used in this paper to the set of numerical simulations of galaxy clusters from [Rasia et al. \(2015\)](#). We obtain the following results: a) using the concentration parameter in the 0.15–

1.0 r_{500} range, we obtain a fraction of CC clusters of $33 \pm 11\%$, b) using the concentration parameter in the 40–400 kpc range, the fraction of CC clusters is $26 \pm 10\%$, c) using the cuspiness of the gas density, the fraction of CC clusters is $38 \pm 11\%$, and d) using the central gas density, the fraction of CC clusters is $48 \pm 13\%$. These numbers are in good agreement with the fraction of CC clusters in our ESZ sample.

9. SELECTION EFFECTS: MALMQUIST BIAS IN X-RAY

The X-ray cluster sample used in this paper is derived from the ROSAT X-ray catalogs which formally used the total X-ray flux as the only selection criterion. Thus, it can be affected by the Malmquist bias leading to over-

TABLE 2
SPEARMAN RANK TEST

Relation	Correlation (X-ray)	Correlation (ESZ)
C_{SB} vs. C_{SB4}	0.87	0.84
C_{SB} vs. δ	0.75	0.69
C_{SB} vs. n_{core}	0.90	0.87
C_{SB4} vs. δ	0.93	0.90
C_{SB4} vs. n_{core}	0.93	0.91
δ vs. n_{core}	0.92	0.88

TABLE 3
 OVER-POPULATION OF CC CLUSTERS

Metric	$\langle L_{CC} \rangle / \langle L_{NCC} \rangle$	Expected Over-population	Observed Over-population
C_{SB}	1.80 ± 0.16	2.7 ± 1.0	1.6 ± 0.3
C_{SB4}	1.63 ± 0.15	2.3 ± 0.7	1.7 ± 0.3
δ	1.57 ± 0.15	2.1 ± 0.7	1.7 ± 0.3
n_{core}	1.69 ± 0.15	2.4 ± 0.8	1.4 ± 0.3

representation of the CC clusters. *CC clusters tend to be more X-ray luminous for the same mass and thus they become over-represented in a purely X-ray flux-limited survey.* To estimate the fractional increase in X-ray luminosity of the CC subsample, we compare the ratio of the observed luminosity to the expected luminosity for the measured mass (using the L_X - M relation given by Equation (22) from Vikhlinin et al. (2009a)) for CC and NCC clusters for all four metrics used to identify CC clusters. We find that CC clusters are on average ~ 1.6 – 1.8 times more X-ray luminous for the same mass (Table 3) than are NCC clusters. These results are consistent with early studies based on *Einstein* imaging data (central excesses over the β -model, (Jones & Forman 1999)), and normalizations of the $L_X - T$ relations for the CC and NCC populations (Allen & Fabian 1998).

The impact of this difference in the total X-ray luminosity on the fractions of CC and NCC clusters is substantial. In a low- z flux-limited survey, the search volume is $\propto L^{3/2}$ so a subpopulation which is intrinsically more luminous by a factor of ~ 1.7 becomes over-represented by a factor of 2.2 above a fixed mass threshold.

A similar bias is still present if we consider clusters in a narrow redshift range, where there is no difference in the search volume. In this case, a flux limit is equivalent to an X-ray luminosity threshold. CC clusters are less massive than NCC clusters for a fixed L_X and hence are more numerous than NCC clusters.

We can quantify the selection effects of CC clusters in X-ray surveys. For simplicity, let us approximate the cluster mass function locally as a power law given by:

$$N(> M) \propto M^{-\gamma}, \quad (9)$$

and assume a power law M - L_X relation as:

$$L_X \propto M^\beta. \quad (10)$$

Let l be the ratio of average luminosities (0.5–2.0 keV band, in the 0 – r_{500} range) at a fixed mass for the CC and NCC populations:

$$l \equiv \langle L_{CC} \rangle / \langle L_{NCC} \rangle, \quad (11)$$

then we would expect the ratio of the number of CC to NCC clusters to be:

$$\Delta \equiv l^{\gamma/\beta}. \quad (12)$$

We computed the ratio of average luminosities at a fixed mass for the CC and NCC populations, l , to be in the range 1.6–1.8 (Table 3). From Vikhlinin et al. (2009a), $\beta = 1.61 \pm 0.14$. To compute the slope of the halo mass function, we averaged the slope of the mass function at the location of each cluster mass in our X-ray sample, using the mass function provided by Warren et al. (2006). We obtained $\gamma = 2.54 \pm 0.79$. With these numbers in hand, we estimate that the CC clusters are over-

represented in our X-ray sample by a factor of $\Delta = 2.1$ – 2.7 (depending on the metric) because of the Malmquist bias.

10. CONCLUSIONS

Using *Chandra* observations, we derived and compared the fraction of cool-core clusters in the *Planck* Early Sunyaev-Zel’dovich (ESZ) sample of 164 detected clusters with $z \leq 0.35$ and in a flux-limited X-ray sample of 100 clusters with $z \leq 0.30$. We use four metrics to identify the presence of a cool-core: 1) the concentration parameter: the ratio of the integrated surface brightness within $0.15 r_{500}$ to that within r_{500} , and 2) within 40 kpc to that within 400 kpc, 3) the cuspliness of the gas density profile: the negative of the logarithmic derivative of the gas density with respect to the radius measured at $0.04 r_{500}$, and 4) the central gas density, measured at $0.01 r_{500}$. We find that:

- In all four metrics that we used, the sample of X-ray selected clusters contains a significantly larger fraction of cool-core clusters compared to the sample of SZ selected clusters ($44 \pm 7\%$ vs. $28 \pm 4\%$ using the concentration parameter in the 0.15 – $1.0 r_{500}$ range as a metric for cool-cores, $61 \pm 8\%$ vs. $36 \pm 5\%$ using the concentration parameter in the 40 – 400 kpc range, $64 \pm 8\%$ vs. $38 \pm 5\%$ using the cuspliness, and $53 \pm 7\%$ vs. $39 \pm 5\%$ using the central density). Our results for the concentration parameter in the 40 – 400 kpc range agree well with the recent results by Rossetti et al. (2017).
- Qualitatively, cool-core clusters are more X-ray luminous at fixed mass. Hence, our X-ray flux-limited sample, compared to the approximately mass-limited SZ sample, is over-represented with cool-core clusters. We describe a simple quantitative model that successfully predicts the observed difference based on the selection bias. Our model predicts an over-population of CC clusters in our X-ray selected sample compared to SZ samples of 2.1 – 2.7 , depending on the metric used to identify CC clusters, with a typical uncertainty of ~ 0.8 , which is consistent within the uncertainties with the observed values in the range 1.4 – 1.7 with a typical uncertainty of ~ 0.3 .
- The results of the four metrics we used to measure the over-population of CC clusters in X-ray samples compared to that in SZ samples are all consistent within their uncertainties.
- While differences in X-ray and SZ cluster selection are significant, they can be quantitatively explained by the effect of cool-cores on X-ray luminosities.

CC clusters are more X-ray luminous than NCC clusters for a fixed cluster mass. Thus, an X-ray flux-limited sample will select a larger fraction of CC clusters compared to an SZ selected cluster sample. The determination of cosmological parameters from an X-ray flux-limited sample in the local Universe can be summarized by determining confidence levels in the highly degenerate Ω_M - σ_8 plane. If cluster masses are determined using a proxy other than the X-ray luminosity (e.g., gas mass, M - Y_X scaling relation, T_X , weak-lensing, hydrostatic mass) there will be no Malmquist bias on the determination of cosmological parameters, simply because when the mass function is constructed, the CC clusters that were wrongly included in the selection will now be excluded from the mass function because they do not satisfy the criterion that their masses are above the mass limit given their redshifts. On the other hand, if the cluster masses are determined by the L_X - M scaling relation, the masses of the CC clusters will be biased high, and

their inclusion in the mass function will lead to a shift towards higher values of Ω_M and σ_8 .

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APPENDIX

We present in Table A1 the values of the metrics for all clusters in the ESZ sample, including the secondary subclusters (on the lines following the primary subcluster, indicated by –). Columns list the cluster name (the prefix PLCKESZ is omitted for simplicity), RA, DEC, redshift, concentration parameter in the 0.15–1.0 r_{500} range, concentration parameter in the 40–400 kpc range, cuspsiness of the gas density profile, central gas density, and the maximum radius where the emission integral is computed. Each metric value is followed by its uncertainty.

TABLE A1 Concentration parameter, Cuspsiness, and Central Density for the *Planck* ESZ sample.

Cluster	RA	DEC	z	C_{SB}	$\sigma_{C_{\text{SB}}}$	C_{SB4}	$\sigma_{C_{\text{SB4}}}$	δ	σ_{δ}	n_{core} (cm^{-3})	$\sigma_{n_{\text{core}}}$ (cm^{-3})	r_{max} (r_{500})
G000.44+41.83	21:04:18.603	-41:20:39.36	0.165	0.275	0.008	0.0585	0.0044	0.611	0.084	0.01482	0.00233	1.68
G002.74+56.18	22:18:39.822	-38:53:58.47	0.141	0.393	0.007	0.0604	0.0030	0.254	0.047	0.01423	0.00371	1.55
G003.90+59.41	22:34:27.334	-37:44:07.88	0.151	0.391	0.007	0.0335	0.0011	0.135	0.029	0.00729	0.00113	1.37
G006.47+50.54	15:10:56.117	+5:44:40.38	0.077	0.591	0.005	0.1674	0.0035	0.920	0.015	0.05946	0.00131	1.43
G006.70+35.54	20:34:46.912	-35:49:24.54	0.089	0.188	0.006	0.0334	0.0016	0.251	0.048	0.00469	0.00096	1.66
G006.78+30.46	16:15:46.073	-6:08:54.61	0.203	0.304	0.009	0.0250	0.0008	0.159	0.030	0.00819	0.00096	1.08
G008.30+64.75	22:58:48.095	-34:48:04.62	0.312	0.218	0.005	0.0422	0.0020	0.289	0.047	0.00831	0.00070	1.50
G008.44+56.35	22:17:45.701	-35:43:32.55	0.149	0.370	0.009	0.0939	0.0049	0.614	0.056	0.01607	0.00215	1.82
G008.93+81.23	0:14:19.305	-30:23:29.33	0.307	0.249	0.004	0.0273	0.0011	0.212	0.048	0.00813	0.00153	1.37
G018.53+25.72	20:03:30.848	-23:23:37.54	0.317	0.110	0.003	0.0141	0.0020	0.033	0.056	0.00284	0.00184	1.42
G021.09+33.25	16:32:46.854	+5:34:31.61	0.151	0.638	0.005	0.3344	0.0069	1.395	0.061	0.13411	0.00361	1.42
G029.00+44.56	16:02:14.068	+15:58:16.23	0.035	0.183	0.005	0.0380	0.0013	0.315	0.076	0.00396	0.00050	1.01
G033.46+48.43	21:52:21.245	-19:32:54.19	0.094	0.282	0.005	0.1452	0.0037	1.036	0.061	0.02163	0.00083	1.68
G033.78+77.16	13:48:52.710	+26:35:31.20	0.062	0.592	0.004	0.1774	0.0036	1.090	0.046	0.04278	0.00092	1.53
G036.72+14.92	18:04:31.215	+10:03:24.21	0.152	0.415	0.009	0.1236	0.0068	0.655	0.073	0.03475	0.00440	1.62
–	18:04:27.892	+10:02:35.55	0.152	0.392	0.008	0.0773	0.0050	0.433	0.078	0.01403	0.00255	1.67
G039.85+39.98	21:27:12.470	-12:10:00.46	0.176	0.124	0.004	0.0228	0.0041	0.119	0.062	0.00277	0.00072	1.69
–	21:26:37.301	-12:06:49.76	0.176	0.075	0.006	0.0808	0.0158	0.081	0.074	0.00736	0.00148	2.03
G042.82+56.61	15:22:29.473	+27:42:18.76	0.072	0.341	0.005	0.0773	0.0019	0.556	0.059	0.02364	0.00097	1.47
G044.22+48.68	15:58:21.100	+27:13:47.87	0.089	0.493	0.005	0.0810	0.0017	0.758	0.053	0.02480	0.00073	1.25
G046.50+49.43	22:10:19.489	-12:10:10.03	0.085	0.277	0.006	0.0348	0.0020	0.254	0.038	0.00588	0.00084	1.60
G046.88+56.49	15:24:11.019	+29:52:45.70	0.115	0.144	0.014	0.0228	0.0049	0.145	0.063	0.00258	0.00055	1.53
–	15:24:22.521	+30:01:09.10	0.115	0.108	0.004	0.0371	0.0026	0.508	0.085	0.00468	0.00083	1.90
G048.05+57.17	15:21:12.694	+30:38:00.59	0.078	0.133	0.004	0.0178	0.0007	0.037	0.034	0.00163	0.00020	1.77
G049.20+30.86	17:20:09.957	+26:37:30.79	0.164	0.620	0.007	0.2313	0.0055	1.238	0.054	0.06126	0.00245	1.48
G049.33+44.38	16:20:30.305	+29:53:35.91	0.097	0.241	0.007	0.0459	0.0029	0.350	0.125	0.00543	0.00089	1.81
G049.66+49.50	22:14:32.554	-10:22:17.84	0.098	0.437	0.009	0.0977	0.0037	0.511	0.069	0.01625	0.00201	1.81
G053.44+36.26	21:35:11.371	-1:02:53.24	0.325	0.273	0.008	0.0536	0.0046	0.468	0.129	0.01374	0.00339	1.70
–	21:35:25.878	-0:57:44.27	0.325	0.350	0.094	0.4745	0.0922	0.115	0.113	0.16250	0.02681	2.39
G053.52+59.54	15:10:12.700	+33:30:34.01	0.113	0.293	0.004	0.0326	0.0009	0.152	0.033	0.00522	0.00057	1.44
–	15:10:13.060	+33:32:26.21	0.113	0.259	0.004	0.0298	0.0007	0.072	0.025	0.00312	0.00025	1.58
G055.60+31.86	17:22:27.300	+32:07:57.98	0.224	0.495	0.007	0.1173	0.0045	0.720	0.031	0.03980	0.00297	1.52
G055.97+34.88	21:35:16.105	+1:25:03.07	0.124	0.282	0.013	0.0451	0.0085	0.150	0.108	0.00489	0.00206	2.04
G056.81+36.31	17:02:42.571	+34:03:38.15	0.095	0.485	0.006	0.1049	0.0023	0.616	0.028	0.02366	0.00123	1.61
G057.33+88.01	12:59:47.654	+27:57:06.81	0.023	0.234	0.003	0.0232	0.0004	0.120	0.023	0.00361	0.00018	1.12
G057.61+34.94	17:09:45.792	+34:27:20.36	0.080	0.163	0.005	0.0253	0.0021	0.371	0.270	0.00449	0.00168	1.82
G057.92+27.64	17:44:15.426	+32:59:31.71	0.076	0.555	0.005	0.2121	0.0046	1.140	0.058	0.03579	0.00142	1.91
G058.28+18.59	18:25:22.292	+30:26:38.42	0.065	0.199	0.005	0.0312	0.0017	0.192	0.056	0.00360	0.00067	1.45
G062.42+46.41	22:23:47.779	-1:39:00.82	0.091	0.294	0.008	0.1466	0.0051	0.943	0.071	0.03207	0.00167	1.96
–	22:23:56.949	-1:35:01.68	0.091	0.256	0.007	0.1044	0.0040	0.840	0.037	0.02285	0.00159	1.90
–	22:23:14.663	-1:39:36.81	0.091	0.317	0.029	0.2421	0.0271	1.177	0.164	0.03242	0.00496	3.04
G062.92+43.70	16:28:38.232	+39:33:03.36	0.030	0.536	0.006	0.1906	0.0031	0.801	0.031	0.03963	0.00122	0.76
G067.23+67.46	14:26:00.269	+37:49:40.52	0.171	0.492	0.008	0.0544	0.0033	0.260	0.038	0.01615	0.00367	1.39
–	14:26:03.448	+37:49:28.87	0.171	0.442	0.007	0.0972	0.0036	0.784	0.030	0.02393	0.00121	1.41
G071.61+29.79	17:47:12.236	+45:12:29.69	0.157	0.141	0.005	0.0270	0.0048	0.232	0.092	0.00363	0.00118	1.83

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TABLE A1 – continued from previous page

Cluster	RA	DEC	z	C_{SB}	$\sigma_{C_{\text{SB}}}$	C_{SB4}	$\sigma_{C_{\text{SB4}}}$	δ	σ_{δ}	n_{core} (cm^{-3})	$\sigma_{n_{\text{core}}}$ (cm^{-3})	r_{max} (r_{500})
G072.63+41.46	16:40:19.460	+46:42:45.63	0.228	0.347	0.005	0.0385	0.0013	0.373	0.033	0.01247	0.00087	1.18
G072.80-18.72	21:22:27.115	+23:11:50.12	0.143	0.330	0.007	0.0732	0.0041	0.872	0.102	0.01786	0.00206	1.47
G073.96-27.82	21:53:36.797	+17:41:43.53	0.233	0.502	0.006	0.1336	0.0041	1.046	0.071	0.06475	0.00273	1.19
G077.90-26.64	22:00:53.012	+20:58:43.93	0.147	0.368	0.008	0.0648	0.0037	0.597	0.122	0.01476	0.00259	1.64
G080.38-33.20	22:26:02.754	+17:22:34.09	0.107	0.316	0.005	0.0417	0.0013	0.212	0.062	0.00566	0.00092	1.86
G080.99-50.90	23:11:33.144	+3:38:08.17	0.300	0.375	0.007	0.0792	0.0033	0.751	0.028	0.02297	0.00232	1.46
–	23:11:48.226	+3:40:51.80	0.300	0.152	0.010	0.0618	0.0089	0.669	0.226	0.01322	0.00491	2.20
G085.99+26.71	18:19:57.122	+57:09:50.82	0.179	0.142	0.006	0.0278	0.0027	0.248	0.106	0.00376	0.00127	1.79
G086.45+15.29	19:38:18.297	+54:09:36.16	0.260	0.492	0.011	0.0860	0.0042	0.553	0.058	0.02315	0.00334	1.42
G092.73+73.46	13:35:18.141	+40:59:59.07	0.228	0.292	0.006	0.0444	0.0030	0.370	0.047	0.01125	0.00175	1.34
G093.91+34.90	17:12:43.585	+64:03:46.90	0.081	0.162	0.004	0.0197	0.0006	0.077	0.038	0.00233	0.00020	1.20
G094.01+27.42	18:21:57.197	+64:20:36.30	0.299	0.563	0.007	0.1890	0.0063	1.209	0.083	0.07306	0.00327	1.43
G096.85+52.46	14:52:58.061	+58:03:00.56	0.318	0.397	0.013	0.0835	0.0170	0.142	0.032	0.03621	0.00478	1.76
G097.73+38.11	16:35:51.314	+66:12:40.87	0.171	0.347	0.006	0.0392	0.0016	0.177	0.046	0.00766	0.00142	1.51
G098.95+24.86	18:54:02.098	+68:23:01.24	0.093	0.367	0.010	0.0966	0.0058	0.728	0.032	0.01629	0.00103	1.85
G106.73-83.22	0:43:24.653	-20:37:24.39	0.292	0.394	0.007	0.0458	0.0020	0.176	0.065	0.01064	0.00243	1.51
G107.11+65.31	13:32:47.351	+50:32:29.58	0.280	0.220	0.004	0.0322	0.0017	0.295	0.029	0.00742	0.00111	1.48
–	13:32:38.660	+50:33:45.07	0.280	0.206	0.005	0.0491	0.0022	0.600	0.055	0.01367	0.00123	1.56
–	13:32:33.121	+50:25:01.44	0.280	0.218	0.005	0.0435	0.0019	0.446	0.084	0.00880	0.00073	1.63
G110.98+31.73	17:03:14.917	+78:39:23.17	0.058	0.220	0.004	0.0217	0.0009	0.126	0.046	0.00367	0.00038	1.36
G112.45+57.03	13:36:05.971	+59:12:08.41	0.070	0.252	0.008	0.0444	0.0068	0.305	0.063	0.00546	0.00073	1.80
G113.82+44.35	14:13:55.482	+71:17:59.81	0.225	0.189	0.015	0.0710	0.0306	0.379	0.083	0.01066	0.00370	1.87
–	14:14:14.032	+71:17:19.62	0.225	0.138	0.008	0.0318	0.0058	0.232	0.075	0.00534	0.00306	1.97
–	14:14:06.680	+71:15:44.77	0.225	0.119	0.011	0.0308	0.0179	0.283	0.153	0.00498	0.00281	1.93
G114.33+64.87	13:15:04.617	+51:49:10.75	0.284	0.317	0.007	0.0444	0.0023	0.400	0.044	0.01172	0.00116	1.55
G115.16-72.09	0:41:50.390	-9:18:09.53	0.056	0.455	0.004	0.1535	0.0030	1.012	0.040	0.04534	0.00113	1.40
G115.71+17.52	22:26:30.303	+78:19:16.11	0.300	0.474	0.011	0.1686	0.0092	0.920	0.080	0.03959	0.00408	1.63
G118.60+28.55	17:24:11.920	+85:53:08.41	0.178	0.335	0.009	0.0534	0.0029	0.461	0.099	0.01043	0.00147	1.42
G121.11+57.01	12:59:35.208	+60:04:15.62	0.344	0.137	0.005	0.0194	0.0049	0.151	0.205	0.00536	0.00396	1.64
G124.21-36.48	0:55:50.297	+26:24:36.47	0.197	0.405	0.006	0.2269	0.0056	0.900	0.042	0.03266	0.00087	1.65
G125.58-64.14	0:56:16.210	-1:14:58.98	0.044	0.164	0.004	0.0229	0.0007	0.221	0.052	0.00258	0.00027	1.58
G125.70+53.85	12:36:57.703	+63:11:13.65	0.302	0.338	0.008	0.0607	0.0032	0.481	0.073	0.01758	0.00235	1.56
G139.19+56.35	11:42:24.113	+58:31:37.19	0.322	0.189	0.006	0.0191	0.0022	0.065	0.088	0.00517	0.00311	1.53
G139.59+24.18	6:21:49.156	+74:42:05.10	0.300	0.519	0.008	0.1826	0.0072	1.085	0.109	0.07301	0.00533	1.47
G143.24+65.21	11:59:13.697	+49:47:41.37	0.211	0.409	0.018	0.1210	0.0265	0.285	0.046	0.01037	0.00162	1.60
–	11:59:32.831	+49:47:07.28	0.211	0.167	0.013	0.0409	0.0075	0.360	0.221	0.00402	0.00182	1.83
G146.33-15.59	2:54:27.386	+41:34:46.82	0.017	0.476	0.012	0.1241	0.0023	0.760	0.018	0.01932	0.00045	0.45
G149.24+54.18	10:58:26.061	+56:47:35.78	0.137	0.285	0.009	0.0308	0.0023	0.250	0.104	0.00638	0.00131	1.51
G149.73+34.69	8:30:59.262	+65:50:22.84	0.182	0.325	0.005	0.0512	0.0015	0.476	0.040	0.01397	0.00103	1.32
G159.85-73.47	1:31:53.170	-13:36:43.29	0.206	0.311	0.007	0.0436	0.0022	0.276	0.056	0.00909	0.00100	1.39
G161.44+26.23	7:21:30.328	+55:45:41.56	0.038	0.313	0.008	0.0671	0.0039	0.390	0.070	0.00755	0.00111	1.10
G163.72+53.53	10:22:28.815	+50:06:24.68	0.158	0.342	0.009	0.0517	0.0039	0.428	0.079	0.01155	0.00173	1.64
G164.18-38.89	2:58:57.595	+13:34:44.19	0.074	0.308	0.005	0.0400	0.0012	0.262	0.040	0.00776	0.00081	1.34
G164.61+46.38	9:38:19.645	+52:02:58.03	0.342	0.357	0.009	0.0872	0.0045	0.423	0.083	0.01742	0.00209	1.70
G165.08+54.11	10:23:39.906	+49:08:32.59	0.144	0.337	0.009	0.0511	0.0032	0.415	0.089	0.01238	0.00232	1.56
G166.13+43.39	9:17:53.077	+51:43:41.38	0.217	0.326	0.006	0.0519	0.0022	0.575	0.024	0.01756	0.00111	1.51
G167.65+17.64	6:38:04.950	+47:47:50.92	0.174	0.260	0.009	0.0302	0.0022	0.163	0.088	0.00591	0.00128	1.61
G171.94-40.65	3:12:57.303	+8:22:08.53	0.270	0.235	0.009	0.0356	0.0024	0.290	0.116	0.00885	0.00156	1.59
G172.88+65.32	11:11:40.472	+40:50:28.25	0.079	0.256	0.007	0.0559	0.0032	0.400	0.090	0.00698	0.00157	2.11
G176.28-35.05	3:38:40.698	+9:58:03.07	0.035	0.718	0.004	0.3876	0.0047	1.242	0.017	0.05916	0.00104	1.09
G180.62+76.65	11:57:17.375	+33:36:39.11	0.213	0.378	0.007	0.1228	0.0050	0.844	0.059	0.03195	0.00255	1.64
G182.44-28.29	4:13:25.196	+10:27:53.66	0.088	0.622	0.005	0.1726	0.0033	0.908	0.056	0.05973	0.00179	1.38
G182.63+55.82	10:17:03.531	+39:02:53.32	0.206	0.467	0.006	0.0986	0.0031	0.634	0.062	0.02822	0.00252	1.63
G186.39+37.25	8:42:57.490	+36:21:59.64	0.282	0.338	0.007	0.0361	0.0027	0.218	0.076	0.01399	0.00410	1.32
G195.62+44.05	9:20:23.927	+30:30:37.51	0.2952	0.131	0.005	0.0170	0.0009	0.044	0.043	0.00238	0.00035	1.52

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TABLE A1 – continued from previous page

Cluster	RA	DEC	z	C_{SB}	$\sigma_{C_{\text{SB}}}$	C_{SB4}	$\sigma_{C_{\text{SB4}}}$	δ	σ_{δ}	n_{core} (cm^{-3})	$\sigma_{n_{\text{core}}}$ (cm^{-3})	r_{max} (r_{500})
–	9:19:34.939	+30:31:54.67	0.427	0.326	0.026	0.1066	0.0131	0.392	0.207	0.01544	0.00611	2.56
–	9:21:10.775	+30:28:04.61	0.427	0.082	0.035	0.0399	0.0544	0.480	0.568	0.01593	0.02757	2.63
G195.77-24.30	4:54:10.021	+2:55:33.68	0.203	0.214	0.004	0.0205	0.0007	0.117	0.036	0.00398	0.00033	1.36
–	4:54:25.560	+2:59:08.98	0.203	0.090	0.004	0.0251	0.0062	0.095	0.073	0.00156	0.00090	2.18
G209.56-36.49	4:33:37.913	-13:15:42.03	0.033	0.438	0.005	0.1892	0.0039	1.200	0.086	0.04229	0.00359	0.79
G218.85+35.50	9:09:12.462	+10:58:29.96	0.175	0.385	0.006	0.0831	0.0031	0.466	0.035	0.01317	0.00150	1.65
G226.17-21.91	5:52:50.842	-21:03:15.06	0.099	0.291	0.008	0.0437	0.0046	0.274	0.069	0.00613	0.00091	1.75
G226.24+76.76	11:55:17.943	+23:24:20.25	0.143	0.488	0.005	0.0985	0.0026	0.666	0.033	0.02751	0.00107	1.39
G228.49+53.12	10:25:58.011	+12:41:08.71	0.143	0.603	0.009	0.2305	0.0082	0.917	0.052	0.07758	0.00512	1.72
G229.21-17.24	6:16:24.830	-21:56:19.24	0.171	0.199	0.006	0.0300	0.0029	0.231	0.119	0.00436	0.00115	1.60
G229.64+77.96	12:01:13.211	+23:06:29.50	0.269	0.218	0.008	0.0238	0.0022	0.141	0.082	0.00575	0.00223	1.43
G229.94+15.29	8:17:25.557	-7:30:30.54	0.070	0.483	0.005	0.0718	0.0019	0.415	0.043	0.01305	0.00090	1.48
G234.59+73.01	11:44:44.158	+19:42:15.97	0.021	0.095	0.001	0.0242	0.0001	0.292	0.016	0.00240	0.00007	0.95
G236.95-26.67	5:47:37.339	-31:52:09.32	0.148	0.340	0.006	0.0452	0.0024	0.309	0.076	0.00968	0.00210	1.59
G239.28+24.76	9:09:20.461	-9:41:03.53	0.054	0.333	0.003	0.0477	0.0011	0.276	0.018	0.00561	0.00022	1.35
–	9:08:47.478	-9:38:28.45	0.054	0.323	0.183	0.1382	0.2078	0.713	0.843	0.02846	0.05574	1.42
G241.74-30.88	5:32:55.628	-37:01:35.71	0.271	0.447	0.009	0.0846	0.0044	0.532	0.082	0.02341	0.00361	1.51
G241.77-24.00	6:05:53.936	-35:18:08.71	0.139	0.536	0.008	0.2448	0.0078	1.134	0.062	0.08282	0.00499	1.88
G241.85+51.53	10:39:40.051	+5:09:39.68	0.070	0.090	0.005	0.0332	0.0083	0.084	0.061	0.00137	0.00035	2.30
G241.97+14.85	8:41:58.360	-17:29:45.45	0.169	0.118	0.003	0.0158	0.0006	0.073	0.025	0.00193	0.00015	1.50
–	8:41:51.490	-17:27:46.97	0.169	0.183	0.004	0.0350	0.0013	0.302	0.055	0.00598	0.00092	1.51
G243.57+67.76	11:32:51.155	+14:29:32.08	0.083	0.246	0.006	0.0362	0.0031	0.181	0.040	0.00442	0.00064	1.70
–	11:32:50.676	+14:27:21.08	0.083	0.268	0.008	0.0696	0.0036	0.635	0.025	0.01276	0.00092	1.76
G244.34-32.13	5:28:52.997	-39:28:13.50	0.284	0.411	0.007	0.1159	0.0043	1.145	0.074	0.03555	0.00249	1.39
G244.69+32.49	9:45:24.590	-8:39:19.44	0.153	0.264	0.009	0.0432	0.0100	0.140	0.063	0.00566	0.00180	1.78
G246.52-26.05	6:01:41.584	-39:59:19.90	0.047	0.133	0.003	0.0179	0.0006	0.052	0.050	0.00123	0.00019	1.54
–	6:02:11.776	-39:57:26.35	0.047	0.184	0.005	0.0431	0.0015	0.287	0.050	0.00278	0.00034	1.31
G247.17-23.32	6:16:31.784	-39:47:46.01	0.152	0.268	0.014	0.1071	0.0252	0.304	0.083	0.00712	0.00156	1.88
G249.87-39.86	4:49:56.204	-44:40:20.25	0.150	0.321	0.007	0.0704	0.0032	0.285	0.064	0.00955	0.00221	2.05
–	4:49:53.125	-44:40:23.36	0.150	0.216	0.007	0.0763	0.0049	0.790	0.136	0.01097	0.00120	2.08
G250.90-36.25	5:10:16.218	-45:19:12.68	0.200	0.377	0.010	0.0645	0.0037	0.350	0.053	0.01260	0.00239	1.58
G252.96-56.05	3:17:57.637	-44:14:17.40	0.075	0.581	0.004	0.2692	0.0048	1.140	0.035	0.06626	0.00186	1.67
G253.47-33.72	5:25:48.812	-47:15:10.22	0.191	0.375	0.009	0.0739	0.0045	0.584	0.158	0.01927	0.00387	1.79
G256.45-65.71	2:25:53.140	-41:54:52.95	0.220	0.388	0.018	0.1507	0.0342	0.848	0.054	0.04070	0.01416	1.60
–	2:25:25.618	-42:00:50.57	0.220	0.197	0.017	0.1490	0.0277	1.047	0.058	0.03069	0.00388	2.46
G257.34-22.18	6:37:14.638	-48:28:18.15	0.203	0.282	0.009	0.0942	0.0058	1.158	0.152	0.02179	0.00342	1.78
–	6:37:29.500	-48:29:40.52	0.203	0.172	0.008	0.0299	0.0041	0.146	0.071	0.00405	0.00197	1.69
G260.03-63.44	2:32:18.714	-44:20:46.38	0.284	0.416	0.023	0.1618	0.0182	1.065	0.165	0.07744	0.01227	1.69
G262.25-35.36	5:16:36.189	-54:30:34.93	0.295	0.156	0.005	0.0245	0.0027	0.185	0.109	0.00553	0.00221	1.37
G263.16-23.41	6:38:48.541	-53:58:26.09	0.227	0.472	0.006	0.1319	0.0040	1.003	0.043	0.04609	0.00206	1.37
–	6:38:44.287	-53:58:26.85	0.227	0.453	0.007	0.1073	0.0034	0.743	0.030	0.02970	0.00158	1.41
G263.20-25.21	6:26:48.188	-54:32:57.24	0.051	0.117	0.003	0.0442	0.0015	0.598	0.062	0.00571	0.00051	1.73
–	6:27:36.008	-54:26:46.65	0.051	0.116	0.002	0.0279	0.0007	0.171	0.025	0.00216	0.00017	1.72
G263.66-22.53	6:45:28.586	-54:13:43.00	0.164	0.403	0.010	0.0738	0.0042	0.644	0.086	0.02070	0.00301	1.39
G264.41+19.48	10:00:01.753	-30:16:37.46	0.240	0.271	0.008	0.0596	0.0043	0.648	0.134	0.01621	0.00302	1.65
G265.00-48.94	3:42:53.069	-53:37:53.35	0.059	0.317	0.005	0.0445	0.0021	0.217	0.028	0.00601	0.00048	1.25
G266.03-21.25	6:58:29.918	-55:56:31.03	0.296	0.331	0.006	0.0254	0.0008	0.280	0.061	0.00955	0.00077	1.11
–	6:58:20.053	-55:56:28.77	0.296	0.299	0.005	0.0989	0.0033	0.962	0.051	0.02120	0.00112	1.21
G266.84+25.07	10:23:50.137	-27:15:22.24	0.254	0.598	0.007	0.2097	0.0059	1.056	0.031	0.07762	0.00345	1.59
G269.31-49.87	3:28:36.732	-55:42:41.79	0.085	0.396	0.009	0.0627	0.0023	0.199	0.046	0.00682	0.00114	1.83
G269.51+26.42	10:36:40.918	-27:31:35.50	0.013	0.426	0.010	0.1282	0.0027	0.463	0.055	0.00835	0.00041	0.46
G271.50-56.55	2:45:28.461	-53:02:03.51	0.300	0.354	0.008	0.0357	0.0030	0.120	0.081	0.00988	0.00364	1.55
G272.10-40.15	4:31:30.202	-61:24:48.44	0.059	0.205	0.088	0.0204	0.0028	0.162	0.109	0.00333	0.00069	0.98
–	4:31:12.696	-61:27:20.58	0.059	0.199	0.004	0.0419	0.0013	0.531	0.025	0.00796	0.00038	0.90
G273.64+63.28	12:00:22.549	+3:20:23.47	0.134	0.203	0.004	0.0355	0.0017	0.304	0.064	0.00610	0.00109	1.52

Continued on next page

TABLE A1 – continued from previous page

Cluster	RA	DEC	z	C_{SB}	$\sigma_{C_{\text{SB}}}$	C_{SB4}	$\sigma_{C_{\text{SB4}}}$	δ	σ_{δ}	n_{core} (cm^{-3})	$\sigma_{n_{\text{core}}}$ (cm^{-3})	r_{max} (r_{500})
G275.21+43.92	11:30:22.201	-14:34:38.17	0.107	0.258	0.006	0.0417	0.0020	0.319	0.110	0.00756	0.00175	1.65
G278.60+39.17	11:31:56.126	-19:56:06.98	0.307	0.259	0.008	0.0410	0.0037	0.397	0.130	0.01199	0.00307	1.39
–	11:31:54.302	-19:55:42.44	0.307	0.317	0.016	0.1091	0.0105	0.780	0.087	0.03229	0.00395	1.53
G280.19+47.81	11:49:46.508	-12:18:50.35	0.156	0.224	0.006	0.0337	0.0032	0.184	0.058	0.00448	0.00095	1.65
G282.49+65.17	12:17:41.196	+3:39:22.03	0.077	0.286	0.006	0.0331	0.0021	0.146	0.047	0.00537	0.00141	1.51
G286.58-31.25	5:31:28.179	-75:10:37.86	0.210	0.248	0.009	0.0396	0.0037	0.296	0.212	0.01587	0.00465	1.67
G288.61-37.65	3:52:30.180	-74:01:56.35	0.127	0.225	0.006	0.0345	0.0023	0.408	0.139	0.00817	0.00189	1.43
G292.51+21.98	12:01:04.779	-39:51:52.89	0.300	0.181	0.004	0.0318	0.0021	0.309	0.077	0.00686	0.00190	1.45
–	12:01:10.496	-39:54:44.42	0.300	0.215	0.009	0.1284	0.0104	0.940	0.113	0.02524	0.00323	1.95
G294.66-37.02	3:03:43.147	-77:52:47.22	0.274	0.321	0.010	0.0474	0.0144	0.240	0.041	0.00998	0.00237	1.40
–	2:59:20.807	-77:52:10.09	0.274	0.258	0.017	0.0725	0.0091	0.399	0.203	0.01175	0.00627	2.20
G295.33+23.33	12:15:27.399	-39:01:58.34	0.119	0.169	0.005	0.0327	0.0024	0.240	0.096	0.00395	0.00116	1.66
G296.41-32.48	3:51:31.364	-82:13:27.86	0.061	0.238	0.007	0.0499	0.0044	0.334	0.069	0.00526	0.00082	1.81
G303.75+33.65	12:54:40.703	-29:13:40.55	0.054	0.330	0.010	0.1854	0.0057	1.435	0.141	0.03161	0.00295	1.94
–	12:54:22.138	-29:00:47.20	0.054	0.331	0.007	0.1652	0.0060	0.939	0.094	0.03347	0.00192	1.89
G304.49+32.44	12:57:22.033	-30:21:49.34	0.055	0.205	0.006	0.0481	0.0034	0.409	0.037	0.00591	0.00062	1.37
G304.67-31.66	23:40:12.802	-85:11:01.81	0.193	0.131	0.006	0.0200	0.0023	0.150	0.168	0.00326	0.00177	1.74
G304.89+45.45	12:57:11.570	-17:24:33.57	0.047	0.195	0.003	0.0846	0.0019	0.905	0.024	0.01788	0.00048	1.14
G306.68+61.06	12:58:41.433	-1:45:43.44	0.085	0.456	0.006	0.1186	0.0027	0.777	0.029	0.02416	0.00118	1.60
G306.80+58.60	12:59:22.339	-4:11:45.31	0.085	0.438	0.007	0.0773	0.0022	0.535	0.049	0.01708	0.00144	1.50
G311.99+30.71	13:27:56.824	-31:29:43.84	0.048	0.302	0.005	0.0611	0.0013	0.506	0.038	0.01224	0.00057	1.66
–	13:29:47.769	-31:36:26.05	0.048	0.149	0.004	0.0606	0.0048	0.701	0.056	0.00968	0.00094	2.08
G313.36+61.11	13:11:29.460	-1:20:27.68	0.183	0.590	0.006	0.1098	0.0027	0.717	0.024	0.04374	0.00190	1.32
G313.87-17.10	16:01:48.426	-75:45:15.56	0.153	0.540	0.007	0.0813	0.0037	0.513	0.036	0.02341	0.00170	1.39
G315.70-18.04	16:31:25.411	-75:06:38.34	0.105	0.201	0.004	0.0249	0.0020	0.137	0.046	0.00350	0.00044	1.42
G316.34+28.54	13:47:28.110	-32:51:57.98	0.039	0.394	0.006	0.0636	0.0014	0.576	0.070	0.01769	0.00069	0.80
G318.13-29.57	19:47:14.773	-76:23:44.99	0.217	0.441	0.010	0.1502	0.0107	0.841	0.070	0.05416	0.00547	1.54
G321.96-47.97	22:49:58.191	-64:25:46.79	0.094	0.313	0.006	0.0723	0.0054	0.303	0.061	0.00702	0.00084	1.61
G324.49-44.97	22:18:00.518	-65:10:52.42	0.095	0.342	0.009	0.1225	0.0054	0.735	0.088	0.03748	0.00221	1.87
G332.23-46.36	22:01:53.194	-59:56:43.51	0.098	0.388	0.005	0.0512	0.0013	0.298	0.052	0.01155	0.00114	1.53
G332.88-19.28	18:13:15.663	-61:26:54.65	0.147	0.347	0.008	0.0477	0.0029	0.296	0.072	0.01085	0.00228	1.58
G335.59-46.46	21:54:05.793	-57:51:41.87	0.076	0.230	0.006	0.0451	0.0039	0.430	0.056	0.00787	0.00093	1.72
G336.59-55.44	22:46:21.491	-52:44:17.54	0.097	0.181	0.006	0.0230	0.0012	0.076	0.050	0.00281	0.00040	1.68
G337.09-25.97	19:14:37.070	-59:28:17.20	0.120	0.501	0.009	0.1818	0.0063	0.764	0.027	0.02517	0.00163	2.02
–	19:13:51.095	-59:33:51.75	0.120	0.488	0.010	0.3395	0.0096	1.053	0.069	0.04536	0.00329	2.62
G340.88-33.34	20:12:37.869	-56:50:45.53	0.056	0.185	0.004	0.0291	0.0006	0.112	0.013	0.00402	0.00011	1.01
G340.95+35.11	14:59:28.730	-18:10:45.08	0.236	0.516	0.007	0.2230	0.0074	1.070	0.034	0.07261	0.00394	1.58
G342.31-34.90	20:23:22.364	-55:35:27.23	0.232	0.286	0.009	0.0388	0.0120	0.162	0.050	0.00767	0.00279	1.51
G342.81-30.46	19:52:08.122	-55:03:40.32	0.060	0.160	0.006	0.0319	0.0019	0.155	0.086	0.00282	0.00065	1.90
G345.40-39.34	20:51:56.959	-52:37:48.21	0.045	0.119	0.005	0.0707	0.0056	0.673	0.051	0.01019	0.00180	2.37
–	20:51:59.518	-52:47:09.10	0.045	0.076	0.003	0.0214	0.0012	0.114	0.131	0.00127	0.00053	1.78
G346.59+35.04	15:15:02.301	-15:22:53.25	0.223	0.118	0.004	0.0153	0.0008	0.103	0.135	0.00249	0.00093	1.48
G347.18-27.35	19:34:51.447	-50:52:16.67	0.237	0.181	0.006	0.0246	0.0041	0.117	0.103	0.00528	0.00214	1.56
G349.46-59.94	22:48:44.562	-44:31:48.94	0.347	0.521	0.008	0.0594	0.0027	0.352	0.041	0.02786	0.00403	1.21

We present in Table A2 the values of the metrics for all clusters in the X-ray sample, including the secondary subclusters (on the lines following the primary subcluster, indicated by –). Columns list the cluster name, *Planck* name (the prefix PLCKESZ is omitted for simplicity; † the prefix PSZ1 is omitted for simplicity), RA, DEC, redshift, concentration parameter in the 0.15–1.0 r_{500} range, concentration parameter in the 40–400 kpc range, cuspsiness of the gas density profile, central gas density, and the maximum radius where the emission integral is computed. Each metric value is followed by its uncertainty.

TABLE A2 Concentration parameter, Cuspsiness, and Central Density for the X-ray sample.

Cluster	<i>Planck</i> name	RA	DEC	z	C_{SB}	$\sigma_{C_{\text{SB}}}$	C_{SB4}	$\sigma_{C_{\text{SB4}}}$	δ	σ_{δ}	n_{core} (cm^{-3})	$\sigma_{n_{\text{core}}}$ (cm^{-3})	r_{max} (r_{500})
2A0335	G176.28-35.05	03:38:40.698	+09:58:03.07	0.035	0.718	0.004	0.3876	0.0047	1.242	0.017	0.05916	0.00104	1.09
A85	G115.16-72.09	00:41:50.390	-09:18:09.53	0.056	0.455	0.004	0.1535	0.0030	1.012	0.040	0.04534	0.00113	1.40
A119	G125.58-64.14	00:56:16.210	-01:14:58.98	0.044	0.164	0.004	0.0229	0.0007	0.221	0.052	0.00258	0.00027	1.58
A133	G149.55-84.16†	01:02:41.707	-21:52:52.58	0.057	0.503	0.005	0.2421	0.0045	1.335	0.077	0.04650	0.00115	1.98
A193		01:25:07.559	+08:41:59.95	0.049	0.295	0.006	0.0596	0.0016	0.428	0.036	0.00825	0.00085	1.44
A376		02:46:03.910	+36:54:18.44	0.049	0.240	0.008	0.0870	0.0031	0.884	0.026	0.01538	0.00068	1.94
A399		02:57:53.422	+13:01:57.47	0.071	0.251	0.004	0.0357	0.0012	0.339	0.049	0.00643	0.00086	1.52
A401	G164.18-38.89	02:58:57.595	+13:34:44.19	0.074	0.308	0.005	0.0400	0.0012	0.262	0.040	0.00776	0.00081	1.34
A478	G182.44-28.29	04:13:25.196	+10:27:53.66	0.088	0.622	0.005	0.1726	0.0033	0.908	0.056	0.05973	0.00179	1.38
A496	G209.56-36.49	04:33:37.913	-13:15:42.03	0.033	0.438	0.005	0.1892	0.0039	1.200	0.086	0.04229	0.00359	0.79
A548e		05:48:38.311	-25:28:40.20	0.041	0.222	0.008	0.0995	0.0047	0.733	0.043	0.01378	0.00129	1.36
A576	G161.44+26.23	07:21:30.328	+55:45:41.56	0.038	0.313	0.008	0.0671	0.0039	0.390	0.070	0.00755	0.00111	1.10
A754	G239.28+24.76	09:09:20.461	-09:41:03.53	0.054	0.333	0.003	0.0477	0.0011	0.276	0.018	0.00561	0.00022	1.35
–		09:08:47.478	-09:38:28.45	0.054	0.323	0.183	0.1382	0.2078	0.713	0.843	0.02846	0.05574	1.42
A970		10:17:23.807	-10:41:07.78	0.059	0.325	0.007	0.0733	0.0034	0.543	0.087	0.00779	0.00068	1.73
A1413	G226.24+76.76	11:55:17.943	+23:24:20.25	0.143	0.488	0.005	0.0985	0.0026	0.666	0.033	0.02751	0.00107	1.39
A1644	G304.89+45.45	12:57:11.570	-17:24:33.57	0.047	0.195	0.003	0.0846	0.0019	0.905	0.024	0.01788	0.00048	1.14
A1650	G306.68+61.06	12:58:41.433	-01:45:43.44	0.085	0.456	0.006	0.1186	0.0027	0.777	0.029	0.02416	0.00118	1.60
A1651	G306.80+58.60	12:59:22.339	-04:11:45.31	0.085	0.438	0.007	0.0773	0.0022	0.535	0.049	0.01708	0.00144	1.50
A1689	G313.36+61.11	13:11:29.460	-01:20:27.68	0.183	0.590	0.006	0.1098	0.0027	0.717	0.024	0.04374	0.00190	1.32
A1736	G312.64+35.09†	13:27:00.923	-27:11:47.19	0.046	0.101	0.003	0.0206	0.0007	0.134	0.082	0.00211	0.00063	2.00
A1767	G112.45+57.03	13:36:05.971	+59:12:08.41	0.070	0.252	0.008	0.0444	0.0068	0.305	0.063	0.00546	0.00073	1.80
A1775		13:41:48.863	+26:22:19.89	0.076	0.279	0.005	0.0823	0.0021	0.880	0.046	0.01393	0.00065	1.93
A1795	G033.78+77.16	13:48:52.710	+26:35:31.20	0.062	0.592	0.004	0.1774	0.0036	1.090	0.046	0.04278	0.00092	1.53
A1831		13:59:15.391	+27:58:34.43	0.061	0.385	0.008	0.1312	0.0048	0.789	0.082	0.01298	0.00104	1.68
A1914	G067.23+67.46	14:26:00.269	+37:49:40.52	0.171	0.492	0.008	0.0544	0.0033	0.260	0.038	0.01615	0.00367	1.39
–		14:26:03.448	+37:49:28.87	0.171	0.442	0.007	0.0972	0.0036	0.784	0.030	0.02393	0.00121	1.41
A2029	G006.47+50.54	15:10:56.117	+05:44:40.38	0.077	0.591	0.005	0.1674	0.0035	0.920	0.015	0.05946	0.00131	1.43
A2034	G053.52+59.54	15:10:12.700	+33:30:34.01	0.113	0.293	0.004	0.0326	0.0009	0.152	0.033	0.00522	0.00057	1.44
–		15:10:13.060	+33:32:26.21	0.113	0.259	0.004	0.0298	0.0007	0.072	0.025	0.00312	0.00025	1.58
A2052		15:16:44.489	+07:01:17.84	0.035	0.532	0.005	0.2585	0.0043	0.970	0.037	0.03395	0.00100	1.05
A2061	G048.05+57.17	15:21:12.694	+30:38:00.59	0.078	0.133	0.004	0.0178	0.0007	0.037	0.034	0.00163	0.00020	1.77
A2063		15:23:05.130	+08:36:34.45	0.035	0.350	0.006	0.1133	0.0021	0.821	0.020	0.01493	0.00046	0.95
A2065	G042.82+56.61	15:22:29.473	+27:42:18.76	0.072	0.341	0.005	0.0773	0.0019	0.556	0.059	0.02364	0.00097	1.47
A2107		15:39:39.091	+21:46:58.25	0.041	0.366	0.006	0.1171	0.0025	0.640	0.035	0.02449	0.00091	1.19
A2142	G044.22+48.68	15:58:21.100	+27:13:47.87	0.089	0.493	0.005	0.0810	0.0017	0.758	0.053	0.02480	0.00073	1.25
A2147	G029.00+44.56	16:02:14.068	+15:58:16.23	0.035	0.183	0.005	0.0380	0.0013	0.315	0.076	0.00396	0.00050	1.01
A2151		16:04:35.792	+17:43:17.15	0.037	0.412	0.016	0.2047	0.0084	0.908	0.047	0.02810	0.00214	1.02
A2163	G006.78+30.46	16:15:46.073	-06:08:54.61	0.203	0.304	0.009	0.0250	0.0008	0.159	0.030	0.00819	0.00096	1.08
A2199	G062.92+43.70	16:28:38.232	+39:33:03.36	0.030	0.536	0.006	0.1906	0.0031	0.801	0.031	0.03963	0.00122	0.76
A2204	G021.09+33.25	16:32:46.854	+05:34:31.61	0.151	0.638	0.005	0.3344	0.0069	1.395	0.061	0.13411	0.00361	1.42
A2244	G056.81+36.31	17:02:42.571	+34:03:38.15	0.095	0.485	0.006	0.1049	0.0023	0.616	0.028	0.02366	0.00123	1.61
A2249	G057.61+34.94	17:09:45.792	+34:27:20.36	0.080	0.163	0.005	0.0253	0.0021	0.371	0.270	0.00449	0.00168	1.82
A2255	G093.91+34.90	17:12:43.585	+64:03:46.90	0.081	0.162	0.004	0.0197	0.0006	0.077	0.038	0.00233	0.00020	1.20
A2256	G110.98+31.73	17:03:14.917	+78:39:23.17	0.058	0.220	0.004	0.0217	0.0009	0.126	0.046	0.00367	0.00038	1.36
A2415		22:05:38.437	-05:35:31.57	0.058	0.402	0.008	0.2494	0.0069	1.373	0.104	0.04912	0.00325	2.13
A2420	G046.50-49.43	22:10:19.489	-12:10:10.03	0.085	0.277	0.006	0.0348	0.0020	0.254	0.038	0.00588	0.00084	1.60

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TABLE A2 – continued from previous page

Cluster	<i>Planck</i> name	RA	DEC	z	C_{SB}	$\sigma_{C_{\text{SB}}}$	C_{SB4}	$\sigma_{C_{\text{SB4}}}$	δ	σ_{δ}	n_{core} (cm^{-3})	$\sigma_{n_{\text{core}}}$ (cm^{-3})	r_{max} (r_{500})
A2426	G049.66-49.50	22:14:32.554	-10:22:17.84	0.098	0.437	0.009	0.0977	0.0037	0.511	0.069	0.01625	0.00201	1.81
A2457		22:35:41.138	+01:29:11.41	0.059	0.219	0.006	0.0763	0.0039	0.756	0.101	0.01903	0.00160	1.80
A2572		23:17:12.803	+18:42:10.29	0.042	0.311	0.008	0.1040	0.0033	0.571	0.053	0.00867	0.00080	1.31
A2589		23:23:57.326	+16:46:39.86	0.042	0.388	0.005	0.1086	0.0021	0.586	0.036	0.01691	0.00088	1.21
A2593		23:24:20.855	+14:38:41.63	0.043	0.206	0.009	0.0487	0.0033	0.399	0.082	0.00509	0.00085	1.62
A2597		23:25:19.765	-12:07:25.96	0.085	0.687	0.005	0.3163	0.0044	1.118	0.019	0.06686	0.00194	1.95
A2626		23:36:30.314	+21:08:48.22	0.057	0.477	0.005	0.1830	0.0033	0.874	0.017	0.02861	0.00070	1.68
A2634		23:38:29.381	+27:01:53.58	0.031	0.165	0.005	0.0640	0.0028	0.733	0.038	0.00926	0.00020	0.95
A2657		23:44:57.622	+09:11:26.36	0.040	0.340	0.006	0.0929	0.0024	0.640	0.021	0.01253	0.00053	1.22
A2665		23:50:50.649	+06:08:59.67	0.056	0.428	0.008	0.1928	0.0066	0.935	0.042	0.03611	0.00258	1.70
A2734		00:11:21.686	-28:51:14.53	0.062	0.290	0.006	0.0826	0.0032	0.544	0.047	0.01058	0.00087	1.57
A3112	G252.96-56.05	03:17:57.637	-44:14:17.40	0.075	0.581	0.004	0.2692	0.0048	1.140	0.035	0.06626	0.00186	1.67
A3158	G265.00-48.94	03:42:53.069	-53:37:53.35	0.059	0.317	0.005	0.0445	0.0021	0.217	0.028	0.00601	0.00048	1.25
A3266	G272.10-40.15	04:31:30.202	-61:24:48.44	0.059	0.205	0.088	0.0204	0.0028	0.162	0.109	0.00333	0.00069	0.98
–		04:31:12.696	-61:27:20.58	0.059	0.199	0.004	0.0419	0.0013	0.531	0.025	0.00796	0.00038	0.90
A3376	G246.52-26.05	06:01:41.584	-39:59:19.90	0.047	0.133	0.003	0.0179	0.0006	0.052	0.050	0.00123	0.00019	1.54
–		06:02:11.776	-39:57:26.35	0.047	0.184	0.005	0.0431	0.0015	0.287	0.050	0.00278	0.00034	1.31
A3391		06:26:20.481	-53:41:35.84	0.051	0.203	0.004	0.0514	0.0021	0.279	0.031	0.00414	0.00030	1.74
A3395	G263.20-25.21	06:26:48.188	-54:32:57.24	0.051	0.117	0.003	0.0442	0.0015	0.598	0.062	0.00571	0.00051	1.73
–		06:27:36.008	-54:26:46.65	0.051	0.116	0.002	0.0279	0.0007	0.171	0.025	0.00216	0.00017	1.72
A3528n		12:54:22.206	-29:00:46.76	0.054	0.332	0.005	0.1665	0.0055	0.858	0.053	0.03590	0.00137	1.90
A3528s	G303.75+33.65	12:54:40.703	-29:13:40.55	0.054	0.330	0.010	0.1854	0.0057	1.435	0.141	0.03161	0.00295	1.94
–		12:54:22.138	-29:00:47.20	0.054	0.331	0.007	0.1652	0.0060	0.939	0.094	0.03347	0.00192	1.89
A3532	G304.49+32.44	12:57:22.033	-30:21:49.34	0.055	0.205	0.006	0.0481	0.0034	0.409	0.037	0.00591	0.00062	1.37
A3558	G311.99+30.71	13:27:56.824	-31:29:43.84	0.048	0.302	0.005	0.0611	0.0013	0.506	0.038	0.01224	0.00057	1.66
–		13:29:47.769	-31:36:26.05	0.048	0.149	0.004	0.0606	0.0048	0.701	0.056	0.00968	0.00094	2.08
A3560		13:32:27.757	-33:08:33.59	0.050	0.208	0.005	0.0457	0.0013	0.243	0.028	0.00348	0.00030	1.50
A3562		13:33:34.727	-31:40:22.49	0.049	0.241	0.005	0.0752	0.0022	0.565	0.030	0.00895	0.00069	1.75
–		13:31:27.476	-31:49:18.14	0.049	0.108	0.003	0.0400	0.0018	0.421	0.069	0.00483	0.00110	2.07
A3571	G316.34+28.54	13:47:28.110	-32:51:57.98	0.039	0.394	0.006	0.0636	0.0014	0.576	0.070	0.01769	0.00069	0.80
A3667	G340.88-33.34	20:12:37.869	-56:50:45.53	0.056	0.185	0.004	0.0291	0.0006	0.112	0.013	0.00402	0.00011	1.01
A3695	G006.70-35.54	20:34:46.912	-35:49:24.54	0.089	0.188	0.006	0.0334	0.0016	0.251	0.048	0.00469	0.00096	1.66
A3822	G335.59-46.46	21:54:05.793	-57:51:41.87	0.076	0.230	0.006	0.0451	0.0039	0.430	0.056	0.00787	0.00093	1.72
A3827	G332.23-46.36	22:01:53.194	-59:56:43.51	0.098	0.388	0.005	0.0512	0.0013	0.298	0.052	0.01155	0.00114	1.53
A3921	G321.96-47.97	22:49:58.191	-64:25:46.79	0.094	0.313	0.006	0.0723	0.0054	0.303	0.061	0.00702	0.00084	1.61
A4038		23:47:42.886	-28:08:34.44	0.029	0.463	0.006	0.1821	0.0028	0.751	0.018	0.02007	0.00059	0.88
A4059		23:57:01.016	-34:45:32.37	0.046	0.488	0.006	0.1474	0.0027	0.693	0.028	0.02525	0.00115	1.95
AWM4		16:04:56.644	+23:55:57.63	0.033	0.436	0.006	0.1811	0.0032	0.677	0.023	0.01385	0.00049	1.23
EXO0422		04:25:51.164	-08:33:34.34	0.039	0.568	0.007	0.3048	0.0054	1.186	0.067	0.04669	0.00149	1.38
Hydra-A		09:18:05.641	-12:05:43.98	0.052	0.616	0.006	0.2454	0.0056	1.026	0.030	0.05451	0.00115	1.37
IC1262		17:33:02.990	+43:45:38.94	0.031	0.497	0.005	0.2548	0.0035	0.871	0.014	0.02359	0.00053	1.28
IC1365		21:13:55.893	+02:33:50.66	0.049	0.243	0.007	0.0512	0.0021	0.401	0.155	0.00769	0.00134	1.33
MKW3s		15:21:51.824	+07:42:31.63	0.045	0.570	0.017	0.2093	0.0324	0.920	0.026	0.02659	0.00072	0.80
MKW8		14:40:39.469	+03:28:13.13	0.027	0.191	0.003	0.0620	0.0020	0.452	0.052	0.00496	0.00042	2.37
–		14:38:21.874	+03:40:11.93	0.027	0.512	0.010	0.0287	0.0011	0.084	0.002	0.12684	0.00011	0.43
NGC6338		17:15:22.990	+57:24:40.27	0.028	0.415	0.013	0.2830	0.0053	1.469	0.053	0.04356	0.00112	0.67
–		17:15:23.167	+57:26:04.65	0.028	0.290	0.009	0.1316	0.0033	0.874	0.070	0.01950	0.00083	0.69
RXJ0341.3+1524		03:41:16.625	+15:24:01.81	0.029	0.347	0.007	0.1100	0.0024	0.401	0.026	0.00630	0.00034	2.73
RXJ1252.5-3116		12:52:34.721	-31:15:59.24	0.053	0.714	0.007	0.4436	0.0079	1.047	0.047	0.06392	0.00279	1.90
RXJ1504.1-0248		15:04:07.427	-02:48:16.47	0.215	0.778	0.005	0.3443	0.0067	1.567	0.054	0.14018	0.00441	1.39
RXJ1524.2-3154		15:24:12.912	-31:54:22.66	0.103	0.597	0.006	0.4128	0.0069	1.447	0.014	0.09196	0.00335	1.95
RXJ1539.5-8335		15:39:34.529	-83:35:23.27	0.073	0.715	0.007	0.3070	0.0069	0.781	0.043	0.04268	0.00246	2.15
RXJ1558.3-1410		15:58:21.651	-14:09:59.28	0.097	0.548	0.006	0.1807	0.0036	0.805	0.025	0.03545	0.00112	1.84
RXJ1720.1+2638	G049.20+30.86	17:20:09.957	+26:37:30.79	0.164	0.620	0.007	0.2313	0.0055	1.238	0.054	0.06126	0.00245	1.48
RXJ1958.2-3011		19:58:14.918	-30:11:11.53	0.117	0.694	0.019	0.7253	0.0185	2.203	0.112	0.19818	0.00995	3.45

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TABLE A2 – continued from previous page

Cluster	<i>Planck</i> name	RA	DEC	z	C_{SB}	$\sigma_{C_{\text{SB}}}$	C_{SB4}	$\sigma_{C_{\text{SB4}}}$	δ	σ_{δ}	n_{core} (cm^{-3})	$\sigma_{n_{\text{core}}}$ (cm^{-3})	r_{max} (r_{500})
RXJ2014.8-2430		20:14:51.619	-24:30:22.88	0.161	0.647	0.007	0.3680	0.0076	1.523	0.056	0.12483	0.00452	1.53
RXJ2344.3-042		23:44:18.277	-04:22:54.04	0.079	0.326	0.006	0.0524	0.0023	0.270	0.070	0.00740	0.00163	1.87
S0405	G296.41-32.48	03:51:31.364	-82:13:27.86	0.061	0.238	0.007	0.0499	0.0044	0.334	0.069	0.00526	0.00082	1.81
S0540		05:40:06.677	-40:50:11.66	0.036	0.398	0.006	0.1874	0.0040	0.767	0.039	0.02517	0.00137	2.66
–		05:42:49.463	-40:59:57.11	0.036	0.517	0.040	0.0287	0.0000	0.085	0.008	0.12681	0.00043	1.18
S1101		23:13:58.595	-42:43:31.06	0.058	0.681	0.005	0.3260	0.0053	0.985	0.045	0.05015	0.00175	2.40
UGC03957		07:40:58.208	+55:25:38.21	0.034	0.554	0.009	0.3042	0.0066	1.039	0.054	0.04315	0.00213	1.35
USGCS152		10:50:26.109	-12:50:42.05	0.015	0.791	0.070	0.7165	0.0936	1.339	0.049	0.05962	0.00160	1.13
ZwCl1215	G282.49+65.17	12:17:41.196	+03:39:22.03	0.077	0.286	0.006	0.0331	0.0021	0.146	0.047	0.00537	0.00141	1.51
ZwCl1742	G057.92+27.64	17:44:15.426	+32:59:31.71	0.076	0.555	0.005	0.2121	0.0046	1.140	0.058	0.03579	0.00142	1.91