BeppoSAX temperature maps of galaxy clusters in the Corona Borealis supercluster: A2061, A2067 and A2124

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ABSTRACT
In this paper we present the analysis of BeppoSAX observations of the cluster pairs A2061–A2067 and A2122–A2124, located in the Corona Borealis supercluster, which have been selected as candidate merging clusters. The aim of this work is to study the physics of the intracluster medium and to look for the possible presence of merging signatures. We derived the global temperatures and abundances and the temperature profiles and maps for these clusters. We do not find any significant evidence of interaction between the clusters forming the pairs, but we detect a candidate shock inside A2061. On the basis of the X-ray and optical properties of this cluster we propose a scenario in which a group is falling inside A2061. This interaction is in the phase in which the cores have not yet met and in which the formation of a shock is expected.

Key words: galaxies: clusters: general – galaxies: clusters: individual: A2061 – galaxies: clusters: individual: A2067 – galaxies: clusters: individual: A2122 – galaxies: clusters: individual: A2124 – X-rays: galaxies: clusters.

1 INTRODUCTION
Clusters of galaxies are now recognized to form in a hierarchical way, by the gravitational merger of smaller clusters and groups. These kinds of events are the most energetic in the Universe, since the Big Bang, with a release of \( \sim 10^{56} \text{erg} \) on a time-scale of the order of a few Gyr (Sarazin 2000).

Numerical simulations (Tormen 1997) revealed that mergings happen along preferential directions which define matter flow regions, at whose intersection rich clusters form. The environment of these intersections is represented by the core of superclusters: given the high local density and the small volumes involved, the ‘cross-section’ for merging between clusters or group-cluster is strongly enhanced and the dynamical processes are accelerated. Therefore, the central parts of superclusters are unique and ideal laboratories where this astrophysical event can be studied.

Applying a percolation algorithm to cluster catalogues, in order to individuate density enhancements of clusters over the mean density, Zucca et al. (1993) obtained catalogues of superclusters at various density excesses. Among the richest structures found there are the Shapley Concentration in the Southern hemisphere and the Corona Borealis supercluster in the Northern hemisphere.

Our group already performed an extensive, multiwavelength study of the Shapley Concentration in the X-ray, optical and radio bands (Bardelli et al. 1996; Ettori, Fabian & White 1997; Bardelli et al. 1998; Venturi et al. 2000). In this region three ‘cluster complexes’ are found, which present cluster merging events at various evolutionary stages.

In order to extend the statistics, we decided to study systems of clusters belonging to the central region of the Corona Borealis supercluster.

In this paper we present the results of BeppoSAX observations of the cluster pairs A2061–A2067 and A2122–A2124.

The plan of the paper is the following. In Section 2 we introduce the Corona Borealis supercluster and in Sections 3 and 4 we describe the data reduction and the determination of the temperature profiles and maps, respectively. In Section 5–7 we present the analysis of A2061, A2067, and A2124, respectively. Finally in Section 8 we discuss and summarize the results.

We assume a flat cosmology with \( \Omega_0 = 1 \) and a value for the Hubble constant of \( H_0 = 100 \text{km s}^{-1} \text{Mpc}^{-1} \).
2 THE CORONA BOREALIS SUPERCLUSTER

The Corona Borealis supercluster, at \( (z) \sim 0.07 \) (Postman, Geller & Huchra 1988), is the most prominent supercluster in the Northern sky.

At an overdensity in number of clusters of \( f \geq 2 \) (Zucca et al. 1993) this supercluster is made up of 10 clusters: A2019, A2056, A2061, A2065, A2067, A2079, A2089, A2092, A2122 and A2124 (see also Cappi & Maurogordato 1992).

The central part of the Corona Borealis supercluster covers a region of \( 6 \times 6 \) deg\(^2\) centred on \( \alpha_{2000} = 15^h 20^m, \delta_{2000} = +30^\circ \) and is made up of seven clusters: four of them (A2056, A2065, A2079 and A2089) are grouped together in the southern part, A2061 and A2067 are close together in the northern part, and A2092 is isolated in the north-eastern part (see also fig. 1 in Small et al. 1998).

A2122 and A2124 are located at the north-east periphery of this central region (\( \sim 5^\circ \) from the centre of the supercluster).

According to Bahcall (1992) the entire supercluster extends for at least \( \sim 100 h^{-1} \) Mpc on the plane of the sky, while according to Small, Sargent & Hamilton (1997) it is only \( \sim 40 h^{-1} \) Mpc along the line of sight.

The dominant cluster of Corona Borealis is A2065 (\( z = 0.0726 \), Struble & Rood 1999). Located in the southern part of the supercluster, it is the only cluster of the supercluster of richness class 2. It shows a late stage of merging (Markevitch, Sarazin & Vikhlinin 1999).

Inside this supercluster two pairs of candidate interacting clusters at high density excess have been found: A2061–A2067 (\( f \geq 10 \)) and A2122–A2124 (\( f \geq 400 \)). All these clusters have richness class 1.

In the present work we first focus on the clusters A2061 and A2067. In order to show the relative position of the two clusters, we present in Fig. 1 the X-ray isophotes from the two BeppoSAX MECS observations (see Section 3) in the 2–10 keV energy range superimposed on a grey-scale image of the existing archive ROSAT Position-Sensitive Proportional Counter (PSPC) pointed observation which contains both clusters. Unfortunately, the PSPC observation is offset by \( \sim 42 \) arcmin, and therefore the point spread function (PSF) is degraded. It can be seen from the PSPC observation that A2061 seems to be elongated towards A2067. This plume of X-ray emission might indicate the presence of interaction between the two clusters. Note that in the BeppoSAX data there is no trace of this elongation because part of it falls under the detector entrance window supporting structure (called strongback). From this image we can estimate that the distance between the centres of the two clusters on the plane of the sky is \( \sim 30 \) arcmin: at the redshift of the clusters (\( (z) \sim 0.076 \)) this distance corresponds to \( \sim 1.8 h^{-1} \) Mpc, i.e. less than 2 Abell radii (\( \sim 3 h^{-1} \) Mpc). On the other hand, the velocity difference between A2061 and A2067 is \( \Delta v \sim 1533 \) km s\(^{-1}\) (Oegerle & Hill 2001): if this \( \Delta v \) were due purely to Hubble flow, the separation between these two clusters would be \( \sim 15.44 h^{-1} \) Mpc, therefore too large for a cluster interaction. However, this velocity difference results from the composition of the unknown relative peculiar velocity and the cosmological distance of the two clusters.

Secondly, we study the clusters A2122 and A2124. These clusters are so near (their \( \Delta v \) is 150 km s\(^{-1}\)), while the distance on the plane of the sky is \( \sim 7 \) arcmin) that there are no data about them as a pair in the literature. There is a lot of information about A2124, while there are very few data about A2122, and sometime they are considered as a single cluster. Because of their small distance on the plane of the sky, they have been observed with a single BeppoSAX pointing centred on the cluster A2124. In Fig. 2 we present an Einstein Imaging Proportional Counter (IPC) image of the diffuse gas of these clusters superimposed on the X-ray isophotes from the MECS observation in the 2–10 keV energy range: the nominal ACO centres (Abell, Corwin & Olowin 1989) are indicated with arrows.

3 OBSERVATIONS AND DATA REDUCTION

The clusters A2061, A2067 and A2124 were observed by the BeppoSAX satellite (Boella et al. 1997a) in the periods 2000 August 8–9, 2000 July 28–29 and 2001 February 5–8, respectively. We discuss here the data from two of the instruments on board BeppoSAX: the Medium–Energy Concentrator Spectrometer (MECS) and the Low–Energy Concentrator Spectrometer (LECS, used here only for A2067). The MECS (Boella et al. 1997b) is composed by two units, working in the 1–10 keV energy range. At 6 keV, the spectral resolution is \( \sim 8 \) per cent and the angular resolution is \( \sim 0.7 \) arcmin full width at half maximum (FWHM). The LECS (Parmar et al. 1997) consists of an imaging X-ray detector, working in the 0.1–9 keV energy range, with 20 per cent spectral resolution and 0.8 arcmin (FWHM) angular resolution (both computed at 1 keV). Standard reduction procedures and screening criteria have been adopted to produce linearized and equalized event files. The MECS (LECS) data preparation and linearization were completed using the specific BeppoSAX data processing systems, respectively.
performed using the SAXDAS (SAXELDAS) package under the FTOOLS environment.

We also analysed PDS (Phoswich Detector System) data for these clusters: we found that no significant detection is present for A2061 and for A2067. For A2124 we found a small excess in the 15–40 keV energy range possibly associated with the X-ray source EXSS 1543.1+3615 (Oppenheimer, Helfand & Gaidos 1997).

We have taken into account the PSF-induced spectral distortions (D’Acri, De Grandi & Molendi 1998) in the MECS analysis using effective area files produced with the EFFAREA program. Note that, due to the displacements of the two MECS units, the region masked by the support window is different in MECS2 and in MECS3: this fact allows us to recover, at least partly, the information in the region 8–12 arcmin from the field centre. A detailed explanation of the MECS analysis is given in De Grandi & Molendi (2001). All MECS and LECS spectra have been background-subtracted using spectra extracted from blank sky event files in the same region of the detector as the source (Fiore, Guainazzi & Grandi 1999).

The observation log is reported in Table 1. We recall that A2122 and A2124 belong to a single BeppoSAX observation. The coordinates reported in this table are the pointing coordinates. The observed count rates for A2061, A2067 and A2124 for the two MECS units and within the central 8 arcmin (corresponding to ~0.50 h⁻¹ Mpc) are also reported in the table.

Recently, Perri & Capalbi (2002) found that a systematic error affects the sky coordinates derived from the LECS and MECS instruments. The corrections depend on the spacecraft roll angle and are of the order of ~30 arcsec for our observations. From now on all the X-ray coordinates will be corrected for this systematic error.

### 4 TEMPERATURE PROFILES AND MAPS

In order to find the global temperature, we extracted a circular region of 8 arcmin (~0.50, ~0.48 and ~0.40 h⁻¹ Mpc for A2061, A2067 and A2124, respectively) from the centre of the MECS data in the range 2–10 keV. This region, although smaller than the extension of the clusters, has been chosen because it is not affected by the absorption caused by the strongback. We fitted the spectrum with a MEKAL (Mewe et al. 1995; Kaastra 1992) model with an absorbing Galactic hydrogen column (WA BSm model), as implemented in the XSPEC package (V10.00). After having checked that the fitted Galactic absorption is consistent with the literature measurement (Dickey & Lockman 1990), we fixed it to this value. The values for each cluster are reported in Table 1.

In analysing temperature profiles and maps we used only the MECS data, for which the correction for the PSF-induced spectral distortions is available. The cluster emission has been divided into concentric annuli, centred on the X-ray emission peak: out to 8 arcmin the annuli are 2-arcmin wide; beyond this radius the annuli are 4-arcmin wide.

However, we limited all the fitting procedures to the cases in which the source counts are more than 30 per cent of the total (i.e., source plus background) counts (see the discussion in De Grandi & Molendi 2002); indeed when the source counts are low, the spectral features of the background could dominate the results.

In order to explore if there is an asymmetry of the temperature distributions we divided the cluster maps into four sectors. Sector I is north-west of the image and the numbers increase clockwise. The value of temperature referred to the 0–2 arcmin region is the same for all the sectors because a circular region was used to fit the data. This analysis has been possible only for A2061 and A2124; the cluster A2067 is too faint to permit meaningful temperature determinations in sectors.

### 5 THE CLUSTER A2061

Abell 2061 is a cluster of richness class 1 and Bautz–Morgan class III; the ACO (Abell, Corwin & Olowin 1989) coordinates are α2000 = 15h 21m 15s and δ2000 = +30° 39’ 17”.

On the basis of 118 redshifts Oegerle & Hill (2001) found that the biweight estimate of the observed location was $C_b = 23.699 \pm 70$ km s⁻¹ and that the biweight estimate of the scale was $s_b = 780 \pm 7$ km s⁻¹. At the redshift of the cluster 1 arcmin corresponds to 62.70 h⁻¹ kpc.

We observed this cluster using an exposure time of 51 163 s and in Fig. 3 we present the MECS isophotes in the 2–10 keV band.

![Figure 3. X-ray isophotes, from a BeppoSAX MECS observation pointed on A2061, superimposed on the optical image from the Digital Sky Survey. The data have been smoothed with a Gaussian of 8 pixel FWHM (1 pixel = 8 arcsec) and the linear step within contours is 0.34, with the lowest isophote corresponding to 0.250 counts per pixel. The labelled objects are described in the text.](https://academic.oup.com/mnras/article-abstract/353/4/1219/977190 by guest on 15 March 2020)
superimposed on the optical image from the Digital Sky Survey. The centroid of diffuse emission has coordinates \( \alpha_{2000} = 15^h 21^m 14^s \), \( \delta_{2000} = +30^\circ 37' 32'' \) and is 1.8 arcmin from the ACO centre, corresponding to \( \sim 0.11 \ h^{-1} \) Mpc. The hot gas distribution appears to be elongated in the north-east--south-west direction, i.e. toward A2067.

Two bright galaxies are located approximately along the major axis of the ellipse described by the isophotes. One of them (dubbed North dominant) is located 3.1 arcmin (\( \sim 0.19 \ h^{-1} \) Mpc) north-east of the X-ray centre; it has a velocity of \( 23 725 \pm 23 \) km s\(^{-1} \) (Oegerle & Hill 1998) and therefore it is at rest with respect to the cluster mean velocity. The other dominant galaxy (dubbed South dominant), located 2.6 arcmin (\( \sim 0.16 \ h^{-1} \) Mpc) south-west of the X-ray centre, has a velocity of \( 22 720 \pm 20 \) km s\(^{-1} \) (Oegerle & Hill 1998), and therefore it has a \( \Delta v \sim 980 \) km s\(^{-1} \) with respect to the centroid. The \( R \) magnitudes of the two galaxies are \( R_{\text{APM}} = 12.24 \) and 12.84, respectively.

In the north-west direction, at 7.9 arcmin (\( \sim 0.50 \ h^{-1} \) Mpc) from the X-ray centre, there is a significant unresolved X-ray peak (\( \alpha_{2000} = 15^h 20^m 45^s, \delta_{2000} = +30^\circ 40' 58''.7 \)). Near this position two different objects are located: a galaxy (\( \alpha_{2000} = 15^h 20^m 45^s 23', \delta_{2000} = +30^\circ 41' 07'; \ R = 13.93 \) without a measured redshift, at \( \sim 20.67 \) arcsec from the peak, and a Seyfert 1 galaxy (\( \alpha_{2000} = 15^h 20^m 43', \delta_{2000} = +30^\circ 41' 23'; \ R = 15.27 \)) at \( \sim 35 \) arcsec from the peak, at \( z = 0.0772 \) (Small et al. 1997), which we associate to the X-ray peak.

### 5.1 Spatial analysis

Looking at MECS X-ray isophotes of the cluster (see Fig. 3), it is clear that it is characterized by an elongated diffuse emission. For this reason we fitted the surface brightness distribution using an elliptical corrected King law

\[
P(x, y) = I_0 \left[ 1 + \left( \frac{x'}{R_1} \right)^2 + \left( \frac{y'}{R_2} \right)^2 \right]^{-3\beta + 0.5} + \text{bck},
\]

where

\[x' = (x - x_1) \cos \theta + (y - y_1) \sin \theta\]

\[y' = -(x - x_1) \sin \theta + (y - y_1) \cos \theta,
\]

in order to take into account the inclination angle \( \theta \) of the cluster.

The variables to be estimated are the normalization \( I_0 \), the positions \( (x_1, y_1) \) of the centre of the cluster, the inclination angle of the cluster \( \theta \), computed clockwise from the north), its core radii \( (R_1, R_2) \), the exponent of the King law \( \beta \). The background (bck) has been estimated from the background map (see Section 3) and, after having rescaled it by the exposure times, was found to be 0.09 counts per pixel. The fit has been performed on a region of 9-arcmin radius by minimizing the \( \chi^2 \) variable between the model and the data, after having masked a circle of 24-arcsec diameter centred on the second X-ray peak described in Section 5. The resulting reduced \( \chi^2 \) is 1.044 with 1254 degrees of freedom. The results of the fit, done in the 2–10 keV energy range, are reported in Table 2. We found \( \beta = 0.634 \), while the mean value of the core radius is 0.265 \( h^{-1} \) Mpc, larger than the average value of 0.08 \( h^{-1} \) Mpc found by Ettori & Fabian (1999) from a sample of 27 clusters.

### Table 2. Results of the bidimensional fit for A2061.

| Normalization | \( R_1 \) | \( R_2 \) | \( \beta \) | \( \theta \) |
|---------------|----------|----------|--------|--------|
| 2.199 \( \pm 0.030 \) counts per pixel | 34.97 \( \pm 1.50 \) pix | 29.18 \( \pm 1.05 \) pix | 0.634 \( \pm 0.023 \) | 116\( ^\circ \) \( \pm 0.8\( ^\circ \) |
| \( 3.13 \pm 0.04 \) \( \times 10^{-6} \) erg \( \text{str}^{-1} \ cm^{-2} \ s^{-1} \) | 0.290 \( \pm 0.012 \) \( h^{-1} \) Mpc | 0.242 \( \pm 0.009 \) \( h^{-1} \) Mpc |

This observed large value of the core radius indicates, together with the other properties described in the previous section, that the cluster is not completely relaxed and the intracluster medium (ICM) is still settling after a major disturbance induced from a merger (see the discussion in Section 8).

From the normalization of the King function it is possible to obtain the central surface brightness, using the appropriate conversion factor from counts to intrinsic flux (i.e. corrected for absorption). Assuming a bremsstrahlung emission from a hot gas with temperature of 4.52 keV, an abundance of 0.10 and a hydrogen column density of \( 1.96 \times 10^{20} \) atoms cm\(^{-2} \) (see Section 5.2), the central surface brightness in the 2–10 keV range was found to be \( I_0 = 3.13 \times 10^{-6} \) erg \( \text{cm}^{-2} \text{str}^{-1} \text{s}^{-1} \).

### 5.2 Global temperature and abundance

We found that the global temperature of this cluster, obtained from the MECS instrument, is \( kT = 4.52^{+0.04}_{-0.06} \) keV with an abundance of \( 0.10^{+0.09}_{-0.08} \) where the errors are at the 90 per cent confidence level. The reduced \( \chi^2 \) is 0.92 with 109 degrees of freedom. In Fig. 4 we show the MECS spectrum of A2061, overplotted to the fit, and the corresponding confidence ellipse of the temperature and abundance parameters.

We determined the temperature and the abundance also in a larger region (within 16 arcmin, corresponding to \( \sim 1 \ h^{-1} \) Mpc), finding \( kT = 4.13^{+0.44}_{-0.38} \) keV and abundance \( 0.06^{+0.10}_{-0.06} \) with a reduced \( \chi^2 \) of

![Figure 4](https://academic.oup.com/mnras/article-abstract/353/4/1219/977190/1219-1230)
0.98 and 127 degrees of freedom. These values are consistent with the previous estimate.

Following the $\sigma - T$ relation of Lubin & Bahcall (1993) [$\sigma = 332 (kT)^{0.6} \text{ km s}^{-1}$], the temperature of $kT = 4.52 \text{ keV}$ implies a velocity dispersion of $821^{+30}_{-26} \text{ km s}^{-1}$, consistent with the value estimated by Oegerle & Hill (2001).

Another way to estimate the correspondence between the velocity dispersion and the hot gas temperature is to calculate $\beta_{\text{spec}}$ (Cavaliere & FuscoFemiano 1976):

$$\beta_{\text{spec}} = \frac{\mu m_p \sigma^2}{kT},$$

where $\mu = 0.60$ is the mean molecular weight, $m_p$ is the proton mass, $\sigma$ is the velocity dispersion of galaxies and $kT$ is the temperature of the cluster gas. Using the value obtained by Oegerle et al. for the velocity dispersion, and the temperature we found, we obtained $\beta_{\text{spec}} = 0.84$, lower than the typical value of 1.1 (Sarazin 1988).

With the temperature estimated in the region 0–16 arcmin, the total luminosity within this region is $L_{2<10\text{keV}} = (1.21 \pm 0.02) \times 10^{44} \text{ erg s}^{-1}$, corresponding to a bolometric luminosity of $L_X = 2.45 \times 10^{46} \text{ erg s}^{-1}$; the flux we obtained in the same region is $F_{2<10\text{keV}} = (1.72 \pm 0.03) \times 10^{-14} \text{ erg cm}^{-2} \text{s}^{-1}$. We found these two values after having subtracted the contribution of the second X-ray peak described at the beginning of this section.

Ebeling et al. (1996) reported the flux for this cluster from the ROSAT All-Sky Survey, assuming a temperature of 5.5 keV. They found $F_{2<10\text{keV}} = 1.46 \times 10^{-11} \text{ erg cm}^{-2} \text{s}^{-1}$, i.e. 15 per cent lower than our value. From the X-ray luminosity function of clusters in the 2–10 keV band, Edge et al. (1990) found $L^* = 2 \times 10^{44} \text{ erg s}^{-1}$; the luminosity we estimated is 39 per cent lower than $L^*$.

### 5.3 Temperature profiles and maps

The next step is the description of the temperature distribution within the cluster by dividing the frame into rings and sectors. Given the low count statistics, the abundance was not constrained by the data, so we fixed it to the value of 0.10, according to the value found with MECS data within 8 arcmin. The spectral analysis was performed after having masked a circle of 3-arcmin radius centred on the second X-ray peak described in Section 5. This peak affects the annuli at 6–8 arcmin and 8–12 arcmin. The results are reported in Table 3. Fig. 5 shows the temperature profile of A2061 in annuli around the cluster centre. The vertical bars correspond to the 68 per cent errors and the horizontal bars represent the bins used to extract the counts. The dotted line corresponds to the value obtained from the global temperature fit. From this figure we note that the profile is slightly decreasing, with the exception of the second point, which is higher than the global value. This is due to a temperature increase in a specific area of the cluster (see below).

Table 3. Spectral results from regions of various radii (arcmin) from the centre of A2061. Errors are at the 90 and 68 per cent confidence level. Abundance is fixed to the value 0.10.

| Radius (arcmin) | $kT$ (keV) | Reduced $\chi^2$ (d.o.f.) |
|----------------|------------|--------------------------|
| 0–2            | $4.35^{+0.87}_{-0.49}$ | 0.64 (48) |
| 2–4            | $5.66^{+0.98}_{-0.74}$ | 0.79 (58) |
| 4–6            | $4.20^{+0.84}_{-0.64}$ | 1.11 (50) |
| 6–8            | $3.22^{+1.03}_{-0.67}$ | 1.02 (27) |
| 8–12           | $1.60^{+1.31}_{-0.62}$ | 0.90 (38) |

In order to explore if there is an asymmetry of the temperature distribution due to the interaction of the intracluster medium with possible material of the A2067 cluster (see Fig. 1), we divided the cluster map into four sectors as shown in Fig. 6. Sector IV points towards the A2067 cluster. Also in this case, we masked the second X-ray peak, which is located in sector I. The results are reported in Table 4. Note that in the 8–12 arcmin annuli, sectors I, II and III, the source counts are 20.0, 17.8 and 18.7 per cent, respectively, of the total counts; that is, the background contribution becomes dominant. In Fig. 7 the temperature profiles in the four sectors are presented. Looking at the image it is possible to note that the temperature distribution is quite isothermal up to 8 arcmin, with the exception of sector IV, for which there is a remarkable increase of the temperature around the 3-arcmin bin which is not consistent (at 2.5$\sigma$) with that of the global fit. This result leads us to suppose that the discrepancy with respect to the global value found in the temperature radial profile in the 2–4 arcmin annulus (see Fig. 5) is due to the presence of this excess.

The spectral fit of the data in the 2–4 arcmin region of sector IV is shown in Fig. 8: the temperature is $kT = 10.67^{+2.87}_{-2.99} \text{ keV}$ (the errors are at the 68 per cent confidence level) and the reduced $\chi^2$ is 0.96 with 44 degrees of freedom.

In order to check the robustness of the temperature determined in this region, we repeated the fit, forcing the abundance to different values in the range 0.00–1.00. The derived temperatures are in the range 9.06–11.45 keV, in any case not consistent with the value from the global fit. Moreover, we checked whether the data could be described by a bremsstrahlung plus a power law: the fit, although
Table 4. Spectral results from regions of various radii (arcmin) from the centre of A2061. Errors are at the 90 and 68 per cent confidence level. Abundance is fixed to the value 0.10. Sectors indicated in italic are those where the source counts are lower than 30 per cent of the total.

| R (arcmin) | Sector | \(kT\) (keV) | Reduced \(\chi^2\) (d.o.f.) |
|-----------|--------|--------------|-------------------------------|
| 2–4       | I      | 4.27±1.45−0.30 | 0.65 (46)                     |
|           | II     | 4.65±1.45−0.31 | 0.45 (49)                     |
|           | III    | 4.78±2.19−1.14 | 0.41 (37)                     |
|           | IV     | 10.67±8.35−3.90 | 0.66 (44)                     |
| 4–6       | I      | 2.91±1.29−0.72 | 0.57 (46)                     |
|           | II     | 5.23±2.65−1.39 | 0.64 (34)                     |
|           | III    | 5.05±5.33−2.40 | 0.69 (49)                     |
|           | IV     | 3.96±1.40−0.73 | 0.58 (24)                     |
| 6–8       | I      | 4.53±2.06−0.25 | 0.36 (57)                     |
|           | II     | 3.80±3.76−1.75 | 0.40 (39)                     |
|           | III    | 2.50±1.69−0.86 | 0.79 (06)                     |
|           | IV     | 2.39±2.29−1.08 | 0.31 (36)                     |
| 8–12      | I      | 2.55±2.05−1.45 | 0.41 (11)                     |
|           | II     | 2.13±1.69−0.80 | 1.10 (13)                     |
|           | III    | 1.08±1.27−0.64 | 1.53 (12)                     |
|           | IV     | 2.77±1.19−0.63 | 1.10 (18)                     |

Figure 7. Temperature map of A2061. The vertical bars correspond to 68 per cent errors, while the horizontal bars represent the bins used to extract the counts. Dotted lines correspond to the global temperature fit. For the first bin a circular region was used to fit the data; consequently the value is the same for all quadrants.

formally acceptable, does not constraint the photon index of the power law.

This result might suggest the presence of a candidate internal shock due to the merger of an infalling group into the main body of the cluster, as we discuss in Section 8.

6 THE CLUSTER A2067

Abell 2067 is a cluster of richness class I and Bautz–Morgan class III; its centre has coordinates \(\alpha_{2000} = 15^h 23^m 14^s\), \(\delta_{2000} = +30^\circ 53' 05''\) and is 1 arcmin from the ACO centre, corresponding to \(\sim 0.11 \text{ h}^{-1} \text{ Mpc}\). This cluster does not appear significantly elongated but shows a diffuse excess in the southern part, corresponding to a galaxy overdensity. Kopylova & Kopylov (1998) reported that A2067 is characterized by the presence of a central dominant galaxy (\(\alpha_{2000} = 15^h 24^m 00^s\), \(\delta_{2000} = +31^\circ 12' 40''\)), but we found that this object is 22.6 arcmin (1.36 \text{ h}^{-1} \text{ Mpc}) from the X-ray centre. Studying the morphological classification of galaxies which belong to A2067 we found two dominant galaxies: one of them, a central dominant galaxy, is located 0.5 arcmin (\(\sim 0.03 \text{ h}^{-1} \text{ Mpc}\)) from the X-ray centre, has a velocity of \(v = 22.061 \pm 54 \text{ km s}^{-1}\) (Postman et al. 1988) and its \(R_{APM}\) magnitude is 12.44. The other dominant galaxy, with a velocity of \(v = 21.576 \pm 50 \text{ km s}^{-1}\) (Postman et al. 1988) is located 4.3 arcmin (\(\sim 0.26 \text{ h}^{-1} \text{ Mpc}\)) from the X-ray centre (\(\alpha_{2000} = 15^h 23^m 08^s\), \(\delta_{2000} = +30^\circ 48' 46''\)) and its \(R_{APM}\) magnitude is 15.97. These dominant galaxies are indicated as cD and D in Fig. 9.

6.1 Global temperature and abundance

Fitting the data extracted from a circular region of 8 arcmin from the centre of the MECS data in the range 2–10 keV we found \(kT = 1.73^{+0.38}_{-0.37} \text{ keV}\) (errors are at the 90 per cent confidence level) with a reduced \(\chi^2\) of 1.52 with 46 degrees of freedom, but the abundance is not constrained. Therefore in order to use all the information present in the BeppoSAX observation, we considered also the data of the LECS instrument in the 0.2–3 keV band extracted from the same region: we obtained \(kT = 1.44^{+0.30}_{-0.37} \text{ keV}\) and an abundance of 0.18^{+0.42}_{-0.16} with a reduced \(\chi^2\) of 1.08 with 16 degrees of freedom. The temperature is consistent with the MECS value.

We have repeated the fit with the MECS data in the 0–8 arcmin region, fixing the abundance to the value found from LECS data: we obtained \(kT = 1.67^{+0.32}_{-0.31} \text{ keV}\) with a reduced \(\chi^2\) of 1.50 with 47 degrees of freedom.
Finally we used the combined LECS+MECS data. In this case, we ran the fits by estimating also the relative normalization between the two instruments: we obtained a value similar to that found by Bardelli et al. (2002) and by Ettori et al. (2000). Therefore we fixed it to the value 0.50. From the LECS+MECS data we found \( kT = 1.54^{+0.22}_{-0.22} \) keV and an abundance of \( 0.19^{+0.16}_{-0.16} \) with a reduced \( \chi^2 \) of 1.39 with 64 degrees of freedom. The temperature is consistent at 0.6\( \sigma \) with that obtained from MECS data and at 0.4\( \sigma \) with that obtained from LECS data; the abundance is consistent at 0.1\( \sigma \) with the value found from LECS data. In Fig. 10 we show the combined LECS+MECS spectrum of A2067, overplotted to the fit.

The temperature of \( kT = 1.54 \) keV implies a velocity dispersion of \( 430^{+49}_{-26} \) km s\(^{-1} \) (errors are at the 68 per cent confidence level) which is consistent with the value estimated by Oegerle & Hill (2001).

From MECS data we found that the total luminosity within 8 arcmin is \( L_{2-10keV} = (0.58 \pm 0.04) \times 10^{43} \) h\(^{-2} \) erg s\(^{-1} \), corresponding to a bolometric luminosity of \( L_X = 2.11 \times 10^{43} \) h\(^{-2} \) erg s\(^{-1} \). According to McKee et al. (1980), the X-ray luminosity in the range 2–10 keV of A2067 is \( L_{2-10keV} < 1.31 \times 10^{43} \) h\(^{-2} \) erg s\(^{-1} \). Our value is \( \sim 97 \) per cent lower than the \( L^* \) value given by Edge et al. (1990).

### 6.2 Temperature profiles

In analysing temperature profiles we fixed the abundance to the value of 0.18, according to the value found with LECS data. The results are reported in Table 5. Note that in the 4–6 arcmin annulus the source counts are 27.1 per cent of the total counts, i.e. lower than 30 per cent of the total and therefore on the border of our acceptability criterion. In Fig. 11 we report the temperature profile of A2067 in annuli around the cluster centre. Looking at the figure it is possible to note that the temperature is roughly constant, i.e. it is isothermal up to 6 arcmin (\( \sim 0.36 \) h\(^{-1} \) Mpc).

Given the low statistics of counts we were not able to divide the cluster into sectors as was done for A2061 and it was not possible to do a bidimensional analysis.

### 7 THE CLUSTER A2124

Abell 2124 is a richness class 1 cluster and Bautz–Morgan class I; its centre has coordinates \( \alpha_{2000} = 15^h 44^m 59^s \), \( \delta_{2000} = +36^\circ 04' \) (Abell et al. 1989). On the basis of 61 redshifts, Oegerle & Hill (2001) estimated \( C_5 = 19684 \pm 110 \) km s\(^{-1} \) and \( S_{50} = 862^{+95}_{-72} \) km s\(^{-1} \). At the redshift of the cluster, 1 arcmin corresponds to 52.92 h\(^{-1} \) kpc.

We observed this cluster with an exposure time of 133,017 s. In Fig. 12 we present the MECS X-ray isophotes superimposed on the optical image from the Digital Sky Survey. The X-ray centre...
Figure 11. Temperature radial profile of A2067. The vertical bars correspond to 68 per cent errors, while the horizontal bars represent the bins used to extract the counts. The dotted line corresponds to the global temperature fit, derived within 8 arcmin.

Figure 12. X-ray isophotes, from a BeppoSAX MECS observation, of the cluster A2124, superimposed on the optical image from the Digital Sky Survey. The data have been smoothed with a Gaussian of 6 pixel FWHM (1 pixel = 8 arcsec) and the linear step within contours is 0.50, with the lowest isophote corresponding to 0.571 counts per pixel. The labelled objects are described in the text.

has coordinates $\alpha_{2000} = 15^{h} 44^{m} 56^{s}$, $\delta_{2000} = +36^{\circ} 06^{\prime} 04^{\prime \prime}$. A2124 is dominated by a single cD galaxy ($\alpha_{2000} = 15^{h} 44^{m} 59^{s}$, $\delta_{2000} = +36^{\circ} 06^{\prime} 34^{\prime \prime}$), with a velocity of $v = 19810$ km s$^{-1}$ and $R$ magnitude of 12.49 (Kopylova & Kopylov 1998). Blakeslee & Metzger (1999) identified an arc-like object at $z = 0.573$ located 27 arcsec along the major axis from the centre of this cD galaxy.

As discussed in Section 2, in this BeppoSAX observation another Abell cluster (A2122) is included with a position north-west of A2124 (in Fig. 12 we indicate the ACO centre of both clusters). Abell 2122 is reported as a cluster of richness 1 and Bautz–Morgan class II–III; its centre has coordinates $\alpha_{2000} = 15^{h} 44^{m} 29^{s}$, $\delta_{2000} = +36^{\circ} 08^{\prime}$ (Abell et al. 1989) and its velocity is $v = 19830$ km s$^{-1}$ (Struble & Rood 1999). There is apparently a lot of confusion in the literature about A2122 and A2124. These two clusters are at a projected separation of 7.3 arcmin. Abell (1958) classified both of them as richness 1 clusters, but assigned distance class 3 to A2122 and distance class 5 to A2124. Looking at the DSS images centred on the two clusters, A2124 appears indeed as a poorer concentration of fainter galaxies 3 arcmin south of the cD (but at the same right ascension). However, the centre of A2122 falls west of the cD, in a region which apparently does not correspond to any significant galaxy concentration. Quite confusingly, in the NASA/IPAC Extragalactic Database (NED) only A2122 is associated to a Zwicky cluster, while the SIMBAD data base gives wrong coordinates for A2122, $\alpha_{2000} = 15^{h} 44^{m} 48^{s}$ and $\delta_{2000} = 36^{\circ} 06^{\prime} 00^{\prime \prime}$ (instead of $\alpha_{2000} = 15^{h} 44^{m} 29^{s}$ and $\delta_{2000} = 36^{\circ} 07^{\prime} 38^{\prime \prime}$, as reported in NED). The available redshift measurements show that the two clusters are at the same distance, at $z = 0.066$: this means that the separation of 7.3 arcmin corresponds to only $\sim 0.39$ $h^{-1}$ Mpc; on this basis and taking into account the X-ray map, we conclude that A2122 and A2124 should be identified with the same cluster.

7.1 Spatial analysis

As done in Section 5.1, we fitted the surface brightness distribution using an elliptical King law; the background (bck) has been estimated from the background map, and was found to be 0.205 counts per pixel. The resulting reduced $\chi^2$ is 0.936 with 1254 degrees of freedom. The results of the fit, done in the 2–10 keV energy range and within a region of 9-arcmin radius, are reported in Table 6. We found $\beta = 0.586$, while the average value of the core radius is 0.122 $h^{-1}$ Mpc.

With these values and the temperature profile (see Section 7.3) we derive a total mass within 0.45 $h^{-1}$ Mpc of $1.11 \times 10^{14} h^{-1}$ M$_{\odot}$.

7.2 Global temperature and abundance

For the MECS global temperature we found $kT = 4.41^{+0.38}_{-0.33}$ keV and an abundance of 0.29$^{+0.10}_{-0.09}$, where the errors are at the 90 per cent confidence level. The reduced $\chi^2$ is 0.98 with 132 degrees of freedom.

The temperature found implies a velocity dispersion of $809^{+24}_{-20}$ km s$^{-1}$ (errors are at 68 per cent confidence level), which is consistent with the value estimated by Oegerle & Hill (2001).

Using the value obtained by Oegerle for the velocity dispersion, and the temperature we found from MECS data in the 0–8 arcmin region, we obtained $\beta_{\text{spec}} = 1.05$, similar to the typical value of 1.1 (Sarazin 1988).

From MECS data we found that the total luminosity within 8 arcmin is $L_{2–10\text{keV}} = (2.82 \pm 0.04) \times 10^{43}$ $h^{-2}$ erg s$^{-1}$, corresponding to a bolometric luminosity of $L_X = 0.56 \times 10^{44}$ $h^{-2}$ erg s$^{-1}$; the flux we obtained in the same region is $F_{2–10\text{keV}} = (0.58 \pm 0.01) \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ to be compared with $F_{2–10\text{keV}} = 0.48 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$, estimated by Ebeling et al. (1996). The luminosity we estimated is 86 per cent lower than the $L_X$ value given by Edge et al. (1990).

7.3 Temperature profiles and maps

In analysing temperature profiles we used the MECS data, and divided the cluster emission in the same way as was done for A2061 and A2067 (see Sections 5.3 and 6.2). Abundance is fixed to the value of 0.29, according to the value found from the global fit. The results are reported in Table 7. In Fig. 13 we report the temperature profile of A2124 in annuli around the cluster centre. Looking at the figure it can be seen that the temperature is not constant, but shows a decrease with increase in radius.

In order to explore if there is an asymmetry of the temperature distribution, we divided the cluster map into four sectors as shown in Fig. 14. The cluster A2122 belongs to sector I, annulus 6–8 arcmin, and, unfortunately, part of its emission falls under the strongback. The results of the analysis are reported in Table 8. Note that in the
Table 6. Results of the bidimensional fit for A2124.

| Normalization                  | $R_1$         | $R_2$         | $\beta$   | $\theta$   |
|-------------------------------|---------------|---------------|-----------|------------|
| 5.189 ± 0.050 counts per pixel| 18.38 ± 0.50 pix | 16.13 ± 0.65 pix | 0.586 ± 0.010 | 95° ± 2° |
| (2.91 ± 0.03) $\times 10^{-6}$ erg str$^{-1}$ cm$^{-2}$ s$^{-1}$ | 0.130 ± 0.004 h$^{-1}$ Mpc | 0.114 ± 0.005 h$^{-1}$ Mpc |           |            |

Table 7. Spectral results from regions of various radii (arcmin) from the centre of A2124. Errors are at the 90 per cent and 68 per cent confidence level. Abundance is fixed to the value 0.29.

| Radius (arcmin) | $kT$ (keV) | Reduced $\chi^2$ (d.o.f.) |
|-----------------|------------|--------------------------|
| 0–2             | 5.44 ± 0.24 | 0.81 (73)                |
| 2–4             | 4.24 ± 0.26 | 1.07 (81)                |
| 4–6             | 3.40 ± 0.29 | 0.91 (66)                |
| 6–8             | 2.82 ± 0.27 | 1.10 (40)                |

Table 8. Spectral results from regions of various radii (arcmin) from the centre of A2124. Errors are at the 90 per cent and 68 per cent confidence level. Abundance is fixed to the value 0.29. Sectors indicated in italic are those where the source counts are lower than 30 per cent of the total.

| R (arcmin) | Sector | $kT$ (keV) | Reduced $\chi^2$ (d.o.f.) |
|-----------|--------|------------|--------------------------|
| 2–4       | I      | 3.67 ± 0.51 | 1.77 (27)                |
|           | II     | 5.10 ± 0.60 | 0.52 (26)                |
|           | III    | 6.12 ± 0.79 | 1.59 (28)                |
|           | IV     | 4.30 ± 0.65 | 1.06 (32)                |
| 4–6       | I      | 3.19 ± 0.56 | 1.02 (20)                |
|           | II     | 3.34 ± 0.56 | 1.33 (20)                |
|           | III    | 2.96 ± 0.56 | 0.74 (18)                |
|           | IV     | 4.14 ± 0.56 | 0.56 (17)                |
| 6–8       | I      | 2.89 ± 0.72 | 0.15 (82)                |
|           | II     | 2.61 ± 0.70 | 1.52 (12)                |
|           | III    | 2.26 ± 0.50 | 0.94 (15)                |
|           | IV     | 6.41 ± 0.78 | 0.26 (12)                |
| 8–12      | I      | 4.14 ± 0.92 | 1.29 (37)                |

8–12 arcmin annulus, sector I, the source counts are 28.9 per cent of the total counts, while in the remaining sectors of the same annulus the source counts are lower than 16 per cent, that is the background contribution becomes dominant. In Fig. 15 the temperature profiles in the four sectors are presented. For the 0–2 arcmin region a circular region was used to fit the data.

Because of a shift between the X-ray centroid and the MECS centre, the strongback support falls partly in the 6–8 arcmin

Figure 13. Temperature radial profile of A2124. The vertical bars correspond to 68 per cent errors, while the horizontal bars represent the bins used to extract the counts. The dotted line corresponds to the global temperature fit, derived within 8 arcmin.

Figure 14. BeppoSAX MECS image of A2124. The concentric circles correspond to the bins of the radial profiles, while the quadrants correspond to the sectors used for the temperature map analysis. The small cross indicates the ACO centre of A2122.

Figure 15. Temperature map of A2124. The vertical bars correspond to 68 per cent errors, while the horizontal bars represent the bins used to extract the counts. Dotted lines correspond to the global temperature fit. For the first bin a circular region was used to fit the data.
annulus: this fact causes a loss of counts in sectors I and IV, which produces bad constraints in the temperature determination, seen as exceedingly high 90 per cent errors (see Table 8).

8 DISCUSSION AND CONCLUSIONS

The aim of this work has been to study the gas temperature distribution of two pairs of clusters (A2061–A2067 and A2122–A2124) located in the inner part of the Corona Borealis supercluster, using BeppoSAX observations.

Although the emission of A2122 falls under the window support of the detector, in the region between the centres of A2122 and A2124 we did not find any evidence of interaction. Also for the pair A2061–A2067 we did not find any clear sign of interaction: on one hand, A2061 is significantly elongated towards A2067, but on the other hand, the velocity difference $\Delta v$ between the two clusters is too large to be entirely due to the peculiar velocity. In order to have an estimate of the relative peculiar motion we assumed a simple model for the collapse of two bodies approaching from infinity. We derived the masses of A2061 and A2067 using the model for the collapse of two bodies approaching from infinity. We found a significant galaxy excess in the position reported as the northern peak for A2061.

Looking at this figure it can be seen that all the studied clusters are in agreement with the relation. It can also be noticed that A2067 is more similar to a galaxy group than to a cluster, given its low temperature and its position in the $L_{X}-T$ plane.

Analysing temperature profiles and maps of these clusters we found that their temperature distributions do not show strong deviations from isothermal behaviour. The only exception is represented by a region in A2061: we found that, in the 2–4 arcmin bin, sector I, there is a significant increase of temperature ($kT = 10.67^{+0.28}_{-0.24}$ keV) which is not consistent at 2.5$\sigma$ with that of the global fit ($kT = 4.52^{+0.28}_{-0.24}$ keV). This feature likely corresponds to the presence of an internal shock.

Our scenario is that a group is falling inside A2061 and forms the shock in the major cluster. The infall is along the axis individuated by the elongation of the cluster ($\sim 116^\circ$), as shown in Fig. 17, which summarizes the geometry projected on the plane of the sky. Note that in the same direction, but on the opposite side, at $\sim 18$ arcmin ($\sim 1.05 h^{-1}$ Mpc) from the X-ray centre, a relic is located, a radio source normally associated with ongoing merging (Kempner & Sarazin 2001). However, the spatial resolution of BeppoSAX is not able to separate the emission of the infalling group from that of A2061.

This hypothesis is consistent with the behaviour of the two dominant galaxies: the north D galaxy is at rest in the velocity space with respect to the cluster, but is significantly offset with respect to the centre of the X-ray emission (at a projected distance of $\sim 0.19 h^{-1}$ Mpc). At a projected distance of $\sim 0.16 h^{-1}$ Mpc from the X-ray centre there is another dominant galaxy, which has a velocity difference with respect to the cluster of $\Delta v \sim 980$ km s$^{-1}$. It is important to note that the axis inclinations of both the dominant galaxies ($\sim 149^\circ$ and $\sim 132^\circ$, respectively) are similar to that of the merger axis.

By studying the bidimensional distribution of optical galaxies we found a significant galaxy excess in the position reported as a square in Fig. 17. It is likely that these galaxies are part of the infalling group.

We suppose that the group and A2061 are in the phase of interaction in which the cores have not yet met: in this phase the formation of a shock between the cores is expected. If the gas within the shocked region is nearly isothermal, we can calculate the ratio between the velocities after ($u_1$) and before ($u_0$) the shock (Markovich et al. 1999, equation 2) as

$$\kappa \equiv \frac{u_1}{u_0} \simeq 0.41 \pm 0.03,$$

where we used the temperatures $T_0 = 4.65$ keV and $T_1 = 10.67$ keV. We used for $T_0$ the value derived for sector II, annulus 2–4 arcmin, which is specular to the shock position with respect to the cluster centre.

Given this value, the expected surface brightness ratio is

$$\frac{S_X}{S_{X_0}} \sim 6.$$

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**Table 9.** General information about A2061, A2067 and A2124. $C_{hi}$ and $S_{bol}$ are taken from Oegerle & Hill (2001), while the other quantities are derived from our analysis (see the text). Errors on temperatures are at the 90 per cent confidence level.

| Cluster    | $kT_{global}$ keV | $L_{bol}$ erg s$^{-1}$ | $F_{2-10keV}$ erg cm$^{-2}$ s$^{-1}$ | $L_{2-10keV}$ erg s$^{-1}$ | $C_{hi}$ km s$^{-1}$ | $S_{bol}$ km s$^{-1}$ |
|------------|-------------------|------------------------|-------------------------------------|-----------------------------|----------------------|---------------------|
| Abell 2061 | $4.5^{+0.48}_{-0.38}$ | $2.45 \times 10^{44}$ h$^{-2}$ | $1.72 \times 10^{11}$ | $1.21 \times 10^{44}$ h$^{-2}$ | $23699 \pm 70$ | $780^{+57}_{-47}$ |
| Abell 2067 | $1.54^{+0.26}_{-0.22}$ | $0.21 \times 10^{44}$ h$^{-2}$ | $8.62 \times 10^{13}$ | $0.58 \times 10^{43}$ h$^{-2}$ | $22166 \pm 79$ | $536^{+49}_{-90}$ |
| Abell 2124 | $4.41^{+0.38}_{-0.33}$ | $0.56 \times 10^{44}$ h$^{-2}$ | $0.58 \times 10^{11}$ | $0.28 \times 10^{44}$ h$^{-2}$ | $19684 \pm 110$ | $862^{+91}_{-69}$ |
Actually we find that the ratio between the counts in the 2–4 arcmin bin, sector IV (position of the shock) and II (at a specular position with respect to the centre of the cluster) is nearly 1. This inconsistency is probably due to the fact that the region affected by the interaction is much smaller than the analysed bin and than the MECS PSF. From simulations, produced with the same characteristics of our observations, we estimated that this shock could be detected only if its sizes exceed $\sim 30 \times 70 h^{-1} \text{kpc}$.

A higher spatial resolution of observation (e.g. with Chandra or XMM–Newton) is needed to assess this scenario.

The resulting difference of the gas flow after and before the shock is (Markevitch et al. 1999, equation 1):

$$v_{\text{col}} = 2 \cdot (u_0 - u_1) \approx 2896^{+804}_{-588} \text{km s}^{-1}$$

where we assume a plasma with mean molecular weight $\mu = 0.60$.

Note that this value of $v_{\text{col}}$ is similar to that of the cluster A3667 (Markevitch et al. 1999).

On the other hand, if we assume that the kinetic energy is completely converted into thermal energy, following Shibata et al. (1999), we find that

$$v_{\text{col}} \approx \left[ \frac{3k(T_1 - T_0)}{\mu m_p} \right]^{1/2} \approx 1735^{+399}_{-293} \text{km s}^{-1}.$$

These two values found for $v_{\text{col}}$, arising from different physical hypotheses, can be considered as upper and lower limits. This velocity range corresponds to a Mach number in the range $2.4 < M < 3.9$.

These values can be compared with the typical value of $M \sim 1.4$ given by the semi-analytical models of Gabici & Blasi (2003); however, considering that the Mach number distribution of mergers happened in the last billion years, the same authors (see their fig. 8) show a significant tail at $M \sim 3$.

In conclusion, the global scenario may be the following.

A group of galaxies, arriving from the north-east, impacted on the cluster A2061. As a consequence of the interaction of these two structures, the galaxies of the group precede its intracluster medium, as predicted by numerical simulation (see, e.g. Tormen et al. 2004). Indeed the X-ray emission excess seen in Fig. 1 north-east of A2061 (labelled as the Plume) could be the remnant of the group ICM, while its galaxies may be located corresponding to the optical overdensity shown in Fig. 17.

The fact that the merging axis points towards A2067 may be an indication of the existence of a filament, on which both A2061 and A2067 lie and along which the group merged in A2061.

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