Radio halo and relic candidates from the NRAO VLA Sky Survey

G. Giovannini\textsuperscript{a,1}, M. Tordi\textsuperscript{b,2} and L. Feretti\textsuperscript{b,3}

\textsuperscript{a} Istituto di Radioastronomia – CNR, via Gobetti 101, I–40129 Bologna, Italy.
Dip. Fisica, Univ. Bologna, Via Berti-Pichat 6/2, I–40127 Bologna, Italy.
\textsuperscript{b} Istituto di Radioastronomia – CNR, via Gobetti 101, I–40129 Bologna, Italy.

Abstract

We present the first results of the search of new halo and relic candidates in the NRAO VLA Sky Survey. We have inspected a sample of 205 clusters from the X-ray-brightest Abell-type clusters presented by Ebeling \textit{et al.} (1996), and found 29 candidates. Out of them, 11 clusters are already known from the literature to contain a diffuse cluster-wide source, while in 18 clusters this is the first indication of the existence of this type of sources. We classify these sources as halos or relics according to their location in the cluster center or periphery, respectively. We find that the occurrence of cluster halos and relics is higher in clusters with high X-ray luminosity and high temperature. We also confirm the correlation between the absence of a cooling flow and the presence of a radio halo at the cluster center.

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\begin{tabular}{ll}
1 & ggiovanni@ira.bo.cnr.it \\
2 & mtordi@ira.bo.cnr.it \\
3 & lferetti@ira.bo.cnr.it \\
\end{tabular}

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1 Introduction

Large-scale radio halos in clusters of galaxies are diffuse radio sources with no apparent parent galaxy, typical sizes of 1 Mpc, low surface brightness and steep radio spectrum. They demonstrate the existence of relativistic electrons and large scale magnetic fields in the intracluster medium. The sources classified as radio halos are located at the cluster centers. Sources with similar properties have also been found at the cluster peripheries: they are called relic sources. Moreover, in some clusters with a central dominant galaxy, the relativistic particles can be traced out quite far, forming what is called a mini-halo (see e.g. 3C 84 in the Perseus cluster, Burns et al. 1992).

The radio halos and relics are a rare phenomenon. They are present in a few rich clusters, characterized by high X-ray luminosity and high temperature. The prototypical example of cluster-wide radio halo is Coma-C, in Coma (see Giovannini et al. 1993 and references therein). The Coma cluster also contains the peripheral relic 1253+275, which is connected to Coma-C through a very low-brightness bridge of radio emission (see e.g. Feretti & Giovannini 1998). Other radio halos studied in detail so far are those in A 2255 (Burns et al. 1995, Feretti et al. 1997a), and in A 2319 (Feretti et al. 1997b). Well studied relic sources are those in A 2256 (Röttgering et al. 1994), A 3667 (Röttgering et al. 1997), and A 85 (Bagchi et al. 1998).

The properties of halos and relics are not yet well understood, because of the low number of known sources of this type. Also, it is not yet clear if radio halos and relics have a common origin and evolution, or should be considered as different classes of sources. Information on a larger sample of halos and relics is crucial to investigate their formation and evolution, and their relation to other cluster properties. To this aim we undertook the search for new candidates of radio halos and relics in the NRAO VLA Sky Survey (NVSS, Condon et al. 1998). In this paper we report the detection of new halo and relic candidates, which significantly increase the number of diffuse sources in clusters. The paper is organized as follows: in Sect. 2 we describe the sample of clusters which were inspected in the NVSS, in Sect. 3 we present the results, in Sect. 4 we give comments on the individual sources and their clusters, in Sect. 5 we discuss the results.

A Hubble constant $H_0=50$ km s$^{-1}$ Mpc$^{-1}$ and a deceleration parameter $q_0=1$ are assumed throughout.

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2 Sample and Source selection

We searched for cluster-wide radio sources in clusters using the public images of the NVSS. This radio survey was performed at 1.4 GHz with the Very Large Array (VLA) in the tightest configuration (D). It has an angular resolution of 45" (HPBW), a noise level of 0.45 mJy (1σ) and covers all the sky north of Declination = −40°.

As a cluster sample we used the sample of X-ray-brightest Abell-type clusters (XBACs) presented by Ebeling et al. (1996), consisting of 283 clusters/subclusters from the catalogue of Abell, Corwin & Olowin (1989, ACO) detected in the ROSAT All Sky survey (RASS) with X-ray flux \( f_X > 5 \times 10^{-12} \) erg cm\(^{-2}\) s\(^{-1}\) in the 0.1-2.4 keV energy range. This is an all-sky, X-ray flux limited sample, complete in the galactic latitude range \( |b| \geq 20° \) and in the redshift interval \( z \leq 0.2 \), but it contains also 12 clusters at lower galactic latitude and 24 clusters with redshift greater than 0.2 that meet the flux criterion (see Tables 3 and 4 in Ebeling et al. 1996).

Because of the lack of short baselines, the NVSS is insensitive to extended structure larger than 15'. Since the known radio halos are about 1 Mpc in size, sources of this type are missed in the NVSS if belonging to nearby clusters. We note indeed that the radio halo in Coma (\( z = 0.0232 \)) is resolved out in the NVSS, because of the lack of short spacings. We have taken as a limiting redshift for the search of diffuse cluster-wide halos and relics the value \( z=0.044 \), which corresponds to a largest detectable linear size of about 1 Mpc. Considering this redshift limit, and taking also into account the declination limit of the NVSS, we ended with a sample of 207 clusters. For each of them, we searched for the NVSS image, and extracted a field of 1°×1°, centered on the cluster position given in the XBACs catalogue. We remark here that this is the X-ray position and may be different from that of the optical cluster center. Moreover, in the case that the X-ray structure is double or more complex, the XBACs position refers to the centroid of the X-ray emission. The two clusters A 1773 and A 3888 fall in the few remaining gaps of the NVSS, and therefore no image is currently available for them. For a few other clusters, the field retrieved from the NVSS is slightly smaller than 1 square degree, because of the existence of gaps at one of the field edges; however, the available image covers a significant region of the clusters. In conclusion, we have finally inspected 205 clusters, for a total of about 0.062 steradians. The redshift distribution of the searched clusters with respect to the distribution of the whole XBACs catalogue is shown in Fig. 1.

To search for the cluster diffuse sources, we used the NVSS images overlaid upon the optical images from the Digitized Palomar Sky Survey (PSS). We considered as diffuse cluster sources the radio features with surface brightness
greater than the 3 $\sigma$ level, which were found to be: i) resolved, ii) not associated with bright galaxies, iii) not clearly related to extended radio galaxies, iv) not simply attributable to the blend of pointlike sources. Thanks to the large images retrieved from the NVSS, we are confident that we could easily recognize and avoid the side lobes of near strong sources possibly present because of dynamical range problems.

We looked into the literature and in the VLA Faint Images of the Radio Sky at Twenty-centimeters (FIRST) Survey (Becker et al. 1995) to discriminate the diffuse sources from discrete unrelated radio sources. In some cases, where no high resolution data are available and the radio structure is ambiguous, we considered the halo and relic candidates as uncertain. We included in our sample also a few cases where the evidence of an extended radio emission is marginal but the presence of a diffuse emission was already known from the literature (see notes to the individual clusters).

3 Results

With the above criteria, we have found diffuse extended emission in 29 clusters, listed in Table 1. In 9 clusters, the presence of a diffuse extended radio source is uncertain, because of the possible contamination of discrete radio galaxies or because the diffuse radio emission is very faint. These clusters are indicated by “u” in column 7 of Table 1.
The redshift distribution of clusters with diffuse sources with respect to that of the inspected clusters is presented in Fig. 2. We remind that we could have missed extended sources because of their low surface brightness. We also are aware that we can miss very extended sources (> 1 Mpc) in the clusters at lowest redshifts because of the poor sampling of short baselines. This implies that the sample of diffuse sources found in this search might be slightly biased toward sources at high redshift. On the other hand, we note that in distant clusters diffuse extended sources could be, in some cases, considered as discrete sources because of the large beam.

According to the literature, we classify the detected extended source as halos, if they are centrally located in the cluster, or relics if they are peripheral. In the case that peripheral relics are projected onto the cluster center, they would be classified as halo sources. More detailed observations will be necessary for a correct classification. The list presented in Table 1 contains most of the well known radio halos and relics, but also includes 18 clusters where this is the first indication of the existence of a diffuse source (see last column in Table 1). Among the latter, 11 are considered good candidates, while 7 are uncertain.

The images of all the diffuse radio sources, overlaid onto the red images of the PSS, are given in Fig. 3.

We present in Table 2 the parameters of the halo and relic candidates, excluding the uncertain diffuse sources, for which the measurement of flux density and extension is very difficult because strong contaminating sources are often present. The radio flux density refers to the extended emission after subtraction of obvious discrete sources. The size is the largest dimension of the diffuse...
radio emission. We are aware that flux densities and sizes can be quite underestimated, because of the low sensitivity to extended structures. Nevertheless, more than half of the sources given in Table 2 have a size larger than 1 Mpc. For the relics, we also give the projected distance between the approximate centroid of the radio emitting region and the X-ray cluster center.
| Name  | z       | RA (J2000) h m s | DEC ° ′ ″ | T keV | $L_X (0.1-2.4) \times 10^{44}$ erg s$^{-1}$ | Radio Type | Previous |
|-------|---------|-----------------|-----------|-------|---------------------------------|------------|----------|
| A 13  | 0.0943$^M$ | 00 13 32.2      | -19 30 03.6 | 4.3$^e$ | 2.24                           | R          | n        |
| A 2744| 0.3080              | 00 14 16.1      | -30 22 58.8 | 11.04$^{AF}$ | 22.05                     | H          | n        |
| A 22  | 0.1310              | 00 20 38.6      | -25 43 19.2 | 6.3$^e$  | 5.31                            | u          | n        |
| A 85  | 0.0555$^P$           | 00 41 48.7      | -09 19 04.8 | 6.2     | 8.38                            | R          | y        |
| A 115 | 0.1971              | 00 55 59.8      | +26 22 40.8 | 9.8$^e$  | 14.57                          | R          | n        |
| A 133 | 0.0603              | 01 02 45.1      | -21 52 48.0 | 3.8     | 3.57                            | u          | n        |
| A 209 | 0.2060              | 01 31 50.9      | -13 36 28.8 | 9.6$^e$  | 13.75                          | u          | n        |
| A 401 | 0.0739              | 02 58 56.9      | +13 34 22.8 | 7.8     | 9.88                            | H          | y        |
| A 520 | 0.2030              | 04 54 07.4      | +02 55 12.0 | 8.33$^{AF}$ | 14.20                    | H          | n        |
| A 545 | 0.1540              | 05 32 23.3      | -11 32 09.6 | 5.5     | 9.29                            | H          | n        |
| A 548b| 0.0424$^{DHK}$       | 05 45 27.8      | -25 54 21.6 | 2.4     | 0.30                            | R          | n        |
| A 665 | 0.1818              | 08 30 57.4      | +65 51 14.4 | 9.03$^{AF}$ | 16.22                    | H          | y        |
| A 754 | 0.0542              | 09 09 01.4      | -09 39 18.0 | 8.7     | 8.01                            | u          | y        |
| A 773 | 0.2170              | 09 17 54.0      | +51 42 57.6 | 9.29$^{AF}$ | 12.52                    | H          | n        |
| A 1300| 0.3071$^L$           | 11 31 54.9      | -19 54 50.4 | 5$^L$   | 23.40                          | H          | y        |
| A 1664| 0.1276              | 13 03 44.2      | -24 15 21.6 | 6.5$^A$  | 5.36                            | R          | n        |
| A 1758a| 0.2800             | 13 32 45.3      | +50 32 52.8 | 8.7$^e$     | 11.22                     | u          | n        |
| A 1914| 0.1712              | 14 26 02.2      | +37 50 06.0 | 10.7$^e$  | 17.93                          | H          | n        |
| A 2069| 0.1145              | 15 24 09.8      | +29 55 15.6 | 7.8$^e$  | 8.74                            | u          | n        |
| A 2142| 0.0894              | 15 58 22.1      | +27 13 58.8 | 11.0    | 20.74                           | u          | y        |
| A 2163| 0.2080              | 16 15 49.4      | -06 09 00  | 13.83$^{AF}$ | 37.50                    | H          | y        |
| A 2218| 0.1710              | 16 35 52.8      | +66 12 50.4 | 7.05$^{AF}$ | 8.99                      | H          | y        |
| A 2219| 0.2281              | 16 40 22.5      | +46 42 21.6 | 12.42$^{AF}$ | 19.80                    | u          | n        |
| A 2256| 0.0581              | 17 04 02.4      | +78 37 55.2 | 7.5     | 7.05                            | R          | y        |
| A 2255| 0.0809              | 17 12 45.1      | +64 03 43.2 | 7.3     | 4.79                            | H          | y        |
| A 2254| 0.1780              | 17 17 46.8      | +19 40 48.0 | 7.2$^e$  | 7.19                            | H          | n        |
| A 2319| 0.0555              | 19 21 05.8      | +43 57 50.4 | 9.3$^{AF}$ | 13.71                    | H          | y        |
| A 2345| 0.1760              | 21 26 58.6      | -12 08 27.6 | 8.2$^e$  | 9.93                            | R+R        | n        |
| A 2390| 0.2329              | 21 53 36.7      | +17 41 32.2 | 10.13$^{AF}$ | 21.25                    | u          | n        |
Caption. Col. 1: cluster name; Col. 2: redshift; Cols. 3 and 4: coordinates of the X-ray cluster center; Col. 5: temperature, where “e” indicates that the temperature has been estimated from the L_X-kT relation; Col. 6: X-ray luminosity in the ROSAT band (0.1-2.4 keV); Col. 7: type of the diffuse radio source (H = halo, R = relic, u = uncertain); Col. 8: previous knowledge in the literature of the existence of a diffuse source in this cluster (n = no; y = yes, reference given in Sect. 4).

The data in Cols. 2, 3, 4, 5 and 6 are taken from Ebeling et al. (1996), except where a more recent reference is given. References are as follows: A = Allen et al. 1995; AF: Allen & Fabian 1998; DHK = Den Hartog & Katgert 1996; L = Lémonon et al. 1997; M = Mazure et al. 1996; P = Pislar et al. 1997.
Fig. 3. Radio images of the diffuse sources (contours), overlaid onto the optical image from the PSS (grey-scale). Contour levels are 0.9, 1.35, 2, 4, 8, 16, 32, 64, 128, 256 mJy/beam.

4 Individual sources

In the following, we give comments on the individual sources and discuss their reliability.

A 13. The diffuse radio source is not much displaced from the cluster center, however it is elongated in shape and does not include the central cluster galaxies. According to the data reported by Slee et al. (1996), the radio sources identified with cluster galaxies account for a total flux of 3.9 mJy, confirming the presence of extended radio emission.

A 2744. Beside the centrally located radio emission, there is also extended structure toward NE which could be either a relic or still related to the halo.

A 22. The diffuse source could be the due to a Wide Angle Tailed radio galaxy plus a Narrow Angle Tailed radio galaxy. It is located at about 14′ from the cluster center, corresponding to ∼2.5 Mpc and would therefore be a relic.

A 85. The relic in this cluster has been recently studied by Bagchi et al. (1998).

A 115. This cluster shows a double morphology in X-ray. The relic belongs to the northern clump.

A 133. Komissarov and Gubanov (1994) report the existence of a very steep spectrum radio source (α > 2) coincident with the first ranked galaxy of this cluster. The high resolution image published by Slee et al. (1994) shows a northern diffuse component of ∼100 kpc, probably not related to the radio galaxy. The emission detected in the NVSS extends to the South where another discrete radio source is present (see also the image by Owen et al. 1993).
Table 2
Parameters of the halo and relic candidates

| Name  | Flux mJy | θ′ | LLS kpc | Dist. kpc | Power $10^{24}$ W Hz$^{-1}$ |
|-------|----------|----|---------|-----------|-----------------------------|
| A 13  | 34       | 6.4 | 880     | 150       | 1.30                        |
| A 2744| 38       | 5.4 | 1700    | –         | 15.5                        |
| A 85  | 46       | 5.5 | 480     | 530       | 0.61                        |
| A 115 | 80       | 6.2 | 1500    | 1050      | 1.34                        |
| A 401 | 25       | 5.3 | 590     | –         | 0.59                        |
| A 520 | 38       | 4.4 | 1080    | –         | 6.74                        |
| A 545 | 41       | 7.4 | 1500    | –         | 4.18                        |
| A 548b| 50       | 5.3 | 360     | 620       | 0.39                        |
| A 665 | 31       | 4.8 | 1100    | –         | 4.41                        |
| A 773 | 14       | 3.1 | 800     | –         | 2.84                        |
| A 1300| 14       | 2.5 | 780     | –         | 5.7                         |
| A 1664| 107      | 8.0 | 1400    | 1350      | 7.50                        |
| A 1914| 50       | 4.4 | 960     | –         | 6.31                        |
| A 2163| 55       | 6.0 | 1500    | –         | 10.2                        |
| A 2218| 9        | 2.3 | 510     | –         | 1.13                        |
| A 2256| 397      | 12.1| 1100    | 590       | 5.77                        |
| A 2255| 45       | 5.2 | 630     | –         | 1.27                        |
| A 2254| 32       | 5.1 | 1140    | –         | 4.36                        |
| A 2319| 23       | 4.8 | 420     | –         | 0.30                        |
| A 2345| 92       | 5.4 | 1200    | 910       | 12.3                        |
|       | 69       | 7.0 | 1560    | 2050      | 9.20                        |

Caption. Col. 1: cluster name; Col. 2: Flux density at 1.4 GHz, after subtraction of obvious discrete sources; Col. 3: maximum angular size; Col. 4: largest linear size; Col. 5: approximate distance from the cluster center, in the case of relics; Col. 6: monochromatic radio power at 1.4 GHz.

The existence of a cluster-wide diffuse emission is uncertain, as well as its connection to the steep spectrum northern diffuse component.

A 209. The presence of extended emission is uncertain due to the existence of
strong discrete sources.

*A 401.* The diffuse emission is very faint and located around the central cD galaxy, unlike the previous images by Harris *et al.* (1980a) and Roland *et al.* (1981).

*A 520.* The diffuse emission is centrally located, but of irregular shape with the present sensitivity.

*A 545.* Despite of the presence of a strong discrete source at the cluster center, the diffuse emission is easily visible. It is rather symmetric and centrally located.

*A 548b.* This cluster consists of many X-ray subclumps (Davis *et al.* 1995). We detect a diffuse source classified as a relic in the NW cluster region, but also extended emission is present around a radio galaxy to the North. In the following analysis, we only consider the NW relic. Further more sensitive observations should clarify whether the two extended features are bright regions of the same source.

*A 665.* The presence of a halo was first reported by Moffet & Birkinshaw (1989) and confirmed by Jones & Saunders (1996).

*A 754.* The existence of a halo in the center of this cluster was suggested by Harris *et al.* (1980b). At the location of the previously reported halo, there are many cluster galaxies, which could account for the emission. Some diffuse emission of size ∼250 kpc is also detected in the NVSS in the eastern peripheral region. The overall cluster-wide extended emission in this cluster is considered uncertain.

*A 773.* The diffuse emission is rather regular in shape and centrally located. The FIRST image shows 3 discrete radio sources whose total flux density is lower that that detected in the NVSS, confirming the presence of diffuse structure.

*A 1300.* The presence of a central radio halo is reported by Lmonon *et al.* (1998), who also classify the SW emission as a relic. Since from the NVSS map the relic is poorly resolved, we only consider in this paper the central radio halo.

*A 1664.* The diffuse radio emission is located in the SW peripheral region of the cluster and shows a regular structure, unlike the relics in Coma and A 3667, which are generally elongated. The X-ray brightness distribution in this cluster is centrally peaked, with an asymmetric extension in the direction of the diffuse radio source (Allen *et al.* 1995).

*A 1758a.* The strongest source to the S is identified with a cluster galaxy.
It shows a Narrow Angle Tailed structure (O'Dea & Owen 1985) with the tail oriented to the SE. In the FIRST image, the easternmost structure is resolved in two compact sources, while the extended emission in between is not detected. It could be a faint halo or the blend of individual radio sources.

**A 1914.** A very steep spectrum radio source ($\alpha > 2$) is reported by Komissarov & Gubanov (1994). From higher resolution images (Roland et al. 1985 and the image retrieved from the FIRST survey) it is evident that the discrete sources cannot account for the extended emission.

**A 2069.** The diffuse emission is located to the SE with respect to the cluster center at a distance of $\sim 6$ Mpc, therefore its classification as a cluster relic is uncertain. The image of this region retrieved from the FIRST survey shows a faint point-like source coincident with the southernmost peak, while the whole structure is resolved out.

**A 2142.** The presence of a halo in this cluster was suggested by Harris et al. (1977). The image here shows that the diffuse radio emission is $\sim 350$ kpc in size and is located around a cluster galaxy. Therefore, we still consider uncertain the classification of this source as a cluster-wide radio halo.

**A 2163.** The presence of a powerful and very extended radio halo has been reported by Herbig & Birkinshaw (1994).

**A 2218.** The existence of a small radio halo was reported by Moffet & Birkinshaw (1989). Here, the diffuse source is barely visible to the SW of the strongest radio source.

**A 2219.** The strong radio source at the cluster center has a tailed structure (as detected in the FIRST survey). It is difficult to safely establish the existence of a diffuse radio emission.

**A 2256.** The extended emission detected here is the brightest region of the complex diffuse radio source in A 2256. This region studied by Röttgering et al. (1994) is at the cluster periphery, while a very low brightness emission, not visible here, permeates the cluster center as detected at 610 MHz by Bridle & Fomalont (1976).

**A 2255.** This cluster contains a central radio halo and a peripheral relic (Burns et al. 1995, Feretti et al. 1997a). Both features are visible in the NVSS, although very faint and at the limit of significance. Based only on the NVSS image, the existence of diffuse sources in this cluster would be considered very uncertain. We note, however, that the radio halo in A 2255 is best imaged at 90 cm, while at 20 cm the halo structure is spotty and irregular also with higher sensitivity observations (Feretti et al. 1997).
Fig. 4. Distribution of the X-ray luminosity of the clusters searched for the presence of a diffuse source. The black squares indicate the halo and relic candidates, while the dashed squares indicate the uncertain sources (see Table 1).

A 2254. The extended emission is centrally located and shows a regular structure.

A 2319. This radio halo has been studied in detail by Feretti et al. (1997b).

A 2345. There are two peripheral extended sources in this cluster located approximately on opposite sides with respect to the cluster center, at distance of ~0.9 and ~2 Mpc. If both sources will be confirmed as diffuse relics, this cluster will be quite peculiar. The only known cluster with 2 relics is A 3667 (Röttgering et al. 1997).

A 2390. The extended emission in this cluster is uncertain, because of the presence of a discrete strong source (Owen et al. 1993).

5 Discussion

The number of new diffuse halos and relics detected in the NVSS is rather high, especially considering that these sources are characterized by steep spectrum and therefore they are better imaged at frequencies lower than 1.4 GHz, and also taking into account the limited surface brightness sensitivity.

The percentage of clusters showing diffuse sources is higher in clusters with high X-ray luminosity as can be deduced from Fig. 4 and Table 3. This trend can also be inferred from Fig. 2, due to the fact that the XBACs sample is
Table 3  
Occurrence of diffuse cluster sources

| Luminosity range | N_s | N_f | N_u |
|------------------|-----|-----|-----|
| $10^{44}$ erg s$^{-1}$ |     |     |     |
| $L_X \leq 10^{44}$ | 173 | 11  | 4   |
| $10 < L_X \leq 20^{45}$ | 23  | 6   | 3   |
| $20 < L_X \leq 30^{45}$ | 7   | 2   | 2   |
| $L_X > 30^{45}$ | 2   | 1   | 0   |

Caption. Col 1: X-ray luminosity range; Col 2: number of searched clusters; Col 3: number of clusters with diffuse halos or relics; Col 4: number of clusters with uncertain diffuse sources.

Fig. 5. Plot of monochromatic radio power at 1.4 GHz versus the cluster X-ray luminosity, for the halo and relic candidates.

flux limited. The percentage of clusters with diffuse sources is in the range 6% to 9% in the clusters with $L_X \leq 10^{45}$ erg s$^{-1}$ and becomes 27% to 44% in clusters with $L_X > 10^{45}$ erg s$^{-1}$. This effect could partly reflect the mentioned bias in the sample against the detection of very extended diffuse sources in the nearby clusters. However, given that a lower limit to the redshift is assumed, the lack of diffuse sources in low X-ray luminosity clusters is real. This result is in agreement with previous findings that cluster-wide halos are present in massive clusters with high X-ray luminosity and high temperature (see e.g. Feretti & Giovannini 1996). Therefore, the diffuse cluster sources are not a rare phenomenon if X-ray luminous clusters are considered.
We have looked for a possible correlation between the radio power of diffuse sources and the cluster X-ray luminosity. The plot of these parameters is given in Fig. 5. Although the data show a large scatter, the lack of high power radio sources in clusters of low X-ray luminosity is clear, while highly luminous X-ray clusters may have extended sources of either high or low radio power. Since the radio powers computed here may be largely underestimated because of missing flux, due to the steep spectrum of halos and relics and the poor sampling of short spacings, further investigation of this correlation is needed.

A complete analysis of the connection between cluster properties and presence of diffuse sources is beyond the scope of this paper. We only note that the clusters A 2744, A 520, A 545, A 773, and A 2254, which are found here for the first time to host a central radio halo, are all non-cooling flow clusters (White et al. 1997, Allen & Fabian 1998). Likewise, all the Abell clusters listed by Allen & Fabian (1998) as non-cooling flow clusters are found to host a radio halo, with the exception of A 2219, where the presence of a halo in considered uncertain but is possible. These results reinforce the strong correlation between the absence of a cooling flow and the presence of a radio halo at the cluster center.

6 Conclusions

We have presented in this paper new halo and relic candidates, found in the NVSS after inspection of a sample of clusters from the XBACs catalogue. We found 29 candidates, which can be divided as follows:

- 11 clusters were already known from the literature. Out of them, 7 contain radio halos (A 401, A 665, A 1300, A 2163, A 2218, A 2255, A 2319), 2 contain relics (A 85, A 2256), while the remaining 2 (A 754, A 2142) cannot be confirmed on the basis of the NVSS images, and are therefore still considered uncertain. We note that in the clusters A 1300 and A 2255, also the existence of a peripheral relic is reported in the literature.

- in 18 clusters, this is the first indication of the existence of a diffuse extended source. Among them, we found 6 clusters with halos (A 2744, A 520, A 545, A 773, A 1914, A 2254), and 5 clusters with relics (A 13, A 115, A 548b, A 1664, A 2345). The cluster A 2345 contains actually 2 relics. The 7 clusters A 22, A 133, A 209, A 1758a, A 2069, A 2219 and A 2390 contain possible diffuse sources, which we indicate as uncertain.

We found that the percentage of clusters showing diffuse sources is higher in clusters with high X-ray luminosity, being 6%-9% in clusters with $L_X \leq 10^{45}$ erg s$^{-1}$ and 27%-44% in clusters with $L_X > 10^{45}$ erg s$^{-1}$. Therefore, the
diffuse cluster sources are not a rare phenomenon if X-ray luminous clusters are considered.

We have found no correlation between the radio power of diffuse sources and the cluster X-ray luminosity. However, we note that the radio powers may be largely underestimated because of missing flux in the NVSS images.

Finally, we note that the large majority of clusters hosting a radio halo do not contain a cooling flow. This reinforces the strong correlation between the absence of a cooling flow and the presence of a radio halo in clusters.

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