High Energy Results from BeppoSAX

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**Abstract.** We review all the *BeppoSAX* results relative to the search for additional nonthermal components in the spectra of clusters of galaxies. In particular, our MECS data analysis of A2199 does not confirm the presence of the nonthermal excess reported by Kaastra *et al.* (1999). A new observation of A2256 seems to indicate quite definitely that the nonthermal fluxes detected in Coma and A2256 are due to a diffuse nonthermal mechanism involving the intracluster medium. We report marginal evidence ($\sim 3\sigma$) for a nonthermal excess in A754 and A119, but the presence of point sources in the field of view of the PDS makes unlikely a diffuse interpretation.
1. Introduction

It is well known that X-ray measurements in the energy range 1-10 keV of thermal bremsstrahlung emission from the hot, relatively dense intracluster gas, have already contributed in an essential way to our understanding of the cluster environment. However, recent researches on clusters of galaxies have unveiled new spectral components in the intracluster medium (ICM) of some clusters, namely a cluster soft excess discovered by EUVE (Lieu et al. 1996) and a hard X-ray (HXR) excess detected by BeppoSAX (Fusco-Femiano et al. 1999) and RXTE (Rephaeli, Gruber, & Blanco 1999). Observations at low and high energies can give additional insights on the physical conditions of the ICM.

Nonthermal emission was predicted at the end of seventies in clusters of galaxies showing extended radio emission, radio halos or relics (see Rephaeli 1979). In particular, the same radio synchrotron electrons can interact with the CMB photons to give inverse Compton (IC) nonthermal X-ray radiation. Attempts to detect nonthermal emission from a few clusters of galaxies were performed with balloon experiments (Bazzano et al. 1984;90), with HEAO-1 (Rephaeli, Gruber & Rothschild 1987; Rephaeli & Gruber 1988), with the OSSE experiment onboard the Compton-GRO satellite (Rephaeli, Ulmer & Gruber 1994) and with RXTE & ASCA (Delzer & Henriksen 1998), but all these experiments reported essentially flux upper limits. However, we want to remind the conclusions of the paper regarding the OSSE observation of HXR radiation in the Coma cluster by Rephaeli, Ulmer & Gruber in 1994: "...It can be definitely concluded that the detection of the IC HEX (high energy X-ray) emission necessitates an overall sensitivity a few times $10^{-6}$ ph cm$^{-2}$ s$^{-1}$ keV$^{-1}$ in the 40-80 keV band. ..To reduce source confusion, detectors optimized specifically for HEX measurements of clusters should have $\sim 1^\circ \times 1^\circ$ fields of view. A level of internal background more than a factor of 10 lower than that of OSSE is quite realistic. Obviously, another very desirable feature of any future experiment is wide energy coverage, starting near (or below) 15-20 keV, in order to independently measure the tail of the thermal emission". In these conclusions it is possible to find the spectral characteristics of the Phoswich Detector System (PDS) onboard BeppoSAX which is able to detect hard X-ray emission in the 15-200 keV energy range. The PDS uses the rocking collimator technique for background subtraction with angle of 3.5°. The strategy is to observe the X-ray source with one collimator and to monitor the background level on both sides of the source position with the other in order to have a continuous monitoring of the source and background. The dwell time is 96 sec. The background level of the PDS is the lowest obtained so far with high-energy instruments onboard satellites ($\sim 2 \times 10^{-4}$ counts s$^{-1}$ keV$^{-1}$ in the 15-200 KeV energy band) thanks to the equatorial orbit of BeppoSAX . The background is very stable again thanks to the favorable orbit, and no modelling of the time variation of the background is required (Frontera et al. 1997).

2. Hard X-ray observations of clusters of galaxies by BeppoSAX

BeppoSAX observed seven clusters of galaxies with the main objective to detect additional nonthermal components in their spectra.
2.1. Coma

The first cluster was Coma observed in December 1997 for an exposure time of about 91 ksec. A nonthermal excess with respect to the thermal emission was observed (Fusco-Femiano et al. 1999) at a confidence level of about 4.5σ (see Fig. 1). The thermal emission was measured with the HPGSPC always onboard BeppoSAX in the 4-20 keV energy range with a FWHM (∼1° × 1°) comparable to that of the PDS (∼1.3°, hexagonal). The average gas temperature is $8.5^{+0.6}_{-0.5}$ keV consistent with the temperature of Ginga of 8.2 keV (David et al. 1993). The χ² value has a significant decrement when a second component, a power law, is added. On the other hand, if we consider a second thermal component, instead of the nonthermal one, the fit requires a temperature greater than 40-50 keV. This unrealistic value may be interpreted as a strong indication that the detected hard excess is due to a nonthermal mechanism. The data are not able to give a good determination of the photon spectral index (0.7-2.5; 90%), but the nonthermal flux $\sim 2.2 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ in the 20-80 keV energy range is rather stable against variations of the power-law index. Binning the PDS data between 40-80 keV the nonthermal flux is lower by a factor about 2 with respect to the upper limit derived by the OSSE experiment (see Fig. 1 of Fusco-Femiano et al. 1999). In the same time a RXTE observation of the Coma cluster (Rephaeli, Gruber & Blanco 1999) showed evidence for the presence of a second component in the spectrum of this cluster, in particular the authors argued that this component is more likely to be nonthermal, rather than a second thermal component at lower temperature.

The first possible explanation for the detected excess is emission by a point source in the field of view of the PDS. The most qualified candidate is X Comae, a Seyfert 1 galaxy (z=0.092). ROSAT PSPC, EXOSAT and Einstein IPC observations report a flux at approximately the same flux level of $1.6 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ in the 2-10 keV energy band. With a typical photon index of 1.8 the variability factor of the source to account for the detected ex-
cess is of the order of 10 which could be still plausible. But luckily enough, X Comae is located just on the edge of the field of view of the MECS (see Fig. 3 of Fusco-Femiano 1999). Considering the location of X Comae and the lack of detection, it is possible to estimate an upper limit to the flux of the source of \( \sim 4 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1} \) (2-10 keV) when BeppoSAX observed Coma which is a factor \( \sim 7 \) lower than the flux of \( \sim 2.9 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1} \) required to account for the nonthermal HXR emission in the PDS. A recent mosaic of the Coma cluster with XMM-Newton (Briel et al. 2000) reports a tentative identification of 3 quasars in the central region, but the estimated fluxes are insufficient to reproduce the excess detected by BeppoSAX. However, we cannot exclude that an obscured source, like Circinus (Matt et al. 1999) a Seyfert 2 galaxy very active at high X-ray energies, may be present in the field of view of the PDS. With the MECS image it is possible to exclude the presence of this kind of source only in the central region of about 30' in radius unless the obscured source is within 2' of the central bright core. We have estimated that the probability to find an obscured source in the field of view of the PDS is of the order of 10% and also Kaastra et al. (1999) independently arrived to the same estimate.

Another interpretation is that the nonthermal emission is due to relativistic electrons scattering the CMB photons and in particular the same electrons responsible for the radio halo emission present in the central region of the cluster, Coma C. In this case we can derive the volume-averaged intrachannel magnetic field, \( B_X \), using only observables, combining the X-ray and radio data (see Eq. 1 of Fusco-Femiano et al. 1999). The value of \( B_X \) is of the order of 0.15 \( \mu \)G and assuming a radio halo size of \( R = 1 \) Mpc at the distance of Coma also the electron energy density (\( \sim 7 \times 10^{-14} \text{ erg cm}^{-3} \)) can be derived. The value of the magnetic field derived by the BeppoSAX observation seems to be inconsistent with the measurements of Faraday rotation of polarized radiation of sources through the hot ICM that give a line-of-sight value of \( B_{FR} \) of the order of 2-6 \( \mu \)G (Kim et al. 1990; Feretti et al. 1995). But Feretti and collaborators inferred also the existence of a weaker magnetic field component, ordered on a scale of about a cluster core radius, with a line-of-sight strength in the range 0.1-0.2 \( \mu \)G consistent with the value derived from BeppoSAX. So, we can argue that the component at 6 \( \mu \)G is likely present in local cluster regions, while the overall cluster magnetic field may be reasonably represented by the weaker and ordered component. However, there are still many and large uncertainties on the value of the magnetic field determined using the FR measurements (Newman, Newman, & Rephaeli 2002). Other determinations of B based on different methods are in the range 0.2-0.4 \( \mu \)G (Hwang 1997; Bowyer & Berghöfer 1998; Sreekumar et al. 1996; Henriksen 1998). The equipartition value is of the order of \( \sim 0.4 \mu \)G (Giovannini et al. 1993).

However, alternative interpretations to the IC model have been proposed essentially motivated by the discrepancy between the values of \( B_X \) and \( B_{FR} \). Blasi & Colafrancesco (1999) have suggested a secondary electron production due to cosmic rays interactions in the ICM. However, this model implies a \( \gamma \)-ray flux larger than the EGRET upper limit, unless the hard excess and the radio halo emission are due to different populations of electrons. A different mechanism is given by nonthermal bremsstrahlung from suprathermal electrons formed through the current acceleration of the thermal gas (Ensslin, Lieu, & Biermann 1999; Dogiel 2000; Sarazin & Kempner 2000; Blasi 2000). At present, due to the
low efficiency of the proposed acceleration processes and of the bremsstrahlung mechanism, these models would require an unrealistically high energy input, as pointed out by Petrosian (2001). Regarding the discrepancy between $B_X$ and $B_{FR}$, Goldsmith & Rephaeli already in 1993 suggested that this discrepancy could be alleviated by taking into consideration the expected spatial profiles of the magnetic field and relativistic electrons. More recently, it has been shown that IC models that include the effects of more realistic electron spectra, combined with the expected spatial profiles of the magnetic fields, and anisotropies in the pitch angle distribution of the electrons allow higher values of the intra-cluster magnetic field, in better agreement with the FR measurements (Brunetti et al. 2001; Petrosian 2001).

2.2. A2199

The cluster has been observed in April 1997 for 100 ksec (Kaastra et al. 1999). The MECS data in the range 8-10 keV seem to show the presence of a hard excess with respect to the thermal emission. Between 9$'$ and 24$'$, the count rate is 5.4±0.6 counts ks$^{-1}$, while the best fit thermal model predicts only 3.4 counts ks$^{-1}$. So, the excess is at a confidence level of $\sim 3.3\sigma$. The PDS data are instead not sufficient to prove the existence of a hard tail. There are some difficulties to account for the presence of a nonthermal excess in this cluster because the electrons responsible for the hard emission would have an energy of $\sim 4$ GeV and a resulting IC lifetime of only $\sim 3\times10^8$ yr. So, these electrons have to be replenished by a continuous acceleration process and this is particularly difficult to explain in A2199 that is a bright cooling flow cluster, a regular cluster without merger events able to release a fraction of the input energy in particle acceleration. However, a source of relativistic electrons may be given via the decay of pions produced by proton-proton collisions between intracluster cosmic rays and gas, as suggested by Blasi & Colafrancesco (1999). We have re-analyzed the MECS data and Fig. 2 shows only a point above the thermal model at the level of $\sim 2\sigma$. However, the cluster is planned to be observed by XMM-Newton that should be able to discriminate between these two different
results of the MECS data analysis, considering the low average gas temperature of about 4.5 keV (David et al. 1993).

2.3. A2256

The cluster A2256 is the second cluster where BeppoSAX detected a clear excess (see Fig. 3) at about 4.6σ above the thermal emission (Fusco-Femiano et al. 2000). The temperature is about 7.4±0.23 keV consistent with the value determined by previous observations of ASCA, Einstein and Ginga. The thermal emission is measured by the MECS taking into account the difference between the two fields of view of the two instruments. Also in this case the χ² value has a significant decrement when a second component, a power law, is added and also in this case the fit with a second thermal component gives an unrealistic temperature which can be interpreted as evidence in favour of a non-thermal mechanism for the second component present in the X-ray spectrum of A2256. The range of the photon index at 90% confidence level is very large: 0.3-1.7. The flux of the nonthermal component is $\sim 1.2 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ in the 20-80 keV energy range, rather stable against variations of the photon index.

There is only a QSO in the field of view of the PDS, QSO 4C+79.16, observed by ROSAT with a count rate of $\sim 0.041$ c/s and about 1.2 c/s are necessary to reproduce the observed nonthermal excess and considering that the QSO is $\sim 52'$ off-axis an unusual variability of about 2 orders of magnitude is required. The MECS image excludes the presence of an obscured source in the central region ($\sim 30'$ in radius) of the cluster. We want to stress that the analysis of A2256 regards two observations (46 & 96 ksec) with a time interval of $\sim 1$ yr (Feb. 98 and Feb. 99) and this analysis does not show significant flux variations. In addition, we have re-observed the cluster after about two years from the previous one and the two spectra are consistent (see Fig. 4) and also in this case the observation is composed of two observations with a time interval of $\sim 1$ month and the analysis does not show significant flux variations. So, this
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Figure 4. A2256 - PDS data of two observations (Feb. 98/Feb. 99 and July 01/August 01). The continuous lines represent the best fit to the two data sets with a thermal component at the average cluster gas temperature of $7.47 \pm 0.35$ keV; the error bars are at $1\sigma$.

results and the fact that the two clusters with a detected hard excess, Coma and A2256, both have extended radio emission, make less plausible the point source interpretation and strongly support the idea of a diffuse nonthermal mechanism involving the ICM.

The diffuse radio emission of A2256 is very complex. It is composed of a relic at a distance of about $8'$ from the center. A broad region ($1 \times 0.3$ Mpc) with a rather uniform and flat spectral index of $0.8 \pm 0.1$ between 610 and 1415 MHz (Bridle et al. 1979). There is a second fainter extended component in the cluster center with a steeper radio spectral index of $\sim 1.8$ (Bridle et al. 1979, Rengelink et al. 1997). Markevitch & Vikhlinin (1997) in their analysis of the ASCA data noted a second component in the spectrum of A2256 in the central spherical bin of radius $3'$. Their best fit is a power law with a photon index of $2.4 \pm 0.3$ which therefore favors a nonthermal component. Considering that there are no bright point sources in the ROSAT HRI image they suggested the presence of an extended source. Also the joint analysis ASCA GIS & RXTE PCA (Henriksen 1999) is consistent with a detection of a nonthermal component in addition to a thermal component. The MECS data do not show this steep nonthermal component in the central bin because the energy range is truncated to a lower limit of 2 keV (Molendi, De Grandi & Fusco-Femiano 2000). So, in conclusion the power law with slope 2.4 found in the ASCA data and the upper limit 1.7 determined by BeppoSAX suggest that two tails could be present in the X-ray spectrum of A2256. The former might be due to the radio halo with the steep index of 1.8 that is not visible in the PDS (we estimate a flux of $\sim 4 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$), and the latter might be due to the relic with a flatter radio index of $0.8 \pm 0.1$ that indicates a broad region of reaccelerated electrons, probably the result of the ongoing merger event shown by a Chandra observation (Sun et al. 2002).
2.4. A1367

A BeppoSAX observation of Abell 1367 has not detected hard X-ray emission in the PDS energy range above 15 keV (P.I.: Y.Rephaeli). A1367 is a near cluster (z=0.0215) that shows a relic at a distance of about 22′ from the center and a low gas temperature of ∼ 3.7 keV (David et al. 1993) that might explain lack of thermal emission at energies above 15 keV. We do not expect presence of nonthermal radiation for two reasons: the radio spectral index $\alpha_{R} = 1.90 \pm 0.27$ (Gavazzi & Trinchieri 1983) seems to indicate the absence of high energy reaccelerated electrons and in any case the steep spectrum gives a negligible flux in the PDS. Besides, the radio region has a limited extent of 8′ corresponding to 300 kpc. The source has been observed also by XMM-Newton and the data analysis is still in progress.

2.5. A3667

A3667 is one of the most spectacular clusters of galaxies. It contains one of the largest radio sources in the southern sky with a total extent of about 30′ which corresponds to about $2.6h^{-1}$ Mpc. A similar but weaker region is present also to the south-west (Robertson 1991; Röttgering et al. 1997). The Mpc-scale radio relics may be originated by the ongoing merger visible in the optical region, in the X-ray, as shown by the elongated isophotes, and in the weak lensing map. The ASCA observation reports an average gas temperature of $7.0 \pm 0.6$ (Markevitch, Sarazin, & Vikhlinin 1999). The temperature map shows that the hottest region is in between the two groups of galaxies confirming the merger scenario. The PDS field of view includes only the radio region in the north of the cluster. A long observation with the PDS (effective exposure time 44+69 ksec) reports a clear detection of hard X-ray emission up to about 35 keV at a confidence level of $\sim 10\sigma$. Instead, the fit with a thermal component at the average gas temperature indicates an upper limit for the nonthermal flux of $\sim 6.4 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ in the 20-80 keV energy range that is a factor $\sim 3.4$ and $\sim 2$ lower than the nonthermal fluxes detected in Coma and A2256, respectively (see Fig. 5). In the IC interpretation this flux upper limit combined with the radio synchrotron emission determines a lower limit to the volume-averaged intrachannel magnetic field of 0.41 $\mu$G.

Given the presence of such a large radio region in the NW of the cluster, a robust detection of a nonthermal component might be expected instead of the upper limit reported by BeppoSAX. One possible explanation may be related to the radio spectral structure of the NW relic. The sharp edge of the radio source ($\alpha_{R} \sim 0.5$) is the site of particle acceleration (Roettiger, Burns & Stone 1999) , while the progressive index steepening with the increase of the distance from the shock ($\alpha_{R} \sim 1.5$) would indicate particle ageing because of radiative losses. In the narrow shocked region, where particle reacceleration is at work, the magnetic field is expected to be amplified by adiabatic compression with the consequence that the synchrotron emission is enhanced thus giving a limited number of electrons able to produce IC X-rays. In the post-shock region of the relic the electrons suffer strong radiative losses with no reacceleration, considering also that the relic is well outside the cluster core. Therefore, the electron energy spectrum develops a high energy cutoff at $\gamma < 10^4$ and the electron energy is not sufficiently high to emit IC radiation in the hard X-ray.
2.6. \textbf{A754 & A119}

The last two clusters, A754 and A119, observed by \textit{BeppoSAX} show an evident merger activity. It is plausible that a considerable fraction of the input energy during a merger process can be released in particle acceleration and remitted in various energy bands. The scope of these observations was to verify whether clusters showing merger events can produce nonthermal X-ray radiation also in the absence of a clear evidence of diffuse radio emission as it is for Coma and A2256.

The rich and hot cluster A754 is considered the prototype of a merging cluster. X-ray observations report a violent merger event in this cluster (Henry & Briel 1995; Henriksen & Markevitch 1996; De Grandi & Molendi 2001), probably a very recent merger as shown by a numerical hydro/N-body model (Roettiger, Stone, & Mushotzky 1998). Therefore, the intracluster medium of A754 appears to be a suitable place for the formation of radio halos or relics. As a consequence, radio and HXR observations of this cluster are relevant to verify the suggested link between the presence of nonthermal phenomena and merger activity in clusters of galaxies. The cluster has been recently observed with the NRAO VLA observatory (Kassim \textit{et al.} 2001), after our \textit{BeppoSAX} proposal, suggesting the existence of a radio halo and at least one radio relic. The presence of a radio halo is confirmed by a deeper observation at higher resolution (Fusco-Femiano \textit{et al.}, in preparation). A754 was observed in hard X-rays with \textit{RXTE} in order to search for a nonthermal component (Valinia \textit{et al.} 1999) and the fit to the PCA and HEXTE data set an upper limit of \( \sim 1.4 \times 10^{-12} \) erg cm\(^{-2}\) s\(^{-1}\) in the 10-40 keV band to the nonthermal emission.

A long \textit{BeppoSAX} observation of A754 shows an excess at energies above about 45 keV with respect to the thermal emission at the temperature of 9.4 keV (see Fig. 6). The excess is at a level of confidence of 3\( \sigma \). The nonthermal flux
Figure 6. A754 - MECS and PDS data. The continuous lines represent the best fit with a thermal component at the average cluster gas temperature of $9.42^{+0.16}_{-0.17}$ keV.

is $\sim 1 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ in the range 40-100 keV consistent with the flux upper limit determined by RXTE ($\sim 1.6 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ in the range 10-40 keV).

There are two possible origins for the detected excess. One is tied to the presence of the diffuse radio emission and the other explanation is due to the presence of the radio galaxy 26W20 in the field of view of the PDS discovered by Harris et al. (Westerbork radio survey, Harris et al. 1980). This source shows X-ray characteristics similar to those of a BL Lac object. The radio galaxy has had several X-ray observations, due to its close proximity to A754, and all these observations give a flux of $\sim 2.3 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ in the 0.5-3 keV energy range. The source shows variability (18% in 5 days in 1992). The fit to the SED for 26W20 (see Fig. 7), where the highest energy points refer to the PDS observation assuming that this source is responsible for the detected excess, requires a flat index of about 0.3 to extrapolate the flux detected by ROSAT in the PDS energy range, taking into account the angular response of the detector. Unfortunately, the source is not in the field of view of the MECS because it is hidden by one of the calibration sources of the instrument. The conclusion is that a HXR observation with spatial resolution is necessary to discriminate between these two interpretations.

Finally, A119 was the last cluster observed by BeppoSAX to detect an additional nonthermal component in its X-ray spectrum. ROSAT PSPC, ASCA and BeppoSAX observations have shown a rather irregular and asymmetric X-ray brightness suggesting that the cluster is not completely relaxed and may have undergone a recent merger (Cirimele et al. 1997; Markevitch et al. 1998; Irwin, Bregman & Evrard 1999; De Grandi & Molendi 2001). The average cluster temperature measured by BeppoSAX is $5.66 \pm 0.16$ keV within 20' and is consistent with previous measurements of Einstein and EXOSAT. The excess with respect to the thermal emission at the average gas temperature measured by the MECS is at confidence level of $\sim 2.8\sigma$ (see Fig. 8). The nonthermal flux is in the range $7 - 8 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ in the 20-80 keV energy range and
Figure 7. Spectral energy distribution for 26W20. The highest energy points refer to the PDS observation. The dotted line is the fit to the SED.

Figure 8. A119 - MECS and PDS data. The continuous lines represent the best fit with a thermal temperature at the average cluster gas temperature of $5.66 \pm 0.16$ keV.
Figure 9. A2256 - Residuals in the form of a ratio of data to a thermal MEKAL model. The best fit temperature for the simulated spectrum is \( \sim 4 \) keV. Full circles and stars are for the PN single and double events spectra, and open circles are for the MOS spectrum.

\[3 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}\] in the 2-10 keV energy band for a photon spectral index in the range 1.5-1.8.

A119 does not show evidence of a radio halo or relic, but the presence of a recent merger event could accelerate particles able to emit nonthermal emission in the PDS energy range. However, the presence of 7 QSO with redshift in the range 0.14-0.58 makes very unlikely that this possible excess at a flux level of \(3 \times 10^{-12} \) erg cm\(^{-2}\) s\(^{-1}\) in the 2-10 keV energy band may be due to a diffuse source. We can instead exclude that the observed excess is due to the radio source 3C29, a FR I source located in the field of view of the MECS at a distance of about 21' from the BeppoSAX pointing.

3. Conclusions

BeppoSAX observed a clear evidence of nonthermal emission in two clusters, Coma and A2256, both showing extended radio regions. In particular, the two observations of A2256 strongly support the presence of a diffuse nonthermal mechanism involving the ICM. These detections and the lack of detection in other clusters seem to indicate that the essential requirement to observe additional nonthermal components at the level of the PDS sensitivity is the presence of large regions of reaccelerated electrons, with Lorentz factor \(10^4\), due to the balance between radiative losses and reacceleration gains in turbulence generated by merger events that must be very recent considering the short lifetime of the electrons.

BeppoSAX, as it is well known, has ceased its activity at the end of April 2002. The next missions able to search for nonthermal components are:

- **INTEGRAL**. In particular, with IBIS, that has a spatial resolution of 12', we have the opportunity a) to localize the source of the nonthermal X-ray emission.
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In the case of a point source it is possible to identify it, while in the case of a diffuse source it is possible to verify whether the nonthermal emission is mainly concentrated in the cluster central region or in the external region, as predicted by the model for the Coma cluster of Brunetti et al. (2001), or it is uniformly spread over the whole radio halo present in the cluster. b) to have a better determination of the photon spectral index.

- **ASTRO-E**. The Hard X-ray Detector (HXD) has a field of view of \(34' \times 34'\) similar to that of the MECS. A positive detection of the nonthermal emission already measured by BeppoSAX in Coma and A2256 would eliminate the ambiguity between a diffuse emission involving the intracluster gas and a point source, considering that the MECS images do not show evidence for point sources.

- The future missions are represented by **NEXT** and **CONSTELLATION**.

These missions will be operative in the next years, but the energy range and the spectral capabilities of XMM-Newton /EPIC give the possibility to localize nonthermal components in regions of low gas temperature as shown by the simulation regarding the radio relic of A2256 performed using the nonthermal flux measured by BeppoSAX (see Fig. 9). This region has a gas temperature of 4 keV likely associated with the ongoing merger shown by a Chandra observation (Sun et al. 2001). So with XMM-Newton we should have the possibility, by comparing the X-ray and radio structures, to constrain the profiles of the magnetic field and of relativistic electrons.

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