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Galaxy Clusters in the *Swift*/BAT Era

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Abstract

We report about the detection of 10 clusters of galaxies in the ongoing *Swift*/BAT all-sky survey. This sample, which comprises mostly merging clusters, was serendipitously detected in the 15-55 keV band. We use the BAT sample to investigate the presence of non-thermal emissions. The BAT clusters do not show significant (e.g. ≥2 σ) high-energy non-thermal emission. The only exceptions are represented by Perseus and Abell 0754 whose high-energy emissions are likely due to two point-like X-ray sources. Using XMM-Newton, Swift/XRT, Chandra and BAT data, we are able to produce upper limits on the Inverse Compton (IC) emission mechanism which are in disagreement with most of the previously claimed non-thermal components. The coupling of the X-ray upper limits on the IC mechanism to radio data shows that in some clusters the magnetic field might be larger than 0.5 μG. We also derive the first log *N* - log *S* and luminosity function distribution of galaxy clusters above 15 keV. This poster presents the main results of our analysis.

Observations and data reduction

BAT survey data from January 2005 March to November 2007 were used to image the hard X-ray sky (15-55 keV). The mean exposure is 3 Ms, being 1.5 Ms and 5 Ms the minimum and maximum exposure times respectively. Above the 5 σ threshold we detected 10 Galaxy Clusters. This is so far the largest complete sample detected above 10 keV. The details of the clusters are reported in Table 1.

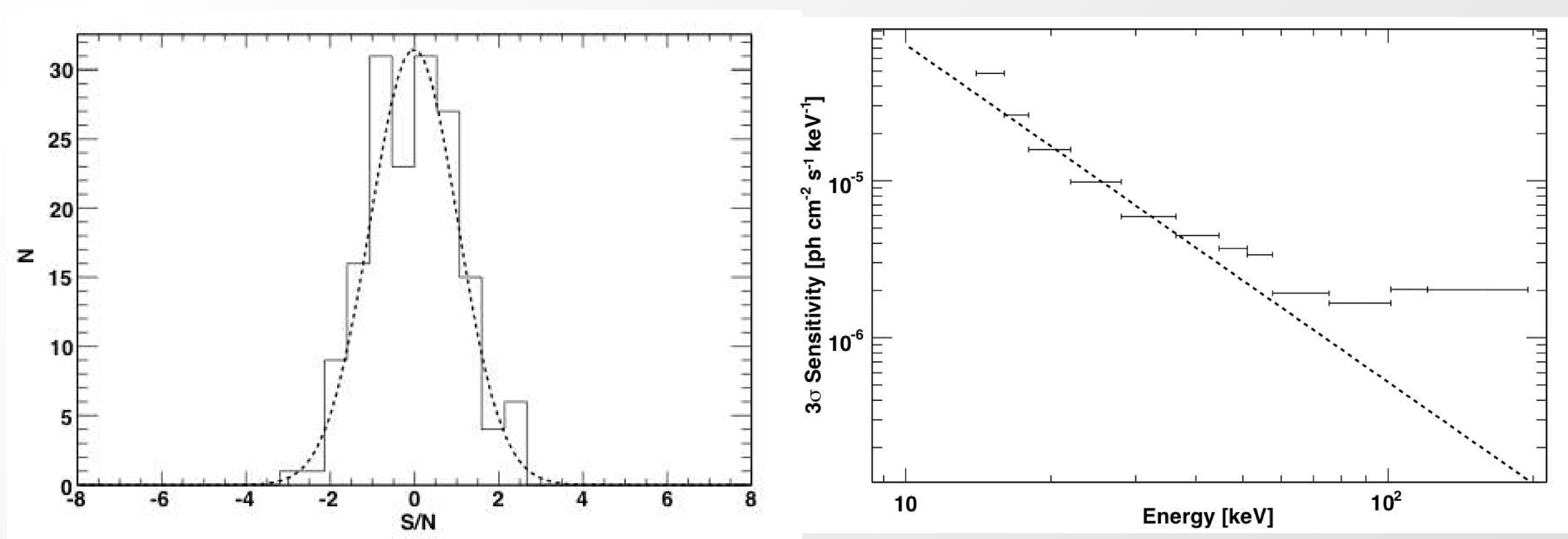
Table 1. Clusters detected in the 15–55 keV band

NAME	R.A. (J2000)	DEC (J2000)	S/N	ID	z	EXPOSURE (Ms)	OFFSET (arcmin)
J0319.8+4130	49.9573	41.5110	28.00	Perseus	0.0175	2.89	0.5
J0431.3-6126	67.8297	-61.4388	5.61	Abell 3266	0.0590	3.81	2.1
J0908.9-0938	137.2391	-9.6346	8.28	Abell 0754	0.0530	2.96	1.8
J1259.4+2757	194.8531	27.9523	19.95	Coma Cluster	0.0230	4.32	5.1
J1347.7-3253	206.9500	-32.9000	5.05	Abell 3571	0.0397	1.78	4.5
J1511.0+0544	227.7500	5.7485	5.33	Abell 2029	0.0770	2.71	0.8
J1558.5+2714	239.6256	27.2417	7.11	Abell 2142	0.0890	3.62	3.3
J1638.8-6424	249.7136	-64.4000	6.90	Triangulum A.	0.0510	1.77	4.9
J1712.3-2319	258.0914	-23.3242	21.63	Ophiucus	0.028	1.30	1.7
J1920.9+4357	290.2405	43.9646	11.72	Abell 2319	0.056	3.87	2.2

BAT Clusters. Significance contours showed for Abell 0754 (left) and Ophiucus (right) superimposed on ROSAT PSPC images.

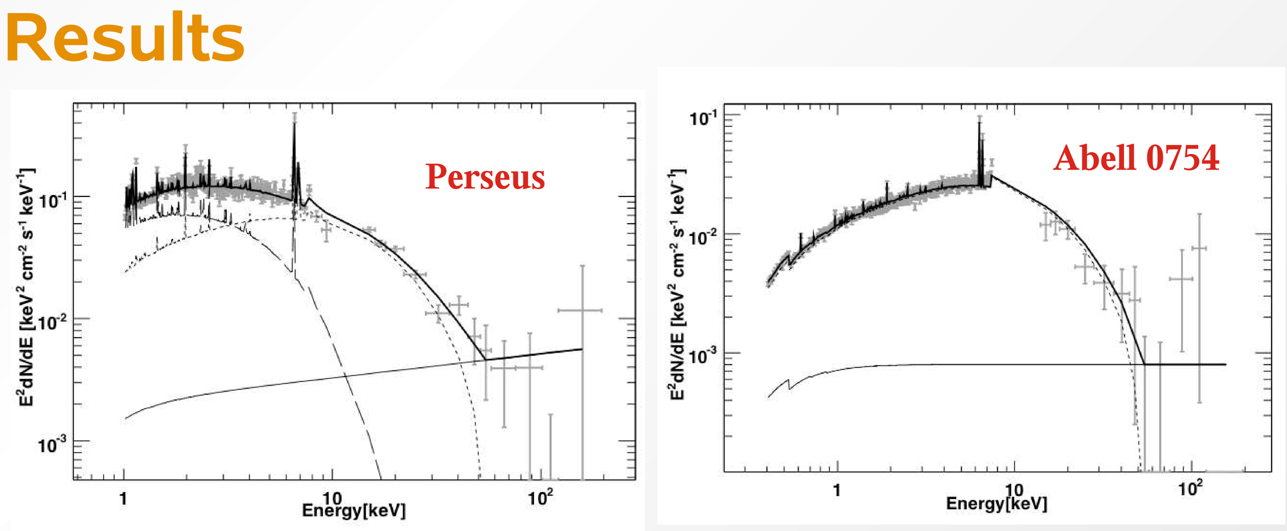
Accuracy of the BAT spectra

For each galaxy cluster we extracted a 15–195 keV spectrum with the method described in Ajello et al. (2008b). Here we recall the main steps: the details can be found in the aforementioned paper. For a given source, we extract a spectrum from each observation where the source is in the field of view. These spectra are corrected for residual background contamination and for vignetting; the per-pointing spectra are then (weighted) averaged to produce the final source spectrum. Thus, the final spectrum represents the average source emission over the time-span considered here (2.5 years). Moreover, the analysis of 160 source-free regions shows that the background subtraction is efficient and accurate in the whole energy range and that BAT spectra are extremely sensitive.



Left panel: Assessment of uncertainties for the 18-22 keV energy channel. The histogram shows the S/N distribution of 160 source-free regions (noise). The dashed line is a fit with a Gaussian profile. The 1 σ width is consistent with 1.0. *Right panel*: 3 σ spectral sensitivity as a function of energy. The dashed line is the Crab Nebula spectrum divided by 1000. As it can be seen the BAT sensitivity reaches, below 1000 keV, 1 mCrab in each energy channel.

Results

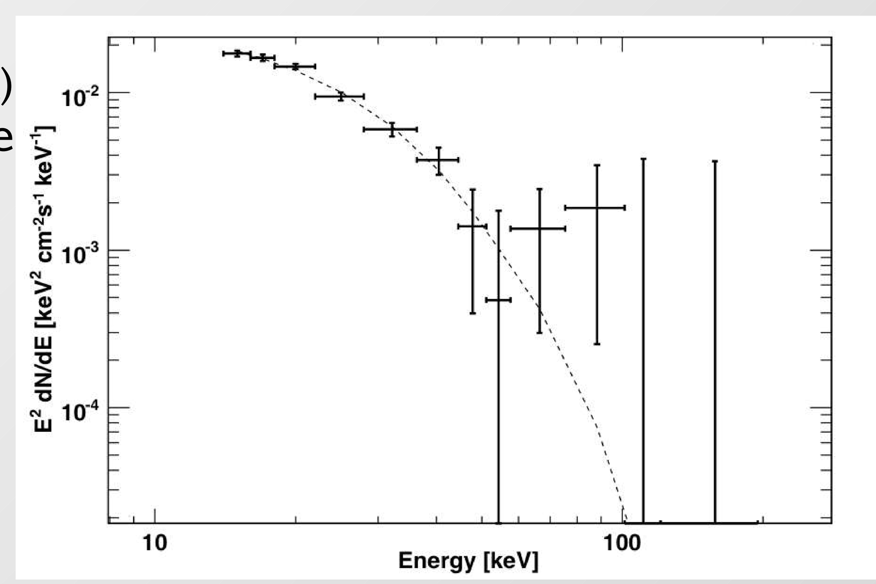


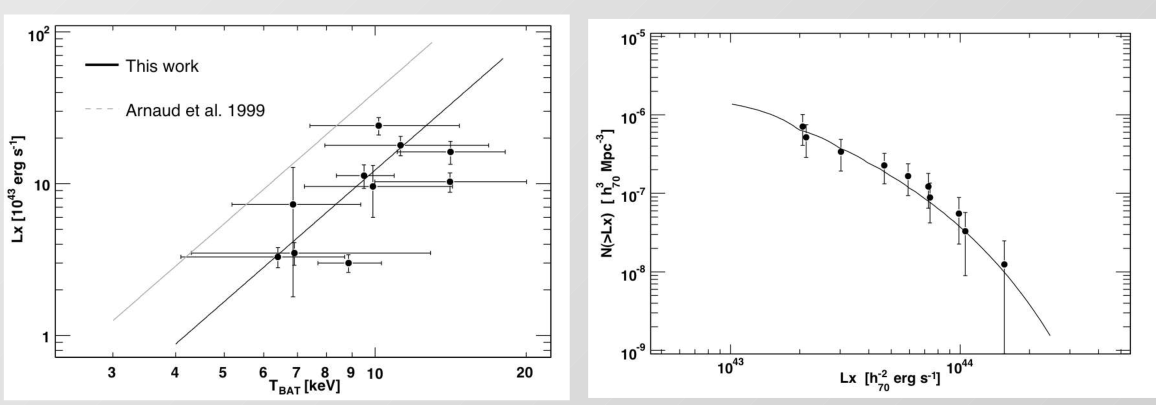
Non-thermal components. Perseus (left) and Abell 0754 (right) are the only clusters where significant emission is detected above 50 keV. However in both cases this emission is due to AGN.

CLUSTER	INSTRUMENT	AGREE?
Perseus	BeppoSAX	✓ AGN
A 3266	--	
A 0754	BeppoSAX	✗ AGN!
A 3571	--	
A 2029	--	
A 2142	BeppoSAX	✗
Triangulum A.	--	
Ophiucus	INTEGRAL/BeppoSAX	✗
A 2319	RXTE	✗

Comparison with previous results. The comparison with previously plublished results show that the BAT upper limits are usually lower than the claimed non-thermal component.

Stacked analysis. The stacked spectrum of the BAT cluster is consistent with with a pure thermal spectrum with a temperature of 10 keV. The upper limit on any non-thermal emission in the 50-100 keV band is 0.3 mCrab (1.9x10^{-12} erg cm^{-2} s^{-1}).





Luminosity-Temperature relation and luminosity function of BAT clusters. *Left:* L_x-T relation for the BAT sample. The black line is the best, power-law, fit to the data while the gray line is the best fit of Arnaud & Evrard (1999) converted to the BAT energy band. Merging clusters, as the BAT ones, are expected to segregate at low luminosity from the L_x-T relation. *Right:* Luminosity function of the BAT clusters. The solid line is the REFLEX luminosity function (Böhringer et al. 2002) converted to the BAT energy band.

References: Ajello, M, Rebusco, P, Cappelluti, N. et al. 2008, submitted to ApJ; available at www.mpe.mpg.de/~majello/ARC08.pdf

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