



**BeppoSAX PDS Archive
AGILE transient in Musca**

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BeppoSAX PDS detection of the AGILE transient in Musca

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Revision History

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Seq	OPn	Source Name	Dist (')	RA	DEC	Type
1	10481	Circinus Galaxy	5.8	212.8827	-61.80252	-OFF
2	10480	Circinus Galaxy	6.1	212.8952	-61.80250	-OFF
3	10482	Circinus Galaxy	6.1	212.8965	-61.80266	-OFF
4	08317	Gal Plane Sur 2	40.5	211.3474	-61.88437	ON
5	08484	Gal Plane Sur 23	45.5	213.5936	-61.09281	+OFF
6	01654	Alpha Cen (Hd 12)	52.5	213.5321	-62.52443	+OFF
7	01656	Alpha Cen (Hd 12)	52.6	213.5366	-62.52621	+OFF
8	01652	Alpha Cen (Hd 12)	52.7	213.5273	-62.53019	+OFF
9	08386	Gal Plane Sur 16	70.0	210.2841	-61.83828	ON
10	12503	Psr J1420-6048 _r	78.7	214.7152	-60.82750	ON
11	12467	Psr J1420-6048	81.2	214.7147	-60.76746	ON
12	12472	Psr J1420-6048	81.3	214.7147	-60.76638	ON
13	08311	Gal Plane Sur 1	103.6	209.9710	-62.88492	ON
14	08380	Gal Plane Sur 15	109.0	208.9332	-62.01262	ON

Table 1: List of PDS pointings in the AGILE error box (see Fig. 1). Coordinates are in degrees, referred to equinox date 2000. The distance listed in column 4 refers to the angular distance of the PDS pointing from the AGILE position.

1 The PDS pointings in the AGILE error box

Following ATel#1394 [1] reporting the detection by AGILE of variable gamma-ray emission from a region in Musca centered at $(l,b) = (312.2,-0.3)$ and radius $30'$, we searched our BeppoSAX PDS Archive (BSAr) for possible PDS pointings in that region (we recall that the PDS FOV is 1.3°).

The PDS pointings around the AGILE error box (shown in orange in Fig. 1) are listed in Table 1. Only the first eight entries, corresponding to four unique PDS targets, are within the AGILE error box. The log of the four unique observations is listed in Table 2.

1.1 -OFF offset field of the Circinus Galaxy observation (OP10480, 10481, 10482)

1.1.1 Spectral analysis

The -OFF field is centered just on the AGILE error box (see Table 2). The difference between the +OFF and -OFF count rate integrals in 15–100 keV, used to evaluate the presence of excesses in the offset PDS fields, gives a value of -0.450 ± 0.032 , that is an excess in the -OFF offset field at a significance level of 14 sigma.

We therefore extracted the PDS spectrum of the -OFF field (assuming as its background the corresponding +OFF spectrum) and the result is shown in Fig. 2. The fit with a power law gives a photon index of 2.2 ± 0.2 , with a normalized χ^2 of 1.44 for 14 dof, and a 15–100 flux of 5×10^{-11} erg cm $^{-2}$ s $^{-1}$ (corresponding to 2.5 mCrab).

RA: 14:10:57.7 DEC: -61:43:57 R: 90'

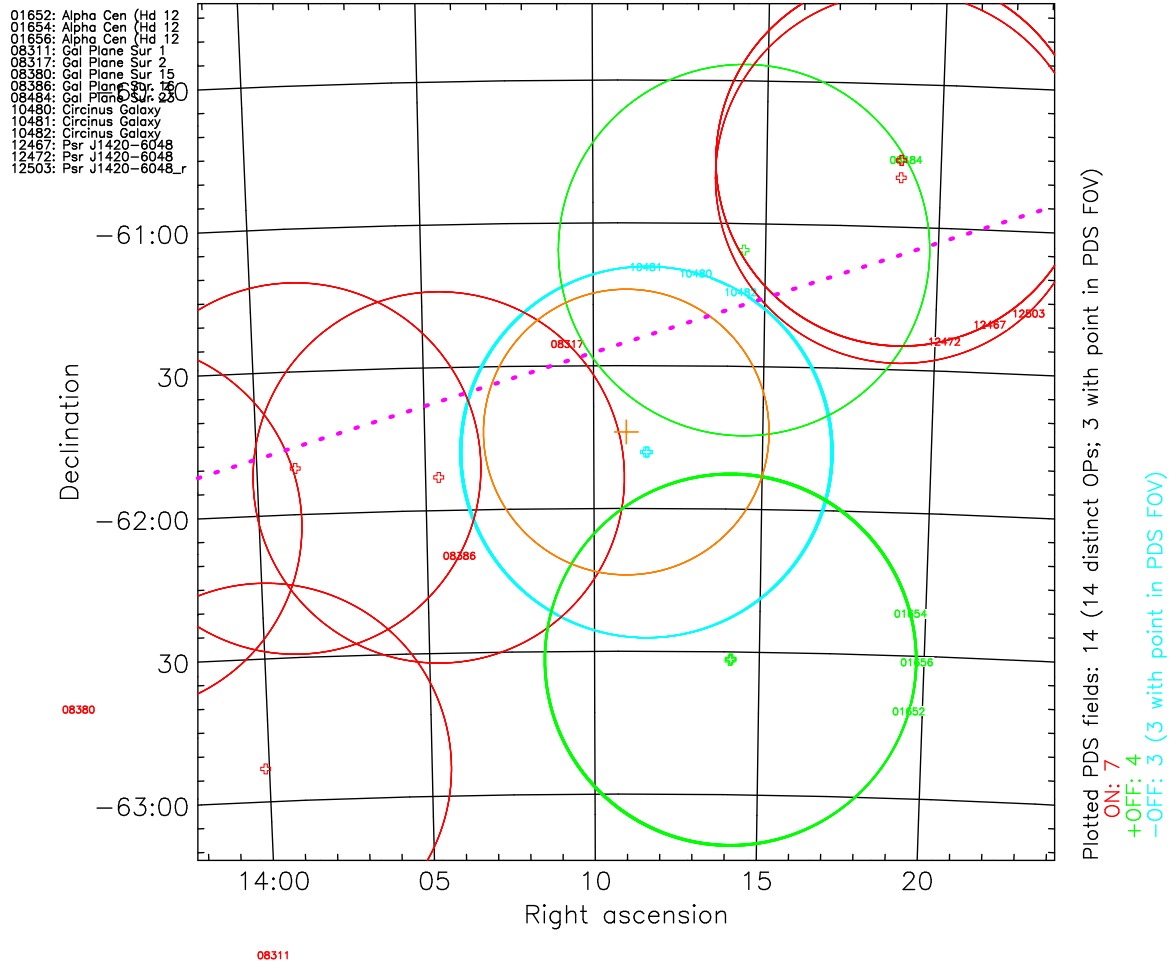


Figure 1: Region centered on the position of the AGILE source (the orange circle) with the PDS pointings color coded according to the pointing type: **ON** pointings, **+OFF** pointings, and **-OFF** pointings. The purple dotted line corresponds to the Galactic plane.

OPn	Type	Date	Duration (ksec)	ON Pointing		-OFF Pointing		+OFF Pointing		Rate ^a (Counts/sec)
				(RA)	(DEC)	(RA)	(DEC)	(RA)	(DEC)	
01654	+OFF	23/02/1997	90	219.7900	-60.68688	225.3298	-58.58426	213.5273	-62.53019	0.422 ± 0.115
08317	ON	29/01/2000	42	211.3474	-61.88437	211.3261	-58.38439	211.3743	-65.38435	0.247 ± 0.069
08484	+OFF	19/02/2000	47	219.4486	-59.15446	224.6408	-56.98190	213.5936	-61.09281	0.145 ± 0.070
10480	-OFF	07/01/2001	220	212.9157	-65.30249	212.8952	-61.80250	212.9425	-68.80244	0.450 ± 0.032

^a Count rate in 15–100 keV

Table 2: Log of the four PDS observations that cover the AGILE error box. Coordinates are in degrees, referred to equinox date 2000.

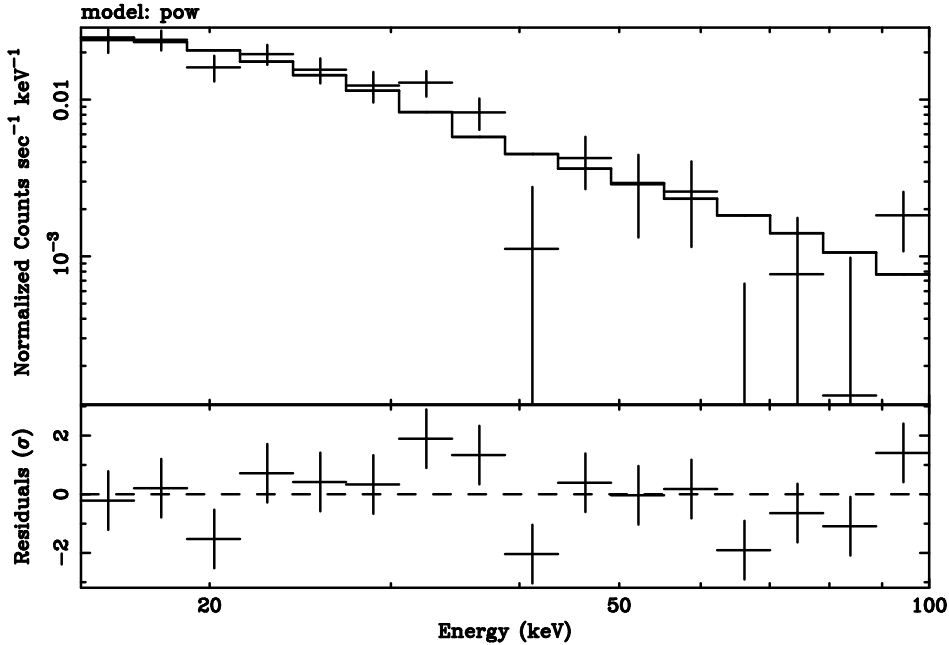


Figure 2: 15–100 keV PDS count rate spectrum (*plus signs*) and the power law best fit model (*histogram*) of the –OFF offset field of the Circinus Galaxy observation. The fit residuals are shown in the bottom panel. As background was used the other PDS offset field.

1.1.2 Temporal analysis

We searched for temporal variability (because of the variable flux measured by AGILE) and we extracted the 15–100 keV count rate integrals computed for each BeppoSAX orbit (about 1.5 hours long). In Fig. 3 we show these count rates as a function of time, together with the corresponding power law photon index and goodness of fit.

It is evident that there is no spectral variability in the source. To investigate on the possible flaring episode centered on point 18, we performed a run test [2,3] on the data point. The probability that the observed 20 runs occur by chance is 90%, therefore we can conclude that the flare is not statistically significant.

1.2 ON pointing of Field02 of the Galactic Plane Survey (OP08317)

This 42 ksec observation was performed on 29/01/2000 and the standard scientific analysis is present at the ASDC Archive [4]. As shown in Table 2 we have only a marginal detection in the PDS. In the MECS image two sources are present (see Fig. 4, right panel. Note that RA goes in the opposite direction with respect to Fig. 1). The one in the AGILE error box is the one marked as source #6 in Table 3, with 2000 coordinates (RA,DEC) = 14 08 00.6, -61 58 19.9.

In Fig. 5 we show the 1.8–100 keV count rate spectrum for source #6, together with its power law best fit (normalized χ^2 of 0.18 for 12 dof). It is characterized by a hard spectrum, with power law photon index $0.87^{+0.29}_{-0.19}$, $N_H = 2.8^{+3.4}_{-2.2} \times 10^{22} \text{ cm}^{-2}$ (compatible with galactic absorption), and unabsorbed 2–10 keV flux of $2.7 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$. The 15–100 keV PDS detection of $0.247 \pm 0.069 \text{ Counts/sec}$ is consistent with

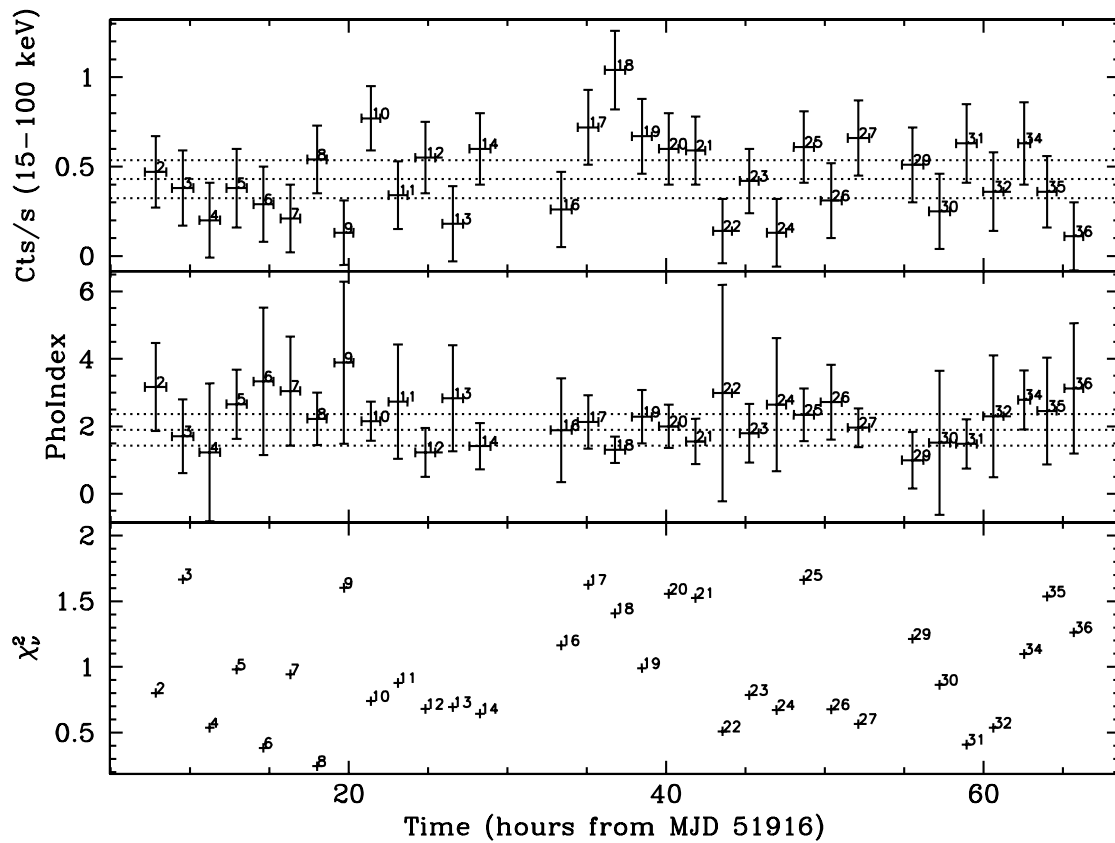


Figure 3: 15–100 keV PDS count rates for –OFF offset field of the Circinus Galaxy observation as a function of time (upper panel). Each point corresponds to a BeppoSAX orbit (1.5 hour). In the central panel we show the best fit power law photon index used to describe the spectrum integrated in each orbit, while the bottom panel shows the corresponding normalized χ^2 . The dotted lines in the upper and central panel mark the weighted average of the data and the $\pm 3\sigma$ interval.

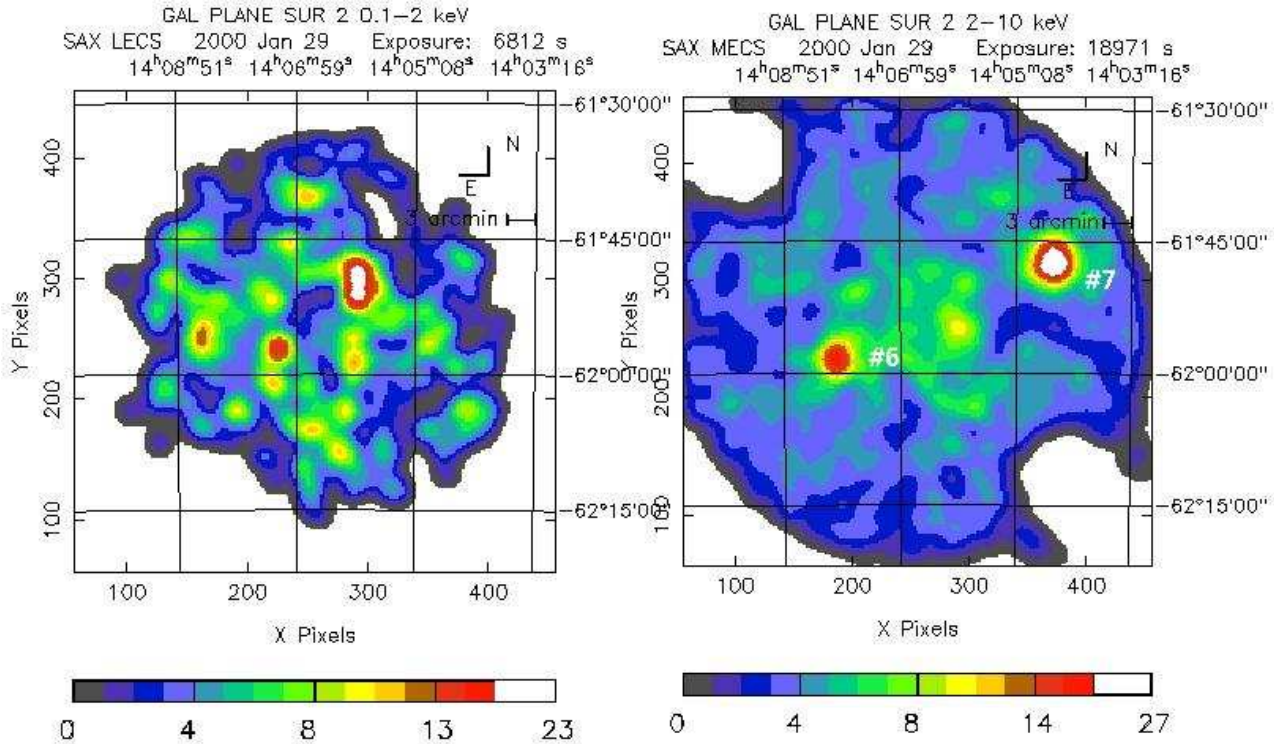


Figure 4: LECS (left) and MECS (right) image of the OP08317 BeppoSAX observation. In the MECS are clearly detected two sources. The one present in the AGILE error box is the left one (note that RA runs in the other direction with respect to Fig. 1, and is listed as #6 in Table 3).

#	Rate ^a (2–10 keV)	pixel		Vig corr	R.A. (2000)	Dec (2000)	S/N
		x	y				
1	2.12 ± 0.74	265.0	230.7	1.09	14 06 32.8	-61 58 41.7	2.85
2	2.42 ± 0.82	261.4	298.6	1.21	14 06 36.9	-61 49 38.4	2.94
3	3.95 ± 0.89	294.8	257.5	1.17	14 05 59.0	-61 55 06.8	4.42
4	2.53 ± 0.83	220.9	240.3	1.17	14 07 22.7	-61 57 24.5	3.03
5	3.23 ± 1.1	306.9	196.0	1.65	14 05 45.0	-62 03 18.7	2.84
6	12.1 ± 1.5	187.6	233.2	1.55	14 08 00.6	-61 58 19.9	7.82
7	48.1 ± 4.0	373.4	317.1	2.70	14 04 30.5	-61 47 06.7	12.0

^a In units of 10⁻³ Counts/sec

Table 3: Sources detected in the MECS field for OP08317. Source #6 is the one in the AGILE error box.

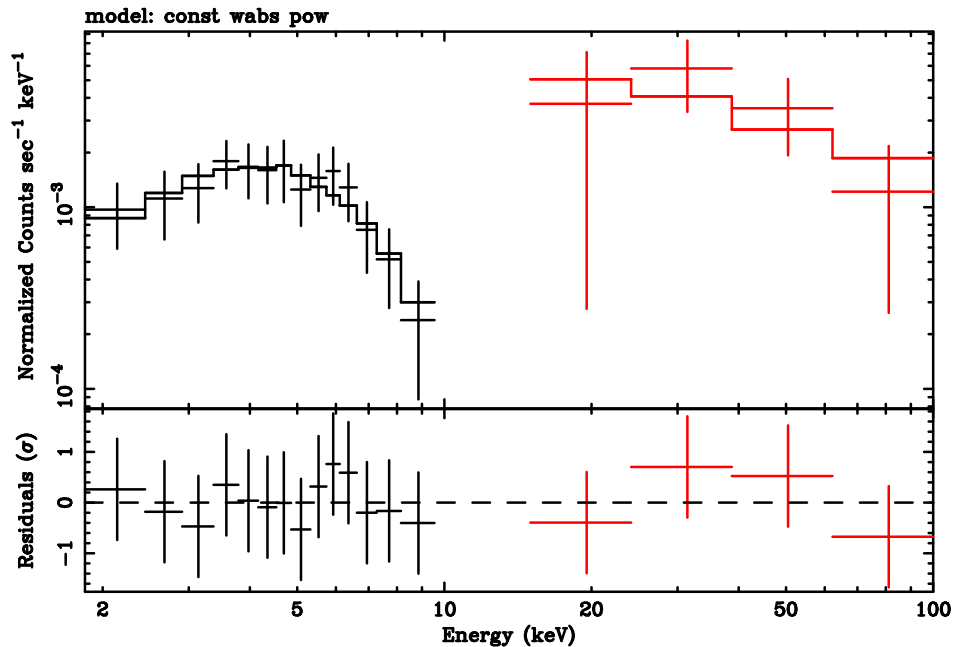


Figure 5: 1.8–100 keV count rate spectrum (*plus signs*) and the power law best fit model (*histogram*) of the source #6 in the OP08317 field. The fit residuals are shown in the bottom panel.

the extrapolation of the MECS spectrum to higher energies (but it is consistent also with the extrapolation of the MECS spectrum of source #7).

Source #6 does not show any temporal variability.

1.3 +OFF pointing of Field23 of the Galactic Plane Survey (OP08484)

This 47 ksec observation was performed on 19/02/2000. PDS detection for this observation: 0.145 ± 0.070 Counts/sec in 15–100 keV.

1.4 +OFF pointing of Alpha Cen observation (OP01652, 01654, 01656)

This 90 ksec observation was performed on 23/02/1997. PDS detection for this observation: 0.422 ± 0.115 Counts/sec in 15–100 keV.

2 Summary

Following ATel#1394 reporting the detection by the AGILE satellite of a variable gamma-ray emission from a region in Musca centered at $(l,b) = (312.2,-0.3)$ and radius $30'$, we have searched in our BeppoSAX PDS Archive for possible PDS pointings in that region.

We actually find that the AGILE error box was observed by PDS four times: in three occasions in one of the offset positions of its rocking collimators, and in an on-axis position in one occasion.



In the 15-100 keV energy band, a marginal evidence of excess counts (0.422 ± 0.115 cts/s) is found in the offset pointing occurred on 23/02/1997 (90 ksec of elapsed time). No evidence of emission (0.145 ± 0.070 cts/s) is found in the pointing occurred on 19/02/2000 (47 ksec).

Instead, in the offset pointing of January 6, 2001 (220 ksec) a significant signal (0.450 ± 0.032 cts/s) was detected. The center of the PDS FOV was almost coincident with the AGILE position. The spectrum of the excess counts is fit with a power law of photon index 2.2 ± 0.2 , with a normalized χ^2 of 1.44 for 14 dof, and a 15–100 keV flux of 5×10^{-11} erg cm⁻² s⁻¹ (2.5 mCrab).

The light curve (32 bins of 1.5 hrs each) does not show significant variability, even if a flaring episode lasting a few bins seems to be there. A run test on the data gives a probability of 90% that the variation observed is due to chance.

The same region was also observed by all BeppoSAX NFIs on 29/01/2000 (42 ksec). A marginal signal (0.247 ± 0.069 cts/s) is found in the PDS data, while the MECS image shows the clear presence of two sources, one of which (the weakest) in the AGILE error box, with 2000.0 equatorial coordinates (RA,DEC) = 14 08 00.6, -61 58 19.9.

The 2–10 keV spectrum of this source is fit with an absorbed power law of photon index 0.86 ± 0.28 , $N_H = 2.2 \times 10^{22}$ cm⁻² (compatible with galactic absorption), and a 2–10 keV unabsorbed flux of 2.5×10^{-12} erg cm⁻² s⁻¹.

If the serendipitous source found with the PDS on January 11, 2001 is identified with the AGILE source, the flux expected assuming the measured spectrum is well below the AGILE sensitivity and would imply the presence of a variable high energy component, the origin of which (Comptonization?) should be investigated.

This text has been submitted as ATel #1419 [5].

References

- [1] Pittori C. et al. 2007. AGILE gamma-ray detection of a variable source in the Musca region, ATel 1394
- [2] Bendat J.S. and Piersol A.G. 1971. *Random Data: Analysis and Measurement Procedures*, Wiley Interscience, New York
- [3] Eadie W.T., Drijard D., James F.E., Roos M. and Sadoulet B. 1988. *Statistical methods in experimental physics*, North Holland Publishing Company
- [4] BeppoSAX Supervised Standard Scientific Analysis, Observation Code 70888002, Target: GAL PLANE SUR 2, available online at <http://www.asdc.asi.it/bepposax/nfiarchive/proc/70888002/html/>
- [5] Orlandini M., Frontera F., Bassani L., Landi R. and Sguera V. 2008. BeppoSAX PDS detection of the AGILE transient in Musca, ATel 1419