XMM-Newton Technical Note

XMM-CAL-TN-232

RGS Diagnostic Trend Analysis Report - 2021

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1 Introduction

The purpose of this note is to report the evolution of several indicators derived from the RGS Diagnostic and Science data. We aim to detect eventual instrument degradation and to describe the necessary changes in the RGS scientific data reduction.

Running the RGS Diagnostic and Trend Analysis tools (see XMM-SOC-SW-TN-0012) we have collected and analysed data from the whole mission up to the end of December 2021 (revolution 4040).

The RGS Diagnostics Tools run automatically over any newly generated PMSFITS file. The reduced data are stored on per revolution basis and some of the results published in the internal RGS monitoring web page[1].

We also process the science data ("ODF") periodically to obtain a series of parameters to characterise the evolution of the instrument, paying special attention to the behaviour of the response of the individual pixels and columns of the detector. The results are analysed statistically to derive trends in the RGS performance.

In this report we present the evolution of the instrument offsets ("system peak") and the bad pixels / columns in the intrument's detectors.

2 System Peak evolution

We have studied the behaviour of the detectors's system peak along 2021.

Figure 1 shows their evolution corresponding to the C nodes of all working CCDs in RGS1 from revolution 3000. They are obtained from the mean values along one revolution of the pixel offset distributions per CCD and node, the offsets being the CCD signals measured by absence of any illumination. In previous reports we notified a significant decrease in the mean offset values of all CCDs around rev 2700. After that, these values have been very stable and varied only by a few percent over very large time periods. In this figure, a small but noticeable drop can also be seen around revolution 3250 affecting all CCDs. A less pronunciated but steady decrease can also be noticed from rev 3450, with another, smaller drop in rev 3650. All these features have been discussed in previous reports.

The behaviour of the system peak in the last year has been very smooth, with a flat trend shown over the last 200 revolutions (roughly 399 days), as can be seen in figure 3.

Node D continues showing a stable, near flat trend since revolution 3000 for all CCDs, with only a slight increase of less than 1% for CCD1. The mean offset values are around 33% larger in node D than in node C (see figure 2).

[1] https://xmmweb.esac.esa.int/internal/int_cal_instr_supp/rgs/monitoring.php

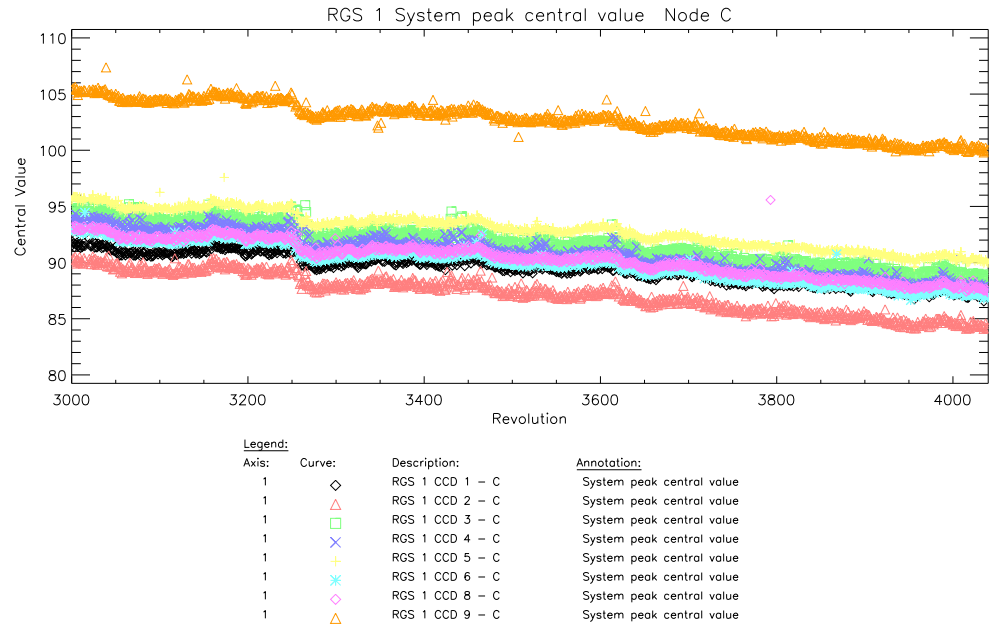

Figure 1: RGS1 - system peak evolution of node C data since revolution 3000.

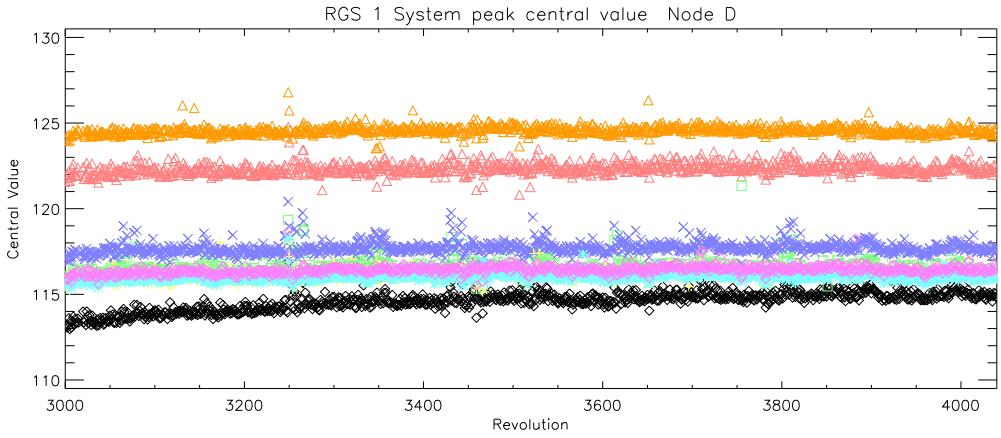

Figure 2: RGS1 - system peak evolution of node D data since revolution 3000. Same symbols as in figure 1

RGS2 offsets show the expected stable trend, with no significant evolution, again with variations averaging within the 1% range compared to last CCF, as shown by Figure 4. Same behaviour can be seen when inspecting the last 200 revolutions (figure 5).

As usual, no info on node D appears in this figure since it has not been in use since revolution 1408.

In case the reader needs information of the evolution of the system peak along the full mission, please refer to previous reports. The most relevants issues to mention affecting the offsets are the

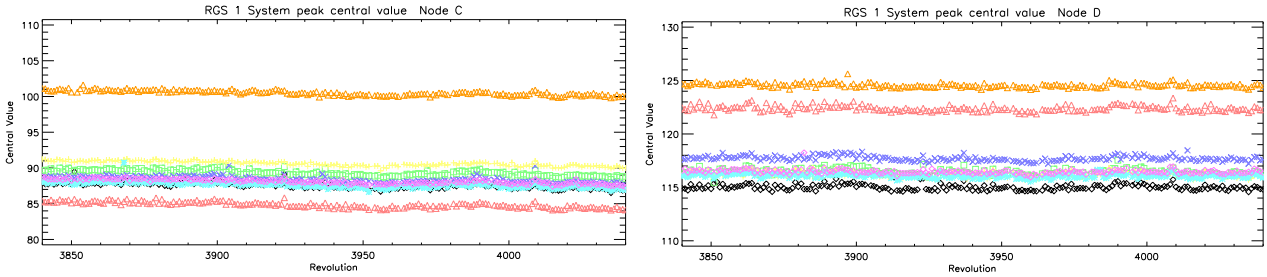

Figure 3: RGS1 - system peak evolution of node C (left) and D (right) since revolution 3840. Same symbols as in figure 1

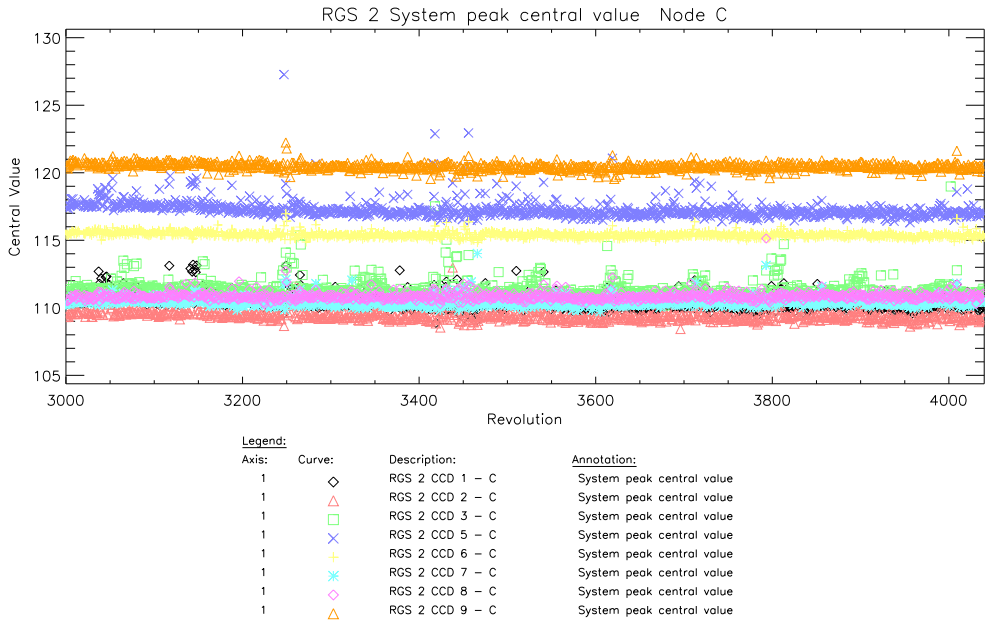

Figure 4: RGS2 - system peak evolution of node C data since revolution 3000.

hot patches in the upper corners near the reading end of CCD1 in RGS1 (see Section 3) and the smoothing of the evolution of the offset values after revolution 532, when the operating temperatures of the RGS were reduced from -80 C to -113 C degrees. This change of temperatures also resulted in a negligible effect of the high radiation events in the pixel offsets.

The default way of subtracting the offsets from the RGS scientific data consists in using the RGS Offset files. These files contain the values derived from the averages of diagnostic images taken during three consecutive revolutions. This has the advantage of resolving the offsets per CCD pixel, covering the variation of the offsets on a pixel by pixel basis. Nevertheless the possibility of subtracting a single offset value per CCD and node is also possible in the SAS (to be used for exceptional cases of lacking diagnostic derived offset files), with the corresponding values contained in the CCF RGS ADUCONV file.

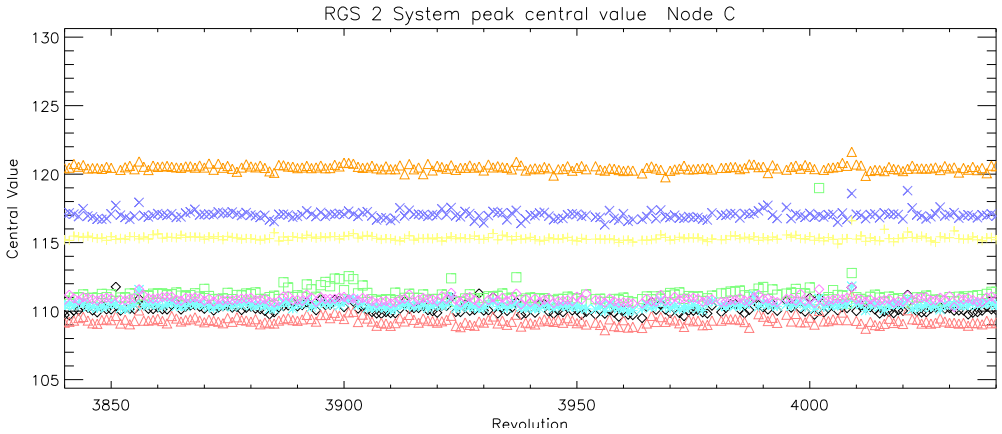

Figure 5: RGS2 - system peak evolution of node C data since revolution 3840. Same symbols as in figure 4

3 Evolution of Hot Columns and Hot Pixels

3.1 Analysis of the Diagnostics data

We have analysed both diagnostic and science data to monitor the evolution of hot columns and pixels of both RGSs. The analysis methods have been discussed in former reports (see XMM-CCF-REL-226[2] and XMM-CCF-REL-370[3]).

There are two persistent hot columns, one in each RGS (RGS1-CCD1-D38 and RGS2-CCD9-C94), as well as the hot spots already reported in several previous reports (e.g.: the latest BADPIX CCF release notes, XMM-CCF-REL-370. The hot columns and the hot spots can be seen in figures 6 and 7

The diagnostic data do not show any new hot column in the last 13 years. The hot spots have not increased their area in the last year either.

The diagnostic bad pixel maps in Figure 6 show the data collected along 2021 corresponding to RGS1 CCD1. We have included the map corresponding to 2017 of the same CCD1 for both nodes to show evolution of the size of the hot spot, clearly marked by the hot column in $X_{CCF} = 38$.

The other permanent hot column detected in the diagnostic data (RGS2-CCD9-C94) is further detected as hot 100% of the time during 2021, as revealed in the corresponding bad pixel map (Fig.7).

[2]https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0226-1-0.ps.gz
[3]https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0370-1-1.pdf

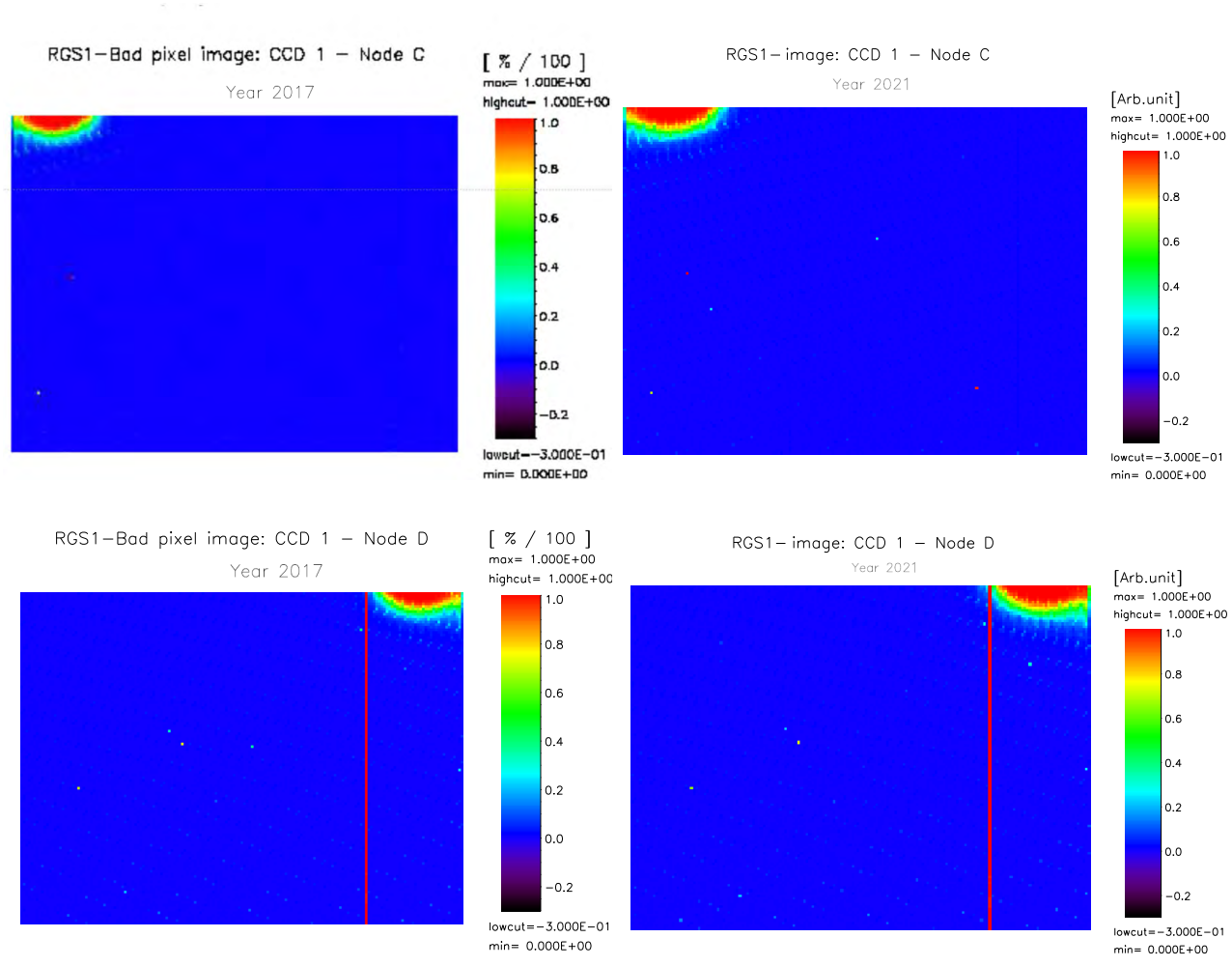

Figure 6: RGS1 - CCD1 node C (up) and D (bottom) bad pixel maps showing the two"hot spots" and the only hot column found in RGS1 in the diagnostic data (column 38 on the D side) in 2017 (left) and 2021 (right).

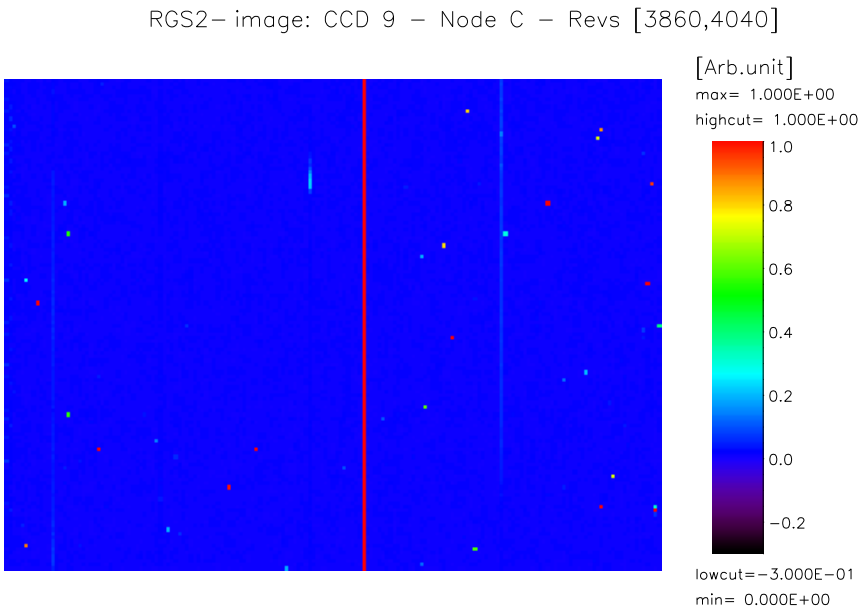

Figure 7: RGS2 - CCD9 C bad pixel maps showing the only hot column detected in the RGS2 Data along last year (already detected in previous years as well).

3.2 Analysis of the Science data

The analysis of the science data is based on the SAS task `rgsbadpix` run over the "ODF". We monitor yearly the number of columns and pixels found to be "hot" by the task, without using the otherwise default parameter `withadvisory=true`, which would be excluding the advisory hot columns and segments present in the valid BADPIX CCF file. In this way we can detect unstable segments and columns, which become hot in certain periods and irregularly.

The map of the bad columns was updated in the on board software (i.e: the CCD pixel segments in the science data that are rejected on board) on the 1^{st} of June, 2021, masking an area of 48 px × 24 px in the upper outer corners of both nodes of RGS1-CCD1. Together with this change on board, the CCF released (RGS1_BADPIX_0040) also contained two new hot columns: RGS1_CCD1_D039 and RGS1_CCD6_C088, flagged as "advisory" as an outcome of the previous RGS Trend Analysis Report (XMM-CAL-TN-0228[4]).

Please refer to XMM-CCF-REL-383[5] for further details on the update of the onboard table of BADPIX and the CCF.

As mentioned in section 3.1, Figure 8 shows that the hot areas in the outer-upper corners of RGS1 CCD1, masked on board, haave slowed, if not stopped, their expansion. The images shown in this section have been produced from the data collected after the update.

Seen on the long term there is a large level of stability in the number of hot stuff found.

[4]https://xmmweb.esac.esa.int/CoCo/CCB/DOC/Attachments/CAL-TN-0228-1-0.pdf
[5]https://xmmweb.esac.esa.int/CoCo/CCB/DOC/Attachments/CAL-SRN-0383-1-0.pdf

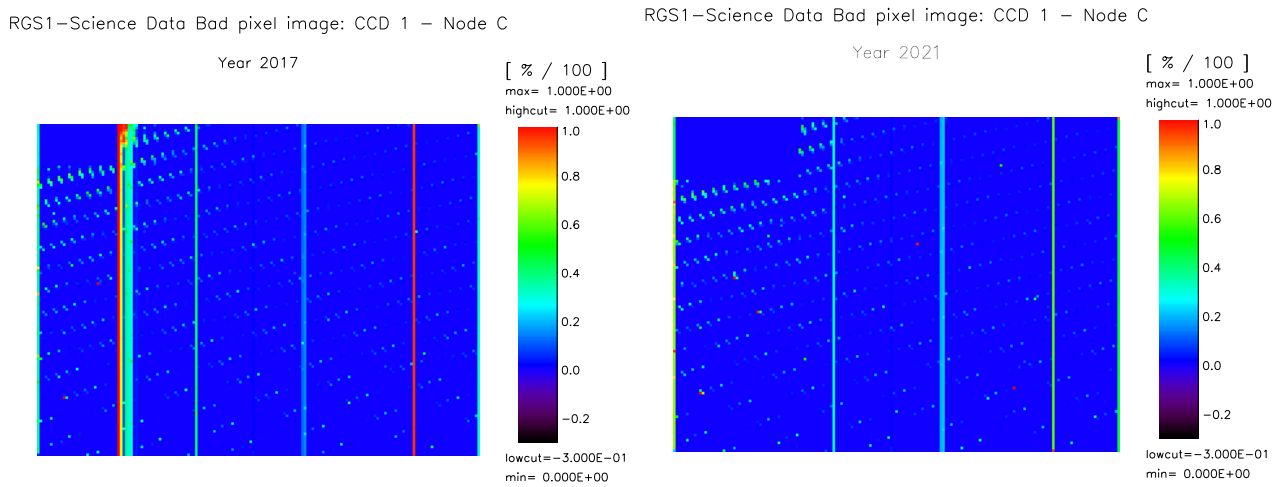

Figure 8: RGS1 - CCD1 bad pixel maps observed in the science data corresponding to data collected along 2017 (left) and 2021 (right).

3.2.1 Number of hot columns per CCD and node

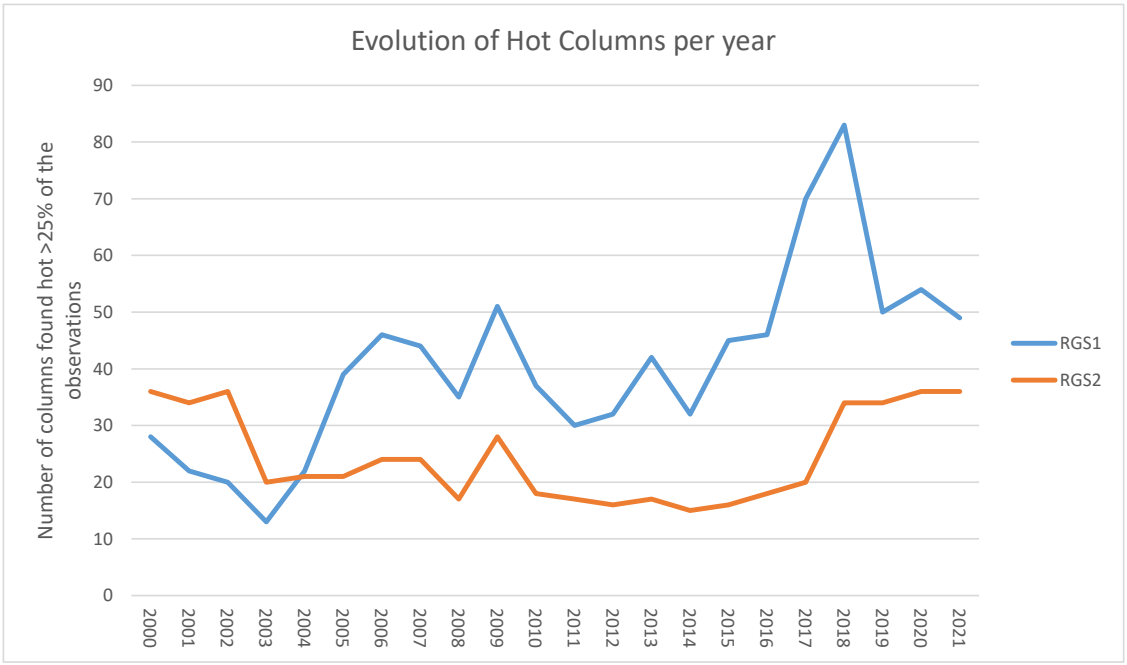

Figure 9: Evolution of the number of columns found hot in more than 25% of the observations.

We have studied the columns found hot in a number of observations along 2021 and traced their evolution in comparisson with the previous years.

Plotting the number of columns found hot $B_c = N_c^{bad}/N_c^{total}$ in more than 25% ($B_c > 0.25$) of

Number of Hot Columns above 25% of the observations in RGS1 per year																		
CCD	1		2		3		4		5		6		7		8		9		Total
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
2000	1	2	2	1	2	3	3	0	1	2	2	3	1	5	0	0	0	0	28
2001	1	2	2	1	2	3	2	0	1	3	2	3	0	0	0	0	0	0	22
2002	1	2	1	1	3	3	2	0	1	1	2	3	0	0	0	0	0	0	20
2003	0	0	0	0	2	0	3	0	1	0	1	3	0	0	3	0	0	0	13
2004	3	0	0	0	4	2	3	0	2	0	2	3	0	0	0	3	0	0	22
2005	13	5	0	0	4	2	3	2	2	0	2	3	0	0	0	3	0	0	39
2006	15	10	0	0	5	2	4	2	1	0	4	3	0	0	0	0	0	0	46
2007	11	6	0	1	6	2	6	1	3	0	4	3	0	0	1	0	0	0	44
2008	4	0	1	1	6	4	6	0	3	2	4	3	0	0	1	0	0	0	35
2009	4	1	1	2	6	4	7	4	4	2	5	5	0	0	3	2	1	0	51
2010	4	0	1	1	6	4	6	0	3	2	4	3	0	0	2	0	1	0	37
2011	3	0	0	1	6	2	6	0	2	1	4	3	0	0	1	0	1	0	30
2012	8	0	0	1	5	2	6	0	2	0	4	3	0	0	1	0	0	0	32
2013	8	0	0	1	6	4	6	0	2	2	4	3	0	0	3	2	1	0	42
2014	7	0	0	1	6	2	6	0	1	0	4	3	0	0	1	0	1	0	32
2015	12	1	0	1	6	4	6	0	3	2	4	3	0	0	2	0	1	0	45
2016	7	9	0	1	6	4	6	0	3	2	5	3	0	0	3	0	1	0	50
2017	9	25	0	1	6	4	7	0	3	2	5	4	0	0	3	0	1	0	70
2018	9	29	1	2	6	4	7	2	3	2	5	5	0	0	3	2	2	1	83
2019	5	3	0	2	6	4	7	2	3	2	5	5	0	0	3	2	1	0	50
2020	6	3	1	2	6	4	7	2	3	2	5	5	0	0	3	2	2	1	54
2021	4	1	1	2	6	4	7	2	3	2	5	5	0	0	3	2	1	1	49

Table 1: Number of columns found hot in at least 25% of the observations in RGS1

the observations analysed (Fig.9), we can see that the consecutive updates of the on board bad pixel tables and the BADPIX CCF have resulted in a decrease of the hot columns from 83 in 2018 to 49 now.

RGS2 follows a well stable trend after the increase noticed in 2018.

For a more detailed study, we have obtained the number of hot columns per CCD and Node at different levels of B_c in the last six years. At the end of this document, tables 5 to 10 show the values for $B_c > 0.50$, $B_c > 0.75$ and $B_c > 0.95$ respectively.

3.2.2 Evolution of columns detected hot above 80% of the observations

In Table 3 we show the evolution of specific hot columns in RGS1 since 2016. This instrument has 9 columns being hot 80% of the observations. Column RGS1_CCD1_C040 has not been hot since the on board bad pixel update mentioned several times along this report. Columns RGS1_CCD1_C146 and RGS1_CCD6_C001, that were hot more than 80% of the observations in 2020, were hot below that threshold this year, although the former was at 78%. These three colums have been removed

Number of Hot Columns above 25% of the observations in RGS2 per year																		
CCD	1		2		3		4		5		6		7		8		9		Total
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
2000	5	2	1	0	0	2	0	0	6	6	4	3	0	0	3	0	3	1	36
2001	4	2	1	0	0	2	0	0	6	4	4	2	1	0	3	0	4	1	34
2002	4	3	1	0	0	2	0	0	7	4	3	2	1	0	4	0	4	1	36
2003	4	2	1	0	0	2	0	0	4	3	0	2	0	1	1	0	0	0	20
2004	4	2	1	0	0	2	0	0	4	3	2	2	0	0	1	0	0	0	21
2005	4	2	1	0	0	2	0	0	4	3	1	2	0	1	1	0	0	0	21
2006	5	2	1	0	0	2	0	0	4	3	1	2	0	1	3	0	0	0	24
2007	5	3	1	0	0	2	0	0	3	3	1	1	0	0	2	2	1	0	24
2008	5	4	1	0	0	2	0	0	1	0	0	0	0	0	1	2	1	0	17
2009	5	4	1	0	0	3	0	0	2	1	1	2	0	0	2	2	3	2	28
2010	5	4	1	0	0	2	0	0	1	0	0	0	0	0	1	2	1	1	18
2011	4	4	1	0	0	2	0	0	1	0	0	0	0	0	1	2	1	1	17
2012	4	4	1	0	0	2	0	0	1	0	0	0	0	0	1	2	1	0	16
2013	5	4	1	0	0	2	0	0	1	0	0	0	0	0	1	2	1	0	17
2014	4	4	1	0	0	2	0	0	1	0	0	0	0	0	1	1	1	0	15
2015	5	4	1	0	0	2	0	0	1	0	0	0	0	0	1	1	1	0	16
2016	5	4	1	0	0	2	0	0	1	1	0	0	0	0	1	1	1	0	17
2017	5	4	1	0	0	3	0	0	1	1	0	0	0	0	2	2	1	0	20
2018	5	5	1	0	1	3	0	0	2	1	2	2	0	0	4	2	4	2	34
2019	5	5	1	0	1	3	0	0	2	1	2	2	0	0	4	2	4	2	34
2020	6	5	1	0	1	3	0	0	2	1	3	2	0	0	4	2	4	2	36
2021	5	5	1	1	1	3	0	0	2	1	3	2	0	0	4	2	4	2	36

Table 2: Number of columns found hot in at least 25% of the observations in RGS2

RGS1: Hot columns above 80% of the observations						
	2016	2017	2018	2019	2020	2021
RGS1_CCD2_D106	0.86	0.90	0.92	0.91	0.92	0.88
RGS1_CCD3_D157	0.67	0.82	0.85	0.83	0.87	0.82
RGS1_CCD3_D093	0.67	0.82	0.85	0.84	0.88	0.83
RGS1_CCD4_C152	0.99	1.00	0.99	0.99	0.99	0.98
RGS1_CCD6_C088	0.83	0.92	0.95	0.96	0.96	0.96
RGS1_CCD6_C124	0.84	0.92	0.95	0.94	0.95	0.94
RGS1_CCD6_D166	0.72	0.86	0.90	0.89	0.90	0.87
RGS1_CCD6_D156	0.99	1.00	0.98	0.99	0.99	0.99
RGS1_CCD6_D076	0.99	1.00	0.98	0.99	0.99	0.99

Table 3: Columns found hot in at least 80% of the observations in RGS1 in nodes C or D in 2021, with their behaviour from 2016.

RGS2: Hot columns above 80% of the observations						
	2016	2017	2018	2019	2020	2021
RGS2_CCD1_C033	0.94	0.97	0.96	0.98	0.98	0.98
RGS2_CCD1_C156	0.84	0.92	0.95	0.94	0.95	0.94
RGS2_CCD1_C159	0.93	0.96	0.96	0.98	0.98	0.97
RGS2_CCD1_D136	1.00	1.00	0.99	1.00	1.00	1.00
RGS2_CCD1_D071	1.00	1.00	0.99	1.00	1.00	1.00
RGS2_CCD3_D151	0.99	1.00	0.98	0.99	0.99	0.99
RGS2_CCD3_D078	0.99	1.00	0.98	0.99	0.99	0.99
RGS2_CCD8_D097	0.71	0.83	0.89	0.90	0.90	0.85

Table 4: Columns found hot in at least 80% of the observations in RGS2 in node C in 2020, with their behaviour from 2016. Notation kept for consistency with RGS1

from the table. The remaining ones showed a bad behaviour since at least 2018.

In the case of RGS2 (see Table 4), only 8 columns are hot above 80% of the observations in the science data. Column RGS2_CCD1_D091 has been hot only in 65% of the observations along 2021, and therefore has been removed from the list. RGS2_CCD8_D097 keeps being hot 85% of the observations.. However, only the already known bad columns have been over 95% in the last three years. These columns (i.e: RGS2_CCD1_C033, RGS2_CCD1_C159, RGS2_CCD1_D071, RGS2_CCD1_D136, RGS2_CCD3_D078 and RGS2_CCD3_D151) are already flagged as `advisory` in the CCF BADPIX.

4 Conclusions

After the analysis of the diagnostic data and hot stuff along 2021, we conclude the following recommendations:

- It is not necessary to release a new RGS1_ADUCONV CCF, containing the average offset values per CCD and node, since the evolution of the Offsets is stable and the differences between the values in that file and the actual levels are less than 5%. For the same reason there is no need of updating the RGS2_ADUCONV CCF either.
- The extension of the hot patch in both the C and D sides of RGS1 CCD1 is stable since the release RGS1_BADPIX_0039 CCF in June, 2021 (see XMM-CCF-REL-381[6]).
- There is no need of changing the CCF for BADPIX for any of the RGSs.
- We will continue the routine monitoring to detect any new effect in the instruments.
- The next trend analysis report will be released at the beginning of 2023.

[6] https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0381-1-1.pdf

RGS1: Number of Hot Columns above 50% of the observations																	
CCD	1		2		3		4		5		6		7		8		9		Total
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
2016	3	3	0	1	2	2	3	0	0	0	2	3	0	0	0	0	0	0	19
2017	3	6	0	1	4	2	4	0	1	0	4	3	0	0	0	0	0	0	28
2018	6	14	0	1	4	2	6	0	1	0	4	3	0	0	1	0	1	0	43
2019	1	0	0	1	5	2	6	0	1	0	4	3	0	0	1	0	1	0	25
2020	2	0	0	1	5	3	6	0	2	0	4	3	0	0	2	0	1	0	29
2021	1	0	0	1	4	2	5	0	1	0	4	3	0	0	1	0	1	0	23

Table 5: Number of columns found hot in at least 50% of the observations in RGS1 in nodes C and D

RGS1: Number of Hot Columns above 75% of the observations																	
CCD	1		2		3		4		5		6		7		8		9		Total
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
2016	2	1	0	1	2	0	2	0	0	0	2	2	0	0	0	0	0	0	12
2017	2	3	0	1	2	2	1	0	0	0	2	3	0	0	0	0	0	0	16
2018	2	4	0	1	2	2	1	0	0	0	2	3	0	0	0	0	0	0	17
2019	1	0	0	1	2	2	1	0	0	0	2	3	0	0	0	0	0	0	12
2020	2	0	0	1	2	2	1	0	0	0	3	3	0	0	1	0	0	0	15
2021	0	0	0	1	0	2	1	0	0	0	2	3	0	0	0	0	0	0	9

Table 6: Number of columns found hot in at least 75% of the observations in RGS1 in nodes C and D

RGS1: Number of Hot Columns above 95% of the observations																	
CCD	1		2		3		4		5		6		7		8		9		Total
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
CCD	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
2016	1	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	4
2017	2	1	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	6
2018	2	2	0	0	0	0	1	0	0	0	2	2	0	0	0	0	0	0	9
2019	0	0	0	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0	4
2020	0	0	0	0	0	0	1	0	0	0	2	2	0	0	0	0	0	0	5
2021	0	0	0	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0	4

Table 7: Number of columns found hot in at least 95% of the observations in RGS1 in nodes C and D

RGS2: Number of Hot Columns above 50% of the observations																	
CCD	1		2		3		4		5		6		7		8		9		Total
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
2016	4	3	1	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	12
2017	4	3	1	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	12
2018	4	4	1	0	0	2	0	0	0	0	0	0	0	0	1	2	0	0	14
2019	4	4	1	0	0	2	0	0	0	0	0	0	0	0	1	2	0	0	14
2020	5	4	1	0	0	2	0	0	0	0	0	0	0	0	1	2	0	0	15
2021	4	4	1	1	0	2	0	0	1	0	0	0	0	0	1	1	0	0	15

Table 8: Number of columns found hot in at least 50% of the observations in RGS2 in nodes C and D

RGS2: Number of Hot Columns above 75% of the observations																	
CCD	1		2		3		4		5		6		7		8		9		Total
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
2016	3	2	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	8
2017	3	2	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	9
2018	3	3	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	10
2019	3	3	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	10
2020	4	3	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	11
2021	3	3	0	1	0	2	0	0	0	0	0	0	0	0	1	1	0	0	11

Table 9: Number of columns found hot in at least 75% of the observations in RGS2 in nodes C and D

RGS2: Number of Hot Columns above 95% of the observations																	
CCD	1		2		3		4		5		6		7		8		9		Total
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
2016	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4
2017	2	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6
2018	3	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	7
2019	2	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6
2020	3	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	7
2021	2	2	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	7

Table 10: Number of columns found hot in at least 95% of the observations in RGS2 in both nodes.