XMM-Newton Technical Note

XMM-CAL-TN-0228

RGS Diagnostic Trend Analysis Report - 2020

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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 December 2020 (revolution 3857).

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 2020.

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 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. 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).

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

Apart from the hot patches in the upper corners near the reading end of CCD1 in RGS1 (see Section 3), the evolution of the offset values became substantially smoother after revolution 532. In that revolution, the operating temperatures of the RGS were reduced from -80 C to -113 C

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

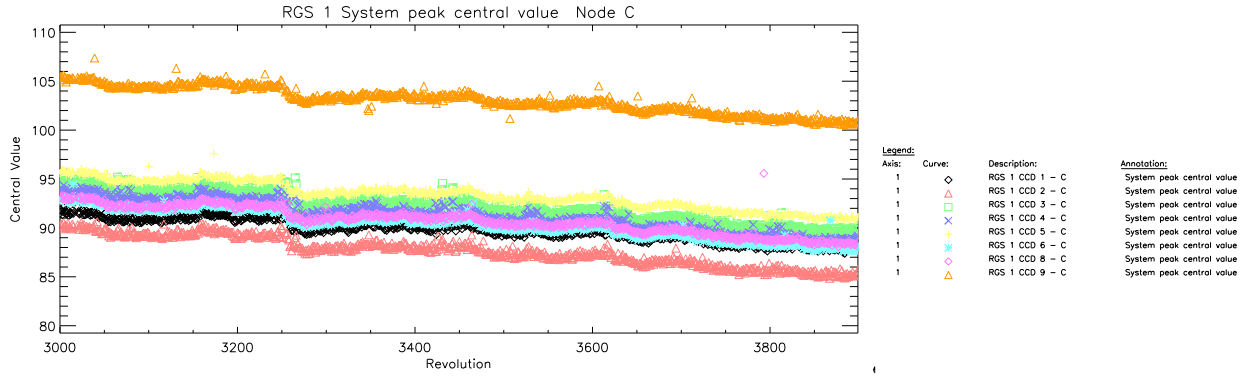

Figure 1: RGS1 - system peak evolution of node C data since revolution 3000.

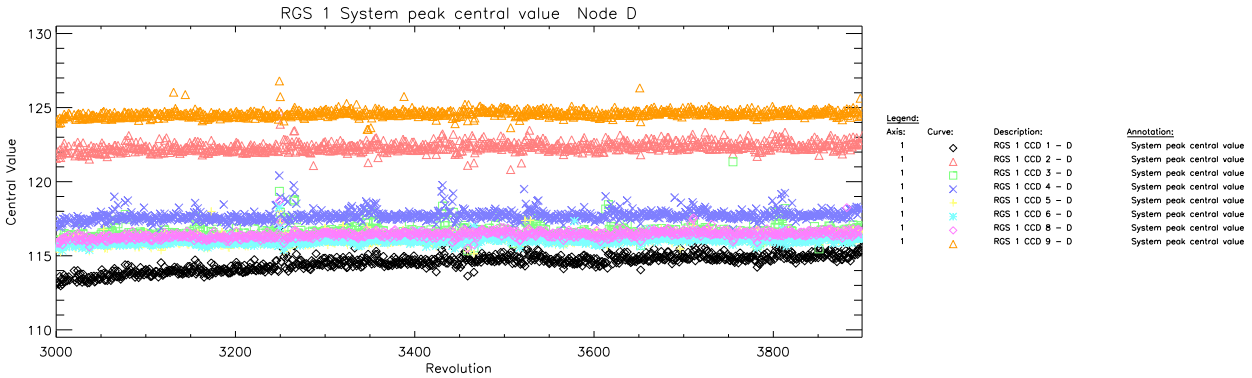

Figure 2: RGS1 - system peak evolution of node D data since revolution 3000.

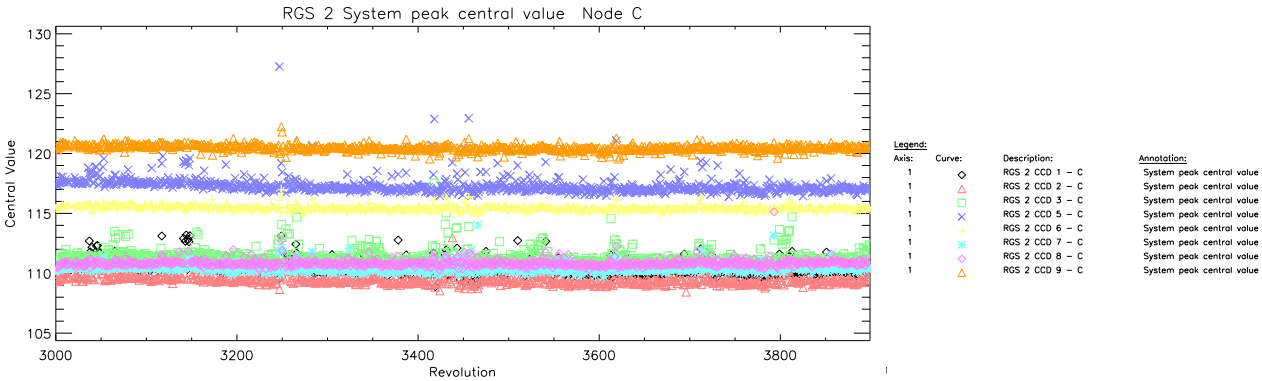

Figure 3: RGS2 - system peak evolution of node C data since revolution 3000.

degrees. A especially remarkable fact is that, while every medium-large to large solar flare produced a sensible change in the offset values during the first period, after cooling down the instruments these were fully insensitive to high radiation events, which continued to happen with approximately the same frequency within the same periods of the solar cycle. This has been extensively commented in previous reports.

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.

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]).

The diagnostic data do not show any increase of hot columns in the last 12 years. There are two persistent hot columns, one in each RGS (RGS1-CCD1-D38 and RGS2-CCD9-C94), as well as the hot spots, whose variation has been reported in the same CCF release notes. The diagnostic bad pixel maps in Figure 4 show the data collected along 2020 corresponding to RGS1 CCD1. Together to node D, we have included the map corresponding to 2017 of the same CCD1 and node to show the expansion 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 2020, as revealed in the corresponding bad pixel map (Fig.5).

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) in March 2019 (please refer to XMM-CCF-REL-370[4] for further details). However, the map of bad pixels and columns loaded on board was set to the previous version during approximately 3.5 months (from the 2nd of October, 2019 to the 16th of January, 2020). This situation has been carefully taken into account during the analysis of the science data by discarding those observations acquired in 2020 with the old version of the Hot Stuff

[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
[4]https://xmmweb.esac.esa.int/docs/documents/CAL-SRN-0370-1-1.pdf

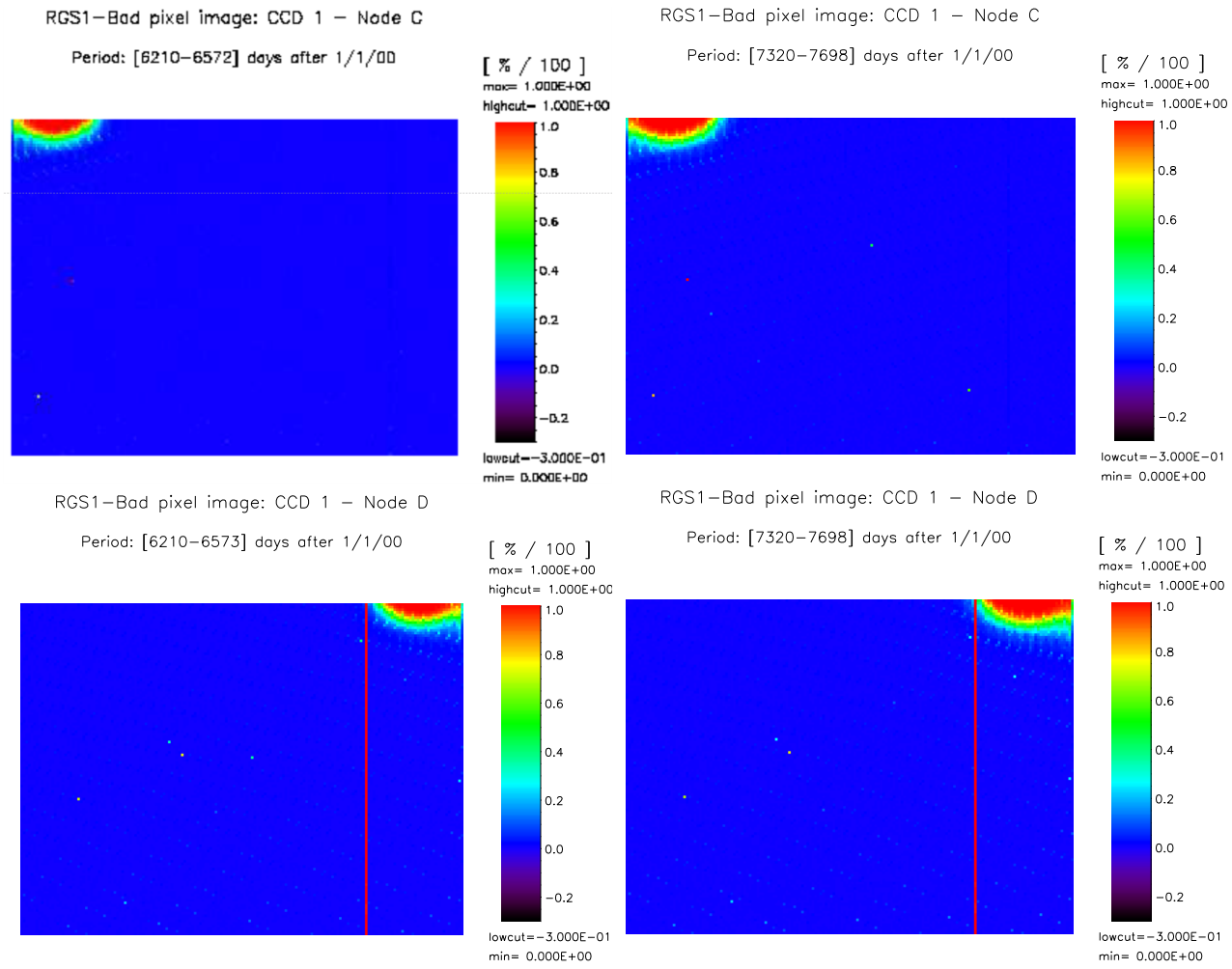

Figure 4: RGS1 - CCD1 node C (up) and D (bottom) bad pixel maps showing the two"hot spots" and the only hot column found in RGS1 in the diagnostic data (column 38 on the D side) in 2017 (left) and 2020 (right).

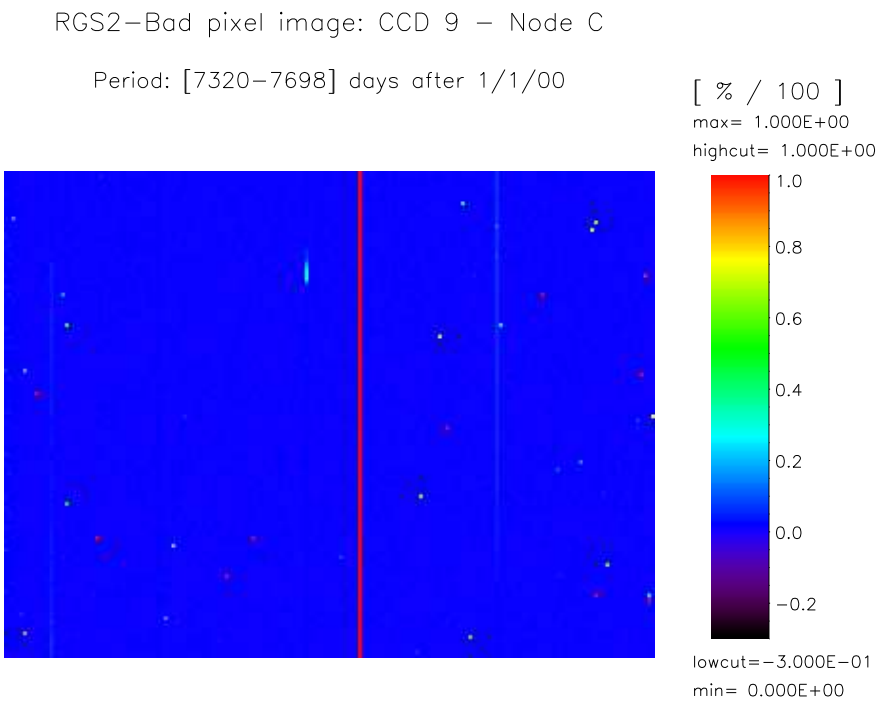

Figure 5: RGS2 - CCD9 C bad pixel maps showing the only hot column detected in the RGS2 Data.

table on board, similarly to what was done in the Trend Analisys Report corresponding to 2019 (see XMM-CAL-TN-0226[5])

As discussed in section 3.1, Figure 6 also shows that the hot areas in the outer-upper corners of RGS1 CCD1 are increasing their size, affecting up to column 43 in both nodes and to rows 105 in node D. This is observed in the science data as hot columns leaking from these hot patches.

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

3.2.1 Number of hot columns per CCD and node

We have studied the columns found hot in a number of observations along 2020 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 the observations analysed (Fig.7), we can see that the significant decrease in 2019 (due to the upload of the hot stuff table on board mentioned above) has been followed by a noticeable increase in 2020. This is due to the expansion of the hot spot in CCD 1, as commented in section 3.1. SAS flags as hot columns below a section of hot pixels, that are not masked on board anymore due to this expansion.

[5] https://xmmweb.esac.esa.int/CoCo/CCB/DOC/Attachments/CAL-TN-0226-1-0.pdf

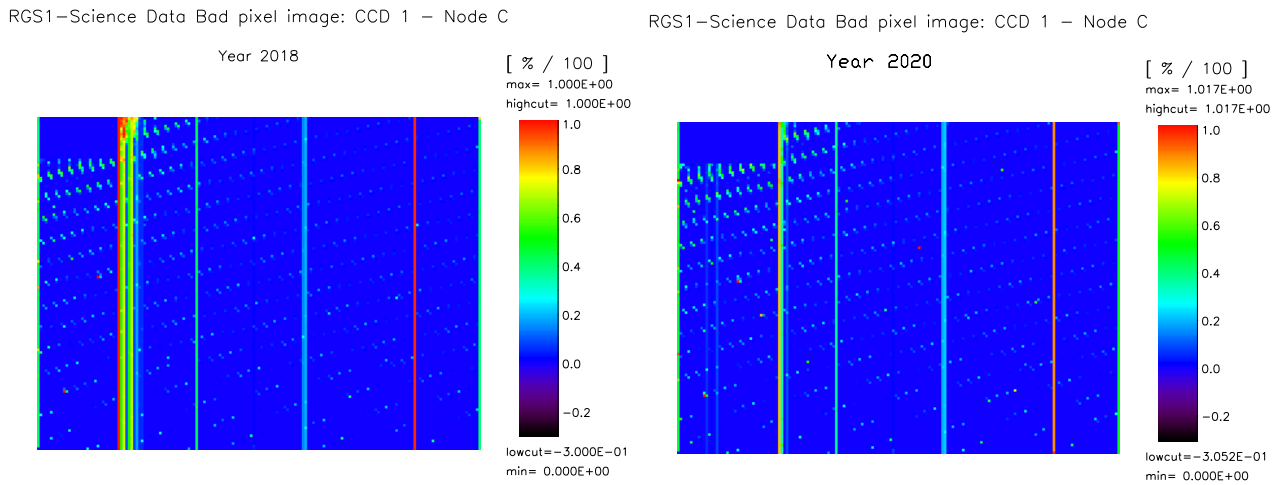

Figure 6: RGS1 - CCD1 bad pixel maps observed in the science data corresponding to data collected along 2018 (left) and 2020 (right). It s noticeable that although the mask in the upper left corner has decreased the number of hot columns below, there are still some hot colums by the internal border due to the expansion of the hot spot.

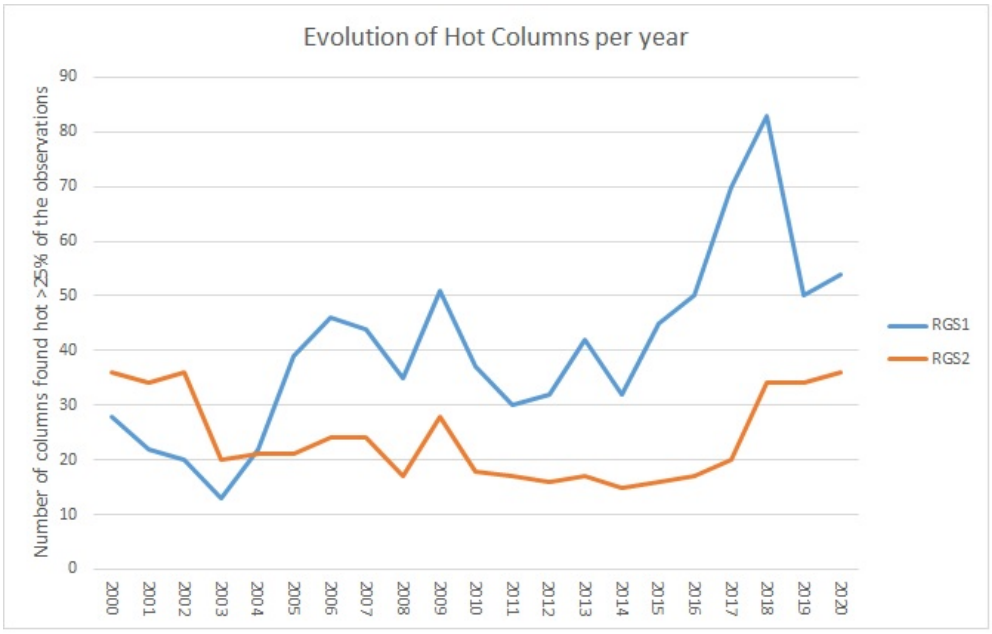

Figure 7: Evolution of the number of columns found hot in more than 25% of the observations.

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 five years. At the end of this document, tables 5 to 10 show the

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

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

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 along the last 5 years. This instrument have 12 columns being hot 80% of the observations. Column RGS1_CCD1_C040 can be associated to the expansion of the hot spot mentioned several times along this report. All the rest showed a bad behaviour since 2016, although RGS1_CCD3_D157, RGS1_CCD3_D093, RGS1_CCD6_C001 and RGS1_CCD6_D166 have increased the ratio above 80% along the last years. Columns RGS1_CCD1_D039 and RGS1_CCD6_C088 have been hot over 95% of the observations for the last threee years, what qualifies them as *advisory hot* in the CCF BADPIX. On the other hand, column RGS1_CCD1_C146 has decreased its ratio to below 95% since 2019.

In the case of RGS2 (see Table 4), only 9 columns are hot above 80% of the observations in the science data. Two of them have been hot for more than an 80% of the observationd once 2016: RGS2_CCD1_D091 and RGS2_CCD8_D097. 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

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

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

RGS1: Hot columns above 80% of the observations					
	2016	2017	2018	2019	2020
RGS1_CCD1_C040				0.40	0.82
RGS1_CCD1_C146	0.93	0.96	0.96	0.81	0.88
RGS1_CCD2_D106	0.86	0.90	0.92	0.91	0.92
RGS1_CCD3_D157	0.67	0.82	0.85	0.83	0.87
RGS1_CCD3_D093	0.67	0.82	0.85	0.84	0.88
RGS1_CCD4_C152	0.99	1.00	0.99	0.99	0.99
RGS1_CCD6_C001	0.41	0.55	0.69	0.69	0.81
RGS1_CCD6_C088	0.83	0.92	0.95	0.96	0.96
RGS1_CCD6_C124	0.84	0.92	0.95	0.94	0.95
RGS1_CCD6_D166	0.72	0.86	0.90	0.89	0.90
RGS1_CCD6_D156	0.99	1.00	0.98	0.99	0.99
RGS1_CCD6_D076	0.99	1.00	0.98	0.99	0.99

Table 3: Columns found hot at least 80% of the observations in RGS1 in nodes C or D in 2020, with their behaviour from 2016.

RGS2: Hot columns above 80% of the observations					
	2016	2017	2018	2019	2020
RGS2_CCD1_C033	0.94	0.97	0.96	0.98	0.98
RGS2_CCD1_C156	0.84	0.92	0.95	0.94	0.95
RGS2_CCD1_C159	0.93	0.96	0.96	0.98	0.98
RGS2_CCD1_D136	1.00	1.00	0.99	1.00	1.00
RGS2_CCD1_D091	0.55	0.66	0.81	0.81	0.83
RGS2_CCD1_D071	1.00	1.00	0.99	1.00	1.00
RGS2_CCD3_D151	0.99	1.00	0.98	0.99	0.99
RGS2_CCD3_D078	0.99	1.00	0.98	0.99	0.99
RGS2_CCD8_D097	0.71	0.83	0.89	0.90	0.90

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

flagged as `advisory` in the CCF BADPIX.

4 Conclusions

After the analysis of the diagnostic data and hot stuff along 2020, we conclude following recommendations:

- It is not necessary to release a new RGS1_ADUCONV CCF, containing an update of the average offset values per CCD and node, since the evolution of the Offsets has stabilised and the differences between the numbers quoted in that file and the actual levels are less than 5%.
- The extension of the affected patch in both the C and D sides of RGS1 CCD1 have been already detected and analysed in the previous report. It has been addressed with the release of an update of CCF RGS1_BADPIX_0039 (see XMM-CCF-REL-381), where the new area has been flagged as hot.
- In parallel, a new version of the Hot Stuff table on board has been developed and tested. It is about to be released at the time of writing this report. It will be included in the DPP v3 19 16 20. Once the onboard table is updated, we will release a new CCF containing the new hot spot as uploaded instead of as advisory.
- The RGS1 CCF for badpixels will contain RGS1_CCD1_D039 and RGS1_CCD6_C088 as new advisory hot columns, and will drop RGS1_CCD1_C146.
- There is no need of changing the RGS2 CCF for BADPIX.
- We will continue the routine monitoring to trace the effects of these last items and to detect any new effect in the instruments.
- The next trend analysis report will be released at the beginning of 2022.

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

Table 5: Number of columns found hot 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

Table 6: Number of columns found hot 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

Table 7: Number of columns found hot 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

Table 8: Number of columns found hot 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

Table 9: Number of columns found hot 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

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