The Behaviour of the XMM–Newton Background: From the beginning of the mission until May 2011

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1 Introduction

This document supersedes XMM-SOC-USR-TN-0014, issue 3.2 The sample analysed here includes data obtained until May 1st 2011, while the previous version covered only until May 2010. The conclusions remain basically unchanged with respect to the previous issue.

The aim of this document is to study the seasonal and long-term behaviour of the XMM-Newton Background. For this purpose we have examined the background in RGS1 and EPIC–pn science observations taken from the beginning of the mission until May 2011.

The first version of this document, issued in January 2007, fulfilled the recommendation made by the XMM–Newton Users Group *"to reassess the EPIC background loading for a 1 year sample in order to investigate a seasonal dependence" (rec. 2006-05-19/34)*.

The contributors to the EPIC and RGS background are described in detail in the XMM-Newton User's Handbook and in the XMM Background Analysis page[1]. This is a short summary of the most relevant features:

The EPIC background has two components: a cosmic X–ray background, and an instrumental background. The latter can be further divided into a detector noise component (dominant below 200 eV) and a second component due to the interaction of particles with the structure surrounding the detectors and the detectors themselves. This component is particularly important above a few keV.

The particle induced background has in turn two components: a stable internal component, due to the interaction of high-energy particles (energies above some 100 MeV) with the structure surrounding the detectors and possibly the detectors themselves, and an external "flaring" component, characterised by strong and rapid variability. This flaring component is attributed to soft protons (with energies below a few 100 keV), which are presumably funnelled towards the detectors by the X–ray mirrors.

The RGS background has also several components, the dominant one being soft protons entering through the mirrors.

[1] http://xmm2.esac.esa.int/external/xmm_sw_cal/background/index.shtml

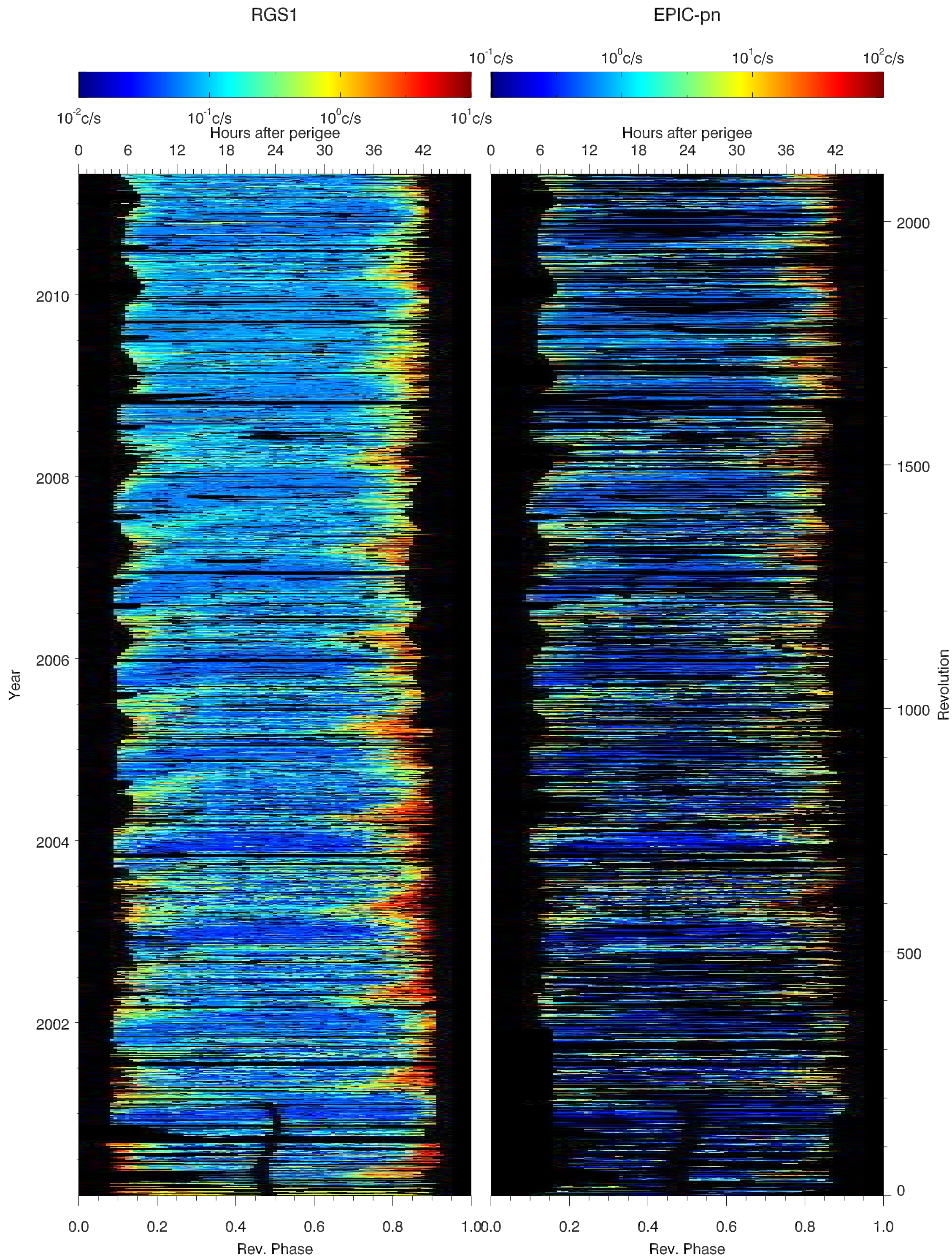


Figure 1: Behaviour of the background in RGS1 (left) and EPIC–pn (right) since the beginning of the mission until May 2011. The selection criteria in Mode/Filter makes EPIC–pn data to be more scarce than RGS. In addition, EPIC–pn science exposures are generally stopped earlier than RGS exposures when approaching perigee passage.

The current understanding is that soft protons are most likely organised in clouds populating the Earth's magnetosphere. The number of such clouds encountered by XMM–Newton in its orbit depends upon many factors, such as the altitude of the satellite, its position with respect to the magnetosphere, and the amount of solar activity.

2 Data Sample and Methodology

In this study we have used the following datasets:

- RGS1 (6792 exposures)
  - RGS1 data since the beginning of the operational phase until May 1st 2011.
  - Spectroscopy mode
  - Background indicator: countrate in CCD9 off axis region (> 1 arcmin away from the on-axis position)
    `(CCDNR==9 && (XDSP_CORR < -0.0003 || XDSP_CORR > 0.0003))`
- EPIC–pn (3655 exposures)
  - EPIC–pn data since the beginning of the operational phase until May 1st 2011
  - Full Frame or Extended Full Frame mode with THIN or MEDIUM filter.
  - Background indicators: high energy events
    `(FLAG==0) && (PI>10000) && (PATTERN==0)`

3 Mission Planning constraints and Operational Procedures

The Radiation Monitor (RM) on–board XMM–Newton is mainly used to detect the entry/exit to/from the Earth radiation belts. Whenever the RM flux is higher than a given threshold (*Radiation Monitor Warning Flag Active*) the MOS cameras are kept closed or commanded to SAFE-STANDBY mode, EPIC-pn is commanded to IDLE mode with the CLOSED filter, and RGS is commanded to SETUP mode. The RM Warning Flag can also be set to “active” during solar flares, leading to the interruption of science observations.

Even before the limit for the RM Warning Flag goes to “active”, high radiation (due either to proximity to perigee or to low–energy protons flares) can be identified with the information provided by the X–ray science instruments, basically the countrate in the MOS peripheral CCDs, in RGS CCD9 and the EPIC–pn Discarded Lines.

Generally speaking, RGS is stopped at higher radiation levels than EPIC. For this reason RGS data have a more complete coverage of the end of the revolution.

In April 2005, science observations started to be scheduled only in the part of the orbit predicted as “low–radiation” by the model by Casale and Fauste (2004). The “high–radiation” time, at the beginning and/or at the end of the revolution, was used for EPIC observations with the filter wheel in the CALCLOSED position (if there was enough time available).

After the implementation of new operational procedures in the MOC in October 2008, CALCLOSED observations at the end of the revolution were dropped. Currently, the last science observation in the revolution is scheduled to last until the end of the Science Window, and it is stopped before only if the radiation reaches the critical level.

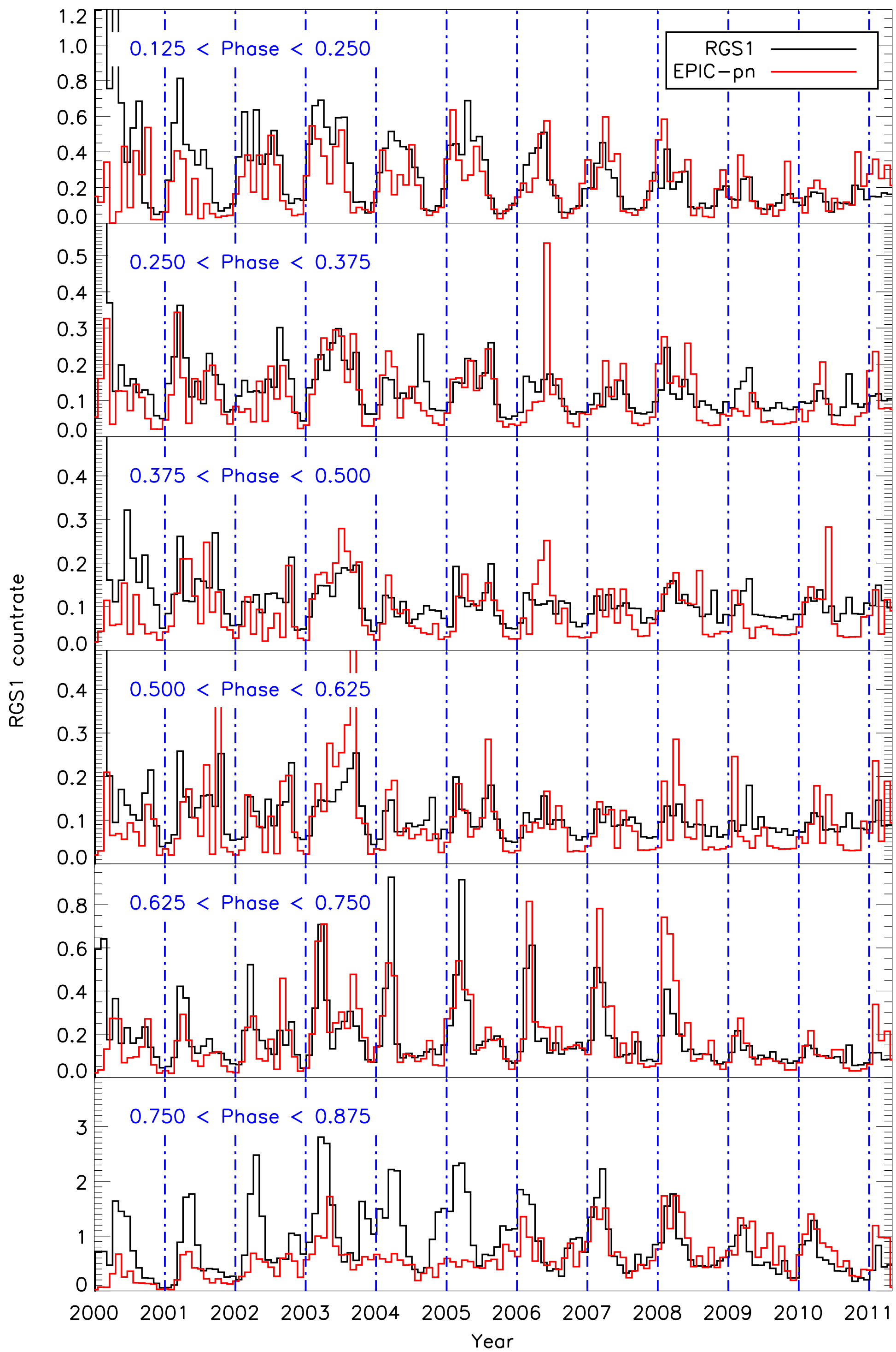
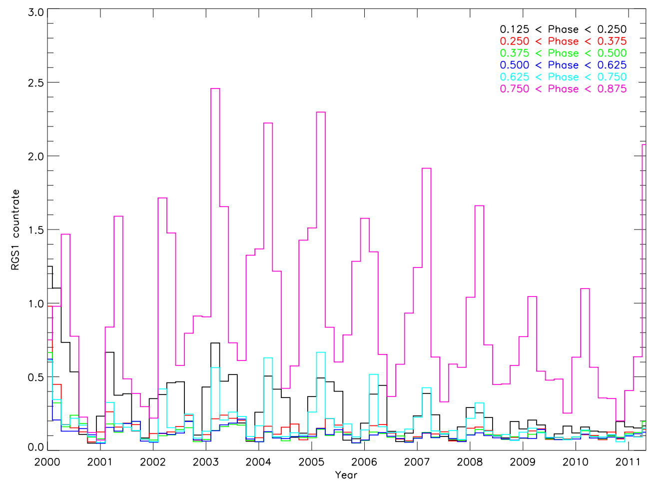


Figure 2: Evolution of the background along the years in different parts of the revolution. Data have been averaged in one month bins. RGS1 is shown in black and EPIC–pn in red. Units are RGS1 cts/s. EPIC–pn data have been arbitrarily scaled and slightly shifted in time for clarity. Note that the different scale in each panel.



Countrate at apogee

Year	Rate ± std
2000	0.17 ± 0.09
2001	0.13 ± 0.06
2002	0.11 ± 0.05
2003	0.13 ± 0.06
2004	0.09 ± 0.03
2005	0.10 ± 0.04
2006	0.09 ± 0.03
2007	0.09 ± 0.03
2008	0.10 ± 0.04
2009	0.09 ± 0.03
2010	0.09 ± 0.03

Figure 3: Similar to Fig. 2, but showing the RGS1 background in different parts of the revolution with the same scale. Data have been averaged in two months bins for clarity. The table on the right lists the average yearly countrate (and its standard deviation) near apogee, between phases 0.45 and 0.55.

4 Overall Trend

Fig. 1 shows the evolution of the background in RGS1 (left) and EPIC–pn (right). It must be noted that, due to the selection of EPIC–pn mode and filter, EPIC data are more scarce. Also, RGS tends to be on for a longer time at the end of the revolution. The conclusions of this report are therefore based mainly on the RGS1 data. As shown below, within the intrinsic scatter in the data, there are not significant differences in the behaviour of the background in both instruments.

In what follows, we have divided the revolution in six parts, from phase 0.125 to 0.875, of ≈ 21.6 ksec each. We refer to the first two parts as the *beginning of the revolution*, to the next two as the *apogee*, and to the remaining two as the *end of the revolution*.

5 Secular Variations

The evolution of the background along the years is shown in Figs. 2 and 3. First thing to note is the agreement in the behaviour of the background in both instruments, which justifies that we base our results mainly in the RGS1 data, due to the poorer coverage of the EPIC–pn data.

There is not any clear long-term trend in the evolution of the background: it has neither increased nor decreased significantly along the eleven years of the mission. The largest changes are seen at the end of the revolution (two bottom panels of Fig. 2), where the peaks of the background increased steadily from 2000 to 2003–2005 (depending on the instrument), and started to decline afterwards. The large differences between RGS1 and EPIC–pn at the very end of the revolution are explained by the scarcity of EPIC data since, as explained above, RGS stays on for a longer time when the radiation is high.

6 Seasonal and Orbital Variations

Figs. 4 and 5 show the behaviour of the monthly background. According to Casale and Fauste (2004), the observed strong seasonal dependence is explained by the asymmetry of the Earth magnetic field along the sunward–antisun line.

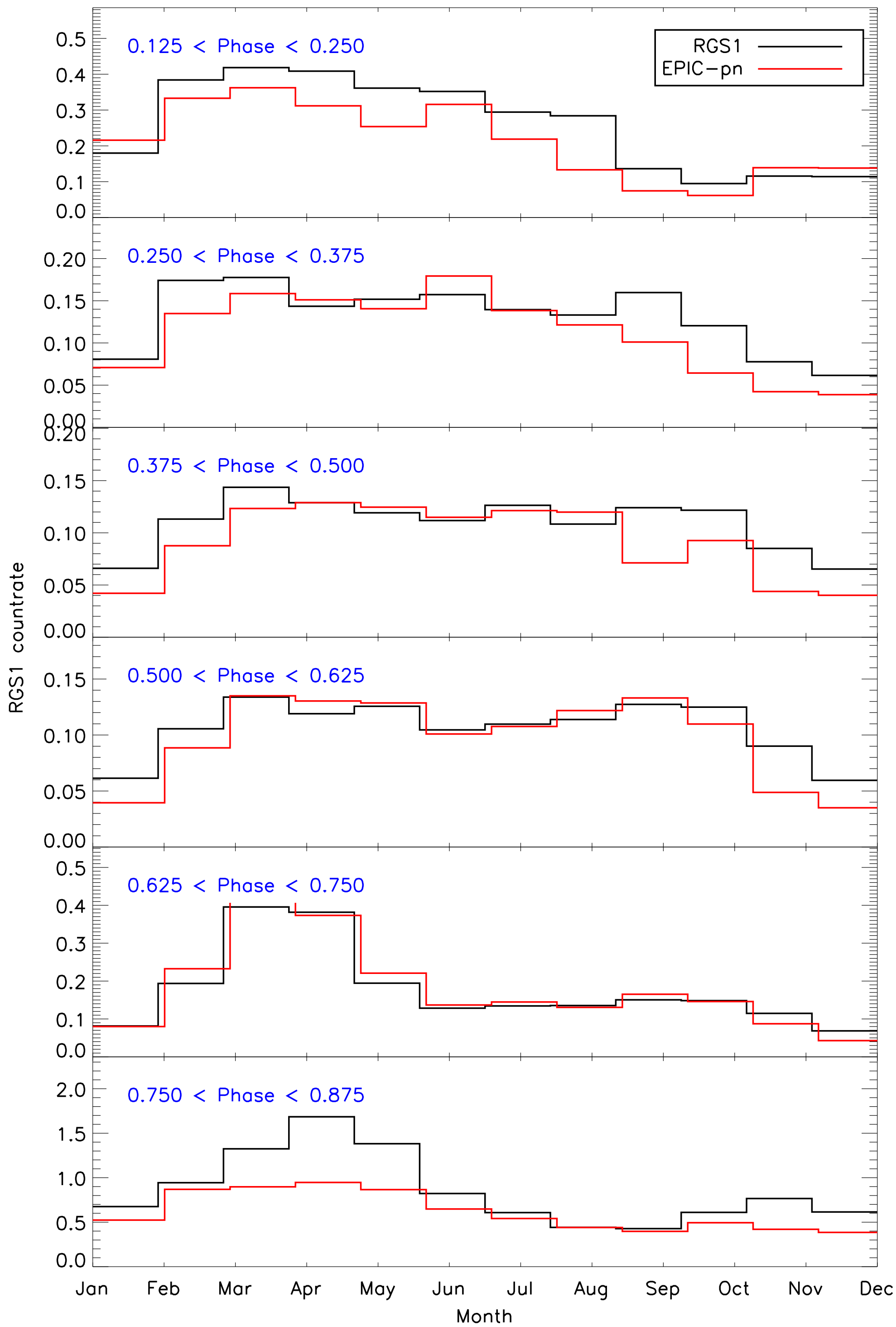


Figure 4: Behaviour of the monthly background in different parts of the revolution. RGS1 is shown in black and EPIC–pm in red. Units are RGS1 cts/s. EPIC–pn data have been arbitrarily scaled and slightly shifted in time for clarity. Note that the different scale in each panel.

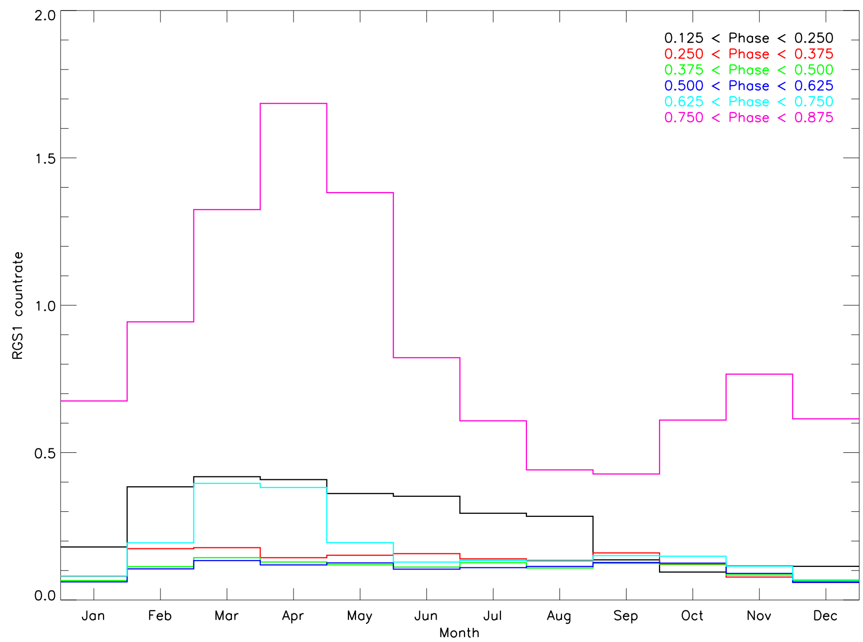


Figure 5: Similar to Fig. 4, but showing the monthly RGS1 background in different parts of the revolution with the same scale.

6.1 The beginning of the revolution

The background at the beginning of the revolution shows a strong "seasonal" effect. The radiation is higher from February to August, while it is lower the rest of the year, reaching the minimum in December and January. The level of the background in the first hours of the revolution may vary by a factor eight along the year. The amplitude of this seasonal variation becomes smaller when approaching apogee.

6.2 The apogee

The behaviour of the background close to apogee is similar to what is observed at the beginning of the revolution: it does not vary significantly during most of the year (March to October), but shows a marked minimum that lasts for about two months (December and January). The level of the background changes by no more than a factor two along the year. If we consider only the period March–October, the amplitude of the variations is a factor 1.5.

6.3 The end of the revolution

The highest background levels and the largest seasonal variations are observed in the second half of the revolution. There is a pronounced maximum around March-April, when the radiation can be up to eight times higher than in August-September. In addition to this, in spring the high–radiation time starts shortly after apogee. The intensity of the peak has been steadily increasing until 2003–2005 (depending on the considered phase), but has decreased since then.

Table 1: Average monthly RGS1 Background Countrate*

	Phase in Revolution [Hours after perigee]					
Month	0.125-0.250 [6-12]	0.250-0.375 [12-18]	0.375-0.500 [18-24]	0.500-0.625 [24-30]	0.625-0.750 [30-36]	0.750-0.875 [36-42]
January	0.18 (0.06)	0.08 (0.02)	0.07 (0.02)	0.06 (0.02)	0.08 (0.04)	0.68 (0.48)
February	0.38 (0.31)	0.17 (0.25)	0.11 (0.17)	0.11 (0.16)	0.19 (0.15)	0.94 (0.58)
March	0.42 (0.29)	0.18 (0.15)	0.14 (0.11)	0.13 (0.07)	0.40 (0.23)	1.32 (0.70)
April	0.41 (0.21)	0.14 (0.04)	0.13 (0.04)	0.12 (0.03)	0.38 (0.20)	1.68 (0.72)
May	0.35 (0.19)	0.15 (0.04)	0.12 (0.03)	0.13 (0.03)	0.19 (0.08)	1.37 (0.61)
June	0.35 (0.20)	0.16 (0.08)	0.11 (0.04)	0.10 (0.04)	0.13 (0.04)	0.82 (0.34)
July	0.29 (0.21)	0.14 (0.06)	0.13 (0.07)	0.11 (0.03)	0.14 (0.05)	0.61 (0.22)
August	0.28 (0.20)	0.13 (0.04)	0.11 (0.04)	0.11 (0.04)	0.14 (0.06)	0.44 (0.16)
September	0.14 (0.14)	0.16 (0.09)	0.12 (0.06)	0.13 (0.05)	0.15 (0.06)	0.43 (0.13)
October	0.09 (0.04)	0.12 (0.05)	0.12 (0.05)	0.12 (0.07)	0.15 (0.05)	0.61 (0.24)
November	0.12 (0.06)	0.08 (0.02)	0.09 (0.03)	0.09 (0.05)	0.11 (0.04)	0.77 (0.56)
December	0.11 (0.05)	0.06 (0.02)	0.07 (0.01)	0.06 (0.01)	0.07 (0.01)	0.61 (0.45)

For reference, the months of minimum and maximum level for each different part of the revolution are marked in green and red, respectively

* The numbers in parenthesis are the standard deviation of the monthly averages

7 Conclusions

The results of this work are summarised in Table 1 and Figures 6 and 7. The table lists the monthly average RGS1 countrate in the different parts of the revolution. Also listed are the standard deviations of each monthly average (i.e. the standard deviation of the monthly averages of the different years). Large standard deviations indicate large year-to-year variations in the given month.

Data clearly show that, although the distance to the Earth is the dominant parameter (as expected, the background is lower close to apogee), it is not the only one, since there is a marked asymmetry in the behaviour of the background when moving away from perigee and when approaching to it.

We do not observe any important long-term change in the behaviour of the background. It has neither increased nor decreased significantly since the beginning of the mission.

The background reaches higher values at the end of the revolution than at the beginning. The high background time does not extend usually beyond orbital phase 0.2 (i.e. ≈ 10 hours after apogee). There are however epochs of the year (around Spring) in which the background starts to rise shortly after apogee.

The behaviour of the background presents a pronounced seasonal effect, independently of the part of the revolution considered. However, while the range of the variations of the background near perigee along the year is not more than a factor two, variations of factors up to five to seven are observed at the extremes of the revolution. Even in the most favourable conditions, the background at the end of the revolution is much higher than the highest value observed at apogee.

References

"XMM-Newton Users Handbook", Issue 2.9, 2011 (ESA: XMM-Newton SOC). (http://xmm.esac.esa.int/external/xmm_user_support/documentation/uhb/index.html)

Casale, M. and Fauste, J., 2004,"Attempt of Modelling the XMM-Newton Radiation Environment" (http://xmm2.esac.esa.int/~xmmdoc/CoCo/CCB/DOC/Attachments/OPS-TN-0004-1-0.pdf)

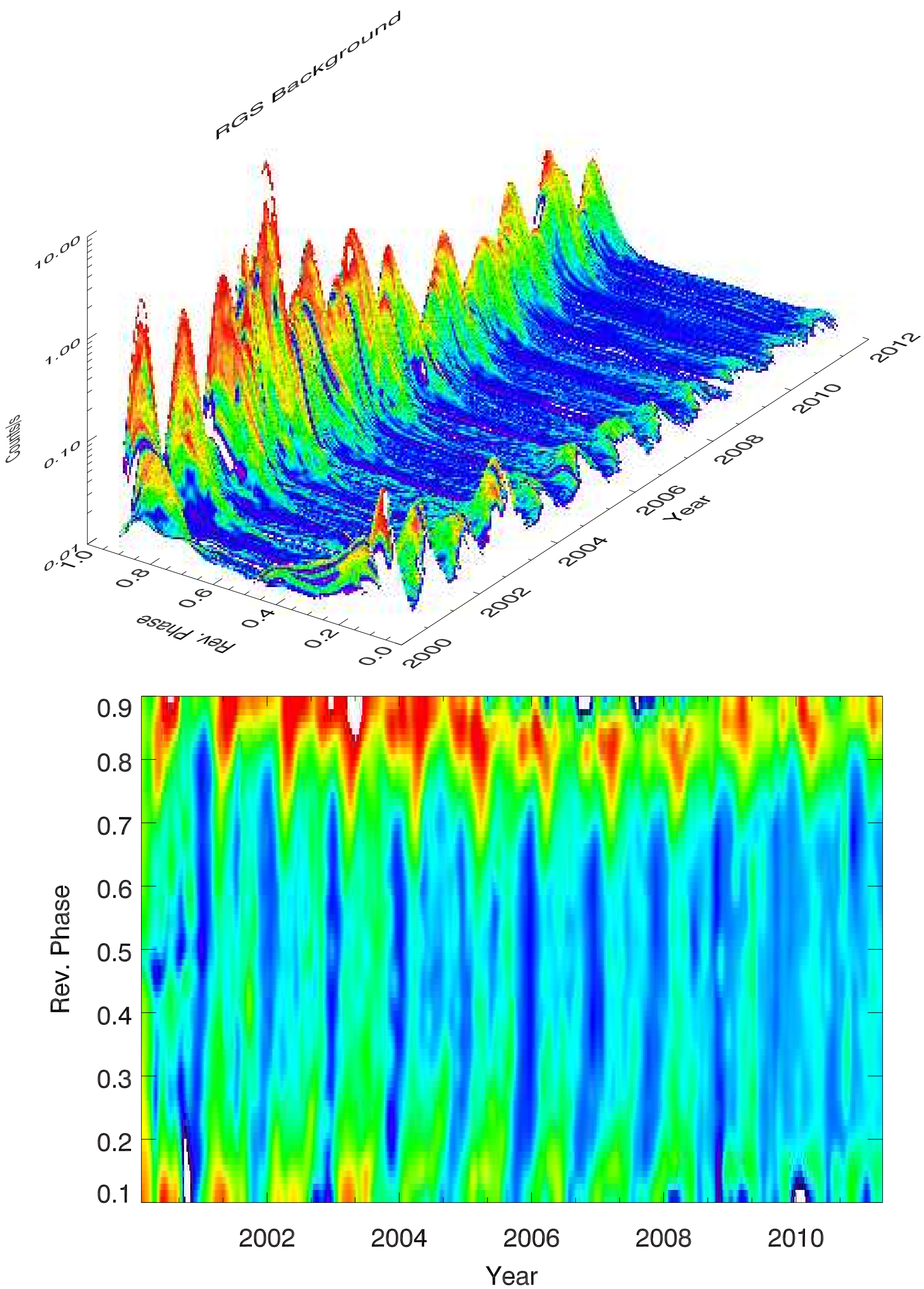


Figure 6: Top: Three–dimensional representation of the RGS1 background by date and by phase in the revolution; Bottom: Projection of the above surface in the Year/Phase plane.

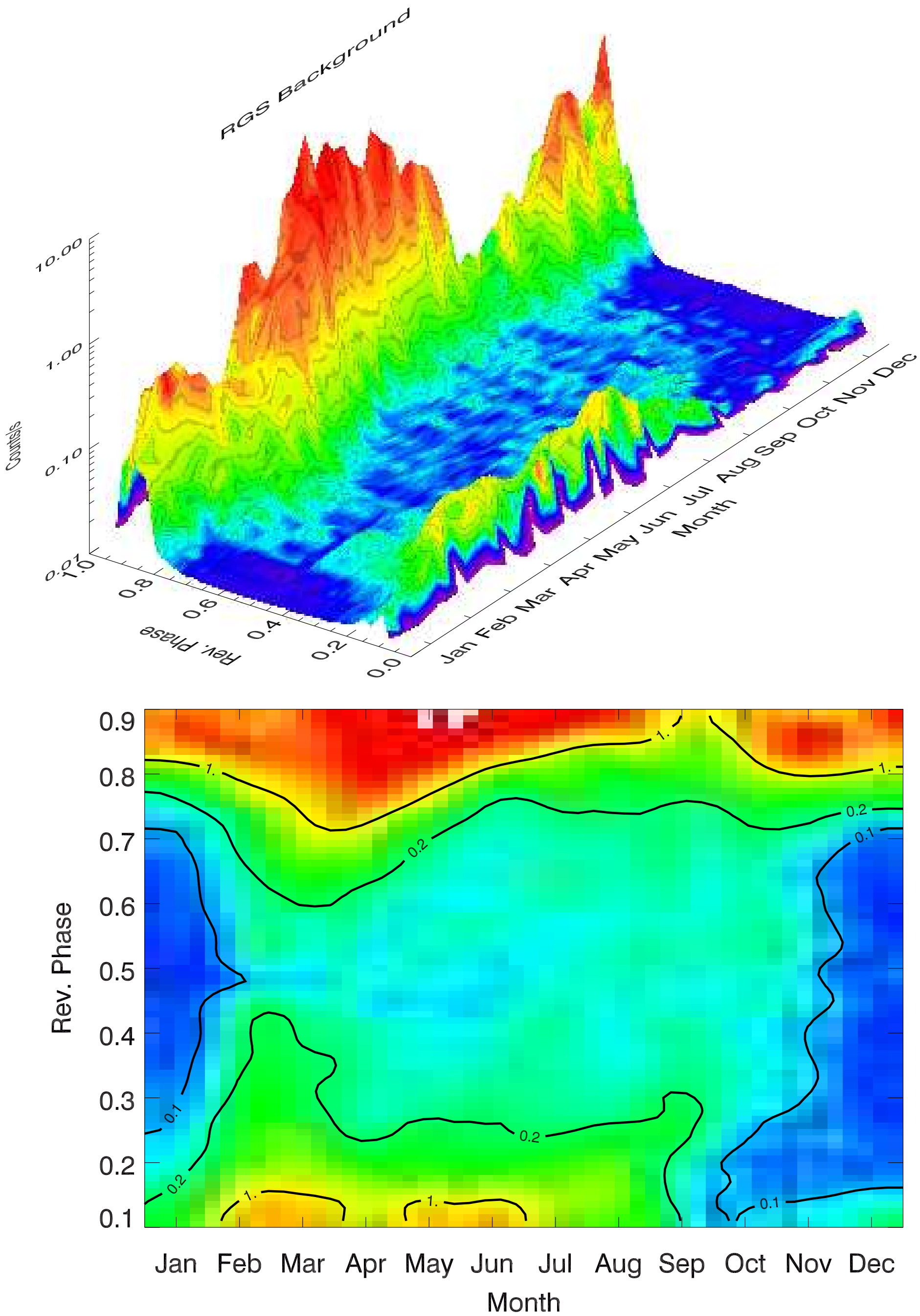


Figure 7: Top: Three–dimensional representation of the RGS1 background by month and by phase in the revolution; Bottom: Projection of the above surface in the Month/Phase plane, showing the contours corresponding to 0.1, 0.2 and 1 cts/s, that define he regions of low (dark blue), medium (light blue–green) and high (yellow–red) background.