Background Rates vs Geomagnetic Rigidity from *Beppo*SAX/PDS and Particle Monitor Measurements

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Abstract: In order to characterize the background of the High Energy instrument aboard the Hard X–ray Modulation Telescope mission, the background measured by the Phoswich Detection System aboard the *Beppo*SAX satellite could be used as baseline.

From this preliminary analysis, the geomagnetic rigidity seems a good candidate for describing the *HXMT* background, because it is a valid indicator of the particle environment around the orbit.

On the other hand, the use of the PDS background light curves could not be very suitable to model the *HXMT* background, because of the much lower modulation with respect to the one expected for *HXMT*.

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Contents

List of Figures

List of Tables

1 Introduction

In order to characterize the background of the High Energy (HE) instrument aboard the Hard X–ray Modulation Telescope (*HXMT*) mission, the background measured by the Phoswich Detection System (PDS) aboard the *Beppo*SAX satellite could be used as baseline.

It is important to stress that this analysis must take into account the completely different orbit inclination of the two missions (43° for *HXMT* vs 3.9° for *Beppo*SAX). The particle environment around the instruments is therefore completely different, and the PDS readouts have to be taken as just indicative. In particular, the orbital modulation in the background is very small, and the duty cycle due to the switch-off during the South Atlantic Geomagnetic Anomaly (SAGA) passages (which were marginal in the case of *Beppo*SAX) is such that at most 20 minutes of scientific data are lost during the ~90 minute orbit (see Figure 4 in [1]).

Another important difference is due to the fact that the PDS background is evaluated in real time by means of the rocking of the collimators. For the HE aboard *HXMT* it will be evaluated by measuring the count rates from a blind (that is, covered) detector, and by means of a background model, that will take into account also the particle environment along the orbit.

Because of this latter point, we think that an important parameter characterizing the particle environment could be the geomagnetic rigidity (GR).

In the following we will present the dependence on the GR of both the count rates as measured directly by the instrument (in Section 2), and detected by the PM (in Section 3).

Details on the analysis of the SAGA characterization as measured by the PM aboard *Beppo*SAX can be found in Campana et al. (2014) [1].

2 Dependency of the PDS background count rate

In Fig. 1 we show a typical 100 ksec PDS background time series. Each data segment corresponds to a *Beppo*SAX orbit. Note the almost absence of any modulation. In the lower panel we show the corresponding value of the GR.

In order to check whether there is a correlation between these two quantities, we plot in Fig. 2 the PDS background rate as a function of the GR for the same data. We then fit the data with polynomials up to the third degree, and the results are summarized in Table 1. As we can see, there is a small modulation in the data (a third degree polynomial fits better the data), but on timescales larger than thousand seconds.

In Table 2 we report the measured background rates obtained by considering the +OFF spectra corresponding to three different ranges of the GR. As expected, the background level decreases with increasing rigidity. On the other hand, the ratio between the rates in different energy bands are the same for all the three rigidity intervals, indicating that the spectral shape of the background seems not to be strongly dependent on rigidity.

Finally, it is important to emphasize that, because of its limited field of view ($\sim 1.^\circ 3 \times 1.^\circ 3$), the diffuse cosmic background gives a negligible contribution to the PDS intrinsic background. For this reason the PDS intrinsic background is mainly due to interactions of cosmic particles with the payload materials.

3 Dependency of the Particle Monitor count rate

Because the GR measures the ability of a particle to penetrate into the Earth magnetic field, we expect that higher the GR value (expressed in GV), lower the count rate (as measured by the PM). Indeed this is what we observe from the PM aboard *Beppo*SAX.

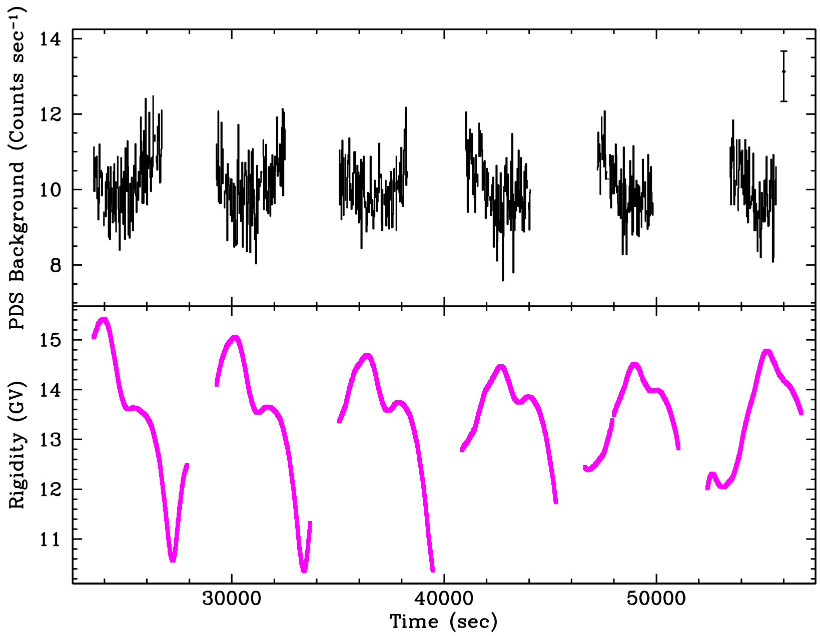

Figure 1: PDS background rate and corresponding rigidity as a function of time for a 100 ksec observation performed on 8 March 1998 (OP03897). Each data segment corresponds to a *Beppo*SAX orbit.

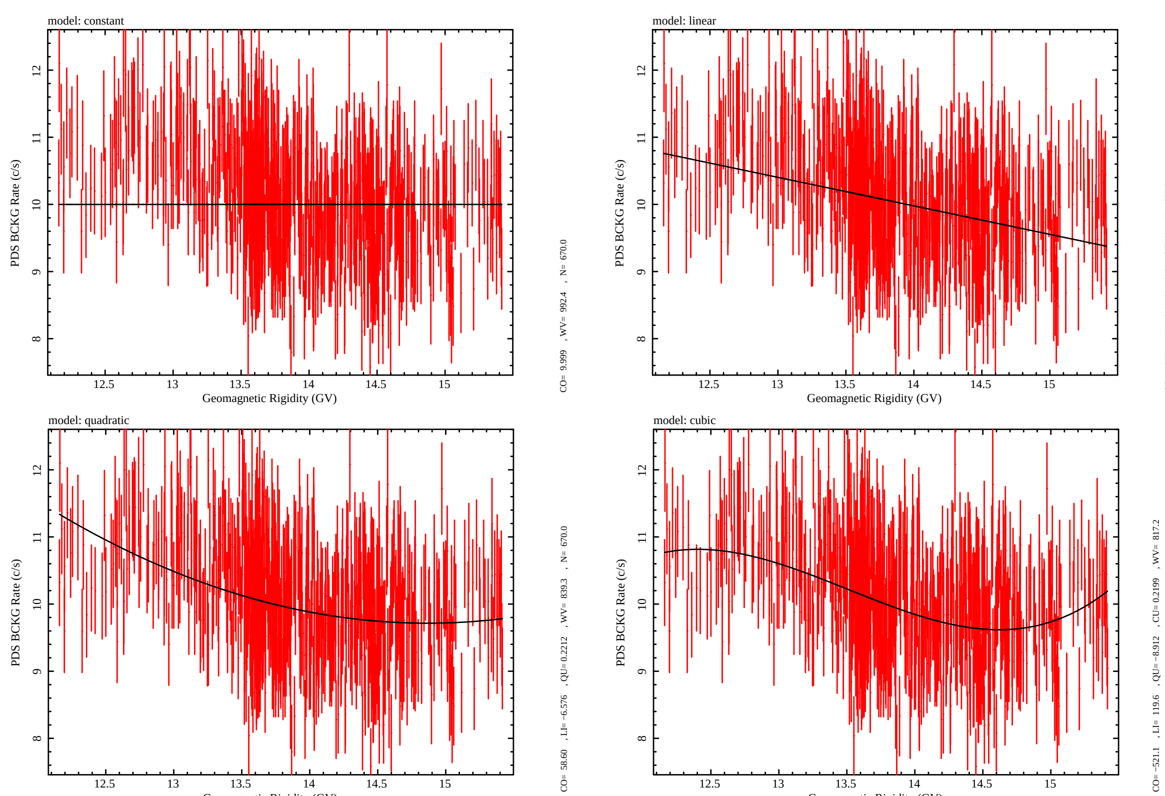

Figure 2: Polynomial fits to the PDS background rate vs geomagnetic rigidity. Data from OP03897.

Model	Best Fit	χ^2	dof
CONS	9.99 ± 0.04	992.4	669
CONS LINR	15.92 ± 0.86 -0.42 ± 0.06	865.8	668
CONS LINR QUAD	58.6^{+11}_{-15} $-6.58^{+2.15}_{-1.65}$ $0.22^{+0.06}_{-0.08}$	839.3	667
CONS LINR QUAD CUBI	-521 ± 203 120 ± 44 -8.9 ± 3.2 0.22 ± 0.08	817.2	666

Table 1: Best fit parameters to the PDS background rate vs geomagnetic rigidity. Data from OP03897 as shown in Fig. 2.

Energy (keV)	**R(10–12 GV)** (counts s^{-1})	**R(12–14 GV)** (counts s^{-1})	**R(14–16 GV)** (counts s^{-1})
15–20	2.445 ± 0.002	2.257 ± 0.001	2.065 ± 0.001
20–40	6.799 ± 0.003	6.529 ± 0.002	6.114 ± 0.002
40–80	9.193 ± 0.004	8.643 ± 0.002	7.966 ± 0.002
80–100	1.930 ± 0.002	1.801 ± 0.001	1.653 ± 0.001

Table 2: PDS background count rate in different energy bands as a function of the GR. While the count rates depends on the GR, the ratio of the count rates in different energy bands do not. This means that the overall background shape does not depend on the GR.

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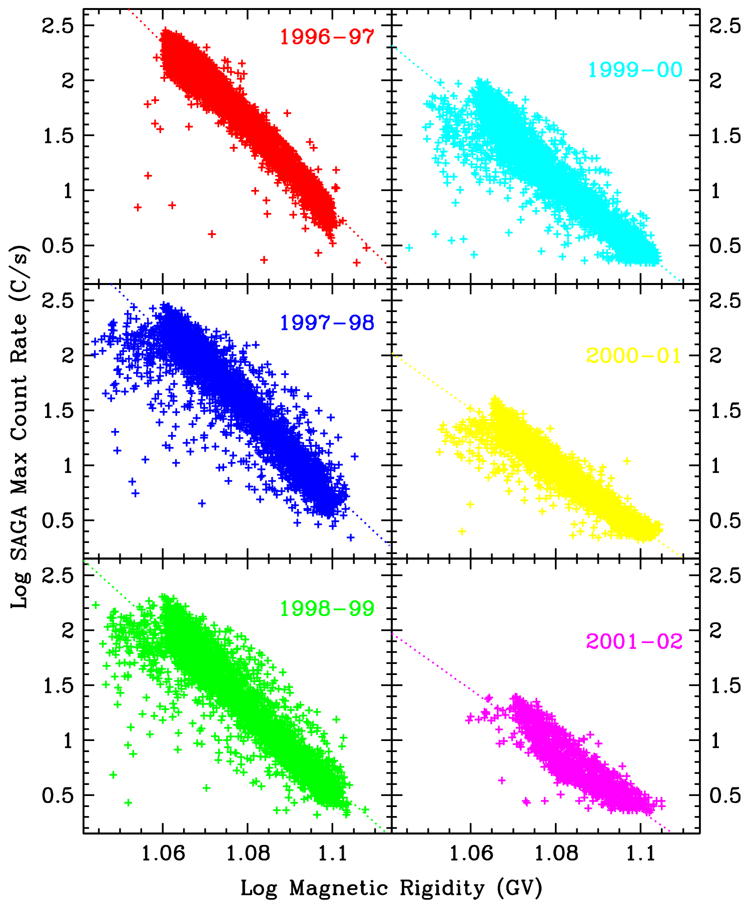

Figure 3: Count rates at the maximum of SAGA passages as a function of the GR as measured by the Particle Monitor aboard *Beppo*SAX. Data have been divided for different epochs because of the different count rates due to the orbital decay. The best fit slopes are the following: 1996–97: -38.1; 1997–98: -36.3; 1998–99: -34.8; 1999–00: -31.6; 2000–01: -27.2; 2001–02: -27.5.

Because of the orbital decay of the *Beppo*SAX orbit, the PM count rate decreased as a function of time, and this is clearly shown in Fig. 3. We fit the correlation with a power law, and we can see that the normalization decreased in time, while the power law index remained more or less constant.

4 Conclusions

From this preliminary analysis, the GR seems a good candidate for describing the *HXMT* background, because it is a valid indicator of the particle environment around the orbit.

By comparing Figures 2 and 3 we can notice that the dependence of the PDS count rates on the rigidity is less strong that the one observed for the Particle Monitor count rates. This is in agreement with what was discussed by Frontera et al. (1981) [2] regarding a transatlantic balloon experiment carrying two X–ray scintillator

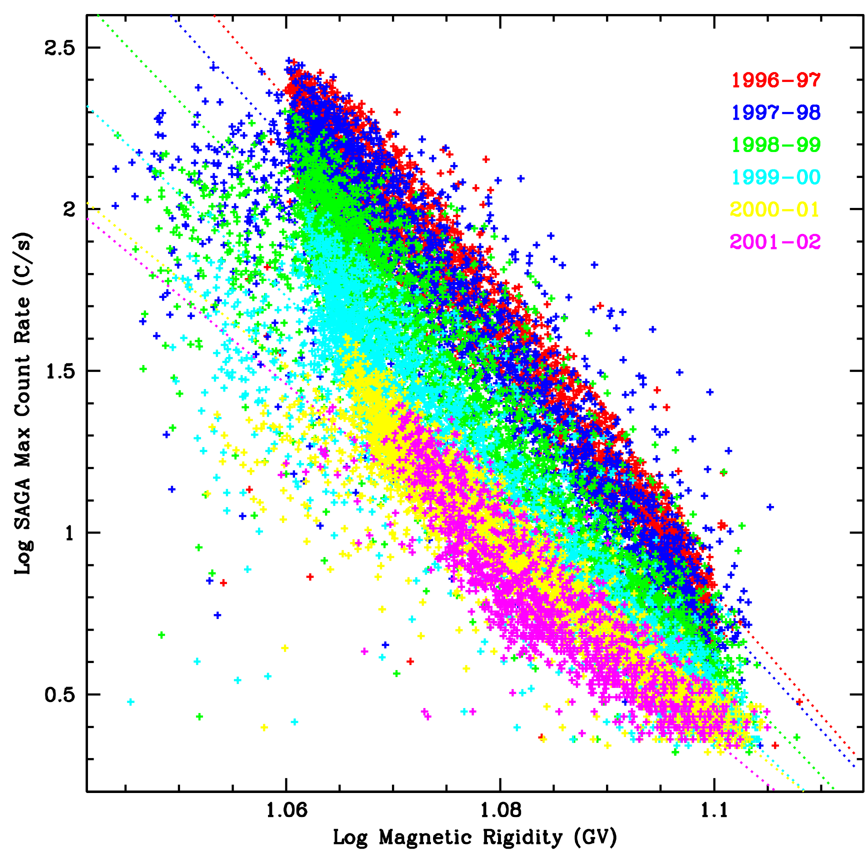

Figure 4: Same as Fig. 3 with all the data in the same panel, in order to notice the difference in the best fit slopes.

detectors.

On the other hand, the use of the PDS background light curves could not be very suitable to model the *HXMT* background, because of the much lower modulation with respect to the one expected for *HXMT*.

References

[1] Campana R., Orlandini M., Del Monte E., Feroci M., and Frontera F. 2014. *The radiation environment in a Low Earth Orbit: the case of BeppoSAX,* Ex. Astron. 37, 599–613

[2] Frontera F., Fuligni F., Morelli E., and Ventura G. 1981. *Hard X-ray latitude effect measured during a transatlantic balloon flight,* Adv Space Research 1, 107–110