Investigating the effect of lowering the pergiee altitude of the INTEGRAL orbit

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1 Introduction

Concern has been raised that the fuel on board INTEGRAL may not be enough to last the intended five years of the mission. One of the sugested ways to solve this problem is to lower the altitude of perigee of the INTEGRAL orbit. Currently the baseline altitude is 10,000 km but this could be decreased to 9500, 9000 or 8500 km. This would result in an increase in the intensity of perigee passages (and therefore an increase in bombardment by charged particles). The chief concern would be an increase in the incident number of higher energy protons (ie above 10 MeV). These produce both a prompt increase in the INTEGRAL background (during passages) and, more importantly, an induced radioactive background component (after passages). During the radiation belt passages the instruments can be switched off and so the prompt background component is easily dealt with. However, the induced component is delayed from the radiation belt passage and cannot be dealt with in a simple way. Since there is always going to be an induced component of the background one needs to determine whether the increase in this component would be significant when changing the perigee from one height to another.

In this report a brief summary of the simulations undertaken using The INTEGRAL Mass Model (TIMM) to investigate the above problem is presented.

2 Simulations

The GGOD software developed at Southampton has been used in conjunction with TIMM to model both the prompt effects of proton bombardment and the more important induced radioactivity. In this report only the induced radioactivity is considered. The input proton spectra (p+/cm^2/s/MeV) used for each altitude are given below:

$F_{10000} = 7.8 \times 10^6 E^{-6.42}$
$F_{9500} = 5.6 \times 10^6 E^{-6}$
$F_{9000} = 7.64 \times 10^6 E^{-5.895}$
$F_{8500} = 6.85 \times 10^6 E^{-5.567}$

ISGRI	PICsIT Single	PICsIT Multi
422.8	1048	468.8

Table 1: *Standard TIMM count rates (c/s) in the various IBIS modes.*

Single	Multi no 511	Multi w/ 511
244	72.02	8.23

Table 2: *Standard TIMM count rates (c/s) in various SPI modes.*

For each of these altitudes INTEGRAL has been bombarded with protons according to the above spectra with energies between 10 and 600 MeV. From these initial simulations the production rates of isotopes have been calculated throughout the entire INTEGRAL satellite. Further sets of simulations are then run which use the production rates, the length of irradiation (t_1) and the time since the end of irradiation (t_2) to calculate the induced background component at time t_2.

The length of irradiation (the duration of the radiation belt passage) has been taken from the report by Hugh Evans (see figure 10) and has been assumed to be 1.3% of one orbit. Since an orbit equals 3 days this gives about 3370 seconds (or 0.936 hours). In this report I consider an orbit to start at time zero with the beginning of the radiation belt passage. The induced background has been calculated at two points in the orbit - at time equals 1 hour and time equals 3 hours (which is therefore 230 and 7430 seconds after the end of the radiation belt passage respectively).

3 Results

The standard TIMM background count rates in IBIS and SPI (at Solar max) are given in tables 1 and 2.

Tables 3 and 4 give the IBIS count rates for the various altitudes at time equals 1 hour and time equals 3 hours. The count rates at time equals 1 hour for 10,000 and 9,500 km altitudes are similar and are a small fraction of the standard rates. The count rates at 9,000 and 8,500 km are increasingly large and at 8,500 km become a reasonable fraction of the standard rates in some modes. At time equals 3 hours almost all of the induced radioactivity has decayed away and the IBIS count rates are very small.

The count rates in the SPI modes at both time equals 1 hour and time equals 3 hours are much less significant than those in IBIS. In this report we have only considered the continuum effects, it may be possible in the early period after irradiation that the background in some lines could be significant in SPI.

From the simulations it is clear that the induced count rates in both IBIS and SPI are very low. The differences between the four altitudes may be significant during the belt passages, but in the first few hours afterwards the induced count rates drop to relatively insignificant levels. The low level of induced radioactivity

Altitude (km)	ISGRI	PICsIT Single	PICsIT Multi
10000	6.37	25.29	9.12
9500	6.64	27.72	8.73
9000	14.63	61.94	20.89
8500	61.04	227.2	82.81

Table 3: *Count rates (c/s) in various IBIS modes at time equals 1 hour.*

Altitude (km)	ISGRI	PICsIT Single	PICsIT Multi
10000	0.14	0.52	0.22
9500	0.2	0.72	0.22
9000	0.38	1.21	0.57
8500	1.58	4.8	1.67

Table 4: *Count rates (c/s) in various IBIS modes at time equals 3 hours.*

Altitude (km)	Single	Multi no 511	Multi w/ 511
10000	0.24	0.09	0.
9500	0.5	0.21	0.
9000	1.16	0.36	0.
8500	3.88	0.77	0.

Table 5: *Count rates in various SPI modes at time equals 1 hour.*

Altitude (km)	Single	Multi no 511	Multi w/ 511
10000	0.01	0.	0.
9500	0.02	0.	0.
9000	0.04	0.	0.
8500	0.07	0.01	0.

Table 6: *Count rates in various SPI modes at time equals 3 hours.*

is most likely due to the low energy nature of the input proton flux. This means that the protons are stopped in the outer layers of INTEGRAL and therefore any induced radioactivity is predominantly confined to outer structure. In SPI this means that most of the radiation is outside the BGO shielding, which therefore suppresses this component of background. Since IBIS has less shielding it is more susceptible to the input protons. The collimator and hopper tend to be activated, and since there is no shielding between them and the detector planes the background is therefore more effected.

Overall a change from 10,000 km altitude to 9,500 km is unlikely to make a significant difference to the background within INTEGRAL. A change down to 8,500 km will have a small effect in the first minutes/hours after the end of radiation belt passages, but in the long term will not result in any significant increase in background.

References

INTEGRAL Radiation Environment, Issue number 3 by Hugh Evans.