Replies to referee #2

We thank the referee for the careful review and all these very helpful comments. Our answers are in italic blue colour, while the updated text is in red.

GENERAL COMMENTS

SREM TC2 channel is a single detector channel. Since no coincidence/veto logics are applied, this channel could include a significant contribution from secondary particles induced by cosmic ray interaction with the s/c. Authors should at least briefly discuss if this is the case, as well as the relative importance of possible sources of background. Since the study covers a long time interval and a relatively wide range of radial distances, spatial and/or temporal variations of the background can be a critical issue for the analysis of quiet-time fluxes (GCR) and could affect the reliability of cross-calibrations along the period under analysis.

Indeed, secondary particles can influence the measurement. Considering different mass distributions of Rosetta and INTEGRAL, it can be assumed that this influence differs for each spacecraft. Under the assumption of a continuous impact averaged over the solar period of 27 days the rather, furthermore assumed, constant contribution might be different for Rosetta and INTEGRAL, but is expected to decrease significantly when performing the cross calibration in similar space environments.

A detailed study on the contribution by secondary particles could be a possible part in a follow-up study, although some work was already carried out at University of Oldenburg (Validation of flux models to characterize the radiation environment in space based on current Rosetta-data, Master thesis, 2017).

Section 2.4 now includes: The TC2 channel could include a significant contribution from secondary particles induced by cosmic ray interaction with the spacecraft itself. As a first approximation, this contribution is expected to be minimised in the cross-calibration process. A full characterisation could be the topic of a follow-up study.

SPECIFIC COMMENTS

Page 3, line 5. Although single detector channels such as TC2 are omnidirectional, it would be helpful for the later interpretation of the data to briefly describe the pointing of the Rosetta SREM aperture during the cruise phase and during the comet encounter.

We agree that it would be useful to study the pointing of the SREM detector, in particular for channels like C2 who are sensitive in a ±20° cone. This should be an interesting follow-up study. Since this study mainly concerns the TC2 channel, we did not spent too much time on it. We briefly discuss this point in Thomas Honig's internship report (see attached, section 5.10). In addition, for the referee, we show here how the comet 67P looks like in the SREM field of view.

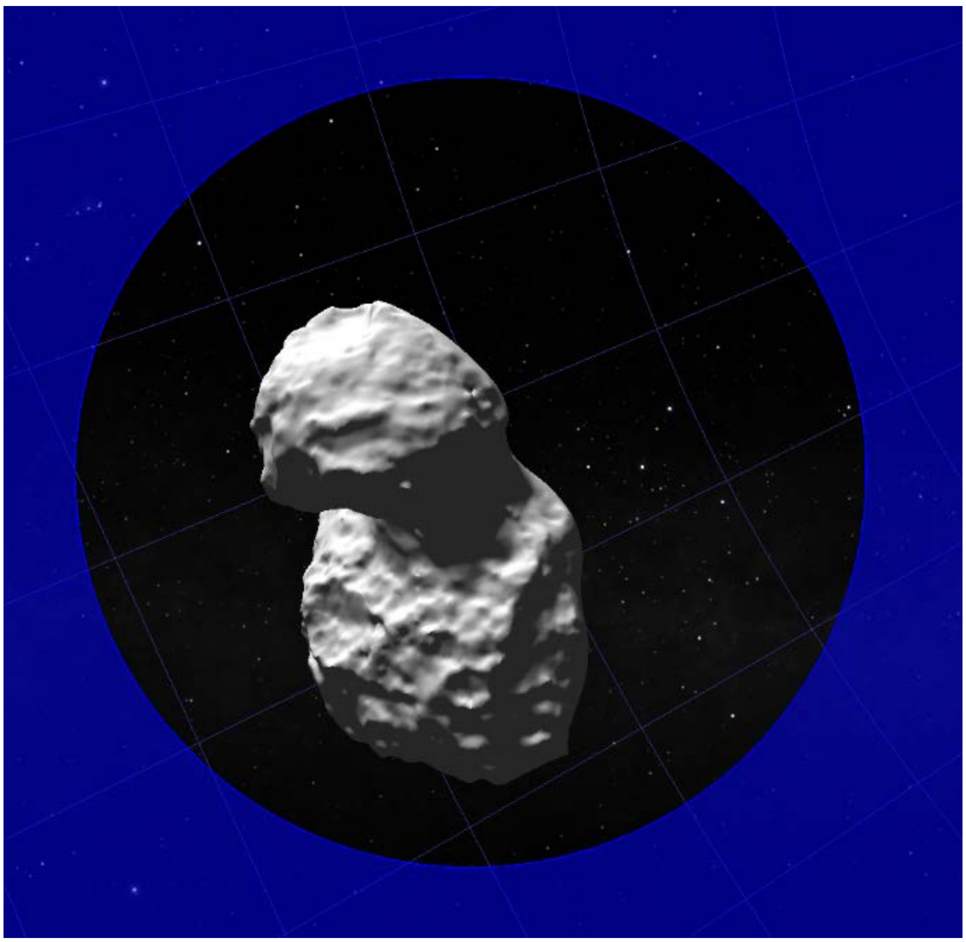


Figure 1: SREM 20x20 field of view, 1 June 2016. Courtesy A. Sanderink.

P3 Table 1. The second column (logic) lists "D1" as logic for channels TC2 and S25. This seems inconsistent with e.g. page 2 line 26 and with Table 1 in Evans et al., 2008. Please check/correct since channel TC2 is the basis of the study presented in the manuscript. Instead of just providing a nominal "49 MeV to infinity" energy range, it would be valuable to discuss

the rigidity or energy range roughly represented by TC2 counting rates (taking into account the typical shape of the modulated GCR spectrum above 49 MeV and probably the energy-dependent instrument response). This information would be quite useful when comparing the inferred radial gradient with previously published results (Page 12).

Agreed; there was a mistake in Table 1. The table was updated and simplified. See below:

Table 1: new Table 1

Channel	Bin	Logic	Particles	Energy range (MeV)
1	TC1	D1	Protons Electrons	27-inf 2-inf
2	S12	D1	Protons Electrons	26-inf 2.08-inf
3	S13	D1	Protons Electrons	27-inf 2.23-inf
4	S14	D1	Protons Electrons	24-542 3.2-inf
5	S15	D1	Protons Electrons	23-434 8.08-inf
6	TC2	D2	Protons Electrons	49-inf 2.8-inf
7	S25	D2	Ions	48-270
8	C1	D1 x D2	Protons	43-86
9	C2	D1 x D2	Protons	52-278
10	C3	D1 x D2	Protons	76-450
11	C4	D1 x D2	Protons Electrons	164-inf 8.1-inf
12	TC3	D3	Protons Electrons	12-inf 0.8-inf
13	S32	D3	Protons Electrons	12-inf 0.75-inf

14	S33	D3	Protons Electrons	12-inf 1.05-inf
15	S34	D3	Protons Electrons	12-inf 2.08-inf

We agree that it would be more useful to provide more precise number than the "nominal "49 MeV to infinity" energy range". However, this is clearly out of scope for this study. Nevertheless, for the TC2 channel, we can provide additional information. The following plot show the SREM GCR response (the X-axis is the energy in MeV). We can see that TC2 is mostly sensitive to particles in the range [200-20000] MeV. We now indicate this range when we compare with published results.

Added in table 1 caption: The study of the detector response to GCR indicates that the TC2 channels is mainly sensitive to energies between 200 MeV and 20 GeV.

New sentence in section 3.2: This result agrees well with previous studies for which the energy range can be compared with the TC2 range of ~0.2 – 20 GeV (e.g. Vos and Potgieter, 2016 / range 0.1-10 GeV; Gieseler and Heber, 2016 / range 0.45-2 GeV).

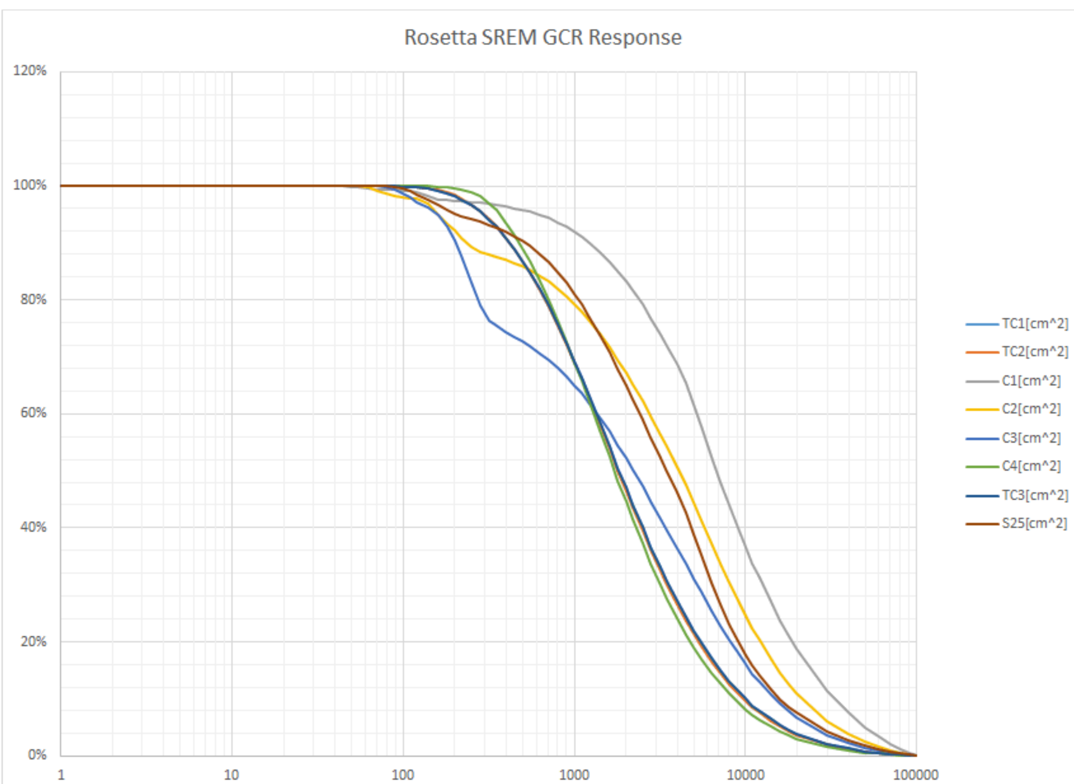


Figure 2: SREM detector response to GCR (for the referee only)

P4 Figure 1, bottom panel. Please define/clarify HEE, since this acronym normally stands for the Heliocentric Earth Ecliptic coordinate system and therefore latitudes would correspond to ecliptic latitudes and not to heliographic latitudes. Do the authors mean HEEQ (Heliocentric Earth Equatorial)? If not, replace "heliolatitude" by "ecliptic latitude". This difference is also relevant for the discussion in P14L10.

"heliolatitude" was replaced by "ecliptic latitude". Figure 1b was updated, see below.

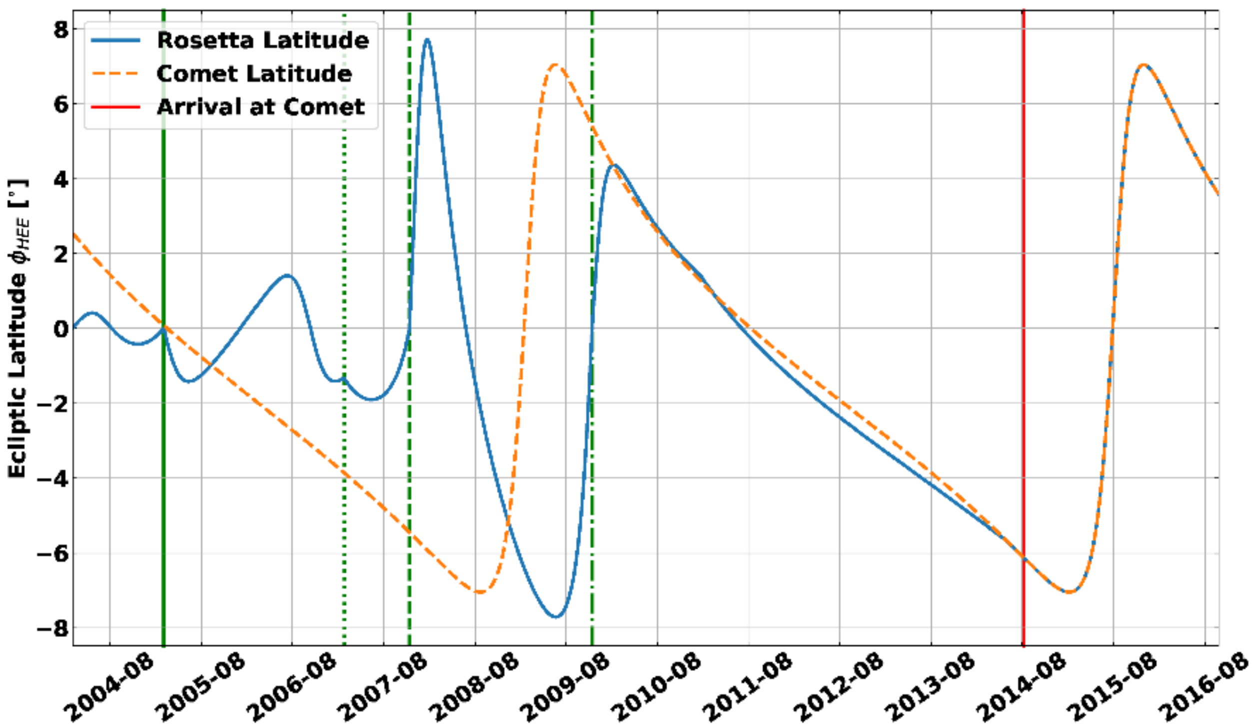


Figure 3: New Figure 1b

P5L19. The SREM channels and the exact procedure used to manually filter solar energetic particle events should be specified. Some events could be difficult to detect in TC2 (but still contribute) but become clearly visible at energies below 49 MeV.

SPEs were removed in two steps.

Step 1):
Based on the „Solar Proton Event Archive" (http://space-env.esa.int/index.php/Solar-Proton-Event-Archive.html) provided by NOAA SEC, SPEs were removed for all near Earth spacecraft. Following http://space-env.esa.int/index.php/NOAA_SPE_Template.html?date=19971104 :"The Event selection criterion is when the NOAA/GOES-9 five minute averaged >10. MeV p+ flux

exceeds 2.0 p+/cm²/s/sr. The event is considered to have ended when the flux returns to below 1 p+/cm²/s/sr". Figure 2 shows an example of SPE period rejection. Since the data is based on geostationary satellites, further SPEs detected by HEND and Rosetta at locations with a significant longitudinal difference with respect to the Earth's heliocentric longitude had to be removed as discussed in step 2).

Step 2):
Numerical outlier detection was applied onto the data sets using a rolling mean outlier detection method. Due to the very noisy nature of the data set it turned out that one would either throw away too much data or would stick with still many outliers. Therefore it was decided to remove all non reported SPEs by hand.

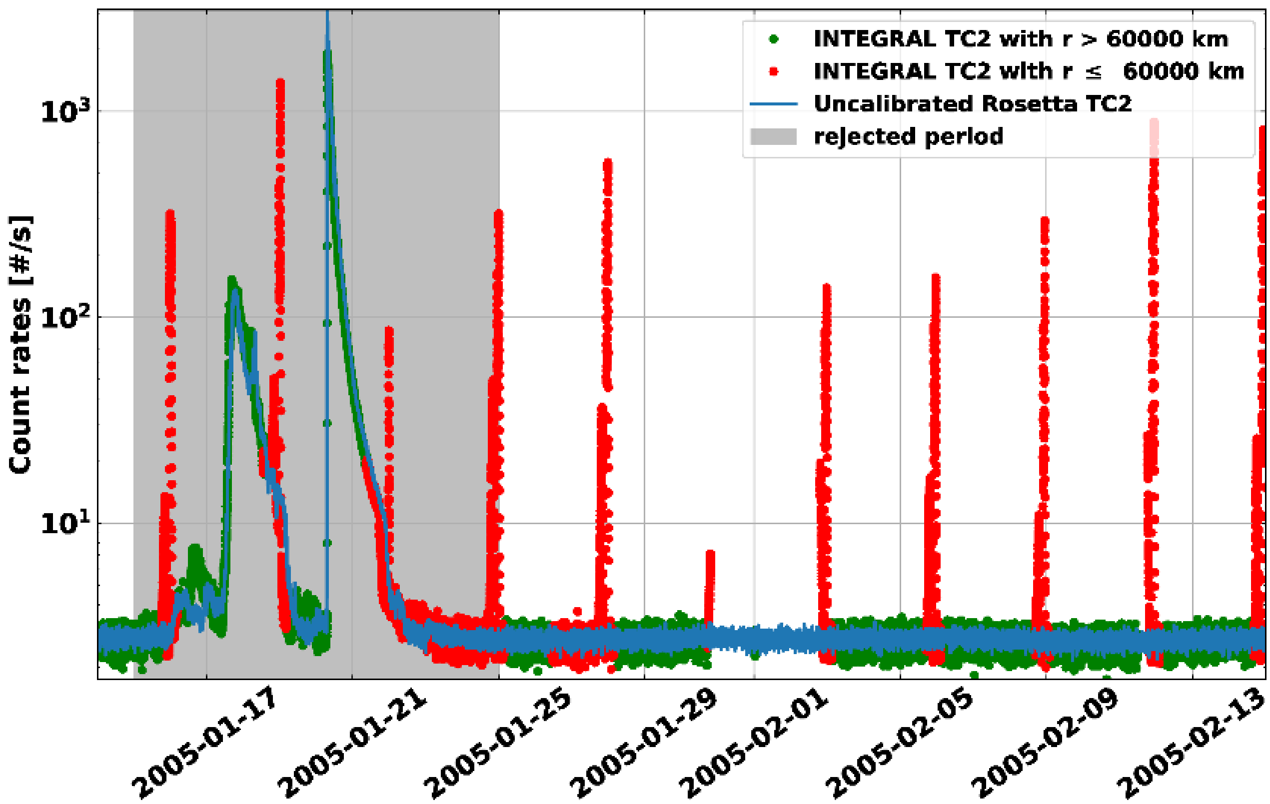


Figure 4: Removing SPE events (for the referee only)

The figure illustrates exemplarily how SPEs were removed by visual inspection (by removing the gray area) and how radiation belt influences on INTEGRAL were removed (red data points were removed with requirement: distance to Earth > 60000km). The quite period as of 2005-01-25 also shows good agreement between uncalibrated Rosetta and INTEGRAL in a similar radiation environment on average.

We have added the link to http://space-env.esa.int/index.php/NOAA_SPE_Template.html?date=19971104 in the relevant paragraph.

P5L25. The reconfiguration of HEND should be explained with further detail. What is the ultimate reason for the count rate increase/offset?

In the HEND data set, there is the errata.txt file (http://pds-geosciences.wustl.edu/ody/ody-m-grs-2-edr-v1/odge1_xxxx/errata.txt) which report about this reconfiguration. This is the only public information that we found. The updated manuscript provides now this reference, in addition to [J. J. Plaut, personal communication]

P6L5-6. "We associate the 2.8% difference….with differences in the sensitivity area of the two SREM detectors". Other factors such as noise levels, obstructions or different s/c mass distribution around the sensor head could contribute to this small difference between the nominally identical units onboard INTEGRAL and Rosetta (as well as Herschel, Planck and Proba-1).

Agreed; the updated manuscript now lists the other factors as well.

P7L23. Is this equation correct? The preceding text mentions that Proba-1 counting rates are systematically lower than INTEGRAL counting rates, then why is INTEGRAL rate (and not Proba-1 rate) multiplied by a number >1 in order to obtain a "corrected" Proba-1 rate directly comparable with INTEGRAL? The same question applies to the rest of cross-calibration equations. Probably this is just a notation problem, but it should be checked.

We have double checked and the cross calibration functions have to be changed as follows:

Count(INTEGRAL) = 1.028 x Count(Rosetta) – 0.127 / s
Count(INTEGRAL) = 0.931 x Count(Herschel) + 0.060 / s
Count(INTEGRAL) = 0.938 x Count(Planck) + 0.028 / s
Count(INTEGRAL) = 1.256 x Count(Proba-1) + 0.154 / s
Count(Rosetta) = 0.035 x Count(HEND) – 0.557 / s

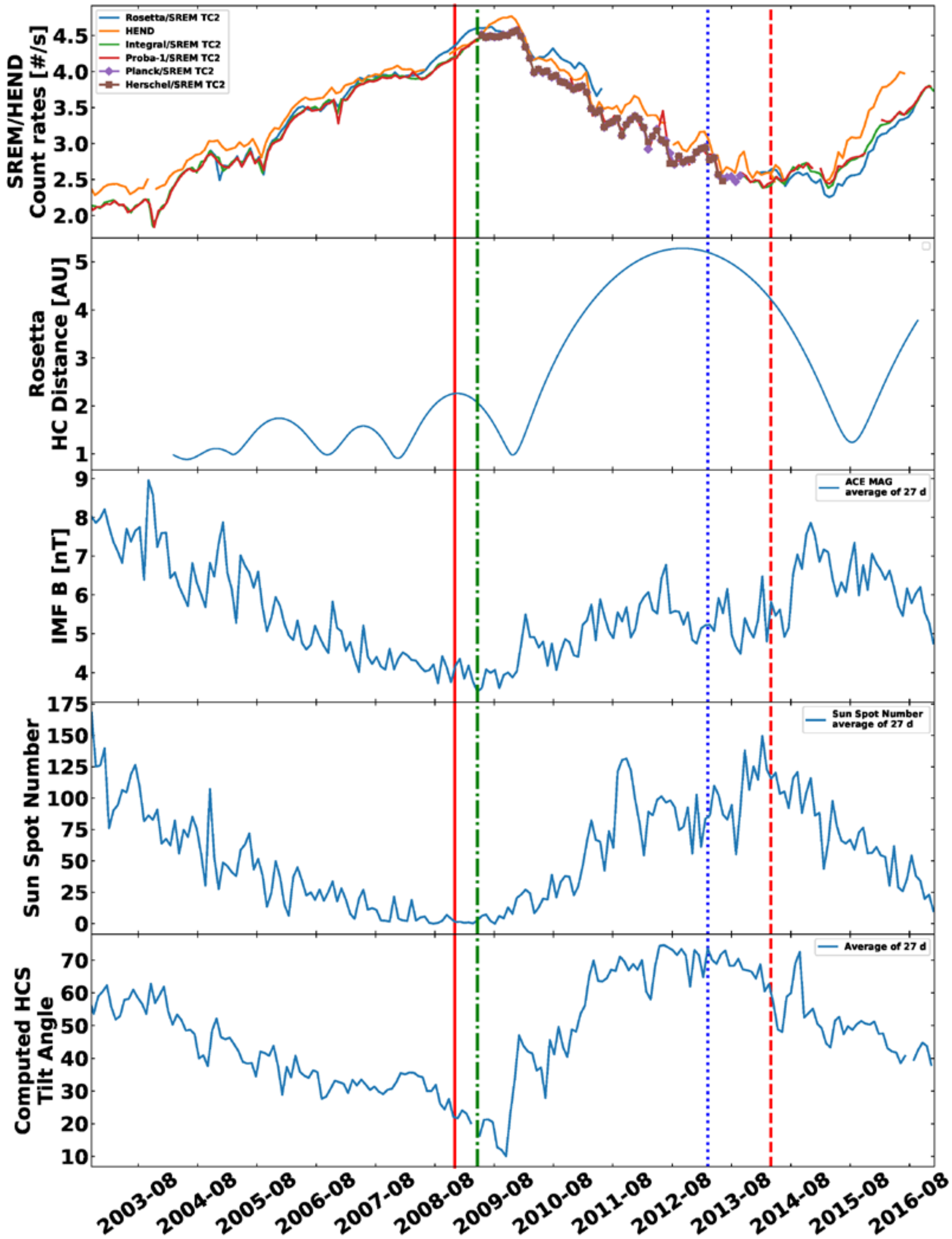
P8L6. See comment P7L23 above and clarify how the calibration factors are applied to HEND data in order to make them directly comparable with Rosetta.

We did a 2-step normalization: Rosetta to INTEGRAL and then calibrated Rosetta to HEND.

The text now says: The HEND neutron monitor HEND is calibrated with respect to SREM-Rosetta, which is calibrated with respect to INTEGRAL

P10 Figure 4. What is the reason for the peaks observed in HEND rates shortly after the vertical red dashed line? The difference between the near-Mars HEND and near- Earth SREM rates seem larger at the end of the plot (2015-16) than at the beginning (2003), while solar activity levels are comparable (although with opposite solar polarity). This, together with the comment on P5L25 raises some doubts about the stability of cross-calibration. Some discussion of these differences could be introduced e.g. in P11L7-8. Visibility of the different lines in the first panel could be improved.

Figure 4 was updated, see below:



The HEND spikes after the vertical red lines were removed, as part of the SPE removals. We should have done that for the submitted manuscript. The larger differences between HEND and INTEGRAL in 2015-2016 are not understood, and are now outlined in the manuscript.

P12L13-14. When citing agreement with Vos and Potgieter, 2016 and Gieseler and Heber, 2016, please mention the rigidity/energy ranges studied by these authors. The radial gradients presented here are based on counting rates accumulated over a broad energy

range, which makes difficult to define a reference energy for comparison (see comment about Table 1 above).

The text was updated accordingly: … (e.g. Vos and Potgieter, 2016 / range 0.1-10 GeV; Gieseler and Heber, 2016 / range 0.45-2 GeV)

P12L16-17 and P14 Figure 6. "After that period, the count rate variation is in very good agreement with the expectation of a positive(?) radial gradient…". This sentence sounds quite confusing since the Rosetta rates remain below the INTEGRAL rates till late 2016 (Figures 4 and 5 and discussion in following pages). In order to make easier the interpretation of Figure 6, I strongly suggest including panels showing the heliocentric distance of Rosetta and the distance between Rosetta and Comet 64P. In order to keep consistency with Figure 4, I also suggest plotting INTEGRAL SREM rates in green color.

There are three periods of interest:

- *Blue dots and red fit: Rosetta pre-hibernation data. Here we see the expected positive gradient, 2.96% per AU.*
- *Orange dots are January-July 2014: period when the attenuation of GCRs is noticed.*
- *Green dots and black fit: July 2014-September 2016. The attenuation is stable, and we see again the expected positive gradient, 2.9% per AU.*

The text now says: „After that period (green points and black fit), the count rate variation and the ratio is in very good agreement..."

Figure 6 was updated and made colors consistent. A new Figure was included (Figure 7) which displays the relevant distances. See below.

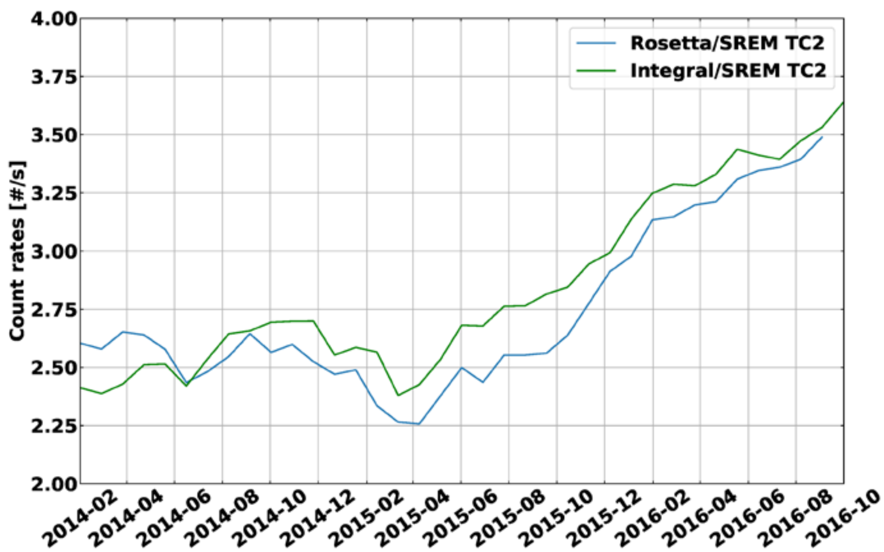


Figure 5: New Figure 6

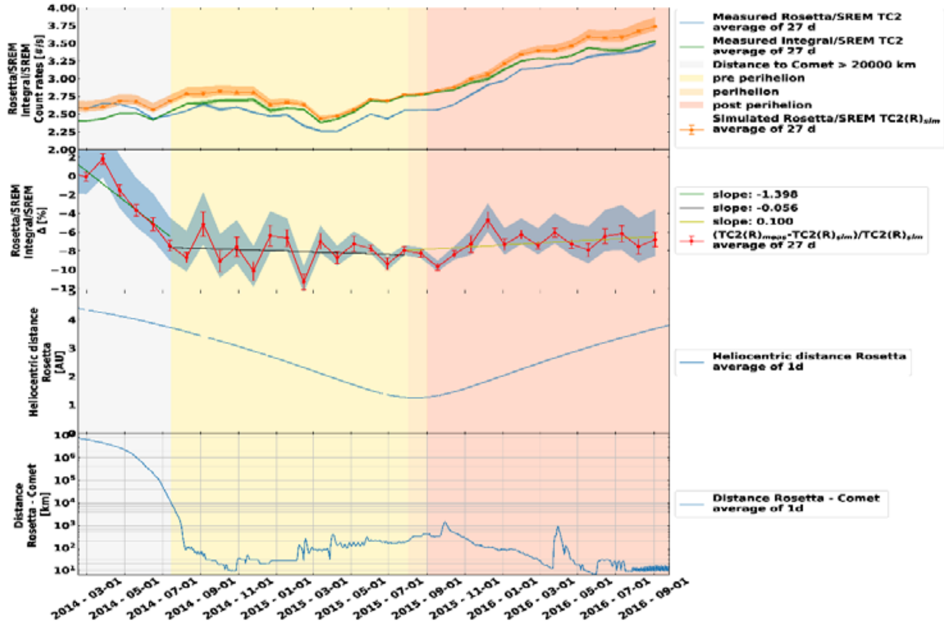


Figure 6: new Figure (figure 7), which includes the heliocentric distance of Rosetta and the Rosetta-comet distance.

P14L13. "The decreasing ratio begins when Rosetta reaches around 20,000 km from the cometary nucleus". See comment above about including distance between Rosetta and the comet in Figure 6.

Figure 7 now includes the Rosetta-nucleus distance.

P14 and P15. Please briefly mention that the counting rates at Mars/HEND always stay higher than those registered near the Earth (Figure 4), even during the period shown in Figure 6. This is consistent with a permanent positive GCR radial gradient and supports that the reduction in the GCR rates at Rosetta compared to Earth is related to the comet approach.

The text was updated with the suggested sentences.

P15L16-17. In order to substantiate this suggestion, the authors should consider including and discussing the local plasma and magnetic field observations by Rosetta during the period shown in Figure 6.

Work is ongoing to see the effect of magnetic fluctuations (effect of turbulence); therefore, we leave this activity for the near future.

MINOR AND TYPOGRAPHIC COMMENTS

Affiliations: Please replace "Universitycity" by "University".

Corrected.

Page 1, Line 21. “Major sources of this radiation are the Van Allen radiation belts,: : :”. The preceding sentences put the focus on missions outside the Earth’s magnetosphere, therefore this reference to radiation belts seems out of place.

Agreed. This reference was removed.

P2L4. “cover a range of heliocentric distances up to 3.5 AU”. Since Rosetta reached 4.5 AU, the term “heliocentric distance” sounds confusing here. Do the authors refer to the difference between the radial distances of two s/c, rather than to the Sun-s/c distance?

We understand the confusion. The word “heliocentric” was removed.

P2L9. “with two of them still operating: : :”. Please specify which ones.

Corrected.

P2L10. I suggest replacing “high energetic charged particles” by “high-energy charged particles” here and elsewhere in the manuscript.

Corrected in three places.

P3 Table 1. I suggest avoiding the redundant “MeV” labelling in the first and second line of the header, e.g. keeping it only in the first line.

Table 1 was updated and simplified, see above.

P3L21. “This sensor is the best one for space weather: : :”. Please reformulate this sentence in a more specific way.

“the best one” was changed by “very adequate”.

P4L11. Replace “Figure 1 shows: : :.” by “Top panel of Figure 1 shows: : :”.

Corrected.

P5L5. Please, replace “and HEND’s orbits: : :” by “and Mars Odyssey’s orbits: : :”.

Corrected.

P5L15. What is the energy and/or intensity threshold of the Solar Proton Event list used here?

We refer here to an answer above.

P6L3. I suggest replacing “the fit curve” by “the linear fit”.

Corrected.

P7L20. Since the energy threshold of SREM TC2 is relatively low (49 MeV), magnetospheric shielding of the lower energy part of the GCR spectrum could also play a role here.

We used data above the magnetosphere (height above 60,000 km); therefore, we think that the magnetosphere has little effect.

P7L39. I suggest replacing "The neutron monitor HEND" by "The HEND neutron detector" or just "HEND- Mars Odyssey".

Corrected.

P8L8. Indeed, the possible effect of Mars shadow would be implicitly included in the empirical cross-calibration procedure.

Since we did not do anything special, the Mars shadow is implicitly included in the cross-calibration.

P8 Table 2. Please add the units of b coefficient in the first row and include a and b uncertainties in the table.

The table was updated accordingly:

Spacecraft 1	*Spacecraft 2*	*a*	*Δa*	*b [1/s]*	*Δb [1/s]*
INTEGRAL	*Rosetta*	*1.028*	*0.005*	*-0.127*	*0.017*
INTEGRAL	*Herschel*	*0.931*	*0.001*	*0.060*	*0.005*
INTEGRAL	*Planck*	*0.938*	*0.001*	*0.028*	*0.005*
INTEGRAL	*PROBA-1*	*1.256*	*0.002*	*0.154*	*0.005*
Rosetta	*HEND*	*0.035*	*0.002*	*-0.557*	*0.025*

P10 Figure 4 caption, P11L10 and P11L27. Replace "sun spot" by "sunspot".

Corrected.

P11L5 and P15L25 "solar rotation (27 days)" While this is OK for the purpose of smoothing longitudinal and transient variations at all locations, 27 days is just the Carrington (synodic and at intermediate latitude) solar rotation period. Therefore, I suggest removing "one solar rotation" and leaving just "27 days".

Corrected.

P11L9 “different heliographic locations”. Do the authors mean “heliospheric locations”?

Corrected.

P11L12 “one of its orbits”.

Corrected.

P11L20 “long-term”.

Corrected.

P11L27 “anticorrelation: : :was calculated”. I suggest replacing either by “anticorrelation: : :was analyzed” or by “correlation coefficient: : :.was calculated”.

Corrected.

P12L14 and P13L10 the term “comet phase” should be clarified/defined.

The comet phase refers to when Rosetta started its nominal mission around comet 67P. This is now clarified.

New text: “(the start of this phase is marked by the red vertical bar on Figure 1b)” *was added after “The slope during the comet phase”.*

P13L12. Replace “dark” by “black”.

Corrected.

P14L16 “hundreds of kg of propellant: : :etc.”. Could this mass loss significantly change the mass environment around the SREM detector and reduce the rate of secondaries contributing to TC2? For completeness, the authors could also mention the separation date of the Philae module and its (small) mass.

We checked during our study that the mass loss due to manoeuvres was not correlated with the SREM data variations.

We added the sentence “For completeness, we checked that the separation with the Philae module in November 2014 did not have noticeable effect.”

P15L22 “they are highly: : :”.

Corrected.

P15L29 “sunspot”.

Corrected.

P15L29. Please replace “annex” by “Annex 1”.

Corrected.

P15L30 Please replace “geographically” by “spatially”.

Corrected.

P15L31 “demonstrated”.

Corrected.

P16L3. The period corresponding to this radial gradient should be mentioned here.

“(between, 2004-10-21 to 2011-05-21)” was added.

P16L4 “this information provides”.

Corrected.

P18L27 Replace “cosmis” by “cosmic”.

Corrected.

P19L24 Replace “intergral” by “INTEGRAL”.

Corrected.

P22 Figure Annex 2. A panel showing the azimuthal separation between Rosetta and the Earth could be added to illustrate the origin of the time delays in the observed o-rotating structures.

Agreed;the azimuthal separation was added in the figure, see below. The caption was updated accordingly.

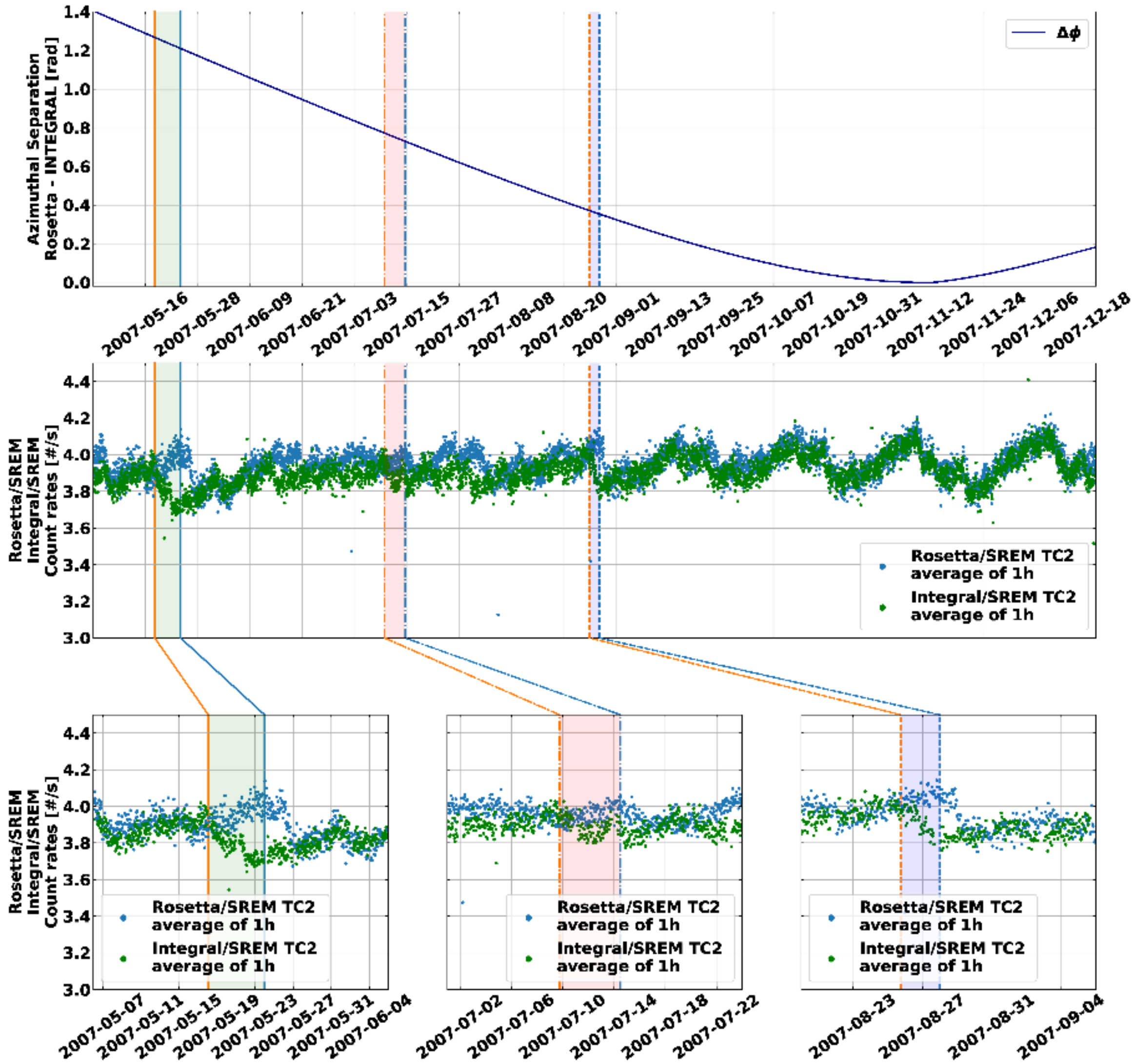


Figure 7: New Figure of Annex 2

The first panel shows the azimuthal separation between Rosetta and INTEGRAL. The second panel shows the count rates of channel TC2 as before. Both panels share the same x-axis (below first panel and above second panel). We see a nice (and expected) correlation between Rosetta and INTEGRAL approaching each other in terms of azimuthal separation and a decreasing time shift in the measured count rates until the point when delta phi vanishes and the count rates match well. Furthermore, color for INTEGRAL has been made consistent.