THE TIME VARIABILITY OF HIFI AND SPIRE SEUS

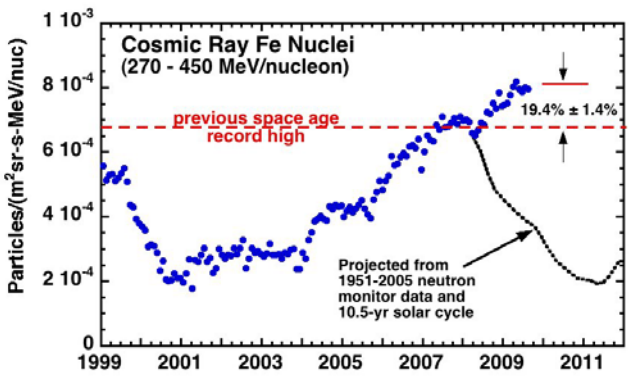
Mark Kidger & Miguel Sanchez-Portal (Herschel Science Centre)
& Alexi Glover (Space Situation Awareness)

Abstract

SEU rates in SPIRE and HIFI are examined over the course of the Herschel mission. There strong evidence of time variability in the SEU rate, with a long-lasting minimum in SEUs in late-2011 and early 2012. The rate of HIFI and SPIRE SEUs seems to be strongly correlated suggesting that they either have a common external cause (suggested to be cosmic rays with energies of several hundred MeV and greater) or, if due to internal electronics, the source is higher up in the electronic chain than the instruments themselves.

Introduction

Herschel was launched during the unusually long and deep solar minimum between Sunspot Cycle 23 and 24, which reached minimum in September 2009 with a smoothed sunspot number of 8.4. It is believed that this exceptional period of very low activity was responsible for the cosmic ray flux reaching a level >20% greater than at any time since 1958 (below).



The Herschel Standard Radiation Environment Monitor (SREM) detects the radiation flux from 10-170MeV (approx). While mainly sensitive to protons, it has some sensitivity to high-energy electrons too. SREM data shows that the background cosmic ray flux dropped by ~40% in the first third of 2010, as solar activity started to build towards the maximum of Cycle 24.

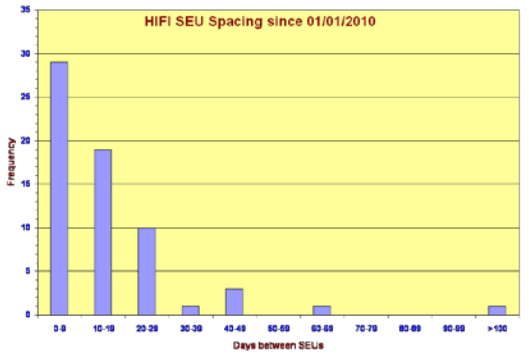
Radiation Effects

There are two major potential radiation effects on Herschel:

Glitching - This was studied by Horeau et al. (2011, RADECS 2011 Proceedings, http://arxiv.org/abs/1207.5597). They found a correlation between the SREM TC2 channel (>39MeV) and the observed glitch rate. There was some evidence of increased glitching during SPEs, although their study stopped in mid-2011, before the strongest SPE activity of the Herschel mission to date, which occurred in early 2012.

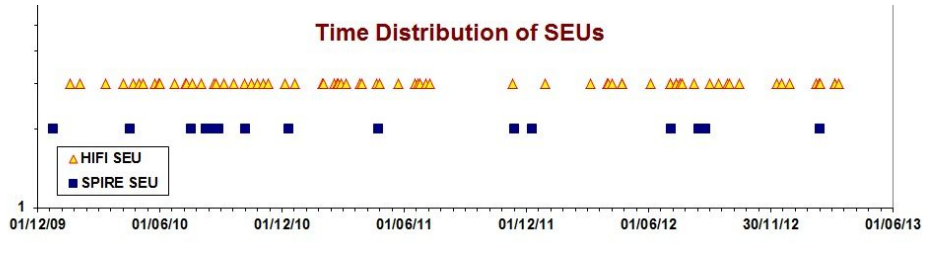
SEUs – Single Event Upsets (SEUs) are bit-flips in memory that are normally regarded as being caused by impact from ionising radiation: both cosmic rays and solar proton storms (SPEs – Solar Proton Events). While most observed SEUs are benign, they may cause significant loss of observing time when a critical area of memory is hit. A severe SEU event caused HIFI to lose its principal power supply chain approximately 3 months after launch.

The effect of **glitching** is well understood and quantified in Herschel data. To date, no observation has been lost due to a high glitch rate either from cosmic radiation, or due to the increased glitching from an SPE. In contrast, **SEUs** are not so well understood and attempts to date to correlate SEUs with solar activity or cosmic radiation have been unsuccessful: this leads to the question: *what is the primary cause of the SEUs in the Herschel instruments?*



The time distribution of HIFI and SPIRE SEUs is shown below

- ***The time distribution is clearly not random.***
- ***SPIRE SEUs are more frequent when HIFI SEUs are more frequent .***
- ***SPIRE SEUs are less frequent when HIFI SEUs are less frequent.***

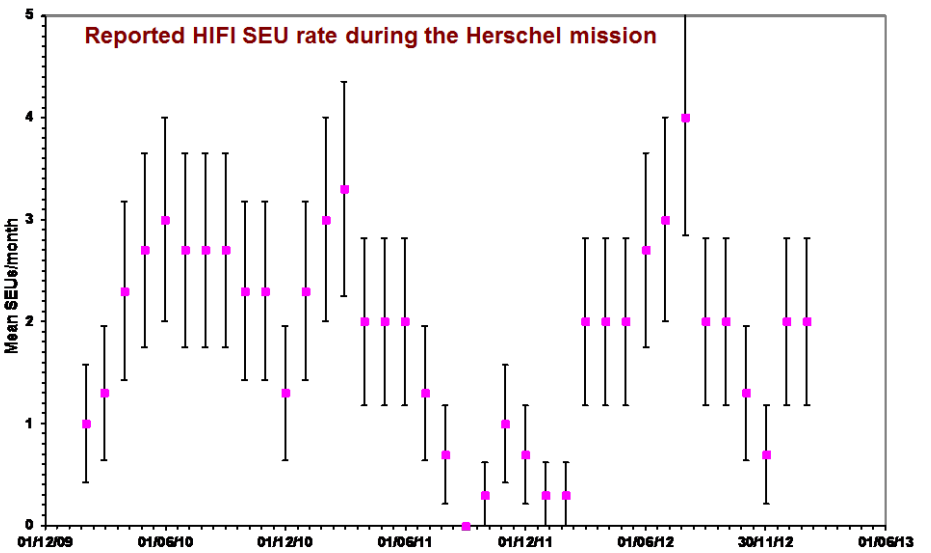


Observed SEUs

Of Herschel's three instruments, only HIFI and, to a lesser extent, SPIRE, are affected by SEUs, as PACS has EDAC memory. The observed rate of SPIRE SEUs is a factor of ≈5 lower than for HIFI thus, here we choose to look at HIFI statistics, as the sample of HIFI SEUs (74) is more suited to statistical analysis than the small number of SPIRE events (15).

Routine checks for SEUs started in late 2009. The first HIFI event to be logged was on January 19th 2010, during instrument re-commissioning. Since then, 73 further SEUs have been identified in a time span of 1159 days, giving a mean rate of 1.9±0.2 SEUs per month compared to the SPIRE rate of 0.36±0.10 SEUs/month.

The histogram of intervals between HIFI SEUs (left) shows a Poisson distribution, although with a longer than expected tail. Looking at the times of arrival (upper right), the very low frequency of SEUs in the second half of 2011 and early 2012 is obvious, during which we observe the three longest intervals between SEUs of the entire time series.

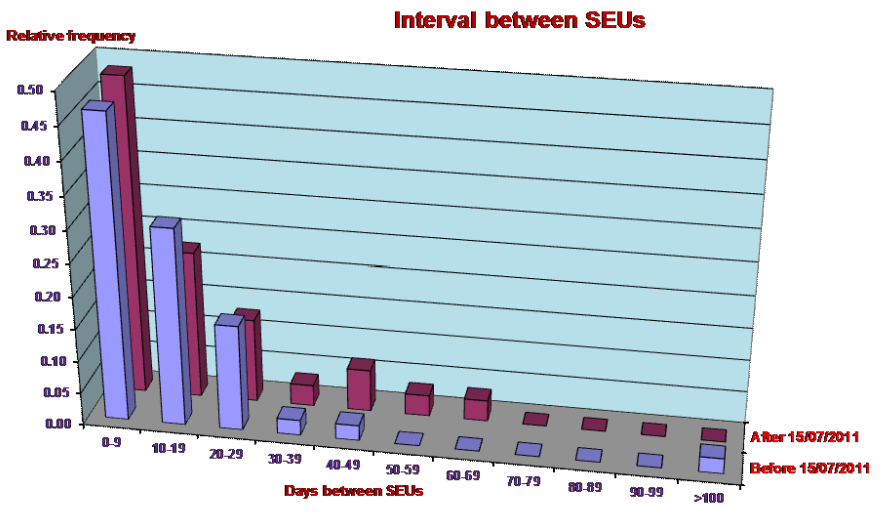


The HIFI SEU rate's time variation. Statistics are calculated as 3-month running means. During the second half of 2011 and early 2012 the rate of HIFI SEUs was extremely low, before the highest rate observed at any time in the mission was observed in mid-2012. The two low values at the start of the record are due to incomplete statistics during the HIFI re-commissioning. There was another, brief minimum at the end of 2012.

The late 2011 discontinuity

Between 10 July 2011 and 07 March 2012 just two HIFI SEUs were registered, after which the rate of SEUs returned to normal. At this time the two longest intervals between SPIRE SEUs were also registered showing that the minima of SEU rates were correlated in the two instruments and thus the likely cause of this minimum is common.

Did this minimum change the characteristics of HIFI SEUs? The mean separation of HIFI SEUs was 12.8 days before the discontinuity and has been 17.0 days since. The histogram of intervals between SEUs is significantly broader since the discontinuity, but this may simply be due to the fact that the discontinuity coincided with the – apparent – solar maximum and thus increased cosmic ray shielding from the heliosphere, agreeing broadly with the trend predicted in the cosmic ray flux (left).



Similarly, in July and August 2010 there was a cluster of SPIRE SEUs. This coincides with a peak in the rate of HIFI SEUs, observable as a strong cluster in the time-distribution plot. Again, the coincidence suggests strongly that there is a common origin.

Conclusions

1. There is a considerable time variability in the mean rate of HIFI SEUs with an extreme range from 0-4 SEUs/month between the start of 2010 and the present.
2. The HIFI and SPIRE SEU rates show a strong time correlation
   - When the rate of HIFI SEUs is elevated, an elevated rate of SPIRE SEUs is observed too.
   - When the rate of HIFI SEUs is low, the observed SPIRE SEU rate is also low.
3. The correlation in SEU rates between SPIRE and HIFI points to a common origin for SEUs in the two instruments.
4. The variation in SEU rates is consistent with the varying cosmic ray background associated with solar cycle 24.
5. The lack of a correlation of SEUs with SPEs, which are mainly composed of protons <200MeV suggests that much higher energy cosmic rays, probably >500MeV are responsible for SEUs.