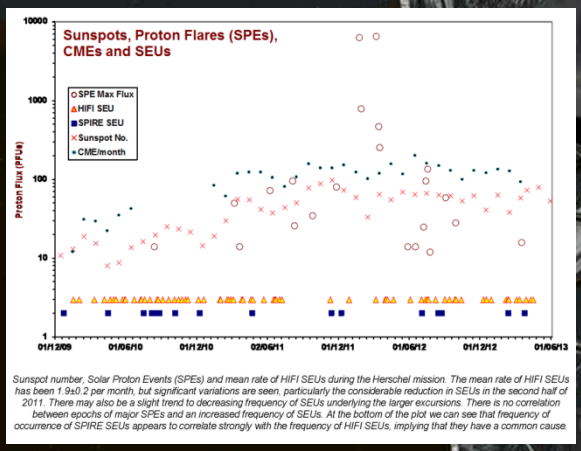
Herschel's SEUs: the plot thickens

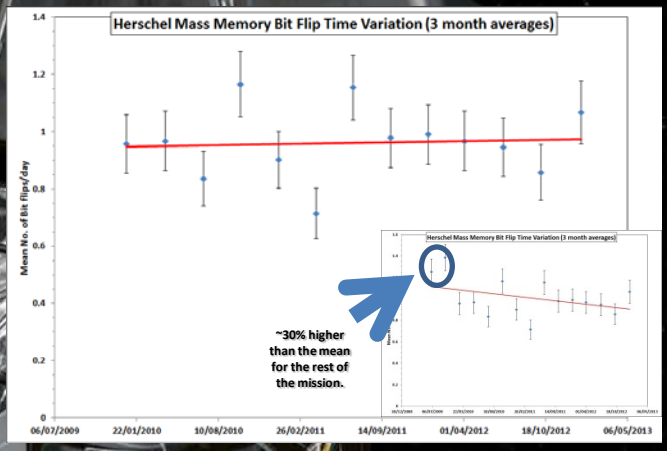
Mark Kidger, Alexi Glover

The current solar maximum has been the lowest since the start of the 20th Century, meaning that cosmic ray fluxes have been correspondingly high. The four year record of the cosmic ray flux from Herschel's SREM shows a drop of a factor ≈2 in the background intensity between 10 and 166MeV between the end of 2009 and the end of mission. It is assumed that the energetic particle flux is the main cause of Single Event Upsets (SEUs), bit-flips in the on-board memory that affects instruments and the satellite mass memory.

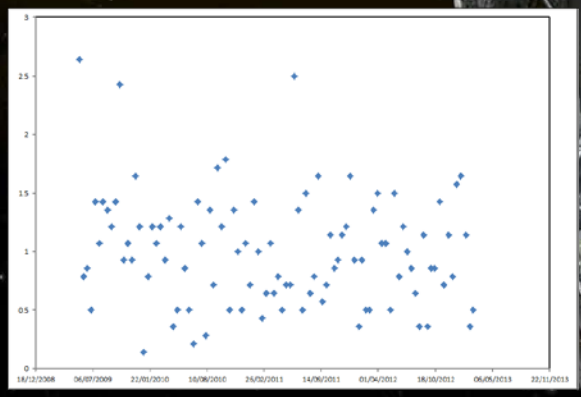
While there is some evidence that the rate of SEUs in Herschel's SPIRE and HIFI instruments were lower around the time of peak solar activity in 2011, a study of bit-flips in Herschel's mass memory finds that although there was a significantly higher rate of bit flips in the first 6 months of the Herschel mission, the rate of bit flips was constant to a high degree from then on. Furthermore, no variations in the rate of bit flips in mass memory exist above the statistical errors between the start of 2010 and the end of mission.



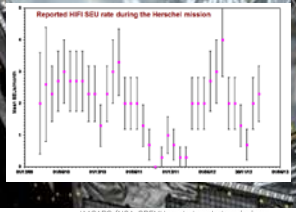
Sunspot number, Solar Proton Events (SPEs) and mean rate of HIFI SEUs during the Herschel mission. The mean rate of HIFI SEUs has been 1.9±0.2 per month, but significant variations are seen, particularly the considerable reduction in SEUs in the second half of 2011. There may also be a slight trend to decreasing frequency of SEUs underlying the larger excursions. There is no correlation between epochs of major SPEs and an increased frequency of SEUs. At the bottom of the plot we can see that frequency of occurrence of SPIRE SEUs appears to correlate strongly with the frequency of HIFI SEUs, implying that they have a common cause.

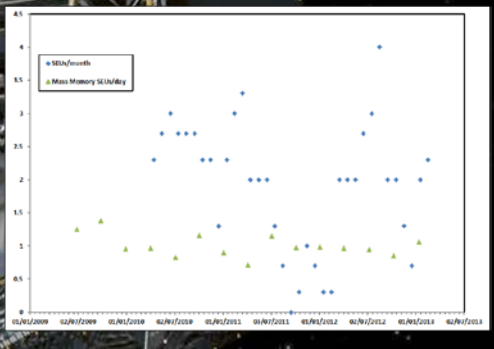


The slight trend to a decreasing number of bit flips through the mission (insert) disappears when we remove the first two points (corresponding to solar minimum), suggesting that the trend is not real. From the end of 2009 to mid-2013, the rate of bit flips is constant within the errors, although the cosmic ray background measured by the SREM drops steadily through the mission (bottom).

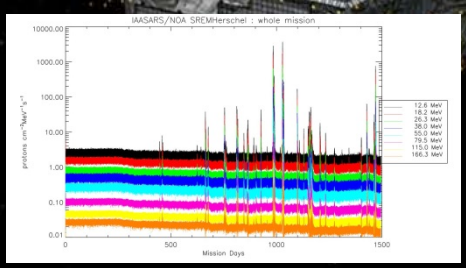


The SEU rate observed for Herschel's HIFI instrument (right) shows a deep minimum in late 2011, but this does not correlate at all with the behaviour of Mass Memory SEUs. There is also a clear trend to lower rates of HIFI SEUs with time, as expected from the decreasing cosmic ray flux.





(Above) Rate of Herschel Mass Memory SEUs.
Mean daily rate of bit flips as weekly averages through the 4-year mission.
There is no obvious long-term trend in the rate of bit flips.
(From raw data kindly supplied by MOC)



(Right) Data from Herschel's SREM (Standard Radiation Environment Monitor) covering the full Herschel mission. A decline in flux at all energies starts at the end of 2009 and lasts through the full mission. Fluxes in mid-2013, when Herschel was switched off, were about half the peak level.
(Plot prepared by Ingmar Sandberg on behalf of the SREM Team)

Conclusions

- Herschel Mass Memory SEUs do not correlate with instrument SEUs, or with the cosmic ray flux at Herschel measured by on-board SREM, suggesting that they have a different origin.
- In contrast, the rate of HIFI SEUs does show a (weak) trend to decrease in frequency with time, consistent with the trend in the (non-solar) cosmic ray flux.
- No correlation of SEUs with SPEs (solar proton storms) is seen, demonstrating that if instrument SEUs are exogenic, they are caused by high energy cosmic rays, probably >500MeV, of greater energy than are observed in the SPEs of the current, Solar Cycle 24.