THE EFFECTS OF SOLAR CYCLE 24 ON HERSCHEL

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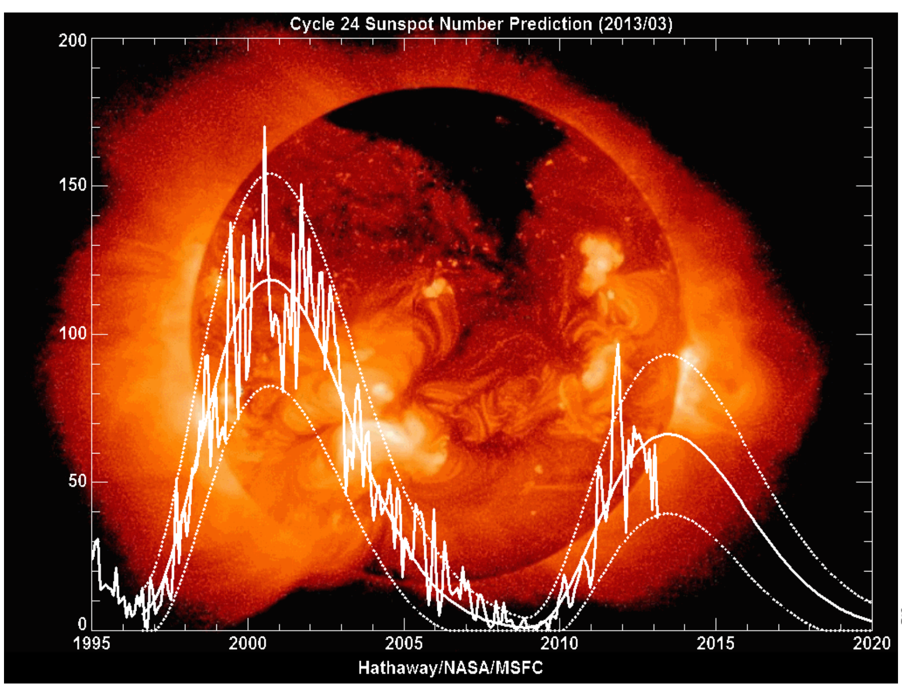
Abstract

Herschel was launched at minimum between Sunspot Cycle 23 and 24, taking up station around the Sun-Earth L2 point, outside the protection of the Earth's magnetic field, at a time when the cosmic ray flux was unusually high. Since launch solar activity has been building towards the expected maximum of Sunspot Cycle 24. We examine the space environment as characterised by sunspot numbers, Solar Proton Events (SPEs), Coronal Mass Ejections (CMEs) and Herschel's SREM radiation counters and the influence, if any, of solar activity on the observed rate of Single Event Upsets (SEUs) in the Herschel instruments.

Introduction

The Herschel Space Observatory was launched into a large (≈3x10^{5}km radius, 6 month period) Lissajous orbit about L2 point of the Sun-Earth system on May 14th 2009. There is considerable interest in the L2 as a benign environment for scientific satellites that offers a series of advantages over low Earth orbit (e.g. no geomagnetically trapped radiation, absence of space debris, greatly reduced Earth avoidance area, etc.) Characterising this region of space is of particular interest for future missions.

The prediction at launch was for a modest peak (sunspot number 90), with maximum in May 2013 [Solar Cycle 24 Prediction Panel, http://www.swpc.noaa.gov/SolarCycle/SC24/index.html, 2009 update], such that Cycle 24 would be the lowest solar maximum since the 1920s, although there is now increasing speculation that maximum may already have passed in 2012 (see below), making it the smallest since 1906.



SEUs and Space Weather Data

Potential space weather influence on the radiation field

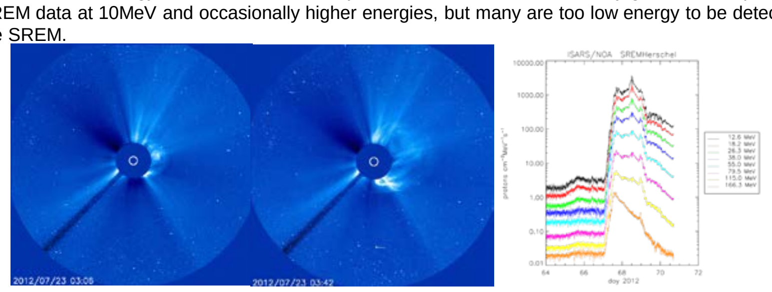
- Solar Proton Events (SPEs)

  Proton storms, usually produced by long-duration x-ray flares close to the centre of the solar disk. Mainly moderate energy protons (<200MeV). Typically arrive 6-12 hours after the x-ray flare (**below, right**). SPE activity in solar cycle 24 has been much lower than in solar cycles 22 and 23.
  - However, there is no evidence that there is any enhancement of SEUs coinciding even with the strongest SPEs, although increases in glitch rates are seen during SPEs.
- The sunspot cycle

  Galactic cosmic rays are known to anti-correlate with the sunspot cycle (see the second poster). Higher solar activity produces a denser heliosphere and better protection from Galactic cosmic rays. Sustained very low solar activity produces a weaker heliospheric bubble and much poorer protection from cosmic rays.
  - However, the correlation with the sunspot cycle is a manifestation of…
- Coronal Mass Ejections (CMEs)

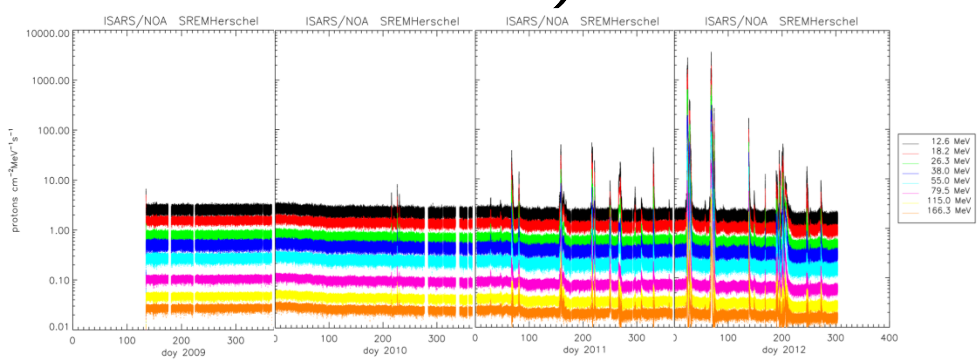
  These are eruptions in sunspots, or sunspot groups or, occasionally, caused by the collapse of magnetic filaments that cause the ejection of large masses of gas at velocities of several hundred kilometres/s (**below, left**).

  These are low-energy events that take ~2 days to arrive. The shock wave may give a small spike in SREM data at 10MeV and occasionally higher energies, but many are too low energy to be detected by the SREM.

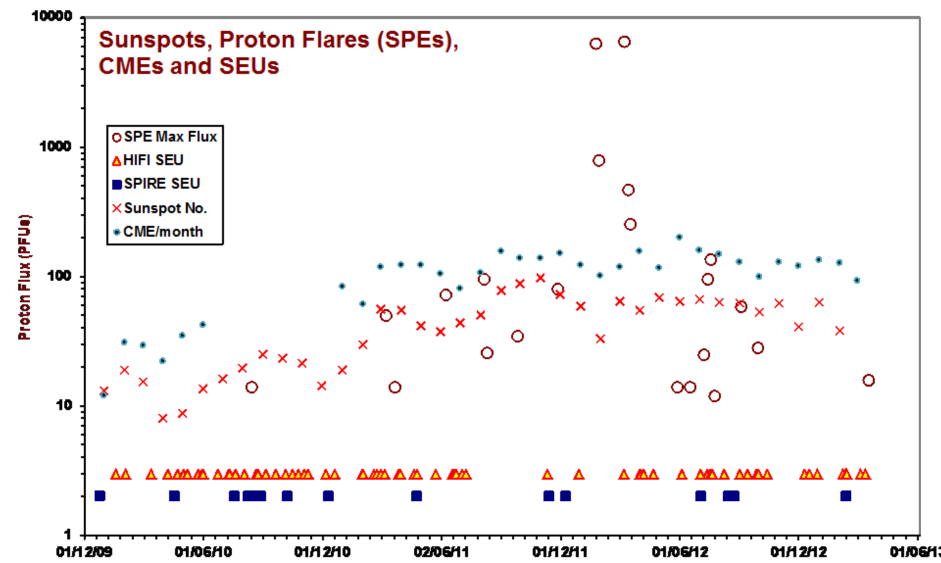


Conclusions

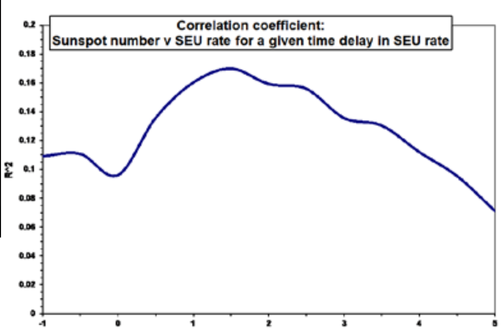
1. There is strong evidence in the data that the rate of SEUs may trail solar activity by ~45 days, with lower rates of SEUs following epochs of high solar activity and vice-versa, possibly due to a shielding effect against high energy cosmic radiation produced by the solar wind, although the physical mechanism is unclear.
2. Despite there being many fewer SPIRE SEUs, a similar effect is shown by the data.
3. This points to a common origin for the SEUs in HIFI and SPIRE.
4. The most likely source of SEUs is high-energy (>500MeV) cosmic rays. These are undetectable by the Herschel SREM.

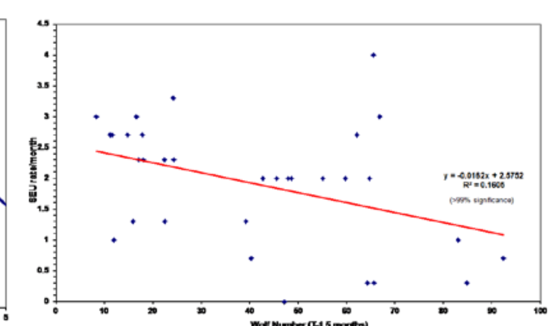


Data from the Herschel SREM (Standard Radiation Environment Monitor) for 2009-2012. The background flux from cosmic rays has dropped approximately 40% at all energies since the start of 2010 as solar activity has increased.



The time distribution of HIFI and SPIRE SEUs represented against three manifestations of space weather: the sunspot number; the monthly frequency of CMEs; and SPEs.

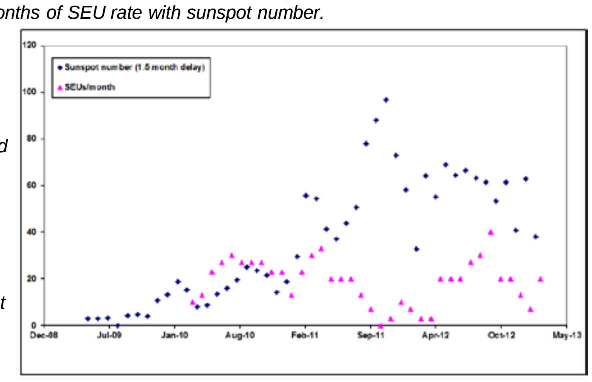


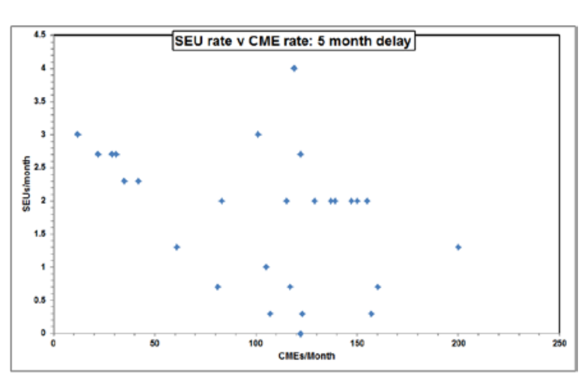


Correlation of rate of HIFI SEUs with the sunspot number: a correlation at ≈99.5% significance is seen for an assumed time delay of 1.5 months of SEU rate with sunspot number.

Possible anti-correlation of SEUs with sunspot number:

- *If we assume that SEU activity trails the sunspot number by 1.5 months we see a good anti-correlation.*
- *The significance is >88.5%.*
- *The significance has increased as more data has been added.*
- *In 1.5 months the solar wind expands out to ~9AU from the Sun.*
- ***But**, the underlying physical mechanism is not obvious.*





Possible anti-correlation of SEUs with CME rate:

- *CMEs give a measure of the complexity and thus shielding power of the solar wind.*
- *Data much less complete, but a good anti-correlation is seen for a 5 month time delay..*
  - *The SOHO-LASCO data archive of CMEs has a 6 month gap in the record in 2010.*
- *Difficult to assess the significance ,as the implied time delay is large and so much of the data for 2010 is missing.*