Herschel S/C temperatures dependence with attitude

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1. Executive summary

Data from OD 45 to OD 101 suggests that the spacecraft CVV, M1 and sun-shield temperatures show signs of being dependent on the Solar Aspect Angle. In particular, a constant rise of the M1 temperature close to the 86 K limiting value could be due to a high irradiation of the Sun-shield after several days dwelling at inclination angles where the sunshield and solar panels receive perpendicular irradiation from the Sun (beta = 0).

2. Introduction

The purpose of this technical note is to give account of correlations found in the Herschel Spacecraft temperatures as part of a routine monitoring at the HSC during part of the Commissioning (CoP) and Performance Verification (PV) phases.

3. CVV, M1 and Sun-shield temperature evolution from OD 78 to OD 101

Figure 1 shows the variation of the CVV, M1 and sun-shield temperatures from OD 78 and 100. The HPSDB mnemonics used for these are the following:

- CVV temperature, sensor T912 ("KD260303")
- M1 temperature, sensor T331 ("KD253302", in the +Z direction)
- Sunshade temperature, sensor T311 ("KM232303", in the +X edge)

The CVV and M1 temperatures were found to be anti-correlated at low frequency but correlated at high frequencies (small peaks) and both curves seem to be dependent on the sun-shield temperature, which in return depends on the Solar Aspect Angle. The CVV temperature came down from 74.2 to 73.8 K in ~ 10 days as expected, after reduction of the PACS DCLM independent heat input, while the M1 temperature started rising with plateaus from 85.1 K to 85.8 K in a way that was not predicted.

We can see that the M1 plateaus match reasonably well in time with high absolute values of beta which correspond to low values of the solar aspect angle ~60; while steep increases are associated to small values of beta (close to zero), which correspond to solar aspect angle of 90 degrees, this is values of normal incidence of the Sun on the Sun-Shield.

Figures 2 and 3 show the M1, CVV and sun-shield temperatures along with the inclination angle beta (which relates to the Solar Aspect Angle, SAA, as SAA = 90 – Abs(beta)). Both figures show a tight correlation between the sun-shield temperatures and the absolute values of beta, with maximum sun-shield temperatures being found for absolute beta values close to 0. degrees, which corresponds to perpendicular incidence of the stellar radiation into the sun-shield. Figure 3 illustrates the 3 hour time-delay between the sun-shield temperature and the beta angle by comparing a version of the beta angle curve shifted in time by 3 hours with the sun-shield temperature. The similarity of both curves is remarkable.

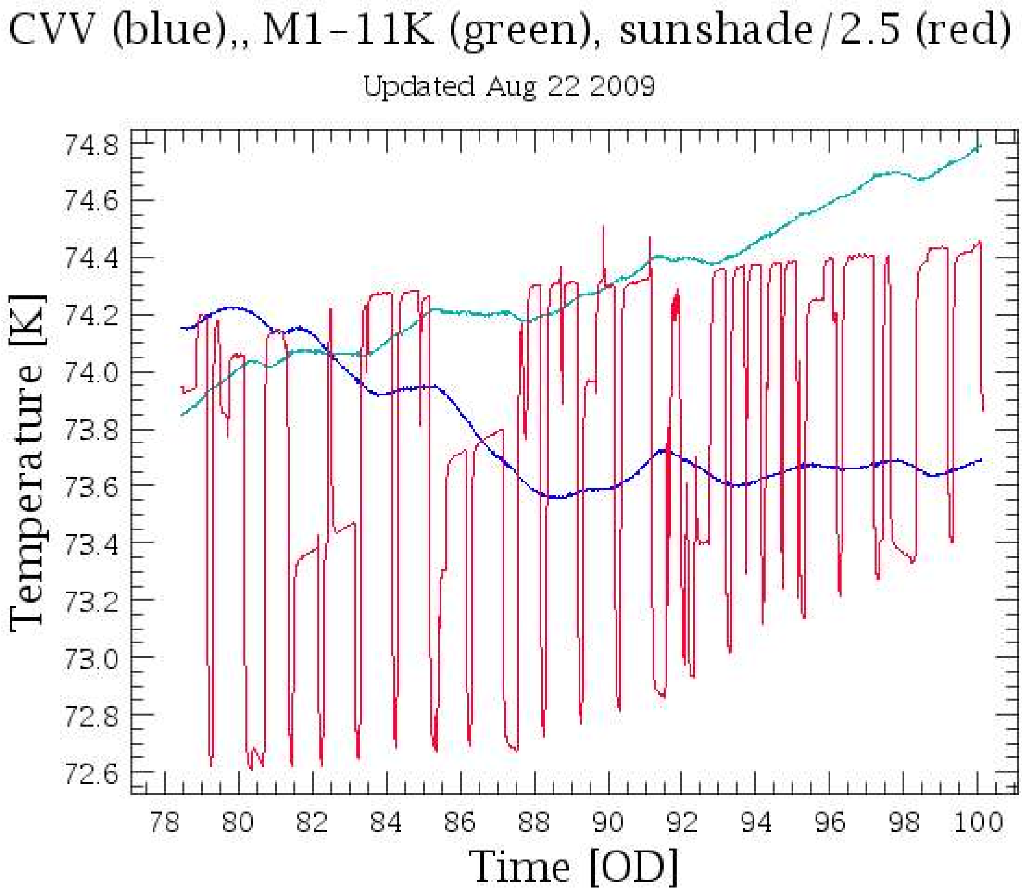

Figure 1: Herschel S/C temperatures from July 29th (OD 78) to Aug 22 2009 (OD 101). The CVV temperature is shown in the blue line, the M1 temperature is shown in green line and the top sun-shield sensor temperature in red. The CVV drops match the M1 plateaus and the sun-shield high values. The M1 temperature plateaus match CVV drop and low sun-shield temperatures. The M1 temperature rises match the high sunshade temperatures. This suggests that sun irradiation of the sunshade at warm telescope attitudes is the cause of the M1 temperature rise.

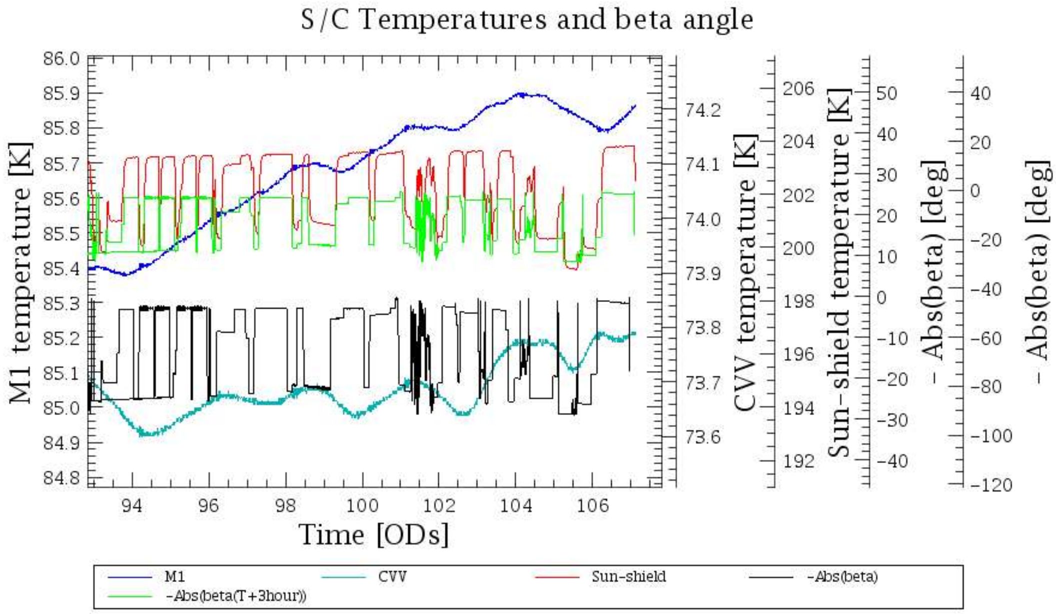

Figure 2: Spacecraft temperatures compared to the inclination angle beta (Solar Aspect Angle = 90 – Abs(beta)). M1, CVV and sun-shield temperatures are plotted with blue, green and red lines, respectively, with the corresponding scales to the right of the figure. In black line, the negative value of the beta angle is plotted for the same days and in light green line, the same beta angle shifted 3 hours back in time to match the sun-shield temperature variations. More detail match is appreciated in Figure 3. High sun-shield temperatures (and beta angles close to 0) match the rises of the M1 temperature while low sun-shield temperatures (and large absolute beta angles) match M1 temperature plateaux.

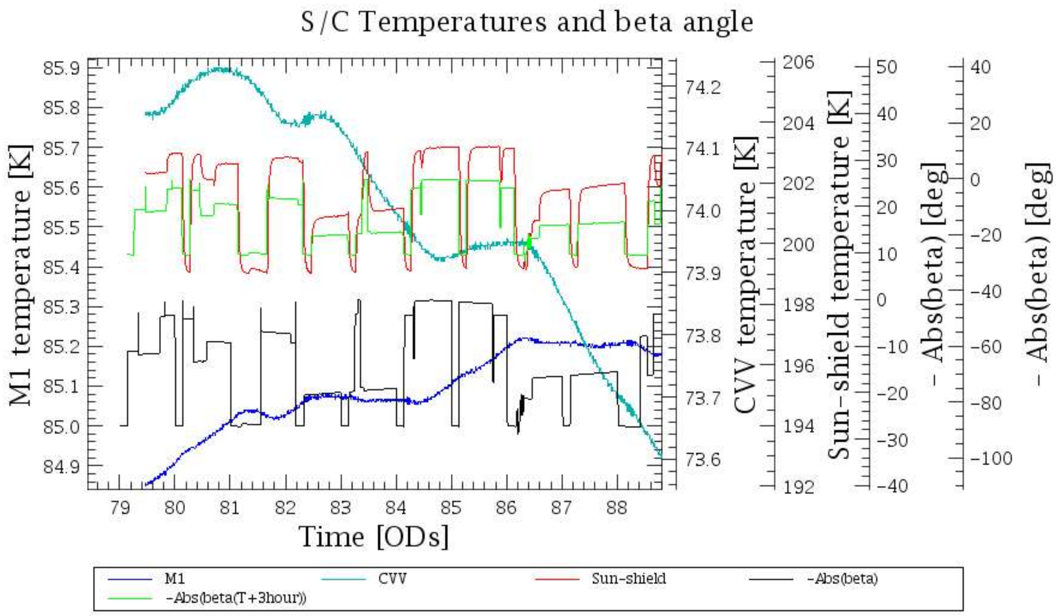

Figure 3: Zoom of Figure 2 showing the detailed match between the sun-shield temperatures and the inverse of the absolute value of the inclination angle beta. The measured time-delay between both curves is of 3 hours

4. Long-term (CoP + PV) temperature drifts

Two main possible explanations are available for the rise of the M1 temperature: i) sun-shield perpendicular illumination and ii) long-term orbital variation of the Lissajous orbit of Herschel, which had maximum distance from the Sun on the Aphelion (July 4th, 2009, OD 22). Both scenarios predict an increase of the mirror temperature with the start of the PV phase (OD 62).

Figure 4 shows the M1 and sun-shield temperatures from the CoP phase to the PV phase. The sun-shield temperatures were on average lower during CoP phase due to the different pointing strategy. At all times the correlation between beta angle an sun-shield temperatures holds. Starting with the PV phase, many OD's have had beta angles close to 0., which led to an increase of the shield, and therefore the mirror, temperatures.

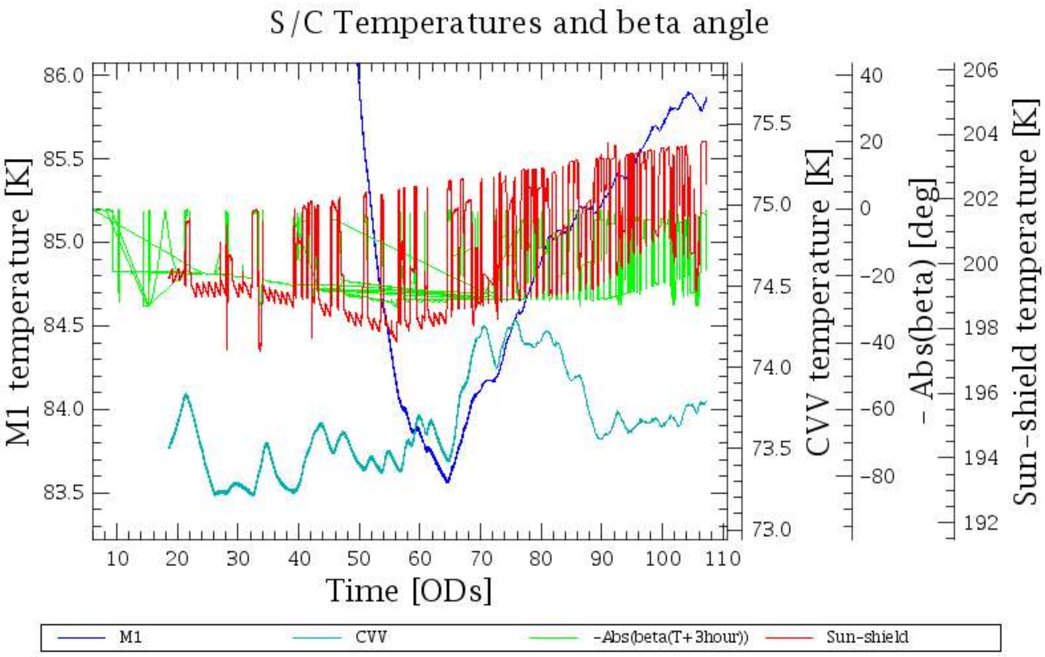

Figure 4: M1, CVV and sun-shield temperature variations since the start of the mission (CoP and PV phases together) compared to the inclination angle beta. The sun-shield temperature and the beta angle correlate at all times. The start of the PV phase on OD 62 marks the start of longer periods at angles close to 0 degrees with a larger sun-shield temperature in average. On top of the day-to-day inclination variations, the sun-shield temperature is showing a smooth increase which could be related to the long-term orbital effect.

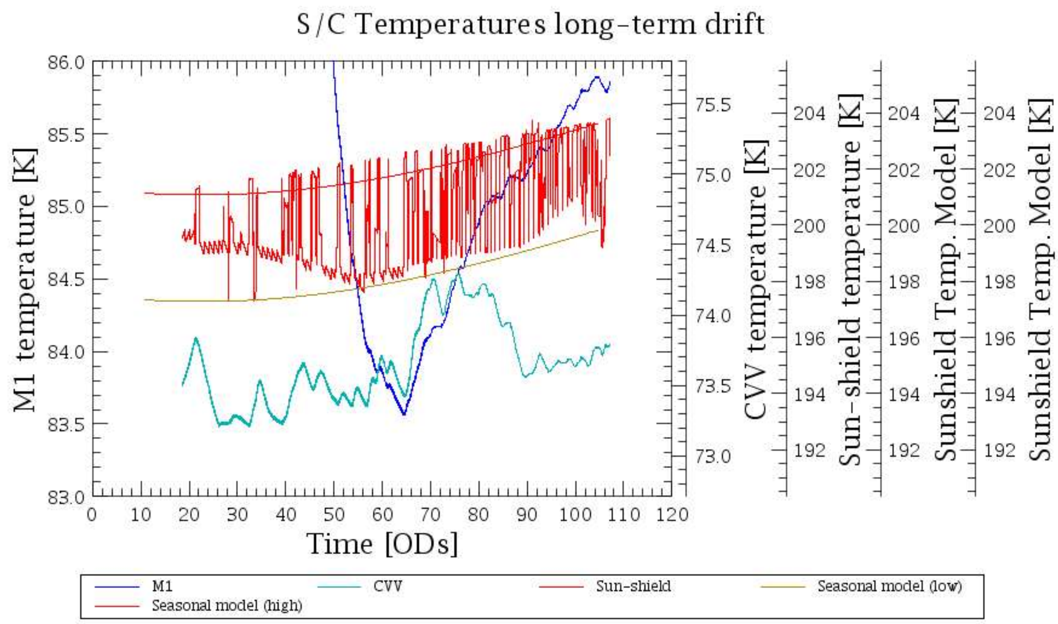

Figure 5: M1, CVV and sun-shield temperature variations since the start of the mission (CoP and PV phases together) compared to a sinusoidal model of the orbital evolution of the S/C temperature, with a minimum at the aphelion (on OD 22, July 4th 209) and a maximum on the perihelion (OD 204, January 4th 2010). The best fit model values to reproduce the sun-shield temperature trend have an amplitude of 2.3 K and a time-scale of half a year.

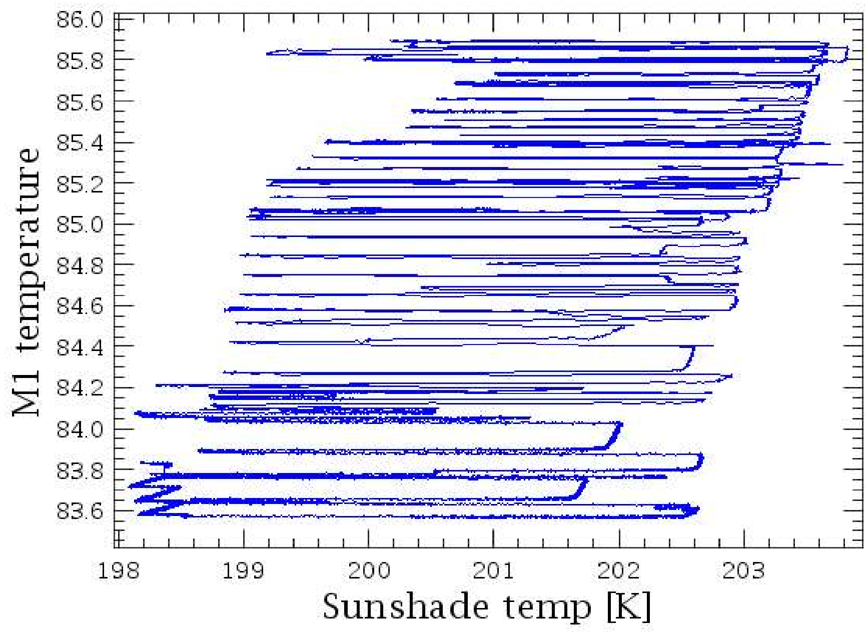

Figure 6: M1 temperature versus the sun-shield temperature from OD 70 to 100. In spite of the large 3-4 K departures of the sun-shield temperatures, an overall mirror temperature increase of 2.2 K can be measured over a mean sun-shield temperature increase of 2 K in the same period of time.

5. Preliminary conclusions (TBW)

1.) The telescope mirror temperature has been steadily increasing since very close to the start of the PV Phase, with the late-CoP low temperature being about 83.4 K. It stabilized now at 85.8 K on OD 101, matching a change in the S/C beta angle.

2.) There is a clear correlation between Sun-shield, SVM-shield and mirror temperatures, with a response time of only a few hours at most.

3.) There is an anti-correlation between the absolute value of the beta-angle and the Sun-shield and SVM-shield temperatures. Beta angles near zero are associated with the hottest shield temperatures (as would be expected) and these are in turn associated with the fastest rise in mirror temperature. Beta angles near zero are much more common in PV Phase than in CoP. During CoP the S/C pointing was kept mostly at high beta angles. During PV Phase we point all over.

4.) Within the regime of mirror temperature variation we are seeing, and may reasonably expect to see, the thermal emission from the mirrors is not expected to dominate observational sensitivity.