PACS photometer calibration block analysis

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ABSTRACT

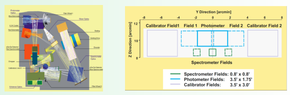
The absolute stability of the PACS bolometer response over the entire mission lifetime without applying any corrections is about 0.5% (standard deviation) or about 8% peak-to-peak. This fantastic stability allows us to calibrate all scientific measurements without using any information from the PACS internal calibration sources. However, the analysis of calibration block observations revealed clear correlations of the internal source signals with the evaporator temperature and a signal drift during the first half hour after the cooler recycling. These effects are small, but can also be seen on sky in repeated standard star measurements. From this analysis we established corrections for both effects which push the stability of the PACS bolometer response to about 0.2% (stdev) or 2% in the blue, 3% in the green and 5% in the red channel, peak-to-peak. After both corrections we still see a correlation of the signals with PACS FPU temperatures, possibly related to a PACS external heat source.

INTRODUCTION

- Each PACS photometer observation is preceded by a standard calibration block measurement that is performed in the target acquisition phase, typically at the beginning of a satellite slew. The science part of a measurement is separated from the calibration block by at least 5s delay.
- Calibration blocks (CBs) last for about 30s and consist of chopped observations of the two PACS internal calibration sources (CSs) with different constant fluxes. CBs were designed to allow monitoring the evolution of bolometer response during an operational day and the full mission lifetime on the basis of a well-defined differential signal from both PACS calibration sources.
- In order to investigate the long term behaviour of bolometer responsivity we compiled a database of CB observations by processing more than 17000 measurements between OD130 and OD1350. CBs are taken from PacsPhoto mode observations. Using this database we searched for different dependencies of CS signals on different instrumental parameters.

INTERNAL CALIBRATION SOURCES

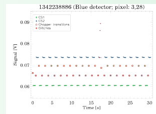
- The two internal calibration sources are placed at the entrance of the instrument to have the same light path for the sky observation and internal calibration.



- The CSs are low emissivity greybody sources providing far-infrared radiation. Their signals are slightly different and set around the level of the telescope background.
- The temperature of PACS CSs are commanded via their resistance settings (CS1 48Ω/55K, CS2 58Ω/60K). Resistance values as well as the temperature of CSs were absolutely stable during the mission.

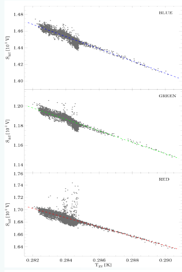
DATABASE OF CALIBRATION BLOCKS

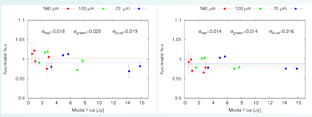
- A photometer CB contains several chopper cycles on both PACS CSs. The chopper moves with a frequency of 0.625Hz between the two PACS CSs. 19 chopper cycles are executed, each chopper plateau lasts for 0.8s producing 8 frames in the down-link.
- Our CB processing scheme contains the following steps: 1) identify the CB within the specific measurement; 2) perform basic data processing steps (photFlatBadPixels, photFlagSaturation, photConvDigit2Volts and photMMTDeglitching); 3) after eliminating chopper transitions (first point in each plateau) and glitch elimination we determine CS1 and CS2 signal levels by computing the robust average of chopper plateaus. Differential signals were determined as $S_{diff} = S_{CS2} - S_{CS1}$.
- As a final step we calculated a robustly averaged signal for the blue and red array using all unmasked pixels.
- Our current CB database contains entries for 17070 observations.

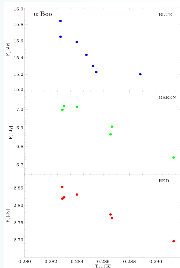


CORRELATION WITH EVAPORATOR TEMPERATURE

- A ^{3}He cooler are used to ensure sub-Kelvin temperature for the operation of PACS photometer. The evaporation of ^{3}He provides a very stable temperature environment at ~300mK. After each cooler recycling procedure, that takes about 2.5h, there are about 2.5 ODs of PACS observations possible.
- The evaporator temperature (T_{EV}) rises towards end of cooling cycles. By investigating the behaviour of S_{diff} as a function of T_{EV} we found a clear correlation between the two parameters for both the blue and the red arrays. The observed trend can be well fitted by a linear enabling the correction for T_{EV} effect.
- Measured flux densities of standard stars extracted from PACS calibration observations showed very similar trend with evaporator temperature.
- Photometry of standard stars can be improved by applying our pixel-based T_{EV} correction for their observations (for details, see presentation by Zoltán Balog).
- The correlation with T_{EV} is very clear, but the related corrections are typically well below 1% although slightly different from pixel to pixel. It is only ~1.3% of all measurements for which this correction is larger than1%.

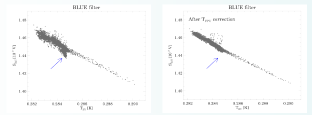


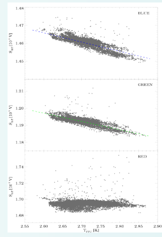




CORRELATION WITH FPU TEMPERATURE

- After the T_{EV} correction, we also looked for remaining trends and correlations.
- We found that differential CS signals also depend on the FPU (Focal Plane Unit) temperature (measured at the FPU structure close to the spacecraft L1 level as given in the instrument HK).
- The observed trend can be well fitted by a linear. Interestingly, the red array is not affected by this phenomenon.
- We cannot exclude that here we see the effect from a PACS external heat source.

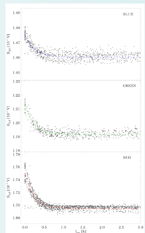




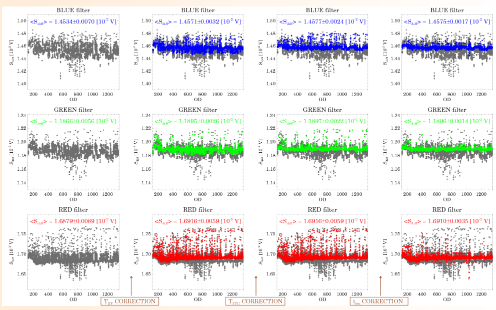
DRIFTING EFFECT AT LOW RECYCLING TIME

- Differential CS signals also depend on time elapsed since the end of the last cooling recycling procedure (t_{rec}). At the very beginning of PACS observing sessions a stabilization effect can be recognized.
- This drifting is only a very small effect and is only seen during the first ~30 minutes after the recycling has finished. In most cases this drift may be usually covered in the initial slew to the first science target after the recycling.
- The observed trend can be well fitted by a simple model:

$$S_{diff} = a_0 * \exp(-t_{rec} / a_1) + a_2$$



EVOLUTION OF DIFFERENTIAL CS SIGNALS



- The stability of the differential CS signal without any correction in the studied observing period:
  - 0.48%, 0.47%, 0.53% (standard deviation) in blue/green/red observations.
- After applying the correction for T_{EV}:
  - 0.22%, 0.22%, 0.35% in blue/green/red observations.
- After applying the correction for T_{FPU}:
  - 0.16%,0.18%, 0.35% in blue/green/red observations.
- After applying the correction for t_{rec}:
  - 0.12%,0.12%, 0.20% in blue/green/red observations.
- Peak-to-peak variations after applying corrections for T_{EV} and t_{rec} :
  - 2%, 3%, 5% in blue/green/red observations.

CONCLUSIONS

- Using our database of calibration block observations we investigated the long term behaviour of differential CS signals which characterize the evolution of bolometer response as well.
- We revealed that variation of evaporator temperature and FPU temperature cause changes in differential signals. Signal levels also show a short drift in the first ~0.5h of observing sessions after the cooler recycling .
- We developed correction methods for all three effects. By applying these corrections the standard deviation of differential CS signals could be decreased significantly.
- The main cause of S_{diff} changes is the variation of evaporator temperature. We note that measured flux densities of standard stars show also a similar dependency on T_{EV}. Our correction derived from the CB analysis will be included in the standard pipeline processing scripts after the validation process is completed. This will improve the photometry for measurements taken either directly after the cooler recycling or very late towards the end of the cooler hold time.
- The drifting effect observed at low recycling time is more important for the red array than for the blue.
- The T_{EV} and the t_{rec} correction could be relevant for variability programmes.
- The bolometer response turned out to be very stable over the entire mission lifetime thus the calibration blocks do not need to be used in the processing of science data.

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