The HERSCHEL/PACS On-Board Data Reduction Concept

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Abstract. This paper describes the raw data processing software of the Photodetector Array Camera and Spectrometer (PACS), an instrument implemented on the Herschel satellite to cope with its restricted downlink bandwidth. The instrument's high raw data rates require not only to use highly specialized lossless compression algorithms, but also to carry out reduction steps that are usually done on ground.

In this context the on-board data reduction ranges from simple data rejection by quality criteria (e.g. glitches) to ramp fitting and integration steps. We show how the on-board software approaches this task and furthermore the critical interrelation with the HERSCHEL ground segment is discussed.

1. Introduction

Cornerstone number four in the ESA Horizon 2000 programme, the mission formerly known as "FIRST", is now named after Sir William Herschel, who discovered the infrared radiation 200 years ago. To be launched in 2007 the Herschel Space Observatory (HSO) will have a radiatively cooled 3.5m telescope and it will carry a science payload complement of three instruments (HIFI, PACS and SPIRE) housed inside a superfluid Helium cryostat (Pilbratt et al. 2001). The satellite's planned lifetime spans over three years and during that time it will let astronomers conduct observations in the far infrared and sub-mm range.

PACS - The Photodetector Array Camera and Spectrometer (Poglitsch et al. 2000) - employs two Ge:Ga photoconductor arrays (stressed and unstressed) as well as two bolometer arrays to allow imaging line spectroscopy and imaging photometry in the 57-210 micron wavelength band. The instrument is built by an international consortium lead by the Max Planck Institute for Extraterrestric Physics in Garching. One of the many new features of PACS is its high-level software (HLSW), which will take a pioneering step towards on-board reduction of science data.

The Austrian responsibility is to develop and implement exactly that part of the PACS on-board software (OBSW) that takes care of all lossless and lossy methods to reduce and prepare the science data for downlink and further processing on ground. Among the points of concern are the preservation of science data quality and quantity, the real-time aspects of this task and the robustness of a software to operate in an autonomous way in space.

2. Problem Statement

PACS houses two 25x18 arrays for spectroscopy, read out at 256 Hz and two bolometer arrays with 32x16 and 64x32 pixels for photometry, read out with a frequency of 40 Hz. As a consequence, the instrument generates a raw data flow of up to 3600 kbit/s in spectroscopy and up to 1600 kbit/s in photometry. Although only either spectroscopy or photometry is being done, these data rates are still by far above the telemetry rate, which is normally restricted to 100 kbit/s.

On the other hand, the restriction on the downlink rate is in the first place driven by the L2-orbit of the satellite (that is about four times the moon's distance), which will only use 2-3 hours per day for telecommunication. As compression only will not fulfill the telemetry requirements, the consequence is to introduce on-board science data processing, but the requirement to use space qualified hardware naturally imposes severe restrictions on the available CPU resources for this software task.

3. On-Board Processing Concept

The goal of our software is not to reduce/compress the data to as little as possible, but to retain as much science within the allowed data rate of 100 kbit/s. Always trying to keep the software flexible and robust at the same time, the following processing steps have evolved during the past two years:

- *data selection and rejection* All detector arrays can be masked arbitrarily to only transmit selected channels. It allows to blind out defunct pixels and on the other hand the observer can find a compromise in the quantity (more pixels) and the quality (less reduction) of his/her data. By selecting only a subset of detectors the observer can still obtain unprocessed raw data this way. Data rejection is also a major feature of the HLSW, allowing to detect and reject glitch (intrinsic/extrinsic) affected samples automatically. In general it may be sufficient to calculate simple averages for this purpose in photometry, whereas in spectroscopy we use RANSAC to determine flawed ramps (Bischof et al. 2000).
- *data processing* On-board data processing focuses on what has to be done on ground anyway. Once the validity of the readouts is ensured by the previous module, the averages/ramps are calculated conventionally using mean/least squares. If the chosen detector setup (esp. the reset interval) does still demand a much higher reduction rate, integration is the - call

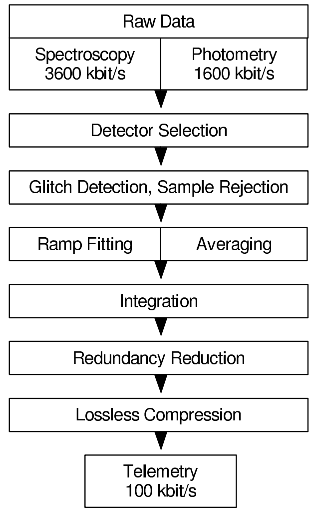

Figure 1. The OBSW Processing Scheme

it inevitable - last resort. That is the lossy part of the reduction scheme therein. Special attention has to be given to the confidence of the data, because after the integration step the control over the data is lost. So the HLSW synchronizes itself with the chopper and provides also additional information about the deglitching process. An evaluation of the compression concept on a theoretical basis (Bischof et al. 2000) points out that this module strongly depends on the correctness of the deglitching process. Once a glitch is left undetected the integrated ramps cannot be corrected any more.

- *data compression* The data processed so far have still some properties we can use to our advantage. Ramps/Averages obtained on the same chopper position (and the same pointing of course) can be pulse-code modulated (i.e. we only encode the differences of subsequent values). That's what we call temporal redundancy reduction. Once this has been done, the offset frames are also - from the histogram point of view - unbalanced and can be spatially reduced. At last a standard lossless compression algorithm (Kordes et al. 1990) is used especially to take care of the ample header information from the detectors.

The general reduction scheme is depicted in figure 1 with the modules described above. Note that none of these steps must cause a delay/interruption in the data flow which would immediately lead to a loss of science data.

4. Ground Segment Interaction

The HERSCHEL ground segment is based on a common, object oriented database system - the Herschel Common Science System (HCSS), implemented using JAVA technology. The HCCS is a common effort of ESA and the three instruments.

The OBSW prepares Telemetry Packets which are downlinked during the daily communication period. The Ingestion process is saving the Telemetry Packets within the HCSS. In parallel science packets are analysed and relevant packets passed to the instrument specific parts of the TMIngestion process.

For PACS the science Telemetry Packets are collected until it is possible to run the decompression algorihm on it. The decompressed data are stored within so called "Data Frames". Data Frames cover a data set of one read out cycle. These Data Frames are the base for further data analysis in near real time (Quick Look Analysis - mostly used during ground based instrument tests) and offline processing within Interactive Ananlysis systems.

The PACS Interactive Analysis system will also support the use of on-board data reduction algorithms in order to verify and improve them using the unreduced raw data which are downlinked for certain detectors in parallel.

5. Conclusion

In this paper we described the PACS on-board software processing concept which combines compression algorithms with real reduction steps. The flexibility of the software ensures that it is still possible to retrieve raw data by trading detector channels, but normally it will be more feasible to run the full scheme including data reduction. So far only simulated data (Bischof et al. 2000) and data from the ISO mission (Kerschbaum et al. 2000) have been used to test the software components, but preliminary data from the detectors look promising.

To put it in a nutshell, PACS strongly depends on the compression/reduction software to take full advantage of its novel detectors.

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References

G. L. Pilbratt, J. Cernicharo, H. M. Heras, T. Prusti, R. Harris eds. "The Herschel mission, scientific objectives and this meeting", *The Promise of the Herschel Space Observatory*, 2001, ESA SP-460

A. Poglitsch, N. Geis, C. Wælkens, "Photoconductor array camera and spectrometer (PACS) for FIRST", 2000, *UV, Optical, and IR Space Telescopes and Instruments VI*, 4013

H. Bischof, A. N. Belbachir, D. Hönigmann, F. Kerschbaum, "A Data Reduction Concept for FIRST/PACS", 2000, *UV, Optical, and IR Space Telescopes and Instruments VI*, 4013, 244

F. Kerschbaum, H. Bischof, A. N. Belbachir, T. Lebzelter, D. Hönigmann, "Evaluation of FIRST/PACS Data compression on ISO Data", 2000, *UV, Optical, and IR Space Telescopes and Instruments VI*, 4013, 253

F. Kordes, R. Hogendoorn, J. Marchand, 1990, *Handbook of data compression algorithms*, ESA TM-06