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Correcting Transients in Unchopped PACS/Herschel Spectroscopy

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Abstract. We present a technique to correct long-term transients in the signal from unchopped spectroscopy with the PACS instrument onboard the Herschel Space Observatory. This kind of transients affects the response of the detector after every big variation of the incident flux and lasts up to 6 minutes. The effect is particularly pronounced in the case of the red array whose response can vary up to 20%, while is less important in the case of the blue array. Correcting these transients is critical especially in the case of short observations since they can affect a large fraction of the observation. A module to correct long-term transients has been developed in Jython and it is part of the data reduction software for Herschel, HIPE, since version 7.0.

1. Transients in PACS Spectroscopy

An IFU spectrograph is available on the PACS instrument onboard Herschel (Poglitsch et al. 2010). It consists of a matrix of 5×5 spatial pixels. For each spatial pixel, the light is dispersed along 16 spectral pixels. In practice, to observe any wavelength range, it is necessary to perform a scan of the wavelength range. In this way, any spectral pixel is exposed to a variable incident flux. The detectors are Ge:Ga arrays which are known to suffer from transient behaviors. Transients consist of variations in the response of the detector after a sudden flux change. A typical observation consists of a calibration block (when internal calibration sources are observed) and observation of the targeted source. The standard mode of observation with PACS uses chopping, that is the source and an OFF position are alternatively observed. The difference of the two observations automatically gets rid of the response variations of the detector. In some cases (extended sources or crowded fields), it is not viable to observe an OFF position. So, the solution is to use the unchopped mode when the telescope is pointed first to the source and then the same wavelength scan is repeated on a region free of sources to have an OFF position, dominated from the emission from the telescope mirror. During the initial calibration observation, the two internal calibration sources are alternatively observed at one key-wavelength (the one closest to the line observed). When the starting flux is very different from that of the calibration sources, a clear long-term transient appears in the data. A transient can appear also when several lines are observed in the same observation since in different part of a source spectrum the continuum can be very different.

In the case of the line scan mode, only a short range of continuum is observed. So, during the scan the flux on the detector is essentially stable and the only transient effect comes from the change in flux from the previous continuum. The transient can be modeled using a linear combination of exponential functions. The transient arising from a sudden decrease in flux is the easiest to model, requiring an exponential function only.

$$1 + a_0 e^{-t/\tau_0} \text{ with } \tau_0 = 250. \tag{1}$$

In the case of the transient after a sudden increase in flux, at least two exponential functions are needed. In the general case, when a drift component is present, a third exponential has to be considered:

$$1 + a_0 e^{-t/\tau_0} + a_1 e^{-t/\tau_1} + a_2 e^{-t/\tau_3} \text{ with } \tau_1 = 10, \text{ and } \tau_2 = 2000. \tag{2}$$

Since some of the time constants of the transient components are very stable for the different pixels, they are fixed in our implementation. To find the best free parameters, the module we developed minimizes the dispersion of the final spectrum for each spatial pixel. This works since in unchopped mode the same wavelength range is observed at least four times at the different stages of the transient in the response.

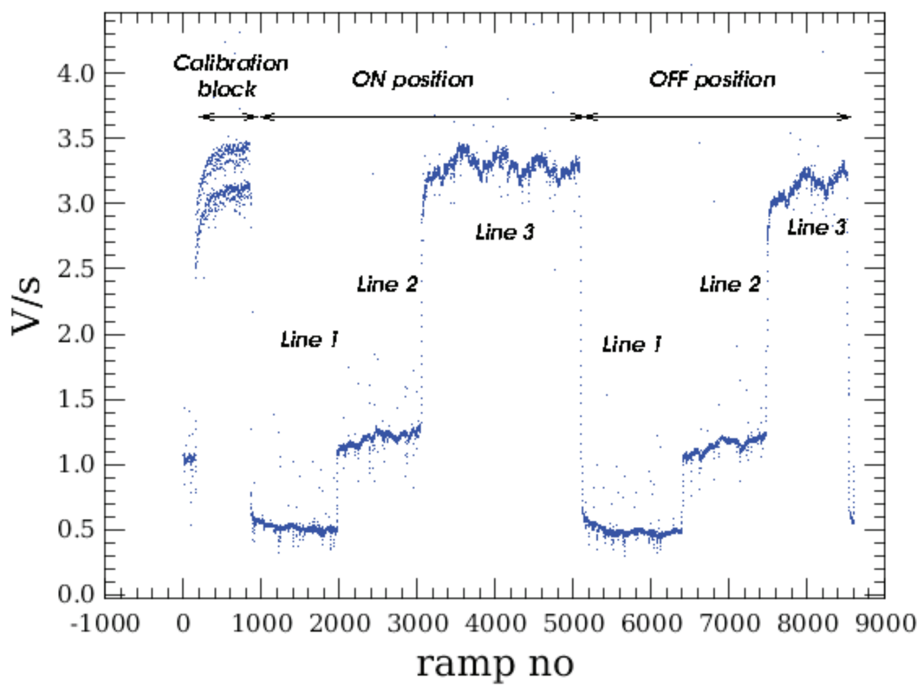

Figure 1. An example of unchopped observation of three different lines. The observation consists of a calibration block (alternating between the two internal calibration sources), three blocks on the source to observe three different lines and three block off-source reobserving the same three wavelength ranges. For each one of these blocks, a minimum of two up-down wavelength scans is performed.

From version 7.0 of HIPE, the software for Herschel data reduction, we introduced a module (specLongTermTransient) for the correction of the long-term transient in the unchopped PACS data. This is working currently only in the case of line spectroscopy. A plotting routine is also available to check for transients and the correction.

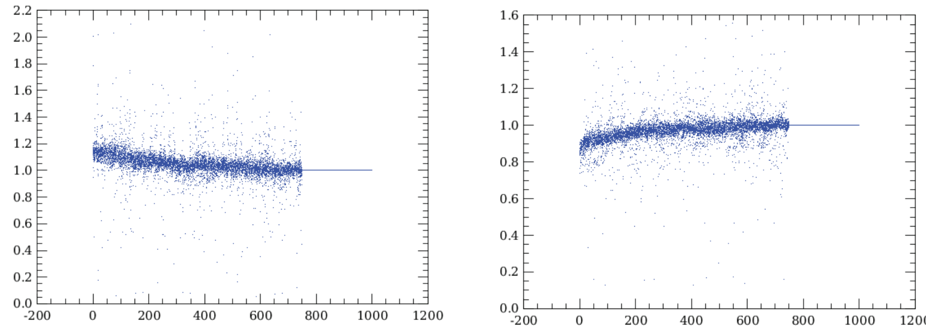

Figure 2. Two examples of transients from two blocks in Figure 1. By normalizing the signal by the signal in the last scan, it is possible to visualize the transient in the response. On the left, the descending transient after the calibration block. On the right, an example of ascending transient from the second line in the ON position. These two types of transients are modeled using the equations 1 and 2 of the paper, respectively.

The module makes use of MINPACK, a robust package for minimization which has been converted to JAVA for this specific task but can be generally used as an alternative minimization technique in HIPE. Because of the presence of glitches in the data and of the inaccurate initial estimates of the parameter values, other conventional methods of minimization often fail. The version of MINPACK is very close to the version maintained by Markwardt in his IDL library (see `http://www.physics.wisc.edu/~craigm/idl/`). Since the task is also very time consuming, we implemented it using multi-threading to take advantage of the availability of multiple cores in modern computers (see poster P062).

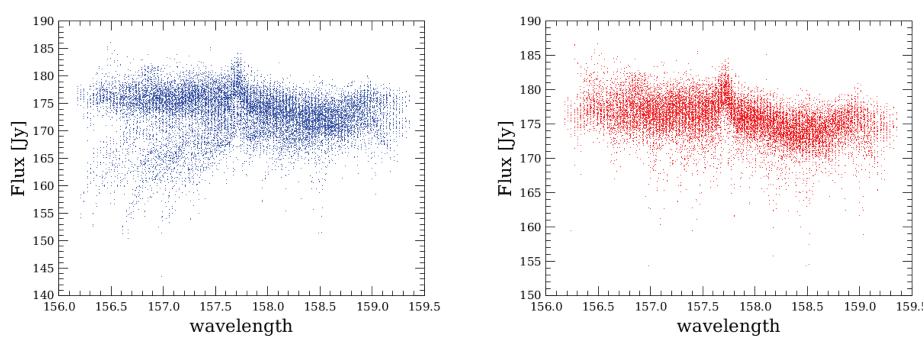

Figure 3. Spectrum from the 16 spectral pixels of the central spatial module. On the left, the spectrum obtained without any transient correction. On the right, the spectrum after applying the transient correction. The noise is drastically reduced allowing a much improved detection of the line.

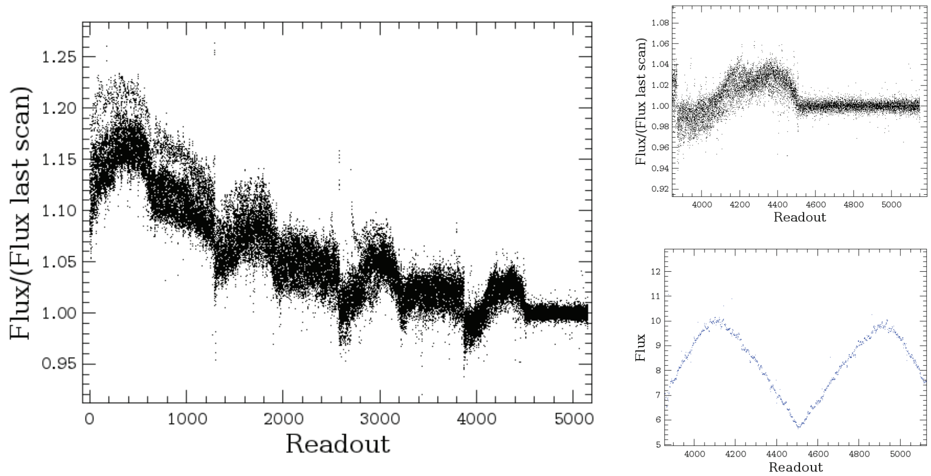

Figure 4. On the left hand, the signal of the central pixel of an observation of Neptune has been normalized to the last scan. The observation consists of 4 up-down scans of the wavelength range. On the top right, the last up-down scan normalized to the last scan is shown. On the bottom right, the flux on the detector during the last up-down scan is plotted. In this case, the continuum is varying dramatically. So, on the top of a general drift in the response, the variation of the continuum generates transients also during the single scans. When the flux increases, the flux recorded by the detector is smaller than the incident flux. So, the ratio of the up and down scans will be lower than one when the flux is increasing in the first scan and bigger than one when the flux is increasing in the last scan. An accurate correction should consider the drift in the response and the response variation during each scan at the same time.

2. Larger Ranges

We are currently investigating the possibility of correcting the transients present in spectra obtained scanning large wavelength ranges. In these cases, as the case of the Neptune range scan in the example, the continuum can change dramatically. So, there will be a transient also due to the change of continuum during each scan. In particular, the transient is stronger when the flux is suddenly increasing so that the flux recorded by the detector is smaller than the incident flux. If we compute the ratio of the two last scans, therefore, we will see a ratio < 1 when the flux is increasing in the first scan and decreasing in the last scan and a ratio > 1 in the opposite situation. To this effect, a general drift in the response is visible. For the best results, the two effects have to be corrected at the same time. A module to correct for these effects in range mode will be probably available in HIPE version 9.

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References

Poglitsch, A., et al. 2010, A&A, 518, L2