Reducing Faint Chopped Observations with ISOPHOT

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Abstract

The ISO archive hosts the considerable number of more than 3200 observations, that were performed in rectangular or triangular chopped mode. Many of them were aimed at sources close to the ISOPHOT detection limits. A good estimation of the statistical uncertainties is therefore highly important and larger uncertainties in the overall flux calibration become acceptable in these cases. The method to reduce faint chopped ISOPHOT observations presented here is more "traditional" compared to other methods based on regular pattern analysis or fourier transforms. However, through better statistics from subdividing integration ramps, rigorous deglitching and baseline removal, very reliable estimates of the uncertainty are possible. It is established here for the detectors C100, P1 and P2, but can principally be extended to other detectors too. The correction of the flux calibration due to transient response is derived empirically and yields a dependence on the ratio of source and background for the C100 detector, while being constants for the P1 and P2 detectors. Especially the C100 method could be useful for some of the extragalactic program data in the ISO archive, that suffered most from a lack of detections.

1 Introduction

This investigation resulted from the need to calibrate a set of chopped measurements on a sample of faint Galaxies with ISOPHOT. In particular the filter bands C_60 and C_100 of the C100 detector were difficult to reduce, because of the high noise and the time dependent response of the detector material. The sources with fluxes at sub-Jansky levels were barely detected, since in anticipation of a better S/N ratio, only relatively short integration times (32-128 sec on-source) were used.

So far various methods to reduce chopped measurements were tried, however without improving calibration accuracies beyond 30 %. For the weakest sources close to the detection limit, a solid estimate of the uncertainties becomes far more important than a perfect flux calibration. Methods that use characteristic patterns (Abraham & Acosta-Pulido 2002) or Fourier methods (Haas priv. comm.) generally have difficulties in estimating the uncertainties, therefore a more traditional method is used here.

The signal losses due to detector transients are corrected in an empirical way, by calibrating the method with observations of known stellar sources. The correction depends on the closeness of the science-measurements and the calibration-measurements in parameter space, i.e. for observations with similar readout-timing, chopper frequency and flux, a similar transient behavior is expected. Systematic effects will therefore mostly cancel out for similar measurement setups.

2 The Data

The chopped measurements at the source-positions were executed with integration times of 64 to 256 seconds, split evenly between source and background. The chopper was operated in triangular

mode' so that two positions opposite to each other with respect to the target were measured alternatingly. The associated FCS-measurements took 32 seconds of integration time. The reset intervals for all measurements were set between 1 and 8 seconds.

3 Data Reduction

The data reduction in PIA (Gabriel et al. 1997) from ERD to SRD level was performed by standard PIA-processing. At ERD to SRD-level processing we deviated from the default settings of PIA by using the 2-level ramp deglitching and ramp-subdivision. The ramp deglitching procedure was run with default parameters. The integration ramps of typically 32 to 64 readouts were subdivided into 8 parts before fitting slopes. At SRD-level deglitching was performed with standard settings, except for the repetition factor, which was set to 5. Individual chopper-plateau deglitching was selected together with max/min-clipping. Generally only the first 10 % of each chopper plateau were deselected, instead of the standard 50 %, to improve the S/N. The orbit-dependent dark-current was subtracted as well.

4 Removal of Longterm Transients

The chopped signal exhibits long transients, that last during most of the measurement and can introduce statistical biases i.e. wrong detections with small numbers of chopper plateaus. This was verified by a simple numerical simulation with 8 chopper plateaus filled by 240 gaussian distributed datapoints. Adding a realistic linear drift to the datapoints resulted in a net-signal easily exceeding the statistical errors. To remove the transients, the signals were divided by a fitted polynomial of order 2 and multiplied by the mean value of all slopes. Due to the faintness of the sources compared to the background, no separation between chopper plateaus is necessary at this stage.

After correcting for chopper vignetting using the standard Cal-G files, the on-source and off-source signals are calculated as the averages of the separated chopper plateaus. The error is estimated using the standard-deviation of the mean. The final source signal is calculated as the difference between on-source and off-source averages.

5 Flux-Calibration

To establish the flux calibration, the signals corresponding to FCS1 were averaged and according to standard procedures (Schulz et al. 2002) converted to a responsivity, using FCS-calibration-tables, illumination tables and filter-to-filter correction matrices. The source signals were converted to fluxdensities using responsivity, filter-to-filter correction, C1-factors and PSF-factor. For C100 pixel 5 (the central pixel of the 3×3 array) was used exclusively, applying the PSF-correction for single pixels.

The intrinsic correction for chopped measurements due to the time dependent response of the detector to flux changes was obtained by processing a number of measurements of faint calibration stars according to the same procedure. The stars were selected to show signal differences comparable to the galaxies.

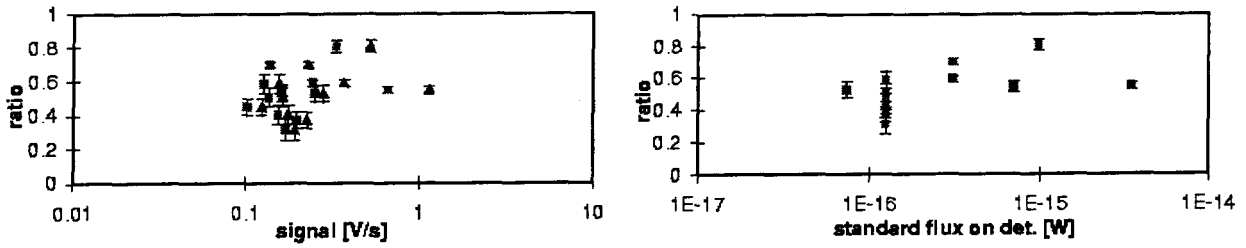

Figure 1: *The ratio of measured and actual flux density of known calibration stars, plotted against absolute detector signal (left) or expected source flux (right).*

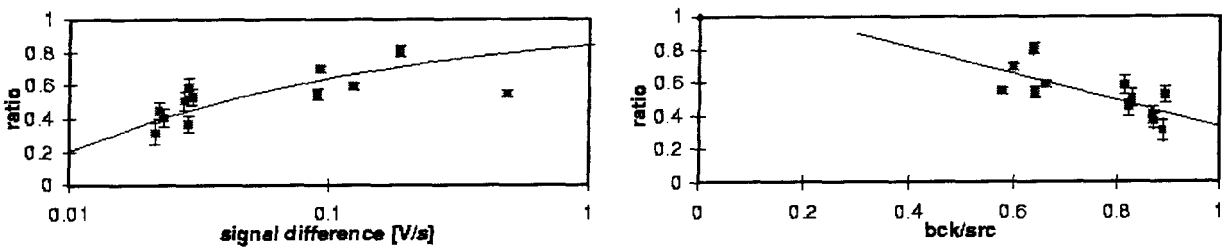

Figure 2: *The same ratio as in the previous diagram, plotted against the logarithm of the difference (left) and the ratio (right) of on-source and off-source signals. The right diagram shows the most consistent relation.*

6 Results

For the 11.5 μm filter 6 measurements of HD172323 and 2 measurements of HR5986 were used. The comparison with the expected fluxdensities calculated for the reference wavelength at 12 μm from model-SEDs, taking into account the spectral resolution of the filterband, gave a ratio of 0.99 +/- 0.14, making a correction unnecessary for the P1-detector. For the 3 measurements with the 25 μm filter of P2 on HR5986, we find a correction factor of 1.20+/-0.11.

HR7310 measured at 60 and 100 μm with the C100 detector showed inconsistent results. Therefore more calibration measurements had to be collected from the archive. Finally the calibration data consisted of two measurements of HR5981 at 60 μm, 4 measurements of HR6705 at 90, 100 and 105 μm and 14 measurements of HR7310 at 60 and 100 microns. The ratios between measured flux and SED-model flux spread between 0.3 and 0.8.

Investigations of possible dependencies of these correction factors showed no correlation with the detector signal or the expected flux (Fig 1). There seems to be some correlation of the factors and the signal difference between on and off-source positions (Fig 2 left), however the most convincing relation was found between the correction factors and the ratio of background and source/signals (Fig 2 right). We fit a straight line with intercept=1.14 and slope=-0.802, that fits the datapoints with an accuracy of about ±20 %. The data covers ratios of source and background signal from 0.58 to 0.89. For a backgrond to source ratio of 1, the fit extrapolates to 33.7 % of the expected flux. This value appears reasonable, considering previous experience with C100 transients and typical beta-factors from Fouks-Theory. Background to source ratios lower than 0.5 are not covered by the investigation and most likely can not be described by a linear fit. Thus the results were corrected according to the formula: $F_{corr} = F/((S_{bck}/S_{src}) * -0.802 + 1.14)$ where F is the fluxdensity after the processing. described above and S_{bck} and S_{src} are the signals of background and source respectively.

7 Summary

A method was described that was developed to reduce chopped ISOPHOT observations of faint sources. A good estimate of the uncertainties becomes crucial in this case. The error estimation is therefore done in a traditional way, where a statistically relevant number of datapoints is provided by subdividing the linearized integration ramps. A removal of the baseline drift is essential to avoid fake detections. The flux calibration is then performed in a standard way, applying all necessary corrections and additionally multiplying the result by an empirical correction factor. For P1 this factor is 1. The P2 detector requires a 20 % correction. For the central pixel of C100, which is best used alone for faint source detections, the correction factor depends on the ratio of the signals from source and background and was derived empirically from an analysis of a number of measurements of known calibration stars.

The results for P1 and P2 only apply to faint point sources and will still suffer from uncertainties in the flux calibration for apertures very different from the standard ones (Schulz et al. 2002). The C100 method is perhaps more interesting considering the systematic reduction of archival chopped data, since it bears less configurational complications and many extragalactic programs suffered just from a lack of detections. An archive query shows a total of 1531 chopped C100 observations, of which 990 were performed in rectangular mode and the rest in triangular mode.

References

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