MODELLING TRANSIENT EFFECTS IN THE IR ARRAY OF THE SHORT WAVELENGTH CHANNEL OF ISOCAM, THE CAMERA ONBOARD THE ISO SATELLITE

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Abstract. The short-wave channel (SW) of ISOCAM, the IR camera on board the ISO satellite, is equipped with a 32 ×32 CID InSb array. This array shares with other detectors of ISO instruments the characteristic of being subject to some time lag when responding to a flux variation. Known as transient effect, this default which is not quite understood (in particular, it does not correspond to a simple time constant), must be corrected for in data processing. Starting from the remark that the lower the signal, the longer the equivalent time constant, we have developped a mathematical model that reproduces quite well the observed behaviour, using only a small set of parameters. In practice, the model consists in solving a functional equation. The model provides the asymptotic value of the stabilized signal, which is in general the information one looks for. An *a posteriori* analysis of the form of the functional equation suggests that the effect relates to surface traps in the semi-conductor, as a rough estimation would confirm.

1. Introduction

Transient effects in practically all detectors in the ISO satellite (Kessler et al., 1996) is certainly one of the major concern for the vast majority of users who have to face the problems of data reduction and calibration. Such time and flux dependant memory effects have been reported for the four instruments onboard ISO : the Short-Wave Spectrometer (SWS) by Schaeidt et al. (1996), the Long Wavelength Spectrometer (LWS) by Swinyard et al. (1996), as well as the photometer (PHOT) by Lemke et al. (1996). The camera ISOCAM, the fourth instrument (Cesarsky et al., 1996), features two channels, one short-wavelength (SW) and one long-wavelength (LW) which both exhibit such a behaviour, with however large differences in the details. The SW channel of ISOCAM is equipped with a 32 ×32 InSb - from SAT (France) (Epstein et al., 1987 ; Tiphène, 1987 ; Tiphène et al., 1987). Despite its original technology (CID = Charge Injection Device), which makes it unique among the ISO detectors, this array features as well transient effects appearing as a time lag when responding to flux variations. The time evolution of the signal has no simple behaviour that could be easily predicted, in which case a straightforward correction algorithm could be applied during data processing, at least to approximate the asymptotic stabilized level. One clear property of the CAM-SW transient effect is the dependance of the stabilization time scale on the current level of charges stored in the considered pixel: the lower the charge, the longer the stabilization. Prompted by this clue, we have developed a phenomenologic approach and found that a general model of this effect was giving a fairly good approximation in most cases. It allows in particular to build *asymptotic* images with, a priori, a better relative photometry between pixels.

2. The transient effect

Long term evolutions are not a real concern for the SW array, as shown by the CAM daily calibration measurements (Boulade et al., 1998), and we will not pay more attention to this question in the following. Short-term effects represent the main problem by far and appear essentially as a lack of stabilization of the signal when a step of flux is applied. This effect is seen whenever the flux decreases or increases and strongly depends on the level of charges in each pixel well. It is especially important – i.e. stabilization is especially long – when the number of charges in the well at beginning of exposure is low. Fig. 1 and 2 show samples of the transient effect in two cases : either a small step of flux starting practically from dark and to which corresponds a slowly increasing signal and a steep decrease after a hit by a particle (glitch). The behaviour of the signal depends essentially on the value of two parameters : the charge at beginning and the step of charge ; any situation where those two parameters are identical will produce a same evolution of the signal with the number of exposure. This last point is important : we must speak of number of exposures rather than of time, since the behaviour is only dependent on the number of exposures and on the charge at each exposure, not on the actual duration of the observation. A consequence is that the best strategy when observing with ISO at very low fluxes was in general to choose a longer integration time than a larger number of exposures for a given duration of the observation.

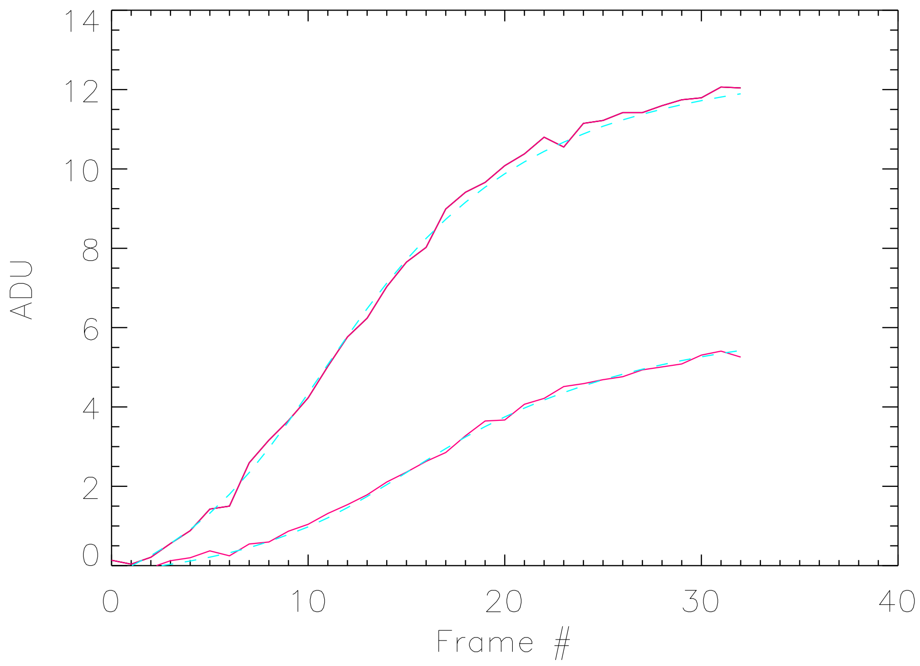

Figure 1. Two examples of the evolution of the signal on two pixels, after a flux step (of different magnitude for each pixel) was applied. Solid line : evolution of the signal (in Analog to Digital Units) of two given pixels submitted to a a positive but small step of flux. The transient effect (no stabilization) is clear. Dashed line: fit of the signal by our model. X-axis unit corresponds to the image number in the sequence, the Y-axis unit is analog to digital converter unit (ADU).

3. Modelling

Models for the correction of the transient effect in CAM-LW have been successfuly developed (Abergel, Désert, Aussel, 1997; Coulais, Abergel, 1998), but they were not able to simulate the very specific behaviour of CAM-SW. We have made several attempts to model this behaviour using combinations of exponential functions with different time constants, but none of them were successful : this is not unexpected since, as previously said, the characteristic time is itself dependent on the level of charges. We then allowed the time constant to vary according to some function of the instantaneous value of the charge in the pixel. We found then, that an universal law was able to reproduce quite well about any situation. The parameters of this law must be tuned to each pixel to have a precise fitting, but there is a rather low dispersion among those values as long as the pixels follow the same history. The law is such that the evolution in time is the same as the charge or discharge of a capacitor where the time constant would be

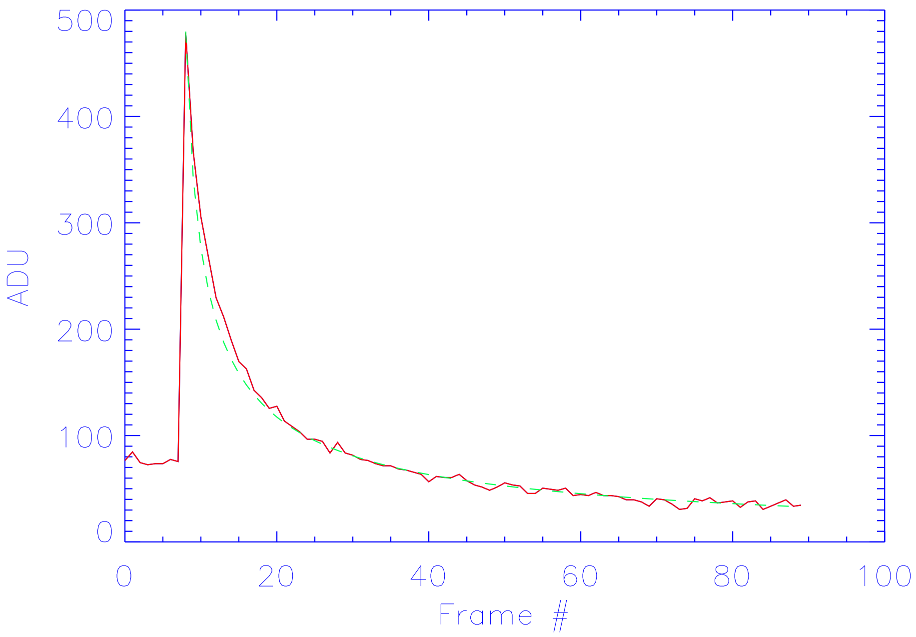

Figure 2. Solid line : same as Fig. 1, but in the case where a particle hit the pixel during the exposure : here, the signal decreases after the hit. Dashed line: the fit of the signal by our model.

inversely proportional to the charge. In other words, the charge $s(n)$ of a pixel after exposure n is the solution of the functional equation :

$$s(n) = s_F + (s_I - s_F)exp[-n\ s(n)/s_0], \tag{1}$$

where s_F is the charge when full stabilization is reached (could be extremely long...), s_I the charge at beginning of the set of exposures and s_0 is a constant with dimension of a charge. One has to solve this equation in $s(n)$ for each pixel. This is done by standard math routines (for instance Newton with IDL). Fig. 2 and 1 shows a fit of the actual signal by the solution of this equation when parameters s_I, s_F and s_0 are properly adjusted : in most cases the fit is very good. Once this solution is obtained, it is then possible to derive the asymptotic value s_F which must correspond to the stabilized value of the signal. Some care must however be exercised on the interpretation of this asymptotic value at very low flux levels, since the uncertainty becomes higher : the signal evolution is practically a noisy straight line and cannot provide a good enough constraint to the model. A package of IDL functions was developed in order to optimize the processing of a complete cube of images. This package is self-consistent but may be implemented in the future within the CAM Interactive Analysis software environment (Ott et al., 1997).

Does this model bring an actual improvement to the quality of the data ? It is difficult to answer this question as long as we cannot compare a calibrated image of an extended faint object with one produced with our algorithm. However, as an example we show in Fig. 3 a comparison of a cut through two images of the edge-on galaxy NGC 891 obtained on one hand with ISOCAM-LW (filter LW1 centered on $4.5\mu m$, see Rouan et al., 1996 for a description of the ISO program) and on the other hand with ISOCAM-SW (filter SW1 centered on $3.6\mu m$), after processing with our algorithm. One does not expect large differences between the two images which are at rather close wavelengths; the good overall fit of the relative variations of flux can be considered as a rather positive indication of the validity of the process.

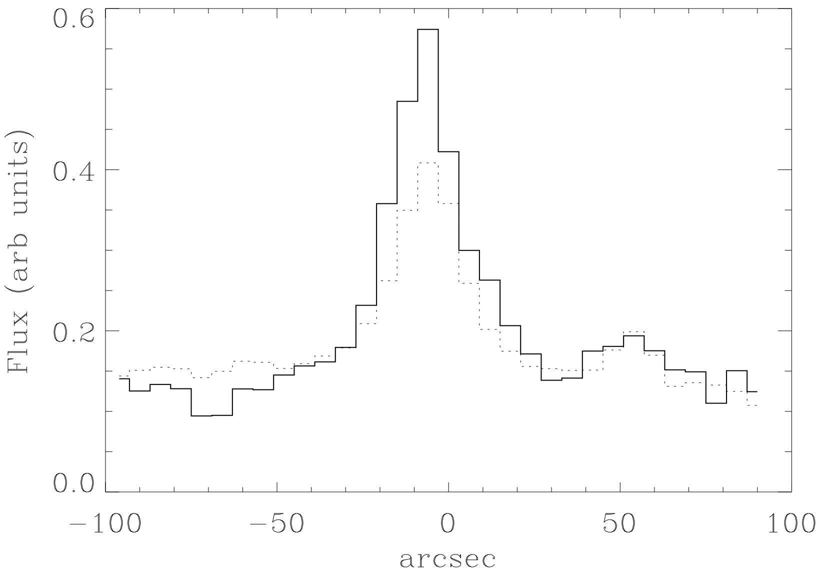

Figure 3. Comparison of cuts along the main axis of the edge-on galaxy NGC 891 in two images obtained with ISOCAM; solid line : image obtained in the short wavelength channel (SW1 filter at 3.6 μm), the cube being processed as described in the text; dotted line: image obtained with the long wavelength channel of ISOCAM (LW1 filter at 4.5 μm).

4. Interpretation

We have not established a detailed physical explanation for the modelled behaviour of the detector, but we think that the evolution of the "time constant" with the charge is likely related to surface traps in the semiconductor (InSb) : those traps have to be filled first with the photo-charges before the well begins to actually store free charges. When examining the trend at low signal, one finds that the amount of trapped charges should be of the order of s_0, i.e. typically 70000 electrons. In terms of trap surface density this corresponds to $7\ 10^8$ e^- cm^{-2}, a realistic figure for this type of detector (Tiphène, 1987).

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