USE AND IMPACTS OF THE ISOCAM DAILY CALIBRATIONS

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ABSTRACT

Responsivity and dark current of ISOCAM, the camera onboard ISO, have been monitored on a daily basis in the middle and at the end of each revolution of the spacecraft. From the growing set of data obtained in similar conditions, we extracted a range of information which allowed checking of the health of the instrument and identification of suspicious behaviour which could have lead to unrevealed functional problems. We present here the set of measurements systematically done and the kind of information retrieved from the data we accumulated.

Key words: ISO – ISOCAM – Trends – responsivity – dark current

1. INTRODUCTION

During the 30 months of in-flight operations of ISO, the behaviour and health of the ISOCAM detectors (Cesarsky et al. 1996) have been monitored on a daily basis. Initially defined to detect any evolution of the detectors which could have led to a tuning of their polarisations, systematic calibration sequences in the middle and at the end of every revolution of the spacecraft have proven, by simple measurements such as dark current and so-called internal flat-field illuminations, to be of great interest for the understanding and calibration of ISOCAM's detectors. These calibrations were not intended to generate direct data flow for basic calibration purposes but they drew our attention on a few points which increased our knowledge of the instrument. The way the ISOCAM main calibrations were done is discussed in Metcalfe (2003) and a summary of the results is given by Blommaert (2003).

The goal of this paper is not to present in detail the results we obtained from these data sets, a detailed discussion being available in Boulade and Gallais (2000) and Gallais and Boulade (1998), but to show that such measurements can bring information which reinforces our confidence in the instrument. We describe the sequences of measurements, then each kind of product is presented and analysed, pointing out a few topics and behaviours which have triggered a deeper investigation.

2. THE SET OF MEASUREMENTS

The goal of these calibrations was to perform simple measurements allowing checking of the stability of the detectors in time, both on short and long term scales. We were looking for repeatable measurements to allow comparisons from one revolution to another. For this purpose, the measurements have been done with the camera alone, avoiding the introduction of any external constraint such as pointing or source characteristics, which is not the case for standard calibration measurements.

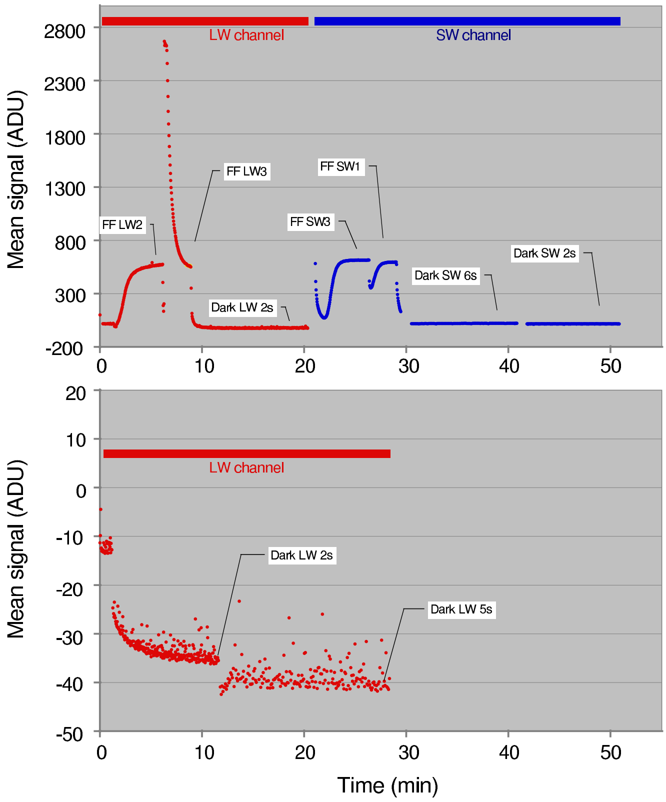

Figure 1. Configurations in the sequences performed in the deactivation window (top) and hand-over window (bottom) seen through the mean signal observed on the detector of the prime channel. FF means "flat-field" and holds for responsivity measurement.

The deactivation sequence has been defined prior to launch and flight operations, based on responsivity and dark current measurements. We used the so-called "Internal Calibration Devices" (ICDs) one for each channel of the camera, each consisting of a black body illuminating an integrating sphere which diffuses the light in the instrument beam, creating a spatially quasi-uniform illumination of the detector. While it has been shown that these ICD's could not be used for absolute flux calibration, nor as correct sources for flat-field derivation, their profiles are reproducible enough to perform comparable measurements. The second type of measurement was the dark current measurement. These have been done in similar instrument configurations to those applied for in-flight calibrations.

The deactivation sequence is split in two parts, each one being devoted to one channel: LW then SW (see figure 1). For each part, the sequence starts by responsivity measurements through 2 selected filters, followed by dark current measurements. It has been tuned during integration and ground-based calibration test campaigns of the instrument to get a stabilised signal on the detectors.

Early in the ISO mission, it appeared that another period of time could be used for similar and complementary measurements: the hand-over window, during which the change of ground based satellite tracking station occurred. During this period of 30 minutes, no commanding to the satellite was authorised while reception of telemetry was still possible. Before entering this window, the instrument was configured to perform dark current measurements with the LW channel (see figure 1). This sequence was automated after revolution 150. Later in the mission, it was adapted to perform complementary dark current measurements at other integration times.

Data reduction was quite simple, consisting in removal of glitches and then extraction of the last frames of the sequence (in order to get rid of stabilisation artifacts). Responsivity images were obtained by subtracting the dark current measurement performed in the same sequence.

At the end of the mission, we had thus secured a set of 744 measurements obtained during the deactivation sequence and 665 hand-over measurements. A few sequences have been lost because of planned engineering operations, contingencies or telemetry drops.

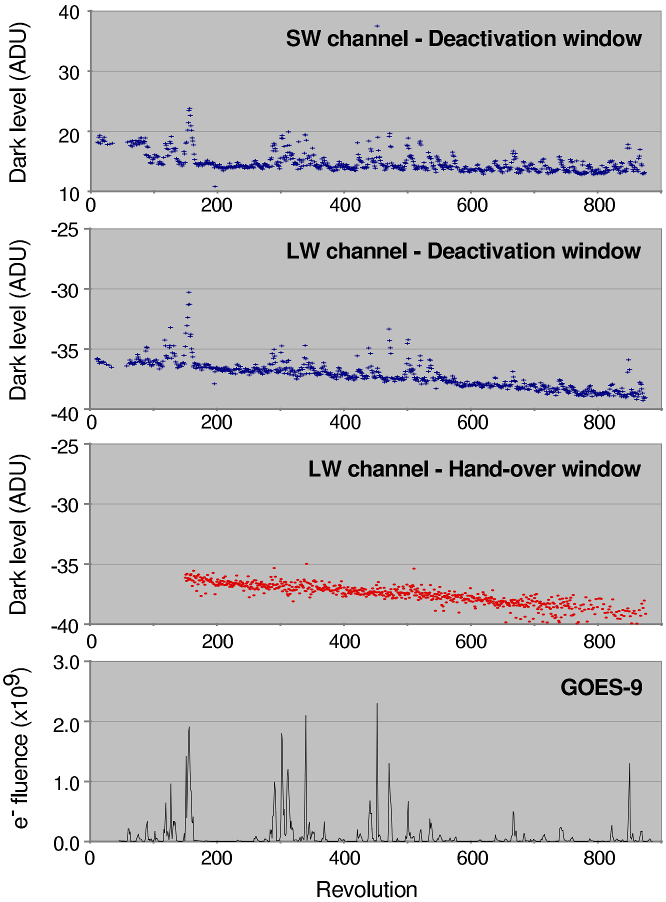

Figure 2. Mean value of dark current level for the 2 detectors, and GOES-9 electron fluence versus revolution number.

3. DARK CURRENT LEVELS

The SW dark current measurement was performed during the deactivation sequence alone while the LW one was done during hand-over and deactivation sequences. The mean level of the dark current for both detectors is plotted in figure 2 versus the revolution number, for the whole mission.

Early in the mission, the instrument appeared to be sensitive to the variation of the electron fluence in the vicinity of the Van Allen radiation belts. All sets of dark current obtained in the deactivation sequence (at the end of a revolution) are similarly affected by spikes, while the LW hand-over measurement (in the middle of a revolution) remains free of these signatures. The complementarity of the measurements associated with i) the lack of such effects in the instrument parameters and ii) the absence of structure in the resulting images led us to conclude the external origin of this additional signal. An impressive correlation has been established between our measurements and the electron fluence as measured by the E1 channel of the geosynchronous GOES-9 satellite of NOAA (see figure 2 bottom). Obviously, the influence by external space weather forbids the use of the deactivation dark current measurements to correct science observations, and care has been taken in the treatment of the responsivity measurements with respect to the dark current contribution.

However, the baseline of each data set shows a slight decrease of the mean level on the detector over time for both channels. This effect is confirmed in the case of the LW channel by the hand-over measurements: data free of space weather contamination. Actually, the long term decrease of the LW dark current level is seen in the images through a differential evolution of the signal on the lines depending on their parity. The evolution of this stripped pattern has been investigated both through the mission (with the present set of data) and within a revolution (with standard calibration data sets), leading to modelling the dark current pattern evolution (see Biviano et al. 2000). This model is applied with success in the reduction of science data and allows removal of the 1 to 2 ADU residual signal which could remain when correcting images for dark current with routine calibrations alone.

4. LW RESETS LEVELS

An image of the LW detector is the result of the difference of two frames: the *End-Of-Integration* frame, containing the signal, and the *Reset* frame, i.e. the frame of the level of the pixels before integration of charges. We extracted this last parameter from the dark current data sets, free of external light influence, and plotted its mean value versus revolution number (see figure 3). In these plots, we can notice i) a decrease of the level by about 25 ADUs along the mission, ii) the absence of spikes in the de-activation data set, confirming the external origin of the additional signal observed in the dark current levels, and iii) 4 drops of the level followed by a slow recovery. This last point has been examined and no such variations have been observed in bias parameters. Because the Reset level acts as the reference level, these drops had no consequence on the resulting difference images. The origin of these events is not identified, but we must point out the ≈ 220 days periodicity. What external fact could have lead to such drops remains an open question.

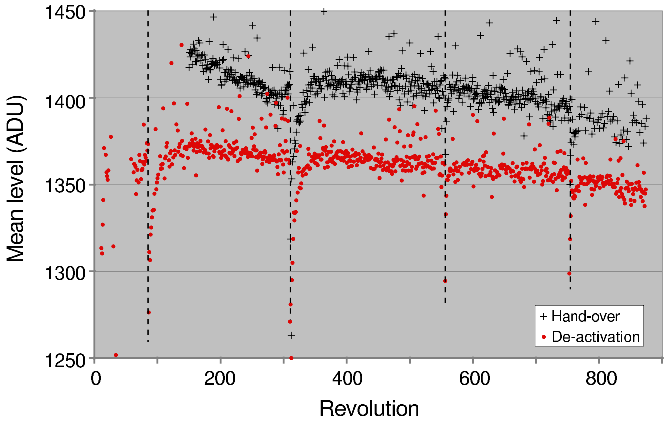

Figure 3. Mean value of LW Reset level versus revolution number for deactivation and hand-over sequences. Vertical dashed lines indicate the location of the drops of signal.

5. RESPONSIVITIES

The first and simplest thing to do with the sets of images obtained under ICD illumination is to plot the mean signal versus the revolution number (examples are given in figure 4). From these curves, the SW channel appears rather stable and the LW one shows a slight decrease of its response with time (about 5% after 800 revolutions). We can explain this decrease by the evolution of the ICD itself because the value of the responsivity derived from observations of standard stars does not have the same behaviour (see Blommaert et al. 2000).

In addition to these general trends, a range of information is contained in these data sets.

The responsivity measurements for the LW channel appeared to be a good tracer of any saturation event which occurred during the revolution on this detector. Examples of such

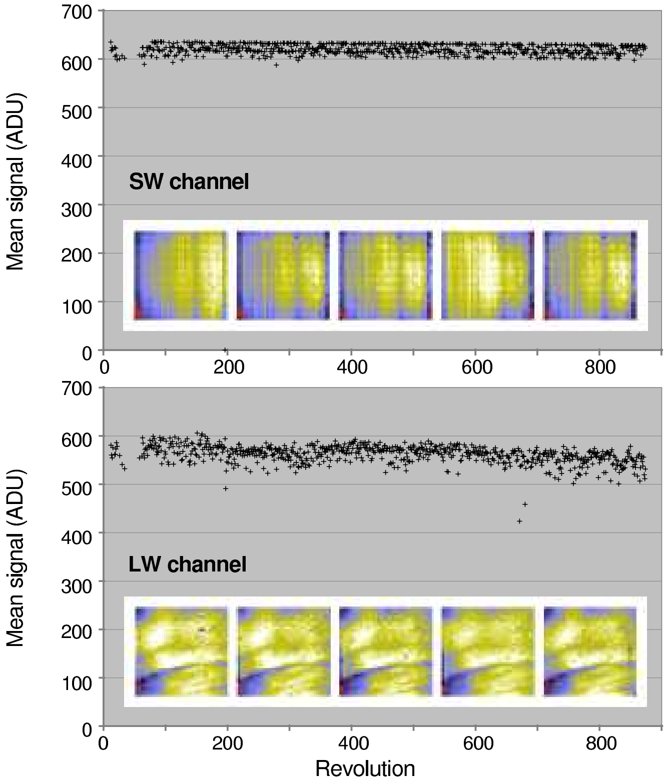

Figure 4. Mean value of the signal on the detectors under illumination of the ICD versus revolution number. Examples of images are given in each case.

memory effects are presented on figure 6. These measurements were systematically inspected in the quality check process of science observations.

On revolution 196, ISO accidentally pointed at the Earth's limb for a while. In consequence of the temperature increase of optical elements in the spacecraft, the LW responsivity decreased by about 12% with respect to its nominal value. On this occasion, the daily responsivity measurements, acting as reference, have been of great interest to follow the recovery of the detector to its nominal characteristics after a few revolutions.

Another piece of information available from these measurements has been the identification of a wheel jitter in the optical path of the instrument. This effect was already known from observations done with the large Fabry mirror (square mirror) of the LW channel which was designed to fit the total field of view obtained on the detector with the 6″ lens: in different observations, the edge of the mirror was seen in the image at various positions. This effect has been revealed trying to explain the 4.5% dispersion and the multi-modal distribution of the SW responsivities. Considering the detector as a 2-cell detector, it has been possible to identify 4 families of flat-field, each one being split in 2 groups (see figure 5). The importance of the vignetting on the left edge from one family to the other confirms the presence of a play in the gears of the instrument's wheels. The same analysis applied to LW responsivity images led to the same conclusion.

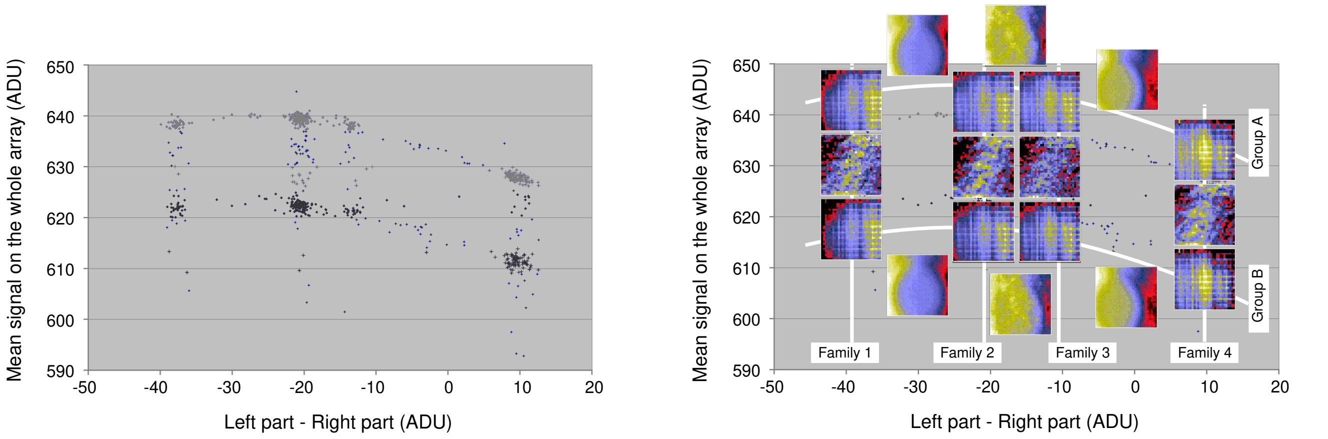

Figure 5. Illustration of the wheel jitter in the images of responsivity in the case of the SW channel. Mean value of the signal on the detector is plotted versus the difference between the mean signal on its left part and the mean signal on its right part. The images on the right plot correspond to the median image of each family together with the image ratio of two adjacent families.

6. LEGACY

The main results from these few hours of otherwise unusable time have contributed, while appearing perhaps at first to be superfluous, to the in-flight characterisation of the camera and to a major increase in the confidence level and the quality of ISOCAM scientific data. Our instrument has performed nominally for the entire and extended duration of the mission. However, the richness of information we derived from the frequent monitoring of basic parameters such as dark current and responsivity of the detectors ensures that we would have been able to detect any malfunctioning of the instrument. More information could have been extracted from our data sets, but the investment must remain realistic in relation to the derived benefits. Our experience shows that every period of time in a space mission must be used: there is always something to learn.

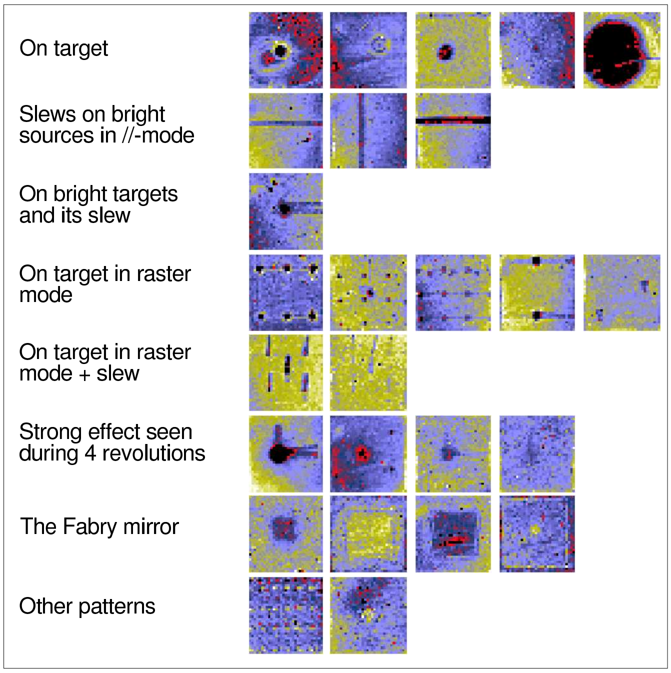

Figure 6. Gallery of saturation memory effects observed on LW responsivity images from the deactivation sequence.

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