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Calibration with the ISOPHOT Interactive Analysis (PIA)

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Abstract. The ISO**P**HOT **I**nteractive **A**nalysis (**PIA**) software was conceived primarily as a tool to be used by the instrument team for the calibration of ISOPHOT. This is one of the four instruments on board the European Space Agency's Infrared Space Observatory (*ISO*), launched in November 1995. Actually, PIA has been extended to form an interactive tool for ISOPHOT data analysis in general, which can be distributed to all interested ISOPHOT observers. In this article, we describe the philosophy behind the implementation of the processing sequences dealing with calibration observations, and how this leads to a general calibration assessment and finally the generation of calibration files, both for commanding the ISOPHOT instrument and reduction of scientific data.

1. Introduction

The ISOPHOT Interactive Analysis (PIA), the analysis tool for ISOPHOT scientific data reduction, is described elsewhere in this volume (Gabriel et al. 1997).

ISOPHOT (Lemke et al. 1996) is the photometric instrument on board *ISO*, the Infrared Space Observatory (Kessler et al. 1996), launched in November 1995 by the European Space Agency.

ISOPHOT is a complex instrument. It contains three subinstruments with various observational modes. This is reflected in a large number of calibration files and procedures, needed both for commanding the instrument ("uplink") and for performing data analysis ("downlink"). In order to facilitate the access, visualization, and analysis of the calibration data, PIA was conceived from the very beginning as a user friendly tool, requiring from the calibration scientists neither a deep knowledge of ISOPHOT data structures and files, nor of the software itself.

The ISOPHOT calibration requirements (IOCRD 1995) were implemented as Calibration Implementation Procedures, describing the detailed observation strategy and measurement sequences, and as Calibration Files Derivation Procedures (CFDP 1995) describing the data reduction path and the derivation of

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the calibration files. On the basis of the latter, calibration processing sequences were set up inside the PIA to automate data reduction steps and combine data to produce the final data products. These are:

- Cumulative information in a form suitable for performing consistency checks for calibration assessment and trend analysis.

- Files used to define the instrument settings controlling an observation, called calibration uplink files (Cal U).

- Files used for calibration of the data along the various processing steps from raw data to final data products (Cal G files). These files are used by both ISOPHOT data reduction packages, the ISOPHOT Standard Product Generation ("pipeline") and the PIA itself. They are also distributed to the observers in FITS format (FITS 1993). A description of standard data processing, data products and Cal G files can be found in Laureijs et al. (1996).

2. Processing Data to Derive Calibration Files

All the (variable) parameters necessary for commanding ISOPHOT are contained in the uplink calibration files. Their determination is crucial for the most optimal set-up of the instrument. Even more stringent requirements apply in the case of the assessment of instrumental effects for the downlink calibration. Here, the best achievable accuracy is required for accurately calibrating the detectors.

Calibration measurements are performed routinely, in addition to those of the extensive Performance Verification Phase (the first two months of *ISO* operations). They are used to increase the accuracy of the calibration, monitor the photometric stability, and look for new, unexpected effects. A database of dedicated tables containing the results of individual measurements has been developed within PIA—these are referred to as "cumulated tables." They allow the user to study the long term behaviour of the various parameters, correlations, interdependencies, and trends.

Data reduction of calibration measurements can be done in several ways. At one extreme is the fully interactive method, which allows detailed inspection at each stage of data reduction. At the other extreme is the fully automatic method, which speeds up routine data reduction. For all cases, a graphical interface is available, which allows access to all variables at all levels of data reduction. It also allows the user to change and test various data reduction parameters. The data reduction follows the steps outlined in the calibration file derivation procedures, written by the calibration scientists. However, it has a high level of flexibility, and allows the user to try alternative ways of processing the data.

There are also certain cases of data correction algorithms where the parameters used are not contained in calibration files. These parameters are testable and changeable via dedicated menus within PIA. The same menus allow investigation of effects and efficiency, and were used by the calibration scientists to obtain the default values, used by the pipeline data reduction.

3. The Graphical Interface

The graphical interfaces for the different calibration items (currently a total of eleven, associated with more than 20 calibration files), were designed individually, but following a general common scheme, including:

- Graphical access to:

  a) the values currently used by the system,

  b) the values contained in the actual calibration files, and

  c) new values which are generated.

- Editing of individual calibration values, allowing individual entries to be manually changed, if necessary.

- The production of both uplink and downlink calibration files. In this case the user may add some information into the file headers, specifying author, date, version, and modifications done, for configuration control. Special routines are then used to produce ASCII or FITS files with the correct format required by the different systems.

For data processing defined in a CFDP, automatic processing sequences were implemented. There are basically two different steps: a) reducing data and adding the results to the "cumulated tables," and b) using all the data recorded in those tables to obtain the final calibration numbers.

A dedicated system for handling the "cumulated tables" has been implemented. The tables can be inspected, variables can be plotted against each other, flags to deselect individual measurements can be edited, etc. Processing the data within the tables to obtain final calibration numbers is done via dedicated menus, which allow selection of all the variables present in the tables.

4. A Simple Example: Derivation of "Dark Current" Values

The residual signal measured without illumination is called the "dark current." This current is always present, and has to be subtracted as a constant. Accurate values for this instrumental effect are especially important for the analysis of very faint sources.

There are several effects which could modify the dark current values, like orbital position of *ISO*,[2] detector temperatures, detector and electronics aging, etc. Therefore, it is necessary to monitor them regularly under different conditions.

The derivation of dark currents is rather simple. However, there are certain effects which have to be corrected for in the data. One is the almost continuous disturbances produced by cosmic particle hits into the detectors during an observation, which are particularly relevant at these low signal levels. Another is given by the signal transient effects due to changing illumination history. These

[2] *ISO* has an extreme elliptical orbit with a distance to the Earth of 1000 km at perigee and 70,000 km at apogee

effects are present in all ISOPHOT data. The detailed correction steps in PIA are described in the PIA User Manual (Gabriel et al. 1996).

At the end of the data reduction, the average dark current signal and noise are recorded in the "dark current cumulated table" along with several other parameters: *ISO*'s orbital position, temperature of the detector assembly, observation date, processing date, etc. The calibration scientist can determine the average value from all recorded measurements, look for trends with orbital position and temperature, and deselect measurements whose quality is affected by memory effects of a prior strong illumination or data taken at times of high space weather activity.

5. Experience with PIA and Outlook

The availability of a well suited interactive data reduction package from the very beginning of the *ISO* mission has been a big advantage for a complex instrument like ISOPHOT. From the calibration point of view, it has helped most in two ways: a) discovering and solving problems rapidly, both on the instrumental side and in the data reduction, and b) deriving new algorithms for data correction and calibration strategies. Its user friendliness, provided by the graphical user interface, has been especially important for the first point. The second capability is mainly provided by the flexible use of internal structures and single programs outside the graphical interface. This last point represents one of the main directions that further PIA development is taking.

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