Development and capabilities of the ISOPHOT Interactive Analysis (PIA), a package for calibration and astronomical analysis

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The ISO**P**HOT **I**nteractive **A**nalysis **PIA**, is a calibration, scientific analysis and visualization tool for accessing and processing ISOPHOT data. ISOPHOT is one of the instruments on board the Infrared Space Observatory ISO, launched in November 1995 by the European Space Agency. PIA is an IDL based package, comprising around 1500 routines including a user friendly graphical interface. All the capabilities of input/output, processing and visualization can be reached from window menus, for all the different ISOPHOT sub-systems in all the different levels of data reduction. This applies, starting from digital raw data, coming from the ISO telemetry, to the final level of calibrated images, spectra, multi-filter, multi-aperture photometry. In this article the needs for such a dedicated package are explained, its development and main design features are described, and an overview of the PIA capabilities in the different areas is given.

1 Introduction

ISOPHOT [1] is one of the four instruments on board ISO, the Infrared Space Observatory [2], launched in November 1995 by the European Space Agency. As the first true space observatory for infrared astronomy, ISO is making available the majority of its observing time to the astronomical community.

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ISOPHOT is the instrument with the widest wavelength coverage within the ISO mission, and also the most complex one. It contains several sub-instruments for performing photometry, polarimetry and imaging in the infrared range of [2.5-240.] microns, and low resolution spectro-photometry in the range [2.5-11.6] microns. Spacecraft raster observations as well as beam chopping are included in different modes.

The different ISOPHOT capabilities lead to a large number of observing modes and corresponding data products, as well as a large number of calibration files needed both for commanding the instrument (uplink) and for performing data analysis. As a consequence, the calibration of the instrument and the general data analysis are rather complex tasks.

An ISO astronomical observation is performed via a template (AOT) designed to carry out a specific type of observation. The scientific data contained in the telemetry undergo complete automatic data reduction (downlink), which provides observers with processed data. The requirements for ISOPHOT pipeline data reduction [3] were defined at an early stage of the ISO mission preparation, resulting in the ISOPHOT Off-line pipeline system [4]. The necessity of a software tool for calibration had been recognized, but no practical steps were undertaken, until 1.5 years prior to launch, thus imposing a very tight schedule for its development. The ISOPHOT interactive analysis system was conceived at this time primarily as the calibration tool for ISOPHOT, for the use of calibration experts. It immediately became clear that it could also be developed as a tool for scientific data analysis, which could be used by general observers. This concept takes into account the commonalities between data reduction both for calibration and for astronomical observations, trying to create a more powerful tool for data analysis than an automatic data reduction tool can ever be.

2 Requirements and main design concepts

User requirements [5] and architectural design [6] documents were the basis for a workplan [7] which foresaw the achievement of the main goals in different areas stage by stage. This can be characterized as follows:

- instrument calibration requirements:
  - Flexible data access at all processing levels
  - Reliable production of calibration files for both the uplink system and the downlink system.
  - Ready and fully tested prior to launch, in order to produce calibration files for both uplink and downlink systems.

- trend analysis requirements:
  - Fast access to all science and housekeeping data, including the capability to study various parameters and to check pipeline products.
  - Ready at launch.
- general scientific analysis requirements:
  - A full processing chain including the production of the final products (eg maps, spectral analysis, photometric tables),
  - A non PHT expert should be able to use it. This requires good on-line help and good documentation.
  - It should be completed during the ISO mission.

The general S/W requirements were the following. PIA should:

- run on different operating systems (at least Unix and VMS),
- be sufficiently 'open' to allow easy functionality extension,
- include mathematical and astronomical libraries,
- offer a full graphical interface, mainly for 'non-experts' use, but also to allow the calibration experts to focus on calibration,
- offer a programming interface, for 'experts' use.

In accordance with these guidelines the decision was taken to build a system based on the commercial package IDL[R] (Interactive Data Language), including a full context sensitive graphical interface to all capabilities. The system should be modular enough to allow the use of single routines at the IDL interactive level, thus giving access to the full potential of IDL combined with the PIA's own data structures and routines. Documentation should cover a general level ('PIA user manual'[8]) and a single routines level (IDL on line help system for PIA library).

3 PIA development summary

PIA has been jointly developed by the ESA Astrophysics Division (responsible for planning, direction and execution) and scientific institutes forming the ISOPHOT consortium. The development has been carried out within the framework of the ISOPHOT Instrument Dedicated Team concept.

The development started under a very tight schedule in April 1994. Coding began in June 1994 and by the end of 1994 PIA V1.0 was distributed among

[R] IDL is a trademark of Research Systems, Inc.

institutes associated with the ISOPHOT project, for ground data calibration analysis. This version was also used for performing the Assembly Integration and Verification (AIV) data analysis. In September 1995, two months prior to ISO's launch, the operational PIA was ready (V2.0). The calibration had been fully system tested. Since ISO's launch, many upgrades have been performed. Both the scientific data analysis modules and the general user interface have been extensively upgraded. The current version, PIA V5.0, is very stable and well documented.

PIA contains more than 500 files, around 1500 routines, and about 133000 lines of IDL code. The total investment for producing the package has been 5.5 man-years.

4 Data handling and reduction

PIA incorporates the full bulk of scientific data per ISOPHOT measurement into a single entity, an IDL 'structure', which is contained in a corresponding internal buffer. Data reduction is organized according to the various levels of processing. Every structure can be reduced to the next level, also contained in its corresponding buffer. PIA recognizes five main levels.

All the structures are handled equally on a given reduction level, despite of their intrinsic differences (different measurements have different lengths; voltages in a measurement by one of the single photometers are in a one-dimensional array, while voltages from a spectrometer measurement are in a two-dimensional array). This is reached by using pointers in the structures and has the advantage that the same interfaces can be used.

All reduction levels are presented under a similar graphical interface, which helps both users and developers. For every reduction level a main window exists, on which all variables from the structure can be accessed / plotted (eg signals from different pixels, temperatures, flags, etc). Data corresponding to variables of the same/different measurements on the same/different levels can be combined and overplotted for comparisons.

Input and output are possible in different formats (FITS[9] and PIA internal format) for all levels. This allows re-processing data from any level in a later session, exporting data to other astronomical software packages, accessing and processing data from the pipeline on every level of reduction.

5 Capability achievements

5.1 Calibration Analysis: All dedicated calibration observations can be processed and the results stored into a system of dedicated tables. These include parameters like orbital position, time of processing, instrument configuration, etc. The cumulated tables are used as databases allowing selection on every variable, from which calibration files are derived both for uplink and downlink, produced directly from the PIA.

Processing can be done from fully interactive, allowing for inspection on every bit, to fully automatic, for speeding up reduction of long and complicated observations. Calibration processing sequences are defined according to the specifications given in the 'Calibration Files Derivation Procedures' (CFDP) written by the calibration scientists.

A dedicated menu exists for every calibration file, which allows displaying, overplotting, correlations of parameters, processing and production of files.

5.2 Trend analysis: A series of relevant parameters for instrument performance are put into dedicated tables, allowing eg for orbital / multi-orbital analysis of detector behaviour.

5.3 Product checking - Pipeline tuning: All files which are produced by the pipeline software, including all calibration files can be inspected, visualized and processed.

Alternative algorithms can be used and results compared to the ones achieved by the pipeline. New data processing algorithms are tested and improved for inclusion into the pipeline.

5.4 Scientific astronomical analysis: The full data reduction chain (from telemetry read-outs digitized numbers to maps including image processing, spectra line fitting, multi-filter and multi-aperture photometric tables) is implemented. Processing can be performed in several modes, from fully interactive to fully automatic.

All the parameters used for data reduction are testable and configurable. Dedicated menus for testing and setting parameters including documentation and statistics are implemented, giving a major advantage compared to the pipeline software, which runs on fixed parameters.

The graphical interface, covering the full capability of the package, is user friendly, easy to understand, usable by every ISO observer without any deep knowledge of IDL, of the PHT instrument, of the data structures.

The package capabilities can also be easily extended, since it is possible to use the data out of PIA on the normal IDL level, and re-import data into PIA. A special documentation chapter of the PIA User Manual [8] deals with this subject.

5.5 Documentation and on-line help: The PIA User Manual [8] is written in hypertext format, and can be used on-line through a browser of the user's choice and from the PIA. Individual sections can also be used individually on-line and are reached context sensitive from the different PIA windows. It describes the graphical interfaces, includes a tutorial, processing algorithms chapters, data structures definitions, etc.

In addition there is documentation for every PIA routine, which can be recalled via the IDL on-line help system.

5.6 Distribution: PIA is distributed freely to all astronomers wishing to use it for ISOPHOT data reduction and analysis. The package is available [a] for various platforms running IDL (from version 3.6 on), its installation is extremely simple.

References

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[a] During the operational phase of ISO, PIA is distributed by the ISOPHOT Data Center at MPIA, Heidelberg, Germany. E-mail: phthelp@orion.mpia-hd.mpg.de