EXPERIENCE AND LESSONS LEARNT BY THE DEVELOPMENT OF THE ISO**P**HOT **I**NTERACTIVE **A**NALYSIS **PIA**

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ABSTRACT

The ISOPHOT Interactive Analysis (PIA), is the calibration, scientific analysis and visualization tool for accessing and processing data from the spectro-photopolarimeter ISOPHOT on board ISO.

In this paper we discuss the lessons learnt by its development. Special emphasis is given to the description of the succesful strategies followed, which are surely important for future astronomical space missions.

1. INTRODUCTION

ISOPHOT [Ref. 1] is one of the instruments on board the Infrared Space Observatory ISO [Ref. 2], launched in November 1995 by the European Space Agency.

The ISOPHOT Interactive Analysis PIA [Ref. 3] is a scientific and calibration data analysis tool for ISOPHOT data reduction.

The PIA software was designed both as a tool for the use of the instrument team for calibration of the PHT instrument during and after the ISO mission, and as an interactive tool for ISOPHOT data analysis for general observers.

PIA is entirely based on the Interactive Data Language IDL[1]. 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.

ISOPHOT supports 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 and for performing data analysis. As a consequence, the calibration of the instrument and the general data analysis are rather complex tasks. An overview of the different observational modes and their pipeline processing is given in another contribution to this conference [Ref. 4].

2. CONCEPTS AND DEVELOPMENT

The ISOPHOT interactive analysis system was conceived primarily as the calibration tool for ISOPHOT [Ref. 5], for the use of calibration experts. Nevertheless, it became clear prior to the start of its development, that it could be developed further 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 versatile tool for data analysis than an automatic data reduction tool can ever be. In addition the concept foresees a very user friendly environment for instrument and calibration experts.

The system was jointly developed by the ESA Astrophysics Division (responsible for planning,

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

direction and execution) and some of the scientific institutes forming the ISOPHOT consortium[2]. It became not only a very powerful calibration tool but also the software tool of choice for the scientific analysis of ISOPHOT data, used widely in more than 50 central astronomical institutes all over the world.

A discussion of the main design concepts of PIA as well as a development summary including the capability achievements of the system are discussed elsewhere [Ref. 6].

3. THE DEVELOPMENT

3.a) The team

Although the necessity of an interactive analysis tool for calibration had been recognized in a very early stage of the ISO development, the development of the package could be started at first one year prior to the official launch date. The framework of the Instrument Dedicated Team [Ref. 7], as a mixed team of ESA and PI supplied manpower dealing with instrument specific tasks, was in this case the key element.

After baseline requirements [Ref. 8] and architectural design [Ref. 9] documents were issued, a small development group was settled, presenting following main strengths:

- a considerably amount of achieved expertise on ISOPHOT instrument calibration analysis,
- good knowledge of ISO and ISOPHOT data structures,
- large experience in development of small and medium size software packages (including some experience in development based on IDL)

The group consisted at the beginning basically of four members, with only one working fully dedicated to this task, the others approximately on a 50% level.

3b) The conditions

Due to the very tight schedule imposed on the development and the manpower shortage, it was not possible to follow strictly the directives on software engineering standards, as normally required by ESA [Ref. 10]. This was acceptable in this case, due to the (in general) non-operational character of the package to be developed. It was also only possible and succesfully because of the small scale of the group involved, with a large level of direct communication.

Another important aspect of the development was the vicinity between PIA developers and calibration scientists working on the ground calibration of ISOPHOT. Soon after development begin, the first main version of PIA could be used for ground data calibration analysis and for performing the Assembly Integration and Verification (AIV) data analysis. A considerable feed-back from its use influenced the further development.

There are parts of the PIA, which have operational character. Both the production of calibration files for instrument commanding (uplink calibration tables) and for off-line processing (downlink calibration tables) belong to this category and were therefore thoroughly and formally tested in a several weeks testing program, under external review.

3.c) IDL as software environment

After discussing different alternatives, the decision was taken to base the interactive analysis system on IDL. The disadvantage presented by using a commercial system (thus imposing its purchase to the users of the system) is a negligible one, compared to the large advantages obtained. Some of them are:

- possibility of checking interactively (including graphical access) every piece of code,
- very easy build-up of graphical interfaces,
- integrated mathematical libraries,
- extended use within the astronomical community (e.g. astrolib, etc),
- availability of public domain routines,
- almost entire portability.

All these advantages imply large savings in manpower needed for the system development.

4. RELATION TO PIPELINE SOFTWARE

PIA was developed completely independent to the ISOPHOT specific pipeline [Ref. 11]. Although the data reduction steps present in the pipeline are common to both systems, and in principle the same calibration files are used, the pipeline architecture presented large difficulties for re-using parts of the existing code. Investigation of this possibility showed that it was more efficient to re-code completely within the interactive environment. This is of course a negative aspect of the ISOPHOT off-line analysis system development.

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Nevertheless, the experience achieved with coding certain algorithms for data reduction made their re-coding easier.

At the time the PIA development began, large parts of the ISOPHOT pipeline were ready, since its coding had started a couple of years before. The most positive aspect of the development of a complete independent system to the pipeline, capable of performing the same scientific analyisis, is the possibility of checking both systems against each other. Testing system versus system is easily done, since PIA is capable of performing exactly the same data reduction steps as the pipeline in a "standard" configuration.

5 THE EXPERIENCE ACHIEVED

After more than one year of ISO operations considerable experience has been achieved by the use of PIA, not only by the ISOPHOT Instrument Dedicated Team (PIDT) in its tasks of e.g. instrument behaviour control, calibration and analysis refinement techniques, but also by a large number of ISOPHOT observers in more than 50 astronomical institutes all over the world[3].

5a) Experience achieved on instrument check and trend analysis:

The possibility of accessing all housekeeping parameters (e.g. bias, temperatures), raw observed values and derived signals and fluxes in graphical and text form, investigate and establish correlations, etc, all with the same software package, provides the PIDT with a powerful instrument for problem detection and investigation in a short timescale, allowing for fast reaction (extremely important in the case of a very limited lifetime mission like ISO).

This capability was used during the short periods given for the "In-orbit instrument check" phase (1 week) and for the "Performace verification" phase (6 weeks) after launch. Operational parameters and fundamental calibration values were fixed during these periods.

Trend analysis tables, designed for orbital / multi-orbital analysis of detector behaviour, allow for predictions and corrections also in long timescale.

5b) Experience achieved on calibration:

Dedicated menues for all calibration files, allowing for displaying, overplotting, obtaining parameter correlations and processing files are used for the calibration work of ISOPHOT, a very complex instrument. Both files for instrument commanding as for off-line processing are produced by PIA and exported to the corresponding systems.

One important element contributing to the flexibility of the system is the possibility given to the users to access all internal buffers. The data can be modified (e.g. by user own defined processing) and the modified data can be set back into the system. This is a very often used option for experts developing new calibration and data reduction algorithms.

Also the use of processing scripts for speeding up processing in batch mode, with the possibility of modification by the PIA users is very often used by the PIDT for reduction of long and complicated observations or for combinations of results from different observations.

5c) Experience on products checking and pipeline tuning:

One of the key elements of the scientific validation of the pipeline products is made by the PIDT by comparisons with PIA products. The access to all pipeline products allows for thorough investigations and led to diverse failures discoveries, not only on the pipeline side but also on the PIA itself.

Several new algorithms for data corrections have been developed within the PIA and then exported to the pipeline, although not all the corrections which can be applied within PIA are suitable to be installed in a pipeline system. Those processes which require a large interactive user intervention will remain confined to PIA.

5d) Experience achieved by general users:

Although the ISOPHOT pipeline software is delivering more and more refined and better products, it was never the expectation that these products can do more than giving the observer an impression of the scientific contents of the observation performed.

For an ISOPHOT observer it is absolutely necessary to work interactively on his/her data, having an access to all the intermediate products and judging him/herself their quality.

The diverse ISOPHOT observational modes with all the different possibilities in the use of several sub-instruments make the data analysis a complicated matter, which is very difficult to be solved without the help of an advanced and user friendly system like PIA.

Special care is put in the documentation (accessible from PIA by a hypertext system), which is continuously updated and extended. Also the installation of the

[3] PIA is distributed freely to all astronomers wishing to use it for ISOPHOT data reduction and analysis.

package is extremely simple. Both elements contribute to the fact, that observers can start to work on their data without any special preparation.

Feed-back from general ISOPHOT observers, both concerning problems found and suggestions for capability extensions, has played a role in the past and will increase its importance in the near future for the further PIA development.

So far, all scientific results in publications including ISOPHOT observations (e.g. those included in the dedicated issue of the "Astronomy and Astrophysics" journal [Ref. 12]) were derived using PIA for the main data analysis.

SUMMARY

The development of an interactive calibration and astronomical analysis system, to be used by experts and general observers, in the case of an instrument like ISOPHOT, has proven to be of great value.

Large flexibility, easy extensibility and full graphical access to all levels of data reductions are some of the large advantages for the data analysis performed by an interactive system like PIA.

Complicated observational modes, combination from several sub-systems, a flux regime of several orders of magnitude, instrumental effects which are partly dependant on the flux and on the space environment conditions, all these elements make it very difficult to fix parameters for correction algorithms which would be valid for every data set. This requires an interactive system for optimal data reduction.

The strategies followed for the PIA development, partly forced by a very late start and lack of manpower, show a high efficiency for the obtained quality of the product.

The ISOPHOT off-line analysis systems present some redundances. The additional costs and complications resulting from the production and maintenance of different systems with complete different architectures could have been avoided by a different planning from the beginning, which foresees a more natural way of deriving a pipeline system from the batch mode use of an interactive system with pre-defined parameters. Such a batch mode is built as an alternative within PIA.

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