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The LARI Method for ISO-CAM/PHOT Data Reduction and Analysis

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Abstract. The techniques and software tools developed for the reduction and analysis of ISO-CAM/PHOT data with the LARI method are presented together with some highlights from the results obtained thanks to their application to different fields.
Designed for the detection of faint sources in ISO raster observations, such method is based on the assumption of the existence of two different time scales in the detectors' transient behaviour, accounting either for fast or slow detectors' response. Thus source lists of great reliability and completeness and an outstanding photometric accuracy are obtained, particularly at low redundancy levels, where the reliability of ISO-CAM/PHOT source lists, even at moderately bright flux levels, has been a long-standing issue.

Key words. methods: data analysis – infrared: general – surveys – catalogues

1. Introduction

All data gathered by the ISO satellite, and particularly those from the its two cameras, ISO-CAM and ISO-PHOT (hereafter simply CAM and PHOT), are very difficult to reduce, both due to the strong transients shown by cryogenically cooled detectors after a flux change (Coulais et al. 2000) and to the frequent and severe cosmic ray impacts yielding a wide variety of qualitatively different effects (common glitches, faders, dippers, drop-outs and others, Claret et al. 1998), generally referred to as glitches.

A number of data reduction methods has thus been developed and tested, mostly on CAM deep fields (e.g. the PRETI method by Starck et al. (1999) and the Triple Beam Switch method by Désert et al. 1999). Unfortunately, such methods proved useless for all PHOT data or on CAM shallower fields,leading to frequent false detections (unreliability) and losses of genuine sources (incompleteness). Besides, these methods suffered from the lack of an efficient way to interactively check the quality of data reduction when needed.

Originally developed as an answer to the problems posed by the reduction of the observatons carried out as part of the ELAIS survey (Oliver et al. 2000) and first presented in Lari et al. (2001), the LARI method has been devised to overcome these difficulties and provide a fully-interactive technique for the reduction and analysis of CAM/PHOT raster observations at all flux levels, particularly suited for the detection of faint sources and thus for the full exploitation of the scientific potential of the ISO Data Archive.

2. The Model

The LARI method describes the sequence of readouts, or time history, of each pixel of CAM/PHOT detectors in terms of a mathematical model for the charge release towards the contacts. Such a model is based on the assumption of the existence, in each pixel, of two charge reservoirs, a short-lived one Q_b (breve) and a long-lived one Q_l (lunga), evolving independently with a different time constant and fed by both the photon flux and the cosmic rays.

Glitches (i.e. the effects of cosmic ray impacts on time history) are identified through filtering of the time history and modelled as discontinuities in the charge release, leaving as free parameters the charges at the beginning of the time history and at the peaks of glitches.

Iteration of the fitting procedure is interrupted when either a satisfactory data-model rms deviation is achieved or the maximum number of allowed iterations is reached. In Figure 1 it is shown how a successful fit is thus able to recover useful information (specifically, source fluxes) from otherwise troublesome parts of the pixel time history.

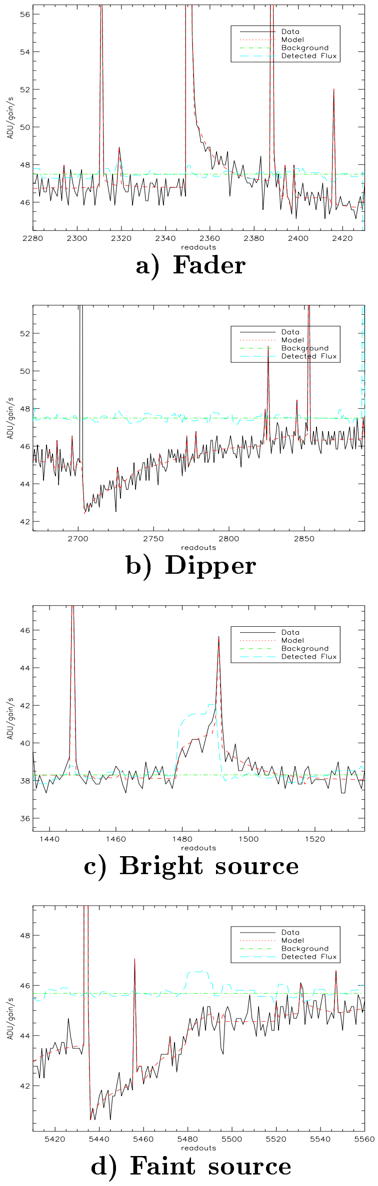

Fig. 1. Different troublesome situations in CAM pixel time histories: a) Recovery of stabilization background level after a fader b) Recovery of stabilization background level after a dipper c) Detection of a bright source hidden by a strong common glitch d) Faint source hidden by the recovery of the stabilization background level after a dipper.

3. The Method

The reduction pipeline consists of the following steps:

- PHOT ramps' linearization (following Rodighiero et al. 2001) and data smoothing (i.e. median averaging over a suitable number of readouts)
- Standard CIA/PIA `raster` structure and data-reduction-dedicated `liscio` structure building
- Dark current subtraction, stabilization (or global, as opposed to local, see below) background level estimation, bright sources' and glitches' identification
- Time history fitting procedure and interactive "repair" on fitting failures
- Interactive checks on sources detected in time history
- Flat-fielding, mapping (i.e. projection of fluxes measured along the pixel time histories onto a sky map), and source extraction (using DAOPHOT's `find`, particularly suited for the detection of point-like sources, as implemented in IDL Astronomy User's Library)
- Interactive checks on sources detected on sky maps and back-projected on pixel time histories
- Source flux autosimulation

The fitting procedure describes the time history of individual pixels according to the mathematical model seen in Section 2, allowing the determination of the breve and lunga charge levels, the local background (i.e. the signal to be expected on the basis of the previously accumulated charges if only the stabilization background flux were hitting the detector) and the flux excess ascribable to potential sources at any given readout).

The so-called autosimulation procedure for source flux estimation accounts for mapping effects in the determination of the total flux of detected sources. Other factors affecting the source flux estimates are then evaluated through simulations and absolute flux calibration.

4. The Software

The method relies on CIA (Ott et al. 2001) and PIA (Gabriel and Acosta-Pulido 1999) for basic raw data reading and manipulation and on home-made IDL routines for the data reduction proper. The massive necessary amount of interactive analysis is carried out with an easy-to-use graphical user interface. , a screenshot of which is shown in Figure 2

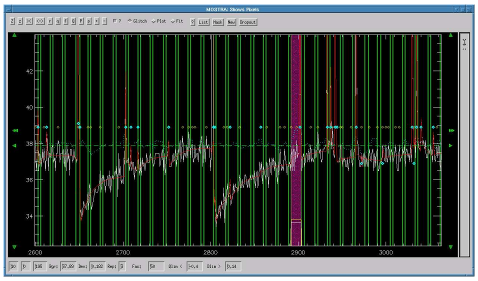

Fig. 2. A screenshot of the IDL widget-based Graphical User Interface.

5. Results / Work in Progress

A list of the different data reduction projects carried out includes:

- ELAIS 15 μm and 90 μm fields (Vaccari et al. 2003)
- Lockman Hole Shallow (LHS) and Deep (LHD) 15 μm and 90 μm fields (Fadda et al. (2003a,b) and Rodighiero et al. (2003a,b), see also Figure 3)
- Hubble Deep Field North and South (HDFs) 7 μm and 15 μm fields
- A few nearby galaxy cluster 7 μm and 15 μm fields

while highlights from the expected results can thus be summarized:

- A catalogue of around 2000 15 μm sources in the 0.5-100 mJy flux range from ELAIS, and the largest catalogue of extragalactic sources provided by any single ISO project
- Catalogues of the uttermost quality in smaller, cosmologically relevant fields such as the LHD and the HDFs

– Flux-level-dependent photometric calibration based on predicted stellar fluxes (CAM) or on internal/external calibrators' reduction (PHOT) (Vaccari et al. 2003; Rodighiero et al. 2003a,b)
– Unambiguous comparison of fluxes obtained with the LARI method with those obtained with different methods on deep fields (e.g. in the HDFs)
– Largely improved extragalactic source counts in the 0.3-100 mJy flux range from LHS and ELAIS (Lari et al. 2003)
– The first study of clustering properties of mid-infrared galaxy population

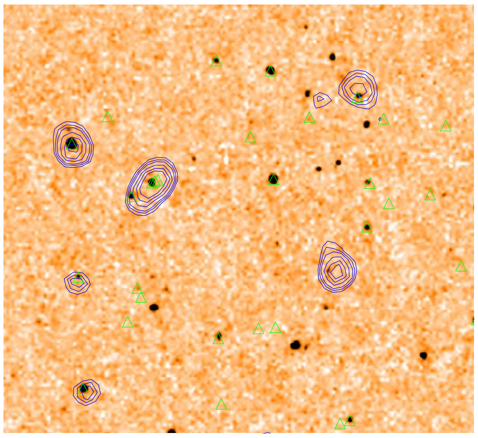

Fig. 3. $15' \times 15'$ Lockman Hole 15 μm map, with overlaid 90 μm contours (blue lines) and radio sources (green triangles, from de Ruiter et al. 1997)

6. Conclusions

Originated as an answer to the problems posed by ELAIS data reduction, the LARI method has evolved into a complete and well-tested system for ISO-CAM/PHOT data reduction and analysis, particularly suited for the detection of faint sources and the interactive check of detected sources. Raster observations carried out with ISO-CAM LW detector at 7 and 15 μm and with ISO-PHOT C100 detector at 90 μm have been successfully reduced, while tests are foreseen to apply the method to other ISO detectors, to ISO-PHOT C200 in particular.

Interactive by its very nature, the method both allows ISO-CAM/PHOT data reduction at all flux levels from scratch and to check the quality of any independent data reduction undertaking, thus leading to extremely reliable and complete source catalogues. It is thus believed that the LARI method can prove a very efficient tool in providing the community with long-awaited agreed-upon results from ISO extragalactic surveys, possibly the ultimate legacy of the ISO mission. Due to the intrinsic limitations of cryogenic detectors and space observations, the method could also be fruitfully applied to data provided by future infrared satellites.

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