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

Carlo Lari (Inst. of Radioastronomy, CNR, Bologna)
Carlotta Gruppioni (Padova Astr. Obs.)
Mattia Vaccari (Dept. of Astronomy, Univ. of Padova)
Francesca Pozzi (Inst. of Radioastronomy, CNR, Bologna)
Giulia Rodighiero (Dept. of Astronomy, Univ. of Padova)
Alberto Franceschini (Dept. of Astronomy, Univ. of Padova)
Dario Fadda (Instituto de Astrofisica de Canarias)
Gianni Zamorani (Bologna Astr. Obs.)

Introduction

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

A number of data reduction methods has thus been developed and tested, mostly on ISO-CAM deep fields (e.g. the PRETI method by Starck et al. 1999, A&AS, 138, 365 and the Triple Beam Switch method by Désert et al. 1999, A&A, 342, 363). Unfortunately, such methods proved useless for all ISO-PHOT data or on ISO-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.

The LARI method (first presented in Lari et al. 2001, MNRAS, 325, 1173) has been developed to overcome these difficulties and provide a fully-interactive technique for data reduction and analysis of ISO-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.

The Model

The LARI method describes the sequence of readings, 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 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. The observed signal S is thus related to the incident photon flux I and to the accumulated charges Q_b and Q_l by the

$$S = I - \frac{\mathrm{d}Q_{tot}}{\mathrm{d}t} = I - \frac{\mathrm{d}Q_b}{\mathrm{d}t} - \frac{\mathrm{d}Q_l}{\mathrm{d}t}$$

where the evolution of these two quantities is governed by the same differential equation, albeit with a different efficiency e_i and time constant a_i

$$\frac{\mathrm{d}Q_i}{\mathrm{d}t} = e_i\, I - a_i\, Q_i^2 \quad \text{where} \quad i = b, l$$

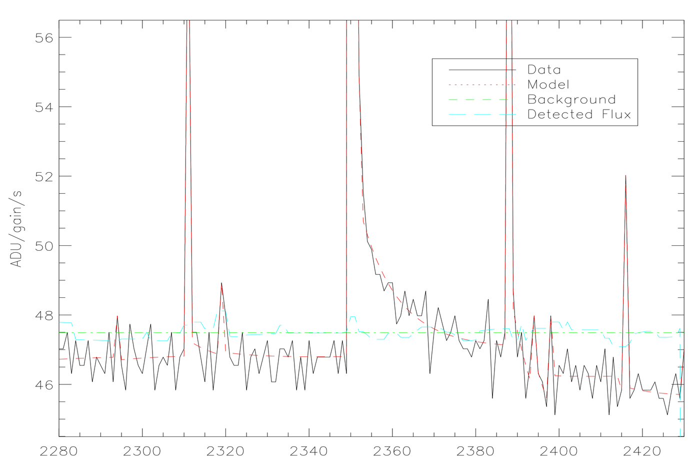
so that

$$S = (1 - e_b - e_l)\, I + a_b\, Q_b^2 + a_l\, Q_l^2$$

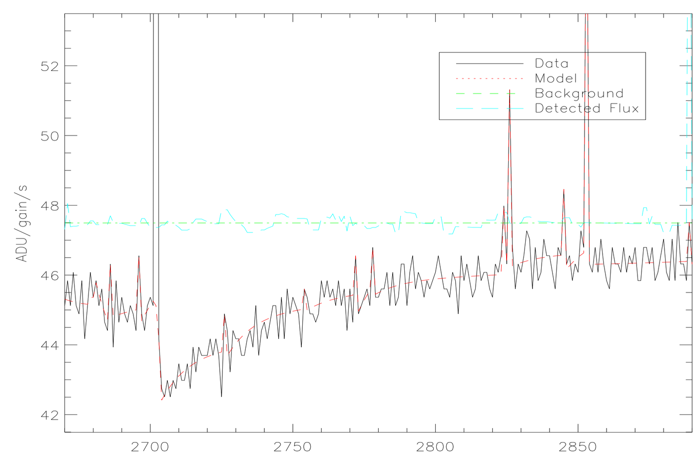
The values of the parameters e_i and a_i are estimated from the data and are constant for a given detector, apart from the scaling of the a_i for the exposure time and the signal level. The model for the charge release, however, is exactly the same for CAM and PHOT detectors.

In practice, an additive offset signal due to thermal dark current is added to both S and I in the equation above when it is estimated to be important, i.e. when the dippers' depth exceeds 10% of the background level.

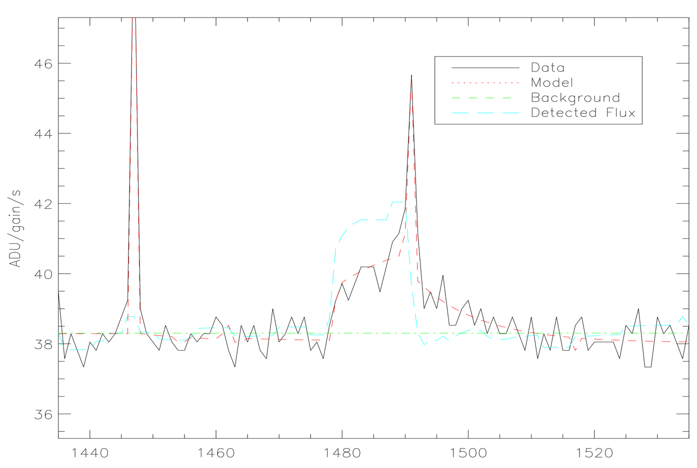
Glitches (i.e. the effects of cosmic ray impacts on time history) are identified and modelled as discontinuities in the charge release, leaving as free parameters the charges at the beginning of the time history and at the peaks of glitches.



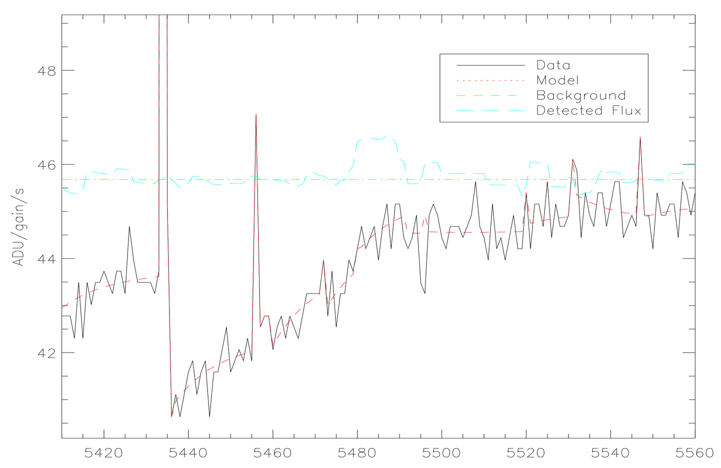
Fader



Dipper



Bright source



Faint source over a dipper

The Method

The reduction pipeline consists of the following steps:

- PHOT ramps' linearization (following Rodighiero et al. 2001, ESA-SP 481)
- CIA/PIA `raster` structure and `liscio` IDL structure building
- Dark current subtraction, background estimation, glitches' identification
- Time history fitting procedure and interactive "repair" on fitting failures
- Interactive checks on sources detected in time history
- Flat-fielding, mapping, and source extraction
- Interactive checks on back-projected sources
- Source flux autosimulation

The delicate autosimulation procedure for source flux estimation accounts for all mapping effects and for transients in detected sources through the following steps:

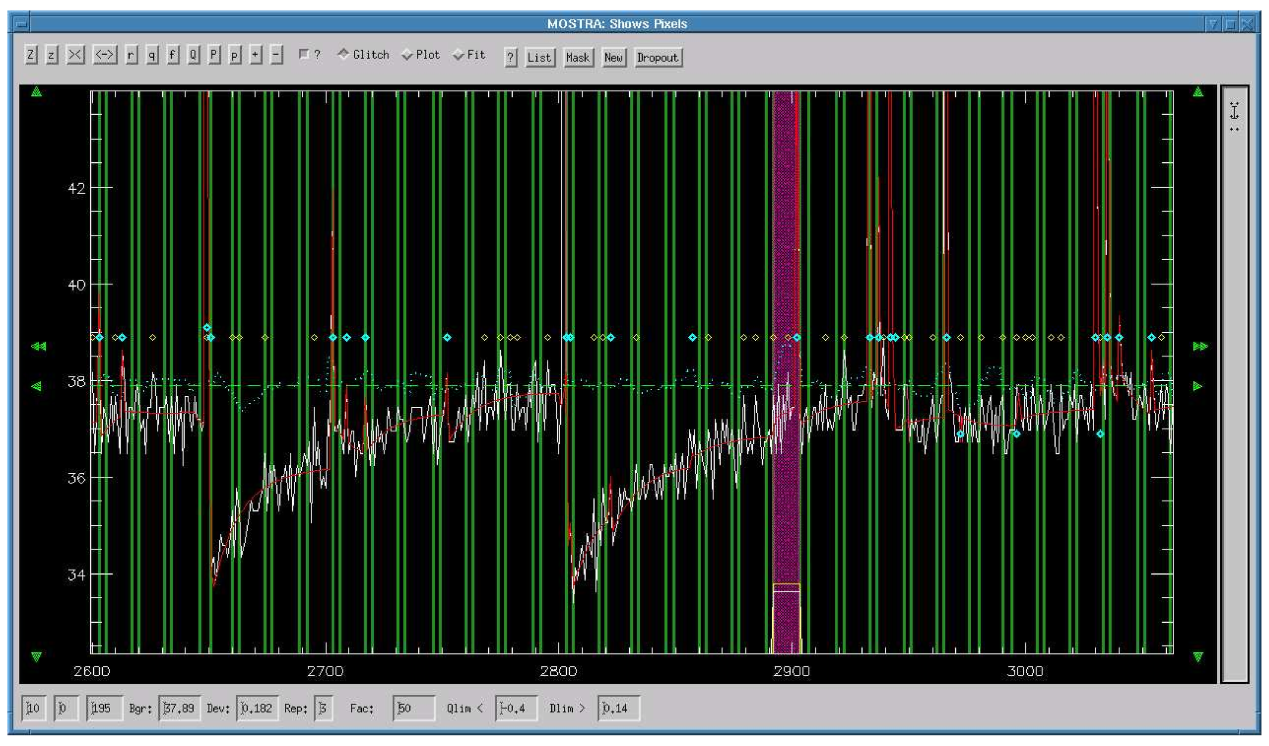
- First guess of source flux, based on its observed peak flux on the map
- Back-projection of source at the detected position on the time history
- Determination of theoretical peak flux on back-projected map
- Source flux correction based on observed / theoretical peak flux ratio

Other factors, namely those arising from the reduction technique and systematic deviations from detectors' nominal sensitivities, can only be evaluated through suitable simulations.

Once the reduction of all rasters of interest has been completed according to the recipe above, one can determine the necessary corrections to nominal astrometry through cross-correlation of detected sources with a suitable reference catalogue and then project nearby or repeated fields onto a common mosaic map, on which source extraction and flux autosimulation can furtherly be performed so as to increase the quality of the reduction through cross-checks of sources on different rasters.

The Software

The method relies on CIA/PIA for basic data manipulation and on home-made IDL routines for the data reduction proper. The massive work of interactive reduction is carried out with an easy-to-use GUI, which allows any kind of "repair" which may be necessary.



A Screenshot of the Interactive Reduction GUI

Results / Work in Progress

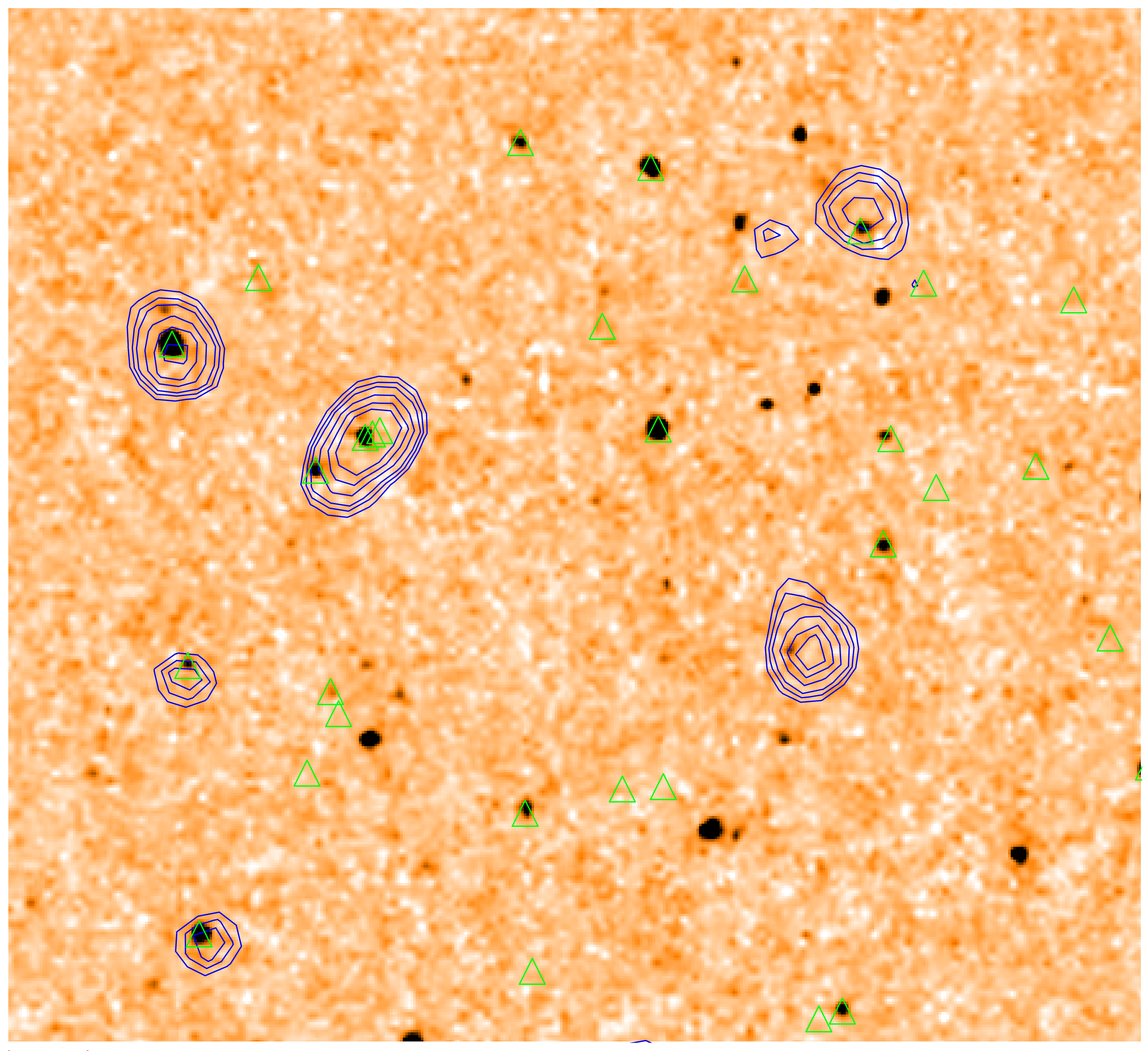
All parameters indicating the goodness of data reduction (reliability, completeness, astrometric and photometric accuracy . . .) are heavily dependent on the adopted observing parameters (exposure time, raster step . . .) as well as on the thresholds chosen in interactive "repair". They thus largely differ from field to field, so that it is not possible to properly summarize them here in any detail.

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

- ELAIS 15 μm and 90 μm fields
- Lockman Hole Shallow (LHS) and Deep (LHD) 15 μm and 90 μm fields
- 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,
- Flux-level-dependent photometric calibration based on predicted stellar IR fluxes (CAM) or on internal/external calibrators' reduction (PHOT)
- 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
- The first study of clustering properties of mid-infrared galaxy population
- Watch out for details in upcoming papers!
  (Pozzi et al., Rodighiero et al., Vaccari et al., Lari et al., Fadda et al.. . .)



$15' \times 15'$ Lockman Hole 15 μm map, with 90 μm contours (blue) and radio sources (green triangles, de Ruiter et al. 1997, A&A, 319, 7)

Conclusions

Originated as an answer to the problems posed by ELAIS data reduction, the LARI method has evolved into a complete 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 extend the method to other detectors.

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 an agreed-upon and substantial scientific return from the ISO Data Archive.