

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

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## 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 **transient behaviour** of the cryogenically cooled detectors and to the frequent and severe **cosmic ray impacts** yielding qualitatively different effects (common glitches, faders, dippers, drop-outs ...).

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 a high number of **false detections** and severe **incompleteness**. Besides, these methods suffered from the lack of an efficient way to interactively check the quality of the data reduction when needed.

The **LARI Method** (first presented in Lari et al. 2001, MNRAS, 325, 1173, hereafter Lari 2001) has been developed to overcome these difficulties and provide a **fully-interactive technique** for the 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 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

$$S = I - \frac{dQ_{tot}}{dt} = I - \frac{dQ_b}{dt} - \frac{dQ_l}{dt}$$

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

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

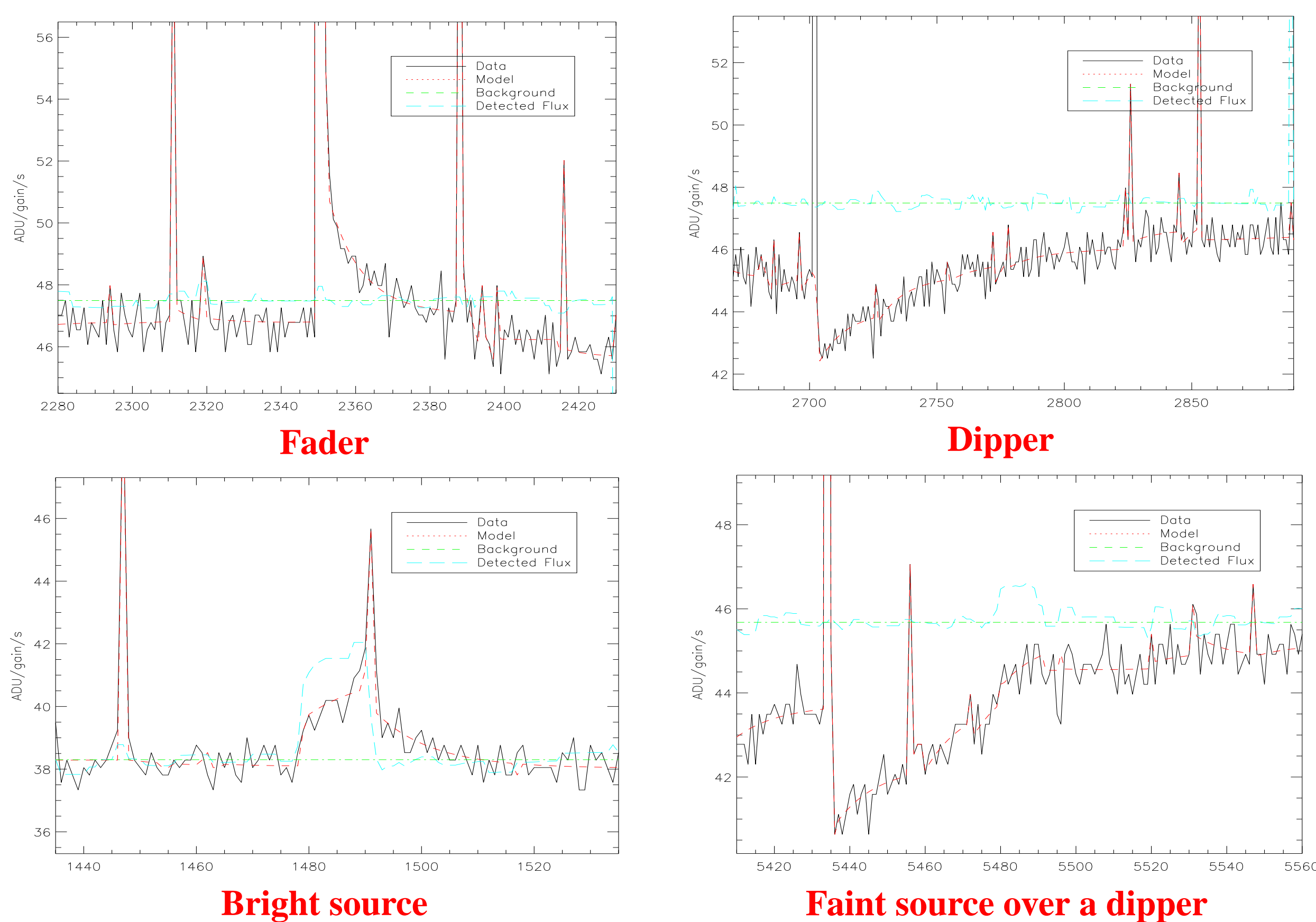
so that

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

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.

The **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.



## 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 project nearby or repeated fields onto a common **mosaic map**, on which source extraction and autosimulation can furtherly be performed so as to increase the quality of the reduction through **cross-checks** on different rasters.

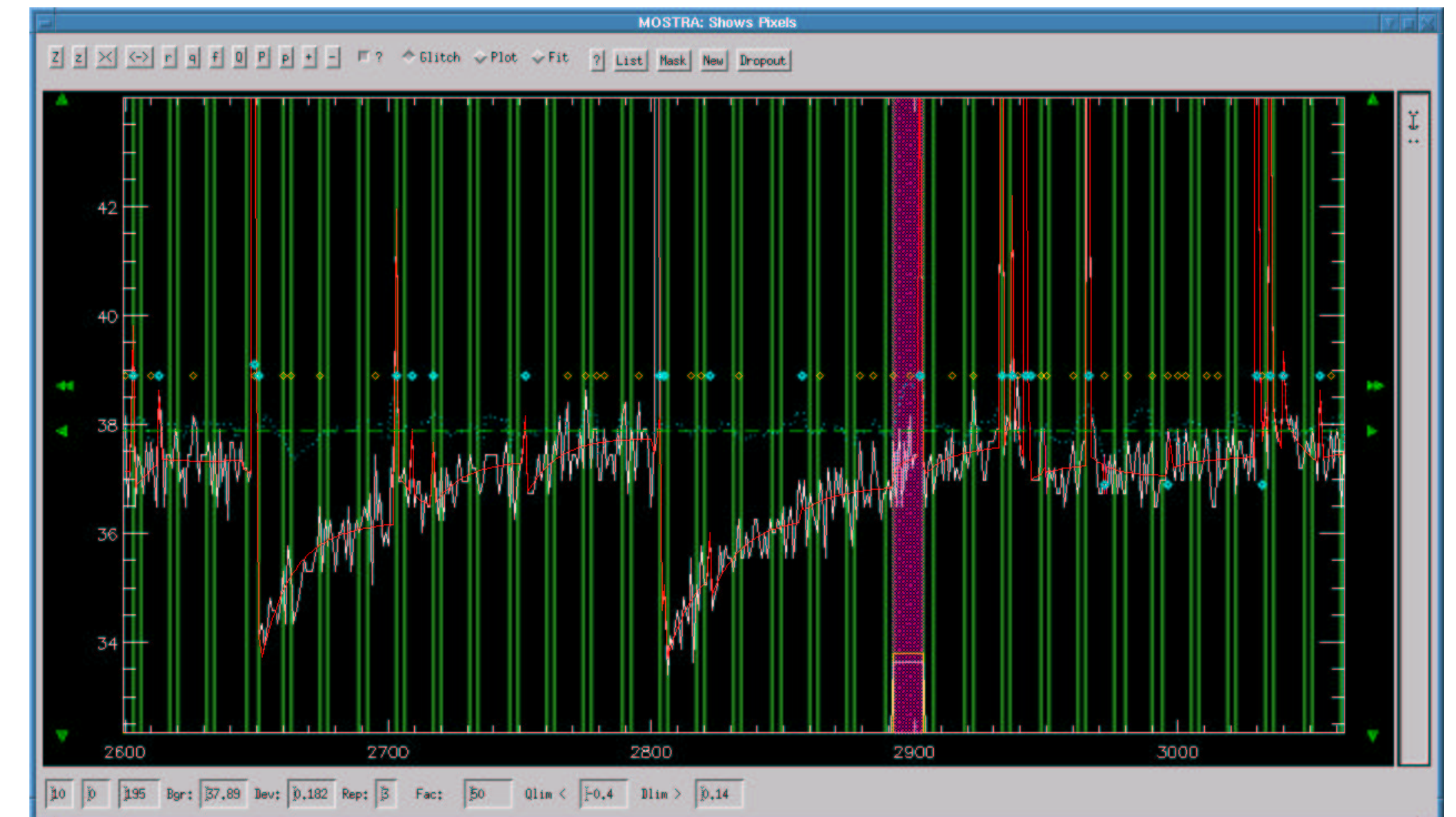
## Conclusions

Originated as an answer to the problems posed by the ELAIS data reduction, the **LARI method** has evolved into a complete system for ISO-CAM/PHOT data reduction and analysis, especially designed 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  $\mu\text{m}$  and with **ISO-PHOT C100** detector at 90  $\mu\text{m}$  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 archive.

## 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

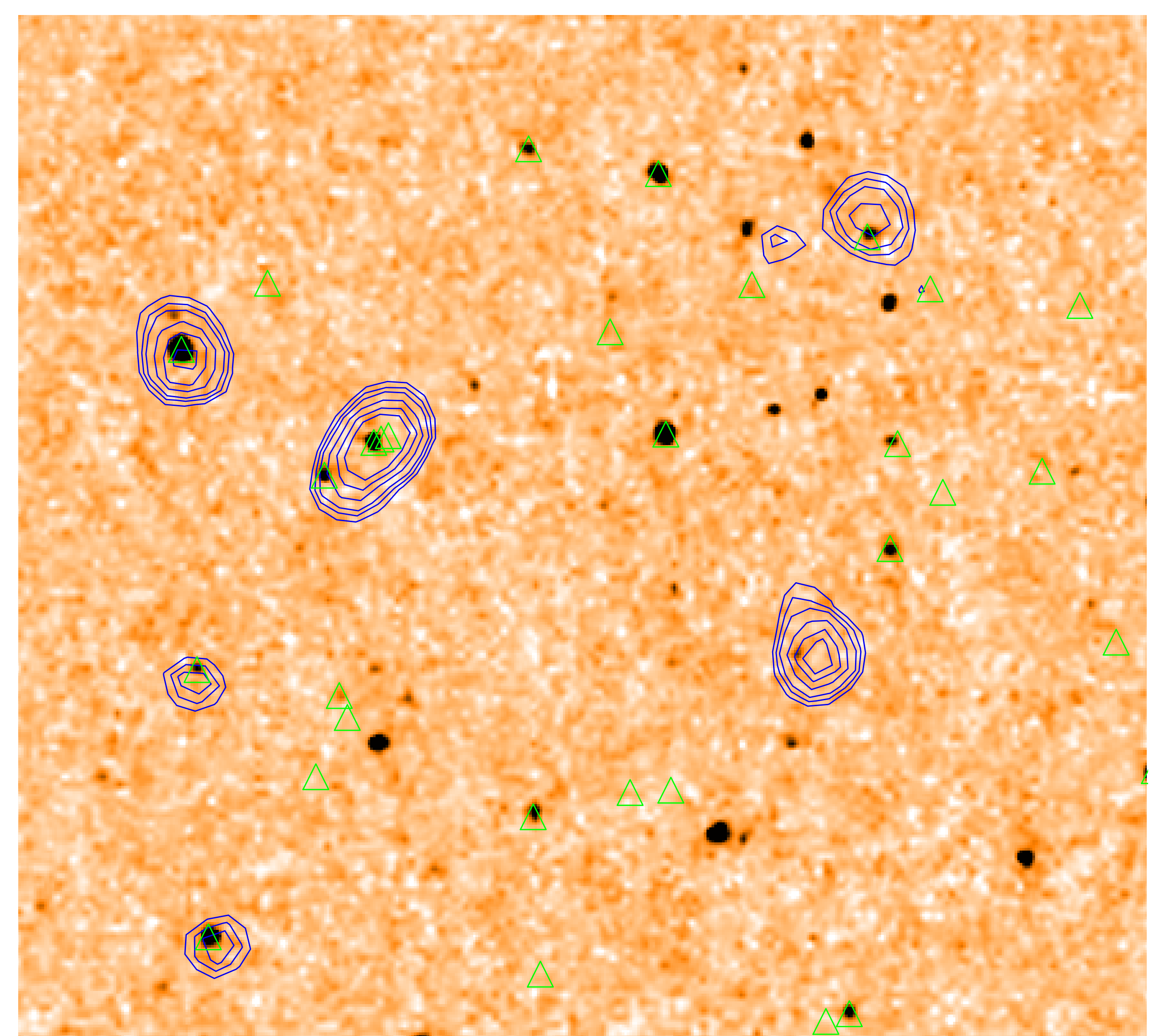
All parameters indicating the goodness of the reduction (reliability, completeness, astrometric and photometric accuracy ...) are heavily dependent on the adopted **observing parameters** (exposure time, raster step ...) as well as on the thresholds chosen in the interactive "repair", and thus can only be evaluated through **simulations**.

While the catalogues resulting from Lari 2001 are successfully being used for different purposes (see e.g. Gruppioni et al. 2002, MNRAS, accepted, astro-ph/0205173 and Matute et al. 2002, MNRAS, 332, L11), and the reduction of several different fields has already been completed, **simulations** and accurate **photometric calibration** are still being carried out, so that it is not presently possible to show detailed results. A list of the different projects being carried out includes:

- ELAIS 15  $\mu\text{m}$  and 90  $\mu\text{m}$  fields
- Lockman Hole Shallow (LHS) and Deep (LHD) 15  $\mu\text{m}$  and 90  $\mu\text{m}$  fields
- Hubble Deep Field North and South (HDFs) 7  $\mu\text{m}$  and 15  $\mu\text{m}$  fields
- A few nearby galaxy cluster 7  $\mu\text{m}$  and 15  $\mu\text{m}$  fields

while highlights from the expected results can thus be summarized:

- A catalogue of around 2000 15  $\mu\text{m}$  sources in the 0.3-100 mJy flux range from LHS and ELAIS
- Flux-level-dependent photometric calibration based on predicted stellar IR fluxes (CAM) or on internal/external calibrators' reduction (PHOT)
- Unambiguous comparison of LARI fluxes with those obtained with different methods on HDFs
- See also talks by Fadda, Rodighiero and Vaccari!



15' x 15' Lockman Hole 15  $\mu\text{m}$  map, with 90  $\mu\text{m}$  contours (blue) and radio sources (green triangles, de Ruiter et al. 1997, A&A, 319, 7)