Quality Control of VLT ISAAC Data

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ABSTRACT

For 3 years the Infrared Spectrometer And Array Camera (ISAAC) has been operating at the 8m Antu (UT1) telescope of the European Southern Observatory Very Large Telescope (ESO VLT). As part of ESO data flow operations ISAAC data are processed and quality control checked by the Data Flow Operations group (often known as QC Garching). at ESO headquarters in Garching. The status of the instrument is checked in terms of QC parameters, which are derived from raw and processed data and compared against reference values. Low level parameters include detector temperature and zero level offset, other parameters include image quality and spectrum curvature. Complicated instrumental behaviors like the odd-even column effect and the appearance of pupil ghosts require more sophisticated QC tools. Instrumental interventions of cryogenic instruments like ISAAC include a defrost and re-freeze sequence which can be traced in trending plots of the QC1 parameters, which are published regularly (see http://www.eso.org/qc). We present recent highlights of the ISAAC QC process and their role as feedback to the observatory to retain the performance of the instrument.

Keywords: Quality Control, ISAAC, data reduction pipeline, trend analysis, cryogenic instruments

1. INTRODUCTION

ISAAC (Cuby et al.[1]) is the first infrared instrument of the VLT. As the last link in the chain of the VLT data flow, the Data Flow Operations group (DFO) at ESO headquarters Garching performs the following tasks: a) the assessment of the quality of raw data and data products; b) pipeline reduction of VLT raw data and assessment of data products; and c) put together science and calibration data and build Service Mode packages to be delivered to the Service Mode observers, (Hanuschik & Amico[3]). In this contribution, we describe the implementation of the quality control process for ISAAC and its recent improvements. An overview on the general QC operations model is given by Hanuschik ei al..[4]

2. GENERAL DATA FLOW

The data flow for ISAAC is very similar to that of other VLT instruments. Raw data are processed by QC Garching in a night-by-night manner. After the raw data of a given night have arrived on the local disk e.g. via ftp over a satellite link, some consistency and completeness checks are performed. All raw data are classified according the **classification** scheme, based on the observation template ID FITS header keyword. The result of this process is lists of raw input frames (so called reduction blocks) to be submitted to pipeline recipes. Basic calibrations like darks do not require other input than the raw frames. But science frames and more sophisticated calibrations like illumination frames can optionally be processed with verified calibration products. Hence a second step is data **association**, with typical tasks like `match with FILTER=Ks` or `among all, take the closest in time`. The result of this process is files which contain the list of associated calibration products. Both the raw science frames as well as the list of associated calibration products are submitted to the ISAAC pipeline procedures for proper reduction of science data sets.

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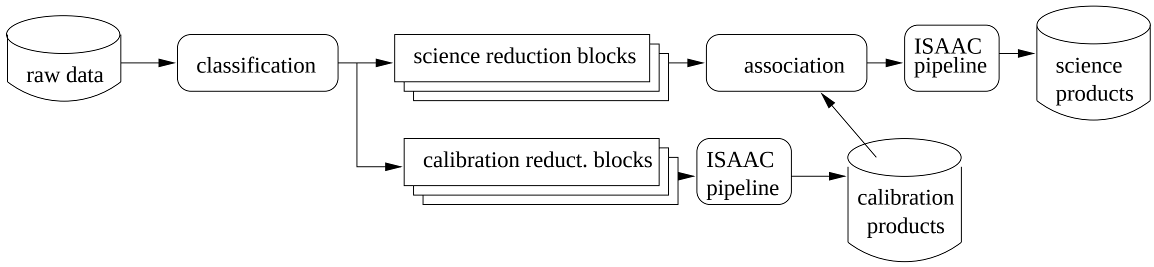

Figure 1. Post observation VLT data flow: Data reduction process. The science data reduction is started with a delay of about 2-4 days with respect to the calibration reduction. While nearly all spectroscopic calibrations are taken directly after the night, more twilight flats are required than can be collected during one night. Hence the association for appropriate twilight flats must be extended for more than 2 nights around the observation night.

3. PRACTICAL QUALITY CONTROL

Our main business is the quality control of the instrument. Our main experience is: one of the most important functionalities of QC is the process which shows for a given product frame the difference with respect to the latest created data product of the same type. Many other QC1 parameters and trending parameters can be derived from the experience gathered from such simple difference frames. The QC process can be divided in three parts.

3.1. Product QC1 parameters

For a given calibration product like a twilight flat frame or an arc product table we extract one or more QC1 parameters from that specific product e.g. QC1 parameters describing the fixed pattern noise or the odd-even column effect of the array. We handle scalar values like zero points as well as vector values like the slit function. The check itself is performed by a comparison of the QC1 parameter with an allowed range set by operational experience. QC1 values outside the valid range are outliers and require special consideration.[4] A second way to check the validity of a product is the comparison with a reference product. We distinguish two kind of reference products, the first one taken at the beginning of the (operational) year and the preceding one, taken a few minutes up to a few days earlier.

3.2. Relations

A second category of QC checks are relations between QC1 parameters and a reference relation which might be either empirical or theoretical. A typical example is the relation fixed pattern noise versus flux. The equivalent comparison relation is a theoretical one, namely the expected linear relation. Another example (Fig. 7) is the dark current versus discrete integration time (DIT). The appropriate comparison relation is the empirical relation taken e.g. from the last night, when dark exposures were taken with different DITs. A final example is the image quality versus seeing relation, for which the comparison relation is again an empirical one (Fig. 4). However the empirical relation cannot be based on one product or all products of one night but must be based on a larger period of time in order to match a large range of seeing values.

3.3. Trending

Long-term variations of the instrument can be monitored by either considering individual QC1 parameters as a function of time or by checking the difference between the current product and the first generated product. (e.g. first product after an instrument intervention, or last product before an instrument intervention, or the first of a given observing period or year). Most of the trending plots are available via the ISAAC QC web interface.

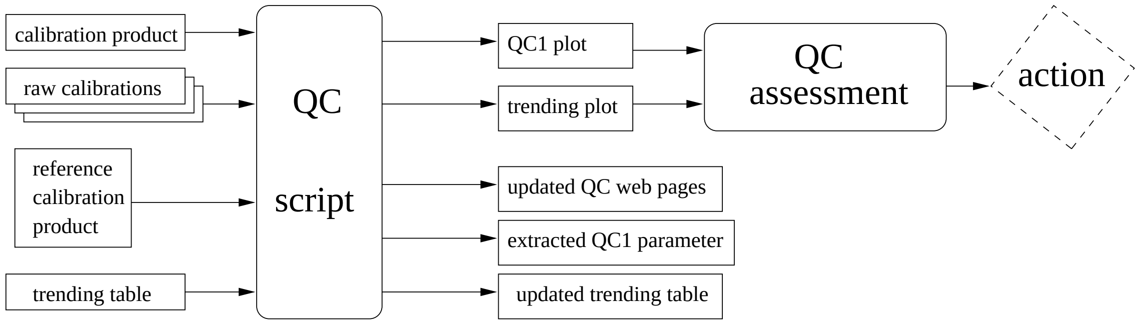

Figure 2. Post Reduction data flow: QC process. Various input sources are required for the QC process. In a first step the QC1 parameters are extracted from the calibration or science product and if appropriate from the ingredient raw frames. Other product properties are visualized as plot diagrams. Relations are handled in the same manner. In a second step, when the QC1 parameter is stored in the trending table, the trending diagrams are updated. Using information from the night logs outliers are classified[4] and if necessary reported to the Observatory staff.

4. ISAAC PIPELINE

There are three main drivers for a pipeline as part of the data flow, depending on the user. One is to provide an on-line quick look facility at the observatory. The purpose is to provide a tool for daily health checks of the instrument, e.g. misalignment of an optical component. Note that at variance to optical instruments equipped with CCD technology, the observing techniques used in the IR together with the high fixed pattern noise of array detectors does not allow to derive quality control parameters in all cases from single raw frames. Such a pipeline must be fast, and should create science data products also for the case that appropriate calibrations are not yet available when the science data are collected.

A second driver is the reduction of calibration and science data to deliver ready to interpret products for the individual scientific purpose of the observing program.

A third driver for a pipeline is to provide a off-line tool with deep-look functionalities, some kind of expert-system for the QC scientist.

The ISAAC pipeline is designed to fulfill the requirements of the observatory. A set of QC1 parameters is performed by the pipeline like zero points, read out noise, FWHM of arc. All other QC1 parameters are derived by shell scripts launching eclipse[2] commands. In so far QC1 parameters are a mixed set of pipeline products, image processing commands and shells scripts. In a few cases to use MIDAS procedures as well.

5. OPERATIONAL SURVIVAL AND OPERATIONAL QC

The implementation of the ISAAC QC data flow,[3] as used for Periods 64-66 (1999 October - 2001 March), has been considerably changed and improved. From Period 67 (2001 April) on, data classification and association was automated using Bourne shell scripts. The ISAAC pipeline recipes are called from shell scripts as well and products are properly renamed to a common naming scheme. The QC process was partially automated as well, and more and more QC1 parameters are defined and monitored.

From the operational point of view the scripts must be able to handle sporadic occurrence of partially corrupt FITS headers, aborted templates, chopped daytime calibrations taken during the end of night, maintenance and test frames and many other operational irregularities like emergency interventions meaning a defrost and re-freeze of the cryogenic instrument.

From Period 68 (2001 October) on we supported darks of the LW-arm Aladdin array and from Period 69 (2002 April) on we included all pipeline supported LW-arm observing modes in our QC operational scheme. Large operational changes occurred on 2002 April 1 when the data format of chopping mode LW-arm files has

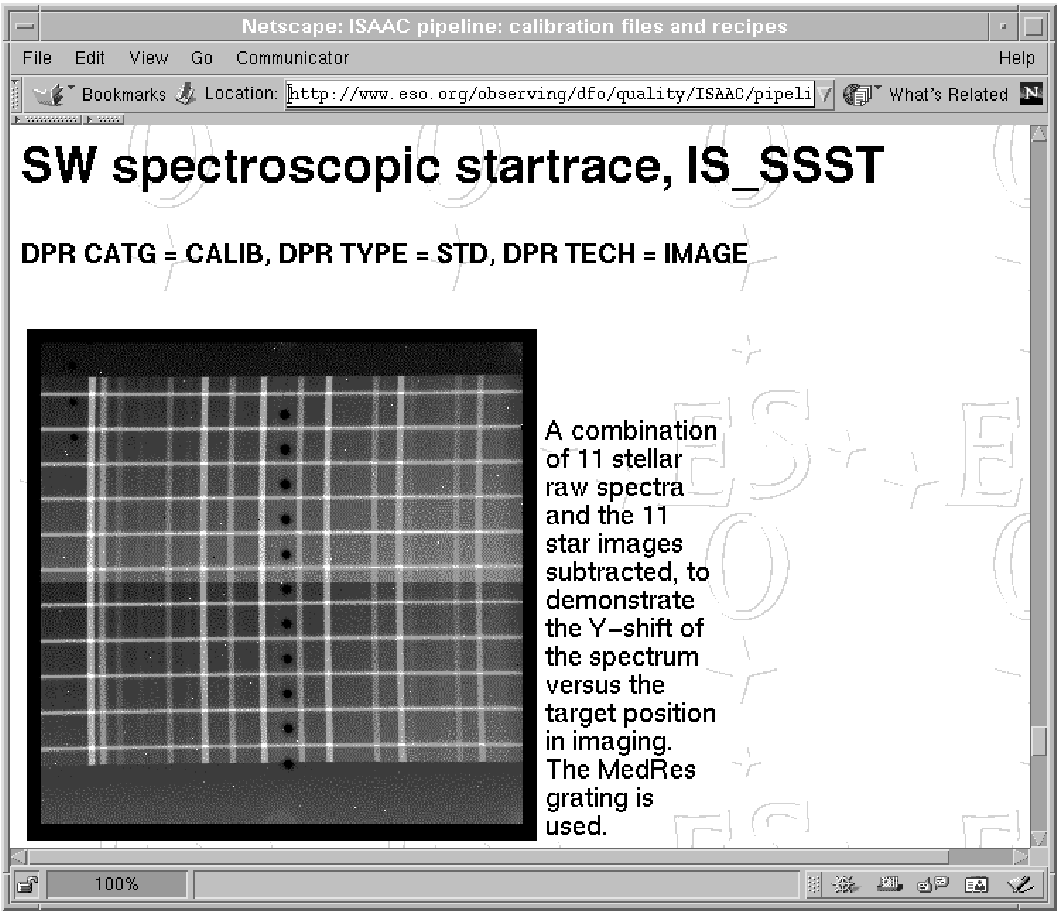

Figure 3. Extraction from the ISAAC QC web pages. Description of the startrace recipe.

changed, and at the end of June 2002, when the LW-arm arm (L-band and M-band) was functionally extended to handle for short wavelength observations (J, K, H bands) as well. Adapting QC scripts to new pipeline versions with changed interfaces is often time-consuming.

A final task for the QC scientist includes building up service mode packages. Here we resort raw frames pipeline products, listings and help files and put it all together to a package to be delivered to the principal investigators. Calibration products are associated from the reduction cascade if possible.

6. ISAAC QC WEB PAGES

Since the beginning of 2001 there are ISAAC QC web pages at **http://www.eso.org/qc**. They provide many results of the QC process and are mainly for the Paranal Science Operations Team. These pages are public, hence every user in particular every ISAAC observer can retrieve QC information from these pages. There is a Service Mode branch consisting of a description of a Service Mode Package. A second branch with title Pipeline explains the reduction cascade and which command line options are used for the ISAAC pipeline recipes. We also give many example products. The third branch of the ISAAC QC web pages is on QC itself. For each product category we provide a general information page, where the relevant public QC1 parameters and their derivation is described. There is also a general download page, where trending plots and trending tables can be retrieved. Plots are provided in postscript and gif format.

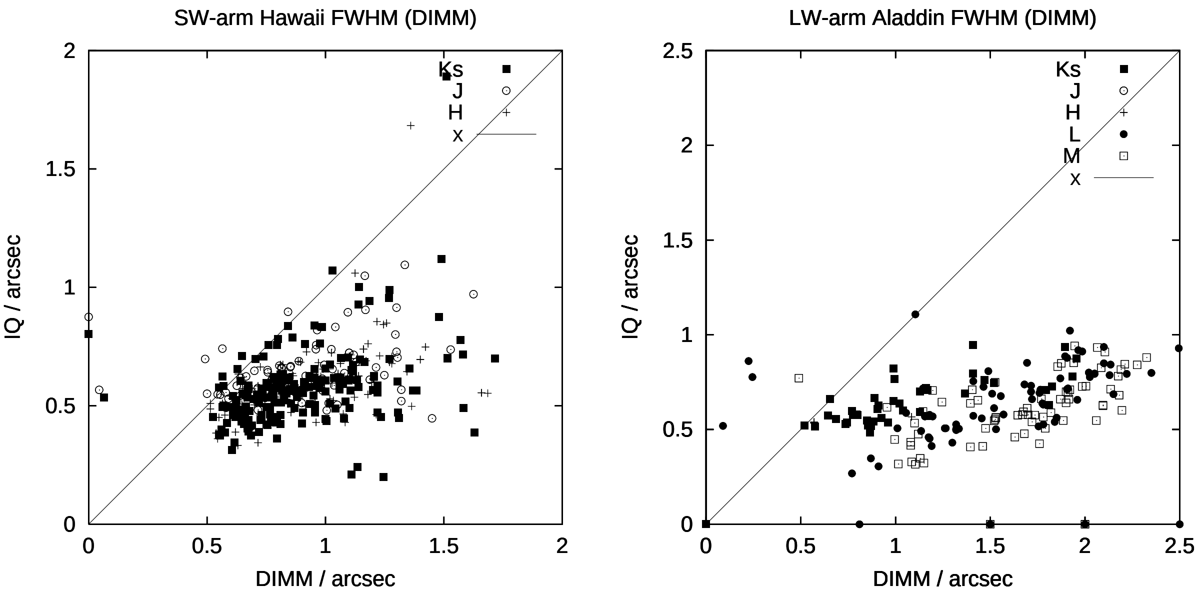

Figure 4. Median image quality of all reduced science imaging frames of the SW-arm Hawaii array (left, from Oct 2001 on) and the LW-arm Aladdin array (right, from April 2002 on).

7. PRODUCTS

As an example for a product QC1 plot we show in Fig. 5 the plot for a dark product frame and its related ingredient raw frames. The setting is LW-arm, DoubleCorrelated readout mode, DIT=5 sec, date = 2002 07 09 meaning this frame was taken shortly after the July 2002 intervention. In this plot we detected a performance loss of the LW-arm Aladdin detector, which was only partially captured by a single QC1 parameter but immediately visible in the plot.

8. RELATIONS

A simple example for a relation between QC1 parameters is the image quality (hereafter IQ) defined as the median FWHM as derived from a science image product and the DIMM monitor. Such a relation cannot be derived from a single dataset but a wide range of seeing must be collected over a longer period of time. In Fig. 4 we show all available image quality measurement from Oct 2001 on and how they relate to the DIMM monitor. Using a $\kappa - \sigma$ clipping the following coefficients for the relation

$$\mathrm{IQ} = a + b * DIMM$$

can be derived.

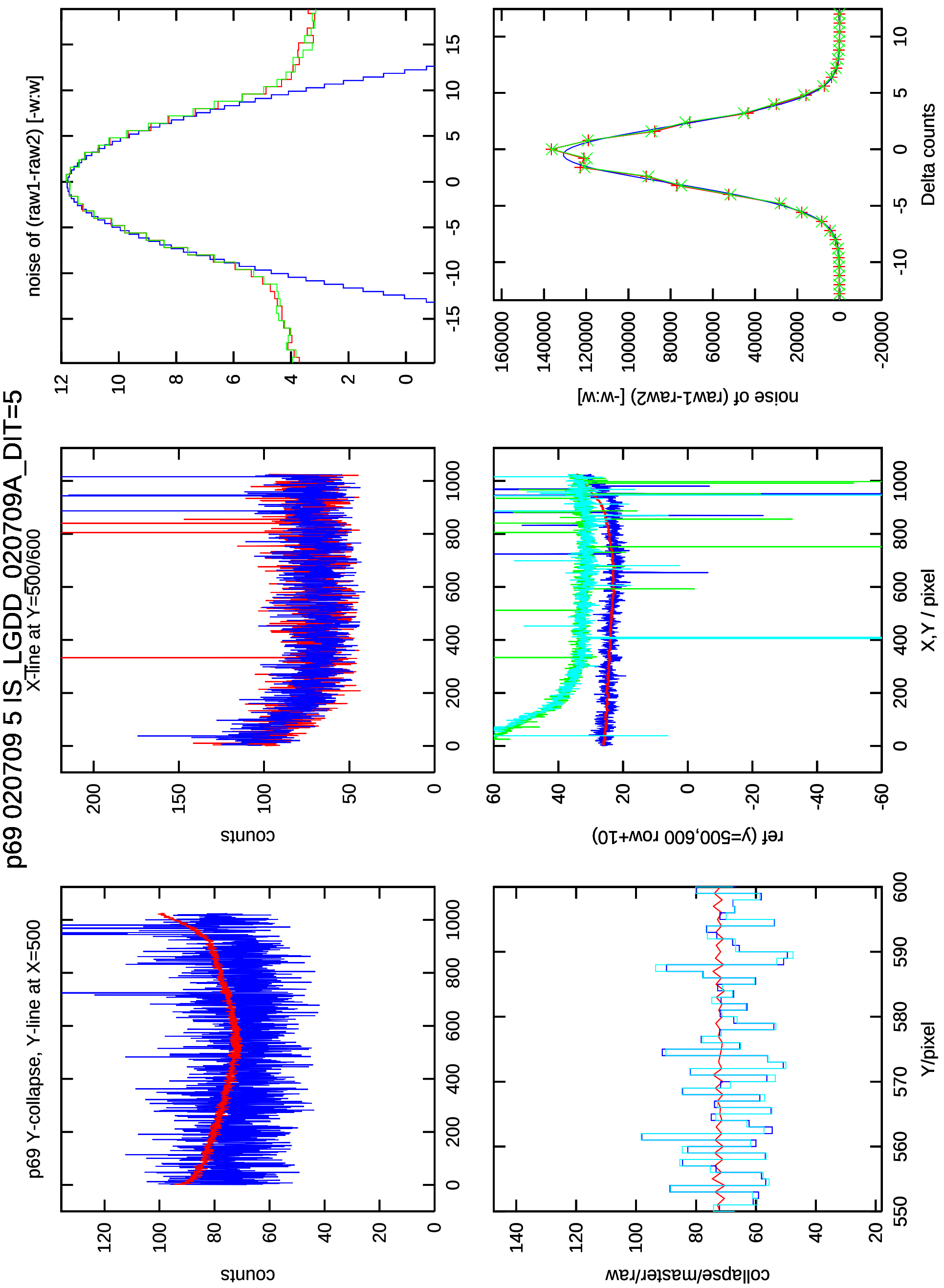

Figure 5. Example product QC1 plot. Upper left: the mean (collapsed) column and the column at X=500 of the product frame. Upper middle : Two rows at Y=500 and Y=600 of the product frame. Lower left: mean column (collapse), column x=500 of the product and of the first of the three raw input files. Lower Middle: The Y=500 row of the product minus the Y=500 row of a reference product. Y=600 row of the product minus the Y=600 row of a reference product. X=500 column of the master minus the X=500 column of a reference product. The reference product is renewed usually once a period or after an intervention. Lower right: Histogram of the difference frame (second raw minus first raw) and Gaussian fit between -3 and 3 counts. Histogram of the raw3-raw2 difference frame. Upper right: As Lower right, except a parabolic function is fit to the central part (-3 to 3 counts) of the log of the raw2-raw1 difference frame. Histogram of the raw3-raw2 difference frame.

Table 1. Coefficients for the linear relation between image quality and seeing of the DIMM monitor for different broad band filters of ISAAC.

arm	band	a	b	number
SW	J	0.43	0.24	81
SW	H	0.32	0.26	110
SW	Ks	0.33	0.26	209
LW	Ks	0.35	0.26	44
LW	L	(0.00)	(0.40)	30
LW	M	0.13	0.29	82

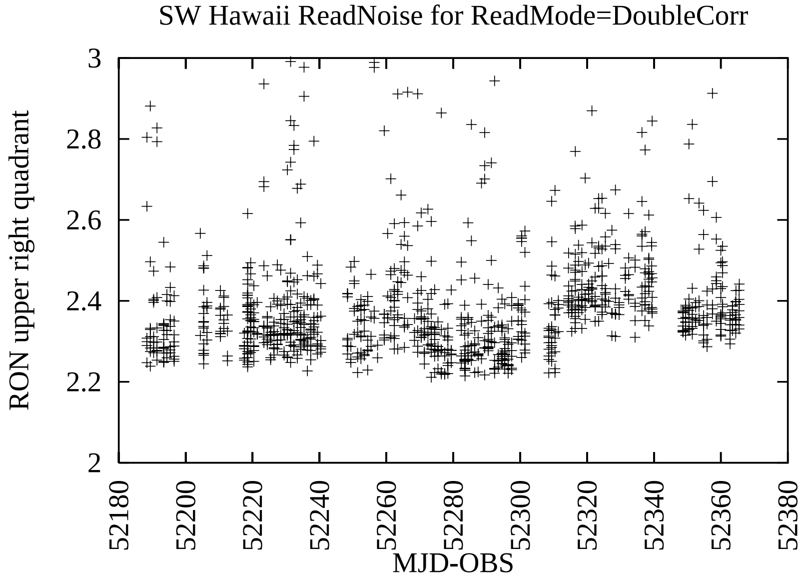

Figure 6. Detector read out noise (random noise) as derived with the dark-ron recipe for the upper right quadrant. The read mode is DoubleCorr as used for imaging. The time range is October 1999 - March 2002. Note that, as a consequence of an exchange of the ADC on Febr. 5 2002, the RON increased by 5%.

9. RECENT HIGHLIGHTS

We selected some highlights which demonstrate several aspects of the QC Garching work and purpose. The first two highlights handle the monitor of intended instrument changes like a configuration change and replacement of an electronic device. Such changes occur under control and do not bear the property of a detected change in the instrument performance.

9.1. ADC replacement

On April 20, the analog-digital converter (ADC) of the Hawaii array went out of order and was exchanged. While the dark current level remained unchanged the statistical noise increased from 2.2 by 3.4 % to 2.3.

9.2. New configuration of the SW detector

On Nov 25 2001 the read out speed of the SW detector was reconfigured. The read out time was doubled to account for a better performance concerning the odd-even column effect of the SW Hawaii array. The minimum

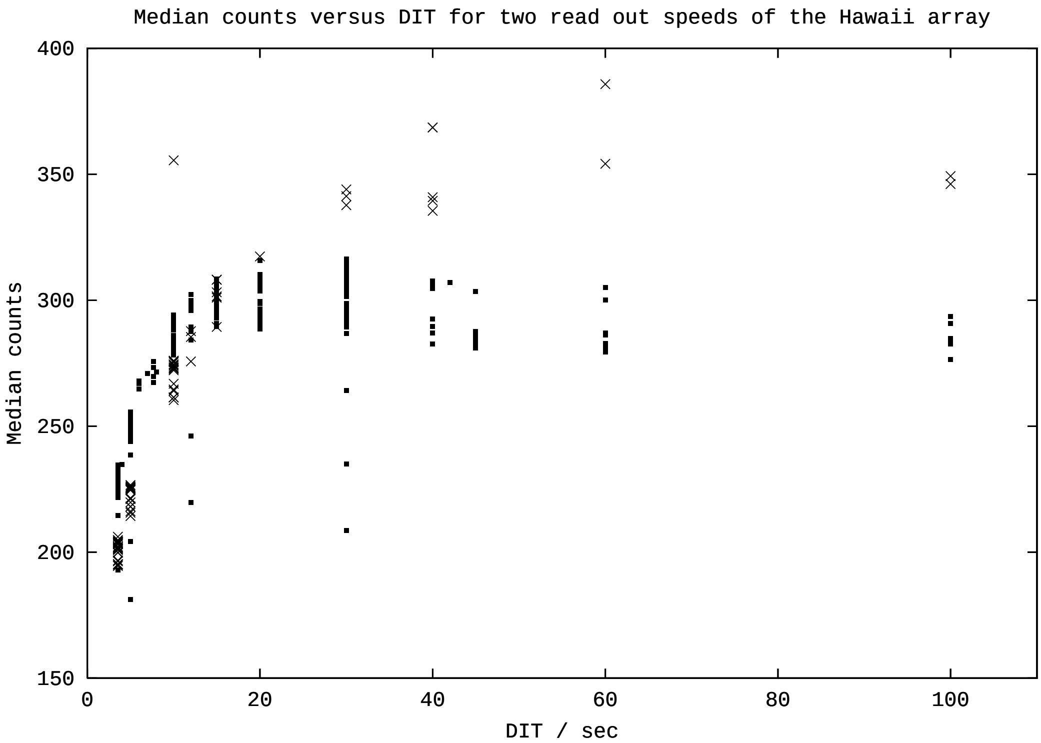

Figure 7. Detector dark current of the SW Hawaii array as a function DIT (discrete integration time). Crosses denote dark current values for `MINDIT=1.77` sec taken between Oct 1 2001 and Nov 25 2001 as well as between Jan 03 2002 and March 30 2002. Squares denote dark current values for the slower read out speed (`MINDIT = 3.55` sec) operating between Nov 25 2001 and Jan 03 2002. The read mode is DoubleCorr as used for SW imaging.

read out time changed from `MINDIT=1.7` sec to `MINDIT=3.55` sec. On Jan 03 the old configuration was used again. Both configurations produce a different median(DIT) relation, which becomes mostly apparent for long DITs.

9.3. Odd Even Column Effect

As an example of a sudden occurrence of a new effect we present the odd even column effect. The odd even column effect is not yet well understood. Empirically it occurs for fast read out modes of the SW Hawaii array, but the direct trigger mechanism is not known. The odd even column effect (hereafter OE) means, that the odd and the even columns of the array differ more and more by their response the larger the mean flux. Meaning that the average of all columns might show a linear relation with flux, while the odd or the even columns alone show a non-linear behavior. For large time ranges, the residual difference between odd and even columns is about 1e-5 and is not a function of the flux. It cancels out when flat fielding. In spring 2001 and in December 2001 the difference rose up to 1e-1, became non-linear, and the non-linearity became a function of time. In the following Fig. 8 we show the deviation of the odd and the even columns from the total as a function of flux for the second outburst of the odd even column effect in Dec 2001. A series of raw twilight flats frames is used, since they provide the largest flux range. As a consequence of these two events the QC1 scripts for the twilight flats were improved. Each set of twilight flat or sky flat raw frames is checked against the odd even column effect. As part of the product QC1 process we plot the odd even columns effects as a relation for all raw frames. Furthermore we parameterize the OE with two QC1 parameters which are collected in a trending table to find long-term variations. Paranal Science Operation and Data Flow System development team developed and implemented the `oddeven` pipeline recipe which removes signatures of the OE. After the

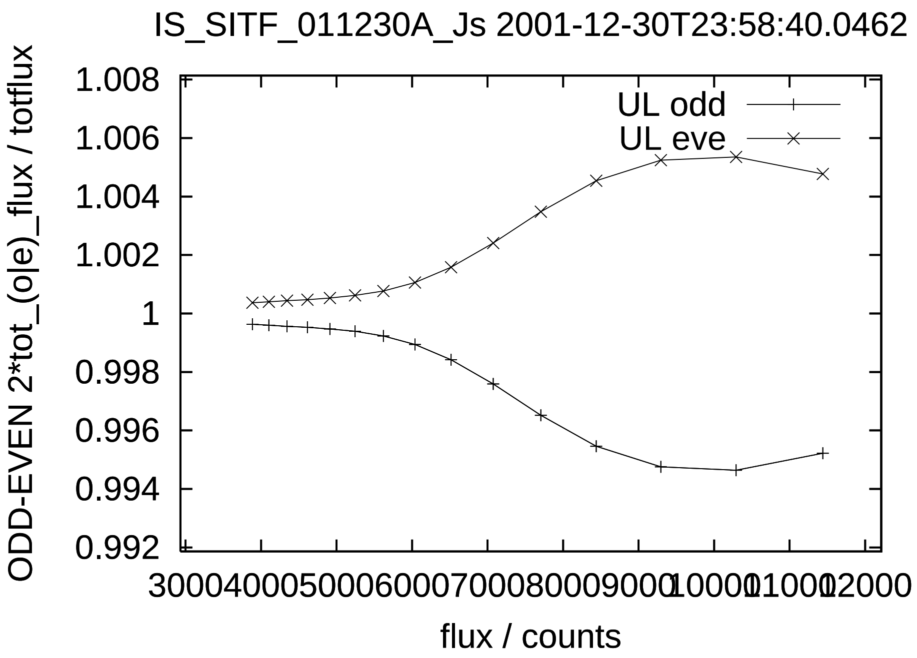

Figure 8. Development of the odd even column effect of the SW Hawaii array in the upper left quadrant as taken from the J-band twilight flat raw frames from Dec 31 2001 UT=00h. A few nights before these lines were horizontal at $1 \pm 1e-5$, meaning an amplitude of less than 1e-5 and linear with flux.

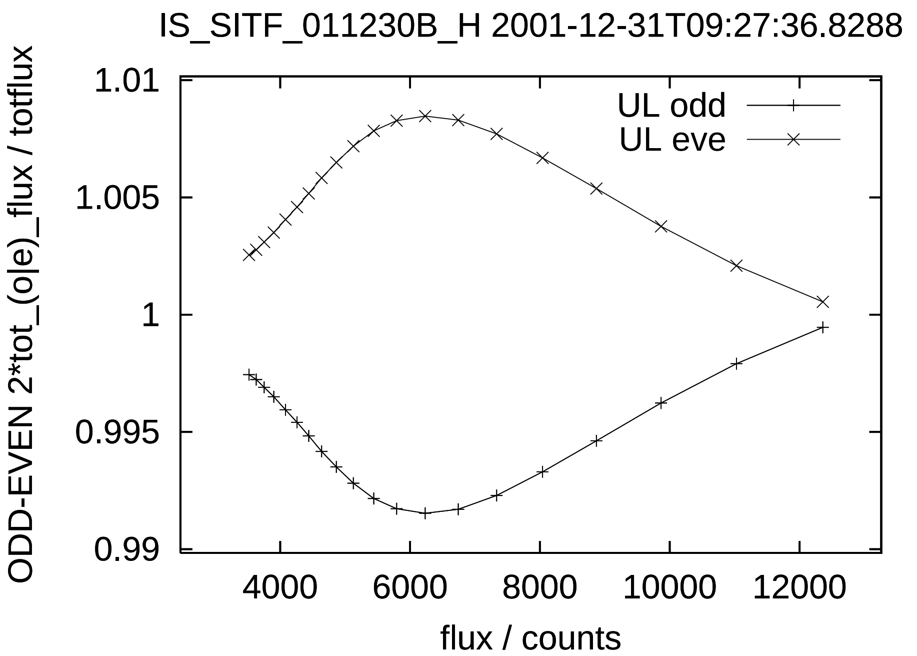

Figure 9. As Fig. 8 but nine hours later for the H-band. Note the changes in the non-linearity. For e.g. the maximum amplitude increased from 0.006 to 0.01 and occurs at lower fluxes of 6000 counts.

instrument emergency intervention in Jan 2001, the OE was reduced to below 10^{-5} and become linear again. After the intervention in Jule 2002 the residual OE become non-linear again, but the amplitude did not exceed 0.4% (when this article was written).

9.4. SW imaging background pattern structure

Another highlight is the sporadic occurrence of background structures in SW imaging products, found in March 2001.

From time to time we found stripes or crossed-like variations of the residual background in SW-arm imaging products. It turned out that these background features can be suppressed for `NDIT * DIT < 100 sec` and for rotator angle differences between two successive jitter raw images below 0.5 degrees. In summary the background features were reduced by a modification of the observatory operations plan. Observation blocks with objects of expected zenith transit are started well before or after meridian transit to diminish the expected differential rotator angle.

9.5. Optical distortion and spectra combination

The `spjitter` recipe assumes target spectra in a so called ABBA sequence, taken with the NoddingOnTheSlit observation template. A and B are target positions on the slit, with a large separation of about the half array size. A-type raw spectra bear a different spectral curvature with respect to B-type spectra and this curvature must be properly corrected by the recipe before co-adding individual spectra. In March 2001 we found product science and standard star spectra not properly co-added. It was first detected in very good seeing nights for the narrow slit (0.3") and for the medium resolution grating. This effect could be traced for bad seeing nights as well and for wide slits and for the low resolution grating.

After several discussions within the instrument operations team (IOT) it came out that the startrace recipe which corrects the spectra curvature was tested and verified on ISAAC data where the overall slope of the spectra (equivalent to the residual tilt of the grating with respect to the array) was below 1 pixel, while in 2001 this tilt was about 10 pixels, and the startrace recipe was not tuned to correct for such large residual grating tilts.

Since the intervention in Jan 2001, the gratings are well aligned and the raw spectra curvature is properly corrected again.

10. SUMMARY AND PROSPECT

We have shown different aspects of QC for ISAAC. We have demonstrated how QC retains the instrument performance and improves the efficiency. The ISAAC QC process is still evolving. As one of the next steps we will improve the QC of the spectroscopic modes. Another topic will be the reduction of the time delay between on-line QC at the observatory and the QC process in Garching.

In a few months from now the first IR adaptive optics system of the VLT NAOS and CONICA will become operational. Due to the functional similarities to ISAAC the present ISAAC QC process will be adapted for NAOS+CONICA.

ACKNOWLEDGMENTS

Thanks to P. Amico for assistance during the QC handover of ISAAC.

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