

VLT VISIR – Controlling Data Quality and Instrument Performance

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ABSTRACT

VISIR is the new ESO VLT instrument mounted at the Cassegrain focus of Melipal (UT3) telescope. At Paranal it is the very first instrument capable of high sensitivity imaging in the N band and Q band mid infrared atmospheric windows. In addition, it features a long-slit spectrometer with a range of spectral resolutions between 150 and 30000. VISIR had been included in the standard VLT data flow operation even before regular observing started in March/April 2005. Data products are pipeline-processed and quality checked by the Data Flow Operations Group in Garching. The calibration data are processed to create calibration products and to extract Quality Control parameters. These parameters provide health checks and monitor instrument's performance. They are stored in a database, compared to earlier data, trended over time and made available on the VISIR Quality Control web pages that are updated daily. We present the parameters that were designed to assess quality of the data and to monitor performance of the MIR instrument. We also discuss the general process of data flow and data inspection.

Keywords: quality control, VISIR, trend analysis, data reduction pipelines, instrument performance

1. INTRODUCTION

The VLT Spectrometer and Imager for the Mid-Infrared (VISIR) is an instrument dedicated to observations through the two mid-infrared (MIR) atmospheric windows: N band (8-13 μm) and Q band (16.5-24.5 μm). It was installed at ESO Paranal Observatory in April 2004 at the Cassegrain focus of the 3rd VLT Unit Telescope – Melipal. First light was obtained in May 2004 and VISIR was offered to the community beginning April 2005. This cryogenic instrument combines diffraction limited high sensitivity imaging capabilities over a field of up to 51 " and long slit grating spectroscopy capabilities with a range of spectral resolutions between 150 and 30000.

In MIR, high atmospheric and telescope backgrounds significantly reduce sensitivity of the ground-based instruments with respect to that of space-born ones. However the main advantage of observing from the ground with large telescopes is superior spatial resolution. Indeed, VISIR at the VLT provides diffraction limited images at $\sim 0.3''$ (FWHM) in the N band, which is an order of magnitude better than what can be obtained with the Spitzer Space Telescope (SST).

VISIR consists of two sub-instruments: imager and spectrometer. They have independent light paths, optics and detectors. The cryogenic optical bench is enclosed in a vacuum vessel and cooled to 33 K for most of the structure and optics. Both imager and spectrometer are equipped with the DRS, former Boeing, 256×256 BIB detectors. Their quantum efficiency is greater than 50% and reaches 65% or more at 12 μm . The detectors were originally cooled down to ~ 7 K. It was decreased to ~ 5 K in December 2005. At this temperature the intrinsic dark current is negligible compared to the background generated by the photons emitted by the telescope and the atmosphere. Nevertheless, it is removed by the observation techniques – chopping and nodding. Both DRS detectors have a fair fraction of bad pixels and display artifacts like e.g. striping, appearances of ghosts, fringes, etc.^{1,2}

The imager consists of two parts: collimator, providing an 18 mm diameter cold stop pupil in parallel light and a wheel with three objectives. The 0.075 " (small field, SF) and 0.127 " (intermediate field, IF) pixel scales

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are offered. The filter wheel is located just behind the cold stop pupil mask. Currently 14 filters are offered and additional filters are in planning.

Spectrometer offers slit spectroscopy at three spectral resolutions with a pixel scale of $0.127''$. The instrument contains two arms: one with low order gratings for the low and medium spectral resolution and the other with large echelle gratings providing high spectral resolution. Both subsystems image the spectrum onto the same detector. Selection between the two arms is done by two pairs of folding flat mirrors. The spectrometer slit wheel is also equipped with a very wide slit ($15.3''$), which enables imaging with the spectrometer detector. This capability is used for object acquisition and centering on the detector.

From the very beginning, the operation of VISIR was designed to follow a scheme common to all the VLT instruments.³ The observations are obtained either in visitor or service mode. In both cases users prepare their observations defining set of observing blocks. In visitor mode user travels to Paranal Observatory to provide on-spot comments and expertise, while in the service mode the observations are executed by the night-time astronomer whenever ambient conditions match the user specifications. The visitor mode data are then packed on-site and collected by the visitor, while all the calibration frames and service mode data are transferred to ESO in Garching for further check by the Data Flow Operation Group (DFO). Here, the quality control (QC) process includes assessing the quality of the raw data (also done at Paranal), quality of products created by pipelines, as well as monitoring performance of the instrument through temporal behavior of the QC parameters.

In this paper we present the general process of VISIR data flow and data inspection. We also introduce the QC parameters that were designed to assess quality of the data and to monitor performance of this MIR instrument.

2. VISIR DATA FLOW OPERATIONS AND QUALITY CONTROL

The standard VISIR data flow operation covers all steps of data handling from initial inspection of the raw frames and quick-look products at Paranal to thorough classification, processing, quality control and packing of service mode (SM) data done in Garching.

As MIR observations depend strongly on the ambient conditions such as humidity, temperature or airmass the SM science observations are accompanied by relevant calibration standard star observations obtained no further than 3 hours apart. During the day, daytime calibrations are taken. They consist of two types of flatfields: technical flatfields used to evaluate state of the detectors and regular flatfields that are distributed with science data. For both imaging and spectroscopic detector the flatfields are performed using warm calibration unit (WCU). WCU mimics extended source black-body radiation where flux is adjusted by changing its temperature. A stack of 7 raw frames is taken where black-body temperature changes from -40 C to 20 C with steps of 10 C . Such flatfields are obtained for most instrument configurations except for filter SiC in the IF and all imaging with the spectroscopy detector (for spectroscopy acquisition). At the moment the scientific value of application of flatfield correction for VISIR data is not established so the daytime calibrations are supplied to the user on an experimental basis. Also, distribution of the flatfields may be discontinued with no previous notice.¹

2.1. Data Classification, Association, and Processing

It is about 2 weeks before the VISIR data obtained at Paranal reach Garching. They are shipped from Chile to Germany about 2 times a week on physical media. Once they are integrated in the Archive system in Garching the QC scientist retrieves all the calibration/technical and SM science data for each night. The frames are organized, classified based on DPR keys, associated according to VISIR calibration plan and pipeline processed.

In first step the calibration frames, i.e. flatfields, imaging and spectroscopic standard stars, as well as technical flatfields and other calibrations taken for technical reasons are sorted and processed. The created master calibrations are quality checked and those which get certified can be associated with science data. Under current scheme all required VISIR calibrations are taken the very same night as the science frames. The technical products are further used for monitoring instrument performance.

Finally the science raw frames are associated with corresponding master calibrations. They include flatfields and standard star observations obtained with matching instrument setup. We associate one set of flatfields and

all the suitable standard star calibrations from the night. This is to provide users with information about MIR conditions over the whole night. Nevertheless, it is carefully verified that there is at least one standard star observation that fulfills the “3 hour” rule.

It is important to mention that currently all the VISIR science data are processed without any calibration cascade. In other words, although the master calibrations are associated they are not used in science data reduction. They can be further utilize by users for flux calibration, bad pixel correction, etc.

The obtained science products are checked for their quality and further distributed to the users with raw frames, associated calibrations, listings, nightlog information, etc.

The VISIR pipeline consists of a number of recipes reducing technical, calibration and science data. The recipes are based on the ESO common pipeline library (CPL). Most of the algorithms have been written by the instrument consortia, while the ESO DFS Department implemented them into common ESO pipeline environment. Synchronized pipeline versions are used in the Paranal science operation and by the QC group in Garching.

Presently the VISIR pipeline supports most offered modes with exception of images obtained with *VISIR_img_obs_GenericChopNod* template. It does not include any dependencies in the reduction cascade although the bad pixel map created by the flatfield recipe may be optionally used as input by other recipes. The VISIR pipeline is used not only to create master calibrations and science products but also to extract a number of specially designed QC parameters that are further monitored by the QC group. Thus, use of pipelines is essential for efficient quality control.

In January 2006 the VISIR pipeline v1.3.7 was released to the public on the ESO web site: <http://www.eso.org/pipelines>, to allow users more personalized processing of VISIR data. The release includes VISIR Pipeline User Manual – a comprehensive summary of recipes, reduction steps, algorithms used, as well as extracted QC parameters.

The VISIR data packages follow the same structure as the other VLT instruments. We distribute all the raw science frames (FITS files), science products, if created, as well as acquisitions of the science templates. They are sorted by observation block (OB) number. The GEN_CALIB directory collects all calibration files (raw and products) that have been measured as part of the regular calibration plan, logs and static calibrations: imaging and spectroscopy standard stars catalog, spectrometer detector quantum efficiency table and atmospheric emission profile. The GEN_INFO directory collects general information like e.g. observing reports. Detailed information about VISIR SM data packages can be found at: <http://www.eso.org/qc/VISIR/ServiceMode/ServiceMode.html>

2.2. Quality Control

Process of quality control performed by the DFO group in Garching includes verification of the quality of the raw data as well as pipeline products, monitoring performance of the instrument, designing new QC parameters and refining the pipeline recipes.⁴ It focuses on parameters related to status of the instrument, i.e. detectors’ temperature, number of bad pixels, and parameters related to observations, i.e. sensitivity, MIR background, etc.

First we examine the calibration products – master flatfields and combined standard stars images/spectra. We check e.g. if they are based on sufficient number of input frames, if they have proper flux level (over or under exposed), if the background was adequately removed, if they are similar to corresponding frames taken on previous nights, if they are consistent with their reference frames, if they show unusual noise pattern, striping, etc. Certified products are archived, while others may be discarded. This is to assure that only the best calibrations are used for reducing science data. Flagged calibrations may also indicate instrument problems and thus, are closely investigated.

Second, we collect extracted QC parameters, store them in database and compare their values with corresponding values from previous days.

Once the quality of the master calibration frames and performance of instrument are assessed, the pipeline reduces the science data. The quality of science products is checked as well. These science frames also contain

VISIR Health Check Plot : SENSITIVITY (+ Average)
 Last QC date: 2006-04-02, last PSO date: 2006-04-10
 last update: 2006-04-12T12:21:32

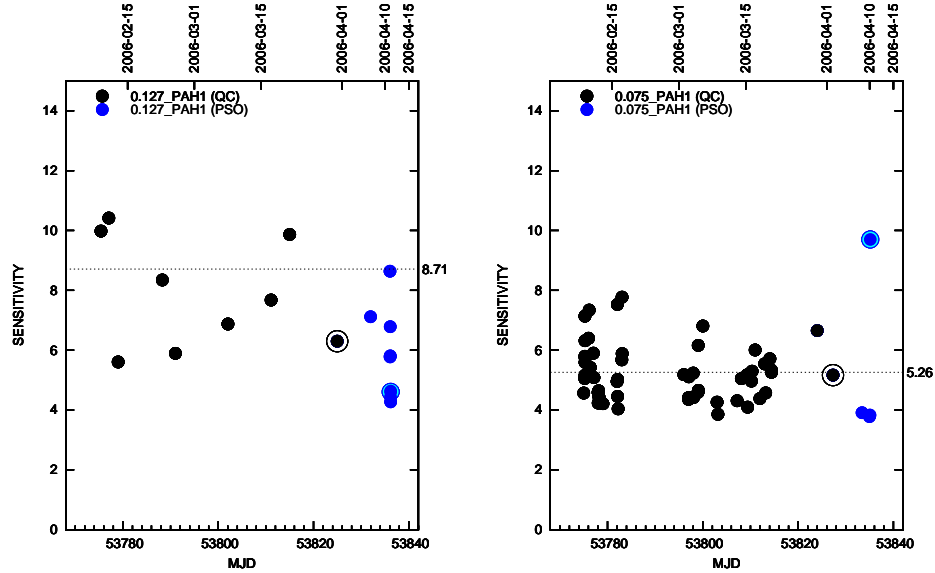


Figure 1. Example of a Health Check plot of VISIR – instrument sensitivity. Only data taken in filter PAH1 and pixel-field-of-view 0.075 and 0.127 are selected. The most recent points (gray) correspond to values from Paranal on-line pipeline runs and black points come from regular processing by QC Garching. Black and shaded circles mark the latest data points. The dotted line is the mean of the black dots.

useful informations concerning instrument stability and observing conditions. Thus, in the case of VISIR, several QC parameters, like e.g. mean background level, are extracted from science products.

The VISIR QC parameters are made available on-line at:
<http://www.eso.org/qc/VISIR/qc/qc1.html>.

Some of them are also plotted as a function of time in the form of Health Check plots (Sect. 2.2.1) and/or Trending plots (Sect. 2.2.2).

2.2.1. Quality Control Parameters

The following VISIR QC parameters are currently monitored:

- detectors' temperature
- number of bad pixels for each detector
- sensitivity in N and Q band
- conversion factor in SF and IF
- mean background level

Temperatures of the imaging and spectroscopic detectors are read from the headers of the VISIR files. The temperature of the imaging detector is considered only when the imager is used (i.e. in the "IMG" instrument mode) and temperature of the spectroscopic detector only when spectrometer is on (i.e. in the "SPC" instrument

VISIR trending QC.BACKGD.MEAN
 Last DFO date: 2006-03-08, last update: 2006-04-10T12:58:02

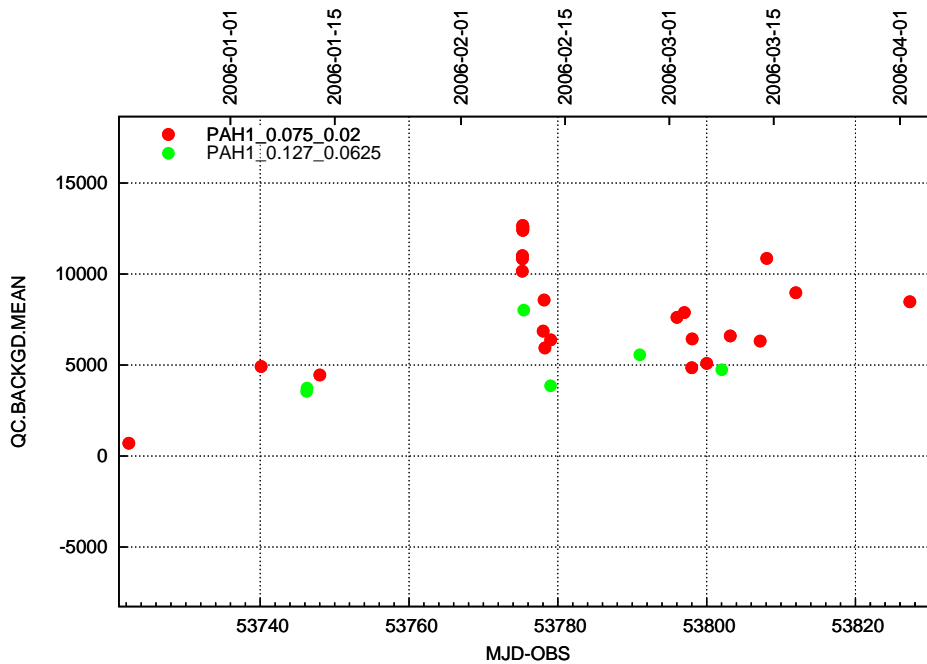


Figure 2. VISIR trending plot of mean background values. Here also only data taken in filter PAH1 and pixel-field-of-view 0.075 (dark points) and 0.127 (gray points) are considered. They were taken with Detector Integration Time 0.02 s and 0.0625 s respectively.

mode). So far collected values reflect December 2005 change of temperature from initial ~ 7 K to about 5.5 K for imager and 4.8 K for spectrometer. The temperatures remain stable within 5%.

Number of bad pixels is measured from the flatfield calibrations. The bad pixel is defined as a pixel with estimated relative gain outside range from 0.2 to 5. Typical numbers are $\sim 100 - 150$ for the IF and up to ~ 500 for SF in case of imaging and ~ 550 for the spectroscopy detector.

VISIR sensitivities are measured based on the observations of MIR calibration standard stars for both imaging and spectroscopy. The sensitivity in a given instrument setup (filter, pixel field of view) is defined as the limiting flux of a point-source detected with S/N of 10 in 1 hour of on-source integration. Measurements with different setups covering N and Q bands are done frequently during the night. The values collected since the beginning of VISIR operation cover now about a full year. It allows a statistical analysis of the sensitivity with respect to instrumental and atmospheric conditions. It indicates that the best measurements approach theoretical expectations, i.e. they are close to background limited performance. However, the 12 months deep calibration database is still not sufficiently long to describe possible long time scale trends.

Conversion factor is derived from the imaging observations of the calibration standard stars. It measures conversion between ADU and Jy. Only the measurements for the filter PAH1, SF and IF are currently monitored.

Mean background level is measured from the Half-Cycle frames. It's value can vary between two extremes of -32000 and +32000 ADU. As in case of the conversion factor only data points for the filter PAH1, SF and IF are currently monitored. Over the year of VISIR operation the mean background level was found lower in months of September-October than in March-April. Within time, as we collect more data points, we will be able to determine if this was just a random fluctuation or this is a typical annual trend.

2.2.2. VISIR Health Check and Trending Plots

In current VLT operation scheme the FITS files arrive from Paranal to Garching with 2 weeks delay. That creates a time gap between the QC parameters derived in Garching and the most recent ones. To assure the up-to-date coverage we include the values from the on-line pipeline processing at the Paranal from last night. Within time the data points from Paranal are replaced by the ones extracted in Garching. These daily updated plots are called Health Check plots and they can be found at:

http://www.eso.org/qc/daily_qc1.html

They are commonly used by day-time astronomers to check recent status of the instrument.

Figure 1 shows an example of VISIR Health Check plot. It displays QC parameter sensitivity as a function of time. The black points correspond to values extracted from products created in Garching while the gray points to values from Paranal pipeline run on latest data. Also, last Garching and last Paranal input data are marked with open circles.

Trending plots show the variation of QC parameters over a period of 4 months. Such a long time coverage is ideal for monitoring stability of QC parameters and detecting possible degrading of e.g. detectors' temperature or sensitivity. They are displayed at:

<http://www.eso.org/qc/VISIR/qc/qc1.html>

Currently there are 10 VISIR trending plots supported. Figure 2 shows one of them – mean background level as a function of time.

3. SUMMARY

VISIR has been integrated in the standard VLT data flow system from the very beginning of its regular operation in March/April 2005. Data are pipeline processed, checked for quality and, in case of the service mode programs, distributed to the users by the QC group in Garching. A number of QC parameters is monitored daily in form of Health Check plots and as Trending plots. The database with QC parameters' values as well as the QC plots are available on-line.

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