Long term performance of the VISIR/VLT instrument before the upgrade

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ABSTRACT

The ESO's VLT Spectrometer and Imager for the Mid–Infrared (VISIR) has been in operation at the Paranal Observatory since 2005. It is equipped with two DRS (formerly Boeing) 256 x 256 BIB arrays. The project to replace detectors into new Raytheon, 1k x 1k AQUARIUS devices as well as to modify observing modes, software, etc. is underway. The VISIR upgrade creates a well defined break point in the instruments' characteristics. For nearly 7 years of the VISIR operations we have been collecting and processing calibration data, in particular observations of the imaging and spectroscopic standard stars, within a regular data flow operation scheme. The derived quality control parameters have been systematically written into a database, which allows the analysis of their temporal behavior. We present an overview of the long term variations of the VISIR quality control parameters: sensitivity, conversion factor and mean background level estimations. The results will be later used to compare performance of VISIR before and after the upgrade.

Keywords: quality control, VISIR, trend analysis, instrument performance

1. INTRODUCTION

The VLT Spectrometer and Imager for the Mid-Infrared (VISIR), installed at ESO Paranal Observatory at the Cassegrain focus of the 3rd VLT Unit Telescope (Melipal) has been in operation for nearly 7 years. It provides diffraction limited imaging in the two mid-infrared (MIR) atmospheric windows: N-band (8-13 μm) and Q-band (16.5-24.5 μm), as well as long slit grating spectroscopy capabilities with a range of spectral resolutions between 150 and 30000.

VISIR consists of two sub–instruments: an imager and a spectrometer. Both are equipped with the DRS (formerly Boeing), 256×256 BIB detectors. The quantum efficiency of the detectors reaches up to 65% in the N-band and has a sharp absorption feature at 8.8 μm. The detectors have a fair fraction of bad pixels and display artifacts like striping, ghosts, fringes, etc. [1, 2].

To enhance the scientific performance of VISIR and to meet expectations from the user community ESO prepared an upgrade of the instrument [3]. It includes installation of improved hardware, optimization of instrument operations and software support. The main part of the upgrade project is replacement of the detectors. The contract was placed with Raytheon Vision Systems in 2007 and new science grade 1k x 1k Si:As Aquarius arrays were delivered to ESO Garching in 2010, where they were thoroughly tested and prepared to be mounted in both VISIR imager and spectrometer. Also, a modified spectroscopic mode covering the N-band in a single observations and several new scientific modes (e.g. coronography and sparse aperture interferometric masks (SAM)) will be implemented. The VISIR operational scheme will be optimized by using information about precipitable water vapor (PWV) from a newly installed PWV monitor. As the PWV is the main source of opacity in mid-IR its monitoring will allow proper planing and scheduling of observations. In addition, the existing data reduction pipeline software will be upgraded to process the raw data into the science ready data products.

Various activities within the VISIR upgrade project have been taking place since 2009 but the actual hardware upgrade at Paranal Observatory started on May 9th, 2012. VISIR is scheduled to be back in operations in September 2012.

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The upgrade creates a well defined break point in the instrument's history as the instrument's configuration will be changed irreversibly. For nearly 7 years of VISIR operations the calibration and scientific data have been collected in ESO Archive. The Back-End Operations Department Quality Control Group in Garching have been further processing calibration observations to monitor health of the instrument and to provide certified quality calibration products for the science data. Collected data can now be used to study instrument performance over the past years.

In this paper we present overview of the long term variations of the quality control parameters collected before the instrument upgrade. We discuss parameters obtained with the imager in Sec. 3 and those with the spectrometer in Sec. 4.

2. VISIR DATA FLOW OPERATIONS

As described earlier [4, 5], the data acquired with VISIR have followed the standard data flow operation scheme from the very beginning of its regular operation. Naturally, the scheme has been evolving with time but the general steps remain unchanged. All the data acquired at the telescope (including calibration and science files) are currently transferred via Internet to ESO Headquarters in Garching within minutes [6]. Here, they are retrieved from the ESO Archive by the Back-End Operations Department Quality Control Group for further inspection and processing. First data are classified and get associated with necessary calibrations as prescribed in the calibration plan. Then, the calibrations/technical data are reduced using the pipeline. Specially designed quality control (QC) parameters that carry information about instrumental and atmospheric signature are calculated by the recipes and written in the product headers. In the last step, the QC parameters are extracted from the headers of the pipeline products and automatically stored in the QC1 database. It can be accessed via:

`http://archive.eso.org/bin/qc1_cgi`

Some of the QC parameters are further used for scoring in the certification process and Health Check monitoring [7]. Assessing health of the different components of the instrument is mainly done by designing particular quality parameters that reflect performance of these components and further, by following their variations with time. They are plotted as Health Check plots and can be found at:

`http://www.eso.org/observing/dfo/quality/ALL/daily_qc1.html`

The Health Check plots are refreshed frequently, whenever new data points are detected (checks are done once per hour). They also contain information about distribution of the data points as it was in the past. Those historical plots provide an opportunity to follow long term behavior of various QC parameters of VISIR.

In [4] the main QC parameters of VISIR were listed. They include parameters focusing on the detectors and parameters derived from observations with the imager and spectrometer.

3. LONG TERM VARIATIONS OF PARAMETERS FROM THE VISIR IMAGER

One of the main QC parameters inferred from the observations of the imaging standard stars is sensitivity. The sensitivity in a given instrument setup (filter, pixel field of view) is defined as the limiting flux of a point-source detected with a S/N of 10 in 1 hour of an on-source integration.

Figures 1, 2 and 3 show the sensitivity measurements that have been collected for different filters since the beginning of VISIR operations. The data are sorted by two pixel scales: 0.075" (small field, SF) and 0.0127" (intermediate field, IF). The sensitivities are compared with theoretical predictions, as in [1]. Only observations executed under "good" weather conditions flag are included. The weather flag is set by the astronomer during the observations. It is based on the measured mid-IR background level.

In Figure 1 we plot sensitivities for the N-band filters. The black dots represent the best observed values for each instrumental setup. We also marked the median sensitivities inferred from each data set. Clearly, the observed sensitivities have not reached the theoretical estimates but for some filters, e.g. ARIII (8.99 μm) or SIV (10.49 μm), they are very close. Also, IF sensitivities are systematically higher than those for SF.

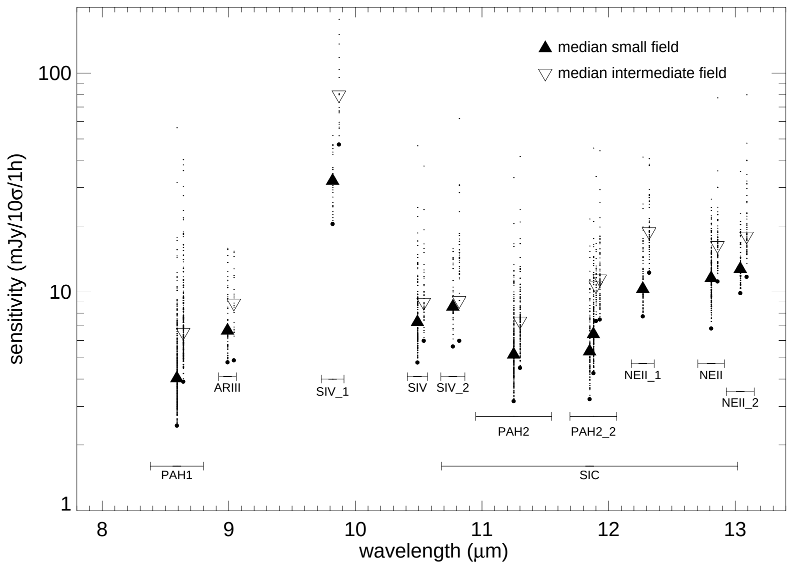

Figure 1. N-band filter sensitivities of the imaging standard stars observed by VISIR. Data for both, small (0.075") and intermediate (0.127") pixel scales are shown. The black dots mark the best observed values, while the open and filled triangles indicate median values for each data set. Horizontal lines correspond to the central wavelength and width of the filters, as well as sensitivities predicted theoretically (as in [1]).

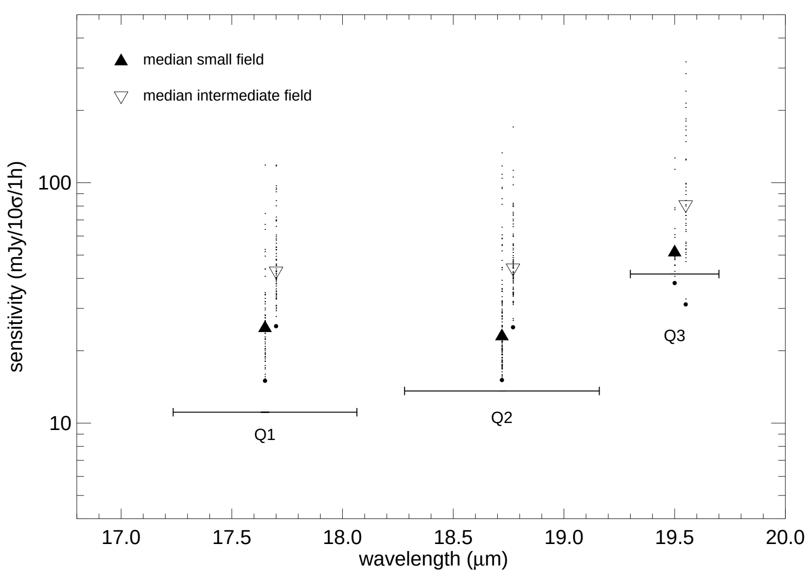

Figure 2. Q-band filter sensitivities of the imaging standard stars observed by VISIR. As above, data for both, small and intermediate pixel scales are plotted. The black dots mark the best observed values, while the open and filled triangles indicate median values for each data set. The horizontal lines correspond to filters' characteristics and their positions to theoretically predicted sensitivities.

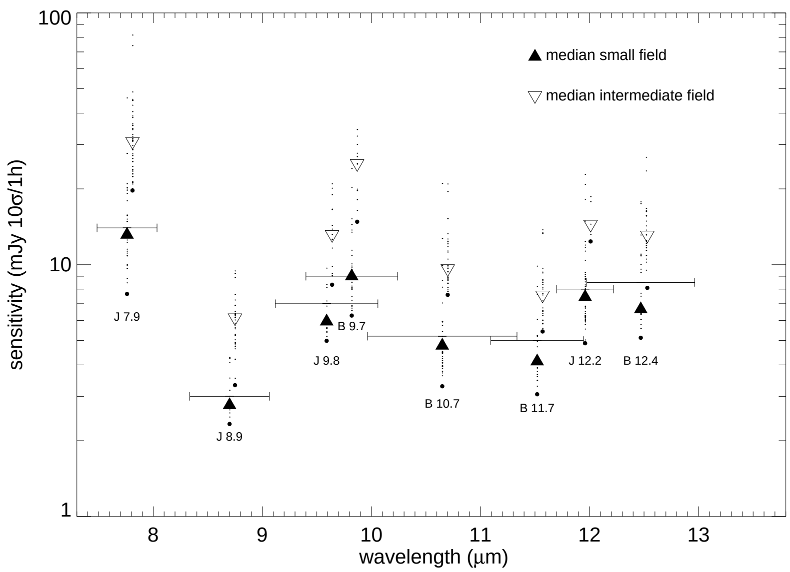

Figure 3. Silicate filters sensitivities of the imaging standard stars observed by VISIR. As in 1, data for both, small and intermediate pixel scales are plotted. The black dots mark the best observed values. The horizontal lines correspond to filters' central wavelengths and widths, while their positions mark originally measured sensitivities listed in Table 3 of the "VISIR User Manual" [1].

In case of the Q-band filters (Figure 2), observed sensitivities for the Q3 filter turn out to be better than predictions.

Figure 3 shows sensitivities that have been observed with the silicate filters since they were installed in VISIR in 2007 [5]. The values are compared with the initially acquired measurements listed in [1]. Within time the collected sensitivities proved to be better than the initial observations. Here also the SF values are better than those of IF.

Another QC parameter derived from the imaging standard star data is the conversion factor. It indicates conversion between ADU and Jy for VISIR observations. Figure 4 shows conversion factor values for selected instrumental setups; filters PAH1 (8.59 μm) and NeII (12.81 μm), for both SF and IF. All observed targets are included. It is apparent that the conversion factor has been mostly constant throughout the years, although there is a clear difference among data for various filters and pixel scales.

Mean background level is measured from the Half-Cycle frames of the imaging standard stars. Its value can vary between two extremes of -32000 and +32000 ADU. Figure 5 shows data points that have been collected since the beginning of operations in 2005. The same instrumental setups as for Figure 4 were selected. However, all the data points clearly follow the same behavior regardless of the filter and pixel scale. The variations correspond to annual periods of better and worse observing conditions - lowest background level during Chilean winter months and highest during Chilean summer months.

4. LONG TERM VARIATIONS OF PARAMETERS FROM THE VISIR SPECTROMETER

In case of spectroscopic observations of the standard stars VISIR pipeline derives sensitivities as function of wavelength. Figure 6 shows examples of the sensitivities from various low resolution observations in all settings offered in the N-band part of the spectrum - from 8.1 μm to 12.4 μm. Data points from frames acquired with slit widths 1.00" and 0.75" are plotted together. We only selected the standard star observations taken in good weather conditions. The distribution of the sensitivities shows clear evidence of the atmospheric molecular absorption at e.g. 9.55 μm, 11.8 μm and 12.5 μm, as well as the known detector feature at 8.8 μm.

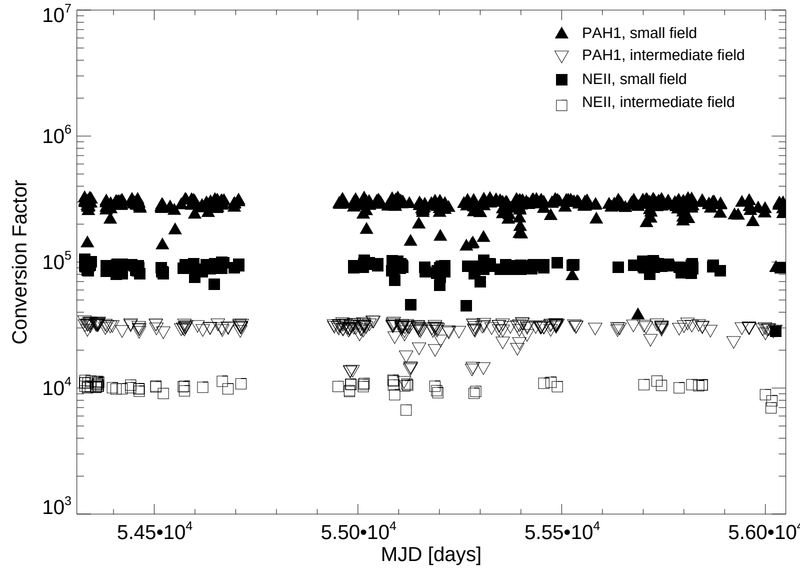

Figure 4. Conversion factor values that have been derived from VISIR observations of imaging standard stars since 2005. Triangles correspond to data points from observations in filter PAH1 (8.59 μm) and squares to data points from observations in filter NeII (12.81 μm). The filled symbols mark data for SF (0.075") and open symbols data for IF (0.127").

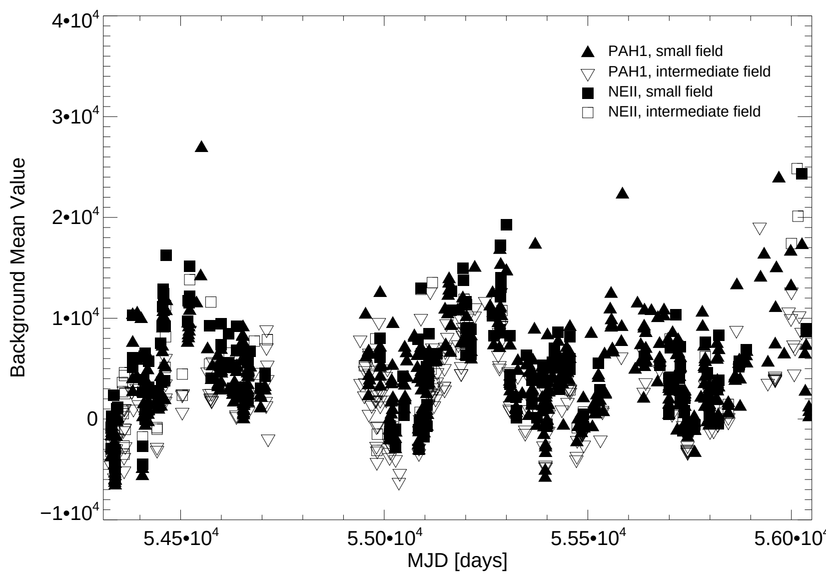

Figure 5. Background mean values as estimated from the VISIR observations of the imaging standard stars. Triangles correspond to values from observations in filter PAH1 (8.59 μm) and squares to values from observations in filter NeII (12.81 μm). The filled symbols mark data for SF (0.075") and open symbols data for IF (0.127").

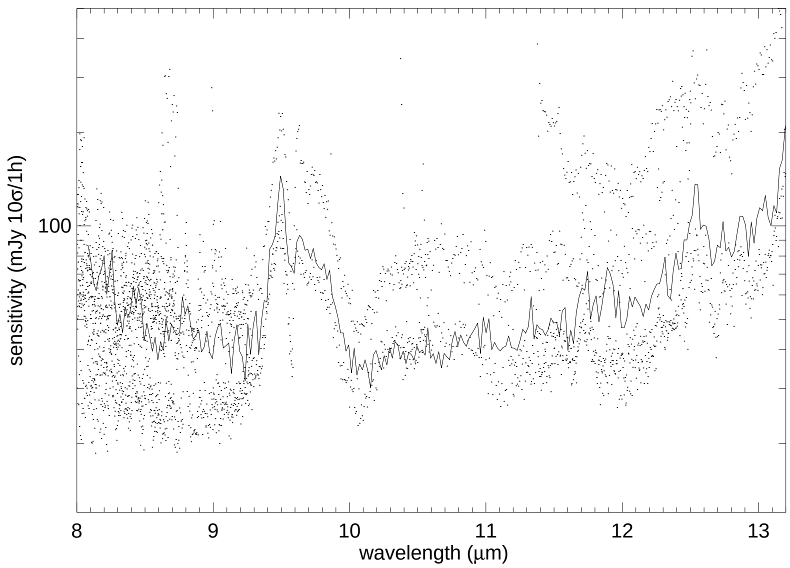

Figure 6. Sensitivity from the VISIR low resolution spectroscopic observations of the standard stars as a function of wavelength. Data taken at different settings within the N-band are included. Dots correspond to observations while the solid line represents median derived from the initial observations of VISIR during commissioning. There are clear signatures of the atmospheric molecular absorption at e.g. 9.55, 11.8 and 12.5 μm. There is also a detector feature at 8.8 μm.

There is an obvious scatter of sensitivities per wavelength. It is most likely due to different content of the PWV, which is the main source of opacity in the mid-IR. The sensitivities are compared with median results derived from the initial observations of VISIR during commissioning. Some of the data points are higher than the median but there are also cases when sensitivities are lower than the median values. In fact, they are consistent with the theoretical model predictions from the "VISIR User Manual" [1].

5. SUMMARY

The upgrade of the ESO's VISIR instrument is underway. The goal is to enhance its scientific performance and to meet requests from the community. The upgrade includes replacement of the DRS 256×256 BIB detectors with new 1k x 1k Si:As Aquarius arrays, modification and introduction of new observing modes, as well as upgrade of software and optimization of instrument operations. After nearly 7 years of VISIR operations its configuration will be irreversibly changed.

To assess the performance of the instrument before the upgrade we analyzed the long term variations of the quality control parameters derived from observations of the standard stars, within our regular data flow operation scheme. The sensitivities measured from the observations of the imaging standard stars turn out to be above theoretically predicted levels, the conversion factor appears to be very stable throughout the years and the background levels show annual variations connected with better and worse observing conditions during the Chilean winter and summer, respectively. The sensitivities from the observations of the spectroscopic standard stars show large scatter but in some cases appear to be consistent with the predictions of the theoretical model.

Our results provide a bench-mark for the comparison of the VISIR performance before and after the upgrade.

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