Calibrating Mid–Infrared Standard Stars

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Summary. The VLT Spectrometer and Imager for the Mid–Infrared (VISIR) is a Paranal 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). As part of standard operations, VISIR has been continuously observing MIR standard stars for more than a year. The derived conversion factors, sensitivities, etc. have been systematically collected in the database, allowing for statistical analysis of their temporal behavior. We analyzed long time variations of the conversion factor of selected VISIR standard stars and found that they show variability of less than 10% in the N band and less than 20% in the Q band.

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 in the Cassegrain focus of the 3rd VLT Unit Telescope – Melipal. The first light was obtained in May 2004 and VISIR was offered to the community from beginning of April 2005. This cryogenic instrument combines diffraction limited high sensitivity imaging capabilities over a field of view of up to 51$''$ and long slit grating spectroscopy capabilities with a range of spectral resolutions between 150 and 30000. So far, two pixel scales have been offered: 0.075$''$ (small field, SF) and 0.127$''$ (intermediate field, IF).

Ground observing in MIR is quite challenging. It's not only that our atmosphere absorbs the majority of MIR radiation from astronomical sources, but it also emits strong background with the spectral shape of a 253 K black body. The telescopes contribute an additional MIR background, estimated to be $<$ 15% in N band. The VISIR instrument is cooled to avoid internal thermal contamination. The detectors are kept at 5-6 K and the interior of the cryostat is kept at 33 K. Special observing techniques are applied to suppress the elevated MIR background. They include differential observations using chopping and/or telescope nodding.

As MIR observations depend strongly on the ambient conditions, such as humidity, temperature or airmass, the science observations are accompanied by relevant calibration standard star observations obtained no further than 3 hours apart. As part of standard operations, VISIR has been continuously observing MIR standard stars for more than a year. The derived conversion factors, sensitivities, etc. have been systematically collected in the database. We present long time coverage of the observations of selected MIR photometric standard stars and discuss possible variability of their conversion factor.

2 The MIR spectro–photometric standard star catalog

VISIR calibrators are selected from the MIR spectro-photometric standard star catalog of the VLT (http://www.eso.org/instruments/visir). It is based on the radiometric all–sky network of absolutely calibrated stellar spectra by Cohen et al. (1999) and supplemented with the MIR standards used by TIMMI2. Zero point fluxes (in Jy) have been calculated for the VISIR filters set by taking into account the measured transmission curve, the detector efficiency and an atmosphere model.

For the project of monitoring photometric precision of VISIR observations, 81 stars have been selected from the catalog. They fulfill basic criteria: (A) non-variability (according to Hipparcos), (B) not being visual binaries (according to SIMBAD), and (C) having absolute calibration errors less than 20%. Out of these, 12 photometric standard stars were further selected for frequent observations. These targets have similar spectral types and are uniformly distributed in the Right Ascension. In addition, their flux in N band, of the order of 10 Jy, is bright enough to be observable in the Q band without reaching non–linearity levels in the N band even in non–ideal background conditions. Every effort is made to observe at least one star from this reduced catalog on each night VISIR is in use. This allows to monitor observable properties of these targets over the long time scale.

3 Data processing and quality control

From the very beginning, the operation of VISIR was designed to follow a scheme common to all the VLT instruments (Quinn et al. 1998). 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 delivering data to principal investigators.

The observations are obtained either in visitor or service mode. The visitor mode data are packed on-site and collected by the visiting astronomer, while all the calibration frames and service mode data are transfered to ESO in Garching for further processing and inspection by the Data Flow Operation Quality Control Group. Here, the data are classified and reduced using pipeline. 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 (Hanuschik & Silva 2002).

3.1 Handling of the standard star observations

The VISIR standard star observations arriving to Garching are first classified, sorted by the instrument setup and processed with dedicated pipeline recipes: *visir_img_phot* and *visir_spc_phot*. 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.

The pipeline products for standard stars are checked for sufficient number of input frames, proper flux level (over or under exposed), adequate background removal, unusual noise pattern, striping, etc. To assure that only the best calibrations are further considered and used for reducing science data only certified products are archived. Flagged calibrations may also indicate instrument problems and thus, are closely investigated.

The VISIR pipeline recipes are used not only to create master standard star frames, but also to extract a number of specially designed parameters.

One of the most important QC parameters are:

- Conversion Factor: It measures conversion between ADU and Jy – $F_{tot.observed}/F_{model}$ [ADU/Jy], where F corresponds to flux.
- 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 S/N of 10 in 1 hour of on–ource integration.
- Mean Background Level: It is measured from the Half–cycle frames. It's value can vary between two extremes of -32000 and +32000 ADU.

3.2 VISIR QC1 database

The QC parameters calculated by the recipes are extracted from the headers of standard star pipeline products and are further stored in the QC1 database. The QC1 database is publicly available at http : //archive.eso.org/bin/qc1_cgi. It contains information for all supported VLT instruments. Each database table includes not only values of the QC parameters but also values of corresponding general and instrument keywords. This enables to correlate temporal behavior of the QC parameters with e.g. instrument setup.

For VISIR there are four database tables:

- *visir_zp_img* – contains parameters from the products of imaging standard stars;
- *visir_zp_spc* – contains parameters from the products of spectroscopic standard stars;

- *visir_flat_img* – contains parameters from the master flat fields of the imaging detector;
- *visir_zp_spc* – contains parameters from the master flat fields of the spectroscopic detector;

The QC1 database web site offers two types of services – the required parameters can be printed or plotted in selected period of time.

The values collected in the tables since the beginning of VISIR operation cover now about a year and a half. This allows a statistical analysis of the QC parameters with respect to instrumental and atmospheric conditions. In particular, we can monitor the temporal behavior of the conversion factor for chosen VISIR standard stars.

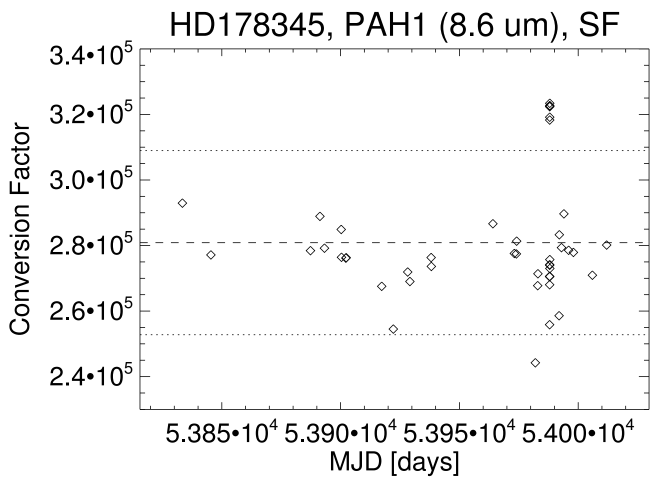

Fig. 1. Conversion factor of the VISIR standard star HD 178345 as a function of time. Only data taken with filter PAH1, centered at 8.6 μm, and small pixel scale (SF) are plotted. The dashed line corresponds to the average value and dotted lines show 10% variations.

4 Results

To ensure good statistical coverage we limited our analysis to targets from the list of the 12 photometric standards selected for frequent observing.

We excluded data points taken at particularly bad observing conditions (significantly larger sensitivity, mean background level) or high airmass.

Figure 1 shows variations of the conversion factor of the standard star HD 178345 measured from the observations taken with filter PAH1 (centered

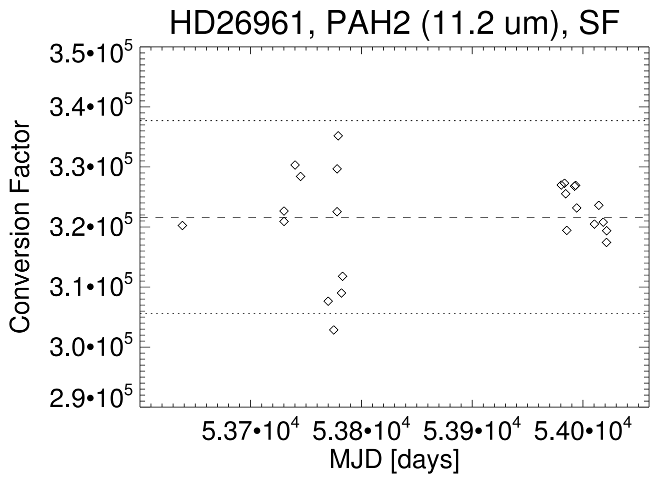

Fig. 2. Conversion factor of the VISIR standard star HD 26961 as a function of time. Only data taken with filter PAH2, centered at 11.2 μm, and small pixel scale (SF) are plotted. The dashed line corresponds to the average value and dotted lines show 5% variations.

at 8.6 μm) and small pixel scale (SF). The variations appear to be at the level of 10% only.

Table 1. Variations of the Conversion Factor

star name	PAH1, 8.6μm SF	PAH2, 11.2μm SH	Q2, 18.7μm SF
HD 12524	10% (17)	8% (15)	6% (2)
HD 26967	8% (25)	6% (24)	11% (7)
HD 41047	9% (15)	11% (15)	10% (3)
HD 75691	8% (19)	7% (16)	<20% (5)
HD 99167	7% (20)	4% (15)	15% (4)
HD 145897	6% (19)	8% (17)	<8% (10)
HD 178345	13% (44)	10% (31)	<20% (11)
HD 198048	6% (8)	6% (12)	<20% (8)

Similar variations of the conversion factor for the standard star HD 26961 are showed on Figure 2. The plotted data points correspond to the observations taken with filter PAH2 (centered at 11.2 μm) and small pixel scale (SF). Here the variations appear to be around 5%.

Table 1 summarizes some of the results. We measured variations of the conversion factor for 10 VISIR standard stars that have been most frequently observed so far. Two filters in the N band, PAH1 and PAH2, and one filter in the Q band, Q2, were selected. The table contains measured variations and also indicates the number of data points available.

The results show that selected MIR standard stars display flux variability of no more than 10% in the N band and of less than 20% in the Q band.

This is an ongoing project that includes effort of many members of the VISIR Instrument Operation Team (IOT). We verify stability of the used VISIR standard stars about each $6 - 12$ months.

References

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