

# Quality Control for UVES-fiber at the VLT-Kueyen Telescope

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## ABSTRACT

UVES-fiber is part of the FLAMES instrument mounted on the 8.2m Kueyen Telescope (UT2) of the ESO VLT. Up to eight single object fibers can be linked from the FLAMES focus to the red arm of the echelle spectrograph UVES. Science and calibration data are pipeline-processed by the Data Flow Operations group of ESO. Parameters to monitor the performance of the instrument are routinely extracted from calibration frames, stored into a database, and monitored over time. In addition to the Quality Control parameters already present for UVES in slit mode, several specific procedures had to be added in order to monitor the performance in the multi-object case. Particular attention is required for the positioning of the fibers on the detector and the transmission of the fibers. In this paper, we present details of the Quality Control process for UVES-fiber and results from the first year of operations.

**Keywords:** quality control, FLAMES, UVES, data reduction pipelines, instrument performance

## 1. INTRODUCTION

The Fiber Large Array Multi-Element Spectrograph<sup>1</sup> (FLAMES) is mounted on the Nasmyth A platform of the Kueyen Telescope (UT2) of the Very Large Telescope (VLT) operated by the European Southern Observatory (ESO). It has three main components: a Fiber Positioner (OzPoz) consisting of two plates allowing configuring of one plate while observing with the other, a fiber link to the red arm of the high-resolution echelle spectrograph UVES (Ultraviolet and Visual Echelle Spectrograph) on the Nasmyth B platform, and the medium-high resolution spectrograph GIRAFFE.

In this article, we describe Quality Control (QC) for the UVES part of FLAMES. This mode is frequently called UVES-fiber, UVES-MOS, or FLAMES-UVES. QC for GIRAFFE is subject of a separate publication.<sup>2</sup>

The fiber link to UVES consists of 16 fibers in total, each with an aperture of 1 arcsec. The resolution is therefore fixed to  $R \approx 47,000$ . Eight fibers are connected from each OzPoz plate so that up to eight objects (or sky regions) can be simultaneously observed. When connected to OzPoz only the red arm of UVES is used, covering wavelengths from 420 nm to 1,000 nm using settings with three different central wavelengths: 520 nm, 580 nm, and 860 nm. Since the separation of the echelle orders on the detector is much smaller for 520 nm only six fibers can be used in this case. For the 580 nm setting, it is possible to observe with an additional fiber the spectrum of a ThAr arc lamp simultaneously with the object fibers (so-called SimCal mode). This allows high-precision radial velocity studies. Only seven object fibers are possible in SimCal mode.

## 2. DATA REDUCTION

A series of calibration measurements is taken in order to monitor the performance of the instrument and to create calibration products needed for science data reduction. Dedicated pipeline software recipes exist for each calibration type and for science extraction.

Fig. 1 shows a graphical representation of the types of raw calibrations, their pipeline products, and the dependencies between them. These dependencies impose processing of raw calibrations in a certain order, i.e. from left to right in the figure. The Data Flow Operations (DFO) group (also called QC Garching) takes this cascade into account when using the pipeline. For quick-look purposes, the pipeline is run on the VLT site Cerro Paranal with a static set of already created calibration products.

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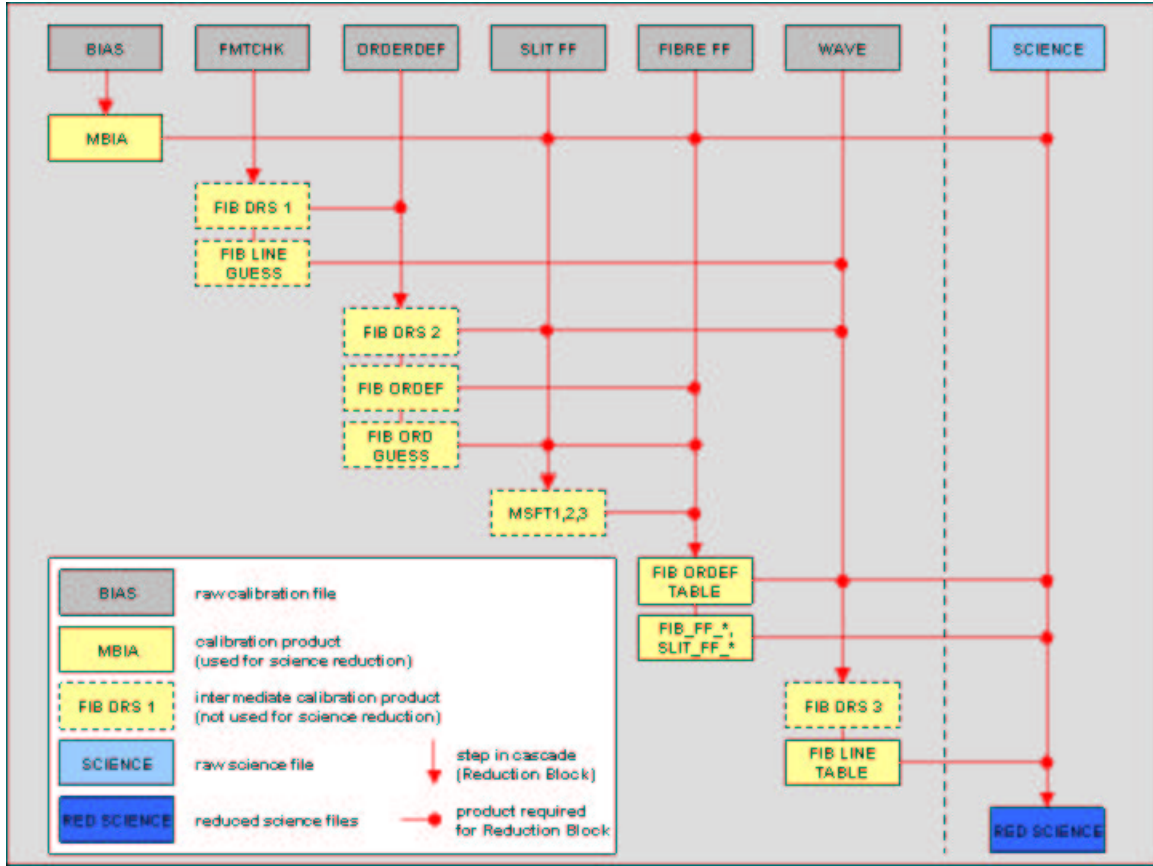


Figure 1. Calibration cascade for UVES-fiber.

Table 1 gives short descriptions of the calibration types and their purposes. More details about pipeline processing can be found in the FLAMES-UVES data reduction manual<sup>3</sup> which is available from the ESO web pages (<http://www.eso.org/projects/dfs/dfs-shared/web/vlt/vlt-instrument-pipelines.html>).

### 3. QUALITY CONTROL

#### 3.1. Overview

A number of Quality Control parameters is defined for each calibration pipeline recipe. They are calculated by QC Garching when the raw frames have arrived there, are stored into a database (available on the Web from <http://archive.eso.org/bin/qc1.cgi>), and are monitored over time. A dedicated set of parameters is also calculated on Paranal and transferred daily to Garching so that the time delay due to shipment of the raw data to Europe can be avoided. All results are accessible from web interfaces (available via <http://www.eso.org/qc>).

Table 2 gives an overview of the most relevant QC parameters for UVES-fiber. Procedures for Quality Control of UVES in standalone mode and general QC aspects can be found in separate articles.<sup>2,4,5</sup>

#### 3.2. Grating Stability

The positions of the fiber traces on the detector have to be known in order to extract and calibrate science spectra automatically. They are measured with a set of fiber flats. The science recipe of the pipeline is able to correct small shifts of up to 2 – 3 pixels in cross-dispersion direction between the fiber flats and the science exposure. Automatic extraction and calibration is not possible for larger shifts. It is, therefore, important that the fiber positions on the detector are stable and that they are routinely monitored.

**Table 1.** Calibration files for UVES-fiber.

file type	description	purpose	products
bias	series of 5 bias frames	detector bias level	master bias
format check	arc lamp exposure through one fiber	physical model parameters, guess wavelength solution	set-up table, guess line table
order def. flat	flat exposure through one fiber	position of orders	set-up table, guess order table, order image
slit flat	set of 3 shifted slit flats	fringing, blaze function	master slit flats
fiber flat	flat exposure through fiber system	fiber position, fiber efficiencies	order table, normalized fiber and slit flats
wave	arc lamp exposure through fiber system	wavelength solution	line table, set-up table

**Table 2.** QC parameters for UVES-fiber.

calibration file	QC parameters
bias	bias level, read-out noise, bias structure
format check	X and Y shifts of spectral format
slit flat	lamp efficiency
fiber flat	fiber efficiency, lamp efficiency
wave	spectral resolution, rms of wavelength solution, number of identified lines, arc lamp efficiency

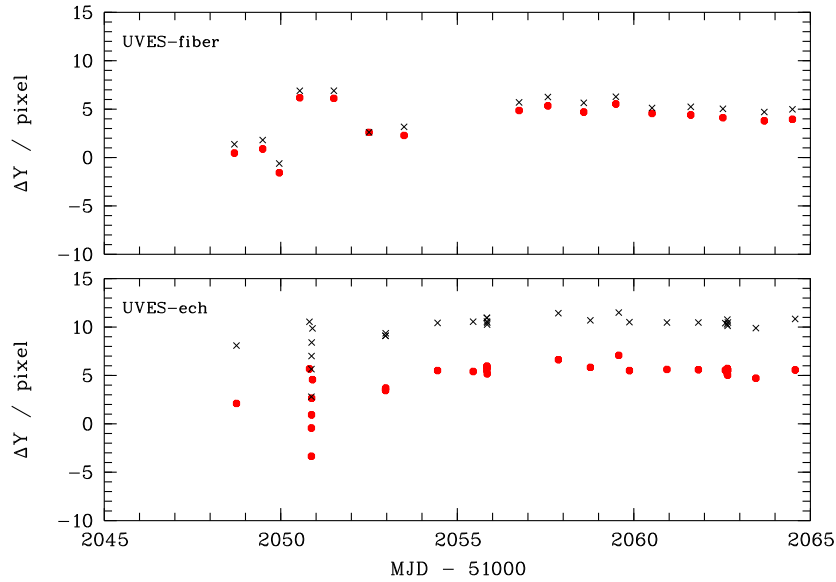
Since the relative positions of the fibers are fixed it is possible to measure the spectral format on the detector by so-called format check calibrations which are arc lamp exposures through one fiber. The pipeline recipe determines the shifts by using a physical model of the spectrograph and by comparison to reference frames.

The positions of the fibers on the detector depend mainly on two hardware components: on the positions of the cross dispersers and gratings of the UVES spectrograph and on the projector that places the fiber bundle on one UVES slit. In order to distinguish between both, it is not sufficient to measure only format checks with UVES-fiber. The format checks taken with UVES without the fiber system have also to be taken into account because these depend only on the grating positions.

Fig. 2 shows an example from February 2004. After a period without observations, shifts of up to eight pixels in cross-dispersion direction occurred between two measurements around  $\text{MJD} - 51000 = 2050$  (upper part of figure). Several tests using UVES without the fiber system (lower part of figure) taken on the same day revealed that the problem is actually due to positioning inaccuracies of the red UVES grating. After exchanging the grating bearing and some additional tests and adjustments, positioning was again stable.

### 3.3. Fibre Efficiency

The transmission capabilities of the fibers are critical for the performance of the whole instrument. It is necessary to detect broken fibers or significant losses in transparency. It is also important to monitor the stability of the relative efficiency between the fibers so that corrections of the extracted flux for differences in efficiency of the fibers are possible. All these functions are measured with exposures of a continuum lamp through the fiber system.



**Figure 2.** Shifts of the spectral format in cross-dispersion direction ( $\Delta Y$ ) in February 2004. Upper panel: data from UVES-fiber format checks with 580 nm central wavelength. Lower panel: same for UVES-echelle (i.e. without fiber system). Crosses denote values for the red upper CCD, filled circles for the lower CCD.

The fiber traces on the detector are extracted and give the total number of measured counts for each fiber. This number is divided by the exposure time and normalized to the median of all eight fibers for one plate. This procedure is useful in order to see relative differences between the fibers, and it is insensitive to changes in one fiber and to changes of the flat field lamp intensity.

A total number of 16 fibers has to be monitored. This number is small if compared to the GIRAFFE case,<sup>2</sup> and it is, therefore, possible to trend each fiber separately over time. The average over certain periods and the rms of the average are calculated in addition to compare the relative efficiencies and to monitor the stability of each fiber. Fig. 3 shows these values for the period of January to March 2004. It shows that the stability is better than 2 % rms for all fibers and better than 1 % for most.

### 3.4. Stability of calibration lamps

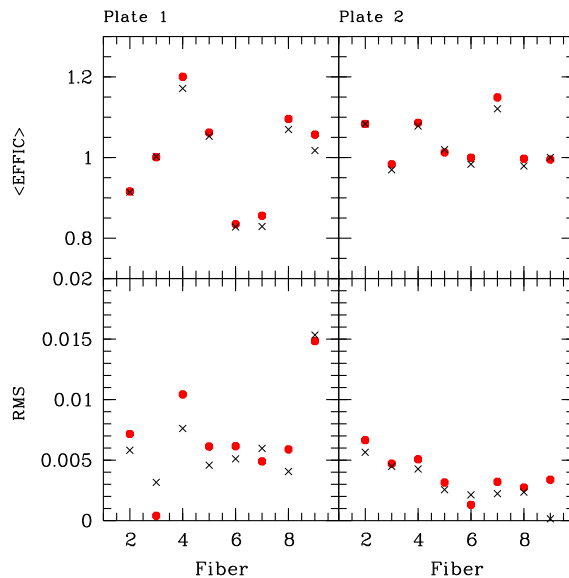
Stability of calibration lamps is necessary for the whole Quality Control and calibration process. Two different types of lamps are used: continuum lamps for order definition, slit, and fiber flats and arc lamps for format check and wavelengths exposures. Of special importance is the SimCal arc lamp because it is switched on during the whole science exposure in SimCal mode. It is, therefore, more likely affected by aging.

The performance of the continuum lamps is monitored by measuring count rates from the respective flat exposures. For the arc lamps, a set of emission lines, which are bright but not saturated in normal exposures, has been identified. The intensities of these lines are measured, averaged, and monitored over time.

Failures or aging effects of the lamps have not occurred since the beginning of regular observations with UVES-fiber.

### 3.5. Wavelength Solution and Resolving Power

Spectral resolution and accuracy of the wavelength solution are crucial for every spectrograph. The resolution, the rms of the wavelength solution, and the number of detected lines are measured from arc lamp exposures for each fiber separately. These numbers give mainly an additional indication of the performance of the instrument since the resolution is fixed by the diameter of the fibers.



**Figure 3.** Average fiber efficiency (top panels) and rms of the average (bottom panels) for plate 1 (left) and plate 2 (right).

#### 4. CONCLUDING REMARKS

UVES-fiber has been used regularly for science observations since February 2003. It has been a very stable instrument with only a few number of failures or problems that affected the quality of science observations. These were due to the fiber projector on the UVES slit and the UVES grating positions. The format check exposure proved to be very useful for detecting these problems. Future developments of the QC process for UVES-fiber include verification of the total instrument throughput and the accuracy of radial velocity measurements.

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