

## ESO Phase 3 Data Release Description for Internal Data Products

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### Abstract

This is the release of reduced 1D spectra from the UVES<sup>1</sup> spectrograph, ECHELLE mode (as opposed to the FIBRE mode), point sources (as opposed to extended sources), taken without the image slicer. Data taken with the absorption cell are also included in the data release. This release includes re-processed UVES data, as well as current and future UVES data not processed before at ESO. The processing scheme is as homogeneous as possible.

The selected data cover the vast majority of the entire UVES data archive, from the begin of operations in March 2000 until present. The data have been reduced with the UVES pipeline, versions `uves-5.1.3` and higher, recipe `uves_obs_scired`. All data have their instrument signature removed (de-bias, flat-fielded), with the exception of the absorption-cell data which have the signature of the iodine cell not removed. Then the data have been extracted, wavelength-calibrated and order-merged. Whenever possible they have been flux-calibrated. The pipeline output products have been converted to the 1D standard binary table<sup>2</sup>.

The processing is performed by the Quality Control Group using a dedicated workflow tool in an automated process. The pipeline processing uses the archived, closest-in-time, quality-controlled, and certified master calibrations. It is important to note that the reduction process itself is automatic, while the quality assessment and certification of the master calibrations was (and still is) human-supervised.

The overall data content is not fixed but grows with time as new data are being acquired and processed (approximately with monthly cadence and with a delay of 1 or 2 months).

The data format follows the ESO 1D spectroscopic standard<sup>2</sup> for so-called phase-3 data products. Each spectrum is a multi-column binary table. There is one product file for each parent raw file. The typical observing pattern of a simultaneous observation in the blue arm and in the red arm is propagated to the data products: there is one blue product and one red product if the original observation used both arms.

This data release offers science-grade data products, with the instrumental signature removed, flux-calibrated (if possible), with error estimates and a list of known shortcomings.

These data products are considered to be ready for scientific analysis. They are expected to be useful for any kind of high-resolution spectroscopic research, including line profile studies and radial velocity studies. For studies of energy distributions the investigator should keep in mind that the UVES instrument is a high-resolution spectrograph, designed for stability and throughput but not for high-precision flux calibration. There are slit losses, and many observations did not care about photometric conditions.

**Disclaimer:** Data have been pipeline-processed with the best available calibration data. However,

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<sup>1</sup> <http://www.eso.org/sci/facilities/paranal/instruments/uves/>

<sup>2</sup> <http://www.eso.org/sci/observing/phase3/p3sdpstd.pdf>

please note that the adopted reduction strategy may not be optimal for the original scientific purpose of the observations, nor for the scientific goal of the archive user.

You may also want to consult the [on-line version of this documentation](#)<sup>3</sup> which is a living document and has further useful links and more details.

## Release Content

The UVES\_ECHELLE IDP release is a stream release. The overall data content is not fixed but grows with time as new data are being acquired and processed (approximately with monthly cadence and with a delay of 1 or 2 months). The data is tagged with "UVES\_ECHELLE" in the [ESO archive user interface](#)<sup>4</sup>.

The first data were published under UVES\_ECHELLE in September 2013, with UVES data from the begin of operations (March 2000 ) until May 2013. The archive is being filled chronologically. New data taken after May 2013 are being added at roughly monthly intervals and with a delay of 1 or 2 months, when all master calibrations for the corresponding time interval are available.

## Data Selection

Data selection is entirely rule-based. It is organized along the following criteria:

- instrument=UVES, observing technique (DPR.TECH) = ECHELLE or ECHELLE,ABSORPTION-CELL (**not** ECHELLE,SLICER or ECHELLE,ABSORPTION-CELL,SLICER or FIBRE)
- category (DPR.CATG) = SCIENCE
- type (DPR.TYPE) = OBJECT or OBJECT,POINT (**not** OBJECT,EXTENDED)

*A priori*, no selection is made on the basis of observing mode (visitor or service), nor on settings. UVES ECHELLE settings are defined by the combination of binning, central wavelength and dichroic filter<sup>5</sup>.

*De facto* we can process only those science data for which certified master calibrations can be found in the archive. These master calibrations were also processed by the Quality Control Group but much earlier in time, close to the date of acquisition in order to provide quick quality feedback to the Observatory. The operational selection pattern for master calibrations evolved over the years. It reflects pipeline evolution and calibration plan changes, and also manpower constraints. In the early years of UVES, the processing focus was on calibrations taken in standard settings and for Service Mode (SM) science data. Later, the calibration scheme was extended to non-standard settings (at best-effort basis), ignoring the Service/Visitor Mode (VM) distinction.

Therefore the completeness ratio for the UVES Echelle science data in this stream is inhomogeneous. For the early years (until 2002) almost no VM data are included. Later, the fraction is close to complete.

Note that the fact that a certain UVES raw file does not have a product in this release does not imply a quality issue with the raw data. It is more likely that this raw file falls into the category of VM science taken in the early years of UVES in non-standard settings. Such data would most likely process fine manually.

In general, the master calibrations were processed with different (earlier) pipeline versions than the science data in this stream. This is not considered an issue since the calibration recipes of the UVES pipeline did not strongly evolve with time.

Science data with the PROGID starting with 60. or 060. have been de-selected, considering them as

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<sup>3</sup> [http://www.eso.org/qc/PHOENIX/UVES\\_ECH/processing.html](http://www.eso.org/qc/PHOENIX/UVES_ECH/processing.html)

<sup>4</sup> [http://archive.eso.org/wdb/wdb/adp/phase3\\_spectral/form](http://archive.eso.org/wdb/wdb/adp/phase3_spectral/form)

<sup>5</sup> more under <http://www.eso.org/qc/UVES/pipeline/settings.html>

test data. Data taken at daytime (with obviously wrong ‘SCIENCE’ tag) have been ignored. Otherwise the metadata tag ‘SCIENCE’ has been blindly accepted from the raw data (originally defined by the PI), thus including sometimes standard stars. This is often evident from the OBJECT metadata key. Also, there are rare cases when test observations were executed under the SCIENCE label. Most very short exposures with no signal fall into that category but have not been suppressed.

All data have been processed up to the wavelength calibration step. The extraction method was always OPTIMAL. The last step, the flux calibration, was undertaken with master response curves (see below). These do not exist for all settings, not even for all standard settings. The products which could be flux-calibrated have the highest reduction level (FLUXCAL=ABSOLUTE, ORIGFILE names start with UV\_SFLX), while the others have FLUXCAL=UNCALIBRATED, names start with UV\_SRED (if taken without absorption cell) or UV\_SREA (if taken with the absorption cell).

There is no raw data selection based on quality. Likewise, we have not considered OB grades: the observations might have any grade between A and D, or X. The availability, or non-availability, of a particular file in this release does not infer any claim about the data quality. E.g. saturated pixels are not flagged by the pipeline. The user is asked to carefully check the data for those cases.

Each product file has exactly one parent raw file. Multiple observations from the same OB *have not been combined*.

## Release Notes

The data reduction used the standard UVES pipeline recipe `uves_obs_scired`. Find a description of the science recipe in the User Manual<sup>6</sup>.

All recipe parameters used were default, except for:

- `reduce.extract.kappa=20` (threshold for cosmic ray rejection, default is 10 and was applied in many cases; choice changed over time);
- `reduce.ffmethod=pixel` (with ‘pixel’, flat-fielding is done in pixel-pixel space, before extraction; the alternative option is ‘extract’, in pixel-order space, after extraction, which is the default; the ‘pixel’ method has been chosen for all data with **central wavelength > 760nm** to suppress residual fringes from the flat field, which would remain with ‘extract’; the ‘pixel’ method has the disadvantage to introduce some artifacts at the order begin and end, therefore it needs a reduction of the inter-order overlap and thereby creates larger spectral gaps in the red wavelength ranges beyond 880 nm; the ‘extract’ method has been chosen for all data with central wavelength below 760nm);
- `reduce.merge_delt1=14` and `reduce.merge_delt2=4` (related to the previous point: this is the amount in pixels of the order begin and end to be truncated; only applied to data with **central wavelength ≥ 760nm**).

The extraction method (`reduce.extract.method`) was always ‘optimal’ (as opposed to ‘linear’). The pipeline uses an initial SNR estimate, based on which it selects the appropriate cross-order extraction profile (Gauss, Moffat, Virtual). Find more details in the User Manual<sup>6</sup>, section 11.1.13.

## Master Calibrations used for data reduction

type (pro.catg)	name (first part)	mandatory* / optional**	content
MASTER_BIAS_{ccd}	UV_MBIA	mandatory	master bias: created from 5 raw bias frames; removes bias level and bias structure
ORDER_TABLE_{ccd}	UV_PORD	mandatory	order table: contains a description of

<sup>6</sup> under the UVES link in <http://www.eso.org/sci/software/pipelines/>

			the echelle order position, used for extraction
LINE_TABLE_{ccd}	UV_PLI1..3 or UV_PLIN	mandatory	line tables (either three, one for each third of the extraction slit, or one for the whole slit), giving the dispersion solution for the extracted spectra
MASTER_FLAT_{ccd}	UV_MFLT	mandatory	master flat: created from three raw flats; used for: removing gain noise, removing the echelle function, removing slit noise; introducing lamp response
MASTER_RESPONSE_{ccd}	UV_MRSP	optional	response curve used for flux calibration; derived from selected sets of standard star measurements, collected for most (but not all) standard settings; removes lamp response and remaining instrument signature
EXTCOEFF_TABLE		optional	used to correct for extinction (optional)

ccd = BLUE | REDL | REDU

\* if missing, pipeline fails

\*\* if missing, final product is not flux-calibrated

## Pipeline Description

Information about the UVES pipeline (including downloads and manual) can be found under the URL <http://www.eso.org/sci/software/pipelines/>. The QC pages<sup>7</sup> about UVES data contain valuable information about the UVES Echelle data, their reduction and the pipeline recipes.

## Data Reduction and Calibration

The QC pages<sup>8</sup> about science reduction describe the details of the main reduction steps. In essence, the bias level and structure is removed, then, depending on the flat-fielding method, either the science data are divided by the flat and then extracted using the order table ('pixel' method), or the other way round ('extract'). Upon extraction, the optimal extraction algorithm determines the sky background and removes the cosmics. Then the extracted orders are wavelength-calibrated, re-binned, and merged, using the line tables. This is the final if no master response curve is available, otherwise that calibration is used to flux-calibrate the extracted spectrum. If so, the spectrum is delivered in physical units (cgs units). Otherwise it comes in arbitrary units (counts) and contains those instrument or atmospheric signatures which cannot be removed by the flat field (chromatic coating efficiencies, atmospheric extinction) or have been added by the flat field (spectral response of the calibration lamp).

Note that in the case of the absorption-cell data, the signature of the iodine cell has *not been removed*.

The flux calibration has been applied for the following central wavelengths: 346, 390, 437, 564, 580, 760, and 860 nm.

The UVES Echelle products are wavelength calibrated. No corrections for barycentric or heliocentric motion have been applied. The corresponding values have been calculated by the pipeline from the observation and are stored in the header (HIERARCH.ESO.QC.VRAD.BARYCOR or HELICOR, in km/s).

<sup>7</sup> [http://www.eso.org/qc/UVES/pipeline/pipe\\_gen.html](http://www.eso.org/qc/UVES/pipeline/pipe_gen.html)

<sup>8</sup> [http://www.eso.org/qc/UVES/pipeline/recipe\\_science.html](http://www.eso.org/qc/UVES/pipeline/recipe_science.html)

The UVES pipeline creates the following product files:

- extracted spectrum (de-bias, flat-fielded, extracted, wavelength-calibrated and rebinned)
- corresponding error file
- background underlying the signal in the slit (sky), by-product from the extraction step
- fluxed spectrum
- corresponding fluxed error

While these pipeline product files are separate (image) fits files, they are finally converted into a single binary table fits file which is the delivered data product, with the wavelength scale as first column and all other products as further columns (see 'File Structure' below).

Contrary to the product files of the UVES pipeline (which generates one product for each detector), the IDP-converted product from the RED arm is a single file. The two non-overlapping red segments have been merged in a single spectrum with non-equal sampling (and no degradation). There is always an unavoidable gap between the two spectral segments due to the geometrical gap between the two red detectors.

## Data Quality

There is some internal quality control on the pipeline process, monitoring:

- quality of the association (checking that the master calibrations are not older than a few days);
- score flag for number of saturated pixels in the raw data;
- QC reports and quick views.

This information has largely been used to improve and fine-tune the processing process. An individual one-by-one inspection of the products has been unaffordable.

**SNR:** the signal-to-noise ratio of the spectra is measured by the ratio of FLUX/ERR (or FLUX\_REDUCED/ERR\_REDUCED giving the equivalent result). Its chromatic slope is as complex as the spectrum itself. As representative numbers, the pipeline calculates an average per echelle order (stored in the header per order as 'HIERARCH ESO QC ORDnn OBJ SN' for BLU spectra, and as 'HIERARCH ESO QC CHIPi ORDnn OBJ SN' for RED spectra). From these numbers, a median has been calculated (omitting the respective first and last order) which is the number quoted as SNR on the query interface and in the header. Note that, as a peculiarity in the red wavelength ranges, those files reduced with the `reduce.ffmethod=pixel` method have a higher SNR in the spectral regions with overlapping echelle orders.

## Known features and issues

The pipeline applies some assumptions on the source:

- If there is more than one target in the slit, it always extracts the brightest source.
- If the cross-dispersion profile of the source is not Gaussian, the UVES pipeline may create artifacts (wrong extraction). This may either happen due to an extended source, or for very high counts, close to or at saturation. A typical symptom of non-Gaussian profiles are ripple artifacts.

**Flux calibration.** The flux calibration is good enough for obtaining a coarse energy distribution but is not of spectrophotometric quality. The slit losses are unknown, and many observations did not care about photometric conditions. The master response curves have been derived from carefully selected individual standard star observations, but they are applied to science data sometimes taken a long time before or after, in many cases years apart. There has been no attempt to correct for these long-term effects.

The flux-calibrated spectra are provided in units of  $10^{-16}$  erg/cm<sup>2</sup>/s/Å.

**Wavelength range of flux-calibrated spectra:** some of the master response curves used for flux

calibration have the initial and the final 25 Angstrom cut off, hence the flux-calibrated spectra have a slightly smaller wavelength range than the extracted ones.

**Spectral gaps.** For spectra of the RED arm, increasingly larger gaps occur beyond about 880 nm, related to the ‘pixel’ flat fielding algorithm. These gaps would be much smaller with the ‘extract’ algorithm which however has strong artifacts from the fringes in the flat field. It was felt that the spectral gaps are of minor impact in general. An investigator interested in the spectral information in those gaps might want to manually reduce the data with the ‘extract’ method.

**Flat-field signatures:** in particular the 346 nm spectra have relatively strong signature of the flat field extraction (repeating undulations on the scale of one echelle order)<sup>9</sup>.

Quite rarely, the 860 REDU spectra have flat-field related artifacts at the begin of echelle orders, right after the order gaps<sup>9</sup>.

Find more documentation about features and issues [on-line](#)<sup>9</sup>.

## Data Format

### Files Types

There exist three different file types, depending on the reduction level (flux calibrated or not) and on the product category:

ORIGFILE names starting with	product category PRO.CATG	Description
UV_SFLX	FLUXCAL_SCI_POINT_<arm>	flux-calibrated product (arm=RED or BLU)
UV_SRED	RED_SCI_POINT_<arm>	extracted and wavelength-calibrated (but unfluxed) product (arm=RED or BLU)
UV_SREA	same, for absorption-cell data	

The following naming convention applies to the ORIGFILE product name:

e.g. UV\_SFLX\_58146\_2001-09-13T09:12:30.326\_RED564d1\_2x2\_21.fits has the components:

<b>ORIGFILE component</b> ...	UV	SFLX	58146	2001-09-13T09:12:30.326	RED564d1_2x2_21.fits
<b>refers to ...</b>	UVES	product type (SFLX or SRED or SREA, where S stands for science)	OB ID	timestamp of raw file acquisition/archival	setup string: RED or BLU for the arm; 564: central wavelength in nm; d1/d2/re/bl: d1/d2 for the use of both arms, with dichroic filters 1 or 2; re/bl for use of the red or blue arm only; 2x2: binning; 21: slit width (=2.1 arcs)

<sup>9</sup> Find examples under

[http://www.eso.org/observing/dfo/quality/PHOENIX/UVES\\_ECH/processing.html#features](http://www.eso.org/observing/dfo/quality/PHOENIX/UVES_ECH/processing.html#features)

Due to the data format of UVES raw data, the UVES products with d1 or d2 in their name always come as a BLU/RED twin taken (almost) simultaneously (although not necessarily with identical exposure times).

## File structure

The UVES products come as binary fits table with multi-column format<sup>10</sup>. The columns are labeled as follows:

column	label	content	UV_SFLX	UV_SRED/UV_SREA
#1	WAVE	wavelength in Angstrom	<b>yes</b>	<b>yes</b>
#2	FLUX_REDUCED	extracted, wavelength-calibrated, sky-subtracted SCIENCE signal, <b>not fluxed</b>	<b>yes</b>	<b>yes</b>
#3	ERR_REDUCED	corresponding error (not fluxed)	<b>yes</b>	<b>yes</b>
#4	BGFLUX_REDUCED	extracted and wavelength-calibrated sky signal, <b>not fluxed</b>	<b>yes</b>	<b>yes</b>
#5	FLUX	like #2 but flux-calibrated, physical units	<b>yes</b>	no
#6	ERR	like #3 but flux-calibrated, physical units	<b>yes</b>	no

\* The UV\_SREA products have the absorption-line spectrum of the absorption cell not removed, they are reduced in exactly the same way as the data without absorption cell.

In the case of the red spectra, the header contains keywords from both pipeline products (remember the pipeline delivers one spectrum per detector; and these are merged into the single IDP binary fits table), distinguished by a field 'CHIP1' or 'CHIP2', resp., in the keyword name.

## File Size

The UVES products have about 3 MB size for the unbinned (1x1) RED arm, and 2 MB for the unbinned BLU arm. Binned products (2x2) come at half this size. Files are always uncompressed.

## Acknowledgment text

According to the ESO data access policy, all users of ESO data are required to acknowledge the source of the data with an appropriate citation in their publications. Find the appropriate text here<sup>11</sup>.

All users are kindly reminded to notify Mrs. Grothkopf (esodata at eso.org) upon acceptance or publication of a paper based on ESO data, including bibliographic references (title, authors, journal, volume, year, page-numbers) and the programme ID(s) of the data used in the paper.

<sup>10</sup> <http://www.eso.org/sci/observing/phase3.html>

<sup>11</sup> <http://archive.eso.org/cms/eso-data-access-policy.html>