EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

ESO - European Southern Observatory
Karl-Schwarzschild Str. 2, D-85748 Garching bei München

Very Large Telescope

Paranal Science Operations

UVES data reduction cookbook

Doc. No. VLT-MAN-ESO-13200-4033

Issue 83, Date 14/09/2008

C. Ledoux, A. Modigliani, G. James
Prepared . . . .
Date Signature

G. Marconi
Approved . . . .
Date Signature

O. Hainaut
Released . . . .
Date Signature

This page was intentionally left blank

Change Record

Issue/Rev.	Date	Section/Parag. affected	Reason/Initiation/Documents/Remarks
Issue 79	04/10/2006		first standalone SciOps version
Issue 82	22/05/2008		update for MIDAS pipeline version 2.9.7
Issue 83	14/09/2008		update of references for P83

This page was intentionally left blank

Contents

1 Introduction

1.1 Purpose

This document describes the usage of the commands of the MIDAS context UVES which allow the user to perform a complete science data reduction. For a thorough description of the UVES MIDAS-based pipeline, the reader is referred to the UVES Pipeline User's Manual, Issue 8. We assume the user is familiar with the concepts of echelle data reduction and we suggest taking a look at the description of the MIDAS context ECHELLE .

The UVES context itself is based on the ECHELLE context. The development of this context has been done under MIDAS version 98NOVpl2.1 and successive. We describe here how to produce master calibration frames, order position and background tables, as well as line tables used for the re-sampling into wavelength space. Finally, the science reduction command will be introduced. All commands used are described in more detail in the help files (`HELP command-name`). It may be useful to make printouts of these help files, which is easily done using the graphical interface of MIDAS help (`CREA/GUI help`).
This cookbook also describes how to prepare calibration solutions either using commands of the context, or scripts. How to reduce multi-object sources on the slit using average or optimal extraction is also described. How to do a simple extraction of extended sources is shortly explained. Finally, session examples to perform data reduction of BLUE and RED data are reported.
In the following examples of UVES data reduction, we suggest the user to adopt as temporary table products in MIDAS format names of maximum 8 characters (plus extension .tbl: e.g. longname.tbl).

1.2 Reference documents

1 *UVES User Manual*, VLT-MAN-ESO-13200-1825
Issue 83, 28/08/2008, A. Kaufer, S. D'Odorico, L. Kaper, C. Ledoux, G. James, H. Sana
2 *UVES Templates Reference Guide*, VLT-MAN-ESO-13200-1567
Issue 83, 28/08/2008, A. Kaufer, C. Ledoux, G. James, H. Sana
3 *UVES Calibration Plan*, VLT-PLA-ESO-13200-1123
Issue 83, 28/08/2008, A. Kaufer, R. Hanuschik, C. Ledoux, G. James
4 *UVES Pipeline User's Manual*, VLT-MAN-ESO-19500-2964
Issue 8, 12/10/2007, P. Ballester, O. Boitquin, A. Modigliani, S. Wolf

1.3 Abbreviations and acronyms

The following abbreviations and acronyms are used in this document:

SciOps	Science Operations
ESO	European Southern Observatory
MIDAS	Munich Image Data Analysis System
FITS	Flexible Image Transport System
VLT	Very Large Telescope

2 Prepare the UVES-Midas session

(1) Start the FLAMES-UVES-Midas session:
`% flmidas`

The pipeline environment will automatically be setup by the two procedures:
`@d pipeline.start` and `@d pipeline.control`. Furthermore the FLAMES and the UVES MIDAS context will be initialized.[1]

(2) Configuration of the display. At the Midas prompt, type:

```
Midas> CONFIG/DISPL
```

Three image displays and two graphic windows will be created. This is a standard setup used by the UVES pipeline procedures. Internally some other MIDAS keywords supporting the graphics and display handling will be set. They will be accessed during the reduction process. The commands `CREATE/GRAP` or `CREATE/DISPL` should not be used in this context.
By default CONFIG/DISP assumes a 1280×1024 pixel sized monitor. In case your monitor is smaller you may reset it using:

```
Midas> CONFIG/DISPL 1200 900
```

where a x and y dimension respectively of 1200 and 900 pixels is assumed. You may add a third parameter, the fill parameter: add 0.8 in order to use only 80% of your terminal.

(3) In the course of this cookbook you will often be confronted with DRS (data reduction system) setup tables. These are *empty* tables which control the data reduction process by the use of their descriptors. All global keywords of the ECHELLE package are stored in these descriptors. In principle, DRS tables are classified saved sessions (see `SAVE/ECHELLE`). These tables guarantee a standardized behavior of the UVES pipeline. DRS tables may be created using `SAVE/DRS`.
In an interactive mode (which is described here) you may switch off the strict use of DRS tables by setting `FORCE_DRS=''NO''`. In that case the commands use the current setting (`SHOW/ECHE`). You may control the process by changing keywords using `SET/ECHE`. Some keywords are controlled by the UVES commands. For a list of restricted keywords see the help files.

(4) An example on how to make use of the reference catalogs which are used in almost all commands of the UVES context is described in the following sections.

3 Generate the first guess solution

Having a so-called format check frame which is a ThAr-exposure taken with a very small slit length you are able to generate a line table which can be used as a first guess solution. This determination is based on computations of a physical model of UVES. For further information

[1] `flmidas` is an alias to (if it does not exist it is useful to create it)
`inmidas -j '@d pipeline.start; @d pipeline.control D;set/context flames $PIPE_HOME/uves/context; mid$mode(3) = 0'`. please use `mid\$mode(3)=0` if you have bash.

on the physical model refer to: P. Ballester and M.R. Rosa (1997), AASuppl 126, 563". As in almost all cases you will start with:

```
Midas> SPLIT/UVES format_TAL.fits
```

Assume `format_TAL.fits` is a format check frame of the blue arm then `SPLIT/UVES` will translate the input file to MIDAS BDF-format file and transform the frame in the way that the wavelength increases from left to right and from bottom to top (standard orientation). The output file will be stored in the local directory as `format_TAL_b.bdf`. In general the command SPLIT/UVES frame.fits generate the MIDAS format file(s) frame_x.bdf (x=b, or l, u for arm Blue and Red respectively).

For the following UVES context command we need first to transform a line reference table from FITS to MIDAS format:

```
Midas> INDISK/FITS thar.tfits thargood_3.tbl
```

Next you pass the transformed calibration frame to `PREDICT/UVES`:

```
Midas> PREDICT/UVES format_TAL_b.bdf thargood_3.tbl
```

The only auxiliary file is a line reference list of a ThAr lamp. By measuring the line positions, identifying them through the physical model and comparing them with the line reference list, this command will finally produce a line table which may work as a first guess solution for `IDENT/ECHE` or `WAVECAL/UVES` (see below) making the wavelength calibration step automatic. In particular this command will produce (for a blue frame and central wavelength 346 nm) the following files:

frame	DO_CLASSIFICATION	meaning
drs_setup_BLUE.tbl	DRS_SETUP_BLUE	calibration table
b346BLUE.tbl	BACKGR_TABLE_BLUE	background table
l346BLUE.tbl	LINE_TABLE_BLUE	line table (guess solution)
o346BLUE.tbl	ORDER_GUESS_TAB_BLUE	order table (guess solution)

At this point the ECHELLE context parameter NBORDI is equal to zero. This means that an automatic determination of the orders is performed.

In principle one could also pass reference frames through a catalogue and give the command

```
Midas> PREDICT/UVES format_TAL_b.bdf predictI.cat predictO.cat
```

where predictI.cat is an image catalog which must contain the line reference table. In this case the output names given above will be present after data reduction in the output catalog predictO.cat. The line table l346BLUE.tbl is the "Guess Solution" and will be classified (in our case) in the catalog as LINE_TABLE_BLUE.

4 Define the order positions

The order positions are usually defined by means of the so called order flatfields – flatfield exposures obtained with a narrow slit producing thin echelle orders. Again, the first step is to make a BDF frame from the FITS file.

```
Midas> SPLIT/UVES order_FF.fits
```

In this example the `order_FF.fits` is an order flatfield of the blue arm. The output file will be stored in the local directory as `order_FF_b.bdf`. We can now create a reference catalog to store all the needed calibration frames. To allow a pipeline check on the guess and final order tables alignment we add also in the reference catalogue the guess order table:

```
Midas> crea/icat refB.cat o346BLUE.tbl DO_CLASSIFICATION
```

Now it is possible to determine the order positions by giving the following command:

```
Midas> ORDERP/UVES order_FF_b.bdf refB.cat refB.cat
```

which creates an order table, a background table, and a DRS setup table.

frame	DO_CLASSIFICATION	meaning
o346_2x1.tbl	ORDER_TABLE_BLUE	Order table
b346_2x1.tbl	BACKGR_TABLE_BLUE	Background table
d346_2x1.tbl	DRS_SETUP_BLUE	DRS setup table
l346BLUE.tbl	LINE_TABLE_BLUE	Line Guess table

All these tables will be stored in the output catalog `refB.cat`. To proceed in the data reduction the line guess table (l346BLUE.tbl, in our case, which we rename as l346_2x1.tbl to evidence the bin setting) and the line reference table (thargood_3.tbl) should be added to this catalog.

```
Midas> -rename l346BLUE.tbl l346_2x1.tbl
Midas> ADD/ICAT refB.cat l346_2x1.tbl
Midas> ADD/ICAT refB.cat thargood_3.tbl
```

The catalog `refB.cat` may now be used as a reference catalog for the next steps of the reduction procedure.
Instead of using order definition flatfields you may also use standard star exposures.

It is worth to mention here that this step has been performed without using a reference DRS table and with automatic order detection (NBORDI=0). In this case, the Hough Transform will determine the orders present on the frame. In case of low photon level in part of the order definition frame, this step may underestimate the number of orders. To have a complete determination of the orders one should visually check that the number of determined orders corresponds to the one present on the frame. If not, it is better to manually set this number (No) using the command SET/ECHELLE NBORDI=No before giving the ORDERP/UVES command. The UVES pipeline indeed uses the results of the physical model which predicts the geometrical spectral format and thus also the number of orders which should be present on the frame. This value is stored in the DRS setup table when the first guess solution is generated. This method is appropriate for the standard setting, and is more robust and uniform than doing an automatic order detection. But in case of a non standard setting, it may well be that due to non-uniform light distribution on the detector (induced by filters eventually present along the light path) the predicted number of orders is greater than the detected one. In this case, using the value of NBORDI contained in the DRS setup table generated from the physical model would lead to an overestimation of the number of orders and to a wrong solution. For this reason, in pipeline releases after version 1.0.2 a quality check on the predicted vs. detected spectral format has been introduced. The expected number of orders can be also set manually (SET/ECHELLE NBORDI=No).

5 Wavelength calibration

For the wavelength calibration you will need a ThAr-lamp exposure, a line reference table, and first guess solutions (order table and line table) which allows the automatic mode of the `UVES` command `WAVECAL/UVES`. The interactive mode may be enforced by its mode parameter. The ThAr-lamp exposure may be obtained using the observation template `UVES_`< *mode* >`_y` (< *mode* >= blue, red, dic1, dic2, y=wave, wavefree).
Again, at first you have to transform the original input file by:

```
Midas> SPLIT/UVES b346_TAL.fits
```

Assuming `b346_TAL.fits` as an exposure of the blue arm, the output from this command will be used as the input file of the wavelength calibration command.The next UVES context MIDAS command uses, for simplicity, the input reference catalog name as the output catalog (`refB.cat`):

```
Midas> WAVECAL/UVES b346_TAL_b.bdf refB.cat refB.cat AUTO
```

This command performs the wavelength calibration using the following default options:

parameter	value	purpose
P4	AUTO	the previously determined line table from refB.cat is used
P5	yes	the procedure generates the resolution plots
P6	Y/[N]	performs (Y/[N]) the wavelength calibration only at order center
P7	Y/[N]	produced output FITS file
P8	[+]	see on line help of command (this parameter control offset and extraction window of object and sky for wavelength calibration solution)

This step generates the line tables for each slit window (sky, object, sky) which will be stored in the output catalog, `refB.cat`, and updates the DRS_SETUP_x (x=BLUE in our example) table

frame	DO_CLASSIFICATION	meaning
l346_2x1_1.tbl	LINE_TABLE_BLUE1	line table lower sky
l346_2x1_2.tbl	LINE_TABLE_BLUE2	line table object
l346_2x1_3.tbl	LINE_TABLE_BLUE3	line table upper sky
d346_2x1.tbl	DRS_SETUP_BLUE	DRS Setup Table

As the ThAr line reference list is no a product of the UVES context you have to ensure that the descriptor `ESO.PRO.CATG` is set to `LINE_REFER_TABLE` (`READ/DESC, WRITE/DESC`).

6 Master calibration files

Master calibration frames – master bias and master flatfields – are used for the science reduction. They are stacked median averages of a set of input frames. They are created by the command `MASTER/UVES`. To keep the data reduction simple, we collect all the bias frames in an image catalog:

```
Midas> CREATE/ICAT biasB.cat bias346_*.fits
```

At first the set of input frames have to be transformed into the standard orientation (wavelength increases from left to right and from bottom to top) and into the MIDAS BDF-file format by means of:

```
Midas> SPLIT/UVES biasB.cat split_bias.cat
```

The transformed data will be stored in the output catalog `split_bias.cat`. Having prepared the input data one can give the command:

```
Midas> MASTER/UVES split_bias.cat refB.cat
```

which produces a master frame for each configuration (blue, red arm lower and upper part), i.e. you may use a mixed set of input frames (e.g.: blue bias frames, red bias frames lower and upper part 5 frames each – as a result you will get 3 master biases.). All products will be stored in the output catalog which again for simplicity has the same name as before (`refB.cat`).

This command will produce a master bias frame:

frame	DO_CLASSIFICATION	meaning
mbBLUE_2x1_b.bdf	MASTER_BIAS_BLUE	Master Bias frame

and its name will be added to the reference catalog.

For the flatfields and as before, for simplicity, we put all the Flat Field frames in one catalog:

```
Midas> CREATE/ICAT ffB.cat ff346_*.fits
```

```
Midas> SPLIT/UVES ffB.cat split_ff.cat
```

The master Flat Field is saved in the usual catalog (`refB.cat`).

```
Midas> MASTER/UVES split_ff.cat refB.cat refB.cat
```

The products of this step are (in our case of BLUE arm data, binning 2x1, slit length = 8 arcsec) the following frames:

frame	DO_CLASSIFICATION	meaning
mf346_2x1_s08_b.bdf	MASTER_FLAT_BLUE	master FF
av346_2x1_s08_b.bdf		average FF
bg346_2x1_s08_b.bdf		bkg

The master Bias is subtracted from the master flatfield (default option M of P4) and no dark is subtracted. One can also subtract a constant bias level (in this case P4=number) this bias level (number) can be determined with STATISTIC/IMAGE on different portions of the bias frames. An inter-order background is also determined and subtracted to the Flat Field frame (the parameter P6 sets the method) The master flat frame is added to the reference catalog.

```
Midas> MASTER/UVES split_ff.cat refB.cat refB.cat 120
```

This example assumes a constant bias of 120 counts used for the master flatfield creation. Furthermore, the master flats will be background subtracted which requires appropriate background tables and DRS setup tables (to be present in the catalog `refB.cat`) – products of `ORDERP/UVES`.

7 Science frame reduction

The science reduction for UVES supports different modes controlled via additional parameters:

ffmode Flatfielding may be done in the pixel-pixel space (`P`) as well as in the extracted pixel-order space (`E`).

extract The extraction of the object may be performed as a simple average (`AVERAGE`) or by the optimal extraction method (`OPTIMAL`). The number of 'rows' to be averaged per order is defined by the MIDAS keyword `SLIT`.

bmeasure The inter-order background subtraction is based on the 'measurements' on the grid of background positions. For each background position the median (`MEDIAN`) or the minimum (`MINIMUM`) within a certain window will be used as the measurement at that point. In case of very narrow inter-order space the minimum method could produce better background images as otherwise the measurements could be contaminated by neighboring orders. Usually the method MEDIAN gives better results than the MINIMUM.

From version 2.0.0 spectra merging can be controlled via parameter P8 which may have 4 components: merge_method, delta_set_switch, delta1, delta2. merge_method is the method used to merge spectra: OPTIMAL or AVERAGE. delta_set_switch is a parameter used to set:

D: Default delta setting (as was in previous pipeline releases, for BLUE arm delta1=delta2=3, for RED arm delta1=delta2=5).

A: Automatic setting of deltas. Appropriate deltas are chosen for each instrument setting. See on line help.

U: User defined deltas. In this case are taken the values of delta1 and delta2 as specified by the user.

delta1: user specified value of delta used to merge the blue edge of the spectra. delta2: user specified value of delta used to merge the red edge of the spectra.

The possible parameter values are shown in brackets (). As usual, at first you have to transform your science frame:

```
Midas> SPLIT/UVES sc.fits split_sc.cat
```

We can reduce the data giving the following UVES context MIDAS command:

```
Midas> REDUCE/UVES split_sc.cat sc_redB.cat refB.cat E OPTIMAL MEDIAN
```

In this case we use P4=E meaning that the Flat Fielding is done in the pixel-order space during extraction. In case of data taken in the far Red (wcal=860), to better correct for the fringing effect one could apply the P method, i.e. doing the Flat Fielding before extraction in the pixel-to-pixel space.

P5=OPTIMAL means we choose optimal extraction. This method has been proven to give good quality for low-to-medium signal to noise (S/N) ratio science objects. For very high S/N it is suggested to use the average extraction method. The optimal extraction may show quality problems appearing as sudden spikes on the spectra. This occurrence can be confirmed also looking at the "weight.bdf" weight image which for a successful extraction should appear uniform with only a few randomly scattered "holes" corresponding to detection (and suppression) of cosmic rays. If instead significant portion of holes in the weight image with a periodicity are noticed, this means that this step has failed and one should use average extraction.

P6=MINIMUM/[MEDIAN] is the background estimation method.

See help SUBTRACT/BACKGROUND for clarification.

Proper setting of parameter P7 allows one to chose (if used P7=N,N,N) one's own setting respectively for the offset, slit, skywind setting. This allows one to use UVES/REDUCE to reduce more than one source on the slit, interactively determining (LOAD/IMA, LOAD/ECH, GET/CURS) and setting (SET/ECHELLE) the values of the three involved parameters. Default setting for P7 is Y,Y,Y which means automatic determination of the three parameters. To use OPTIMAL extraction with multi sources the real keyword OBJSET has to be appropriately set (see more in section 13).

The command `REDUCE/UVES` will reduce every science frame stored in the input catalog using the appropriate calibration frames from the reference catalog refB.cat. So, for each configuration there has to be a complete reference set. In this example, there has to be two sets – one for the lower red and one for the upper red arm. In principle you are able to mix blue and red arm exposures for the science reduction process.

Finally, all products will be stored in the output catalog sc_redB.cat. The following data products will be created (only the products of the lower CCD (EEV) of the red arm are shown

– in principle they are always the same for the other configurations):

Filename	Format	ESO.PRO.CATG	Description
r_rbf_0_l.bdf	1D (wav)	REDUCED_SCI_POINT_REDL	extracted, flatfielded, wavelength calibrated merged, sky subtracted science frame
m_rbf_0_l.bdf	1D (wav)	MERGED_SCI_POINT_REDL	extracted, flatfielded, wavelength calibrated, merged, science frame
w_xb_rbf_0_l.bdf	2D (wav-ord)	WCALIB_SCI_POINT_REDL	extracted, wavelength calibrated science frame
wfxb_rbf_0_l.bdf	2D (wav-ord)	WCALIB_FF_SCI_POINT_REDL	extracted, flatfielded, wavelength calibrated frame
errmrbf_0_l.bdf	1D (wav)	ERRORBAR_SCI_POINT_REDU	standard deviation of reduced science frame
var_rbf_0_l.bdf	1D (pix-ord)	VARIANCE_SCI_POINT_REDU	variance of flatfielded, extracted science frame

reduced: debiased, inter-order background subtracted, flatfielded, re-sampled, merged and sky subtracted data.
merged: merged orders, no sky subtraction (one dimensional).
wavelength calibrated: re-sampled extracted orders.
sky: sky contribution is determined from the two sky windows below (sky(1)) and above the object (sky(2)) in each order. For the optimal extraction the weights used for the object extraction are applied to the averaged sky.
From pipeline release 1.3.0 on are also created, in case of optimal extraction, frames with optimally extracted sky. These contains in the frame name the sequence opt_sky_ . The second column of the table shows the hierarchical FITS header keyword for the product category. By means of this keyword the products may easily be identified. The MIDAS output catalog uses this keyword as identifier field. In case of the upper CCD of the red arm the category extension _REDL changes to _REDU and for the blue arm to _BLUE.
The prefix of the filenames also immediately shows the different product types:
w: wavelength calibrated, f: flatfielded, x: extracted, b: background subtracted data file. The prefix m indicates merged data which are implicitly always 'wfxb' data.

Filename	Format	ESO.PRO.CATG	Description
w_xb_sky_REDL1.bdf	2D (wav-ord)	WCALIB_SKY1_REDL	extracted, wavelength calibrated sky(1) frame
wfxb_sky_REDL1.bdf	2D (wav-ord)	WCALIB_FF_SKY1_REDL	extracted, flatfielded and wavelength calibrated sky(1) frame
m_sky_REDL1.bdf	1D (wav)	MERGED_SKY1_REDL	extracted, wavelength calibrated, flat fielded, merged sky(1) frame
w_xb_sky_REDL2.bdf	2D (wav-ord)	WCALIB_SKY2_REDL	extracted, wavelength calibrated sky(2) frame
wfxb_sky_REDL2.bdf	2D (wav-ord)	WCALIB_FF_SKY2_REDL	extracted, wavelength calibrated, flatfielded sky(2) frame
m_sky_REDL2.bdf	1D (wav)	MERGED_SKY2_REDL	extracted, wavelength calibrated, flat fielded, and merged sky(2) frame
m_sky_REDL.bdf	1D (wav)	MERGED_AV_SKY_REDL	extracted, flatfielded, wavelength calibrated, merged, average of sky(1) and sky(2) frame
w_xb_rbf_8.bdf	1D (wav)	WCALIB_FLAT_OBJ_REDL	extracted, wavelength calibrated, flatfield of the object
w_xb1_rbf_8.bdf	2D (wav-ord)	WCALIB_FLAT_SKY1_REDL	extracted, wavelength calibrated flatfield
w_xb2_rbf_8.bdf	2D (wav-ord)	WCALIB_FLAT_SKY2_REDL	of the two sky windows

Note also that with automatic determination of the offset,slit,skywind parameters (P7=Y,Y,Y), it may happen that due to a big value of the object offset, automatically determined during data reduction, one sky window is less than 4 pixels wide so that the data reduction procedure automatically switches to one (from a default value of two) sky extraction window. See also the help of the command REDUCE/UVES for more information on how to properly set user defined extraction parameters in case of optimal extraction.

For operational purposes, from pipeline version 1.1.1 on, we have decided to produce "dummy" solutions also relative to the extraction window which is automatically suppressed. This is to keep the same order in the pipeline data products. Such solutions, which have no physical meaning, are labeled with the prefix "dummy" in the file name. The real solutions are as before the one obtained considering only the "good" sky extraction window.

The errorbar image (filenames having prefix errm) is obtained as the square root of the variance frame (varm...). The variance frame is calculated considering the contribution from the read out noise and from the source. In case of average extraction this is calculated per pixel. The variance of the flat fielded object is next given propagating the variance for the ratio (extracted object)/(extracted flat field). In case of optimal extraction an input variance is calculated as described above. This will follow transformations similar to the flux until in the end after having evaluated the best Gaussian cross order profile coefficients, it is evaluated for each X point the chi-square between a normalized Gaussian times a variable amplitude (to which is added the found background) and the actual spectra doing the quadratic sum along the cross order direction and using as weight the input variance. For a number of values of amplitudes one gets corresponding values of chi square. Assuming that the chi square as a function of the amplitude is a parabola near the minimum, one can calculate which is the change in amplitude that generates a unitary increase of the chi square. This change can be assumed as an error associated with the amplitude and from this one can get an estimate of the variance associated to the optimal extraction process. Clearly this variance value depends on how good is the Gaussian model approximation assumed from the cross order profile.

Up to version 2.9.7, optimal extraction was having problems (apparent strange ripples and patterns within an order on a few pixel scale) in particular for high S/N data (greater than around 50). Those problems were solved in the latest version. For very high S/N (¿ 200) data, the user may still want to use the average extraction. Remember also that Average extraction, as suggested by the name, makes an average of the extracted signal along the extraction slit. So the intensities of data reduced with optimal and average extraction differ approximatively by a factor equal to the slit size in pixel. Flux calibrated merged spectra may be generated if a master response frame is added in the input reference catalog. In this case using average extraction the products have same units as the ones generated using optimal extraction.

Because it is difficult to model the light profile coming from the image slicer and to estimate the sky contribution from the image slicer, data should be extracted with AVERAGE method and NO sky subtraction. For this instrument setting during science spectra extraction the pipeline recognizes if the frame has been created using an Image Slicer and in such a case it is automatically set to the relevant extraction parameters (object extraction slit, extraction method, sky subtraction option).

Optimal extraction quality has been improved a lot in the latest release. We can now prudently say that usually the extraction quality is quite good. It is important to check it using the command

```
Midas> MPLOT/CHUN [order_trace_x] [half_size_y] [switch]
```

where x=BLUE,REDL or REDU, half_size_y is half size in bin units of the plots in Y direction, and switch can assume values pos(ition) or fwhm, respectively for the plots of the cross order chunk position or FWHM distributions. These plots display in black the values of the raw data (pos/FWHM) for each chunk, in green the values predicted from the first fit after some pre-cleaning of outliers, in blue the last fit after k-sigma clipping of residual outliers and in magenta are shown the points used to determine the last fit. Good extraction is typically reached when the black points are well fit by the blue ones. As the plots show, the point distribution has usually a well aggregated parabolic distribution with sloppiness and curvature typically of a small fraction of pixel. So in general, the fit for position and FWHM is parabolic. In case the data distribution is not well aggregated (this may happen for particularly low S/N data) it might happen that the fit gives too big values for the sloppiness and the curvature. To prevent such a problem thresholds and checks on these parameters are set in the code so that if the fit is not very good and the parabola fit parameters are wrong the fit is switched first to linear and eventually to uniform. The linear (or even uniform) approximation is a safer approximation than a parabolic one to fit a highly scattered point distribution. The user should always check to have a reasonably good fit (max scatter in y bin should be 0.1-0.3 bins).

Having a proper master response frame (provided by DFO) and adding it in the input reference catalogue one could also produce flux calibrated merged spectra (having prefix flx_).

8 Calibration scripts

In order to make life a bit easier, three additional MIDAS procedures exist, which may help to fill your calibration database for later science reduction. The first command `PREPARE/CALDB` puts all the calibration commands mentioned before together into one script so that one has only to create an input catalog for a certain UVES setting and pass it to this procedure.

First, one collects in an image catalog all the main calibration fits files:

1. raw formatcheck frame ('fits')
2. raw order definition flatfield ('fits')
3. ThAr lamp exposure ('fits')
4. raw list of biases ('fits')
5. raw list of flat fields ('fits')

And apply SPLIT/UVES to get the data in the proper format and orientation:

```
Midas> CREA/ICAT raw_fits.cat *.fits
Midas> SPLIT/UVES raw_fits.cat raw_split.cat
```

Next, one prepares a catalog refer.cat containing the ThAr line reference table in the MIDAS format:

```
Midas> INDISK/FITS thargood_3.tfits thargood_3.tbl
Midas> CREA/ICAT refer.cat null DO_CLASSIFICATION
Midas> ADD/ICAT refer.cat thargood_3.tbl
```

Finally one applies the PREPARE/CALDB script with the following syntax:

```
Midas> PREPARE/CALDB raw_split.cat refer.cat
```

Assume one has created an input catalog for binned data (2×1) of the central wavelength 346 nm then after having executed the script one will get at the end all the necessary calibration solutions which are listed in an output catalog `ref346_2x1.cat`. Use

```
Midas> SAVE/CALDB ref346_2x1.cat /data/caldb
```

to store the solutions in one's calibration database.

The third command allows one to retrieve the complete set of calibration frames from the calibration database:

```
Midas> GET/CALDB ref346_2x1.cat /data/caldb
```

in order to be well prepared for the science reduction:

```
Midas> REDUCE/UVES sc346_2x1_b.bdf sc346.cat ref346_2x1.cat E OPT MED
```

For more details and additional options please read the on line help of the commands.

9 UVES data display and hardcopy

The echelle data may be displayed using the command `PLOT/UVES`. For a detailed description please see the help file (`HELP PLOT/UVES`).

```
Midas> PLOT/UVES extract.bdf 1,13 0,100 ``title'' extract.ps
```

Furthermore, a hardcopy utility is provided: `HARDCOPY/PLOT` especially for hardcopies of the image displays as the usual hardcopy command `COPY/DISP` only properly works for non-covered displays.

```
Midas> HARDCOPY/PLOT P ff_346.ps ff_346.bdf
```

This will produce a postscript hardcopy (`ff_346.ps`) of the input file `ff_346.bdf`. Additionally, the main characteristics will be printed at the bottom of the plot. By default, the hardcopy facility is disabled. You may enable it doing:

```
Midas> HARDCOPY/PLOT ON
```

Use `OFF` instead of `ON` in case you wish to disable hardcopies. This may be useful, as some UVES commands are sensible to the hardcopy command status.

10 Saving the keyword setup

The keywords used during the reduction of the data may/should be saved in a so called data reduction system setup tables (DRS tables). These are classified products which may be identified by the UVES commands. These tables control the whole reduction process. If you are changing some of the ECHELLE context keywords using `SET/ECHELLE` you should store these changes for later use in a DRS table:

```
Midas> SAVE/DRS drs_346.tbl
```

This call will save all ECHELLE keywords in the MIDAS table `drs_346.tbl` as MIDAS descriptors, existing DRS tables will be overwritten.

11 Message level

The output of information is reduced to a minimum for use of the UVES context within the pipeline infrastructure. When using the context in an interactive mode it could be helpful to get some more information. In this case you may control the message level by:

```
Midas> VERBOSE/OUT VERY
```

Instead of VERY you may use ON or OFF which switches back to the default message level or, even more, switches all the messages off except for warnings and error messages.

12 Automatic preparation of calibration solutions

To quickly prepare calibration solutions with default parameter settings, it is worth to describe the use of the script uves_popul.sh, included as part of the distribution in $PIPE_HOME/uves/uves/scripts/ directory (which should be included in your local PATH).

This script can be executed from any shell with the following syntax (we suppose to be in the directory where the raw FITS files are located):

$PIPE_HOME/uves/uves/scripts/uves_popul.sh raw_fmtchk.fits raw_orderpos.fits raw_wavecal.fits raw_bias*.fits raw_flat*.fits ThAr_ReferLineTable.fits

where the input raw data refers to a coherent instrument setting (same instrument arm, mode, central wavelength and binning); the script starts a MIDAS session and produces results in the directory
$HOME/midwork/tmpwrk/

In particular this creates a subdirectory: $HOME/midwork/tmpwrk/data/ which contains all the calibration solutions.

Moreover in $HOME/midwork/tmpwrk/ the files xORDER.tbl, xLINE.tbl, xBACKGR.tbl will be present to be used as input reference of the MIDAS command INIT/ECHELLE x (x=BLUE or REDL, REDU). This command sets up all the important keywords of the echelle environment.

The uves_popul.sh is a script which executes the procedure uves_prepcalib.prg. This procedure executes in series all the main UVES pipeline reduction steps involved in the calibration data analysis. Mainly it executes the command CONFIG/INSTR on the reference catalog to get, set or check: mode, the detector involved, the central wavelength, the binning factor, if a dichroic is inserted.

Next, it executes the first main data reduction step: it runs the physical model to determine the geometrical predicted spectral format, a first guess solution for the line (dispersion relation) and the order tables and generates a first DRS SETUP table; if a reference formatcheck frame (MASTER_FORM_x, x=BLUE or REDL, REDU) is provided it also does a QC stability check.

These data (ORDTAB, DRSTAB) are used in the following data reduction step, the order position determination (ORDERP/UVES). In this step an Hough Transform is performed to determine the order positions. Initially it is given (through a SAVINI/ECH DRSTAB

READ command) as parameter to DEFINE/HOUGH the number of orders as predicted by the physical model (previous step). In standard configuration settings, this number usually coincides with the actual number of orders on the detector. On particular non standard configurations, due to the presence of some filter along the path, it may be possible that the detector illumination may drop to almost zero on some regions and for this reason the detected number of orders is lower than the one predicted by the physical model. For this reason the order position procedure always does a quality control check (check the standard deviation of the :RESIDUAL column in the order table which may have a jump in case the predicted number of orders is greater than the detected one) and eventually iteratively decrease the number of orders given as input parameter to DEFINE/HOUGH.

Finally the ORDER, BACKGR and DRS_SETUP tables are produced. The following step is the wavelength calibration (WAVECAL/UVES). Next the Master bias and the Master Flat frames are created. To use the calibration database data in an interactive MIDAS section, for example to reduce a science frame, one has to convert the FITS data to MIDAS format.

13 Reduction of more than one object source on the slit

The UVES pipeline has been designed to do automatic data reduction of point-like sources well centered on the slit. Some users may be interested to observe and reduce data of more than one object on the slit. For this purpose we have upgraded some commands to allow the user to interactively perform a proper extraction. This is still possible in a manual session using the UVES context. Here we give a small example which may be adapted to the user's needs.

Let's suppose the user has on the slit two adjacent spectra. Let's suppose the user has used the uves_popul.sh to prepare all the data calibrations. During this step the echelle fundamental data tables are also produced: yORDER.tbl, yLINE.tbl, yBACKGR.tbl (y=BLUE or REDU,REDL).

Let's suppose these tables, the calibration solutions and the science raw data to be reduced are available in our directory (here for example indicated with raw_sci_two_sources_x.bdf).

We would give the following commands:

```
Midas> SPLIT/UVES raw_sci_two_sources_x.bdf
Midas> INIT/ECHE y
Midas> LOAD/ECHE
Midas> GET/CUR
```

With this last command you overplot the detected order trace to have a reference to get the extraction parameters offset, slit, skywind (this last for average extraction).

were `x=b` or `x=l`, `x=u` and `y=BLUE` or `y=REDL`, `y=REDU` respectively for the BLUE or REDL,REDU chip.

So you can calculate the values of off, slit, skywind (skywind in general is a 4 component parameter: skywind=skyw(1),skyw(2),skyw(3),skyw(4)), for each of the object to be extracted.

```
Midas> SET/ECHE offset=off1 slit=slit1 skywind=skywind1
Midas> SAVINI/ECHE drstab.tbl
Midas> REDUCE/UVES raw_sci_two_sources_x.bdf out.cat ref.cat E A MED N,N,N
```

Where `drstab.tbl` indicates the drs setup table being used. Here we use P7=N,N,N meaning we have dis-activated (N) the automatic setting respectively of the offset,the slit, and the sky-window (used in average extraction) values, and used the corresponding values set manually (SET/ECHE). We have also saved our setting in the drs setup table. In our case we have used average extraction, but we could also use optimal extraction. Similarly the other object can be reduced.

It is probably useful to write some more here in case the user would like to extract two sources on the slit using optimal extraction and a manual setting of the extraction parameters.

For simplicity we start the discussion with the extraction of a single source. This case is typically treated in an automatic way by the pipeline. The discussion helps to understand the meaning of each relevant parameter, also for the more general case in which one has to extract more than one object, case in which automatic extraction would fail.

Be `obj_trace` the position of the object as measured (LOAD/IMA LOAD/ECHELLE GET/CUR) with respect to a reference position (for example the order trace).

Be `ord_trace` the position of the order trace.

Be `offset` the offset chosen for the extraction, this being the center of the extraction slit (`slit_ext`).

The parameter `objset`, used in the optimal extraction, is the distance of the object from the center of the extraction slit `slit_ext`. It is used as first guess to start the Gaussian fit of the object's light distribution cross order profile within the extraction slit. Next the optimal extraction algorithm searches automatically for the best object position to achieve within an order an overall best fit of the cross order profile.

These parameters are related by the following relation

`offset+objset=obj_trace-order_trace`

The slit of integration will be centered at the position `order_trace+offset`.

The user could get such a formula, taking into account the previous information, for example doing a plot, in which one has, for a numerical example an object trace at position 40, an order trace at position 20 and the extraction slit centered at position 25. Let's also suppose that one would like to have an extraction window of 36 pixels.

We have chosen this sequence as it is simpler and all the parameters are positive.

With our numbers `objset=object_trace-order_trace-offset=40-20-(25-20)=40-20-5=15` which is actually what one can measure on a scaled plot.

Obviously `objset` and `offset` have a sign and the situation can change: If one puts the integration slit below the order trace the `offset` will be negative. Similarly one can have a situation for which `objset` is negative.

To make things easier, if the extraction window is centered on the object (this means `objset=0`), the parameter `offset` measures the distance of the object trace from the order trace, which is exactly what one would imagine.

When is all this important? Usually one will have only one `object` in the slit and in such a case `offset` is automatically determined by offset/echelle so that one can take `objset=0` (as the pipeline does in default mode) and the optimal extraction will start to search for the object at the slit center without any problem.

A more interesting case happens when there is more than one object in the (full) slit, and in particular if the two sources are very close to each other (as may happen for traces of lensed quasars or in a binary system). Obviously one does not want to use a slit covering both objects otherwise the spectral information coming from the two spectra will be mixed (moreover doing so the optimal extraction would get crazy trying to fit both traces). It is also suggested not to have a small integration window centered on each object (`objset=0`), as probably one would cut-off part of the object and/or not well estimate the sky.

In such a case it is better to chose an `offset` and an integration slit such that the slit includes one object (but not the adjacent) and a lot of sky on one side of the object. It is not a good idea to have in this case `objset=0` and leave the optimal extraction search for the object position as in this particular situation the object will be near the slit border and the algorithm may not be clever enough to find the object. For this reason one has to specify `objset`, the starting offset with respect to the slit center. Following these indications and choosing an extraction slit size such that at least three pixels are left on each side of the object, one can iteratively do optimal extraction of all the sources.

If all is done correctly in the setting of these parameters, one can notice that the object position reported by the optimal extraction at each order varies slightly with the order position and it is quite close to the value `slit_ext/2+objset` set from the user.

It is always a good practice, after optimal extraction, to use the command MPLOT/CHUN to display the trace object positions (or FWHM) as a function of X and verify that a good fit was obtained. It is only necessary to check one trace. This means that the extraction slit includes only one object. Moreover the magenta points should fit well to the dark ones, this being an indication of a good extraction.

Another interesting test one could do is to get the best combination of parameters to have a reasonable extraction, and next, satisfying the formula above, move the extraction window until the object exits from it. At this point the optimal extraction will start to have problems giving warnings like:

Warning: IMASK_COUNTER LESS THAN 10

meaning that only a small number of chunks are left after a k-sigma clipping step over position (or FWHM values), a situation typical of very low S/N data, even more if no signal is in the extraction window as it can happen at a certain point in the proposed exercise.

In such last case the plots from MPLOT/CHUN (and of the extracted spectra) will be much worse..

After such explanations we add only how, in practice, we could activate such settings, using the numbers given.

```
Midas> SET/ECHE offset=5 slit=36
Midas> write/key objset/r/1/1 15
Midas> SAVINI/ECHE drstab.tbl
Midas> REDUCE/UVES raw_sci_two_sources_x.bdf out.cat ref.cat E O MED N,N,N
Midas> MPLOT/CHUN order_trace_y.bdf 3 obj
Midas> MPLOT/CHUN order_trace_y.bdf 3 fwhm
```

where `x=b` or `x=l`, `x=u` and `y=BLUE` or `y=REDL`, `y=REDU` respectively for the BLUE or REDL,REDU chip. Here we have also reported the command to check, after extraction, the quality of the order tracing.

14 Reduction of extended sources

The possibility to do simple reduction of extended sources has also been included on the pipeline version 1.0.6 on. In this case the source is extracted with a 1 bin extraction slit and a variable offset scanning the full length of the observation slit. So the order is rotated-flat fielded, wavelength calibrated and finally merged. The command to be used is:

```
Midas> REDUCE/SPAT split.cat out.cat ref.cat BckMeasMeth,FfMeth,MerMeth
MerSwitch,delta1,delta2
```

split.cat is an input image catalog with images to be reduced oriented in the proper way (SPLIT/UVES), for example the one produced as described in the normal data reduction for science data. out.cat is an output image catalog produced from the pipeline. ref.cat is the reference catalog for science data reduction produced as described in the section for normal data reduction. BckMeasMeth is the background measurement method (MIN, MED, see help subtract/background) FfMeth is the flat fielding method, which can assume values "E", "P" or "N" with the same meanings as the corresponding parameter in the command REDUCE/UVES. MerMeth is the merging method, which can assume values "O" (Optimal), "A" (Average), "N" (Noappend), with similar meaning as for the standard MIDAS command MERGE/ECHELLE.

We suggest not to use REDUCE/SPAT after having used on the same data REDUCE/UVES. In fact after the flat fielding or the background have been applied on the science frame the pipeline sets given descriptors so that it can recognize that the corresponding operation does not need to be repeated. If the user has already processed a science frame with REDUCE/UVES the science frame may be already background and flat field corrected (if the flat field correction has been performed pixel to pixel), thus the user may not be able to choose and do the proper background and flat field methods offered by the REDUCE/SPAT command itself.

Default values for parameter P4 are MED, E, A. One could use as MerMeth "O" to have a better behaviour in the overlapping region between one order and the next, or if not satisfied, the Noappend option to have each order in one corresponding image file.

MerSwitch is the parameter controlling the setting of deltas used in the merging of the spectra. It can have values D (Default), A (Auto) or U (User-defined) which have the same meaning as the corresponding subparameter of parameter P8 in REDUCE/UVES command. Delta1 controls the amount of overlapping considered in the merging of the blue edge of a spectra. delta2 controls the amount of overlapping considered in the merging of the red edge of a spectra. Using option A the pipeline will use predefined delta1 and delta2 parameter values. As those parameters affect significantly the quality of merged spectra we suggest the user to use the U option and choose appropriate values for delta1 and delta2. See also on line help of parameter P5 for command REDUCE/SPAT

Blue data, for setting 346, might be better reduced using a NO flat fielding mode, because in the short wavelength range of this setting, the flat field data might have been taken in non-appropriate conditions. This rarely happens as LN2 lamps with a proper behaviour are being used.

The products generated by this procedure are the following: If p1 is the MIDAS procedure parameter specifying the input frame:

- xb2d_{p1} is the background subtracted, extracted (rotated), frame,

- fxb2d_{p1} is the background subtracted, extracted (rotated) flatfielded, frame,
- wfxb2d_{p1} is the background subtracted, extracted (rotated) flatfielded, wavelength calibrated frame,
- mwfxb2d_{p1} is the background subtracted, extracted (rotated) flatfielded, wavelength calibrated, merged frame.

In case "Noappend" the merging option is chosen, the procedure generates an image frame per each order with indexed names such as the following:
mwfxb2d_{p1}0001....mwfxb2d_{p1}00NN, where NN is the number of extracted orders. This last option may be used if the user has not found proper values of delta1 and delta2 parameters.

15 Session example: Blue Data

We refer now to a case of BLUE arm data with wcent=346 nm and 2x1 binning.

15.1 Default Display Initialization

```
Midas> CONFIG/DISP 1600 1200 0.6
```

15.2 Predictive Format Determination

```
Midas> SPLIT/UVES frmtChk346_TAL.fits
Midas> INDISK/FITS thargood_3.tfits thargood_3.tbl
Midas> PREDICT/UVES frmtChk346_TAL_b.bdf thargood_3.tbl
```

15.3 Order Position Determination

```
Midas> crea/icat refB.cat o346BLUE.tbl DO_CLASSIFICATION
Midas> SPLIT/UVES order_ff346.fits
Midas> ORDERP/UVES order_ff346_b.bdf refB.cat refB.cat
Midas> -rename l346blue.tbl l346_2x1.tbl
Midas> add/icat refb.cat l346_2x1.tbl
Midas> add/icat refb.cat thargood_3.tbl
```

15.4 Wavelength Calibration

```
Midas> SPLIT/UVES wcal346_TAL.fits
Midas> WAVECAL/UVES wcal346_TAL_b.bdf refB.cat refB.cat AUTO yes
```

15.5 Master Bias Determination

```
Midas> CREATE/ICAT biasB.cat bias346_*.fits
Midas> SPLIT/UVES biasB.cat split_biasB.cat
Midas> MASTER/UVES split_biasB.cat refB.cat
```

15.6 Master Flat Determination

```
Midas> CREATE/ICAT ffB.cat ff346_*.fits
Midas> SPLIT/UVES ffB.cat split_ff346.cat
Midas> MASTER/UVES split_ff346.cat refB.cat refB.cat
```

15.7 Science Reduction

```
Midas> SPLIT/UVES sc_346.fits
Midas> REDUCE/UVES sc_346_b.bdf reducedB.cat refB.cat E O MED
```

16 Session example: Red Data

We refer now to a case of RED arm data with wcent=580 nm and 1x1 binning.

16.1 Default Display Initialization

```
Midas> CONFIG/DISP 1600 1200 0.6
```

16.2 Predictive Format Determination

```
Midas> SPLIT/UVES frmtChk580_TAL.fits
Midas> INDISK/FITS thargood_3.tfits thargood_3.tbl
Midas> PREDICT/UVES frmtChk580_TAL_l.bdf thargood_3.tbl
Midas> PREDICT/UVES frmtChk580_TAL_u.bdf thargood_3.tbl
```

16.3 Order Position Determination

```
Midas> crea/icat refB.cat o580REDL.tbl DO_CLASSIFICATION
Midas> add/icat refB.cat o580REDU.tbl
Midas> SPLIT/UVES order_ff580.fits split_order.cat
Midas> ORDERP/UVES split_order.cat refR.cat
Midas> -rename l580REDL.tbl l580L_1x1.tbl
Midas> -rename l580REDU.tbl l580U_1x1.tbl
Midas> ADD/ICAT refR.cat l580L_1x1.tbl
Midas> ADD/ICAT refR.cat l580U_1x1.tbl
Midas> ADD/ICAT refR.cat thargood_3.tbl
```

16.4 Wavelength Calibration

```
Midas> SPLIT/UVES wcal580_TAL.fits split_wcal.cat
Midas> WAVECAL/UVES split_wcal.cat refR.cat refR.cat AUTO yes
```

16.5 Master Bias Determination

```
Midas> CREATE/ICAT biasR.cat bias580_*.fits
Midas> SPLIT/UVES biasR.cat split_biasR.cat
Midas> MASTER/UVES split_biasR.cat refR.cat
```

16.6 Master Flat Determination

```
Midas> CREATE/ICAT ffR.cat ff580_*.fits
Midas> SPLIT/UVES ffR.cat split_ff580.cat
Midas> MASTER/UVES split_ff580.cat refR.cat refR.cat
Midas> ADD/ICAT refR.cat mf580_1x1_s08_l.bdf,mf580_1x1_s08_u.bdf
```

16.7 Science Reduction

```
Midas> SPLIT/UVES sc_580.fits split_sc.cat
Midas> REDUCE/UVES split_sc.cat reducedR.cat refR.cat E O MED
```

___oOo___