EUROPEAN SOUTHERN OBSERVATORY

VERY LARGE TELESCOPE

UVES Pipeline User's Manual

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Change Record

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0.9.1	2000-01-22	Appendix B	Added cookbook in appendix B
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1.1	2000-06-30	All	comments, expanded procedure descriptions, appendix C
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1.1.1	2001-05-31	cap1-4-5 appA-B-C	revised, added/updated figures
1.2.0	2001-07-12	appB	updated
2	2001-09-10	version	same as 1.2.0 but for DFS archiving
3	2001-10-11	appB	clarification on automatic preparation of calibration solutions
4	2002-03-22 2003-03-10	cap1,4,5 appA,B,C	revised to reflect V1.4.0. Some additions, clarifications Document restructured
5	2003-07-21		Upgrade to pipeline version 2.0.0
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7	2004-09-30		Upgrade to pipeline version 2.2.0
8	2007-10-06		Upgrade to pipeline version 2.9.7

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Chapter 1

Introduction

1.1 Purpose

The UVES Pipeline as a subsystem of the VLT Dataflow is intended to be used by Paranal Science Operations (PSO) to assess the quality of the ongoing observations and to monitor the instrument's health. On Paranal the pipeline does automatic data reduction using calibration and reference frames which are updated from time to time. This allows the observer to have a quick check of the ongoing observation to verify the S/N of the extracted spectrum, to detect a degradation of the performance of the instrument, to decide whether an observation has to be repeated, or to monitor the instrument's health. The pipeline is also used by Garching Data Flow Operations (DFO) to create science products for Service Mode programs, to generate master calibration data and to perform quality control on data of the instrument. In this scenario there is also the human intervention aimed to select the best calibrations and reference solution possible to produce reduced data (typically wavelength calibrated, background subtracted one dimensional spectra) to a specified degree of accuracy reported in the README file associated with the delivered data. Finally the UVES pipeline or the UVES context in MIDAS may be used also by astronomers who want to perform basic reduction of their scientific data in a standardized fashion. This manual is adressed mostly to astronomers. It can be useful to operations even though we have decided to describe aspects strictly related to operations in another document ([10]). It should be understood as being an introduction into the several reduction recipes that are provided.

The document issue 8 reflects the status of the Pipeline version UVES pipeline V2.9.7 for UVES as of 2007-10-12.

1.2 Overview

In this chapter we indicate the purpose of this document; what the latest improvements are with respect to previous public releases; we list reference documents, useful abbreviations and acronyms, and a glossary.

Chapter 2 gives a very compact description of the UVES instrument and lists which frames are necessary to reduce an observation.

Chapter 3 is adressed to users who attempt for the first time to reduce UVES data. Section 3.1 gives some information on important points of the data reduction. It is adressed to any pipeline user. Section 3.2 describes how to use the UVES context.

Section 3.3 lists some known problems indicating possible causes and possible solutions. It is addressed mainly to users of the UVES context.

A more detailed description, useful to DFO, PSO but also to users of the UVES context, of the different UVES reduction recipes reporting the recipe name, input and reference frames, data products, associated templates, its purpose, used parameters and a more detailed description in form of text or graphic is given in chapter 4.

At the end there are some useful appendixes. Appendix A describes how astronomers can install the UVES pipeline. In Appendix B we supply the main information (template signature, DPR keywords, DO category, pipeline recipe, relevant instrument parameters) for the supported raw data frames used from the pipeline during data reduction. It is useful in particular for DFO and PSO users wanting to have a reference document on the main information used by the pipeline to identify a raw frame and associate to it the proper master calibration product; for astronomers to help to identify each possible UVES frame.

Information on the usage of the UVES pipeline within the Data Flow System (DFS) environment in support of UVES operations is given in [10]. There, in particular, you can find an overview of the DFS and a description on how to use the pipeline therein, how the calibration data base is structured, what the possible Reduction Blocks are, a cookbook for operations and examples of the basic UVES pipeline rule files. It is a reference for PSO, DFO and UVES pipeline maintainers.

Updated information on the UVES pipeline can be obtained at the following URL: http://www.eso.org/pipelines. Other useful information on the UVES pipeline and UVES Quality Control pages can be found at the following URL:
http://www.eso.org/observing/dfo/quality/ . Users can submit problem reports either by issuing a software problem report (using the tool accessible internally to DFO and PSO) or by sending an e-mail to midas@eso.org or to usg-help@eso.org. Constructive suggestions and comments, which may eventually improve the package or the documentation, are also welcome and can be sent to the given addresses. These will be considered and if appropriate, feedback will be given in successive releases.

1.3 Improvements with respect to version 2.2.0

The present version of the UVES pipeline has been improved with respect to version 2.2.0 mainly in the following ways (for more information please see the Release Notes of the pipeline tar file distribution):

- Improved optimal extraction quality.
- Improved ThAr lines catalog accuracy.
- Fixed some compilation warnings to improve code portability.
- Fixed bugs setting the target offset during the efficiency computation.
- Fixed bugs computing the variance.
- Fixed bugs in using different merging options in REDUCE/SPAT
- Prevented the possibility to have guess and final order tables misaligned.
- Support of TFLAT data reduction. Additional quality control parameters computation.
- The FITS header of pipeline products has been uniformed across instrument pipelines.
- Updated the present documentation.

1.4 Reference documents

[1] VLT Data Flow System Operations Model for VLT/VLTI Instrumentation
VLT-PLA-ESO-19000-1183
[2] VLT Data Flow System Specifications for Pipeline and Quality Control
VLT-SPE-ESO-19600-1233
[3] Data Flow for VLT instruments Requirement Specification
VLT-SPE-ESO-19000-1618
[4] DFS Pipeline & Quality Control – User anual
VLT-MAN-ESO-19500-1619
[5] ESO DICB – Data Interface Control Document
GEN-SPE-ESO-19940-0794/2.0
http://archive.eso.org/dicb/
[6] VLT UVES Calibration Plan VLT-PLA-ESO-13200-1123
http://www.eso.org/instruments/uves/doc
[7] VLT UVES User Manual VLT-MAN-ESO-13200-1825
http://www.eso.org/instruments/uves/doc
[8] VLT Data Flow System Gasgano DFS File Organizer User's Guide
VLT-PRO-ESO-19000-1932
http://www.eso.org/observing/gasgano/
[9] VLT UV-Visual Echelle Spectrograph Template Reference Guide
VLT-TRE-ESO-13200-1567
http://www.eso.org/instruments/uves/doc/
[10] UVES Pipeline Operation's Manual
VLT-MAN-ESO-19500-2965

1.5 Abbreviations and acronyms

ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
CalibDB	Calibration Database
DHS	Data Handling Server
DO	Data Organizer
DFS	Data Flow System
DMD	Data Management and Operations Division
DRS	Data Reduction System
ESO	European Southern Observatory
ESO–MIDAS	ESO's Munich Image Data Analysis System
ETC	Exposure Time Calculator
FITS	Flexible Image Transport System
GUI	Graphical User Interface
OB	Observation Block
PAF	VLT-PArameter File
RB	Reduction Block
RBS	Reduction Block Scheduler
RTD	Real Time Displayer
UT	Unit Telescope
UVES	UV-Visual Echelle Spectrograph for the VLT
VLT	Very Large Telescope

1.6 Glossary

Calibration Database : Database containing master calibration data.

DO : Data Organizer, a DFS component which classifies and analyses the content of any incoming raw frame and creates the corresponding Reduction Block (RB), if appropriate. Assembles calibration frames and raw data to be processed following data reduction recipes (data reduction procedures) specified in a RB.

Exposure : a synonym for the acquisition of a single data frame, typically resulting in a single FITS file.

Observation : a coordinate sequence of telescope, instrument, and detector actions that results in a scientific or technical dataset.

Observation Block : Smallest observational unit within the Data Flow System. It contains a sequence of high level operations, called "template", that need to be performed sequentially and without interruption in order to insure the scientific usefulness of an observation. Observation Blocks may contain scheduling requirements. They are used both in Visitor and Service Mode to acquire data.

Optimal extraction Extraction procedure designed with the purpose of minimizing the variance of the extracted spectra, especially in the case of a spectral data with low signal-to-noise (SNR) ratio. The theoretical maximum gain in low-SNR spectra, with respect to standard extraction, is about 40% more SNR, that amounts to a gain in effective exposure time of 70%. The algorithm needs to know the spatial light distribution of the object.

Physical model : Storing relevant physical information on the UVES instrument in a C program is possible to predict the UVES geometrical spectral format including number of orders, order position and the wavelength associated to each pixel for a given instrument setting as specified in the FITS header of the processed FITS file. In particular the UVES pipeline uses formatcheck frames, which are ThAr exposures with a narrow slit. The use of the UVES physical model in the formatcheck step allows the pipeline to automatize and standardize the data reduction for any instrument setting.

Pipeline product : Result of the execution of a Reduction Block.

QC0 : Quality Control level 0. On-Line tool that checks whether Service Mode OBs have been executed under the conditions specified by the astronomer. QC0 is executed on raw data.

QC1 : Quality Control level 1. QC1 consists of quality checks on pipeline processed data. The QC1 parameters are used to assess the quality of calibration products and the performance of the instrument.

Reduction Block (RB) :A Reduction Block is an ASCII file containing all the relevant information to do a pipeline data reduction. It indicates the observing instrument, the data reduction recipe to be executed, the pipeline product file prefix its full path, input raw files and their identification assigned by the DO, input reference and calibration files with their classification assigned by the DO. Each file name must appear with its complete path.

Reduction Block Scheduler (RBS) : tool which schedules and executes RBs created and sent by the DO. RBS sends the RB to the DRS (MIDAS) which will actually perform the reduction.

Reduction pipeline : Subsystem of the DFS in charge of pipeline processing. Applies reduction recipes and its parameters (calibration frames) on raw frames to generate pipeline products.

Reduction recipe : standard procedure for reducing observational data in a standard way. Recipes are implemented for each of the instrument templates. Those scripts take as input raw frames and execute them in a particular Data Reduction System (DRS).

Script : In the UVES pipeline we use this term to indicate a shell script which, if the user provides the correct input, allows the execution of one or more pipeline data reduction steps. Script may be used in support of pipeline data reduction.

Service Mode : observing operations mode where the astronomer submits a detailed description of their observing program to ESO for later possible execution. Service Mode programs are executed primarily in order of their OPC assigned priority but only when the astronomer specified observing conditions are achieved on site.

Standard extraction Extraction procedure for which the signal along an order is integrated using a fixed width extraction window covering all the spectrum across the spatial direction.

Template : a high-level data acquisition operation. Templates provide means to group commonly used procedures into well defined and standardized units. They can be used to specify a combination of detector, instrument, and telescope configurations and actions. Templates have input parameters described by a template signature, and produce results that can serve as input to other templates.

Visitor Mode : observing operations mode where the astronomer is present at the telescope when the observing program is being executed.

Chapter 2

UVES instrument and data

This section, after a very compact overview of the UVES instrument, lists all the frames necessary to reduce a science frame. It is addressed to any user who is going to receive UVES data, and is an introduction to the next chapter, which is more oriented to UVES data reduction.

More information on possible supported raw frames indicating which FITS keyword can be checked to univocally identify (from the pipeline point of view) a raw frame, and which keywords are used in the automatic association of raw frames to master calibration products are given in Appendix B. Recipe name, DO category, template name and DPR keywords are listed. It is addressed mainly to DFS users willing to cross check, for example, correctness of a Reduction Block.

2.1 The UVES instrument

UVES is a two-arms cross-dispersed echelle spectrograph covering the wavelength range 300 - 500 nm (blue) and 420 - 1100 nm (red) with the possibility to use dichroics. The spectral resolution for a 1 arcsec slit is about 40,000. The maximum resolution that can be attained with still adequate sampling, using a narrow slit, is about 110,000 in the red and 80,000 in the blue. For a detailed description of the instruments refer to e.g. [7]. UVES has also a fibre link to FLAMES, the Fibre Large Array Multi-Element Spectrograph, the multy-object, intermediate and high resolution spectrograph mounted at the Nasmith A platform of UT2 of the VLT. The fibre link to the UVES red arm is fed by eight fibres with a nominal resolution power of R=47000.

2.2 Required data

To reduce a science frame, the following calibration frames are available:

- Formatcheck frames
- Bias(es)
- Dark(s)
- Order definition
- Flat field(s)
- Wavelength calibration
- Reference standard star observation

It is also necessary to have handy a reference (ThAr) line table, and in order to process standard stars, an atmospheric extinction table, and a calibrated standard star flux table. DFO recently provides to PIs who got observation time with UVES also an extra table which may be used to calibrate in flux the science merged frame.

2.2.1 Formatcheck frames

It is necessary to have a special formatcheck frame taken with a ThAr lamp and a narrow slit. This is used in combination with a physical model of UVES and the information contained in the FITS header and in a ThAr reference line table, to find a "guess" solution of the spectral format (order locations and wavelength calibration). This allows the user later on to obtain robust and automatic spectral format solutions.

2.2.2 Biases

Bias frames give the read out of the CCD detector of zero integration time with the shutter closed. Usually they are taken as a set of 3-5 exposures from which, through stacking, a Master Bias is created thus reducing the read out noise. This needs to be subtracted for example from the science frame to get the signal contribution from the source only.

2.2.3 Darks

Dark frames are measured occasionally, for BLUE and RED arms separately, with the shutter closed. They are used to measure the dark current. They are measured for 1x1 and 2x2 binnings with typical exposure times of 1h. There are also open-shutter DARKs (since December 2001). They include, in addition to the CCD dark current, contributions from the camera enclosure. Typical values are reported on the ESO Website under www.eso.org/observing/dfo/quality/UVES/qc/dark_qc1.html As the contribution of UVES dark exposures may be considered, in first approximation, negligible, they can be excluded from the data reduction chain as we will assume here in the following section.

2.2.4 Order definition frame

An order definition frame is a calibration exposure obtained with a narrow slit illuminated by a continuum lamp. It is a very high signal-to-noise ratio echelle frame describing precisely the order location.

2.2.5 Flat Field frames

Flat Field frames are long slit exposures taken with a continuum lamp. They give information on the response of the detector, allowing to measure variations in efficiency at small (pixel-to-pixel), intermediate (fringing, in the far red) and large (the blaze function) scale. Usually they are taken as a set of 3-5 frames which after bias subtraction are stacked in a master to reject statistical outliers like cosmic ray events. The final Master Flat field is also background subtracted to eliminate diffused light from the orders in the inter-order regions. Science frames need to be corrected for pixel-to-pixel variations and the blaze function through division by the master flat field.

2.2.6 Wavelength calibration

Wavelength calibration frames are long slit exposures taken (for UVES) with a ThAr arc lamp. They are used to find the wavelength calibration solution.

2.2.7 Reference standard star

Reference standard star calibrations are observations of standard stars for which the emitted spectra is known and which allows to determine the following:

- The response curve (i.e. the conversion between the science spectrum and a flux calibrated spectrum). The response curve provides a relative calibration flux which is better than the correction by the flat lamp (which corrects for the order-by-order blaze function, but still contains the lamp spectral slope).
- The overall efficiency (DQE) of telescope+instrument+detector (corrected for atmosphere extinction). This function can be evaluated for trending.

The observer will be able to reduce science data of the following types when using the described calibration frames:

- Point-like sources. The UVES pipeline has been designed with the purpose to be able to reduce this kind of source.
- Extended sources. In September 2000 we introduced simple data reduction of this kind of source.
- Multi object sources. It is possible to reduce with some limitation in an interactive section more than one source on the slit.

Chapter 3

UVES Data Reduction

This chapter introduces the reader to the UVES pipeline data reduction. In the first section we give a short description of the main data reduction steps. We suggest the astronomer to read it before starting a practical data reduction section which is described in section 3.2. The syntax of each main UVES context command is given in the online help. A Troubleshooting guide is in section 3.3. More details on each data reduction step and UVES pipeline commands are given in chapter 4.

3.1 High level documentation

In order to fully reduce a set of images, including calibration and science frames, the following steps need to be complete:

- First guess solution generation
- Order definition
- Wavelength calibration
- Master bias, dark and flat field frames
- Instrument response
- Science reduction

3.1.1 First guess solution generation

This recipe implements the UVES physical model. This recipe is of crucial importance for the UVES pipeline for several reasons. It allows automatic data processing and finding (thanks to the use of a physical model of UVES) of good initial "guess" solutions. These are necessary, for example, to obtain a stable solution in the order definition or to allow automatic wavelength calibration with the guess method. Moreover it provides reference values to do instrument quality control and stability checks. It may use a formatcheck frame as a reference to measure instrument spectral format shifts and eventually spot when it is necessary to realign the instrument in the event of macro Earthquakes. It is also the first step in a chain of data reduction steps of the uves_obs_redchain recipe shell script which allows automatic production of calibration solutions to support all of the many UVES instrument modes.

In this step, the geometry of the spectral format (order position and wavelength calibration) is predicted. This will be refined in successive data reduction steps such as in the order position determination and in the wavelength calibration. Inputs are a ThAr formatcheck frame (a ThAr frame obtained with a short slit) and a reference line table. Products for each chip (BLUE, REDL and REDU) are: a Data Reduction Software (DRS) Setup table (the main product), an order table, a background table and a line table (1st guess). This step generates very useful quality control plots (see Figure 3.1) showing respectively the shape of XDIF (difference in X between model predicted and observed line positions) vs. X (1st plot) and vs. Y (2nd plot), the YDIF (difference in Y between model predicted and observed line positions) vs. X (3rd plot) and vs. Y (4th plot), and the plots of YDIF vs. XDIF (a combined plot of the previous ones, 5th plot) and of Y vs. X (to show how each different color corresponds to a different region in the detector, 6th plot). These plots are finally saved and called pm_w_CHIP.ps (where w is an integer number equal to the wavelength setting in nm and CHIP can be EEV or MIT).

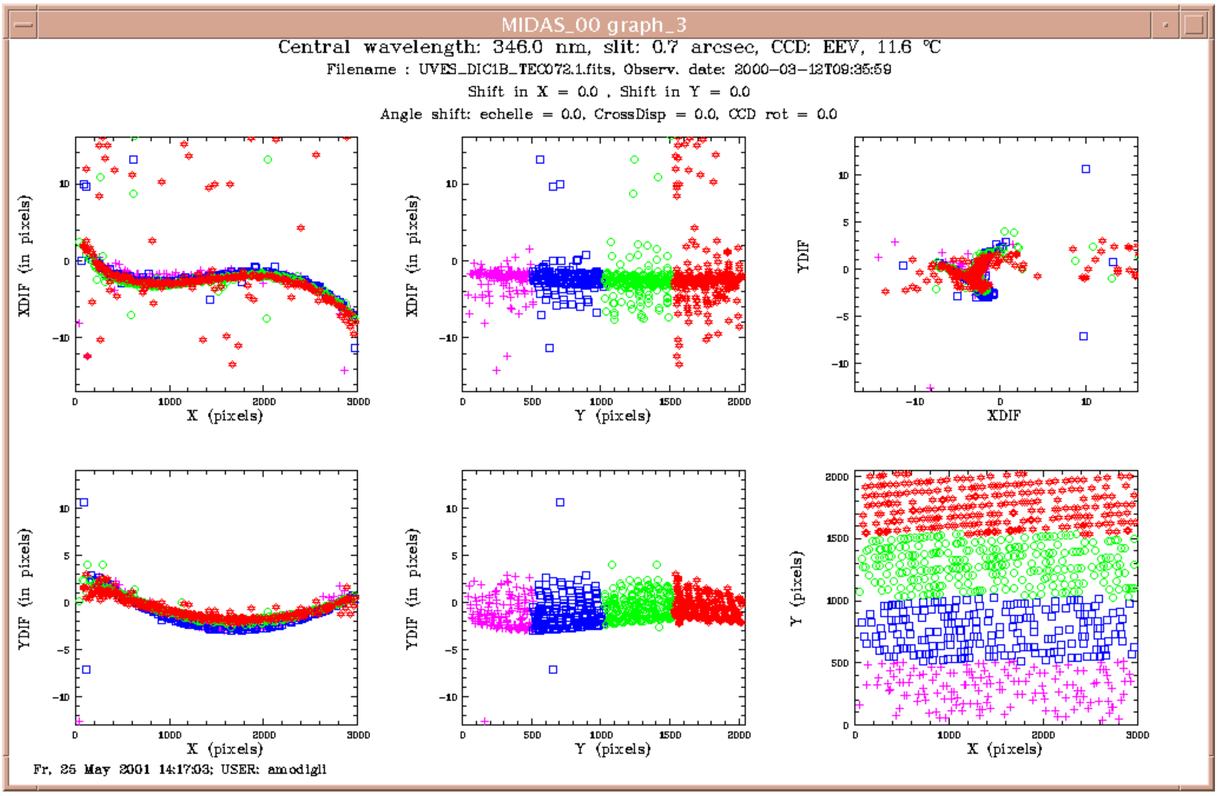

Figure 3.1: Physical model plots. A well concentrated distribution with mean ordinate zero is an indication of good matching between the model predictions and the line positions in a formatcheck frame.

As described in Ballester et al., "The UVES Data Reduction Pipeline", ESO Messenger No. 101, this step is successful if the mentioned plots, in particular the plots showing XDIF vs X and YDIF vs Y, show a well aggregated (sigma of XDIF and YDIF < 3-5 pixels) distribution of points possibly horizontally and centered at ordinate value equal to zero (see Figure 3.2). Vice versa, in the case of a scattered distribution of points, it means that the physical model predictions are not appropriate for the actual formatcheck frame in consideration. This may occur in the case of an instrument set-up misalignment, for example induced by a strong Earthquake, which results in formatcheck variations along Y greater than approximately 10 pixels (usually the physical model is robust enough to find a good solution for lower shifts).

The physical model finds a good first guess solution if the actual spectral format is stable within around $\pm$ 10 pixels in X or Y. The precision of the spectral format determination

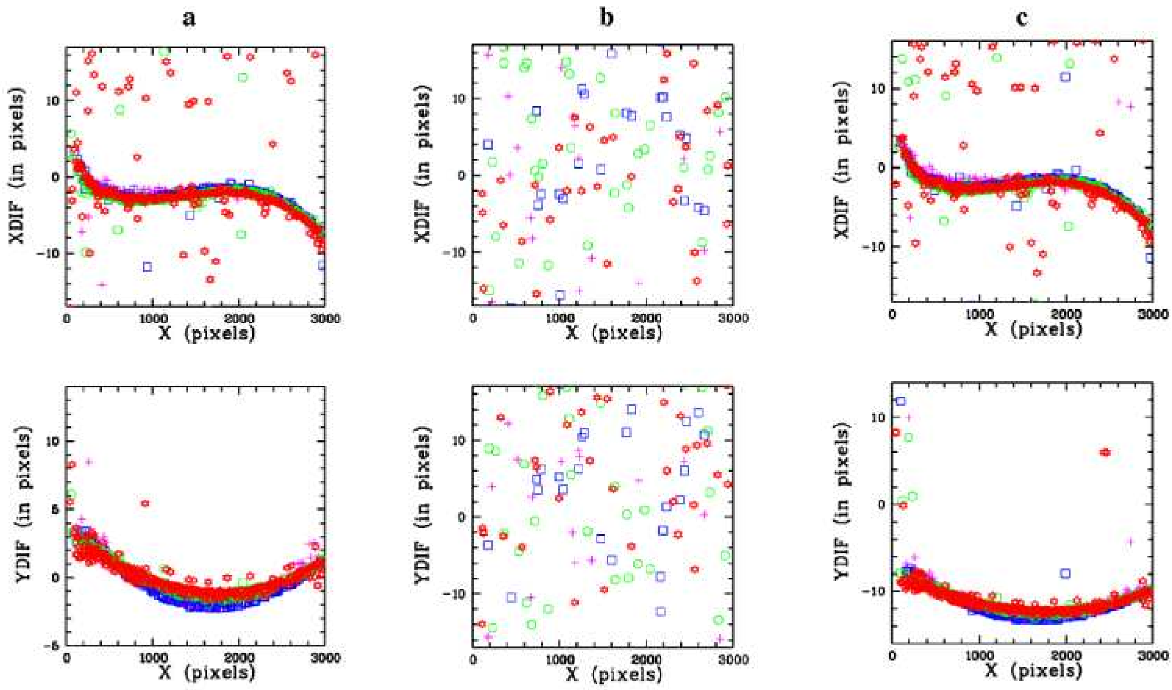

Figure 3.2: The May 12, 2000 earthquake event as detected from the physical model control plots. The normal result obtained after successful line matching (a) produces a well concentrated distribution with mean ordinate zero. The earthquake event causes the lines matching step to fail (b). Adjusting the model by -10 pixels (along the cross-order direction) again matches the instrument configuration (c).

as predicted by the physical model in the pipeline is the same as the one of the UVES ETC (which implements the same physical model). This precision is of the order of better than 2-3% for the Blue arm and better than 1% for the Red arm for the dispersion coordinate and better than 5 pixels on the value of the Y position. This precision refers only to the guess solution. The actual precision reached by the wavelength calibration is reported in the README file associated with the delivered data.

In case one receives data which give physical model plots with a complete scatter of points, we describe here shortly how to recover a good solution during interactive data reduction.

The parameters to be changed are (see the help for the command PREDICT/UVES) **mbox, trans, angle**, corresponding respectively to parameters P4, P5, P6.

The parameter **mbox=mboxX,mboxY** is the measurement box within which a matching line is searched. This multiple parameter should be increased to be able to more likely match the line position as calculated by the physical model with the corresponding line position on the detector. The detected line should fall into the box centered on the line position calculated by the model.

The parameter **trans=transX,transY** contains respectively, the X and Y translation components to be applied to the model to recover the solution. If the point distribution is scattered, it means that a significant shift (approximately > 10 pixels) has occurred in one (or both) directions. In this case one should try to variate X and/or Y (one parameter at the time) by steps initially of 3 pixels until a better concentration of points is reached, refining the solution at 1 pixel step.

Version 2.1.0 in case one leaves the default setting of **trans** to 0,0 it applies a shift of 6.5 pixels for the MIT (upper) chip (transY=6.5). If the user would like to modify this value instead the command FMTSTA/UVES and PREDICT/UVES uses the user defined values. This information should be taken considered by a user willing to improve a plot obtained using parameters defaults.

Another parameter to be changed eventually is **angle=echAngle,CCDangle,CCDrot**. Typically **echAngle** should be kept constantly equal to zero. More likely one should change **CCDangle** and/or **CCDrot** (one at the time) in steps of 0.01-0.1 deg until a better distribution is reached.

The parameters **trans** and **angle** should be varied one at a time initially chosing a high value of **mbox** (80,80 or 70,70) and next, when a good solution is found, verifying that the quality of the plot remains almost the same even when one decreases the value of **mbox** parameters to 40,40 (standard values). Shifts of instrument spectral format are more frequent along the Y direction, which could be recovered by modifying just the corresponding **offset** parameter. In case of non-standard observational settings taken with a camera tilt (which implies in an **offset** along X direction), if any data reduction problem is noticed, one can try to recover the solution by adjusting only the offset along the X direction.

To proceed easily and quickly in this operation one should follow the following steps:

1. Use as master formatchecks, frames that result in physical model plots with a very good aggregation, and having the same instrumental setting as the one which is not giving a very precise aggregation, and set their ESO.PRO.CATG value to MASTER_FORM_x (x= BLUE or REDL,REDU). These can be found in directory fluves/calib of the release tar file.
2. Use them and the current formatcheck frame to quickly evaluate Y and X **trans** (shifts), using the commands LOAD/IMA and GET/CUR.
3. Use the master formatchecks (lower and upper chip frames) and the Th-Ar Line reference table, put them in a reference catalogue, and use the command FMT-STA/UVES to do the formatcheck step on the Fibre FF data, using as P4 (match window) parameter values 80,80, and for P5 the **transX, transY** values previously determined.
4. Iterate the previous step by adjusting P5 (`xy_trans`) and using the information provided by the Xshift and Yshift values reported from the stability test until the points converge. In practice one has to add the value (with sign) of the found shift to the corresponding `xy_trans` component until the value of the shifts become less than one pixel for each component.
5. Try to reduce the P4 (`xy_mbox`) value gradually to 40,40. Repeat the two previous steps. When the X and Y shifts are smaller in absolute value than 5 pixels start to reduce P4 at 10 pixels steps from 80,80 to 40,40 until one get with 40,40 X and Y shifts values less than one pixel shift.

3.1.2 Order definition

In this step the order positions are determined. The inputs are a short slit flat field frame and a DRS setup table.

Optional input is the guess order table created by PREDICT/UVES or FMTSTA/UVES. We recommend the user to provide this extra input as we found that otherwhise occasionally the order table generated by this step may be misaligned with the guess line table created by the physical model and consequently the wavelength calibration and the science reduction may be affected. That problem was due to the fact that while the physical model to insure robustness and stability of the solution traces only orders which traces more than half of the chip, the command ORDERP/UVES finds a number of orders equal to the predicted ones indipendently from their location. This pipeline introduces a check if the user provides the guess order table which insure that the guess order table (and so the gues line table) are aligned with the final order table.

The main product is an order table. Other products are a background table and an updated DRS setup table.

This command does a Hough transform on the thin flat field frame searching for a number of orders equal to the one predicted from the physical model and eventually correcting this number in the case the light distribution has a sudden drop (induced for example by the presence of some filter along the light path).

3.1.3 Wavelength calibration

This step performs the wavelength calibration using the previously determined solution for the first guess line table and the order table. A wavelength calibration solution is produced for each of the three (sky1, obj, sky2) extraction windows. The wavelength calibration is based on the ECHELLE context MIDAS commands EXTRACT/ECHELLE SEARCH/ECHELLE, IDENTIFY/ECHELLE.

The orders are extracted (EXTRACT/ECHELLE) using the average method. Three extractions are performed. In the first, the object is extracted with a default extraction slit of 15 pixels and its offset is measured with respect to the trace of the order. Next two extractions, when done with appropriate offsets and extraction windows, allow to evaluate the sky contribution.

Using a proper setting of parameter P8, with an interactive data reduction, one may also specify proper offset(s) and extraction windows for the object and the sky. For more details on this particular solution please refer to the help of the command WAVECAL/UVES.

The reason the UVES pipeline has set a reasonably small value for the object extraction slit is that it has been designed to do automatic extraction of point like sources centered on the slit. 15 pixels corresponds in the blue to approximatively 3.75 (CD1-CD2) and in the red to 2.7 (CD3) and 2.55 (CD4) arcsecs which should be enough to have, in the extraction slit, most if not all the point-like sources in a good seeing condition (< 0.8 arcsec).

To reduce to the minimum the sky contribution to the noise, the extraction slit should be the shortest one which includes the object and the minimum sky contribution still sufficient to clearly distinguish the object contribution from the sky one. This condition also allows the pipeline to determine the sky contribution very well, leaving all the remaining slit length to the sky extraction slits.

As the UVES instrument is highly non linear it is important to determine different wavelength calibration solutions on different positions along the full slit length. The command SEARCH/ECHELLE searches for calibration lines in a given wavelength calibration echelle spectra. The threshold value (relative to the identification of the local background) is initially set equal to 10% of the median of the intensity of the extracted spectra. The emission lines are searched, eventually decreasing the threshold until a sufficient number (1000) of lines is identified.

The line identification is based on the MIDAS command IDENTI/ECHELLE. The line positions are initially assumed to be the ones found by SEARCH/ECHELLE. This step is repeated twice. First using the following setting: TOL, DC=5, WLCOPT=1D, where TOL is the tolerance setting in the DRS setup table. TOL is the tolerance on the global rms error of the dispersion relation. It gives in pixel units the threshold above which outliers are removed. Relaxing TOL means to accept less accurate global dispersion relations and increase the possibility of misidentifications. It should be kept less than 1. The default value 0.6 adopted for TOL has demonstrated to be good in terms of final precision and robustness of the algorithm. Higher accuracy (at the possible prize of a decreased robustness) may be obtained decreasing this value down to 0.07 (using the improved ThAr reference table, thargood_3.tfits). This value, stored in the DRS setup table, is set at the first time the DRS setup table is created during the data reduction chain, i.e. during the formatcheck step. DC is the degree of the polynomial defining the dispersion relation. WLCOPT specifies the dispersion relation type.

Next, the step is repeated using tolerance TOL, DC=4, WLCOPT=2d and the object line table is used as the reference line table with the GUESS method. The reason one does a first identification with 1D polynomial and high value of its order is to increase significantly the number of line identifications coming from the guess solution found with the physical model. Later on a 2D solution with lower degree guarantees to get a better solution on the global wavelength range. The tolerance TOL is automatically adjusted by the command IDENTI/ECHELLE to take into account the eventual binning along the dispersion direction.

For quality control purposes, it is important to check at the end of each calibration process, the plot of the residual difference in wavelength between the lines listed in a reference line table and the corresponding values found from the calibration. This plot gives an indication of the precision (the ordinate is expressed in Angstrom units) of the wavelength calibration at different order values (see Figure 3.3).

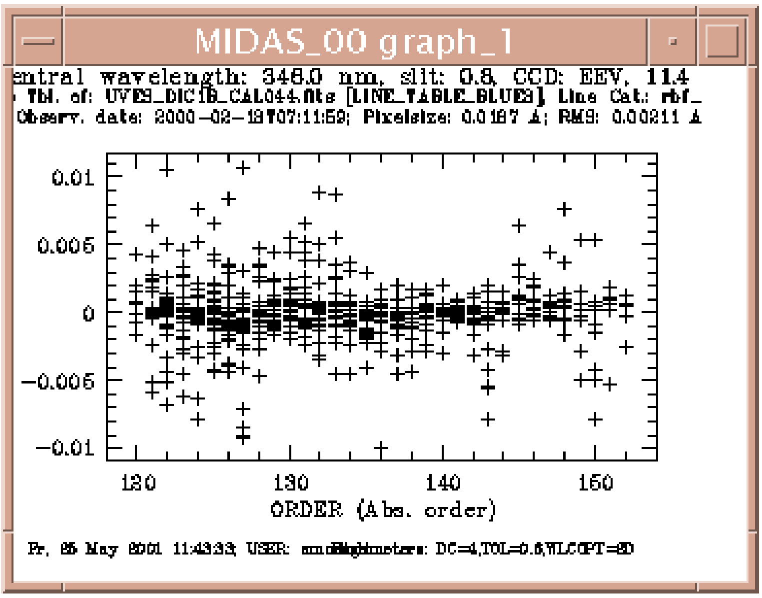

Figure 3.3: The residuals plots give an idea of the reached precision for the different orders during wavelength calibration. In the plot the residuals (the differences between the positions of the lines listed in the reference table and the corresponding values as found in the frame, expressed in Angstrom units) as a function of the order positions are reported.

After having determined the wavelength calibration solution for the object extraction window, resolution plots are produced. These plots display DX (line FWHM) as a function of X (1st plot) and Y (4th plot), the resolution as a function of X (2nd plot) and Y (5th plot) and λ (3rd plot), with different colors corresponding to different regions of the detector (as displayed in the 6th plot). Useful information is also provided in the header of the image such as the central wavelength, the slit width CCD and temperature settings, the filename and the observing date, the median, the mean and sigmas of DX of the resolution (see Figure 3.4). This plot is also saved with name resol_lWLEN_CCD_BINNING_2.tbl.ps, where WLEN is the central wavelength setting, CCD is the CCD ID (EEV or MIT), BINNING is the binning setting, 2 is the object extraction slit identification number.

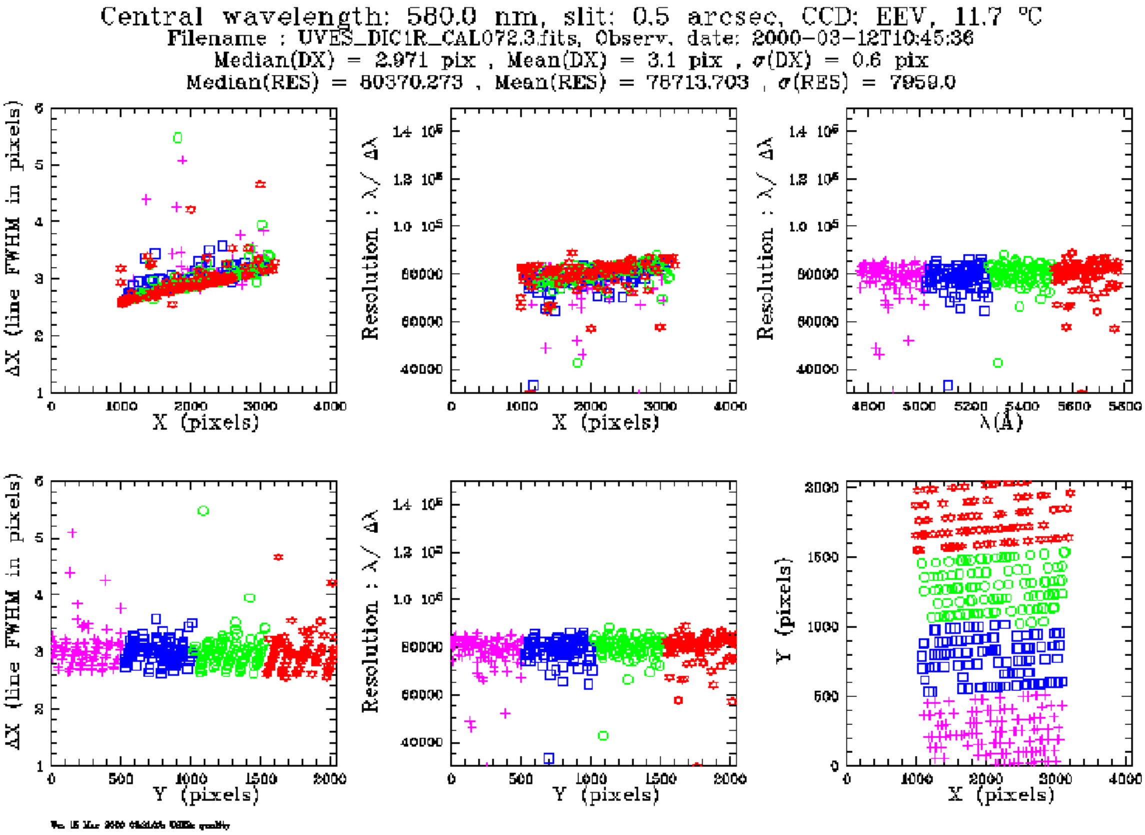

Figure 3.4: These plots show the FWHM of ThAr lines (left) and the instrument resolution (centre) as a function of the position on the detector along the X and Y directions, and finally the resolution versus wavelength (upper right) and the distribution of measured lines over the detector (bottom right).

3.1.4 Creation of master bias, master dark, master flat frames

During this step a master bias frame is produced from a set of biases, a master dark is produced from a series of darks (darks are not frequently taken for UVES) and a master flat is produced from a set of flats.

The master frame is created through a medium stacked mean. Master darks and flats are also successively bias subtracted. The master flat is also background subtracted. In general, the background subtraction is done by fitting a low order polynomial (the method POLY is usually more stable), or using a spline function (the method SPLINE is usually more precise but not always stable), or using a smoothing function (method SMOOTH).

Other parameters affecting the background extraction are BKGDEG, which specifies the degree of the polynomial fitting along the Y direction; BKGSMO, which defines the radius of the filter/smooth applied in the determination of the background and BKGSTEP, which determines the cadence step with which the frame that evaluates the background is sampled. BKGRAD (radX, radY) determines the dimension of the box inside which the background is determined.

The background measurement (bmeasur) is also an important parameter which can be set to MINIMUM or MEDIAN. In the case of a SPLINE background determination, a fit of the MINIMUM or of the MEDIAN of the background positions inside the measurement box is done.

In the pipeline release version 1.1.1, we included some modifications in the background estimation as a result of the very careful analysis of the extraction quality of the background in POLY and SPLINE methods. The previous background extraction, in case of Flat Field, was taken using the POLY method (which is numerically more robust) and POLDEG=4,5 BKGDEG=3, BKGSTEP=100, BKGSMO=1000, BKRAD=10,2, bmeasur=MINIMUM. For the science extraction, a method SPLINE was used. Method POLY, bmeasur=MINIMUM, and fixed BKGSTEP, demonstrated to be inferior to method SPLINE, appropriated parameters, bmeasur=MEDIAN mainly as:

- Method POLY may have problems near detector borders in particular on the left hand side where also the detected signal is very low.
- MEDIAN method is usually more appropriate than MINIMUM except when the inter-order space is too low (less than typically 4-5 y pixels) or even zero. In these cases (which may occur if the frame is taken with a slit greater than the standard setting) the method MINIMUM gives better results. In these non standard cases, the decision (to flat field the image) is left to the user.
- In the case of BLUE binned frames to have a BKGSTEP=100 implies (in case of 2x2 binning) having only 15 window points over which the background is estimated, this leading sometimes to a not very precise extraction. A better choice would be to have a BKGSTEP which self-adapts to the size of the active detector area and to the detector binning.

In the end, after several tests, we decided to assume the following default parameters, both for science data reduction and master FF generation:

SPLINE, MEDIAN, BKGDEG=1, BKGSMO=0, BKGSTEP=50*{sizeX}/4096,
BKGRAD=25*{sizeX}/4096,2 and to have a post smoothing after extraction with radX and radY radii which depend on the frame and on the wavelength setting. Having slightly smaller radX values in background estimation on Flat Field images demonstrated to be more precise with a significant improvement with respect to the previous parameter setting, in particular in the regions where the signal is very low. Background extraction from science frames (also during efficiency determination) is taken with radX values greater than in the case of Flat Field frames, as obviously science frames usually have lines (which must not affect the background estimation) which are not present in the flat exposures.

In the RED 860 setting for which the frame shows a lot of structure, we have chosen quite a wide radY smoothing value. With BKGSMO=0 and BKGDEG=1 it is possible to fit exactly the background points with a linear spline. BKGSMO gives the average size of residuals after the extraction. A BGKSMO value of 1000 corresponds to having, on average, final residuals between fit and raw image, of the order of 1. So BKGSMO should be kept very small. To have a smooth background image on the contrary, BKGSMO should be not too small. The problem is that with values BKGSMO=50-1000 the extraction quality with method spline, in some cases is not very precise in the detector regions where the signal is low. When BKGSMO is small (2-50) one can notice a significant increase in the computation time. So, it was finally decided to adopt BKGSMO=0 and to do a post smoothing of the image to remove residual local sharp background variations.

The adopted parameters demonstrated to be appropriate to get a good and robust background estimation on all the possible instrument settings. In the extreme blue, where standard lamps give less intense flat images, to have better flat fields the user can ask to have them taken with a LN2 lamp. The parameter P4=bmode specifies if the subtraction of the master bias (M) should be done using a smoothed version of the master bias (S), the average of the master (A) or a constant ($< num >$). Similar to P4 is P5 applied to the master dark subtraction.

3.1.5 Instrument response and efficiency determination

During this step the instrument response function and the telescope+instrument+detector detection efficiency is determined. In the automatic pipeline processing the following UVES context commands are executed in cascade: REDUCE/UVES (method optimal) which extracts the STD star. For a description of this data reduction step we invite the reader to look at the Science reduction section.

RESPONSE/UVES which determines the response of the instrument by comparing the wavelength calibrated frame with the corresponding reference spectrum of a catalog.

During this step the reference spectrum (ALIGN/STD) is first extracted by comparing the coordinates of the standard star measurement with the ones of the reference standard star catalog and storing the resulting spectrum in a table. The name of the identified standard star is returned (let's call it std_star_name). The table containing the std star spectrum will be called std_star_name.tbl.

Next, the instrument response is determined, doing first a FILTER/MEDIAN of the reduced input spectrum, and a FILTER/SMOOTH, to smooth out sudden jumps. Next the ratio between the reference flux table and the extracted standard star spectrum is calculated. This ratio is cleaned to eliminate the possibility of having boundary effects. This finally gives the instrument response (stored in the file resp_UVES_CCD_CD_ID_ARM.bdf where (CCD is the detector CHIP name, EEV or MIT, CD_ID is the Cross Disperser ID, ARM is the selected ARM, BLUE or REDL,REDU).

The main data product of this step is the merged response. This is used to calibrate the reduced merged science spectrum in flux. Other products are the wavelength calibrated response and the reference flux table of the standard star.

EFFICIENCY/UVES-computes the efficiency of the telescope+instrument+detector. In this step the reference spectrum is extracted (ALIGN/STD) and the efficiency is calculated. After the definition of several involved constants, the background is subtracted from the science frame. The instrument response is calculated as the ratio between the extracted rebinned spectrum and the standard star tabulated flux

The instrument DQE is determined: the response is merged and rescaled to take into account the atmospheric extinction. After computation of the effective counts per ergs (*ctsperg*) and of the conversion factor between ergs and second (*erg2phot*) the following formula is used:

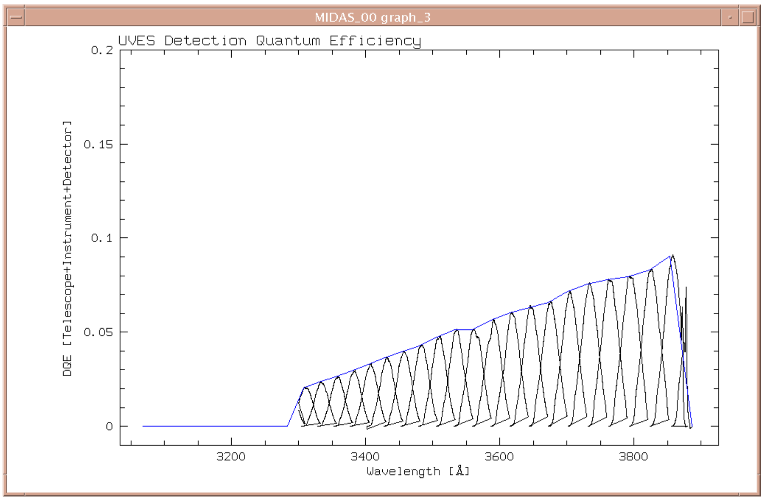

Figure 3.5: The UVES pipeline also produces plots of the instrument efficiency which could be used to monitor the instrument health and, from time to time, upgrade the UVES Exposure Time Calculator predictions.

$$eff = \frac{ccd\_gain}{nphot}$$

where

$$nphot = \frac{1}{ctsperg} \cdot erg2phot \cdot binsize \cdot texp \cdot Atel$$

and *binsize* is the detector bin size *text* the exposure time and *Atel* the effective telescope area. In the end the efficiency at each order is displayed on the main graphical window (MIDAS_NN_graph3, see Figure 3.5). This graph is also produced in form of a postscript file called eff_x.ps (x=BLUE,REDL,REDU). The main product of this data reduction step is the efficiency table (eff_x.tbl).

3.1.6 Science reduction

Science data are reduced applying several steps:

- The input raw frame is transformed (rotated and flipped; red frames are split in two corresponding to the two red CCDs), the pre and overscan regions are chopped off. The bias is subtracted using a master bias frame.
- Should the line and order table be misaligned (this may occur in previous releases to 2.9.7) the recipe finds on the fly an order table aligned with the line table.
- The inter order background is subtracted. For more information on this step see earlier what was written for the corresponding step applied during master flat field generation.
- In case the FF method is set to "P" (pixel-to-pixel space), the processed frame is divided by the flat field. This solution may be valid for very long wavelength settings (Red 860) to remove the fringing effect.
- The orders are extracted using the OPTIMAL or AVERAGE methods following the order trace position solution contained in the order table. In the case of OPTIMAL extraction, the sky subtraction (both continuum and lines) and the cosmic ray rejection are automatically performed, since optimal extraction assumes a Gaussian

shape profile for the object. Optimal extraction assumes full slit as extraction slit. In AVERAGE extraction mode, cosmic ray rejection is not performed, and it is necessary also to extract the sky. The pipeline, originally designed to extract point like sources, assumes the object extraction slit as being 15 pixels wide, centered on the object. On two sides, two extraction slits are defined for the sky (if there are at least 4 pixels of space, otherwise only one extraction window, above or below the object position, according to the value of the object position offset). The appropriate setting of the parameter P7 (see help of REDUCE/UVES) can switch on/off ([Y]/N,[Y]/N,[Y]/N) the automatic setting of the offset, the extraction slit and the sky window (this is used only in average extraction) parameters setting. The option N of the correspondent sub parameter allows the user to set, at will, each parameter (using the MIDAS commands SET/ECHE and SAVINI/ECHE). If only one sky window is considered, "dummy" results for the other sky extraction windows are produced. These are labeled using the prefix "dummy_" for the correspondent pipeline data products. This decision was adopted because, for operations, it is important to keep the same data numbering schema and sequence of the pipeline data products.

- In the case when the FF method is set to "E" (default setting for the automatic pipeline data processing), flat fielding occurs during extraction. In such a case the flat field is extracted with the same method as the object and after extraction the extracted object is divided by the extracted flat field. If the FF method is set to "N", no flat fielding is performed. This is suggested in case one has not got a good flat field which may happen for certain periods in the extreme blue.
- The background-subtracted, extracted, flat fielded object is wavelength calibrated and finally merged.
- Merging can be done using optimal or average methods and by controlling the subcomponents of the parameter P5 in REDUCE/UVES for the values of spectra overlapping on the red and blue sides of each order.
- In case of Average extraction, each sky is extracted and (if the flat field method is set to "E") the flat field is extracted in the appropriate sky window, and if appropriate the sky is flat fielded, wavelength calibrated and merged. Finally, in case of average extraction, the mean of the two merged skies is subtracted from the merged object.

3.1.7 Notes on optimal extraction

During OPTIMAL extraction, the orders are rectified taking into account the order table and are virtually resampled (process in which the intensity of the echelle spectra is redistributed in the new rectified spectra). This step should remove all the order inclination and curvature. Next the algorithm determines the distribution of the object's Y position and cross order FWHMs along the order. To obtain these with a good precision the algorithm divides the order in chunks collapsing along the dispersion direction a number of columns (presently 32). The obtained distributions are expected to be approximately uniform. Indeed it has been noticed that a residual inclination and a curvature, both of the order of a fraction of a pixel, are still present after rotation either in the distribution of the center positions of the Gaussians in the cross order profile of each chunk or in the distribution of the FWHM. For this reason, a parabolic fit of the object distribution of positions and FWHMs with appropriate k-sigma clipping is performed to eliminate outliers. The resulting fit, together with other relevant parameters, is stored in a table, called order_trace_x.tbl (x=BLUE or REDL, REDU). Using the command MPLOT/CHUN [order_trace_x.tbl] [y_half_size] [switch] where switch can assume values "position" or "fwhm", one could create a multiple plot (see Figure 3.6). This shows the corresponding distribution of original chunk points (black), initial fit (green), final fit (blue) and points considered in the final fit (magenta). These plots are very important to assess the quality of the order tracing. A very good fit should not differ from the original distribution by more than 0.1-0.3 pixels, at least when the original point distribution is well aggregated.

For low S/N data, where usually the uncertainty of determination of each position (or FWHM) is higher, the Gaussian fit may be less precise and in case the slope or the curvature of the parabola exceeds some limits it may be automatically switched to linear or uniform in the worst cases. Such scatter might sometimes be due to the presence of unremoved cosmic rays. In fact, the step that fits the distribution of position/FWHM values is performed on each order after their division in chunks by the associated intensity integration, but before the step of cosmic ray removal through a k-sigma algorithm is performed. In cases of very low S/N data contaminated by cosmic rays, a cosmic ray may significantly modify the position/FWHM distribution. In such cases one could apply the command FILTER/COSMIC on the science data before doing optimal extraction.

Once the fit of positions and FWHMs has been performed, the routine evaluates the intensity (amplitude of a Gaussian cross order profile) and the background (base of the Gaussian) and does a k-sigma clipping with threshold equal to 5 sigmas plus an additional term quadratically proportional to the rough medium of the S/N value at the center of the order. The k-sigma clipping is used to remove cosmic rays (for low S/N data). The threshold is relaxed to get an AVERAGE extraction in case of high S/N data.

OPTIMAL extraction should be used for low and medium S/N data as it automatically removes cosmic rays. This improved version of optimal extraction (from this pipeline release, 2.9.7) the optimal extraction works quite well also with high S/N data. For very high S/N data, where the effect of the cosmic rays is negligible and there is no need to improve S/N, it is advisable to use the AVERAGE extraction method.

Using the command MPLOT/BKGR it is possible to monitor the quality of the background extraction (see Figure 3.7).

If more than one object is present on the slit please consult section 3.2.12 on page 36. For extended sources please consult section 3.2.13 on page 39.

3.2 How to use the MIDAS context UVES: a cookbook

This section describes the usage of the commands of the MIDAS context UVES which allow the user to perform a complete science data reduction. 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 ECHELLE context.

The UVES context itself is based on the ECHELLE context. The development of the context has been developed under the MIDAS version 98NOVpl2.1 and succesives. We describe how to produce master calibration frames, order position and background tables as well as line tables used for the re-sampling into the 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 described. Finally, session examples to do data reduction of BLUE or RED data are reported. In the following examples of UVES data reduction we suggest the user to use as temporary table products in MIDAS format names of maximum 8 chars (plus extention .tbl: e.g. longname.tbl).

3.2.1 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 mon-

[1] `flmidas` is an alias to (if it does not exist it is useful to create)
`inmidas -j '@d pipeline.start; @d pipeline.control D;set/context flames $PIPE_HOME/uves/context'.`

itor 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.

3.2.2 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 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.

3.2.3 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	LIine 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).

3.2.4 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 wavelenght 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`).

3.2.5 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`.

3.2.6 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. See also section 4.1.5 to have more information on the background extraction. 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 3.2.12).

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 correspondent 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 has been solved thanks to a collaboration with Michael Murphy. For very high S/N (¿ 200) data, the user may still want to use 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 this 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 slopeness and curvature typically of a small fraction of pixel (see Figure 3.6 on page 54). 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 slopeness 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 fx_).

3.2.7 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.

3.2.8 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 satus.

3.2.9 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.

3.2.10 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.

3.2.11 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).

As described in chapter 5 it 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.

3.2.12 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.

3.2.13 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 lengh 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 correspondent 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 recognise that the corresponding operation does not need to be repeated. If the user has allready 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 correspondent 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 correspondent 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.

3.2.14 Session example: Blue Data

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

Default Display Initialization

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

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
```

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
```

Wavelength Calibration

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

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
```

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
```

Science Reduction

```
Midas> SPLIT/UVES sc_346.fits
Midas> REDUCE/UVES sc_346_b.bdf reducedB.cat refB.cat E 0 MED
```

3.2.15 Session example: Red Data

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

Default Display Initialization

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

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
```

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
```

Wavelength Calibration

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

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
```

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
```

Science Reduction

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

3.3 Troubleshooting guide

We present here a selected list of known problems with a possible solution indicated. In case the user might find new problems, please send an e-mail to midas@eso.org or to usg-help@eso.org. DFO and PSO can submit a Software Problem Report.

3.3.1 Installation problems

setup

Symptom(s)

- The installation fails
- Some compilation error message is given, this being missing the binary **ar**.

Possible cause(s)

- The binary **ar** is missing.

Proposed solution(s)

- Run the command `which ar`. If you have as an answer an empty line, it means that the command is not in your path. Ask your local system administrator what is necessary to add in your path.

Justification Installation procedure assumes you have a minimal set of UNIX commands available.

setup

Symptom(s)

- compilation failing

Once a user reports the following error message:

```
/usr/im/midas/99NOVpl2.2/local/default.mk:97:
/export/diskd/dmd_df/esomidas/99NOVpl2.2/local/make_options:
No such file or directory

make[1]: *** No rule to make target
'/export/diskd/dmd_df/esomidas/99NOVpl2.2/local/make_options'.
Stop.

make[1]: Leaving directory
'/a/snijor/export/home/snijor1/randich/pipe/uves/pipe/proc'
```

Possible cause(s)

- Improper MIDAS installation
- The file $MIDASHOME/$MIDVERS/local/default.mk has the first 2 lines, setting the values of $MIDASHOME and $MIDVERS, not as you would expect.

Proposed solution(s)

- Ask your local system administrator to correct the default.mk file.
- Ask your local system administrator to reinstall (correctly) MIDAS.

Justification The installation of MIDAS was not correct. One possibility could be that, after installation (which sets such two lines accordingly to the $MIDASHOME and the $MIDVERS of the release being installed), the directory location of the MIDAS package has been moved elsewhere, not updating such lines. So even if you are pointing with $MIDASHOME to the right place where MIDAS actually is, such file which, if sourced, sets several default environment variables useful for the installation of the UVES pipeline, silently changes $MIDASHOME so that you cannot find it later on other necessary files.

UVES context initialization

Symptom(s)

- You get the message

```
mode(3) = 0
^^^
Invalid or non existing key name ...
Keynames (max. 15 chars.) have to begin with a letter.
Local keynames should not match system keynames like e.g. USER, LOG, ERROR, ...
```

Possible cause(s)

- You have initialized your section in a way incompatible with your MIDVERS (02FEBpl1.1 or successives).

Proposed solution(s)

- In your alias flmidas (see 3.2.1) you have used `mode(3) = 0` instead of `mid$mode(3) = 0'`. Use `mid\$mode(3) = 0` if you have bash.

Justification From MIDVERS=02FEBpl1.1 on conventions have been changed to not have conflicts between global keywords used from MIDAS and from UVES pipeline.

Problem in using computers with 32 bits deph color display

Symptom(s)

- Several problems during data reduction and execution of several commands of the UVES pipeline (involving the display).

Possible cause(s)

- You have a computer with a 32 bit (true colour) deph screen.

Proposed solution(s)

- Give the command `init/disp p5=rgbq` before the command config/display.

Justification This is a known problem not yet solved at low level (MIDAS).

Problem using the scripts

Symptom(s)

- Error messages are reported, no window is displayed.

Possible cause(s)

- In your path are not defined the commands: `xdialog` (HP-UX), or `xmessage` (SunOS,Linux,OSF1)

Proposed solution(s)

- Check to have in your path the specified commands

Justification The given commands are used to display messages. If not defined you get an error.

Symptom(s)

- When you run the script a window is popped up, but reports the error: cannot execvp inmidas

Possible cause(s)

- You have `inmidas` defined as an alias. This is an error.

Proposed solution(s)

- Unalias `inmidas` and check that the command `inmidas` is in your path:
- `unalias inmidas`
- `which inmidas`

Justification inmidas should be in your path and not defined as an alias to be an executable from the shell.

3.3.2 UVES context commands

PREDICT/UVES

Symptom(s)

- In the output plots, the XDIF-X and YDIF-X plots do not appear as elongated "clusters" of points with characteristic size $\approx 3 - 5$pixels, possibly horizontal and centred at ordinate value zero, as they should, but show loss of aggregation or, even worse, scattered points.
- Later on, during data reduction, the wavelength calibration step fails.

Possible cause(s)

- The format check frame you are reducing is considerably shifted with respect to the standard case (possibly due to an occasional instrument spectral format shift induced for example by a macro earthquake).

Proposed solution(s)

- See HELP file and high level documentation on page 3.1.1 on how to adjust the parameters of the physical model.

Justification This step uses the UVES physical model to predict the spectral format. Such a model has been calibrated during UVES commissioning, choosing appropriate values of its parameters to cover all the main settings. These are specified internally into the physical model code. At the same time reference formatcheck frames have been taken to check for the instrument stability. Should a significant earthquake event occur, this can be detected during Operations, and the instrument is realigned to the reference configuration. The user will not receive such data.

Symptom(s)

- The steps fails
- The formatcheck frame image shows a very dim or non detectable order trace.

Possible cause(s)

- The calibration exposure has been aborted. This results in a frame with not enough signal to detect the order trace.

Proposed solution(s)

- In this case there is no solution. Usually in such cases at least another frame is taken so that the user should have at least one good frame to reduce his data.

Justification(s)

- Operations may require to abort a calibration. In such cases the calibration is repeated so that the user always has a complete, good data set.

ORDERP/UVES

Symptom(s)

- The traces of the found order positions do not overlap with the ones of the actual frame.
- A number of orders, different from the one visually detectable is found.

Possible cause(s)

- The predicted number of orders (stored in keyword NBORDI), is greater than the actual number of orders detectable on the frame.

Possible solution(s)

- Check overlayed position of orders on image. In case of unsatisfactory results, standard ECHELLE keywords can be adjusted (NBORDI; SET/ECH NBORDI=....).

Justification(s) This problem is due to the fact that a geometrical format check is initially predicted from the physical model. This may not take into account the actual instrument configuration (in particular the presence along the light path of filters which may suppress light in certain regions of the detector) and so there could be a discrepancy between the predicted geometrical spectral format and the actual physical distribution of the light. From pipeline version after 1.0.3 this problem has been fixed through a quality check on the SIGMA value of the :RESIDUALS column in the Order table (STATISTIC/TAB). If this has a value greater than 1 Å, NBORDI is decreased and the Hough Transform is repeated.

ORDERP/UVES

Symptom(s)

- The traces of the found order table are not aligned with the one of the guess order table (or of the guess line table).

Possible cause(s)

- The formatcheck and order trace frame are slightly shifted one to the other or the illumination of the frames is different.
- The user has not put in the reference catalog the ORDER_GUESS_TAB_x (x=BLUE or REDL,REDU) table.

Possible solution(s)

- Add in the reference catalog the ORDER_GUESS_TAB_x (x=BLUE or REDL,REDU) table.

Justification(s) This problem is due to the fact that the guess order table generated by the command PREDICT/UVES (or FMTSTA/UVES) on purpose traces only orders which are present on at least half of the detector's chip. This to insure a robust wavelength calibration and a uniform data reduction.

On the other hand the command ORDERP/UVES performs an Hough transform on the whole detector's chip and thus may identify also orders which have a very short trace. As the number of order traces searched is by default the one predicted by the physical model, which is less than the number of traces actually present, due to possible spectral format instabilities or detector non-uniform illumination it may happen that different traces are detected, and that the guess order table is not aligned with the table produced by this command unless one imposes a constraint on the detector area where order traces are searched. This is possible providing in input the guess order table generated by PREDICT/UVES (or FMTSTAB/UVES).

WAVECAL/UVES

Symptom(s)

- The step fails.

Possible cause(s)

- This step may fail in case the right DRS setup table is not used. This may happen if the central wavelength parameter of the instrument setting is not standard.

- This step may fail if the initial line guess solution produced by the UVES physical model on a formatcheck frame (PREDICT/UVES), is not appropriate. See above.

Proposed solution(s)

- In such cases one should use the uves_popul.sh script and a complete calibration data set taken with the same instrument setting to produce the right set of calibration data.
- In case the PREDICT/UVES has not given a proper solution, see above in the troubleshooting for PREDICT/UVES how to recover a good solution.

Justification

- The wavelength calibration can work in an automatic way only if a good guess solution is given. This is the one generated by the UVES physical model on a formatcheck frame (PREDICT/UVES) corresponding at the same instrument setting on which the ThAr frame is taken to do the wavelength calibration.
- In case the PREDICT/UVES has not given a proper solution, see above in the troubleshooting for PREDICT/UVES for proper justification.

Moreover, we also suggest to check residuals of wavelength calibration and resolution plots for quality assessment.

WAVECAL/UVES

Symptom(s)

- The precision of the found wavelength calibration is not sufficient.

Possible cause(s)

- Too high tolerance value adopted.

Proposed solution(s)

- Reduce the tolerance. If you like a nominal value of the tolerance (which will be automatically rescaled in case of spectra binned along dispersion direction) for example of 0.07, use the commands SET/ECHELLE TOL=0.07 SAVINI/ECH drs.tbl and repeat again the wavelength calibration (WAVECAL/UVES). The new value of TOL will be used.

Justification For pipeline data reduction in support of UVES operations a nominal value of TOL=0.6 has demonstrated to be very good in terms of robustness and quality. Higher precision of the resulting wavelength calibration solution may be achieved (provided one has a sufficient number of line identifications for each order) decreasing the tolerance and so eliminating more outliers. The average RMS of the solution will decrease in an approximatively linear way. Be careful to have always a reasonable number (10-20) of lines in each order.

MASTER/UVES

Check master frame images. In the case of flat-field, check carefully the background of the master image, which should be subtracted successfully over the whole frame. This is the most delicate part of the process, and can be viewed more precisely setting the keyword BKGVISU=YES.

Symptom(s)

- The command MPLOT/BKGR (see help) gives not a very good match of bkg and raw flat field image.

Possible cause(s)

- The BCKGMTD keyword is not set appropriately.

Possible solution(s)

- In case of improper background subtraction, the BCKGMTD keyword can be changed either in the DRS setup table or directly in the command line.

Justification Sometimes to use BCKGMTD=MINIMUM can be preferred to BCKGMTD=MEDIAN (default setting). This may happen when the inter order space in the Flat Field image is very small (less than 3-4 Y pixels) so that the background image in the evaluation window, specified by the background table, is affected by the light level at the borders of the flat field image.

REDUCE/UVES

Symptom(s)

- Not very good quality of optimally extracted spectra.

Possible cause(s)

- Data reduction of a very high S/N source.

Possible solution(s)

- Use average extraction.

Justification Since the pipeline version 1.0.6, optimal extraction quality has improved significantly and the algorithm assumes a Gaussian profile for the intensity light distribution across the order. In particular in case of very high S/N sources this approximation may fail and it is more appropriate to do average extraction.

REDUCE/UVES

Symptom(s)

- Not very good quality of optimally extracted spectra.
- Not very good quality of the quality plots from the command MPLOT/CHUN

Possible cause(s)

- Data reduction of a very low S/N source.

Possible solution(s)

- Do a FILTER/COSMIC of the science frame before optimal extraction.

Justification During optimal extraction the distribution of object position and FWHM along the order are initially evaluated. This step is evaluated on a number of chunks (collapsed subsets of an order), before actually doing cosmic ray k-sigma clipping. In case of very low S/N sources this means that the eventual occurrence of a cosmic in a chunk can affect the position or FWHM distribution, this leading to a successive loss of accuracy in the data reduction. An initial removal of possible cosmic ray signature would help.

REDUCE/UVES

Symptom(s)

- Not very good quality of optimally extracted spectra.
- Not very good quality of the quality plots from the command MPLOT/CHUN which also shows two traces for the position.

Possible cause(s)

- Data reduction of more than one object on the slit

Possible solution(s)

- Do an interactive data reduction of each object source as explained on page 36.

Justification Clearly problems may occur trying to reduce more than one object in the extraction slit. The optimal extraction algorithms find problems to fit two different traces.

REDUCE/UVES

Symptom(s)

- Not very good quality of optimally extracted spectra.
- Not very good quality of the quality plots from the command MPLOT/CHUN.
- Very high value of extracted object FHWM compared to the extraction slit.

Possible cause(s)

- Data reduction of an extended source.

Possible solution(s)

- Use command REDUCE/SPAT.

Justification When the cross-order light profile FWHM of the extracted object is quite wide compared to the extraction slit (this may happen for objects intrinsically extended or in case of particularly bad seeing), the optimal extraction finds difficulty in evaluating the sky background value.

REDUCE/UVES, REDUCE/SPATIAL, EFFICIENCY/UVES

Symptom(s)

- During optimal extraction is reporeted the error message:
  Computing the variance of the input frame...
  (ERR) SCDRDx: ref0014.tbl + COEFFC - INPINV

Possible cause(s)

- The table in question has the COEFFC descriptor of 12 chars while a MIDAS command executed by the pipeline (SUBTRACT/BACK and within it COMPUTE/REGRESS) want to have a 20 char value.

Proposed solution(s)

- If you are starting from FITS files, identify which tfits file corresponds to the table (be it my_table.tfits) in question and then give the following commands:

  ```
  INDISK/FITS my\_table.tfits my\_table.tbl
  write/descriptor COEFFC/c/1/20 my\_table,{COEFFC}
  OUTDISK/FITS my\_table.tbl my\_table.tfits
  ```

  In case of red arm data these commands need to be repeated for both lower and upper chips.
- Alternatively the problem can be solved within each affected procedure (uves_mkmaster.prg, uves_reduce.prg, uves_efficiency.prg, uves_reduce_spat.prg) adding before the command SUBTRACT/BACKGROUND the following lines:

  ```
  show/desc {ORDTAB} COEFFC >Null
  if {outputi(3)} .lt. 20 then
       write/descriptor {ORDTAB} COEFFC/c/1/20 {ORDTAB},COEFFC
  endif
  ```

Justification Some echelle command generate improperly COEFFC values of 12 char while COMPUTE/REGRESSION want to have 20 char. This need to be fixed in MIDAS.

3.3.3 Operational related problems

DFS00734

Symptom(s)

- Bad quality for extraction of 346 data
- Bad quality of the weight image.

Possible cause(s)

- Very high S/N
- Use of pipeline version previous than 1.0.7
- Object at the slit border

Proposed solution(s)

- Use pipeline versions after 1.0.7.

Justification This problem occurred very early in UVES Operations (2000/6/30). The UVES pipeline has been designed to reduce point-like sources well centered on the slit. Such conditions were not satisfied. Moreover the source had very high S/N, a condition which makes the extraction quality more problematic, a problem which was overcome in versions 1.0.7 and in which a more accurate order tracing has been implemented and a k-sigma threshold dependent as a parabolic function slowly also from the S/N ratio.

DFS00784: uves_pupul.sh crashing on a non standard setting

Symptom(s)

- wavelength calibration crashing
- order definition plots, after Hough transform, shows that orders are not well identified.

Possible cause(s)

- predicted number of orders is greater than the actually detected.
- the non standard setting shows a light distribution not uniform with a sudden decrease of intensity on a region of the detector.

Proposed solution(s)

- Use UVES pipeline version from 1.0.1 onwards.

Justification The non-standard setting in question had a sudden decrease in intensity. This was the reason why the number of detectable orders from the Hough transform algorithm was smaller than that predicted. The physical model which has information on the standard instrument setting may predict a geometric spectral format that does not take into account conditions like the presence of a particular filter. This filter might have an efficiency drop in a certain wavelength region, this causing a dimming of the light incident on the CCD, below a threshold of order detectability. Eventually this may lead to a tentative detection of a very high number of orders that results in a bad order table and finally into problems in the wavelength calibration step as reported. All such problems are solved in the releases after 1.0.1 by inserting a quality check: the SIGMA of the :RESIDUAL column in the order table shows a sudden jump if the predicted number of orders is greater than the actual detected ones. In such a case the procedure from release 1.0.1 on iteratively decreases the number of orders predicted by the physical model until the QC check is satisfied. This overcomes the spotted problem.

DFS00965: PREDICT/UVES, FMTSTA/UVES

Symptom(s)

- Physical model plots showing not very good aggregation in non standard setting

Possible cause(s)

- Use of non standard setting

Proposed solution(s)

- No solution proposed.

Justification The problem is known, and it is present in non-standard settings showing plots with not optimal quality, but this symptom does not compromise the wavelength calibration.

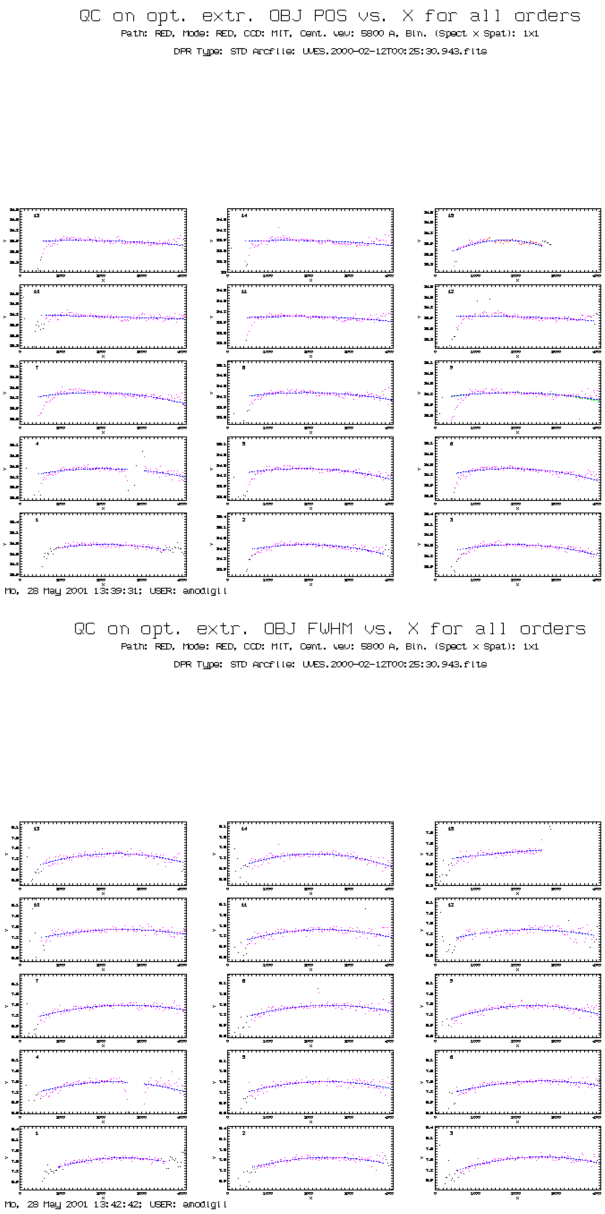

Figure 3.6: Multiple plots, each reporting as a function of the dispersion (X) coordinate of each chunk (group of collapsed pixel spectra) the Y (cross-order) object position (upper plot) and FWHMs (lower plot) of the Gaussian distribution assumed to model the cross order object distribution profile. Dark points are data points. Green are the first fit points, blue are the last (after k-sigma if occurred) points, magenta are the data points used for the last fit. As shown the slope and the curvature after order rotation are still present, different between order and order, and of the order of a fraction of a pixel (the Y plot size is 1.8 pixels). The scatter of data points from the fit on order 4 is due to the presence on the RED MIT CCD of a dead column not removed during science reduction. As shown the fit is not affected by these CCD defects..

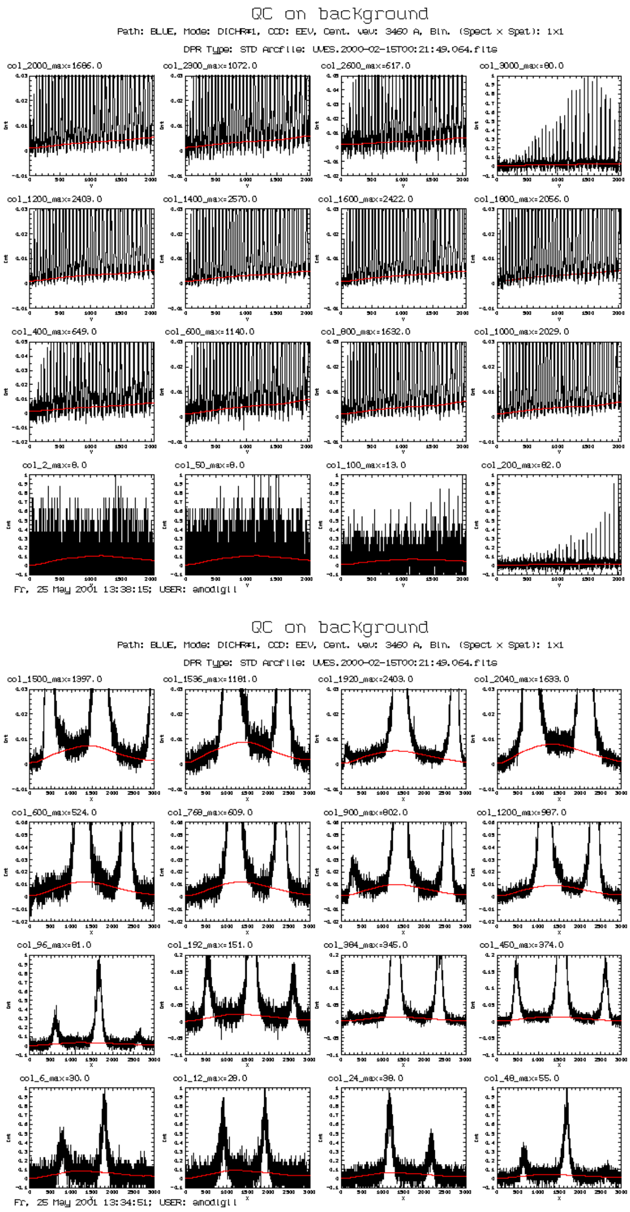

Figure 3.7: With the command MPLOT/BKGR it is possible to check the background extraction quality. Here are shown on normalized coordinates with appropriate ranges to show the region near the background, on predetermined detector positions, the plots of the intensity of the raw image (black) and the ones of the correspondent background image (red). In the abscissa are respectively the cross-order (upper plot) and dispersion (lower plot) direction.

Chapter 4

Reduction recipes and scripts

This chapter gives information on the pipeline recipe data processing. Each main data reduction recipe is described as a schematic flow chart and with a text description, clearly indicating input, output and data reduction parameters. Moreover we shortly indicate how to run each provided data reduction script and what its purpose is.

A reduction recipe is a description of a reduction step to be applied to a given list of frames. The reduction step will be carried out in a Data Reduction System (DRS) to be specified in the configuration files (see below). As yet, the only supported DRS is ESO–MIDAS.

There are two configuration files describing the recipes:

- the reduction recipe definition file (file suffix `.rrd`).
  This contains the specification of input and output and defines the parameters which control the data processing. Please see [10] and [4] for examples.
- reduction recipe implementation file (file suffix `.rri`).
  This describes the mapping of input and output files and parameters to actual MIDAS parameters and the MIDAS procedure which is executed. Please see [10] and [4] for examples.

When a Reduction Block (RB) is executed (see [10]) the Reduction Block Scheduler (RBS) loads the `.rrd` and `.rri` files according to the recipe specified in the reduction block, and builds a MIDAS command line that passes all needed information to MIDAS. The filenames of the input– and reference–files are not directly passed to MIDAS (since thereby MIDAS' limitation of 8 parameters could be exceeded) but written to ASCII files whose filenames are specified on the command line. The recipe procedure will then evaluate these ASCII files to identify the input– and reference frames.

Each of these recipes usually performs a few basic steps which are mainly: to display useful information; to initialize the UVES and ECHELLE MIDAS contexts; to initialize some keywords to default values; to copy raw frames to a local directory and convert them to MIDAS format; to extract some information on: the input data, extraction parameters and recipe which are logged in the output products; to do the actual data reduction; to log the QC1 information produced in an output ASCII file; to disable the context; to convert products to FITS format; to check if any error occurred and issue the proper message; to terminate the data reduction reporting the total execution time.

The following recipes are available for the UVES pipeline:

`uves_cal_predict`	– To determine the order and line positions from so called format check exposures and measure spectra shifts with respect to master formatcheck frames
`uves_cal_orderpos`	– To determine the order positions from the order definition flatfields
`uves_cal_mkmaster`	– To create a master frame from a set of calibration frames (bias, dark, flat)
`uves_cal_wavecal`	– To determine the dispersion relation
`uves_cal_response`	– To reduce a standard star spectrum and determine the instrument response and the telescope+instrument+detector detection efficiency
`uves_cal_ccdtest`	– To perform CCD test to get CCD characteristics.
`uves_cal_extrord`	– To do an order average extraction of echelle spectrum (this recipe is seldom used)
`uves_obs_scired`	– For science image reduction (optimal extraction, flat field correction, wavelength calibration, order merging) with sky subtraction.

There are also some scripts:

`uves_ccdtest.sh`	– To determine major CCD characteristics from a set of bias and flat field frames
`uves_dosubmit.sh`	– To submit a frame to the pipeline for its reduction
`uves_effic.sh`	– To reduce a standard star spectrum and determine the instrument response and the telescope+instrument+detector detection efficiency
`uves_format.sh`	– To create a line table based on the physical model of UVES and measure the spectral shifts with respect to the master spectra.
`uves_orderpos.sh`	– To create an order table, a background table and a drs setup table.
`uves_plot.sh`	– To plot merged spectra from the science reduction.
`uves_popul.sh`	– Main procedure to populate the CalibDb.
`uves_reduce.sh`	– To do science reduction using average extraction.
`uves_reduceOPT.sh`	– To do science reduction using optimal extraction.
`uves_resol.sh`	– To determine the dispersion relation in each subwindow of the order extraction window (sky, object, sky) and plot the spectral resolution.
`uves_stability.sh`	– To monitor the UVES stability.
`uves_wavecal.sh`	– To do the wavelength calibration.

The following subsections give a description of the individual recipes and scripts of the UVES Pipeline. For each recipe its name, the required input and reference frames and the products it creates are listed.

A recipe can create several products, one of which is assumed to be the *main* product of this recipe. This main product is underlined. The indices of the product files as described in [10] are also given.

Also listed are the observation templates that are associated to the recipe (if there are any), the parameters controlling the processing and a description of the algorithm.

The main data reduction steps produce also QC1 (Quality Control Level 1, quality control information product of the pipeline data processing) information stored either in the FITS header of the product files, and/or stored by the automatic QC1 logging system (which is not provided to the user community).

4.1 Calibration frame generation

4.1.1 First guess wavelength calibration solution

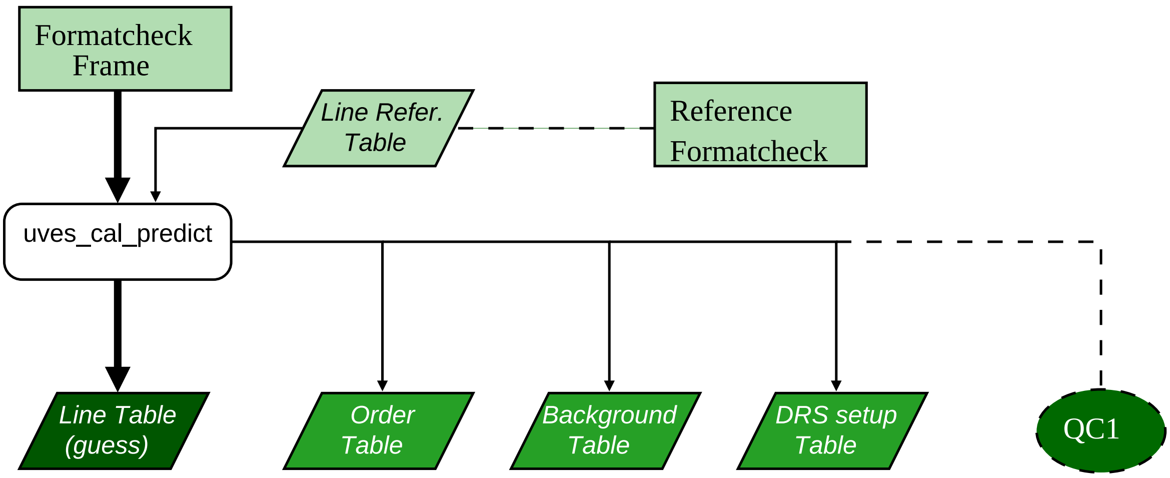

Figure 4.1: Illustration of the line table generation of the first guess solution based on the physical model of UVES. A so called formatcheck frame is obtained with an arc lamp (ThAr) exposure and a narrow slit.

- recipe name: `uves_cal_predict`
- corresponding UVES context command: `FMTSTA/UVES`(PREDICT/UVES has similar sintax but does not do the stability check)
- input frames:
  `ARC_LAMP_FORM_y`
  `y=BLUE,RED`
- optional input frames:
  master formatchecks:
  `MASTER_FORM_y`
- reference frames:
  `LINE_REFER_TABLE` (required)
  `MASTER_FORM_y`(y: RED, BLUE) (optional)
- data products:

<u>`DRS_SETUP_x`</u>	0000
`ORDER_TABLE_x`	0001
`BACKGR_TABLE_x`	0002
`LINE_TABLE_x`	0003

  `(x: BLUE, REDL, or REDU)`
- associated template:
  `UVES_x_tec_fmtchk`
  `(x: blue, red, dic1, dic2)`

- purpose:
  It creates a line and an order tables based on the physical model of UVES. These are used as first approximations in the following steps of the data reduction (order determination and wavelength calibration). It creates also a DRS Setup table. It can be used as a first step to create calibration data for non standard UVES settings. A QC1 analysis, if a master frame is present, measures the spectral shifts with respect to master spectra.
- fixed parameters (P1-P3):
  - P1: input ThAr format-check frame. Default ?
  - P2: input line reference catalogue. In case of FMTSTA/UVES the catalogue should contain also a reference formatcheck frame. Default +.
  - P3: catalogue to save products. Default +.
- variable parameters (P4-P8):
  - P4: XYDIM. Dimension of the measurement box (X,Y). Default 40,40.
  - P5: XYTRN. Translation of the ccd (X,Y). Default 0,0.
  - P6: ANGLE. Angle offsets (echelle, CD, CCD-rot). Default 0,0,0.
  - P7: XYOFF. Measurement position offsets (X,Y) from the predicted position. Default 0,0.
  - P8: FLAGS. Display [Y]/N, fit regression [Y]/N, compute polynomial regression [Y]/N.? Default Y,Y,Y.
- Note: A DRS SETUP table is a data reduction system setup table, an empty table which controls the data reduction process by the use of its descriptors. DRS setup tables are classified saved MIDAS sessions (SAVE/ECHELLE) which guarantee a standardized behavior of the UVES pipeline.

  MASTER_FORM_y (y=BLUE,RED) are reference format-check exposures used at QC1 level to measure the instrument stability as a function of the atmospheric conditions and time. This analysis can be done only if a matching format-check exposure in the local CalibDB is present.

  Observations: This procedure can be used in a standard UVES context section as the first step of a complete data reduction sequence to create all the master calibrations frames necessary to do the science reduction (provided one has a reference ThAr table and all raw frames corresponding to the same instrument setting). Alternatively to a more interactive MIDAS section one can run the script uves_popul.sh to automatically generate a complete set of master calibrations.

  These procedure has problems if the ThAr exposure has been aborted (and so there is no signal on the frame).
- description:
  The set of input frames contains only *one* arc lamp exposure obtained with a short slit (formatcheck exposure). The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case). The actual MIDAS procedure after an initial setting of relevant data reduction parameter starts to predict the line positions.

  The procedure runs the physical model to obtain a first guess calibration solution: it determines the echelle order and line position table from an arc lamp exposure obtained with a short slit (format check exposure). This type of exposure enables a simultaneous order tracing as well as a calculation of the line positions (ThAr). These computations are based on a physical model of UVES. The physical model predictions are compared with the arc lamp exposure in order to optimize the echelle order and line position table solution. The line table may be used as

a first guess solution in the wavelength calibration process (WAVECAL/UVES, IDENTI/ECHE).
Once the reference line table predicted positions are projected on the input frame image, the procedure displays the differences between projections and measurements. This results are reported on the third MIDAS_graph window as six plots respectively XDIF vs. X, XDIF vs. Y, YDIF vs. XDIF, YDIF vs X, YDIF vs Y, Y vs X. Such plots are saved with the name pm_wlen_chip.ps (where wlen is the central wavelength instrument setting in nm and chip is the detector chip name, EEV or MIT). As described in Ballester et al., "The UVES Data Reduction Pipeline", The ESO Messenger No. 101, this step is successful if the mentioned plots, in particular the plots showing XDIF vs X and YDIF vs X, show a well aggregated (sigma of XDIF and YDIF typically less than 3-5 pixels) distribution almost horizontal and centered around ordinate value equal to zero (see Fig. 3.1 at pag. 12). Vice versa, in case of a completely scattered point distribution, it means that the physical model predictions are not acceptable anymore and one needs to adjust the physical model parameter offsets (please consult the high level documentation and the on line help for more information).
Then the procedure creates a line, an order table (first guess) and saves the global keywords in a DRS setup table (SAVE/ECHELLE).
Then a QC1 stability check may be performed. If the formatcheck exposure matches a corresponding master formatcheck frame in the calibration database, the positions of the predicted lines are measured on the frame and the spectral shifts in dispersion and cross-dispersion with respect to the master frame are determined: it saves the table with the measured positions of the reference frame and merges the column of the current and the reference format check tables and computes the shifts in X, Y, wavelength, does a statistic on these shifts storing median and mean of each shift column value, saving the result on an output table. Next it logs the pressure, central wavelength setting, temperature and the summary from the stability check (average and median shift on X and Y) on a log file using the general QC1 logging system.

4.1.2 Order table generation

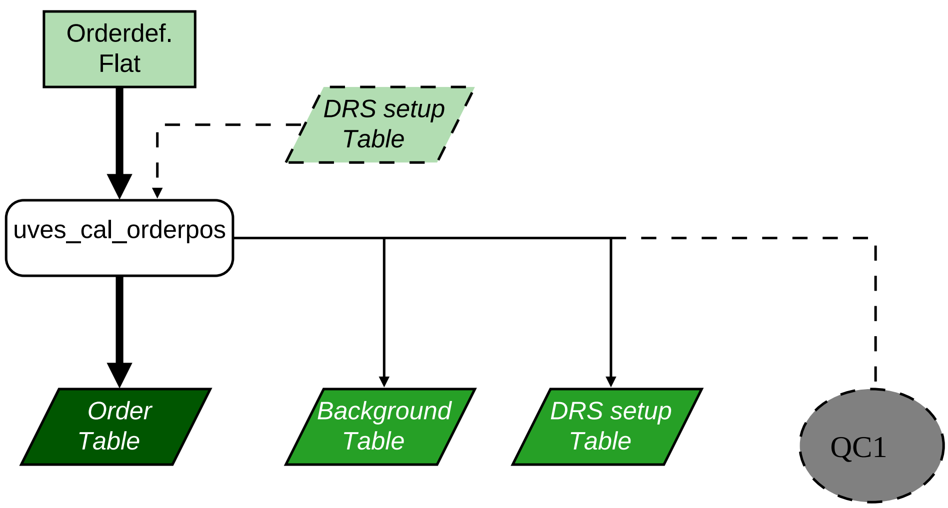

Figure 4.2: Illustration of the order and background table generation.

- recipe name:
  `uves_cal_orderpos`
- corresponding UVES context command:
  `ORDERP/UVES`
- input frames:
  `ORDER_FLAT_y` or
  `y=BLUE`or RED.
- reference frames:
  `DRS_SETUP_x` (optional, recommended)
- data products:

`ORDER_TABLE_x`	0000
`BACKGR_TABLE_x`	0001
`DRS_SETUP_x`	0002

  `(x: BLUE, REDL, or REDU)`
- associated template:
  `UVES_x_tec_orderdef`
  `(x: blue, red, dic1, dic2)`
- purpose:
  Does an order tracing and saves the positions in an order table.
- fixed parameters:
  - P1: Input order reference frame or catalogue. Default ORDREF.
  - P2: Name of output catalogue. Default +.
  - P3: Name of reference input catalogue. Default +.
- possible variable parameters: none.
- description:
  The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case). Some preliminary check on input catalog data is performed. The instrument keyword setting is configured. The procedure gets the DRS SETUP table, sets the background and the order table output names, performs a Hough-transform for each exposure using DEFINE/HOUGH of the ECHELLE context which returns an order table as well as a background table. The procedure takes advantage of the use of a physical model to get from the DRS SETUP table the predicted number of orders as first guess value of the parameter NBORDI of the command DEFINE/HOUGH. This for stability and reproducibility reasons, to be sure that at least when the order definition frame is well illuminated the DEFINE/HOUGH command gives always the same result. As the physical model does not take into account the possible filter sequence which is present along the optical path, the geometrical predicted spectral format may differ from the one actually detected. It may happen that on some region of the detector a sudden drop of illumination occurs, due to the low transmission characteristics of some filter at that wavelength. In this case the HOUGH transform, trying to identify more orders than actually are present, would find a non acceptable solution. This occurrence corresponds to have a very big value of the sigma of the column :RESIDUAL in the order table, whose values should be a small fraction of an Angstrom (typically of the order of 0.2 Å). To prevent such an occurrence, the procedure performs an automatic quality control check: in case the sigma of the column :RESIDUAL of the order table is smaller than 1 Angstrom, the predicted number of orders is decreased of one unit. As soon as the right number of orders is reached, the sigma of :RESIDUAL drops off one order of magnitude, usually to a value much smaller

than the threshold (1Å). So the HOUGH transform is performed and a good quality order table is determined.
During the order determination the procedure displays first the central part of the order trace and next the entire refined order trace. The actual keyword settings are stored in the DRS setup table. Usually, the set of input frames contains only *one* order definition flat, but you may put more than one in order to get a set of calibration tables. The use of a DRS setup table (output from recipe `uves_cal_predict` or of the command PREDICT/UVES) is recommended to ensure successful detection of all echelle orders on the frame. In the end the DRS setup table is updated.

4.1.3 Master bias generation

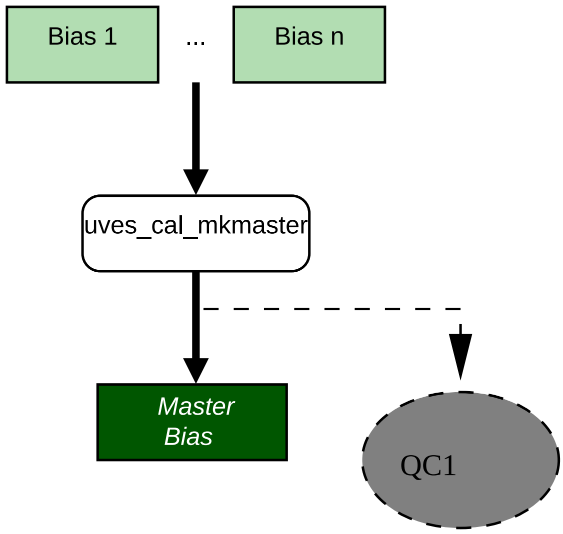

Figure 4.3: Illustration of the master bias generation.

- recipe name:
  `uves_cal_mkmaster`
- correspondent UVES context command:
  `MASTER/UVES`
- input frames:
  `BIAS_y` or
  `y=BLUE`or RED
- reference frames:
  none
- data products:
  `MASTER_BIAS_x` `0000`
  `(x: BLUE, REDL, or REDU)`
- associated template:
  `UVES_x_cal_bias`
  `(x: blue, red, dic1, dic2)`
- purpose:
  Does a median stacked average of all bias frames in the set of input frames
- standard parameters:
  - P1: Image catalogue with calibration frames (biases,darks or flats).

  - P2: Output catalogue name for products.
  - P3: Reference catalogue containing: reference Master Bias (for darks/flats), DRS table (for flats), background table (for flats).
- possible variable parameters:
  - P4: BMODE. Bias subtraction mode. Possible values are M(aster), S(moothed), A(verage), <number>. Default is M.
  - P5: DMODE. Dark subtraction mode. Possible values are M,S,A,<number>. Default is M.
  - P6: BGMTD. Background measurement method [MEDIAN]/MINIMUM. Default is MEDIAN.
- Note: if master bias and/or dark are specified they are subtracted in the creation of the master flat. The background is subtracted (from flat).
- Observation: some bad row parallel to the x (dispersion) direction appear on some bias frames of RED arm. These are due to problems in charge transfer in the CCD. From version 1.0.9 on this effect is automatically cleaned.
  Sometimes some problems of execution can be found if the RBs were created in an incorrect way. This may happen when using a wrong template event which may be triggered by an aborted observation.
- description:
  The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case).
  Separates from the input catalog bias, dark and flat type frames. Next on each of the possible 3 kinds of frames, does a master creation: creates a reference and a reduced frame catalog, define wavelength, binning, slit width of the corresponding frame. .

```
Bias definition. For the input bias there are four possibilities:
   <num>: Constant bias. Takes the given constant value as bias
   to be subtracted or if no value has been specified, assume
   such a constant as 0.

   M: if it has been specified a Master frame this is used as bias to
      be subtracted (default).
   S: take the SMOOTHED version of the input frame,
   A: take the AVERAGE of the input frame.
```

  Determines the median stacked average of all biases in the set of input frames.
  Displays the result, and averages the input data taking the MEDIAN of all input data at each pixel. Classifies the products. It is known that the RED EEV detector chip has some trap column and the MIT chip a dark column and some trap columns. For the master creation, in the case of the RED chips, the corresponding pixels are corrected taking a linear interpolation of adjacent pixels on the Y direction.
  As a quality control check, the read out noise of the master bias and of a raw bias frame, the median of the master bias, and the presence of eventual structure (slope) along X and Y directions are computed. These values are logged as QC-LOG and stored as FITS keywords.

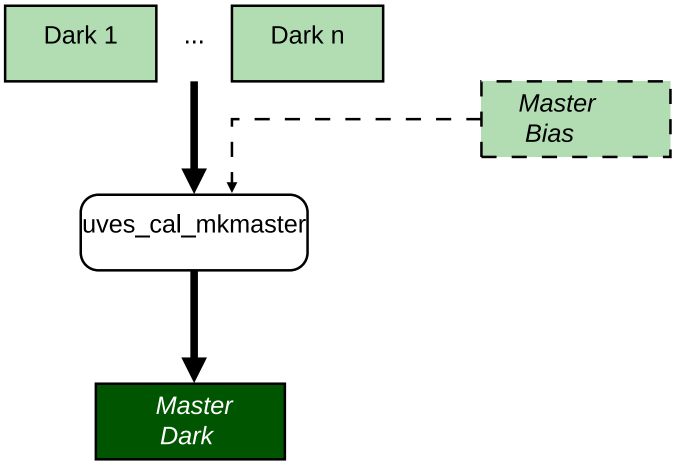

Figure 4.4: Illustration of the master dark generation.

4.1.4 Master dark generation

- recipe name:
  `uves_cal_mkmaster`
- correspondent UVES context command:
  `MASTER/UVES`
- input frames:
  `DARK_BLUE` or
  `DARK_RED`
- reference frames:
  `MASTER_BIAS_x` (optional)
- data products:
  `MASTER_DARK_x` 0000
  `(x: BLUE, REDL, or REDU)`
- associated template:
  `UVES_x_cal_dark`
  `(x: blue, red, dic1, dic2)`
- purpose:
  Does a median stacked average of all dark frames in the set of input frames
- standard parameters:
  - P1: Image catalogue with calibration frames (biases,darks or flats).
  - P2: Output catalogue name for products.
  - P3: Reference catalogue containing: reference Master Bias (for darks/flats), DRS table (for flats), background table (for flats).
- possible variable parameters:
  - P4: BMODE. Bias subtraction mode. Possible values are M(aster), S(moothed), A(verage), <number>. Default is M.
  - P5: DMODE. Dark subtraction mode. Possible values are M,S,A,<number>. Default is M.
  - P6: BGMTD. Background measurement method [MEDIAN]/MINIMUM. Default is MEDIAN.
- description:

Does a transformation of each echelle frame of the set of input frames (rotate, split if necessary). Determines the median stacked average of all darks in the set of input frames. Before averaging, the darks may be bias subtracted. The bias subtraction is controlled by the BMODE parameter:

- `BMODE=M`: The recipe tries to find a master bias which gets subtracted from the dark.
- `BMODE=`*number*: The recipe subtracts a constant *number* as a bias level from the single dark frames.
- detailed description:
  The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case).
  Separates from the input catalog, the bias, dark and flat type frames. Next on each of the possible 3 kinds of frames, does a master creation: creates a reference and a reduced frame catalog, define wavelength, binning, slit width of the corresponding frame. .

```
Dark definition. For the input dark there are four possibilities:
<num>: Constant dark. Takes the given constant value as dark to
       be subtracted or if no value has been specified, assume
       such a constant as 0.

    M: if it has been specified a Master frame this is used as bias
       to be subtracted (default).
    S: take the SMOOTHED version of the input frame,
    A: take the AVERAGE of the input frame.
```

  Subtracts the bias.
  Determines the median stacked average of all darks in the set of input frames. Displays the result, and averages the input data taking the MEDIAN of all input data at each pixel. Classifies the products.

Note: the same recipe supports also parasitic light frames data reduction. Their keywords are specified in chapter B

4.1.5 Master flat generation

- recipe name:
  `uves_cal_mkmaster`
- correspondent UVES context command:
  `MASTER/UVES`
- input frames:
  `FLAT_BLUE` or
  `FLAT_RED`
- reference frames:
  `BACKGR_TABLE_x`
  `DRS_SETUP_x` (optional)
  `MASTER_BIAS_x` (optional)
  `MASTER_DARK_x` (optional)
- data products:

MASTER_FLAT_x	0000
BKG_FLAT_x	0001

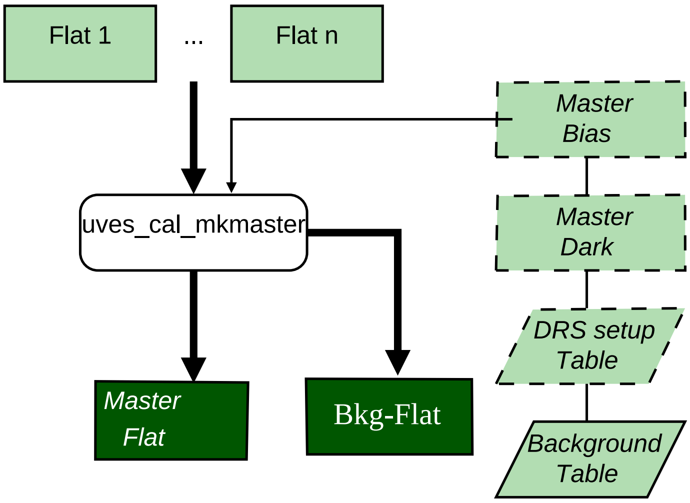

Figure 4.5: Illustration of the master flatfield generation.

`(x: BLUE, REDL, or REDU)`

- associated template:
  `UVES_x_cal_y`
  `(x: blue, red, dic1, dic2)`
  `(y: flatatt, flatfree)`
- purpose:
  Does a median stacked average of all flatfield frames in the set of input frames
- standard parameters:
  - P1: Image catalogue with calibration frames (biases,darks or flats).
  - P2: Output catalogue name for products.
  - P3: Reference catalogue containing: reference Master Bias (for darks/flats), DRS table (for flats), background table (for flats).
- possible variable parameters:
  - P4: BMODE. Bias subtraction mode. Possible values are M(aster), S(moothed), A(verage), <number>. Default is M.
  - P5: DMODE. Dark subtraction mode. Possible values are M,S,A,<number>. Default is M.
  - P6: BGMTD. Background measurement method [MEDIAN]/MINIMUM. Default is MEDIAN.
- description:
  The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case). Determines the median stacked average of all flatfields in the set of input frames. Finally, the averaged flatfield gets inter order background subtracted. The inter order background positions are defined by the background table. Before averaging each flatfield may be bias and dark subtracted. All these subtractions are controlled via the mentioned parameters:
  - `BMODE=M`: The recipe tries to find a master bias which gets subtracted from the flatfield.
  - `BMODE=`*number*: The recipe subtracts a constant *number* as a bias level from the single flatfield frames.
  - `DMODE=M`: The recipe tries to find a master dark which gets subtracted from

the flatfield.

- DMODE=*number*: The recipe subtracts a constant *number* as a dark level from the single flatfield frames.
- BGMTD=MEDIAN: Take the median of measurement box centered on each interorder background position.
- BGMTD=MINIMUM: Instead of taking the median take the minimum when measuring the background.
- detailed description:
  The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case).
  Separates from the input catalog, the bias dark and flat type frames. Next on each of the possible 3 kinds of frames, does a master creation: creates a reference and a reduced frame catalog, define wavelength, binning, slit width of the corresponding frame.
  Subtracts the bias and the temporally normalized dark from the flat.
  Determines the median stacked average of all Flats in the set of input frames. Subtracts the background (for more information on this crucial step please read Appendix 3.1 on page 3.1.4). In the end the procedure displays the result, and averages the input data taking the MEDIAN of all input data at each pixel. Classifies the products.
  In the extreme blue, where standard lamps give less intense flat images, to have better flat fields the user can ask to take them with a LN2 lamp.

Note: the same recipe supports also Deuterium Lamp and Absorption Cell Lamp Flats frames data reduction. Their keywords are specified in chapter B

4.1.6 Line table generation

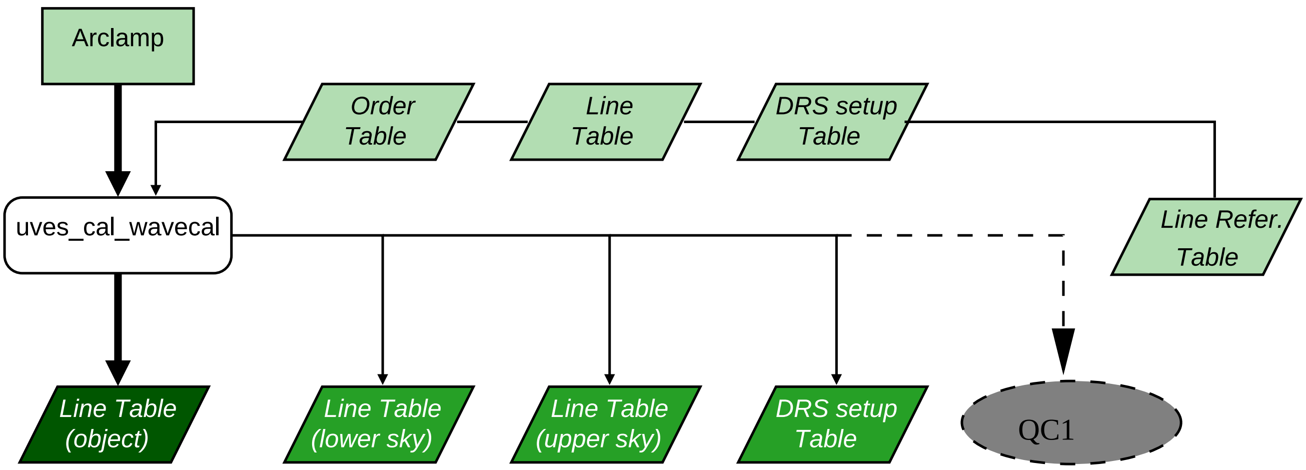

Figure 4.6: Illustration of the wavelength calibration.

- recipe name:
  `uves_cal_wavecal`
- correspondent UVES context command:
  `WAVECAL/UVES`
- input frames:

ARC_LAMP_BLUE or
ARC_LAMP_RED

- reference frames:
  DRS_SETUP_x
  ORDER_TABLE_x
  LINE_TABLE_x
  LINE_REFER_TABLE
  (x:REDL, REDU or BLUE)
- data products:

LINE_TABLE_x2	0000
LINE_TABLE_x1	0001
LINE_TABLE_x3	0002
DRS_SETUP_x	0003

  (x: BLUE, REDL, or REDU)
- associated template:
  UVES_x_cal_y
  (x: blue, red, dic1, dic2)
  (y: wave, wavefree)
- purpose:
  Determines the dispersion relation in each sub window of the order extraction window (sky, object, sky).
- standard parameters:
  - P1: Input raw ThAr frame catalogue. Default ?
  - P2: Output product catalogue name. Default +.
  - P3: Input Reference catalogue containing order and DRS setup tables,line reference table and optionally the line guess table (if one likes to have automatic, not interactive data reduction). Default +.
- possible variable parameters:
  - P4: MODE. Wavelength calibration mode: [auto]/interactive. Default AUTO.
  - P5: RPLT. Produce spectral resolution plot? [Y]/N. Default Y.
  - P6: CENT. Do wavelength calibration only at the center? Y/[N]. Default N.
- observation:
  this step fails only if the right DRS setup table is missing. This may happen if the central wavelength instrument setting is not standard. To overcome this problem one should use the script uves_popul.sh and a complete coherent (taken with the same instrument configuration) set of raw data to produce the proper set of master calibration solutions (and consequently also the proper DRS setup table).
- description:
  The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case). Next, the detection of the strongest lines in the arclamp exposure is done. The identification of the lines is performed with the help of the line reference table. This identification is based on the first guess solution passed as the two reference frames: order and line table. They are results of previous steps (uves_cal_orderpos.prg; uves_cal_predict.prg), respectively. From the identified lines the dispersion relation may be determined and will be stored as a line table for each sub window of the order extraction slit (lower sky, object, upper sky, if P6=N or only object if P6=Y).
  The line identification process is performed: lines are extracted with average method;

next the emission lines which lie above a background level (set initially to 10% of the mean of the extracted spectra and eventually adjusted until one gets at least 1000 lines) are searched; the wavelength calibration solution is derived twice, the first time using a 1D solution (WLCOPT=1D) and a polynomial of order 5 (DC=5) and the second using a 2D solution and a polynomial of degree 4. Very important here is the tolerance parameter (TOL). This defines (in pixel units) a threshold. Points which lie from the correspondent wavecal solution above TOL are considered as outliers. The pipeline assumes as compromise between robustness and precision a default value of 0.6. This value is automatically rescaled in case of frames binned along the dispersion direction. If the user prefers a higher precision solution (and has good data so that in each full order there are at least 10-20 good identifications), the TOL parameter can be reset and saved in the current DRS setup table (set/echelle TOL=user_value; savini/echelle drs_table.tbl).
Important information is shown in the resolution plots, a multiple plot where the FWHMs of ThAr lines (left) and the instrument resolution (center) as a function of the position on the detector along X and Y directions, and the resolution versus wavelength (upper right) and the distribution of measured lines over the detector (bottom right) are displayed (see Fig. 3.4 at pag. 17).
This information is extracted from the ASCII file resolution_LINTAB.dat file (where LINTAB is the name of the line table produced for the object: lWCEN_BIN_2, were WCEN is the instrument wave setting, and BIN the binning) and saved also in the postscript file postscript.ps. Other useful information is contained in the residuals plots, displayed in the small MIDAS graphs, which indicate the discrepancy in Angstrom units between the wavelegth solution found for the identified lines and their value as recorded in the ThAr reference line table (see Fig. 3.3 on pag. 16). This information is also provided in the ASCII file dat.dat. Finally the procedure predicts the spectral format and the resolution in the ASCII files free_sp_rg_LINTAB.dat and resolution_LINTAB.dat and other information about the wavelegth calibration solutions for each window in the files disp_res_lWCEN_BIN_i.tbl.dat (i=1,2,3).
The determined average and median resolving power are logged to the QC1 logging system.
After the data products are classified the procedure ends.

4.1.7 Instrument response and efficiency calculation

- recipe name:
  `uves_cal_response`
- correspondent UVES context commands:
  `REDUCE/UVES`,RESPONSE/UVES, EFFICIENCY/UVES
- input frames:
  `STANDARD_y` or
  `y=BLUE`or RED
- reference frames:
  `DRS_SETUP_x`
  `ORDER_TABLE_x`
  `LINE_TABLE_x`
  `LINE_REFER_TABLE`
  `FLUX_STD_TABLE`
  `EXTCOEFF_TABLE`

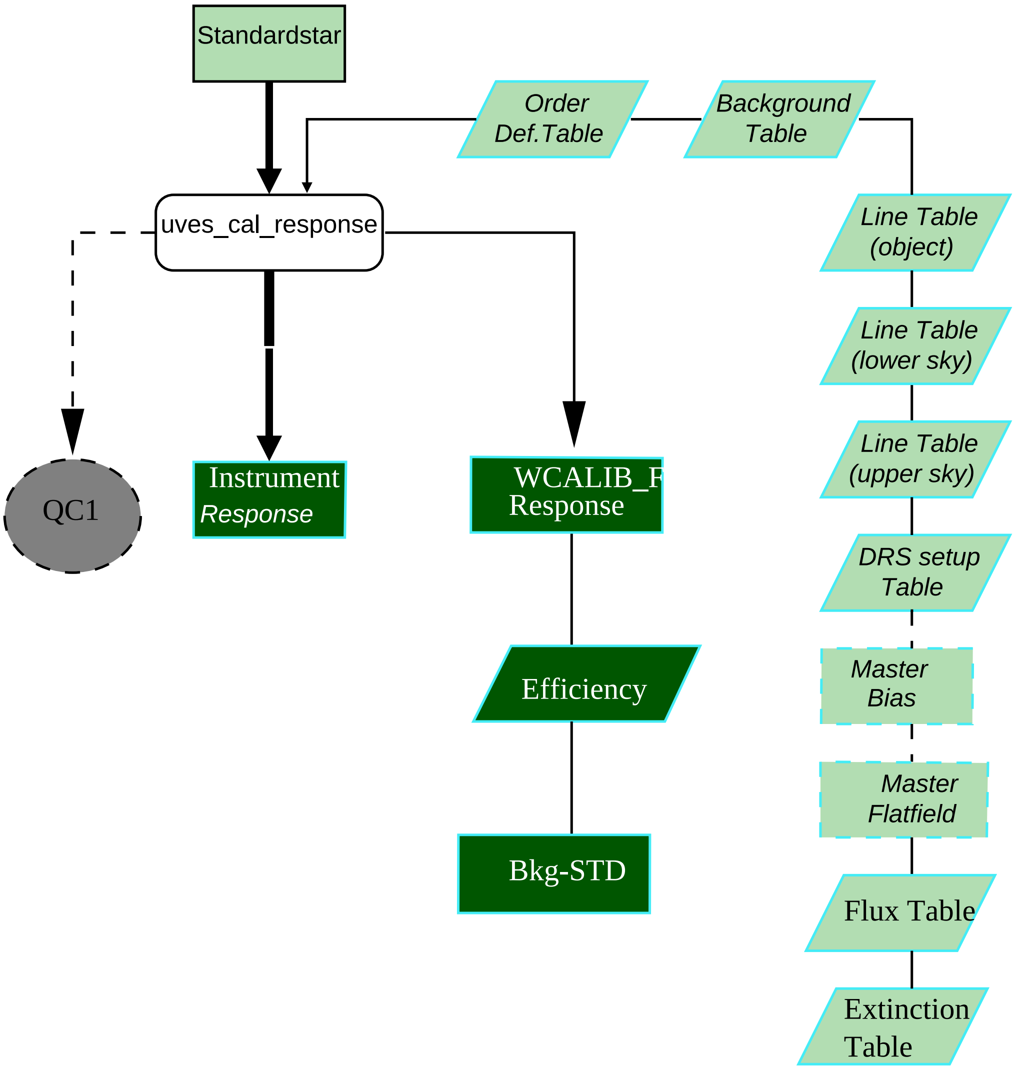

Figure 4.7: Illustration of standard star processing.

- data products:

`INSTRUMENT_RESPONSE_x`	0000
`WCALIB_FF_RESPONSE_x`	0001
`RED_STD_x`	0002
`EFFICIENCY_TABLE_x`	0003
`BKG_STD_x`	0004

  `(x: BLUE, REDL, or REDU)`
- associated template:
  `UVES_x_obs_y`
  `(x: blue, red, dic1, dic2)`
  `(y: std, stdfree)`
- purpose:
  Determines the instrument response function and the telescope+instrument+detector detection efficiency (sky, object, sky).
- standard parameters:
  - P1: Input raw frame or catalogue. Default ?.
  - P2: Output products catalogue. Default +.

  - P3: Input reference catalogue. Default ?.
- possible variable parameters (affects only the initial extraction of the object):
  - P4: FFMTD. Flatfielding method (P,E,...). UVES context command default ?. Recipe default E.
  - P5: EXMTD. Extraction method (AVERAGED,OPTIMAL). UVES context command default ?. Recipe default OPTIMAL.
  - P6: BGMTD. Background measurement method (MEDIAN, MINIMUM). UVES context command default ?. Recipe Default MEDIAN.
- description:
  Initially it does a science reduction of the observed object. Then it determines the instrument response function from a standard star spectrum and the corresponding flux table. In this operation the extracted std star spectra is filtered with a median filter and the result is smoothed. Next the reference flux table of the observed std star is divided by the smoothed extracted std star spectrum and after some cleaning to eliminate boundary effects this gives the instrument response. Also a wavelength calibrated, flatfielded and merged response is produced.
  In addition the telescope+instrument+detector efficiency is determined: First the standard star spectrum is extracted by summing the counts over the full slit. The extracted spectrum is corrected for the atmospheric extinction, the telescope area, the exposure time, the spectral bin size, and the CCD conversion factor. The efficiency is computed by comparing the number of detected photons with the absolute flux given in the (interpolated) flux table.
  The formulae adopted are:

  $$eff = \frac{ccd\_gain}{nphot} \qquad nphot = \frac{1}{ctsperg} \cdot erg2phot \cdot binsize \cdot texp \cdot Atel$$

  where *ccd_gain* is the gain of the ccd, *nphot* is the number of detected photons, *ctsperg* is the number of detected counts per erg, *erg2phot* is the erg to photon conversion factor, *binsize* is the size of a bin *texp* is the exposure time and *Atel* is the telescope effective area.
  In the end the computed efficiency for each order is displayed on the main graphical output window (MIDAS_NN_graph3, see Figure 3.5). This graph is also produced in form of a postscript file called eff_x.ps (x=BLUE,REDL,REDU).
  The computed efficiency at the blaze wavelength of each order is saved to the data product and logged to the QC1 logging system.

4.2 Technical recipes

4.2.1 CCD characterization

- recipe name:
  `uves_cal_ccdtest`
- corresponding UVES context command:
  `CCDTEST/UVES`
- input frames:
  bias and screen flat exposures:
  `BIAS_RED` or
  `BIAS_BLUE`
  `SCREEN_FLAT_RED` or
  `SCREEN_FLAT_BLUE`
- reference frames:
  `none`
- data products:
  `CCD_TABLE_x` 0000
  `(x: BLUE, REDL, or REDU)`
- associated template:
  `UVES_x_tec_ccdflat`
  `(x: blue, red)`
- purpose:
  Determines the major CCD characteristics from a set of bias and flatfield frames.
- standard parameters:
  - P1: Input catalogue containing a set of at least 5 biases and 9 pairs of screen flats all frames split. Default ?.
  - P2: output product catalogue name. Default +.
- possible variable parameters: none.
- variables:

  `MAX_TIME`

- short description:
  The set of bias frames (minimum 5) and the set of flatfield frames (must be pairs of equal exposures time) are used to determine the following CCD characteristics (based on the MIDAS CCDTEST context):

```
mean bias level [ADU],
sdev of mean bias [ADU],
no. of hot pix/cols,
min. exp. level [e-],
max. exp. level [e-],
average countrate [ADU/sec],
conversion factor [e-/ADU],
error for conv. factor,
readout noise [e-],
error for readout noise,
shutter error [sec],
positive linearity deviation [%],
```

`negative linearity deviation [%].`

In addition, for the 1x1 binned flatfields, the intensities are measured in 9 fields distributed over the frame as

```
1 2 3
4 5 6
7 8 9
```

to detect possible edge contamination. One field per chip is identified as a reference field. The relative intensities with respect to this reference field are saved to the data product. All results are logged to the QC1 system.

- description:
  This procedure is based on the MIDAS ccdtest context. It performs in series several bias tests:
  - B1: Creates the combined bias frame. The result is loaded into the display and the file {p3}_aver.ps is generated where {p3} gives the name of the output (averaged) bias.
  - B2: From the combined bias frame, rows and columns are averaged and plotted. The resulted plots are stored in the files {p3}_avcol.ps and {p3}_avrow.ps
  - B3: Hot pixels are found. The combined bias frame is median filtered and subtracted from the original. A plot is generated showing the positions of the hot pixels and the affected columns (file {p3}_hotpix.ps). A MIDAS table ({p3}_hotpix.tbl) is generated.
  - B4: The first and the last frame of the input catalogue are inspected. For the first frame a histogram of the pixel values is made, ignoring the hot pixels. The plot file is created also as a postscript file: {p3}_hist.ps. For the last frame in the catalogue, after preliminary correction of hot pixels, a histogram of the pixel values is made. Then the frame is rebinned.
  - B5: The bias level and its standard deviation are determined. For each input frame in the catalogue after hot pixel correction, the mean bias and the standard deviation are determined, making an average on a given box and applying a median filter. The overall mean bias level and mean sigma is computed.

  Then other tests are performed:
  - T1: the transfer and the linearity table are determined,
  - T2: the linearity curve and the shutter error are calculated,
  - T3: the transfer curve is computed.

  On the input flats the CCD contamination is determined (see above short description).

4.3 Science Recipes

4.3.1 Order extraction

- recipe name:
  `uves_obs_extrord`
- correspondent UVES context command:
  `uves_extrord.prg`
- input frames: every echelle spectrum `FLAT` or
  `ARC_LAMP`
  `STANDARD`
  `SCIENCE`
- reference frames:
  order position table(s), background table(s), DRS setup tables.
  `ORDER_TABLE_x`
  `BACKGR_TABLE_x`
  `DRS_SETUP_x`
  (x=REDL, REDU or BLUE)
- data products:
  order extracted frame
- associated template:
  `UVES_x_obs_y`
  `(x: blue, red, dic1, dic2)`
  `(y: exp, expfree)`
- purpose:
  Does an order extraction of an echelle spectrum.
- standard parameters:
  - P1: Input raw frame or catalogue. Default ?.
  - P2: Output products catalogue. Default ?.
  - P3: Input reference frames catalogue. Default ?.
- possible variable parameters: none.
- variables:

  `MAX_TIME`

- description:
  The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case). Extract the order by means of the order table.
- comment:
  This recipe is used only for quicklook purpose (very rarely).

4.3.2 Science frame reduction

- recipe name:
  `uves_obs_scired`
- correspondent UVES context command:
  `REDUCE/UVES`
- input frames:
  arc lamp exposures:

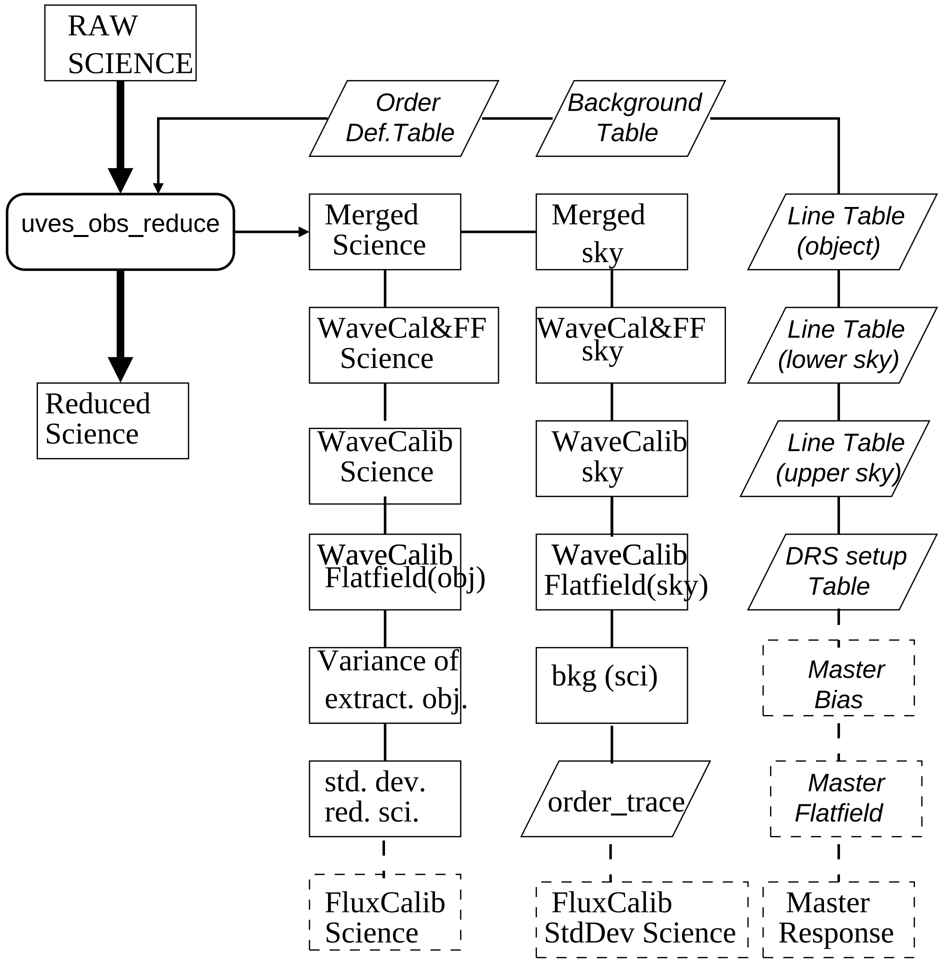

Figure 4.8: Illustration of the full science spectrum reduction (with flux calibration).

`SCIENCE`

- reference frames:
  order position table(s), background table(s), line table(s), DRS setup tables, master bias, master flatfield
  `ORDER_TABLE_x`
  `BACKGR_TABLE_x`
  `LINE_TABLE_x`
  `DRS_SETUP_x`
  `MASTER_BIAS_x`
  `MASTER_FLAT_x`
  `MASTER_RESPONSE_x`(optional)

  (`x`:REDL, REDU or BLUE)
- data products (for optimal extraction):
  reduced science frame

RED_SCI_POINT_x	0000
MERGED_SCI_POINT_x	0001
WCALIB_SCI_POINT_x	0002
WCALIB_FF_SCI_POINT_x	0003
WCALIB_FLAT_OBJ_x	0004

ERRORBAR_SCI_POINT_x	0005
VARIANCE_SCI_POINT_x	0006
BKG_SCI_x	0007
ORDER_TRACE_x	0008
CRMASK_x	009
MERGED_SKY_x	0010
FLUXCAL_SCIENCE_x	0011
ERRORBAR_SCIENCE_x	0012
(x: BLUE, REDL, or REDU)	

- data products (for average extraction):
  reduced science frame

RED_SCI_POINT_x	0000
MERGED_SCI_POINT_x	0001
WCALIB_SCI_POINT_x	0002
WCALIB_FF_SCI_POINT_x	0003
WCALIB_SKY1_x	0004
WCALIB_FF_SKY1_x	0005
MERGED_SKY1_x	0006
WCALIB_SKY2_x	0007
WCALIB_FF_SKY2_x	0008
MERGED_SKY2_x	0009
MERGED_AV_SKY_x	0010
WCALIB_FLAT_SKY1_x	0011
WCALIB_FLAT_SKY2_x	0012
WCALIB_FLAT_OBJ_x	0013
ERRORBAR_SCI_POINT_x	0014
VARIANCE_SCI_POINT_x	0015
BKG_SCI_x	0016
FLUXCAL_SCIENCE_x (if MASTER_RESPONSE_x is in)	0017
ERRORBAR_SCIENCE_x (if MASTER_RESPONSE_x is in)	0018
(x: BLUE, REDL, or REDU)	

- associated template:
  `UVES_x_obs_y`
  `(x: blue, red, dic1, dic2)`
  `(y: exp, expfree)`
- purpose:
  Does a science reduction.
- variables:

```
MAX_TIME
```

- standard parameters:
  - P1: Input science raw frame catalogue. Default ?.
  - P2: Output products catalogue. Default ?.
  - P3: Reference frames catalogue. Default ?.
- Possible variable parameters:
  - P4: FFMTD. This parameter sets the flatfielding method. If set to "E" the flatfielding occurs during extraction, in the sense that both the science spectra and the flatfield are extracted and next the science is divided by the flatfield.

If set to "P" the flat-field is done before extraction in the pixel-to-pixel space. This method is suggested to eliminate the fringing effect when this is relevant as in the far red (wlen=860 nm). If set to "N" no flat field is applied. This setting may be appropriate when the user has not a good flat field. Default is "E".

- P5: EXMTD. This parameter sets the extraction method. If set to "OPTIMAL", optimal extraction is performed. During optimal extraction, the input spectra is rotated-resampled and collapsed on chunk sizes of 32 pixels to remove any residual local noise. For each chunk, the order position is derived using a Gaussian fit cross-order model. Next, a polynomial fit of such distribution is done. For each pixel of each order, keeping fixed positions and FWHMs found in the fit, a Gaussian fit of the cross-order amplitude and sky background level is performed with simultaneous fit of k-sigma clipping in cosmic rays. The extracted spectrum amplitude is determined from this step. A variance and an error bar are also associated to this spectrum. In case of "AVERAGE" extraction the spectra is integrated on a fixed extraction slit SLIT=15 pix size centered on the object position (offset/echelle) taking into account the order distribution defined by the input order table. The value of SLIT is set in the DRS SETUP table. Default is "OPTIMAL".
- P6: BGMTD. This parameter sets the background method. Possible values are "MEDIAN" and "MINIMUM". In case of "MEDIAN" it is assumed the median within a box (whose sizes are set by the "BKGRAD" keyword). at the background positions defined by the background table of the reference catalogue. In case of "MINIMUM" the minimum is taken instead. Default is MEDIAN.
- P7:INTMTD. This extra parameter is present to allow the user to eventually adjust the integration extraction windows. Default is Y.
- P8: merge_method, delta_set_switch, delta1, delta2.
  - merge_method is the method used to merge spectra: OPTIMAL or AVERAGE. Default is O.
  - delta_set_switch is a parameter used to set:
    - D: delta setting (as was before, 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. Suggested. See on line help.
    - U: User defined deltas. In this case are taken the values of delta1 and delta2 as specified by the user.

    Default is D.
  - delta1: user specified value of delta used to merge the blue edge of the spectra. Default is 0.
  - delta2: user specified value of delta used to merge the red edge of the spectra. Default is 0.

- description:

The input echelle frame is appropriately oriented (rotated, split if necessary as in the RED arm case). Subtract bias. Subtract interorder spectrum. Divide by flat field (if appropriate, in pixel-to-pixel space before extraction or during the extraction as specified by the parameter P4). Extract the order by means of the order table. Resample (using as constant wavelength step 2/3 of the minimum wavelength step

size on the frame) and merge. Perform the Sky subtraction (during the extraction in case of optimal extraction, or in the end after merging, subtracting the merged sky averaged on the usually two sky extraction window, in case of average extraction). The extraction method can be Optimal (default method for OBJ or STD star) or average. In case of Image Slicer selection the extraction method is Average and no sky subtraction is performed. In case of optimal extraction cosmic rays are removed during extraction. For average extraction cosmic rays are not removed.
To monitor the extraction quality two commands have been created, MPLOT/CHUN and PLOT/CHUN which display the distribution of object positions for each chunk and of the cross order light distribution FWHM as a function of the dispertion coordinate for all the extracted orders (black points). Also the initial (green) and final (blue) fit to the points and the corresponding points (magenta) considered in the last fit are displayed. A good extraction quality is typically obtained, in particular when the data traces are well aggregated, when the maximum scatter between the data and the fit is less than 0.1-0.2 bin (see Fig. 3.6 on page 54).
The error bar image is obtained as the square root of the variance frame. 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)/(flat field). In case of optimal extraction an input variance is calculated as described before. 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 correspondent values of chi square. Assuming the chi square as a function of the amplitude is a parabola near the minimum, one can calculate what is the change in amplitude which generates a unitary increase of the chi square. This change can be assumed as error associated to the amplitude and from this one can get an estimate of the variance associated with the optimal extraction process. Clearly this variance value depends on how good the Gaussian model approximation (assumed from the cross order profile) is.

4.4 Scripts

We list here some useful scripts which perform automatic data reduction using default parameter values if the correct input FITS files are provided. To avoid problems in their execution the user needs to have defined the commands `xmessage` (SunOS, Linux, OSF1) or `xdialog` (HP-UX) in the path. Also the command `inmidas` should be in the path (and not to be defined as an alias).

4.4.1 Do a frame submission

- Gasgano script name:
  `uves_dosubmit.sh`
- input frames:
  any fits
- data products:
  any correspondent appropriate one.
- purpose:
  To submit a frame to the pipeline for its reduction.

4.4.2 CCD test

- Gasgano script name:
  `uves_ccdtest.sh`
- input frames: list
  list of selected input files:
  series of biases [BIAS_x]
  series of screen flats pairs [SCREEN_FLAT_x]
  (x: BLUE, REDL, REDU)
- purpose:
  Determine major CCD characteristics from a set of bias and flat field frames
- description:
  The set of bias frames (minimum 5) and the set of flatfield frames (must be pairs of equal exposures time) are used to determine the following CCD characteristics (based on the MIDAS CCDTEST context):

```
mean bias level [ADU],
sdev of mean bias [ADU],
no. of hot pix/cols,
min. exp. level [e-],
max. exp. level [e-],
average countrate [ADU/sec],
conversion factor [e-/ADU],
error for conv. factor,
readout noise [e-],
error for readout noise,
shutter error [sec],
positive linearity deviation [%],
negative linearity deviation [%].
```

  In addition for the 1x1 binned flatfields the intensities are measured in 9 fields distributed over the frame as

```
1 2 3
4 5 6
7 8 9
```

to detect possible edge contamination. One field per chip is identified as the reference field. The relative intensities with respect to this reference field are saved to the data product. All results are logged to the QC1 system.

4.4.3 Instrument efficiency

- Gasgano script name:
  `uves_effic.sh`
- input frames: list
  list of selected input files:
  standard star exposure [STANDARD_y]
  DRS table [DRS_SETUP_x]
  order table [ORDER_TABLE_x]
  background table [BACKGR_TABLE_x]
  line tables [LINE_TABLE_xn]
  Master Flat [MASTER_FLAT_x]
  Master Bias [MASTER_BIAS_x]
  standard star flux table [FLUX_STD_TABLE]
  atmospheric extinction table [EXTCOEFF_TABLE]
  (y: BLUE, RED; x: BLUE, REDL, REDU; n=1,2,3)
- data products:
  UVES instrument efficiently plots.
- purpose:
  To monitor the instrument health. See also 4.1.7.

4.4.4 Uves Formatcheck

- Gasgano script name:
  `uves_format.sh`
- input frames: list
  list of selected input files:
  Formatcheck frame [ARC_LAMP_FORM_x]
  ThAr line table [LINE_REFER_TABLE_x]
  (x: BLUE, REDL, REDU)
- data products:

LINE_TABLE_x	0000
ORDER_TABLE_x	0001
BACKGR_TABLE_x	0002
DRS_SETUP_x	0003

`(x: BLUE, REDL, or REDU)`

- purpose:
  Creates a line table based on the physical model of UVES.
- description:
  see subsection 4.1.1.

4.4.5 Uves Orderpos

- Gasgano script name:
  `uves_orderpos.sh`
- input frames: list
  list of selected input files:
  Order position flat frame [ORDER_FLAT_x]
  DRS setup table [DRS_SETUP_x]
  (x: BLUE, REDL, REDU)
- data products:

ORDER_TABLE_x	0000
BACKGR_TABLE_x	0001
DRS_SETUP_x	0002

  (x: BLUE, REDL, or REDU)
- purpose:
  Does order extraction performing an Hough transform of the order definition flat starting to search for a number of orders as specified from the DRS table. If such number of order is not found (Quality Control check) it starts to iteratively decrease the expected number of orders and repeats the Hough transform until it reaches a convergence condition.
- description:
  see subsection 4.1.2.

4.4.6 Plot spectra

- Gasgano script name:
  `uves_plot.sh`
- input frames:
  UVES pipeline spectra.
- purpose:
  To plot merged spectra from science extraction.

4.4.7 Calibration database population

- Gasgano script name:
  `uves_popul.sh`
- input frames: list
  list of selected input files:
  Formatcheck frame [ARC_LAMP_FORM_x]
  Orderdefinition frame [ORDER_FLAT_x]
  ThAr line reference table [LINE_REFER_TABLE]
  ThAr exposure [ARC_LAMP_x]
  biases [BIAS_x]
  flats [FLAT_x]
  (x: BLUE or REDL, REDU)
- data products:
  Frames for the CalibDb.

- purpose:
  Generate frames to populate the CalibDb.
  See appendix 3.2 (UVES context cookbook).

4.4.8 Science reduction (average extraction)

- Gasgano script name:
  `uves_reduce.sh`
- input frames: list
  `list`of selected input files:
  `science`exposure [SCIENCE_y]
  `DRS`table [DRS_SETUP_x]
  `order`table [ORDER_TABLE_x]
  `background`table [BACKGR_TABLE_x]
  `line`tables [LINE_TABLE_xn]
  `master`bias [MASTER_BIAS_x]
  `master`flat [MASTER_FLAT_x]
  (`y:`BLUE, RED; x: BLUE, REDL, REDU; n=1,2,3)
- data products:
  reduced science spectra using average extraction.
- purpose:
  To produce science spectra using average extraction. See also 4.3.2.

4.4.9 Science reduction (optimal extraction)

- Gasgano script name:
  `uves_reduceOPT.sh`
- input frames: list
  `list`of selected input files:
  `science`exposure [SCIENCE_y]
  `DRS`table [DRS_SETUP_x]
  `order`table [ORDER_TABLE_x]
  `background`table [BACKGR_TABLE_x]
  `line`tables [LINE_TABLE_xn]
  `master`bias [MASTER_BIAS_x]
  `master`flat [MASTER_FLAT_x]
  (`y:`BLUE, RED; x: BLUE, REDL, REDU; n=1,2,3)
- data products:
  reduced science spectra using optimal extraction.
- purpose:
  To produce science spectra using optimal extraction. See also 4.3.2.

4.4.10 Resolution plots

- Gasgano script name:
  `uves_resol.sh`
- input frames: list
  list of selected input files:
  ThAr exposure [ARC_LAMP_x]

DRS table [DRS_SETUP_x]
order table [ORDER_TABLE_x]
guess line table [LINE_TABLE_x]
line reference catalog [LINE_REFER_TABLE]
(x: REDL, REDU or BLUE)

- data products:

LINE_TABLE_x2	0000
LINE_TABLE_x1	0001
LINE_TABLE_x3	0002
DRS_SETUP_x	0003

(x: BLUE, REDL, or REDU)

- purpose:
Determines the dispersion relation in each sub window of the order extraction window (sky, object, sky) and plots the spectral resolution.
- description:
Creates the dispersion relation solution saved as a line table and produces a resolution plot as a POSTSCRIPT file. In the end the input DRS_SETUP table is updated.

4.4.11 Uves stability check

- Gasgano script name:
`uves_stability.sh`
- input frames: list
list of selected input files:
Formatcheck frame [ARC_LAMP_FORM_x]
Reference Formatcheck frame [MASTER_FORM_x]
ThAr line table [LINE_REFER_TABLE_x]
(x: BLUE, REDL, REDU)
- data products:

LINE_TABLE_x	0000
ORDER_TABLE_x	0001
BACKGR_TABLE_x	0002
DRS_SETUP_x	0003

(x: BLUE, REDL, or REDU)

- purpose:
Creates a line table based on the physical model of UVES. Measures the spectral shifts with respect to master spectra.
- description:
see subsection 4.1.1.

4.4.12 Wavelength calibration

- Gasgano script name:
`uves_wavecal.sh`
- input frames: list
list of selected input files:
ThAr exposure frame [ARC_LAMP_x]

DRS table [DRS_SETUP_x]
Order table [ORDER_TABLE_x]
Guess line table [LINE_TABLE_x]
ThAr line reference table [LINE_REFER_TABLE_x]
(x: BLUE, REDL, REDU)

- data products:

`LINE_TABLE_x1`	`0000`
`LINE_TABLE_x2`	`0001`
`LINE_TABLE_x3`	`0002`
`DRS_SETUP_x`	`0003`

`(x:  BLUE, REDL, or REDU)`

- purpose:
  Creates a line table based on the physical model of UVES.
- description:
  see subsection 4.1.6.

Appendix A

Installation of the online and offline Pipeline

In this chapter we give a very compact description of what the proper environment and the proper procedure to install the pipeline are. It is addressed to the astronomer who needs to install the pipeline.

A.1 Environment

In order to use the full functionality of the UVES Pipeline the following environment is required:

- A workstation or PC running a UNIX operative system, 256 MB main memory (at least 512 MB to reduce FLAMES-UVES data)
- UVES pipeline releases from 2.9.7 on, requires ESO–MIDAS version 07SEPpl1.1, or higher

A number of system variables has to be set properly to install the UVES pipeline and run the UVES context:

`$MIDASHOME`	MIDAS root directory
`$MIDVERS`	MIDAS version (07SEPpl1.1)
`$PIPE_HOME`	Location where the pipeline is being installed

A.2 Installation

1. Be sure to have defined and have existing two basic environment variables: MIDASHOME and MIDVERS, for example:

   setenv MIDASHOME /midas
   setenv MIDVERS 07SEPpl1.1
2. For normal users we have the following (CDROM) installation procedure. Be PIPE_CDROM the environment variable specifying where is the CDROM tar file distribution.

   cd $PIPE_CDROM

gunzip fluves_cdrom_2.9.7.tar.gz
tar xvf fluves_cdrom_2.9.7.tar
cd fluves
./setup.sh
Next follow the instructions given at the end of the installation.

3. To upgrade the pipeline in case of having changed just a few modules under $PIPE_HOME/uves/uves/ or $PIPE_HOME/uves/flames tree

   cd $PIPE_HOME/uves
   make update

Appendix B

Supported raw frames

In this appendix we describe all possible types of raw frames for the different observing modes. The different frame types can be identified by the values of the DPR keywords of their FITS headers (see [5]). These keywords are generated by the UVES templates (for a description of the UVES templates see [9]). A given frame type can be processed by one or a few different dedicated Pipeline recipes. The individual Pipeline recipes are described in chapter 4. In most cases, reference data frames are needed to reduce a given frame. These reference data have to match the input frame in a number of instrument parameters (e.g. to apply a flat field correction to a science frame only a flat field frame taken in the same central wavelength, same slit length, etc. will be used for the correction). These parameters are listed under *relevant instrument parameters*. Additional supported raw frames relative to the FLAMES-UVES data reduction are described in the correspondent FLAMES-UVES Data Reduction User's manual.

The following raw frame types are possible:

- Relevant instrument parameters group 1 common to all raw frames:

Number of CCD chips:	`NCHIP`
Conversion e→ADU:	`ESO DET OUT1 CONAD`
x-binning:	`ESO DET WIN1 BINX`
y-binning:	`ESO DET WIN1 BINY`
Window start in x:	`ESO DET WIN1 STRX`
Window start in y:	`ESO DET WIN1 STRY`
No of pixels in x:	`ESO DET WIN1 NX`
No of pixels in y:	`ESO DET WIN1 NY`

- Relevant instrument parameters group 2 common to some raw frames:

Grating used:	`ESO INS GRATj ID`
Central wavelength used:	`ESO INS GRATj WLEN`
Slit width used:	`ESO INS SLITi WID`
Slit length used:	`ESO INS SLITi LEN`
Filter used:	`ESO INS FILTi ID`
`i`: 2 (`BLUE`), 3 (`RED`)	
`j`: 1 (`BLUE`), 2 (`RED`)	

B.1 Bias frames

- Template signature:
  `UVES_x_cal_bias`

(x: blue, red, dic1, dic2)

- DPR keywords:
  ESO DPR CATG = CALIB
  ESO DPR TYPE = BIAS
- DO category:
  BIAS_BLUE (NCHIP = 1)
  BIAS_RED (NCHIP = 2)
- Pipeline recipe: uves_cal_mkmaster
- Relevant instrument parameters: group 1.

B.2 Dark frames

- Template signature:
  UVES_x_cal_dark
  (x: blue, red, dic1, dic2)
- DPR keywords:
  ESO DPR CATG = CALIB
  ESO DPR TYPE = DARK
  ESO DPR TECH = IMAGE
- DO category:
  DARK_BLUE (NCHIP = 1)
  DARK_RED (NCHIP = 2)
- Pipeline recipe: uves_cal_mkmaster
- Relevant instrument parameters: group 1.

B.3 Parasitic Light frames

- Template signature:
  UVES_x_cal_flatfree
  (x: blue, red, dic1, dic2)
- DPR keywords:
  ESO DPR CATG = CALIB
  ESO DPR TYPE = PARASITIC
  ESO DPR TECH = IMAGE
- DO category:
  PDARK_BLUE (NCHIP = 1)
  PDARK_RED (NCHIP = 2)
- Pipeline recipe: uves_cal_mkmaster
- Relevant instrument parameters: group 1.

B.4 Order definition flat fields

- Template signature:
  UVES_x_tec_orderdef
  (x: blue, red, dic1, dic2)
- DPR keywords:
  ESO DPR CATG = CALIB

`ESO DPR TYPE = LAMP,ORDERDEF`
`ESO DPR TECH = ECHELLE`

- DO category:
  `ORDER_FLAT_BLUE` (`NCHIP = 1`)
  `ORDER_FLAT_RED` (`NCHIP = 2`)
- Pipeline recipe: `uves_cal_orderpos`
- Relevant instrument parameters groups 1, 2.

B.5 Spectroscopic flat fields

- Template signature:
  `UVES_x_cal_y`
  `(x: blue, red, dic1, dic2)`
  `(y: flatatt, flatfree)`
- DPR keywords:
  `ESO DPR CATG = CALIB`
  `ESO DPR TYPE = LAMP,FLAT`
  `ESO DPR TECH = ECHELLE`
- DO category:
  `FLAT_BLUE` (`NCHIP = 1`)
  `FLAT_RED` (`NCHIP = 2`)
- Pipeline recipe: `uves_cal_mkmaster`
- Relevant instrument parameters groups 1, 2.

B.6 Deuterium lamp flat fields

- Template signature:
  `UVES_x_cal_y`
  `(x: blue, red, dic1, dic2)`
  `(y: flatfree)`
- DPR keywords:
  `ESO DPR CATG = CALIB`
  `ESO DPR TYPE = LAMP,DFLAT`
  `ESO DPR TECH = ECHELLE`
- DO category:
  `DFLAT_BLUE` (`NCHIP = 1`)
  `DFLAT_RED` (`NCHIP = 2`)
- Pipeline recipe: `uves_cal_mkmaster`
- Relevant instrument parameters: groups 1, 2.

B.7 Telluric lamp flat fields

- Template signature:
  `UVES_x_cal_y`
  `(x: blue, red, dic1, dic2)`
  `(y: flatfree)`
- DPR keywords:

ESO DPR CATG = CALIB
ESO DPR TYPE = LAMP,TFLAT
ESO DPR TECH = ECHELLE

- DO category:
  IFLAT_BLUE (NCHIP = 1)
  IFLAT_RED (NCHIP = 2)
- Pipeline recipe: uves_cal_tflat
- Relevant instrument parameters: groups 1, 2.

B.8 Format check spectra

- Template signature:
  UVES_x_tec_fmtchk
  (x: blue, red, dic1, dic2)
- DPR keywords:
  ESO DPR CATG = CALIB
  ESO DPR TYPE = LAMP,FMTCHK
  ESO DPR TECH = ECHELLE
- DO category:
  ARC_LAMP_FORM_BLUE (NCHIP = 1)
  ARC_LAMP_FORM_RED (NCHIP = 2)
- Pipeline recipe: uves_cal_predict
- Relevant instrument parameters: groups 1, 2.

B.9 Wavelength calibration spectra

- Template signature:
  UVES_x_cal_y
  (x: blue, red, dic1, dic2)
  (y: waveatt, wavefree)
- DPR keywords:
  ESO DPR CATG = CALIB
  ESO DPR TYPE = LAMP,WAVE
  ESO DPR TECH = ECHELLE
- DO category:
  ARC_LAMP_BLUE (NCHIP = 1)
  ARC_LAMP_RED (NCHIP = 2)
- Pipeline recipe: uves_cal_wavecal
- Relevant instrument parameters: groups 1, 2.

B.10 Standard star spectra

- Template signatures:
  UVES_x_obs_y
  (x: blue, red, dic1, dic2)
  (y: std, stdfree)
- DPR keywords:

`ESO DPR CATG = CALIB`
`ESO DPR TYPE = STD`
`ESO DPR TECH = ECHELLE`

- DO category:
  `STANDARD_BLUE` (NCHIP = 1)
  `STANDARD_RED` (NCHIP = 2)
- Pipeline recipe: `uves_cal_response`
- Relevant instrument parameters: groups 1, 2.

B.11 Science spectra

- Template signatures:
  `UVES_x_obs_y`
  `(x: blue, red, dic1, dic2)`
  `(y: exp, expfree)`
- DPR keywords:
  `ESO DPR CATG = SCIENCE`
  `ESO DPR TECH = ECHELLE`
- DO category:
  `SCIENCE_BLUE` (NCHIP = 1)
  `SCIENCE_RED` (NCHIP = 2)
- Pipeline recipe: `uves_obs_scired`
- Relevant instrument parameters: groups 1, 2.

B.12 Science spectra with image slicers

- Template signatures:
  `UVES_x_acq_imsl`
  `(x: blue, red, dic1, dic2)`
- DPR keywords:
  `ESO DPR CATG = SCIENCE`
  `ESO DPR TECH = ECHELLE`
- DO category:
  `SCIENCE_BLUE` (NCHIP = 1)
  `SCIENCE_RED` (NCHIP = 2)
- Pipeline recipe: `uves_obs_slicer_scired`
- Relevant instrument parameters: groups 1, 2,

Slicer Number:	`ESO INS SLIT1 NAME`
Number of Slices:	`ESO INS SLIT1 NO`

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