



# EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral

Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

## VERY LARGE TELESCOPE

### VISIR Pipeline User Manual

VLT-MAN-ESO-19500-3852

Issue 1.6

Date 21st September 2016

Prepared: L.K.Lundin 21st September 2016  
Name Date Signature

Approved: P.Ballester  
Name Date Signature

Released: M. Peron  
Name Date Signature

No content on this page

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	3 of 67

### Change record

Issue/Rev.	Date	Section/Parag. affected	Reason/Initiation/Documents/Remarks
1.0	1st February 2006	All	For VISIR pipeline 1.3.7
1.1	1st October 2007	All	For VISIR pipeline 2.0.0
1.3	21st January 2008	All	For VISIR pipeline 3.2.0
1.4	4th April 2014	All	For VISIR pipeline 3.5.1
1.5	25th February 2016	All	For VISIR pipeline 4.1.7
1.6	18th April 2016	All	For VISIR pipeline 4.2.0
1.7	21st September 2016	All	For VISIR pipeline 4.3.2

No content on this page

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	5 of 67

## Contents

<b>1</b>	<b>Introduction</b>	<b>9</b>
1.1	Purpose . . . . .	9
1.2	Acknowledgements . . . . .	9
1.3	Scope . . . . .	9
1.4	Reference Documents and Applicable Documents . . . . .	9
<b>2</b>	<b>Overview</b>	<b>11</b>
<b>3</b>	<b>VISIR Instrument Description</b>	<b>12</b>
3.1	Instrument overview . . . . .	12
<b>4</b>	<b>Quick start</b>	<b>14</b>
4.1	VISIR pipeline recipes . . . . .	14
4.2	An introduction to Gasgano and EsoRex . . . . .	14
4.2.1	Using Gasgano . . . . .	15
4.2.2	Using EsoRex . . . . .	16
4.2.3	Imaging GUI . . . . .	20
<b>5</b>	<b>Known Problems</b>	<b>25</b>
<b>6</b>	<b>Instrument Data Description</b>	<b>26</b>
6.1	General Data Layout - Aquarius detector . . . . .	26
6.1.1	Half-Cycle mode . . . . .	26
6.1.2	Burst mode . . . . .	26
6.2	General Data Layout - DRS detector . . . . .	27
6.3	General frames . . . . .	27
6.4	Imaging frames . . . . .	28
6.5	Spectroscopy frames . . . . .	28
<b>7</b>	<b>Static Calibration Data</b>	<b>30</b>
7.1	Imaging Standard Stars . . . . .	30
7.2	Spectroscopy Standard Stars . . . . .	30

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	6 of 67

7.3	Spectrometer Detector Quantum Efficiency . . . . .	31
7.4	Atmospheric Emission Spectrum . . . . .	31
<b>8</b>	<b>Data Reduction</b>	<b>32</b>
8.1	Reduction Cascade . . . . .	32
8.2	VISIR pipeline recipes . . . . .	32
8.3	Unsupported Observation Modes . . . . .	32
<b>9</b>	<b>Pipeline Recipe Interfaces</b>	<b>33</b>
9.1	visir_img_reduce . . . . .	33
9.1.1	Input files for visir_img_reduce . . . . .	33
9.1.2	Input Parameters for visir_img_reduce . . . . .	34
9.1.3	Products from visir_img_reduce . . . . .	34
9.1.4	QC Parameters from visir_img_reduce . . . . .	35
9.2	visir_img_dark . . . . .	36
9.2.1	Input files for visir_img_dark . . . . .	36
9.2.2	Input Parameters for visir_img_dark . . . . .	36
9.2.3	Products from visir_img_dark . . . . .	36
9.2.4	QC Parameters from visir_img_dark . . . . .	37
9.3	visir_spc_reduce . . . . .	37
9.3.1	Input files for visir_spc_reduce . . . . .	37
9.3.2	Input Parameters for visir_spc_reduce . . . . .	38
9.3.3	Products from visir_spc_reduce . . . . .	38
9.3.4	QC Parameters from visir_spc_reduce . . . . .	39
9.4	Product Description . . . . .	39
9.4.1	Imaging product data . . . . .	39
9.4.2	Spectroscopic product data . . . . .	40
<b>10</b>	<b>Algorithms</b>	<b>41</b>
10.1	General Algorithms . . . . .	41
10.1.1	Bad pixel detection and cleaning . . . . .	41
10.1.2	Distortion correction . . . . .	41

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	7 of 67

10.1.3	Creation of combined image . . . . .	41
10.1.4	Imaging Photometric Calibration . . . . .	43
10.1.5	Wavelength Calibration . . . . .	44
10.1.6	Spectrum Extraction . . . . .	45
10.1.7	Spectral Photometric Calibration . . . . .	46
10.1.8	Imaging Photometric Calibration . . . . .	46
10.1.9	Computation of Strehl Ratio . . . . .	46
10.2	Recipe Algorithms . . . . .	47
10.2.1	visir_img_ff . . . . .	47
10.2.2	visir_img_dark . . . . .	47
10.2.3	visir_img_reduce . . . . .	47
10.2.4	visir_spc_reduce . . . . .	47
<b>A</b>	<b>Installation</b>	<b>52</b>
A.1	Supported platforms . . . . .	52
A.2	Building the VISIR pipeline . . . . .	52
A.2.1	Requirements . . . . .	52
A.2.2	Compiling and installing the VISIR pipeline . . . . .	53
<b>B</b>	<b>QC Parameters</b>	<b>54</b>
<b>C</b>	<b>Abbreviations and acronyms</b>	<b>67</b>

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	8 of <a href="#">67</a>



ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	9 of 67

# 1 Introduction

## 1.1 Purpose

The VISIR pipeline is a subsystem of the *VLT Data Flow System* (DFS). It is used in two operational environments, for the *ESO Data Flow Operations* (DFO), and for the *Paranal Science Operations* (PSO), in the quick-look assessment of data, in the generation of master calibration data, in the reduction of scientific exposures, and in the data quality control. Additionally, the VISIR pipeline recipes are made public to the user community, to allow a more personalised processing of the data from the instrument. The purpose of this document is to describe a typical VISIR data reduction sequence with the VISIR pipeline.

This manual is a complete description of the data reduction recipes used by the VISIR pipeline, reflecting the status of the VISIR pipeline as of 21st September 2016 (version 4.3.2).

## 1.2 Acknowledgements

We want to thank Eric Pantin, CEA and Ralf Siebenmorgen for providing valuable ideas for improving the pipeline recipes. We thank also Yves Jung, who played a major role in the development of the first version of the pipeline. The feedback we received in numerous discussions with our “beta-testers”, VISIR Instrument Scientists Alain Smette, Stephane Brilliant and Konrad Tristram, and VISIR Quality Control Scientists Danuta Dobrzycka and Burkhard Wolff was very much appreciated.

In particular we want to thank Daniel Asmus and Valentin Ivanov, who were a continuous source of useful ideas for improving the pipeline recipes, and for their extensive testing.

## 1.3 Scope

This document describes the VISIR pipeline used at ESO-Garching and ESO-Paranal for the purpose of data assessment and data quality control.

Updated versions of the present document may be found on [17]. For general information about the current instrument pipelines status we remind the user of [7]. Quality control information are at [6].

Additional information on QFITS, the Common Pipeline Library (CPL) and ESOREX can be found respectively at [12], [15]. The Gasgano tool is described in [16]. A description of the instrument is in [8]. The VISIR instrument user manual is in [9] while results of Science Verifications (SV) are at [3].

## 1.4 Reference Documents and Applicable Documents

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	10 of 67

- [1] ESO. *Parameters for setting the VISIR Spectrometer*. VLT-TRE-VIS-14321-5046.
- [2] ESO. *VISIR Calibration Plan*. VLT-PLA-VIS-14300-0009.
- [3] ESO, <http://www.eso.org/science/vltsv/visirsv/>. *VISIR Science Verification home page*. 9
- [4] ESO. *VLT Data Flow System Specifications for Pipeline and Quality Control*. VLT-SPE-ESO-19600-1233.
- [5] ESO/DMO. *ESO DICB – Data Interface Control Document*. GEN-SPE-ESO-19400-0794 (3.0). 27, 28, 29
- [6] ESO/DMO/DFO, <http://www.eso.org/observing/dfo/quality/>. *ESO-Data Flow Operation home page*. 9
- [7] ESO/DMO/DFO, <http://www.eso.org/observing/dfo/quality/pipeline-status.html>. *VISIR Pipeline Current Status*. 9
- [8] ESO/INS, <http://www.eso.org/instruments/visir/>. *VISIR instrument home page*. 9
- [9] ESO/INS, <http://www.eso.org/instruments/visir/doc/>. *VISIR instrument home page*. 9, 12, 30, 31, 41
- [10] ESO/SDD/DFS, <http://www.eso.org/observing/cpl/download.html>. *Common Pipeline Library Reference Manual*. VLT-ESO-MAN-19500-2721.
- [11] ESO/SDD/DFS, <http://www.eso.org/observing/cpl/download.html>. *Common Pipeline Library User Manual*. VLT-MAN-ESO-19500-2720.
- [12] ESO/SDD/DFS, <http://www.eso.org/cpl>. *CPL home page*. 9, 41, 46
- [13] ESO/SDD/DFS. *Deliverables Specification*. VLT-SPE-ESO-19000-1618 (2.0).
- [14] ESO/SDD/DFS. *DFS Pipeline & Quality Control – User Manual*. VLT-MAN-ESO-19500-1619.
- [15] ESO/SDD/DFS, <http://www.eso.org/cpl/esorex.html>. *ESOREX home page*. 9
- [16] ESO/SDD/DFS, <http://www.eso.org/gasgano/>. *Gasgano User's Manual*. VLT-PRO-ESO-19000-1932. 9
- [17] ESO/SDD/DFS, <http://www.eso.org/pipelines>. *VISIR Pipeline Web Page*. 9
- [18] Rio Y. et al. *VISIR: A mid infrared imager and spectrometer for the VLT*, spie vol. 2475, pp. 286-295, orlando edition, April 1995. VLT-TRE-VIS-14321-5046.
- [19] Rio Y. et al. *VISIR: The mid infrared imager and spectrometer for the VLT*, spie vol. 3354, pp. 615-626, kona, hawaii edition, March 1998.
- [20] P.-O. Lagage. *The final design of VISIR, the mid-infrared imager and spectrometer for the VLT*.
- [21] P.-O. Lagage et al. *Result of the phase A study for the VLT Mid-infrared instrument: VISIR*, the eso messenger no. 80, pp. 13-16 edition, June 1995.
- [22] P.-O. Lagage et al. *VISIR at PDR*, the (eso) messenger, no. 91, pp. 17-21 edition, March 1998.

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	11 of 67

## 2 Overview

In collaboration with instrument consortia, the Data Flow Systems Department (DFS) of the Data Management and Operation Division is implementing data reduction pipelines for the most commonly used VLT/VLTI instrument modes. These data reduction pipelines have the following three main purposes:

**Data quality control:** pipelines are used to produce the quantitative information necessary to monitor instrument performance.

**Master calibration product creation:** pipelines are used to produce master calibration products (*e.g.*, combined bias frames, super-flats, wavelength dispersion solutions).

**Science product creation:** using pipeline-generated master calibration products, science products are produced for the supported instrument modes (*e.g.*, combined ISAAC jitter stacks; bias-corrected, flat-fielded FORS images, wavelength-calibrated UVES spectra). The accuracy of the science products is limited by the quality of the available master calibration products and by the algorithmic implementation of the pipelines themselves. In particular, adopted automatic reduction strategies may not be suitable or optimal for every scientific goal.

Instrument pipelines consist of a set of data processing modules that can be called from the command line, from the automatic data management tools available on Paranal or from Gasgano.

ESO offers two front-end applications for launching pipeline recipes, *Gasgano* [6] and *EsoRex*, both included in the pipeline distribution (see Appendix A on page 52). These applications can also be downloaded separately from <http://www.eso.org/gasgano> and <http://www.eso.org/cpl/esorex.html>. An illustrated introduction to Gasgano is provided in the "Quick Start" section 4 on page 14.

The VISIR instrument and the different types of VISIR raw frames and auxiliary data are described in sections 3 on the following page, 6 on page 26, and 7 on page 30.

A brief introduction to the usage of the available reduction recipes using Gasgano or EsoRex is presented in section 4 on page 14. In section 5 on page 25 we advise the user about known data reduction problems providing also possible solutions.

An overview of the data reduction, what are the input data, and the recipes is provided in section 8 on page 32.

More details on what are inputs, products, quality control measured quantities, and controlling parameters of each recipe is given in section 9 on page 33.

More detailed descriptions of the data reduction algorithms used by the individual pipeline recipes can be found in section 10 on page 41.

In appendix A on page 52 the installation of the VISIR pipeline recipes is given.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	12 of 67

### 3 VISIR Instrument Description

This section provides a brief description of the VISIR instrument.

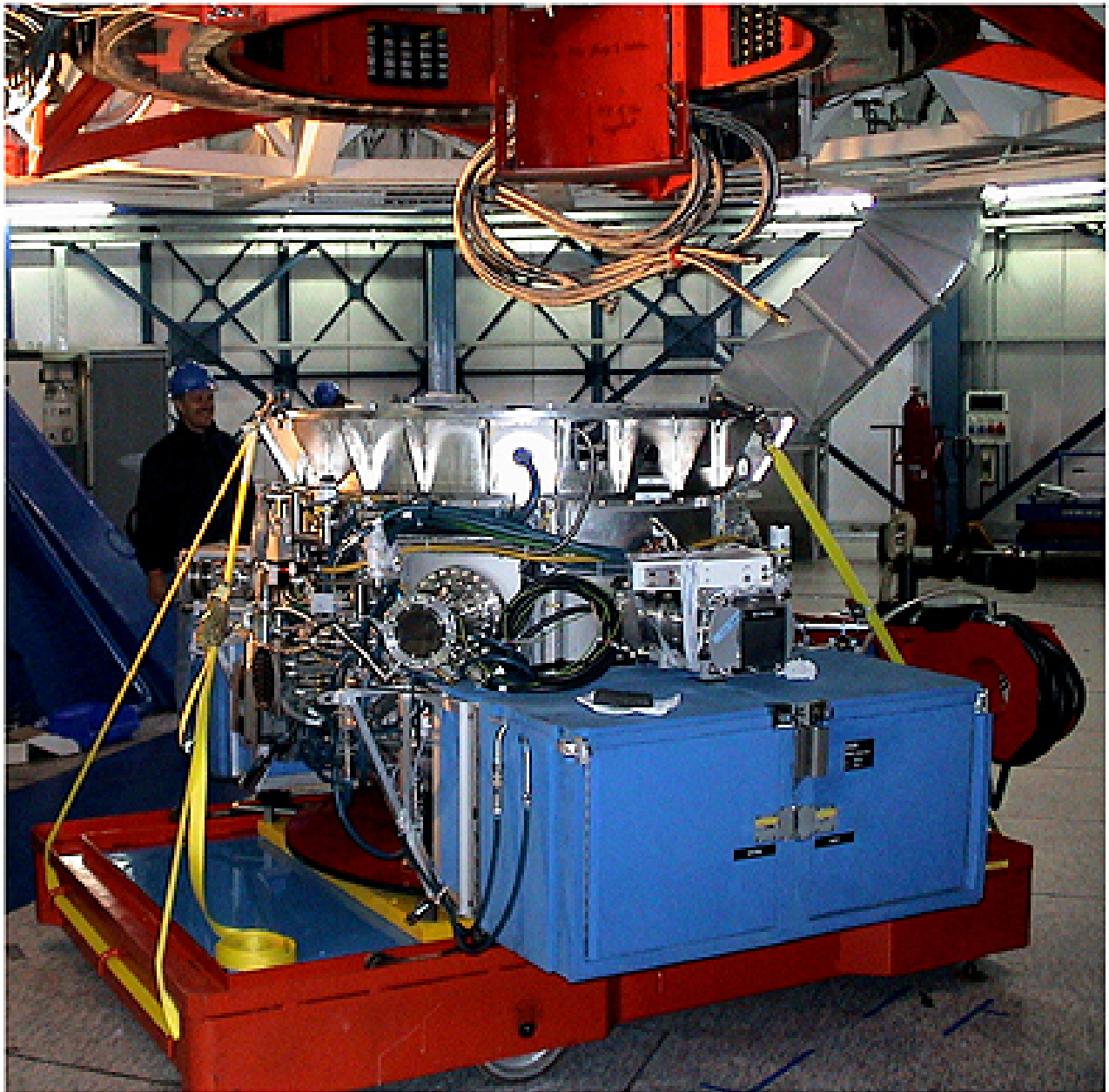
A more complete documentation can be found in the VISIR User Manual, downloadable from <http://www.eso.org/instruments/visir/doc>

VISIR has been developed under ESO contract by CEA/DAPNIA/SAP and NFRA/ASTRON. The instrument has been made available to the community and started operations in Paranal in April 2005.

#### 3.1 Instrument overview

For a description of the VISIR instrument, please see [9]. *Parameters for setting the VISIR Spectrometer* (VLT-TRE-VIS-14321-5046) contains more information about the VISIR spectrometer.

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	13 of 67



## VISIR under the Cassegrain Focus of the 8.2-m VLT Melipal Telescope

ESO PR Photo 16a/04 (12 May 2004)

© European Southern Observatory



Figure 3.1.1: *VISIR under the Cassegrain Focus of the 8.2m VLT Melipal Telescope.*

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	14 of 67

## 4 Quick start

This section describes the most immediate usage of the VISIR pipeline recipes.

### 4.1 VISIR pipeline recipes

For reduction of science and calibration data, the current VISIR pipeline offers several recipes of which most of them are internal utility or legacy recipes. Currently the following four recipes can be used to handle raw input data:

**visir\_img\_reduce** Executes the full imaging reduction chain including stacking of exposures and photometry. Internally it calls a collection of sub recipes which are also available as standalone versions.

**visir\_spc\_reduce** Executes the full spectroscopy reduction chain including stacking of exposures, undistortion, wavelength calibration and photometry. Internally it calls a collection of sub recipes which are also available as standalone versions.

**visir\_util\_repack** Repacks the various raw detector data formats (see 6) into a format more suitable for following processing steps. This includes extracting the single exposures into separate files and optionally applying the chop/nod background subtraction.

**visir\_img\_dark** creates a dark image and maps of hot, cold and deviant pixels from a sequence of dark exposures in both imaging and spectroscopy.

### 4.2 An introduction to Gasgano and EsoRex

Before being able to call pipeline recipes on a set of data, the data must be properly classified, and associated with the appropriate calibrations. The *Data Classification* consists of tasks such as: "What kind of data am I?", e.g., FLAT, "to which group do I belong?", e.g., to a particular Observation Block or template. *Data Association* is the process of selecting appropriate calibration data for the reduction of a set of raw science frames. Typically, a set of frames can be associated if they share a number of properties, such as instrument and detector configuration. As all the required information is stored in the FITS headers, data association is based on a set of keywords (called "association keywords") and is specific to each type of calibration<sup>1</sup>.

The process of data classification and association is known as data organisation. The *DO Category* is the label assigned to a data type as a result of data classification.

An instrument pipeline consists of a set of data processing modules that can be called from different host applications, either from the command line with *EsoRex*, from the automatic data management tools available at Paranal, or from the graphical *Gasgano* tool.

*Gasgano* is a data management tool that simplifies the data organisation process, offering automatic data classification and making the data association easier (*even if automatic association of frames is not yet provided*).

<sup>1</sup>The data association is based on the value of the triplet of FITS keys DPR.CATG, DPR.TYPE and DPR.TECH

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	15 of 67

*Gasgano* determines the classification of a file by applying an instrument specific rule, while users must provide this information to the recipes when they are executed manually using *EsoRex* from the command line. In addition, *Gasgano* allows the user to execute directly the pipeline recipes on a set of selected files.

#### 4.2.1 Using Gasgano

To get familiar with the VISIR pipeline recipes and their usage, it is advisable to begin with *Gasgano*, because it provides a complete graphic interface for data browsing, classification and association, and offers several other utilities such as easy access to recipes documentation and preferred data display tools.

*Gasgano* can be started from the Command Line Interface in the following way:

```
gasgano &
```

Figure 4.2.1 shows the *Gasgano* main window with the 4 VISIR calibration files automatically loaded, which is the configuration of the publicly available version 4.3.2 of the VISIR pipeline.

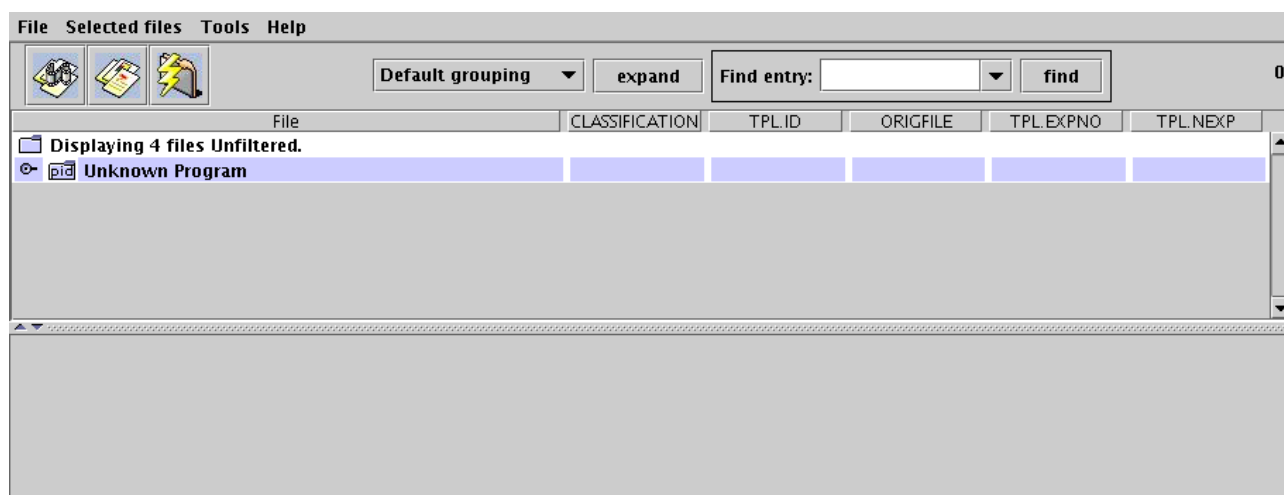


Figure 4.2.1: The *Gasgano* main window with the VISIR calibration files.

The VISIR calibration files become visible with their DO categories, when the file browser is expanded as shown in figure 4.2.2 on the following page. With the pull-down-menu *File->Add/Remove Files* directories containing VISIR data can be added, as shown in figure 4.2.3 on page 17. Figure 4.2.4 on page 18 shows the example data set distributed with the public release of the VISIR pipeline.

The data are hierarchically organised as preferred by the user. After each file name are shown the classification, the template id, the original filename, the template exposure number and the number of exposures in the template.

More information about a single frame can be obtained by clicking on its name: the corresponding FITS file header will be displayed on the bottom panel, where specific keywords can be opportunely filtered and searched. Images and tables may be easily displayed using the viewers specified in the appropriate *Preferences* fields.

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	16 of 67

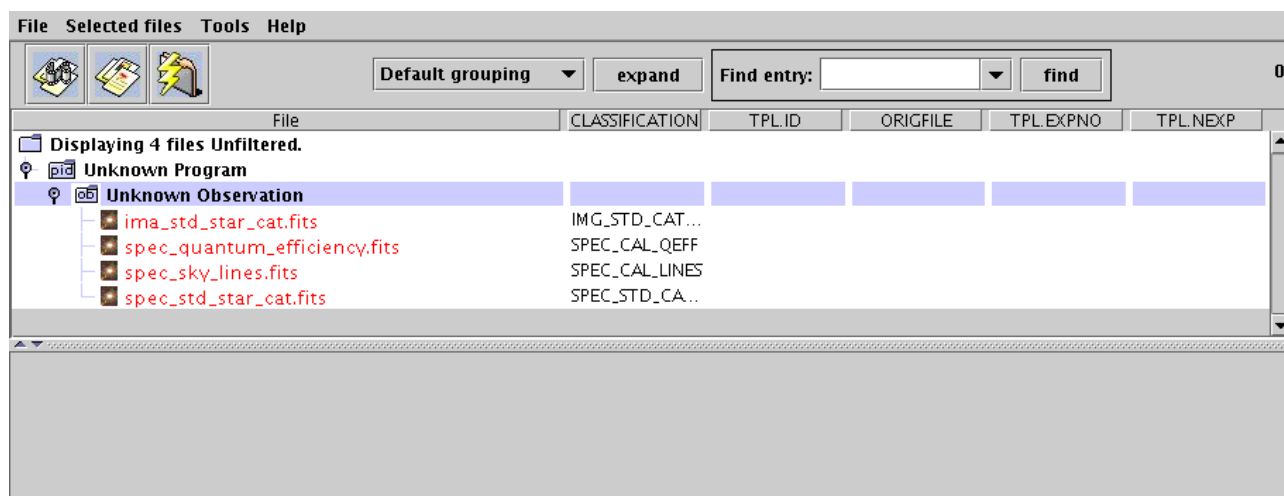


Figure 4.2.2: The *Gasgano* main window with expanded file view of the initially loaded calibration files.

Frames can be selected from the main window with a <CTRL>-left-click for processing by the appropriate recipe: on Figure 4.2.5 on page 19, the example spectroscopic FITS-files and the three spectroscopic calibration files have been selected and the pull-down-menu with the VISIR recipes is shown.

Selecting the appropriate recipe, *visir\_spc\_reduce*, will open a *Gasgano* recipe execution window (see Figure 4.2.6 on page 22), having all the specified files listed in its *Input Frames* panel.

Help about the recipe may be obtained from the *Help* menu. Before launching the recipe, its parameters may be modified on the *Parameters* panel (on top). The window contents might be saved for later use by selecting the *Save Current Settings* entry from the *File* menu, as shown in figure.

At this point the recipe can be launched by pressing the *Execute* button. Messages from the running recipe will appear on the *Log Messages* panel at bottom, and in case of successful completion the products will be listed on the *Output Frames* panel, where they can be easily viewed and located back on the *Gasgano* main window. The successful processing of the example data can be seen in figure 4.2.7 on page 23.

Please refer to the *Gasgano User's Manual* [6] for a more complete description of the *Gasgano* interface.

## 4.2.2 Using EsoRex

*EsoRex* is a command line utility for running pipeline recipes. It may be embedded by users into data reduction scripts for the automation of processing tasks. On the other side, *EsoRex* doesn't offer all the facilities available with *Gasgano*, and the user must classify and associate the data using the information contained in the FITS header keywords (see section 6.3 on page 27). The user should also take care of defining the input set-of-frames and the appropriate configuration parameters for each recipe run:

**The set-of-frames:** Each pipeline recipe is run on a set of input FITS data files. When using *EsoRex* the filenames must be listed together with their DO category in an ASCII file, the *set-of-frames* (SOF), that



ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	17 of 67

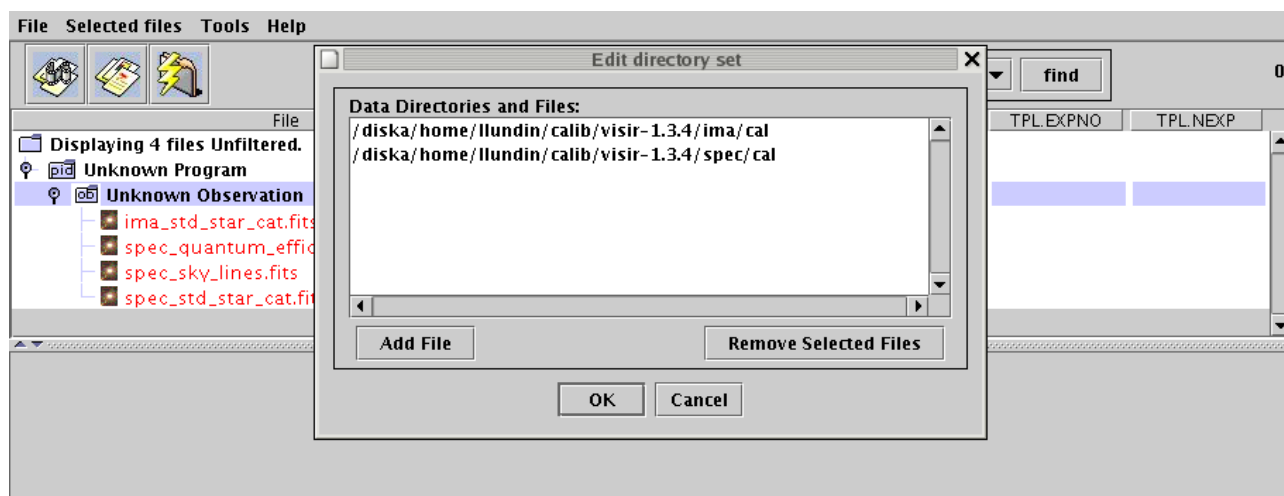


Figure 4.2.3: The *Gasgano* main window with the file loader window on top.

is required when launching a recipe.<sup>2</sup>

Here is an example of an SOF suitable for the *visir\_spc\_obs* recipe:

```
VISIR.2004-09-03T23:23:11.260.fits SPEC_OBS_LMR
VISIR.2004-09-03T23:24:05.263.fits SPEC_OBS_LMR
VISIR.2004-09-03T23:24:52.508.fits SPEC_OBS_LMR
VISIR.2004-09-03T23:25:45.026.fits SPEC_OBS_LMR
spec/cal/spec_sky_lines.fits SPEC_CAL_LINES
spec/cal/spec_quantum_efficiency.fits SPEC_CAL_QEFF
```

Note that the VISIR pipeline recipes do not verify the correctness of the DO category specified by the user in the SOF. The reason of this lack of control is that VISIR recipes are just one component of the complete pipeline running on Paranal, where the task of data classification and association is carried out by separate applications. Moreover, using *Gasgano* as an interface to the pipeline recipes will always ensure a correct classification of all the data frames, assigning the appropriate DO category to each one of them (see section 4.2.1 on page 15).

Such a procedure requires that the input FITS data are given a classification different from the one they should have.

If such a classification is done with FITS data that are not suitable for the given recipe, the recipe will most likely complete with a more or less descriptive error message, but there is a risk that the recipe will complete without any indication that the input is in fact invalid and the output flawed.

**EsoRex syntax:** The basic syntax to use ESOREX is the following:

**esorex [esorex\_options] recipe\_name [recipe\_options] set\_of\_frames**

To get more information on how to customise ESOREX (see also [6]) run the command:

<sup>2</sup>The set-of-frames corresponds to the *Input Frames* panel of the *Gasgano* recipe execution window (see figure 4.2.6 on page 22).

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	18 of 67

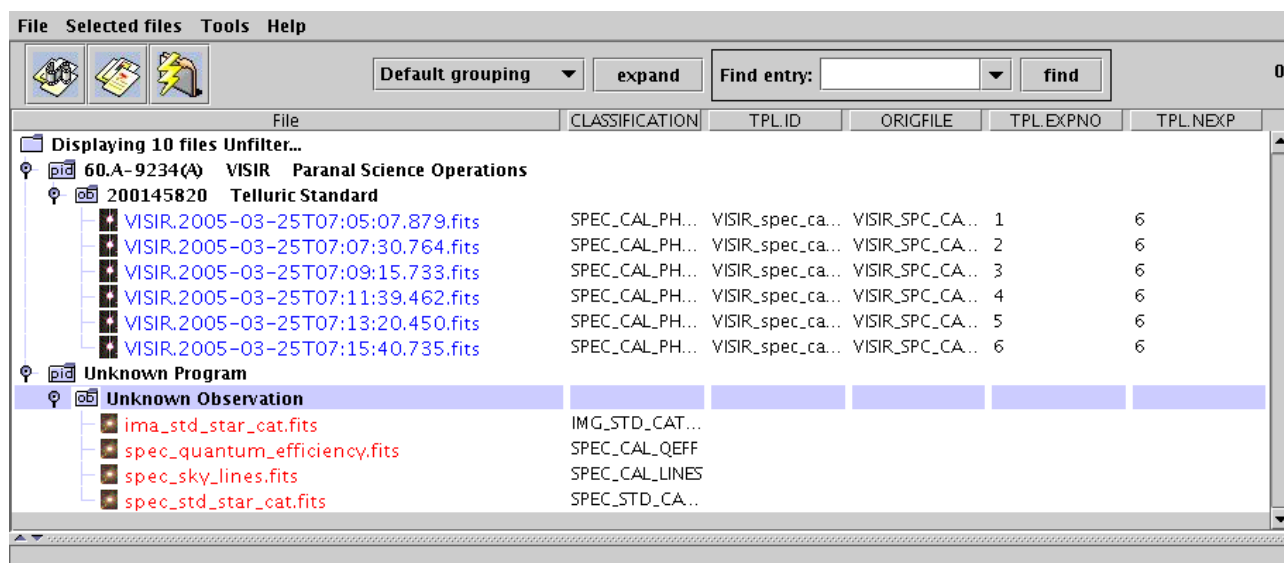


Figure 4.2.4: The Gasgano main window with the example FITS files loaded.

### esorex - -help

To generate a configuration file `esorex.rc` in the directory `$HOME/.esorex` run the command:

### esorex - -create-config

A list of all available recipes, each with a one-line description, can be obtained using the command:

### esorex - -recipes

All recipe parameters (aliases) and their default values can be displayed by the command

### esorex - -params recipe\_name

To get a brief description of each parameter meaning execute the command:

### esorex - -help recipe\_name

To get more details about the given recipe give the command at the shell prompt:

### esorex - -man-page recipe\_name

**Recipe configuration:** Each pipeline recipe may be assigned an *EsoRex* configuration file, containing the default values of the parameters related to that recipe.<sup>3</sup> The configuration files are normally generated in the directory `$HOME/.esorex`, and have the same name as the recipe to which they are related, with the filename extension `.rc`. For instance, the recipe `visir_img_reduce` has its *EsoRex* generated configuration file named `visir_img_reduce.rc`, and is generated with the command:

### esorex - -create-config visir\_img\_reduce - -jy\_val=5

The definition of one parameter of a recipe may look like this:

<sup>3</sup>The *EsoRex* recipe configuration file corresponds to the *Parameters* panel of the *Gasgano* recipe execution window (see figure 4.2.6 on page 22).

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	19 of 67

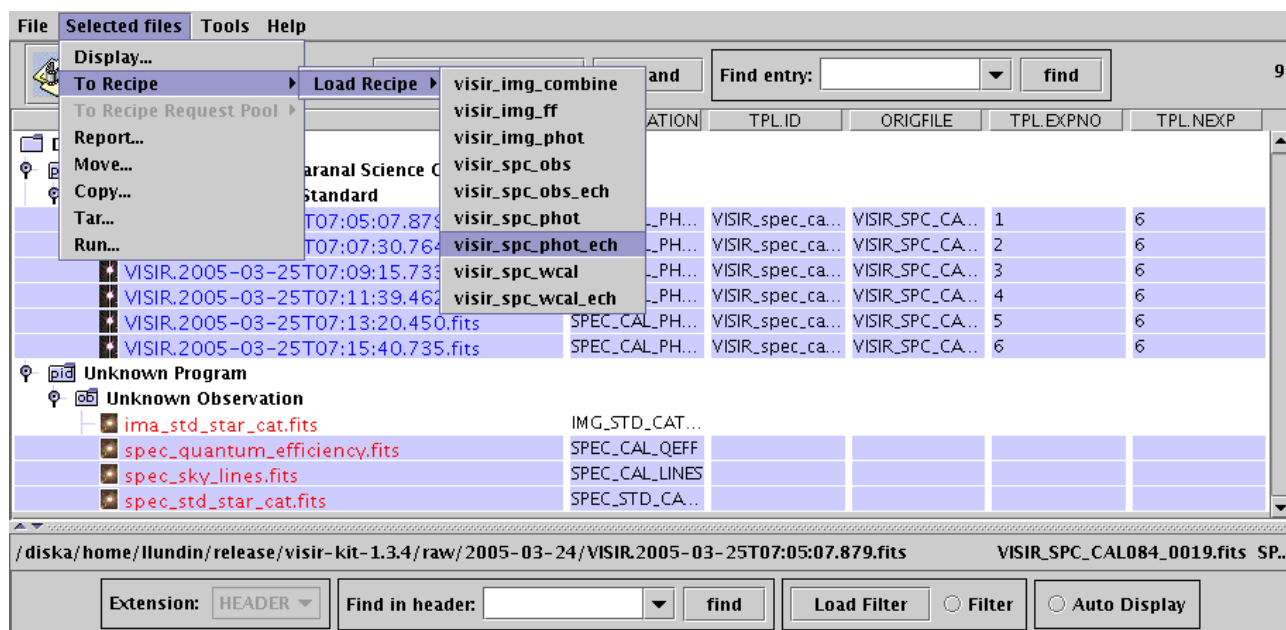


Figure 4.2.5: The Gasgano main window with selected files and the pull-down-menu with the VISIR recipes.

```
visir.visir_img_reduce.jy_val=5.
```

In this example, the parameter `visir.visir_img_reduce.low` is set to the value 5. In the configuration file generated by *EsoRex*, one or more comment lines are added containing information about the possible values of the parameter, and an alias that could be used as a command line option.

Given a recipe named *visir\_recipe\_name* the command

**esorex - -create-config visir\_recipe\_name**

Generates a default configuration file **visir\_recipe\_name.rc** in the directory **\$HOME/.esorex**<sup>4</sup>.

A recipe configuration file different from the default one can be specified on the command line:

**esorex - -recipe-config=my\_alternative\_recipe\_config**

Recipe parameters are provided in section 9 on page 33 and their role is described in section 10 on page 41.

More than one configuration file may be maintained for the same recipe but, in order to be used, a configuration file not located under `$HOME/.esorex`, or having a name different from the recipe name, should be explicitly specified when launching a recipe.

**Recipe execution:** A recipe can be run by specifying its name to *EsoRex*, together with the name of a set-of-frames. For instance, the following command line would be used to run the recipe *visir\_spc\_reduce* for processing the files specified in the set-of-frames *visir\_spc\_reduce.sof*:

**esorex visir\_spc\_reduce visir\_spc\_reduce.sof**

<sup>4</sup>If a number of recipe parameters are specified on the command line, the given values will be used in the created configuration file.

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	20 of 67

The recipe parameters can be modified either by editing directly the used configuration file, or by specifying new parameter values on the command line using the command line options defined for this purpose. Such command line options should be inserted after the recipe name and before the SOF name, and they will supersede the system defaults and/or the configuration file settings. For instance, to set the *visir\_img\_reduce* recipe *jy\_val* threshold parameter to 5, the following should be typed:

**esorex visir\_img\_reduce -jy\_val=0.5 visir\_img\_reduce.sof**

Here are some more examples of running a recipe:

```
esorex --output-prefix=test visir_img_reduce test.sof
esorex --msg-level=debug visir_spc_reduce spc_phot.sof
```

For more information on *EsoRex*, see <http://www.eso.org/cpl/esorex.html>.

### 4.2.3 Imaging GUI

The imaging gui provides a quick overview of the results of the processing step which is in charge of detecting objects, determining shifts between them and rejecting bad exposures. The GUI (Figure 4.2.8 on page 24) presents these results in several plots and allows to tune the parameters the recipe.

On the right hand side the recipe parameters used in the last iteration are displayed (see 1 on 4.2.8 on page 24) Below the parameter boxes are two buttons to either accept the current results or repeat the recipe with the changed parameters.

The left hand area contains several plots which allow to quickly explore the data and the results of the object detection. The primary line plot (see 2 on 4.2.8 on page 24) shows several statistics for each chop nod corrected image in the input data. By default it shows the correlation to of each image to the correlation template shown in plot 5. By clicking on the radiobox next to the image the shown statistics can be changed, currently available are:

- Correlation: normalized correlation to the template
- Full width half maximum of the object in X and Y
- Median absolute deviation of the image
- Standard deviation of the image

The statistic plot can be clicked to see the corresponding image in the center middle plot (4).

The image middle left image (see 3 on 4.2.8 on page 24) shows the average of all chop-nod corrected images in the raw data without any correction applied. The diamonds in this image show the detected pivot beam positions.<sup>5</sup> When the beam detection failed the button above 3 will be colored red. If one wants the rest of the reduction to not consider the whole image as one beam the button must be clicked to select the rough positions

<sup>5</sup>These positions must not be exact, it is just used to determine the region in the image where a beam is present

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	21 of <a href="#">67</a>

of the beams manually. It can also be used to only select a single object for the rest of the reduction instead of all of them.

By right clicking on the image plots one can change the used color map and scale of the images. Also one can detach the images to view them at a larger scale.

The bottom plot 6 shows a scatter plot detected shifts between the objects. These shifts will be applied during the coaddition phase of the reduction.

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	22 of 67

File Help

Current Queued Executing

**Parameters**

Name	Value	Default	Range
visir.visir_spc_phot_ech.phi	0.0	0.0	
visir.visir_spc_phot_ech.ksi	0.0	0.0	
visir.visir_spc_phot_ech.eps	0.0	0.0	
visir.visir_spc_phot_ech.delta	0.0	0.0	
visir.visir_spc_phot_ech.nodding			
visir.visir_spc_phot_ech.auto_bpm	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
visir.visir_spc_phot_ech.rem_glitch	<input type="checkbox"/>	<input type="checkbox"/>	
visir.visir_spc_phot_ech.purge_bad	<input type="checkbox"/>	<input type="checkbox"/>	
visir.visir_spc_phot_ech.union	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
visir.visir_spc_phot_ech.rej	0 0	0 0	
visir.visir_spc_phot_ech.plot	0	0	
visir.visir_spc_phot_ech.orderoffset	0	0	
visir.visir_spc_phot_ech.offsets			
visir.visir_spc_phot_ech.fixcombi	<input type="checkbox"/>	<input type="checkbox"/>	

**Input Frames**

Include	Filename	Classification		
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:05:07.879.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:07:30.764.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:09:15.733.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:11:39.462.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:13:20.450.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:15:40.735.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	spec_quantum_efficiency.fits	SPEC_CAL_QEFF	Locate	Display
<input checked="" type="checkbox"/>	spec_sky_lines.fits	SPEC_CAL_LINES	Locate	Display
<input checked="" type="checkbox"/>	spec_std_star_cat.fits	SPEC_STD_CATALOG	Locate	Display

**Product Naming**

Product Root Directory: /diska/home/llundin/release/visir-kit-1.3.4 Browse Naming Scheme: Numeric

Execute

**Output Frames**

Clear

**Log Messages**

Save Clear

Add to pool

Request Pool

Execute Selected

Figure 4.2.6: The Gasgano recipe window with the recipe visir\_spc\_phot\_ech.

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	23 of 67

File Help

Current Queued Executing

**Parameters**

Name	Value	Default	Range
visir.visir_spc_phot_ech.phi	0.0	0.0	
visir.visir_spc_phot_ech.ksi	0.0	0.0	
visir.visir_spc_phot_ech.eps	0.0	0.0	
visir.visir_spc_phot_ech.delta	0.0	0.0	
visir.visir_spc_phot_ech.nodding			
visir.visir_spc_phot_ech.auto_bare			

**Input Frames**

Include	Filename	Classification	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:05:07.879.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:07:30.764.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:09:15.733.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:11:39.462.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:13:20.450.fits	SPEC_CAL_PHOT_H...	Locate	Display
<input checked="" type="checkbox"/>	VISIR.2005-03-25T07:15:40.735.fits	SPEC_CAL_PHOT_H...	Locate	Display

**Product Naming**

Product Root Directory: /diska/home/llundin/release/visir-kit-1.3.4 Browse Naming Scheme: Numeric

Execute

**Output Frames**

Filename	Classification	Locate	Display
visir_spc_phot_ech_tab_0000.fits	SPC_PHOT_HRG_TAB	Locate	Display
visir_spc_phot_ech_0000.fits	SPC_PHOT_HRG_COMBINED	Locate	Display
visir_spc_phot_ech_weight_0000.fits	SPC_PHOT_HRG_WEIGHT	Locate	Display

**Log Messages**

/diska/home/llundin/release/visir-kit-1.3.4/visir\_spc\_phot\_ech\_tab\_0000.fits  
/diska/home/llundin/release/visir-kit-1.3.4/visir\_spc\_phot\_ech\_0000.fits  
/diska/home/llundin/release/visir-kit-1.3.4/visir\_spc\_phot\_ech\_weight\_0000.fits  
Completion status: SUCCESS

Save Clear

Figure 4.2.7: The Gasgano recipe window with the recipe visir\_spc\_phot\_ech successfully completed.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	24 of 67

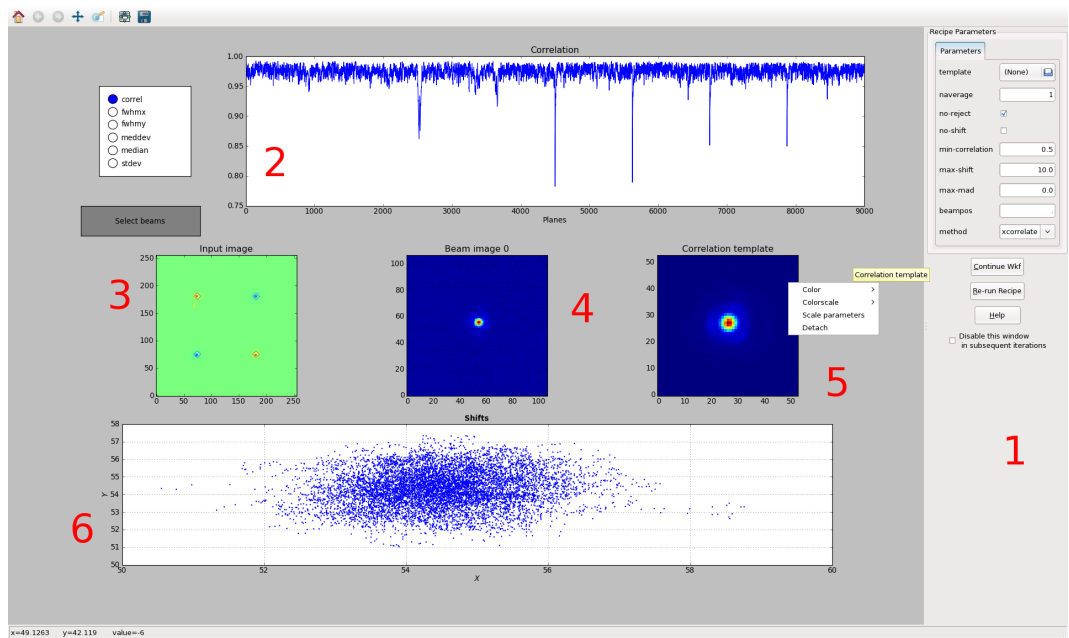


Figure 4.2.8: Screenshot of the imaging GUI.



<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	25 of 67

## 5 Known Problems

The known problems of the VISIR pipeline version 4.3.2 are:

- The pipeline does currently not directly support extraction of spectra from extended sources. It does provide the necessary intermediate products to allow this extraction manually, see the product description [9.3](#) on page [37](#) and algorithm description [10.1.6](#) on page [45](#).
- On *MacOS* and under *Gasgano* the parallelization of the recipes does not work. Processing on these platforms can be significantly slower than on *Linux*.
- The long slit spectrum extraction assumes that all beams fall on the detector.
- The spectral calibration does not take the drift of the high resolution spectroscopy scanner into account.
- In a few cases the Strehl ratio exceeds 1.
- The linearity correction is not well determined and will degrade low signal count data.
- For the Aquarius detector in low resolution mode the wavelength calibration has not yet been optimized and an error of about 5 pixels or  $0.05\mu m$  must be assumed.

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	26 of 67

## 6 Instrument Data Description

VISIR data uses the FITS format and can be separated into *raw* frames and *product* frames. Raw frames are the unprocessed output of the VISIR instrument observations, while product frames are the result of the VISIR pipeline processing. In addition the VISIR pipeline uses a set of calibration (FITS-) files (standard stars catalogs, detector characteristics, etc.).

Any raw or product frame can be classified on the basis of a set of keywords read from its header. Data classification is typically carried out by the DO or by *Gasgano* [6], that apply the same set of classification rules. The association of a raw frame with calibration data (*e.g.*, of a science frame with a standard star catalogue) can be obtained by matching the values of a different set of header keywords.

Each kind of *raw* frame is typically associated to a single VISIR pipeline recipe, *i.e.*, the recipe assigned to the reduction of that specific frame type. In the pipeline environment this recipe would be launched automatically.

In the following all raw and product VISIR data frames, that can be reduced by the VISIR pipeline version 4.3.2, are listed, together with the keywords used for their classification and correct association. The indicated *DO category* is a label assigned to any data type after it has been classified, which is then used to identify the frames listed in the *Set of Frames* (see section 4.2.2 on page 16).

Raw frames can be classified as *imaging* frames or *spectroscopy* frames. Their intended use is implicitly defined by the assigned recipe.

### 6.1 General Data Layout - Aquarius detector

#### 6.1.1 Half-Cycle mode

A raw VISIR file for the regular half cycle image mode is a FITS-file containing several extensions. The primary header contains only information about the observation, like the date, target, detector integration time, the number of detector integration etc. The image data is contained in FITS extensions following the primary header. Each image data extension contains its own header which contains only information which is specific to this extension. The type of image contained in the extension is defined in the ESO DET FRAM TYPE key. The main data has the type HCYCLE1 or HCYCLE2 which means it are half cycle exposures, containing the averaged integrations of one chop cycle. Depending on the observation settings the frames can also contain the average of all half cycles of one type.

Typically the last extension in the file contains the total integration image with the type INT. This image contains the average of all half cycles, were the on and off chop states are subtracted. This usually allows one to see the observed object as the subtraction removes most of the background.

#### 6.1.2 Burst mode

In burst mode no averaging of integration images is done and each integration is stored in the FITS file. In this case it contains all images in one extension stored as a three dimensional cube. The cube can be located in the primary extension together with the primary header or it can be stored in the extension following the primary header, depending on the mode in which the data was taken. Due to limitations in the FITS standard the latter is preferred if one wants to compress the file to save storage space. The lossless rice compression algorithm

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	27 of 67

is recommended for integer type burst data. Averaged burst data (as indicated by the ESO DET NAVRG key) typically compresses less efficiently unless one applies a lossy compression algorithm.

## 6.2 General Data Layout - DRS detector

A raw VISIR file is an extension-less FITS-file. The data unit is a cube with  $NAXIS3 = 2n + 1$  planes<sup>6</sup>, where  $n$  is the number of chopping cycles, which is specified in the FITS-card with the key `HIERARCH ESO DET CHOP NCYCLES`. For each chopping cycle two so called Half-Cycle exposures are made, the A-image from the on-source position of the chopper, and the B-image from the off-source position of the chopper. Each half-cycle image is normalized by IRACE to an exposure time of one DIT; in other words, each half-cycle image is the average over the NDIT individual exposures. For each chopping cycle two planes are stored in the cube. The first two planes correspond to the first chopping cycle and contain:

- The Half-Cycle A-image,  $A_1$ . The pixel-values in each Half-Cycle image are offset by -32768, i.e. 32768 has to be added to each pixel in order to obtain the physical pixel value.
- The difference between the two Half-Cycle images,  $A_1 - B_1$ .

Similarly, the  $(2 \times i - 1)$ th and  $(2 \times i)$ th planes correspond to the  $i$ th chopping cycle and contain

- The Half-Cycle A-image,  $A_i$ , stored with an offset identical to  $A_1$ .
- The average of the current and all previous Half-Cycle difference images,  $(A_1 - B_1 + A_2 - B_2 + \dots + A_i - B_i)/i$ .

The last plane of the cube contains the average of all Half-Cycle difference images, i.e. it is identical to the  $(2 \times n)$ th plane.

## 6.3 General frames

These are data that can be obtained using any of the two instrument modes (imaging, spectroscopy), as is the case for flat field exposures. The keyword `ESO INS MODE` is set accordingly to 'IMG' for imaging frames, and to 'SPC' for spectroscopy frames, to indicate the intended use for the data.

- **Dark image:**

Processed by: `visir_img_dark`

Association keywords: `INSTRUME = VISIR`

Classification:

DPR.CATG	DPR.TYPE	DPR.TECH	DO Category
CALIB	DARK	IMAGE	IM_CAL_DARK
CALIB	DARK	SPECTRUM	SPEC_CAL_DARK

See [5] for a definition of the values of DPR.CATG, DPR.TYPE and DPR.TECH.

<sup>6</sup>Before 2004-08-31 another data layout was used. The description of this now obsolete format is limited to the statement that it is also supported by the VISIR pipeline

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	28 of 67

## 6.4 Imaging frames

- **Science Observation:**

Processed by: `visir_img_reduce`

Association keywords: INSTRUME = VISIR

Classification:

DPR.CATG	DPR.TYPE	DPR.TECH	DO Category
SCIENCE	OBJECT	IMAGE, CHOPNOD, JITTER	IM_OBS_CHO_NOD_JIT
SCIENCE	OBJECT	IMAGE, CHOPPING, JITTER	IM_OBS_CHO_JIT
SCIENCE	OBJECT	IMAGE, NODDING, JITTER	IM_OBS_NOD_JIT
SCIENCE	OBJECT	IMAGE, DIRECT, JITTER	IM_OBS_DIR_JIT

- **Standard Star:**

Processed by: `visir_img_reduce`

Association keywords: INSTRUME = VISIR

See [5] for a definition of the values of DPR.CATG, DPR.TYPE and DPR.TECH.

## 6.5 Spectroscopy frames

These frames are generated with the VISIR spectrometer.

- **Long Slit Science Observation:**

Processed by: `visir_spc_reduce`

Association keywords: INSTRUME = VISIR

Classification:

DPR.CATG	DPR.TYPE	DPR.TECH	DO Category
SCIENCE	OBJECT	SPECTRUM, CHOPNOD	SPEC_OBS_LMR

- **Long Slit Standard Star:**

Processed by: `visir_spc_reduce`

Association keywords: INSTRUME = VISIR

Classification:

DPR.CATG	DPR.TYPE	DPR.TECH	DO Category
CALIB	STD	SPECTRUM, CHOPNOD	SPEC_CAL_PHOT

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	29 of <a href="#">67</a>

- **Echelle Science Observation:**

Processed by: `visir_spc_reduce`

Association keywords: INSTRUME = VISIR

Classification:

DPR.CATG	DPR.TYPE	DPR.TECH	DO Category
SCIENCE	OBJECT	ECHELLE	SPEC_OBS_HRG

- **Echelle Standard Star:**

Processed by: `visir_spc_reduce`

Association keywords: INSTRUME = VISIR

Classification:

DPR.CATG	DPR.TYPE	DPR.TECH	DO Category
CALIB	STD	ECHELLE	SPEC_CAL_PHOT_HRG

See [\[5\]](#) for a definition of the values of DPR.CATG, DPR.TYPE and DPR.TECH.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	30 of 67

## 7 Static Calibration Data

This section describes the input required by the VISIR pipeline in addition to the instrument data. This input data is all stored as single-extension FITS tables.

### 7.1 Imaging Standard Stars

The catalogue of imaging standard stars currently contains information about 426 stars. For each star the catalogue contains the following information:

- The star name, e.g. HD108903.
- Spectral type, e.g. M3.5V.
- Right ascension and declination.
- The flux [ $Jy$ ] for each of the 23 supported imaging filters.
- The flux [ $Jy$ ] for each of the 6 supported spectroscopy filters.
- The flux [ $Jy$ ] for each of the 3 supported coronagraphy filters.

This catalogue is stored in the file `ima/cal/ima_std_star_cat.fits`.

See also [9].

### 7.2 Spectroscopy Standard Stars

The catalogue of spectroscopy standard stars currently contains information about 469 stars, namely the 425 standard stars used for imaging and an additional 44 Hipparcos standard stars. For each star the catalogue contains the following information:

- The star name, e.g. HD108903 or HIP100469.
- Right ascension and declination.
- The model flux [ $W/m^2/m$ ] for 2300 wavelengths in the range 5 to 28  $\mu m$ .

This catalogue is stored in the file `spec/cal/spec_std_star_cat.fits`.

See also [9].

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	31 of 67

### 7.3 Spectrometer Detector Quantum Efficiency

The spectrometer detector quantum efficiency at various wavelengths is stored in `spec/cal/spec_quantum_efficiency.fits`. The quantum efficiency ranges from about 1% to close to 70% (at  $11.9\mu\text{m}$ ). See figure 7.3.1. The quantum efficiency for the Aquarius detector is not yet fully characterised. Currently values provided by the manufacturer are used which may not be correct for the mode the detector is used in and does not account for any optical elements in the instrument.

See also [9].

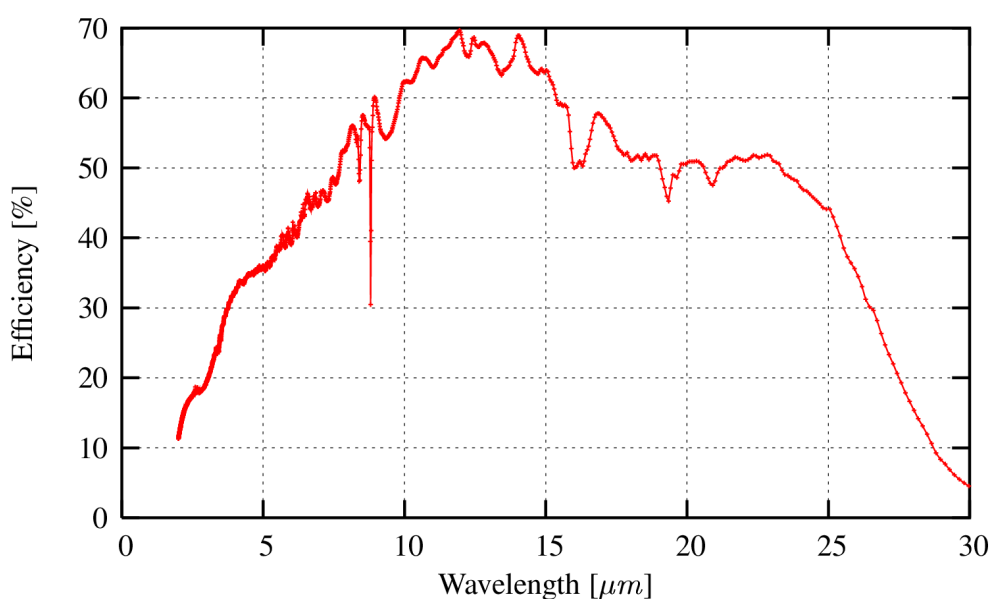


Figure 7.3.1: The DRS Detector Quantum Efficiency.

### 7.4 Atmospheric Emission Spectrum

The atmospheric emission spectrum (normalized to 1) has been created using the HITRAN database of molecular line parameters and the US Standard Atmosphere atmospheric profile, for an altitude of 2600m and 1.5mm of precipitable water vapor at zenith.

The atmospheric emission is stored in `spec/cal/spec_sky_lines.fits`.

See also [9].

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	32 of 67

## 8 Data Reduction

In this section the usage of the VISIR pipeline recipes is described.

### 8.1 Reduction Cascade

The reduction cascade is a schematic representation of the recipe dependencies for pipeline products. The new pipeline technically has a dependency chain between recipes many utility recipes, but in general it is recommended to use the reduce recipes which will execute the sub-recipes in the right order. The Reflex workflows shipped with the pipeline shows a graphical representation of the dependency chain.

The old pipeline recipes for the DRS data is still available, it does not contain any dependencies with the exception that the output bad-pixel map of the **visir\_img\_ff** recipe may optionally be used as input by the other recipes.

### 8.2 VISIR pipeline recipes

The new Aquarius VISIR pipeline version 4.3.2 offers a set of 2 stand-alone recipes intended for fundamental operations.

The new recipes also support the old DRS data.

Imaging data reduction:

**visir\_img\_reduce:** Runs the complete imaging reduction chain. Depending on the input data and its tags it will reduce standard star calibration data or science observations.

In order to do that it repacks the data (**visir\_util\_repack**), detects objects and corrects shifts (**visir\_util\_detect\_shift**) and shift-and-adds the frames together (**visir\_util\_run\_swarp**).

Spectroscopic data reduction:

**visir\_spc\_reduce:** Runs the complete spectroscopic reduction chain. It supports low, medium and high resolution mode. Depending on the input data and its tags it will reduce standard star calibration data or science observations.

In order to do that it repacks the data (**visir\_util\_repack**), corrects distortion (**visir\_util\_undistort**) and does a wavelength calibration (**visir\_spc\_obs**).

Section 9 on the facing page gives a general description on the use of recipes, together with more detailed information on the individual recipes.

### 8.3 Unsupported Observation Modes

A few VISIR templates lead to observations that are currently not supported by the pipeline. Amongst the currently offered science templates, this is only the case for the **VISIR\_img\_obs\_GenericChopNod** template, used for raster (or mosaic) imaging.



ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	33 of 67

## 9 Pipeline Recipe Interfaces

This section provides for each recipe examples of the required input data (and their classification). In the following we assume that `/path_file_raw/filename_raw.fits` and `/path_file_cal/filename_cal.fits` are existing FITS files (e.g. `/data1/visir/com2/VISIR.2004-09-01T09:47:39.316.fits` and `/cal/visir/spec/cal/spec_quantum_efficiency.fits`).

We also provide a list of the pipeline products for each recipe, indicating their default recipe name (eventually replaced by `esorex` to a given standard), the value of their FITS keyword `HIERARCH ESO PRO CATG` (in short `PRO CATG`) and a short description.

For each recipe we also list in a table the input parameters (as they appear in the recipe configuration file), the corresponding aliases (the corresponding names to be eventually set on command line) and their default values. Also quality control parameters are listed. Those are written in the headers of the relevant pipeline products. More information on instrument quality control can be found on <http://www.eso.org/qc>.

In addition to the products mentioned below, all recipes produce a PAF (VLT Parameter File), which is used in the ESO pipeline operations for quality control. The information in this file is the quality control data also found in the recipe products and as such this intermediate file can be ignored.

### 9.1 visir\_img\_reduce

The VISIR pipeline recipe *visir\_img\_reduce* combines a stack of chopped, jittered and/or nodded exposures and can compute the sensitivity for standard star observations.

#### 9.1.1 Input files for visir\_img\_reduce

The input Set-Of-Frames shall specify at least one pair of files with one of the DO categories:

DO Category	Type	Explanation
IM_OBS_CHO_NOD_JIT	Raw Frame	Pairs of science Exposures

When provided with calibration data and a standard star catalog the recipe will compute the sensitivities.

DO Category	Type	Explanation
IM_CAL_PHOT	Raw Frame	Pairs of photometric calibration Exposures
or		
IM_OBS_CHO_NOD_JIT	Raw Frame	Pairs of science Exposures
IMG_STD_CATALOG	Calibration	Catalogue of imaging standard stars

Optionally a bad pixel map and a linearity table can be provided to perform the appropriate corrections on the data. The linearity correction is currently not very accurate and likely only suitable for observations with large signal counts. On low counts the correction will severely distort the results. To also apply it to the data the parameter `--lincorrect=TRUE` must be set.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	34 of 67

DO Category	Type	Explanation
STATIC_MASK	Calibration	Bad pixel map
LINEARITY_TABLE	Calibration	Linearity table

### 9.1.2 Input Parameters for visir\_img\_reduce

The recognized recipe options are

Parameter	Possible Values (with <b>default</b> )	Explanation
planestart	<b>0</b>	Plane number to start repacking from, earlier planes are skipped.
planelimit	<b>-1</b>	Limit number of processed input planes. It will process until at least this number of input images have been processed or the full dataset has been completed. Always full chop cycles need to be repacked so the number is adjusted upward to the next multiple of images per chop cycle. smaller-equal 0 for no limit.
trimlow	<b>0</b>	Burst data only. Number of additional planes to cut from before each plane with chopper.
trimhigh	<b>0</b>	Burst data only. Number of additional planes to cut from after each plane with chopper.
lincorrect	<b>FALSE,TRUE</b>	A value of -1 does not skip the plane of the movement. Apply linearity correction to data. May distort low signal count data.
naverage	<b>1</b>	Number of planes to average before attempting to detect the shifts.
beampos	<b>NONE</b>	Define the positions of the beams. These positions are cut by the window to extract the single beam images. Format: sign:x,y,window;sign:x,y,window;... where sign is "pos" or "neg" depending on whether the beam is positive or negative. The window is optional and defines the size of the cut image around the beam. The default window is the chop throw. E.g.: pos:50,60;neg:50,160;
output-all	<b>FALSE</b>	Output a coadded image for each input file in addition to the complete coaddition.
jy_val	<b>-999.</b>	The flux of the standard star in Jansky.
delete-temp	<b>TRUE</b>	Defaults to the value from the standard star catalogue Delete temporary files created during processing

### 9.1.3 Products from visir\_img\_reduce

Successful completion of this recipe will, depending on the input DO category, create one of these FITS-files

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	35 of 67

File name	Product Category (PRO CATG)	Explanation
visir_util_join_bCOMBINED.fits	IMG_OBS_COMBINED	the combined image (science).
visir_util_join_bCOMBINED.fits	IMG_PHOT_COMBINED	the combined image (calibration).

Additionally, the raw chop-nod corrected corrected image is produced: visir\_util\_repack\_mean.fits See [9.4.1](#) on page [39](#) for a description of this product.

#### 9.1.4 QC Parameters from visir\_img\_reduce

This recipe generates the Quality Control parameters

```
QC BACKGD MEAN
QC BACKGD SIGMA
QC EXPTIME
QC EXECTIME
QC JYVAL
QC STARNAME
QC FILTER
QC NELEC
QC NPHOT
QC FLUXTOT
QC FLUXSNR
QC FLUXSNR NOISE
QC FLUXSNR RADIUS1
QC GAUSSFIT FWHM_MAX
QC GAUSSFIT FWHM_MAX_ERR
QC GAUSSFIT FWHM_MIN
QC GAUSSFIT FWHM_MIN_ERR
QC GAUSSFIT ANGLE
QC GAUSSFIT ANGLE_ERR
QC GAUSSFIT PEAK
QC GAUSSFIT PEAK_ERR
QC FWHMX
QC FWHMY
QC SENSIT
QC AREA SENSIT
QC CONVER
QC STREHL
QC STREHL ERROR
```

and writes them in the FITS header of its products. See appendix [B](#) on page [54](#) for their definition.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	36 of 67

## 9.2 visir\_img\_dark

The VISIR pipeline recipe *visir\_img\_dark* creates a dark image and three maps of hot, cold and deviant pixels in both imaging and spectroscopy.

### 9.2.1 Input files for visir\_img\_dark

The input Set-Of-Frames shall specify at least two files with one of the DO categories:

DO Category	Type	Explanation
IM_CAL_DARK	Raw Frame	Calibration Exposure
SPEC_CAL_DARK	Raw Frame	Calibration Exposure

### 9.2.2 Input Parameters for visir\_img\_dark

The recognized recipe options are

Parameter	Possible Values (with <b>default</b> )	Explanation
rej_bord	"%u %u %u %u", " <b>50 50 50 50</b> "	Rejected left right bottom and top border [pixel].
hot_t	float, <b>10.0</b>	Hot pixel map threshold.
cold_t	float, <b>6.0</b>	Cold pixel map threshold.
dev_t	float, <b>5.0</b>	Deviant pixel map threshold.
nsamples	integer, <b>100</b>	Number of samples for Read-Out Noise (RON) computation.
hsize	integer, <b>2</b>	Half size of the window for Read-Out Noise (RON) computation.

### 9.2.3 Products from visir\_img\_dark

Successful completion of this recipe will, depending on the input DO category, create one of these two sets of FITS-files

File name	Product Category (PRO CATG)	Explanation
visir_img_dark_set01_avg.fits	IMG_DARK_AVG	The dark image (imaging).
visir_img_dark_set01_hotpix.fits	IMG_DARK_HOT	The map of hot pixels (imaging).
visir_img_dark_set01_coldpix.fits	IMG_DARK_COLD	The map of cold pixels (imaging).
visir_img_dark_set01_devpix.fits	IMG_DARK_DEV	The map of deviant pixels (imaging).
visir_img_dark_set01_avg.fits	SPEC_DARK_AVG	The dark image (spectroscopy).
visir_img_dark_set01_hotpix.fits	SPEC_DARK_HOT	The map of hot pixels (spectroscopy).
visir_img_dark_set01_coldpix.fits	SPEC_DARK_COLD	The map of cold pixels (spectroscopy).
visir_img_dark_set01_devpix.fits	SPEC_DARK_DEV	The map of deviant pixels (spectroscopy).

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	37 of 67

#### 9.2.4 QC Parameters from visir\_img\_dark

This recipe generates the Quality Control parameters

```
QC DARKMED
QC NBCOLPIX
QC NBHOTPIX
QC NBDEVPIX
QC RON1
QC RON2
QC RON3
...
```

and writes them in the FITS header of its products. See appendix B on page 54 for their definition.

### 9.3 visir\_spc\_reduce

The VISIR pipeline recipe *visir\_spc\_reduce* performs a wavelength calibration followed by spectrum extraction from a combined image. It can also compute sensitivities for standard star observations. It works for low and high resolution including echelle mode.

#### 9.3.1 Input files for visir\_spc\_reduce

The input Set-Of-Frames shall specify files with DO categories:

DO Category	Type	Explanation
SPEC_OBS_LMR	Raw Frame	Science Exposures (at least one pair)
or		
SPEC_OBS_HR	Raw Frame	Science Exposures (at least one pair)
or		
SPEC_OBS_HRG	Raw Frame	Science Exposures (at least one pair)
or		
SPEC_CAL_PHOT	Raw Frame	Calibration Exposures (at least one pair)
or		
SPEC_CAL_PHOT_HRG	Raw Frame	Calibration Exposures (at least one pair)
 SPEC_CAL_LINES	 Calibration	 Atmospheric Transmission
SPEC_CAL_QEFF	Calibration	Detector Quantum-Efficiency

Optionally a bad pixel map and a linearity table can be provided to perform the appropriate corrections on the data. The linearity correction is currently not very accurate and likely only suitable for observations with large signal counts. On low counts the correction will severely distort the results. For this reason the correction is by default only applied to the sky spectrum used for the wavelength calibration. To also apply it to the data the parameter `--lincorrect=TRUE` must be set.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	38 of 67

DO Category	Type	Explanation
STATIC_MASK	Calibration	Bad pixel map
LINEARITY_TABLE	Calibration	Linearity table

### 9.3.2 Input Parameters for visir\_spc\_reduce

The recognized recipe options are

Parameter	Possible Values (with <b>default</b> )	Explanation
lincorrect	<b>FALSE</b> , TRUE	Apply linearity correction to data. May distort low signal count data.
plot	<b>0</b> , 1, 2	See subsection 9.1 on page 33. The figures in section 10 on page 41 have been made with plot=2.
slit_skew	float, <b>0.52</b>	Distortion correction: Skew of slit [degrees] (clockwise)
spectrum_skew	float, <b>1.73</b>	Distortion correction: LMR Skew of spectrum [degrees] (counter-clockwise). Not used in High Resolution.
vert_arc	float, <b>-.08</b>	Distortion correction: LR Detector vertical curvature [pixel].
hori_arc	float, <b>0.0</b>	Distortion correction: LMR Detector horizontal curvature [pixel].
orderoffset	integer, <b>0</b>	Echelle order offset. The offset is relative to the main order. The allowed range of offsets depend on the selected echelle-mode and covers 4 or 5 orders, e.g. -2,-1,0,1,2. If the main order is e.g. 8 an order offset of +1 will cause the recipe to base the data reduction on order 9. With a positive order offset the central wavelength becomes smaller while for a negative order offset the central wavelength becomes larger.
rl	integer, <b>0</b>	Reject leftmost columns in spectrum extraction zero means all columns on the left are used. In cross-dispersion mode a (small) negative number may be used (pixel)
rr	integer, <b>0</b>	Reject rightmost columns in spectrum extraction zero means all columns on the left are used. In cross-dispersion mode a (small) negative number may be used (pixel)

Please see 10.1.2 on page 41 for a description of the distortion correction. The default values for the two parameters of the curvature correction are set to values that are optimal in low resolution spectroscopy. High resolution is currently not corrected.

### 9.3.3 Products from visir\_spc\_reduce

Successful completion of this recipe will create the FITS-file

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	39 of 67

File name	Product Category (PRO CATG)	Explanation
visir_spc_obs_tab.fits	SPC_PHOT_TAB	the spectral table.
or		
visir_spc_obs_tab.fits	SPC_OBS_LMR_TAB	the spectral table.

See [9.4.2](#) on the next page for a description of this product.

### 9.3.4 QC Parameters from visir\_spc\_reduce

This recipe generates the Quality Control parameters

```
QC BACKGD MEAN
QC XC
QC XCSHIFT
QC PHDEGREE
QC PHDISPX0
QC PHDISPX1
QC PHDISPX2
QC XCWLEN
QC XCDEGREE
QC XCDISPX0
QC XCDISPX1
QC XCDISPX2
QC GAUSSFIT FWHM
QC GAUSSFIT FWHM_ERR
QC GAUSSFIT PEAK
QC GAUSSFIT PEAK_ERR
QC XFWHM
QC XCENTROI
QC EXPTIME
QC EXECTIME
QC SENS MEDIAN
QC SENS MEAN
QC SENS STDEV
QC STARNAME
```

and writes them in the FITS header of its products. Some keys may not be written depending on whether the input were calibration or science frames. See [appendix B](#) on page [54](#) for their definition.

## 9.4 Product Description

### 9.4.1 Imaging product data

This product has one of these product categories: IMG\_OBS\_COMBINED, IMG\_PHOT\_COMBINED

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	40 of 67

The file contains data in its primary data unit and three extensions. The primary data unit contains the combined image the combination of a list of chopped, nodded and optionally jittered images. See also subsection [10.1.3](#) on the next page.

The first extension with extension name `BAD_PIXEL_MAP` contains the pixels which must be considered bad for the data in the combined image. Note that due to the chop-nodding data the bad pixel map may be empty even when the input did have a static bad pixel map as a bad pixel in one chop cycle can be corrected by the data from other cycles which have a different throw offset.

The second extension with extension name `ERROR_MAP` contains the errors associated to each pixel of the data image. Note that the error is determined from the sky background of the chop-nod corrected images and thus can be a constant value if there are no bad pixels. Pixels which marked as bad in the bad pixel map will have infinite value.

The third extension with extension name `WEIGHT_MAP` contains the weights associated to each pixel of the data image. It is computed from the error map via:  $\omega = \frac{1}{\sigma^2}$

#### 9.4.2 Spectroscopic product data

This product has one of these following product categories: `SPC_OBS_LMR_TAB`, `SPC_OBS_HRG_TAB`, `SPC_PHOT_TAB` or `SPC_PHOT_HRG_TAB`

The file contains of three extensions, the first extension contains a binary table containing the extracted spectra, sky model and sensitivities for photometric data. The second extension contains the 2d undistorted and chop-nod corrected images and the third extension contains the 1d spectral extraction weights extended to a 2d image along the wavelength axis (note: this is not related to the errors).

The table contains 6 to 8 columns and one row per detector pixel in wavelength direction. The last two columns are only present in photometric data.

**WLEN** The wavelength of the light detected on that detector row [*m*].

**SPC\_MODEL\_PH** The intensity of the model spectrum at the wavelength that the physical model predicts will be detected on that detector row. The displacement (in pixels) between the two model spectra is written in the FITS card with the key `HIERARCH ESO QC XCSHIFT` [*Jradian m<sup>-3</sup>s<sup>-1</sup>*].

**SPC\_MODEL\_XC** The intensity of the model spectrum at the wavelength in column `WLEN` [*Jradian m<sup>-3</sup>s<sup>-1</sup>*] shifted by the displacement.

**SPC\_SKY** The intensity of the extracted sky spectrum at the wavelength in column `WLEN` [*ADU s<sup>-1</sup>*]

**SPC\_EXTRACTED** The intensity of the extracted (object) spectrum at the wavelength in column `WLEN` [*ADU s<sup>-1</sup>*].

**SPC\_ERROR** The error (noise per pixel) on the extracted intensity at the wavelength in column `WLEN` [*ADU s<sup>-1</sup>*].

**STD\_STAR\_MODEL** The flux of the standard star at the wavelength in column `WLEN` [*mJy*].

**SENSITIVITY** The sensitivity at the wavelength in column `WLEN` [*mJy*].



<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	41 of 67

## 10 Algorithms

In this section the data reduction procedures applied by the pipeline recipes currently in use (see section 8.2 on page 32) are described in some detail.

### 10.1 General Algorithms

Several algorithms, such as wavelength calibration or bad pixel cleaning, are used by several recipes, and are thus described separately.

#### 10.1.1 Bad pixel detection and cleaning

The bad pixels are detected in the Half-Cycle frames as those whose pixel value exceeds the fixed limit 65000 (this comparison is done after the offset of 32768 has been added to the pixels of the Half-Cycle frames). In spectroscopic long slit mode the cleaning of bad pixels can be avoided, since the subsequent distortion correction ignores the bad pixels. Otherwise, bad pixels are cleaned by interpolation with the neighboring pixels, (using the CPL function *cpl\_detector\_interpolate\_rejected()*, see [12]).

#### 10.1.2 Distortion correction

In spectroscopic long slit mode the optical distortion is known analytically. This is used to directly correct the distortion, by interpolating the distortion corrected pixel value from the source pixels. This interpolation ignores source pixels that are marked as bad. The VISIR User's manual [9] describes the optical distortion correction in greater detail. In that description,  $\Phi$  is equal to slit\_skew,  $\Psi$  is equal to spectrum\_skew,  $\Delta$  is equal to hori\_arc and  $\epsilon$  is equal to vert\_arc. The interpolation itself is done with using the CPL function *cpl\_image\_get\_interpolated()*, see [12].

#### 10.1.3 Creation of combined image

The final combined image is created from the input images via the process depicted in 10.1.1 on the next page.

- The raw data is unpacked into the four different states, two chopping states, called on and off state, and the two nodding states, named A and B. These states are then subtracted in order to obtain the background corrected images:

$$A_{on} - A_{off} - (B_{on} - B_{off})$$

The chop/nod corrected images thus contain four or three beams depending on whether perpendicular or parallel mode is used.

- The average of all the background corrected data is used to determine the initial beam positions. Then the image is cut around these positions with a window of the chop throw in pixel. The sign of the images



<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	43 of 67

the sensitivities, the noise must be estimated from the background of the image.

This is estimated by assuming the background noise has a gaussian distribution. The median absolute deviation is calculated and multiplied with 1.4826 to obtain an estimate for the standard deviation. The median absolute deviation is used so one is only sensitive to the background fluctuations and not the object.

In science measurements one is interested in the actual uncertainty of the object flux. In order to estimate the standard deviation of each pixel in the time series of each pixel in the images is calculated. The accuracy of this method depends on the number of exposures available. For observations with very few exposures the uncertainties generated by the pipeline should not be trusted. It is very well suited for burst mode observations where the number of frames is high.

- Now that the offset between each single beam image and its uncertainties is known, the images are combined via subpixel precision shift-and-add coaddition.

This is done in two steps. First each image is resampled to the same projection with a lancosz3 kernel.

Each beam state (chop on/off, nod A/B) is then averaged separately. It works on per input file basis so if you input four raw files created in perpendicular mode <sup>7</sup> you receive eight averaged images and their weight maps, one per beam per input rawfile.

These images are then summed to receive the final flux of the object.

#### 10.1.4 Imaging Photometric Calibration

The photometric calibration is carried out on the sum of all combined beam files.

Each pixel is scaled to the same contribution to prevent bad pixels present in the object aperture from influencing the result too much. It is recommended to position the object so the number of bad pixels around the object is minimal. If that cannot be prevented a jittered observation mode should be chosen.

- The background flux,  $F_{bg}$  is estimated as the median intensity of the pixels that are between  $R$  and  $R + 10$  pixels away from the star center, where  $R = 20$ .
- The flux of the star,  $F(r)$  is computed as the flux within  $r$  pixels from the star corrected for  $F_{bg}$ , for  $r = 1, 2, 3, \dots, R$
- The uncertainty of the flux is the propagated background pixel error obtained from the chop-nod corrected images.

$$\sigma(F(r)) = \sqrt{\sum_{i=1}^{n_{pix}} \sigma_{pix}^2}$$

In the general case this will be almost equal to the background pixel error of the summation image scaled by the square root of number of pixels in the flux aperture but more precise as the error is not obtained from a resampled image.

---

<sup>7</sup>Each nodding position creates one rawfile so if you record four nodding positions you obtain four raw files, each containing two chop states.

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	44 of 67

- The radius that maximizes the signal to noise ratio

$$\text{SNR}_{\max} = \max_{r=1}^R \frac{F(r)}{\sigma(F(r))}$$

is determined.

- The catalog contains a model flux,  $F_{\text{model}}$ , in unit  $Jy$ .
- The sensitivity is then computed in unit  $mJy$  at  $10\sigma$  in 1 hour as

$$10^3 \cdot F_{\text{model}} \cdot \frac{10}{\text{SNR}_{\max}} \cdot \sqrt{t/3600s}$$

where the exposure time  $t$  depends on the type of image.

The total flux is also computed as:

$$F_{\text{total}} = F(R)$$

The conversion factor is the reciprocal this value.

### 10.1.5 Wavelength Calibration

The dispersion relation is approximated by a second degree polynomial,  $\lambda(i) = \lambda_0 + i \cdot a + b \cdot i^2$ ,  $i = 1, 2, \dots, 1024$ , where  $\lambda(i)$  is the wavelength at the center of the  $i$ 'th pixel. Thus in long slit mode,  $\lambda(i)$ ,  $i = 512.5$  is the central wavelength. For low resolution mode the pipeline uses following parameters as a first guess:

$$\lambda_0 = 6.8126\mu m \quad a = 0.0092488\mu m \quad b = -2.22766 \cdot 10^{-6}\mu m$$

For high resolution mode the physical model described in *Parameters for setting the VISIR Spectrometer* (VLT-TRE-VIS-14321-5046) includes as dispersion relation a first degree polynomial  $\lambda_{ph}(i) = i \cdot \Delta\lambda_{ph} + \lambda_{ph,0}$ . For the Aquarius detector  $\Delta\lambda_{ph}$  needs to be increased by the ratio in pixel field of view between the old and new detector:  $0.127/0.0757$

The parameter  $\lambda_0$  is optimized to the data in the following way:

- 1 The field direction in a Half-Cycle frame is collapsed, producing a 1-dimensional spectrum of the atmosphere. See figure 10.1.2 on page 48.
- 2 A model spectrum is created from a model of the atmospheric emission. See figure 10.1.2 on page 48.
- 3 The offset,  $\Delta i$ , (in pixels) that maximizes the cross-correlation between these two spectra is used to determine  $\lambda_0$ , since  $\lambda_0 - \lambda_{ph,0} = \Delta i \cdot \Delta\lambda_{ph}$ .  $\Delta i$  is determined with subpixel accuracy. See figure 10.1.3 on page 49.

For the Aquarius detector in low resolution mode the wavelength calibration has not yet been optimized and an error of about 5 pixels or  $0.05\mu m$  must be assumed.

The model spectrum is created as follows:

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	45 of 67

- The atmospheric emission is assumed to be equivalent to that of a black body at 253 K.
- This emission is multiplied with the emissivity of the atmosphere, see section 7.4 on page 31.
- This is smoothed by convolution with a function that is itself a convolution of two functions:

**A Gaussian** with

$$\sigma = \frac{w_{\text{FWHM}}}{2\sqrt{2\ln 2}},$$

where the spectral FWHM is defined as  $w_{\text{FWHM}} = \lambda L / R$ , with  $L$  being the Linear dispersion and  $R$  being the spectral Resolution as defined by the optical model. With  $L$  in unit pixel/ $m$  and  $\lambda$  in unit  $m$ ,  $w_{\text{FWHM}}$  is in unit pixel.

**A Top-hat** with a width of  $\frac{w_{\text{slit}}}{w_{\text{pfov}}}$ , where  $w_{\text{slit}}$  is the value of the FITS-card with the key `HIERARCH ESO INS SLIT1 WID` which has unit arcseconds and where  $w_{\text{pfov}} = 0.127$  arcseconds/pixel is the spectral slit width.

See figure 10.1.4 on page 50 for an example of such a smoothing function.

- Added to that is the emission of the telescope itself, assumed to be equivalent to that of a black body with the temperature of the main mirror (retrieved from the FITS header) and with an emissivity of 0.12.
- The model spectrum is lastly multiplied by the detector quantum efficiency.

### 10.1.6 Spectrum Extraction

The spectrum is extracted from the combined image with the following optimal extraction method:

- If the spectrum is obtained in long slit mode, each row is supposed to have a mean of zero. In order to ensure this the actual mean of each row is computed and subtracted from each row.
- The standard deviation of the noise in the resulting image is estimated using an iterative  $\sigma$ -clipping ( $\sigma=3$ ).
- Each flux,  $F(\lambda)$ , in the 1D-spectrum is computed as a weighted average of the pixels in the field direction. The weights are the same for all wavelengths, they are obtained by collapsing the spectral dimension of the 2D-spectrum and normalizing the absolute flux of this 1D-image to 1.
- A pixel with an absolute value less than  $\sigma=3$  times the standard deviation of the noise is considered noise and is excluded from the weighted average. See figure 10.1.5 on page 51.

For each wavelength in the extracted 1D-spectrum the noise,  $\sigma(F(\lambda))$  is computed as follows:

- The above spectrum extraction identifies for each wavelength a number of pixels in the mean-corrected image as being noise. The standard deviation of these pixels is computed.
- For each wavelength the 2-norm of the spatial weights of the non-noisy pixels is computed.
- $\sigma(F(\lambda))$  is the product of these two numbers. See figure 10.1.5 on page 51.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	46 of 67

### 10.1.7 Spectral Photometric Calibration

The spectral photometric calibration is carried out as follows:

- The model flux,  $F_{\text{model}}(\lambda)$ , is obtained from the standard star catalog for the wavelengths in the extracted spectrum.
- The sensitivity in unit  $mJy$  at  $10\sigma$  in 1 hour is then computed for each wavelength  $\lambda$  as

$$\frac{F_{\text{model}}(\lambda) \cdot \sigma(F(\lambda)) \cdot 10 \cdot \sqrt{t/3600s}}{F(\lambda)},$$

where  $F(\lambda)$  and  $\sigma(F(\lambda))$  is the extracted intensity and its error estimate at wavelength  $\lambda$  (see subsection 10.1.6 on the previous page), and where the exposure time  $t$  is  $\text{DIT} \cdot \text{NDIT} \cdot \text{NFILES} \cdot \text{NCHOP} \cdot 2$ , with the factor 2 due to the Half-Cycle chopping.

### 10.1.8 Imaging Photometric Calibration

#### 10.1.9 Computation of Strehl Ratio

The computation of the Strehl ratio is carried out on the combined image in a circle with a radius  $R = 3$  arcseconds (around the center of the first positive star).

The recipe assumes that the extent of the star is limited by a circle with radius  $R_{\text{star}} = 2$  arcseconds.

The Strehl ratio is computed with these steps:

- The background flux,  $F_{\text{bg}}$  is estimated as the flux of the pixels located between  $R_{\text{star}}$  and  $R$  whose intensities are in the 10th percentile and not in the 90th percentile.
- The flux of the star,  $F_{\text{star}}$  is computed as the flux within  $R_{\text{star}}$  corrected for  $F_{\text{bg}}$ , and  $I_{\text{star,max}}$  is the peak intensity of the star.
- The ideal Point Spread Function is computed as the inverse Fourier Transform of the ideal Optical Transfer Function, which is based on the telescope and instrument characteristics.  $F_{\text{psf}}$  is the flux of the PSF and  $I_{\text{psf,max}}$  is its peak intensity.
- The Strehl ratio is then

$$\frac{I_{\text{star,max}}}{F_{\text{star}}} / \frac{I_{\text{psf,max}}}{F_{\text{psf}}}.$$

The error bound on the Strehl ratio is

$$c \cdot \pi \cdot \sigma_R \cdot w_{\text{pfov}} \cdot R_{\text{star}}^2 / F_{\text{star}},$$

where  $c = 0.007/0.0271$  is determined empirically, where  $w_{\text{pfov}}$  is the imaging pixel field of view (obtained from the FITS card with key `ESO INS PFOV` with unit arcseconds/pixel), and where  $\sigma_R$  is the estimated noise on the pixels located between  $R_{\text{star}}$  and  $R$ , (using the CPL function `cpl_flux_get_noise_ring()`, see [12]).

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	47 of <a href="#">67</a>

## 10.2 Recipe Algorithms

### 10.2.1 `visir_img_ff`

This is the algorithm used by this recipe:

- For each flat-field image the median (intensity) is computed.
- For each pixel on the detector, the pixel intensity is plotted against the corresponding median.
- Ideally, all pixels should have an equal gain thus the plots should be straight lines with a slope of 1. Since this is not the case, some pixels have a relative gain greater than 1 while others have a relative gain less than 1. For each pixel this relative gain is stored in the main product of the flat-field recipe.
- Pixels with a relative gain outside the range from 1/5 to 5 are flagged as bad in the produced bad-pixel map.

### 10.2.2 `visir_img_dark`

The dark image is computed as the mean of the input dark images.

### 10.2.3 `visir_img_reduce`

This is the algorithm used by this recipe:

- The image combination described in subsection [10.1.3](#) on page [41](#).

### 10.2.4 `visir_spc_reduce`

This is the algorithm used by this recipe:

- The bad pixel detection described in [10.1.1](#) on page [41](#).
- The distortion correction described in [10.1.2](#) on page [41](#).
- The wavelength calibration described in [10.1.5](#) on page [44](#).
- The image combination described in subsection [10.1.3](#) on page [41](#).
- The spectrum extraction described in subsection [10.1.6](#) on page [45](#).
- The photometric calibration described in subsection [10.1.7](#) on the facing page.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	48 of 67

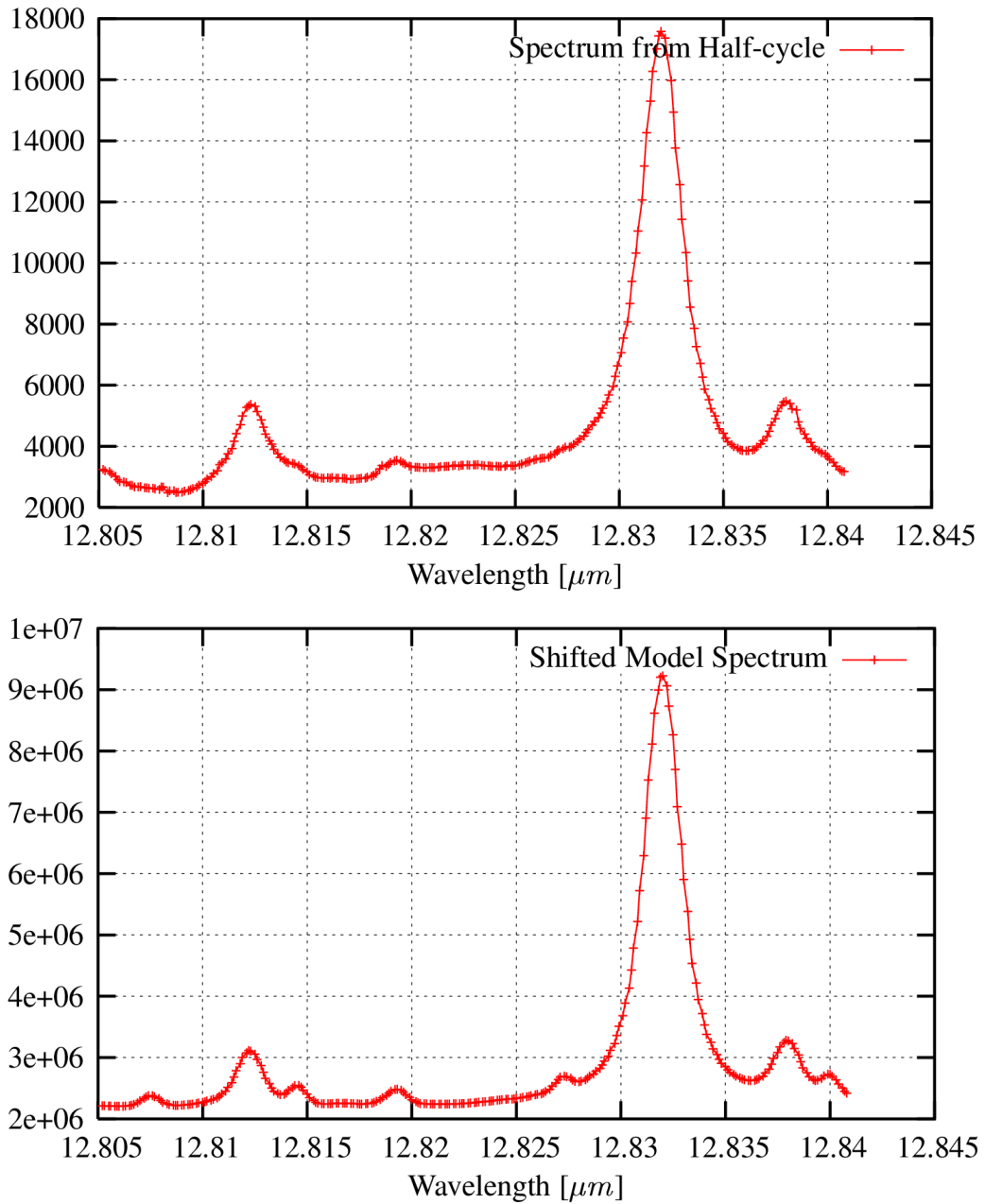


Figure 10.1.2: Example of Atmospheric spectrum from a 1/2-cycle frame and the corresponding, shifted model spectrum that maximizes the cross-correlation with that spectrum.



<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	49 of 67

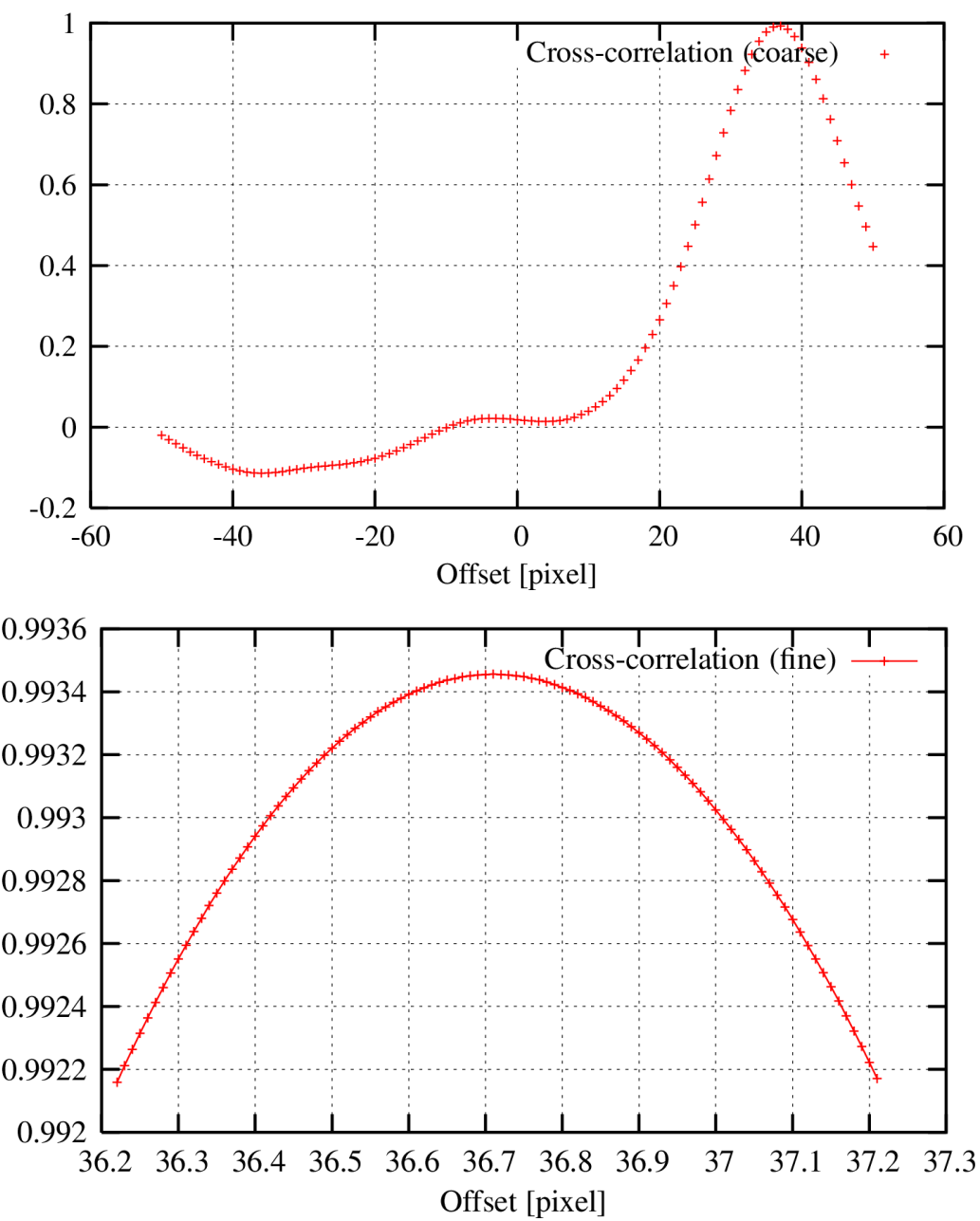


Figure 10.1.3: The cross-correlation (coarse and fine) as a function of pixel-shift.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	50 of 67

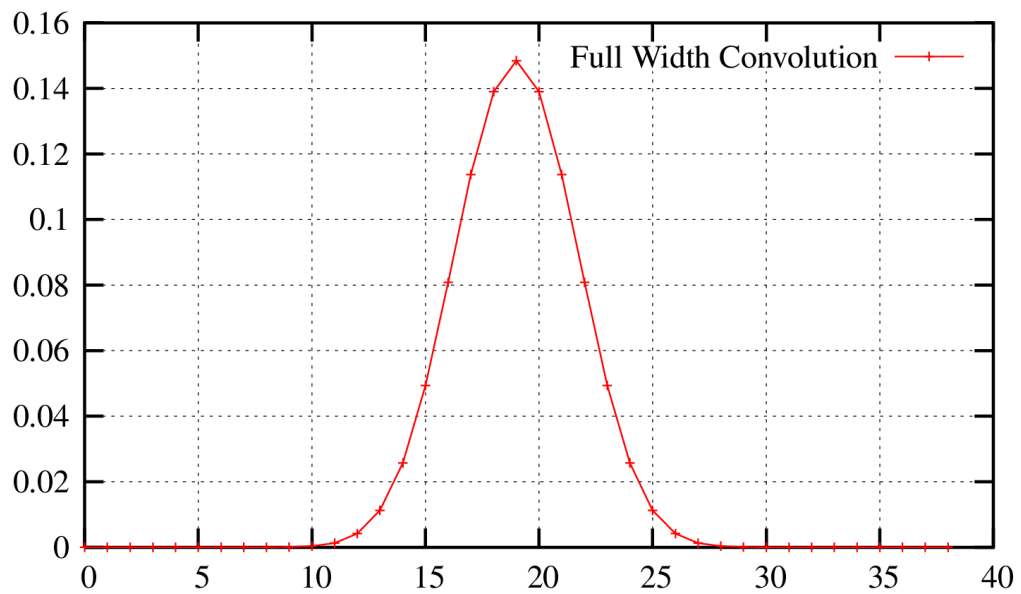


Figure 10.1.4: The symmetric convolution profile used to smooth the model spectrum. The area under the profile is 1. The instrument settings for this example is  $\lambda_{central} = 12.818\mu m$  in High Resolution Long Slit mode, with  $w_{slit} = 5.9\text{pixel}$  and  $w_{FWHM} = 5.25\text{pixel}$ .

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	51 of 67

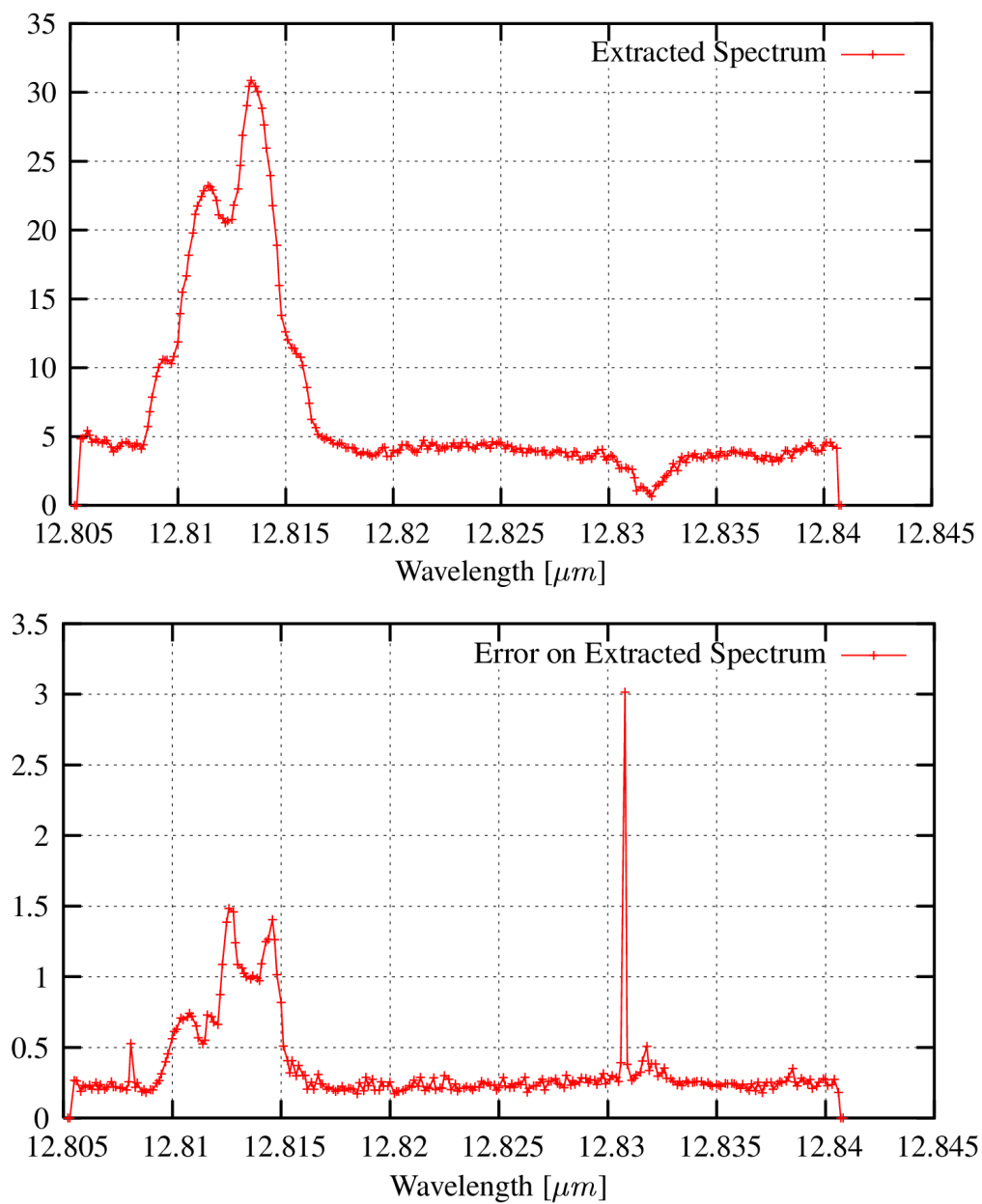


Figure 10.1.5: Example of an extracted spectrum and its error.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	52 of 67

## A Installation

This chapter gives generic instructions on how to obtain, build and install the VISIR pipeline version 4.3.2. Even if this chapter is kept as up-to-date as much as possible, it may not be fully applicable to future releases. For instructions on installation of future releases, the reader is therefore advised to check the installation instructions delivered with such future releases. The supported platforms are listed in Section A.1. It is recommended reading through Section A.2.2 before starting the installation.

A bundled version of the VISIR pipeline with all the required tools and an installer script is available from <http://www.eso.org/pipelines>, for users who are not familiar with the installation of software packages.

### A.1 Supported platforms

The VISIR pipeline version 4.3.2 is verified and supported on the VLT target platforms:

- Scientific Linux 6.3 64 bit

The usage of the GNU build tools should allow to build and run the VISIR pipeline on a variety of platforms. As such, the VISIR pipeline version 4.3.2 is known to build and to produce correct output with esorex on these platforms:

- Ubuntu 14.04 64 bit
- Fedora 20 64 bit
- Mac OS X 10.10

### A.2 Building the VISIR pipeline

This section shows how to obtain, build and install the VISIR pipeline from the official source distribution.

#### A.2.1 Requirements

To compile and install the VISIR pipeline one needs:

- one of the C compilers listed above,
- a version of the `tar` file-archiving program,
- the GNU software: `gzip`, `perl`, `make`.

On the above mentioned systems a Java Development Kit (JDK) version 1.7 will additionally allow the usage of Gasgano (part of this distribution).

ESO	VISIR Pipeline User Manual	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	53 of 67

### A.2.2 Compiling and installing the VISIR pipeline

Here is a description of the installation procedure:

1. Change directory to where you want to retrieve the VISIR pipeline recipes 4.3.2 package. It can be any directory of your choice but not:

```
$HOME/gasgano
$HOME/.esorex
```

2. Download from the ESO ftp server, <http://www.eso.org/pipelines>, the latest release of the VISIR pipeline distribution.

3. Unpack using the following command:

```
tar xf visir-kit-4.3.2.tar.gz
```

4. Install: after moving to the top installation directory,

```
cd visir-kit-4.3.2
```

it is possible to perform a default installation using the available installer script (*recommended*):

```
./install_pipeline
```

The execution may take a few minutes.

By default the script will install the VISIR recipes, *Gasgano*, *EsoRex*, all the necessary libraries, and the static calibration tables, into a directory tree rooted at `$HOME`. A different path may be specified as soon as the script is run.

The only exception to all this is the *Gasgano* tool, that will always be installed under the directory `$HOME/gasgano`. Note that the installer will move an existing `$HOME/gasgano` directory to `$HOME/gasgano.old` before the new *Gasgano* version is installed.

**Important:** the installation script would ensure that any existing *Gasgano* and *EsoRex* setup would be inherited into the newly installed configuration files (avoiding in this way any conflict with other installed instrument pipelines).

Alternatively, it is possible to perform a manual installation (*experienced users only*): the `README` file located in the top installation directory contains more detailed information about a step-by-step installation.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	54 of 67

## B QC Parameters

This appendix describes the QC Parameters created by the VISIR pipeline:

Parameter Name: QC BACKGD MEAN  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: ADU  
Comment Field: Background level from Half-Cycle frames.  
Description: Background level from Half-Cycle frames. This number does not include the offset correction.

Parameter Name: QC BACKGD SIGMA  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: ADU  
Comment Field: Background noise.  
Description: Background noise determined with 5 iterations of sigma=3 clipping.

Parameter Name: QC CAPA  
Class: header|qc-log  
Context: process  
Type: string  
Value Format: %s  
Unit:  
Comment Field: The pixel capacity (large, small or problem)  
Description: The pixel capacity (large, small or problem) based on DET VOLT1 DCTA9 and DET VOLT1 DCTB9 (in imaging) DET VOLT2 DCTA9 and DET VOLT2 DCTB9 (in spectroscopy). If the mean of DCTA9 and DCTB9 is less than 1: small If the mean of DCTA9 and DCTB9 exceeds 4.5: large, otherwise problem. DRS detector only.

Parameter Name: QC CONVER  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	55 of 67

Unit: ADU/Jy  
Comment Field: The conversion factor in imaging  
Description: The conversion factor in imaging

Parameter Name: QC DARKMED  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %f  
Unit: ADU  
Comment Field: Dark current  
Description: Median of the dark produced image

Parameter Name: QC EXPTIME  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: seconds  
Comment Field: Exposure time  
Description: Exposure time

Parameter Name: QC EXECTIME  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: seconds  
Comment Field: Execution time  
Description: Execution time of observation. Approximated from time between start of observation (DATE-OBS) and time of output file written (DATE).

Parameter Name: QC FILTER  
Class: header|qc-log  
Context: process  
Type: string  
Value Format: %20s  
Unit:  
Comment Field: The filter used to observe the star.  
Description: The filter used to observe the star.

Parameter Name: QC FLUXSNR  
Class: header|qc-log

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	56 of <a href="#">67</a>

Context: process  
Type: double  
Value Format: %e  
Unit: ADU  
Comment Field: Star flux obtained for the best SNR.  
Description: Star flux obtained for the best SNR.

Parameter Name: QC FLUXSNR NOISE  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: ADU  
Comment Field: Noise obtained for the best SNR.  
Description: Noise obtained for the best SNR.

Parameter Name: QC FLUXSNR RADIUS1  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: pixels  
Comment Field: Radius if best SNR appearture.  
Description: Radius if best SNR appearture.

Parameter Name: QC FLUXTOT  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: ADU  
Comment Field: Total flux of the star.  
Description: Total flux of the star.

Parameter Name: QC FPNOISE  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %f  
Unit: ADU  
Comment Field: Fixed Pattern Noise  
Description: Largest noise component in raw images

Parameter Name: QC GAUSSFIT FWHM\_MAX



<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	57 of 67

Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixels  
 Comment Field: FWHM of major axis of the star  
 Description: The Full Width at Half Maximum of the major axis computed via a 2 dimensional Gauss fit.

Parameter Name: QC GAUSSFIT FWHM\_MAX\_ERR  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixels  
 Comment Field: Error of FWHM of major axis of the star  
 Description: The error of Full Width at Half Maximum of the major axis computed via a 2 dimensional Gauss fit.

Parameter Name: QC GAUSSFIT FWHM\_MIN  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixels  
 Comment Field: FWHM of minor axis of the star  
 Description: The Full Width at Half Maximum of the minor axis computed via a 2 dimensional Gauss fit.

Parameter Name: QC GAUSSFIT PEAK  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: ADU / s  
 Comment Field: Peak of Gauss fit  
 Description: Peak value of 2 dimensional Gaus fit.

Parameter Name: QC GAUSSFIT PEAK\_ERR  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: ADU / s

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	58 of 67

Comment Field: Error of peak of Gauss fit  
Description: Error of peak value of 2 dimensional Gaus fit.

Parameter Name: QC GAUSSFIT ANGLE  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: deg  
Comment Field: Angle between X axis and major axis  
Description: Angle between X axis and major axis of ellipse, counted counterclockwise. Computed from 2d Gauss fit.

Parameter Name: QC GAUSSFIT ANGLE\_ERR  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: deg  
Comment Field: Error of angle between X axis and major axis  
Description: Error of angle between X axis and major axis of ellipse, counted counterclockwise. Computed from 2d Gauss fit.

Parameter Name: QC GAUSSFIT FWHM  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: pixels  
Comment Field: Median of FWHM of spectrum on the spatial axis  
Description: Median of FWHM of spectrum on the spatial axis.  
Computed as median from FWHM of 1 dimensional Gauss fits of each pixel of the wavelength axis.

Parameter Name: QC GAUSSFIT FWHM\_ERR  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: pixels  
Comment Field: Error of median of FWHM of spectrum on the spatial axis  
Description: Error of median of FWHM of spectrum on the spatial axis.  
Computed as median from FWHM of 1 dimensional Gauss fits of each pixel of the wavelength axis.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	59 of <a href="#">67</a>

Parameter Name: QC FWHMX NEG1  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixels  
 Comment Field: FWHM in x of the first negative star  
 Description: The Full Width at Half Maximum in x of the first negative star. -1 if not computed.

Parameter Name: QC FWHMX NEG2  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixels  
 Comment Field: FWHM in x of the second negative star  
 Description: The Full Width at Half Maximum in x of the second negative star. -1 if not computed.

Parameter Name: QC FWHMX POS1  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixels  
 Comment Field: FWHM in x of the first positive star  
 Description: The Full Width at Half Maximum in x of the first positive star. -1 if not computed.

Parameter Name: QC FWHMX POS2  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixels  
 Comment Field: FWHM in x of the second positive star  
 Description: The Full Width at Half Maximum in x of the second positive star. -1 if not computed.

Parameter Name: QC FWHMY NEG1  
 Class: header|qc-log  
 Context: process  
 Type: double

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	60 of 67

Value Format: %e  
Unit: pixels  
Comment Field: FWHM in y of the first negative star  
Description: The Full Width at Half Maximum in y of the first negative star. -1 if not computed.

Parameter Name: QC FWHMY NEG2  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: pixels  
Comment Field: FWHM in y of the second negative star  
Description: The Full Width at Half Maximum in y of the second negative star. -1 if not computed.

Parameter Name: QC FWHMY POS1  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: pixels  
Comment Field: FWHM in y of the first positive star  
Description: The Full Width at Half Maximum in y of the first positive star. -1 if not computed.

Parameter Name: QC FWHMY POS2  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: pixels  
Comment Field: FWHM in y of the second positive star  
Description: The Full Width at Half Maximum in y of the second positive star. -1 if not computed.

Parameter Name: QC JYVAL  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: Jansky  
Comment Field: Jansky value for a given star in a given band from a catalog.

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	61 of 67

Description: Jansky value for a given star in a given band from a catalog.

Parameter Name: QC LAMPFLUX  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: ADU/s  
Comment Field: The median flux of the first lampflat difference per DIT.  
Description: The median flux of the difference between the first two lampflats using the central part of the detector, divided by the DIT. Used to monitor the lamp evolution.

Parameter Name: QC NBBADPIX  
Class: header|qc-log  
Context: process  
Type: integer  
Value Format: %d  
Unit: pixels  
Comment Field: Number of bad pixels.  
Description: Number of bad pixels.

Parameter Name: QC NBCOLPIX  
Class: header|qc-log  
Context: process  
Type: integer  
Value Format: %d  
Unit: nb of pixels  
Comment Field: Number of cold pixels  
Description: Number of cold pixels

Parameter Name: QC NBDEVPIX  
Class: header|qc-log  
Context: process  
Type: integer  
Value Format: %d  
Unit: nb of pixels  
Comment Field: Number of deviant pixels  
Description: Number of deviant pixels

Parameter Name: QC NBHOTPIX  
Class: header|qc-log  
Context: process

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	62 of 67

Type: integer  
Value Format: %d  
Unit: nb of pixels  
Comment Field: Number of hot pixels  
Description: Number of hot pixels

Parameter Name: QC PHDEGREE  
Class: header|qc-log  
Context: process  
Type: integer  
Value Format: %d  
Unit:  
Comment Field: The degree of the model dispersion polynomial  
Description: The degree of the dispersion polynomial from the physical model. It is currently 1 for the DRS detector and 2 for the Aquarius detector.

Parameter Name: QC PHDISPX0  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: meter  
Comment Field: wavelength = PHDISPX0 + i \* PHDISPX1, i=1,2,...  
Description: The constant term of the dispersion polynomial from the physical model, wavelength = f(pixel).

Parameter Name: QC PHDISPX1  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: meter/pixel  
Comment Field: wavelength = PHDISPX0 + i \* PHDISPX1, i=1,2,...  
Description: The linear term of the dispersion polynomial from the physical model, wavelength = f(pixel).

Parameter Name: QC PHDISPX2  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: meter/pixel  
Comment Field: wavelength = PHDISPX0 + i \* PHDISPX1, i=1,2,...

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	63 of 67

Description: The quadratic term of the dispersion polynomial from the physical model,  $\text{wavelength} = f(\text{pixel})$ .

Parameter Name: QC RONi  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %f  
Unit: ADU  
Comment Field: Read-out noise of the ith pair of the set  
Description: Measured read-out noise on the whole array.

Parameter Name: QC SENSIT  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: mJy/10sigma/1hour  
Comment Field: The sensitivity in imaging  
Description: The sensitivity in imaging

Parameter Name: QC AREA SENSIT  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: mJy/10sigma/1hour  
Comment Field: The sensitivity in imaging scaled to noise of 1 arcsecond  
Description: The sensitivity in imaging scaled to noise of 1 arcsecond apperture.

Parameter Name: QC SENS MEAN  
Class: header|qc-log  
Context: process  
Type: double  
Value Format: %e  
Unit: mJy  
Comment Field: Mean of the spectroscopic sensitivities  
Description: Mean of the spectroscopic sensitivities over the whole spectral range

Parameter Name: QC SENS MEDIAN  
Class: header|qc-log  
Context: process

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	64 of <a href="#">67</a>

Type: double  
 Value Format: %e  
 Unit: mJy  
 Comment Field: Median of the spectroscopic sensitivities  
 Description: Median of the spectroscopic sensitivities over the whole spectral range

Parameter Name: QC SENS STDEV  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: mJy  
 Comment Field: Standard deviation of the spectroscopic sensitivities  
 Description: Standard deviation of the spectroscopic sensitivities over the whole spectral range

Parameter Name: QC STARNAME  
 Class: header|qc-log  
 Context: process  
 Type: string  
 Value Format: %30s  
 Unit:  
 Comment Field: Standard star name  
 Description: Standard star name

Parameter Name: QC STREHL  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit:  
 Comment Field: The strehl ratio  
 Description: The strehl ratio

Parameter Name: QC STREHL ERROR  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit:  
 Comment Field: The error bound on the strehl ratio  
 Description: The error bound on the strehl ratio



<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	65 of 67

Parameter Name: QC XC  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit:  
 Comment Field: The cross-correlation, ranging from 0 to 1.  
 Description: The cross-correlation between the observed sky spectrum and a model spectrum that has been shifted such that it has maximal cross-correlation with the observed sky spectrum. Range from 0 to 1.

Parameter Name: QC XCDEGREE  
 Class: header|qc-log  
 Context: process  
 Type: integer  
 Value Format: %d  
 Unit:  
 Comment Field: The degree of the calibration dispersion polynomial  
 Description: The degree of the dispersion polynomial from the cross-correlation. It is currently 1 for the DRS detector and for the Aquarius detector.

Parameter Name: QC XCDISPX0  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: meter  
 Comment Field: wavelength = XCDISPX0 + i \* XCDISPX1, i=1,2,...  
 Description: The constant term of the dispersion polynomial from the cross-correlation, wavelength = f(pixel).

Parameter Name: QC XCDISPX1  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: meter/pixel  
 Comment Field: wavelength = XCDISPX0 + i \* XCDISPX1, i=1,2,...  
 Description: The linear term of the dispersion polynomial from the cross-correlation, wavelength = f(pixel). It is currently equal to PHDISPX1.

Parameter Name: QC XCDISPX2

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	66 of 67

Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: meter/pixel  
 Comment Field: wavelength = XCDISPX0 + i \* XCDISPX1, i=1,2,...  
 Description: The quadratic term of the dispersion polynomial from the cross-correlation, wavelength = f(pixel). It is currently equal to PHDISPX2.

Parameter Name: QC XCENTROI  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixel  
 Comment Field: The x-centroid of the spectrums brightest object  
 Description: The location (centroid) in the field-direction of the brightest object of the spectrum

Parameter Name: QC XCSHIFT  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixel  
 Comment Field: The shift in pixels of the model spectrum  
 Description: The shift in pixels of the model spectrum that maximizes the cross-correlation between the observed sky spectrum and the model spectrum. A positive number means that the FITS- headers WLEN is too large. The range is bound by the detector size, -256 to 256

Parameter Name: QC XFWHM  
 Class: header|qc-log  
 Context: process  
 Type: double  
 Value Format: %e  
 Unit: pixel  
 Comment Field: The Full Width at Half Maximum of the object at XCENTROI  
 Description: The Full Width at Half Maximum of the brightest object of the spectrum, located at XCENTROI

<b>ESO</b>	<b>VISIR Pipeline User Manual</b>	Doc:	VLT-MAN-ESO-19500-3852
		Issue:	Issue 1.6
		Date:	Date 21st September 2016
		Page:	67 of <a href="#">67</a>

## C Abbreviations and acronyms

ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
CalibDB	Calibration Database
CPL	Common Pipeline Library
DFO	Data Flow Operations department
DFS	Data Flow System department
DMD	Data Management and Operations Division
DRS	Data Reduction System
ESO	European Southern Observatory
ESOREX	ESO-Recipe Execution tool
FITS	Flexible Image Transport System
FOV	Field Of View
FPN	Fixed Patter Noise
GUI	Graphical User Interface
OB	Observation Block
PSO	Paranal Science Operations
QC	Quality Control
RON	Read Out Noise
SOF	Set Of Frames
UT	Unit Telescope
VLT	Very Large Telescope