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VERY LARGE TELESCOPE

X-shooter User Manual

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Date: 09.02.2010

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CHANGE RECORD

ISSUE	DATE	SECTION/PARA. AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
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1. Introduction

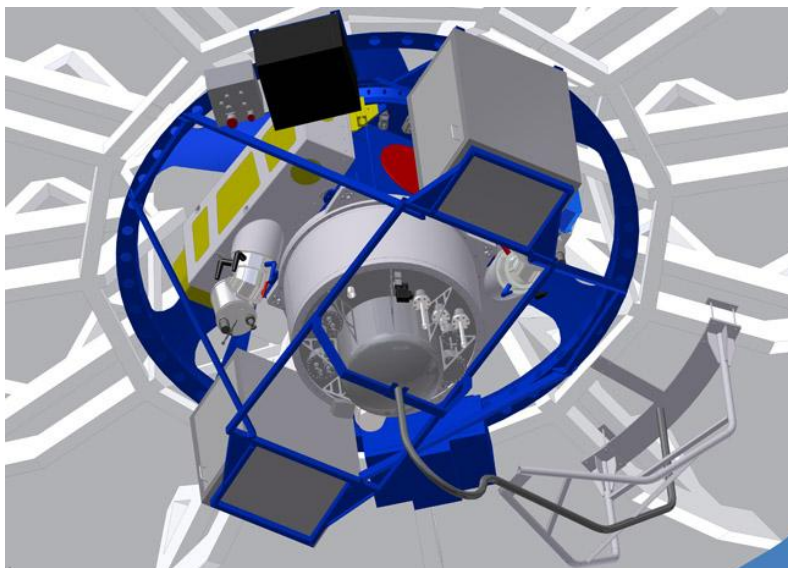


Figure 1: 3D CAD view of the X-shooter spectrograph at the Cassegrain focus of one of the VLT Unit Telescope.

Table 1: X-shooter characteristics and observing capabilities

Wavelength range	300-2500 nm split in 3 arms
UV-blue arm	Range: 300-550 nm in 12 orders Resolution: 5100 (1" slit) Slit width: 0.5", 0.8", 1.0", 1.3", 1.6", 5.0" Detector: 4k x 2k E2V CCD
Visual-red arm	Range: 550-1000 nm in 14 orders Resolution: 8800 (0.9" slit) Slit width: 0.4", 0.7", 0.9", 1.2", 1.5", 5.0" Detector: 4k x 2k MIT/LL CCD
Near-IR arm	Range: 1000-2500 nm in 16 orders Resolution: 5100 (0.9" slit) Slit width: 0.4", 0.6", 0.9", 1.2", 1.5", 5.0" Detector: 2k x 1k Hawaii 2RG
Slit length	11"
Beam separation	Two high efficiency dichroics
Atmospheric dispersion compensation	In the UV-Blue and Visual-red arms
Integral field unit	1.8" x 4" reformatted into 0.6" x 12"



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1.1 Scope

The X-shooter User Manual provides extensive information on the technical characteristics of the instrument, its performances, observing and calibration procedures and data reduction.

1.2 X-shooter in a nutshell

X-shooter is a single target spectrograph for the Cassegrain focus of one of the VLT UTs covering in a single exposure the spectral range from the UV to the K band. The spectral format is fixed. The instrument is designed to maximize the sensitivity in the spectral range through the splitting in three arms with optimized optics, coatings, dispersive elements and detectors. It operates at intermediate resolutions ($R=4000-14000$, depending on wavelength and slit width) sufficient to address quantitatively a vast number of astrophysical applications while working in a background-limited S/N regime in the regions of the spectrum free from strong atmospheric emission and absorption lines. A 3D CAD view of the instrument attached to the telescope is shown on Figure 1. Main instrument characteristics are summarized in Table 1.

X-shooter was built by a Consortium involving institutes from Denmark, Italy, The Netherlands, France and ESO. Name of the institutes and their respective contributions are given in Table 2.

1.3 Shortcuts to most relevant facts for proposal preparation

Table 2: collaborating institutes and their contributions

Collaborating institutes	Contribution
Copenhagen University Observatory	Backbone unit, UVB spectrograph, Mechanical design and FEA, Control electronics
ESO	Project Management and Systems Engineering, Detectors, final system integration, commissioning, logistics
Paris-Meudon Observatory, Paris VII University	Integral Field Unit, Data Reduction Software
INAF - Observatories of Brera, Catania, Trieste and Palermo	UVB and VIS spectrograph, Instrument Control Software, optomechanical design.
Astron, Universities of Amsterdam and Nijmegen	NIR spectrograph, contribution to Data Reduction Software

- The fixed **spectral format** of X-shooter: see Table 9 on page 25
- **Spectral resolution** as a function of slit width: see Table 10 on page 26
- Information on the **IFU**: see page 15
- Information on **limiting magnitudes** in the continuum: see Section 2.3.3 on page 26
- Information on **observing modes**: see section 3.1 on page 30
- Observing strategy and **sky subtraction**: see Section 3.3 on page 31
- **Overhead** computation: see Section 3.4 on page 33



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1.4 List of Abbreviations & Acronyms

This document employs several abbreviations and acronyms to refer concisely to an item, after it has been introduced. The following list is aimed to help the reader in recalling the extended meaning of each short expression:

A&G	Acquisition and Guiding
ADC	Atmospheric Dispersion Compensator
AFC	Active Flexure Compensation
DCS	Detector Control Software
DFS	Data Flow System
DIT	Detector Integration Time
ESO	European Southern Observatory
FDR	Final Design Review
GUI	Graphical User Interface
ICS	Instrument Control Software
IFU	Integral Field Unit
ISF	Instrument Summary File
IWS	Instrument Workstation
LCU	Local Control Unit
N/A	Not Applicable
PAE	Preliminary Acceptance Europe
P2PP	Phase 2 Proposal Preparation
TBC	To Be Clarified
QE	Quantum Efficiency
SNR	Signal to Noise Ratio
TBD	To Be Defined
TCS	Telescope Control Software
TLI	Threshold Limited Integration
TSF	Template Signature File
VLT	Very Large Telescope

1.5 Reference Documents

1. X-shooter Calibration plan, v1.0, XSH-PLA-ESO-12000-0088
2. X-shooter Templates Reference Manual, v0.2, XSH-MAN-ITA-8000-0031

2. Technical description of the instrument

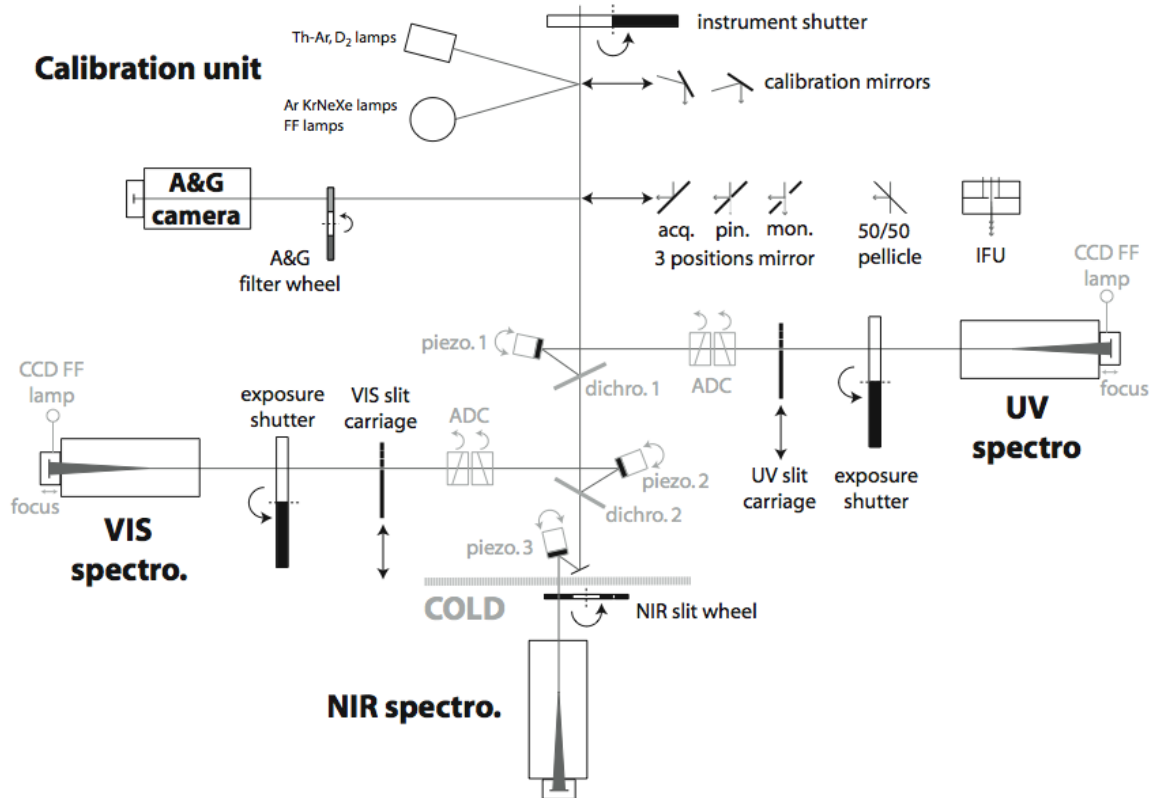


Figure 2: Schematic overview of X-shooter

2.1 Overview of the opto-mechanical design

Figure 2 shows a schematic view of the layout of the instrument. It consists of four main components:

- The backbone which is directly mounted on the Cassegrain derotator of the telescope. It contains all pre-slit optics: the calibration unit, a slide with the 3-positions mirror and the IFU, the acquisition and guiding camera, the dichroic box which splits the light between the three arms, one piezo tip-tilt mirror for each arm to allow active compensation of backbone flexures, atmospheric dispersion compensators (ADCs) in the UVB and VIS arms and a warm optical box in the NIR arm.

- The three arms are fixed format cross-dispersed échelle spectrographs that operate in parallel. Each one has its own slit selection device.

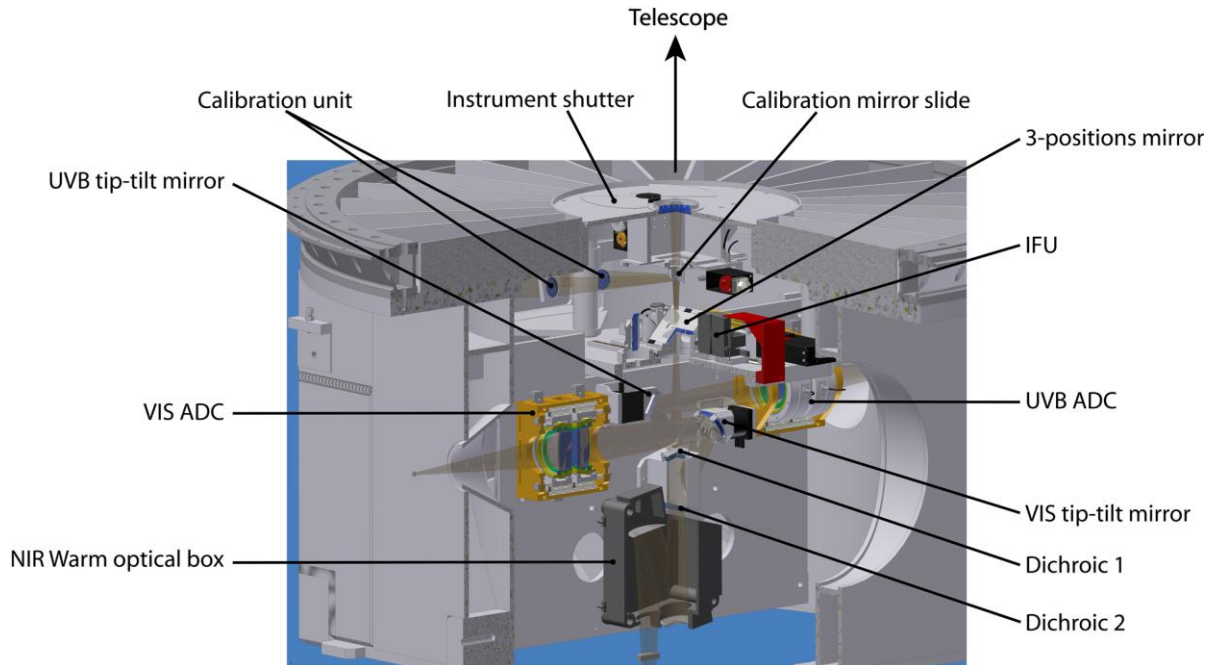


Figure 3: 3D view of a cut through the backbone.

- The UV-Blue spectrograph covers the 300 – 550 nm wavelength range with a resolving power of 5100 (for a 1" slit)
- The Visible spectrograph covers the range 550 - 1000 nm with a resolving power of 7500 (0.9" slit).
- The near-IR spectrograph: this arm covers the range 1000 - 2500 nm with a resolving power of 5100 (0.9" slit). It is fully cryogenic.

2.2 Description of the instrument sub-systems

This section describes the different sub-systems of X-shooter in the order they are encountered along the optical path going from the telescope to the detectors (see

Figure 2). The functionalities of the different sub-units are explained and reference is made to their measured performance.

2.2.1 The Backbone

The Instrument Shutter and The calibration unit

In the converging beam coming from the telescope, the first element is the telescope entrance shutter which allows safe daytime use of X-shooter for tests and calibration without stray-light entering the system from the telescope side.

Then follows the Calibration Unit that allows to select a choice of flat-fielding and wavelength calibration lamps. This unit consists of a mechanical structure with calibration lamps, an integrating sphere, relay optics that simulate the f/13.6 telescope beam, and a mirror slide with 3 positions that can be inserted in the telescope beam:



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- one free position for a direct feed from the telescope,
- one mirror which reflects the light from the integrating equipped with:
 - wavelength calibration Ar, Hg, Ne and Xe Penray lamps operating simultaneously
 - three flatfield halogen lamps equipped with different balancing filters to optimize the spectral energy distribution for each arm
- one mirror which reflects light from:
 - a wavelength calibration hollow cathode Th-Ar lamp
 - a D₂ lamp for flatfielding the bluest part of the UV-Blue spectral range

A more detailed description of the functionalities of the calibration system is given in Section 4.

The Acquisition and Guiding slide.

Light coming either directly from the telescope or from the Calibration Unit described above reaches first the A&G slide. This structure allows to put into the beam either:

- a flat 45° mirror with 3 positions mirror:
 - *acquisition and imaging*: send the full 1.5'×1.5' field of view to the A&G camera. This is the position used during all acquisition sequences;
 - *spectroscopic observations and monitoring*: a slot lets the central 10"×15" of the field go through to the spectrographs while reflecting the peripheral field to the A&G camera. This is the position used for all science observations.
 - *artificial star*: a 0.5" pinhole used for optical alignment and engineering purposes;
- the IFU (described below on page 15);
- a 50/50 pellicle beam splitter at 45° used look down into the instrument with the A&G camera and is exclusively used for engineering purposes.

The IFU

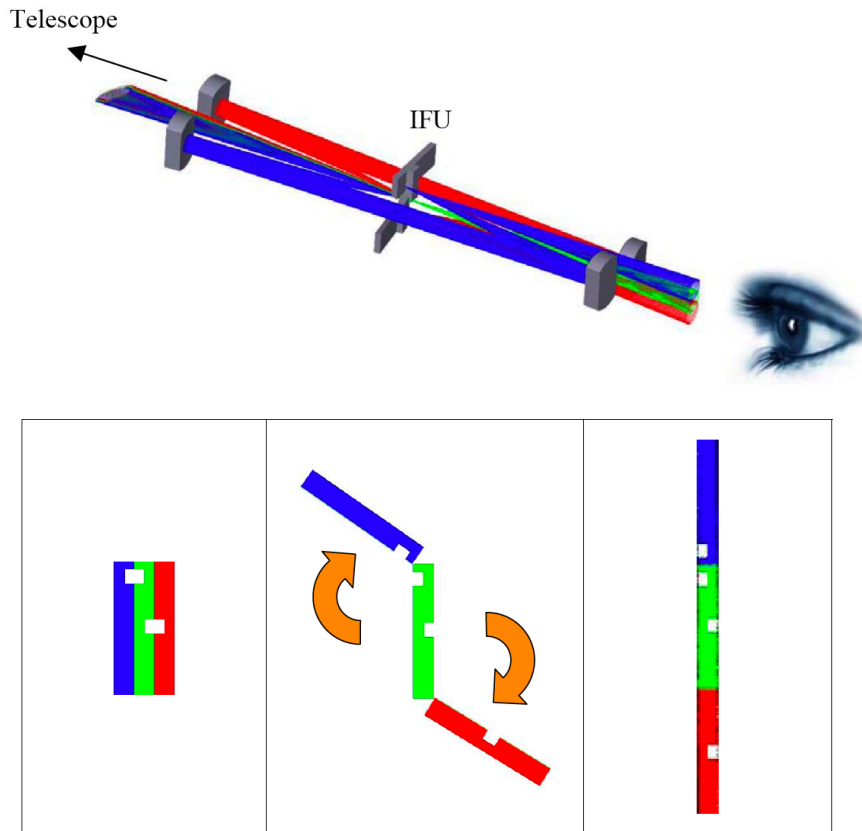


Figure 4: *Top*: view of the effect of the IFU. The central field is directly transmitted to form the central slitlet (green) while the each lateral field (in blue and red) are reflected toward a pair of spherical mirrors and realigned at the end of the central slice to form the exit slit. *Bottom*: The field before (left) and after the IFU (right). The IFU acts such that the lateral fields seems to rotate around a corner of their small edge. The two white slots are not real gaps but just guides to help visualize the top and the bottom of each slice in the drawing.

The Integral Field Unit is an image slicer that re-images an input field of 4"x1.8" into a pseudo slit of 12"x0.6". The light from the central slice is directly transmitted to the spectrographs. The two lateral sliced fields are reflected toward the two pairs of spherical mirrors and re-aligned at both ends of the central slice in order to form the exit slit as illustrated in Figure 4. Due to these four reflections the throughput of the two lateral fields is reduced with respect to the directly transmitted central one. The measured overall efficiency of the two lateral slitlets is ~85% of the direct transmission but drops to ~50% below 400 nm due to reduced coating efficiency in the blue.

The Acquisition and Guiding Camera

The A&G camera allows to visually detect and centroid objects from the U- to the z-band. This unit consists in:

- a filter wheel equipped with a full UBVRI Johnson filter set and a full Sloan Digital Sky Survey (SDSS) filter set. Transmission curves are provided in appendix 5.4.

- a Peletier cooled, 13 μm pixel, 512 \times 512 E2V broad band coated Technical CCD57-10 onto which the focal plane is re-imaged at f/1.91 through a focal reducer. This

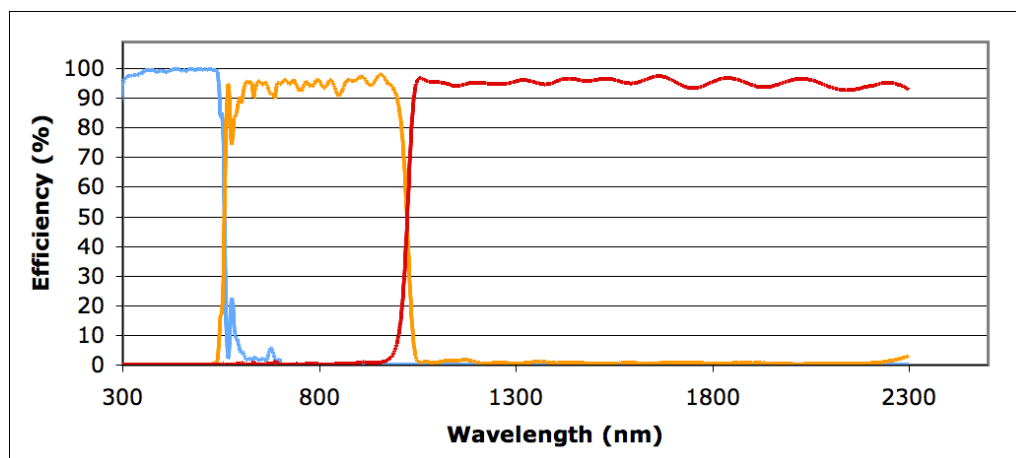


Figure 5: The combined efficiency of the two dichroic beam splitters. *In blue*: reflection on dichroic 1; *in orange*: transmission through dichroic 1 and reflection on dichroic 2; *in red*: transmission through dichroics 1 & 2.

setup provides a plate scale of 0.173"/pix and a field of view of 1.47' \times 1.47'. The QE curve of the detector is provided in appendix 5.3.

This acquisition device –that can also be used to record images of the target field through different filters– provides a good enough sampling to centroid targets to <0.1" accuracy in all seeing conditions and reaches limiting magnitudes given in columns 4 and 5 of Table 3.

Table 3: The overall transmission in UBVRI (column 3) along with effective central wavelength and FWHM (columns 1 and 2) of the A&G Camera UBVRI filters. Limiting magnitudes to a SNR of 5 and 10 reached in 3s integration are given in column 4 and 5. These were computed over an area containing 80% of the energy for a seeing of 0.8", for airmass 1, with sky brightness 3 days from new moon.

Filter	[1] Effective Central λ	[2] Effective FWHM	[3] Efficiency incl. atmosphere	[4] Limiting Mag. (3s, SNR=5)	[5] Limiting Mag. (3s, SNR=10)
U	370 nm	39 nm	10%	21.1	20.2
B	441 nm	100 nm	17%	23.1	22.2
V	535 nm	80 nm	27%	22.8	21.9
R	639 nm	116 nm	21%	22.4	21.5
I	829 nm	175 nm	16%	21.9	21.0

The dichroic box

Light is split and distributed to the three arms by two highly efficient dichroic beam splitters. These are the first optical elements encountered by the science light. The first dichroic at an incidence angle of 15° reflects more than 98% of the light between 350 and 543 nm and transmits ~95% of the light between 600 and 2300 nm. The second dichroic, also at 15° incidence, has a reflectivity above 98% between 535 nm and 985 nm and transmits more



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than 96% of the light between 1045 and 2300 nm. The combined efficiency of the two dichroics is shown in Figure 5: it is well above 90% over most of the spectral range.

The flexure compensation tip-tilt mirrors

Light reflected and/or transmitted by the two dichroics reaches, in each arm, a folding mirror mounted on piezo tip-tilt mount. These mirrors are used to fold the beam and correct for backbone flexure to keep the relative alignment of the three spectrograph slits within less than 0.02" at any position of the instrument. They also compensate for shifts due to atmospheric differential refraction between the telescope tracking wavelength (fixed at 470 nm for all X-shooter observations) and the undeviated wavelength of the two ADCs (for UVB and VIS arms) and the middle of the atmospheric dispersion range for the NIR arm.

The Focal Reducer and Atmospheric Dispersion Correctors

Both UVB and VIS pre-slit arms contain a focal reducer and an ADC. These focal reducer-ADCs consist of two doublets cemented onto two counter rotating double prisms. The focal reducers bring the focal ratio from $f/13.41$ to $\sim f/6.5$ and provide a measured plate scale at the entrance slit of the spectrographs of 3.91"/mm in the UVB and 3.82"/mm in the VIS. The ADCs compensate for atmospheric dispersion in order to minimize slit losses and allow orienting the slit to any position angle on the sky up to a zenith distance of 60°. The zero-deviation wavelengths are 405 and 633 nm for the UVB and the VIS ADCs respectively. In the AUTO mode, their position is updated every 60s based on information taken from the telescope database.

The NIR arm is not equipped with an ADC. The NIR arm tip-tilt mirror compensates for atmospheric refraction between the telescope tracking wavelength (470 nm) and 1310 nm which corresponds to the middle of the atmospheric dispersion range for the NIR arm. This means that this wavelength is kept at the center of the NIR slit. At a zenithal distance of 60° the length of the spectrum dispersed by the atmosphere is 0.35", so the extremes of the spectrum can be displaced with respect to the center of the slit by up to 0.175". If measurement of absolute flux is an important issue, the slit should then be placed at parallactic angle.

2.2.2 The UVB spectrograph

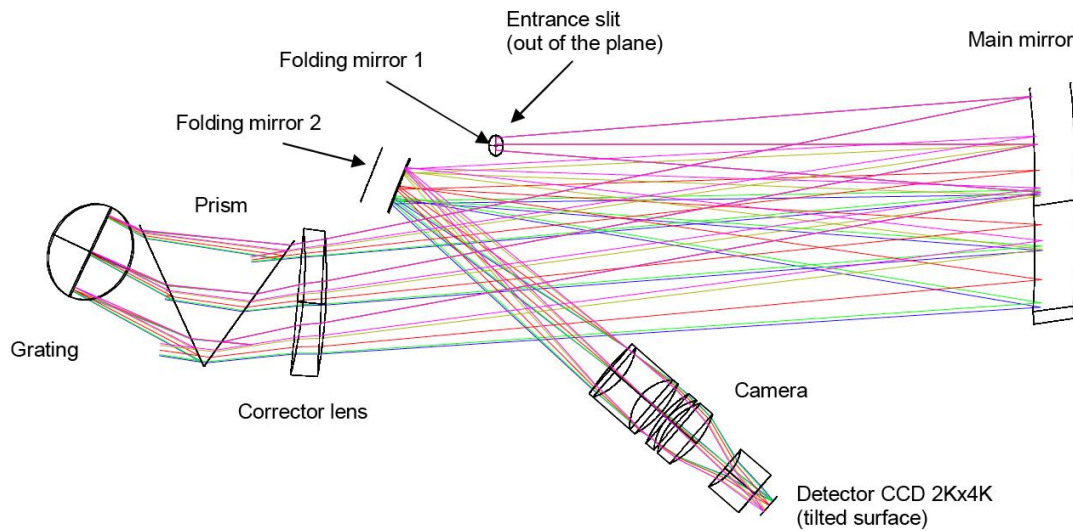


Figure 6: The UVB spectrograph optical layout

Slit carriage

The first opto-mechanical element of the spectrograph is the slit carriage. Besides the slit selection mechanism, this unit consists of a field lens placed just in front of the slit to reimage the telescope pupil onto the spectrograph grating, and the spectrograph shutter just after the slit. The slit mask is a laser cut Invar plate manufactured with the LPKF Laser Cutter used for FORS and VIMOS. It is mounted on a motorized slide in order to select one of the 9 positions available. All science observation slits are 11" high and different widths from 0.5" to 5" (the latter for spectro-photometric calibration) are offered. In addition a single pinhole for spectral format check and order tracing and a 9-pinhole mask for wavelength calibration and spatial scale mapping are available (see Table 4).

Table 4: UVB spectrograph slits and calibration masks

Size	Purpose
0.5"×11" slit	SCI / CAL
0.8"×11" slit	SCI / CAL
1.0"×11" slit	SCI / CAL
1.3"×11" slit	SCI / CAL
1.6"×11" slit	SCI / CAL
5.0"×11" slit	CAL
Raw of 9 pinholes of 0.5" ∅ spaced at 1.4"	CAL
0.5" ∅ pinhole	CAL



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Optical layout

The optical layout of the UVB spectrograph is presented in Figure 6. Light from the entrance slit, placed behind the plane of the figure, feeds a 5° off-axis Maksutov-type collimator through a folding mirror. The collimator consists of a spherical mirror and a diverging fused silica corrector lens with only spherical surfaces. The collimated beam passes through a 60° silica prism twice to gain enough cross-dispersion. Main dispersion is achieved through a 180 grooves/mm échelle grating blazed at 41.77°. The off-blaze angle is 0.0°, while the off-plane angle is 2.2°. After dispersion, the collimator creates an intermediate spectrum near the entrance slit, where a second folding mirror has been placed. This folding mirror acts also as field mirror. Then a dioptric camera (4 lens groups with CaF2 or silica lenses, 1 aspherical surface) reimages the cross-dispersed spectrum at f/2.7 (plate scale 9.31"/mm) onto a detector that is slightly tilted to compensate for a variation of best focus with wavelength. The back focal length is rather sensitive to temperature changes. It varies by ~22.7µm/°C which corresponds to a defocus of 9µm/°C or ~0.08"/°C. This is automatically compensated at the beginning of every exposure by moving the triplet+doublet of the camera by -10.9µm/°C.

Detector

The UVB detector is a 2048×4102, 15µm pixel CCD from E2V (type CCD44-82) of which only a 1800×3000 pixels window is used. The CCD cryostat is attached to the camera with the last optical element acting as a window. The operating temperature is 153K. The CCD control system is a standard ESO FIERA controller shared with the VIS CCD. The list of readout modes offered for science observations is given in Table 5.

Table 5: List of detector readout modes offered for science observations. *The 2x2 binning is not recommended whenever a good inter-order background subtraction is required (see also section 2.4.5).

Readout mode name	Gain [e-/ADU]		Speed [kpix/s]	Binning	
	UVB	VIS		Spatial dir.	Dispersion dir.
100k/1pt/hg	High [0.62]	High [0.595]	Slow [100]	1	1
100k/1pt/hg/1x2				1	2
100k/1pt/hg/2x2*				2	2
400k/1pt/lg	Low [1.75]	Low [1.4]	Fast [400]	1	1
400k/1pt/lg/1x2				1	2
400k/1pt/lg/2x2*				2	2

One more readout mode (1000×1000 window, low gain, fast readout, 1x1 binning) exclusively used for flexure measurement and engineering purposes is also implemented. Measured properties and performances of this system are summarized in Table 6. The associated shutter, located just after the slit is a 25mm bi-stable (2 coil, zero dissipation) shutter from Uniblitz (type BDS 25). Full transit time is 13ms. Since the slit is 2.8mm high (11" at f/6.5), the illumination of the detector is homogenous within <<10ms.



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	UVB	VIS	NIR
Detector type	E2V CCD44-82	MIT/LL CCID 20	substrate removed Hawaii 2RG
Operating temperature	153 K	135 K	81 K
QE	80% at 320 nm 88% at 400 nm 83% at 500 nm 81% at 540 nm	78% at 550 nm 91% at 700 nm 74% at 900 nm 23% at 1000 nm	85%
Number of pixels	2048×3000 (2048×4102 used in windowed readout)	2048×4096	2048×2048 (1024×2048 used)
Pixel size	15 μm	15μm	18μm
Gain (e ⁻ /ADU)	High: 0.62 Low: 1.75	High: 0.595 Low: 1.4	2.12
Readout noise (e ⁻ rms)	Slow: 2.5 Fast: 4.5	Slow: 3.1 Fast: 5.2	Short DIT: ~25 DIT>300s: ~8.0
Saturation (ADU)	65000	65000	45000 (for a single readout). TLI used for long DITs
Full frame readout time (s)	1x1, slow-fast: 70-19 1x2, slow-fast: 38-12 2x2, slow-fast: 22-8	1x1, slow-fast: 92-24 1x2, slow-fast: 48-14 2x2, slow-fast: 27-9	0.88 (for a single readout)
Dark current level	<0.2e ⁻ /pix/h (TBC)	<1.1e ⁻ /pix/h (TBC)	21 e ⁻ /pix/h
Fringing amplitude	-	~5% peak-to-valley	-
Non-linearity	Slow: 0.4% Fast: 1.0%	Slow:0.8% Fast: 0.8%	<1% up to 45000 ADUs
Readout direction	Main disp. dir.	Main disp. dir.	-
Prescan and overscan areas	1x1 and 1x2: X=1-48 and 2097-2144 2x2: X=1-24 and 1049-1072	1x1 and 1x2: pix 39-48 and 2097-2144 2x2: 19-24 and 1049-1072	-
Flatness	<8μm peak-to-valley		

Table 6: measured properties of the X-shooter detectors



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2.2.3 The VIS spectrograph

Slit carriage

The slit carriage of the VIS spectrograph is identical to that of the UVB but the available slits are different. All the science observation slits are 11" high and different widths are offered from 0.4" to 5" (see Table 7).

Table 7: VIS spectrograph slits and calibration masks

Size	Purpose
0.4"×11" slit	SCI / CAL
0.7"×11" slit	SCI / CAL
0.9"×11" slit	SCI / CAL
1.2"×11" slit	SCI / CAL
1.5"×11" slit	SCI / CAL
5.0"×11" slit	CAL
Row of 9 pinholes of 0.5" Ø spaced at 1.4"	CAL
0.5" Ø pinhole	CAL

Optical layout

The optical layout of the VIS spectrograph is very similar to that of the UVB (see Figure 6). The collimator (mirror+corrector lens) is identical. For cross-dispersion, it uses a 49° Schott SF6 prism in double pass. The main dispersion is achieved through a 99.4 grooves/mm, 54.0° blaze échelle grating. The off-blaze angle is 0.0° and the off-plane angle is 2.0°. The camera (3 lens groups, 1 aspherical surface) reimages the cross-dispersed spectrum at f/2.8 (plate scale 8.98"/mm) onto the detector (not tilted). Focussing is obtained by acting on the triplet+doublet sub-unit of the camera. However, unlike the UVB arm, the back focal length varies less than 1µm/°C (image blur <0.004"/°C) hence no thermal focus compensation is needed.

Detector

The VIS detector is 2048×4096, 15µm pixel CCD from MIT/LL (type CCID-20). Like for the UVB arm, the cryostat is attached to the camera with the last optical element acting as a window. The operating temperature is 135K. It shares its controller with the UVB detector and the same readout modes are available (see Table 5). Measured properties and performances are given in Table 6. The shutter system is identical to the UVB one.

2.2.4 The NIR spectrograph

The NIR spectrograph is fully cryogenic. It is cooled with a liquid nitrogen bath cryostat and operates at 105 K.

Pre-slit optics and entrance window

After the dichroic box and two warm mirrors M1 (cylindrical) and M2 (spherical, mounted on a tip-tilt stage and used for flexure compensation, see description on p. 17) light enters the cryostat via the Infrasil vacuum window. To avoid ghosts, this window is tilted 3 degrees about the Y-axis. After the window, light passes the cold stop, and is directed towards the entrance slit via two folding mirrors M3 (flat) and M4 (spherical).

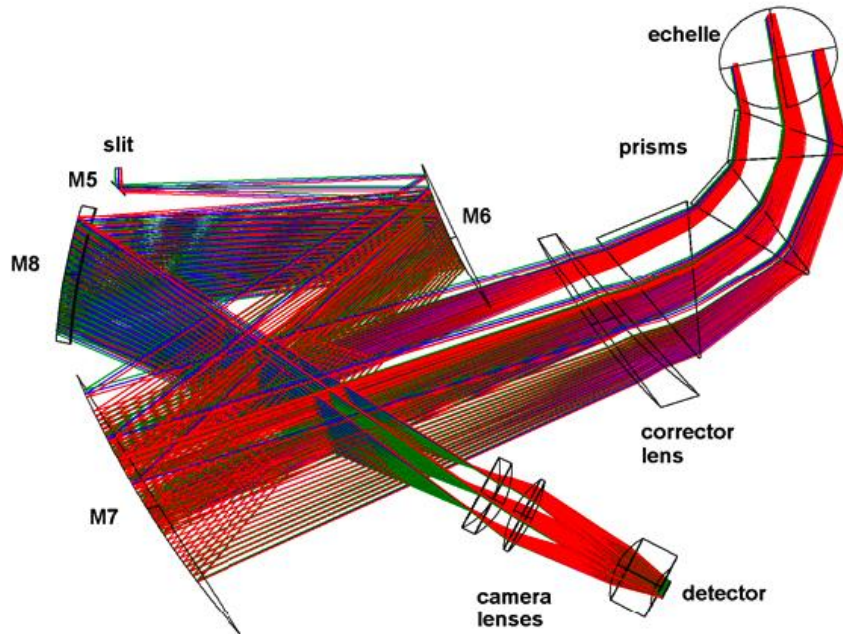


Figure 7: The NIR spectrograph optical layout.

Slit wheel

A circular laser cut Invar slit mask is pressed in between two stainless steel disks with 12 openings forming the wheel. The wheel is positioned by indents on the circumference of the wheel with a roll clicking into the indents. All the science observation slits are 11" high and different widths are offered from 0.4" to 5" (see Table 8).

Table 8: NIR spectrograph slits and calibration masks

Size	Purpose
0.4"×11" slit	SCI / CAL
0.6"×11" slit	SCI / CAL
0.9"×11" slit	SCI / CAL
1.2"×11" slit	SCI / CAL
1.5"×11" slit	SCI/CAL
5.0"×11" slit	CAL
Raw of 9 pinholes of 0.5" Ø spaced at 1.4"	CAL
0.5" Ø pinhole	CAL

Optical layout

The optical layout of the NIR spectrograph is presented in Figure 7. The conceptual design is the same than for the UVB and the VIS spectrographs. Light entering the spectrograph via the entrance slit and folding mirror M5 feeds an off-axis Maksutov-inspired collimator. In this



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case, the collimator is made of 2 spherical mirrors M6 and M7 plus an Infrasil corrector lens (with only spherical surfaces). In order to get enough cross dispersion, three prisms are used in double path. Prism 1 is a 35° top angle made of Infrasil; prisms 2 and 3 are two 22° top angle ZnSe prisms. This design provides an almost constant order separation. Main dispersion is provided by a 55 grooves/mm échelle grating with a blaze angle of 46.07°. The off-blaze angle is 0.0°, while the off-plane angle is 1.8°. After dispersion, the collimator creates an intermediate spectrum near the entrance slit, where M8, a spherical mirror, acts as a field mirror, relocating the pupil between L2 and L3, the last lenses of the camera. The fixed focus camera re-images the échellogramme onto the detector at f/2.1 (plate scale 12.1"/mm).

Detector

The NIR detector is a Teledyne substrate-removed HgCdTe, 2k×2k, 18µm pixel Hawaii 2RG from of which only 1k×2k is used. It is operated at 81K. Measured characteristics and performances are given in Table 6. Sample-up-the-ramp (non-destructive) readout is always used. This means that during integration, the detector is continuously read out without resetting it and counts in each pixel are computed by fitting the slope of the signal vs. time. In addition, Threshold Limited Integration (TLI) mode is used to extend the dynamical range for long exposure times: if one pixel is illuminated by a bright source and reaches an absolute value above a certain threshold (close to detector saturation), only detector readouts before the threshold is reached are used to compute the slope and the counts written in the FITS image for this pixel are extrapolated to the entire exposure time (see Finger et al. 2008, Proc. SPIE, Vol. 7021 for a more detailed description).

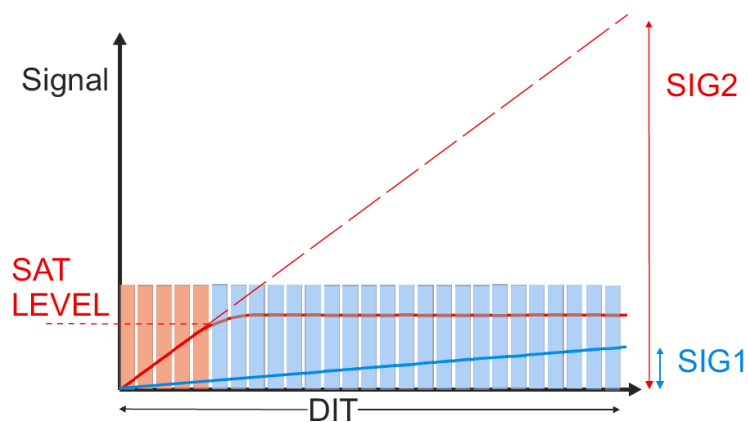


Figure 8: Saturation threshold for nondestructive sampling and extrapolation of detector signal for high flux levels. For pixels with high flux (red) only readout values below SATLEVEL (orange rectangles) are taken into account in the calculation of the slope and values written in the FITS files are extrapolated to the full DIT (SIG2). For low flux pixels (blue) all nondestructive readouts are used (light blue rectangles). Figure courtesy of Finger et al. (2008).

Note that for operational reasons only a limited number of DITs is offered to the user in case of exposures longer than 300s (see 3.3)

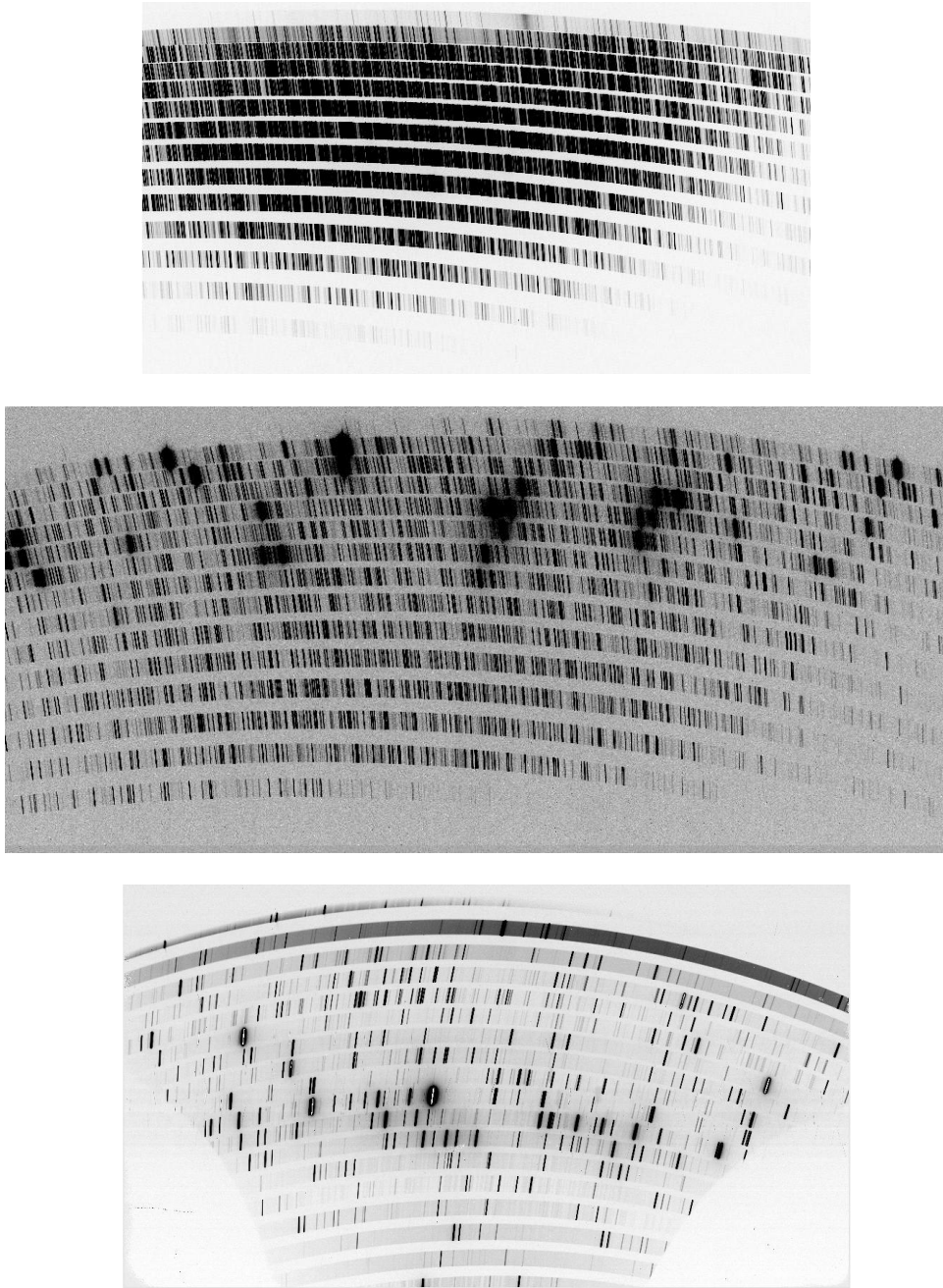


Figure 9: example of UVB (top), VIS (middle) and NIR (bottom) calibration frames. Strong order curvature and varying slit tilt and scale are clearly visible.



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Table 9: X-shooter spectral format

Order	Min. wavelength [nm]	Blaze wavelength [nm]	Max. wavelength [nm]
UVB			
24	293.6	312.2	322.3
23	306.2	325.0	336.2
22	320.0	339.8	351.4
21	335.1	356.1	368.0
20	351.8	373.5	386.2
19	370.1	393.2	406.4
18	390.6	414.5	428.9
17	413.4	438.8	454.0
16	439.1	466.4	482.2
15	468.3	496.8	514.2
14	501.6	531.0	550.8
13	540.1	556.0	593.0
VIS			
30	525.3	550.5	561.0
29	535.8	568.0	580.2
28	554.6	585.9	600.8
27	575.2	607.7	622.9
26	597.4	629.5	646.8
25	621.3	653.8	672.5
24	647.2	682.1	700.4
23	675.4	711.2	730.7
22	706.1	742.6	763.8
21	739.7	777.6	800.0
20	777.0	815.8	839.8
19	817.6	860.2	883.8
18	862.9	904.3	932.7
17	913.7	957.3	987.4
16	970.7	1001.6	1048.9
NIR			
26	982.7	1005.8	1034.2
25	1020.5	1046.0	1076.7
24	1062.0	1089.6	1122.9
23	1106.6	1137.0	1173.1
22	1155.2	1188.6	1228.0
21	1208.2	1245.2	1288.5
20	1266.5	1307.5	1355.2
19	1330.3	1376.3	1429.4
18	1400.8	1452.8	1511.5
17	1479.5	1538.2	1604.0
16	1567.1	1634.4	1708.7
15	1667.8	1743.3	1823.3
14	1785.7	1867.9	1952.8
13	1922.6	2011.5	2102.0
12	2082.9	2179.3	2275.6
11	2272.3	2377.28	2480.7



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2.3 Spectral format, resolution and overall performances

2.3.1 Spectral format

The spectral format of X-shooter is fixed. The spectral ranges on the detector and blaze wavelength for each order are given in Table 9 and an example of ThAr slit frame for each arm is shown Figure 9. The whole spectral range is covered by 12 orders in the UVB, 15 in the VIS, and 16 in the NIR. Orders are strongly curved (parabolic) and the spectral line tilt varies along orders. Both slit height and width projection also vary from order to order and along each order due to a variable anamorphic effect introduced by the prisms (crossed twice). For instance, the projected slit height (11") measured at the center of an order changes from:

- UVB: 65.9 pixels (0.167"/pix) at order 14 to 70.8 pixels (0.155"/pix) at order 24
- VIS: 65.9 pixels (0.167"/pix) at order 17 to 72.0 pixels (0.153"/pix) at order 30
- NIR: 52.4 pixels (0.21"/pix) at order 11 to 59.9 pixels (0.184"/pix) at order 26

The minimum separation between orders is ~4 (unbinned) pixels to allow inter-order background evaluation.

The dichroic crossover region between UVB-VIS and VIS-NIR is at 559.5 nm and 1024 nm respectively:

- Between UVB and VIS, the region where the combined dichroics transmit less than 80% is 556.0 -- 563.8 nm (7.8 nm wide). This region falls in the UVB order 13 and VIS order 29. Note that the VIS order 30 will still get some flux since dichroics still reflect/transmit ~15% of the light at 550nm.
- Between VIS and NIR, the combined dichroics transmit less than 80% of the light between 1009.5 – 1035 nm (35.5 nm wide). This transition region falls in the VIS order 16 and NIR orders 26 and 25.

2.3.2 Spectral resolution and sampling

The user can only affect the spectral resolution through the choice of slit width (and to some extent with the binning in UVB and VIS). The resolution and pixel sampling (without binning) as a function of the slit width is given in Table 10.

Table 10: Resolution as a function of slit width

Slit width	UVB		Slit width	VIS		Slit width	NIR	
	R $\lambda/\Delta\lambda$	Sampling [pix/FWHM]		R $\lambda/\Delta\lambda$	Sampling [pix/FWHM]		R $\lambda/\Delta\lambda$	Sampling [pix/FWHM]
0.5	9100	3.5	0.4	17400	3.0	0.4	11300	2.0
0.8	6200	5.2	0.7	11000	4.8	0.6	8100	2.8
1.0	5100	6.3	0.9	8800	6.0	0.9	5600	4.0
1.3	4000	8.1	1.2	6700	7.9	1.2	4300	5.3
1.6	3300	9.9	1.5	5400	9.7	1.5	3500	6.6
IFU	7900	4.1	IFU	12600	4.2	IFU	8100	2.8

2.3.3 Overall sensitivity

The total efficiency has been measured on sky using several standard stars observed during commissioning. Based on these values, the expected limiting AB magnitudes at blaze in 1 hour for a S/N of 10 per spectral bin are given in Figure 10.



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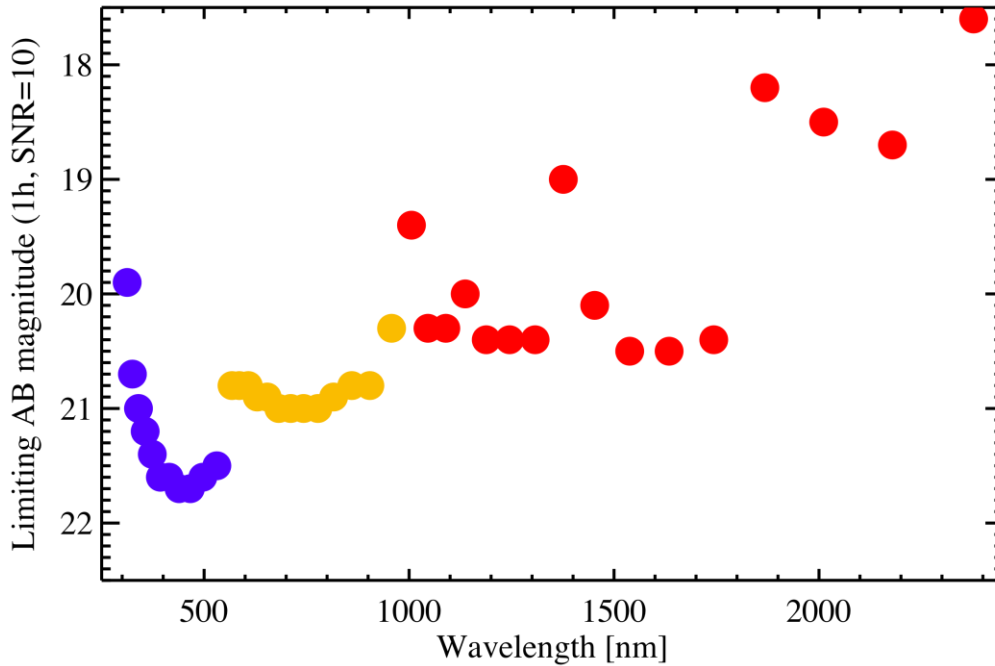


Figure 10: Limiting AB magnitude of X-shooter per spectral bin (using 2 pixels binning in the spectral direction) at S/N=10 in a 1 hour exposure. Other parameters: air mass 1.2, 0.8" seeing, 3 days from new moon, 1" slit for UVB, 0.9" slit for VIS and NIR. The ESO ETC was used to compute these values. The model uses overall efficiencies measured during commissioning. Note that these performance estimates assume no degradation of the SNR in the extraction process or in the sky subtraction. The decrease in efficiency to the blue side of the UVB range is due to the atmospheric absorption, at the red side of the VIS band it is due to the decrease in efficiency of the CCD, while on the long-wavelength side of the NIR range it is due to the rise of the thermal background.



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2.4 Instrument features and problems to be aware of

2.4.1 UVB and VIS detectors sequential readout

UVB and VIS detectors share the same FIERA controller. While both arms can expose simultaneously, readout is done sequentially. In practice, this means that if an exposure finishes in one of the arms while the other one is being read out, the shutter of the second arm is closed but readout is delayed until data from the first arm are fully transferred to disk.

2.4.2 Effects of atmospheric dispersion

In IFU mode, there is no correction for atmospheric dispersion (see section 3.3.1)

2.4.3 Remnance

The presence of remnants in the various detectors is still under study. However, after a few months of operation it has been verified that long DITs (namely 1800s DITs) in the NIR arm, especially when used continuously during the night, leave significant remnants by the thermal background in the K band and by the strongest sky emission lines. These remnants may still be visible in the morning DARK calibrations and certainly affect the night time observations which follow the long exposures. For this reasons starting from P85 the DIT=1800s is no longer offered. Remnants due to the thermal background in the reddest order of the K-band, has been observed, occasionally, also with shorter DIT. This is currently under discussion and analysis.

Remnants have been observed in the three arms also after ThAr calibrations (arcs, 2D-maps or format-checks). For this reasons we discourage attached arc calibrations during the night (see section 4.4). The optimal exposure time which allows the detection of a sufficient number of lines minimizing the presence of remnants is being discussed. During day time, arc exposures are taken last, in order to not affect the other calibrations.

2.4.4 Ghosts

Back reflections in the two dichroics produce almost in focus ghost spectra in the bottom of the slit (negative x in **Error! Reference source not found.**) particularly noticeable in the dichroic cut-off region between UVB and VIS arms when putting a bright object on the top part of the slit (positive x). It is strongest in the last order of the UVB spectrum in the wavelength range of the dichroic reflectivity cut-off (see Figure 11, left). In the VIS, the ghost is noticeable in several orders and its intensity is <0.5% of the parent spectrum (see Figure 11, right). It is particularly relevant when observing a bright object with the nod on slit template.

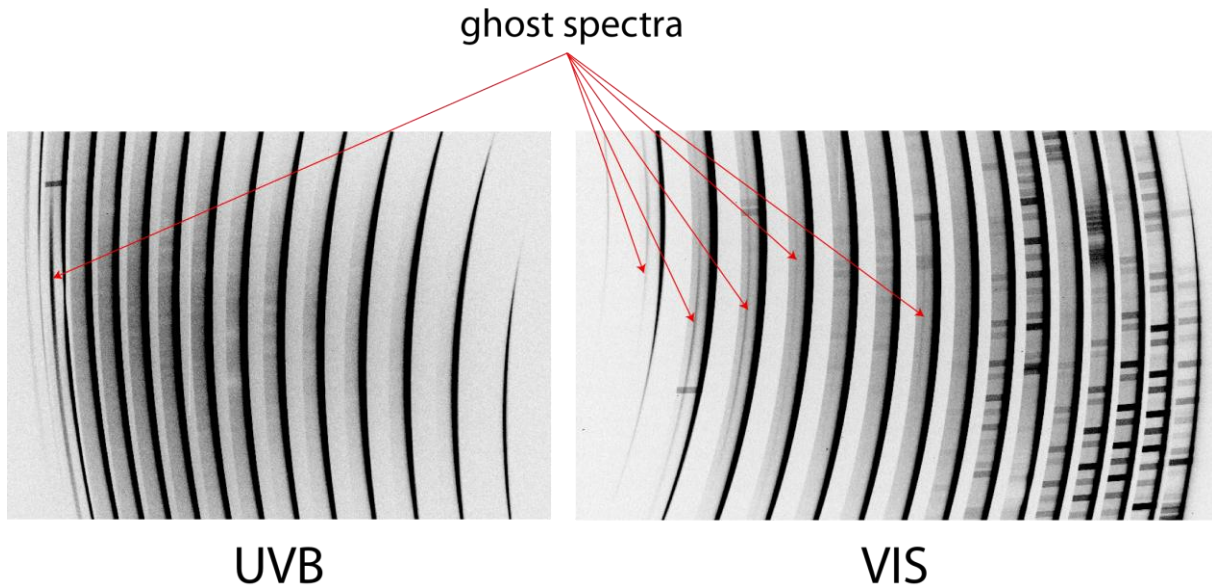


Figure 11: ghost spectra in UVB and VIS produced by back reflection in the two dichroics

2.4.5 Inter-order background

Inter-order background subtraction is a difficult task, in particular where order spacing is minimum in the red part of the VIS (~4 unbinned pixels). Therefore, whenever a good inter-order background subtraction by the pipeline is important, we recommend not using the 2x2 binning mode.

2.4.6 Instrument stability

Backbone flexures

The active flexure compensation (AFC) allows to maintain the three slits aligned with respect to the reference A&G pinhole to within ~0.02" in both at any rotation angle for ZD<60°. Without the flexure compensation running (e.g. in case of failure of the calibration lamp during the night), this alignment is kept within ~0.1".

Spectrograph flexures

From 0° to 60° zenithal distance for any rotator angle, the spectra format in all three arms stays within ~1.2 pixels from the zenith position.



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3. Observing with X-shooter

3.1 Observing modes and basic choices

X-shooter offers two observing modes: SLIT spectroscopy and IFU spectroscopy. The spectral format is fixed for both observing modes. The three arms (UVB, VIS and NIR) operate in parallel.

In SLIT mode, the user can select, for each arm independently, a slit width among those listed in Table 10.

In IFU mode, the only important parameter the user has to choose is the wavelength that is placed and kept fixed at the centre of the IFU during observations.

In both observing modes, one of the detector readout modes given in section 2.2.2 can be selected for the UVB and the VIS arm independently. The readout mode is fixed for the NIR arm.

All X-shooter science observing blocks (OB) are composed of an acquisition template (see 3.2) followed by one or several science templates selected depending on the observing strategy chosen by the user.

3.2 Target acquisition

Target acquisition for SLIT and IFU modes is almost identical. The main steps of a typical acquisition sequence are the following:

1. Preset the telescope to the target coordinates and set the adaptor-rotator to the chosen position angle.
2. UVB and VIS ADCs start tracking to compensate for atmospheric dispersion in SLIT mode or set to their OFF position (i.e. at minimum deviation) in IFU mode.
3. Backbone flexure is measured by cross-correlating an arc lamp spectrum taken with the Acquisition and Guiding slide 0.5" pinhole and an arc spectrum taken with the 0.5" pinhole present in each slit slide. Commands are sent to the three tip-tilt mirrors based on computed flexures.
4. The Acquisition and Guiding slide is set to MIR position: the field is now visible in the acquisition camera and an acquisition image can be acquired.
5. The spectroscopic target is identified (or the reference object in case of blind offset) and its coordinates on the detector are determined by a centring algorithm.
6. The telescope is offset to the reference pixel on the detector corresponding to the position of the image the Acquisition and Guiding slide reference pinhole corrected in real time from effects of atmospheric refraction between the wavelength of the selected acquisition filter and the telescope tracking wavelength (470 nm for SLIT mode, user selected for IFU observations)
7. Loop over steps 5 and 6.
8. When the observer is satisfied with the object centring, an acquisition image is saved and the Acquisition and Guiding slide is either set to the spectroscopic observations position (10" x 15" slot) in SLIT mode or to the IFU position along with other mode specific instrument setup.
9. In alternative to step 8, in case of a blind offset, the offsets are applied before acquiring the final image and moving to spectroscopic observation position.



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10. At this point, the instrument is ready for science observations.

This acquisition sequence is performed by one of the two acquisition templates: `XSHOOTER_slit_acq` or `XSHOOTER_ifu_acq`, depending on the selected observing mode. A full description of these templates is given in section 5.1.2. Note that the instrument setup is done within the acquisition template so that for instance an IFU observation can *never* follow a SLIT acquisition sequence and vice versa.

At the end of the acquisition sequence, an acquisition image of the field is saved after blind offsets have been applied (if any). FITS header keywords HIERARCH ESO SEQ AG XCEN and YCEN record the location of the centre of the SLIT or IFU in the image.

3.3 Spectroscopic observations

3.3.1 Overview and important remarks

Observing strategies

X-shooter science templates support different observing strategies: staring (commonly used for UV and visible observations), nodding along the slit (classical near-IR observations, for SLIT only), offsetting to a fixed sky position (for extended objects) or lets the user free to choose any sequence of offsets (e.g. for mapping). Note that due to the small field of view of the IFU, we recommend to offset to a pure sky position in case good sky subtraction is needed.

Effect of atmospheric dispersion

In SLIT mode, effects of atmospheric dispersion are automatically corrected in the UVB and VIS arms thanks to the two ADCs.

In *IFU mode however, there is no correction for atmospheric dispersion* (the two ADCs come *after* the IFU in the light path and are set to their OFF position where they do not disperse light). The user has to choose which wavelength will be kept fixed at the centre of the IFU during observations using the `SEQ.IFU.WLGT` parameter in the `XSHOOTER_ifu_acq` template. It is set to the middle of the atmospheric dispersion range (470nm) by default. Users are therefore recommended to orient the IFU parallel to the parallactic angle whenever possible and should keep in mind that at high airmass, the amplitude of the dispersion is larger than the 4" of the IFU field.

Exposure time in the NIR arm

Only a limited choice of DIT values is allowed for the NIR observations in service mode. This has been decided uniquely on an operational basis, i.e. to avoid endless daytime calibrations. In particular, there are not constraints for short NIR exposure (up to 300s), while only the following selection is available in the case of longer exposure (≥ 300 s): DIT=300, 480, 600, 900 and 1200 s. Note that the DIT=1800s is no longer offered as it has been verified that it leaves remnants (see section 2.4.3).

3.3.2 Staring (SLIT and IFU)

With the `XSHOOTER_slit_obs_Stare` and `XSERHOOT_ifu_obs_Stare` templates, one or more spectra are taken with each arm independently at a fixed position on sky. For each arm, the user chooses the exposure time and the number of exposures. Exposures are



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completely asynchronous i.e. in each arm, whenever an exposure is finished the next one starts immediately, independently of what is happening with the other arms.

3.3.3 Staring synchronized (SLIT and IFU)

Whenever exposures in the three arms have to be parallel, the templates `XSHOOTER_slit_obs_StareSynchro` or `XSHOOTER_ifu_obs_StareSynchro` should be used. In this case, the number of exposures is fixed to one per arm. Exposure times can still be different in each arm but the exposures are synchronized to their mid-time. In case the exposure times in all three arms are identical, exposures in the three arms will have the same start time within approximately one second. In case of different exposure times, the mid-exposure time of the three will coincide within about one second.

3.3.4 Nodding along the slit (SLIT only)

This corresponds to the standard way of observing in the near-IR primarily aimed at a double pass sky subtraction. The template `XSHOOTER_slit_obs_AutoNodOnSlit` automatically nods the telescope between two positions (A and B) along the slit. The user defines a *Nod Throw* and optionally a small *jitter* box (in the slit direction). The *Nod Throw* is defined as the distance between the two nodding position i.e. the center of the two jitter boxes inside the slit (see Figure 12). One cycle is a pair of AB or BA observations. Cycles are repeated in ABBA sequences. For each arm, the user chooses the number of exposures at each position and the exposure time (both identical for all A and B positions). Exposures are asynchronous. Note that nodding is not offered in IFU mode because the field of view (4"x1.8") is too small to nod within the IFU. Also note that it is not possible to move the target in one arm independently from the other arms.

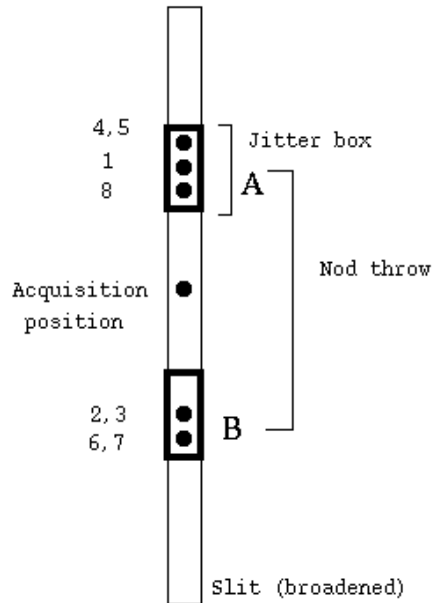


Figure 12: conventions used for nodding along slit observations. The sequence illustrated here corresponds to 4 cycles (8 exposures, ABBAABBA) with a non-zero jitter box.

3.3.5 Fixed offset to sky (SLIT and IFU)

When observing extended objects for which there is no or not enough pure sky in the 11" slit to perform a good sky subtraction one should use the template `XSHOOTER_slit_obs_FixedSkyOffset` or `XSHOOTER_ifu_obs_FixedSkyOffset`. It allows alternating between an object (O) and sky position (S) with the possibility of adding a small jittering around the object and the sky position. One cycle is a pair of OS or SO observations. Cycles are repeated in OSSO sequences. For each arm, the user chooses the number of exposures taken at each position and the exposure time (both identical for all A and B positions). Exposures are asynchronous.

3.3.6 Generic offset (SLIT and IFU)

These are the most flexible observing templates. `XSHOOTER_slit_obs_GenericOffset` and `XSHOOTER_ifu_obs_GenericOffset` allow the user to define any pattern by providing a list of (cumulative) telescope offsets. This is particularly useful in case one wants to map on object with several slit or IFU positions. The number of exposures taken at each position and the exposure time (both identical at all positions) have to be defined. Exposures are asynchronous.

3.4 Instrument and telescope overheads

3.4.1 Summary of telescope and instrument overheads



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Table 11: overheads

Acquisition and setup		
Telescope pointing, guide star acquisition, start active optics. X-shooter backbone flexure measurement.	360s	
Interactive acquisition loop	180s	
Instrument setup at the end of acquisition	SLIT: 30s	
	IFU: 60s	
Observations		
Detector readout	UVB	1x1, slow / fast: 70s / 19s
		1x2, slow / fast: 38s / 12s
		2x2, slow / fast: 22s / 8s
	VIS	1x1, slow / fast: 92s / 24s
		1x2, slow / fast: 48s / 14s
		2x2, slow / fast: 27s / 9s
NIR	0.88s	
Each telescope offset	15 s	

3.4.2 Example of execution time computation

Below a generic example of how total execution time shall be estimated.

For a nod on slit sequence with:

- 2 cycles (ABBA sequence, returning to the original position at the end of template)
- 1 UVB, 2 VIS and 3 NIR exposures per position
- integration times 900s in UVB in 1x2 slow, 450s in VIS in 1x2 slow, and 300s in NIR

the total execution time splits as follows:

- Pointing / acquisition / SLIT setup: 360s + 180s + 30s = 570s
- At each position the total integration and readout time per arm is:
 - UVB: $1 \times (900 + 38) = 938\text{s}$
 - VIS: $2 \times (450 + 48) = 996\text{s}$
 - NIR: $3 \times (300 + 0.88) = 902\text{s}$

The three arms operating in parallel, the total time spent at each position is given by the slowest arm, in this case the VIS one: 996s. So the total integration and readout time is $4 \times 996\text{s} = 3984\text{s}$

- Total telescope offsets: $4 \times 15 = 60\text{s}$

So, the total execution time for this observing block is: $570\text{s} + 3984\text{s} + 60\text{s} = 4614\text{s}$



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4. Calibrating and reducing X-shooter data

4.1 X-shooter calibration plan

The calibration plan of X-shooter is described in detail in document [RD1]. A summary is given in Table 12. All frequencies in this table are TBC.

Table 12: X-shooter calibration plan summary

Calibration	UVB frames	VIS frames	NIR frames	Frequency	Purpose
Bias	5/read. mode	5/read. mode		weekly	Master bias and check CCD bias properties
NIR darks			3 per DIT	daily	Master dark, bad pix. map
Slit/IFU flats	5/setting D ₂ lamp 5/setting halo. lamp	5/setting		daily	Pixel-to-pixel variations, blaze function correction
Arcs single pinhole	1	1	1 ON-OFF	weekly	Pipeline calibration: first guess disp. solution.
Flat single pinhole	1 D ₂ lamp 1 Halo. lamp	1	1 ON-OFF	weekly	Pipeline calibration: order localization
Arcs multi-pinhole	1	1	1 ON-OFF	weekly	Wavelength and spatial scale determination
Arcs through slit/IFU	1/setting	1/setting	1 ON-OFF / setting	daily	Wavelength shift between multi-pinholes and slits, spectral resolution
IFU slitlet distances	2	2	2	6-monthly	Pipeline calibration: cube reconstruction
Radial velocity standard	2	2	2	On request	Accurate radial vel. calibration
Telluric standard		2	2	1/obs.	Correct for telluric abs.
Spectro-photometric standard	2	2	2	daily	Response curve, absolute flux calib.

4.2 Wavelength and spatial scale calibration

As described in section 2.3.1, the spectral format of X-shooter is relatively complex with highly curved orders, variable line tilt, dispersion and spatial scale along each order. Using just long slit arc spectra is not sufficient because it is essential to also calibrate the change of spatial scale (just measuring the slit height is not accurate enough).

Wavelength and spatial scale are well calibrated simultaneously with a dedicated mask of 9 equidistant pinholes present in each slit unit (see Table 4, Table 7 and Table 8) in combination with the ThAr lamp (the use of ThAr lamp for the NIR arm is TBC). Exposure time for each arm is given in Table 13. An example of such a frame is given in Figure 13. The templates used for this calibration is `XSHOOTER_slit_cal_UvbVisArcsMultiplePinhole` and

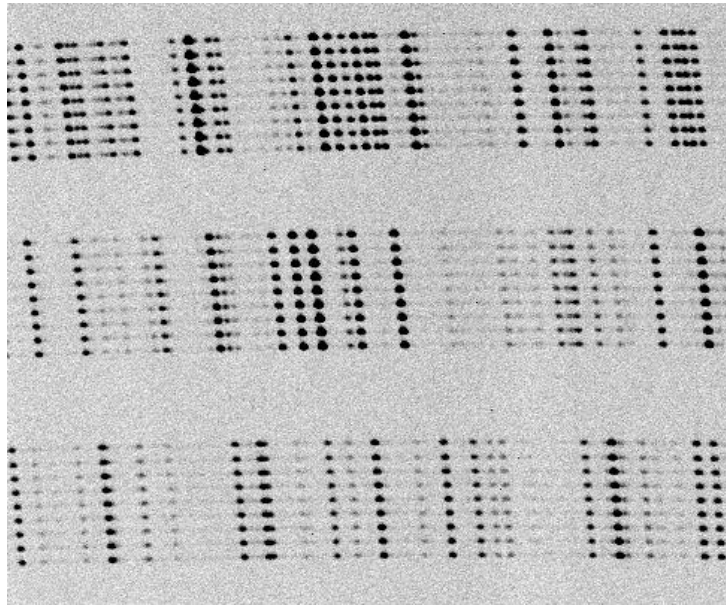


Figure 13: portion of a 9-pinhole ThAr VIS frame used for wavelength and spatial scale calibration.

`XSHOOTER_slit_cal_NIRArcsMultiplePinhole` (provisional: those two templates will be merged into a single one if the use of the ThAr lamp for the NIR arm is confirmed). The accuracy of the wavelength calibration typically achieved using the X-shooter Data Reduction Software is better than $\sim 2\text{km/s}$ over the whole wavelength range (TBC for the NIR arm). In this process, the quality of the list of lines used to perform the calibration is critical (in particular, it has to be carefully cleaned from blends). Such a ThAr line list will be made available on the X-shooter web page and provided together with the X-shooter Data Reduction Software package.

Full slit ThAr spectra are also useful to correct the slight (fixed) displacement between the 9-pinhole masks and each slit. This is also used to monitor the spectral resolution of the different spectrographs. Templates to use for these calibrations are `XSHOOTER_slit_cal_UVBVisArcs`, `XSHOOTER_slit_cal_NIRArcs`, `XSHOOTER_ifu_cal_UVBVisArcs`, `XSHOOTER_ifu_cal_NIRArcs`.



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4.3 Flat-field

Flatfield spectra allow to correct for the pixel-to-pixel variations in detector sensitivity as a function of impinging wavelength of the light and to correct for the structures introduced by imperfections of the slits. They also provide a good correction of the blaze function of the échelle.

Table 13: exposure time for ThAr arc frames and flat field frames. Values are given for the fast readout, low gain mode (in UVB and VIS) for a 1.0" or 0.9" slit and the IFU. For the flatfield, values can be adapted to other slit widths and readout modes applying a simple scaling.

UVB 1x1, low gain		VIS 1x1 low gain		NIR	
ThAr arc lamp					
Slit 1.0"	30 s (TBC)	Slit 0.9"	5 s	Slit 0.9"	0.66 s
IFU	45 s (TBC)	IFU	4 s (TBC)	IFU	1.32 s
9-pin.	15 s	9-pin.	10 s	9-pin.	0.66 s
Flatfield					
Slit 1.0"	D ₂ 7.3 s Halo 19.3 s	Slit 0.9"	18.8 s	Slit 0.9"	40 s
IFU	D ₂ 14 s Halo 32 s	IFU	52 s	IFU	60 s

For each arm, a dedicated halogen lamp with appropriate balancing filters is available to give well-exposed, flat continuum spectra at all wavelengths within a reasonably short exposure time (see Table 13). A deuterium lamp is used for the spectral region shortwards of 350 nm. Flatfielding the whole spectral range therefore requires four exposures (2 in UVB, 1 in VIS and one in NIR) that have to be taken sequentially. Flatfield templates are:

- XSHOOTER_slit_cal_UVBLowLampFlat (UVB deuterium lamp flat)
- XSHOOTER_slit_cal_UVBHighLampFlat (UVB halogen lamp flat)
- XSHOOTER_slit_cal_VISLampFlat
- XSHOOTER_slit_cal_NIRLampFlat

And their equivalent for IFU flatfield named XSHOOTER_ifu_cal_...LampFlat.

Note that low frequency fringes with peak-to-valley amplitudes up to ~5% are present in the red part of the VIS spectra.

4.4 Attached calibrations

It is possible to include arc and flat calibration in an observing OB (see Table 35 to Table 42 for the selection of offered night time attached calibrations). However, we strongly discourage taking night time attached arcs in the VIS arm (SLIT or IFU) because of remnants caused by a few strong ThAr lines. These remnants persist in the following exposure for up to one hour affecting the subsequent observations. Therefore, attached VIS arcs can be granted only in visitor mode or in service mode which will be executed only at the very end of the night, if possible. The user should refer to Table 13 to select the exposure time of the attached calibrations.



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4.5 Spectrophotometric calibration

4.5.1 Telluric absorption correction

The visual-red and a near-IR part of the spectrum are strongly affected by the absorption lines of the Earth's atmosphere. Many of these telluric lines do not scale linearly with airmass, so it is necessary to observe a star with a well-known spectrum at the same airmass and with the same instrument setup as that used for of the science target. Furthermore, the strength of the telluric lines varies with time, so it is also necessary to observe the telluric standard soon after or soon before the science observation. Two templates are designed for this purpose: `XSHOOTER_slit_cal_TelluricStd` and `XSHOOTER_ifu_cal_TelluricStd`.

In general, we use either main sequence hot stars (B0 to B4 whenever possible, or to B9 otherwise) or solar analogs as telluric standards selected from the Hipparcos Catalog.

Unfortunately, hot stars still contain some features, usually lines of hydrogen and helium, which can be difficult to remove. If the regions around the hydrogen and helium lines are of interest, then one can also observe a late type star, which should have weak hydrogen and helium lines. This star is then used to correct for the helium and hydrogen absorption in the spectrum of the hot star. Some hot stars also have emission lines or are in dusty regions. These stars should be avoided. The V-I colour of the star can be used as an indicator of dust. For stars hotter than A0, it should be negative. And lastly, hot stars tend to lie near the galactic plane, so there may be situations where there are no nearby hot stars.

Solar analogs, (for the purpose of removing telluric features) are stars with spectral type G0V to G4V. These standards have many absorption lines in the IR, particularly in the J band. The features can be removed by dividing by the solar spectrum that has been degraded to the resolution of the observations.

In addition to hot stars and solar analogs, IR astronomers have used other stellar types as telluric standards. For example, F dwarfs are commonly used.

Users should think carefully about which star is best for their program. Although the Observatory will automatically observe a telluric standard for service programs, we cannot guarantee that we will make the best choice, as this depends on the science users wish to do. If you think that a specific spectral type suits your program better than others, we recommend that you submit calibration OBs.

4.5.2 Absolute flux calibration

Spectrophotometric standard stars can be used to obtain the absolute efficiency of the instrument and derive an absolute flux calibration of the science data. These observations are done with the wide 5.0" slit with dedicated templates `XSHOOTER_slit_cal_StandardStar` and `XSHOOTER_ifu_cal_StandardStar`.

The classical set of UV-optical standard stars from Oke (1990, AJ 99, 1621) and Hamuy et al. (1994, PASP 106, 566) do not cover the whole spectral range of X-shooter thus making calibration of full spectral range of X-shooter problematic. To remedy this situation dedicated 2 years observing campaign has been undertaken as an ESO Observatory Programme (PID 278.D-5008) to extend to the near-IR a subset of 12 standard stars from the two references cited above to the near-IR. Tabulated fluxes for those 12 stars from 300 to 2500 nm will be made available at the beginning of X-shooter operations to allow an absolute flux calibration



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to the 5-10%. Details of this programme can be found in Vernet et al. (Proc. SPIE 7016, 2008, available on the X-shooter web pages).

4.6 The X-shooter pipeline

The X-shooter data reduction pipeline is being developed and tested. It is expected to be ready by the start of operations. It will fully support both instrument modes (SLIT and IFU) and deliver the following products:

- Sky subtracted, cosmic ray hits cleaned, flux and wavelength calibrated 2D spectra, rectified to a regular grid in wavelength and spatial directions. 1D extracted spectra will be produced whenever a bright enough object is detected.
- 3D reconstructed data cubes will be produced for IFU data.
- Additional products to verify the quality of the results and a set of Quality Control parameters instrument health check and trend analysis.



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5. Reference material

5.1 Templates reference

In the following sections all the currently defined X-shooter templates are listed with their free and fixed parameters. When using the P2PP tool the user has to fill only the fields (keywords) shown on white background colour in the following tables. Keywords shown on gray background colour are fixed within the template itself and can only be modified by the astronomer operating the instrument during the night or during daytime calibration activities.

5.1.1 Orientation and conventions

X-shooter follows the standard astronomical offset conventions and definitions.

The positive position angle (PA) is defined from North to East. This is the value that should be entered in the TEL.ROT.OFFANGLE in all the acquisition templates to set the slit position angle on the sky. The fits header keyword HIEARCH ESO ADA POSANG is all X-shooter data is *minus* the position angle of the slit on the sky. Note that the value "9999" can be used to set the position angle to the parallactic angle. Note also that the parallactic angle is that at the time of the preset/acquisition. The slit is not maintained at the parallactic angle during the science exposure.

Offsets are always given in arc seconds, but the reference system can be chosen to be the sky (Alpha, Delta) or X-shooter slit coordinate system (X,Y). Offset conventions are illustrated in **Error! Reference source not found.** Templates use **cumulative offsets**: the position at a given time is derived from the *sum* of all offsets specified so far in the template. For example, the series of offsets: 0, -10, 0, 10 brings the telescope back to the original position for the last exposure. This example could have been for instance the definition of a series in which we define an exposure on object, followed by two sky exposures at -10" of the original position, before pointing back on the object for the fourth exposure.

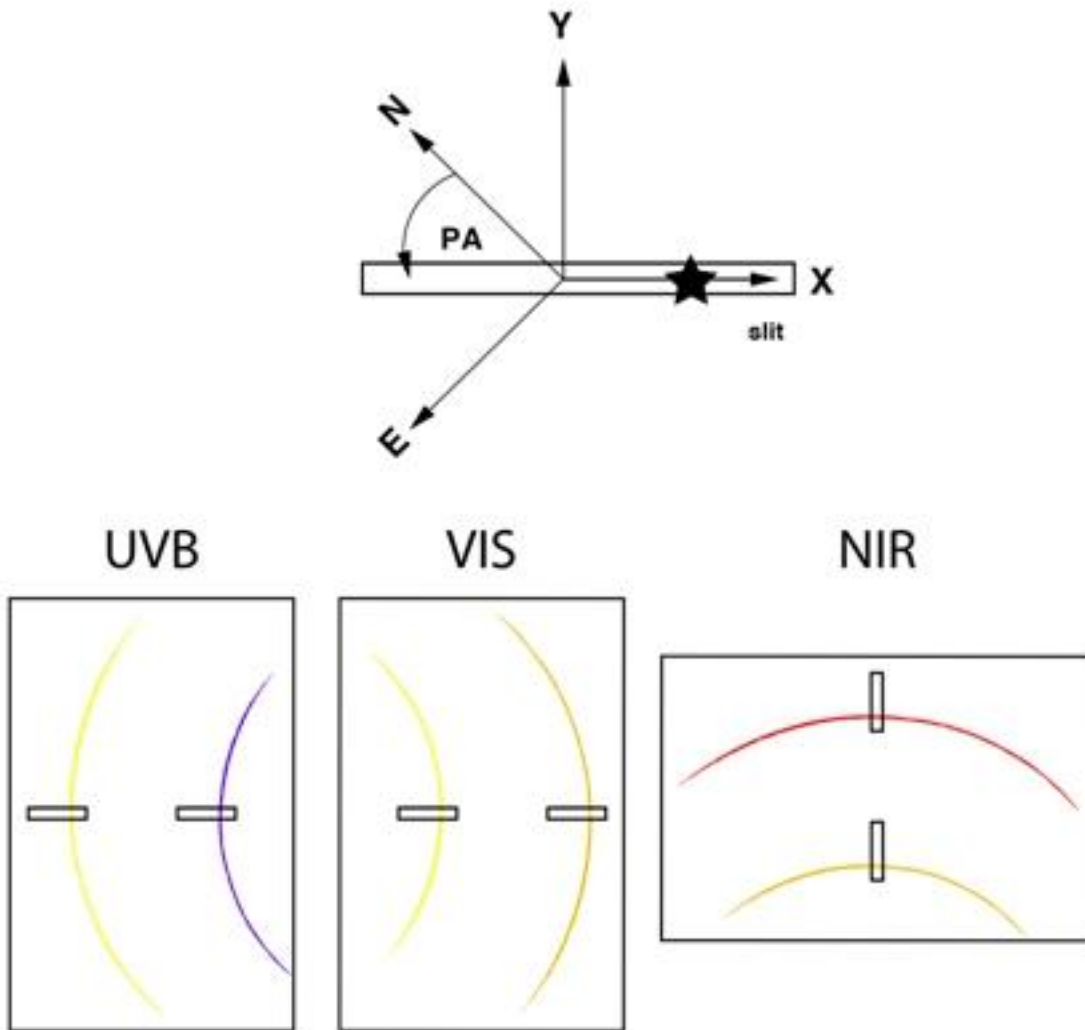


Figure 14: The slit coordinate system and correspondence between object position in the slit and position on the spectrum for each arm. An object at positive x (black star top panel) produces spectra placed as illustrated in the bottom panels. NOTE: a positive offset in the x or y direction will move the object in direction of +x and +y axis.



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5.1.2 Acquisition templates

Slit acquisition templates

Table 14: User defined and fixed keywords for XSHOOTER slit acq.

XSHOOTER_slit_acq			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
TEL.TARG.ALPHA		000000.000	Target RA
TEL.TARG.DELTA		000000.000	Target DEC
TEL.TARG.EQUINOX	-2000..3000	2000	Equinox
TEL.TARG.PMA	-10.0..10.0	0.0	RA proper motion ("/yr)
TEL.TARG.PMD	-10.0..10.0	0.0	DEC proper motion ("/yr)
TEL.TARG.EPOCH	1950, 2000	2000	Epoch
TEL.TARG.ADDVELALPHA		0.0	RA differential tracking velocity ("/s)
TEL.TARG.ADDVELDELTA		0.0	DEC differential tracking velocity ("/s)
TEL.TARG.OFFSETALPHA	-36000 .. 36000	0.0	RA blind offset ("
TEL.TARG.OFFSETDELTA	-36000 .. 36000	0.0	DEC blind offset ("
TEL.ROT.OFFANGLE	-179.99..179.99 9999.	9999.	Slit position angle on Sky 9999. for parallactic angle
INS.FILT1.NAME	u', g', r', i', z', U, B, V, R, I		A&G filter
DET4.WIN1.UIT1	0..36000		TCCD exposure time
TEL.AG.GUIDESTAR	CATALOGUE, SETUPFILE, NONE	CATALOGUE	Telescope guide star selection mode
TEL.GS1.ALPHA		0.0	Guide Star RA
TEL.GS1.DELTA		0.0	Guide Star DEC
<i>Fixed parameters</i>			
DET1.WIN1.UIT1		2	AFC UVB exposure time
DET2.WIN1.UIT1		0.5	AFC VIS exposure time
DET3.DIT		1	AFC NIR DIT
DET3.NDIT		1	number of AFC NIR DITs
SEQ.AFC.CORRECT	F, T	T	AFC correct flag
SEQ.AFC.WSIZE		64	Window size for AFC Cross Correlation
SEQ.AFC.MAXD		20	Maximum distance for AFC Cross Correlation
SEQ.PRESET	T, F	T	Preset flag
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument mode

Table 15: User defined and fixed keywords for XSHOOTER slit acq rmm.

XSHOOTER_slit_acq_rmm			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			



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SEQ.RRM.REGISTER	T, F	T	Register OB in RRM system
SEQ. RRM.VISITOR	T, F	T	Allow RRM activation in visitor mode
TEL.TARG.DELTA		000000.000	Target DEC
TEL.TARG.EQUINOX	-2000..3000	2000	Equinox
TEL.TARG.PMA	-10.0..10.0	0.0	RA proper motion ("/year)
TEL.TARG.PMD	-10.0..10.0	0.0	DEC proper motion ("/year)
TEL.TARG.EPOCH	1950, 2000	2000	Epoch
TEL.TARG.ADDVELALPHA		0.0	RA differential tracking velocity ("/s)
TEL.TARG.ADDVELDELTA		0.0	DEC differential tracking velocity ("/s)
TEL.TARG.OFFSETALPHA	-36000..36000	0.0	RA blind offset (")
TEL.TARG.OFFSETDELTA	-36000..36000	0.0	DEC blind offset (")
TEL.ROT.OFFANGLE	-179.99 ... 179.99, 9999.	9999.	Slit position angle on Sky 9999. for parallactic angle
INS.FILT1.NAME	u', g', r', i', z', U, B, V, R, I		A&G filter
DET4.WIN1.UIT1	0..36000		TCCD exposure time
TEL.AG.GUIDESTAR	CATALOGUE, SETUPFILE, NONE	CATALOGUE	Telescope guide star selection mode
TEL.GS1.ALPHA		0.0	Guide Star RA
TEL.GS1.DELTA		0.0	Guide Star DEC
<i>Fixed parameters</i>			
DET1.WIN1.UIT1		2	AFC UVB exposure time
DET2.WIN1.UIT1		0.5	AFC VIS exposure time
DET3.DIT		1	AFC NIR DIT
DET3.NDIT		1	number of AFC NIR DITs
SEQ.AFC.CORRECT	F, T	T	AFC correct flag
SEQ.AFC.WSIZE		64	Window size for AFC Cross Correlation
SEQ.AFC.MAXD		20	Maximum distance for AFC Cross Correlation
SEQ.PRESET	T, F	T	Preset flag
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument mode

IFU acquisition templates

Table 16: User defined and fixed parameters for XSHOOTER_ifu_acq.

XSHOOTER_ifu_acq			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
TEL.TARG.ALPHA		000000.000	Target RA
TEL.TARG.DELTA		000000.000	Target DEC
TEL.TARG.EQUINOX	-2000..3000	2000	Equinox
TEL.TARG.EPOCH	1950, 2000	2000	Epoch



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TEL.TARG.PMA	-10.0..10.0	0.0	RA proper motion ("/year)
TEL.TARG.PMD	-10.0..10.0	0.0	DEC proper motion ("/year)
TEL.TARG.ADDVELALPHA		0.0	Additional velocity RA in "/s
TEL.TARG.ADDVELDELTA		0.0	Additional velocity DEC in "/s
TEL.TARG.OFFSETALPHA		0.0	RA blind offset (")
TEL.TARG.OFFSETDELTA		0.0	DEC blind offset (")
TEL.ROT.OFFANGLE	-179.99..179.99, 9999.	9999.	IFU position angle on Sky 9999. for parallactic angle
INS.FILT1.NAME	u', g', r', i', z', U, B, V, R, I		A&G filter
DET4.WIN1.UIT1	0..36000		TCCD exposure time
SEQ.IFU.WLGT	300..2000	470	Wavelength for target centring and tracking
TEL.AG.GUIDESTAR	CATALOGUE, SETUPFILE, NONE	CATALOGUE	Telescope guide star selection mode
TEL.GS1.ALPHA		0.0	Guide Star RA
TEL.GS1.DELTA		0.0	Guide Star DEC
<i>Fixed parameters</i>			
DET1.WIN1.UIT1		2	AFC UVB exposure time
DET2.WIN1.UIT1		0.5	AFC VIS exposure time
DET3.DIT		1	AFC NIR DIT
DET3.NDIT		1	Number of AFC NIR DITs
SEQ.AFC.CORRECT	F, T	T	AFC correct flag
SEQ.AFC.MAXD		20	Maximum distance for AFC cross correlation
SEQ.AFC.WSIZE		64	Window size for AFC cross correlation
SEQ.PRESET	T, F	T	Preset flag
INS.MODE	SLITSPEC, IFUSPEC	IFUSPEC	Instrument mode

Table 17: User defined and fixed parameters for XSHOOTER_ifu_acq_rrm.

XSHOOTER_ifu_acq_rrm			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
SEQ.RRM.REGISTER	T, F	T	Register OB in RRM system
SEQ. RRM.VISITOR	T, F	T	Allow RRM activation in visitor mode
TEL.TARG.ALPHA		000000.000	Target RA
TEL.TARG.DELTA		000000.000	Target DEC
TEL.TARG.EQUINOX	-2000..3000	2000	Equinox
TEL.TARG.EPOCH	1950, 2000	2000	Epoch
TEL.TARG.PMA	-10.0..10.0	0.0	RA proper motion ("/year)



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TEL.TARG.PMD	-10.0..10.0	0.0	DEC proper motion (" /year)
TEL.TARG.ADDVELALPHA		0.0	Additional velocity RA in "/s
TEL.TARG.ADDVELDELTA		0.0	Additional velocity DEC in "/s
TEL.TARG.OFFSETALPHA		0.0	RA blind offset ("
TEL.TARG.OFFSETDELTA		0.0	DEC blind offset ("
TEL.ROT.OFFANGLE	-179.99..179.99, 9999.	9999.	IFU position angle on Sky 9999. for parallactic angle
INS.FILT1.NAME	u', g', r', i', z', U, B, V, R, I		A&G filter
DET4.WIN1.UIT1	0..36000		TCCD exposure time
SEQ.IFU.WLGT	300..2000	470	Wavelength for target centring and tracking
TEL.AG.GUIDESTAR	CATALOGUE, SETUPFILE, NONE	CATALOGUE	Telescope guide star selection mode
TEL.GS1.ALPHA		0.0	Guide Star RA
TEL.GS1.DELTA		0.0	Guide Star DEC
<i>Fixed parameters</i>			
DET1.WIN1.UIT1		2	AFC UVB exposure time
DET2.WIN1.UIT1		0.5	AFC VIS exposure time
DET3.DIT		1	AFC NIR DIT
DET3.NDIT		1	Number of AFC NIR sub-integrations (NDIT)
SEQ.AFC.CORRECT	F, T	T	AFC correct flag
SEQ.AFC.MAXD		20	Maximum distance for AFC cross correlation
SEQ.AFC.WSIZE		64	Window size for AFC cross correlation
SEQ.PRESET	T, F	T	Preset flag
INS.MODE	SLITSPEC, IFUSPEC	IFUSPEC	Instrument mode

5.1.3 Science templates

Slit observations

Table 18: Parameters for stare mode observations with the template XSHOOTER slt_obs Stare.

XSHOOTER slt_obs Stare			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	0.9x11	VIS slit
INS.OPTI5.NAME	see Table 8	0.9x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB Exposure Time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS Exposure Time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode



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DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXPO.UVB	0..100	1	UVB number of exposures
SEQ.NEXPO.VIS	0..100	1	VIS number of exposures
SEQ.NEXPO.NIR	0..100	1	NIR number of exposures
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument Mode

Table 19: Parameters for synchronized stare UVB, VIS and NIR observations with the template `XSHOOTER slt obs StareSynchro`.

XSHOOTER_slt_obs_StareSynchro			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	0.9x11	VIS slit
INS.OPTI5.NAME	see Table 8	0.9x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0.88..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..9999	1	number of DITs
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument Mode

Table 20: Parameters for the template `XSHOOTER_slt_obs_AutoNodOnSlit`. It allows to observe nodding along the slit.

XSHOOTER_slt_obs_AutoNodOnSlit			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	0.9x11	VIS slit
INS.OPTI5.NAME	see Table 8	0.9x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..9999	1	Number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures



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			per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposures per offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposures per offset position
SEQ.SKYTHROW	0..10	5	Nod Throw in “
SEQ.JITTER.WIDTH	0..2	0	Jitter box width in “
SEQ.NABCYCLES	0..100	1	Number AB or BA cycles
SEQ.OFFSET.ZERO	T, F	T	Return to Origin?
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument Mode

Table 21: Parameters for the template XSHOOTER_slit_obs_FixedSkyOffset. It allows to alternate object and sky observations.

XSHOOTER_slit_obs_FixedSkyOffset			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	0.9x11	VIS slit
INS.OPTI5.NAME	see Table 8	0.9x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB Exposure Time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB read-out mode
DET2.WIN1.UIT1	0..36000		VIS Exposure Time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS read-out mode
DET3.DIT	0.88..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposures per offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposures per offset position
SEQ.FIXOFF.RA	-100..100	1	RA fixed offset (“)
SEQ.FIXOFF.DEC	-100..100	1	DEC fixed offset (“)
SEQ.JITTER.WIDTH	0..2	0	Jitter box width in “
SEQ.NABCYCLES	0..100	1	Number OS or SO cycles
SEQ.OFFSET.ZERO	T, F	T	Return to Origin?
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument Mode



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Table 22: Parameters for the template XSHOOTER_slit_obs_GenericOffset. It allows to decide the sequence of offsets and object or sky observations.

XSHOOTER_slit_obs_GenericOffset			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	0.9x11	VIS slit
INS.OPTI5.NAME	see Table 8	0.9x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposures per offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposures per offset position
SEQ.OFFSET.COORDS	SKY,SLIT	SKY	Offset coordinate type (RA/DEC or X/Y) in “
SEQ.RELOFF1	-1000..1000	1	List of RA/X offsets (“)
SEQ.RELOFF2	-1000..1000	1	List of DEC/Y offsets (“)
SEQ.OBS.TYPE	O,S	O S	List of observation type (object or sky)
SEQ.NOFFSET	0..100	2	Number of offsets
SEQ.OFFSET.ZERO	T, F	T	Return to Origin
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument Mode

IFU observations

Table 23: User defined and fixed parameters for IFU observations in stare mode with the template XSHOOTER ifu_obs_Stare.

XSHOOTER_ifu_obs_Stare			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures
SEQ.NEXP.VIS	0..100	1	VIS number of exposures



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SEQ.NEXP.NIR	0..100	1	NIR number of exposures
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1x12.6	UVB slit
INS.OPTI4.NAME	see Table 7	1x12.6	VIS slit
INS.OPTI5.NAME	see Table 8	1x12.6	NIR slit

Table 24: User defined and fixed parameters for the template XSHOOTER_ifu_obs_StareSynchro to perform synchronized observations in stare mode.

XSHOOTER_slit_ifu_StareSynchro			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1x12.6	UVB Slit slide
INS.OPTI4.NAME	see Table 7	1x12.6	VIS Slit slide
INS.OPTI5.NAME	see Table 8	1x12.6	NIR Slit slide

Table 25: User defined and fixed parameters for the template XSHOOTER_ifu_obs_FixedSkyOffset. It allows to alternate object and sky observations taking the sky at fixed position.

XSHOOTER_slit_ifu_FixedSkyOffset			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposures per offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposures



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			per offset position
SEQ.FIXOFF.RA	-100..100	1	RA fixed offset (")
SEQ.FIXOFF.DEC	-100..100	1	DEC fixed offset (")
SEQ.JITTER.WIDTH	0..2	0	Jitter box width in "
SEQ.NABCYCLES	0..100	1	Number OS or SO cycles
SEQ.OFFSET.ZERO	T, F	T	Return to Origin?
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1x12.6	UVB slit
INS.OPTI4.NAME	see Table 7	1x12.6	VIS slit
INS.OPTI5.NAME	see Table 8	1x12.6	NIR slit

Table 26: User defined and fixed parameters for the template XSHOOTER_ifu_obs_GenericOffset. It allows any sequence of offsets and object or sky observations.

XSHOOTER_ifu_obs_GenericOffset			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposures per offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposures per offset position
SEQ.OFFSET.COORDS	SKY, SLIT	SKY	Offset coordinate type RA/DEC or X/Y
SEQ.RELOFF1	-1000..1000	1	List of RA/X offsets (")
SEQ.RELOFF2	-1000..1000	1	List of DEC/Y offsets (")
SEQ.OBS.TYPE	O,S	O S	List of observation type (object or sky)
SEQ.NOFFSET	0..100	2	Number of offsets
SEQ.OFFSET.ZERO	T, F	T	Return to Origin?
SEQ.AGSNAPSHOT	T,F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1x12.6	UVB Slit slide
INS.OPTI4.NAME	see Table 7	1x12.6	VIS Slit slide



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INS.OPTI5.NAME	see Table 8	1x12.6	NIR Slit slide
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5.1.4 Night-time Calibration Templates

Spectro-photometric Standard Stars

Table 27: User and fixed keywords for XSHOOTER_slit_cal_SpecphotStdStare. The template is identical to that for slit observation in stare mode except for some of the default parameters.

XSHOOTER_slit_cal_SpecphotStdStare			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	5.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	5.0x11	VIS slit
INS.OPTI5.NAME	see Table 8	5.0x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXPO.UVB	0..100	1	UVB number of exposures
SEQ.NEXPO.VIS	0..100	1	VIS number of exposures
SEQ.NEXPO.NIR	0..100	1	NIR number of exposures
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument Mode

Table 28: User defined and fixed parameters for XSHOOTER_slit_cal_SpecphotStdOffset. The template is identical to that for alternate object-sky slit observations except for some of the default parameters.

XSHOOTER_slit_cal_SpecphotStdOffset			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	5.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	5.0x11	VIS slit
INS.OPTI5.NAME	see Table 8	5.0x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposures per



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			offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposures per offset position
SEQ.FIXOFF.RA	-100..100	1	RA fixed offset (")
SEQ.FIXOFF.DEC	-100..100	1	DEC fixed offset (")
SEQ.JITTER.WIDTH	0..2	0	Jitter box width in "
SEQ.NABCYCLES	0..100	1	Number OS or SO cycles
SEQ.OFFSET.ZERO	T, F	T	Return to Origin?
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC, IFUSPEC	SLITSPEC	Instrument Mode

Table 29: User defined and fixed parameters for XSHOOTER_ifu_cal_SpecphotStdStare. The template is identical to that for the IFU observations in stare mode.

XSHOOTER_ifu_cal_SpecphotStdStare			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures
SEQ.NEXP.VIS	0..100	1	VIS number of exposures
SEQ.NEXP.NIR	0..100	1	NIR number of exposures
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC,IFUSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1x12.6	UVB slit
INS.OPTI4.NAME	see Table 7	1x12.6	VIS slit
INS.OPTI5.NAME	see Table 8	1x12.6	NIR slit

Table 30: User defined and fixed parameters for XSHOOTER_ifu_cal_SpecphotStdOffset. The template is identical to the XSHOOTER_ifu_obs_FixedSkyOffset

XSHOOTER_ifu_cal_SpecphotStdOffset			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB read-out mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)



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DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS read-out mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposures per offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposures per offset position
SEQ.FIXOFF.RA	-100..100	1	RA fixed offset (")
SEQ.FIXOFF.DEC	-100..100	1	DEC fixed offset (")
SEQ.JITTER.WIDTH	0..2	0	Jitter box width in "
SEQ.NABCYCLES	0..100	1	Number OS or SO cycles
SEQ.OFFSET.ZERO	T, F	T	Return to Origin?
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	SLITSPEC,IFUSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1x12.6	UVB slit
INS.OPTI4.NAME	see Table 7	1x12.6	VIS slit
INS.OPTI5.NAME	see Table 8	1x12.6	NIR slit

Telluric standards

Table 31: User and fixed keywords for XSHOOTER_slit_cal_TelluricStdStare. The template is identical to the XSHOOTER_slit_obs Stare one.

XSHOOTER_slit_cal_TelluricStdStare			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	0.9x11	VIS slit
INS.OPTI5.NAME	see Table 8	0.9x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXPO.UVB	0..100	1	UVB number of exposures
SEQ.NEXPO.VIS	0..100	1	VIS number of exposures
SEQ.NEXPO.NIR	0..100	1	NIR number of exposures
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?



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<i>Fixed Values</i>			
INS.MODE	IFUSPEC,SLITSPEC	SLITSPEC	Instrument Mode

Table 32: User defined and fixed parameters for SHOOT_slit_cal_TelluricStdNod. The template is identical to the XSHOOTER slit_obs_AutoNodOnSlit one.

XSHOOTER_slit_cal_TelluricStdNod			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	0.9x11	VIS slit
INS.OPTI5.NAME	see Table 8	0.9x11	NIR slit
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..9999	1	Number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposures per offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposures per offset position
SEQ.SKYTHROW	0..10	5	Nod Throw in “
SEQ.JITTER.WIDTH	0..2	0	Jitter box width in “
SEQ.NABCYCLES	0..100	1	Number AB or BA cycles
SEQ.OFFSET.ZERO	T, F	T	Return to Origin?
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	IFUSPEC,SLITSPEC	SLITSPEC	Instrument Mode

Table 33: User defined and fixed parameters for SHOOT_ifu_cal_TelluricStdStare. The template is identical to XSHOOTER ifu_obs_Stare.

XSHOOTER_ifu_cal_TelluricStdStare			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)



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DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures
SEQ.NEXP.VIS	0..100	1	VIS number of exposures
SEQ.NEXP.NIR	0..100	1	NIR number of exposures
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1x12.6	UVB slit
INS.OPTI4.NAME	see Table 7	1x12.6	VIS slit
INS.OPTI5.NAME	see Table 8	1x12.6	NIR slit

Table 34: User defined and fixed parameters for SHOOT_ifu_cal_TelluricStdOffset. The template is identical to XSHOOTER ifu_obs FixedSkyOffset.

XSHOOTER_ifu_cal_TelluricStdOffset			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB Exposure Time (s)
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB read-out mode
DET2.WIN1.UIT1	0..36000		VIS Exposure Time (s)
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS read-out mode
DET3.DIT	0..36000		NIR Detector Integration Time (s)
DET3.NDIT	1..20	1	number of DITs
SEQ.NEXP.UVB	0..100	1	UVB number of exposures per offset position
SEQ.NEXP.VIS	0..100	1	VIS number of exposure per offset position
SEQ.NEXP.NIR	0..100	1	NIR number of exposure per offset position
SEQ.FIXOFF.RA	-100..100	1	RA fixed offset (arcsec)
SEQ.FIXOFF.DEC	-100..100	1	DEC fixed offset (arcsec)
SEQ.JITTER.WIDTH	0..2	0	Jitter box width in arcsec
SEQ.NABCYCLES	0..100	1	Number OS or SO cycles
SEQ.OFFSET.ZERO	T, F	T	Return to Origin?
SEQ.AGSNAPSHOT	T, F	F	Take an acquisition image before science exposures?
<i>Fixed Values</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1x12.6	UVB slit
INS.OPTI4.NAME	see Table 7	1x12.6	VIS slit
INS.OPTI5.NAME	see Table 8	1x12.6	NIR slit



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Attached night calibrations

Table 35: Parameters for the template XSHOOTER_slt_cal_UVBVISArcsAtt.

XSHOOTER_slt_cal_UVBVisArcsAtt			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time
DET1.READ.CLKDESCR	see Table 5	400/1pt/lg	UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time
DET2.READ.CLKDESCR	see Table 5	400/1pt/lg	VIS readout mode
SEQ.NEXPO.UVB	0..100	1	No. of UVB exposures
SEQ.NEXPO.VIS	0..100	1	No. of VIS exposures
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	SLITSPEC	Instrument Mode

Table 36: Parameters for the template XSHOOTER_slt_cal_UVBLampFlatAtt.

XSHOOTER_slt_cal_UVBLampFlatAtt			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
DET1.WIN1.UIT1.HIGHF	0..36000		UVB exposure time (High Flat)
DET1.WIN1.UIT1.LOWF	0..36000		UVB exposure time (Low Flat)
DET2.READ.CLKDESCR	see Table 5		VIS readout mode
SEQ.NEXPO.HIGHF	0..100		No. of exposures (High Flat)
SEQ.NEXPO.LOWF	0..100		No. of exposures (Low Flat)
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	SLITSPEC	Instrument Mode

Table 37: Parameters for the template XSHOOTER_slt_cal_VISLampFlatAtt.

XSHOOTER_slt_cal_VISLampFlatAtt			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
DET2.WIN1.UIT1	0..36000		VIS exposure time
DET2.READ.CLKDESCR	see Table 5		VIS readout mode
SEQ.NEXPO	0..100		No. of exposures
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	SLITSPEC	Instrument Mode

Table 38: Parameters for the template XSHOOTER_slt_cal_VISLampFlatAtt.

XSHOOTER_slt_cal_NIRLampFlatAtt			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
DET3.DIT	0..36000		NIR exposure time (DIT)
DET3.NDIT	0..20		No. of NIR sub-integrations
SEQ.NEXPO	0..100		No. of exposures



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<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	SLITSPEC	Instrument Mode

Table 39: Parameters for the template XSHOOTER ifu cal UVBVisArcsAtt.

XSHOOTER ifu cal UVBVisArcsAtt			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
DET1.WIN1.UIT1	0..36000		UVB exposure time
DET1.READ.CLKDESCR	see Table 5		UVB readout mode
DET2.WIN1.UIT1	0..36000		VIS exposure time
DET2.READ.CLKDESCR	see Table 5		VIS readout mode
SEQ.NEXPO.UVB	0..100	1	No. of UVB exposures
SEQ.NEXPO.VIS	0..100	1	No. of VIS exposures
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode

Table 40: Parameters for the template XSHOOTER ifu cal UVBLampFlatAtt.

XSHOOTER ifu cal UVBLampFlatAtt			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
DET1.WIN1.UIT1.HIGHF	0..36000		UVB exposure time (High Flat)
DET1.WIN1.UIT1.LOWF	0..36000		UVB exposure time (Low Flat)
DET2.READ.CLKDESCR	see Table 5		VIS readout mode
SEQ.NEXPO.HIGHF	0..100		No. of exposures (High Flat)
SEQ.NEXPO.LOWF	0..100		No. of exposures (Low Flat)
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode

Table 41: Parameters for the template XSHOOTER ifu cal VISLampFlatAtt.

XSHOOTER ifu cal VISLampFlatAtt			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
DET2.WIN1.UIT1	0..36000		VIS exposure time
DET2.READ.CLKDESCR	see Table 5		VIS readout mode
SEQ.NEXPO	0..100		No. of exposures
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode

Table 42: Parameters for the template XSHOOTER ifu cal NIRLampFlatAtt.

XSHOOTER ifu cal NIRLampFlatAtt			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
DET3.DIT	0..36000	60	NIR exposure time (DIT)
DET3.NDIT	0..20	1	No. of NIR sub-



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			integrations
SEQ.NEXPO	0..100		No. of exposures
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode

5.1.5 Daytime Calibration templates

Slit and IFU arc lamp calibrations

Table 43: User and fixed keywords for XSHOOTER slit cal UVBVisArcs.

XSHOOTER_slit_cal_UVBVisArcs			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
<i>Free Parameters</i>			
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
INS.OPTI4.NAME	see Table 7	0.9x11	VIS slit
DET1.WIN1.UIT1	0..36000	30	UVB exposure time
DET1.READ.CLKDESCR	see Table 5	400/1pt/lg	UVB readout mode
DET2.WIN1.UIT1	0..36000	5	VIS exposure time
DET2.READ.CLKDESCR	see Table 5	400/1pt/lg	VIS readout mode
SEQ.NEXPO.UVB	0..100	1	No. of UVB exposures
SEQ.NEXPO.VIS	0..100	1	No. of VIS exposures
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode

Table 44: User and fixed keywords for XSHOOTER slit cal NIRArcs.

XSHOOTER_slit_cal_NIRArcs			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
INS.OPTI5.NAME	see Table 8	0.9x11	NIR Slit slide
DET3.DIT	0..36000	0.66	NIR Exposure Time
DET3.NDIT	1..20	1	Number of DITs
SEQ.NEXPO	0..100	1	No. of NIR exposures
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode

Table 45: User and fixed keywords for XSHOOTER ifu cal UVBVisArcs

XSHOOTER_ifu_cal_UVBVisArcs			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET1.WIN1.UIT1	0..36000	45	UVB Exposure Time
DET1.READ.CLKDESCR	see Table 5	400k/1pt/lg	UVB readout mode
DET2.WIN1.UIT1	0..36000	4	VIS Exposure Time
DET2.READ.CLKDESCR	see Table 5	400k/1pt/lg	VIS readout mode
SEQ.NEXPO.UVB	0..100	1	No. of UVB exposures
SEQ.NEXPO.VIS	0..100	1	No. of VIS exposures
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1.0x12.6	UVB slit



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INS.OPTI4.NAME	see Table 7	1.0x12.6	VIS slit
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Table 46: User and fixed keywords for XSHOOTER slit cal NIRArcs.

XSHOOTER_ifu_cal_NIRArcs			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET3.DIT	0..36000	1.32	NIR Exposure Time
DET3.NDIT	1..20	1	Number of DITs
SEQ.NEXPO	0..100	1	No. of NIR exposures
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode
INS.OPTI5.NAME	see Table 8	1.0x12.6	NIR slit

Flatfield

Table 47: User and fixed keywords for XSHOOTER slit cal UVBLampFlat

XSHOOTER_slit_cal_UVBLampFlat			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
INS.OPTI3.NAME	see Table 4	1.0x11	UVB slit
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET1.WIN1.UIT1.HIGHF	0..36000	7.4	Halogen lamp exposure time
DET1.WIN1.UIT1.LOWF	0..36000	2.8	D ₂ lamp exposure time
SEQ.NEXPO.HIGHF	0..100	5	Number of Halogen lamp exp
SEQ.NEXPO.LOWF	0..100	5	Number of D ₂ lamp exp.
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode

Table 48: User and fixed keywords for XSHOOTER slit cal VISLampFlat

XSHOOTER_slit_cal_VISLampFlat			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
INS.OPTI4.NAME	see Table 4	0.9x11	VIS slit
DET2.WIN1.UIT1	0..36000	8	VIS Exposure Time
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
SEQ.NEXPO	0..100	5	VIS # of exposure
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode

Table 49: User and fixed keywords for XSHOOTER slit cal NIRLampFlat.

XSHOOTER_slit_cal_NIRLampFlat			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
INS.OPTI5.NAME	see Table 8	0.9x11	NIR slit
DET3.DIT	0..36000	40	NIR exposure time



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DET3.NDIT	1..20	1	Number of DITs
SEQ.NEXPO	0..100	5	NIR No. of exposure
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode

Table 50: User and fixed keywords for XSHOOTER ifu cal UBVLampFlat

XSHOOTER_ifu_cal_UBVLampFlat			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB readout mode
DET1.WIN1.UIT1.HIGHF	0..36000	12.3	Halo. lamp exposure time
DET1.WIN1.UIT1.LOWF	0..36000	4.7	D ₂ lamp exposure time
SEQ.NEXPO.HIGHF	0..100	5	Number of Halo. lamp exp
SEQ.NEXPO.LOWF	0..100	5	Number of D ₂ lamp exp.
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	1.0x12.6	UVB slit

Table 51: User and fixed keywords for XSHOOTER ifu cal VISLampFlat

XSHOOTER_ifu_cal_VISLampFlat			
<i>Free Paramters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET2.WIN1.UIT1	0..36000	12.2	VIS Exposure Time
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS readout mode
SEQ.NEXPO	0..100	5	VIS No. of exposure
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode
INS.OPTI4.NAME	see Table 7	1.0x12.6	VIS slit

Table 52: User and fixed keywords for XSHOOTER ifu cal NIRLampFlat.

XSHOOTER_ifu_cal_NIRLampFlat			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET3.DIT	0..36000	60	NIR exposure time
DET3.NDIT	1..20	1	Number of DITs
SEQ.NEXPO	0..100	5	NIR No. of exposures
<i>Fixed Value</i>			
INS.MODE	IFUSPEC,SLITSPEC	IFUSPEC	Instrument Mode
INS.OPTI5.NAME	see Table 8	1.0x12.6	NIR slit



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Format check

Table 53: User and fixed keywords for XSHOOTER_slit_cal_UVBVisArcsSinglePinhole

XSHOOTER_slit_cal_UVBVisArcsSinglePinhole			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET1.WIN1.UIT1	0..36000	40	UVB Exposure Time
DET1.READ.CLKDESCR	see Table 5	400k/1pt/lg	UVB readout mode
DET2.WIN1.UIT1	0..36000	15	VIS Exposure Time
DET2.READ.CLKDESCR	see Table 5	400k/1pt/lg	VIS readout mode
SEQ.NEXPO.UVB	0..100	1	No. of UVB exposures
SEQ.NEXPO.VIS	0..100	1	No. of VIS exposures
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	Pin_0.5	UVB slit
INS.OPTI4.NAME	see Table 7	Pin_0.5	VIS slit

Table 54: User and fixed keywords for XSHOOTER_slit_cal_NIRArcsSinglePinhole.

XSHOOTER_slit_cal_NIRArcsSinglePinhole			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET3.DIT	0..36000	10	NIR Exposure Time
DET3.NDIT	1..20	5	Number of DITs
SEQ.NEXPO	0..100	1	NIR # of exposure
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode
INS.OPTI5.NAME	see Table 8	Pin_0.5	NIR slit

Order definition

Table 55: User and fixed keywords for XSHOOTER_slit_cal_UVBLampFlatSinglePinhole

XSHOOTER_slit_cal_UVBLampFlatSinglePinhole			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET1.WIN1.UIT1.HIGHF	0..36000	30	UVB exposure time (High Flat)
DET1.WIN1.UIT1.LOWF	0..36000	20	UVB exposure time (Low Flat)
DET1.READ.CLKDESCR	see Table 5	400k/1pt/lg	UVB readout mode
SEQ.NEXPO.HIGHF	0..30	1	No. of exposures (High Flat)
SEQ.NEXPO.LOWF	0..30	1	No. of exposures (Low Flat)
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 8	Pin_0.5	UVB Slit slide

Table 56: User and fixed keywords for XSHOOTER_slit_cal_VISLampFlatSinglePinhole.



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XSHOOTER_slit_cal_VISLampFlatSinglePinhole			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET2.WIN1.UIT1	0..36000	60	VIS exposure time
DET2.READ.CLKDESCR	see Table 5	400k/1pt/lg	VIS readout mode
SEQ.NEXPO	0..100	1	No. of exposures
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode
INS.OPTI4.NAME	see Table 7	Pin_0.5	VIS slit

Table 57: User and fixed keywords for XSHOOTER_slit_cal_NIRLampFlatSinglePinhole

XSHOOTER_slit_cal_NIRLampFlatSinglePinhole.			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET3.DIT	0..36000	1	NIR exposure time
DET3.NDIT	1..20	1	Number of DITs
SEQ.NEXPO	0..100	1	NIR No. of exposures
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode
INS.OPTI5.NAME	see Table 8	Pin_0.5	NIR Slit slide

Arcs multi-pinhole: wave maps

Table 58: User and fixed keywords for XSHOOTER_slit_cal_UVBVisArcsMultiplePinhole.

XSHOOTER_slit_cal_UVBVisArcsMultiplePinhole			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET1.WIN1.UIT1	0..36000	15	UVB exposure time
DET1.READ.CLKDESCR	see Table 5	400k/1pt/lg	UVB readout mode
DET2.WIN1.UIT1	0..36000	10	VIS exposure time
DET2.READ.CLKDESCR	see Table 5	400k/1pt/lg	VIS readout mode
SEQ.NEXPO.UVB	0..100	1	UVB No. of exposure
SEQ.NEXPO.VIS	0..100	1	VIS No. of exposure
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode
INS.OPTI3.NAME	see Table 4	Pin_row	UVB Slit slide
INS.OPTI4.NAME	see Table 7	Pin_row	VIS Slit slide

Table 59: User and fixed keywords for XSHOOTER_slit_cal_NIRArcsMultiplePinhole.

XSHOOTER_slit_cal_NIRArcsMultiplePinhole			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET3.DIT	0..36000	5	NIR exposure time
DET3.NDIT	1..20	10	Number of DITs
SEQ.NEXPO	0..100	1	NIR No. of exposures
<i>Fixed Value</i>			
INS.MODE	SLITSPEC,IFUSPEC	SLITSPEC	Instrument Mode
INS.OPTI5.NAME	see Table 8	Pin_row	NIR Slit wheel



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Detector calibrations

Table 60: User and fixed keywords for XSHOOTER gen cal Bias

XSHOOTER_gen_cal_Bias			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB read-out mode
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS read-out mode
SEQ.NEXPO.UVB	0..100	1	UVB No. of exposures
SEQ.NEXPO.VIS	0..100	1	VIS No. of exposure
<i>Fixed Value</i>			
DET1.WIN1.UIT1		0	UVB exposure time
DET2.WIN1.UIT1		0	VIS exposure time

Table 61: User and fixed keywords for XSHOOTER gen cal DarkUVBVis

XSHOOTER_gen_cal_DarkUVBVis			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET1.WIN1.UIT1	0..36000	3600	UVB Exposure Time
DET1.READ.CLKDESCR	see Table 5	100k/1pt/hg	UVB read-out mode
DET2.WIN1.UIT1	0..36000	3600	VIS Exposure Time
DET2.READ.CLKDESCR	see Table 5	100k/1pt/hg	VIS read-out mode
SEQ.NEXPO.UVB	0..100	1	UVB No. of exposures
SEQ.NEXPO.VIS	0..100	1	VIS No. of exposures
<i>Fixed Value</i>			

Table 62: User and fixed keywords for XSHOOTER gen cal DarkNIR

XSHOOTER_gen_cal_DarkNIR			
<i>Free Parameters</i>			
<i>Keyword</i>	<i>Range</i>	<i>Default Value</i>	<i>Label in P2PP</i>
DET3.DIT	0..36000		NIR Exposure Time
DET3.NDIT	1..20	1	Number of DITs
SEQ.NEXPO	0..100	3	No. of NIR exposures
<i>Fixed Value</i>			



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5.2 Slit masks

5.2.1 UVB

Table 63: full description of the UVB slit mask

Position	Size	Physcal size (μm)	Purpose
1	0.5" \varnothing pinhole	126 \varnothing hole	CAL
2	5"×11" slit	1256 × 2763	CAL
3	1.6"×11" slit	402 × 2763	SCI / CAL
4	1.3"×11" slit	327 × 2763	SCI / CAL
5	0.8"×11" slit	201 × 2763	SCI / CAL
6	1"×12.6" slit	251 × 3165	With IFU only
7	Raw of 9 pinholes of 0.5" \varnothing spaced at 1.4"	126 \varnothing holes spaced by 352	CAL
8	0.5"×11" slit	126 × 2763	SCI / CAL
9	1.0"×11" slit	251 × 2763	SCI / CAL

5.2.2 VIS

Table 64: full description of the VIS slit mask

Position	Size	Physcal size (μm)	Purpose
1	0.5" \varnothing pinhole	131 \varnothing hole	CAL
2	5"×11" slit	1307 × 2875	CAL
3	1.5"×11" slit	392 × 2875	SCI / CAL
4	1.2"×11" slit	314 × 2875	SCI / CAL
5	0.7"×11" slit	183 × 2875	SCI / CAL
6	1.0"×12.6" slit	261 × 3294	With IFU only
7	Raw of 9 pinholes of 0.5" \varnothing spaced at 1.4"	131 \varnothing holes spaced by 352	CAL
8	0.4"×11" slit	105 × 2875	SCI / CAL
9	0.9"×11" slit	235 × 2875	SCI / CAL

5.2.3 NIR

Table 65: full description of the NIR slit mask

Position	Size	Physcal size (μm)	Purpose
1	0.5" \varnothing pinhole	270 \varnothing hole	CAL
2	5"×11" slit	2695×5683	CAL
3	0.9"×11" slit	485×5683	SCI / CAL
4	1.0"×12.6" slit	544×6510	With IFU only
5	1.2"×11" slit	647×5683	SCI / CAL
6	tilted slit		TECH (focus)
7	1.5"×11" slit	809×5683	SCI/CAL
8	Blind		
9	0.4" \varnothing pinhole	216 \varnothing hole	TECH
10	0.4"×11" slit	216×5683	SCI/CAL



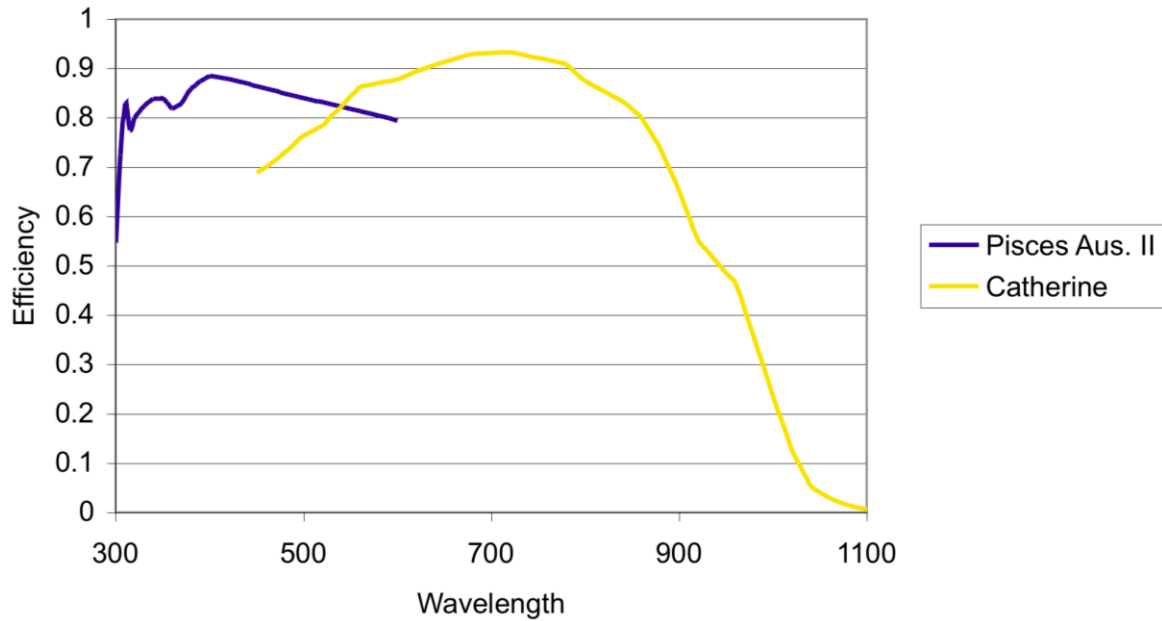
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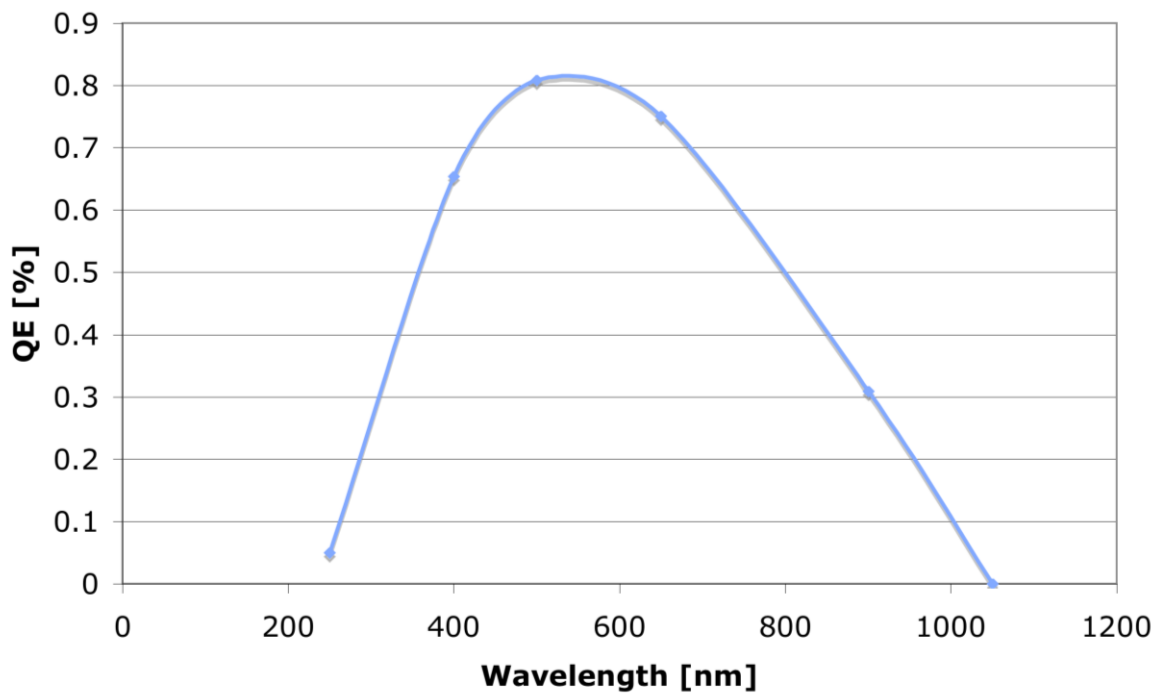
11	Raw of 9 pinholes of 0.5" ∅ spaced at 1.4"	270 ∅ holes spaced by 723	CAL
12	0.6"×11" slit	323×5683	SCI/CAL

5.3 Detector QE curves

UVB-VIS Detectors



A&G Camera CCD

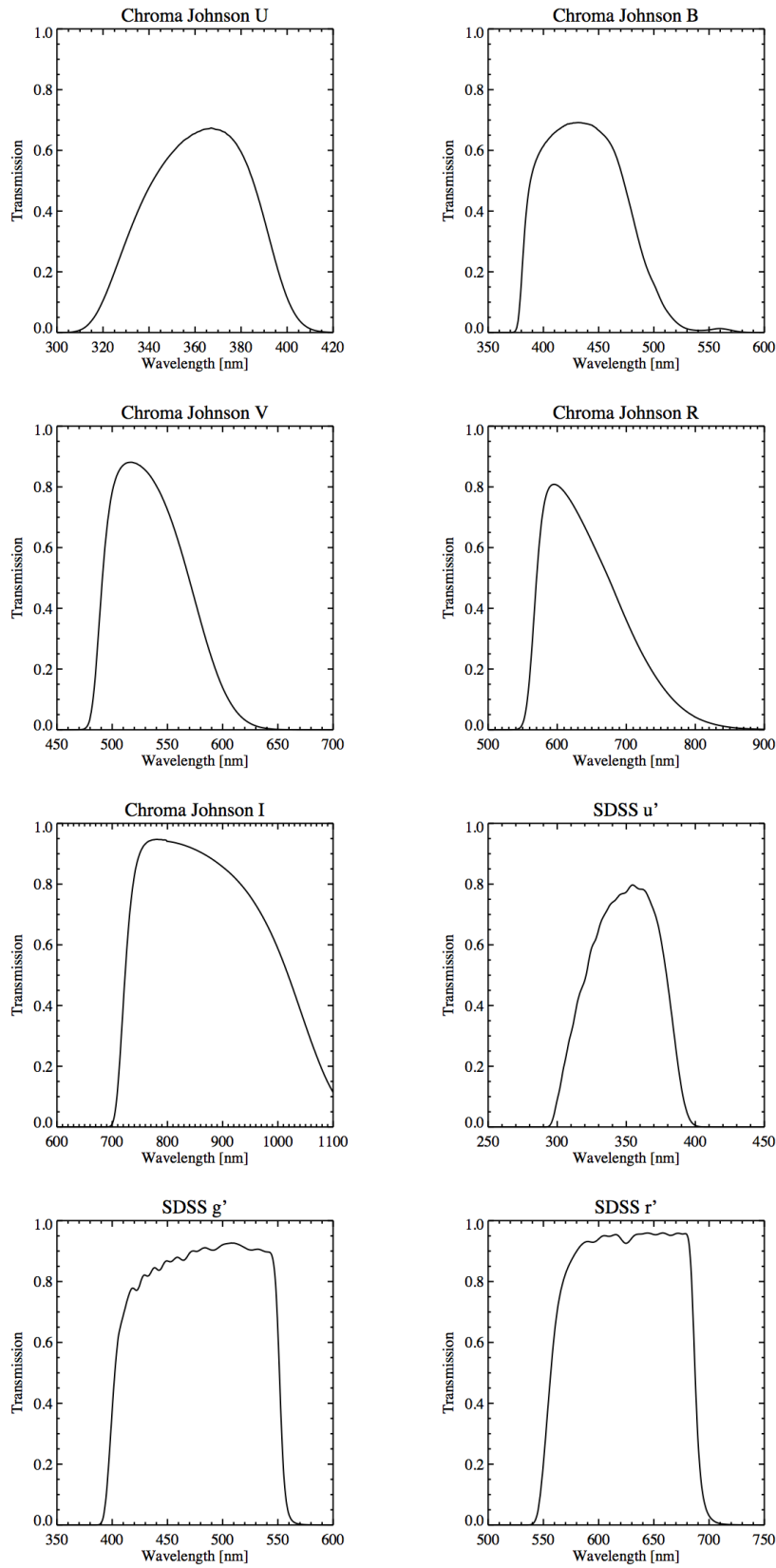




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5.4 A&G camera filter curves





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