SPHERE

Observation modes and sequences

Man-PA	Sci	Syst	CP	IRD	IFS	ZIM
	x					

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2				**03/11/08**	FDR **issue**
		2 4			Added IFS-H
		3.3			Re-visited QLA ; SQLA not a deliverable
		3.4 13.1			Precision concerning a new coronagraph selection
		4.2.4.1			IRDIS detector read-out time, file production time
		6.2			Precisions on DPI sequence
		13.2			IFS FF only during telescope preset (not AO acq)
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		13.6.1			Added off-axis image
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1. GENERAL ASPECTS

1.1 Scope of the document

This document presents a list of SPHERE observation modes, and corresponding observation sequences. It can be used as a common reference by the groups working on the astronomical use of SPHERE (science group), on the instrument control definition (INS), and on the instrument data flow (DRH).

1.2 Applicable Documents

No.	document name	document number, Iss./Rev.
AD 1	SPHERE Top Level Requirements	VLT-SPE-SPH-14690-0082
AD 2	SPHERE Technical Specifications	VLT-SPE-ESO-14690-0083

1.3 Reference Documents

No.	document name	document number, Iss./Rev.
RD 2	SPHERE Modes and Devices definition tables	VLT-LIS-SPH-14690-0148, issue 2
RD 3	SPHERE Instrumentation Software User Requirements Specification	VLT-SPE-SPH-14690-0092, issue 2
RD 4	SPHERE Instrumentation Software Functional Specifications	VLT-SPE-SPH-14690-0194, issue 2
RD 5	SPHERE Data Flow System Impact	VLT-TRE-SPH-14690-0241
RD 6	SPHERE Data Reduction Library Specification	
RD 7	SPHERE Exposure Time Calculator Specifications	VLT-SPE-SPH-14690-0247
RD 8	SPHERE Operation Plan	VLT-PLA-SPH-14690-0236
RD 10	CPI Calibration plan	VLT-PLA-SPH-14690-0223
RD 11	IFS Calibration plan	VLT-PLA-SPH-14690-0200
RD 12	IRDIS Calibration plan	VLT-PLA-SPH-14690-0197
RD 13	ZIMPOL Calibration plan	VLT-PLA-SPH-14690-0227

1.4 Acronyms

ADC	Atmospheric Dispersion Compensator
AO	Adaptive Optics
BB	Broad Band
CI	Classical Imaging
CP	Common Path
CPI	Common Path and Infrastructure
ETC	Exposure Time Calculator
DBI	Dual Band Imaging
DCS	Detector Control Software
DPI	Dual Polarization Imaging
DIT	Detector Integration Time
DM	Deformable Mirror

DRH	Data Reduction and Handling
DTTP	Differential Tip-Tilt Plate
DTTS	Differential Tip-Tilt Sensor
FDR	Final Design Review
FLC	Ferro-electric Liquid Crystal
FoV	Field of View
HW	HardWare
HWP	Half-Wave Plate
IFS	Integral Field Spectrograph
INS	Instrument Software
IRDIS	Infra-red Differential Imaging and Spectrometer
LRS	Low Resolution Spectroscopy
LSS	Long Slit Spectroscopy
MB	Mega bytes
MRS	Medium Resolution Spectroscopy
NB	Narrow Band
NCPA	Non-Common Path Aberrations
ND	Neutral Density
OB	Observation Block
OS	Observing Software
PA	Position Angle
PSF	Point Spread Function
PTTM	Pupil Tip-tilt Mirror
QLA	Quick-Look Analysis
RTC	Real-Time Computer
RTD	Real-Time Display
SAXO	Sphere extreme Adaptive Optics
SPHERE	Spectro-Polarimetric High contrast Exoplanet REsearch
Tbd	to be defined
Tbc	to be confirmed
TTM	Tip-Tilt Mirror
VLT	Very Large Telescope
WFS	WaveFront Sensor
ZIMPOL	Zurich IMaging POLarimeter

1.5 Overview

Section 2 presents the list of SPHERE observation modes.

Section 3 provides general information about data to be archived (Section 3.2) and about the information available during the observation to control the observation quality (Section 3.3). To go into more details than this overview, the actual corresponding requirements and the foreseen way to satisfy them are described in INS and DRH documents [RD 3,4,5,6].

Sections 4 to 12 present for each observation mode:

- The corresponding instrument set-up, and in particular the user-defined parameters. (this information is presented in a exhaustive and systematic way in the “Modes and Devices” table [RD 2])
- The sequence and a summary of required calibrations (as from sub-systems calibration plans [RD 10-13]
- The summary of corresponding overheads
- The overview of produced data.

Section 13 describes specifically the sequences involved for target acquisition.

2. LIST OF OBSERVING MODES

Table 1 Summary list of SPHERE observation modes

Mode	Sub-mode	Description			Science case
		Module/Spectral range	*De-rotator*	*Set-up/options*	
IRDIFS	**NIR SUR**	Simultaneous IFS (Y-J) + IRDIS/DBI (in H)	pupil stab.	Dedicated corono	Large survey for exoplanet detection in NIR for hundreds of targets (baseline set-up)
	NIR OBS		Pupil or field stab	any/no corono	specific characterization with both IFS and IRDIS
	IFS-H	Simultaneous IFS (Y-H) + degraded IRDIS/DBI (in K)	Pupil or field stab	any/no corono	Specific characterization using IFS up to H band
IRDIS alone	**DBI**	Dual Band Imaging (any filter pair: Y to Ks)	Pupil or field stab.	Any/no corono	Characterization of companions in outer field, IFS detection confirmation
	DPI	Dual Polarization Imaging (any BB/NB filter: Y to Ks)	field (pseudo) stab or fixed.	Any/no corono CP HWP in	Polarized circumstellar source like disks
	LSS	Long slit spectroscopy	Field stab.	Low OR medium resolution	Characterization of known companions
	CI	Classical imaging (any BB/NB filter: Y to Ks)	Pupil or field stab.		General use NIR HAR imaging
ZIMPOL alone	**P1**	high precision polarimetry mode without de-rotation (any BB/NB filter)	De-rotator fixed	Any/no corono CP HWPs in	Highest (absolute) precision polarimetry mode
	P2	Polarimetry mode with de-rotation (any BB/NB filter)	Field stab.	Any/no corono CP HWPs in	High precision polarimetry suited for fainter targets
	P3	Polarimetry mode with de-rotator close to P1 position (any BB/NB filter)	“pseudo” field-stab.	Any/no corono CP HWPs in	High precision polarimetry with reduced de-rotator polar and cross-talk
	I	Imaging (any BB/NB filter)	Field stab or de-rotator fixed	Same or distinct filters on 2 arms Any/no corono CP HWPs out, fast modulator off	High angular imaging, diff. NB imaging

This section summarizes a high level description of supported SPHERE observation modes. This list can be used in other documents. This list of main observing modes is defined according to the main science purposes (astrophysical context), to the main instrumental configuration used, and the main operation sequences and calibration procedures involved.

These observing modes are defined in the following sections, including:

- Specific set-up properties, list of user-defined parameters
- Sequences
- Produced data, including, QLA, pipelines procedures and quality control parameters

3. GENERAL INFORMATION

We present here general information, valid to all observing modes.

3.1 Instrumental set-up description

Exhaustive HW set-up as a function of observing mode is described in the dedicated excel table [RD2]. For presentation reason and for version control reason, it is not duplicated here. For each observing mode, a sub-section on “set-up” is then not intended to be exhaustive but rather: i/ to highlight important set-up specificities and ii/ to point out the user-defined parameters.

3.2 Data to be archived

Generally speaking the following data is to be archived during normal observations. More details are presented in [RD5]. Specificities, if any, are detailed in the corresponding observing mode description.

- IRDIS data: IRDIS detector frame data consists of 2 quadrants of the 2k detector, ie 2k x 1k x 4bytes = 8 MB.
- IFS data: IFS detector frame data consists of a full 2k detector, ie 2k x 2k x 4bytes = 16 MB
- ZIMPOL data: ZIMPOL includes 2 detectors. And each detector frame data consists of a 2k x 2k detector read-out in 2x2 pixel binning mode, ie 1k x 1k x 2 bytes = 2MB array.

The general case is that each produced science detector frame (every DIT) is archived and can be used individually in data reduction and analysis recipes: they are not summed up or averaged before archiving because statistical information and/or field rotation between 2 successive DITs can be significant and important to use in data analysis.

- AO data: during an observation, the data related to AO servo loop should also be archived and retrievable for data reduction and analysis purposes (see [RD 3]):
  - List of scalars representative of statistics of AO correction: every ~30 s.
  - If NIR observations: Time-average DTTS image every 30s: 100x100x4bytes
  - Snapshot of AO data (coming from WFS and DTTS) every ~1s: slopes (2480+2)x4bytes, voltages (1377+2)*4bytes, intensities (1240+1)*2bytes

The exact way to organize this data content into files (number and frequency of produced files) is presented in [RD 4].

3.3 Quick-look analysis

In a general manner, we identify the need for the following classes of information for the user observing with SPHERE:

1. some quality criteria to assess the quality of data that are being produced (Section 3.3.1 and 3.3.2). This information can be used in the acquisition produced for fine adjustment or acquisition validation ; it is also useful during all the time of the observation. These criteria are to be produced on-the-fly, and displayed as plots of the corresponding values as a function of time
2. general image display (like usual RTD functionality): section 3.3.3
3. preliminary data analysis obtained during the night, shortly after a given OB is completed (section 3.3.4). Even if not the final data reduction and analysis, such results are important

so as to estimate the quality and interest of observation performed and thus to optimize long term observation surveys. Such analysis can be made in a pipeline mode, with recipes using file header information (concerning the set-up used, templates in which the data were produced etc…) [RD 6]. In this sense, this step is not really "quick-look" analysis: it is NOT performed by INS on-the-fly.

Note that, at the time of this document writing (Oct. 08), the following description is to be considered as a wish list. The consortium is ready to provide for such a functionality (by combining the use of the regular data reduction pipeline + a dedicated back-end translating the pipeline regular outputs into appropriate image/profiles to be displayed) BUT this functionality is currently not considered as a deliverable. This part, in italic, is presented here for information, and not for review.

3.3.1 Quality criteria for NIR sub-systems

Table 2 Quality criteria available on-line, during NIR observations

Quality criteria after each DIT: immediate reaction by operator required			
Procedure	**Reason**	**IRDIS**	
Detector flux check (in detector flux units)	Are we working in relevant linearity domain of detector ? variability monitoring of corono extinction	Min/Max/total of predefined detector areas centered on coronagraph	
Source centering on coronagraph (mandatory for good observations)	Problems in DTTS loop, or ADC residuals – chromatism…	Estimator based on pre-defined detector areas centered on coronagraph	

3.3.2 Quality criteria for ZIMPOL

Same as NIR (detector flux check and centering check) +

- noise level analysis on sub-frame (e.g. 20x20 pixels) at user-defined position
    - Add-up sub-frame of a serie
    - Noise in polarization signal of single sub-frame (sigma, <I>)
    - Noise in polarization signal for summed sub-frame (sigma)

3.3.3 General image display for NIR sub-systems and ZIMPOL

- General image display is expected to be similar to usual VLT RTD.
- \+ for IFS, specific processing and display is foreseen to extract monochromatic images and profiles

General detector image display			
Procedure	**Reason**	**IRDIS**	**IFS**

On-the fly detector image display functionalities - Zoom - Color scale (linear, log, min-max …) - Fixed pattern save / fixed pattern subtraction - Pixel values - Statistics on a user-defined detector area - Extracted plot	Reveals more subtle instrumental problems; detect unexpected problems with the source; detect relatively bright companions on the spot	Both active quadrants displayed on a RTD (2k x 1k)	Detector images (2k x 2k) On a few field (monochromatic) images, extracted over tabulated detector areas, on-off band images, profiles.

3.3.4 Short term pipeline (preliminary analysis) for NIR sub-systems

**** This content of this section is currently not considered as a deliverable. It is presented here only for information, not for review ****

As introduced in section 3.3, the following list is considered as valuable information for the on-line astronomer (on-site, shortly after the OB are completed) to know about the obtained SNR on the data, the stellar environment of the target, even if not optimal for deep companion detection.

The wished available data content is presented in the following tables, as a function of the observing mode. The data format is:

- *I for image*
- *P for profile*
- *S for spectrum*

3.3.4.1 IRDIS

Produced data	***format***	***Processing***	***IRDIS modes***
"deep image": Time-averaged cosmetic-corrected images	***I***	*Cosmetic correction (dark, FF, badpix)* *Frame combination including: dithering, field de-rotation, average, filter/polar swap*	*DBI, DPI, CI*
PSF wing profile	***P***	*Profile extraction from previous image*	*DBI, DPI, CI*
Image – average profile	***I***	*As above + subtraction of the average profile*	*DBI, DPI, CI*
Difference of the 2 quadrants	***I***	*Difference of the 2 quadrants (deep images) after appropriate centering, spatial scaling and*	*DBI, DPI*

		flux scaling)	
Filtered difference of the 2 quadrants	***I***	*As above + filtering out azimuthally extended patterns*	*DBI, DPI*
Estimator for contrast performance	***P***	*5 x Rms of the previous image, as a function of separation*	*DBI, DPI*
Rough "candidate finder"	***I***	*Previous image with threshold at N-sigma.*	*DBI, DPI*

3.3.4.2 IFS

Produced data	***format***	***Processing***
"monochromatic deep image": Time-averaged cosmetic-corrected images	***I***	*As IRDIS:* *Cosmetic correction (dark, FF, badpix)* *Frame combination including: dithering, field de-rotation, average, filter/polar swap* *Plus:* *Use of default lambdas or interactive lambda selection* *Extraction of monochromatic images*
"polychromatic deep image"	***I***	*As above + spatial rescaling before sum* *Definition of lambdas to be summed up (default = all channels)*
PSF wing profile	***P***	*Profile extraction from previous images (as IRDIS)*
Mean spectrum of the image	***S***	*Spectrum I(λ) averaged over the image*
Spectrum of a specific area of the image	***S***	*Interactive definition of a specific image area (box)* *Spectrum extraction + display*
Image – average profile	***I***	*(as IRDIS)*
Difference of the 2 deep images	***I***	*Definition of lambda mask (on/off)* *Corresponding image extraction (polychromatic deep images)* *Difference after centering, and flux scaling*
Filtered difference of the 2 deep images	***I***	*As above + filtering out azimuthally extended patterns (as IRDIS)*
Estimator for contrast performance	***P***	*5 x Rms of the previous image, as a function of separation (as IRDIS)*
Rough "candidate finder"	***I***	*Previous image with threshold at N-sigma. (as IRDIS)*

3.3.4.3 ZIMPOL

Produced data	***format***	***Processing***
As IRDIS +		
Polarization degree	***I***	*Subtract images corresponding to orthogonal polarization to create image of P*
Radial polarization sensitivity	***P***	*Determine noise level on radial profile on P*

3.3.4.4 Display functionalities

Image display functionalities:

- *Zoom*
- *Color scale (linear, log, min-max..), boundary setting*
- *Pixel values*
- *Image coordinates: WCS (if available in data header), indication of image center (if available in header), pixel coordinates wrt border or to center, distance to center + PA*
- *Statistics on a user-defined detector area*
- *Extracted plot*
- *Image saving (ps, jpg,…), printing*

Profile display functionalities:

- *Zoom (in both x and y)*
- *Units (pixels and physical units, if available in header)*
- *Scale (in x and y) : linear, log, boundary setting*

Spectrum display functionalities:

- *Zoom (in both x and y)*
- *Units (x : pixels or microns, if available in header ; y: ADUs, physical units if available, possible normalization)*
- *Scale (in x and y) : linear, log, boundary setting*
- *Possible 'overplot' ; clear ..*

3.4 Restrictions on the coronagraph selection

The centering of the star on the coronagraph is critical. Its stability in time is ensured

- In NIR, by the slow dedicated servo-loop, keeping the star on a given location on the NIR detector DTTS (DTTS reference slope)
- And in VIS, by the stability of DTTP.

This centering is invalidated by any hardware move of the coronagraphic focal plane exchanging unit. As a consequence, *whenever a new NIR coronagraphic mask is set, the definition of the new corresponding DTTS reference slope must be performed again immediately* (before any further observations), *and in VIS the "zero position of the DTTP" must be re-defined.*

To guarantee that this constraint is satisfied, the possibility to select a new coronagraphic mask is restricted to the only following cases:

- In the CPI-TEC templates (it can start with setting a new coronagraph before doing the actual reference slope measurement)
- in an acquisition template: if the selected coronagraph mask is new, then the template sequencer should automatically perform the same operations as in the CPI-TEC templates.
- The software does not move the coronagraphic focal plane device unless in the 2 previous cases (in particular the coronagraph stays where it is at the end of a template, and does not go back to any 'home' position).

Note: the stellar centering on the slit is by far less demanding than the centering on the coronagraph. As a consequence, it is authorized to move the slit out/in without the need of a new DTTS reference slope measurement: it may be the case, in particular, in order to select the right target during the acquisition.

4. IRDIFS : IRDIS AND IFS SIMULTANEOUSLY

This observing mode will be used the largest fraction of the SPHERE observation time so as to search for exo-planets or sub-stellar companions around hundreds of stars. For this purpose, a unique set-up will be used, in the “**NIRSUR**” sub-mode, so as to guarantee an homogeneous and optimised data product. The corresponding set-up is called the *NIR survey* set-up, for which the only remaining user-defined parameters are directly related to the target itself (coordinates and flux). In particular, a specific coronagraph is selected (after the AIT and commissioning) and always used. This coronagraph selection will in particular take into account the performance over the wide spectral band from Y to H band. The de-rotator tracking law is “pupil-stabilized”.

This IRDIFS observing mode (using IFS and IRDIS/DBI simultaneously) will also be used, for more specific observation cases, for instance when revisiting an already detected companion, or in case of a particularly faint companion. In such a situation, while the observation sequence remains identical to NIRSUR, the user may select a different set-up:

- The coronagraph mode (optimized for a specific observation case, which may also include non-coronagraphic mode). However, note that the coronagraph is defined for the whole OB, including both acquisition and observation (the coronagraph is not a user-defined parameter for an observation template).
- The de-rotator mode: field or pupil stabilized

The corresponding sub-mode is **NIROBS**.

Additionnally, IFS may be used up to H band. This defines the observing sub-mode **IFS-H.** Under such circumstances, a different dichroic splitter is used, sending K band only towards IRDIS. Operationally, IRDIS (in K) and IFS are still operating simultaneously: this case is still a sub-mode of the general IRDIFS mode. However, the user should be aware that the IRDIS K-band performance will degraded (wrt to IRDIS-alone K-band observation) primarily because the performance of the coronagraph, optimized for IFS Y-H and not in K.

4.1 *Set-up*

See “Mode_Devices” table [RD2] for exhaustive description.

Summary of user-defined parameters in the *NIRSUR* sub-mode:

- DIT (min, max), NDIT, NEXP for IFS and for IRDIS
- Number of dithering positions for IFS and for IRDIS
- If relevant (only for H2H3 filter pair, not in case of IFS-H): number of IRDIS filter swap

Extended user-defined parameters for the NIROBS and IFS-H sub-modes observation:

- de-rotator mode: field or pupil stabilized.
- If field-stabilized, field orientation.
- Coronagraph type

4.2 *Sequences*

4.2.1 Baseline scenario

Pre-requisites:

- Acquisition done: this includes the coronagraph set-up, AO servo loop closed, the check for target flux and centering. Any detection of abnormal flux or centering at this stage is an anomaly. It is not solved during the observation template; it can motivate to abort an observation template so as to re-do an appropriate acquisition.

Sequence:

- HW set-up (NIROBS only, only if a new field orientation is specified)
- Image, QLA criteria display and check: possibility to adjust DIT for both IFS and IRDIS. If modified, the expected durations of the corresponding IRDIS and IFS total observations are re-computed. Warning if they differ by more than 2 (tbc) minutes.
- Start of IRDIS and IFS integrations, in parallel (meaning no synchronization in between start and end):
    - IRDIS: sequence as described in section DBI with filter swap (see 5.2.1) loop including image dithering and filter swap.
    - IFS: simple loop on image dithering: Loop on number of dithering positions: NDITHERING_IFS
        - Go to dithering position
        - Take NEXP_IFS detector images (DIT)

Notes:

- Dithering pattern, DIT, NDIT, NEXP are in general different for IRDIS and IFS
- Template is over when both IRDIS AND IFS integration loops are over (template check should include the verification that these two sequences have approximately the same duration).

Precision on image dithering:

In DCS detector read-out mode (= baseline), the number of photo-electrons detected in each pixel is obtained as the difference of the number of photo-electrons measured in that pixel at the end and at the beginning of the DIT. There is no shutter used here. The effective DIT is the time difference between the 2 individual reads. So the minimum DIT is the read-out time (~1.3 s for IFS, and 0.65s for IRDIS). Note that the DIT is identical for each pixel of the detector, but the period of illumination is different. From the beginning of the first individual read to the end of the second individual read, some pixels are integrating. There can be no image dithering over this complete period.

Consequently, the detailed sequence for image dithering is as indicated in Figure 1

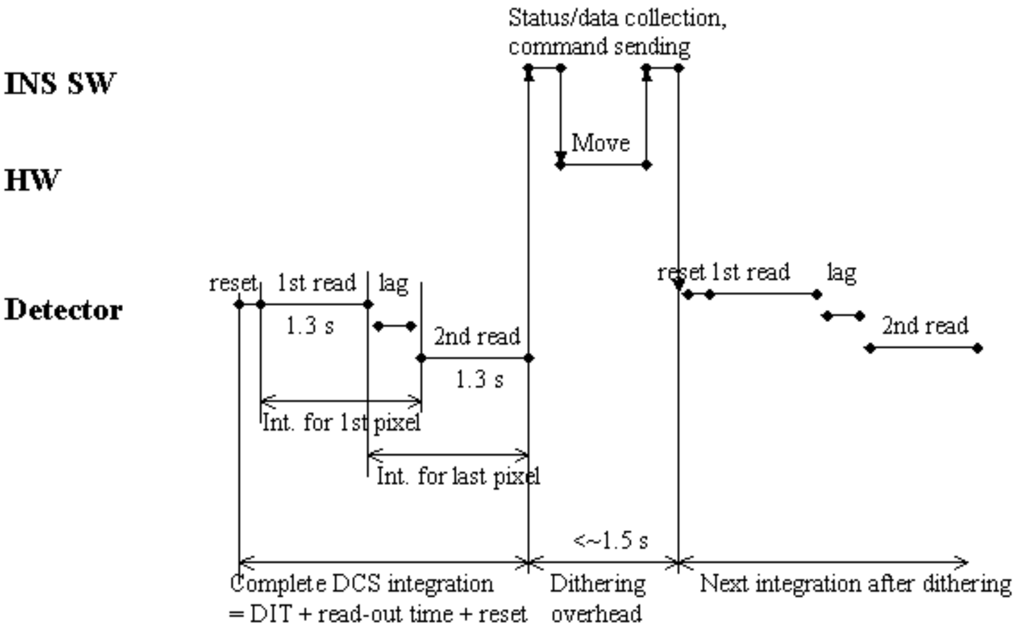

Figure 1 Schematic sequence for image dithering, in case of DCS read-out for IFS. For IRDIS, the scheme is similar with a read-out time of 0.65s instead of 1.3s.

4.2.2 Alternative scenarii

none

4.2.3 Required calibrations

Night-time calibrations are very limited, with mainly weekly or monthly astrometric or photometric reference targets.

On opposite, day-time calibrations are quite demanding, even if they are expected to be very repeatable and done in an automatic way.

Current estimation time for regular daily calibration is 3h30. This total is dominated by 3 items, the duration of each of them needs to be confirmed (it might eventually be shorter): NIR detector darks, IRDIS FF calibration, and NIR NCPA (frequency might be reduced).

On top of these regular daily operations, twive a week, an additional 1h or 1h30 will be needed for complete IFS detector FF calibration or SAXO interaction matrix.

Table 3 Calibrations needed for IRDIFS observations

	ID	*Name*	*Freq.*	*Duration*	*Remarks*
Night-time				**<~20 MN**	(assuming <~1 of the on-sky calibration is done / night)
	IFS-SCI-01 IRD-SCI-01	Astrometry	~1/w + on request	(20mn)	See also IFS-MON-18 (suitability of same target calibrators for both IFS and IRDIS in parallel TBC)

	IFS-SCI-02 IRD-SCI-02	Flux calibration	~1/m + on request	(20 mn)	Same binary star used for both IFS and IRDIS (tbc)
	IFS-SCI-03 IRD-SCI-03	Instrument throughput	~1/m + on request	(15mn)	Same standard photometric star used for both IFS and IRDIS
	IFS-SCI-04	Atmospheric calibration	On request	(20 mn)	Assumed not needed in general if some early type star spectrum available
	IFS-SCI-08	Sky flat	1/yr	(18 mn)	See IFS-TEC-04
	IFS-SCI-09	Sky background	On request	(13 mn)	Useful for faint extended objects
	IFS-TEC-03	Night-time Detector FF	5-10/d	(3 mn)	Assumed execution during telescope preset
Day-time				**3H30** **(5H)**	(3h30 is usual value ; 5h twice / week) (1)
	IFS-TEC-01	Bias & Dark	1/day	60 mn tbc	IFS and IRD calib made in parallel. Freq tbc
	IRD-TEC-01	Bias & Dark	1/day		
	IFS-MON-18	Distortion map	1/w	(10 mn)	IFS and IRD calib made in parallel
	IRD-MON-10	Distortion map	1/w		
	IFS-TEC-03	Detector FF (short)	1/day	(10 mn)	In parallel to IRDIS calibrations (IFS internal lamp)
	IFS-TEC-04	Spectra location/IFS FF	1/w	(30 mn)	When performed, In parallel to IRD-TEC-02 (tbc)
	IFS-SCI-10	Wavelength calibration	2/day	5 mn	
	IFS-MON-14	Camera focus	1/w	(15 mn)	
	IFS-TEC-02	Detector FF	1/week	(2h)	The day of the week when this calibration is performed, it can be done in parallel to IRD-TEC-02
	IRD-TEC-02	Instrument Flat field linearity, Bad Pixel	2/day	30 mn	30 mn for one DBI config, repeated in evening and morning (=1h/d)
	IRD-TEC-06	IRDIS aberrations	On request	(15 mn)	For additional info on WFE, if useful for data analysis.
	IRD-xx	Other rare calibrations or monitoring	1/m or 1/yr		
	IFS-MON-xx	Other IFS	1/m or		

		monitoring	1/yr		
	SAXO-TEC-16	Performance check	1/d	5 mn	
	SAXO-TEC-09.1 & 10	NIR NCPA	1/d	60 mn	
	SAXO-TEX-01.1	WFS ref slopes	1/d	3.5 mn	
	SAXO-TEC-02 & 03	Off set voltages & IM	1/w	(90 mn)	
	CPI-TEC-01	On-corono centering	1/day	5 mn	
	SAXO-TEC-05	DTT IM	1/day	5 mn	
	SAXO/CPI-xx	Other rare calibrations or monitoring	1/m or 1/yr		

(1) These duration estimations are probably conservative. They are to be revisited i/ to check for each calibration frequency and duration, and ii/ to refine the optimized operation sequences and in particular the definition of what can be done in parallel.

4.2.4 Summary of overheads

4.2.4.1 List of overheads

For IRDIS:

- Detector read-out: 0.65 s
- Dithering: <1.5 s
- Filter swap: <5 s
- Data file production: <~ 1s

For IFS:

- Detector read-out: 1.3 s
- Dithering: <1.5 s
- Data file production: <~ 1s

4.2.4.2 Typical examples

As typical examples, we consider here 2 cases: bright/faint star observation.

- *Bright star example*: short DIT is used to avoid detector saturation; to reach a very high contrast performance, a total of ~100 dithering positions are used, for a total effective integration time of ~1300 s. For IRDIS, filter swap is performed every 5 dithering positions. Note: to match the duration of simultaneous IRDIS and IFS operations, the exact DIT can be adjusted separately for IRDIS and IFS.

Table 4 Example of typical integration sequence in IRDIFS on a bright target

	DIT	# frames / dithering position	Ndither	Nswap	total # frames	overheads					total int. time	total exec. time (inc; 15' target acq.)
						read - out	dither	swap	file	*total*		
IRDIS	1,8	10	100	20	1000	650	150	100	100	*1000*	**1800**	**3700**
IFS	1,3	10	100	-	1000	1300	150	-	100	*1550*	**1300**	**3750**

- *Fainter star example*: DIT=10s (with no significant field rotation smearing). Because sensitivity (and photon noise) is more critical here, a larger total integration time is reached and also not so many dithering positions are required. In this example, keeping a filter switch every few minutes induces a filter switch operation at each dithering displacement.

Table 5 Example of typical integration sequence in IRDIFS on a fainter target

	DIT	# frames / dithering position	Ndither	Nswap	total # frames	overheads					total int. time	total exec. time (inc; 15' target acq.)
						read-out	dither	swap	file	*total*		
IRDIS	10	15	25	25	375	244	37,5	125	25	*431*	**3750**	**5081**
IFS	10	15	25	-	375	488	37,5	-	25	*550*	**3750**	**5200**

4.3 Produced data

- Archived data:
  - IFS data and IRDIS data (each detector frame)
  - AO data
- QLA

5. IRDIS DBI

5.1 Set-up

See “Mode_Devices” table [RD2].

Summary of user-defined parameters for an observation

- DIT, number of detector frames per dithering position (NDIT, NEXP)
- Number of dithering positions
- Filter (note that the selection of the filter pair induces the selection of the corresponding broad band filter in the common wheel, used as a blocking filter)
- filter swap parameter (capability available only for one filter pair: H2H3)
- De-rotator:
    - Pupil (=default) or field stabilized
    - if field stabilized: field orientation

(coronagraph: various NIR coronagraph may be used ; its selection is not made here but during the previous acquisition)

5.2 Sequences

For one filter pair H2H3 (used in the NIRSUR observation mode), in H band, the filter pair is duplicated in the IRDIS dual filter wheel, so as to swap the 2 filter images on the detector (and wrt to the rest of the instrument and its potential artifacts). The corresponding sequence is described in 5.2.1. For the observations in the other filter pairs, it is not possible to perform such a filter swap ; the corresponding sequence is described in 5.2.2.

5.2.1 Scenario including filter swap

Comments on filter swap and detector dithering and Naming conventions:

During the complete observation of one target, a total number of NSWAP filter swaps has to be performed (typically NSWAP >~10, or in other words, the time between 2 filter swap <~few minutes) ; and a total of NDITHERING detector positions has to be used (typically, NDITHERING = 1, 25, or 100). Filter swap is performed every few detector movements (= every NDITHERING / NSWAP), without interrupting the overall cycle of the detector dithering pattern.

Sequence:

- HW set-up
    - if a new field orientation is specified (in field stabilized mode)
    - if a new filter pair is specified
- Image display and check (validation by user, possibility to adjust DIT)
- Loop on the total number of detector positions: k=1 to NDITHERING
    - Go to dithering position k
    - Take NEXPxNDIT detector frames (DIT)
    - Every NDITHERING / NSWAP iteration (ie IF (k mod NDITHERING / NSWAP) equal 0 THEN): Swap filter

As a summary, at the end of the loop, have been obtained:

- NDITHERING detector positions according to a pre-defined pattern
- NSWAP filter swaps
- NEXP x NDIT x NDITHERING detectors frames

5.2.2 Scenario without filter swap

Sequence:

- HW set-up
    - if a new field orientation is specified (in field stabilized mode)
    - if a new filter pair is specified
- Image display and check (validation by user, possibility to adjust DIT)
- Loop on number of dithering positions:NDITHERING
    - Go to dithering position
    - Take NEXPxNDIT detector frames (DIT)

(summary: number of frames = NDITHERINGxNEXPxNDIT)

5.2.3 Required calibrations

The calibration needed for IRDIS DBI is very similar to the IRDIS and CPI part of IRDIFS calibrations.

Quantitatively, with respect to IRDIFS observing mode, the total day-time calibration for IRDIS alone is hardly shorter (because, for IRDIFS, some calibrations are performed in parallel). On opposite, it may be even significantly longer if numerous IRDIS DBI configurations (filters) are used during the night, because of additional IRDIS FF calibration. The exact dependence of this IRD-TEC-02 on the configuration needs to be closely monitored so as to avoid critical operational issues!

Table 6 Calibratons needed for IRDIS DBI

	ID	*Name*	*Freq.*	*Duration*	*Remarks*
Night-time				**<~20 MN**	(assuming <~1 of the on-sky calibration is done / night)
	IRD-SCI-01	Astrometry	~1/w + on request	(20mn)	
	IRD-SCI-02	Flux calibration	~1/m + on request	(20 mn)	Same binary star used for both IFS and IRDIS (tbc)
	IRD-SCI-03	Instrument throughput	~1/m + on request	(15mn)	Same standard photometric star used for both IFS and IRDIS
Day-time				**3H20** **(5H)**	(3h20 is usual value ; 5h once / week) assuming IRDIS FF done in only one config: TBC !

	IRD-TEC-01	Bias & Dark	1/day	60 mn	Freq tbc
	IRD-MON-10	Distortion map	1/w	(10 mn)	
	IRD-TEC-02	Instrument Flat field linearity, Bad Pixel	2/day	30 mn	30 mn for one DBI config, repeated in evening and morning (=1h/d/DBI config)
	IRD-TEC-06	IRDIS aberrations	On request	(15 mn)	For additional info on WFE, if useful for data analysis.
	IRD-xx	Other rare calibrations or monitoring	1/m or 1/yr		
	SAXO-TEC-16	Performance check	1/d	5 mn	
	SAXO-TEC-09.1 & 10	NIR NCPA	1/d	60 mn	
	SAXO-TEX-01.1	WFS ref slopes	1/d	3.5 mn	
	SAXO-TEC-02 & 03	Off set voltages & IM	1/w	(90 mn)	
	CPI-TEC-01	On-corono centering	1/day	5 mn	
	SAXO-TEC-05	DTT IM	1/day	5 mn	
	SAXO/CPI-xx	Other rare calibrations or monitoring	1/m or 1/yr		

5.2.4 Summary of overheads

5.2.4.1 List of overheads

- Detector read-out: 0.65 s
- Dithering: <1.5 s
- Filter swap: <5 s
- Data file production: <~ 1s

5.2.4.2 Typical example

See IRDIS part in 4.2.4.2

5.3 Produced data

- Archived data:
  - IRDIS data (each detector frame)
  - AO data
- QLA

6. IRDIS DPI

This observing mode makes possible differential polarization imaging. Two orthogonal linear polarizations are observed simultaneously on two detector quadrants. The direction of the selected polarization can be selected (and modulated) using the HWP at the entrance of the system in CPI: HWP2-IR.

6.1 Set-up

See “Mode_Devices” table [RD2]. Note that, by default, both Stokes Q and U are measured. Also, a baseline and an alternative scenarii are described below. It is expected that the selection of the optimal sequence is defined during AIT or commissioning and only one sequence is proposed to the user.

Summary of user-defined parameters for an observation

- DIT, number of detector frames per dithering position (NDIT, NEXP)
- Filter in IRDIS common filter wheel
- polarization:
    - polarization offset angle γ
- De-rotator: field stabilized (if so: field orientation η) or “pseudo field stabilized”

(coronagraph: various NIR coronagraph may be used ; its selection is not made here but during the previous acquisition)

6.2 Sequences

The sequences are similar to Zimpol polarization observation modes, because the purpose and main modulation tricks are identical: simultaneous of 2 orthogonal polars, and possibility to select the observed polar orientation and to modulate it with HWP2-IR at the entrance of the instrument.

In general, as for ZIMPOL, it is possible to observe with various command laws of de-rotator:

- With tracking de-rotator (field stabilized): see ZIMPOL P2 sequence in section 10.2.1. As for ZIMPOL, the selected field orientation can be modified in a list of successive field orientation (see 10.2.2.2)
- With “pseudo field-stabilized” mode where instrumental polar is well controlled (de-rotator remains close to P1 position) but field stabilized during short period and moved by steps: see section 11.2

We present first these sequences, similar to Zimpol, in section 6.2.1. In section 6.2.2, we present an alternative scenario where the selection of stokes U (wrt Stokes Q) is made by changing the polarizers in IRDIS dual wheel, instead of rotating the entrance HWP2-IR. The selection between these two scenarii will be made at AIT and/or commissioning.

6.2.1 Scenarii similar to Zimpol polar

pseudo field-stabilized

Sequence:

- CP set-up including
    - De-rotator: “field-stabilized” tracking law + initial position at “P1 position”

- HWP2 tracking, orientation according to the polar (user-defined) position γ/2

- *IRDIS* set-up: filter, ND
- Image, QLA criteria display and check: possibility to adjust DIT
- Loop on the k field orientations
  - reset de-rotator to P1 position minus an offset (so that P1 position is reached in the middle of the current iteration) + “field-stabilized” tracking law. (+Q)
  - NDIT
  - rotation of HWP2 to γ/2+22.5 (+U)
  - NDIT
  - rotation of HWP2 to γ/2+67.5 (-U)
  - NDIT
  - rotation of HWP2 to γ/2+45 (-Q)
  - NDIT
  - rotation of HWP2 back to γ/2

Notes for this “pseudo field-stabilized” sequence:

- It is important that the +Q and –Q exposures, as well as the +U and –U exposures are distributed symmetrically in time with respect to the nominal P1 de-rotator position
- NDIT should be defined so that the duration of each iteration is short enough so that the de-rotator remains “close enough” to the neutral “P1 position”. “Close enough” is ~ 6 degrees according to the maximum acceptable instrumental polarization and polarization cross-talk..

Field-stabilized

See zimpol P2 sequence with CPI set-up including

- De-rotator: “field-stabilized” tracking law + initial position corresponding to the user-defined field orientation η
- HWP2 tracking (law for field de-rotation), orientation according to the polar (user-defined) position γ/2

6.2.2 Alternative scenario

In this alternative scenario, switching from Stokes Q to U is made by changing the pair of wire grid analyzer located inside IRDIS cryostat (instead of changing the orientation of HWP2-IR by 22.5°). HWP2-IR is still used to exchange the images on the detector quadrants (+Q ←→ -Q ; +U ←→ -U) to remove the fixed instrumentation polarization.

In this case the field orientation loop becomes:

Loop on the k field orientations

- reset de-rotator to P1 position minus an offset (so that P1 position is reached in the middle of the current iteration) + “field-stabilized” tracking law. (+Q)
- NDIT
- Wire grid switch (0-90 to 45-135 pair) (+U)
- NDIT
- rotation of HWP2 to γ/2+45(-U)
- NDIT

- o Wire grid switch (45-135 to 0-90 pair) (-Q)
- o NDIT
- o rotation of HWP2 back to γ/2

6.2.3 Required calibrations

For IRDIS/DPI the night-time calibration significantly depend on the exact observing program. It is foreseen that these night-time calibration are consequently to be define by the astronomer himself ('on request'). The case of observations requiring high absolute polarisation measurement might be quite time-cosumng. The total corresponding night-time calibration time is to be precised, as a function of the dependence of polarization on the filters and de-rotator orientation.

For day-time calibrations: same remarks as for IRDIS/DBI.

Table 7 Calibrations needed for IRDIS/DPI

	ID	*Name*	*Freq.*	*Duration*	*Remarks*
Night-time				**VARIABLE**	Possibly long if high absolute polar accuracy needed.
	IRDIS-SCI-05	PSF reference	On request	20 mn	Freq depending on obs pg ; useful for extended sources.
	IRDIS-SCI-06	Polar 0 point & Efficiency	>~1/d	20mn	Freq and duration depending on obs pg: better absolute accuracy induces more numerous settings (function of de-rotator, filter)
	IRDIS-SCI-07	Instrumental & telescope Polarization	On request (up to each target)	20mn	Same remark
Day-time				**3H30** **(5H)**	(3h30 is usual value ; 5h once / week) assuming IRDIS FF done in only one config: TBC !
	IRD-SCI-08	Large spatial scale FF	On request	13mn	Function of filter/ND. Freq depending on obs pg ; useful for extended sources.
	IRD-TEC-01	Bias & Dark	1/day	60 mn	Freq tbc
	IRD-MON-10	Distortion map	1/w	(10 mn)	
	IRD-TEC-02	Instrument Flat field linearity, Bad Pixel	2/day	30 mn	30 mn for one config, repeated in evening and morning (=1h/d/config)
	IRD-TEC-06	IRDIS aberrations	On request	(15 mn)	For additional info on WFE, if useful for data analysis.

	IRD-MON-06	Polar efficiency	1/w	(15 mn)	
	IRD-MON-07	Instrumental polar ofset	1/w	(15 mn)	
	IRD-MON-08	Polar crosstalks	1/w	(15 mn)	
	IRD-xx	Other rare calibrations or monitoring	1/m or 1/yr		
	SAXO-TEC-16	Performance check	1/d	5 mn	
	SAXO-TEC-09.1 & 10	NIR NCPA	1/d	60 mn	
	SAXO-TEX-01.1	WFS ref slopes	1/d	3.5 mn	
	SAXO-TEC-02 & 03	Off set voltages & IM	1/w	(90 mn)	
	CPI-TEC-01	On-corono centering	1/day	5 mn	
	SAXO-TEC-05	DTT IM	1/day	5 mn	
	SAXO/CPI-xx	Other rare calibrations or monitoring	1/m or 1/yr		

6.2.4 Summary of overheads

6.2.4.1 List of overheads

- Detector read-out: <0.65 s
- polarization swap (with HWP2-IR or with wire grid): <5 s
- Data file production: <~ 1s

6.2.4.2 Typical example

Concerning overhead estimations, the situation is similar to IRDIS DBI with overhead dominated by detector read-out time for bright (short DIT) targets. For faint targets, DIT can become significantly larger than 10s thanks to field stabilization. In such a situation, the observation efficiency will be more directly related to the night-time calibration needs, depending on exact observation program requirements.

6.3 Produced data

- Archived data (similar to DBI):
  - IRDIS data (each detector frame)
  - AO data
- QLA:

- No additional on-line quality criteria defined wrt DBI (see generic list in section 3.3.1 and 3.3.3)
- Short term pipeline is similar to DBI (section 3.3.4) with the following remarks:
  - the 2 compared channels are polarimetric instead of spectral
  - polar switch replaces DBI filter switch
  - image de-rotation operations are either irrelevant or with different rotation law (if de-rotator fixed).

7. IRDIS LSS

7.1 Set-up

See "Mode_Devices" table [RD2].

In LSS, de-rotator is in field-stabilized mode. The field orientation is user-defined and driven by the PA of the off-axis source (companion, disk etc…) to be observed. The spectral range and the corresponding blocking filters are pre-defined for respectively LRS and MRS.

Summary of user-defined parameters and comments:

- Field orientation
- Slit
- Spectral resolution (LRS or MRS)
- DIT, NDIT, NEXP

7.2 Sequences

7.2.1 Baseline scenario

Pre-requisites:

- Acquisition done: target is centered on slit, under central mask ; field and slit orientation are known accurately enough, and set in requested position. (Requiring a new field orientation needs to go through a new acquisition template.)

Sequence:

- image check, adjust DIT
- integration: NEXP x NDIT detector frames

7.2.2 Alternative scenarii

One modulation capability could be to perform a 180° field rotation. This scheme is not considered as baseline now but can be defined by the user by 2 successive templates with appropriate field orientation parameter.

7.2.3 Required calibrations

Table 8 Calibrations needed for IRDIS LSS

	ID	*Name*	*Freq.*	*Duration*	*Remarks*
Night-time				**<~20 MN**	(assuming <~1 of the on-sky calibration is done / night)
	IRD-SCI-02	Flux calibration	~1/m + on request	(20 mn)	Same binary star used for both IFS and IRDIS (tbc)
	IRD-SCI-04	Armospheric calibration	on request	(15mn)	Associated to targets later than K
Day-time				**3H30** **(5H)**	(3h30 is usual value ; 5h once / week)

	IRD-TEC-01	Bias & Dark	1/day	60 mn	Freq tbc
	IRD-MON-10	Distortion map	1/w	(10 mn)	
	IRD-TEC-02	Instrument Flat field linearity, Bad Pixel	2/day	30 mn	30 mn repeated in evening and morning (=1h/d/config)
	IRD-TEC-05	Wavelength calibration	1/d	10 mn	10' is the total for both LRS and MRS
	IRD-xx	Other rare calibrations or monitoring	1/m or 1/yr		
	SAXO-TEC-16	Performance check	1/d	5 mn	
	SAXO-TEC-09.1 & 10	NIR NCPA	1/d	60 mn	
	SAXO-TEX-01.1	WFS ref slopes	1/d	3.5 mn	
	SAXO-TEC-02 & 03	Off set voltages & IM	1/w	(90 mn)	
	CPI-TEC-01	On-corono centering	1/day	5 mn	
	SAXO-TEC-05	DTT IM	1/day	5 mn	
	SAXO/CPI-xx	Other rare calibrations or monitoring	1/m or 1/yr		

7.2.4 Summary of overheads

Wrt DBI, the overheads associated with detector read-out are reduced thanks to:

- Longer DIT authorized in field-stabilized mode
- Larger dispersion in MRS

On opposite, target acquisition may be a few minutes longer (section 13.6.2)

7.3 Produced data

- Archived data (similar to DBI):
  - IRDIS data (each detector frame)
  - AO data
- QLA:
  - No additional on-line quality criteria defined wrt DBI (see generic list in section 3.3.1 and 3.3.3)
  - Short term pipeline recipes: tbd

8. IRDIS CI

This observing mode is very similar to IRDIS/DBI where the 2 images produced on the 2 detector quadrants are obtained in the same (common) filter, instead of two contiguous filters of a filter pair. The sequence is very similar. The final steps of data quick-look and data analysis are limited (no operations related to the 2 images re-scaling and subtraction).

8.1 Set-up

See “Mode_Devices” table [RD2].

Summary of user-defined parameters and comments:

- DIT, NDIT, NEXP
- Filter selection (to be chosen for BB or NB among the list of legal combinations of IRDIS wheels ; Dual filter wheel in ‘clear’ position)
- De-rotator: pupil or field stabilized (if field-stabilized: field orientation)

8.2 Sequences

8.2.1 Baseline scenario

See IRDIS/DBI without filter swap, in section 5.2.2

8.2.2 Alternative scenarii

None

8.2.3 Required calibrations

	ID	*Name*	*Freq.*	*Duration*	*Remarks*
Night-time				**VARIABLE**	
	IRDIS-SCI-05	PSF reference	On request	(20 mn)	Freq depending on obs pg ; useful for extended sources.
	IRD-SCI-01	Astrometry	~1/w + on request	(20mn)	
	IRD-SCI-02	Flux calibration	~1/m + on request	(20 mn)	Same binary star used for both IFS and IRDIS (tbc)
	IRD-SCI-03	Instrument throughput	~1/m + on request	(15mn)	Same standard photometric star used for both IFS and IRDIS
Day-time				**3H30 (5H)**	(3h30 is usual value ; 5h once / week) assuming IRDIS FF done in only one config: TBC !
	IRD-SCI-08	Large spatial	On	(13mn)	Function of filter/ND.

		scale FF	request		Freq depending on obs pg ; useful for extended sources.
	IRD-TEC-01	Bias & Dark	1/day	60 mn	Freq tbc
	IRD-MON-10	Distortion map	1/w	(10 mn)	
	IRD-TEC-02	Instrument Flat field linearity, Bad Pixel	2/day	30 mn	30 mn for one config, repeated in evening and morning (=1h/d/config)
	IRD-TEC-06	IRDIS aberrations	On request	(15 mn)	For additional info on WFE, if useful for data analysis.
	IRD-xx	Other rare calibrations or monitoring	1/m or 1/yr		
	SAXO-TEC-16	Performance check	1/d	5 mn	
	SAXO-TEC-09.1 & 10	NIR NCPA	1/d	60 mn	
	SAXO-TEX-01.1	WFS ref slopes	1/d	3.5 mn	
	SAXO-TEC-02 & 03	Off set voltages & IM	1/w	(90 mn)	
	CPI-TEC-01	On-corono centering	1/day	5 mn	
	SAXO-TEC-05	DTT IM	1/day	5 mn	
	SAXO/CPI-xx	Other rare calibrations or monitoring	1/m or 1/yr		

8.2.4 Summary of overheads

Overheads dominated by either detector read-out or target acquisition.

8.3 Produced data

- Archived data (similar to DBI):
    - IRDIS data (each detector frame)
    - AO data
- QLA:
    - No additional on-line quality criteria defined wrt DBI (see generic list in section 3.3.1 and 3.3.3)
    - Short term pipeline recipes: sub-set of DBI (tbd)

9. ZIMPOL P1

This mode is defined with fixed CP de-rotator orientation. If this induces both field and pupil rotation, this also minimizes and lets fixed any instrumental polarization effect, for highest (absolute) polarization accuracy.

9.1 Set-up

See “Mode_Devices” table [RD2].

By definition, in common path, de-rotator is fixed, in a position minimizing the polarization induced by de-rotator and the polarization cross-talk. Before it, telescope polarization is oriented in a fixed direction thanks to the rotating HWP1, and it is compensated by M4.

Inside Zimpol, HWP-Z is out, and Z-COMP orientation is fixed (minimizing CP polarization), tilt possibly servo-controlled.

Summary of user-defined parameters for the observation (on top of the acquisition parameters including the target description):

- polarization mode:
  - polarization offset angle γ
  - One Stokes parameter (Stokes Q) or 2 Stokes Q-U observations
- Beam-splitter between WFS and ZIMPOL: grey (20/80) or dichroic
- ZIMPOL filters (chosen independently on each arm) + ND
- read-out mode (modulation mode is fast in P1)
- Detector integration time (DIT), number of integrations per series (NDIT). Note: NDIT should be an even number (odd indices of NDIT start with a FLC phase opposite to even indices)
- detector dithering scheme: k positions of the image on detector.
- Servo control of polar compensation : yes or no . (to update an optimized inclination of the Z-compensator). If yes, uses on-line data analysis to servo Z-COMP tilt. Frequency : tbd.

(coronagraph: various VIS coronagraph may be used ; its selection is not made here but during the previous acquisition)

9.2 Sequences

9.2.1 Baseline scenario: Stokes Q and U measurement

Pre-requisites:

- Acquisition done (image quality ok)

Sequence

- CP set-up including
  - De-rotator in its fixed position
  - HWP1 tracking
  - HWP2 tracking (law for fixed de-rotator), orientation according to the polar initial (user-defined) position γ/2

- ZIMPOL set-up (if necessary): filter, ND, FLC,…
- Image, QLA criteria display and check: possibility to adjust DIT
- If "servo control of polar compensation": start servo control on the basis of detector images. If not, open loop control of Z-COMP according to a pre-defined model.
- Loop 1 on the k dithering positions
    - Go to dithering position k
    - Loop 2: m times (number of polarimetric cycles)
        - NDIT (note: NDIT is even. Change the FLC phase wrt detector modulation at every DIT)
        - rotation (switch) of HWP2 to γ/2+45
        - NDIT
        - rotation (switch) of HWP2 to γ/2+22.5
        - NDIT
        - rotation (switch) of HWP2 to γ/2+67.5
        - NDIT
        - rotation (switch) of HWP2 back to γ/2

9.2.2 Alternative scenarii

- For measurement of only one Stokes parameter, the polarimetric cycle modulates only between 2 HWP2 positions (γ/2 and γ/2+45) instead of 4
- There might be no dithering (k=1)

9.2.3 Required calibrations

For night-time observations, the calibration duration may be dominated by the calibration of the telescope polarization. This will depend on the required absolute polarization, but also on the eventual overall polarization properties of the telescope+instrument properties (dependence on filter, HWP1 + M4 polar compensation, dependence on pointing direction and stability.

For day-time calibration, the current estimations are quite long, but also conservative. Will need to be followed and adjusted are: the frequency and duration for darks, the need for both ZIM-TEC-04 and 05 and their duration, the VIS NCPA measurement frequency, and the SAXO IM.

Table 9 Calibrations needed for ZIMPOL P observations

	ID	*Name*	*Freq.*	*Duration*	*Remarks*
Night-time				**<1H**	
	ZIM-SCI-01	Astrometry	1/w	(20 mn)	
	ZIM-SCI-02	Photometry	1/w	(20 mn)	Freq depending on pg: if absolute photometry needed
	ZIM-SCI-03	Telescope polarization	1/day	20 mn	For one filter and one zenith position
	ZIM-SCI-04	Telescope zero point	0.5/d	20 mn	

		polarization angle			
Day-time				**~4H30**	(under assumption SAXO IM is done daily)
	ZIM-TEC-01&02	Bias Dark	2/d	20 mn	Freq tbc
	ZIM-TEC-04	Intensity flat	1/d	< 30 mn	(5mn per setup). Total duration depending on nb of filters during night
	ZIM-TEC-05	Sky flat	2/d	< 30 mn	(5mn per setup). Total duration depending on nb of filters during night
	ZIM-TEC-06	Mo/Dem polarization efficiency	1/d	30 mn	(5mn per setup)
	ZIM-MON-06	Astrometric distortion	1/w	(5mn)	
	ZIM-MON-xx	Other rare calibration or monitoring	1/m or 1/yr		
	SAXO-TEC-16	Performance check	1/d	5 mn	
	SAXO-TEC-13 & 14	VIS NCPA	1/d	60 mn	
	SAXO-TEX-01.1	WFS ref slopes	1/d	3.5 mn	
	SAXO-TEC-02 & 03	Off set voltages & IM	1/w or on request	90 mn	Note: to be re-done after change of Z/WFS splitter (baseline is daily operation)
	CPI-TEC-02	On-corono centering	1/day	5 mn	
	SAXO/CPI-xx	Other rare calibrations or monitoring	1/m or 1/yr		

9.2.4 Summary of overheads

9.2.4.1 List of overheads

- Frame transfer:
  - Full frame (1k x 1k data array of binned pixels): 0.1 s (goal 0.05 s),
  - Central window (300x300 data array of binned pixels ~1''x1''): goal 0.018 s
- Detector read-out: the detector read-out (of the pixels charges transferred onto a buffer area) is made during the following detector integration ; the read-outs induce no overhead if DIT is longer than detector read-out.

- Full frame: 1 s
- Central window: 0.15 s

- dithering: < 3s
- HWP2 switch: < 5s

9.2.4.2 Typical example: α Cen (P1, Stokes Q)

Adopted science scenario:

Search of planets in extremely bright and near star with anticipated orientation of polarization for possible planets (e.g. alpha Cen A and B, Sirius, Procyon …):

Indications exists that from RV studies that a low mass planet is present which is at the time of these observations at maximum elongation in an orbit close to the binary star plane. Thus *the expected orientation of the polarization signal is known* (projection of a vector which is perpendicular to this plane). Dedicated search of this signal with a Q measurement for a polarization offset angle γ as defined by the orientation of the orbital plane of the binary.

Measurement:

- P1 mode observation
- Only Q measurement with offset angle γ
- Small coronagraph
- Filter R-band (arm1 and arm2)
- integration time 0.1 sec for a windowed frame, nDIT=1000
- no dithering because the field rotation is sufficient to correct for detector inhomogeneities.

Observing run:

- Standard star calibration
  (may be needed at the beginning of the night, or for calibrations of a new – for a given run – instrument setup)
- Acquisition of target
- Setup AO control loop and coronagraph centering

- loop 1: (3 times 4360 sec = 13080 sec)
- optimize centering of star on mask (300 sec)
- loop: 20-time Stokes Q measurement (20 x 203 sec = 4060 sec)
- 1000 DIT of 0.1 sec with γ/2 (100 sec)
- rotation (switch) of HWP2 (3 sec)
- 1000 DIT of 0.1 sec with γ/2+45 (100 sec)

9.3 Produced data

- Archived data
  - ZIMPOL data (each detector frame, two detectors)
  - AO data
- QLA (see 3.3.2 and 3.3.3)

10. ZIMPOL P2

This observing mode includes CP de-rotator rotation to stabilize the field (at a user-defined orientation η). Correspondingly, HWP2 and HWPZ rotations are adjusted to keep the selection of the desired on-sky polarization and compensate the CP instrumental polarization.

10.1 Set-up

See "Mode_Devices" table [RD2].

Summary of user-defined parameters and comments:

- same as in P1 (section 9.1)
- + orientation of the field on the detector η
- + FLC modulation mode (user choice)
- – no servo loop possibility for polarization compensator tilt in P2

10.2 Sequences

10.2.1 Baseline scenario

The sequence mentioned below is similar to P1, but the de-rotator command law is "field stabilized" instead of fixed. The corresponding field orientation η is user-defined.

Sequence:

- CP set-up including
  - De-rotator: "field-stabilized" tracking law + initial position corresponding to the user-defined field orientation η
  - HWP1 tracking
  - HWP2 tracking (law for field de-rotation), orientation according to the polar (user-defined) position γ/2
- ZIMPOL set-up (if necessary): COMP, HWPZ, filter, ND, FLC, TTM
- Image, QLA criteria display and check: possibility to adjust DIT

(no pol comp servo loop)

- Loop 1 on the k dithering positions
  - Go to dithering position k
  - Loop 2: m times (number of polarimetric cycles)
    - NDIT (note: NDIT is even. Change the FLC phase wrt detector modulation at every DIT)
    - rotation (switch) of HWP2 to γ/2+45
    - NDIT
    - rotation (switch) of HWP2 to γ/2+22.5
    - NDIT
    - rotation (switch) of HWP2 to γ/2+67.5
    - NDIT

- rotation (switch) of HWP2 back to γ/2

10.2.2 Alternative scenarii

10.2.2.1 Same remarks as for P1

- For measurement of only one Stokes parameter, the polarimetric cycle modulates only between 2 HWP2 positions (γ/2 and γ/2+45 instead of 4
- There might be no dithering (k=1)

10.2.2.2 Multiple field orientations

Instead of performing the complete observation with only one field orientation η as in the baseline scenario, *this sequence could be repeated with a list of successive field orientations η_l defined by the user*. A potential astrophysical companion will then appear at different locations on the detector, and wrt possible instrumental artifacts. This could be used in the data analysis to reduce false alarm probability.

10.2.3 Required calibrations

Same as P1 (see 9.2.3)

10.2.4 Summary of overheads

10.2.4.1 List of overheads

Same as P1 (see 9.2.4.1)

10.2.4.2 Typical example: ε Ind (P2, Stokes Q and U)

Adopted science scenario:

Normal search of planets around a star with no particular properties

Measurement:
- P2 mode observation
- Q and U measurements γ=0, η=0
- Small coronagraph, RI-filter
- integration time 5 s (no overhead related to detector read-out), full frame, nDIT=20
- with dithering

Observing run:
- Standard star calibration

  (may be needed at the beginning of the night, or for calibrations of a new – for a given run – instrument setup)
- Acquisition of target
- Setup AO control loop and coronagraph centering

- loop i=1…3 (3 times 4450 sec = 13 350 sec)
- optimize centering of star on mask (300 sec)
  - loop, k=1…10 times Q-U measurements (4150 sec)
    - centre field on detector pixel x_k,y_k (dither position) (3 sec)
    - rotation (switch) of HWP2 (3 sec)
    - 20 DIT of 5 sec with γ/2 = 0 (100 sec)
    - rotation (switch) of HWP2 (3 sec)
    - 20 DIT of 5 sec with γ/2 = 45 (100 sec)

- rotation of HWP2 to the U-direction (3 sec)
- 20 DIT of 5 sec with γ/2 = 22.5 (100 sec)
- rotation (switch) of HWP2 (3 sec)
- 20 DIT of 5 sec with γ/2 = 67.5 (100 sec)

<table>
<tr><th></th><th>Loop centering</th><th>Loop on Dithering / Q-U meas.</th><th>HWP2 positions</th><th>Time per iteration</th><th>Total time</th></tr>
<tr><td>On target integration</td><td rowspan="5">3</td><td rowspan="4">10</td><td rowspan="3">4</td><td>20 x 5</td><td>12000</td></tr>
<tr><td>Detector overhead</td><td>0</td><td>0</td></tr>
<tr><td>HWP2 switch overhead</td><td>3</td><td>360</td></tr>
<tr><td>Dithering overhead</td><td></td><td>3</td><td>90</td></tr>
<tr><td>Centering overhead</td><td></td><td></td><td>~300</td><td>900</td></tr>
<tr><td>Target first acquisition</td><td></td><td></td><td></td><td>~900</td><td>900</td></tr>
<tr><td>Total overhead</td><td></td><td></td><td></td><td></td><td>2250</td></tr>
</table>

10.3 Produced data

Same as P1 (see 9.3)

11. ZIMPOL P3

The “pseudo field-stabilized” sequence is defined so as to combine advantages of P1 (with corresponding good absolute polar accuracy) and the P2 field stabilization capability. The first part requires the de-rotator to remain close to the “neutral” position as selected for P1 ; the second part requires the de-rotator to track during integrations. Hence, this mode proposes to use the de-rotator to track the field rotation around the “P1-position”. This ensures the field is stabilized during the integration (during a maximum period dependent on the pointing direction) ; but the absolute field orientation is not chosen, and is increased by steps at each iteration of the loop.

Similar to P2, with field stabilized during the integrations, but the observation is repeated with various field orientations, automatically computed so that the de-rotator orientation remains close to its P1 position, so as to minimize corresponding polarization or cross-talks induced by this device.

11.1 Set-up

See “Mode_Devices” table [RD2].

Summary of user-defined parameters and comments:

- same as in P1 (section 9.1)
- + FLC modulation mode (user choice)
- + Type of pseudo field stabilized mode: fixed time for one derotator position or maximum offset for derotator from nominal P1 position (software calculates number of DIT per position)

11.2 Sequences

11.2.1 Baseline scenario

For each field orientation, a sequence similar to P2 is performed.

Sequence:

- CP set-up including
    - De-rotator: “field-stabilized” tracking law + initial position at “P1 position”
    - HWP1 tracking
    - HWP2 tracking, orientation according to the polar (user-defined) position $\gamma/2$
- ZIMPOL set-up (if necessary): COMP, HWPZ, filter, ND, FLC, TTM
- Image, QLA criteria display and check: possibility to adjust DIT
- Loop 1 on the k field orientations
    - reset de-rotator to P1 position minus an offset (so that P1 position is reached in the middle of the current iteration) + “field-stabilized” tracking law. (+Q)
    - NDIT
    - rotation (switch) of HWP2 to $\gamma/2+22.5$ (+U)
    - NDIT
    - rotation (switch) of HWP2 to $\gamma/2+67.5$ (-U)
    - NDIT

  - o rotation (switch) of HWP2 to γ/2+45 (-Q)
  - o NDIT
  - o rotation (switch) of HWP2 back to γ/2

Notes for this “pseudo field-stabilized” sequence:

- It is important that the +Q and –Q exposures, as well as the +U and –U exposures are distributed symmetrically in time with respect to the nominal P1 de-rotator position
- NDIT should be defined so that the duration of each iteration is short enough so that the de-rotator remains “close enough” to the neutral “P1 position”. “Close enough” is TBD according to the maximum acceptable instrumental polarization and polarization cross-talk..
- This scheme could also be combined with dithering (at the same time as re-setting de-rotator)

11.2.2 Required calibrations

Same as P1 (see 9.2.3)

11.2.3 Summary of overheads

11.2.3.1 List of overheads

Same as P1 (see 9.2.4.1) + de-rotator reset ~5 s

11.2.3.2 Typical example: ε Eri (P3, Stokes Q and U)

Adopted science scenario:

Search of planets and search of a extended polarization signal due to scattered light from a disk. This requires that a good absolute polarimetric accuracy is achieved. Thus, not only sensitivity is required but also very good calibration of the instrument polarization.

Measurement:

- P3 mode observations (reset of de-rotator after few minutes)
- Q and U measurements γ=0, η newly defined for each series
- integration time 5 sec, full frame, nDIT=20 per series
- I band filter, large coronagraph
- with dithering (same time interval between ditherings and de-rotator resets)
- Q and U measurement symmetric with respect to P1 de-rotator position, thus
  - o Reset de-rotator and dithering position
  - o Stokes +Q and +U measurement before P1 position followed by –U and –Q measurement after P1 position

Observing run:

- Standard star calibration

  (may be needed at the beginning of the night, or for calibrations of a new – for a given run – instrument set-up)
- Acquisition of target
- Set-up AO control loop and coronagraph centering

- loop i=1…3 (3 times 4550 sec = 13 650 sec)
- optimize centering of star on mask (300 sec)
  - loop, k=1…10 times Q-U measurements (4250 sec)

- reset de-rotator to P1 position minus small offset (so that P1 position is reached after $\gamma/2=0$ and $\gamma/2 = 22.5$ HWP2 position) (10 sec)
- centre field on detector pixel x_k,y_k (dither position) (3 sec)
- rotation (switch) of HWP2 (3 sec)
- 20 DIT of 5 sec with $\gamma/2 = 0$ (100 sec)
- rotation (switch) of HWP2 (3 sec)
- 20 DIT of 5 sec with $\gamma/2 = 22.5$ (100 sec)
- rotation of HWP2 to the U-direction (derotator at P1) (3 sec)
- 20 DIT of 5 sec with $\gamma/2 = 67.5$ (100 sec)
- rotation (switch) of HWP2 (3 sec)
- 20 DIT of 5 sec with $\gamma/2 = 45$ (100 sec)

<table>
<tr><th></th><th>Loop centering</th><th>Loop on Dithering / Q-U meas / Field orient. .</th><th>HWP2 positions</th><th>Time per iteration</th><th>Total time</th></tr>
<tr><td>On target integration</td><td rowspan="6">3</td><td rowspan="5">10</td><td rowspan="3">4</td><td>20 x 5</td><td>12000</td></tr>
<tr><td>Detector overhead</td><td>0</td><td>0</td></tr>
<tr><td>HWP2 switch overhead</td><td>3</td><td>360</td></tr>
<tr><td>De-rotator overhead</td><td></td><td>10</td><td>300</td></tr>
<tr><td>Dithering overhead</td><td></td><td>3</td><td>90</td></tr>
<tr><td>Centering overhead</td><td></td><td></td><td>~300</td><td>900</td></tr>
<tr><td>Target first acquisition</td><td></td><td></td><td></td><td>~900</td><td>900</td></tr>
<tr><td>Total overhead</td><td></td><td></td><td></td><td></td><td>2550</td></tr>
</table>

11.3 Produced data

Same as P1 (see 9.3)

12. ZIMPOL I

12.1 Set-up

See “Mode_Devices” table [RD2].

In particular, polarimetric devices including HWP1, HWP2, Z-Comp, HWP-Z are OUT. FLC is OUT and OFF (not modulating)

Summary of user-defined parameters and comments :

- de-rotator
- Beam-splitter between WFS and ZIMPOL: grey or dichro
- ZIMPOL filters (may be different on the 2 arms) ; ND
- Detector integration time (DIT), number of integrations per series (NDIT).
- detector dithering scheme: k positions of the image on detector. Note: dithering IS compatible with coronagraphic observation: dithering means that the part of the image that is recorded on detector changes (not that the star moves wrt coronagraph).
- Number of filter switch positions: if ONE then there is no switch (= baseline scenario) ; if > 1, then extended scenario.

12.2 Sequences

12.2.1 Baseline scenario

Pre-requisites:

- Acquisition done (image quality ok)

Sequence

- CP set-up
- ZIMPOL set-up (if necessary): filter, ND, TTM
- Image, QLA criteria display and check: possibility to adjust DIT
- Loop 1 on the k dithering positions
  - Go to dithering position number k
  - NDIT

12.2.2 Extended scenario with filter switching

In case that the filters on the two detector arms are different (e.g Filter1 = Hα and Filter2 = Hα_continuum), a sequence may include the filter switching between the 2 arms. The integration loop then becomes:

- Loop 1 on the k dithering positions
  - Go to dithering position number k
  - Loop 2 : m times (number of filter switches)
    - Set-up Filter1 on arm1 and Filter2 on arm 2
    - NDIT

- Set-up Filter2 on arm1 and Filter1 on arm 2
- NDIT

This case, with m>1, is a natural extension of the previous baseline scenario.

12.2.3 Required calibrations

Calibrations related to polarization are not needed here.

Table 10 Calibrations needed for ZIMPOL I observations

	ID	*Name*	*Freq.*	*Duration*	*Remarks*
Night-time				**<20 MN**	
	ZIM-SCI-01	Astrometry	1/w	(20 mn)	
	ZIM-SCI-02	Photometry	1/w	(20 mn)	Freq depending on pg: if absolute photometry needed
Day-time				**~4H00**	(under assumption SAXO IM is done daily)
	ZIM-TEC-01&02	Bias Dark	2/d	20 mn	Freq tbc
	ZIM-TEC-04	Intensity flat	1/d	< 30 mn	(5mn per setup). Total duration depending on nb of filters during night
	ZIM-TEC-05	Sky flat	2/d	< 30 mn	(5mn per setup). Total duration depending on nb of filters during night
	ZIM-MON-06	Astrometric distortion	1/w	(5mn)	
	ZIM-MON-xx	Other rare calibration or monitoring	1/m or 1/yr		
	SAXO-TEC-16	Performance check	1/d	5 mn	
	SAXO-TEC-13 & 14	VIS NCPA	1/d	60 mn	
	SAXO-TEX-01.1	WFS ref slopes	1/d	3.5 mn	
	SAXO-TEC-02 & 03	Off set voltages & IM	1/w or on request	90 mn	Note: to be re-done after change of Z/WFS splitter (baseline is daily operation)
	CPI-TEC-02	On-corono centering	1/day	5 mn	
	SAXO/CPI-xx	Other rare calibrations or monitoring	1/m or 1/yr		

12.2.4 Summary of overheads

- Detector frame transfer and read-out: see 9.2.4.1
- dithering: < 3s

12.3 Produced data

- Archived data
  - ZIMPOL data (each detector frame, two detectors)
  - AO data
- QLA (see 3.3.2 and 3.3.3)

13. TARGET ACQUISITION SCHEMES

13.1 Selecting a new coronagraph

As mentioned in section 3.4, the move of coronagraphic focal plane device is restricted. The acquisition template is one place where the user may select a new coronagraph.

If the user-selected coronagraph is different than the current one, then the template should automatically perform the actions as described in the CPI calibration “DTTS reference slopes” [RD 10]. This operation involves the record of images on IRDIS or ZIMPOL with the entrance internal source, and it will take a few minutes. When completed, the rest of the acquisition sequence can proceed normally.

The previous note applies for both NIR (using IRDIS to record NIR images) and VIS (using ZIMPOL).

For IRDIS/LSS, when setting a new slit (changing from a coronagraph to a slit, or changing of slit), the sequence to bne applied is described in section 13.6.2. The alignment check (and possibly some correction) is performed on the astronomical target. Unlike for coronagraphy, the requirement on alignment accuracy is not so severe that it requires to record images of the entrance internal source.

13.2 Overview (assuming an unchanged coronagraph)

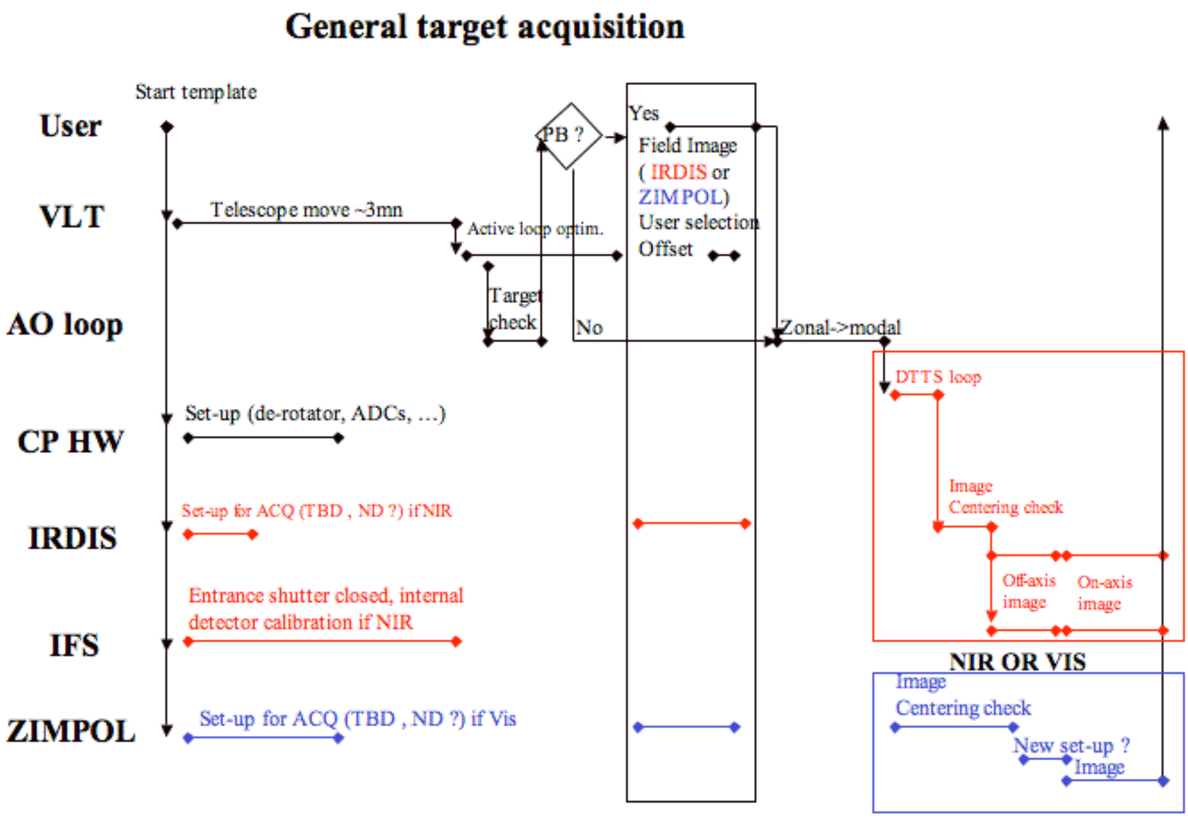

Figure 2 Overview of target acquisition sequence (assuming the current coronagraph is used).
Either ZIMPOL (blue) is active for visible observations (NIR instruments are “protected”) or NIR instruments (IRDIS+IFS or IRDIS alone) are active.

Figure 2 presents an overview of target acquisition. Whether ZIMPOL is used, IRDIS alone or IRDIS+IFS, the general scheme is similar, including:

- Telescope preset (during which set-up operations of sub-system can already start). In NIR survey mode, when necessary, IFS internal calibration can start at the beginning of the telescope preset, and can last up to when the NIR acquisition is ready for final image check.
- Closing AO WFS loop. This step may start a little bit before the active optics loop is optimised, as soon as target position is fixed. If the target is not found in the WFS FoV, it may be necessary to use the science detector to get a wider image, with IRDIS or ZIMPOL (possibly with mosaicing) depending on the context
- Image control on science detector. For NIR observations, this step starts with closing the DTTS loop.

13.3 Set-up

Summary of user-defined parameters for all but LSS mode:

- Target description:
  - Coordinates
  - Flux for AO WFS, and in observation band (Vis or NIR)
- Coronagraph type (see section 13.1)
- De-rotator:
  - Command law: fixed, pupil or field stabilized
  - If field stabilized: field orientation η
- Parameters for IFS internal FF: nb of FF frames

User-defined parameters for LSS (in coronagraphic focal plane, the slit is inserted, the de-rotator is in field-stabilized mode)

- Target description:
  - Coordinates
  - Flux for AO WFS, and in observation band (Vis or NIR)
- Spectral resolution: “low” or “medium”
- Slit position angle (defines the required field orientation as provided by the de-rotator)

13.4 Telescope preset, and sub-systems set-up

During all this step, the NIR instruments (IFS and IRDIS) are “protected”: ND for IRDIS, shutter closed for IFS.

The telescope preset operations are defined by VLT operation procedures, including

- The displacement of the telescope and dome according to the target coordinates
- the acquisition of a selected off-axis guiding star by the guide-probe
- closing the loop of the telescope active optics up to an optimized and stabilized image quality

Corresponding typical overheads are 3min in average for telescope preset, and ~0.75 min for guide star acquisition.

During the telescope preset, the following actions can start concerning the sub-systems:

- if IRDIFS, IFS can perform internal calibrations, using internal lamp, not seeing any light from outside, and not sending light outside IFS: see IFS calibration plan [RD 11]
- CPI set-up according to the required set-up for following observations, including:
  - de-rotator orientation setting (as a function of the telescope pointing direction and of the user-defined offset constraint) + start the de-rotator tracking law
  - if NIR: IR-ADC
  - HWPs if involved
- V-ADC according to target on-sky coordinates
- AO initial set-up:
  - HW set-up:
    - Spatial filtering = ‘Wide-field’

        - TBC: filter: automatically defined according to expected AO flux
    - RTC set-up by SAXO OS: reference slopes = “null” (tbd TFu) ; offset voltage =”acquisition mode”, command law = “open loop”
    - Detector read-out mode: standard ‘initial detector mode’
- If NIR: IRDIS HW including protecting ND.
- If VIS: ZIMPOL set-up as required by user (filters, Z-COMP, HWPZ, corono, density,..).+ protecting ND.

13.5 AO acquisition

AO acquisition up to a closed loop stabilized image includes the following operations.

Exact starting conditions are to be precised (with ESO). It does not in principle need to wait for the finalized active optics image quality to start.

13.5.1 Baseline scenario

- Target check: check for the *presence* of the target in the WFS 2.1” FoV. Check of rough order of magnitude photo-electron count wrt visible magnitude. This check involves a combination of measured flux (e-/subpupil/frame), WFS frame rate, WFS filter, WFS/ZIMPOL splitter, and star magnitude in Vis.

  Success condition of this step: target is seen in the WFS (even if in the border of sub-pupils) so that the loop will be able to be closed. If not: see alternative scenario in section 13.5.2. This step is completed with a validation by the user (tbc).
- First closed loop with low gain zonal matrix
    - NCPA correction: OS sends to RTC reference slopes associated to i/ optical aberration on WFS optical beam + ii/ optical aberrations on science optical beam.
    - Closing the loop with pre-defined low gain zonal matrix
    - Computations based on circular files data (20 s):
        - modal optimization and Kalman filter parameter optimization
        - target visible flux check
- Modal loop
    - Apply computed modal command matrix
    - first AO loop performance estimation
    - Pinhole size computation and adjustment (1s)
    - New modal optimization (20 s) + updated performance estimations
- If NIR: DTTS Auxiliary loop (can be started after the first closed loop with low gain zonal matrix, ie in parallel with modal loop)
    - OS sends to RTC the reference slopes (nominal position on DTTS where the target should be for coronagraph maximum efficiency, could account for ADC residual correction if observation wavelength is different than DTTS effective wavelength).
    - Full DTTS detector read out
    - PSF position estimation by RTC using a correlation procedure with a pre-defined correlation map → to derive the offset wrt the reference slope

- RTC sends offset command to DTTP for NIR PSF centering
- The procedure is re-done till PSF centering accuracy is lower than 1 pixel.
- RTC reconfigures DTTS read-out mode with a hard window of 16x16 (goal 32x32) pixels.
- DTTS Background: is not re-measured at this stage. The background map to be used is the one measured, with the same DTTS read-ut mode, during the calibration performed at the beginning of the night.
- NIR flux check (wrt NIR target magnitude)
- DTTP loop closed

Successful conditions:

- Characterized and checked target flux
- Characterized AO correction conditions and optimized set-up (spatial filtering, and command law)
- Closed loop for PTTM, TTM, DTTP and DM (including normal offload of tilt and defocus to VLT)
- Active tracking law for V-ADC and de-rotator + IR-ADC if ‘NIR’ obs

13.5.2 Alternative scenarii

If the target is not found in WFS FoV, or if the user thinks some error may be present (surprising flux, crowded field…) then a larger FoV should be imaged. This alternative scenario is likely to require one or few additional minutes, involving the sub-system science detectors and some interaction with the user.

IF NIR observations, IRDIS is used as an imager (Note: in case of IRDIS slit spectroscopy, this means that the focal slit and the dispersive element are removed. See also 13.6.2)

- Set-up: current set-up + additional CPI ND.
- Images and real-time display
- Interaction with user: user clicks on relevant target as seen on IRDIS image. System should derive the appropriate offset so that the identified direction be seen by WFS
- Telescope offset
- Go back to normal WFS acquisition

IF VIS observations, ZIMPOL is used as a field imager

- Set-up: current setup + additional ND.
- Images and real-time display
- Interaction with user:
    - If target not found, enter a loop of mosaic images to explore the complete 8” ZIMPOL FoV (and not only the 3.5” FoV as imaged instantaneously). The large FoV display may use image binning for practical reason. Note that the corresponding display of the large mosaic FoV is only dedicated to identify the source of interest: no functionality for distortion/overlap/slight mis-orientation is foreseen.

        - When target found, user clicks on relevant target as seen on ZIMPOL image. System should derive the appropriate offset so that the identified direction be seen by WFS
    - Telescope offset
    - Go back to normal WFS acquisition

13.6 Check on science detectors

13.6.1 NIR imaging observations

In case of NIR observations, the DTTS loop and a valid calibration of coronagraph position (as measured on DTTS) should guarantee an appropriate centering on coronagraph, and corresponding extinction. However, it can be safe to check this directly on IRDIS science detector with a “safe” set-up (not likely to induce long detector persistence if coronagraphic extinction not as expected)

- Preliminary image check with IRDIS only (IFS still protected). “safe set-up” includes ND. Check of centering and coronagraphic extinction as expected. The QLA estimation for target centering on coronagraph is used here

  If de-centering is abnormally “large” (threshold value TBD), warning to operator and template aborted. Recommendation for new coronagraphic position calibration (also called “DTTS reference slopes”). Note that this case is supposed to be exceptional: the DTTS reference slope stability + the re-measurement of DTTS reference slopes when changing the coronagraph focal mask should prevent from such a de-centering.
- IRDIS and IFS switch to “end-of-acquisition” set-up (user-defined)
- Off-axis image of the source (offset performed with offset-slopes on DTTS + CPI ND) ; IFS and IRDIS record an image and archive it (it will be used for data reduction and analysis purposes for PSF quality control and flux calibration). Then target back to on-axis
- IRDIS and IFS image

13.6.2 NIR IRDIS slit spectroscopy

13.6.2.1 Baseline scenario

In the considered baseline scenario, it is assumed that the slit position is accurately known on DTTS, and the slit orientation is also accurately known in the de-rotator reference frame. As a consequence, DTTS loop ensures that the target is well centered on slit. And the de-rotator set-up ensures the appropriate orientation of the slit onto the sky (for instance including a faint off-axis companion onto the slit)

In such a situation, the NIR check is only an IRDIS detector image.

13.6.2.2 Alternative scenario: need for slit position/orientation check

If the slit orientation/position are not known accurately enough, or if the QLA estimator of the target de-centering is above a tbd threshold, then they have to be measured again. More precisely, the exact conditions requiring to execute the following sequence have to be precised during AIT.

Procedure

- Set-up:
    - dispersive device (grism or prism) out, BB filter H, ND in (depending on target magnitude)

- slit out
- compute the target position on IRDIS detector
- set-up: slit in (target is not far from slit center, so that the slit shape is well illuminated ; integration time dependent on stellar brightness ; time needed < 1 mn)
- compute effective slit position/orientation on IRDIS detector (based on correlation with pre-defined slit mask, and Gaussian fitting of the correlation peaks)
- Send target offset command (by shifting the DTTS reference slope) as a function of the computed target and slit center positions
- If measured slit orientation not exactly as expected, send orientation offset command to de-rotator.

13.6.3 VIS observations

The considered baseline scenario here is the case when the target is centered on a coronagraphic mask ; the imaged FoV may be offsetted.

Here, no DTTS loop ensures the centering. In general, an interaction with user is required for fine centering of target wrt ZIMPOL coronagraph is required (to take into account potential atmospheric differential refraction between WFS and ZIMPOL effective wavelength, coronagraph position uncertainty), before the selection of observed FoV (possibly off-axis).

- Preliminary target centering check with ZIMPOL, using a “safe set-up” for ZIMPOL (avoiding any potential problem of saturation if any). The QLA estimation for target centering on coronagraph is used here
  - ZIMPOL FoV on coronagraphic axis
  - If de-centering is abnormally “large” (threshold value TBD), warning to operator and template aborted. Recommendation for new coronagraphic position calibration.
- ZIMPOL switch to “end-of-acquisition” set-up (user-defined) and to required FoV (possibly not centered on coronagraph.
- ZIMPOL image

Alternatively, in case of no coronagraph, the fine centering step is irrelevant.