E U R O P E A N   S O U T H E R N   O B S E R V A T O R Y

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VLT PROGRAMME

VLT SURVEY TELESCOPE

VLT Software

OmegaCAM Instrument Software
OmegaCAM Templates Manual

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CHANGE RECORD

ISSUE	DATE	SECTION/PAGE AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
0.1	02/04/2004	All	First issue for PPAE
1.0	13/05/2004	See details below	Second issue for PPAE, after corrections according to RIXes received
		3.1	Entry for ROT.OFFANGLE changed to P, units added, ranges for TEL.TARG.ALPHA and DELTA (RIX/OCAM/PAE/3111/DBA/03), added keywords TEL.GS1.ALPHA, DELTA, MAG (RIX/OCAM/PAE/3111.TSZ/08). Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.2	Upper limit for TEL.TARG.DELTA set to 450000 (RIX/OCAM/PAE/3111/DBA/05), added keywords TEL.GS1.ALPHA, DELTA, MAG (RIX/OCAM/PAE/3111.TSZ/08). Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.4	NODEFAULT for exposure time (RIX/OCAM/PAE/3111/DBA/01) Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.5, 3.7, 3.9	Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.11	Max exposure level 55,000 ADUs (RIX/OCAM/PAE/3111/DBA/01) Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.12	Changed pattern number to label (RIX/OCAM/PAE/3111/DBA/09, b) Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.14, 3.7	Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.15	Explanation expanded (RIX/OCAM/PAE/3111/DBA/10) Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.16, 3.12, 3.18	Label with units where applicable (RIX/OCAM/PAE/3111/DBA/02)
		Table 1	Corrected list of filters (RIX/OCAM/PAE/3111/DBA/11)
1.1	15/11/2004	See details below	Issue for PAE, applied corrections as per RIXes received (see VST-TRE-ESO-23100-0040).
		1.2, 1.3	Inserted list of applicable and reference documents (RIX/OCAM/PAE2/3111/ALO/02).
		1.4	Removed acronyms not related to this document (RIX/OCAM/PAE2/3111/ALO/03). Added new acronyms.
		2.2.2	Subsection added (Offsetting Modes and Observing Strategies).
		2.3, 2.4, 2.5	Written. These sections were empty in the previous releases.
		3	Added yet other physical units in labels where applicable (RIX/OCAM/PAE/3111/DBA/02)
		3.1, 3.2	Changed range for ADC Setting (RIX/OCAM/PAE2/3080/DBA/01e). Changed 'Diff RA/DEC' to 'Additional Velocity RA/DEC [arcsec/s]'.
		3.2	Upper limit for TEL.TARG.DELTA not under our control, set to 900000 (RIX/OCAM/PAE/3111/DBA/05).
		3.4, 3.5, 3.6, 3.7, 3.10	Corrected range for INS.LAMP.SET (RIX/OCAM/PAE2/3080/DBA/01).
		4	Section added: description of jitter and dither patterns. (RIX/OCAM/PAE2/3111/FSE/08)
		5	Section added: explanation of P2PP entry fields.
1.2	13/04/2006	Many	Removed OCAM_img_cal_cte template, merged OCAM_img_obs_zpkey and OCAM_img_obs_zpuser templates, renamed OCAM_img_obs_monit in OCAM_img_cal_monit.
		2.5, 2.5.4	Added text for the OCAM_img_cal_zp template
1.3	1/7/2011		Updated after Commissioning 2
		Many	OCAM → OMEGACAM
		1.1	VLT → VST
		1.3	Updated some documents numbers and issue dates.
		2.1	Corrected typo. Updated definition of Observation Description.

		2.2.2	Updated list of Offsetting Modes.
		2.3.1	Added warning about possibility that acquisition procedure can change. Removed references to telescope guide probe. Specified that IA acquisition may include a few corrections and that IA/AO are not performed in SSOs observations.
		2.3.2	Removed references to telescope guide probe.
		2.4.1	Specified that AG and IA loops are stopped before shutter is closed.
		2.4.2	Specified that AG and IA loops are stopped before shutter is closed.
		2.5.1	Specified that bias and dark are carried out by observatory staff.
		2.5.2	Specified that flats are carried out by observatory staff.
		2.5.3	Specified that sky flats are carried out by observatory staff and that offset steps are larger than in jitter template.
		3.1	Updated table of template parameters.
		3.2	Updated table of template parameters.
		3.5	Typo in parameters table.
		3.6	Typo in parameters table.
		3.7	Added OCS.STRTG.
		3.8	INS.FILT.NAME no longer a hidden parameter.
		3.10	DET1.WIN1.UIT1 no longer a hidden parameter. Corrected typo in exposure time list.
		3.13	Added OCS.STRTG. Added reference to dither pattern description. Corrected size of CCD gaps.
		3.14	Added OCS.STRTG. Added reference to jitter pattern description.
		3.15	Updated limits of TEL.TARG.OFFSETALPHA/DELTA
		5.3	Updated description of P2PP labels.
		5.4	Updated table of filters.
		5.5	Section added.

TABLE OF CONTENTS

ESO

	OmegaCAM Instrument Software OmegaCAM Templates Manual	Doc. Issue Date Page	VST-MAN-OCM-23100-3111 1.3 11/07/2011 5 of 24

1   INTRODUCTION

1.1   Scope

All observations with the VST are carried out with "observing blocks" (OBs). OBs are prepared with the phase 2 proposal preparation software P2PP. With P2PP the mode specific observation templates will be selected by the users and the parameter fields ("keywords") are set to the user specified values.

The OmegaCAM Templates Manual describes the templates and keyword available for OmegaCAM.

1.2   Applicable Documents

The following documents, of the exact issue shown, form a part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this document, the contents of this document shall be considered as a superseding requirement.

Reference	Document Number	Issue	Date	Title
[AD1]	INS-SPE-ESO-23100-0002	1.0	30/10/2001	OmegaCAM Technical Specifications
[AD2]	VST-SPE-OCM-23100-3061	1.2	30/10/2001	OmegaCAM INS User Requirements
[AD3]	VLT-MAN-ESO-17240-2240	4	31/03/2004	INS Common Software for Templates

1.3   Reference Documents

The following documents are referenced in this document.

Reference	Document Number	Issue	Date	Title
[RD1]	VST-MAN-OCM-23110-3110	1.2	30/06/2010	OmegaCAM User Manual
[RD2]	VST-MAN-OCM-23110-3080	2.2	15/11/2004	OmegaCAM Operations and Maintenance Plan
[RD3]	VST-SPE-OCM-23100-3062	1.2	31/10/2001	OmegaCAM INS Functional Specifications
[RD4]	VST-SPE-OCM-23100-3063	1.1	30/10/2001	OmegaCAM Instrument Control Software Design Description
[RD5]	VST-SPE-OCM-23100-3064	1.1	31/10/2001	OmegaCAM Observation Software Design Description
[RD6]	VST-SPE-OCM-23100-3065	1.1	30/10/2001	OmegaCAM Guide and Image Analysis Software Design Description
[RD7]	VLT-MAN-ESO-17220-1332	4	19/04/2004	HOS/Broker for Observation Blocks User Manual
[RD8]	VLT-MAN-ESO-?????-????	2	30/06/2010	P2PP for Surveys User Manual
[RD9]	1993AJ....105.1206T		March 1993	An exposure guide for taking twilight flatfields with large format CCDs

1.4 Abbreviations and 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:

ADC	Atmospheric Dispersion Corrector
AG	Auto-Guide
AO	Active Optics
BOB	Broker for Observation Blocks
CCD	Charge Coupled Device
CS	Constraint Sets
ESO	European Southern Observatory
GS	Guide Star
IA	Image Analysis
INS	Instrumentation Software Package
OB	Observation Block
OD	Observation Description
N/A	Not Applicable
P2PP	Phase 2 Proposal Preparation tool
SSO	Solar System Object
TBD	To Be Defined
VLT	Very Large Telescope
VST	VLT Survey Telescope

1.5 Glossary

No special definition is introduced in this manual

1.6 Stylistic Conventions

The following styles are used:
bold
   in the text, for commands, filenames, pre/suffixes as they have to be typed.
italic
   in the text, for parts that have to be substituted with the real content before typing.
`teletype`
   for examples.
<name>
   in the examples, for parts that have to be substituted with the real content before typing.

bold and *italic* are also used to highlight words.

2 OmegaCAM Templates

2.1 Introduction: Observation Blocks, Templates, Keywords

Observation Block (OB): an OB consists of a list of "templates", which themselves consist of a list of mode and instrument specific "keywords". The templates and keywords are translated to commands to be sent to the telescope and instrument to setup all components for the observations.

Following the general P2PP architecture, two types of Observation Blocks can be specified:

> *"ObsBlocks"* night time observations, science and standard star exposures;
>
> *"CalBlocks"* day time calibrations, bias, darks.

Night time "ObsBlocks" consist of the target information, a single acquisition template and the observation description (OD) with a small selection of science observation templates. The day time "CalBlocks" consist of a small selection of calibration templates (but no acquisition templates). Besides this, constraint sets (CS) and scheduling information are requested in particular for the preparation of service mode observations.

The target information and the constraint sets are not described below, since they are general for all instruments and their description can be found in the P2PP manual **[RD8]**.

Observation Description (OD): this defines the sequence of setups and exposures for scientific or calibration purposes. It consists of one or more templates and the respective keywords. If several templates are included, their execution follows the sequence in the list. Several OBs can be organized into groups, concatenations, or time-links. See the P2PP for surveys User Manual **[RD8]** for more information.

2.2 OmegaCAM Templates: Acquisition, Science and Calibration

2.2.1 OmegaCAM Observing Modes

OmegaCAM defines one observing mode only: imaging, acronym 'img'.

2.2.2 Offsetting Modes and Observing Strategies

Scientific observations with OmegaCAM are performed using templates that implement one of three Offsetting Modes: STARE, DITHER or JITTER. They differ in the kind of offsets that are used between exposures, and in the final data product.

Observing Strategies, on the other hand, extend beyond templates and OBs. They can relate to how fields are laid out during observation preparation, and employ one of the basic Offsetting Modes defined above. They can define additional instructions about scheduling of observations and reduction of data products. The Observation Strategies currently defined for OmegaCAM are: STANDARD, FREQ, DEEP and MOSAIC. They can be specified by the user using P2PP during the preparation of the scientific OBs.

Offsetting Modes and Observing Strategies are described in detail in the OmegaCAM User Manual **[RD1]**.

2.2.3 Template Types

Three template types are used with OmegaCAM: target acquisition templates, science observation templates and (mostly day time) calibration templates. The following naming convention (see **[AD3]**) is used:

Acquisition templates	`OMEGACAM_img_acq_xxx`
Calibration templates	`OMEGACAM_img_cal_xxx`
Observation templates	`OMEGACAM_img_obs_xxx`

2.2.4 Template Keywords

The parameters of the templates and the respective observations are to be specified in the template specific list of keywords. The keywords correspond to functionalities (for instance setups of the instrument, telescope preset) supported by the templates. Within P2PP the keywords are designated by the names of P2PP entry fields. For any keyword an allowed range and a default value is defined. The keywords themselves are not visible from P2PP. The tables in section 3 list (separately for each template) the keywords names, their value range and defaults together with the P2PP name as shown in the view panel of P2PP. In general only the keywords which will be in status "NODEFAULT" have to be set by the users, while the keywords already set to default values should remain at the original default value in almost all cases. Hidden parameters cannot be modified and will not appear at any place in P2PP.

2.2.5 Overheads

Overheads associated to observations with OmegaCAM are described and quantified in the OmegaCAM User Manual **[RD1]**.

2.3 Acquisition Templates

2.3.1 Normal Acquisition

Note: at the time of this writing not all the details of the acquisition procedure have been fixed. While the main steps should remain the same, it is possible that some operations (e.g. filter and temperature dependent focus offsets) are executed in a different order w.r.t. what is written here or completely omitted.

During normal acquisition the telescope is preset to the target and autoguide and image analysis are initialized, following this sequence of actions:

1. Preset telescope and (in parallel) setup instrument with user specified filter;
2. Apply filter and (if enabled) temperature dependent focus correction;
3. Initialize OmegaCAM autoguide and image analysis system

Normally, the auxiliary CCDs located in the focal plane of the instrument are used to do autoguiding (AG) and image analysis (IA). In this case, initialization of AG includes selection of guide stars (usually one per guide CCD) and locking of AG loop, while initialization of IA consists, as a minimum, in the selection of IA stars and may include a few measurement/correction iterations.

For observations of Solar System Objects (SSOs), guiding is currently not possible, but differential tracking rates may be specified. While observing SSOs, image analysis and active optics corrections are not performed. More details can be found in **[RD1]**.

2.3.2 Move Bright Star to Gap

This template is used to drop a bright star down the gaps between CCDs in the mosaic, in order to reduce stray light. Choice of the star is performed interactively:

1. Preset telescope and (in parallel) setup instrument with user specified filter;
2. Apply filter- and (if enabled) temperature-dependent focus correction;
3. Loop:
    - 3.1. Perform one exposure with user specified exposure time and display resulting image;
    - 3.2. Prompt user to select star to be dropped down the nearest gap in the mosaic or to exit loop;
    - 3.3. User selects the star, offset is computed and, after user confirmation, applied to the telescope;
    - 3.4. Ask user whether to continue loop, if yes then go to 3.1;
4. Initialize OmegaCAM autoguide and image analysis system.

This template cannot be used in combination with differential tracking for Solar System Objects.

2.4 Science Templates

The science exposure templates allow the execution of science exposures with a user-specified observing strategy and filter (see **[RD1]** for more information). The templates perform instrument setups, telescope offsets and sequences of science exposures.

2.4.1 Jitter, Dither and Offset

Used to observe with several pointings in the sky and performing offsets in between exposures. The target must be acquired with sidereal tracking only, i.e. jitter and dither is not provided for observations of Solar System Objects. This check will be performed by the P2PP verification software.

1. Offset telescope and (in parallel) setup first exposure: exposure time and filter name;
2. Apply filter and (if enabled) temperature dependent focus correction;
3. For the requested number of exposures:
    - 3.1. Check that, if enabled, AG and IA are setup correctly;
    - 3.2. Start scientific exposure;
    - 3.3. Start AG and IA loop;
    - 3.4. A few seconds before the end of the exposure: stop AG and IA loop;
    - 3.5. Wait for exposure to finish (shutter is closed) and readout from scientific mosaic to start;
    - 3.6. Offset telescope and (in parallel) setup next exposure: exposure time and filter name;
    - 3.7. Apply filter- and (if enabled) temperature-dependent focus correction;
    - 3.8. Wait until readout has finished and data from the FIERAs has been written to disk;
    - 3.9. Go to point 3.1;
4. Offset telescope back to preset position;
5. Wait for all acquired data to be merged in final files and archived.

2.4.2 Stare

Used to observe with one fixed pointing position. Target can be acquired with either sidereal or non-sidereal tracking.

1. Setup first exposure: exposure time and filter name;
2. Apply filter- and (if enabled) temperature-dependent focus correction;
3. For the requested number of exposures:
    3.1. Check that, if enabled, AG and IA are setup correctly;
    3.2. Start scientific exposure;
    3.3. Start AG and IA loop;
    3.4. A few seconds before the end of the exposure: stop AG and IA loop;
    3.5. Wait for exposure to finish (shutter is closed) and readout from scientific mosaic to start;
    3.6. Setup next exposure: exposure time and filter name;
    3.7. Apply filter- and (if enabled) temperature-dependent focus correction;
    3.8. Wait until readout has finished and data from the FIERAs has been written to disk;
    3.9. Start asynchronous (i.e. parallel) merging of data products in final FITS file to be archived;
    3.10. Go to point 3.1;
4. Wait for all acquired data to be merged in final files and archived.

Note that step 3.6 is performed even if in the stare template it is possible to specify one filter and exposure time only. This happens because the exposure is actually performed through library code which is general enough to allow every exposure to have different setups. The execution of setup in step 3.6 doesn't introduce any significant overhead, since the control software takes no actions for those setup parameters that do not change since the previous setup command (e.g. requesting a filter that is already in the optical path doesn't cause a filter exchange to happen).

The template code is shared by the `OMEGACAM_img_obs_stare` and `OMEGACAM_img_cal_zp` templates. For the last template the number of exposures is fixed to 1, while the user can select the exposure time and filter name.

2.5 Calibration Templates

Calibration templates define the procedure and the parameters for the execution of calibration exposures. Almost all calibration templates are executed during daytime, hence there must not be an acquisition template in the corresponding calibration OBs. The only templates that do not conform to this rule are the skyflat and photometric zero-point calibration templates which are executed on the sky with the 'img_acq' acquisition template (see Sect. 2.3.1, above).

The following types of calibration templates exist: templates taking exposures without opening the shutter (bias, dark, readnoise), templates based on dome flat field exposures (dome flat, gain, quick, shutter homogeneity), the twilight flatfield template and the photometric zero-point calibration template.

2.5.1 Bias and Dark

These templates perform exposures without opening the shutter. Bias and dark exposures are carried out by the observatory staff during daytime. Users do not have to submit OBs for these kinds of calibration data.

1. Setup CCD with user-specified exposure time (fixed to zero for biases);
2. For the requested number of exposures:
    2.1. Start exposure (without opening the shutter);
    2.2. Wait for exposure to finish (shutter is closed) and readout from scientific mosaic to start;
    2.3. Setup exposure time for next exposure;
    2.4. Wait until readout has finished and data from the FIERAs has been written to disk;
    2.5. Start asynchronous (i.e. parallel) merging of data products in final FITS file to be archived;
    2.6. Go to 2.1;
3. Wait for all acquired data to be merged in final files and archived.

Templates that follow this procedure (and that share the underlying code implementing it) are `OMEGACAM_img_cal_bias`, `OMEGACAM_img_cal_dark` and `OMEGACAM_img_cal_readnoise`.

2.5.2 Dome Flat

Performs exposures with the CCD illuminated by the light coming from the calibration lamps set. Note that in OmegaCAM two such sets exist, see Sect. 5.4 for more details. Dome flat exposures are carried out by the observatory staff during daytime. User do not have to submit OBs for these kind of calibration data.

1. If not already on then switch lamps on, setup CCD with user-specified exposure time, insert requested filter;
2. Wait for lamps warm-up if not already warm;
3. For the requested number of exposures:
    3.1. Start exposure;
    3.2. Wait until readout has finished and data from the FIERAs has been written to disk;

3.3.   Start asynchronous (i.e. parallel) merging of data products in final FITS file to be archived;

3.4.   Go to 3.1;

4.   Wait for all acquired data to be merged in final files and archived.

Note that calibration lamps are **not** switched off at the end of the template, but they are automatically switched off by the instrument software at the **end of the OB.** This allows to combine several dome flat templates in the same OB without having to wait for the lamp warm-up/cool-down times in between templates.

Templates that follow this procedure (and that share the underlying code implementing it) are `OMEGACAM_img_cal_domeflat`, `OMEGACAM_img_cal_gain`, `OMEGACAM_img_cal_quick`, and `OMEGACAM_img_cal_shutter`.

2.5.3   Sky Flat

Acquires a specified number of sky (twilight) flats, through a given filter. Exposure time is computed automatically on the basis of the requested exposure level, following Tyson and Gal **[RD9]**. Exposures are jittered, with the same pattern as in OMEGACAM_img_obs_jitter, but larger offsets (default 30 arcsec). Sky flat exposures are carried out by the observatory staff during twilight. User do not have to submit OBs for these kind of calibration data.

1.   Setup instrument with filter and initial estimate for the exposure time;

2.   Loop:

2.1.   Perform an exposure, measure exposure level, estimate exposure time for next exposure;

2.2.   If next exposure time outside allowed range set exposure time to a predefined default else exit loop;

2.3.   Ask user whether to continue, if yes go to 2.1;

3.   For the requested number of exposures:

3.1.   Start scientific exposure;

3.2.   Start AG and IA loop;

3.3.   Wait for exposure to finish and readout from scientific mosaic to start;

3.4.   Stop AG and IA loop;

3.5.   Offset telescope and (in parallel) setup next exposure: exposure time;

3.6.   If enabled, apply temperature-dependent focus correction;

3.7.   Wait until readout has finished and data from the FIERAs has been written to disk;

3.8.   Go to point 3.1

4.   Offset telescope back to preset position;

5.   Wait for all acquired data to be merged in final files and archived.

2.5.4   Photometric Zero Point Calibration

Executes one exposure using the 'obs_stare' template with a user selected filter.

3 Templates Description

The following sections list in tabular form for each template:
1. The template keywords;
2. The value range for the keywords;
3. The default values;
4. The P2PP name of the keyword entry fields;
5. The selection and entry option for the keyword.

Keyword order: in the tables below the keywords are ordered as follows:
1. DET keywords: parameters for CCD setup and exposure time
2. SEQ keywords: Sequence keywords for series of exposures etc.
3. TEL keywords: parameters for telescope preset, guiding, offsets etc
4. INS keywords: parameters for instrument setup

Selection and entry options for the keywords: different selection and entry options exist for the actual value of the keyword entered by the user in the template form:

• Single value in "Range" column: keyword parameter is fixed. No user modification is possible. "F" (fixed) in column "Entry".

• List of values in "Range" column: several predefined (named) values for the keyword are possible. Selection of the actual ones for template execution is done via a pull-down menu. "P" (pull-down menu) in column "Entry".

• Range of values in "Range" column: the actual value should fall within a wider range of possible values (indicated by for instance 0.25÷100000.0). The actual one to be used for the template execution has to be entered by typing. "T" (type) in column "Entry".

Hidden parameters: several templates contain so-called hidden keywords. These keywords are needed for the proper execution of the templates, but they are not meant to be changed by the user. Therefore, they are hidden from the P2PP display, i.e. no P2PP entry field is assigned to them, but they appear in the exported version of the OB. The user cannot modify the values of hidden keywords.

3.1 OMEGACAM_img_acq

Preset the telescope to the coordinates of the target associated with the Observation Block. After telescope has been preset, and if autoguiding has been enabled, GSs will be acquired. Operator intervention will be requested to activate autoguiding (by confirming GSs selection or overriding it) if requested. For SSO observations autoguiding is not activated.

Parameter	Range	Default	P2PP Label	Entry
TEL.TARG.ALPHA	0 ÷ 240000	NODEFAULT	Right Ascension	T
TEL.TARG.DELTA	-900000 ÷ 900000	NODEFAULT	Declination	T
TEL.TARG.EQUINOX	-2000 ÷ 3000	2000	Equinox	T
TEL.ROT.OFFANGLE	0.0, 90.0, 180.0, 270.0	0	Rotator offset angle [deg]	T
TEL.TARG.ADDVELALPHA	-15 ÷ 15	0	Additional Velocity RA [arcsec/s]	T
TEL.TARG.ADDVELDELTA	-15 ÷ 15	0	Additional Velocity DEC [arcsec/s]	T
TEL.AG.START	T F	T	Acquire guide star?	T
TEL.GS1.ALPHA	0 ÷ 240000	0	RA of 1st guide star	T
TEL.GS1.DELTA	-900000 ÷ 900000	0	DEC of 1st guide star	T
TEL.GS1.MAG	0 ÷ 25	12	Magnitude of 1st guide star	T
TEL.GS2.ALPHA	0 ÷ 240000	0	RA of 2nd guide star	T
TEL.GS2.DELTA	-900000 ÷ 900000	0	DEC of 2nd guide star	T
TEL.GS2.MAG	0 ÷ 25	12	Magnitude of 2nd guide star	T
TEL.ADC.TYPE	NONE COORD	NONE	ADC Setting	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
OCS.AG.START	T F	T	Start autoguiding	T

3.2 OMEGACAM_img_acq_movetogap

Works as the "normal" acquisition template (above) except that, after the preset, operator intervention is requested to interactively specify a telescope offset that allows to drop one bright star into CCDs gaps.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	1	Exposure time [s]	T
TEL.TARG.ALPHA	0 ÷ 240000	NODEFAULT	Right Ascension	T
TEL.TARG.DELTA	-9000000 ÷ 900000	NODEFAULT	Declination	T
TEL.TARG.EQUINOX	-2000 ÷ 3000	2000	Equinox	T
TEL.ROT.OFFANGLE	0.0, 90.0, 180.0, 270.0	0	Rotator offset angle [deg]	T
TEL.TARG.ADDVELALPHA	-15 ÷ 15	0	Additional Velocity RA [arcsec/s]	T
TEL.TARG.ADDVELDELTA	-15 ÷ 15	0	Additional Velocity DEC [arcsec/s]	T
TEL.AG.START	T F	T	Acquire guide star?	T
TEL.GS1.ALPHA	0 ÷ 240000	0	RA of 1st guide star	T
TEL.GS1.DELTA	-9000000 ÷ 900000	0	DEC of 1st guide star	T
TEL.GS1.MAG	0 ÷ 25	12	Magnitude of 1st guide star	T
TEL.GS2.ALPHA	0 ÷ 240000	0	RA of 2nd guide star	T
TEL.GS2.DELTA	-900000 ÷ 900000	0	DEC of 2nd guide star	T
TEL.GS2.MAG	0 ÷ 25	12	Magnitude of 2nd guide star	T
TEL.ADC.TYPE	NONE COORD	NONE	ADC Setting?	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
OCS.AG.START	T F	T	Start autoguiding	T

3.3 OMEGACAM_img_cal_bias

Acquire N bias exposures, with opaque filter in optical path and shutter closed. Integration time is zero.

Parameter	Range	Default	P2PP Label	Entry
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T

Hidden parameters:

Parameter	Range	Value	Function	Entry
DET1.WIN1.UIT1	0 ÷ 43200	0	Exposure time [s]	T

3.4 OMEGACAM_img_cal_dark

Acquire N dark exposures, with opaque filter in optical path and shutter closed. The user specifies integration time.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	NODEFAULT	Exposure time [s]	T
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T

3.5 OMEGACAM_img_cal_domeflat

Acquire N dome flats. Telescope is preset to point towards the flat-field screen (without tracking), calibration lamps are switched ON automatically. The user specifies exposure time.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	NODEFAULT	Exposure time [s]	T
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
INS.LAMP.SET	"Set 1", "Set 2", "default", "non-default"	1	Calibration lamps	P

3.6 OMEGACAM_img_cal_gain

Same as OMEGACAM_img_cal_domeflat, with N=20 and exposure time = 2, 60, 50, 4, 8, 40, 30, 1, 16, 24, 24, 16, 1, 30, 40, 8, 4, 50, 60, 2 s. Used to determine and monitor CCD gain.

Parameter	Range	Default	P2PP Label	Entry
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
INS.LAMP.SET	"Set 1", "Set 2", "default", "non-default"	1	Calibration lamps	P

Hidden parameters:

Parameter	Range	Value	Function	Entry
DET1.WIN1.UIT1	0 ÷ 43200	2,60,50,4,8,40,30,1,16,24,24,16,1,30,40,8,4,50,60,2	Exposure time [s]	T
SEQ.NEXPO	1 ÷ 100	20	Number of exposures	T

3.7   OMEGACAM_img_cal_monit

Same as stare, with N=1 and composite filter. Used for photometric calibration monitoring.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	1	Exposure time [s]	T
OCS.STRTG		NODEFAULT	Observing strategy	T

Hidden parameters:

Parameter	Range	Value	Function	Entry
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T
INS.FILT.NAME	See Table 1	u_g_r_i_SDSS	Filter	P

3.8   OMEGACAM_img_cal_quick

Same as OMEGACAM_img_cal_domeflat, with N=1 and composite filter. Used for a quick health check of the instrument.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	1	Exposure time [s]	T
INS.LAMP.SET	"Set 1", "Set 2", "default", "non-default"	1	Calibration lamps	T
INS.FILT.NAME	See Table 1	r_SDSS	Filter	P

Hidden parameters:

Parameter	Range	Value	Function	Entry
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T

3.9   OMEGACAM_img_cal_readnoise

Same as OMEGACAM_img_cal_bias, with N=2. Used to measure and monitor the CCD readout noise.

Hidden parameters:

Parameter	Range	Value	Function	Entry
DET1.WIN1.UIT1	0 ÷ 43200	0	Exposure time [s]	T
SEQ.NEXPO	1 ÷ 100	2	Number of exposures	T

3.10   OMEGACAM_img_cal_shutter

Same as OMEGACM_img_cal_domeflat, with N=4 and exposure times=10.0,0.1,0.1,10.0 s. Used to verify homogeneity in the exposure time over the scientific mosaic.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	10.0,0.1, 0.1, 10.0	Exposure time [s]	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
INS.LAMP.SET	"Set 1", "Set 2", "default", "non-default"	1	Calibration lamps	T

Hidden parameters:

Parameter	Range	Value	Function	Entry
SEQ.NEXPO	1 ÷ 100	4	Number of exposures	T

3.11 OMEGACAM_img_cal_skyflat

Acquire N sky (twilight) flats, through a given filter. Exposure time is computed automatically on the basis of the requested exposure level. Exposures are jittered, with the same pattern as in OMEGACAM_img_obs_jitter.

Parameter	Range	Default	P2PP Label	Entry
DET.EXPLEVEL	1 ÷ 55000	20000	Requested intensity level [ADU]	T
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T
TEL.TARG.OFFSETSIZE	0.5 ÷ 10	1	Step size in jitter offset patterns [arcsecs]	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P

3.12 OMEGACAM_img_cal_zp

Same as stare, with N=1. Used for photometric calibration of zero point for the key or user bands.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	1	Exposure time [s]	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
OCS.STRTG		NODEFAULT	Observing strategy	T

Hidden parameters:

Parameter	Range	Value	Function	Entry
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T

3.13 OMEGACAM_img_obs_dither

Observe with N pointings (default 5, maximum TBD) in the sky, with offsets ≈ maximum gap between detectors (≈ 400 pixels) between exposures. Target acquired with sidereal tracking only. Dither patterns are described in detail in Sect. 4.2.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	NODEFAULT	Exposure time [s]	T
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T
TEL.TARG.OFFSETSIZEX	0 ÷ 999	25	Step size in x [arcsec]	T
TEL.TARG.OFFSETSIZEY	0 ÷ 999	85	Step size in y [arcsec]	T
TEL.TARG.DX	0.0 ÷ 25	8	Unexposed gap size in x [arcsec]	T
TEL.TARG.DY	0.0 ÷ 85	8	Unexposed gap size in y [arcsec]	T
TEL.TARG.PATTERN	diag, starext	diag	Dither pattern name	P
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
OCS.STRTG		NODEFAULT	Observing strategy	P

3.14 OMEGACAM_img_obs_jitter

Observe with N pointings (2-20) in the sky, with small offsets (≈ 5 pixels) between exposures. Target acquired with sidereal tracking only. Jitter patterns are described in detail in Sect. 4.1.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	NODEFAULT	Exposure time [s]	T
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T
TEL.TARG.OFFSETSIZE	0.5 ÷ 10	1	Offset step size [arcsecs]	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
OCS.STRTG		NODEFAULT	Observing strategy	P

3.15 OMEGACAM_img_obs_offset

Observe with N pointings in the sky, with user-defined offsets in between exposures. Offsets are relative to the respective previous position in the sequence. If fewer offset are defined than the number of exposures requested, the list of offsets is cycled through. Target acquired with sidereal tracking only.

Parameter	Range	Default	P2PP Label	Entry
DET1.WIN1.UIT1	0 ÷ 43200	NODEFAULT	Exposure time [s]	T
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T

TEL.TARG.OFFSETALPHA	-9999 ÷ 9999	0.0	List of tel. RA offsets [arcsec]	T
TEL.TARG.OFFSETDELTA	-9999 ÷ 9999	0.0	List of tel. DEC offsets [arcsec]	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
OCS.STRTG		NODEFAULT	Observing strategy	P

3.16 OMEGACAM_img_obs_stare

Observe with one fixed pointing position. Target acquired with either sidereal or SSO tracking.

Parameter	**Range**	**Default**	**P2PP Label**	**Entry**
DET1.WIN1.UIT1	0 ÷ 43200	NODEFAULT	Exposure time [s]	T
SEQ.NEXPO	1 ÷ 100	1	Number of exposures	T
INS.FILT.NAME	See Table 1	NODEFAULT	Filter	P
OCS.STRTG		NODEFAULT	Observing strategy	P

4   Jitter and Dither Patterns

4.1   Jitter patterns

The aim of jittering is to make sure blemishes on the CCDs do not wipe out particular sources or parts of the sky. Masking the blemishes (i.e., giving them zero weight) in the co-addition of exposures accomplishes this. Jittering also helps to average out any residual systematic errors due to, for example, imperfect pixel response calibration. Jittering does *not* help to bridge the inter-CCD gaps of the mosaic in the focal plane.

The basic tactic when jittering is to make sure no two exposures point at the same X or Y coordinates. Thus, N-point jitter patterns need to fill N pointings on an N × N grid, such that every row and column is used exactly once. This ensures that bad rows or columns are not hit repeatedly.

The patterns illustrated below are all derived from the same formula, which can be extended to large N. The principle is to keep the pattern as compact as possible, but to keep the pointings reasonably far from each other as well.

The algorithm assigns N pointings on an N × N grid as follows. It first fills in the central 0,1,2,or 3 pointings, leaving a multiple of 4. Those pointings are then arranged as a set of nested, rotated squares, new ones being added alternately on the outside and on the inside of the grid.

In detail the algorithm for an N-point jitter is:

```
N4= int(N/4)           ! number of outer squares to make
L=N/2-0.5              ! grid points are -L -L+1 ... L-1 L  in X and Y
# Assign central 0,1,2 or 3 points
if N%4=0    X={} Y={}
if N%4=1    X={0} Y={0}
if N%4=2    X={0.5 -0.5} Y={0.5 -0.5}
if N%4=3    X={1 0 -1}  Y={1 -1 0}
D=0.5 * (1 + N%4)    ! first positive X or Y position still empty
for i=0 to N4-1      ! construct N4 squares: (a,b) is the corner
  if i%2=0           ! make corner with X as large, Y as small as possible
    a=L-0.5*i
    b=D+1.5*i
  else               ! make corner with X and Y as small as possible
    a=D+0.5+1.5*i
    b=a-1
  if int(a)%2 =0     ! flip every second square
    a=-a
  X=X concat {a b -a -b}
  Y=Y concat {b -a -b a}
```

On output X and Y are the X and Y offsets with respect to the center, in units of a step size. The step size is be chosen by the user and should be of the order of an arcsecond.

The patters for N=1 to 20 are shown in Figure 1, below. For very large N this pattern is no longer optimal–it tends to populate the diagonals of the grid. More evenly spread solutions exist.

(Note that OmegaCAM offset patterns need to be specified as relative offsets with respect to the previous position: the jitter template converts the absolute X and Y from the above recipe to relative offsets.)
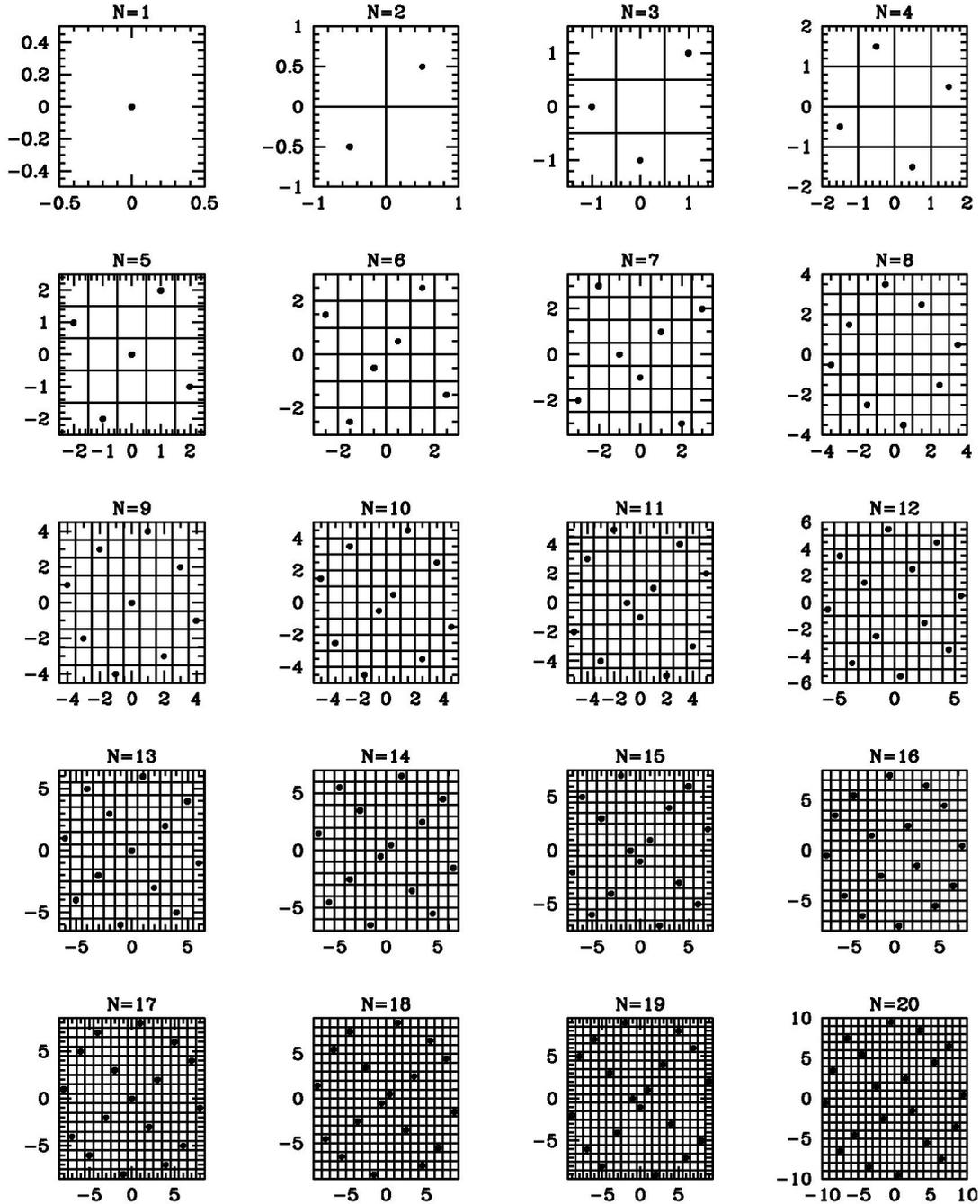
Figure 1: Jitter patterns for N=1 to N=20. Each dot represents a pointing center. The grids shown are in units of the step size that can be specified for a jitter observation.

4.2 Dither patterns

The purpose of dithering is to remove the imprint of inter-CCD gaps in the detector mosaic. Offsets are taken that are sufficiently large for these gaps to fall on different parts of the sky in each exposure. Co-addition of the images then gives as homogeneous an exposure as possible. For N exposures it is unavoidable that some parts of the image will have been seen in at most N-2 exposures.

Two dither strategies are offered. The first, 'diag', simply offsets the telescope by the same amount between successive exposures. The size of the steps X and Y is as large as the largest gap in the mosaic–about 25 arcsec in X and 85 arcsec in Y. For N=5, this results in the following exposure map over the field:
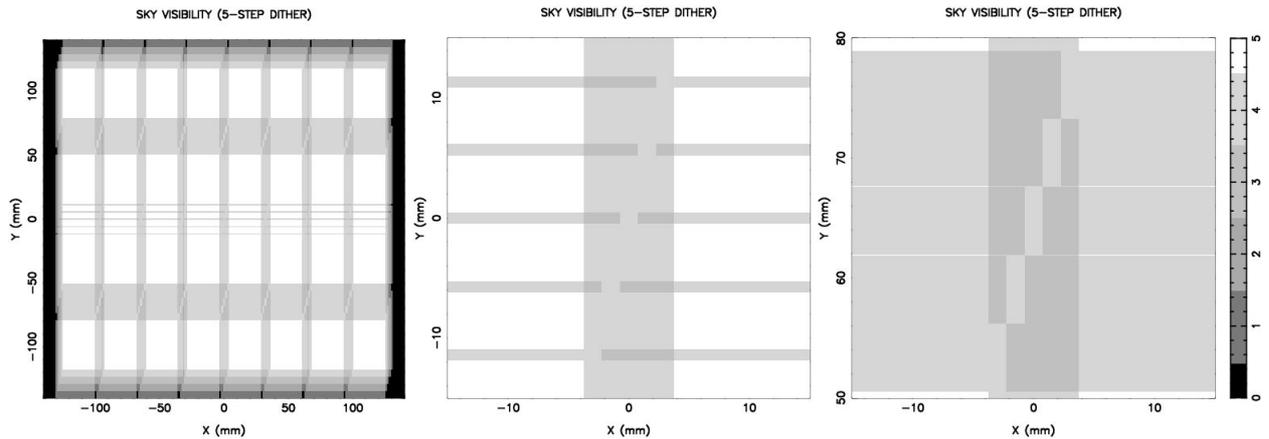
Figure 2: Relative exposure level over the field in a 5-point 'diag' dither pattern. From left to right: full field, region near center of the field, region near a large inter-CCD gap.

The second pattern, '*starext*', is designed to cover the field as uniformly as possible with the constraint that a small area is to be left unexposed. This can be used to keep a bright star off the CCDs and hence reduce stray reflections. Because of this extra constraint, this pattern produces a less uniform exposure over the field than the 'diag' pattern. The pattern is basically a rotated square grid of four pointings, plus the central pointing. It is illustrated in Figure 3. Starext would normally be used in conjunction with the `movetogap` acquisition template to position the bright star at the intersection of row and column gaps.
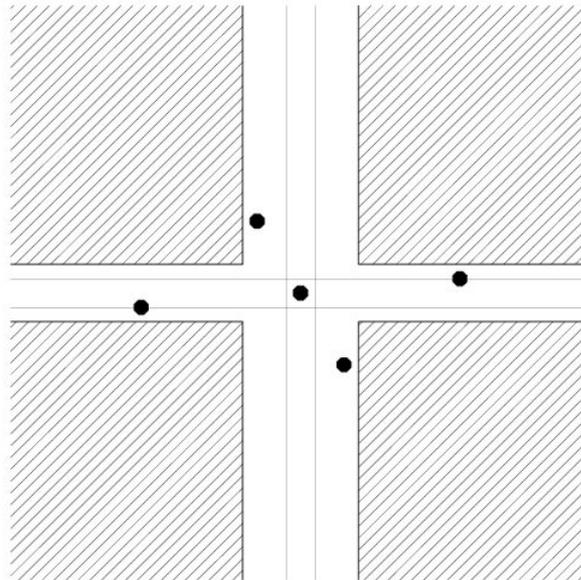
Figure 3: The 'starext' pointing pattern. The five dots show where a bright star is placed, always in between the (shaded) CCD pixels. The small box around the star, whose size corresponds to how close the star gets to the pixels, is left unexposed by the pattern.

If N>5 the pattern is repeated, but with the addition of progressively larger diagonal offsets of (1,1), (-1,-1), (2,2), (-2,2) arcsec, etc. These decrease the size of the unexposed area by a corresponding amount.

The starext pattern is illustrated in Figure 4. It covers the field quite uniformly, while keeping 14 small rectangles of size DX × DY unexposed. These are located near the intersection of the gaps between CCD rows and columns between rows 1 and 2, or between rows 3 and 4. Placing a bright star in the center of one of these areas will keep it off the CCDs in all N exposures.

The starext pattern has four parameters that govern its action:

XGAP   size of the gap in X to bridge (default 25 arcsec)
YGAP   size of the gap in Y to bridge (default 85 arcsec)
DX   X-size of the area to keep unexposed in the N=5 pattern (default 8 arcsec)
DY   Y-size of the area to keep unexposed in the N=5 pattern (default 8 arcsec)

The offsets with respect to the center of the field are then

$(0,0)$
$+/-$ $((3 \, XGAP-DX)/2 \, , (YGAP-DY)/2)$
$+/-$ $((XGAP-DX)/2 \, , (-3YGAP+DY)/2)$

Normally DX<XGAP. If DX>XGAP but <2 XGAP, then an area of 2 XGAP – DX is left unexposed; similarly in Y. This leads to greater overlap between the CCDs but no better field coverage. If DX=XGAP then three of the exposures will be taken at the same X-position, which can cause bad columns in the CCDs to overlap.

The gap between rows 2 and 3 (11 arcsec) is 70 arcsec narrower than the other gaps in Y, so if DY is chosen between 70 and 81 arcsec then a further row of seven unexposed areas is formed along the X-axis. Each of these gaps has a size DX × (DY-70 arcsec). Such a pattern produces rather large unexposed areas along the wider dead rows, though.
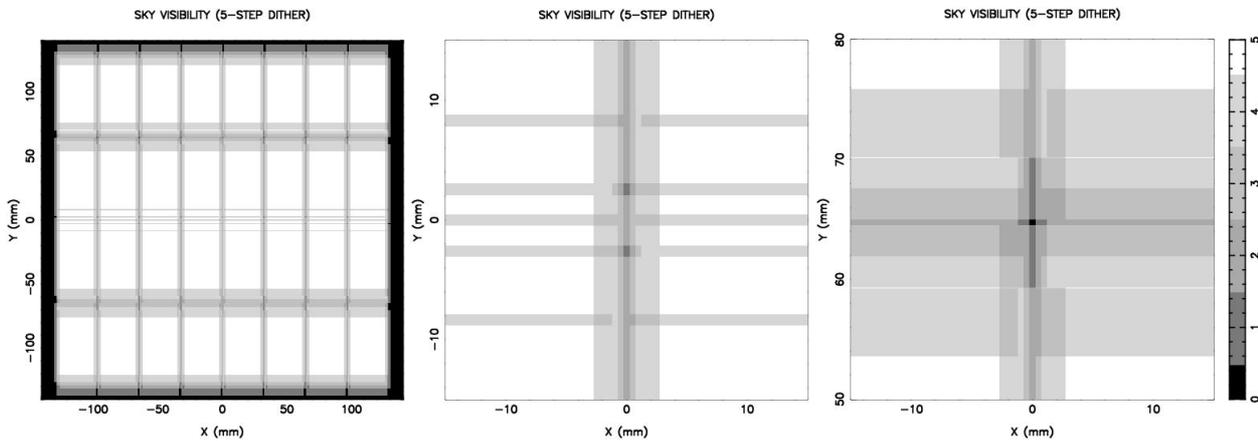
Figure 4: Relative exposure level over the field in a 5-point 'starext' dither pattern. The central square in the right-hand panel is left unexposed.

5 Explanations of the P2PP Entry Fields

5.1 User defined P2PP entry fields – DET keywords

Exposure Time Exposure time of an individual exposure in seconds. Default is NODEFAULT: user input is expected. The shortest exposure time for OmegaCAM shutter is <1ms, see **[RD1]** for more details.

Exposure Level Requested intensity level in ADUs. This parameter is used by the OMEGACAM_img_cal_skyflat template to compute the exposure time for sky flats. Default is 20000 ADU.

5.2 User defined P2PP entry fields – SEQ keywords

Number of Exposures The number of exposures to be taken for a given instrument setup. This is the total number of exposures that will be taken by the respective template. Default is 1.

5.3 User defined P2PP entry fields – TEL keywords

Rotator offset angle Angle of the telescope rotator on the sky. It is measured in degrees South over East. Possible values are 0.0°, 90.0°, 180.0°, and 270.0°. Default is 0.0°.

Additional Velocity RA The velocity of the non-sidereal tracking and auto guiding in right ascension. The value is given in arcsec/s on the sky. Default is 0 arcsec/s.

Additional Velocity DEC The velocity of the non-sidereal tracking and auto guiding in right ascension. The value is given in arcsec/s on the sky. Default is 0 arcsec/s.

Start autoguiding? Specify if OmegaCAM autoguide corrections have to be applied. The value is T/F (True/False). Default is T.

RA of 1st/2nd guide star The right ascension of the user selected guide star in hhmmss. Equinox is J2000. Default is 0: 00^h 00^m 00^s, which means that the operator will interactively pick a suitable guide star (or that a guide star will be selected automatically from a catalogue).

DEC of 1st/2nd guide star The declination of the user selected guide star in ±ddppss. Equinox is J2000. Default is 0: 00° 00′ 00″, which means that the operator will interactively pick a suitable guide star (or that a guide star will be selected automatically from a catalogue).

Magnitude of 1st/2nd GS Magnitude of the user selected guide star. Default is 12.

ADC Setting The following options are supported for the Atmospheric Dispersion Corrector (ADC): "COORD" and "NONE". If "NONE" is specified, then the ADC will not be in the path during the observation. If "COORD" is specified, then the ADC will be in the path during observation and will be set according to the telescope coordinates.

Offset step size Size of the telescope offset steps, in seconds of arc in the sky, when observing using the **jitter** pattern (see Section 4.1). Default is 1 arcsec.

Step size in X Size of the telescope offset steps in seconds of arc in the sky, along CCD mosaic X direction, when observing using the **diag dither** pattern (see Section 4.2). Range is 0÷999 arcsec. Default is 25 arcsec. For the camera position angles 0 and 180 degrees, an offset in +X implies a telescope offset towards East. For the camera position angles of 90 and 180 degrees an offset in +X implies a telescope offset towards North.

Step size in Y Size of the telescope offset steps in seconds of arc in the sky, along CCD mosaic Y direction, when observing using the **diag dither** pattern (see Section 4.2). Range is 0÷999 arcsec. Default is 85 arcsec. For the camera position angles 0 and 180 degrees, an offset in +Y implies a telescope offset towards North. For the camera position angles of 90 and 180 degrees an offset in +Y implies a telescope offset towards East.

Unexposed gap size in X Size, in seconds of arc in the sky, of the area to be left unexposed along the CCD mosaic X direction, when observing using the **starex dither** pattern (see Section 4.2). Range is 0÷25 arcsec. Default is 8 arcsec.

Unexposed gap size in Y Size, in seconds of arc in the sky, of the area to be left unexposed along the CCD mosaic Y direction, when observing using the **starex dither** pattern (see Section 4.2). Range is 0÷85 arcsec. Default is 8 arcsec.

Dither pattern name Name of the dither pattern to use (see Section 4.2). One of 'diag', 'starext'. Default is 'diag'.

List of tel. RA offsets List of telescope offsets in right ascension, in seconds of arc on the sky, to be applied when observing using the generic OMEGACAM_img_obs_offset template. Range is -9999÷9999 arcsec, default is 0 arcsec.

List of tel. DEC offsets List of telescope offsets in declination, in seconds of arc on the sky, to be applied when observing using the generic OMEGACAM_img_obs_offset template. Range is -9999÷9999 arcsec, default is 0 arcsec.

5.4   User defined P2PP entry fields – INS keywords

Filter Name Name of filter to be selected from the filter pull-down menu. Since P2PP is an off-line preparation tool, it is not connected to the real database of the operational instrument, so that it cannot verify whether a filter is actually installed in the instrument. See Table 1 for a list of filters currently available for OmegaCAM. More information on filters can be found in **[RD1]**. Default is NODEFAULT: user input is expected.

Lamp Set Calibration lamp set to use for dome flat fields. In OmegaCAM two sets of lamps are available: they are simply named 1 and 2. One set is declared the *default* and used for routine daily calibrations, meanwhile the second set (spare) is cross-calibrated against the first. Once the lifetime of the default set of lamps has expired, its role is taken over by the other set, which then becomes the default, and the former set is replaced with new lamps. For further information see **[RD2]**. The user has the option to select the default set, the non-default one, or explicitly set 1 or 2. Not surprisingly, the default is to use the *default* lamp set.

Table 1: OmegaCAM filters in P2PP

Filter Name in P2PP	Filter Type
u_SDSS	SDSS u′
g_SDSS	SDSS g′
r_SDSS	SDSS r′
i_SDSS	SDSS i′
z_SDSS	SDSS z′
B_JOHN	Johnson B
V_JOHN	Johnson V
v_STRM	Strömgren v
H_ALPHA	Hα, 4 quadrants, redshifts 0,0.01,0.02,0.03
NB_659	Hα, redshift 0 (private filter VPHAS+)
u_g_r_i_SDSS	SDSS u′, g′, r′, i′
NB_454_494_533_575	Mosaic of four blue narrow band filters (private)
NB_617_710_755_817	Mosaic of four red narrow band filters (private)
NB_852_861_869_878	"Night sky leak" filter (private filter Munich Obs.)
opaque	Opaque aluminium filter (for protection)

5.5   User defined P2PP entry fields – OCS keywords

Strategy Observing strategy. This keyword is not used by the ESO data reduction pipeline, but may be used to specify observations taken with a particular purpose. This information is taken into account in some of the OmegaCAM consortium's data processing. Possible values are: "Deep", "Freq", "Mosaic" and "Standard".

  Deep is for deep integrations, possibly taken at selected atmospheric conditions over several nights; the standard image pipeline will not combine images taken over several nights.

  Freq is used for observations which frequently visit (monitor) the same field on timescales ranging from minutes to months.

Mosaic   is used for observations that map areas of the sky larger than 1 degree. The combination of various field centers into one image is not considered a standard pipeline task.

Standard   is meant for all the rest: observations that consist of a single observation block.

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