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Very Large Telescope
Paranal Science Operations
GRAVITY Template Manual

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Contents

1 INTRODUCTION

1.1 Scope

This document describes the observing templates for the 2nd generation VLTI instrument GRAVITY. This document will need to be used for preparing GRAVITY observations for observations in P99. Like with other VLT instruments, observations with GRAVITY are carried out making use of **observation blocks** (OBs). The OBs must be created by the user during Phase-2 preparation with the P2PP tool. An OB is a set of observing templates that describe and detail the target acquisition and the data recording. The user has to define the values of the template **keywords** (parameters).

The Template Manual requires the user to have some basic understanding of the GRAVITY instrument. If you are a first time user, we recommend to read the GRAVITY User Manual for P99:

`http://www.eso.org/sci/facilities/paranal/instruments/gravity/doc`

The OBs are prepared with the P2PP tool. For its installation and documentation of its usage see: `http://www.eso.org/observing/p2pp`. GRAVITY specific templates will be downloaded by the P2PP tool itself. If help is needed, we kindly point the reader towards the step by step tutorial for using P2PP with the GRAVITY templates.

Finally, the VLTI manual needs to be consulted for description of the system which are not instrument specific (e.g. AT configurations, limited magnitudes for field guiding, etc.) that one needs for preparing VLTI observations: link to VLTI User Manual

1.2 Contact information

In case of questions or suggestions related to Phase-2 preparation, please contact the ESO User Support Department (`usd-help@eso.org`).

1.3 Period of validity of this manual

This manual is valid for observations with GRAVITY during ESO Period 99, starting April 1st, 2017 and ending October 31st, 2017.

1.4 Glossary

- **Constrain Set (CS)**
  List of requirements for the conditions of the observation that is given inside an OB. OBs are only executed under this set of minimum conditions.
- **Observation Block (OB)**
  An Observation Block is the smallest schedulable entity for the VLT. It consists of a sequence of Templates. Usually, one Observation Block include one target acquisition and up to three exposure templates.
- **Observation Description (OD)**
  A sequence of templates used to specify the observing sequences within one or more OBs.

- **Observation Toolkit (OT)**
  Tool used to create queues of OBs for later scheduling and possible execution (service mode).

- **Proposal Preparation and Submission (Phase-I)**
  The Phase-I begins right after the CfP (Call-for-Proposals) and ends at the deadline for CfP. During this period the potential users are invited to prepare and submit scientific proposals. For more information, see:

  `http://www.eso.org/observing/proposals.index.html`

- **Phase-2 Proposal Preparation (P2PP)**
  Once proposals have been approved by the ESO Observation Program Committee (OPC), users are notified and the Phase-2 begins. In this phase, users are requested to prepare their accepted proposals in the form of OBs, and to submit them by Internet (in case of service mode). The software tool used to build OBs is called the P2PP tool. It is distributed by ESO and can be installed on the personal computer of the user. See:

  `http://www.eso.org/observing/p2pp`.

- **Service Mode (SM)**
  In service mode (opposite of the "Visitor-Mode"), the observations are carried out by the ESO Paranal Science-Operation staff (PSO) alone. Observations can be done at any time during the period, depending on the CS given by the user. OBs are put into a queue schedule in OT which later sends OBs to the instrument.

- **Template**
  A template is a sequence of operations to be executed by the instrument. The observation software of an instrument dispatches commands written in templates not only to instrument modules that control its motors and the detector, but also to the telescopes and VLTI sub-systems.

- **Template signature file (TSF)**
  File which contains template input parameters.

- **Visitor Mode (VM)**
  The classic observation mode. The user is on-site to supervise his/her program execution.

1.5 Modifications for P99

1.5.1 Instrument

P99 sees an expansion in the possible uses of GRAVITY by the community. First, GRAVITY is offered with the UTs and their MACAO systems. This increases the offered limiting magnitude by three. Secondly, the instrument's low spectral resolution setting can be used (only) in dual-field mode.

1.5.2 Templates

For P99, two template changes are implemented with respect to the templates from the past period and science verification.

- The biggest change is the split of the acquisition template according to single or dual field set-up. The split results in the absence of DF keywords in a SF observation, which should increase the transparency and ease of use. For DF observations there are no differences to the acquistion template apart from the name (see Sect. 2.2.2).
- The second change is the addition of a keyword that describes the expected visibility which is introduced for operational reasons.
- We would also like to make the reader aware of an improvement in the table of recommended exposure times

2 GRAVITY TEMPLATES

The number of GRAVITY OB templates for P99 is minimal and grouped according to the mode, i.e. either single-field (SF, on-axis fringe-tracking using the science star) or dual field (DF, off-axis fringe tracking using a reference star). Thus a SF and DF template for (1) preset, acquisition and fringe search and (2) fringe observation (for either science or calibrator). The templates need user-provided input for a limited number of keywords.

2.1 Observing modes

A description of the GRAVITY observing modes can be found on the public GRAVITY web pages for the science users. In summary, the instrument consists of two independent interferometers, the so-called fringe-tracker (FT) and the science spectrometer (SC). The fringe-tracker stabilizes the fringes on the science target (in single-field mode) or a nearby fringe-tracking reference star (in dual-field mode). This observing strategy allows exposures of up to 30 s on the science spectrometer without losing significant fringe contrast. The observing wavelength is for both channels the K-band ($2.0 - 2.45\,\mu$m). In P99 (as in the past period) only the imaging mode is offered. The astrometric mode will be offered at a later stage. The following setups of GRAVITY can be used for P99:

- Two distinct field modes: the dual-field and the single-field. In single-field mode the light of the science target is split 50/50 between fringe-tracker and science channel. In dual-field mode a nearby object (separation with the science target $1.5'' \leq d \leq 4''$ for ATs and 0.4" $\leq d \leq$ 2" for UTs) is used for fringe-tracking. All the light of the science target is injected into the science channel.
- Three spectral setups for the science spectrometer :
  1. Low Resolution $R \sim 20$ (DF only)
  2. Medium Resolution $R \sim 500$ (SF and DF)
  3. High Resolution $R \sim 4000$ (SF and DF)

  Note, the resolution of the fringe-tracker is fixed at $R \sim 20$ and its data is always delivered in the fits files. Hence the reason for low resolution for the SC spectrometer in dual field only.
- Two polarisation modes for the fringe-tracker & science spectrometer:

1. Split polarisation (only linear polarisation).
2. Combined polarisation.

For the best visibility accuracy "split polarisation" is recommended. In case of faint objects and SNR limitations "combined polarisation" is recommended. The polarisation mode has to be the same for fringe-tracker and science spectrometer.

- Telescope configurations of four ATs or four UTs.

Table 1 in Sect. 2.3.2 gives some preliminary guidelines for DIT values for the science spectrometer (the table has been updated with respect to the past period). The fringe-tracker DIT is set automatically based on the object's **correlated** K-band magnitude. It should be noted that the STRAP tip-tilt unit on the ATs or the AO unit MACAO on the UTs is a prerequisite for observations with GRAVITY. For proper MACAO/STRAP operations the Coudé guide star must be suitably bright for guiding. See VLTI user manual for the limiting brightness.

2.2 The acquisition template

According to P2PP rules, the first template in an OB must be an acquisition template. For GRAVITY, the name of this template is either *GRAVITY_single_acq* or *GRAVITY_dual_acq*. The sequence of these templates are very similar. They start by a "preset": the target coordinates (α, δ) are sent to the telescopes and the delay lines, so they can slew to the position corresponding to the target coordinates at preset time. Once the VLTI is tracking and Coudé-guiding, the target(s) should be seen on the *Acquisition Camera* of GRAVITY. Internal actuators take care of the field rotation and ensure that the target(s) is/are injected into the fringe-tracker and science channel fibers. In dual-field mode the internal differential delay lines are preset such that they compensate the differential optical path between the two objects. The final step in the acquisition template is to search and track fringes. The search uses a saw tooth pattern around the nominal fringe position (i.e. zero OPD). As soon as the fringes are found and the control loop is locked the acquisition template is finished and the science exposures defined in the observation template can commence.

What follows is a detailed description of some important definitions and parameters of the acquisition templates. The user is advised to read through these subsections in order to create the acquisition template correctly.

2.2.1 Which star is which in single-field mode?

As GRAVITY observations may need up to three different objects (telescope Coudé guide star, instrument fringe-track object and instrument science object), the user can find in these two subsections details on how the different objects are defined in the acquisition template.

In GRAVITY SF mode, the science star and the FT star are the same object. The SF acquisition template only lists the keyword related to the science object. In standard observing, one can either chose telescope on-axis or off-axis Coudé guiding. In telescope on-axis guiding, the observation uses only one star to guide the telescope, to track the fringes and to record the science data. If the science star is not bright enough for the optical telescope guiding system, another, off-axis star can be chosen to guide the telescope. This is explained in detail in the VLTI user manual.

2.2.2 Which star is which in dual-field mode?

In order to make efficient use of the VLTI field of view of 4" (ATs) and 2" (UTs), GRAVITY DF observations are preset at the telescope to coordinates that correspond to a position in between the FT and SC source. The system does this automatically based on the coordinates and the separation provided in the acquisition template. (The coordinates in the target field are those of the FT star.) This implementation means that coudé guiding in dual-field is **always** off-axis. Therefore, the user has to chose "setuptfile" in dual-field model and provide the properties of the coudé guide star. In most cases, the latter is the FT star as it is usually the brightest both in the optical (for STRAP) and in the near-IR (for fringe tracking). However the guide star can also be a third object (distance restrictions apply, see VLTI user manual) when both the FT and SC objects are too faint for STRAP. It is also possible that the target of scientific interest is the Coudé guide star, e.g. when it is much bluer than the FT object and therefore the brighter object in V for STRAP guiding.

2.2.3 Proper motion and parallax

The knowledge of the current object coordinates (RA,DEC) determines the ability to predict the fringe position. For targets with a proper motion larger than 50 mas/year or a parallax greater than 100 mas it is important to provide both values in the acquisition template. If not provided, the fringe search can take significantly longer than normal. For an effective use of the allocated time we request that the known proper motions are incorporated into the OBs.

2.2.4 STRAP guiding with the ATs

The Auxiliary Telescopes guide by means of the STRAP tip-tilt sensor. The VLTI user manual gives details on STRAP which we summarize here. It is not possible under any weather conditions to perform GRAVITY observations without the telescopes properly guiding. The requirements for successful STRAP guiding are:

- The guide star must be brighter than $V = 13^m$. Note however that the tip-tilt correction drops significantly in K with a STRAP guide star fainter than 11th magnitude and that by Coudé guiding on a star of $V = 13^m$, the K-band limit for the SC object drops by 1 magnitude.
- The guide star must be within a radius of <15" from the science target, implementing the limits for fringe-tracking at the VLTI. The effective tip-tilt correction drops with distance from the science target, so it is recommended that the user chooses a guide star as close as possible. A rule of thumb is that the magnitude limit is brighter by 1 magnitude for every 15" from the science object.
- It is requested that the faintest (if variable) V magnitude of the guide star is given in the keyword `COU.GS.MAG`.

2.2.5 Science and fringe-tracking target K magnitudes

The `SEQ.FT.ROBJ.MAG` keyword should be used to specify the **correlated** K magnitude of the fringe-tracking object. This value is the $-2.5 \times^{10} \log(\text{Visibility}) + \text{K}$ for a visibility expected on the longest baseline of an "open telescope triplet" (or non-closed triangle for example AT1-AT2, AT2-AT3 and AT3-AT4). This baseline does not correspond to the longest baseline of the quadruplet as fringe tracking will make use of so-called bootstrapping (i.e. if one knows the zero-OPD on two of the baselines of a closed triangle then the remaining one can be deduced, e.g. if ZOPD on baseline 12 and 23 are known then the ZOPD on 13 can be deduced).

In single-field mode the **correlated** K magnitude is equivalent to the science target correlated K magnitude. In dual-field mode this corresponds to the correlated K magnitude of the reference object used for fringe-tracking. In dual-field mode the correlated K magnitude of the science target should be independently provided using the keyword `SEQ.INS.SOBJ.MAG`.

2.2.6 Field guiding H magnitude

The `SEQ.FI.HMAG` keyword should be used to specify the uncorrelated H magnitude of the science source (in single field) or the H-band brightest of the two objects (SC or FT) in dual field. The *Acquisition Camera* uses the H band light for the object acquisition and slow field guiding.

2.2.7 Selecting the polarisation mode

Observations can be done in polarisation split or combined mode. In split mode a Wollaston prism is introduced in the beam. It splits the two linear polarisations on the detector. This increases the visibility accuracy as polarisation phase shifts originating from the optical train are separated. The disadvantage however is that the light is spread over twice as many pixels, i.e. the read noise is increased. In case of bright targets (where read noise can be neglected) the split mode is to be preferred. The combined mode should be used in case of faint objects, where read noise dominates the SNR. Currently FT and SC have to be in the same polarisation mode. Polarisation split mode can be chosen by setting the keywords `INS.FT.POL` and `INS.SPEC.POL` to *IN*. The combined mode is chosen with *OUT*.

2.2.8 Selecting the resolution mode

In P99 in SF two spectral resolutions are offered (medium and high), whereas in DF all three can be chosen. The spectral mode can be selected by setting the keyword `INS.SPEC.RES` to *LOW*, *MED* or *HIGH*. The choice of resolution mode depends on whether it is SF or DF, the target brightness, science goals, desired visibility accuracy (SNR) and available observing time. As a "rule-of-thumb" the user should consider high resolution (and combined polarisation) only for targets brighter than K<5.5. Otherwise the necessary on-source integration time exceeds 1 h for any reasonable SNR. Fainter targets should be observed in medium resolution (DF and SF) or low resolution (DF only). The reason why low resolution is offered in DF only is that the FT resolution is the same as SC and those SC low resolution in SF would imply duplication of data (as the same polarization is imposed).

2.2.9 Fringe-tracker

GRAVITY by default operates always with the internal fringe-tracker. It is not possible to use GRAVITY without this system. The DIT of the fringe-tracker is automatically selected based on the correlated K magnitude of the FT object provided by the user.

Currently, fringe-tracking is feasible under the following conditions:

- Seeing below 1.5 arcseconds
- The transparency should be CLR or better.
- τ_0 above 1.5 ms
- Altitude above 40 degrees
- The target must not be brighter than K=-2^m because the fringe-tracker saturates otherwise.
- Under good seeing (better than 1") the limiting correlated magnitude is K=6^m in single-field mode and K=6.5^m in dual-field mode on the ATs. For seeing between 1-1.5" the limiting magnitude is K=5^m in single-field mode and K=5.5^m in dual-field. The limiting magnitudes with the UTs are 3 magnitudes fainter for each of the two meteorological boundary condition.
- The correlated magnitude has to fulfill the above criteria on at least three baselines that do not form a triangle (e.g. 13/23/24, or 12/13/14). In this case it is possible to boot-strap other baselines with lower visibilities.

These numbers should be regarded as preliminary given that knowledge of the performances of a new instrument under certain weather conditions is limited.

2.2.10 Dual-field mode

In dual-field mode the R.A. and Dec. offset in [mas] of the science target relative to the fringe-tracking object has to be provided with the keywords `SEQ.INS.SOBJ.X` and `SEQ.INS.SOBJ.Y`, i.e. the coordinates of the FT source are the reference. As a result, these coordinates also need to be filled out in the "target" tab in P2PP (i.e. the `TEL.TARG` keywords in Sect. 2.4). The binary separation should be accurate to better than 100 mas. If the separation is poorly known the time to fringe search might increase significantly, i.e. the observing efficiency could be reduced. See also Sect. 2.2.2 for the definition of the FT, SC and Coudé guide objects.
The requirements for the dual-field mode are:

- Science target correlated K magnitude must not differ more than 3 mag from fringe-tracker source.
- The separation between fringe-tracker source and science target must be within the range $[0.4'', 2'']$ for UTs and $[1.5'', 4'']$ for ATs.

2.3 The observation template

Following the acquistion template, the user has to chose a science observation template. This template is the second and the last one in any GRAVITY OB. It is used to record the fringe and sky data. There are currently only four templates:

1. single-field science target, *GRAVITY_single_obs_exp*
2. single-field calibrator, *GRAVITY_single_obs_calibrator*
3. dual-field science target, *GRAVITY_dual_obs_exp*

4. dual-field calibrator, *GRAVITY_dual_obs_calibrator*

The templates use identical keywords. The appropriate template should be chosen according to the mode (single/dual) and the target (science/calibrator). Each template allows a sequence of exposures. The sequence consists of science target exposures (OBJECT) and off-source exposures (SKY). The observing sequence can be defined by the user with the keyword `SEQ.OBSSEQ`. The sequence can contain any combination of object (O) and sky (S) exposures. The `SEQ.SKY.X` and `SEQ.SKY.Y` are used to select the offset of the sky exposure. These offsets will move the GRAVITY internal actuators in the directions given. Make sure that in dual-field the sky offset will not position the SC star on the FT fibre or vice versa. Safest is to offset perpendicular to the binary separation vector.

2.3.1 Integration time

The DIT of the fringe-tracker is automatically set based on the provided correlated K-band magnitude. The DIT `DET2.DIT` for the science spectrometer should be chosen according to the mode and science target **uncorrelated** K-band magnitude. Table 1 lists the suggested DITs for the various modes and magnitudes. The number of frames (NDIT) per exposure can be specified with `DET2.NDIT.OBJECT` for the science exposure and `DET2.NDIT.SKY` for the sky exposure.
The following requirements apply:

1. The total exposure time (DIT x NDIT) must not exceed 300 s.
2. The number of science frames (NDIT) must not exceed 300 and be more than 10.

Note: Stability of the instrument asssessed during the commissioning shows that the DIT of the Science and Calibrator targets need not be the same, contrary to VLTI practice and experience with the other instruments.

2.3.2 Execution time

A conservative estimate of a CAL/SCI sequence is one hour. Each acquisition takes roughly 10 min (it can take longer on faint targets). About 20 min have to be spent for object and sky exposures. **Note:** The calibrator has to be observed with the same configuration and thus the total execution time for one calibrated visibility spectrum is 60 minutes (SCI-CAL).

For this period, we apply the following model for the calculation of the execution time for SF:

$$\text{exectime} = 600\,\text{sec} + \text{DIT} \times \text{NDIT} \times \text{NEXP} + 40\,\text{sec} \times \text{NEXP} \tag{1}$$

and for DF:

$$\text{exectime} = 900\ \text{sec} + \text{DIT} \times \text{NDIT} \times \text{NEXP} + 40\,\text{sec} \times \text{NEXP}, \tag{2}$$

where NEXP is the number of exposure entered in the observing template keyword OBSSEQ (see following section). For background limited data, the default is to use the same number of NDIT for S(ky) and O(bject).

A typical example on how to fill the 30 minutes would be the following:

In single-field: If we have a OSO sequence, we have to subtract 600 min offset and 3*40 sec offset, leaving 1080 sec, or 360 seconds for each exposure, which is too much.

Table 1: Summary of available modes, spectral and polarisation configurations, telescopes (Tel), uncorrelated K magnitudes (K) and suggested DITs for the science spectrometer. In DF the same DITs are adopted as in single-field except that the appropriate DF DIT corresponds to that of a star 0.7 mag brighter (K_{df}=K - 0.7). This reflects that in dual-field the light is not split 50/50 between FT and SC. Likewise for UT observations, one choses a AT SF DIT that corresponds to a star 3 (or 3.7) magnitudes brighter than the UT science target. Note that the DIT for the calibrator **can** be different from the one used for the science object. P99 is the first period with UT observations and the recommended DITs in this table are highly preliminary. **Performances are strongly seeing dependent.**

Mode	Spec	Pol	Tel	K	DIT [s]
Single-field	MR	Comb	AT	$-1.0<K\leq1.0$	0.3
Single-field	MR	Comb	AT	$1.0<K\leq2.5$	1.0
Single-field	MR	Comb	AT	$2.5<K\leq3.0$	3.0
Single-field	MR	Comb	AT	$3.0<K\leq3.5$	5.0
Single-field	MR	Comb	AT	$3.5<K\leq4.5$	10.0
Single-field	MR	Comb	AT	$5.0<K\leq9.0$	30.0
Single-field	MR	Split	AT	$-2.0<K\leq0.0$	0.3
Single-field	MR	Split	AT	$0.0<K\leq1.5$	1.0
Single-field	MR	Split	AT	$1.5<K\leq2.5$	3.0
Single-field	MR	Split	AT	$2.5<K\leq3.0$	5.0
Single-field	MR	Split	AT	$3.0<K\leq4.0$	10.0
Single-field	MR	Split	AT	$4.0<K\leq9.0$	30.0
Single-field	HR	Comb	AT	$-2.0<K\leq-0.5$	1.0
Single-field	HR	Comb	AT	$-0.5<K\leq0.5$	5.0
Single-field	HR	Comb	AT	$0.5<K\leq2.0$	10.0
Single-field	HR	Comb	AT	$2.0<K\leq9.0$	30.0
Single-field	HR	Split	AT	$-2.0<K\leq-0.5$	3.0
Single-field	HR	Split	AT	$-0.5<K\leq0.0$	5.0
Single-field	HR	Split	AT	$0.0<K\leq 1.0$	10.0
Single-field	HR	Split	AT	$1.0<K\leq 4.5$	30.0
Dual-field	all	all	AT	$K-0.7$	-
Single-field	all	all	UT	$K-3.0$	-
Dual-field	all	all	UT	$K-3.7$	-

Table 2: Overview of DIT and recommended NDIT values for different number of exposures for SF and DF mode. The value DIT* NDIT should be less than 300 seconds, while the total execution time of the OB is <=1800 seconds. The number of science frames (NDIT) must not exceed 300.

DIT (s)	Nexp (O S ..)	NDIT SF	Execution time SF	NDIT DF	Execution time DF
1.0	2	300	1280	300	1580
	3	300	1620	260	1800
	4	260	1800	185	1800
	5	200	1800	140	1800
3.0	2	100	1280	100	1580
	3	100	1620	85	1785
	4	85	1780	60	1780
	5	65	1775	45	1775
5.0	2	60	1280	60	1580
	3	60	1620	50	1770
	4	50	1760	35	1760
	5	40	1800	25	1725
10.0	2	30	1280	30	1580
	3	30	1620	25	1770
	4	25	1760	18	1780
	5	20	1800	14	1800
30.0	2	10	1280	10	1580
	3	10	1620	-	-

So, we typically need to use OSOS, leaving 1040 sec, or 260 sec per exposure. So, for magnitude 1 in MR, this would typically be DIT=1s and NDIT=260. Or, for magnitude 1 in HR, this would typically be DIT=30s and NDIT=8.

2.3.3 Acquisition camera frames

The internal *Acquisition Camera* is used for the object acquisition as well as slow pupil and tilt guiding. By default each science exposure contains one acquisition frame (NDIT=1) with an integration time DIT=0.7 s. This means the user obtains an H-band image of the science target with roughly 4” field-of-view.

2.4 User keywords

In the following tables, we give for each template the keywords that have to be set by the user with the P2PP tool.

2.4.1 GRAVITY_dual_acq.tsf

Parameter	Range *(Default)*	Label
SEQ.FT.ROBJ.NAME	(Name)	FT object name
SEQ.FT.ROBJ.MAG	-10...30 *(0)*	FT object correlated magnitude
SEQ.FT.ROBJ.DIAMETER	0...300 *(0)*	FT object diameter (mas). Only required for **calibrator** OBs.
SEQ.FT.ROBJ.VIS	-0...1.0 *(0)*	FT object visibility
SEQ.SC.SOBJ.NAME	(Name)	SC object name
SEQ.SC.SOBJ.MAG	-10...30 *(0)*	SC object correlated magnitude
SEQ.SC.SOBJ.DIAMETER	0...300 *(0)*	SC object diameter (mas). Only required for **calibrator** OBs.
SEQ.SC.SOBJ.VIS	-0...1.0 *(0)*	SC object visibility
SEQ.INS.SOBJ.X	150...7000 *(0)*	RA offset of science target in mas.
SEQ.INS.SOBJ.Y	150...7000 *(0)*	DEC offset of science target in mas.
SEQ.FI.HMAG	-10...25 *(0)*	AcqCam guide star magnitude in H
TEL.TARG.PARALLAX	-20...20 *(0)*	FT object parallax (arcseconds)
INS.SPEC.RES	LOW MED HIGH *(MED)*	Science spectrometer resolution LOW, MED or HIGH.
INS.FT.POL	IN OUT *(IN)*	Fringe-tracker polarisation mode split (IN) or combined (OUT). Currently INS.FT.POL and INS.SPEC.POL have to be in the same mode.
INS.SPEC.POL	IN OUT *(IN)*	Science spectrometer polarisation mode split (IN) or combined (OUT). Currently INS.FT.POL and INS.SPEC.POL have to be in the same mode.
COU.AG.GSSOURCE	SETUPFILE SCIENCE *(SCIENCE)*	Coude guide star (GS) input. This can be either the science object (SCIENCE), a guide star (SETUPFILE). See section 2.2.2.
COU.AG.ALPHA	RA *(0.)*	GS RA if SETUPFILE
COU.AG.DELTA	DEC *(0.)*	GS DEC if SETUPFILE
COU.AG.PMA	-10...10 *(0)*	GS proper motion in RA
COU.AG.PMD	-10...10 *(0)*	GS proper motion in DEC
COU.GS.MAG	0...25 *(0.)*	GS magnitude in V. This must be supplied and in the case of a variable star the faintest magnitude should be given.
TEL.TARG.PMA	-10...10 *(0)*	FT object proper motion in RA
TEL.TARG.PMD	-10...10 *(0)*	FT object proper motion in DEC
TEL.TARG.ADDVELALPHA	-15...15 *(0)*	Differential tracking in RA
TEL.TARG.ADDVELDELTA	-15...15 *(0)*	Differential tracking in DEC

2.4.2 GRAVITY_single_acq.tsf

Parameter	Range *(Default)*	Label
SEQ.SC.SOBJ.NAME	(Name)	SC object name
SEQ.SC.SOBJ.MAG	-10...30 *(0)*	SC object correlated magnitude
SEQ.SC.SOBJ.DIAMETER	0...300 *(0)*	SC object diameter (mas). Only required for **calibrator** OBs.
SEQ.SC.SOBJ.VIS	-0...1.0 *(0)*	SC object visibility
SEQ.FI.HMAG	-10...25 *(0)*	AcqCam guide star magnitude in H
TEL.TARG.PARALLAX	-20...20 *(0)*	SC object parallax (arcseconds)
INS.SPEC.RES	MED HIGH *(MED)*	Science spectrometer resolution LOW, MED or HIGH.
INS.FT.POL	IN OUT *(IN)*	Fringe-tracker polarisation mode split (IN) or combined (OUT). Currently INS.FT.POL and INS.SPEC.POL have to be in the same mode.
INS.SPEC.POL	IN OUT *(IN)*	Science spectrometer polarisation mode split (IN) or combined (OUT). Currently INS.FT.POL and INS.SPEC.POL have to be in the same mode.
COU.AG.GSSOURCE	SETUPFILE SCIENCE *(SCIENCE)*	Coude guide star (GS) input. This can be either the science object (SCIENCE), a guide star (SETUPFILE). See section 2.2.2.
COU.AG.ALPHA	RA *(0.)*	GS RA if SETUPFILE
COU.AG.DELTA	DEC *(0.)*	GS DEC if SETUPFILE
COU.AG.PMA	-10...10 *(0)*	GS proper motion in RA
COU.AG.PMD	-10...10 *(0)*	GS proper motion in DEC
COU.GS.MAG	0...25 *(0.)*	GS magnitude in V. This must be supplied and in the case of a variable star the faintest magnitude should be given.
TEL.TARG.PMA	-10...10 *(0)*	FT object proper motion in RA
TEL.TARG.PMD	-10...10 *(0)*	FT object proper motion in DEC
TEL.TARG.ADDVELALPHA	-15...15 *(0)*	Differential tracking in RA
TEL.TARG.ADDVELDELTA	-15...15 *(0)*	Differential tracking in DEC

2.4.3 Acquisition keywords

Below follows a more detailed description of the keywords in the acquisition templates:

- `SEQ.FI.HMAG`: is the uncorrelated H band magnitudes of the brightest target in the field (usually the fringe-tracking target). This target will be used for slow field guiding with the *Acquisition Camera*.
- `SEQ.FT.ROBJ.MAG`: is the correlated K magnitude of the fringe-tracking target. This parameter is required to set the optimum DIT of the fringe-tracker.

- `TEL.TARG.PMA/PMD`: RA/DEC proper motion of the fringe-tracking target in arcsec/yr. This parameter is required for high proper motion (>50 mas/yr) objects to estimate correct fringe position.
- `TEL.TARG.PARALLAX`: This keyword specifies the parallax of the fringe-tracking target. It is required for accurate fringe positioning if the parallax exceeds 100 mas.
- `TEL.TARG.ADDVELALPHA/DELTA`: These keywords should be used for object moving on the sky with a large differential motion, as e.g. asteroids or comets. For the objects with normal proper motion (a few arcseconds/year) should fill in the field `proper motion RA/DEC` (units are in arcsec/year) in the bottom right of the P2PP window.
- `COU.AG.GSSOURCE`: This keyword is used to tell the system which source shall be used for Coudé guiding (see Sect. 2.2.2).
  - In **single-field mode** the keyword can have the following values:
    - `SCIENCE`: Coudé guiding on the science object. The coordinates are those given in the `RA/DEC` fields in the target tab of P2PP.
    - `SETUPFILE`: Coudé guiding on a chosen guide star different from the science object. The coordinates are those given in the `COU.AG.ALPHA/DELTA` fields in the acquisition template. Please note the constraints for STRAP/MACAO guide star in section 2.2.4 and that these constraints are also pertinent if Coudé guiding are attempted on the `SCIENCE` object.
  - In **dual-field mode** it must always be `SETUPFILE`. The coordinates given in `COU.AG.ALPHA/DELTA` can either be the fringe-tracking target coordinates or the coordinates of a different guide star (Sect. 2.2.2).
- `COU.AG.ALPHA/DELTA`: Coordinates of the Coudé guide star. These keywords should only be specified if the keyword `COU.AG.GSSOURCE` is set to `SETUPFILE`. Otherwise they should be `0.0` as the Coudé Guiding will use the science target to guide on.
- `COU.AG.PMA/PMD`: RA/DEC proper motion of the Coudé guide star in arcsec/yr. These keywords should only be specified if the keyword `COU.AG.GSSOURCE` is set to `SETUPFILE`. Otherwise they should be `0.0` as the Coudé Guiding will use the science target to guide on.
- `COU.GS.MAG`: Coudé guide star Visual magnitude. This should **always** be specified. In the case of a variable star the faintest magnitude should be given.
- `INS.FT.POL` and `INS.SPEC.POL`: These keywords set the desired FT and SC polarisation configuration. It can be:
  - `IN`: Wollaston prism is moved in. The s and p polarisation are split on the detector. This mode offers the highest visibility accuracy at the cost of higher read noise since the light is split over twice as many pixels. This mode is suggested for very bright targets.
  - `OUT`: Wollaston prism is moved out. Both polarisations are combined on the detector. This mode is suggested for faint targets.

  Note: Currently the polarisation setting for FT and SC have to be the same.

- INS.SPEC.RES: This keyword sets the desired SC spectral configuration. It can be:
  - lOW: The medium resolution grism is used (R∼20).
  - MED: The medium resolution grism is used (R∼500).
  - HIGH: The high resolution grism is used (R∼4000).

  LOW can only be requested in DF mode.

- FT.ROBJ.DIAMETER: This keyword is only required for a calibrator (if available). It is used by the pipeline to correct for the calibrator intrinsic size and visibility.

- SEQ.INS.SOBJ.MAG: is the correlated K magnitude of the science target in dual-field mode. This parameter is required to set the parameters for the science spectrometer fringe guiding.

- SEQ.INS.SOBJ.DIAMETER: This keyword is only required for calibrator observed in dual-field mode. It is used by the pipeline to correct for the calibrator intrinsic size and visibility. It is however suggested to observe calibrators in single-field mode (also if used for dual-field science targets). Therefore this keyword is normally not required.

- SEQ.INS.SOBJ.X/Y: RA/DEC offsets in milli-arcseond of the science target relative to fringe-tracking target. The offsets have to be known to better than 100 mas in order to avoid delays in the fringe search. If this value is calculated from the positions of each component, the distance in RA (in mas) should include the cos(DEC) term. The offsets have to be provided for the epoch of the observation. For binaries with high differential proper motion this offset can change significantly within one period.

2.4.4 GRAVITY_single_obs_exp.tsf, GRAVITY_single_obs_calibrator.tsf, GRAVITY_dual_obs_exp.tsf and GRAVITY_dual_obs_calibrator.tsf

Parameter	Range *(Default)*	Label
DET2.DIT	0.3 1 3 5 10 30 60 100 300 *(0.3)*	SC frame integration time (DIT in s)
DET2.NDIT.OBJECT	10. . . 300 *(25)*	Number of science target frames (NDIT)
DET2.NDIT.SKY	10. . . 300 *(25)*	Number of sky frames (NDIT)
SEQ.SKY.X	100. . . 2000 *(1000)*	Sky offset in RA (mas).
SEQ.SKY.Y	100. . . 2000 *(1000)*	Sky offset in DEC (mas).
SEQ.OBSSEQ	O S *(O S)*	Observing sequence of science (O) and sky (S) exposures.

A detailed explanation of the keywords in the observing template follows:

- DET2.DIT: SC frame integration time in seconds.

- DET2.NDIT.OBJECT/SKY: Number of science/sky frames per exposure. The total exposure time (DIT x NDIT) should not exceed 300s. For the best accuracy it is suggested to use a similar number of frames for science and sky.

- SEQ.SKY.X/Y: Internal actuator sky offset in RA/DEC (mas), these offsets are used for taking the sky exposure. These offsets will move the actuator in the given directions.

- `SEQ.OBSSEQ`: Observing sequence of science (O) and sky (S) exposures. Any sequence is possible as long as the total execution time does not exceed the limits discussed in section 2.3.2. As a tradeoff between efficiency and accuracy it is suggested to use a sequence like O S O.

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