Protocol for Ground Based Observations of SpectroPhotometric Standard Stars. III. Main Spectrophotometric Campaign

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Abstract

When trying to build a large set of ground based SpectroPhotometric Standard Stars for calibrating Gaia BP/RP spectra and G-Band images to a few % in absolute flux, it is essential to maintain the maximum homogeneity in data quality and treatment. This is especially true when data come from different observing sites around the globe and are obtained and treated by different persons. The observation protocols and the data reduction protocols are sets of detailed instructions for observers and collaborators that participate in the large effort required. This observation protocol concerns the main spectrophotometric campaign to build the Gaia SPSS grid.

Document History

Issue	Revision	Date	Author	Comment
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Acronym	**Description**
2MASS	Two Micron All Sky Survey
BFOSC	Bologna Faint Object Spectrograph and Camera
BP	Blue Photometer
CAFOS	Calar Alto Faint Object Spectrograph
CAHA	Centro Astronómico Hispano-Alemán
CU	Coordination Unit
DOLoRes	Device Optimized for the LOw RESolution
DU	Development Unit
EFOSC	ESO Faint Object Spectrograph and Camera
EON	End of Night report
EOR	End of Run report
ESO	European Southern Observatory
ETC	Exposure Time Calculator
GUI	Graphical User Interface
IFP	Instrument Familiarization Plan
NTT	New Technology Telescope
OB	Observing Block
PA	Parallactic Angle
REM	Rapid Eye Mount telescope
ROSS	REM Optical Slitless Spectrograph
RP	Red Photometer
RVS	Radial Velocity Spectrometer
SDSS	Sloan Digital Sky Survey
SEGUE	Sloan Extension for Galactic Understanding and Exploration
SPSS	Spectro-Photometric Standard Star
TNG	Telescopio Nazionale Galileo
WD	White Dwarf (star)
Wiki-Bo	Local CU5-DU13 Wiki pages at the Bologna Observatory

Contents

1 Introduction

Our task is to create a grid of SpectroPhotometric standard Stars to calibrate all Gaia BP/RP spectra and G-band photometry and possibly also RVS spectra (ST-002). The calibration model of Gaia photometry is still under refinement (PMN-001; PMN-002; PMN-003; SR-002), but it requires a large number (of the order of 200–300) of SPSS flux tables, calibrated with an accuracy of a few percent (see FVL-014, for requirements on SPSS flux tables). Such a large and homogenous database, matching all the above requirements, does not exist yet. To this aim, we defined a set of *Primary SPSS* (GA-001), that will be calibrated on the three CALSPEC *Pillars* (Bohlin, 2007), and which will be the ground-based calibrators of the *Secondary SPSS* (GA-003), i.e., the actual Gaia SPSS grid.

The observing strategy (MBZ-001) is based on the fact that spectrophotometric observations require a large amount of observing time in excellent sky conditions. Therefore, we split the main observing campaign into relative spectrophotometry and absolute photometry. Relative calibration of spectra obtained in good (but not necessarily photometric) conditions will provide the correct spectral shape, while absolute photometry will provide the correct spectral zeropoint. The absolute photometry observing procedure is described in the second observing protocol (EP-003), while this protocol describes the procedures needed for spectroscopic observations.

We run two observing campaigns at the moment, the *main campaign* just described, and the *auxiliary campaign* to test our candidate SPSS for variability or, better, to monitor their constancy. The observing protocol for auxiliary observations can be found in EP-003. Both campaigns make use of six different observing facilities (LF-001; GA-002), namely:

- BFOSC at the Loiano Cassini telescope, Italy, mainly for imaging;
- CAFOS at the 2.2 m Calar Alto telescope, Spain, imaging and spectra;
- DOLoRes at the TNG La Palma telescope, Spain, imaging and spectra;
- LaRuca at the 1.5 m San Pedro Martir telescope, Mexico, imaging;
- ROSS at the REM La Silla robotic telescope, Chile, relative photometry;
- EFOSC at the NTT La Silla telescope, Chile, imaging and spectra.

1.1 Observations checklist

The checklist (Table 1) describes the main steps of a spectroscopic run, and refers to the appropriate sections for more details.

TABLE 1: **Spectroscopy checklist.**

Task	Details	When	Section
Documentation	Wiki-Bo, Livelink	before run	Sec. 2
IFP tests needs	Wiki-Bo, contact us	before run	Sec. 2.1
Target selection	Wiki-Bo, STARALT	before run	Sec. 2.2
Exptimes	Wiki-Bo, ETCs	before run	Sec. 2.3
Setups	blue and red grisms/gratings		Sec. 2.3
	and wide and narrow slits		
Daytime calibrations	IFP tests	if needed	Sec. 2.1
	Bias × 5–10	daily	Sec. 3.1
	Lamp flats, 5–10 × setup	daily	Sec. 3.2
	Wave lamps, 5–10 × narrow slits	daily	Sec. 3.4
Twilight calibrations	Skyflat 1–3 × setup	once per run	Sec. 3.3
Flux calibrations	1–2 (pseudo-)Pillars × 3–2	every night	Sec. 4.1 and 4.2
	full sequence	first passage	
	wide slit only	later passages	
Telluric standard	full sequence × 1–3	at least once per run	Sec. 4.1 and 4.3
SPSS observations	full sequence	all targets as needed	Sec. 4.1 and 4.4
Morning calibrations	see above	if necessary	Sec. 3
End of night report	Web form (Wiki-Bo)	each morning	Sec. 5.1
Observing logs	Electronic form (Wiki-Bo)	each morning	Sec. 5.1
End of run report	Web form (Wiki-Bo)	end of run	Sec. 5.2
Data Delivery	CD & DVD by post	ASAP	Sec. 5.2

2 Run Preparation

You can find all you need to prepare your run in Wiki-Bo, our local Wiki pages in Bologna[1]. In particular you might find interest in:

- The *“Documentation”* section;
- The *“Summary of all our observing runs”* table;
- The *“Primary and Secondary SPSS”* tables;

The two most important steps, in which you will almost always need to contact us for help[2], are the target selection (Section 2.2), and the verification of the IFP tests still missing for the instrument/telescope you are observing at (Section 2.1 and EP-001). More details on run preparations can be also found in EP-003.

[1] `http://yoda.bo.astro.it/wiki`, using the credentials guest and gubana.
[2] The best person for target selection is G. Altavilla, while for the IFP calibrations it is S. Marinoni.

Reliable instrument manuals and miscellaneous information can be found for NTT[3], for CAHA[4], for TNG[5], and specifically for the DOLoRes GUI (graphycal user interface)[6]. Detailed step-by-step operating instructions for CAFOS@CAHA can be found in Appendix A. In any case, telescope operators are always present at TNG, NTT, and Cassini, while at CAHA they are available in case of problems and can give an introduction to the telescope/instrument on the first night. Similarly, night astronomers can provide help during the first night at all sites, and are available in case of problems.

2.1 Missing IFP observations

Because we are trying to obtain very high precision flux calibrations of both images and spectra, we need to perform several tests (linearity, consistency, stability and so on), which are summarized in the Livelink documents by GA-004, SMR-002, and other documents in preparation.

To check if IFP calibration frames are needed for your telescope and instrument combination[7] you can check the IFP pages in Wiki-Bo, or you can contact us. Once the need for new IFP data is assessed, you can follow the instructions in EP-001 to carry out the observations.

2.2 Targets selection

ID	Name	RA	Dec	B	V	Type	Abs. Phot	Short Var.	Long Var.	Spectra
343	sdss14511	20 42 42.4	-00 34 03.7	15.374	15.099	-	2xObs	Not Yet	4xObs	Done
338	GJ625	16 25 24.62	+54 18 14.77	11.80	10.17	M2V	2xObs	Done	4xObs	Not yet
242	WD1210+533	12 13 24.62	+53 03 57.5	13.78	14.12	O...	Not Yet	Data	1xObs	Not Yet
350	LTT377	00 41 30.47	-33 37 32.02	11.99	10.54	K	1xData	Done	04xData	Obs,Data
135	WD1615-154	16 17 55.25	-15 35 52.40	13.217	13.422	DA	2xObs	No	9xObs	Data
119	WD1031-114	10 33 42.76	-11 41 38.35	12.82	13.00	DAn	3xObs	Data	9xObs	Done
101	WD0046+051	00 49 09.90	+05 23 19.01	12.92	12.36	DZ7-8	4xObs	Done	9xObs	Done

FIGURE 1: Portion of the Secondary SPSS list.

To select targets you should use the information in the Wiki-Bo "*Observations*" section tables, which summarize the Primary and Secondary SPSS observations . Generally speaking, all objects with a *"yellow label"* (incomplete observations) or an *"orange label"* (not observed yet) in the *"spectra"* column should be considered when building your target list (see Figure 1). Additional tools for easily selecting stars from the Wiki-Bo tables can be found in the table pages, and some more details on target selection can be found in EP-003.

[3] http://www.eso.org/sci/facilities/lasilla/telescopes/ntt/index.html
[4] http://www.caha.es/alises/cafos/cafos.html
[5] http://www.tng.iac.es/instruments/lrs/manuals/TNG-DOLORES-001.pdf
[6] http://www.tng.iac.es/instruments/lrs/manuals/QuickUserGuide.pdf
[7] Special attention is needed in those cases where the instrument CCD is replaced by a new one.

To assign priorities, consider the following guidelines:

- Primary SPSS generally should have priority over Secondary SPSS;
- SPSS that already have other kinds of observations (lightcurve, absolute photometry) should have priority over SPSS that we did not start observing yet;
- SPSS around the ecliptic poles should have higher priority;
- SPSS belonging to other surveys (SDSS, SEGUE, 2MASS) generally should have higher priority than normal SPSS;
- SPSS of rare spectral types should have generally higher priority than those of the more represented spectral types;
- SPSS that can only be observed at one particular telescope should have precedence over those that can be observed by other telescopes as well.

Once your target list is ready, you should find the STARALT[8] tool very useful to prepare visibility charts, and those charts could be uploaded in the relevant section of the Wiki-Bo run page. Similarly, if the finding charts for your target SPSS cannot be found in the relevant SPSS pages in Wiki-Bo, or are not of the desired quality, you are encouraged to create new ones and to put them in Wiki-Bo. Finding charts can be prepared with DS9[9], ALADIN[10], or the ESO FIMS[11] package. If you prepare new finding charts, please do conform to the guidelines illustrated by EP-003, and please do upload them in Wiki-Bo if you have writing permission, or otherwise send the images to one of us. Examples of good finding charts can be found on the single SPSS pages in Wiki-Bo or in GA-001.

For some observatories (i.e., ESO) you must prepare your observations in advance in the form of *"Observing Blocks"*. These should *always* be uploaded in Wiki-Bo, in the *"Observations preparation"* section of the run page.

2.3 Instrument setups and exposure times

For each of the four used spectrographs, the Gaia BP/RP spectral range (330–1050 nm) is covered with two different low-resolution setups, a red one and a blue one. Also, there are two different slit widths used, the narrow slit (generally around 1.5 times the seeing) and the wide slit (generally 5 or 6 times the seeing). Table 2 summarizes the setups for each instrument. The Loiano BFOSC was only used in the beginning, but since it lacks the wide slit we decided to use it mainly for imaging.

[8] `http://catserver.ing.iac.es/staralt/`
[9] `http://hea-www.harvard.edu/RD/ds9/`
[10] `http://aladin.u-strasbg.fr/aladin.gml`
[11] `http://www.eso.org/sci/observing/phase2/FORS/FIMS.html`

TABLE 2: **Spectroscopy setups.**

Instrument	Blue Grism	Red Grism	Narrow Slit	Wide Slit
EFOSC@NTT	GR-11	GR-16	1.5"	10"
CAFOS@CAHA	B200	R200	2", 2.5"	11.7"
DOLoRes@TNG	LR-B	LR-R	2"	10"
BFOSC@Loiano	GR3	GR5	1.5", 2", 5"	—

Table 3 shows instead the link to the instrument exposure time calculators (ETC), provided by the telescope staffs. The exposure times should always be computed by taking into account the previous experience with the same instruments, and always checked at the telescope by measuring the approximate S/N ratio (which should be >100 over most of the spectral range) obtained after each exposure.

TABLE 3: **ETC web pages.**

Instrument	Web page
EFOSC@NTT	`http://www.eso.org/observing/etc/`
CAFOS@CAHA	`http://w3.caha.es/prada/tcl/script/cafos_im.html`
DOLoRes@TNG	`http://www.tng.iac.es/observing/expcalc/spectro/`
BFOSC@Loiano	*no etc – use past experience*

3 Daytime and twilight calibrations

With the term *instrumental calibrations* or *instrumental calibration frames*, we mean the frames needed to remove the instrumental fingerprint from the images. Some of these frames, such as dark frames and bad pixel masks, are only taken once (or yearly at most), so they are not described here. If they are needed for a particular run, the observing instructions can be found in EP-001. If photometry (imaging) observations are also foreseen for one or more nights in a spectroscopic run, the instruction for photometry calibrations can be found in EP-003.

3.1 Bias frames

Because we want to have a high S/N in the daily master bias for each night, we need series of at least 5 bias frames[12], but if there is enough time for calibrations 10 is better.

Instrument specific tips on bias and observing sections:

[12]For very old instruments, the Bias pattern can vary during the night. Ask your support astronomer whether it is necessary to take Bias frames during the night as well.

- **NTT.** CCD observing sections are strictly defined when preparing OBs, the only thing to remember is that imaging is done with 1×1 binning, while spectroscopy is always done with 2×2 binning; there are no reliable overscan strips;
- **TNG.** Use full frame, which includes two overscan strips, one along columns and one along rows;
- **Calar Alto.** The CCD is large and reading slow (180 sec). There are specific CCD sections for photometry and spectroscopy, so all spectroscopic observations should be done with the following section: [400:1600,1:1650] ($<$120 sec readout);
- **Loiano.** Use full frame; no overscan sections are available.

3.2 Lamp flats

Lamp flats should be taken during the afternoon and, for some telescope (i.e., ESO) also during the observations. To ensure a good S/N ratio, at least 5 flats should be taken, and if there is sufficient time, 10 would be better. When starting the spectroscopic flats sequence, the lamp should be already warm and stable and the appropriate lamp should be chosen for each grism (blue and red) and slit (narrow and wide), checking the instrument manuals or asking the telescope staff. The first one or two frames should be visually inspected to ensure that they are of good enough quality, in particular, the flats should have the maximum number of counts allowed (avoiding saturation and non-linearity, usually $<$55 000 ADU, see GA-004), so that also the less sensitive edges are sufficiently exposed.

Instrument specific tips on spectroscopic lamp flats:

- **NTT.** The telescope operator has pre-defined OB templates that you can use for spectroscopic flats; also, for the red grism GR-16, the OB template foresees spectroscopic lamp flats taken during night time, close to each SPSS observation to take better care of fringing;
- **Calar Alto.** Example of lamps and exposure times used in past runs for dome spectroscopic flats are: the 2000 W lamp (the brightest), 15 sec for B200 and 5 sec for R200; the 150 W lamp (the weakest), 30 sec for B200 and 12 sec for R200; there is also a variable power lamp that you can try; more details can be found in Appendix A;
- **Loiano.** No specific indication reported in the logs; if BFOSC will be used again in the future for spectroscopy, the telescope staff should be asked for advice.

3.3 Sky flats

Spectroscopic sky flats are needed to apply the illumination correction. One good sky flat for each setup (blue and red grisms, narrow and wide slits)[13] should be sufficient for the whole observing run. The flat should have the maximum allowed number of counts (avoiding saturation). To be sure to have the optimal flats, if possible, more than one exposure should be taken with each setup, ideally three. But of course, spectroscopic sky flats take a lot of time so this is not mandatory.

3.4 Wavelength calibration lamps

Most low-resolution spectrographs are not bench mounted and therefore are subject to position dependent flexures (SMR-002), requiring calibration lamps to be taken during the night, close to the targets. All our instruments fall in this category. Night-time lamps, however, can be time consuming therefore the best observing strategy is to take relatively low S/N lamps close to the targets during the night, and very high S/N lamps each afternoon.

Wavelength calibration lamps are only taken with the narrow slit, because wide slit spectra will be calibrated afterwards, using cross-correlation with the narrow slit spectra, that can be calibrated with much higher precision.

It is extremely important to compare a lamp taken with a certain exposure time with the available extracted lamp images and atlases available at each telescope site or other reference plots: slightly different exposure times can render a lamp totally impossible to recognize. In other words, make sure that the chosen exposure time allows our data analysts to easily identify emission lines.

Instrument specific tips on wavelength calibration lamps:

- **NTT.** Detailed instructions can be found in the ESO manuals and in the OB template manuals[14];
- **Calar Alto.** To calibrate spectra with sufficient precision, more than one lamp can be switched on simultaneously, always starting from the Hg lamp, which takes a bit more time to warm-up; more detailed instructions and exposure times can be found in Appendix A;
- **TNG.** Three lamps are available (Ar, Ne+Hg, and Kr), that can be switched off simultaneously; they require of the order of 20 sec for LR-R and of 30 sec for

[13] If possible, skyflats should be taken also for narrow slit spectra. In principle, narrow slit spectra are taken only for wavelength calibration purposes. In most practical cases, however, they can be effectively corrected for differential flux losses and used to add more flux, or to beat down fringing.

[14] `http://www.eso.org/sci/`

LR-B when stable. Separately, a He lamp is available for LR-B, and it requires approximately 2 sec;

- **Loiano.** There is a helium-argon (HeAr) lamp that can be used with exposure times around 30 sec.

4 Night time observations

When a night is fully dedicated to spectroscopy, the only three types of observations are: those of the *pillar* (or *pseudopillar*) needed to calibrate the spectral shape, i.e. to perform a relative flux calibration; those of a *telluric standard*, needed to remove atmospheric absorption features from SPSS spectra; and those of the actual *SPSS candidates*. If photometric observations are also foreseen for some nights in a spectroscopic run, the observing instructions can be found in (EP-003).

If the sky conditions are clear and promise to be photometric, often you will prefer to perform absolute photometry for obvious reasons, but please remember that we also need some absolute spectrophotometry to verify our method. Especially if your target list contains some *Primary SPSS* which do not have absolute spectrophotometric observations done already, please consider dedicating the night to absolute spectrophotometry. Regardless of the photometricity of the night, the spectroscopy observing protocol remains the same as described in the next sections.

4.1 Target acquisition operations

Generally, all telescope operations are performed by the night assistant or telescope operator, so you do not need to know the details of these operations. However, there are some exceptions (see Appendix A and below). Please keep in mind the following points:

- **Telescope focus.** Having the telescope in focus is important to look for visual companions around candidate SPSS in case of imaging, and to gather most of the flux within the slit in case of narrow slit spectroscopy. The focus should be monitored during the night and adjusted if the temperature changes significantly or if the seeing appears degraded with respect to the seeing monitor (e.g., the DIMM, in the case of ESO) or previous exposures;

- **Telescope pointing (and guiding).** After pointing the telescope, the field and the SPSS should be recognized with the help of a finding chart: many of our SPSS candidates have high proper motion so it is essential to be certain of the target;

- **Parallactic angle alignment.** Especially when doing narrow slit spectroscopy, the slit must be aligned along the parallactic angle (PA) to avoid as much as possible differential light losses with wavelength. If the procedure of aligning to the PA is not too complex, it would be useful to apply it also in the case of wide slit spectra. The PA should be recomputed relatively often (∼30–45 min approximately) when observing at low elevations[15], and for long exposures the PA should be computed using the time in the middle of the exposure rather than at the beginning of it;

- **Slit centering.** Please try to put always the main object (SPSS or pillar) approximately in the center of the slit, not only in the dispersion direction (obviously), but also along-slit; if there is more than one object falling into the slit, please explain clearly which is the SPSS in the observing logs (Section 5);
- **Imaging.** Most telescopes allow you to obtain an image showing the field of view, sometimes with the slit position indicated; we suggest you always take this kind of images whenever possible, for a-posteriori image recognition in case of trouble (especially if more than one star falls into the slit length);
- **Quality control.** In the pre-slit imaging please be sure that there are no companions falling into the slit in such a way to contaminate the SPSS or pillar flux; in the spectroscopy, please be sure that S/N>100 over most of each spectrum (except for the borders) and that the spectrum is never saturated or close to the non-linear region (<55 000 ADU, see GA-004).

4.2 Pillar or pseudo-pillar

The *Pillar* is one of the three SPSS by Bohlin (2007), namely G191-B2B (or SPSS 001), GD71 (or SPSS 002), and GD153 (or SPSS 003), described in details by GA-001. When there is no pillar visible, one of the *Primary SPSS* candidates – possibly belonging to the CALSPEC dataset – can be chosen as the night calibrator: in this case we refer to it as *pseudo-pillar*. Also, if the chosen pillar or pseudo-pillar does not cover the entire night, it is wise to observe a second one.

Ideally, a pillar should be observed three times at (very) different airmasses. Or, if two pillars are used to cover two parts of the night, each pillar should be observed twice at (very) different airmasses.[16] The first time a pillar is observed in one given night, the whole observing sequence

[15] The PA changes more rapidly at high elevations, but in that case the atmospheric refraction is not so strong, so PA alignment is not crucial. At low elevations refraction is important, therefore even small misalignments can have a large impact on the shape of a spectrum.

[16] Observing the (pseudo)-pillar at different airmasses is necessary to build the extinction curve of the night. If the night is not photometric, the extinction curve is meaningless, and it would lead to a wrong spectral zeropoint, so one could use the tabulated (seasonal) extinction curve and save observing time. The zeropoint can be corrected with absolute photometry (MBZ-001). However, this is true if, and only if, the exctinction variations due to clouds, humidity, or calima are grey. If they are not grey, also the shape of the extinction curve changes, leading to an error not only on the zeropoint, but also on the shape of the resulting spectra. In this case, deriving an extinction curve for each night can tell us not only if a night is photometric or not, but also if a non-photometric night is grey or

(Section 4.4) should be executed. The second (or third) time a pillar is re-observed during the night, it is sufficient to take the wide slit exposures.

TABLE 4: **Suggested telluric standards**

Name	Ra	Dec	V mag	Notes
VMa2	00:49:09.90	+05:23:19.01	12.36	Bessell (1999)
L745-46A	07:40:20.79	-17:24:49.10	12.98	Bessell (1999)
HZ43	13:16:21.85	+29:05:55.44	12.66	Bessell (1999)
EG131	19:20:34.93	-07:40:00.05	12.28	Bessell (1999)
L1363-3	21:42:41.00	+20:59:58.20	13.27	Bessell (1999)
Feige110	23:19:58.40	-05:09:56.21	11.40	Bessell (1999)
WD2008-600	20:12:31.00	-59:56:51.00	∼16	Subasavage et al. (2007)
WD0123-262	01:25:24.00	-26:00:44.00	15.0	see Wiki-Bo

4.3 Telluric standard star

One telluric standard should be observed during the run at different airmasses (1–3 exposures), close to the airmasses of the targets. If there is not enough time to obtain 3 exposures in the same night, one exposure can be taken each night at different airmasses, possibly using the same standard for the whole run. A list of suggested telluric standards can be found in Table 4.

4.4 SPSS observing sequence

Ideally, one full SPSS (or telluric standard, pillar, or pseudo-pillar) observational sequence should contain three wide slit spectra for each of the two setups (the blue and red setups, see Table 2), and one narrow slit spectrum for each of the two setups. The narrow slit spectra should always be followed or preceded by a wavelength calibration lamp.

To memorize the concept, we often refer to this strategy as the *wwwnllnwww* strategy, because at most telescopes it is more convenient to start with the wide slit (the three *w*) spectra of one setup, followed by the narrow slit spectrum (*n*) and its related wavelength calibration lamp (*l*), as described in Table 5. At this point, the setup can be changed and the sequence repeated in the opposite order: first the lamp, then the narrow slit and finally the wide slit spectra. If you need to change the sequence order, please always take the wavelength calibration lamps close to their respective narrow spectra.

It is more convenient to observe the blue setups farther away from the horizon, so if one object is rising it is better to start with the red setup, if it is setting, it is better to start with the blue

not. If the night is grey, the data can be used for our purposes, otherwise they have to be thrown away. The bottom line is that we need always to observe the (pseudo-)pillar at different airmasses, regardless of the night quality.

TABLE 5: **Suggested spectroscopy observing sequence.**

Task
3×wide slit with first grism
1×narrow slit with first grism
1×wavelenght calibration lamp with first grism
— *change grism* —
1×wavelenght calibration lamp with second grism
1×narrow slit with second grism
3×wide slit with second grism
NTT: take lamp flat close to target for red grism (to better minimize fringing)

one, although aligning the slit to the parallactic angle minimizes diffraction problems already (see Section 4.1).

5 Closing operations

End of Night Report

Night Info

Run ID:		**Example:** P-001, V-003, M-005 (see Runs summary)
Starting Date:		**Format:** YYYY-MM-DD
Start of Night:		**Format:** UT (HH:MM:SS) Start of first Science Image
End of Night:		**Format:** UT (HH:MM:SS) End of last Science Image
Observing Site:		**Choose:** Loiano, CAHA, La Palma, La Silla, San Pedro, Other
Telescope:		**Choose:** Cassini, 60cm, 2.2m, TNG, REM, 1.5m, Other
Instrument:		**Choose:** BFOSC, CAFOS, DoLoRes, ROSS, REMIR, La Ruca, Other

FIGURE 2: Initial portion of the EON submission web form.

Date: **25/05/2008**
File prefix: **JVRA/JVSA**

Observatory: Roque de los Muchachos, La Palma (TNG)

Instrument: **LRS@TNG**
Observer(s): **M. Bellazzini, A. Bragaglia G. Andreuzzi + G. Mainella**

File:	*Object Lamp*	*Filter/ grism*	*Slit/ mask/ other*	*Exp. Time*	*Starting time UTC*	*Airmass*	*Seeing*	*ID*	*RA*	*DEC*	*Remarks*
JVRA											Afternoon: rain
0002-0012	bias				14:40						Bin 1x1, readout in 26s
0015-0024	flat	LRB	2"	15	14:55						Flat x10, 2",LR-B
0025-0034	Flat	LRB	5"	15	15:05						Flat x10, 5",LR-B: saturates in red
0037-0046	Flat	LRB	5"	8	15:17						Flat x10, 5",LR-B: faint in blue
0049-0058	Flat	LRB	5"	4	15:28						

FIGURE 3: Initial portion of a compiled electronic night log form.

5.1 End of night activities

It is of uttermost importance, to track observations and to facilitate data reductions, that you send to Bologna your *end-of-night report* (EON) and your *electronic observation logs*. You can find both in Wiki-Bo:

- A web based form for submitting the EON report can be found in the *"Observations Pages"* (Figure 2); there is also an ascii file template for those who prefer to send the report by e-mail;
- A template for compiling electronically the observing logs (Figure 3), prepared by S. Ragaini, can also be found in the *"Observations Pages"*; if hand written logs are compiled instead, they should be scanned and sent in electronic form.

5.2 End of run activities

To facilitate us in tracking observations we need your *end-of-run report* (EOR), and to be able to safely store data for analysing them, we need you to send us the raw data:

- A web based form for submitting the EOR report can be found in the *"Observations Pages"*, very similar to the one for EON reports (Figure 2); there is also an ascii file template for those who prefer to send the report by e-mail;
- The raw data can be sent in many ways, but we prefer by far to receive them already backed up on CDs or DVDs, possibly with the data of different nights saved in different subdirectories.

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A Instrument specific instructions: CAFOS

Originally prepared by J.M. Carrasco & G. Altavilla

Some more information on CAFOS can be found at `http://www.caha.es/alises/cafos/cafos.html`. Here we describe the operating instructions necessary to perform observations with the various instrument GUIs (graphical user interfaces). A general view of the monitors and interfaces can be seen in Figure 4.

A.1 Starting up the system

The telescope and instrument controls can be run from the telescope building, or from the library building, where a more comfortable control room was set-up. We will assume that the observer works in the library building.

On the first night the telescope staff will be glad to illustrate the controls, and they will be always available in case of problems, but you are expected to perform the observations by yourself, there is no telescope operator.

A.1.1 Dome startup

- To have control of the dome from the library monitors, be sure to switch the appropriate button in the telescope building to "remote": the dome start GUI should show a green light.
- Start the dome GUI from a terminal with the command line: "`start_domec &`".

A.1.2 Telescope startup

- You first need to allow remote control of the telescope from the library building, by typing: "`start_teleserver &`" in a terminal.
- On the telescope interface you can now start the telescope by clicking on the "`On`", "`Hydraulics`", "`Drives`", and the "`Domec`" buttons.
- When the mirror covers are closed, there is a green light on "`M1 Cover closed`", if you click the "`Startup`" button, the light changes color and the button name changes to "`Shutdown`": the mirror covers are now open.
- Do not forget to set the dome position to "`Auto`", otherwise the dome will not follow the telescope movements.

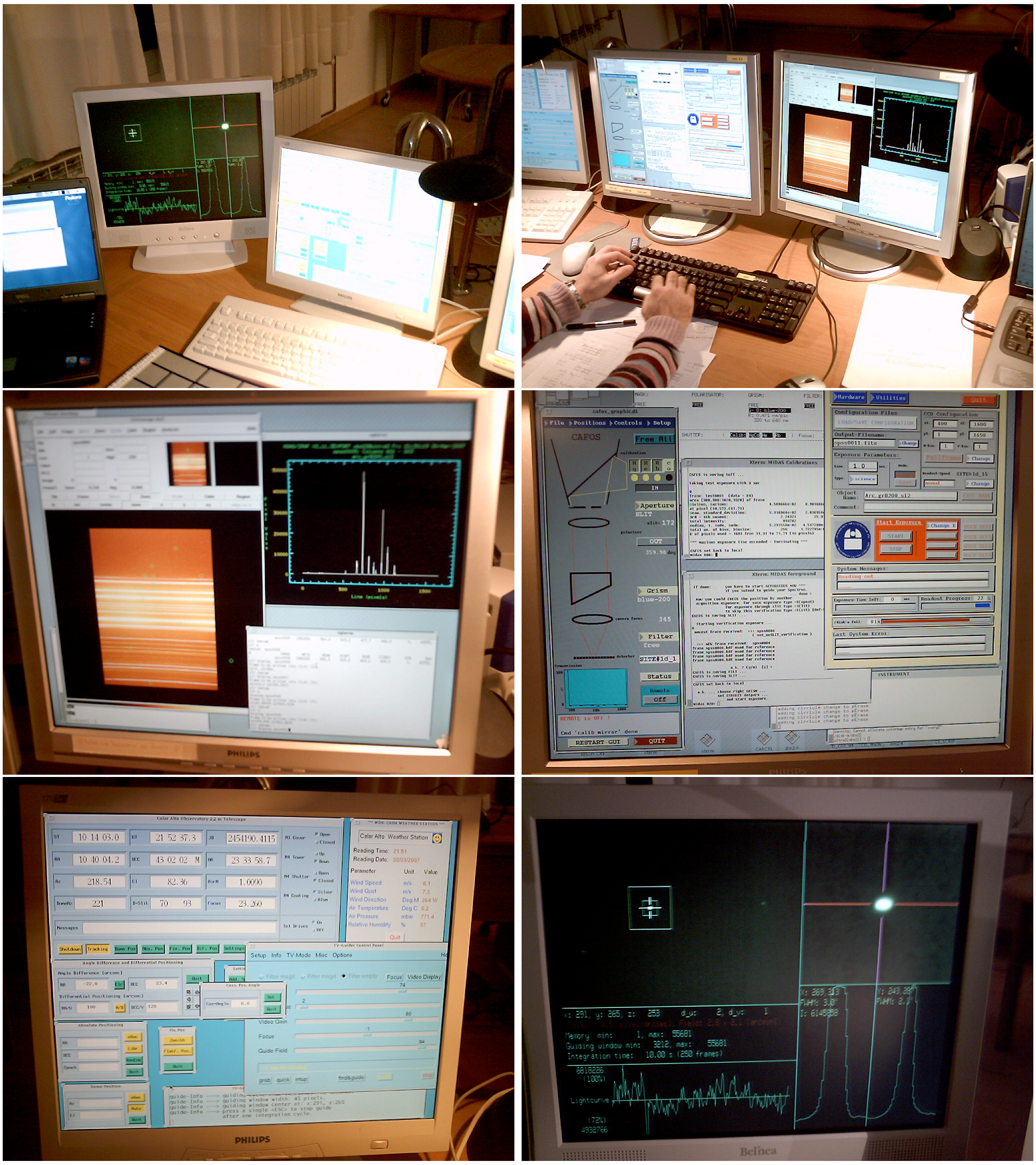

FIGURE 4: Views of the control-room computer monitors during observations with CAFOS@CAHA. *Top left:* the TV monitor can be seen on the left monitor, while the telescope controls are on the right monitor. *Top right:* the leftmost monitor is the telescope control, the central monitor shows the exposure control and instrument monitor, the right monitor is where the user can work on the data. *Middle left:* a zoom-in on the user monitor. *Middle right:* a zoom-in on the exposure control monitor. *Bottom left:* a zoom-in on the telescope monitor. *Bottom right:* a zoom-in on the TV monitor.

A.1.3 Instrument startup

- Run on a terminal: "`start_cafos &`".
- Make sure that "`Polarizer`" is always "`out`".
- If you click on the right button on the desktop and select "`Cass 2.2`", you will open a small GUI which will be later useful to change the CAFOS orientation.

A.1.4 CCD startup

- Run in a terminal "`start_ccd &`".
- Select the directory to save the data (e.g., "`/disk-b/obs22_images/jordi`") using "`Change`" in "`Output Filename`". A new terminal appears, where you can type the "`Image prefix`" and the "`Observer`".
- Be sure that the two CCD sections for imaging and spectroscopy are properly defined and saved:
    1. In spectroscopy mode, we use the region: $400 < X < 1600$; $1 < Y < 1650$. To define it, use the "`Change`" button in "`CCD configuration`" to type this section in the appropriate field. Be sure that the binning is set to 1. Use "`LOAD/SAVE CONFIGURATION`" to store this CCD section as "`USER DEF 4`", selecting the name "`user_def4.par`" for the file in which you store it.
    2. In photometry mode, we use the standard configuration: $513 < X, Y < 1536$. This should be already stored as "`USER DEF 1`", otherwise you can set it with the instructions above.

A.1.5 Target list upload

There are two ways of introducing the coordinates to point the telescope: to introduce the coordinates manually, or to select a position from a stored catalogue. You may want to upload your target list in advance to make your life easier during the night.

1. To manually point the telescope you have to type the object coordinates into the "`Abs. Pos.`" GUI, but then (at least in the first runs) there is a systematic offset in the pointing, therefore you should enter and offset of 120" to the South in the "`Dif. Pos.`" GUI.
2. To select a star from one of the uploaded catalogues, you do not need to enter any systematic offset of 120", it is already implemented in the pointing model. To upload a catalogue for later use during observations:

- Prepare an ascii file with a target on each row; the file must have the following columns "`name | alpha | delta | epoch` ", all separated by the vertical dash symbol. For example: "`BD+28 4211 | 21:51:11.02 | +28:51:50.36 | 2000.0`".
- Copy the catalogue file in the working directory.
- Enter "`obscat22 &`" in a terminal.
- Upload the catalogue by entering the filename and path in the "`Catalogue`" field.
- Now you can access the catalogue at any time from the telescope GUI.

A.2 Daytime and twilight calibrations

A.2.1 Bias sequence

Useful MIDAS scripts are available to facilitate the execution of calibration frames sequences. In the case of bias frames, the "`multibias`" routine automatically changes the exposure type to "`dark`", the exposure time to zero seconds, and the object name to a preset, numbered list:

- Be sure that the lights in the dome are closed in the dome GUI.
- Open the MIDAS environment by typing "`calibs`" on a terminal. In the past you used to need to open it with "`quick`" and "`x322`".
- Type "`explain`" to see the list of all enabled commands.
- Run the "`multibias`" procedure with the spectroscopic and the photometric CCD sections, as needed (see Section A.1.4), to produce the required number of bias frames (see Section 3.1).

A.2.2 Imaging dome flats

- Type "`ffl`" on a terminal to switch on the dome lamps. Different lamps with different powers are available (2000, 1000, 150 W and another with selectable power ranging from 1 to 10 W).
- Make sure that the previous lamp has been correctly and completely switched off before switching on the next one.
- Send the telescope to the flat screen by clicking "`Fix Pos`" and "`Flat. Pos.`" on the telescope GUI.
- Remember to open the mirror covers (see Section A.1.2).

- Select the correct instrument configuration (choose filter, photometric CCD section, remove slits ...) using the exposure GUI.
- Use the exposure GUI (see Figure 4) to select exposure times according to the indicative values of Table 6.

TABLE 6: **Indicative imaging exptimes with warm lamps.**

Filter	**lamp**	**exptime**	**counts**	**Notes**
B	150 W	30 sec	≃36000	
V	150 W	5 sec	≃35000	
R	10 W	20 sec	≃33000	Counts tend to increase with time after switching on

You can also use the MIDAS routine “`FF_dome`”, after configuring the instrument and switching on the appropriate lamp as explained above. The routine will tell you when the lamps get too hot and need to be changed:

- Run the MIDAS routine “`FF_dome`” from a terminal.
- When asked for “`UserDef`”, reply “`1`”, which is the default for imaging.
- Select “`Filter number`”, which is 2 for B, 3 for V, and 4 for R.
- Select also the “`Filter name`”, which is B, V, or R in our case.
- Leave the “`FF level`” to its default value, which is >80 000.
- Select the appropriate “`Number of exposures`” (usually 10).
- Leave “`Max. expos. time`” to its default value, which is two minutes.
- Set CAFOS in remote.
- Repeat these steps for every filter.
- Switch off the lamps.

A.2.3 Spectroscopic dome flats

- Type “`ffl`” on a terminal to switch on the dome lamps. Different lamps with different powers are available (2000, 1000, 150 W and another with selectable power ranging from 1 to 10 W).
- Make sure that the previous lamp has been correctly and completely switched off before switching on the next one.

- Send the telescope to the flat screen by clicking "`Fix. Pos.`" and "`Flat. Pos.`" on the telescope GUI.
- Remember to open the mirror covers (see Section A.1.2).
- Select the correct instrument configuration (choose grism, spectroscopic CCD section, remove filters, choose slit ...) using the exposure GUI.
- Use the exposure GUI (see Figure 4) to select exposure times according to the indicative values of Table 6.
- Change the observation type to "`flat`" (this has to be done even if you decide to use the MIDAS macro, see below).
- Select the appropriate exposure time, using the values in Table 7 as guidelines (this has to be done even if you decide to use the MIDAS macro, see below).

TABLE 7: **Indicative spectroscopy exptimes with warm lamps.**

Slit	**grism**	**lamp**	**exptime**	**peak counts**
2.5"	B200	2000 W	15 sec	≃40000
	R200	2000 W	5 sec	≃32000
5.0"	B200	2000 W	9 sec	≃42000
	R200	2000 W	3.5 sec	≃42000
11.7"	B200	150 W	30 sec	≃30000
	R200	150 W	12 sec	≃31000

Now you can obtain flats manually or with the MIDAS routine "`multiexp`""

- Type "`multiexp`" on a terminal.
- Select:
  1. The number of exposures (usually 10).
  2. The object name (for example, "`specflatB200sl2.5`").
  3. Type return after "`Ok to start`", when you are ready.
- Repeat for each slit/grism combination (by updating the exposure GUI manually every time before starting "`multiexp`", see above).
- Remember to switch off the lamps when you are done.

A.2.4 Wavelength calibration lamps

High S/N lamps should be taken in the afternoon (take several lamps with all grism/slit combinations) and later, during night-time single or shorter lamps should be taken close to each narrow slit spectrum. These instructions are valid in both cases:

- During night-time observations, stop guiding (Section A.3.2), but keep on tracking.
- Correctly set up the instrument (i.e., remove any filters, set the CCD section to spectroscopy, select appropriate grism, slit, and exposure time in the instrument GUI).
- Switch on the lamps: start with Hg first, it needs to be warm to be able to see the 10139Å line, and it is better to do the red grism first (approximately 3 seconds of exposure for a 2.5" slit), because the lamps should be warmer for the blue grism (approximately 1.5 seconds of exposure for a 2.5" slit).
- Start the exposure: you can stop the exposure if needed by clicking on "`Stop`". Later you can "`Abort`" to clean the memory and throw away the exposure, "`Resume`" to start exposing again, or "`Read-out`" to store the photons collected up to the "`Stop`" in a fits file.
- When the lamps are completed, remember to switch them off[17].
- During night-time observations, remember to start guiding again.

A.2.5 Imaging sky flats

- Point the telescope to an empty sky region (a list of coordinates can be found in EP-003); instructions on how to point the telescope can be found in Section A.3.1.
- Select the appropriate instrument configuration (choose filter, photometric CCD section, remove slits ...) using the exposure GUI.
- If you take imaging sky flats in the evening twilight, you should follow the filter sequence B, V, and R, while in the morning twilight you should follow R, V, and B.
- Activate telescope tracking (not guiding).
- Use the MIDAS routine "`FF_evening`" or "`FF_morning`", as appropriate, to launch an automatic sky flat sequence.

[17] Note that it is not possible to switch off the lamps in rapid succession, because the system is programmed to let the lamps cool down.

A.2.6 Spectroscopy sky flats

Unfortunately, there are no special routines to perform spectroscopic sky flats automatically.

A.3 Night time operations

A.3.1 Pointing the telescope

- Select the uploaded catalogue which contains your targets (Section A.1.5).
- Double click on your star (a single click does not have any effect) to select your target.
- Click on "`execute`" to send the telescope to position. Be certain that you have double-clicked before, by checking the telescope coordinates once it stops moving.[18]
- Click on "`Set name`" to automatically set the target name in the catalogue as the "`Object`" header keyword of your fits file.

A.3.2 Tracking and guiding

- Click on "`Tracking`" on the telescope GUI to start tracking.
- To start guiding, select a guide star in the field of the TV monitor and:
  1. Click on "`grab`" on the TV guider panel of the telescope GUI, to enter grab mode.
  2. Select an appropriate level of the gain (typically around 70) depending on the brightness of stars in your field.
  3. Stop integrating by clicking on the "`stop`" button.
  4. Click on the "`Video Display`" button to enable the TV monitor.
  5. If there is a suitable guide star in the field besides your target (assuming you are in "`Slit view`" mode), you can select it directly by clicking on it on the TV monitor, otherwise you can switch to "`Guide field`" mode to explore the surroundings for a suitable guiding star. In case of faint stars you can integrate with "`Intup`" instead of "`Grab`".
  6. Once you are happy with you guide star, quit the TV monitor using the right mouse button.

[18] It the telescope does not move, or does not go to the chosen coordinates, try to click on the "`Teleserver`" button.

7. Now you can click on "`guide`" on the TV guider panel in the telescope GUI and proceed with your observations.

A.3.3 PA aligning

- Compute the parallactic angle with the web calculator[19].
- Transform the result to make it lower than 180 degrees (e.g., 270 becomes 90), and enter the result in two interfaces, in the following order:
  1. First, start a new GUI with the right mouse button, selecting "`Cass 2.2`" from the option menu, on the rightmost monitor (not shown in Figure 4). A new interface for setting the PA appears. Enter the above angle in the field and click on "`Move`". Now you have rotated CAFOS, but the telescope does not know it yet.
  2. Move now to the telescope GUI, open the dialog "`Cass. Pos. Angle`" using the "`Set angle`" green button. Take the angle you used to rotate CAFOS and add 90 degrees to it if you are guiding with "`Slit view`", otherwise leave it as it is if you are guiding with "`Field view`". Enter it in the field and then click on "`Set`".

A.3.4 Focus

- Point the telescope to a region in the sky with isolated stars.
- Be sure that telescope is tracking, by clicking "`Tracking`" in the telescope paddle.
- Stop telescope guiding with "`tvg`" if it is activated, because the focusing routine produces image movements that cannot (and should not) be corrected.
- Run the MIDAS routine "`FSEQ/TELES`":
  1. Set the instrument to free with "`Free all`" in the CAFOS interface.
  2. Enter the exposure time (usually 10 seconds).
  3. Enter the number of steps (usually the default – 9 steps – is ok).
  4. The routine pauses while you set CAFOS to "`Remote`".
  5. Choose a the V filter by entering 4 (relatively red filters allow for easier focussing).
  6. Enter the "`tube temperature`" and expected focus value (default is 22).

[19] `http://www.caha.es/CAHA/OBS_UTIL/parang.html`

7. Select "`inspec <imagename>`" or "`load <imagename>`", and then "`focus <imagename>`".
8. An image with 9 offset images of the visible stars appears: clicking once on the desired star zooms it in.
9. Click with the left mouse button on all the 9 exposures, from bottom to top.
10. Enter the focus position of the first image and the increment (the default is "`[22.4,0.1]`").
11. Answer N to "`Do you want to save seeing?`".
12. Answer Y to "`Do yo want to set TELESCOPE focus?`".

- You may want to take note of your focus position and seeing in the logs.

A.3.5 Taking Images

- Point the telescope to your desired position (Sections A.1.5 and A.3.1); be sure to recognize your field with a finding chart.
- Select a guide star and start guiding (Section A.3.2), of course, the telescope must be tracking as well.
- Set the CCD section to photometry (Section A.1.4) in the instrument/exposure GUI.
- Set the desired exposure time, filter (remember to remove slits and grisms), and start the exposure using the instrument GUI.
- You can stop the exposure if needed by clicking on "`Stop`". Later you can "`Abort`" to clean the memory and throw away the exposure, "`Resume`" to start exposing again, or "`Read-out`" to store the photons collected up to the "`Stop`" in a fits file.

A.3.6 Taking Spectra

- Point the telescope to your desired position (Sections A.1.5 and A.3.1); be sure to recognize your field with a finding chart.
- Be sure the telescope is tracking (Section A.3.2).
- Align the telescope rotator (and CAFOS) to the PA angle (Section A.3.3).
- Put your star in the slit[20] using the TV guider panel of the telescope GUI:

[20] During the pilot program, this was done using the MIDAS routine "`offset/slit`", which was easy to follow. The problem was that that the routine asked the user to stop the TV guiding every now and then. This way, it was necessary to take an additional image, to be sure that the routine worked properly and the star was inside the slit, with an obvious increase in the total needed time.

1. Insert the slit using the instrument GUI (with the "`cafos_graphic.dl`" interface).
2. Open the TV guider panel of the telescope GUI, by entering "`tvg`" on a terminal.
3. Select the key "`s`" to select cassegrain spectroscopy.
4. Opt out any FOCES option by answering "`N`", because we are using CAFOS all the time.
5. Open the "`TV_Mod`" menu in the "`tvg`" and select the "`Slit View`" option.
6. Click on "`grab`" on the TV guider panel of the telescope GUI, to enter in grab mode.
7. The screen image on the TV monitor changes to show the stellar field around the target.
8. Use "`MCP Gain`" to make the image brighter, to better recognize the stars. Values around 70-80 are convenient.
9. At this point, the slit appears as a dark stripe in the TV monitor, against the background, which covers the target when properly centered. If you do not see the slit clearly enough, either make the background brighter by changing the gain, or try moving the star slightly out of the slit to better see its borders.
10. Mark the position of the slit on the TV monitor screen by left-clicking on its center.
11. Now you can center the star into the slit with the appropriate GUI, that can be opened by right clicking with the mouse on the desktop and selecting "`Paddle 2.2`" from the option menu.

- Now that the object is in the slit, you can start guiding again (Section A.3.2).
- Be sure that the dome screens are not producing vignetting ("`El.`" value must be between the two values shown in "`D-Slit`". If it is near some of the margins, click "`eXec`" in "`Dome position`" window.
- Set the CCD section to spectroscopy (Section A.1.4) in the instrument/exposure GUI.
- Set the desired exposure time, grism (remember to remove filters), and slit and start the exposure using the instrument GUI.
- You can stop the exposure if needed by clicking on "`Stop`". Later you can "`Abort`" to clean the memory and throw away the exposure, "`Resume`" to start exposing again, or "`Read-out`" to store the photons collected up to the "`Stop`" in a fits file.

A.3.7 Preliminary spectra reduction

You can use the MIDAS routine "`spectrum`" to perform a quick reduction of the obtained spectra. The reduced spectra will be stored in: "`/disk-b/obs22-images/midasql`".

A.4 Ending the session

When the observing night is over, or when the weather is getting too bad:

- Stop any ongoing exposure.
- Stop guiding the reference star.
- Click on the "`Shutdown`" button of the telescope GUI. This procedure moves the telescope to the zenith, stops tracking and closes the mirror covers.
- Close the Dome.