Manual for the preparation of the observing material for LBT/LUCI

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version 1.2

LUCI instrument

LUCI1 and LUCI2 are a couple of almost identical infrared instruments. In seeing limited mode they provide imaging, long slit spectroscopy (LS) and multi-object spectroscopy (MOS) over a 4 arcminute square field of view. The wavelength range is between 0.89 μm (LUCI1) or 0.96 μm (LUCI2) and 2.44 μm. Three gratings are available, working in different resolution regimes spanning from low (R ≈ a few hundred) to medium (R < 30000) resolution (see tables below). Each instruments has also diffraction limited capabilities (AO mode) with a field of view of 30 arcseconds using the adaptive capabilities of the secondary mirrors and a natural reference star (imaging only). This technology can be also used with the large field of view camera used for seeing-limited, in the enhanced seeing mode (ESM). This allows to improve the FWHM of a factor 0.75. For better seeing enhancement ARGOS time can be requested. With ARGOS you get about a factor of 2 improvement over seeing-limited mode. Further informations about LUCI instruments and their properties can be found at the webpage: https://sites.google.com/a/lbto.org/luci/

Grating	Band	Order	λ_{cen} [μm]	50 % Cut on/off [μm]	Resolution [$\lambda_{cen}/\delta\lambda$]	Free Spectral Range [μm]	Dispersion [μm/pix]
G210	K	2	2.20	2.02 – 3.18	5000	0.328	0.mm
G210	H	3	1.65	1.41 – 1.90	5900	0.202	0.mm
G210	J	4	1.25	1.09 – 1.41	5800	0.150	0.mm
G210	z	5	0.97	0.89 – 1.11	5400	0.124	0.mm
G200	HK	1	1.93	1.32 – 2.40	1900/2600	0.880	0.mm
G200	zJ	2	1.17	0.90 – 1.25	2100/2400	0.440	0.mm
G150	Ks	2	2.15	1.81 – 2.40	4150	0.533	0.mm
G040	K	2	2.20	2.02 – 3.18	5000	0.nnn	0.mm
G040	H	3	1.65	1.41 – 1.90	5900	0.nnn	0.mm
G040	J	4	1.25	1.09 – 1.41	5800	0.nnn	0.mm
G040	z	5	0.97	0.89 – 1.11	5400	0.nnn	0.mm

General characteristics of the gratings for seeing-limited observations. The resolution is given in all cases for the N1.80 camera using a 2-pixel (0.5") wide slit at the central wavelength for all gratings (see LUCI manual for scaling to the N3.75 camera).

		LUCI1				LUCI2			
Filter Name	Filter wheel	λ_C [μm]	FWHM [μm]	τ_{peak} %	τ_{avg} %	λ_C [μm]	FWHM [μm]	τ_{peak} %	τ_{avg} %
z	2	0.957	0.195	98.4	94.3	0.965	0.196	93.8	89.9
J	2	1.247	0.305	91.2	83.2	1.250	0.301	90.9	87.1
H	2	1.653	0.301	95.0	90.5	1.651	0.291	92.1	85.4
K	2	2.194	0.408	90.1	85.7	2.199	0.408	92.1	84.5
K_s	2	2.163	0.270	90.7	86.8	2.161	0.270	91.7	85.9
zJspec	2	1.175	0.405	93.1	90.4	1.175	0.405	93.1	90.4
HKspec	2	1.950	0.981	95.0	86.3	1.953	0.998	95.7	88.3
Y1	1	1.007	0.069	67.3	65.2	1.007	0.069	67.3	65.2
Y2	1	1.074	0.065	94.2	92.8	1.074	0.065	94.2	92.8
OH_1060	1	1.065	0.010	68.6	65.2	1.065	0.010	68.6	65.2
OH_1190	1	1.194	0.010	80.4	78.6	1.194	0.010	80.4	78.6
HeI	1	1.088	0.015	65.2	64.6	1.088	0.015	65.2	64.6
P_gam	1	1.097	0.010	81.1	80.0	1.096	0.010	70.4	68.9
P_beta	1	1.283	0.012	86.1	85.5	1.284	0.013	85.8	85.2
J_low	1	1.199	0.112	95.4	93.5	1.199	0.112	95.4	93.5
J_high	1	1.303	0.108	95.3	93.2	1.303	0.108	95.3	93.2
FeII	1	1.646	0.018	91.2	89.5	1.645	0.018	91.1	88.0
H2	1	2.124	0.023	87.9	84.9	2.127	0.023	83.9	82.0
Br_gam	1	2.170	0.024	79.4	76.5	2.171	0.023	83.1	82.0

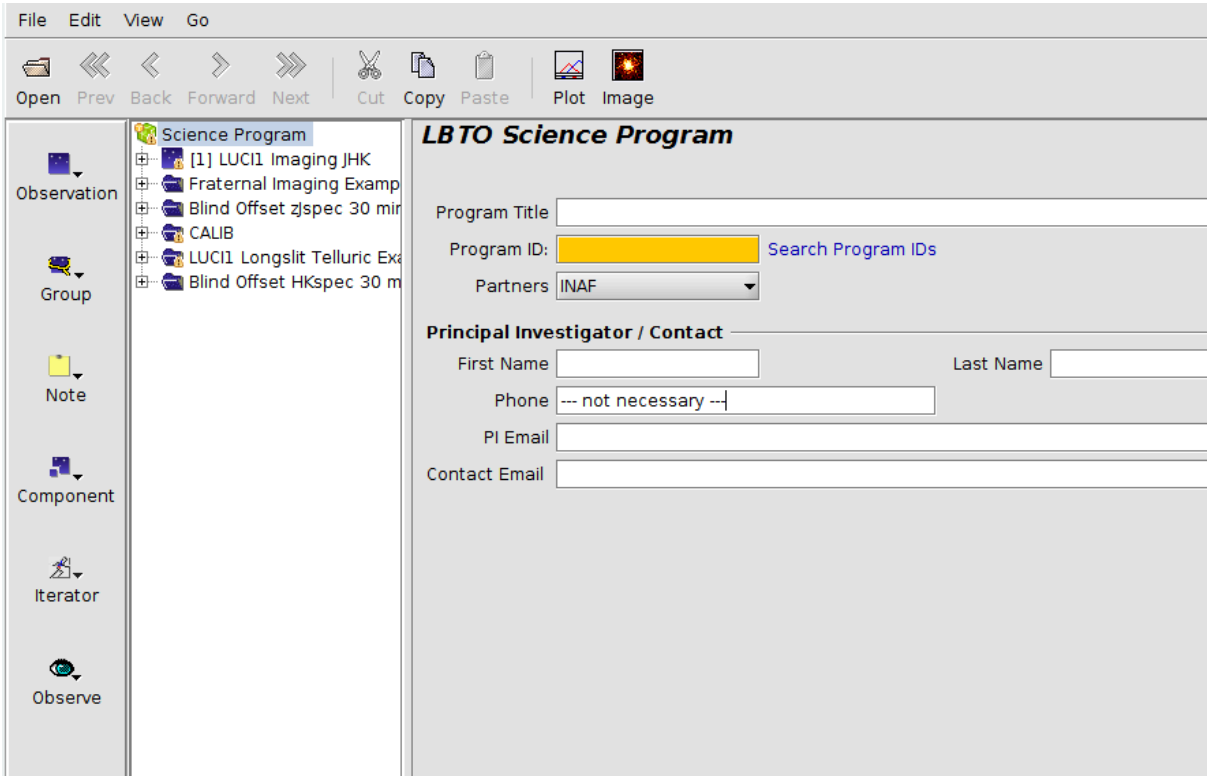
Characteristics of the available filters.

All the updates about the instruments can be find in the following link:
http://www.lbto.org/for-investigators.html

1) General Rules

The files to be supplied to LBT Team for observations are as follows:

OT (Observing Tool) File;
OB scripts generated with the OT;
File with masks for MOS observations;
README file (external to the OT file) with the observational strategy, suggestions, preferences (filters and targets priority, etc.);
FINDING CHARTS in the infrared (the same filter and as deep as the acquisition images, e.g. 2MASS), of both scientific and calibration (telluric standard) targets;
Scripts for the calibrations: darks, flats, spectrophotometric standar.



Example of the first page of the OT Science program. Please fill all necessary fields.

2) The OT tool. Things to know for LUCI

The Observing Tool (OT) tool can be downloaded from:
https://sites.google.com/a/lbto.org/observing-tool-manual/

Please find the OT libraries and tutorials at:
https://sites.google.com/a/lbto.org/observing-tool-manual/observing-tool/ot-libraries
https://sites.google.com/a/lbto.org/observing-tool-manual/observing-tool/ot-tutorial

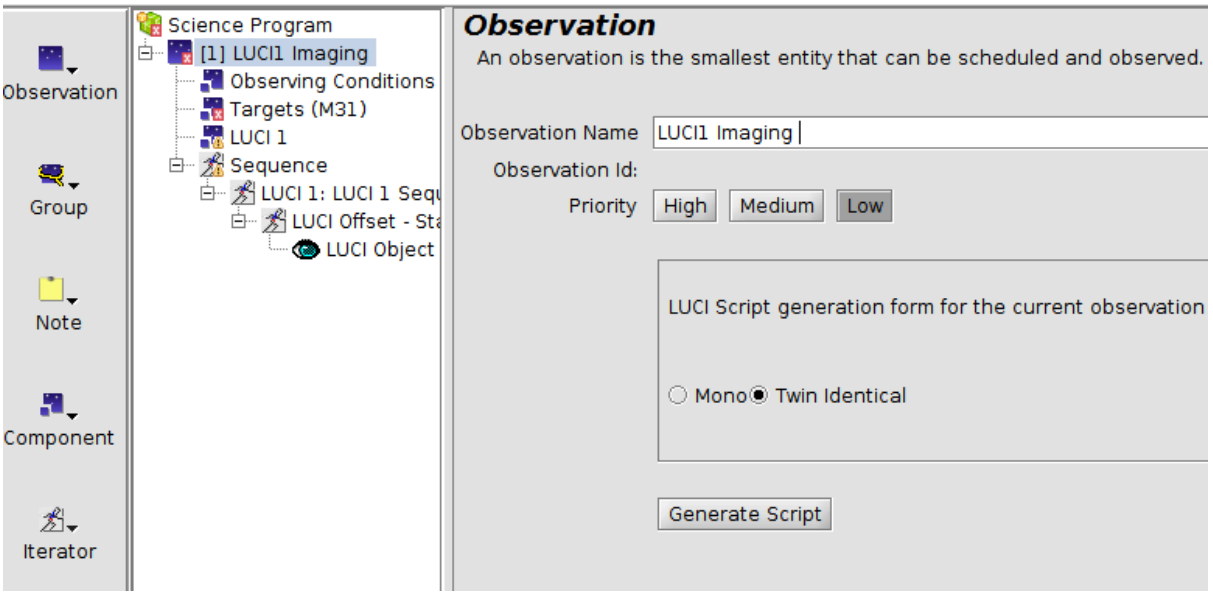
The Observing Tool libraries contain example observations and templates, e.g. commonly used configurations and sequences that may be copy-and-pasted into a your science program. The easiest way to prepare OBs with OT is to find in the library the preferred instrument (Luci 1 or 2; in general it does not matter, except for G150 grating available in LUCI1 only) and the instrument mode (imaging, long slit, multi object spectroscopy-MOS). You must copy the example under your program, and modify it according to your science. Please find in the following the preliminary steps necessary to create OBs with the OT:

1. Open the LBTO Observing Tools (LBTO OT);
2. Click new program;
3. File-Import XML- select the library (eg. LUCI: LBT-LUCI-Library), The LUCI Library will open in a new OT window;
4. Expand the folder of the instrument and the observing mode
5. Highlight the Template for the desired type of observation and then click **COPY** in the Main Toolbar.

6. Back in the *empty* Science Program **PASTE** the observations by hitting **PASTE** in the Main Toolbar
7. Complete the template with your observation details.
8. In the section *LBTO Science Program* put the name of your project, in *Program ID* put number of your Proposal ID , and as *Partners* put INAF.
9. In the section *Observations*, please change the Observation name (e.g., name of your target).

2.1 General advice in the use of the OT

Additional instrument configurations under sequence: if you plan observations in more than one instrument configuration (e.g. mask, grating, filter), but with the same offsets, then it is useful to use the sequence iterator. If not present already under Sequence, then add one (Iterator button on the left->LUCI sequence), and move the offset part inside with your mouse. Afterwards, under the LUCI sequence, you can select the configuration you prefer. Thus select filter/grating, central-lambda, readout and save mode (see below). You can add how many steps you want, one for each configuration. The first configuration step is also visible under LUCI component.



Example of imaging program. Please note the *Targets* and *LUCI 1* Environments

3) LUCI IMAGING

1. Science Program: put PI and title. IMPORTANT: change partner name with INAF Imaging OBs have just one component.
2. Observing Conditions: insert observing constraints. Nnote: leave *water vapor* as “any”.
3. Target Environment:
   a) put the name and coordinates of the target (or acquisition star).
   b) Unless you do not want guiding be sure that Telescope mode is on active (for AO/ESM see the dedicated section).

c) Open Manual GS and load catalog and the image survey clicking on the tab “images”. If you are not happy with the image survey, you can change under the “Catalog” tab. Usually DSS2 IR or 2mass are ok. If a target is visible there, it will also be in the acquisition.
d) locate a star with 11<R<15 (if the program requires seeing<1, then R<16 is fine too) within the guide star region (semi-circular region). Please be sure that the guide probe (yellow rectangle) does not obscurate any of you targets or acquisition star.
e) select +LUCIGS and click on the guide star, this will add the star under “targets” in the OT. If you are not happy with your choice, you can change position angle at the bottom of the “targets” environment and look for a better guide star that fall in the guide region.

4. LUCI1 or LUCI2 environments:
   a) select the appropriated camera(N3.75), filter, grating (mirror), and No Mask under mask position.
   b) For the exposure time: keep Nexpo=1, DIT=2.51, Save mode=integrated, Readout=LIR. Then change NDIT so that Texp=DIT*NDIT is the exposure time for which your target is visible according to ETC.
5. Under Sequence, in the LUCI offset component, choose the dithering pattern that you prefer. We recommend using the random dithering pattern.

About offsets: Under the Sequence, you can manage the offsets:
Please check under the offset component that the probe does not cover your target for any offset position (just select the offset and check in the MANUAL GS).
In the offset component, Offsets bigger than 30” can gives problems with the guiding. Most important, remember that to have a good sky subtraction it is best to avoid having the telescope too often in the same offset position. Thus please use the random dithering pattern. See Sec 8.2.4 of LUCI manual for further details.

About exposure time: For a good sky subtraction, is better to keep the exposure time per offset (NEXPxDITxNDIT)<60s (100s in shorter wavelengths may be ok). For faint targets you can increase DIT, but be sure to not have other bright targets in the field that can saturate and leave persistency on the detector.

If you plan to use multiple instrument configurations, follow the instructions given in the general advice in the use of the OT.

Before saving: be sure that you create the script in monocular. After that, you can generate your script from the **Observation Element**, and export the OT file (File->Export as xml), that you need to send to the LBT team.

4) LUCI longslit

1. Science Program: put PI and title. IMPORTANT: change partner name with INAF. Longslit OBs are separated in 2 parts: acquisition (Acq) and science (Sci).
2. Observing Conditions: insert observing constraints. Note: leave *water vapor* as “any”.
3. Target Environment:

a) In the acquisition you first put the name and coordinates of the target (or acquisition star).
b) Unless you do not want guiding be sure that Telescope mode is on active (for AO/ESM se the dedicated section).
c) Open Manual GS and load catalog and the image survey clicking on the tab “images”. If you are not happy with the image survey, you can change under the “Catalog” tab. Usually DSS2 IR or 2mass are ok. If a target is visible there, it will also be in the acquisition.
d) locate a star with 11<R<15 (if the program requires seeing<1, then R<16 is fine too) within the guide star region (semi-circular region). Please be sure that the guide probe (yellow rectangle) does not obscurate any of you targets or acquisition star.
e) select +LUCIGS and click on the guide star, this will add the star under “targets” in the OT. If you are not happy with your choice, you can change position angle at the bottom of the “targets” environment and look for a better guide star that fall in the guide region.

4. LUCI1 or LUCI2 environment:
   a) select the appropriated camera(N3.75), filter (the one where the target is brighter), grating (mirror), and select mask in turnout under mask position.+
   b) For the exposure time: keep Nexpo=1, DIT=2.51, Save mode=integrated, Readout=LIR. Then change NDIT so that Texp=DIT*NDIT is the exposure time for which your target is visible according to ETC (S/N>=20).
5. Do not touch the Sequence OT component, unless you know what you are doing, it is usually fine as it is.

Now you can move to the science. Copy targets/acquisition star and the same guide-star from the acquisition (there are copy-paste tabs to help you). If you changed position angle, be sure that it is the same that you have chosen for the acquisition.

If you plan to observe just with one filter/grating configuration just do the following:

1. Under the instrument component (LUCI1 or LUCI2) select N1.8 camera, the filter and grating you have chosen (zJspec and HKspec with G200 grating), the central wavelength, the slit, and mask in FPU.
2. Under Sequence, in the LUCI offset component, choose the dithering pattern that you prefer.

If you plan to use multiple instrument configurations, follow the instructions given in the general advice in the use of the OT.

About Offsets: Under the Sequence, you can manage the offsets:
Please check under the offset component that the probe does not cover your target for any offset position (just select the offset and check in the MANUAL GS)
In the offset component, please remember that you only offset in Y in longslit. Offsets bigger than 30” can gives problems with the guiding. Most important, remember that to have a good sky subtraction it is best to avoid having the telescope too often in the same offset position. So for faint targets ACBD is preferred to ABBA. Also, we suggest to use ABAB instead of ABBA. See Sec 8.2.4 of LUCI manual for further details.

About exposure times and detector configuration in Longslit Science part:

1. for exposures longer than DIT=60 sec, it is better to use readout MER (and “Normal” save mode) because reduces the readout noise.
2. For exposures longer than 60s, it is better to use NDIT=1, NEXP=1. If you need more exposures, please add more offsets.
3. Stay in one offset position for more than 300 seconds gives in general not optimal results when removing the sky.
4. For the reasons above, when using MER, it makes no sense using save mode integrated.
5. For exposures shorter than 60-100 sec, you can use readout LIR and savemode integrated. In this case, it is a good idea to split the the exposures to avoid saturation: e.g DIT=2.51 and NDIT=24, to obtain ~60 sec exposure time per offset.

Saving the OBs: be sure that you create the acquisition and science scripts both in monocular, and that the right item is selected in “acquisition+observation”. After that you can generate your script (click on *Generate Script* button), and export the OT file (File->Export as XML), that you need to send to the LBT team.

5) LUCI MOS

1. Science Program: put PI and title. IMPORTANT: change partner name with INAF. MOS OBs are separated in 2 parts: acquisition (Acq) and science (Sci).
2. Observing Conditions: insert observing constraints. Note: leave *water vapor* as “any”.

For MOS observations the *Targets* item will automatically populate when the LMS file is uploaded. Therefore, first go to the *Instrument* item (LUCI1 or LUCI2):

3. LUCI1 or LUCI2 environment:
    a) Select the lms file of the mask you want to use and select *mask in turnout* under mask position (the information of the target will also be uploaded in the *Targets* item). Check that the appropriated camera is selected (N3.75), filter (the one where the target is brighter), grating (mirror).
    b) For the exposure time: keep Nexpo=1, DIT=2.51s, Save mode=integrated, Readout=LIR. Then change NDIT so that Texp=DIT*NDIT is the exposure time for which your target is visible according to ETC (S/N>=20). DIT*NDIT~60s is usually ok.
4. Target Environment:
    a) Under *Targets* item, be sure that telescope mode is on *active*.
    b) Select the guide star: open Manual GS and load catalog and the image survey clicking on the tab “images”. If you are not happy with the image survey, you can change under the “Catalog” tab. Usually DSS2 IR or 2mass are ok. If a target is visible there, it will also be in the acquisition.
    c) locate a star with 11<R<15 (if the program requires seeing<1, then R<16 is

fine too) within the guide star region (semi-circular region). Please be sure that the guide probe (yellow rectangle) does not obscurate any of you targets or acquisition star.

d) select +LUCIGS and click on the guide star, this will add the star under “targets” in the OT. Please note that in the case of MOS observations, you cannot rotate the field otherwise you won’t see the stars in the alignment slits.

5. Do not touch the Sequence OT component, unless you know what you are doing, it is usually fine as it is.

Now you can move to the science. Also in this case, simply upload the lms file of your mask under the Instrument item (LUCI1 or LUCI2) Be sure that guide-star is the same as for the acquisition.

If you plan to observe just with one filter/grating configuration just do the following:

1. Under the instrument component (LUCI1 or LUCI2) select N1.8 camera, the filter and grating you have chosen (zJspec and HKspec must be used together with the G200 grating), the central wavelength, the slit, and mask in FPU.
2. Under Sequence, in the LUCI offset component, choose the dithering pattern that you prefer.

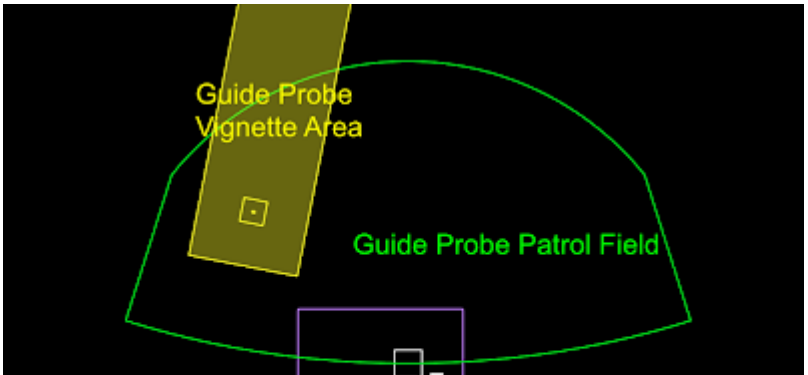
If you plan to use multiple instrument configurations, follow the instructions given in the general advice in the use of the OT.

6) AO and ESM modes

In the case of Diffraction limited and Enhanced Seeing Mode (ESM) you need to provide an AO reference star together with the usual guiding star. The constraints to the guiding star are the same as for seing limited observations (11<R<15 if the program requires seeing<1, then R<16 is fine too).

In both cases, the AO reference stars can be in the magnitude range 3.5 down to 16.5. The quality of the on axis (i.e. on the reference star itself) correction you get, is strongly dependent on the brightness of the AO reference star as well as the the turbulence in the atmosphere. The off-axis correction will decrease with distance from the reference star because of anisoplanatism. **It is recommended to contact the LBT and AO team (details are given in the call for proposals) for designing your observing observing scripts.**

Please note that reference library of reference for Diffraction-Limited (AO), and ESM observation is separated from the one for seeing-limited observations.



OT Visualization of the Guide Probe Patrol field, Guide Probe Vignetter Area, N30 Science Field, and AO reference Field.

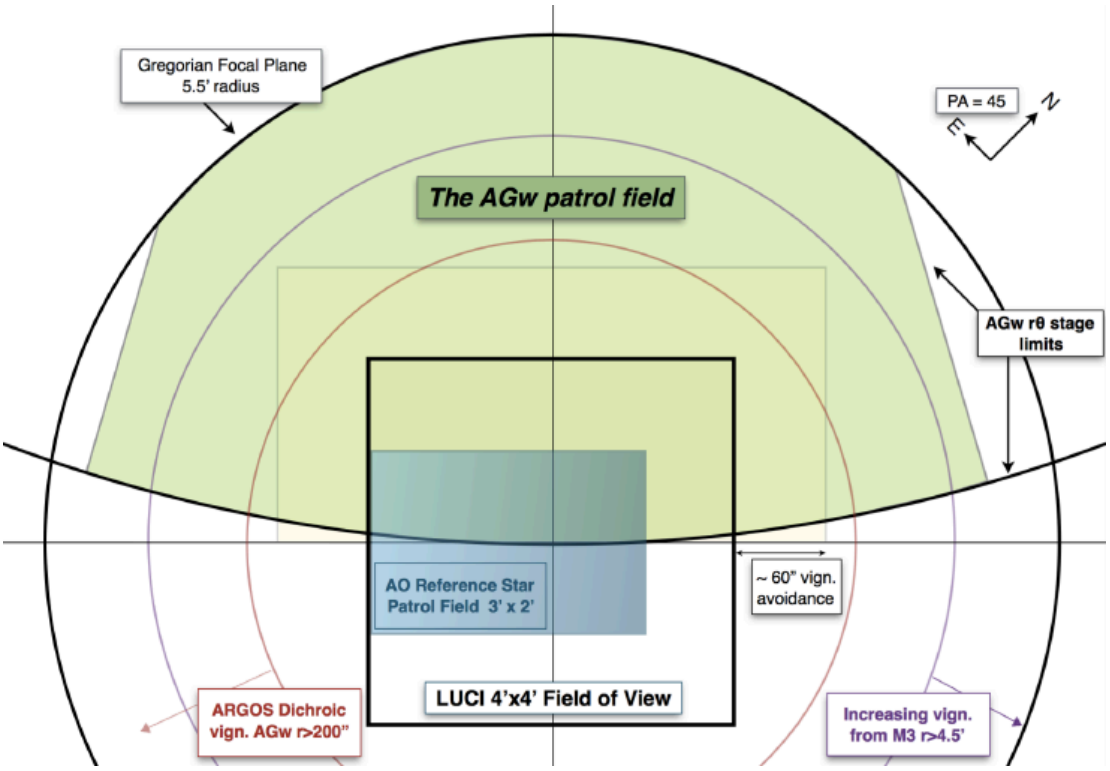
6.1 AO (Diffraction limited) mode with FLAO or SOUL

These observations will make use of the N30 camera with a FOV of ~30”x30”. The AO reference star must lie within the 3’x2’ AO patrol field and can be inside the N30 camera field and can also be your science target (see above figure).

To insert a AO referece star please do the following:

1. *Switch to Target Environment:*
   a) Be sure that Telescope Mode is on *Adaptive* .
   b) Open Manual GS and load catalog and the image survey clicking on the tab *images*. If you are not happy with the image survey, you can change under the *Catalog* tab. Please check that the R and I band magnitudes are comparable, to avoid to select stars that are bright in R because of a bright H emission line. You can also check (esternally) a catalog reporting r-sloan magnitudes.
   c) locate a star with R<16.5 within the AO patrol field (see above figure). Be aware that according to the performances you want to achieve and the distance of your science target the faint limit may change.
   d) select *+LUCI AO* and click on the AO star, this will add the star under “targets” in the OT. Please be sure that the AO star is always within the AO patrol field during the offsets.

Note: The upper part of the patrol field can be vignetted by the guide probe. This will have no effects on the N30 field.



AGw Patrol Field. Diagram shows patrol fiels and vignetted areas. The AO Reference Field is the off center shaded 3'x2' field

6.2 Enhanced Seeing Mode - ESM

These observations will make use of the N3.75 or N1.8 cameras. The AO reference star must lie within the 3'x2' AO patrol field and can be inside the 4'x4' field of view (see above figure).

To insert a AO referece star please do the following:

2. *Switch to Target Environment:*
   a) Be sure that Telescope Mode is on *Enhanced Seeing (ESM)* .
   b) Open Manual GS and load catalog and the image survey clicking on the tab *images*. If you are not happy with the image survey, you can change under the *Catalog* tab. Please check that the R and I band magnitudes are comparable, to avoid to select stars that are bright in R because of a bright H emission line. You can also check (esternally) a catalog reporting r-sloan magnitudes.
   c) locate a star with R<16.5 within the AO patrol field (see above figure).
   d) select *+LUCI AO* and click on the AO star, this will add the star under "targets" in the OT. Please be sure that the AO star is always within the AO patrol field during the offsets.

Note: The upper part of the patrol field can be vignetted by the guide probe. The amount of vignetting depends on where the AO Ref Star is located within the patrol field. However, this impacts the bottom section of the 4'x4' field (below ~1 arcmin).

7) Calibrations

7.1 Telluric stars: (for MOS telluric please see also below)

It is recommended to copy the examples from the library (under *LUCI LongSlit Examples/Templates, Telluric Longslit Examples/Templates*), and only adjust the target, guiding star, instrument configuration (the same used for the science). Leave the exposure times and offset of the example. In the library there is a list of A0V and G2V telluric stars, please select a star according to these rules:

1. Distance: the distance between the science target and the telluric must be below 30 degrees.
2. Brightness: - check the K band magnitude (~V band for A0V stars). For grating G200 must be K>8 mag, for G210 and G150 (LUCI1 only) must be K>7.

Moreover, the acquisition should be taken through crossed filters. Make sure the filters in the *sequence* are consistent with those selected under *instrument*. Depending on the magnitude of the Telluric, select the suitable crossed filter combination (see table below):

Filters	Extinction [mag]
P_gamma+J	0.8
HeI+J	2.35
OH_1060+z	3.9
HeI+z	7

The crossed filter OH_1060+z is the recommended choice.

7.2 Telluric for MOS

The example OBs in the library must be modified. First we consider the acquisition part:

1. Upload the lms file of your mask under the *Instrument* item (LUCI1 or LUCI2).
2. In the *Instrument* item, check that Telluric *YES* is selected (on the right).
3. Under *Targets*, put the name of the telluric star you selected (e.g. HIP 10185). The coordinates should auto populate. If not, do it manually.
4. Under *Targets* item, be sure that telescope mode is on *active*.
5. Be sure to use crossed filters. See table above.
6. Select the guide star: open Manual GS and load catalog and the image survey clicking on the tab “images”. If you are not happy with the image survey, you can change under the “Catalog” tab. Usually DSS2 IR or 2mass are ok. If a target is visible there, it will also be in the acquisition.
7. locate a star with 11<R<15 (if the program requires seeing<1, then R<16 is fine too) within the guide star region (semi-circular region). Please be sure that the guide probe (yellow rectangle) does not obscurate any of you targets or acquisition star.
8. select +LUCIGS and click on the guide star, this will add the star under “targets” in

the OT. Note that you cannot rotate the field otherwise you won't see the telluric in the slits.

9. For the exposure time: very small exposure time is necessary. The one given in the example is fine (e.g. DIT=2.51 and NDIT=3).
10. Under Sequence, in the first LUCI Offset, click the Telluric MOS button to activate it, then push the button.
11. In the pop-up, check Acquisition and select the slit you wish to acquire on. When you click "Create", the first offset will be calculated. We recommend the one most of the left (smallest x value, the default choice).
12. In the next LUCI sequence item, change the crossed filter to be consistent with your previous choice.

Now go in the Telluric Science part of the OB.

1. Upload the lms file of your mask under the *Instrument* item (LUCI1 or LUCI2).
2. Under the instrument component (LUCI1 or LUCI2) select N1.8 camera, and the same configuration (filter, grating , central wavelength) you have selected for the science MOS observation.
3. For the exposure time: very small exposure time is necessary. the default (NDITxDIT<60s) are usually fine. Use readout mode LIR and save mode integrated (default choice).
4. Under *Targets*, change target and guide star. They must be the same as for the acquisition part.
5. Offsets: under sequence, in the offset item, click on Telluric MOS (telluric must be YES under *Instrument* item). The first slit must be the same used for the acquisition. The second should be one far off, (the one with the largest x value). No other target slits are usually necessary.
6. Be sure that for both target slits AB offsets are selected.

7.3 Standards:

Spectrophotometric standards:

Due to slit losses and variable sky conditions is difficult to use spectrophotometric standards. Telluric standards can be used for relative flux calibration. For absolute calibration, the PI is recommended to scale the flux using photometry of the target.

Photometric standards: we can, instead, observe photometric standards, although for JHKs filters it is recommended to calibrate against 2MASS field stars.

7.4 Flats, lamps, darks:

Flats, lamps:

Please copy the examples given in the library for flats and lamps. Do not change exposure times. Change only the central wavelength and mask. Note that the exposure times are not the same for both LUCI instruments, so you need to prepare separated scripts.

Darks:

Please copy the examples in the library. Change exposure time and readout configuration. They must be the same used for the science and telluric observations (same NDIT, DIT, readout, save mode). You can add steps with different configuration under the *Sequence section.*

8) Readme file

It is preferred to have the readme file in an external file in text format (txt). The readme file must contain the following information:

1. PI name
2. PI contact email and (if possible) phone number
3. Target coordinates and magnitude in the NIR, or of the acquisition star(s).
4. Position angle angle if a particular angle is necessary
5. Central wavelength if different from the default one
6. observing constraints (seeing, sky transparency). Airmass and sky brightness are usually not important in the NIR, except in exceptional cases.
7. A brief summary of the observing strategy
8. Calibrations needed, if not standard

9) Finding charts

Finding charts must have a Field of view of 2 arcmin x 2 arcmin. The image must be have filter and depth compatible to what we can see in the acquisition image (exptime~60 sec). 2MASS is the recommended choice.
Please indicate:

1. Orientation N-E;
2. Scale;
3. FOV 2'x2' for spectroscopy, 4'x4' for imaging;
4. Targets (or acquisition stars) in evidence;

10) Useful links

Exposure time calculator (ETC) for LUCI:
https://sites.google.com/a/lbto.org/luci/preparing-to-observe/exposure-time-calculator
Esemples of LUCI OBs:
https://sites.google.com/a/lbto.org/observing-tool-manual/observing-tool/ot-tutorial/luci-ot-examples
OT Library:
https://sites.google.com/a/lbto.org/observing-tool-manual/observing-tool/ot-libraries