

# MISTRAL CookBook

Version 07/04/2022

## MASTER GUIDELINE

«Before writing a MISTRAL proposal, this cookbook you will read»



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The general purpose of this cookbook is to allow observers to successfully perform their observations: from the target selection to the instrument operations, and up to the final data reduction. The cookbook presents basic instructions to follow in the document core. The Appendix gives more detailed information, allowing more precise investigations, as well as examples of spectra and images, to give a flavor of what MISTRAL can achieve.

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# I) MISTRAL basics

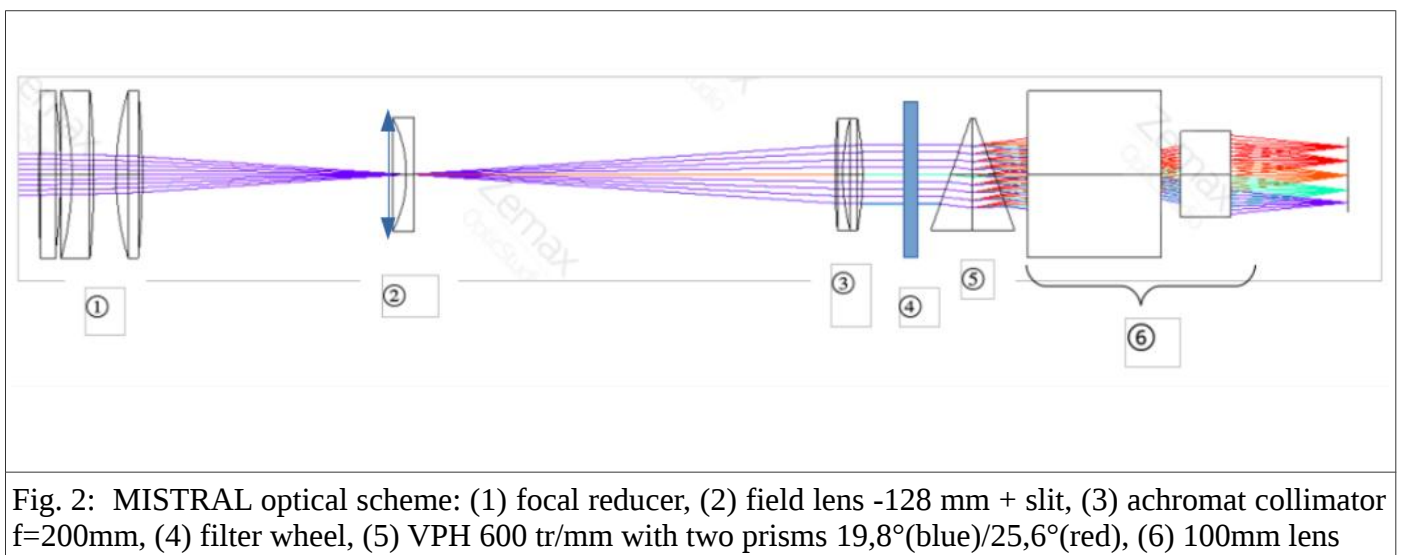
## 1) General instrument description

MISTRAL is a spectro-imager adapted to the folded-Cassegrain focus of the 1.93m telescope via a focal reducer. The focal reducer allows to go from a f-number F/15 to F/6. At the exit of the spectro-imager, the f-number is F/3. The entrance slit is presently 112 microns wide, translating to 1.9 arcsec on the sky. Main characteristics are given in Table 1.

Table 1: Main MISTRAL characteristics

Wavelength range	4200-8200A (blue setting) or 5800-9950A (red setting)
Spectral resolution	R~750 @ 6000A
Fixed Slit width	1.9 arcsec
Optical efficiency (Telescope+spectro)	Estimated at 0.3 @ 6000A (assuming seeing + slit of 2")
Imaging FOV	5.1 arcminutes full light (9' in total)
Filter wheel	G', r', i', z', Y, H $\alpha$ , [OIII], SII, H $\beta$ , red, blue order separation filters
CCD	Andor series iKon-L 936, 27.6 x 27.6 mm / 2048 x 2048 pixels of 13.5 $\mu$ each, Deep Depletion CCD
Spectral calibration	Ar/Hg/Xe lamps for wavelength, Tungsten for Flat Field
Sampling	0.48 arcsec for 13.5 micron pixels
Grism	Blue: Two prism 19,8° with VPHG 600 tr/mm @600nm d=50mm Red: Two prism 25.6° with VPHG 600 tr/mm @900nm d=50mm
Camera lens	Blue: Nikon AF-S 100 mmF/1,4 Red: Objectif XENON-EMERALD 2.9/100-L

Fig. 2 gives the MISTRAL optical scheme.



We also give in appendix the Zeemax predicted spot diagrams.

## 2) Computer architecture

There is an embedded rugged PC (MISTRALtube) directly on board of the instrument. This was chosen to optimize the USB connections with the different modules. Among these modules, there is an IP-power to power on/off the other modules. The instrument is connected via Ethernet to another PC, MISTRALburo, in the observing room. Fig. 3 summarizes the general architecture.

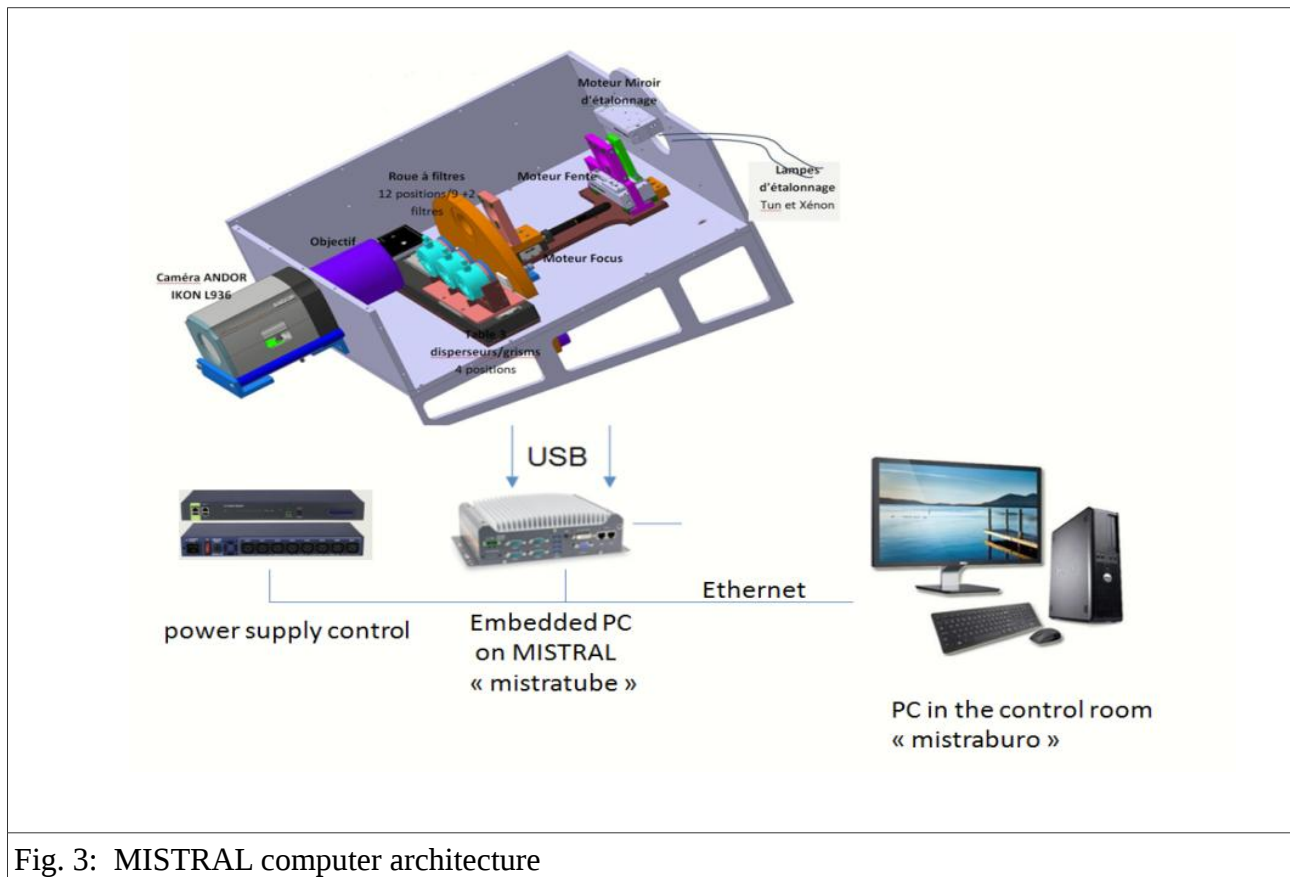


Fig. 3: MISTRAL computer architecture

### 3) Electronic elements

Table 2 gives the main MISTRAL electronic components.

Components	Alim	Link	Parameters	Control	Precision	Remarks
<b>Camera IKON L936 Andor</b>	IP_Power relay n°2	USB n°1	Ctrl through MaxIm DL	Images	/	CCD temperature -90°C with chiller
<b>Cooler Koolance</b>	IP_Power relay n°5	/	ON/OFF	/	Ambiant +~10°C	Water temperature not retro-controlled
<b>Table Dispersors Thorlabs</b>	IP_Power relay n°5	USB n°2	4 pos/Course 300mm	Incremental Coder	1mm	Initialisation at start
<b>Filter Wheel FLI</b>	IP_Power relay n°5	USB n°3	12 positions/9 filters	Incremental Coder	~1°	Initialisation at start / 50mm filter (5mm from centre OK)
<b>Focus Thorlabs</b>	IP_Power relay n°5	USB n°2	Course 10mm	Incremental Coder	6 µm	Initialisation at start
<b>Horizontal slit Thorlabs</b>	IP_Power relay n°5	USB n°2	Course 50mm	Incremental Coder	6 µm	Initialisation at start
<b>Calibration mirror Thorlabs</b>	IIP_Power relay n°5	USB n°2	Course 50mm	Incremental Coder	1mm	On/Off field
<b>Tungsten lamp HL-2000-LL</b>	IP_Power relay n°6	/	ON/OFF	Power Measure		Lampe 12V/20W/1,7A / ON/OFF par un relai
<b>Xe,Hg AR Lamps Ocean Optics</b>	IP_Power relay n°4, 7	TTL 5v	ON/OFF	Power Measure		On/Off through relay
<b>Control power IP POWER</b>	220V	RJ45	/	Power Measure		
<b>Deflector mirror 45°</b>	IP_Power relay n°3, 8	Engine	2 positions	Captors		End course captor
<b>Rugged PC Intel Core i5 8500</b>	IP_Power relay n°1	RJ45	Windows 10 Pro IOT E.	/		Telescope embedded PC linked by ethernet

Table 2: Main MISTRAL electronic components

## 4) Mechanical design

Within the T193 Cassegrain Bonnette, there is a motorised 45° flat mirror which can be moved in to redirect the light onto MISTRAL (folded Cassegrain) or out to the other instrument, SOPHIE, at the straight Cassegrain focus.

MISTRAL is permanently mounted (except when visitor instruments are used) on one of the side slots of the T193 “Bonnette” (folded Cassegrain). Fig. 4 shows the mechanical design. The instrument includes four Thorlabs motorized stages used to move/remove elements from the optical path: the slit, the grisms, the filters and the calibrating mirror. It also provides a way to optimize the instrument focusing. The FLI filter wheel has 12 positions. Calibrating lights are inserted within the optical path by four optical fibers via the calibration mirror which needs to be moved in. In order to facilitate the operability and stability of the instrument, all the calibration lamps, power supplies and electronic modules have been integrated directly in the mechanical structure of the instrument.

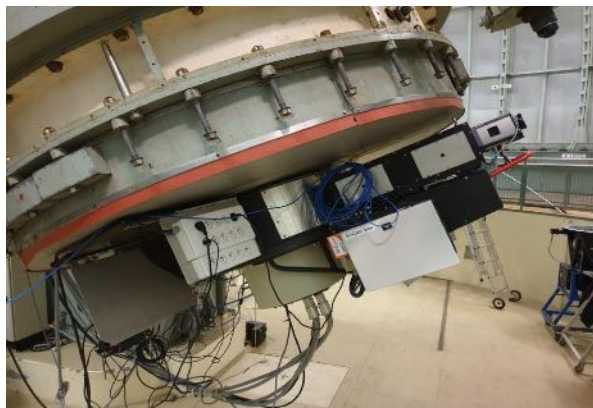


Fig. 4: MISTRAL installed at the folded Cassegrain focus of the 1.93m telescope at OHP

## 5) Working environment

Fig. 5 presents the working environment for MISTRAL inside the T193 control room. To the left is the personal visiting astronomer's place, where you can install your personal laptop and connect it to an additional screen (through a VGA connection). To the right is a four-screen wall. The two upper screens are for the control of the spectrograph, and the two lower screens are for preparation of the observations (exposure time calculators, night planner, etc.), data reduction (spectrum and image quick look tools, ..etc...), web pages, etc. At the extreme right, you have a (cable-)phone (04 92 70 64 48).



Fig. 5: working environment for MISTRAL



## 6) MISTRAL Control command

The two upper screens (see Fig. 6) are controlled by the PC "MISTRALtube". This PC is physically mounted on the T193 telescope and directly pilots the instrument itself. The various panels of these screens are described below.

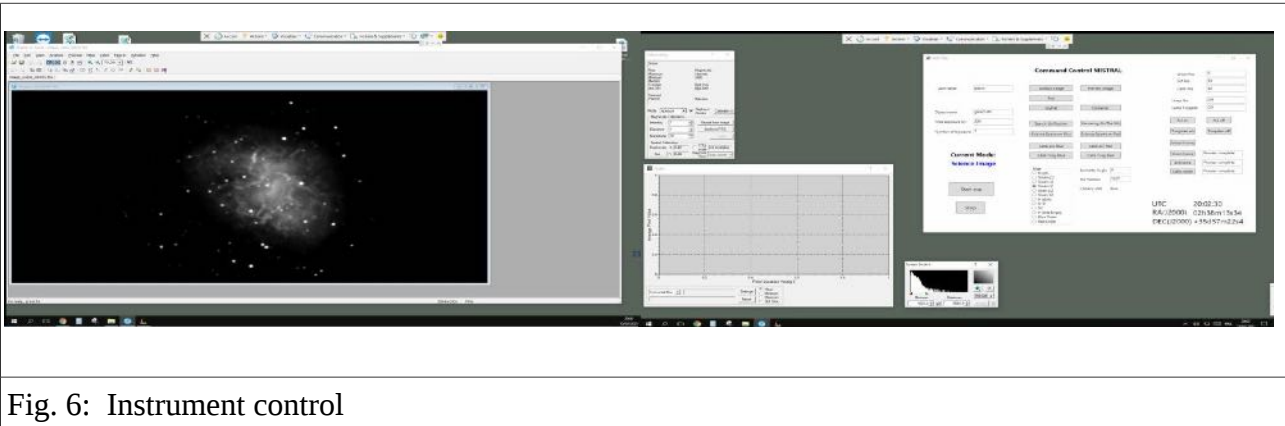


Fig. 6: Instrument control

a) First, to the right of Fig. 6, one sees the MISTRAL command control interface (details in Fig.7).

- It allows to launch predefined MISTRAL observing sequences. Several observing modes are offered, which differ by the position of the various elements in the optical path. These elements are the filter wheel (12 positions), the spectral dispersors (blue and red VPH, associated with a blue and red entrance lens), and the slit (1.9 arcsec wide). Light from calibration lamps (HgArXe spectral lamps and Tungstene flatfield lamp) can also be injected in the optical path. These modes are summarized in Table 3.

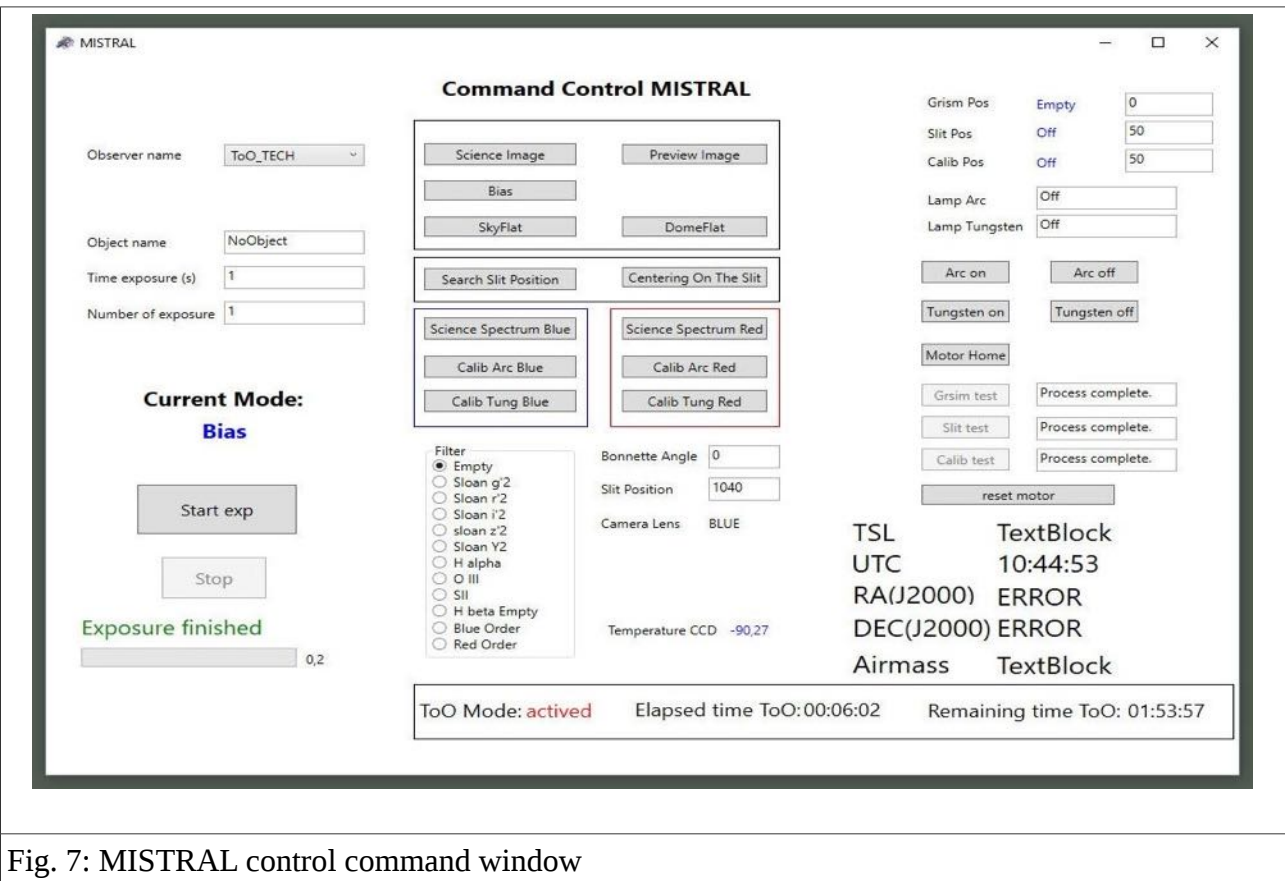


Fig. 7: MISTRAL control command window

Table 3: Summary of different MISTRAL operating modes

N° Mode	Mode	Camera shutter	Camera reading speed	Filter wheel position	Dispersion	Slit	Calibration Mirror	Wavelength calibration lamp	Spectral flatfield lamp	Images saved?
1	Bias	Closed	50 kHz	N/A	N/A	N/A	off	off	off	yes
2	Preview Image	Open	3 Mhz	Choose filter	off	off	off	off	off	no
3	Science Image	Open	50 kHz	Choose filter	off	off	off	off	off	yes
4	SkyFlat/DomeFlat	Open	50 kHz	Choose filter	off	off	off	off	off	yes
5	Search Slit Position	Open	3 Mhz	Empty	off	on	off	off	off	possible
6	Centering on the Slit	Open	3 Mhz	Choose filter	off	off	off	off	off	no
7	Science Spectrum (blue/red)	Open	50 kHz	Blue or Red Order	On (blue/red)	on	off	off	off	yes
8	Calib Arc (blue/red)	Open	50 kHz	Blue or Red Order	On (blue/red)	on	on	on	off	yes
9	Calib Tung (blue/red)	Open	50 kHz	Blue or Red Order	On (blue/red)	on	on	off	on	yes

(1): Mode to measure the camera offset signal.

(2): Mode to center image on targets (imaging mode), and to focus the telescope. Fast reading with relatively high reading noise. These images are not saved.

(3): The goal is to take science images.

(4): Mode to take flat field images with the goal of correcting the differential spatial CCD response. Has to be done preferentially on the sky (see below), and within each filter. Response is very different from a filter to another one.

(5): Mode to locate the slit “x” position within the CCD before moving the telescope to push the target within the slit. Slit is seen thanks to the sky surface brightness. Rapid reading mode.

(6): Mode to move the target at the slit position. Rapid reading mode. Images are not saved.

(7): This is the mode to take the spectrum of your science target (blue or red disperser). In principle to be done without regular filters (unless you really have special reasons), and with an order separation filter for the red disperser.

(8): To take wavelength spectral calibrations in order to relate “x” position to wavelength.

(9): To take spectral flat fields in order to correct for CCD differential spectral response.

- It allows to choose the filter to put in the optical path (see Appendix XIII for response curves of the offered filters)

- It offers basic information about the positions of the different elements (grism, slit, calibration mirror positions, and status of calibration lamps).

- It shows buttons designed to move manually the different spectrograph elements. These are only active in expert mode, a priori not offered for regular operations.

- It allows the observer to manually enter the “bonnette” angle and the slit position. It also indicates the camera lens presently mounted. These informations are stored as keywords in the fits headers.

- It asks for the observer and object names, as well as the required exposure time and the number of requested exposures.

- The observer has a “start exposure” button to launch the exposure, and a “stop” button to stop a sequence of several observations (running exposure achieved and saved).

- Finally, the current mode is displayed, authorizing you (or not) to start the requested sequence.

**GUIDELINE: «Select the mode you need, but wait for permission from the window (Current mode) before clicking on “Start Exp”»**

b) To the left is the Maxim DL window for image visualization after acquisition (a MISTRAL image of the Crab Nebula is shown in Fig. 8), along with some pre-processing tools which allow to perform basic operations on the images (extraction of the flux along a line, a box, etc. + basic statistics on the regions). This is useful to e.g. locate precise objects on a image or to show some flux variations along a 2D spectrum (see other MaxImDL windows to the right of Fig. 8). The MaxIm DL is a tool in itself and allows many more operations but usually only the most basic ones are needed (see also <https://diffractionlimited.com/help/maximdl/MaxIm-DL.htm>). In any case we warn the user against uncontrolled and unsupported MaxImDL uses on the PC "MISTRAL-tube" because this can affect directly the control of the MISTRAL instrument itself.

**GUIDELINE: “Data treatment on the PC "MISTRAL-tube" you will not perform, unless you (REALLY) know what you are doing”**

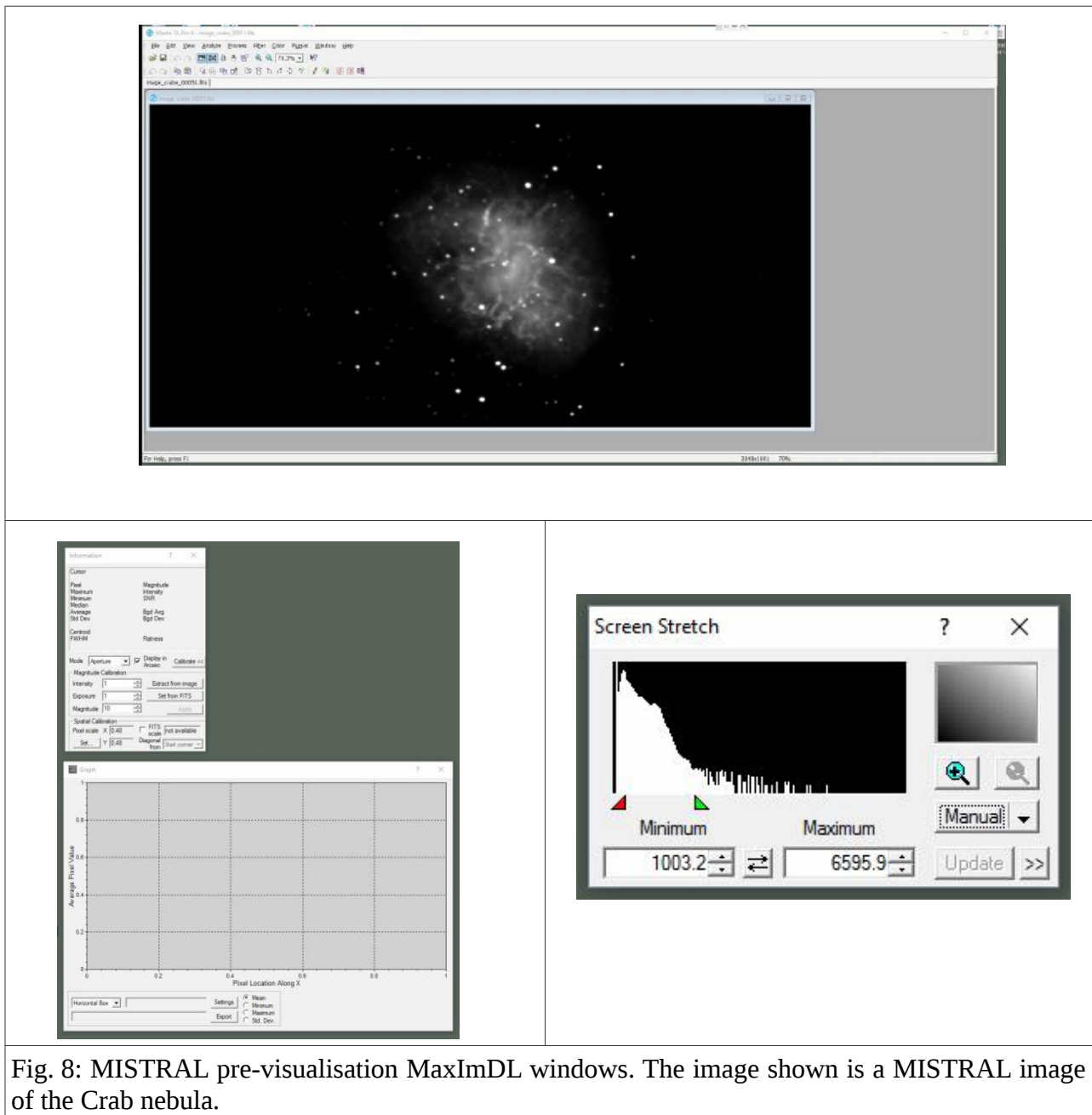


Fig. 8: MISTRAL pre-visualisation MaxImDL windows. The image shown is a MISTRAL image of the Crab nebula.

## 7) Screens of the PC "MISTRAL-buro"

As already said, the two lower screens are dedicated to the preparation of observations (exposure time calculators, night planner, etc.), data reduction (spectrum quick look tool, etc.), web pages, and all personal observer's tasks. They also offer a coordinate server. This is the window showing the telescope coordinates, in principle located in the lower right screen. If not present, you have to launch the "telnet\_coord.exe" icon (on the lower left screen)

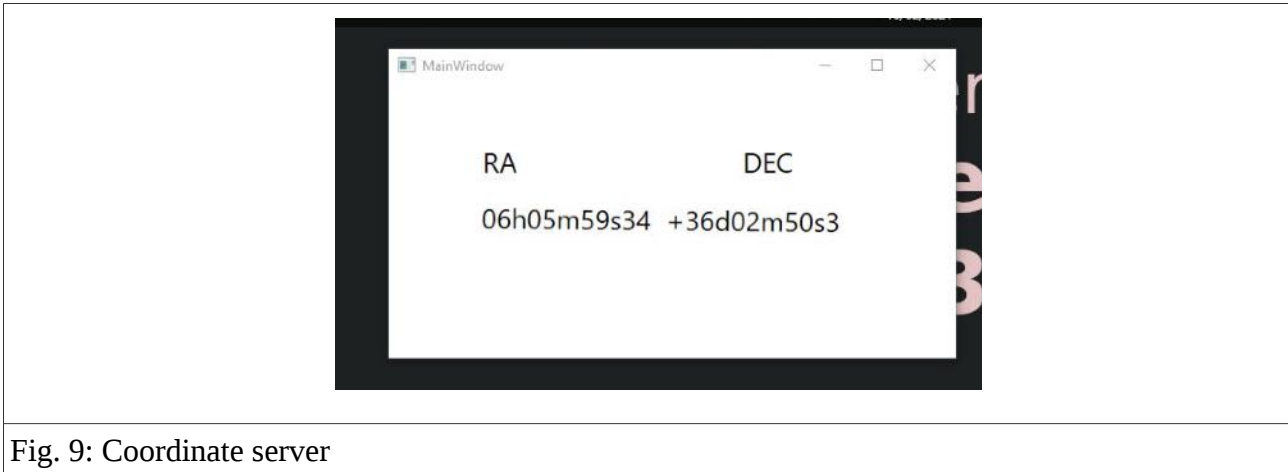


Fig. 9: Coordinate server

## 8) General directory management

The generated fits files are first stored within PC MISTRALtube. However, this is NOT the place where you can play with them. They are also duplicated into the other PC MISTRALburo. Science images (slow reading mode) are located by default in the "DATA/date/username" directory and are reachable through the "Access to data" icon. Working files (pointing images, object through slit, ..etc...: fast reading mode) are stored in a subdirectory called "workfile" (DATA/date/username/workfile). Username is the one requested in the Command Control MISTRAL window (upper right screen). Date is the current date.

**Warning: if you change the username during the night, it will create a new directory**

## 9) Start mode

In principle, you should find the whole system online when you arrive at the telescope. If this is not the case, the process to follow is presently described.

- you must restart UltraVNC Viewer



You have to give the right IP address of the VNC server (in principle the first in the list, proposed by default). Then “connect” and enter password (available in the observing room). It opens a window on the upper left screen.

You have to enlarge/maximize the window to cover the two upper screens.

You can now restart the Mistral icon.



By default we suggest you put the MISTRAL window inside the upper right screen and the MaxImDL inside the upper left screen.

# 10) Panic mode



a) As every system, the MISTRAL control command may experience troubles.

*First level:* windows are frozen: first, try to kill the blocked processes (windows). As you are working remotely, you have to send the CTRL-ALT-DEL by clicking on the corresponding button at the upper left of the upper left screen:



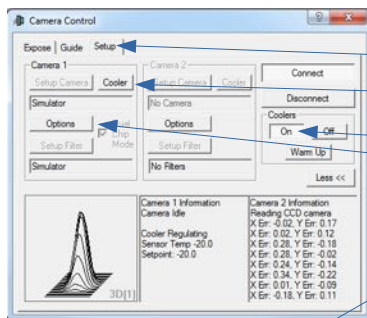
*Second level:* hardware problems as blocked motors, lamps, CCD reading/link: you have to make a reset of the MISTRAL electronics through the PANIC BUTTON (right lower of the bottom left screen). In this case, you have to restart the process described in 9)



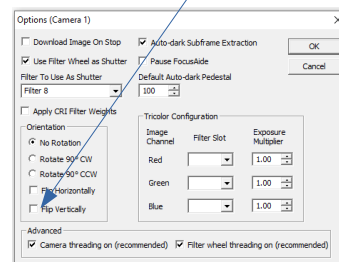
*Level three:* the PC "MISTRAL-tube" is blocked, unavailable, or not functioning: you have to reset the PC also through the PANIC BUTTON. In this case, restart the process described in 9)

*Level four:* use the wonderful cable phone to your right and call the support astronomer / support engineer, being as kind and compliant as possible ...

*To check in any case:* in case of crash/reboot/..etc... or if the temperature in the MISTRAL command control window is turning to red (significantly hotter than -90deg), you have to check that the CCD is cooled actively. For this you have to check the MaximDL window "Camera Control"



Activate the "Setup" button, click on the "Cooler" button to check if the temperature is really setuped at -90deg. If not, do it, and click "OK". Finally, put the cooler "on". Last step is to click on "Options" and activate the camera orientation to flip it vertically.



**Congratulations, you are back in the competition!**

In case of really unsolvable problems, you can contact the support astronomer at the numbers and/or emails he will give you before the start of the run

## II) Going deeper into MISTRAL operations

### 1) CCD reading modes

Several CCD reading modes are available (nominal temperature of the CCD:  $\sim -90^\circ$ , saturation level:  $\sim 60\,000$ ). Two modes have been extensively tested and they are the only ones offered: fast mode (3 MHz) and slow mode (50 kHz). They are briefly described in Table 4. The fast mode is adapted for technical operations such as telescope focus or pointing, thanks to the very short reading time allowing e.g. real-time object focusing. We do not recommend to use this mode for science operations, where slow mode offers a nearly three times lower read-out noise. In principle, you do not have the choice of the reading mode in the described MISTRAL modes in Table 3.

<b>Table 4</b>	Fast mode: 3 MHz	Slow mode: 50 kHz
Read Out Noise	11 e <sup>-</sup>	4 e <sup>-</sup>
Reading time	0.7 sec	40 sec
Gain in e <sup>-</sup> /ADU	1.03	1.03
Best for	Telescope Focus / pointing	Science Operations

### 2) Blue vs Red dispersor: response function

The dispersor (blue or red) has to be chosen before the beginning of the run in order for the right camera lens to be mounted. In principle this camera lens can also be changed (two lenses are available: blue and red). However, the lens cannot be changed during the night because the operation has to be done by technical staff. The best that can be done is to change it during the day between two nights. *And remember that a change of lens requires also to redo all the calibrations!* In order to measure the CCD spectral response, several standard spectrophotometric stars were observed. Fig. 10 shows the computed spectral response for the blue dispersor / blue lens (from Feige 15 observations) and for the red dispersor / red lens (from HR1544 observations).

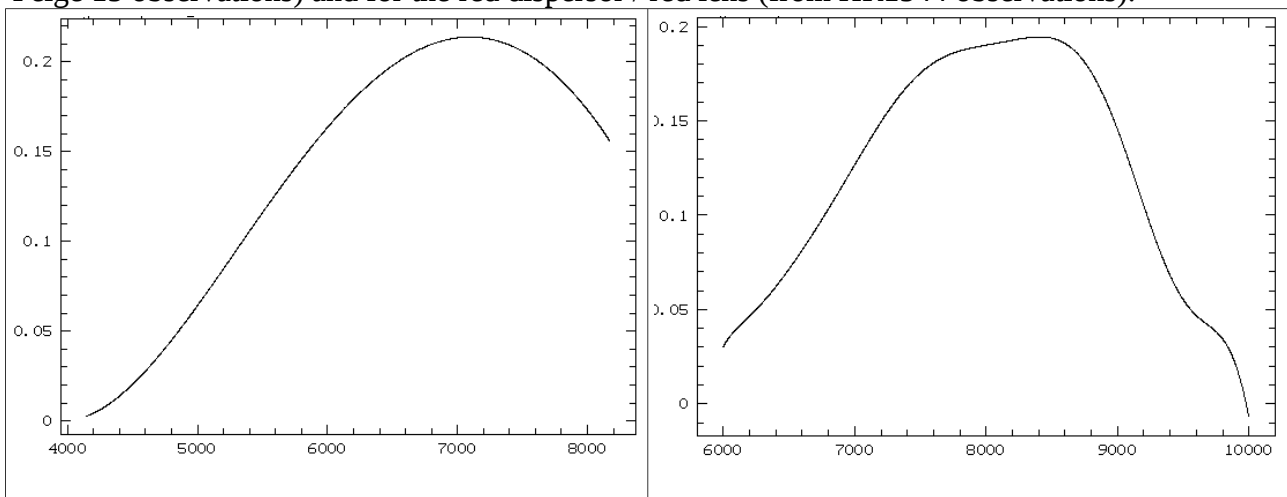


Fig. 10. Relative CCD spectral response. Left: blue dispersor / blue lens (from Feige 15 observations). Right: red dispersor / red lens (from HR1544 observations).

**GUIDELINE: «Well before your MISTRAL run, your wavelength domain you will choose»**

**GUIDELINE: «If your wavelength domain you want to change during your run, you have to warn the staff as early as possible »**

### 3) Red disperser pros and cons: fringing and sky lines

On the one hand, the red configuration offers an interesting efficiency close to 1 micron (see Fig.10). This can be very useful to study objects with intrinsically red lines such as the H Paschen lines. This configuration is also crucial to study (bright enough) redshifted objects with lines in the near infrared domain. It is also very convenient in imaging as it allows the use of a Y filter, crucial to detect embedded objects or to increase the wavelength coverage e.g. for photometric redshifts. On the other hand, at wavelengths redder than  $\sim 8000\text{\AA}$ , the spectra are polluted by numerous sky emission lines. Moreover, despite the fact that the MISTRAL CCD is a deep depletion device, fringing is still visible when observing at the red end of the MISTRAL wavelength range.

#### A) Imaging mode:

Figure 11 shows the typical fringing patterns we can expect with the MISTRAL images within the g', r', i', z', and Y filters. These are <1hour images of the Xclass3091 cluster of galaxies, where we draw the background contours in order to put in evidence possible regular patterns. We detect no strong fringing for the g', r', i', and z' bands. Such a fringing is however visible in Y band under the form of a linear oblique pattern. Defining a test line perpendicular to the pattern main direction, we followed the background intensity fluctuation. Figure 12 shows that this fluctuation has a weak amplitude of the order of  $\pm 2\%$  (without any correction applied other than the standard sky flat).

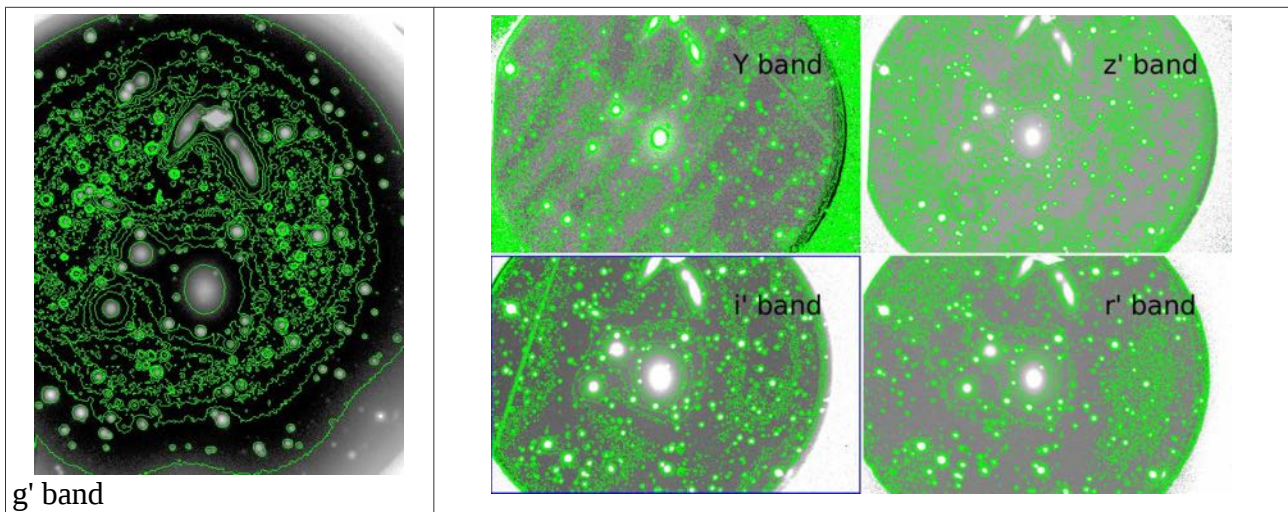


Fig.11. Images of Xclass3091: Y band: 1hour, z' band: 40min, i' band: 50min, r' band: 40min, g' band: 60min. In green, ds9 contours enhancing signal close to the sky background.

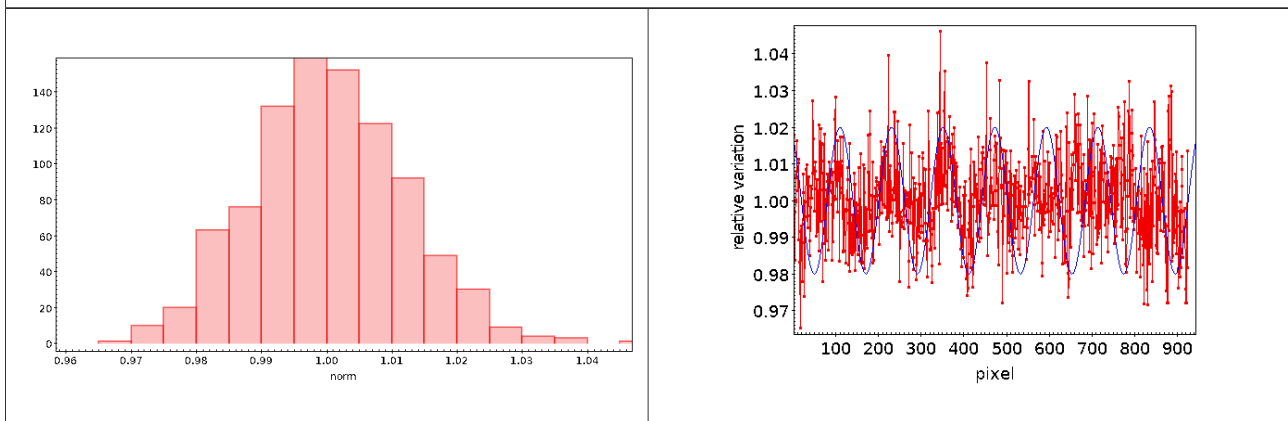


Fig. 12. Left: histogram of the relative (wrt sky level) flux variation along the test line. Right: position along the test line (in pixels) vs the flux variation. Blue curve : arbitrary sinusoidal curve.



## ***B) Spectroscopic mode:***

The situation is less favorable when considering spectral observations because the fringing contribution is not averaged over a large spectral range, within the Y band filter. We have used spectral flatfield exposures to investigate the fringing level. Figure 13 shows an example of detected fringing. It can reach +/-7 % of the signal.

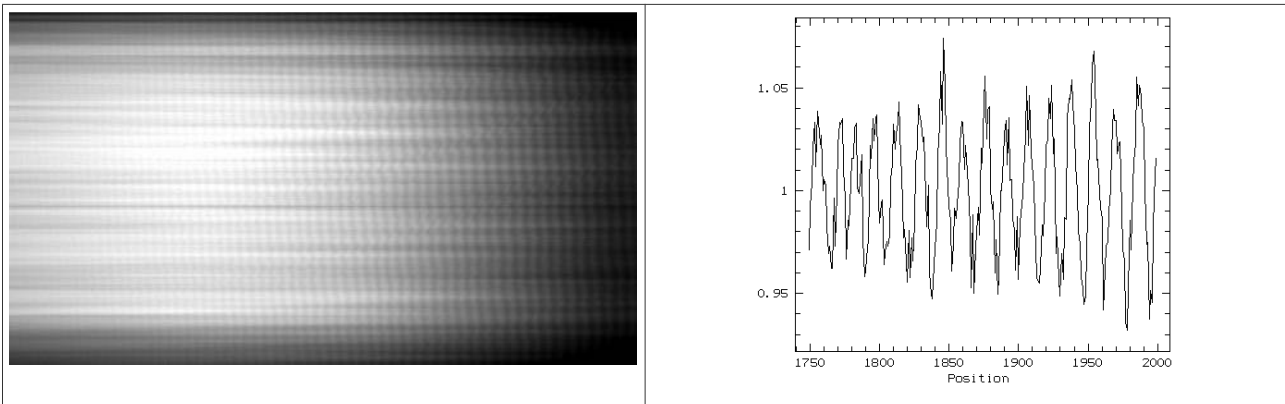


Fig 13. Left: last third (toward the red edge) of a spectral flatfield. Right: normalized value (expressed in percentage of the flux) of the fringing over the last 250 pixels of the CCD.

We give in Appendix VIII a possible method to get rid of these variations. This is however not integrated at the moment in the data reduction software.

**GUIDELINE: «The fringing and the numerous sky lines at  $\lambda > 8000\text{\AA}$  you will not forget when red observations you will plan »**

#### 4) MISTRAL internal guiding

This guiding offers a  $\sim 70\text{arcmin}^2$  accessible field of view. This allows the telescope to automatically guide on  $V < 17$  stars. This guiding device being physically attached to MISTRAL, it is not strongly affected by mechanical flexions. It ensures a punctual object to stay within the slit for at least 2 hours (see Fig. 14). The percentage of sky fields where no star will be available to ensure guiding was estimated, based on the HST Guide Star Catalog (<http://tdc-www.harvard.edu/catalogs/hstgsc.html>). Basically all sky positions have at least a suitable star for guiding, and 85% have at least three (see Fig. 16).

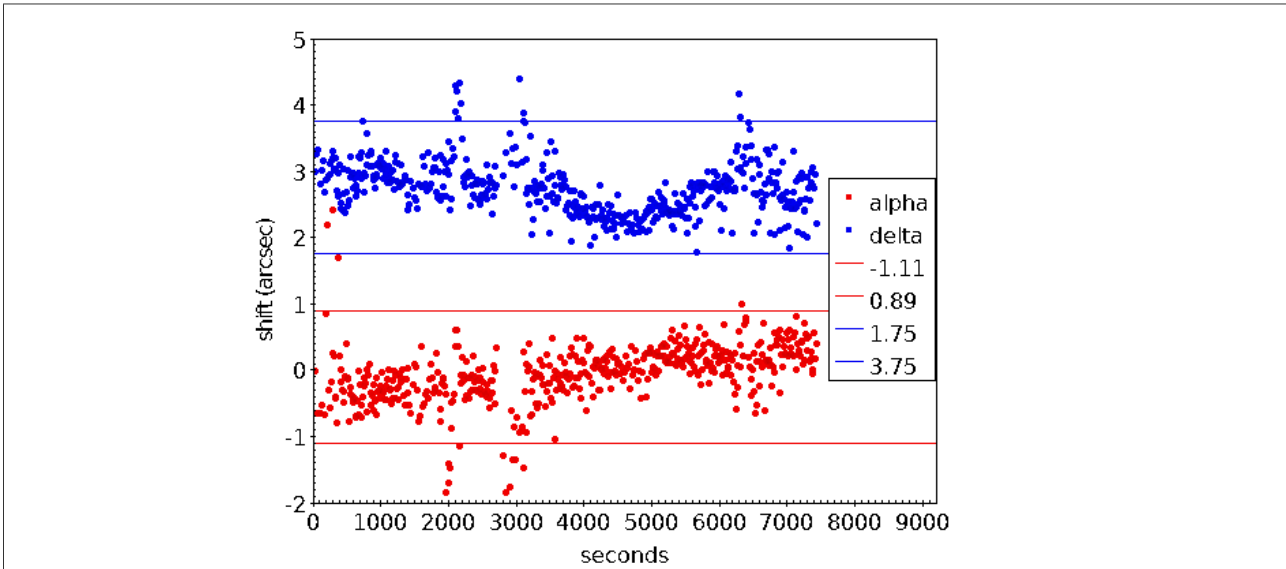


Fig. 14: typical expected drifting in alpha and delta directions. The slit width is shown as the horizontal blue and red double lines. Punctual departure in the guiding where due to passing clouds inducing the loss of the guiding star.

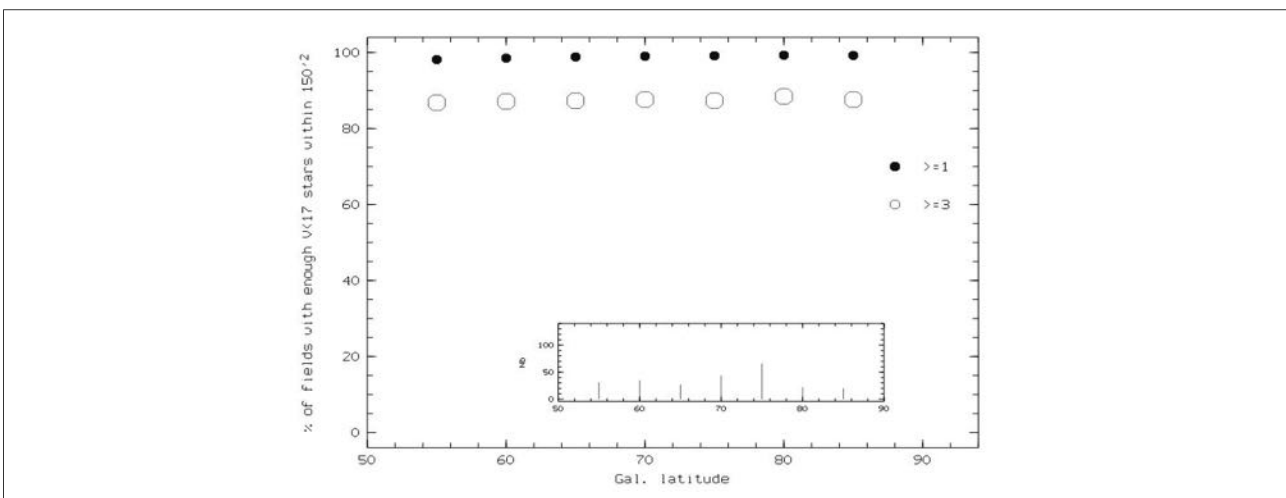


Fig. 16. Percentage of fields providing at least one star and at least three stars with the new MISTRAL internal guiding. The inset gives the number of stars in these fields as vertical bars.

## 5) Optical distortion in imaging mode

Optical distortion is sometimes a problem in imaging mode. The goal of the present section is to investigate this distortion. For this, the imaging 2020 June run allowed the observation of the Xclass3264 cluster of galaxies (under a bad seeing of  $\sim 4$  arcsec, and without filter). We then compared this MISTRAL image with the corresponding SDSS image in the  $g'$  filter. For this, we measured the  $x,y$  coordinates of the objects in the MISTRAL image and in the SDSS  $g'$  image. We then found the linear transformation to apply to the MISTRAL coordinates in order to get the SDSS coordinates. Figure 17 shows the superposition of both coordinates within the central  $5' \times 5'$ . Within the seeing limit, no clear optical distortion is visible.

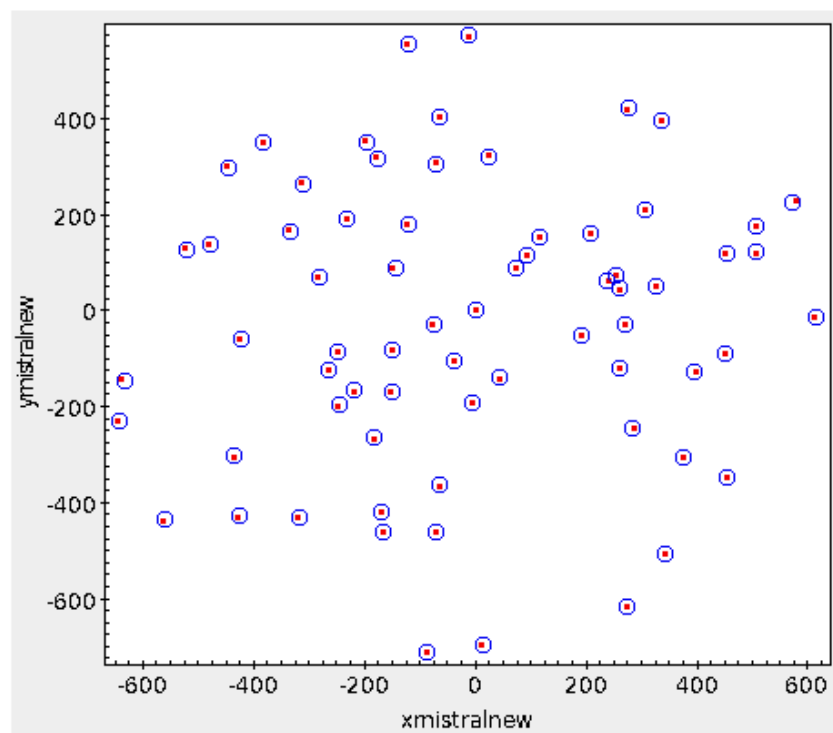


Fig. 17. Circles: SDSS positions, dots: MISTRAL positions (pixels).

## 6) Internal reflections

### a) Stars

The different optical elements along the optical path generate, as in every instrument, reflections towards the CCD. When dealing with bright objects, these reflections (ghosts) can mimic real objects. Their intensity was estimated using Zeemax simulations: assuming a typical  $V < 22$  star population from the Besançon model (<https://model.obs-besancon.fr/>), we predicted what would be the resulting ghosts for such a sample (see e.g. Fig.18).

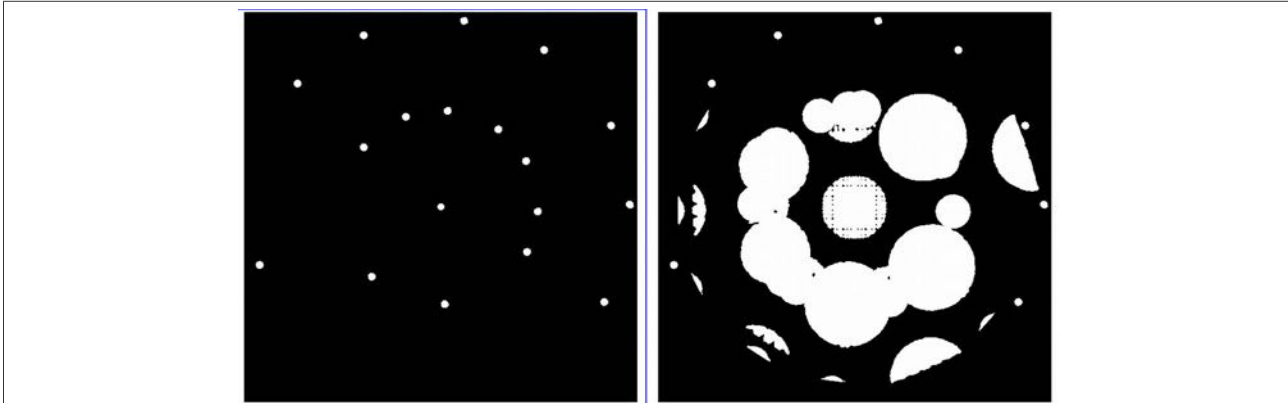


Fig. 18. Example of MISTRAL Zeemax simulation (not taking into account the entrance lens). Left: input objects. Right: resulting ghosts.

Such « fake » objects are most of the time fainter than any real object which can be accessed by MISTRAL in imaging mode, by at least 5 magnitudes (see e.g. Fig.19). So their contribution to catalogs of real objects is negligible.

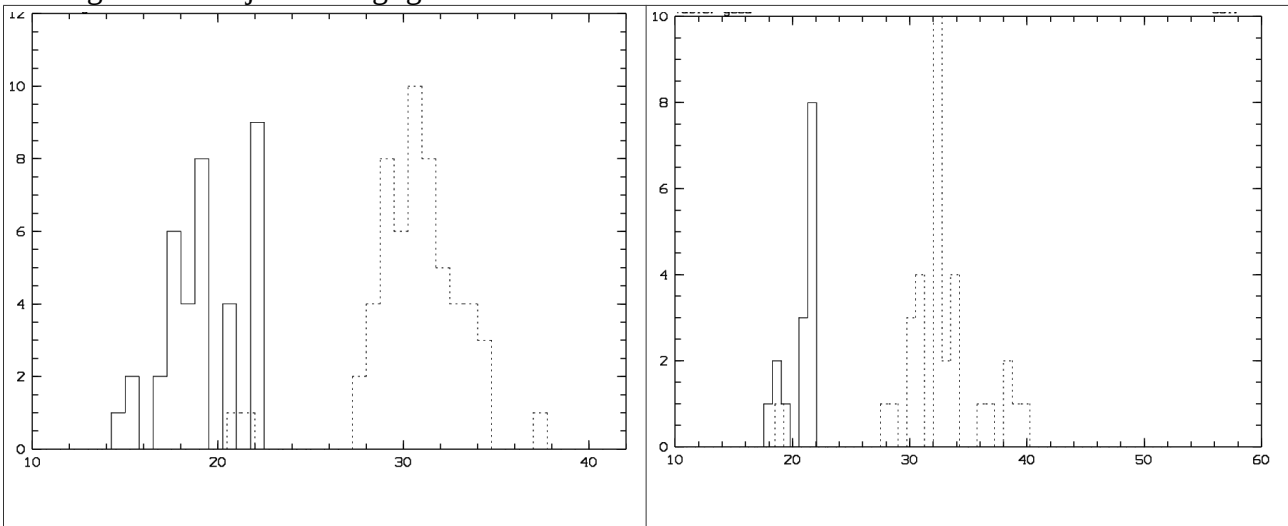


Fig. 19. Input V band magnitudes of a star population: continuous histogram. Output ghost V band magnitudes: dashed histogram. Left figure: typical star population at galactic latitude of +30deg. Right figure: typical star population at galactic latitude between 60 and 90 deg.

If these ghosts are located on top of real objects, they can also induce some error in the magnitude measurements of real stars. Considering the mean star populations of Fig. 19, in the worst case (close to the galactic plane where we have the brightest stars), the magnitude induced error is statistically less than 0.01 magnitude. Close to the northern galactic pole, where the stars are

statistically fainter, the value is even smaller, of the order of 0.001 magnitude. In any case, these measurement errors are by far dominated by the seeing and sky induced uncertainties. Extreme cases were also investigated. We tested  $V=4.4$  stars and predicted ghosts of  $V>24$  magnitude. The induced magnitude error of such a bright star is lower than 0.05 magnitude, that is of the same order as the sky/seeing induced magnitude uncertainty.

## b) Galaxies

The effect of star ghosts on more extended objects (= galaxies) was also investigated in the Zeemax simulations.  $V=[15, 20]$  galaxies experience statistical magnitude errors of  $\sim 0.02$  magnitude, induced by ghosts of a statistical population of stars at any galactic latitude. In the most extreme case of bright stars having their ghost falling right on a galaxy, consequences are more important and given in Table 5.

V magnitude of polluting star	V magnitude of affected galaxy	Induced magnitude error
11.9	15	0.02
11.9	17	0.06
11.9	19	0.32
9.4	15	0.09
9.4	19	1.65

Table 5: Induced galaxy magnitude errors by stars of different magnitudes having their ghost falling right on the galaxy.

As a conclusion, galaxy magnitudes should not be strongly affected by ghosts of a star populations, even if in a few cases, very bright stars in the field may affect relatively faint galaxies.

### III) Planning the night

#### 1) Object observability

In case you do not know how to predict the observability of your favorite objects, you may use this planner: <https://iris-observability.lam.fr/>. Developed for the IRIS telescope, it allows to compute the visibility of any object from the OHP site.

**GUIDELINE: «The planner you will use, in order to avoid bad encounters with the Moon in the vicinity (or telescope collisions) »**

#### 2) OHP sky

The sky brightness at OHP is relatively high (<http://www.obs-hp.fr/guide/camera-120/camera-120.shtml#ciel>) and you must check that this will not erase your targets if you plan e.g. to follow faint features. Table 6 gives the sky brightness at several wavelengths.

Table6: sky brightness across the MISTRAL spectral domain			
MISTRAL blue domain		MISTRAL red domain	
3800-5200 A	4900-6700 A	5600-8400 A	7200-9000 A
21.7 mag.arcsec <sup>-2</sup>	20.7 mag.arcsec <sup>-2</sup>	20.1 mag.arcsec <sup>-2</sup>	19.0 mag.arcsec <sup>-2</sup>

**GUIDELINE: «Too low surface brightness objects you will not try to observe»**

Second, observers must keep in mind that the OHP sky can be significantly polluted by public lights of the nearby cities (St Michel, Mane, Forcalquier, Manosque, or even Marseille). This pollution is the strongest around the sodium D1/D2 doublet around 5900A. Figure 20 shows a MISTRAL sky spectrum observed in January 2021 where this doublet is clearly visible and will affect significantly any science spectrum between 5800 and 6100A. This will make the detection of weak spectral features in this wavelength range possibly problematic.

**GUIDELINE: «Too faint features close to the Na doublet you will not hope to detect»**

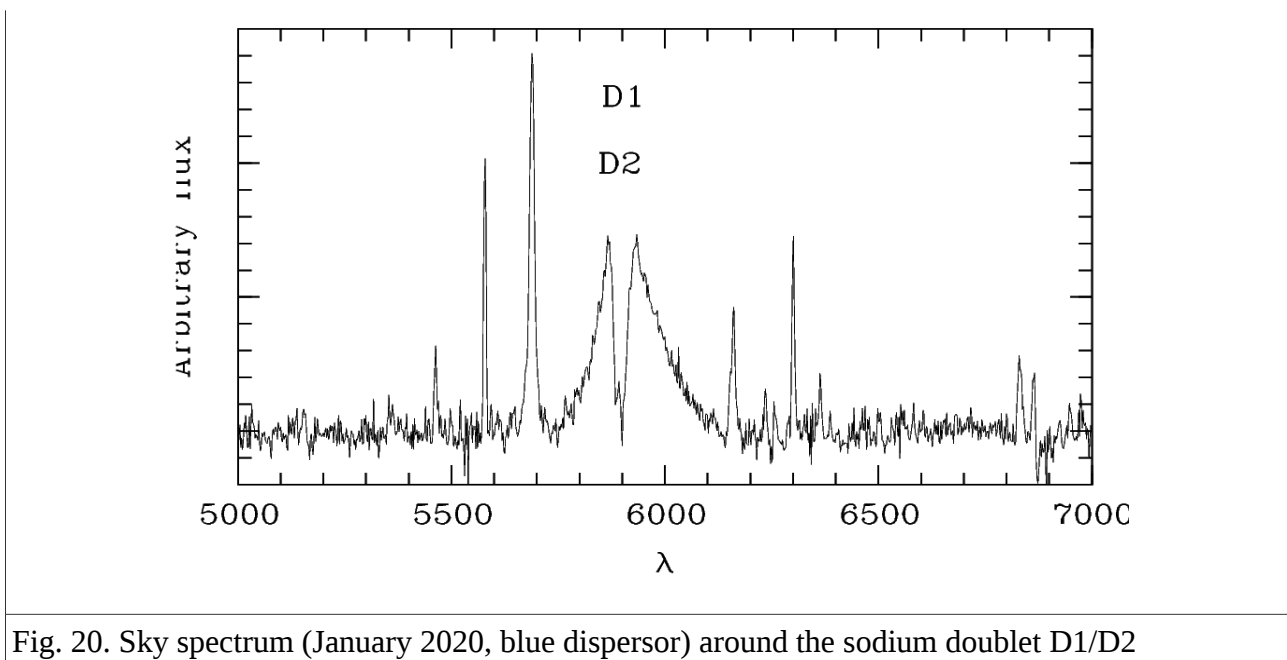


Fig. 20. Sky spectrum (January 2020, blue dispersor) around the sodium doublet D1/D2

### 3) Estimate your exposure times

#### a) Are your objects not too bright ?

This may appear only as a « rich-astronomer » issue, but it is important to first check that your objects are not too bright. Besides the CCD saturation level, you have to take into account the fact that the accuracy of the exposure time is limited by the shutter behavior for short exposures (iris shutter, not translation shutter). This must be taken into account when trying to relate observed and theoretical fluxes for (too) bright standard stars. To investigate the MISTRAL shutter behavior and the accuracy of the measured exposure time, we have acquired ten spectral flatfield exposures for different exposure times. For each exposure, we have measured the mean flux within a 10x10 pixel square at the (1505,505) coordinates (a place where the flux is high). Figure 21 gives the mean flux as a function of the exposure time (dots). The same figure also gives the linear relation fitted on these dots for exposure times larger than 1sec: selecting only the exposure times larger than 1sec, where the exposure time / flux relation is expected to be linear, we determine the parameters of this relation. For very short exposures, the curve does not follow the observations, as expected.

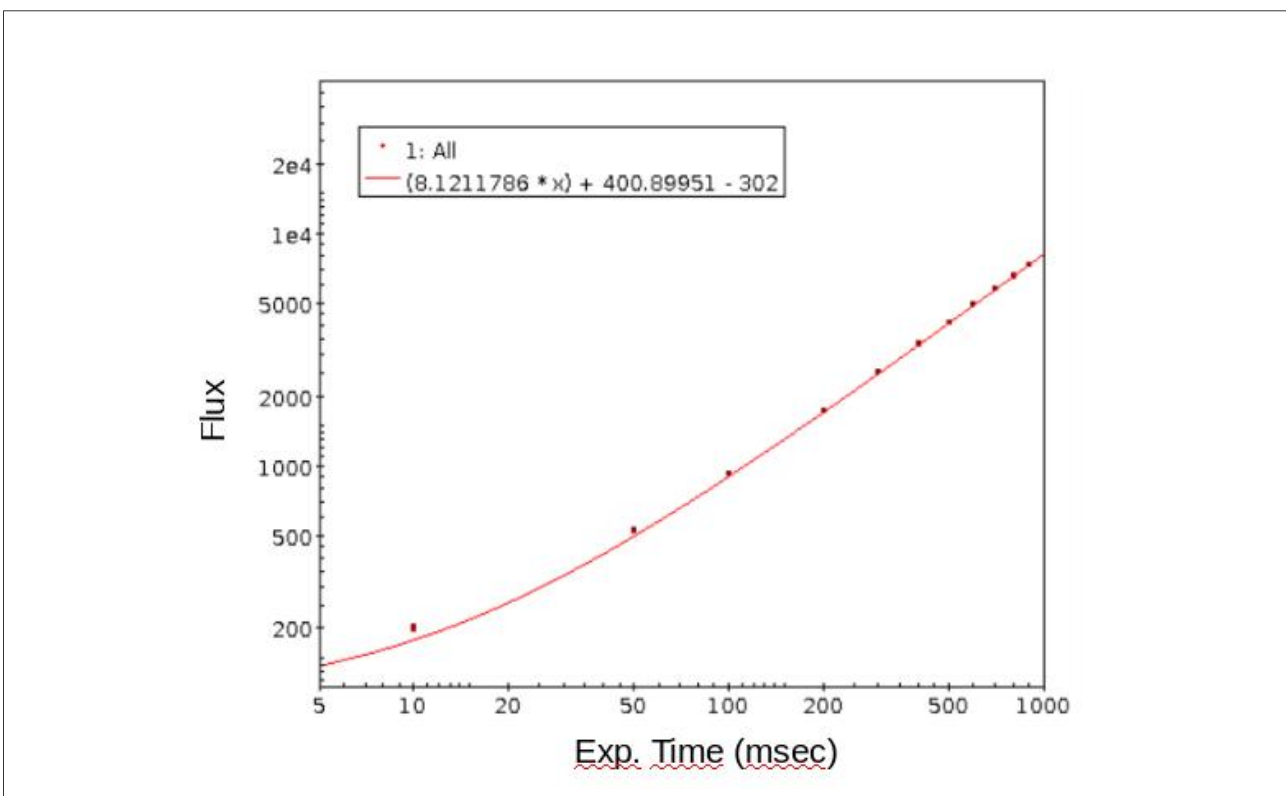


Fig 21. Dots: log-log mean flux (along the y direction) in a 10x10 pixel area versus the requested exposure time (in millisec, along the x axis). The red curve is the mean relation computed for exposure times larger than 1sec.

We determined more precisely the exposure time where the relation becomes non-representative of the observations. For this, we have computed the dispersion between the fluxes of the ten images for each chosen exposure time. We have then compared this value to the difference between the mean flux for this given exposure time and the flux predicted by the model (shown in Fig.21). Fig. 22 shows the variation of this difference in terms of number of sigma versus the exposure time. In other words, this figure gives the number of sigma separating the mean observed flux and the modeled flux (if the shutter closing time was null). It appears that exposure times shorter than 0.6sec start to show observed fluxes significantly lower (at the 2sigma level) than the expected

ones. These 0.6 seconds therefore typically represent the minimum exposure time we recommend with MISTRAL.

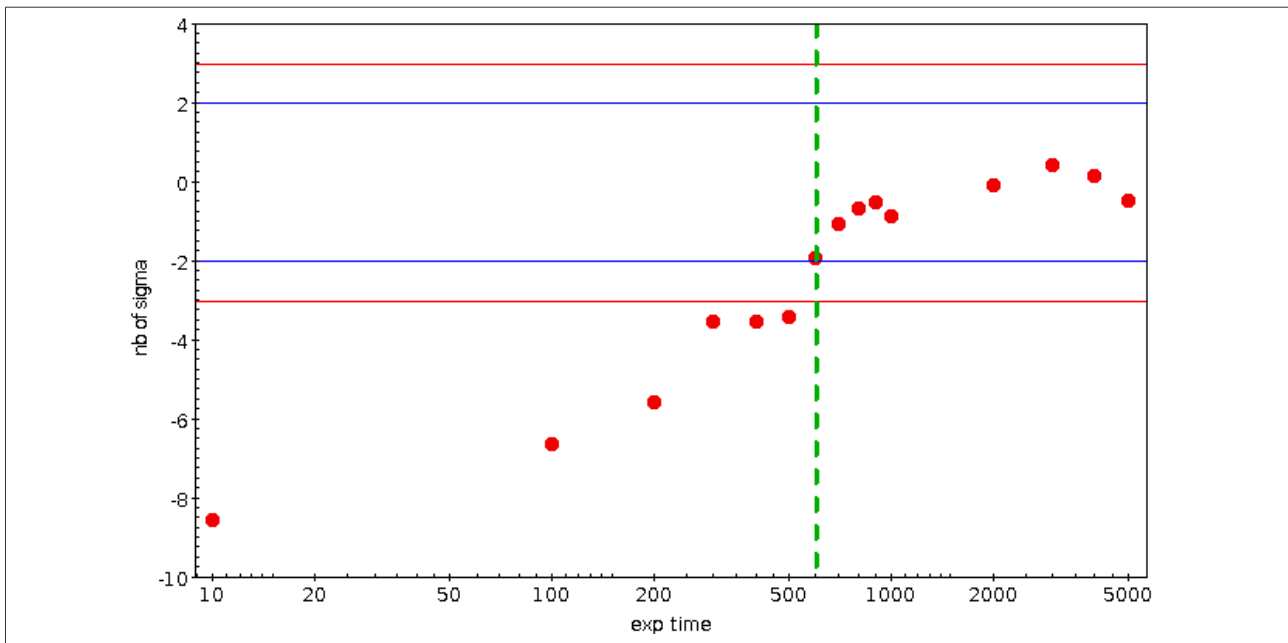


Fig.22. Number of sigma separating the mean flux and the modeled flux, as a function of exposure time (millisecond). Blue and red lines show the 2 and 3 sigma levels.

During our technical runs, we explored this limit. Under clear sky conditions, point-like objects with a flux within the slit (1.9arcsec wide) typically brighter than  $V \sim 2$  (depending on their spectrum) will be problematic to follow. They would require too short exposure times to not saturate the CCD.

**GUIDELINE: « $V < 2$  (through the slit) point-like targets you shall not observe»**

## b) Spectral Exposure Time Calculator

We provide an exposure time calculator (ETC) designed to give the observer a typical exposure time for her/his targets. This estimate is based on several dozen of objects observed during technical runs and offers the choice of the wavelength range (blue/red), of the expected seeing, of the target V band magnitude, of the required S/N for the expected most intense spectral line (assuming it falls within the spectral range), of the nature of this line (absorption or emission line), and of the physical shape of the target (point source or extended source modeled by a Gaussian).

The ETC is basically using a N-parameter space of these characteristics and fits a model at the place of the target in the considered space in order to give an exposure time. We show in Fig. 23 an example of such a plane within the (magnitude, S/N, exposure time) space. We also give in Appendix I the list of observations used to define these planes.

The ETC requests:

- (1) Moon conditions in terms of Moon illumination (choice between 0.25, 0.5, 0.75 and 1) and object angular distance to the Moon (choice between 45deg, 90deg, 135deg and 180deg).
- (2) expected seeing



- (3) extended (or not) nature of the object
- (4) if needed, intrinsic FWHM of the object if modeled by a Gaussian. This is the angular size of the object before seeing convolution

At this step, the ETC is computing the percentage of flux arriving on the CCD after convolution of the object signal by the seeing and the slit (1.9arcsec wide). This percentage will be applied to the given target magnitude.

- (5) V band magnitude of the object
- (6) Air Mass (using the OHP extinction curve). You can also add an additional extinction in magnitude to take into account a potential cloud-induced extinction
- (7) required S/N
- (8) expected nature of the object spectrum (emission line or absorption line)
- (9) chosen wavelength range (blue or red VPH/lens)

The ETC is now able to fit a model to real observations within the adapted space in order to give you an estimated exposure time. 3D views similar to those on Fig. 23 are also provided to allow the observer to manually adjust her/his exposure time estimate as a function of the place of the target in the sheet.

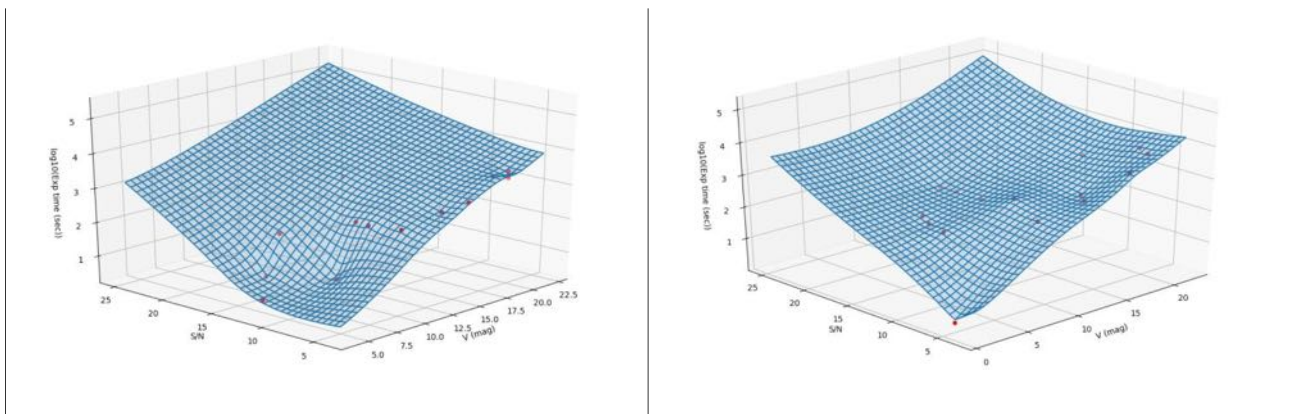


Fig. 23. Examples of ETC surfaces within the (magnitude, S/N, exposure time) space. Left figure: blue mode. Right figure: red mode. Red dots are real observations.

In order to give a quick flavor of the faintest reachable objects you can hope to measure with MISTRAL, we summarize in Table 7 the V band magnitudes corresponding to a total exposure time of 1 hour, with a S/N of 3, for point-like objects, under a median seeing (for OHP) of 2.5 arcsec, and with moon conditions: 135 deg from moon, 25% illumination.

Table7	Abs lines blue	Abs lines red	Em lines blue	Em lines red
Max V mag.	<19.5	<19.5	<20.5	<20.

**GUIDELINE: «before targeting V>>19-21 objects with MISTRAL, another telescope you may consider»**

## c) Imaging Exposure Time Calculators

We provide two exposure time calculators (ETCs) designed to give to the observer a typical exposure time for her/his targets in imaging. This estimate is based on observations of several fields (XCLASS 3091 cluster of galaxies, A400 cluster of galaxies, and at2021ft transient field) observed in  $g', r', i', z'$  and Y bands under different seeing and airmasses. They were observed with different exposure times as well, between 1 min and 60 minutes. They were all at relatively low galactic latitudes, providing catalogs of several hundreds of stars. These stars were separated from galaxies using the SDSS images available for these fields. We used simulations to degrade the shape of these stars before re-detecting them (to take into account the seeing and object extension).

ETCs are then using a N-parameter space of these characteristics and fit a polynomial function (order 2) for the place of the target in order to give an exposure time. We show in Fig. 24 an example of such a surface within the (magnitude, S/N, exposure time) space.

The technique used to generate an exposure time typically consists in the following steps:

- (1) select the filter you want to use in imaging
- (2) give the expected seeing
- (3) give the extended (or not) nature of the object
- (4) if needed, give the intrinsic FWHM of the object if modeled by a Gaussian; this is the angular size of the object before seeing convolution
- (5) give an additional extinction in magnitudes to take into account a potential cloud-induced extinction
- (6) give the Air Mass to compute the magnitude loss due to the atmosphere (using the OHP extinction curve)
- (7) give the targeted magnitude

At this step, the two ETCs differ:

- (7) give the required S/N or give the detection percentage you want

The ETC is now able to fit a polynomial model on real observations within the chosen space in order to give an estimated exposure time. 3D views similar to those on Fig. 24 are also provided to allow the observer to manually adjust her/his exposure time estimate as a function of the place of the target in the explored space. In the first case, the ETC will give you the exposure time needed to detect objects at the required magnitude to have S/N larger than the required one. In the second case, the ETC will give the exposure time needed to detect objects with the requested magnitude with a probability larger than the requested one (and with low S/N typically lower than 2).

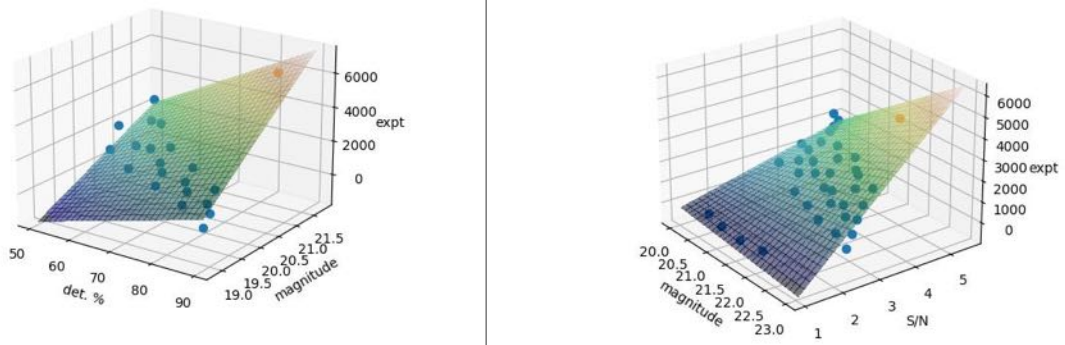
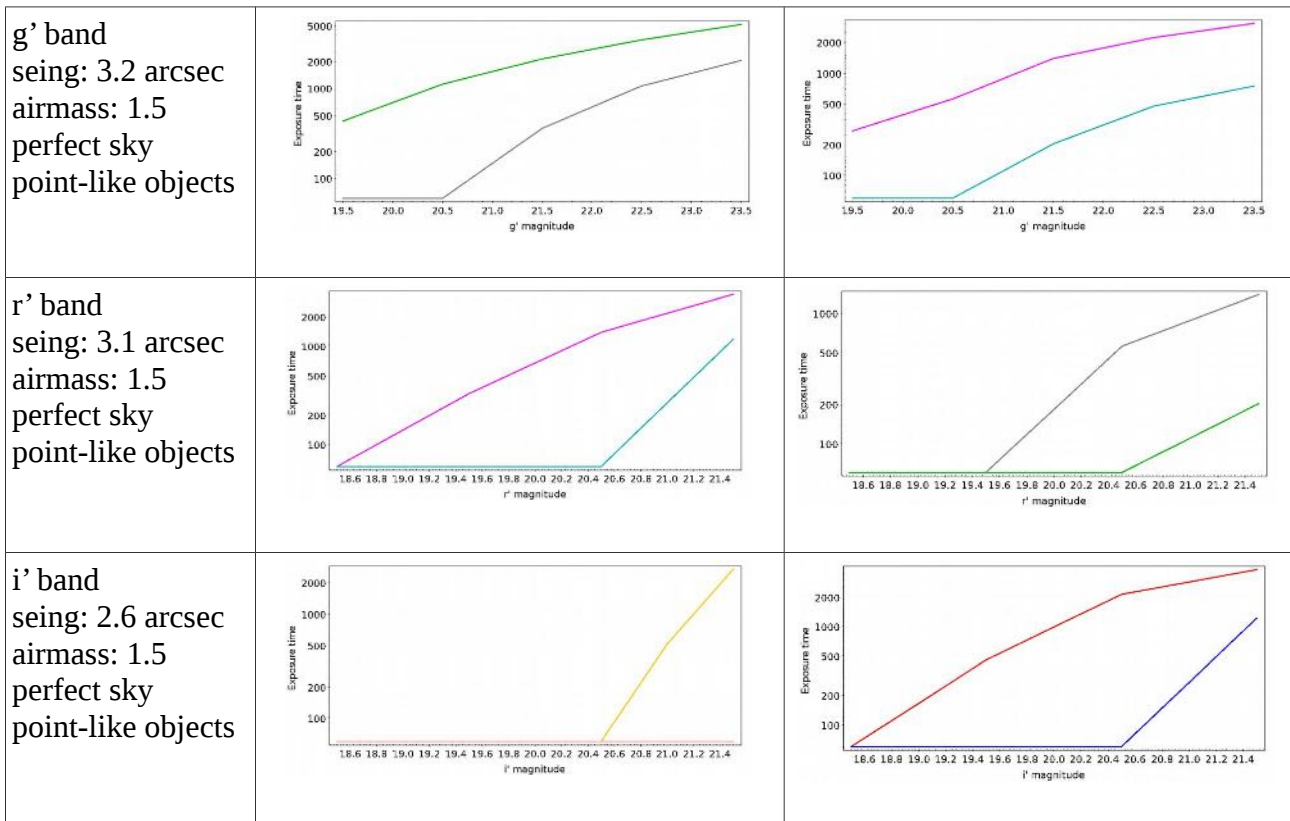
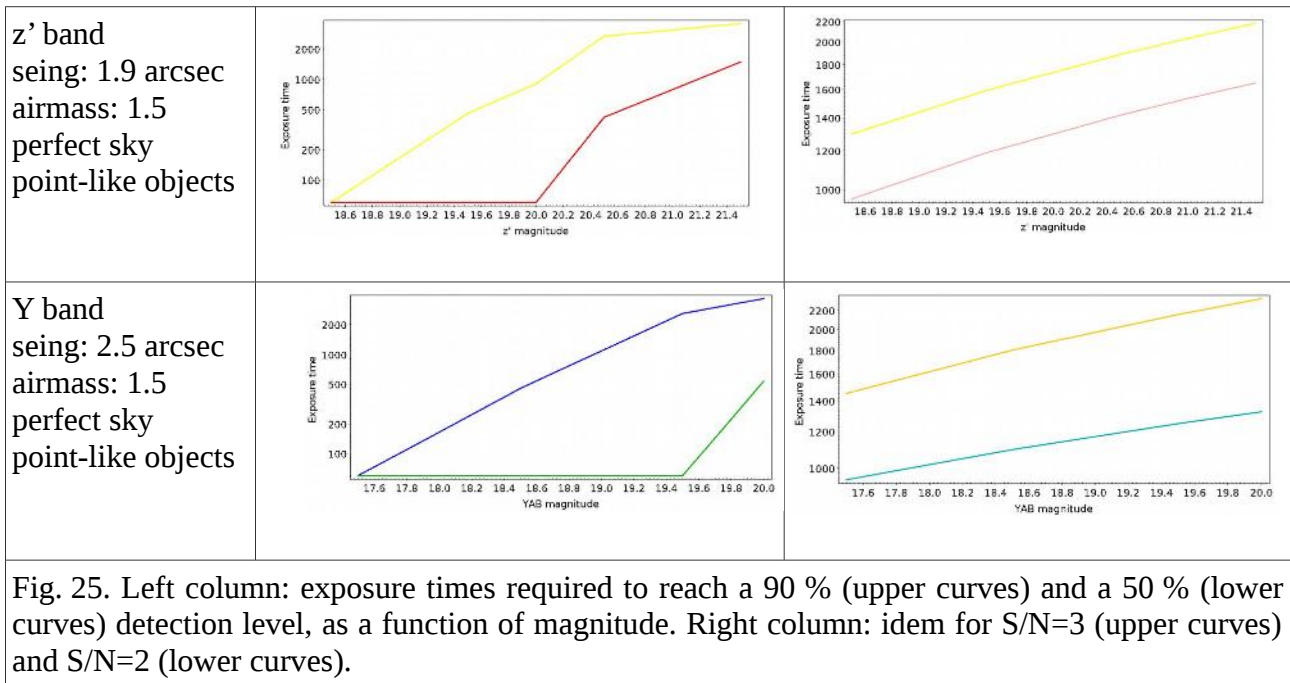


Fig. 24. Examples of imaging ETC surfaces within the (magnitude, S/N, exposure time) space (left figure) and within the (magnitude, detection percentage, exposure time) space (right figure). Blue dots are used to generate the constraint sheets (polynomial models) and orange dot is the place of your target within the sheet.

As for the spectroscopic ETC, a quick flavor is given of the relation between exposure time and reachable magnitudes in Fig. 25 for the grizY bands and various seeing conditions.





#### d) Overheads and typical operating times

Now you know for how long you want to observe your science targets. You need then to estimate the overheads you will have to deal with. We give in this section the maximal and minimal durations of steps (1) to (5) as recorded during MISTRAL qualification runs. The maximal durations correspond to objects that are very difficult to locate as e.g. transients embedded in large galaxies. Most of the time, the steps are achieved faster than the listed durations. Some steps also depend on the astronomical object characteristics and we give in Table 8 these durations as a function of several object V-band magnitudes.

Table 8	V~18.5	V~16.5	V~15
(1) point + find guiding star	[5; 10] min	[5; 10] min	[5; 10] min
(2) place object at slit position	[5; 10] min	[5; 8] min	[1; 5] min
(3) verify that object light is passing through the slit	<2 min	<2 min	<2 min
(4) get spectra of the object	Observer's choice	Observer's choice	Observer's choice
(5) get spectral calibrations	3 min	3 min	3 min
<b>Total overheads + calibrations</b>	<b>~[15; 25] min</b>	<b>~[15; 25] min</b>	<b>~[10; 20] min</b>

**Focus:** in addition to these times, the observer also needs to schedule in her/his observing plan at least one telescope focus per night. This is done in general at the beginning of the night and the required duration for this operation is generally of the order of **5min**. Adjustements (requiring only a few minutes) may have to be done during the night if external conditions are strongly varying.

**Field rotation:** despite the fact that the MISTRAL instrument cannot be rotated itself, the T193 adapter allows to rotate the field. This operation can be useful when several objects are visible in

the field, in order to fit more than one target within the slit. This task is not automatized for this telescope but can be manually done by the night assistant. The typical duration of such a task is **of the order of 5 min** if you already know the slit PA you want to apply. **Note that for a purely north-south orientation of the slit, you have to set the rotator at between +3 and +4deg.**

**GUIDELINE: «When writing a proposal, overheads you will not neglect, or enough time you will not have to finish your program»**

## IV) During the night

Having mastered all the previous steps can appear as a rewarding achievement. However, some major steps remain before enjoying your final reduced data. Not even talking about convincing the TAC to give you observing time, you need to apply the correct observing procedure in order to achieve good scientific results. Who was, indeed, never driven to despair after an observing run because some calibrations were lacking? So here is a secure strategy to be reasonably sure not to be penalized by bad choices (weather permitting...).

### 1) First step : get offsets

These are 0sec CCD exposures with closed shutter before or after the night. This can even be done during day time. This is the less penalizing step because offsets are very stable with MISTRAL (see Appendix VI) and could be approximated by subtracting a constant. We note that observing Darks is not mandatory (the Dark Current is supposed to be less than  $3 \text{ e}^-/\text{hour}$  at  $-90\text{deg}$ ). They do not increase significantly the reduction quality with MISTRAL.

### 2) Second step : get imaging flatfields

This is crucial in order to correct for the CCD response inhomogeneities across the field of view. This simply consists in observing a uniform light source and then deducing the CCD response. This uniform light source can traditionally be a white screen illuminated by some continuous lamp (domeflats), or the sky itself before the dark night, when stars are still below the sky level (skyflats). The T193 telescope has no flatfield screen on the dome, so the best way, by far, is to use the sky technique.

Do not forget to observe skyflats in all the filters you plan to use, as imaging flatfields can be VERY different from a filter to another one (see e.g. Appendix VII).

Do not observe a single flatfield image per filter, as you will have no way to get rid of cosmic rays, Elon Musk satellites, or other fancy sky perturbations or statistical variations. Usually, observing five flats per filter is a good compromise between statistics and time needed to achieve the task.

Exposure times are very variable and depend on the sky level. However, we do not recommend to expose for more than 1min because it may cause the first stars to be detected (or the flat to be saturated)

Be also prepared to run as the night (or the day at the end of the night) is arriving very fast. Don't panic however. If you do not have enough time to finish all your filters on a given night, you can finish during another night. Skyflats results are usually stable enough to be acceptable over a few nights period. But we do not recommend to use the same skyflats from a run to another.

**GUIDELINE: «(Sky!!) imaging flatfield you will not forget to observe in each of your filters during the run»**

### 3) Third step: estimate the exposure time to get an image of target

One of the key science drivers of MISTRAL is the transient spectroscopic follow-up. In this framework, it is crucial to know the magnitude we can reach in imaging versus the exposure time. This allows to predict exposure times needed to e.g. detect transients and to place them through the slit for spectral purposes. Nothing is more irritating than waiting a few minutes exposure (plus reading time) and realizing that the exposure is not deep enough to see the target(s) correctly or to place it through the slit. This step must therefore not be neglected.

- For this, the basic (easy...) way is to use Table 9 (or the figures in Appendix III if you want more precise values) to predict an approximate exposure time allowing you to reach the required imaging magnitude depth. This is based on several observations made under various atmospheric conditions in terms of airmass, sky transparency, seeing, etc. The results are therefore valid for « mean » OHP observing conditions.

- You can also use the two imaging ETCs previously described to have an exposure time more adapted to several parameters as airmass, seeing, sky transparency, etc. As already said, the first imaging ETC will predict an exposure time for a given magnitude and detection percentage, disregarding the signal to noise. This case is adapted to be sure to detect a target to place it within the slit, without being intrinsically interested in the object image itself. The second ETC will give you an exposure time to detect an object at a given magnitude and at a given signal to noise. This is more adapted to the study of the images themselves, for example to make some basic morphological studies (but remember, we are at OHP, with « several » arcsec seeing) as star/galaxy separation.

As a conclusion, the only (valid) reason to take the risk to shorten a pre-image is if you run after a very rapid transient. This typically only applies for GRBs.

Tab 9	90% completeness for point sources under average observing conditions
g'	20 min: g'~20.5
r'	10 min: r'~20.
i'	10 min: i'~21
z'	10 min: z'~19.5
Y	10 min: YAB~18.5

**GUIDELINE: «Long enough your (pre)image you will expose»**

## 4) Getting a usable spectrum: a cookbook within the cookbook

OK, here we are: trying to get a spectrum! The process of obtaining usable spectra of a given astronomical object consists in the following steps. Automated procedures are designed to move the MISTRAL elements for each of these steps.

### (1) Point the telescope at the right place

This is done in imaging mode (see Table 9) with the most favorable filter according to the object characteristics. Starting from theoretical coordinates, the telescope is approximately pointed and a first image is acquired (mode 3 of Table 3: « preview image », then “start exposure”) and compared to a finding chart. The usual pointing accuracy of the telescope (but depending on hour angle and declination) is presently good enough to have your target within the MISTRAL field of view. The process is iterated until a satisfactory telescope position is reached. The mode (3) saves the images you obtained. Finally, a guiding star has to be found. This is the task of the night assistant. Given the actual T193/MISTRAL capacities (sensitivity, FOV), he should be able to find such a suitable star in >99 % of the sky regions.

### (2) Determine the slit position

For this, you have to use the “Search Slit Position” mode (mode 5 in Table 3) within the Command Control MISTRAL window and press “start exposure”. This moves the slit in the optical path. An image (rapid reading mode) is then automatically taken and shows the sky through the slit. A pop-up window propose an x-position of the slit (has to be close to ~1040, unless smething went wrong). You have to validate it by clicking on “ok”. At this step, you should see the slit on the image (upper left screen).

If slit is not visible or x-position is very different from the 1040 value, you have make the operation again (should not occur).

### (3) Place the target at the slit position

Two possible situations:

- The target is a relatively bright object and you can see it in imaging mode with exposure times typically shorter than ~10 seconds. Use the “centering on the slit” (mode 6 of Table 3) button and press “start exposure”. This first removes the slit from the field of view and continuously takes images with the chosen exposure time. You should see the object moving toward the slit shaddow. This is usually done by the night assistant. He/she has a direct view on your screen and is able to move the field to have the target at the slit location you indicate him/her.

- The target is too faint to be detected with short exposure times (~10 seconds). The previous process will then become very uncomfortable and you will need to use a differential positioning on the slit. For this, you first need to make a deep enough science image (mode 3 of Table3: “Science Image”+”Start exposure”) to see the target. On this image you note the target's x,y coordinates. You then compute the difference [  $(x_{\text{slit}} - x_{\text{target}}) * \text{spatial\_sampling}$ ] in x position between the object and the slit, in order for the night assistant to know by how much he has to move the telescope in RA. You do the same [  $(500 - y_{\text{target}}) * \text{spatial\_sampling}$ ] in Y position to approximate the DEC shift to apply. The value of the spatial sampling is 0.48 arcsec. This process assumes that the field rotator is oriented north-south. This process is not possible for now if other orientations are set.



At this step, it is highly recommended to follow a second time the whole process: deep image without slit, locate the target coordinates, recompute the offset  $(x_{\text{slit}} - x_{\text{target}}) * \text{spatial\_sampling}$ , and apply eventually the RA shift; and same for DEC.

Given the MISTRAL imaging capabilities, trying to observe an object not visible in 10 second exposures will however be pretty rare.

#### (4) Science spectrum

You can now launch a “Science Spectrum” + “start exp” (mode 7 of Table 3 and pray to detect something after this centering job).

#### (5) Get spectral calibrations

You will use modes 8 and 9 of Table 3. These two last steps (wavelength calibrations and spectral flat fields) involve the injection in the instrument of the light from spectral calibration lamps and then from a Tungstene spectral flatfield lamp. They can be done after step (4) and are detailed in the following.

**GUIDELINE: « These 5 steps you will follow, or into trouble you may run »**

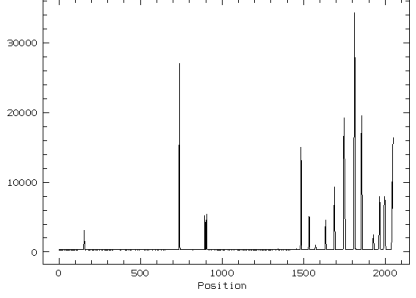
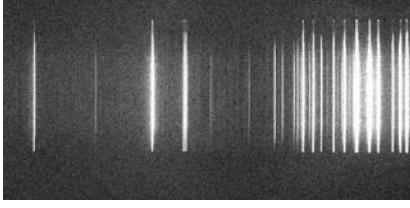
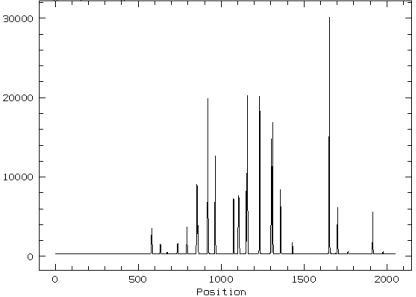
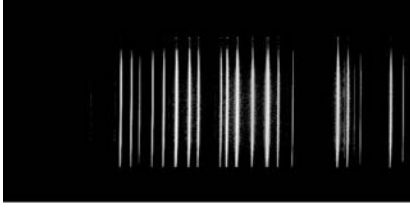
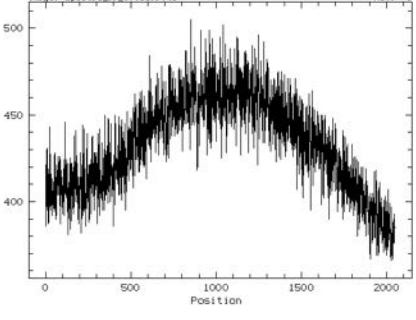

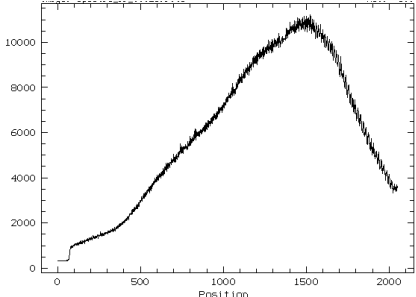
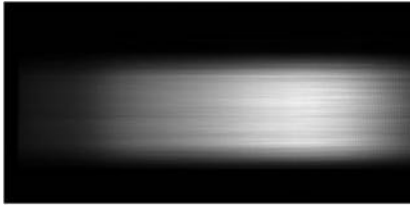
### 5) Spectral calibrations: when and how ?

As shown in the Appendix II, we recommend to make at least one set of spectral calibrations per telescope position during the night (before and/or after a set of spectral science exposures on a given object). We are working on enhancing the instrument spectral stability, but this is not yet solved. Table 10 gives typical exposure times and typical results for the blue and red ranges.

We also give in Appendix II the annotated wavelength calibration spectra of our Hg, Ar, Xe lamps, useful to make your own wavelength calibration if you do not plan to use the local spectral reduction tool.

It could be tempting not to take the time to make a spectral calibration after each series of science observations for a given object/telescope-position: « one per night, humm, this is largely enough ». Unless you really do not need a good velocity accuracy (say, better than 400 km/s, see Appendix II), we strongly recommend NOT to bypass this step, and to take two calibration spectra after each object series. If you forget this and realize only afterwards that your "standard" spectral calibration is not good enough, the only way to escape is then to use the sky lines in order to wavelength calibrate your spectra or, rather, to calculate the wavelength shift between your object spectrum and the master calibration. This solution is however not supported by the actual reduction tool.

**GUIDELINE: « Two spectral calibrations per science series you will do, or you will fail to properly calibrate your data »**

Table10	Typical exposure times and results	
Wavelength calibration HgAr	Blue range: 60 sec	
		
	Red range: 60 sec	
		
Spectral flatfields	Blue range: 2 sec	
		
	Red range: 2 sec	
		

## 6) Spectral FlatFields

Similarly to imaging flatfields, spectral flatfields are used to correct the CCD pixel to pixel response along the y-axis (not wavelength dispersed). We expect to have a spectral flatfield intensity variation (1) along the x-axis, due to the wavelength-dependent efficiency of the spectral dispersor (here a VPH) + CCD response, which will be corrected via the observation of a spectro-photometric standard star and (2) along the y-axis similar to what we have for an imaging flatfield (including e.g. the slit default). Fig. 26 shows a spectral flatfield. We see the expected sensitivity variation along the x-axis. The variation along the y-axis is corrected via the FlatField, but is however not perfectly smooth and presents horizontal bands (slit defaults). The level of these bands is however low and this is most of the time not affecting significantly the reduced spectra.

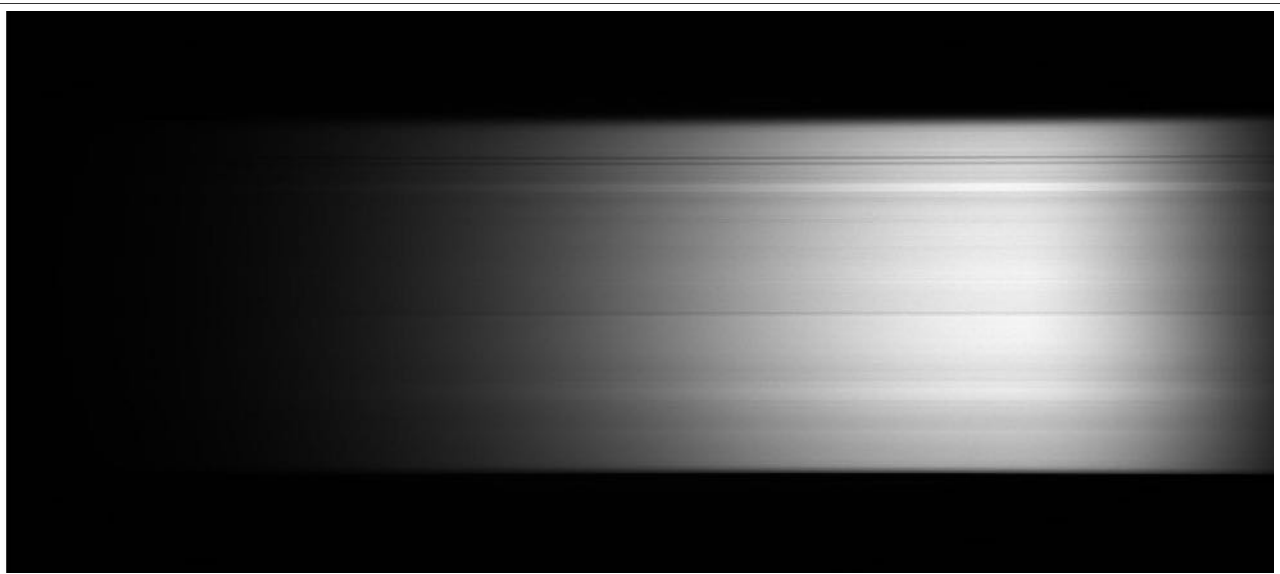


Fig. 26. 2D map of a spectral flatfield.

## V) Data reduction

### 1) Files format

MISTRAL will generate single HDU fits files with the naming conventions given in Table 11

MISTRAL_obj_Spectre_date.fits	2D science spectrum
MISTRAL_obj_Image_date.fits	science image
MISTRAL_cal_Domflat_date.fits	Dome flat frames
MISTRAL_cal_Skyflat_date.fits	Sky flat frames
MISTRAL_cal_Bias_date.fits	Offset frames
MISTRAL_cal_Dark_date.fits	Dark frames
MISTRAL_cal_Specflat_date.fits	Spectral flat fields lamp (Tungsten)
MISTRAL_cal_Arc_date.fits	Spectral wavelength calibration lamp spectra (HeArXe)

The date is given with the « AAAAMMJJ\_HHMMSSUT » format and is expressed in UT time.

Each of these categories has the keywords listed in Appendix X and allows you to use your own software to reduce data, if you wish.

Some keywords are duplicated, such as the exposure time, to possibly deal with different data handling codes requiring different keyword conventions. However, we recommend the user to check for the requirements of her/his data handling code, as we have not, by far, covered all the different possibilities.

**GUIDELINE: « If using your own data reduction codes, the keyword names of the MISTRAL fits files you will check »**

## 2) Quick look at spectral data during the night

We first provide a local reduction tool able to give you a real-time basic spectral reduction (= a 1D spectrum) to judge if your data are good enough for your science goals. It is better not to realize only after the end of your run that the spectra do not have the required S/N... This code is based on the Automated SpectroPhotometric Image REDuction package, ASPIRED (author: Marco Lam) and has been tuned to the MISTRAL needs. This is a Python code, available at the T193 observing room (and not requiring any Python knowledge). Iconized in the lower right screen of the mistralburo PC, it will first ask you for the files you want to involve in the data reduction through a graphical interface, and the places in the raw 2D spectrum where you want to extract the object and the sky. Then, it will automatically produce a 1D wavelength calibrated spectrum.

More precisely, it starts from a raw 2D science spectrum, and uses spectral flat fields, wavelength calibration 2D spectra, and offsets that you provide. These files are listed in an ascii file created by the graphical interface (which you do not have to edit). An example of such an ascii file content is:

```
light, spectre_HD20041_00038.fits, 0
flat, spectre_ff_00030.fits, 0
flat, spectre_ff_00031.fits, 0
bias, offset_00001.fits, 0
bias, offset_00002.fits, 0
bias, offset_00003.fits, 0
bias, offset_00004.fits, 0
bias, offset_00005.fits, 0
arc, spectre_hgar_00028.fits, 0
arc, spectre_hgar_00029.fits, 0
```

With such an input list, the code will automatically:

- provide a detection of the objects in the science spectral image, extract and draw a non-wavelength calibrated 1D spectrum (Fig.27) from the specified Y position

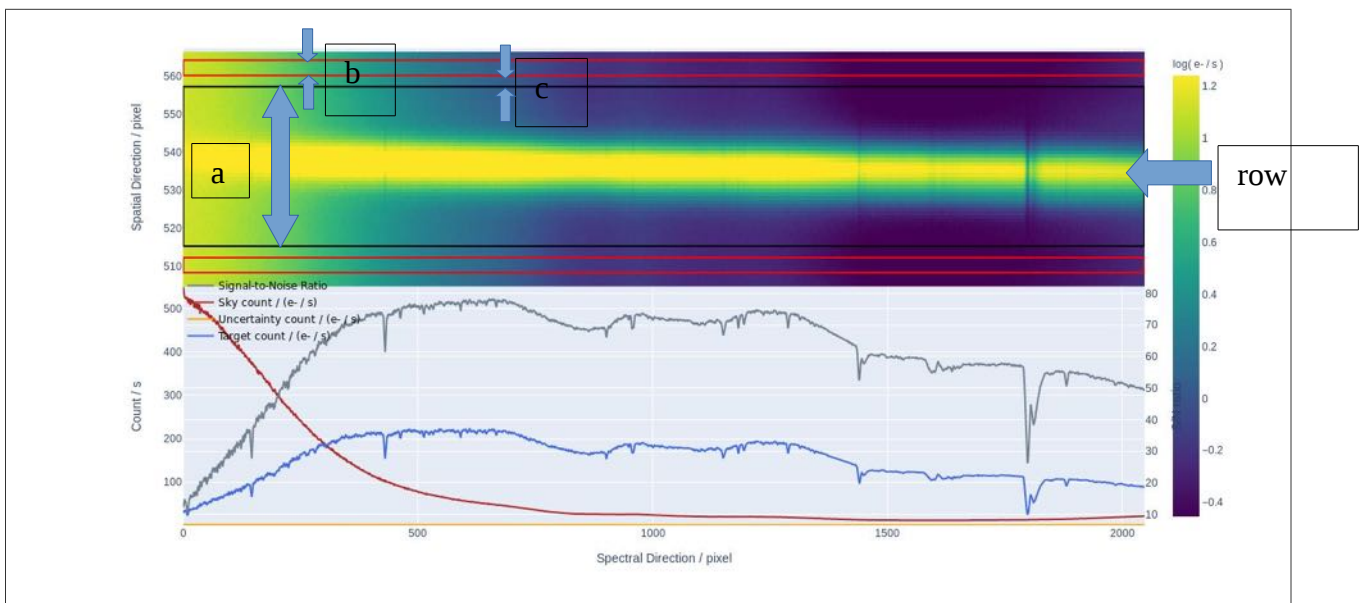


Fig. 27. Detection of the objects in the science spectral image and non-wavelength calibrated 1D spectrum. The Object is located between the blue lines, the Sky is taken between the red lines.

- make an automatic wavelength calibration along the object path, from an automatic line detection and identification in the calibration spectrum provided (see Fig.28).

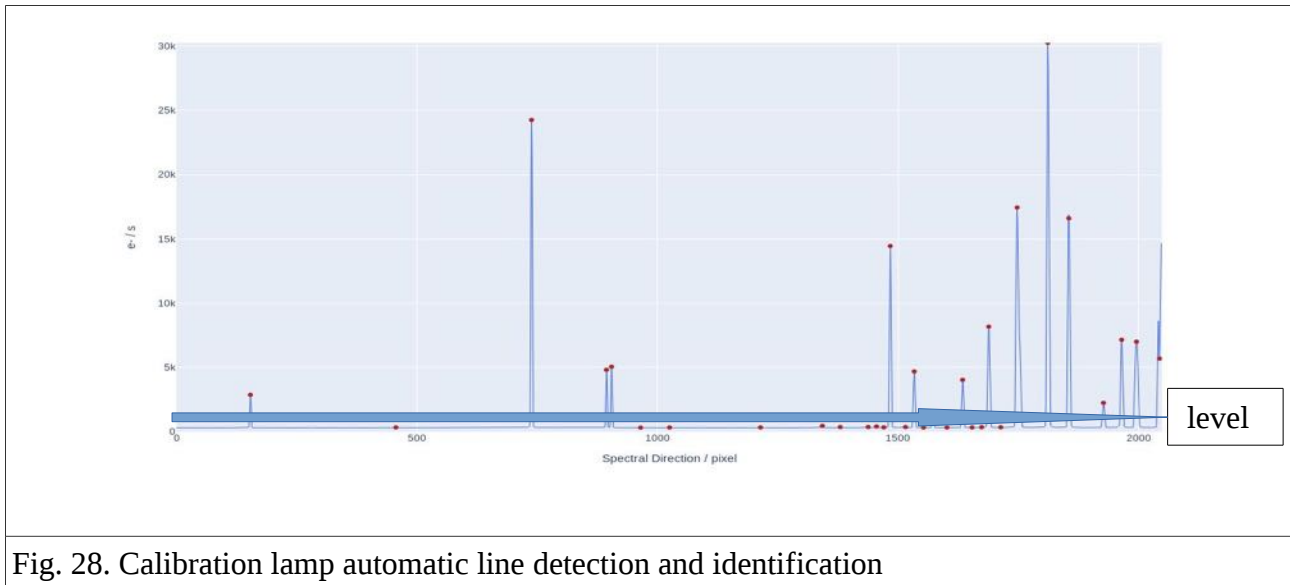


Fig. 28. Calibration lamp automatic line detection and identification

- provide a (non-flux calibrated) final 1D spectrum taking into account the observatory extinction curve and give a view of this 1D spectrum (Fig. 29) available in linear or log scale.

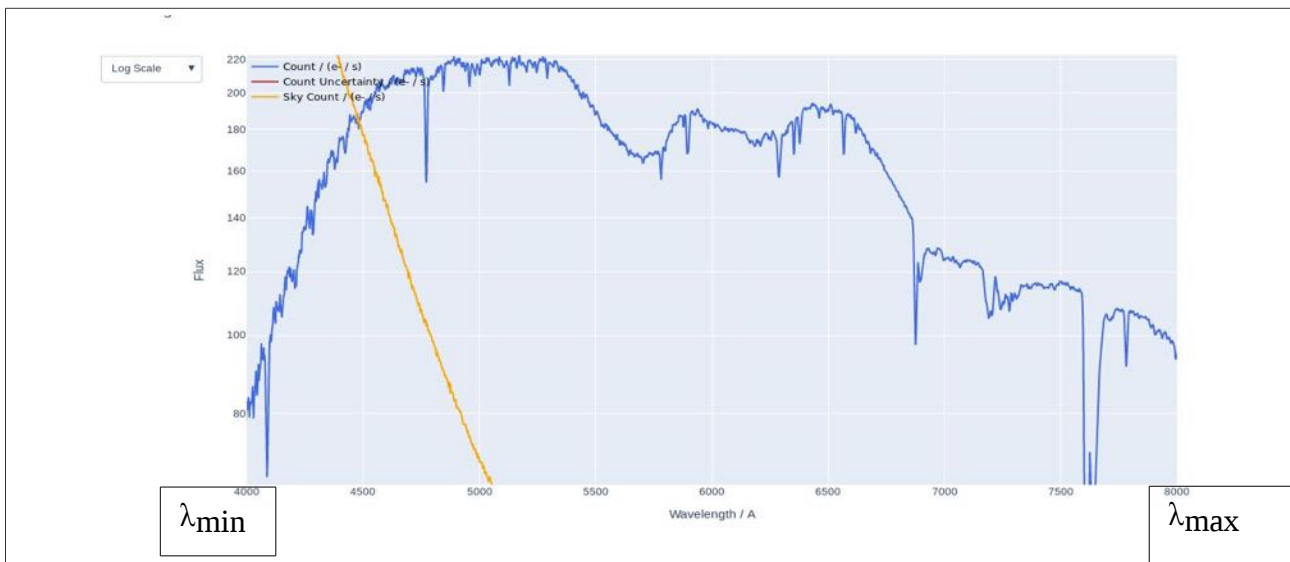


Fig. 29. Non-flux calibrated final 1D spectrum accounting for the observatory extinction curve

The whole process takes a few dozen seconds and only requests to launch the « quicklook.py » icon on the reduction PC, selecting the files you want to examine, and providing the code with approximate initial and final wavelength ( $\lambda_{\min}$   $\lambda_{\max}$  in Fig. 29), the Y line where the object to extract resides (row in Fig. 27), minimal level detection of lines in the wavelength calibration image (level in Fig. 28), and widths of objects and sky extraction (a, b, and c in Fig. 27).

The style of command the icon is launching is: `python3.6 quicklook.py  $\lambda_{\min}$   $\lambda_{\max}$  level row a b c`

We give in the Appendix the content of « quicklook.py » in order for the observer to see the details of the procedure.

**GUIDELINE: « The quicklook code during the night you will use, to ensure that the quality of your data is adequate»**

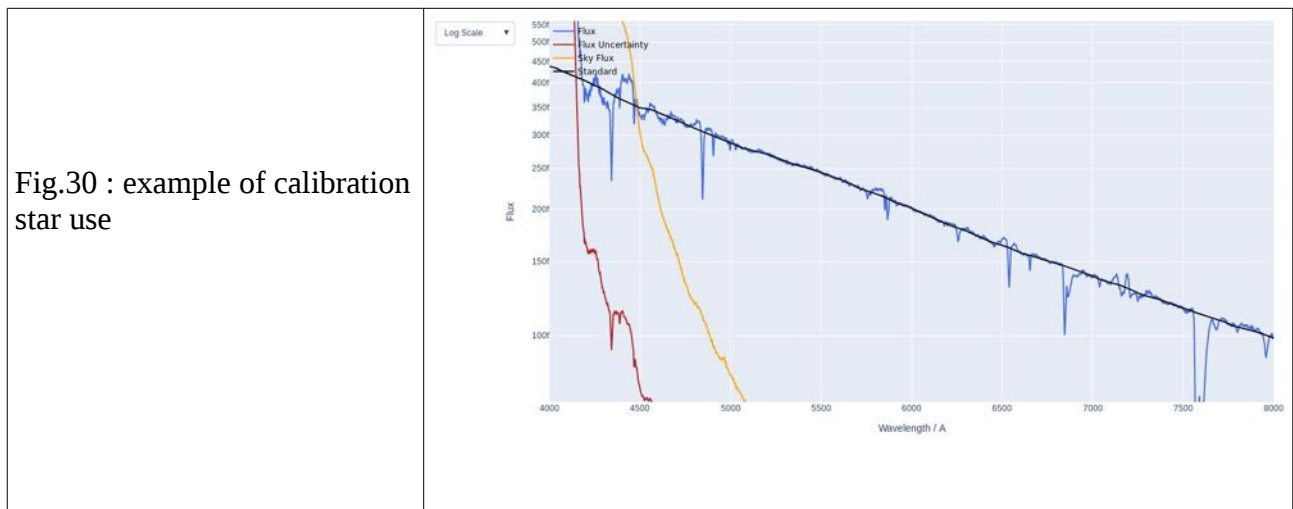
### 3) Publication-level data reduction process

Another version of the code is offered at the telescope to produce flux calibrated 1D spectra, or at least 1D spectra corrected for the MISTRAL spectral response. This implies the use of calibration stars observed in the same way as the science targets. We give in Table 12 a possible selection of such stars well visible from the OHP site and for which calibrated spectra are already available within the soft reduction framework. It basically means that you do not have to search yourself the www for calibrated values.

Star name	RA (J2000)	DEC (J2000)	V magnitude
HD 19445	03 08 25.6	+26 19 51	8.1
Feige 15	01 49 09.5	+13 33 12	10.4
Kopff 27	17 43 55.8	+05 24 48	10.3
Hiltner 600	06 45 13.4	+02 08 15	10.44

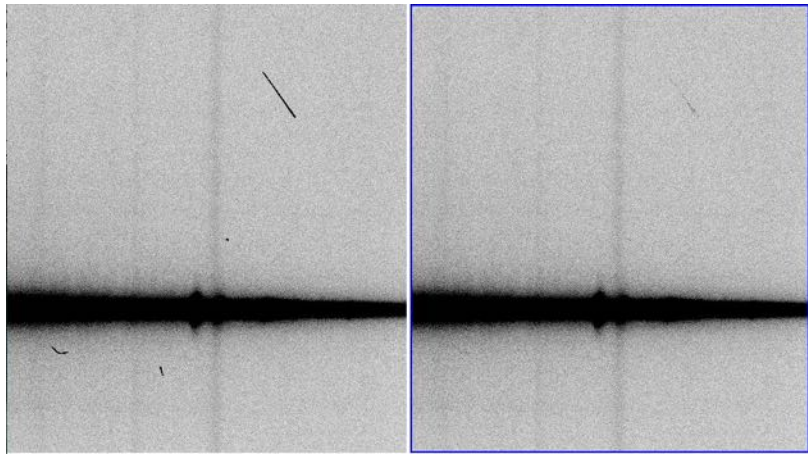
Table 12. Arbitrary selection of calibration stars

This version of the reduction code repeats the quicklook operations for the chosen calibration star. It gives a view of the internal calibration of this star (see Fig. 30: black versus blue lines). This will allow the code to produce the adapted response function in order to compute a flux calibrated spectrum.



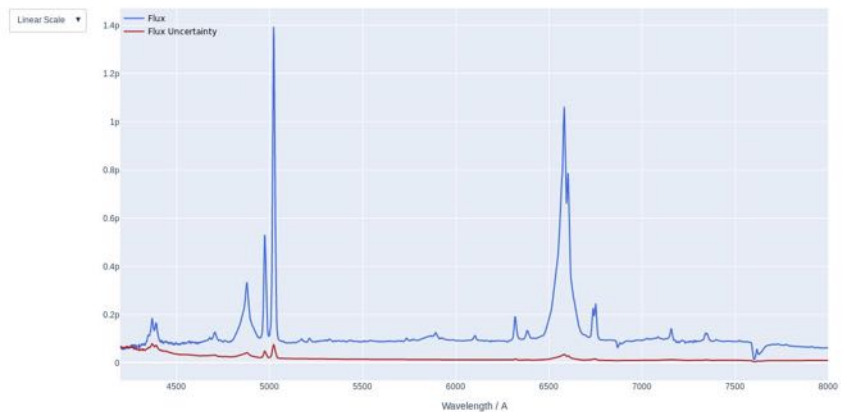
A stricter cosmic ray subtraction is also performed. We show in Fig.31 a typical example of the cosmic ray removal for an observation of NGC4151.

Fig.31 : cosmic ray removal for an observation of NGC4151 (performed 14/02/2021). Left : before, Right : after removal.



Finally a flux calibrated spectrum is produced, as shown in Fig. 32.

Fig.32: final flux calibrated spectrum of NGC4151



The duration of this more advanced process is of the order of a few minutes (especially if you have to select the files to reduce), two or three times longer than the basic process described in the previous section. It can be run during the night if you are making relatively long exposures, but is more adapted to a day-time use.

A last reduction code version is under work. It will be designed to improve the sky subtraction, mainly at the red end of the red disperser. This part is also affected by fringing. The Appendix VIII describes a way to get rid of this problem with on/off observations. However, we can also wavelength calibrate the 2D spectra, line per line (instead of doing it for a single line, after the 1D spectrum extraction).



## 4) MISTRAL database

The raw MISTRAL generated fits files are systematically archived after the end of the night in order to be accessed later by the astronomical community. A one year proprietary period is ensured (science data visible but not downloadable except by PI, calibration data immediately public), unless special request by observer. Data are first stored on a NAS server located in Marseille in the framework of CeSAM (<https://cesamsi.lam.fr/instance/mistral/home>), before feeding the database itself. Then, data are accessible through a www ANIS interface. The whole process is detailed in Fig.30. The CeSAM backup strategy is described in Fig.31 and ensures the data to not be lost in case of system/disk failure. The details of the process of the data ingestion in the database is shown in Fig.32.

A way to make final (observer-) reduced spectra and potential added-values (measured fluxes, lines characteristics, magnitudes, ..etc...) available is also offered through the ASPIC SNO (<http://cesam.lam.fr/aspic/>) under simple request (see Fig.30). This portal is dedicated to give access to added values produced from several public spectroscopic or spectrophotometric surveys. These added values are hosted at the Centre de données astrophysiques de Marseille (CeSAM), Laboratoire d'Astrophysique de Marseille (LAM), France.

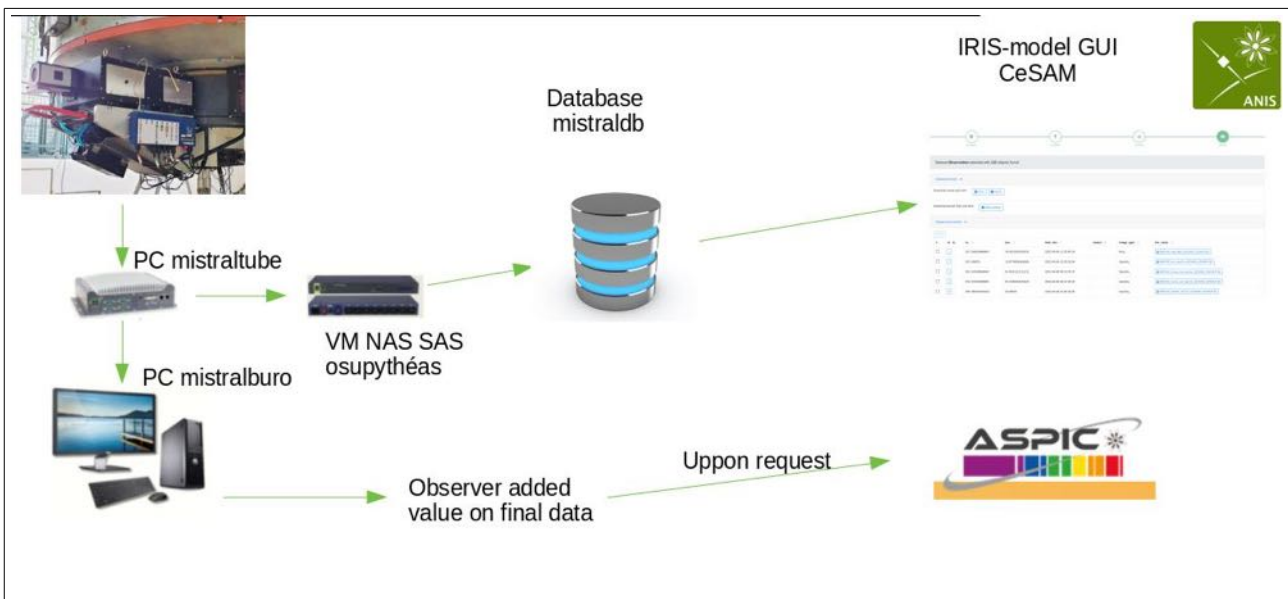


Fig.33 : global architecture of the data management

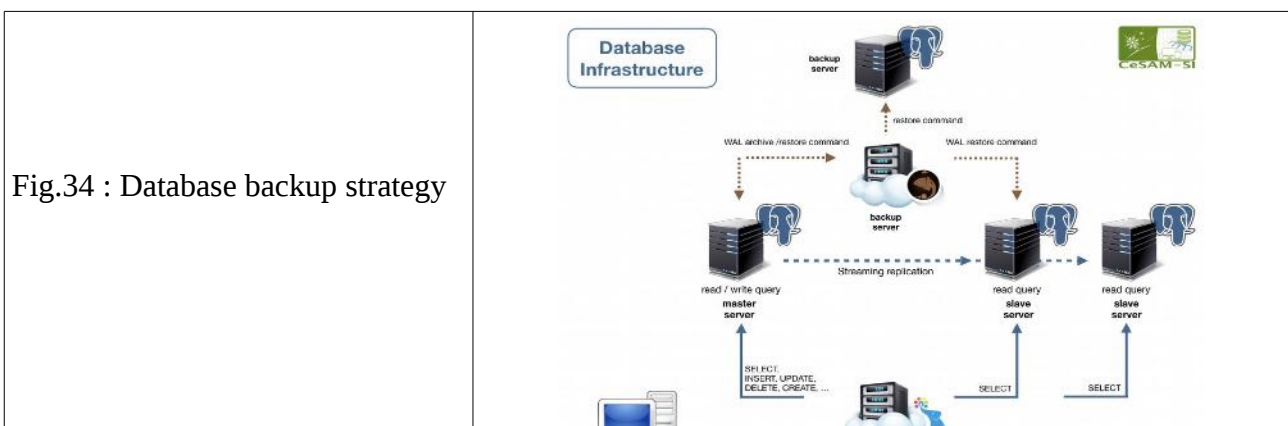


Fig.34 : Database backup strategy



## VI) ToO procedure

MISTRAL was also built in order to be able to follow target of opportunity (ToO) procedures. When you submit a MISTRAL proposal, you therefore have the possibility to request ToO observations.

### 1) Alert mode general rules

Not all nights are opened to possible ToOs and a potential ToO observation is subject to the following rules:

- A shared calendar gives the nights able to host a ToO observation (link will be given to granted PIs). This calendar is regularly updated to take into account technical events on the instruments/telescope. It is also taking into account the fact that, due to internal rules, an alert can not occur more frequently than one time every 3 nights.
- There is two kinds of possible alerts : day-time trigger by contacting the OHP direction, and night-time trigger for urgent alerts requiring an immediate (<1hour) reaction.
- Night time trigger : the night operator is in charge of deciding to go (or not) on the target. Decision tree is as follow :
  - night status has to be « green » (see shared calendar)
  - there is a validated ToO proposal, with still available time
  - weather is OK
  - MISTRAL is working/mounted
  - target is observable (coordinates, telescope inclination, ..Etc...)
- The maximal duration of an alert in 2hours (including overheads)
- If all previous criteria are satisfied, before moving to the ToO target, the ongoing exposures (MISTRAL or SOPHIE) will have to be achieved, except if the remaining duration is larger than 30min.
- In case of technical problems occurring on the MISTRAL instrument, if these are not solved after 20min, the alert is cancelled/postponed and the telescope backs to normal operations.

**GUIDELINE: « A ToO you will trigger only if the previous rules aware of you are, or the fury of the observing colleague you may suffer...»**

## 2) PI/night operator communications

If a ToO procedure is initiated, you will be able to interact with the night operator using the Slack tool. Interactions will also be possible via emails or phone, but, except for special cases, we strongly suggest you to use Slack. Connection details will be given to the PI in case of accepted proposals or validated DDT observations.

When the telescope will be on your target, you will be allowed to proceed as you want, alternating imaging and spectroscopy as you want. Night operators are experienced enough to operate the instrument for you.

All observed data will be automatically downloaded (as soon as observed) to a cloud hosted in Marseille by the OSU PYTHEAS (connection details will be given to you if successful proposal). The transfer time is typically of a few seconds. You then will be able to download your data to your working place, and to treat them as you want. This will allow you to interact in nearly real time with the night operator, as if you were at the telescope.

We recall you that when you will be close to the maximal duration of your observation (the time you requested, and 2 hours at maximum : there is a count-down in the observing room), the night operator will have to close your slot.

**GUIDELINE: «A maximal duration of 2hours you will obey, or the fury of the night operator (and of the observing colleague, and of the OHP direction, and .....) you may suffer...»**