HELP
specINTI / specINTI Editor V2

Sol'Ex/Star'Ex project: http://www.astrosurf.com/solex

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1. Object

This document introduces **specINTI** and **specINTI Editor** (version V2 and later). It is not intended as a complete user manual, but rather as a reminder of the main functions in common situations, covering high and low spectral resolution processing modes, as well as a section dedicated to spectra of extended objects (such as nebulae). Please refer to this document if you have any doubts about the workflow.

To begin with, let's recall that **specINTI** is the main calculation engine for spectra processing, while **specINTI Editor** is a graphical interface that interacts with specINTI by providing two essential files:

- A **configuration file**, defining the spectra processing parameters;
- An **observation file**, containing the spectral data to be analyzed.

These two files can be edited directly in specINTI Editor, which integrates several tools to simplify this work, as well as visualizing the results of processing and quality.

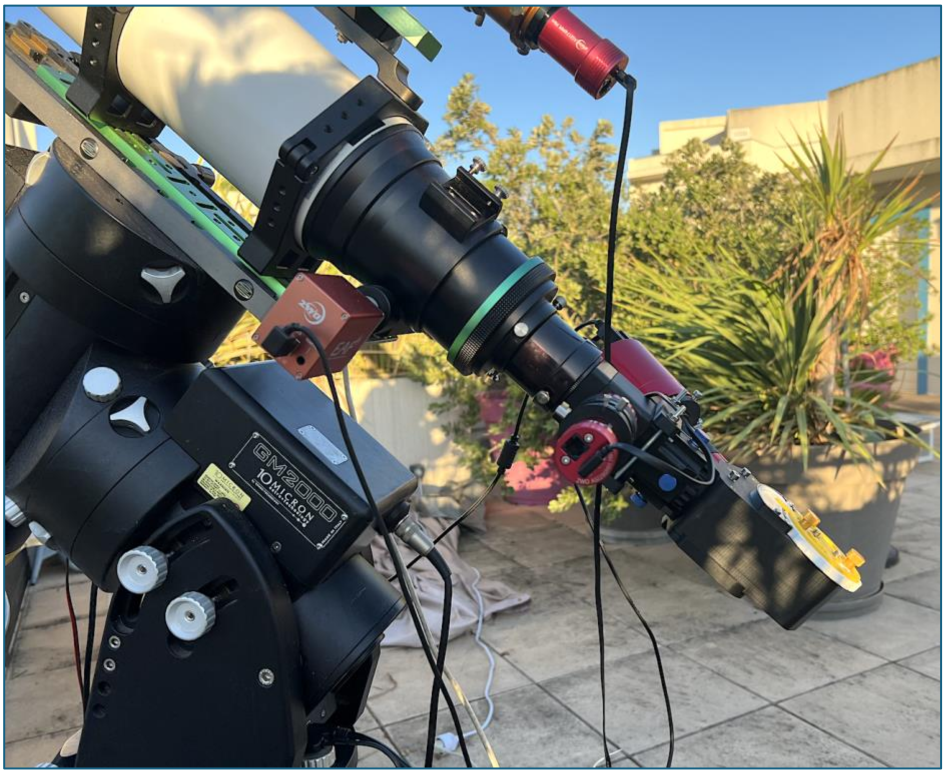
You can download the specINTI/specINTI Editor package here:
http://valerie.desnoux.free.fr/inti/specinti_editor.zip

2. Processing spectra at high spectral resolution

2.1 Introduction

In this section, we describe the processing of high-resolution spectra centered on the H-alpha line, starting from scratch: we have neither the spectral calibration function nor the instrumental response.

We are working from a sequence of spectra acquired with a Star'Ex HR spectrograph mounted at the focus of an Askar 107PHQ refractor. The spectrograph is equipped with a 26-micron-wide Star'Ex GEN2 slit, and the camera used is a ZWO ASI533MM in 1x1 binning mode. The observation took place on the night of October 2-3, 2024.



The center of the telescope's entrance pupil is illuminated continuously by a 1 mm-diameter plastic optical fiber, connected to a neon lamp at the other end. We therefore work in **lateral mode**: the line spectrum of the neon lamp is recorded simultaneously with that of the star. We focus on a region of the spectrum covering the H-alpha line (6563 Å) and the red He I line (6678 Å).

Spectrum images are cropped as soon as they are acquired to an area surrounding the spectral trace, to save storage space and speed up calculations.

The data from the processed example (images, .YAML files) are grouped together in a compressed file that you can **download here**.

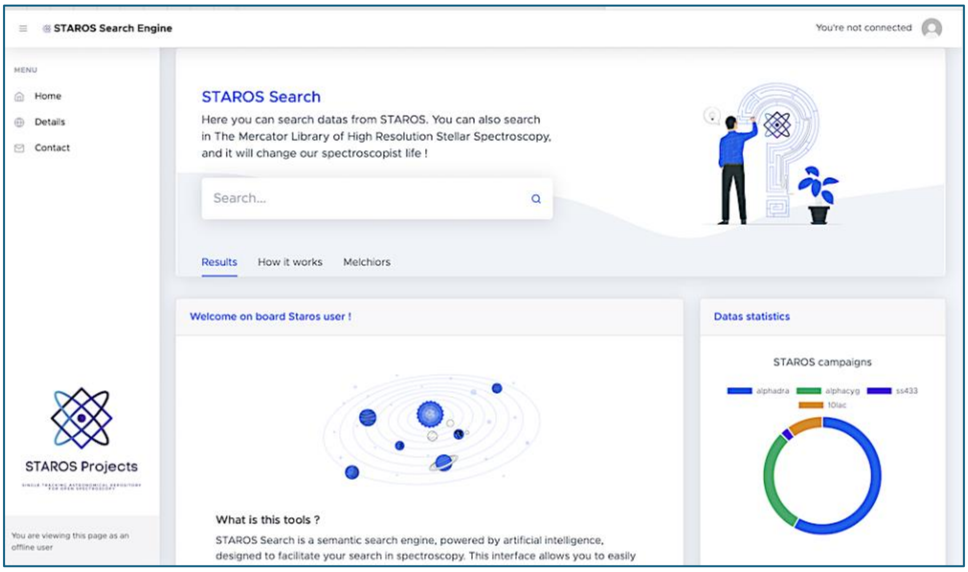
2.2. The reference spectrum

Our main objective is to determine the instrumental response to the incident luminous flux. This process begins with the acquisition and processing of the spectrum of a reference star, whose energy profile is faithfully known. This profile corresponds to the star's true energy distribution, as it would be observed outside the Earth's atmosphere and with a perfect instrument.

Our reference spectrum comes from the Melchiors database, a vast library of 3,256 spectra covering a wavelength range from 380 to 900 nm, with a resolution of R = 85,000. These spectra were obtained using the HERMES spectrograph, installed on the Mercator telescope at the Roque de los Muchachos observatory in La Palma. The Melchiors database can be found at the following address:
https://www.royer.se/melchiors.html

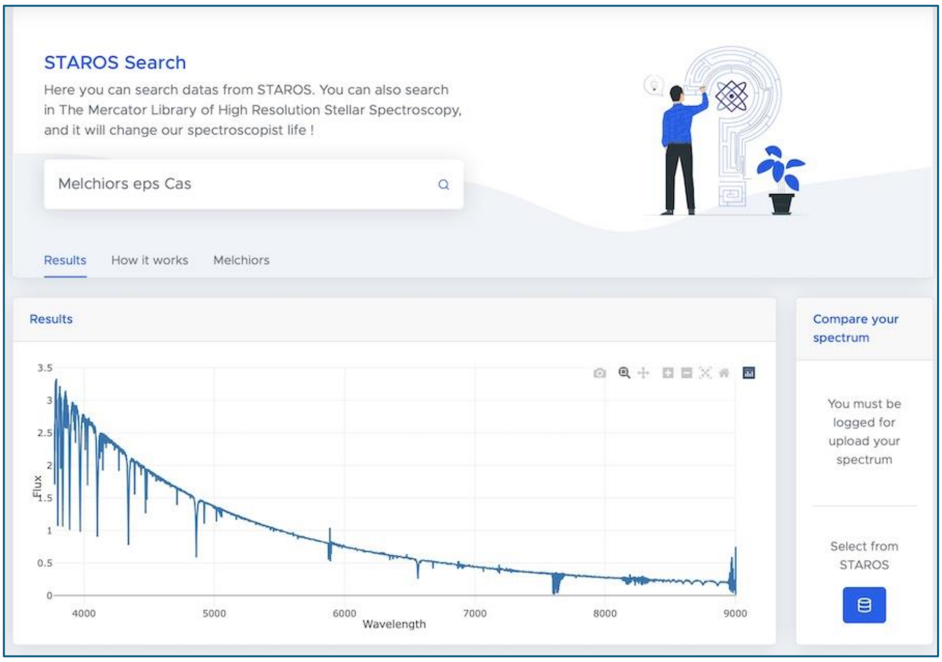
We chose to observe the **epsilon Cas** star (HD11415, an underactive Be star), for which the reference spectrum is available in the Melchiors database. This star is well positioned in the sky, bright (V = 3.4) and has a smooth continuum, ideal for assessing instrumental response.

The easiest way to extract a spectrum from the Melchiors database is to use the "Search" tool, a subset of the STAROS database, available free of charge and without registration. See at this address :
https://search.staros-projects.org



In the search field, simply type: **Melchiors esp Cas**

After a few seconds, the spectrum of the epsilon Cas star is displayed:



From this same interface, you can download the spectrum in FITS format, directly compatible with specINTI. We recommend that you save this spectrum in your **working folder**, the same one that contains the images to be processed. Give this file a name that's easy to identify and remember. In this example, we adopt : **_ref_epscas.fits**.

Our raw images can be found in the folder "D:\starex412" (of course, you'll probably have a different name - here, "412" refers to observation night number 412 carried out with Star'Ex).

Note: the addition of the "_" character at the beginning of the name distinguishes reference files or processed data from raw data. We encourage you to adopt this convention.

Note that the choice of the eps Cas star for this demonstration is not very judicious, as it is of the 'Be' type, and therefore likely to vary over time. Preferably, select a star with a reputation for stability, such as 10 Lac or Altair, to assess the instrumental response.

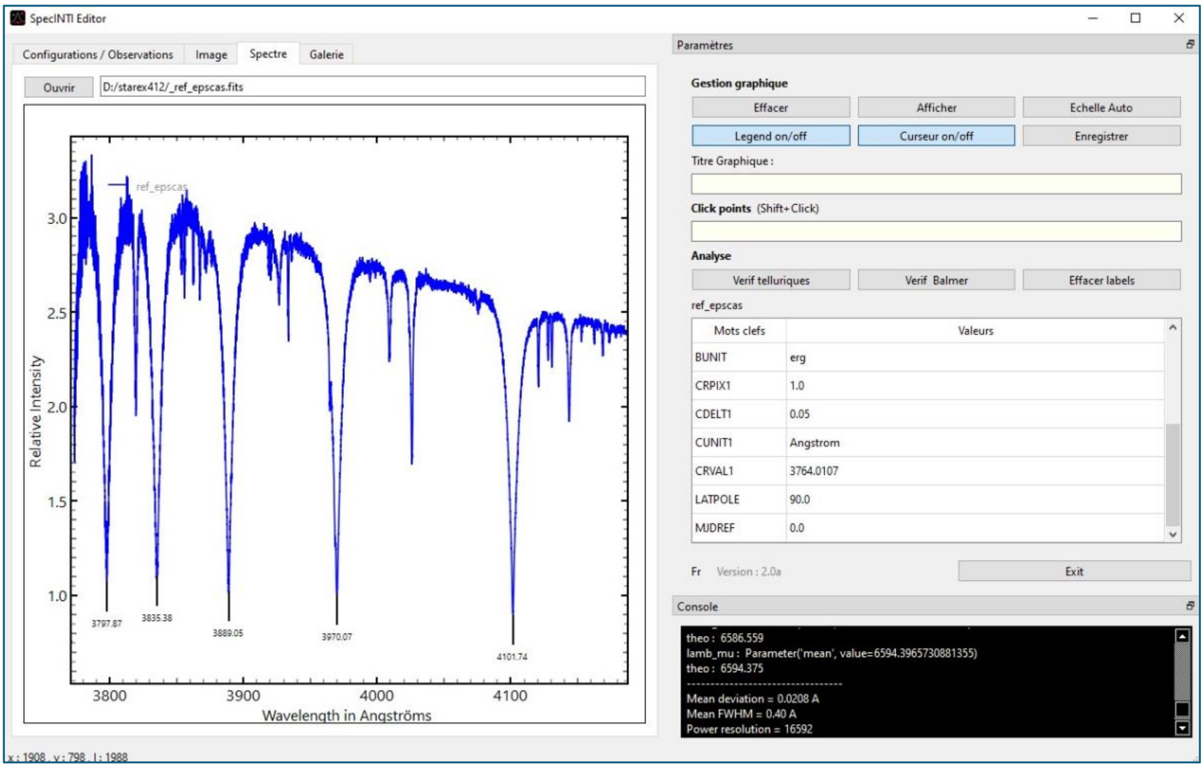
2.3. Displaying spectra and images

We assume that you have downloaded and installed **specINTI Editor V2**. Let's see how to display the spectrum of the reference star via the interface.

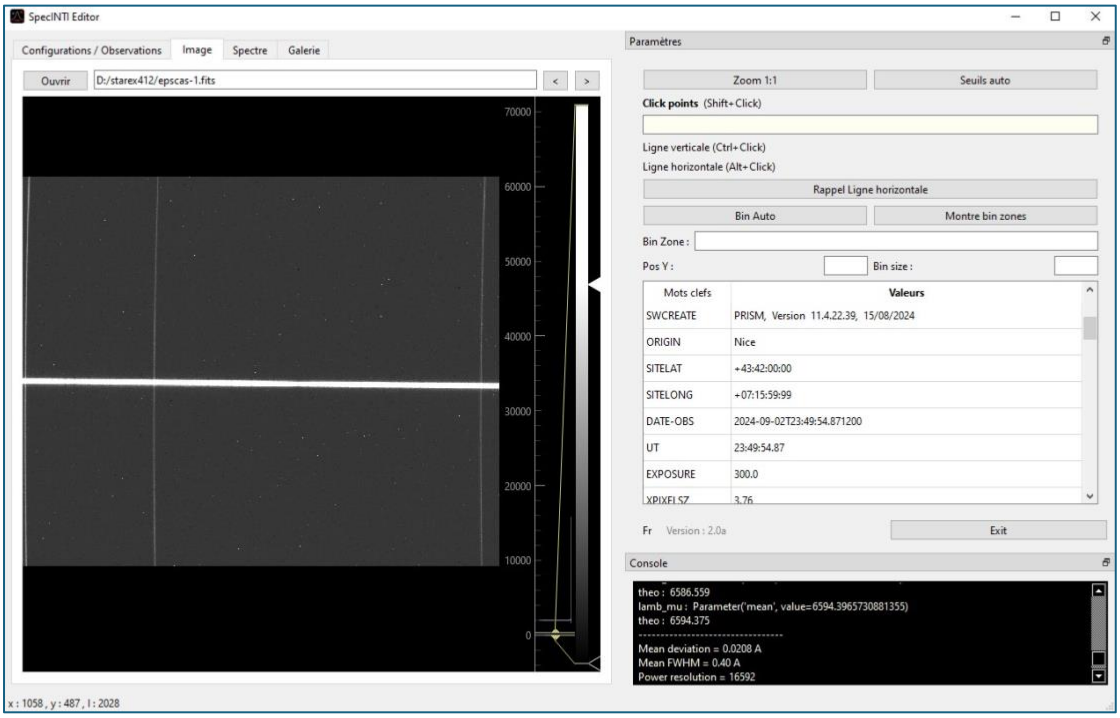
From the "Configurations / Observations" tab, the first task is to designate the working directory, in this case "D:\starex412". To do this, click on the "Directory" button:

Next, open the "Spectrum" tab and load the "_ref_epscas" file into memory by clicking on the "Open" button.

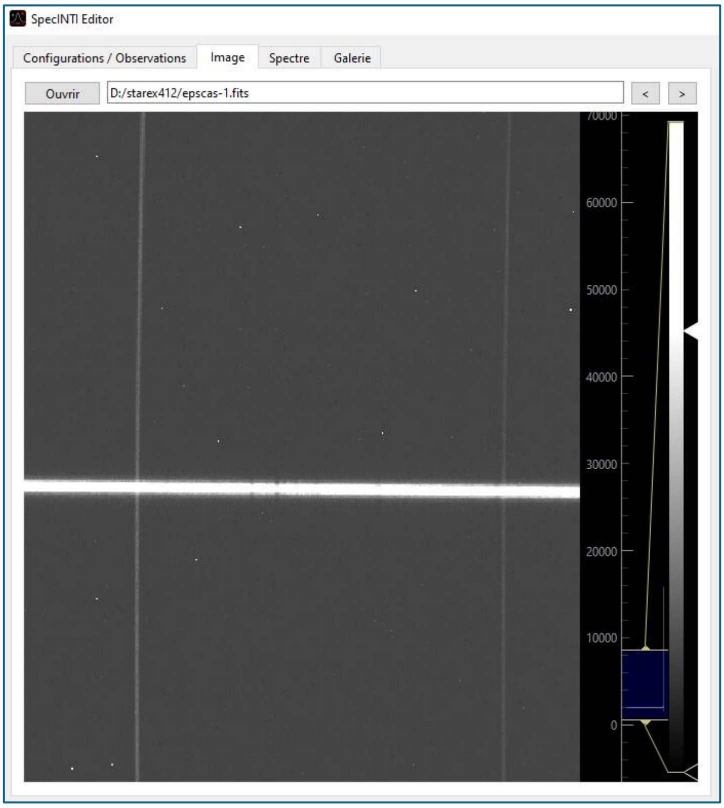
At this point, you can interact with the spectrum in a number of ways: zoom in vertically or horizontally by holding down the right mouse button, move around the graph by dragging the mouse with the left button held down, or move a cursor (vertical bar) that displays wavelength and intensity in real time. You can also identify telluric lines by clicking on the "Telluric Check" button, bring up a context menu (left-click) to modify the graph's appearance, export it, and much more.



We have taken four images of the spectrum of the star epsilon Cas, with exposures of 300 seconds each (acquired using Prism software). You can view their contents by accessing the "Image" tab:



As with spectra profiles, you can zoom in/out, move around, use the mouse wheel... On the right-hand side, you can examine the FITS header of the file. Familiarize yourself with modifying image contrast and brightness using the side ruler:



The "< >" arrow buttons at top right allow you to simply load the images in the sequence in succession (espcas-1, ... epscas-4), which is very useful for detecting acquisition anomalies in case of doubt.

2.4. Processing the raw spectrum without the instrumental response

Let's return to our main subject: determining the **instrumental response**.

Note that we're working in lateral mode, since the star's spectrum and the neon lines are simultaneously available in the same image, with the latter occupying the entire height of the slit. The permanent presence of these neon lines simplifies spectrum processing, notably by automating wavelength calibration.

We will carry out a complete processing of the four spectra of the epsilon Cas star, with the exception of correcting the instrumental response, since this is not yet known at this stage.

Of course, we need the DOFs (Dark, Offset, Flat). For reasons of space, we don't supply these master images individually, but only their combination, the master image files: _dark, _offset and _flat (note the use of the "_" character).

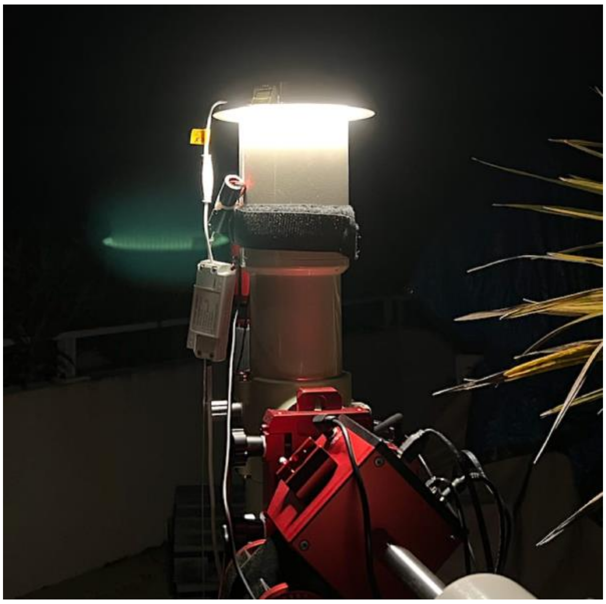
Learn how to manage DOFs

For information, the DOF set for this observation includes :

- 20 images of the offset signal (taken with a very short exposure time and in the dark). These images are saved in the working directory under the names o-1, o-2, ..., o-20.

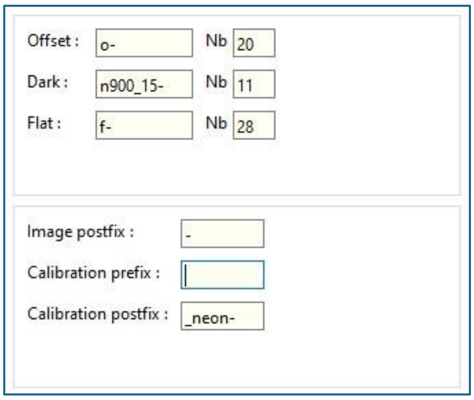
- 11 dark signal images (acquired with an exposure time of 900 seconds and in the dark). The images were taken in daylight, with the entire Star'Ex placed in a refrigerator, the spectrograph's entrance blocked, the door closed as tightly as possible, and the power and USB cables for the science camera routed through. The camera is kept at the same temperature as that adopted for stargazing (here, -15°C, the camera is a ZWO ASI533MM Pro). The images are named n900_15-1, ..., n900_15-11.

- 28 flat-field images, obtained by placing a domestic LED lighting panel in front of the lens, while positioning the tube vertically. The exposure time is 6 seconds per image. Although the panel is dazzling, the LEDs produce very little red light, which explains the relatively long exposure time. These images are called f-1, f-2, ..., f-28.



A (really useful!) tip: get into the habit of naming your DOFs the same way every time!

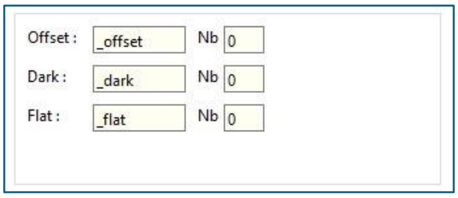
The very first time you process a spectrum, you **must** implicitly indicate the DOF name and number so that this information appears in the observation file:



If you click on the "Autofill" button, the software will automatically detect the number of images, so you won't have to fill in these fields manually. You can also use this opportunity to fill in the "Postfix image" field with a dash (-) and the "Postfix calibration" field with "_neon-". This way, you won't have to worry about these settings the next time you use *specINTI Editor*.

Once your first star is processed with these parameters, specINTI generates the following master DOF files in the working folder: *_dark*, *_offset*, and *_flat* (these names are imposed).

To process the next star, you can now write more simply:

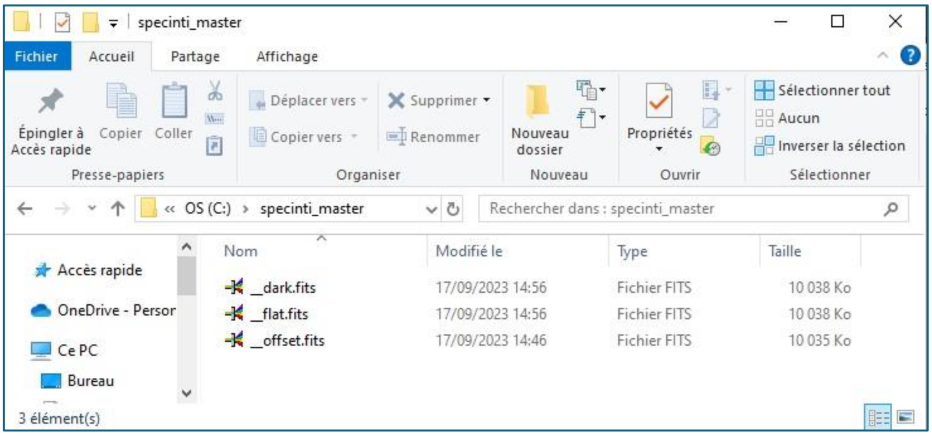


This will be true for all the stars of the night, and even for the processing of many nights of observation with these same DOFs (in this case, more than 10 nights elapsed before we decided to refresh them). However, there is a slight drawback. A good practice is to create a separate folder for each observation night, which you index with the date or an observation number, as in our example. This means copying the three master files _dark, _offset and _flat from one directory to another.

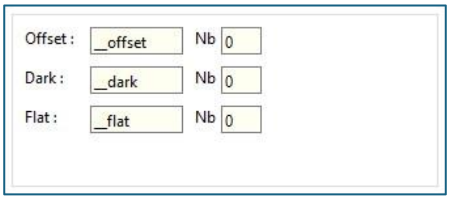
Windows only
You can simplify the process even further if you wish. From the root of your main disk "C:", create the following folder (note that the name is imposed):

C:\specinti_master

Copy your three DOFs into this folder, adding a double underscore in front of each name (__):



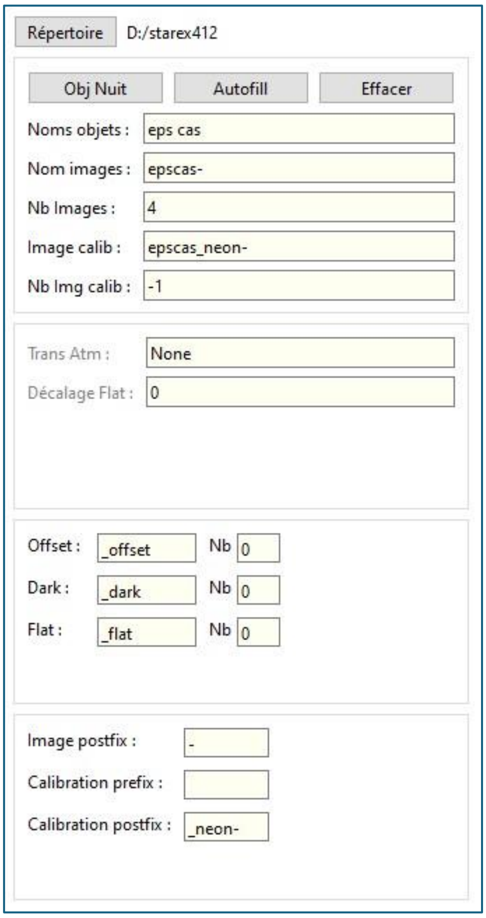
From now on, all you have to do is indicate in the SpecINTI Editor interface :



You no longer have to worry about copying DOFs from one night to the next.

The raw image files of the star are called epscas-1.fits... epscas-4.fits. These are still simple names, with a root that SIMBAD can understand, except that we've omitted the space between "eps" and "fits" (avoid blanks in your file names, we're doing science here!).

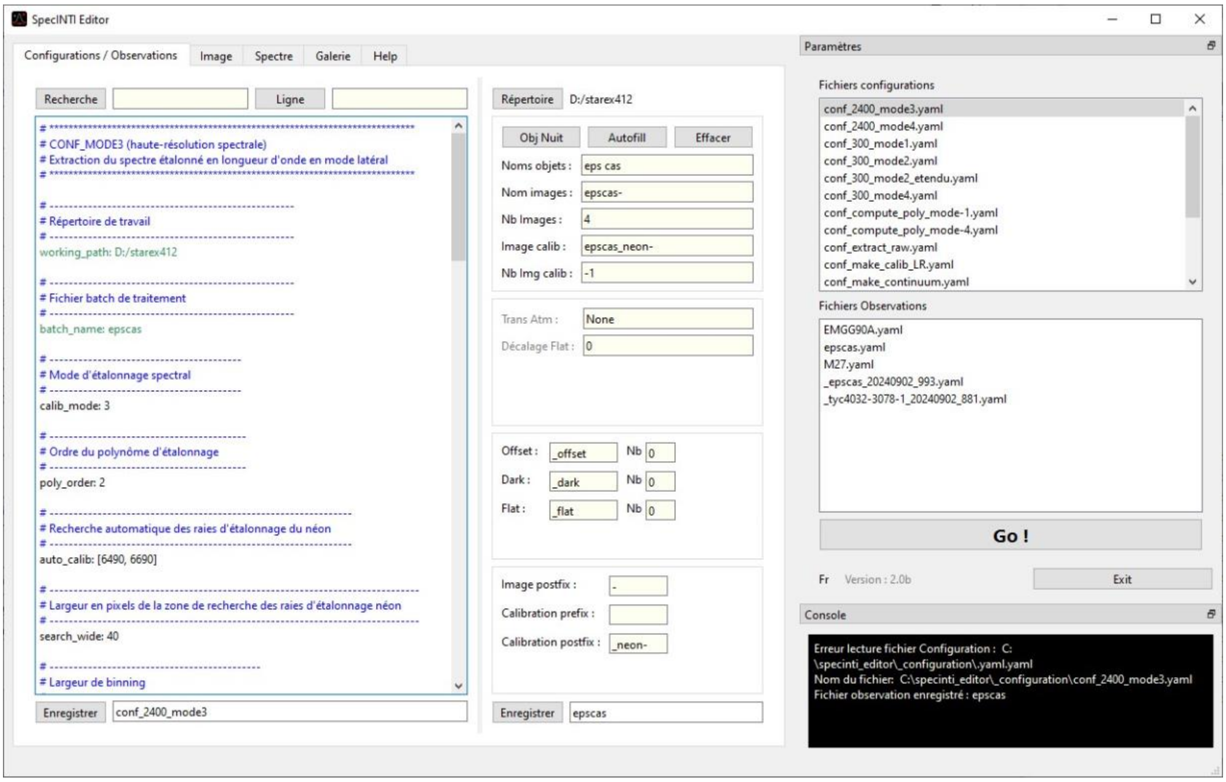
Here's how to set up the observation file for our star. Remember: just fill in the first "Object names" box with "eps Cas" (or "eps cas"), then click on "Autofill" to have the fields filled in automatically - thanks to the judicious naming of images during acquisition:



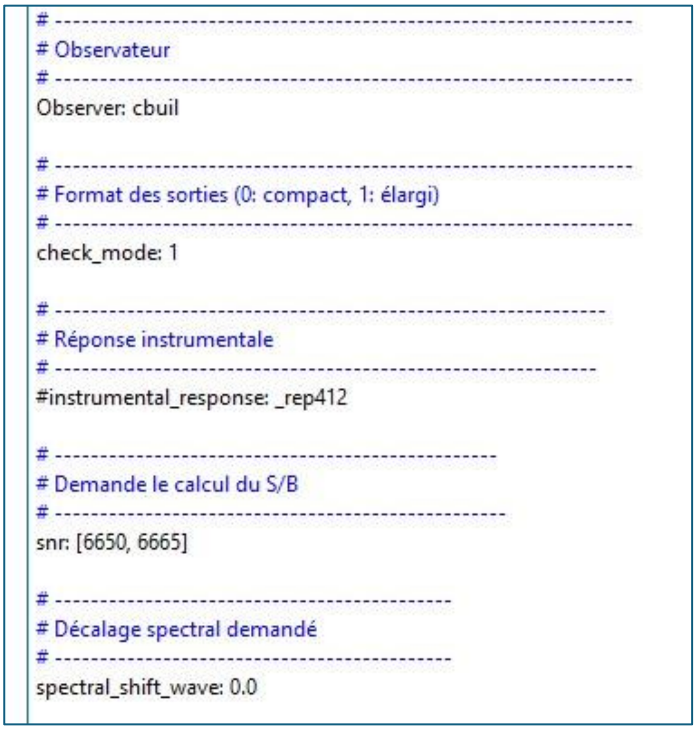
You are free, however, to name your files as you wish, but in this case the automatic functions based on simple naming rules will be inoperative. In this case, you'll have to enter all the information for each field by hand.

Next, we need to use the configuration file best suited to our situation. We recommend using the **conf_2400_mode3.yaml** file, specifically written to exploit data acquired in lateral mode for fully automated spectral calibration. Check for it, or copy it into the "**_configuration**" directory of the specINTI installation folder. For it to appear in the list of configuration files after copying, you need to restart the application.

Double-click on the title, and the contents will appear in the left-hand window:

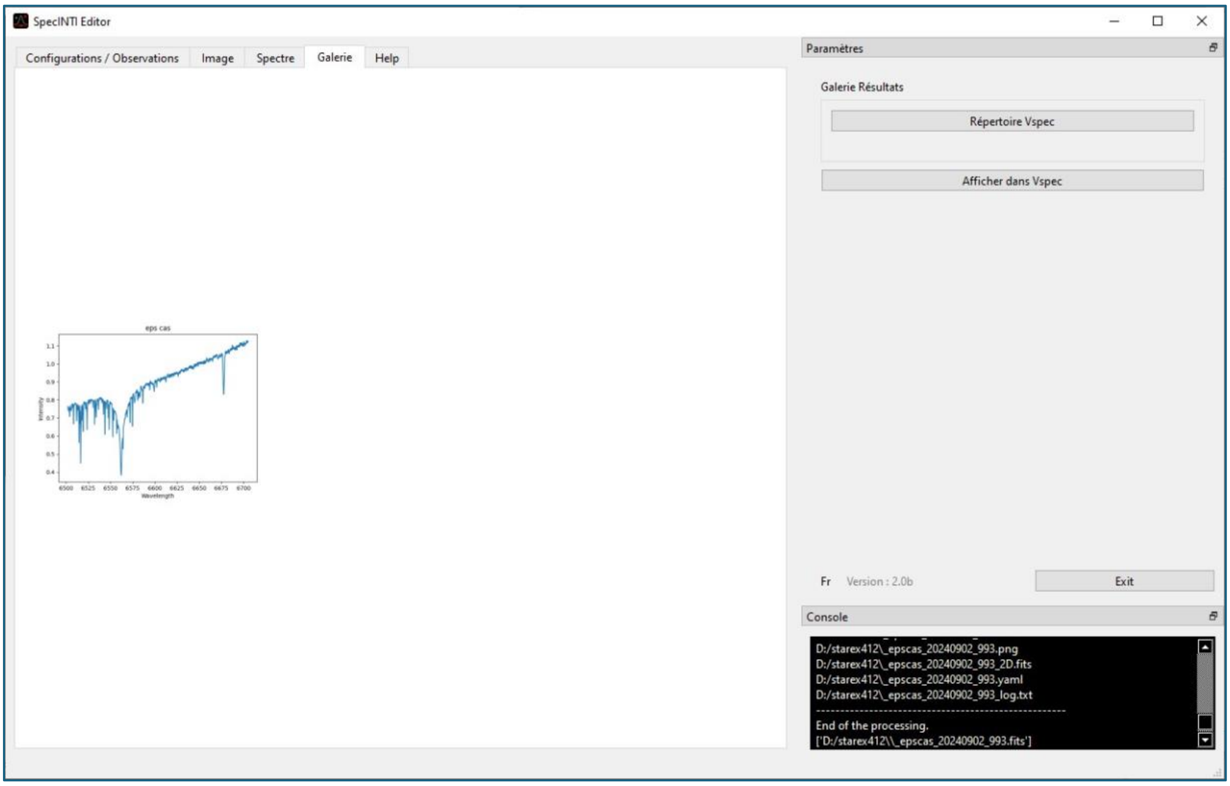


Please note that you must specify that the instrumental response is currently unknown, by temporarily commenting out the **instrumental_response** command (a pound sign in front of the line):


```
# ----------------------------------------------------------------
# Observateur
# ----------------------------------------------------------------
Observer: cbuil

# ----------------------------------------------------------------
# Format des sorties (0: compact, 1: élargi)
# ----------------------------------------------------------------
check_mode: 1

# ------------------------------------------------------------
# Réponse instrumentale
# ------------------------------------------------------------
#instrumental_response: _rep412

# ------------------------------------------------
# Demande le calcul du S/B
# ------------------------------------------------
snr: [6650, 6665]

# -------------------------------------------
# Décalage spectral demandé
# -------------------------------------------
spectral_shift_wave: 0.0
```

Everything is almost ready for processing. Click on the "Save" button in the **observation file** (this automatically updates the "working_path" argument in the configuration file). Also click on the "Save" button in the **configuration file**. Finally, click on the "Go" button.

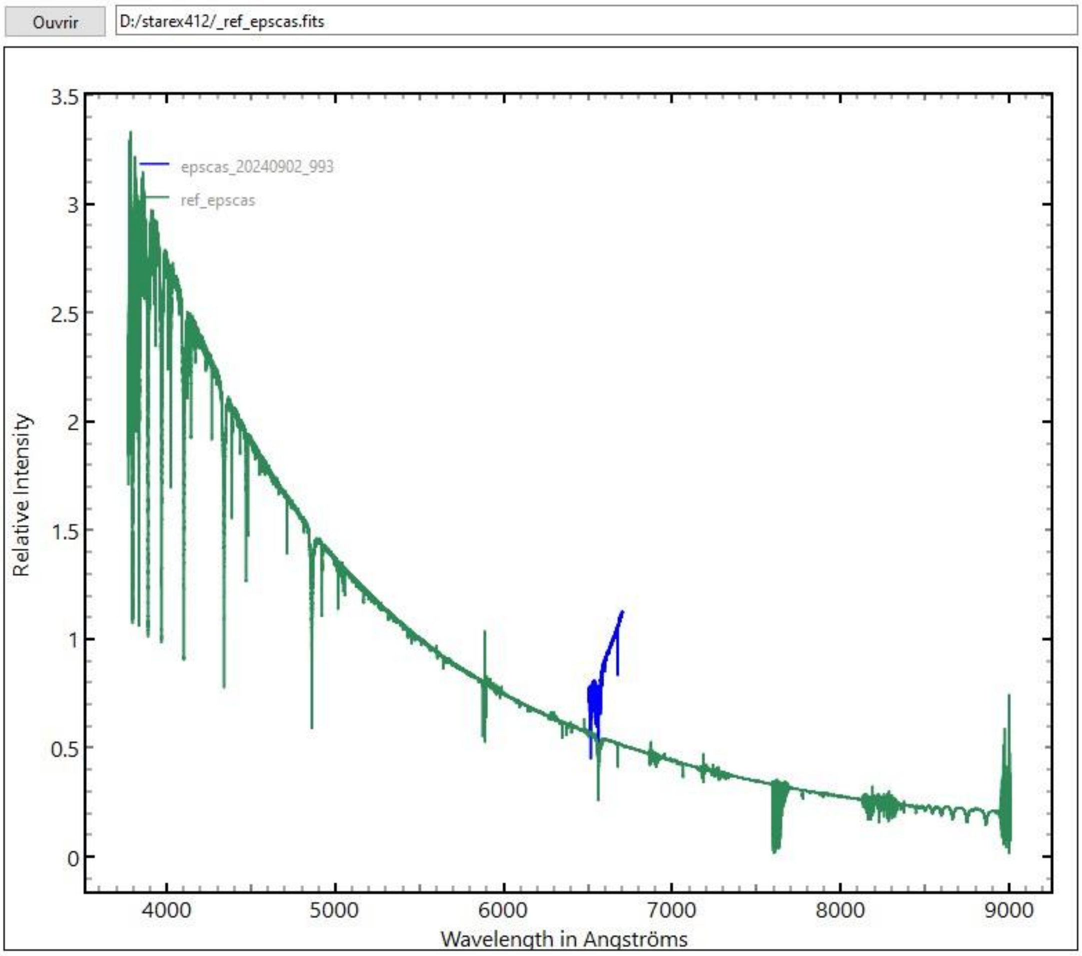
Behind the main program window, a console displays information on the processing progress (note that it may be hidden by other windows). At the end of processing, the result is displayed as a thumbnail. You also have a local console, which is another way of examining the processing history directly in the interface.



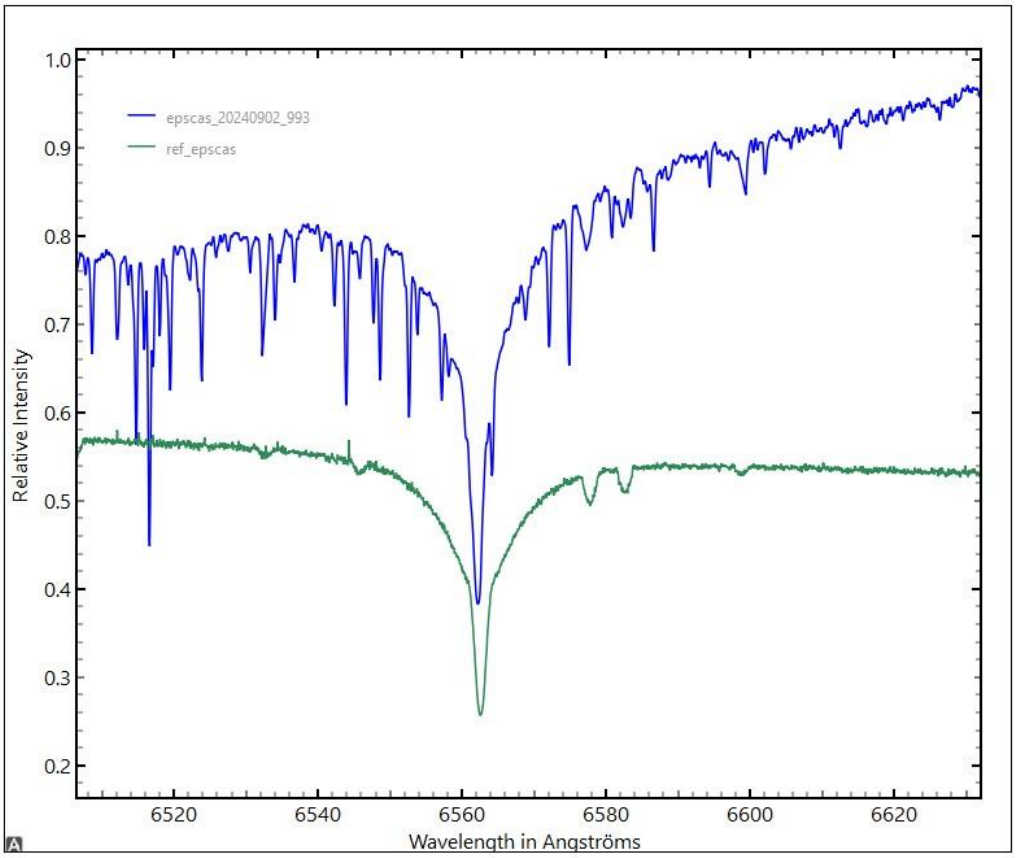
2.5. Response calculation

You can, of course, examine the profile resulting from the previous processing, using all the features offered by the "Spectrum" tab. The name of this profile is made up of the name of the star associated with the date, for example here :
_epscas_20240902_993.fits.

It's very instructive to compare the appearance of the spectrum calculated in this way with what it would look like if the instrument's specific response were corrected. It's very simple. First display the calculated profile, then click on the "Open" button again to load the reference profile from the Melchiors database. In this way, several curves can be displayed on the same graph:



The Star'Ex spectrum is displayed in blue. It covers only a small portion of the visible spectrum. Enlarge the area around the H-alpha line:

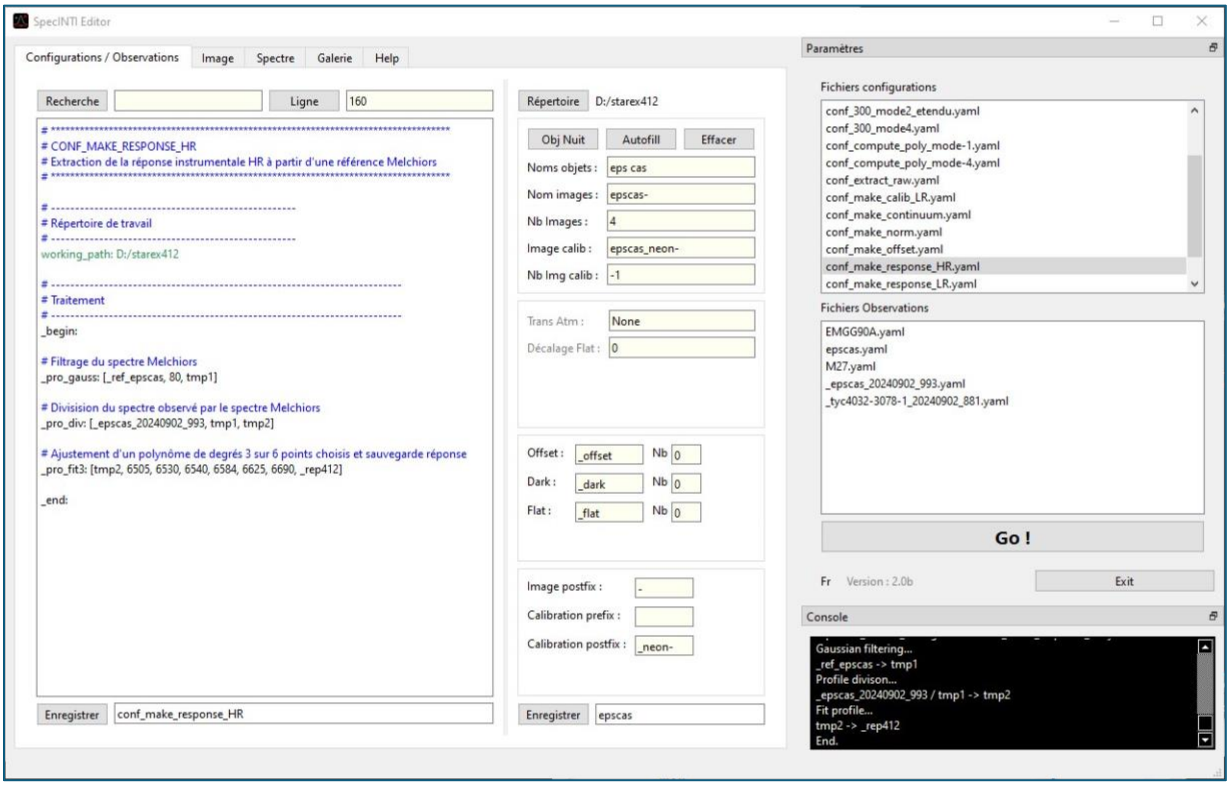


There is a certain similarity between these two spectra, but there are also significant differences. The telluric lines of water vapor are present in our spectrum, but not in that of the Melchiors base. Above all, the mean shape of the continuum is inverted. This difference is due to the instrumental response of our equipment, not taken into account here, as well as the color of the LED lamp used to produce the flat-field image, which is much more blue than red.

The instrumental response is obtained by **dividing** the observed spectrum by the reference spectrum. This operation directly provides the instrumental response, as the spectrum of the epsilon Cas star we have calculated is similar to the one we would observe outside the Earth's atmosphere. If you take a close look at the configuration file, you'll find the **corr_atmo** command, which calculates the transmission of the atmosphere at the time of observing the star, allowing you to simulate an observation in the absence of the atmosphere.

We're going to use a small utility to perform this division, in the form of a command file containing calculation functions. This file is called **conf_make_response_HR.yaml** (you can rename it as you wish). Copy it to the program's **"_configuration**" directory if it is not already there.

Open the "**Configurations / Observations**" tab and select the configuration file **conf_make_response_HR.yaml** to view its contents:



The functions are enclosed between the "**_begin**" and "**_end**" keywords:

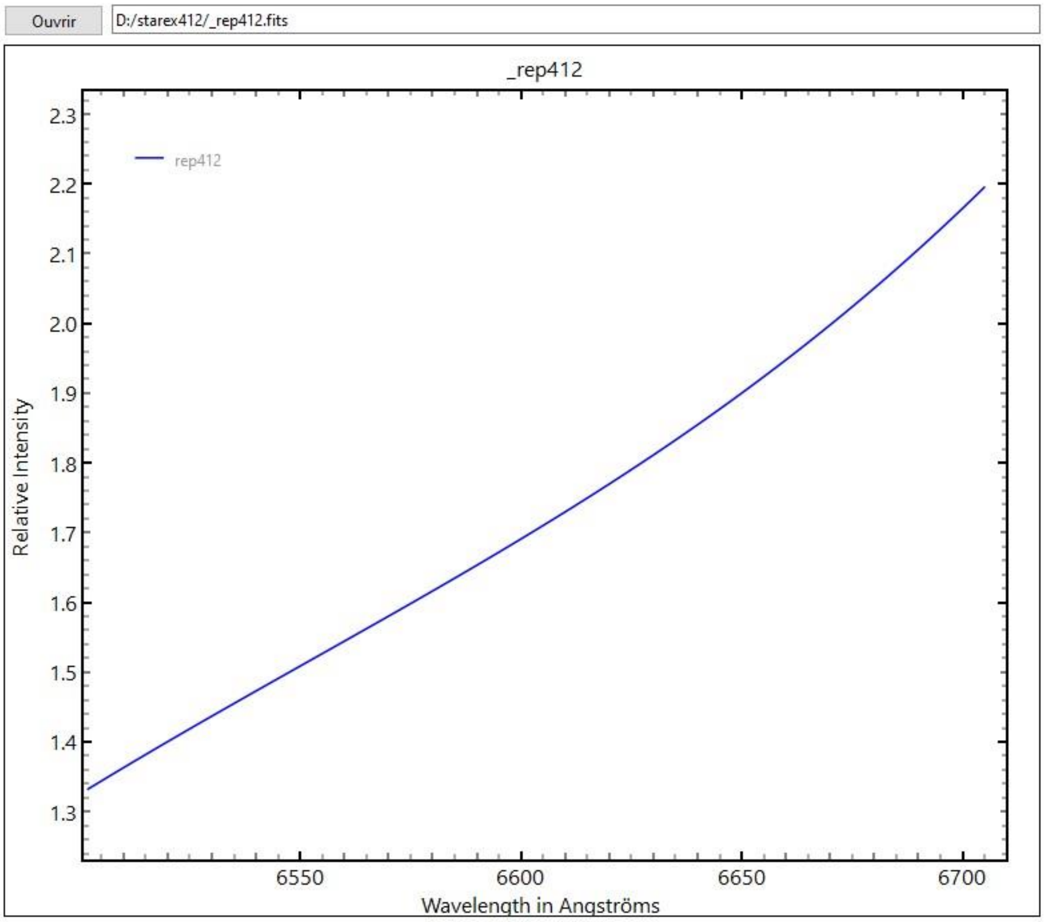
```
# ***********************************************************************************
# CONF_MAKE_RESPONSE_HR
# Extraction de la réponse instrumentale HR à partir d'une référence Melchiors
# ***********************************************************************************

# --------------------------------------------------
# Répertoire de travail
# --------------------------------------------------
working_path: D:/starex412

# ----------------------------------------------------------------------
# Traitement
# ----------------------------------------------------------------------
_begin:

# Filtrage du spectre Melchiors
_pro_gauss: [_ref_epscas, 80, tmp1]

# Divisision du spectre observé par le spectre Melchiors
_pro_div: [_epscas_20240902_993, tmp1, tmp2]

# Ajustement d'un polynôme de degrés 3 sur 6 points choisis et sauvegarde réponse
_pro_fit3: [tmp2, 6505, 6530, 6540, 6584, 6625, 6690, _rep412]

_end:
```

The first function (**_pro_gauss**) performs a smoothing of the Melchiors spectrum to adapt it to the lower spectral resolution of the Star'Ex instrument. Next, the actual division is calculated (**_pro_div**). The last function determines a polynomial function of degree 3 from six points in the spectrum, defined by their wavelengths, while avoiding telluric lines (for example, if you examine the spectrum, the 6505 A wavelength is free of telluric lines and represents the local continuum well).

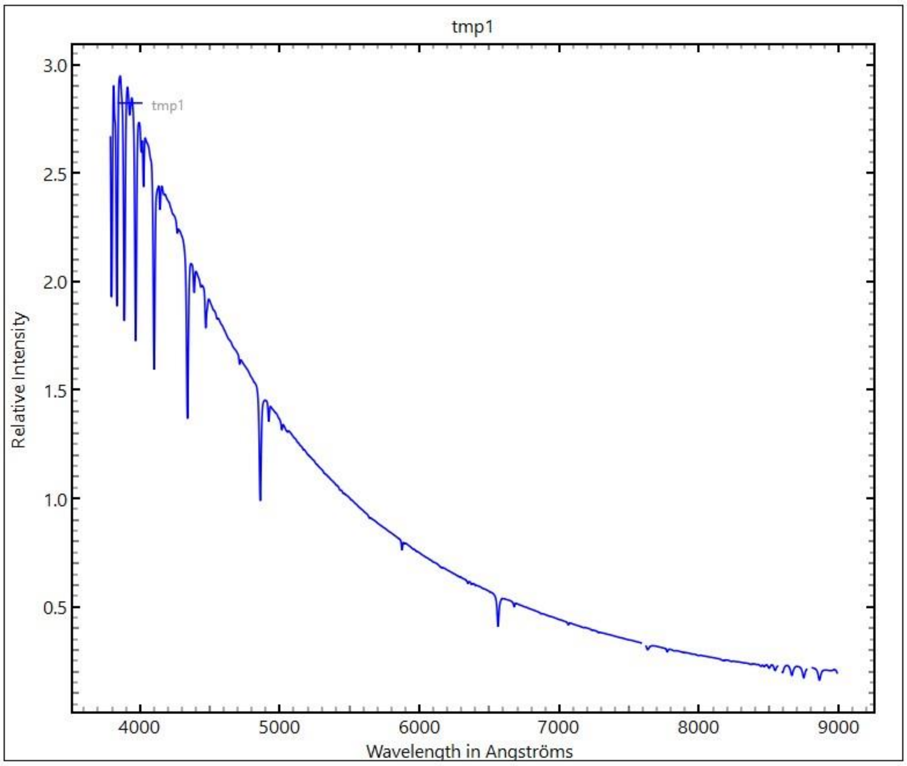
The parameters must be modified manually to process the appropriate files. When filtering, be sure to indicate that the processing applies to the Melchiors reference file (_ref_epscas). For division, first enter the name of the star's observed spectral profile as the first parameter of the **_pro_div** function. Finally, modify the last parameter of the **_pro_fit3** function to enter the name of the desired instrumental response file, in this case "_rep412" (meaning that this is a response file calculated from the spectra of observation number 412). These operations are a bit tedious, but remember that they're rarely performed - **we don't calculate an instrumental response every night**, far from it.

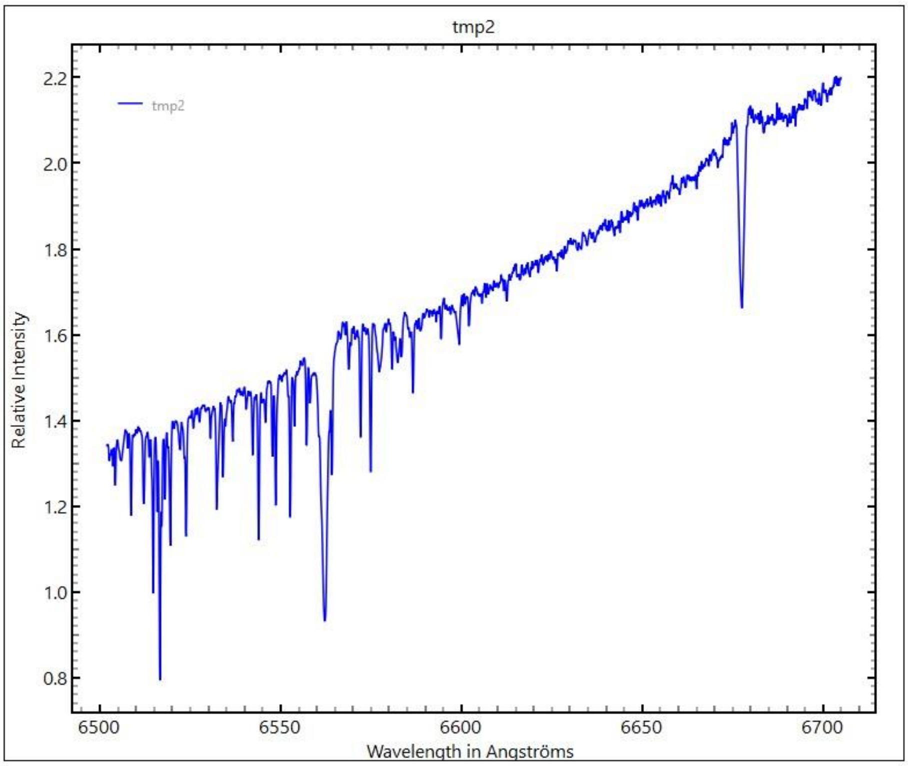
Before launching specINTI with this configuration file, check that the "working_path" parameter points to the correct working folder. Tip: click on the "Save" button in the observation file to easily update this setting.

Click on "Go! The calculation is fast. Here's the result:



To understand how the calculation works, take a look at the temporary file "tmp1", which is the smoothed spectrum of the Melchiors star, and the file "tmp2", which is the instrumental response before smoothing. These files are in the working directory





Taking barycentric speed into account

The Melchiors spectrum is identical to that obtained by observing the center of the Sun. However, our own observatory is mobile relative to the star due to the Earth's annual revolution around the Sun. When comparing the Melchiors spectrum with the observed spectrum, close examination reveals that the H-alpha line is slightly shifted between the two. This shift is caused by the star's apparent radial velocity, induced by the Earth's rotation around the Sun.

To correct this, simply add the following line to the "conf_2400_mode3.yaml" configuration file:

corr_bary: 0

Then compare the spectrum before and after this barycentric correction. Note that the difference is minimal and that, in both cases, the spectral response will be virtually identical.

Please note: remove this barycentric correction if your spectra are intended for certain professional databases, such as BeSS, for example.

2.6. Using the instrument response

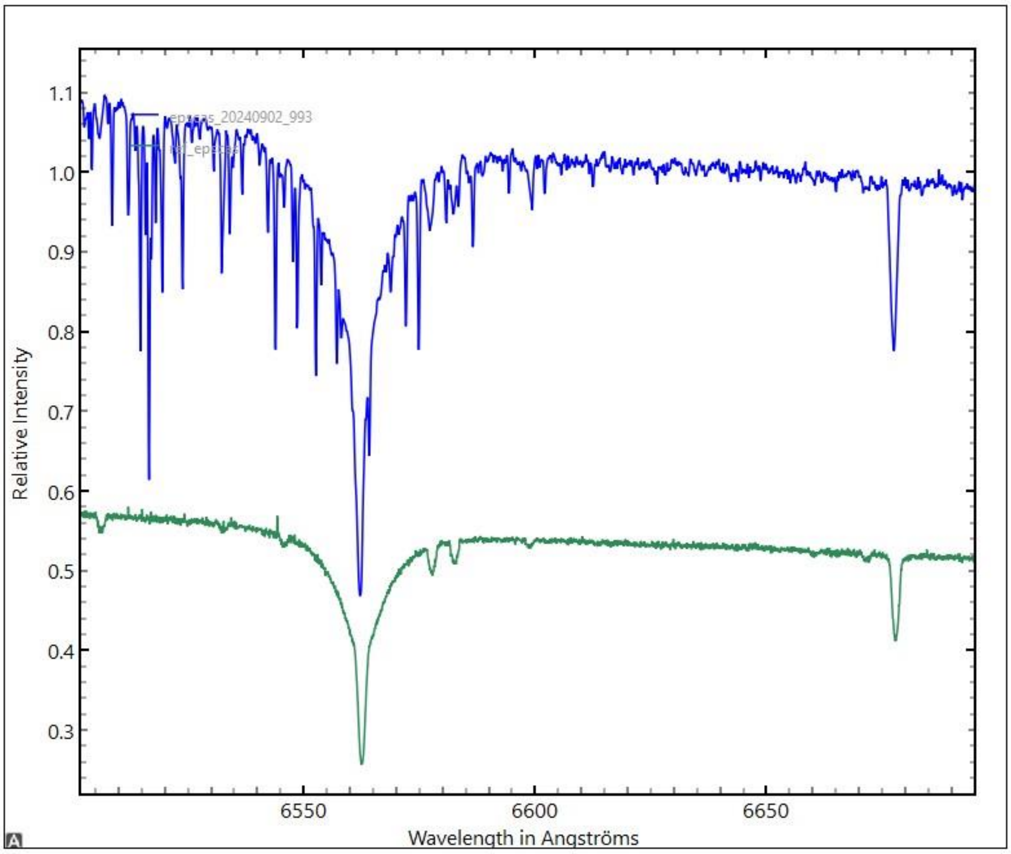
You can now process all the spectra from your observation night, as well as those from subsequent nights, using the response file we've just calculated. In fact, Star'Ex is sufficiently stable, and the calculated curve sufficiently smooth, to have an instrumental quasi-constant, which means you won't have to recalculate it often.

Don't forget to remove the comment on the **instrumental_response** line:

```
# -------------------------------------------------------------
# Réponse instrumentale
# -------------------------------------------------------------
instrumental_response: _rep412
```

From now on, the only configuration file you'll need on a regular basis is **conf_2400_mode3.yaml**, for fast, automatic and reliable processing of your observation nights.

As an example, restart the processing of the epsilon Cas star using the instrumental response found. To do this, remove the comment in front of the **instrumental_response** parameter line as described above. Here's the final result (in blue) compared with the Melchiors spectrum (in green):

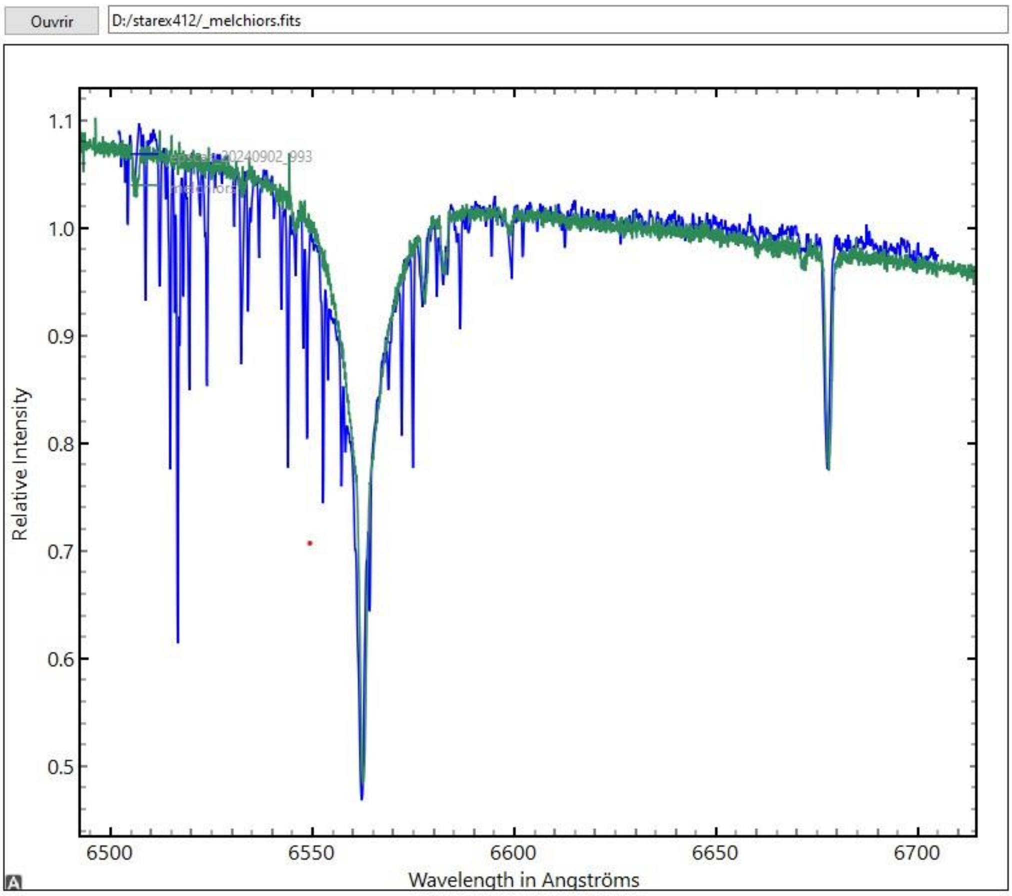


Spectrum standardization

Comparing the two spectra is not straightforward, as they do not have the same normalization point at unity. This problem is easily remedied by running specINTI with the configuration file **conf_make_norm.yaml**, where the **pro_norm** function takes care of the normalization between two wavelength bounds:

```
# ***************************************************************
# CONF_MAKE_NORM
# Normalise un spectre à l'unité
# ***************************************************************

# --------------------------------------------------
# Répertoire de travail
# --------------------------------------------------
working_path: D:/starex412

# ---------------------------------------------------------
# Normalisation à l'unité dans un intervalle spectral
# ---------------------------------------------------------
_pro_norm: [_ref_epscas, 6620, 6640, _melchiors]
```

This gives (we now display the contents of the _melchiors.fits file:



3. Processing low-resolution spectra

3.1 Introduction

The second part of this checklist is dedicated to processing spectra at low spectral resolution.

To illustrate the procedure, we also use data from a Star'Ex spectrograph, but this time equipped with a 300 line/mm grating (as opposed to the 2400 t/mm used for high resolution). The slit is a 26-micron GEN2 model, and, as before, the imaging instrument is an Askar 107PHQ refractor.

As always, we need to observe a reference star at least once to determine the instrumental response. The epsilon star Cassiopeiae will be used once again. Its spectrum, corrected for the effects of the Earth's atmosphere, has already been extracted from the Melchiors database (see section 2.2). The observation took place during the night of October 3 to 4, 2024, and we acquired 10 spectra, each with a 5-second exposure.

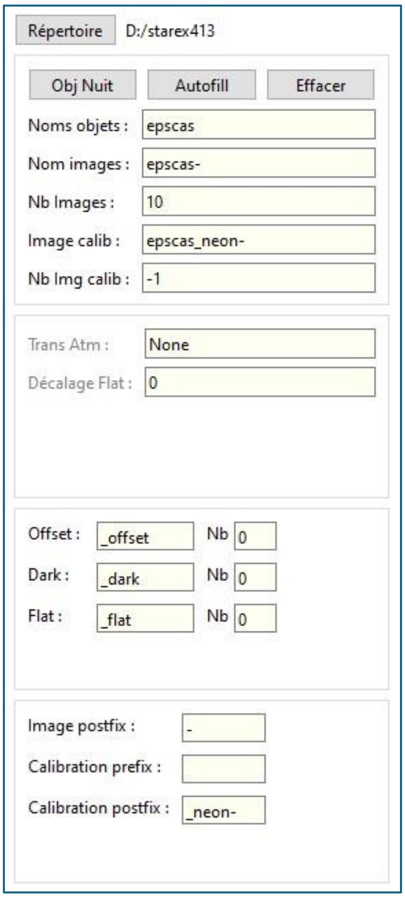
The flat-field is obtained on site, at night, by illuminating the lens entrance with a set of 5 tungsten lamps (MagLite type, and this is just one example), through a tracing paper diffuser to even out the pupil illumination.

The images and . YAML files required for processing can be **downloaded here**.

Processing low-resolution spectra is only slightly more complex than high-resolution spectra. Indeed, one key step is less automatable: wavelength calibration. This is where we'll start.

3.2. Wavelength calibration

This is how our observation file is written:

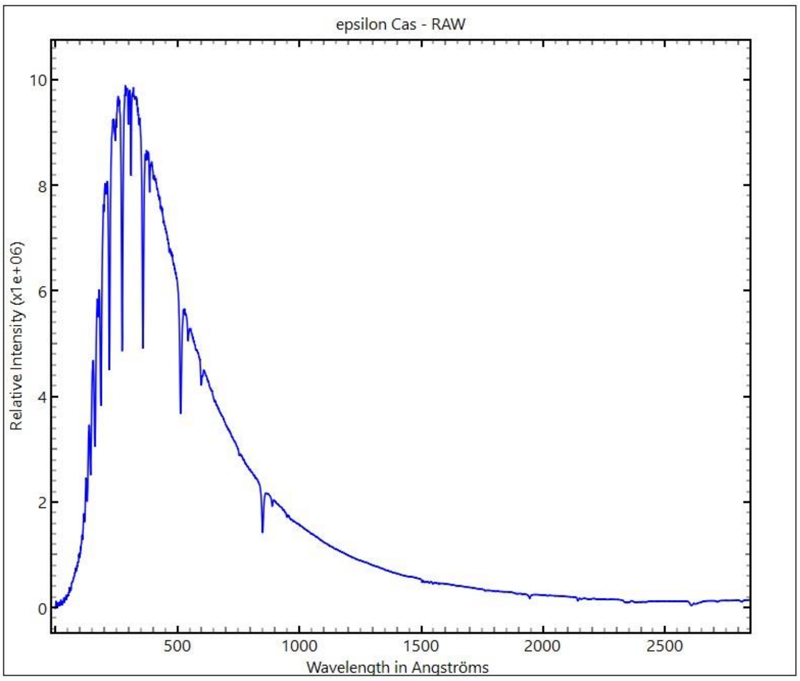


Here are the 10 images of the star's spectrum, along with the DOFs (note that they differ from those used in high-resolution, because although the camera is also an ASI533MM, it's a different model).

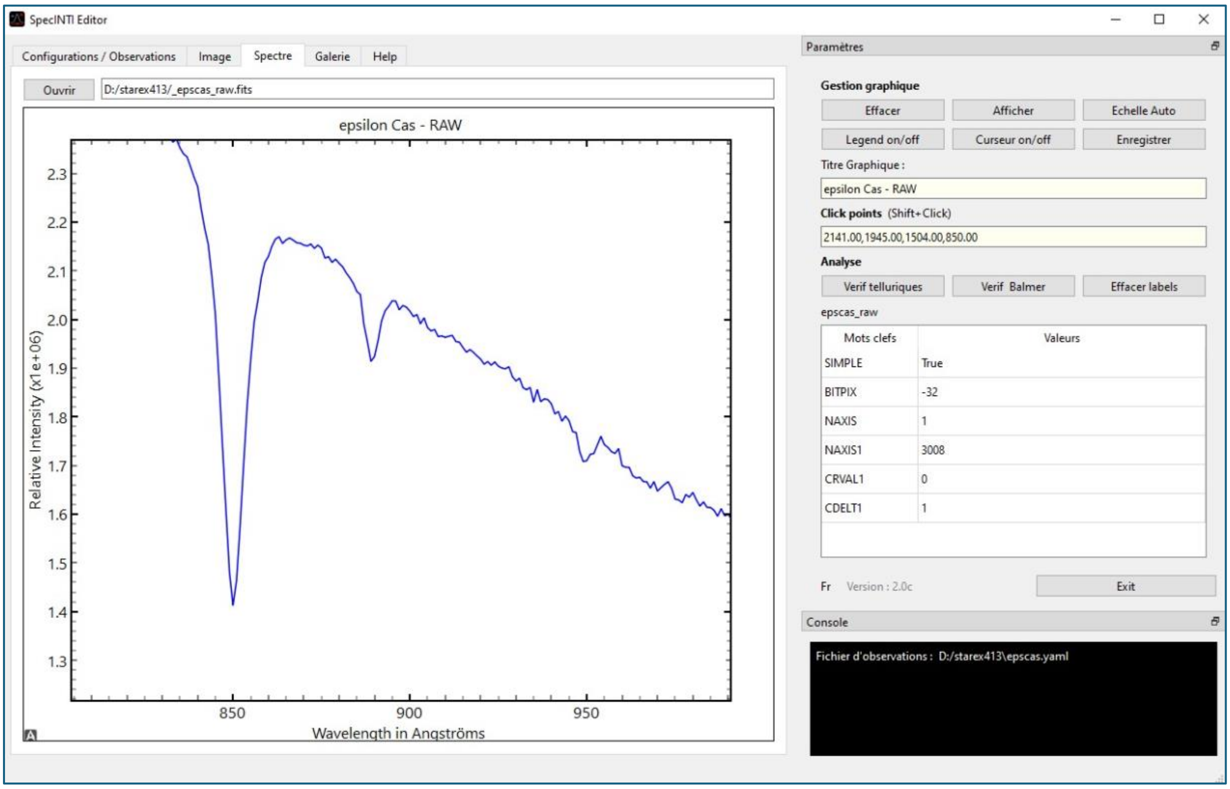
It's important to note that we haven't used a calibration lamp for this observation. Instead, we're relying on the natural lines present in the spectrum of the epsilon Cas star, essentially the Balmer series of hydrogen, clearly visible in this type of star.

The first step is to extract the raw spectral profile, i.e. a still uncalibrated spectrum, expressed in pixel rank rather than wavelength. To perform this operation, we use the configuration file **conf_extract_raw.yalm** :

The software writes the light intensity distribution to the **_epscas_raw.fits** file. Here's how it looks from specINTI Editor's "Spectrum" tab:



The position of the Balmer lines in pixels in this profile is plotted, while associating the corresponding wavelength with each. We also include the O_2 line located at 6869.1 Å, which is clearly identifiable. To list the positions, simply *Ctrl* + *Click* on the line troughs:



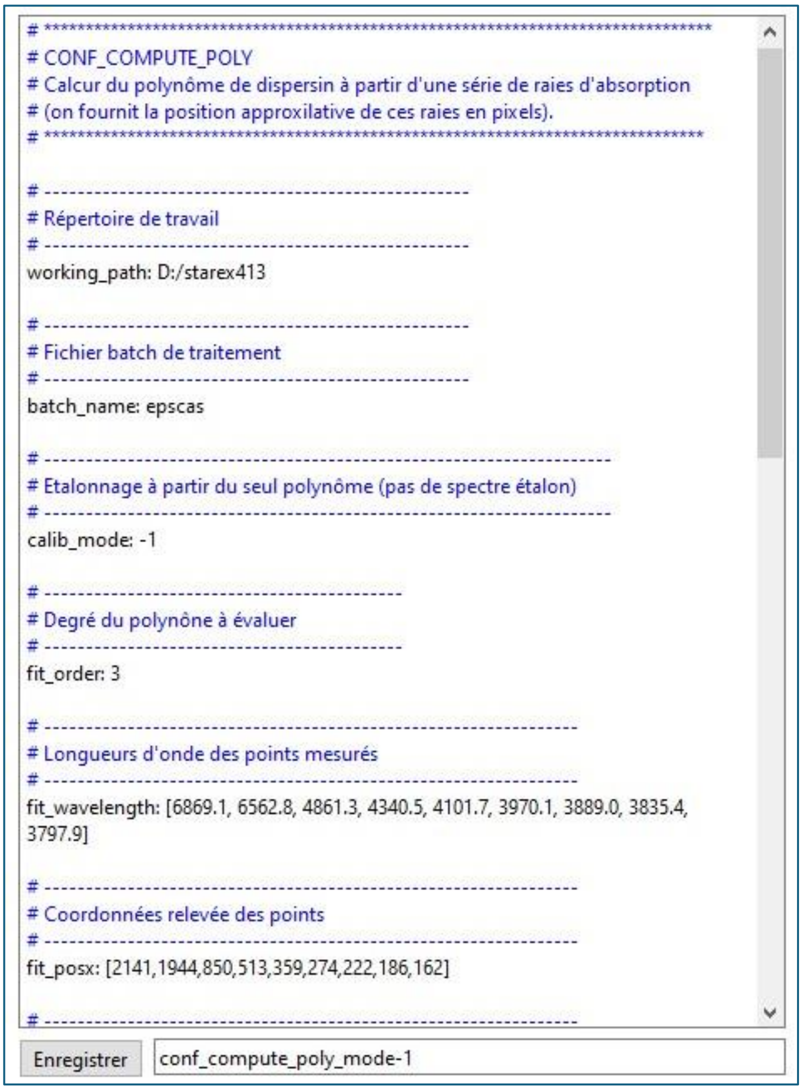
Here are the values found in our example, with the associated wavelengths:

--
Coordinates of surveyed points
--

fit_posx: [2141,1944, 850, 513, 359,274, 222,186,162]

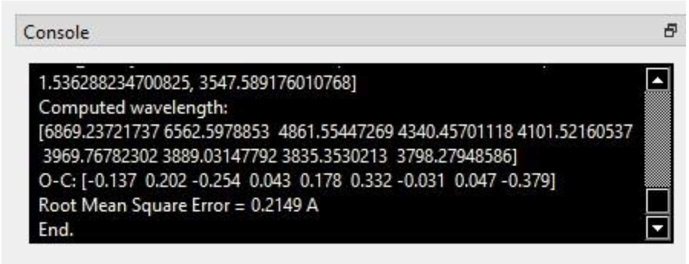
Wavelengths of measured points
---
fit_wavelength: [6869.1, 6562.8, 4861.3, 4340.5, 4101.7, 3970.1, 3889.0, 3835.4, 3797.9]

Launch specINTI with the configuration file **conf_compute_poly_mode-1**. This rather complicated name (which you can change) means that the position pairs "pixel number versus wavelength" are used to define the spectral dispersion law via a polynomial function (chosen here of degree 3):



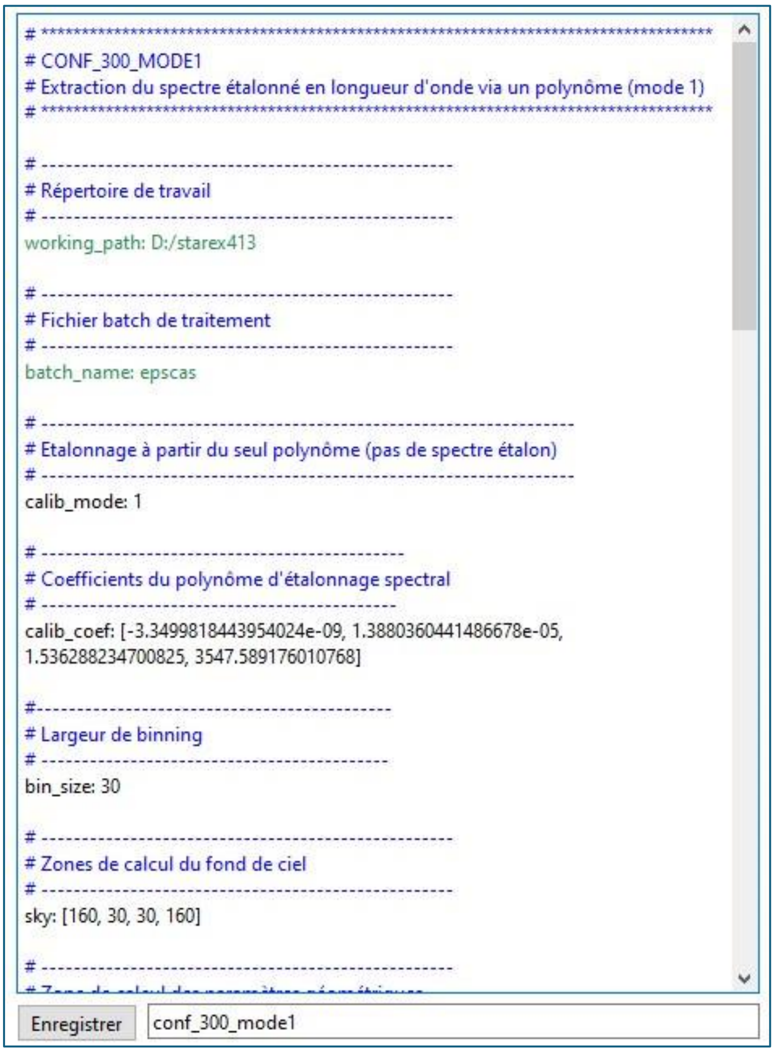
```
# ******************************************************************************
# CONF_COMPUTE_POLY
# Calcur du polynôme de dispersin à partir d'une série de raies d'absorption
# (on fournit la position approxilative de ces raies en pixels).
# ******************************************************************************

# --------------------------------------------------
# Répertoire de travail
# --------------------------------------------------
working_path: D:/starex413

# --------------------------------------------------
# Fichier batch de traitement
# --------------------------------------------------
batch_name: epscas

# ------------------------------------------------------------------
# Etalonnage à partir du seul polynôme (pas de spectre étalon)
# ------------------------------------------------------------------
calib_mode: -1

# ------------------------------------------
# Degré du polynône à évaluer
# ------------------------------------------
fit_order: 3

# ----------------------------------------------------------------
# Longueurs d'onde des points mesurés
# ----------------------------------------------------------------
fit_wavelength: [6869.1, 6562.8, 4861.3, 4340.5, 4101.7, 3970.1, 3889.0, 3835.4,
3797.9]

# ----------------------------------------------------------------
# Coordonnées relevée des points
# ----------------------------------------------------------------
fit_posx: [2141,1944,850,513,359,274,222,186,162]

# ----------------------------------------------------------------
Enregistrer   conf_compute_poly_mode-1
```

The software returns the coefficients of the polynomial in the console (note that the RMS error of fit is small, around 0.2 angstroms):

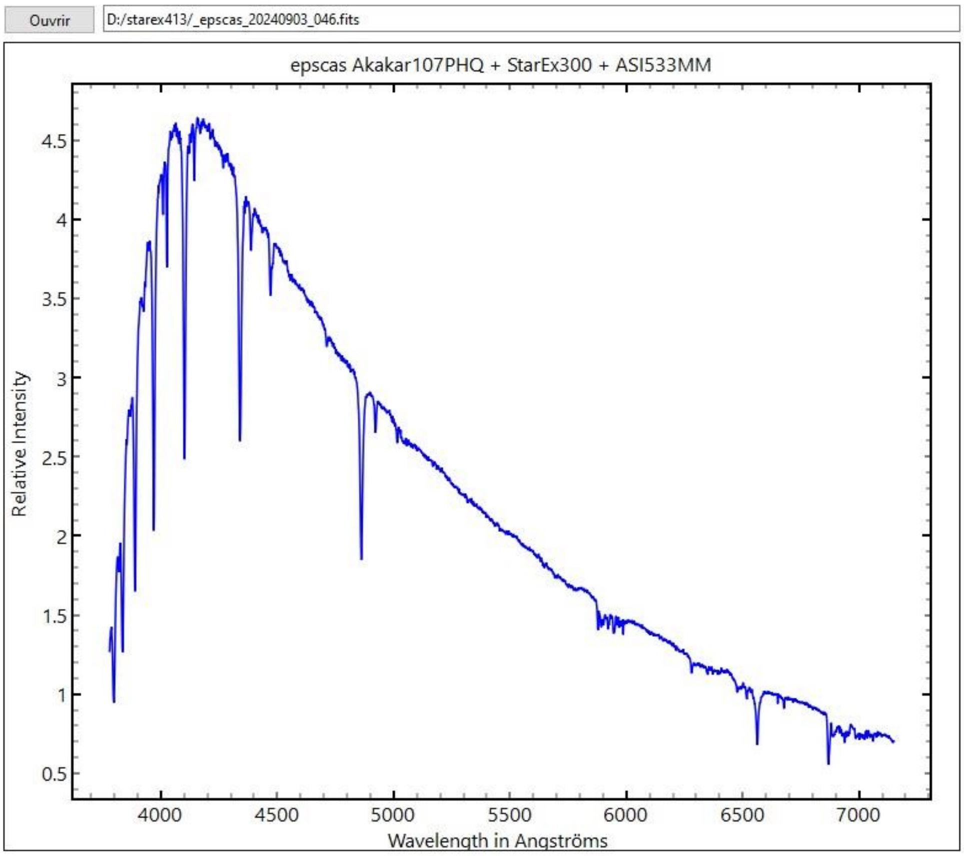


3.3. Assessing instrumental response

The calibration coefficients obtained are then copied and pasted into the configuration file **conf_300_mode1.yaml**. This will be your companion from now on if you follow the procedure described. This command file tells specINTI to calculate the spectrum using a spectral calibration based solely on a polynomial. For the moment, we're commenting on the **instrumental_response** parameter in this file, since the aim is precisely to evaluate this response. The approach followed here is very similar to that used to estimate the instrumental response at high resolution:



The result is the apparent spectrum, calibrated in wavelength, that would be observed outside the Earth's atmosphere:



All that remains is to divide this spectrum by the Melchiors spectrum of the epsilon star Cas (the **_ref_epscas.fits** file).

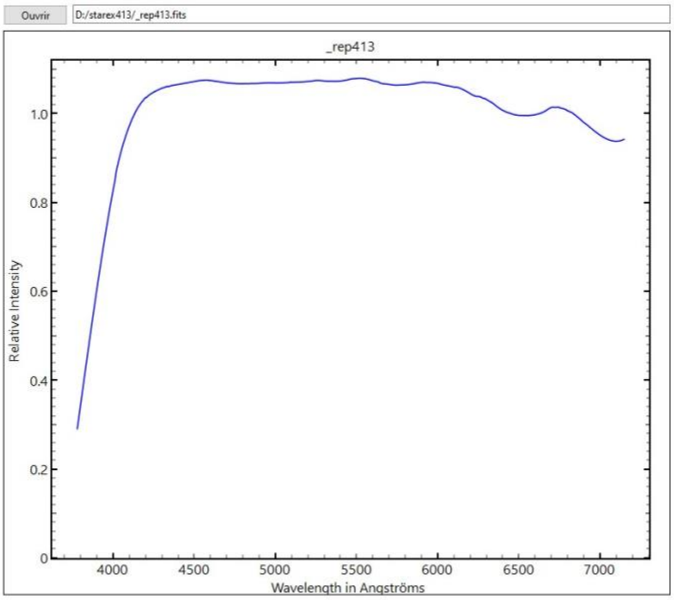
For this we use the short utility **conf_make_response_LR.yaml**, whose contents are :

```
# ****************************************************************************
# CONF_MAKE_RESPONSE_LR
# Extraction de la réponse instrumentale en basse resolution
# à partir d'une référence Melchiors
# ****************************************************************************

# ---------------------------------------------------
# Répertoire de travail
# ---------------------------------------------------
working_path: D:/starex413

# ---------------------------------------------------
# Traitement
# ---------------------------------------------------
_begin:

# Filtrage du spectre Melchiors (HR -> LR)
_pro_gauss: [_ref_epscas, 70, tmp1]

# Retrait des bandes telluriqes dans le spectre observé
_pro_clean: [_epscas_20240903_046, 6830, 7030, tmp2]
_pro_clean2: [tmp2, 6260, 6315, tmp2]
_pro_clean3: [tmp2, 5857, 6030, tmp2]

# Division du spectre observé par la spectre Melchiors
_pro_div: [tmp2, tmp1, tmp3]

# Lissage du résultat de la division
_pro_blur2: [tmp3, 600, tmp4]

# Normalisation et et sauvegarde de la réponse instrumentale
_pro_norm: [tmp4, 6620, 6640, _rep413]

# Normalisation du spectre Melchiors pour comparaison (facultatif)
_pro_norm2: [tmp1, 6620, 6640, tmp0]

_end:
```

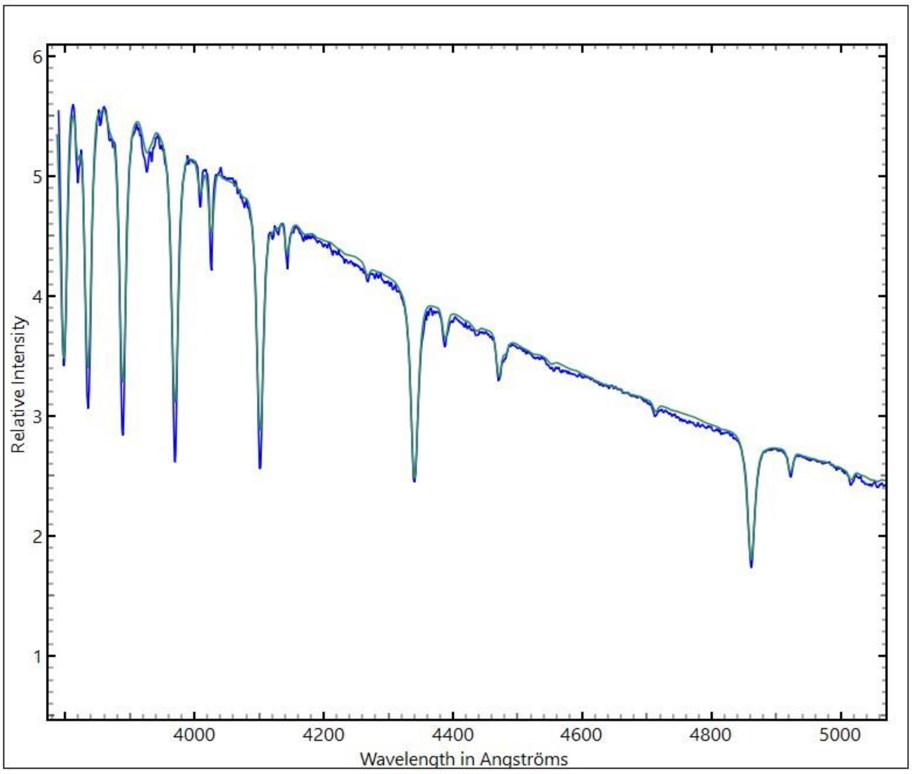
Enregistrer | conf_make_response_LR

First, we reduce the resolution of the Melchiors spectrum (**_pro_gauss**). The **_pro_clean** functions interpolate regions of the spectrum that are too marked by telluric lines (they are therefore erased, and their wavelength bounds are provided). The rest is similar to what we've seen for high spectral resolution.

Here is the resulting profile, the "_rep413" spectral profile:



We can now restart the complete processing of the star by integrating this response in the configuration file **conf_300_mode1.yaml**, which will no doubt be your basis for processing the spectrum of bright stars from now on. The spectrum obtained (in blue in the graph below) corresponds well to the reference spectrum (in green), validating the accuracy of our instrumental response.



The job is done: the spectrum is calibrated spectrally and in relative flux.

3.4. Low-resolution observations of faint stars

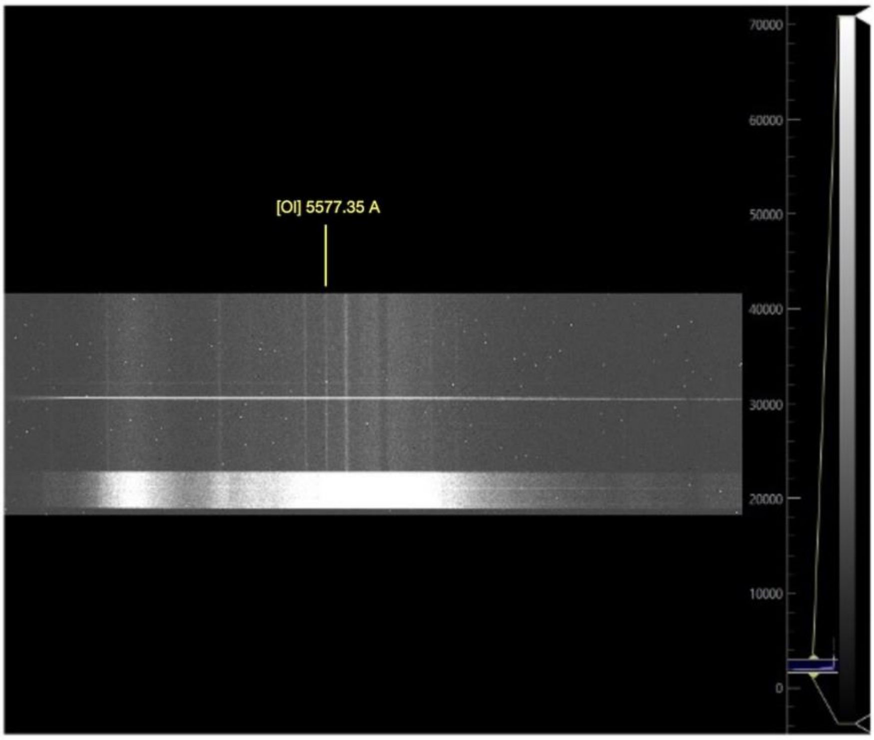
Balmer lines are rarely used to calibrate spectra during routine observations. Indeed, these lines are not always visible, especially if the star is relatively cool (of spectral type G to M), not very luminous, or if the spectrum is exotic or unknown (as in the case of galaxies, for example). In these situations, it is still possible to use natural lines to calibrate wavelength spectra. In this case, we rely on the lines present in the background light, free of charge. These nocturnal lines, originating from urban light pollution (mercury) or the earth's stratosphere, are imprinted in the image at the same time as the star's spectrum, as soon as the exposure time is long enough (a few minutes). We can therefore use the lateral calibration mode, which is extremely practical because it automates the processing of spectra to a high degree, and is very precise.

The procedure is in two stages:

1. **Evaluation of the dispersion polynomial**, as explained in section 3.2, when observing a bright star. With the exception of the first term of this polynomial, which corresponds to a global displacement of the spectrum in the detector plane (linked to the various pointings on the sky causing differential mechanical bending), the other terms can be considered as instrumental constants. This is why reference stars are rarely observed: only once a night and for a single star, if you're picky or suspect a change in the instrument. Otherwise, a weekly or monthly check is sufficient, as is the case with the Star'Ex instrument if you use it correctly.

2. **Use the lines in the night sky** to update only the first term of the polynomial (called the "constant"). The spectrum is then shifted in wavelength by translation. This procedure will be recalled here, using the stratospheric oxygen line [OI], located at 5577.35 Å, which is always present, although its intensity varies.

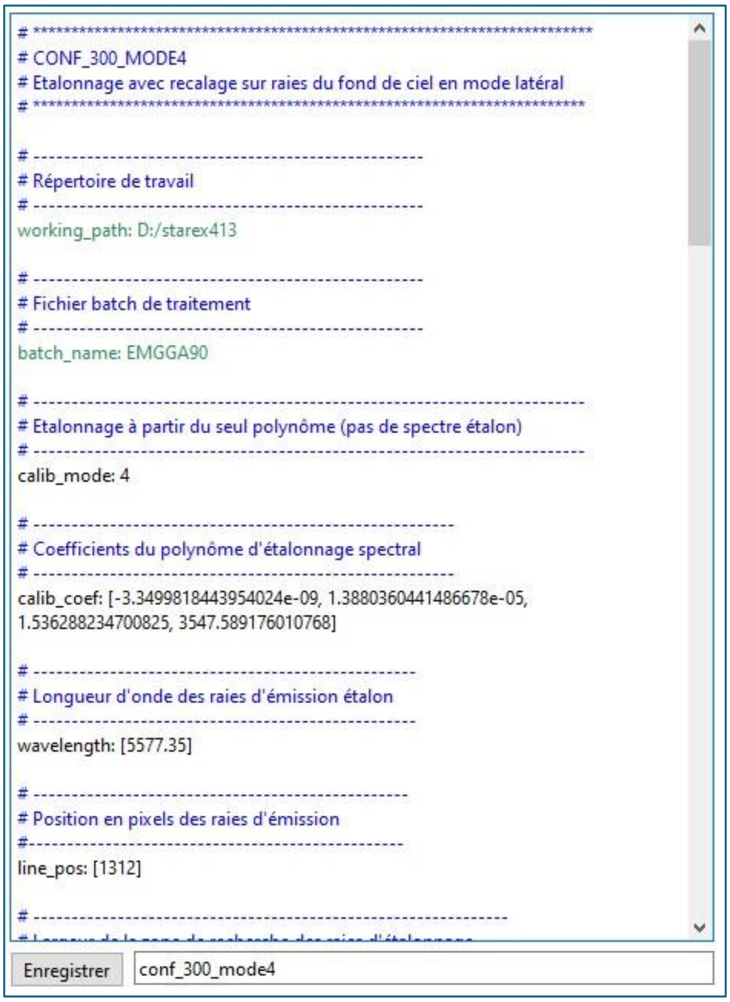
As a typical example, we're interested in observing the Be star EM*GGA90, magnitude V=11.2. The instrument used is again the Star'Ex LR, placed at the focus of an Askar 107PHQ refractor (107 mm in diameter). Below, the appearance of one of the 2D spectra from a sequence of 6, each exposed for 900 seconds:



You've already downloaded these spectral images along with those from epsilon Cas.

We now use the configuration file **conf_300_mode4.yaml** for processing. As the name suggests, it is adapted to work on spectra from a Star'Ex spectrograph equipped with a 300 line/mm grating. Mode 4 means that we will find the first term of the dispersion polynomial by exploiting one or more standard lines in lateral mode (these line(s) are present at the same time as the star spectrum in the spectrum image.

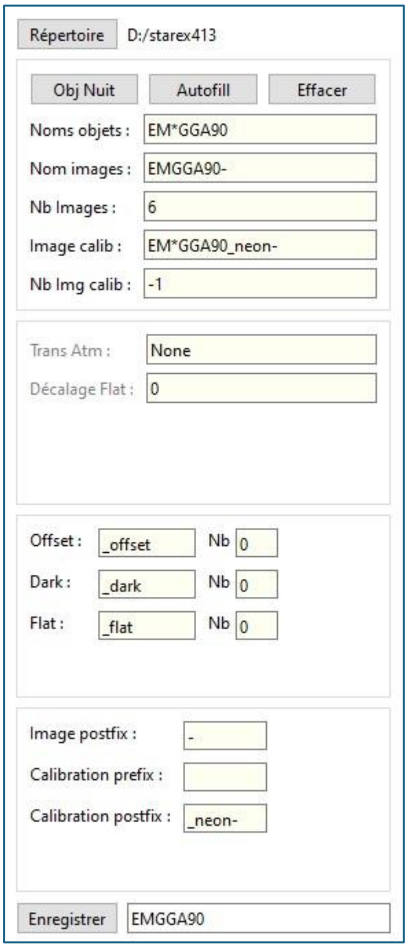
Compared to the configuration file **conf_300_mode1.yaml** used in the previous section, we have added parameters aimed at increasing the signal-to-noise ratio (**sky_mode**, **kernel_size**, **sigma_gauss**, **extract_mode**). We have to be careful with the kernel_size parameter, as the algorithm used to eliminate telegraph noise is only effective if the spectrum is correctly sampled (close to 3.5 pixels/FWHM at least), and here we're at the limit. The penalty is the appearance of artifacts. This is something to keep a close eye on when using a relatively compact telescope, as is the case here.)



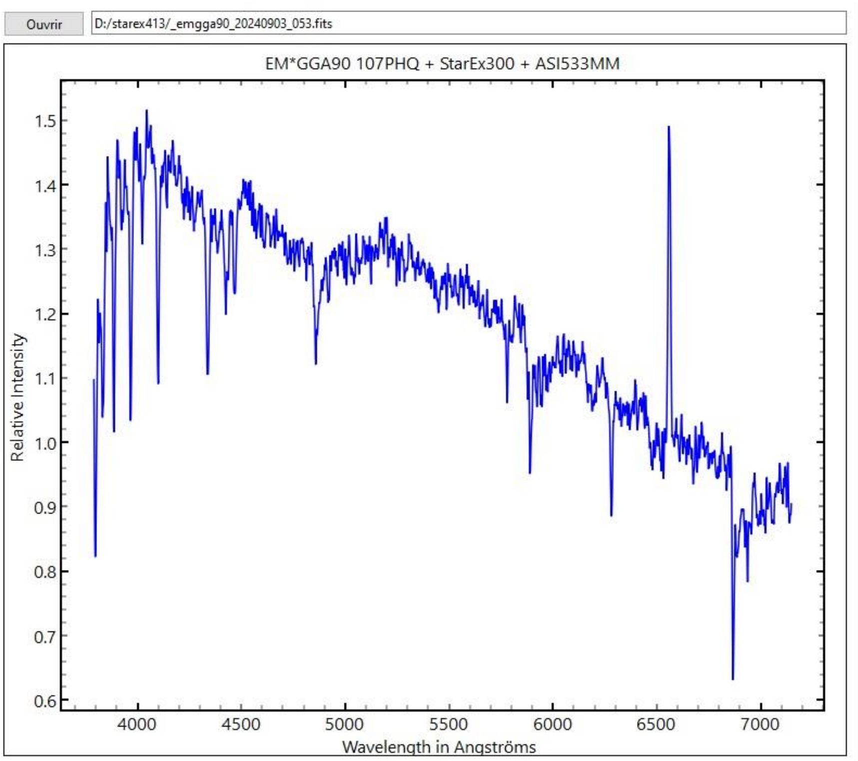
```
# ***********************************************************************
# CONF_300_MODE4
# Etalonnage avec recalage sur raies du fond de ciel en mode latéral
# ***********************************************************************

# -------------------------------------------------
# Répertoire de travail
# -------------------------------------------------
working_path: D:/starex413

# -------------------------------------------------
# Fichier batch de traitement
# -------------------------------------------------
batch_name: EMGGA90

# --------------------------------------------------------------------
# Etalonnage à partir du seul polynôme (pas de spectre étalon)
# --------------------------------------------------------------------
calib_mode: 4

# -----------------------------------------------------
# Coefficients du polynôme d'étalonnage spectral
# -----------------------------------------------------
calib_coef: [-3.3499818443954024e-09, 1.3880360441486678e-05,
1.536288234700825, 3547.589176010768]

# ------------------------------------------------
# Longueur d'onde des raies d'émission étalon
# ------------------------------------------------
wavelength: [5577.35]

# -----------------------------------------------
# Position en pixels des raies d'émission
#-----------------------------------------------
line_pos: [1312]

# ------------------------------------------------------------
```

Enregistrer conf_300_mode4

The parameters of the observation file are as follows:



Here's the result, showing a fairly strong H-alpha line:



A few reminders to close this section:

In our example, the brightness of the photometric zone at the bottom of the image may be greater than that of the observed star. In this case, specINTI will fail to automatically determine the vertical position of the trace of the star's spectrum, and the processing result will be erroneous.

The solution is to exclude the part of the image corresponding to the photometric zone (or any other disturbing object). To do this, simply add the following parameter to the configuration file:

pos_exclude: [180, 270]

where (180, 270) are the vertical coordinates of a zone considered valid for processing.

If the star track is barely visible because the object is very dim, you can manually define the vertical position of the track by adding :

ypos : 426

It is also possible to refine the spectrum trace search by making it floating, but limited to the height of the binning zone, using a negative value :

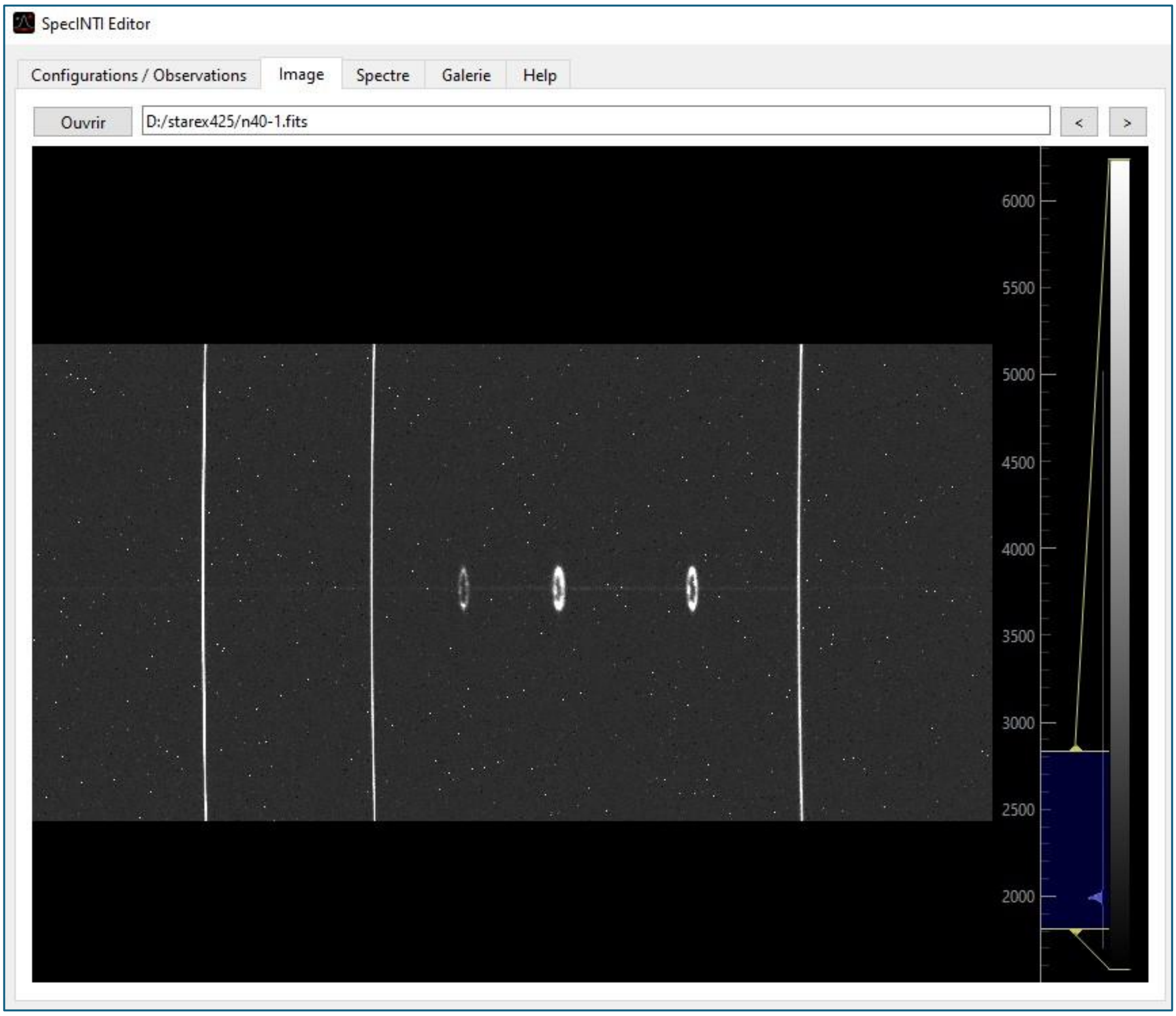
ypos: -426

Be careful when using the **ypos** parameter. It should only be used in exceptional cases. As soon as you no longer need it, let specINTI find the spectrum trace itself. So remember to remove this parameter from the configuration file once it's no longer needed (or add it as a comment).

4. Reminders on processing large-surface objects

If you have to process the spectrum of an object with a large surface area, a few precautions need to be taken.

Here's a typical raw image of such an object, the planetary nebula NGC 40 observed at high resolution (Star'Ex HR, on an Askar 107PHQ refractor, exposure time 900 seconds, side illumination by an input fiber):



The oval shape of the lines (hydrogen + nitrogen) is due to the radial expansion velocity of the gas in the nebula (Doppler-Fizeau effect).

The accuracy of the automatic evaluation of the vertical coordinate (Y) of the spectrum trace is very uncertain here. Force this position by adding the **ypos** parameter to the configuration file. For example:

ypos : 367

By the same token, specINTI is unable to find the value of the tilt of the spectrum trace in such a situation on its own. You've probably processed the spectrum of a star previously, so the current value of this "tilt" is returned in this case to the output console and therefore known. You must then provide this value in degrees via the TILT parameter. For example, add the following line to the configuration file (wherever you like):

tilt: -0.06

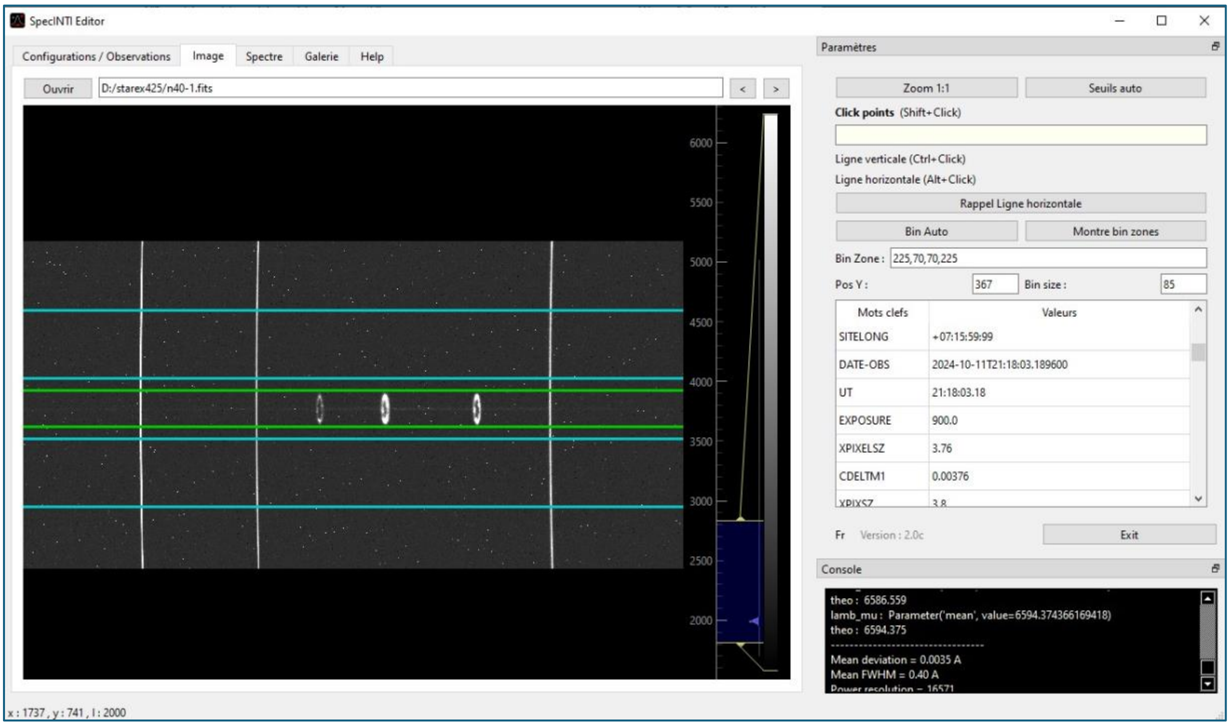
The height of the binning zone must also be taken into account. Typically, it should be as wide as the object's spectrum. For example, if the object is 85 pixels high,

bin_size: 85

The calculation zones of the sky background must be set aside accordingly, for example :

sky: [225, 70, 70, 225]

This gives (note that specINTI Editor V2 allows the drawing of binnning and sky background calculation zones, which made it easier to find the right values):



In relation to the processing of a star's spectrum, remove the optimal mode of spectrum extraction, making :

extract_mode : 0

The rest of the process is similar to star processing, but given the changes made to the configuration file, it's advisable to create a new, recognizably named configuration file, so that you can reuse it without confusing it with the standard star processing file.

One last point: it can happen that the object whose spectrum you are analyzing does not have a valid name in SIMBAD, which can pose a problem, especially if you want to retrieve its equatorial coordinates to calculate atmospheric transmission. This can happen, for example, with a comet.

In this case, you need to tell specINTI the name of an object close to the one observed, and whose name is recognized by SIMBAD (usually a star). Simply add to the :

near_star: arcturus

or

near_star : HD132336

These examples can of course be adapted to suit your needs. As always, remember to remove this line or comment it out if it is no longer required (when processing the next object).