

INTI

Processing guide: imaging in the helium line

1. Introduction

We know that the chromosphere is visible in the light of spectral lines emitted by it, such as the well-known red hydrogen line (H-alpha), or those of the ultraviolet calcium doublet. These emissions are particularly visible because they coincide with absorption lines in the photosphere. This conjunction produces high-contrast images of the chromosphere.

But there are many other chromospheric emissions, including that of the yellow helium line (He I) at 5875.65 Å wavelength. But since this emission does not correspond to an absorption line, it is extremely discrete. This leads to the use of special tools to reveal the image of the Sun in the color of this chemical element. The purpose of this data sheet is to show how you can use INTI to extract this information from your SER files obtained with Sol'Ex.

To do this, we'll use INTI's "Free line" tool. The operations to be performed are divided into three steps:

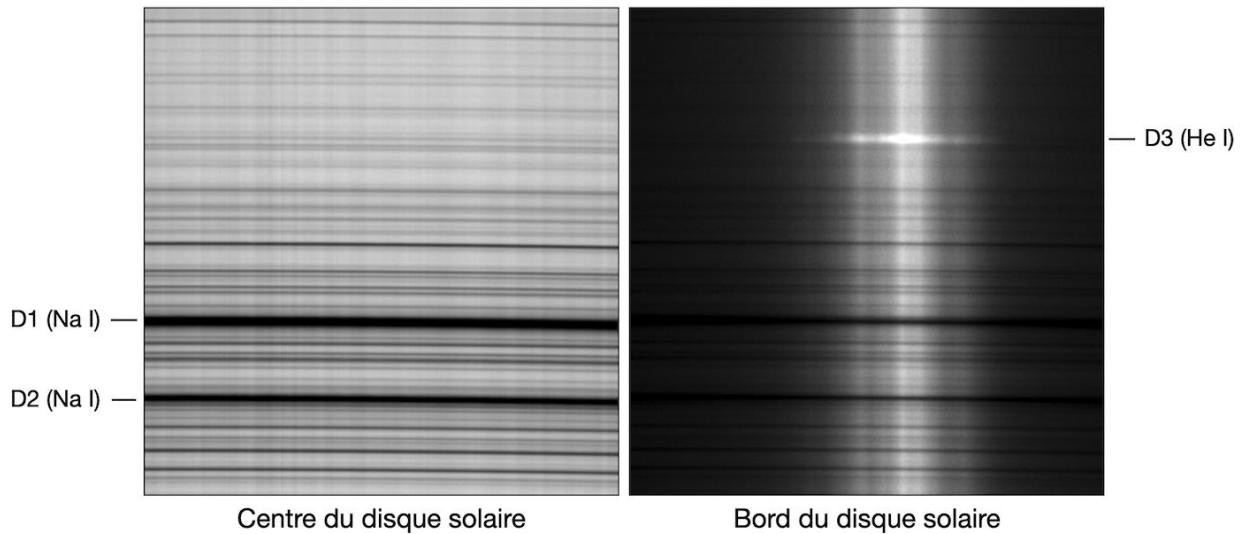
- Calculation of the polynomial that models the shape of the spectral lines from a separate SER file.
- Locate the assumed position of the He I line in another separate SER file.
- Calculation of the spectral image in helium light with subtraction of an average continuum image, from a final specific SER file.

This division may seem a little complicated at first glance. The assumption is that there is no well-marked absorption line close to the helium line that can be used to calculate a line deformation polynomial in a more direct way (the opposite situation is described in the processing guide dedicated to observing the solar corona).

To observe and generate an image of the solar disk in a shallow, low-contrast spectral line, INTI offers the "Free Line" tab. We will perform the necessary operations from this tab.

2. Data acquisition required for the computation of the D3 helium image

This is the theater of our operations, the spectrum around the sodium doublet:



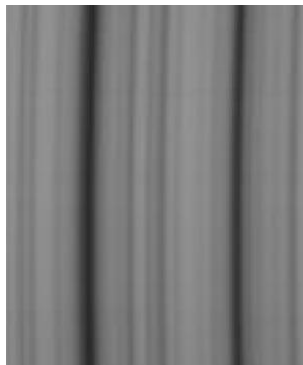
On the left, we have a small portion of the solar spectrum in the vicinity of sodium lines D1 and D2, visible at the bottom of the image in absorption. The spectrum is produced with the slit in the center of the disk image.

On the right, the Sun is almost out of the slit, its edge tangent to the slit. We then see an "inversion" spectrum, with the chromosphere seen in profile and the D3 helium line in emission. This is the way to spot this detail in the spectrum.

The grating must therefore be rotated to cover the wavelengths around the helium D3 line at 5875.65 Å, in the vicinity of the famous sodium doublet, lines D1 and D2, at 5889.97 Å and 5895.94 Å respectively.

Video 1 - Scanning the sun's disk on a near-dark spectral line.

Do not change the orientation of the grating but move the acquisition ROI - ROI = Region Of Interest (from SharpCap software, for example). It's not useful to know which spectral line you're dealing with, as it's only its shape that will be used to calculate the polynomial modelling the appearance of the lines, but the D1 line is ideal for this purpose:

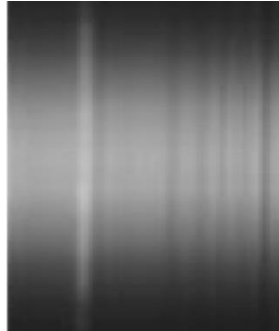


Video 2 - Acquire a static-mode SER video of the D3 yellow line.

Move the ROI to the region of the yellow D3 helium line (do not touch the Sol'Ex diffraction grating, i.e. its wheel).

To see the D3 line clearly, as we've just noted, you need to observe very close to the solar limb, where it reveals itself as a "bright" line by pushing the exposure time.

With the slit tangent to the slit, make a SER film of 20 to 100 frames (no more), without moving the frame (hence the term "static"): Move the ROI to the region of the yellow D3 helium line (do not touch the Sol'Ex diffraction grating, i.e. its wheel).

**Video 3 - Finally, make a video acquisition of the same ROI by moving the mount.**

Without modifying the ROI, we produce one SER video (or several in a row) in the classic way, by scanning the solar disk:



You must be careful not to saturate the solar continuum, especially in the center of the disk. Carefully lower your camera gain to do this, with a small safety margin.

Note: you may find it complicated to carry out 3 distinct types of acquisition to finally obtain an image of the Sun in the yellow He I line. First of all, it's a matter of getting the hang of it (a protocol, in short). But the deeper reason for this complication lies in the fact that there is no absorption line in the very close vicinity of the D3 line, which would enable us to correctly measure both the shape of the lines (polynomial) and obtain the actual image of the disk in helium. The closest line is D1. You might consider enlarging the ROI area to include both the D1 and D3 lines, but beware of the size of the SER files and your computer's possible limitations in terms of image reading speed. Please refer to the solar corona processing guide to see how to proceed with a single SER file from the "Free Line" tab in the right circumstances, in the presence of an absorption line in the same spectral field as an invisible line that is the focus of our attention.

3. Polynomial computation and localization of the helium line

3.1. Using video 1 of the intense dark line to calculate the polynomial

As an example, we'll use file 09_44_21.ser, the well-contrasted absorption line in video 1:

- Go to the "General" tab.
- Select SER file 09_44_21.ser from the list.
- Click on Ok.

INTI will detect the darkest spectral line and calculate the polynomial. It will also produce an image xxx_mean.fit, which is the average of all the frames in the video file.

The coefficients of this polynomial, found in the output terminal, mathematically describe the curved shape of the spectral lines generated by Sol'Ex :

Coef a*x², b*x, c :3.2024e-05 -0.040165 37.06

Note: from the "General" tab, when there are several lines in the image, INTI simply chooses the darkest of those it finds. In this case, the SER_09_47_40 video is centered on the sodium doublet, but it's the blackest line that's used for the calculation (the D1 line).

3.2. Use of static video 2 of the area near the limb

In our example, the file is named 09_47_40.ser :

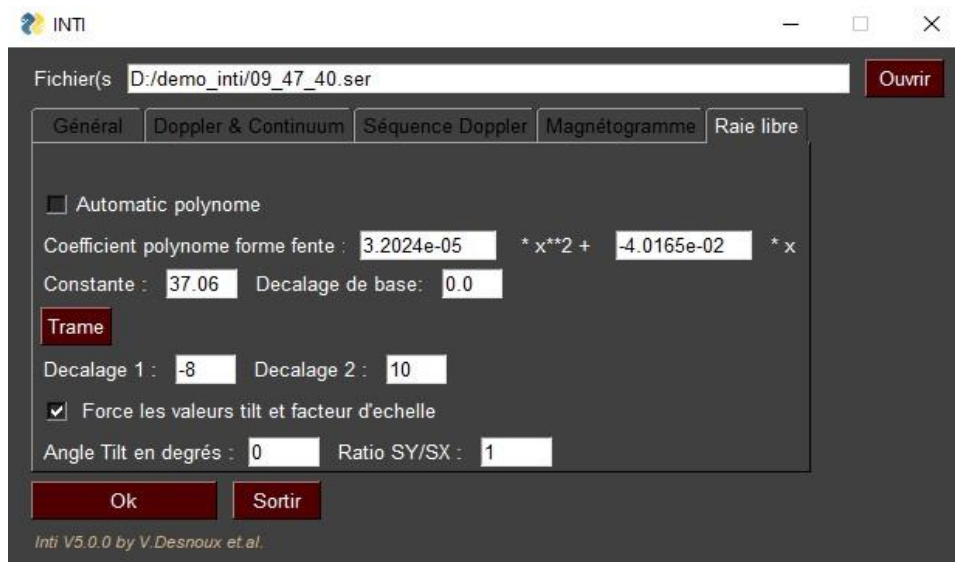
- Remain on the "General" tab
- Select file 09_47_40.ser
- Click on ok.

Even if the mount has not been moved to perform the classic solar disk scan, INTI will use this static SER film to calculate the average frame image, then attempt to reconstruct the images of a disk. This "average" image will be used to locate the position of the helium line, even if this line is not normally perceptible.

Note: after pressing Ok, the average image of the SER file obtained statically on the solar limb quickly appears, only to fade out and be replaced by images giving a distorted form of the content of the SER video thus analyzed. As the video is static, these images will be irrelevant, so disregard them. You can get rid of them by pressing the <Enter> key on the keyboard. The most important thing here is to create the file _09_47_40_mean.fits in the directory where your SER files are located, to which we'll return later.

4. Use of the polynomial in the "Free" tab

Open the "Free" tab and enter the previously calculated polynomial coefficients in the appropriate fields (these values are available in the console, but also in the log file 09_44_21_log.txt)



First of all, make sure that the "Automatic polynomial" option is unchecked. In fact, the "Free Ray" tab offers two possibilities:

Option 1: Unchecking this option forces INTI to use the polynomial coefficients calculated previously. In other words, you're forcing INTI to use a given line shape, and this is the right option.

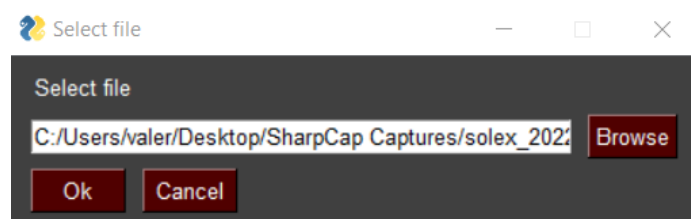
Option 2: By checking this option, INTI will update the coefficients on its own, using the current SER file processed. We don't want this here, because in the helium line region there are no intense absorption lines that would allow accurate calculation.

In the interface, the term "Constant" is associated with the polynomial constant "c" calculated earlier. For your information, the distortion polynomial was calculated using the horizontal coordinate at the very bottom of the image, at the extension of the line.

5. Choosing the polynomial constant

Click on the "Frame" button in the "Free" tab.

From the popup window that opens, find and select the image fits _09_47_40_mean extracted by INTI from the SER file associated with video 2 (static limb scan):



Click on Ok.



The "average frame" image is displayed. But please note that this is not a simple average of the frames that make up the static SER_09_47_40 video. INTI has also performed an operation to correct the distortion of the lines, making them perfectly vertical. INTI uses the coefficients of the polynomial we've just provided. In other words, this is how the spectrum would look if the Sol'Ex instrument didn't produce geometric distortions (by its very principle, every optical system is a victim of optical aberrations, and this distortion is one of them).

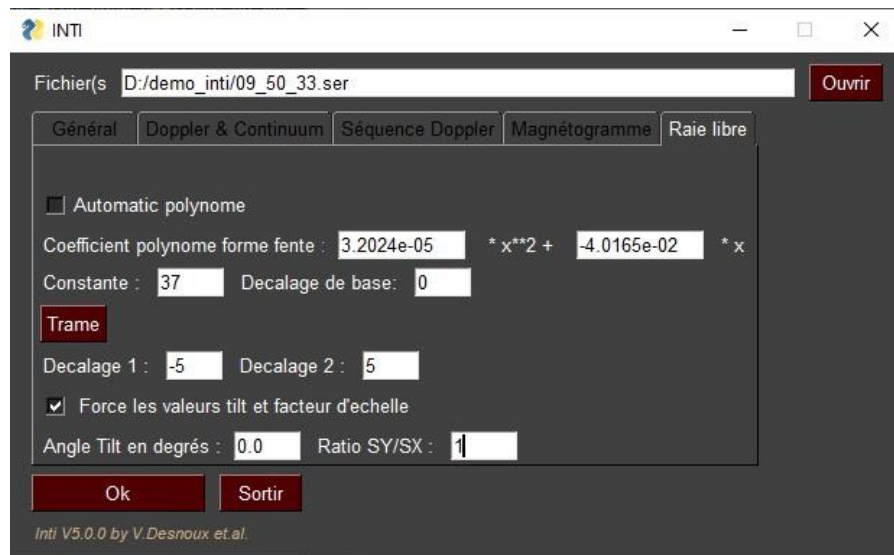
Place the mouse on the image at the position of the bright line (the helium emission line), then left-click with the mouse.

The x and y position of the click is displayed at the top of the image, along with the intensity of the image at that point.

Close the window containing the rectified line image by clicking on the cross at top right, or by pressing the "Esc" key.

The constant value is automatically modified in the "Free line" tab. The x-coordinate of the line (horizontal, relative to the left edge of the image) is transferred.

In this case, the value is 37 (always a whole number at this stage):



It is this new constant value that tells INTI where the helium line is located in your SER files (assuming that the recording instrument is mechanically stable so that this position does not change over time), even though it is normally invisible.

Note: the rectified line image is available in your working directory under the name xxxx_check.fits.

6. Construction of the disk image in the helium line

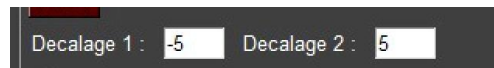
From the "Free line" tab, select video file 3, an unsaturated SER film centered on the helium zone: 09_50_33.ser

The helium line, with its very low contrast, will produce a very pale image of the Sun if we simply construct it from its intensity alone.

The idea is to subtract from the intensity of this line, the intensity measured in the immediate neighboring continuum, on either side of the D3 line. This subtraction, known as a "differential" measurement, is the great advantage of the "Free Line" tab. It brings out very subtle details in your observations.

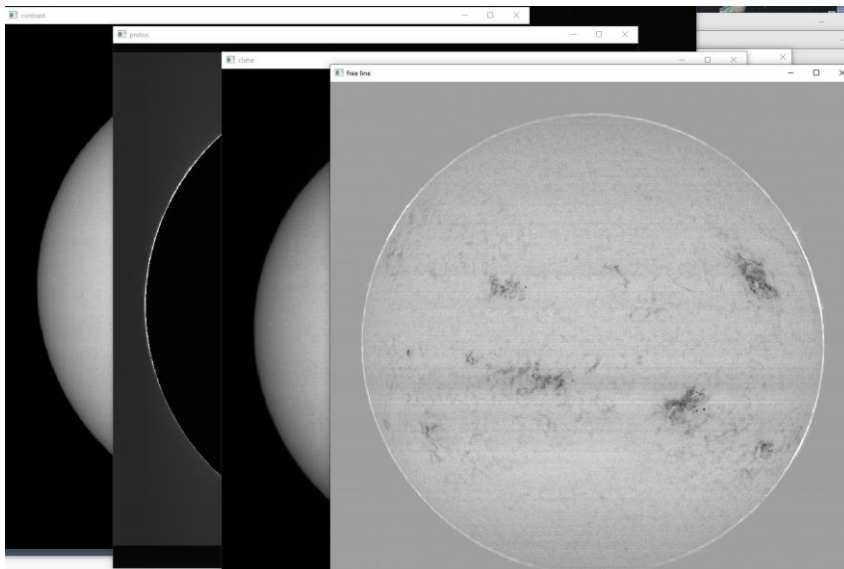
We choose to measure the intensity of the spectral continuum 5 pixels to the left of the assumed position of the helium line and 5 pixels to the right. INTI will calculate for you the average of the two intensity values found at these locations and subtract it from the intensity measured in the D3 line. These relative positions are called "Offsets" in the INTI interface. The sign is important. Since we're measuring the continuum to the left of the nominal line, we need to indicate a negative value for this coordinate. A negative value corresponds to the blue side of the observed line, while a positive value corresponds to the red side.

This is how we write:



Once you've clicked on Ok, and the calculation is complete, a series of images appears on the screen for a few seconds.

(You can clear them by pressing the "Enter" key on the keyboard)



The most interesting image here is the one named `_09_05_33_free.fits`: it's the appearance of the Sun in the pure helium line after removing the spurious continuum signal.

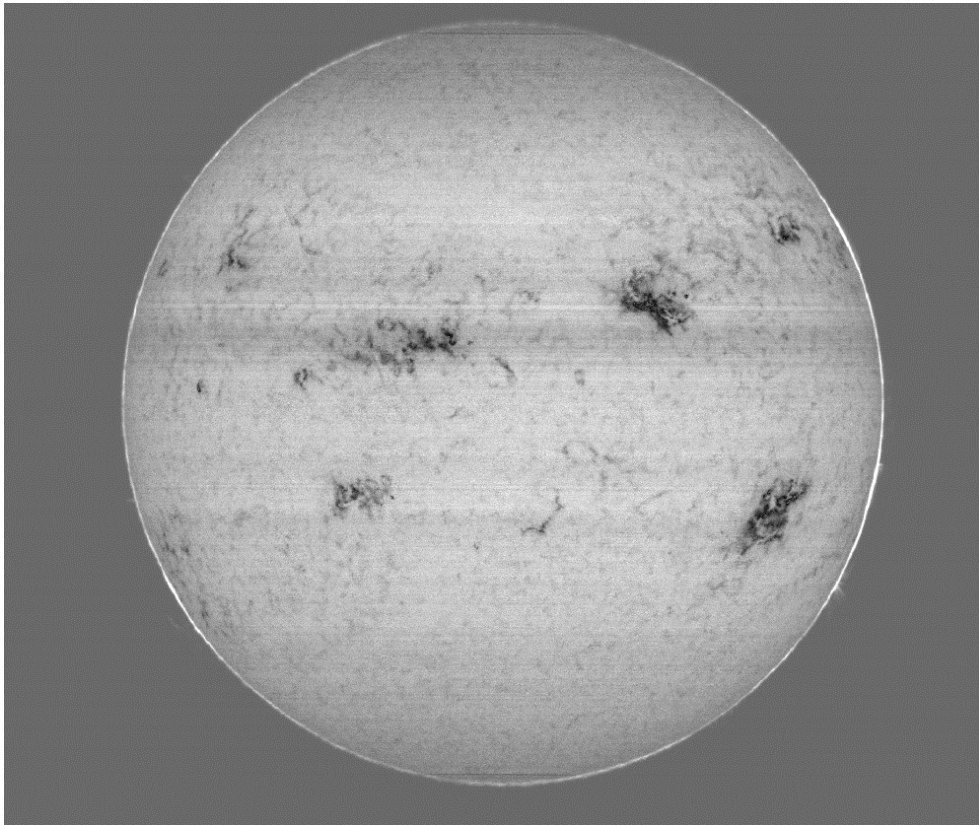


Image Christian Buil – Sol'Ex sur lunette TS de 80mm de focale 480mm

A few more details...

You may be wondering why we chose the coordinates $(-5, 5)$ for the continuum. It's arbitrary... but absolutely! The idea is not to designate an area of the continuum too close to the helium line, so that the measurement is not polluted by the light from the line itself.

On the other hand, it's not a good idea to go too far from the line of interest to find the continuum (i.e. 20 pixels to the left or right), as you run the risk of using a continuum signal that is not representative of the immediate vicinity of the helium line.

Care must be taken when choosing the offset values to avoid accidentally falling into a spectral line, which will interfere with the final image. Examine the "mean" image for this.

There's another precaution to take. Test the $(-1, +1)$ values with our example: you'll get a totally washed-out helium image. In effect, you're almost subtracting helium from itself. This is because the helium line is physically wider than a single pixel.

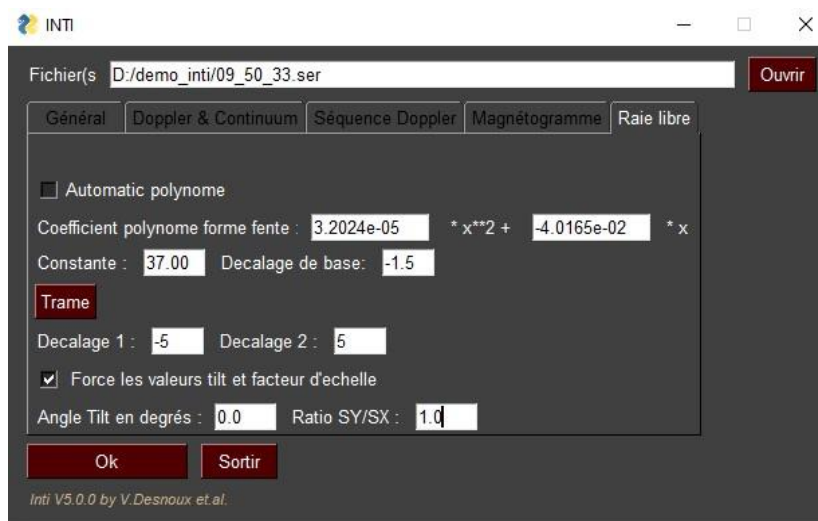
This observation on the significant width of the helium line leads us to reflect: it's a pity to be content with a single column of pixels in the spectrum to capture the light of this chemical element. By simultaneously exploiting several lines, we can reduce the noise in the image through averaging. INTI makes this possible.

Here's how it works: (1) go to the "General" tab, (2) pull down the "Advanced" tab, (3) tick the "Noise reduction" option, (4) open the "Free line" tab (important: don't stay in the "General" tab), (5) click "Ok".

At the end of processing, you'll have a less noisy helium image. In detail, INTI averages the intensity at the line position and the half-intensity measured at +/-1 pixel from this position. INTI does the same for continuum measurements.

Another important feature of the "Free Line" tool is that you can modify the value of the distortion polynomial constant by hand. In doing so, you change the analysis wavelength. Remember, we graphically found $x = 37.0$ for the position of the helium line. Change the value of the constant, e.g. 38.5 instead of 37.0, then "Ok". The resulting image is different. In fact, by moving 1.5 pixels (in this case towards red), we leave the helium line, so that the spectral signature of this element fades in the final image. It's perfectly possible to move into the blue wing of the helium line, for example by -1.5 pixels, by adopting the constant $c = 37.0 - 1.5 = 35.5$.

Another alternative for shifting the analysis wavelength is to leave the constant value (37.0) unchanged, but to adjust the "Base shift" parameter. For example, to return to the previous example, do:



Note that the constant or offset can be set to a fraction of a pixel. This means you can fine-tune these values, for example, to iteratively adjust the best contrast for a detail of the Sun. This makes the "Free line" tab a very powerful tool.

Note: at the end of each process, INTI returns the average intensity at the center of the processed image. This is the "Average Intensity" value that you find as output in the console. This information is useful for certain jobs, such as making sure you're at the heart of an absorption line when necessary.

Finally, note that at the very bottom of the "Free line" tab, you can adjust the "Tilt" and Y/X scale ratio, values returned by processing video 1 from the "General" tab, and that you can choose or not to apply these corrections. In our example, to do a precise job, you need to do:

