LISA Pack

High Luminosity Spectrograph

User Guide

& Reference Manual

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Part I

LISA Pack User Guide

Introduction

This manual will help you starting with your LISA Pack spectrograph. Our intention is to guide you step by step from box opening to high quality spectra processing. LISA Pack is ready to use: most of critical tunings have been made in our factory. We did our best to make this instrument simple to use. Spectrography is a scientific activity which requires methodology: we will describe the key steps to ensure the best efficiency for your observations.

There are three major steps to go through:

1. Setup your instrument (including software). This must be done during daylight, on a table. During this step, you'll make your first spectra (of Sunlight).
2. Install your spectrograph on your telescope. It is better to perform this during daylight.
3. Taking and data reduction your first star spectra.

Our experience shows that new comers to spectroscopy often want to go straight to the telescope. This is a mistake. There are too many parameters to put under control, and most of them should be tuned during daylight.

LISA Pack is tuned when you receive it, but you can have to make changes for any reason. You will find all information for that at the end of the document.

> This document is specially written for LISA Pack users. It can be extended to all LISA users: the difference is that acquisition and guiding cameras are not setup in Shelyak Instruments factory, and can differ from Atik cameras. When there is a specificity for LISA users, it will be written in such boxed text.

Software

Software are provided on the CD Rom. We invite you to check regularly for updates - spectrography is moving fast.

You can of course use your own software environment: a raw spectrum is a classical 2D image, and many software can deal with it. But using the software tools we propose garantees that you will get high quality spectra.

Prerequisites

In this document, we assume that you're new to spectrography, but that you're already familiar with basics of astrophotography. Specially, we'll not cover here the following points:

- Setup and tune your telescope. You must be able to point and track a star. Ideally, autoguiding will work.
- Basics for a PC usage under MS Windows. You can install, start and use most common software. You have such a PC available, with Windows 7 installed (it also works with older versions of MS Windows - but we use MS Windows 7 in this document).
- Astronomy imaging. You know what is a dark, an offset, a flat field, and classical image processing.

> If you've already made some deep sky images, with long exposure, and a good processing, moving to spectrography will be easy for you - a new adventure, which gives access to a new dimension of Astronomy.

We invite you to join the increasing Shelyak Instruments users and amateur spectroscopist community on Spectro-L yahoo group [1] and Aras forum[2] to share your own experience and ask questions to the community. We are really interested to see your results there.

Do not hesitate to contact us if you have any comment.

Enjoy Spectroscopy !

Olivier Thizy[3] *François Cochard*[4]

1. http://groups.yahoo.com/group/spectro-l/
2. http://www.spectro-aras.com/forum/
3. *olivier.thizy@shelyak.com*
4. *francois.cochard@shelyak.com*

1 Discover your LISA Pack

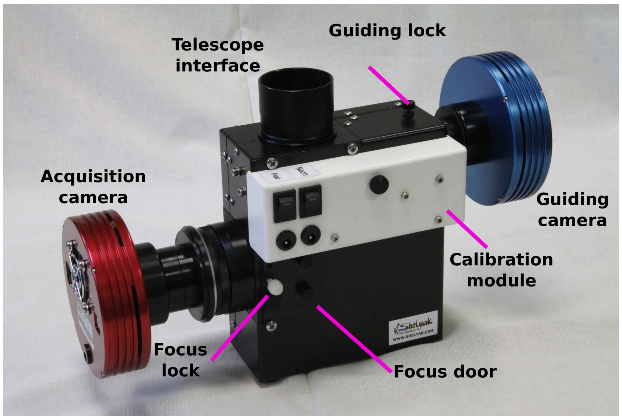
1.1 Out of the box

When you receive your LISA Pack, you should find these elements:

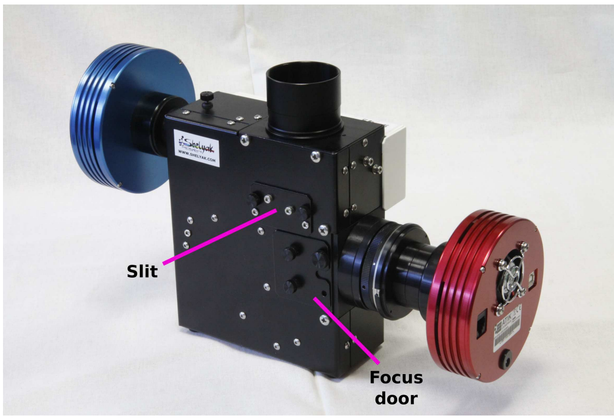
1. The LISA spectrograph, with two cameras and calibration module,
2. Travelling case,
3. Power supply (230V to 12V, 7A),
4. Power supply cable (230V),
5. 4-way cable for camera and calibration module power,
6. Two USB cables,
7. A tool set, if you need to tune the instrument,
8. Documentation & software on a CD-ROM.,
9. *Optional: Near-IR kit and Large slit.*

1.2 LISA Pack overview

LISA is a high luniosity slit-based spectrograph (F/5), designed to observe faint or extended targets. It is mounted directly at prime focus of the telescope and includes a guiding feature. In one exposure, it covers the full visible domain (400 to 700 nm).



LISA Pack, Calibration side

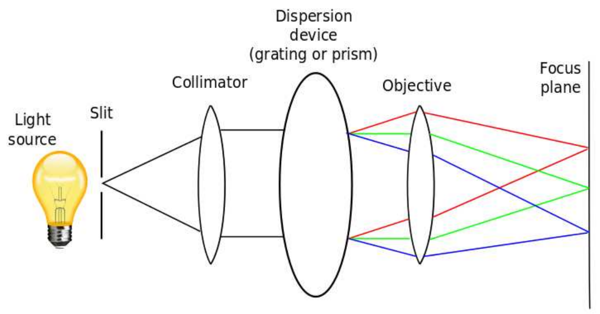


LISA Pack, Slit side

LISA spectrograph and LISA Pack only differ by the presence of cameras (Atik 314L+ and Atik Titan) and calibration module. The spectrograph by itself is exactly the same in both cases.

1.2.1 Spectrograph principle

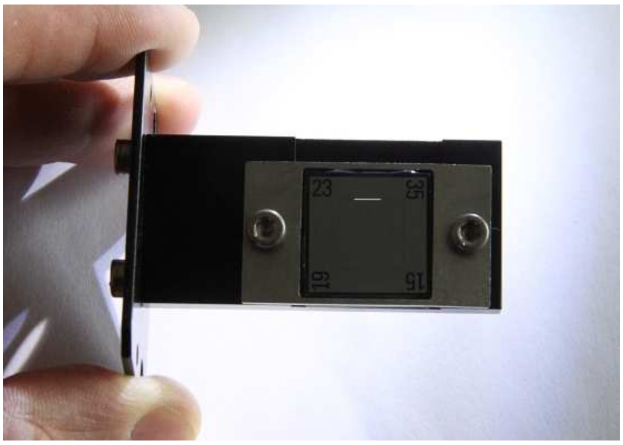
Most of the spectrographs are based on the same principle: a light source (slit, see below) is collimated by a collimator lens, then spread out by an optical element (prism or grating), and refocused with an objective lens on a sensor (Camera CCD chip for instance) to form the spectrum:



Of course, the smaller the source is, the finest will be the spectrum: to get enough resolution, we must have a source small enough. In astronomy, source is - usually - a star. Luckily, this is close to a ponctual object. Ponctual ? not really indeed. Even if the actual source is very small, its image is enlarged by the atmosphere and the telescope. The bigger the telescope, the bigger will be the star image (in fact, image size depends on two parameters: the telescope focal length and the seeing of the sky).

To control the source size, there is a slit at the entrance of the spectrograph. This slit gives the object size for the spectrograph. Then, the spectrograph disperses the light source - going through the slit - in a spectrum. **The resolution of the spectra is given by the slit width and internal optics**. You simply have to adapt and tune the telescope in order to get the maximum light in the slit.

In the pictures below, you can see the slit holder and the slit in front of a clear light:



Spectroscopy is used in many applications. But spectroscopy applied to astronomy have some specificities:

1. The light source is usually faint: you must have an efficient optical system to take opportunity of each photon.
2. To get light from the source, you must use a telescope, which is moving at earth's speed.

The LISA Pack, mounted on the telescope, is compact and rigid, to make a stable spectrum over the time. It also offers a guiding system in your LISA: a guiding camera looks at telescope field of view, with "missing slit", to help you guiding - or even auto guiding - your telescope.

> The slit width impacts spectra resolution. This is an intrinsic parameter of the spectrograph. In fact, the spectrum you obtain is the image of the slit spread out depending on the wavelength (the color). If you change the slit width, you change the resolution of your spectrum.
> But if you unfocus the telescope, you don't alter the resolution - you only lose light. This is the same for the telescope tracking: if you cannot track properly, you lose light, but you don't alter resolution.

Dispersion and resolution

The dispersion is the wavelength band coverer by one pixel. It is given in Å / pixel. It depends on the pixel size and spectrograph optics. The resolution is the ability to see details in the spectrograph. It depends on slit width, optics and CCD. It is given in Å.When spectrograph design is optimal, the smallest detail covers 2+ pixels. Note that resolution depends on wavelength.

Resolution power is defined as $R = \lambda/\Delta\lambda$, where$\Delta\lambda$ is the smallest visible detail, and λ is the reference wavelength. R is a number without unit, and is almost constant for any wavelength. LISA Pack Resolution Power is about R=1000.

1.2.2 Basic Elements of LISA

The LISA is made of two main parts:

- top, there is the guiding unit (which includes parts dedicated to calibration, see blue section below).
- bottom, there is the spectrograph itself (green section).

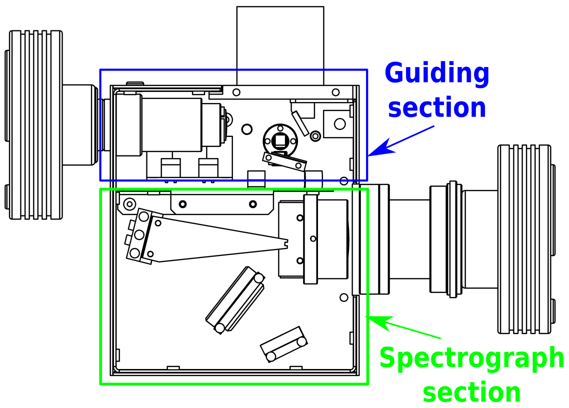


Fig.1.1 shows the details.

Fig.1.2 describes in detail the light path for both spectrograph and guiding section. For spectrograph section, star light is focused by the telescope (1), goes through the slit (2), is reflected by the mirror (3 & 4), is transformed in a parallel beam (5) by the collimator. Then, it is diffracted (6) by the grating, goes through the objective lens, and converges (7) towards the CCD sensor (8). For guiding section, all light coming from telescope (1) which does not pass through the slit (2) is reflected towards the guiding mirror (9), sent to the guiding optics (10), and refocused (11) at the guiding camera sensor (12).

The focal length of the collimator is 130mm. The focal length of the camera lens is 88mm. This means that the slit image will be multiplied by 88/130=0.68 on the CCD. The focal length for both guiding doublets are the same (75mm). Then, the ratio between object in telescope focus plane and image in guiding camera is 1:1.

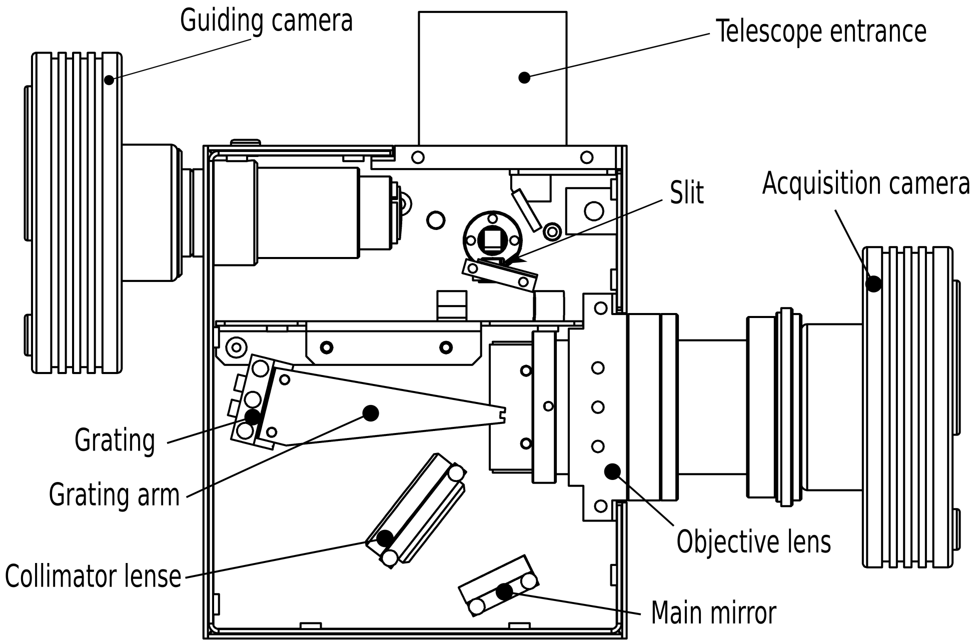


Figure 1.1: Inside LISA

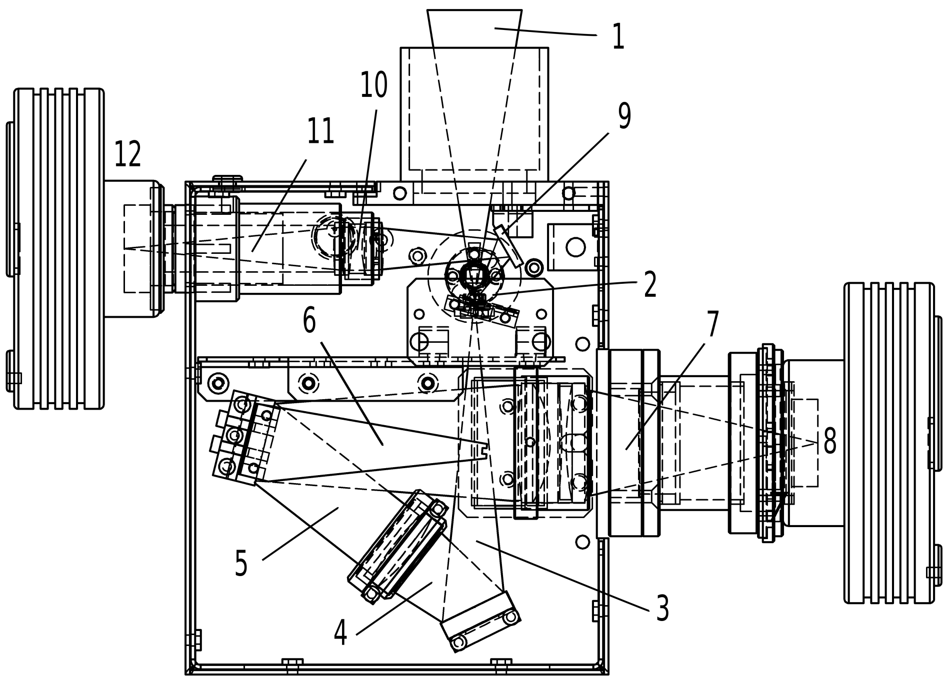


Figure 1.2: Optical schematic

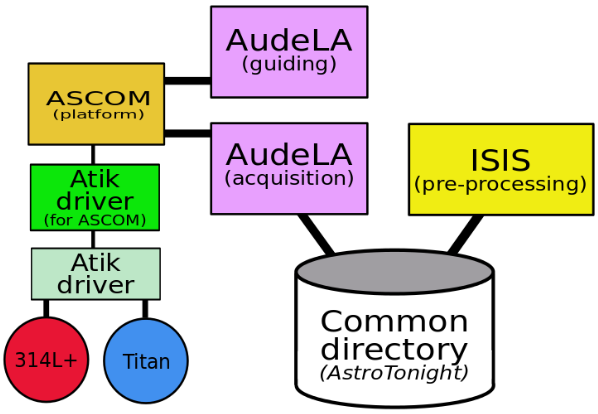
2
Install software

You'll find all required software on the CD Rom. This documentation will guide you to use your instrument, but won't replace the official software's documentation. You should refer to these documentations to discover their full capacity.

Software installation can differ on your own PC, depending on the Windows version, and on drivers already installed on your machine. This demonstration is made from a Windows 7 Home Premium edition - 64 bits version.

2.1 Software presentation

You will use different free software with your LISA Pack. All of them are available on the CD, but check each software website for regular update. Here is a global description of software elements:



2.1.1 AudeLA for acquisition

AudeLA[1] is used for images acquisition.

If you don't use Atik cameras, you can prefer an other software than AudeLA for acquisition. The only strong requirement is that you can get FITS format images (files with .fit or .fits extension).

2.1.2 ASCOM platform & drivers

Atik cameras (Titan for guiding and 314L+ for acquisition) are provided with ASCOM driver. ASCOM [2] is a platform made to standardize the connexion between astronomy software and hardware devices (cameras, telescopes, and so on). You need to install ASCOM platform and drivers. Atik cameras in AudeLA will be seen as ASCOM cameras.

2.1.3 ISIS for data reduction

ISIS[3] is developed by Christian Buil[4] - a pioneer in astronomy imaging & spectroscopy (Christian also designed the optical architecture of your LISA). ISIS contains a full data reduction module, dedicated to LISA Pack spectra. The philosophy of this software is to enclose as much as possible complex operations, to make data reduction fast, easy and of high quality - this is the best way so far to get the best result.

2.1.4 VisualSpec for spectral data analysis

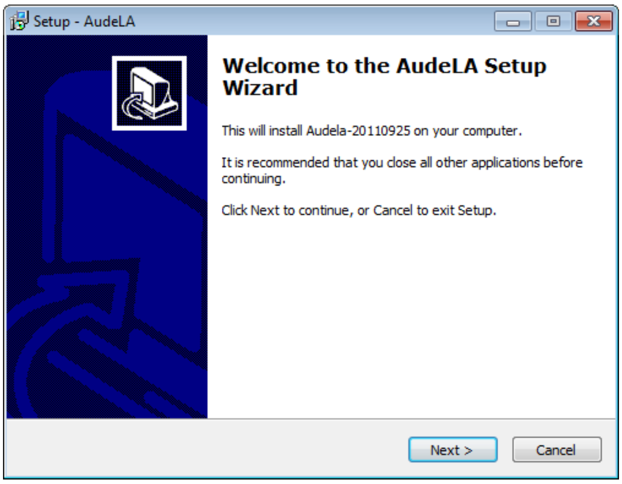
VisualSpec (or Vspec)[5] is developed by Valérie Desnoux. It is made to manipulate and analyze spectral profiles. It is not strictly required to get a spectrum from LISA and will not be detailed here. But it will help you to analyze data, such as line identification, spectra comparison, and so on. With the experience, you'll see it is a useful tool.

2.2 AudeLA installation

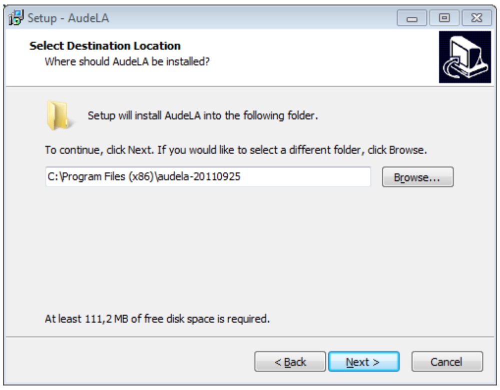
AudeLA software is available on CD: double-click on CD:/ Software - AudeLA / AudeLA-2.0.20110925.exe (or latest version). When you launch it (you may have

1. http://www.audela.org/
2. http://ascom-standards.org/
3. http://www.astrosurf.com/buil/isis/isis.htm
4. http://www.astrosurf.com/buil/
5. http://astrosurf.com/vdesnoux/

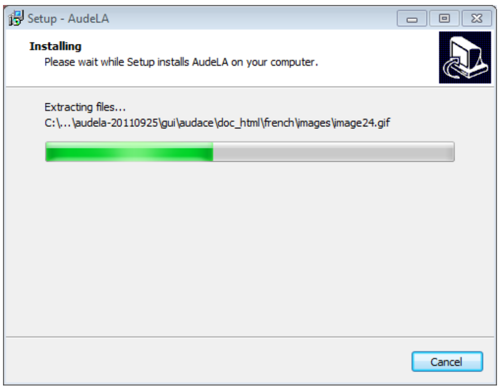
some warning messages - accept them), you will get the installation window:



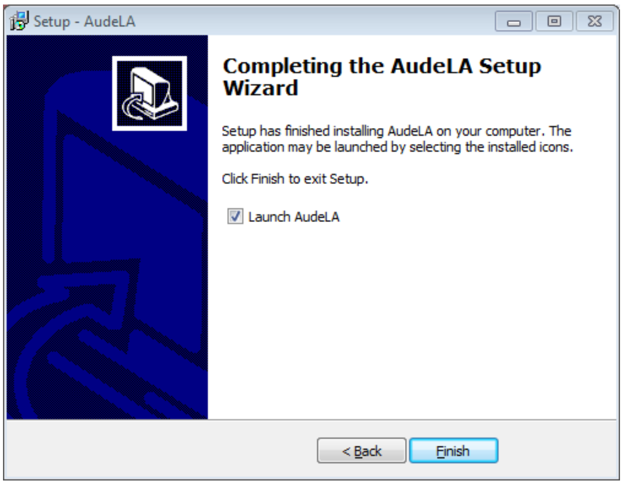
Click Next. You will have several steps to accept (agreement, information...), and choose your installation directory:



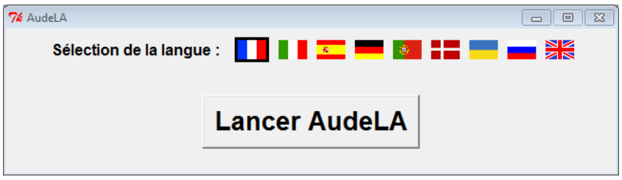
We recommend to accept the default proposal - click Next. Again, you will have several step to read & accept, up to the installation by itself:



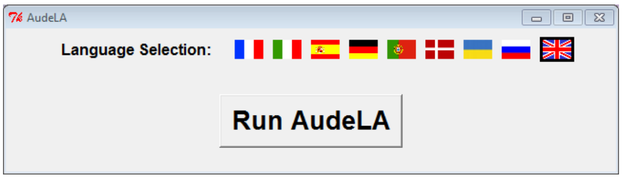
At the end, you'll have this last step:



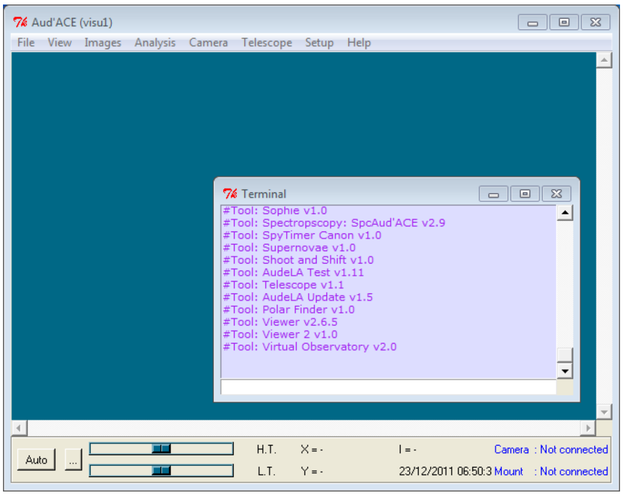
Click on Finish to lauch AudeLA. You will have the configuration screen in french:



You can switch it to english by clicking the british flag:

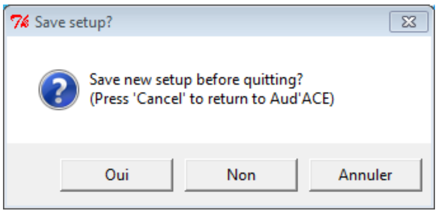


Click on Run AudeLA. You will have two windows: the big one is the main, in which you can display images. The small one is the console, in which you can type instructions.



You can move the console window out of the main window, to prevent the overlapping.

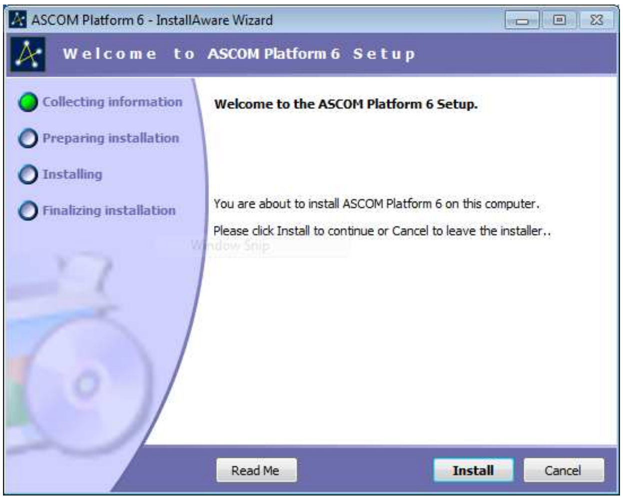
Let's stop here for the moment. You will setup the configuration during the first acquisition. You can exit AudeLA by closing any of both windows - you will have a message to save the configuration. Click yes, to keep the windows positions you just defined.



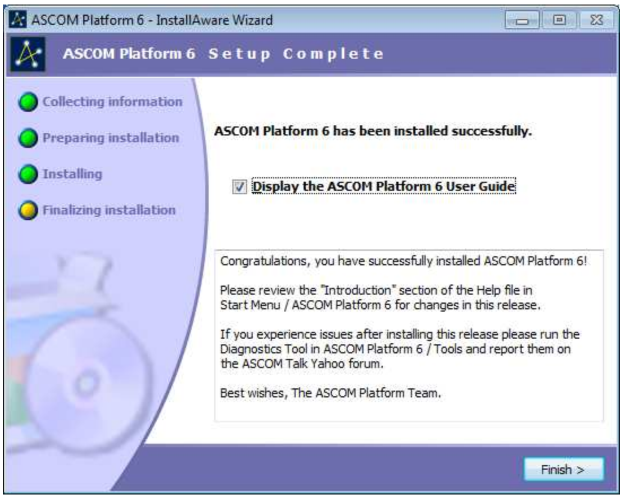
2.3 Camera installation

2.3.1 ASCOM Platform

Next step is to install ASCOM platform, rev 6 (or latest version). You will find it on the CD in the folder "Software - ASCOM". Launch ASCOMPlatform6.exe. After several questions (accept default options), you will have the installation window:



Click on Install button. At the end of the process (it takes some seconds), click on Finish button:

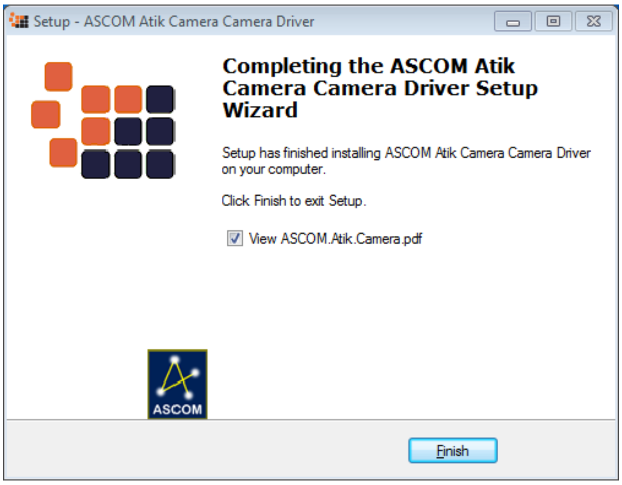


When the installation is finished, you have two new icons on your desk: ASCOM Diagnostics and Profile-Explorer.

2.3.2 Atik driver for ASCOM

After ASCOM platform installation, you must install Atik driver for ASCOM. Again, it is on the CD, in folder "Drivers / Atik". Click on "Atik Camer Setup (ASCOM).exe". You will get the installation window:

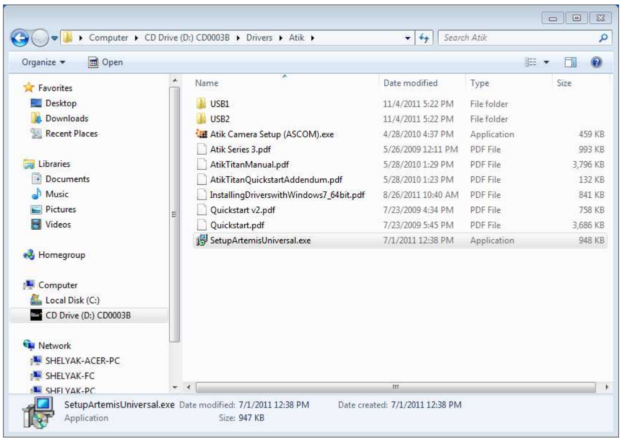
Click on Next >. In the next window, click on Install. The installation is ver short (few seconds), and you have the last installation window:



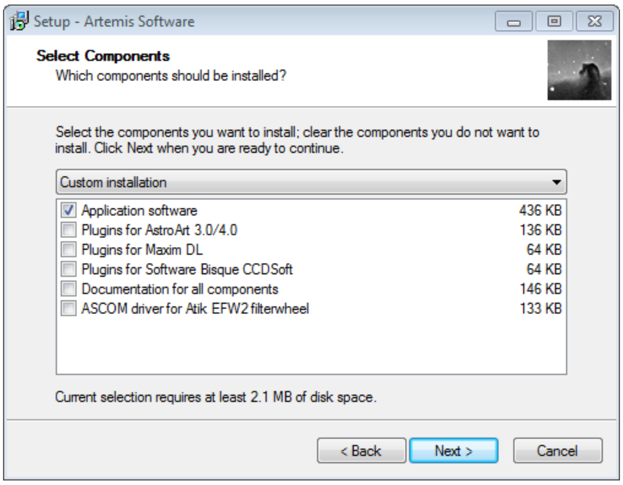
The driver is now installed.

2.3.3 Install Artemis software

This software will not be used in our application, but it contains a library (DLL) which is required for driver proper working. The software is on the CD, in directory /Drivers/Atik. The file to select is SetupArtemisUnivesal.exe:



Double-click on this file and let the installation going through all steps. When you have the choice for the modules to install, you can only select the application:

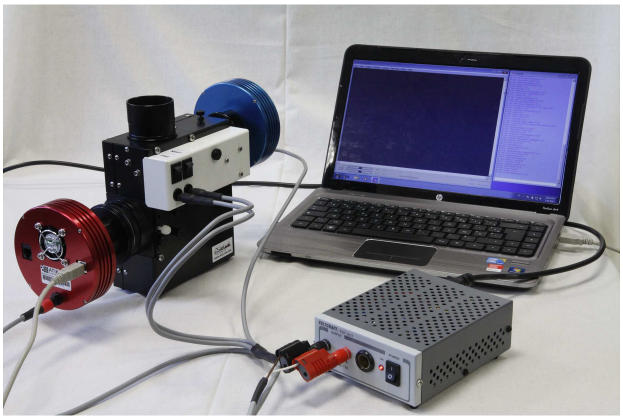


The installation finishes by a confirmation window:

Your PC is close to be ready to acquire images from Atik cameras (314L+ as well as Titan).

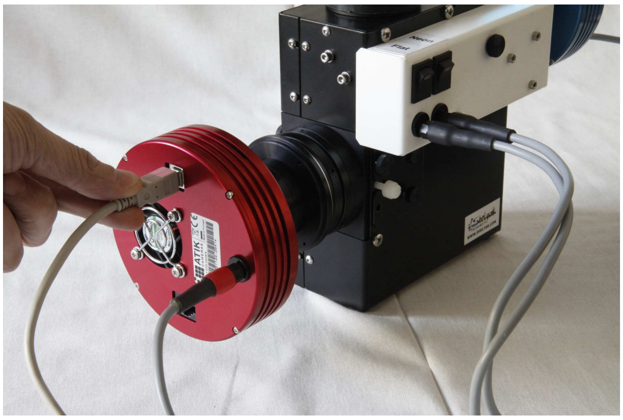
2.3.4 Cameras connection

You need to connect the Atik cameras to complete the software installation. Put the LISA Pack on a table, not too far from your computer. Install the power supply, and the Power supply cable. The red connector goes to the acquisition camera (red), and the blue connectors goes to the guiding camera (blue). The two remaining connectors are to be connected to the Calibration module. Switch on the Power Supply. The two camera fans should start running. Ensure that calibration lamps (flat & neon) are off (green lights switched-off).

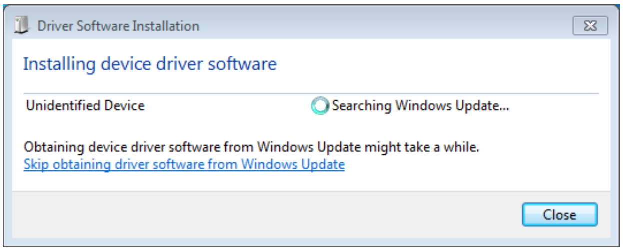


Start the PC, and wait until Windows is up and running.

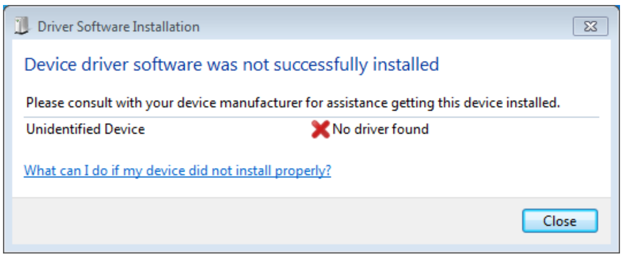
Connect the USB cable from acquisition camera (red) to the PC:



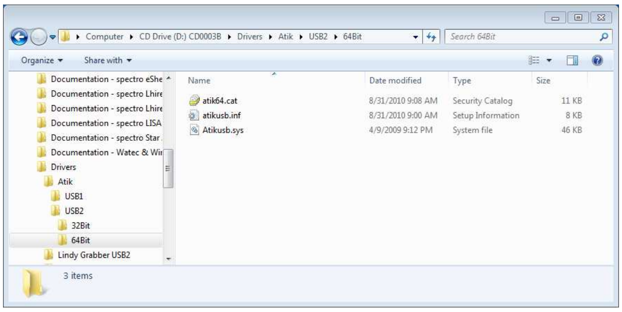
As soon as you connect the cable, Windows tries to install the Atik driver:



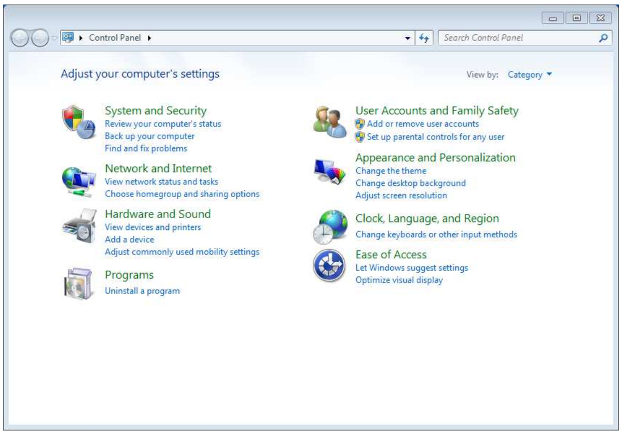
But it (probably) fails, because it cannot find it on the computer, neither on the web:



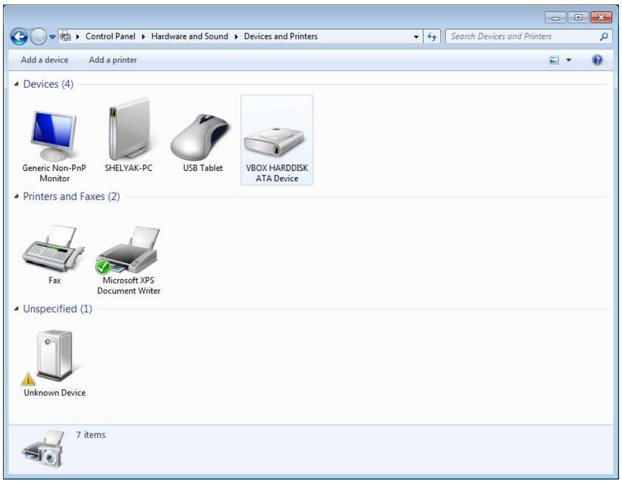
You have to indicate windows where to find the driver. It is on the CD, in the directory /Drivers /Atik /USB2 /64Bit (of course, if you're running a 32bits version, choose 32Bit instead of 64Bit). In this directory, there are several files:



Here is the process to install manually the drivers. Start the Windows Control Panel (click on Start button, then Control Panel). You get this screen:

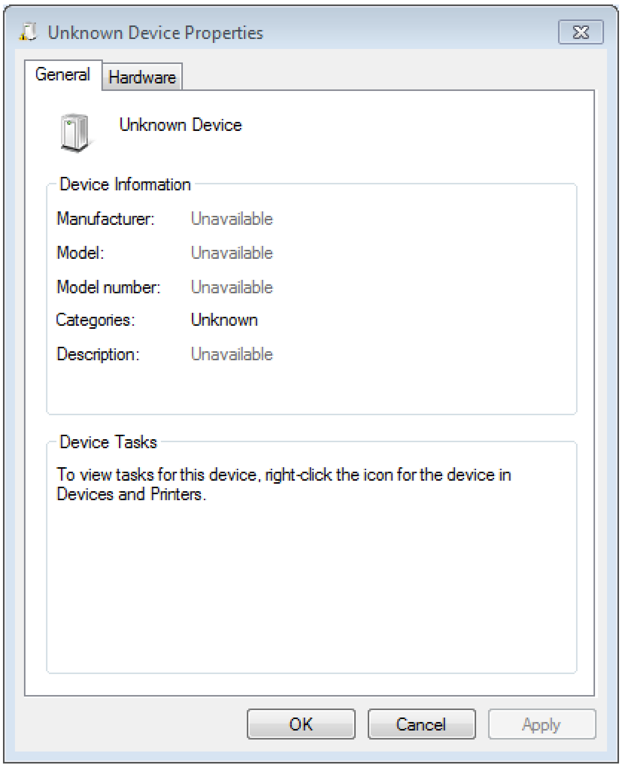


In the “Hardware and Sound” section, click on “View devices and printers”:

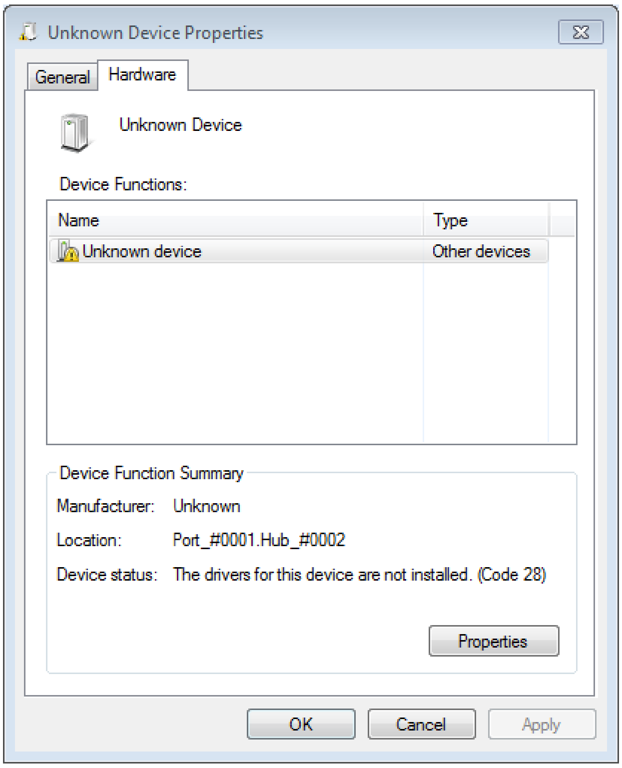


The Atik camera is the “Unknown Device” in the “Unspecified” section. The flag confirms that driver is not installed properly.

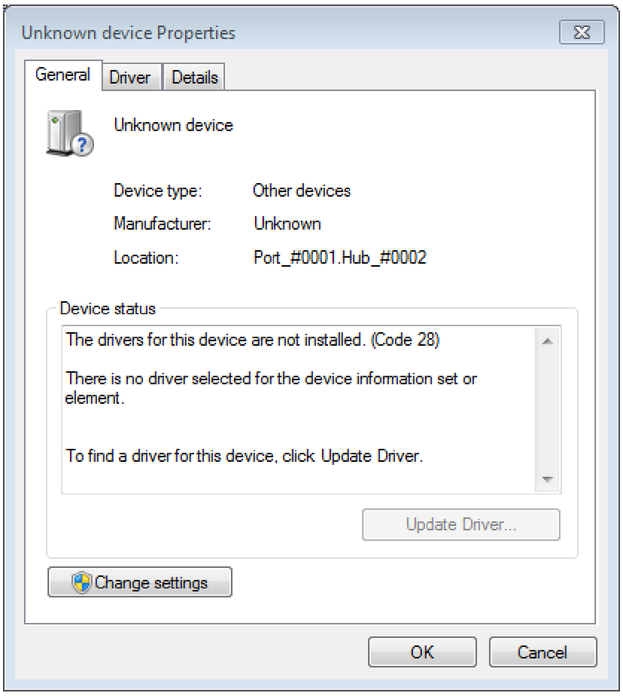
Right click on the “Unkown device” icon, and select Properties:



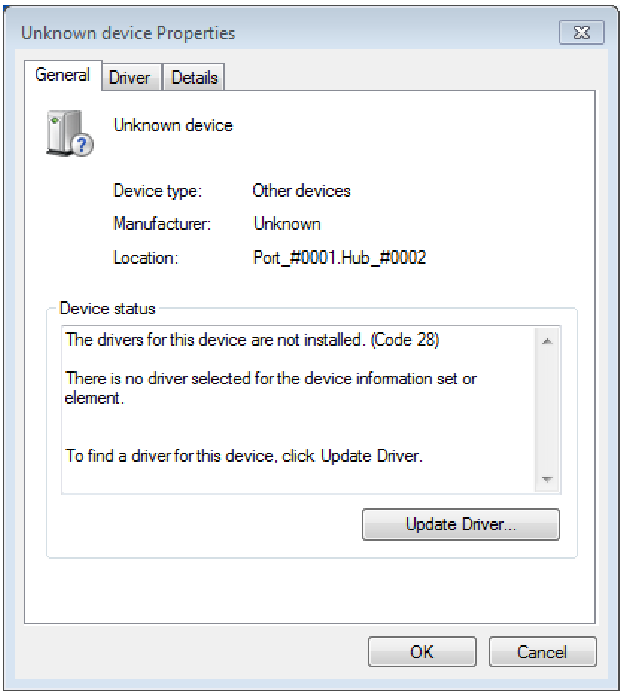
Then, click on tab Hardware (top of the window):



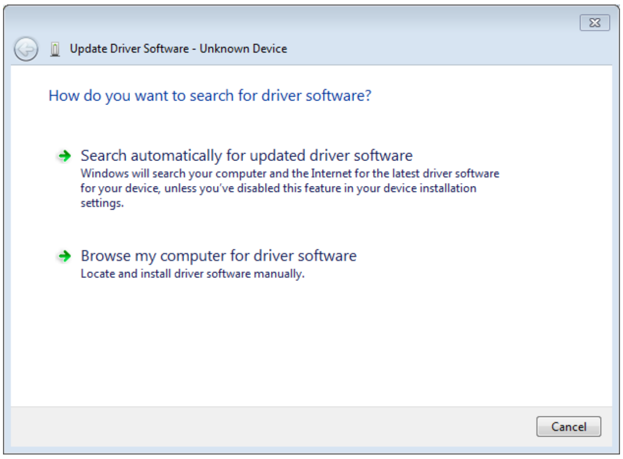
Then, click on Properties:



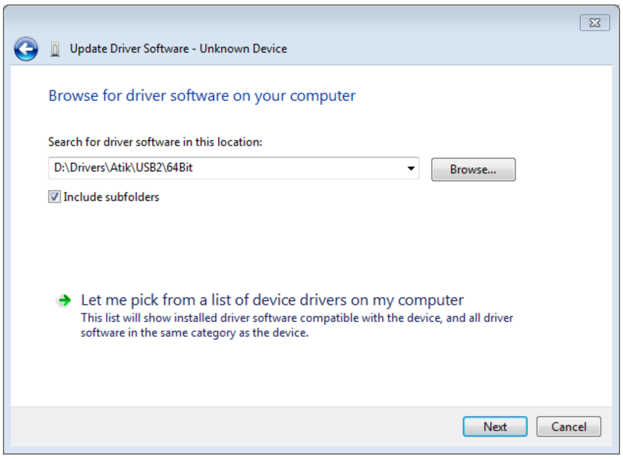
Then, click on the button "Change settings" (bottom part of the window). A new window pops-up:



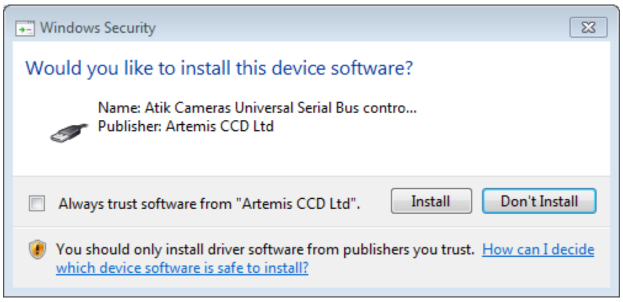
Click on the button "Update Driver":



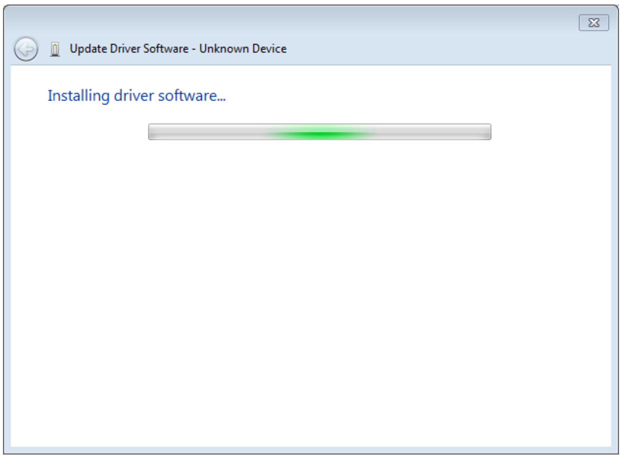
Choose the option “Browse my computer for driver software”. You will be asked for the location of the driver. Select the proper directory on the CD (there is no need to copy the files on your PC). Reminder: the directory is /Drivers /Atik /USB2 /64Bit.



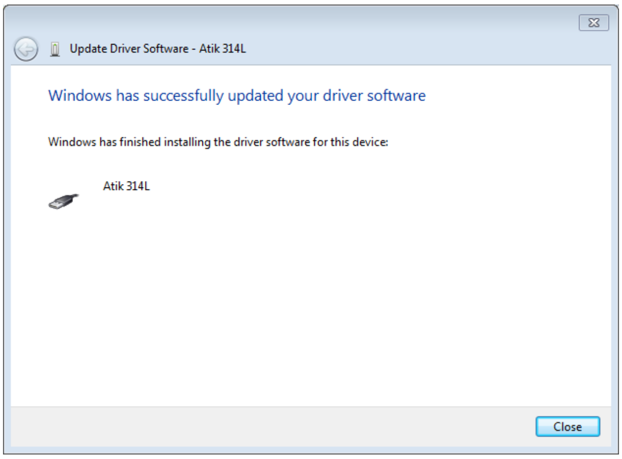
Then, click Next. It asks for the confirmation of the installation. Click Install:



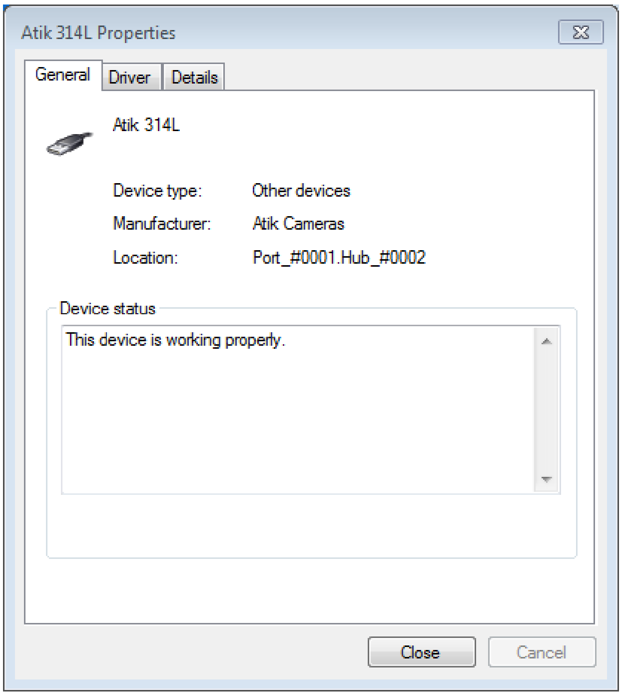
Installation takes some seconds



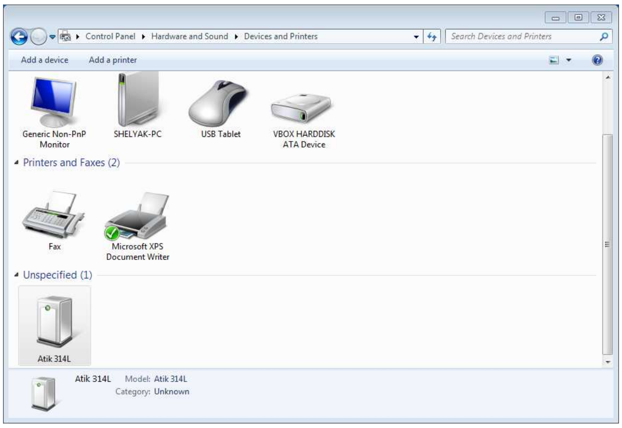
At the end, you have a message confirming the installation went well:



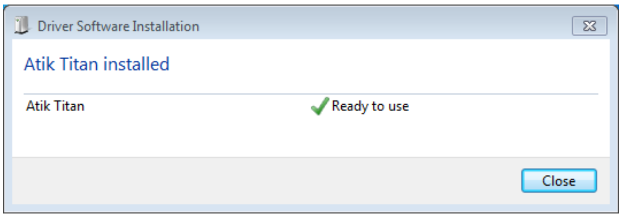
This is confirmed also by



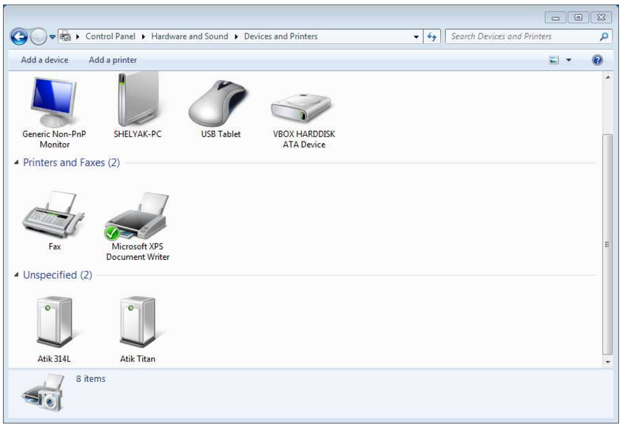
And the new status of the device in the control panel: the camera is now recognized:



You can now connect the second Atik camera (Titan, for guiding - the blue one). This time, the driver installation goes well, because driver is already installed:



and you can see in the control panel that there are now two cameras (314L and Titan):

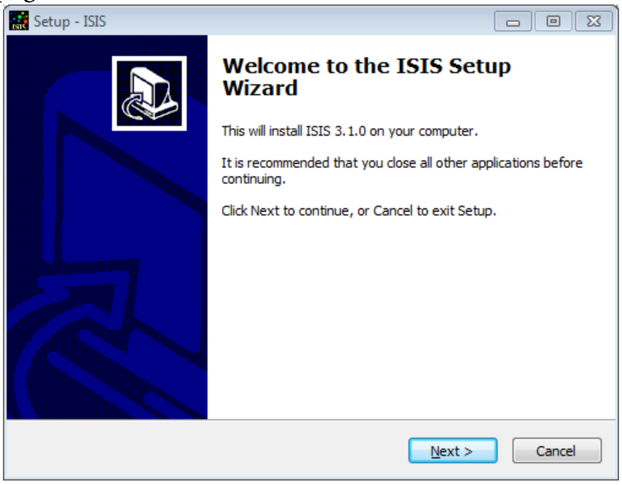


All the software and driver installation is now completed. You are now ready to take your first images.

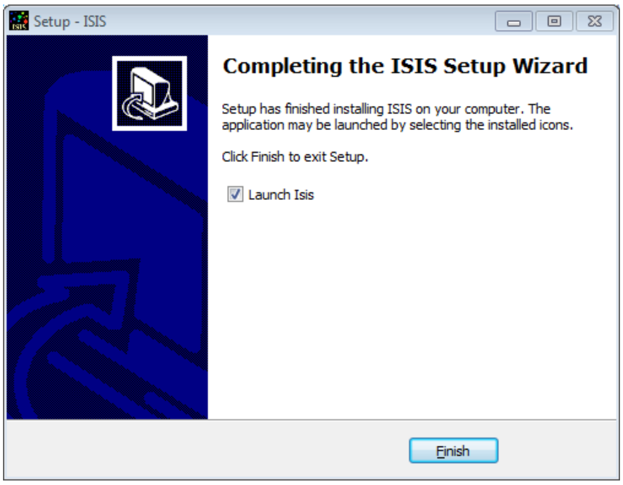
2.4 ISIS installation

ISIS software is on the CD, in folder "Software - ISIS". Launch ISIS4.0.0.Install.exe (or latest version). After a warning window, you'll have to choose the language - default is english:

Click OK. You will have the Welcome installation page:

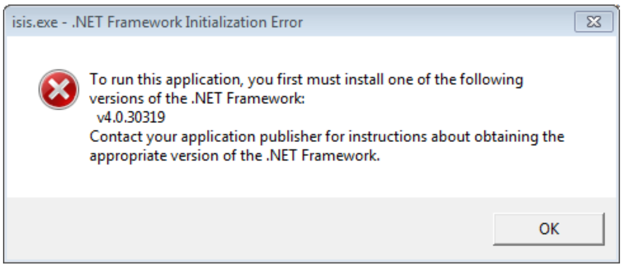


Click on Next >. Choose the installation folder (we suggest to keep the default value). Follow the next steps with proposed values. At the end of the process, you'll have the final installation window:



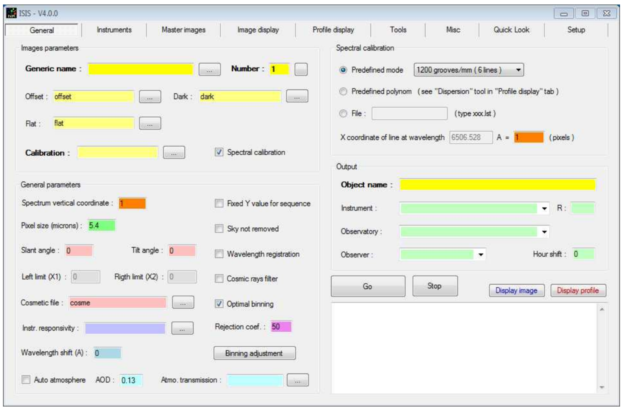
Click on Finish... it will launch ISIS.

Potentially, you can have a message requiring to install .NET Framework (it is installed on any recent PC):

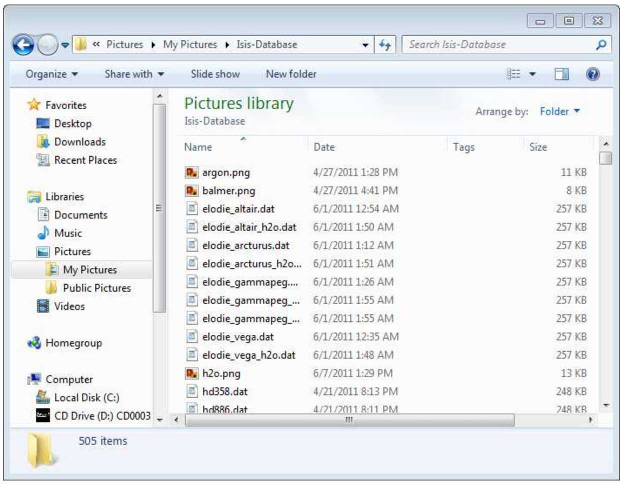


If this is the case, install this framwork from Internet: http://msdn.microsoft.com/fr-fr/netframework/aa569263, or type .NET framework in Google.

The ISIS window is the following:



ISIS contains its own spectra library, which is very useful to get some reference spectra. You must install it as well. The library is an independant file (to allow a spearate update, in case of). You can find the library ont the CD, or on ISIS website. This is a compressed (.zip) file. Extract the files in the directory you want - for instance, in "My Pictures / ISIS-Database" directory. The database itself is simply a list of spectra files:



ISIS is now ready for processing. We will see later how to use it.

3 Check your LISA

In this chapter, you'll setup and check all the instrument to prepare first spectrum acquisition in "comfortable conditions": during daylight, on a table. It is key to understand that most of the instrument tunings can be done during daylight - this is quite different from classical astronomy.

3.1 Create a working directory

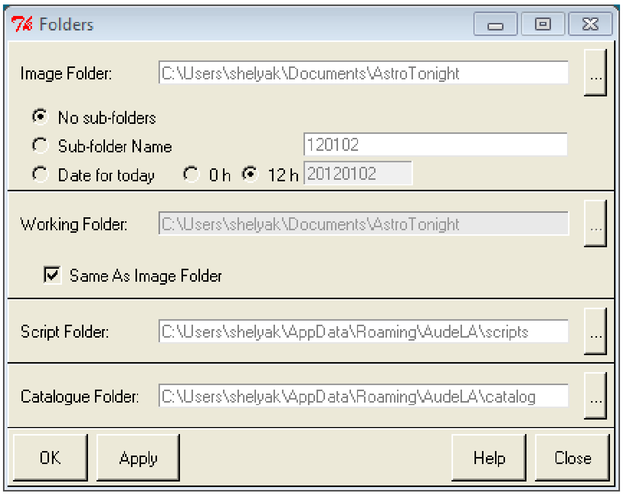
Since you will work with several software, it is simpler to make them all work in the same directory. Using a well identified directory for all your observations helps to classify and archive images and profiles. At the end of the night, you can copy all the content of this directory in your archive place - and clean up this directory to prepare next observation. For the following of this document, we assume that your common directory is called *AstroTonight*.

3.2 Setup AudeLA parameters

Here are some initial parameter setup you can do when you first run with AudeLA:

Setup / Langage: select here menu langage.

Setup / Folders: define working directory for your images. Select your *AstroTonight* directory:



Click on OK. From now, AudeLA will store images in this *AstroTonight* directory, and will load images from this file.

Change there also your default directory for your scripts and your catalogs - by default your user directory.

Setup / External programs: check there your favorite software are well set up.

Setup / Observer location: Indicate here your name and your observatory position which will be stored in FITS files. If your observatory is already known by the MPC (Minor Planet Center), you can just provide your observatory 3-digits code to get the location details.

Setup / Images files: Indicate if you want to store your image in 16bits or 32bits. Usually we leave it in 16bits knowing you can force 32bits during processing, for exemple when you add multiple images together (option "bit pix") File are in FITS format; you can select the file extension (usually ".fit" or ".fits"). It is also possible to have compressed FITS file, which reduce usually by half the file size on your hard drive. AudeLA can manage this option in almost all modules.

Setup / Appearance: select there default colors and make your Aud'ACE unique!

Setup / Fonts: change there your font size if you have trouble to read the default size on your screen.

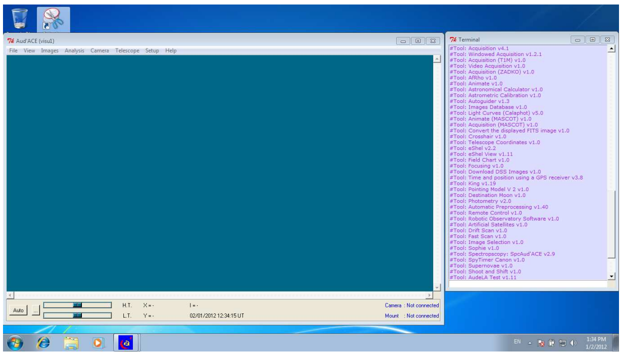
Setup / Optical: Indicate there the optical configuration of your scope (diameter, focal...). Those information will be sotred in your FITS file and can be used for automatic astrometry for exemple. You can define up to three optics: main scope, guiding scope and electronic finder for exemple.

Setup / Tool selection: AudeLA is powerful thanks to multiple modules. By default, they are all active but Aud'ACE menu can be too long then. Define there which module you want to be visible to you. You can also define a function key which will run the module when pressed. F2 is a special key as the associated module will be automatically opened when Aud'ACE is launched.

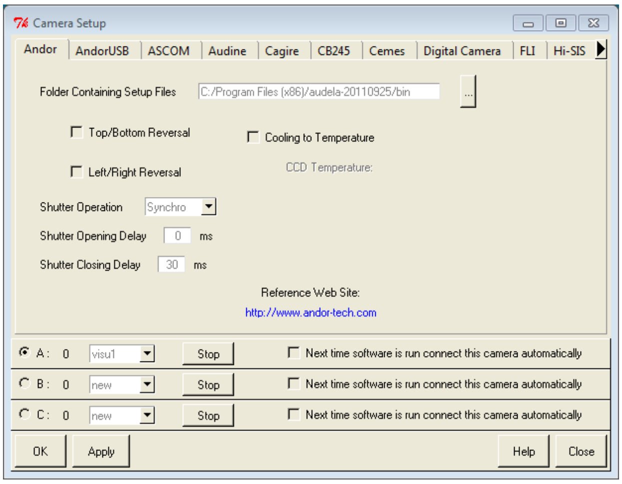
3.3 Starting cameras

3.3.1 Acquisition camera

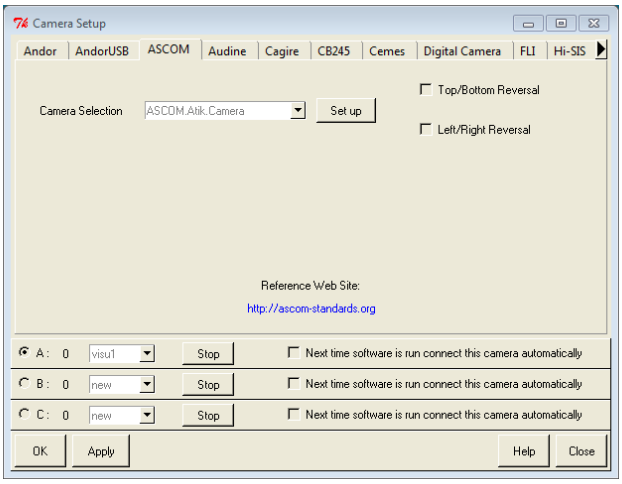
Start AudeLA software. You should have this screen:



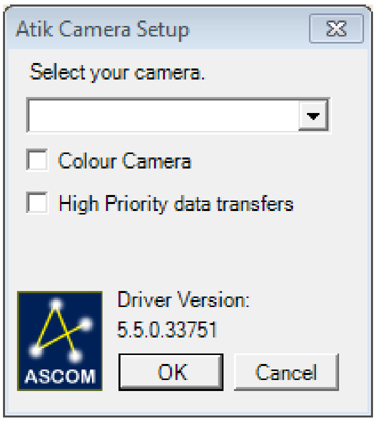
Go to the menu Setup/camera. The camera selection window pops-up:



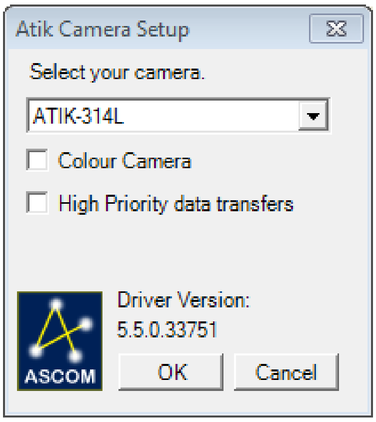
Select "Ascom" tab (because Atik camera is connected through ASCOM driver):



Click on Set up button, to select the camera. Again, a new window pops-up:



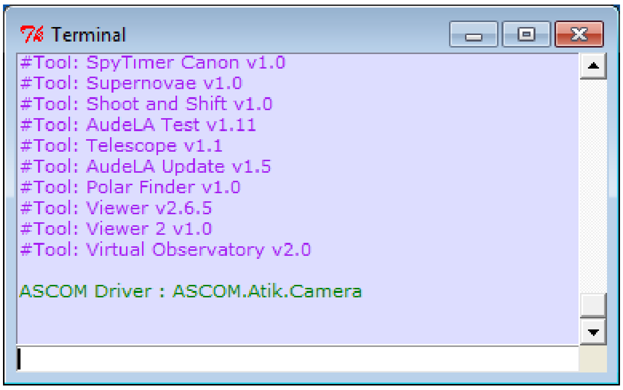
In the List Box, you have the choice between 314L (Atik 314L+) and HS (Titan). Select 314L:



Click on OK button. Click then on the OK button of the AudeLA camera configuration window.

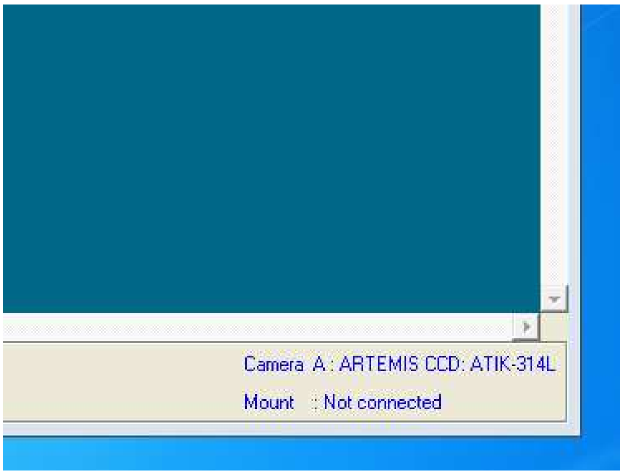
BMost of AudeLA windows have several buttons: "OK", "Apply", "Help" and "Close". "OK" is a combination of "Apply" and "Close". Select "Apply" if you want to keep the window open.

You can see in the AudeLA console that camera is properly configured:



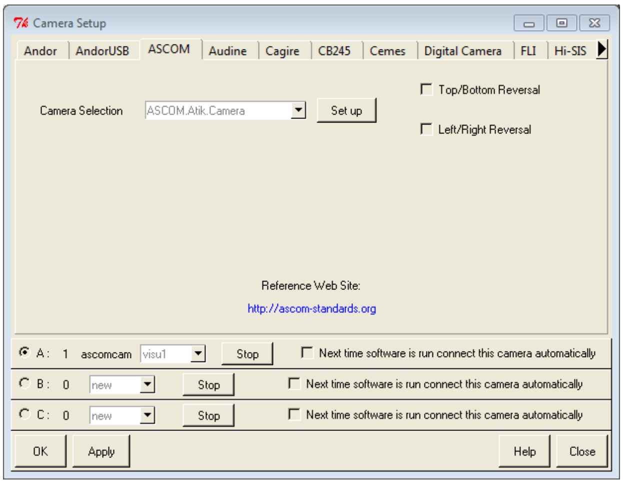
Another way to check that camera is properly configured is to check in the bottom right angle of the

AudeLA main window. The camera 314L is declared:

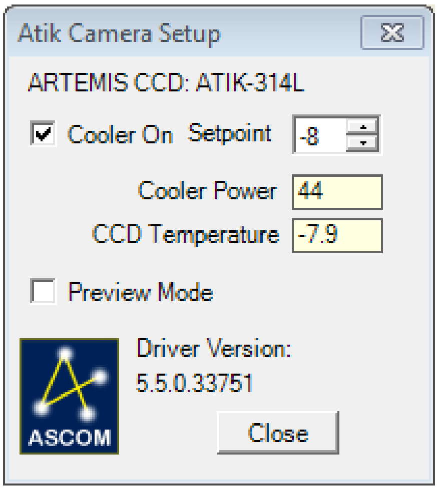


Cooling the Acquisition camera

The Atik 314L+ camera can be cooled down, to reduce the electronic noise. Having a cooled camera allows to make longer exposure time, with better SNR (Signal to Noise Ratio). It is key in astronomy. To activate the cooling, go again to menu Setup / Camera, and click on "Set Up" button (like when you selected the camera):



Then, the ASCOM panel appears. Click the "Cooler On" check button. And select the temperature target for the camera. The temperature is controlled electronically. You must choose a temperature as low as possible for a better quality, but with some margin for the colling capacity. The cooling power should remain below 80% at the beginning of the night. A good value is around 25°C below the ambient temperature. In the below example, we've choosed -8°C - room temperature was about 18°C at this moment. After some minutes, you can read that actual camera temperature is close to -8°C, and the cooling power is around 50%. There is still some cooling capacity, in case of the ambient temperature would rise-up in coming hours.



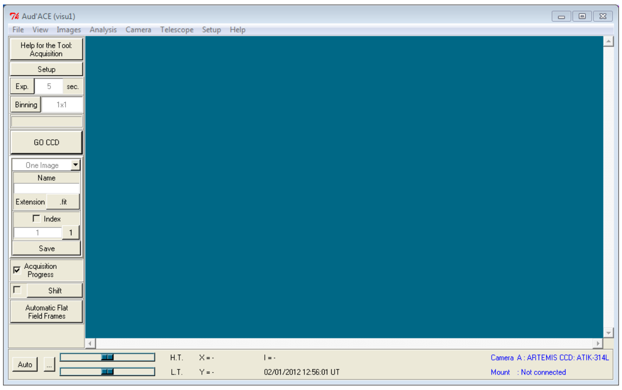
Cooling the camera will have several visible effects in the images: less noise, less hot pixels, lower offset level...

Close the camera setup window.

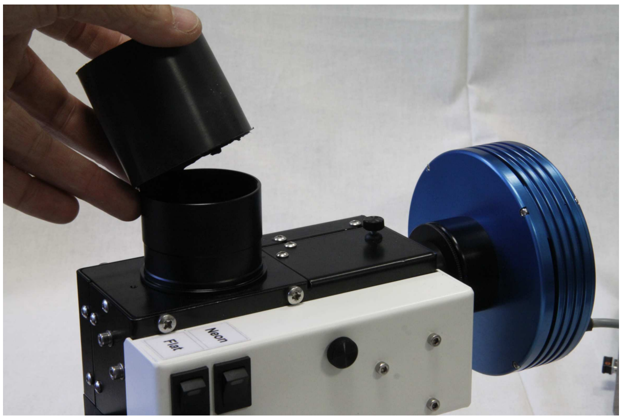
In AudeLA, use the CLOSE button to close the camera setup window. If you click on Ok, it will restart the camera, without setting temperature target.

First image

Select menu Camera, then Acquisition. A new panel appears on the left of the main window. This panel gives all controls to drive camera acquisition:

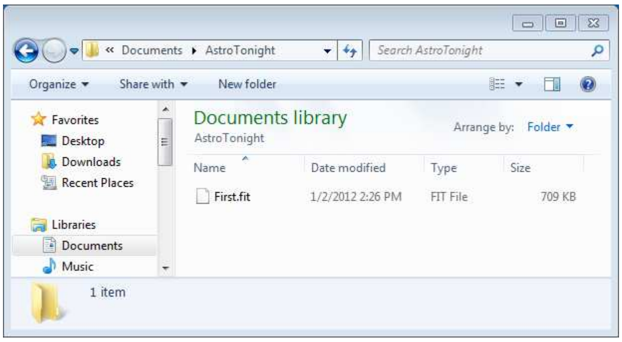


select an exposure time of 1 second, binning 1x1. Remove the cap from telescope interface:



Now... launch the camera acquisition by clicking on button GO. After some seconds, you see your first spectrum:

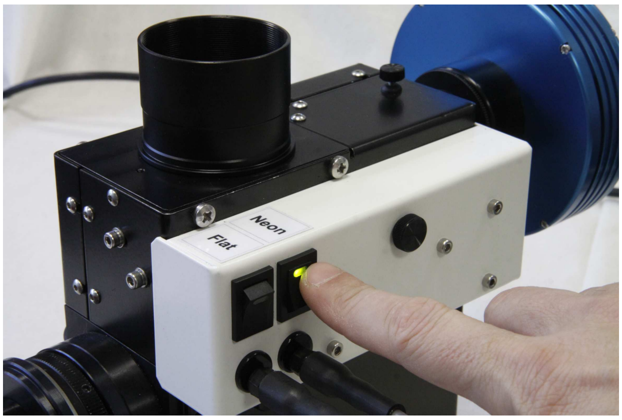
Depending on the light you have in the room, the image can be significantly different. In our case, we had some energy saving lamp. Also, depending on the intensity of the light in your room, you may have to adapt the exposure time. Make some tests with different times. You can save this image - your first one ! Give a file name to your image - for instance First - and click on button Save. You can check that image has been recorded in your AstroTonight directory. The full file name is First.fit (the .fit extension has been added by AudeLA):



Now, use the integrated neon light. You'll be in more controlled conditions.

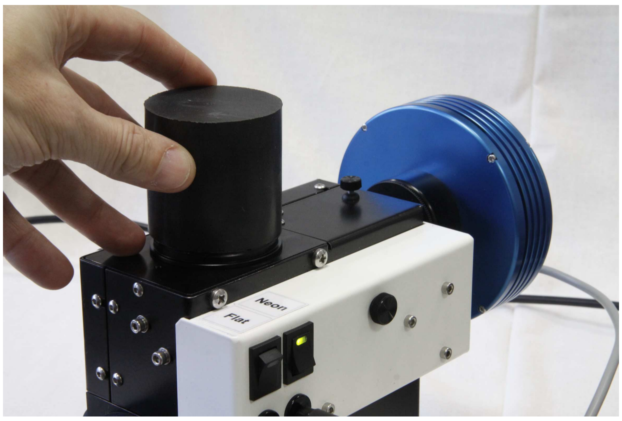
For basic LISA (not LISA Pack), the calibration module is optionnal. If you don't have this module, you must put some neon light in front of the spectrograph entrance, or in front of the calibration window (on the side).

Switch ON the neon light. The green light on the calibration module must be on - and when you switch on the button, you hear the electromagnet moving the screen in front of the slit.

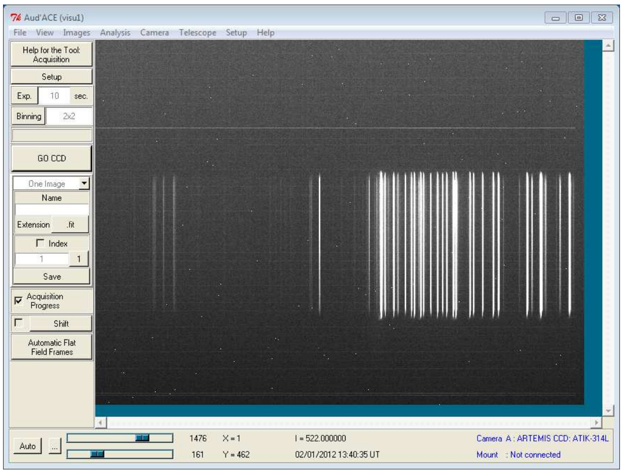


What happens when you switch on neon in calibration module ? Neon lamp is powered on. And a white screen is moved in front of the slit, with two effects: slit is enlighted with neon light coming from calibration module, and the light coming from telescope is obstructed - this allows to make calibration images even when telescope is pointed towards a star. Then, the spectrograph received neon light in exactly same conditions as the sky light.

Put the cap on the light entrance, to prevent any light leakage:



Launch acquisition, with exposure time of 20 seconds, and binning 1x1. You should have this image:



At this stage, you must check there is no major issue with the tunning of the camera - if the camera has moved since the tunning in our factory. They are four key elements to check quickly:

- The spectrum is properly focused,
- The spectrum is horizontal,
- The spectrum is well positionned in the image,
- The image is in the right orientation (left-right),

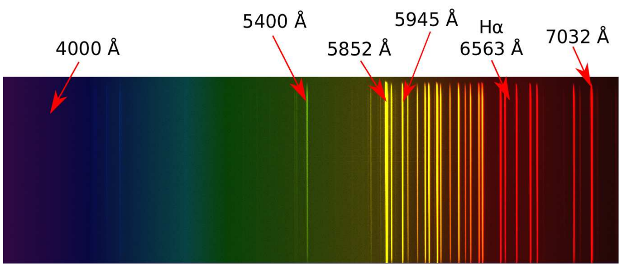
If you have any doubt on these points, go to the Reference Manual to check your instrument more precisely.

Spectral range

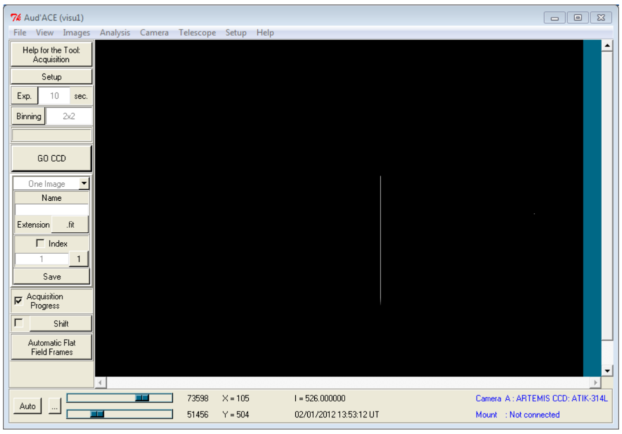
The light is spread out horizontally in the image. The blue part (around 400 nm) is on the left side of the image, the red part (around 700 nm) is on the right.

> Depending on the document you read, wavelengths are given in nm (nanometer, $10^{-6}m$) or in Å (angström, $10^{-7}m$). Both are really used... this is important that you mention clearly the unit on all your results.
>
> Just remember that 1 nm = 10Å. And visible range is from 400 to 700nm, or 4000 to 7000 Å.

The Atik camera is black and white, but if you had a color camera, you should see them along the spectrum:

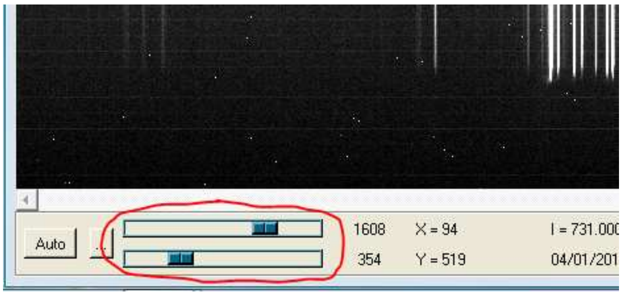


Imagine that each line of the spectrum (from left to right) is an image of the slit for a given color. If the light source were a purely monochromatic light, you should have something like that:

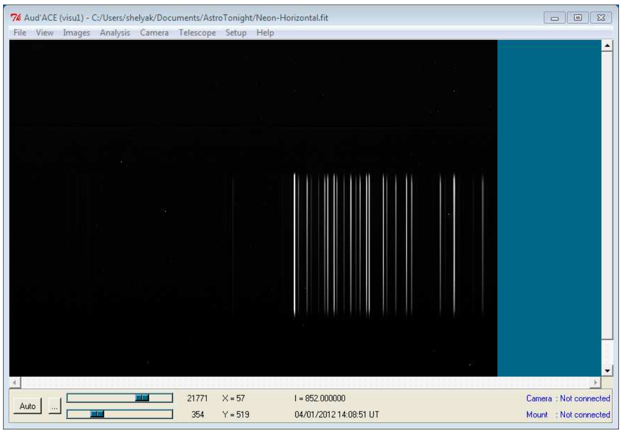


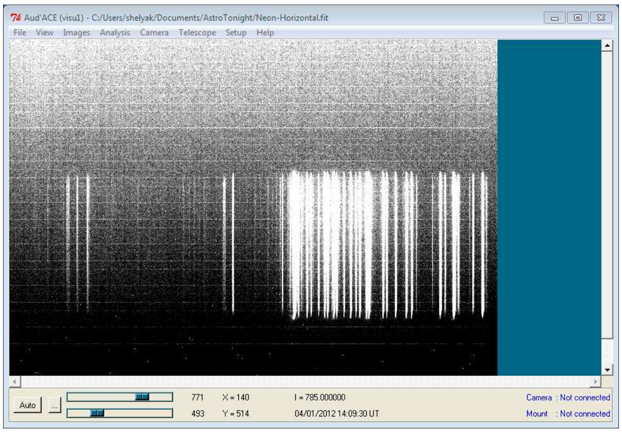
Visualization

You can change the thresholds of the image, to see details in some regions. This is to be done by moving cursors on bottom left of the images:



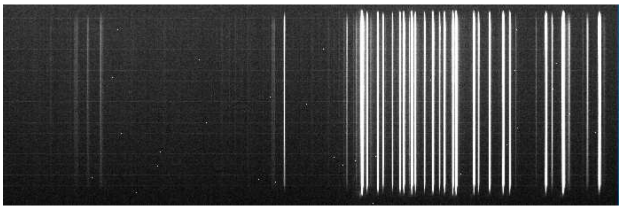
Make some tests to change the visualization of the image:



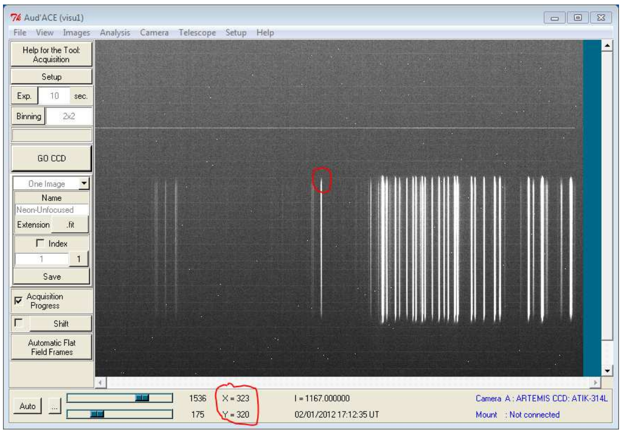


Basic calculation

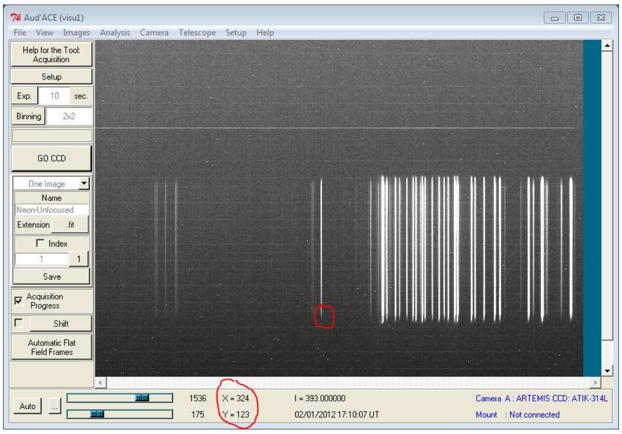
Let's take some time on this first neon image:



As you can see, the spectrum is limited in height. This is due to the slit length. We can make a simple calculation: the slit is roughly 4mm long. The LISA is scaling the image by about 0.7. Then, actual slit image on the CCD is 4x0.7mm = 2,8mm (or 2800μm). The ATIK 314L+ camera has pixels of 6,45μm. Then, spectrum height should be around 2800/6.45=434 pixels. We can measure this value in the image: simply put the cursor of AudeLA on the top end of the spectrum, and look at the X / Y position, on the bottom right corner:



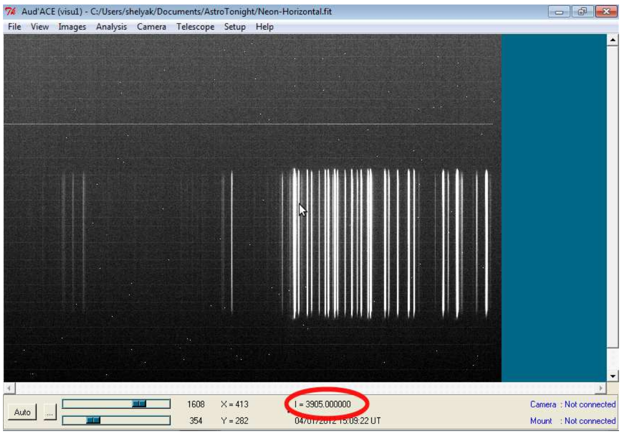
Do the same at the bottom end of the spectrum:



The spectrum height is the difference between top and bottom ends: it should be close to 430 pixels.

Prevent the saturation

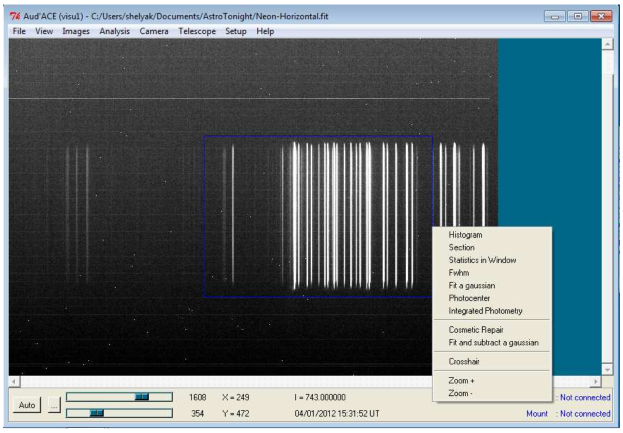
There is another key test to make at this moment: we have to test that no pixel of the image is saturated. Move the cursor in the brightest area of the image, and look at pixel intensity, given at bottom right of AudeLA window. In the next example, the intensity is at 3905 ADU:

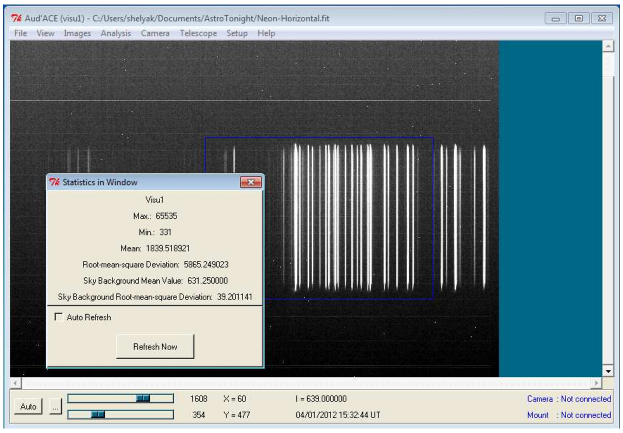


ADU (Analog to Digital Unit) is the unit of the pixel intensity. For each ADU counted, the pixel has received a certain number of photons. This is an intrinsic parameter of the camera. The digital capacity of the camera, or the Dynamics, gives the highest ADU level that camera can provide. This is another intrinsic parameter of the camera.

The dynamics of the ATIK 314L+ camera is 65535 ADU (Analog to Digital Unit). No pixel must reach this level: it would be saturated.

You can also select an area (rectangle) which contains the spectrum, by clicking one corner, and drag the mouse up to the opposite corner without releasing the mouse button. Right-click and select statistics in the pop-up menu: you'll see max pixel value in the area:





We see that in our case, Max value is 65535... bad luck: the image is saturated.

The pixel intensity is an intrinsic parameter of the image. When you change visualization thresholds, it does not affect the intensity, but only what you see on the screen.

The way to prevent saturation is to reduce the exposure time during acquisition. Make some tests with different exposure times, to see the effect on the spectrum level. The optimal situation is when the highest pixels are at less than 70% of the camera dynamic - roughly 40.000 ADU.

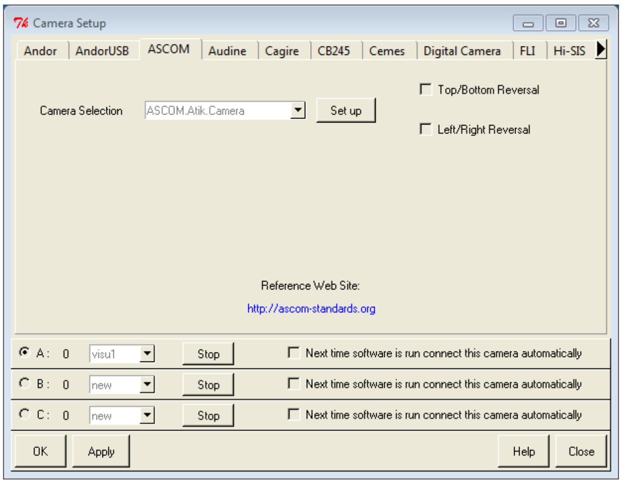
What if you saturate the image ? There is no risk to damage the camera. But in this case you're not able anymore to measure a signal difference, because camera cannot go above 65535 ADU. If you continue to enlight CCD, level will remain at 65535 - and you don't see any change. In few words, if your image is saturated, you cannot use its data. Keeping unsaturated images must be a permanent attention.

3.3.2 Guiding camera

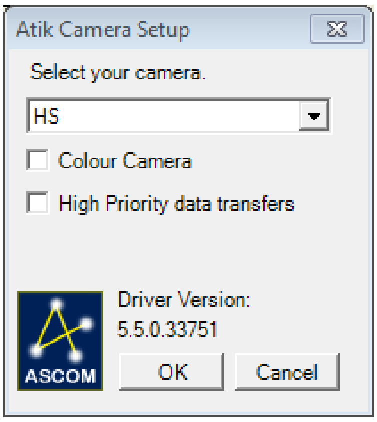
Let's switch now to Guiding camera. Connect the USB cable from guiding camera (blue) to the PC. Launch a new instance of AudeLA.

Audela software cannot manage two Atik cameras at the same time. If you want to use AudeLA for autoguiding as well as for acquisition, you must run a second instance of AudeLA.

Go to the menu Setup / Cameras, to open the camera selector Select Ascom tab...



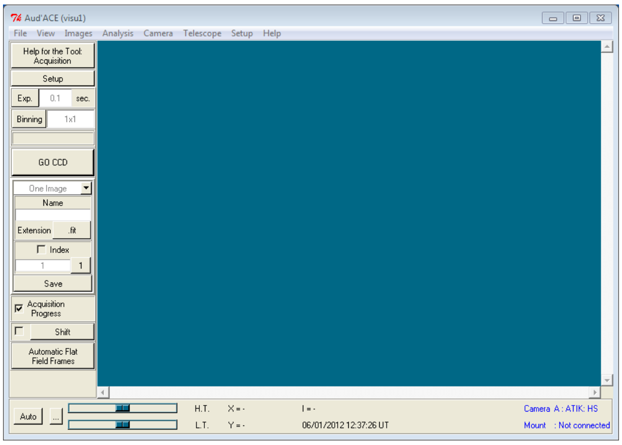
Click on Set Up button, to make appear the ASCOM camera selector, and choose HS in the list:



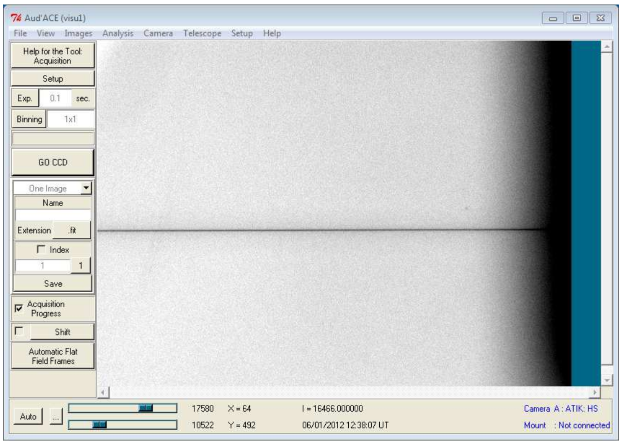
Click OK, and then OK to apply the camera choice.

Atik Titan camera has no cooling feature. This is not required for guiding images (short exposures).

Select menu "tools", and Acquisition. The acquisition tool appears on the left:

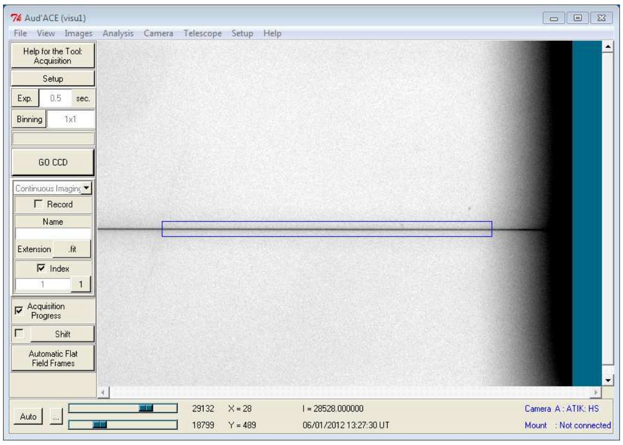


Remove the rubber cap from the telescope mounting ring. Put a diffuse paper on the telescope entrance - to prevent camera saturation, and get homogeneous light. Select an exposure time of 0.1 second, binning 1x1. Launch acquisition: click on button GO. You should have this kind of image:



The horizontal line is the slit. This is the light entrance for the spectrograph. If you cannot see it properly, change the image thresholds, as shown for acquisition camera. Depending on your specific conditions, you can have to adapt the exposure time to prevent the saturation. Check with moving the cursor everywhere in the image that there is no saturation - you can also select a rectangle and look at the statistics. In our case, the max value is around 18.000 ADU: we're far from saturation (max acceptable value is also 65535 for this camera).

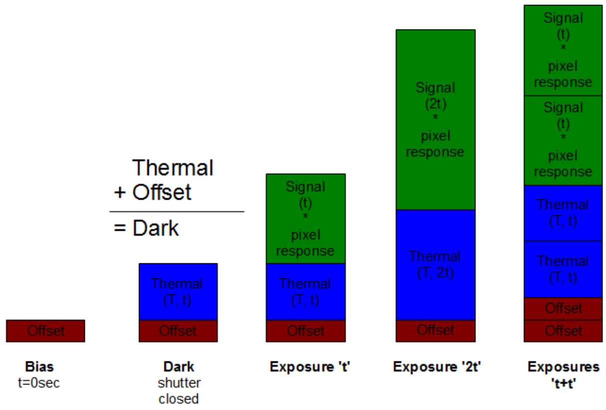
You can see on the right part of the image that there is a black area. This is the shadow of the calibration screen: this is normal. In fact, the useful part of the slit is in the center of the image. Remember that actual slit length is around 4mm. In the below image, we've shown the approxiamtive useful area (blue rectangle):



If the slit is not horizontal, or unfocused, go to the reference manual for tuning. But this has no direct impact on spectra quality.

3.4 Different types of images

Your spectrograph is now ready for operation. In the previous sections, we've mainly used neon spectrum. In fact, when observing stars, we will use different types of images, which are required for a proper data reduction. In this section, we will describe the purpose of each of them and how to obtain them.



If you use a CCD camera, each image will be affected by the electronic. Several defect can actually be removed using dark, offset anf flat field frames.

To avoid negative signal digital conversion, CCD cameras have a fix offset on the analog signal which is called Offset. Any data readout from the CCD chip include this offset.

> Offset images are also called Bias in some documents. In this User Guide, we made the choice to use Offset, but consider it is equivalent to Bias.

This offset is fairly stable and once you have a master offset frame, you can keep it for long time. You can make one again once per year approximately. It is also not too much temperature dependant. Because it is very stable, you can improve your data by taking a long series of offset frame (around 100 exposures) and perform a median average to create a mooth master offset frame for your camera. Median average is better than a simple average as it will totally remove out of the ordinary defect on some of your images, such as cosmic rays for example.

CCD chip have a tendancy to build electrons over time, specially at high temperature. This temperature dependant effect is called « thermal noise ». The thermal noise is included in dark frames which are exposures taken with the camera shutter closed; the offset is also included in.

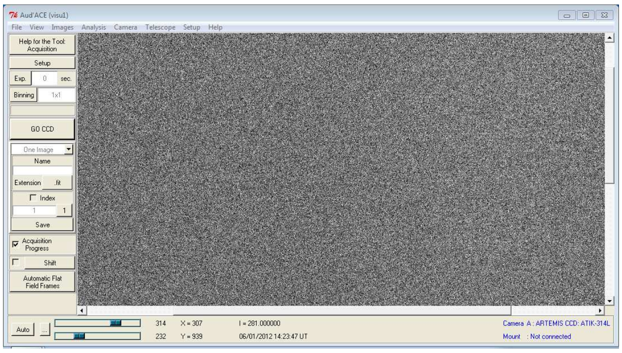
Hot pixels are individual cells that are particularly sensitive to this thermal noise and tend to saturate quickly during long exposure. Those hot pixels will have to be processed separately (usually replaced by the average of the surrounding pixels). An interesting property of thermal noise is that it is linear to the exposure time. For exemple, a thermal noise of a 2sec exposure is twice the thermal noise of 1sec exposure. This means that you can extrapolate any shorter thermal noise frame from a master thermal noise frame with long exposure – assuming you have mapped the hot pixel properly. This is done by doing a median average of a a long exposure dark frame serie (at least 7 frames, if possible more). Most astronomical software require both the offset frame and the dark frame to pre-process your image. The thermal noise is of course embeded in the dark frame. Be very careful as the thermal noise (thus the dark frame) is very sensitive to temperature. Make sure to use a Dark frame taken with the same temperature as your spectra. If your camera doesn't have a temperature regulation, you should take dark frame close to the time you expose your spectra. Some software can still extrapolate a proper thermal noise map based on the area of your chip with no signal, which is very easy in the case of LISA spectra. You do not have to rebuild your dark frame every night; you can create your library of dark frames taken at different temperatures and use it for several months.

Flat field is a spectrum of the tungsten lamp inside the calibration unit. This flat will be mainly used to get low frequencies non uniformity, caused by dust on the CCD front glass for exemple or overall instrumentation vigneting. Make sure to take a long serie (about 15 exposures) of flat spectra as the processing will divide your spectra by this flat. The signal has to be as high as possible without any saturation.

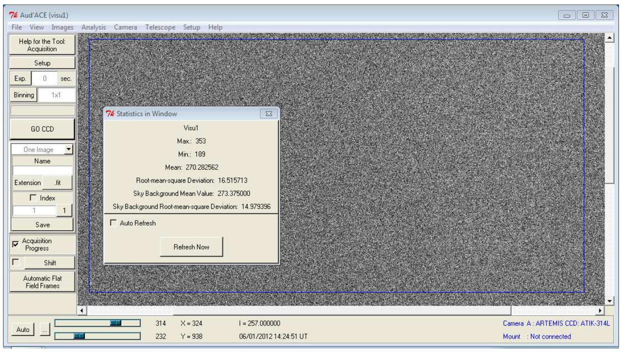
Wavelength calibration spectrum is an emission spectrum from a lamp. In LISA Pack, you will use the neon inside calibration unit. Take three exposures each time to do a median of them and remove any single exposure defect.

3.4.1 Offset (Bias) image

For the Atik 314L+ camera, the average level is around 300 ADU (it varies from one camera to the other). To get an offset image, put a cap on the LISA light entrance, to ensure that no light comes in. Take an exposure of 0 second, binning 1x1.



You can measure the average level in the image (draw a rectangle, and right-click to get the statistics in the window):

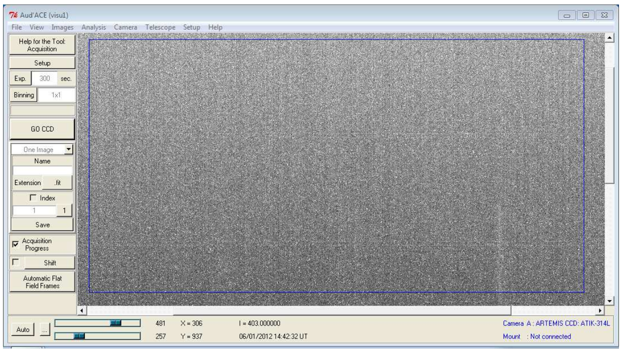


3.4.2 Dark frames

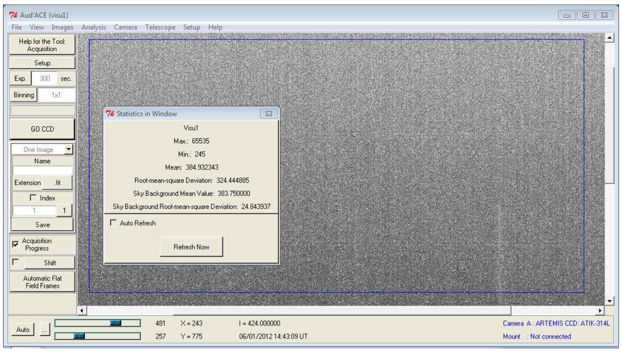
A dark frame is taken with the same conditions as a spectrum (exposure time, temperature), but with no light coming into the spectrograph.

If, for instance, your star spectra are made with 300s exposure, dark frames must be taken with the same duration. These images can be log to obtain... since they are only dependant on the instrument, not on the observing conditions, we can make these images once, and keep them in a reference directory.

Here is a typical dark frame of 300 second exposure (and binnng 1x1, of course):

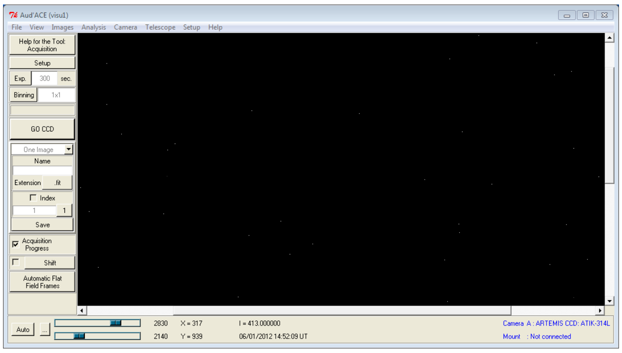


It looks to be very similar to offset... in fact, they are details between both images. Look at the average level of the image:



The mean value is now 384 ADU; it was 270 in the offset. The difference (384 - 270 = 114 ADU) is due to thermal activity of the CCD during the exposure. An other difference is that there are some hot pixels. In the above image, the Max value is... 65535: it is saturated ! Should we drop the image ?

No... there is only a few pixels at this level (they are hot pixels: their level is growing too fast compared to others), and the data reduction will eliminate them. Change the visualization high threshold at about 5000 ADU and the low threshold at about 2000 ADU. At this level, most pixels are black (because they are all around 384 ADU in average). But you can see that some pixels are still white; these are the hot pixels:

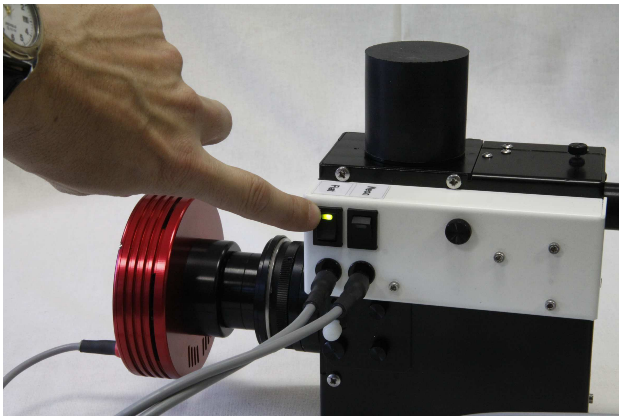


3.4.3 Tungsten flat spectrum

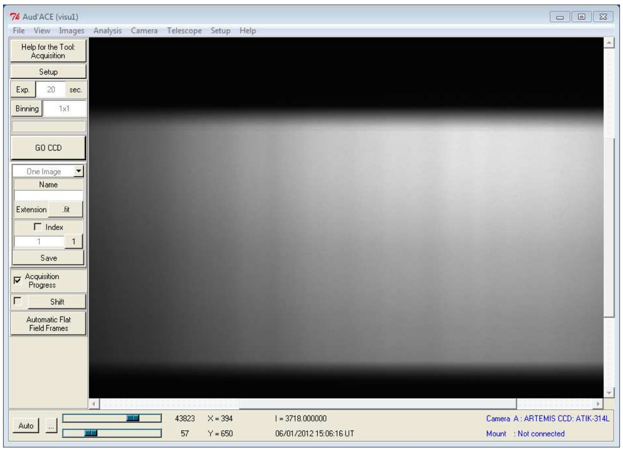
The tungsten lamp of the calibration module is used to get an "as flat as possible spectrum". This is an incandescent lamp, with no emission or absorption lines.

> For basic LISA (not LISA Pack), the calibration module is optionnal. If you don't have this module, you must put some white light in front of the spectrograph entrance.

To get a flat, switch on the Flat lamp on the calibration module (you should hear the electro-magnet):



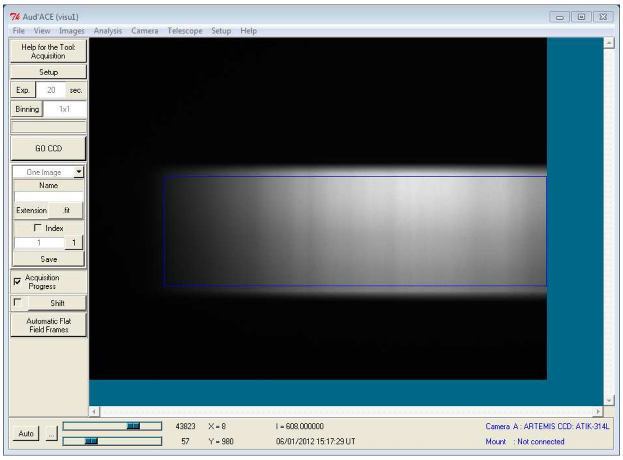
and launch an acquisition image of 20s, binning 1x1. You should see this:



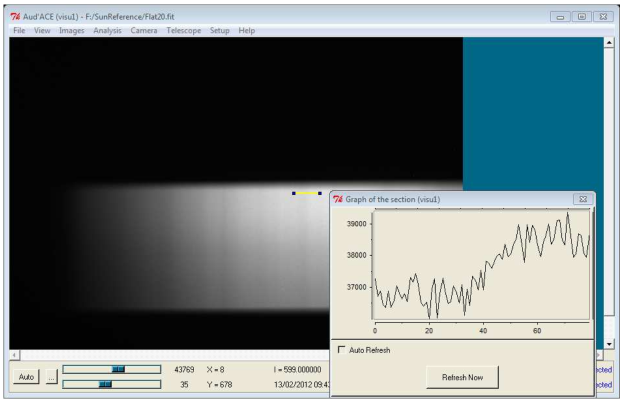
You can adapt the exposure time to get the highest possible level - with no saturation. Reminder: optimal level is close to 70% of the camera dynamics. Depending on your screen size, the image can be wider than the window. You can change the viewing scale of AudeLA window. Go to Menu / View, and select Zoom x 0.5.

What do we see ? This is the spectrum of the white light. It seems quite fuzzy, but in fact, this is a very precise spectrum. Imagine this is the image of the slit,when it moves along the colors (wavelength) from UV on left to IR on right. You can see that the spectrum is dark on the left. Does it mean that there is no more signal in the UV domain ? No. But in this range, lamp intensity is lower and the CCD is less efficient... then the image is fainter.

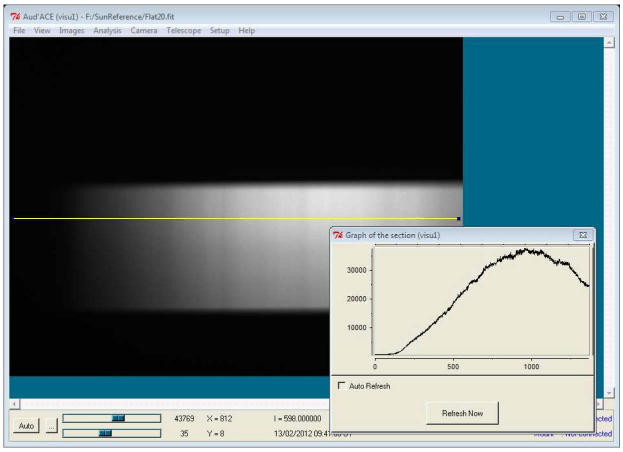
Of course, the useful area of the image will always be in the light rectangle - like below (blue rectangle). All black top and bottom areas will never be used - except in some special cases to get the dark level of the image (since these parts are never enlighted, they can be used as dark indication):



At this stage, you can use a useful tool of audela: the section viewer. Go to menu Analysis / Section. A new window appears, with a yellow line in the middle of the image:



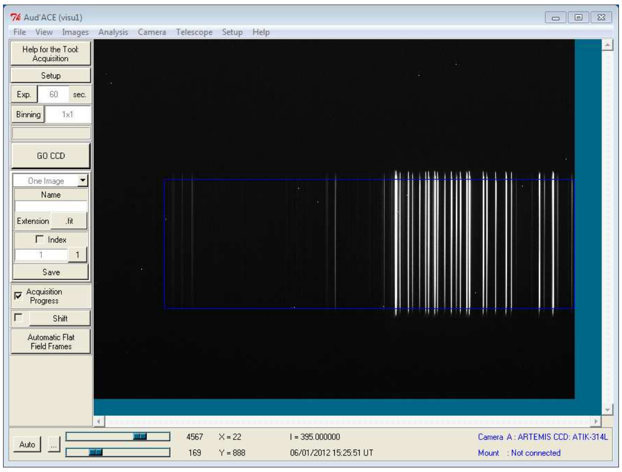
The graph shows the level of pixels (in ADU), along the yellow line. You can move each end of the line to see the section of the part if the image you want. If you extend the line all along the spectrum, you'll have a rough profile of the spectrum:



At the end of this step, don't forget to switch-off the Flat light.

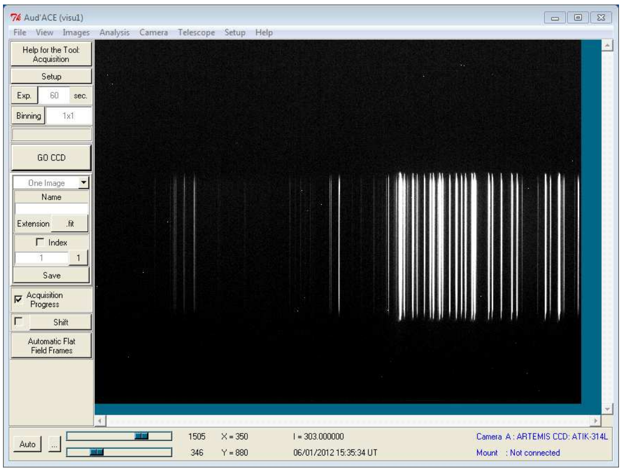
3.4.4 Neon spectrum

During the camera setup, you've already made several neon acquisitions:



We've let the same blue rectangle as previous image. Of course, the spectrum area is exactly the same as the flat spectrum. But in this case, we have no more continuum (continuous spectrum), but a serie of lines, mainly on red side (you can look at your neon light in the LISA... it is really red). The purpose of the neon spectrum is to give a reference for wavelength calibration during the data reduction. Since neon spectrum is very well known, we can define the actual wavelength for each of the lines, with a very good precision.

The above image is a 60 seconds exposure. When you look at the image level, you can see that it is saturated. Should we reject it ? Again... No. Only some lines are saturated. We could reduce the exposure time to solve the issue... but now, look at the low level lines, by moving thresholds to 500 (low) and 1500 (high):

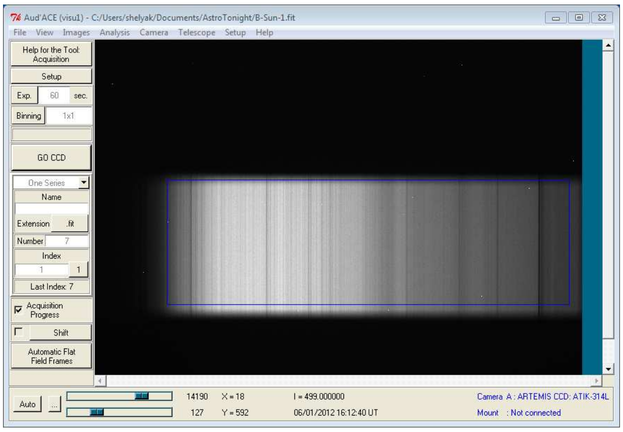


You can see on the left (blue side of the spectrum) that there are some faint lines. These lines will be very useful to calibrate the spectrum wavelength all along the visible range. Then, we prefer to saturate some lines in the red part (they will be not taken into account during data reduction), to get good calibration lines in the blue part. Of course, if your specific setup is different from this one (no saturation at all, for instance), you can adapt the exposure time.

At the end of this test, don't forget to switch-off the neon light.

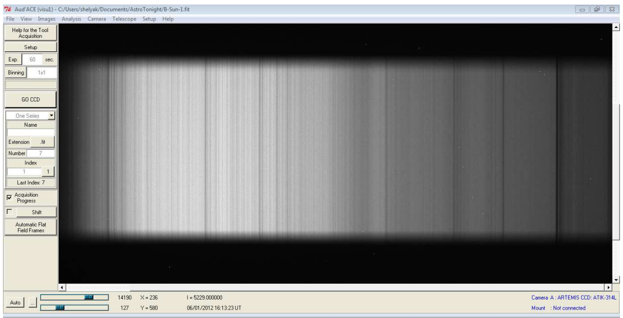
3.4.5 Object spectrum

So far, we have made only "technical images"... but the LISA is made to look at star light. Of course, the most important images are the star spectra. During daylight, we can take one star spectrum: the Sun. This is simple: ensure that there is some Sun light coming into the room (even cloudy, rainy, snowy weather). Switch-off any artificial lamp in the room. Remove cap from the telescope interface, and put a diffuse paper. Launch an acquisition in binning 1x1. The exposure time is very dependant on your specific conditions. For the below image, we were in a dark room (only a small window far away from the LISA), with a rainy weather - hard to be in worse conditions. However, in 60 seconds exposure, here is the result:



If you are in better conditions (sunny day, close to a window - or even direct Sun light onto the LISA), reduce significantly the exposure time - it can be less than one second (LISA is very, very sensitive). Check that your image is not saturated - no more than 70% of the camera dynamics (around 40.000 ADU)

This spectrum is a wide continuum, in which you can see many sharp absorption lines. Each line reveals a chemical element in the Sun chromosphere (or in the earth atmosphere for some of them). You can zoom in the image, there is really a high number of lines (note that around 30.000 lines have been identified by professionnals in the Sun spectrum):



Of course, the Sun's spectrum fills the whole useful area in the CCD, because all the slit is enlighted. When you will get star spectra, you will have only a line, because the star is ponctual.

You can also take spectra of surrounding lamps, and see the differences from one to another.

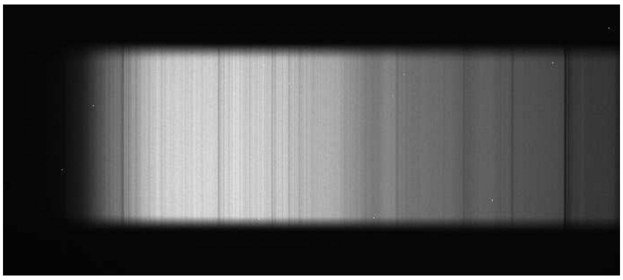
An important step is now achieved: your LISA spectrograph is up and running, and you are able to acquire all images required to pre-porcess a high quality spectrum.

4 First spectrum: the Sun

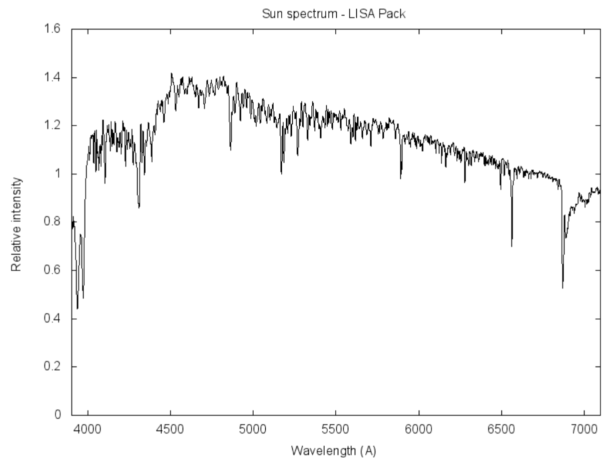
In this section, you will perform a full observation, from images acquisition to data reduction. Again, you will work with the Sun, because it is available everywhere, and do not require to use a telescope. But you will see later on that working on a non solar star spectrum will be very similar to this first session.

> Data reduction & data analysis.
> Data reduction is the list of operations that extract scientific data of the object (star...) from raw images. It must be done by the observers, who knows the instrumental effect of his setup. Data analysis is any operation made on scientific data, to focus on some features. It is done by the scientist - not the observer. For instance, correcting the spectrum from helicentric velocity to make radial velocity measurement, or removing the continuum to focus on absorbtion lines shape are data analysis operations.

Data reduction is the operation which starts from this (raw data, 2D image):



and gives a calibrated profile like this (reduced 1D profile):



To get such a spectrum, you need several reference images, defined in the previous section: Dark, Flat, Offset, Calibration, Object.

Extracting the scientific information from these images is a complex operation. Luckily, ISIS software will do the computation for you. Your only responsibility is to provide ISIS with the right images, in order to allow it to process properly the different steps.

> Start any observing session by opening a personal log file: a simple text file, in which you can write any significant element you will encounter during the observing session. For instance, you can describe shortly your instrument setup, the reason for the observation, the goal... and during the observation, any useful information (camera temperature, any event that gives some information on the images...). In future, these informations will be very useful to recall the observing conditions.

4.1 Images acquisition

you will make all the images **during daylight**, in a room where Sun light is the only light in the room[1].

1. If you cannot acquire these images for any reason, a demo set is available on the CD-Rom.

Think to switch-off artificial lights.

> It prefectly works if weather is cloudy or rainy: in all cases, this is always the Sun light which comes to us. The general profile can vary with your conditions (weather, room...), but it will work in any case.

All acquisitions are made in **binning 1x1**.

Setup the camera temperature about 25°C under ambiant temperature (cooling power below 80%).

Don't change any tuning (focus, rotation, grating position...) during all the acquisition session.

In this table, you'll find the list of images you must acquire with your LISA.

Image type	Nb	Exp. time	Comment
Object (Sun)	3	*	Exp. Time depends on your situation
Offset	1	0 sec	LISA closed
Dark frame	1	60 sec	LISA closed
Flat	1	~20 sec	LISA closed, Flat light on
Neon	1	~60 sec	LISA closed, Neon light on. Some lines are saturated

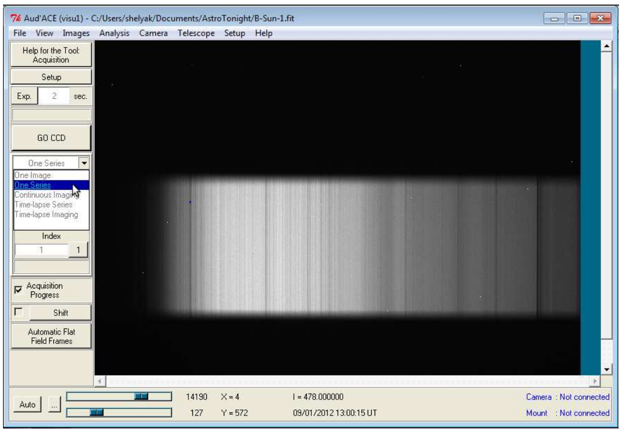
At the end of the acquisition, you must have 7 images (at least) in your working directory *AstroTonight*.

Sun spectrum

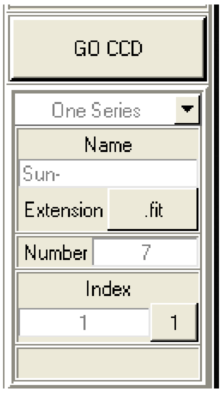
The light level is very dependant on your own situation. It can be from less than one second to one minute, or even more. Start with 3 seconds, for instance, and look at the result. Move the cursor in the image, in the heighest region, to look at the max level image. You can also measure the max level of the whole spectrum area (draw a rectangle, right click "statistics in window"). Adjust the exposure time, to have the max value at less than 70% of the dynamics (around 40.000 ADU).

Let's take an example. We assume you have made an acquisition of 1 second. The max level in the image is around 10.000 ADU. The goal is to have around 40.000 ADU. Then, you can shoot for 4 seconds.

When you have found the right exposure time, make a serie of three (or more) images. In AudeLA, you can acquire automatically a serie of image and save it: select "serie" in the acquisition tool.



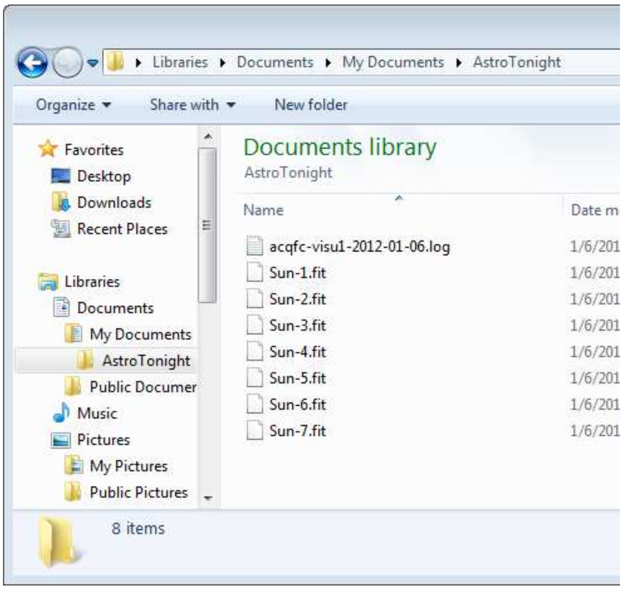
You now get a new acquisition panel:



Fill the different fields: exposure time, the binning, name, number of images, an index. The index should be 1: this is the index of the next image (in the above example, the first image name will be Sun-1). You can reset the index at 1 by clicking on the button "1". Click the button GO to launch the acquisition.

> Choosing a proper name for your file is important for next steps. The name must be explicit, and simple. It must be finished by a '-'. In our case, let's choose Sun-. The '-' will be followed by the index of the image (Sun-1, Sun-2, and so on). If you choose name with a number, like HD299315 and you forget to put the '-' at the end, the images will be named HD2993151, HD2993152, HD2993153... which is very confusing. Using the '-' will give HD299315-1, HD299315-2, HD299315-3... which is better.

Each image is successively displayed when it is read out. You can check that images are properly recorded in your image directory are available. Note that each image have the root name, and an index at the end. The file extension is .fit, because files are in FITS format:



FITS format is the 'standard' for astronomical imaging (and some other area like medecine). It contains digital data - each pixel of the image - and a header with keywords describing the image. You can read in AudeLA (like in most of astronomy software) the header, and find for instance the exposure time, the date, the size of the image, and so on. Remember that a FITS file not only contains the image itself, but also many data on the image, which are accessible to user. You can check if a FITS file is compliant to the spec on the NASA website: http://fits.gsfc.nasa.gov/fits_verify.html

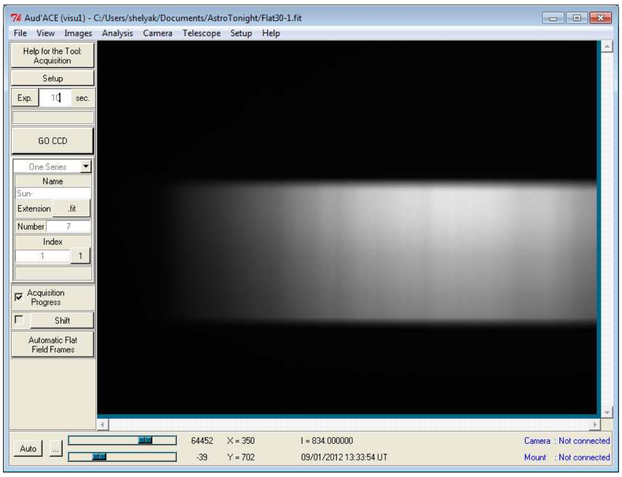
Beside the Sun-* images, you have also a log file called acqfc-visu-*.log. This file is generated by AudeLA, to track all acquisitions made during the session. One log file is created per day. You can open this file with a single text editor. It can be very helpful in some conditions. Keep in mind that this information is available.

Neon spectrum

Perform the same operation with the neon light. Put the cap on the telescope mounting ring. Switch-on the neon light, and make some tests to find the right exposure time (in binning 1x1, "One image" mode). When you have defined the right exposure time, launch a serie of acquisitions, called for instance Neon60-. At the end, check that the files are in your working directory. Swicth-off the neon.

Flat spectrum

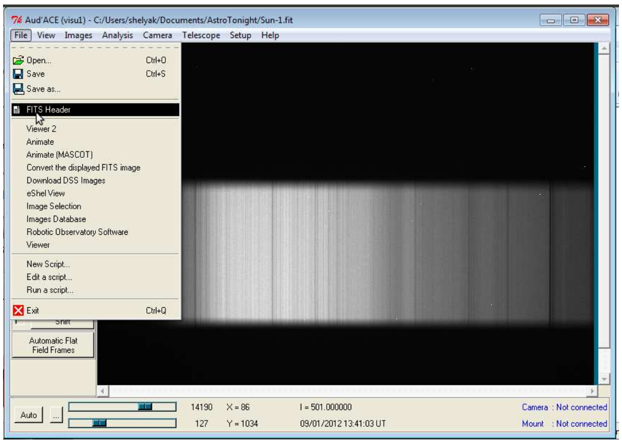
Again, perform the same operation, with Flat light (tungsten). Switch-on the Flat light, and make some tests to adjust the exposure time starting at 20 seconds. Launch the acquisition, called for instance Flat20-. Switch-off the Flat light.



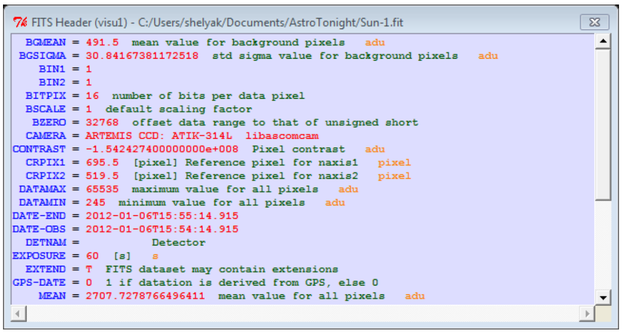
Dark frame

Dark frame is made in same conditions as previous images, but with no light coming into the spectrograph (put the cap on the telescope interface). The exposure time must be at least the longest exposure time of all other images. If your neon is 60 seconds, your flat is 30 seconds and your object is 120 seconds, the dark exposure should be at minimum 120 seconds. If you have very different times (for instance 5 seconds for the flat and 300 seconds for the object), we recommend to make two diferent series of darks, with 5 and 300 seconds.

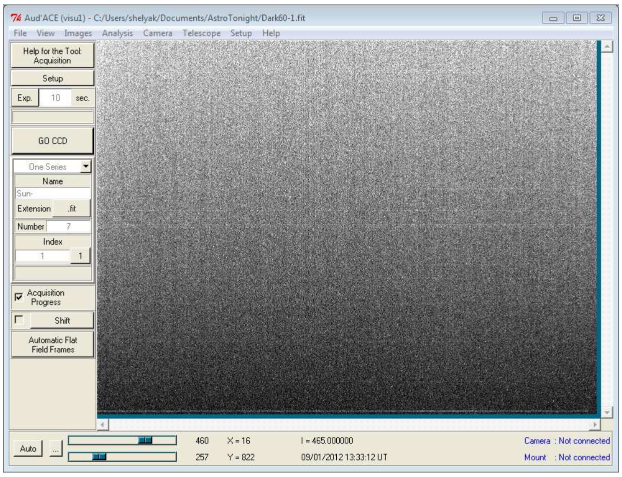
It happens that you don't remember the exposure time of previous images... we can easily recover this information. For instance, we can load the first Sun image (Sun-1.fit) in AudeLA. Select Menu / FITS header:



This opens the FITS header panel, in which you can see all keywords, including "Exposure". In our case, we see that this acquisition duration was 60 seconds:

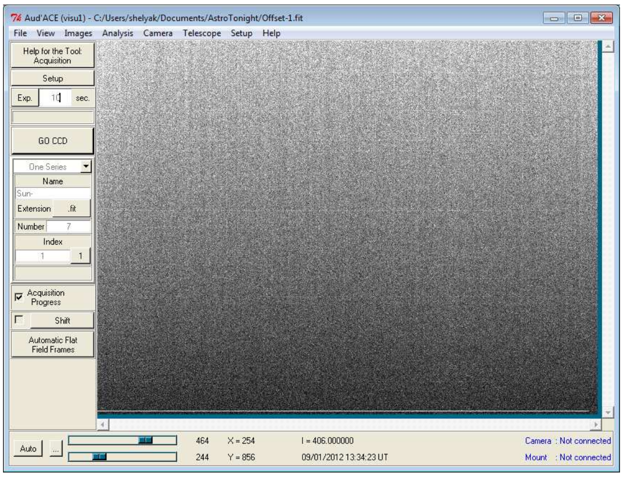


When you have defined the needed times, launch the acquisition of dark frame, called for instance Dark60- (if exposure is 60 seconds):



Offset image

Last acquisition to make is the easiest one: offset. This is the same as dark, but with null exposure time. Launch an acquisition called Offset- for instance:



We have finished the acquisition side of the operation: we have all data ready for reduction.

4.2 Data reduction with ISIS

In few words, data reduction consists in:

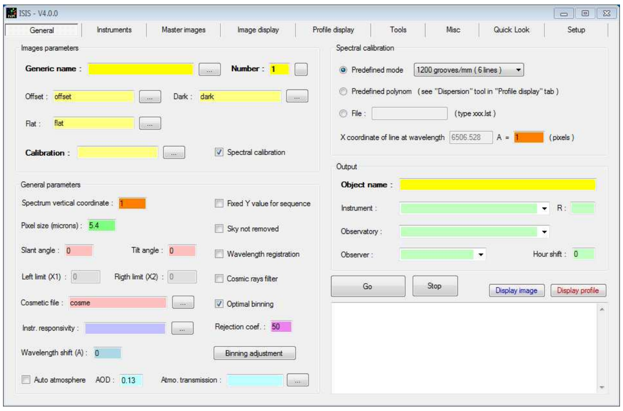
- Correcting 2D images with Offset, Dark, Flat, cosmetic issues (hot pixels, cosmics)
- Adding/combining 2D images (with geometric corrections),
- Extracting profile (2D image -> 1D profile) in the best possible conditions (collect all available infrmation),
- Wavelength calibration,
- Instrumental response correction.

You will process in several passes:

- The first one gives a basic wavelength calibration.
- The second step will make a better calibration law.
- The third one is to define the Instrumental response curve.

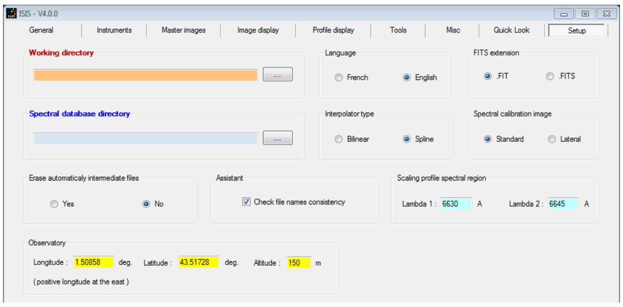
ISIS is a dedicated software to reduce astronomy spectra. It can be used for many instruments, but has specific features to simplify the LISA images processing. In this section, you will see how to proceed in detail with the images you got. You will start in a very basic mode, then you'll add some operations that will improve the quality of the final result.

Start ISIS software. You should have this window:



In the top of the window, you have several tabs (General, Instruments...).

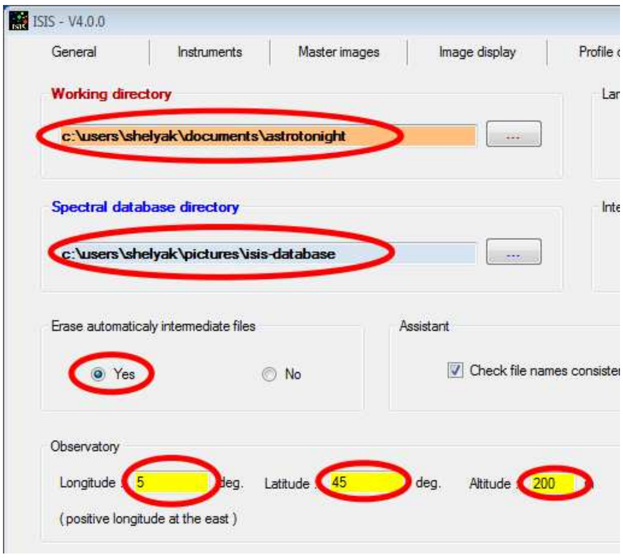
Click on the last one: Setup. This is where you can define general parameters for the software:



In this configuration panel, you must give following informations:

- Working directory (the famous *AstroTonight*),
- The Spectral database directory (where you have installed the database file),
- Select Yes in the area "Erase automatically intermediate files": we don't need to keep the temporary files.
- The information regarding your Observatory- longitude, latitude and altitude,

The result should be similar to this window:



4.2.1 First step: basic data reduction

Go back to the tab "General". Fill the following parameters in the main window:
In the Images parameters area:

- Generic name of the Object: Sun- (without the index),
- Number of Object images (3): you can get it automatically by clicking on the small button beside the cell "Number",
- Offset file name: Offset,
- Dark file name: Dark60,
- Flat file name: Flat20,
- Calibration file name: Neon60,

In the General parameters area:

- Pixels size: 6,45μm (this is for the Atik 314L+ camera),
- Remove the cosmetic file name (the default value is cosme),
- Select the option "Sky not removed": in our case, the sun light fulfill the slit, and we don't have the information for the sky background,

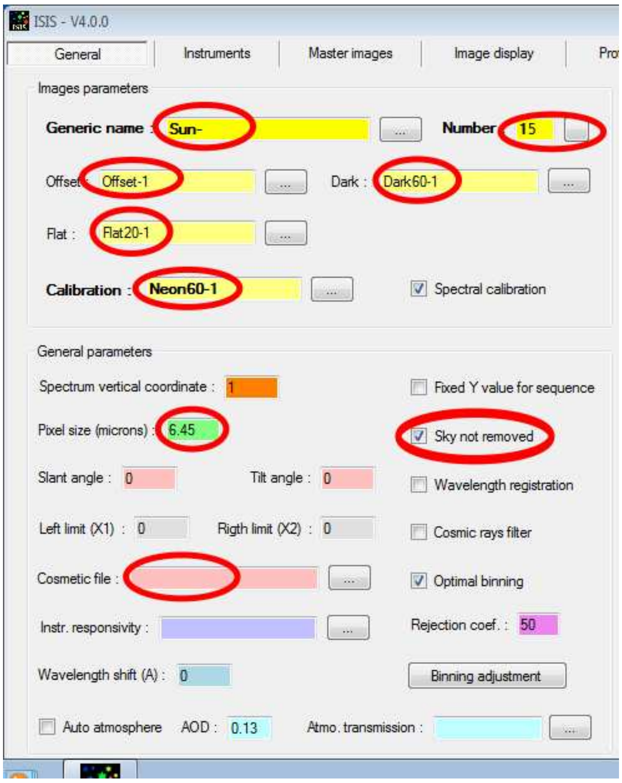
In Spectral calibration area

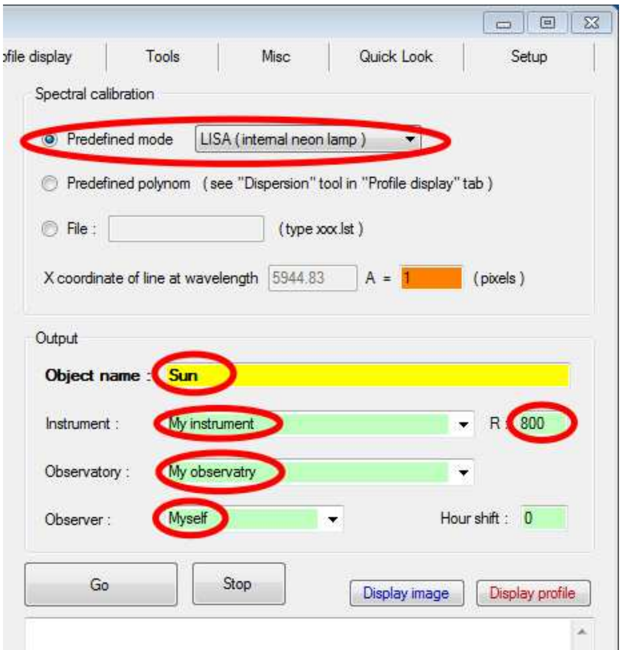
- Select "Predefined mode", and choose the option "LISA (internal neon lamp)"

In the Output area (these data are not required for the data reduction, but they will be added in the resulting file's header):

- Object name: Sun,
- Instrument: Give the name of your own instrument, with details. For instance, LISA_247 - C11 F_6 - Atik314L+,
- R: Indicate the typical resolution for your instrument. For the LISA, we consider it is R=1000,
- Observatory: Give the name of your observation place,
- Observer: Give your name,

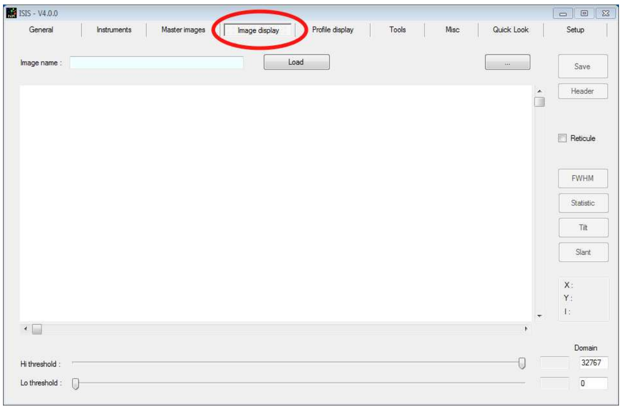
At the end, you should have these data in the window:



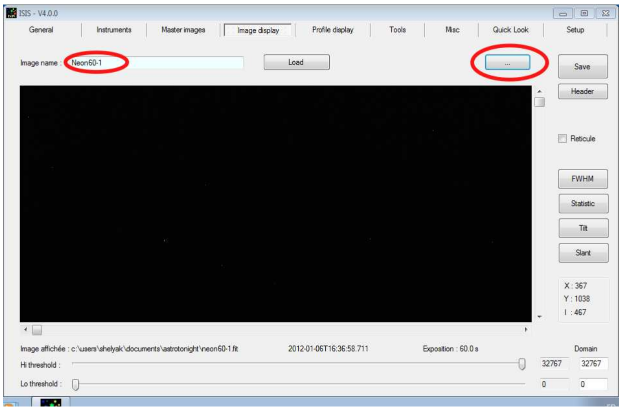


At this stage, you need to give one more information to ISIS, for wavelength calibration. You can see that there are two orange cells in the window, with “Spectrum vertical coordinate” (General parameters) and “X coordinate of line at wavelength 5944,83A” (Spectral calibration). This cells must be filled to tell ISIS where is roughly the spectrum in the image. To do this, we need to look at the neon image.

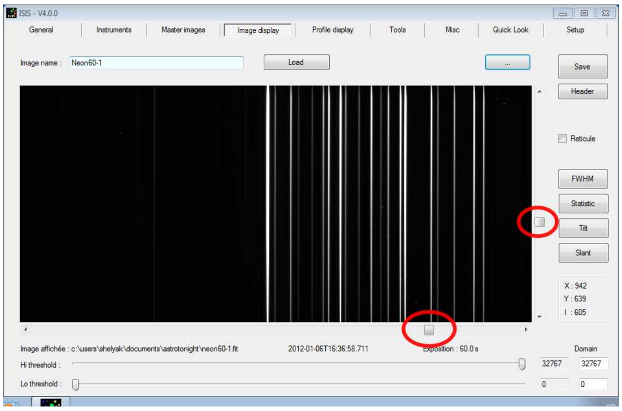
Go to the tab “Image display”:



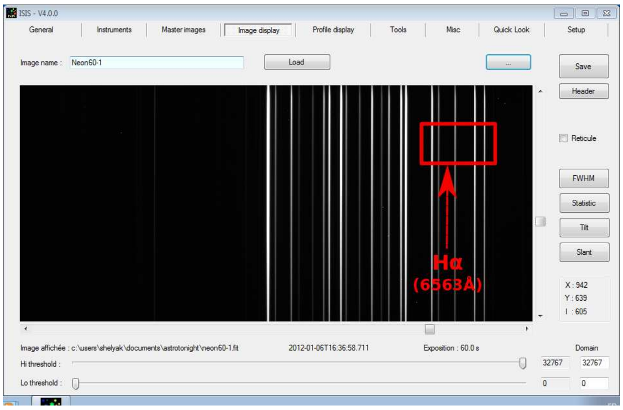
Click on button “...”, to choose the file. Select Neon60. You will - probably - have a black image:



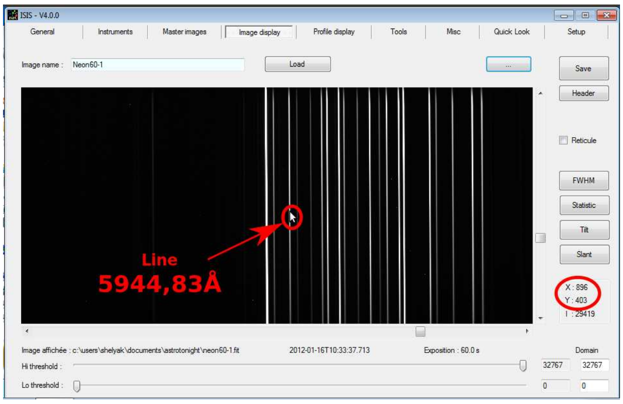
It is black, because the image is much bigger than the screen, and the neon spectrum is not in the default displayed area. Use both cursors around the image to see the spectrum:



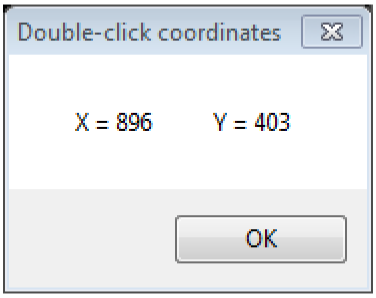
With the experience, you will be soon able to recongize this typical neon pattern by yourself. For instance, there is a group of 5 lines on the right of the image which are typical of the Hα area:



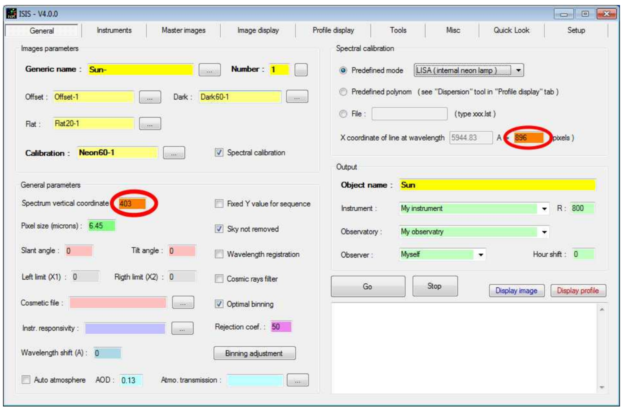
In this image, we must identify the line at 5944,83Å. This is the line shown in this image:



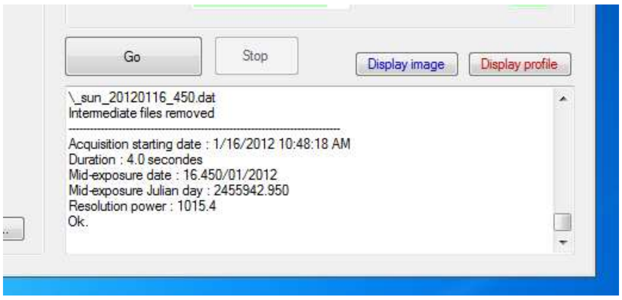
Double click on this line, in the middle of the spectrum (vertically). You will get a small window showing the position you clicked. This is the information you need:



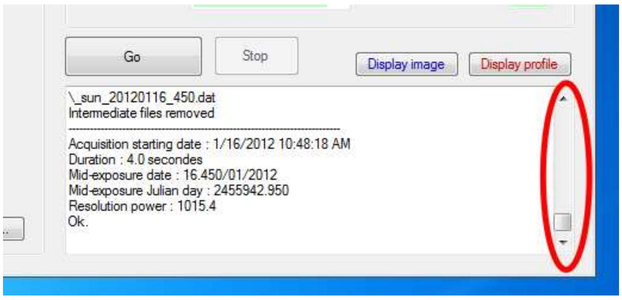
Record these values, and go back to the General tab. Copy the values in the two orange cells:



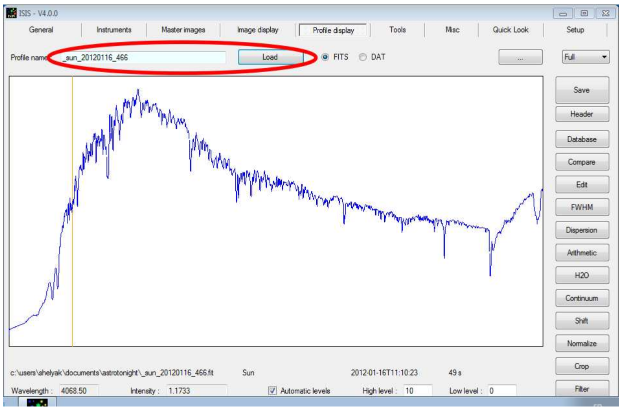
Now, launch the data reduction by clicking the Go button (bottom right of the General tab). You will see that all operations are described in the console area. It takes some seconds, and at the end you should have this message:



You can look at the full log by moving the cursor on the right of the console:



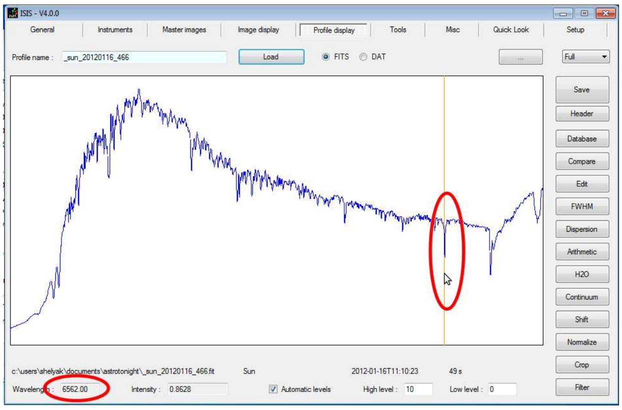
When the reduction is finished... where is the result ? It is accessible in the Profile Display tab - or you can also go directly there by clicking on the "Display profile", right above the console. The file name has been automatically filled with the final spectrum profile. You just have to click on the Load button to display it:



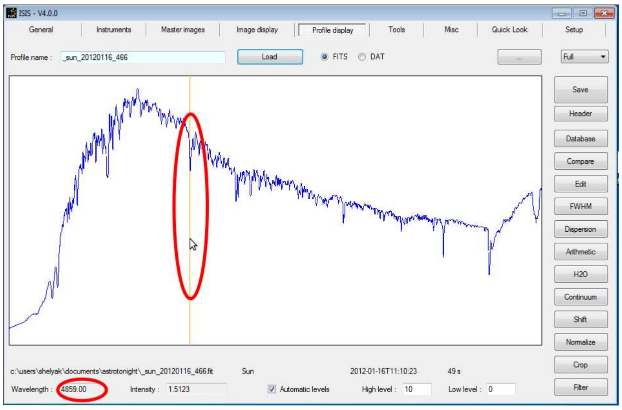
This is your first spectrum - congratulations !

The spectrum has been saved on the hard disk under the name shown in the file name field above. You can save it with an other name by clicking on the Save button. and choose the name you want.

Let's look in detail at this profile. If you move the cursor along the profile, you will see in the left bottom the wavelength and intensity for each pixel. We can look for some typical spectral lines visible in the Sun: Hα is at 6563Å. This is the first "Balmer" line. It is one of the deepest lines in the Sun:



The second Balmer line, Hβ is at 4861Å. This is an other deep line, on the left (blue) part of the spectrum:

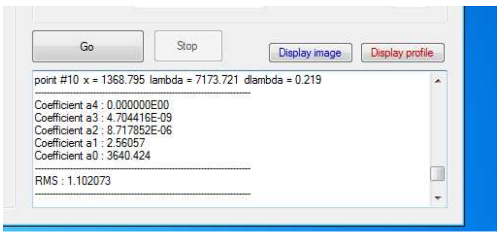


You can scan the Sun spectrum to check that all lines are properly calibrated. You can also check that spectrum starts below 4000Å and goes up to more than 7000Å. This is compliant to LISA spectral range.

> Keep in mind that ISIS has made the calibration of the spectrum, based on the neon image you gave it, and the position of the 5944,83Å line. If you had given wrong data, calibration would have been bad.

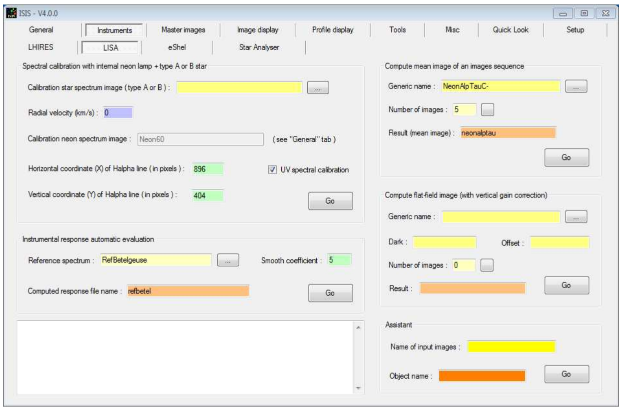
4.2.2 Second step: Improving wavelength calibration

So far, the calibration of the spectrum has been made with default LISA parameters recorded in ISIS. In the log window, you can see the accuracy of the calibration (RMS):



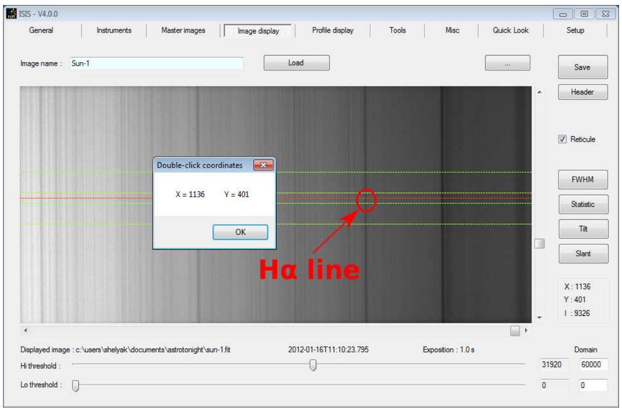
The value of 1.10 is the mean error between theoritical lines position and actual ones. In this case, it means that calibration error is around 1Å. You can improve this - you can improve this by a factor of 3.

Go to the Instrument / LISA tab:

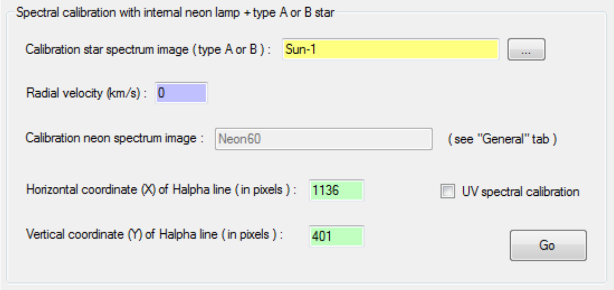


Focus on the area "Spectral calibration with internal neon + type A or B star". As you can see in the neon spectrum, most of lines ar on the red part. Only few lines appear in blue part, with long exposure time (ie 60 seconds or more). A good wavelength calibration requires to have lines well dipatched all along the visual range. To complete the neon spectrum, ISIS can use a star spectrum. Ideally, it must be a hot star (A or B type), because these star have only few deep lines. But for the moment, you only have a Sun spectrum... you'll deal with it.

Fill the field "Calibration star spectrum image (type A or B)", with the Sun-1 imge. Unselect "UV spectra calibration". Fill the Hα coordinates. To get these coordinates, you must look at Sun-1 image, and recognize Hα line (see image below). Double click on the line - you'll get a small window with coordinates:

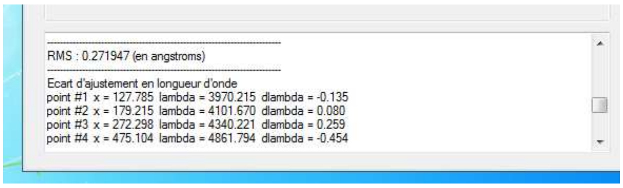


You will have this:



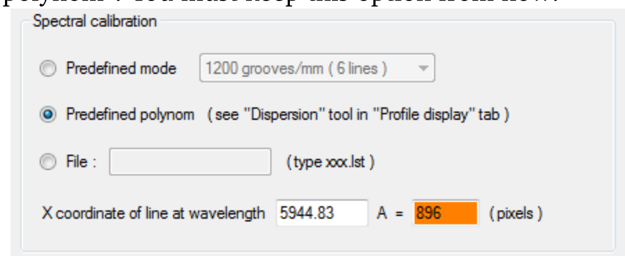
Note that you cannot change the file name for "Calibration neon spectrum image". This file name is given in the General tab. In fact, when you run the precise calibration calculation in Instrument / LISA tab, ISIS will restart the whole data reduction, with the parameters defined in the General tab. In this case, ISIS will base its calculation on two different calibration images: the neon one, and the Sun one - and it will combine the results.

Click on Go button. The calculation takes some seconds. You can see the result in the log window. When calculation is finished, you can look at the calculation accuracy:



In this case, RMS is now 0.27 Å: you've a significant improvement (initial value was 1.1Å).

A new calibration polynom is now recorded: it will replace from now the ISIS default value. In the General tab, you can see that the Spectral calibration option has been automatically changed to "predefined polynom". You must keep this option from now:

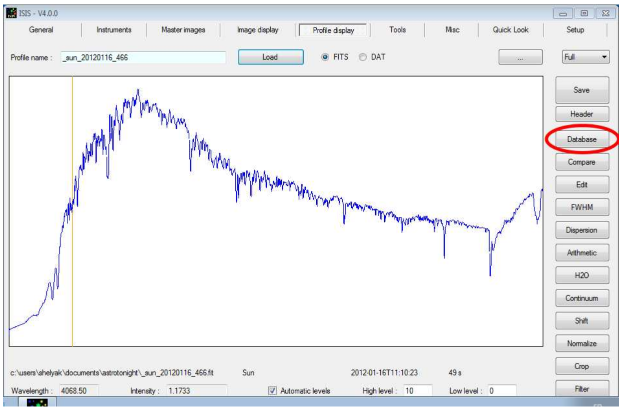


Calibration calculation.
Wavelength calibration consists in calculating the matching wavelength for each spectrum pixel. This is done with a polynom (up to degree 4), because dispersion is not linear. The principle is to identify some known lines in the spectra, and use them to fit the best possible polynom.

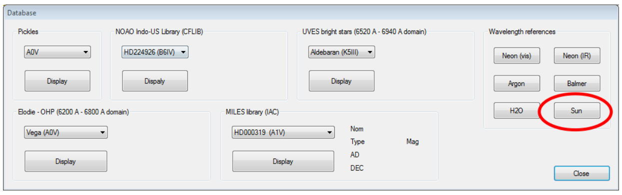
To complete this operation, you must re-run the data reduction with this new configuration - in the General tab, simply click on Go button. The result will be very similar to initial one (the calibration error is too small to be visible), but it is really improved.

4.2.3 Third step: Correcting the Instrumental Response curve

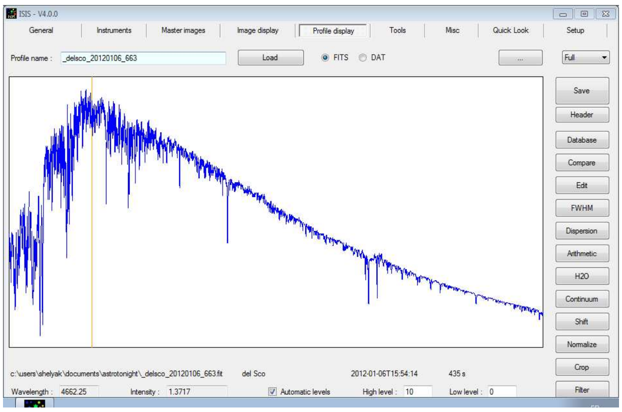
You can see properly the lines in the profile, and you've a good wavelength calibration. But what about the general profile of the Sun's spectrum ? In the ISIS database, there is a catalog solar spectrum. You can compare it to your own result. In the Profile display tab, there is a list of buttons on the right. Click on the Database button:



You will get a new window:



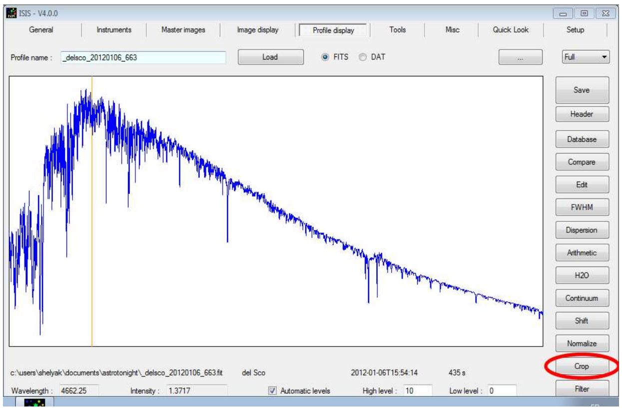
You can see several catalogs. Take some time to visit them, but you may focus on the Sun spectrum, available on the right of the panel. If you click on the Sun button, you will load the reference spectrum of the Sun in the Profile display window. Close the database window, and look at this new profile:



It is significantly different than what you get. What happens ? Several things. Firstly, the spectral range is not the same: your spectrum covers a little bit more than 4000Å to 7000Å. The above spectrum covers from 3500Å to more than 10000Å. Secondly, your spectrum is not (yet) corrected from Instrumental Response.

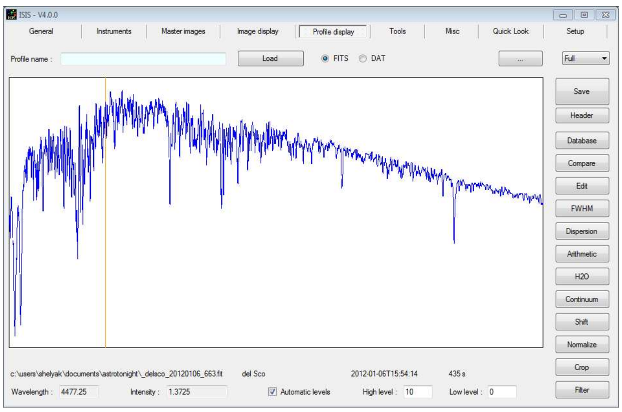
Instrumental Response curve.
The spectrograph is a combination of optical elements (lenses, mirror, CCD chip...). Each of them has its own sensitivity vs the wavelength. For instance, a CCD chip has low sensitivity in Blue, but very good in Red, even in near infrared (NIR). At the end, the whole instrument has a global sensitivity, and you can establish a Response curve: this is the profile of the instrument. You will divide the result by this curve to get the actual spectrum of the observed object.

You will now build your Instrumental Response curve. Start by cropping the Sun Reference spectrum. In the Profile display tab, there is a Crop button. Click on it:

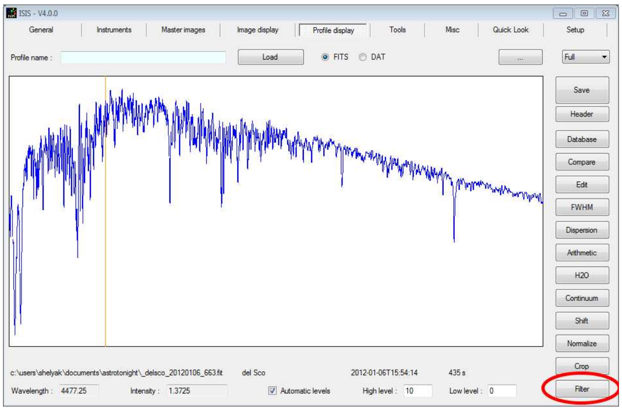


You will get a small window asking for cropping limits. Type 3900Å to 7100Å, and click on Applied:

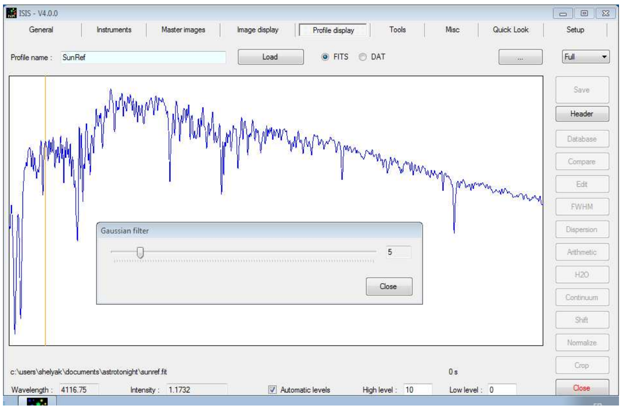
Then, you will get the same spectrum, but in a smaller range:



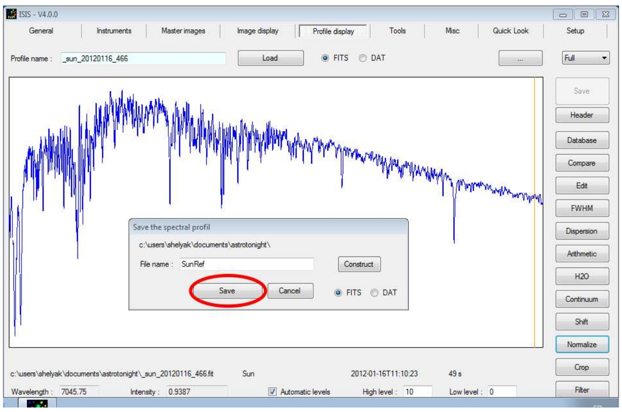
The Sun spectrum is very rich: there is many lines in it. So many, that it is difficult to see the continuum of the star. During the night, you'll use hot stars for this operation: you will see that hot star has a very continuous spectrum, with only few deep lines. To compensante this issue, we recommand to filter the spectrum at this stage. Click on the Filter button, in bottom part of the window:



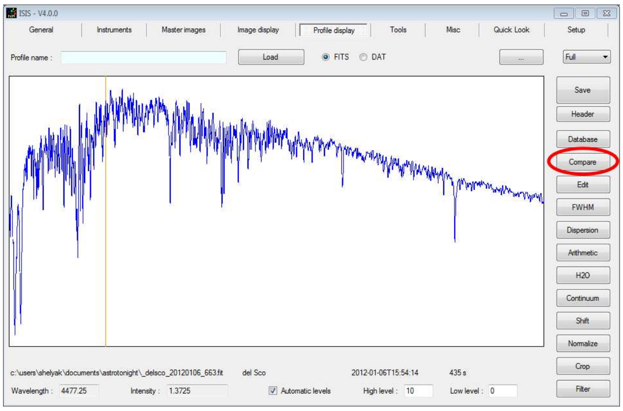
A new panel appears, with a cursor that make the filtering more or less important. Move this cursor, and see the effet (the spectrum is smoothed). A good value for the filter value is 5:



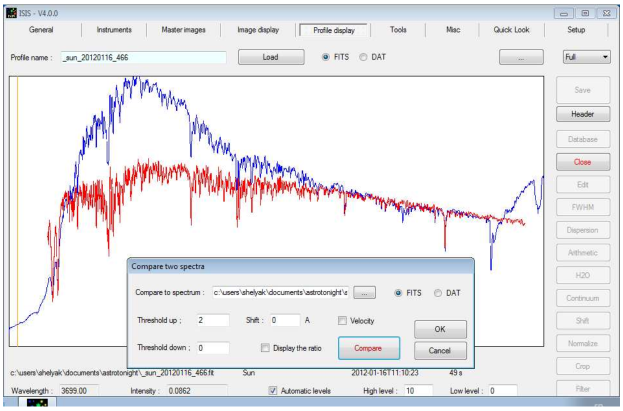
This is the reference spectrum you will use to calculate your Instrumental response. Save this file - for instance with name RefSun (in fits format). To do it, click on button Save, and fill the required field:



You can compare both spectra (the reference one and the one you acquired). Click on the Compare button on the left of the window:

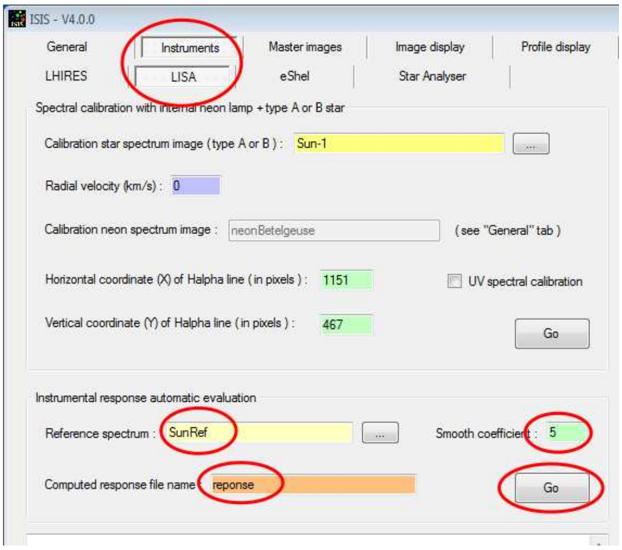


You will see a new panel, in which you can select the spectrum you want to compare. Select your own Sun spectrum. Keep all other fileds and click on Compare:



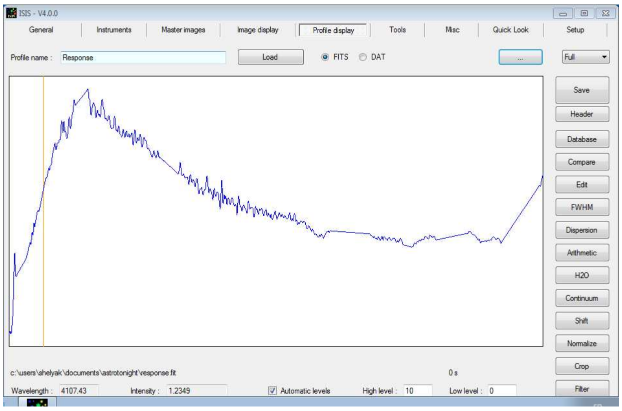
You can see that both spectra have not the same general shape (this is because of the response curve), but all major lines are perfectly aligned - this confirms visually that your spectrum is properly calibrated.

Now, go to the Instrument / LISA tab, and in the bottom left area, give the Reference file name (SunRef in your case), and give a name for the spectral resposne curve - for instance Response (it will be saved in FITS format, again). Give a smooth coefficient (to eliminate sharpest details in the profile). Starting value can be 10. Finally, click on Go button:

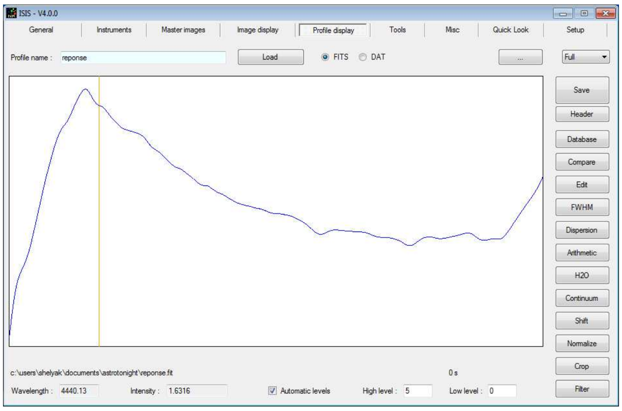


Calculating the response curve is a simple division between the Sun observation and the Sun reference spectrum, but in ISIS process, the observed sun is recalculated - to ensure the process is correct, double check that you didn't change the parameters in the General tab.

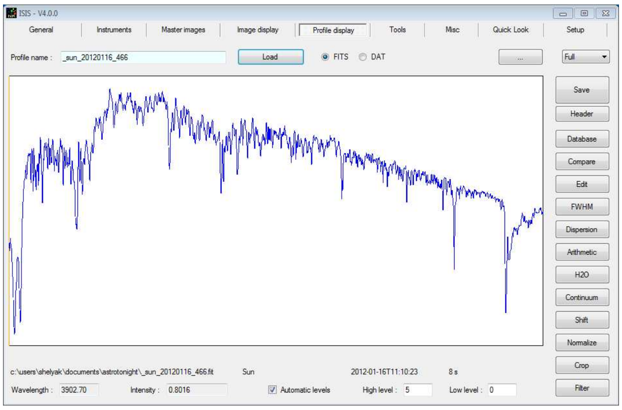
You can now see the Response curve profile in the Profile display tab (the file name is automatically-loaded):



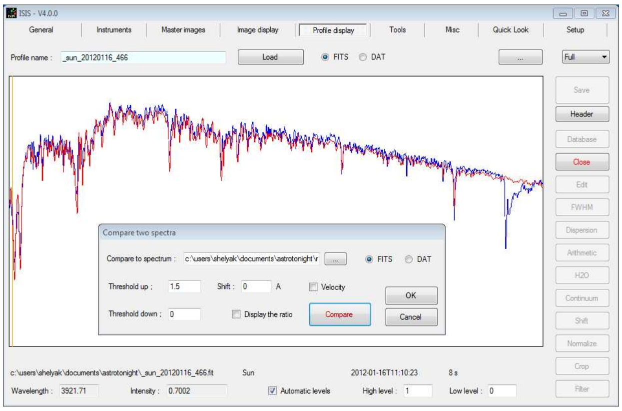
The remaining noise in the profile is due to the number of lines in Sun spectrum. This will not exist anymore on stars - you will take a hot star spectrum to build the Instrumental response. But in the Sun case, it is better to increase the smooth coefficient (in the below image, smooth coefficient is 50), to have something similar to this:



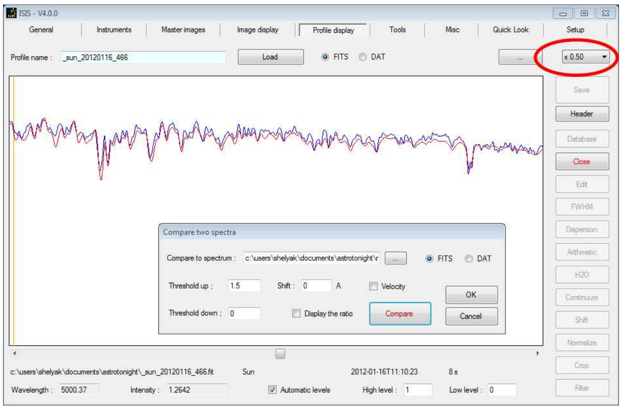
When this Response curve is done, you must re-run the data reduction with this new element. Go back to General tab. The field "Instr. responsivity" has been filled with the name you defined in previous step. Click on Go button, and look at the result in Display tab:



This is very similar to the Sun spectrum found in the database... You can again make the comparison:



To better see the details, you can zoom in the profile using the selector on top right of the window:



You can see that all details in the spectrum are not noise, but real signal... this is the magics of spectroscopy.

You have now fully processed your first Sun spectrum. To do this, you've gone through several steps: first basic calculation, then improved wavelength calibration, then Instrumental Response correction. You will use the same path for the stars spectra. But the accurate calibration and the Instrumental Response curve can be done only once during the observing session: it does not change if you don't change the observing conditions. Then, you have to take some time for the first data reduction (in real life, it takes only few seconds, if you have the right images), but it is quicker for the next observations.

5 Install the LISA Pack on the telescope

You are now familiar with your LISA Pack, and you know what images you need to make a successful observation. It is time to go to the telescope, and prepare the instrument for the first observing night.

Ideally, the installation must be done during daylight: it is more comfortable, and you don't lose any observing time. But before doing the installation itself, you must first check that your telescope is properly collimated and the mount is polar aligned. If you install the telescope the same day as the LISA Pack, it is preferable that you check the telescope itself before mounting the LISA Pack onto telescope.

LISA Pack is optimized for a F/5 beam. If your telescope is far from this value (Schmidt-Cassegrain telescope are usually around F/10) , we recommend to make an optical adaptation, to make it as close as possible to F/5. If you don't make this adaptation, it will work (you'll have a spectrum !), but you will lose light and efficiency.

5.1 Mechanical installation

Install the LISA Pack on your telescope. The mechanical interface can differ from one instrument to the other, but the simplest way is usually to mount the spectrograph in the 2" eypiece holder. In the below image, the LISA Pack is mounted with a focal reducer, to change the telescope F/D from 10 to 6.3.

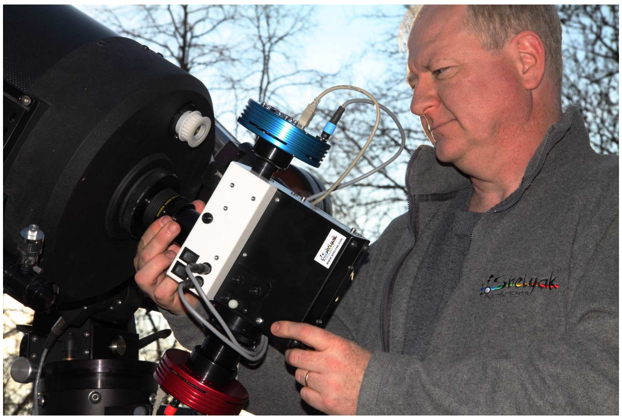
Choose the orientation of the spectrograph in such a way that a movement of the mount along AD axis will move the image along the slit.

> When you align the spectrograph to telescope movements, you make pointing and guiding much easier: movements of the telescope in AD and DEC will be seen in the guiding image as horizontal and vertical.

Tighten securely the instrument.

> Seeing spectrograph falling down on the groundis is not a good experience. We highly recommend to attach the spectrograph on the telescope with a wire or cable.

Install all the cables of the LISA Pack (power supply, USB) and telescope.



Install them in such a way that the telescope can move in any direction without tearing out cables, or even pulling them out - it would affect immediately the guiding.

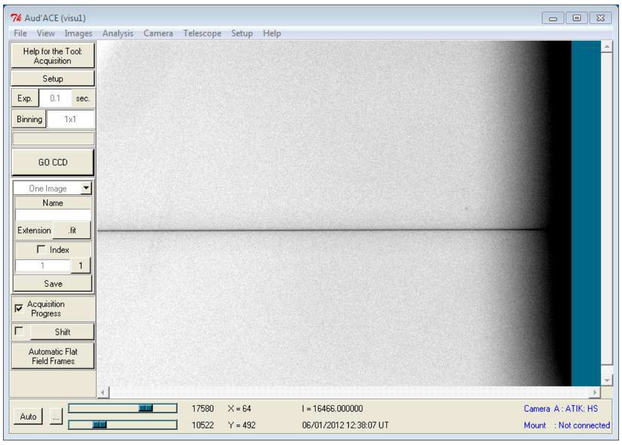
5.2 Balance the mount

Because of the spectrograph wheight, balanced position can be very different from usual configurations you know - specially for small instruments. You can have to add extra-wheight to balance the instrument.

> Attach all the cables together in one of the tripod leg, with enough free length for the movement of the spectrograph. Check that in no positions cables will be on the ground. Proceeding this way, the cable wheight embbeded by the mount is always the same, and balancing is not affected. In some cases, this helps a lot to achieve a good guiding.

5.3 Focus the telescope

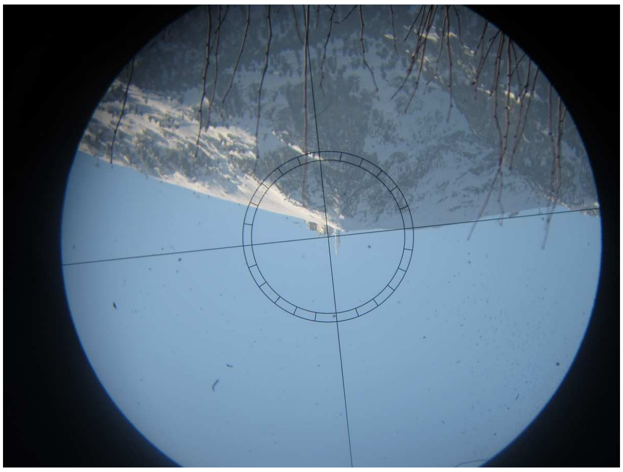
Switch on the PC, and start AudeLA software (or the guiding software you prefer) to get guiding image. You should get something like that - the slit must be sharp and horizontal (if not, refer to 3.3.2):



Now, we have to focus the telescope to see an object at the infinite. We could wait for the night (and stars) to do it, but it can be difficult to do in some conditions (star are faint, and in the beginning, we don't know the position of the focusing - even roughly). We must be able to scan all focus range quickly to find the appropriate position. To do that, look for some object as far as possible in the landscape (mountain, tree, urban light...). Lauch acquisition in continuous mode, and change the focus until you see the object (in below image, we see the Chamrousse station on top of the mountain close to Grenoble):

5.4 Align the finder

To make easy the object finding during the night, you have to align your finder to the telescope. In the previous step (focusing), you choosed an object at the infinite. Once you see this object in your guiding image, tune the finder to see it in the center of the finder too.



> This operation is very dependant on your setup. But take the opportunity of this step to make easy to find your object during the night. The guiding is not that big, and you can lose a lot of time turning around your target. The time you spend during the day to make this alignment will save a lot of time during the night.

5.5 Connect the telescope to the PC

We will not go in detail of the autguiding in this document: it is highly dependant on your own setup. But most telescopes can be controlled by the PC, for pointing, guiding, and even autoguiding. If you have this capability in your setup, this is the right moment to activate the connexion.

The instrument is now ready for observing.

5.6 Last check...

A good way to check that everything is Ok, you can launch a full serie of images: Sun, neon, flat and dark frames. Double check that images are properly stored in the *AstroTonight* directory. Check that all images are Ok (focus, orientation...).

You can now wait for night and stars...

6
First observing night

We highly recommend to start your first observing session at least two hours before the night. There are some operations to do before starting observation itself:

- Switch-on acquisition camera and its cooling,
- Prepare *AstroTonight* directory,
- Open a log file to record all events of the night,
- Check & setup session parameters of the software,
- Select the targets,
- Focus the telescope.

The goal of the observation is to make your first quality star spectrum, including data reduction. Compared to the Sun observation you made recently, there are some differences:

- Star spectra require telescope pointing and guiding,
- Acquisition camera must be cooled down, to allow long exposures
- Because of the low light level, you will run not only one image of each type (star, dark , flat, neon...), but series of images,
- The star spectrum is not anymore a large band (Sun light covered all slit), but a single line of some pixels wide.
- You will need to start with a hot star observation (A or B type), to get a good Instrumental Response curve.

> Why taking several images ? There are several reasons. It improves the Signal to Noise Ratio (SNR), by averaging the noise. It can prevent for saturing images by splitting exposure time. It can prevent for any bad event during acquisition (cloud or guiding issue, for instance): you can elminate only some images, and keep the good ones. A good figure is around 5-10 images per target and single exposure time up to 15 minutes.

6.1 Prepare your observing session

6.1.1 Start the equipment

Switch-on all the instrument elements: telescope, cameras, PC.

Start AudeLA software, and select the Atik 314L+ camera.

Start the camera cooling. It requires some time ($\sim$15 minutes) to stabilize.

> Keeping the CCD at the same temperature during all night is important to prevent any thermal effect in the images - remember that dark frames are very dependant on the CCD chip temperature.

6.1.2 Clean-up *AstroTonigh* directory

Archive and erase all data in the working directory (called *AstroTonight* so far). This directory must be empty at the beginning of the night. Open a log file for the night.

6.1.3 Select your targets

Take some time to choose your first targets. We suggest to observe easy stars: bright, high in the sky. Of course, you can prepare a list of target - in this case, you can choose stars of several spectral types, to see the differences. You can also add a Be star (like gam Cas, if it is visible for you). you'll see how fun these objects are.

You also have to choose a reference star (A or B type), to get the Instrumental Response curve. This is the first star you will observe. This star must also be bright, and high in the sky (more than 30° above horizon). You will find in figure 6.1 a list of potential targets, classified by the position in the sky. All the details (coordinates, type, and so on) of these stars are detailed in figures 6.2, 6.3 and 6.4.

<table>
<tr><th></th><th>+60° / +90°</th><th>+30° / +60°</th><th>0° / +30°</th><th>0° / –30°</th><th>–30° / –60°</th><th>–60° / –90°</th></tr>
<tr><td>0h–1h</td><td rowspan="6">HR 922 – 5.8 – B9V</td><td rowspan="3">7 Tri – 5.2 – A0V
62 And – 5.3 – A0V</td><td rowspan="2">4 Ari – 5.8 – B9.5V</td><td rowspan="2">HR 220 – 5.5 – B9V
28 Cet – 5.5 – A1V
49 Cet – 5.6 – A1V
HR 51 – 5.7 – B9V</td><td rowspan="3">HR 520 – 5.0 – A1V
HR 498 – 5.7 – A1V</td><td rowspan="6">Kap Men – 5.4 – B9V</td></tr>
<tr><td>1h–2h</td></tr>
<tr><td>2h–3h</td><td rowspan="2">tet Ari – 5.5 – A1Vn
zet Ari – 4.8 – A1V
4 Tau – 5.1 – A0Vn</td><td rowspan="2">17 Eri – 4.7 – B9Vs
rho Cet – 4.8 – A0V
28 Eri – 5.2 – A1V
HR 652 – 5.2 – B9V
HR 845 – 5.3 – A0V</td></tr>
<tr><td>3h–4h</td><td rowspan="3">ksi Aur – 4.9 – A2V
HR 1482 – 5.6 – A0V</td><td rowspan="3">HR 1835 – 5.5 – A1V
HR 1947 – 5.8 – B8V</td></tr>
<tr><td>4h–5h</td><td rowspan="2">HR 1315 – 5.2 – B9Vn
18 Ori – 5.5 – A0V
HR 1576 – 5.7 – B9V</td><td rowspan="2">HR 1621 – 4.8 – B9V
HR 1723 – 5.0 – B9V
HR 1367 – 5.3 – A0V
10 Lep – 5.5 – A0V
HR 1792 – 5.6 – A0V</td></tr>
<tr><td>5h–6h</td></tr>
<tr><td>6h–7h</td><td rowspan="6">HR 2209 – 4.7 – A0Vn</td><td rowspan="3">21 Lyn – 4.6 – A1V
11 Lyn – 5.8 – A2V</td><td rowspan="2">26 Gem – 5.2 – A2V
HR 2589 – 5.9 – B8Vn</td><td rowspan="2">tet Lep – 4.6 – A0V
HR 2244 – 4.9 – B9V
HR 2180 – 5.4 – A0V
HR 2502 – 5.6 – B9.5V</td><td rowspan="3">HR 2791 – 5.2 – A1V
HR 2940 – 5.6 – B9.5V
HR 2279 – 5.7 – B9V
HR 2345 – 5.7 – A0V</td><td rowspan="6">HR 4138 – 4.7 – A1V
HR 3370 – 5.5 – A0V
HR 2194 – 5.6 – A0V
HR 3081 – 5.7 – B9V
HR 3721 – 5.8 – A0V</td></tr>
<tr><td>7h–8h</td></tr>
<tr><td>8h–9h</td><td rowspan="2">8 Cnc – 5.1 – A1V
Lam Cnc – 5.9 – B9.5V</td><td rowspan="2">30 Mon – 3.9 – A0V
HR 3383 – 5.7 – A1V</td></tr>
<tr><td>9h–10h</td><td rowspan="3">26 UMa – 4.4 – A2V
hr 3592 – 5.7 – A2V</td><td rowspan="3">omi Hya – 4.6 – B9V
HR 4502 – 5.5 – A0V
HR 3927 – 5.7 – A0V
HR 4056 – 5.9 – B9V</td></tr>
<tr><td>10h–11h</td><td rowspan="2">53 Leo – 5.3 – A2V
7 Vir – 5.3 – A0V
69 Leo – 5.3 – A0V</td><td rowspan="2">bet Crt – 4.4 – A1V
tet Crt – 4.6 – B9.5Vn
del Sex – 5.1 – B9.5V</td></tr>
<tr><td>11h–12h</td></tr>
<tr><td>12h–13h</td><td rowspan="6">del Umi – 4.3 – A1Vn
HR 6025 – 5.4 – A0Vn
HR 4687 – 5.4 – A1V</td><td rowspan="3">81 UMa – 5.5 – A0V</td><td rowspan="2">HR 5037 – 5.6 – A2V
29 Com – 5.7 – A1V</td><td rowspan="2">47 Hya – 5.1 – B8V
3 Crv – 5.4 – A1V
HR 5167 – 5.8 – A0V</td><td rowspan="3">HR 4933 – 4.8 – A0V
HR 5489 – 4.9 – A0V
HR 4620 – 5.3 – B9V
HR 4735 – 5.5 – B9V</td><td rowspan="6">ome Oct – 5.8 – B9.5V
HR 4597 – 5.8 – B9V
HR 5786 – 5.9 – B9V</td></tr>
<tr><td>13h–14h</td></tr>
<tr><td>14h–15h</td><td rowspan="2">chi Boo – 5.2 – A2V
108 Vir – 5.6 – B9.5V</td><td rowspan="2">HR 5332 – 5.5 – A0V
4 Lib – 5.7 – B9.5V
57 Hya – 5.7 – B9V</td></tr>
<tr><td>15h–16h</td><td rowspan="3">69 Her – 4.6 – A2V
50 Boo – 5.3 – B9Vn</td><td rowspan="3">sig Ara – 4.5 – A0V
HR 6420 – 5.7 – B9V
HR 6572 – 5.7 – A0V
HR 6275 – 5.9 – B9V</td></tr>
<tr><td>16h–17h</td><td rowspan="2">gam Oph – 3.7 – A0V
iot Oph – 4.3 – B8V
78 Her – 5.6 – A1V</td><td rowspan="2">4 Sgr – 4.7 – B9V
HR 6070 – 4.7 – A0V
50 Lib – 5.5 – A0Vs</td></tr>
<tr><td>17h–18h</td></tr>
<tr><td>18h–19h</td><td rowspan="6">HR 9013 – 5.0 – A1Vn
HR 8844 – 5.8 – A0V</td><td rowspan="3">HR 7444 - 5.3 – A2V
51 Dra - 5.3 - A0Vn
7 Cyg - 5.7 - A1V</td><td rowspan="2">HR 6955 – 5.7 – A2V
HR 7086 – 5.8 – A1V
HR 6883 – 5.9 – A2V</td><td rowspan="2">lam Aql – 3.4 – B9Vn
61 Sgr – 5.0 – A2V
HR 7380 – 5.6 – B9V</td><td rowspan="3">zet CrA – 4.7 – B9.5V
HR 7223 – 5.9 – A0V</td><td rowspan="6">eta Tuc – 5.0 – A1V
phi Oct – 5.4 – A0V</td></tr>
<tr><td>19h–20h</td></tr>
<tr><td>20h–21h</td><td rowspan="2">29 Vul – 4.8 – A0V
35 Vul – 5.3 – A1V
27 Vul – 5.5 – B9V
11 Peg – 5.6 – A1V</td><td rowspan="2">tet Cap – 4.0 – A1V
lam Cap – 5.5 – A1V
17 Cap – 5.9 – A1V</td></tr>
<tr><td>21h–22h</td><td rowspan="3">iot And – 4.3 – B8V</td><td rowspan="3">HR 8366 – 5.4 – A2Vn</td></tr>
<tr><td>22h–23h</td><td rowspan="2">rho Peg – 4.9 – A1V
23 Peg – 5.7 – B9Vn
21 Peg – 5.8 – B9.5V</td><td rowspan="2">iot Aqr – 4.2 – B8V
106 Aqr – 5.2 – B9V</td></tr>
<tr><td>23h–24h</td></tr>
</table>

Figure 6.1: Reference stars (B & A type)

Name	Magn.	Sp. Type	AD	DEC	HD	SAO
10 Lep	5,5	A0V	05 31 07.62809	-20 51 49.1644	HD 36473	SAO 170506
106 Aqr	5,2	B9V	23 44 12.07893	-18 16 36.9688	HD 222847	SAO 165854
108 Vir	5,7	B9.5V	14 45 30.20425	+00 43 02.1895	HD 129956	SAO 120642
11 Lyn	5,9	A2V	06 37 38.38609	+56 51 27.1077	HD 46590	SAO 25842
11 Peg	5,6	A1V	21 47 13.96237	+02 41 10.0481	HD 207203	SAO 127060
17 Cap	5,9	A1V	20 46 09.98789	-21 30 50.5188	HD 197725	SAO 189667
17 Eri	4,7	B9Vs	03 30 37.05823	-05 04 30.5239	HD 21790	SAO 130528
18 Ori	5,5	A0V	05 16 04.13416	+11 20 28.8737	HD 34203	SAO 94426
21 Lyn	4,6	A1V	07 26 42.85187	+49 12 41.4907	HD 58142	SAO 41764
21 Peg	5,8	B9.5V	22 03 19.03215	+11 23 11.5765	HD 209459	SAO 107625
23 Peg	5,7	B9Vn	22 05 34.67418	+28 57 50.3193	HD 209833	SAO 90217
26 Gem	5,2	A2V	06 42 24.32722	+17 38 43.1118	HD 48097	SAO 96015
26 UMa	4,5	A2V	09 34 49.43259	+52 03 05.3165	HD 82621	SAO 27298
27 Vul	5,6	B9V	20 37 04.67254	+26 27 43.0087	HD 196504	SAO 88903
28 Cet	5,6	A1V	01 06 05.14842	-09 50 21.6739	HD 6530	SAO 147606
28 Eri	5,2	A1V	03 47 39.65058	-23 52 28.8352	HD 23878	SAO 168836
29 Com	5,7	A1V	12 48 54.21284	+14 07 21.3146	HD 111397	SAO 100283
29 Vul	4,8	A0V	20 38 31.33888	+21 12 04.2467	HD 196724	SAO 88944
3 Crv	5,5	A1V	12 11 03.83904	-23 36 08.7202	HD 105850	SAO 180546
30 Mon	3,9	A0V	08 25 39.63201	-03 54 23.1178	HD 71155	SAO 135896
35 Vul	5,4	A1V	21 27 40.05720	+27 36 30.9396	HD 204414	SAO 89720
4 Ari	5,9	B9.5V	01 48 10.93603	+16 57 19.9768	HD 10982	SAO 92637
4 Lib	5,7	B9.5V	14 43 13.55130	-24 59 51.9093	HD 129433	SAO 182795
4 Sgr	4,7	B9V	17 59 47.55508	-23 48 58.0876	HD 163955	SAO 186061
4 Tau	5,1	A0Vn	03 30 24.46716	+11 20 11.1876	HD 21686	SAO 93463
47 Hya	5,2	B8V	13 58 31.14642	-24 58 20.0979	HD 121847	SAO 182134
49 Cet	5,6	A1V	01 34 37.77884	-15 40 34.8979	HD 9672	SAO 147886
50 Boo	5,4	B9Vn	15 21 48.57532	+32 56 01.3005	HD 136849	SAO 64656
50 Lib	5,5	A0Vs	16 00 47.63255	-08 24 40.8864	HD 143459	SAO 140897
51 Dra	5,4	A0Vn	19 04 55.16590	+53 23 47.9627	HD 178207	SAO 31371
53 Leo	5,3	A2V	10 49 15.43057	+10 32 42.7270	HD 93702	SAO 99305
57 Hya	5,8	B9V	14 47 57.55833	-26 38 46.1560	HD 130274	SAO 182883
61 Sgr	5,0	A2V	19 57 57.03129	-15 29 29.3554	HD 188899	SAO 163141
62 And	5,3	A0V	02 19 16.79595	+47 22 47.9081	HD 14212	SAO 37948
69 Her	4,6	A2V	17 17 40.25427	+37 17 29.3995	HD 156729	SAO 65921
69 Leo	5,4	A0V	11 13 45.55346	-00 04 10.2202	HD 97585	SAO 118731
7 Cyg	5,8	A1V	19 27 25.95887	+52 19 13.5737	HD 183534	SAO 31673
7 Tri	5,2	A0V	02 15 56.28521	+33 21 32.0226	HD 13869	SAO 55397
7 Vir	5,4	A0V	11 59 56.91293	+03 39 18.7141	HD 104181	SAO 119156
78 Her	5,7	A1V	17 31 49.57878	+28 24 26.9981	HD 159139	SAO 85182
8 Cnc	5,1	A1V	08 05 04.48834	+13 07 05.5757	HD 66664	SAO 97542
81 UMa	5,6	A0V	13 34 07.30510	+55 20 54.3673	HD 118214	SAO 28803

Figure 6.2: List of reference stars (1/3)

Name	Magn.	Sp. Type	AD	DEC	HD	SAO
bet Crt	4,5	A1V	11 11 39.48783	-22 49 33.0593	HD 97277	SAO 179624
chi Boo	5,3	A2V	15 14 29.15853	+29 09 51.4577	HD 135502	SAO 83729
del Sex	5,2	B9.5V	10 29 28.70222	-02 44 20.6862	HD 90882	SAO 137600
del UMi	4,3	A1Vn	17 32 12.99671	+86 35 11.2584	HD 166205	SAO 2937
eta Tuc	5,0	A1V	23 57 35.07819	-64 17 53.6293	HD 224392	SAO 255609
gam Oph	3,8	A0V	17 47 53.55973	+02 42 26.2000	HD 161868	SAO 122754
HR 1315	5,2	B9Vn	04 14 36.23274	+10 00 41.0529	HD 26793	SAO 111680
HR 1367	5,4	A0V	04 20 39.01323	-20 38 22.6434	HD 27616	SAO 169354
HR 1482	5,6	A0V	04 41 24.12862	+48 18 03.1629	HD 29526	SAO 39688
HR 1576	5,8	B9V	04 55 50.15389	+15 02 25.0044	HD 31373	SAO 94212
HR 1621	4,9	B9V	05 01 25.58052	-20 03 06.9147	HD 32309	SAO 169981
HR 1723	5,0	B9V	05 15 24.37202	-26 56 36.6324	HD 34310	SAO 170238
HR 1792	5,6	A0V	05 24 28.48967	-16 58 32.8063	HD 35505	SAO 150416
HR 1835	5,6	A1V	05 28 15.33533	-37 13 50.7485	HD 36187	SAO 195887
HR 1947	5,8	B8V	05 38 43.52561	-40 42 26.3223	HD 37717	SAO 217450
HR 2180	5,5	A0V	06 08 57.86539	-22 25 38.6780	HD 42301	SAO 171293
HR 2194	5,7	A0V	06 06 09.38182	-66 02 22.6387	HD 42525	SAO 249448
HR 220	5,6	B9V	00 48 01.06468	-21 43 20.9909	HD 4622	SAO 166585
HR 2209	4,8	A0Vn	06 18 50.77630	+69 19 11.2310	HD 42818	SAO 13788
HR 2244	5,0	B9V	06 15 44.88569	-13 43 06.2928	HD 43445	SAO 151283
HR 2279	5,8	B9V	06 19 40.95612	-34 23 47.7288	HD 44323	SAO 196686
HR 2345	5,8	A0V	06 24 13.84199	-60 16 52.7697	HD 45557	SAO 249535
HR 2502	5,7	B9.5V	06 46 39.01559	-10 06 26.4968	HD 49147	SAO 151911
HR 2589	5,9	B8Vn	06 56 25.83302	+09 57 23.6674	HD 51104	SAO 96294
HR 2791	5,2	A1V	07 18 33.51266	-39 12 37.0314	HD 57240	SAO 197836
HR 2940	5,7	B9.5V	07 36 43.91969	-48 49 48.6020	HD 61391	SAO 218841
HR 3081	5,8	B9V	07 49 40.99310	-66 11 45.5020	HD 64484	SAO 249978
HR 3370	5,5	A0V	08 27 16.75574	-70 05 36.5444	HD 72337	SAO 250235
HR 3383	5,8	A1V	08 34 01.61816	-02 09 05.5830	HD 72660	SAO 136044
HR 3592	5,7	A2V	09 04 00.39988	+54 17 01.9811	HD 77309	SAO 27105
HR 3721	5,9	A0V	09 17 27.56922	-74 44 04.5265	HD 80950	SAO 256600
HR 3927	5,7	A0V	09 54 51.23170	-50 14 38.2572	HD 86087	SAO 237483
HR 4056	6,0	B9V	10 18 28.24411	-41 40 06.5599	HD 89461	SAO 221948
HR 4138	4,7	A1V	10 30 20.12710	-71 59 34.0602	HD 91375	SAO 256722
HR 4502	5,5	A0V	11 41 19.79057	-43 05 44.3987	HD 101615	SAO 222960
HR 4597	5,9	B9V	12 02 37.69286	-69 11 32.2330	HD 104600	SAO 251699
HR 4620	5,3	B9V	12 08 14.71198	-48 41 32.9487	HD 105416	SAO 223235
HR 4687	5,5	A1V	12 18 49.98448	+75 09 38.0207	HD 107193	SAO 7540
HR 4735	5,6	B9V	12 26 51.69000	-32 49 48.4379	HD 108323	SAO 203477
HR 4933	4,8	A0V	13 03 33.30528	-49 31 38.1518	HD 113314	SAO 223870
HR 498	5,7	A1V	01 42 02.99377	-36 49 56.2995	HD 10538	SAO 193261
HR 5037	5,7	A2V	13 21 41.64387	+02 05 14.0741	HD 116160	SAO 119899
HR 51	5,8	B9V	00 14 54.51542	-09 34 10.4503	HD 1064	SAO 128660
HR 5167	5,8	A0V	13 45 36.89030	-26 06 57.6301	HD 119752	SAO 181931

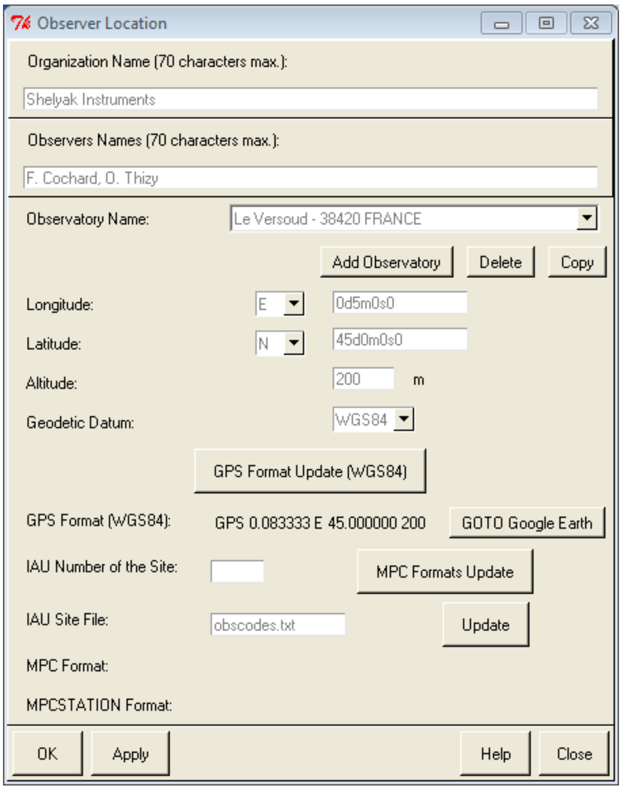
Figure 6.3: List of reference stars (2/3)

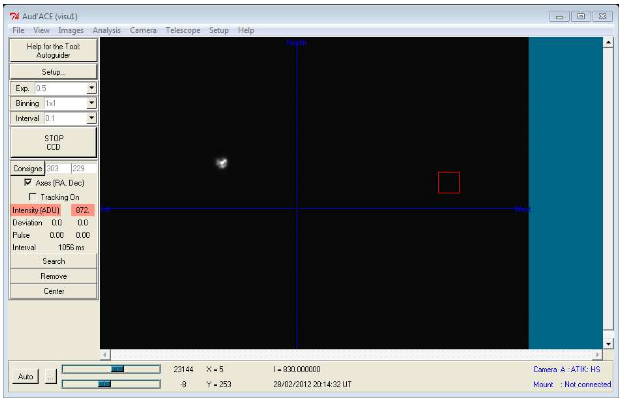
Name	Magn.	Sp. Type	AD	DEC	HD	SAO
HR 520	5,0	A1V	01 46 06.26346	-53 31 19.3279	HD 10939	SAO 232520
HR 5332	5,5	A0V	14 15 24.08494	-18 12 02.4879	HD 124683	SAO 158448
HR 5489	4,9	A0V	14 44 59.20161	-35 11 30.5745	HD 129685	SAO 205899
HR 5786	5,9	B9V	15 41 54.68382	-76 04 55.0619	HD 138867	SAO 257310
HR 6025	5,4	A0Vn	16 06 19.67620	+67 48 36.4805	HD 145454	SAO 16962
HR 6070	4,8	A0V	16 18 17.90017	-28 36 50.4768	HD 146624	SAO 184301
HR 6275	5,9	B9V	16 56 28.76899	-52 17 01.4884	HD 152527	SAO 244285
HR 6420	5,7	B9V	17 18 47.82907	-44 07 47.0906	HD 156293	SAO 227813
HR 652	5,3	B9V	02 12 54.46962	-30 43 25.7732	HD 13709	SAO 193573
HR 6572	5,8	A0V	17 41 16.24072	-46 55 18.5858	HD 160263	SAO 228279
HR 6883	6,0	A2V	18 22 35.31853	+12 01 46.8522	HD 169111	SAO 103648
HR 6955	5,8	A2V	18 31 04.44914	+16 55 42.8042	HD 170878	SAO 103800
HR 7086	5,9	A1V	18 48 53.38616	+19 19 43.3984	HD 174262	SAO 104129
HR 7223	6,0	A0V	19 06 55.60705	-48 17 56.9176	HD 177406	SAO 229493
HR 7380	5,7	B9V	19 26 56.48284	-29 44 35.6170	HD 182681	SAO 188127
HR 7444	5,3	A2V	19 34 41.25930	+42 24 45.0369	HD 184875	SAO 48601
HR 8366	5,5	A2Vn	21 56 22.76964	-37 15 13.1601	HD 208321	SAO 213414
HR 845	5,4	A0V	02 49 54.18207	-27 56 31.1374	HD 17729	SAO 168082
HR 8844	5,9	A0V	23 14 37.10616	+74 13 52.5743	HD 219485	SAO 10664
HR 9013	5,0	A1Vn	23 47 54.77158	+67 48 24.5072	HD 223274	SAO 20853
HR 922	5,9	B9V	03 07 18.99782	+64 03 27.3379	HD 19065	SAO 12608
iot And	4,3	B8V	23 38 08.20130	+43 16 05.0649	HD 222173	SAO 53216
iot Aqr	4,3	B8V	22 06 26.22742	-13 52 10.8615	HD 209819	SAO 164861
iot Oph	4,4	B8V	16 54 00.47151	+10 09 55.2982	HD 152614	SAO 102458
kap Men	5,5	B9V	05 50 16.78640	-79 21 40.9076	HD 40953	SAO 256248
ksi Aur	5,0	A2V	05 54 50.78082	+55 42 25.0084	HD 39283	SAO 25450
lam Aql	3,4	B9Vn	19 06 14.93898	-04 52 57.2007	HD 177756	SAO 143021
lam Cap	5,6	A1V	21 46 32.09739	-11 21 57.4391	HD 207052	SAO 164639
lam Cnc	5,9	B9.5V	08 20 32.13630	+24 01 20.3198	HD 70011	SAO 80113
ome Oct	5,9	B9.5V	15 11 08.81659	-84 47 16.1255	HD 131596	SAO 258717
omi Hya	4,7	B9V	11 40 12.78970	-34 44 40.7733	HD 101431	SAO 202695
phi Oct	5,5	A0V	18 23 36.44823	-75 02 39.3950	HD 167468	SAO 257584
rho Cet	4,9	A0V	02 25 57.00560	-12 17 25.7104	HD 15130	SAO 148385
rho Peg	4,9	A1V	22 55 13.67197	+08 48 58.1932	HD 216735	SAO 127839
sig Ara	4,6	A0V	17 35 39.58957	-46 30 20.4618	HD 159217	SAO 228162
tet Ari	5,6	A1Vn	02 18 07.53838	+19 54 04.1862	HD 14191	SAO 92877
tet Cap	4,1	A1V	21 05 56.82783	-17 13 58.3021	HD 200761	SAO 164132
tet Crt	4,7	B9.5Vn	11 36 40.91335	-09 48 08.0912	HD 100889	SAO 138296
tet Lep	4,7	A0V	06 06 09.32339	-14 56 06.9188	HD 41695	SAO 151110
zet Ari	4,9	A1V	03 14 54.09731	+21 02 40.0103	HD 20150	SAO 75810
zet CrA	4,7	B9.5V	19 03 06.87698	-42 05 42.3858	HD 176638	SAO 229461

Figure 6.4: List of reference stars (3/3)

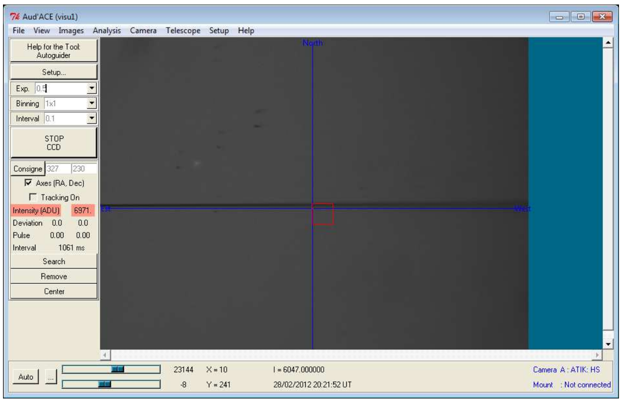
6.1.4 Setup session parameters

All Audela parameters must be setup: several key parameters are written in the FITS file header. Refer to 3.2. Have a special attention to observers names, instrument configuration and observatory data:





Of course, during the night you don't see the slit anymore in the guiding image. But it is still here, of course. In the below image, we've put a flashlight in front of the telescope. The slit image is not properly focused, because of bad optical conditions (the lamp beam is not coming from infinite):



6.2 Acquisition - Reference star

6.2.1 Point the reference star

So far, you have used the standard acquisition tool for both acquisition and guiding cameras. For the guiding section, you may use preferably the guiding tool. It is accessible from menu "Telescope / Autoguider". It has great features dedicated to guiding function, such as dynamic reticule.

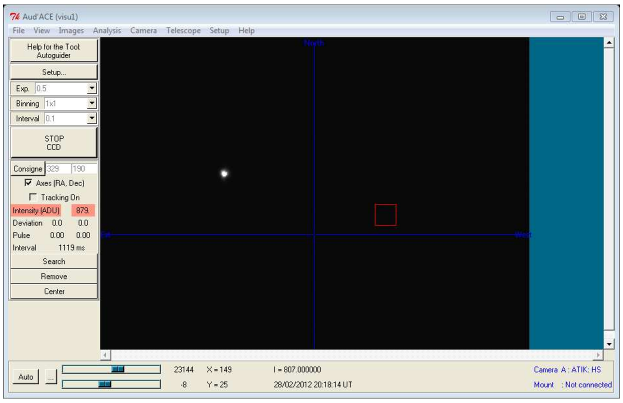
Point the telescope towards the reference star you choosed. In the beginning, select a quite long exposure time (0,5 seconds or more) for the guiding camera, to be sure to see the star obviously:

6.2.2 Focus the telescope

Since you focused the telescope on the landscape, it is probable that it is not perfectly focused on the star. Take some time to do it. When your target is in the guiding image, you can adapt the guiding exposure time to prevent any saturation.

You must focus the telescope, not the guiding camera (it is already done, and you have checked it with the sharpness of the slit).

At the end of this operation, you must see the star focused:

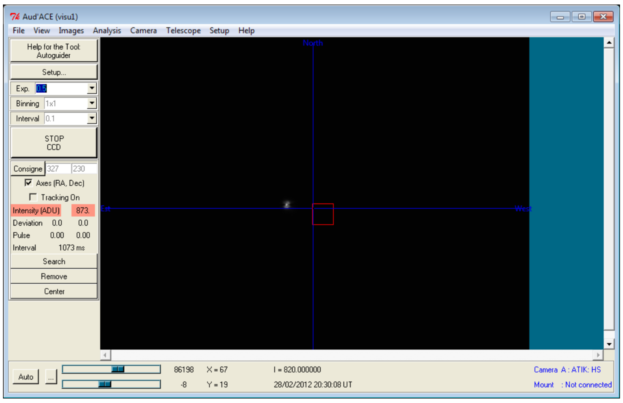


You can use the dynamic measurement of the star image level, to prevent saturation. Draw a large rectangle around the star, and right click. Select Statistics in window

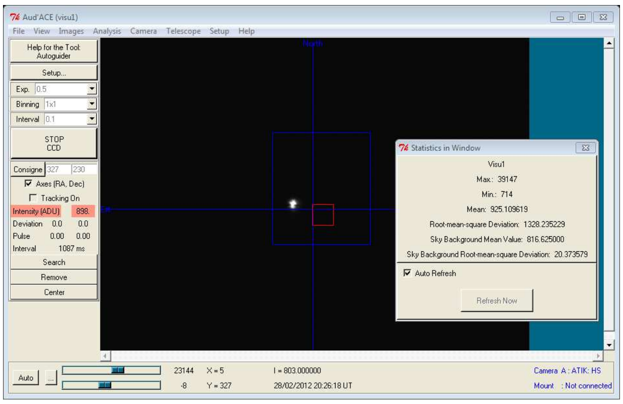
6.2.3 Put the star in the slit

Put the reticule some pixels below the slit (simply dragand drop it by clicking any of the blue line).

Move the telescope to put the star in the middle of the slit:



You can use the dynamic measurement of the star image level, to prevent saturation. Draw a large rectangle around the star, and right click. Select Statistics in window:



When star crosses the slit, it should disappear from the guiding image. In fact, the star never totally disappear from the guiding image. In normal conditions, star image is slightly bigger than the the slit. Even if most of light goes in the slit, some percents are still visible in the guiding image. This is generally enough to guide.

New observers often choose a two long exposure time, and the star is saturated, or close to. This is a mistake: if you do that, you don't see a significant intensity difference when the star crosses the slit.

During the star spectra acquisition, you will need to track the star, and keep it in the slit. The movement of the star can be due to several phenomena: poor mount alignment, bad telescope tracking, wind, and so on. You must find the right corrections to collect as much light as possible. Keep this in mind: when the star disappears in the guiding image, it means the star light is sent to the spectrograph. Any light you see in the guiding image is lost for the spectrograph.

Remember: if during exposure the star goes out of the slit, the intrinsic quality of the spectrum will not be affected. There will be only less light, and the SNR will be lower.

If the star moves along the slit during the exposure, the spectrum will be wider (vertically) in the image - this is not a big problem if it is at a reasonable scale.

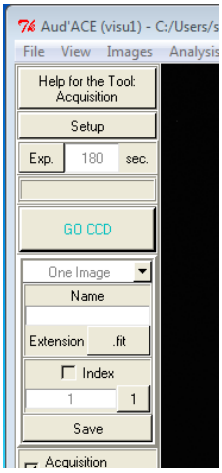
In extreme conditions (faint object), you may have an alternative strategy for guiding: using a brighter star in the field of guiding view.

You can activate the guiding feature of AudeLA, but this is not the purpose of this document. If you double-click the star, the red square will be moved around the star, and star center will be recalculated for each image.

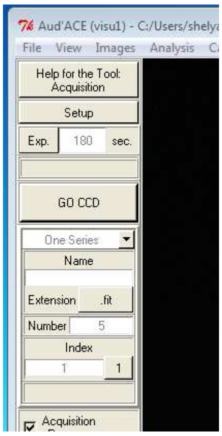
6.2.4 Acquire reference star spectrum

When you consider that guiding is under control, you can start acquisitions. For each image below, you will have to define the exposure time required to get 70% of the camera dynamics. The exposure time for star images (reference and target) is very dependant on telescope diameter and on target. With bright objects (up to mag 3 or 4), only few seconds (even less) is enough. For fainter objects (magnitude up to 8, or more), you can make exposure of 5 minutes (300 seconds), and adapt the number of images to the magnitude of the star. You can always start with short exposures (i.e. 10 seconds), and evaluate proper exposure time from highest reached level.

In AudeLA, the acquisition can be done in different modes. The basic mode is to take one image:



In this mode, you can take images one by one - and decide to save them or not. This is the ideal mode when you are tuning the parameters (like exposure time). When it is done, you have a second mode, to acquire a serie of images automatically. For next steps, you will use this mode:



In this mode, give a root file name (remember: it is preferable to finish it by "-"), choose the number of images, put the index at 1 (this is to make the first image named "name-1"), and click on GO CCD. The whole serie is recorded on the disk. In your first case, record 7 spectra of the reference star, for instance.

6.2.5 Record reference images

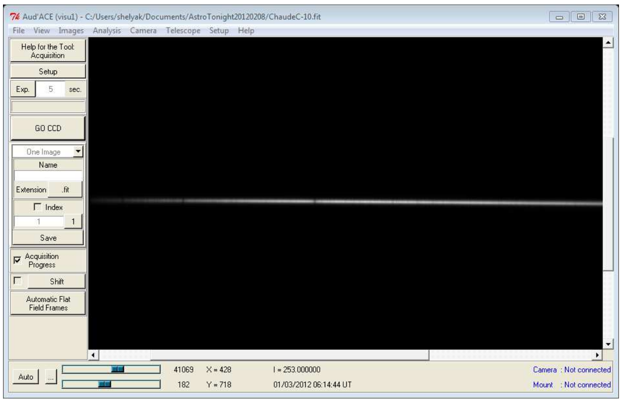
After this star spectrum, immediately make the other images - without moving the telescope.

To run properly the data reduction, you will need the following images (as you did for the Sun):

Image type	Nb	Exp. time	Comment
Reference star	7	*	Depends on your case
Flat	5	~20 sec	Flat light on
Neon (short)	3	~10 sec	Neon light on
Offset	5	0 sec	Telescope closed
Dark frame	5	*	Telescope closed. Duration depends on other acquisitions. At least 20 seconds.

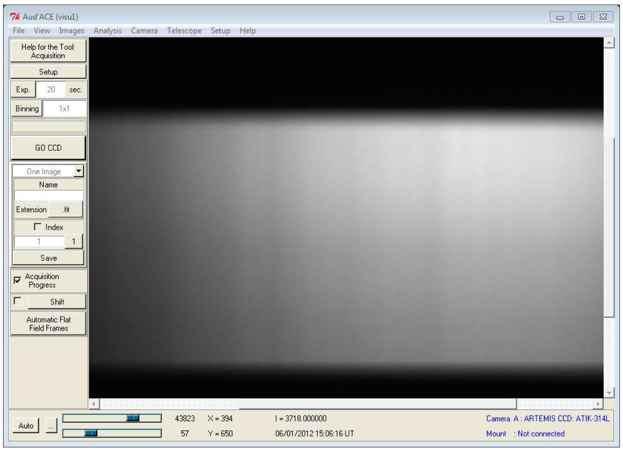
Launch the acquisitions for all these series of images.

For the reference star, the spectrum looks like the below image. You see some deep absorbtion lines:

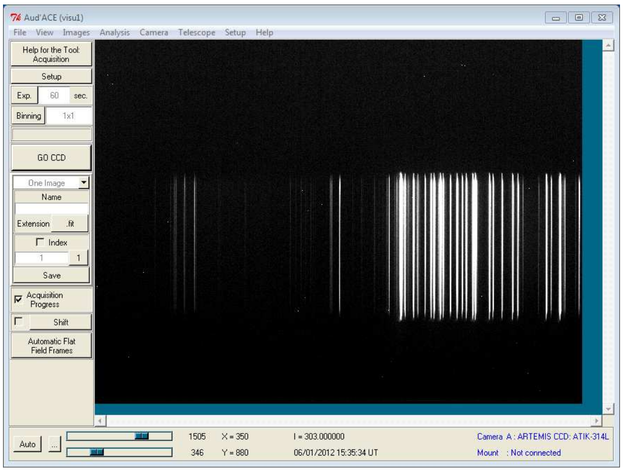


Always double check that no image is saturated - and have enough signal.

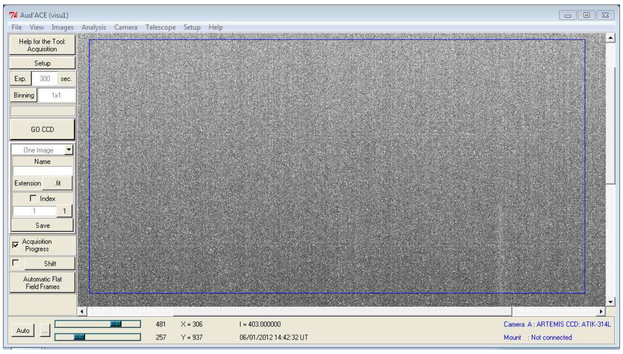
Flat field is done by switching-on the Flat lamp on the calibration module.



The same for neon light: switch-off the Flat lamp, and switch-on the neon on the calibration module.



Dark frames:



6.3 Acquisition - Target star

Now point your first target. Adapt the exposure time to get the optimal level (less than 70% of the camera dynamics). Launch the acquisition of a serie of images.

6.3.1 New calibration images

As soon as you have acquired your target spectrum, launch a new neon serie. Do the same after any new target spectrum. There is no need to re-do other images (flats, offsets, darks), because these images do not change during the same observing session.

> Do not move the telescope between star spectrum and neon spectrum. The goal is to get calibration image in exactly the same conditions.

> For long observations (one hour or more), we suggest to record a neon serie before *and* after the star spectrum. During the exposure, the telescope moves and the position of the spectrum can slightly move in the image, because of mechanical flexions. The move, if it exists is very small, but in some cases, you'll be happy to get data for a more accurate wavelength calibration.

6.3.2 Ending observing session

When you have acquired all the spectra you need, take some time to double check that you have all reference images. It is very frustrating to end the night with a lot of images, and discover the day after that you have not all the data to reduce them. Have a special care for dark frames: you must have some with the longest exposure time of all your spectra. It can happen that your first spectra were 10 seconds long (for instance), and during the night you decided to go for fainter objects, with 60 seconds exposures. In such a case, ensure that you have 60 seconds dark frames. You can do them at any time - just ensure that the camera temperature is always the same.

When you have finished all acqusitions, copy the *AstroTonight* directory to your Archive directory.

> Archive data of the night immediately after the acquisition: as soon as you start data reduction, there is a risk that you alter original data... with a copy in your archives, you can always go back to initial status.

Exit software & switch-off all the installation: cameras, flat & neon light, telescope and so on.

6.4 Reduce the data

You now have all the data ready for reduction with ISIS software. You will use the same way as for Sun Spectrum, with only few differences. Again, we will proceed step by step:

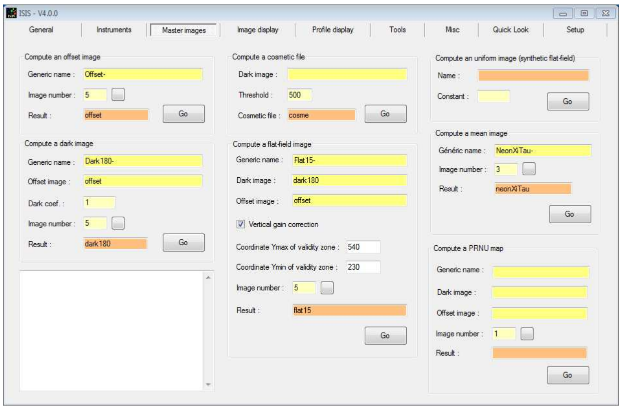
- Create master images from reference images (dark, flat...)
- Basic data reduction of the reference star,
- Improve the wavelength calibration (using neon + hot star),
- Build the Instrumental Response curve,
- Reduce each star spectrum with these elements.

To illustrate the data reduction, we use in this document a serie of images taken in real conditions. These images have been made with a C11 telescope (0.28m), close to Grenoble. The reference star we used is ksi Tau (B9V type). And the main target we observed is Betelgeuse, in Orion (cool star, M2 type). At the end of our observation, we have following files:

File name	Nb	Type	Exp. time	Comment
XiTau-	5	Object	60 sec	ksi Tau - reference star (hot star, B9V)
Betelgeuse-	3	Object	10 sec	Main target
NeonXiTau-	3	Neon	10 sec	Neon for ksi Tau
NeonBetelgeuse-	3	Neon	10 sec	Neon for Betelgeuse
Flat15-	5	Flat	15 sec	Flat
Dark180-	5	Dark	180 sec	Dark frames
Offest-	5	Offset	0 sec	Offset

6.4.1 Master images

To improve the image quality, you've taken not only one reference image, but series of images. You will start the data reduction by combining these series to get higher quality reference images. In ISIS, go to Master images tab:

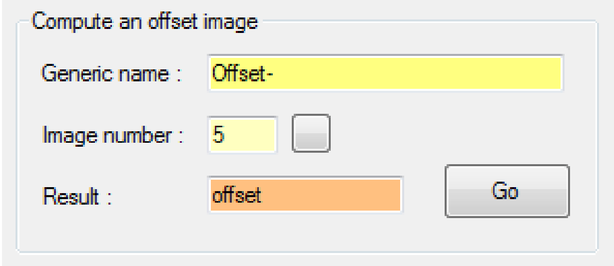


In this page, there is an area for each type of reference image. You'll make a master offset, a master dark frame, and a master flat field. You will also compute a master neon (for both ksi Tau and Betelgeuse).

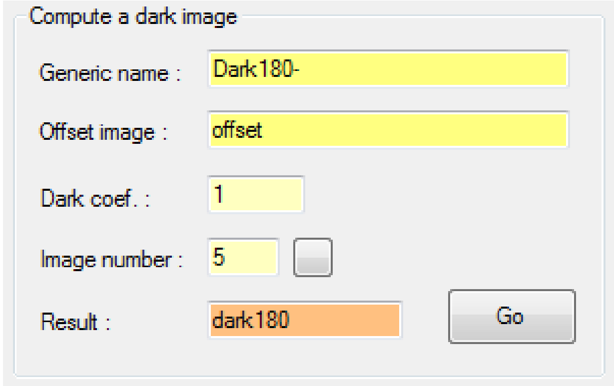
In this example, we used capital initial letter for the raw image file names, and initial lower case letter for master images.

For each type of images, fill the fields, and click on Go button. To get the number of images, click on the small button beside the "Image number" field.

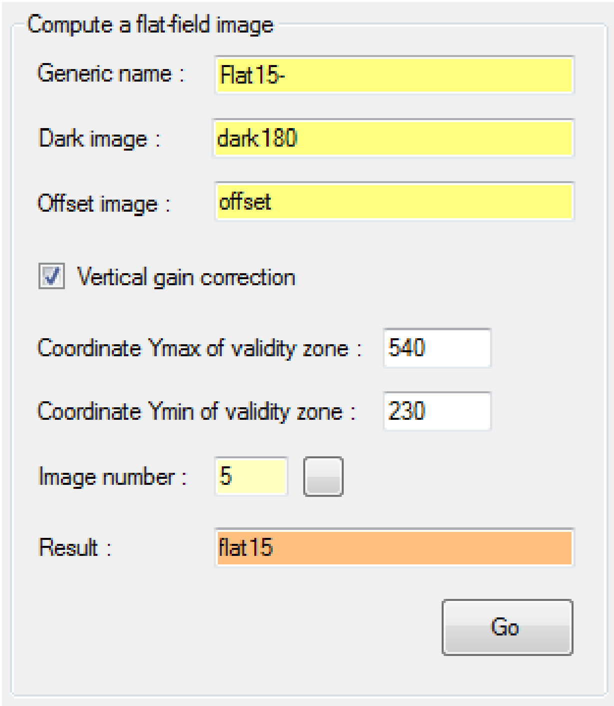
For offset images:



For dark frames:

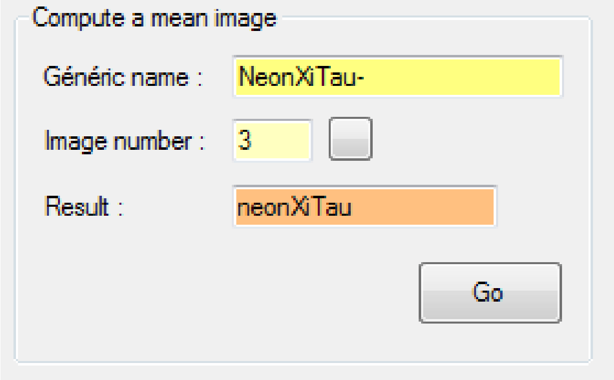


For flat fields, you must indicate the position of the flat area in the image. You can define these values by displaying the Flat15-1.fit image, and move the cursor in the edges of the flat area.

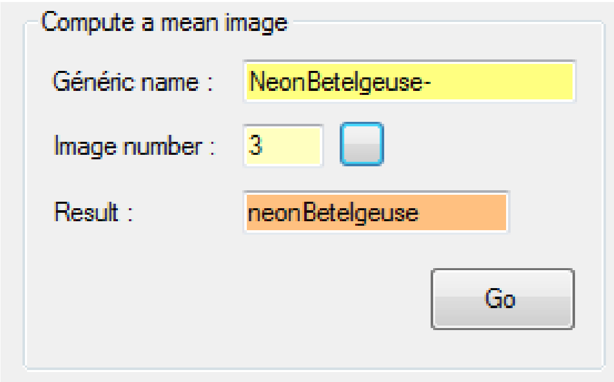


Vertical gain correction field tells ISIS to take care of the gradient along vertical line in the flat image. This gradient is due to unperfect uniformity of the slit enlightment with the flat light.

For the neon images:



Re-run the last operation with the neon for Betelgeuse:

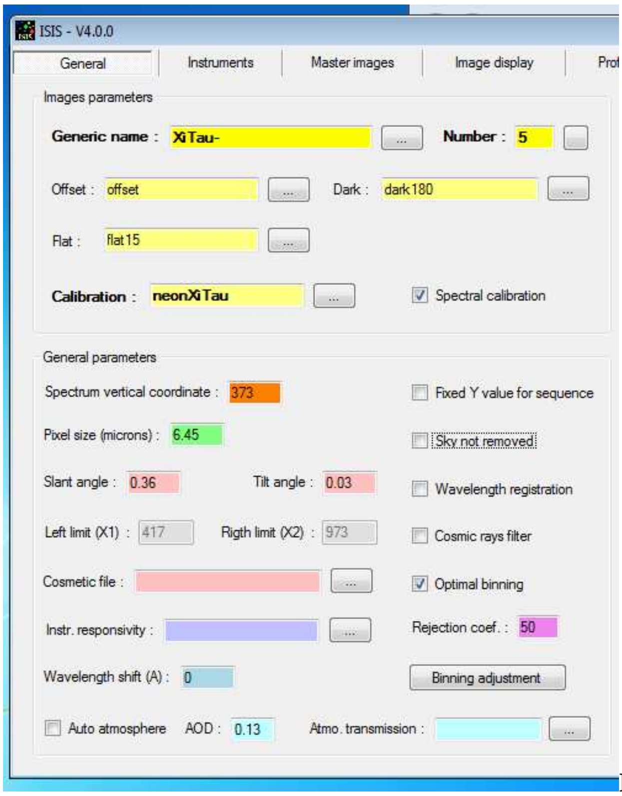


You have now computed all master images. You can check in the AstroTonight directory that they are properly recorded.

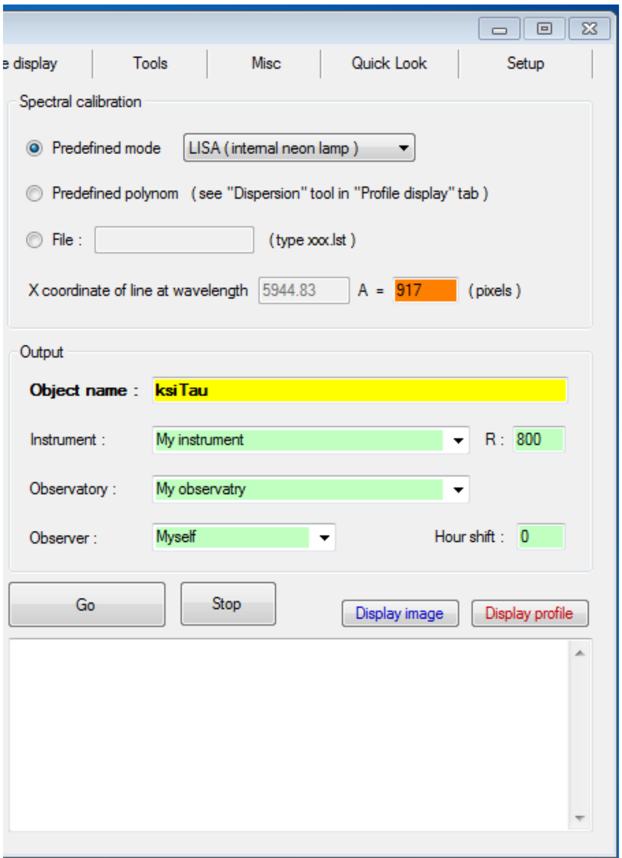
6.4.2 Basic reduction of reference star

Go to the General tab, and fill the parameters with these elements:

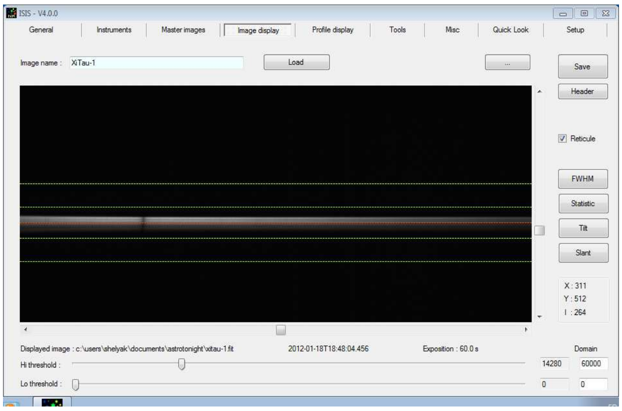
- Generic name: XiTau- (there is 5 images),
- reference images: all files you just created,
- Pixel size: 6,45μm,
- No cosmetic and Instrumental response file,
- “Sky not removed” not selected



In the Spectral calibration area, select “Predefined mode”, and LISA (internal neon lamp). Open the neon image and double-click on the line at 5944,83Å. Copy the X value in the spectral calibration area (917 in the below case):



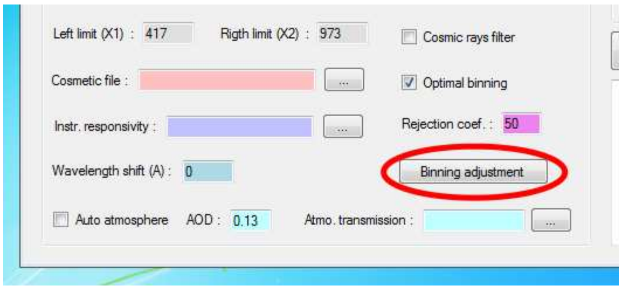
Now, open the XiTau-1 image, and double click in the spectrum. If you select the “Reticule” option, you will see the limits that ISIS will use for the calculation:



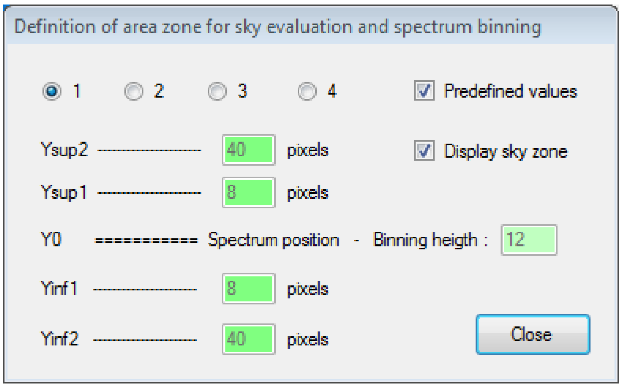
The middle area (around red line) gives the limit that ISIS uses to collect signal. The two bands between yellow lines (below and above the spectrum) will be used to define the sky background spectrum and to correct the star spectrum from the sky pollution.

You will see that spectrum becomes wider in the blue area (left end). It is due to optical limits of LISA. The whole spectrum must be contained withi the two internal yellow lines.

If you consider that the bundaries are not correct for your situation, you can change the values in the General tab / Binning adjustment button:



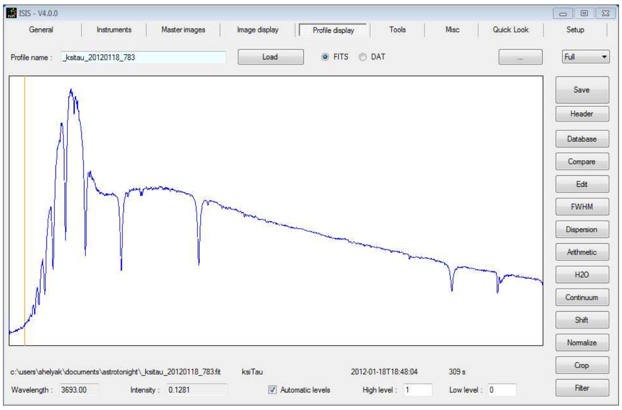
In this window, you can select the values you want:



Binning ? in this case, it means that ISIS combines several pixel lines to get all signal contained in the image. Even if your instrument is perfectly tuned, the spectrum will be spread on several lines: it is better to use all available data. This meaning of binning is quite different from pixel binning in the camera (this was a hardware combination of pixels). The simplest binning is the addition of pixels vertically. ISIS uses a more optimized way of binning.

Go back to General tab. Note that when you double clicked on the spectrum, ISIS automatically filled the Y position of the spectrum.

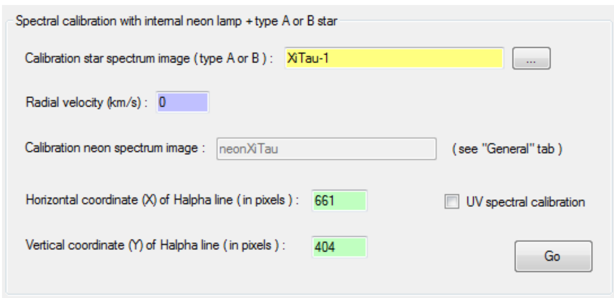
All parameters are now given to ISIS: you can run the calculation - click on Go button. After few seconds, when it is done, you can go to the Display profile tab, and load the results (file name is prefilled):



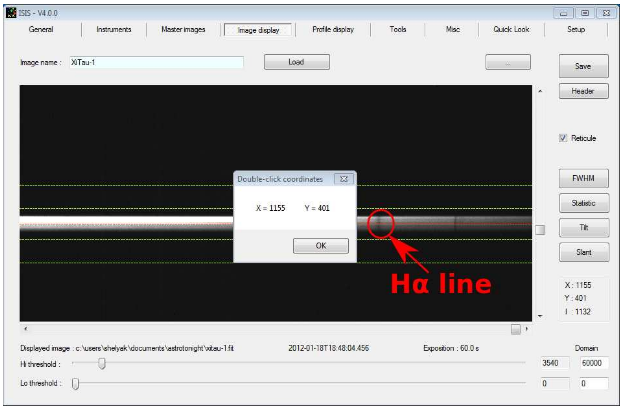
You can immediately see the deep absorption lines. This is typical for a A type star. You can check that basic calibration is Ok, by looking at Hα (6563 Å) and Hβ (4861 Å). You can also look at the RMS for calibration (in the log window) - in our case, it is 1.06Å.

6.4.3 Improving calibration

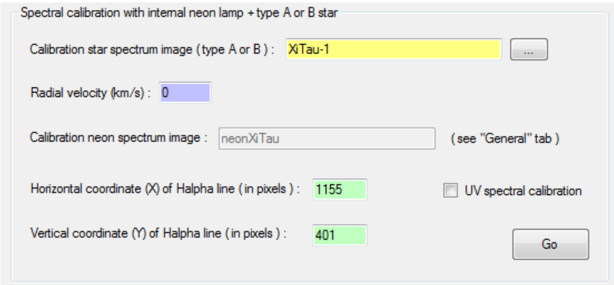
The second step is to improve the wavelength calibration, by using hot star balmer lines. Go to the Instrument / LISA tab, and focus on the area “Spectral calibration with neon lamp + type A or B star”. Fill the star name:



Display the XiTau-1 image, and double click on the Hα line. It is at the right end of the spectrum:



This double-click fills the X and Y values in the Instrment / LISA panel:



You can now start the calculation, and look at the result. In our case, the RMS is reduced to 0.47 Å.

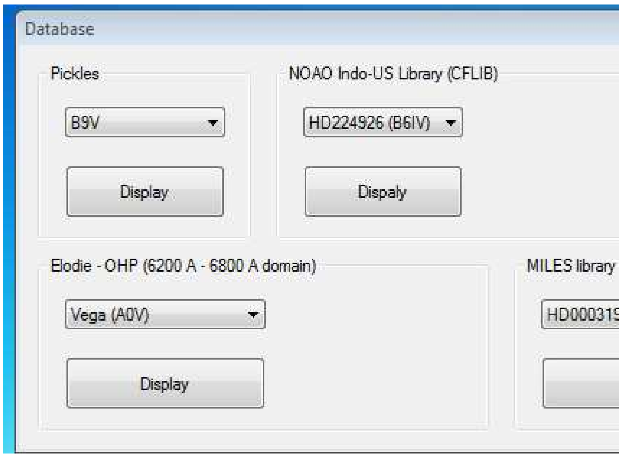
You can still improve this RMS by using a long exposure neon image (60 seconds or more). Even if there are some saturated lines in the red part of the spectrum, you will reveal some fainter lines in the blue part, and give more calibration information to ISIS. In our case, best calibration is 0.34 Å.

6.4.4 Instrumental Response curve

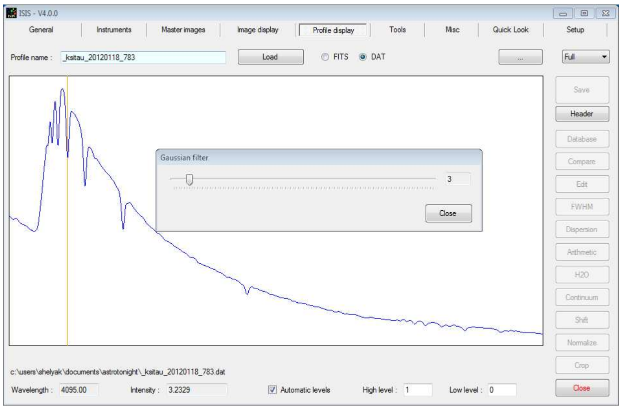
Following step is to build the Instrumental Response curve. You will proceed exactly the same way as for the Sun:

- Find a reference spectrum in the database,
- Reduce resolution to LISA's (if needed),
- Save it as the reference spectrum,
- Calculate the Response curve.

In our case, the reference star we used is ksi Tau. This is a B9V star (magnitude 3.7). In the database, select the Pickles B9V profile:

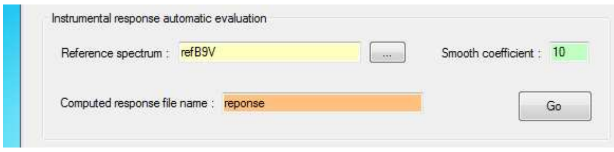


The dispersion of the spectrum is 5 Å/pixel. Smooth it with the filtering tool (with a coefficient 3, for instance):

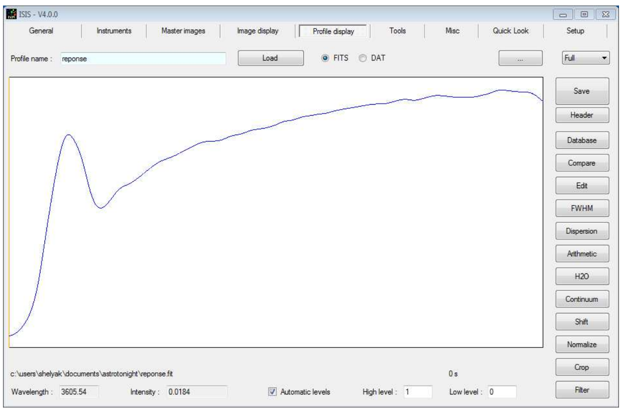


Save it as the reference spectrum - ie refB9V.fit.

Go to the Instrument / LISA tab, and fill the fields of the Instrumental response area (10 is a good starting value for smooth coefficient):



Click on Go, and look at the result in Display tab:



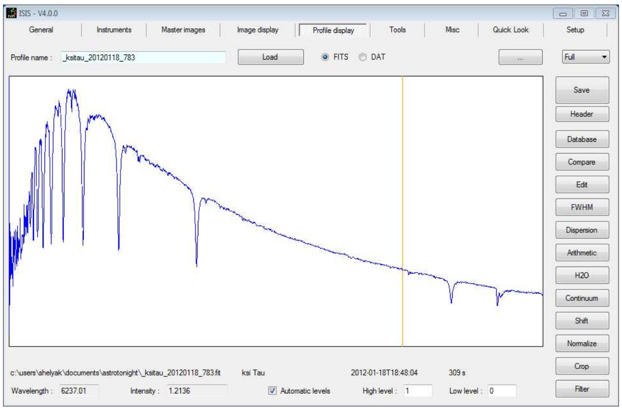
You have now finished the preparation of your data reduction. All of this has to be done only once per session, of course. You can now apply these elements to all the stars you observed during the night.

6.4.5 Data reduction of other targets

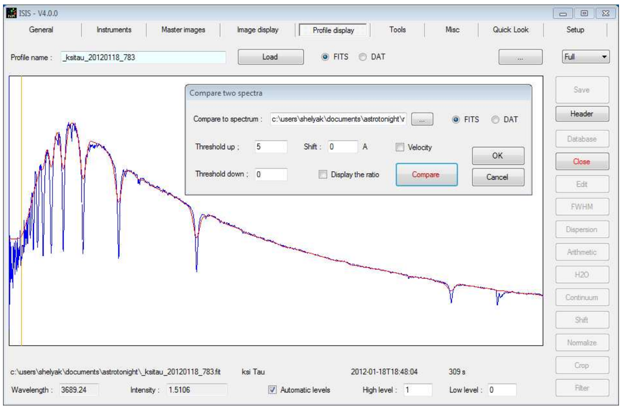
First, you have to re-run the data reduction of your reference star (ksi Tau in our case) with all the elements - high precision calibration and instrumental response correction.

Go to the General tab and check that all fields are properly filled - it is down automatically by ISIS. Take a special care of Instrumental response file name and Spectral calibration mode (predefined polynom).

Run the data reduction, and look at the result:



As usual, check quickly that calibration is OK with Hα and Hβ. You can also compare to your B9V reference spectrum:



You can now run data reduction for all other spectra you have acquired during the night. Of course, the only elements to change are:

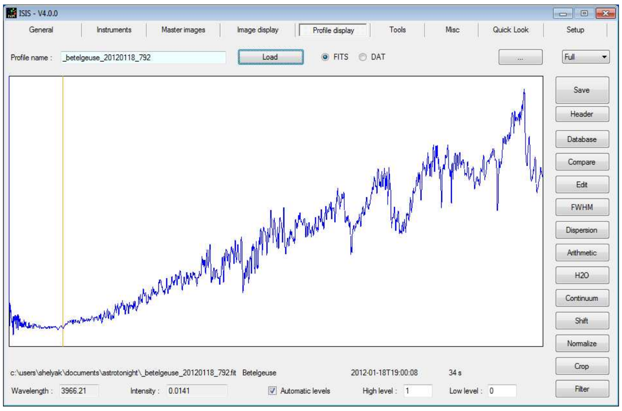
The spectra file name (and potentially the number of files),

The calibration file name (neon taken just after the object),

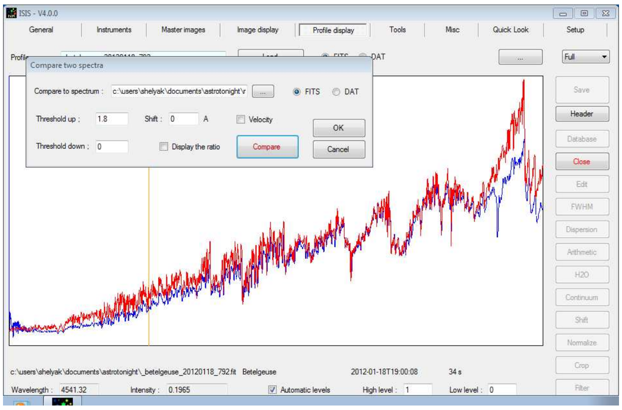
The object name, for the output file.

... That's it. Simply click on Go, and your spectrum is processed in a few seconds.

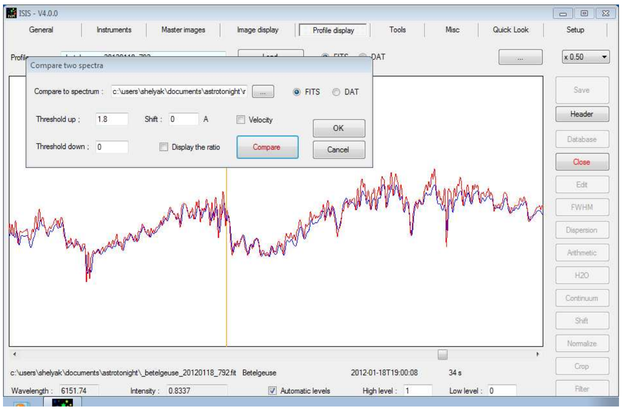
In our example, our target was Betelgeuse - a cold star:



Of course, the profile is very different from the hoter reference star. To check that this profile is correct, you can compare it to a spectrum frm the database: Betelgeuse is a M2 star (it is also called HD39801). For instance, in the Miles database, there is a spectrum of this star (list is sorted by HD number):



Zoom in the image, to see details:



The compliance between our observation and the reference spectrum is very good.

Congratulations for this great achievement - welcome in spectroscopy !

Of course, if you have observed several objects during the night, you can reduce them the same way.

7
Next steps

You have now passed all the steps to get your first reduced spectrum. With the experience, you will perform acquisition and data reduction more and more efficiently. In this section, we've put some tips and tricks to improve your observations. Improving observation means better data quality (up to professionnal quality level data), and better efficiency in your observing process.

7.1 Improve data quality

7.1.1 Signal / Noise Ratio (SNR)

Star light is faint... and you spread it with your spectrograph. At the end of the chain, only few photons reach each pixel of your CCD camera. The whole instrument (telescope, spectrograph, camera) limits your ability to detect faint signal. The quality of your spectrum is directly linked to the level of signal you get on your CCD, compared to the "noise" of the instrument, which is its limit of detection. This is what we call the Signal / Noise Ratio (SNR).

Improving SNR can be done in two ways: reduce the noise or increase the signal.

Reducing the noise is hard: it is limited by physics. But we can do it to a certain extend. For instance, by cooling down the camera, you reduce the internal activity of the CCD, and reduce the noise.

The best way to improve SNR is then to increase the Signal. It can be done by several ways:

- Increase exposure time (the SNR will be increased as the square root of the time multiplication),
- Increase the telescope size (this is why professionals are always looking for bigger telescopes),
- Ensure that most of the light is going through the spectrograph. Star image and slits are very small (few μm), and it is very easy to lose high portion of the light because of instrument.

The two main rasons for losing light at telescope entrance are usually:

- Telescope focusing. If the focus is not optimal, the object size will be bigger than the slit width, and only some percent of the object's light will enter in the instrument.
- Position of the star in the slit. It is very easy to put the star just beside the slit. The result is the same: you lose a high percentage of your source.

The best way to improve this point is to check that when star crosses the slit, it mostly disappear. Tune properly your guiding camera exposure time to prevent any saturation.

> If the star disappears from guiding image when crossing the slit, it means that most of light goes through the spectrograph.

With the experience, you will know how much signal your instrument can get, for a given magnitude. You also have to compare your data with others, with similar equipments, to have an external reference (see 7.3). If you see that this level is lower than usually, take some time to find the source of this loss.

To go further in SNR improvement, you can make two operations:

Measure the total power of your spectrum, and tune the telescope focusing to optimize this measuement.

Compare the total power with and without slit (be careful, when you remove the slit, you have then to check and probably tune again the focus). Of course, when slit is removed, you cannot track anymore the star, but it will give you the percentage of light going through the telescope when slit is present.

7.1.2 Resolution

The resolution of your spectrum comes mainly from the spectrograph itself. LISA resolution power[1] is better than 1000 around Hα. During the data reduction,

1. Resolution power gives the ability of the spectrograph to see details. It is calculated as $\lambda/\Delta\lambda$, where$\Delta\lambda$ is the smallest visible detail in the spectrum.

ISIS software calculates the actual resolution power. Check your result is close to this value.

> The resolution is calculated from the width of neon lines ($\Delta\lambda$ = FWHM of neon lines. The better is the focus of neon lines, the better is the resolution. To optimize the focus, you can use the focus tool of AudeLA.

7.1.3 Wavelength calibration

Take a special care to the wavelength calibration. In usual conditions, you should have a RMS smaller than 0.5 Å. Take the time to record a neon image after each object (without moving the telescope), and use this image for the data reduction. Always double check that there is no major error in calibration. The simplest way is to look at balmer lines position.

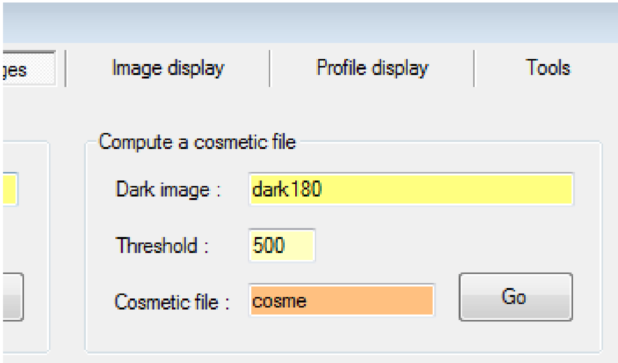
7.1.4 Autoguiding

Autoguiding is very dependant on your equipment. Autoguiding means that you send the guiding image to the computer, which controls the telescope based on star movement in the image. AudeLA software can do that (like many other software).

Autoguiding is not only for comfort (when you activate the autoguiding, you don't need to permanently check the guiding image anymore), but it also improves the spectrum quality, because it works always in same conditions.

7.1.5 Cosmetic file

The CCD chip has some "hot pixels". These pixels are much more sensitive than others. These pixels will give wrong measurements. It is better to remove them from your image. It can be managed by ISIS software, by creating a map of hot pixels. All pixels considered as hot are replaced in the image by an average of the pixels beside. To get the hot pixels map, you use a dark frame, and record all pixels above a certain value. Go to the Master images tab, and focus on "Computing a cosmetic file" area:



Give the threshold value - for instance 500 ADU (in the dark we use, most of pixels are close to 0 ADU). Click on Go button, and look at the console: you'll see the number of hot pixels detected. In our case we have 50 pixels - it is a usual value. Of course, the number of hot pixels depends on the threshold value, but getting around 100 hot pixels is considered as usual.

> The master dark not really a dark frame, but the thermal map of the camera: the offset has been removed. This is why the average level of image is close to zero.

You can use the hot pixels map in the General tab. Simply give the name of your map file in the field "Cosmetic file", and re-run the data reduction. ISIS will now include this hot pixels list in its calculation.

7.1.6 Instrumental Response curve

We described a simple way to get the Instrumental Response curve with ISIS. In fact, this is a tricky operation. The response curve can evolve with some parameters, like sky conditions, target position in the sky (air mass), reddening, and so on. To be perfect, you would need a reference star close to our target, of the same spectral type, with similar magnitude... and this never happens. Getting a bad response curve will have an immediate effect: the general profile of your spectrum is disturbed. It is a too long story for this document, but keep in mind that getting the proper Instrumental Response curve requires some experience.

7.2 Improve productivity

7.2.1 Keep the same setup

The best way to improve your productivity is to keep always the same setup, and always process the same way. Of course, observers often want to improve their setup (this is a good behavior), but as soon as you change parameters in your setup, you have to adapt (to change...) your process. Sometime, it is preferable to keep the same conditions, for both quality and productivity.

7.2.2 Dark frames library

Dark frames are long exposure time images (at least the longest exposure time of your objects). And the more you can get darks, the better it will be (you will improve dark frames SNR). Then, this is a very constrainful operation - that we should do at the end of the night, to know the longest exposure time.

But dark frames are intrinsic data of your equipment. It only depends on the temperature and exposure time. They don't depend on the observing conditions. Then... there is no need to do them during the observing session itself: you can do them once, for instance during a cloudy night (or even day - just take care of light leaks).

We suggest that you make your own dark frames library, with different exposure times and different camera temperature (you can even put the camera in the fridge to simuate cold night). Take high number of images, and create master darks from them once.

7.2.3 Exposure time

We suggest you to always use the same exposure time for your observations (typically 5 minutes - 300 seconds - for faint objects). Of course, the total exposure time will depend on the object magnitude, but you can adapt the total exposure time by changing the number of exposure. They are several avantages to proceed this way:

- You can reuse always the same dark frames,
- Data reduction is very fast (no parameter is changed),
- No risk of error during acquisition (you never change the time).

There is some limits with this process, for instance for bright objects or extremely faint objects, but in general it will make your life easier.

7.2.4 Prepare your observation

Amateur astronomers often wait for the last minute to decide what to observe. We recommend to prepare your observation long in advance. If you properly organize your observing session, you will optimize the targets order, their position in the sky (the higer is the best), and so on. You can even define the exposure time for each object, depending on their brightness.

If you are looking for target and observing programs, you can look at Shelyak Instruments website[2]: we've listed many ideas, from easy to ambitious level.

7.2.5 Reduce your data quickly

It is very usual that amateur take time to observe during the night, and wait for the day after for data reduction. Be careful: if you wait for two long, you'll probably never reduce your data. And getting raw data on your hard disk is like if you did nothing. We strongly encourage you to reduce your data immediately after the acquisition. At this time, you have all in mind, and there is much less risks of mistakes during data reduction.

7.3 Share your results

Our experience shows that the best way to improve your data is to compare your results to others. When you compare your spectra with results of experienced people - with comparable instrument, of course - you can have an idea of the room for improvement you have in front of you. We encourage you, for instance, to observe Be stars, and look at BeSS database[3] for comparable observations. You can even send your spectra to the database - they will be checked by administrators who give feedbacks if this is improvable.

In addition, be sure that spectroscopy is still at a pionneer stage. All the data you collect are of the highest interest for the scientific community: don't keep them for yourself.

7.4 Get pro-like quality spectra

Very often, amateur astronomers think they are not able to provide high quality data, comparable to professionnal one. Of course, amateurs usually don't have professionnal instruments - but the quality of the data is more a question of methodology than instrument. And you will see quickly that you can reach professionnal quality, with just enough rigourness. You can even contribute to research in several Pro-Amateur collaborations. In few words, to get good quality data, you need to take care of:

- Auto-guiding is activated
- Repeatable configuration and process
- Proper data reduction: SNR, Wavelength calibration, Instrumental response curve correction.
- File format (see for instance BeSS file format)
- Raw data are seriously archived and backup

> Never forget that when you're observing the spectra of an object, you're probably the only one to do it at this time on earth - this is an incredibly valuable data... and you must absolutely archive it very carefully (raw images as well as processed data).

2. www.shelyak.com - menu spectroscopy / educationnal & projects
3. http://basebe.obspm.fr/basebe/Accueil.php?flag_lang=en

8 Typical observing session

Here is a summary of a typical observing session, to ensure data quality and productivity. It is a basic checklist that you can use every time you observe.

Preparation

- Start-up the equipment, and cool down the acquisition camera (max 80% of cooling power),
- Check your session parameters in AudeLA and ISIS: observer's names, observing site, equipment, working directory...
- Archive & erase all files in your *AstroTonight* directory,
- Check your computer time, at better than 1 second (the exposure date & time will be based on it),
- Open a log file,
- Run a test for all images: sky (Sun's spectrum), neon, flat, and check that all is Ok (images correct, files headers with proper data...),
- Prepare your target's list,
- Acquire dark and offest images and prepare master images (or copy from master directory).

During observation

For each target oservation, you will have to:

- Point the target (start with reference star),
- Run the acquisition,
- Get calibration images (neon),
- Get flat field images,
- fill in the log file with any significant information that will help in the future to remember the observing conditions,
- Check that images are properly recorded in *AstroTonight* directory,
- *(run data reduction during the next observation),*

At the end of the night

- Double check that you have all reference images (dark frames, offset, falt fields, neon, reference star, objects)
- Archive securely your raw data

Part II

LISA Pack Reference Manual

1
LISA Pack features

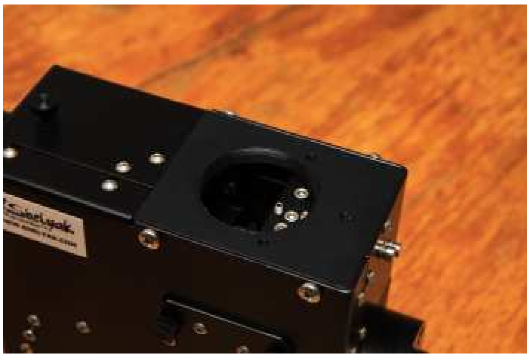
1.1 Technical specifications

You will find in the table 1.1 all the technical features of the LISA Pack, and main dimensions in the figure 1.1

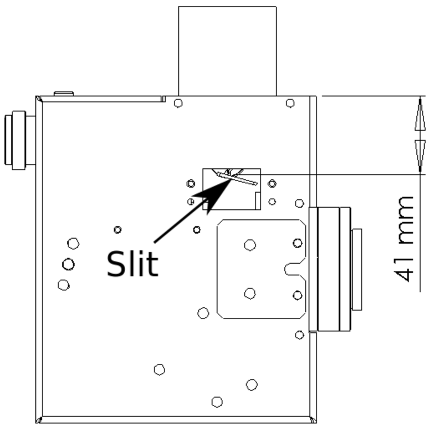
1.2 Mechanical interfaces

1.2.1 Telescope interface

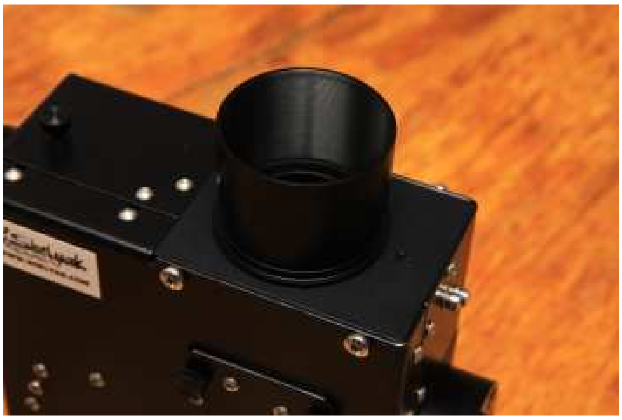
LISA front plate includes a standard T-mount thread (M42 x 0.75mm):



Backfocus is 41mm (distance from the top flat face of the instrument and the slit position):



For your convenience, the LISA is shipped with a M42/2” adaptor. This is the simplest way to mount it on a telescope.



1.2.2 Acquisition camera interface

The acquisition CCD camera is mounted on the camera interface. Depending on your camera, we can provide different adaptors (most CCD camera have a T-mount thread). LISA adaptor have two threads :

- Internal thread is M35x1mm. It is used for Shelyak Instruments adaptors.
- External thread is T-mount standard (M42x0.75mm, 54.85mm backfocus). It can be used for standard adaptors, or to mount directly a DSLR (with T-ring).

The backfocus of the T-mount standard is 54.85mm from flat face to the focus point. The tuning range for LISA allow to put the focus plane (CCD plane) at +/-5mm of this position:

Feature	Value	Comment
Mechanics		
Dimensions	335 x 205 x 120 mm	overall - see drawing
Weight (LISA Pack)	2,5 Kg	without cables
Weight (LISA only)	1,6 Kg	without cameras, without cables
Telescope interface	Thread M42 x 0.75 mm	
Slit backfocus	41 mm	see below
Power supply connections		
Atik cameras	12V (+in center), **5,5 x 2.1 mm**	314L+ (acquisition) & Titan (guiding)
Calibration module	12V (+in center), **5,5 x 2.5 mm**	Neon & tungsten (flat)
Spectrograph		
Resolution Power	R=1000+	
Bandwidth	4000 - 7000 Å	see text for IR option
Aperture	F/D = 5	
Slit	23 µm x 4 mm	can be changed to 15µm, 19µm or 35µm
Calibration precision	better than 1 Å	
Collimator focal length	130 mm	
Camera lens focal length	88 mm	
Dispersion grating	300 g/mm - 30 x 30 mm	blazed at 500 nm
Acquisition camera (Atik 314L+)		
Interface	T-mount or Shelyak adaptor	see text
CCD Chip	1392 x 1040 pixels	
Pixel size	6,45 µm	
Image size	9 x 6,7 mm	
Guiding camera (Atik Titan)		
Interface	C-mount	see text
CCD Chip	659 x 494 pixels	
Pixel size	7,4 µm	
Image size	4,9 x 3,6 mm	
Magnification	1:1	

Table 1.1: technical features of LISA Pack

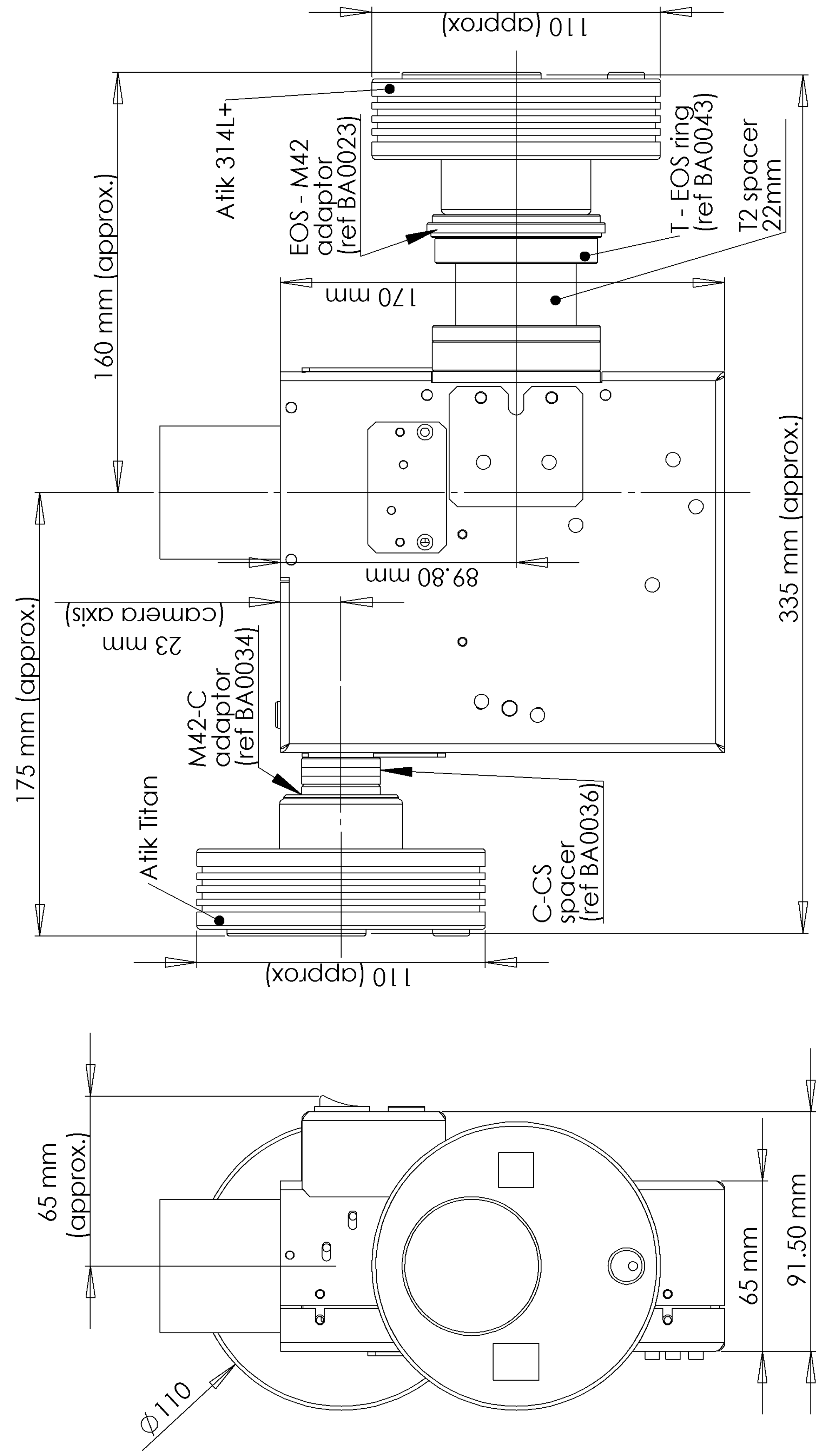
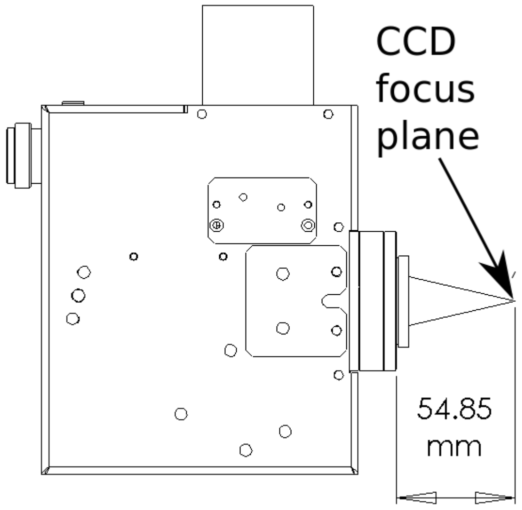
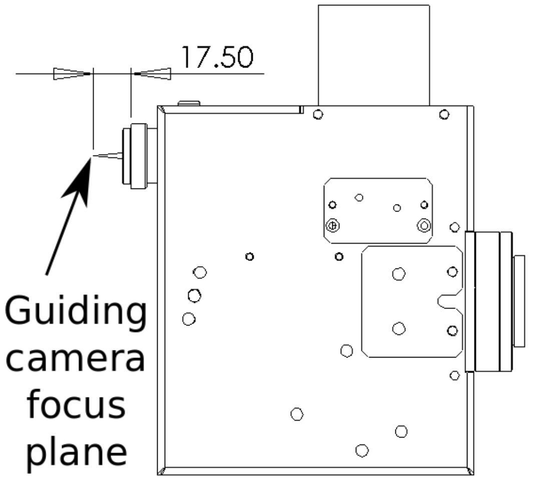


Figure 1.1: LISA Pack drawing



1.2.3 Guiding camera interface

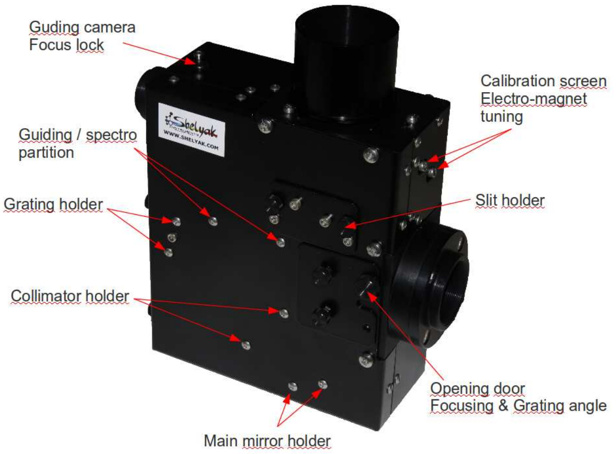
The guiding port is a C-mount (1" diameter, 32 thread / inch, backfocus 17.5mm) used by several guiding camera and is a standard among video camera.



2
Tuning the LISA spectrograph

Most elements of LISA Pack are tunable. You'll find here all details to make proper tunning. Some operations can be complex. Ensure you clearly understand them before starting any change in the instrument. If you have any doubt, don't hesitate to ask us for advices.

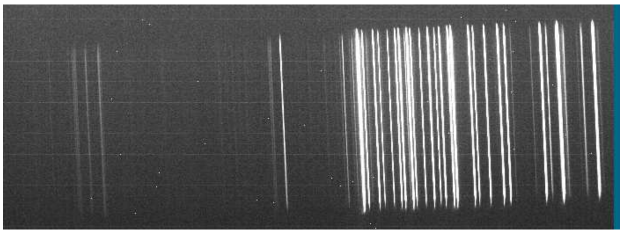
In the below image, we show the LISA spectrograph, with the function of each screw.



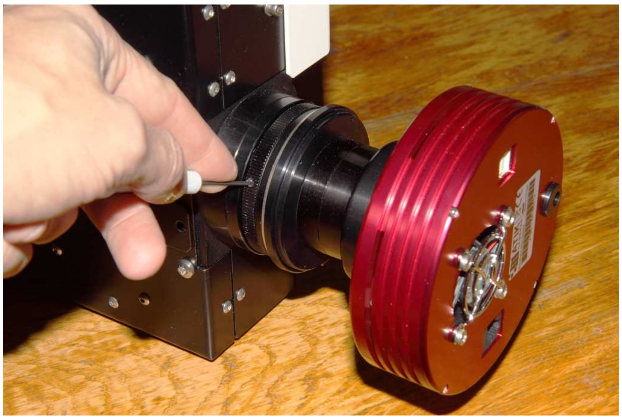
2.1 Acquisition camera

2.1.1 Angular position

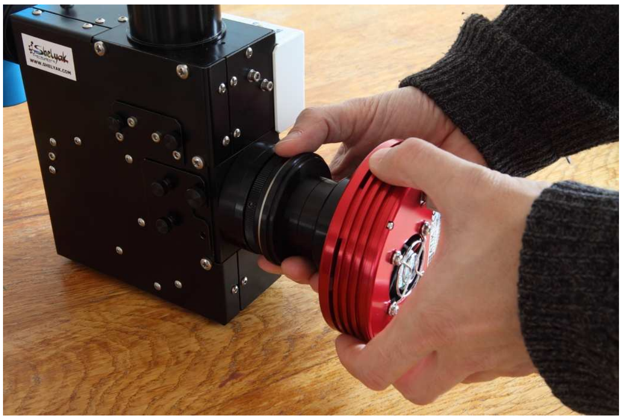
The spectrum must be as horizontal as possible. If the camera has rotated, you will see something like this:



If you are in this situation, you must tune the camera angle. Ensure that camera ring is well tightened. Then, untighten the three small screws on the T-mount adaptor:



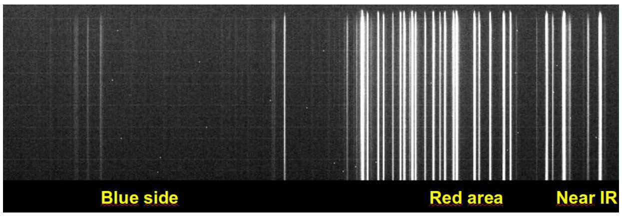
You can then rotate the camera:



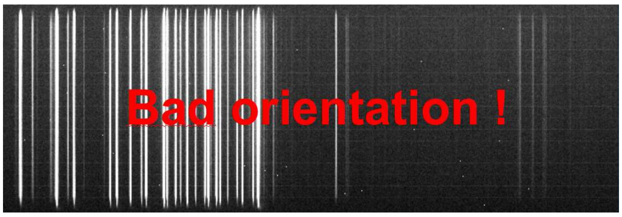
Define the right position and tighten the three screws.

> If you are not using Atik camera, you must first check that backfocus is correct. Backfocus is the distance between the spectrograph and the CCD plane. The right position can be adapted with adaptor rings. Contact us if you need assistance.

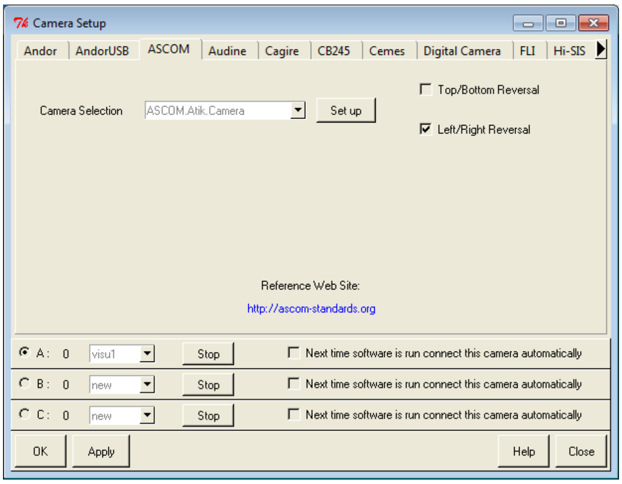
An other element to check is that your spectrum is properly oriented. The red part of the spectrum is on the right (lower temperatures), and the blue side (high temperatures) is on the left. With the experience, you will be able to recognize this spectrum. check that the orientation is correct in your case:



In some conditions, you could have the image in the below configuration. It is the same image, but reversed, as if we saw it in a mirror:

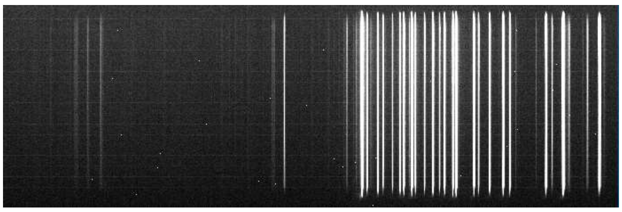


If your image is in this configuration, it can be because camera is mounted in reversed position (rotation of 180°). It can also be due to the “horizontal mirror” option is selected in the configuration panel of the camera. You must reverse it by unselecting this option (go to Setup / Camera):

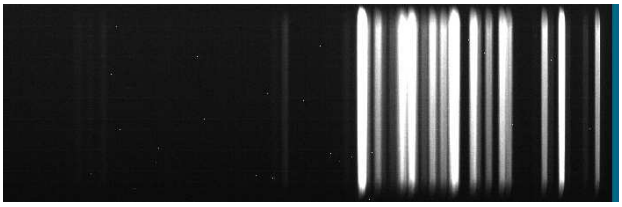


2.1.2 Focusing the spectrograph

Focusing the spectrograph is key to get the full resolution of the instrument. You must see sharp lines in the neon image. Below is a correct image:

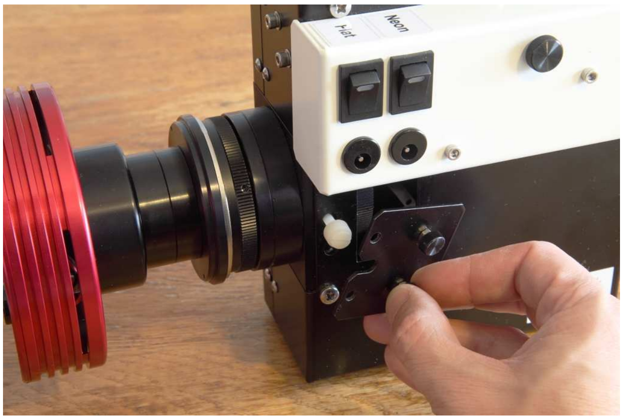


To give you some reference, here is the same neon spectrum, but with a badly focused spectrograph:

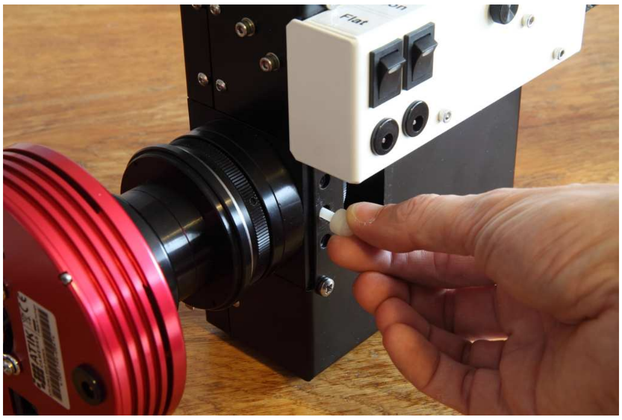


If you are in the second case, it means that your instrument must be tuned.

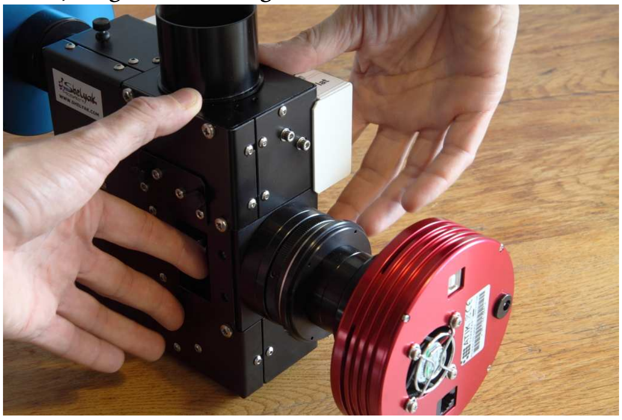
Open both doors on LISA sides: just remove the big screws (one per door), and slide them gently towards the camera:



Untighten the white plastic screw on the side. This screw is to lock the main optics in position:



You can now move the LISA main optics, with one finger in each door opening. Take regular images with the camera and rotate the lense in the direction that improves the focus (close the openings to prevent light saturation). Bright lines must become thiner and thiner, brighter and brighter:



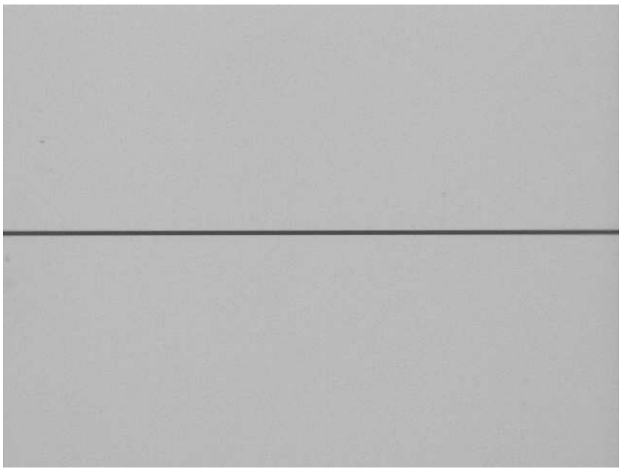
Once you have found the approximate position for the lense (optimal focus), take some time to fine tune it. The most efficient way is to measure the Full Width at Half-Maximum (FWHM) of a line near the center of the CCD, and make it as small as possible.

> You can calculate the theoritical FWHM for your setup. Optimal width is to have lines FWHM of about 2.5 pixels (Nyquist criteria). Let's take an example : in our configuration, the slit is 23μm. The CCD pixels are 6.45μm large. The slit image will be 23 x 0.68 = 15.6μm (the slit image is multiplied by 0.68 in LISA), which is 2.4 pixels (15.6 / 6.45). It is close to the optimal value of 2.5.

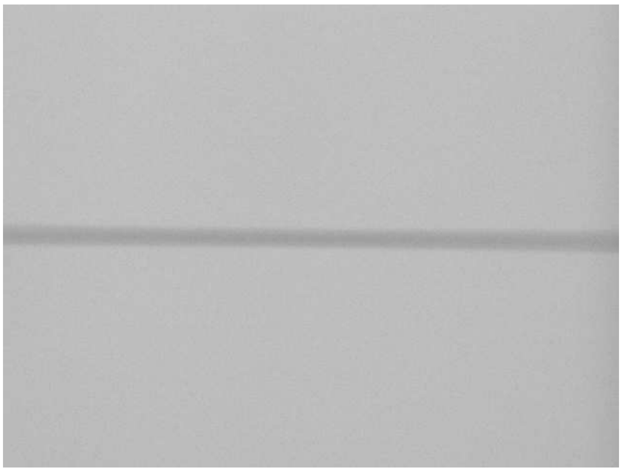
To get to this resolution, the accuracy required on the lense rotation is about 1/10th of a turn (1/10mm). Tighten the plastic screw (main lense locking). Do not remove the CCD camera from the LISA before you install it on the telescope. If you remove the camera from the LISA, check the focus again.

2.2 Guiding image

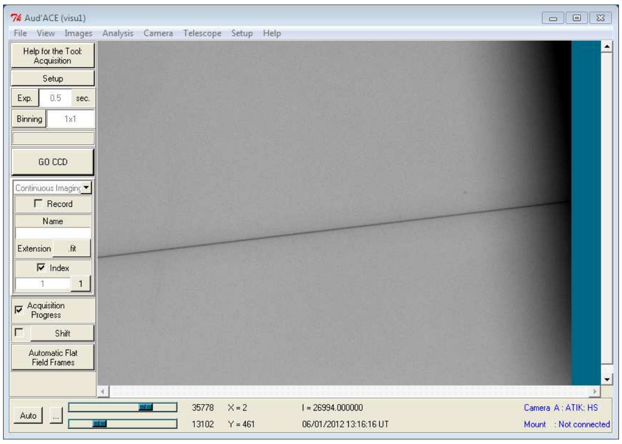
The guiding image must show a good slit image. The below image is correct:



If the camera is unfocused, you can see:



And if the camera is rotated, you'll someyhing like:



And if the guiding mirror is untuned, the slit is not in the middle of the image anymore:

There are two elements to tune to correct these issues:

- Tuning the guiding camera to focus and rotate the slit image,
- Aligning the guiding mirror, to put the slit center in the middle of the guiding image.

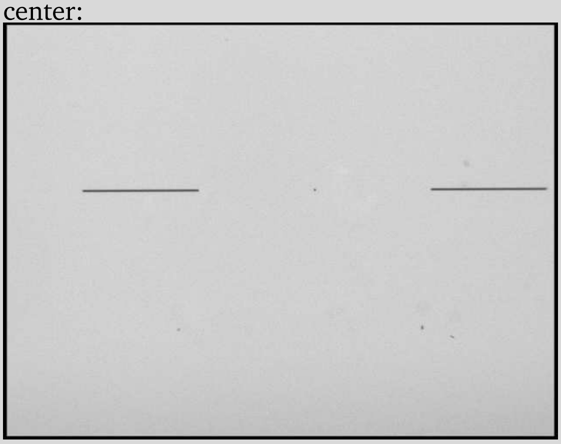
2.2.1 Focus and rotation

You can tune the slit focus and rotation in one step: Untighten the guiding camera blocking screw, and move the guiding camera until the slit is sharp and horizontal. If this tuning has changed, you can have something like:

2.2.2 Slit center is not in the middle of the image

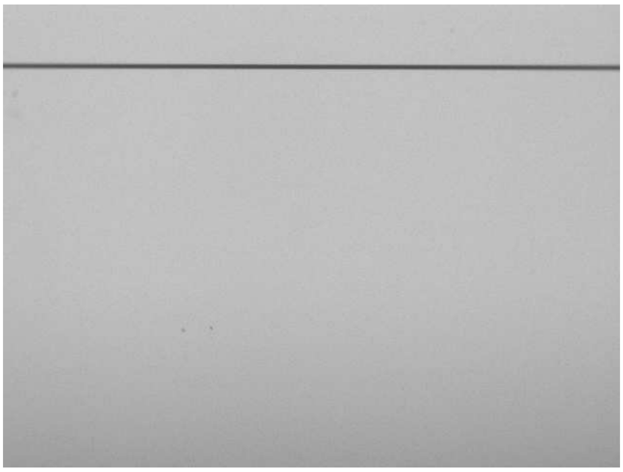
The guiding mirror can be tuned from the telescope opening. There a 4 screws to do it:

The tuning is very senstive: you must look at the guiding image when you move the mirror. It is better to do it with the optionnal tuning slit (19μm hole + 50/75/100μm slits - ref. SE0105): you can see immediately the slit center:

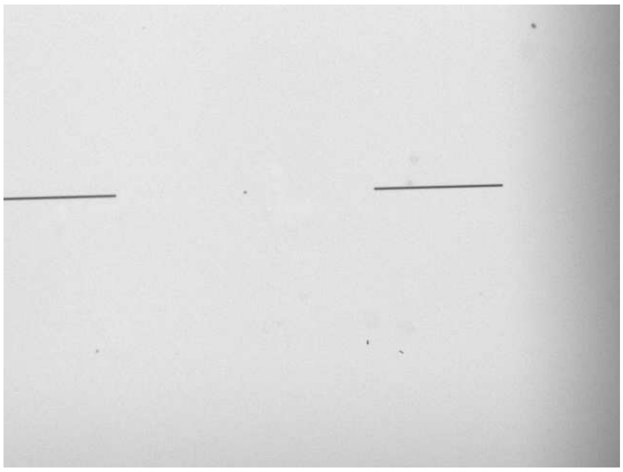


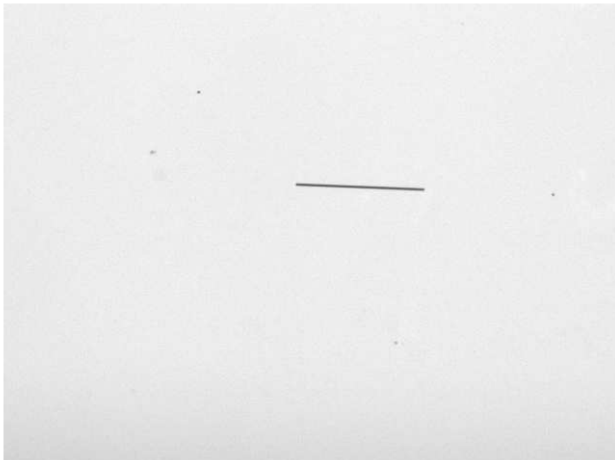
Untighten the two bigger screws (external):

You can move the slit vertically in the image by changing small screws position:



Rotate the mirror holder around its axis : the slit position will move horizontally (in the below images, we used the optional tuning slit):





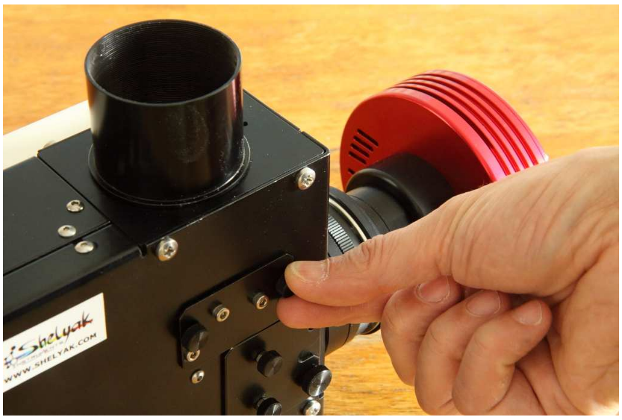
2.3 Slit maintenance

You can easily access to the slit, for several reasons:

- There is some dust on it,
- You want to change the slit width (slit has 4 positions: 15μm, 19μm, 23μm, 35μm),
- You want to replace the slit by the optional complementary slit (19μm hole + 50/75/100μm slits - ref. SE0105).

Each time you remove and replace the slit, you potentially lose the spectrograph focus. You must at least check after this operation that the focus is still good, and re-tune it if needed.

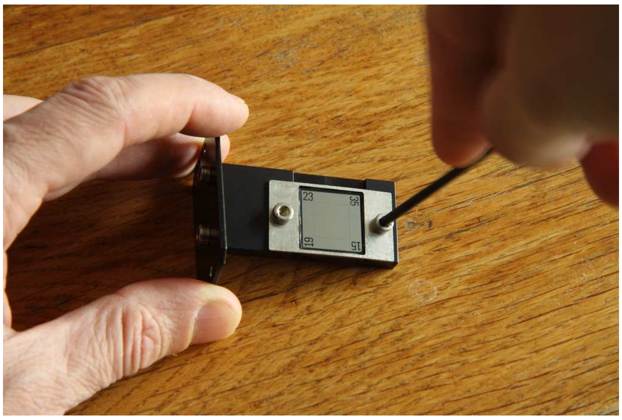
Remove the two screws of the slit holder (no tool required):

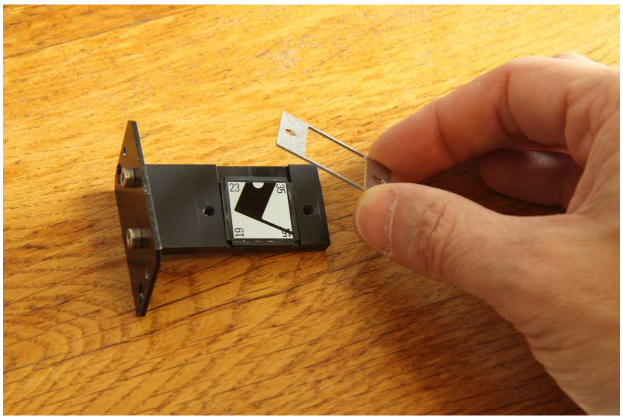


Then, remove carefully the slit from the LISA spectrograph:

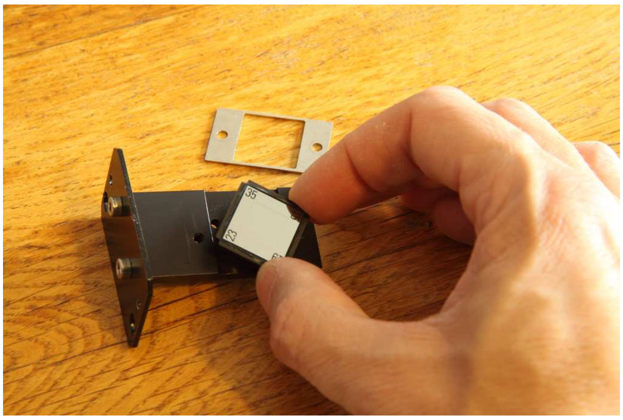
Do not put your finger on the slit, and don't use any abrasive product to clean it up - like for any optical surface.

You can change the slit width. Remove the two screws on the slit bracket.



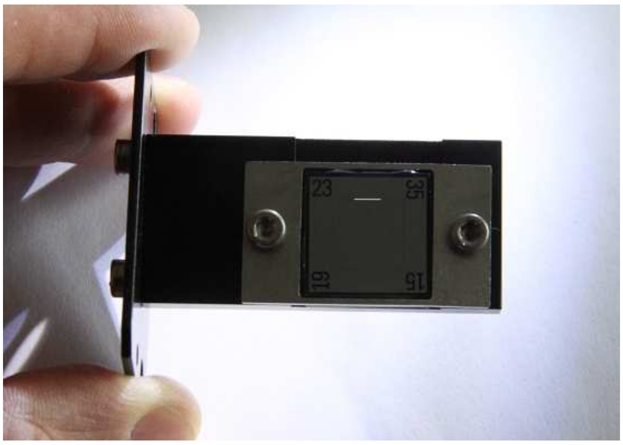


You can them rotate the slit itself in the position you want:



When you tighten the screws, ensure the slit edge is exactly parallel to the slit holder:

When the slit is in place, check that you've selected the right width. Look through a clear light to see the slit: its width is written on the left. In the below example, the slit is 23μm (this is the standard configuration):



Put the slit holder back onto the spectrograph, and tighten gently the two screws. Check immediately the focus of the LISA, and re-tune it if required.

2.4 Mounting & Removing the Calibration module

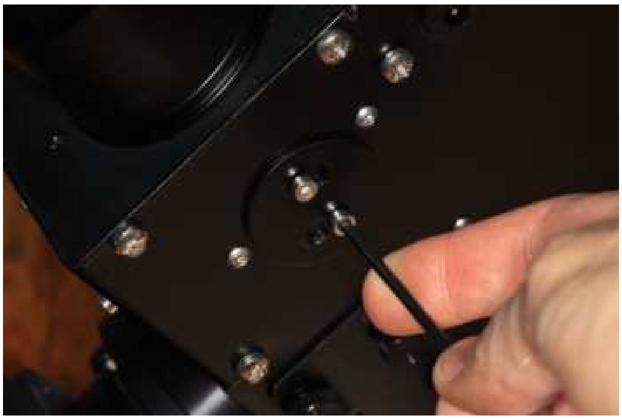
Remove the calibration module if you need to replace a lamp. Remove first the screw in the middle of the calibration module (no tool required):

Then, remove carefully the module, and unplug the connector (this connector supplies the electromagnet inside the LISA):

Access to the neon lamp (calibration) or the tunsten lamp (flat fields).

If, for any reason you want to use the LISA spectrograph without calibration module, think to put a screw where the calibration module is atteched:

and mask the calibration window, to prevent any light leakage:



2.5 Opening / closing your LISA spectrograph

> Be careful: this operation is complex. It must be done only if you exactly know what you're doing.

In some specific conditions, you may have to open the LISA. After such an operation, check the tuning is still Ok, and probably refine it. The LISA is made of two major assemblies: the chassis, and the cover.

- The chassis includes all optical elements of the spectrograph (slit, main mirror, collimator, grating, camera lense). This is done to make possible to tune the instrument when it is opened.
- The covers contains all elements for guiding and calibration.

The chassis and the cover don't have the same height: the splitting line is not in the middle of the instrument. The Chassis is the thinest part, and the Cover the thickest.

2.5.1 Opening

Both parts can be separated. To do so, follow strictly these instructions:

Remove both acquisition and guiding cameras.

Remove 2 screws (M3x10mm) from the the Chassis side:

Remove 2 screws (M4x10mm) from the Telescope plate side (Chassis side):

Remove 2 screws (M4x10mm) from the CCD camera plate side (Cover side):

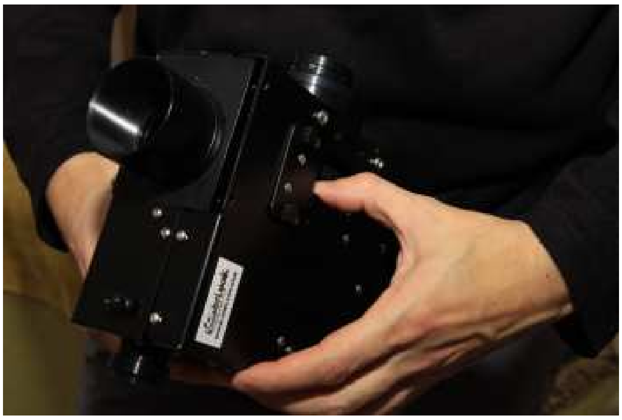
Untighten 9 screws (M3x10mm) all around the spectrograph, on the Chassis:

These screw can be left in place – no need to remove them completely:

Remove the two side doors (remove one big screw for each, and slide the doors towards the CCD camera):

Remove the plastic screw (main lens lock):

Take the instrument like on the picture: put one thumb in each door opening, CCD camera holder towards yourself:



Slighltly open the instrument, keeping both sides parallel. This can be quite difficult the first time: do it very carefully. If necessary, use a small tool (like a screwdriver) to start the opening (you can slide it between two sides). Take care to not damage the painting:

The LISA is now open. Be very careful with the optical elements: they are very fragile. Think to protect them against dust and finger prints.

2.5.2 Closing

Closing the LISA is exactly the same operation, in the reverse order. The most complex part is to slide properly the two sides together. Present them with precision, well parrallelly fitting. Engage the Telescope plate and the CCD plate first (check they are exactly at the right position):

Slide both sides together, until the box is closed. Check all area is properly positionned, all around the spectrograph.

Put back all screws in this order:

- Two M3x10 screws on the side first:

- Four M4x10 screws on telescope plate and on the camera holder,

- Tighten the nine M3x10 screws all around the LISA,

- Close the two side doors (you can do it after focusing the spectrograph),

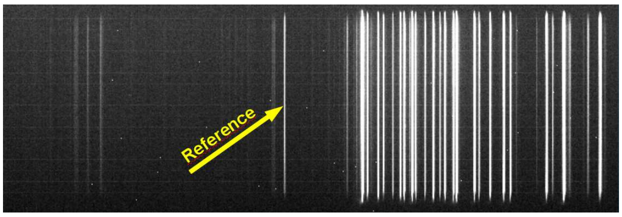
- Plastic screw for lens blocking.

2.6 Tuning the grating angle

> Be careful: this operation is complex and very precise. Do it only if you absolutely need it, and if you're sure to understand the procedure.

This operation is done while LISA is closed.

The grating angle is key to get the best spectrum quality in LISA. This is a sensitive tuning, which must be done by an experienced user only. To make this tuning, put the LISA on a stable surface (large table, for instance), and install the CCD acquisition camera. You must have the full setup operational to take some spectra, using neon light. Nature is well made: in the neon spectrum, we have a bright line exactly in the middle of the image - when the LISA Pack is properly tuned. Its wavelength is 5400Å. This reference line is given in yellow here:



Defining the best grating angle is necessary to

- get the expected wavelength bandwidth (4000 to 7000 Å) within the CCD surface,
- get focused lines in the widest banwdwidth.

The expected horizontal position precision for this line is $\pm$ 0.2mm. With the Atik camera (6,45μm pixels), it is equal to $\pm$ 30 pixels. In other words, the reference line must be in the pixel range 666 to 726.

The horizontal position of the spectrum is given by the grating angle. You can move the grating angle thanks to the grating arm inside the LISA and accessible from the side opening:

To make the tuning, remove the side door below the slit:

Untighten the two screws on the grating holder (do not touch to the central screw, it is the rotation axis of the folder).

Do not remove the screws : the grating would fall down into the instrument.

Use the grating lever (in the door opening) to precisely change the grating angle, and tighten back the screws.

When you change the grating angle, the spectrum will be moved horizontally (along wavelength axis) in the image. Make some tests : move the grating lever by a very small angle, and look at the effect in the image. Train yourself to put a given spetrum line at a given position (pixel X in the image).

When you've defined the optimal position, tighten securely the two screws on the grating holder, and put back the door.

2.7 Focusing and aligning the collimator

Be careful: this operation is complex and very precise. Do it only if you absolutely need it, and if you're sure to understand the procedure.

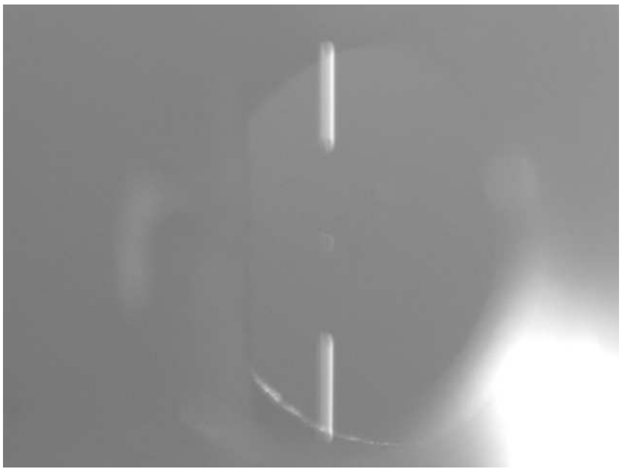
This operation should be done while LISA is open. Special toling is required for this operation. The collimator tuning (focus and alignment) is made in our factory before shipping. This section explains how to tune it if needed. Be careful: this is a complex operation, which must be done only by an experienced user.

To work in good conditions, the grating must be enlighted by a parallel light beam. This parallel beam is made by the collimator doublet. The doublet must be perfectly focused on the slit.

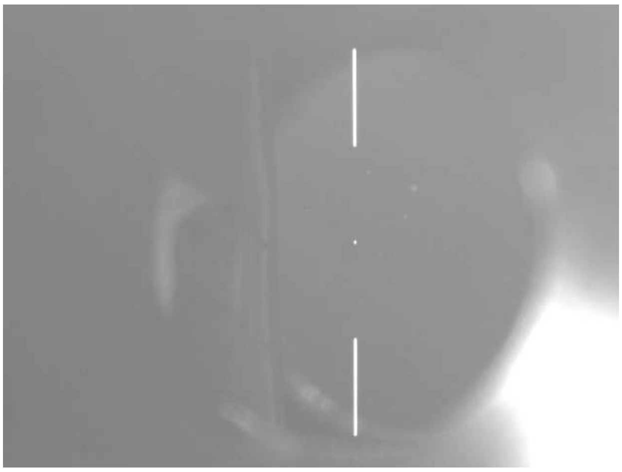
To make this operation, use the tuning slit (provided as an option by Shelyak Instruments - ref. SE0105), with a 19μ hole in the center:

- Focusing the doublet should be done this way:
- Open the LISA (see 2.5).
- Remove the grating holder, and put it in a safe place.
- Use any optical device focused at the infinite. It can be a telescope finder, or a camera with lense focused at the infinite.
- Look with this optical device through the collimator doublet, towards the main mirror.
- Align it properly to see the slit.
- Untighten the doublet screw:

- Rotate the doublet until the slit image is perfectly focused. In this first image, the slit is not focused:



The same image with a good focusing:

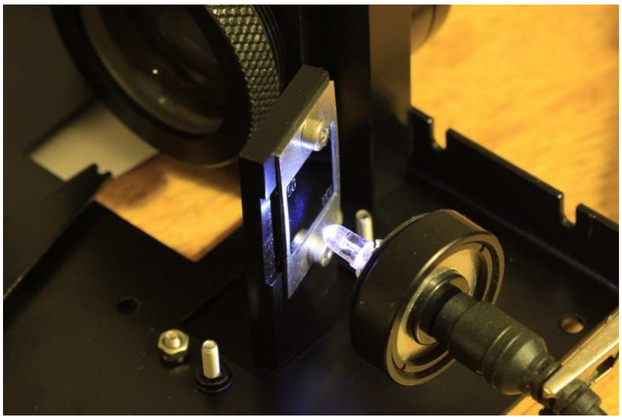


Be careful : this process is valuable only if your optical device have been focused at infinite first.

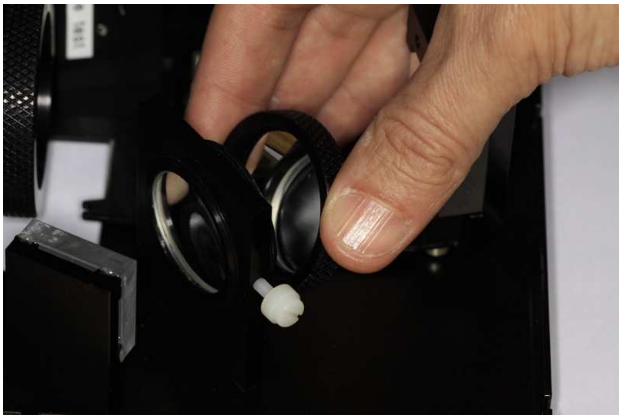
Once the optimal position is found, tighten back the collimator screw.

To make the instrument properly aligned, we then must tune the collimator axis towards the slit center.

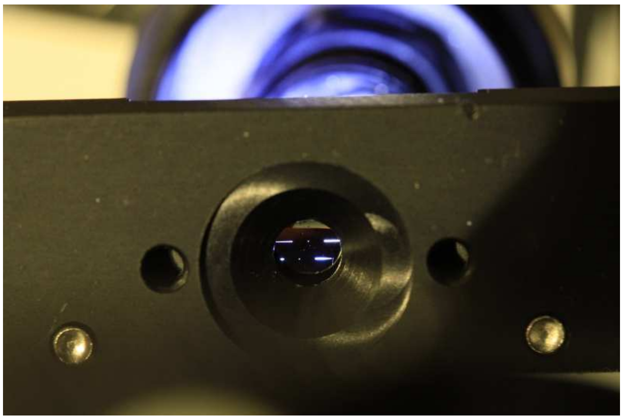
We use an autocollimation process to do it: put all your setup in a dark room (very dark). Enlight the slit with an intense lamp (for instance, white LED just in front of the slit):



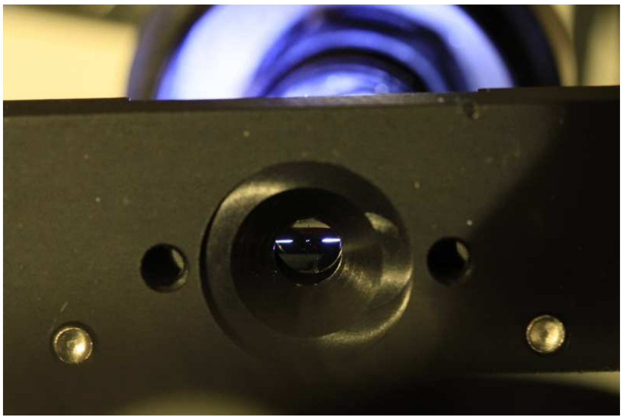
Put a mirror against the collimator holder:



Look at the slit image, close to the slit itself. When the alignment is correct, both slit and slit image must be mixed. In the first image, the collimation is not good.



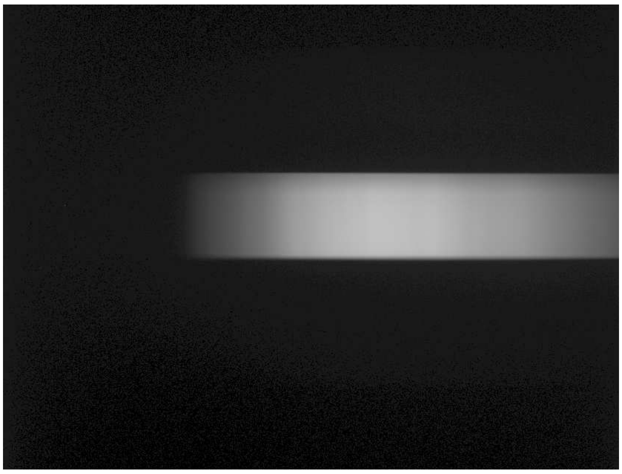
To change the alignment, untighten the collimator holder, and rotate it gently until slit and images are aligned:



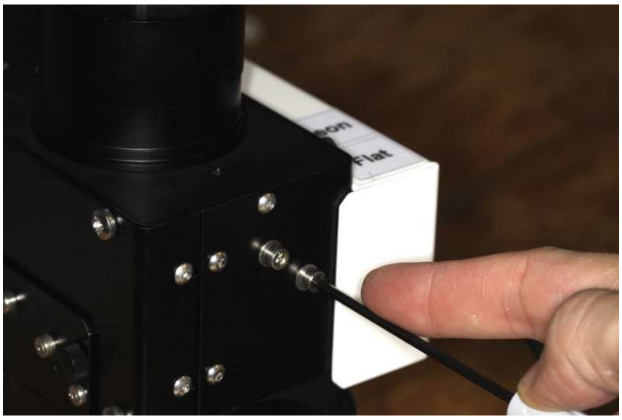
If you need to give an inclination angle to the holder, put a small piece of paper between holder and chassis. Once the alignment is optimal, tighten back the two collimator holder screws. Mount back the grating holder. Close the LISA (see 2.5). Tune the grating angle (see 2.6). Your LISA is ready for observation.

2.8 Tuning the calibration screen

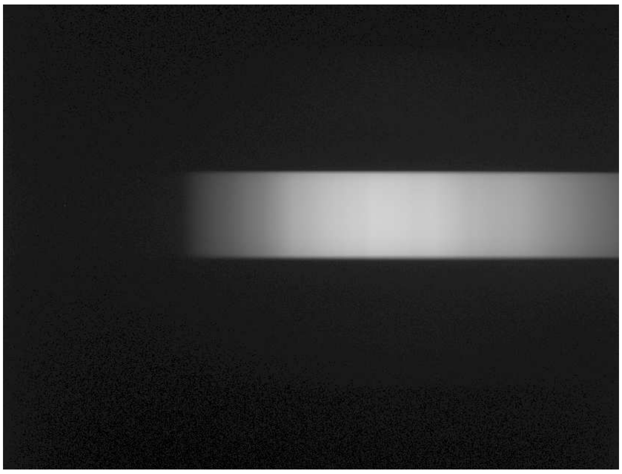
The calibration screen is made to enlight the slit with calibration light sent through the calibration window. The position of the calibration screen is tunable by moving the electro-magnet which control it. If the calibration screen is not properly tuned, the calibration spectra will not be perfectly homogeneous (transversal direction, along vertical axis in below image), and some light coming from sky can pollute the reference spectrum:



You can improve this by moving the electromagnet position. Untighten the two screws (do not remove them completely - the electromagnet would fall down in the instrument), and move them horizontally (use the screwdriver):



Once it is OK, tighten back the two screws. The flat should be now well homogeneous along a vertical line:



3
LISA Pack accessories

3.1 Near Infra-Red convserion kit

The LISA can be configured in two modes : visible and Near Infra-Red (NIR). The standard configuration is visible. You can switch to NIR configuration, using the NIR conversion kit, provided as an option by Shelyak Instruments (ref. SE0096). There are three differences between VIS and IR configurations:

- The grating is different (VIS is blazed at 500 nm, IR is blazed at 1000nm)
- There is a blocking filter after the slit in the IR configuration, to prevent any second order spectrum mixed with the IR part of the first order
- The CCD camera spacer makes an angle of 4° with the spectrograph face, to ensure a good focus along spectral range.

3.2 Complementary slit

The LISA Pack slit has 4 possible values: 15 μm, 19 μm, 23 μm (standard), 35 μm. As an option, we also provide a complementary slit (ref. SE0105), which includes 4 additionnal configurations: 50 μm; 75 μm, 100μm and a special slit with a hole of 19 μm in the middle of two short slits. This last position is very useful for the tuning of the instrument:

When using this option, the spectrum looks like: