Getting Started in Astronomical Spectroscopy with RSpec

Document Version 1.10. To check for more recent versions, click this link.

Introduction

This document is a basic introduction to capturing and processing calibrated astronomical spectra using the RSpec software and either a Star Analyser grating or a slit spectrometer.

The Star Analyser grating is designed specifically for astronomical spectroscopy. It mounts on your telescope or DSLR camera just like any other 1.25" filter. It's easy to use and produces clear, easy-to-work-with spectra. These spectra are similar to those that a prism produces.

Once you capture a spectrum on a camera sensor, you can use RSpec to convert the image data into a profile intensity graph. These graphs have dips and peaks that are caused by absorption and emission of light by the stellar gases. Using these spectral features, you can often determine the chemical composition of the star as well as other physical properties, including star type and approximate temperature, and sometimes radial velocity, etc.

RSpec is also an excellent tool for processing spectra produced by high-end slit spectrometers. Everything in this document applies to slit spectra also, with the exception of the section on wavelength calibration. If you are using a slit spectrometer, see video 29 at this link for information on using RSpec to calibrate slit spectra.

For additional tutorials on using RSpec to capture star spectra, see the videos at www.rspec-astro.com/more-videos.

How to get help

Have questions? There are lots of ways to get answers:

- Our **online forum** is a wonderful place to ask questions: link. The members of our community love to answer questions. Our membership includes experts who can help you get past any roadblock you may encounter. No question is too simple, so don't hesitate to ask us to help.

- Our **on-line chat** application will get you in touch with someone who has answers: either the author of RSpec (Tom Field) or someone else who is experienced and friendly. If the chat app tells you we're not available, leave a message!

- **Email**: You can send an email to us directly if you have the email address or you can use our contact form: link. Be sure to include your email address so we can respond!

Free practice run

We have a great video of Tom Field teaching an hour-long, hands-on workshop at an SAS/AAVSO conference.

We encourage you to view the workshop video and follow along step-by-step with RSpec running on your computer. Go to this link to download:

- a trial version of the RSpec software
- the workshop sample data files
- a complete video of the workshop.

This is a great way for you to practice the procedures described on the following pages.

1. Selecting the right Star Analyser

There are two models of the Star Analyser: SA-100 and SA-200. These differ in the angle at which they deflect the spectrum. To determine the best Star Analyser and spacing for your particular setup, see the explanation and calculator here at www.rspec-astro.com/calculator.

For the most commonly used equipment configurations, the calculator is likely to tell you that the Star Analyser 100 is the optimal grating. In certain situations, however, the calculator may indicate that the SA-200 is best suited. This is most often the case when the grating is mounted relatively close to the sensor (for instance, in a filter wheel).

2. Mounting the Star Analyser

Mount the Star Analyser on your camera or filter wheel at the distance from the sensor determined by the calculator in step 1. The distance provided by the calculator is approximate. Low-resolution spectroscopy is very forgiving, so the actual distance between the grating and sensor doesn't have to exactly match that called for by the calculator.

> *Note:* As noted in the instructions for step 1, if you are using a DSLR, you may need our AD-58 or AD-T2 adapter: link.

Locate the alignment mark on the Star Analyser, as shown below.

This mark allows you to screw the Star Analyser into your camera nosepiece or filter wheel so the star's image and its spectrum are positioned "horizontally" on the camera sensor as shown below. (Notice in the image below that the brighter spectrum is to the right of the star image.) For example, in the case of a DSLR, the proper image is obtained if the mark on the Star Analyser is on the right side of the camera (where "right side" means the side on your right as you stand behind the camera and look through the viewfinder.)

To confirm and fine-tune the Star Analyser's rotational position, capture an image using any imaging software you wish. If the spectrum does not appear to be horizontal, rotate the grating a bit and capture another test image. Don't worry if this fine tuning takes a few tries. This is a trial and error process.

> *Note:* It is not necessary that the spectrum be exactly horizontal. After you capture the image, the RSpec software can rotate the spectrum to be closer to horizontal. In some rare circumstances, however, using software rotation can introduce minor artifacts into the spectrum. Software rotation may also slow the software on large images and also make it more difficult to point your telescope, because the orientation of the spectrum is at a different angle than you are seeing.

You can fine-tune your grating's rotation during the day by using a compact light source located across the room or the light in an adjacent room viewed through a door that is open only an inch or two. In the early evening, a distant street light can suffice.

> *Warning!* **<u>Never</u>** look at the sun through a telescope or camera lens or viewfinder or directly.

After getting the Star Analyser aligned on a telescope, it's helpful to secure it in that position. You can use the lock ring that came with the Star Analyser, although that can be a bit cumbersome. Alternatively, you can secure the Star Analyser with a small bit of removable silicon bathtub caulk or Teflon tape applied to the threads of the grating filter cell.

3. Capturing data

You can use either a monochrome or color camera to capture images. Monochrome is a bit more sensitive. But sensitivity is not critical because there are lots of bright stars to study. Color can be helpful if you're teaching or doing public outreach. That's because color cameras, while not as sensitive, produce spectra that are easier for newcomers to appreciate and understand because of their ROYGBIV appearance.

We strongly encourage you to use a mono camera if you have one already or are choosing a camera specifically for the Star Analyser and science in general. Color cameras make it somewhat more difficult to move beyond visual spectra processing into more advanced activities, like color temperature, etc. These difficulties come from the fact that the colors aren't "true" because of the 3 Bayer filters, which also cause a loss of resolution. Color cameras can also result in loss of spectral range due to the UV/IR cut filters and artifacts produced by color cameras. But, as noted above, for outreach and general introductions, color has more visual impact on newcomers.

You should begin by capturing the spectrum of a bright Type A star like Vega or Sirius. That's because these stars have clear Hydrogen Balmer lines.

Please stop here and re-read the above paragraph. **<u>It's very important to start with a Type A star!</u>**

To get started, point your telescope (or DSLR) at a Type A star like Vega or Sirius and capture an image with your camera.

3.1 The big picture

Capturing astronomical spectra is very much like capturing other astronomical images. You need to take into account:

- **Exposure time**: You need long enough exposures to capture sufficient photons for a bright image. But if you use too long an exposure, you saturate your camera.
- **Focus**: You need to have good focus.
- **Tracking**: For longer exposures, your equipment needs to track the motion of the stars in the sky.

> *Note:* there are some exceptions to this. See the Tracking section further down in this document.

None of these are particularly difficult, and they're not much different from in the requirements for visual imaging. Getting the correct exposure and focus can require a bit of trial and error. The next couple of sections walk you through that.

> *Note*: if you are new to astrophotography we encourage you do some initial imaging *without the Star Analyser.* You need to be comfortable finding, focusing, tracking and correctly exposing targets without the Star Analyser before you add one. We also encourage you to choose targets when they are high in the sky, away from the horizon and to avoid nights with bad seeing. If even the stars directly overhead are twinkling, it will be difficult to capture useful spectra.

3.2 Using a still camera

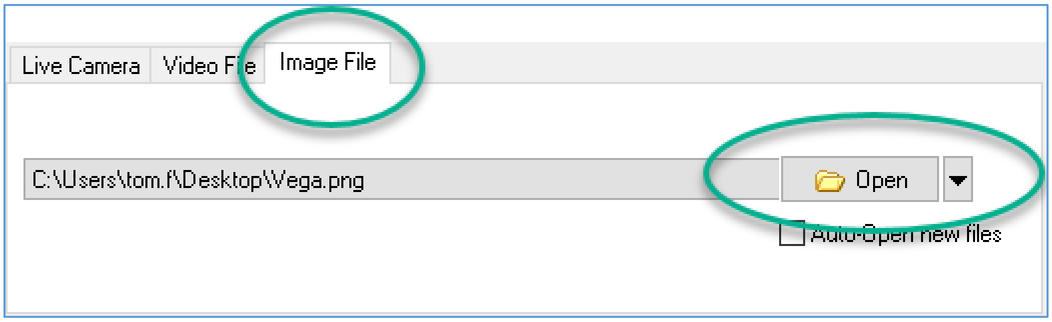
If you're using a still camera, continue to use whatever imaging software you've used in the past to control your camera and download images. The RSpec software can read any bmp, FITS, jpg, png, tiff, or DSLR raw file.

If you're using a DSLR, we recommend you use either the camera control software from the camera vendor, or a program like BackyardEOS or BackyardNIKON.

Note that Raw DSLR files are often quite large and aren't generally necessary for low-resolution spectroscopy. Low compression (lossless) JPGs from your DSLR are faster and easier to work with.

You can capture good spectra without removing the IR filter from your DSLR. Although any spectroscopic features in the deep red will not generally be visible, the majority of the features you'll work with at this stage won't be affected by the filter.

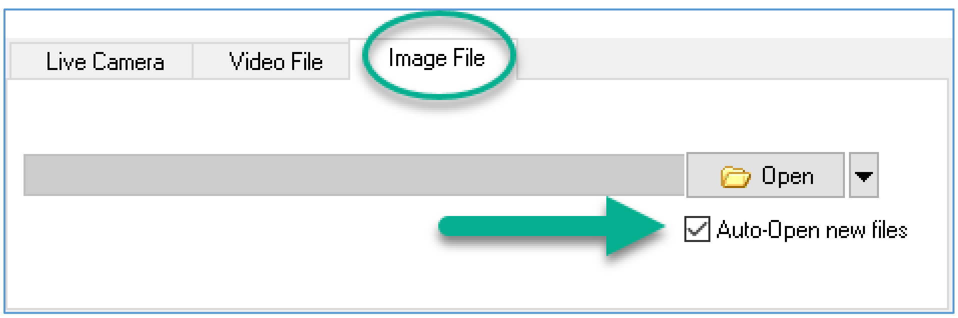
To view a captured image in RSpec, use the **Open** button on the RSpec **Image File** tab, as shown below:



Hint: You can also open an image in RSpec by using your mouse to drag-and-drop a file from Windows Explorer onto the image panel in RSpec.

3.3 If you're using RSpec in the field and wish to view spectra as you capture images

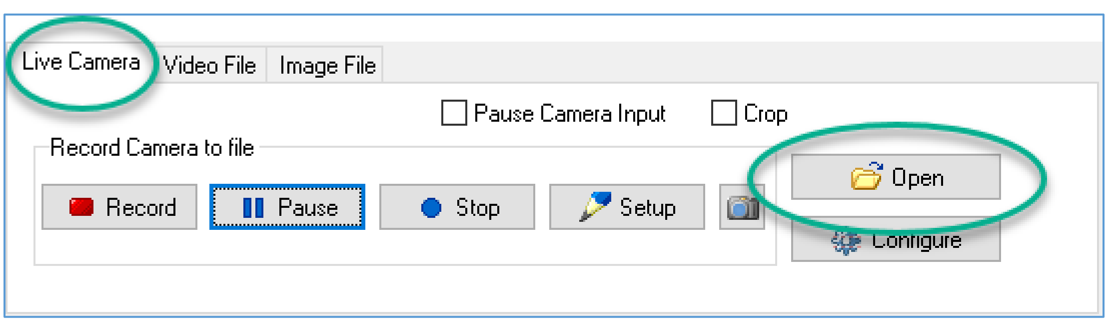
You can configure RSpec to automatically open any new image that appears in a folder of choice. With this option enabled, when your camera software saves an image file in the chosen folder, RSpec will open it automatically. This allows you to examine your images as you capture them, making your imaging session smoother and faster. *This feature is really helpful when you're focusing.* To take advantage of this feature, put a checkmark on the **Auto-Open** box as shown below.



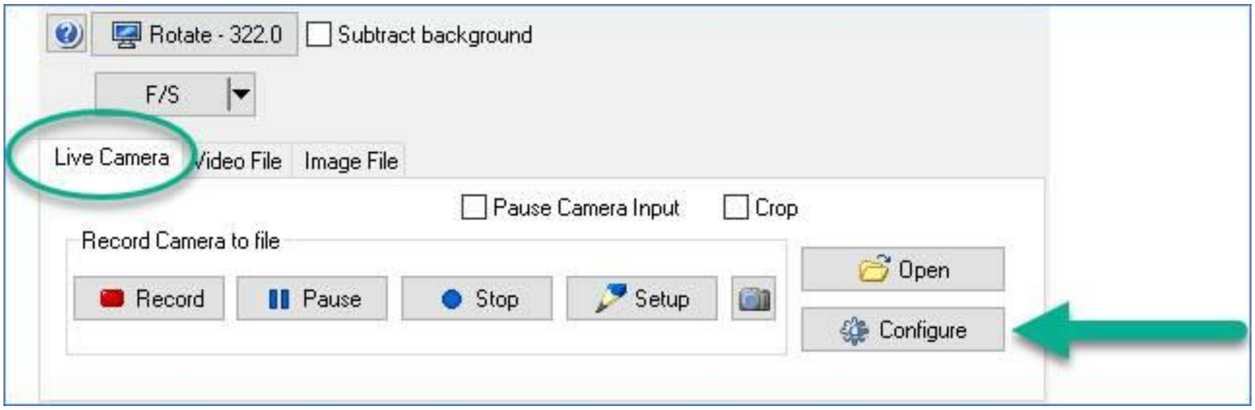
To specify which folder the auto-open feature monitors, go to the **Advanced** tab on RSpec's **Options** screen.

3.4 Using an astronomical video camera

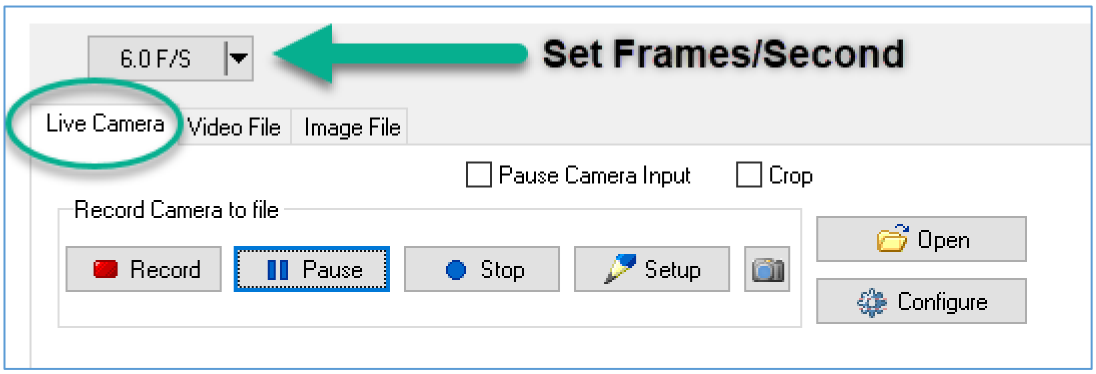
If you are using a video camera that has DirectX drivers, RSpec can display the video stream as it is captured in real time. First, select the camera by clicking on the **Open** button as shown below:



If you're using a video camera that has large frames (>16 megapixels) or a very fast frame rate, you may need to reduce the frame size and/or slow down the frame rate a bit. To reduce the frame size or make other changes to your camera's configuration, use the Configure button in RSpec (as shown below) to access your camera's configuration screen. On that screen, you might also configure your video camera for a region of interest (ROI) that just includes the star and spectrum.



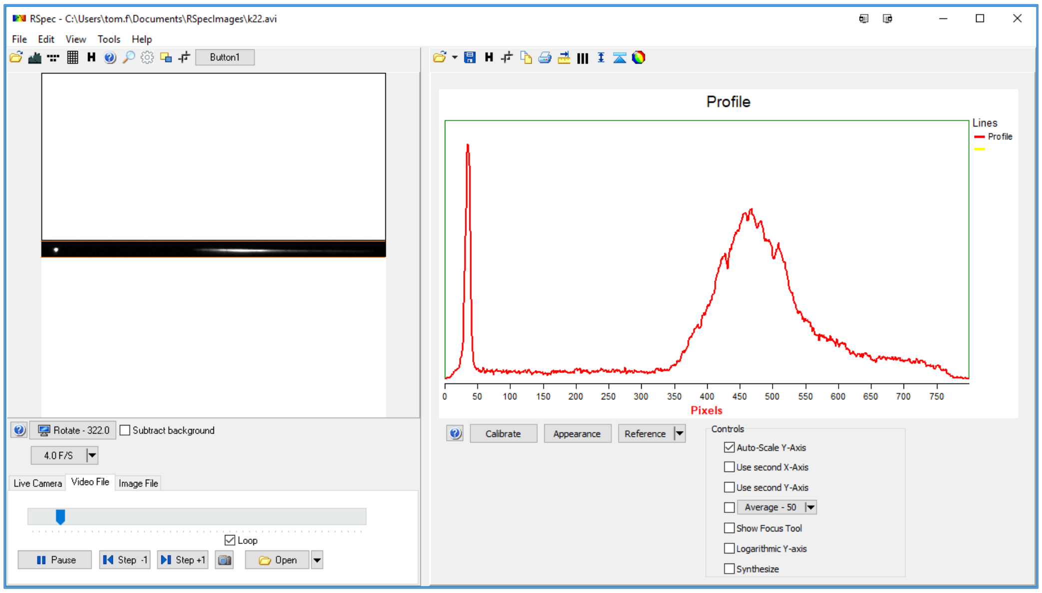
To slow down the video frame rate of your camera, use the same Configure option above to access your camera's settings. Or, you can use the RSpec **F/S** ("Frames/second) button shown below:



Some video cameras can also optionally produce static images (e.g. FITS, JPG, PNG), perhaps even stacking them on the camera. If you prefer longer exposures, you can use these static images from your camera. Use your camera's control software to capture images directly to your hard disk or SSD. Then, open the images in RSpec as you would open any other image file, as discussed previously.

4. Examining your image

The RSpec screen consists of two side-by-side panels as shown below:



The left panel of this RSpec screen contains the image as seen through the telescope or camera lens; the right panel contains a profile graph that we will discuss in a moment.

With proper exposure levels and focus, the left panel of your screen should contain a star and spectrum as shown below (in color or mono). We're showing a color version. If you're using a mono camera, your image will, of course, be in black and white.

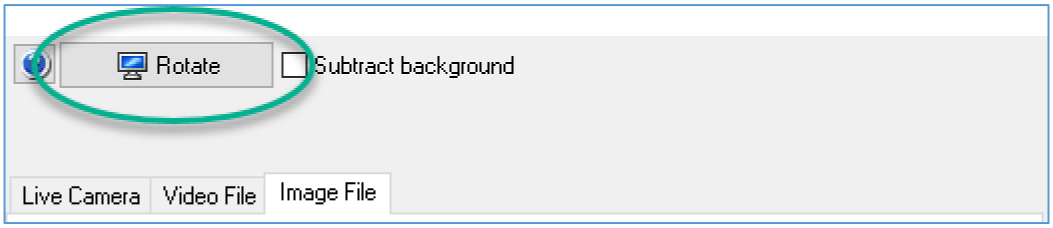
Leftmost in the image below is the round image of the star itself. This is a small portion of the starlight that passed *straight through* the diffraction grating without being diffracted.

To the right of the star is its spectrum. This is starlight that was diffracted by the grating.

If the star or spectrum don't appear in your initial images, don't worry – on the next few pages we'll show you how to improve your image.

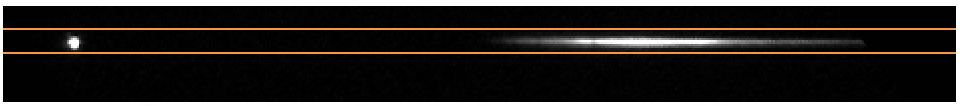
If no stars are visible in the image in the left panel, make sure your telescope or camera is pointed properly, lengthen your exposure time, and experiment with different focus settings, as discussed on the following pages.

If the star and spectrum are not horizontal, you can rotate the image using the **Rotate** button, as shown below:



4.1 Adjusting the orange sampling lines

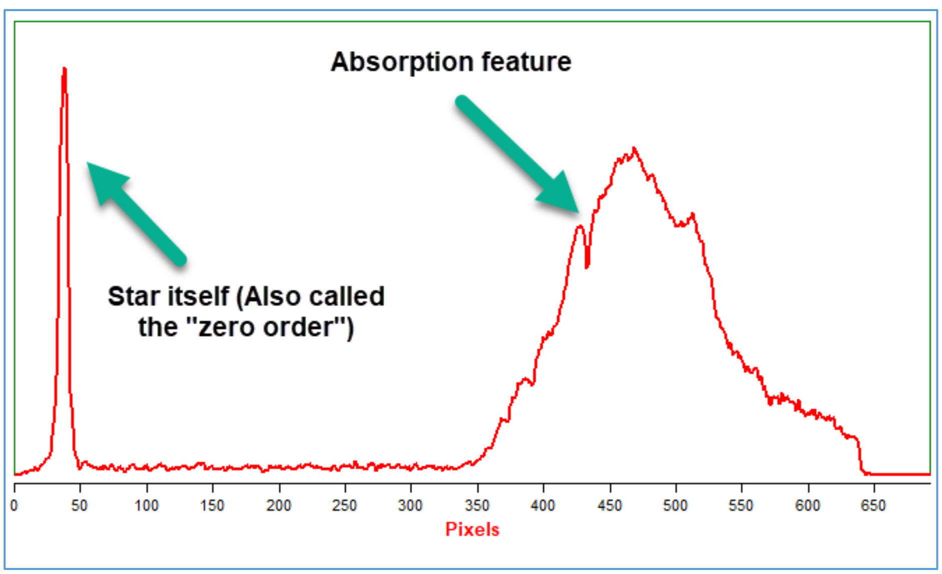
If you can see a star (even if its spectrum is not visible to its right), hold down your mouse and move the orange sampling lines so they snugly bracket the star above and below, as shown below:



Orange lines bracketing a star and its spectrum

4.2 Your first profile graph

If you have sufficient exposure and good focus, you should see a graph on the right side of the RSpec screen, as shown below:



The graph should have dips in it similar to the one at about 425 pixels in the above image. Absorption features are caused, for example, by the star's Hydrogen absorbing specific wavelengths.

5 Getting the best spectrum you can

Even if you can see absorption features in the graph on the right side of the RSpec screen, you may be able to improve the clarity of features in the graph, as described in the section below.

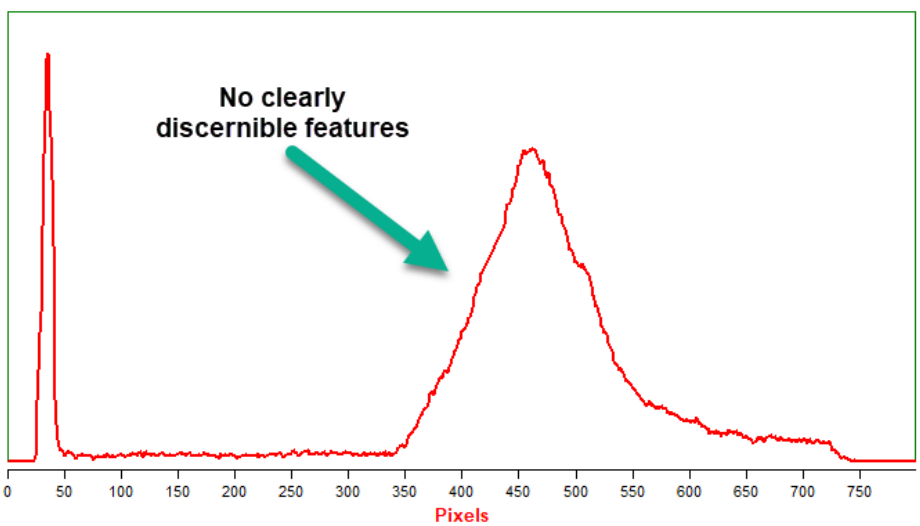
In normal astronomical imaging (without a grating), a star's photons fall on a *handful* of CCD pixels.

When you add a Star Analyser grating, it spreads out the same number of photons across *hundreds* of pixels. This means that images will be much dimmer.

When you add a diffraction grating to your telescope, because the light is spread out, the sensitivity of your system drops by 5 or 6 magnitudes. That means if your normal limiting magnitude is 15, with a grating it will be 9 or 10.

If your exposure time is too short, or seeing is bad, or the target star is out of focus, you may not be able to see the absorption dips in the spectrum as shown in the graph above.

Below is an example of how a spectrum appears if it is poorly focused or captured with bad seeing. It's a type A star, but notice that it has almost no discernable features (dips or peaks.) An under-exposed image would have the same problem.



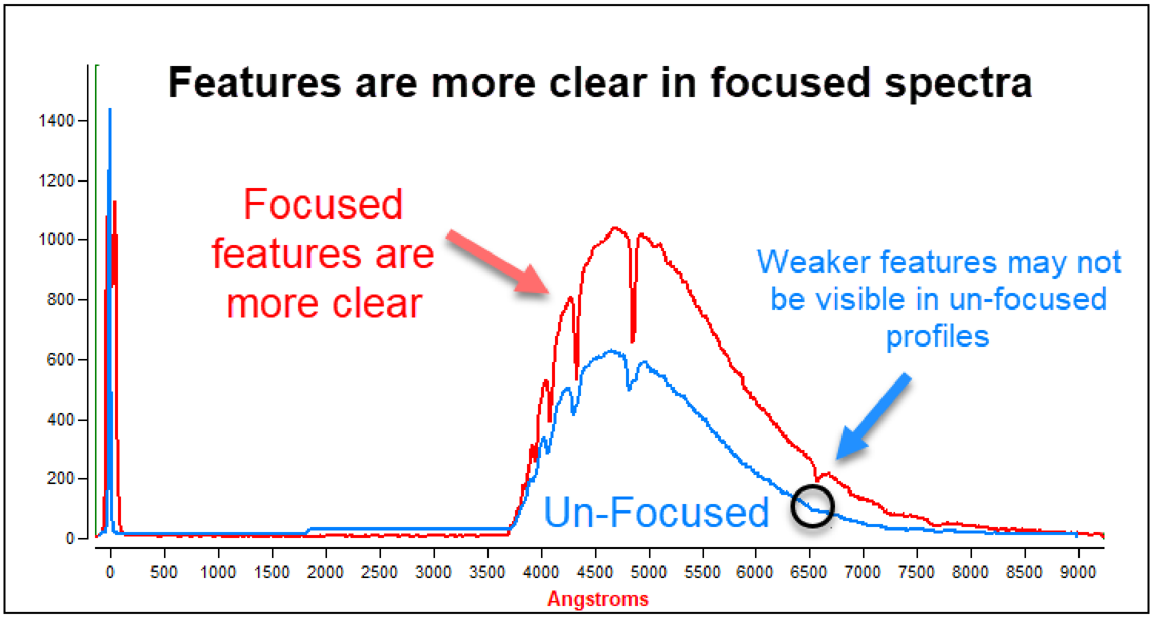
The above problem would also happen if your spectrum isn't dispersed ("spread out") enough because the grating is too close to the sensor or your DSLR zoom is too low.

It is not possible to calibrate or study a spectrum that is as noisy or feature-free as this one

In the following sections, we'll discuss how to reduce the noise in your spectra so that the spectroscopic features (dips/absorption and peaks/emission) are as pronounced as possible.

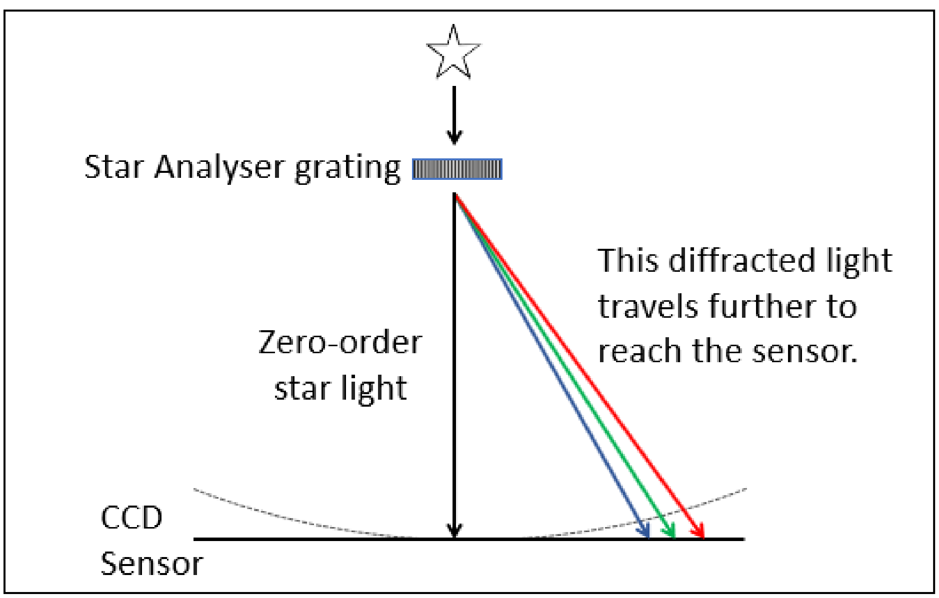
5.1 How does incorrect focus affect a spectrum profile?

The image below shows two profiles of the same Type A star.
The blue profile was captured after focusing on the star. Features are weak, distorted or missing.
The red profile is the correctly focused spectrum. Features are sharp and deep.



5.2 Why is the focus for a spectrum different than the its zero-order star?

Diffracted light travels further to reach the CCD than the zero-order star light. The longer light path requires different focus.



5.3 How to Achieve Good Focus on a Spectrum

Achieving proper focus on a spectrum captured with a slit-less device can be a challenge. If you focus on the star, the spectrum will not be in focus.

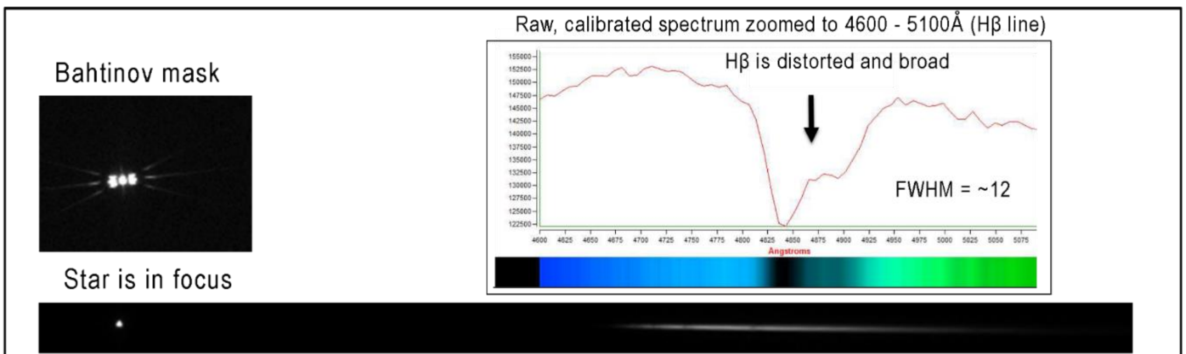
The two samples below were captured with <u>different focus settings</u>.

The <u>first sample</u> is focused <u>on the star</u> using a Bahtinov mask. (https://en.wikipedia.org/wiki/Bahtinov_mask) Examining the profile graph, we can see that the Hβ line is distorted. It's overly wide and has a small "bump" on the right.

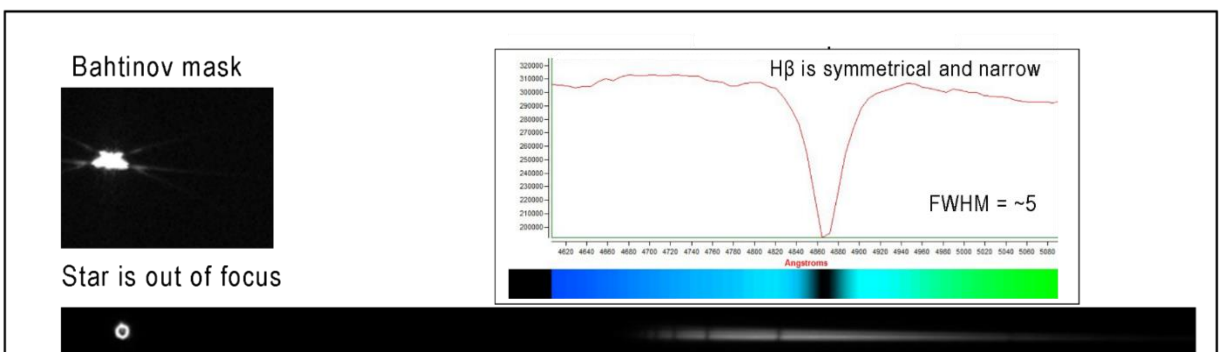
The <u>second sample</u> is focused <u>on the spectrum</u>. Even though the star is out of focus, the Hβ line is narrow and symmetrical with a lower FWHM.

<u>Recommended focusing technique</u>: initially focus on the zero order star. Then gradually adjust focus for the sharpest features in the profile graph.

Provided your equipment configuration hasn't changed, the amount you have to <u>de-focus</u> from the zero order to get best spectrum will be the same for all targets. Make a note how much you have to defocus for the best spectrum profile. On subsequent spectra of any star type, you can first focus on the star and then simply de-focus that same amount.



Sample 1: Focus was done on the star



Sample 2: Focus was done on the spectrum

5.4 Exposure time

If the spectrum image and profile graph from your camera aren't sharp and crisp, the image may be underexposed, poorly focused, or captured when the seeing was bad.

Take a series of images with different exposures and focus settings until you see a spectrum similar to Sample 2 in the preceding section. You may even be able to spot in your image a tiny gap in the spectrum like you can in Sample 2.

Don't worry about over-exposing the star. RSpec can handle that with no problem!

5.5 Stacking images

If you've done much deep sky imaging in the past, you may be familiar with the process of stacking (averaging) images to remove noise and increase image quality. You can stack images of spectra in the same way you stack visual images of planets or galaxies.

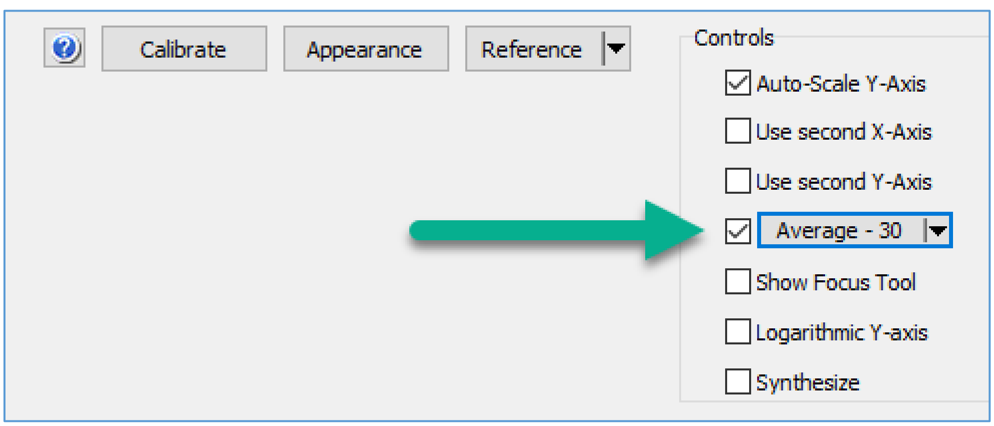
We recommend against adding the extra step of stacking at this stage. As we discussed earlier, your first spectra should be of bright stars so that stacking is not necessary.

Later, when you've mastered the process and you're capturing the spectra of dimmer stars, you can stack them using whatever software you've used in the past. Two popular and free stacking programs are Deepsky Stacker (DSS) or AstroStakkert.

5.6 Stacking video images

Most video cameras have limited sensitivity and very short exposure times. This can make it challenging to capture spectra of all but the brightest stars.

However, if you're using a video camera, RSpec can stack images in real-time. This can lead to dramatic improvement of your spectra profile graphs by reducing noise (increasing SNR). See video 6 here link. To start stacking in RSpec, add the checkmark shown below.

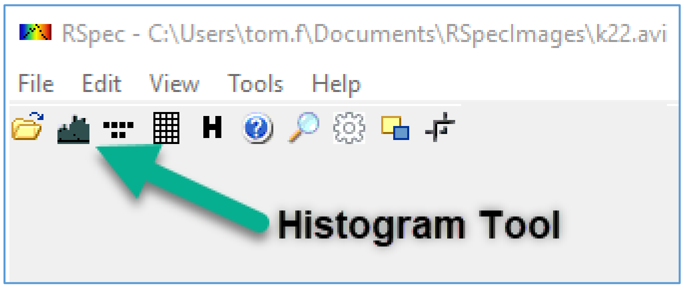


Note that real-time stacking introduces a bit of a lag, since the profile graph that the software displays is the average of many previous frames going back several seconds or more. This means if you adjust focus or change something else in your imaging chain, it may take a few seconds for the change to appear in the graph.

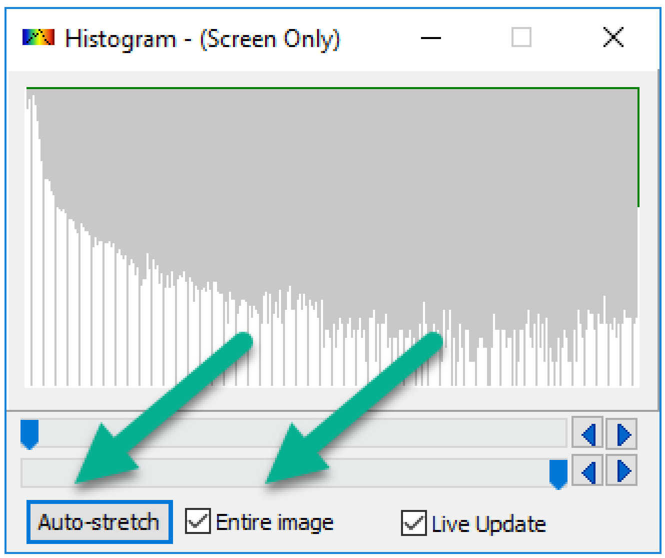
Generally, stacking of more than 30 frames does not further improve a video spectrum.

5.7 Using the Histogram tool if you aren't seeing your star and spectrum

If you're not seeing any stars or any spectra (or if they're hard to see) on the left hand side of the RSpec screen, try adjusting the image contrast with the RSpec **Histogram** tool. Open the tool by clicking on the icon shown below:



On the Histogram screen that appears (below), put a checkmark next to "Entire Image" and then click the "Auto-stretch" button:



The above steps will adjust the display on the screen to show your image with the best contrast, and may reveal additional stars and spectra that were previously not visible.

After the Histogram screen has stretched your image, you should be able to see your target star and spectrum. You can also fine tune your image's contrast by manually dragging the blue sliders on the window above.

Note that the histogram screen adjusts the screen view only, not your data.

When you can see your target star and spectrum, bracket the star with the orange lines as described previously. Then, remove the checkbox from the "Entire Image" option on the histogram screen. This will speed up RSpec by restricting the amount of the image it's processing.

For more details on using the RSpec histogram screen, watch video 10 at this link.

5.8 Focusing

Poor focus can also be the source of “fuzzy” spectra whose profile graphs may not show clear emission or absorption features.

Begin your imaging session by adjusting your focus so that the star is a small compact circle in the image. If your seeing is bad (high winds, etc.) you may not be able to achieve a small, compact circle. In that case, you may have to wait for a calmer night.

When you’ve focused on the star, the spectrum will still be a tiny bit out of focus. See Sample 2 in an earlier section of this document.

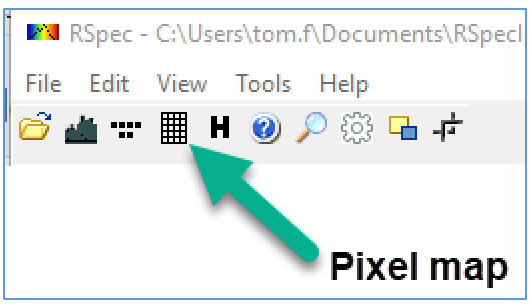
Fine-tune your image by taking repeated images and adjusting your focus so that the *spectrum* in the image has sharp points at the left and right ends, and is as narrow (from top to bottom) as you can get it.

For best results, experiment by making small changes in focus and observing the profile graph on the right side of screen. *Your goal is for the features (like the dip on the Hydrogen beta absorption line) in the profile graph to be as deep as possible*. This will indicate you’ve achieved optimal focus.

5.9 Measuring exposure levels

After you’ve fine-tuned your focus, you can check your exposure levels.

To measure your exposure levels, click the **Pixel Map** button, as shown below:



Watch video 27 at this link to see how the Pixel Map works.

Also watch the first 1:20 of video 31 on the same page. And if you’re using a color camera, see video 37 and 38.

If you’re using a FITS camera, be sure to go to the **Options** screen and set RSpec for 32 bit processing when using the pixel map. This will allow you to see the full 0 to 65,535 range of pixel values.

The key to the pixel map is that you want the maximum values of the spectrum portion of the image (ignoring the star) to be about 40% to 80% of the full well-depth of your camera. Full well depth on FITS cameras is 65,535. Full well depth on most other cameras (including video) is 255.

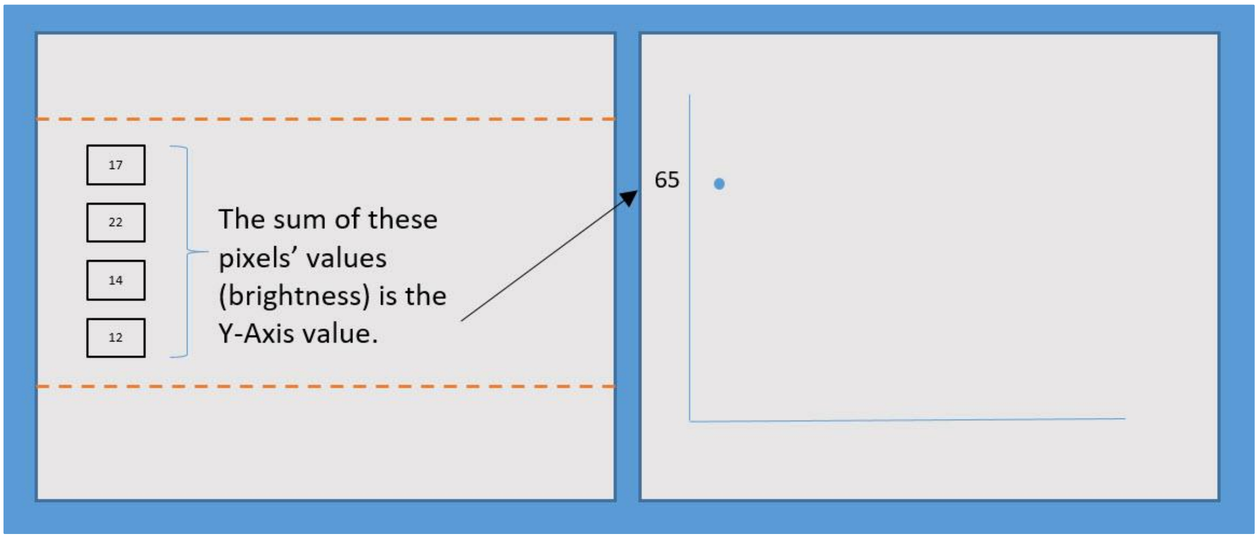
Don’t worry if your star is over-exposed. You can use the measure lines later on the graph to determine the exact center wavelength of the peak.

It’s worth spending some time experimenting with focus and exposure times as we’ve discussed. Unless you have good exposure levels and good focus, your spectra may be too noisy for you to clearly see the dips and peaks (absorption and emission features) necessary to calibrate and extract scientific data.

5.10 Tracking

As in deep sky imaging, to avoid smearing on all but the shortest exposures, it's important that your telescope/camera track the stars as they move in the sky.

However, RSpec introduces an exception to this rule. To explain why, we'll need to get a bit more technical for a moment. When converting your spectrum image to a profile graph, RSpec restricts its attention to the region of the image between the orange lines, summing the intensity of all the pixels in each column of pixels within that region, as shown below:



Because RSpec is summing the pixel intensities in each column, it doesn't matter if your tracking error is *vertical* (which would smear the data vertically. RSpec is going to sum up the pixels in each column to arrive at the same total anyway. To assure the tracking error is vertical, you'd need to make sure your camera and grating are oriented properly.

But, actually, it gets even better than that. RSpec's Rotate screen has a de-slant feature that will internally rotate an image even if the tracking error isn't exactly vertical. See video 19 at this link, starting at 2:07 for how this works.

The **Slant** feature in RSpec is especially valuable if you're using a DSLR on a stationary tripod with no tracking.

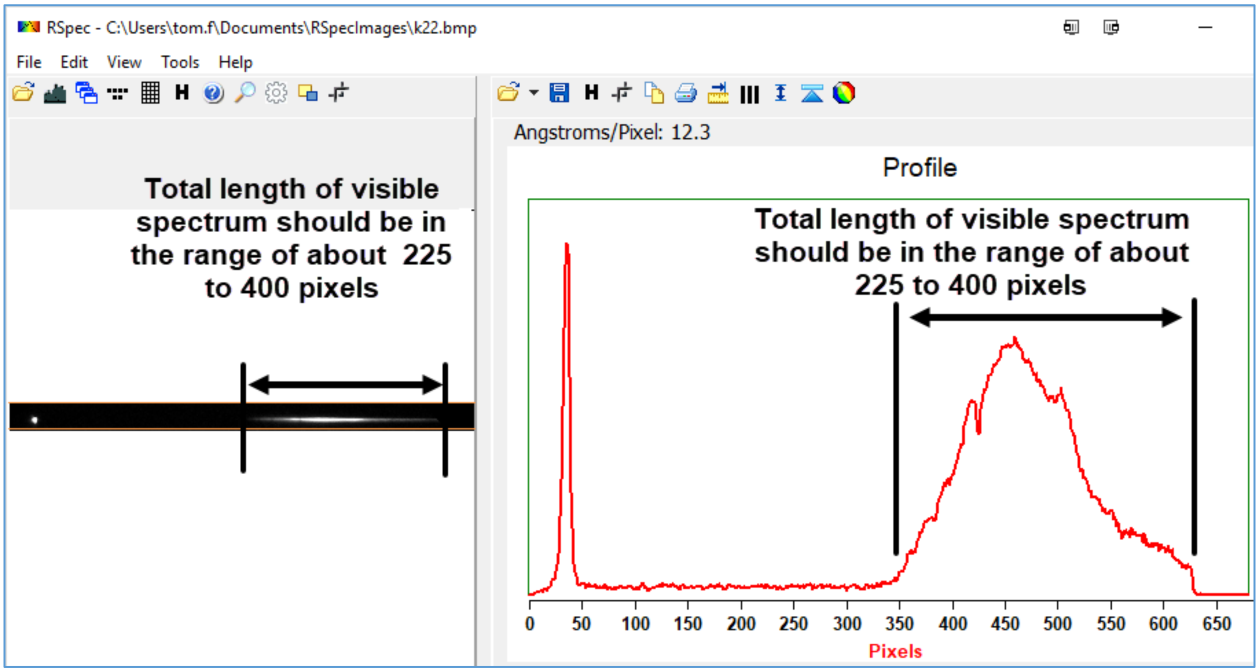
> *Note:* We still encourage you to work at getting the best tracking you can on your telescope or DSLR. Each time you process an image (changing pixels by rotating or de-slanting) you may be degrading the data somewhat. In most cases, the impact of this is minimal, if visible at all. But as you move up to more advanced processing, it may become more significant.

5.11 Insufficient dispersion

A lack of visible features in the spectrum will also occur if the spectrum is not long enough from end to end. The length of the spectrum is determined by how far your grating is from the sensor, the level of zoom on a DSLR (if you're using an objective grating), and the lines/mm of the grating itself.

If you mount your grating according to the numbers provided by our calculator (see Section 2 above), your dispersion will be in the correct range.

To double check that you have a workable dispersion, examine the spectrum image or profile graph. A good general rule of thumb is that length from end to end of the spectrum should be in the range of about 225 to 400 pixels, as shown below:



If the spectrum is too spread out (meaning a low “Angstroms/pixel” value), it will be too dim or noisy, because extra exposure time is necessary to capture the more spread out spectrum.

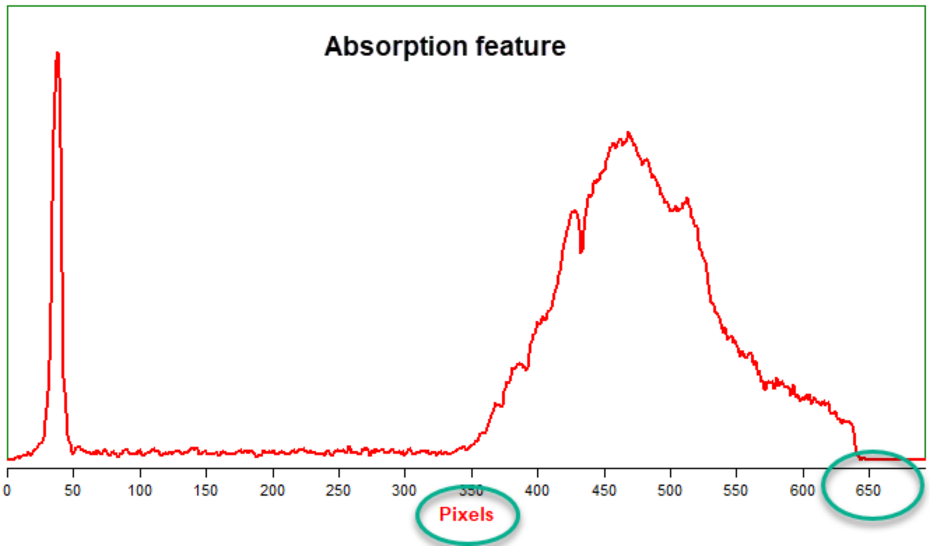
But if the spectrum isn’t sufficiently spread out (the Angstroms/pixel value is too high), the spectrum may not be sufficiently spread out to reveal the dips and peaks.

If your spectrum isn’t approximately the length described above, use the calculator on our site to determine the proper mounting distance. (For DSLRs with objective gratings on the lens cap threads, you would simply adjust your zoom lens to change the length of the spectrum.)

6 Calibrating a spectrum

6.1 Scientific data

When you first capture an image, the x-axis on the profile graph is in “Pixels” as shown below:



In the above example, the maximum x-value is about 650 *pixels* because that’s the *width* of our camera sensor in pixels.

In order to do any science with your data, we need to change the x-axis units from “Pixels” to “Angstroms.”

This process is called “Wavelength Calibration.”

Calibrating your spectrum is a simple process if you use a star’s Hydrogen Balmer lines. That’s why we recommended earlier that you begin with a Type A star.

To see how to calibrate your spectra, please watch video 3 here: https://www.rspec-astro.com/more-videos/. Basically, the calibration process consists of two steps:

1. Tell RSpec in which pixel column the star appears. (This corresponds to a wavelength of zero Angstroms and is at approximately 40 pixels in the diagram above)

   Finding the star in the graph is, of course, easy. It’s the big, sharp peak on the left.

2. Tell RSpec in which pixel column the Hydrogen Beta dip appears – approximately 440 in the diagram above.

   Finding the Hydrogen Beta absorption feature can be a bit hit or miss the first time you do it. It will be the sharpest deep dip. It is usually – but not always – to the left of the broad peak. This process is further discussed in section 6.3.

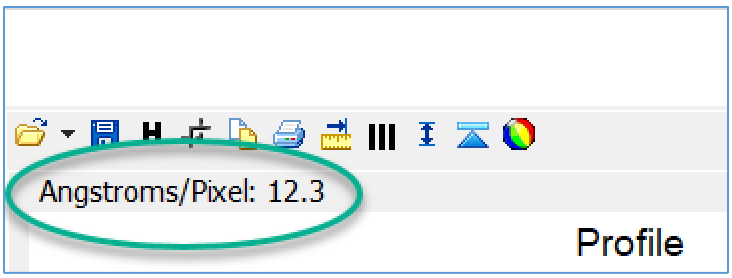
With the above two pieces of information, RSpec can convert the x-axis scale in the profile graph from pixel columns to Angstrom wave lengths.

After you have calibrated the spectrum of a Type A star, RSpec can apply that calibration information to calibrate *any* spectrum that was captured using the identical configuration of imaging equipment. (This is why we suggest that you firmly secure the Star Analyser once it is properly aligned.) This procedure is called "One Point Calibration" and it's almost like magic because it allows you to calibrate stars *about which you know nothing*. For details on One Point Calibration, please watch video 24: link.

If you're using a slit spectrometer, see videos 29 (and in some cases, video 20) at this link for information on using RSpec to calibrate slit spectra.

6.2 Confirming your calibration

If your grating is positioned properly, the Angstroms/Pixel value displayed above the Profile Graph will be between approximately 8 and 15, as shown below.

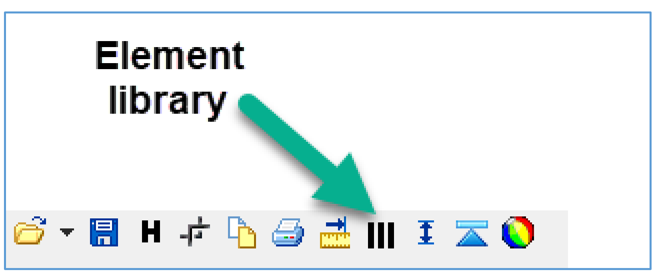


If the value you see on your screen isn't in the proper range, refer to sections above that discuss grating placement and dispersion.

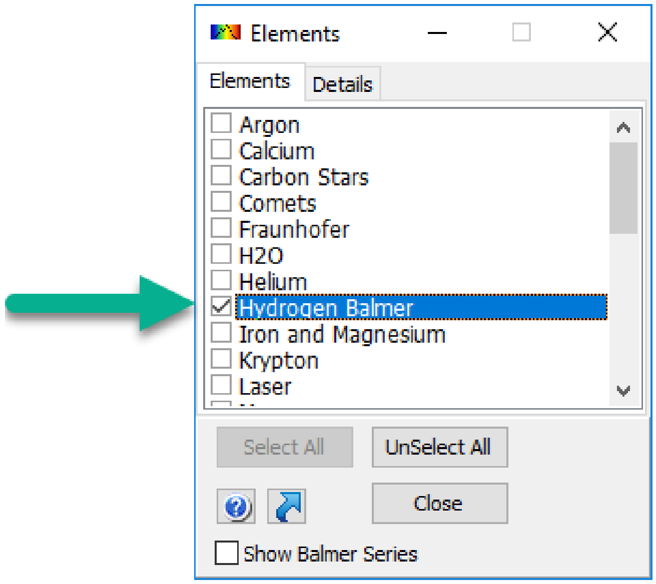
After you've calibrated your spectrum, you can confirm your results using the **Element Library**.

For this next step, you must be able to see absorption features in the profile graph. If they aren't visible, please refer to the previous sections that discuss image quality, focus, tracking, and exposure levels.

Click the toolbar button that looks like jailcell bars, as shown below:

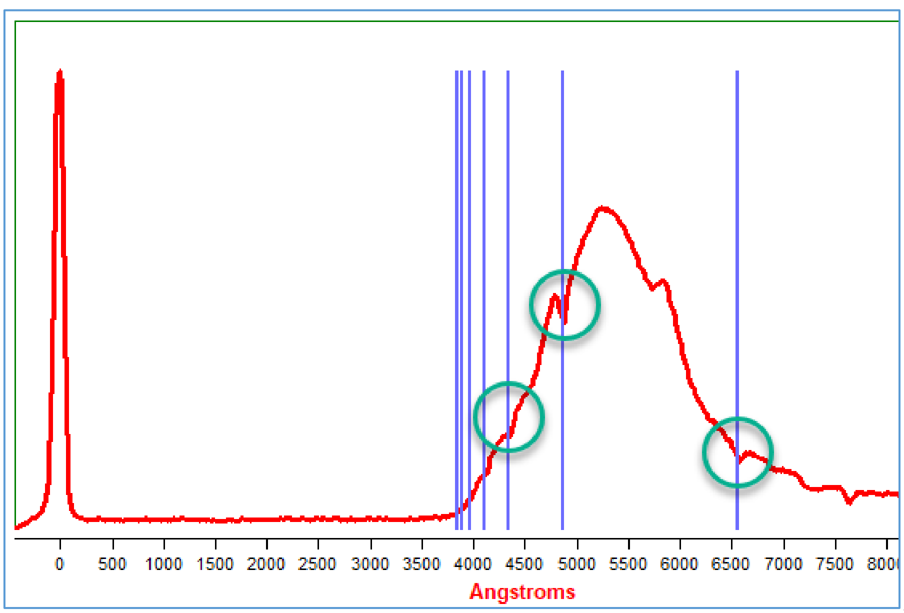


The window below will appear. Put a checkmark next to Hydrogen Balmer:



A profile graph like the one below will appear. This particular screen-capture contains the profile (in red) of Vega displayed with the Hydrogen Balmer reference lines (in blue.)

Notice that the blue reference lines go through dips in the red data lines! This indicates that you have successfully performed wavelength calibration.



6.3 Correcting your wavelength calibration if necessary

Suppose you have just done a wavelength calibration on your spectrum, as described above. But then, when you compare the Element reference lines (in blue), it doesn't look like the screen above. Instead, the blue reference lines don't go through the features in the spectrum's profile (in red). ☹

This means that you probably didn't identify the correct absorption feature (dip) in the spectrum as your Hydrogen Beta. RSpec has a clever tool to help you locate the Balmer lines in your spectra. For details, see this video: link.

7 What next?

This manual has shown you the simple steps to get started capturing and processing spectra.

The Star Analyser User's Manual also has some helpful information and a great FAQ: link.

Once you are comfortable capturing the spectra of a bright Type A star, there are lots of exciting projects you can do.

Below are some examples.

7.1 Make a catalog of star types

Professional astronomers classify stars into one of several types. The common star types are identified by one of the letters in: OBAFGKM.

A good first project is making a visual catalog of star types.

To see an example of a catalog of star types that was created with just a video camera, see this link.

This is a straightforward project. You'll need to make a list of stars of each type that are high in the sky during your observing sessions. Capture the images and then calibrate them using the RSpec One Point Calibration process. Finally, use RSpec's File, Export Profile menu option to export each star's color synthesized spectrum profile to a separate file. Finally, stitch all the exported files into one image using a program like Photoshop or Microsoft Word.

See Appendix I in the Star Analyser 100 manual at this link for a list of bright stars broken down by spectral types.

7.2 Determine approximate star type and star temperature

By comparing the spectra profile curves in RSpec to professionally calibrated curves, you can determine the approximate star type and thus its approximate temperature.

Before you make the comparison, you need to remove the effect from the fact that your camera is more sensitive to green than blue or red light. This process is call "instrument response calibration" and is documented in videos 15 and 30 at this link.

7.3 Observe Wolfe-Rayet stars

Wolf-Rayet stars have fascinating *emission lines* that appear as peaks in your spectrum. These are late stage stars that are pretty bright and easy to capture. For an example, see this link. For a helpful list of the brightest Wolfe-Rayet stars, see Appendix II in the Star Analyser 100 manual. (link) HD192103 is frequently visible in the Northern hemisphere for example."

7.4 Monitor variable stars

You can easily observe the change in temperature and spectrum of variable stars as they change in magnitude. For example, here's an animation of LL Lyrae as it changes over a just a few hours, as captured with a 4" refractor: http://www.rspec-astro.com/sample-projects/#lyrae.

7.5 See rapid changes in transient phenomena

Novae and supernovae often have fascinating spectra that change over a short period of time. The scientific community needs early spectra and monitoring of these objects. Most supernovae will be too dim (once you've lost 5 or 6 magnitudes of light due to spreading it out into a spectrum.) But keep your grating handy, because every so often a bright supernova makes an appearance. These can be fascinating to observe spectroscopically. See link.

Are you wondering how supernovae are classified? It's done with their spectra. See this terrific graphic that shows the spectroscopic differences between supernovae types: link.

7.6 Exoplanets, anyone? No? How about the cosmological red shift?

Unfortunately, the Doppler shifts caused by exoplanets on their host star are in the sub-Angstrom range, far smaller than even most expert amateurs can measure using expensive equipment. However, the cosmological red shift of a quasar that is billions of light years away is large enough to easily observe: link.

7.6 ET, anyone? Detect the Methane atmosphere of Neptune and Uranus

The search for ET includes using spectroscopy to study the spectra of exoplanet atmospheres. Exoplanets are far too dim for us to do such a study with our modest amateur equipment. However, with a Star Analyser you can detect the atmosphere of a planet in our own solar system.

Neptune and Uranus are visually small enough that they act as point sources. This means that you can capture their spectra using a slit-less Star Analyser. You then subtract out the spectrum of a sun-like star, to yield the spectrum of the planet itself: link. It's not difficult to detect the Methane on these planets with a Star Analyser.

7.7 Bright, broad-lined emission line stars

P Cygni is a Blue Supergiant and is one of the most luminous stars in the Galaxy. It is famous for the characteristic spectrum line profile which bears its name – an emission line paired closely with a blue shifted absorption line.

Most of the spectra we've discussed so far have *absorption* features rather than *emission* features. P Cygni is a great examples of a star that shows strong emission spectra and that is accessible with a smaller telescope and a Star Analyser. Check out Wikipedia or another source to understand why these stars have their unique features.

Unfortunately, only the red emission P Cygni feature can be detected in a low resolution spectrum. The blue shifted absorption line can't be observed with just a Star Analyser. It requires a high resolution spectrometer (with a slit) to be detected. But the Hydrogen and Helium emission lines are clearly visible using just a slit-less Star Analyser on P Cygni.

If you're in the Southern hemisphere, you can observe the P Cygni-type star Gamma 2 Velorum to see the same type of features.

The scientific community has several ongoing initiatives that involve using spectra collected by amateurs. See the AAVSO Spectroscopy section (link) or the BeSS database (link).

8.0 Books

There are lots of helpful books on both theoretic and practical amateur spectroscopy. See this link for details.

We want to hear from you!

This is a personal note from Tom: we spent a lot of time working on this manual so that your experience with the Star Analyser would be a good one.

I think we did a pretty good job.

But, you are the ultimate judge.   I'd love to hear how you feel:

- Did you like this manual?
- Was it helpful?
- Is there anything you thought could be improved?
- What was the biggest stumbling block you encountered getting started?

You can email me directly or send a message via our Contact form: link.

Thank you.