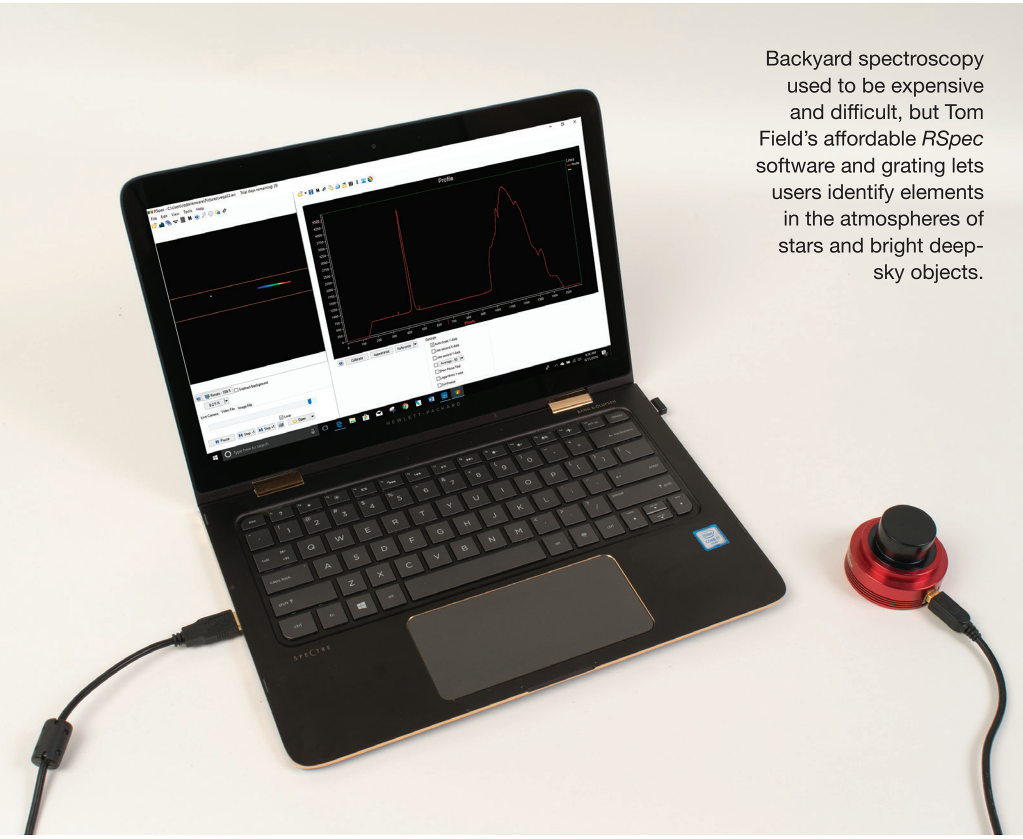
Backyard Spectroscopy with *RSpec*

Try your hand at real-time science with your telescope.



Backyard spectroscopy used to be expensive and difficult, but Tom Field's affordable *RSpec* software and grating lets users identify elements in the atmospheres of stars and bright deep-sky objects.

RSpec Real-Time Spectroscopy

U.S. Price: $109

RSpec-astro.com

What We Like

Remarkably effective for both capturing and analyzing spectra

Works with inexpensive diffraction grating

Intuitive

What We Don't Like

Lacks a printed manual

Sensitive to camera driver problems

FOR ME, ASTRONOMY COMES IN TWO PARTS. A portion of my time is spent as an astronomy educator, teaching the science of the universe. But I'm also an amateur astronomer, and in that aspect I've mostly confined myself to observing pretty stuff. Occasionally, however, I long to put a little more science into my amateur astronomy. I've found just the thing for that, a clever software program called "*RSpec*."

As you may have guessed from its name, *RSpec* is concerned with spectroscopy. This software, combined with a simple diffraction grating and a digital camera, allows users to record and analyze the spectra of bright stars to reveal which elements are present in these distant suns.

It had been known for centuries that shining a beam of light through glass or crystal could produce a rainbow (Isaac Newton coined the term color spectrum for the rainbow produced by a prism), but they were mostly considered pretty curiosities until German physicist Gustav Kirchhoff came along in the 19th century. Early researchers had noted that some spectra showed curious vertical lines crossing the rainbow. Kirchhoff realized these lines were the fingerprints of the elements. Each element has its own particular set of lines at specific wavelengths.

Devices called spectroscopes were developed that could tease more information out of starlight beyond the elements that are present in the star's atmosphere. For example, we can study a star's spectrum to learn how massive and hot it is. Is the star old or young? How does it compare to other stars? With a sensitive camera and enough light-gathering aperture, you can even move beyond stars, analyzing the light of deep-sky objects including nebulae and galaxies. Amateurs have become involved in spectroscopy, but it typically required substantial investment in equipment in the form of a high-resolution spectroscope, a cooled CCD camera, and complex software. *S&T* Contributing Editor Tom Field's *RSpec* changes all that, making spectroscopy affordable and easy.

Required Equipment

While *RSpec* works well analyzing spectra obtained with a spectroscope, the program can analyze spectra recorded through an inexpensive diffraction grating — a piece of glass ruled with thousands of lines that cause it to function like a prism. And though diffraction gratings are not as effective as a conventional spectroscope, they can still produce remarkably detailed spectra.

ALL PHOTOS BY THE AUTHOR

Amateurs interested in dipping their toes in the world of spectroscopy with *RSpec* can get started with the addition of a Star Analyser 100 Grating ($195, available at **https://is.gd/RSpec**). This diffraction grating is grooved with 100 lines per millimeter and mounted in a 1¼-inch filter cell that can be screwed onto the threaded nosepieces included with most astronomical cameras. There are also adapters available that allow the grating to be attached to the lens of a DSLR camera.

Most popular picture formats, including JPG, BMP, and FIT, are supported. The program is not demanding in terms of computing horsepower and worked fine with my seven-year-old laptop running Windows.

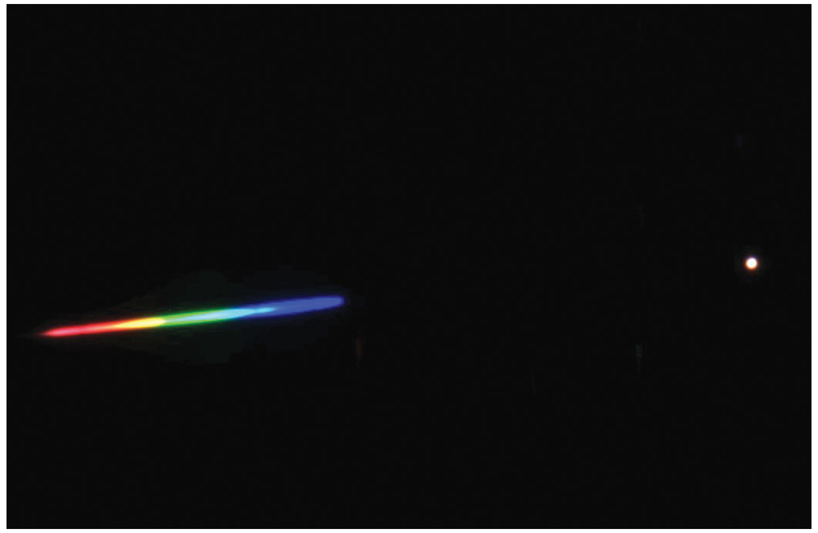
The only requirement is that the optical system has enough focal length to provide good resolution of spectra. In the interest of seeing how inexpensive I could keep spectroscopy, I employed my old ZWO ASI120MC, a color video-type camera paired with an 8-inch Schmidt-Cassegrain telescope and an f/7 focal reducer yielding an effective focal length of 1,500 mm. This turned out to be almost perfect for *RSpec*, providing bright images with an image scale of close to the recommended 10 angstroms per pixel. Using the telescope at f/10 got me even closer, but it became difficult to fit the image of the star and its spectrum onto the small chip of my camera. The 8-inch aperture is more than enough to obtain the spectra of many stars and deep-sky objects.

Lastly, there is the *RSpec* software. The program is available for Windows (XP and newer) as a downloadable compressed ZIP file from the *RSpec* website. Downloading and installing *RSpec* was quick and easy, and I was exploring its features within minutes.

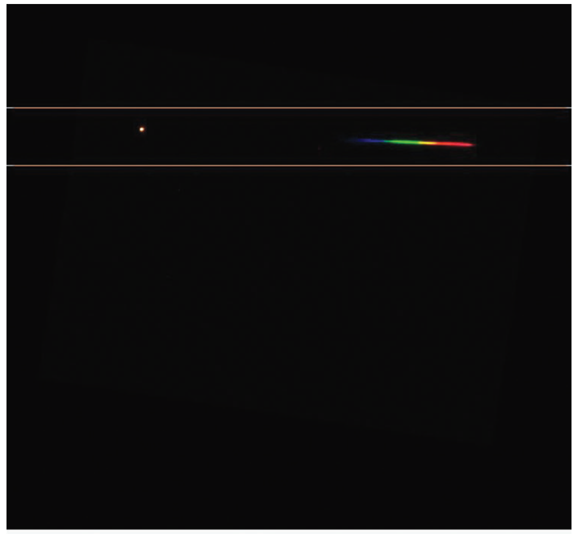
The program's user interface is clean and relatively simple. The screen is divided into two halves, an imaging half that displays the camera's live feed or still images, and a "Profile" half. The Profile section in *RSpec* is the graph that represents the spectrum. Many amateur astronomers think of spectra as images of the spectral rainbow, but in professional astronomy in the computer age, spectra are almost always graphs like *RSpec*'s, plotting intensity on the vertical scale versus wavelength on the horizontal scale.

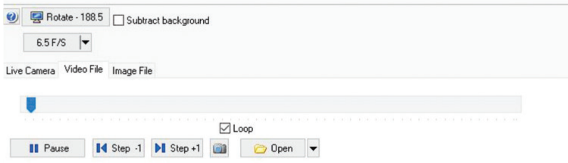
▲ *RSpec* accepts two 1¼-inch cell-mounted diffraction gratings required to spread your target's light into a spectrum that is then analyzed by the software. The Star Analyzer 100 Grating includes 100 lines per inch that mounts on the nosepiece of your camera. The Star Analyzer 200 Grating provides 200 lines per inch, better suited for use in filter wheels.

One issue I had involved my cameras. After connecting the ZWO ASI120MC camera to my laptop computer and opening *RSpec*, I had trouble getting the program to recognize the camera. An email to the author brought the suggestion that I install the latest drivers for my camera from ZWO's website. After doing so, the program connected to the camera immediately, and all was



▲ Using the Star Analyzer 100 on the author's 8-inch Schmidt-Cassegrain with a ZWO ASI120MC camera produces two spectra of the target star (in this case, Vega) — one on each side of the target. Only one spectrum is required, so choose the brightest of the two.





▶ To begin analyzing a spectrum, you first need to import your spectrum image or video and rotate the image using the Rotate command to place the target star on the left and its spectrum on the right.

well thereafter. A similar issue occurred when I tried using a different camera, so make sure you have installed the latest drivers for your own cameras.

Capturing Spectra

The process of recording spectra is simple. Select the Live Camera tab and choose your camera from the list that appears after clicking the Open button. Exposure and other adjustments are accessed with a Configure menu. One unfamiliar control for spectroscopy newbies is rotate. This slider allows the image to be rotated to the standard convention in spectroscopy, placing the star's image on the left of the screen and its spectrum to its right. This only affects the displayed image and is not saved with a recording. Finally, two onscreen "bars" are positioned with the mouse to frame the star and its spectrum. This tells *RSpec* to concentrate on the area between the lines.

You may have wondered what the R in *RSpec* means: It stands for real-time, as in real-time spectroscopy. As soon as the star and its spectrum are properly placed in the video window, the spectrum's graph appears in the Profile section of the screen. You can analyze the star in real time without recording or saving any images. However, I preferred to concentrate on getting good recordings in the field and analyze the spectra the next day.

With star and spectrum onscreen, I clicked Record to capture my first target, Vega. It's a bright *A*-type star, and *RSpec*'s author warns users to begin with a star of that spectral type. These stars display strong hydrogen *Balmer lines*, which are useful for calibrating the program. Like any grating, the Star Analyzer produces two rainbows — two spectra, one on either side of the star's image, and one is brighter than the other. Use the brighter of the two.

Spectrometry

Browsing the *RSpec* website and asking Tom Field a question or two had been sufficient to allow me to capture spectra, but before beginning to analyze my stars, I thought I'd better read *RSpec*'s manual, but I was somewhat surprised to learn that there is none. Well, at least no *written* manual. The program's website contains a library of professional-quality instructional videos detailing every aspect of the software. While I still wished for written instructions, they weren't really necessary. The process of calibrating and analyzing spectra is amazingly simple.

Before doing anything else, *RSpec* must be calibrated. First, the *x*-axis of the Profile needs to be converted from pixels to angstroms (used to express wavelength). Once calibrated, the elements represented by the dips in the graph (the absorption lines caused by elements in the star's atmosphere) are easy to determine.

Calibration requires just a few steps. Open your video or image file of an *A*-type star and its spectrum. If the Profile is jumping around as the video plays due to atmospheric seeing, tick the Average box at the bottom of the Profile screen. That will steady the graph down. I let my video play until I came to a section that showed the dips, the spectral lines, distinctly. I then paused the video and began the calibration process.

Open *RSpec*'s Calibrate window using Tools > Calibrate. Looking at the Profile, you'll notice a thin spike on the left separate from the rest of the graph. That is the star itself, which you use as the first calibration point. Move the mouse cursor to the spike's peak and click. The star's pixel value will be automatically entered in the Calibrate Point 1 field. Below that is a field for wavelength. Tick the Zero box to its left.

Calibration Point 2 is on the actual spectrum to the right of the spike. The goal is to click on a dip caused by a known absorption line. That's why it's important to use a prominent *A*-type star for calibration. *A*-types show the hydrogen Balmer lines strongly, and the H-beta line is particularly easy to locate; it's the first dip to the left of the Profile's peak. Click on that "valley" and enter "4861" in the wavelength field. And that's it — calibration is complete and should be saved for use with other stars.

The program can overlay lines of various elements on the calibrated Profile so you can verify your calibration is accurate. Clicking the Elements icon (three vertical lines) in the Profile section's toolbar yields a window with a list of various element lines. Tick the Balmer Series box and the Balmer lines will be drawn on the Profile. If the hydrogen beta line runs through the dip you selected, you are good.

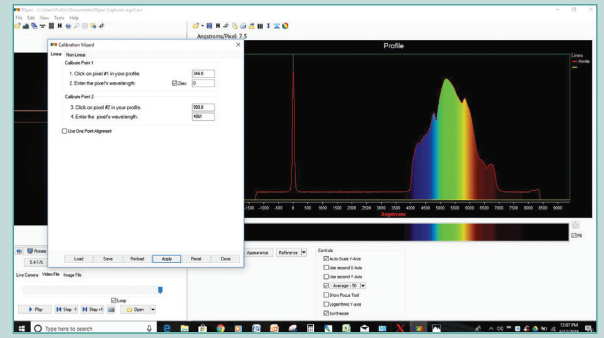
Note that due to poor seeing and other factors, spectral lines may not always coincide exactly with the Profile's valleys. Also, some of the dips may not be strong depending on the sensitivity of the camera and the spectral dispersion the telescope delivered. I was thrilled to see my graph showed the Balmer lines right where they should be.

RSpec offers plenty of features. You can use the Elements utility to identify other elements and features in the spectrum. Once calibrated, the profile graph can even be converted into a rainbow using the Synthesize function. While not really as useful as the graph, it's prettier and impresses my students.

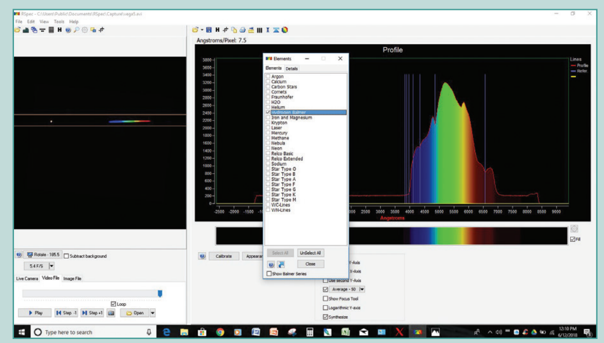
The next step is imaging different star types. Analyzing the spectra of various star classifications combined with a little reading can teach a lot about stars and stellar evolution. Once you are proficient at analyzing the absorption lines of stars, you might try examining the emission lines of nebulae.

Beyond that? Amateurs equipped with *RSpec* and modest telescopes like my 8-inch SCT are doing some amazing science, which range from analyzing the atmospheres of the solar system's gas giants, to determining the red shifts of distant objects including quasars. Thanks to *RSpec*, the limit is not your equipment but your imagination.

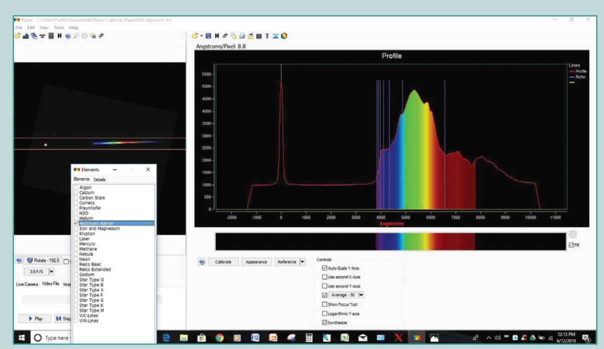
Contributing Editor ROD MOLLISE enjoys getting some real science out of his time at the telescope.



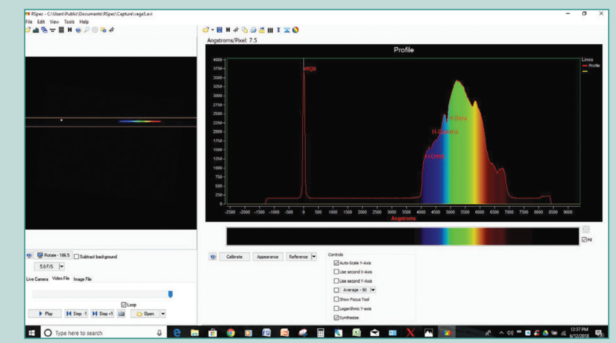
The final step before *RSpec* is ready to analyze spectra is to calibrate the program using an *A*-type star using the Calibrate function from the pull-down menu. Select the peak in the left side of the graph as Calibration Point 1, and select the first dip in the spectrum, which should represent the first Balmer line, H-Beta, and insert "4861" to denote its wavelength in angstroms.



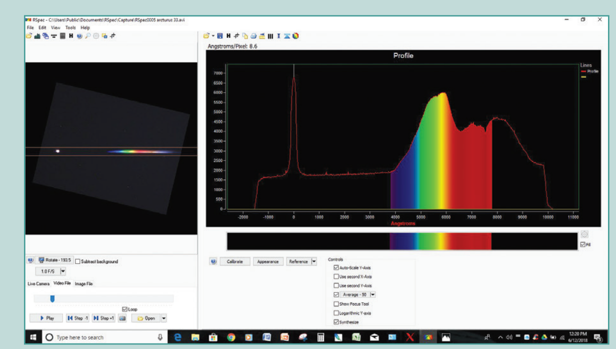
When calibration is complete, you can open the Elements window in the Profile section and overlay the points of known elements. This screen shows the location of the hydrogen Balmer lines found in the spectrum of Vega.



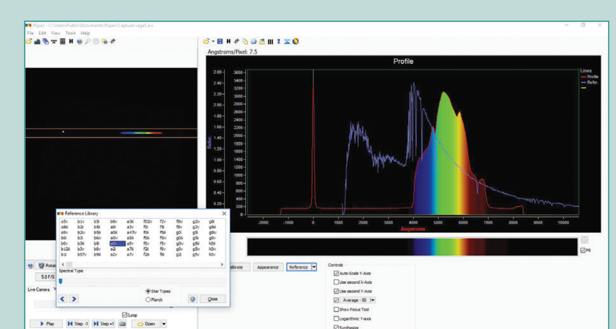
Calibration should be saved so you can later apply it to other recorded spectra like that of Regulus seen at right.



RSpec also allows you to label the elemental lines in your spectrum.



The spectrum of the *K*-type star Arcturus looks very different from that of an *A*-type star like Vega.



Another interesting feature of *RSpec* is its ability to overlay and compare the spectra of different targets. This graph compares the spectrum of Vega to that of another *A*-type star.