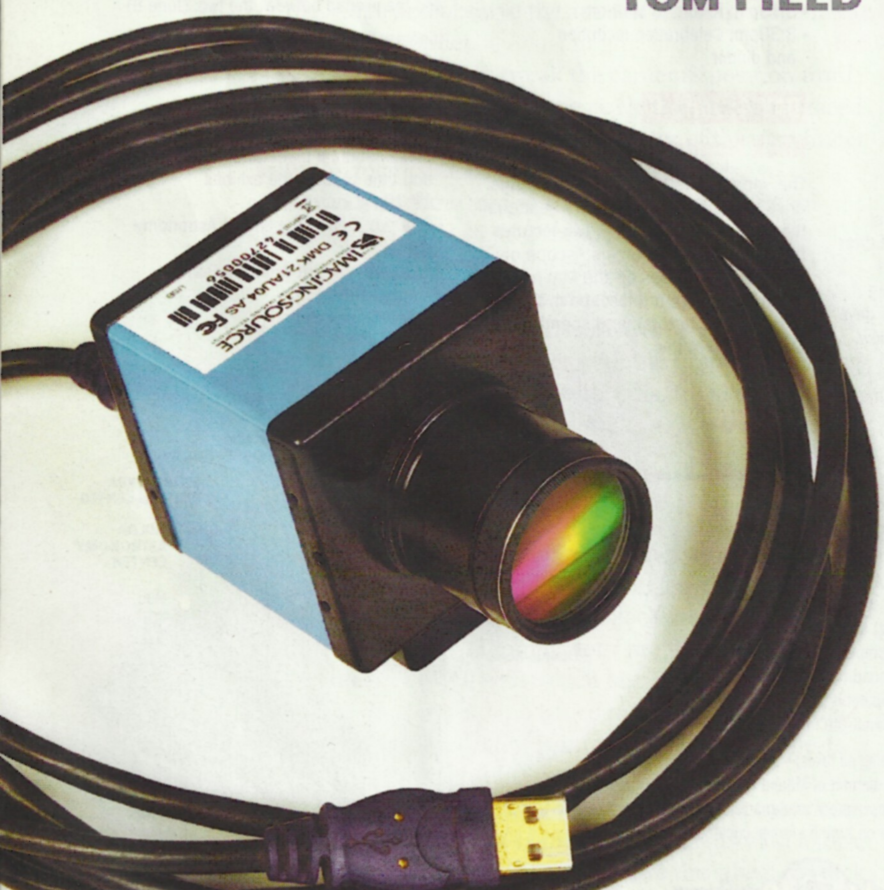
Spectroscopy for Everyone

TOM FIELD

With inexpensive equipment, you can easily reveal the spectral signatures of everything from nearby planets to distant quasars



Imagine using a 90-mm telescope in a light-polluted backyard to detect methane in the atmosphere of Uranus. Or how about turning an inexpensive security camera toward a quasar 2 billion light-years away and recording its redshift, seeing firsthand evidence of the expansion of the universe? What if you could aim a simple video camera at a comet and capture the spectroscopic signatures of the complex organic molecules that are thought to be the building blocks of life? Sound exciting? I speak from experience when I say that it is. And in recent years more and more amateurs are discovering this new dimension of observing and imaging.

Although spectroscopy is one of the principal tools of astronomical research, until recently it's been relatively costly and too complicated for most amateurs. But that's changing. With the simple hardware and user-friendly software now available, it's become much easier to get started in spectroscopy. In some ways, it's even easier than astrophotography because it's quantitative — you leave behind the qualitative visual aesthetics demanded by the human eye. But make no mistake: spectroscopic results can be just as captivating as color images of celestial objects.

I've also found that spectroscopy has greatly expanded my understanding of astronomy. It's one thing to have

The spectra appearing with this article were captured with a Star Analyser grating attached to digital cameras such as the Imaging Source video camera shown here. Amateurs have obtained excellent results with everything from simple webcams to advanced astronomical CCD cameras.

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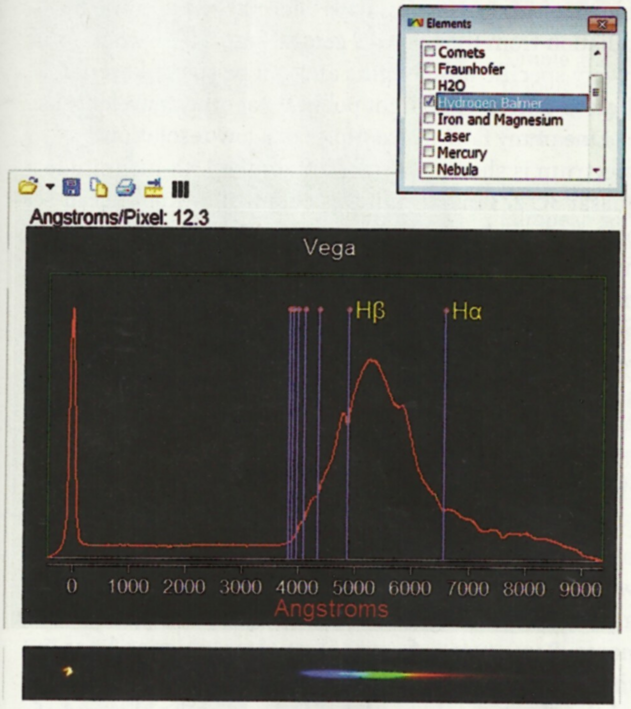
transmit only the "important" astronomical wavelengths while filtering out those of artificial light sources. By definition, spectroscopy spreads out light by wavelength, making it easy for us to observe astronomical features at certain wavelengths while ignoring the light pollution occurring at others.

Another advantage of spectroscopy is that you can learn observing techniques with very easy objects such as the bright star Vega. On your first spectroscopic outing, you can shoot an image of the object's spectrum and later analyze the image to produce a profile graph of the spectrum. With bright objects, you can even use modern software to create real-time simultaneous views of the spectrum *and* the profile graph. In addition to being exciting, seeing spectroscopic features in real time, such as dips in the profile due to hydrogen absorption in a star's atmosphere, makes it easy to focus and adjust our equipment for the best results.



The author's *RSpec* software can create real-time graphs along with reference lines of prominent spectral features for a spectrum captured with a video camera. The webcam image in the window at bottom, obtained with an 8-inch Schmidt-Cassegrain telescope, shows the star Vega as a bright dot (called the zero-order image) at left and its spectrum at right. The window above it shows the spectrum's graph with reference positions for the hydrogen Balmer lines.

passive, theoretical knowledge of a subject, but once I started doing spectroscopy, I found that I was reading astronomical literature much more closely and with a much deeper understanding.

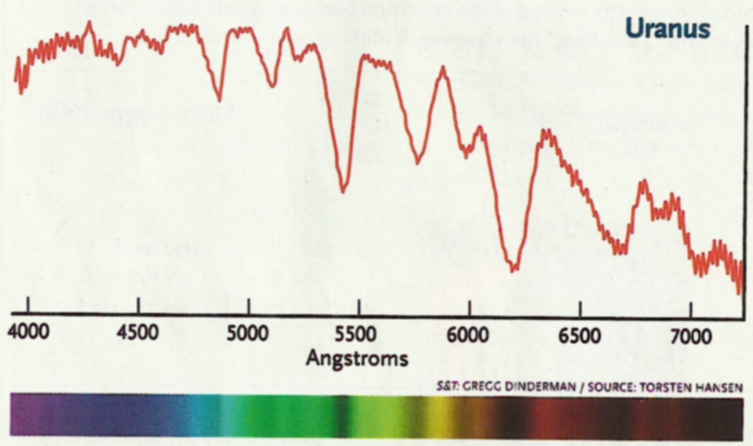
Getting started in spectroscopy can be surprisingly affordable, especially if you already own a camera. Amateurs are doing quality spectroscopic work with DSLRs, video cameras, webcams, and, of course, astronomical CCD cameras. The only additional hardware you need is an inexpensive diffraction grating that splits light into the rainbow-like spectrum we frequently see in publications. A diffraction grating capable of producing the low-resolution spectra accompanying this article costs about $180.

If you live in an urban area you'll be glad to know that, unlike astrophotography, spectroscopy tolerates light pollution very well. For example, one of the pioneers of amateur CCD imaging and spectroscopy, Christian Buil (http://astrosurf.com/buil), achieves outstanding results from his light-polluted home in France.

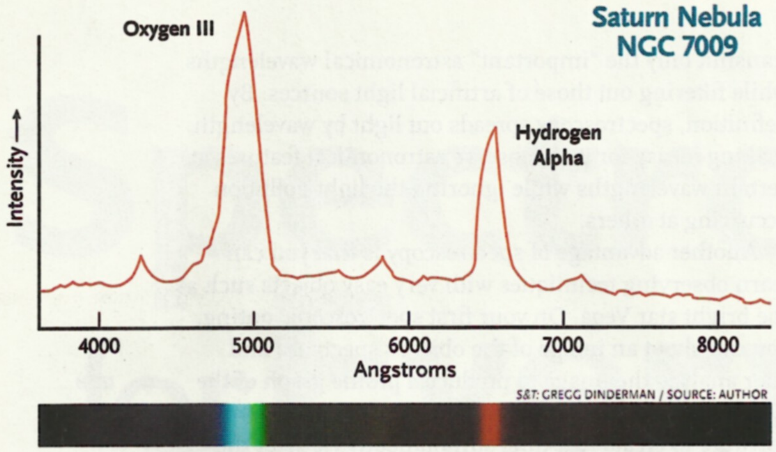
Today's light pollution typically occurs in specific ranges of the visual spectrum. So-called light-pollution filters take advantage of this limited spectral range and

There are many interesting objects that we can study with low-resolution spectroscopy. For example, it's easy to detect the atmosphere of Uranus. As seen in the illustration below, deep dips in the long-wavelength (red) portion of the profile graph are due to atmospheric methane that is absorbing sunlight. Reflected sunlight shows as the highest-intensity part of the profile on the left, blue-green end of the graph. This pattern explains why Uranus appears blue-green in a telescope — the sunlight that Uranus reflects is missing most of its red due to methane absorption.

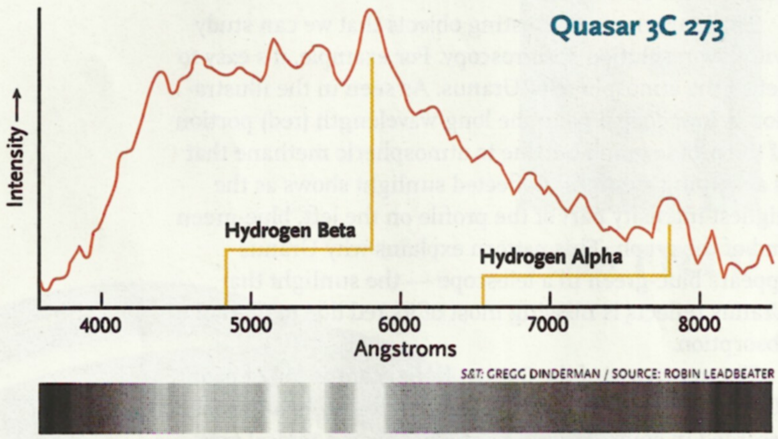
The spectrum of the Saturn Nebula at the top of page 70 illustrates that meaningful spectroscopic data can be recorded in spite of light pollution. This is a typical spectrum for emission nebulae. The bright emission lines are



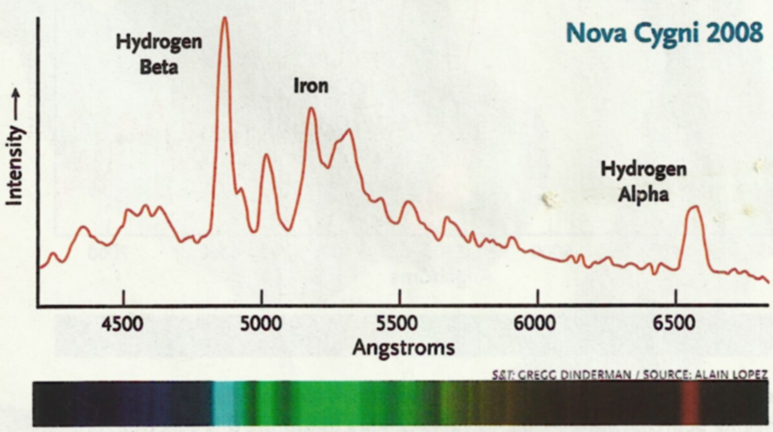
German amateur Torsten Hansen used an 8-inch Newtonian reflector and Imaging Source DMK 21AU04.AS video camera to capture this spectrum of Uranus, which has been corrected for the spectral variations of sunlight and the camera's response. Deep dips in the spectrum are due to absorption by methane in the planet's atmosphere.



The spectra of most emission nebulae show just a few bright lines. The well-known planetary NGC 7009 includes prominent emissions due to oxygen and hydrogen, which can be seen in this spectrum captured with a 9¼-inch Schmidt-Cassegrain telescope and astronomical CCD camera.



Using a 9-inch Cassegrain reflector and modified low-light security camera, English amateur Robin Leadbeater recorded the spectrum of the 13-magnitude quasar 3C 273 in Virgo. Its hydrogen emission lines are shifted toward the red end of the spectrum because cosmic expansion is essentially "stretching" the wavelength of the quasar's emitted light.



Novae and supernovae are often readily identified by their spectral signatures. This spectrum of a nova that appeared in Cygnus in March 2008 (V2468 Cyg) was captured with a DSLR and reveals emissions from hydrogen and iron.

due to ionized gases that have been excited to shine by radiation from the nebula's central star. These lines occur at very specific wavelengths and can be spotted even if there is considerable light pollution at other wavelengths.

One of my favorite examples of a low-resolution spectrum is shown at center left for the 13th-magnitude quasar 3C 273 in Virgo. It was obtained by Robin Leadbeater (www.threehillsobservatory.co.uk). Using a modified low-light security camera and a 9-inch telescope, he made a stack of forty 30-second exposures. The quasar's hydrogen emission lines are shifted about 16% toward the red end of the spectrum, because the universe's expansion is "stretching" the wavelength of the quasar's light. A simple calculation shows that this redshift corresponds to a distance of about 2 billion light-years. It's remarkable that backyard equipment can measure such distances!

In the study of variable stars, there's a golden opportunity for spectroscopists to collaborate with photometrists who are making brightness measurements. For example, amateurs are using low-resolution spectroscopy to classify novae. Some types of novae show clear emission lines in the red part of the spectrum due to iron and hydrogen, while other types have a lot of features at the blue end of the spectrum with the rest of the profile virtually featureless. Easily obtainable spectra of these objects enable rapid identification of their types.

Like novae, supernovae also have characteristic spectral features that allow us to determine their type. Every year a few supernovae occur that are brighter than magnitude 14 and can be recorded spectroscopically using modest amateur equipment.

The spectroscopic work mentioned above can be done with an inexpensive, slitless spectrograph. But if you catch the spectroscopy "bug" and want to advance your skills, there is commercial equipment available to do higher-resolution spectroscopy. The European amateur community has done a lot of pioneering work in this field. A high-resolution, slitted spectrograph opens up additional observing opportunities, such as measuring the rotational speed of Saturn's rings, the radial velocities of stars, and detecting spectroscopic-binary stars and exoplanets.

One particularly important high-resolution observing opportunity is a professional/amateur collaboration involving *Be* stars. These are hot *B*-type stars with at least one emission line (usually one of the hydrogen Balmer

During the 2011 Northeast Astronomy Forum last April, *Sky & Telescope*'s senior editor Dennis di Cicco spoke with author Tom Field about amateur spectroscopy. You can watch a video of the interview and see a demonstration of Field's *RSpec* software at www.SkyandTelescope.com/tfield.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Gratings and Spectrographs

Simple gratings for capturing the low-resolution spectroscopy featured in the accompanying article are available from several sources including:

Paton Hawksley Education Ltd.
European source: www.shelyak.com
U.S. source: www.rspec-astro.com

Rainbow Optics
www.starspectroscope.com

Rigel Systems
www.rigelsys.com

Advanced spectrographs capable of capturing high-resolution spectra are manufactured by:

Baader Planetarium
www.baader-planetarium.com

Santa Barbara Instruments Group (SBIG)
www.sbig.com

Shelyak Instruments
www.shelyak.com

During a recent meeting of the Society for Astronomical Sciences, Olivier Thizy demonstrated the LHiRes spectrograph made by Shelyak Instruments.

lines). The spectra of some *Be* stars can vary over periods from several hours to many years. Scientists don't fully understand the cause of these variations, or the actual structure and characteristics of these stars or their circumstellar disks that give rise to the emission lines. Amateurs are working with professionals to monitor spectroscopic changes of *Be* stars on various timescales and contributing their results to an international database maintained at the l'Observatoire de Paris–Meudon (**http://basebe.obspm.fr/basebe**).

As with visual imaging, successful spectroscopy involves properly post-processing your images. When I started out, I couldn't find any spectroscopy software that would allow me to easily go from the image of a spectrum to a calibrated profile graph. To fill this gap, I wrote a program that I call *RSpec* (**www.rspec-astro.com**). In addition to creating profile graphs from still images, it can make real-time profiles from images obtained with a video camera. It is currently used by observers, teachers, and in outreach programs.

I can't close without mentioning the annual August meeting of spectroscopists at l'Observatoire de Haute Provence (OHP) in southern France. This gathering brings an international collection of amateurs together in a star party/workshop format. Nights are for observing and days are for learning, with lectures and spectrum-processing workshops. All levels of amateur spectroscopists are welcome at OHP, and I learned a tremendous amount at the 2010 meeting. My wife and I were warmly welcomed and we found the language barrier almost nonexistent. We look forward to attending again this year (as well as spending some extra time exploring the beautiful French countryside). If you get involved in spectroscopy, OHP should be on your "must-go" list. You won't regret it.

It's amazingly easy to get started in spectroscopy. With a minimal investment, you can achieve meaningful and compelling results, and I encourage everyone to jump in and give it a try! You'll find that spectroscopy is a challenging and rewarding activity. And I'm sure your appreciation and understanding of the physical science of astronomy will grow by leaps and bounds. ✦

*Despite living in rainy Seattle, Washington, **Tom Field** is an enthusiastic observer. He wishes to thank the amateur spectroscopy community for its enormous assistance and patience in coaching him and others as they entered the field.*

Further Reading

Only a handful of books have been written for amateur spectroscopists, but the latest is also one of the best. Ken Harrison's *Astronomical Spectroscopy for Amateurs* (ISBN 978-1-4419-7238-5) is heavily illustrated and packed with valuable information on the design, construction, and use of spectrographs. There's ample background on the science of spectroscopy, and most chapters are accompanied by reading lists and up-to-date links to material on the web. Of special note is a chapter on observing projects for backyard spectroscopists, with sections on the Sun, planets, many types of stars, and deep-sky objects. The $34.95 book is an excellent resource for everyone interested in the subject. See **www.springer.com** for more information.