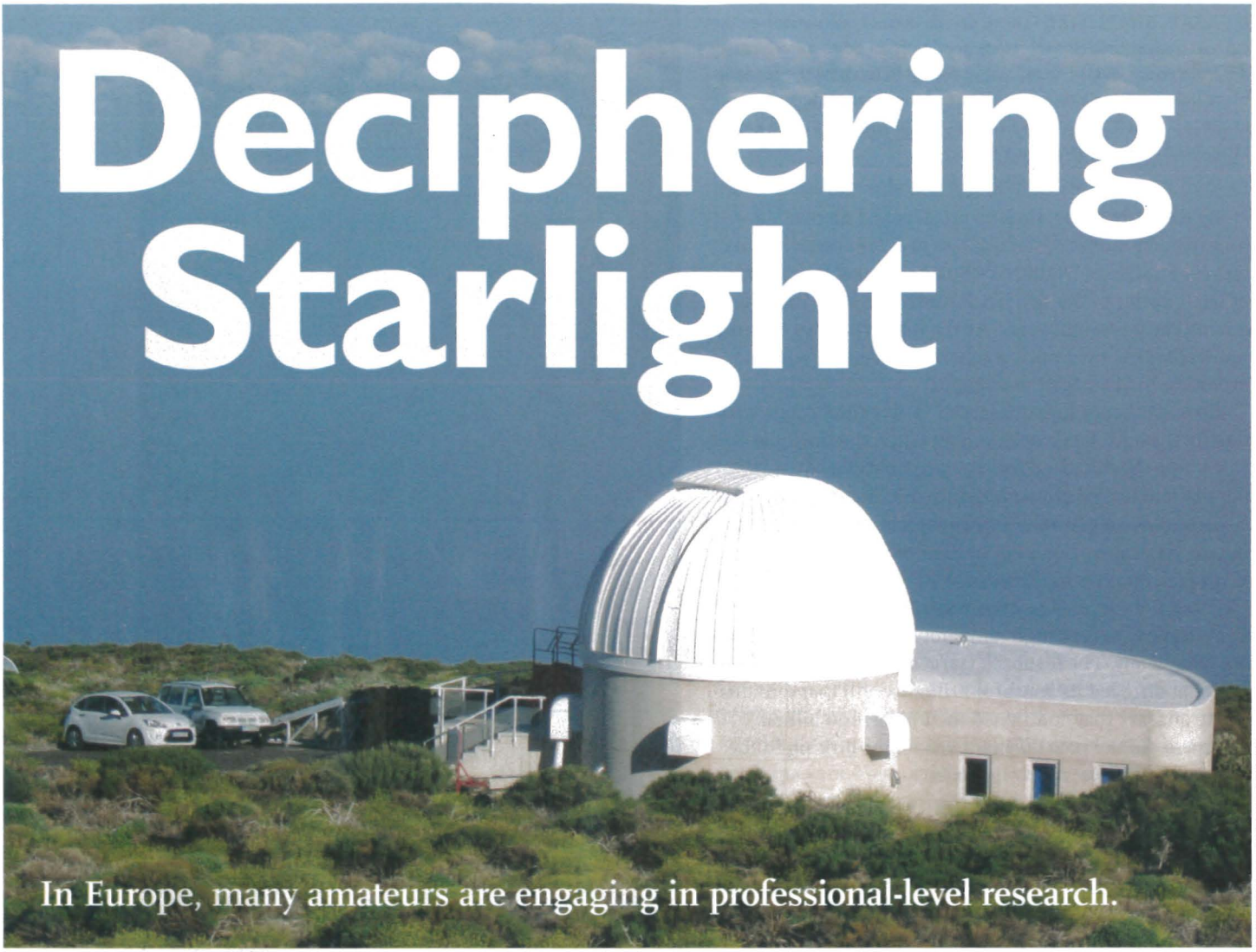
Deciphering Starlight



In Europe, many amateurs are engaging in professional-level research.

CONVENTO GROUP / THOMAS EVERSBERG

Jan Hattenbach

An unusual group of tourists visited Tenerife in the Canaries this summer. These people were not attracted by the island's beautiful beaches and volcanoes. Instead, they came to work arduous night shifts on a professional 31-inch telescope, just to observe three inconspicuous stars in Cygnus. And each of these amateur astronomers was willing to shell out $1,300 for travel and to rent the telescope. "To these volunteers, working at a professional observatory is the greatest thing imaginable," says team leader Thomas Eversberg. "Yes, we're somewhat crazy, but what amateur astronomer isn't?"

Many amateurs would agree with this assessment. But why make amateur astronomy a costly and stressful exercise? It's supposed to be fun, right? Obviously, for some it means a lot more.

Studying Stellar Winds

The recent advent of professional survey telescopes has diminished the backyard observer's opportunity to contribute scientifically in certain areas, such as asteroid and comet discovery. But the emergence of inexpensive, high-resolution, off-the-shelf spectrographs is filling the gap. Even when coupled to modest-size telescopes, spectrographs can yield scientifically useful results by revealing a star's temperature, chemical composition, and prevailing physical conditions of atomic excitation and ionization.

Using the 31-inch reflector of the Institute of Astrophysics of the Canaries, Eversberg and his colleagues

NOT JUST A TOURIST SITE European amateurs flock to the island of Tenerife to use the 31-inch telescope housed in this dome. Owned by Spain's Institute of Astrophysics of the Canaries, the observatory sits at an elevation of 2,390 meters.

observe three Wolf-Rayet stars in Cygnus named WR 134, 135, and 137. Their photospheres are shrouded by dense gas clouds that move and rotate at high velocities. A visual observer won't notice anything unusual about these stars, but the clouds produce bright emission lines in the stellar spectra. By studying these lines, astronomers explore the connection between the stars' hidden surfaces and their powerful winds, and test for periodicities and random clumping in these winds.

"We're a textbook example of pro-am collaboration in astronomical spectroscopy," says Eversberg, who works for the German Space Agency in Bonn, but who does this spectroscopy research on a volunteer basis. Eversberg initiated the campaign with Anthony Moffat (University of Montreal, Québec). In 2009 they motivated amateurs to visit Tenerife to observe the periastron of the ultra-hot binary WR 140, the best-studied member of a class of objects called *colliding-wind binaries* (*S&T:* April 2011, page 28). The campaign yielded five times more spectra than a solely professional periastron campaign in 2001. With this amateur data, astronomers improved their knowledge of the system's mass, orbital period, and orbital inclination.

With colleagues from around the world, Eversberg and Moffat formed the ConVento group, comprising professionals and amateurs dedicated to stellar-wind phenomena (ConVento is Italian for "with wind"). ConVento members mostly use their own backyard observatories, but operating the professional facility on Tenerife has been the highlight of the campaign. "Our success in 2009 facilitated our proposal to acquire observation time for the 2013 campaign," says Eversberg. "Professionals know us now, and they know what we're capable of."

Catching One-Time Events

Professionals have access to the most advanced telescopes and instruments at the world's best observing sites, but they lack what amateurs possess in abundance — time. Long-term measurements, surveys, and monitoring require weeks or even months of telescope time, which are difficult to obtain at overbooked professional observatories. An 8- to 20-inch telescope coupled with an off-the-shelf spectrograph does the job just as well. Taking spectra of bright stars is possible even under light-polluted urban skies. And if you're clouded out one night, your colleagues will help out.

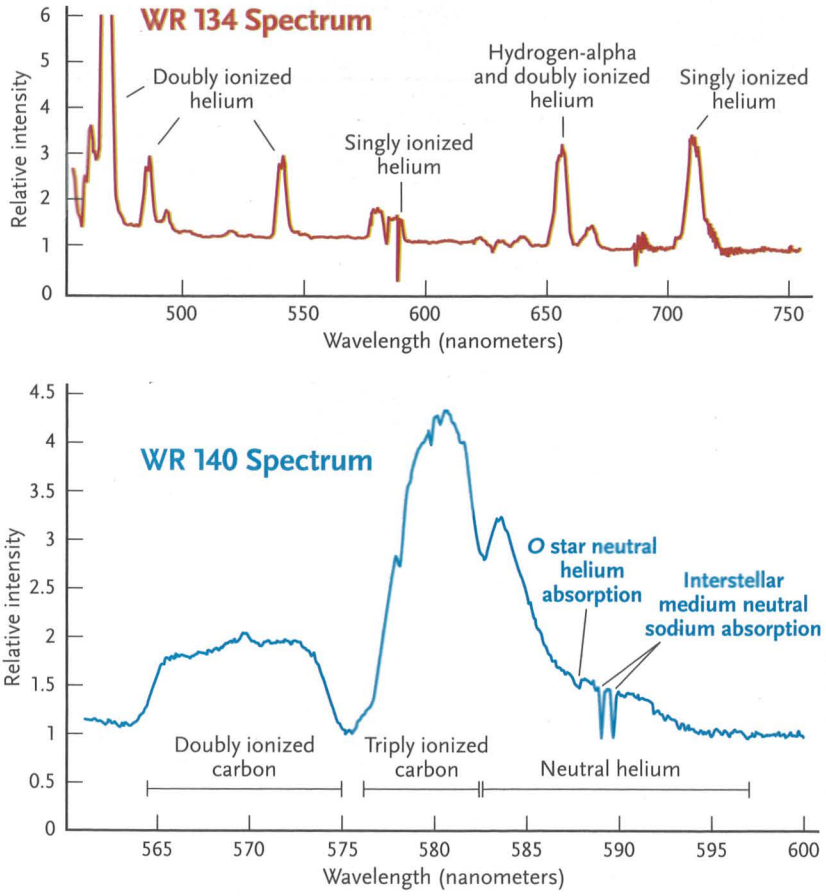
Spectroscopy has thus become a new and thriving field of "citizen science," especially among European amateurs. Though growing, the numbers are still comparatively small. "There are about 30 serious observers in France right now, with maybe another 100 people interested in the field," says Thierry Garrel, a member of the French Astronomical Ring for Access to Spectroscopy (ARAS), the most active amateur organization on the continent.

But those dedicated few are absorbed by their work. "Spectroscopy can be a dull exercise," says Eversberg.

CONVENTO GROUP / THOMAS EVERSBERG (3)

AMATEURS GO PRO ***Top:*** **European amateurs have earned considerable observing time on this 31-inch professional reflector on Tenerife. They use it to take spectra of Wolf-Rayet stars and binary systems with energetic colliding stellar winds.** ***Center:*** **German astronomer Thomas Eversberg has coordinated this impressive amateur science campaign.** ***Bottom:*** **German amateur Daniel Weiss works in the observatory's control room.**

DON GOLDMAN



SOURCE: CONVENTO GROUP (2)

COLLIDING-WIND BINARY ***Above:*** **The ConVento group amateurs took this spectrum of WR 140, a binary system in which the winds from two massive stars (an *O* and a Wolf-Rayet star) are colliding. The spectrum was taken on November 24, 2008, when the two stars were at their closest approach.**

BLAZING STAR ***Top left:*** **This amateur astrophoto shows WR 134 (the bright reddish star at center) and its surrounding nebula, which is gas ejected by the star's powerful stellar wind.** ***Center left:*** **The ConVento amateur group used an echelle spectrograph to take this visible-light spectrum of WR 134. The data reveal various emission lines from hydrogen and helium.**

"You spend countless nights taking data for some other person to analyze, and worse, they're not pretty pictures, just graphs and numbers." But your reward isn't just finding your name on a scientific paper. As Eversberg points out, "Instead of taking the millionth image of the Orion Nebula, we're witnessing events that happen just once."

Consider long-period eclipsing binaries. Astronomers know of several dozen such systems, in which two stars periodically eclipse each other, but only a few have been fairly well studied. Their long orbital periods make them perfect for amateurs. The best-known example is Epsilon Aurigae, which went through its minimum from 2009 to 2011 as a dark cloud of gas and dust passed in front of the primary star. The previous eclipse occurred 27 years earlier, before amateurs had spectrographs. In the March 2012 *S&T*, British amateur spectroscopist Robin Leadbeater reported that more than 800 spectra taken by amateurs had been added to the wealth of data that now helps astronomers understand the strange eclipsing cloud. By observing the potassium absorption line at 770 nanometers, Leadbeater could see the eclipsing cloud months before it dimmed the star — and long after the official eclipse had ended.

Other long-period eclipsing binaries include AZ Cassiopeiae and VV Cephei, with orbital periods of 9.3 and 20.3 years, respectively. VV Cep is a prototype of variable binaries consisting of an aging supergiant and a hot dwarf star, whose spectra exhibit strong hydrogen and iron emission lines. These lines emanate from extended gaseous shrouds around the stars, and the way they evolve in time relates to wind patterns and velocities, and various stellar and orbital parameters.

With an eclipse of AZ Cas just concluded, Cezary Galan (Nicolaus Copernicus University, Poland) is urging amateurs to monitor the star through 2014. "A dense coverage with photometric and spectroscopic observations is needed," writes Galan on his website. "The long timescales of changes in AZ Cas demand the involvement of a large number of observatories to reduce the dependency on weather conditions and guarantee success during the important phases of the eclipse." As of early June 2013, amateurs had submitted about two-thirds of the 250 total spectra. "The interest in this campaign has significantly exceeded my expectations," says Galan.

Meanwhile, Darryl Sergison (University of Exeter, UK) is asking amateurs to spectroscopically monitor low-mass T Tauri stars to help astronomers gain a clearer picture of the environment around young solar-type stars and

PAOLO BERARDI

FRENCH SPECTROSCOPISTS Two French amateurs, Thierry Garrel (left) and Pierre Dubreuil, pose with their equipment at the 2012 amateur spectroscopy workshop in France. Most amateur spectroscopy is done with backyard telescopes such as these.

to characterize their various disk, accretion, and outflow structures. The study peaks in this autumn, but monitoring of three target stars began in late 2012.

The best example of a long-term project is the international *Be* stars campaign, which has been running for more than a decade. Approximately 20% of all *B*-type stars (which make up about 20% of all naked-eye stars) exhibit emission lines of hydrogen and sometimes helium and iron, which vary on timescales of hours to decades. Astronomers think the emission is caused by gas shrouds or disks ejected by the stars' fast rotation, which produces centrifugal forces at the equator that are strong enough to overcome gravity. But the spectral variability is poorly understood. Amateur spectra are critical. Astronomers in general have collected more than 72,000 spectra of about 600 different *Be* stars, but 29,000 of them (40%) have been taken by just 49 amateurs. Stored in the *Be* Star Spectra database, and maintained by amateurs and professionals alike, they have served astronomers in almost two-dozen publications.

For links to websites relating to amateur spectroscopy, visit SkyandTelescope.com/amateurspectra.

Becoming an Amateur Spectroscopist

Amateurs have many other interesting targets at their disposal, from novae and supernovae to passing asteroids and comets. All of these campaigns benefit from the emergence of off-the-shelf spectrographs. Just 10 years ago, amateurs lacked the instruments necessary for any high-resolution spectroscopic study unless they could build them by themselves.

Motivated by the desire to provide simple yet powerful instruments for amateurs to do serious research, in 2003 French amateur astronomers François Cochard, Olivier Thizy, Christian Buil, and Yvon Rieugné designed what was to become Lhires, a commercial high-resolution spectrograph for amateurs. Today, their company, Shelyak Instruments, offers instruments of all resolution classes at a variety of prices. Another European source comes

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TYPICAL SETUP This amateur setup shows a Celestron C5 coupled with a Shelyak Instruments Lhires III, a top-of-the-line, high-resolution spectrograph that sells for about $4,100. Lower-price spectrographs can also produce excellent scientific results.

from Jesús Rodríguez, Carlos Guirao, and Gerardo Ávila, engineers at the European Southern Observatory, and Vadim Burwitz, a professional astronomer at the Max Planck Institute for Extraterrestrial Physics in Germany. Their Club of Aficionados in Optical Spectroscopy (CAOS) has formed a collaboration with the German company Baader Planetarium to offer spectrographs to the amateur community.

But hardware is just one part of the story. How do you know if you have the necessary skills to be an amateur spectroscopist? "The technique is not self-explaining," says Eversberg. Internet forums and newsgroups, such as those hosted by ARAS or the German Spektroskopie-forum, are crucial. Here, spectroscopy aficionados exchange knowledge on observation techniques and equipment, plan new campaigns, and discuss results. Most discussions are in English, allowing almost anyone to jump in.

European amateurs, with their different languages and cultures, have turned a seeming disadvantage into a virtue. Because national groups are small, international cooperation is essential. Every campaign includes people from all over the continent and, increasingly, the world. If you want to participate, please note that for data acquisition, it's essential that you know how to manage your telescope and a CCD camera, because the spectrograph is just an additional part of your equipment. Also be aware that professional astronomers do most of the analysis because it usually requires specialized training.

Nevertheless, even in the internet age, nothing beats meeting fellow enthusiasts in person. Since 2004, European spectroscopists have gathered yearly at the Observatoire de Haute Provence in France for a one-week workshop. "To my knowledge, this is the only star party dedicated to spectroscopy," says Thizy, who is one of the organizers. With more than 40 telescopes equipped with different types of spectrographs, it's the best way to get in touch with the field and it's participants, and beginners are always welcome. "Each year, we receive a growing number of guests, amateurs and professionals alike, and attendance is international," adds Thizy. "If you have your own equipment, bring it. This is a very practical training session." The 2013 workshop takes place August 1st to 6th.

"Within 10 years, spectroscopy has become a thriving field in amateur astronomy. It's still small and highly specialized, but it enables amateurs "to go pro" like few others. And it's growing. With equipment easily available and affordable, observation projects numerous, and increasing numbers of professionals requesting support, more pro-am collaborations will emerge in the future. Work will not run out; there is much more to discover. ✦

Jan Hattenbach is a freelance writer, amateur astronomer, and science communicator in Germany who recently took his first spectrum of a quasar.

Resolution in Spectroscopy

Resolving power ($R = \lambda/\Delta\lambda$, with $\Delta\lambda$ the smallest distinguishable wavelength interval in a spectrum at wavelength λ), specifies what you can "see" with your spectrograph, as aperture does for telescopes. Values larger than 10,000 are considered "high," which are necessary to reveal details of single lines and their time evolution. Simple slitless spectrographs reach less than 1,000 and are therefore considered to be low-resolution instruments. They don't enable precise measurements of specific lines but are still highly capable instruments. Newcomers use them to learn about spectroscopy, but because high resolution limits the magnitude of reachable objects, some observers also employ them to study faint novae, supernovae, and quasars.