

The eShel III Pushes the Limits

By François Cochard

The third generation of Shelyak Instruments' fibre-fed echelle spectrograph



Manual version — Credit: Shelyak



Motorised version (PrimaLuceLab focuser) — Credit: Shelyak

The eShel III in its manual version, with a custom-calculated 122 mm Petzval lens — Photo credit: Shelyak Instruments

The eShel III in a nutshell

The eShel III spectrograph is one of the major instruments in Shelyak Instruments' range. It is the third generation of this instrument, combining high resolution ($R \sim 10,000$; orders 25 to 60) and a wide spectral range (approximately 370 to 910 nm).

This instrument has two particular characteristics.

First, it is a spectrograph based on an echelle grating, which works at very high orders. This is what gives it its high resolution, despite a relatively modest number of lines per millimetre. These orders are dispersed by a prism (called the cross-disperser), perpendicular to the direction of the first dispersion. It is this very clever optical configuration — opticians are incredible inventors — that produces the characteristic image of an echelle spectrograph, with many orders that read like the lines of a book: the end of one line continues on the next line.

Second, the eShel III spectrograph is a fibre-fed instrument. That is, the spectrograph itself is fixed. The light is collected by an injection and guiding head (FIGU) mounted on the telescope and sent into an optical fibre whose other end serves as the light source for the spectrograph. The major advantage of this solution is that the spectrograph is decoupled from the telescope and stays fixed, generally in a room close to the telescope. It therefore undergoes no flexure when the telescope moves across the sky, which ensures great stability in the observations — a critical point, particularly when seeking high accuracy in wavelength calibration. In general, the room in which the spectrograph is installed has small temperature variations compared with the temperature inside the dome, which brings additional stability.

What's new in the eShel III: an optimised lens

The eShel is an emblematic case of the progress made over time on our instruments. The first generation of the eShel was made up solely of standard components: the collimator doublet, the prism and the lens were all “off-the-shelf” parts. Then, over time, the various elements were optimised: with the eShel II, the collimator doublet and the prism were improved and made to our own specifications.



Custom-calculated 122 mm Petzval lens. The lens focusing ring is noticeably smoother than on the eShel II

The eShel III takes a step that seemed impossible only a few years ago: it incorporates a lens calculated specifically for this application. This brings significant improvements, beyond our initial expectations. The focal length is optimised to make the best use of the sensor chosen for the eShel III (IMX571). The lens diameter is optimal to almost entirely eliminate vignetting — no loss of light, even at the ends of the extreme orders. And above all, the handling of chromatism, as well as the anti-reflection coating, is optimised to extend the usable orders even further.

You have probably noticed that the eShel III camera is tilted (by about 15°) relative to the lens axis. This is the most visible effect of the handling of chromatism — the optical aberration that means not all colours are focused in the same plane. As, in an eShel image, the red orders are on one side of the sensor and the blue orders on the other, this tilt can be used to correct chromatism. It is clearly this camera angle that makes it possible to gain several orders in the red and in the blue.

One might think that gaining a few orders in the red and blue is scientifically anecdotal. In fact, it matters far more than that: the blue and the near UV are the domain of high energies (novae and supernovae, cataclysmic variable stars, explosions and shocks). Conversely, the red and the near IR are the domain of cold matter (interstellar matter, comets, nebulae). The visible range as we know it on Earth is strongly tied to the Sun's emission range. Extending observations into the blue (UV) and the red (IR) greatly extends the fields of study of the other objects in the universe.

For the record, what pushed us to create this new lens is the announced obsolescence of the lens used until now on the eShel II. In fact, most photographic lens manufacturers are removing fixed-focal-length lenses from their catalogues — precisely those we need for the best performance in spectroscopy. It is therefore a blessing in disguise: we now have noticeably better performance, because the lens is optimised for our precise application.

Key takeaway — the eShel III incorporates a 122 mm focal length Petzval lens calculated specifically for spectroscopy, with a sensor tilt of about 15° that corrects chromatism and extends the usable orders in the blue as well as in the red.

Two versions: manual and motorised

We took advantage of this complete mastery of the lens to offer two mechanical versions. The first is manual, as the eShel II was; the second is motorised. These two versions correspond to quite distinct uses.

If you observe next to the telescope, the manual version is probably the most suitable. Focusing is done by turning the lens ring. Note simply that the focusing ring is noticeably smoother than that of the eShel II; it is easier to achieve very precise focusing.

If you work remotely — whether a few metres from the telescope or thousands of kilometres away, an increasingly common case — then the motorised version will be your preference. You can then fine-tune the focus through your computer. We chose a PrimaLuceLab focuser, which is not only very precise but can also be controlled in many ways (USB, Wi-Fi, Ethernet, ASCOM or INDI...).



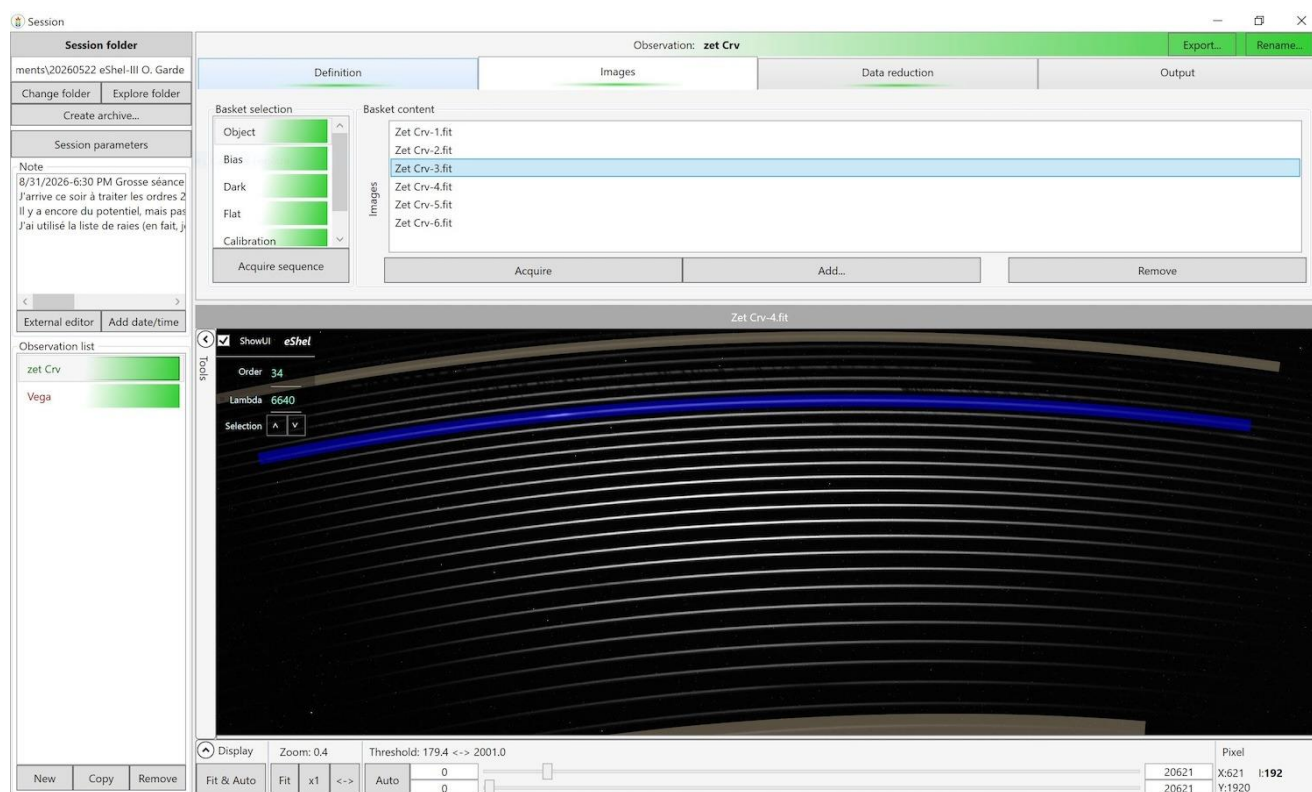
The two versions of the eShel III lens: manual (left) and motorised (right) — Photo credit: Shelyak Instruments

Upgrading from eShel II to eShel III

This is a point that is close to our hearts: if you already have an eShel II, you can easily convert it into an eShel III simply by changing the lens. If that is your case, we have provided product references covering only the lens — in both versions of course, manual or motorised. Changing the lens is simple.

A new version of Demetra to match the new performance

Producing echelle spectrum images is one thing... processing that data is much better! The Demetra software can support you in using your eShel III, from spectrum acquisition through to data reduction; it can thus produce scientifically usable spectra, free of all instrumental effects, and calibrated both in wavelength and in relative intensity.



Demetra's acquisition module, with an echelle spectrum being processed — Photo credit: Shelyak Instruments

The announcement of the eShel III comes with a new version of Demetra (version 9), to take the extreme orders into account. With this version of Demetra, you will be able to process orders 27 to 59, i.e. a wavelength range between 379 and 853 nm.

Obviously, eShel III images offer a few additional usable orders (say 22 to 62, i.e. 360 to 1,000 nm). But the wavelength calibration method used by Demetra, which relies on a thorium lamp, shows its limits here: there are no longer enough thorium lines in these extreme orders! We have a few avenues to explore to get around these limits and extend the eShel III's possibilities even further, but it will take a little time.

Note that the images produced by the eShel III and Demetra are perfectly standard (FITS format), so you can process them with your own tools.

eShel III: an improved eShel II

The eShel II spectroscope had a photographic lens with an 85 mm focal length that is no longer manufactured. Shelyak Instruments therefore designed its own Petzval-type optic with a 122 mm focal length. This “custom-made” design has made it possible to optimise the overall quality of the spectra produced: more uniform focusing from one end of the spectrum to the other, and more orders accessible in the near UV and especially the near IR.

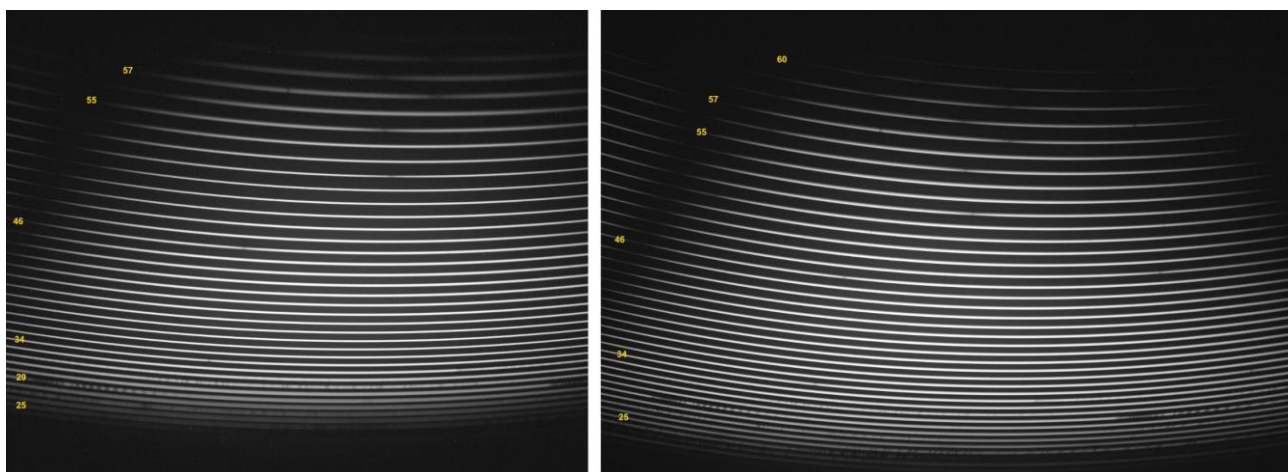
The lenses, themselves available in manual and motorised versions, allow your eShel II to be upgraded. The motorised version includes a PrimaLuce Lab focuser. Changing the optic is simple, but it absolutely requires a sensor larger than the ATIK 460EX camera generally used with this instrument. We therefore recommend using a monochrome Sony IMX571 sensor, and more particularly the ASI 2600 MM Pro, which is directly compatible with the eShel III.

Superior performance: comparison with the previous version of the eShel

The main advantage of the eShel III is that it makes the orders more uniform in focus, both in the extreme blue and in the near IR, which extends the usable spectral range by several orders.

- The eShel II made it possible to obtain a spectrum of orders 31 to 57 inclusive (approximately 390 to 760 nm).
- The eShel III now makes it possible to obtain a spectrum of orders 25 to 60 inclusive (approximately 373 to 910 nm).

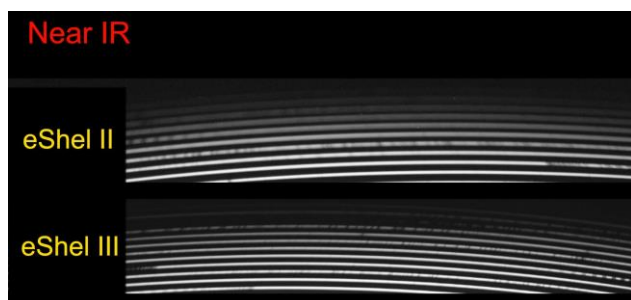
The images below show the difference in focusing in the extreme orders between the two versions. For those who already own an eShel II and would like to move to the eShel III, the only constraint is that you must have an APS-C format sensor of 23.5×15.7 mm, and not a smaller sensor such as the ICX825 (9×6.7 mm).



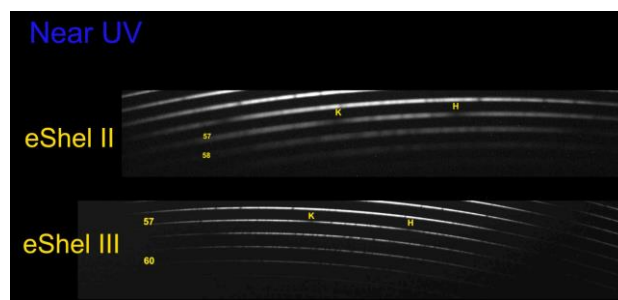
eShel II spectrum (85 mm optic + Sony ICX825 camera) and eShel III spectrum (122 mm optic + Sony IMX571 camera)

The eShel III is thus a major evolution, allowing a wider spectral range to be explored than the previous version. The uniform focusing from one order to the next gives a more constant resolution across the whole spectrum, which makes it an ideal instrument to operate remotely, with very good repeatability of the data produced from one night to the next.

The detail below shows the extreme orders in the near IR and the near UV, for both versions.



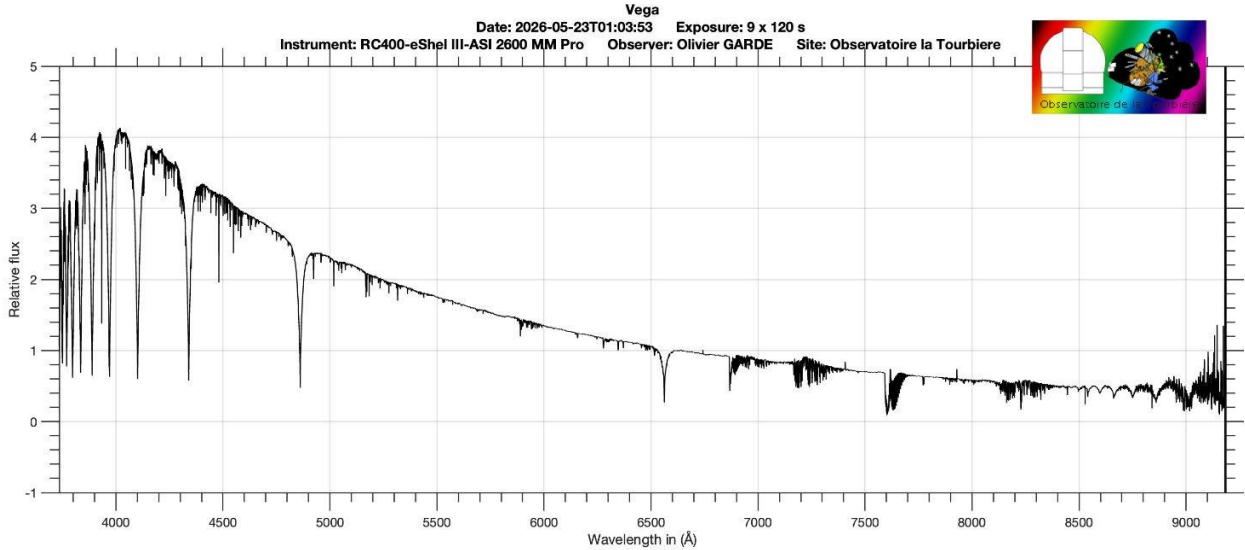
*Extreme orders, near IR: eShel II (top) / eShel III (bottom)
— Credit: Olivier Garde*



Extreme orders, near UV, Ca H and K lines: eShel II (top) / eShel III (bottom) — Credit: Olivier Garde

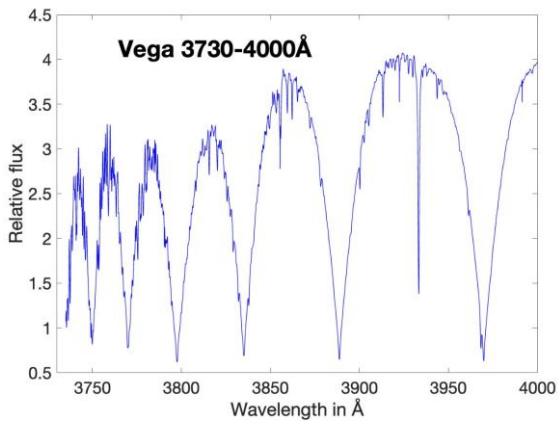
Example result on Vega

Here is the Vega spectrum obtained with the eShel III on a 406 mm diameter Ritchey-Chrétien telescope: 9 exposures of 120 s each with an ASI 2600 MM Pro (gain 101, cooled to -10°C) in 2×2 binning, processed with the IRIS software by modifying the line.lst file to add lines in the near UV and near IR (the original file went no further than 4000 Å and 7500 Å).

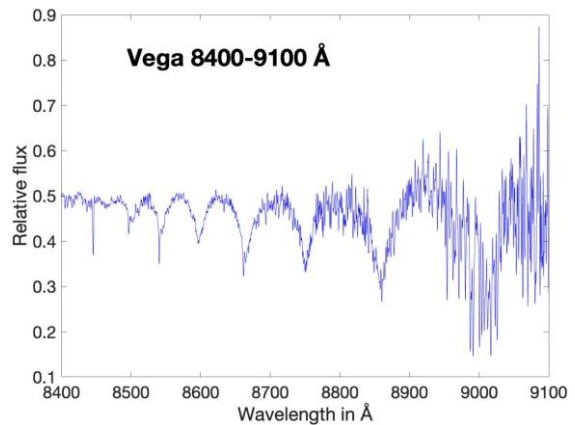


Complete Vega spectrum, from 3700 to over 9100 Å — Photo credit: Olivier Garde / La Tourbière Observatory

The spectral range is approximately 3730 Å to 9100 Å (order 60 to 25 inclusive). The detail of certain orders for the Balmer series of lines up to H₁₃, and for the Paschen series in the near IR, makes it possible to see the last lines of those series (Pa 13 among others).



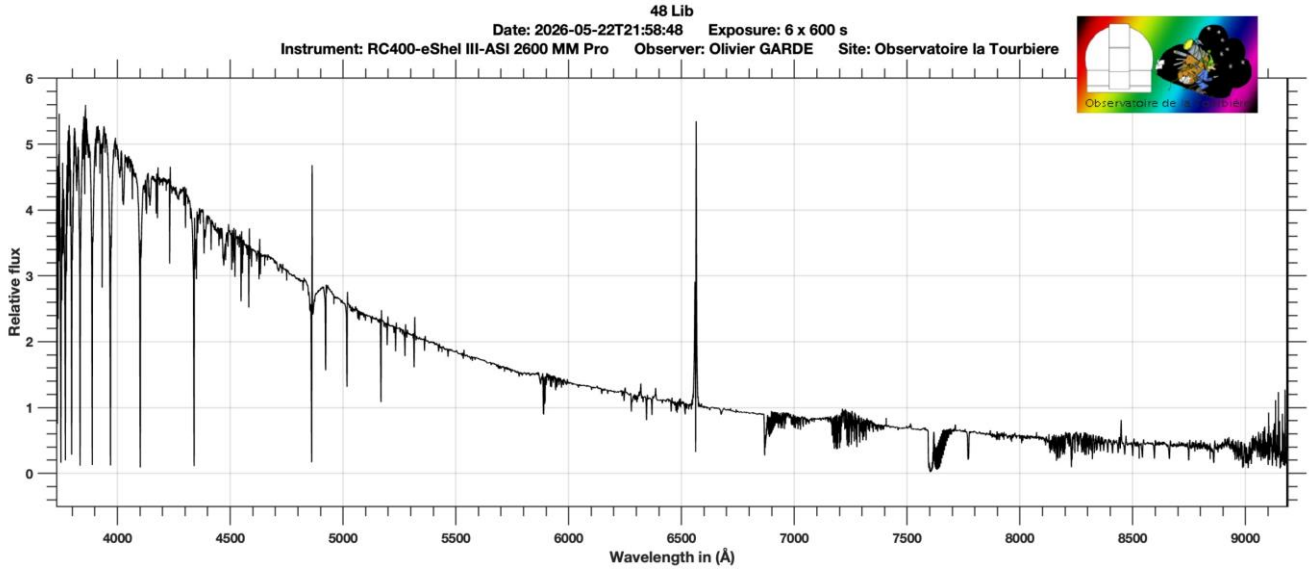
Balmer series, 3730 to 4000 Å — Credit: Olivier Garde



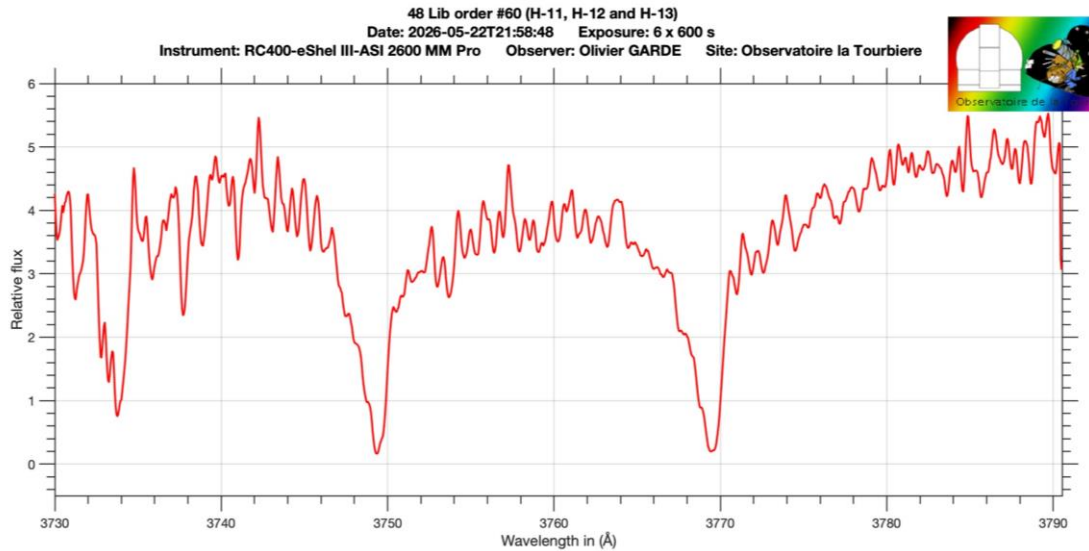
Paschen series, 8400 to 9100 Å — Credit: Olivier Garde

Spectrum of the Be star 48 Lib

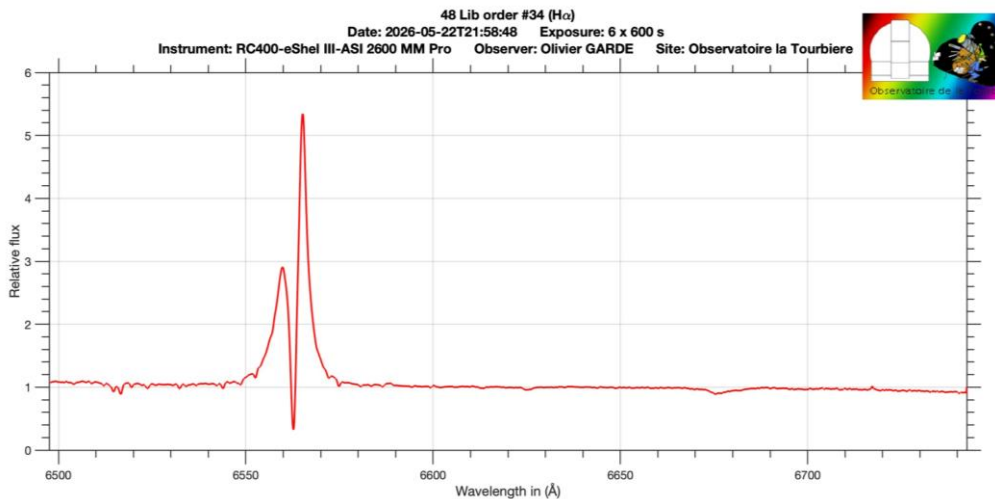
The spectrum was obtained with the same configuration as for Vega, on this Be star of magnitude $V=4.87$, with 6 exposures of 600 s each.



Merged spectrum of orders #25 to 60 inclusive of the Be star 48 Lib — Photo credit: Olivier Garde / La Tourbiere Observatory



Order #60: calcium H and K lines (near UV) — Credit: Olivier Garde



Order #34: P Cygni profile of the H-alpha line — Credit: Olivier Garde

An eShel III Spectrograph at the Haute-Provence Observatory

First observing campaign for the R~10,000 echelle spectrograph



The 1m dome at nightfall, just before the first eShel III spectrum was produced — Photo credit: Olivier Garde



The 1 m telescope on its fork mount — Photo credit: Olivier Garde

By Olivier Garde

The Haute-Provence Observatory (OHP), France, is a legendary site for the discovery of the first exoplanet in 1995 by Michel Mayor and Didier Queloz (both 2019 Nobel Prize winners in Physics). The site is renowned for its work in spectroscopy, and particularly for radial velocity measurements with the SOPHIE spectrograph on the site's 1.93 m telescope, dedicated to exoplanet research.

Among the site's many domes, the T100 dome was built in the 1960s on the initiative of Marcel Golay of the Geneva Observatory. It houses a 1 m diameter telescope on an equatorial fork mount, later fitted, in the 1970s, with an analogue correlation spectrograph: Coravel.

In early 2026, the OHP decided on a makeover of this telescope, both for the mechanical side (replacement of the motors and control electronics) and to install the very first eShel III spectrograph, on 13 July — which was able to produce its first spectrum the night after its installation. This spectroscopic project was funded by the universities of Paris-Saclay and Montpellier, and it is used by university students in practical classes, as well as by Master's and PhD students. The combination of this 1 m telescope with the eShel III makes it a formidable asset for producing echelle-type spectra.

Installing the spectrograph

On 13 July, Olivier Garde arrived at the OHP site in the early afternoon with all the elements needed to install the eShel III spectrograph:

- The injection head (FIGU), which feeds the star's light into a 50 μm optical fibre and also allows autoguiding on the target to keep the star on the fibre core. This head is optimised for a telescope focal ratio of $f/9$, with the addition of an Astro-Physics CCDT67 focal reducer to bring the telescope's native focal ratio from $f/14.5$ down to $f/9$ — a condition necessary to avoid losing too much flux in the fibre.

- The calibration module, comprising a thorium/argon hollow-cathode lamp and its high-voltage power supply, as well as a halogen lamp to produce flat-field images. The module also allows the head to be controlled remotely, via the switches on the housing or an RS232 protocol, so that it can be driven with acquisition software such as Demetra.
- The eShel III spectrograph itself: an echelle (multi-order) type, it gives spectra from approximately 370 to 910 nm with an average resolution of $R = 10,000$ in this configuration. Its use with an optical fibre allows the spectrograph to be located away from the telescope, freeing it from the mechanical constraints linked to the telescope's position.
- Two 20 m optical fibres: one of 50 μm linking the head to the spectrograph, the other of 200 μm linking the calibration module to the head.

The observatory supplied the two cameras itself: a spectral camera based on a monochrome Sony IMX571 sensor (APS-C format, 23.5×15.7 mm, 3.76 μm pixels, 16-bit dynamic range), and an autoguiding camera based on a monochrome Sony IMX174 sensor, with a large 11×7.1 mm array and good detection of even very faint stars (5.86 μm pixels).



The eShel III spectrograph fitted with its spectral camera — Photo credit: Olivier Garde



The head installed at the telescope focus, with its autoguiding camera and the two optical fibres — Photo credit: Olivier Garde

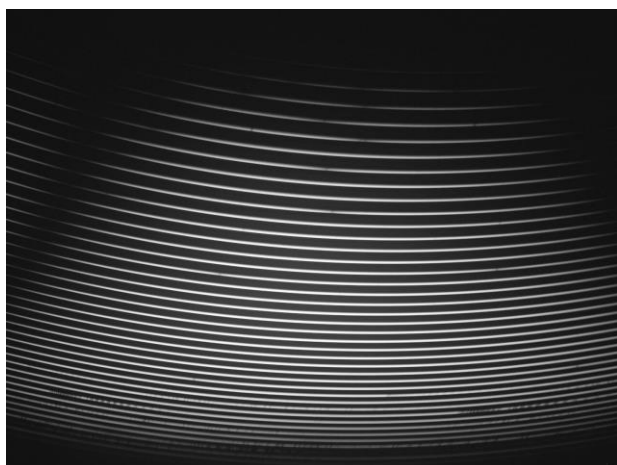
Adjustments and first tests

With the observatory's technicians, the head was installed on the telescope output, on a 2-inch barrel, with the focal reducer upstream set at the correct back focus to obtain the required $f/9$ ratio. The cables, fibres and power supplies were then connected, running along the telescope's right ascension axis to the control room.

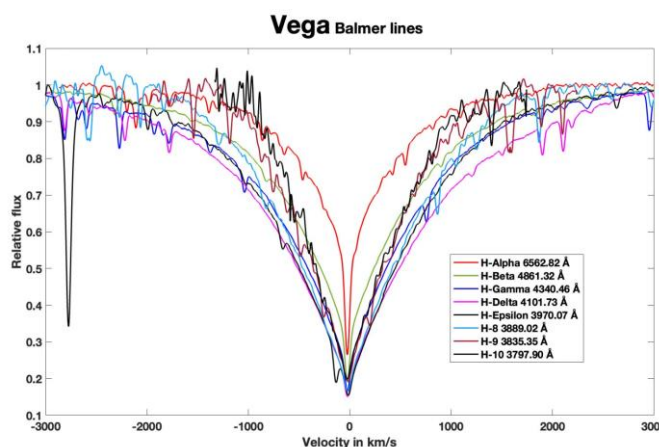
The spectrograph itself was installed in a separate room at the bottom of the dome, sheltered from light and from large temperature variations — an important criterion, because a temperature variation of just 1 °C can cause velocity drifts of the order of 100 m/s. Three focusing adjustments were then carried out: the image of the fibre core on the autoguiding camera, the spectral image on the science camera (using a thorium lamp spectrum and the manual focuser), then the image of a star on the autoguiding sensor, by adjusting the telescope's secondary mirror.

First spectrum on Vega

The first target was Vega, a standard star of magnitude $V = 0.03$, which made it possible to adjust the autoguiding and pointing, and to test the quality of the telescope's tracking in equatorial mode. This AoV spectral-type star shows the hydrogen lines (Balmer series) from H-alpha to the H13 line in the near UV, around 3730 Å. The spectrum was exposed for 60 seconds, with a camera gain of 101 (ASI 2600 MM Pro).



First raw Vega spectrum with the eShel III, produced with the OHP's T1m — Credit: Olivier Garde



Velocities of the Balmer lines (Matlab script) — Credit: Olivier Garde

CONCLUSION

The eShel III significantly improves on the eShel spectroscope by producing spectra that are more uniform from one order to the next and by extending the spectral range covered.

The manual version offers the same focusing principle as the eShel II, by turning the focusing ring; it is more precise than on the original 85 mm lens, and the ring can also be locked once the right setting has been found, which was not possible with the old model.

The motorised version will have its full place in remotely operated configurations, to adjust the eShel III's focus precisely. The focuser can be controlled, among other ways, via an ASCOM or INDI driver supplied with the focuser.

For those who already have an eShel II and wish to upgrade their spectrograph to this new version, they can buy either of the two upgrades (manual or motorised). The upgrade instructions explain how to remove the old optic and fit the new one easily.

Don't miss any news on astronomical spectroscopy: subscribe to the Shelyak Instruments newsletter at www.shelyak.com

Sources: Shelyak Instruments blog (shelyak.com). "Avec le eShel III, repoussons les limites", "eShel III : un eShel II amélioré" and "Un spectrographe eShel III à l'Observatoire de Haute Provence" (original French titles), by Olivier Garde

Links to the products webpages

<https://www.shelyak.com/produit/eshel-iii-lens-motorized-version/?lang=en>

<https://www.shelyak.com/produit/eshel-iii-objective-lens-manual-focuser/?lang=en>