Investigation of the Semi-Detached Binary System β Lyrae with BACHES Echelle Spectrograph and Remote Calibration Unit (RCU)

by Dipl.-Phys. Bernd Koch, Baader Planetarium GmbH

Abstract

The semi-detached binary system β Lyrae has been investigated by the means of spectroscopy with BACHES echelle spectrograph and Remote Calibration Unit (RCU).

Baches echelle spectrograph

A powerful high-resolution echelle spectrograph, like **BACHES**[1] from Baader Planetarium GmbH, is mandatory for investigating the rapid variation of the spectral lines' profiles during the mutual revolution of the stellar components (Fig. 1).

Fig. 1: BACHES echelle spectrograph with attached CCD camera SBIG ST-8300M and fiber connection to Remote Calibration Unit (RCU).

β Lyrae is a stellar object well suited for echelle spectrographs like BACHES, which are superior to usual blazed grating spectrographs of comparable resolution. Almost the complete visual and near-infrared spectrum from 3900Å to 8000Å, in particular the significant wavelength range from approximately 4300Å to 7600Å for β Lyrae, can be recorded on a single CCD exposure with BACHES' high spectral resolution of about 18,000 (Fig. 2).

The spectrum was calibrated with ESO-MIDAS[2] software in a virtual box of Windows 7.

[1] www.baader-planetarium.de/baches
[2] www.eso.org/sci/software/esomidas/

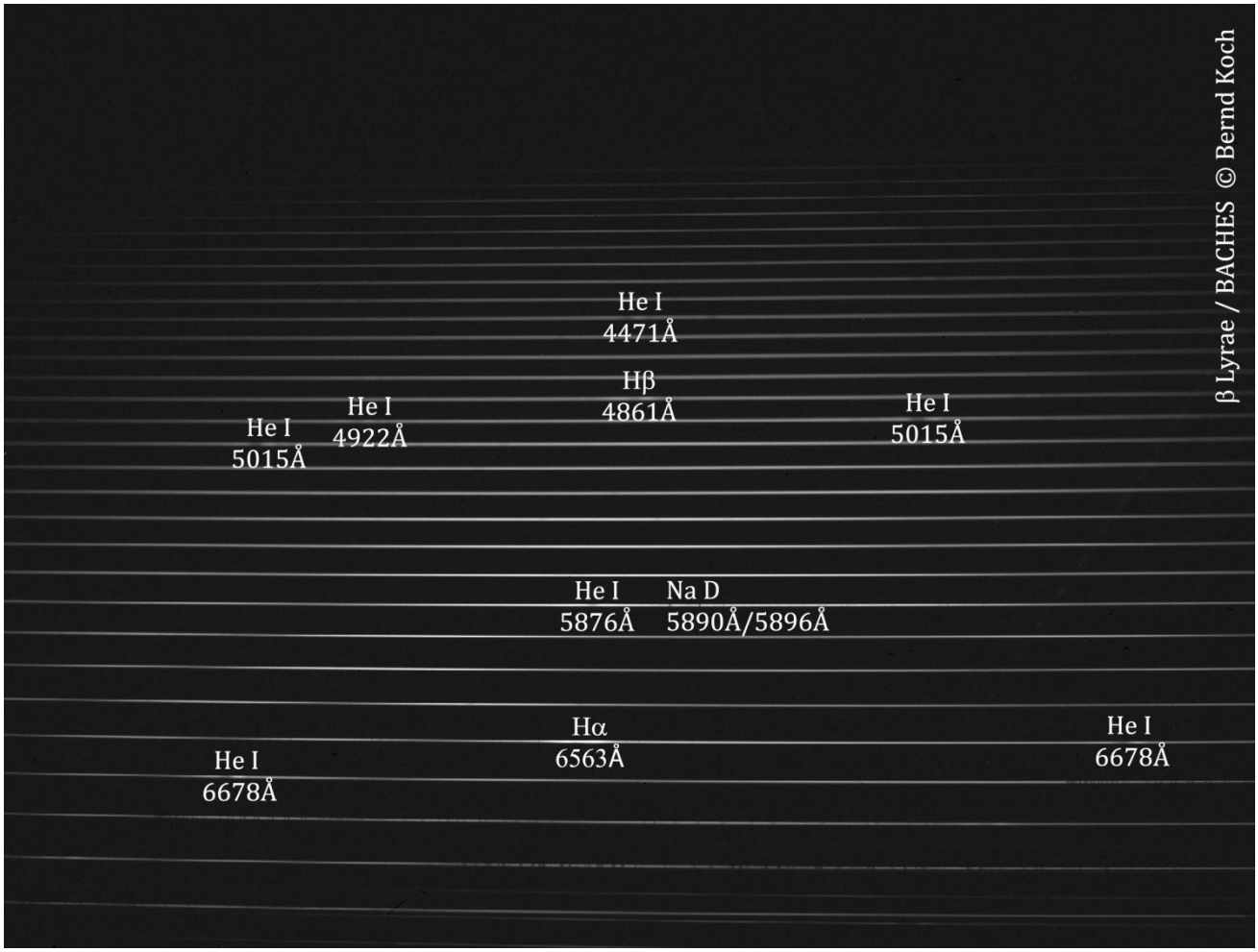

Fig. 2: Spectrum of semi-detached binary system β Lyrae, taken on June 8, 2014 at 00:07:24 UT. The spectrum was recorded with BACHES echelle spectrograph and a SBIG ST-8300M CCD camera, Pixel size 10.8 µm. This is a single 300s exposure from which a darkframe has been substracted.

Calibration of the BACHES echelle spectrum has been accomplished by ESO-MIDAS. A Thorium-Argon lamp and a halogen lamp from the fiber coupled Remote Calibration Unit (RCU) provided the reference spectrum (Fig. 3) and the flatfield spectrum (Fig. 4), respectively.

Fig. 3: This well-known Thorium-Argon (ThAr) reference spectrum was supplied by the Remote Calibration Unit (RCU), coupled to the BACHES by a 2.5m glass fiber. The spectrum was taken with the BACHES echelle spectrograph and an SBIG ST-8300M CCD camera, pixel size 10.8 µm. This is a single 20s exposure from which a darkframe has been subtracted.

Fig. 4: This halogen lamp flatfield spectrum was supplied by the Remote Calibration Unit (RCU), coupled to the BACHES with a 2.5m glass fiber. The spectrum was taken with the BACHES echelle spectrograph and an SBIG ST-8300M CCD camera, pixel size 10.8 µm. This is a single 20s exposure from which a darkframe has been subtracted.

After calibration of the wavelength, the windows software VisualSpec[3] by Valérie Desnoux was used to normalize the spectrum, which also was able to synthesize a color spectrum (Fig. 5).

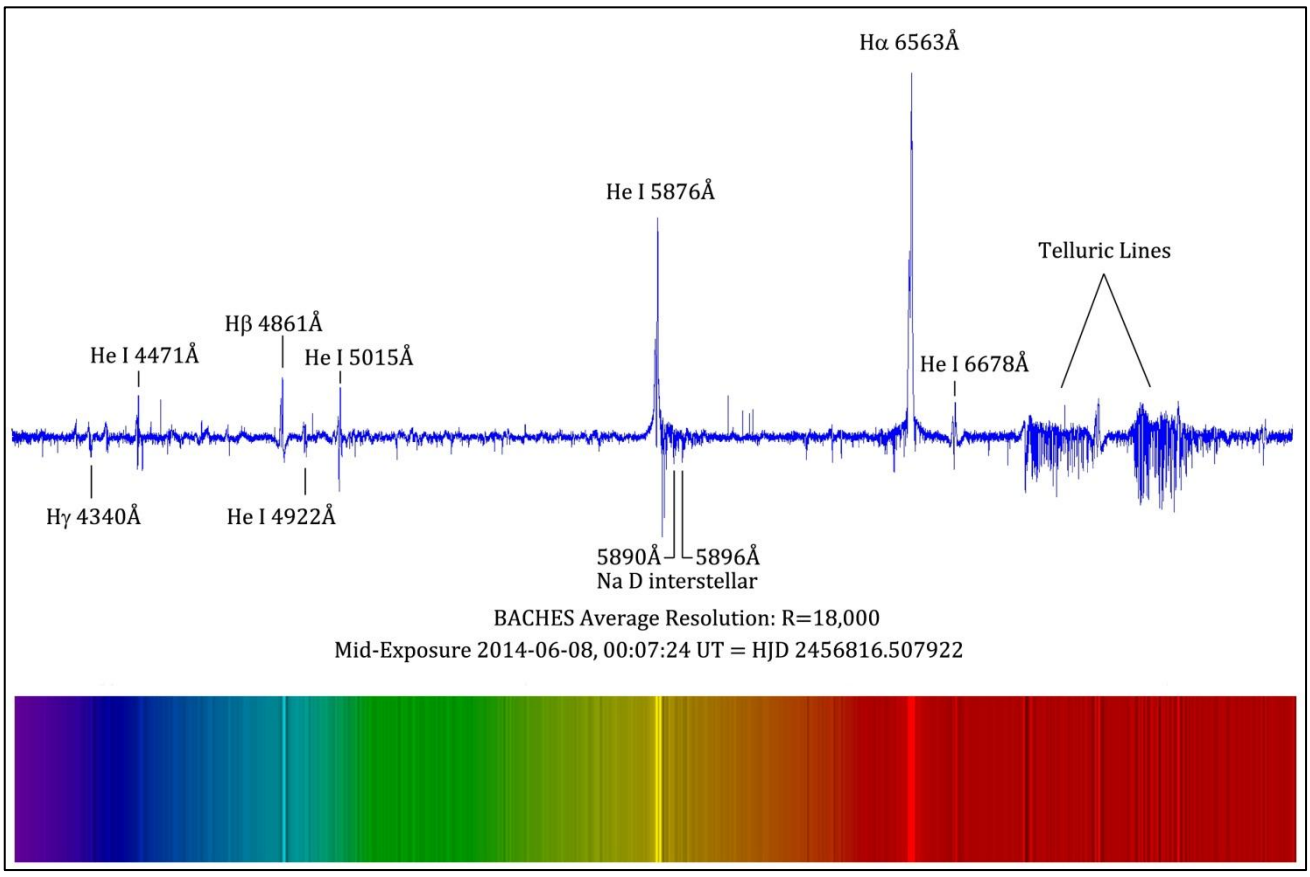

Fig. 5: The pseudo-continuum was removed by processing the calibrated spectrum (by ESO-MIDAS) with VisualSpec software, which also was able to synthesize a color spectrum. A normalized spectrum is shown.

Spectrum of the semi-detached binary star β Lyrae

β Lyrae is a semi-detached binary system of a probably B8 type primary star and probably a B or A9/F type secondary star. The latter is difficult to decipher. The fainter, less massive star (let's say B8) was once the more massive member of the pair and evolved to a giant star. Because the pair is in a close orbit, this star overflowed its Roche lobe as it expanded and transferred most of its mass over to its companion. The original secondary, now the more massive star, is surrounded by an accretion disk from this mass transfer. This accretion disk blocks our view of the secondary star, lowering its apparent luminosity and making it difficult to pinpoint its stellar type.The amount of mass being transferred between the two stars is about 2×10^{-5} solar masses per year [2]. This near-contact binary is a bright, fascinating stellar object for successful spectroscopy even with small telescopes.

Variations of specific spectral lines of Hydrogen (H) and Helium (He) have been the subject of scientific investigations [3,4]. Depending on the selected spectral line, the observer looks at different locations of origin of the observed emissions of the semidetached eclipsing binary (Fig. 6).

Temporal spectral variations can be identified as variable emissions of a gaseous shell, the accretion disk, and the stellar wind. They are found at different positions along the spectrum (Fig. 5-10).

[3] www.astrosurf.com/vdesnoux/

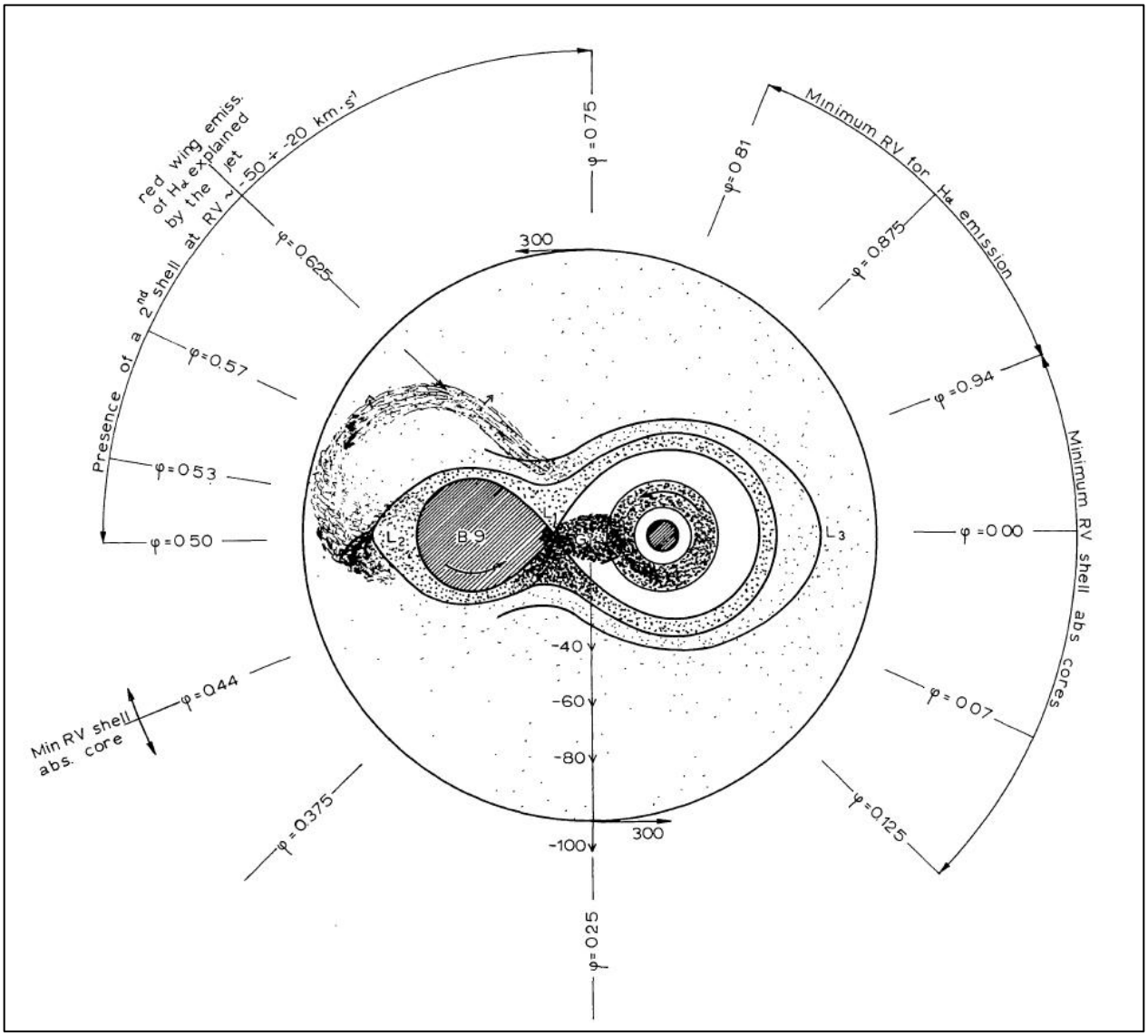

Fig. 6: The β Lyrae binary system has been investigated extensively from the ultaviolet to the red part of the spectrum in a 1971 campaign with the 1.52m coudé telescope of the Haute Provence Observatory (CNRS). The authors of this publication compiled a model of the envelope and the gaseous stream resulting from their observations ([1] Flora, Hack; 1975).

Measurement of stellar flux and gas velocity in this very complex binary system with gaseous shells and mass transfer is being investigated at hydrogen Hα 6563Å line and particularly at the helium lines He I 5876Å and He I 6678Å (Fig. 8, 9).

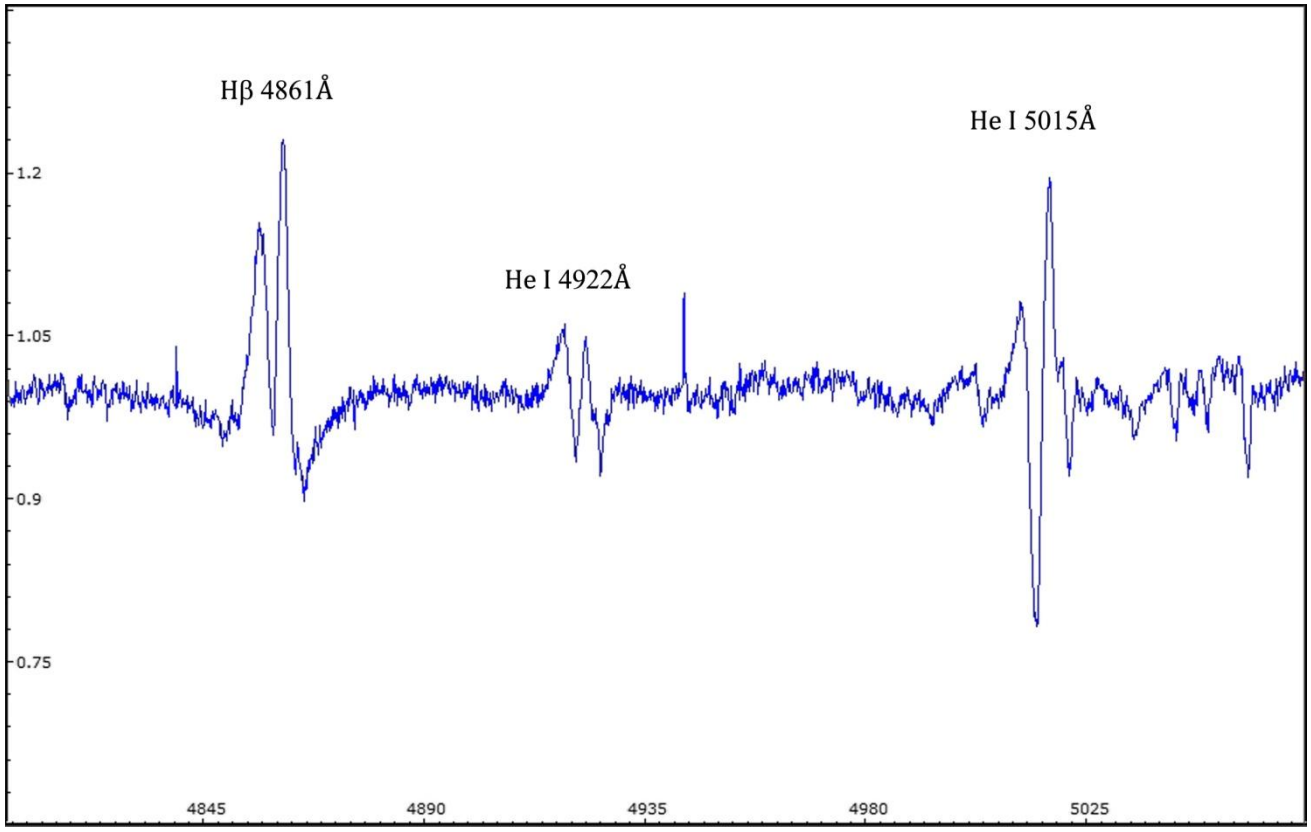

Fig. 7: This is a section of the recorded BACHES echelle spectrum showing varying strength of emission and absorption in the P-Cygni-Profiles at Hβ 4861Å, He I 4922Å, and He I 5015Å with different flux.

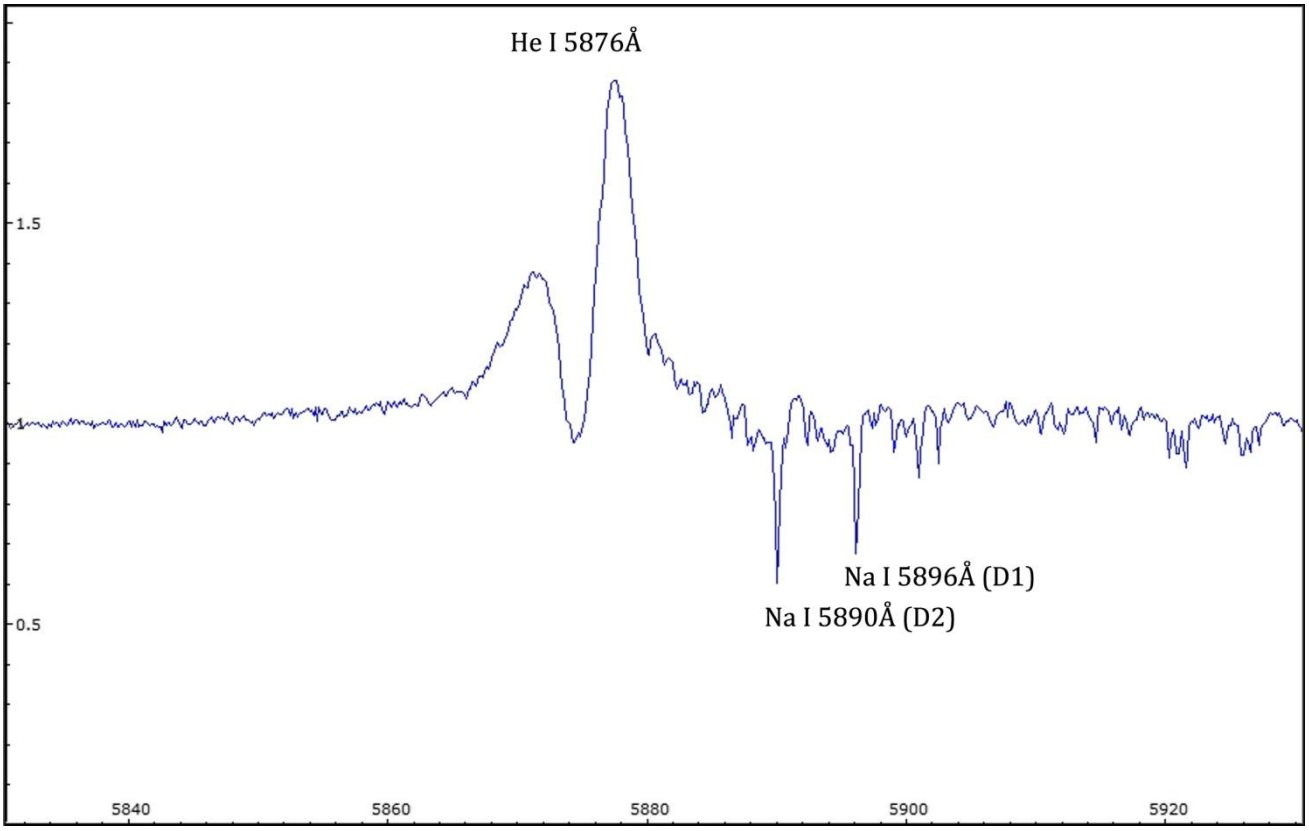

Fig. 8: P-Cygni-profile of β Lyr at He I 5876Å is close to the narrow interstellar Sodium lines (Na I Doublet D1, D2). "The He I 5876Å and the He I 6678 lines are well suited for the study of the stellar wind from the [B8...] B9 component of β Lyr" (Etzel, Meyer; 1983). The Na I Doublet may also be used to map interstellar absorption along the line of sight (Welsh et al.; 2010).

Investigation of the Semi-Detached Binary System β Lyrae with BACHES Echelle Spectrograph

"A preliminary analysis of an extensive collection of interferometric, spectroscopic and photometric observations of the bright Be star β Lyr lead to the following main conclusions: (1) The bulk of the H-alpha and He I 6678 emission seems to originate in jets of material perpendicular to the orbital plane of the binary. The jets are associated with the more massive component of the binary (star 1) and probably emanate from the `hot spot' in the disk, i.e. the region of interaction of the gas stream flowing from the Roche-lobe filling B6-8II component (star 2) toward star 1. Some contribution to the emission also comes from a region located between the two stars (the gas stream and the 'hot spot') and from the 'pseudoatmosphere' of the accretion disk around star 1." [….] (Harmanec, et al., Abstract; 1996).

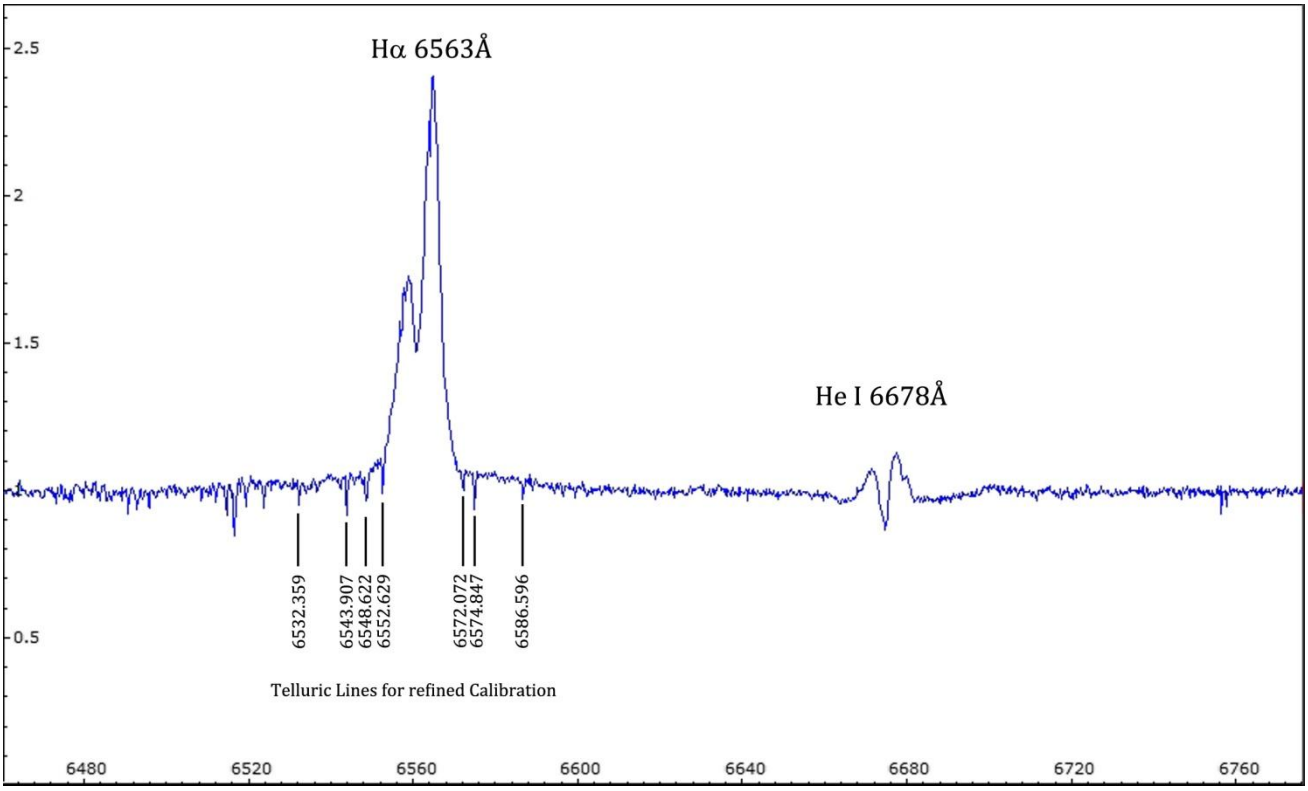

Fig. 9: Detail near Hα 6563Å and He I 6678Å. The precisely known wavelengths of the telluric lines around Hα can be used for fine calibration of that section of the spectrum.

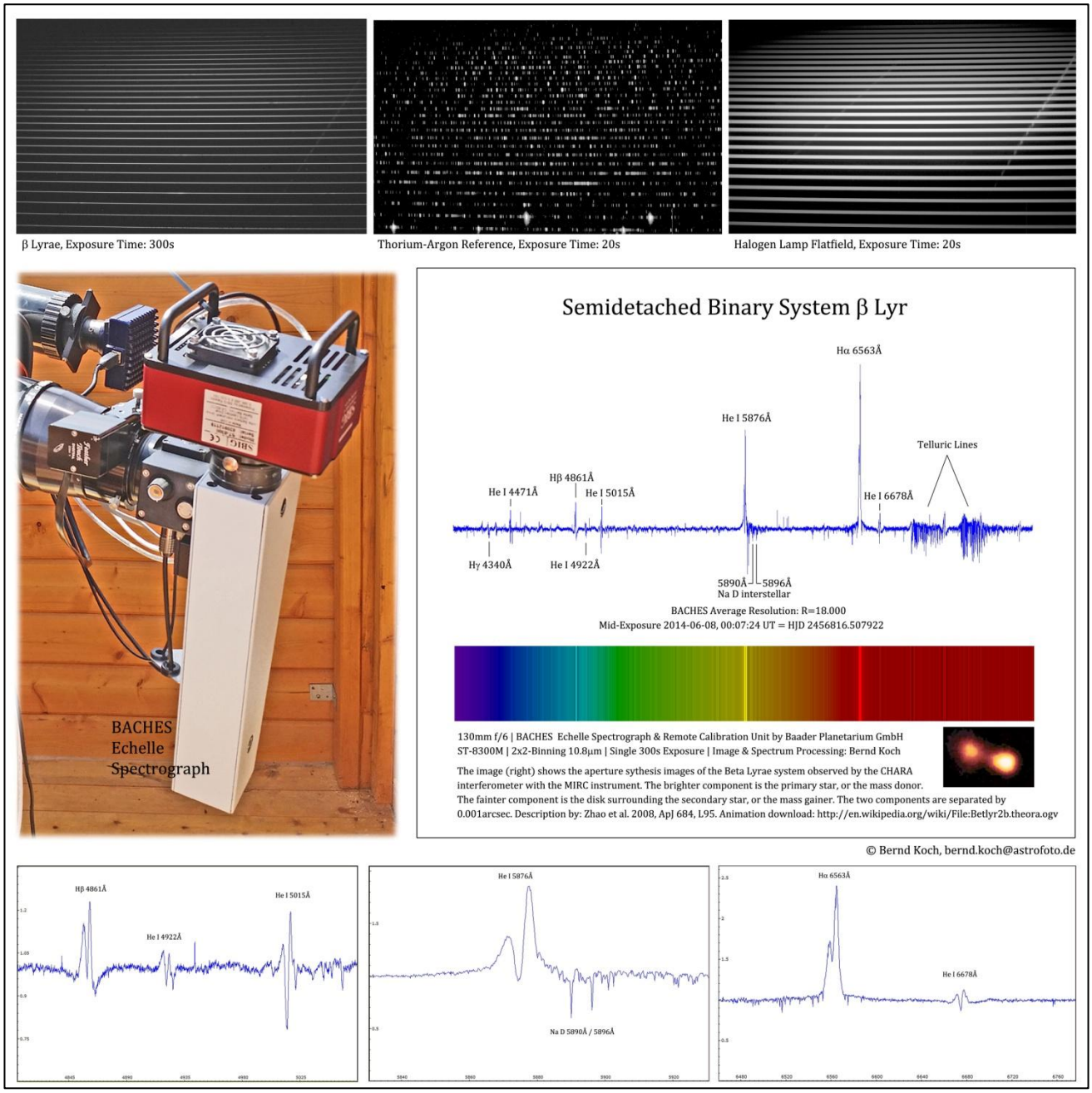

Fig. 10: In the upper row of the β Lyrae poster, on the left, a single 300-second spectrum exposure is shown; it was recorded with a BACHES and an SBIG ST-8300M CCD camera attached to a 130mm refractor. For calibration, the Remote Calibration Unit (RCU) was used. A Thorium-Argon reference spectrum and a halogen lamp flatfield spectrum were also recorded, each exposed for 20 seconds.

Conclusion

The spectrum of β Lyrae clearly demonstrates that high resolution stellar spectroscopy with the BACHES echelle spectrograph is worthwhile even with small telescope apertures. However, depending on the brightness of the investigated object, increasing the signal-to-noise ratio by exposing and subsequently stacking several spectra, may be strongly advised. The purpose of this investigation was to demonstrate the advantage of an echelle spectrograph over a classic blazed grating spectrograph which only covers only a small part of the complete visual spectrum with a single exposure.

References

[1] Flora, U., Hack, M. "Spectrographic observations of beta Lyr during the international campaign of 1971" Astronomy and Astrophysics, Suppl. Ser., Vol. 19, p. 57 – 89 (1975)
http://adsabs.harvard.edu/abs/1975A%26AS...19...57F

[2] Summary adapted from http://en.wikipedia.org/wiki/Beta_Lyrae

[3] Etzel, P. B., Meyer, D. M., "The Stellar Winds in Beta Lyrae".
http://adsabs.harvard.edu/full/1983PASP...95..891E

[4] Harmanec, P. et al., "Jet-like Structures in Beta Lyrae. Results of Optical Interferometry, Spectroscopy and Photometry", Astronomy and Astrophysics, v.312, p.879-896 (1996)
http://adsabs.harvard.edu/abs/1996A%26A...312..879H

[5] Welsh, B. Y. et al., "New 3D gas density maps of NaI and CaII interstellar absorption within 300 pc"
http://www.aanda.org/index.php?option=com_article&access=standard&Itemid=129&url=/articles/aa/pdf/2010/02/aa13202-09.pdf

All images, except of Fig. 6, by the author.

Contact: Bernd Koch, Soerth/Westerwald, Germany | Bernd.Koch@astrofoto.de