BACHES

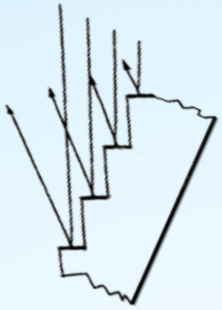
Echelle Spektrograph

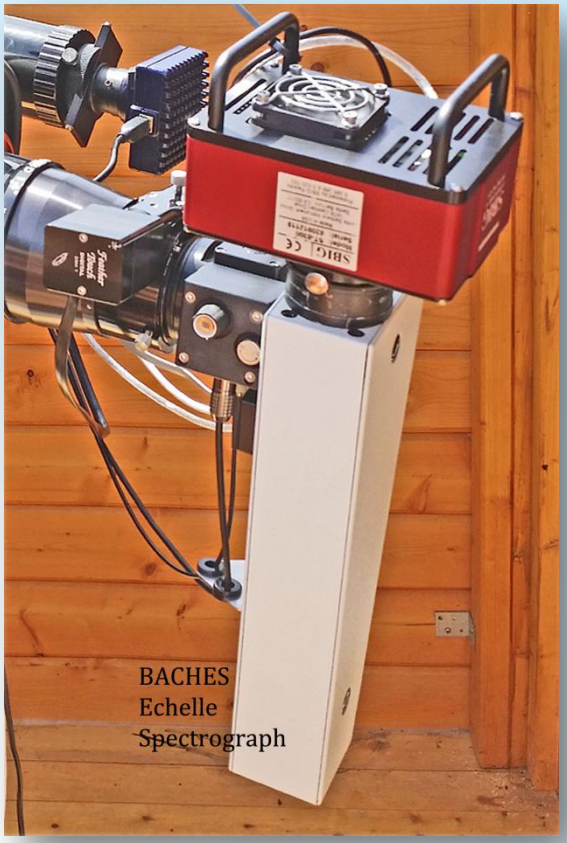
and Remote Calibration Unit

CEDIC March 6-8, 2015 Baader Planetarium GmbH Bernd Koch

The BACHES Echelle Spectrograph

- ✓ BACHES is the acronym for BAsic ECHElle Spectrograph
- ✓ „Echelle“ is a french word, which means „ladder“
- ✓ Developed by ESO Scientists and Baader Planetarium GmbH

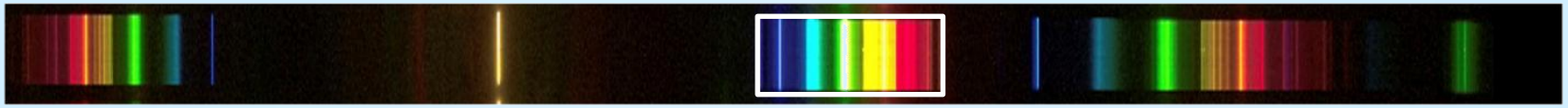




A conventional Blazed Grating Spectrograph

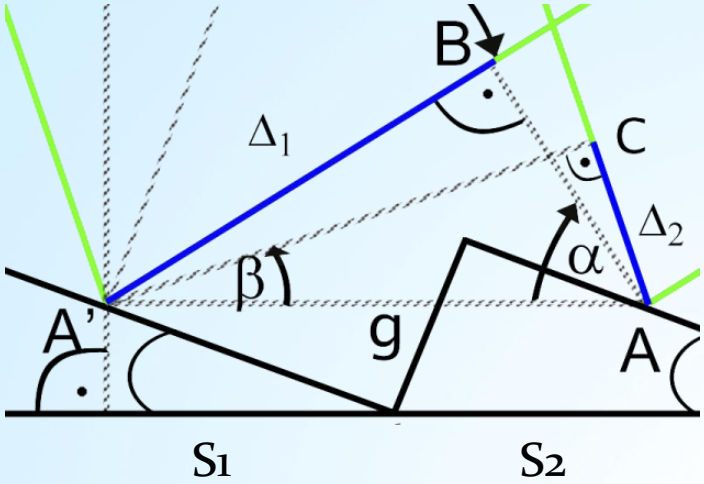
Designed for maximum efficiency in the first order

Higher orders order not useable due to overlap



Fluorescent lamp

m = -1 m = 0 m = 1 m = 2 m = 3



Additive interference occurs when the total path difference Δ of light from adjacent slits (S1) and (S2) is an integer multiple of the wavelength λ:
The phase is then the same, so the beams' intensity add.

$\Delta = m\lambda = \Delta_1 - \Delta_2 = g(\sin\alpha - \sin\beta)$ with m =0, ±1, ±2

g: Groove spacing, m: Order number

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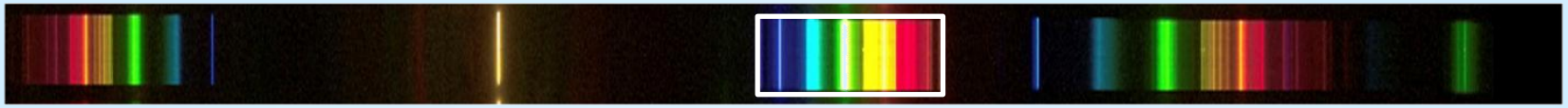
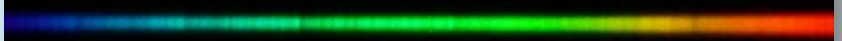


First order | Zero order | First order | Second order | Third order

Fluorescent lamp

Low resolution when a full frame spectrum
from 360 nm to 1000 nm is required

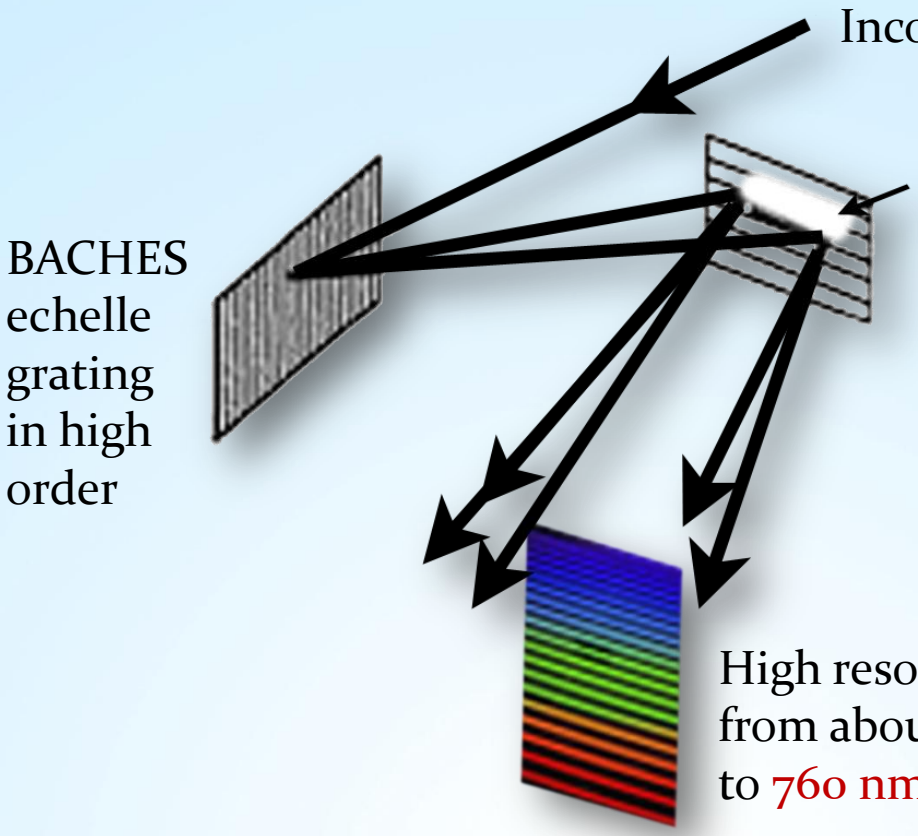


"wasted space" on CCD sensor

High resolution only in a small wavelength range
due to limited size on a CCD sensor

"wasted space" on CCD sensor

The Echelle Optical Path



Adopted from C. R. Kitchin, Optical Astronomical Spectroscopy

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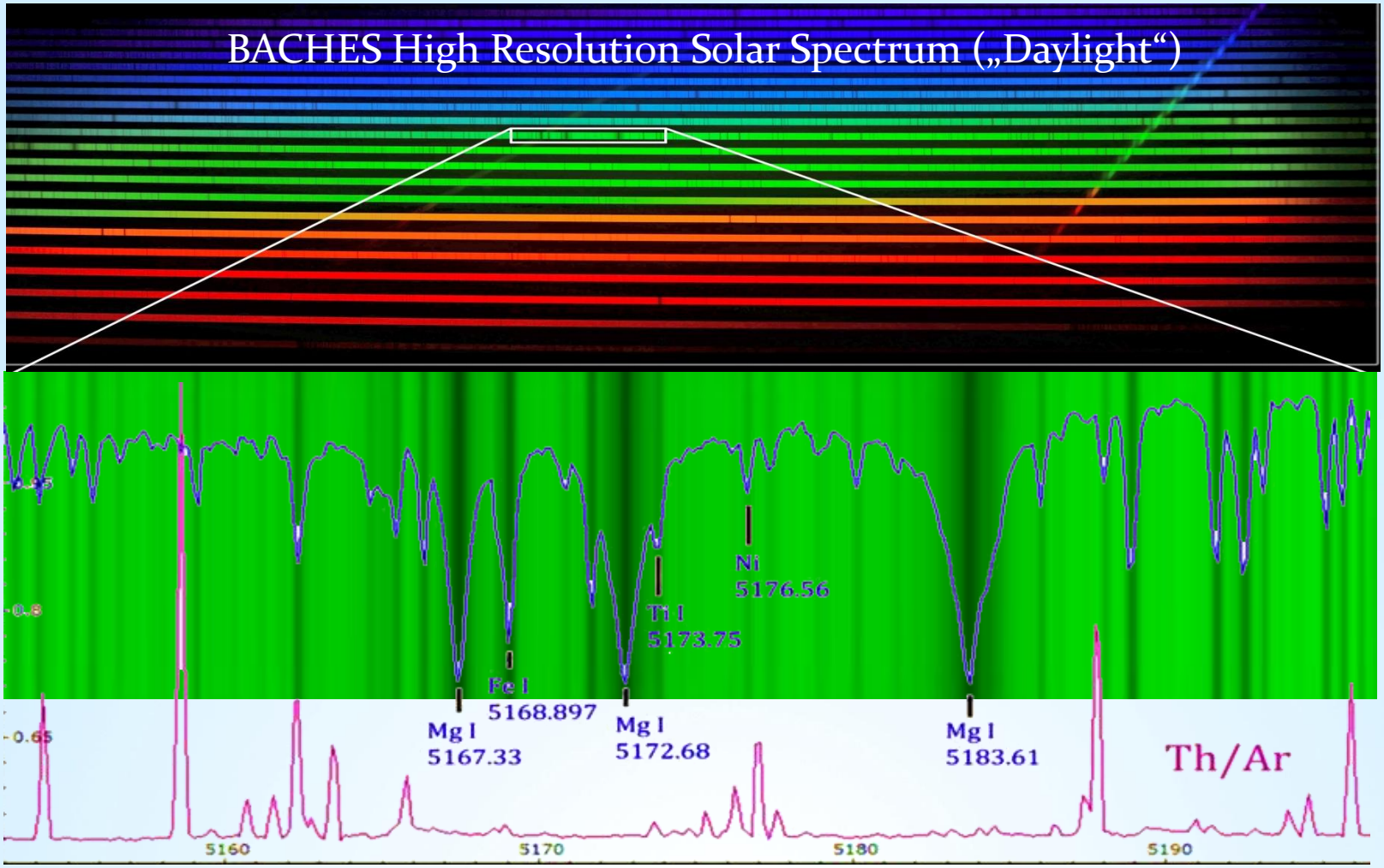

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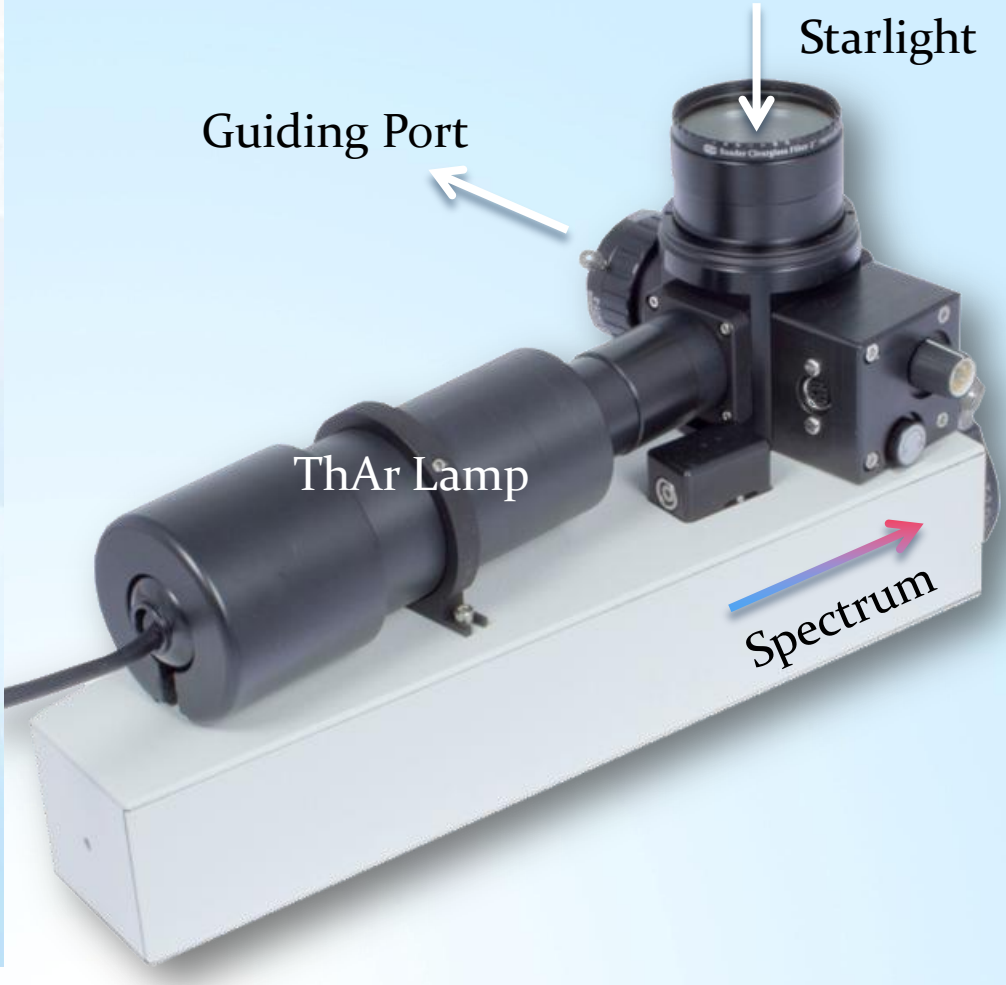
BAADER BACHES ECHELLE-SPECTROGRAPH

High Resolution Echelle Spectrograph with Autoguiding Port and Remote Calibration Port

- average spectral resolution **R = 18,000**
- optimized wavelength range **392-800nm***
- changeable **25 and 50µm** slits. Slit length 125µm
- light and compact, **only 1350g** (without CCD camera)
- high mechanical stability, FE designed, **torsion deformation below 9µm** at 180° rotation
- optimized for sensor sizes **ca. 15x10mm, 9µm Pixel** (i.e. KAF-1603), usable with 7x4mm sensor sizes (i.e. ST-402) and **DSLR's**
- collimator focal ratio **f/10**
- optimized for 8" to 24" **f/10 telescopes** (full resolution from f/8 to f/12)
- delivered in **calibrated condition**
- solenoid switches between the **light from the telescope** and the **ThAr calibration and flatfield lamp** of the RCU
- manual red LED for **Slit-Focusing**
- **two optional BACHES calibration versions available:** ***Standard*** with ThAr lamp mounted on BACHES body (with separate power supply). ***Professional*** with Remote Calibraion Unit (RCU) with built-in ThAr lamp and halogen flatfield lamp remotely controlled via web interface

* depending on the size of the sensor

BACHES Calibration Version *Standard*



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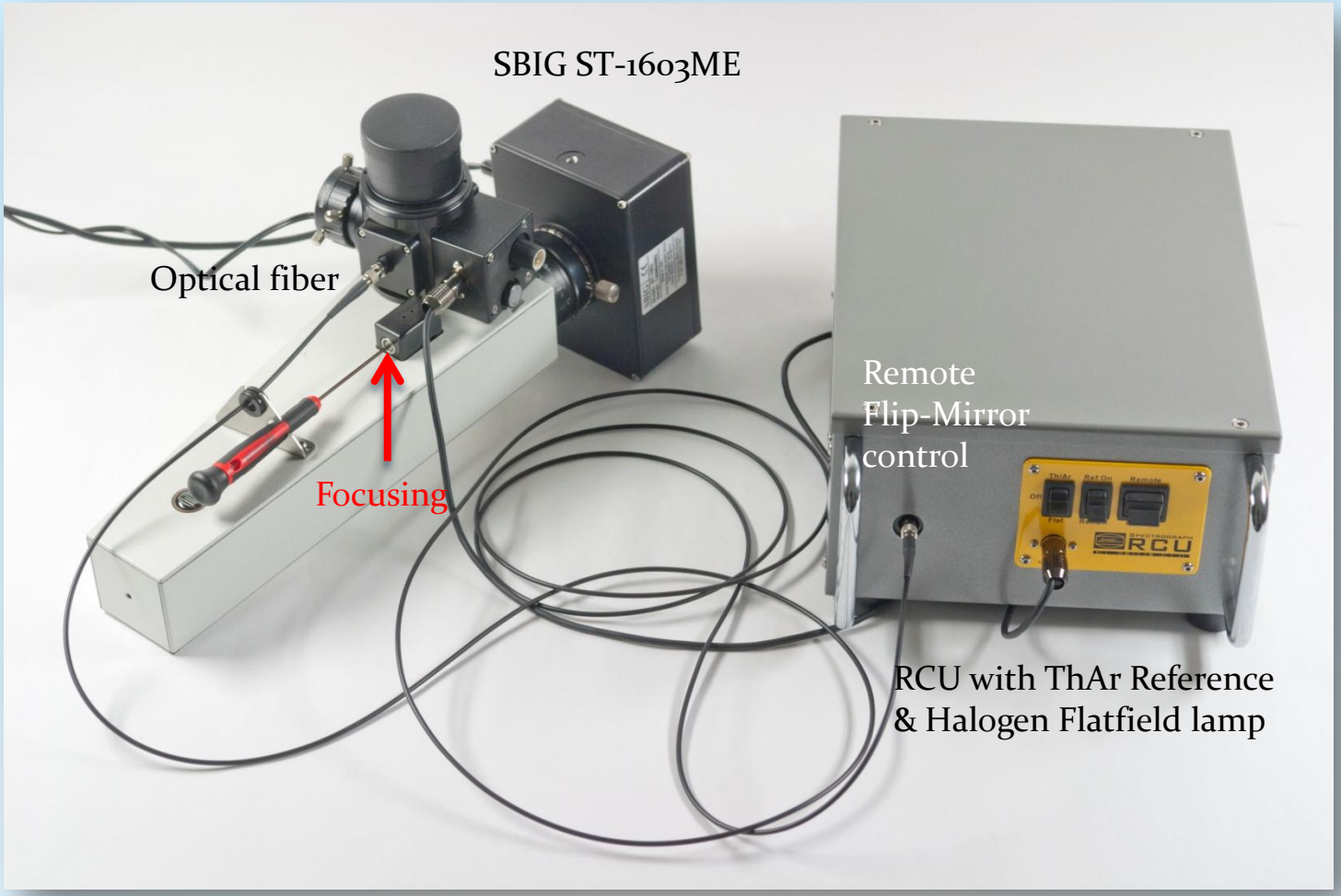
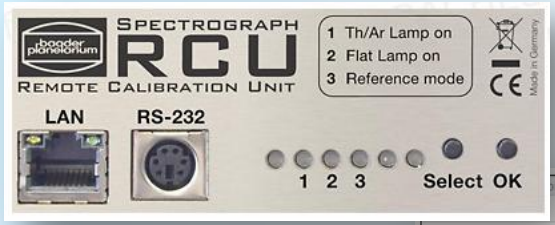
BACHES Calibration Version *Professional* with Remote Calibration Unit RCU



BACHES
Echelle Spektrograph
and Remote Calibration Unit

1. Glass fiber coupler
2. Power connector for motor
3. Three position switch for OFF, Th/Ar ON, or flat-field ON
4. Two position switch for coupling calibration mirror in BACHES
5. Two position switch to select remote and manual operation



Rear panel

Remote control by Internet Browser

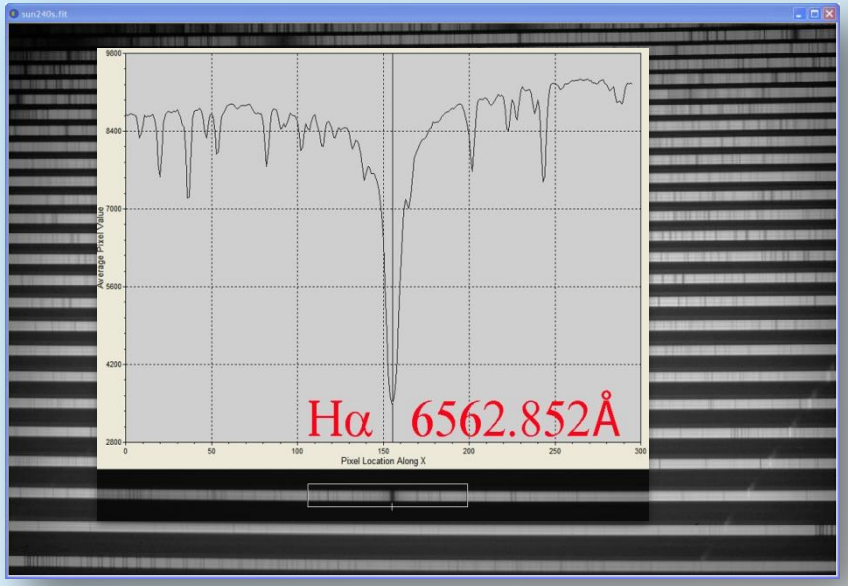
SPECTROGRAPH RCU
REMOTE CALIBRATION UNIT

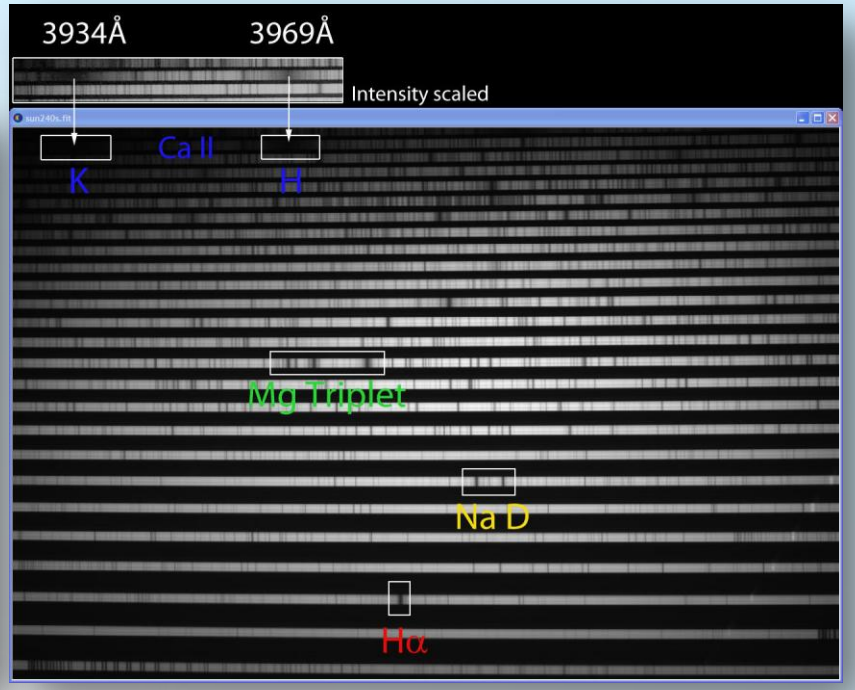
Accurate and Professional Calibration of BACHES Echelle-Spectra

- **switchable** between fully manually controlled and fully remote controlled
- integrated **ThAr lamp and white light lamp** for spectral calibration and flatfielding
- **integrated power supply** for all components
- **high voltage 15mA current control** for maximum ThAr lamp efficiency
- **pre-aligned fiber coupling** to BACHES for the ThAr lamp and flatfield lamps, with a removable 50µm fiber, 2.5m in length
- **6 pin, 2.5m power cable** for the BACHES solenoid to switch between the **telescope light** and **the flatfield lamp**
- Remote control via **10/100 Mbit/s 10base Ethernet** (RJ-45), TCP/IP protocol
- integrated web server **for fast and easy internet access** with any web browser
- additional local PC remote control via **RS232 serial line**
- size **320mm (L) x 215mm (W) x 125mm (H)**. L=345mm with handles
- weight net **5.6kg.** Power supply **230V AC, 25W**
- shielded case with four rubber pads for **vibration damping**
- **optional mounting accessories**, for either a 19“ rack or direct telescope attachment, respectively

Calibration of BACHES Echelle Spectra

1. Manual calibration by identification of spectral lines -> selected orders only

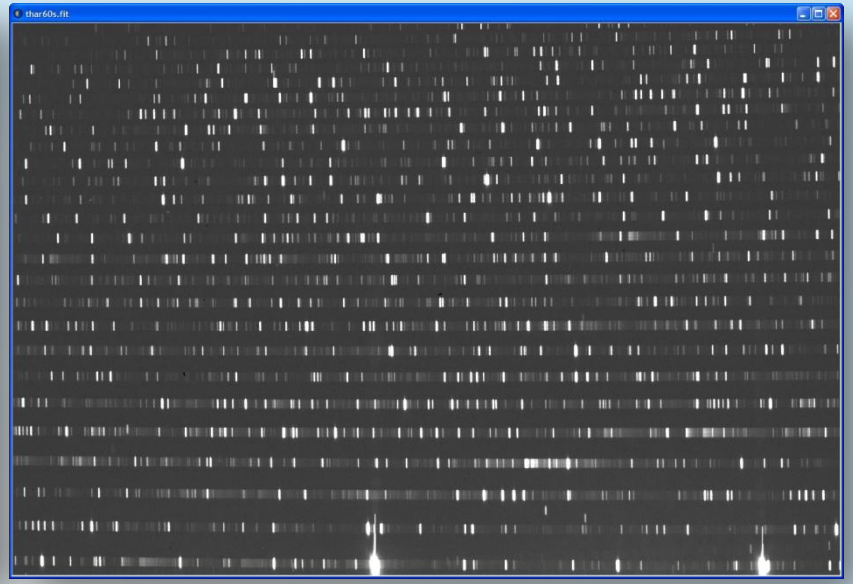




- Daylight spectrum -> Class G2 V
- Prominent spectral lines from Ca II (K) to Hα

Calibration of BACHES Echelle Spectra

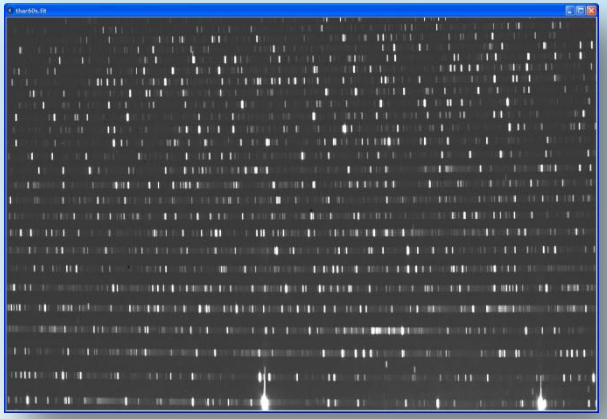
2. Manual wavelength calibration with the Thorium-Argon reference lamp



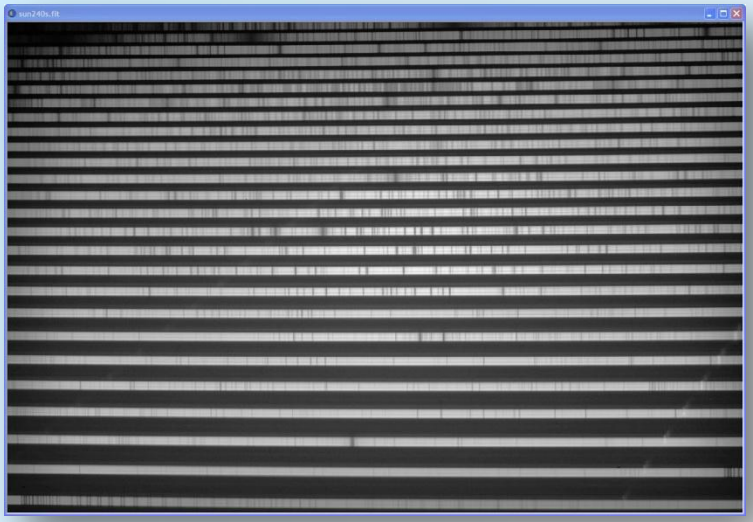
- Daylight spectrum -> Class G2 V
- The Thorium-Argon spectrum provides about 1,000 precisely known wavelengths for calibration

Calibration of BACHES Echelle Spectra

3. Semi-automatic calibration with the RCU's Thorium-Argon reference lamp and flatfield lamp with ESO-MIDAS



✓ ThAr reference spectrum



Daylight spectrum -> Class G2 V

✓ Halogen flatfield spectrum

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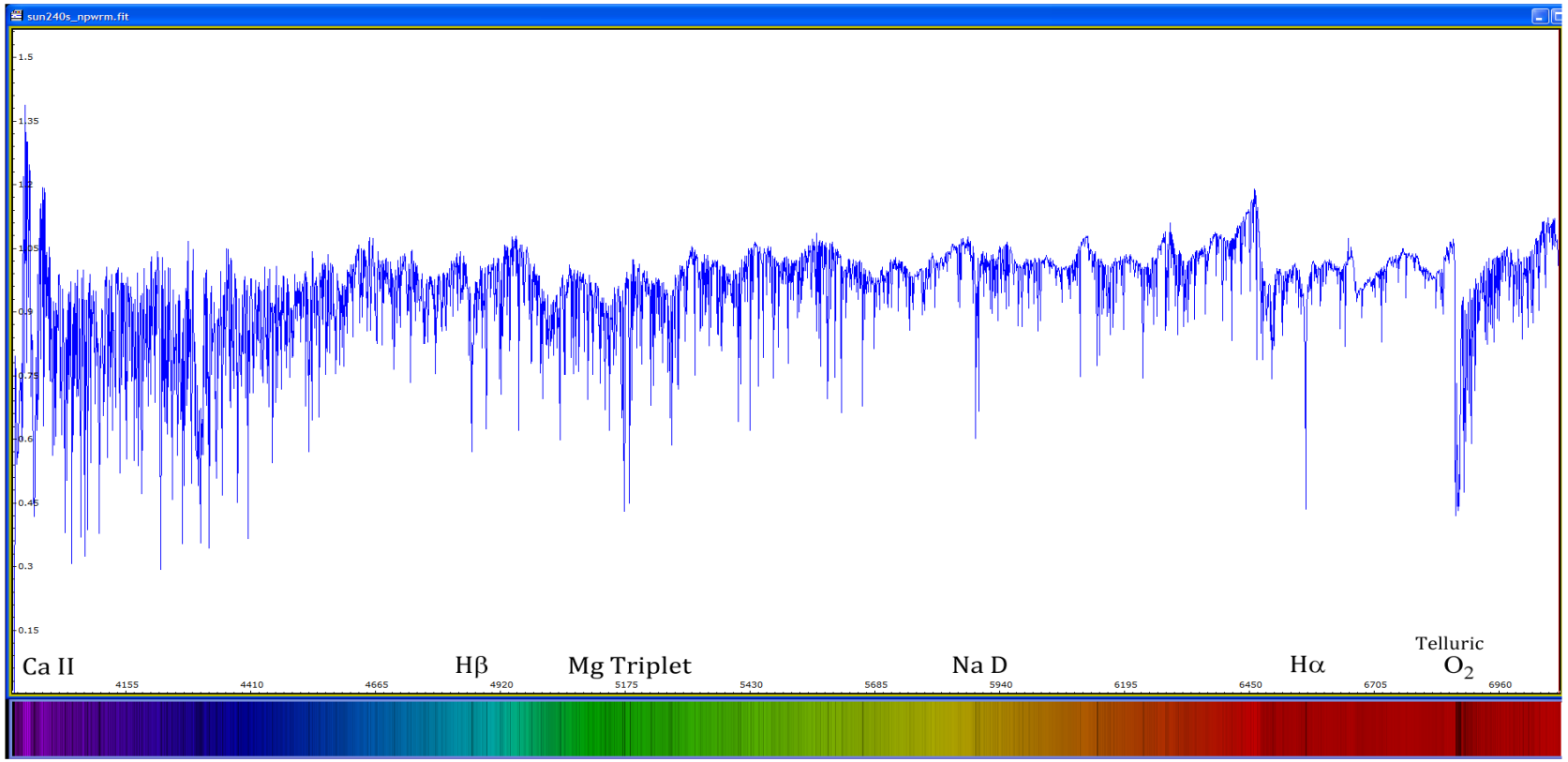
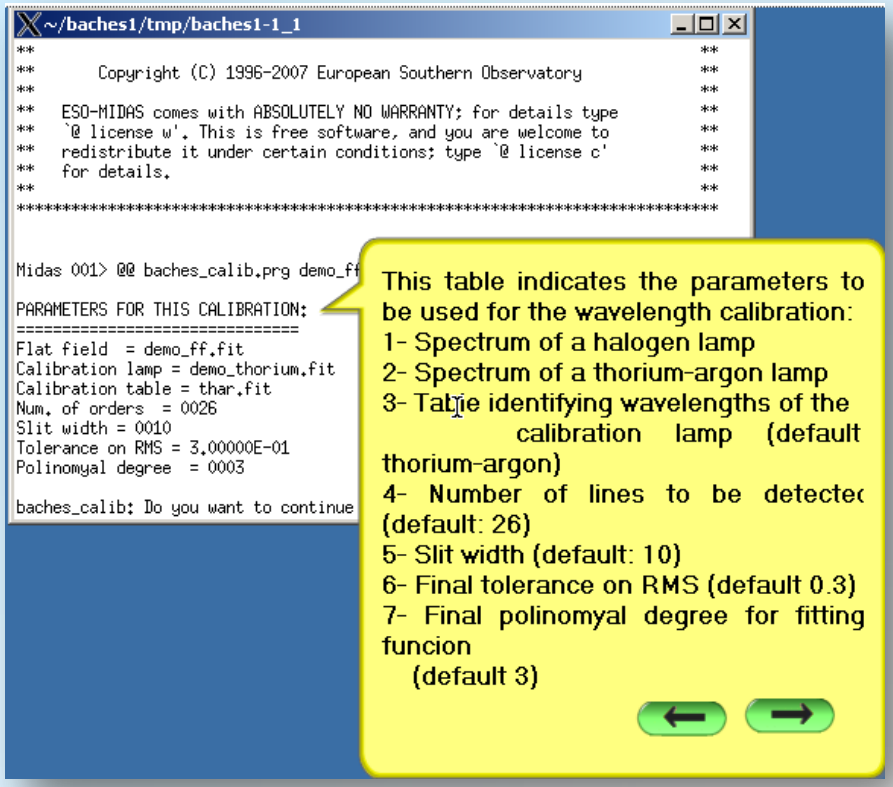
Solar spectrum 3923Å - 7084Å



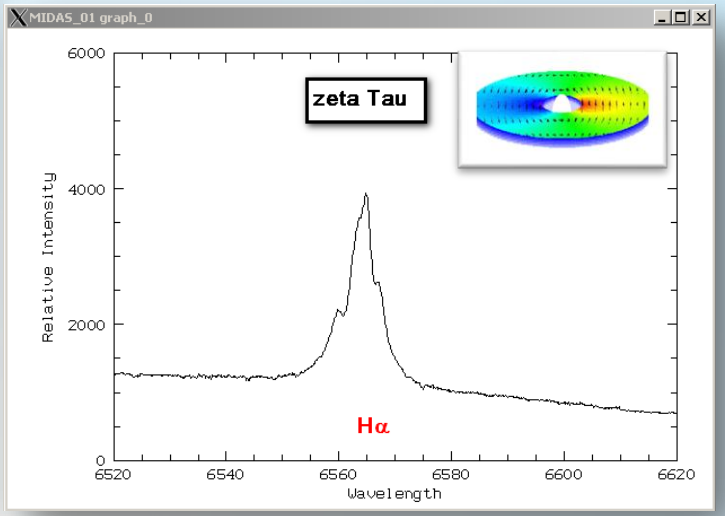
Daylight spectrum taken on December 21, 2014 with BACHES Echelle Spectrograph and SBIG ST-1603ME Camera. Calibration spectra obtained with Remote Calibration Unit (RCU). Spectrum calibrated with ThAr-Reference lamp and Halogen Flatfield lamp. Spectrum calibration with ESO MIDAS software. Wavelength calibration mean RMS=0.015Å.
Bernd Koch, Baader Planetarium GmbH, Mammendorf/Germany -- www.baader-planetarium.de

Calibration of BACHES Echelle Spectra

5. How to semi-automatically calibrate with ESO-MIDAS -> Video Tutorial



Wavelength calibration of
the emission line star zeta Tau:
www.baader-planetarium.de/baches/



Calibration of BACHES Echelle Spectra

6. How to semi-automatically calibrate with ESO-MIDAS -> manual & exercise files:

www.baader-planetarium.de/baches/download/midas_manual_e.pdf

Scientific Application of BACHES Echelle

- Emission line stars: Simultaneous monitoring of variations in stellar flux at different wavelengths

Example: Semi-detached binary star beta Lyrae.
Purpose: Tracking variations during a binary orbit **silmultaneously** at different wavelengths in the BACHES echelle spectrum

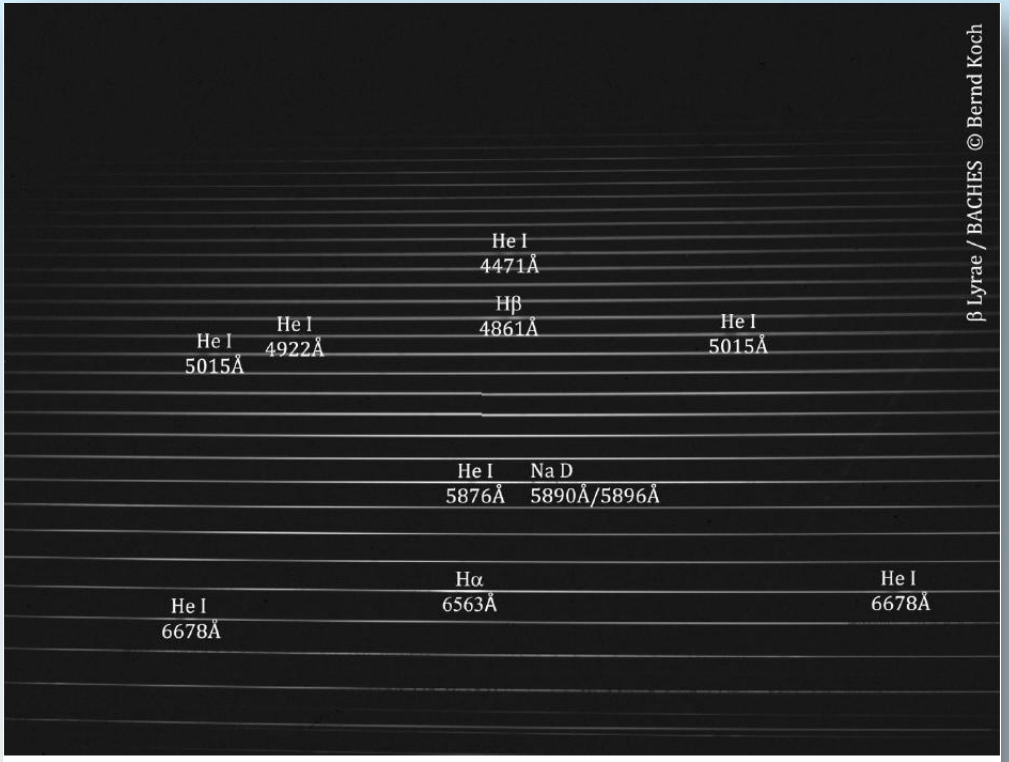
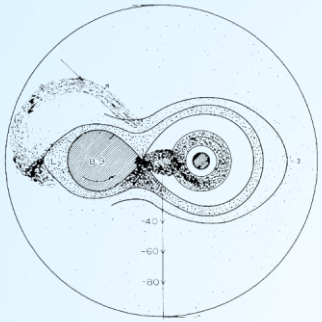
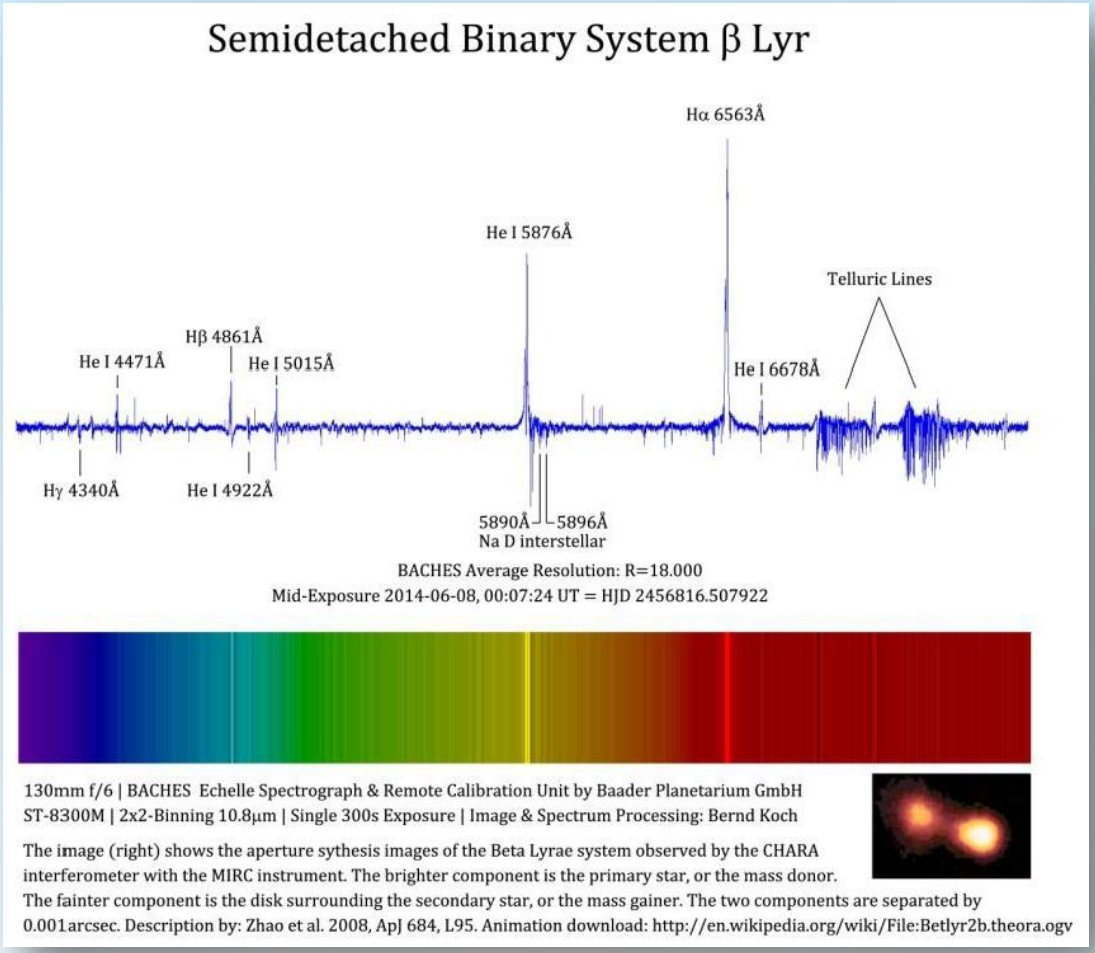


Fig. 2: Spectrum of semi-detached binary system β Lyrae, taken on June 8, 2014 at 00:07:24 UT. The spectrum was recorded with BACHES echelle spectrograph and a SBIG ST-8300M CCD camera, Pixel size 10.8 µm. This is a single 300s exposure from which a darkframe has been substracted.



Scientific Application of BACHES Echelle



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Scientific Application of BACHES Echelle

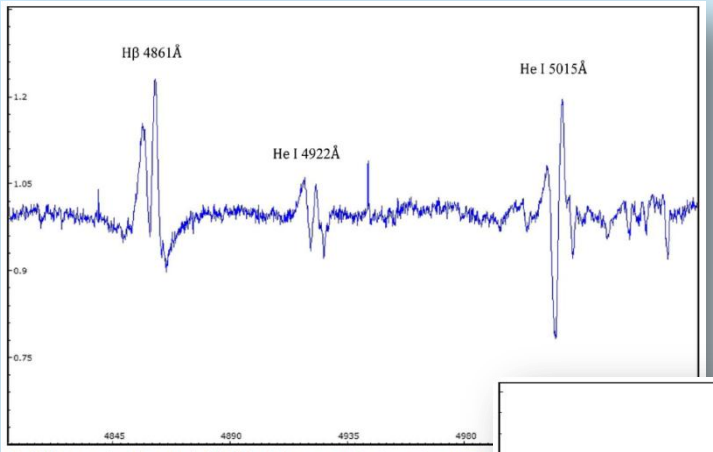


Fig. 7: This is a section of the recorded BACHES echelle spectrum showing varying strength o
P-Cygni-Profiles at Hβ 4861Å, He I 4922Å, and He I 5015Å with different flux.

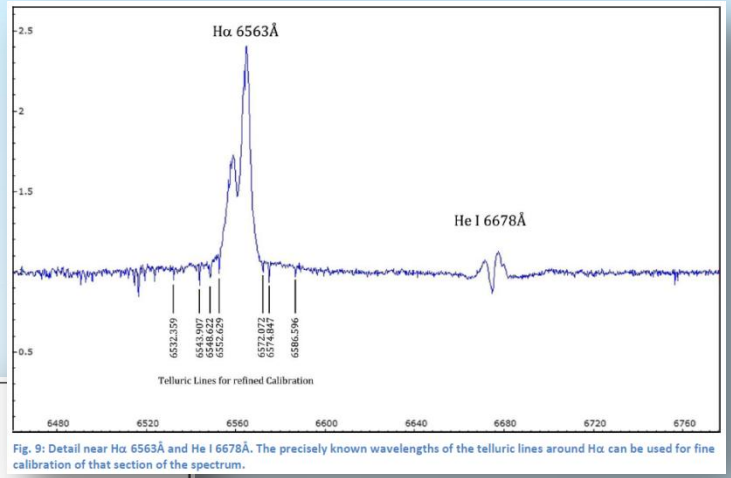


Fig. 9: Detail near Hα 6563Å and He I 6678Å. The precisely known wavelengths of the telluric lines around Hα can be used for fine calibration of that section of the spectrum.

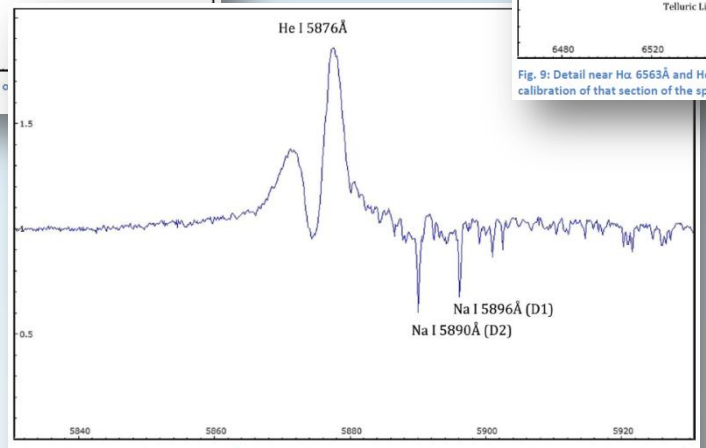


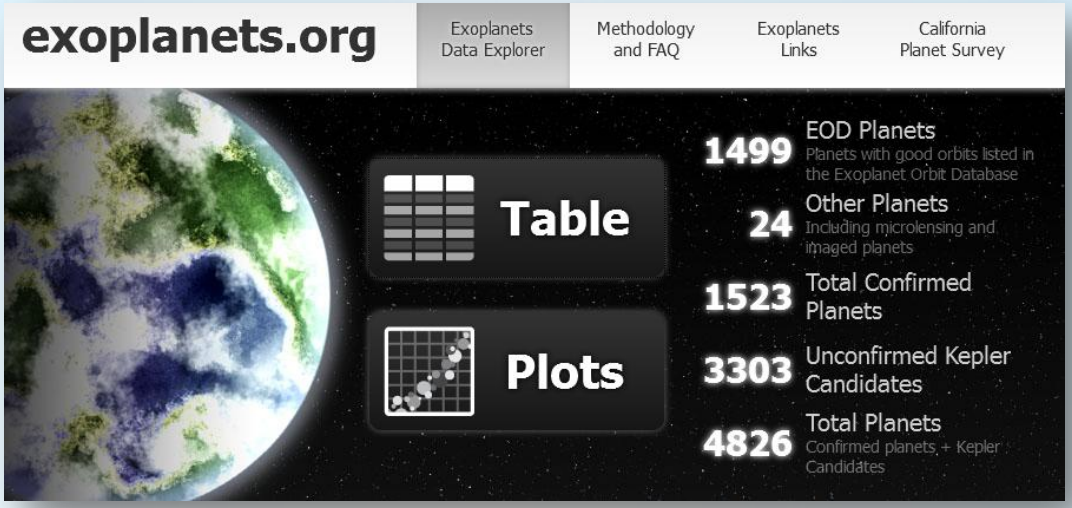
Fig. 8: P-Cygni-profile of β Lyr at He I 5876Å is close to the narrow interstellar Sodium lines (Na I Doublet D1, D2). "The He I 5876Å and the He I 6678 lines are well suited for the study of the stellar wind from the [B8...] B9 component of β Lyr" (Etzel, Meyer; 1983). The Na I Doublet may also be used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

http://www.baader-planetarium.de/baches/download/beta_lyr_baches_poster_e2_bernd_koch.pdf

Scientific Application of BACHES Echelle

The average spectral resolution of R=18,000 and precisely coverage of the full visible spectrum from 392nm to 760nm make BACHES scientifically useful for the

- Analysis of stars with orbiting Exoplanets. The planet influence on the radial velocity of the parent star by approximately Jupiter-sized exoplanets can be studied by means of spectroscopy (revealing a lower mass limit) and photometry (planet size and orbit)



Thank you very much for your attention

BACHES Website:
www.baader-planetarium.de/baches/

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