



BACHES

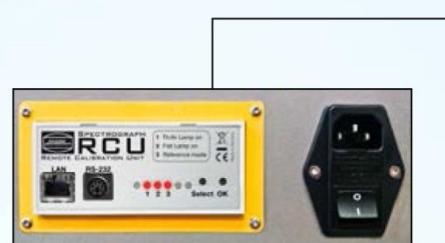
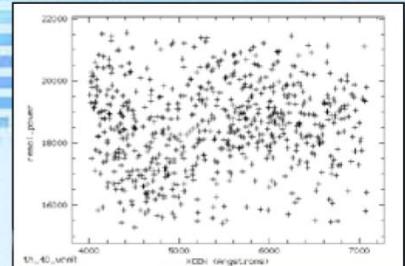
ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



A New Level of
SCIENTIFIC SPECTROSCOPY
with small Telescopes

www.baader-planetarium.de/baches



CEDIC March 6-8, 2015

Baader Planetarium GmbH

Bernd Koch



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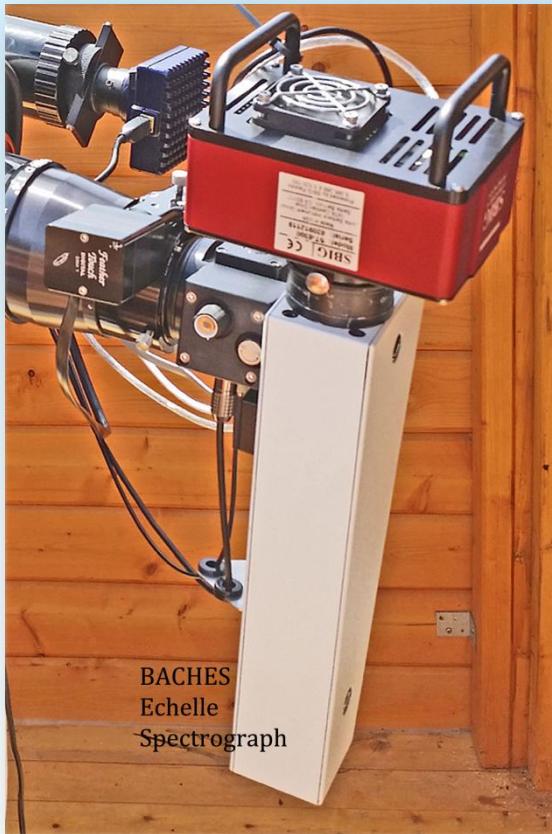
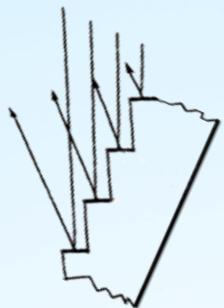
ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



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





BACHES ECHELLE SPEKTROGRAPH

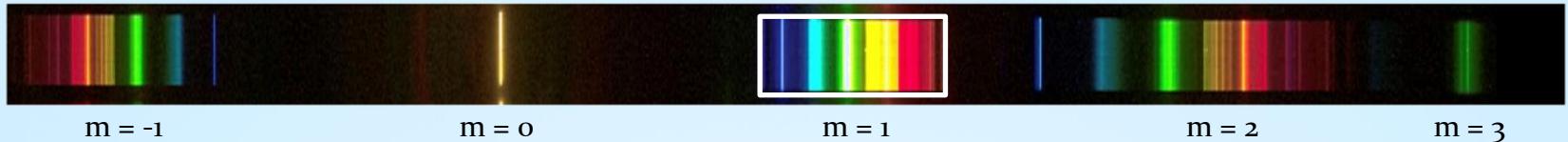
and Remote Calibration Unit



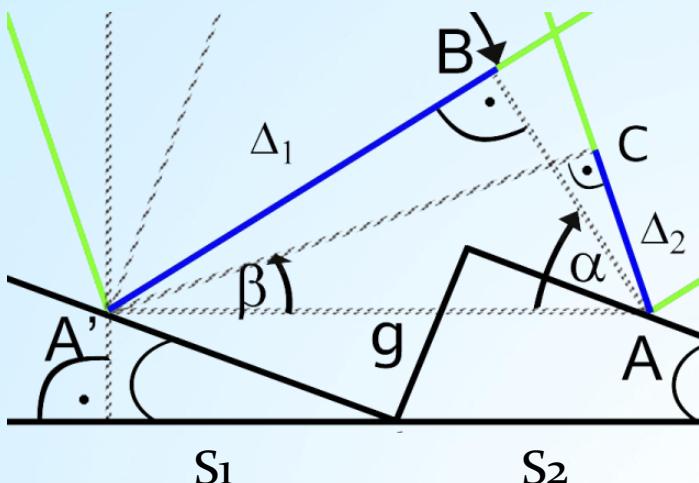
A conventional Blazed Grating Spectrograph

Designed for maximum efficiency in the first order

Higher orders order not useable due to overlap



Fluorescent lamp



Additive interference occurs when the total path difference Δ of light from adjacent slits (S_1) and (S_2) is an integer multiple of the wavelength λ :
The phase is then the same, so the beams' intensity add.

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

g: Groove spacing, m: Order number



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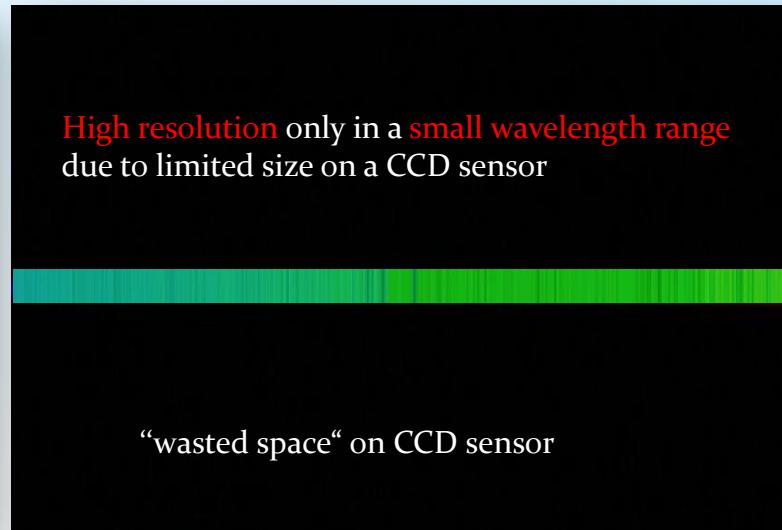
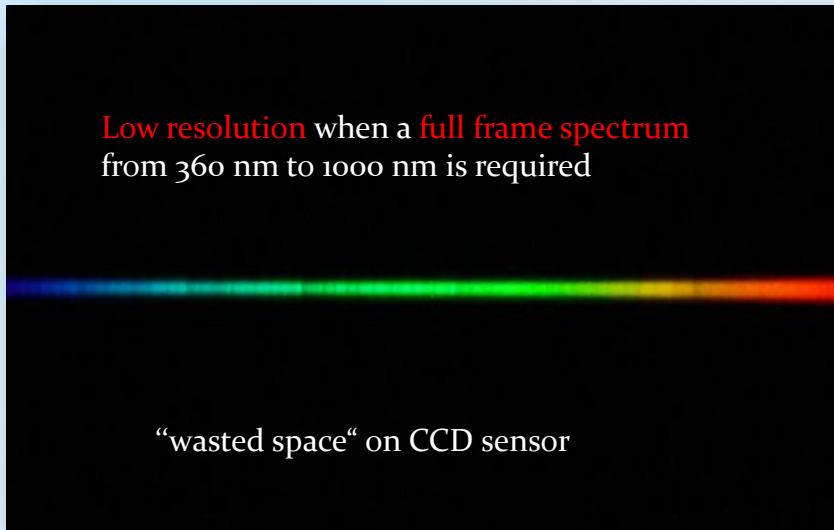
A conventional Blazed Grating Spectrograph

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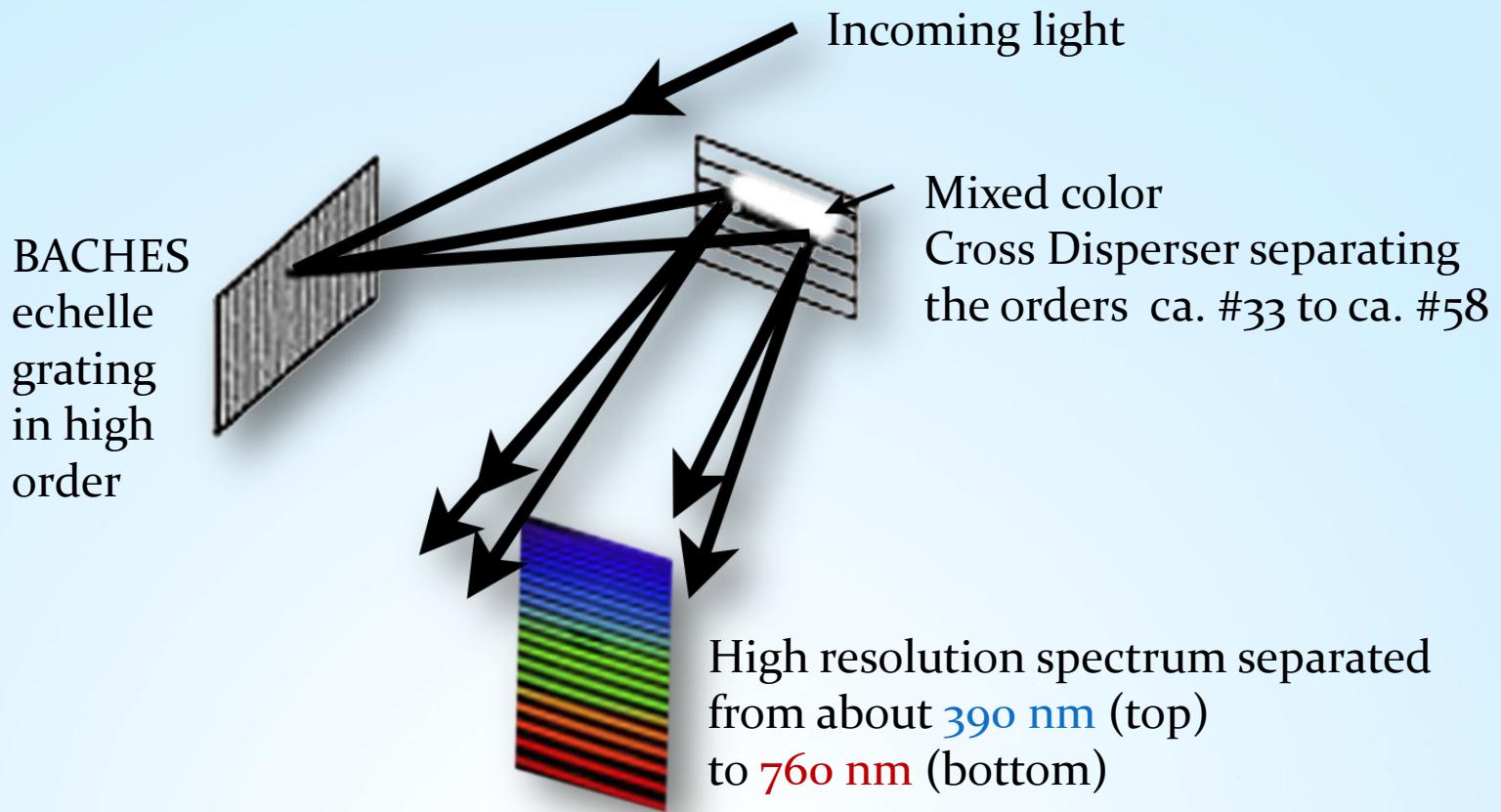
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The Echelle Optical Path



Adopted from C. R. Kitchin, Optical Astronomical Spectroscopy

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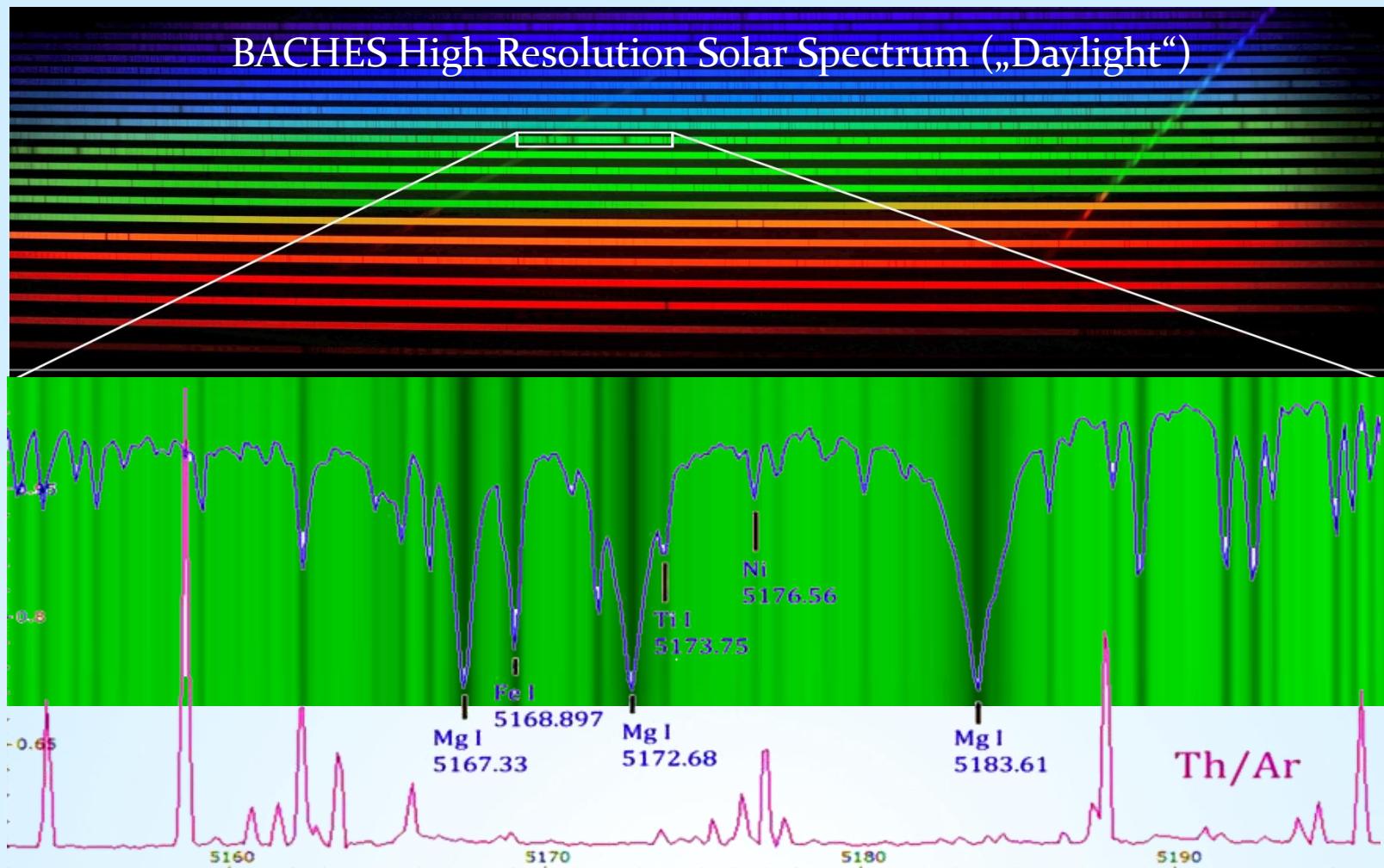
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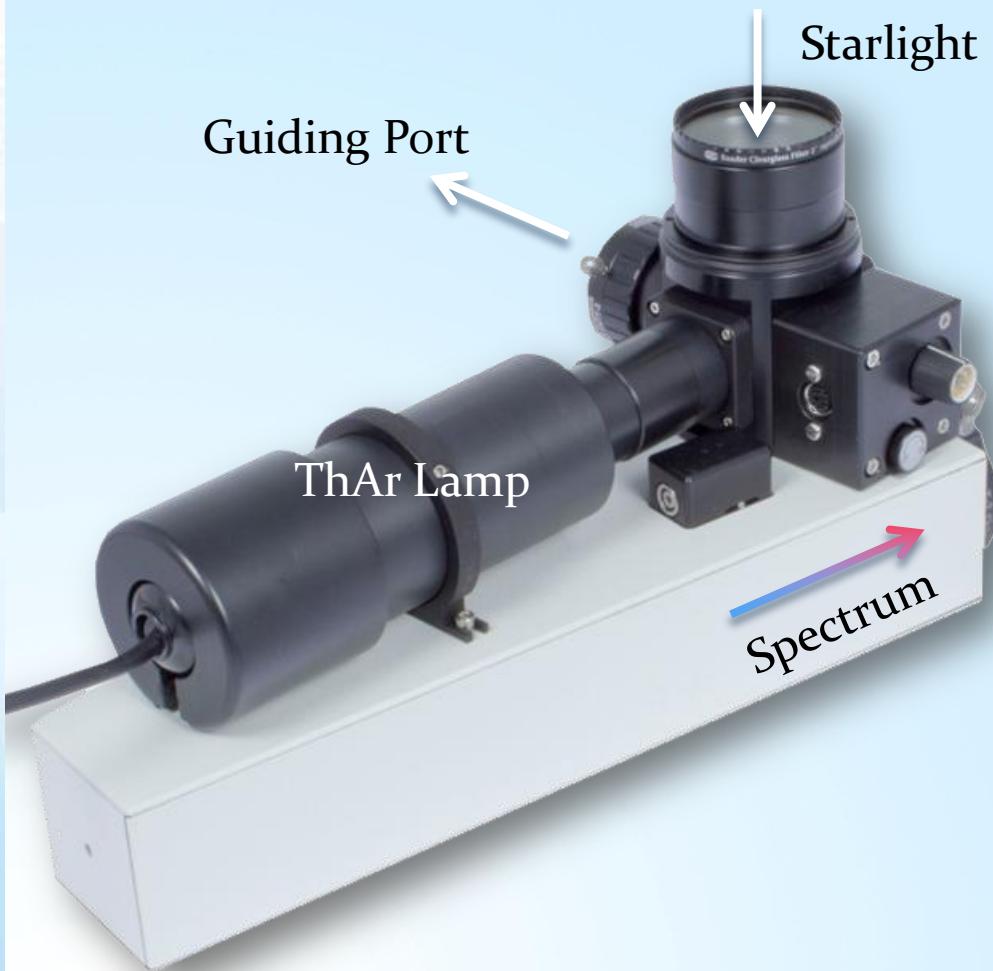
ECHELLE-SPECTROGRAPH

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 50 μm slits. Slit length 125 μm
- light and compact, only 1350g (without CCD camera)
- high mechanical stability, FE designed, torsion deformation below 9 μm at 180° rotation
- optimized for sensor sizes ca. 15x10mm, 9 μm 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 Calibration 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*





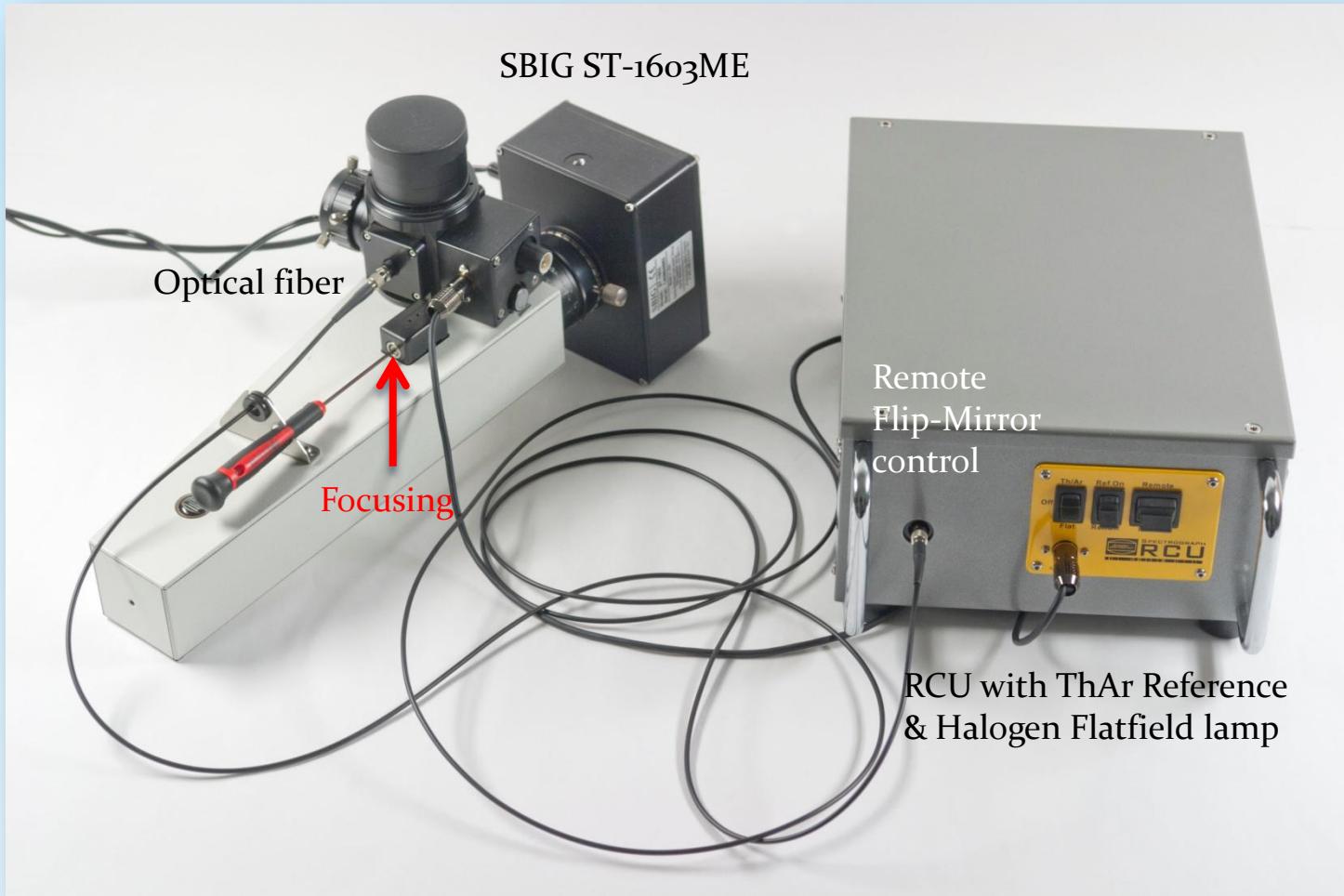
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and Remote Calibration Unit



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



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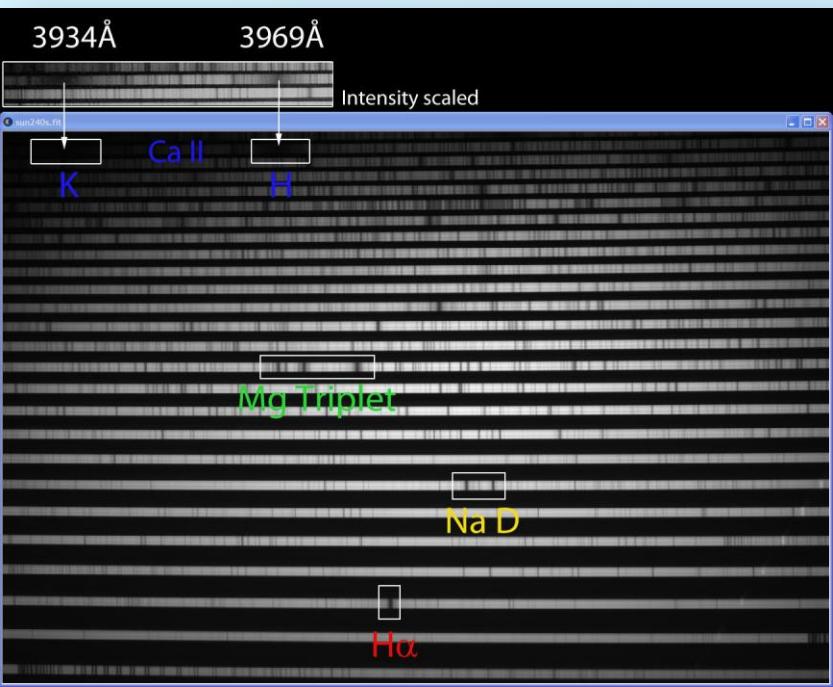
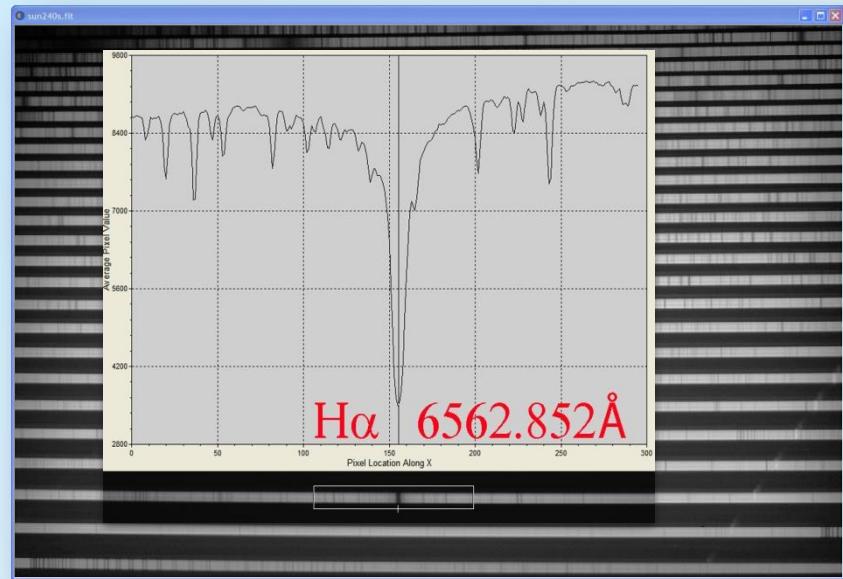
ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



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 H α



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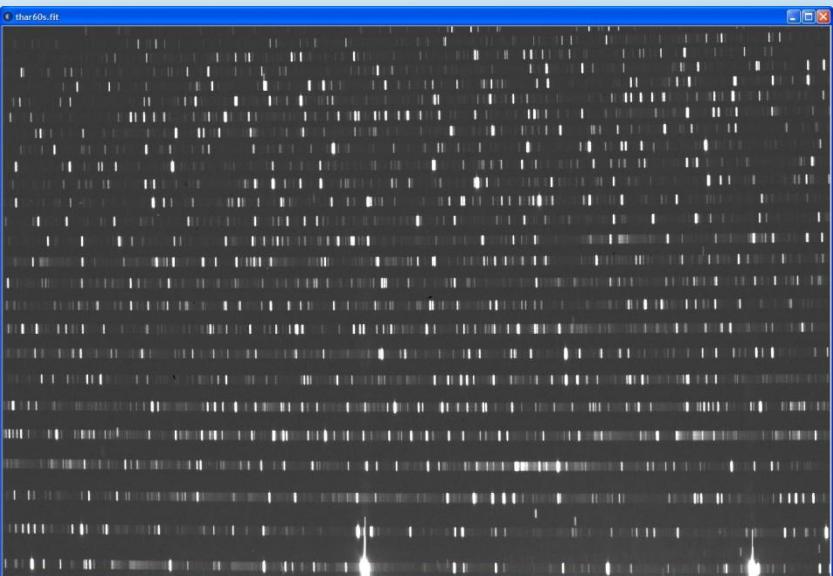
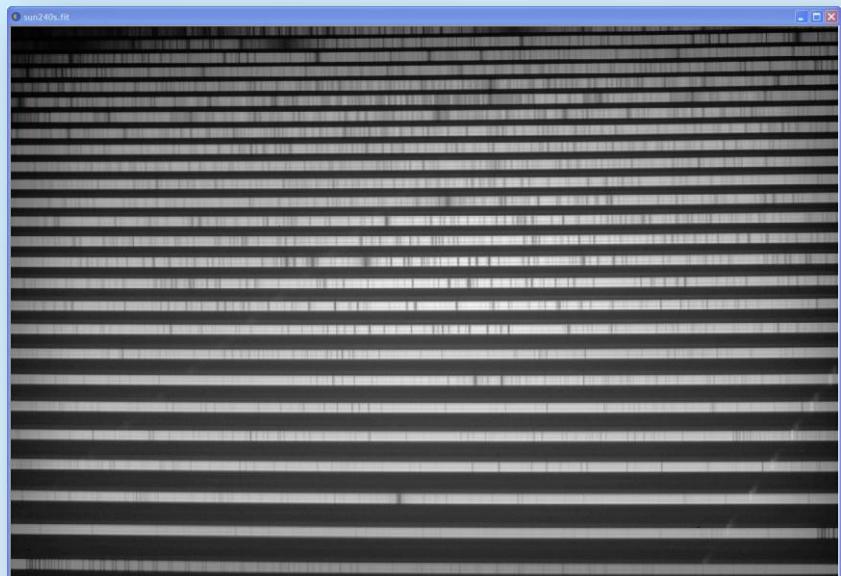
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Calibration of BACHES Echelle Spectra

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



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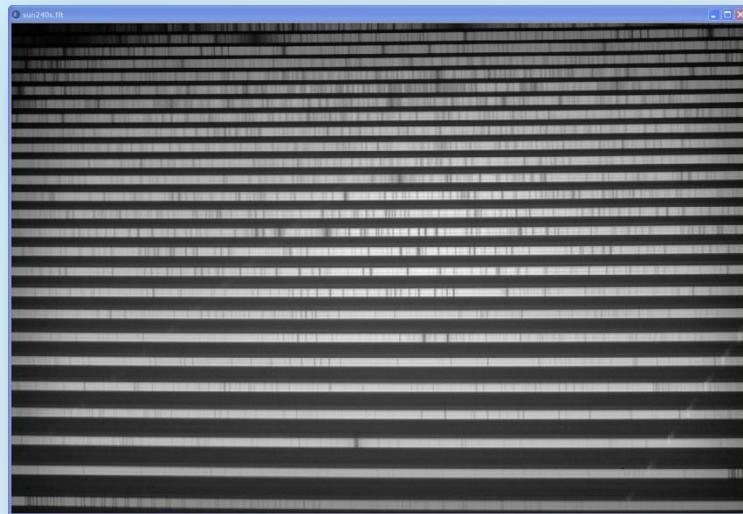
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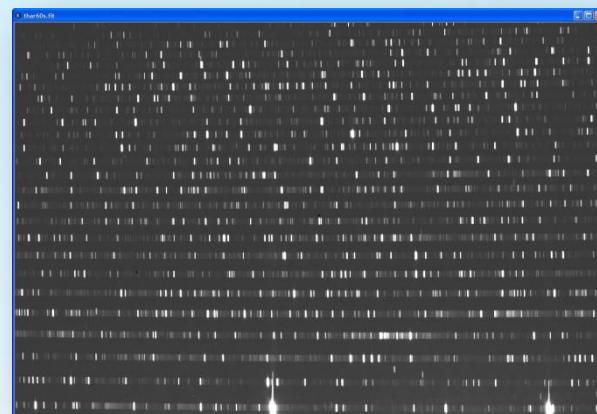


Calibration of BACHES Echelle Spectra

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



Daylight spectrum -> Class G2 V



✓ ThAr
reference
spectrum



✓ Halogen
flatfield
spectrum





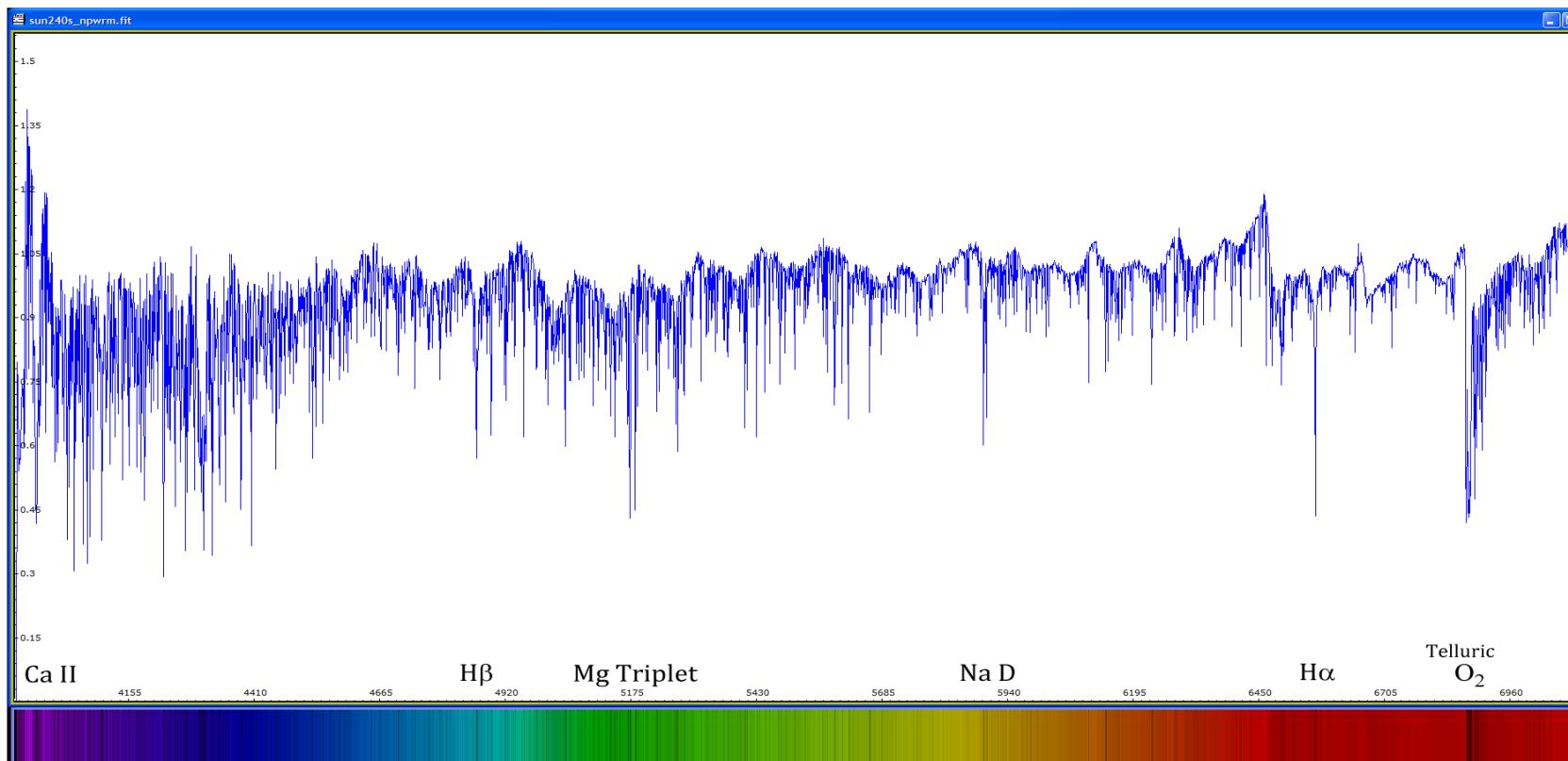
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Solar spectrum 3923Å - 7084Å



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



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Calibration of BACHES Echelle Spectra

5. How to semi-automatically calibrate with ESO-MIDAS -> [Video Tutorial](#)

```
X ~/baches1/tmp/baches1-1_1
**
** Copyright (C) 1996-2007 European Southern Observatory
**
** ESO-MIDAS comes with ABSOLUTELY NO WARRANTY; for details type
** '@ license w'. This is free software, and you are welcome to
** redistribute it under certain conditions; type '@ license c'
** for details.
**
*****
```

Midas 001> @@ baches_calib.prg demo_ff

PARAMETERS FOR THIS CALIBRATION:

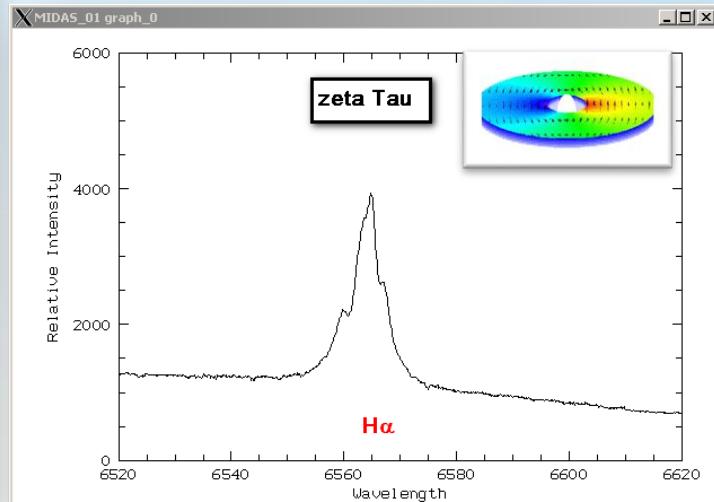
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Flat field = demo_ff.fit
Calibration lamp = demo_thorium.fit
Calibration table = thar.fit
Num. of orders = 0026
Slit width = 0010
Tolerance on RMS = 3.00000E-01
Polinomyal degree = 0003
```

baches_calib: Do you want to continue

This table indicates the parameters to be used for the wavelength calibration:
1- Spectrum of a halogen lamp
2- Spectrum of a thorium-argon lamp
3- Table identifying wavelengths of the calibration lamp (default thorium-argon)
4- Number of lines to be detected (default: 26)
5- Slit width (default: 10)
6- Final tolerance on RMS (default 0.3)
7- Final polinomyal degree for fitting function (default 3)

← →

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





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and Remote Calibration Unit



Calibration of BACHES Echelle Spectra

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

**Calibration of
BACHES Echelle Spectra
with ESO-MIDAS**

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The diagram illustrates the BACHES Echelle Spectrograph system. It shows the main spectrograph unit with its various ports and accessories, connected to a computer via Ethernet and RS-232. A separate Remote Calibration Unit (RCU) is shown as an optional accessory. The system is designed for semi-automatic calibration using ESO-MIDAS.

BAADER BACHES ECHELLE-SPECTROGRAPH
High Resolution Echelle Spectrograph with Autoguiding Port and Remote Calibration Port

BAADER PLANETARIUM
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Baader-Planetarium.de • kontakt@baader-planetarium.de • Celestron-Deutschland.de

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



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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

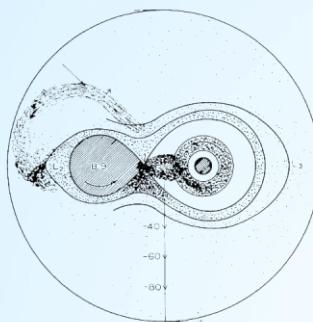


Fig. 2: Spectrum of semi-detached binary system β Lyrae, taken on June 8, 2014 at 00:07:24 UT. The spectrum was recorded with BACHES echelle spectrograph and a SBIG ST-8300M CCD camera, Pixel size 10.8 μm . This is a single 300s exposure from which a darkframe has been subtracted.



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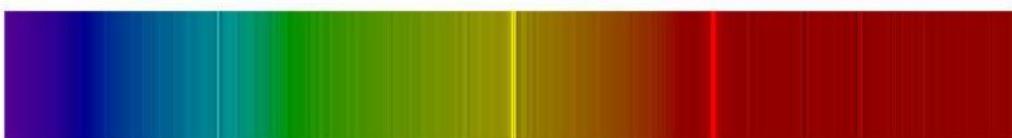
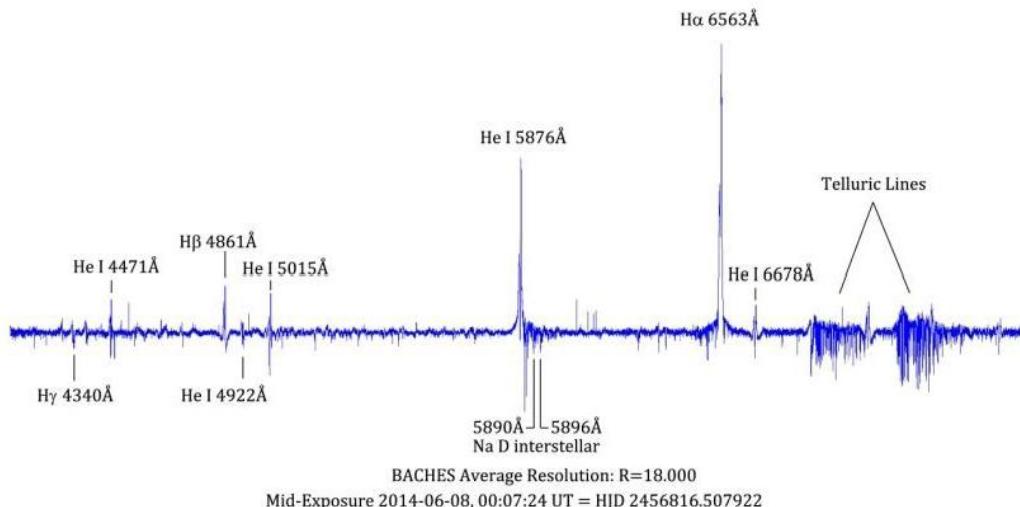
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Scientific Application of BACHES Echelle

Semidetached Binary System β Lyr



130mm f/6 | BACHES Echelle Spectrograph & Remote Calibration Unit by Baader Planetarium GmbH
ST-8300M | 2x2-Binning 10.8 μ m | Single 300s Exposure | Image & Spectrum Processing: Bernd Koch



The image (right) shows the aperture synthesis images of the Beta Lyrae system observed by the CHARA interferometer with the MIRC instrument. The brighter component is the primary star, or the mass donor.

The fainter component is the disk surrounding the secondary star, or the mass gainer. The two components are separated by 0.001arcsec. Description by: Zhao et al. 2008, ApJ 684, L95. Animation download: <http://en.wikipedia.org/wiki/File:Betlyr2b.theora.ogg>

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Scientific Application of BACHES Echelle

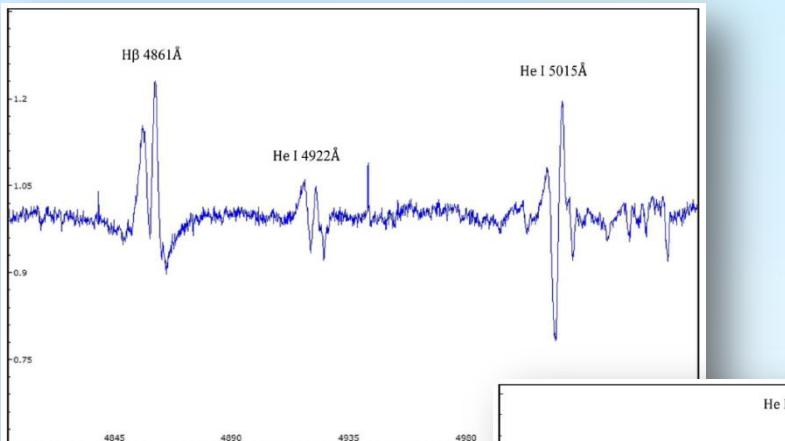


Fig. 7: This is a section of the recorded BACHES echelle spectrum showing varying strength of P-Cygni-Profiles at H β 4861Å, He I 4922Å, and He I 5015Å with different flux.

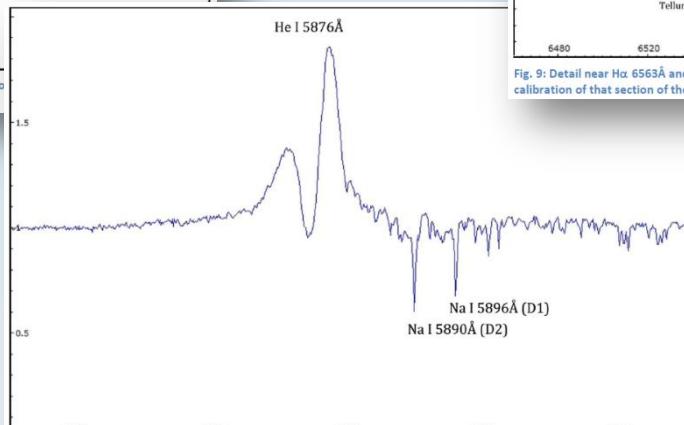


Fig. 8: P-Cygni-profile of β Lyr at He I 5876Å is close to the narrow interstellar Sodium lines (Na I Doublet D1, D2). "The He I 5876Å and the He I 6678 lines are well suited for the study of the stellar wind from the [B8...] B9 component of β Lyr" (Etzel, Meyer; 1983). The Na I Doublet may also be used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

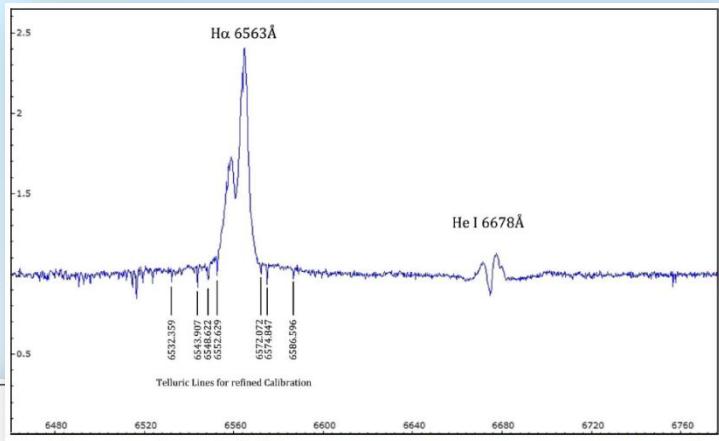


Fig. 9: Detail near H α 6563Å and He I 6678Å. The precisely known wavelengths of the telluric lines around H α can be used for fine calibration of that section of the spectrum.

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

CEDIC March 6-8, 2015

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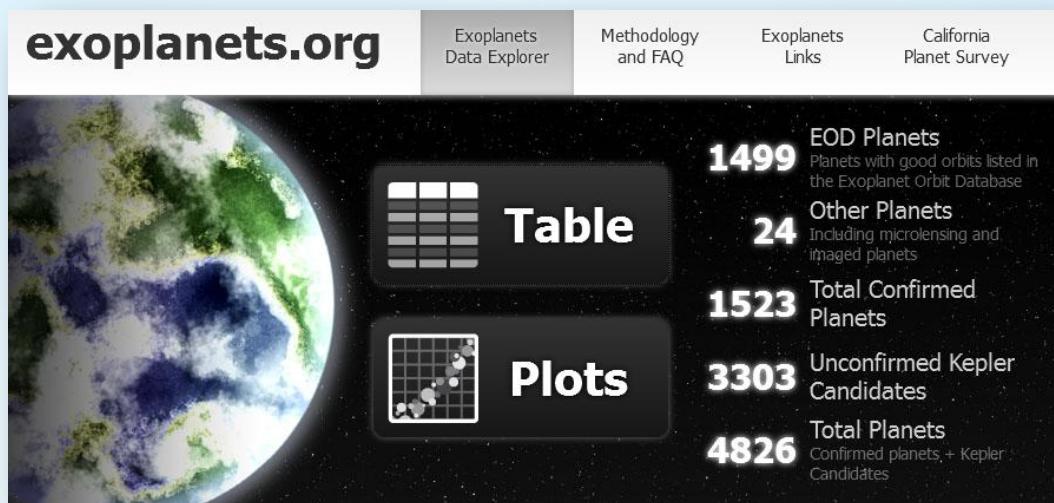
and Remote Calibration Unit



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)





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Thank you very much for your attention



BACHES Website:

www.baader-planetarium.de/baches/

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