



# BACHES

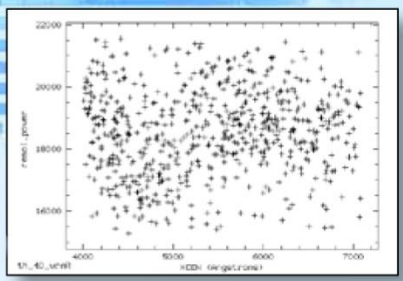
## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



A New Level of  
**SCIENTIFIC SPECTROSCOPY**  
with small Telescopes

[www.baader-planetarium.de/baches](http://www.baader-planetarium.de/baches)





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and Remote Calibration Unit



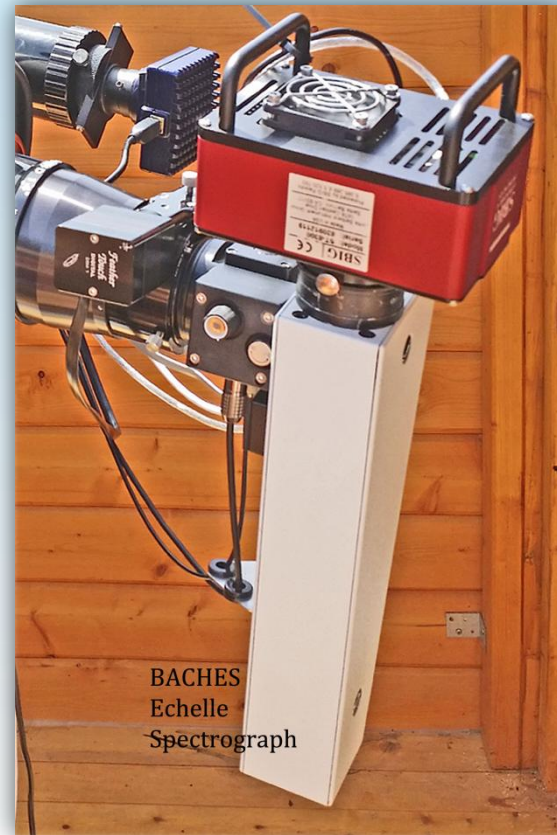
## The BACHES Echelle Spectrograph

✓ BACHES is the acronym for **B**asic **E**chelle **S**pectrograph

✓ „Echelle“ is a french word, which means „ladder“



✓ Developed by ESO Scientists and Baader Planetarium GmbH





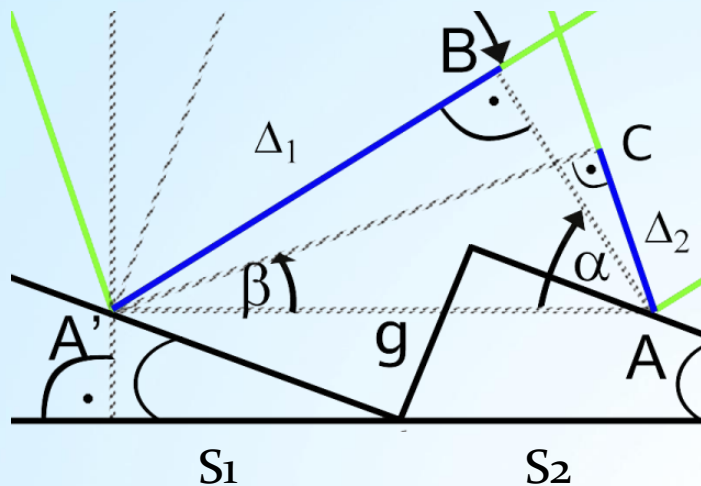
## A conventional Blazed Grating Spectrograph

Designed for maximum efficiency in the first order

Higher orders order not useable due to overlap



Fluorescent lamp



Additive interference occurs when the total path difference  $\Delta$  of light from adjacent slits ( $S_1$ ) and ( $S_2$ ) is an integer multiple of the wavelength  $\lambda$ :  
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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## ECHELLE SPEKTROGRAPH

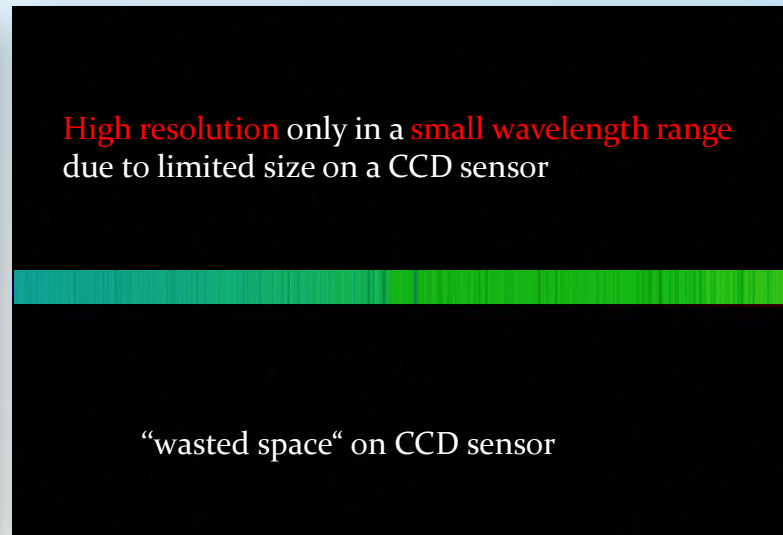
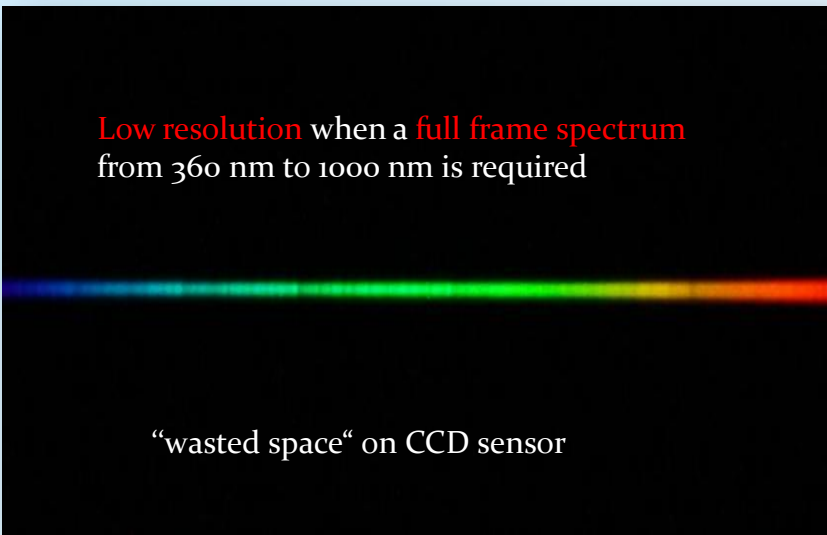
and Remote Calibration Unit



## A conventional Blazed Grating Spectrograph

Designed for maximum efficiency in the first order

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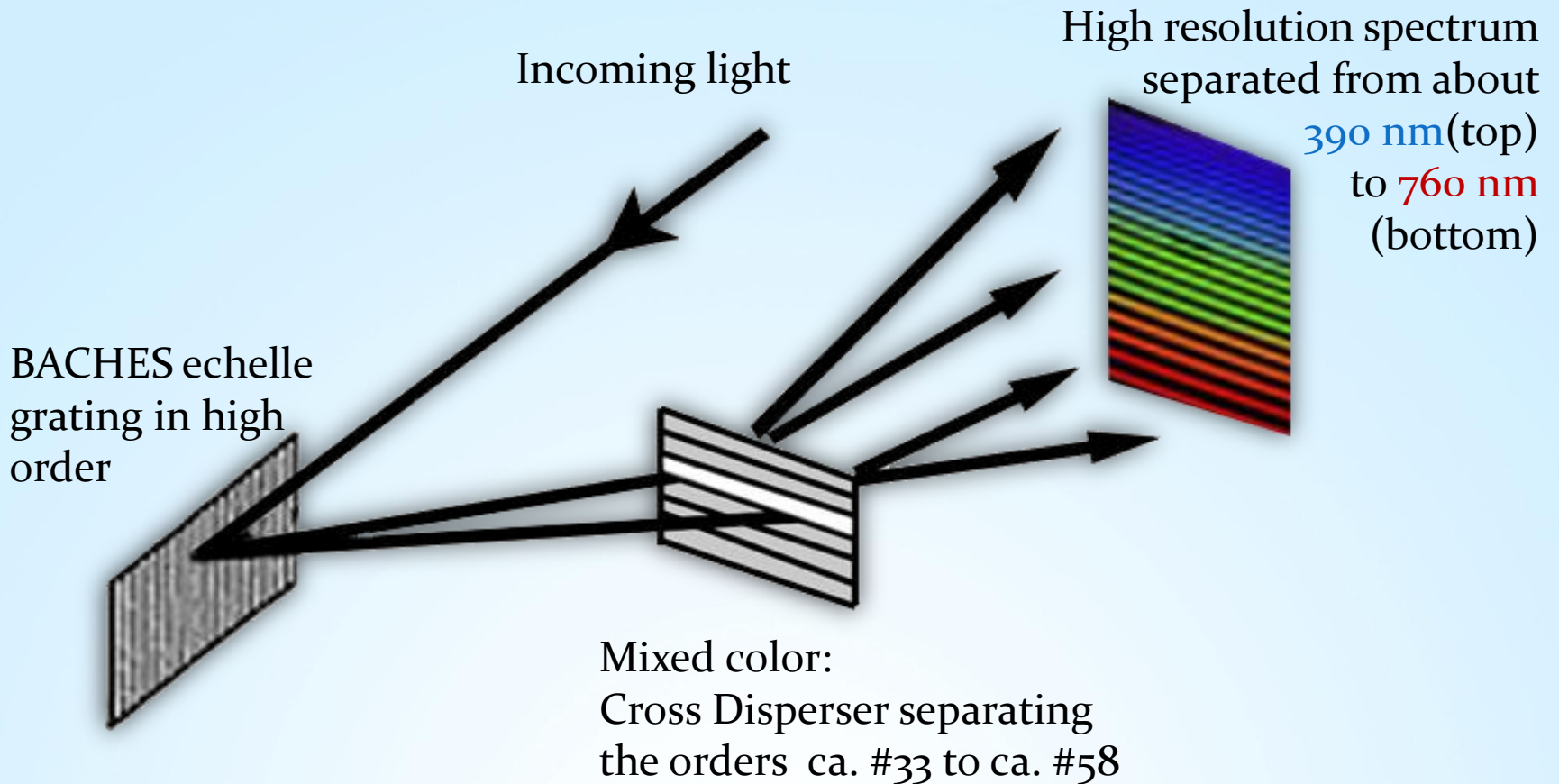


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## The Echelle Optical Path



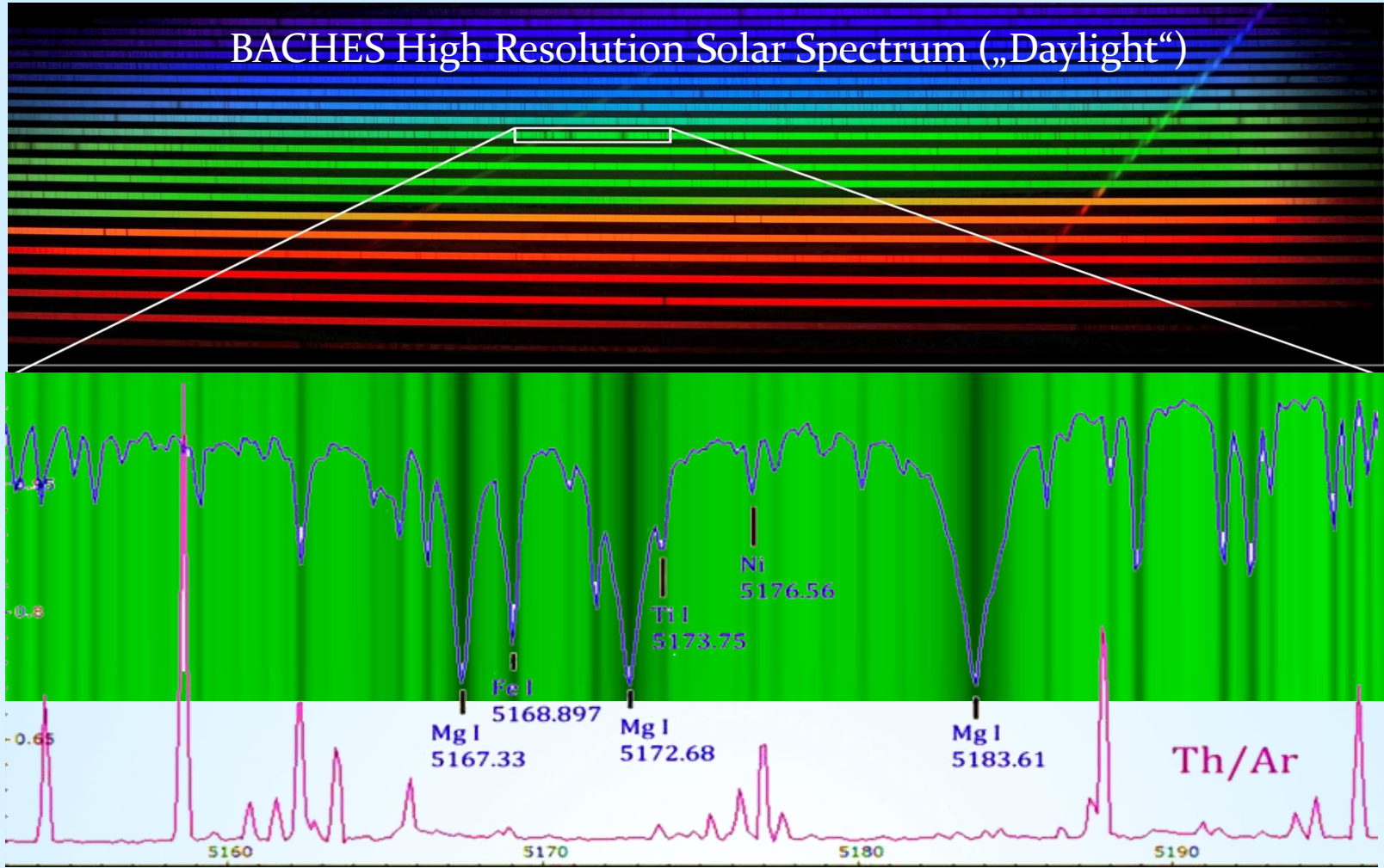


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BACHES High Resolution Solar Spectrum („Daylight“)





# BACHES

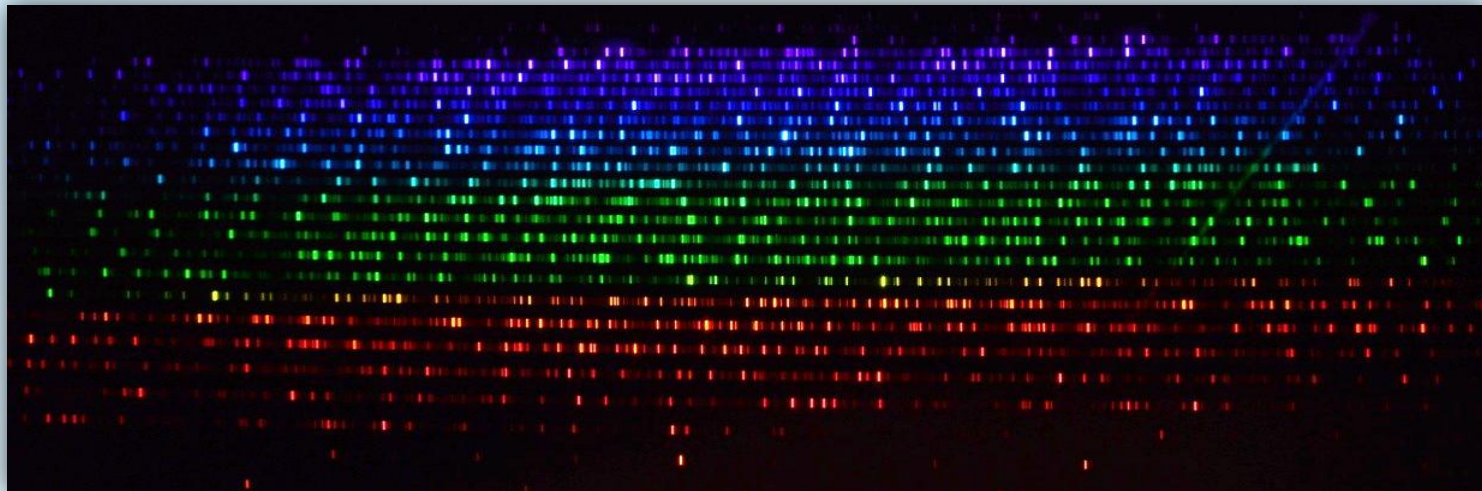
## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



## BACHES Considerable Advantages

- High average spectral resolution  $R = 18\ 000$
- Complete spectrum from about 392nm to 800nm can be captured with a **single** exposure (depends on size of the sensor)
- Constant focus over a wide temperature range
- Spectra lines perpendicular to spectral orders. No slanted lines
- Spectral orders almost parallel to each other





# BACHES

## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



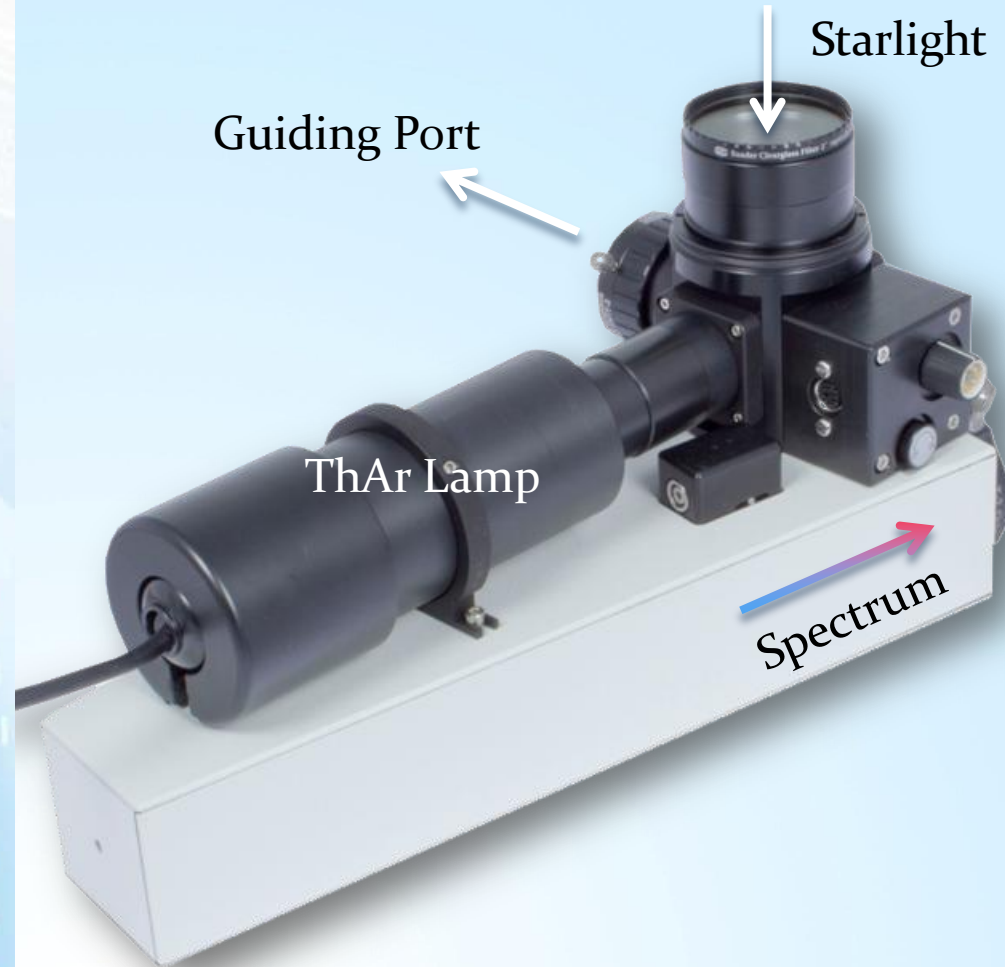
## BAADER BACHES ECHELLE-SPEKTROGRAPH

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 $\mu\text{m}$**  slits. Slit length 125 $\mu\text{m}$
- light and compact, **only 1350g** (without CCD camera)
- high mechanical stability, FE designed, **torsion deformation below 9 $\mu\text{m}$**  at 180° rotation
- optimized for sensor sizes **ca. 15x10mm, 9 $\mu\text{m}$  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*





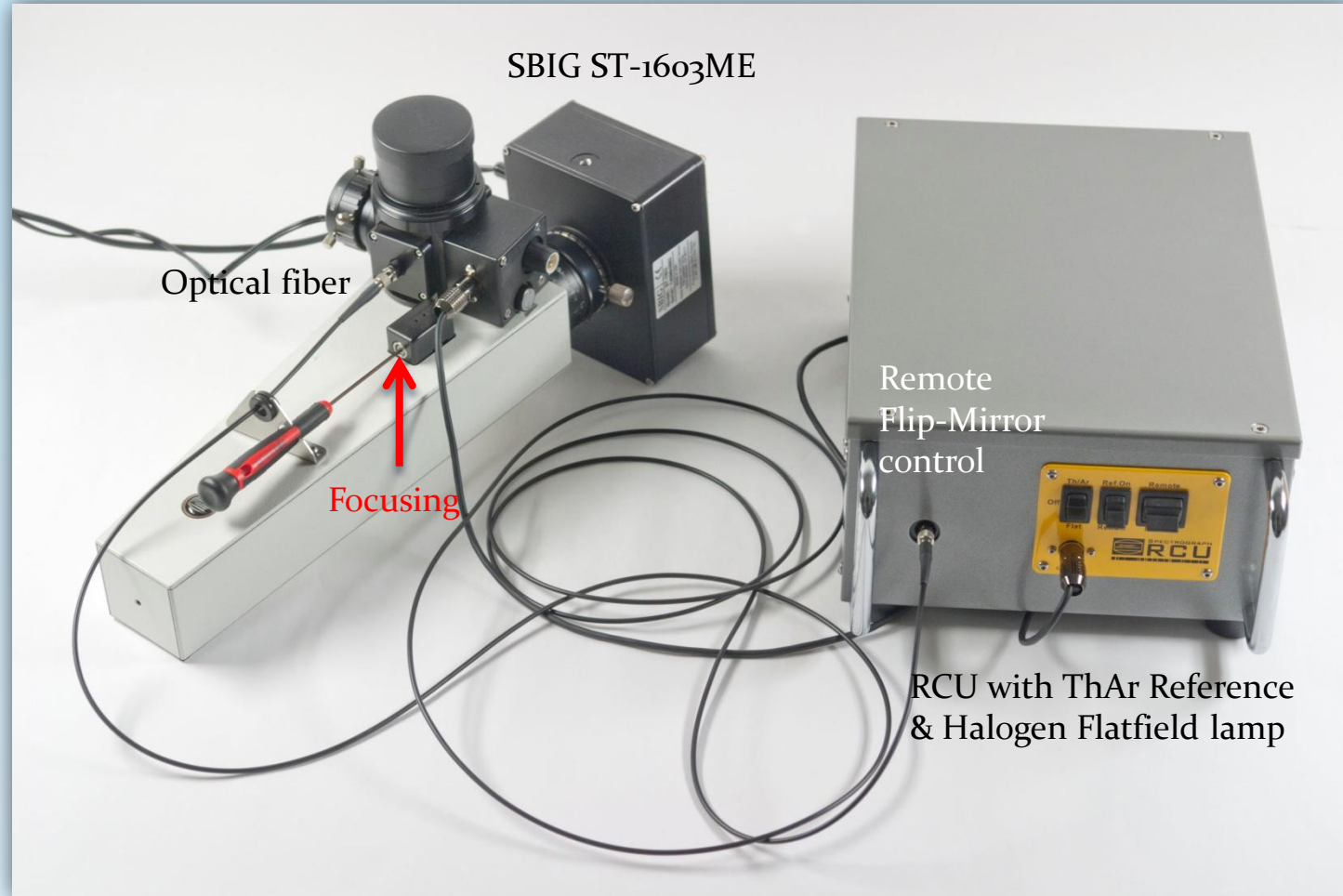


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## BACHES Calibration Version *Professional* with Remote Calibration Unit RCU





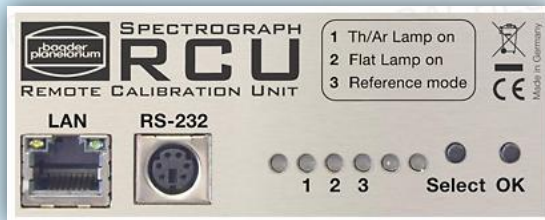
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## ECHELLE SPEKTROGRAPH

### 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

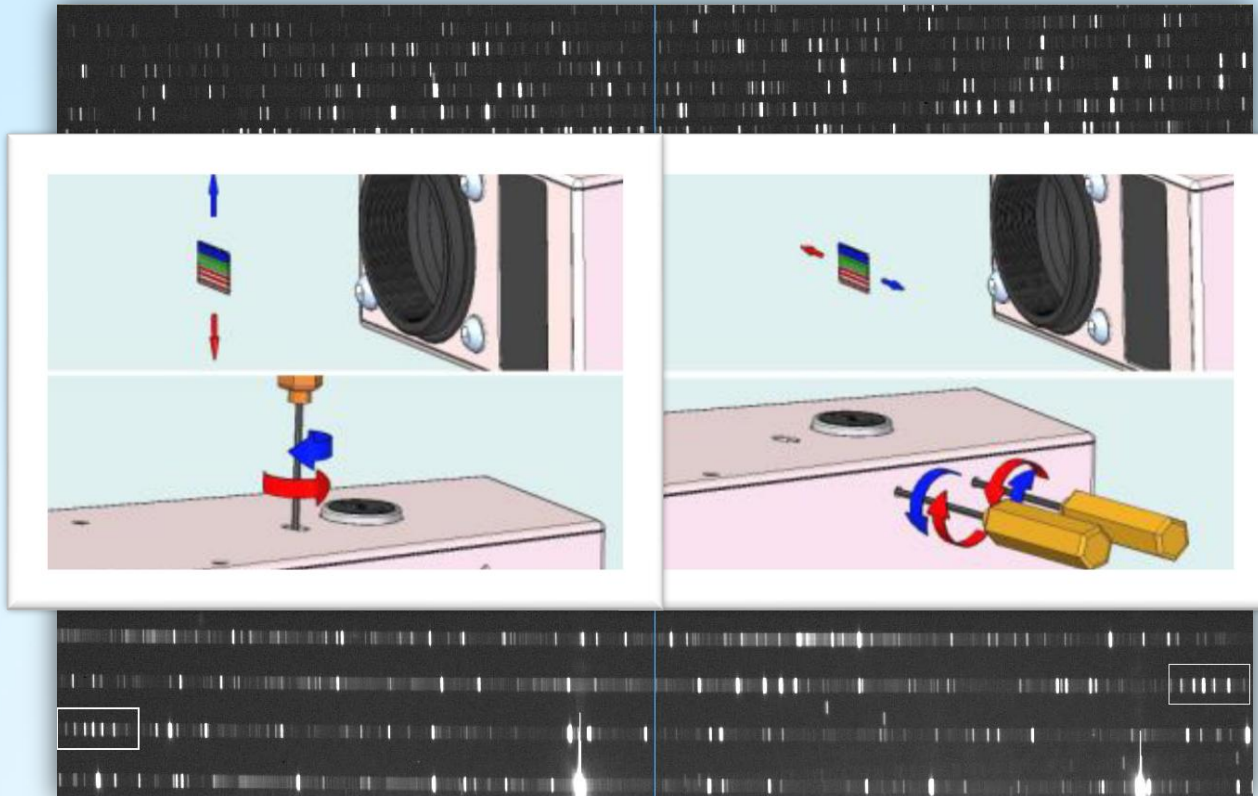


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## Alignment of BACHES Echelle Spectra



Recommended minimum Sensor Size: 9 x 13 mm

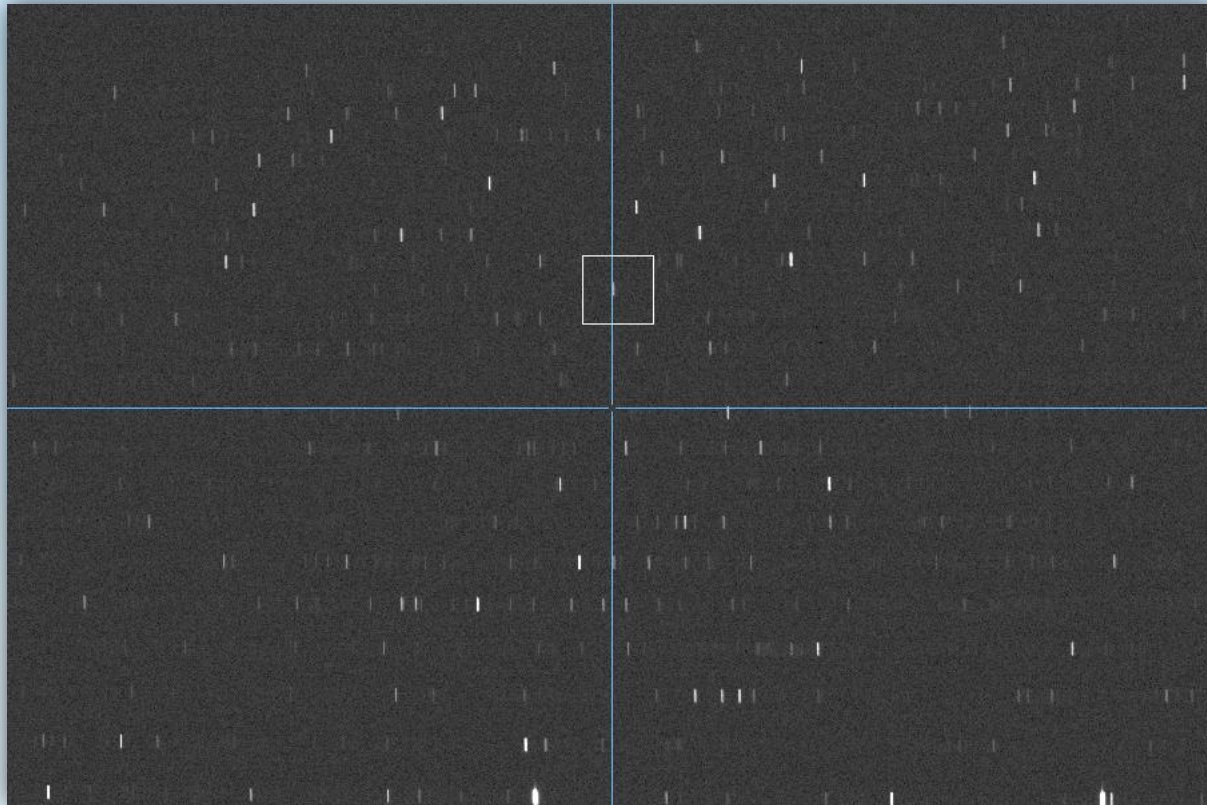


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## Spectrum Focusing





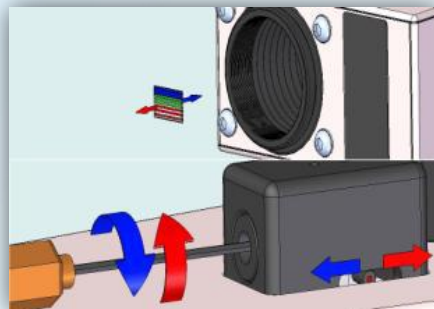
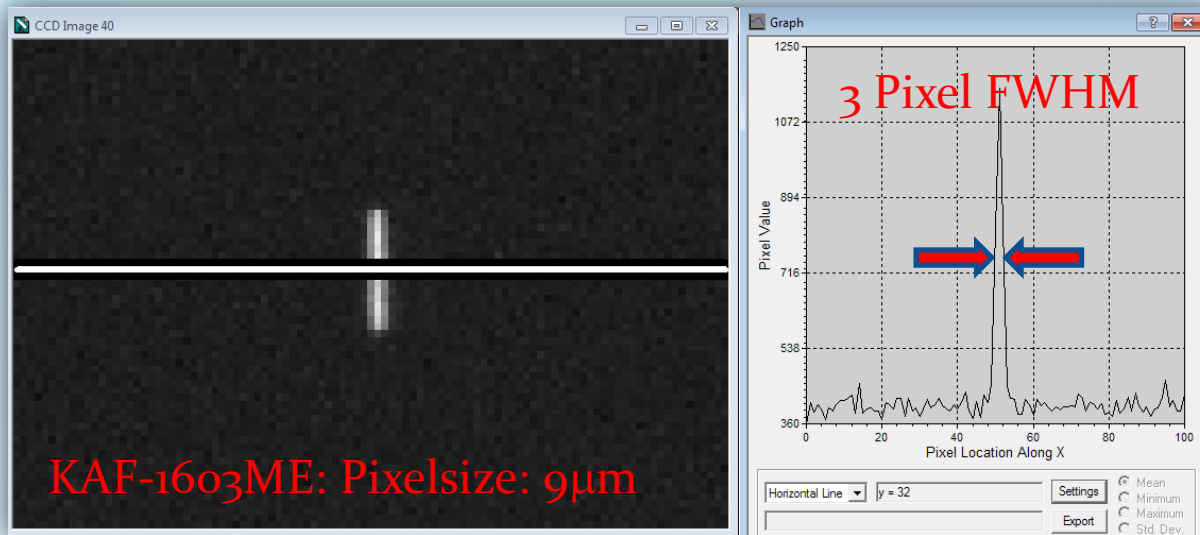
# BACHES

## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



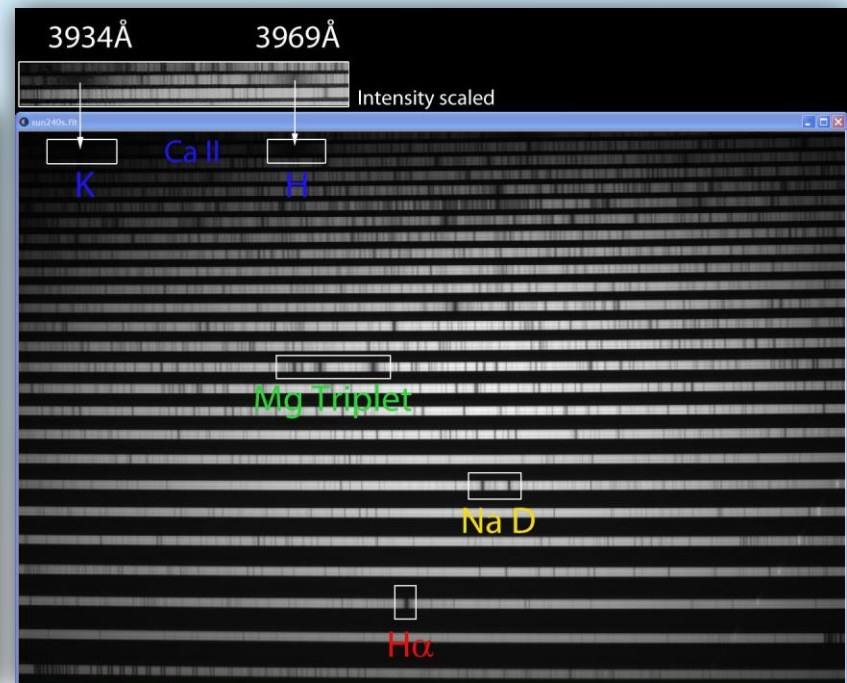
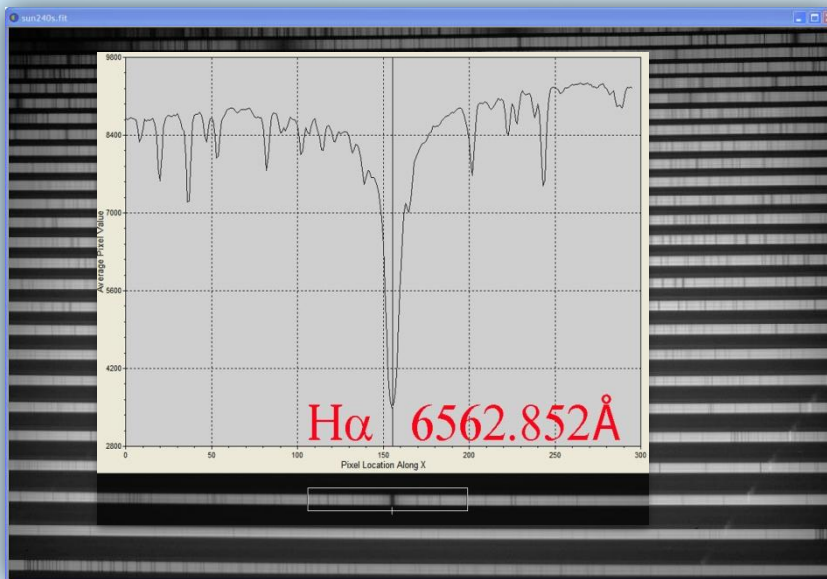
## Spectrum Focusing





## 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



# BACHES

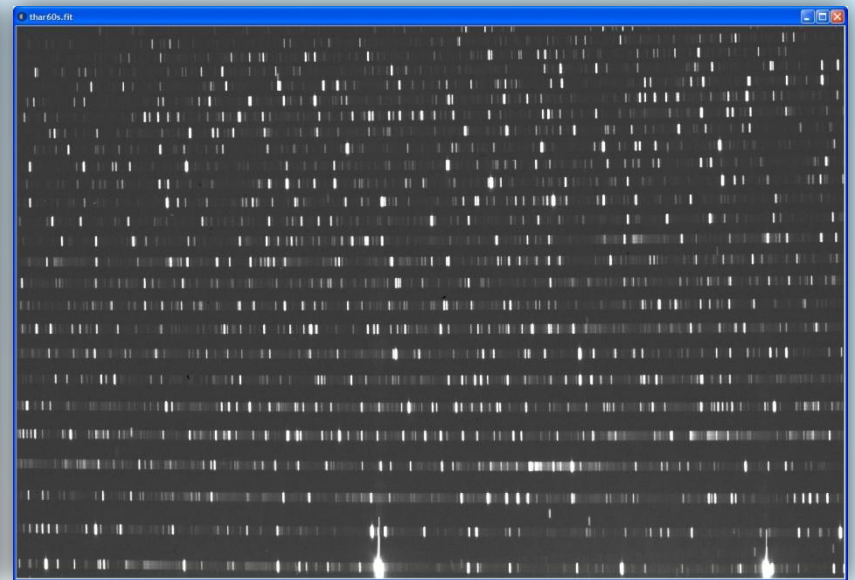
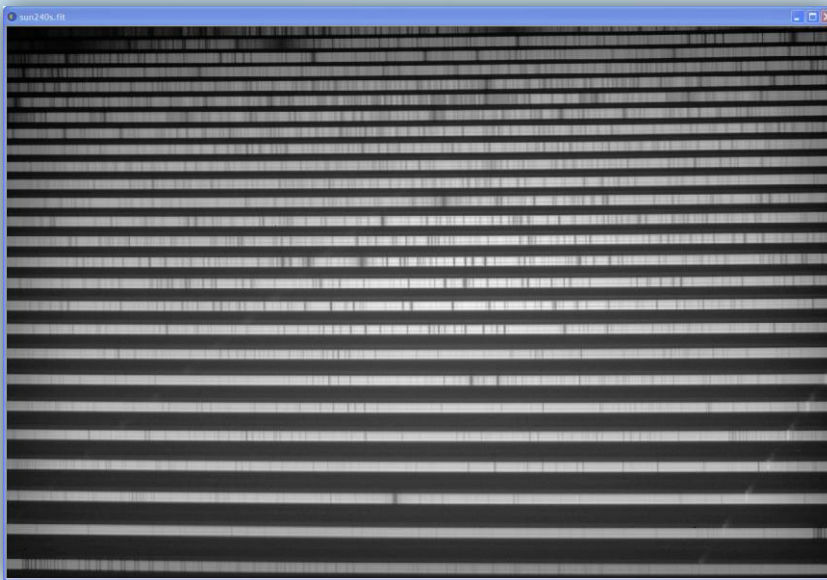
## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



# 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 **2,000** precisely known wavelengths for calibration



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## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit

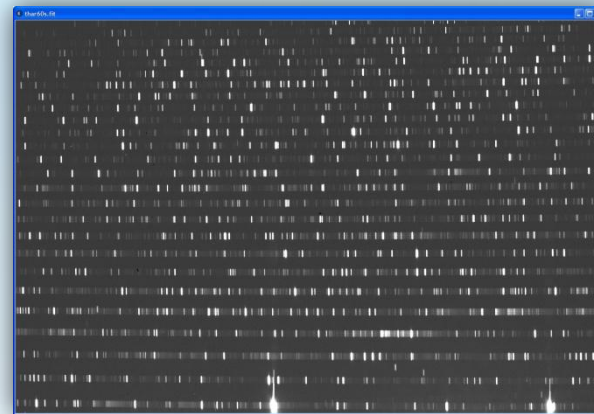


## Calibration of BACHES Echelle Spectra

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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# Calibration of BACHES Echelle Spectra

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

```

~/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:
=====
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

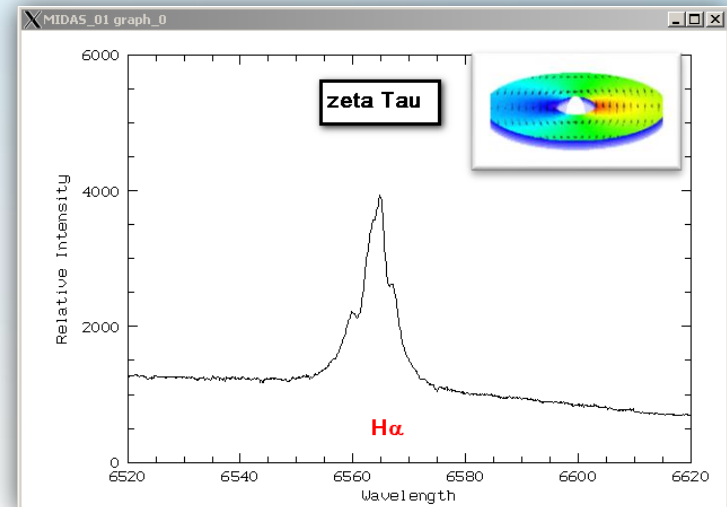
baches_calib: Do you want to continue
  
```

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/](http://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**

A New Level of SCIENTIFIC SPECTROSCOPY with small Telescopes  
[www.baader-planetarium.de/baches](http://www.baader-planetarium.de/baches)

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

SPECTROGRAPH RCU REMOTE CALIBRATION UNIT  
 Accurate and Professional Calibration of BACHES Echelle-Spectra

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

[www.baader-planetarium.de/baches/download/midas\\_manual\\_e.pdf](http://www.baader-planetarium.de/baches/download/midas_manual_e.pdf)

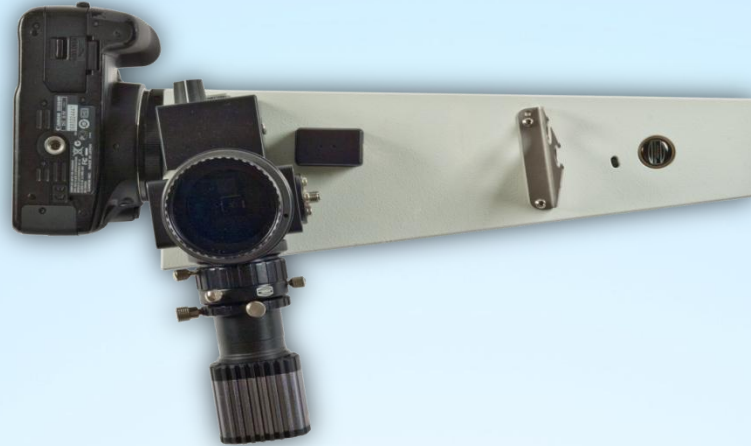


# BACHES

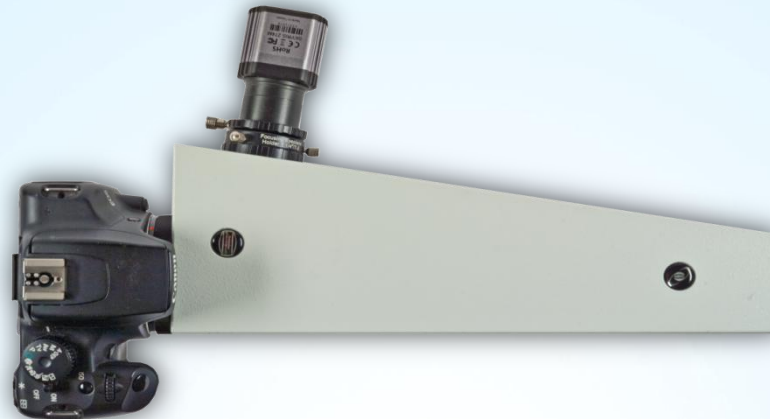
ECHELLE SPEKTROGRAPH  
and Remote Calibration Unit



## BACHES & DSLR Camera Layout



Guiding Camera (Skymis 274M)





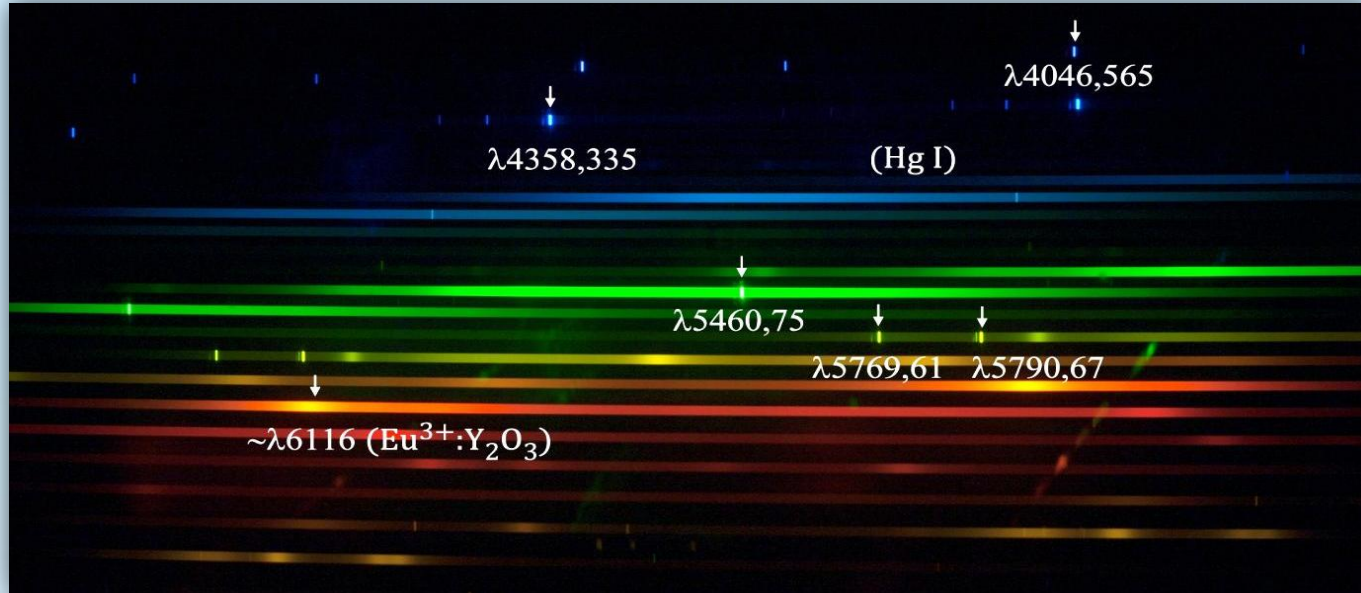
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## ECHELLE SPEKTROGRAPH

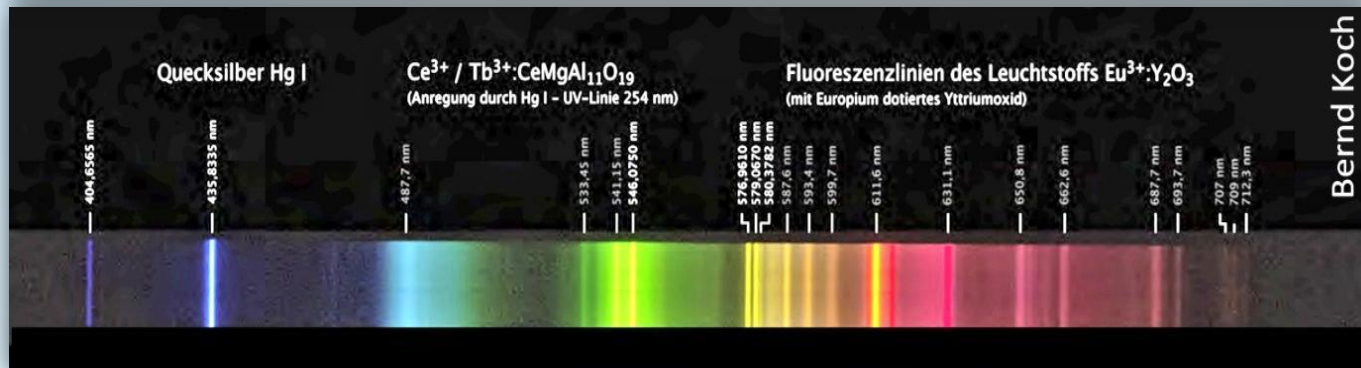
and Remote Calibration Unit



### BACHES & DSLR Camera: Energy Saving Lamp



BACHES



DADOS 200L/mm

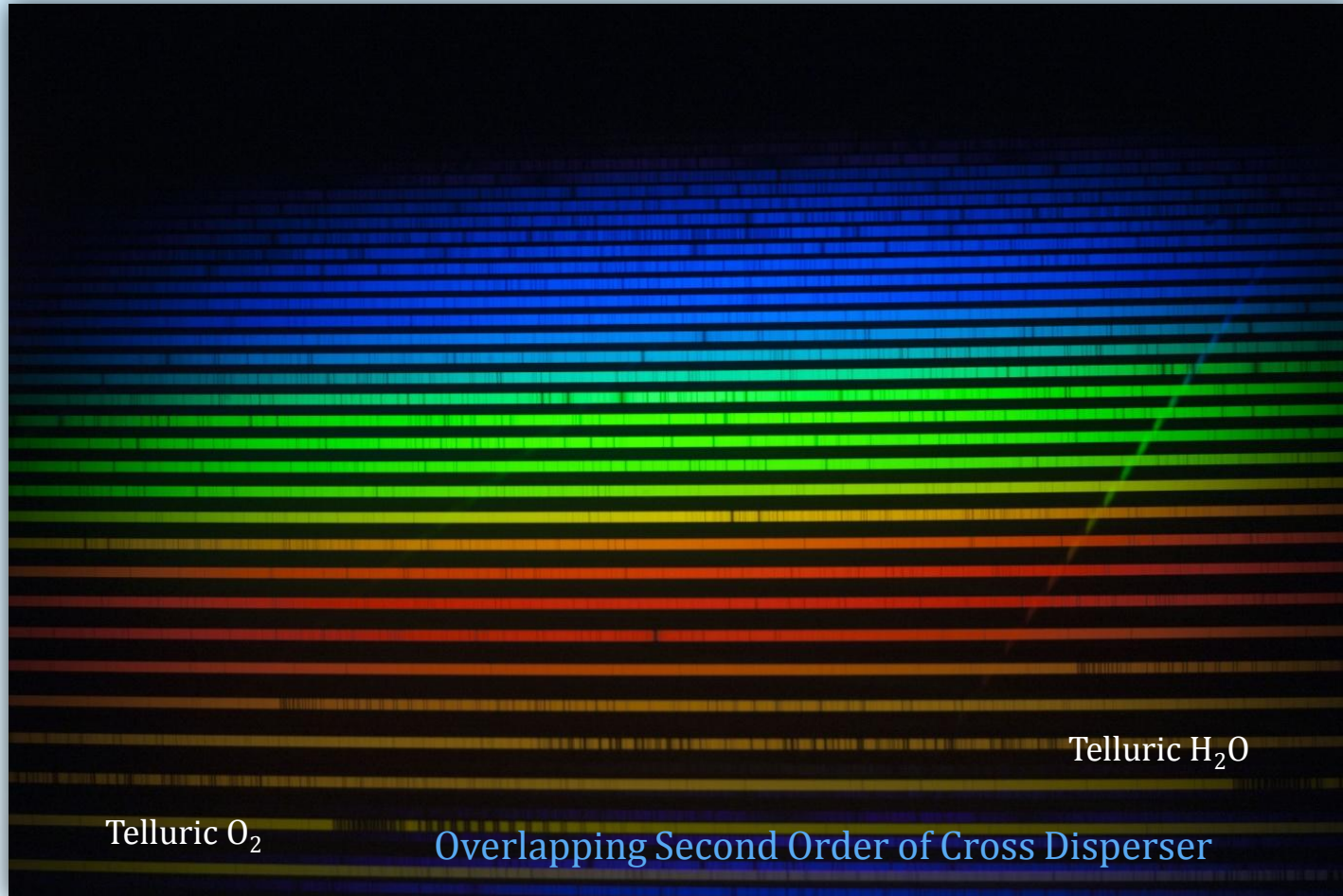


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## BACHES Solar Spectroscopy





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## ECHELLE SPEKTROGRAPH

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## Investigating Telluric Infrared Lines in the Solar Spectrum with a Baader 495nm Longpass Filter

Real Filter-Spectrum, taken with MPI-DADOS-Spectrograph  
Ca Hg H $\beta$  OIII H $\gamma$  Na H $\delta$  O $_{2\text{em}}$  O $_{2\text{em}}$

Comparison Solar-Spectrum (incl. Solar absorption lines)

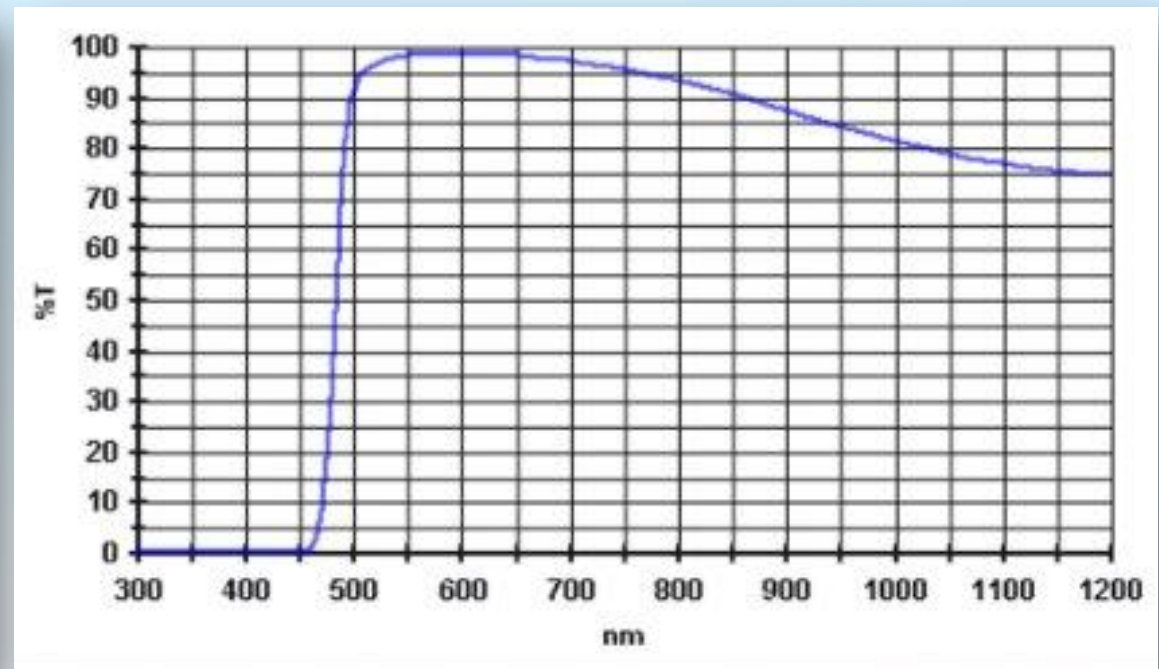
**BAADER Yellow Color Filter**  
495nm Longpass

baader planetarium  
2"

Phantom Group<sup>®</sup> coated Item No. 2458311  
Planeoptically polished for sharp image at high magnification  
Multi-coated for max contrast - no reflections, scatter, or dimming

More Light than w. any other YG Yellow-Filter

**BAADER Yellow - Filter 2"**





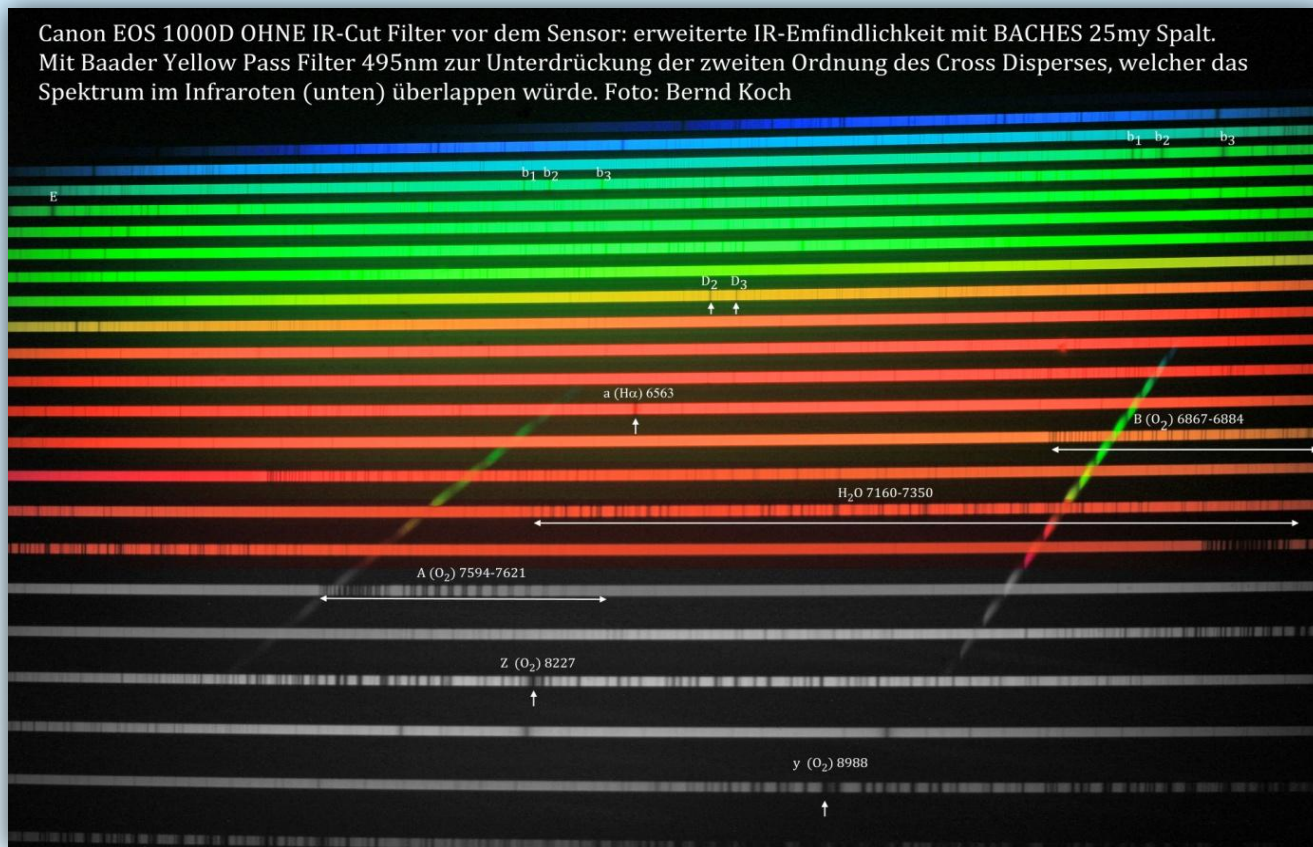
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## ECHELLE SPEKTROGRAPH

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## Investigating Telluric Infrared Lines in the Solar Spectrum with a Baader 495nm Longpass Filter



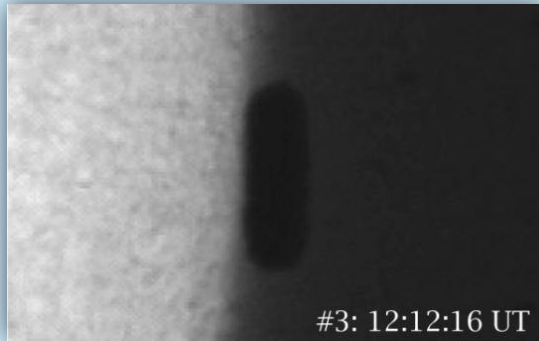


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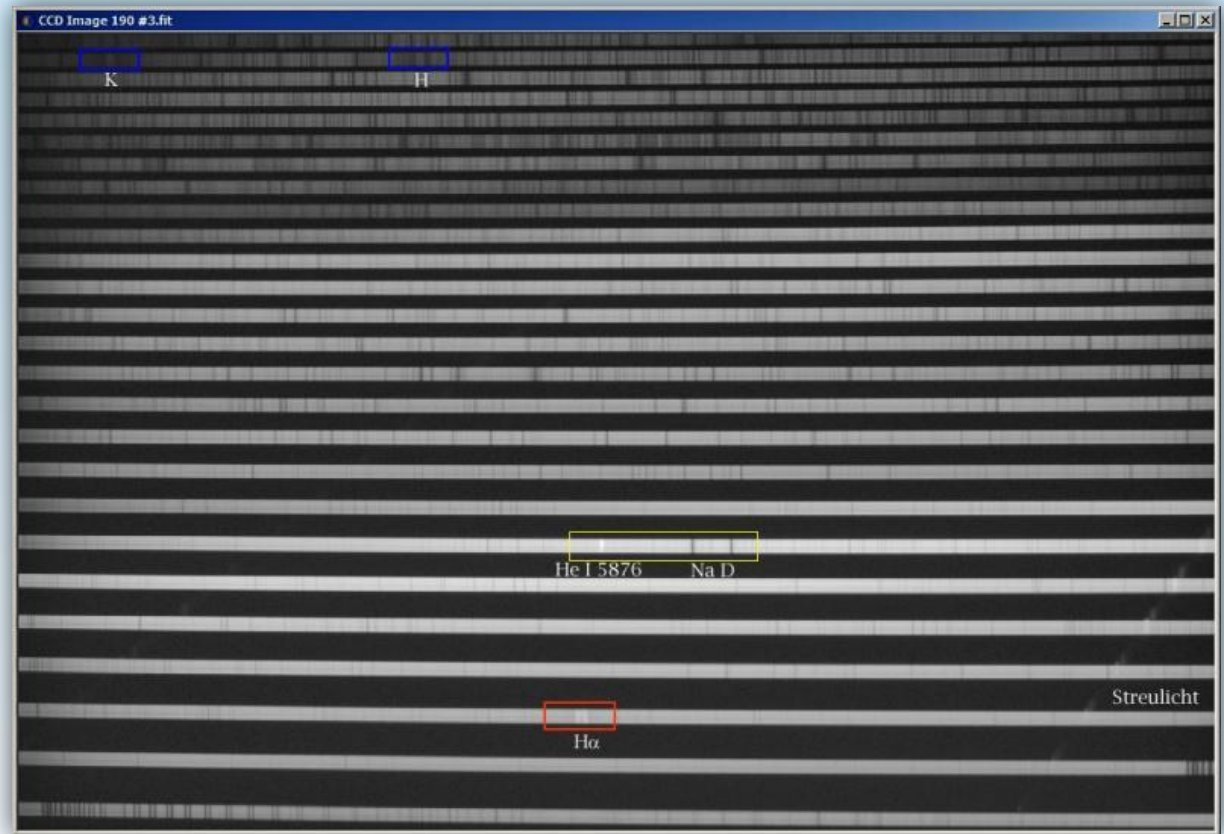
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## Solar Chromosphere Spectrum from Ca II 3934Å to H $\alpha$ 6563Å



Refractor 130mm f/6 +  
1.5x Barlow Lens  
Baader AstroSolar D=3.8  
BACHES 25 $\mu$ m Slit





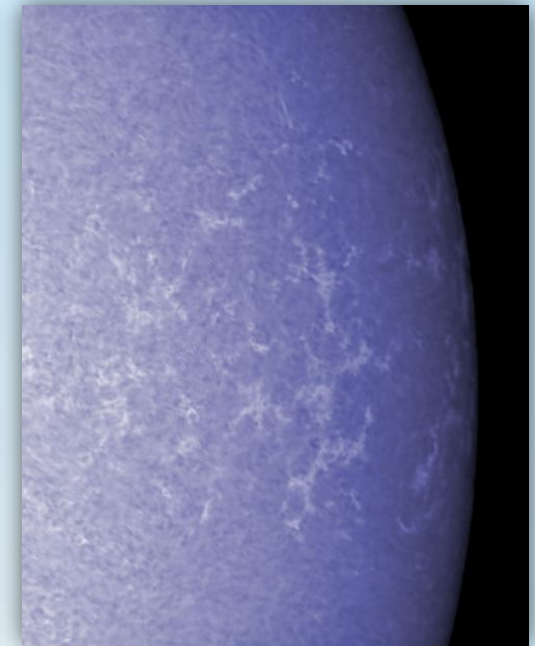
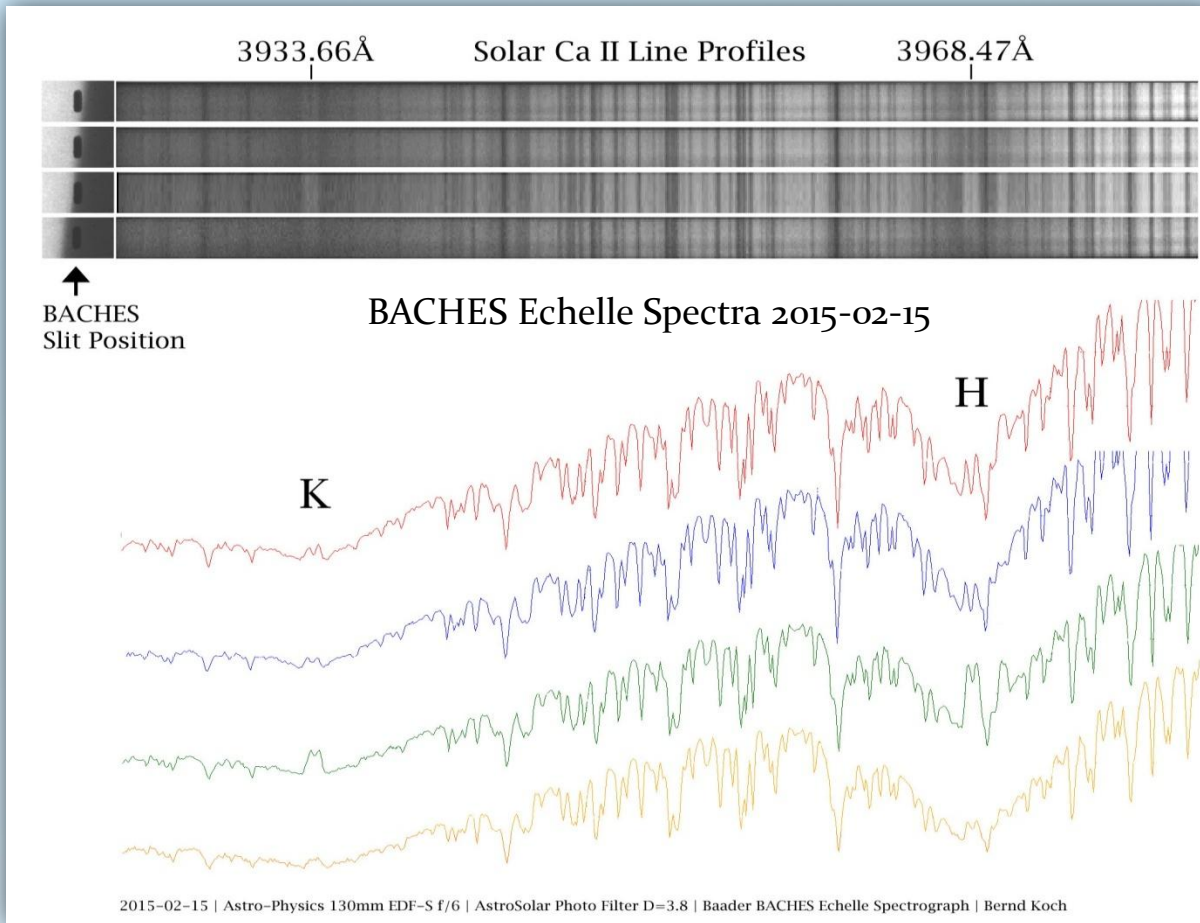


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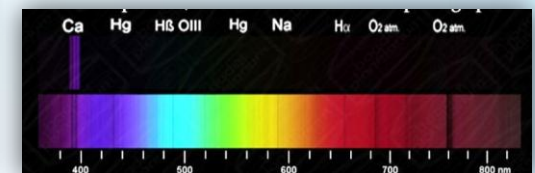
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## Solar Calcium Ca II Lines 3933.66Å and 3968.47Å

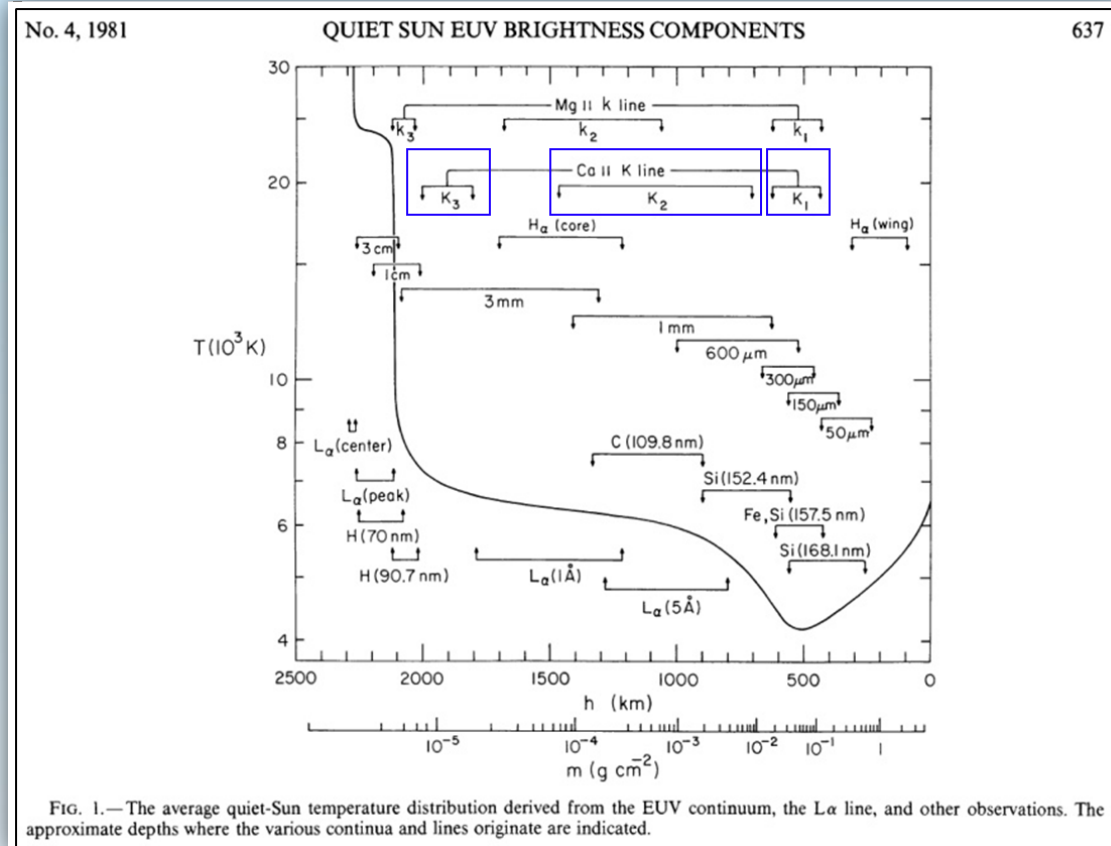


Baader Calcium K-Line Filter





## Solar Photosphere/Chromosphere Ca II K-Line 3933.66Å



Vernazza, J.E. et al., Structure of the solar chromosphere. III - Models of the EUV brightness components of the quiet sun The Astrophysical Journal Supplement Series, 45:635-725, 1981 April, <http://adsabs.harvard.edu/abs/1981ApJS...45..635V>



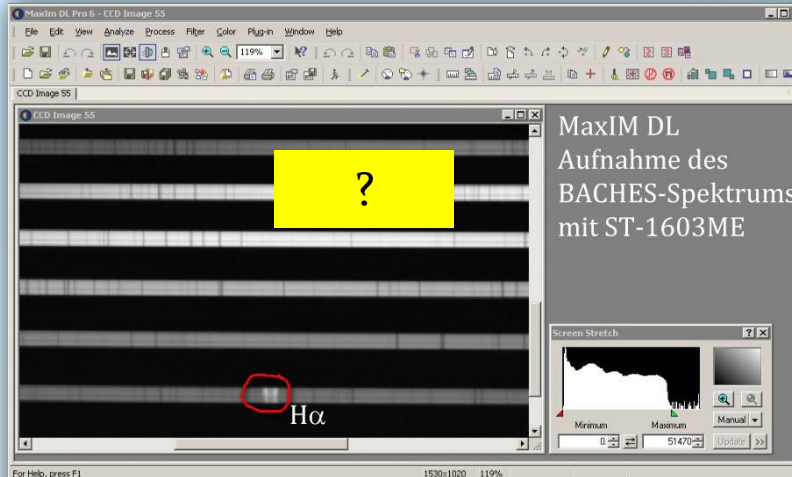
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## ECHELLE SPEKTROGRAPPH

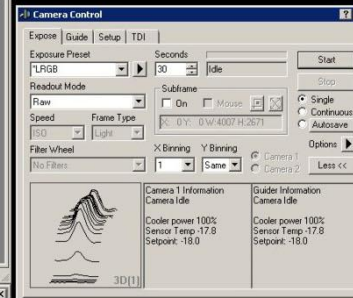
### and Remote Calibration Unit



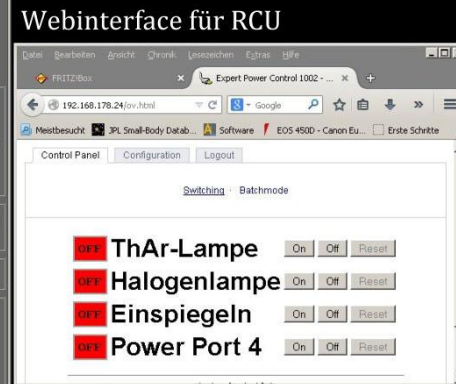
## Solar Chromosphere Spectrum $H\alpha$ 6563Å



Beobachtung der Sonne mit dem  
BACHES Echelle am 15.2.2015



10Micron Keypad  
GM2000HPS





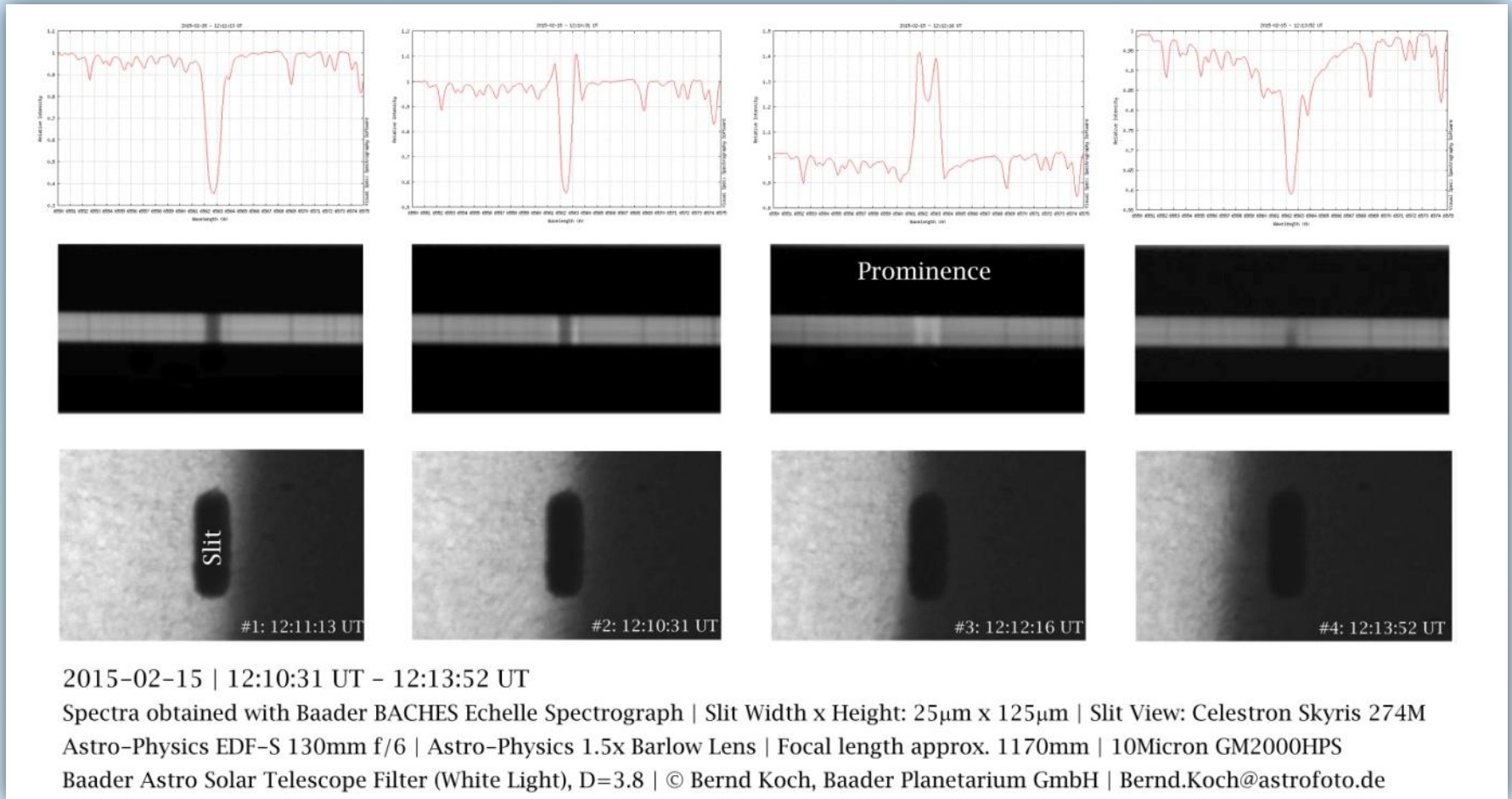
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## ECHELLE SPEKTROGRAPH

### and Remote Calibration Unit



## Solar Photosphere/Chromosphere Spectrum H $\alpha$ 6563Å



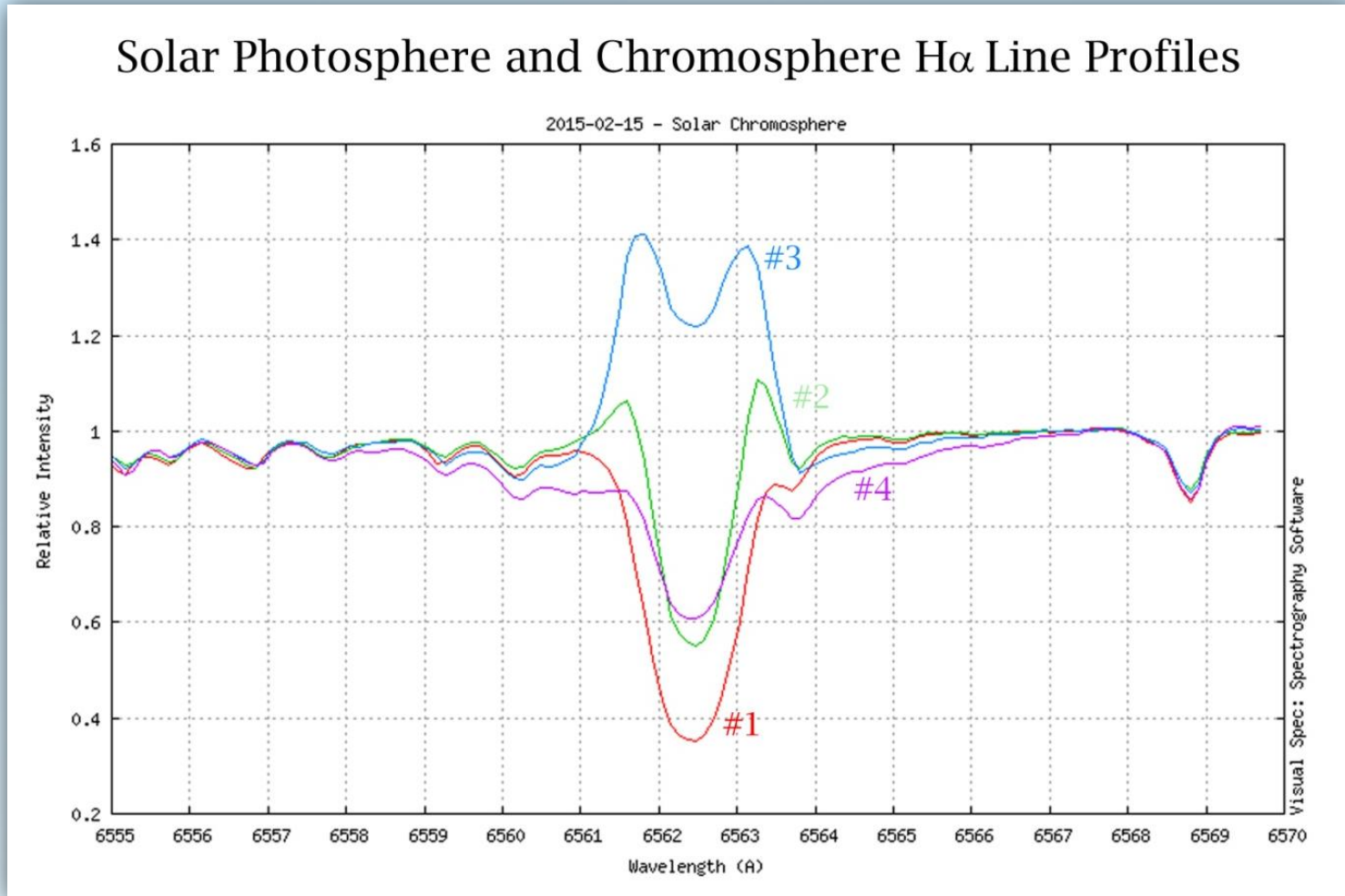


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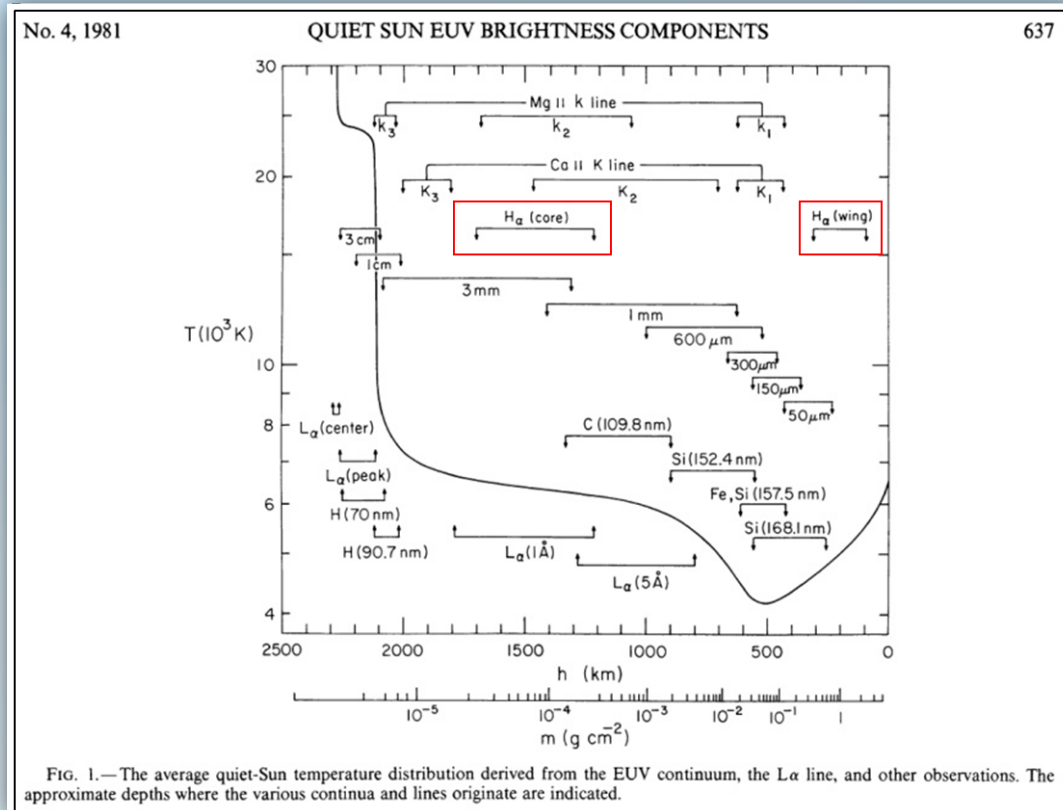


## Solar Photosphere/Chromosphere Spectrum H $\alpha$ 6563Å





## Solar Photosphere/Chromosphere Spectrum $H\alpha$ 6563Å



Vernazza, J.E. et al., Structure of the solar chromosphere. III - Models of the EUV brightness components of the quiet sun The Astrophysical Journal Supplement Series, 45:635-725, 1981 April, <http://adsabs.harvard.edu/abs/1981ApJS...45..635V>



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## Solar Chromosphere Spectrum: ?

MaxIM DL Aufnahme des BACHES-Spektrums mit ST-1603ME

H $\alpha$

Beobachtung der Sonne mit dem BACHES Echelle am 15.2.2015

10Micron Keypad GM2000HPS

Skyris 274M gesteuert von FireCapture zur Positionierung des Spalts

Weißlicht-Bild (AstroSolar-Folie): Spalt am Sonnenrand trifft auf eine hier unsichtbare Protuberanz

Webinterface für RCU

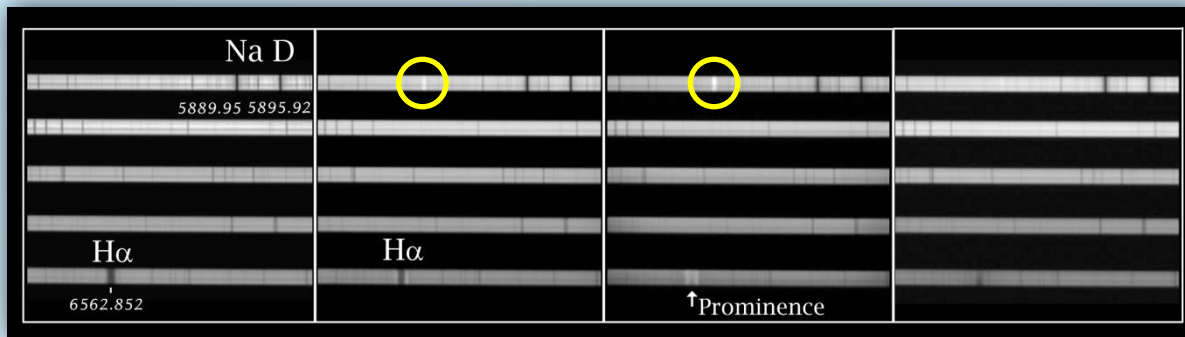
RA 21h51m46.2s  
Dec -12° 40' 22" J







## Year 1868: Signature of unknown chemical element



- Unidentified spectral line close to Sodium D<sub>1</sub>,D<sub>2</sub>
- Discovered by french astronomer Jules Janssen in solar spectrum August 19, 1868
- 1870: Norman Lockyer, english astronomer postulates a new element
- He calls it „Helium“ according to the greek god Helios
- 1895: English Chemist William Ramsay extracts Helium
- [https://en.wikipedia.org/wiki/Solar\\_eclipse\\_of\\_August\\_18,\\_1868](https://en.wikipedia.org/wiki/Solar_eclipse_of_August_18,_1868)



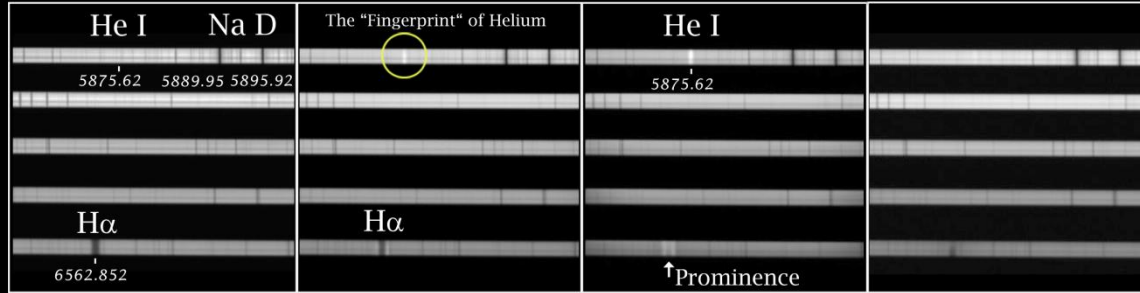
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## Helium in the Solar Chromosphere

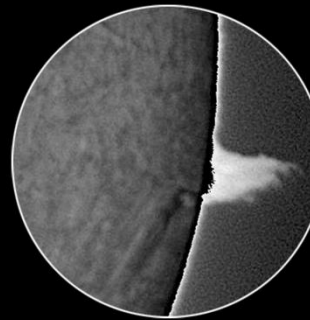


Photosphere

Chromosphere

2015-02-15

Spectra: Baader BACHES Echelle Spectrograph  
 Slit Width/Height: 25 $\mu$ m x 125 $\mu$ m  
 Video Still Images: Celestron Skyris 274M  
 Astro-Physics EDF-S 130mm f/6  
 Astro-Physics 1.5x Barlow Lens  
 Focal length approx. 1170mm  
 Baader Astro Solar Telescope Filter (White Light)  
 Mount: 10Micron GM2000HPS



Prominence

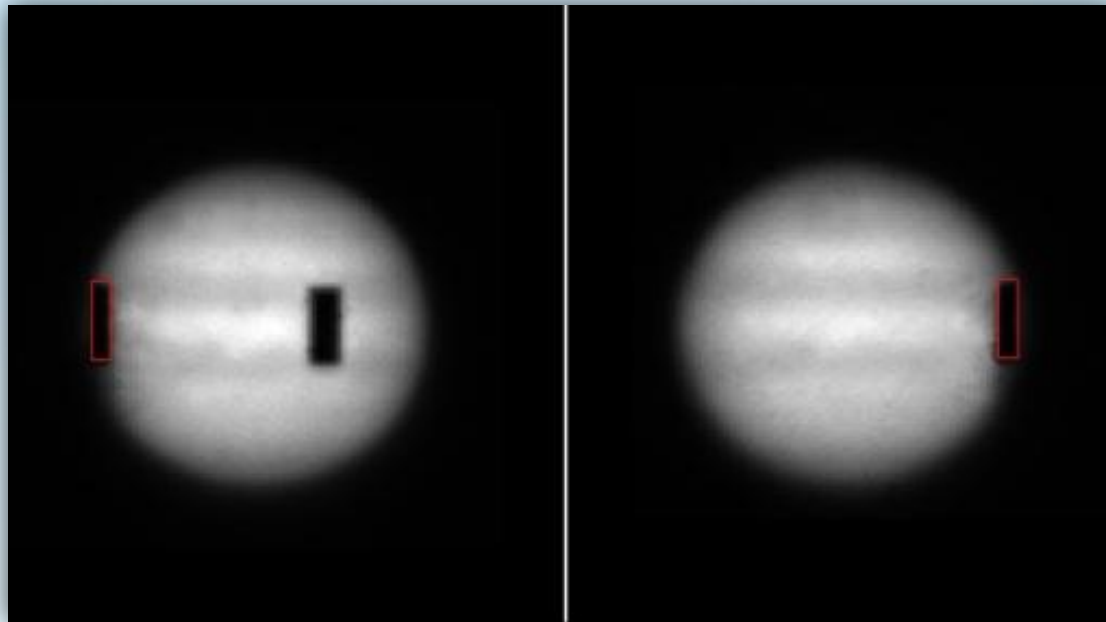
H $\alpha$  Image, 12:59:14 UT  
 Teide Observatory  
 gong.nso.edu

© Bernd Koch, Sörth/Germany  
 Bernd.Koch@astrofoto.de



## The Rotation of Planet Jupiter

$$v_{rot} \cdot \sin i = \frac{|v_r|}{4} = c \cdot \frac{\Delta\lambda}{4\lambda}$$



2016-03-10. BACHES 25µm slit set at left and right edge of Jupiter. Image of the Skyris 274M video guiding camera. Telescope: Celestron 14 EdgeHD with 0,7x reducer setted on GM2000HPS mount



# BACHES

## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



## The Rotation of Planet Jupiter

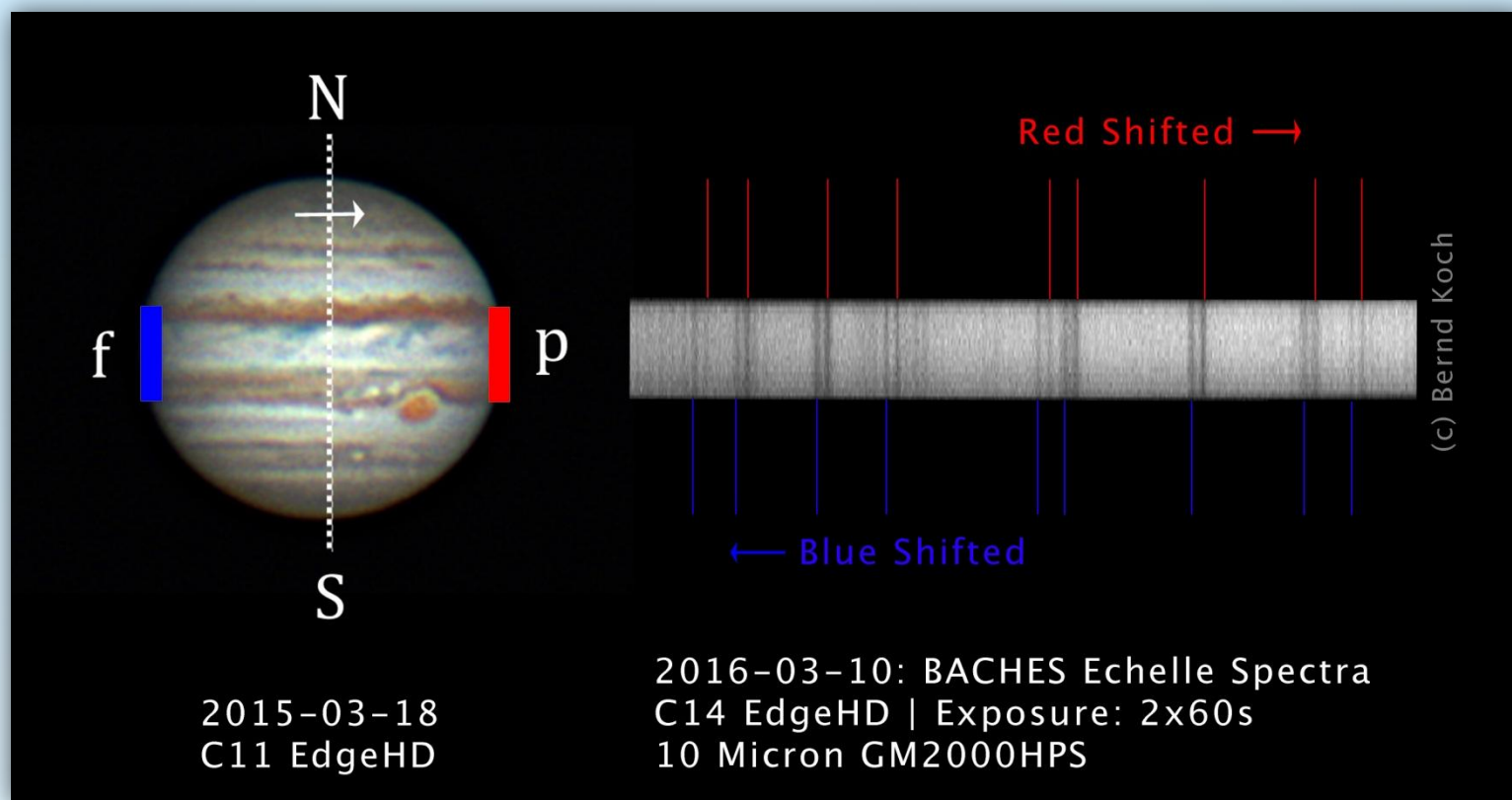


Spectrum of planet Jupiter 2016-03-10. C14 EdgeHD | BACHES Echelle Spektrograph | SBIG ST-1603ME. Two 60s spectra, taken at left and right edge of Jupiter, were co-added to reveal line doubling. The distance between both lines is about  $1\text{\AA}$ . Please note the double lines in the bottom row: These are telluric lines of Oxygen, by chance also separated about  $1\text{\AA}$ . Not subject to Jupiter!



## The Rotation of Planet Jupiter

$$v_{rot} \cdot \sin i = \frac{|v_r|}{4} = c \cdot \frac{\Delta\lambda}{4\lambda}$$

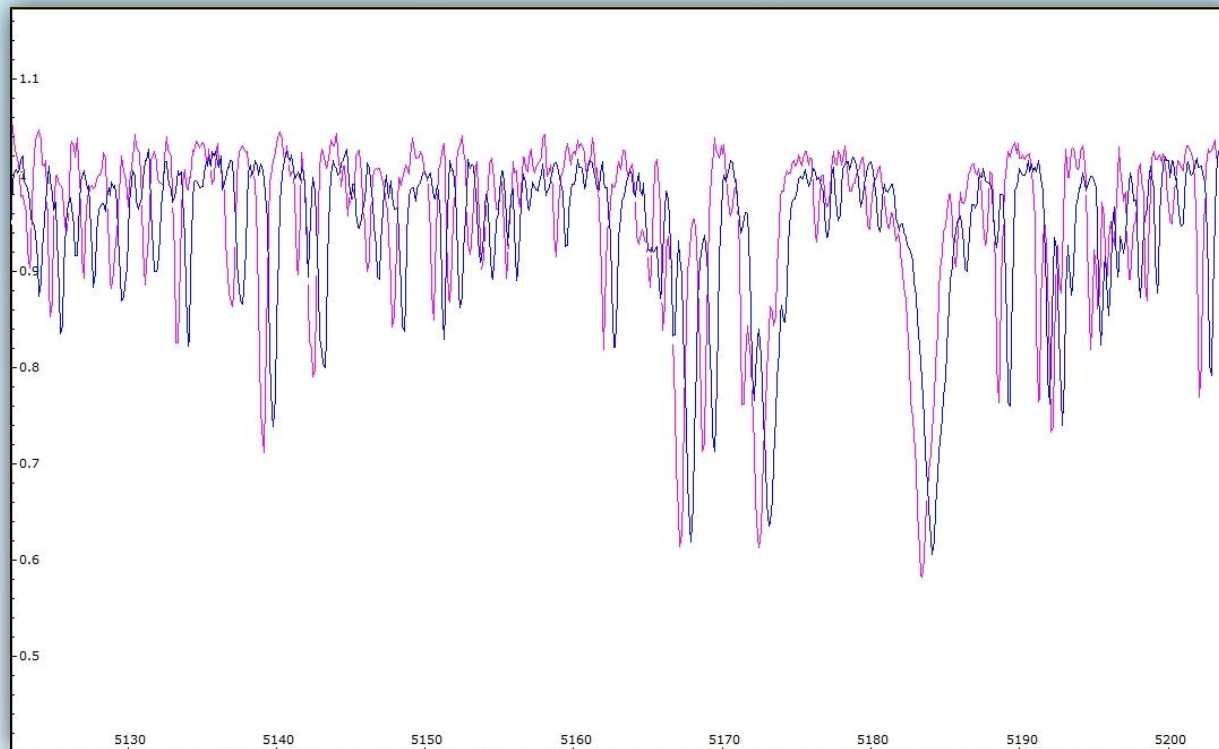




## The Rotation of Planet Jupiter

**Around the Mg – Triplet:**  $\Delta\lambda = 0.72\text{\AA}$ . Center Wavelength:  $\lambda = 5160\text{\AA}$

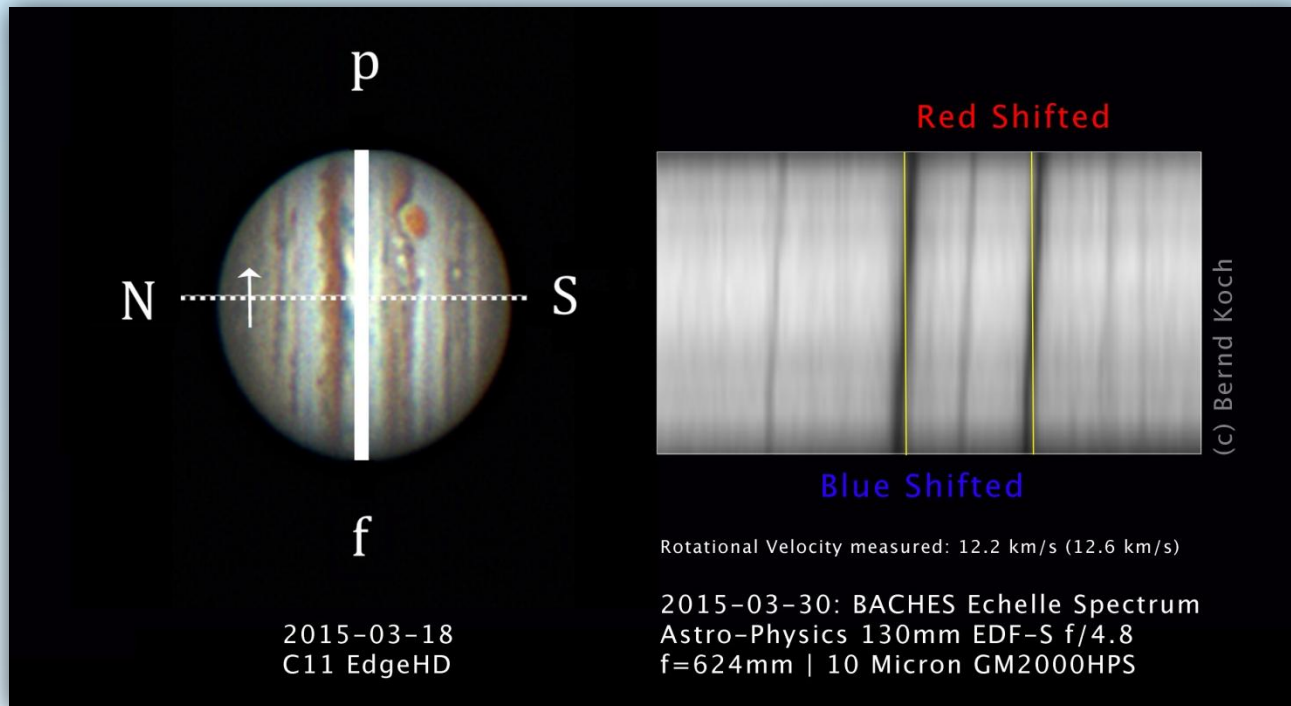
$$v_{rot} = c \cdot \frac{\Delta\lambda}{4\lambda} = 299792.5 \frac{km}{s} \cdot \frac{0.72\text{\AA}}{4 \cdot 5160\text{\AA}} = 10.5 \frac{km}{s} \text{ (-16,6\%), correct: } 12.6 \frac{km}{s}$$





## The Rotation of Planet Jupiter

$$v_{rot} \cdot \sin i = \frac{|v_r|}{4} = c \cdot \frac{\Delta\lambda}{4\lambda}$$





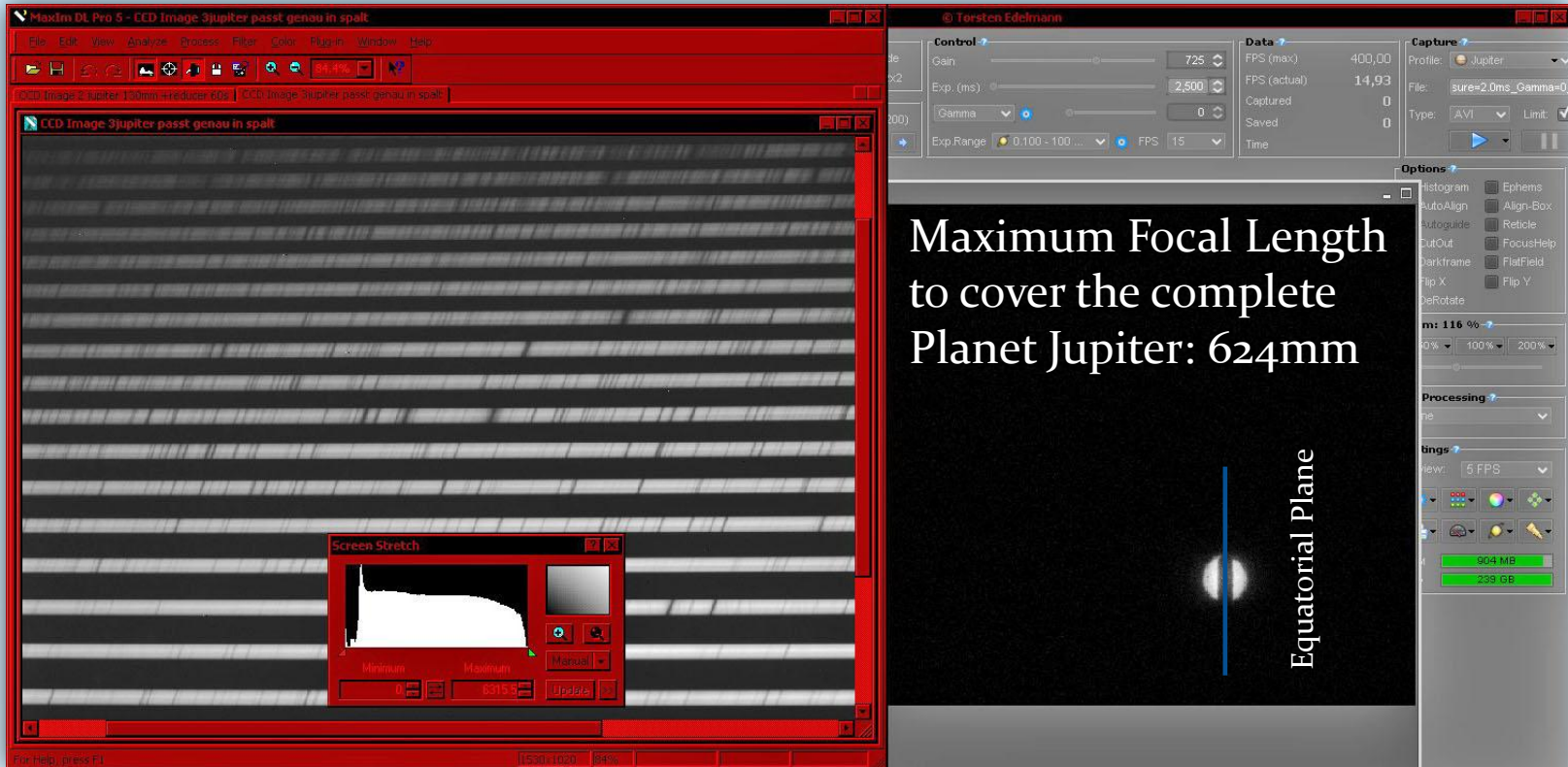
# BACHES

## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



## The Rotation of Planet Jupiter



**Left:** Complete Jupiter spectrum obtained with BACHES Echelle, Slit width 25 $\mu$ m. 130mm refractor, 624mm focal length, exposure 60s with SBIG ST-1603ME. **Right:** Video window (FireCapture software) with 90° rotated Jupiter image. During exposure manual guiding by means of the 10Micron keypad.



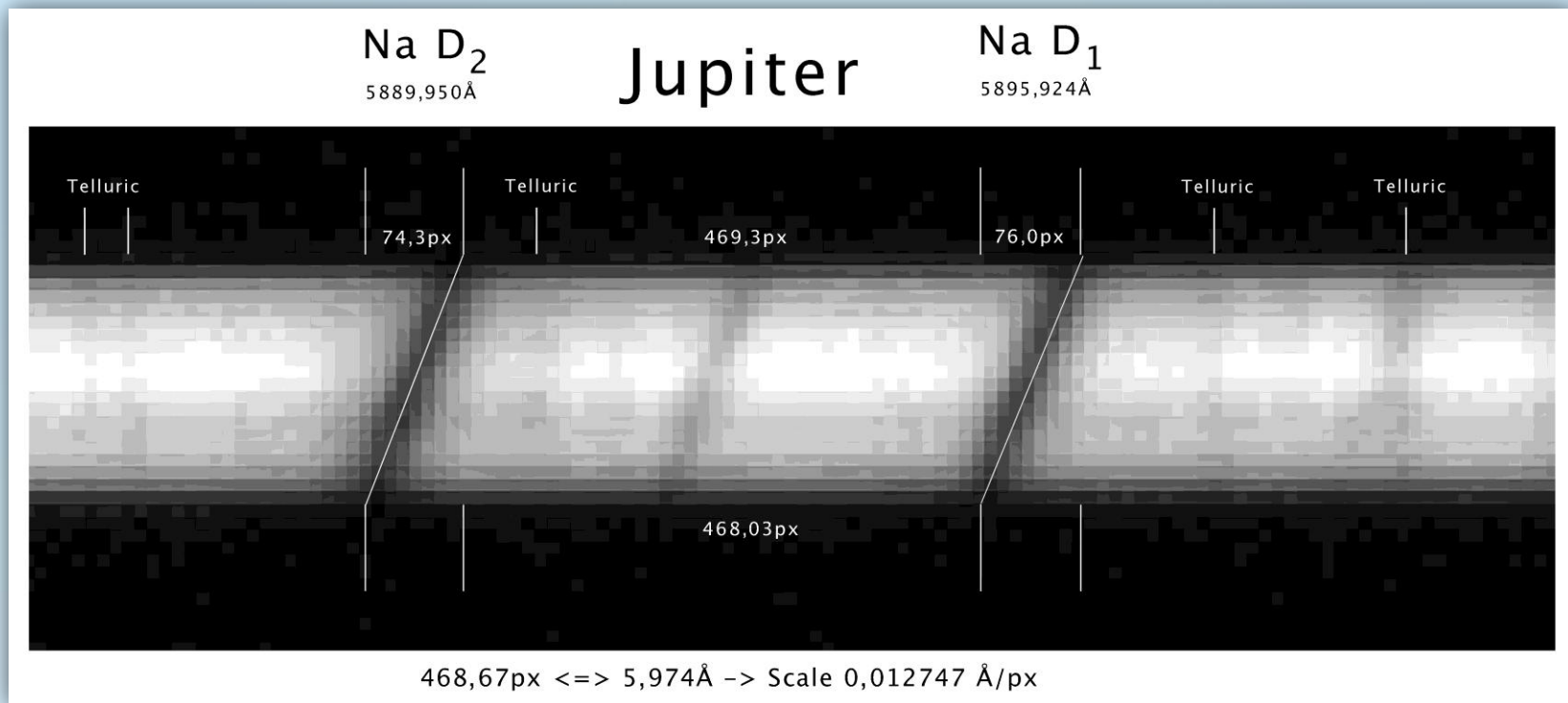


# BACHES

ECHELLE SPEKTROGRAPH  
and Remote Calibration Unit



## The Rotation of Planet Jupiter





## The Rotation of Planet Jupiter

30.3.2015:  $i = 89.9^\circ \approx 90^\circ$ ;  $\sin i = 1$ ; Einzelmessung des Versatzes der Linien D1 und D2

$$D1 - \text{Linie: } \Delta\lambda = 76.0px \cdot 0.012747 \frac{\text{\AA}}{px} = 0.9687\text{\AA}; \lambda = 5895.924\text{\AA}$$

$$v_{rot} = c \cdot \frac{\Delta\lambda}{4\lambda} = 299792.5 \frac{km}{s} \cdot \frac{0.9687\text{\AA}}{4 \cdot 5895.924\text{\AA}} = 12.31 \frac{km}{s}$$

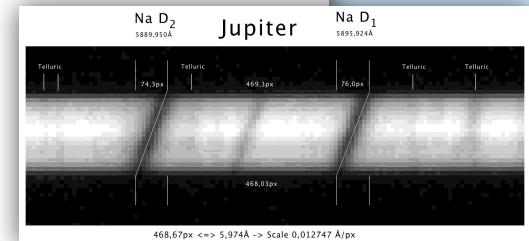
$$D2 - \text{Linie: } \Delta\lambda = 74.3px \cdot 0.012747 \frac{\text{\AA}}{px} = 0.9471\text{\AA}; \lambda = 5889.950\text{\AA}$$

$$v_{rot} = c \cdot \frac{\Delta\lambda}{4\lambda} = 299792.5 \frac{km}{s} \cdot \frac{0.9471\text{\AA}}{4 \cdot 5889.950\text{\AA}} = 12.05 \frac{km}{s}$$

Mittelwert aus zwei Einzelmessungen:  $v_{rot} = 12.18 \frac{km}{s} \pm 0.13 \frac{km}{s}$

Mit dem Äquatorradius des Planeten Jupiter  $r = 71492 km$  beträgt die Rotationsdauer am

$$\text{Jupiteräquator: } T = \frac{2\pi r}{v_{rot}} = \frac{2\pi \cdot 71492 km}{12.18 km/s} = 36879.9s = 10h 14.6m$$



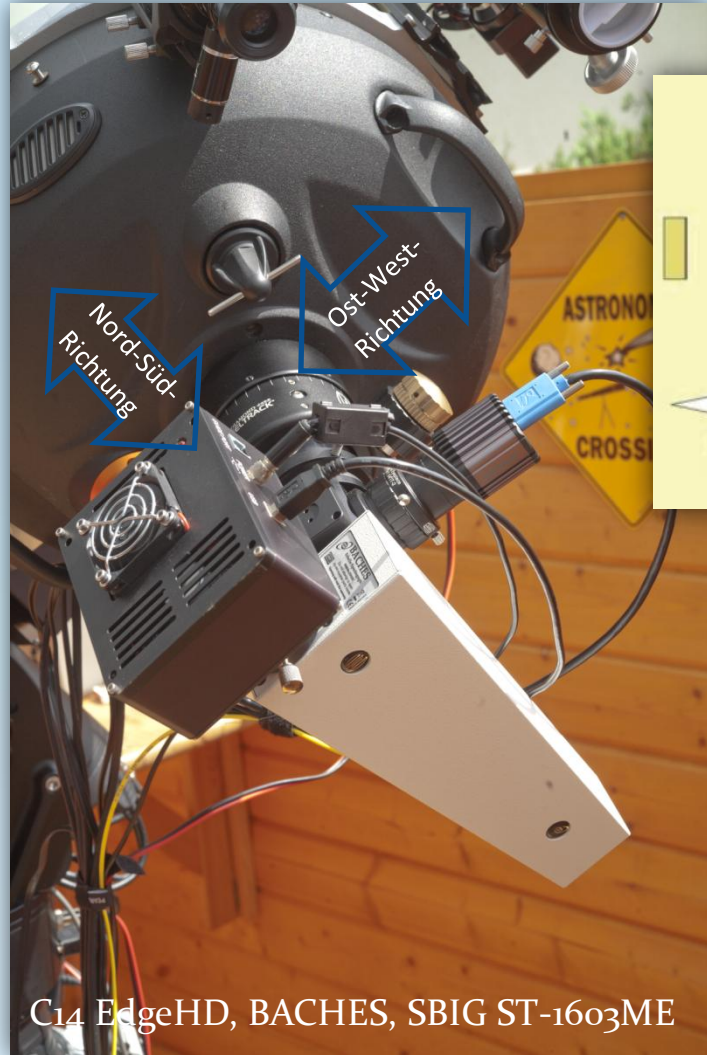
Jupiter	Correct Value	Measured	Difference
$v_{rot}$	12.6 km/s	12.2 km/s	-3.2%
$T$ (Equator)	9h 55.5m	10h 14.6m	+3.2%



# BACHES

## ECHELLE SPEKTROGRAPH

### and Remote Calibration Unit

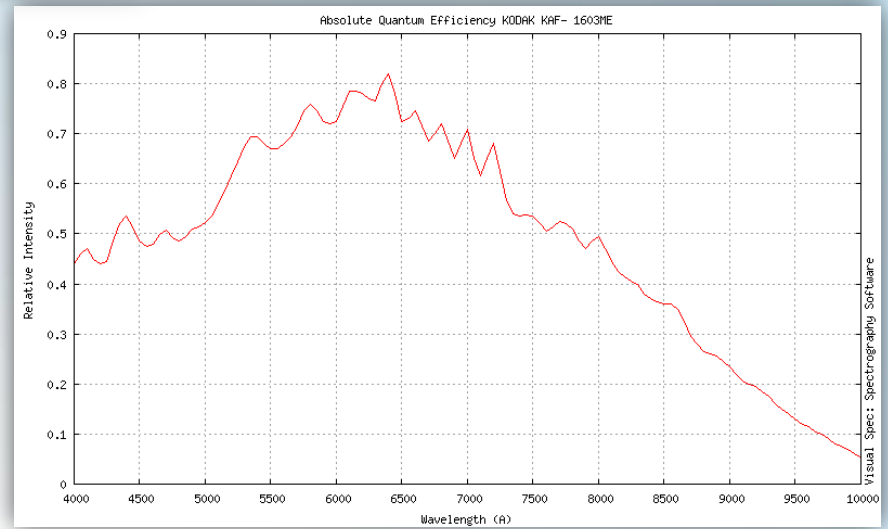


C14 EdgeHD, BACHES, SBIG ST-1603ME



## BACHES & CCD Camera attached to the Telescope

Imaging CCD.....	Kodak KAF-1603ME
Imaging/Pixel Array.....	1530 x 1020 pixels
CCD Size.....	13.8 x 9.2 mm
Total Pixels.....	1.56 million
Pixel Size.....	9 x 9 microns
Full Well Capacity.....	~100,000 e-
Dark Current e/p/s at 0 C.....	1e-/pixel/sec at 0 deg.
Antiblooming.....	NABG Only
Peak QE.....	>80%





# BACHES

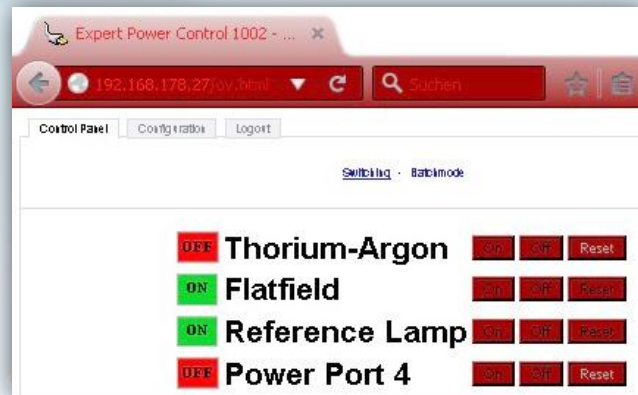
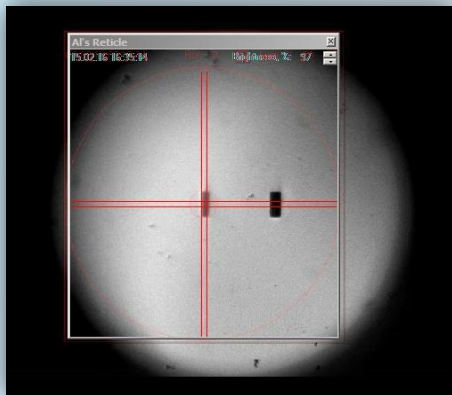
## ECHELLE SPEKTROGRAPH

### and Remote Calibration Unit



Spectrum guiding on a star:  
**Manual Guiding** with any TIS or  
 Celestron Skyris  
 Video Camera

RCU Web Interface



	Skyris 274M (825155)
A/D Wandler	12-bit
Maximale Bildrate	20 fps
Sensor	Sony ICX274AL Monochrome CCD
Teleskopanschluss	1 1/4" Stutzen und C-Gewinde
Temperaturbereich	40°C bis -40°C
Optisches Fenster	Nein
Verschluss	Global
Software-Kompatibilität	iCap, IC Capture, DirectShow
Sub-Framing	Wählbar
Stromversorgung	Über USB
Kameraauflösung	1600x1200
Sensorgroße	8,5 mm x 6,8 mm
Pixelgröße	4,4 µm²
Systemvoraussetzungen	PC / Laptop mit Windows XP/Vista/7/8 & freiem USB 2.0/3.0 Port
Gewicht	0,1 kg



# BACHES

## ECHELLE SPEKTROGRAPH

### and Remote Calibration Unit



Guider Camera Control  
FireCapture

Spectrum guiding on a star: Manual Guiding

The screenshot displays a complex software interface with several windows:

- Top Left:** Camera control panel with settings for light mode, gain (500), FPS (20.94), and exposure time (0.03).
- Top Center:** A spectral graph showing a prominent H $\alpha$  emission line.
- Top Right:** MaxIm DL Pro 6 - CCD Image 2 VV Cep 300s window showing a spectrum of the star VV Cep.
- Middle Left:** A window titled "AI's Reticle" showing a circular crosshair.
- Middle Right:** A window titled "VV Cep" showing a CCD image of the star.
- Bottom Left:** "Expert Power Control 1002" window with buttons for Thorium-Argon, Flatfield, Reference Lamp, and Power Port 4.
- Bottom Center:** "Observatory" window showing a star chart with a circled star.
- Bottom Right:** "Telescope Drive Control" window showing coordinates for HD 208816 (Star mv 4.80, RA 21h56m39.4s, Dec +63°37'33" J) and a control panel with directional buttons.

BACHES 25 $\mu$ m Slit

RCU Web Interface

Star Chart MaxIm DL

Telescope  
Drive Control

Spectrum Exposure  
Control MaxIm DL

C14



# BACHES

## ECHELLE SPEKTROGRAPH

### and Remote Calibration Unit



## Spectrum self-guiding on a star: *SpecTrack* Guiding Software

**NEW!**

**SpecUI 2** SpecUI Guiding Software

GUIDE | RCU | TELESCOPE

Exposure: time (s) 0.088, gain 176, preset Star

Guide: Center Star 500, Stop X Y, Auto exp.

RMS Dec: 1.489", RMS Ry: 1.325"

790.161 494.887 0.011 176 11

**ThAr Spectrum**

Maxim DL Pro 6 - CCD Image 1

CCD Image 1

**BACHES**

Park Position C14 EdgeHD / GM2000HPS

**MaxIm DL Control**

Exposure Preset: [LRGB] 160, Readout Mode: Raw, Speed: Light, Filter Wheel: No Filters

Camera 1 Information: Cooler power 88%, Sensor Temp -15.2, Setpoint -15.0

Guider Information: Cooler power 88%, Sensor Temp -15.2, Setpoint -20.0

**10Micron Keypad**

RA 23h 42m 51.7s  
Dec -39° 27' 51" J

**Database Maxim DL**

View RA: 23h 42m 50s, View Dec: -39° 27' 53", View FOV: 1", Rotator PA: 180°

Mouse RA: 23h 43m 21s, Mouse Dec: -38° 37' 45", Mouse AL: 00° 31' 53", Mouse Az: 184° 27' 41"

GSC813.1316 (Star) RA: 23h 28m 51s, Dec: -39° 10' 30", Mag: 13.8



# BACHES

## ECHELLE SPEKTROGRAPH

### and Remote Calibration Unit



## Spectrum self-guiding: *SpecTrack* Guiding Software

- ✓ GUIDE: *The Imaging Source (TIS)* or *Celestron Skyris* video cameras supported
- ✓ RCU: Full Thorium-Argon and halogen-flatfield lamp control (Ethernet)
- ✓ TELESCOPE: Chose your favourite ASCOM driver
- ✓ Position of slit defined by mouse
- ✓ Keeps an object on the slit
- ✓ Can be used also for guiding of astrophotos

**NEW!**

Calibration	
Calibration matrix	Double[]-Array
Calibration move (arcsec)	60
Minimum pixels per star	20
Pixel scale (arcsec/pixel)	0.34567432713409574
Star detection threshold (counts)	10
Telescope settle time (ms)	1000
RCU	
IP address	192.168.178.27
Ports	(Auflistung)
Scope	
ASCOM driver	ASCOM.FreijallIGM.Telescope
Default Dec input	-30:13:08.78
Default pulse duration (ms)	500
Default RA input	23:07:40.35
Guider sensitivity	500
Guider threshold X	0.05
Guider threshold Y	0.05
ASCOM driver	
Telescope ASCOM driver ID.	

SpecTrack 0.1

GUIDE RCU TELESCOPE

Disconnect Configure Center slit

Exposure: 0.1638 Set - + Zoom IN

Gain: 1023 Set - + Zoom OUT

Speed: Faint Star - + Set Fit

Define slit

Frame: Stop 500 ms

Guide: Center Star: 500 New Log

Stop [X] [Y] Settings

Calibrate [ ] Auto exp. About

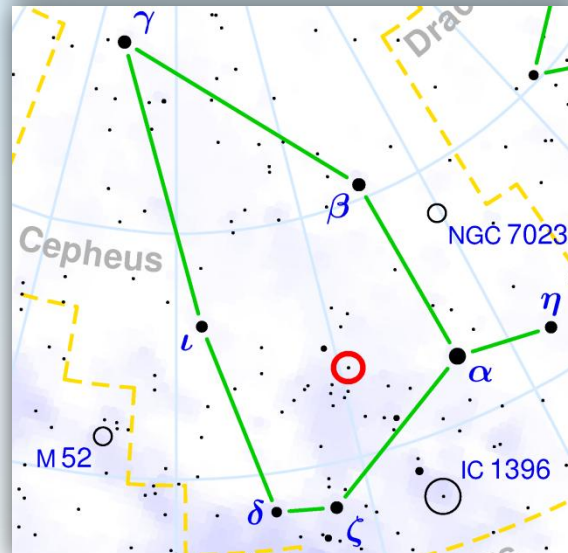
RMS (X): 0.206 RMS (Y): 0.199

X: 760.363 Y: 718.911 E: 0.1638 G: 1023 I: 284



# Eclipsing Binary VV Cephei

Observation data	
Epoch J2000	Equinox J2000
Constellation	Cepheus
Right ascension	21 <sup>h</sup> 56 <sup>m</sup> 39.14385 <sup>s</sup> [1]
Declination	+63° 37' 32.0174 <sup>″</sup> [1]
Apparent magnitude (V)	4.91 <sup>[2]</sup> (4.80 - 5.36 <sup>[3]</sup> )
Characteristics	
U-B color index	+0.43 <sup>[4]</sup>
B-V color index	+1.73 <sup>[4]</sup>
Variable type	EA + SRc <sup>[3]</sup>
<b>A</b>	
Spectral type	M2 Ia <sup>b</sup> [2]
U-B color index	+2.07 <sup>[4]</sup>
B-V color index	+1.82 <sup>[4]</sup>
<b>B</b>	
Spectral type	B0-2 V <sup>[2]</sup>
U-B color index	-0.52 <sup>[4]</sup>
B-V color index	+0.36 <sup>[4]</sup>

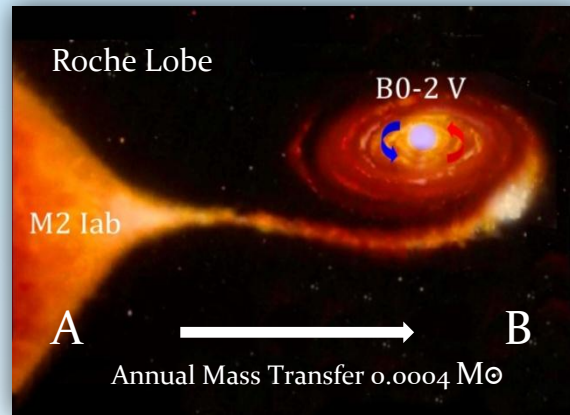


Astrometry	
Parallax (π)	1.33 ± 0.20 <sup>[1]</sup> mas
Distance	4.9k ly (1.5k <sup>[5]</sup> pc)
Absolute magnitude (M <sub>V</sub> )	-6.93 <sup>[6]</sup>
Orbit <sup>[7]</sup>	
Period (P)	7,430.5 days
Semi-major axis (a)	16.2 ± 3.7 <sup>[2]</sup> <sup>a</sup> (12.7 AU)
Eccentricity (e)	0.346 ± 0.01
Inclination (i)	84 <sup>[8]</sup> <sup>a</sup>
Semi-amplitude (K <sub>1</sub> ) (primary)	19.43 ± 0.33 km/s
Semi-amplitude (K <sub>2</sub> ) (secondary)	19.14 ± 0.68 km/s
Details	
<b>A</b>	
Mass	2.5 <sup>[9]</sup> or 20 <sup>[10]</sup> M <sub>⊙</sub>
Radius	1,050 <sup>[8]</sup> (-1,800 <sup>[10]</sup> ) R <sub>⊙</sub>
Temperature	3,826 <sup>[2]</sup> K
<b>B</b>	
Mass	8 <sup>[9]</sup> or 20 <sup>[7]</sup> M <sub>⊙</sub>
Radius	13 <sup>[7]</sup> R <sub>⊙</sub>
Metallicity	-0.14 <sup>[11]</sup>
Age	25 <sup>[12]</sup> Myr

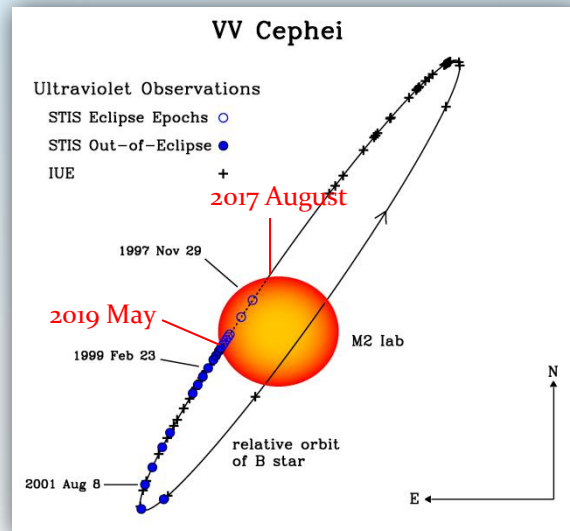




# Eclipsing Binary VV Cephei



Observation data	
Epoch J2000	Equinox J2000
Constellation	Cepheus
Right ascension	21 <sup>h</sup> 56 <sup>m</sup> 39.14385 <sup>s</sup> [1]
Declination	+63° 37' 32.0174 <sup>″</sup> [1]
Apparent magnitude (V)	4.91 <sup>[2]</sup> (4.80 - 5.36 <sup>[3]</sup> )
Characteristics	
U-B color index	+0.43 <sup>[4]</sup>
B-V color index	+1.73 <sup>[4]</sup>
Variable type	EA + SRc <sup>[3]</sup>
A	
Spectral type	M2 lab <sup>[2]</sup>
U-B color index	+2.07 <sup>[4]</sup>
B-V color index	+1.82 <sup>[4]</sup>
B	
Spectral type	B0-2 V <sup>[2]</sup>
U-B color index	-0.52 <sup>[4]</sup>
B-V color index	+0.36 <sup>[4]</sup>



Astrometry	
Parallax (π)	1.33 ± 0.20 <sup>[1]</sup> mas
Distance	4.9k ly (1.5k <sup>[5]</sup> pc)
Absolute magnitude (M <sub>V</sub> )	-6.93 <sup>[6]</sup>
Orbit <sup>[7]</sup>	
Period (P)	7,430.5 days
Semi-major axis (a)	16.2 ± 3.7 <sup>[2]*</sup> (12.7 AU)
Eccentricity (e)	0.346 ± 0.01
Inclination (i)	84 <sup>[8]*</sup>
Semi-amplitude (K <sub>1</sub> ) (primary)	19.43 ± 0.33 km/s
Semi-amplitude (K <sub>2</sub> ) (secondary)	19.14 ± 0.68 km/s
Details	
A	
Mass	2.5 <sup>[9]</sup> or 20 <sup>[10]</sup> M <sub>⊙</sub>
Radius	1,050 <sup>[8]</sup> (-1,800 <sup>[10]</sup> ) R <sub>⊙</sub>
Temperature	3,826 <sup>[2]</sup> K
B	
Mass	8 <sup>[9]</sup> or 20 <sup>[7]</sup> M <sub>⊙</sub>
Radius	13 <sup>[7]</sup> R <sub>⊙</sub>
Metallicity	-0.14 <sup>[11]</sup>
Age	25 <sup>[12]</sup> Myr

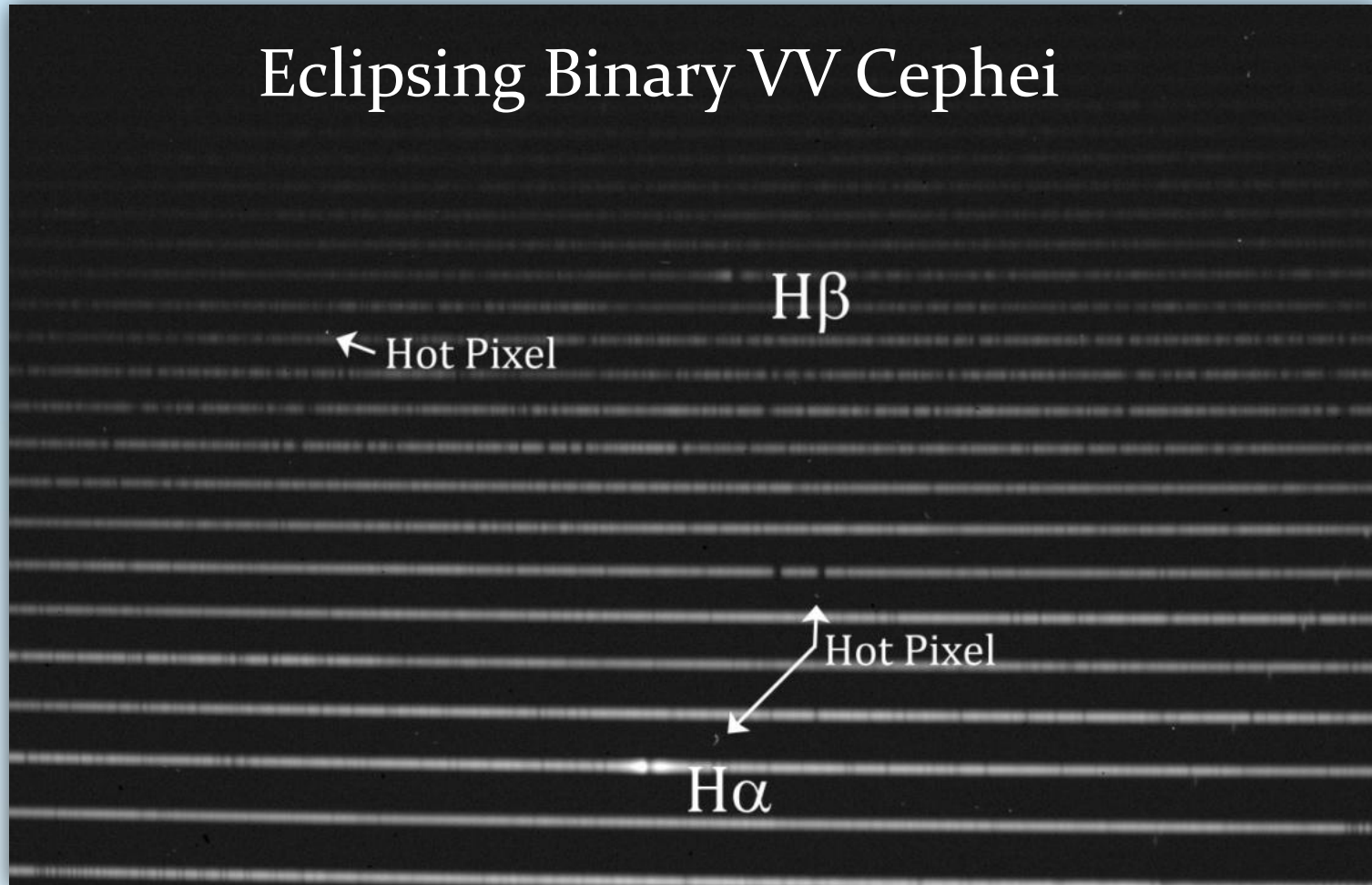


# BACHES

ECHELLE SPEKTROGRAPH  
and Remote Calibration Unit



## Eclipsing Binary VV Cephei



2015-10-11 | 21.23 UT



# BACHES

## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



## Eclipsing Binary VV Cephei

**Midas > calib/baches ff16os.fit thar8os.fit 22 20 20 0 0.1**

Orders: 22 | Width: 20 px | Extract: 20px | 0 | RMS: 0.1Å

SPECTRAL ORDER	NO. LINES	WL START	WL END	STD. DEV. ANGSTROEM
54	15	4068.25	4201.01	0.00411
53	21	4144.87	4280.23	0.00559
52	23	4224.45	4362.49	0.00489
51	25	4307.17	4447.98	0.00554
50	23	4393.21	4536.89	0.00451
49	22	4482.78	4629.43	0.00483
48	28	4576.10	4725.82	0.00468
47	28	4673.39	4826.32	0.00466
46	31	4774.92	4931.18	0.00564
45	25	4880.97	5040.69	0.00559
44	22	4991.85	5155.19	0.00451
43	30	5107.88	5275.00	0.00503
42	27	5229.45	5400.52	0.00466
41	26	5356.94	5532.16	0.00537
40	29	5490.81	5670.38	0.00444
39	31	5631.54	5815.68	0.00549
38	36	5779.68	5968.63	0.00520
37	40	5935.82	6129.84	0.00569
36	38	6100.63	6300.00	0.00487
35	21	6274.85	6479.89	0.00565
34	20	6459.30	6670.35	0.00609
33	19	6654.93	6872.36	0.00429

MEAN RMS: 0.00506

Each of the 22 orders from #33 to #54  
Will be saved calibrated in wavelength  
(RMS 0.00506Å) and saved in separate files  
for further processing:  
FITS, PNG, PDF



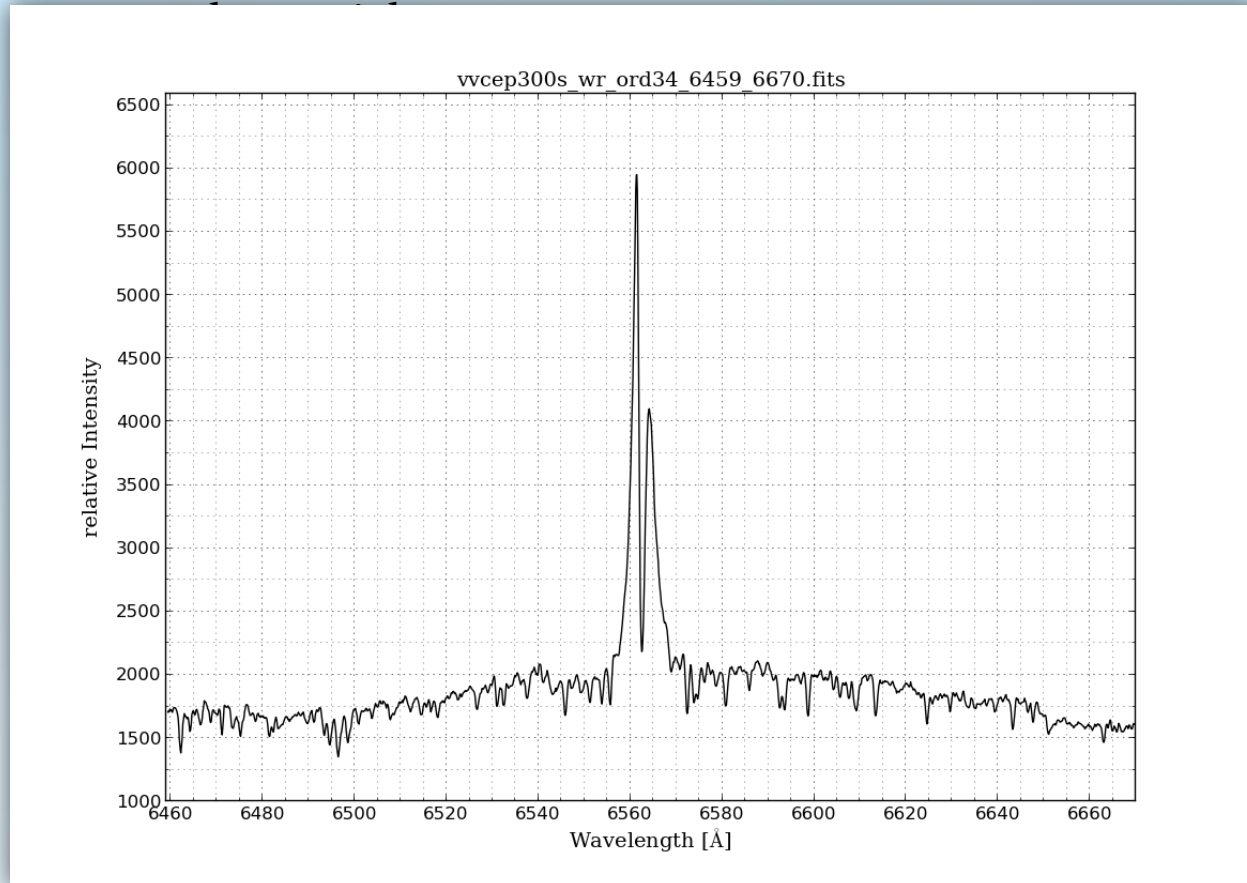
# BACHES

ECHELLE SPEKTROGRAPH  
and Remote Calibration Unit



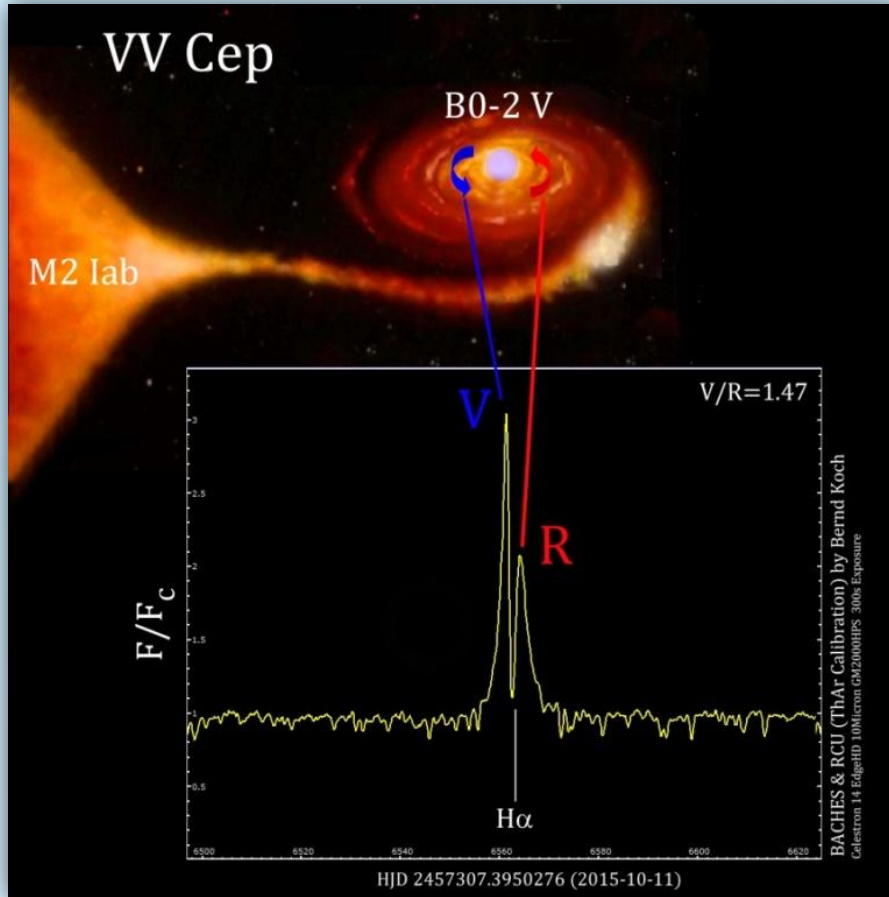
## Eclipsing Binary VV Cephei

Order #34 contains H $\alpha$ : 6459Å bis 6670Å





## Eclipsing Binary VV Cephei



Normalized peak intensities:  
V = 2.99, R = 2.04:  $V/R \approx 1.47$

Equivalent Width between 6550Å bis 6570Å  
 $EW_{\alpha} \approx -14.2\text{\AA}$

Heliocentric Radial Velocity of central  
Absorption:  $HRV \approx -14.0\text{ km/s}$

2015-10-11 | 21.24.30 UT  
HJD=2457307.39437



# BACHES

## ECHELLE SPEKTROGRAPH

### and Remote Calibration Unit



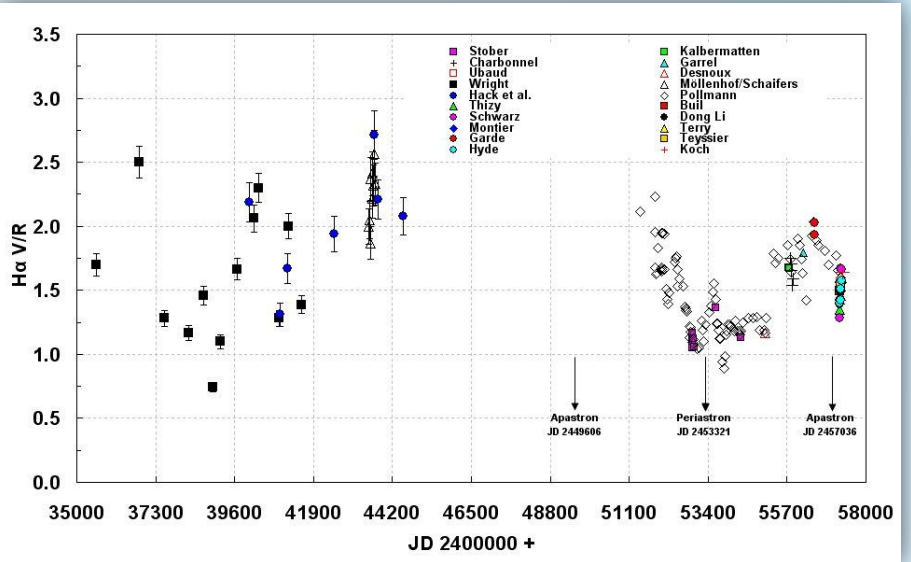
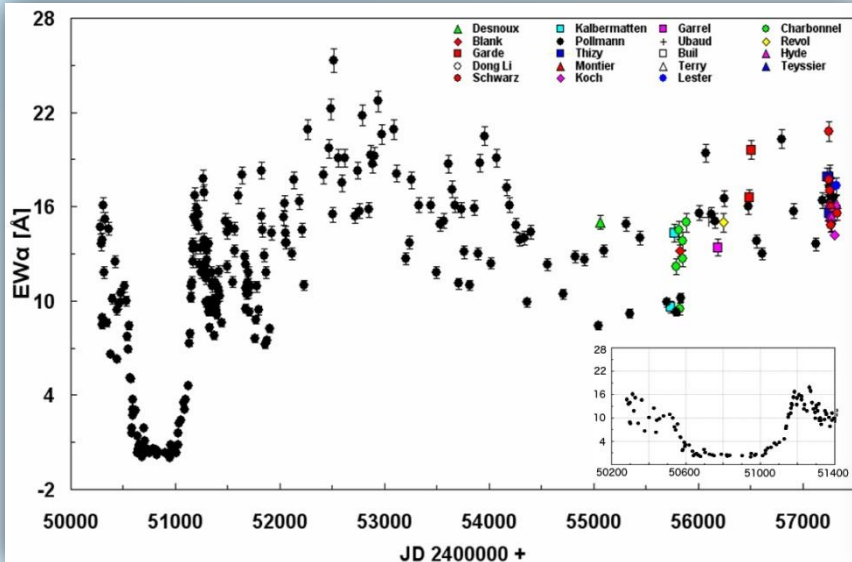
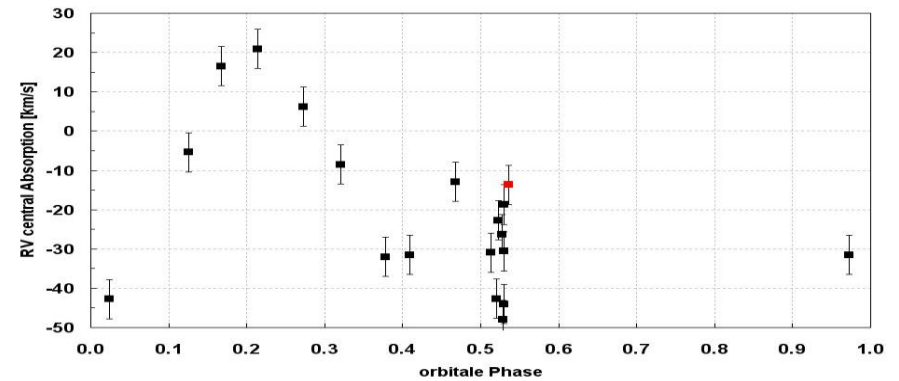
COMMISSIONS 27 AND 42 OF THE IAU  
 INFORMATION BULLETIN ON VARIABLE STARS  
 Number 6156

Konkoly Observatory  
 Budapest  
 11 January 2016  
 HU ISSN 1587 - 2440 (on-line)

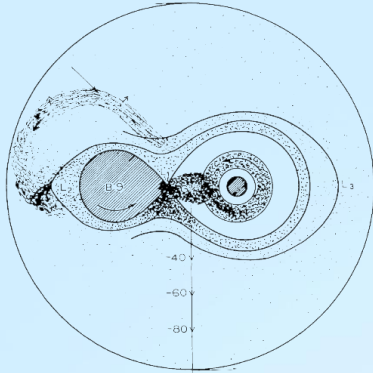
## The Long-term Binary System VV Cep

Pollmann, E.<sup>1</sup>; Bennett, P. D.<sup>2</sup>; Hopkins, J. L.<sup>3</sup>

- (1) International Working Group ASPA, Emil-Nolde-Str. 12, 51375 Leverkusen, Germany, e-mail: ernestospec @ hotmail . de
- (2) Department of Astronomy & Physics, Saint Mary's University, Halifax, NS B3H 3C3, e-mail: pbennett @ ap . smu . ca
- (3) 7812 West Clayton Drive, Phoenix, Arizona USA, e-mail: phjeff @ hposoft . com



Ernst Pollmann, <http://ibvs.konkoly.hu/cgi-bin/IBVS?6156>



## Semi-Detached Binary Star $\beta$ Lyrae

### 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 **simultaneously** at different wavelengths in the BACHES echelle spectrum



Fig. 2: Spectrum of semi-detached binary system  $\beta$  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  $\mu$ m. This is a single 300s exposure from which a darkframe has been subtracted.

$\beta$  Lyrae / BACHES © Bernd Koch



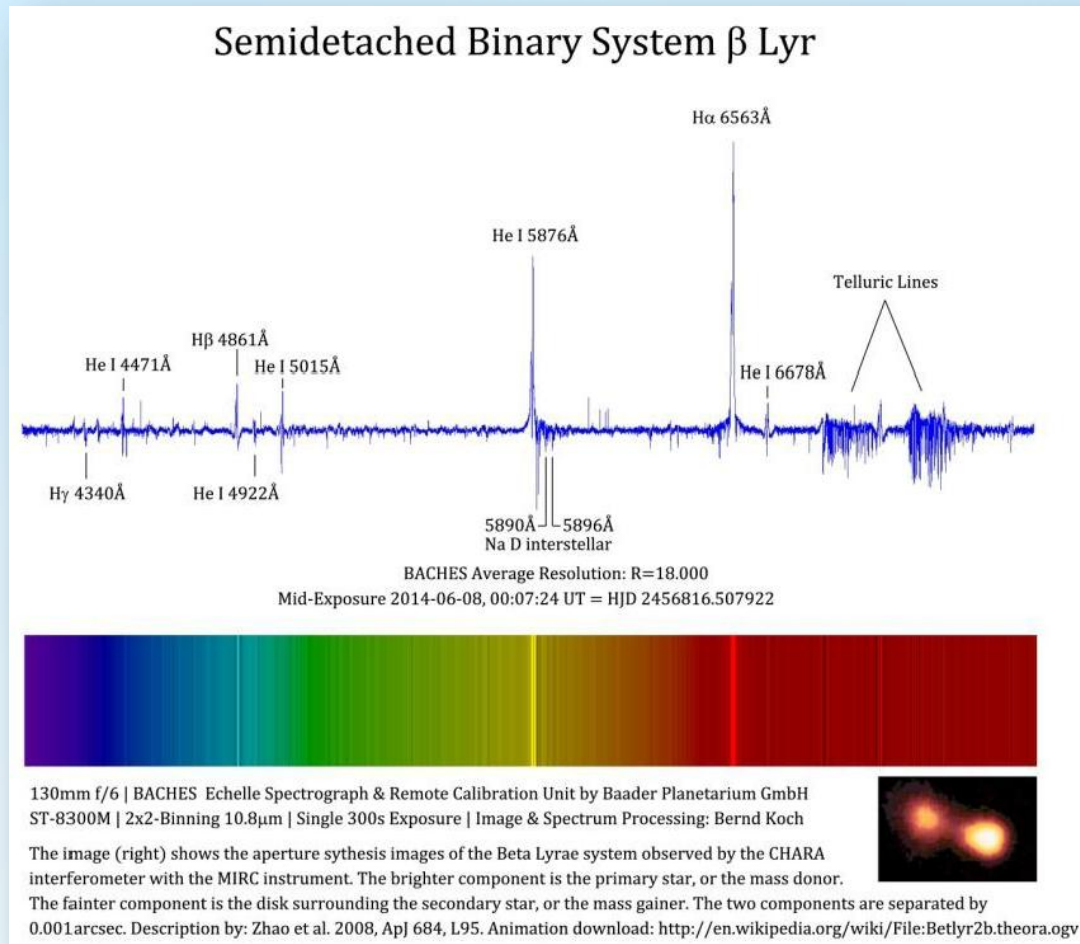
# BACHES

## ECHELLE SPEKTROGRAPH

### and Remote Calibration Unit



## Semi-Detached Binary Star $\beta$ Lyrae



www.baader-planetarium.de/baches/





# BACHES

## ECHELLE SPEKTROGRAPH

and Remote Calibration Unit



## Semi-Detached Binary Star $\beta$ Lyrae

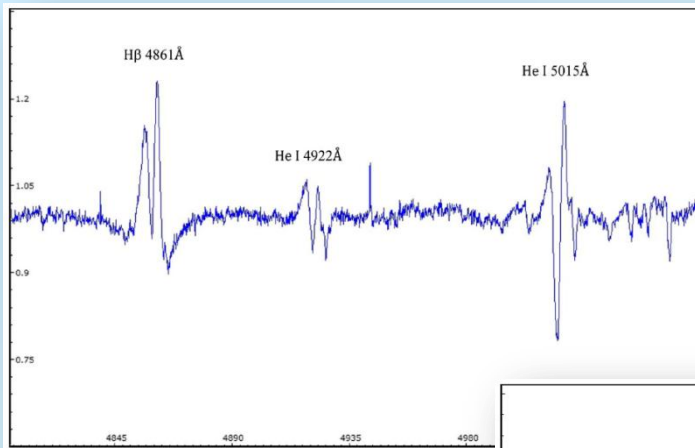


Fig. 7: This is a section of the recorded BACHES echelle spectrum showing varying strength of P-Cygni-Profiles at H $\beta$  4861Å, He I 4922Å, and He I 5015Å with different flux.

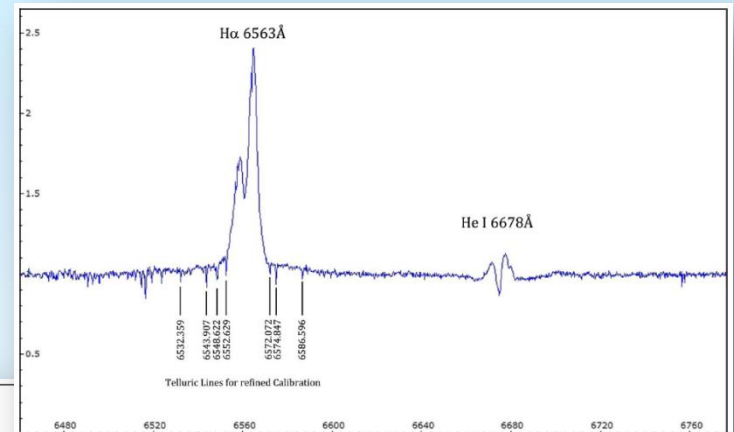


Fig. 9: Detail near H $\alpha$  6563Å and He I 6678Å. The precisely known wavelengths of the telluric lines around H $\alpha$  can be used for fine calibration of that section of the spectrum.

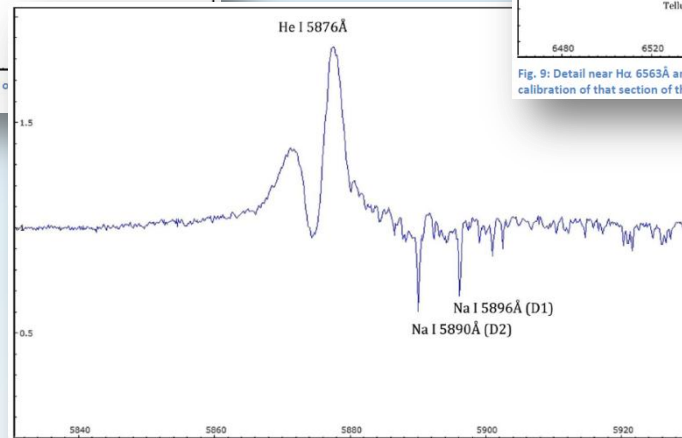


Fig. 8: P-Cygni-profile of  $\beta$  Lyr at He I 5876Å is close to the narrow interstellar Sodium lines (Na I Doublet D1, D2). "The He I 5876Å and the He I 6678 lines are well suited for the study of the stellar wind from the [B8...] B9 component of  $\beta$  Lyr" (Ettel, Meyer; 1983). The Na I Doublet 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](http://www.baader-planetarium.de/baches/download/beta_lyr_baches_poster_e2_bernd_koch.pdf)



# BACHES

ECHELLE SPEKTROGRAPH  
and Remote Calibration Unit



## Thank you very much for your attention

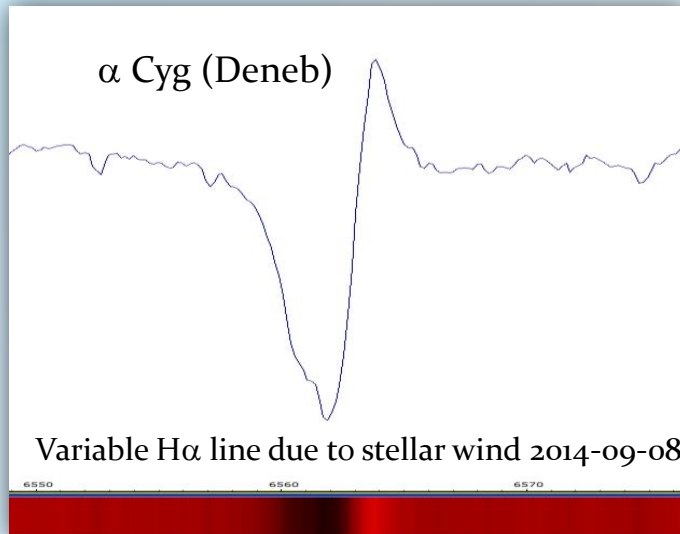
**BACHES Website:**

[www.baader-planetarium.de/baches/](http://www.baader-planetarium.de/baches/)

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ATT Essen May 21, 2016 | Bernd Koch | Baader Planetarium GmbH