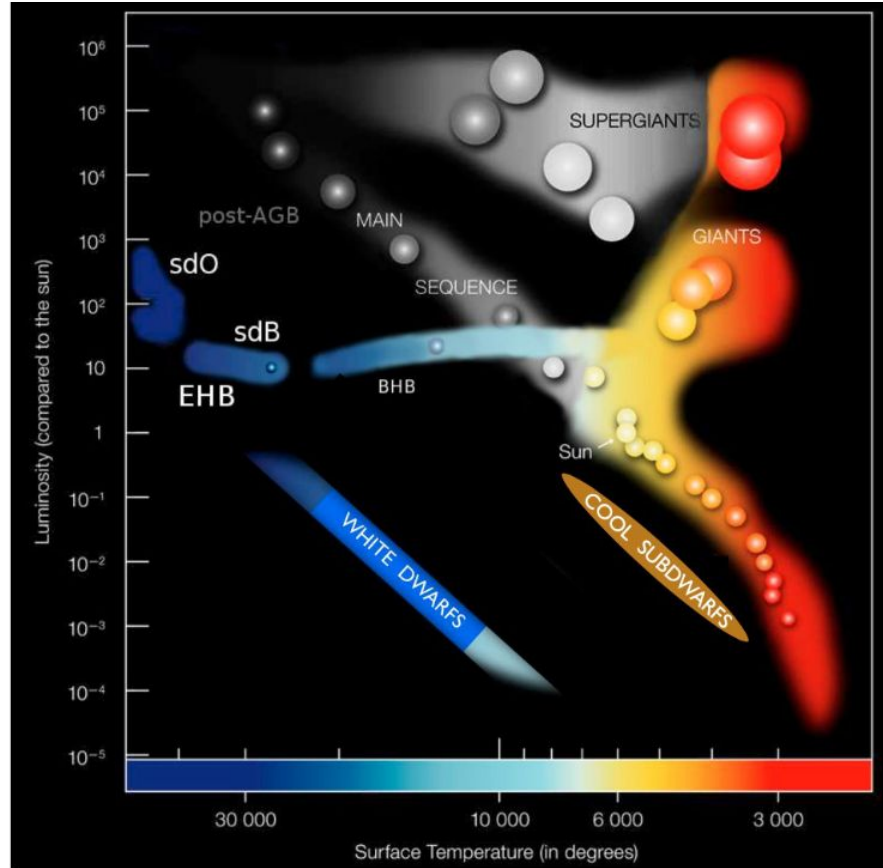


Study into the Binarity of BHB Stars

Partík, Vojtěch | Pininti, Vivek Reddy | Vávra, Michael

Introduction

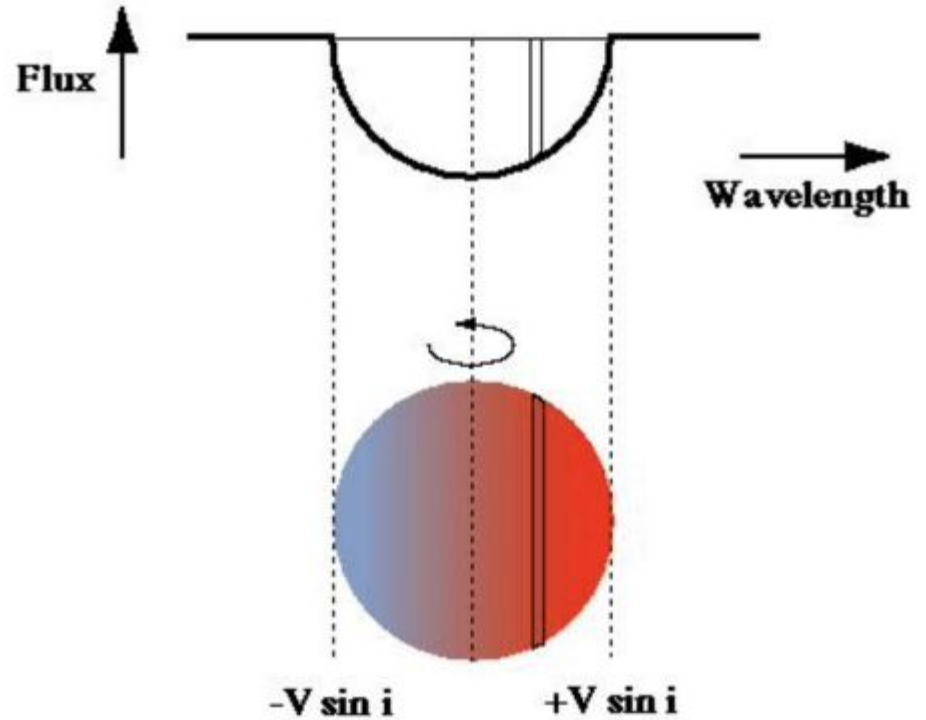
- BHB binaries
- EHB - binary interaction
- EHB vs BHB binary?
- BHB binaries? Created by binary interactions?



From Heber (2009); copyright Annual Review of Astronomy & Astrophysics

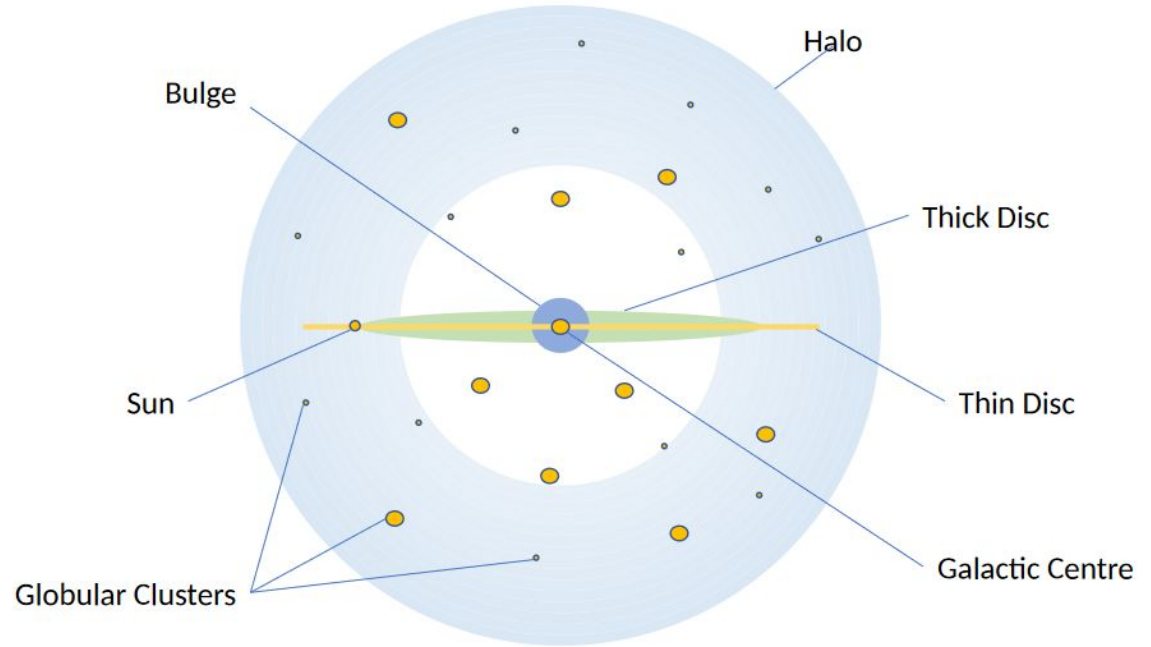
Introduction

- Spectral lines
- Radial velocities
- Doppler effect
- Rotational speed \propto width of spectral lines



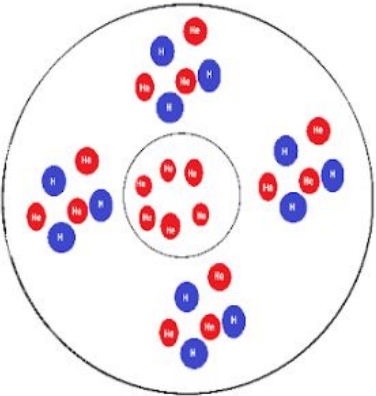
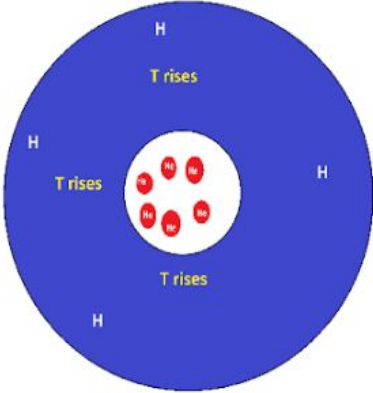
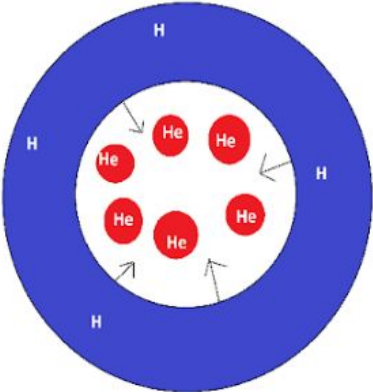
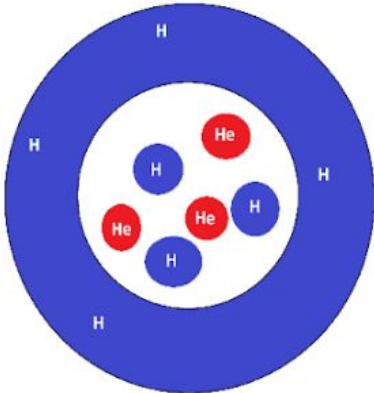
Introduction

- BHB in Halo
- Sun 220 km/s
- BHB $v_{\text{tan}} > 145$ km/s

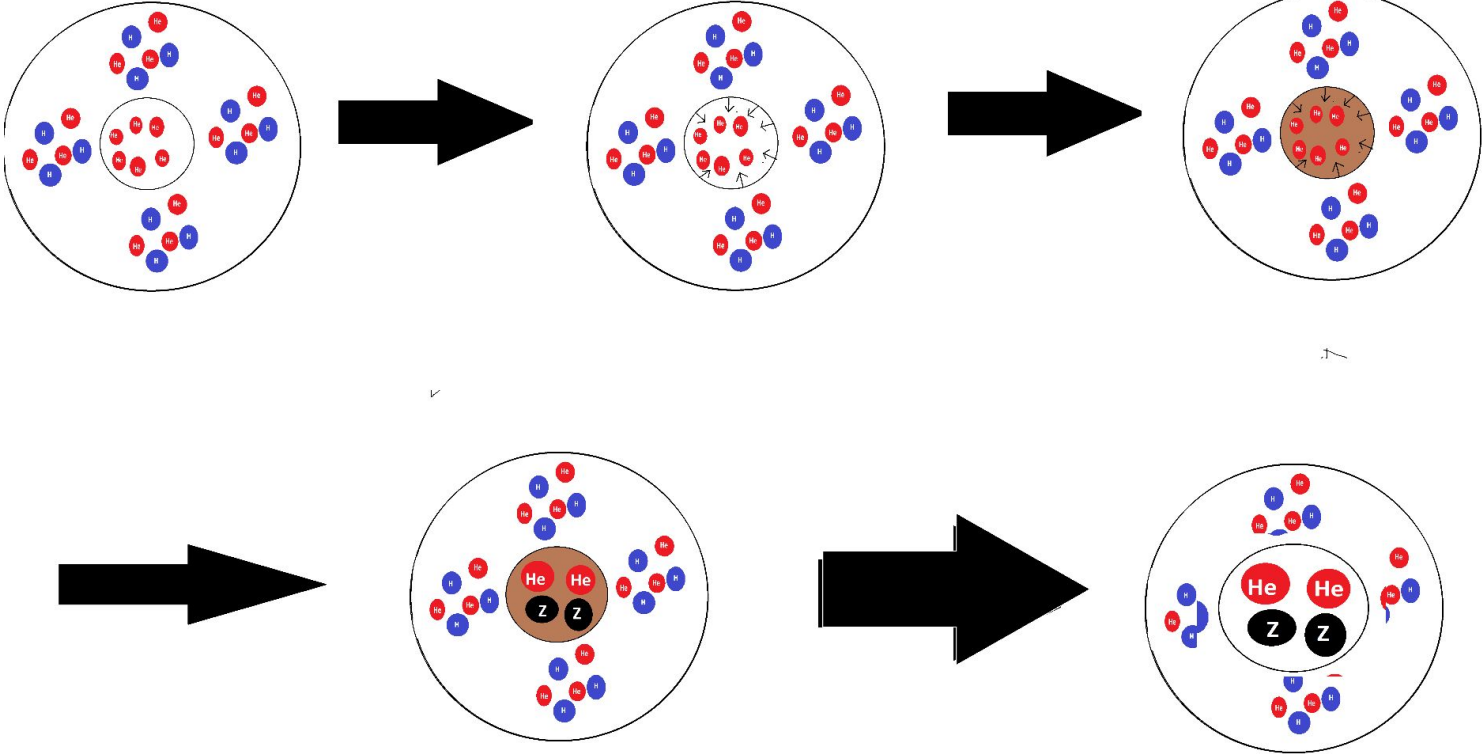


Courtesy of Rick Culpan

From MS to RGB



From RGB to BHB



Object Selection

→ ~28000 BHB-candidates

→ Gaia DR3 Quality Criteria

- ◆ Parallax > 0
- ◆ Parallax error $< 20\%$
- ◆ Proper motion error $< 20\%$
- ◆ $-0.6 < \text{phot_bp_rp_excess_factor_corrected} < 0.6$
- ◆ $\text{astrometric_sigma_5d_max} < 1.5$

→ Magnitude cut

- ◆ initially, < 10.5 , later relaxed to < 10.9

→ Filtering by time of the year

- ◆ At most 6 hrs away from the Sun's RA on either side

→ Filtering by location

- ◆ altitude of objects at least 50°
 - $\delta > 10^\circ$

Instruments

Perek 2m Telescope



OES

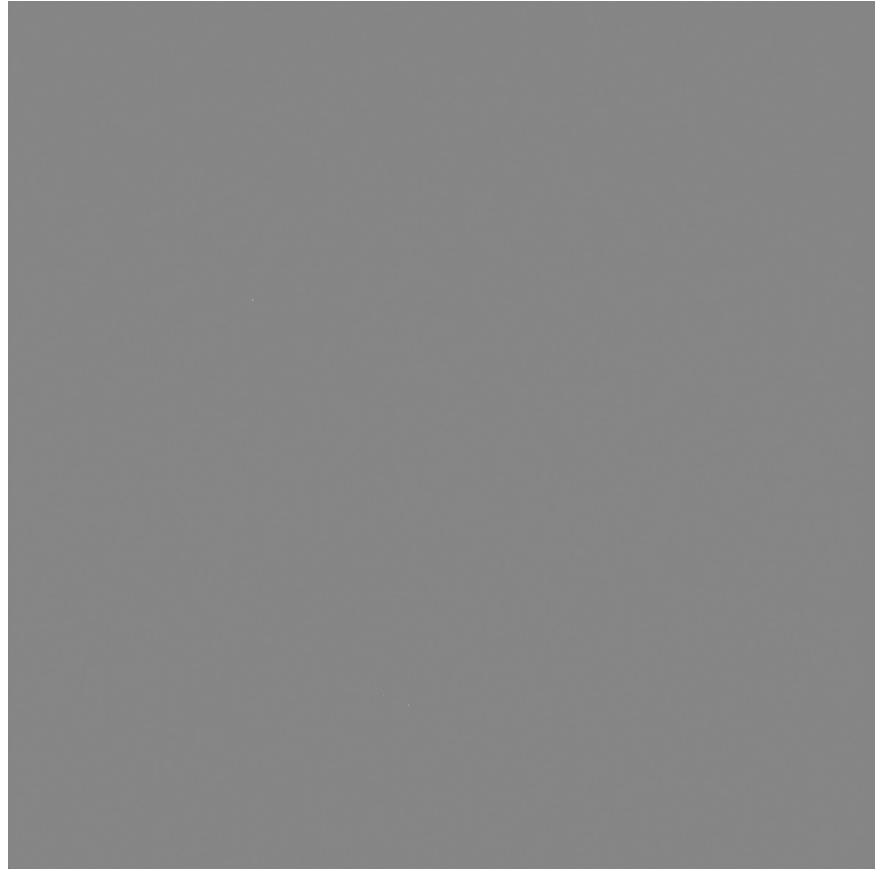


Obtaining data

Calibration frames

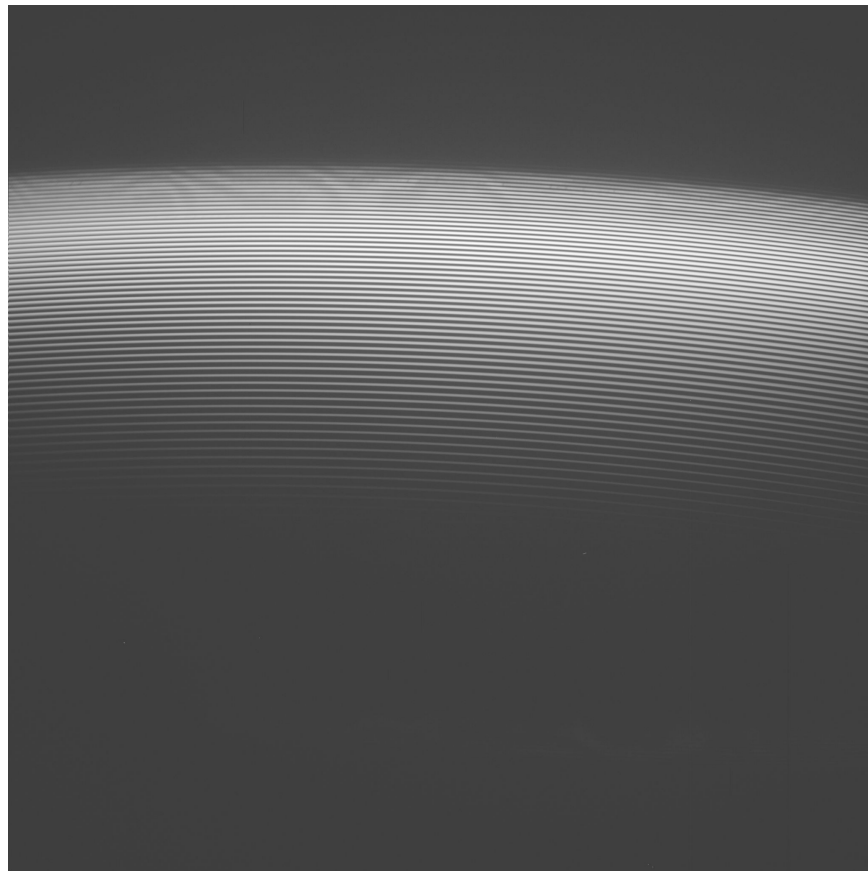
Obtaining data

Calibration frames · ZERO (BIAS)



Obtaining data

Calibration frames · FLAT



Obtaining data

Calibration frames · COMPARISON

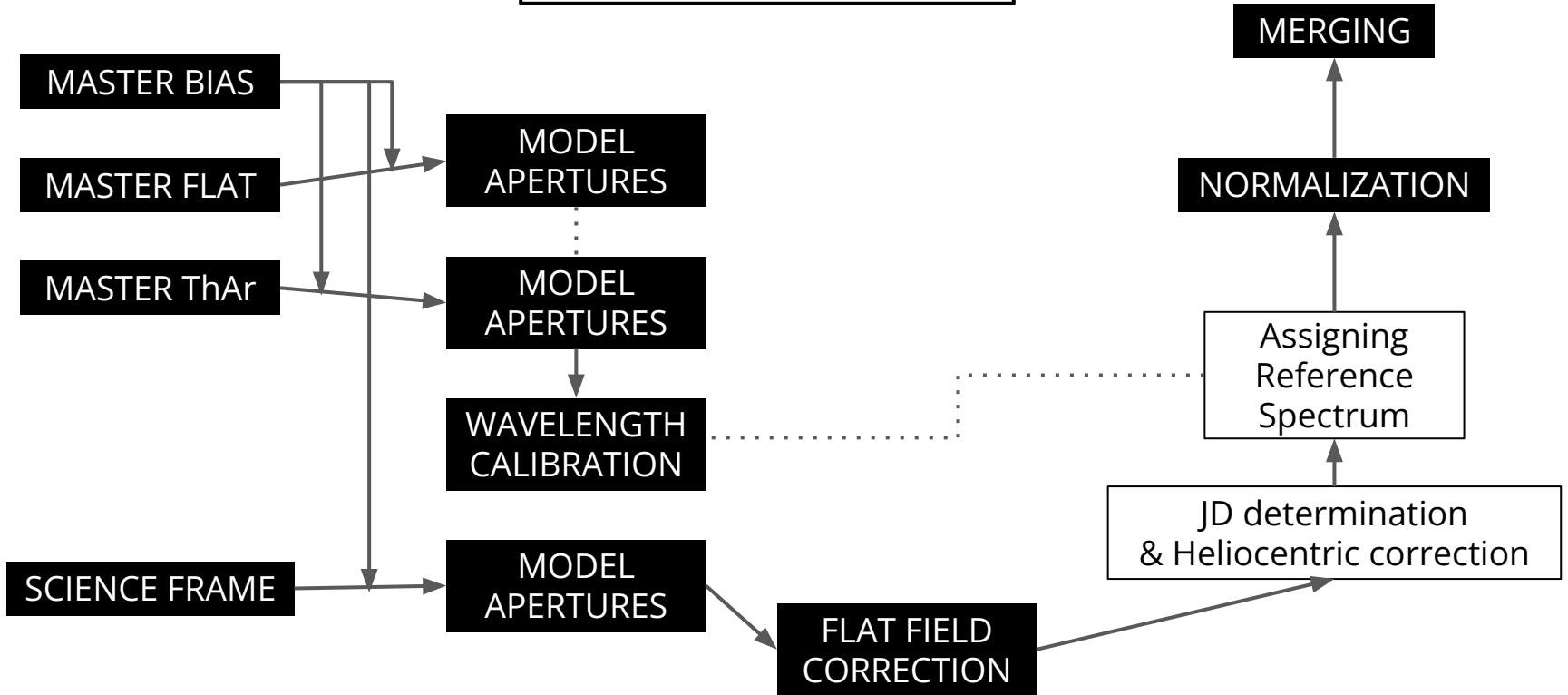
Thorium-Argon lamp



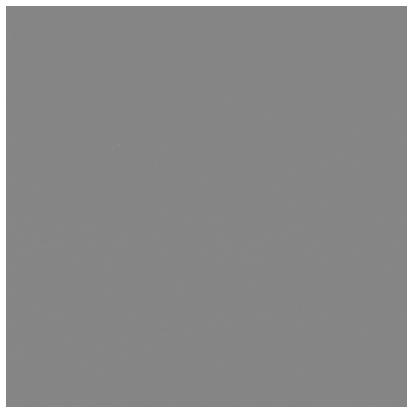
Data Reduction



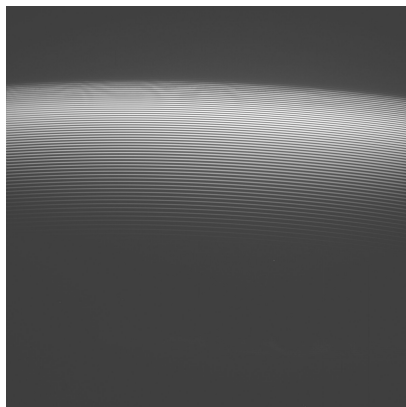
THE ALGORITHM



BIASES



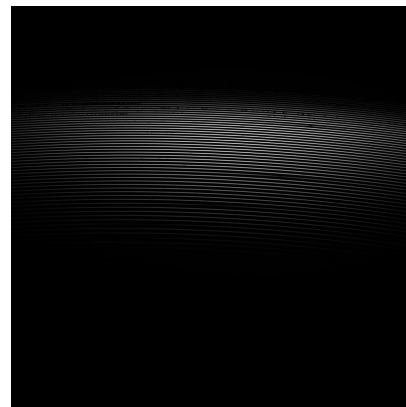
FLATS



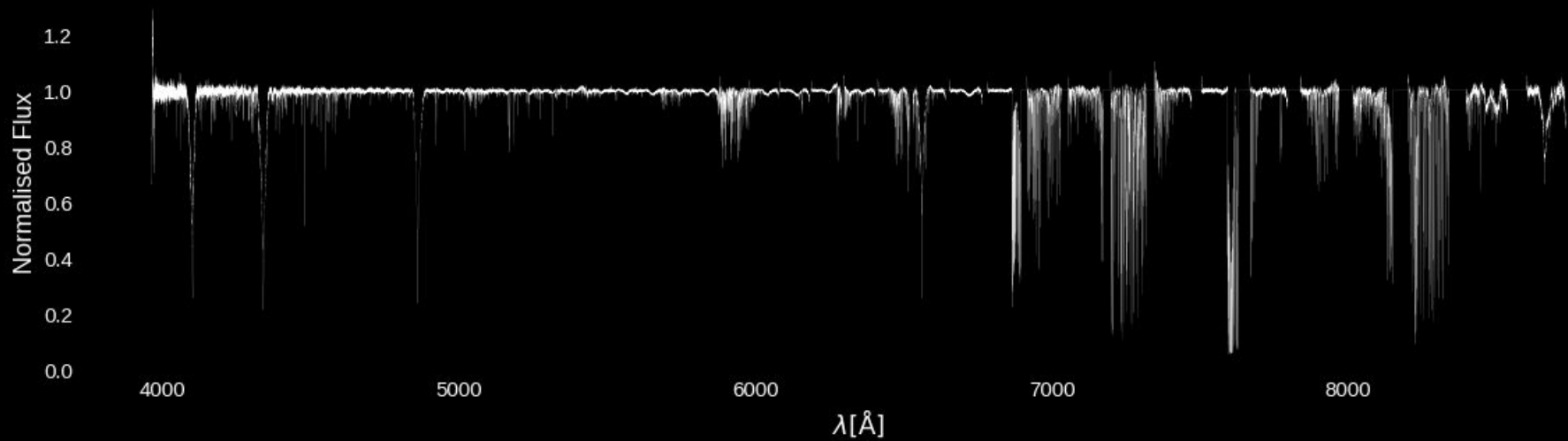
COMPS



SCIENCE

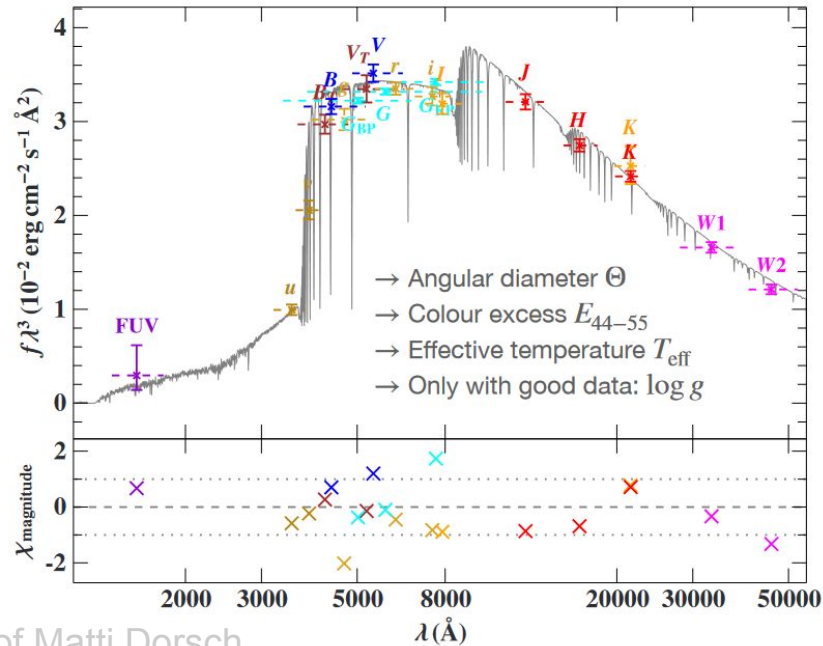


NORMALISED & MERGED SPECTRA



SED = Spectral energy distribution

- Measurements in different filters -> SED -> T_{eff} and L/L_{\odot} -> put in HR diagram



Courtesy of Matti Dorsch

https://www.astro.physik.uni-potsdam.de/~mdorsch/analysis_basic.pdf

An approximate position of a star in HR diagram

- HR diagram is also M_V vs B-V colour

$$M_V = V_0 + 5 - 5\log_{10}(d [\text{parsecs}]) \cong V_0 + 5 + 5\log_{10}(p [\text{arcseconds}])$$

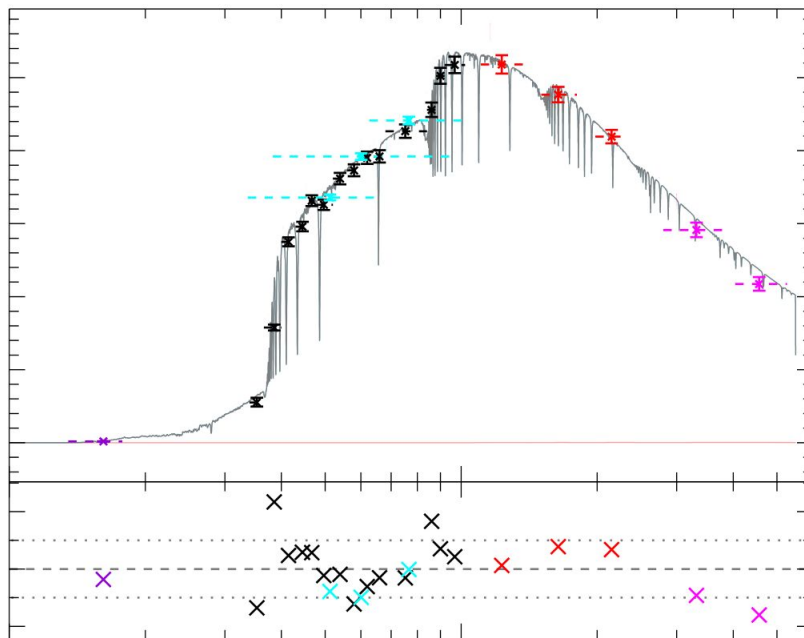
p = parallax

V_0 = magnitude in filter V corrected by interstellar extinction

B = magnitude in filter V uncorrected by interstellar extinction

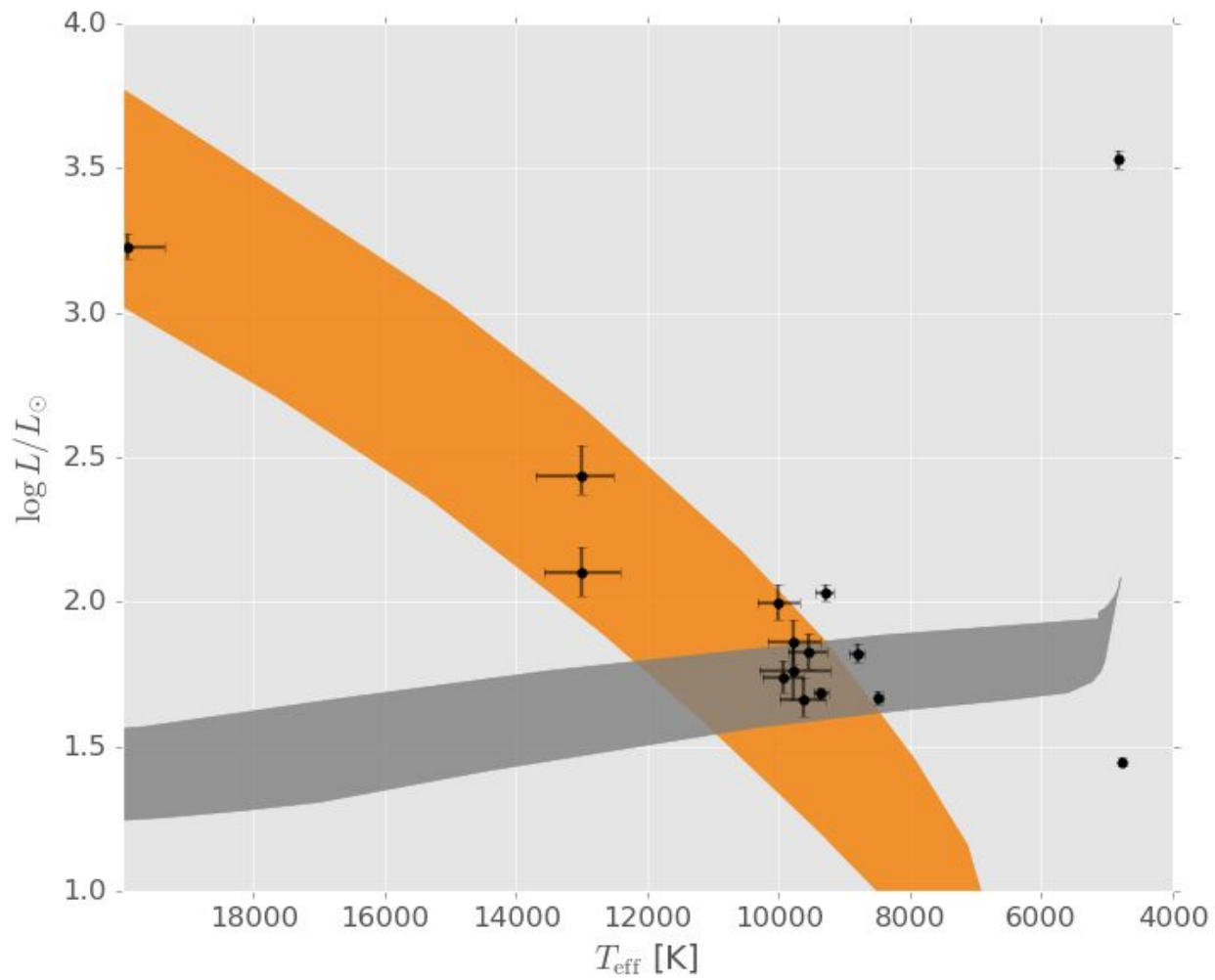
SED of ours measured stars

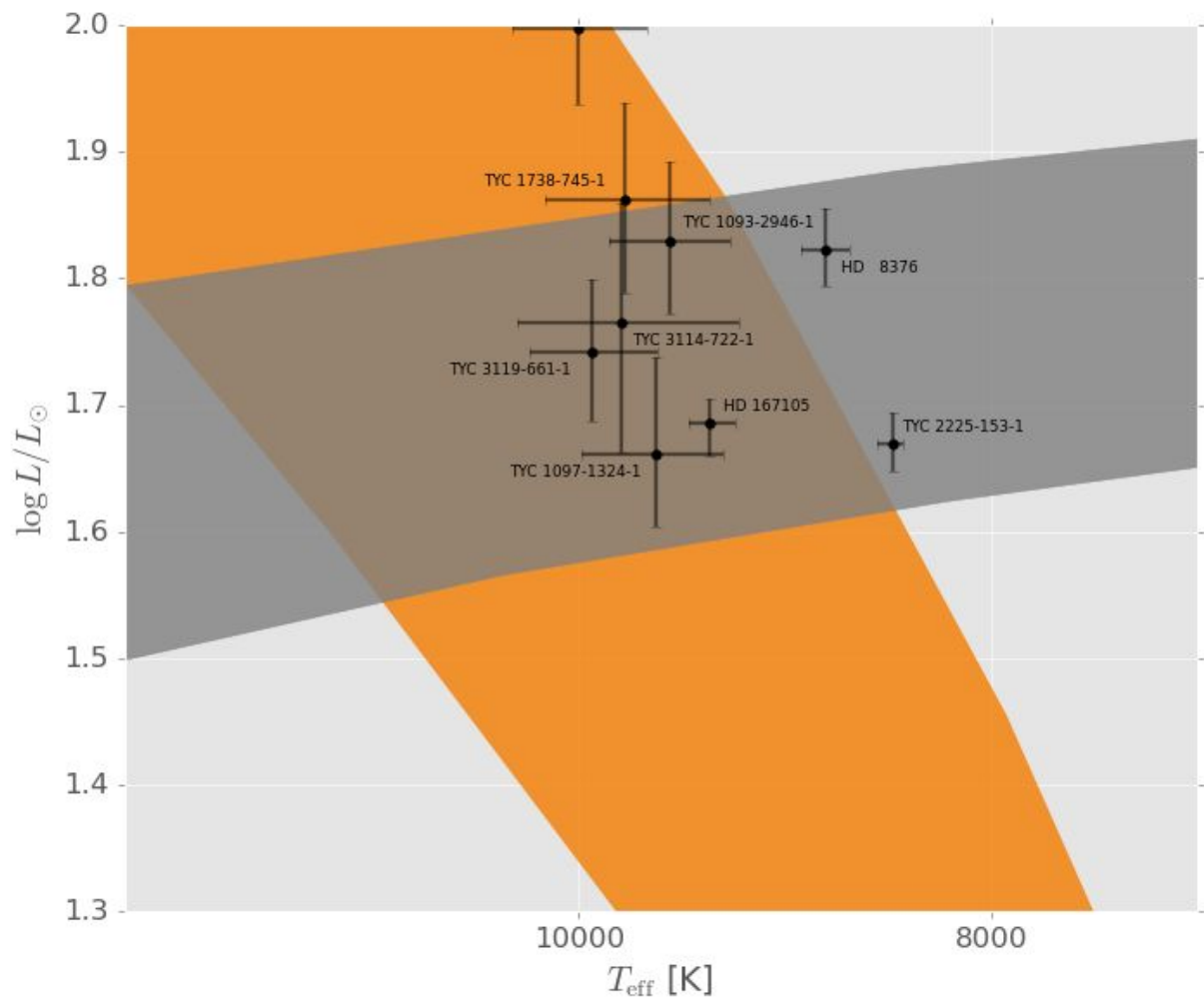
- For example SED of star TYC 2225-153-1 we measured



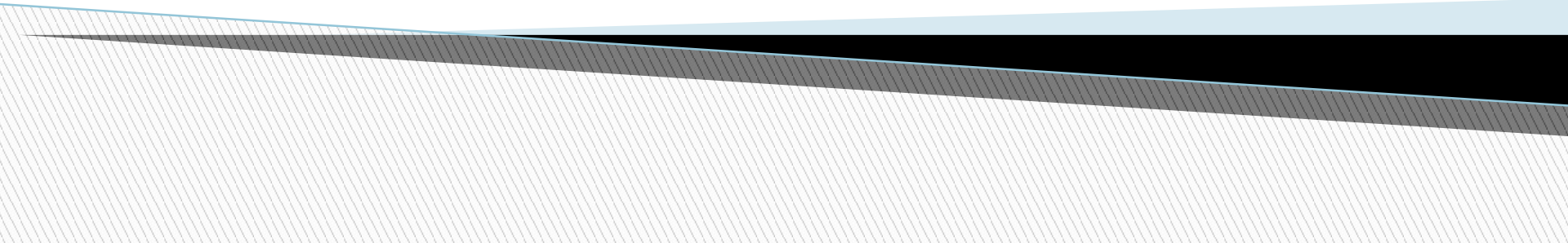
How to create SED of a star

- `isis photometry_auto.sl` Gaia DR3 ID
- Searches in different catalogues



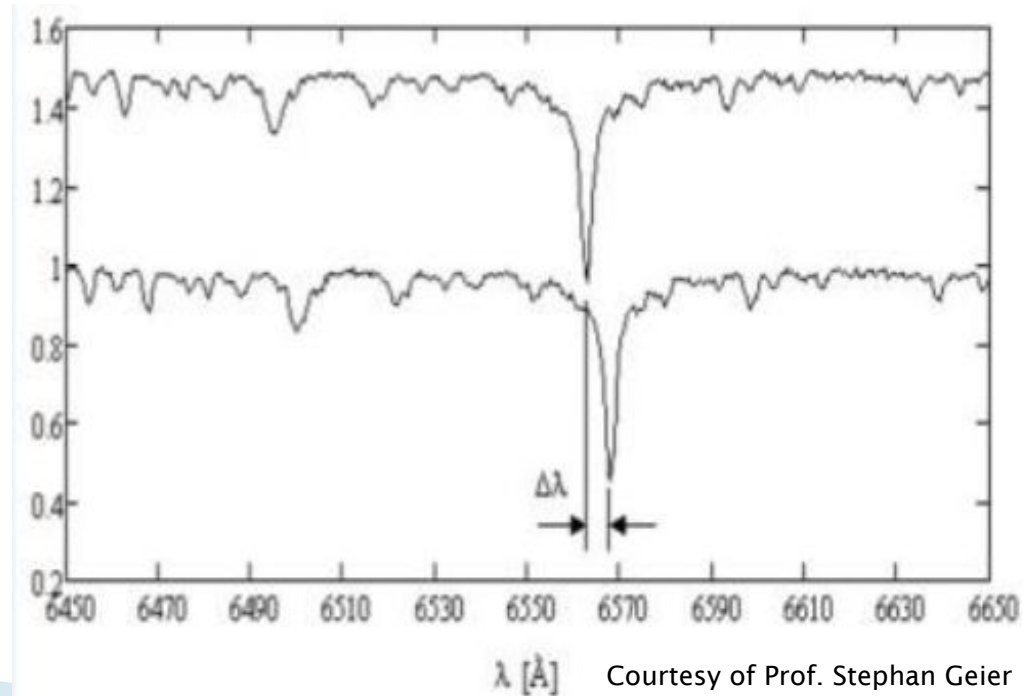


Radial velocity



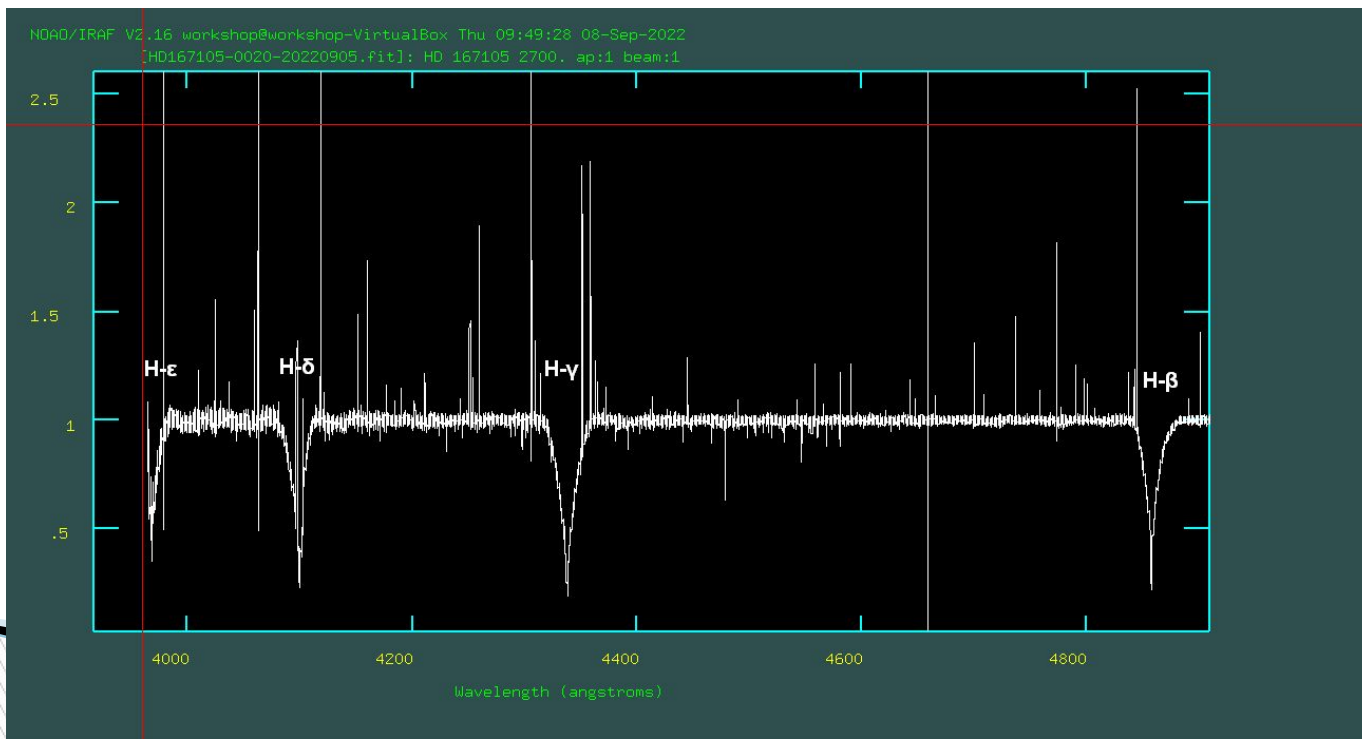
Method

▶ Doppler shift: $v_{rad} = c \cdot \frac{\Delta\lambda}{\lambda_{lab}}$ for $v \ll c$



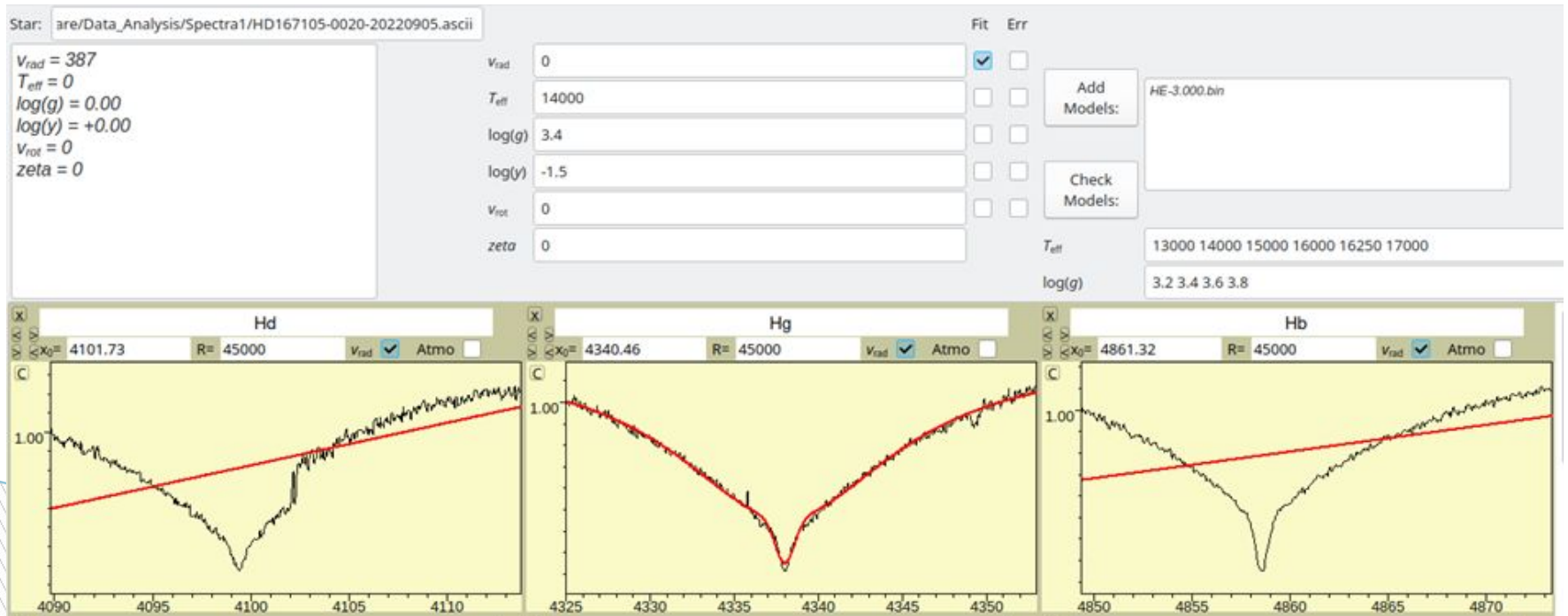
Method

- Acquired spectrum (example HD 176105)

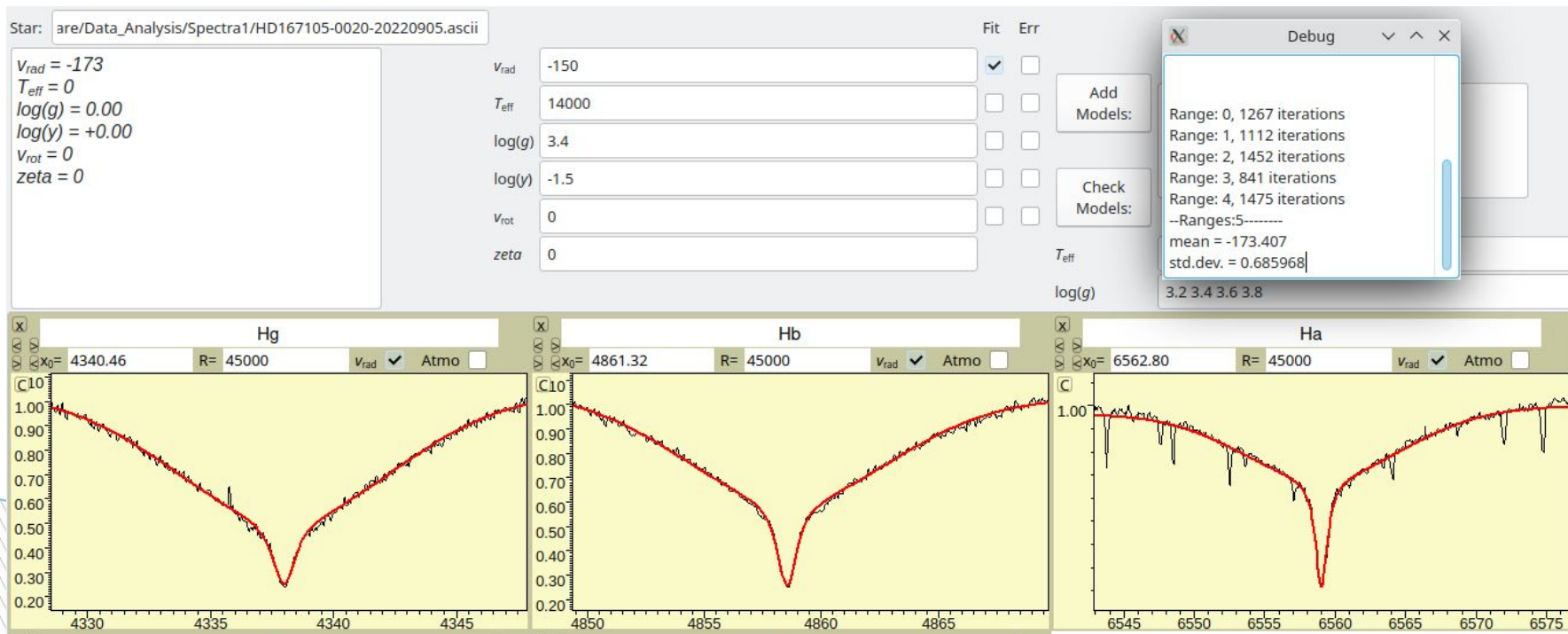


Spectrum Plotting and Analysis Suite (SPAS)

- Spectrum into ASCII and import to SPAS

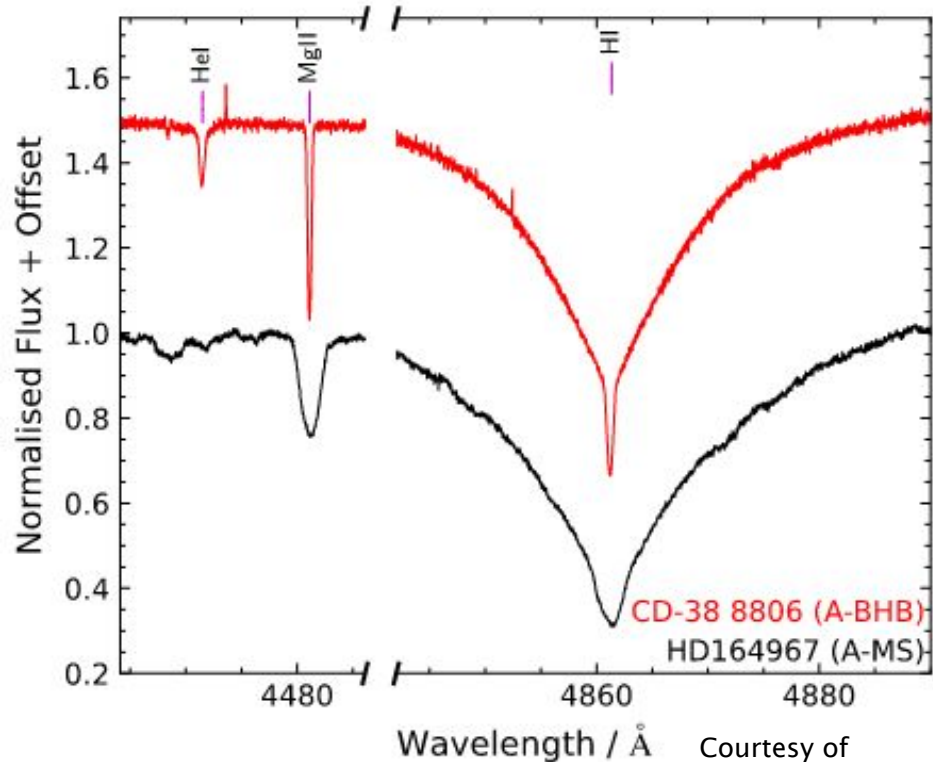


Spectrum Plotting and Analysis Suite (SPAS)



Identifying BHB stars

- Old, metal-poor
- Slow rotators
- Sharper absorption lines



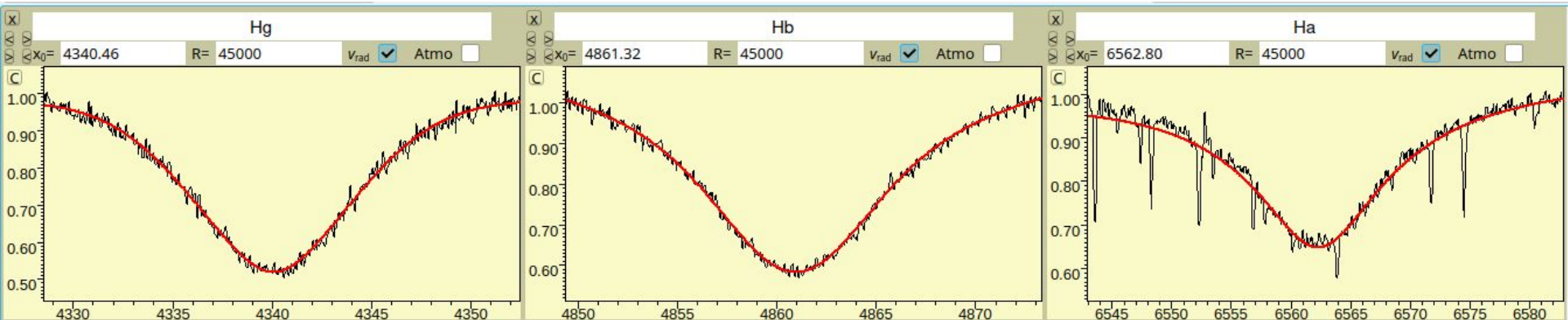
Courtesy of
Matti Dorsch

BD+18 3429

RA: 17:39:20.947

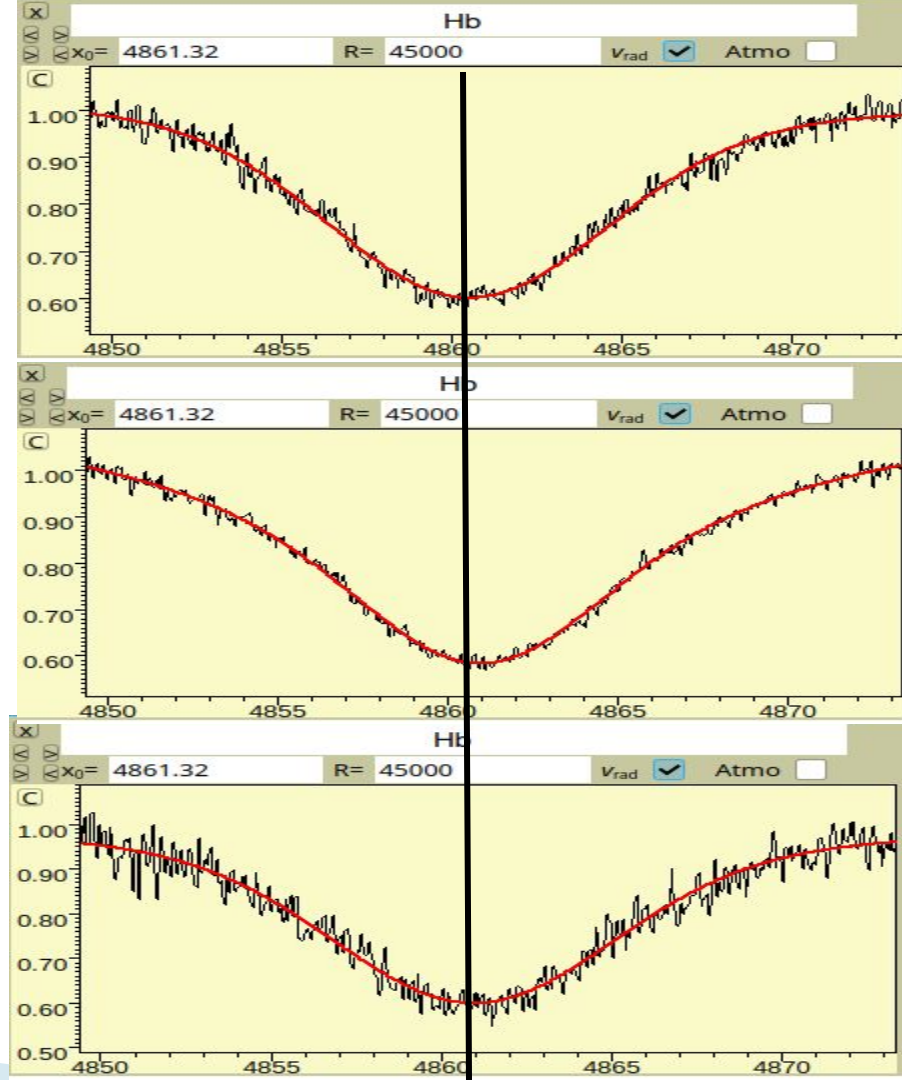
Dec: 18:20:29.50

mag (G): 9.22



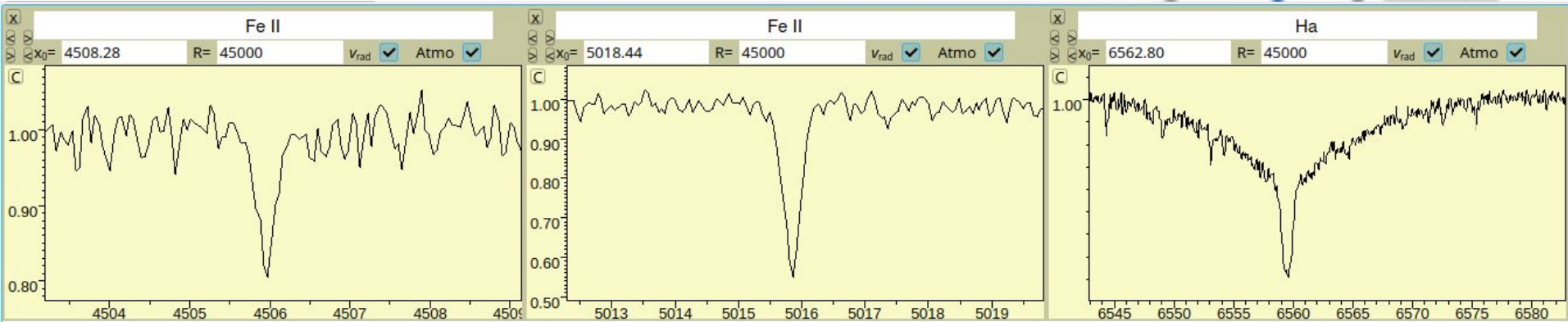
BD+18 3429

- ▶ 9.9.2021
 - $v_{rad} = (-54.43 \pm 2.00)$ km/s
- ▶ 12.8.2022
 - $v_{rad} = (-21.778 \pm 2.30)$ km/s
- ▶ 30.8.2022
 - $v_{rad} = (-25.70 \pm 0.63)$ km/s
- ▶ We can detect very slight shift
- ▶ Very wide lines
- ▶ Long period MS binary star



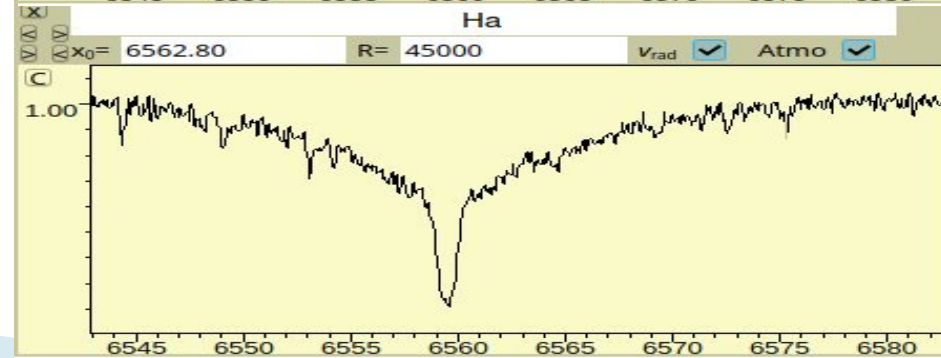
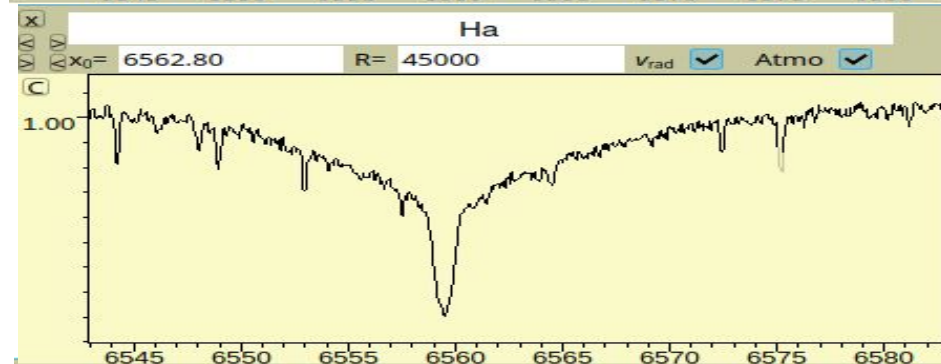
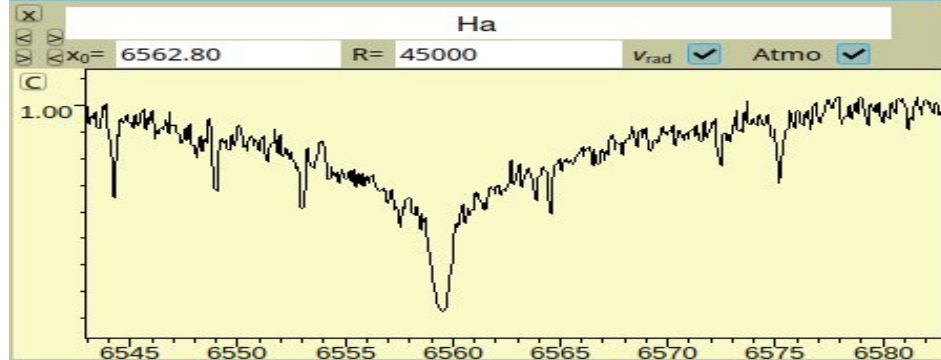
TYC 1738-745-1

- RA: 00:39:01.6427
- Dec: 24:12:06.609
- mag (G): 10.36



TYC 1738-745-1

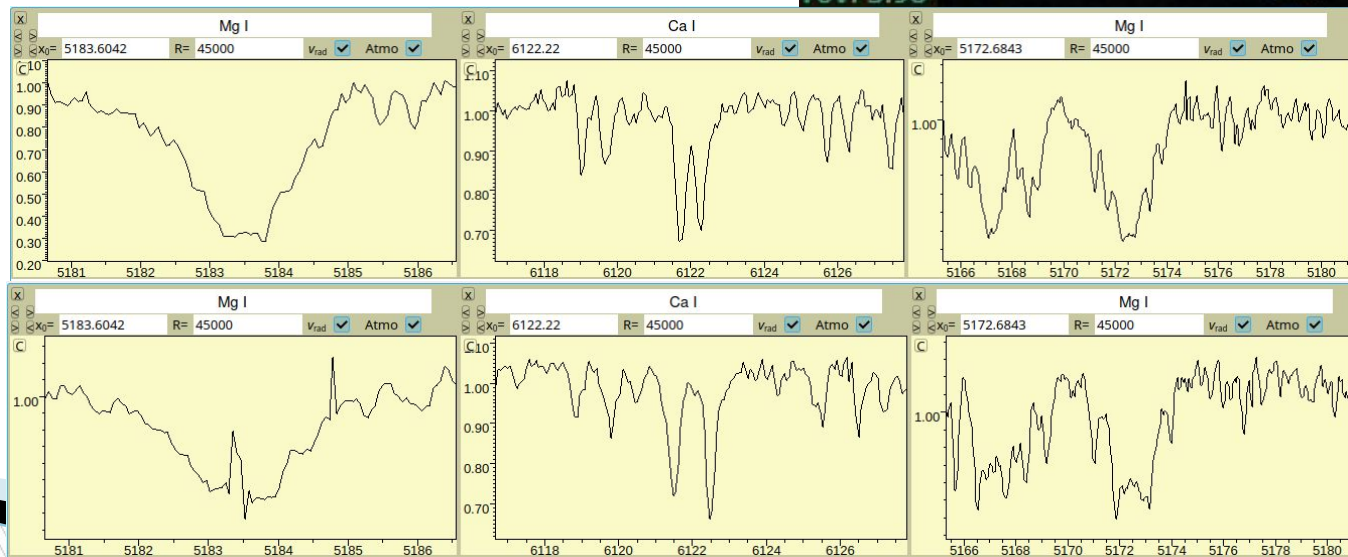
- ▶ 13.9.2021
 - $v_{rad} = (-155.55 \pm 0.95)$ km/s
- ▶ 14.9.2021
 - $v_{rad} = (-155.01 \pm 0.63)$ km/s
- ▶ 3.9.2022
 - $v_{rad} = (-154.74 \pm 0.81)$ km/s
- ▶ Narrow H lines
- ▶ Likely a BHB star
- ▶ No apparent line shift



BD+20 5391

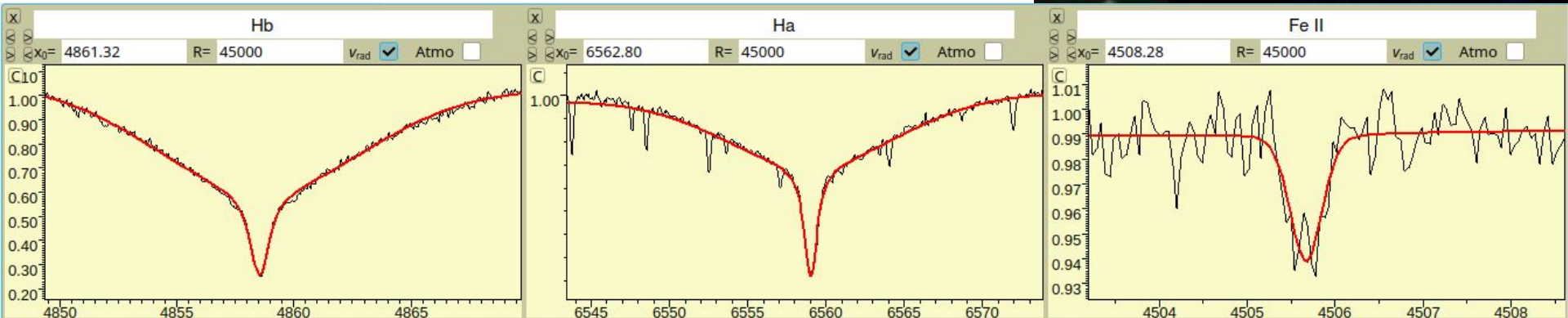
- RA: 23:53:44.7349
- Dec: 21:34:44.124
- mag (G): 9.41

- 12.8.2022
- **2.9.2022**
- Red binary giant



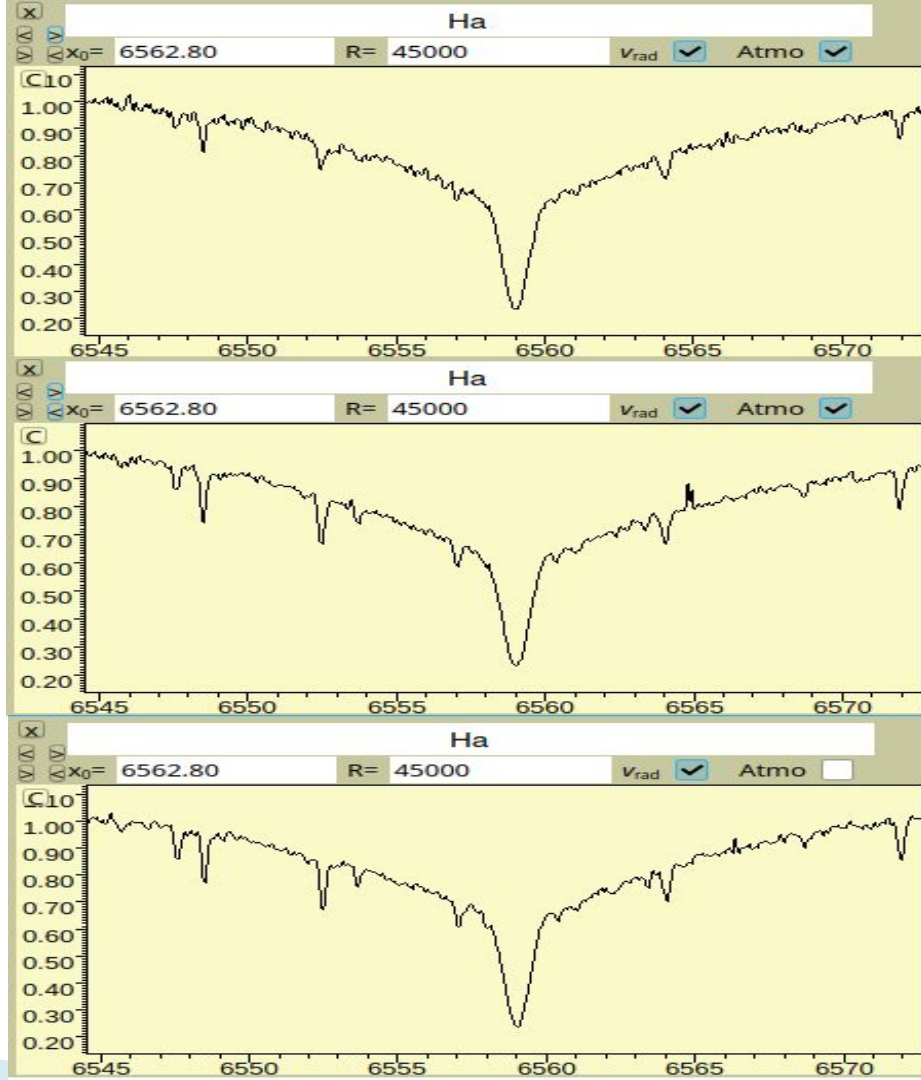
HD 167105

- RA: 18:11:06.307
- Dec: 50:47:32.49
- mag (G): 8.95



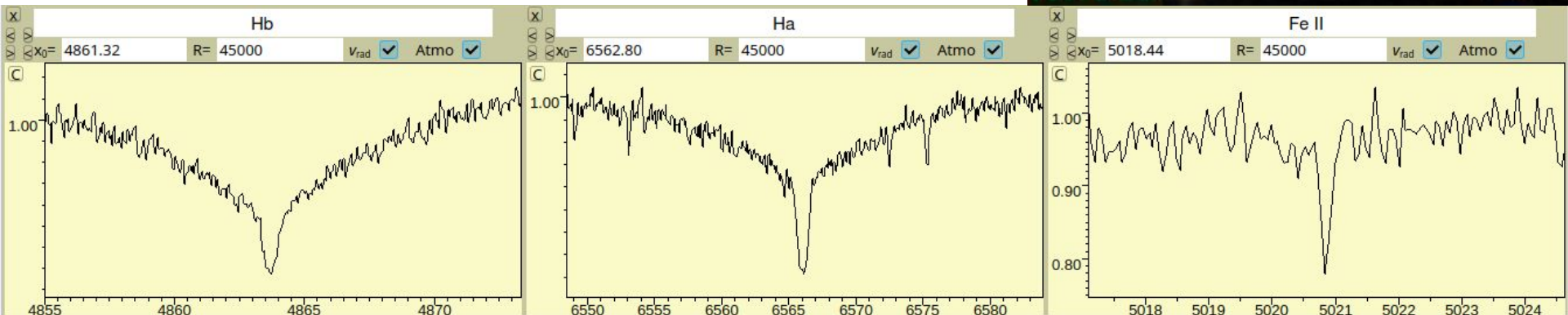
HD 167105

- ▶ 8.9.2021
 - $v_{rad} = (-173.87 \pm 0.73)$ km/s
- ▶ 14.9.2021
 - $v_{rad} = (-173.53 \pm 1.65)$ km/s
- ▶ 5.9.2022
 - $v_{rad} = (-173.71 \pm 0.50)$ km/s
- ▶ Narrow H lines
- ▶ Likely a BHB star
- ▶ No apparent line shift



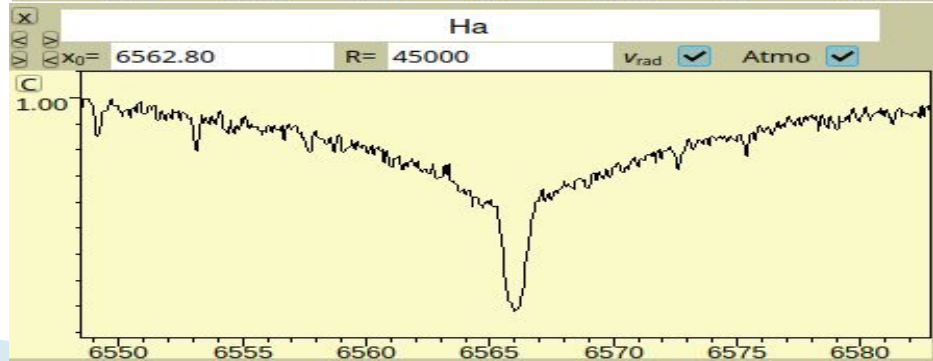
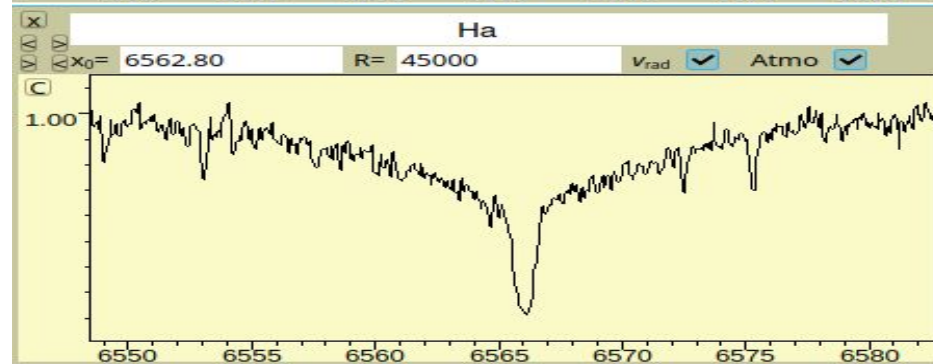
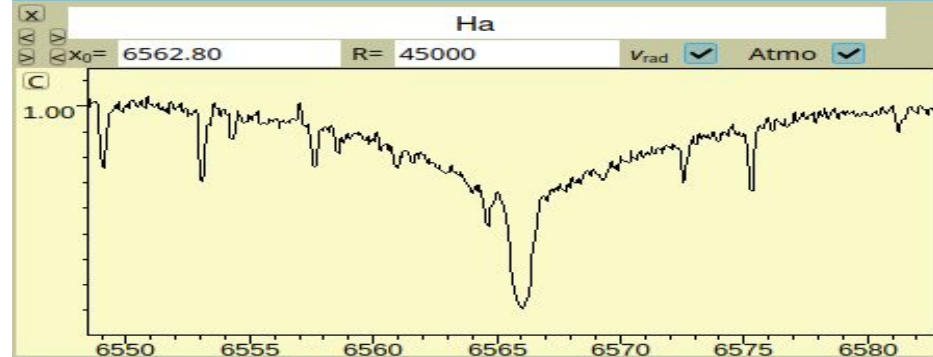
HD 8376

- RA: 01:23:28.2884
- Dec: 31:47:12.260
- mag (G): 9.61

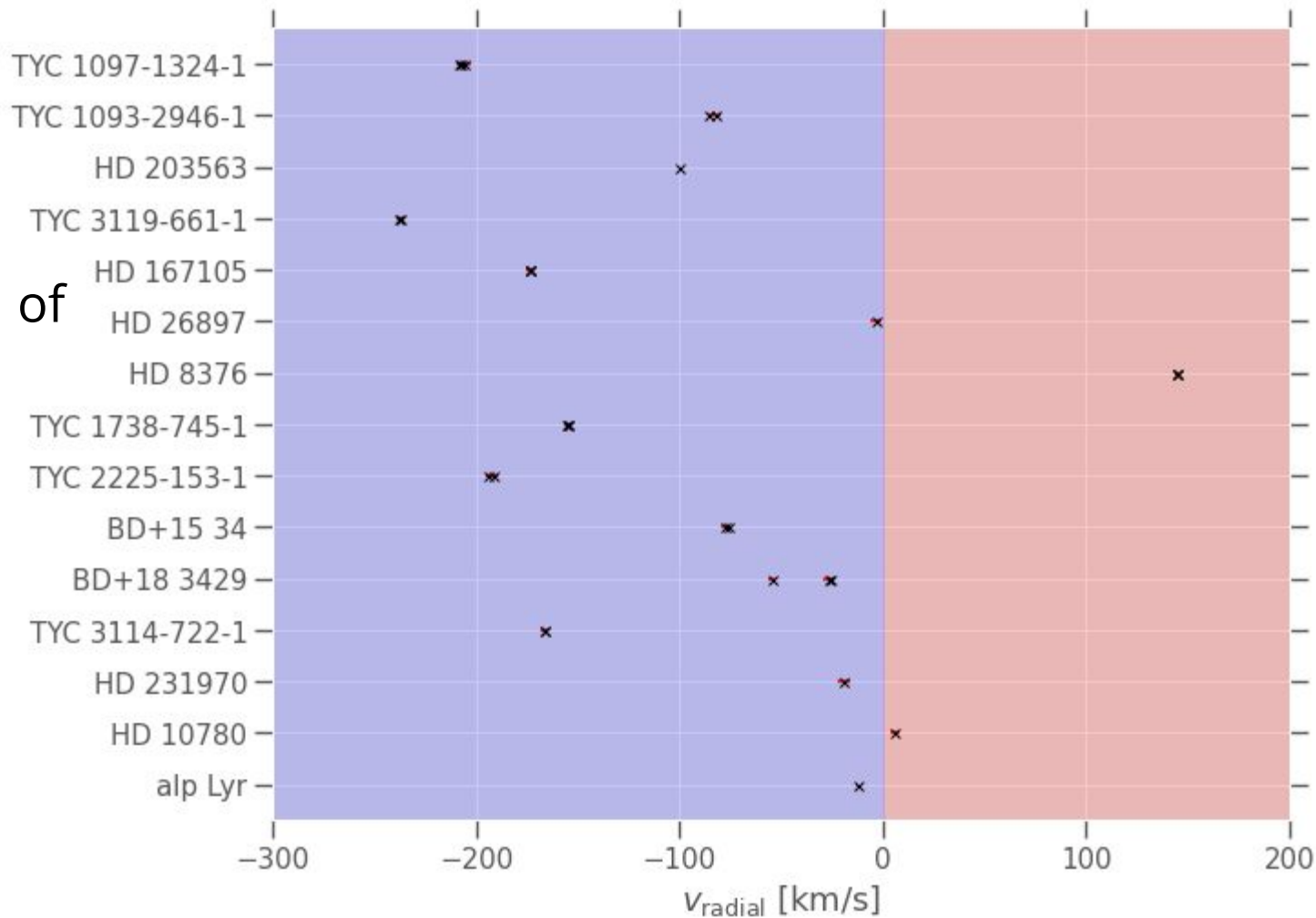


HD 8376

- ▶ 10.9.2021
 - $v_{rad} = (144.07 \pm 0.36)$ km/s
- ▶ 13.9.2021
 - $v_{rad} = (144.26 \pm 0.67)$ km/s
- ▶ 3.9.2022
 - $v_{rad} = (144.83 \pm 0.72)$ km/s
- ▶ Narrow H lines
- ▶ Likely a BHB star
- ▶ No apparent shift



The distribution of radial velocities in our sample



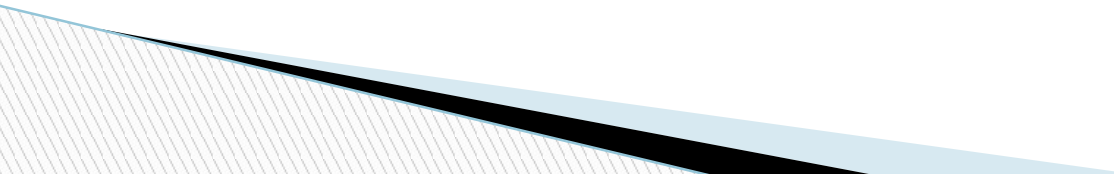
List of all observed likely–BHB stars and their v_{rad}

Date	Object	v_{rad} [km/s]	σ [km/s]	Date	Object	v_{rad} [km/s]	σ [km/s]
28.04.2022	TYC 3114-722-1	-166.5	1.6	10.09.2021	HD 8376	144.1	0.4
30.08.2022	TYC 3114-722-1	-166.6	1.0	13.09.2021	HD 8376	144.3	0.7
12.08.2022	BD+15 34*	-77.6	1.7	03.09.2022	HD 8376	144.8	0.7
30.08.2022	BD+15 34*	-76.2	-	08.09.2021	HD 167105	-173.9	0.7
12.08.2022	TYC 2225-153-1	-191.7	3.1	14.09.2021	HD 167105	-173.5	1.7
02.09.2022	TYC 2225-153-1	-194.2	0.6	05.09.2022	HD 167105	-173.7	0.5
13.09.2021	TYC 1738-745-1	-155.5	1.0	30.04.2022	TYC 3119-661-1	-237.0	1.8
14.09.2021	TYC 1738-745-1	-155.1	0.6	05.09.2022	TYC 3119-661-1	-237.8	0.5
03.09.2022	TYC 1738-745-1	-154.7	0.8	12.06.2022	TYC 1097-1324-1	-208.5	0.8
24.07.2022	TYC 1093-2946-1	-86.0	0.2	18.06.2022	TYC 1097-1324-1	-205.9	3.6
05.09.2022	TYC 1093-2946-1	-82.6	2.9	05.09.2022	TYC 1097-1324-1	-208.1	1.6
05.09.2022	HD 203563**	-100.1	0.2				

*inconclusive, our observation cut short due to clouds, possible BHB

**inconclusive, slow rotator, peculiar star, possible BHB,

Conclusion

- Reduced 35 spectra of 15 stars out of which 8 - 10 were BHB stars
 - Did not find any binary BHB stars
 - Might mean that BHB stars do not need a binary interaction in order to exist, maybe they do not even like it
 - Different generation mechanism?
- 

Thank you!

We would like to thank the Ondřejov observatory for hosting us and the organizers for a very pleasant stay!

