B supergiants with XTGRID

Dramatic poetry in 5 stanzas

by Peter Nemeth

POEMS

Physics of Extreme Massive Stars

Marie-Curie-RISE project
funded by the European Union

asu Astronomický ústav AV ČR

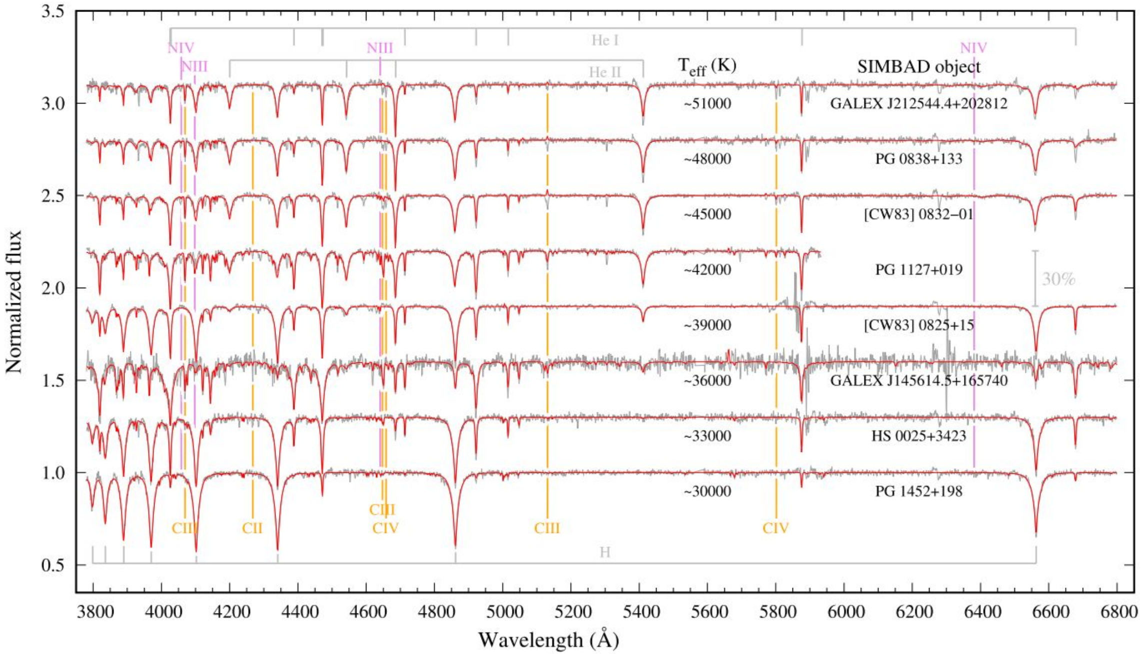
Chapter 1: Prologue

Successful modeling of subdwarf and MS B type stars

Peculiar He-dominated “normal”/post-merger/semi-compact stars

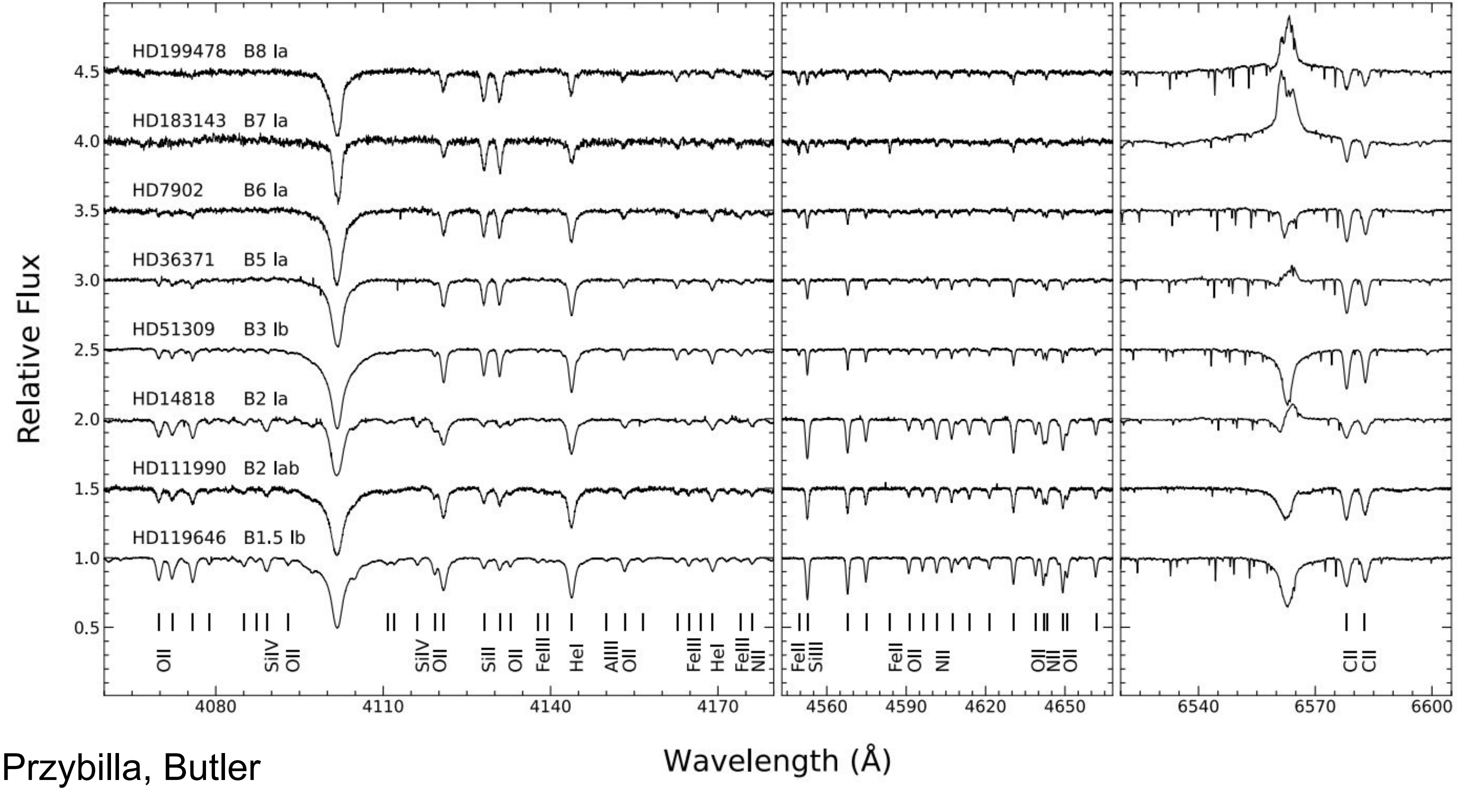
Utilizing Tlusty models

Let us repeat it for
B supergiants!



Luo, Németh, Wang, Pan
2024, ApJSS 271, 21

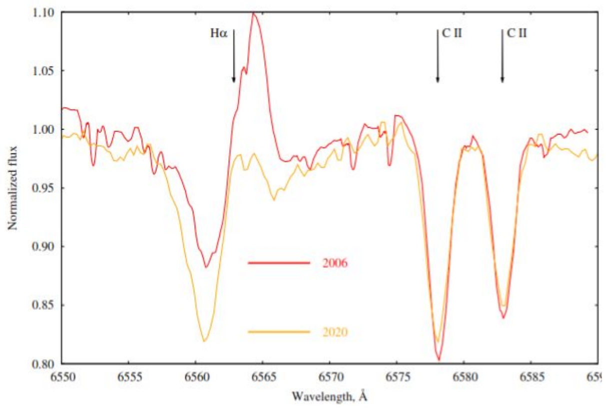
Chapter 1: Prologue



Weßmayer, Przybilla, Butler
2022, A&A 668, A92

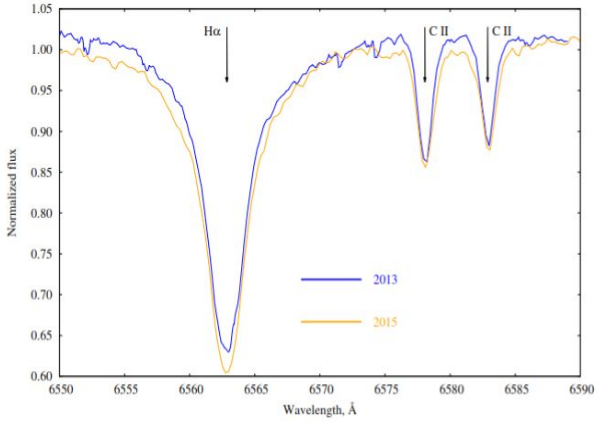
Chapter 1: Prologue

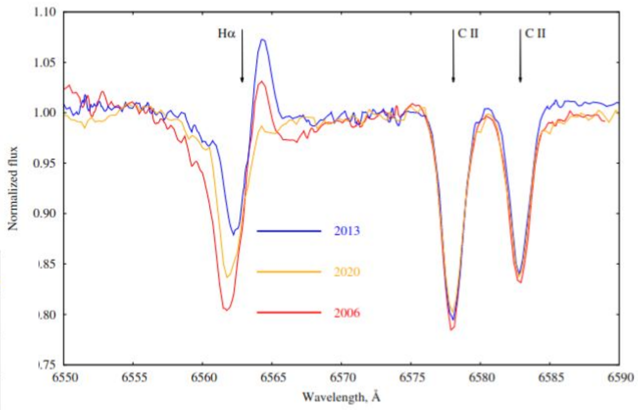
We used the REOSC spectrograph attached to the Jorge Sahade 2.15 m telescope at the Complejo Astronómico El Leoncito (CASLEO), San Juan, Argentina.
Covering a range of 4275 - 6800 A at R~13000.



HD 42087

HD 52089



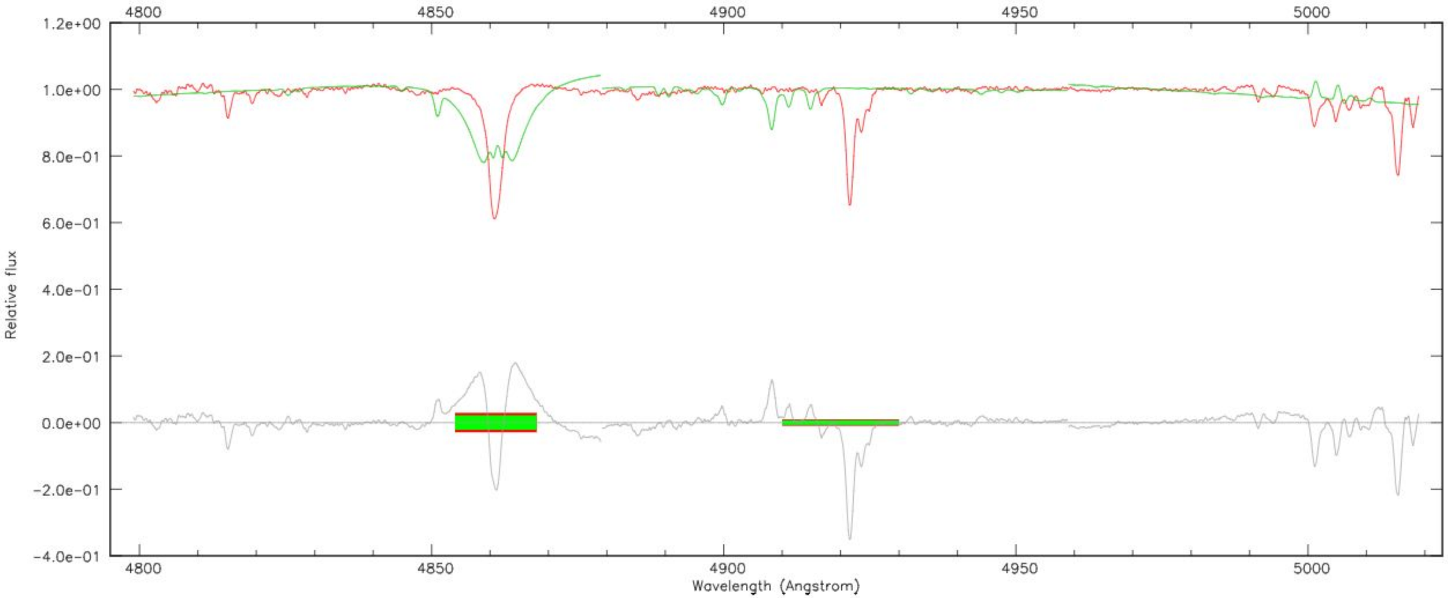


HD 58350

Chapter 2: Conflicts

TLUSTY does not work as expected! Convergence issues

OSTAR and BSTAR interpolations cannot reproduce the observations



Chapter 2: Success!

Added CMFGEN to XTGRID to model the photosphere and wind in spherical geometry

HD 52089

HD 58350

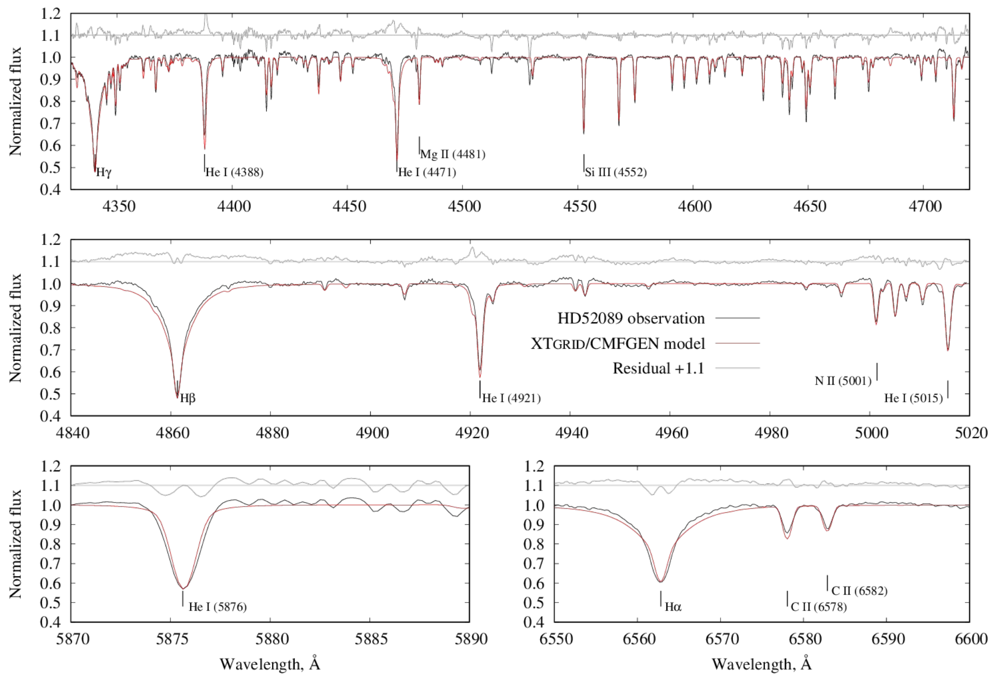
HD 42087

Sánchez Arias, Németh, de Almeida, Ruiz Diaz, Kraus, Haucke
2023, Galaxies 11/5, 93

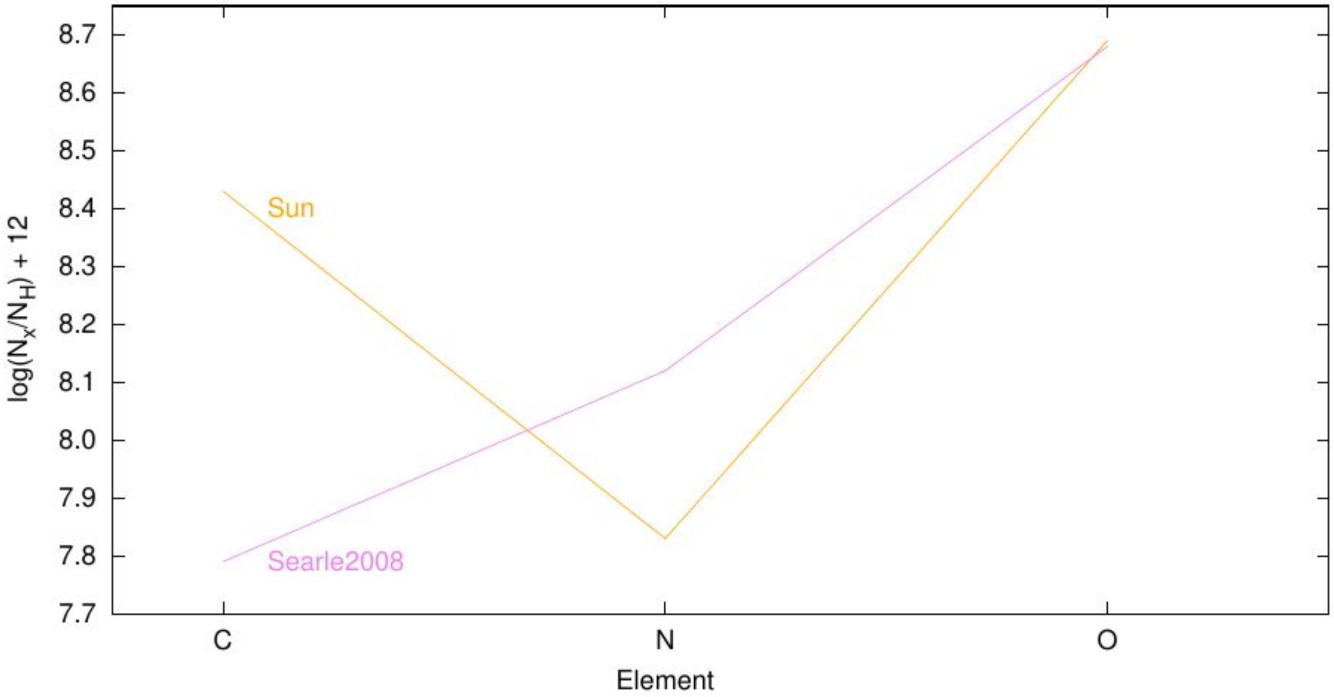
Although with limited models, the observations could be reproduced!

~12 month$!

$\dot{M}$, β, v_∞, R, v_t, f; Teff, logg, He, **CNO**, Si, Fe



Chapter 2: Success! But.



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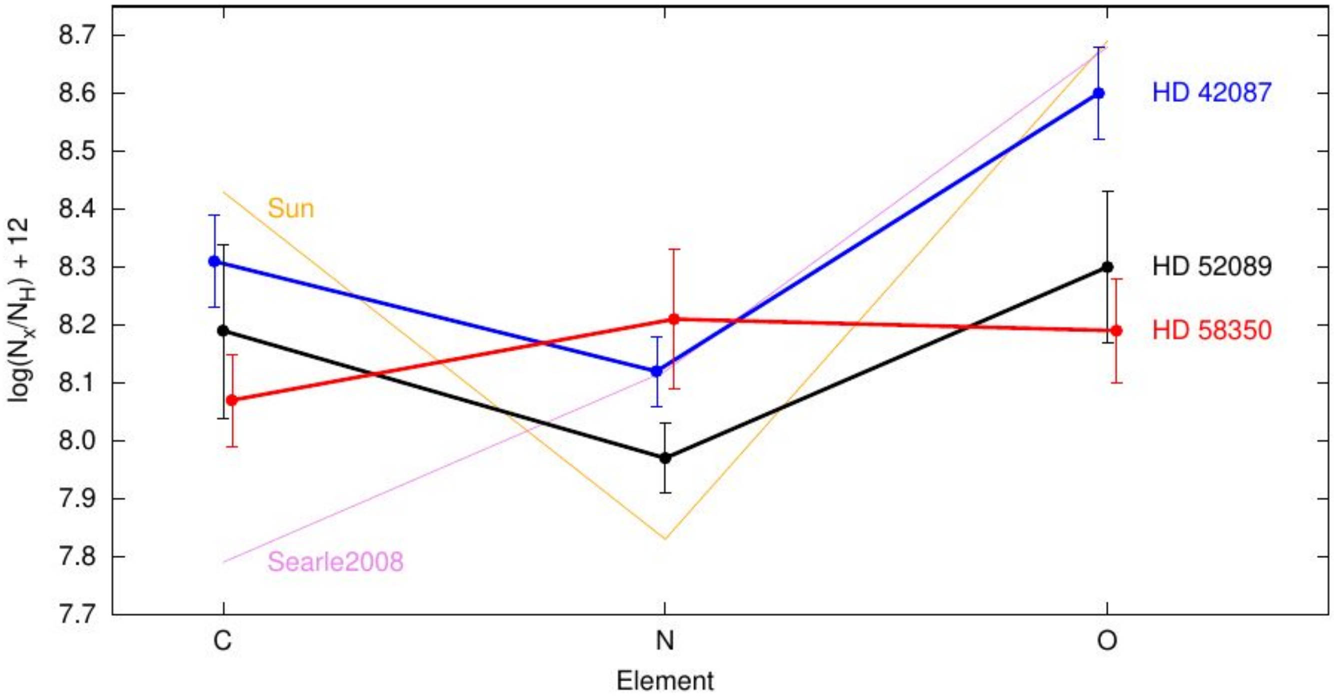


Assumption: global stellar parameters (M,L,A) are invariant between observations

The mass loss is negligible relative to the stellar mass

The luminosity is constant, only energy redistribution

The surface abundances are constant

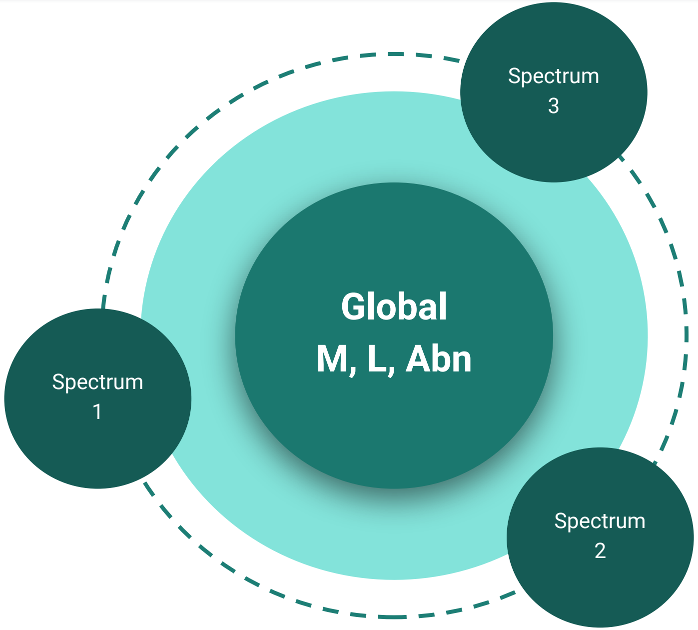
Allows to combine different observations over months or decades

$$L = 4\pi R^2 \sigma T_{\rm eff}^4$$

$$M = \frac{gR^2}{G}$$

$$ABN = [\text{mean}, \text{median}, \text{max}, \ldots]$$

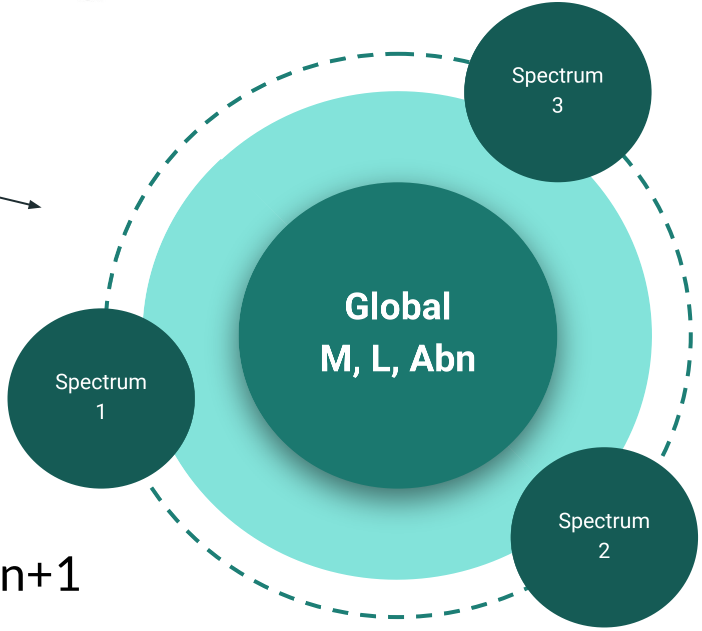
Global moving average for M, L, A



$$L = 4\pi R^2 \sigma T_{\rm eff}^4$$

$$M = \frac{gR^2}{G}$$

Iteration: n



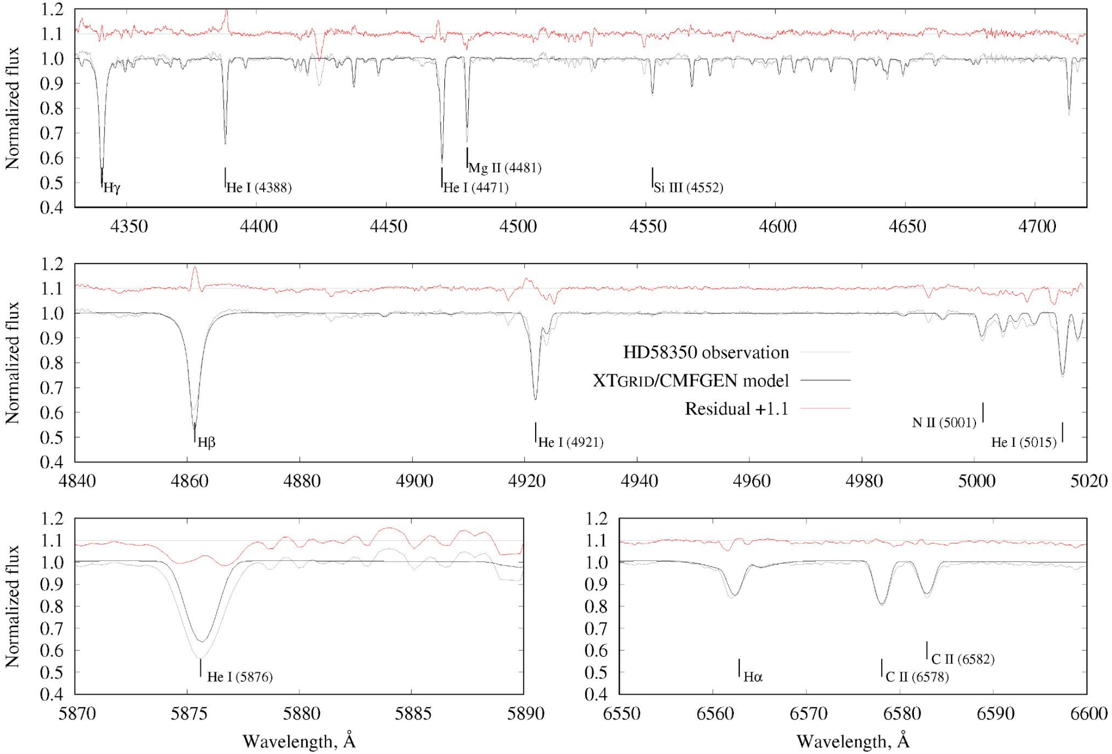
$$ABN = [\text{mean}, \text{median}, \text{max}, \ldots]$$

Iteration: n+1

To do ...

Even though the fit was reassuring, the limited SNR, calibration, and sampling diverted the focus towards HD 14143

HD 58350



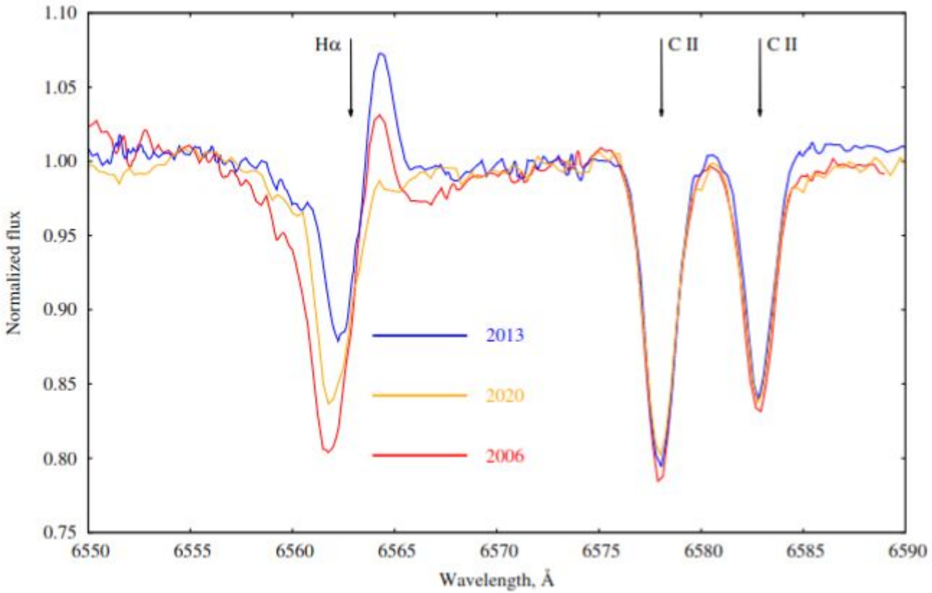
Sánchez Arias, Németh, de Almeida, Ruiz Diaz, Kraus, Haucke
2023, Galaxies 11/5, 93

To do ...

Even though the fit was reassuring, the limited SNR, calibration, and sampling diverted our focus towards HD 14143.

We started Chapter 4.

HD 58350



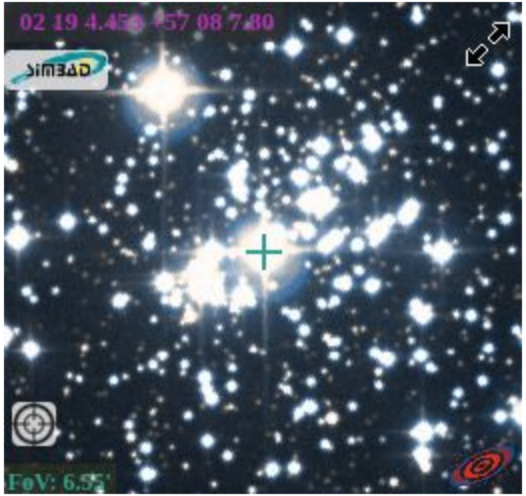
Sánchez Arias, Németh, de Almeida, Ruiz Diaz, Kraus, Haucke, 2023, Galaxies 11/5, 93

HD 14134 = 61 And

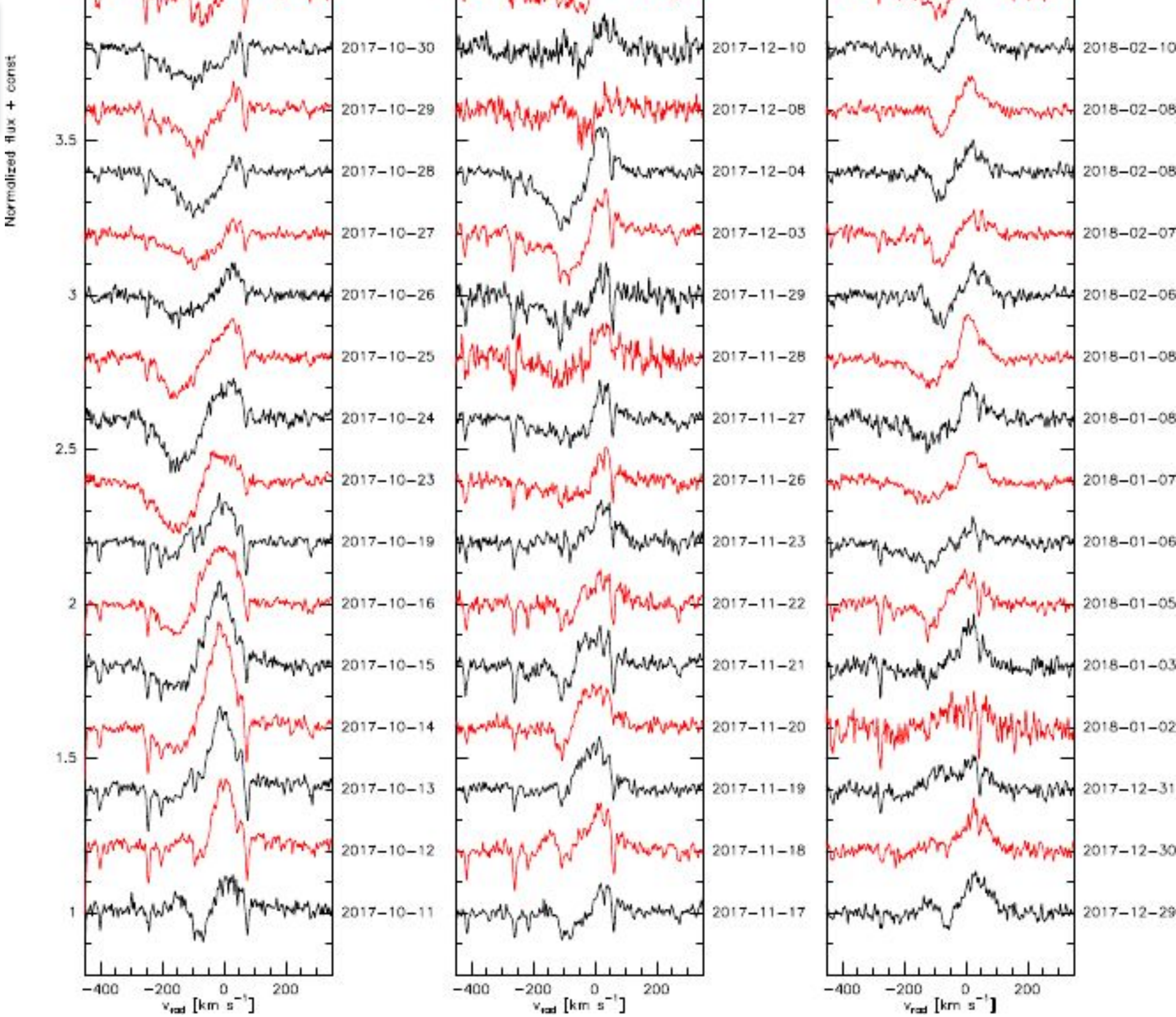
Long term monitoring is available

High SNR

Wild variable



Simbad/Aladin

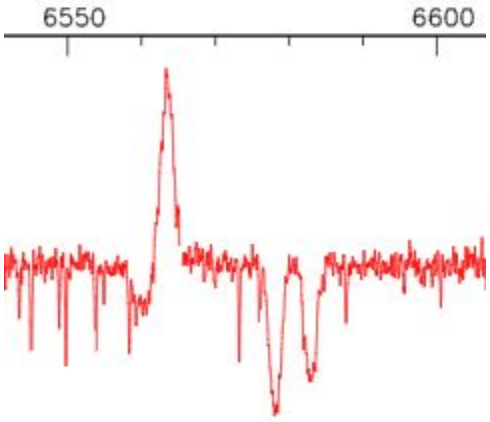


2017 Oct — Nov — Dec spectra

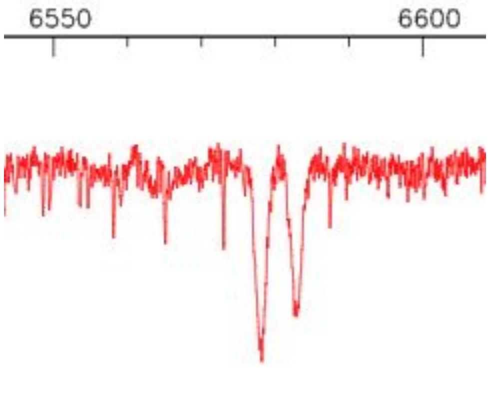
We fit all three spectra with constraints: **same M, L, abundances**

We are interested in the photospheric variations (T, logg, R) due to pulsations.

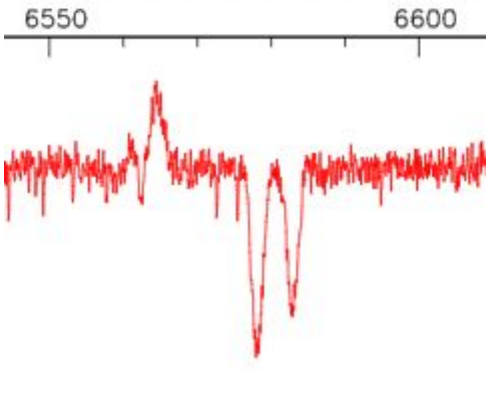
2017 10 14



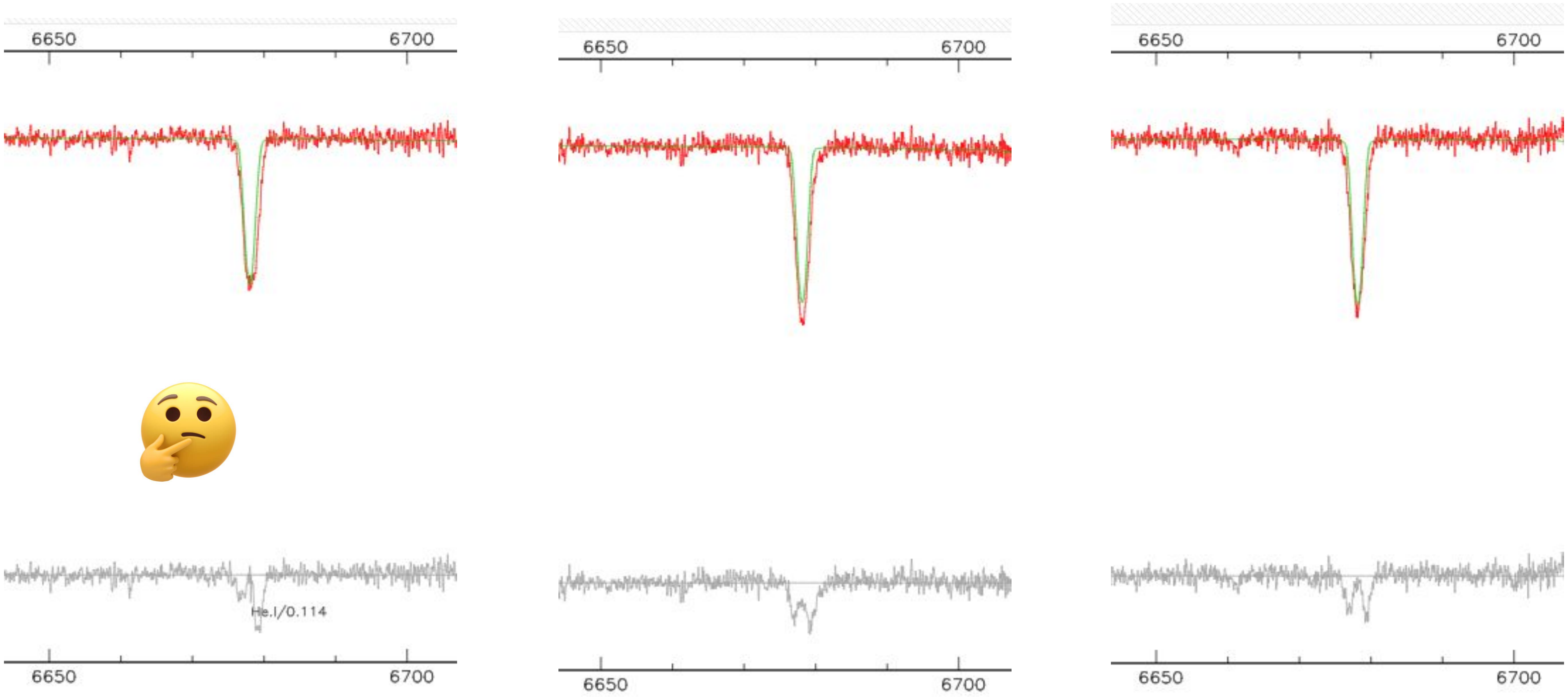
2017 11 14



2017 12 29

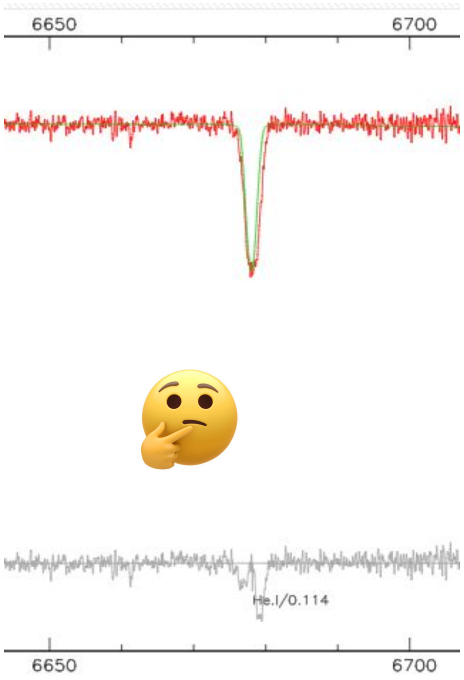


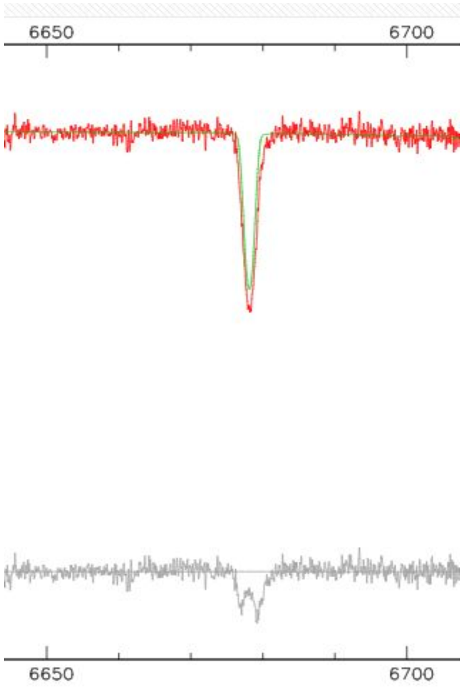
Helium profiles (He/H = 0.4)

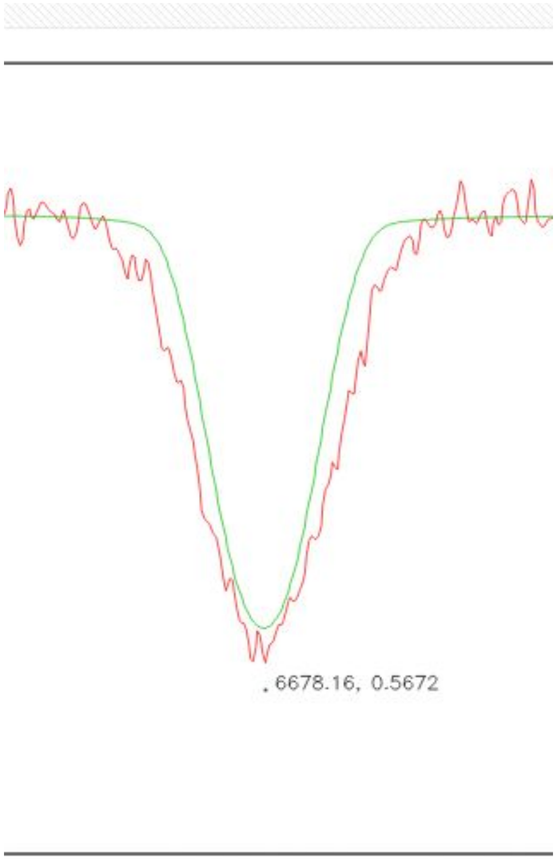


Chapter 4: New complications

Helium profiles (He/H = 0.4)

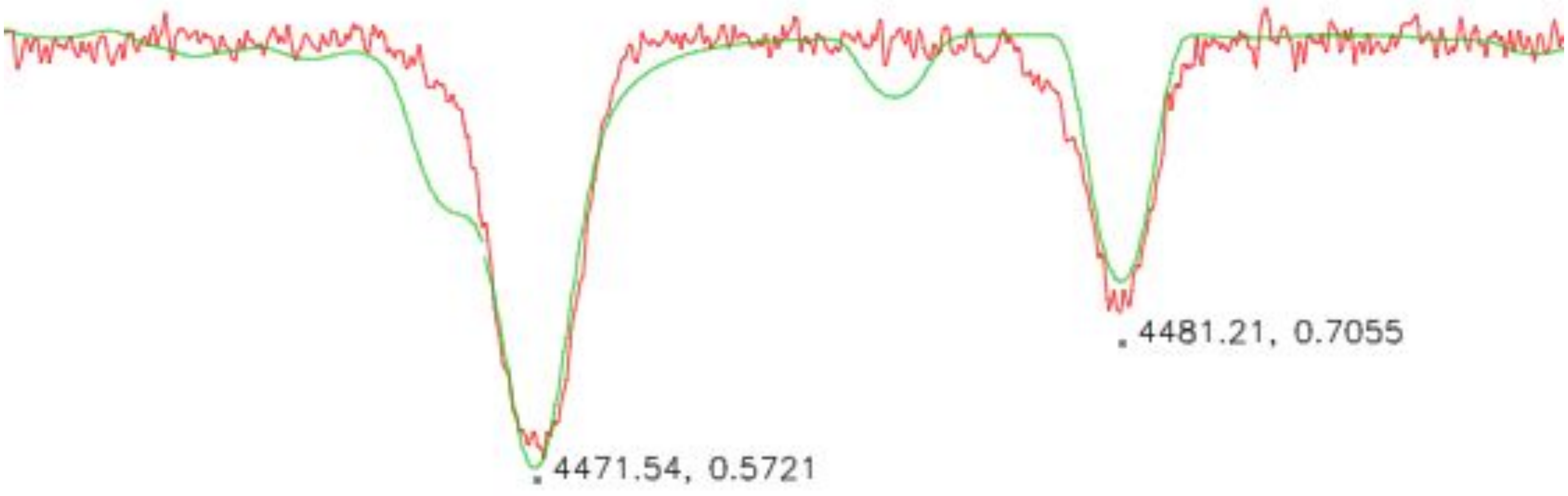






Chapter 4: New complications

Helium profiles (He/H = 0.4)



Chapter 4: New complications in HD 14134

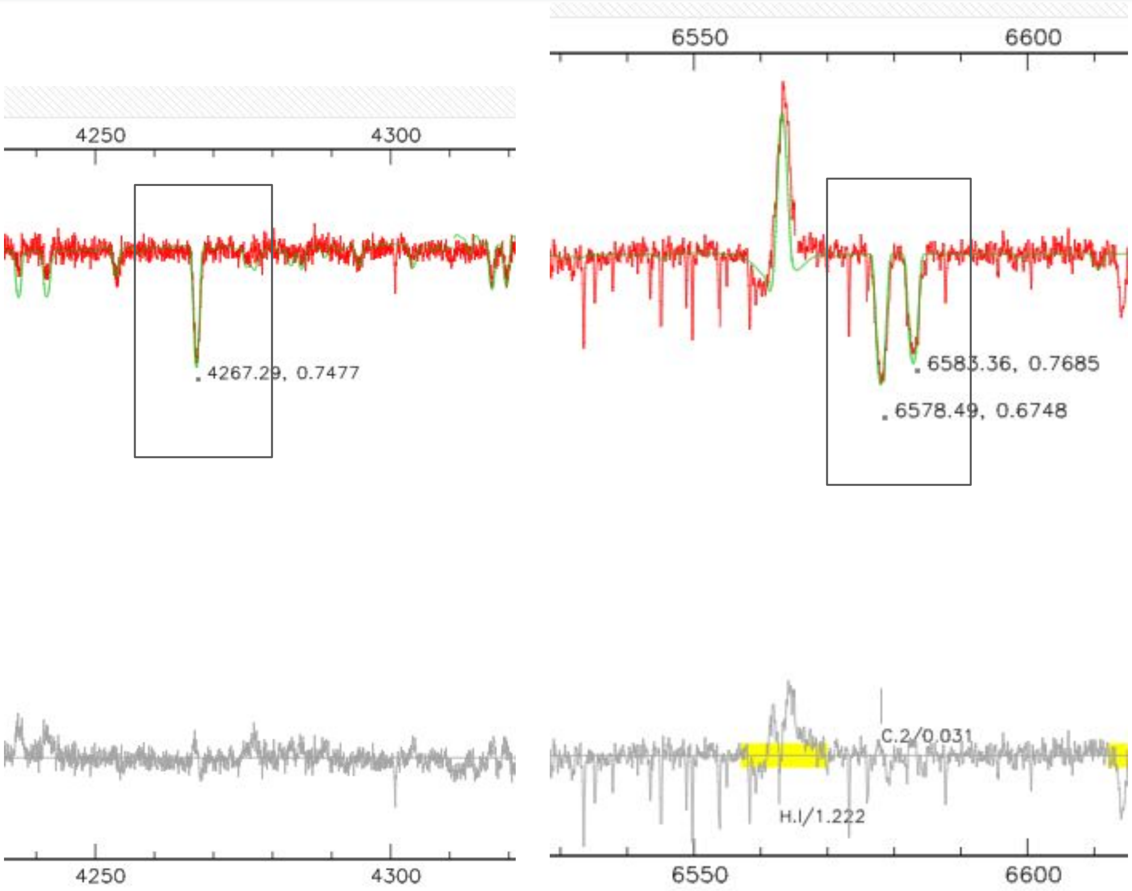
Carbon profiles

2017 10 14

εC = 8.75

εN = 8.53

εO = 9.04



Note on diagnostic lines

We derive logg from H-gamma, T_{eff} from Si lines and equilibria, …

Okay for comparisons, but we can always find some nice match for some parts of the spectrum with confidence even if the model is inadequate or wrong

The global approach is favorable if the model is able to reproduce all significant features of the observed object

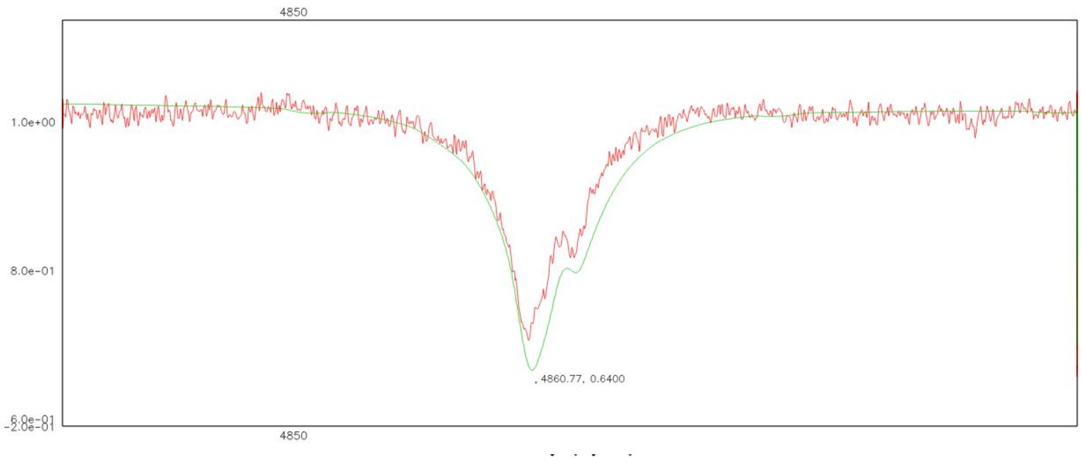
Observed

Asymmetric line profiles

Highly variable wind

Each line prefers a different turbulent velocity

The density profile of the wind requires a high (varying?) value of Beta

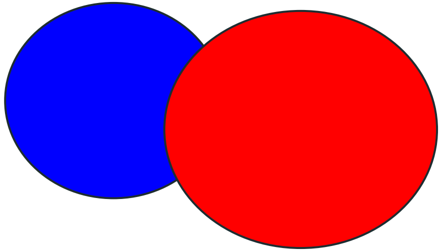


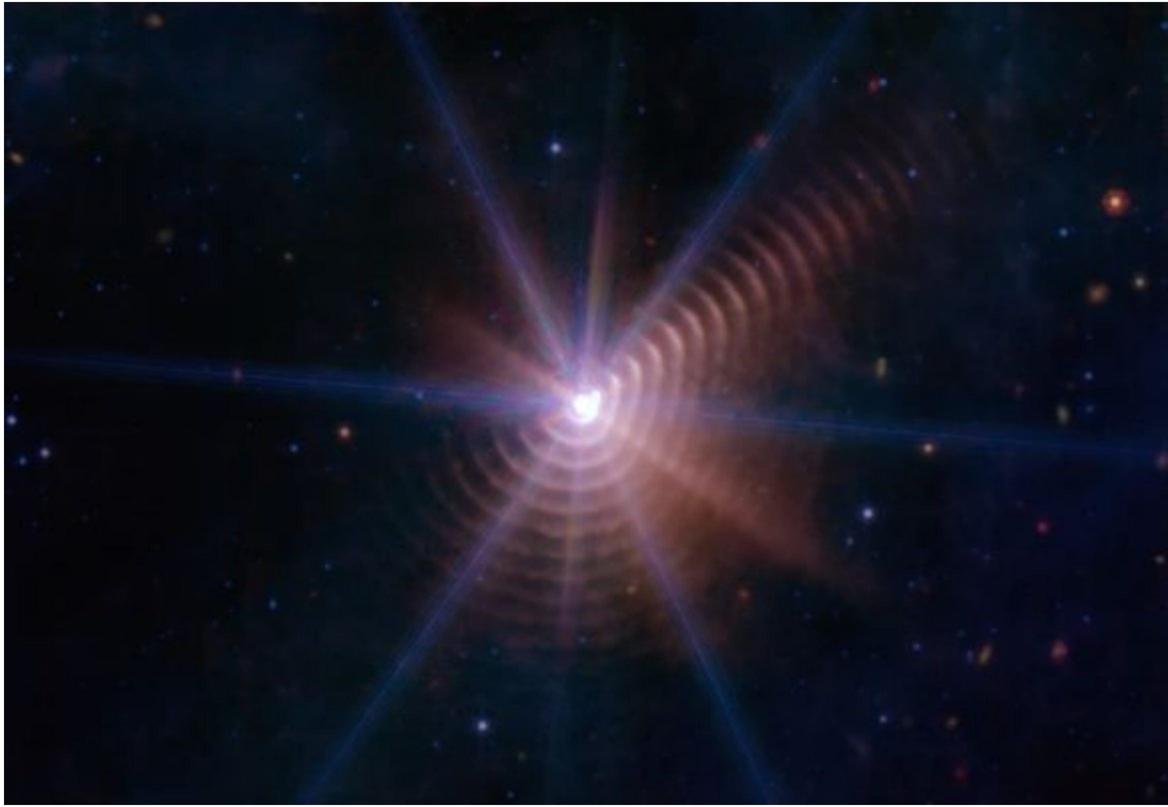
Clues for future development

Modulated mass loss, clumping?

Non-spherical geometry due to pulsations or binarity?

Beta-law inadequate?





WR 140 (JWST/MIRI/Judy Schmidt)

Models are being calculated

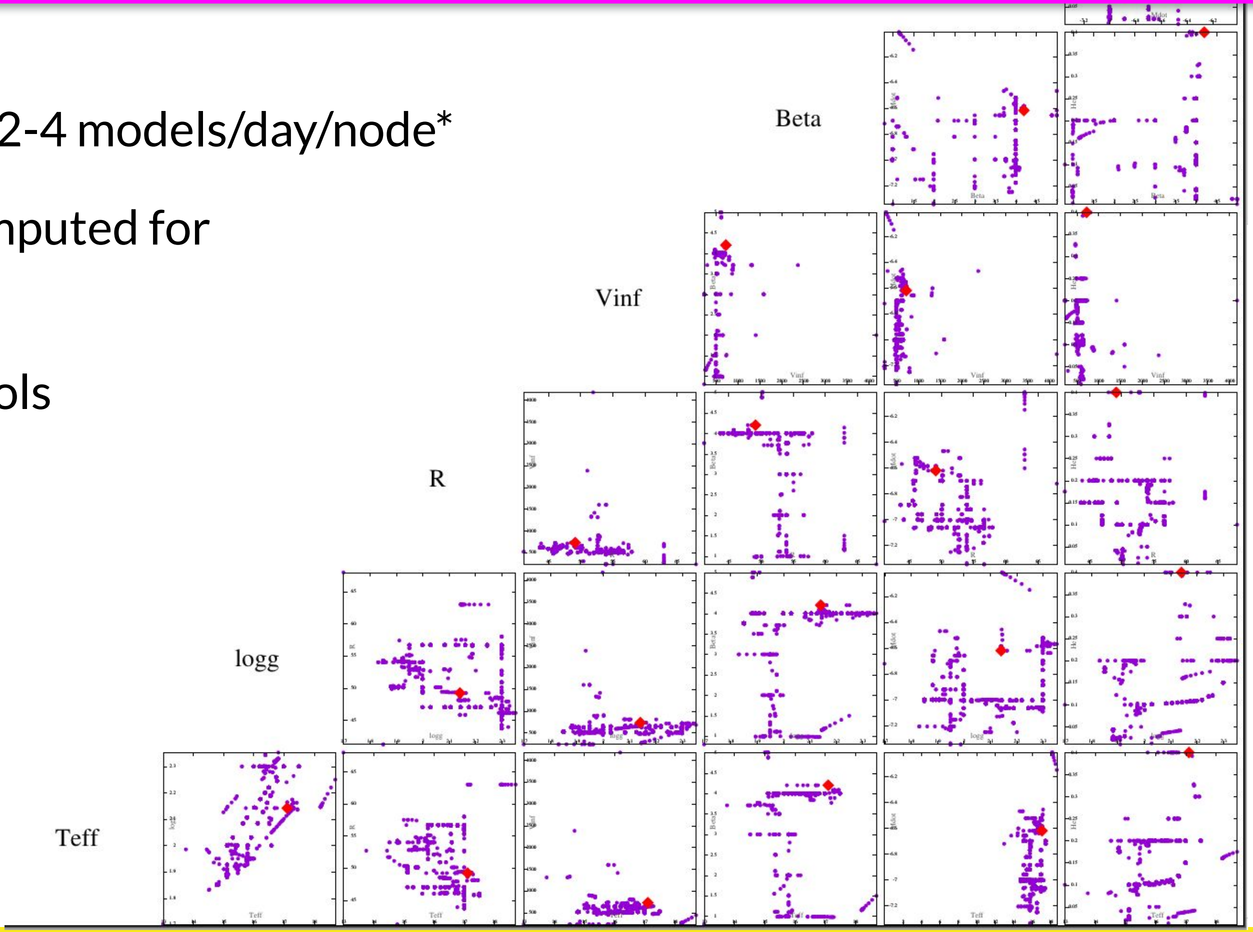
Models are generated at 2-4 models/day/node*

Synthetic spectra are computed for
UV, Vis and IR regions

Suitable for future ML tools

Up to 32 dimensions

*16 core AMD Ryzen



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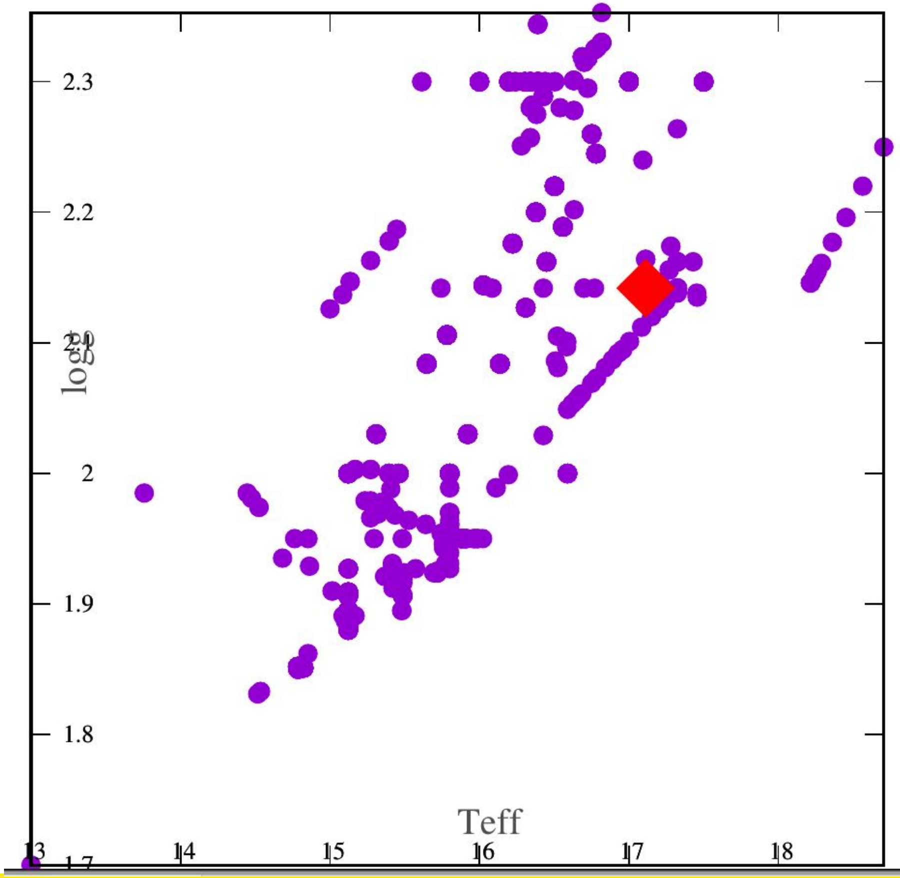
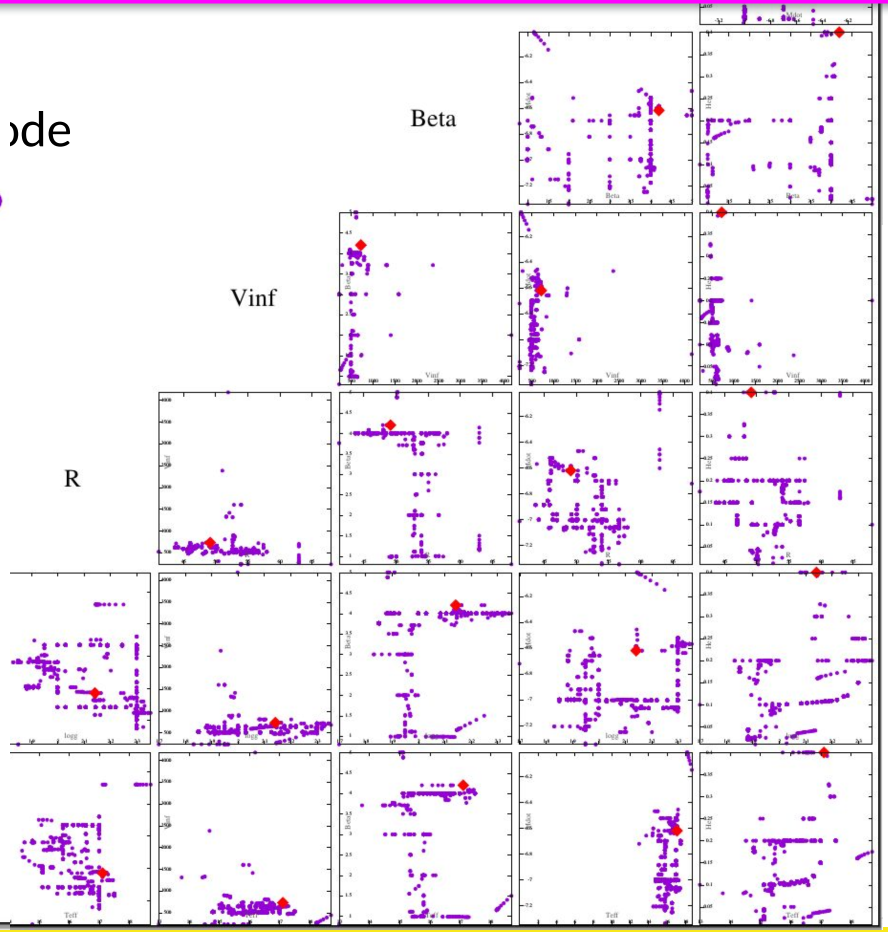




Solved within POEMS

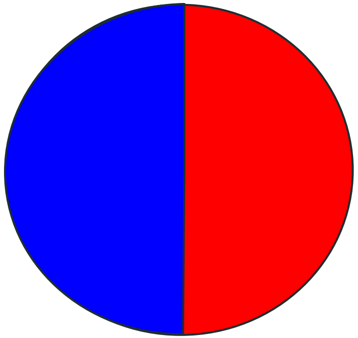
Automated CMFGEN model calculations

Model failure recovery and tolerance

Framework and a web interface

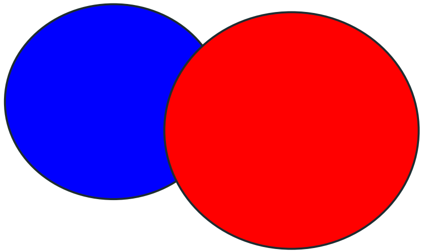
Advanced nearest neighbor interpolator (ANNI)

Global minimization with variable weights or diagnostic lines/ranges



Global constraints for multispec analysis

Multicomponent fits: stacking 1D models for two hemispheres or a binary, using flux dilution



Considerations

The “*poetic tool*” is ready, we need to *play* on it.

Major assumption in XTGRID: the applied model atmospheres (TLUSTY or CMFGEN) are able to reproduce the observation.
Then it is up to the procedure to find the best combination of parameters that minimize the merit function.

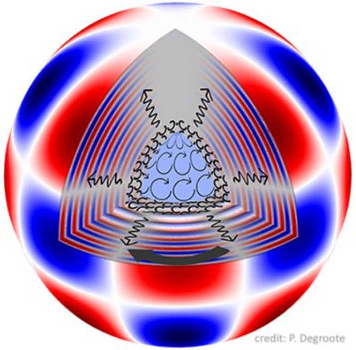
The repeated failure to model pulsating B-supergiants imply that the current models are inadequate.

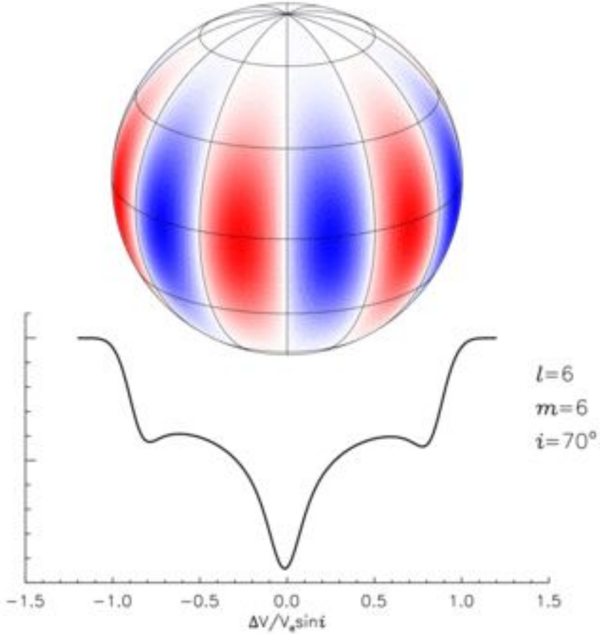
O type, WR, LBV and transition stars?

Chapter 5: Epilogue

After tremendous work and lengthy modeling, we still have almost nothing established!

For the fundamental parameters of pulsating B supergiants from time resolved spectroscopy we very likely will need surface integration or 3D models.





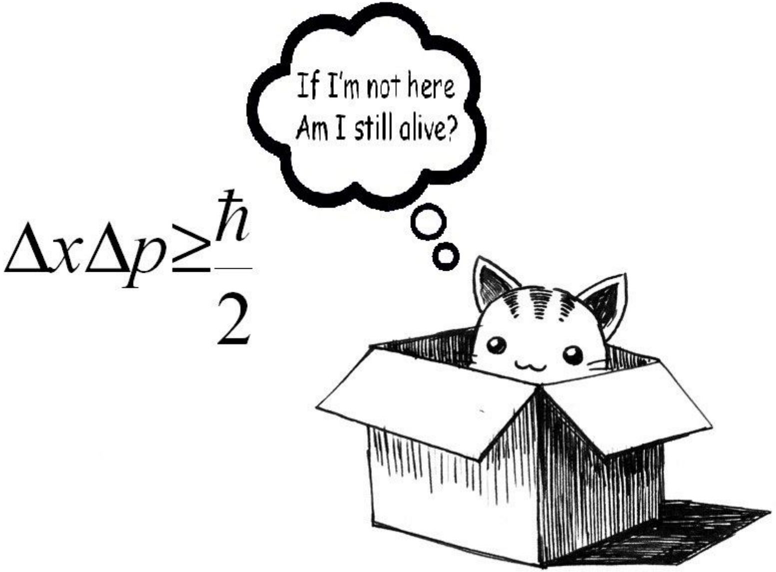
credit: P. Degroote

Chapter 5: Epilogue

We are only at the beginning of a beautiful cruise in understanding and modeling B supergiants

B stars in XTGRID

Bloody B Binaries in the Beautiful Brazil



Peter: ρ Leo