Ups...! We did it again...

New observational evidence for HVA events

K. Pivoňková[1] S. Simón-Díaz[2] O. V. Maryeva[3]

[1]Department of Theoretical Physics and Astrophysics, Masaryk University, Czech Republic

[2]Instituto de Astrofísica de Canarias, 38 200 La Laguna, Tenerife, Spain

[3]Astronomical Institute of the Czech Academy of Sciences, Czech Republic

Introduction

- variability of Hα line of late B– and early A–type supergiants
- what is HVA?
- hypothesis that may explain the source of HVA and why do we observe only 8 early type supergiants showing those extraordinary events

- new observational evidence of HVA

HD 21389

Physical Characteristics

- A0 type supergiant star
- member of Cam OB1 association
- belongs to α Cyg variables
  - low amplitude variability in brightness and radial velocities

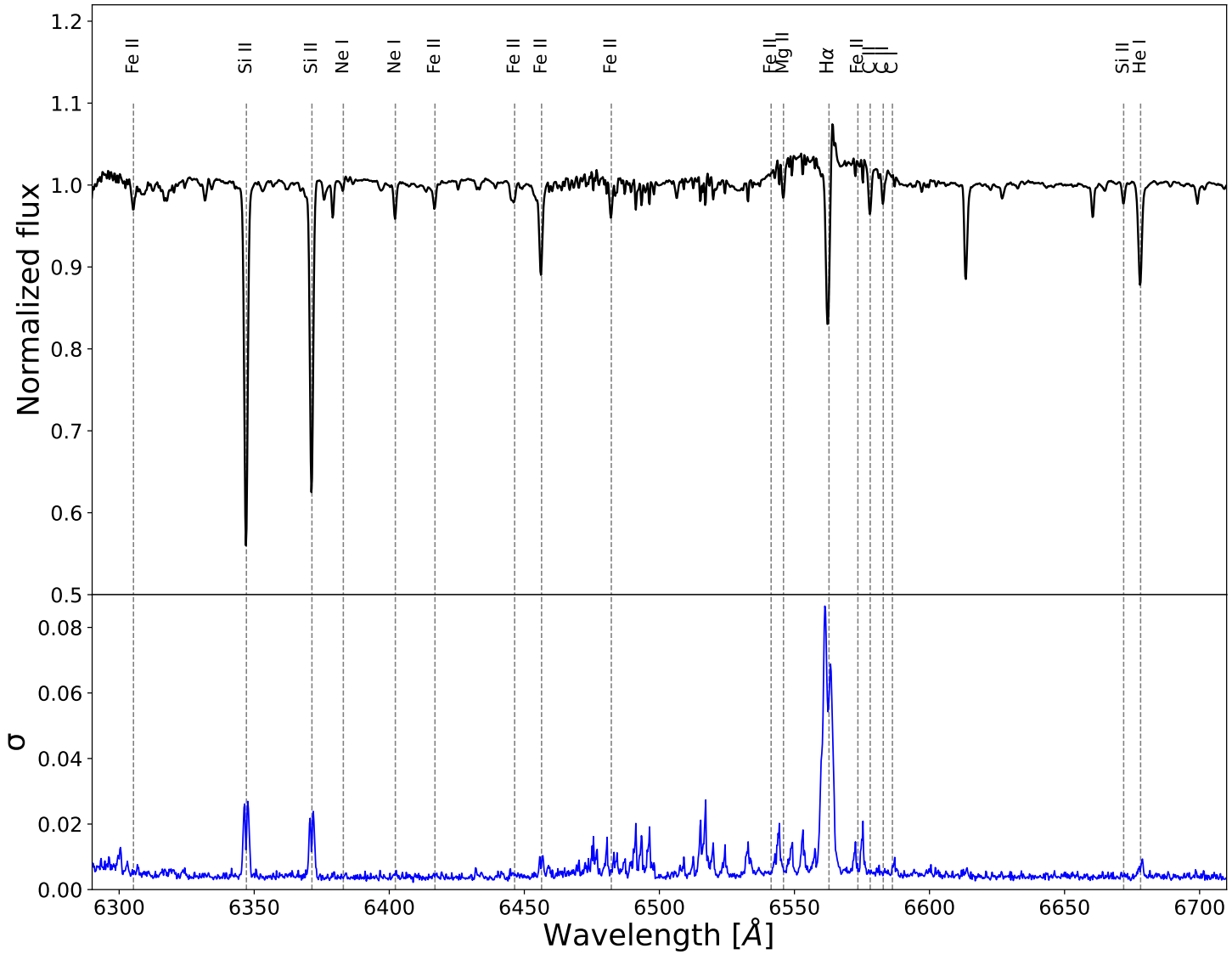
Parameters	Values	References
M $[\mathrm{M}_\odot]$	19.3	Verdugo et al. 1999b
M_V [mag]	-7.56	
T_{eff} [K]	9730	Verdugo et al. 1999b
R $[\mathrm{R}_\odot]$	97	Verdugo et al. 1999b
$\log L/L_\odot$	4.87	de Jager et al. 1988
$\log g$ [cgs]	1.7	Takeda 2000
v_∞ $[\mathrm{km}\cdot\mathrm{s}^{-1}]$	218	Talavera & Gómez de Castro 1987
$\dot{M}$ $[\mathrm{M}_\odot\cdot\mathrm{yr}^{-1}]$	$-4.2\cdot10^{-7}$	Barlow and Cohen 1977

HD 21389

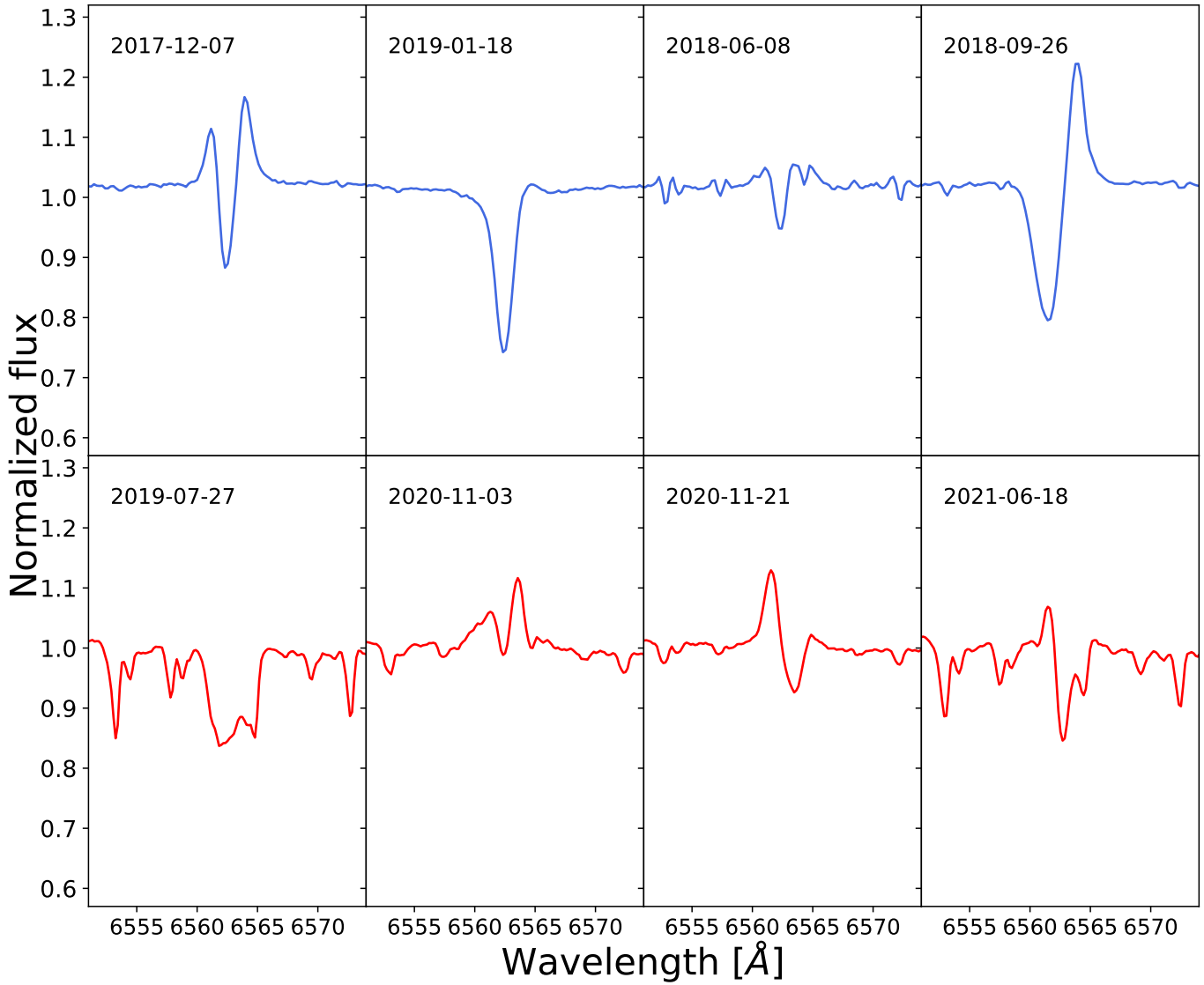
Previous Observation

- suspected as a spectroscopic binary (Campbell et al. 1911)
- presents variability in Balmer lines (strongest in Hα)
  - and in other metallic lines (both in lines' profile and radial velocities)
    - $\rightarrow$ associated with its active and quiescent phases
- member of rare group showing High Velocity Absorption events (HVA)

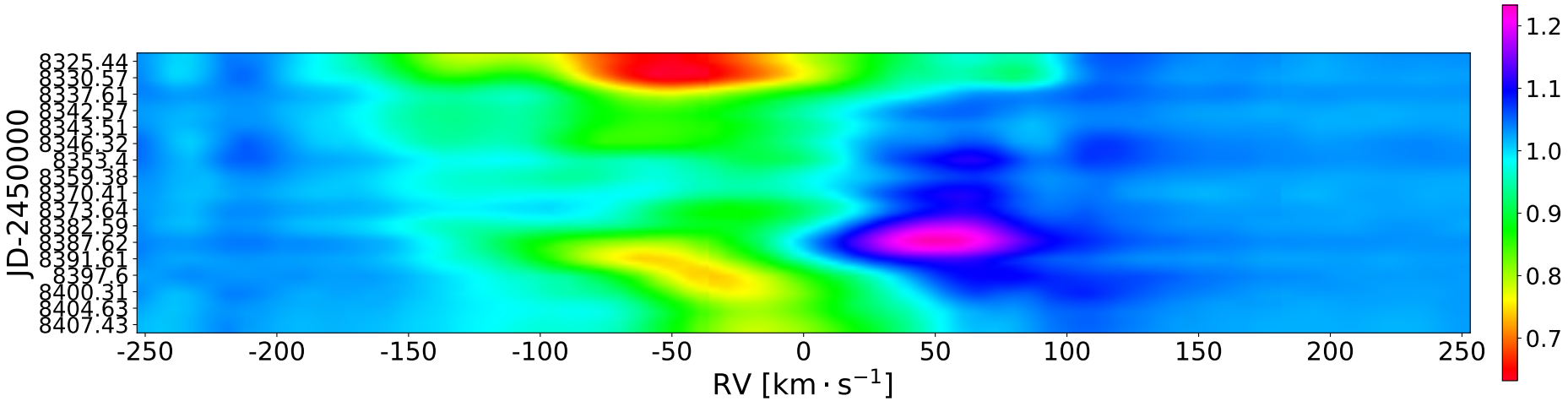
Temporal Variance Spectrum (TVS)



Hα line

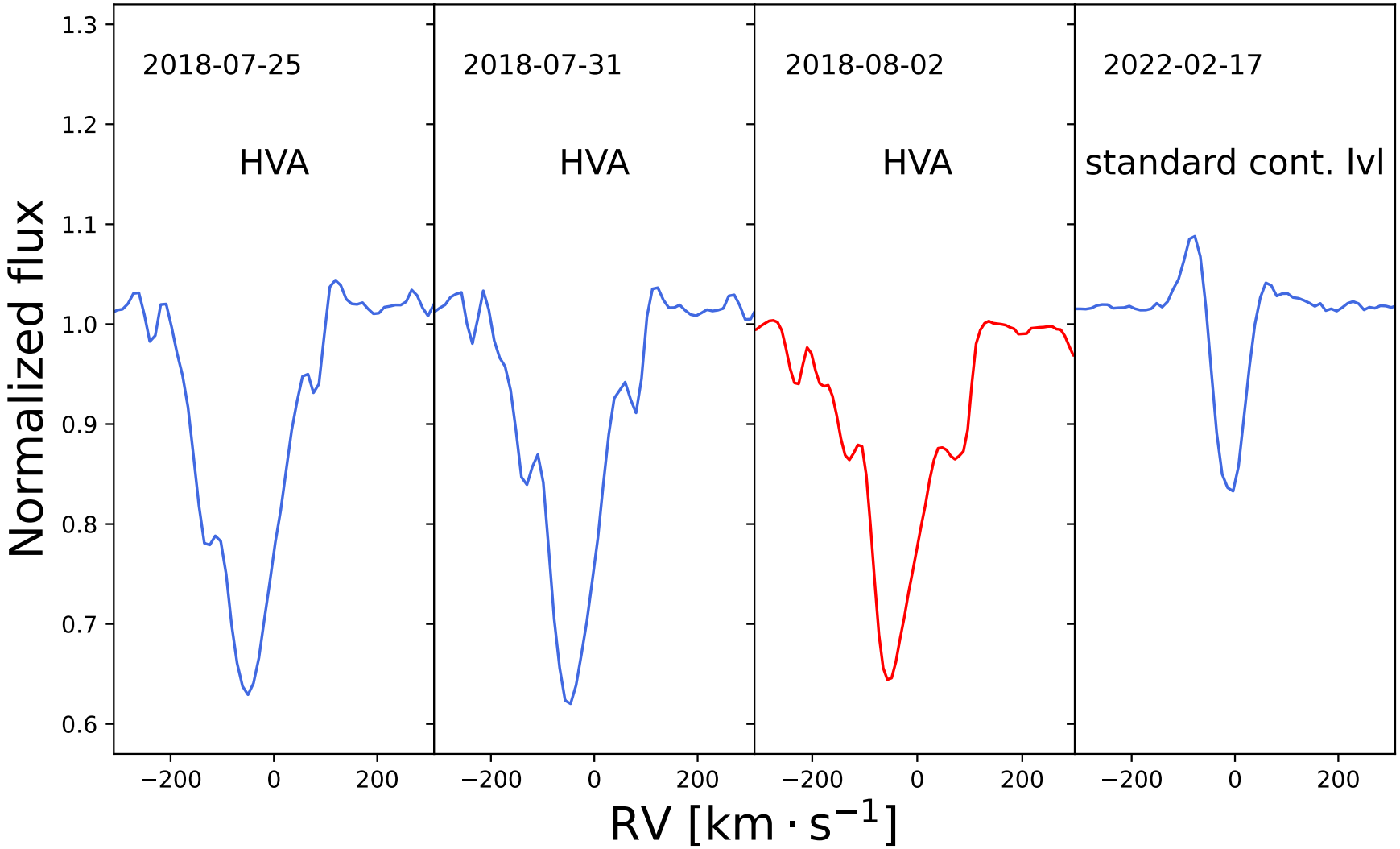

2017-12-07
2019-01-18
2018-06-08
2018-09-26
2019-07-27
2020-11-03
2020-11-21
2021-06-18
Normalized flux
Wavelength [Å]
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
6555 6560 6565 6570

Hα line – HVA event



Dynamic spectrum intercepting final phase of HVA that HD 21389 underwent in July 2018. Color scale represents the flux The reddest part correspond to HVA event.

Hα line – HVA event



Lines' profile appearance during HVA event.

IACOB database

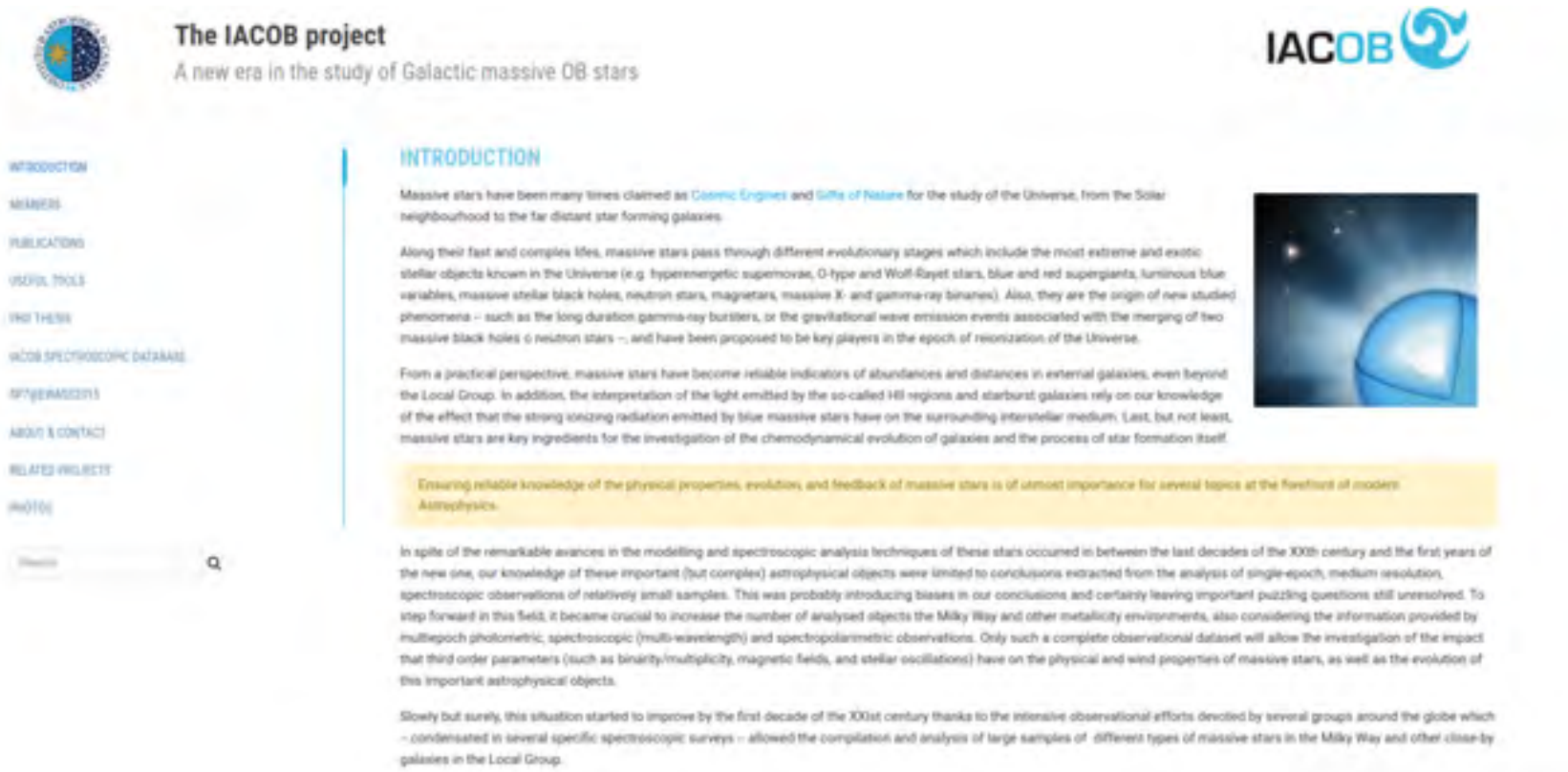


Figure: IACOB project webpage

How many of them behave the same way?

- now we know about 8 of them
- why?

Supergiants showing HVA
HD 213989
HD 21291
Rigel
Deneb
HD 199478
HD 91619
HD 96919
HD 207260

Do they have something in common?

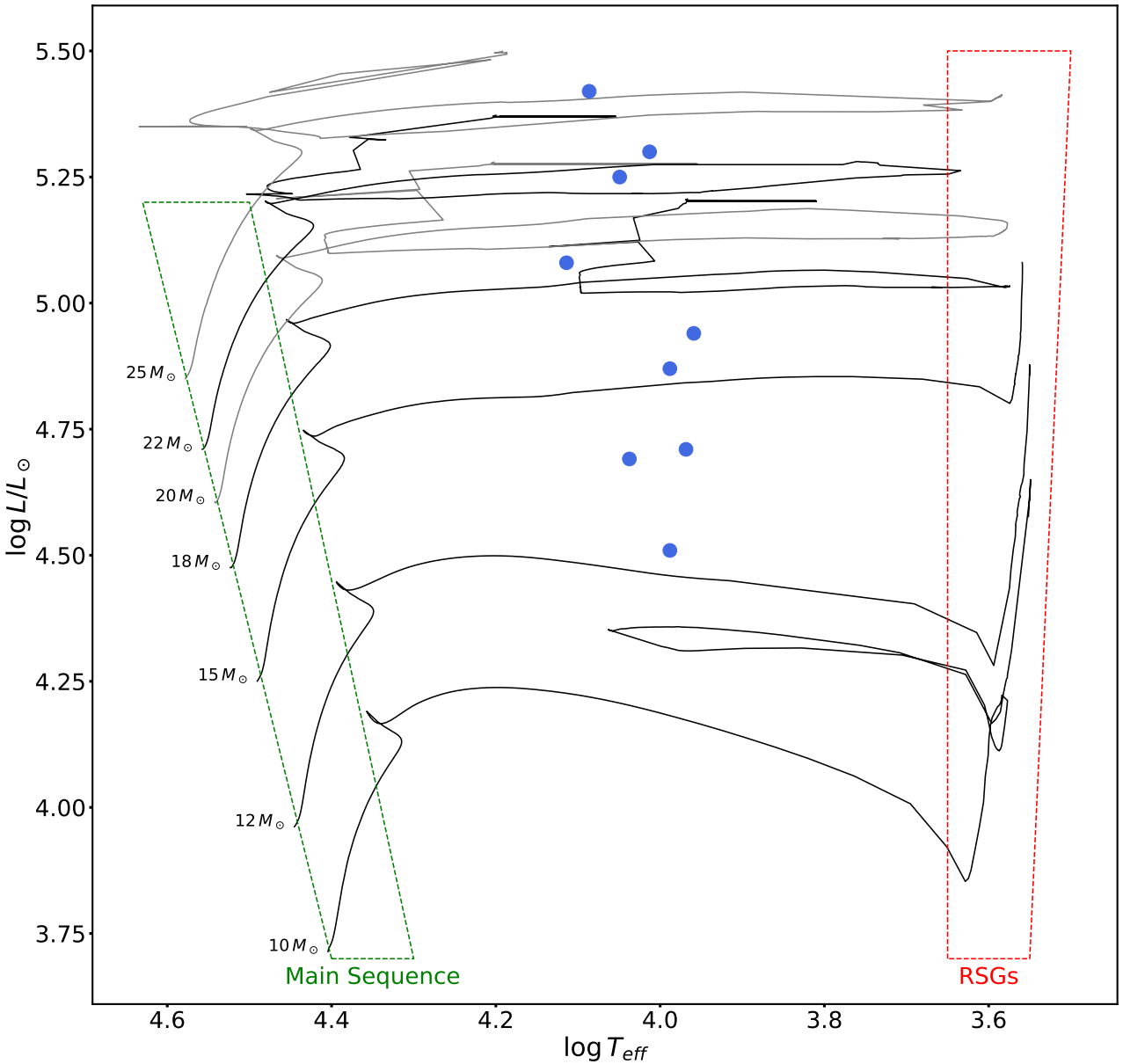
Do they have something in common?

YES, but not much at least what we know :(

Variability type

- all of them belongs to α Cyg type variables
  - pulsating stars
  - low amplitude variability
  - variability in line profiles is typical
  - mainly in Hα line

Evolutionary status



Evolutionary status

all objects showing HVA are αCyg variables:

- **Deneb**
  - evolving from the main sequence towards the right to RSG branch (Schiller 2007)
  - **BUT:** referred to be in the post-red supergiant stage by Przybilla et al. 2010
- **Rigel**
  - pulsational characteristics implies that Rigel already underwent RSG stage and evolving blue-wards (Saio, Georgy & Meynet 2013)
- **HD 21389**
  - sun-like abundances (N/C, N/O) $\rightarrow$ evolving right in its first crossing (Corliss, Morrison & Adelman 2015)

Results for HD 21389

- variability on different time scales
- most interesting behavior in Hα line
- weak X strong HVA event
- we have only(mainly) observational data

- physical causes of HVA – comparison of observed profiles with models
- would it be possible to find more of them?

Evidence for new HVA events

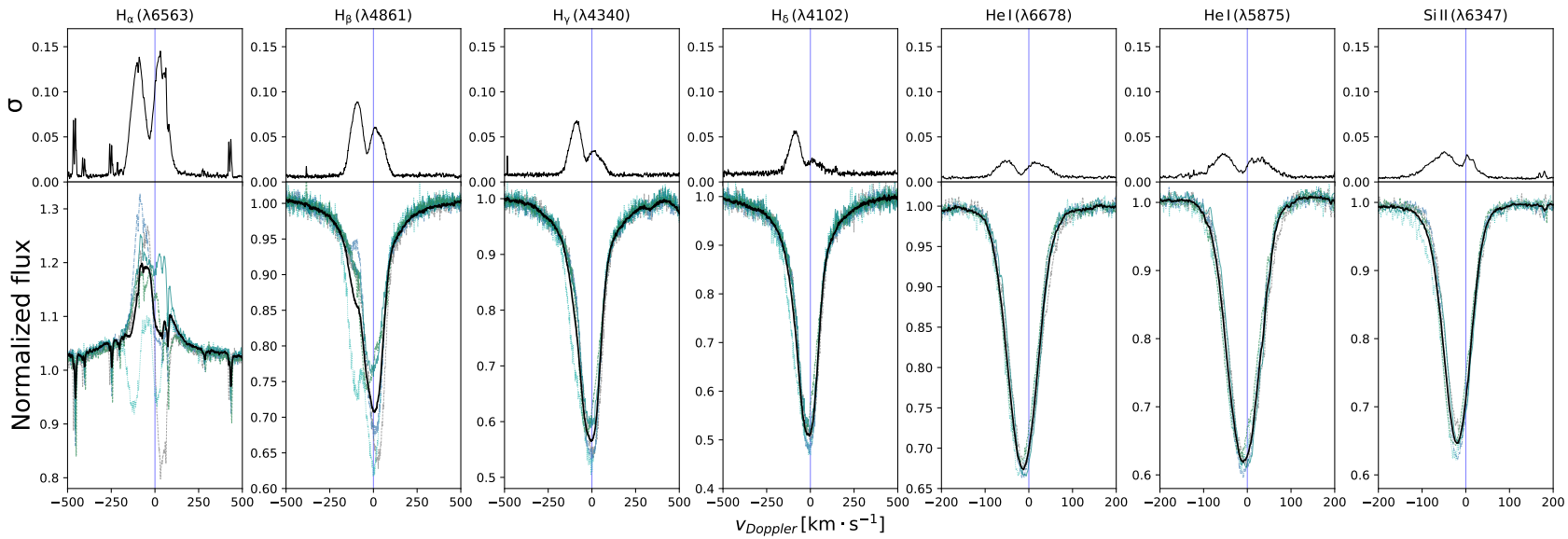


Figure: TVS of HD 199478. Highly blue-shifted Hα lines' profile has been taken during HVA event.

Evidence for new HVA events

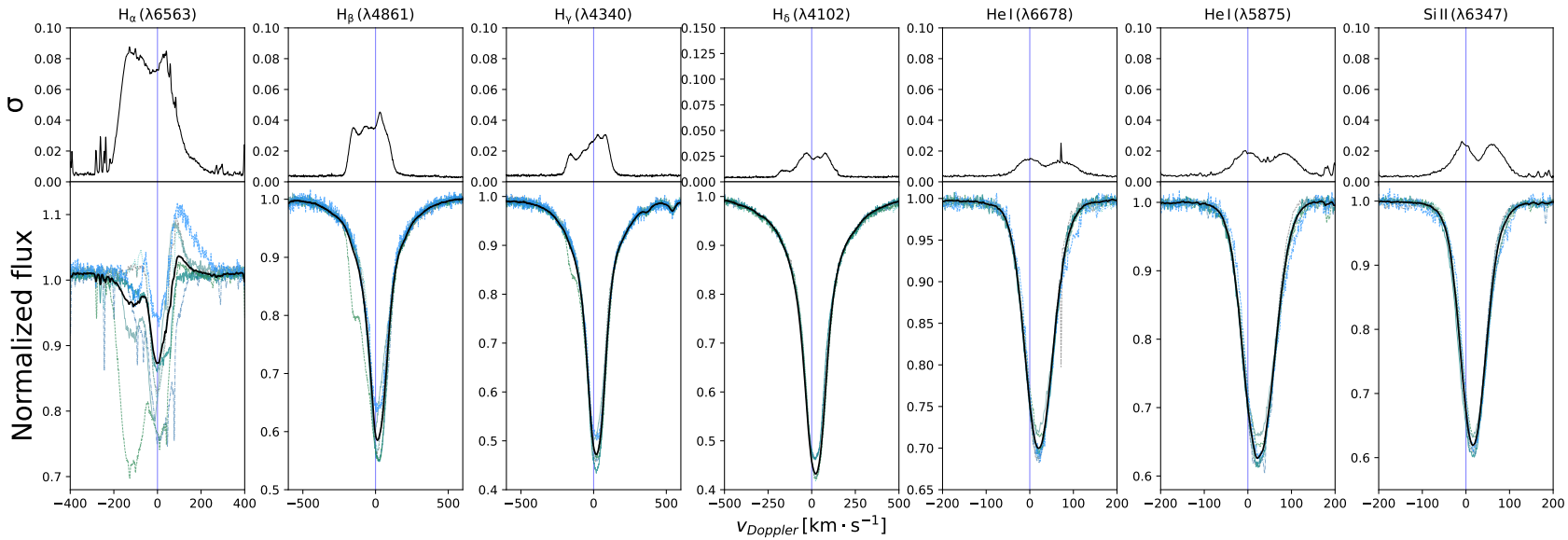


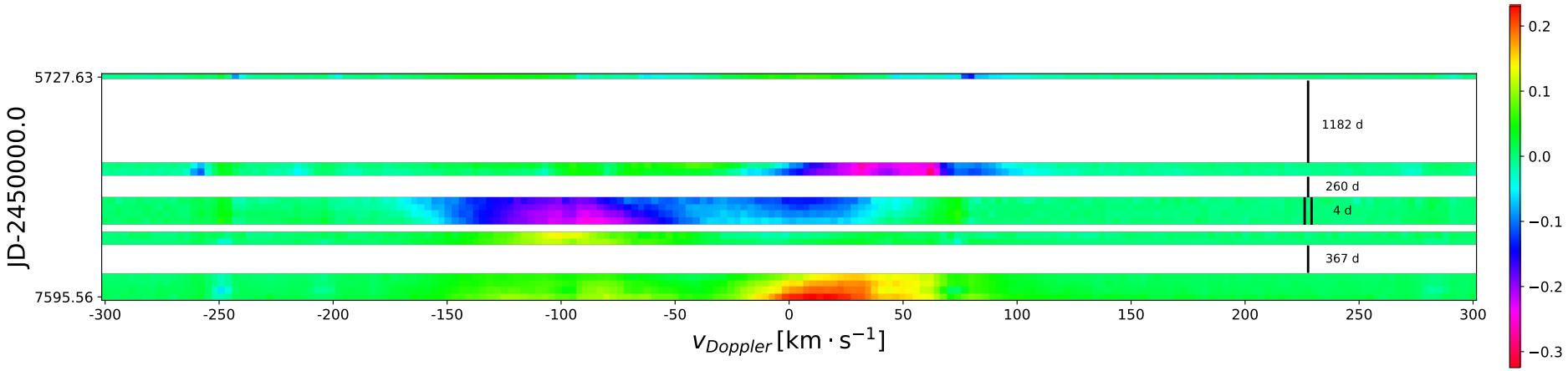
Figure: TVS of HD 34085. Highly blue-shifted Hα lines' profile has been taken during HVA event.

So, what's going on during HVA?

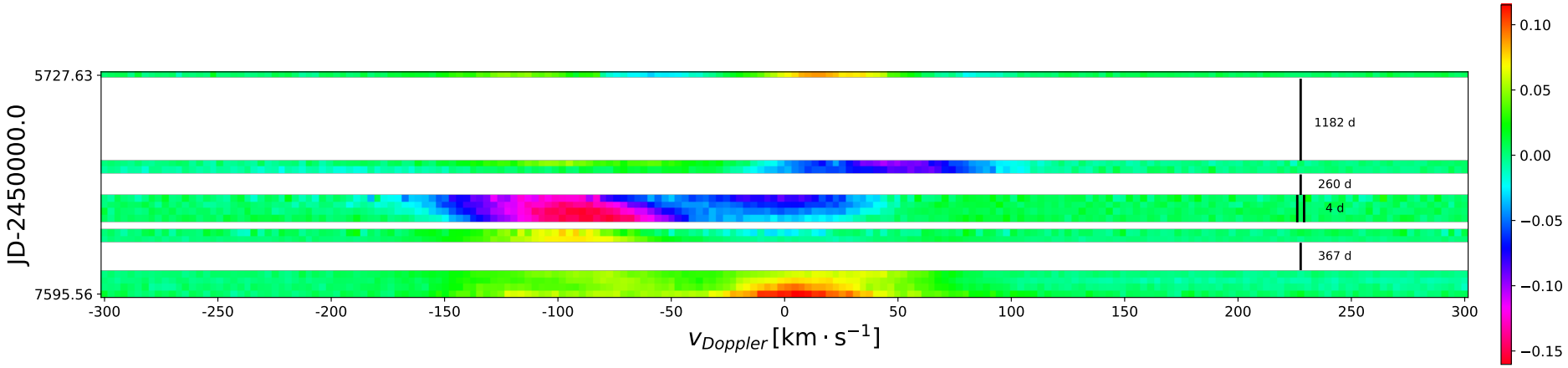
- HUGE macro structures may explain the depth of Hα HVA profiles
- HUGE macro structures ($\geq R_{\odot}$) = clumps moving towards OR away from the observer may explain the shift in $v_{Dopller}$/ RV of line cores/RV of absorption components
- can they be formed in the very upper layers of the atmosphere?
  - because there is an evidence of imprint of HVA in photospheric lines (Ismailov 2020, Ismailov 2021)

- HVE??? (High Velocity Emission events)
  - caused by geometry $\rightarrow$ $v\,sin(i)$?
  - or...?

HD 199478

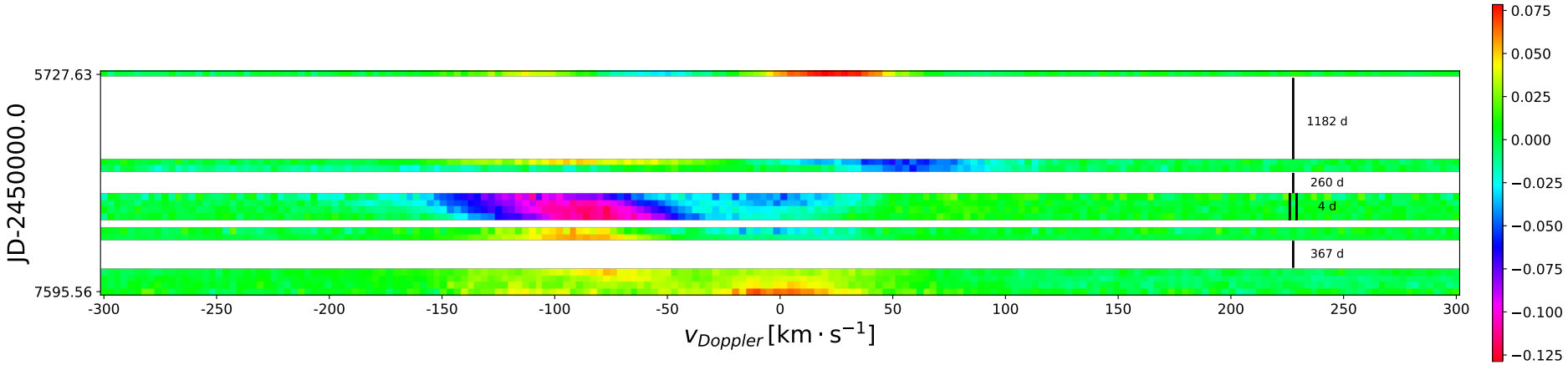


(a) Residual dynamic spectrum of Hα line.

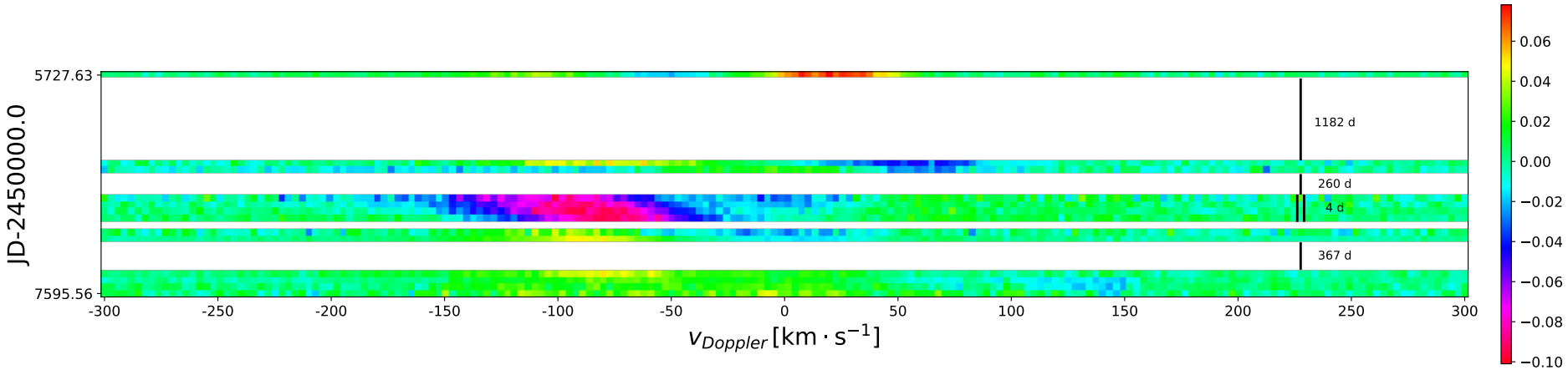


(b) Residual dynamic spectrum of Hβ line.

HD 199478



(c) Residual dynamic spectrum of Hγ line.



(d) Residual dynamic spectrum of Hδ line.

So, what's going on during HVA?

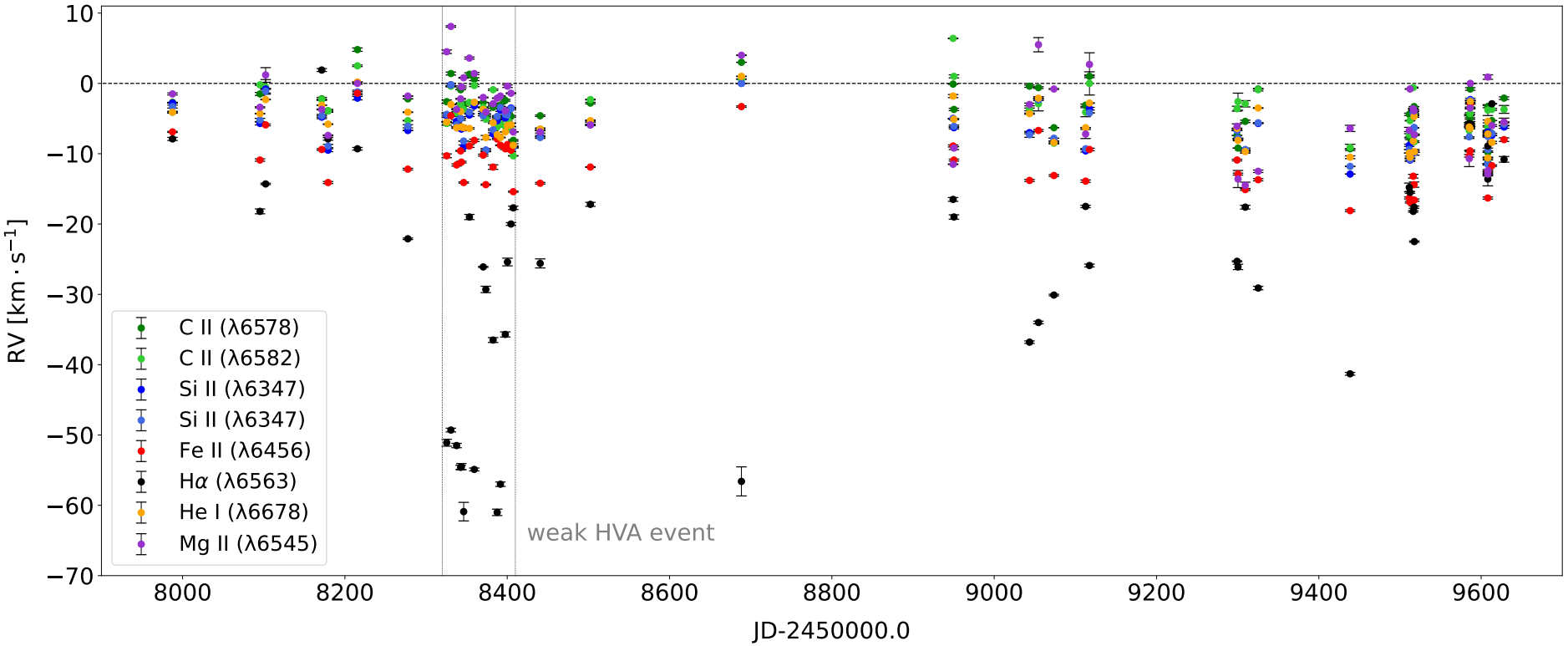


Figure: No imprint in photospheric lines.

HD 199478

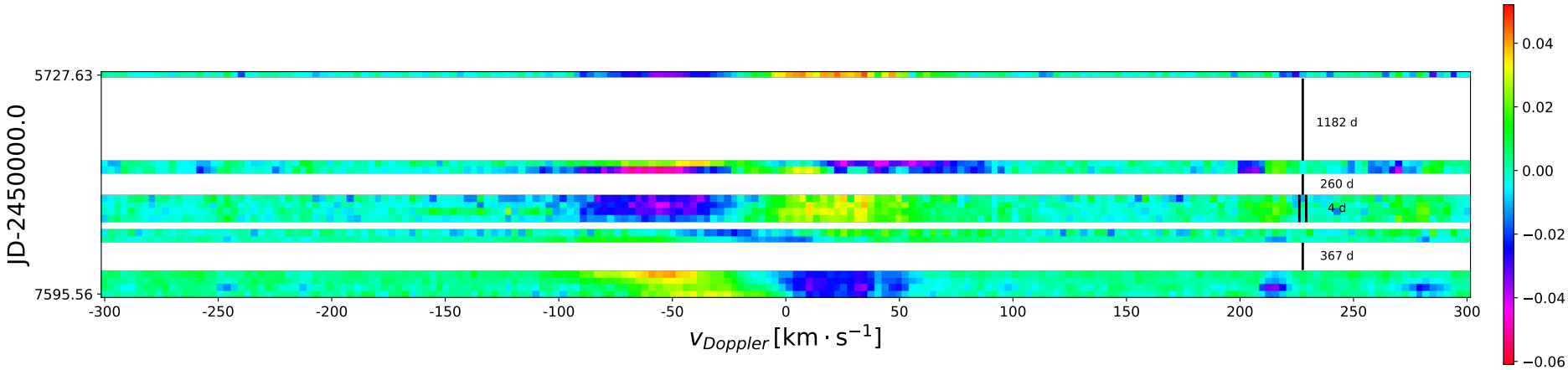


Figure: Residual dynamic spectrum of He I (λ5876) line.

HD 199478

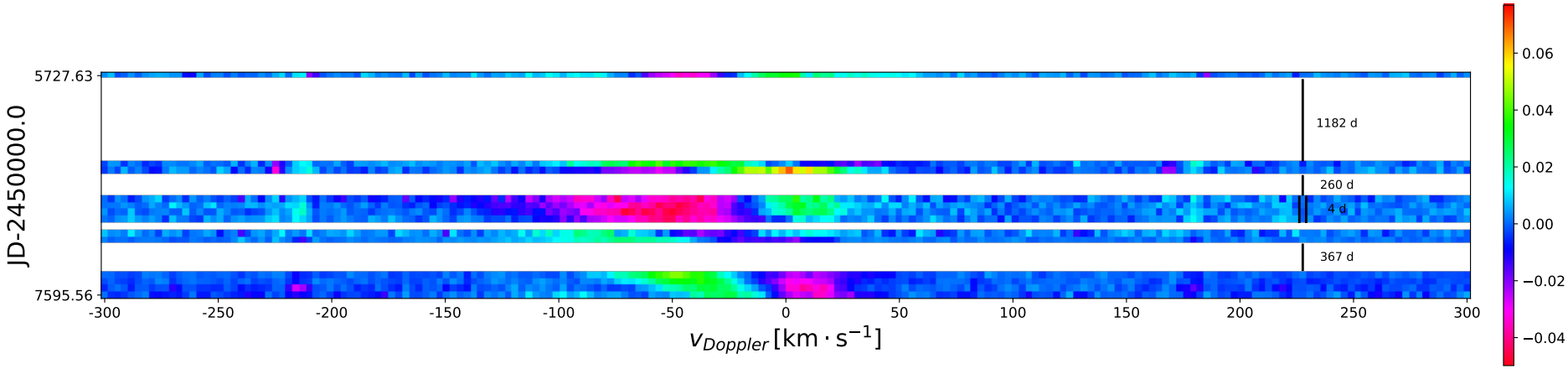


Figure: Residual dynamic spectrum of Si II (λ6347) line.

HD 34085

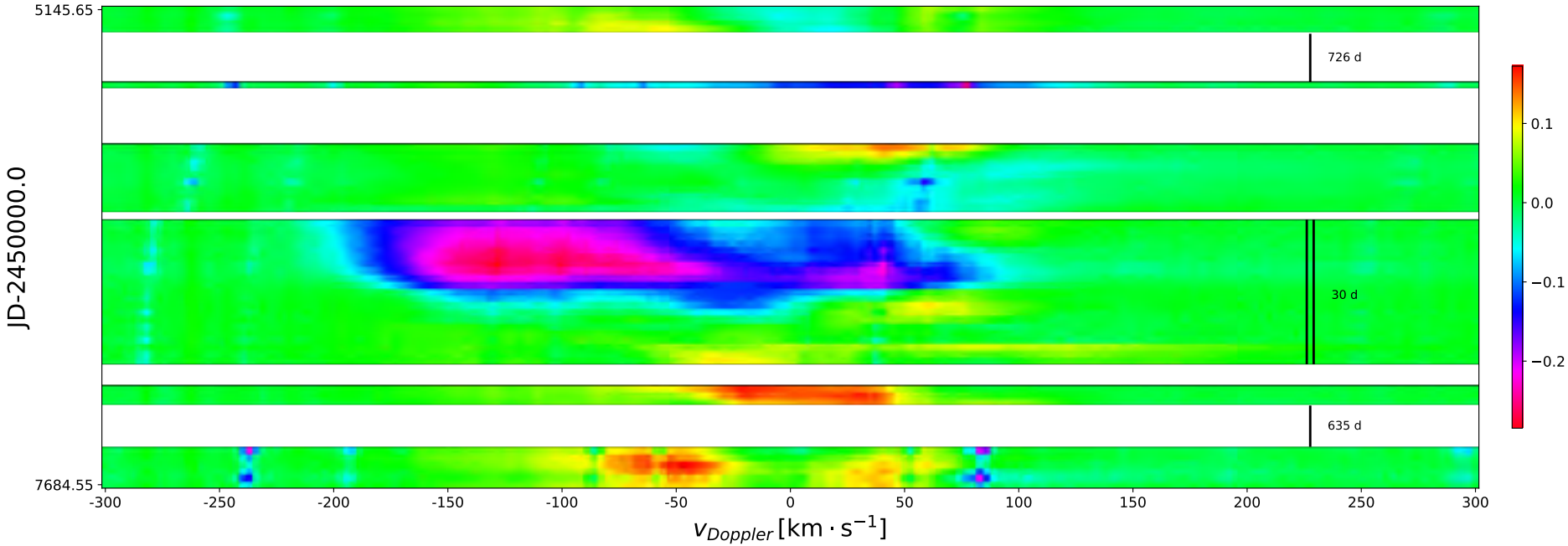


Figure: Residual dynamic spectrum of Hα line.

HD 34085

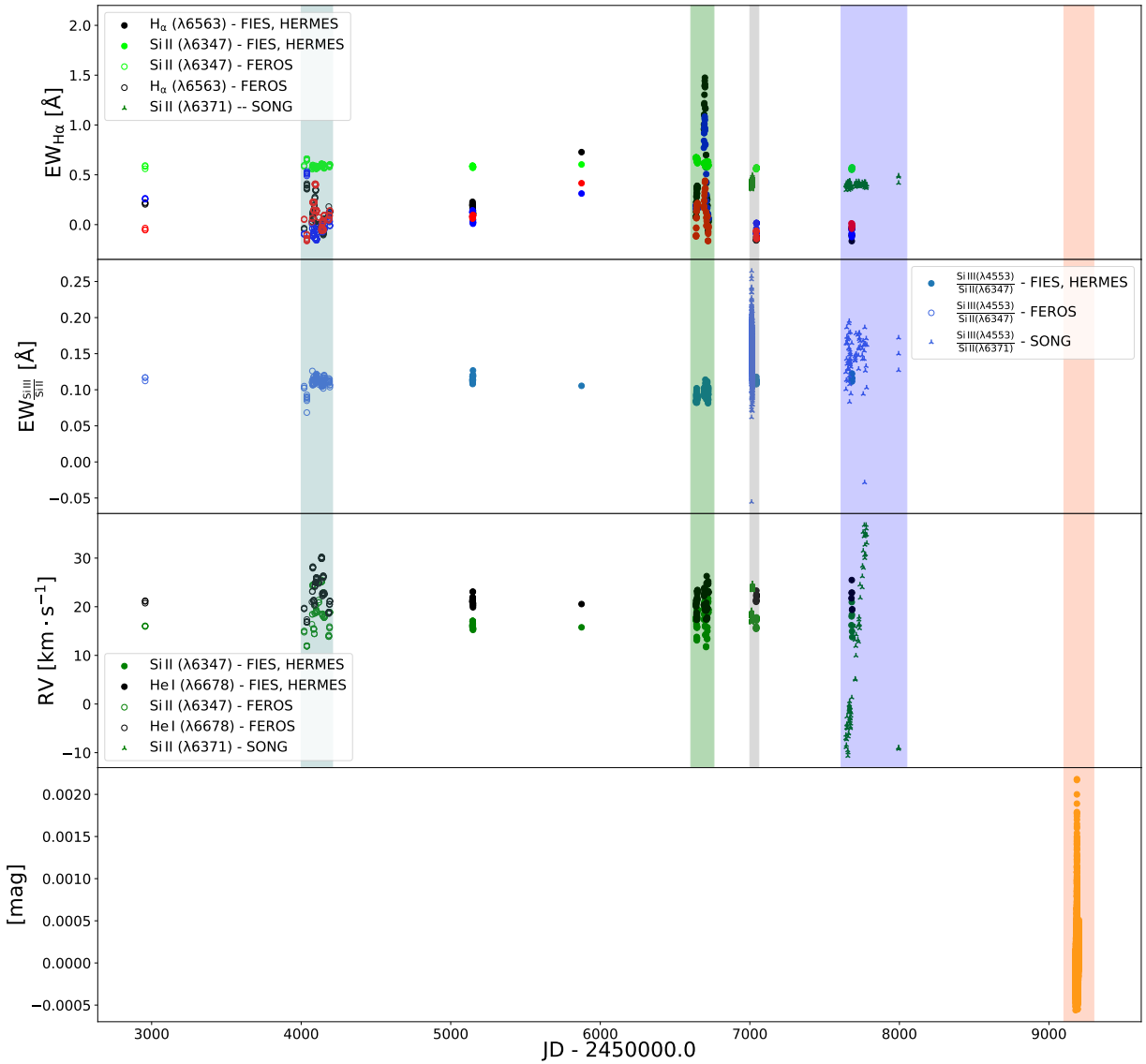


Figure: RV and EW of selected lines of Rigel.

HD 34085

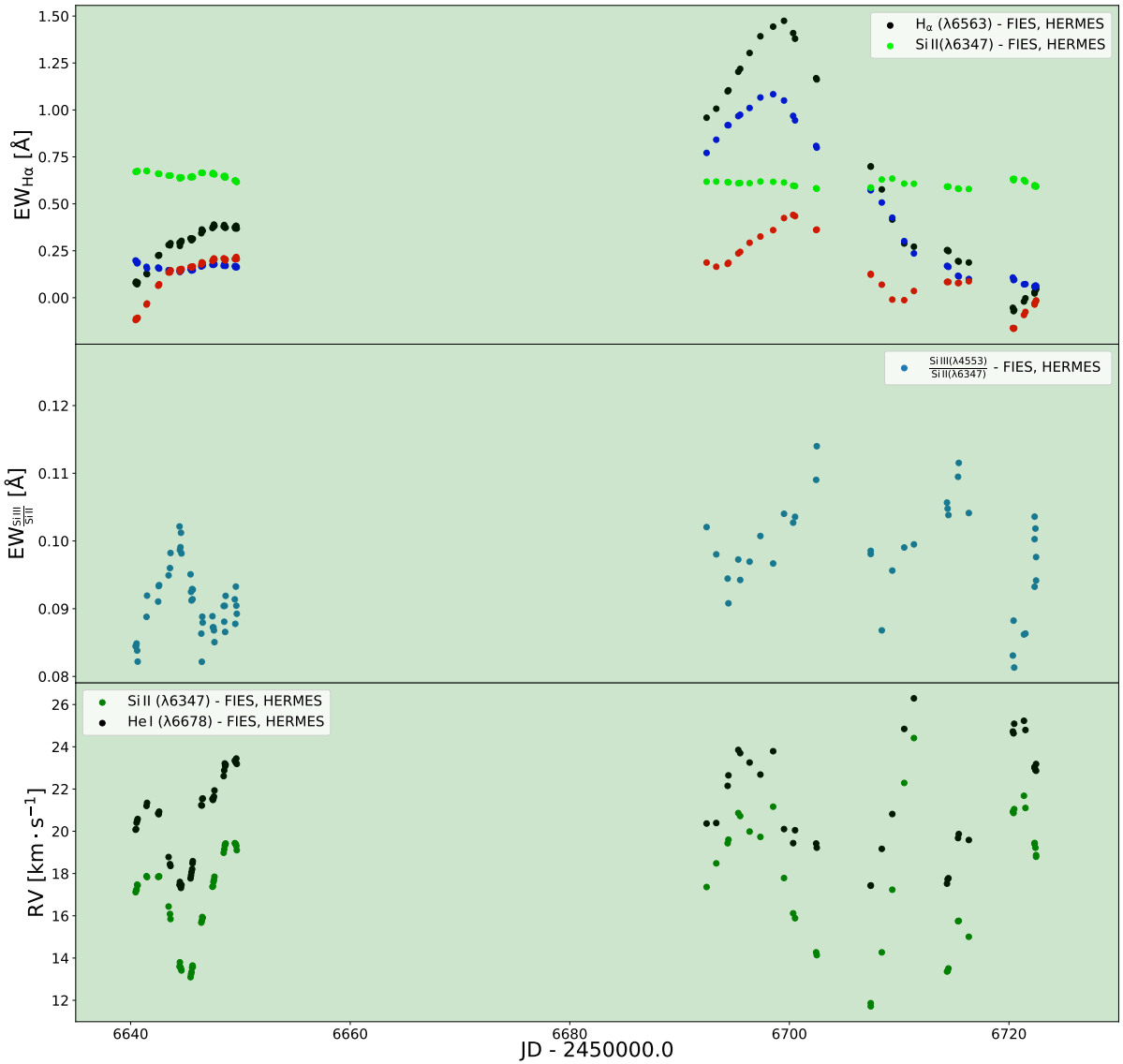


Figure: Zoomed part of previous figure I.

Evidence for HVA events - Rigel

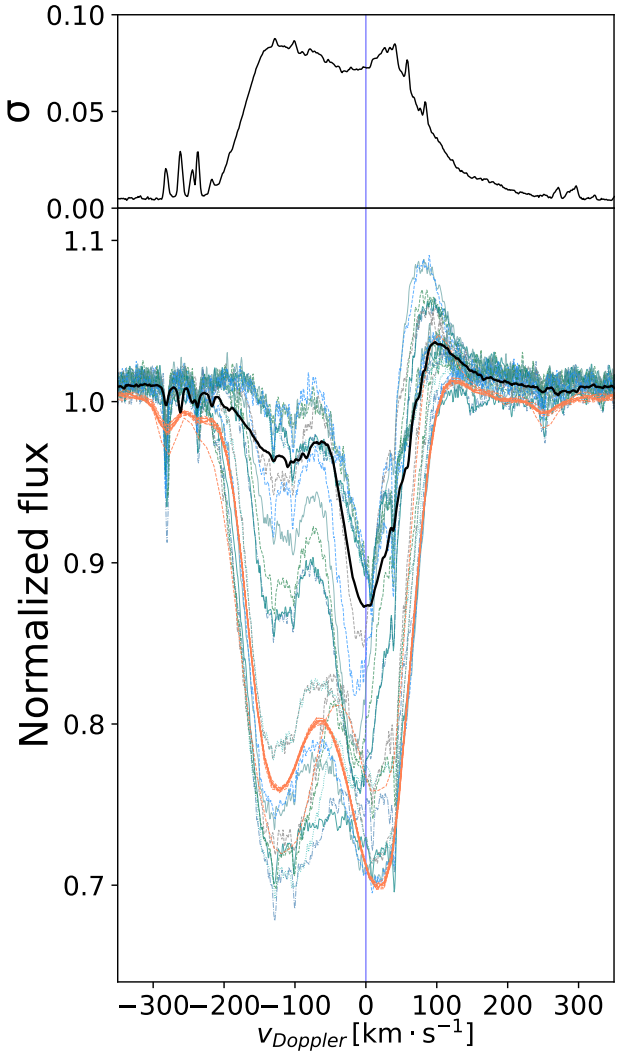


Figure: TVS of HD 34085. Highly blue-shifted Hα lines' profile has been taken during HVA event.

HD 34085

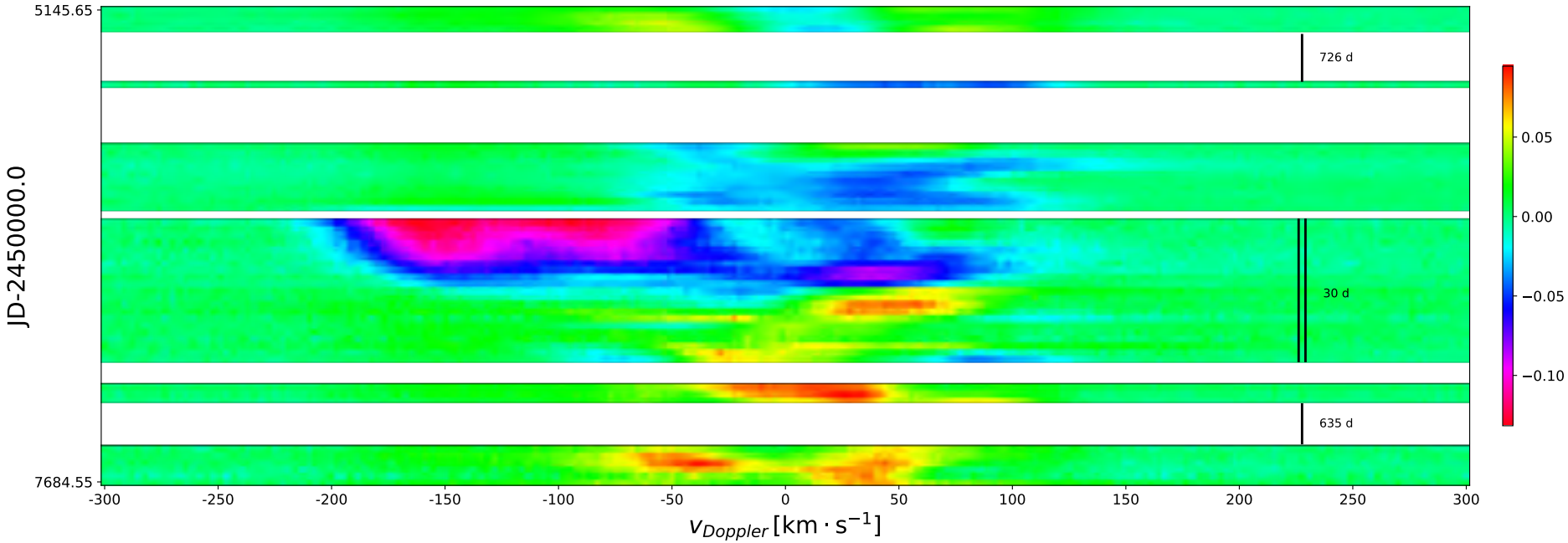


Figure: Residual dynamic spectrum of Hβ line.

HD 34085

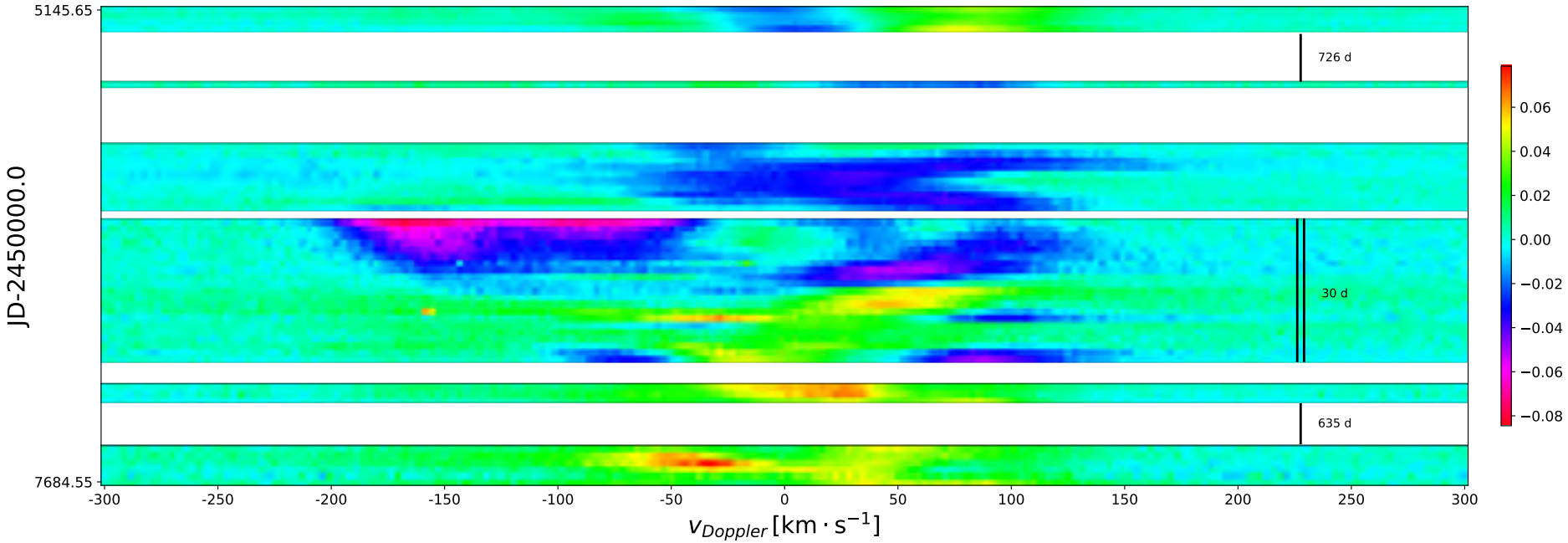


Figure: Residual dynamic spectrum of Hγ line.

HD 34085

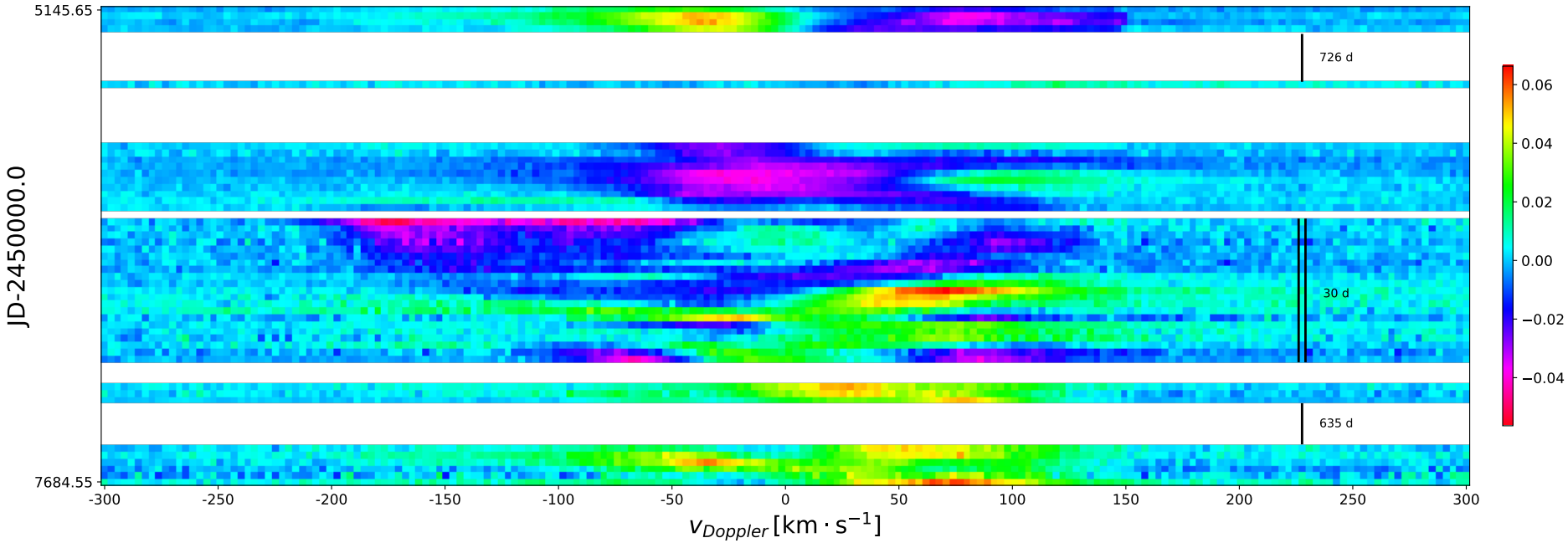
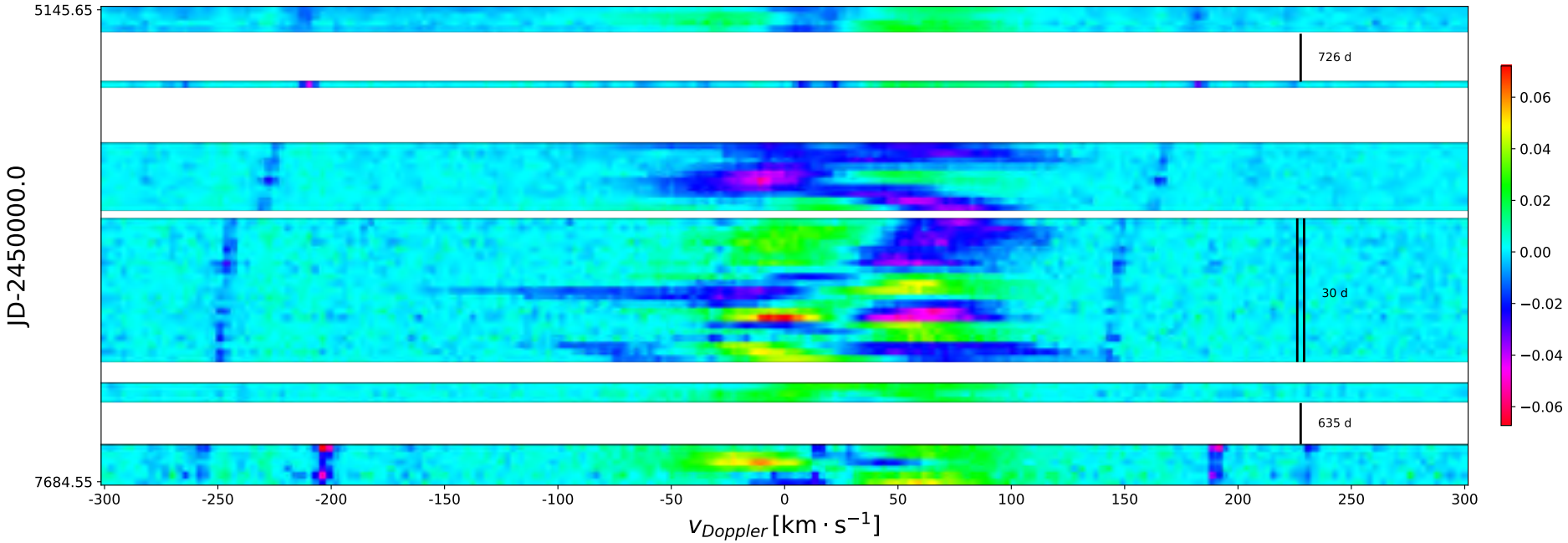


Figure: Residual dynamic spectrum of Hδ line.

HD 34085



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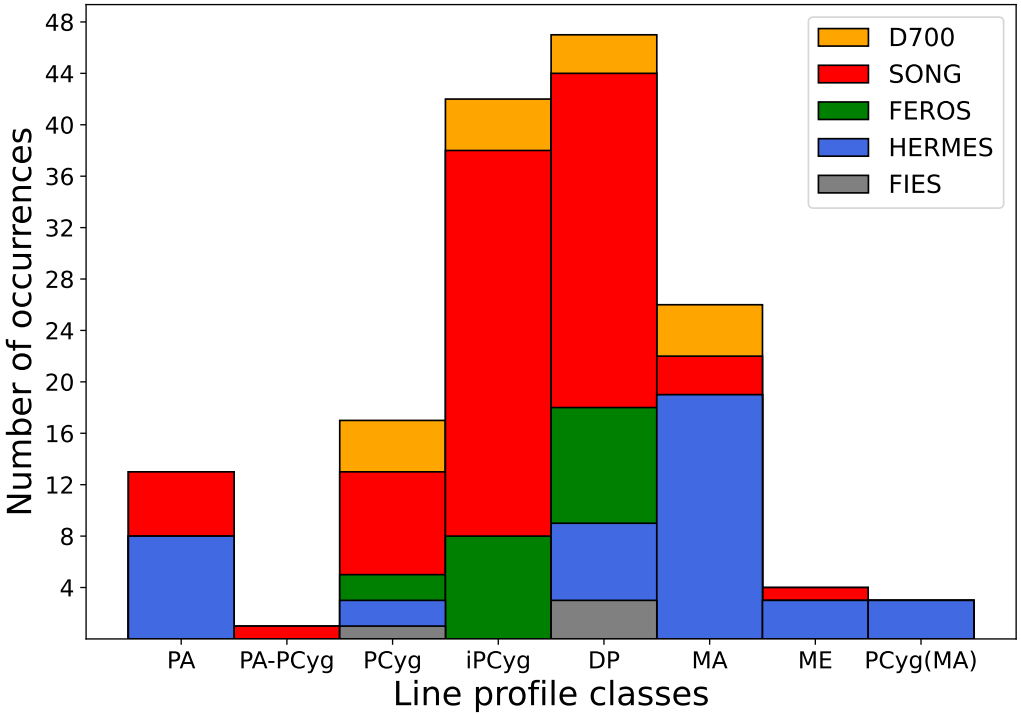


PA - pure absorption profile

PA-PCyg - pure absorption profile turning smoothly to PCyg

PCyg - PCyg type profile

iPCyg - inverse PCyg type profile

DP - double-peaked profile

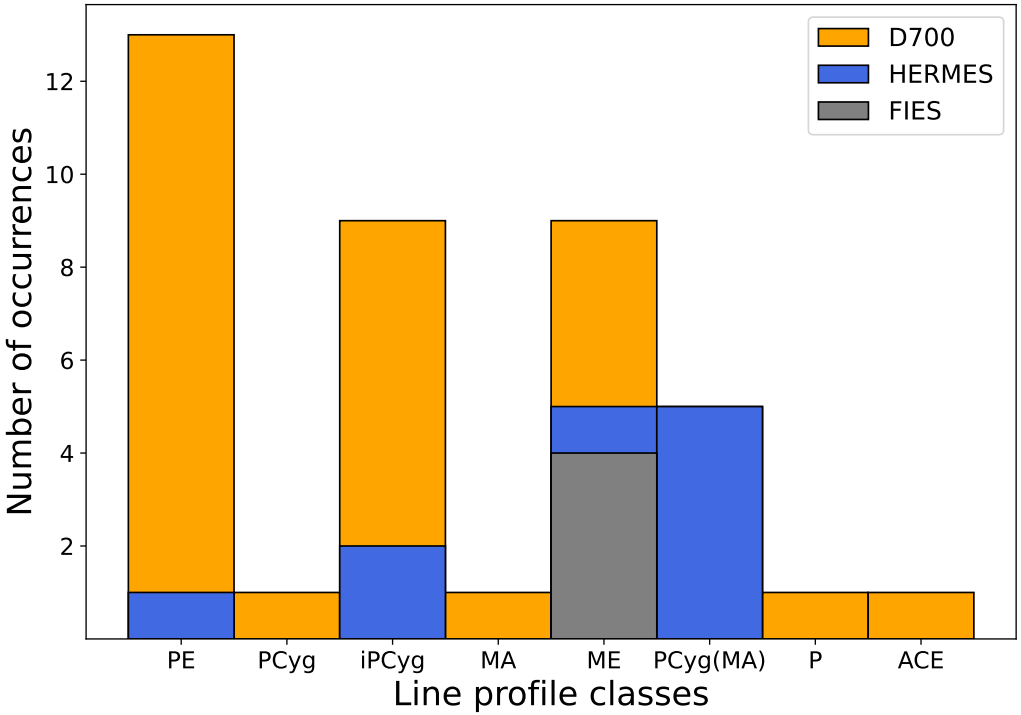
MA - absorption profile with multiple components

ME - emission profile with multiple components

PCyg(MA) - PCyg type profile with multiple absorption components

Figure: Morphology histogram of Hα line profiles.

HD 199478



PE - pure emission profile
PCyg - PCyg type profile
iPCyg - inverse PCyg type profile
DP - double-peaked profile
MA - absorption profile with multiple components
ME - emission profile with multiple components
PCyg(MA) - PCyg type profile with multiple absorption components
P - peculiar profile
ACE - absorption profile with central emission components

Figure: Morphology histogram of Hα line profiles.

Future insights

- how long does the HVA take? - in average
- comparison with the rotational period
- do the macro structures survive more that one rotational period?
- estimation of RV during the maximum $\rightarrow$ comparison with v_∞
- is there contribution of other effects (eg. binarity or pulsations)?
- **do the results correspond to the hypothesis???**
- is it possible to see HVA in light curves?
- would it be possible to say (based on the hypothesis) why do we observe just a few of them?

Thank You for Your Attention!