Advantages of using TMT High-Resolution Optical Spectrograph for study of chemically peculiar stars

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Chemically peculiar stars

Main sequence stars show peculiar abundance of many chemical species, while some of these stars have a strong magnetic field.

The observed peculiar abundance of chemical species is related just to the stellar atmosphere and does not reflect the chemical composition of the whole star.

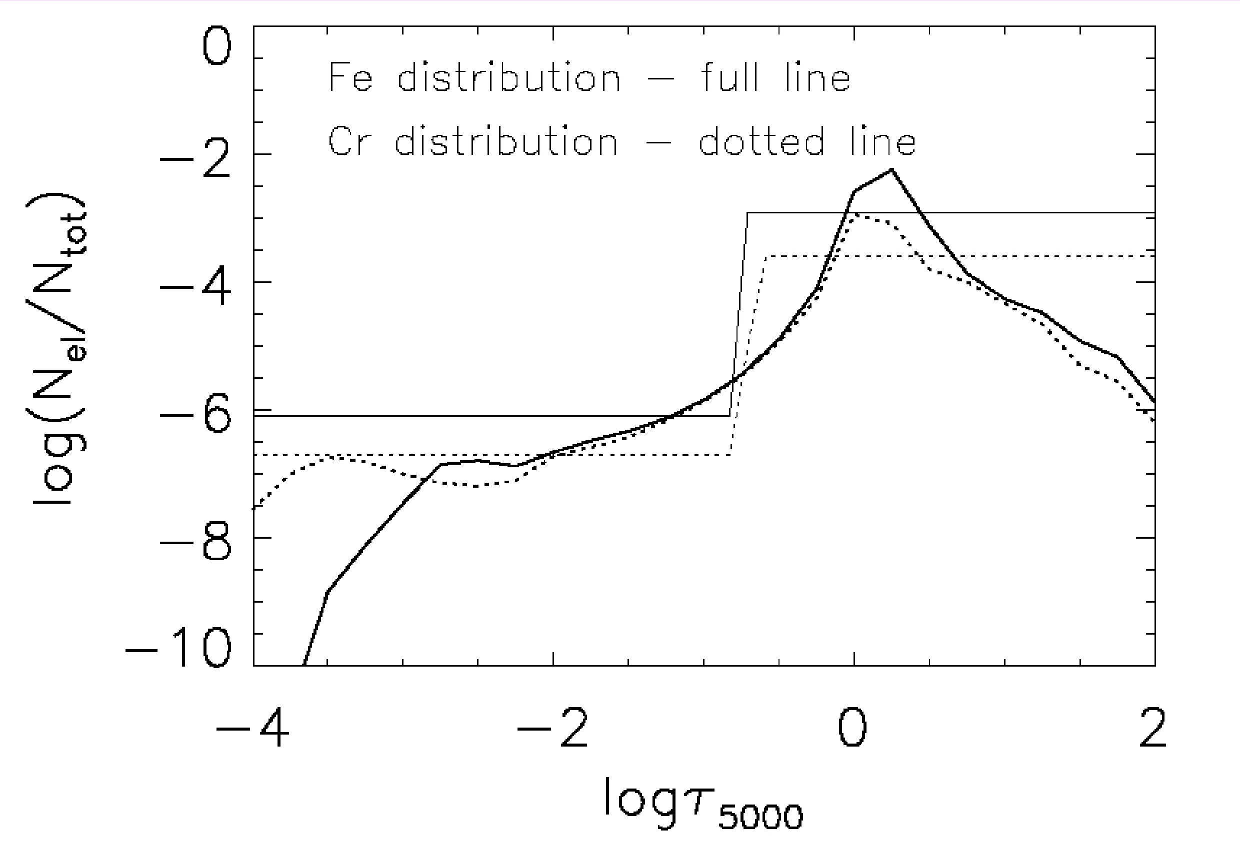
Phenomenon of the main sequence CP stars

10-15% of stars on the main sequence are chemically peculiar (Gomez et al. 1998, Bagnulo 2002).
Preston (1974) has classified them as Ap and Bp stars

Ap		Bp
SrCrEu: α Gem A, ζ UMa A	Magnetic stars	He-strong: δ Ori B
Si: CU Vir		He-weak SiSrTi: α Scl
HgMn: 53 Tau, ζ CMi	Non-magnetic stars	He-weak
Am: α Gem B, 15 UMa		λ Boo: ρ Vir, λ Boo

Spectropolarimetric observations (Shorlin et al. 2002)

Phenomenon of the main sequence CP stars

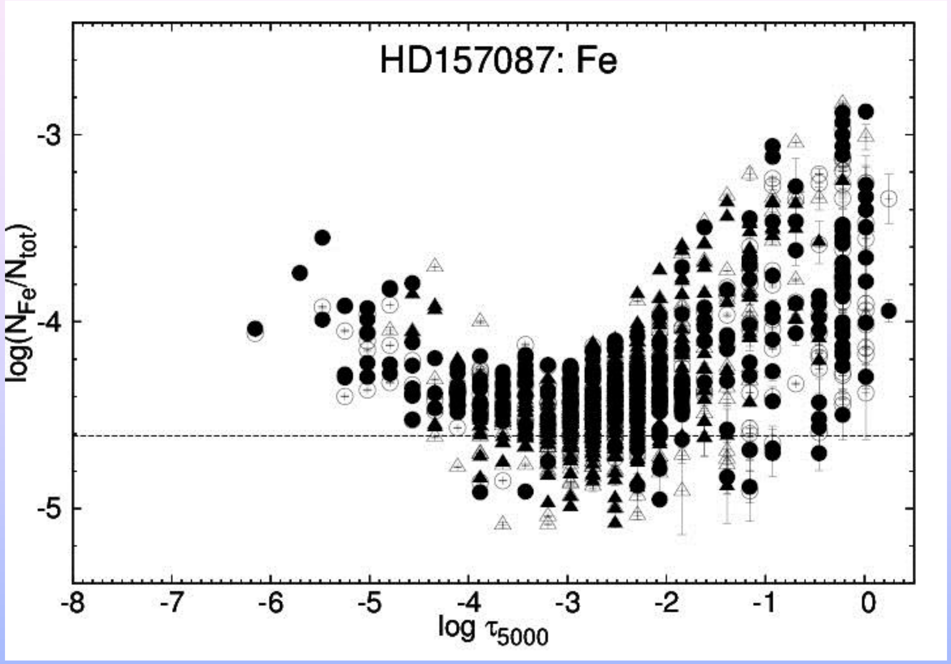


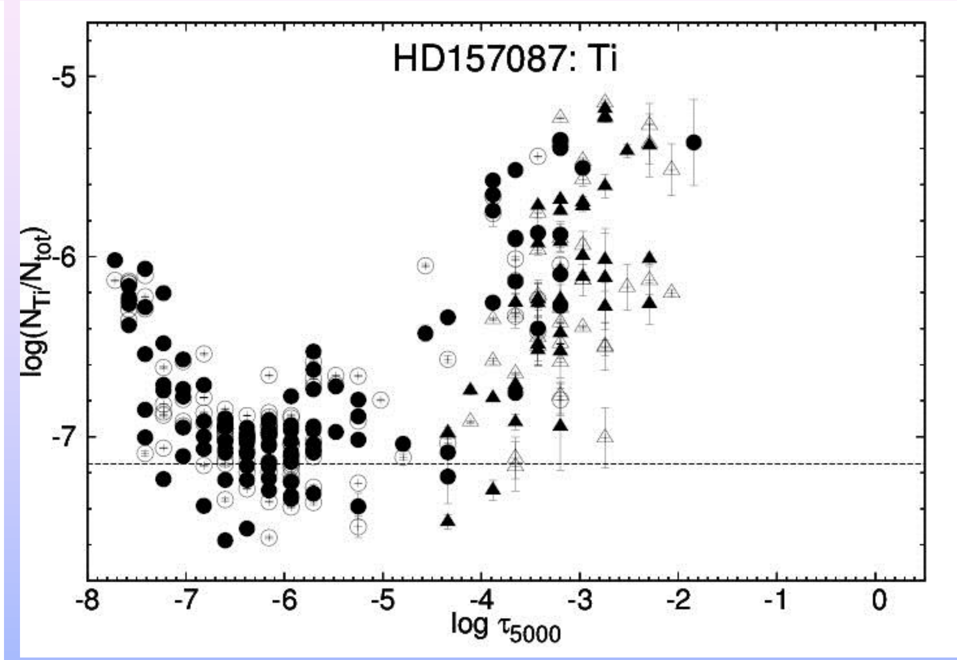
Some chemical elements show vertical stratification of their abundance (Ryabchikova et al. 2002)

Atomic diffusion (Michaud 1970) can explain qualitatively these features.

Comparison of the empirical data for vertical stratification of Fe and Cr (fine lines) with the results of numerical modeling of abundance stratification taking into account the effect of atomic diffusion (thick lines) for β CrB.

Project VeSElkA: Vertical stratification





log τ_{5000}= -0.5:-3.2 a = 0.29 ± 0.01
log τ_{5000}= -3.2:-8.0 a = -0.28 ± 0.03

log τ_{5000}= -1.5:-6.0 a = 0.42 ± 0.04
log τ_{5000}= -6.0:-8.0 a =-0.54 ± 0.06

Similar behavior of abundance stratification has been found for Fe and Ti in HD41076, HD148330 (Khalack et al. 2017) and HD157087 (Khalack 2018).

Using TMT HROS for study of CP stars

The High-Resolution Optical Spectrograph (HROS) with R~25000, 50000, and 100000, combined with the multi-object capability, is considered as a potential instrument for the TMT that will be in high demand by the scientific teams engaged in the galactic and stellar astrophysics.

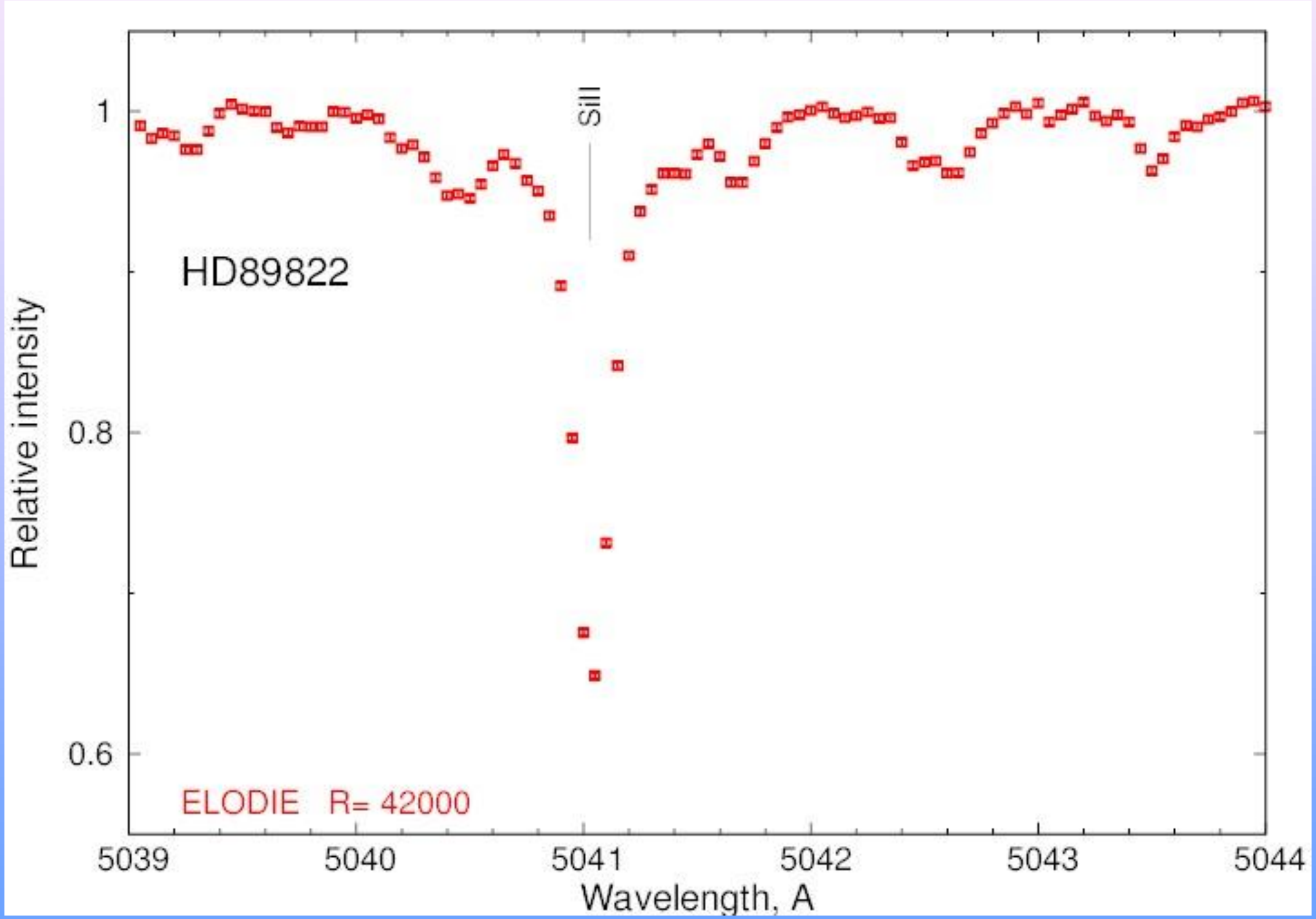
Taking full advantage of the TMT large aperture, HROS will provide a unique opportunity to study:

- binary systems (SB2)
- line profile variability in chemically peculiar (CP) stars
- Zeeman and Partial Paschen-Back splitting in magnetic CP stars
- CP stars in open clusters and nearby galaxies

Study of SB2 binary systems

HD89822 is a CP star (α^2 CVn type) that belongs to a SB2 system

Spectral region of SiII 5041A line observed with ELODIE and ESPaDOnS



Study of SB2 binary systems

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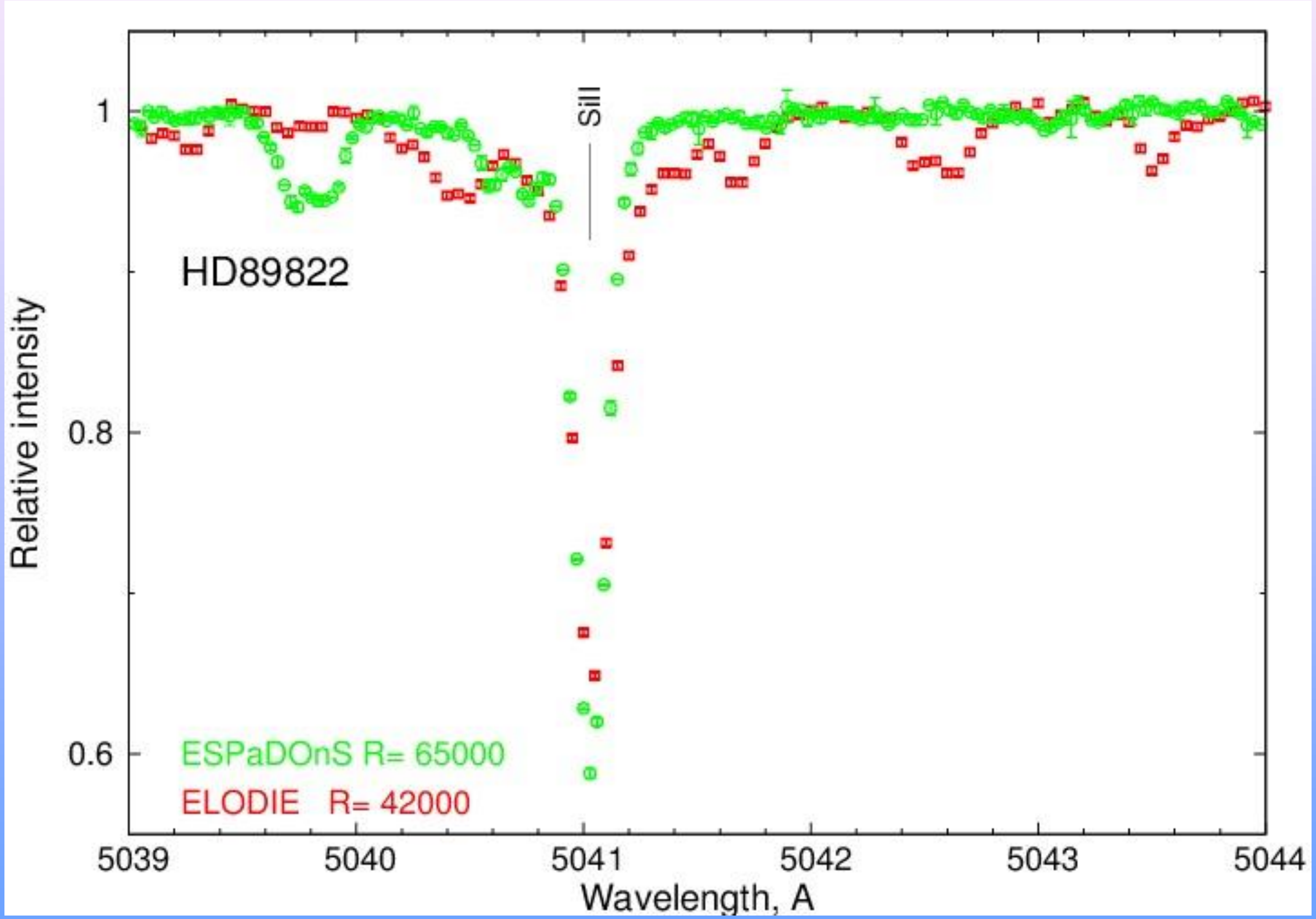
Higher spectral resolution is desirable and can be achieved with TMT HROS

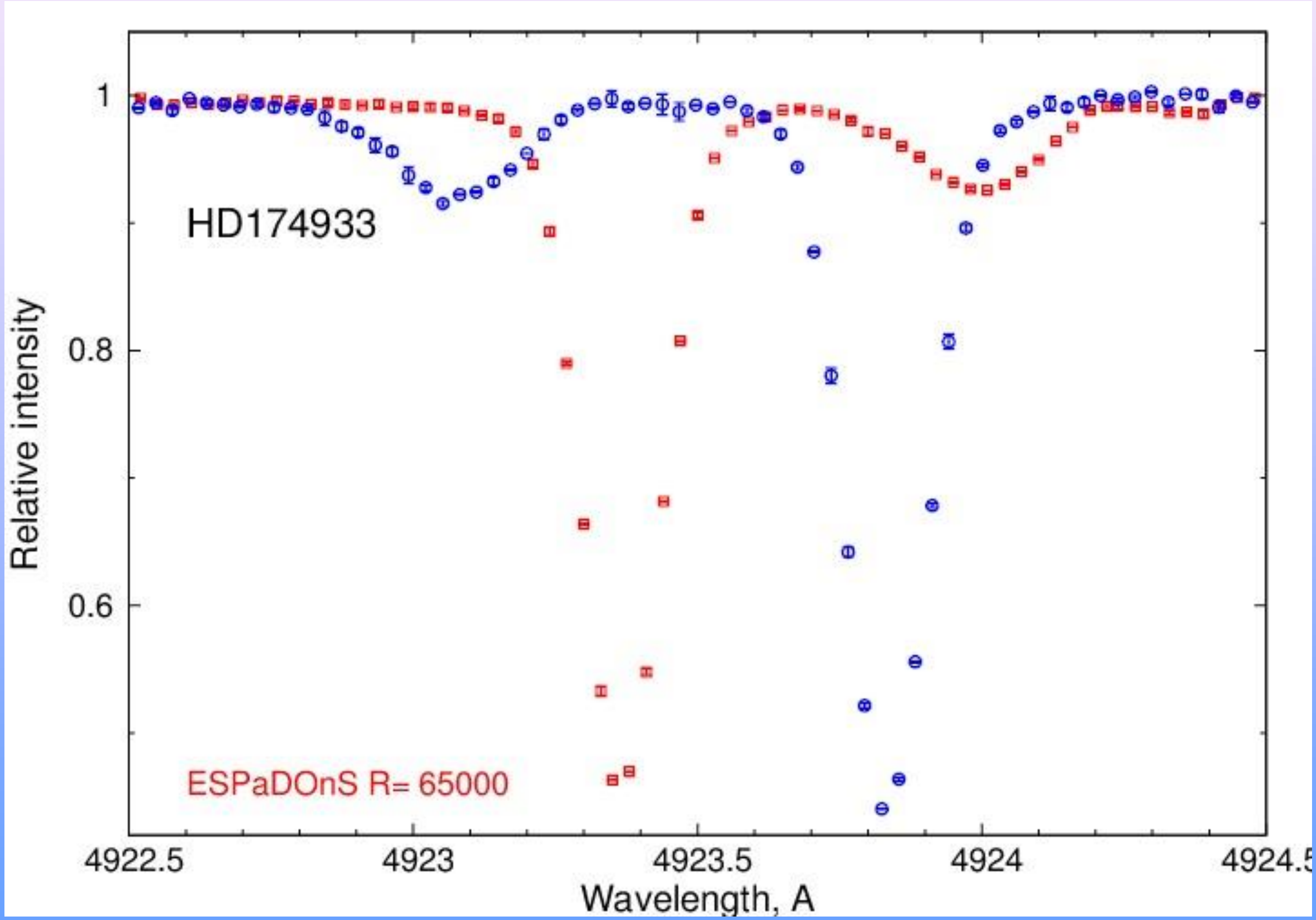


Study of SB2 binary systems

HD174933 (112 Her) is spectroscopic binary (SB2) that includes a HgMn star (B9p Hg)

Spectral region of FeII 4924A line observed with ESPaDOnS

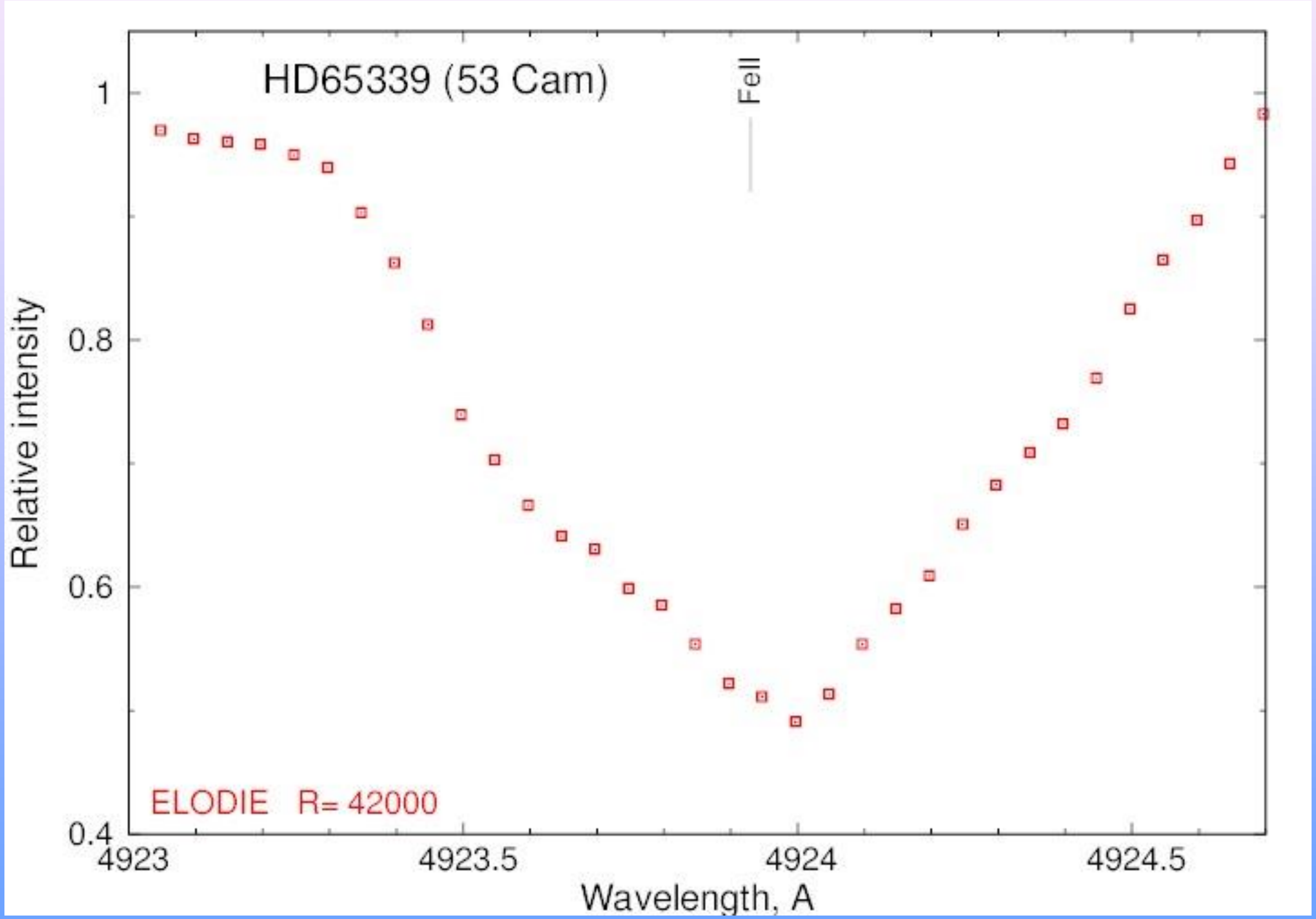
The high spectral resolution is required to distinguish the lines that belong to different components and to perform tomographic separation



Study of line profile variability

HD65339 (53 Cam) is a magnetic CP star that shows variability of line profiles

Spectral region of FeII 4924A line observed with ELODIE, ESPaDOnS and SOPHIE



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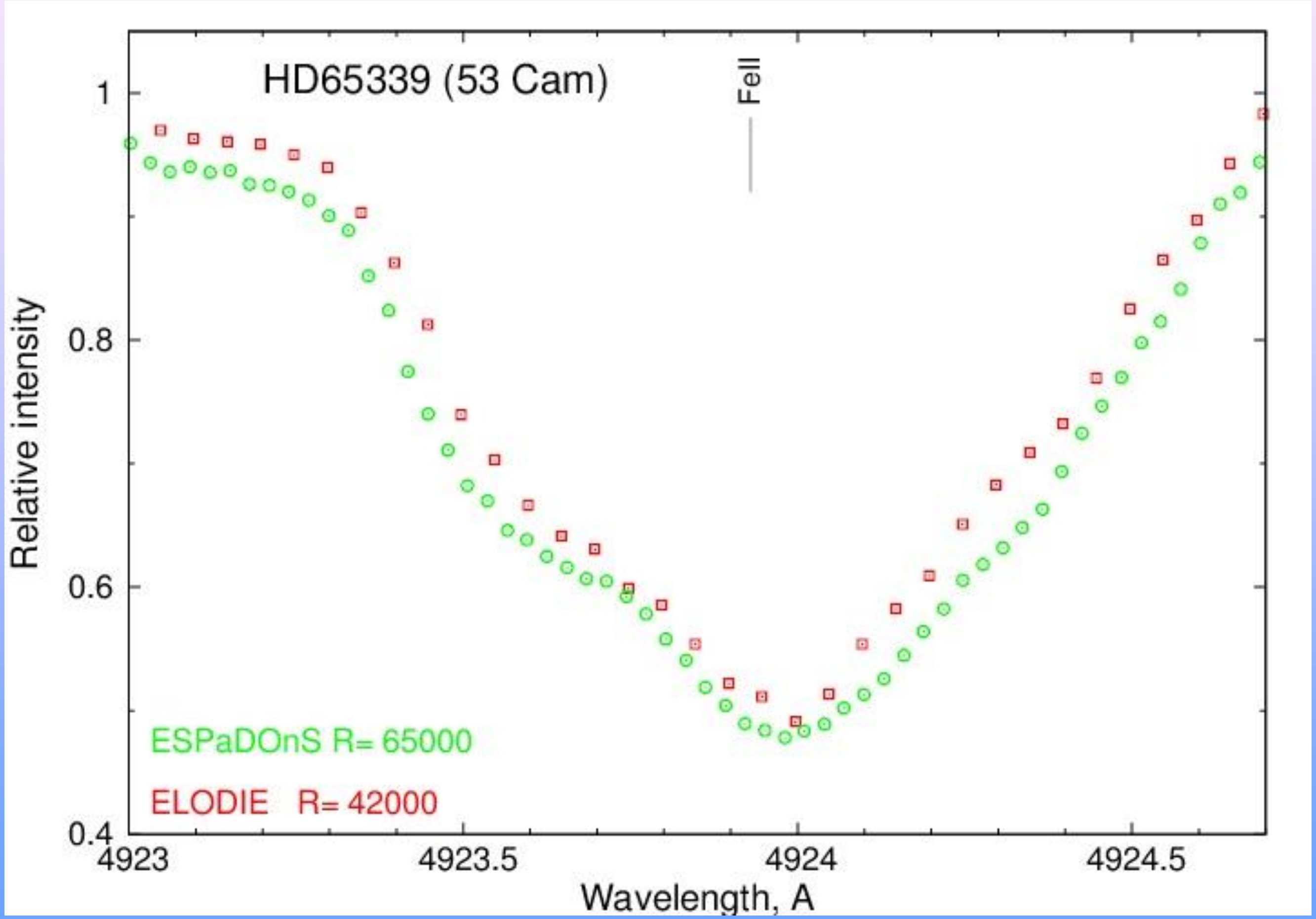

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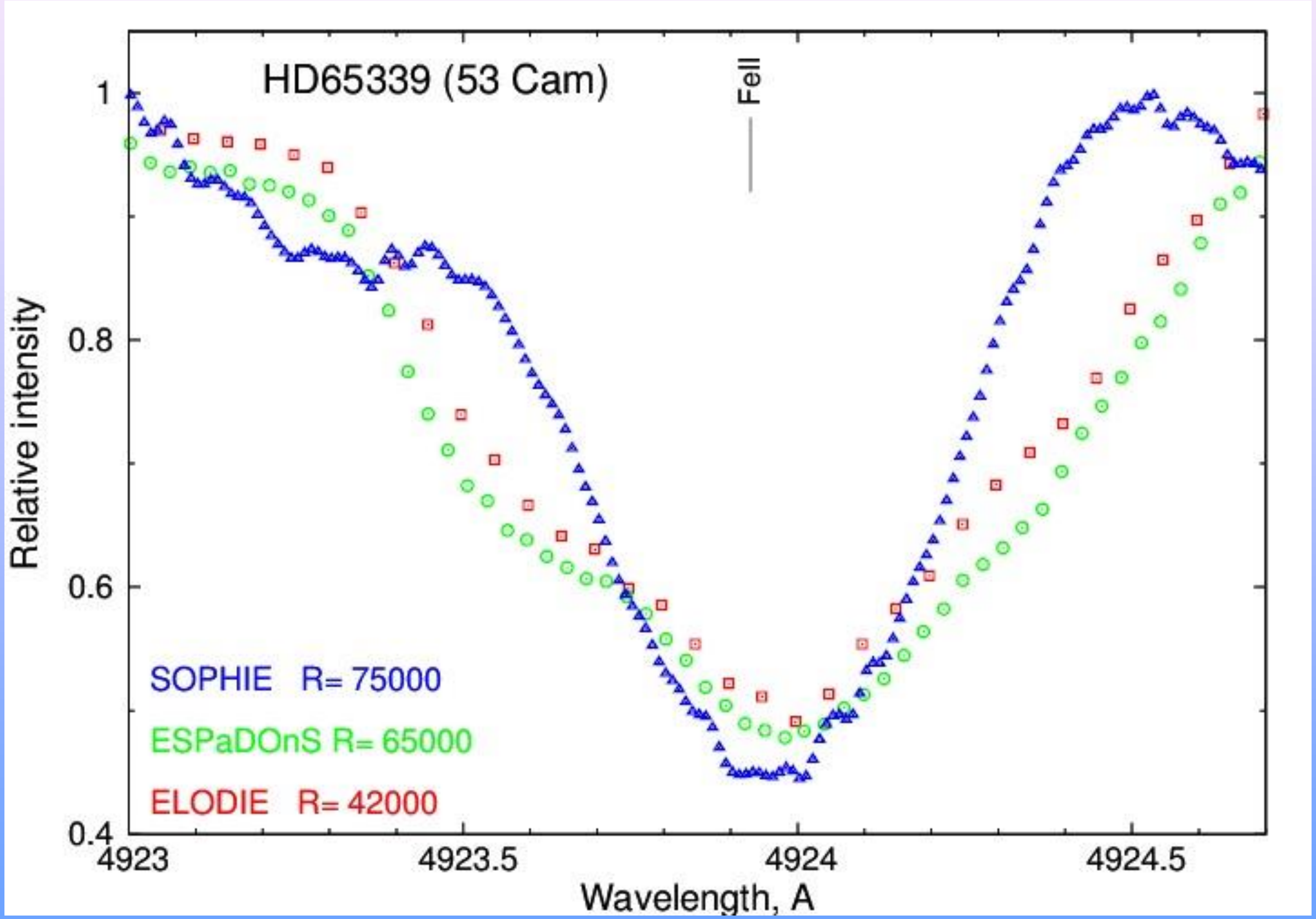
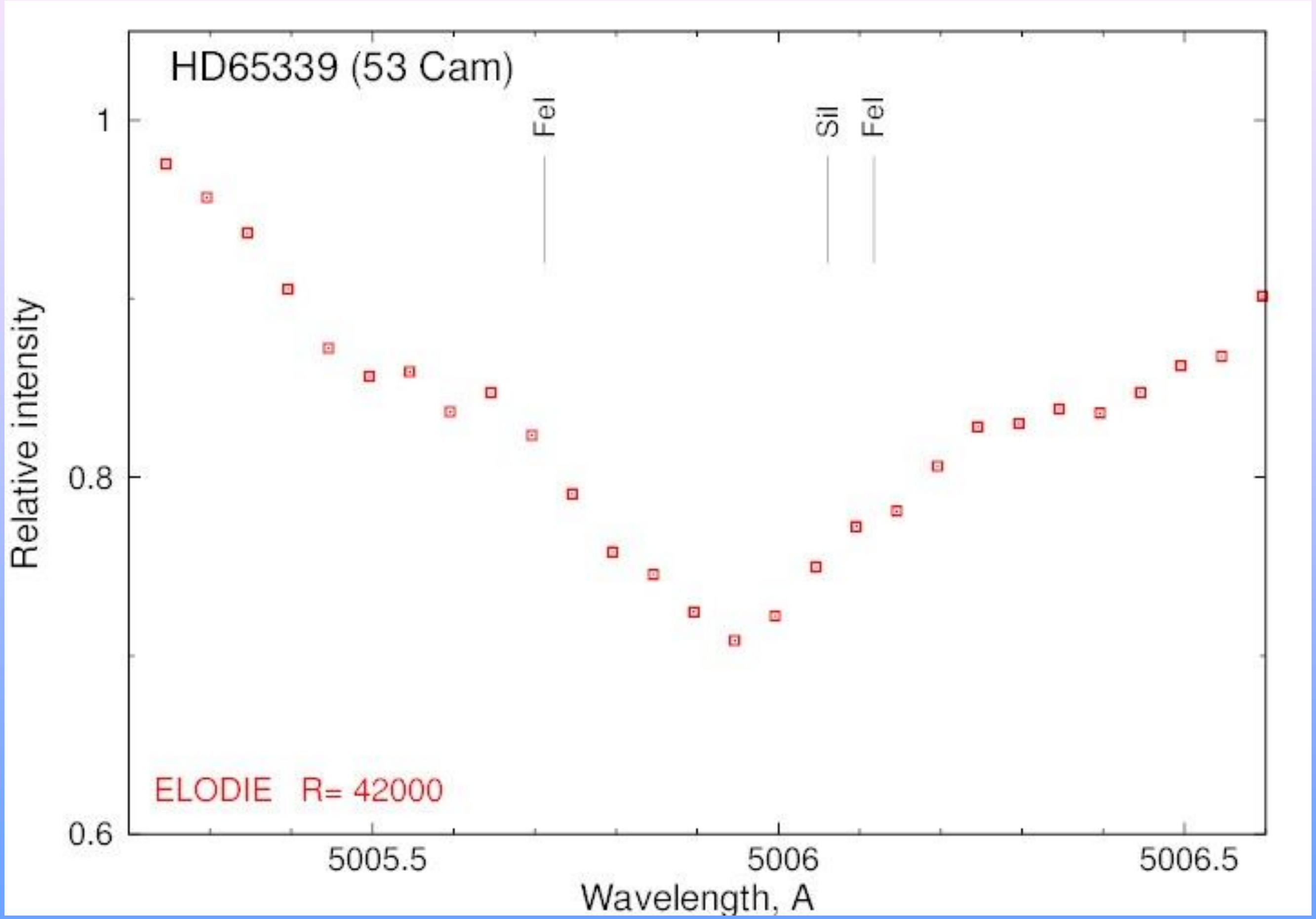
TMT HROS will provide spectra with higher spectral resolution R =100000



Study of line profile variability

HD65339 (53 Cam) is a magnetic CP star that shows variability of line profiles

Spectral region around 5005-5007AA observed with ELODIE, ESPaDOnS and SOPHIE



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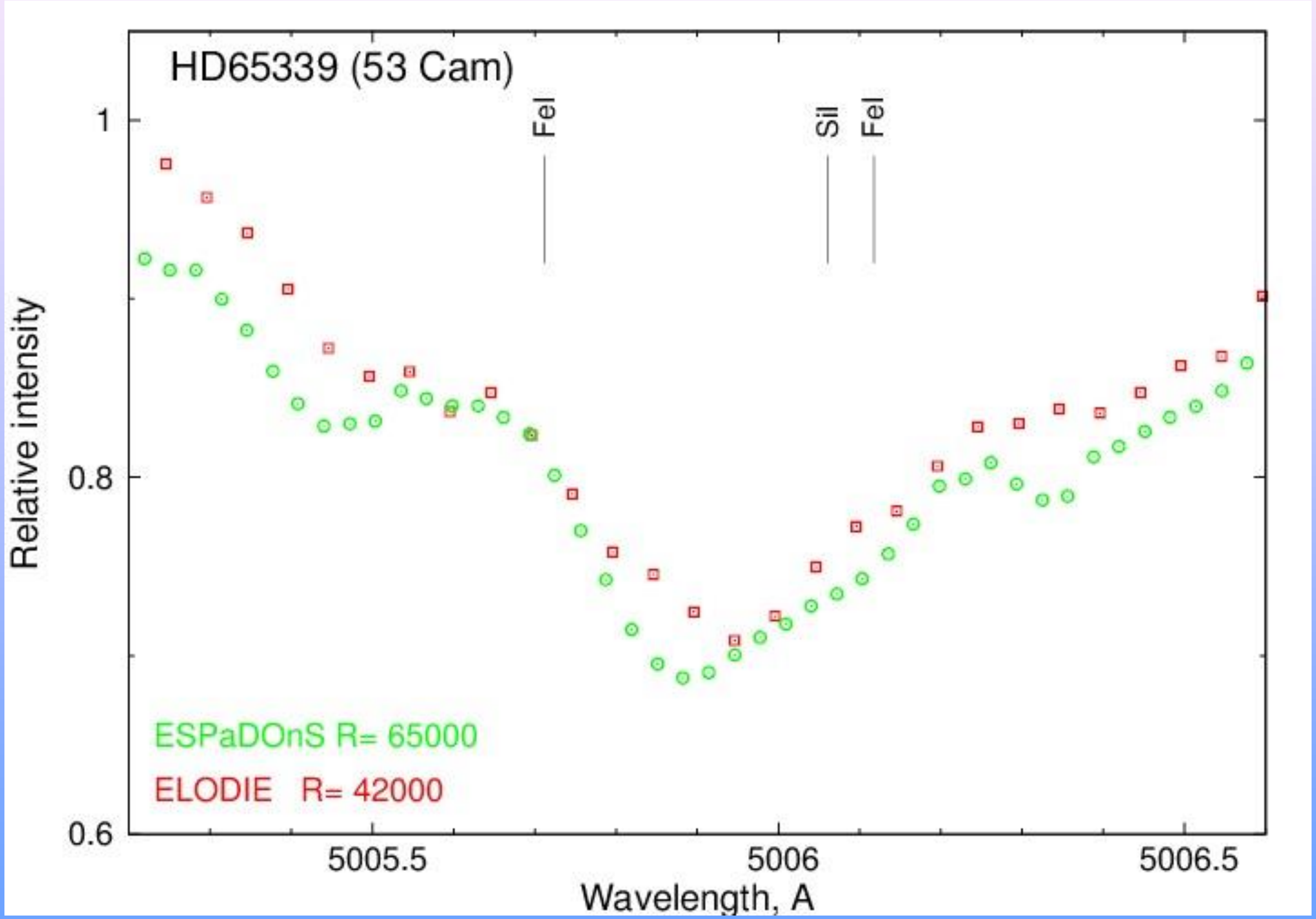

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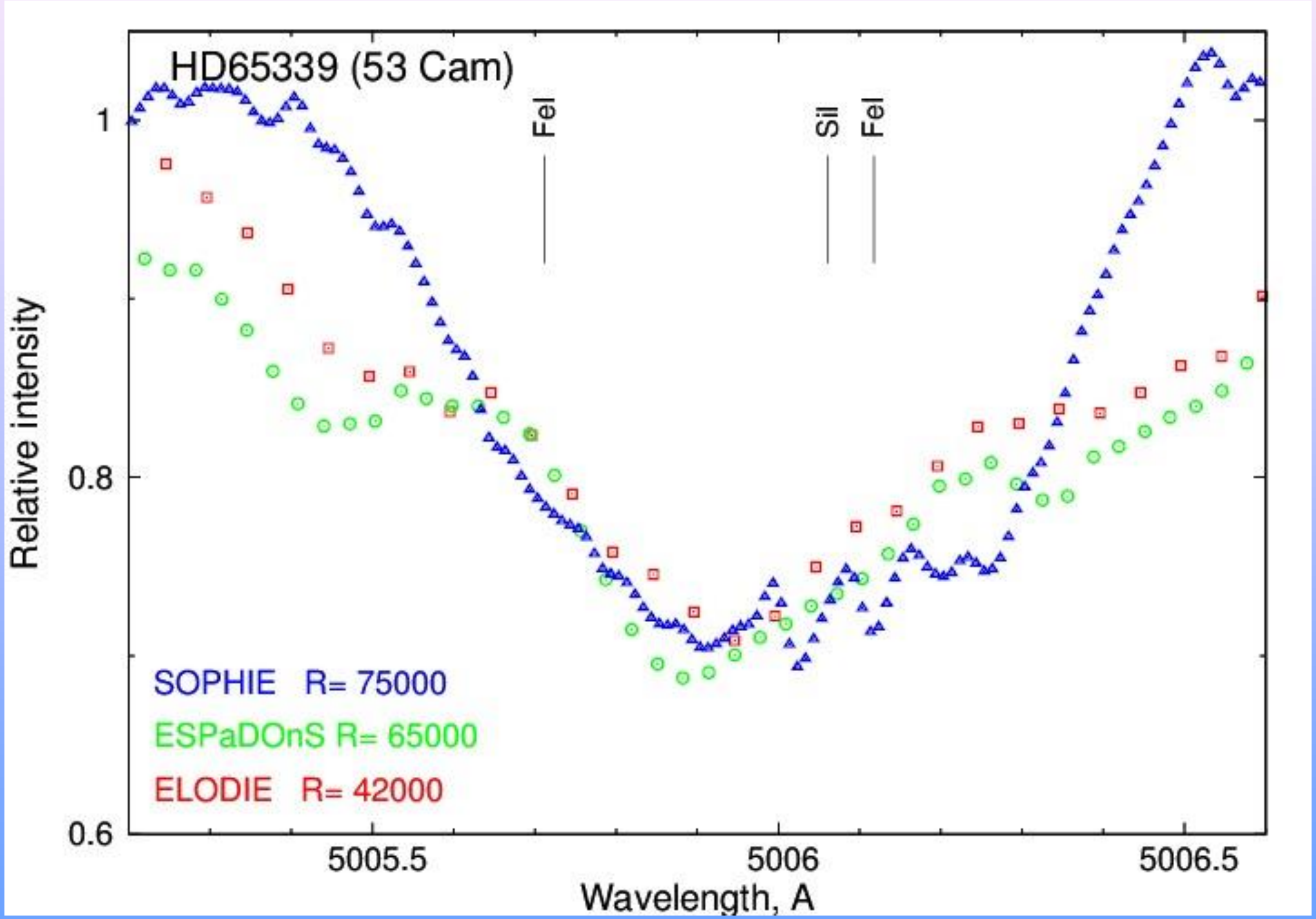

Study of line profile variability

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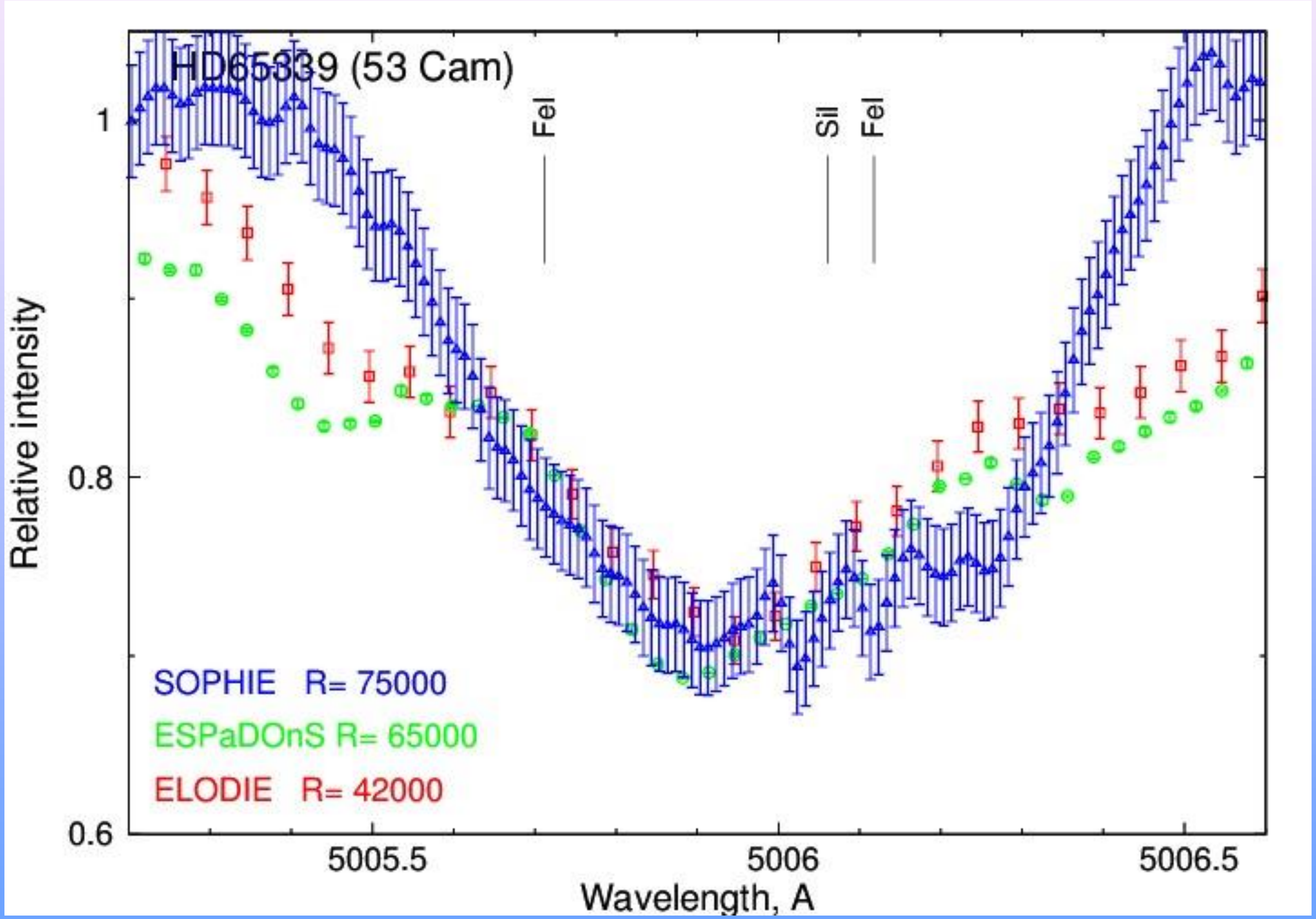
Spectral region around 5005-5007AA observed with ELODIE, ESPaDOnS and SOPHIE

SNR for ELODIE and SOPHIE data is relatively small

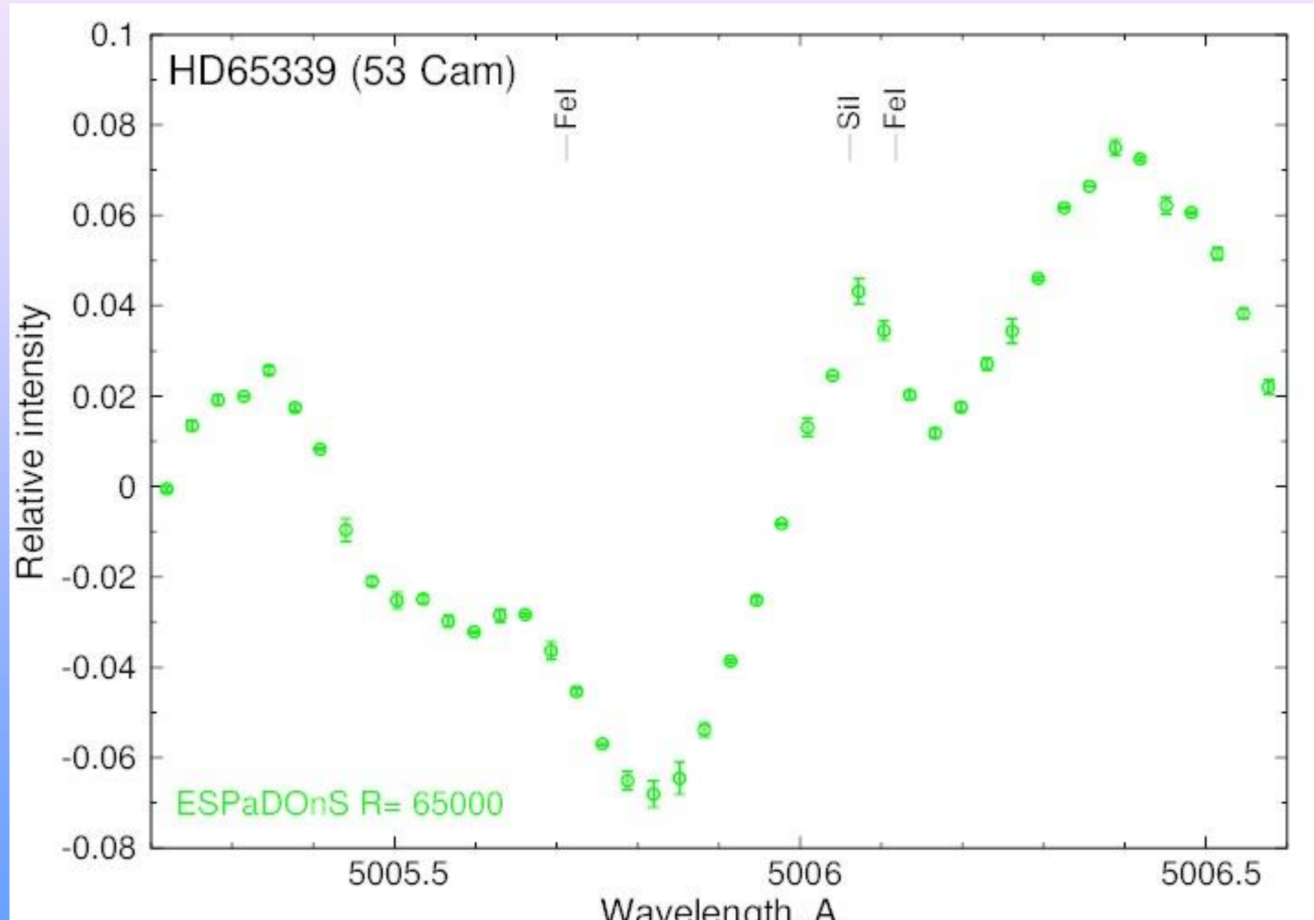
TMT HROS will provide better SNR for spectra



Study of line profile variability

HD65339 (53 Cam) is a magnetic CP star that shows variability of line profiles

Stokes V profile



Spectral region around 5005-5007AA observed with ESPaDOnS

Stokes V profile shows Zeeman splitting of lines

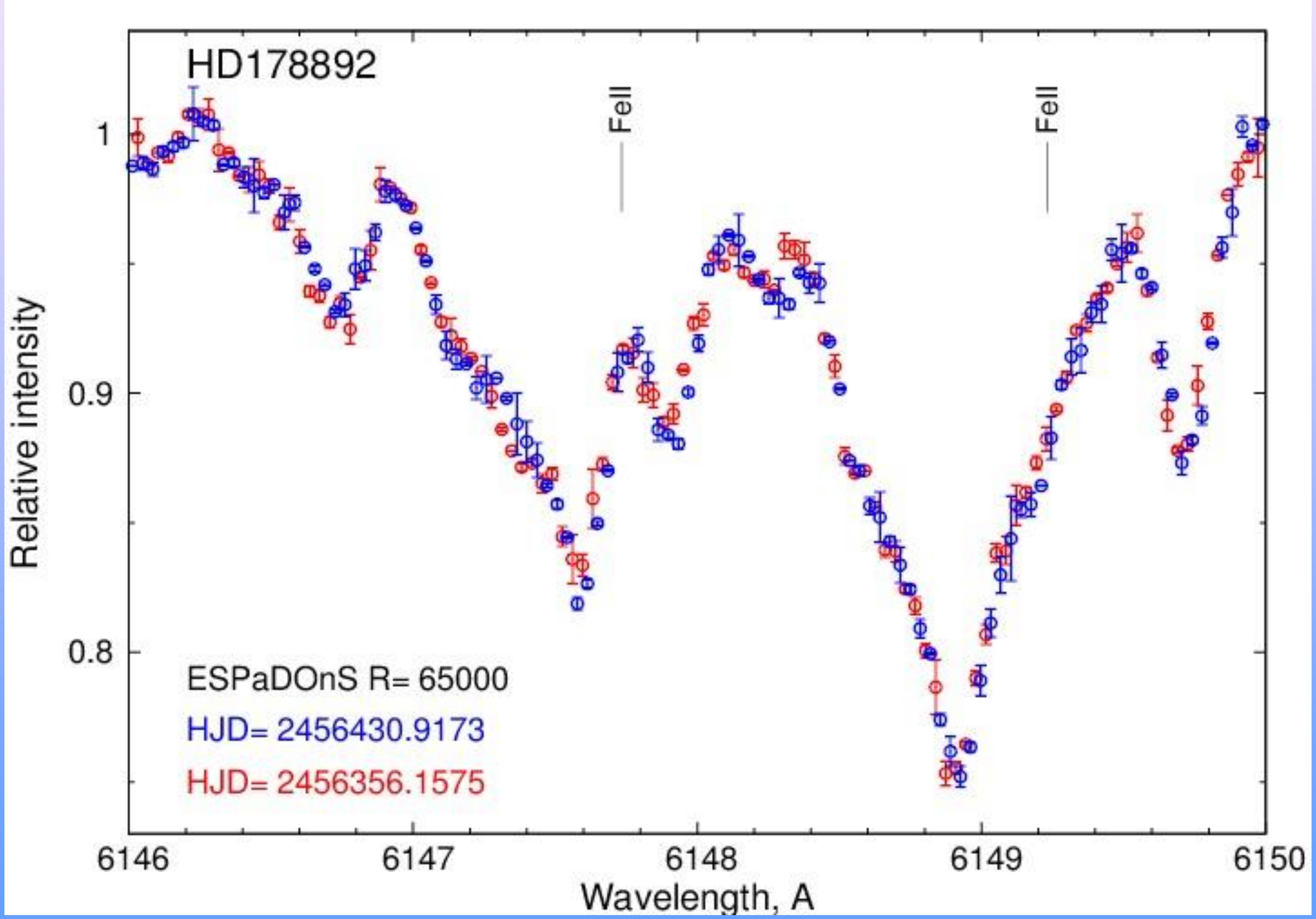
Spectropolarimetry with TMT HROS will be very useful

Study of line profile variability

HD178892 is a CP star with strong magnetic field (B_s= 34kG) and variable line profiles (Romanyuk et al. 2015)

Stokes I profile

Spectral region around 6147-6150AA observed with ESPaDOnS



Study of line profile variability

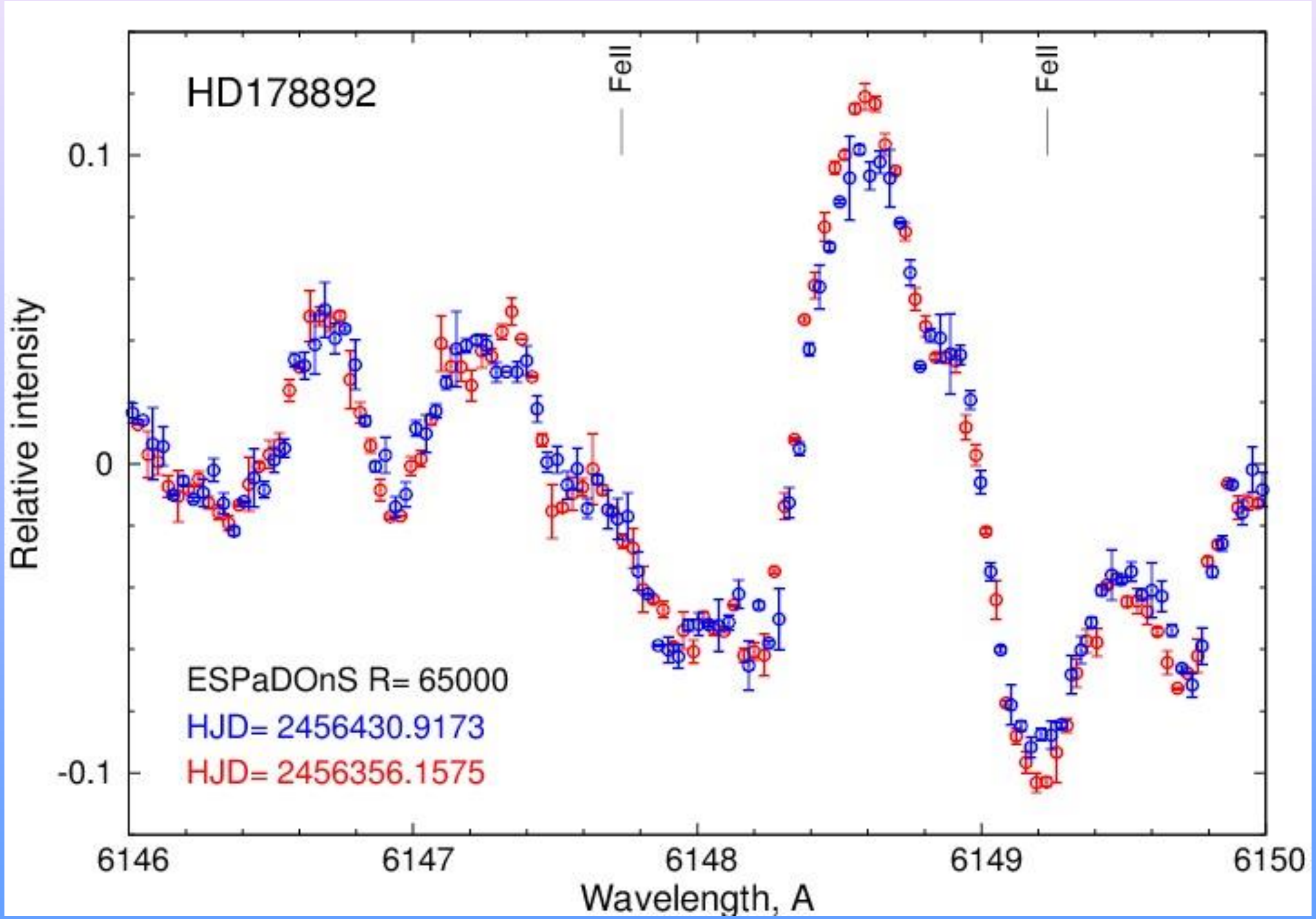
HD178892 is a CP star with strong magnetic field (B_s= 34kG) and variable line profiles (Romanyuk et al. 2015)

Stokes V profile

Spectral region around 6147-6150AA observed with ESPaDOnS

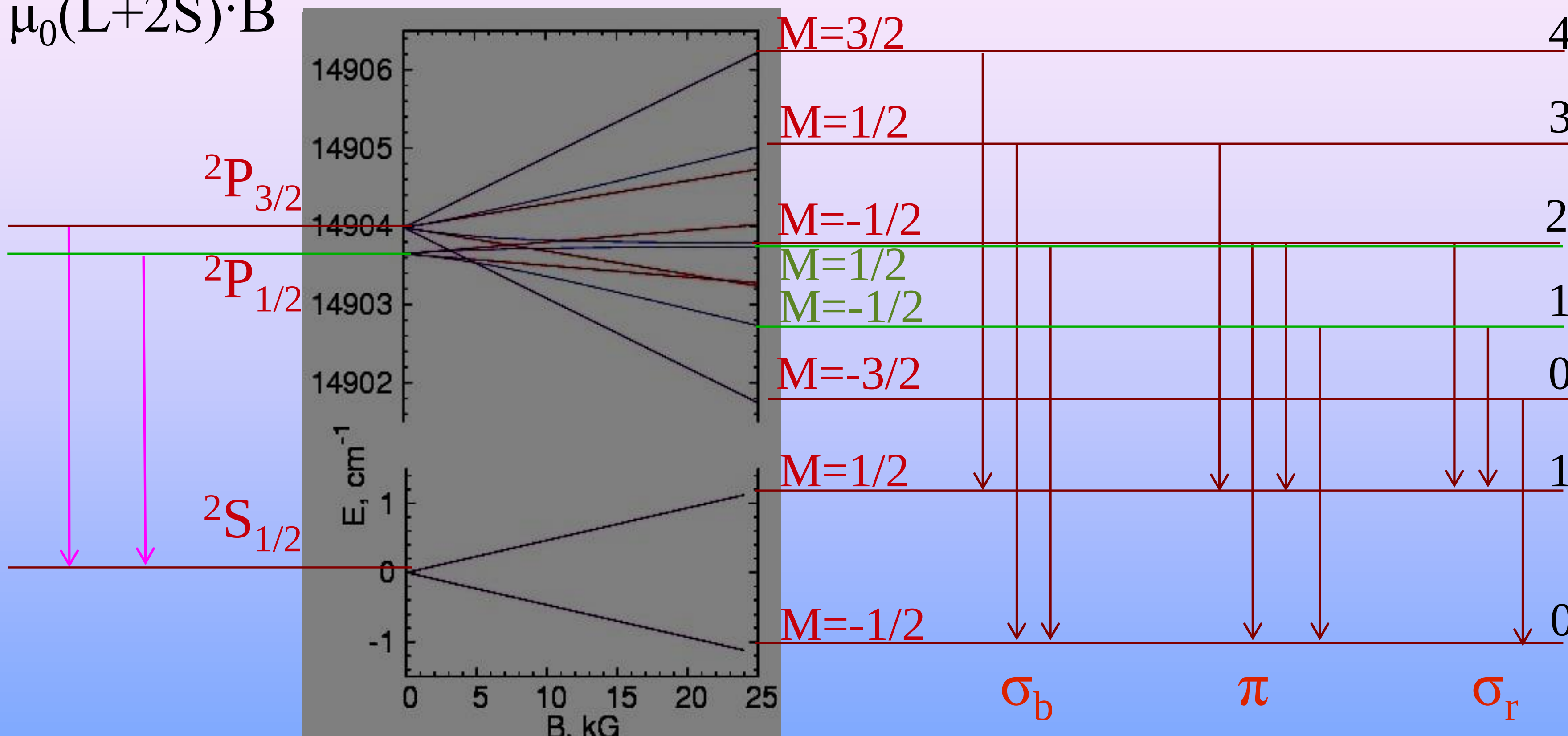
Stokes IV profiles show signatures of magnetic splitting

For strong magnetic fields the Paschen-Back effect is prominent



Paschen-Back effect

In this regime the energy levels for the LiI λ6708A resonance doublet have to be found by diagonalization of the total Hamiltonian $H = H_0 + \mu_0(\vec{L}+2\vec{S})\cdot\vec{B}$



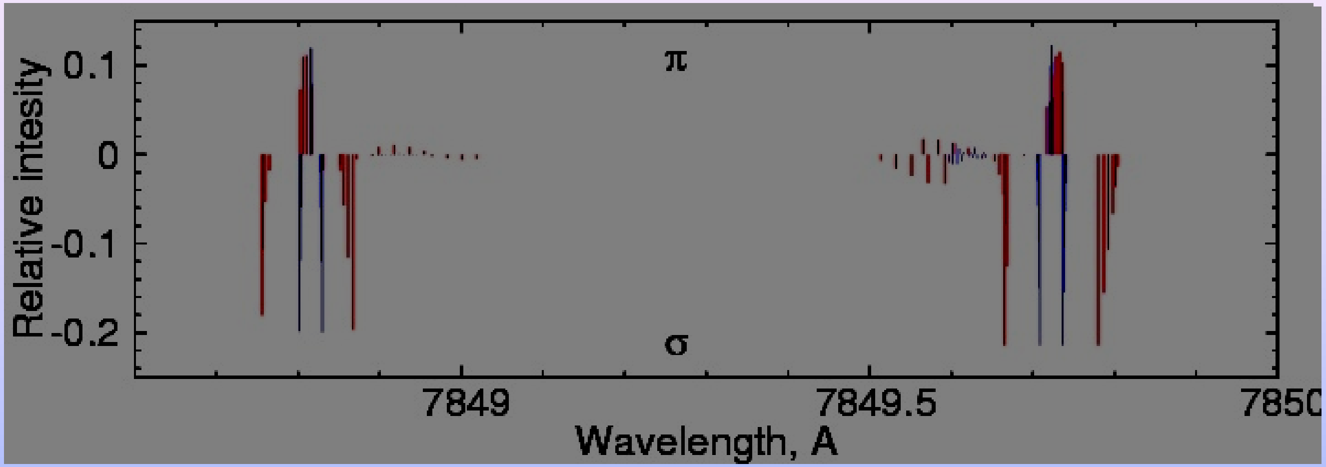
Relative intensities of split components also depend on the magnetic field strength.

Paschen-Back effect

Assuming that magnetic field lines are directed to us, the relative intensities of splitted components for SiII λ7849A triplet (transitions $^2F_{5/2} \rightarrow {}^2D_{3/2}$, $^2F_{5/2} \rightarrow {}^2D_{5/2}$ and $^2F_{7/2} \rightarrow {}^2D_{5/2}$) are for:

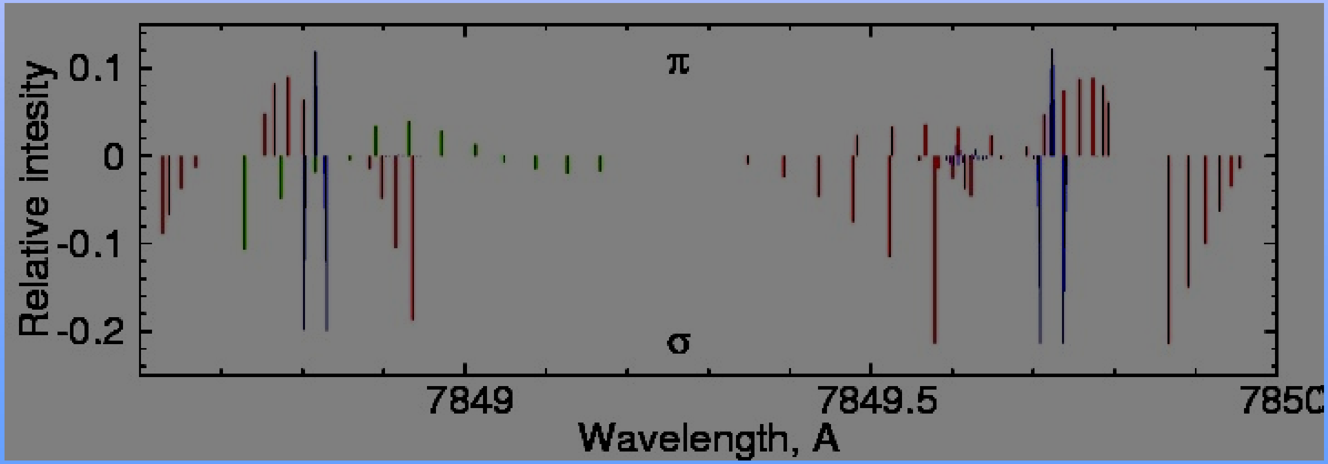
B=0.5kG (blue)

B=2 kG (red)



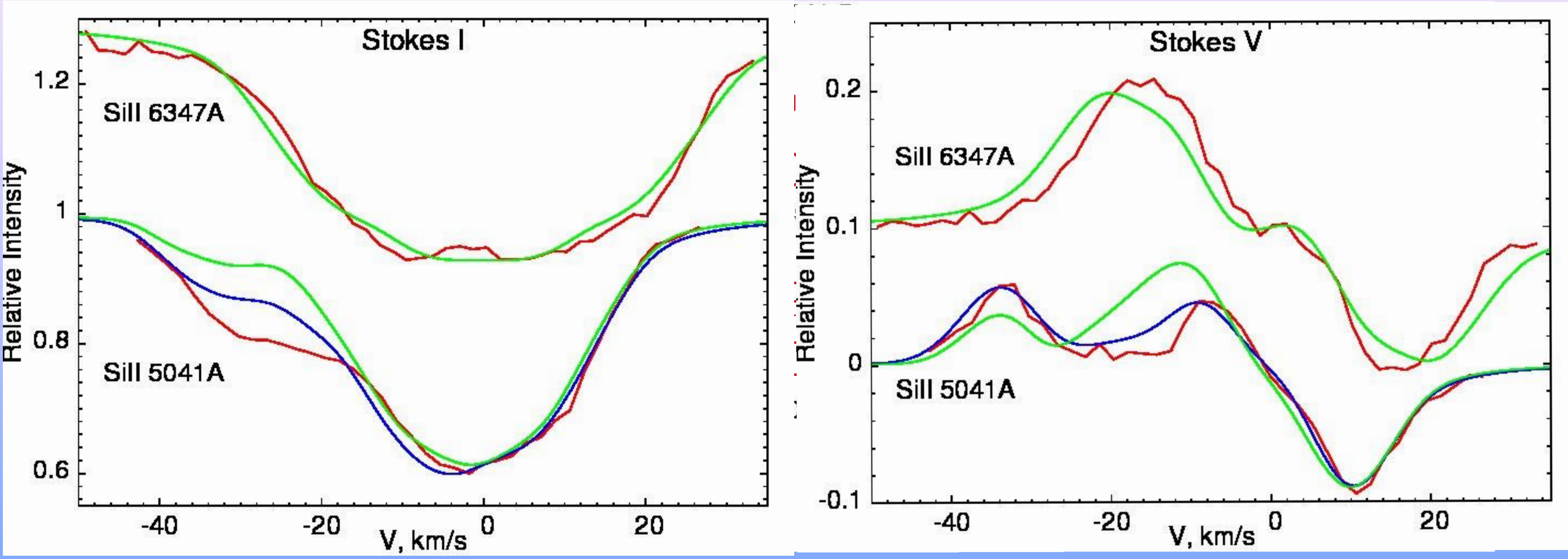
B=5 kG (red)

Transition $^2F_{7/2} \rightarrow {}^2D_{3/2}$ (green)



Study of Zeeman and PPB effects

The best fit results for the SiII 5041A and 6347A line profiles (red) in HD318107 taking into account Zeeman (green) and Partial Paschen-Back (blue) effect (Khalack and Landstreet 2012).



High resolution spectropolarimetry with TMT HROS will help to identify the forbidden transitions caused by the PPB effect.

CP stars in open clusters and nearby galaxies

A list of CP stars suitable for observation with the TMT HROS can be compiled based on the catalog of Ap, HgMn and Am stars by Renson & Manfroid (2009).

27 known CP stars are located in the open clusters in our galaxy (Paunzen et al. 2018).

Some CP stars have been found in open clusters in the Small Melanic Cloud (Paunzen 2008, https://www.univie.ac.at/webda).

Spectra of these CP stars can be acquired with the TMT HROS to study their stellar evolution in the environments with different metallicity.

Acknowledgements

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The operations at the Canada-France-Hawaii Telescope are conducted with care and respect from the summit of Mauna Kea which is a significant cultural and historic site.

ELODIE spectra were retrieved from the ELODIE archive at Observatoire de Haute-Provence (OHP, http://atlas.obs-hp.frelodie/)

SOPHIE spectra were retrieved from the SOPHIE archive at Observatoire de Haute-Provence (OHP, http://atlas.obs-hp.fr/sophie/)

Thank you
for your attention!