

First results from



the Potsdam Echelle Polarimetric and Spectroscopic Instrument for the LBT

Klaus G. Strassmeier w/

Ilya Ilyin, Michi Weber, Arto & Silva Järvinen, Manfred Woche, Thorsten Carroll,
Engin Keles, Matthias Mallonn, et al.

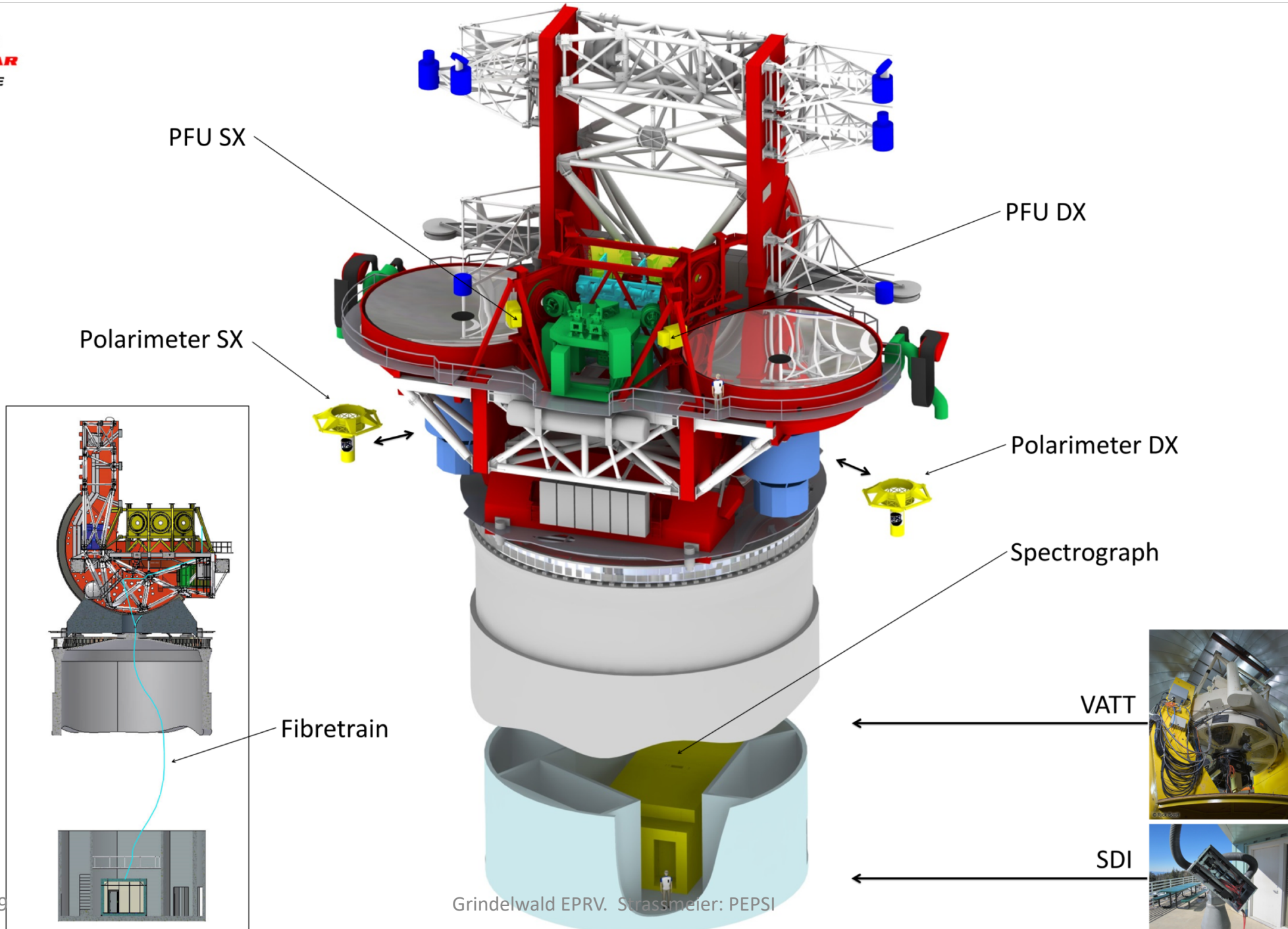
Leibniz-Institute for Astrophysics Potsdam (AIP), Germany

LBT:



(two-bedroom condominium good to $\lambda/8$)

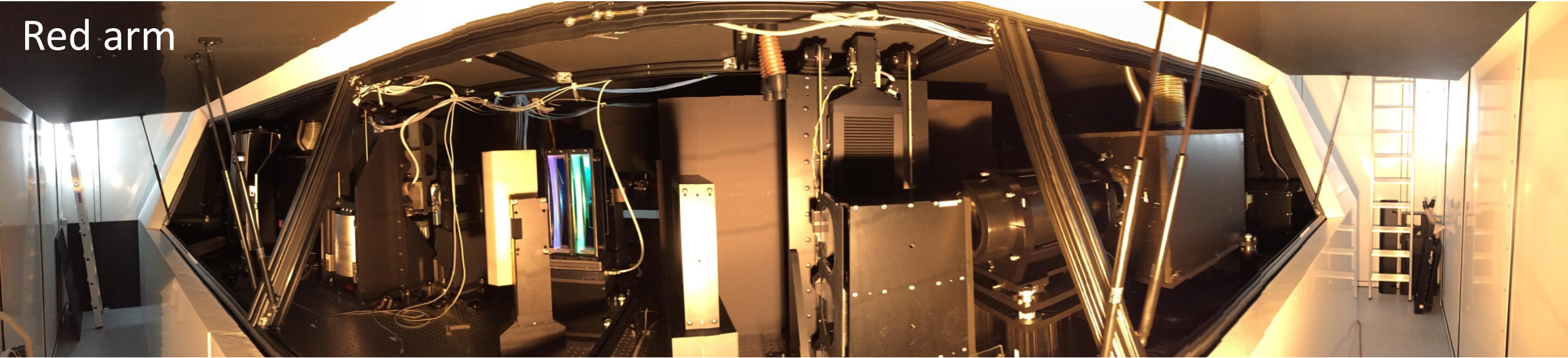




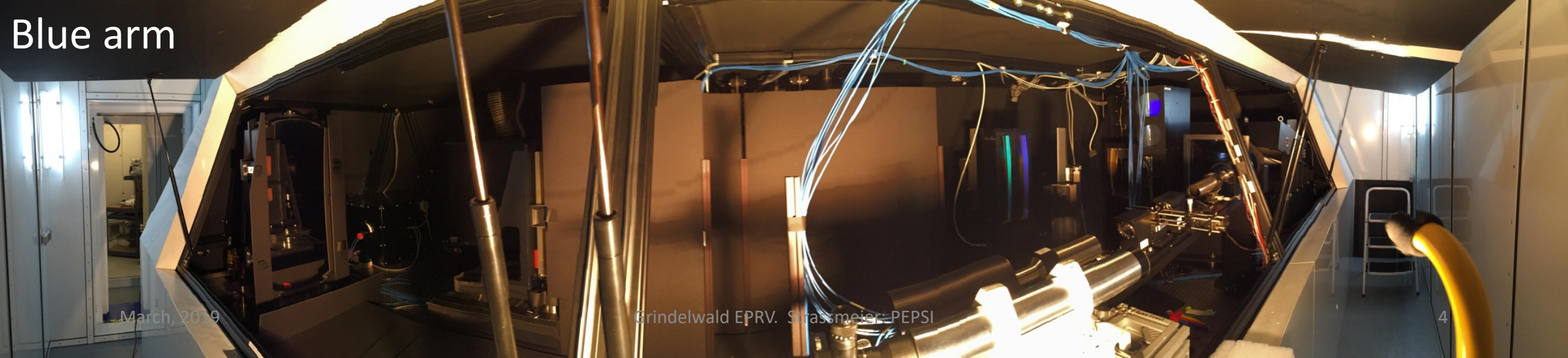
Panoramic view within chamber



Red arm

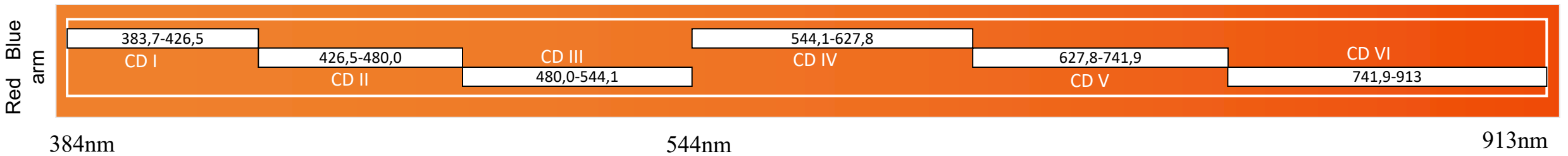
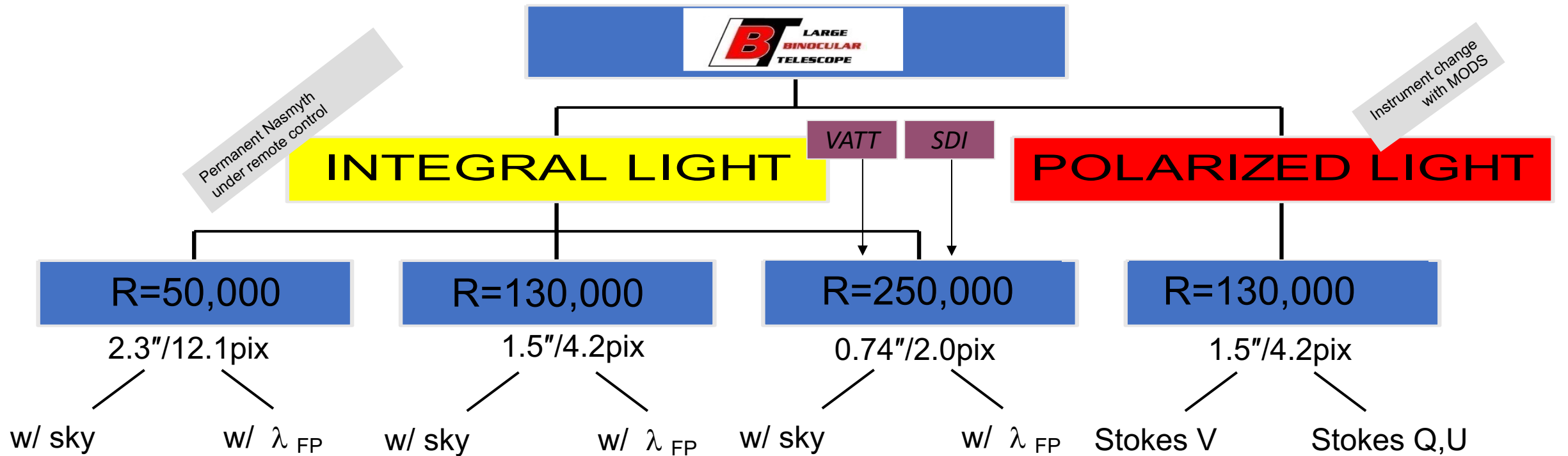


Blue arm





PEPSI observing modes



..... continuous wavelength coverage in 3 exposures



„Deep spectrum project“





The fingerprint of a star: Arcturus = α Boo

Arcturus = α Boo (HR 2610) is a prototypical cool and giant of spectral classification G2.0 III with a surface temperature of 4200 K, 1.5 times cooler than the Sun. It is the brightest star in the constellation of Boötes. The spectra shown in this figure were obtained with the Potsdam Echelle Polarimeter and Spectrometer (PEPS) of the Large Binocular Telescope (LBT) in the form of a series of wavelength-resolved spectra (A&A 612, A44, A45, A46) from the top left corner to the bottom right corner. The PEPS spectra cover a wavelength range from 4000 Å to 9000 Å with an average spectral resolution of $R \approx 12,000$ to $20,000$.

Multiple spectra at different spectral regions, each wavelength-resolved from 0.1 nm dispersion (20 Å) and 0.1 nm resolution (0.1 nm) were obtained with the PEPS. The spectra were obtained with the PEPS in the form of a series of wavelength-resolved spectra (A&A 612, A44, A45, A46) from the top left corner to the bottom right corner. The PEPS spectra cover a wavelength range from 4000 Å to 9000 Å with an average spectral resolution of $R \approx 12,000$ to $20,000$.

Individual exposure levels had 2000 counts and were obtained on April 9, 2016. A subset of spectral absorption lines is identified for the purpose of wavelength calibration. The absorption features are identified in the spectra and are labeled with their corresponding wavelength. The absorption features are identified in the spectra and are labeled with their corresponding wavelength. The absorption features are identified in the spectra and are labeled with their corresponding wavelength.

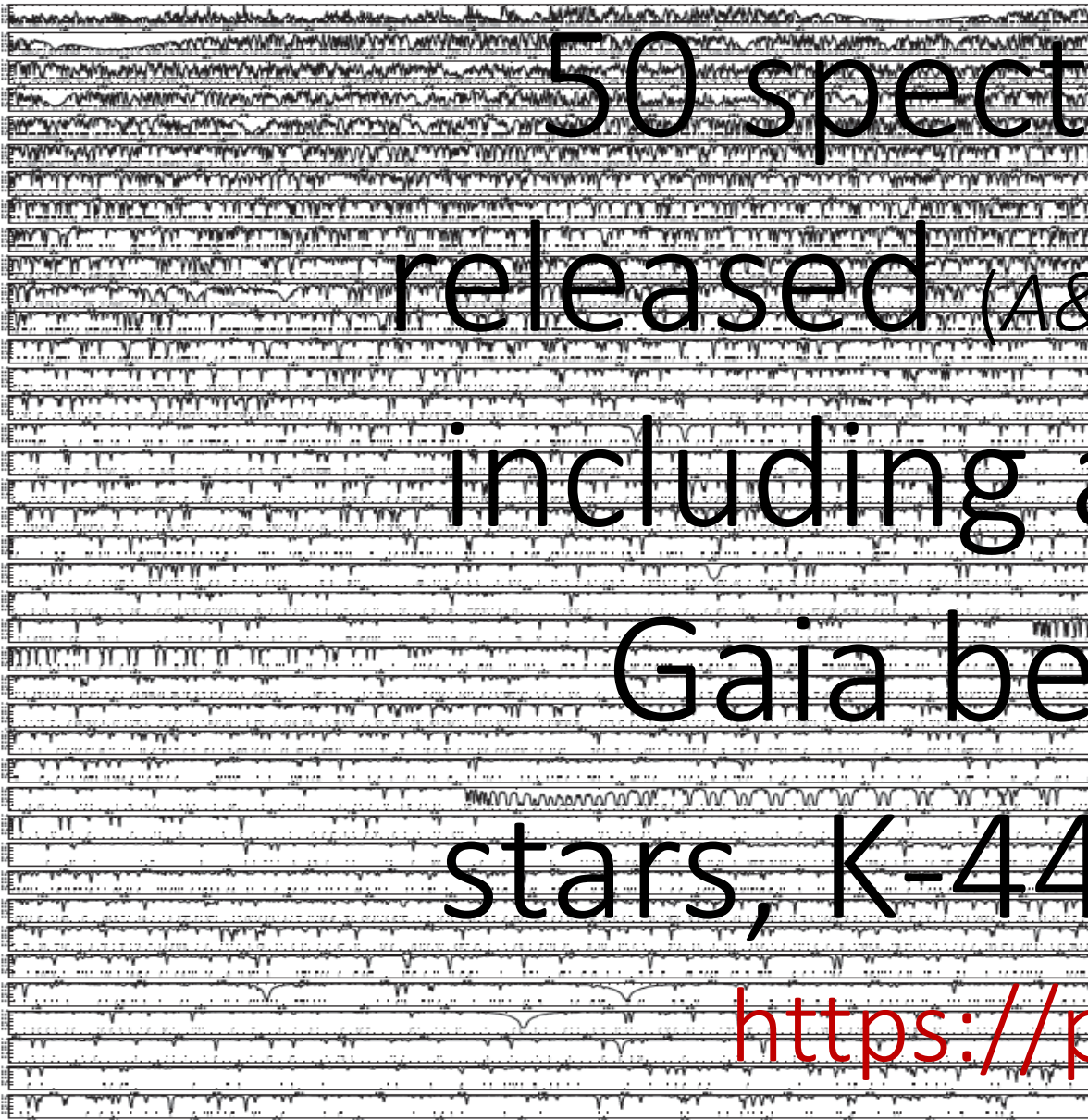


The fingerprint of a star The Sun

On 10/10/2016, three 3000 Å wide-off-band spectra of the Sun were taken by the PEPSI and others. When solar spectra were taken in the Sun's core, the Sun's surface is seen by the PEPSI. The spectra were obtained with the PEPSI in the form of a series of wavelength-resolved spectra (A&A 612, A44, A45, A46) from the top left corner to the bottom right corner. The PEPSI spectra cover a wavelength range from 4000 Å to 9000 Å with an average spectral resolution of $R \approx 12,000$ to $20,000$.

Individual exposure levels had 2000 counts and were obtained on April 9, 2016. A subset of spectral absorption lines is identified for the purpose of wavelength calibration. The absorption features are identified in the spectra and are labeled with their corresponding wavelength. The absorption features are identified in the spectra and are labeled with their corresponding wavelength.

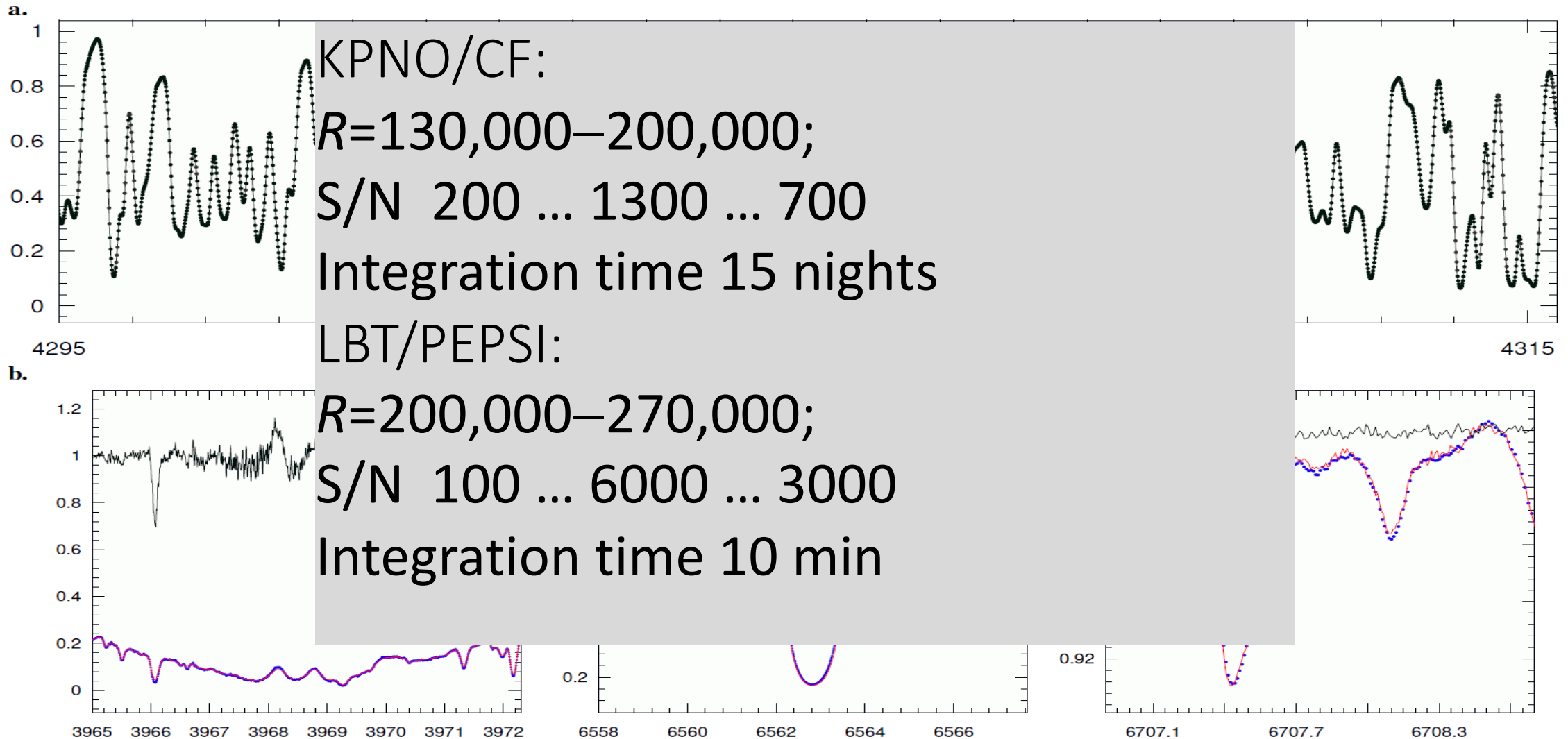
Individual exposure levels had 2000 counts and were obtained on April 9, 2016. A subset of spectral absorption lines is identified for the purpose of wavelength calibration. The absorption features are identified in the spectra and are labeled with their corresponding wavelength. The absorption features are identified in the spectra and are labeled with their corresponding wavelength.



50 spectral atlases
released (A&A 612, A44, A45, A46);
including all northern
Gaia benchmark
stars, K-444 & the Sun

<https://pepsi.aip.de>

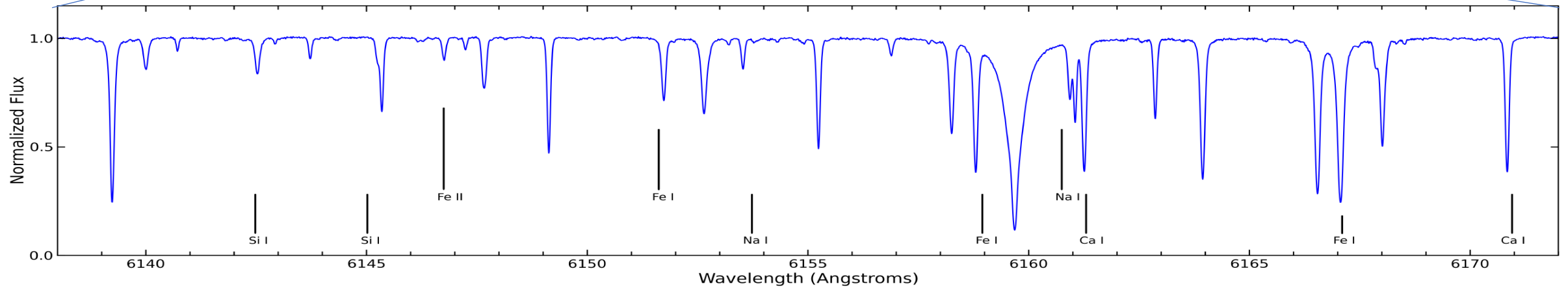
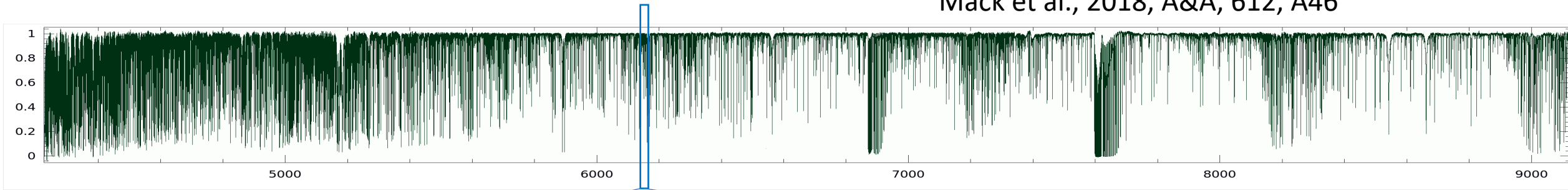
Arcturus: comparison with KPNO atlas (Hinkle et al.)



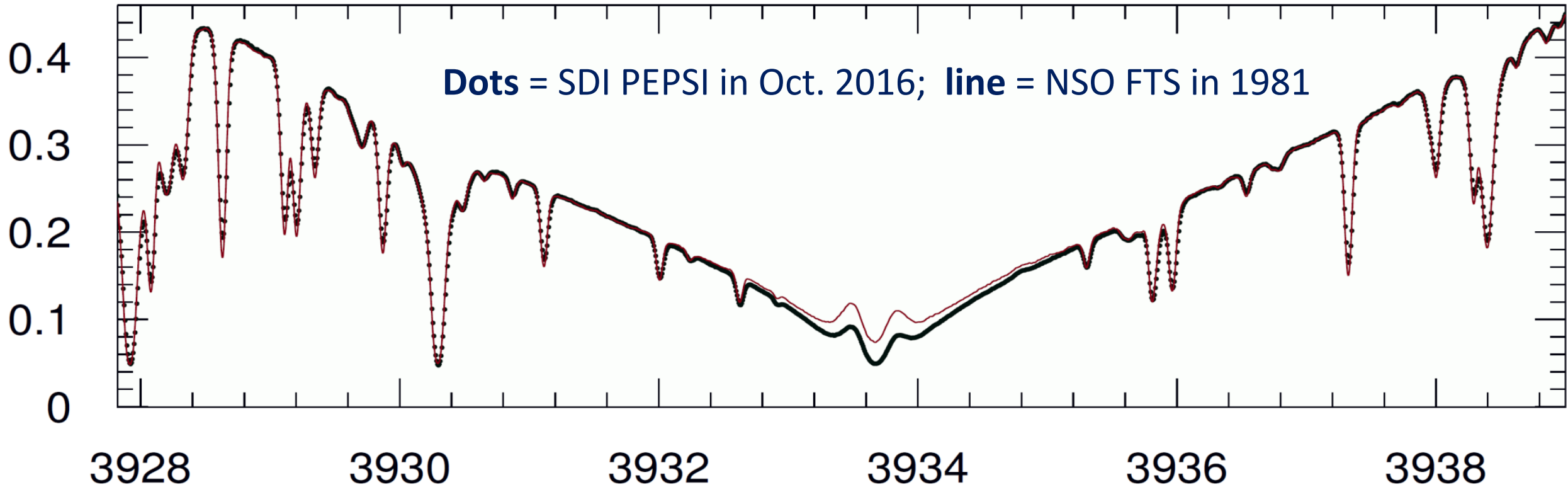
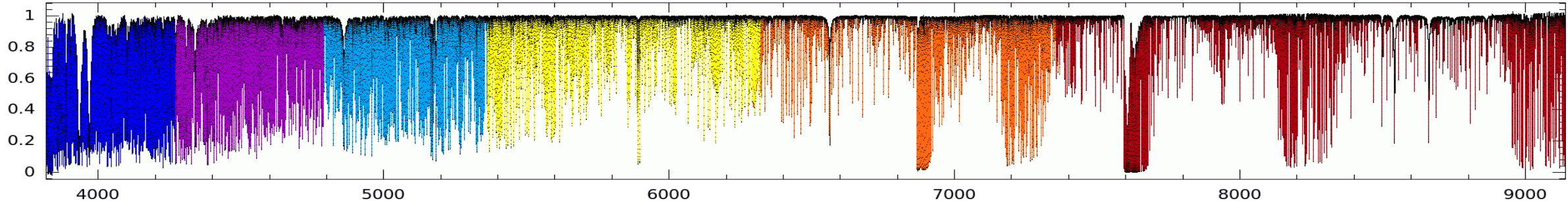
Kepler-444: age 10-11 Gyr, 5 planets. Abundance analysis



Mack et al., 2018, A&A, 612, A46

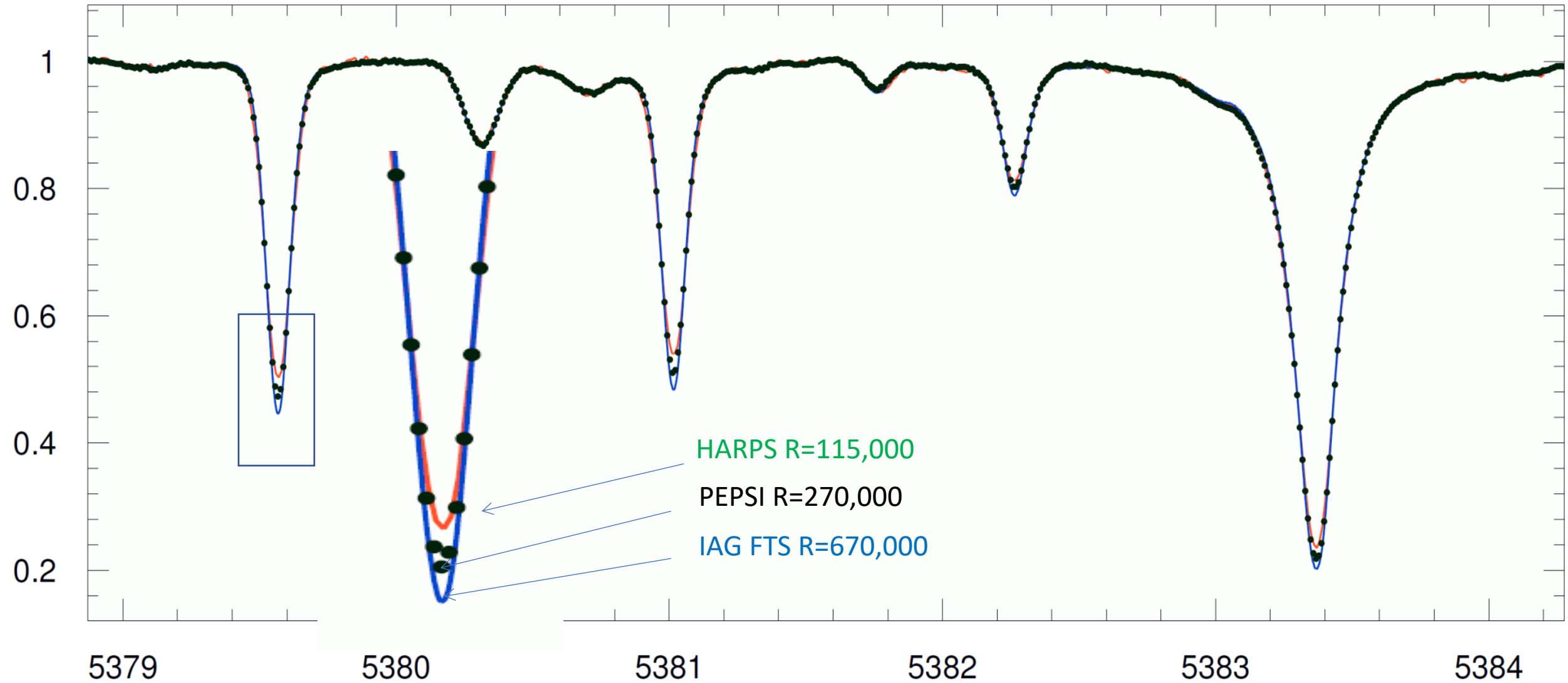


The toughest test of all: the Sun



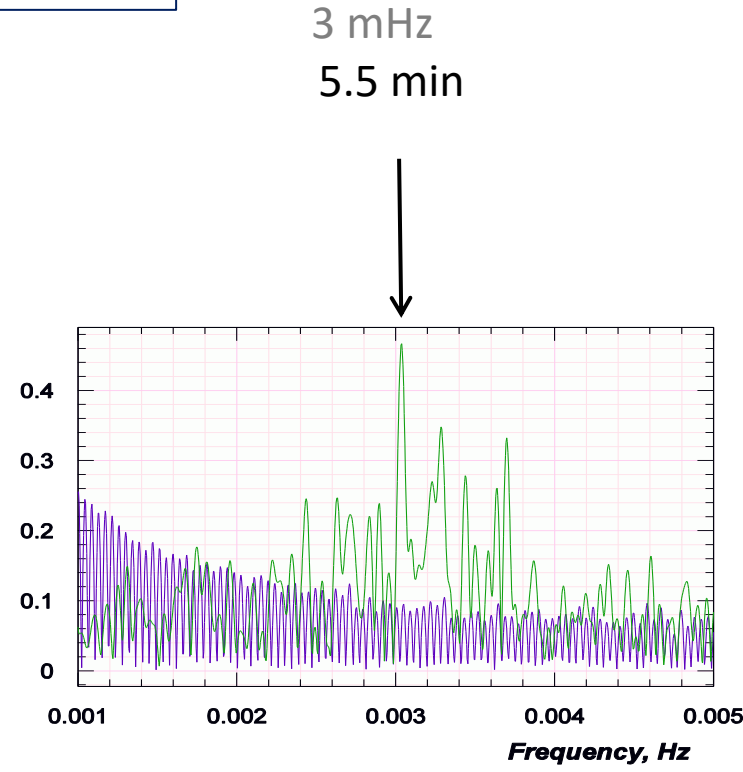
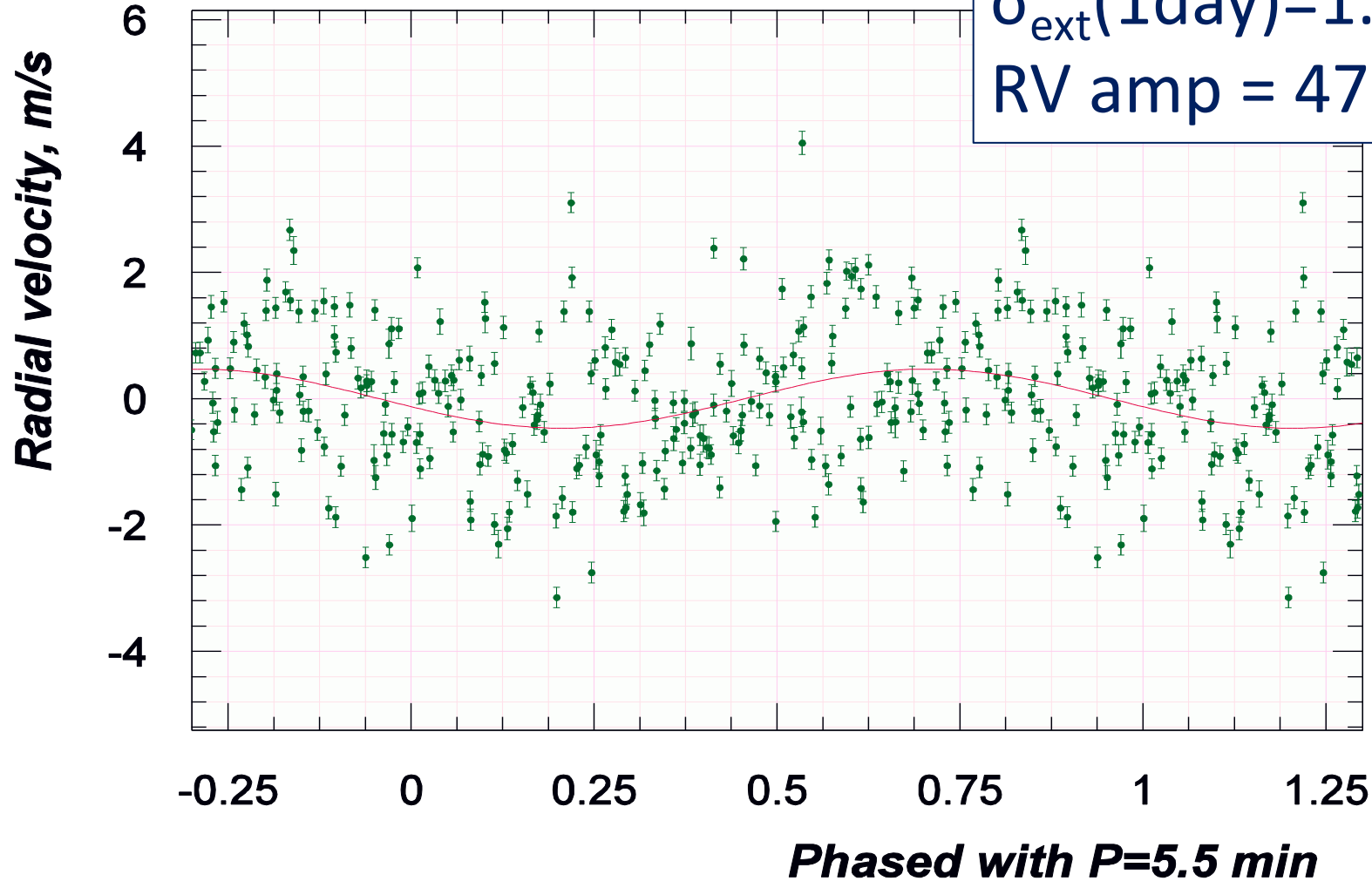


C I 5381.8 Å



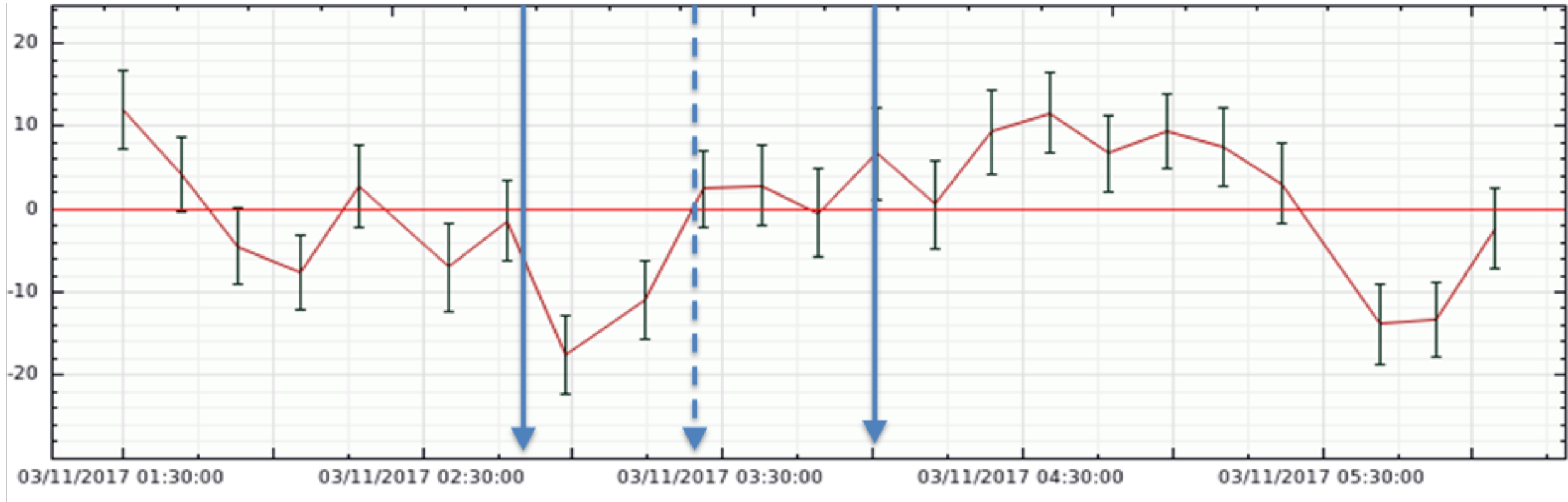
Chamber RV stability reached in 2017: Solar p-mode oscillations detected

$\sigma_{\text{ext}}(1\text{day})=1.2 \text{ m/s}$
RV amp = 47 cm/s



RVs of TRAPPIST-1g transit

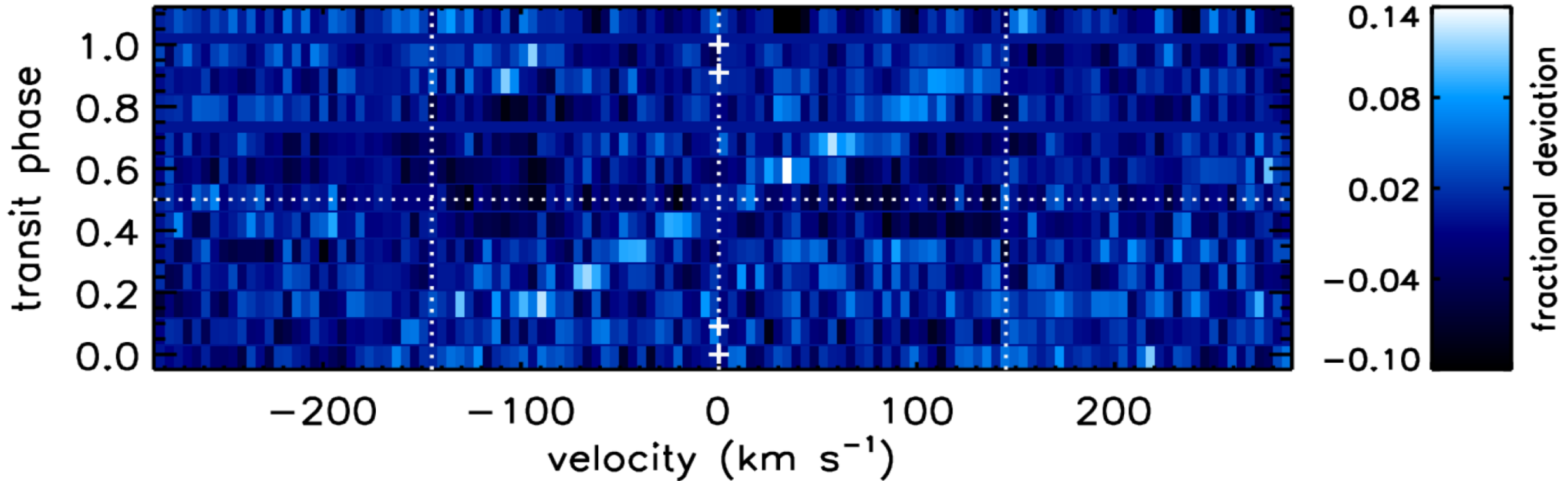
(m/s)



Transit Nov. 3, 2017: Trappist-1 ($V=18.8$, $I=14.0$): **rms = 5 m/s** w/ integration time of 10 min.

Bender (UA), Edwards (LBTO) *et al.* and AIP PEPSI team.

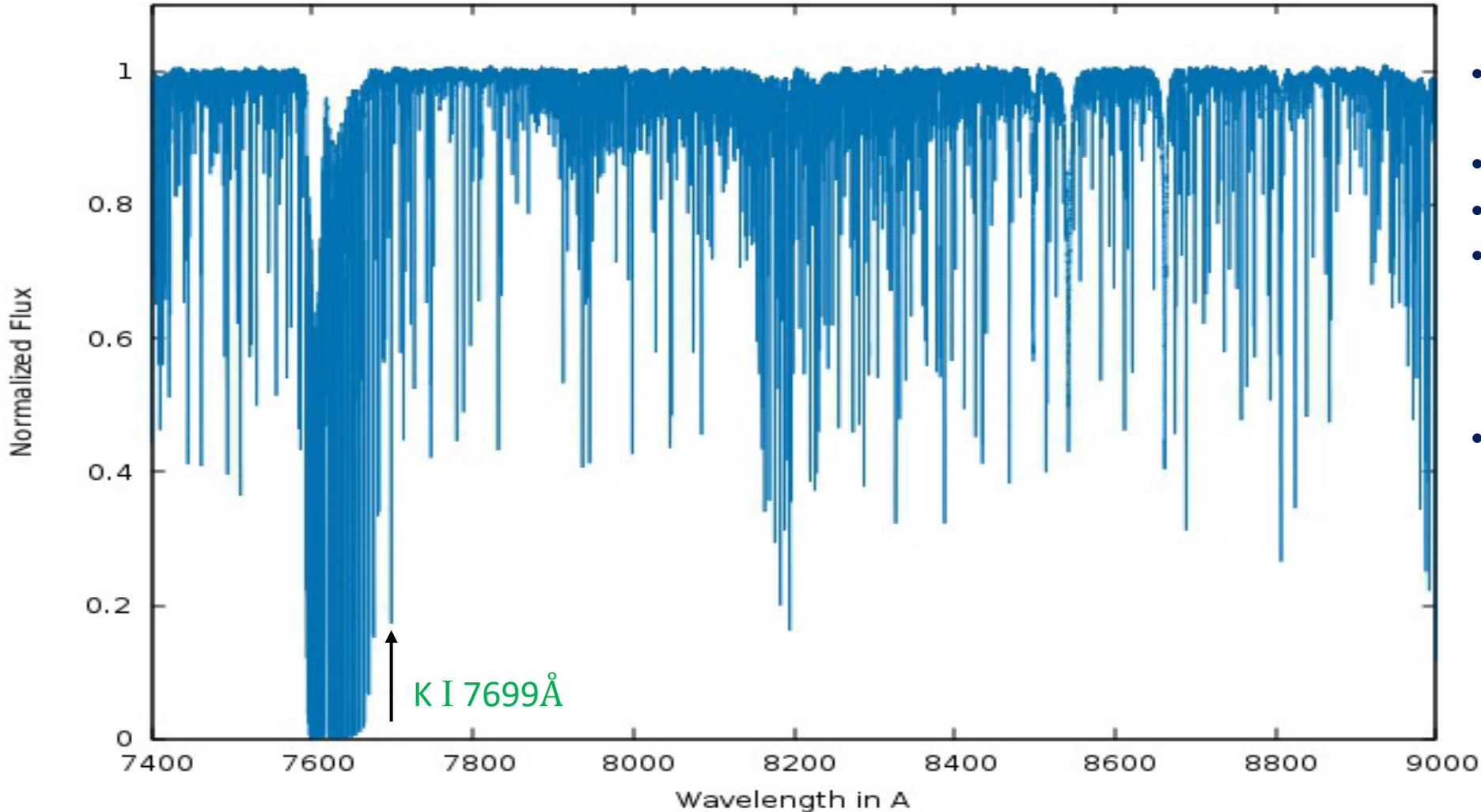
KELT-21: direct detection of its planet at optical wavelengths



Johnson (OSU) and the AIP PEPSI team,
 „KELT-21b: A Hot Jupiter Transiting the Rapidly Rotating Metal-poor Late-A Primary
 of a Likely Hierarchical Triple System”, *AJ* [155](#), 100 (2018)

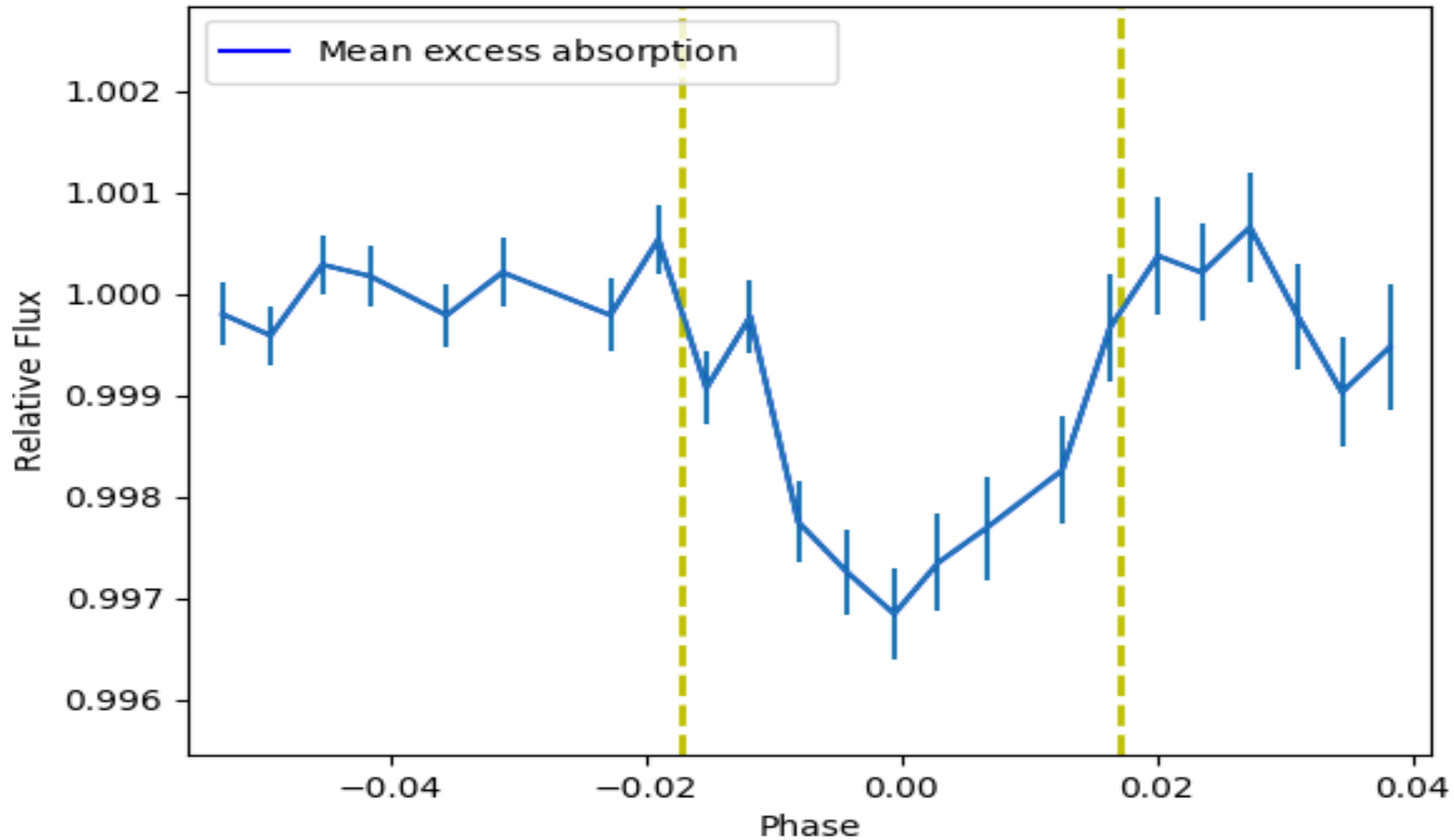
Potassium detection in HD189733b

(Keles et al., 2019, MNRAS, submitted)



- Transit in October 2017 during POL commissioning
- $R=130,000$
- 24 exposures w/ $S/N \approx 500$
- Building excess absorption specs from different bins centered on KI line (up to 2 ref bins)
- Best result for 0.5 \AA

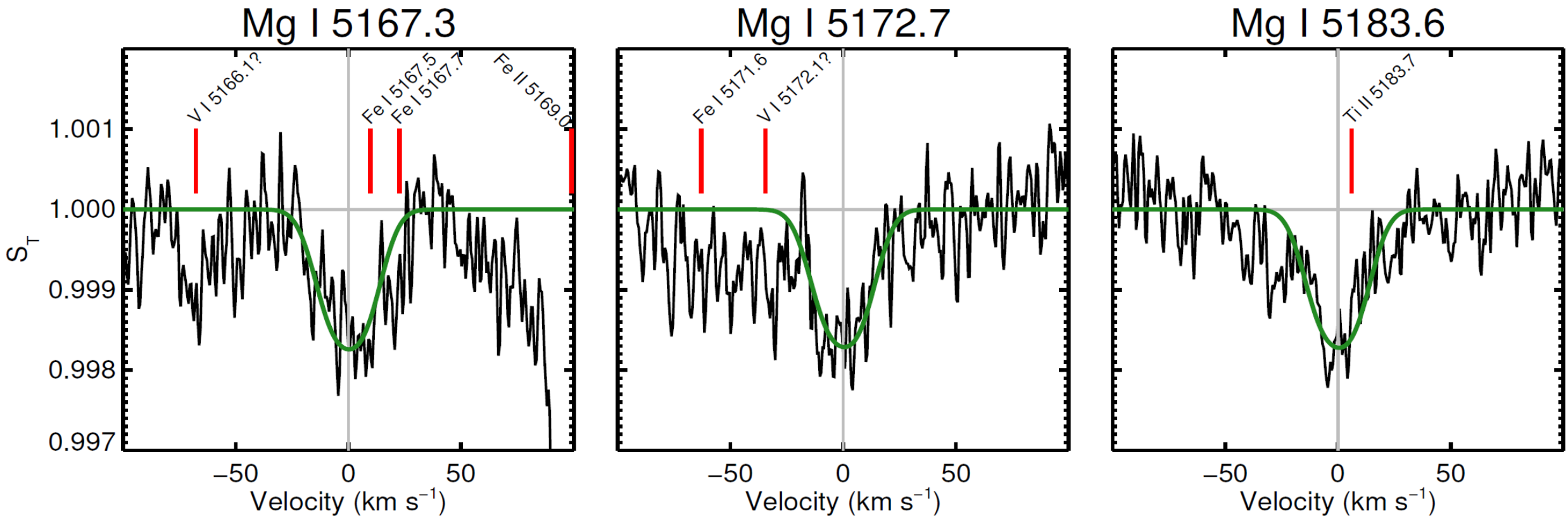
8 σ potassium detection in HD189733b



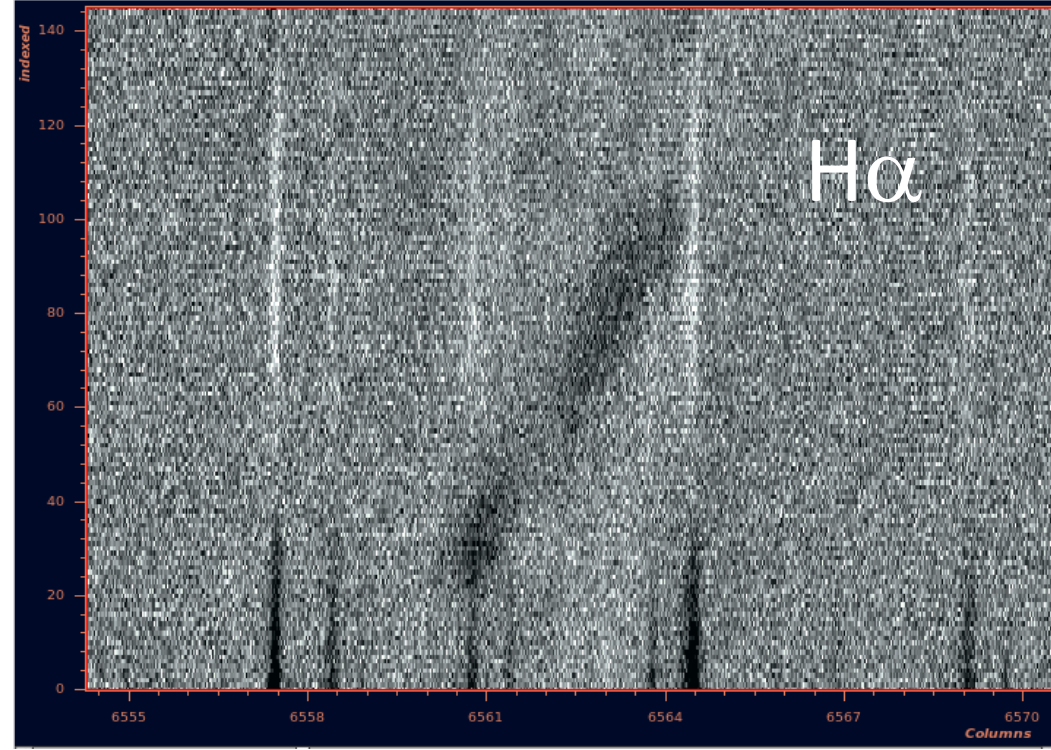
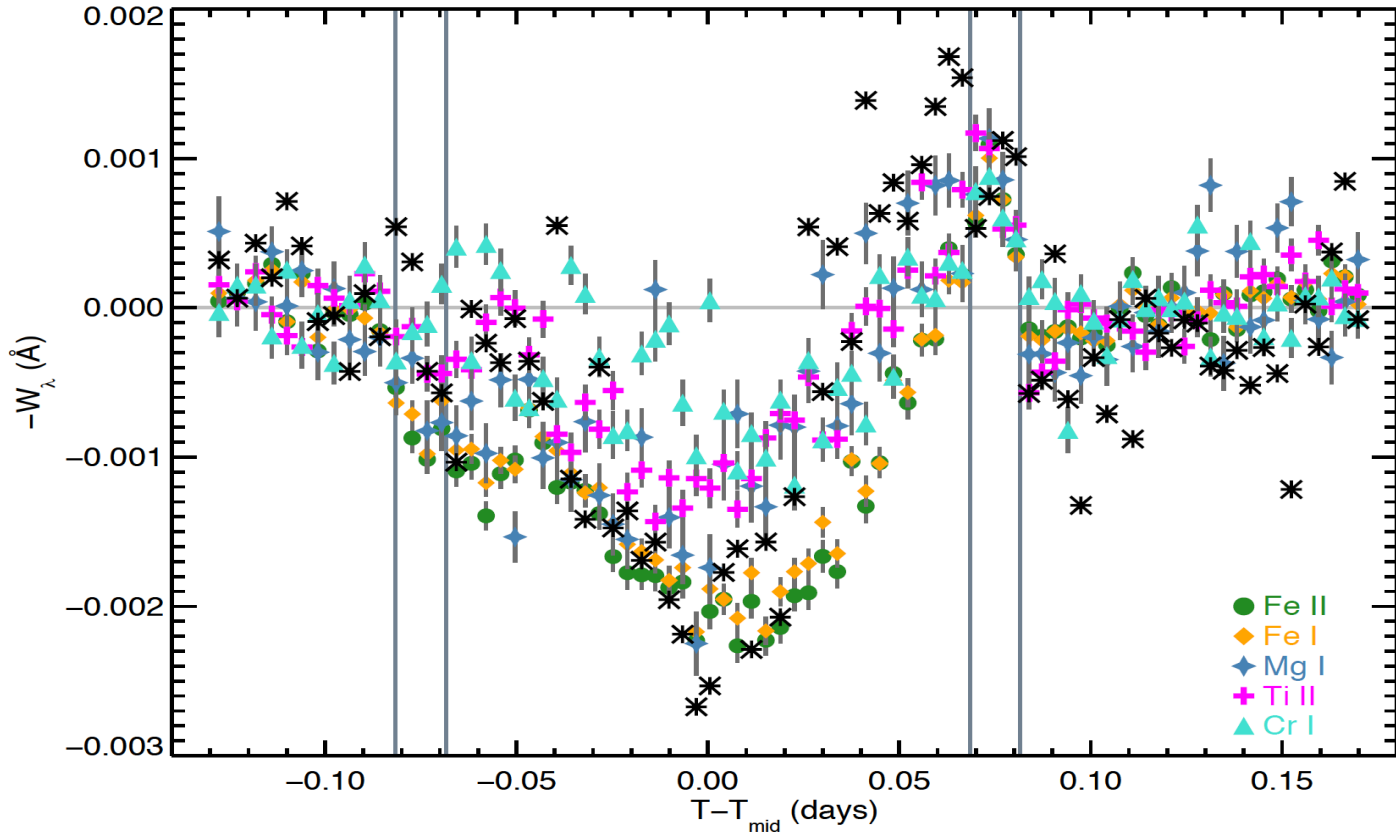
Kelt-9b atmospheric spectrum - detection of Fe & Ti but also Cr I and Mg I



Ratio spectrum „star inside transit“ / „star outside transit“: CD III, 4750-5430Å, $R=50,000$

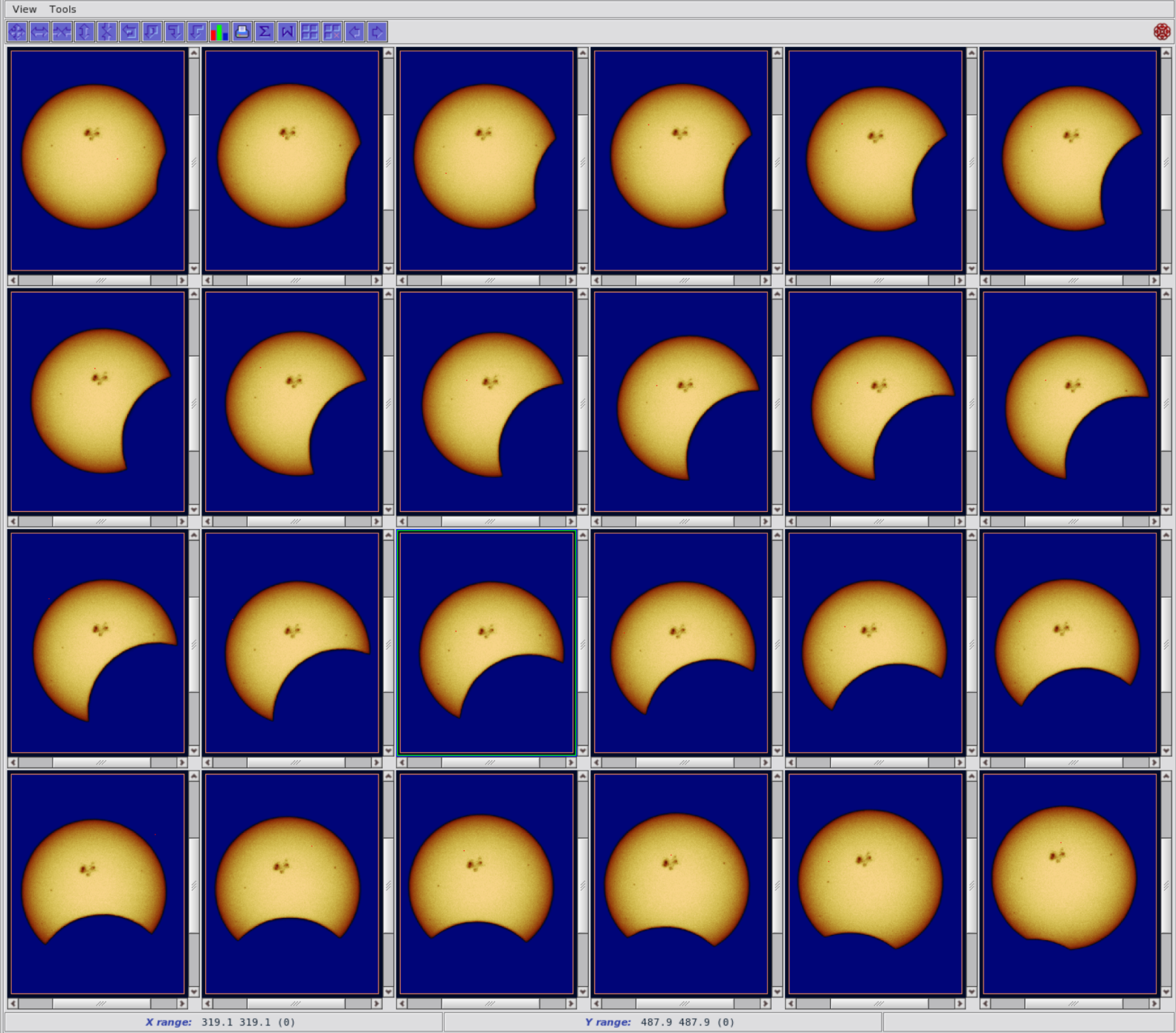


KELT-9b: detection of Fe & Ti but also Cr I and Mg I



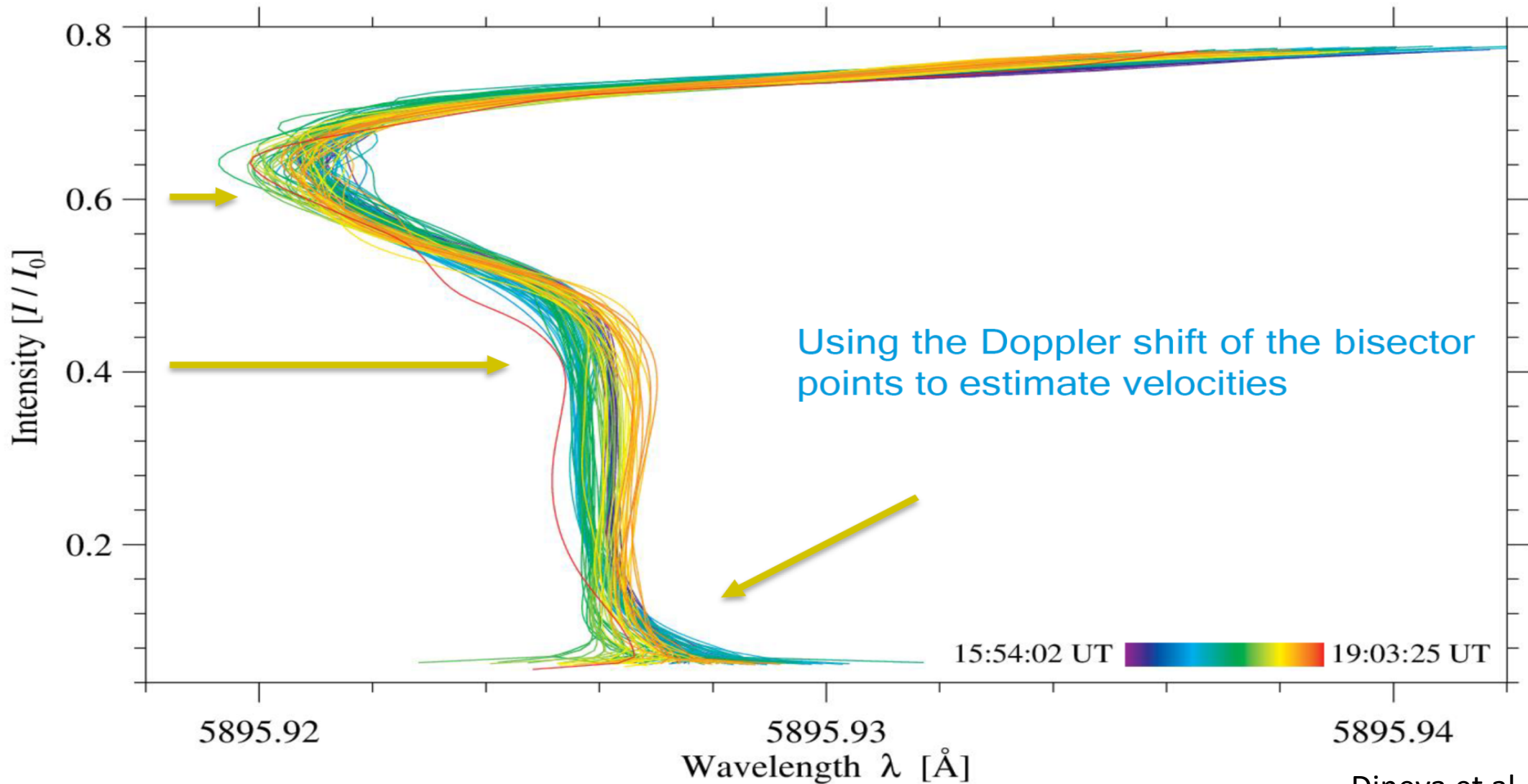
W. Cauley et al. 2019, *AJ*, **157**, 69

„Detections of Mg I in the thermosphere of Kelt-9b”

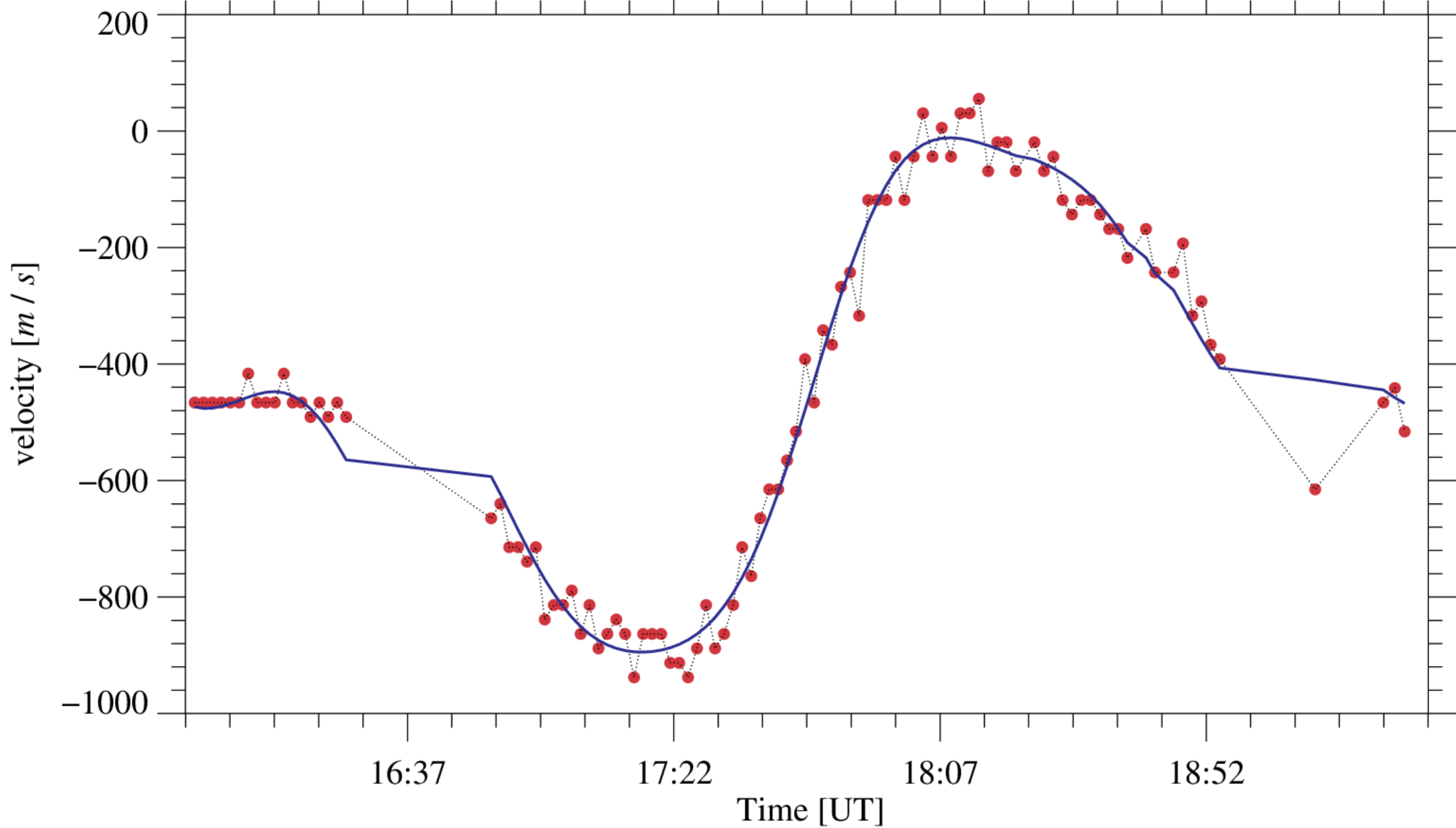


Solar eclipse August 11, 2018

Na D₁ line bisector during eclipse



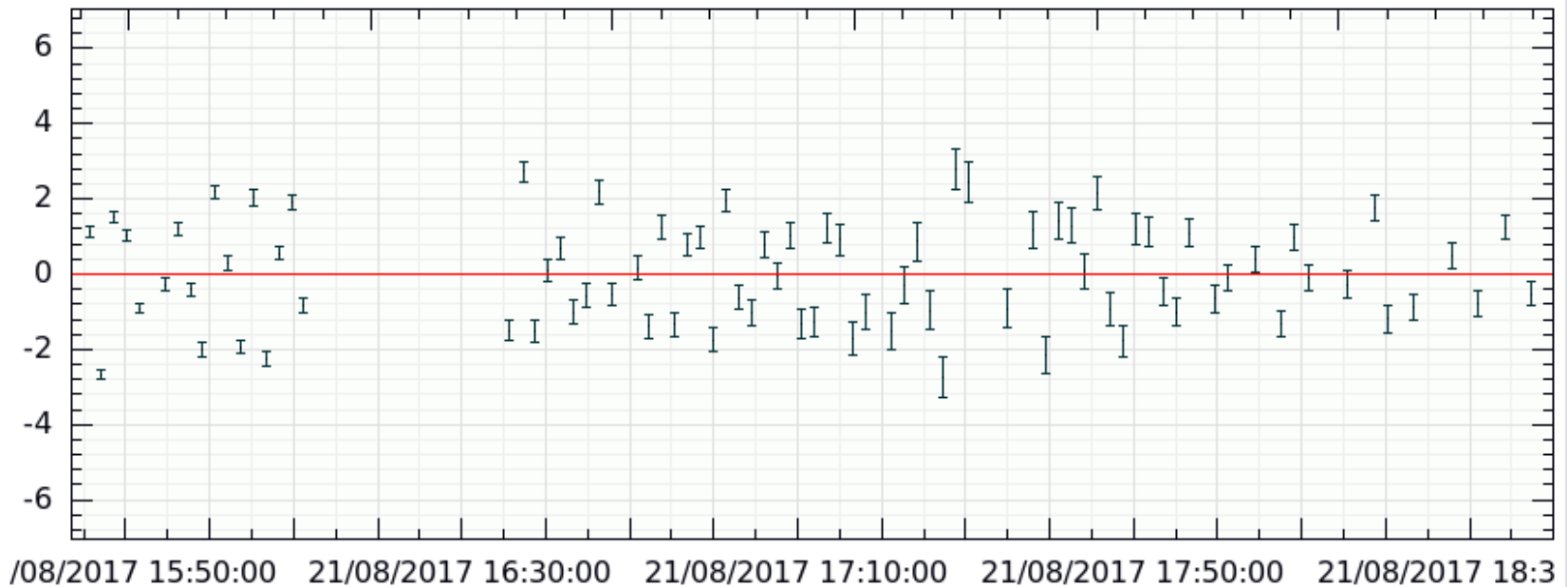
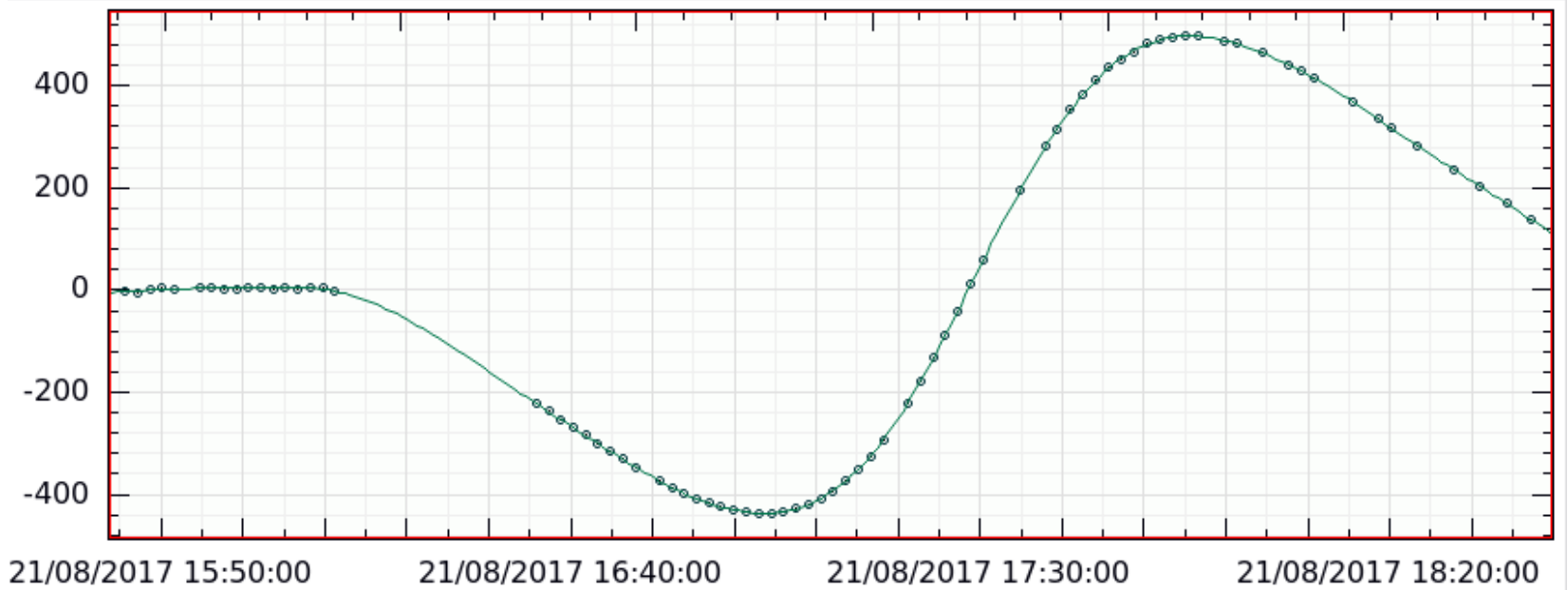
Dineva et al. 2019, in prep



... and from
photospheric
lines with full
CD IV coverage

(rms ≈ 1 m/s)

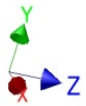
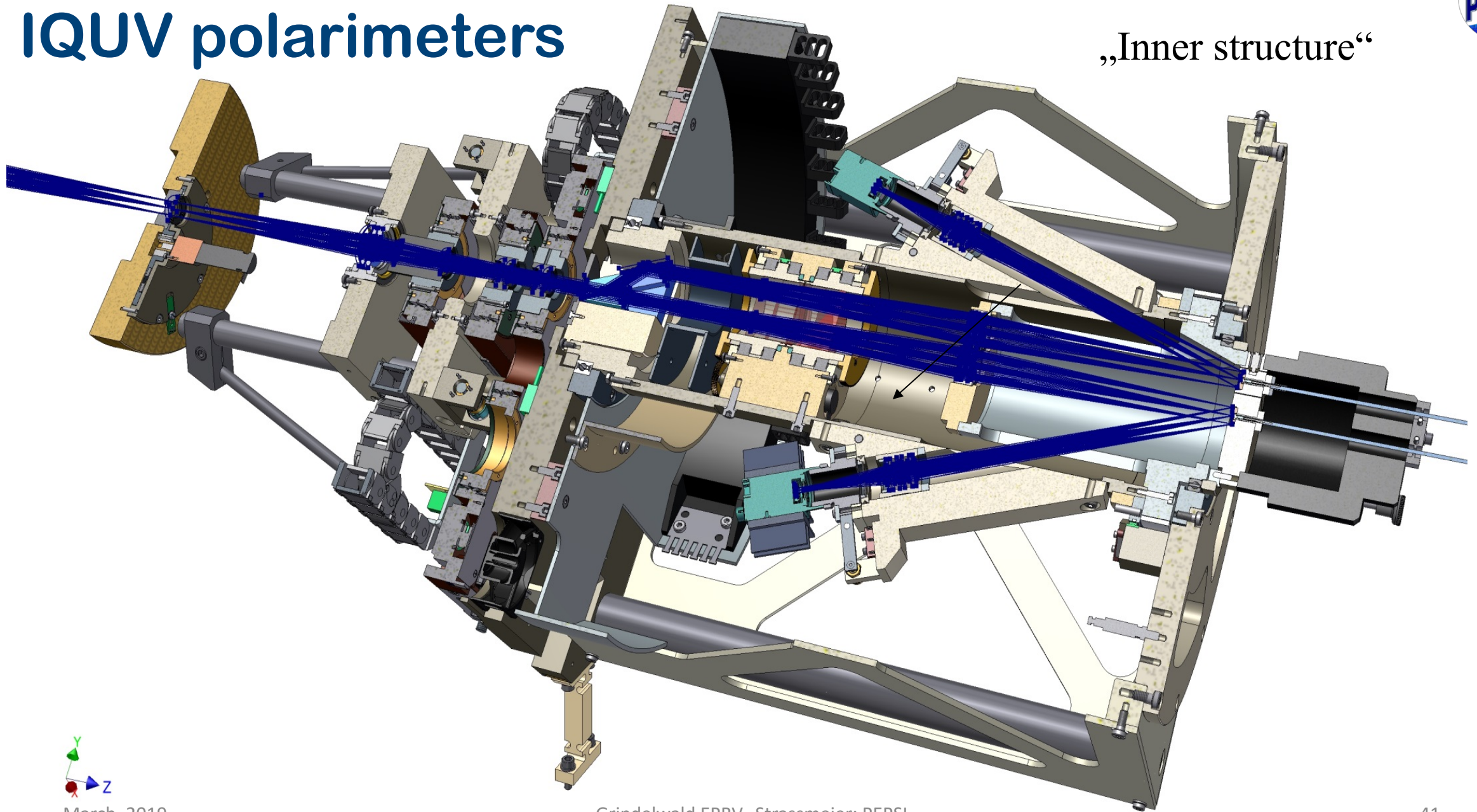
See also Reiners et al.
2016, A&A 595, A26 for
the March 2015 eclipse



IQUV polarimeters



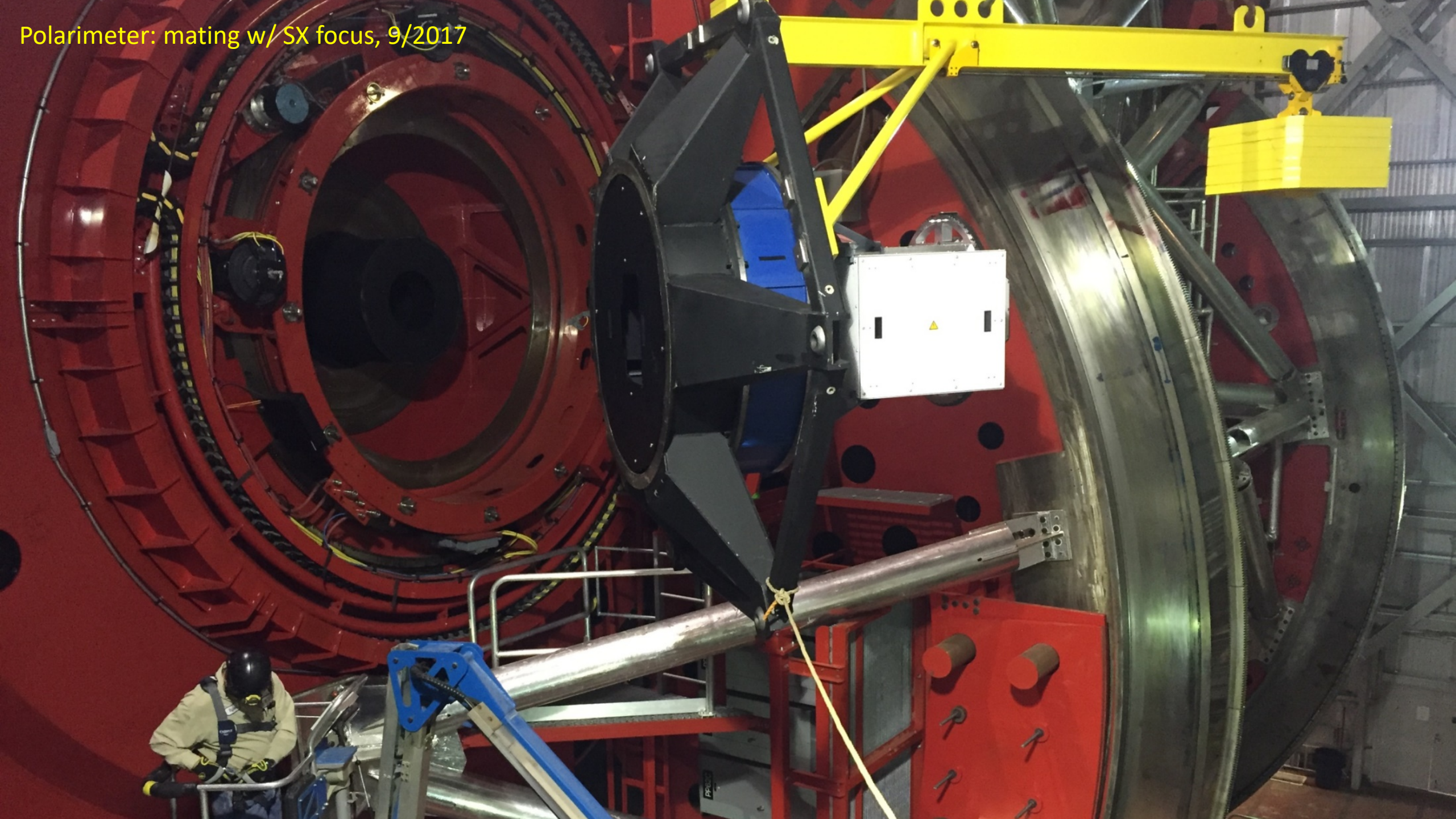
„Inner structure“



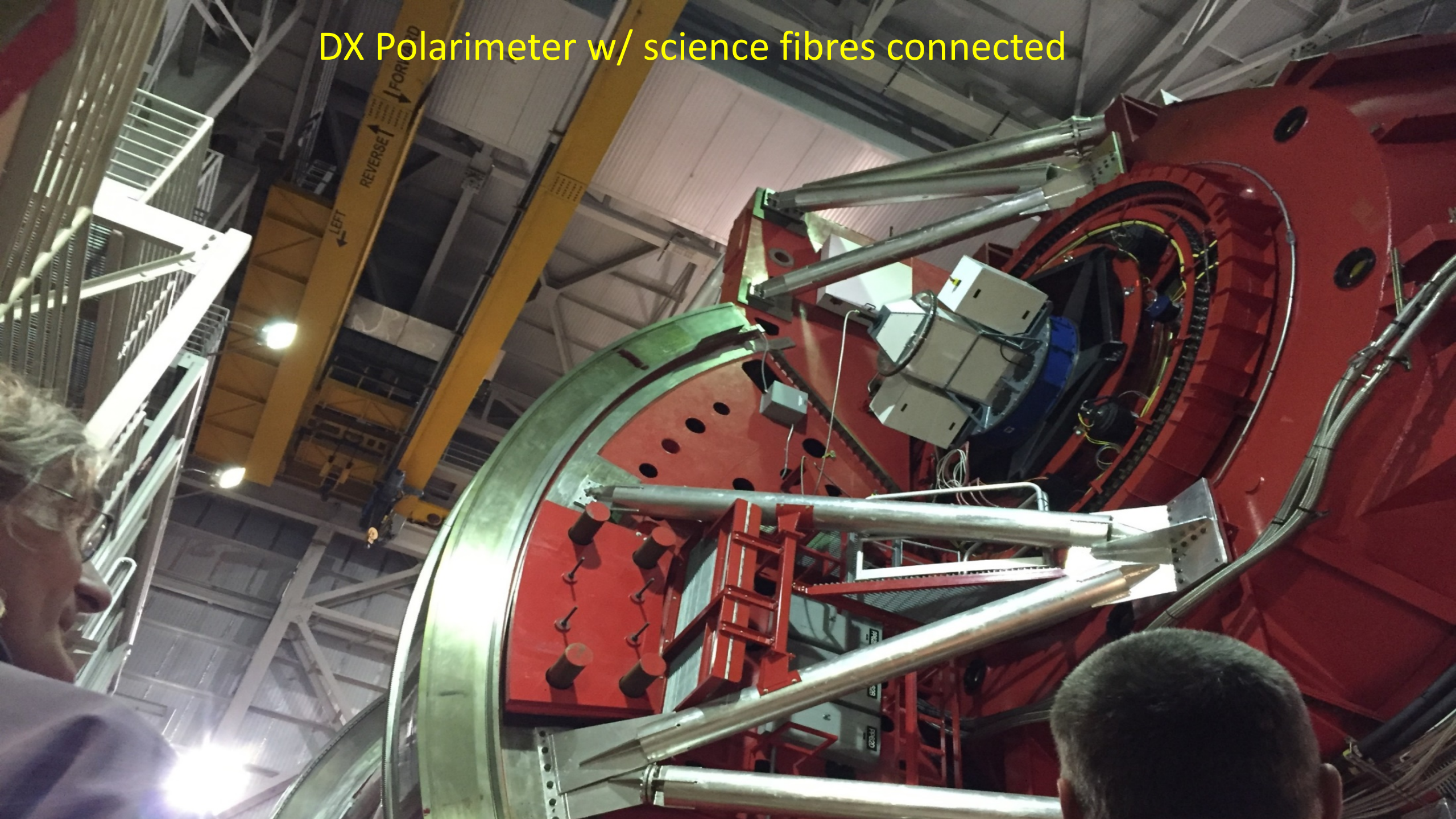
March, 2019

Grindelwald EPRV. Strassmeier: PEPSI

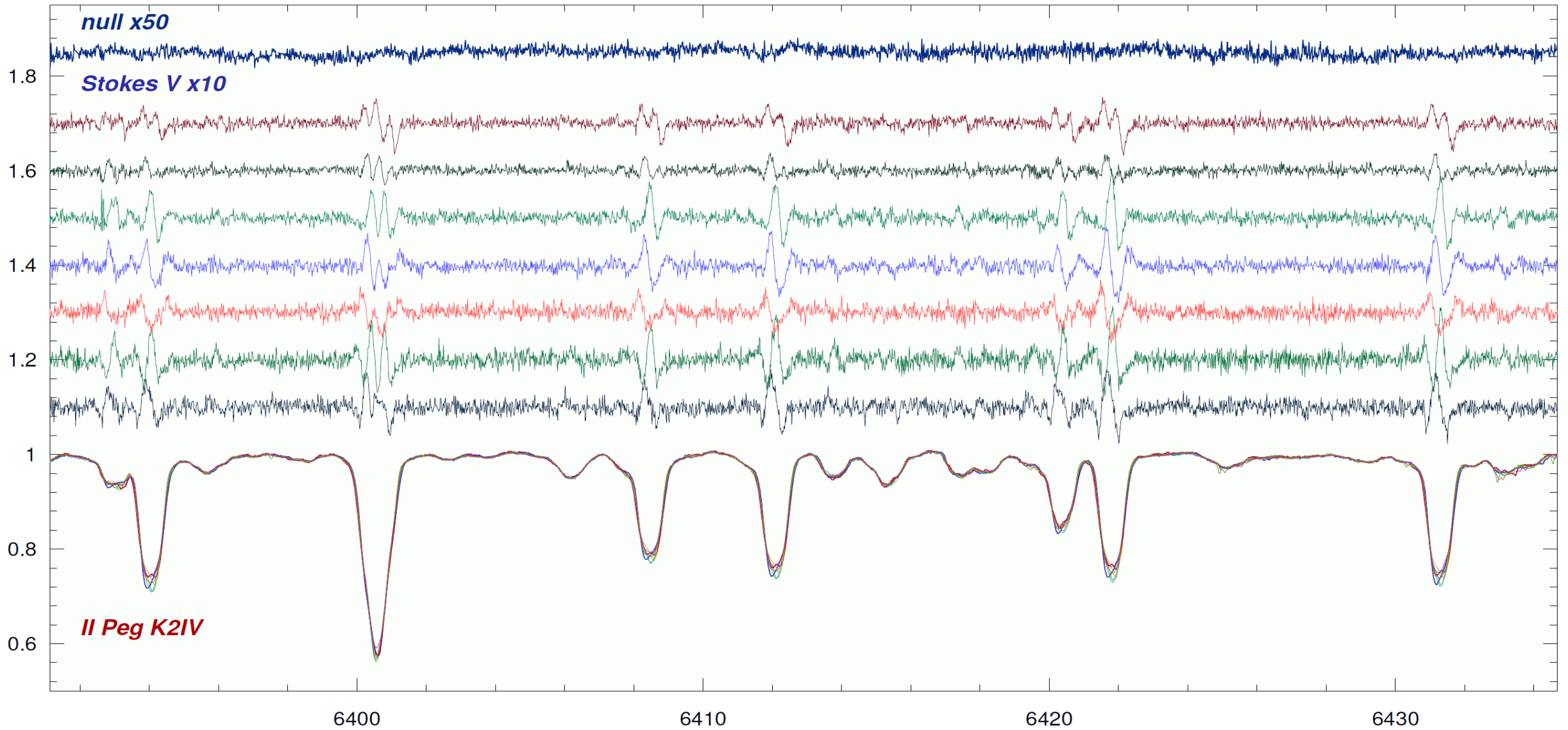
Polarimeter: mating w/ SX focus, 9/2017



DX Polarimeter w/ science fibres connected

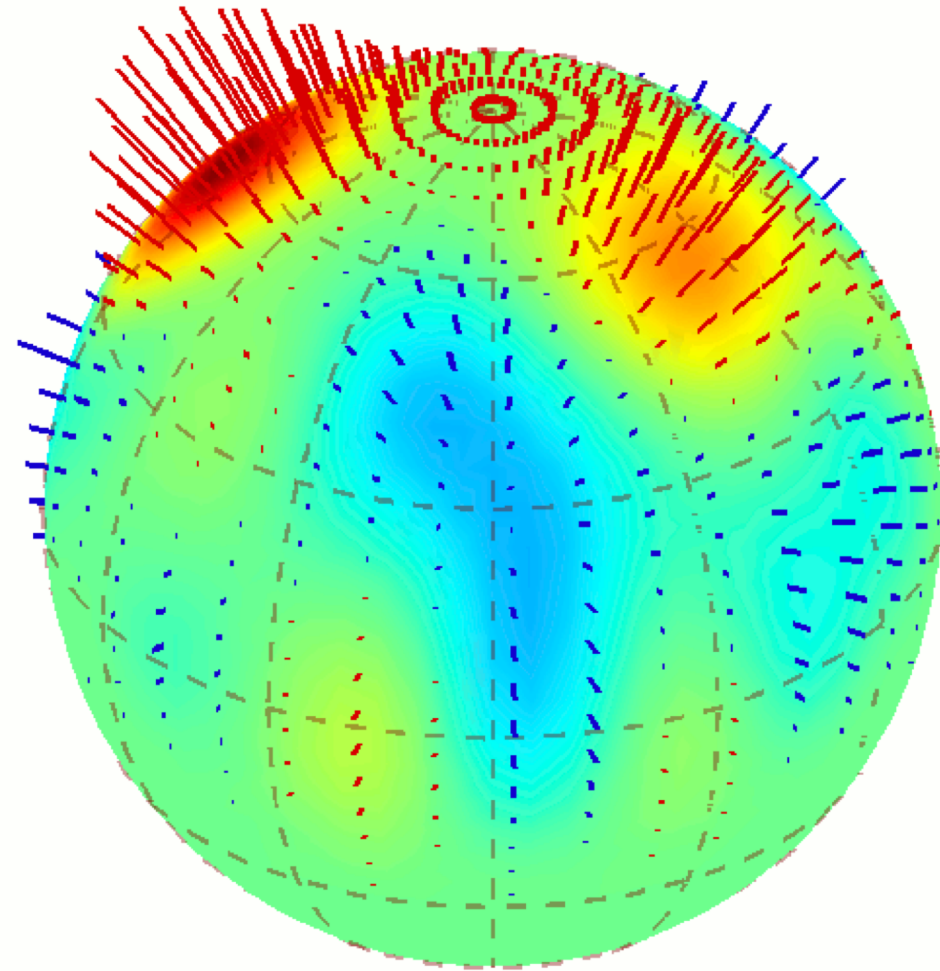
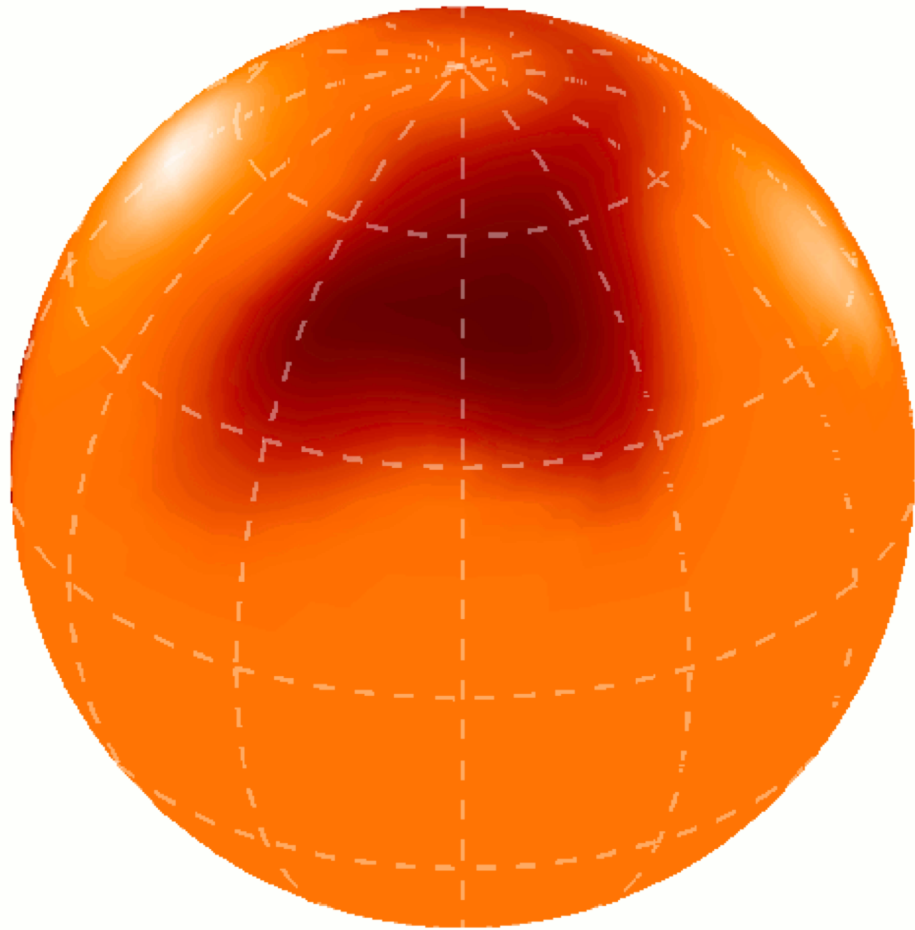


Magnetically active star II Peg

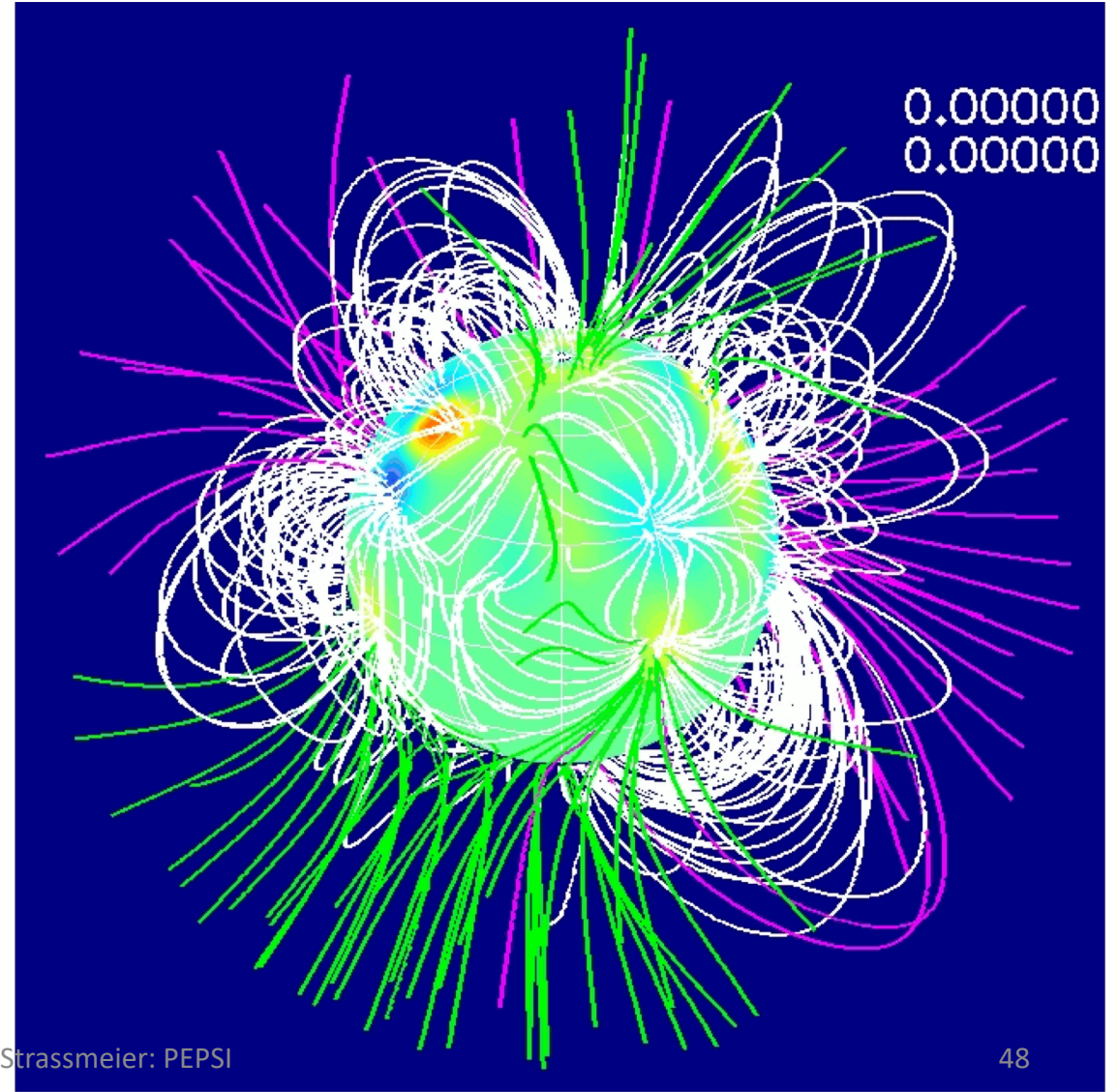
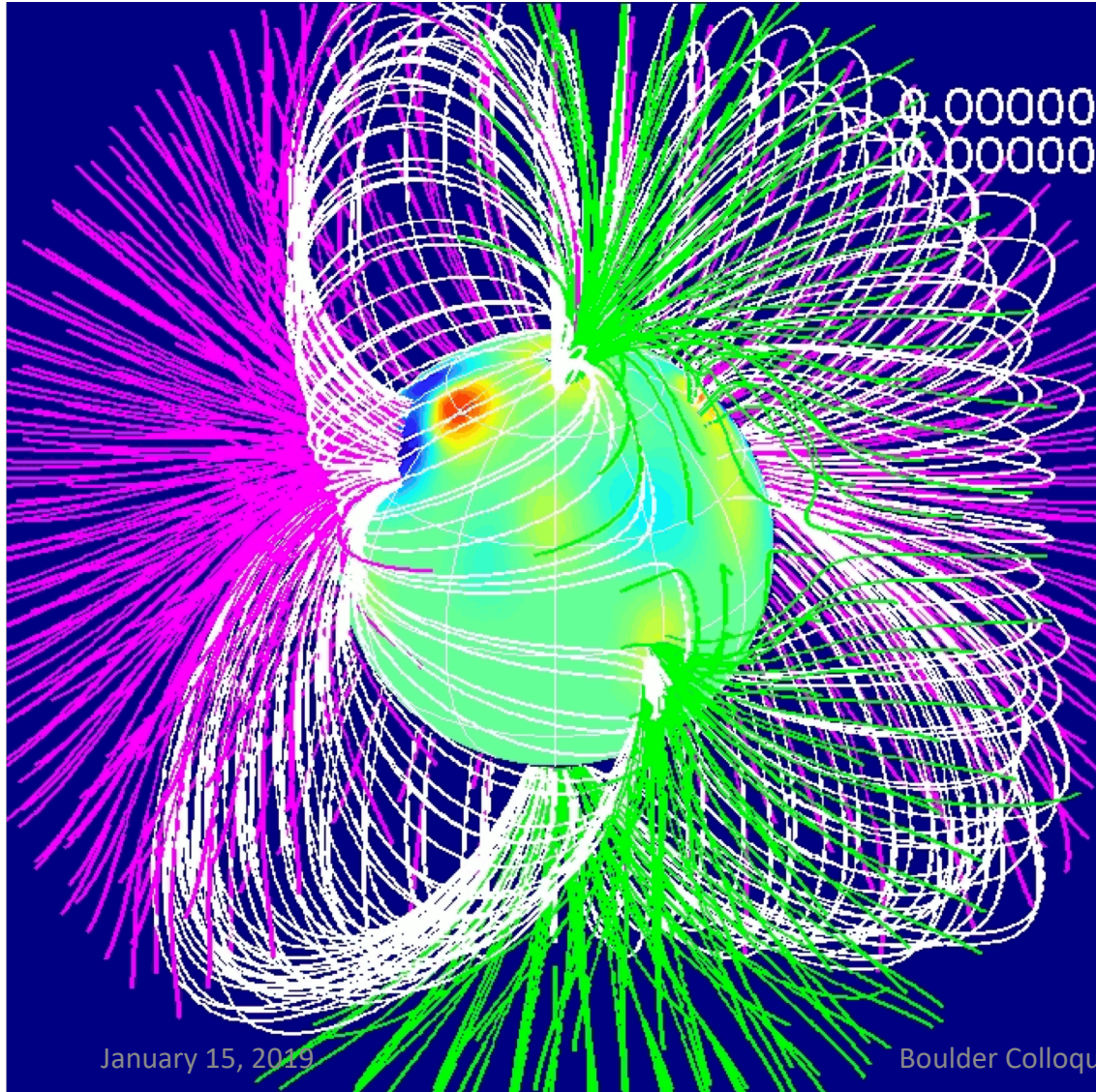


Magnetically active star II Peg

(Strassmeier et al. 2019, A&A, in press)



Warm & cool spot of opposite polarity: evidence for flux loops



Summary

- Exoplanets analyzed so far: Kelt-21b, Kelt-9b, HD189733b, Trappist-1g.
- In work: XO-2, Kelt-5, Wasp-76, Wasp-77, K-1514, HD222175, HD209458, KC11C039..., Epic2111..., K2-99, Wasp-12, Epic247..., K2-260, K2-232, Sun (partial eclipse 8/2018), Moon (total eclipse 1/2019 in IQUV).
- PEPSI is a hi-res **spectrograph** and **polarimeter** for the 2x8.4m LBT.
- Two fibres per telescope = **4 spectra per echelle order**
- λ 384-913nm; $R=50.000$ (12px), 130.000 (4px), 250.000 (2px); Stokes IQUV in $R=130.000$.
- **Stabilized** to $RV < 1\text{m/s}$ on short-term; long-term tbd but $< 5\text{ m/s}$
- 450m fibre feed from 1.8m **VATT**
- Sun-as-a-star telescope **SDI – soon with its own polarimeter**
- Use w/ LBT and VATT in **remote control** from Potsdam, SDI runs automatic



ASK FOR MORE
www.pepsi.de