

# Fe and TiO in the dayside emission spectrum of WASP-33b

2020/08/27 - David Cont



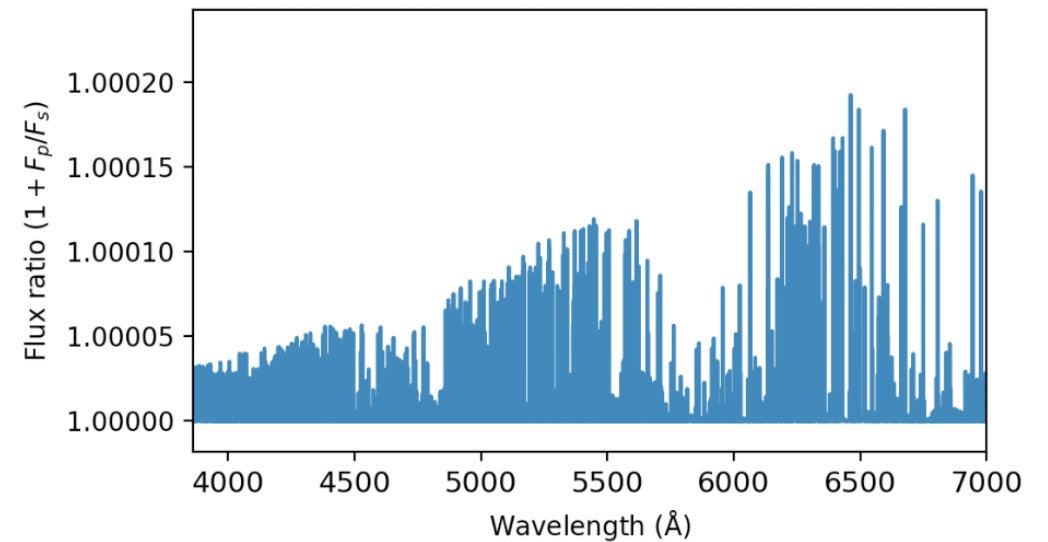
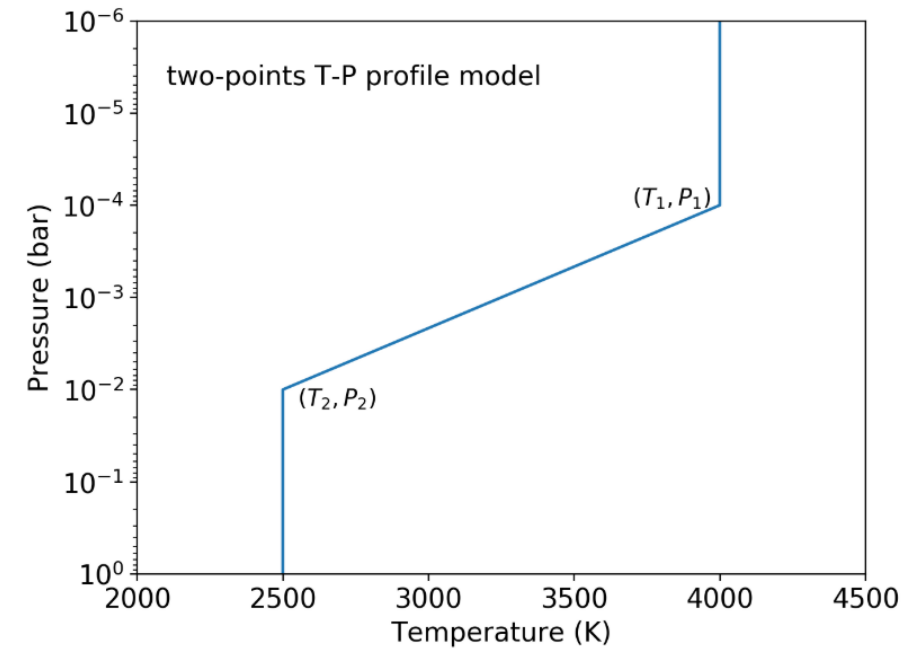
Heating mechanism in the upper atmosphere of Ultra-hot Jupiters



Inverted T-p profile



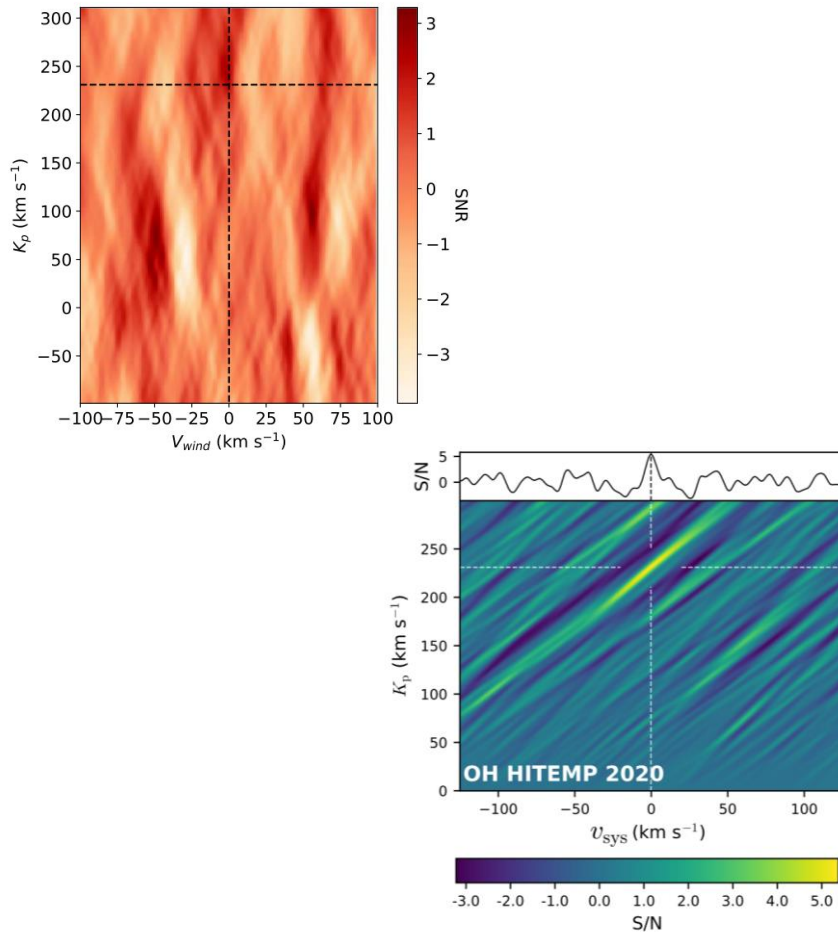
Spectral lines are in emission



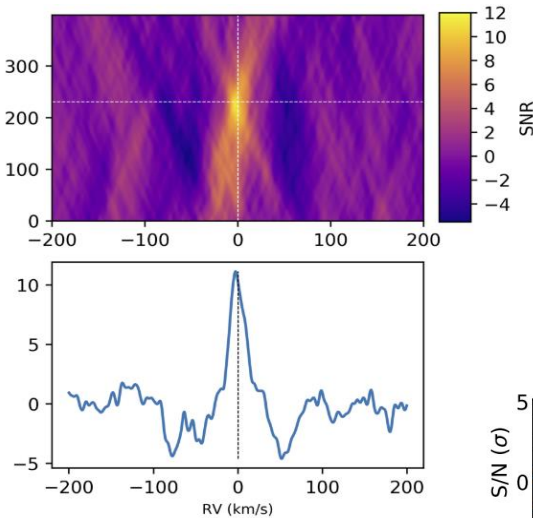
Yan+2020

# Role of different chemical species for atmospheric heating is unclear. Atoms, Ions, Metal Oxides, Metal Hydrates,...?

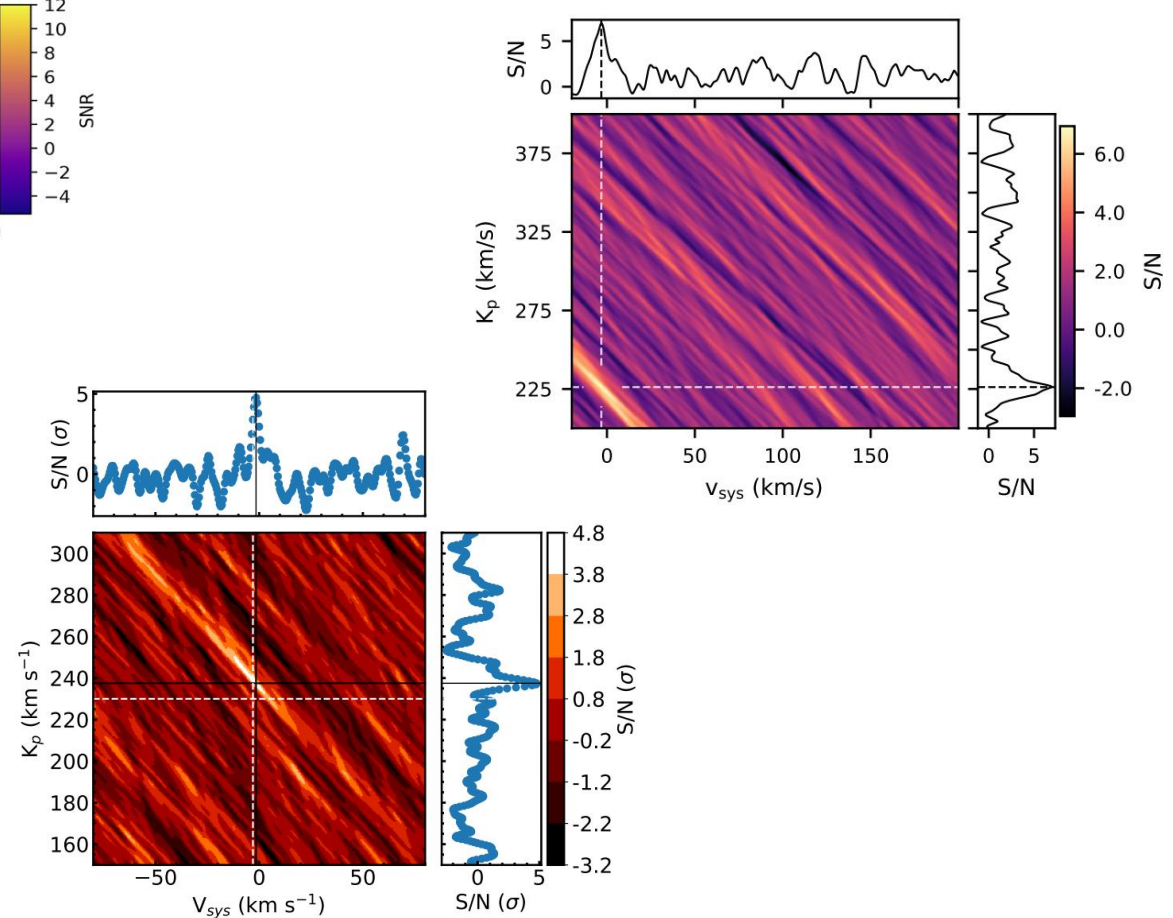
### FeH (Kesseli+2020)



### Ca<sup>+</sup> (Yan+2020)



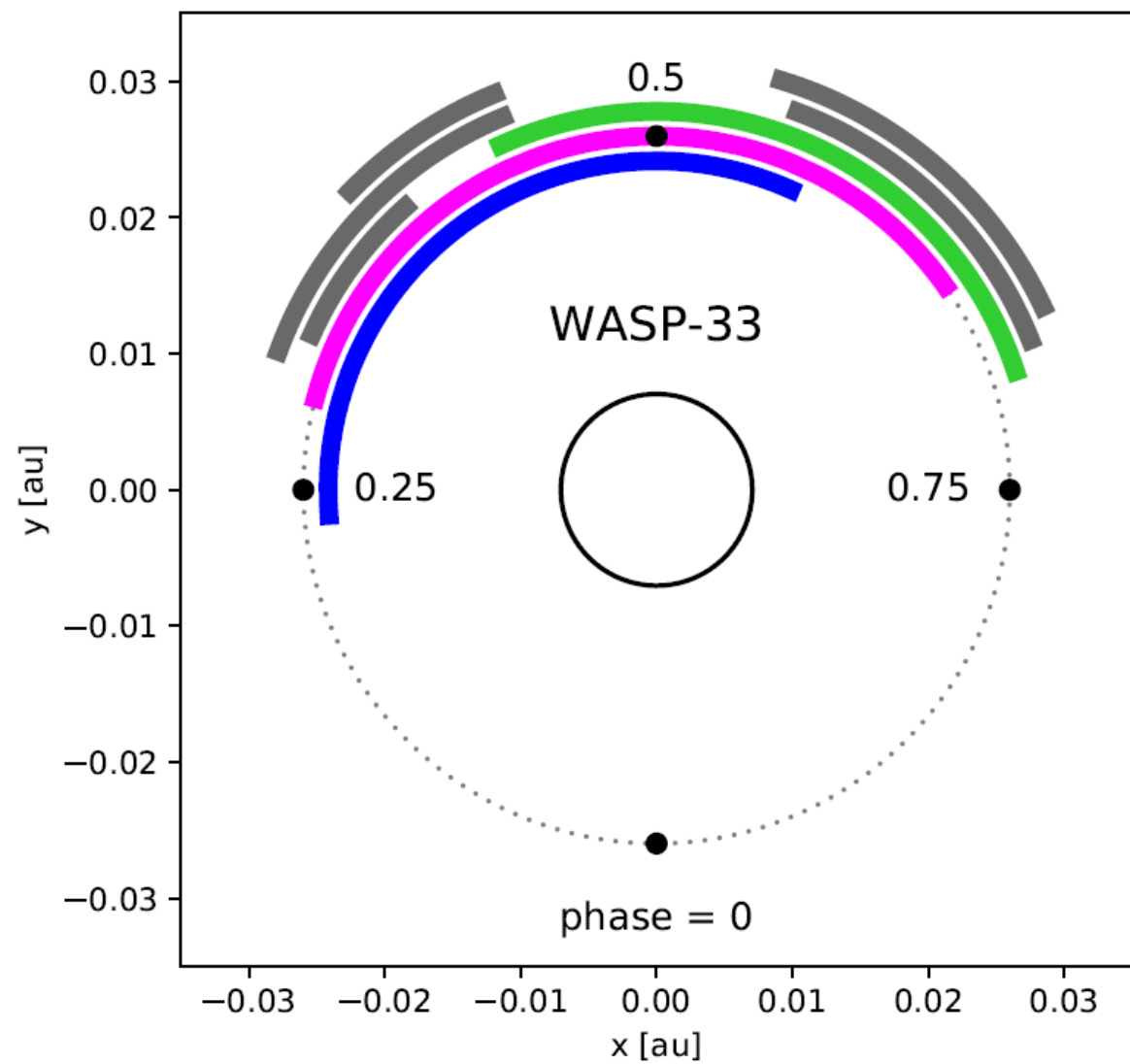
### Fe (Nugroho+2020)

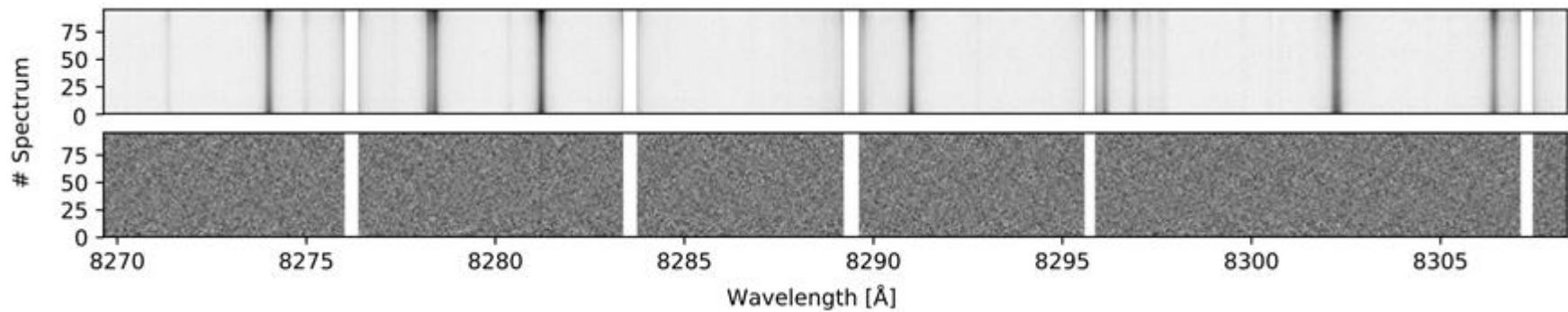


### OH<sup>-</sup> (Nugroho+2021)

### TiO (Nugroho+2017)

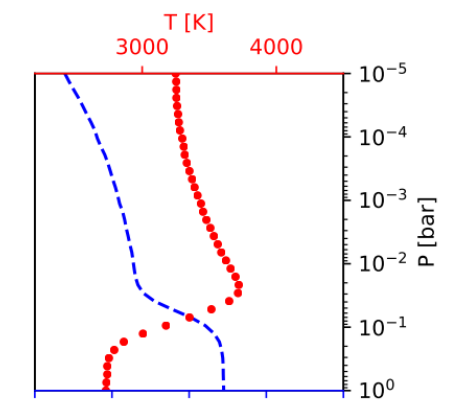
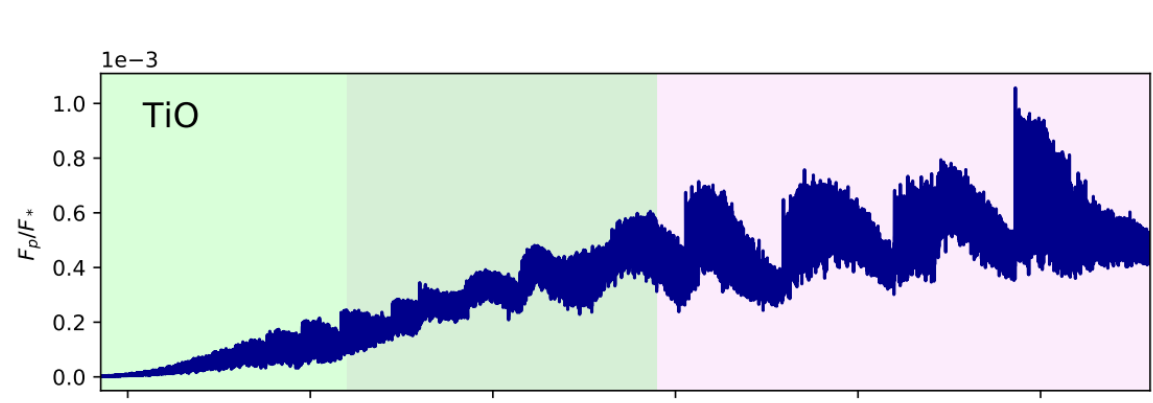
Instrument	Exposure time	$N_{\text{spectra}}$
<i>New data</i>		
CARMENES	300 s	105
HARPS-N	200 s	125
HARPS-N	200 s	155
<i>Archival data</i>		
ESPaDOnS	90 s	110
ESPaDOnS	90 s	55
ESPaDOnS	90 s	110
ESPaDOnS	90 s	110
ESPaDOnS	90 s	55



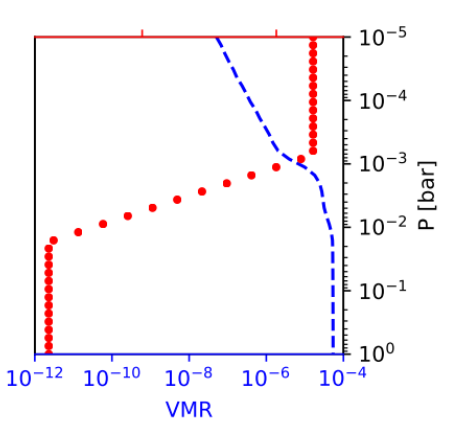
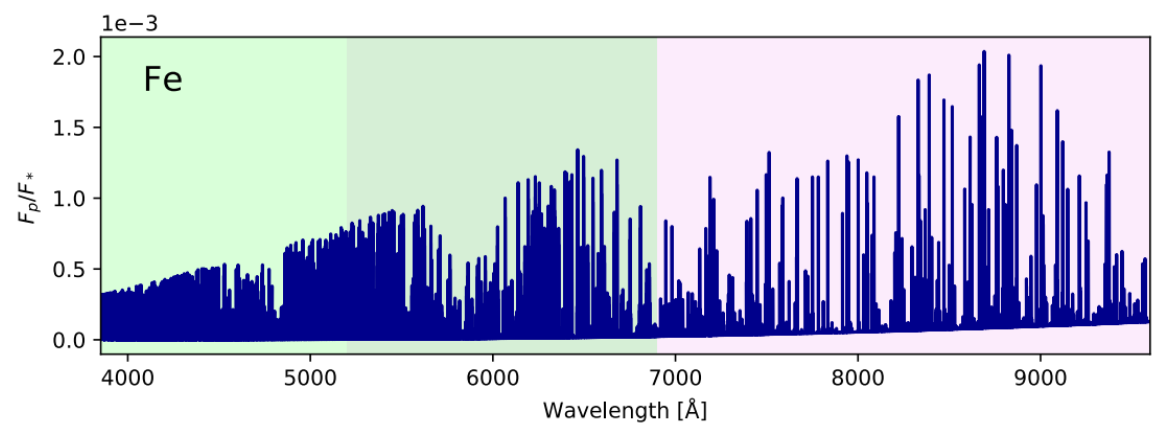


normalized spectra

stellar and telluric lines removal with SYSREM

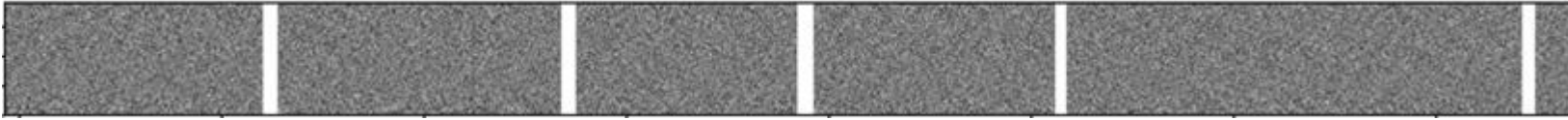


moderate temperature for the TiO atmosphere (to avoid TiO dissociation)  
(Haynes+2015)

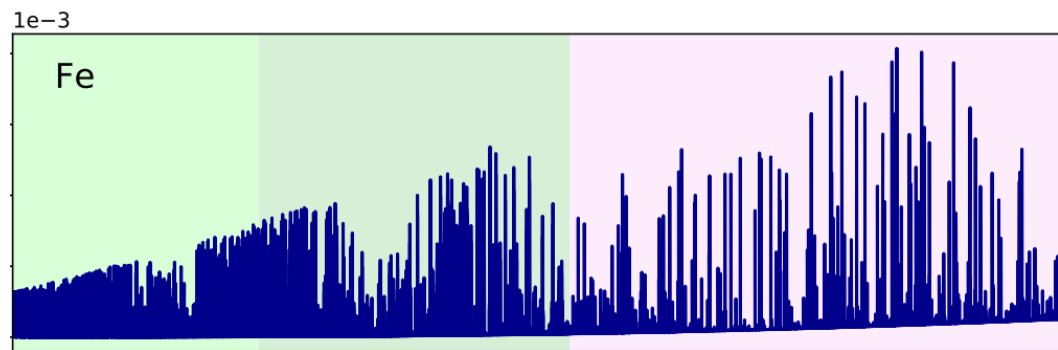
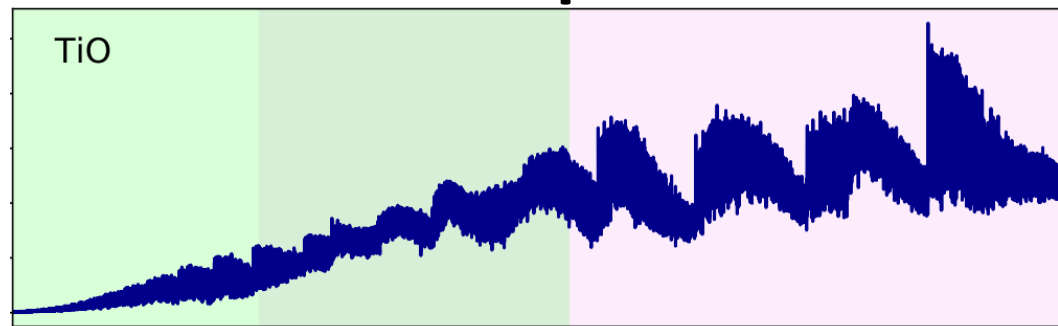


higher temperature for Fe  
(Yan+2020)

## residual spectra



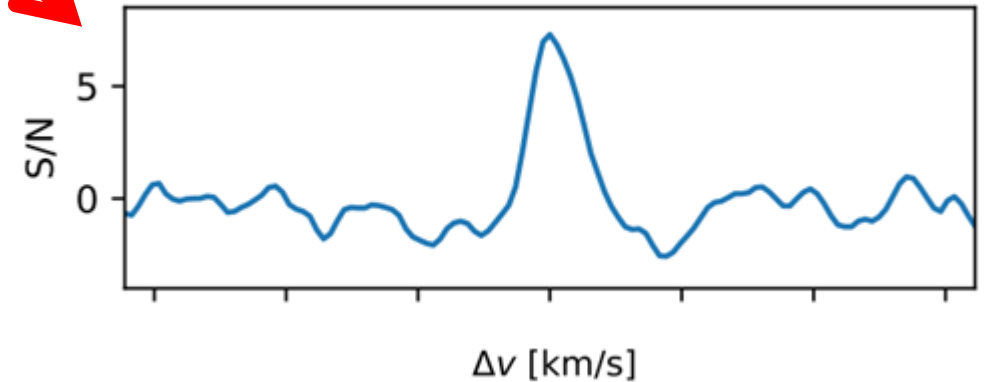
## model spectra



\*

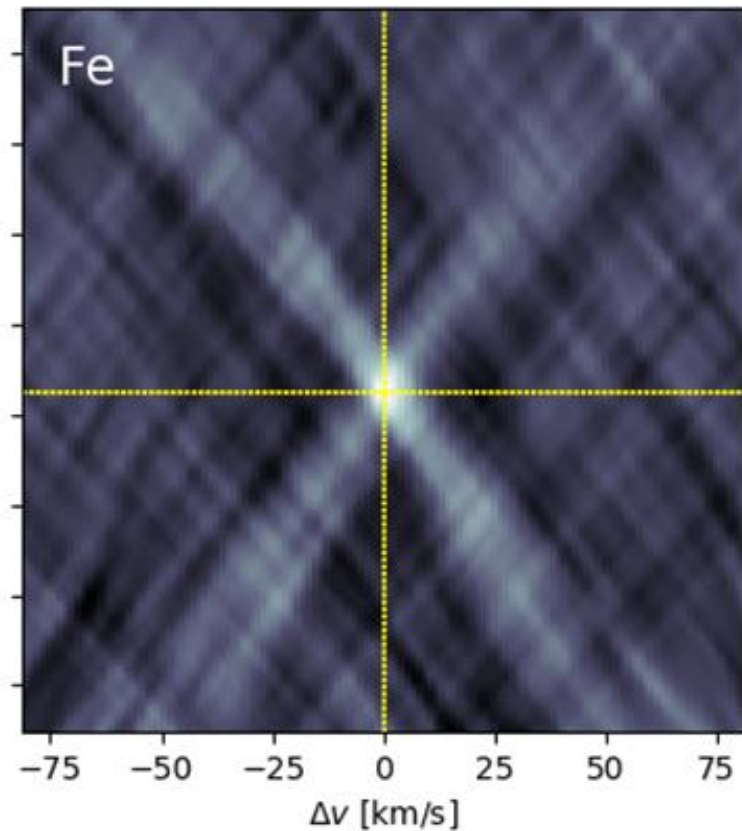
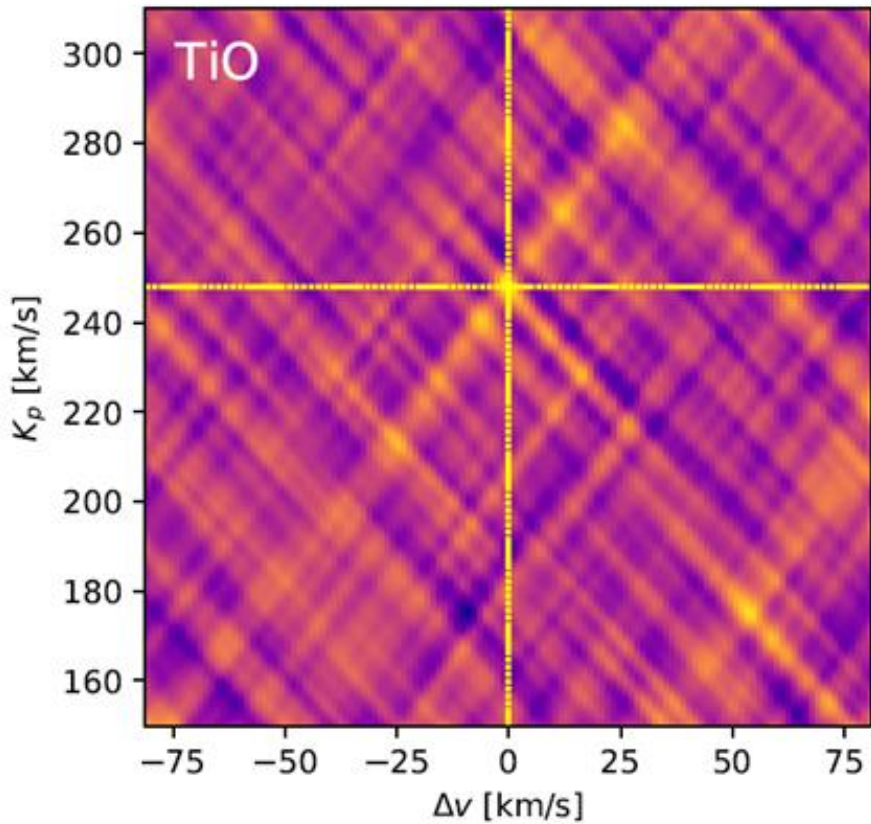
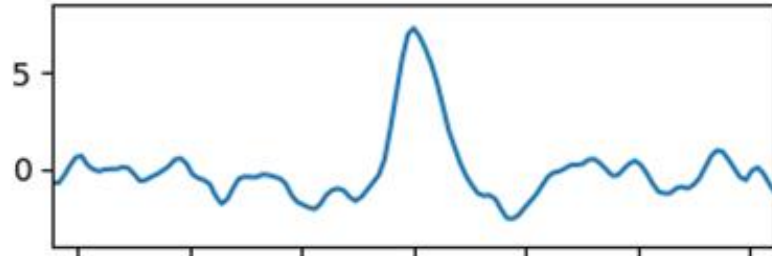
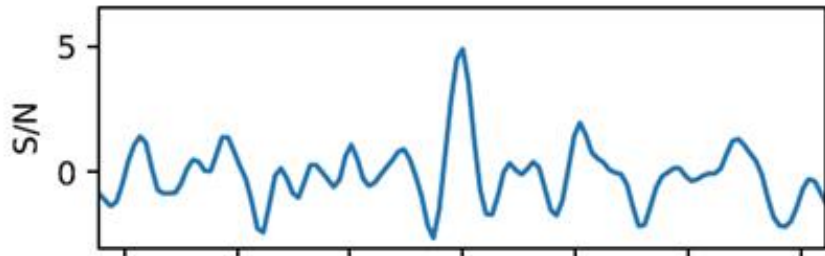


## Cross-correlation function



Model spectrum is similar to the real planetary spectrum:

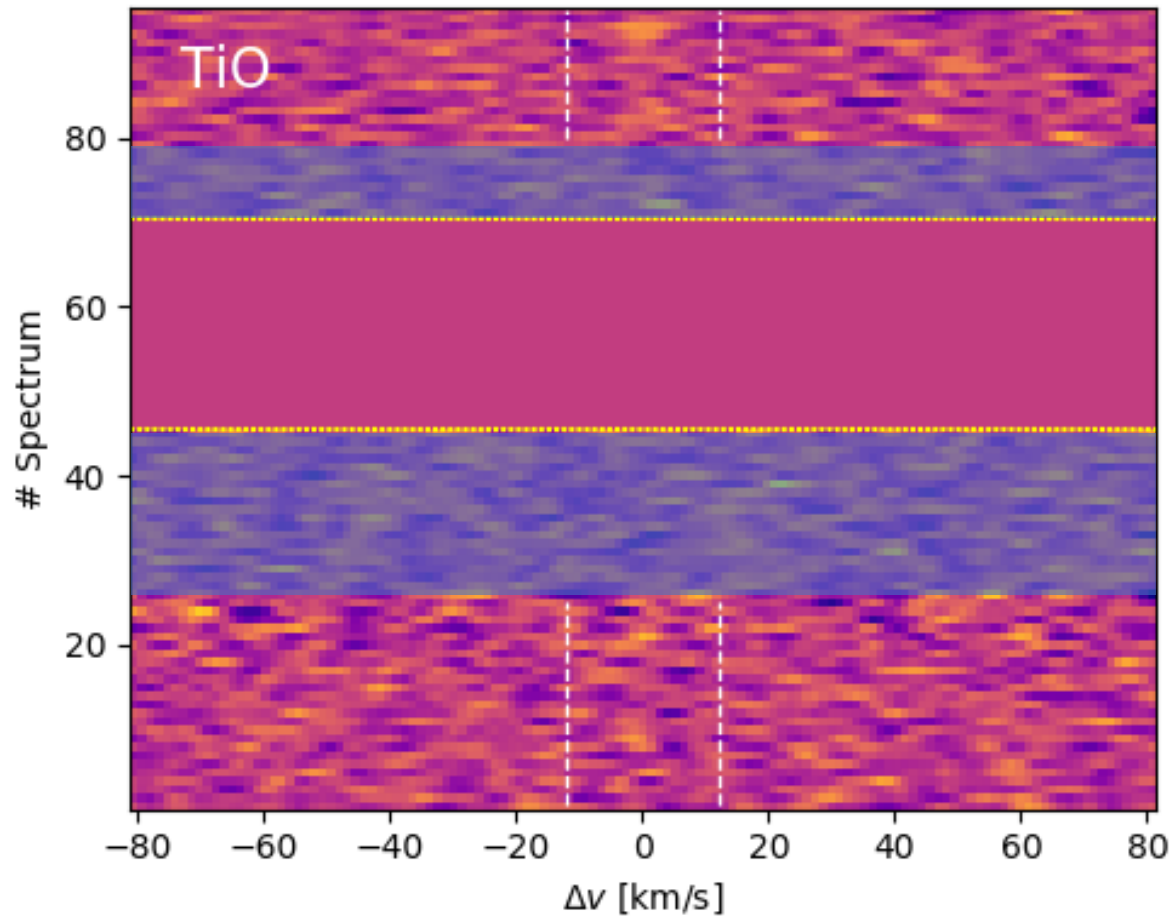
Cross-correlation combines the numerous weak planetary lines into a detectable signal.



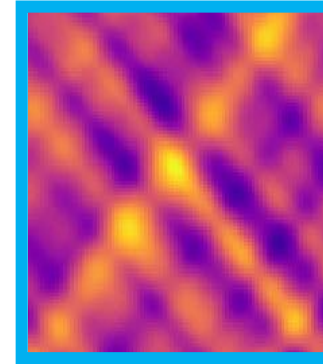
Instrument	S/N	$K_p$ [km s <sup>-1</sup> ]	$\Delta v$ [km s <sup>-1</sup> ]
<i>TiO</i>			
CARMENES	4.9	248.0 <sup>+2.0</sup> <sub>-2.5</sub>	0.0 <sup>+2.6</sup> <sub>-2.6</sub>
HARPS-N		no significant detection	
ESPaDOnS		no significant detection	
<i>Fe</i>			
CARMENES	5.7	228.0 <sup>+3.5</sup> <sub>-5.0</sub>	1.3 <sup>+3.9</sup> <sub>-3.9</sub>
HARPS-N	4.5	225.0 <sup>+2.0</sup> <sub>-5.0</sub>	-0.8 <sup>+4.0</sup> <sub>-2.4</sub>
ESPaDOnS	6.2	225.0 <sup>+3.5</sup> <sub>-5.0</sub>	0.0 <sup>+3.6</sup> <sub>-3.6</sub>
Combined	7.3	225.0 <sup>+4.0</sup> <sub>-3.5</sub>	0.0 <sup>+2.6</sup> <sub>-2.6</sub>

**Expected:  $K_p = 231$  km/s**

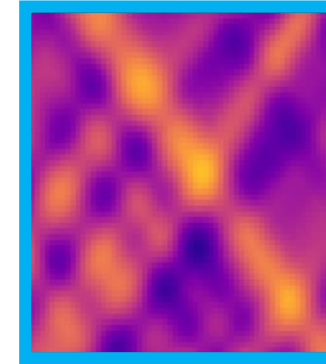
# No TiO signature close to eclipse



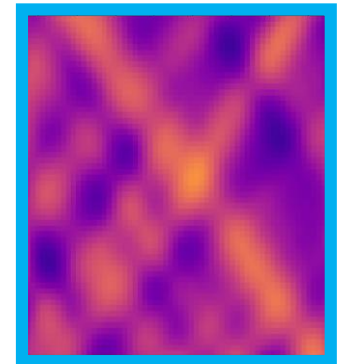
0.37-0.60



0.41-0.59



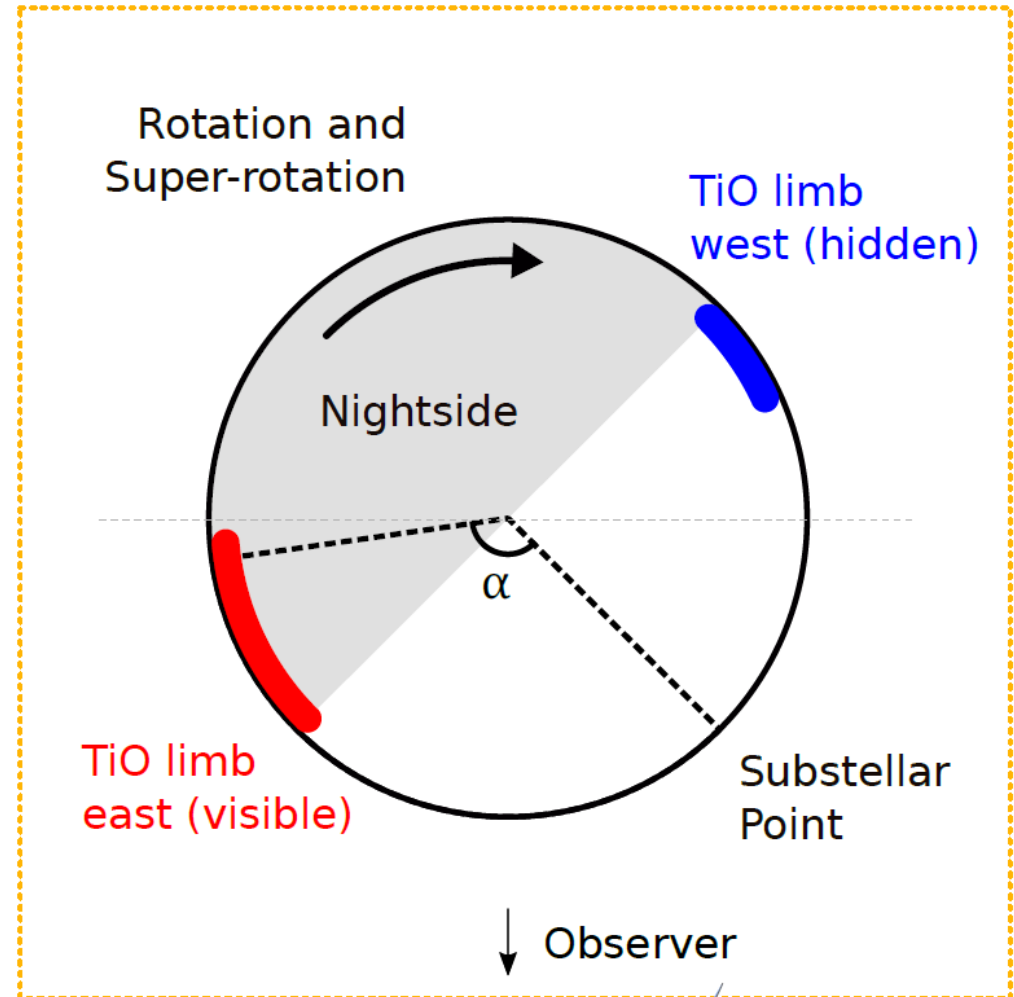
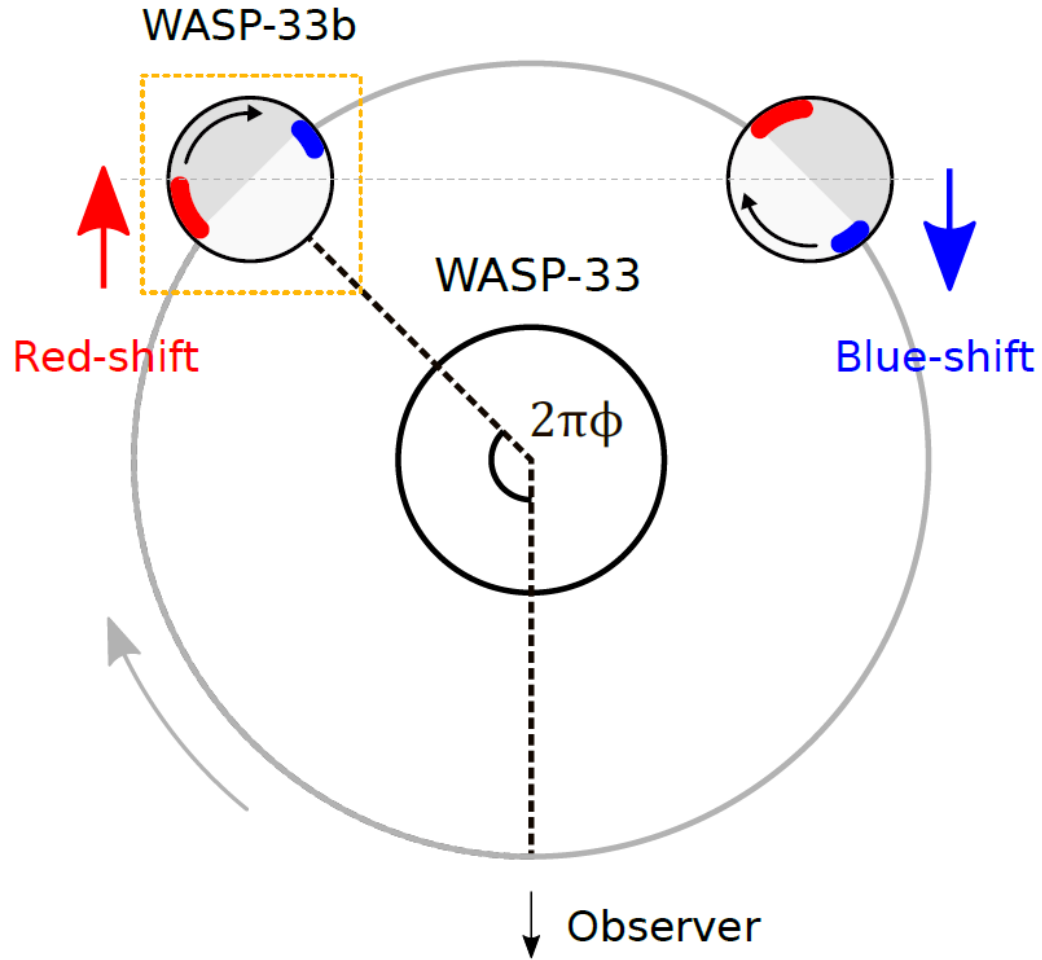
all spectra



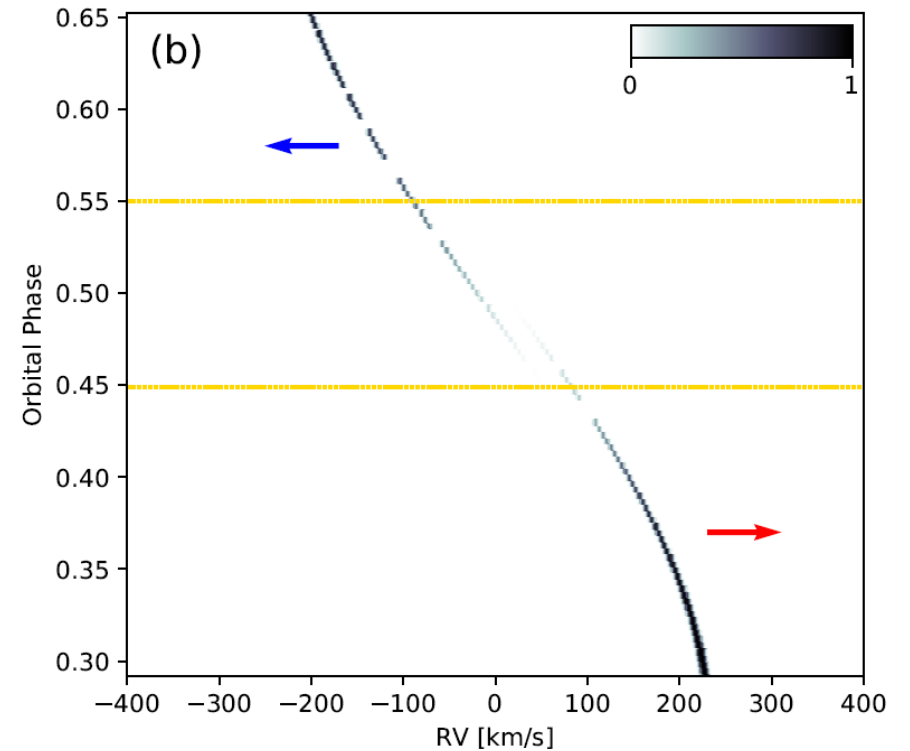
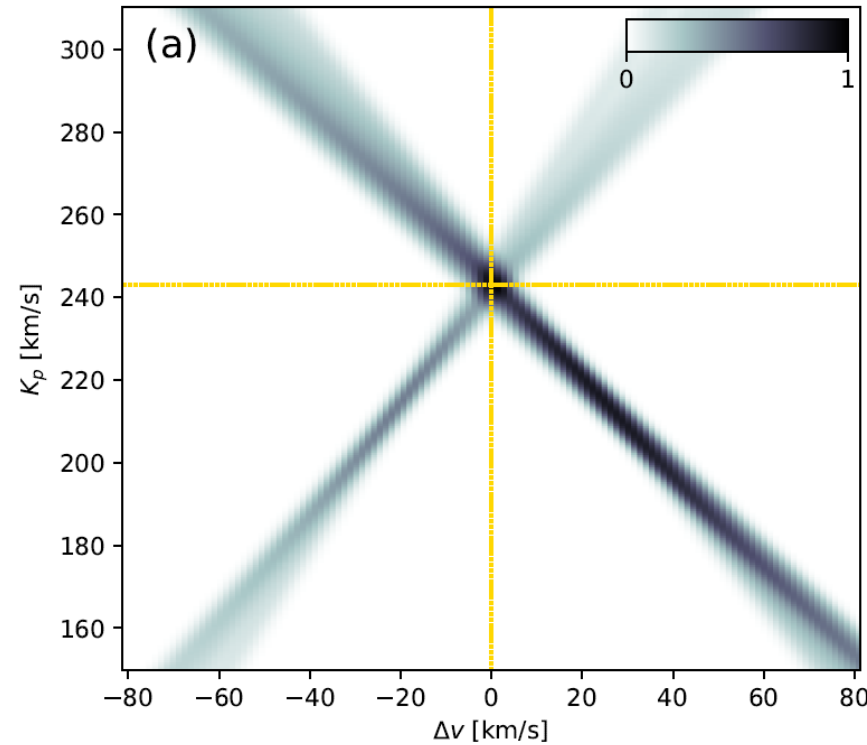
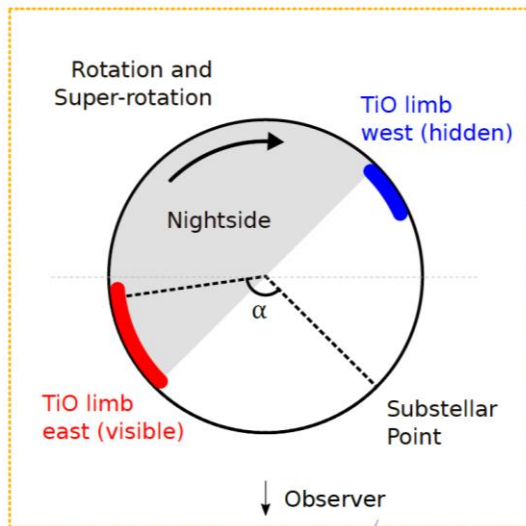
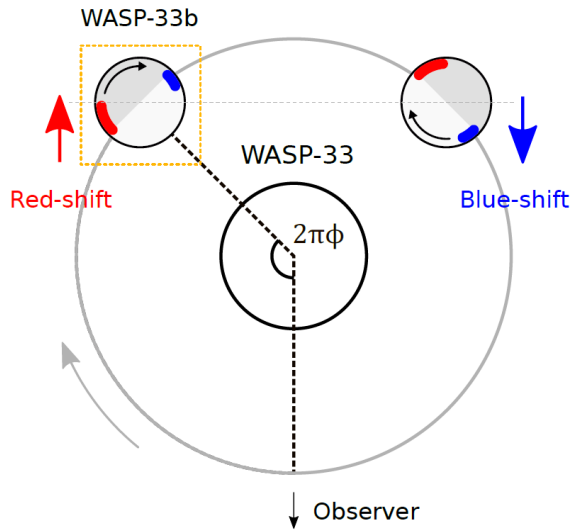
Exclusion of spectra between orbital phase 0.37 and 0.60.



# TiO-depleted hot spot

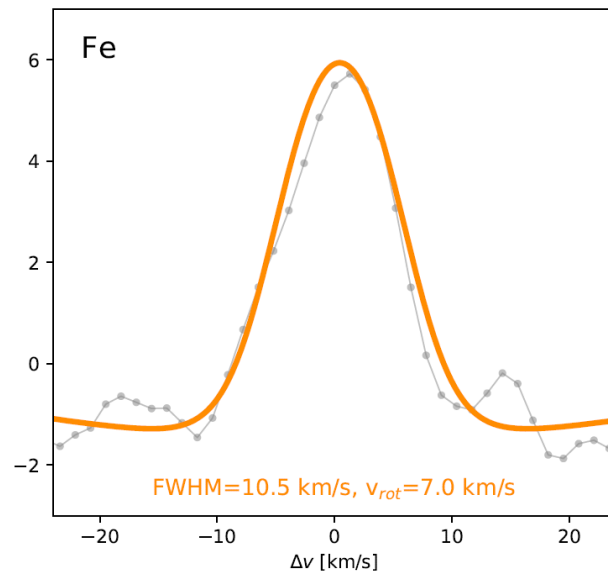
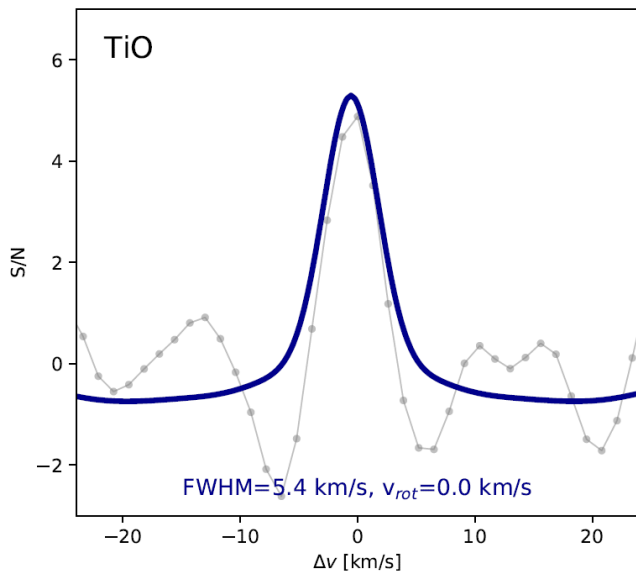
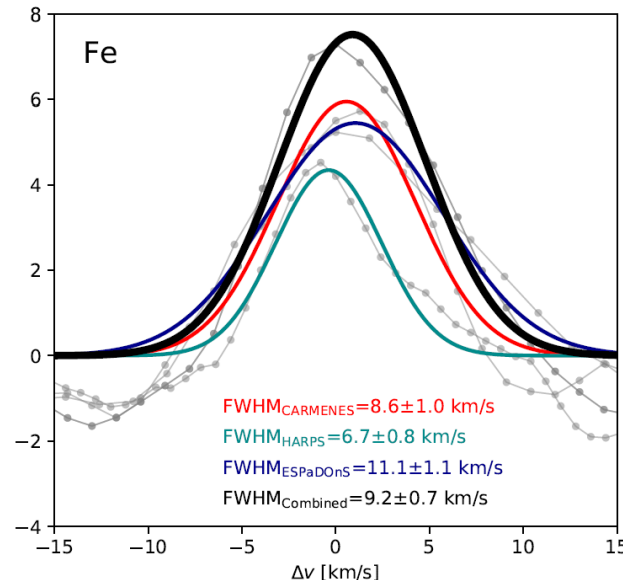
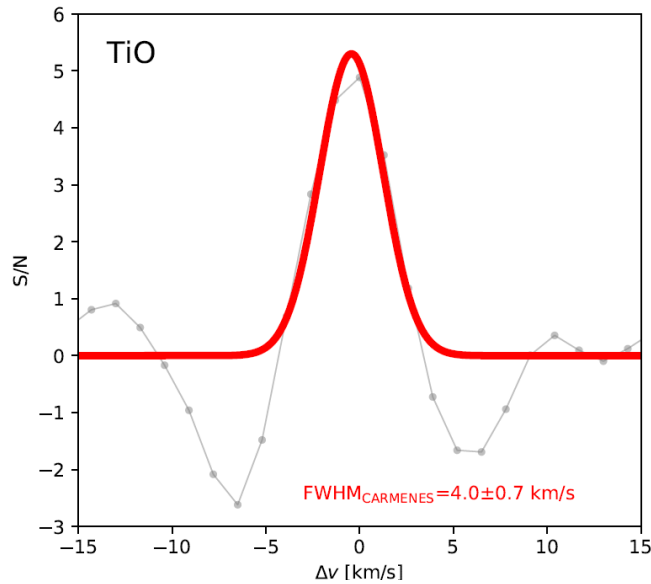


# TiO-depleted hot spot



TiO dissociation in the hottest atmospheric region?  
A hot spot could explain the  $K_p$  offset of TiO!

# Broadening of the line profile



Broadening of Fe lines stronger than for TiO lines

Simulated CCFs

- TiO - no rotational broadening
- Fe - rotational broadening with  $v_{\text{rot}} = 7 \text{ km/s}$

# Summary

## Observations of WASP-33b with CARMENES and HARPS-N

### TiO

- $K_p = 248 (+2.0 -2.5)$  km/s
- Narrow line profile

TiO undergoes mostly thermal dissociation and is only present close to the terminator regions

### Fe

- $K_p = 225 (+4.0 -3.5)$  km/s
- Rotationally broadened line profile

Homogeneous Fe distribution in the dayside atmosphere

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**Astronomy  
&  
Astrophysics**

## Detection of Fe and evidence for TiO in the dayside emission spectrum of WASP-33b

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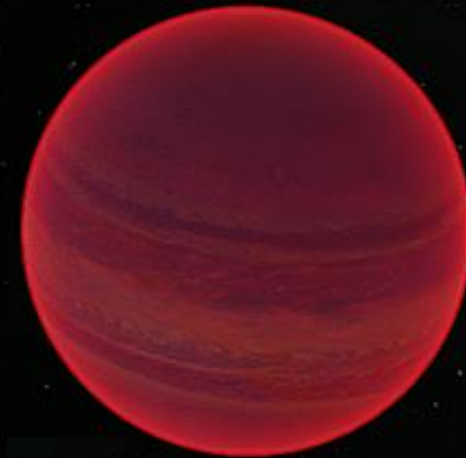
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**Many thanks for your attention :)**

