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August 27th

OH on the day-side of an ultra hot Jupiter, WASP-33b

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Nugroho 2021 ApJL 910 L9

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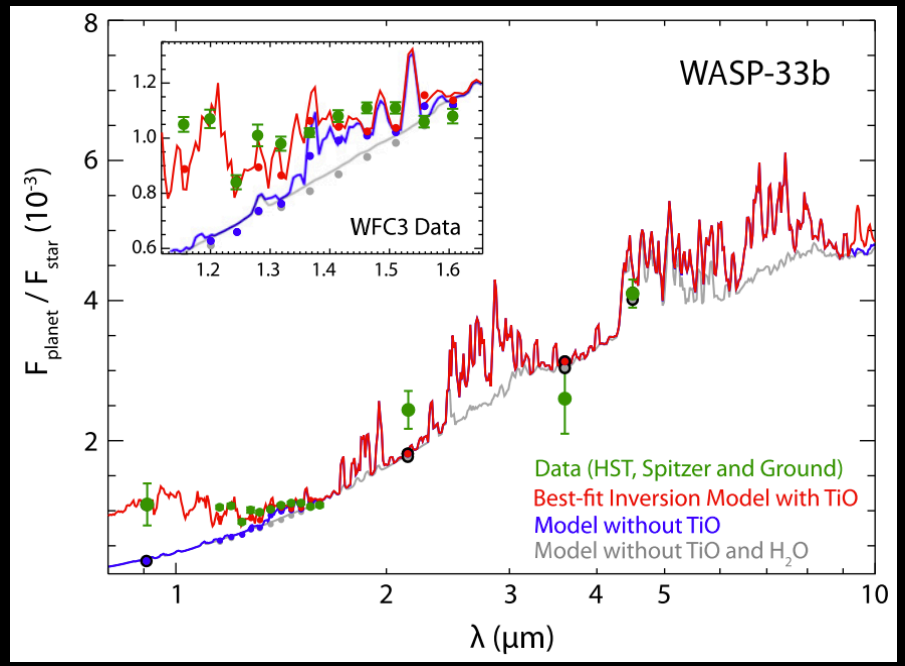
What's so special about WASP-33b

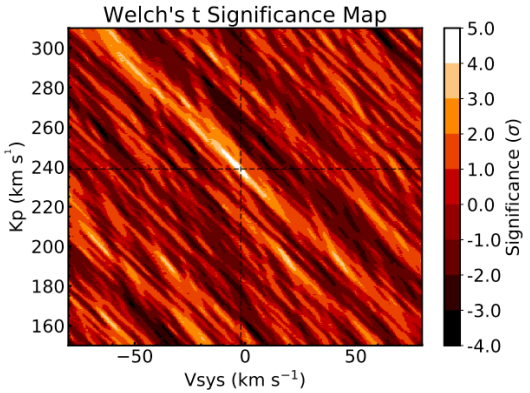
- Ultra-hot Jupiter (T_{day} > 3000 K)
- Orbiting bright delta scuti A-type star
- It has a stratosphere
- The orbit is precessing (Johnson et al. 2015)



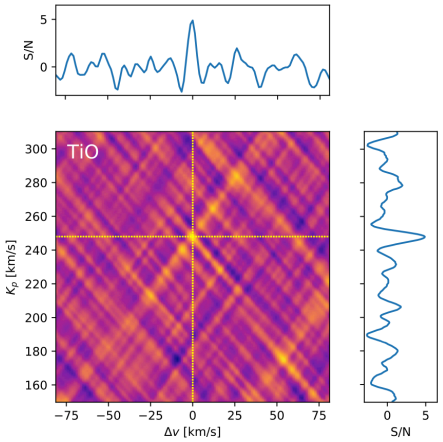
Haynes et al. 2015

What's so special about WASP-33b

TiO

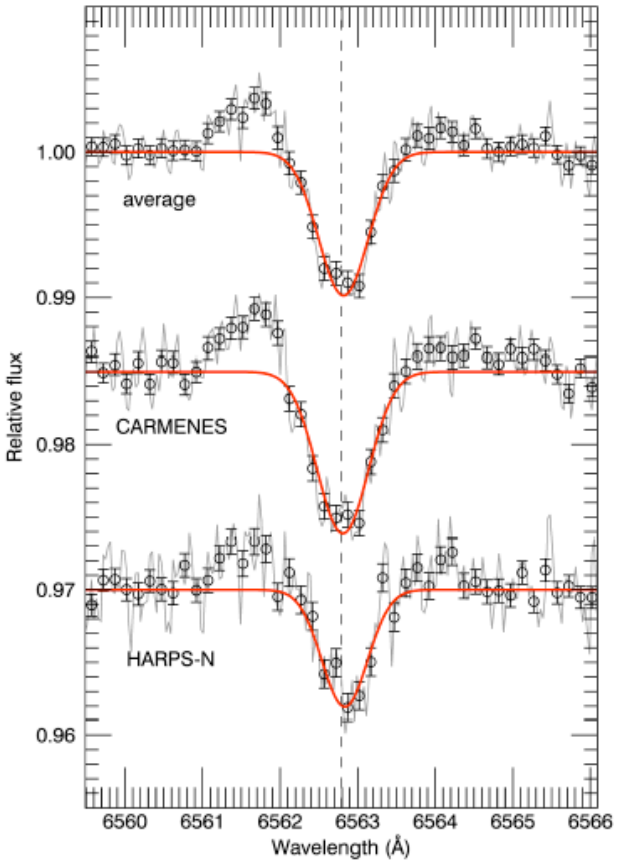


Nugroho et al. 2017



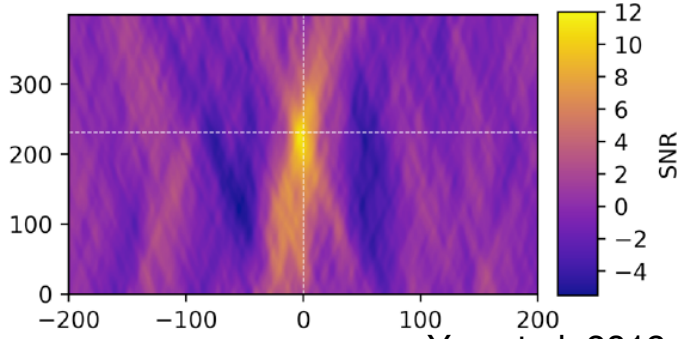
Cont et al. 2021

H alpha

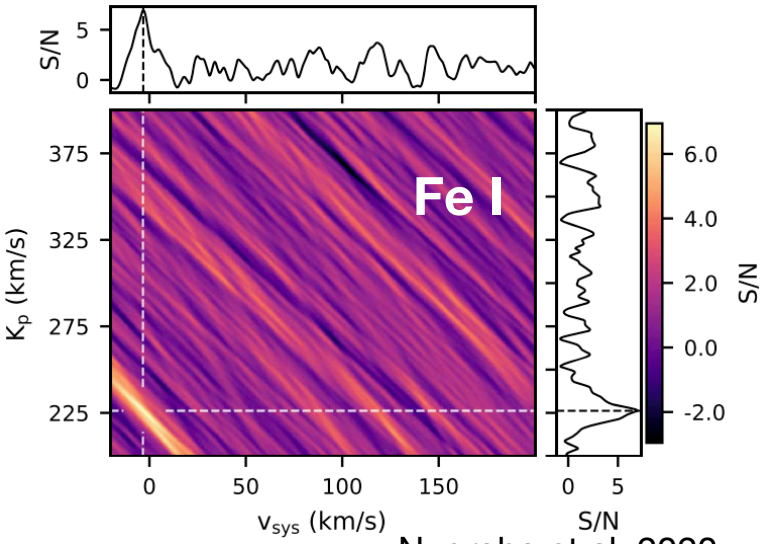


Yan et al. 2020

WASP-33b Ca$^+$ combined

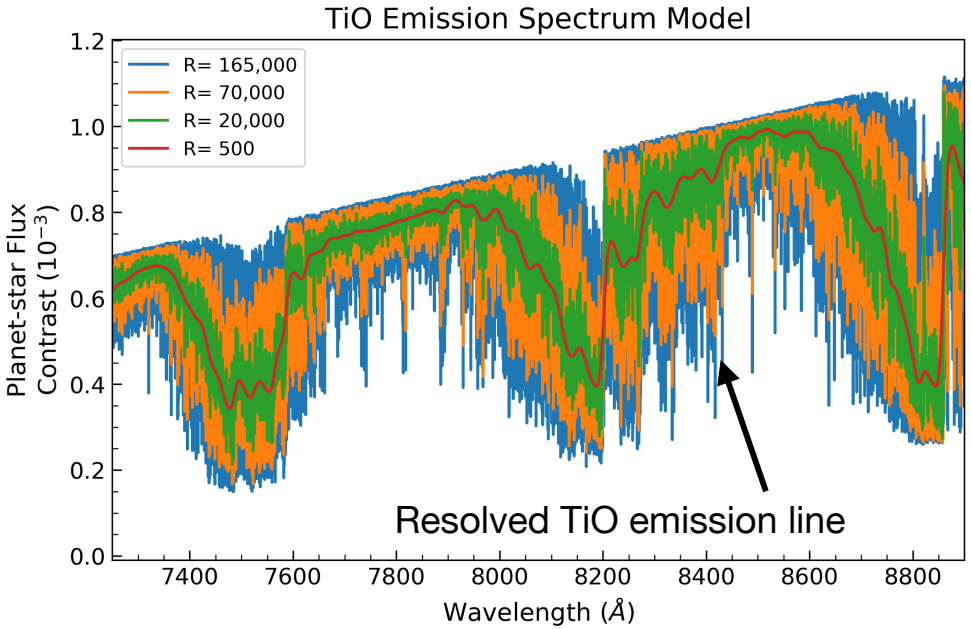


Yan et al. 2019

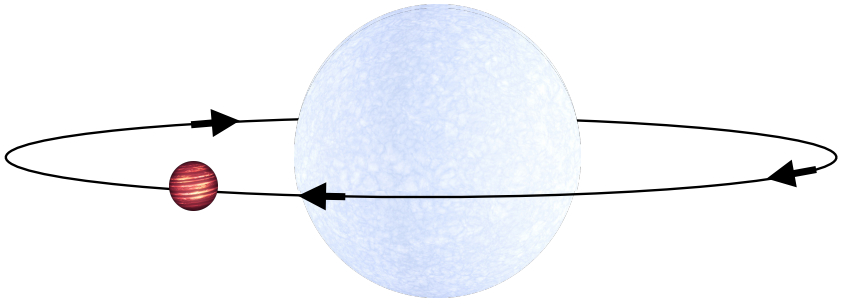


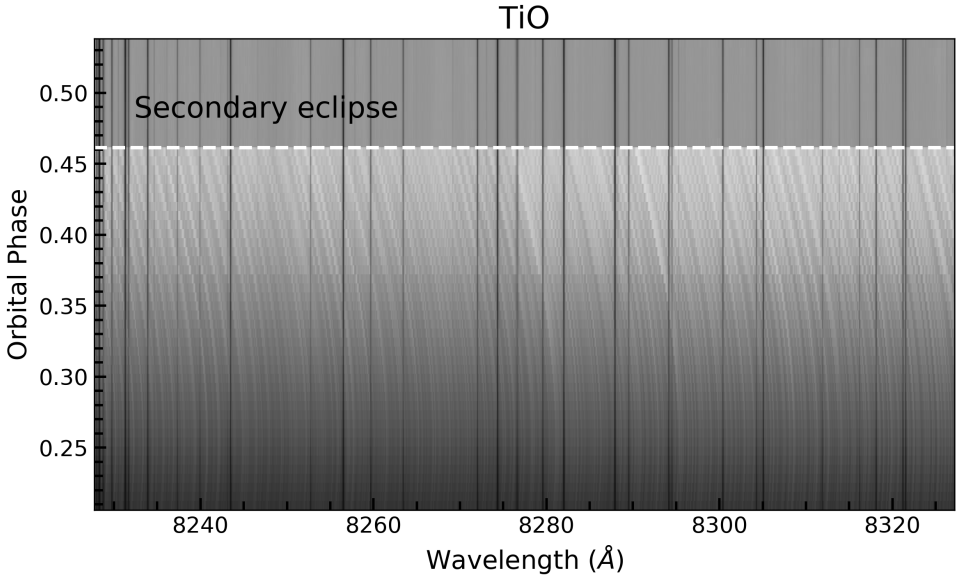
Nugroho et al. 2020
Cont et al. 2021

Advantages of High-resolution Spectroscopy



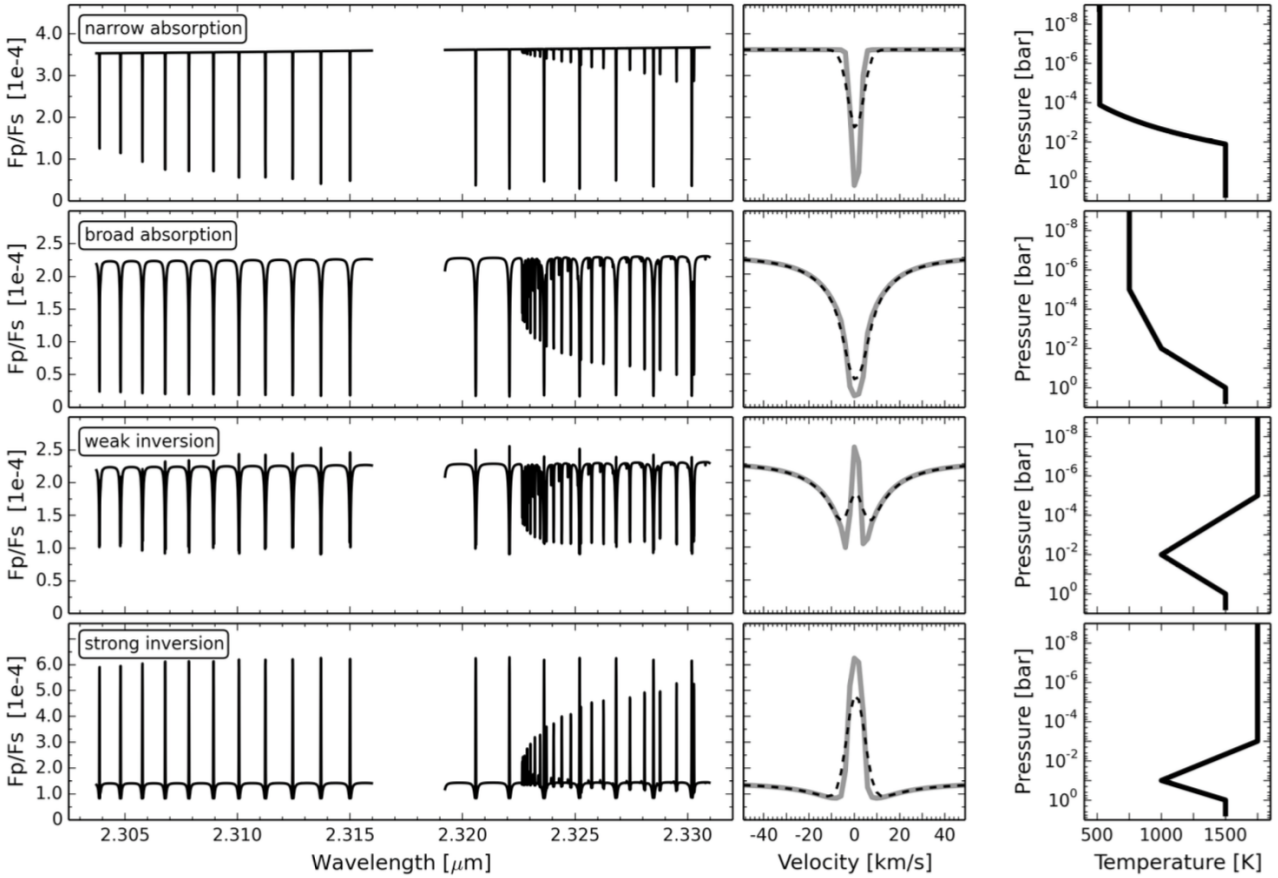
Can be distinguished from the telluric/stellar lines





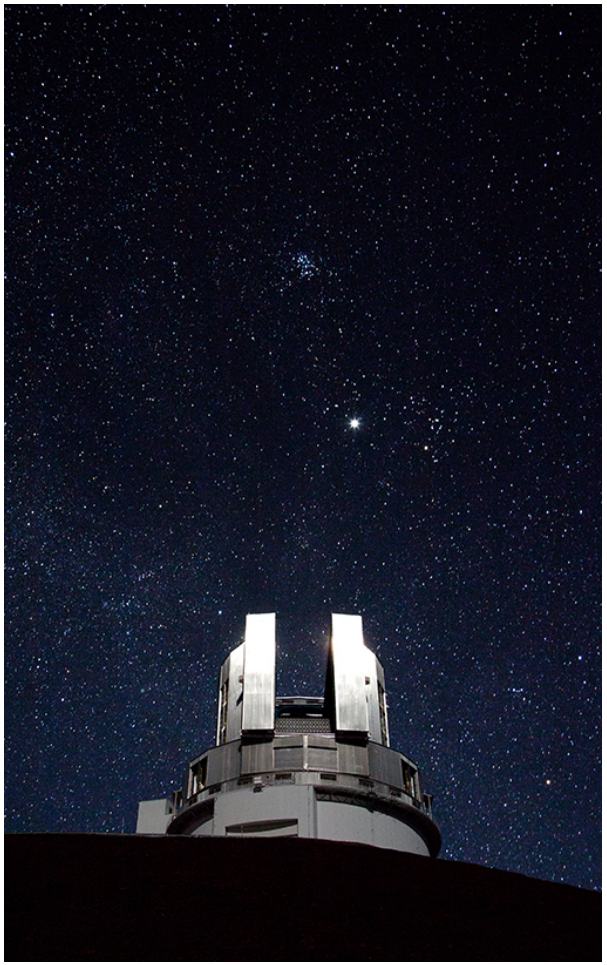
Advantages of High-resolution Spectroscopy

Sensitive to the line shape! → • **Temperature profile, rotational broadening, etc.**



Schwarz et al. 2015

Observing WASP-33b using Subaru telescope



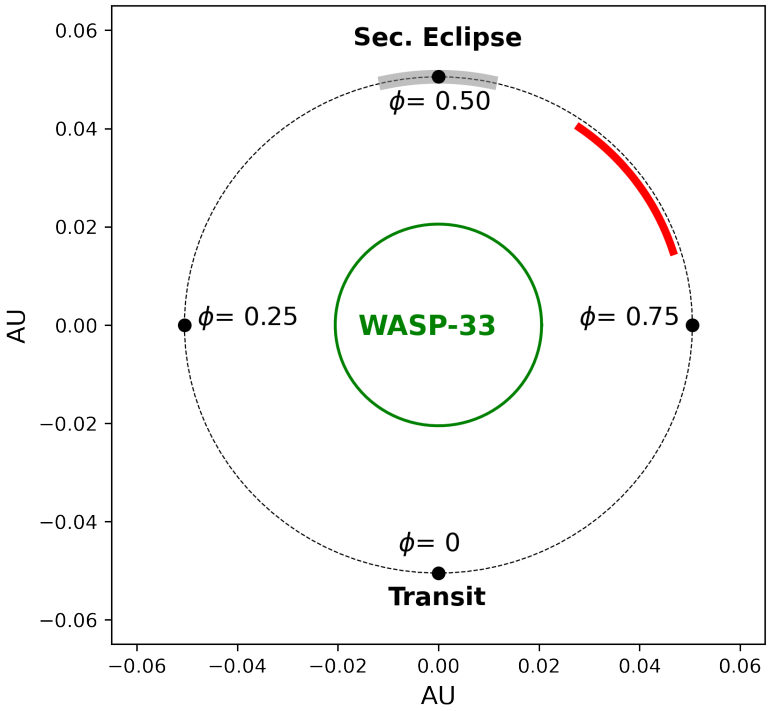
InfraRed Doppler (IRD) instrument
0.97-1.75 μm, R~ 70,000

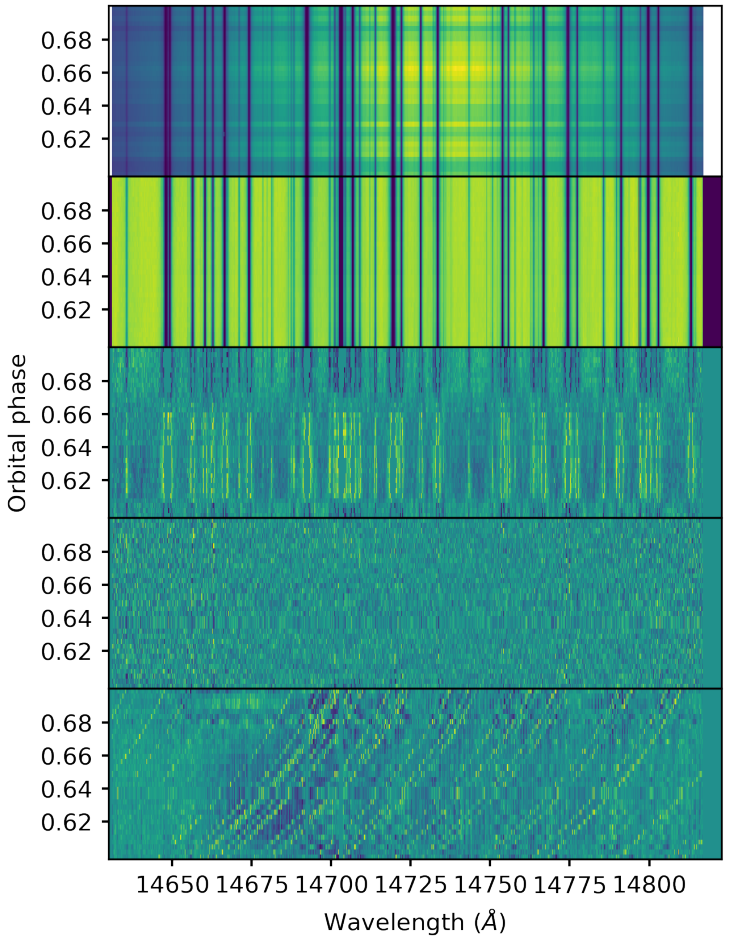
~~2018~~ High humidity/cloudy

~~2019~~ High humidity/cloudy

~~2020~~ High humidity+telescope issue
Only 3 hours of data

Data processing



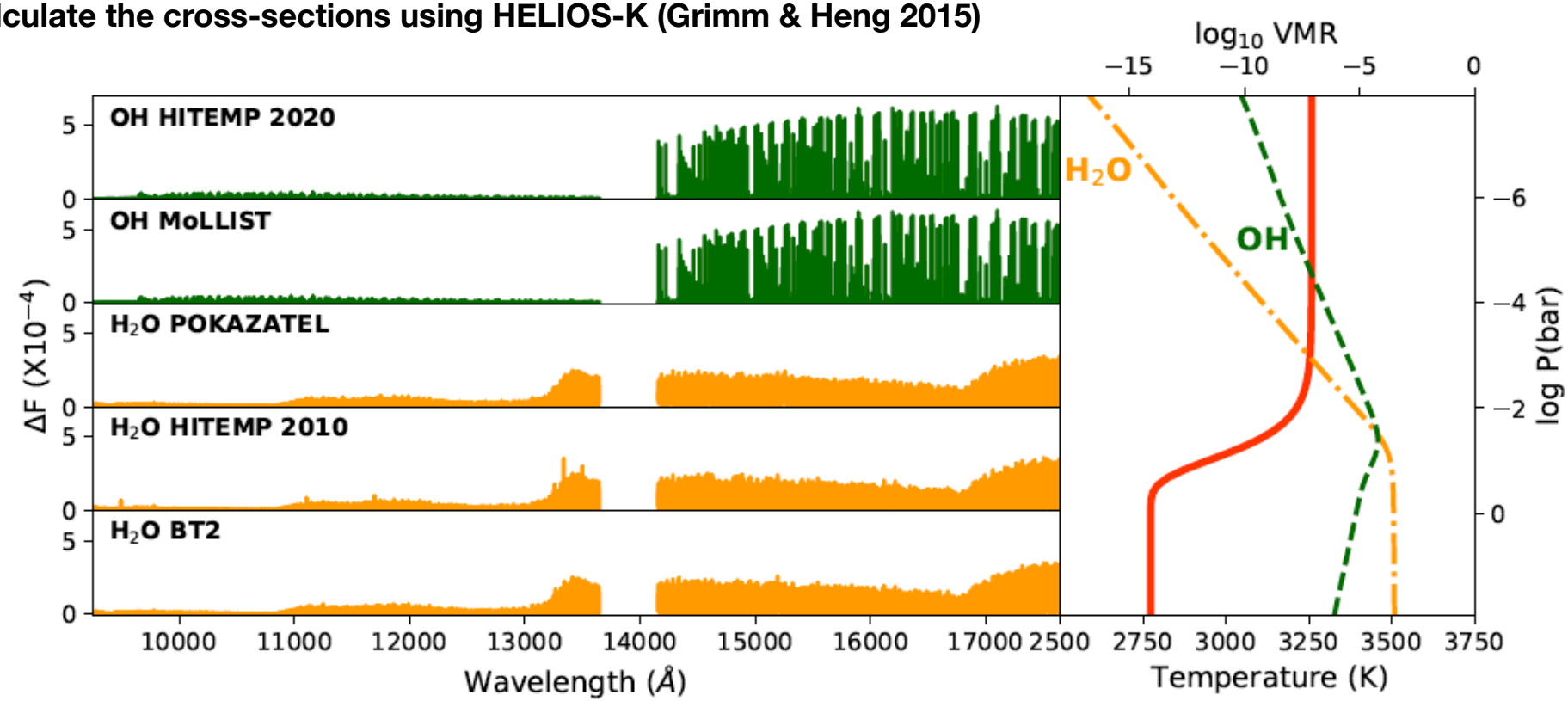


- Raw
- Normalised
- Mean-subtracted
- 3 SysRem
- Injected signal

Nugroho et al. 2021

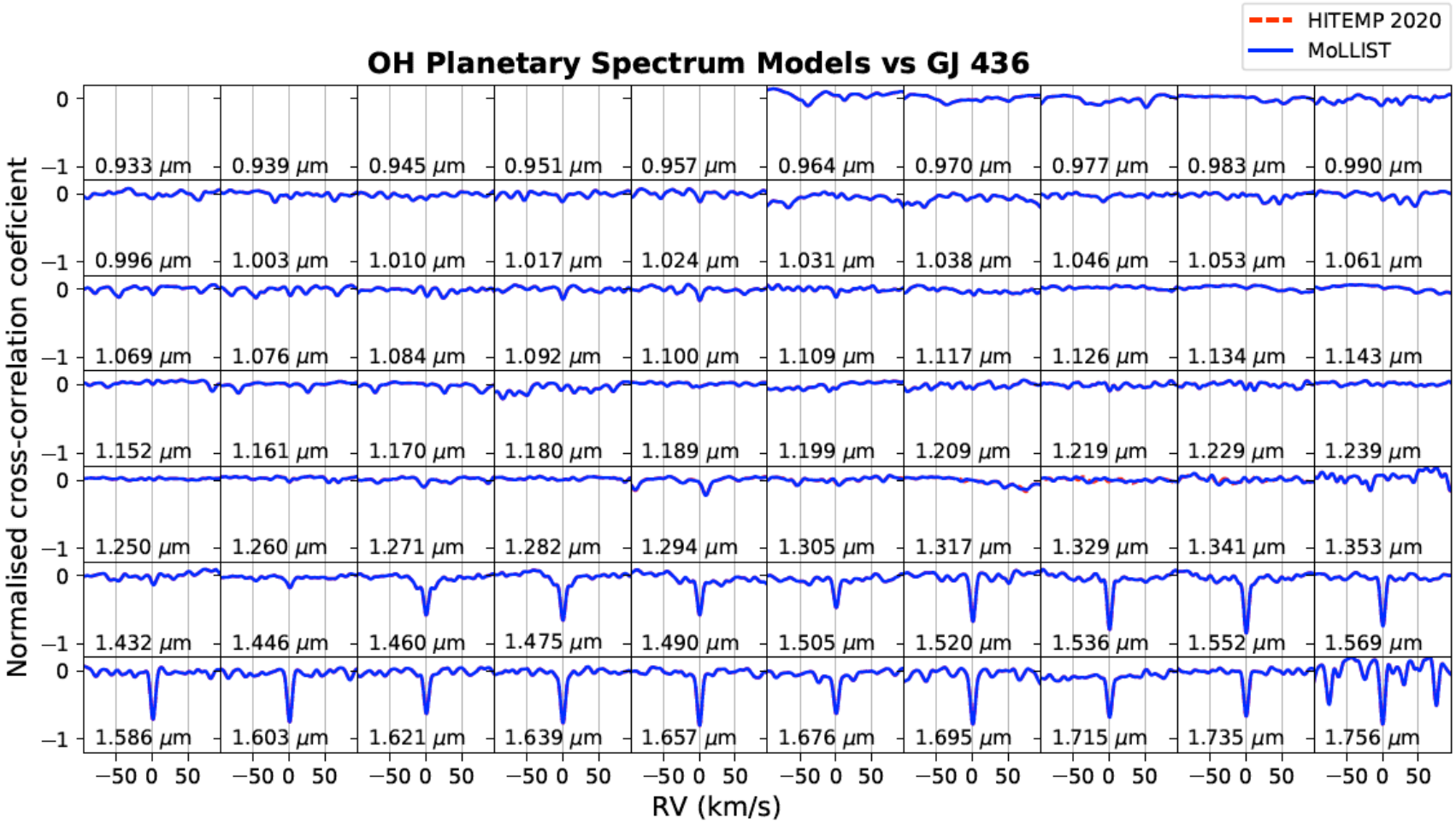
WASP-33b spectrum templates

Calculate the cross-sections using HELIOS-K (Grimm & Heng 2015)



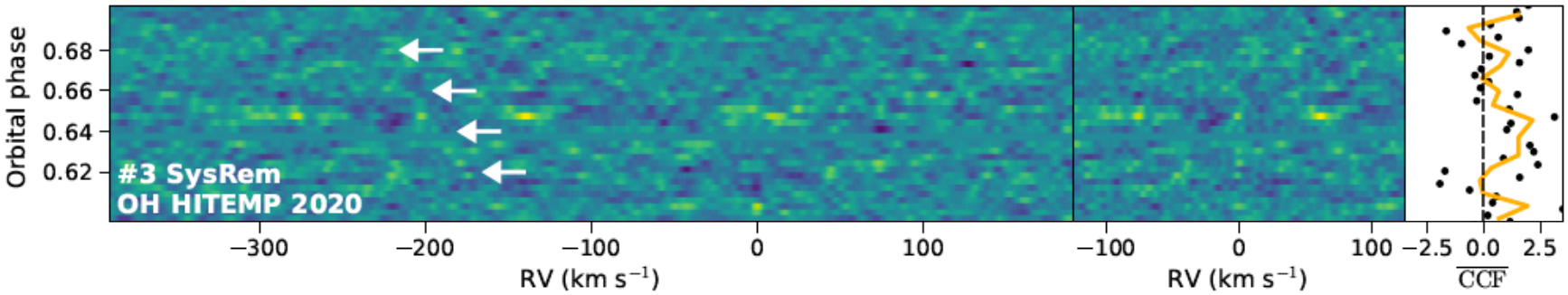
Nugroho et al. 2021

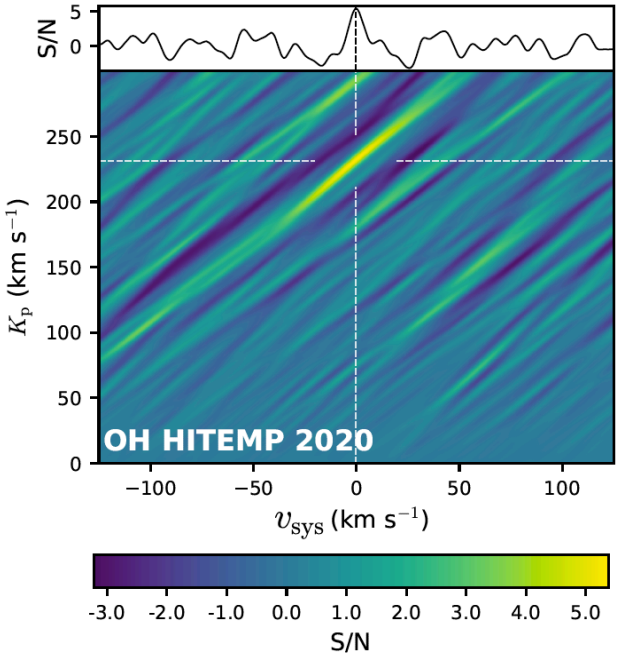
OH template vs M-dwarf spectrum

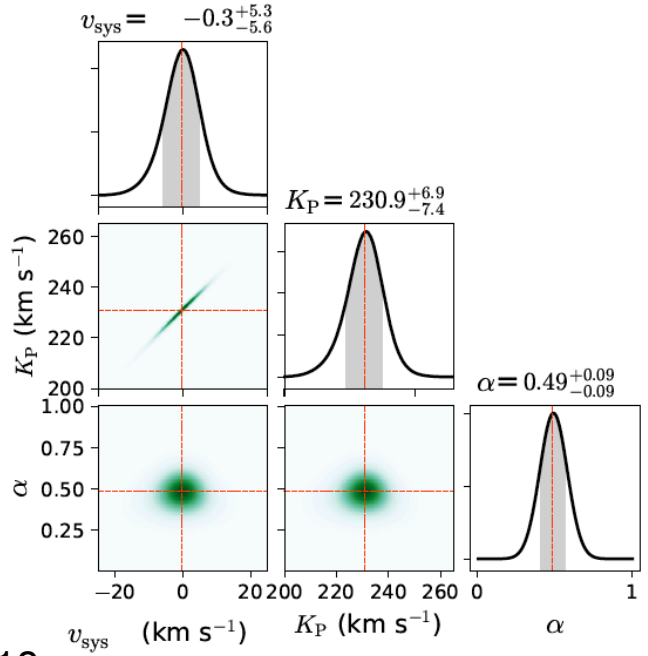


Nugroho et al. 2021

OH emission!

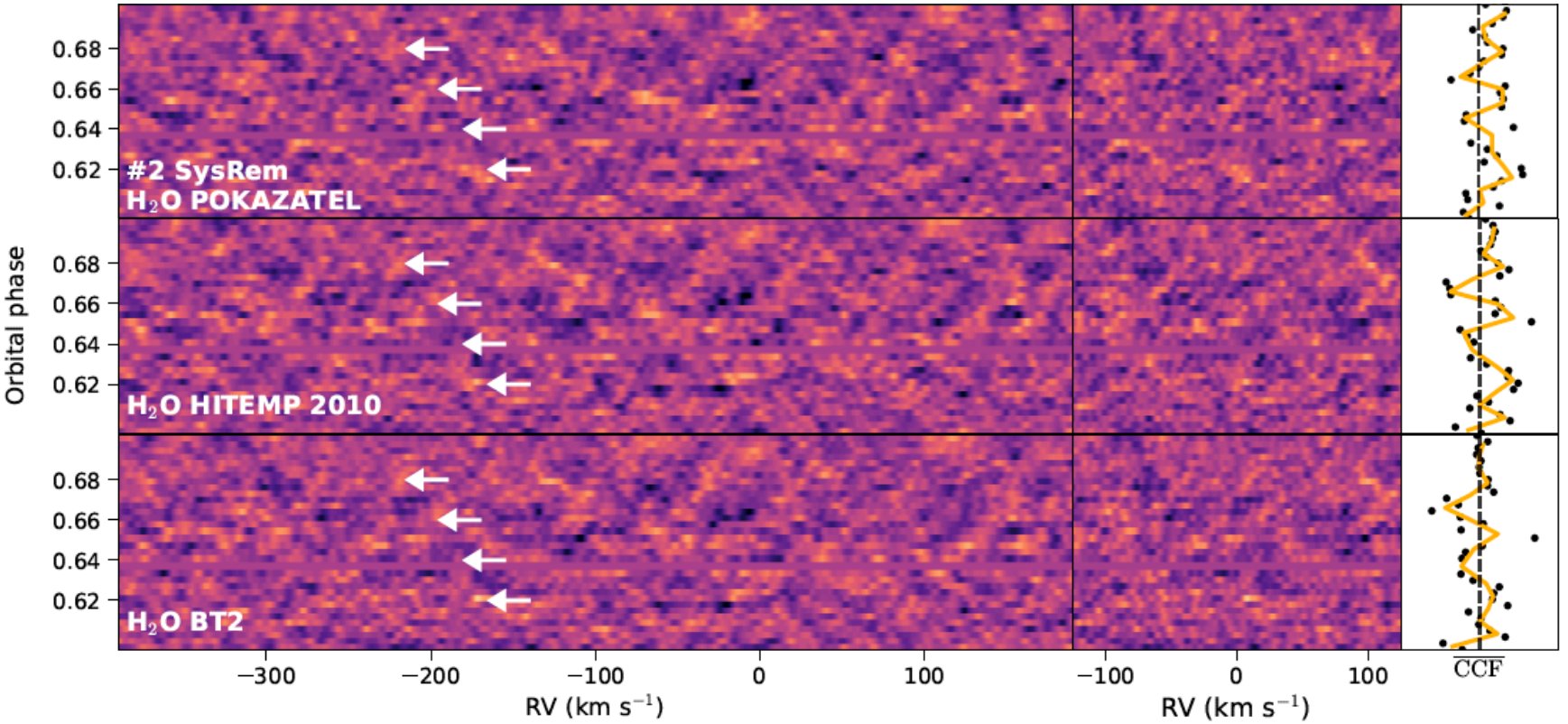






Nugroho et al. 2021

Possible H_2O emission?

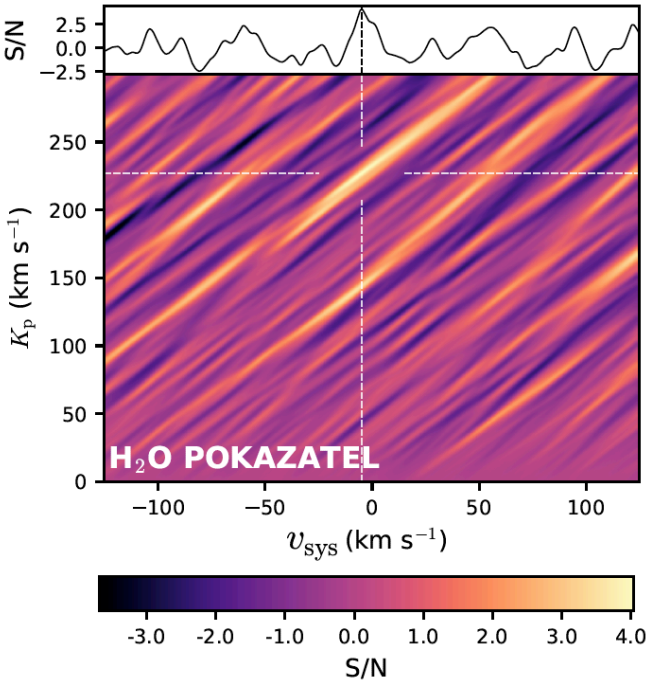


Nugroho et al. 2021

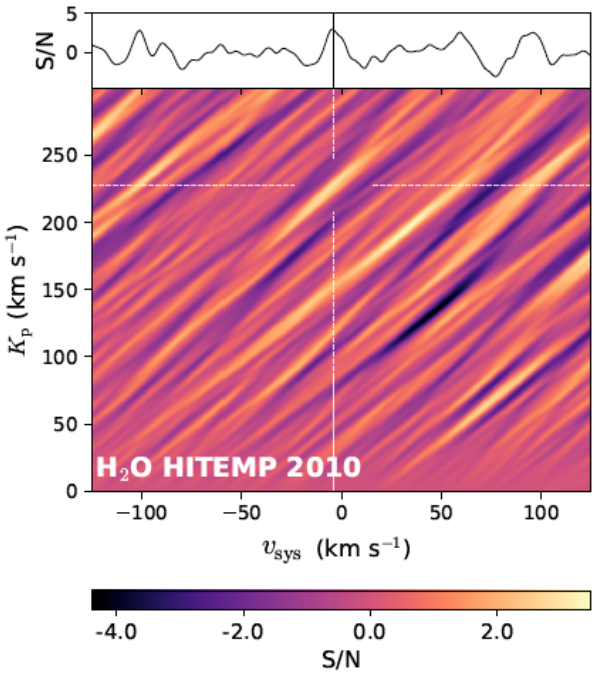
Line list dependency: completeness vs accuracy?

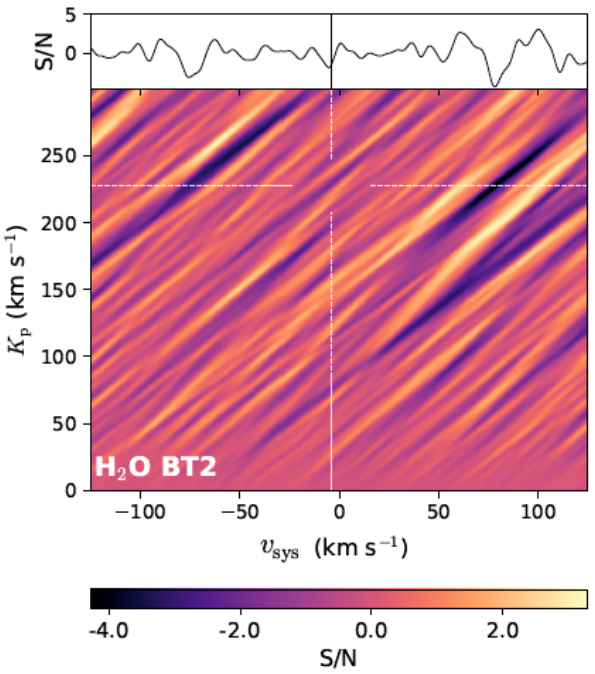
See also Webb et al 2020, Gandhi et al. 2020

More complete at high temperature



Strong lines are more accurate?





Nugroho et al. 2021

OH in the atmosphere of ~~ultra~~ hot Jupiter

HD 189733b

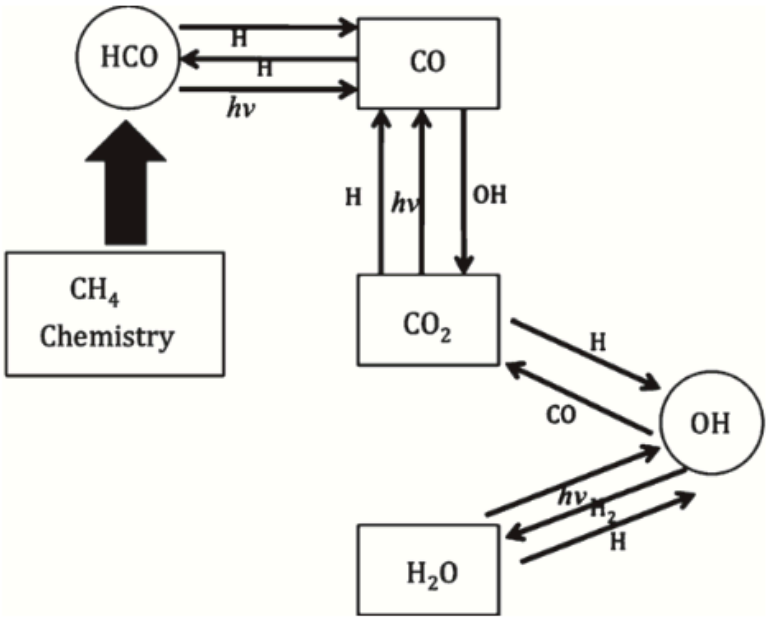
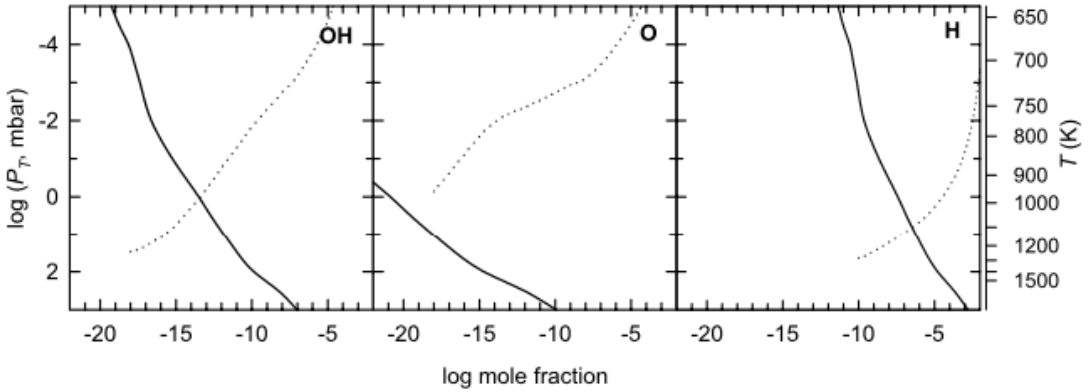


Figure 5. Photochemical web illustrating the important chemical pathways that govern the production and loss of the observable species. The boxes represent the observed species and the circles represent species yet to be observed but are key in the production and loss of the observed constituents.

Line et al. 2010

HD 209458b

Thermochemical (solid lines) vs photochemical (dotted lines)

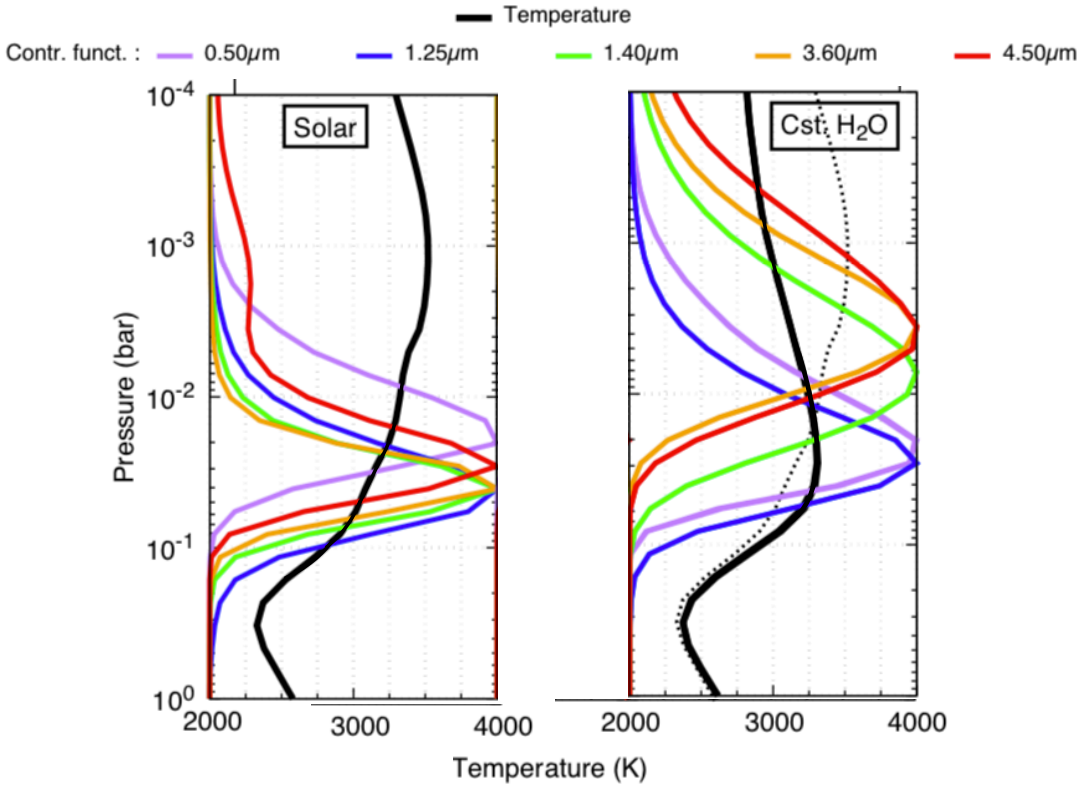


Visscher, Lodders & Fegley 2006

OH + weak H_2O: thermal dissociation

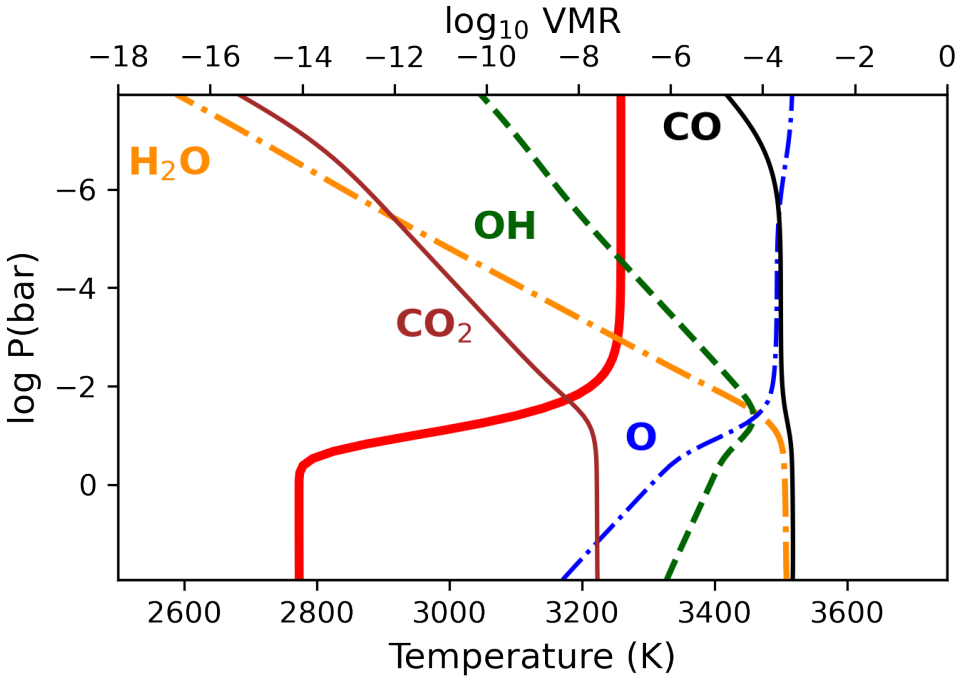
Thermal dissociation

Const. abundance



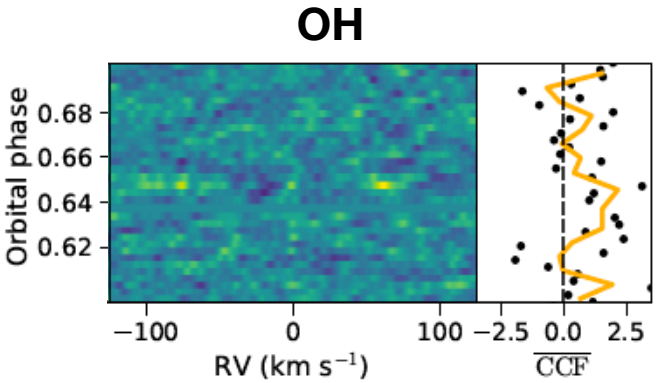
Parmentier et al. 2018

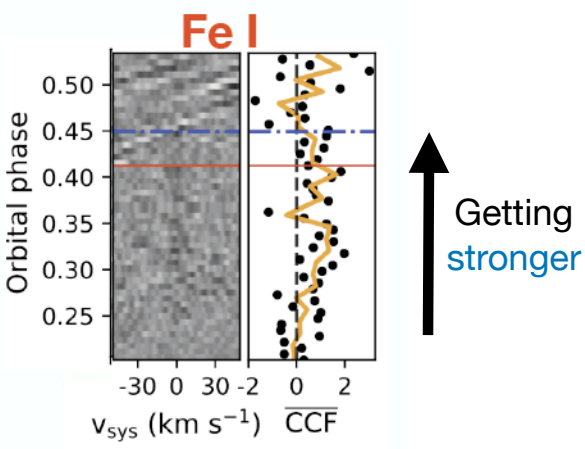
FastChem

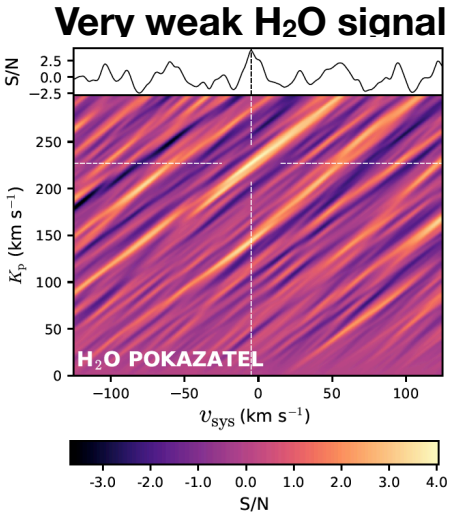


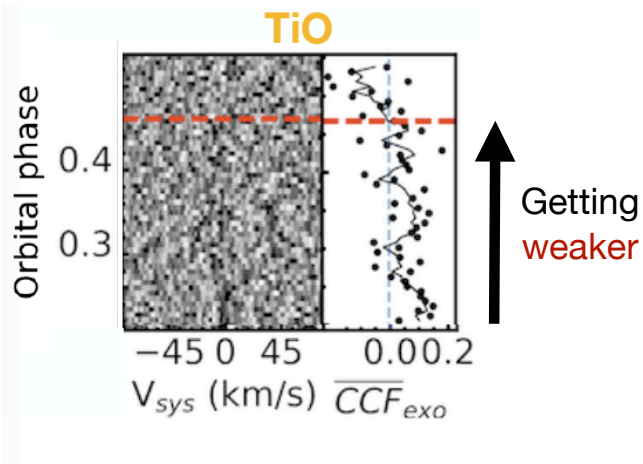
OH is one of the dominant O-bearing molecule in the ultra-hot Jupiter atmosphere

What we know so far…









- First OH detection in a planet outside the solar system
- H_2O is thermally dissociated-> OH
- OH is one of the dominant O-bearing molecules in the UHJ atmospheres
- TiO is detected in CARMENES data only by **excluding** the orb. phase of 0.37-0.60 (Cont et al. 2021)
- Possible observational evidence of a hot-spot on the day-side of WASP-33b