

# Spatial characterization of the trailing and leading limbs of WASP-76b: Detection of H<sub>2</sub>O and HCN at high-resolution.

Alejandro Sánchez-López

**Collaborators:** R. Landman, N. Casasayas-Barris, A. Kesseli, and I.A.G. Snellen

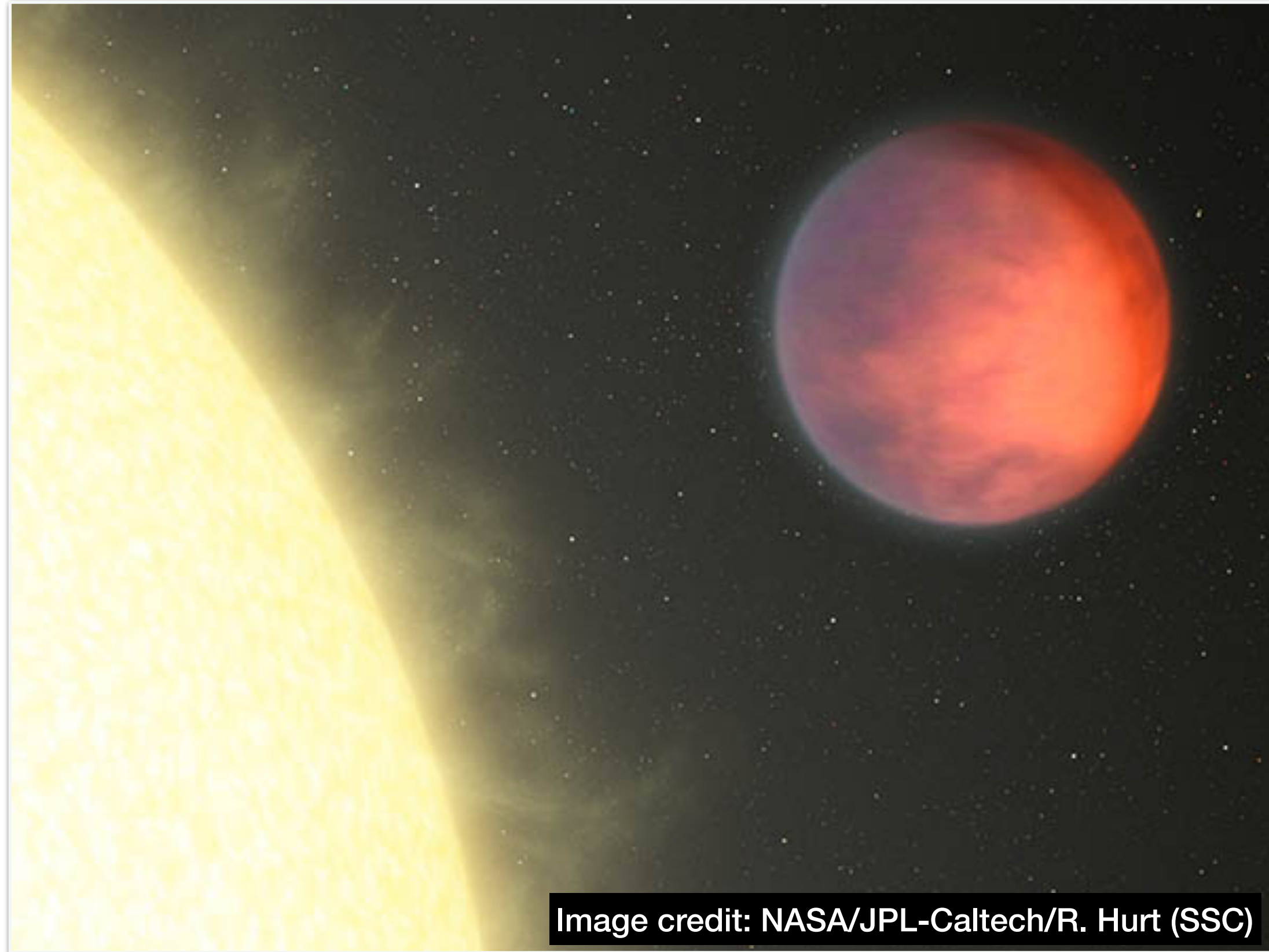


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ESO's Exoplanet Atmospheres Workshop 27/08/2021

Image credit: Christine Daniloff/MIT, Julien de Wit

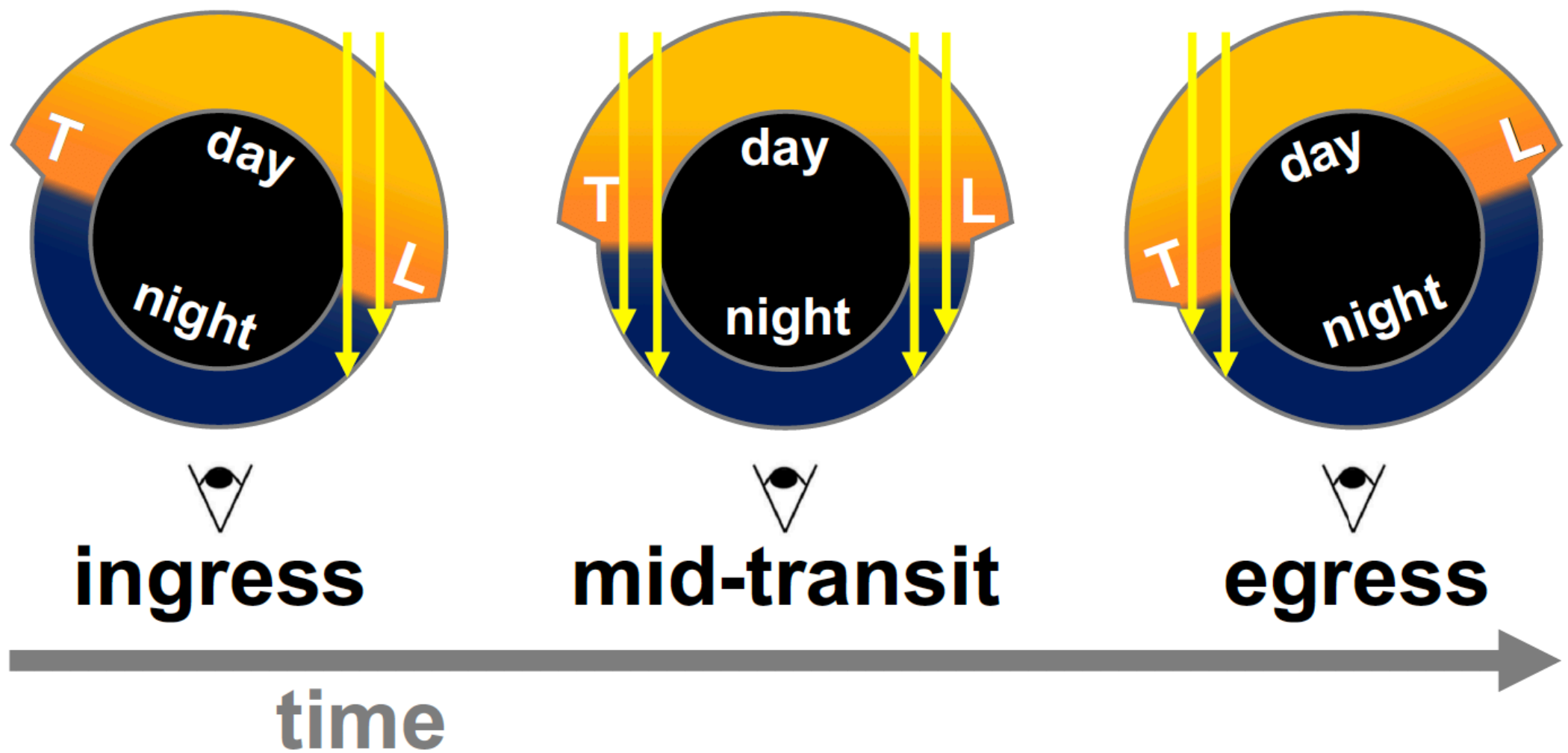
# Introduction



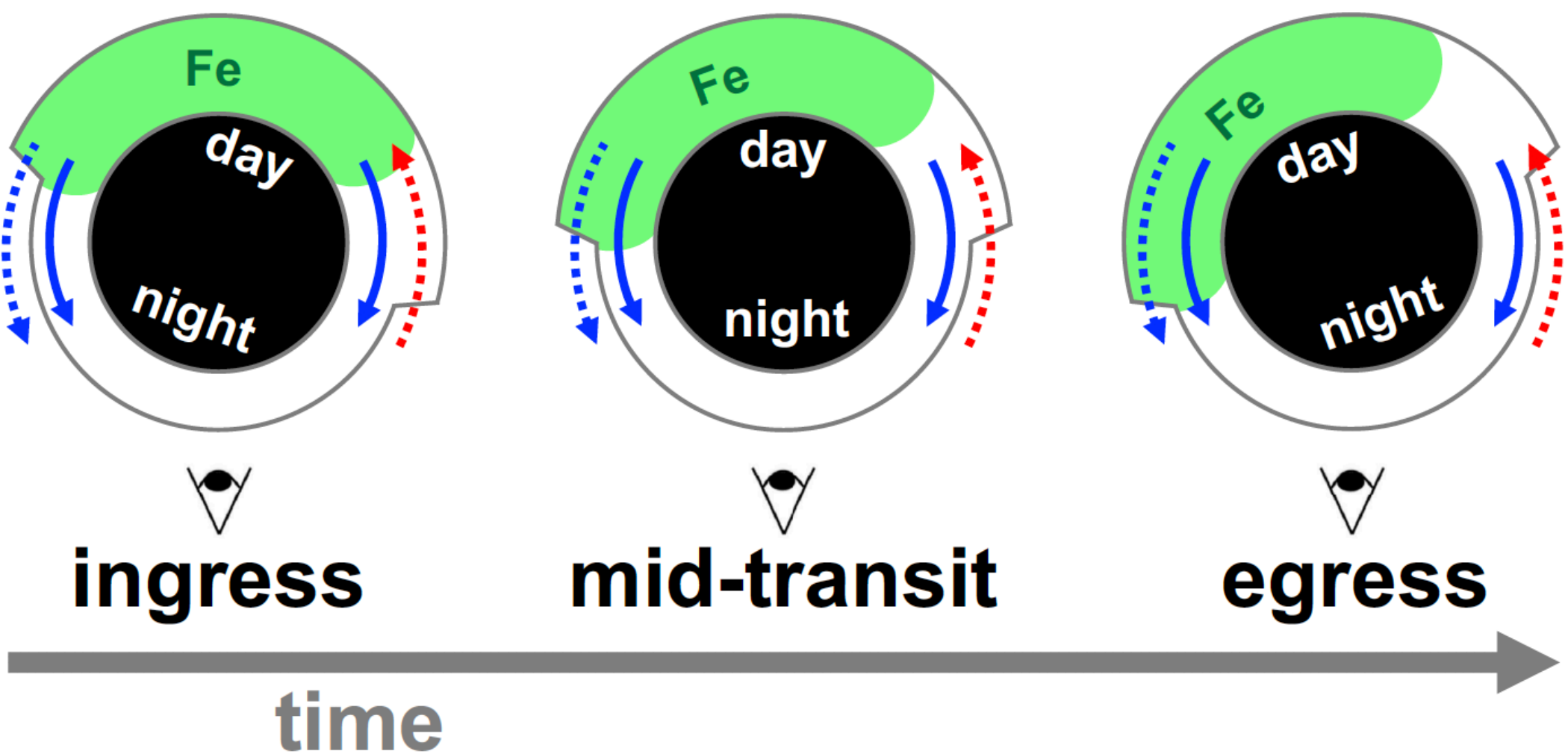
- **Ultra-hot Jupiters (even hotter...)**: Particularly exotic targets with dayside temperatures  $> 2000$  K (KELT-9 b, WASP-33 b, WASP-76 b, etc.).



# Introduction

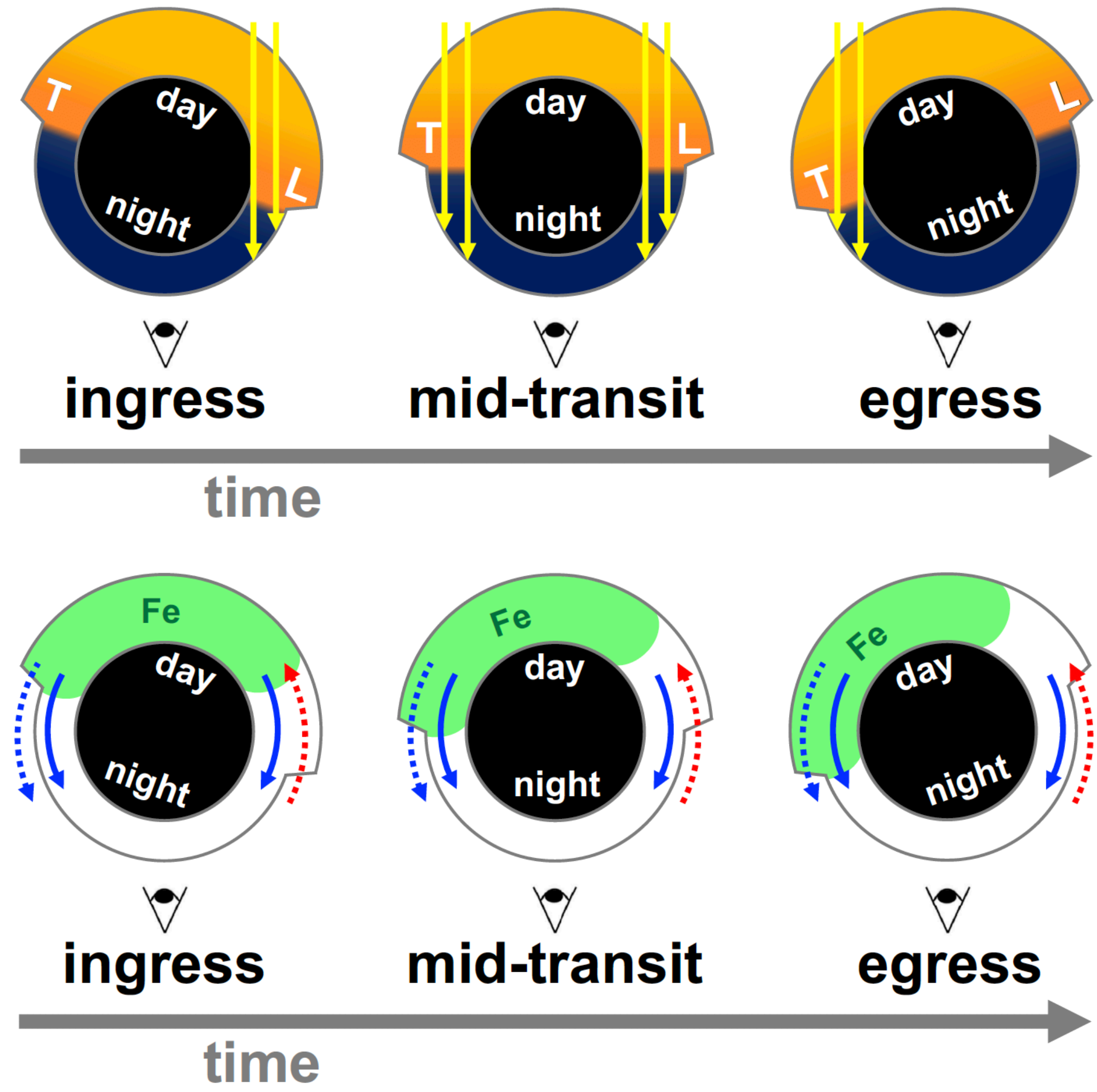


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- Close-in orbit causes large change in viewing angle of the planet from Earth (about  $30^\circ$  WASP-76 b).



Wardenier et al. (2021), MNRAS, Vol. 506, Issue 1

# Introduction

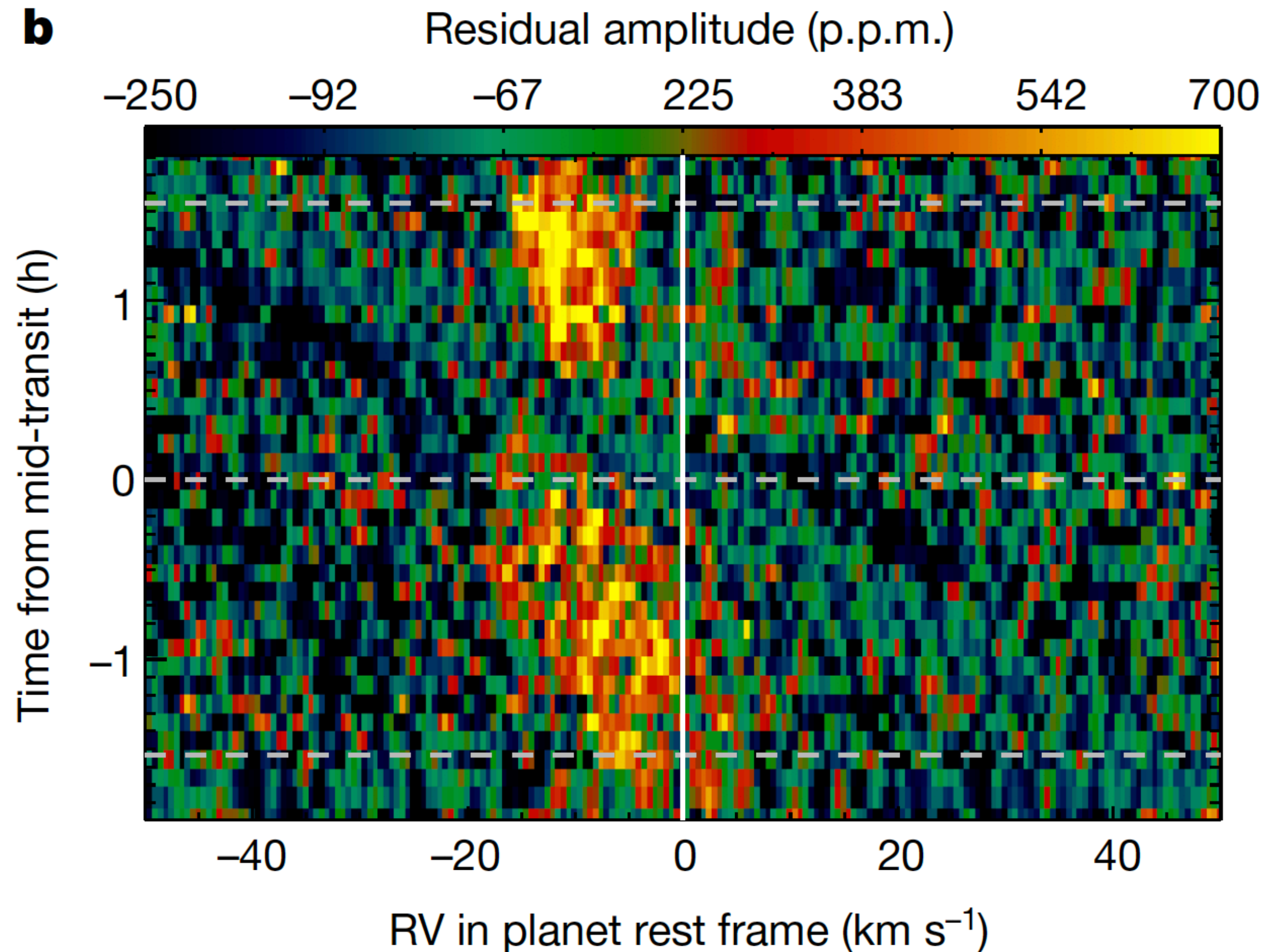


Wardenier et al. (2021), MNRAS, Vol. 506, Issue 1

- **Ultra-hot Jupiters (even hotter...):** Particularly exotic targets with dayside temperatures  $> 2000$  K (KELT-9 b, WASP-33 b, WASP-76 b, etc.).
- Close-in orbit causes large change in viewing angle of the planet from Earth (about  $30^\circ$  WASP-76 b).
- Atmospheric regions probed through the leading and trailing limbs are significantly different. Shown studying Fe I in Ehrenreich et al. (2020) (confirmed in Kesseli & Snellen, 2021).



# Introduction



*Ehrenreich et al. (2020), Nature, Vol. 580, 597*

- Signal is progressively blueshifted as evening terminator comes into view.
- In 2nd half, the morning terminator region has rotated out of view and zero velocity component disappears, pointing at condensation in nightside.
- But, **condensation might not be required**: uniform iron abundances and a large temperature contrast between limbs can also cause asymmetry (*Wardenier et al. 2021, see Joost's talk!*).

# Main scientific question

- ▶ Could this same behaviour be observed in molecular absorption signals?

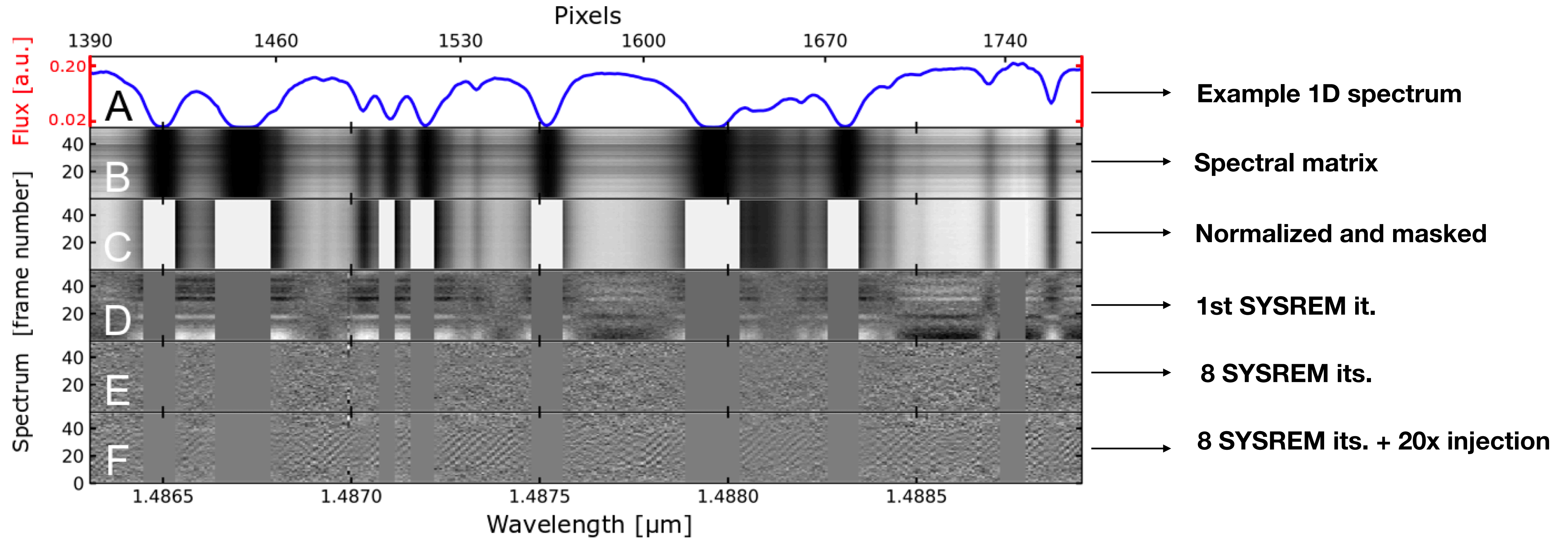


# Main scientific question

- ▶ Could this same behaviour be observed in molecular absorption signals?
- ▶ Molecules such as H<sub>2</sub>O are not expected to rain out in the nightside —> Potential asymmetries due to very different day and nightside scale heights?

# Observations and analysis

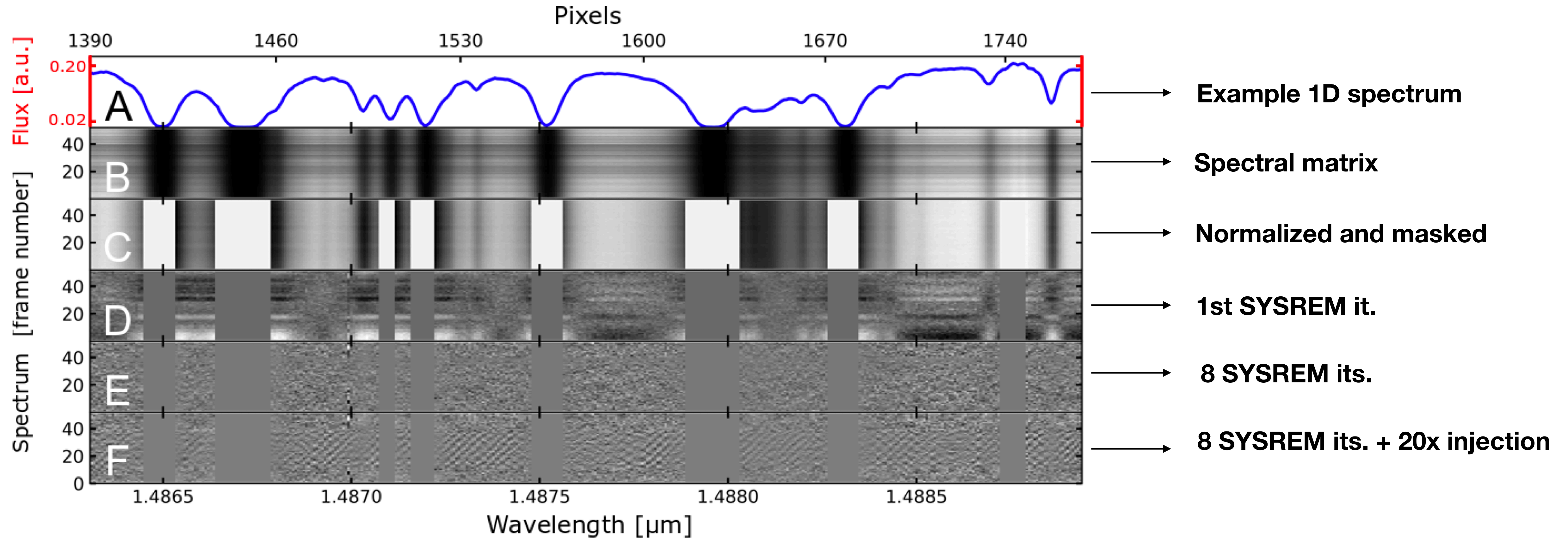
Public near-infrared **high-resolution spectra** ( $R \sim 80,400$ ) of WASP-76b observed with **CARMENES** on 4th October, 2019.





# Observations and analysis

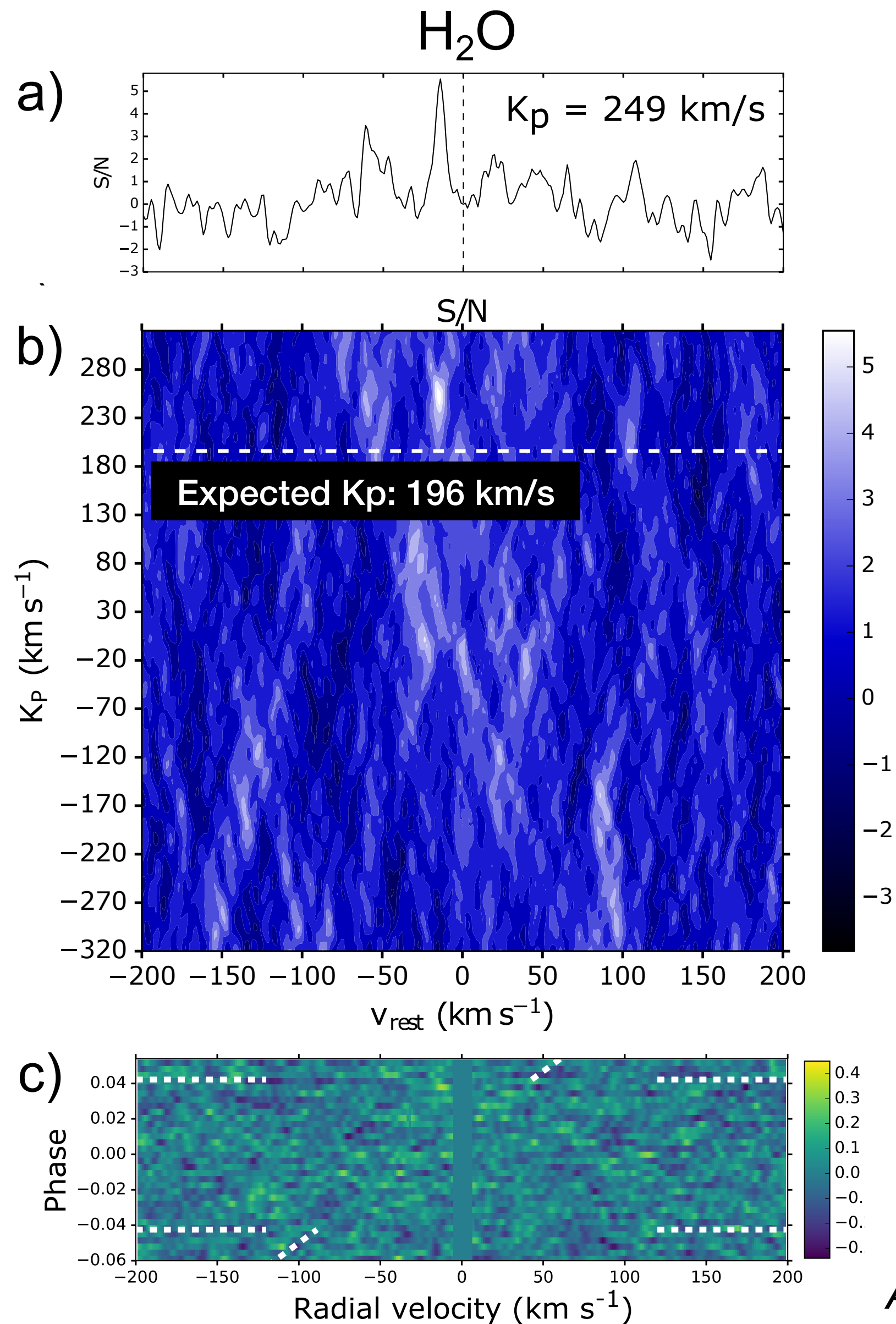
Public near-infrared **high-resolution spectra** ( $R \sim 80,400$ ) of WASP-76b observed with **CARMENES** on 4th October, 2019.



**Cross-correlation** of residual spectra with absorption templates of H<sub>2</sub>O, HCN, NH<sub>3</sub>, CO, CO<sub>2</sub>

# Results: Detection of H<sub>2</sub>O and HCN

*on going work!*



▶ **H<sub>2</sub>O detection at a SNR ~ 5.5** (already detected at low-res, see Tsiaras et al. 2018; and Edwards et al. 2020).

▶ **Blueshifted by -12 km/s** (day to nightside winds). Potentially from evening terminator?

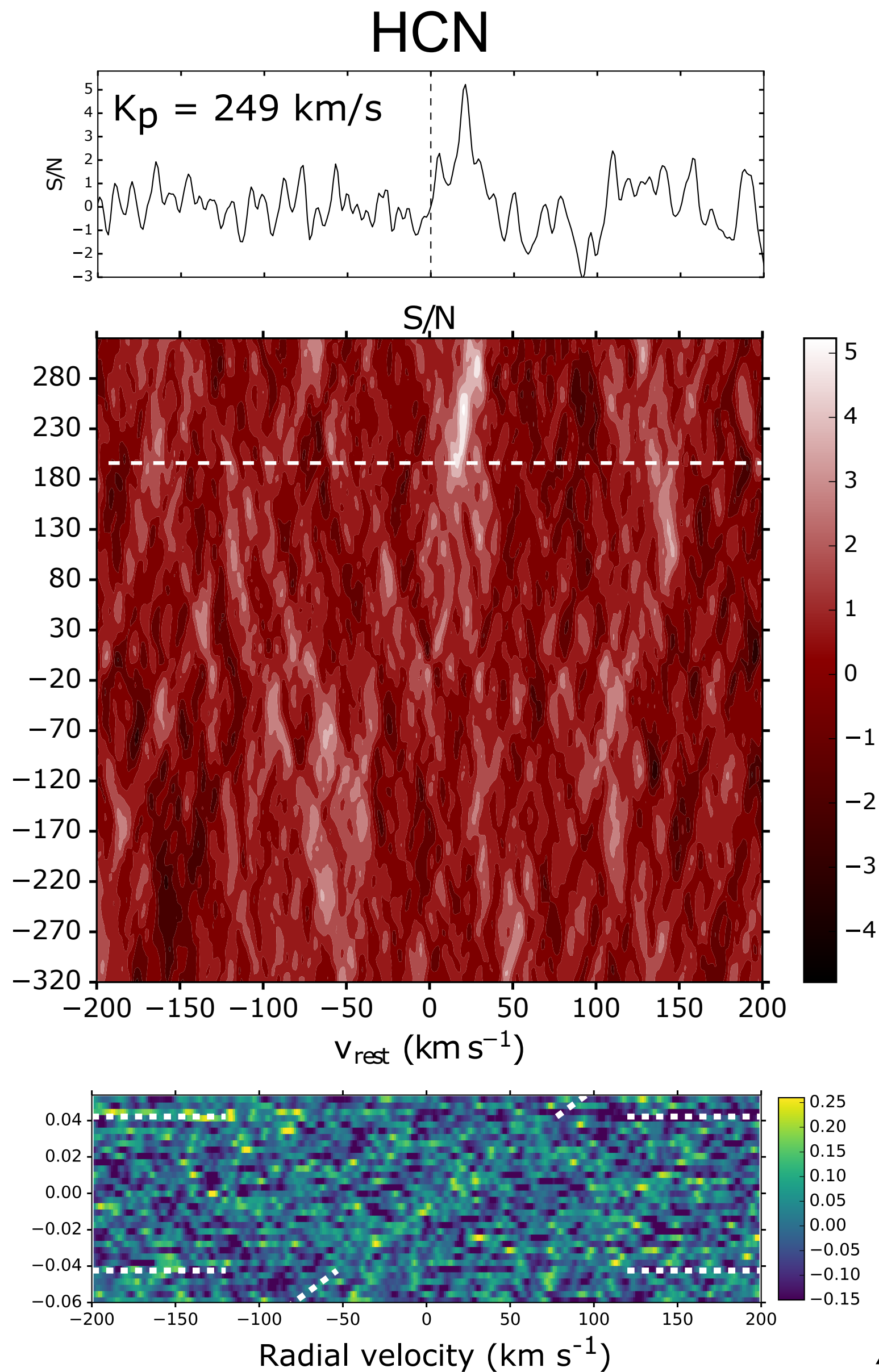
▶ **K<sub>p</sub> displaced. Max. significance ~249 km/s. Expected ~196 km/s.** No clear explanation for mismatch.

*A. Sánchez-López et al. in prep.*



# Results: Detection of H<sub>2</sub>O and HCN

*on going work!*



▶ HCN detection at a SNR  $\sim 5.2$ .

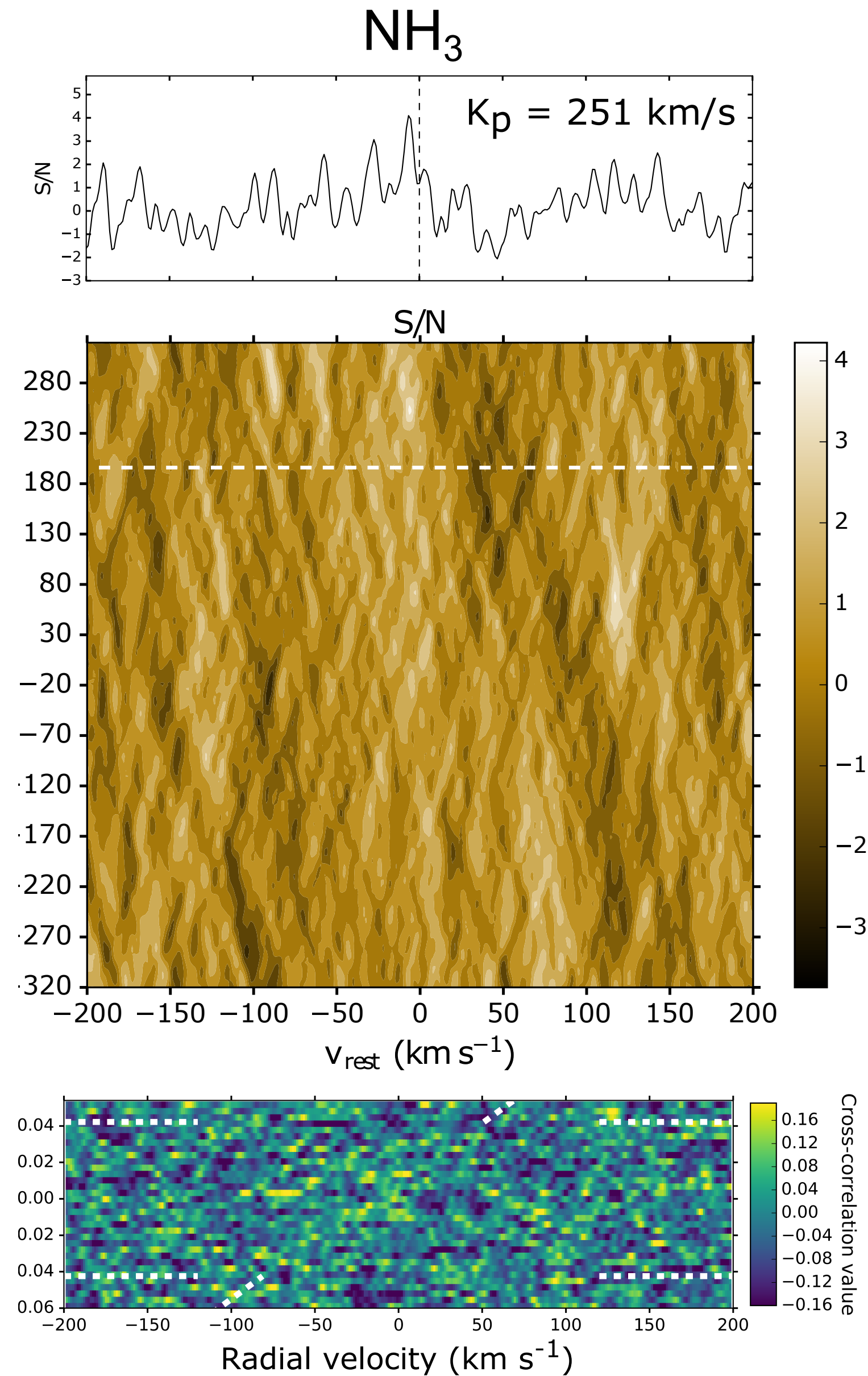
▶ Signal is redshifted by about +20km/s. Atmospheric layers moving away from the observer, although uncertainties are large.

▶  $K_p$  of maximum significance signal also displaced!

*A. Sánchez-López et al. in prep.*

# Results: Formal detection of H<sub>2</sub>O and HCN

*on going work!*



▶ NH<sub>3</sub> tentative signal at SNR of 4.2.

▶ Blueshifted by  $\sim -6$  km/s.

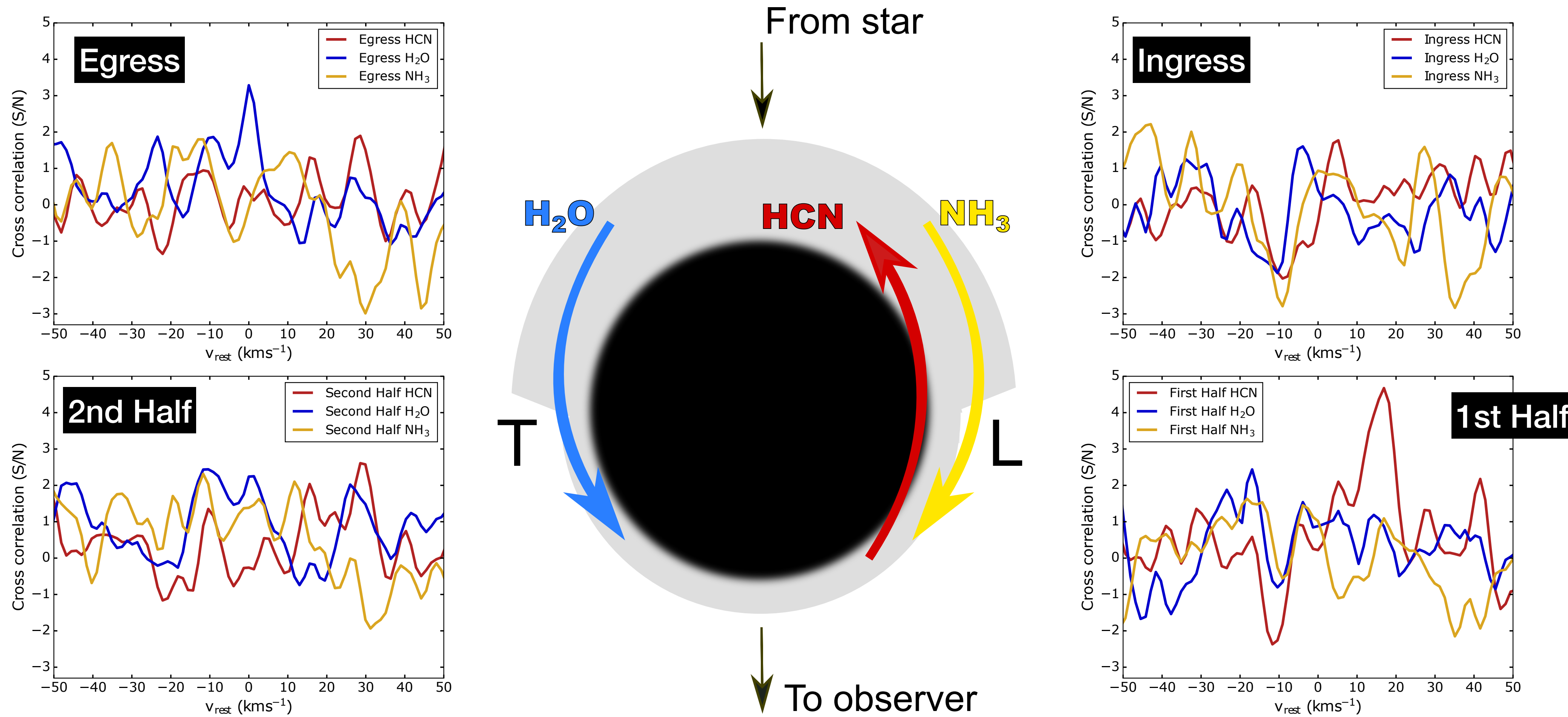
▶  $K_p$  of maximum significance signal also displaced... but signal is too weak to confirm.

A. Sánchez-López et al. in prep.



# Results: Time-dependence of signals. Expected $K_p$ (196 km/s)

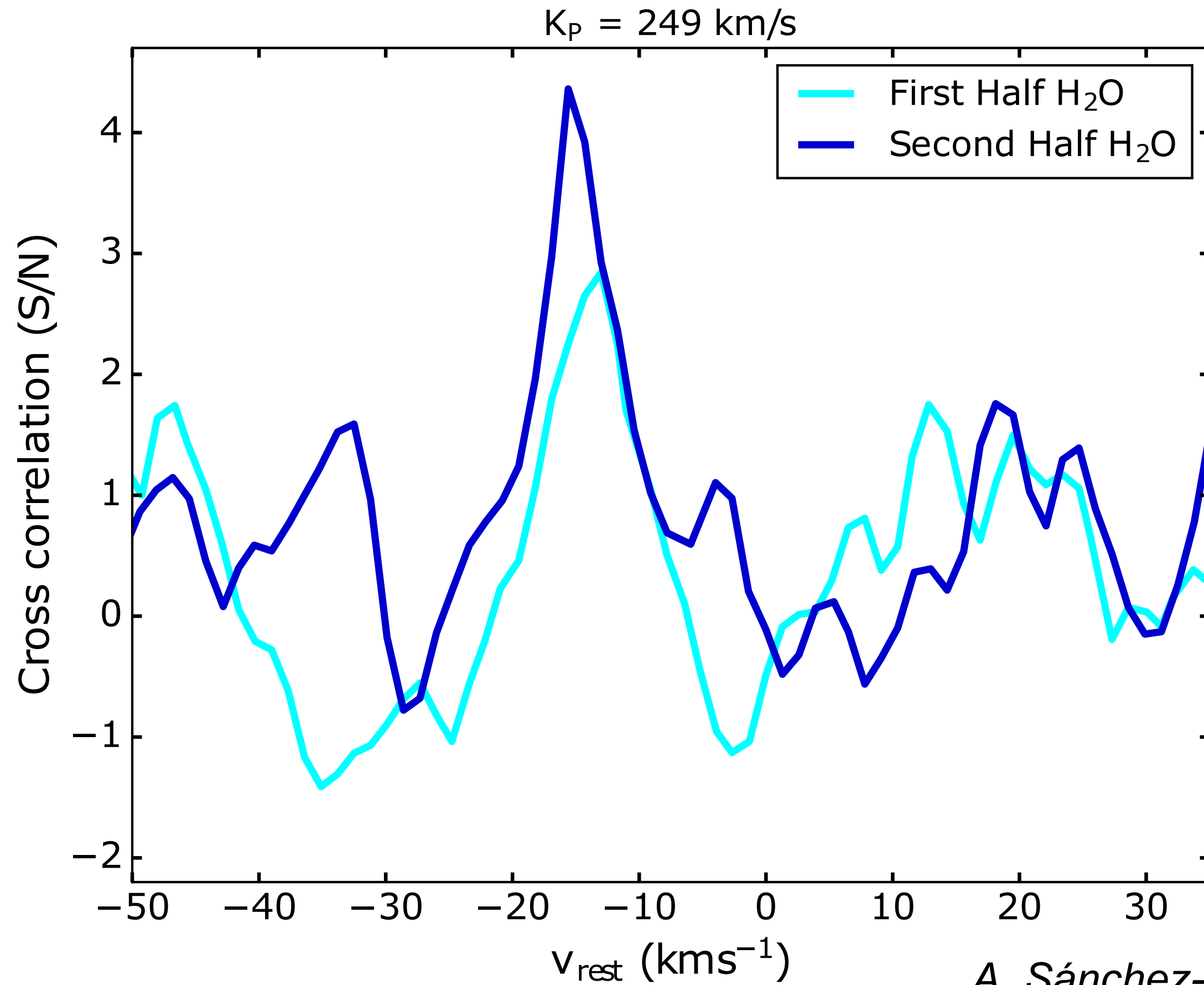
*on going work!*



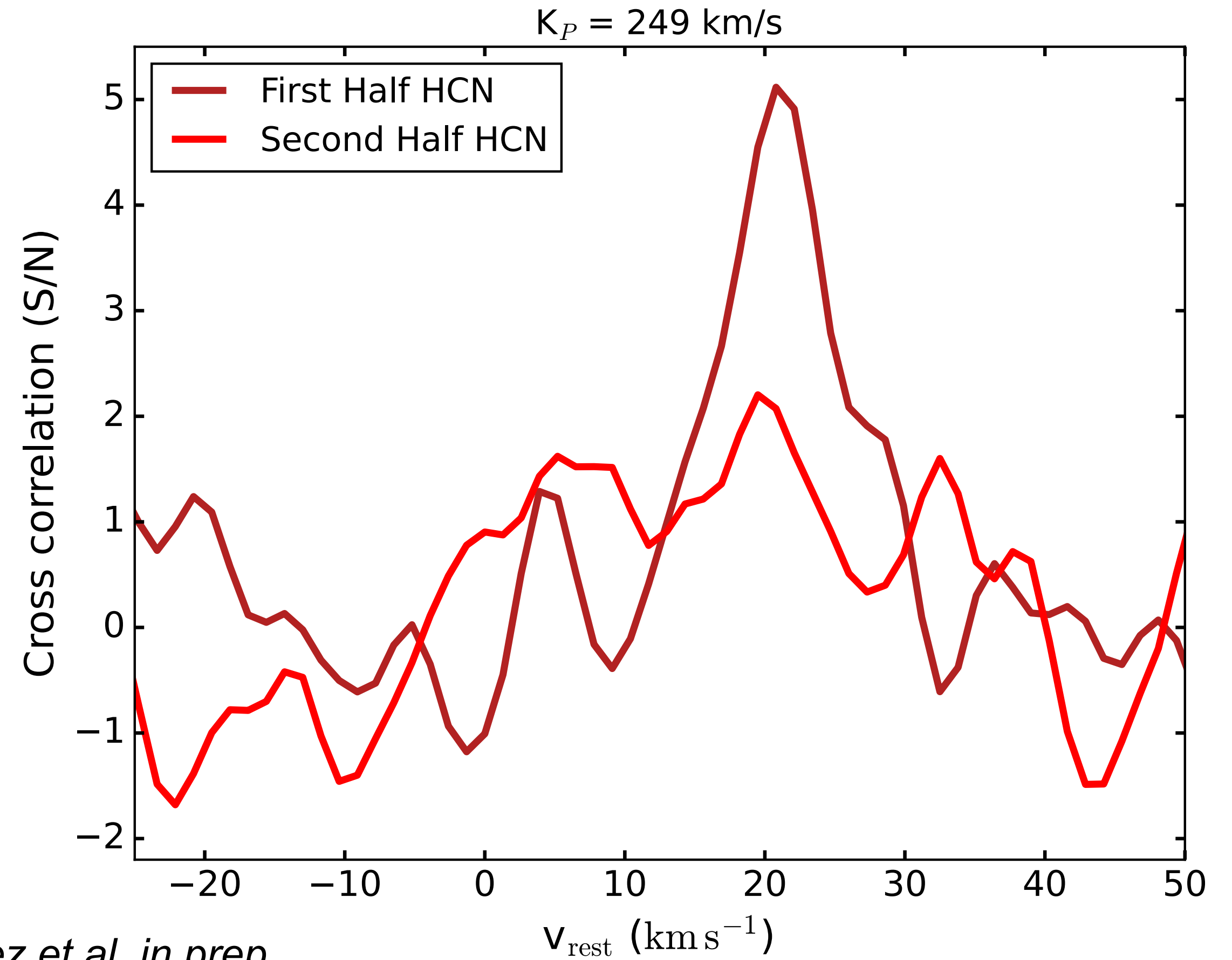
*A. Sánchez-López et al. in prep.*

# Results: Time-dependence of signals. Max. Significance $K_p$

*on going work!*



*A. Sánchez-López et al. in prep.*



**Marginally stronger in 2nd half,  
but low observational evidence.**

**Contribution mainly  
from 1st half.**



# Summary and conclusions

- Formal detection of H<sub>2</sub>O and HCN in the transmission spectra of WASP-76b. Tentative signal of NH<sub>3</sub>.
- Puzzling Doppler shifts and K<sub>p</sub> values.
  - ▶ No clear explanation for K<sub>p</sub> ~ 250 km/s (expected 196 km/s).
  - ▶ H<sub>2</sub>O blueshifted by -12 km/s. Mainly from evening terminator? (Low observational evidence).
  - ▶ HCN signal at +20 km/s. Disappears in 2nd half of the transit. Coming from the morning terminator?
- **New observations and better SNRs needed to refute or confirm the results!!**



**Thank you!!**