Characterising the atmosphere of ultra hot Jupiters: MASCARA-2b

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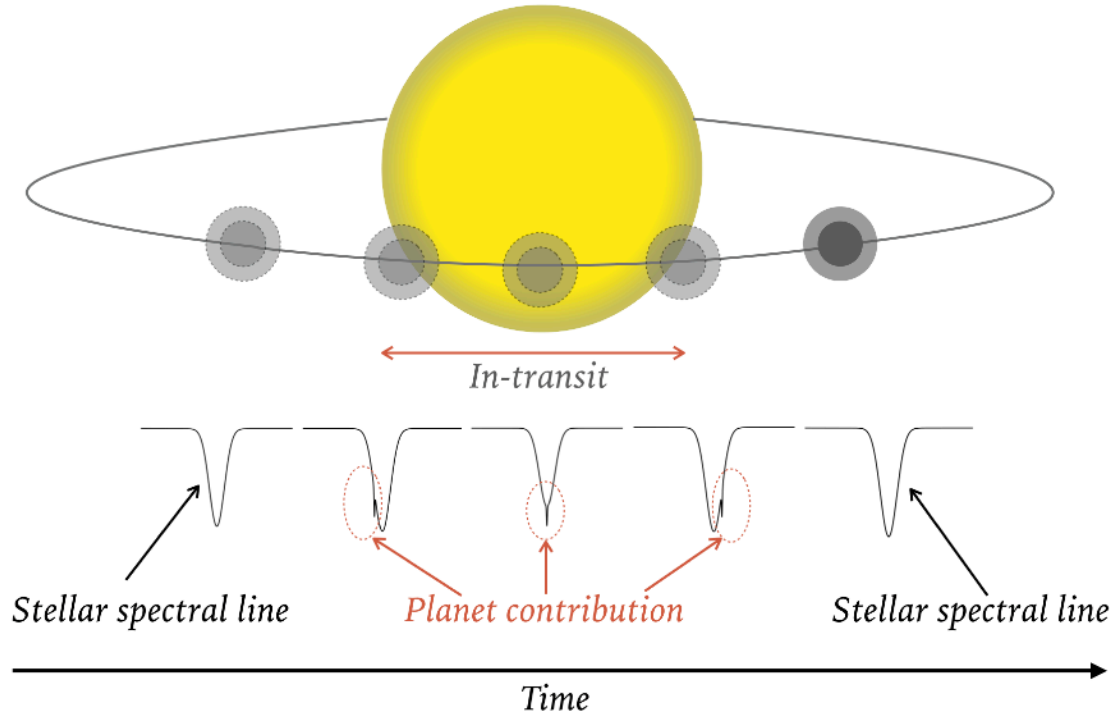
Results published in A&A: Casasayas-Barris et al. (2019)

Ultra hot Jupiters orbit very close to their host star and consequently receive strong irradiation that makes their atmospheric chemistry different from the common gas giants. We study the atmosphere of one of these particular hot planets, MASCARA-2b / KELT- 20b, using four transit observations with high resolution spectroscopy facilities. Three of these observations were performed with HARPS-N and one with CARMENES. At high resolution, the transmission residuals show the effects of Rossiter-McLaughlin (RM) and center- to-limb variations (CLV) from the stellar lines profiles, which we correct to finally extract the transmission spectra of the planet. We clearly observe the absorption features of CaII, FeII, NaI, Hα and Hβ in the atmosphere of MASCARA-2b, and indications of Hγ. The results are consistent with theoretical models of ultra hot Jupiters atmospheres, suggesting the emergence of an ionised gas on the day-side of such planets. Calcium and iron, together with other elements, are expected to be singly ionised at these temperatures and be more numerous than its neutral state.

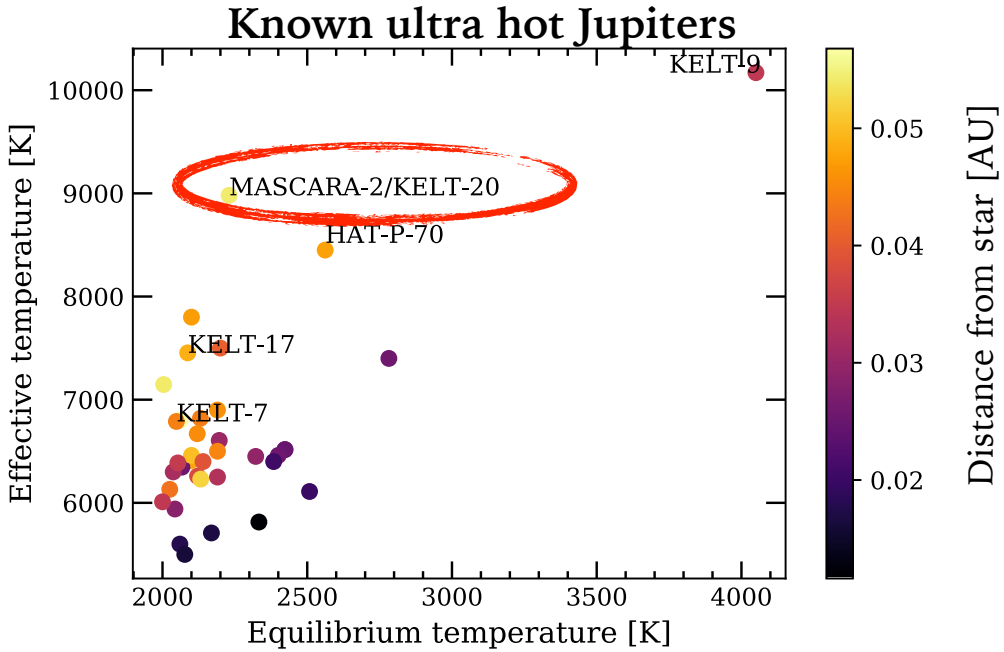
Context: high resolution transmission spectroscopy & ultra hot Jupiters

Transmission spectroscopy: when the planet crosses the stellar disc from our line-of-sight (transit), part of the stellar light goes through the exoplanet atmosphere, and its signatures appear imprinted in the stellar flux. These features form the **transmission spectrum**.

At **high resolution spectroscopy** (R>60 000) individual atmospheric features can be resolved, which are shifted due to the radial velocity variation that exoplanet experiences during the transit with respect the observer.



Ultra hot Jupiters are extreme exoplanets with relatively short periods, located very close to their stellar hosts, and have Teq >2000K. As they are tidally locked, the temperatures at their permanent day-side are even higher, and strong winds are expected between the two sides.



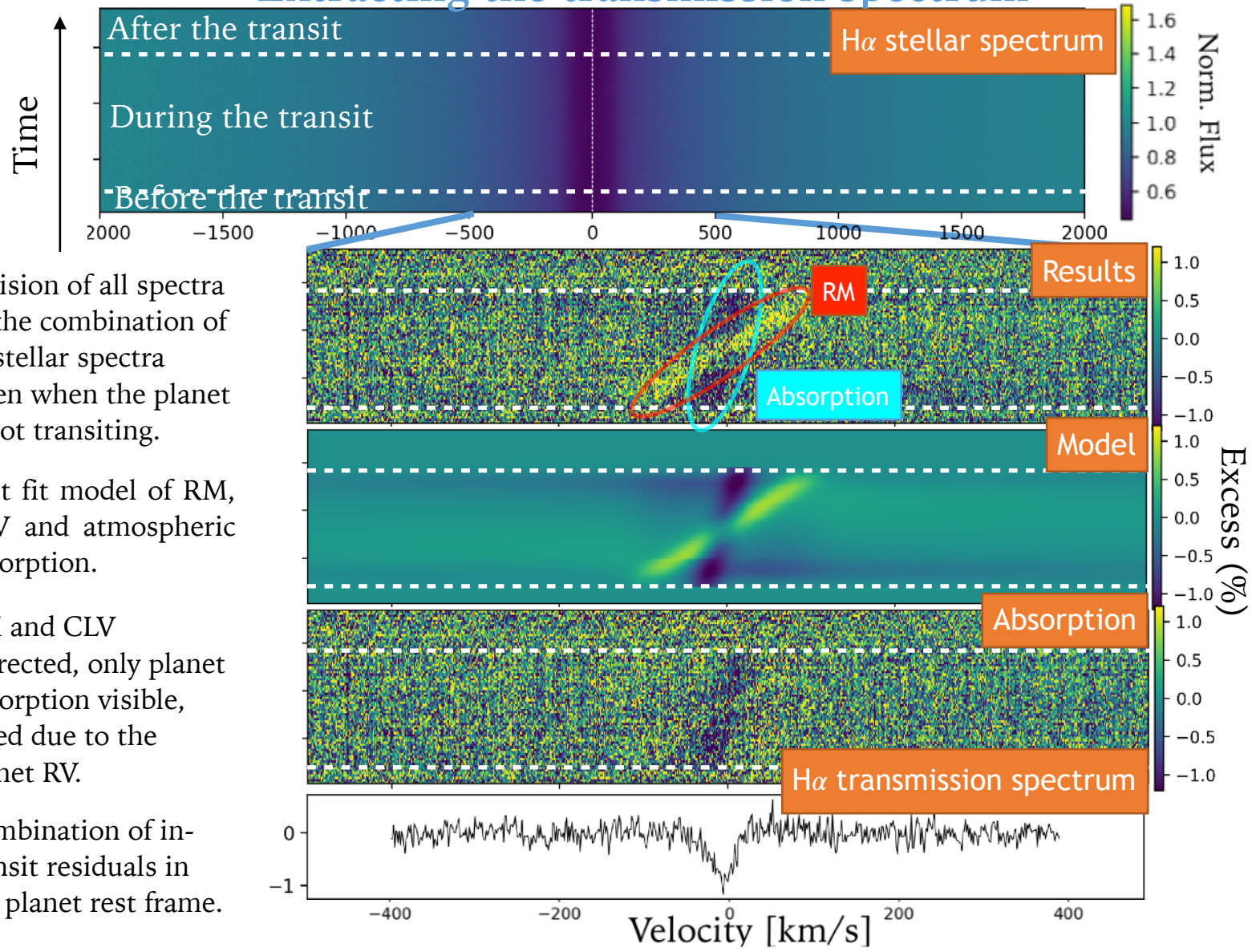
Observations & data reduction: extracting the exoplanet transmission spectrum

Observations

Continuous exposures before, during and after the exoplanet transit

3 transits with HARPS-N
1 transit with CARMENES

Extracting the transmission spectrum



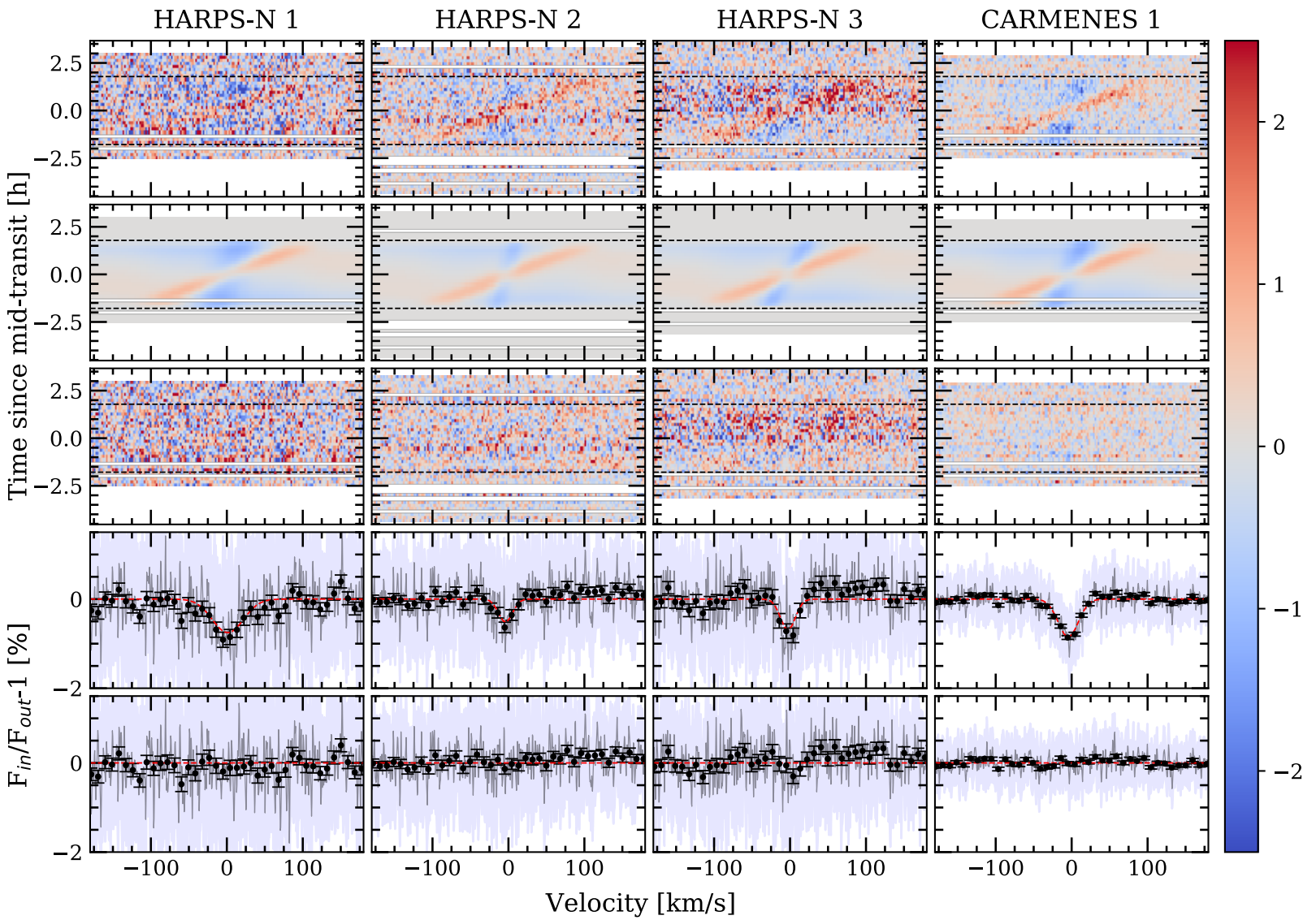
Division of all spectra by the combination of all stellar spectra taken when the planet is not transiting.

Best fit model of RM, CLV and atmospheric absorption.

RM and CLV corrected, only planet absorption visible, tilted due to the planet RV.

Combination of in-transit residuals in the planet rest frame.

Results: 2D maps around Hα



Individual results around Hα

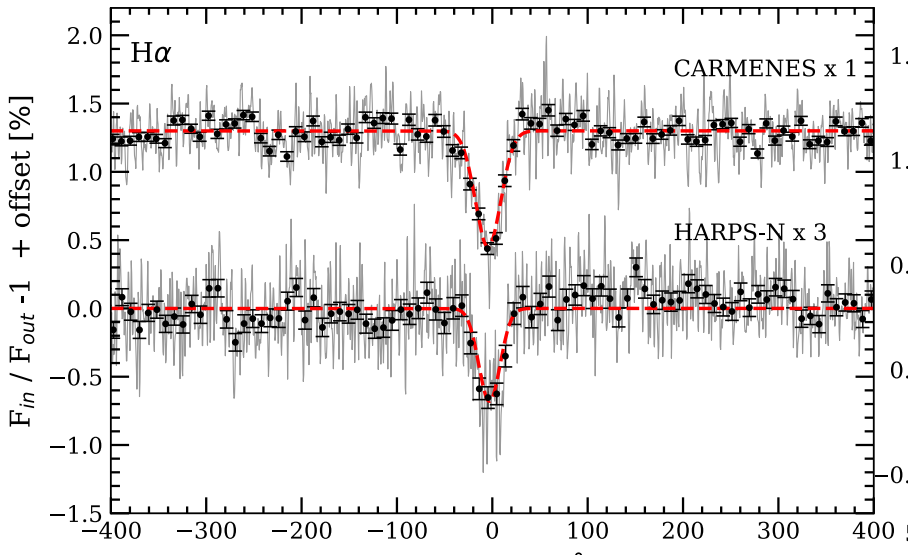
Best fit model containing CLV, RM and Hα absorption

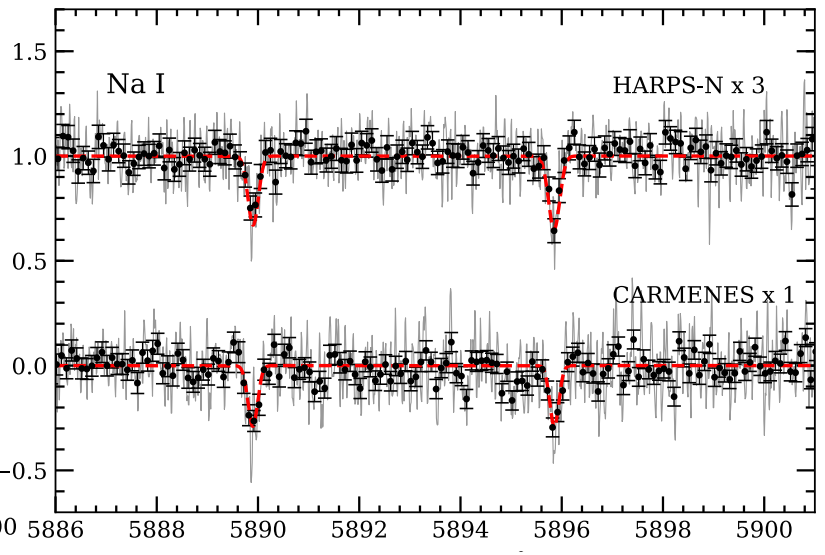
Residuals: observations - model

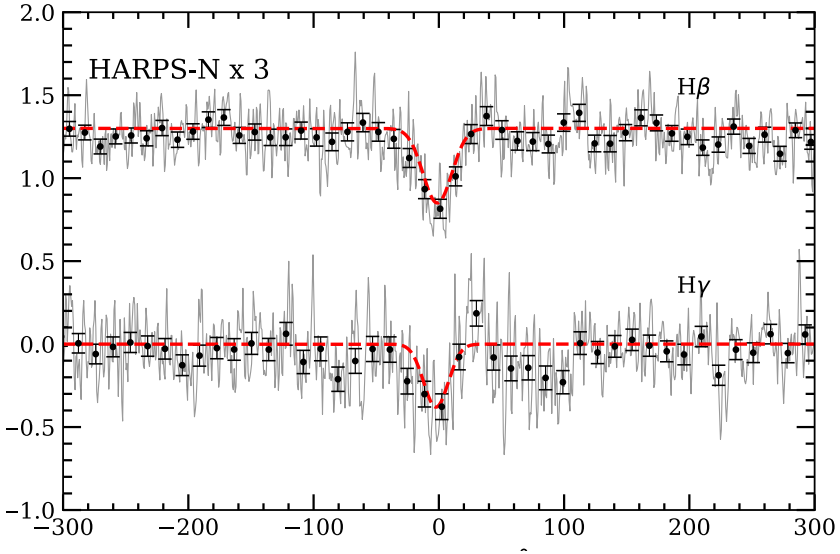
Transmission spectrum

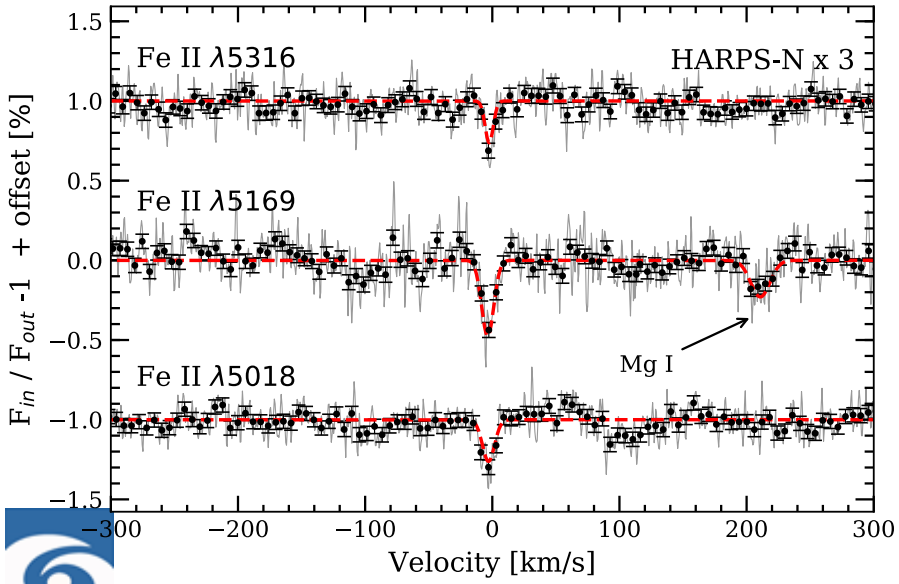
The Hα absorption corresponds to ~ 1.2 *Rp*, which implies an expanded atmosphere, as a result of the gas heating caused by the irradiation received from the host star.

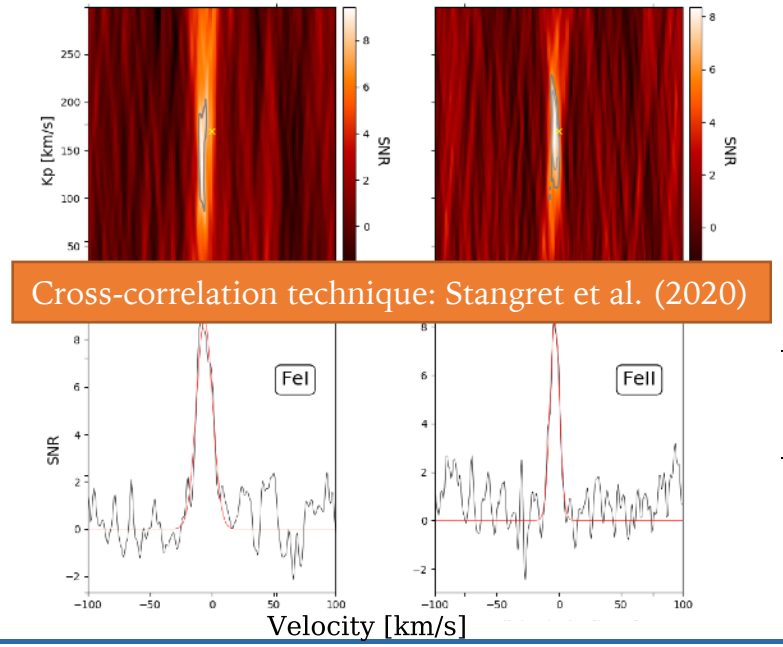
Results: Detection of Balmer lines, NaI, CaII, FeI and FeII



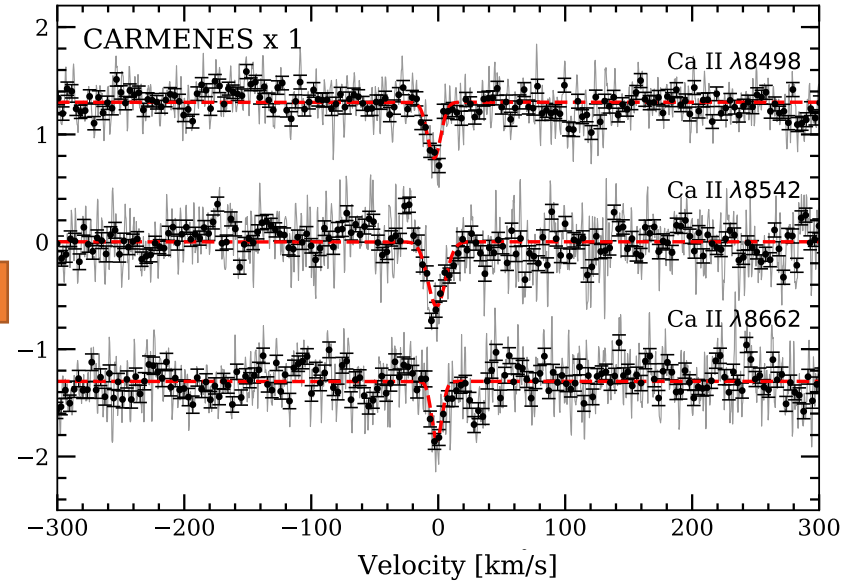








Cross-correlation technique: Stangret et al. (2020)



Impact and prospects for the future

Conclusions

- Hα, Hβ, NaI, CaII, and FeII are detected in the atmosphere of the ultra hot Jupiter MASCARA-2b using transmission spectroscopy
- CLV & RM effects correction is important for accurate retrieval of atmospheric features
- Fe I and Fe II also detected using cross-correlation techniques (Stangret et al. 2020, Nugroho et al. 2020, Hoeijmakers et al. 2020)
- Similar detections in other ultra hot Jupiters: **KELT-9b** in (Yan & Henning 2018, Hoeijmakers et al. 2018, Cauley et al. 2019), and in **WASP-76b** (Seidel et al. 2019), **WASP-33b** (Yan et al. 2019), **WASP-121b** (Bourrier et al. 2020)
- We only observe the terminator region. Probably, **winds emerging from day-side transporting ionised material to the terminator.**

Future

- Study the **ingress and egress transmission spectra** in order to look for dynamical differences between the day and night sides (e.g. Ehrenreich et al. 2020)
- **Secondary eclipse observations** to directly study the day-side spectrum and have a full picture of the exoplanet atmosphere. Due to the high temperature of MASCARA-2b, emission of iron is probably expected (e.g. Brogi et al. 2020, Yan et al. 2020 submitted)