Modelling the 3D high-resolution spectral properties of WASP-121b and WASP-189b

Elspeth K.H. Lee[1], Bibiana Prinoth[2], Daniel Kitzmann[1], Shang-Min Tsai[3] & Jens Hoijemakers[2]

[1]Center for Space and Habitability, University of Bern, Gesellschaftsstrasse 6, CH-3012 Bern, Switzerland
[2]Lund Observatory, Department of Astronomy and Theoretical Physics, Lunds Universitet, Solvegatan 9, 222 24 Lund, Sweden
[3]Atmospheric, Oceanic & Planetary Physics, Department of Physics, University of Oxford, Oxford OX1 3PU, UK

Abstract

The large scale heights and dayside atmospheric temperatures make ultra hot Jupiters (UHJs) a favourite target for low and high resolution spectral observations. We investigate the 3D atmospheric properties of the UHJs WASP-121b and WASP-189b using the Exo-FMS GCM model (Lee et al. 2021, MNRAS, 506). The radiative-transfer (RT) scheme for the GCMs was upgraded to include several near-UV (NUV) absorbing species such as Fe, Fe+ and SiO, following the 1D radiative-convective equilibirum modelling results by Lothringer et al. (2020, ApJL, 1). We then run the GCM models for both planets for 3050 days, taking the last 50 day average as the final result. The GCM outputs are then post-processed for transmission and emission spectra using the 3D Monte Carlo RT model gCMCRT (Lee et al. 2022, arXiv:2110.15640) at low-resolution and compared to available observational data. We then process the GCM models at high spectral resolution including Doppler shifting of lines due to winds and planetary rotation for the HARPS instrument for WASP-189b following Prinoth et al. (2022, NatAst, in press). WASP-121b is then processed at high resolution at optical wavelengths as a full phase curve.

WASP-121b

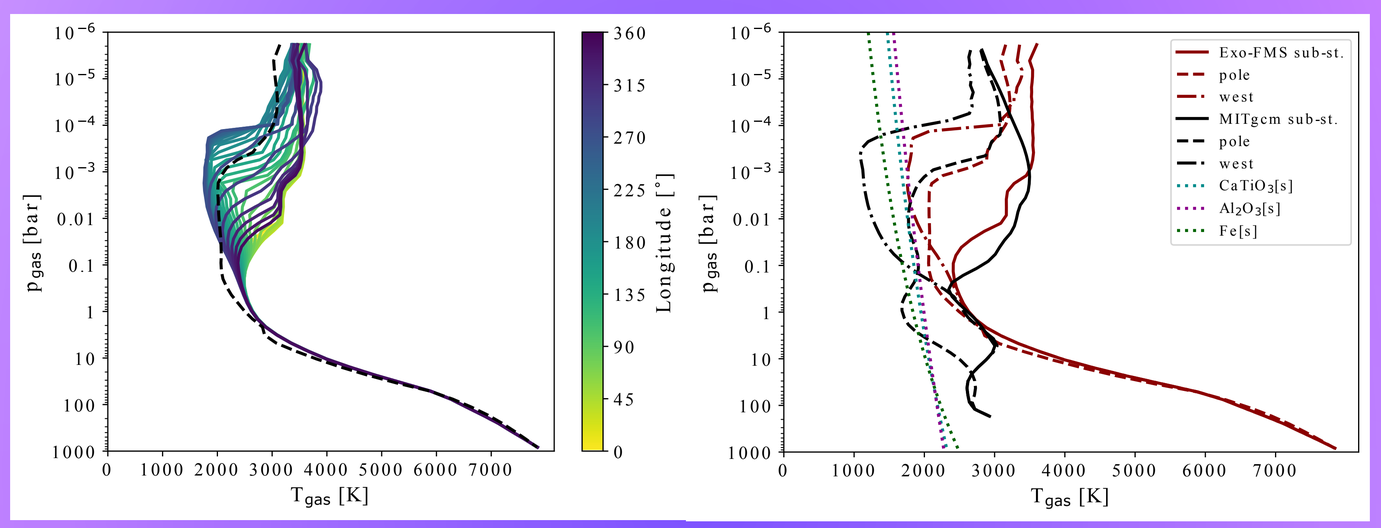


Figure 1.
Left: Temperature-pressure (T-p) structures at the equatorial regions (colour bar) and pole (dashed).
Right: Comparing the Exo-FMS T-p stuctures to the Parmentier et al. (2018, A&A 617) SPARC/MITgcm models.

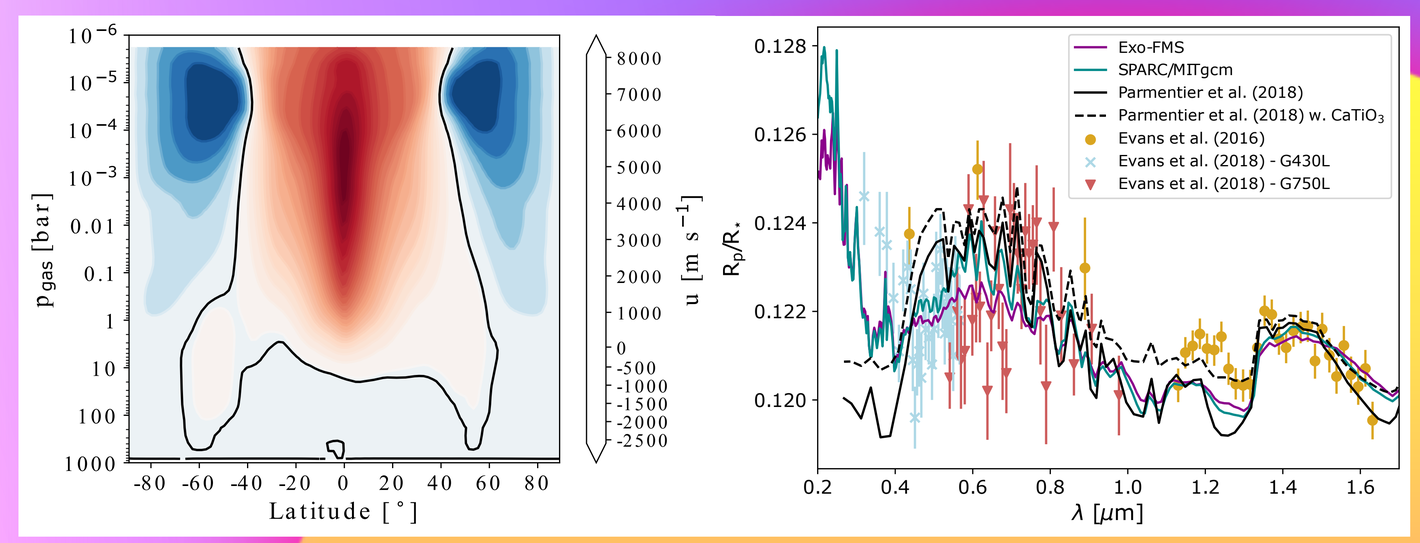
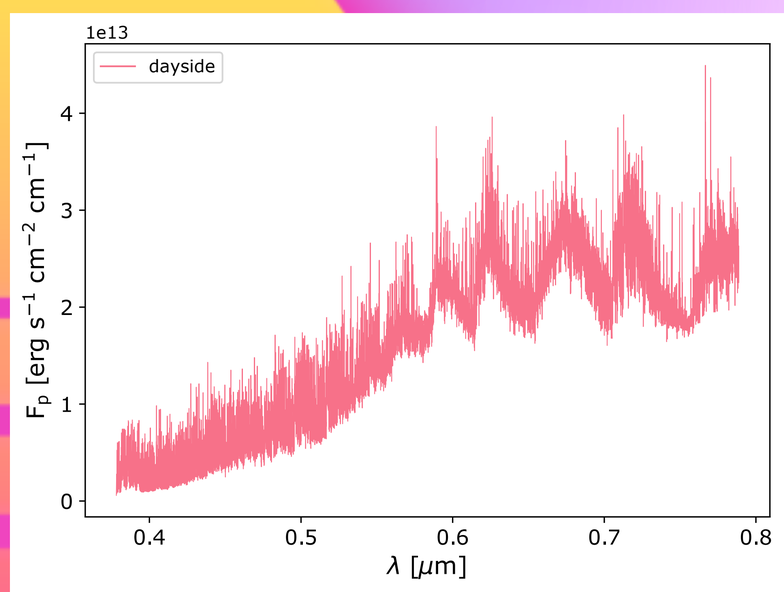


Figure 2.
Left: Zonal mean zonal velocity of the GCM winds.
Right: Transmission spectra at low-resolution comparing to available HST data.

Figure 3.
High-resolution emission spectra (~120,000 spectral points) of the dayside hemisphere.



WASP-189b

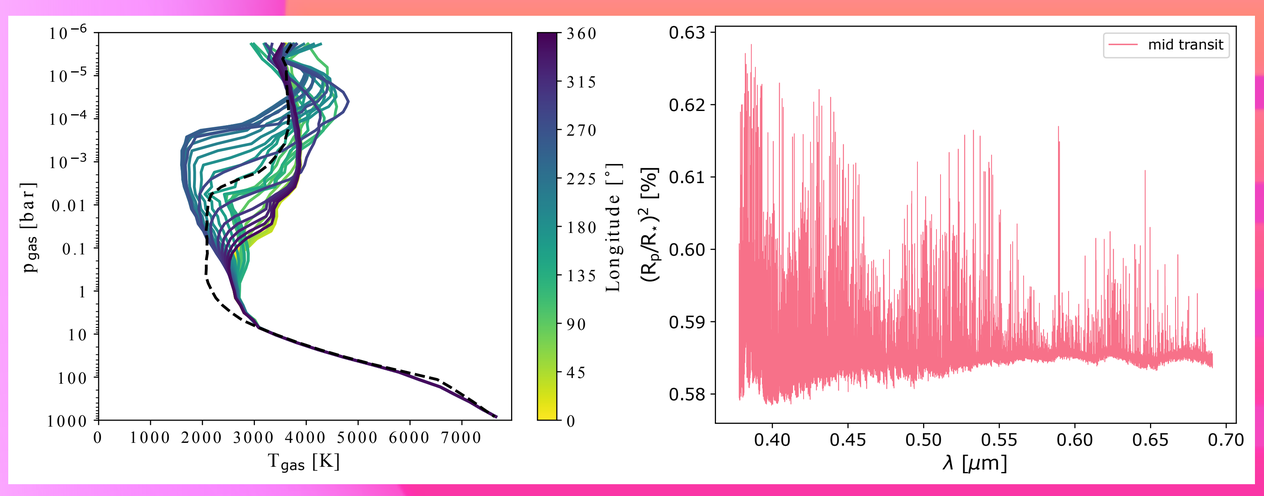


Figure 4.
Left: Temperature-pressure (T-p) structures at the equatorial regions (colour bar) and pole (dashed).
Right: High-resolution transmission spectra (~80,000 spectral points) at mid-transit.

Conclusions

The addition of NUV absorbers creates a dynamically detached layer at very low pressures, where strong lines at high resolution and optical wavelengths are probed.
This suggests that assuming isothermal conditions for cross-correlation techniques may be ok in these cases. Our results also suggest that high-resolution studies may be probing the dynamical properties of a distinct upper atmospheric layer, something that high-resolution studies should bear in mind for future interpretations of data.