Peering above the clouds of the warm Neptune GJ 436b with CRIRES+

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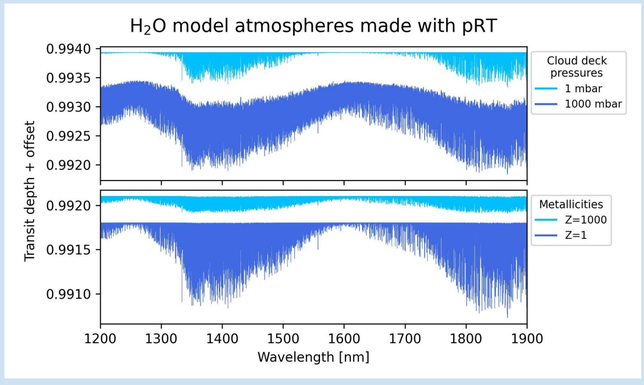
1 Introduction

Earth- to Neptune-mass exoplanets

- Often flat transmission spectrum at low resolution
  - High-altitude clouds and/or
  - High atmospheric metallicity
- E.g. Archetypical warm Neptune GJ 436b [1]

Potential of high resolution spectroscopy

- Sensitive to absorption above potential clouds
- Might resolve cloud-metallicity degeneracy [2]



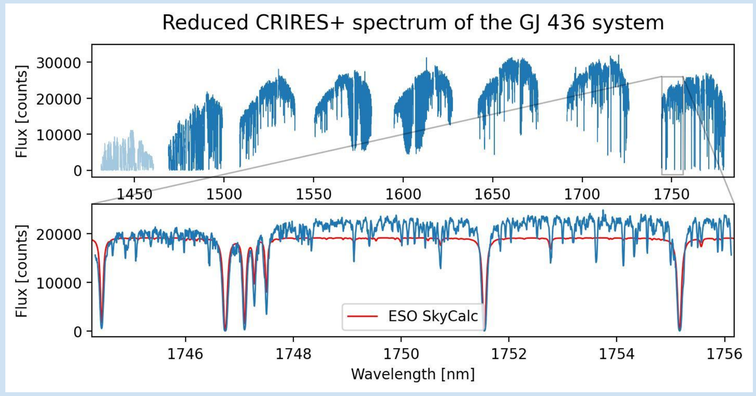
2 Data & Methods

Observations

- High resolution spectroscopy from VLT/CRIRES+
- H-band: 1490−1780 nm
- Three observing nights, only one good quality

Detection pipeline

- Tellurics & stellar lines removed with SYSREM [3]
- Cross-correlation with model atmospheres from petitRADTRANS (pRT, [4])

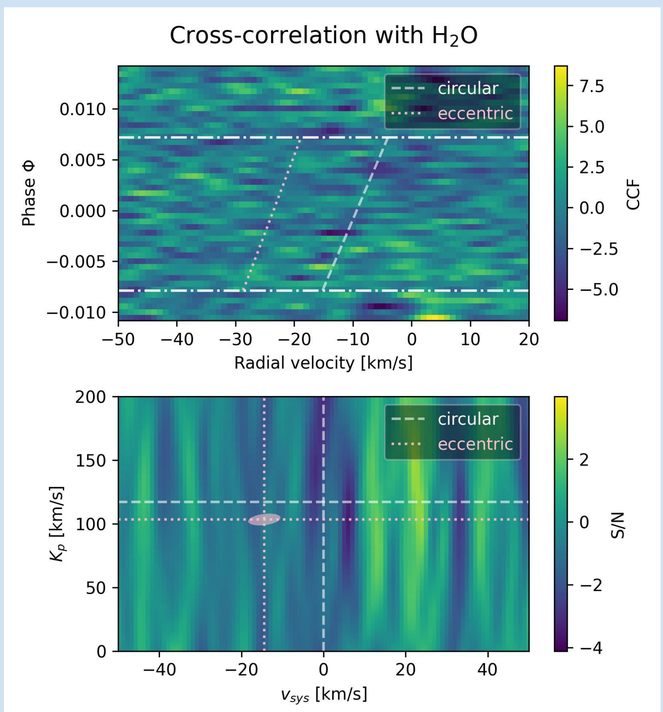


3 Results

Non-detection of H_2O, CH_4, CO, OH, NH_3

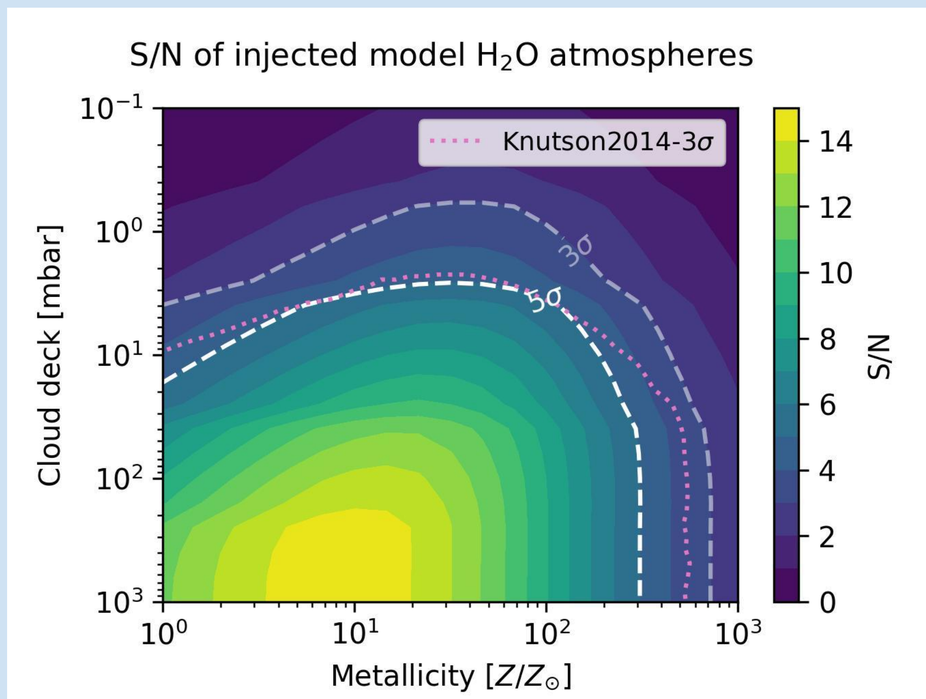
Eccentric vs. circular

- Eccentricity = 0.145
- Radial velocity of eccentric orbit shifted compared to circular orbit



Constraints from injecting model atmospheres

- High S/N atmospheres (> 5) unlikely for GJ 436b
- GJ 436b most probably has
  - High-altitude clouds (P < 10 mbar) and/or
  - High metallicity (> 300× solar)



4 Conclusion

Four high S/N transits may allow detection of

- 10-100× solar metallicity, clouds at 1 mbar
- 1000× solar metallicity, clouds below 100 mbar

Comparable constraints from

- One transit with CRIRES+ (this study)
- Four transits with HST [1]

References

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[3] Tamuz, O., Mazeh, T., & Zucker, S. 2005, MNRAS, 356, 1466
[4] Mollière, P., Wardenier, J. P., van Boekel, R., et al. 2019, A&A, 627, A67