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Detection of carbon monoxide in the high-resolution day-side spectrum of HD 189733b

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Abstract

High-resolution (R~100,000) observations using CRIRES on the VLT have been used to search for the carbon monoxide, carbon dioxide, water and methane molecules in the day-side atmosphere of the exoplanet HD 189733b. We found a 5-sigma absorption signal of CO at 2.3 micron, which enables us to put constraints on the depth of the CO lines. Upper limits for the other gases were obtained. We will also discuss present and future possibilites of high-resolution observations of exoplanets.

1. Introduction

In the last few years the study of the atmospheres of exoplanets has made great progress. Currently there are dozens of transiting planets for which atmospheric signal have been measured at multiple bands in the infrared. Great progress has been made in obtaining these measurements. The next step, medium resolution spectroscopy of transiting planets, promise to reduce some of the uncertainty in the composition in exoplanet atmospheres that is currently there. n this context, high resolution spectroscopy can yield extremely useful and complementary information regarding the planet's chemical composition, since individual molecules can be targeted. Recently, high-resolution spectroscopy has yielded detections of CO in the transmission spectrum of HD 209458b [4] and in the thermal emission spectrum of the non-transiting planet tau Boo b[1][3]. Also on 51 Peg b[2], a potentially strong signal was found for CO and H_2O.

2. Data analysis

Observations of the transiting planet HD 189733b were taken using CRIRES on the VLT at a resolution of R=100,000, at phases shortly before and after secondary eclipse. Two wavelength settings were explored: at 2.0 micron to look for CO_2 and H2O, and at 2.3 micron to look for CO, H_2O and CH_4. We removed stellar and telluric signals using singular value decompositions and correlate the reduced data with models spectra of the exoplanet atmosphere covering a wide parameter range.

3. Results

We find a 5-sigma detection of CO in absorption at 2.3 micron (see Fig. 1) and determined a corresponding line contrast (the depth of the absorption lines divided by the stellar flux) of 4.5+/-0.9 x 10^{-4}. Upper limits for methane, carbon dioxide and water vapour were obtained.

A model-independent determination of the stellar and planetary mass has been determined, revealing results consistent with those determined by stellar radial velocity measurements, in combination with spectral modelling. More observations of the type we present here can yield a precision and the stellar and planetary mass better than currently available.

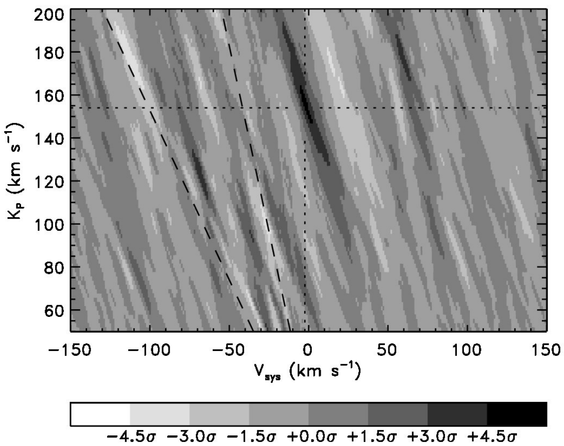

Figure 1: Cross-correlation values as a function of system velocity and planet radial velocity magnitude. The dashed line indicates where stellar CO lines are expected to leave the largest contamination signal. The area in between the dashed lines can also be contaminated by stellar residuals. The dotted lines indicate the system velocity of HD 189733 and the peak position of Kp.

4. Summary and conclusions

The detected CO signal shows that the day-side temperature profile of HD 189733b does not show an inversion at the pressures probed by the CO lines and the continuum (roughly between 0.5-10^{-5} bar), and that any potential cloud or haze layer does not obscure the cores of the CO lines. On its own, the line contrast derived here cannot be used to constrain the CO abundance, but it can be used in combination with e.g. secondary eclipse observations to put tighter constraints on the CO abundance and temperature profile of HD 189733b.

More optimal wavelengths to look for molecules other than CO using high-resolution spectroscopy were determined using a sensitivity analysis. Also, the possibility of observations of the night-side of hot Jupiters was investigated, indicating a potentially important role of high-resolution spectroscopy in exploring the three-dimensional structure of exoplanets.

Acknowledgements

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References

[1] Brogi, M., Snellen, I.A.G., de Kok, R.J., Albrecht, S., Birkby, J and de Mooij, E.J.W.: The signature of orbital motion from the dayside of the planet tau Bootis b, Nature, 486, 502-504, 2012

[2] Brogi, M., Snellen, I.A.G., de Kok, R.J., Albrecht, S., and Birkby, J.: Detection of molecular absorption in the dayside of exoplanet 51 Pegasi b?, the Astrophysical Journal, 767, 27, 2013

[3] Rodler, F., Lopez-Morales, M., and Ribas, I, Weighing the non-transiting hot Jupiter tau Boo b, the Astrophysical Journal, 753, L25, 2012

[4] Snellen, I.A.G., de Kok, R.J., de Mooij, E.J.W, and Albrecht, S.: The orbital motion, absolute mass and high-altitude winds of exoplanet HD 209458b, Nature, 465, 1049-1051, 2010