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Water detection in the near infrared in HD 189733 b with CARMENES

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Abstract

The current scientific interest on radial velocity surveys around M type stars has pushed the development of high-resolution high-stabilized spectrographs in 4-m class telescopes. Such is the case of the Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Échelle Spectrographs (CARMENES, [1]). The capabilities of CARMENES provide us with the opportunity of extending the scientific exploitation of the instrument to the field of exo-atmospheres. Therefore, we have used CARMENES to detect the water vapour signature in the atmosphere of the Hot Jupiter HD 189733 b using tranmission spectroscopy in the primary transit. To do so, we have used the Cross-correlation (CC) technique for high-resolution spectra as in [2], [3], [4].

1. Cross-Correlation Technique applied to CARMENES

We observed one of the transits of HD 189733 b with the near-infrared (NIR) channel of CARMENES. The spectra were reduced by the CARMENES pipeline. After properly removing hot pixels and cosmic rays, we normalized the spectra and masked the strongest telluric absorption and emission lines. For the removal of the telluric and stellar variations during the observations we used an iterative Principal Component Analysis algorithm called SYSREM ([5], [6]), succesfully applied in [4]. The spectra were then cross-correlated with H_2O transmission models that were created with the Karlsruhe Optimized and Precise Radiative Transfer Algorithm (KOPRA, [7]). An example can be seen in Fig. 1.

2. Water vapour detection with CARMENES

We detect the H_2O signature in the atmosphere of HD 189733 b using the NIR wavelength coverage of CARMENES (0.96–1.71 μm) with a signal-to-noise ratio, SNR > 6 (Fig. 2) at a significance level > 6σ. The signal was found to be slightly blueshifted, hence indicating the presence of winds in the terminator region flowing from the day to the night-side. We tested several templates for the CC with two different pressure-Temperature profiles and two possible H_2O abundances (VMR= 10^{-4}, 10^{-5}). We found that their effect in the model (e.g. line shapes and depths) does not translate in significantly different SNRs nor significances (Fig. 3).

We explored the possibility of individually detecting H_2O in the two stronger bands at wavelength ranges $1.06 - 1.23\,\mu m$ and $1.29 - 1.54\,\mu m$, and in the combination of the other weaker bands in the covered region (see Fig. 1). We found the H_2O signal individually for each of them with SNR∼4.

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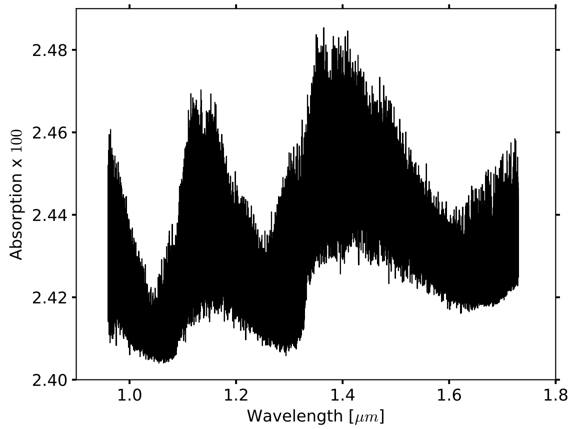

Figure 1: Example of absorption model calculated with KOPRA for HD 189733 b in the CARMENES NIR spectral range. The contribution of the solid planetary disk (i.e., opaque at all wavelengths) has been included.

the members of the CARMENES Consortium (MPIA, IAA, LSW, ICE, IAG, UCM, TLS, IAC, HS, CAB, and CAHA). Financial support also provided by the UCM, the C. A. de Madrid, the Spanish Ministerios de Ciencia e Innovación and MINECO, and the FEDER/ERF funds under grants AYA2011-30147-C03-01, -02, and -03, AYA2012-39612-C03-01, and ESP2013-48391-C4-1-R. Based on observations collected at CAHA, operated jointly by the MPIA and the IAA-CSIC.

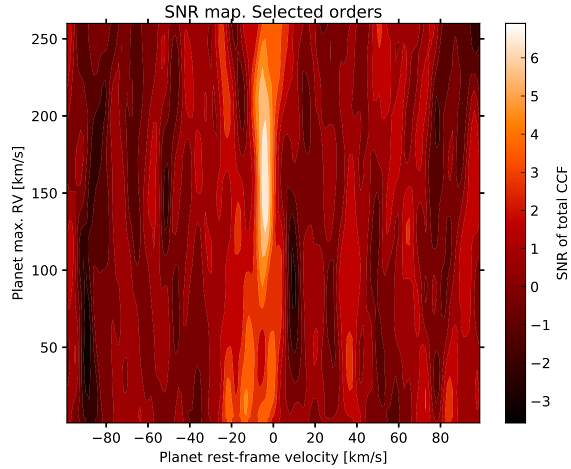

Figure 2: Signal-to-noise ratio as a function of the planet rest frame velocity and radial velocity semi-amplitude (K_p). The strongest SNR is found at the expected K_p and rest velocity intervals of the exoplanet.

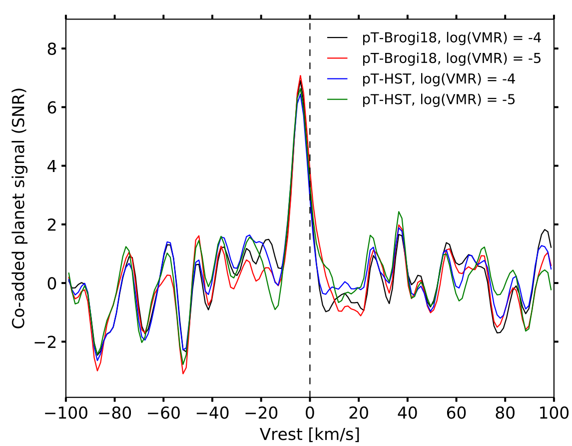

Figure 3: CCF, plotted as SNR, as a function of the planet rest frame velocity for all the models tested and for the maximum SNR-K_p pair. All models allow us to detect H_2O, but a degeneracy between p-T profiles and abundances is shown.

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