The Mg I signature in High-Resolution Transmission Spectra of Exoplanets

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Overview

The announcement of the first detection of an atomic species in the atmosphere of an exoplanet dates back to almost 20 years ago. High resolution transit spectroscopy data acquired with ground-based telescopes can be used for measurements of exoplanet atmosphere properties and permits to discriminate between signals in different reference frames. The identification and measurement of the relative strengths of spectral lines and bands in the transmission spectra of exoplanets have been used to put constraints on the atmospheric composition and thermal structure (e.g. Vidal-Madjar et al. 2003; Wyttenbach et al. 2015), and on their formation scenario and evolution. Recently, Cauley et al. (2018) and Hoeijmakers et al. (2019) observed the Mg I triplet in KELT-9 b (Gaudi et al. 2017) transmission spectrum. Magnesium absorption can be used to as a probe for exoplanet mass loss rates estimation (Bourrier et al. 2015) and is an important coolant in hot planet atmospheres (Huang et al. 2017). This work aims to create a tool able to detect weak spectral lines, paving the way to the biosignatures detection in the high-resolution transmission spectra of exoplanets.

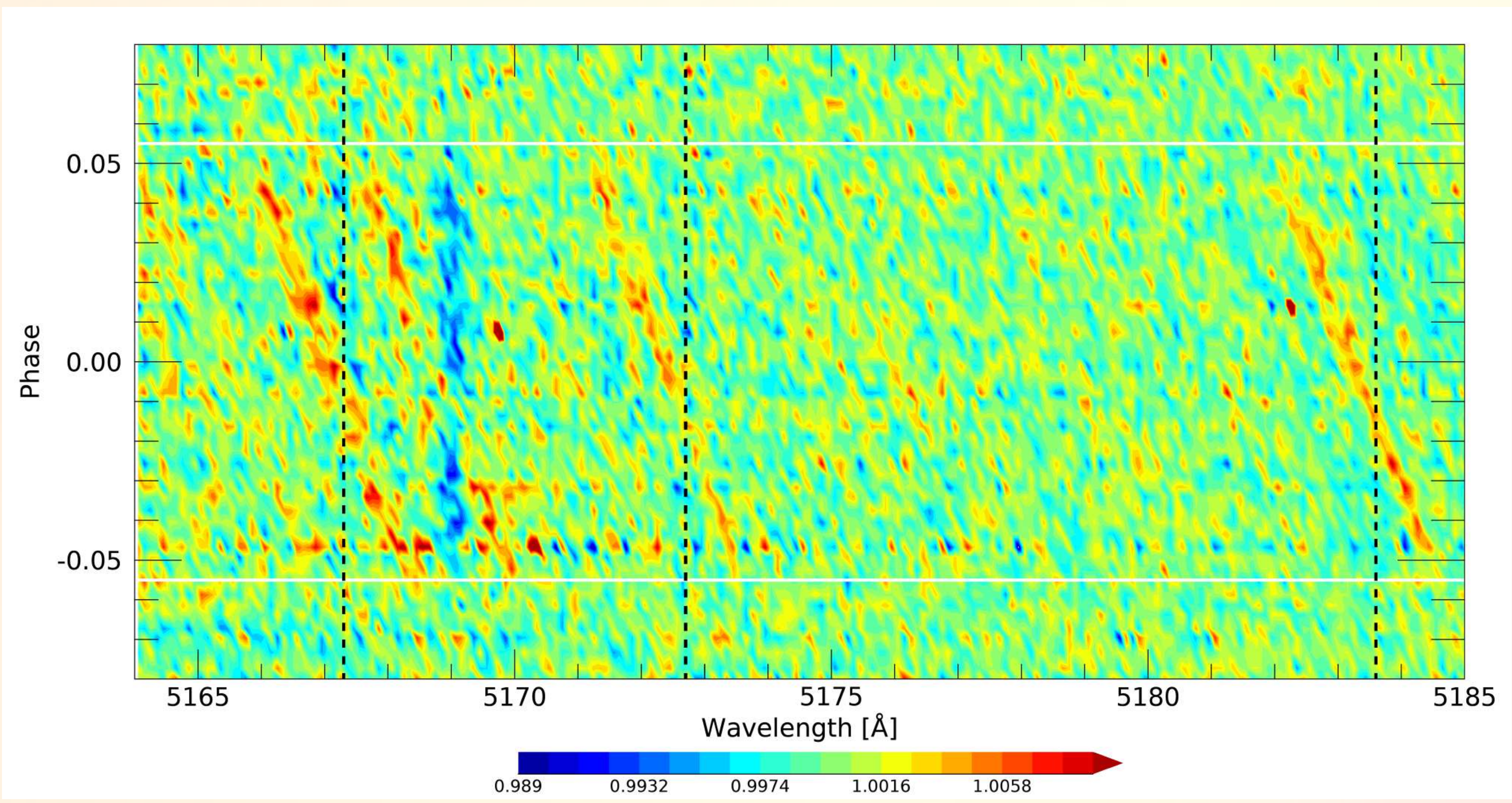

Fig.1: Tomography of the transmission spectrum of KELT-9 b in the wavelength space. The black dashed lines indicate the position of the three Mg I lines. The vertical blue traces show the absorption in the planet reference frame, while the red oblique traces are due to the stellar effects (center-to-limb variations and stellar rotation, e.g. Borsa & Zannoni 2018). The absorption line at 5169.03 Å is a Fe II line, an element known to be present in the atmosphere of the planet (Hoeijmakers et al. 2018). This is a confirmation of the goodness of our analysis.

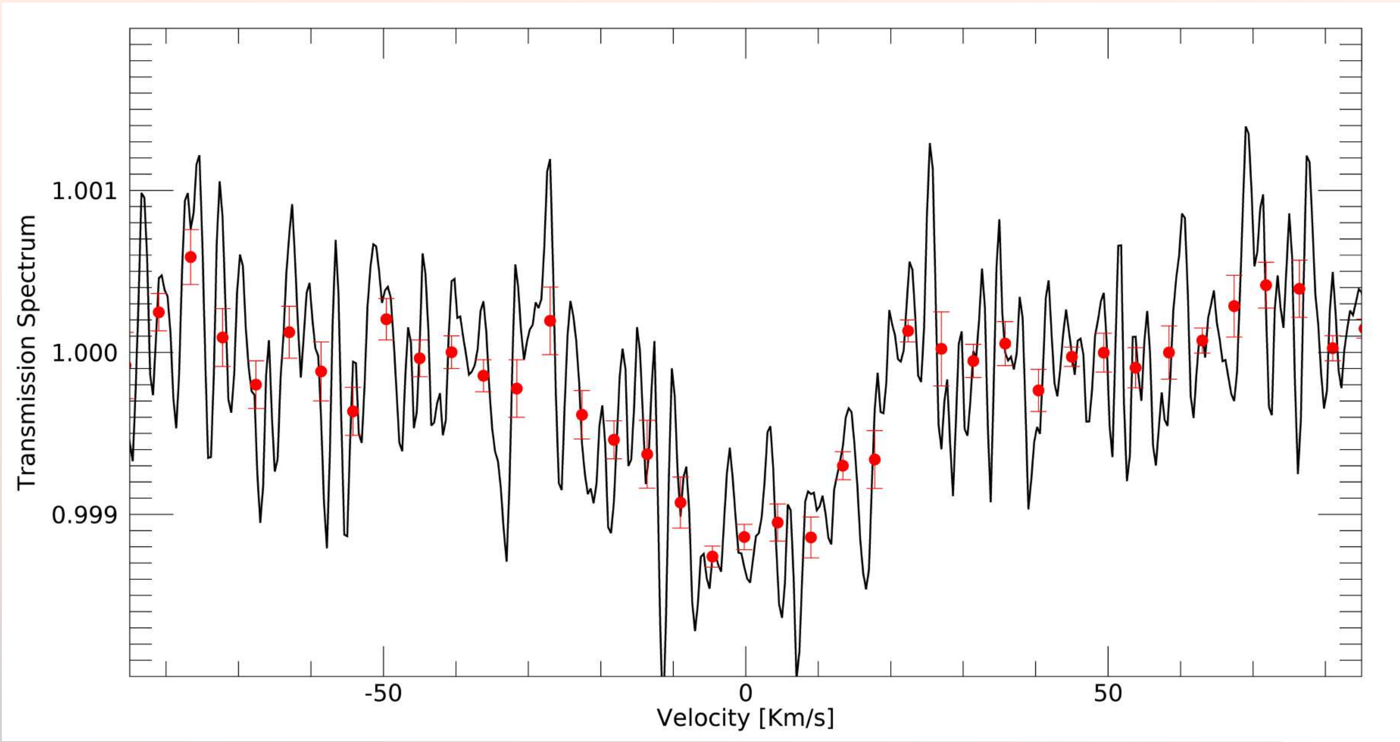

Fig.2: Transmission spectrum of KELT-9 b in the radial velocities space, where the co-added absorption lines of Mg I are centered at 0 km/s.

Future Work

Analyzing the spectra in both wavelength and velocity space, it is evident that stellar signals (CLV and stellar rotation) have a major impact in the quantitative analysis of Mg I. Dealing with these signals will be the next step.

The tool we developed works well in Mg I detection, and will be easily adapted for the detection of any possible biomarker in high-resolution transmission spectra of exoplanets.

WORK IN PROGRESS

Method

High-resolution spectra recorded from the ground bear the imprint of Earth's atmosphere. It is not known how the telluric magnesium behaves, so we make the assumption that, within a night, the possible magnesium telluric absorption can be corrected as other telluric features.

In our analysis we followed the procedure adopted by Wyttenbach et al. (2015) and we divided each in-transit spectrum by the master-out stellar spectrum, and then we shifted and summed in the planetary reference frame all the individual residual transmission spectra. We aim at analyzing the magnesium triplet lines, centered at 5167.32, 5172.68 and 5183.60 Å, so we analyzed the spectrum in the range of wavelength between 5160 and 5200 Å.

In order to achieve a higher signal-to-noise ratio, we separated the three lines and turned into the radial velocities space, setting each line center to zero. Then we co-added the three lines of the HARPS-N transmission spectrum magnesium triplet in the space of radial velocity, with the result that the magnesium signature becomes more evident.

Mg I in KELT-9 b

In the framework of the GAPS project (Poretti et al. 2016), we observed KELT-9 during four transits of KELT-9b (Borsa et al. 2019) using HARPS-N and GIANO-B in GIARPS configuration (Claudi et al. 2017), for a total of 226 spectra. The instruments are located at Telescopio Nazionale Galileo (INAF) at the Roque de los Muchachos Observatory, La Palma, Spain.

Following the procedure described before, we analyzed the high-resolution spectra of KELT-9 and obtained the transmission spectra in the planetary reference frame. No strong absorption of the magnesium triplet can be seen on the single lines (**Fig.1**), but when we co-add the three lines in the velocity space, the magnesium trace is more evident (**Fig.2** and **3**).

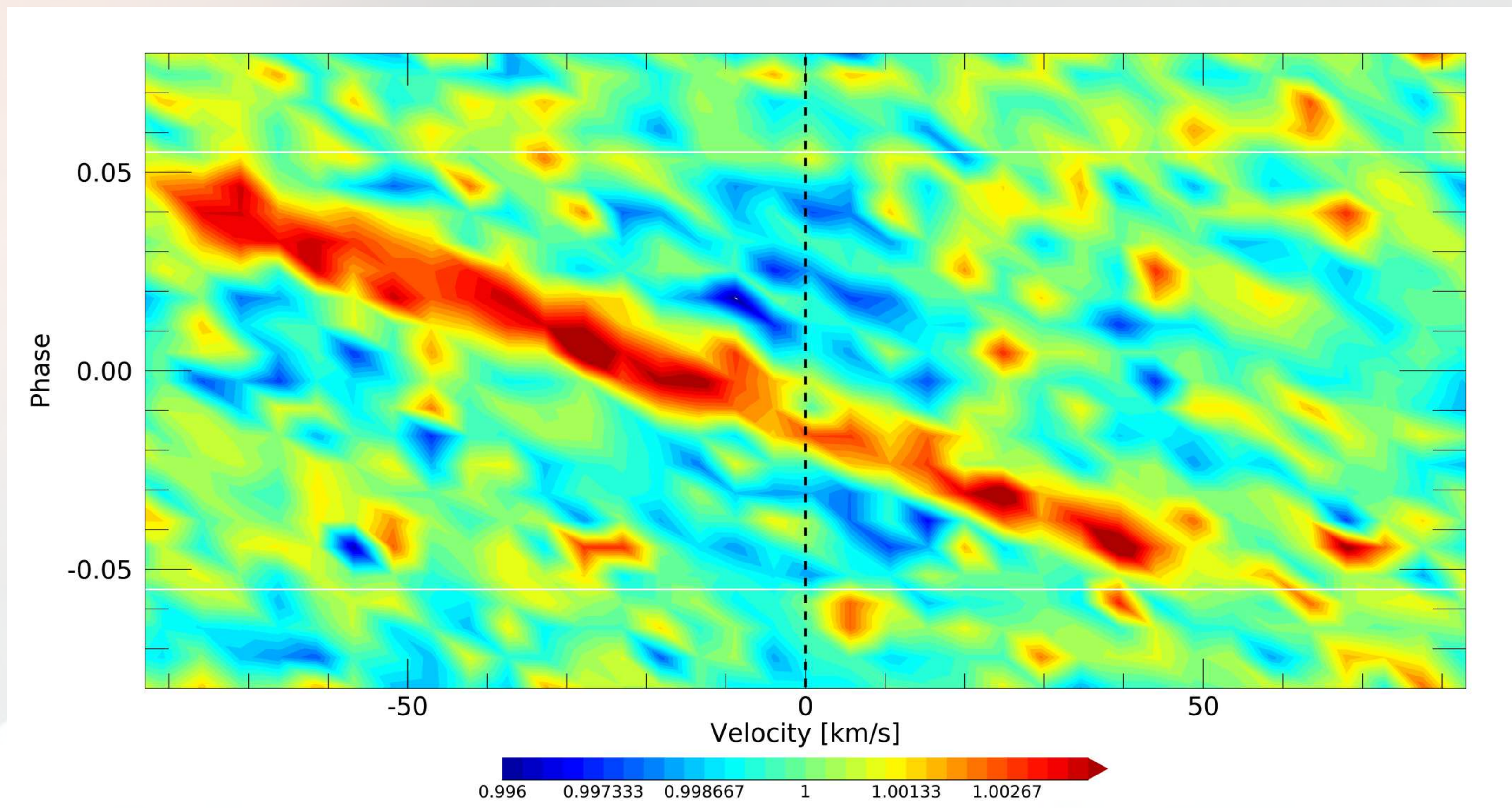

Fig.3: Tomography of the transmission spectrum of KELT-9 b in the radial velocities space. The black dashed line indicate the position of the Mg I co-added lines. The vertical blue trace shows the absorption in the planet reference frame and in this case the Mg I is more evident than for the single lines (**Fig.1**). The red oblique trace is due to stellar effects. Tomography confirms that the traces of Mg I seen in the transmission spectrum of KELT-9 b are associated to the planetary atmosphere and not to the star.

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