Exoplanetary System HD 189733 - Chromosphere, Transit, Activity

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Abstract. We present a study of the temporal evolution of the chromospherically sensitive lines in the transiting exoplanetary system HD 189733 using high-resolution UVES spectra. With its fast temporal cadence of only 45 s and its wide spectral coverage, our time series is ideal to study the influence of the transiting planetary disk on chromospheric lines. We measured the equivalent width and central line depression of the Ca II H and K lines, Hα, and the Ca II infrared triplet. While all these lines show temporal evolution on a scale potentially induced by the occulting planetary disk, strong intrinsic stellar variability prevents us from uniquely ascribing the observed variation to the planetary transit.

1. Introduction

The exoplanetary system HD 189733 consists of a K1V star ($V = 7.7$ mag) and a transiting hot Jupiter ($P_{\rm orb} = 2.219$ days) (Bouchy et al. 2005). HD 189733 is one of the most active planet host stars known to date as evidenced by strong Ca II H and K line emission, flares (Pillitteri et al. 2014), and strong X-ray emission. Currently, the star remains the only star for which a planetary X-ray transit has been observed (Poppenhaeger et al. 2013).

1.1 Observation

We observed HD 189733 with the UVES high resolution spectrograph (ESO/VLT UT2). The observations cover the whole transit event (110 min) and time before and after the transit (260 min). We obtained a densely sampled ($\sim$45 s; exposure time of 30 s) spectral time series. To minimize readout time, we used the "ultrafast" CCD readout mode. The spectra cover the wavelength range from 3750–9460 Å and have been obtained with a spectral resolution of 60 000.

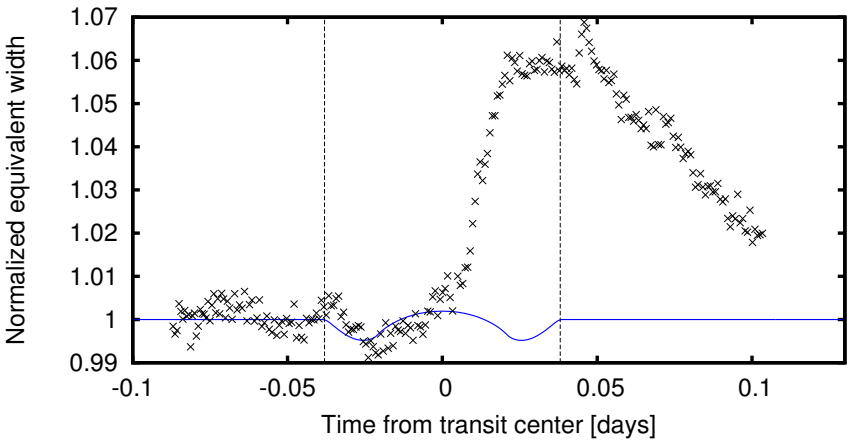

Figure .1: Black crosses: normalized equivalent width of Ca II H and K line cores. Blue solid line: model of the chromospheric transit.

This outstanding data set allows us to study the behavior of several chromospherically sensitive spectral lines (CaII H and K lines, Hα, and Ca II IR triplet) which are located in the blue, red, and near infrared part of the spectra.

2. Transit in Ca II H and K lines

The difference in the center-to-limb variation between the photosphere and chromosphere produces a time-dependent change in the equivalent width (EW) of the Ca II H and K line cores as the planet traverses the stellar disk. In Fig. .1, we show the (normalized) EW along with a model obtained by dividing transit models with linear limb darkening coefficient of 0.6 for the photosphere and a homogeneously bright chromosphere. While the measured EW shows variation on the predicted scale, the time series is clearly dominated by intrinsic stellar variability – in particular, a flare ignited at about mid-transit time.

3. Central depression and equivalent width

The temporal variation of the central depression (CD = 1−central relative flux) and of the equivalent width in selected chromospheric lines were studied. The abrupt change in the middle of the transit caused by a flare is visible in all the studied lines (see the top plots in Fig. .2).

We performed the Pearson and Spearman tests to check for the correlation between the evolution of the spectral lines. The Ca II and Hα lines show a strong correlation.

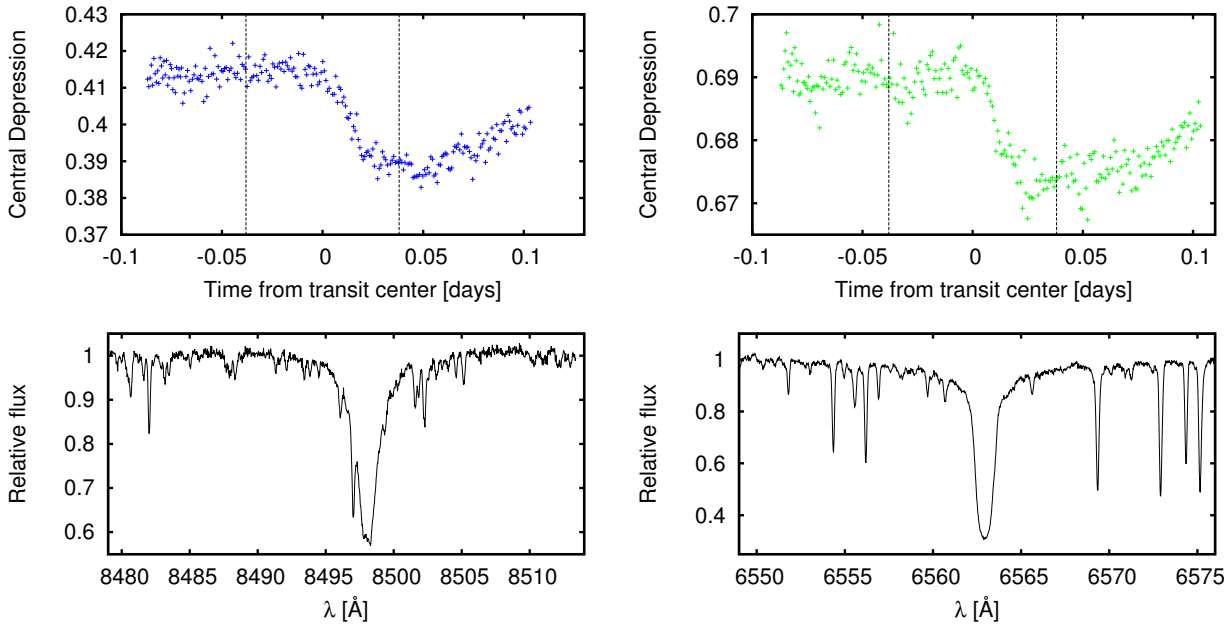

Figure .2: Top: Central depression of the Ca II triplet line at 8498 Å (left) and of the Hα (right). The dashed lines indicate the start and the end of the transit. Bottom: Ca II IR triplet line 8498 Å (left) and Hα (right) as observed with UVES.

4. Discussion

We measured the equivalent width and central depression of selected chromospheric lines (Ca II H and K, Ca II IR triplet, and Hα) of the exoplanetary system HD 189733 during one transit event and studied their temporal variation.

Our analysis reveals a phase of relative quiescence comprising the first half of the time series and, thus, also the transit. Even in this phase, however, we detect a variability on a scale, which could be caused by the transiting planetary disk. The second part of the time series is heavily affected by intrinsic stellar variability. Most likely, the eruption of a flare was observed, whose influence is well traced in all analyzed lines.

The increased amplitude of chromospheric variability caused by the flare allows us to study the mutual correlation of the observed chromospheric lines at high spectral and temporal resolution. We found strong linear correlation between the central depression and equivalent widths of the lines.

The results presented here show that our unique UVES data set allows a detailed study of chromospheric characteristics of one of the best-studied planet host stars known to date. Although intrinsic stellar variability is strong, the quality of the data may even allow to extract a planetary signal.

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References

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