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Atmospheric signatures by transit of HD209458 with VLT/UVES

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Abstract. In our search for clues as to the nature of the exosphere of HD209458 (Moutou *et al.*, 2001 ; Moutou *et al.*, 2003, Iro *et al.*, 2004), we have acquired VLT/UVES data during an ambitious observational campaign performed in June-September 2002 and covering 6 transits of the exoplanet. The resolving power was R=100000 in the 0.475-0.68 micron range. We search for ions and neutral molecules (such as H2O+, CO+, CH+, etc) originating in the planets exosphere and located in the evaporated material around the planet, occulting its primary star. We present in this paper a tentative search in the spectral regions where features of sodium or H_2O^+ can be present.

Keywords. Exoplanets, transits, exosphere, atmosphere, techniques: spectroscopic, (stars:) planetary systems, line: identification.

1. Introduction

HD209458b, the first discovered extrasolar planet transiting its star, has been subject to several studies constraining the composition of its atmosphere (see Table 1), in particular Na (Charbonneau *et al.* 2002; Narita *et al.* 2005), HeI (Moutou *et al.* 2003), CO (Deming *et al.* 2005) , H (Bundy & Marcy 2000; Vidal-Madjar *et al.* 2003; Vidal-Madjar *et al.* 2004; Winn *et al.* 2004; Narita *et al.* 2005), O, C and Si (Vidal-Madjar *et al.* 2004), Ca (Bundy & Marcy 2000; Narita *et al.* 2005; Shkolnik *et al.* 2005) and Fe (Bundy & Marcy 2000; Narita *et al.* 2005).

Our group has searched for such signatures since the first detection of 51 Pegasi from the ground and also from space with ISO (Coustenis *et al.* 1997, Rauer *et al.* 2000). We performed observations with UVES in the 0.33-0.67 μm region at high spectral resolution. We searched for ions and neutral molecules originating in the planet's exosphere and located in the evaporated material around the planet, occulting its primary star (Coustenis *et al.* 1997). Iro *et al.* (2004) presented the planet-induced chromospheric activity on HD209458 in these data as well as the He feature at 1.083 μm with data from VLT/ISAAC (Moutou *et al.* 2003). In this paper, we focus on the search for features from Na and H_2O^+.

2. The 2002 UVES campaign

We used VLT/UVES to observe HD209458 in 2002 over 6 of its transits, thus accumulating the time required to obtain a S/B of about 1000, required in order to detect

Constituent		Position	Note	Reference
Na	D	5893 Å	< 0.02 %	Charbonneau *et al.* (2002)
	D1 D2	5896.06 Å 5890.09 Å	< 0.03 %	Narita *et al.* (2005)
He	He I	1.083 μm	< 0.5 %	Moutou *et al.* (2001; 2003)
H	Lyα	1215.67 Å	15 % (1 σ)	Vidal-Madjar *et al.* (2003)
	Hα	6563 Å	< 0.1 % < 0.81 %	Winn *et al.* (2003) Narita *et al.* (2005)
	H I	1215 Å	5.3 % (1 σ)	Vidal-Madjar *et al.* (2004)
	Hβ	4861.45 Å	< 3.6 % < 0.68 %	Bundy & Marcy (2000) Narita *et al.* (2005)
	Hγ	4340 Å	< 2.7 % < 1.57 %	Bundy & Marcy (2000) Narita *et al.* (2005)
O	O I	1305 Å	12.8 % (1 σ)	Vidal-Madjar *et al.* (2004)
C	C II	1335 Å	7.5 % (1 σ)	Vidal-Madjar *et al.* (2004)
Si	Si IV	1394 Å	No detection	Vidal-Madjar *et al.* (2004)
Ca	Ca II K Ca II H Ca II & K	3943 Å 3968 Å	Not quantified < 14 %	Shkonlik *et al.* (2005) Bundy & Marcy (2000)
	Ca I		< 2.14 %	Narita *et al.* (2005)
Fe	Fe I	4384 Å	< 3.3 % < 1.08 %	Bundy & Marcy (2000) Narita *et al.* (2005)
	Fe I	6024.2 Å	< 0.84 %	Narita *et al.* (2005)
CO		2 μm	Very weak (no detection)	Deming *et al.* (2005)

Table 1. Detections of atmospheric constituents in HD209458b.

a possible evaporated exosphere. The observations were spread out between June and September 2002. An equivalent time of observation was dedicated to the observation of the system off-transit, to supply a spectrum of comparison of the primary star equivalent to the on-transit spectrum. Finally, a particular effort was devoted to the calibration of the event, at the same time by inserting frequent observations of a comparison star so as to insure the determination of the telluric contribution, and to provide a high-quality calibration of the instrument.

The data are in the course of analysis since the beginning of 2003. The production of a spectrum of transmission with no telluric or stellar contamination requires a meticulous reduction which we perform ourselves. We note the excellent quality of the majority of the spectra.

3. Data analysis

We averaged the spectra for all the transits in order to obtain ON-transit and OFF-transit spectra with a better S/N ratio. We then calculate the difference between the ON- and the OFF-spectra for the spectral ranges of interests. We note dissymmetric features in the region of H_2O^+ lines at 6544 (see Fig. 1) and 6193 Å (see Fig. 2) (the nominal position of the H_2O^+ line is 6198 Å). Another region that we are investigating is the Na

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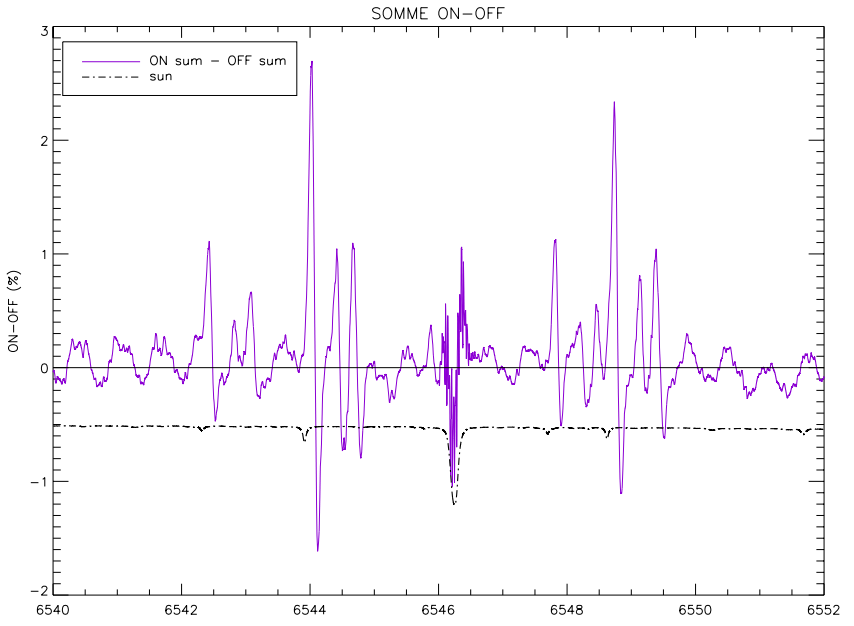

Figure 1. Difference between the sum of all the OFF-transit spectra and the sum of all the ON-transit spectra. The solar spectrum is shown in arbitrary units. We find a strong dissymmetry between ON and OFF at the H_2O^+ line position at 6544 Å.

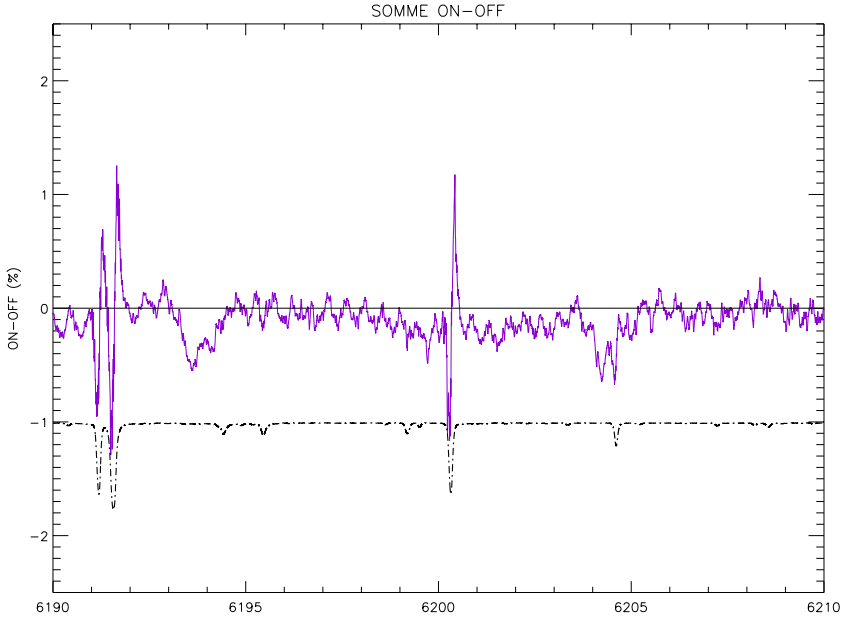

Figure 2. Search for $H2O^+$ (nominally at 6198 Å): zoom. The search in this region is complicated by the presence of a strong Fe line, but there seem to be unidentified features at 6193.5 Å and 6204.5 Å.

line doublet at 5891.9 and 5893.2 Å where we note a dissymetry between the On- and the OFF- transit spectra.

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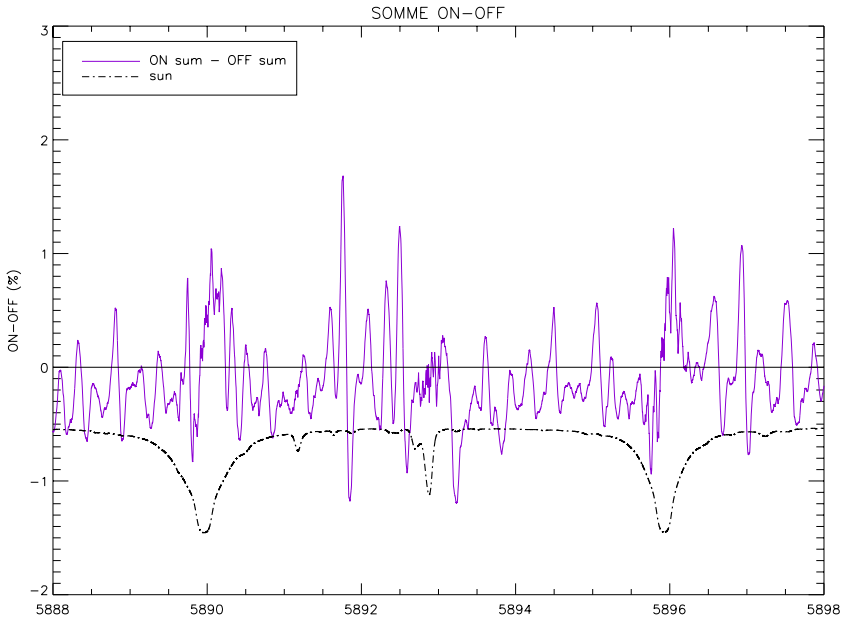

Figure 3. On- and off-transit spectra of HD209458 taken with UVES and the flux difference observed in two different orders within the Na band at 5893 Å. A zoom in the doublet region is shown, with a possible feature at 5893.2 Å.

4. Perspectives

The spectral ranges contained in the data presented in this paper include positions of possible features from Hα (6563 Å) and Hβ (4861 Å), Fe (6024 Å), O I (5577 and 6364 Å), CO^+ (4911 and 5490 Å). The analysis of these spectral regions are in progress.

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