Atmospheric characterization of the ultra-hot Jupiter MASCARA-2b/KELT-20b

Detection of Ca II, Fe II, Na I, and the Balmer series of H ($H\alpha$, $H\beta$, and $H\gamma$) with high-dispersion transit spectroscopy (Corrigendum)

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A&A, 628, A9 (2019), <https://doi.org/10.1051/0004-6361/201935623>

Key words. planetary systems – methods: observational – techniques: spectroscopic –
 planets and satellites: individual: MASCARA-2b – planets and satellites: individual: KELT-20b – errata, addenda

The original article has two errors which are corrected below and which do not have any impact on the conclusions.

1. In Fig. 7 of the original article, the labels inside the plot are inverted. The corrected figure is shown in Fig. 1.
2. There was an error in the constant value used for the conversion between the standard deviation (σ) and the full width at half maximum (FWHM) when fitting the exoplanet atmospheric absorption with a Gaussian profile. As a result, all of the FWHM values shown in the original article change by a constant value. The affected tables and figures from the main text are those containing FWHM information, that is to say, Tables 4, 5, and Fig. 13. In the appendix, this affects Table B.1 and all corner plots from Appendix D (Figs. D.1–D.7). The corrected tables and figures are presented below in the same order as in the original article.

Fig. 1. Transmission spectra around $H\alpha$ line obtained with all nights of HARPS-N combined and CARMENES data (Night 4), with an offset for a better visualisation. The best-fit Gaussian profiles are shown in red. In grey, we show the original transmission spectrum and the black dots show the data binned in 0.2 Å intervals.

Table 1. Best fit parameters and $1\text{-}\sigma$ error bars from the Markov chain Monte Carlo (MCMC) analysis of the $H\alpha$ line for each individual night and combined HARPS-N observations.

	h [%]	$FWHM$ [km s $^{-1}$]	K_p [km s $^{-1}$]	v_{wind} [km s $^{-1}$]	$R_\lambda^{(*)}$ [R_p]	$R_\lambda(h)^{(\S)}$ [R_p]
HARPS-N 1	$-0.75^{+0.10}_{-0.11}$	$48.4^{+10.7}_{-8.9}$	$140.3^{+39.0}_{-42.1}$	$1.3^{+3.0}_{-2.9}$	$1.21^{+0.04}_{-0.05}$	$1.24^{+0.06}_{-0.06}$
HARPS-N 2	$-0.52^{+0.10}_{-0.11}$	$21.6^{+5.1}_{-5.4}$	$101.5^{+33.7}_{-33.5}$	$-3.9^{+2.1}_{-2.4}$	$1.08^{+0.03}_{-0.03}$	$1.17^{+0.06}_{-0.07}$
HARPS-N 3	$-0.69^{+0.10}_{-0.11}$	$22.7^{+3.6}_{-3.3}$	$196.0^{+30.1}_{-32.0}$	$-2.8^{+2.2}_{-2.2}$	$1.15^{+0.04}_{-0.04}$	$1.22^{+0.06}_{-0.06}$
CARMENES 1	$-0.85^{+0.03}_{-0.03}$	$31.3^{+1.3}_{-1.2}$	$166.2^{+7.3}_{-7.4}$	$-4.5^{+0.5}_{-0.5}$	$1.21^{+0.01}_{-0.01}$	$1.27^{+0.02}_{-0.02}$
HARPS-Nx3	$-0.68^{+0.06}_{-0.06}$	$26.3^{+2.4}_{-2.2}$	$165.6^{+16.7}_{-16.6}$	$-3.0^{+1.2}_{-1.2}$	$1.13^{+0.02}_{-0.02}$	$1.22^{+0.04}_{-0.04}$

Notes. $(*)$ Effective radius value obtained from the best fit model of the CLV and RME effects. $(\S)$ Effective radius was calculated considering the absorption value, h , and assuming a continuum level of $(R_p/R_\star)^2 = 1.382\%$.

Table 2. Summary of the results obtained in the analysis is presented here for the different species and instruments.

		h [%]	$R_\lambda(h)$ [R_p]	v_{wind} [km s $^{-1}$]	$FWHM$ [km s $^{-1}$]	K_p [km s $^{-1}$]	$AD_{\text{TS}}^{1.5\text{\AA}}$ [%] $(*)$	$AD_{\text{TLC}}^{1.5\text{\AA}}$ [%] $(\ddagger)$	$AD_{\text{EMC}}^{1.5\text{\AA}}$ [%] $(\P)$
$H\alpha$	Hx3	-0.68 ± 0.06	1.22 ± 0.04	-3.0 ± 1.2	26.3 ± 2.4	165.6 ± 16.7	0.33 ± 0.05	0.30 ± 0.05	0.36 ± 0.14
	Cx1	-0.85 ± 0.03	1.27 ± 0.02	-4.5 ± 0.5	31.3 ± 1.3	166.2 ± 7.4	0.44 ± 0.04	0.43 ± 0.05	0.40 ± 0.14
$H\beta$	Hx3	-0.45 ± 0.05	1.15 ± 0.03	-1.2 ± 1.4	26.9 ± 3.5	136.2 ± 18.6	0.13 ± 0.04	0.17 ± 0.04	0.14 ± 0.08
$H\gamma$	Hx3	-0.38 ± 0.08	1.13 ± 0.05	-2.3 ± 2.7	23.0 ± 5.8	135.0 ± 34.8	0.09 ± 0.05	0.07 ± 0.09	0.08 ± 0.04
CaII	Cx1	-0.56 ± 0.05	1.18 ± 0.03	-1.9 ± 0.6	12.7 ± 1.4	157.7 ± 8.2	0.16 ± 0.04	0.14 ± 0.04	0.11 ± 0.09
NaI	Hx3	-0.34 ± 0.05	1.11 ± 0.03	-3.1 ± 0.9	12.7 ± 2.8	182.5 ± 14.3	0.05 ± 0.03	0.08 ± 0.03	0.07 ± 0.05
	Cx1	-0.29 ± 0.04	1.10 ± 0.03	-3.2 ± 0.7	11.1 ± 1.7	176.6 ± 11.7	0.04 ± 0.03	0.03 ± 0.04	0.08 ± 0.08
FeII	Hx3	-0.33 ± 0.05	1.11 ± 0.03	-2.8 ± 0.8	10.0 ± 1.7	174.4 ± 14.0	0.04 ± 0.03	0.01 ± 0.03	0.04 ± 0.04

Notes. Hx3 corresponds to the analysis of three HARPS-N nights combined and Cx1 refers to the analysis of the unique transit observed with CARMENES. $(*)$ Absorption depth measured in the transmission spectrum for a $1.5\text{ \AA}$ passband. $(\ddagger)$ Absorption depth measured in the transmission light curve for a $1.5\text{ \AA}$ passband. $(\P)$ Centre of the EMC distribution was computed for a $1.5\text{ \AA}$ passband.

Fig. 2. *Top:* $FWHM$ values vs. $R_\lambda(h)$. *Bottom:* v_{wind} values vs. $R_\lambda(h)$. The measurements obtained with HARPS-N data are shown with dots, while those obtained with CARMENES data are marked with stars. The horizontal blue dashed line shows the mean v_{wind} value at $-2.4 \pm 1.0\text{ km s}^{-1}$. All values were extracted from Table 2.

Table 3. Best fit parameters and 1- σ error bars from the MCMC analysis.

		h [%]	$FWHM$ [km s ⁻¹]	K_p [km s ⁻¹]	v_{wind} [km s ⁻¹]	R_λ (*) [R_p]	R_λ (§) [R_p]
$H\beta$	HARPS-N 1	-0.20 ^{+0.16} _{-0.19}	20.4 ^{+22.2} _{-13.0}	110.6 ^{+85.5} _{-71.7}	-5.1 ^{+8.0} _{-6.6}	1.12 ^{+0.04} _{-0.03}	1.07 ^{+0.11} _{-0.13}
	HARPS-N 2	-0.57 ^{+0.07} _{-0.08}	22.8 ^{+3.9} _{-3.6}	131.8 ^{+19.3} _{-18.4}	-1.5 ^{+1.6} _{-1.7}	0.89 ^{+0.03} _{-0.03}	1.19 ^{+0.04} _{-0.05}
	HARPS-N 3	-0.38 ^{+0.08} _{-0.09}	33.5 ^{+9.7} _{-8.3}	166.3 ^{+55.6} _{-43.7}	+4.2 ^{+3.6} _{-3.5}	0.86 ^{+0.03} _{-0.03}	1.13 ^{+0.05} _{-0.06}
	HARPS-Nx3	-0.45 ^{+0.05} _{-0.05}	26.9 ^{+3.7} _{-3.3}	136.2 ^{+18.7} _{-18.5}	-1.2 ^{+1.4} _{-1.5}	0.91 ^{+0.02} _{-0.02}	1.15 ^{+0.03} _{-0.03}
$H\gamma$	HARPS-N 1	-0.29 ^{+0.13} _{-0.26}	40.9 ^{+78.0} _{-21.9}	189.7 ^{+43.7} _{-105.8}	-1.4 ^{+7.2} _{-6.3}	1.01 ^{+0.05} _{-0.05}	1.10 ^{+0.08} _{-0.17}
	HARPS-N 2	-0.43 ^{+0.10} _{-0.12}	23.4 ^{+7.8} _{-6.4}	101.5 ^{+43.7} _{-105.8}	-4.0 ^{+2.8} _{-3.0}	0.86 ^{+0.03} _{-0.03}	1.15 ^{+0.07} _{-0.08}
	HARPS-N 3	-0.28 ^{+0.17} _{-0.23}	25.6 ^{+25.8} _{-15.5}	104.6 ^{+81.0} _{-65.8}	-2.8 ^{+8.5} _{-7.5}	0.78 ^{+0.05} _{-0.05}	1.13 ^{+0.05} _{-0.06}
	HARPS-Nx3	-0.38 ^{+0.08} _{-0.09}	23.0 ^{+6.2} _{-5.5}	135.0 ^{+34.1} _{-35.6}	-2.3 ^{+2.5} _{-3.0}	0.85 ^{+0.02} _{-0.03}	1.13 ^{+0.05} _{-0.06}
$NaI D_2$	HARPS-N 1	-0.37 ^{+0.14} _{-0.16}	8.2 ^{+5.5} _{-3.0}	151.4 ^{+35.4} _{-36.4}	-0.9 ^{+2.5} _{-2.6}	0.92 ^{+0.05} _{-0.05}	1.13 ^{+0.09} _{-0.10}
	HARPS-N 2	-0.12 ^{+0.02} _{-0.02}	133.6 ^{+3.7} _{-8.3}	137.1 ^{+78.3} _{-91.1}	1.4 ^{+9.0} _{-9.6}	0.97 ^{+0.04} _{-0.04}	1.04 ^{+0.01} _{-0.01}
	HARPS-N 3	-0.28 ^{+0.08} _{-0.10}	20.6 ^{+11.8} _{-8.6}	103.3 ^{+26.8} _{-26.4}	-1.3 ^{+2.2} _{-2.4}	0.94 ^{+0.04} _{-0.04}	1.10 ^{+0.05} _{-0.07}
	HARPS-Nx3	-0.33 ^{+0.06} _{-0.06}	12.3 ^{+3.7} _{-2.7}	171.1 ^{+15.2} _{-12.8}	-2.4 ^{+0.9} _{-0.9}	0.94 ^{+0.03} _{-0.03}	1.11 ^{+0.04} _{-0.04}
	CARMENES 1	-0.29 ^{+0.04} _{-0.04}	11.6 ^{+1.8} _{-1.6}	176.5 ^{+12.8} _{-12.3}	-2.8 ^{+0.8} _{-0.8}	0.91 ^{+0.02} _{-0.02}	1.10 ^{+0.03} _{-0.03}
$NaI D_1$	HARPS-N 1	-0.29 ^{+0.11} _{-0.11}	14.1 ^{+7.1} _{-4.4}	177.8 ^{+39.9} _{-41.4}	-2.2 ^{+2.4} _{-2.4}	0.97 ^{+0.06} _{-0.05}	1.10 ^{+0.07} _{-0.07}
	HARPS-N 2	-0.12 ^{+0.01} _{-0.02}	132.8 ^{+4.4} _{-10.4}	143.3 ^{+75.2} _{-93.1}	-7.4 ^{+8.6} _{-5.7}	0.90 ^{+0.04} _{-0.03}	1.04 ^{+0.01} _{-0.01}
	HARPS-N 3	-0.09 ^{+0.02} _{-0.02}	113.3 ^{+17.9} _{-30.2}	196.5 ^{+40.9} _{-79.3}	-6.4 ^{+9.6} _{-6.1}	0.97 ^{+0.04} _{-0.04}	1.03 ^{+0.01} _{-0.02}
	HARPS-Nx3	-0.35 ^{+0.05} _{-0.05}	13.3 ^{+2.6} _{-2.1}	194.0 ^{+15.1} _{-14.4}	-3.9 ^{+0.9} _{-0.9}	0.91 ^{+0.03} _{-0.03}	1.12 ^{+0.03} _{-0.03}
	CARMENES 1	-0.29 ^{+0.04} _{-0.04}	10.9 ^{+1.7} _{-1.4}	176.8 ^{+10.8} _{-10.6}	-3.6 ^{+0.7} _{-0.7}	0.90 ^{+0.02} _{-0.02}	1.10 ^{+0.03} _{-0.03}
$CaII \lambda 8498 \text{ \AA}$	CARMENES 1	-0.52 ^{+0.05} _{-0.05}	12.3 ^{+1.9} _{-1.2}	173.2 ^{+7.8} _{-7.5}	-3.2 ^{+0.6} _{-0.6}	0.87 ^{+0.03} _{-0.03}	1.17 ^{+0.03} _{-0.03}
$CaII \lambda 8542 \text{ \AA}$	CARMENES 1	-0.60 ^{+0.04} _{-0.04}	16.3 ^{+1.4} _{-1.3}	139.2 ^{+8.9} _{-9.2}	-1.3 ^{+0.6} _{-0.6}	1.09 ^{+0.02} _{-0.02}	1.20 ^{+0.03} _{-0.03}
$CaII \lambda 8662 \text{ \AA}$	CARMENES 1	-0.55 ^{+0.06} _{-0.06}	9.6 ^{+1.5} _{-1.3}	160.7 ^{+8.0} _{-7.8}	-1.1 ^{+0.5} _{-0.5}	0.95 ^{+0.02} _{-0.03}	1.18 ^{+0.04} _{-0.04}
$FeII \lambda 5018 \text{ \AA}$	HARPS-Nx3	-0.26 ^{+0.04} _{-0.05}	11.0 ^{+1.8} _{-1.8}	181.9 ^{+18.3} _{-18.7}	-2.7 ^{+1.1} _{-1.1}	1.19 ^{+0.03} _{-0.03}	1.09 ^{+0.03} _{-0.03}
$FeII \lambda 5169 \text{ \AA}$	HARPS-Nx3	-0.47 ^{+0.05} _{-0.05}	11.3 ^{+1.5} _{-1.4}	170.6 ^{+8.3} _{-7.8}	-3.6 ^{+0.5} _{-0.5}	1.18 ^{+0.02} _{-0.02}	1.16 ^{+0.03} _{-0.03}
$FeII \lambda 5316 \text{ \AA}$	HARPS-Nx3	-0.26 ^{+0.05} _{-0.06}	7.8 ^{+2.0} _{-1.5}	170.8 ^{+14.4} _{-16.6}	-2.1 ^{+0.8} _{-0.8}	1.18 ^{+0.03} _{-0.03}	1.09 ^{+0.03} _{-0.04}
	CARMENES 1	-0.55 ^{+0.08} _{-0.09}	14.3 ^{+3.2} _{-2.8}	139.6 ^{+32.3} _{-22.6}	+0.2 ^{+1.7} _{-1.3}	1.24 ^{+0.05} _{-0.06}	1.18 ^{+0.05} _{-0.05}
$MgI \lambda 5173 \text{ \AA}$	HARPS-Nx3	-0.23 ^{+0.03} _{-0.04}	17.8 ^{+3.4} _{-2.7}	159.6 ^{+30.9} _{-23.8}	-0.9 ^{+1.7} _{-1.9}	1.23 ^{+0.02} _{-0.02}	1.08 ^{+0.02} _{-0.02}

Notes. (*)Effective radius value obtained from the best fit model of the CLV and RME effects. (§)Effective radius was calculated considering the absorption value, h , from the best-fit model and assuming a continuum level of $(R_p/R_\star)^2 = 1.382\%$.

Fig. 3. Correlation diagrams of MCMC analysis of the $H\alpha$ line of CARMENES (left) and HARPS-N data analysis (right).

Fig. 4. Correlation diagrams of MCMC analysis of the H β (left) and H γ (right) lines obtained with the HARPS-N data analysis.

Fig. 5. Correlation diagrams of MCMC analysis of the Ca II triplet lines of CARMENES. The Ca II 8498 Å diagram is shown in the top left panel, Ca II 8542 Å is in the top right panel, and 8662 Å is in the bottom panel.

Fig. 6. Correlation diagrams of MCMC analysis of the Na I D2 line of CARMENES (*left*) and HARPS-N data analysis (*right*).

Fig. 7. Correlation diagrams of MCMC analysis of the Na I D1 line of CARMENES (*left*) and HARPS-N data analysis (*right*).

Fig. 8. Correlation diagrams of MCMC analysis of the Fe II triplet lines. The Fe II $\lambda 5018$ Å diagram is shown in the *top left* and Fe II $\lambda 5169$ Å is in the *top right*, both of which result from the HARPS-N combined data analysis. The Fe II $\lambda 5316$ Å diagrams are shown in the *bottom panels*: the HARPS-N analysis is on the *left* and the CARMENES analysis is on the *right*.

Fig. 9. Correlation diagrams of MCMC analysis of the Mg I line at 5173 Å.