MASCARA-3b

A hot Jupiter transiting a bright F7 star in an aligned orbit

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ABSTRACT

We report the discovery of MASCARA-3b, a hot Jupiter orbiting its late, bright (V = 8.33) F-type host every 5.55149 ± 0.00001 days on an almost circular orbit (e = 0.085±0.023). It is the fourth exoplanet discovered with the Multi-site All-Sky CAmeRA (MASCARA), and the first of these which orbits a late-type star. Follow-up spectroscopic measurements were obtained in and outside of transit with the Hertzsprung SONG telescope. Combining the MASCARA photometry and SONG radial velocities reveals a radius and mass of 1.35 ± 0.05 R\textsubscript{Jupiter} and 4.2 ± 0.2 M\textsubscript{Jupiter}. In addition, SONG spectroscopic transit observations were obtained on two separate nights. From analyzing the mean out of transit broadening function we obtain v\textsubscript{sin i} = 20.4 ± 0.4 km s\textsuperscript{-1}. In addition, investigating the Rossiter-McLaughlin effect, as observed in the distortion of the stellar lines directly, we find the projected obliquity to be λ = 10.5 ± 24.9 deg, consistent with alignment.

Key words. Planetary systems – stars: individual: MASCARA-3

1. Introduction

With more than 4000 planets confirmed to date, the field of exoplanets has experienced a huge growth since its beginning two decades ago. This large number of discoveries has in particular been the product of extensive ground- and space-based transit photometry surveys, such as the missions of HAT (Bakos et al. 2004), WASP (Pollacco et al. 2006), CoRoT (Barge et al. 2008), Kepler (Borucki et al. 2010) and K2 (Howell et al. 2014). However, because of saturation limits, these surveys are prevented from monitoring the brightest stars.

Transiting planets orbiting bright stars are important since they offer follow-up opportunities not available for fainter sources, allowing for detailed characterisation of the planets atmosphere and the systems orbital architecture. This includes the detection of e.g. water in the planetary atmosphere through high-resolution transmission spectroscopy (e.g. Snellen et al. 2010) and measurements of its spin-orbit angle through observations of the Rossiter-McLaughlin (RM) effect.

From space, the brightest exoplanet host stars are currently being probed thanks to the launch of TESS (Ricker et al. 2015), while ground-based projects doing the same include KELT (Pepper et al. 2007) and the MASCARA (the Multi-Site All-sky CAmeRA) survey (Talens et al. 2017b). The latter aspires to find close-in transiting giant planets orbiting the bright stars well suited for detailed atmospheric characterisation. This has so far led to the discovery and characterisation of MASCARA-1, MASCARA-2 and MASCARA-4, three hot Jupiters orbiting A-type stars (Talens et al. 2017a, 2018b; Dorval et al. 2019).

In this paper we report the discovery, confirmation and characterisation of MASCARA-3b, the fourth planetary system found through the MASCARA survey. MASCARA-3b is a hot Jupiter with a 5.6 day period, and orbits a bright late F-type star (V = 8.33). In Sec. 2 the discovery observations from MASCARA and the spectroscopic follow-up observations with SONG (Stellar Observation Network Group, Andersen et al. 2014) are described. The analysis and results of the host star are presented in Sec. 3 while Sec. 4 contains the investigation and characterisation of its planet. The results are presented and discussed in Sec. 5.

2. Observations

In this section two different kinds of observations are presented: the MASCARA photometry and the SONG spectroscopy (see Table 1).

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During the final preparations for this paper, we learned of the publication of the discovery of the same planetary system by the KELT-team; KELT-24 (?)

Article number, page 1 of 7
**MASCARA**: The MASCARA survey is described in Talens et al. (2017b). In short, it consists of two instruments: one covering the northern sky at the Observatory del Roque de los Muchachos (La Palma, Spain) and one targeting the southern hemisphere at the European Southern Observatory (La Silla, Chile). Each instrument consists of five wide-field CCD’s, which record images of the local sky throughout the night employing 6.4 sec exposure times. Aperture astrometry is performed on all known stars brighter than \( V = 8.4 \). The light curves are extracted from the raw flux following the procedure described in Talens et al. (2018a), and transit events are searched for using the Box Least-Square (BLS) algorithm of Kovács et al. (2002).

MASCARA-3 has been monitored since early 2015 by the northern instrument, totalling more than 27247 calibrated photometric data points, each consisting of 50 binned 6.4-second measurements (i.e. 320 sec per data point). A frequency analysis was performed on the light curve measurements by computing its BLS periodogram, revealing a peak at a period of 5.55149 days. Phasefolding the light curve using this period, we performed a preliminary analysis on the system, obtaining parameter values useful for spectroscopic follow-up (see Table 2). The resulting phasefolded lightcurve is shown in Fig. 1.

**SONG**: Succeeding the transit detection in the light curve of MASCARA-3, follow-up spectroscopy was executed using the 1 meter Hertzsprung SONG telescope (Andersen et al. 2017) at Observatory del Teide (Tenerife, Spain). The observations were done in order to validate and characterise the planetary system. The telescope is equipped with a high-dispersion echelle spectrograph which covers the wavelength range 4400 – 6900 Å. A total of 92 spectra were obtained between April 2018 and April 2019, employing a slit width of 1.2 arcsec resulting in a resolution of \( R \sim 77,000 \). The exposure times had been varied between 600 and 1800 sec. We used longer exposure times out of transits and shorter exposure times during transits to reduce phase smearing. 45 of the observations were gathered during two planetary transits occurring on May 29, 2018 and November 28, 2018. For the first transit our spectroscopic observations cover the entire transit. However, due to bad weather only a single spectrum was taken out of transit. On the second night we obtained a partial transit and post egress spectra.

As we analyze the RM effect in this system using the Doppler Tomography technique we did not use an iodine cell for observations taken during transit nights, but sandwiched each observation with ThAr exposures for wavelength calibration. From these spectra we obtained cross-correlation functions (CCFs) and Broadening Functions (BFs) Rucinski (2002). Spectra not taken during transit nights were obtained with an iodine cell inserted into the light path.

The spectra and radial velocity (RV) extraction was performed following Grundahl et al. (2017). The RV data points are estimated to have internal instrumental uncertainties of \( \sim 31 \) m sec\(^{-1}\). The resulting RVs and their uncertainties are listed in Table A.1.

**3. Stellar characterisation**

We determined the spectroscopic effective temperature \( T_{\text{eff}} \) = 6415 ± 110 K and metallicity \([\text{Fe/H}] = 0.09 \pm 0.09\) dex using SpecMatch-emp (Yee et al. 2017), classifying it as an F7 star. SpecMatch-emp compares the observed spectrum with an empirical spectral library of well-characterised stars. Using the Bayesian Stellar Algorithm BASTA (Silva Aguirre et al. 2015) with a grid of BaSTI isochrones (Pietrinferni et al. 2004; Hidalgo et al. 2018), we combined the spectroscopically derived \( T_{\text{eff}} \) and \([\text{Fe/H}] \) with the 2MASS \( JHK \) magnitudes (see Table 1) and Gaia DR2 parallax (\( \pi = 10.33 \pm 0.11 \) mas) to obtain a final set of stellar parameters. Given the proximity of the star we assumed zero extinction along the line of sight. This way we derived a stellar mass \( M_\star = 1.30^{+0.04}_{-0.03} M_\odot \), radius \( R_\star = 1.52^{+0.03}_{-0.02} R_\odot \), and stellar age \( = 2.8^{+0.5}_{-0.6} \) Gyr.

**4. Photometric and spectroscopic analysis**

The overall analysis of the photometry and RV data is done in a similar fashion as for MASCARA-1b (Talens et al. 2017a) and...
Table 3. Literature and best-fit parameters for the stellar analysis of MASCARA-3. Sources: *Extracted from Gaia DR2 (Gaia Collaboration et al. 2018) https://gea.esac.esa.int/archive/). †Parameters from 2MASS (Cutri et al. 2003). ‡From the Icyho catalogue (Høg et al. 2000). The remaining parameter values are from this work.

| Parameter | Value |
|-----------|-------|
| Identifiers | HD 93148 |
| Spectral type | F7 |
| Right ascension, $\alpha$ (J2000.0)* | $10^5$ $47^\circ$ $38.351''$ |
| Declination, $\delta$ (J2000.0)* | $+71^\circ$ $39'$. $21.16''$ |
| Parallax, $\pi$ (mas)* | 10.3±0.1 |
| Distance (pc)* | 97±1 |
| V-band mag., $v^T$ | 8.33±0.01 |
| J-band mag., $j^T$ | 7.41±0.02 |
| H-band mag., $h^T$ | 7.20±0.04 |
| K-band mag., $K^T$ | 7.15±0.02 |
| Effective temperature, $T_{\text{eff}}$ (K) | 6415 ± 110 |
| Surface gravity log $g_\star$ (cgs) | 4.18±0.01 |
| Metallicity, [Fe/H] (dex) | 0.09 ± 0.09 |
| Age (Gyr) | 2.8±0.16 |
| Stellar mass, $M_\star$ ($M_\odot$) | 1.30±0.04 |
| Stellar radius, $R_\star$ ($R_\odot$) | 1.52±0.03 |
| Stellar density, $\rho_\star$ (g cm$^{-3}$) | 0.52±0.02 |

MASCARA-2b (Talens et al. 2018b) and is outlined in the following section. Given the transit phase coverage and low Signal-to-Noise Ratio (SNR) of the RM detection we modified our analysis for that this data set accordingly. We give details on that in sections 4.2.1 and 4.2.2.

4.1. Joint photometric and RV analysis

The binned, phasefolded MASCARA light curve is modelled employing the model by Mandel & Agol (2002), using a quadratic limb-darkening law. The free parameters for the transit model are the orbital period ($P$), a particular mid-transit time ($T_0$), the semi-major axis scaled by the stellar radius ($\alpha/R_\star$), the scaled planetary radius ($R_p/R_\star$), the orbital inclination ($i$), the eccentricity ($e$) and the argument of periapsis ($\omega$) and finally the quadratic limb-darkening parameters ($c_1$) and ($c_2$). For efficiency, the inclination, eccentricity and argument of periapsis are parameterized through cos $i$, $\sqrt{\cos i}$ and $\sqrt{\sin i}$.

For the modelling of the RV observations, we only use spectra obtained with an iodine cell insert in the light path (Table A1). This excludes data taken during transit nights. The RV data is compared to a Keplerian model where the stellar RV variations are caused by the transiting object. The additional parameters needed to describe the RV data are the RV semi-amplitude ($K$) and a linear offset in RV ($\gamma$). In addition, we allow for a linear drift of the RV data points, $\gamma$, caused by e.g. a long-period unseen companion.

To characterise the planetary system we jointly model the light curve and the RVs. Since we fit to the phasefolded light curve, we impose Gaussian priors $P = 5.55149 \pm 0.00002$ days and $T_0 = 2458268.455^{+0.002}_{-0.003}$ BJD retrieved from the photometric analysis described in Section 2. In addition we impose Gaussian priors of $c_1 = 0.3797$ and $c_2 = 0.2998$ (Caret & Bloemen 2011; Eastman et al. 2013) with a conservative uncertainties of 0.1. Furthermore, by using the spectroscopic value of the density $\rho_\star = 0.52^{+0.04}_{-0.03}$ g cm$^{-3}$ as a prior, we can constrain the orbital shape and orientation (see e.g. Van Eylen & Albrecht 2015 and references therein).

The log-likelihood for each data set is given as

$$\ln L = \frac{1}{2} \sum_{i=1}^{N} \ln \left( \frac{-\ln \left( \sigma_i^2 + \sigma_{p,i}^2 \right)}{\sigma_i^2 + \sigma_{j,i}^2} \right)$$

with $O_i$ and $C_i$ being the $i$'th of $N$ data and model points in each data set. For the two data sets we introduce two jitter terms $\sigma_{p,i}$ and $\sigma_{j,i}$ to capture any unaccounted noise. These jitter terms are added in quadrature to the internal errors $\sigma_i$ when calculating the maximum likelihood. The total log-likelihood is the sum of eq. 1 for the photometry and RV together with an additional likelihood term accounting for priors.

The posterior distribution of the parameters are sampled through emcee, an MCMC multi-walker Python package (Foreman-Mackey et al. 2013). We initialize 200 walkers close to the maximum likelihood. They are evaluated for 10000 steps, with a burn-in of 5000 steps which we disregard. By visually inspecting trace plots we have checked that the solutions have converged at that point. In Table 4 we report the maximum likelihood values of the MCMC sampling. The quoted uncertainty intervals represent the range that excludes 15.85% of the values on each side of the posterior distribution and encompass 68.3% of the probability. Fig 2 and 3 displays the data and best-fit models for the joint analysis of the light curve and the RVs.

4.2. Analyzing the stellar absorption line

Modelling the stellar absorption lines is carried out in a similar way as was done in Albrecht et al. (2007) and Albrecht et al. (2013). However we modified our approach of comparing the model to the data. We did this because we found that BFs created from our data had a too low SNR to be useful in determining $\lambda$ through analysis of the RM effect. Nevertheless they more faithfully represent the width of the stellar absorption lines than the CCFs which have large "wings" (see Fig. 4). We have not been able to determine the exact underlying reason for this, but we suspect that the low SNR in the spectra is to blame. Determining the correct continuum level in low SNR high resolution spectra is extremely difficult. For the case of MASCARA-3, this problem is enlarged due to the fast stellar rotation and therefore wide
stellar absorption lines. A mismatch in the continuum would lead to a low SNR in the derived BF. The same mismatch in the continuum correction would lead to enlarged "wings" in the CCFs. We therefore first obtained a measure for $\sin i_*$ by comparing our out of transit stellar line model to an average out of transit BF. We then analyze the "planet shadow" in the transit data.

Concerning the model for comparison to the out of transit and in transit data we did the following: We created a 201x201 grid containing a pixelated model of the stellar disk. The brightness of each pixel on the stellar disk is scaled according to a quadratic limb-darkening law with the parameters $c_{1,3}$ and $c_{2,3}$ and set to zero outside the stellar disk. Each pixel is also assigned a radial velocity assuming solid body rotation and a particular projected stellar rotation speed, $v\sin i_*$. The RVs of each pixel are further modified following the model for turbulent stellar rotation as described in Gray (2005). This model has two terms. A micro-turbulence term modelled by a convolution with a Gaussian, which $\sigma$-width we describe here with the parameter $\beta$. The second term in this model encompasses radial and tangential macro turbulence surface motion. Its $\sigma$-width we assign the parameter $\zeta$. The modelled stellar absorption line model is then obtained by disk integration. Finally the Gaussian convolution also includes the Point Spread Function (PSF) of the spectrograph added in quadrature. Because of the low SNR of our spectra we do not include convective blueshift in our model.

### 4.2.1. Out of transit stellar absorption line

To measure $v\sin i_*$ we compared our out of transit line model to the BFs taken out of transit. We used only data from the second transit night as little data was obtained out of transit during the first transit night (Fig. 5). In addition to the five model parameters, $c_{1,3}$, $c_{2,3}$, $v\sin i_*$, $\beta$, and $\zeta$, we also vary a jitter term $\sigma_{jitter}$ during the fitting routine. We impose Gaussian priors of $\beta = 2.7$ km sec$^{-1}$ (Coelho et al. 2005) and $\zeta = 6.1$ km sec$^{-1}$ (Gray 1984), both with uncertainty widths of 0.5 km sec$^{-1}$. The best-fit parameters are again found by maximizing the log-likelihood from eq. 1 using emcee in the same way as in Sec. 4.1. The best-fit parameters are given in Table 4, while the data and best-fit model are shown in Fig. 4.

### 4.2.2. The Doppler shadow

We observed spectroscopic transits during the nights 29-5-2018 and 28-11-2018. This was done, in order to validate the companion being a planet orbiting the host star and to obtain the projected spin-orbit angle (or projected obliquity, $\lambda$) of the system.

### Table 4. The best-fitting and derived stellar, planetary and system parameters for MASCARA-3. The parameters are extracted from the joint analysis on the photometry and RV (Sec. 4.1), the analysis on the mean out of transit BF (Sec. 4.2.1) and the analysis on the contour of the shifted and binned Doppler shadow residuals (Sec. 4.2.2).

| Parameter | Value | Section |
|-----------|-------|---------|
| Quadratic limb darkening (MASCARA), $c_{1,2}$ | $(0.40 \pm 0.07, 0.31 \pm 0.07)$ | 4.1 |
| Systemic velocity, $v$ (km s$^{-1}$) | $-5.62 \pm 0.01$ | 4.1 |
| Linear trend in RV, $\gamma$ (m s$^{-1}$ yr$^{-1}$) | $-0.037 \pm 0.029$ | 4.1 |
| Orbital period, $P$ (days) | $5.51949 \pm 0.00001$ | 4.1 |
| Time of mid-transit, $T_c$ (BJD) | $2458268.455 \pm 0.002$ | 4.1 |
| Scaled planetary radius, $R_P/R_*$ | $0.091^{+0.002}_{-0.003}$ | 4.1 |
| Scaled orbital distance, $a/R_*$ | $9.5 \pm 0.16$ | 4.1 |
| RV semi-amplitude, $K_*$ (m s$^{-1}$) | $40 \pm 12$ | 4.1 |
| $\sqrt{\sin i}$ | $0.19^{+0.07}_{-0.10}$ | 4.1 |
| $\cos \omega$ | $0.21 \pm 0.04$ | 4.1 |
| $\sin i$ | $0.034^{+0.012}_{-0.014}$ | 4.1 |
| Jitter term phot., $\sigma_{jitter}$ | $0.0021 \pm 0.0001$ | 4.1 |
| Jitter term RV, $\sigma_{jitter, RV}$ (km s$^{-1}$) | $0.050 \pm 0.08$ | 4.1 |
| Quadratic limb darkening (SONG), $c_{1,2}$ | $(0.66 \pm 0.09, 0.40 \pm 0.09)$ | 4.2.1 |
| Microturbulence, $\beta$ (km s$^{-1}$) | $4.3 \pm 0.6$ | 4.2.1 |
| Macroturbulence, $\zeta$ (km s$^{-1}$) | $9.4 \pm 0.4$ | 4.2.1 |
| Proj. rotation speed BF, $v\sin i_*$ (km s$^{-1}$) | $20.4 \pm 0.4$ | 4.2.2 |
| Jitter term RM out of transit, $\sigma_{jitter, out}$ (m s$^{-1}$) | $0.003 \pm 0.002$ | 4.2.1 |
| Proj. rotation speed contour, $v\sin i_*$ (km s$^{-1}$) | $20.3 \pm 8.1$ | 4.2.2 |
| Projected obliquity, $\lambda$ (deg) | $10.5 \pm 24.9$ | 4.2.2 |
| Contour rotation $f$ (deg) | $-4.0$ | 4.2.2 |
| Contour offset $f$ | $0.295$ | 4.2.2 |
| Contour scaling $b$ | $0.21$ | 4.2.2 |

### Derived parameters

| Parameter | Value |
|-----------|-------|
| Orbital eccentricity, $e$ | $0.085^{+0.003}_{-0.002}$ |
| Argument of periastron, $\omega$ (deg) | $41^{+13}_{-20}$ |
| Orbital inclination, $i$ (deg) | $88.1_{-7.7}^{+8.8}$ |
| Impact parameter, $b$ | $0.32 \pm 0.01$ |
| Total transit duration, $T_{trans}$ (hr) | $4.68 \pm 0.09$ |
| Full transit duration, $T_{T} (hr)$ | $3.81 \pm 0.07$ |
| Semi-major axis, $a$ (au) | $0.067 \pm 0.002$ |
| Planetary mass, $M_p$ (M$\text{Jup}$) | $4.2 \pm 0.2$ |
| Planetary radius, $R_p$ (R$\text{Jup}$) | $1.35 \pm 0.05$ |
| Planetary mean density, $\rho_p$ (g cm$^{-3}$) | $2.3 \pm 0.3$ |
| Equilibrium temperature, $T_{eq}$ (K) | $1473 \pm 28$ |

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**Fig. 3.** The RV data from the SONG telescope (grey) with the best-fit keplerian model (black) from the joint photometric and RV analysis. The data is plotted as a function of time (left) and phasefolded (right), to highlight the fact that we allowed for the possibility of a linear trend in the RV. In the panel on the right side the best fitting RV trend was removed from the data and model. The best-fit parameters are displayed in Table 4. The bottom plot shows the residuals.
During transit, the planet will block some of the star, de-
forming the absorption line by reducing the amount of blue- or
redshifted light visible to the observer at a particular phase of a
transit. Subtracting the distorted in-transit absorption lines to
the out of transit line will therefore reveal the planetary "shadow,"
cast onto the rotating stellar photosphere. For solid body rotation
out of transit line will therefore reveal the planetary "shadow"
transit. Subtracting the distorted in-transit absorption lines to
the mean out of transit CCF, which erroneously leads to an enlarged
value as our final result we do prefer the

\begin{equation}
\theta = \sin \phi = \frac{\sin \psi}{\sin \lambda}
\end{equation}

5. Discussion and Conclusions

From the joint photometry and RV analysis we obtain a planetary
mass of $4.2 \pm 0.2 \, M_{\text{Jup}}$ and a planetary radius of $1.35 \pm 0.05 \, R_{\text{Jup}}$.

The planet revolves around its host star on an almost circular or-
bit ($e = 0.085^{+0.023}_{-0.022}$) every 5.55149 $\pm$ 0.00001 days at a distance
of 0.067 $\pm$ 0.002 au, making MASCARA-3b a hot Jupiter. With
an incident flux of $F = (10.6 \pm 0.9) \times 10^6 \text{ erg s}^{-1} \text{ cm}^{-2}$ above the
inflation threshold of $F = 2 \times 10^6 \text{ erg s}^{-1} \text{ cm}^{-2}$ [Demory & Sea-
ger[2011], the planet might be affected by inflation mechanisms,
despite having a mean density above that of Jupiter.

It is still unclear whether hot Jupiters primarily originate
from High Eccentricity Migration (HEM) or disk migration (for
a review, see [Dawson & Johnson[2018]). The former process
would lead to at least occasionally large obliquities while the lat-
ter process would lead to low obliquities, assuming good align-
ment between stellar spin and angular momentum of the proto-
planetary disks, but see also ?. However the interpretation of hot
Jupiter obliquities might be more complicated than originally
thought. This is because tidal interactions might have aligned
the stellar spin and the orbital angular momentum in some of
the systems, in particular in systems where the host stars have a con-
vective envelope, leading to fast alignment of the planets orbital
spin with the stellar rotation [Winn et al[2010], Albrecht et al.

With an effective temperature of $T_{\text{eff}} = 6415 \pm 110 \, \text{K}$,
MASCARA-3 will have a relatively slow alignment timescale
for a hot Jupiter of its mass and distance. It is also interesting
to note that the orbital eccentricity suggests a near circular orbit.
MASCARA-3b appears to belong to a dynamically cold popu-
lation consistent with an arrival at its current orbit via disk mi-
igration instead of HEM. Consistent with this picture is that we
have not fund a long term RV trend which would indicate the
presence of a third body in the system, that could have initiated
HEM migrations via a scatter event or secular dynamics, like
Kozai-Lidov cycles. However the time line of our observations
is to short to exclude such a body.

While finalizing the manuscript we learned of another pa-
er paper reporting the discovery of this planet-star system published
by the KELT team. Though no observations or analyses were
shared, the planet and system parameters from our papers are
for the most part in agreement. The only major difference is the
RV semi-amplitude, and thereby the derived planetary mass.

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(MLA). The Gaia mission website is https://cosmos.esa.int/gaia. The
Gaia archive website is https://archives.esac.esa.int/gaia

![Figure 4](image-url). The mean out of transit BF (grey) with the best fitting stellar
absorption line model (black). For comparison the dashed line shows
the mean out of transit CCF, which erroneously leads to an enlarged
line-width due to its "wings," which we assume are caused by a none
perfect normalization of the low SNR spectra, see text.
The spectroscopic transit of MASCARA-3 observed on the night of 29-05-2018 (left) and 28-11-2018 (right). Both plots show the observed CCFs, with the subtraction of the mean out of transit CCF obtained from the second night. Before subtraction, these CCFs are scaled and offset to their model-counterpart in intensity (all CCFs) and scaled in velocity-space (in-transit CCFs), in order to account for uneven normalisation due to differences in flux-levels and PSF changes. The vertical dashed lines mark the best-fit value of the transit ingress, mid-transit time and egress.

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Fig. 5. The enhancement (v sin i ⋆, λ) grid together with the best-fit 1σ 2D Gaussian model (dashed). For each (v sin i ⋆, λ) pair the grid values are constructed by shifting the model and shadow bump a corresponding amount, such that the model shadow bump is centered at zero. This is followed by collapsing the shifted data shadow in intensity space. The contour signal at a specific (v sin i ⋆, λ) value is then the resulting value of the collapsed, shifted data shadow at a velocity of zero.
Appendix A: Extra material

Table A.1. Radial velocities at different times for MASCARA-3 using the SONG telescope. We list the barycentric time of mid-exposure and the RVs corrected for barycentric motion. All spectra were taken with the iodine cell as reference. The instrumental uncertainty ($\sigma_{RV}$) is estimated to be 31.1 m s$^{-1}$. However the data appears to present an additional jitter term (see Table 4).

| Time (BJD)  | RV+6000 (m s$^{-1}$) |
|------------|------------------------|
| 2458223.357685 | 621.2                  |
| 2458224.382018 | 183.5                  |
| 2458225.434460 | 69.6                   |
| 2458233.607846 | 727.4                  |
| 2458234.418452 | 764.2                  |
| 2458235.720058 | 251.5                  |
| 2458236.641036 | 17.4                   |
| 2458237.678446 | 141.1                  |
| 2458238.692052 | 598.9                  |
| 2458241.674223 | -82.6                  |
| 2458243.368995 | 286.2                  |
| 2458245.410918 | 814.5                  |
| 2458246.571993 | 230.8                  |
| 2458247.398019 | -11.4                  |
| 2458248.368253 | 97.5                   |
| 2458249.365280 | 466.3                  |
| 2458250.368275 | 847.5                  |
| 2458250.681785 | 833.6                  |
| 2458251.366037 | 694.6                  |
| 2458251.666389 | 480.9                  |
| 2458252.366480 | 194.1                  |
| 2458253.365122 | 140.3                  |
| 2458254.365100 | 242.9                  |
| 2458255.374490 | 606.8                  |
| 2458256.384282 | 806.4                  |
| 2458257.382395 | 327.3                  |
| 2458259.383303 | 3.4                    |
| 2458263.567251 | 141.9                  |
| 2458265.589542 | 280.1                  |
| 2458267.372280 | 799.4                  |
| 2458268.609046 | 305.9                  |
| 2458270.572919 | 4.5                    |
| 2458274.379165 | 175.1                  |
| 2458280.423224 | 17.4                   |
| 2458283.600292 | 812.6                  |
| 2458418.763646 | 151.7                  |
| 2458426.556824 | 203.5                  |
| 2458434.627715 | 647.1                  |
| 2458439.611331 | 705.5                  |
| 2458448.692687 | 279.8                  |
| 2458449.708606 | 654.5                  |
| 2458450.690659 | 690.4                  |
| 2458453.742034 | 73.5                   |
| 2458454.745732 | 478.9                  |
| 2458586.621310 | 30.9                   |
| 2458594.703421 | 722.2                  |
| 2458598.446201 | 155.2                  |