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# Overcoming stellar activity in the transit and eclipse-timing variation analysis of WASP-52 b

## Updated orbital and system parameters, and ephemerides

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**Abstract.** Precise ephemeris and system parameters of transiting exoplanets are critical parameters for efficient scheduling of transiting exoplanet observations from space missions like James Webb Space Telescope, Pandora SmallSat, and ARIEL. We present updated system parameters and further investigate previously suggested long-term transit timing variation for the transiting hot Jupiter WASP-52 b, orbiting an active star of type K2V, known for displaying spot crossing events during transit observations. In this work, we performed a homogeneous analysis to refine the ephemeris and system paramaters for WASP-52 b, followed by a transit-timing variation analysis in search for period variations. We employed an updated version of the EXOTIC code and dynamic nested sampling to perform a joint fit of photometric and radial velocity observations, and strategies to mitigate the contamination from stellar activity present in the data. The dataset spans 10 years of transit monitoring from 105 ground-based observations by citizen science contributors employing sub-meter telescopes, together with transit and eclipse light curves from space missions, and archival ephemerides and radial velocity data from the literature. Our preliminary results show no signs of the previously suggested orbital decay for the exoplanet WASP-52 b, but we managed to confirm the presence of a third body in the planetary system, besides achieving more precise orbital and system parameters, and projected ephemerides.

**Resumo.** Parâmetros e efemérides precisos de exoplanetas em trânsito são informações críticas para o agendamento eficiente de observações de trânsitos de exoplanetas por missões espaciais como as James Webb Space Telescope (JWST), Pandora SmallSat e ARIEL. Apresentamos aqui efemérides e parâmetros atualizados para o sistema WASP-52, investigando mais a fundo variações do tempo de trânsito de longo prazo que foram sugeridas previamente para o Júpiter quente WASP-52 b, transitando uma estrela ativa de tipo K2V, conhecido por apresentar eventos de cruzamento de manchas estelares durante observações de seu trânsito. Neste trabalho, realizamos uma análise homogênea para refinar a efemérides e os parâmetros do sistema para WASP-52 b, seguida por uma análise de variação do tempo do trânsito em busca por variações do período orbital. Empregamos aqui uma versão atualizada do código EXOTIC e o algoritmo 'nested sampling' para realizar um ajuste conjunto de observações fotométricas e de velocidade radial, além de estratégias para mitigar a contaminação pela atividade estelar presente nos dados. O conjunto de dados abrange 10 anos de monitorações por 105 observações de solo por cientistas cidadãos contribuidores dos projetos Exoplanet Watch da NASA, ExoClock da ESA e Exoplanet Transit Database (ETD) da Sociedade Astronômica Tcheca (CAS), empregando telescópios sub-métricos. Conjuntamente, utilizamos curvas de luz de trânsitos e eclipses de missões espaciais, e dados de arquivos de efemérides e velocidades radiais da literatura na nossa análise. Nossos resultados preliminares não indicam sinais anteriormente reportados sugerindo um decaimento orbital para o exoplaneta WASP-52 b, mas permitem confirmar a presença de um terceiro corpo no sistema planetário, além de atingir parâmetros mais precisos para a órbita e o sistema, e para efemérides projetada.

**Keywords.** (Stars:) starspots – Stars: activity – Stars: planetary systems

### 1. Introduction

WASP-52 b is a hot-Jupiter exoplanet, orbiting a K2V-type star. In its discovery paper, Hébrard et al. (2013) identified signals of a possible +40 m s-1 deviation for the period of 15 months in the radial velocity (RV) data with the SOPHIE and CORALIE spectrogtaphs, pointing to a possible presence of a massive component pulling the system towards us. Also, later, Salisbury, Kolb, Norton, Haswell (2021) identified signals of a possible orbital decay, using ground-based data and ephemerides from the literature, which would turn WASP-52 b into a very interesting target, since it is one of the few hot-Jupiters tidaly locked to its star.

Currently, there are more than 10 years of ground-based photometric observations in the citizen science databases NASA Exoplanet Watch, Exoplanet Transit Database (ETD), and ExoClock Project (Kokori et al. 2023), more recent RV observations with the HARPS spectrograph, as well as space observations from the NASA missions James Web Space Telescope (JWST), Hubble Space Telescope (HST), Spitzer, and TESS, besides many ephemerides data already published in the literature.

The star WASP-52 is known to be active, incurring in the presence of 'bumps' in the light curve data during transits of its exoplanet, due to the contamination from starpots in its surface (Fournier-Tondreau et al. 2025). In gereral, the spot occultations by the transiting exoplanet close to mid-transit could affect the determination of the transit depth, mimicking transit depth variations (TDVs), whereas those close to the transit ingress/egress-time could affect the determination of the contact points, mimicking transit duration variations (TDVs).

### 2. Observations

Here we employed the 10 years of ground-based transits observations of WASP-52 b available on the NASA Exoplanet Watch/AAVSO Exoplanet Database (154 transits), the Exoplanet Transit Database (ETD) (70 transits), the ExoClock project (39 transits), and from the POST and OpenScience observatories (Salisbury, Kolb, Norton, Haswell 2021). We also aggregated RV data from SOPHIE and CORALIE instruments (Hébrard et al. 2013), and HARPS RVBank v2 (Perdelwitz et al. 2024) for the HARPS instrument, together with space observations from JWST NIRISS/SOSSo1 GR700XD (1 transit, GTO 1201), HST STIS/G430L and G750L (3 transits, GO-14767), Spitzer IRAC/CH1 and CH2 (3 phase curves, Program 13038), JWST NIRSpec/PRISM Clear (1 eclipse, GTO 1224), and mid-transit times from the literature (7 transits).

## 3. Results

First, we performed a radial verlocity (RV) analysis using the packages `kepmodel` (Delisle, Ségransan, Buchschacher, Alesina 2016) for the RV model, and `s+leaf` (Delisle, Hara, Ségransan 2020; Delisle, Unger, Hara, Ségransan 2022) for the stellar jitter in order to account for the stellar variability, and an additional trend model, fitting the model using the Dynamic Nested Sampling algorithm implemented by the package `Ultranest` (Buchner 2021) (see Figure 1):

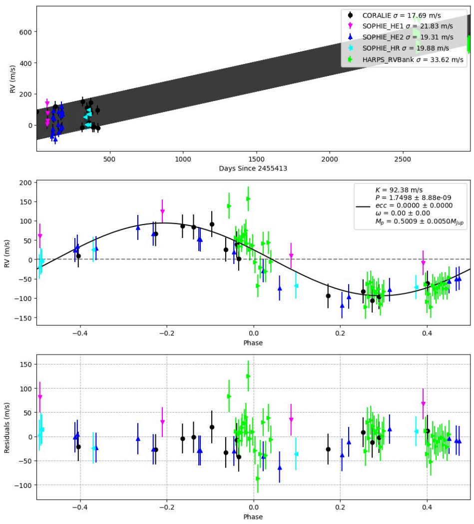


**Figure 1.** Top: The time series subplot with the RV measurements and trended best fit model (Model *trend*). Middle: Phase-folded subplot with the RV curve for WASP-52 b and the best fit model parameters. Bottom: Phase-folded subplot with the RV residuals after removing the contribution for the planetary orbit. The residuals give us numerical insight that the observations match the predicted model. The standard deviation of the residuals is listed in the legend of the top subplot for each data set.

Next, we homogeneized the photometric data refitting the data and checking for stellar contamination via 3-sigma cutout based on the resulting parameters, and performed a joint fit of the RV data together with the transit, eclipse and ephemeris data using the software EXOplanet Transit Interpretation Code (`EXOTIC`) (Zellem et al. 2023) and the package `Ultranest`. And, lastly, the O-C analysis was performed for linear and quadratic ephemerides models, also using (`EXOTIC`) and Dynamic Nested Sampling, with outlier detection using a Mixture Model (Hogg, Bovy, Lang 2010), and the model selection via Bayesian Information Criteria (BIC), in favor of the linear model (see Figure 2).

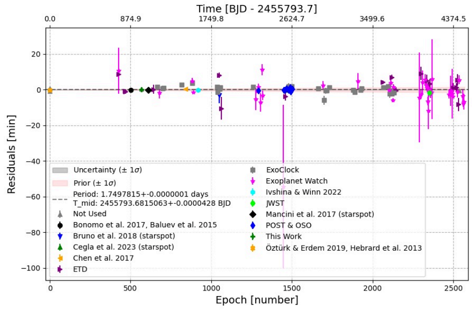


**Figure 2.** O-C plot for mid-transits of WASP-52 b considering a linear model. The residuals are shown in minutes and represent the difference between the observed and calculated mid-transit times based on a fixed linear ephemeris. The grey bar denotes a $1\sigma$ uncertainty. The pink shared area indicates the propagated uncertainty of the posterior of the prior ephemeris incorporating the updates from the model. The dashed black line represent the linear ephemeris model. The narrow distribution of residuals around the non-linear ephemeris model validates the high precision of the updated orbital parameters for this model. The transit mid-times estimated from Kokori et al. (2023) and from Exoplanet Watch on 30/Oct/2023 are displayed just for comparison.

## 4. Conclusions

This reserach consists on to the most comprehensive analysis of the exoplanet WASP-52 b, containing more than 100 light curves from transit and eclipse observations from many telescopes on the ground and in space, besides radial velocity (RV) data from multiple instruments, and ephemerides from the literature. Such diversity of data sources required a previous data homogenization step, as well as the adequate treatment for the removal of strongly contaminated data from the stellar activity and from systematic errors from the observing instruments.

First, aggregating the most recent RV data with the HARPS instrument, it was possible to confirm the acceleration of the system towards our direction (upward tendency in the fitted model), compatible with Hébrard et al. (2013), possibly due to a third massive object in the system. However, contrary to Salisbury, Kolb, Norton, Haswell (2021), we could not confirm the possible orbital decay of the exoplanet, and neither was detected a signal of any perturbation from an additional planet on this system.

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