

ORIGINAL RESEARCH BY YOUNG TWINKLE STUDENTS (ORBYTS): EPHEMERIS REFINEMENT OF TRANSITING EXOPLANETS II

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ABSTRACT

We report follow-up observations of four transiting exoplanets, TRES-2 b, HAT-P-22 b, HAT-P-36 b and XO-2 b, as part of the Original Research By Young Twinkle Students (ORBYTS) programme. These observations were taken using the Las Cumbres Observatory Global Telescope Network's (LCOGT) robotic 0.4 m telescopes and were analysed using the HOlonom Photometric Software (HOPS). Such observations are key for ensuring accurate transit times for upcoming telescopes, such as the James Webb Space Telescope (JWST), Twinkle (Edwards et al. 2019) and Ariel (Tinetti et al. 2018), which may seek to characterise the atmospheres of these planets. The data have been uploaded to ExoClock and a significant portion of this work has been completed by secondary school students in London.

INTRODUCTION

Transit photometry has yielded thousands of exoplanets over the last two decades. While the time for the next time is well known just after discovery, the accuracy of this prediction degrades over time due to the accumulation of errors on the period. Unless the ephemerides are well known, upcoming facilities will be unable to characterise the atmosphere of a planet. Maintaining accurate orbital ephemerides is becoming increasingly difficult due to the sheer number of targets and will require a coordinated effort by many groups and telescope networks.

The Exoplanet Transit Database (ETD, Poddaný et al. (2010)) provides a platform for users to upload observations and citizen scientists have contributed thousands of light curves. These have been used in a number of studies (e.g. Mallonn et al. 2019; Edwards et al. 2020). ExoClock¹ endeavours to stimulate engagement with citizen scientists who have access to telescopes, allowing them to contribute to the upcoming ESA Ariel mission. The site ranks the potential

¹ www.exoclock.space

Ariel targets from [Edwards et al. \(2019\)](#), prioritising those that have a large uncertainty in their next transit time and those which have not recently been observed. These can then be filtered by the location of the observer and the telescope size, providing a list of exoplanet transits which would be observable in the near future. In collaboration with ExoClock, the Exoplanet Watch project is another coordinated effort to collect follow-up observations of exoplanet transits with small telescopes, organised in the USA. Exoplanet Watch will deliver similar information, focused on targets that will be observed by JWST ([Zellem et al. 2019, 2020](#)).

Original Research By Young Twinkle Students (ORBYTS) is an educational programme in which secondary school pupils work on original research linked to the Twinkle Space Mission under the tuition of PhD students and other young scientists ([McKemmish et al. 2017a](#)). Previous projects have included calculating accurate molecular transition frequencies ([Chubb et al. 2018; McKemmish et al. 2017b; Darby-Lewis et al. 2019](#)), studying planetary aurorae ([Wibisono et al. 2020](#)) and spectral studies of the composition of protostellar regions ([Holdship et al. 2019](#)).

During this project, which follows on from that detailed in [Edwards et al. \(2020\)](#), the students selected suitable follow-up targets, scheduled observations and analysed the observational data with the aim of refining planetary transit parameters.

METHODS

We selected medium and high priority targets from the ExoClock website and obtained transit observations of TRES-2 b ([O’Donovan et al. 2006](#)), HAT-P-22 b ([Bakos et al. 2011](#)), HAT-P-36 b ([Bakos et al. 2012](#)) and XO-2 b ([Burke et al. 2007](#)). The observations were taken using LCOGT’s network of 0.4 m telescopes ([Brown et al. 2013](#)) and analysed using HOPS². HOPS aligns the frames and normalises the flux of the target star by using selected comparison stars before performing a transit fit with pylightcurve ([Tsiaras et al. 2016](#)).

During the fitting, the only free parameters were the planet-to-star ratio (R_p/R_s) and the transit mid time (T_0). The other parameters were fixed to the literature values from [Öztürk & Erdem \(2019\); Bakos et al. \(2011\); Wang et al. \(2019\); Bonomo et al. \(2017\)](#) for TRES-2 b, HAT-P-22 b, HAT-P-36 b and XO-2 b respectively and the limb darkening coefficients calculated from [Claret et al. \(2013\)](#).

RESULTS AND FUTURE WORK

The observed transits and recovered mid-times are shown in [Figure 1](#). For HAT-P-36 b and XO-2 b, the literature ephemeris predicted the mid-times both precisely and accurately, suggesting these ephemerides can be confidently used for planning future observations. ExoClock’s algorithm had flagged as they had not been observed for a significant amount of time. The ephemerides of TRES-2 b were also very precise but potentially less accurate as they do not agree with our fitted mid time. A deeper analysis, with all literature data and potentially additional observations, is needed to confirm this.

The data for HAT-P-22 b is noticeably poorer due to the brightness of the target and because there were no other stars of a similar brightness within the telescope’s field of view. The LCOGT network allows users to defocus the telescope, increasing the saturation time, and this technique would be useful for future observations. These are needed as the literature uncertainties on this planet are relatively high and, although consistent to 1σ , our observation appears to show a shift in the transit time.

Our data have been uploaded to ExoClock and, along with observations from other users, will help ensure the ephemerides of these planets are well known for potential atmospheric studies. Programmes which incorporate public engagement, educational outreach or citizen scientists have a rich literature of successful projects in the exoplanetary field (e.g. [Lintott et al. 2013; Wang et al. 2013; Baluev et al. 2015; Eisner et al. 2020; Nair & Varghese 2020](#)) and future ORBYTS projects will continue to collect transit data to help prepare for upcoming space-based telescopes.

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² <https://github.com/ExoWorldsSpies/hops/>

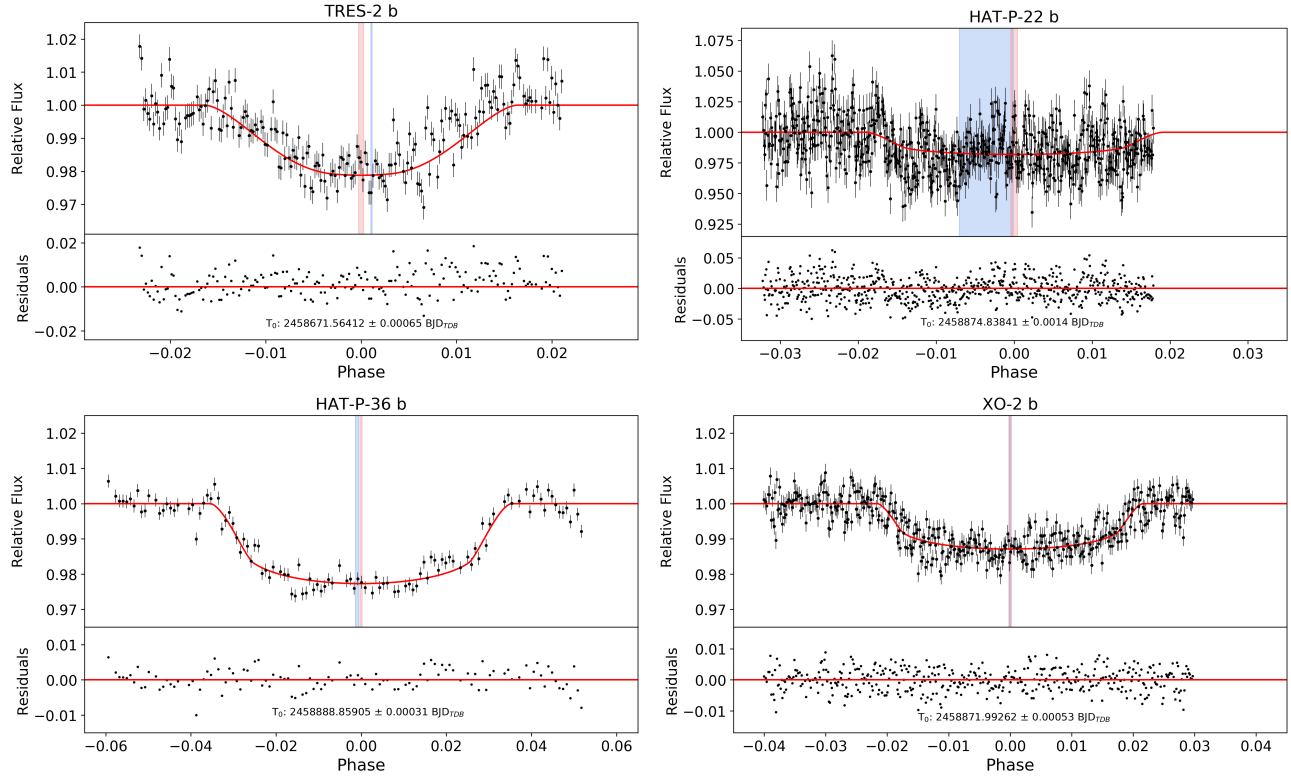


Figure 1. Transit observations obtained of TRES-2 b, HAT-P-22 b, HAT-P-36 b and XO-2 b. In each case, the data is shown in black with the best-fit transit model in red. The blue filled region indicates the predicted transit mid-time based upon literature ephemeris while the red denotes the fitted mid-time, both with 1σ errors. The mid-times were converted to BJD_{TDB} using the tool from Eastman et al. (2010).

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