Photometric Study of the Transiting Exoplanet HAT-P-39 b

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Abstract

In this study, we present the planetary parameters and an investigation of the orbital period of the Hot Jupiter HAT-P-39 b. Thirty-four transit light curves were obtained from the Transiting Exoplanet Survey Satellite, ExoClock project, and literature ground-based data. The planetary parameters of HAT-P-39 b were refined using the TransitFit package. We determined an updated transit epoch of T_c =2455208.7505 ± 0.0002 (BJD_{TDB}) and an orbital period, P = 3.5438744 ± 2×10^{-7} days. Based on the (O-C) diagram from this study, no significant change in the orbital period of HAT-P-39 b was found, which may conclude that there is no nearby massive exoplanet in this system.

Background and Overview

Exoplanets are planets that orbit stars outside the Solar System. Observations from telescopes are essential for studying exoplanets. This includes observations from both ground-based and space-based telescopes, such as **TESS**, and the networking of program observers like **ExoClock**.

HAT-P-39 b, a hot Jupiter orbiting the host F-type star HAT-P-39 (V=12.3, M_P= 0.599 ±0.1M_J, R_P= 1.571 ±0.1 R_J, T_{eff}=6424 K and RA = $07^h35^m01.97^s$ DEC = +17°49'48.3") with a period of 3.54387 days, was discovered by Hartman et al. 2012.

We used data from TESS across four sectors, two observation datasets from ExoClock, and four nights of data from Hartman et al. (2012), the parameters of the exoplanet HAT-P-39 b were used to fit the light curves. All data were analyzed using the **transit method**.

This study present the results of planetary parameters from the light curves modeling and study the orbital period changes from the O-C diagram of the hot Jupiter HAT-P-39 b.

Methodology

Transit Method

The transit method is a technique to detect the brightness signal when a planet crosses its parent star as shown in Figure. 1. The brightness during transit duration will be dropped due to the planet blocking flux of the host star, which can be expressed as Equation (1).

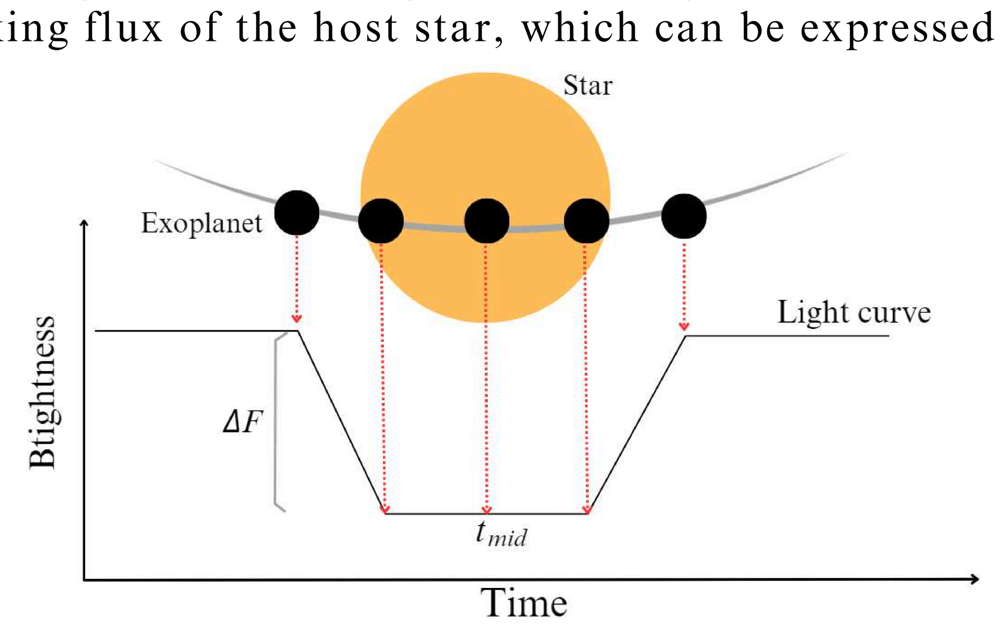


Figure 1 : The diagram shows the light variation due to a transit.

We model each transit light curve using `TransitFit` (Hayes et al. 2024), which employs the transit model from `batman` (Kreidberg 2015) and uses the dynamic nested sampling routines of `dynesty` (Speagle 2020) to derive planetary parameters. Figure 2 shows the best-fit model along with three example light curves. The parameters of the hot Jupiter HAT-P-39b are listed in Table 1. The O-C diagram, shown in Figure 3, is used to study orbital period variations.

$$\Delta F = \frac{F_{\text{no transit}} - F_{\text{transit}}}{F_{\text{no transit}}} = \left(\frac{R_p}{R_*}\right)^2 \quad ......(1)$$

Where ΔF is the transit depth , R_P is the radius of the exoplanet, and $R_\star$ is the host star.

The O-C diagram

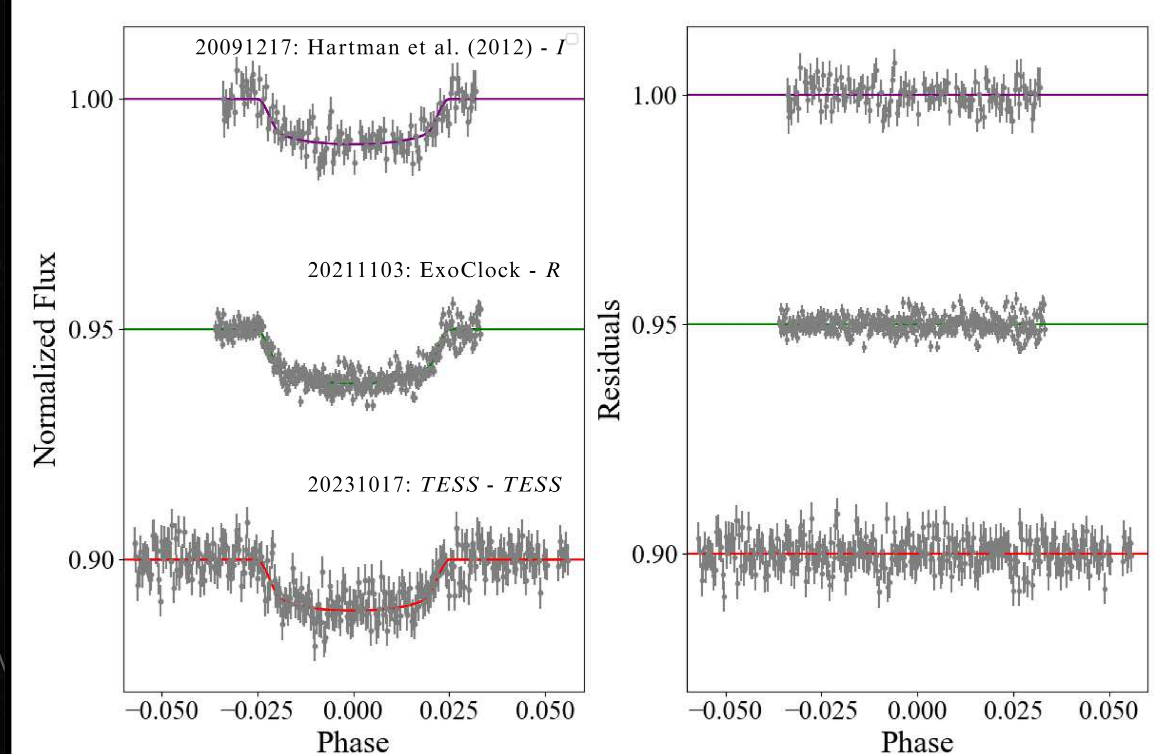
The O-C diagram represents the time difference between the observed mid-transit time (O) and the calculated time (C) from the linear ephemeris equation, as a function of time ($Epoch$) in Equation (2). The O-C diagram analysis helps to study changes in the planets transiting in front of the star, which can further reveal details such as periodic changes or the presence of other objects in the system.

$$T_{\text{mid}}(E) = T_0 + P_{\text{orb}} \cdot E \quad ......(2)$$

where T_0 and P_{orb} are the reference time and the orbital period of the linear ephemeris model, respectively. E is the epoch number. $T_{mid}(E)$ is the calculated mid-transit time at a given epoch E.

Results

Next, we show the results of the light curves fitting from the best fit model, with three example light curves in Figure 2. The parameters of the hot Jupiter HAT-P-39 b are shown in Table 1. The O-C diagram is used to study orbital period variations, as shown in Figure 3.



Parameter	Value
P(days)	$3.5438744 \pm 2\times10^{-7}$
T_c(BJD)	2455208.7505 ± 0.0002
a/R_*	6.49 ± 0.08
i(deg)	86.1 ± 0.3
R_p/R_* (i band)	0.1019 ± 0.0003
R_p/R_* ($TESS$)	0.0988 ± 0.0003
R_p/R_* (R band)	0.093 ± 0.001

Table 1 : The planetary parameter of HAT-P39 b

Figure 2 : *Left panels:* Normalized flux as a function of phase-folded transit light curves for HAT-P-39 b, based on our observations. The best-fitting model is shown in different colors according to the filter: purple for the I-band, green for the R-band, and red for the $TESS$ filter.
Right panels: Residual light curve after model subtraction.

The O-C diagram

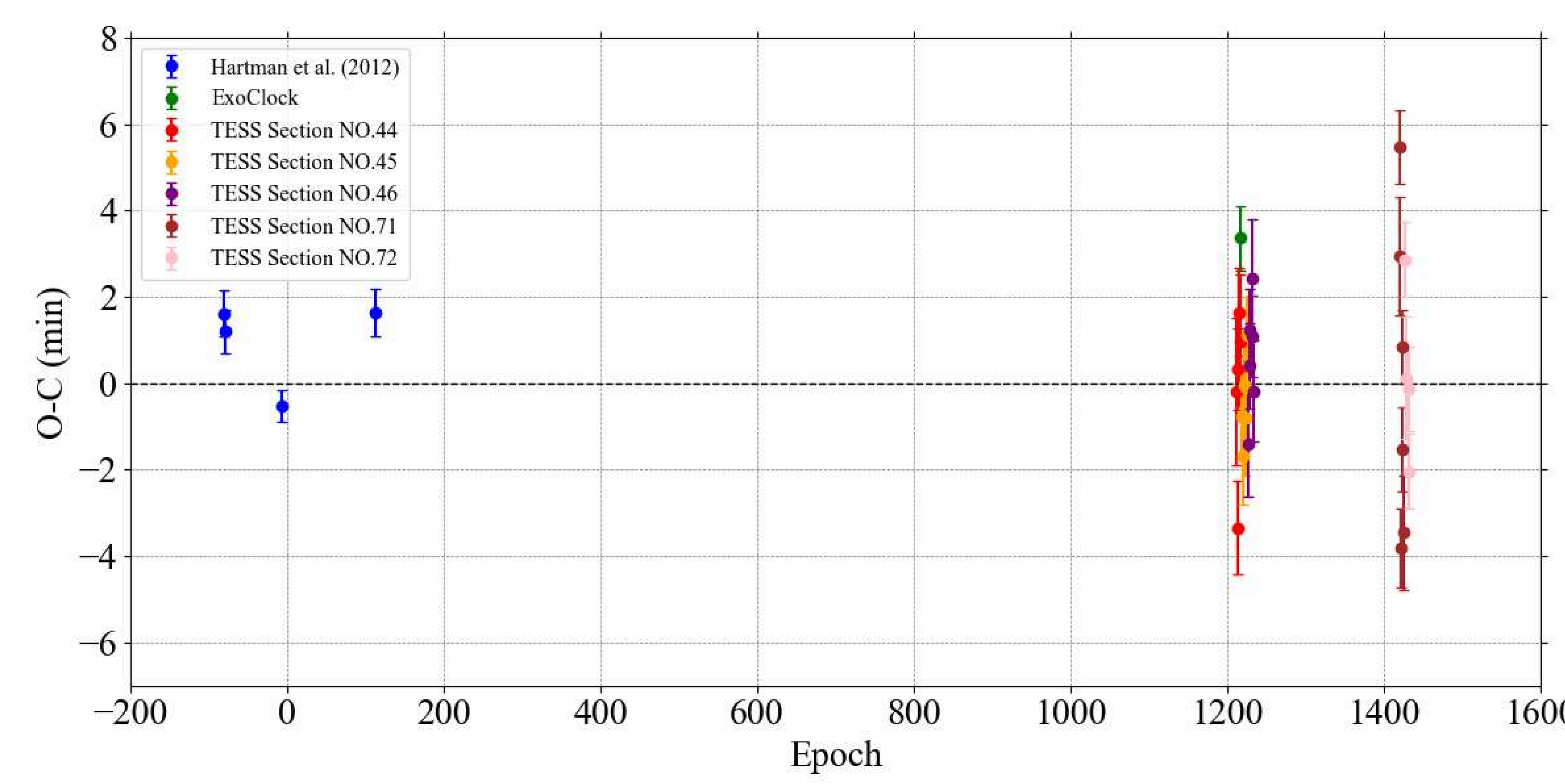


Figure 3 : The O-C diagram of the HAT-P-39 b

The update linear ephemeris is derived as:

$$T_{\text{mid}}(E) = 2455208.75049\ ^{+0.00041}_{-0.00041}\ + 3.53870\ ^{+0.000005}_{-0.000005}\ E$$

Conclusions

We combined light curves from TESS, ExoClock, and published ground-based data to model the transit light curves of HAT-P-39 b. The planetary parameters obtained from this study are consistent with the parameters in the literature. The orbital period analysis found no significant variations in HAT-P-39 b's orbit, suggesting the absence of a nearby massive exoplanet in the system.

References

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