Searching for Short Term Transit Timing Variation in Exoplanetary System WASP-19

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Abstract:- We have presented here the short term transit timing analysis of the exoplanet WASP-19b, one of the first detected ultrashort period gas giant planets. For this, we have considered total 250 complete transits, which include 116 light curves from Transiting Exoplanet Survey Satellite (TESS), a space based telescope, 62 full transits from Exoplanet Transit Database (ETD) and 72 from the literature, covering a 13-yr baseline. By fitting a linear ephemeris model to the mid-transit time data, we derived new transit ephemeris for WASP-19b, which is consistent and even more precise than the previous results. The best-fit ephemeris with reduced chi-square greater than 1 indicates that the linear ephemeris model does not represent the transit time data well and there is a possibility of the presence of Transit timing variation (TTV) in the system. Comparing the mid-transit times of WASP-19b derived from the TESS light curves with those estimated using the linear ephemeris of Petrucci et al. (2020), we have found a median difference of ~66.83 s between these two timings. From this, it appears that the TESS transits of WASP-19b occur later than the predictions of linear ephemeris of Petrucci et al. (2020). To probe, whether this TTV is a short term one, we look for the periodicity in the timing residuals of linear ephemeris model by computing a generalized Lomb-Scargle periodogram and we have not found any significant periodicity in the timing residuals. The highest peak power obtained in the periodogram has the false alarm probability (FAP) of 15%, which is found below from the threshold values (i.e. FAP =5% and 1%). Due to lack of any signature of periodicity, the short-term TTV induced by an additional planet might not be present in the system. Because there is no evidence of short-term TTV , it encouraged us to look for the long-term TTV that may be produced by either orbital decay or apsidal precession phenomenon in the WASP-19 system.

Introduction:-

- The short-period (P ~ 19 h) gas giant extrasolar planet, WASP-19b, (M_P = 1.11 M_J , R_P = 1.39 R_J) was discovered by Hebb et al. (2010).
- Given the brief time it takes to orbit once around its host, WASP-19b was one of the first ultrashort period planets discovered.
- It is hosted by an active G8V solar-type Star star (Age ~ 11 Gyr ; Hebb et al. 2010; Knutson, Howard & Isaacson 2010; Anderson et al. 2013; Huitson et al. 2013; Tregloan-Reed et al. 2013).

Light Curve Analysis:-

- To determine the mid-transit times, all the above said light curves were analyzed using the ***Transit Analysis Package*** (TAP: Gazak et al. 2012).
- For each light curve analysis, 5 MCMC chains each with a length of 10^5 links were used.
- To set up the initial values of parameters, as well as to analyze the transit light curves, we followed the same procedure as adopted by Jiang et al. (2013).
- For TESS light curves, the values of quadratic limb-darkening coefficients were taken from the Tables of Claret et al. (2017), whereas the values of quadratic limb-darkening coefficients for V, R, I and clear filters were calculated using ***EXOFAST***[3] onlinetool.
- The mid-transit times determined from transit light curves of WASP-19b are then used for the timing analysis.

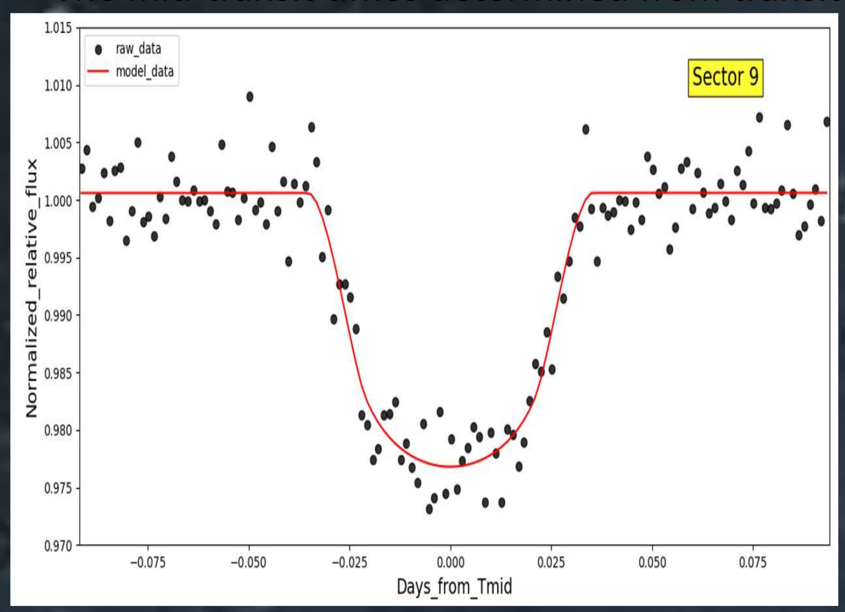

Figure 1. :- the normalized relative flux of Wasp-19 as a function of the time

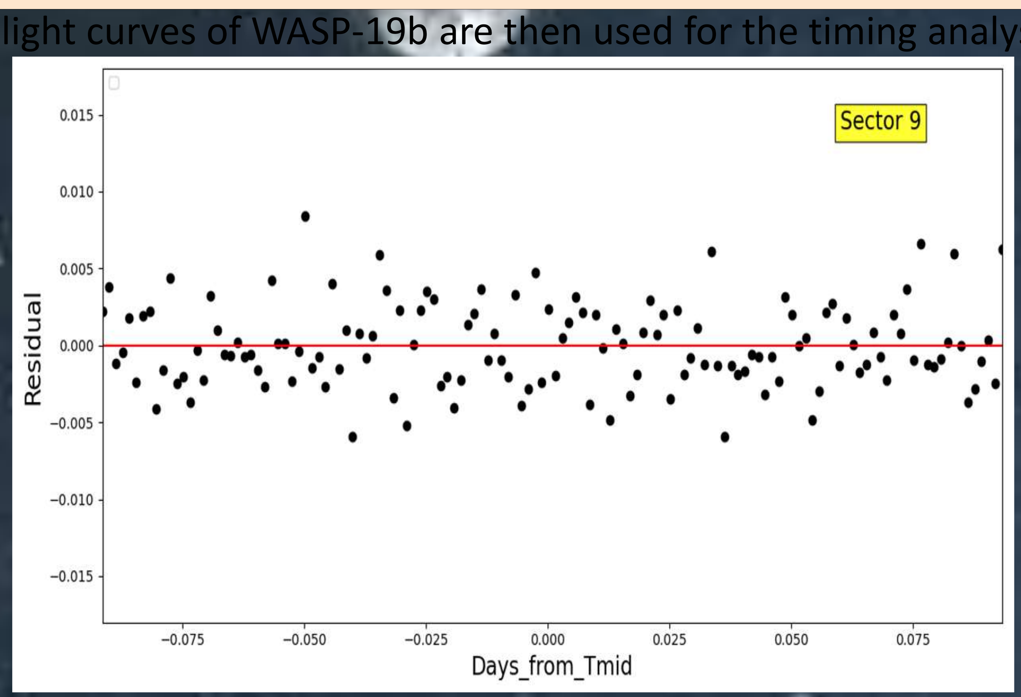

Figure 2. :- the corresponding residuals.

Generalized Lomb-Scargle Periodogram:-

- Here, we have searched for a short-term TTV, which may be due to the presence of an additional planet in the WASP-19 system and because of an additional planet, a periodic TTV should be present in the O-C data. Here, O-C denotes the difference between the observed mid-transit time, O, and the calculated mid-transit time derived from the transit ephemeris, C.
- To search for periodicity in the O-C data, we computed a ***generalized Lomb-Scargle periodogram*** (Zechmeister & Kurster 2009) in the frequency domain. The periodogram defined by the resulting spectral power as a function of frequency is shown in ***Figure 3.***
- In this periodogram, we found the ***False Alarm Probability (FAP)*** of ***15.0%*** for the highest power peak is found below the threshold levels (i.e. FAP=5% and FAP=1%).

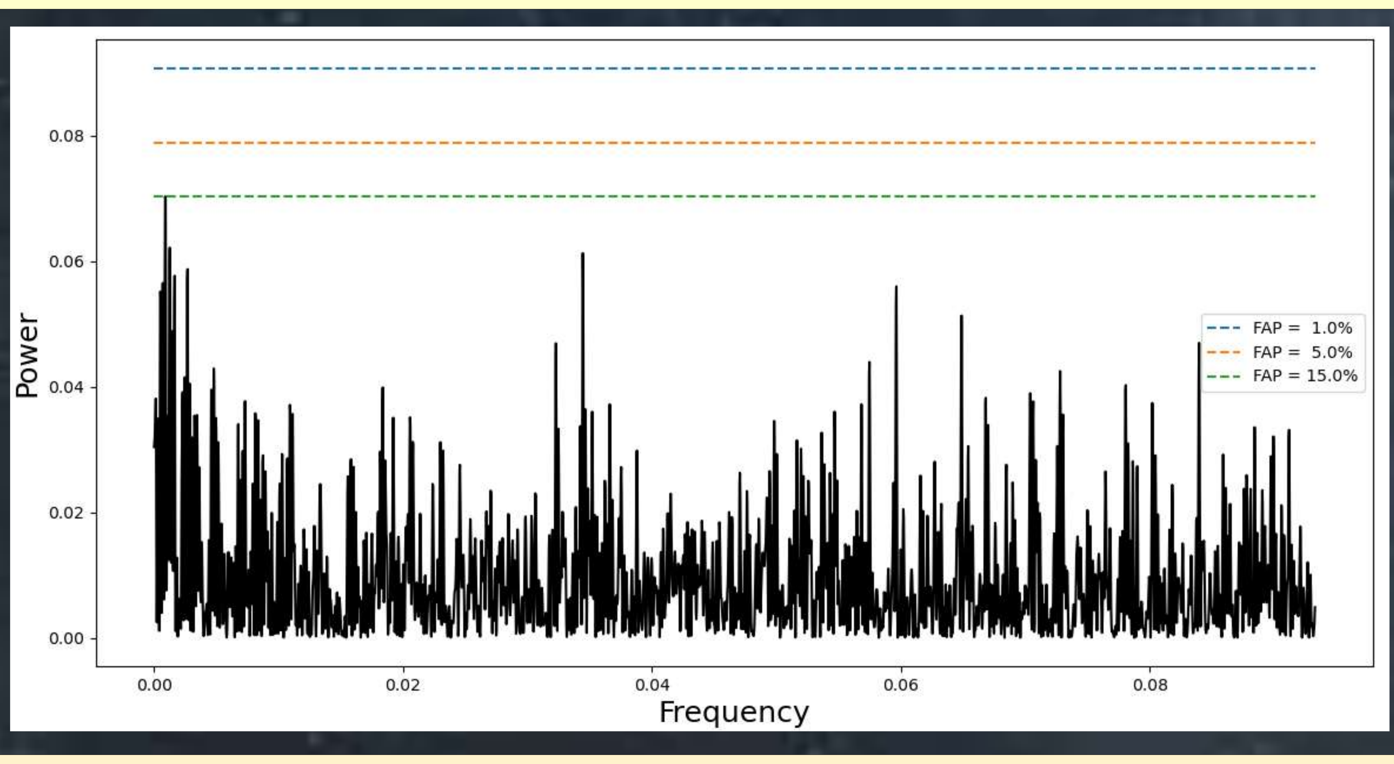

Figure 3. Generalized Lomb–Scargle periodogram for 250 O-C data of **WASP-19b.** The dotted line indicates the FAP level of the highest power peak at the frequency of 0.00125 rad/period. The dashed lines from top to bottom indicate the threshold levels of FAP=1% and FAP=5%, respectively.

[1] https://www.nasa.gov/tess-transiting-exoplanet-survey-satellite

[2] http://var2.astro.cz/ETD/

[3] https://astroutils.astronomy.osu.edu/exofast/limbdark.shtml

Observational Data:-

Object Name	No. of Transit Light Curves	Data Reference
WASP-19b	**116**	**TESS[1] (sectors 9, 36, 62, 63)**
	62	**ETD**
	72	**Literature**

The Initial Parameter Setting:-

Parameter	Initial Value	During MCMC Chains
P (days)	0.788839	Fixed
i (degree)	79.17	A Gaussian prior with σ = 0.32
a/R_*	3.533	A Gaussian prior with σ = 0.038
R_p/R_*	0.14541	Free
T_m	Set by eye	Free

Timing Analysis Results:-

New Linear Ephemeris:-

We have refined the transit ephemeris for the orbital period P and mid-transit time T0 by fitting a linear function: Tm (E) = PE + T0 to 203 mid-transit times data with the emcee MCMC sampler implementation (Foreman-Mackey et al. 2013) . The best-fit values of P and T0 are given below:

P = 0.78883908 ± 0.0000000115252 days
T_0 = 2454775.3380795396 ± 0.0000321 (BJD_{TDB}).

Comparing the mid-transit times of WASP-19b derived from the TESS light curves with those estimated using the linear ephemeris of Petrucciet al. (2020), we have found a timing difference of ~ 66.83s. Because of these timing differences, and the poor model fittings to timing data with $\chi red\ 2$ > 1, we suspect the possibility of TTV in the wasp-19 system.

Conclusions & Future Work:-

- For the precise TTV analysis, we have combined 116 transit light curves observed by TESS with 72 light curves from the literature and 62 transit curves (with Data Quality, DQ < 3) from the ETD. In total ***250 transit light curves*** are considered for this work.
- The homogeneously determined mid-transit times from these light curves enabled us to refine the transit ephemeris. The derived ephemeris are ***consistent*** and even ***more precise*** than the previous results.
- From our timing analysis, we have found the possible presence of TTV in the WASP-19 system.
- From the frequency analysis, it is found the WASP-19 ***system does not show any signature of periodicity.***
- The absence of short term TTV now motivates us to look for long term TTV, which may be due to ***orbital decay, apsidal precession, line of sight acceleration, Applegate mechanism or Star-spots.***
- In order to confirm the presence or absence of additional planet in the WASP-19 system, further follow-up observation of transits would be required.

References:-

1) Anderson D. R. et al., 2013, MNRAS, 430, 3422
2) Claret, A. 2017, A&A, 600, A30
3) Hebb L., et al., 2010, ApJ, 708, 224
4) Huitson C. M. et al., 2013, MNRAS, 434, 3252
5) Knutson H. A., Howard A. W., Isaacson H., 2010, ApJ, 720, 1569
6) Petrucci R., Jofré E., Gómez Maqueo Chew Y., Hinse T. C., Mašek M., Tan T. G., Gómez M., 2020, MNRAS, 491, 1243
7) Tregloan-Reed J., Southworth J., Tappert C., 2013, MNRAS, 428, 3671
8) Zechmeister, M., & Kürster, M. 2009, A&A, 496, 577

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