A Comprehensive homogenous investigation of orbital ephemeris and transmission spectrum of WASP-19 b

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OBJECTIVES

- Verifying the orbital ephemeris of the ultra-hot Jupiter WASP-19 exoplanet
- Conducting a detailed analysis of the atmospheric properties of WASP-19 b via transmission photometry and spectroscopy

WASP-19 SYSTEM

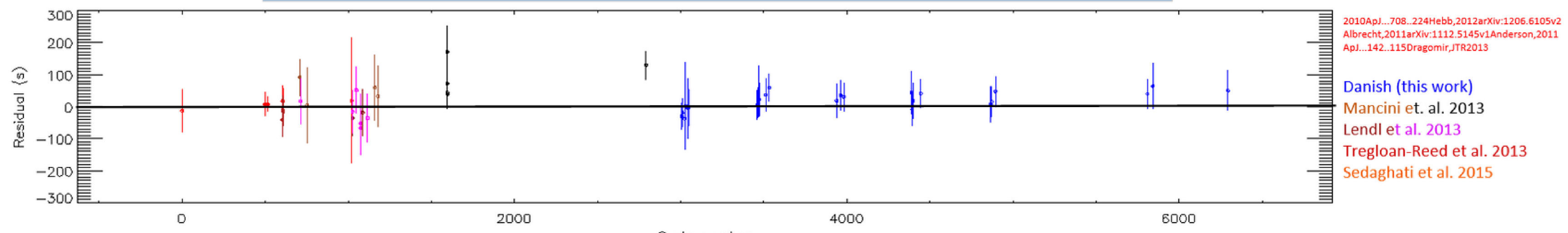
WASP-19 b is a hot-Jupiter exoplanet with mass of around 1.376 Rjup and radius of about 1.165 Mjup. Because of its ultra-short orbital period (0.78 days), they are expected to experience significant tidal interactions with its host stars. This will result in angular momentum and energy transfers between the planetary orbit and the stellar rotation. One effect of this interaction is orbital decay: decrease in the orbital period of the planet and therefore the progressively earlier occurrence of transits in a system.

Orbital Period Study

The effects of tides are small on a human timescale. So, with the most promising system (like WASP-12 b, WASP-19 b), it will be more prominent to search for transit timing variations (TTVs) in the systems.

There could be multiple possible causes of TTVs and Orbital decay has been confidently detected in only one system: WASP-12 (Hebb et al. 2009; Maciejewski et al. 2016; Patra et al. 2017; Maciejewski et al. 2018). WASP-4 is also known to have a decreasing orbital period (Bouma et al. 2019; Southworth et al. 2019) but the origin of this is not yet settled (Baluev et al. 2020; Bouma et al. 2020; Turner et al. 2022).TTVs can arise due to the light-time effect caused by long-period companions in a system, as has been found for TrES-5 (Maciejewski et al. 2021)

Plot of the residuals of the timings of mid-transit versus a linear ephemeris



Red: Theoretical papers | Blue: Unpublished Danish Data | Brown: Published Danish Data | Black: ESO GROND | Dark red: Euler | Magenta: TRAPPIST | Firebrick: NTT | Dark orange: VLT FORS2

The photometric data are reduced and the light curve is fitted using `PRISM-GEMC` along with their starspots (if present)

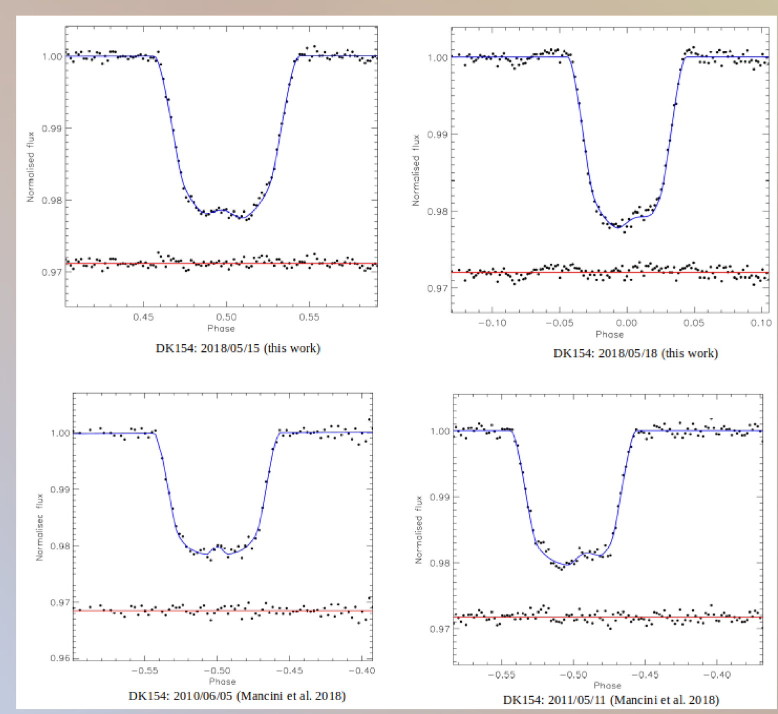
The data points shows a sine wave pattern. This indicates that theres some kind of periodic variation. This can be confirmed by calculating the cubic and quadratic ephemeris and calculating the tidal quality factor (Q*)

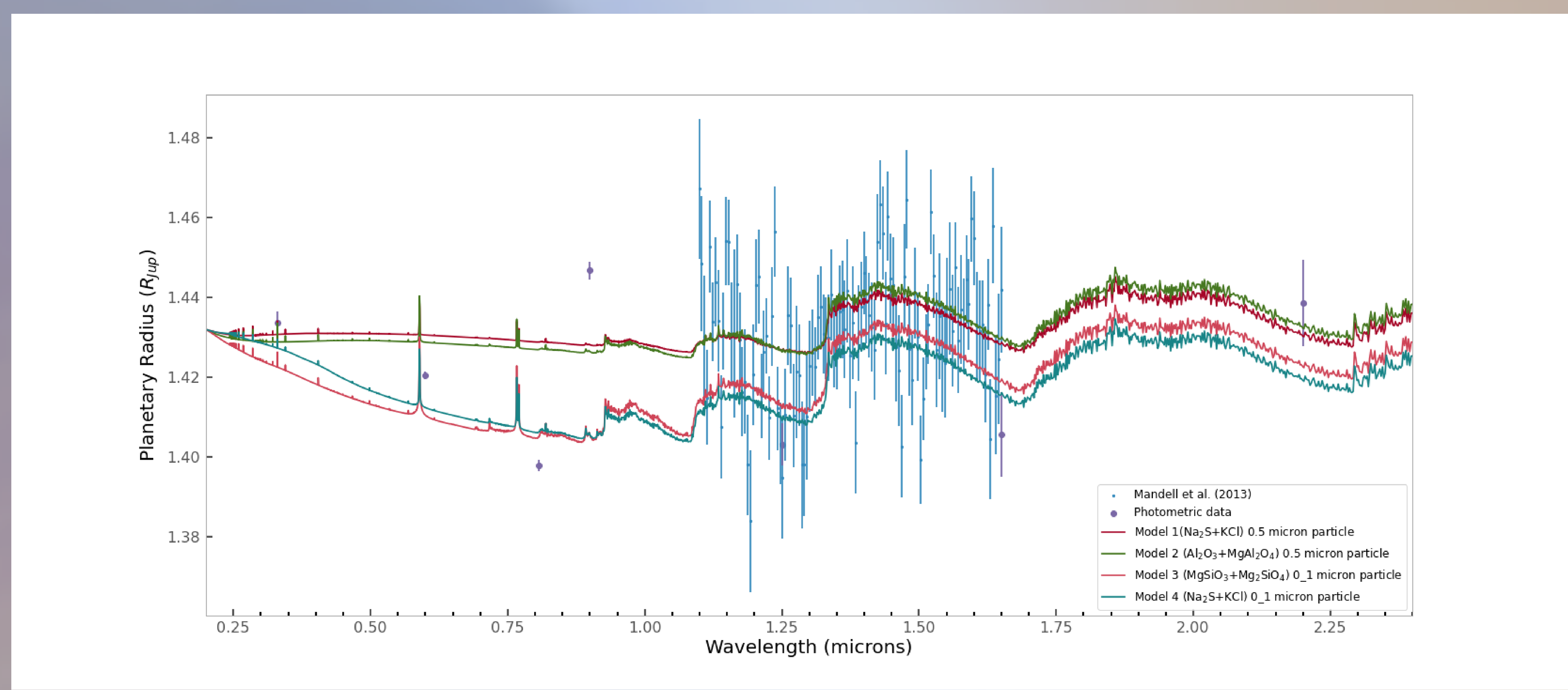
Tidal Qality factor $$Q'_\star = \frac{3}{2}\frac{Q_\star}{k_2}$$

Transmission Photometry and Spectroscopy

Transmission photometry measures the overall decrease in the planet-star flux ratio during transit across a given bandpass.
WASP-19A is an active host star with its surface littered with starspots, which if not correctly modeled, systematics are introduced into the transit timing measurements and transit depth, which latter affects the exoplanetary transmission spectrum.

Transit-Starspot model: `PRISM`[1]: PRISM code is used to model a planetary transit over a spotted star and the optimisation algorithm `GEMC` for finding the global best fit and associated uncertainties. To acquire the best precision measurements, we fitted all the possible starspots in the light curve.





In this work, the HST WFC3 data from Mandell et al. 2013 was modelled using MCMC method. To which the photometric data was added. The Rp vales of these photometric datapoints are corrected for the starspot anomalies in the light curve. As this was modelled using MCMC method, the best fit was considered to be the one with the lowest chi-squared value. In this case, it is the Model 3 data with chi-square value: 1.72

FUTURE WORK

- Investigate more on Orbital ephemeris by calculating Quadratic and cubic ephemeris as well to verify the TTV
- To model the photometric and spectroscopic data using **petitRADTRANS** retrieval model

SUMMARY

The period study of WASP-19 b shows sine wave pattern which might have some variation in the transit times. This study provides valuable insights into the orbital characteristics of WASP-19 b and highlights importance of continued monitoring of exoplanets for more accurate ephemeris. Transmission photometry is a simpler and is also efficient method for studying exoplanet atmospheres, especially for bright targets

References: [1]Tregloan-Reed et al. 2013, 2015, 2018; L. Mancini et al. 2021; John Southworth et al. 2022; Mandell et al. 2013, Mancini et al. 2012, Sedaghati et al. 2015,

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