Tidally induced TTVs: Application to K2-265 b

Gabriel O. Gomes[1,2], Emeline Bolmont[2] and Sergi Blanco-Cuaresma[3]

[1]University of Sao Paulo, [2]University of Geneva, [3]Harvard-Smithsonian Center for Astrophysics

Abstract: We have investigated the transit timing variations (TTVs) induced by planetary tidal interactions. The main type of planets for which such effects could be observable are rocky super-Earths. For this study, we have included a recently-developed equilibrium tides model in a stable N-body code called Posidonius. An application to the super-Earth K2-265 b was considered. We have verified that tidally induced TTVs could be potentially observable especially in the case of non-synchronous spin-orbit resonant states for the planet. The spin-orbit resonance leading to the biggest TTV amplitudes is the 3:2 resonance, for which even a baseline of 2 years would be able to cause a TTV of some seconds in the case of a homogeneous K2-265 b on an eccentric orbit.

Motivation

In recent studies, transit and occultation data have been used to determine the tidal dissipation factor of hot-Jupiter-hosting stars (see e.g., Yee et al. 2020). The study of tidally induced TTVs caused by planetary tides in small planets have been studied for the TRAPPIST-1 system (see Bolmont et al. 2020), but the influence of aspects such as the rotation, eccentricity and viscosity of the planet have not been investigated. Using tidally induced TTVs can be a useful tool to probe the values of such parameters for rocky close-in planets.

Methods

1. We implemented the creep tide theory (Ferraz-Mello 2013) in the Posidonius N-body code (Blanco-Cuaresma and Bolmont 2017). The implementation was checked by comparing the results of Posidonius with a secular code (Gomes et al. 2021).
2. We obtained the transit data by using Posidonius. The errors in the values of the TTV data were of the order 10^{-4} s, thus confirming the precision of the new version of Posidonius.

Results

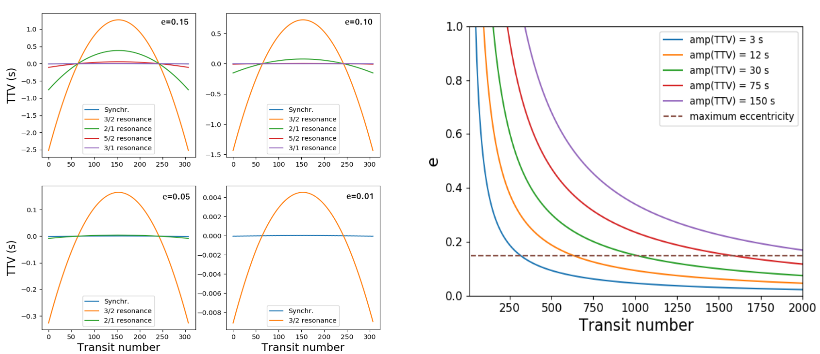

Figure 1. Results for the tidally induced TTVs of a homogeneous K2-265 b considering the variation of several parameters. In the left panel, we can see the influence of the rotation rate and the eccentricity value on the TTV curves. The right panel shows the isoTTV curves, that is, the values of eccentricity and number of transit events which are necessary for obtaining a given TTV amplitude.

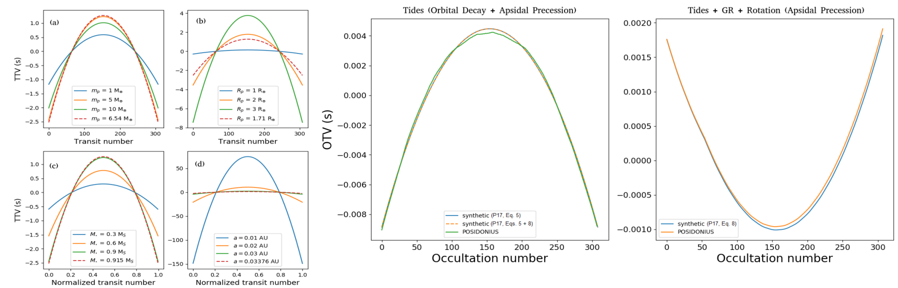

Figure 2. Four panels on the left show the influence of tuning: planetary mass and radius, stellar mass and semi-major axis on the TTVs. The two panels on the right show the occultation timing variation (OTVs) considering the effects of general relativity and tides.

1. The 3:2 and 2:1 spin-orbit resonant states lead to bigger amplitude TTVs compared to other rotational states (see Fig 1, four panels on the left). If a precision of the order 20-30 s is reached for the transit timing data, approximately 6 years of transit data would be necessary to actually detect the tidally induced TTVs (see Fig 1, panel on the right, green curve), for an eccentric K2-265 b in a 3:2 spin-orbit resonance.
2. The best exoplanetary systems for which tidally induced TTVs can be detected are close-in planets around slow-rotating massive stars (see Fig 2, left panels).
3. The influence of tidally induced orbital decay can be confused with apsidal precession induced TTVs. If occultation data are also analysed, the degeneracy can be broken and orbital decay can be disentangled from apsidal precession (see Fig 2, panels on the right).

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