Exoplanets Transit Timing Variation and Transit Duration Variation Catalogue from TESS

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Abstract. Exoplanets are planets that orbit around other stars outside the solar system. One of methods that can be used to locate them is transit method whereby the variation of the flux from the host star is observed when the planet passes in front of it. The time between ingress and egress is called transit duration and the middle point of the flux dip is called mid-transit time. These transit durations and mid-transit times can be affected by an existence of a third body in the system because of its gravitational influence. The third body can be the planet's moon or another planet in the system. In This project, TESS (Transiting Exoplanet Survey Satellite) raw light curve were used to perform curve-fitting and optimize transit parameters. The period of transit timing variation (TTV) is computed together with a false alarm signal to predict the existence of a third body. Dividing full light curve into transits and fitting each transit separately are applied in order to optimize prior parameters. Three host stars are primarily used to evaluate the performance of our method: WASP-126, which does not show the existence of WASP-126 c with false alarm signal of 0.99; TOI-216.01 and TOI-216.02 with false alarm signals around 0.

1. Objective

1. To compute Transit Duration Variation (TDV) and Transit Timing Variation (TTV) of confirmed planets from TESS.
2. To find periodicity of TESS TTV and TDV signals

2. Experiment

1. Data Pre-processing

1.1. Importing data from exoplanet.archive and exoplanet.fop

Import data from the online resources and combine them into a single .csv file because the resources contain blank columns. An example, WASP-126b, is imported in order to check the performance. The criteria, period around 3 days, is applied in order to ensure data points of TTV signal is sufficient to find its periodicity.

1.2. Storing necessary information about exoplanets
Including period, ratio of planet's radius and stellar radius (rp), mid-transit time, ratio of semi-major axis and stellar radius (a), and inclination from Exoplanet Archive and Exofop TESS mission.

2. Implementing Transitfit to optimize transit parameters

2.1 Performing the transit fitting
Generating the prior file containing parameter in 1.2 and data file pointing to location of light curve file. The outputs from Transitfit package are fitted light curve, prior, and summary file. However, the variation for each parameter must be large enough for searching the minimum.

2.2. Dividing full light curve into single transits
Using mid-transit time and time in light curve file to calculate epochs, and using epochs to slice transits. Each light curves are sliced into transit files which present more than 10 transits as the criteria predicts.

2.3. Performing the transit fitting separately for each transit
Using the prior from the first fitting as prior for this fitting, and using sliced transits as data files. Therefore, each transit provides the optimized parameter which is computed for TTV signal in the next step.

3. Visualizing transit duration (TTV) and transit timing (TDV) variation

3.1. Computing TTV and TDV
Computing TTV and TDV from fitted parameters. TDV signal is computed from optimized parameters from curve-fitting while TTV is computed by change of mid-transit time value of each transit from full light curve.

3.2. Plotting TTV and TDV with respect to epochs
Plotting TTV and TDV signals from 3.1 with respect to epochs, time normalized by period and full light curve's mid-transit time.

4. Fitting transit timing variation by sine function

4.1. Applying Fourier transformation
Performing Fourier transformation to compute frequency of the curve. Lomb-scargle package is applied to deal with transit light curves which contain discrete data.

4.2. Computing false alarm signal to confirm the peak signal
False alarm signal indicates probability of the peak to be noise. The primary result shows that WASP-126b is around 99%, which means there is no signal of WASP-126c, and TOI-216.01 and TOI-216.02 signals are around 0%, respectively, which means false alarm signal from TOI-216.01 confirms the existence of TOI-216.02 ,and vice versa.

3. Expected results

Transit Duration Variation (TDV) and Transit Timing Variation (TTV) Catalogue from selected exoplanets are obtained. For example, TTV signal from WASP-126. Moreover, the catalogue could provide false alarm signal for each exoplanets to show the existence of third body.

References

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