PERFORMANCE OF TRANSIT MODEL FITTING IN PROCESSING 4 YEARS OF KEPLER DATA

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Abstract

We present transit model fitting performance of the latest release (9.1, July 2013) of the Kepler Science Operations Center (SOC) Pipeline in processing 4 years (16 quarters) of flight data. Threshold Crossing Events (TCEs), which are transit candidate events, are generated by the Transiting Planet Search (TPS) component of the pipeline and subsequently processed in the Data Validation (DV) component. The transit model is used in DV to fit TCEs to derive parameters that are used in various diagnostic tests to disposition planetary candidates. In the latest release of the Kepler SOC pipeline, reduced parameter fits are included in DV to improve the robustness of the transit model fit. New model fit diagnostic figures that appear in DV export products are also presented. Funding for the Kepler Mission has been provided by the NASA Science Mission Directorate.

Reduced parameter fits

Standard transit model

The standard transit model includes the following five fit parameters:
- transit epoch time ($T_0$, i.e. central time of first transit),
- orbital period ($P$),
- impact parameter ($b$),
- ratio of planet radius to star radius ($R_p/R_*$),
- ratio of semi-major axis to star radius ($a/R_*$).

Other parameters such as transit depth, transit duration, planet radius, semi-major axis, and equilibrium temperature are derived from the five fit parameters and given stellar parameters.

Reduced parameter fit algorithm

The performance of the fitter will suffer when there is insufficient information in the light curve to uniquely determine the impact parameter. In such instances the fitter shows poor convergence performance.

In the latest release of the Kepler SOC pipeline, a reduced parameter fit is included in DV. The impact parameter is set to a fixed value and the four remaining parameters are fitted. The standard transit model fit is implemented after a series of reduced parameter fits in which the impact parameter is varied between 0 and 1. Initial values for the standard transit model fit parameters are determined by the reduced parameter fit with the minimum chi-square metric.

Reduced parameter fit example

Diagnostic plots for the planet Kepler-11b illustrate how the chi-square metrics and fitted parameters of the reduced parameter fit vary as a function of impact parameter. The impact parameter is set to fixed values of 0.1, 0.3, 0.5, 0.7, and 0.9 respectively. The outputs of the reduced parameter fit with the minimum chi-square metric are marked with red dashed lines in the diagnostic plots.

Processing 4 years of Kepler data with DV 9.1

Overall statistics (Tenenbaum et al. 2013, in prep)

- Four years (16 quarters) of science data, collected by the Kepler spacecraft from May 13, 2009 to April 8, 2013, were processed by release 9.1 of the Kepler SOC pipeline in August 2013.
- 9,771 target stars generated a TCE in TPS and ran in DV. 9,743 target stars completed DV.
- 16,285 TCEs were generated in TPS and DV.
- 149 TCEs were labeled as suspected eclipsing binaries (based on <25% transit depth).
- 684 TCEs failed in all transit fits.
- 15,452 TCEs completed all transit fits successfully.
- 837 TCEs failed in odd/even transit fits.
- 14,615 TCEs completed odd/even transit fits successfully.

Comparison between DV and KOI parameters

Fig. 4 DV fitted orbital period versus KOI orbital period (left: all periods, right: periods ranging from 0 to 20 days)

Fig. 5 DV derived transit depth versus KOI transit depth (left: all transit depths, right: transit depths ranging from 0 to 500 ppm)

New transit model fitting diagnostic figures in the DV 9.1 report

Fig. 6 Folded unfolded (left) and whitened (right) flux time series of Kepler-11b. Colored triangles mark the occurrence of transits of all planet candidates.

Fig. 7 Diagnostic plot of all transit fits of Kepler-11b (Dark green dots indicate data points with robust fit weights > 0.1).

Fig. 8 Diagnostic plot of odd/even transit fit of Kepler-11b (The horizontal red lines show derived depths of odd and even transits).