Recent Improvements in the Kepler Mission’s Transiting Planet Detection Algorithm

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Abstract

We describe recent developments in the algorithm used by the Kepler Mission to detect the periodic reductions in stellar flux which are the characteristic signature of a transiting planet. The algorithm has been extended to allow searches in which the flux from a given star falls on different detectors within the focal plane at different times, which is necessary in order to accommodate the spacecraft’s periodic axial rotations (“quarterly rolls”). A robust estimator of stellar noise characteristics allows the noise analysis process to function correctly in the presence of extremely deep transits such as those produced by an eclipsing binary or a Jovian or super-Jovian transit. Techniques for eliminating false detections due to step changes in pixel sensitivity or other non-transit phenomena have been incorporated into the algorithm. We also discuss future improvements to the detection algorithm, including a robust detection statistic which will permit far more effective filtering of false-positive detections.

Components and Primary Functions

- Kepler rotates by 90° about its axis every 93 days to keep its solar panels pointed at the sun. This causes light from each target to fall on different CCDs over the course of the mission, each of which unique performance characteristics. In order to search for long-period planets, TPS needs to combine the light from these sensors into a single flux time series.

- Detect systematic and other errors in raw light curves, remove excess flux due to aperture crowding, and condition light curves for the transiting planet search

- Perform statistical tests to validate candidate planets

- Compute all LC targets but not on SC targets.

- Robust Noise Estimation

- Sudden Pixel Sensitivity Dropouts (SPSDs)

- Future Improvements

In order to limit the number of false-positive detections, TPS cuts all targets which have a multiple event statistic under 7.1 σ, and a ratio of multiple to single event statistics under 2. The latter cut eliminates some true-positive events, so a future robust multiple event statistic will allow this cut to be relaxed or eliminated outright.

Multiple Quarter Operation

Kepler rotates by 90° about its axis every 93 days to keep its solar panels pointed at the sun. This causes light from each target to fall on different CCDs over the course of the mission, each of which unique performance characteristics. In order to search for long-period planets, TPS needs to combine the light from these sensors into a single flux time series.

In the figure above, a representative 6-quarter time series is shown in blue, with inter-quarter gaps in red. TPS performs median correction, edge defringing, removal of narrow-band harmonics, and filling of gaps in a manner which minimizes the disturbance of the overall power spectral density of the time series.

Robust Noise Estimation

Extremely deep and/or frequent transits perturb the estimate of stellar noise, resulting in enhanced CDPP and reduced SNR compared to actual values.

This perturbation is eliminated by replacing the standard RMS estimator of statistical fluctuations with a scaled Median Absolute Deviation (MAD) estimator, which computes the median absolute deviation from the median value, and scales by the RMS / MAD ratio for Gaussian noise. The small number of large excursions due to deep transits are ignored in this estimate.

Sudden Pixel Sensitivity Dropouts (SPSDs)

Sudden Pixel Sensitivity Dropouts (SPSDs) are step changes in individual pixel responses due to certain types of cosmic ray impacts. Many SPSDs are detected and corrected in PDC, but some are passed through to TPS, where they can cause false-positive detections.

In the figure above, the excluded data values are shown in red, including data in blue.