Dynamic Black-Level Correction and Artifact Flagging in the Kepler Data Pipeline

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Abstract

Instrument-induced artifacts in the raw Kepler pixel data include time-varying crosstalk from the fine guidance sensor (FGS) clock signals, manifestations of drifting moiré pattern as locally correlated non-stationary noise and rolling bands in the images which find their way into the calibrated pixel time series and ultimately into the calibrated target flux time series. Using a combination of raw science pixel data, full frame images, reverse-clocked pixel data and ancillary temperature data the Kepler pipeline models and removes the FGS crosstalk artifacts by dynamically adjusting the black level correction. By examining the residuals to the model fits, the pipeline detects and flags spatial regions and time intervals of strong time-varying black-level (rolling bands) on a per row per cadence basis. These flags are made available to downstream users of the data since the uncorrected rolling band artifacts could complicate processing or lead to misinterpretation of instrument behavior as stellar. This model fitting and artifact flagging is performed within a new stand-alone pipeline module called Dynablack.

We discuss the implementation of Dynablack in the Kepler data pipeline and present results regarding the improvement in calibrated pixels and the expected improvement in co-rendering performance as a result of including FGS corrections in the calibration. We also discuss the effectiveness of the rolling band flagging for downstream users and illustrate with some affected light curves.

Funding for the Kepler Mission has been provided by the NASA Science Mission Directorate.

Dynamic Black-Level Correction - Dynablack

Pipline Data Flow

The pipeline component Dynablack performs black level calibration in a two-step process. Input pixel data are fit to a multi-component model cadence-by-cadence. Then the resulting fit coefficients are fit across cadences using ancillary temperature data. CAL uses smoothed Dynablack fit results to perform black level corrections on the collateral, background and target pixels for each long or short cadence.

Dynamic Black Level Model Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Time Interval</th>
<th>Baseline Dynablack</th>
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</thead>
<tbody>
<tr>
<td>Cadence by Cadence</td>
<td>Row Dependence</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Column Dependence</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Parallel FGS cross-talk</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Frame FGS cross-talk</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>More Pattern – Rolling Band</td>
<td>Monitored</td>
</tr>
<tr>
<td>Across Cadences</td>
<td>Time Dependence</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Temperature Dependence</td>
<td>x</td>
</tr>
</tbody>
</table>

All terms in the baseline CAL black-level model were static except for the row dependence. Dynablack now enables more complete modeling and accounts for cadence-time and temperature trends, as well as monitoring of moiré pattern and undershoot.

Black-Level Model Component Descriptions

Handling Black-Level Model Coefficients over Multiple Cadences

Spatial fit coefficients vs. time for channels 2.1 and 2.2 are shown. An adaptive fitting algorithm models coefficients as either discrete, constant, time and/or temperature dependent or smoothed.

Dynablack Input Data

- Full Frame Images collected 3 times per quarter
- Reverse-clocked long cadence collected 3 times per quarter
- Collateral Data with each long cadence – Tracking Black (Virtual Columns) - summed across 14 columns (1191-1132)
- Masked and Virtual Smear (Rows) - summed over 12 rows each (718, 1047, 1056)
- Artifact Removal Pixels (ARPs) with each long cadence – Cover time-varying FGS crosstalk
- Also permit undershoot measurement following charge injection rows (1060-1063)

Effect of Dynablack on Calibrated Pixel Time Series

Derived black-level corrections are applied to smear collateral in CAL and both black and smear corrections are applied to target and background pixels. The plots below compare differences between masked and virtual smear pixels and FGS crosstalk-affected background pixels over time series both with and without Dynablack correction. Note 20 ppm for a 12th magnitude star is 600 electrons/cadence.

References
