K2 Data Release Notes 33: 
Campaign 4 Reprocessing

KSCI-19154-002

K2 Data Analysis Working Group

September 14, 2020

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These data release notes were originally prepared by members of the Data Analysis Working Group, and made available as webpages in July, 2019, when the data were originally delivered to the Milksulski Archive for Space Telescopes. They are reproduced here for permanent archiving, with edits for clarity and consistency.

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1 At a Glance

1.1 Pointing
- RA: 59.0759116 degrees
- Dec: 18.6605794 degrees
- Roll: -167.6992793 degrees

1.2 Targets with Data at MAST
- 15,847 EPIC IDs in long cadence (LC)
- 122 EPIC IDs in short cadence (SC)
- Many custom targets (see §2.2)

1.3 Full-Frame Images (FFI)
- ktwo2015051131033-c4_ffi-cal.fits
- ktwo2015092174954-c4_ffi-cal.fits

1.4 First and Last Cadences
- Start Time: 2015-02-08 06:50:09.177 UTC
  - Long Cadence Number: 103744
  - Short Cadence Number: 3100780
- End Time: 2015-04-20 04:32:47.045 UTC
  - Long Cadence Number: 107213
  - Short Cadence Number: 3204879

1.5 Pipeline

No features of the pipeline or data files have changed from Data Release 32 (but there have been numerous changes the last release of C4 data under Data Releases 6 and 10).

Figure 1: Distribution of the Kepler magnitudes of observed LC targets.

Figure 2: Left: Schematic of the C4 field-of-view with high-profile objects shown. Right: A full-frame image (FFI) taken during C4, with a flux scaling designed to highlight features of interest.
2 Features and Events

2.1 Pointing and Roll Performance

The C4 pointing and roll behavior are well within the limits of that seen in other K2 campaigns. The pipeline-calculated maximum distance between the derived and nominal positions for any target (the “maximum attitude residual”, or MAR) for C4 is less than 2 pixels, well under the 4-pixel limit accommodated by the C4 aperture halos. Users should note that, while within limits, the roll error does increase towards the end of the campaign and may result in increased photometric noise.

Figure 3: The roll-error (left) and maximum distance (right) between the photometrically derived attitude (PAD) and the nominal position plotted against time for C4.

2.2 Targets

The Mikulski Archive for Space Telescopes (MAST) K2 Data Search and Retrieval Page has an option to select data by Object Type, including sections for the custom targets listed below. The corresponding custom EPIC IDs for the masks can also be found in the custom aperture file hosted at MAST.

2.3 Pleiades and Hyades

The Pleiades and Hyades are notable features in Campaign 4, and include several bright stars that significantly saturate the detector.

One Director’s Discretionary Target program was approved in Campaign 4 which observes the nine 3–5 mag B-stars and red giants in the Pleiades and Hyades open clusters. The targets were observed using circular pixel masks (20 pixels in radius) that cover the wings of the PSF but not the entire saturation bleed.

The two stars in the Hyades are γ Tau and δ_1 Tau. The seven stars in the Pleiades are: Alcyone (η Tau), Atlas (27 Tau), Electra (17 Tau), Maia (20 Tau), Merope (23 Tau), Taygeta (19 Tau) and Pleione (28 Tau). These stars are all listed in the EPIC, however their data are listed by custom aperture number at the MAST in the range 200007765–200007773.

Figures 4 and 5 show an FFI of module 15, which covers the Pleiades cluster, in two different flux scalings.
2.4 Trans-Neptunian Object

The Trans-Neptunian Object 2002 KY14 was observed in Campaign 4 by creating 1340 masks that cover the path of the TNO. The custom aperture numbers range from 200006425–200007764.
3 Data Quality and Processing Notes

3.1 Light Curve Quality

As in other campaigns, the 6-hour spacecraft roll cycle dominates the systematic errors in C4 simple aperture photometry light curves. The pipeline CDPP 12th magnitude noise benchmark for C4 (DR33) is comparable to that seen in other campaigns with similar star density.

The magnitude dependence of CDPP and its distribution over the focal plane are shown in Figure 6 and Figure 7. CDPP statistics for various magnitude bins are given in an attached file, also printed below.

Attached file: c4_bin1.00_sc1.00_CDPP_Summary_19071014.txt
Figure 6: 6.0-hr CDPP measurements for all targets as a function of Kepler magnitude. Dim targets have poorer overall photometric precision than bright targets, but can look better because the residual sawtooth falls below the noise floor. Saturated targets tend to have lowest CDPP, but often show a residual sawtooth.

### 3.2 Non-Optimal Background Correction near the Pleiades

Background removal for channels near the Pleiades has larger than normal residuals. These large residuals occur on mod.outs 10.3 and 15.1 through 15.4 due to the background on these channels being dominated by dust clouds near the Pleiades. The rich spatial structure of the Pleiades’ dust clouds is poorly captured by the low order ($\leq 4$) polynomial model used to fit the background flux, with the best fit for these channels being given by a constant. This fit is done for every cadence, and the result is higher than normal background residuals, with residuals as large as 7 times the standard deviation of the background pixel values. (Normal residuals are typically less than the background standard deviation.)

It is recommended to be cautious when using light curves or the background model on these channels. Note that the FLUX column of the target pixel files contains calibrated pixels with the background subtracted. The amount of background that was subtracted per pixel can be found in the FLUX_BKG column and restored, if desired.

Local background estimates per star may produce higher-quality results. The change in the constant background level on these channels over time is in family with the median background change on other channels.
Figure 7: 6.0-hr CDPP measured as a function of position on the focal plane, for 12th and 14th magnitude dwarf stars. The photometric precision is generally better near the center of the focal plane where the variations in roll angle produce less pixel motion. All cadences coincident with a definite thruster firing are gapped.
3.3 Large Number of Saturated Stars

Due to the Hyades and Pleiades clusters, there is a large number of bright stars that saturate the detector in Campaign 4. Users are cautioned to ensure that their target(s) are not affected by these bright, bleeding stars prior to analysis. For example, Figure 8 highlights the number and extent of bleed trails on channel 52. Figure 9 shows an example of a typical target that is severely affected by the bleed from a bright star on the same column — examining a target’s TPF image in this manner will reveal if it is affected directly by a bright stars’ bleed.

Figure 8: A scaled image of channel 52 (module.out = 15.4) showing the extent of charge bleeding due to saturated stars.
3.4 Poor Smear Correction on Channel 25, Column 777

The very bright (Kp=5.775), nearby (55.2 ly) solar-like star 39 Tauri was observed in Campaign 4. It is so bright that it saturates the smear calibration columns, and thus smear correction for column 777, and possibly neighboring columns, is not optimal. Caution is encouraged when analyzing other targets on this column as a result of the saturation and poor calibration, especially those at lower row numbers.

39 Tauri was only observed with a typical 4-halo aperture (instead of a dedicated disk as is more typical for bright stars). Thus, any analysis of 39 Tauri itself will be more challenging compared to analysis of other bright stars with dedicated disks.
3.5 Several Stars Show Higher Than Expected Flux

There is a group of target stars whose measured flux is more than twice that expected from their EPIC Kepler magnitudes. Figure 10 shows that these stars fall into spatial groups that are aligned with RA and Dec, rather than focal plane coordinates, strongly indicating that the cause of this anomaly is catalog error. The source of this error is presently unknown and is not correlated with Kepflag values. The optimal apertures used to generate light curves for these targets may be smaller than optimal, reducing their photometric precision.

Figure 10: All C4 target stars plotted in celestial coordinates, colored by their Kepler magnitude inferred from their observed flux minus their Kepler magnitude from the EPIC catalog. There are two square-like regions and a line of blue markers, indicating stars whose inferred Kepler magnitude is about a magnitude smaller than their catalog magnitude, indicating that these stars are about a magnitude brighter than expected.
3.6 Stars Show Lower Than Expected Flux

As shown in Figure 11, comparison of the measured flux to the flux based on their Kepler magnitudes in the EPIC catalog shows that ~3,752 stars (23.8% of all stellar targets) are too bright by about a magnitude. The EPIC catalog field Kepflag gives the provenance of the Kepler magnitude estimate by listing the catalog magnitudes used to estimate the Kepler magnitude. Stars with Kepflag = “JHK” or “J” have Kepler magnitudes that are generally overestimated. These stars appear at all magnitudes, but predominantly have EPIC Kepler magnitudes dimmer than 14. The optimal apertures used to generate light curves for these “JHK” or “J” targets may be larger than optimal, reducing their photometric precision.

![Normalized Flux, kepmag prov = gri or BV](image1)

![Normalized Flux, kepmag prov = JHK or J](image2)

Figure 11: Histograms of the relative flux for C4 stellar targets. Left: the relative flux distribution of stellar targets with EPIC Kepflag values of “gri” or “BV”, showing that their measured flux is consistent with the expected flux. Right: The relative flux distribution of stellar targets with EPIC Kepflag values of “JHK” or “J”, showing that the observed flux is less than half the expected flux.

3.7 Stellar Targets with Negative Lightcurve Values

Seventy-four stellar targets show negative flux values in their SAP_FLUX light curves, which is somewhat more than normally seen. Most of these are very dim, near background level targets at the edge of the focal plane where K2 roll has the largest impact, so it is not surprising that the roll causes negative flux values after background removal. The bright targets with negative flux values either have isolated negative flux outliers or are on the Pleiades channels, where there are large background residuals due to the constant background model on these channels, see above.