K2 Data Release Notes 22:
Campaign 15

KSCI-19138-002

K2 Data Analysis Working Group

September 14, 2020

NASA Ames Research Center
Moffett Field, CA 94035
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Approved by: ________________________ Date: 2020-09-14
Douglas Caldwell, Data Analysis Working Group Lead

Approved by: ________________________ Date: 2020-09-14
Jeffrey L. Coughlin, Science Office Director
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Jeffrey L. Coughlin
Kepler Science Office Director
MS 244-30
NASA Ames Research Center
Moffett Field, CA 94035-1000
kepler-scienceoffice@lists.nasa.gov
# DOCUMENT CHANGE LOG

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<td>May 29, 2020</td>
<td>001</td>
<td>All</td>
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<tr>
<td>September 14, 2020</td>
<td>002</td>
<td>Section 3</td>
<td>Removed the section &quot;Missing CDPP Values for 50% of Non-Custom Targets&quot; as MAST has updated these FITS files to now include the (previously missing) CDPP values. Also, previous release notes erroneously reported CDPP measurements were based on 6.5-hr duration; corrected to 6.0-hr duration CDPP.</td>
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1 At a Glance

1.1 Pointing
- RA: 233.6175730 degrees
- Dec: -20.0792397 degrees
- Roll: 166.7780778 degrees

1.2 Targets with Data at MAST
- 35,078 EPIC IDs in long cadence (LC)
- 118 EPIC IDs in short cadence (SC)
- Many custom targets (see § 2.3)

1.3 Full-Frame Images (FFI)
- ktwo2017246053350-c15_ffi-cal.fits
Note: Only one FFI was collected during C15.

1.4 First and Last Cadences
- Start Time: 2017-08-23 22:18:11 UTC
  - Long Cadence Number: 149142
  - Short Cadence Number: 4462720
  - Long Cadence Number: 153449
  - Short Cadence Number: 4591959

1.5 Pipeline
No features of the pipeline or data files have changed from Data Release 21.
2 Features and Events

2.1 Pointing and Roll Performance

The C15 pointing and roll behavior are well within the limits of that seen in other K2 campaigns for the majority of the campaign. The pipeline calculated maximum distance between the derived and nominal positions for any target (the “maximum attitude residual”, or MAR) for C15 is less than 2.5 pixels, well under the 3-pixel limit accommodated by the aperture halos. There were far fewer anomalous thruster firing events in C15 than were seen in recent campaigns prior to C14.

As mentioned in the C14 (Data Release 20) release notes, a change in the on-board fine point fault logging threshold results in additional cadences being flagged as “Spacecraft is not in fine point” (QUALITY flag bit #16, decimal=32768). Starting with Data Release 21, the pipeline is now ignoring the spacecraft not-in-fine-point flag, and instead is using the “Spacecraft is in coarse point” flag (QUALITY flag bit #3, decimal=4). This flag is set by the project based on the measured pointing error exceeding 1.5 pixels for 4 or more continuous cadences, or exceeding 2.5 pixels for a single cadence. The pipeline will treat these “coarse-point” cadences similar to how “not-in-fine-point” cadences were treated in previous campaigns up to and including C14 — while previously both SAP\_FLUX and PDCSAP\_FLUX were gapped based on the “not-in-fine-point” flag, now the PDCSAP\_FLUX will be gapped based on the “coarse-point” flags (with SAP\_FLUX not affected). The project recommends that starting with C15, users look to QUALITY flag bit #3 as an indicator of poor spacecraft pointing.

![Figure 3: The roll-error (left) and maximum distance (right) between the photometrically derived attitude (PAD) and the nominal position plotted against time for C15.](image)

Figure 3: The roll-error (left) and maximum distance (right) between the photometrically derived attitude (PAD) and the nominal position plotted against time for C15.
2.2 Solar Flares and Coronal Mass Ejections (CMEs) During Observations

From September 6—10, 2017 (during C15 observations) the Sun emitted 27 M-class and four X-class flares and released several powerful coronal mass ejections, or CMEs. The effect of these flares and CMEs is visible in K2 data during C15, most notably in the measured dark current level for all channels; Figure 4 provides examples for channels 15 and 25. Peak dark current emission occurred around long cadences 149142 + 675, 901, and 957, respectively, corresponding to BJD 2458003.23, 2458007.85, and 2458009.00. Users are urged caution in interpreting astrophysical events in observed targets that have similar timing and duration to these CME events.

![Figure 4: The dark level measured on channel 15 (top) and channel 25 (bottom) during during C15.](image-url)
2.3 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.

2.3.1 Galaxies

There are 3,485 galaxies targeted in the C15 field of view all of which used standard aperture masks.

2.3.2 Clusters

The field of view contains the old globular cluster NGC 5897, which was tiled with a 6x6 array of 15x15 pixel tiles for a total of 8100 pixels (IDs 200194922–200194957).

The C15 field of view also overlaps a portion of the young (∼11 Myr-old) star association Upper Sco, the most nearby OB star association (400 light-years away). Targets observed in this association include:

- Delta Sco: one of the best-studied Be-type stars, known for outbursts in 2000 and 2011. The target is very bright (Kp=2) and thus observed using a custom circular mask (ID 200194910)
- Several other bright B- and A-type stars (Kp=4–6)
- Hundreds of low-mass pre-main sequence stars

2.3.3 Other Notable Targets

- 38 Solar System objects, including:
  - Asteroid Ryugu: target of the Hyabusa 2 sample return mission (IDs 200194922–200194787)
  - 3 Main-belt asteroids: Fantasia, Neujmina, and Stereoskopia
  - 4 Comets: 94P/Russell, 130P/McNaught-Hughes, C/2014 F3 (Sheppard-Trujillo), and C/2014 W2 (PANSTARRS)
  - 16 Jupiter Trojans and 14 Trans-Neptunian Objects
- Targets being observed in short cadence include:
  - GW Lib: a cataclysmic variable with a white dwarf that pulsates (ID 249251294)
  - 2MASS 1507-1627: an L5-type Brown Dwarf located just 24 light-years from Earth (ID 249914869)
  - K2-38: an exoplanet system with two transiting super-Earths discovered in K2 Campaign 2 (ID 204221263)
3 Data Quality and Processing Notes

3.1 Light Curve Quality

As in previous campaigns, the 6-hour spacecraft roll cycle continues to dominate the systematic errors in C15 simple aperture photometry light curves. The pipeline CDPP 12th magnitude noise benchmark for C15 is the lowest seen since C6. It is comparable to that seen in early campaigns with similar star density (C6, C8, C10), but is well below that seen in C12, also with similar star density. While there is not a definitive cause for the improved precision, it is likely due to a combination of the relatively low star density, the return to more stable pointing (compared to recent campaigns), and the updated pipeline version (in particular the use of the coarse-point flags).

The magnitude dependence of CDPP and its distribution over the focal plane are shown in Figure 5 and Figure 6. CDPP statistics for various magnitude bins are given in an attached file, also printed below.

Attached file: c15_bin1.00_sc1.00_CDPP_Summary_18020113.txt

Kepler Data Analysis Handbook Supplement
6.0 hr CDPP Summary
Generated by MATLAB program cdpp_stats.ismember.m using quasiCdpp
  collected by fovPlottingClass.compile fov_statistics_from_taskDirs
Bin Width 1 mag, CDPP in ppm, dwarfs identified by logg >=4
File Name: c15_bin1.00_sc1.00_Summary.txt
Star list: /home/jevancle/matfiles/files/k2StellarPropertiesStruct.mat
This file created: 01-Feb-2018 13:23:10
MJD 58150.55775
Column Definitions
1. KepMag bin
2. Number of dwarfs
3. 10th percentile CDPP for dwarfs
4. Median CDPP for dwarfs
5. Number of stars in list in bin
6. 10th percentile CDPP of all stars
7. Median CDPP for all stars
8. Number of giants
9. 10th percentile CDPP for giants
10. Median CDPP for giants
11. Noise model CDPP
12. Fraction of all stars < noise model, percent

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Figure 5: 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.
Figure 6: 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.
3.2 Targets With Incorrect Flux Scaling

During the analysis of C15 data, the DAWG uncovered an inconsistency in how targets with high proper motion are handled. It was noted that there is a target with an anomalously high average value for the PDC corrected flux, corresponding to a Kp=7.5 mag star when it should be a magnitude Kp=12 star. The issue was traced to the fact that the target EPIC 250111823 (Ross 802) is a high-proper motion star (-448, -624 mas/yr) that is ∼12 arcsec from its J2000 catalog position. The photometric analysis code (PA-COA) was not supplied with proper motion information and did not find a star at the catalog position. The code correctly reverted to the flight target aperture (which does account for proper motion), but computed the flux-fraction in aperture (FFIA∼0.03) and crowding metric based on the assumption that the target was well outside the flight aperture. The low flux-fraction in aperture caused the PDC flux time series (PDCSAP_FLUX) to be scaled up by a factor of ∼1/0.03, or ∼33. The time variation of the PDCSAP_FLUX is correct for the target aperture, only mis-scaled. The SAP_FLUX is unaffected by this bug.

There is a potential mis-scaling for any targets with accumulated proper motion since J2000 that is larger than ∼1.5 pixels (∼6 arcseconds). Users should check for potentially mis-scaled PDCSAP_FLUX for any of the C15 targets with accumulated proper motion ≥ 1 pixel (∼4 arcseconds).

3.3 Targets Affected by CAL Bug

Due to a bug in the smear tables, column 928 on channel 33, and column 1008 on channel 47, had both their real and virtual smear values gapped, which resulted in values of “0.0” for the flux along the entire column. This might potentially affect the light curves of the following targets, which contain the affected column in their pixel-stamp image. Users may want conduct custom photometry that excludes or accounts for the affected column.

The EPIC IDs of the affected targets are 249868223, 249921937, 249924613, 249934130, and 249198204.

3.4 Dynamic Black Correction

A new feature of the Kepler pipeline that was implemented for K2 processing, starting with Data Release 21, is the use of Dynamic Black Correction, or “Dynablack”, which is essentially a more sophisticated algorithm to perform the CCD pixel-level calibration that accounts for time varying, instrument-induced artifacts when calibrating the data.

Dynablack uses the full-frame images and collateral pixels to provide two main benefits compared to traditional pixel calibration:

- Correct thermally dependent fine guidance sensor crosstalk pixels.
- Identify rolling-band artifacts (see §6.7 of the Kepler Instrument Handbook) with flags in the target pixel files.

For the latter case, users can use the new RB_LEVEL flags in the FITS files. See §A.1.1 of the Kepler Data Release 25 Notes and §2.3.2 of the Kepler Archive Manual for information on how to interpret and utilize the RB_LEVEL flags. Users should note that the RB_LEVEL test at the shortest duration (3 hours) is overly sensitive to instrument noise and does not offer a reliable indicator of the presence of rolling band pattern noise. Because the binary “Rolling Band Detected” QUALITY and SAP_QUALITY flags (bits 18, 19) in the target pixel files and light curve files are based on a rolling band detection at any of the test durations, they also do not provide a reliable indicator of the presence of rolling band pattern noise. The RB_LEVEL flags at durations of 6 hours and longer provide the best indication of the presence of rolling band artifacts.
3.5 Short Cadence Light Curves

Starting with Data Release 21, short-cadence light curves are now produced and available at MAST, though users are strongly cautioned that no work was done to adapt the Kepler pipeline’s detrending module (PDC), developed for Kepler data, to work well on K2 data. Thruster firings are especially poorly corrected for most short-cadence targets, and other systematic features may not be corrected well. See Figure 7 for an example of remaining systematics in short-cadence data around thruster firings. However, some targets do have adequate detrending in short-cadence, and even in the cases of poor detrending, short-term astrophysical variation can be seen for targets where such astrophysical variation exists. See Figure 8 where the $\sim$18 min periodic variations of the AM CVn type binary HP Lip are readily apparent in the C15 short-cadence light curve. The hope is that producing these short-cadence light curves overall benefits the community compared to not producing them, even if they may only be used for initial inspection of the short-cadence data, which might prompt users to perform their own short-cadence detrending, or better adapt the existing long-cadence Cotrending Basis Vector (CBV) files for use in detrending the short-cadence data.

![Figure 7: The Exoplanet Host K2-38 / EPIC 204221263](image1)

![Figure 8: The AM CVn type Binary HP Lip / EPIC 250105131](image2)