NASA/TM—202500000000

TESS Data Release Notes:
Sector 1751, DR136

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April 13, 2026

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Acknowledgements

These Data Release Notes provide information on the processing and export of data from the Transiting Exoplanet Survey Satellite (TESS). The data products included in this data release are full frame images (FFIs), target pixel files, light curve files, collateral pixel files, cotrending basis vectors (CBVs), and Data Validation (DV) reports, time series, and associated xml files.

These data products were generated by the TESS Science Processing Operations Center (SPOC, Jenkins et al., 2016) at NASA Ames Research Center from data collected by the TESS instrument, which is managed by the TESS Payload Operations Center (POC) at Massachusetts Institute of Technology (MIT). The format and content of these data products are documented in the Science Data Products Description Document (SDPDD). The SPOC science algorithms are based heavily on those of the Kepler Mission science pipeline, and are described in the Kepler Data Processing Handbook (Jenkins, 2020). The Data Validation algorithms are documented in Twicken et al. (2018) and Li et al. (2019). The TESS Instrument Handbook (Vanderspek et al., 2018) contains more information about the TESS instrument design, detector layout, data properties, and mission operations.

The TESS Mission is funded by NASA's Science Mission Directorate.

This report is available in electronic form at
https://archive.stsci.edu/tess/

1 Observations

TESS Sector 1751 represents a dedicated observation of the interstellar comet 3I/ATLAS[1]. The sector was designed to leverage the high cadence and precision of TESS photometry over multi-day time scales to provide insights into the comet's activity following its closest approach to the Sun. This planned special sector interrupted normal operations in Sector 99 near the end of physical orbit 209, pointed to the comet field for ∼7 days, and then returned to normal operations in orbit 210.

In this sector, data collection was paused for two events. The first was a safe mode event, which occurred about 18 hr after the start of observations, and lasted for 2.81 days. The solar panel orientation was not updated for the Sector 1751 pointing, which resulted in limited energy generation. The subsequent increase in TESS's battery discharge rate triggered the safe mode. The second was the planned data downlink near apogee between orbits 209 and 210, lasting 0.21 days. In total, there are 4.25 days of science data collected in Sector 1751.

Table 1: Sector 1751 Observation Times

	UTC	TJD[a]	Cadence #
Start of Observations in Orbit 209b	2026-01-15 06:01:17	4055.75170	2036374
Start of Safe Mode	2026-01-15 23:59:17	4056.50031	2036912
End of Safe Mode	2026-01-18 18:51:17	4059.28642	2038919
End of Observations in Orbit 209b	2026-01-19 05:29:17	4059.72947	2039237
Start of Orbit 210a	2026-01-19 10:31:17	4059.93919	2039389
End of Observations in 210a	2026-01-22 11:59:17	4063.00030	2041592

[a] TJD = TESS JD = JD - 2,457,000.0
(The horizontal black lines mark gaps in the light curves.)

The spacecraft pointing was set to RA (J2000): 109.4916°; Dec (J2000): 21.8424°; Roll: 84.3356°. This pointing was designed to align the comet's path along a column of pixels on Camera 2, CCD 3. See the TESS project Sector 1751 observation page[2] for the coordinates of the spacecraft pointing and center field-of-view of each camera. Fields-of-view for each camera can be found at the TESS Guest Investigator Office observations status page.[3]

Given its short duration and focused objective, only a subset of the pipeline modules were run to produce data products relevant to the science goals at hand. The data products delivered to the MAST for this sector are as follows: calibrated target-pixel files for 37 postage stamps, each 50×50 pixel in size, that follow the comet's path at 2-minute and 20-second cadences, light curves for PPA targets at 2-minute and 20-second cadences, and calibrated FFIs at 200-second cadence.

[1] https://tess.mit.edu/news/tess-special-observations-of-interstellar-comet-3i-atlas-january-2026/
[2] https://tess.mit.edu/observations/3i_atlas/
[3] https://heasarc.gsfc.nasa.gov/docs/tess/sector.html

1.1 Targets and Light Curves

The design of the SPOC pipeline does not allow for the photometry of moving objects. As such, the selection of targets in Sector 1751 was designed to enable the production of calibrated target-pixel files from which comet measurements can be extracted. This was achieved by selecting the nominal number of photometer performance assessment (PPA) targets for 2-min and 20-sec observing modes, 120 and 36 per CCD, respectively. These targets are required to compute the TESS WCS solution in the SPOC pipeline. In addition, 37 target postage stamps for the comet, each 50×50 pixels in size, were selected to trace its motion across the sector. Each comet postage stamp is tied to a unique TIC ID, but they are centered to capture the comet's path.

In total, there were 613 targets chosen for 20-second cadence observations and 1957 targets chosen for 2-minute cadence observations. Light curves are computed for all targets but only delivered to MAST for the PPA targets in each observing mode, 1920 and 576 at 2-minute and 20-second cadences, respectively. The PPA targets were fully processed by the pipeline and did not produce warnings during aperture assignment.

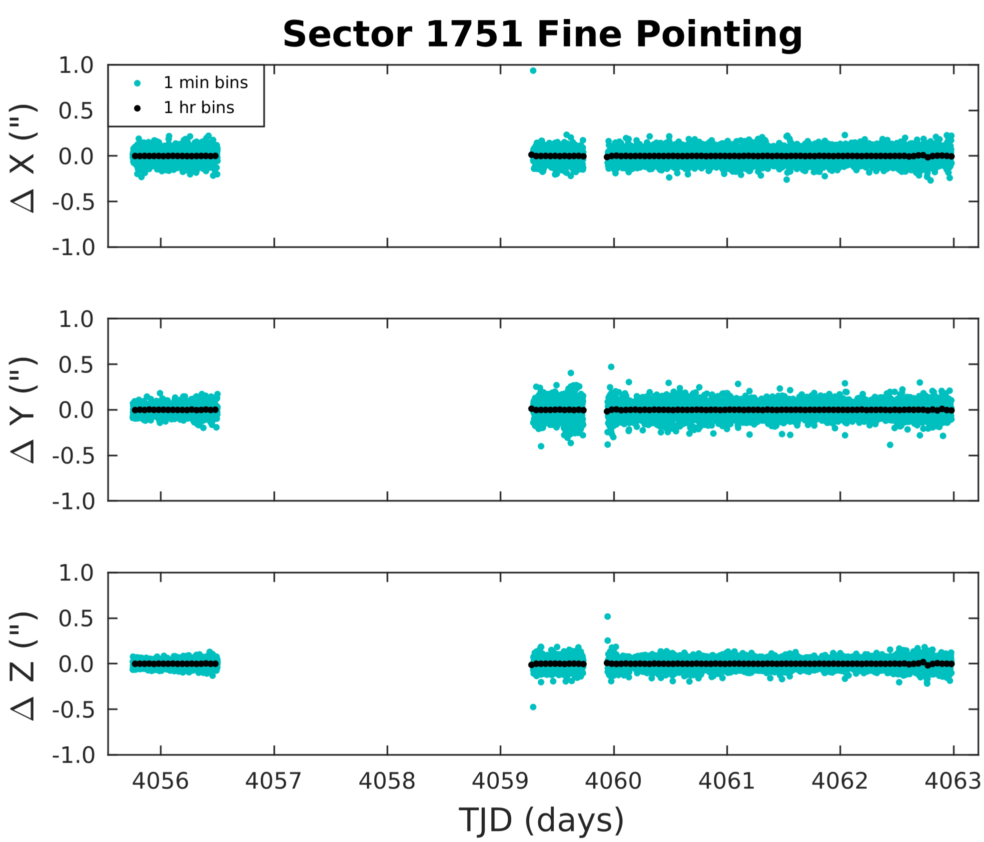

Figure 1: The delta-quaternions from each camera have been converted to spacecraft frame, binned to 1 minute and 1 hour, averaged across cameras. Long-term trends (such as those caused by differential velocity aberration) have also been removed. The ΔX/ΔY directions represent offsets along the detectors' rows/columns, while the ΔZ direction represents spacecraft roll.

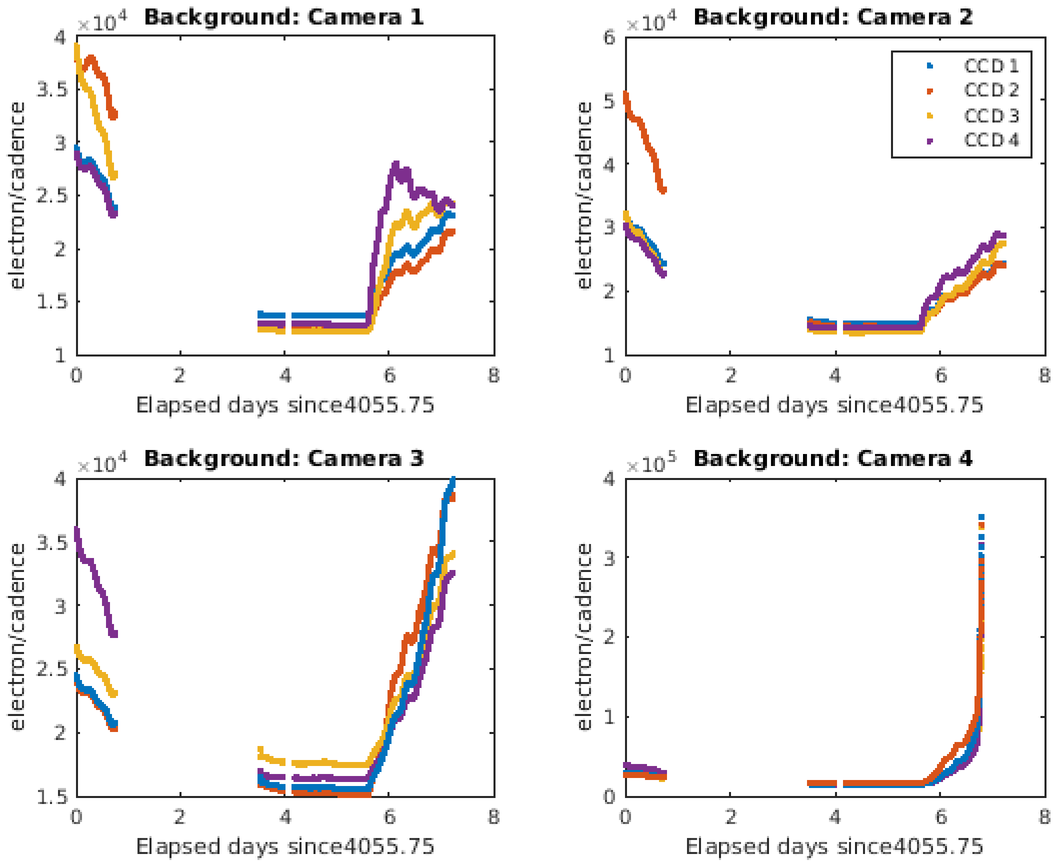

Figure 2: Median background flux across all targets on a given CCD in each camera. The changes are caused by variations in the orientation and distance of the Earth and Moon. Comet 3I/ATLAS fell on Camera 2, CCD 3.

1.2 Spacecraft Pointing and Momentum Dumps

The pointing in Sector 1751 was set at -0.4 degrees in ecliptic latitude. The four science cameras were oriented along the Ecliptic plane. Cameras 1 and 4 were used for guiding in Orbits 209b and 210a. A momentum dump was performed in between the two orbits. The momentum dumps are performed at the end of each data downlink just before data collection resumes. Data impacted by momentum dumps and data downlinks are marked with data quality flags (see Appendix A). Figure 1 summarizes the pointing performance over the course of the sector based on Fine Pointing telemetry.

1.3 Scattered Light

The timing of Sector 1751 was chosen to minimize the impact of scattered light. Figure 2 shows the median value of the background estimate for all targets on a given CCD as a function of time. Times of high background correspond to times when the Earth and/or Moon approach the camera's field of view causing scattered light from these bright objects to enter the cameras. The viewing geometry of the Earth and Moon relative to TESS's pointing in Sector 1751 are shown in Figure 3. Figure 3 shows the angle between each camera's boresight and the Earth or Moon—this figure can be used to identify periods affected by scattered light and the relative contributions of the Earth and Moon to the image backgrounds. Scattered light increases as the camera boresight angle between the Earth and Moon is $\lesssim 35°$ and will strongly impact photometric observations for angles $\lesssim 25°$. Data impacted by scattered light are marked with data quality flags (see Appendix A).

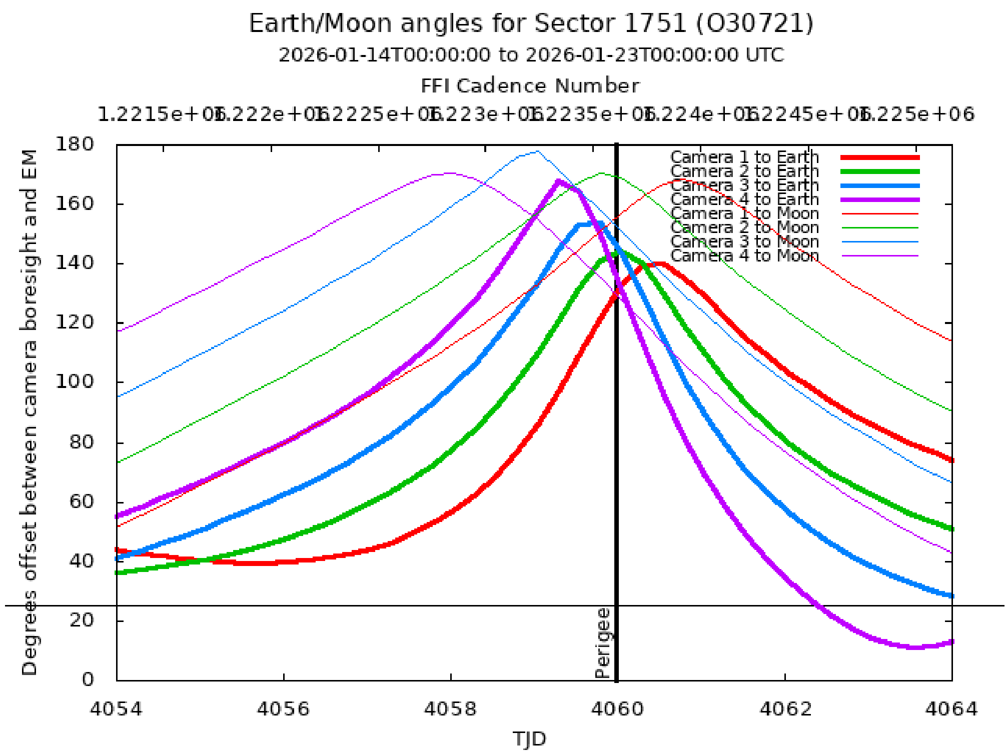

Figure 3: Angle between the four camera boresights and the Earth/Moon as a function of time. When the Earth is within ∼25° of a camera's boresight, transiting planet searches may be compromised by high levels of scattered light. At larger angles, up to ∼35°, scattered light patterns and complicated structures may be visible. At yet larger angles, low level patchy features may be visible. Scattered light from the Moon is generally only noticeable below ∼35°. This figure can be used to identify periods affected by scattered light and the relative contributions of the Earth and Moon to the background. However, the background intensity and locations of scattered light features depend on additional factors, such as the Earth/Moon azimuth and distance from the spacecraft. Comet 3I/ATLAS fell on Camera 2, CCD 3.

1.4 Smear Correction Contamination

Due to the shutterless operation of the TESS instrument (see TESS Instrument Handbook, §9.5), data calibration involves subtracting a smear correction. The "smear rows" are virtual pixels (not physical pixels) that provide an estimate of the contaminating flux that accumulates in each pixel during the ∼0.02 s shutterless frame transfer. The smear correction, estimated from the smear rows, is subtracted from the whole column. However, bright stars located in the science frame, upper buffer rows, and lower science frame rows can bleed into the smear rows resulting in an overestimated smear correction. An overestimated smear correction in calibrated data products can be identified by one or more consecutive columns that are anomalously dark relative to neighboring columns, whereas the raw/uncalibrated images do not reveal an anomalously dark column relative to its neighbors. Mitigating an overestimated smear correction may require a custom calibration that robustly interpolates across the contaminated smear columns or a robust smear estimate from the science frame.

1.5 Data Anomaly Flags

The SDPDD (§9) lists data quality flags and the associated binary values used for TESS data. Appendix A describes each Data Anomaly Flag in more detail.

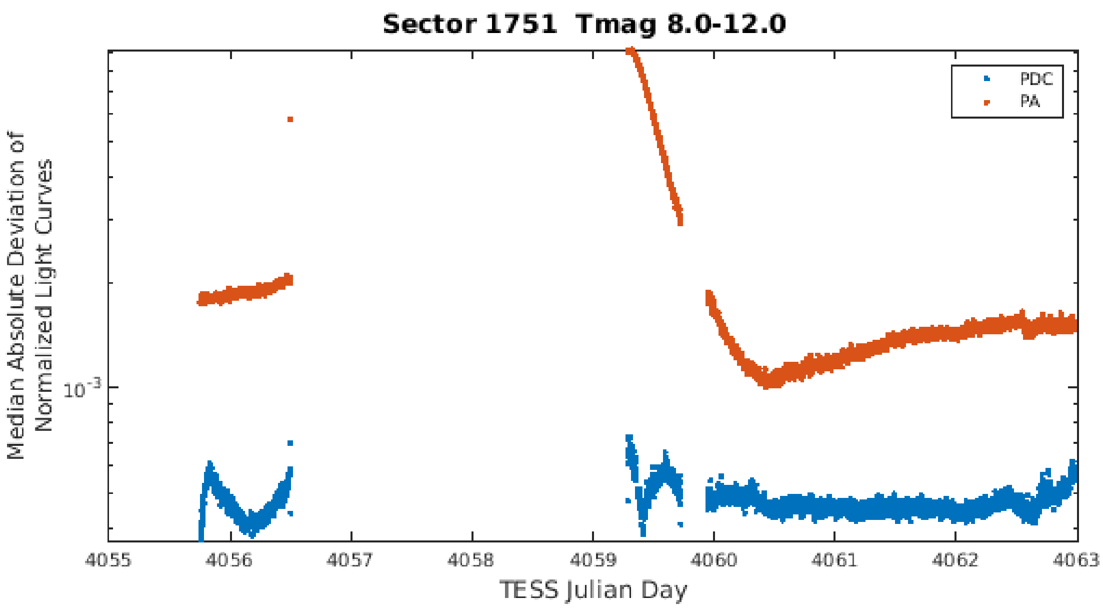

Figure 4: Median absolute deviation (MAD) for the two-minute cadence data from Sector 1751, showing the performance of the cotrending after identifying Manual Exclude data quality flags. The MAD is calculated in each cadence across stars with flux variations less than 1% for both the PA (red) and PDC (blue) light curves, where each light curve is normalized by its median flux value. The scatter in the PA light curves is much higher than that for the PDC light curves, and the outliers in the PA light curves are largely absent from the PDC light curves due to the use of the anomaly flags.

2 Pipeline Performance and Results

2.1 Light Curves and Photometric Precision

The short duration and large gaps in Sector 1751 present challenges to systematic error correction (PDC). Figure 4 shows an assessment of the PDC systematic error correction of

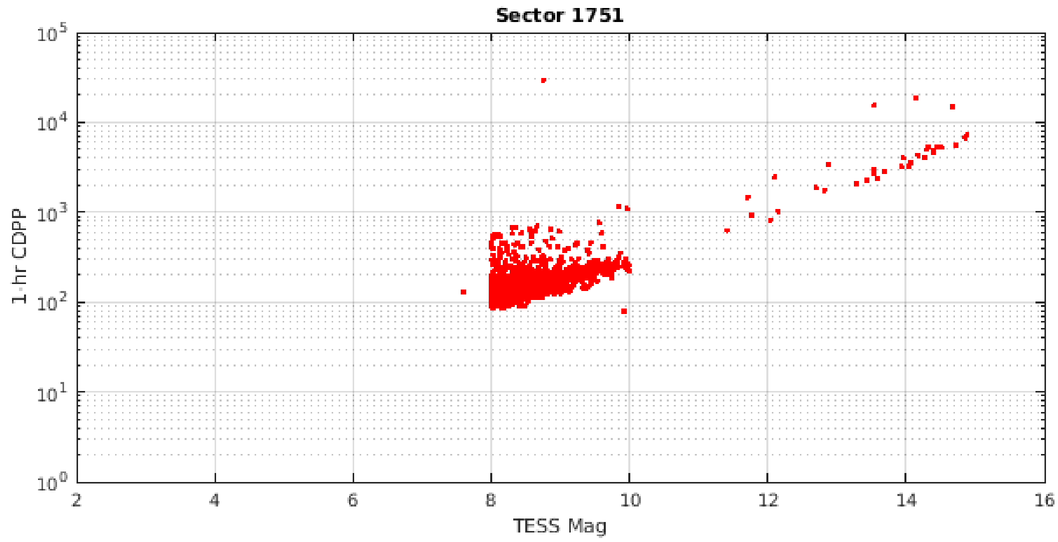

Figure 5: 1-hour CDPP. The red points are the RMS CDPP measurements for the 1920 light curves from Sector 1751 plotted as a function of TESS magnitude.

the pipeline by comparing simple aperture photometry light curves from PA and the PDC systematic-error corrected light curves. Although the PDC light curves show a reduction in systematic noise, the quality of the correction is likely worse than that of a typical sector.

Figure 5 shows the achieved Combined Differential Photometric Precision (CDPP) at 1-hour timescales for two-minute targets. The axes of this figure span the typical range of targets in a TESS sector. Targets falling between 8th and 10th magnitude are the PPA targets which have CDPP values that are typical of a normal sector: $\sim$ 200ppm at 10th magnitude. The scatter of other targets are comet postage stamps.

We encourage users to examine several light curve quality assessment values (CROWDSAP, PDC_TOT, PDC_COR, and PDC_NOI) that are available in the light curve data product FITS headers; in particular, in the second FITS header of light curve data products (see SDPDD).

The CROWDSAP keyword represents the fraction of flux in the photometric aperture attributable to the target star (after background correction). A low value for CROWDSAP indicates that other stars contribute a significant amount of flux to the target and the light curve may not isolate variability for the target star of interest.

The keywords PDC_TOT, PDC_COR, and PDC_NOI assess the quality of the PDC cotrending procedure. Values of the PDC keywords range from 0.0 to 1.0, with values towards 1.0 indicating a high quality of the PDC cotrending outcome (KDPH; §8.3.3.XIV). The correlation goodness metric (PDC_COR), is calibrated such that a value greater than 0.8 means there is less than 10% mean absolute correlation between the target under study and all other targets on the CCD. The introduced noise metric (PDC_NOI) is calibrated such that a value greater than 0.8 means the power in broad-band introduced noise is below the level of uncertainties in the flux values. The total goodness metric (PDC_TOT) provides an overall summary of the cotrending quality.

2.2 Transit Search and Data Validation

Due to the short duration of Sector 1751, the small number of targets, and the limited performance of systematic error correction, the SPOC transit search was only performed to assess the CDPP of the PPA-target light curves (see Figure 5). No TCE or data validation products were produced as part of this sector.

Appendix A: Details of Data Anomaly Flags

See the SDPDD (§9) for a list of data quality flags and the associated binary values used for TESS data.

The following flags are set by hand, based on mission operations and spacecraft telemetry: bits 1 and 2 (Attitude Tweak and Safe Mode).

Cadences marked with bits 3, 4, 6, and 12 (Coarse Point, Earth Point, Reaction Wheel Desaturation Event, and Predicted Straylight) are flagged based on spacecraft telemetry. Cadences marked with bits 2 and 4 (Safe Mode and Earth Point) have `NULL` values for the timestamps and data in the target-pixel files and light curve files.

Note that just after the data downlinks near apogee (midpoint of each orbit), the spacecraft pointing is still settling for 20 to 60 seconds after data collection resumes. Cadences during this time are marked with bit 8 (Manual Exclude, described below).

Cadences marked with bit 5 and 10 (Argabrightening Events and Impulsive Outlier) were identified by the SPOC pipeline. Bit 5 marks a sudden change in the background measurements. In practice, bit 5 flags are caused by rapidly changing glints and unstable pointing at times near momentum dumps. Bit 10 marks an outlier identified by PDC and omitted from the cotrending procedure.

The 20-second data mode includes cadences marked with bit 7 and 11 (Cosmic Ray in Optimal Aperture and Cosmic Ray in Collateral Pixel). These flags indicate cadences affected by cosmic rays that are removed by the pipeline, and can be found in both the TPF and LC files. The data provided in the archive products are corrected for cosmic rays, and a `FITS` table extension in the TPF and Collateral Pixel File details the cosmic rays identified and removed by the pipeline at the pixel level.

Cadences marked with bit 8 (Manual Exclude) are ignored by PDC, TPS, and DV for cotrending and transit searches. These cadences were identified using spacecraft telemetry from the fine pointing system. All cadences with pointing excursions >7 arcsec (0.3 pixel) were flagged for manual exclude. These cadences can also be set manually in order to identify off-nominal data collection (e.g., engineering tests, spacecraft anomalies, etc).

The predicted stray light flag (bit 12, value 2048) is marked in the FFIs and flags times when the Earth/Moon are near the camera FOVs and may interfere with guiding or saturate the detectors. We strongly recommend that users inspect the FFI data before removing images marked with bit 12, as this flag is set based on predictions from mission planning and is known to be conservative with respect to the quality of data usable for analysis. This flag is disabled for the 2-minute and 20-second data products.

The scattered light exclude flag (bit 13, value 4096) identifies cadences at which individual targets are affected by scattered light.

If the Earth/Moon interference is strong enough to saturate the detector, all targets on a CCD slice will be affected and the data are unusable. Cadences with bad calibrations due to saturation are now explicitly marked with bit 15 (value 16384, "Bad Calibration Exclude"). For some cadences, the majority of targets on a CCD may be flagged for scattered light and not enough valid data remains to derive cotrending basis vectors in PDC. No systematic error correction can be applied at these times. This situation is identified by bit 16 (value 32768, "Insufficient Targets for Error Correction Exclude").

FFIs were only marked with bits 3, 4, 6, 8, 12, and 15 (Coarse Point, Earth Point, Reaction Wheel Desaturation Events, Manual Exclude, Straylight, and Bad Calibration Exclude). There are no WCS coordinates for FFIs that coincide with momentum dumps (bit 6).

References

Jenkins, J. M. 2020, Kepler Data Processing Handbook: Overview of the Science Operations Center, Tech. rep., NASA Ames Research Center

Jenkins, J. M., Twicken, J. D., McCauliff, S., et al. 2016, in Proc. SPIE, Vol. 9913, Software and Cyberinfrastructure for Astronomy IV, 99133E, doi: 10.1117/12.2233418

Li, J., Tenenbaum, P., Twicken, J. D., et al. 2019, *PASP*, 131, 024506, doi: 10.1088/1538-3873/aaf44d

Twicken, J. D., Catanzarite, J. H., Clarke, B. D., et al. 2018, *PASP*, 130, 064502, doi: 10.1088/1538-3873/aab694

Vanderspek, R., Doty, J., Fausnaugh, M., et al. 2018, TESS Instrument Handbook, Tech. rep., Kavli Institute for Astrophysics and Space Science, Massachusetts Institute of Technology

Acronyms and Abbreviation List

BTJD Barycentric-corrected TESS Julian Date

CAL Calibration Pipeline Module

CBV Cotrending Basis Vector

CCD Charge Coupled Device

CDPP Combined Differential Photometric Precision

COA Compute Optimal Aperture Pipeline Module

CSCI Computer Software Configuration Item

CTE Charge Transfer Efficiency

Dec Declination

DR Data Release

DV Data Validation Pipeline Module

DVA Differential Velocity Aberration

FFI Full Frame Image

FIN FFI Index Number

FITS Flexible Image Transport System

FOV Field of View

FPG Focal Plane Geometry model

KDPH Kepler Data Processing Handbook

KIH Kepler Instrument Handbook

KOI Kepler Object of Interest

MAD Median Absolute Deviation

MAP Maximum A Posteriori

MAST Mikulski Archive for Space Telescopes

MES Multiple Event Statistic

NAS NASA Advanced Supercomputing Division

PA Photometric Analysis Pipeline Module

PDC Presearch Data Conditioning Pipeline Module

PDC-MAP Presearch Data Conditioning Maximum A Posteriori algorithm

PDC-msMAP Presearch Data Conditioning Multiscale Maximum A Posteriori algorithm

PDF Portable Document Format

POC Payload Operations Center

POU Propagation of Uncertainties

PPA Photometer Performance Assessment

ppm Parts-per-million

PRF Pixel Response Function

RA Right Ascension

RMS Root Mean Square

SAP Simple Aperture Photometry

SDPDD Science Data Products Description Document

SNR Signal-to-Noise Ratio

SPOC Science Processing Operations Center

SVD Singular Value Decomposition

TCE Threshold Crossing Event

TESS Transiting Exoplanet Survey Satellite

TIC TESS Input Catalog

TIH TESS Instrument Handbook

TJD TESS Julian Date

TOI TESS Object of Interest

TPS Transiting Planet Search Pipeline Module

UTC Coordinated Universal Time

WCS World Coordinate System

XML Extensible Markup Language