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TESS Data Release Notes: Sectors 1 – 6, Multi-sector Search, DR12

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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). This data release is a combined, multi-sector transit search only. The underlying data products from individual observing sectors have been previously released. The data products included in this data release are the Data Validation (DV) reports, time series, and associated xml files for the threshold crossing events (TCEs) found by searching a combined data set including data from multiple observing sectors.

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 \(SDPDD\)](#)¹. 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, 2017](#)).² The Data Validation algorithms are documented in [Twicken et al. \(2018\)](#) and [Li et al. \(2019\)](#). The TESS Instrument Handbook³ ([Vanderspek et al., 2018](#)) contains more information about the TESS instrument design, detector layout, data properties, and mission operations.

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

¹<https://archive.stsci.edu/missions/tess/doc/EXP-TESS-ARC-ICD-TM-0014.pdf>

²<https://archive.stsci.edu/kepler/manuals/KSCI-19081-002-KDPH.pdf>

³https://archive.stsci.edu/missions/tess/doc/TESS_Instrument_Handbook_v0.1.pdf

1 Data

TESS Data Release 11 consists of results from a transiting planet search conducted with the combined data from Sectors 1 through 6. Figure 1 shows the Right Ascension (RA) and Declination (Dec) of all two-minute targets, color-coded by the number of sectors for which each target was observed. Targets with new data in Sector 4, 5, or 6 that were observed in at least one other earlier sector were subjected to a multi-sector planet search (see Data Release 3 and Data Release 6 for Sector 1–2 and Sector 1–3 multi-sector planet searches, respectively). The data are the same 2-minute cotrended light curves presented in previous single sector data releases. Table 1 provides basic information and data release note URL entries for the observations of each sector. The observations span a 164.7 day interval.

Table 2 summarizes the total number of targets with multi-sector data. A supplemental table⁴ lists the targets searched in this data release, including a string indicating which sectors the target was observed in, whether the target produced a TCE or not, and whether the target completed DV analysis or not.

1.1 Planet Search Excludes

In this multi-sector planet search, additional cadences were excluded beyond the single sector searches. These cadences were selected by running the multi-sector TPS pipeline module and flagging cadences associated with an excess number of TCEs. TCEs that are clustered in time are likely triggered by systematic effects from the instrument or errors in the light curves. The planet-search-exclude cadences apply to all targets for all cameras and they can be identified in the DV time series data products where the ‘QUALITY’ bit string is zero but the ‘PDCSAP_FLUX’ is not-a-number (NAN) or null.

Table 1: Sectors Searched

| Sector # | Physical Orbits | Start TJD ^a | End TJD | Data Release # |
|----------|-----------------|------------------------|----------|----------------|
| 1 | 9,10 | 1325.293 | 1353.178 | 1 |
| 2 | 11,12 | 1354.101 | 1381.515 | 2 |
| 3 | 13,14 | 1385.90 | 1406.292 | 4 |
| 4 | 15,16 | 1410.900 | 1436.849 | 5 |
| 5 | 17,18 | 1437.826 | 1464.400 | 7 |
| 6 | 19,20 | 1468.270 | 1490.044 | 8 |

^a TJD = TESS JD = JD - 2,457,000.0

⁴https://archive.stsci.edu/missions/tess/catalogs/targetinfo/tess_multisector_01_06_drn11_targetinfo_v02.txt

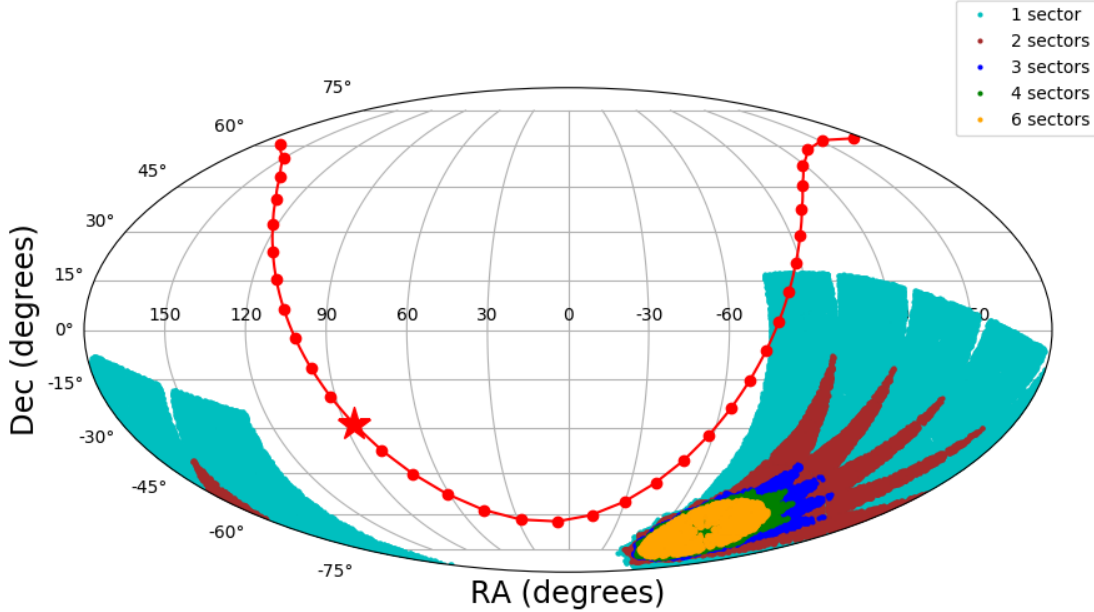


Figure 1: Right Ascension and Declination for all TESS two-minute targets, color-coded by the number of sectors in which that target was observed.

2 Transit Search and Data Validation

The light curves of 15806 targets observed in Sectors 1 through 6 were subjected to the transit search in TPS. Figure 2 shows the 1-hour CDPF for the combined light curves of these targets. Threshold Crossing Events (TCEs) at the 7.1σ level were generated for 1497 of these targets. A search for additional TCEs in potential multiple planet systems was conducted in DV through calls to TPS. A total of 2834 TCEs were identified in the SPOC pipeline on 1496 unique target stars. There was 1 target (33879968) that caused a run-time error in DV, and the TCEs associated with that target are not available in the archived data products. Targets with errors are flagged in the supplemental target information table, and visual inspection of these cases did not yield plausible planet candidates. Table 3 provides a breakdown of the number of TCEs by target. Note that targets with large numbers of TCEs are likely to include false positives.

Figure 3 gives the distribution in period–transit depth space of the TCEs found in the multi-sector search. The top panel shows the distribution of orbital periods for the TCEs. After rapidly declining for periods between 1 and 5 days, the distribution shows a broad tail towards the longest period allowed ($\lesssim 160$ day) while requiring at least two transit events. Small excesses of TCEs at a given period can primarily be associated with scattered light

Table 2: Targets With Number of Sectors Observed

| Number of Sectors | Target Count |
|-------------------|--------------|
| 2 | 6339 |
| 3 | 2782 |
| 4 | 1263 |
| 5 | 2302 |
| 6 | 3120 |

Table 3: Sector 1 – 6 TCE Numbers

| Number of TCEs | Number of Targets | Total TCEs |
|----------------|-------------------|------------|
| 1 | 719 | 719 |
| 2 | 460 | 920 |
| 3 | 163 | 489 |
| 4 | 89 | 356 |
| 5 | 40 | 200 |
| 6 | 25 | 150 |
| – | 1496 | 2834 |

and momentum dump features (see below).

The vertical histogram in the right panel of Figure 3 shows the distribution of transit depths derived from limb-darkened transiting planet model fits for TCEs. The model transit depths range down to the order of 100 ppm, but the bulk of the transit depths are considerably larger.

Figure 4 shows the number of TCEs at a given cadence that exhibit a transit signal and highlights observing epochs with pointing and scattered light variations. Problematic epochs can be identified with the large ($>3\sigma$) peaks.

3 TOI Matching

DV is provided with the latest TESS Object of Interest (TOI) IDs and ephemerides at the time it is executed. The ephemerides of all TCEs identified in the SPOC pipeline are matched against those of the existing TOIs (Twicken et al., 2018). Target-level matches (e.g., TOI 144) are reported in the DV archive products if the TIC ID of a DV target is the same as the TIC ID of a TOI. Planet-level matches (e.g., TOI 144.01) are reported if there is high correlation between the ephemeris of a TCE and that of a TOI hosted by the same target star.

TOI matching was not configured correctly in the multiple-sector transit search described in these Release Notes. Although target-level matches were correctly reported in the DV archive products, the planet-level ephemeris matches were not correctly reported. In this

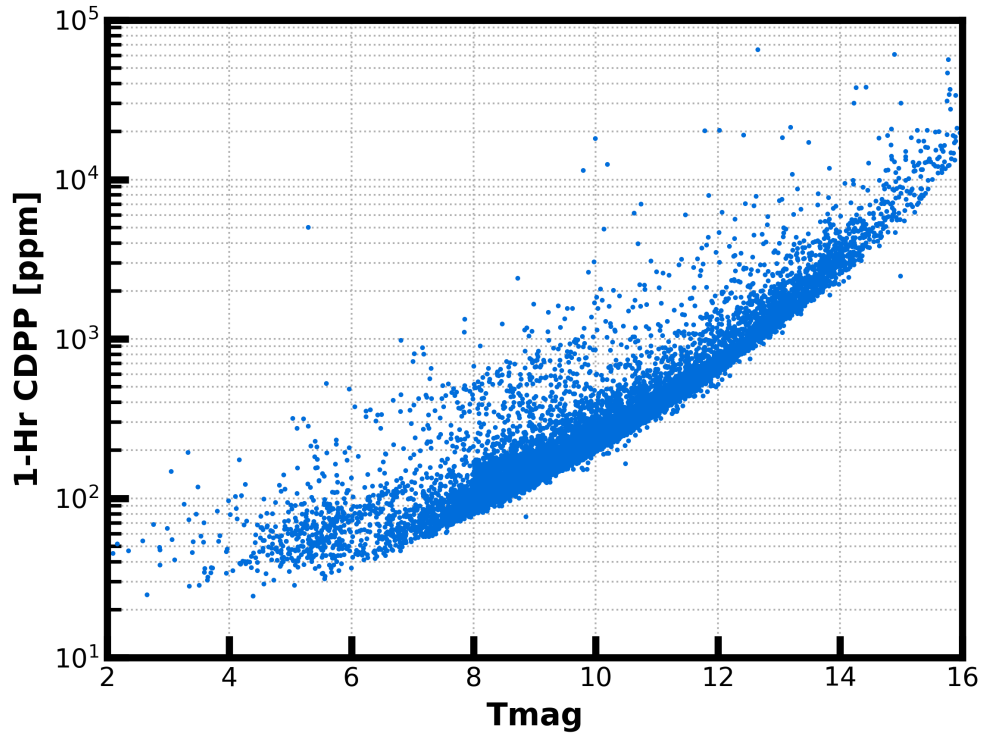


Figure 2: 1-hour CDPP. The points are RMS CDPP measurements for the 15806 light curves from the Sectors 1 – 6 multi-sector search plotted as a function of TESS magnitude.

transit search, the DV archive products incorrectly state that all of the TOIs were missed at the planet level. Users are advised to trust the target-level TOI identifications in the DV products for this transit search, and to ignore all references to TOIs at the planet level.

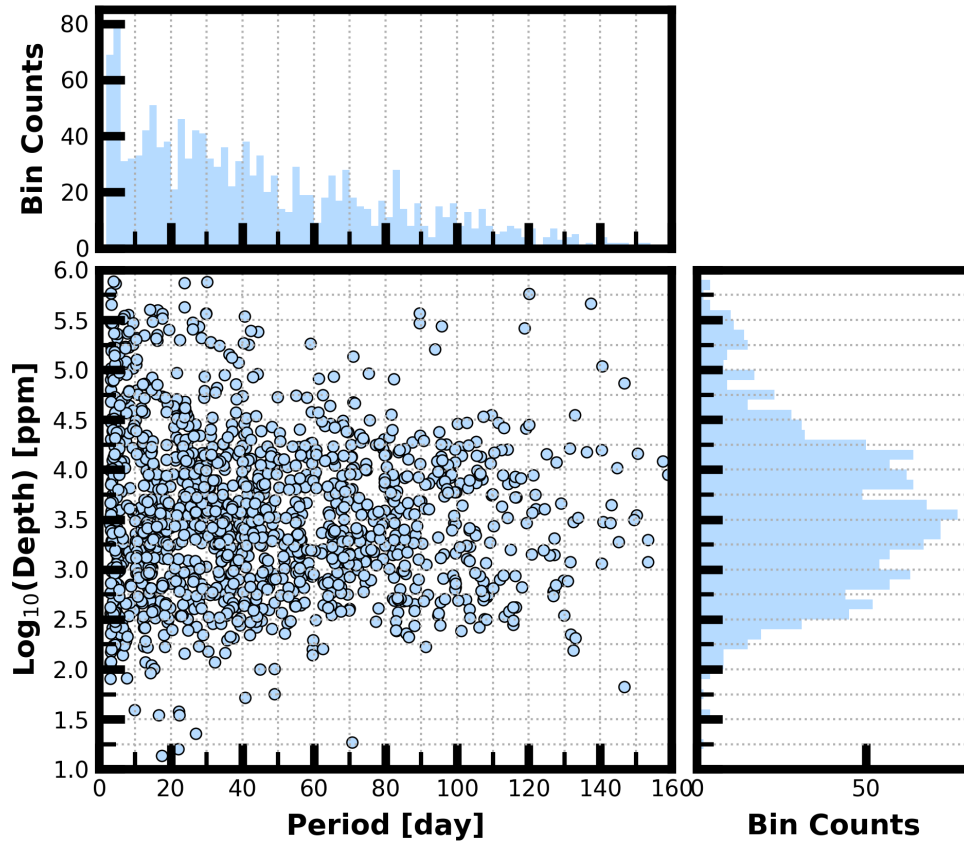


Figure 3: Lower Left Panel: Transit depth as a function of orbital period for the 2834 TCEs identified for the Sectors 1 – 6 multi-sector search. For enhanced visibility of long period detections, TCEs with orbital period <0.5 days are not shown. Reported depth comes from the DV limb darkened transit fit depth when available (or the DV trapezoid model fit depth if the limb darkened transit fit is not available). Top Panel: Orbital period distribution of the TCEs shown in the lower left panel. Right Panel: Transit depth distribution for the TCEs shown in the lower left panel.

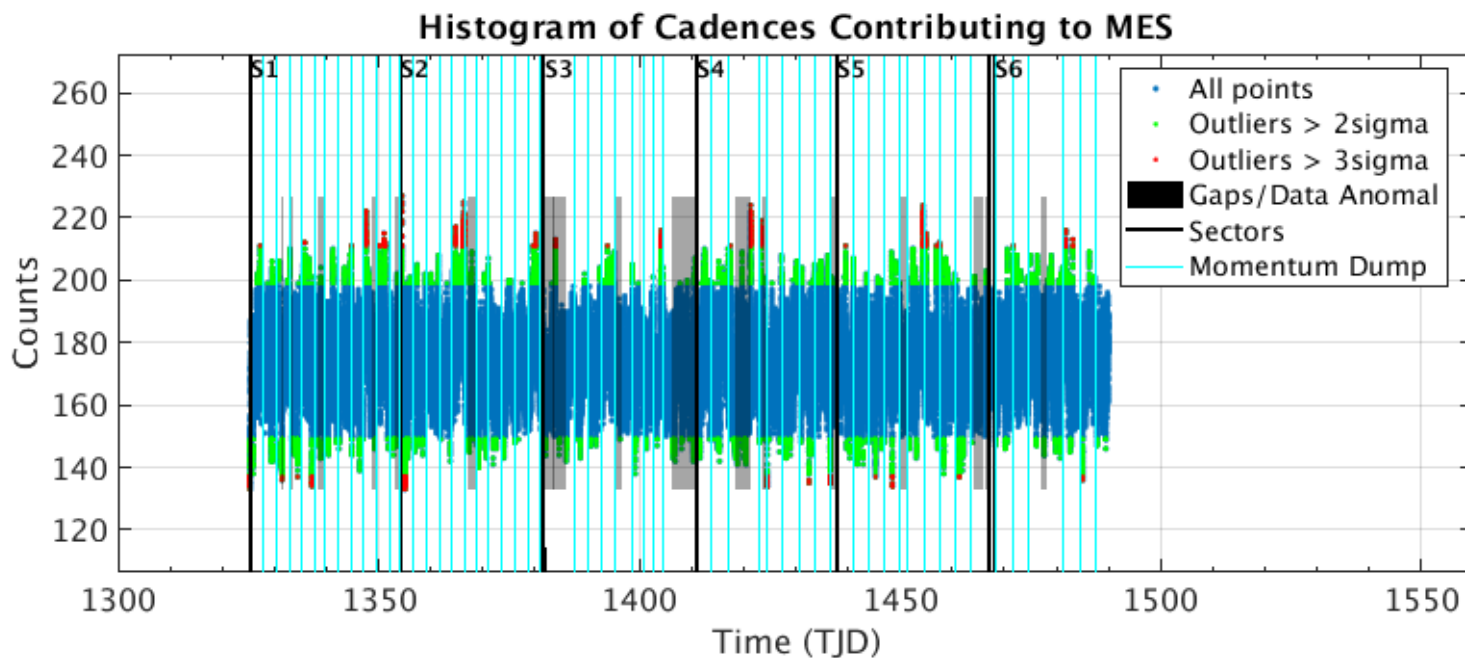


Figure 4: Number of TCEs at a given cadence exhibiting a transit signal. Isolated peaks are caused by a single event and result in spurious TCEs. The peaks typically align with pointing instabilities and strong background variations. TCE ephemerides are projected back to the start of Sector 1 even if the associated targets were not observed that early in the mission.

References

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Acronyms and Abbreviation List

| | |
|--------------|---|
| BTJD | Barycentric-corrected TESS Julian Date |
| CDPP | Combined Differential Photometric Precision |
| Dec | Declination |
| DV | Data Validation Pipeline Module |
| KDPH | Kepler Data Processing Handbook |
| MAST | Mikulski Archive for Space Telescopes |
| MES | Multiple Event Statistic |
| NAN | Numerical Not-A-Number |
| POC | Payload Operations Center |
| ppm | Parts-per-million |
| RA | Right Ascension |
| RMS | Root Mean Square |
| SDPDD | Science Data Product Description Document |
| SNR | Signal-to-Noise Ratio |
| SPOC | Science Processing Operations Center |
| 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 |
| XML | Extensible Markup Language |