# T'DA Data Release Notes

# Data Release 6 for TESS Sectors 14+15+26

TASOC-0006-01

TESS Data for Asteroseismology (T'DA)

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October 26, 2021

This report is prepared by the Coordinated Activity T'DA of the TESS Asteroseismic Science Consortium (TASC), which is responsible for light curve preparation for asteroseismology.

Raw photometry for 2-min (TPF) and 30-min (FFI) cadence targets from TESS Sectors 14+15+26 are released with this note, in addition to systematics corrected light curves, resulting in 9,716,678 light curve files.

The data summarised in this report can be queried via the TESS Asteroseismic Science Operation Center (TASOC)[1] data base. We are in the process of also making the data available as a High Level Science Product (HLSP) on The Mikulski Archive for Space Telescopes (MAST)[2]. The TASOC pipeline used to generate the data is open source and available on GitHub[3].

Before using data from this release we strongly recommend you read through this note, the TASOC papers (Handberg et al. 2021; Lund et al. 2021) and consult the TESS Instrument Handbook (Vanderspek et al. 2018).

[1] https://tasoc.dk
[2] https://archive.stsci.edu/hlsp/tasoc
[3] https://github.com/tasoc

These notes are the collective effort of the 100+ members of the TESS Data for Asteroseismology (T'DA) Coordinated Activity, led by

**Handberg, Rasmus, T'DA Chair, TASC SC.**
**Buzasi, Derek, T'DA Chair, TASC SC.**
**Tkachenko, Andrew, T'DA sub-chair for classification, TASC SC.**
**White, Timothy R., T'DA sub-chair for saturated stars.**

The following members deserve special notice for their important contributions to the T'DA efforts:

Armstrong, David
Audenaert, Jeroen
Bedding, Timothy R.
Bell, Keaton
Bugnet, Lisa
Carboneau, Lindsey
Chontos, Ashley
Garcia, Rafael
Hall, Oliver J.
Hon, Marc T. Y.
Kuszlewicz, James
Lund, Mikkel N.
Molnár, László
Pereira, Filipe
Pope, Benjamin

# Pointing

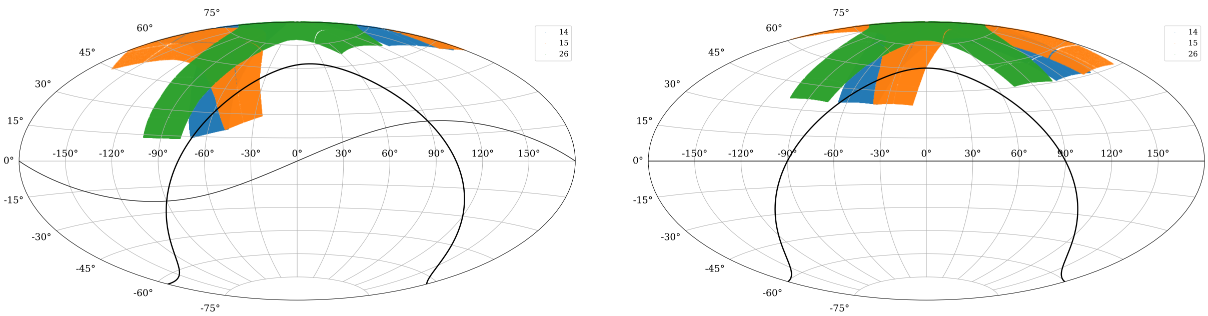



**Figure 1:** Pointing and FOV observations in equatorial coordinates (left) and ecliptic coordinates (right). See Table 1 for detailed pointing information. Thin black line is ecliptic, thick black line is the galactic plane.

Note – The spacecraft centre pointing vector ("Bore sight"), is at the middle of the camera array, midway between cameras 2 and 3. All coordinates are in degrees.

**Table 1:** Information on the FOV of Sectors 14+15+26. All coordinates are in degrees.

| Sector | Camera 1 | | Camera 2 | | Camera 3 | | Camera 4 | |
|---|---|---|---|---|---|---|---|---|
| | RA | Dec | RA | Dec | RA | Dec | RA | Dec |
| 14 | 297.7619 | 29.1881 | 287.0536 | 51.8282 | 256.1832 | 71.5698 | 174.6437 | 71.3012 |
| 15 | 316.9121 | 35.5697 | 298.1783 | 55.9001 | 252.3755 | 68.6304 | 196.7468 | 60.8581 |
| 26 | 270.5315 | 25.5647 | 270.3316 | 49.5642 | 269.6945 | 73.5626 | 92.8329 | 82.4295 |

**Table 2:** Information on timing of observations in Sectors 14+15+26.

| Sector | Start (TJD) | End (TJD) | Start (UTC) | End (UTC) |
|---|---|---|---|---|
| 14 | 1683.34686 | 1710.20241 | 2019-07-18 20:19:29 | 2019-08-14 16:51:28 |
| 15 | 1711.35796 | 1737.40795 | 2019-08-15 20:35:28 | 2019-09-10 21:47:27 |
| 26 | 2010.26061 | 2035.13282 | 2020-06-09 18:15:17 | 2020-07-04 15:11:16 |

Note. – TJD = "TESS Julian Day" = JD - 2457000.

# Targets

For this release both Full-Frame Images (FFI; 30-min) and Target Pixel Files (TPF; 2-min) for Sectors 14+15+26 have been analysed. A total of 9,941,189 targets have been processed, resulting in 9,716,678 light curve files. Table 3 gives the number of data sets released for the individual sectors, and the number of targets processed. The total number of processed targets is higher that the number of released data sets, either because targets are rejected during the data validation or because a target being processed might have already been identified as being contained within the aperture of a brighter target. In such a case the fainter target will not be assigned its own data set, but be included in the contamination metric of the brighter target. We have currently limited the FFI processing to a TESS magnitude of 15.

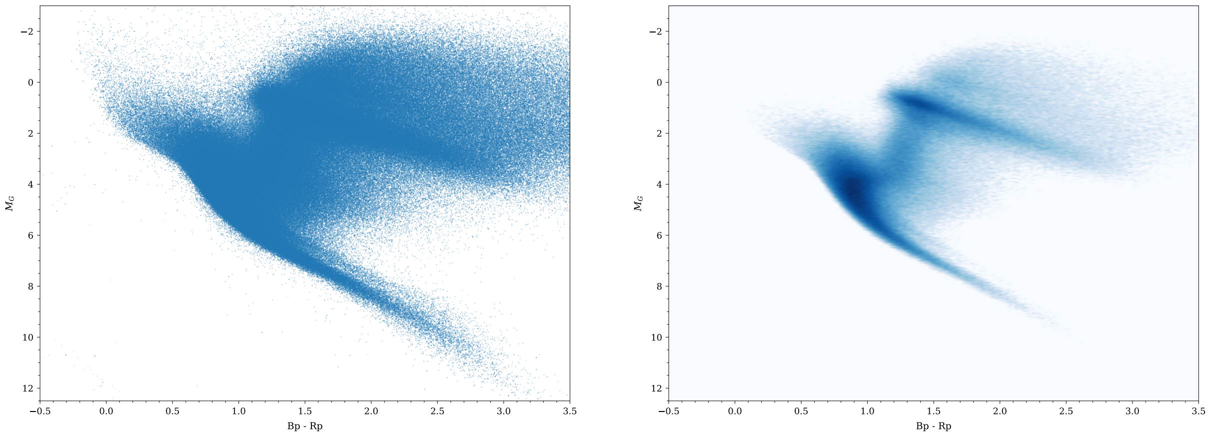



**Figure 2:** Color-magnitude diagram for the extracted targets in Gaia DR2 colors. Left panel shows the actual positions of each individual target, while the right shows the same as a distribution using a Gaussian kernel density estimation.

**Table 3:** Number of data sets released and targets processed.

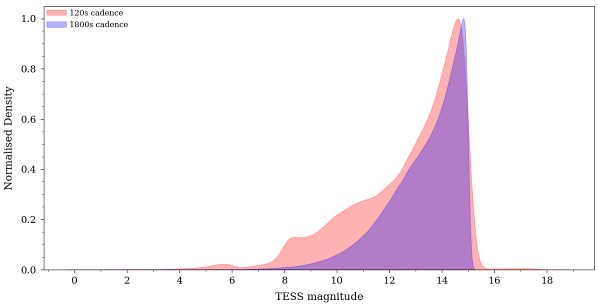
| Sector | Cadence (s) | Processed | Extracted | CBV | Ensemble |
|---|---|---|---|---|---|
| 14 | 1800 | 4,097,208 | 1,805,215 | 1,805,215 | 1,801,314 |
| 15 | 1800 | 3,372,579 | 1,644,936 | 1,644,936 | 1,644,439 |
| 26 | 1800 | 2,072,523 | 1,326,023 | 1,326,023 | 1,324,042 |
| 14 | 120 | 161,952 | 62,274 | 62,274 | 0 |
| 15 | 120 | 141,387 | 59,541 | 59,541 | 0 |
| 26 | 120 | 95,540 | 48,894 | 48,894 | 0 |
| Total | | 9,941,189 | 4,946,883 | 4,946,883 | 4,769,795 |

Note – "Processed" and "Extracted" refers to the number of targets processed by the photometric pipeline and the number of extracted raw light curves from them. "CBV" and "Ensemble" refers to the number of released targets in using each correction method. The last line indicates the number of targets observed in all sectors.

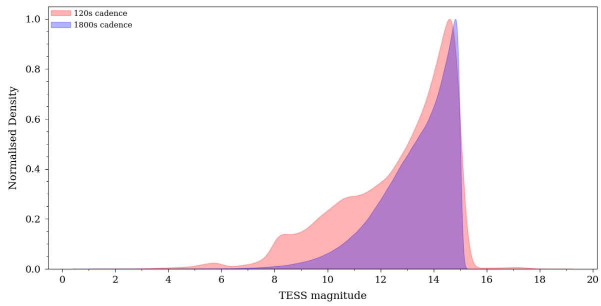
Note that we are extracting more targets in the 2-min cadence than the observed number of targets (normally ∼20,000). This is due to the TASOC photometric pipeline being able to extract "secondary" targets if they falls within the observed pixels of another primary target.

The magnitude distributions for extracted targets are shown in Figure 3.

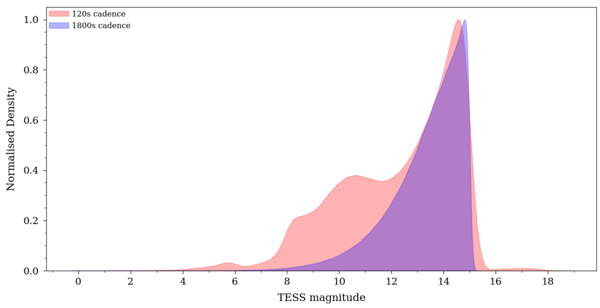
**Figure 3:** Magnitude distribution for stars covered by this release, normalised to a maximum of 1.




**(a)** Sector 14.




**(b)** Sector 15.




**(c)** Sector 26.

# Photometry

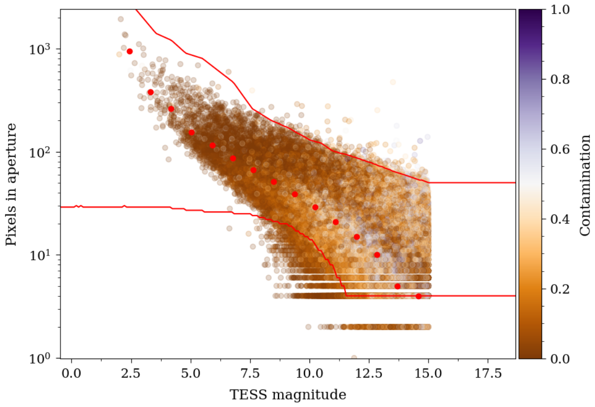
*Photometry pipeline version: 6.2*

See Handberg et al. (2021) for details.

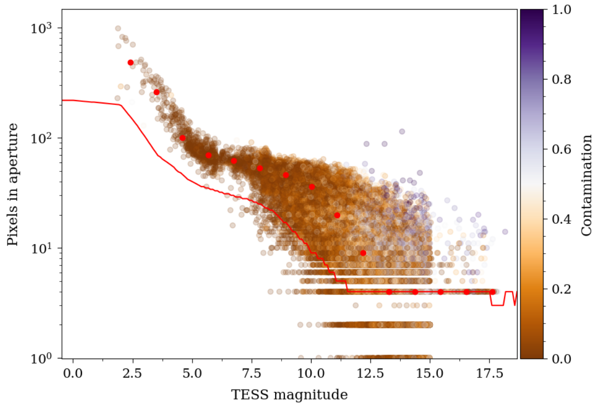
Figure 4 shows the sizes of the defined apertures as a function of TESS magnitude. A minimum aperture of 4 pixels has been adopted for the TASOC processing – targets with smaller apertures in Figure 4 are situated on CCD edges and have not been released. The full red lines give the boundaries used in the data validation (affected target plotted with small markers). For 2-min cadence targets only a lower bound is used because the upper aperture limit is typically set by the downloaded stamp size. One should be aware of contamination (see below), especially at high magnitudes – as seen from Figure 4 the faint targets with larger-than-average apertures are typically significantly contaminated.

Figure 5 shows the contamination metric (given in the FITS light curve header as `AP_CONT`) for each star as a function of TESS magnitude. Make sure to keep this value in mind when interpreting signals extracted for a given star – the metric gives the fraction of flux in the light curve contributed from stars other than the main one, calculated from the magnitudes of identified stars found within the defined aperture of the main star. *Note therefore that flux in the aperture from a neighbouring star that does not lie within the aperture is not taken into account.* The World Coordinate Solution (WCS) provided with the aperture in the FITS file can be used to identify which other stars fall within the aperture of the main star. Points at 1.1 and 1.2 in Figure 5 indicate targets where contamination could not be calculated. These targets are rejected during data validation and therefore not released.

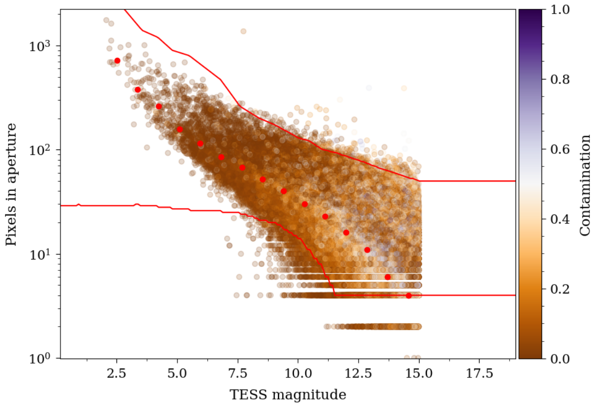
**Figure 4:** Pixel in apertures as a function of TESS magnitude. The left panels show apertures for 30-min cadence FFI targets, while the right panels show apertures for 2-min TPF target. The individual points are colour-coded by the contamination. The full red lines give the boundaries for the data validation. The red circles give the median binned values for the aperture sizes.



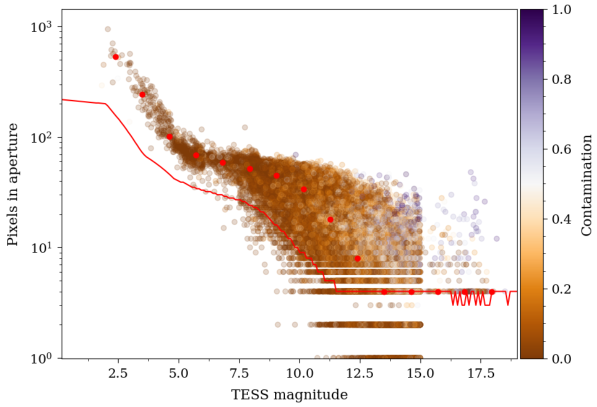

**(a)** Sector 14, ffi.



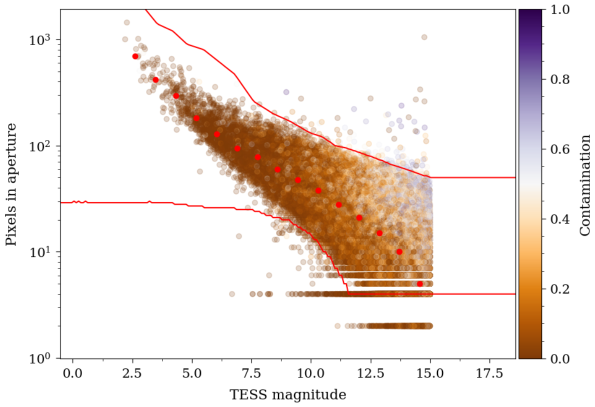

**(b)** Sector 14, tpf.



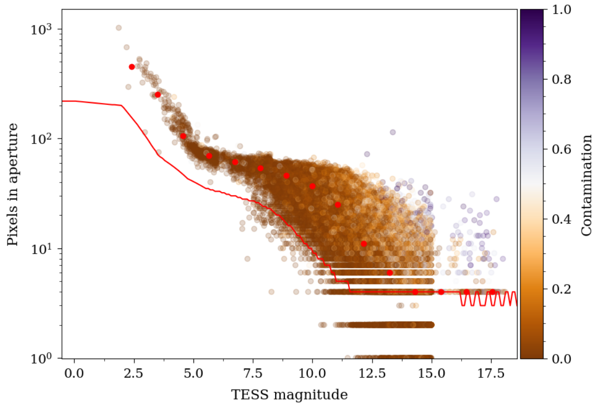

**(c)** Sector 15, ffi.




**(d)** Sector 15, tpf.

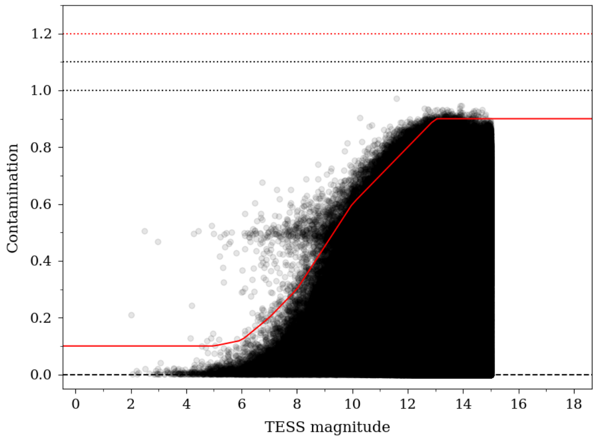



**(e)** Sector 26, ffi.

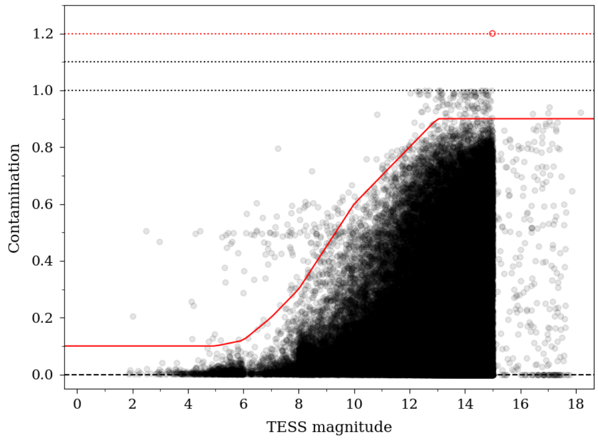



**(f)** Sector 26, tpf.

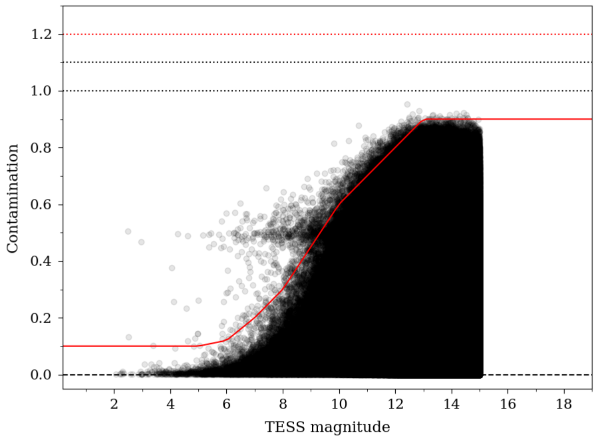
**Figure 5:** Contamination metric as a function of TESS magnitude. For each Sector the left (right) panel gives contamination for FFI (TPF) data. The red full curve gives the boundary used in the photometry data validation.



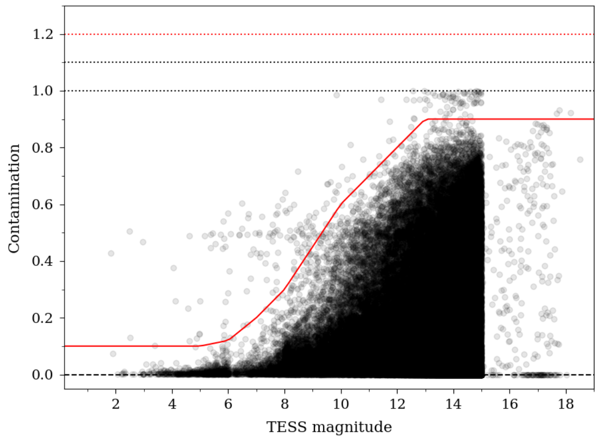

**(a)** Sector 14, 1800s cadence.



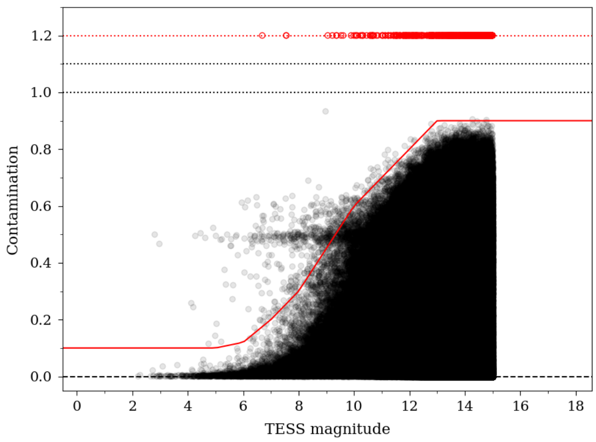

**(b)** Sector 14, 120s cadence.



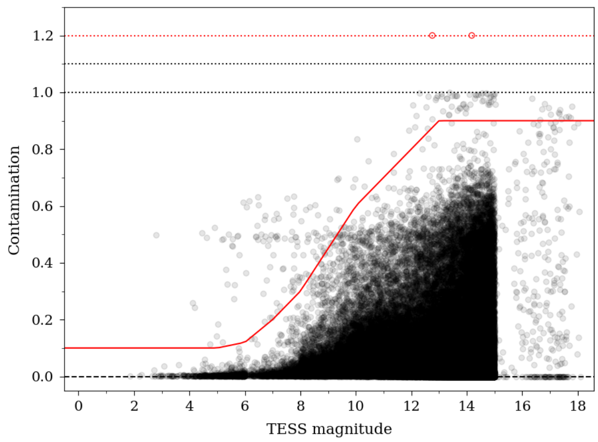

**(c)** Sector 15, 1800s cadence.




**(d)** Sector 15, 120s cadence.

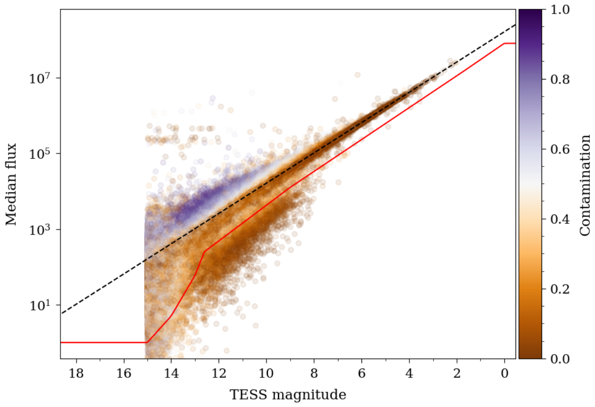



**(e)** Sector 26, 1800s cadence.

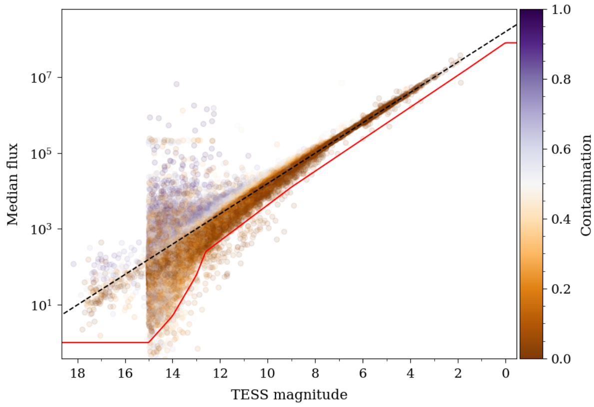



**(f)** Sector 26, 120s cadence.

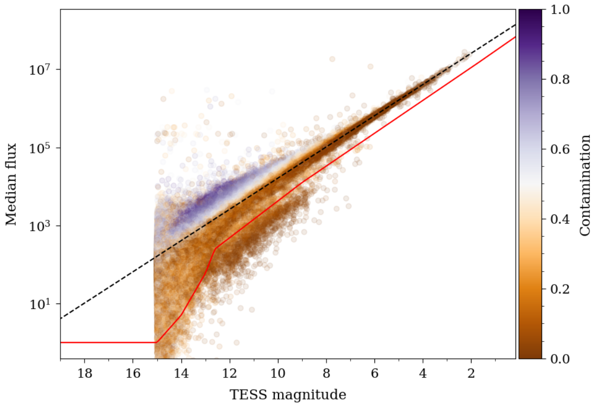
**Figure 6:** Relation between extracted flux from aperture and the TESS magnitude, colour-coded by contamination. The left (right) panels show values for 30-min FFI (2-min TPF) data. The black dashed line gives the individual relations obtained following the prescription in Handberg et al. (2021). The full red line gives the adopted boundary for the data validation.



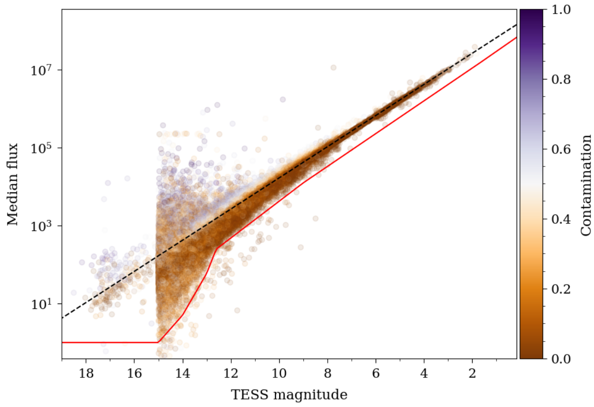

**(a)** Sector 14, 1800s cadence.



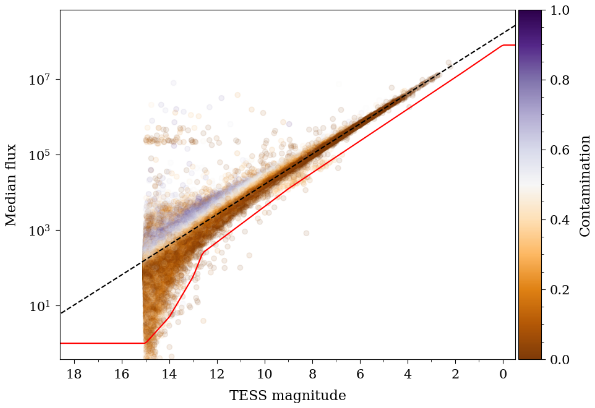

**(b)** Sector 14, 120s cadence.



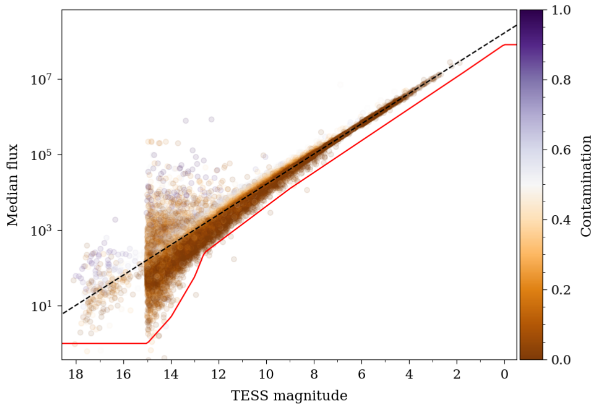

**(c)** Sector 15, 1800s cadence.




**(d)** Sector 15, 120s cadence.




**(e)** Sector 26, 1800s cadence.




**(f)** Sector 26, 120s cadence.

# Corrections

*Corrections pipeline version: 2.0*

See Lund et al. (2021) for details.

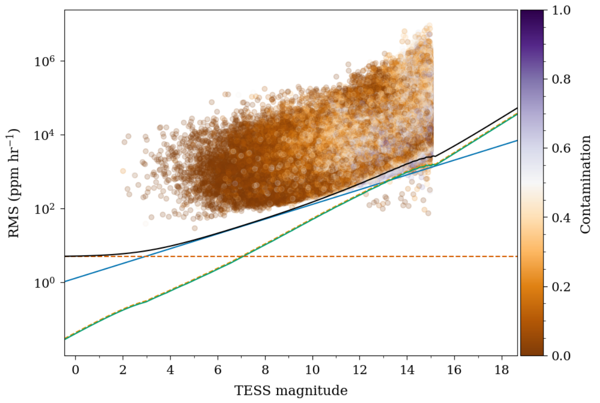
The photometric quality of the corrected light curves is summarized in Figures 7–8. Figure 7 shows the 1 hour root-mean-square (RMS) noise in parts-per-million (ppm) as a function of TESS magnitude; Figure 8 gives the point-to-point Median-Differential-Variability (MDV) (corresponding to RMS on time scale of observing cadence). For the expected-noise curves we used relations for mean flux (Figure 6) and number of aperture pixels (Figure 4) as a function of TESS magnitude derived from the processed data. As seen the extracted light curves generally follow the expected noise characteristics.

# Data format

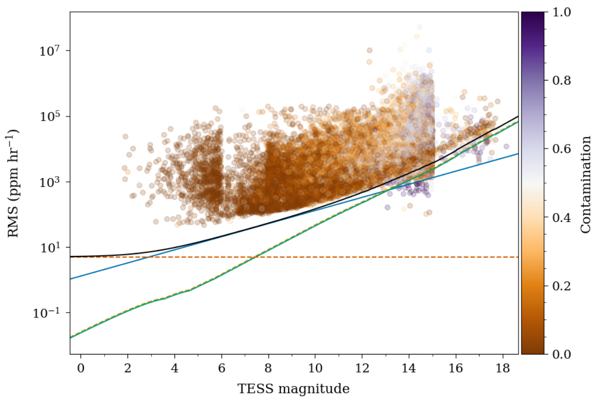
*Data file format version: 1.4*

See Handberg et al. (2021) and Lund et al. (2021) for details about file formats.

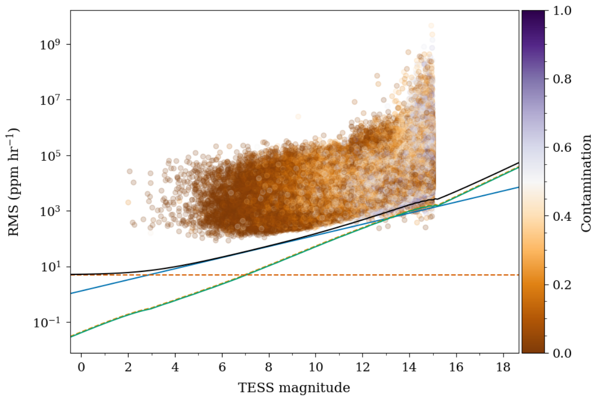
**Figure 7:** RMS noise on 1 hour time scale for stars covered by this release. The lines give the predicted noise estimates following Sullivan et al. (2015) (red full: shot noise; yellow full: read noise; green dashed: zodiacal noise; black full: total noise).



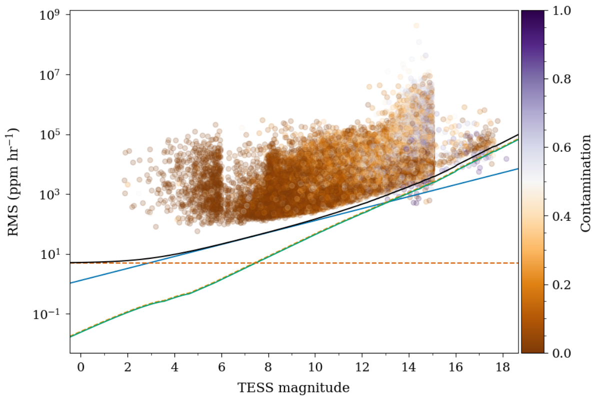

**(a)** Sector 14, 1800s cadence, cbv corrected.



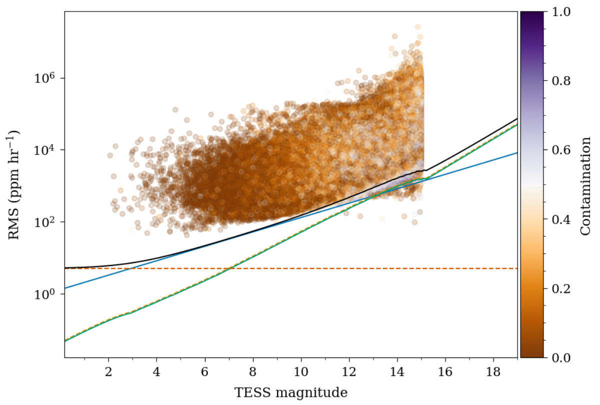

**(b)** Sector 14, 120s cadence, cbv corrected.



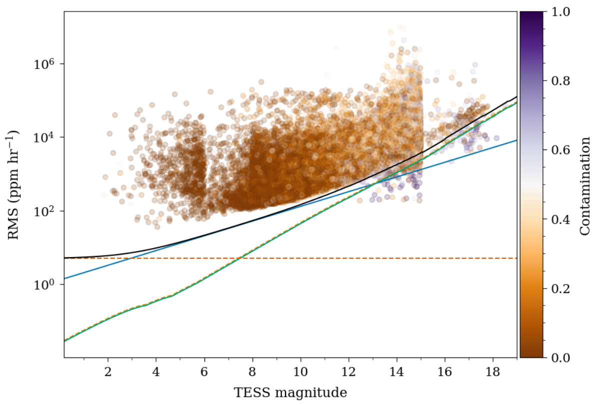

**(c)** Sector 14, 1800s cadence, ensemble corrected.



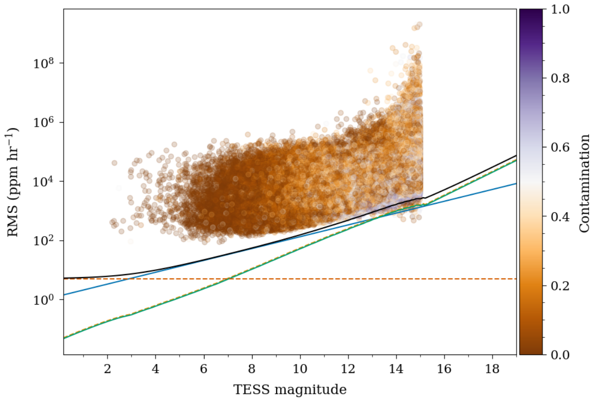

**(d)** Sector 14, 120s cadence, ensemble corrected.



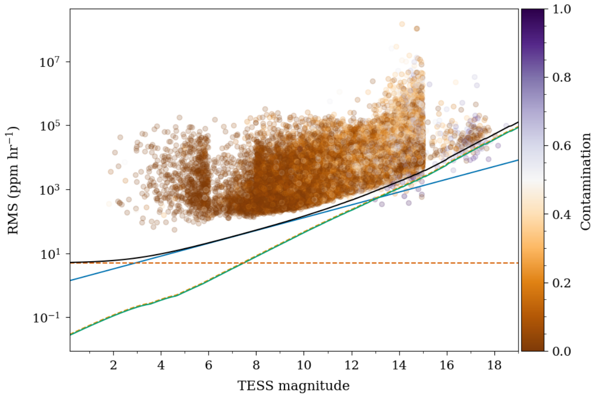

**(e)** Sector 15, 1800s cadence, cbv corrected.



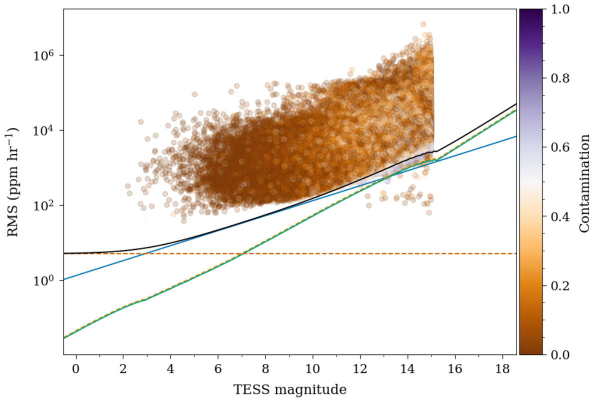

**(f)** Sector 15, 120s cadence, cbv corrected.



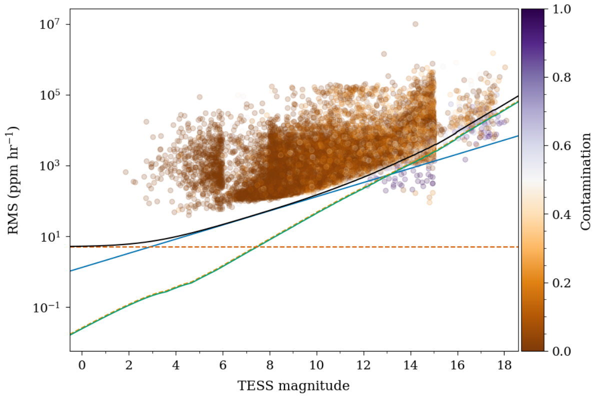

**(g)** Sector 15, 1800s cadence, ensemble corrected.



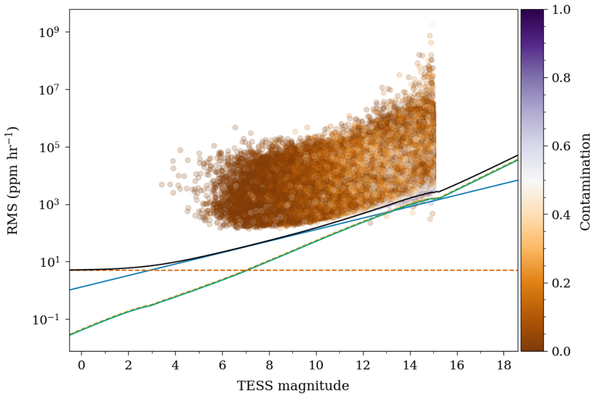

**(h)** Sector 15, 120s cadence, ensemble corrected.



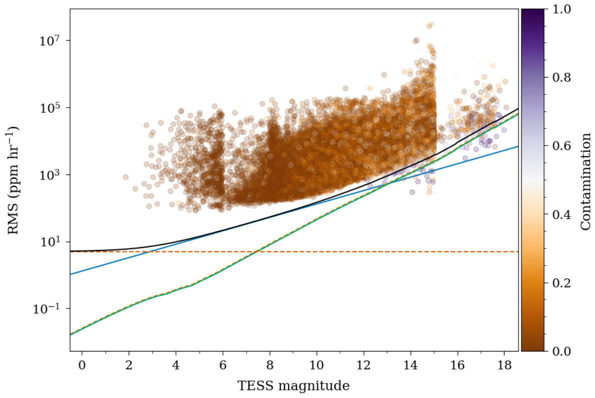

**(i)** Sector 26, 1800s cadence, cbv corrected.




**(j)** Sector 26, 120s cadence, cbv corrected.

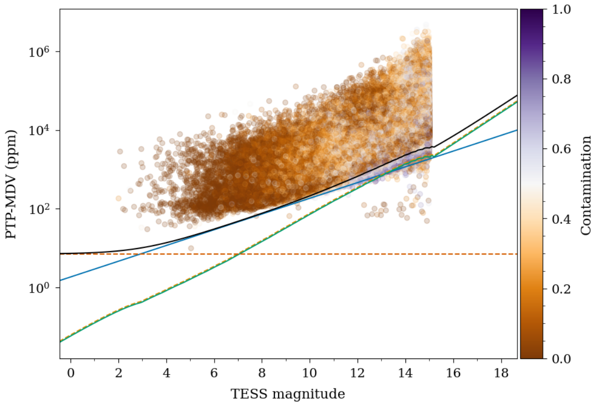



**(k)** Sector 26, 1800s cadence, ensemble corrected.

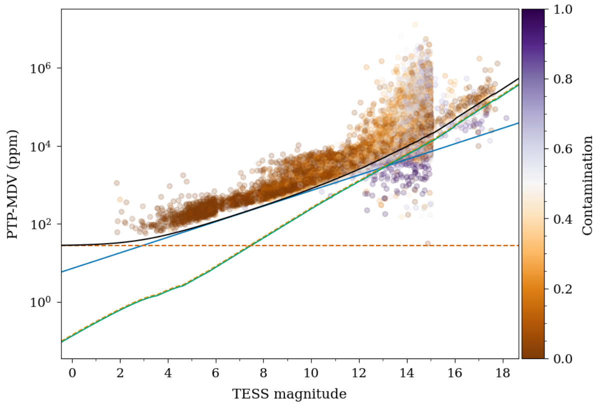



**(l)** Sector 26, 120s cadence, ensemble corrected.

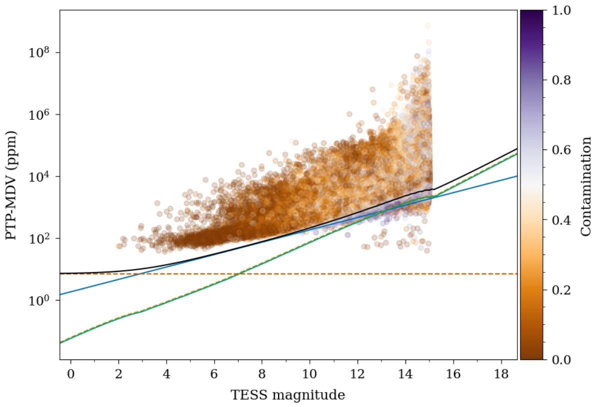
**Figure 8:** Point-to-point Median-Differential-Variability (MDV) for stars covered by this release (left: 1800 sec cadence; right: 120 sec cadence). The lines give the predicted noise estimates following Sullivan et al. (2015) (red full: shot noise; yellow full: read noise; green dashed: zodiacal noise; black full: total noise).



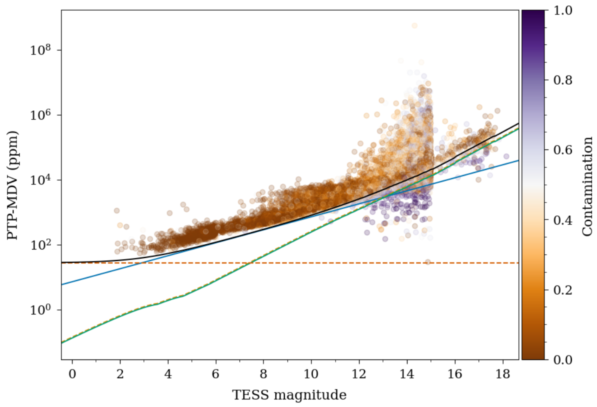

**(a)** Sector 14, 1800s cadence, cbv corrected.



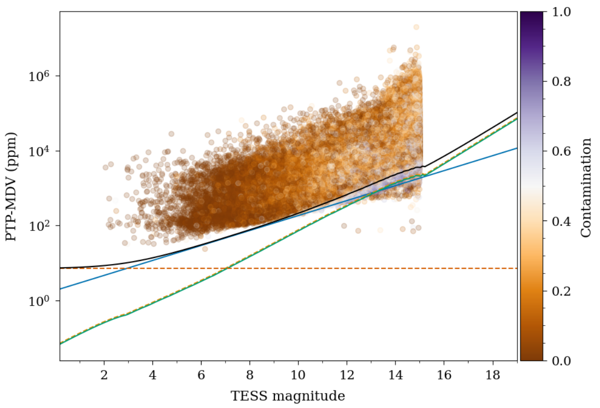

**(b)** Sector 14, 120s cadence, cbv corrected.



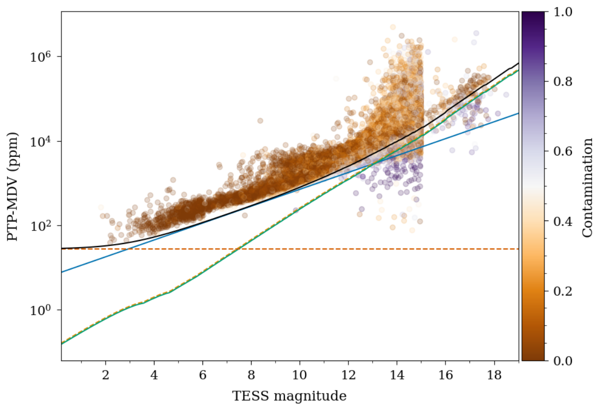

**(c)** Sector 14, 1800s cadence, ensemble corrected.



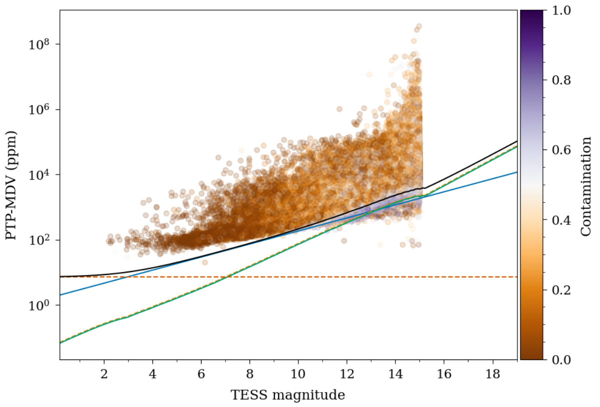

**(d)** Sector 14, 120s cadence, ensemble corrected.



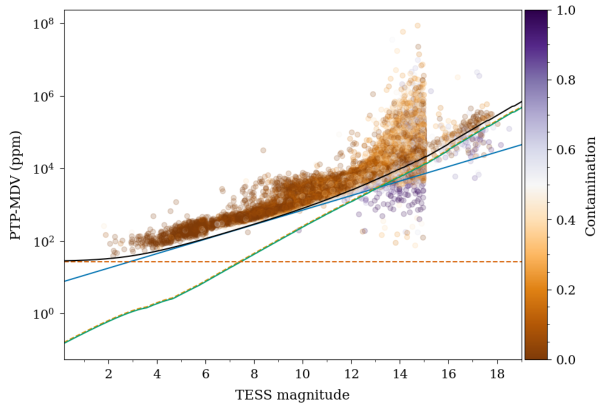

**(e)** Sector 15, 1800s cadence, cbv corrected.



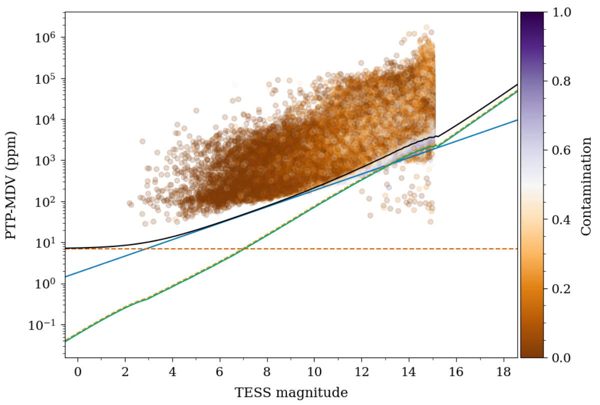

**(f)** Sector 15, 120s cadence, cbv corrected.



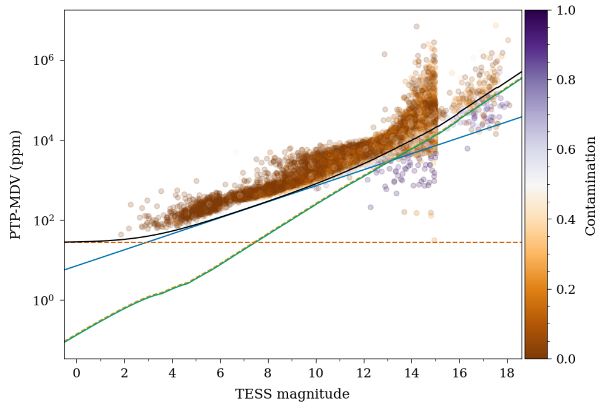

**(g)** Sector 15, 1800s cadence, ensemble corrected.



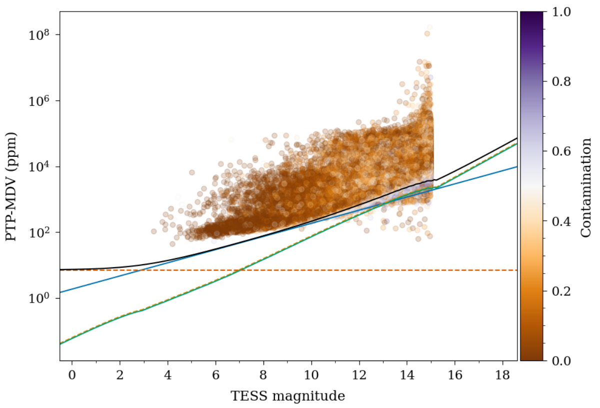

**(h)** Sector 15, 120s cadence, ensemble corrected.



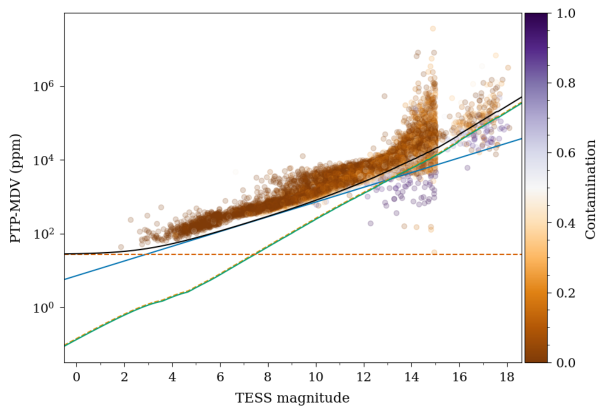

**(i)** Sector 26, 1800s cadence, cbv corrected.




**(j)** Sector 26, 120s cadence, cbv corrected.




**(k)** Sector 26, 1800s cadence, ensemble corrected.




**(l)** Sector 26, 120s cadence, ensemble corrected.

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