

LIGHT CURVES FOR ALL STARS OBSERVED IN *TESS* FULL FRAME IMAGES: SECTOR 1 AND BEYOND

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INTRODUCTION

In Oelkers & Stassun (2018), we published a difference imaging analysis toolset intended for the reduction of full-frame images (FFIs) from the Transiting Exoplanet Survey Satellite (*TESS*; Ricker et al. 2014; Sullivan et al. 2015) and demonstrated its performance with the simulated FFI data that were available before launch (Jenkins et al. 2018). We have now adapted this code based on the first sectors of real FFIs, and are able to extract light curves for all stars identified in the TESS Input Catalog (TIC; Stassun et al. 2018) included in the final *TESS* on-sky footprint. This research note describes our public release of these light curves through the *Filtergraph* data visualization service (Burger et al. 2013) at <https://filtergraph.com/tess ffi>. The portal initially is populated with light curves from *TESS* Sector 1, and will be updated regularly as FFIs from additional sectors become publicly available.

DATA REDUCTION

The FFIs are reduced largely following the routines described in (Oelkers & Stassun 2018). Here we briefly summarize the substantive changes now implemented in the reduction of the real FFI data.

1. We used the first image in the time series as the ‘master’ frame, instead of a median combination of all frames. We found minimal loss of quality in the differenced frames as a result, and thus elected for this simplified approach.
2. Images were *not* resampled for alignment to the master frame, as the movement of the stellar centroids is found to be below 1 pixel.
3. Fluxes for all stars were extracted from the master frame using a fixed aperture radius of 3.5 pixels (73.5'') and sky annulus radii of 5-7 pixels (105 – 147'').
4. To correct the light curve of a given star for systematics, we identified 100 other stars (“trend stars”) that were of similar magnitude, and at least 10 pixels away. The trend stars’ light curves were median combined, weighted by the inverse variance of the residuals of the trend star light curve relative to the target star light curve, and this median trend subtracted from the target star light curve. We refer to these as *CLEAN* light curves in § 3.
5. We *did not* correct stars for systematics that appear to be highly contaminated by neighboring stars. These were initially flagged if the observed magnitude was $> 4\sigma$ discrepant relative to the magnitude expected from the TIC, where σ was determined from bright ($T < 11$) stars on the same CCD. If the sum of the fluxes of all other stars within 7 pixels was more than 5 times that of the star in question, it was not corrected for systematics.

Figure 1 shows our achieved photometric precision for stars having a 2-min cadence light curve from NASA in Sector 1 (Jenkins et al. 2010). For this comparison, we converted the provided PDC_SAPflux to magnitude, binned the data in 30-min intervals, and calculated the r.m.s. for a single day of observation.

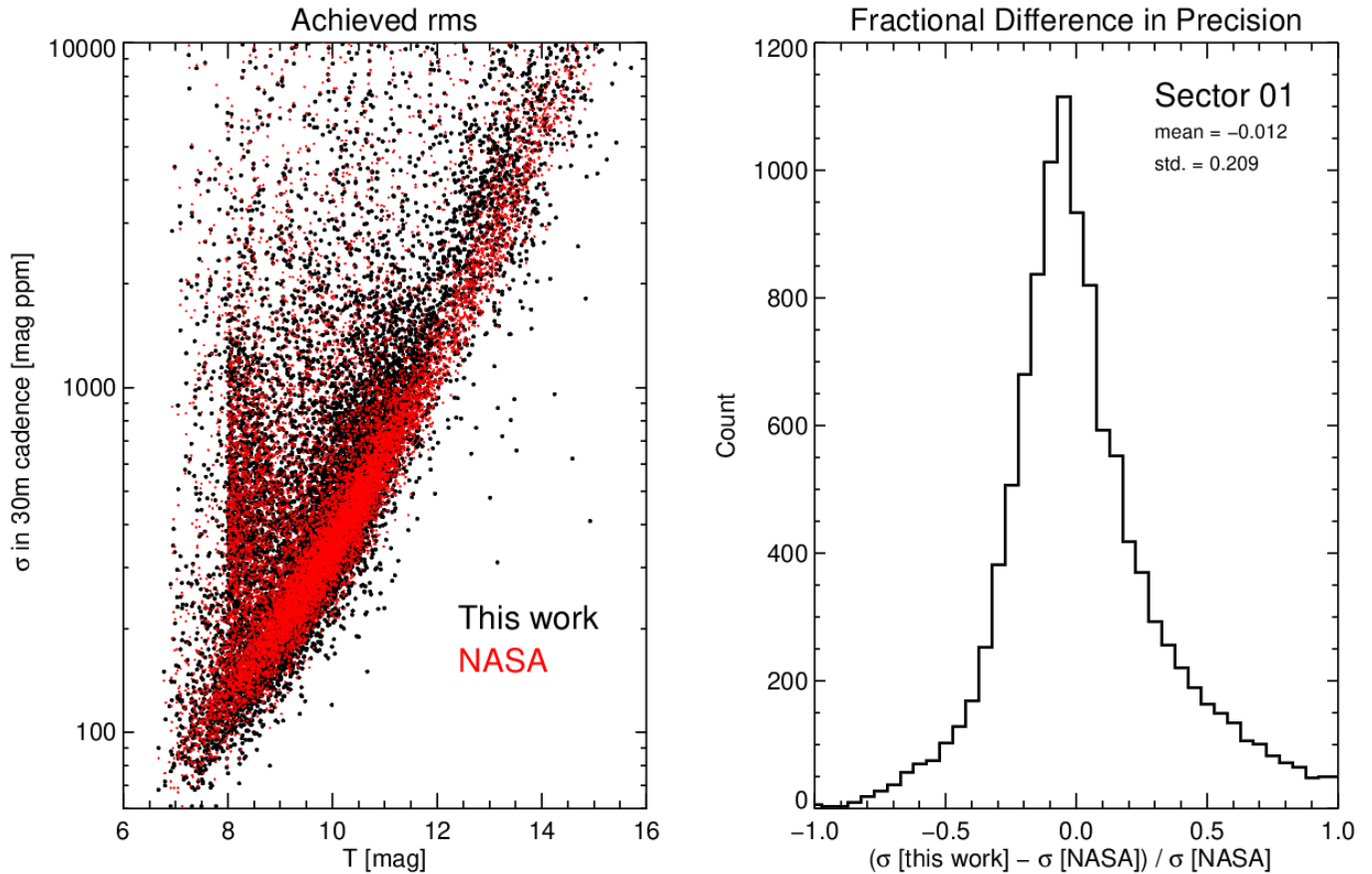


Figure 1. (*Left:*) The precision achieved in one day of observation in this work (black dots), and the precision of the same stars reduced by NASA (red dots), after binning the 2-minute light curves into 30-minute intervals. (*Right:*) Fractional difference in the precision achieved between our light curves and those produced by NASA. We find good overall agreement, with a mean difference of only $\sim 1\%$ and a scatter of $\sim 20\%$.

DATA PRODUCTS

The following data products are provided for each Sector:

1. *RAW Light Curves:* These light curves, not corrected for systematics, are provided as ASCII files with 3 columns: time (BTJD-2457000), instrumental magnitude, and photometric error from the IDL routine APER. The light curve naming convention is (TIC ID)_(sector)_(camera)_(ccd).1c, where (TIC ID) is the star’s TIC ID number, (sector) is the sector of observation, (camera) is the camera number, and (ccd) is the CCD number.
2. *CLEAN Light Curves:* Stars deemed not overly contaminated (see § 2) have been corrected for systematics. These light curves share the same format as the RAW curves.
3. *Differenced Images:* The differenced images are provided as FITS files in a bulk download.
4. *Variability Metrics:* Photometric variability metrics from Oelkers et al. (2018), including the r.m.s. (in 30-min and 60-min bins) and Welch-Stetson J and L (Stetson 1996). We also provide the highest power Lomb-Scargle and Box-Least-Squares periods (including significance metrics) from VARTOOLS (Hartman & Bakos 2016).
5. *Plotted Light Curves:* A .jpg of each light curve is provided through the *Filtergraph* portal. Users may filter on a specific star, and click the link to show the plotted light curve.

We offer the following qualifications as guidance for use of these data products:

1. The periods from *VARTOOLS* are provided for convenience only; they have not been vetted and should only be used as a guide for identifying possibly periodic variability, eclipses, etc.
2. Features that occur at both the beginning and middle of a sector’s 27-day observing window should be carefully vetted to ensure they are not due to telescope repointing after data downlinks.
3. The *CLEAN* light curves had systematics removed on the basis of features common to 100 other stars; it is thus unlikely, but possible, that some residual variability common to those stars was injected into the target star’s light curve.
4. The *TESS* pixel scale is $21''$. Multiple sources within the same aperture will exhibit similar behaviors.

DATA ACCESS AND FUTURE REDUCTIONS

Users are able to access these data through the *Filtergraph* data visualization portal at the URL https://filtergraph.com/tess_ffi/. Users can select light curves by sector, using the pull-down menu at the top left. Please cite [Oelkers & Stassun \(2018\)](#) and [Burger et al. \(2013\)](#) when using any of these data products in publication.

We plan to continue to use our pipeline to reduce *TESS* FFIs as the data for additional sectors are observed, typically within 2–3 weeks of the FFIs becoming public. All data products will be released through the *Filtergraph* visualization portal at the URL https://filtergraph.com/tess_ffi. We encourage readers to visit the *Filtergraph* portal, and we welcome suggestions for improvements.

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