TESS Satellite Light Curve Analysis: Download, Convert, and View with TOPCAT

Camila Cárdenas Uribe*
Universidad sidad de Antofagasta, Antofagasta, Chile

(Dated: May 10, 2025)

This practice reinforces the fundamental concepts involved in performing a basic process of downloading, processing, and visualizing light curves from the Transiting Exoplanet Survey Satellite (TESS), a NASA mission launched in 2018. The light curve files corresponding to Sector 73 were obtained through the Mikulski Archive for Space Telescopes (MAST) by executing the script *tesscurl_sector_73_lc.sh*, which downloads the data in FITS format. A subset of approximately 20 FITS files was selected for further analysis and converted to CSV format using the TOPCAT tool. Subsequently, a shell script was created to list the names of all the resulting CSV files into a single text file, which was then split into smaller files, each containing five filenames. Finally, the CSV light curves were reloaded into TOPCAT and plotted in two dimensions using relevant columns such as time and flux, allowing the visualization of variability and potential transit signals present in the data.

I. INTRODUCTION

The Transiting Exoplanet Survey Satellite (TESS) is a space telescope launched by NASA in 2018, designed to conduct a photometric survey of nearly the entire sky with the goal of identifying exoplanets using the transit method. The TESS observes regions of the sky called *sectors* over approximately 27-30 days intervals with 30 minute cadence full frame images, recording light curves of thousands of stars [3]. These light curves can detect small, periodic decreases in stellar brightness, which can indicate a planet passing in front of its host star. The Transiting Exoplanet Survey Satellite (TESS) is a space telescope launched by NASA in 2018, designed to conduct a photometric survey of nearly the entire sky with the goal of identifying exoplanets using the transit method. This telescope, observes regions of the sky called "sectors" over intervals of approximately 27–30 days, recording light curves of thousands of stars.

The exoplanets are planets orbiting stars outside the Solar System, that is, those that pass in front of the host star observed by the telescope. One of the most successful methods implemented in this practice for their detection is the *transit method*, which consists of monitoring the brightness of a star over time [1]. When a planet passes in front of its star, from the observer's perspective (telescope), it causes a drop in the recorded light flux, generating a characteristic signal in the light curve called variability. The TESS survey uses the Mikulski Archive for Space Telescopes (MAST) to store and distribute these data. This repository is maintained by the Space Telescope Science Institute (STScI) and centralizes scientific data from various space missions, including TESS, Hubble, and Kepler [2]. From this portal, it is possible to access photometric and spectroscopic data archives in different standard formats for the astronomical community, such as Calibrated FFIs, Target Pixel, Uncalibrated FFIs, Fast Target Pixel, Light curve, and Fast Light curve. The data we are interested in downloading from MAST are light curves initially presented in the *Flexible Image Transport System* (FITS) format, widely used in astronomy to store images, spectra, and tables with structured metadata. However, to facilitate their visualization and analysis with tools such as TOPCAT, FITS files can be converted to *Comma-Separated Values* (CSV) format, which is more accessible for use in tabular analysis environments. The download process is automated through a script that can run in shells.

II. METHODOLOGY AND RESULTS

A. Light Curve Download from MAST

The TESS photometric data was obtained through the MAST official website, as described in the previous section I, using the bulk download portal available at:`https://archive.stsci.edu/tess/bulk_downloads/bulk_downloads_ffi-tp-lc-dv.html` From this portal, the script *tesscurl_sector_73_lc.sh* was downloaded, which automates the download of the Sector 73 light curves in FITS format. This script uses curl commands to retrieve the files directly from the MAST servers, thus facilitating access to the data

* Institutional email: camila.cardenas.uribe@uamail.cl

without requiring manual file-by-file interaction.

```
#!/bin/sh
curl -C - -L -o tess2023341045131_lc.fits
https://mast.stsci.edu/api/v0.1/Download/
file/?uri=mast:TESS/product/
tess2023341045131_lc.fits
```

In this excerpt, the file *tess2023341045131_lc.fits* is downloaded and sent to the download directory. To run the script, we granted the right to execute it using *chmod +x*, executed it with the command ./ and stopped the download after 20 files with the manual command *Ctrl + C*.

```
chmod +x tesscurl_sector_73_lc.sh
./tesscurl_sector_73_lc.sh
```

B. Converting FITS files to CSV with TOPCAT

The FITS files are loaded into TOPCAT, as described in the previous section I, using the File/Load Table panel. Here, the 20 *.fits* files are selected after using System Browser and the Open option is selected.

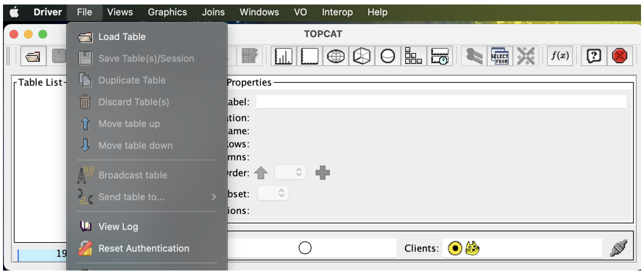


FIG. 1. Loading fits files in table version.

To save tables as CSV files, select the File panel from the menu again but now select the Save Table option. Here, choose a name/path, and in *Format* select CSV.

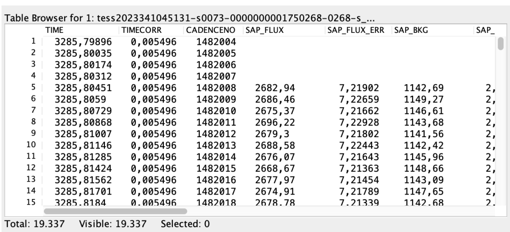


Table Browser for 1: tess2023341045131-s0073-0000000001750268-0268-s_...

	TIME	TIMECORR	CADENCENO	SAP_FLUX	SAP_FLUX_ERR	SAP_BKG	SAP_
1	3285,79896	0,005496	1482004				
2	3285,80035	0,005496	1482005				
3	3285,80174	0,005496	1482006				
4	3285,80312	0,005496	1482007				
5	3285,80451	0,005496	1482008	2682,94	7,21902	1142,69	2,
6	3285,8059	0,005496	1482009	2686,46	7,22659	1149,27	2,
7	3285,80729	0,005496	1482010	2675,37	7,21662	1146,61	2,
8	3285,80868	0,005496	1482011	2696,22	7,22928	1143,68	2,
9	3285,81007	0,005496	1482012	2679,3	7,21802	1141,56	2,
10	3285,81146	0,005496	1482013	2688,58	7,22443	1142,42	2,
11	3285,81285	0,005496	1482014	2676,07	7,21643	1145,96	2,
12	3285,81424	0,005496	1482015	2668,67	7,21363	1148,66	2,
13	3285,81562	0,005496	1482016	2677,97	7,21454	1143,09	2,
14	3285,81701	0,005496	1482017	2674,91	7,21789	1147,65	2,
15	3285,8184	0,005496	1482018	2678,78	7,21339	1142,68	2,

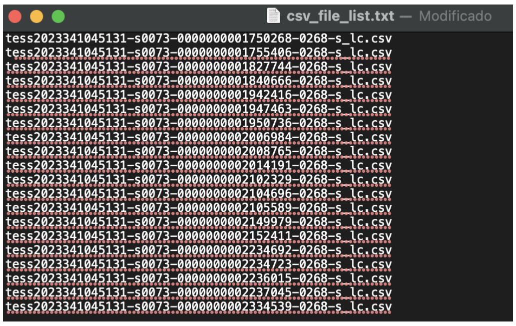
Total: 19.337 Visible: 19.337 Selected: 0

FIG. 2. Viewing files in table format.

C. The .txt file with the names of the .CSV files

The shebang line is written, which tells the operating system that the script should be executed using the bash interpreter (Bourne Again Shell). Then the *ls *.csv* command is used, which lists all the files ending in *.csv* in the working directory and redirects the output to a file called *csv_file_list.txt* concatenated with " > ". Each file name is saved on a separate line within that text file. To ensure that it was executed after granting the permissions as in the previous section II A, a message is printed in the terminal indicating that the *.txt* file has been successfully created.

```
#!/bin/bash
ls *.csv > csv_file_list.txt
echo "Created file csv_file_list.txt"
```



csv_file_list.txt — Modificado

```
tess2023341045131-s0073-0000000001750268-0268-s_lc.csv
tess2023341045131-s0073-0000000001755406-0268-s_lc.csv
tess2023341045131-s0073-0000000001827744-0268-s_lc.csv
tess2023341045131-s0073-0000000001840666-0268-s_lc.csv
tess2023341045131-s0073-0000000001942416-0268-s_lc.csv
tess2023341045131-s0073-0000000001947463-0268-s_lc.csv
tess2023341045131-s0073-0000000001950736-0268-s_lc.csv
tess2023341045131-s0073-0000000002006984-0268-s_lc.csv
tess2023341045131-s0073-0000000002008765-0268-s_lc.csv
tess2023341045131-s0073-0000000002014191-0268-s_lc.csv
tess2023341045131-s0073-0000000002102329-0268-s_lc.csv
tess2023341045131-s0073-0000000002104696-0268-s_lc.csv
tess2023341045131-s0073-0000000002105589-0268-s_lc.csv
tess2023341045131-s0073-0000000002149979-0268-s_lc.csv
tess2023341045131-s0073-0000000002152411-0268-s_lc.csv
tess2023341045131-s0073-0000000002234692-0268-s_lc.csv
tess2023341045131-s0073-0000000002234723-0268-s_lc.csv
tess2023341045131-s0073-0000000002236015-0268-s_lc.csv
tess2023341045131-s0073-0000000002237045-0268-s_lc.csv
tess2023341045131-s0073-0000000002334539-0268-s_lc.csv
```

FIG. 3. Output with the list of names of the 20 files .csv

D. Splitting the .txt file with the list of .csv table names

In this section, the .txt file from the previous section, which contains a list of CSV files, is split into smaller files, each with exactly 5 lines (names). To split, use split as the main command. -l 5 specifies that each generated file must contain 5 names from the *csv_file_list.txt* file. The output file name is then set to *csv_split_*. By default, this command will generate files with names like *csv_split_aa*, *csv_split_ab*, etc. Finally, the results are printed using ls.

```
#!/bin/bash
split -l 5 csv_file_list.txt csv_split_
echo "Split file:"
ls csv_split_*
```

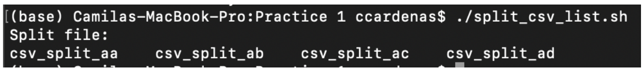


FIG. 4. Result obtained by separating the .txt file into four files with 5 names each.

E. Visualizing Light Curves with TOPCAT

Light Curve Visualization with TOPCAT Once the FITS files were converted to CSV format, TOPCAT was run again. The CSV files obtained in section II B were loaded by selecting multiple files simultaneously from the File/Load Table/File Browser option. For each file, a light curve plot was generated using TOPCAT's Plane Plot tool, selected from Graphics/Plane Plot shows in the Appendix. The curves were constructed by assigning the TIME column corresponding to the $time/BJD$ (Barycentric Julian Date) on the X axis. The column corresponding to the $PDCSAP\_FLUX$ photometric flux in $e-/s$ was assigned to the Y axis. This type of visualization allows direct observation of exoplanet variability using the previously studied transit method.

III. CONCLUSION

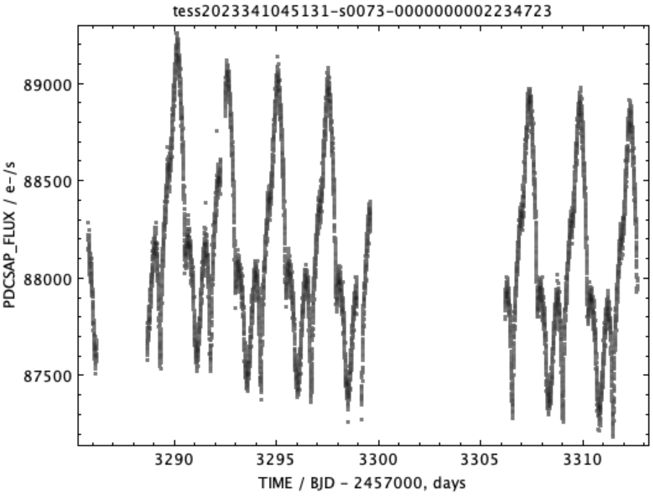
This practice session consolidated key knowledge in the management, processing, and visualization of data, in this case from a TESS satellite survey. The project downloaded light curves from the MAST file, converted them from FITS to CSV format using TOPCAT, and used shell scripts to organize the information. The graphical representation of the light curves as a function of time and flow, also available in the repository associated with this practice [1] , allowed the project to identify characteristic behaviors of the observed systems, including potential transit events that could be studied in detail in subsequent work.

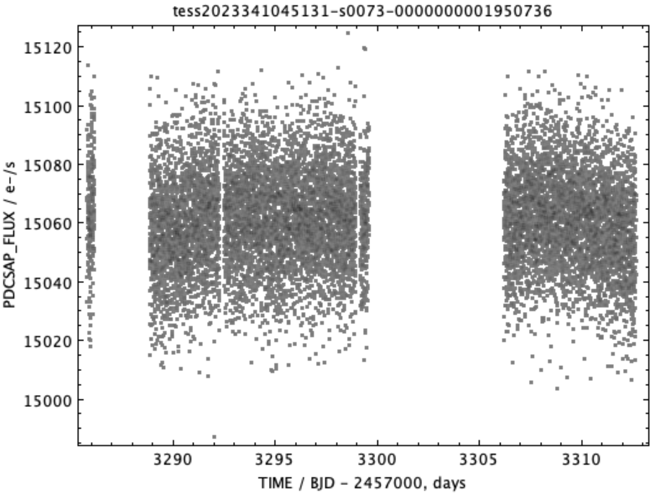
[1] Borucki, W. J., Scargle, J. D., and Hudson, H. S. (1985). Detectability of extrasolar planetary transits. *Astrophys. J.*, 291:852–854.

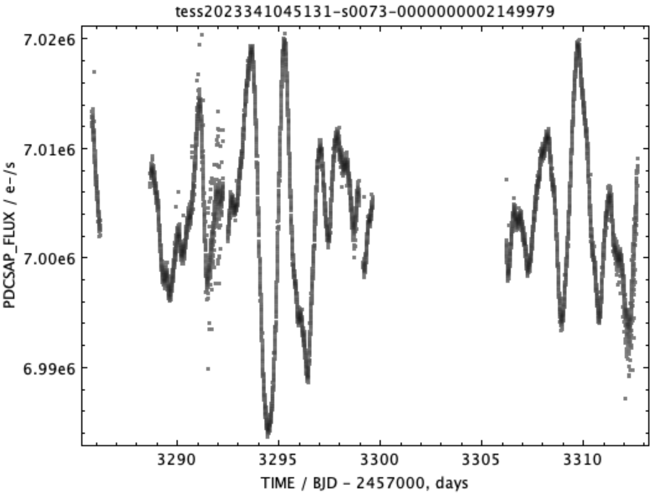
[2] NASA (2008). Mikulski archive for space telescopes (mast). *science nasa gov*.

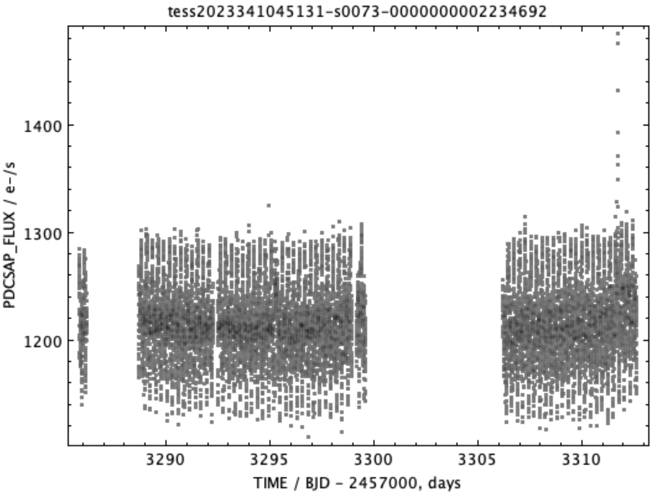
[3] Ricker, G. R., Latham, D. W., Vanderspek, R. K., Ennico, K. A., Bakos, G., Brown, T. M., Burgasser, A. J., Charbonneau, D., Clampin, M., Deming, L. D., Doty, J. P., Dunham, E. W., Elliot, J. L., Holman, M. J., Ida, S., Jenkins, J. M., Jernigan, J. G., Kawai, N., Laughlin, G. P., Lissauer, J. J., Martel, F., Sasselov, D. D., Schingler, R. H., Seager, S., Torres, G., Udry, S., Villasenor, J. N., Winn, J. N., and Worden, S. P. (2018). Transiting Exoplanet Survey Satellite (TESS). 215:450.06.

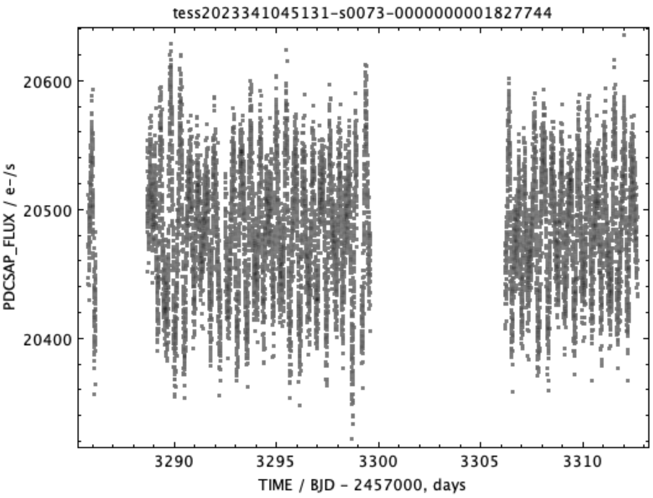
[1] Repository: `https://github.com/CamilaCU1613/Astroinformatics_Practice.git`

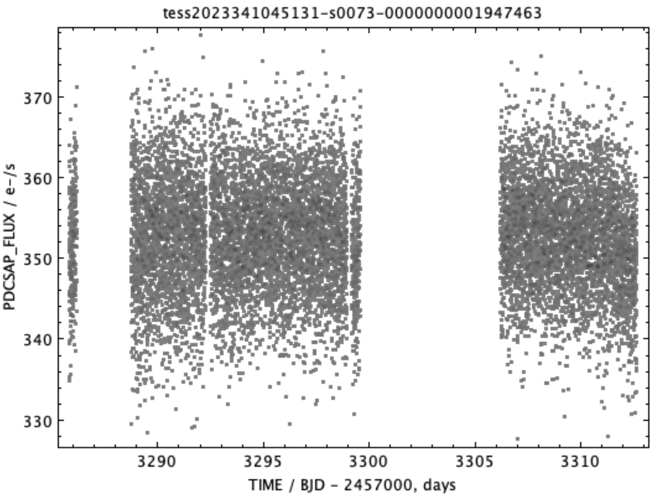

tess2023341045131-s0073-0000000002234723
PDCSAP_FLUX / e-/s
89000
88500
88000
87500
3290
3295
3300
3305
3310
TIME / BJD - 2457000, days

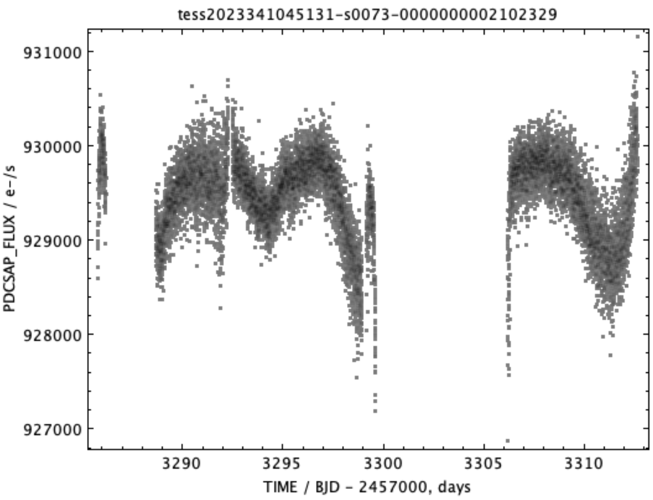

tess2023341045131-s0073-0000000001950736
PDCSAP_FLUX / e-/s
15120
15100
15080
15060
15040
15020
15000
3290
3295
3300
3305
3310
TIME / BJD - 2457000, days

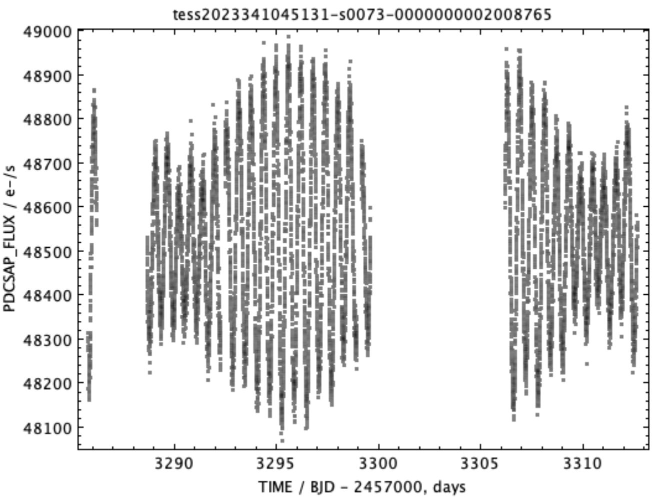

tess2023341045131-s0073-0000000002149979
PDCSAP_FLUX / e-/s
7.02e6
7.01e6
7.00e6
6.99e6
3290
3295
3300
3305
3310
TIME / BJD - 2457000, days

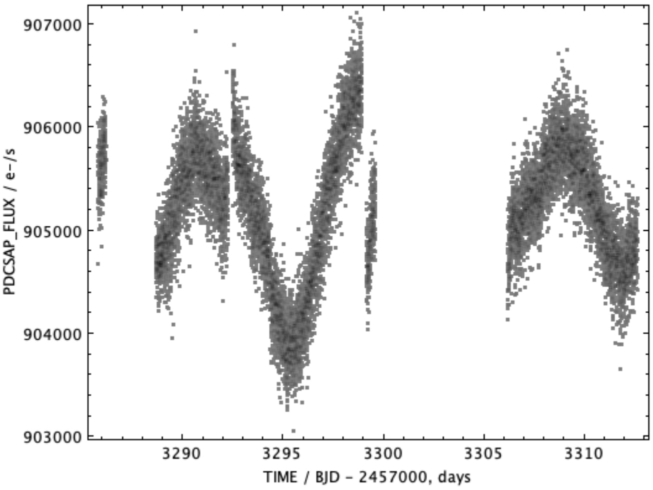

tess2023341045131-s0073-0000000002234692
PDCSAP_FLUX / e-/s
1400
1300
1200
3290
3295
3300
3305
3310
TIME / BJD - 2457000, days


tess2023341045131-s0073-0000000001827744
PDCSAP_FLUX / e-/s
20600
20500
20400
3290
3295
3300
3305
3310
TIME / BJD - 2457000, days

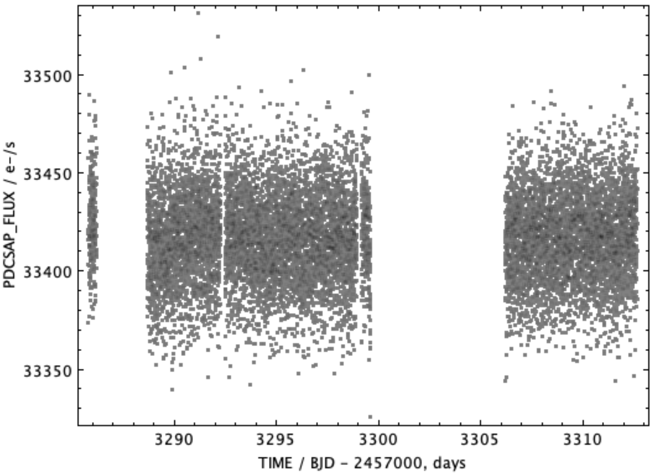

tess2023341045131-s0073-0000000001947463
PDCSAP_FLUX / e-/s
370
360
350
340
330
3290
3295
3300
3305
3310
TIME / BJD - 2457000, days


tess2023341045131-s0073-0000000002102329
PDCSAP_FLUX / e-/s
931000
930000
929000
928000
927000
3290
3295
3300
3305
3310
TIME / BJD - 2457000, days

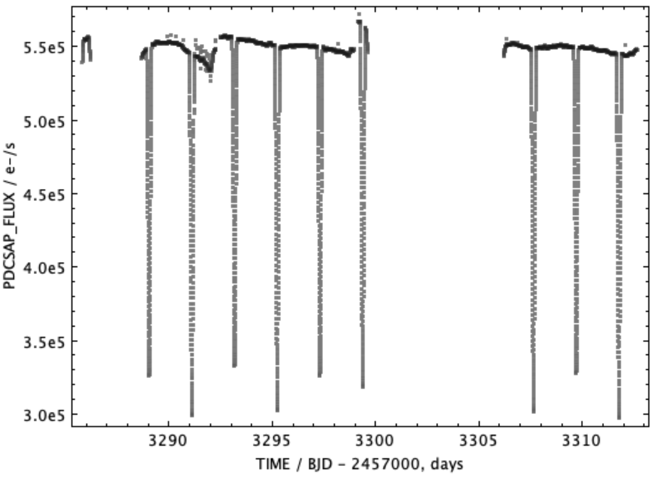

tess2023341045131-s0073-0000000002008765
PDCSAP_FLUX / e-/s
49000
48900
48800
48700
48600
48500
48400
48300
48200
48100
3290
3295
3300
3305
3310
TIME / BJD - 2457000, days



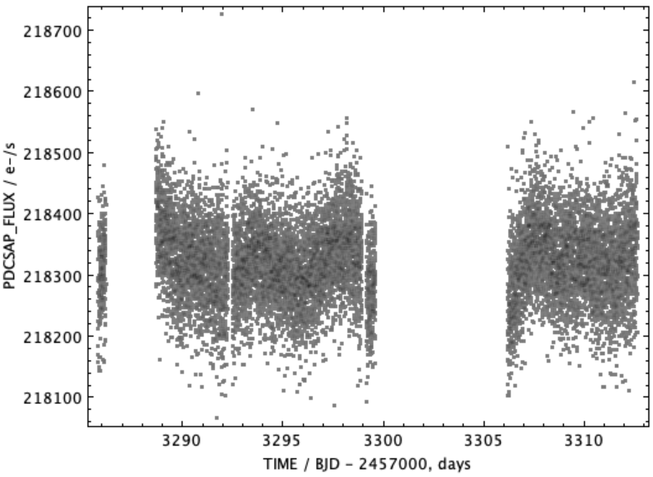
tess2023341045131-s0073-0000000002014191



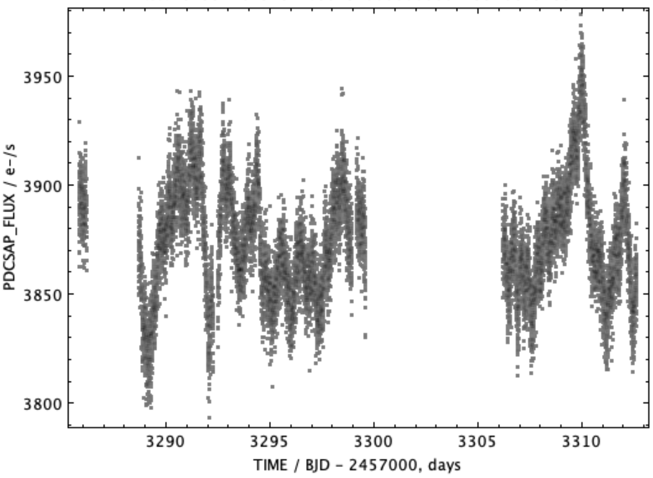
tess2023341045131-s0073-0000000002236015



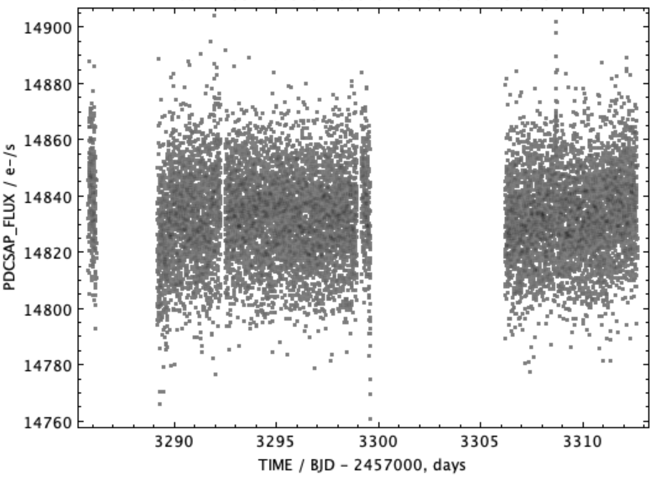
tess2023341045131-s0073-0000000001942416



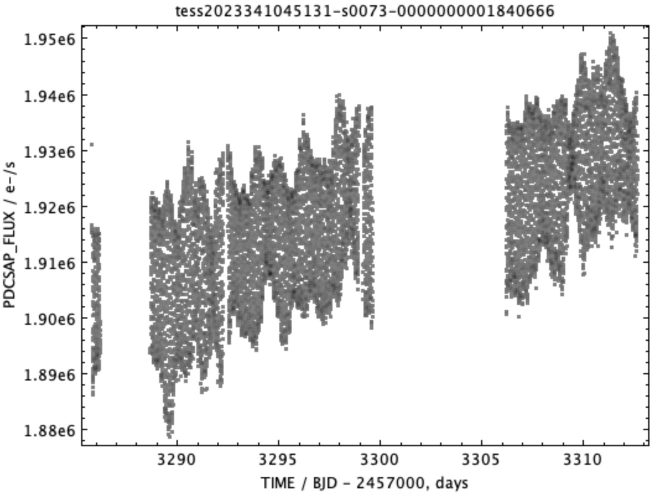
tess2023341045131-s0073-0000000001755406-0268



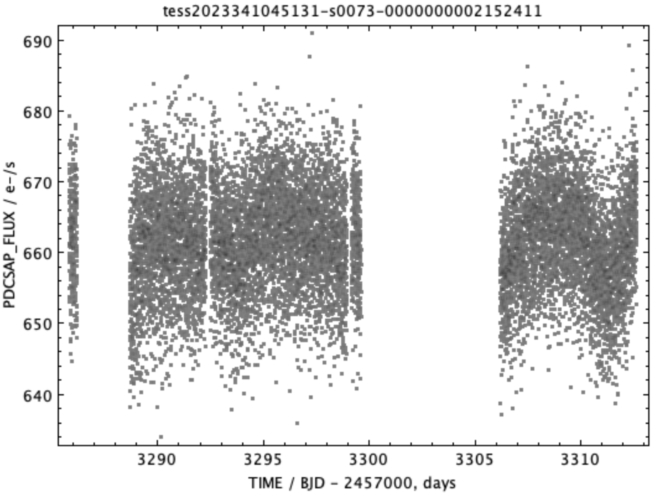
tess2023341045131-s0073-0000000002237045

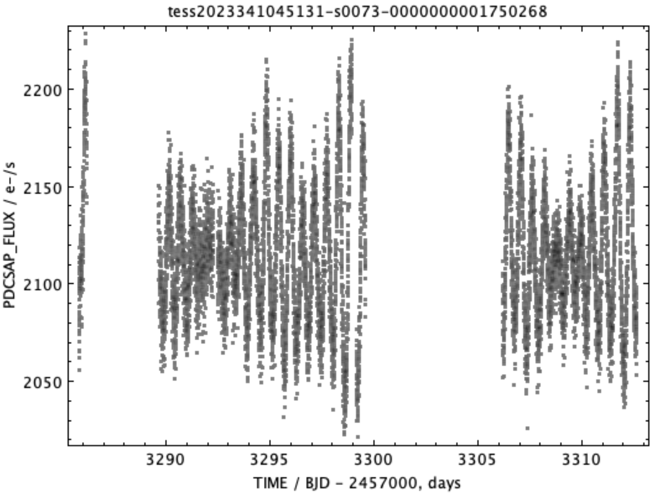


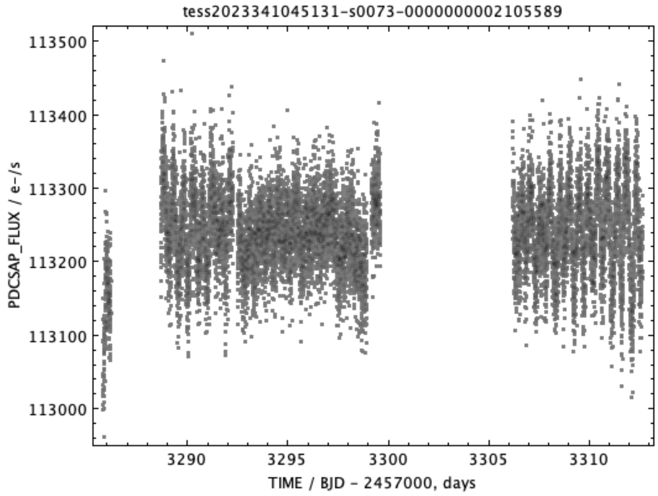
tess2023341045131-s0073-0000000001840666

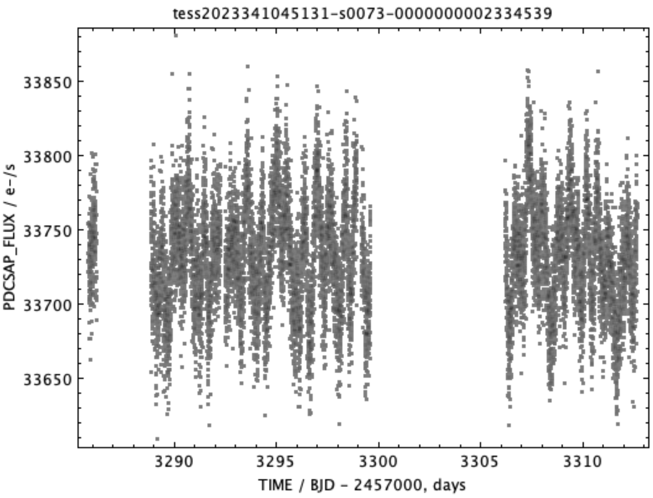


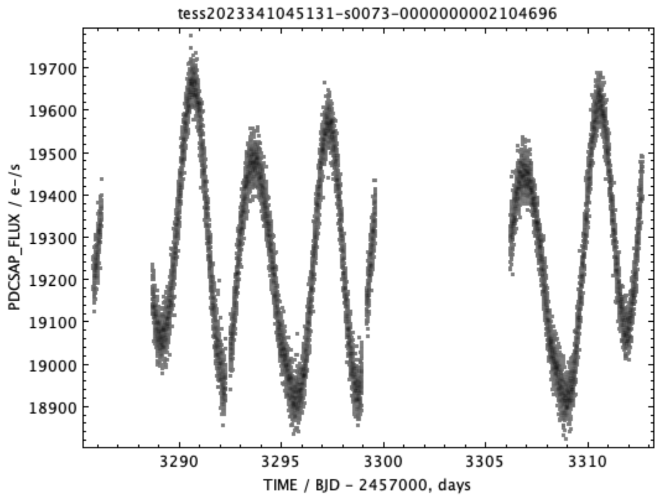
tess2023341045131-s0073-0000000002152411




tess2023341045131-s0073-0000000001750268
PDCSAP_FLUX / e-/s
TIME / BJD - 2457000, days


tess2023341045131-s0073-0000000002105589
PDCSAP_FLUX / e-/s
TIME / BJD - 2457000, days


tess2023341045131-s0073-0000000002334539
PDCSAP_FLUX / e-/s
TIME / BJD - 2457000, days


tess2023341045131-s0073-0000000002104696
PDCSAP_FLUX / e-/s
TIME / BJD - 2457000, days