A Search for Transiting Exocomets in TESS Sectors 1-26

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1. Introduction

- Aim: Quantify the frequency of exocomet detection as a function of stellar age and spectral type.
- The Kepler mission discovered exocomet transits in photometry for the first time (R2018, K2019).
- TESS expands the sample of stars with an all-sky survey; building from the work done in K2019 with Kepler.
- We present four new exocomet candidates from our search of 15.5 million lightcurves from TESS for stars brighter than Tmag = 13, along with the recovery of the exocomet transit around Beta Pic (Z2019).
- We also performed injection-recovery tests and determined the occurrence rates given the detection efficiency of our pipeline.

2. Search Method

- Lightcurves are cleaned from sector-by-sector systematics and then smoothened with a median filter from Wōtan (H2019).
- A moving average to compute the SNR over a range of box widths using a test-statistic.
- Width range from 0.1 - 2.5 days wide.

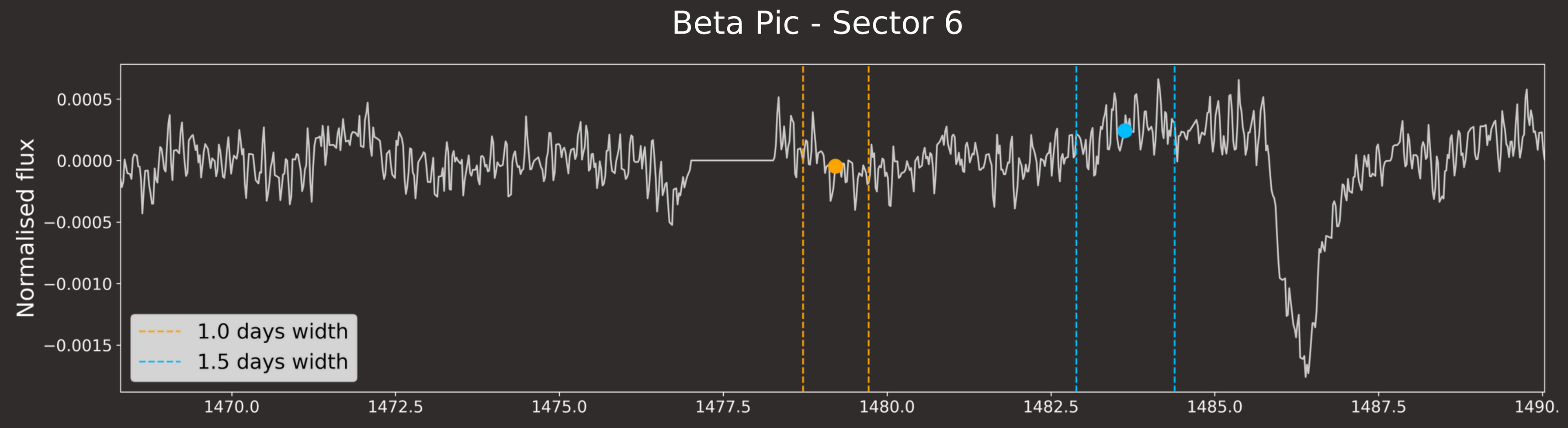


Fig 1: A 30-minute lightcurve of Beta Pic at TESS Sector 6. The dashed lines represent different box widths. The dots represent the mean flux within the respective the box widths.

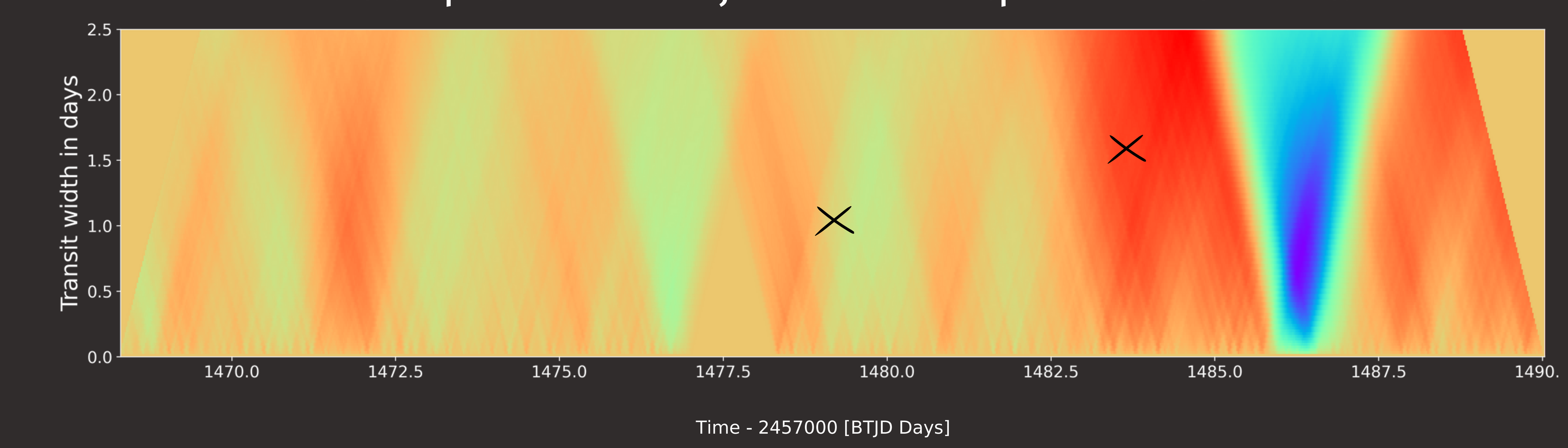


Fig 2: The corresponding t-statistic of the lightcurve in Fig 1. The crosses correspond to the two widths in Fig 1.

3. Characterising Transit Shapes

- Exocomets are characterised by their asymmetry.
- We make use of a skewed Gaussian to quantify the shape parameters of our transit events.

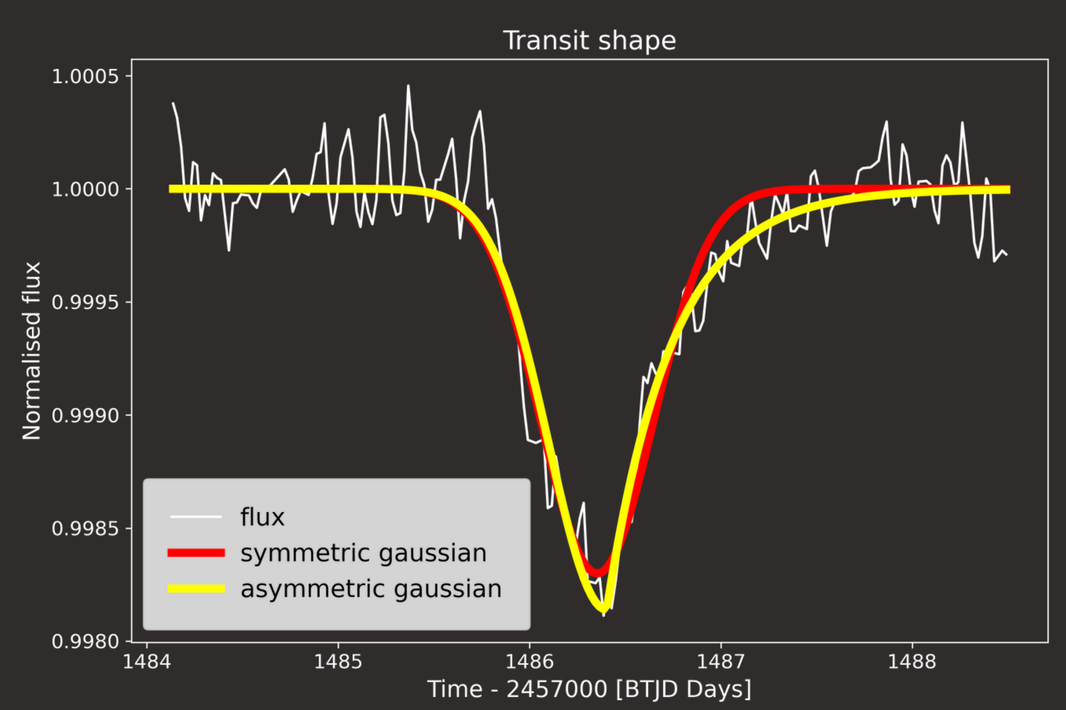


Fig 3: A close-up of the Beta Pic transit. The red line is the symmetric Gaussian model, and the yellow line is a skewed (asymmetric) Gaussian to characterise a cometary shape.

4. Candidates

- We conducted several vetting stages to remove false positives and known sources.
- This includes setting constraints on the characteristics of the events (SNR, duration, transit depth, asymmetry, skewness).
- Other false positives included "common time transits".
- We manually vetted the candidates that passed all the above conditions to remove background-related false positives.

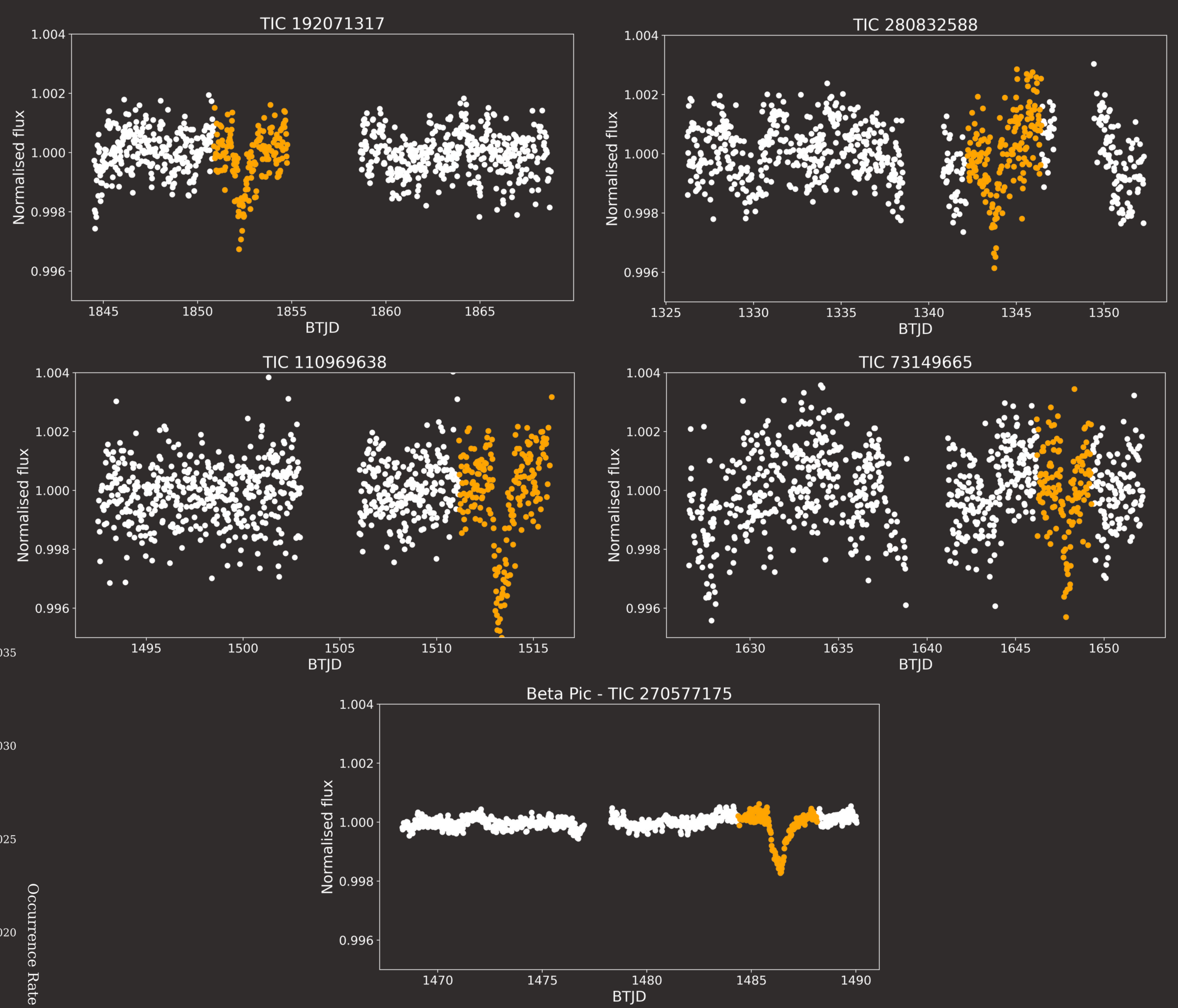


Fig 4: The TESS lightcurves of our exocomet candidates

5. Occurrence Rates

- We can estimate the occurrence rates of exocomet detections for our parameter space.

Fig 5: A grid of the occurrence rates across the parameter space of our sample. The black crosses are where the candidates are located in our parameter space, and the blue text is the corresponding "true" occurrence rate.

References

R2018: Rappaport. S, Likely Transiting Exoxomets with Kepler, MNRAS, arXiv:1708.06069v2

K2019: Kennedy. G, An Automated Search for Transiting Exocomets, MNRAS, arXiv:1811.03102

F2019: Feinstein. A, eleanor: An Open-source Tool for Extracting Light Curves from the TESS FFIs, arXiv:1903.09152

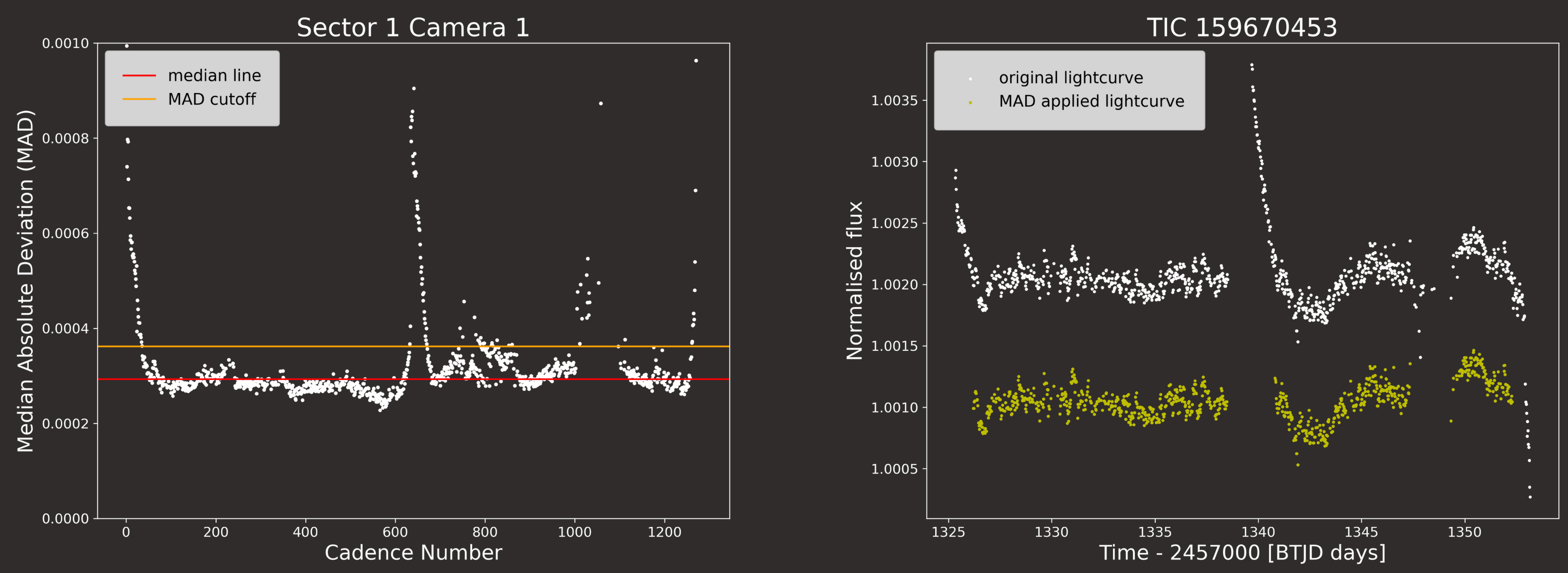
H2019: Hippke, M: Wōtan - Comprehensive Time-series Detrending in Python, AJ, arXiv:1906.00966

Z2019: Zeiba. S, Transiting exocomets detected in broadband light by TESS in the β Pictoris system, arXiv:1903.11071v2

Extra Stuff

A. Removing Common Systematics

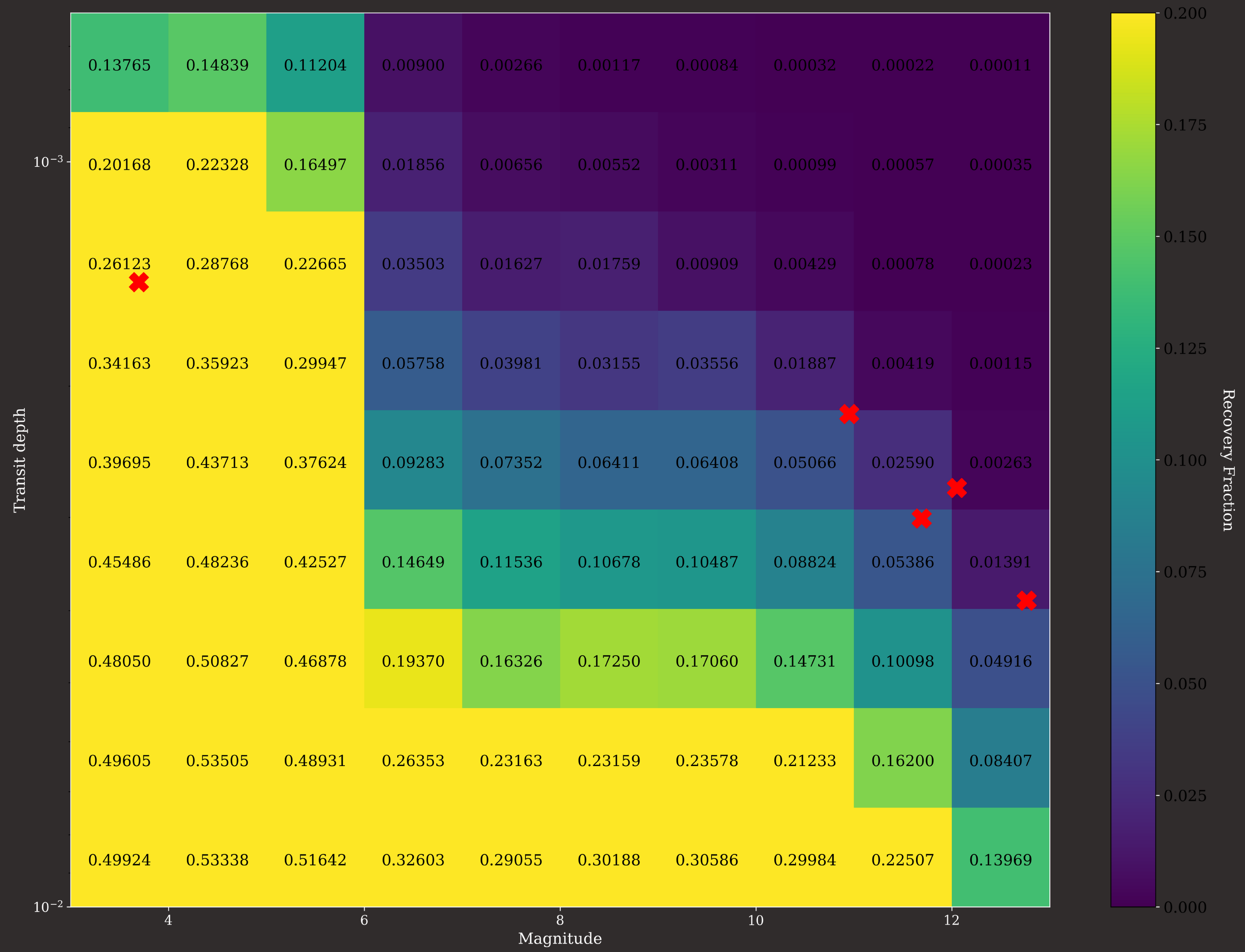
The Median Absolute Deviation (MAD) applied on TESS Sector 1, Camera 1 as an example. Points above 3 sigma from the median MAD line are removed from all lightcurves in this sector-camera combination. An example of this cut is applied to the lightcurve of TIC 159670453.



Note: some sector-camera combinations are noisier than others. S1, C1 is considered "slightly noisy"

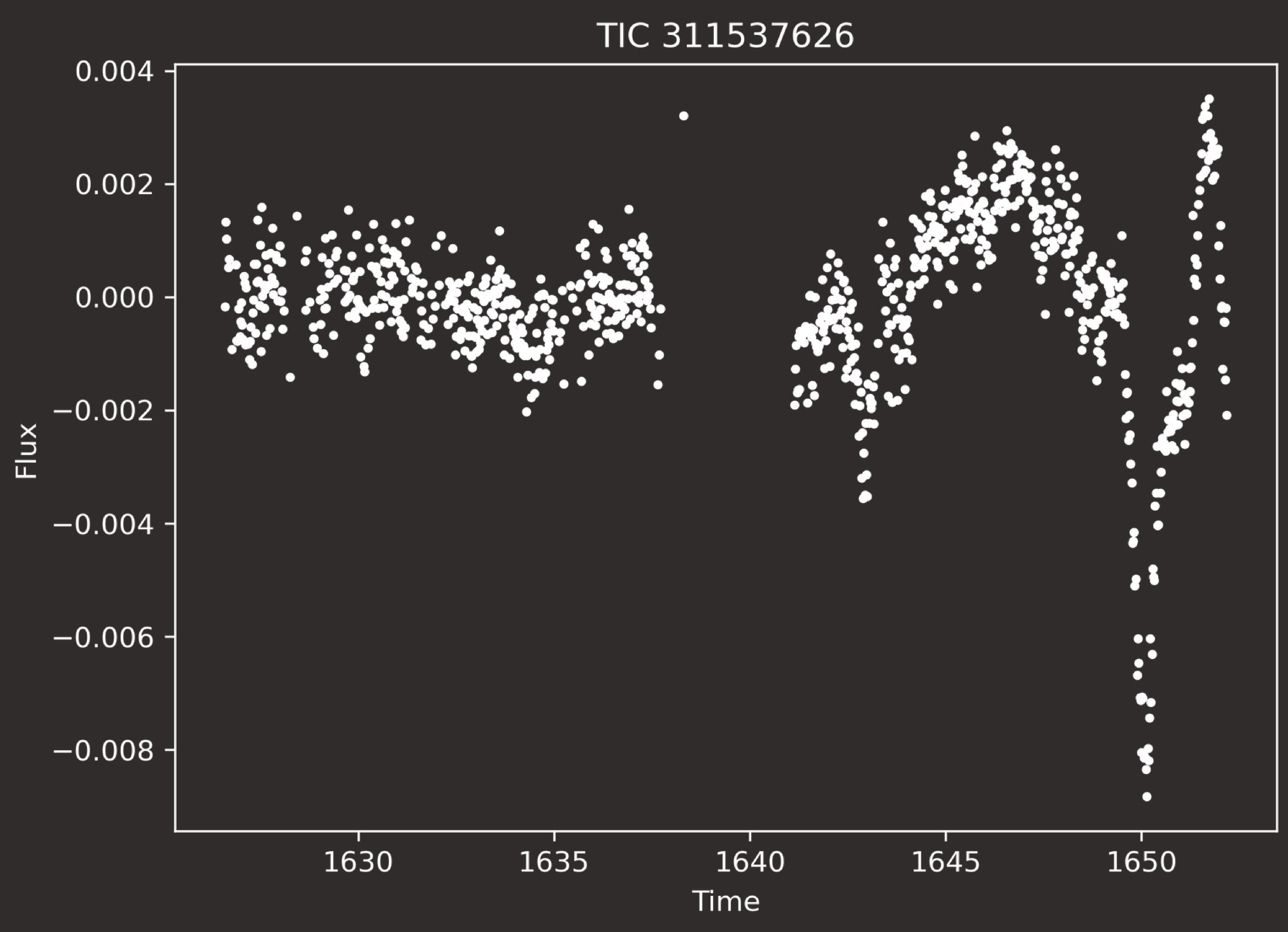
B. Injection Recovery

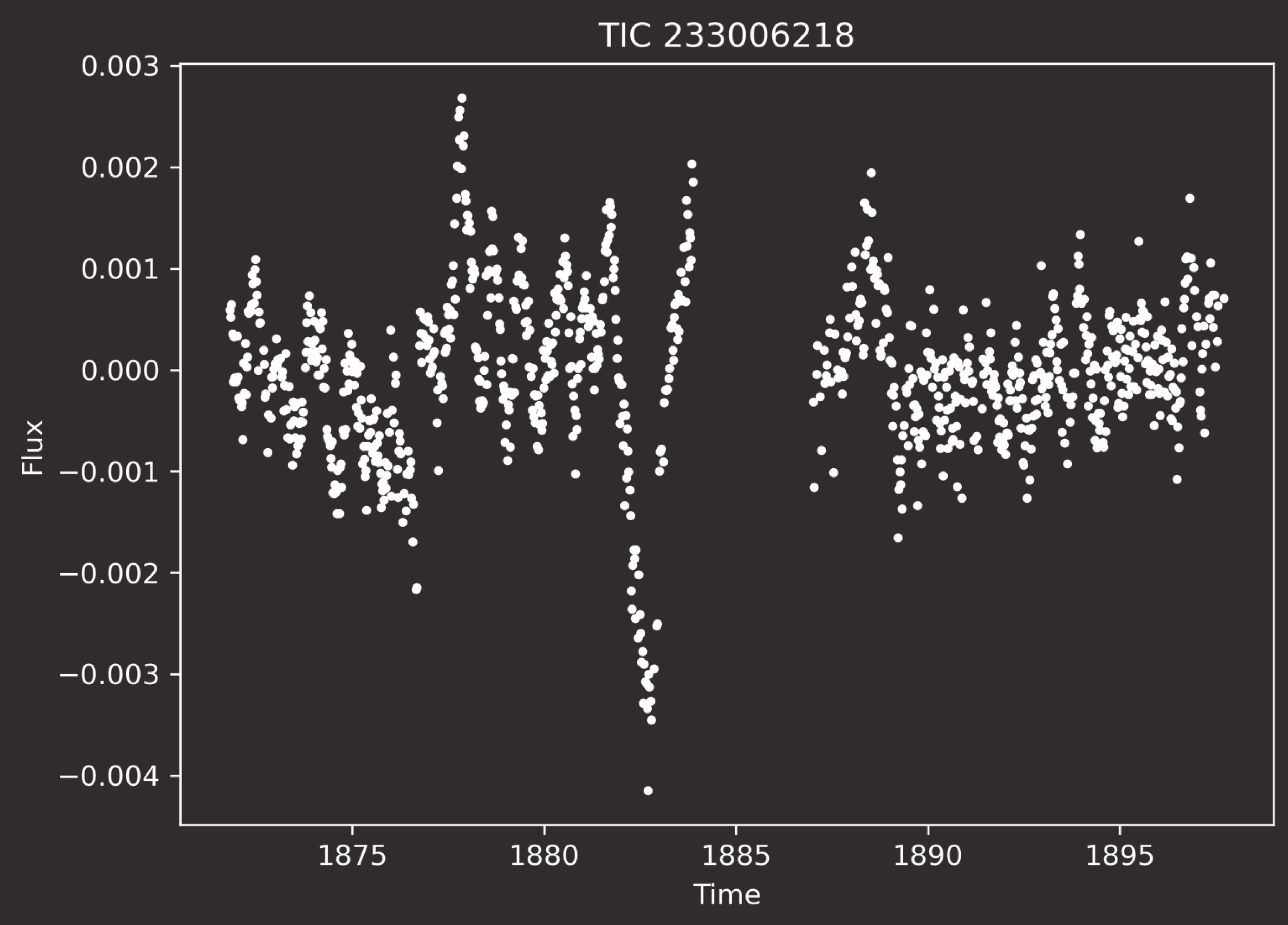
The detection efficiency of our pipeline with all the thresholds to characterise exocomet transit shapes applied

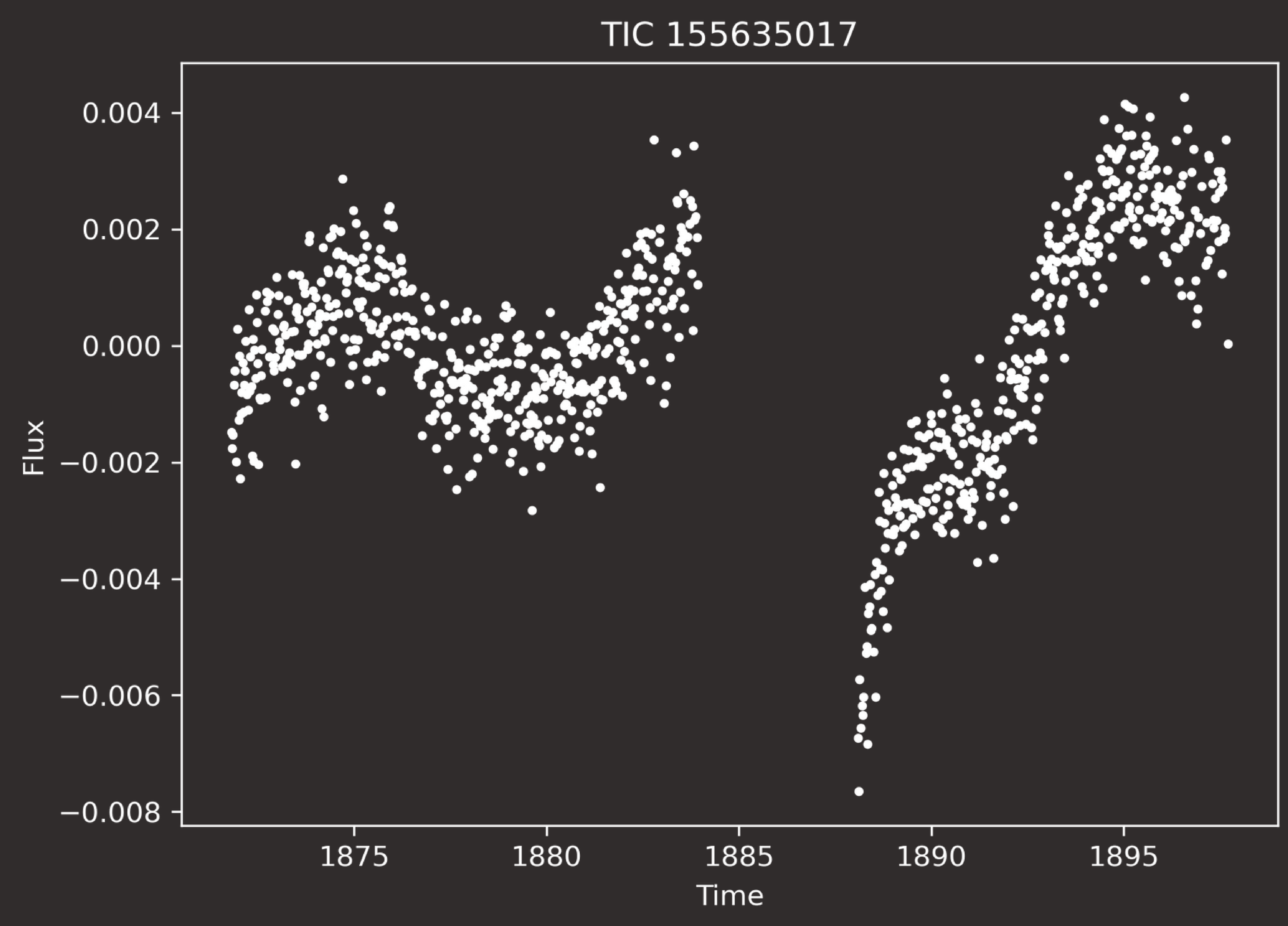


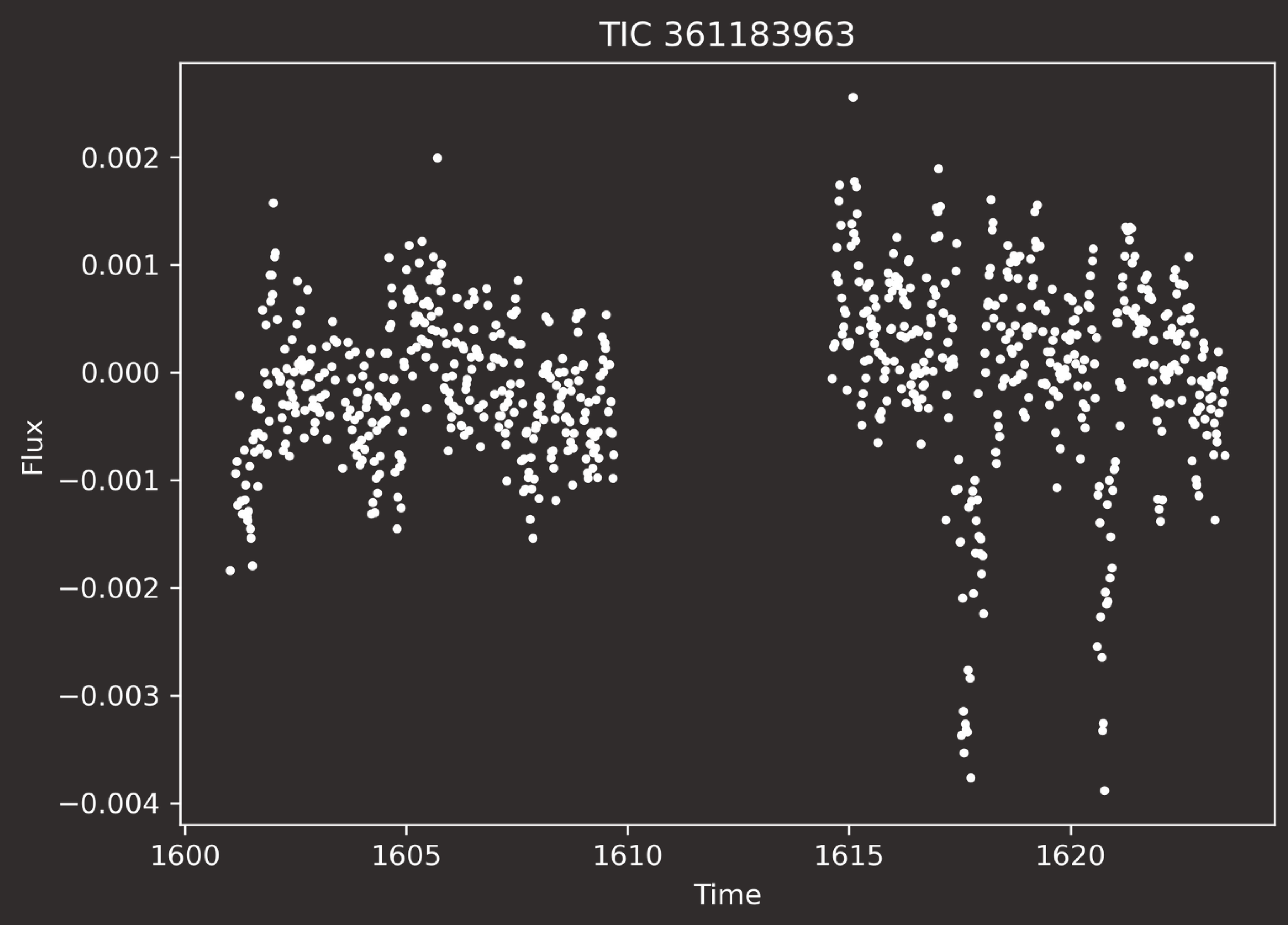
Detection Efficiency of 999923 Exocomet transits with all thresholds applied

C. Examples of False-Positive Detections

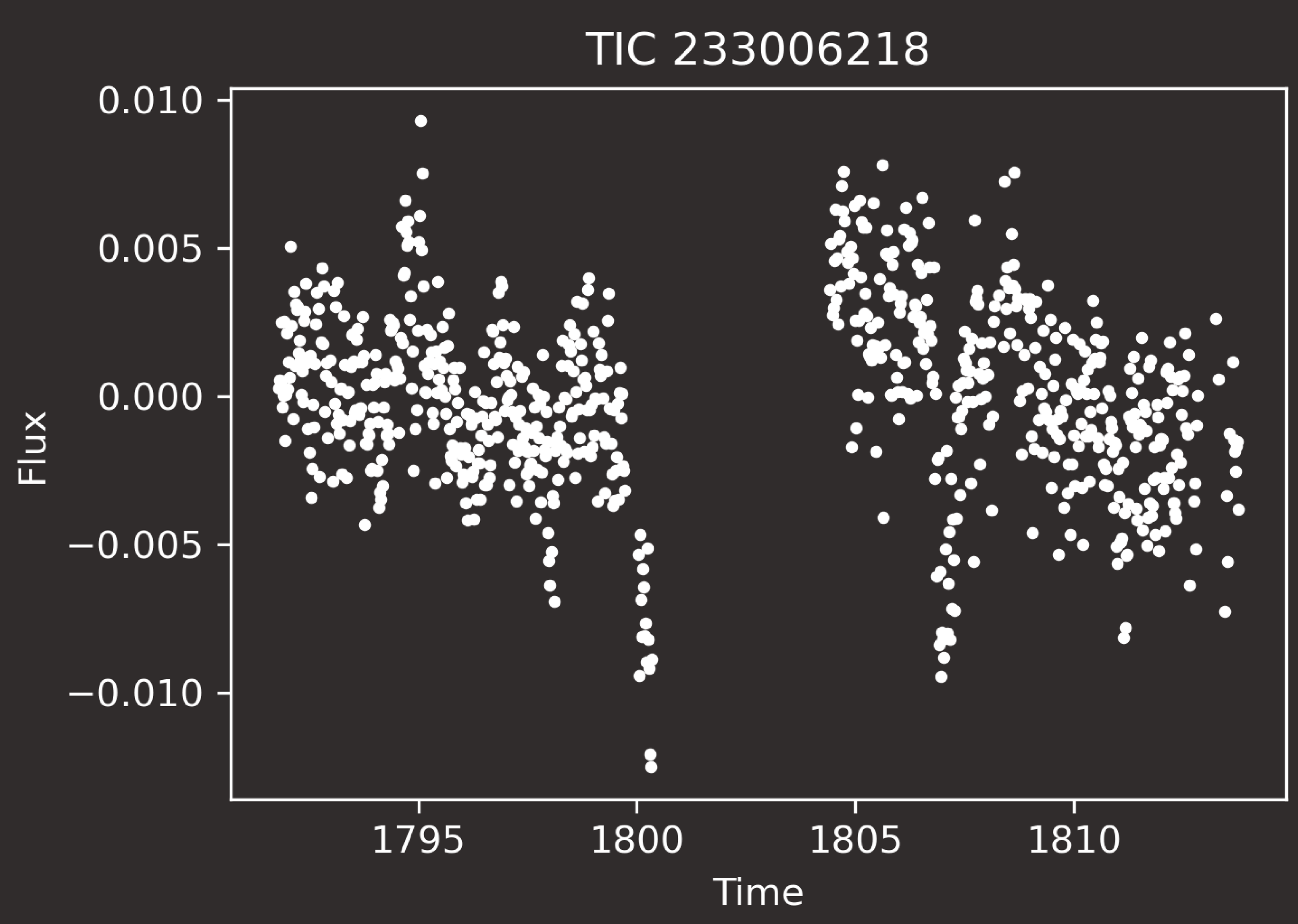


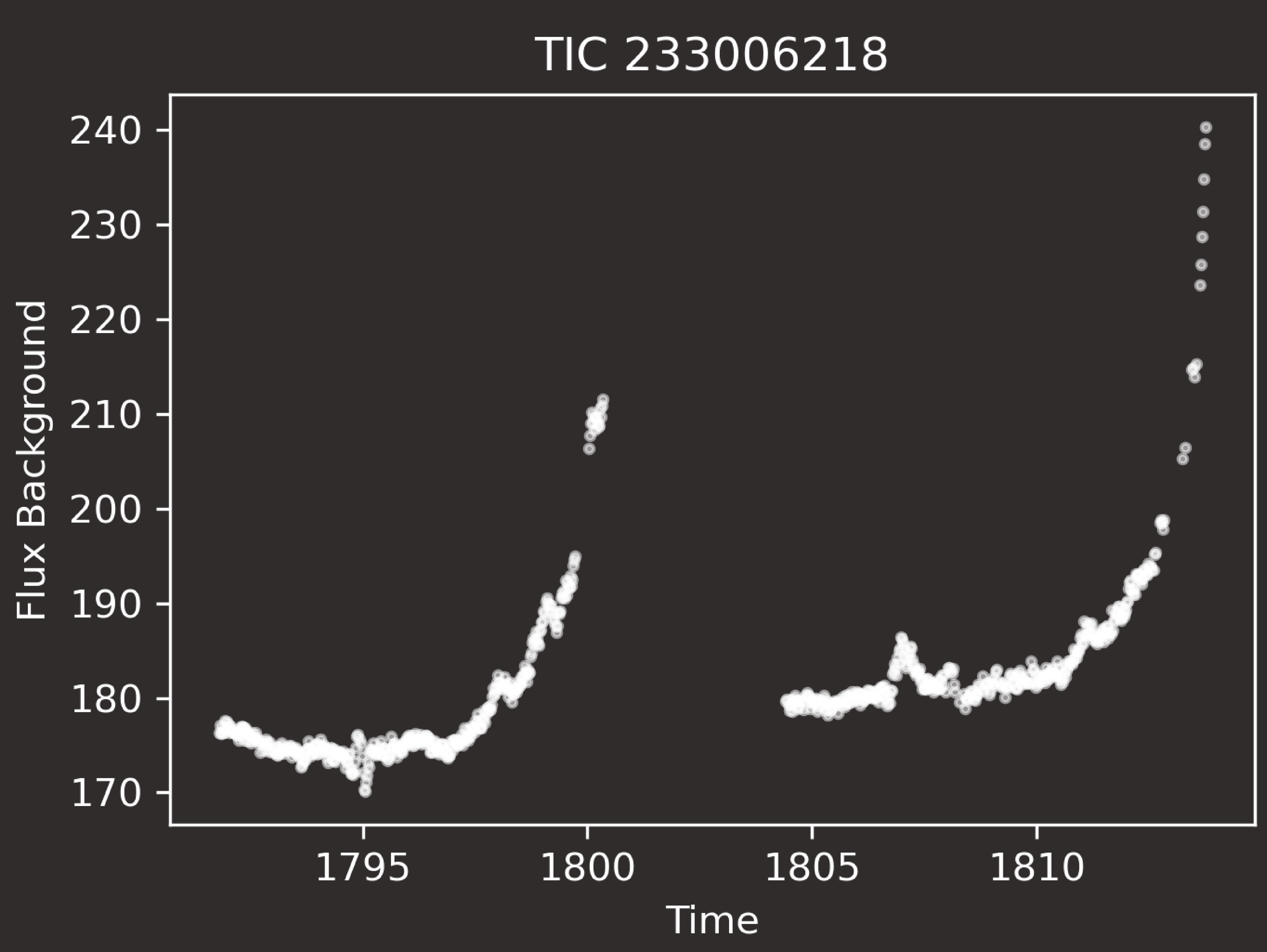






C.2. Examples of False-Positive Detections - Manual Vetting





Example of TIC 233006218 - a false positive due to a background object

D. Candidates - Full-sized