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NEW VARIABLE STARS FROM TESS SECTOR 93

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Abstract: In this paper, we present results from the fifth iteration of the Star Hunters citizen-science project, focused on the search for new variable stars in TESS Sector 93. Using systematics-corrected TESS photometry (`PDCSAP_FLUX`) from MAST, we analyzed candidate light curves, estimated periods with Lomb-Scargle periodograms, measured amplitudes after outlier removal and smoothing, and assigned variability types based on light curve morphology and supporting catalog checks. We identified 74 variable stars, classified 45 of them, and left 29 as unknown; reliable periods and initial epochs were determined for 25 stars. The sample includes eclipsing binaries, pulsating variables, rotational variables, flare stars, magnetic variables, and oscillating red giants.

Key words: variable stars – light curves – TESS – period analysis – citizen science – time-domain astronomy

1 Introduction

Citizen-science projects have shown that amateur astronomers can contribute solid results to variable star research, especially in the discovery of new variable stars, when the work is supported by a clear methodology and mentors. Previous educational programs showed that students can successfully perform time-series analysis, period calculation, and classification of variable stars (Percy, 2006) (Percy, 2008). More recent projects based on data from the Transiting Exoplanet Survey Satellite (TESS) confirmed that collaborations between professional astronomers, amateur astronomers, and students can produce scientifically reliable catalogs and classifications (Kostov et al., 2025).

The Star Hunters (SH) project series (SH-0, SH-1, SH-2, SH-3) (Dzygunenko et al., 2026), organized by the Clear Skies Foundation (CSF), has already demonstrated its significance for the development of Ukrainian astronomy and has attracted strong interest from young and amateur researchers. This paper presents the fifth iteration of the project

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(Star Hunters-4), which was designed using both external citizen-science experience and lessons learned from previous SH iterations.

In this iteration, we increased the number of mentors, improved the educational materials, and introduced a platform for uploading and reviewing candidate objects. Participants without prior experience in earlier SH projects were required to complete a lecture course and pass a final test with a minimum passing score. This process was important for providing a foundational knowledge for students, before giving them access to the research platform. Before participant access, administrators prepared the platform with all relevant data from the selected TESS sector.

We used data from TESS because it provides continuous observations of a large number of stars and high-quality photometry for variability studies (Ricker et al., 2015). TESS observes wide sky sectors (about $24° \times 96°$), and each sector is monitored for approximately 27.4 days. Selected targets are observed in short-cadence mode (2 min), which is suitable for identifying short-period variables. In this work, we analyzed stars from TESS Sector 93 (PDCSAP_FLUX).

Our goal was to analyze variable stars from Sector 93, cross-check candidates in SIMBAD and VSX to identify stars not previously classified as variable, determine periods with supporting diagnostics (periodograms and phase curves), and assign variability classes where possible. This research format does not require long formal training, but it requires structured preparation and quality control. In total, 6 students completed the training stage and joined the research phase.

This project was designed to involve young citizen scientists in a full research cycle, from selecting candidates to variability classification. The paper is organized as follows: Sec. 2 describes the data and methods, Sec. 3 presents the main results, and Sec. 4 summarizes the implications and conclusions.

2 Methods and algorithms

A detailed description of the workflow used in the Star Hunters project was presented in our earlier paper based on the first iteration of the Star Hunters 0 project (Dzygunenko et al., 2026). Here, we provide a concise summary of the methodology used for the analysis of TESS Sector 93 targets.

We obtained TESS photometric data from the Mikulski Archive for Space Telescopes (MAST) (MAST, 2025) and used systematics-corrected SPOC light curves (PDCSAP_FLUX) as the primary data product. Each candidate was first visually and statistically inspected for astrophysical variability. We rejected light curves dominated by instrumental trends, strong contamination/artifacts, or a low signal-to-noise ratio.

To verify novelty and previous classifications, each candidate was cross-checked against major databases and catalogs: SIMBAD[1], NASA ADS[2], AAVSO VSX[3], TESS Eclipsing Binary catalog[4], and ExoFOP-TESS[5].

[1] https://simbad.cds.unistra.fr/simbad/
[2] https://ui.adsabs.harvard.edu/
[3] https://www.aavso.org/vsx/
[4] https://tessebs.villanova.edu/
[5] https://exofop.ipac.caltech.edu/tess/

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For periodic candidates, we estimated periods using the Lomb-Scargle periodogram.

For all confirmed variables, we measured amplitude in three steps. First, we removed outliers with iterative sigma clipping (up to five iterations), rejecting points that satisfy $|m_i - \tilde{m}| > 3\sigma$. Second, we applied an N-point linear smoothing to reduce random noise ($m_{i,\mathrm{new}}$). Third, we measured the variability amplitude from the smoothed curve as

$$A = \max_i(m_{i,\mathrm{new}}) - \min_i(m_{i,\mathrm{new}})\,.$$

This gives a reliable value of amplitude, considering the TESS signal-to-noise ratio and potential outliers. It is important to also note that the procedure for amplitude calculation was not done automatically, but rather semi manually. For each variable star light curve, students checked for outliers and artifacts, and assessed how well the method performed; if any corrections were needed, they were applied (and the final checks were performed by the mentors as well). But the overall methodology for amplitude calculation stayed fixed throughout the sample.

For periodic stars, we also determined an initial epoch T_0 (time of primary minimum for eclipsing systems, or reference maximum/minimum for pulsators, depending on morphology). To keep the results consistent across all targets, we used a unified initial epoch reference with JD = 2457000. Because the approximation of extrema was performed using polynomials $\sum_{i=0}^{n}(a_i x^i)$ of degree n where $n \in (3, 10)$, it was highly important to choose a symmetrical extremum for each periodic target to obtain reliable results.

For eclipsing binaries, subtype classification was based on light-curve morphology (, Prša et al., 2022): (i) EA - detached systems, (ii) EB - semi-detached systems, (iii) EW - overcontact/ellipsoidal-like systems. For pulsating stars, we evaluated whether each object is consistent with known pulsator classes by combining absolute magnitude, spectral type, position on the Hertzsprung-Russell diagram, as well as considering periodicity (where it was applicable). Locations of the new pulsating variable stars are illustrated in Fig.1. The source of this figure [6].

[6] https://commons.wikimedia.org/wiki/File:MS_and_RGB_isochrones.png

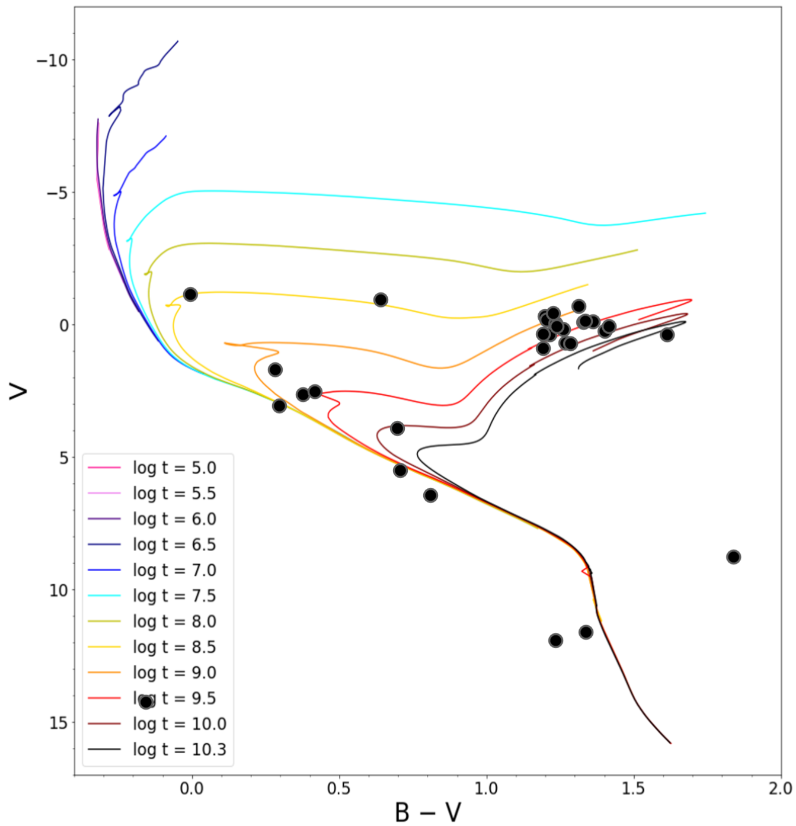

Figure 1: Location of new pulsating variable stars on the colour-magnitude diagram. The solid lines represent isochrones for various stellar ages, where $\log t$ is the decimal logarithm of age in years.

3 Results

The final sample contains 74 newly identified variable stars from TESS Sector 93. The full list of objects (TIC ID, variability type, amplitude, period, and initial epoch) is presented in Table 1.

The processed Sector 93 dataset contained 12067 objects in total, and our initial sample included 1744 objects. From this initial sample, we reliably identified 74 new variable stars; 45 stars were assigned to specific variability classes, while 29 objects remain unknown at the current stage. We determined periods and initial epochs for 25 stars, where a reliable approximation of extremum was available. The measured amplitudes span from 2.72 to 754.78 mmag, and the derived periods range from 0.03427 to 13.34101 days.

4 Discussion

In Sector 93, the processed dataset contained 12067 objects in total, and we analyzed 1744 objects as the initial sample. In this iteration of the Star Hunters project, we identified 74 variable stars in TESS Sector 93. Among them, 45 objects were assigned to specific

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variability classes, while 29 objects remain in the unknown group. We determined periods and initial epochs for 25 stars using a unified reference system.

The final sample includes eclipsing binaries, pulsating stars, rotational variables, flare stars, magnetic variables, and oscillating red giants. This distribution shows that a mentor-guided citizen-science workflow can produce a diverse and scientifically useful set of variable-star detections from TESS data.

At the same time, the current analysis has clear limitations. In many cases, photometry alone is not sufficient for a subtype classification, especially for pulsating variables, or quasi periodic behavior. For such objects, additional information (e.g., spectroscopy, multiband photometry, or at least multi band photometry data) is needed.

Another limitation is sample selection bias introduced at the training and candidate selection stages. To keep the workflow feasible for students, we prioritized targets with cleaner light curves and clearer variability signatures. As a result, more complex cases were less represented in the final sample.

Overall, the project achieved its two main goals: (i) producing a validated list of new variable stars in TESS Sector 93 (ii) training young citizen scientists in a full research cycle, from candidate inspection to period analysis and classification.

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5 Appendix A

The abbreviations used in Table 1 are listed in the footnote.[7]

Table 1: List of 74 newly discovered variable stars. Stellar classification is written as a standard abbreviation.

TIC ID	Var. Type	A (mmag)	P (days)	T_0 (JD)	T (K)	M
1360553342	UV Ceti	329,7	9,45495	2460849,70	3400	10,29
140945145	UV Ceti	57,7	6,01254	2460853,43	3400	10,97
150393302	ROT	4,6	5,71755	2460841,82	5200	5,93
150542225	ROT	84,5	5,53829	2460843,93	3900	8,07
141152400	ROT	6,4	4,74294	2460841,18	5900	3,61
1338860086	ELL	90,5	3,55893	2460837,18	-	-
150102127	ELL	15,8	3,31288	2460851,77	-	-
1404446263	UV Ceti	346,2	2,44337	2460834,57	-	-
150163695	unknown	20,7	13,34101	2460835,76	-	-
151298209	EB	26,7	1,85985	2460853,11	-	-
1361506769	EB	285,3	1,69033	2460853,25	-	-
150394361	unknown	3,5	1,57985	2460852,93	-	-
1340879278	ROT	189,9	1,46776	2460831,66	-	-
167656243	ELL	7,7	1,20713	2460830,86	-	-
1340808791	EA	97,4	1,19316	2460841,08	-	-
151689186	unknown	57,8	1,02009	2460853,33	-	-
149449530	magnetic variable	11,2	0,62369	2460841,30	7100	2,43
150431617	UV Ceti	53,9	0,32671	2460832,08	3400	10,68
1312615531	magnetic variable	754,8	0,31220	2460854,99	-	5,15
112910526	EW	287,5	0,17514	2460839,04	-	-
103898308	DSCT	23,8	0,08694	2460838,40	7400	-0,87
150636911	DSCT	10,1	0,08062	2460841,07	-	-1,05
149154927	DSCT	12,5	0,05440	2460830,74	7600	1,55
125867733	DSCT	9,5	0,05214	2460852,18	7600	2,81
150431712	DSCT	5,6	0,03427	2460837,58	7700	2,31
150430837	unknown	2,7	-	-	-	-
150440755	UV Ceti	43,1	-	-	3200	13,11
1512991853	UV Ceti	86,6	-	-	3300	-
1523490773	UV Ceti	105,0	-	-	3200	-
152545328	oscillating red giant	4,3	-	-	5400	-0,30
149274312	unknown	15,3	-	-	-	-
13173449	oscillating red giant	5,4	-	-	4300	-0,09

(continued on next page)

[7]EA = detached eclipsing binary (Algol type); EB = semi-detached eclipsing binary (β Lyrae type); EW = overcontact eclipsing binary (W UMa type); ELL = ellipsoidal variable; DSCT = δ Scuti variable; DCEPS = classical Cepheid (s-Cepheid subtype); CWA = W Virginis type (Population II Cepheid); ROT = rotational variable; UV Ceti = flare star class.

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Table 1: Continued.

(continued from previous page)

TIC ID	Var. Type	A (mmag)	P (days)	T_0 (JD)	T (K)	M
13182985	oscillating red giant	7,2	-	-	4200	0,23
119438520	oscillating red giant	6,2	-	-	4200	-0,10
140658982	ROT	8,8	-	-	5200	5,05
1361086490	unknown	424,7	-	-	-	-
119502952	unknown	7,6	-	-	-	-
119732016	oscillating red giant	4,2	-	-	4500	0,82
119945362	oscillating red giant	7,5	-	-	4100	0,62
120202141	oscillating red giant	4,3	-	-	4400	-0,64
121577936	oscillating red giant	8,7	-	-	4300	0,66
124166949	oscillating red giant	6,5	-	-	4700	0,35
140510714	oscillating red giant	6,1	-	-	4400	-0,13
140579537	unknown	26,6	-	-	-	-
141769434	unknown	13,6	-	-	-	-
141809220	unknown	13,2	-	-	-	-
149540013	oscillating red giant	8,3	-	-	4100	0,15
149879070	unknown	3,6	-	-	-	-
119774846	unknown	10,9	-	-	-	-
141757441	unknown	17,3	-	-	-	-
1343580465	UV Ceti	279,7	-	-	3400	-
150103650	oscillating red giant	8,2	-	-	4300	-0,17
118141254	oscillating red giant	7,3	-	-	4400	0,34
118282622	oscillating red giant	6,9	-	-	4300	0,05
112907750	unknown	7,0	-	-	-	-
119224086	unknown	13,5	-	-	-	-
119280053	unknown	10,4	-	-	-	-
118319282	oscillating red giant	4,0	-	-	4300	0,32
111977318	unknown	5,9	-	-	-	-
100310036	unknown	24,8	-	-	-	-
101471054	unknown	8,7	-	-	-	-
102633056	oscillating red giant	4,5	-	-	4800	-0,05
103149882	unknown	9,7	-	-	-	-
109896650	unknown	5,8	-	-	-	-
110530353	unknown	3,4	-	-	-	-
111368754	unknown	3,2	-	-	-	-
148199331	oscillating red giant	5,8	-	-	4500	0,05
148538970	unknown	5,5	-	-	-	-
149305792	unknown	8,1	-	-	-	-
149346163	unknown	12,2	-	-	-	-
149347296	unknown	9,3	-	-	-	-
167087316	unknown	17,2	-	-	-	-
167574667	unknown	8,0	-	-	-	-
167654890	oscillating red giant	5,7	-	-	4400	-0,40

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6 Appendix B

All TESS light curves for the 74 newly identified variable stars are shown below. Each figure presents a grid of 10 light curves (5×2), labeled with TIC IDs above each panel.

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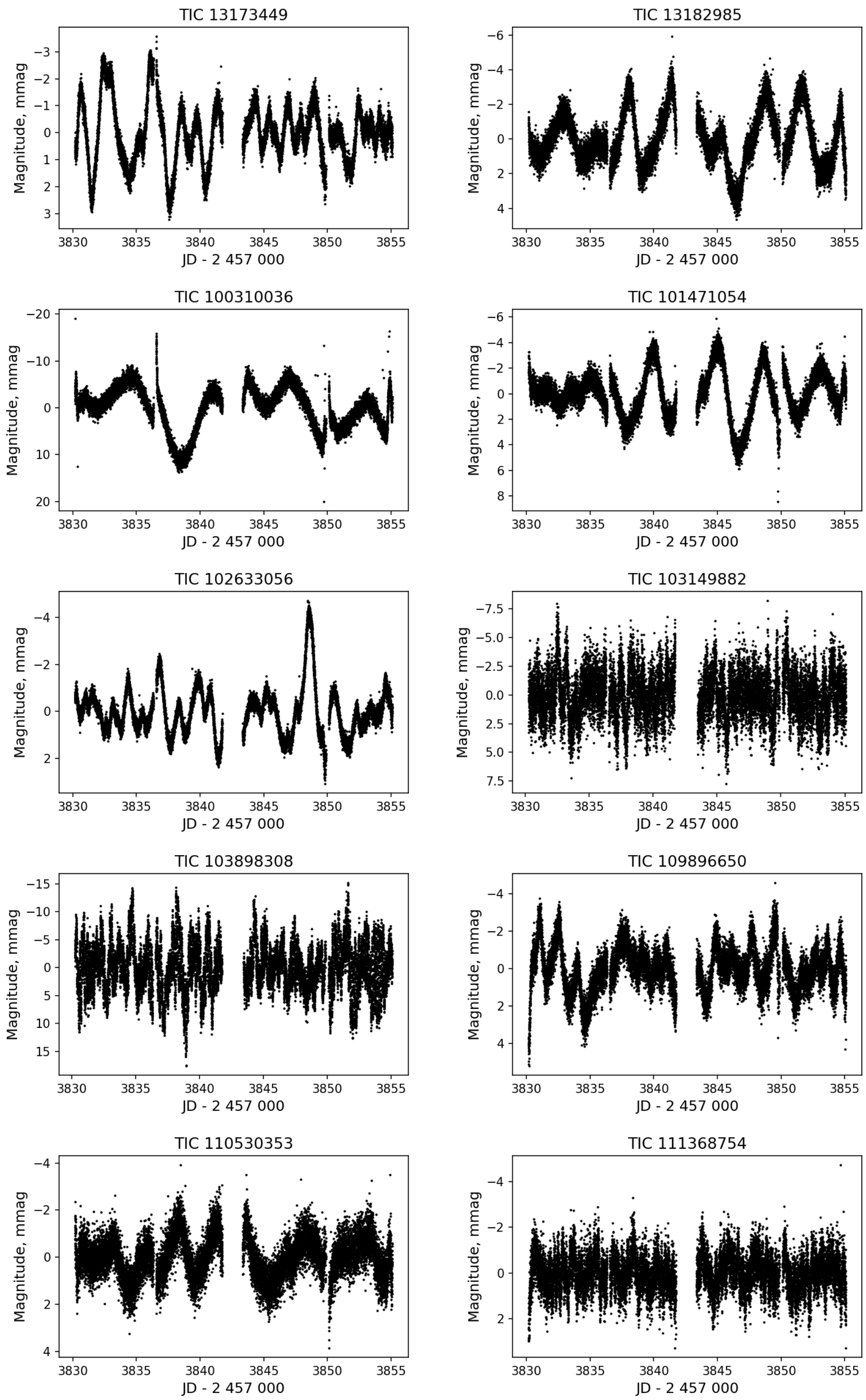

Figure 2: Grid of light curves for objects 1-10.

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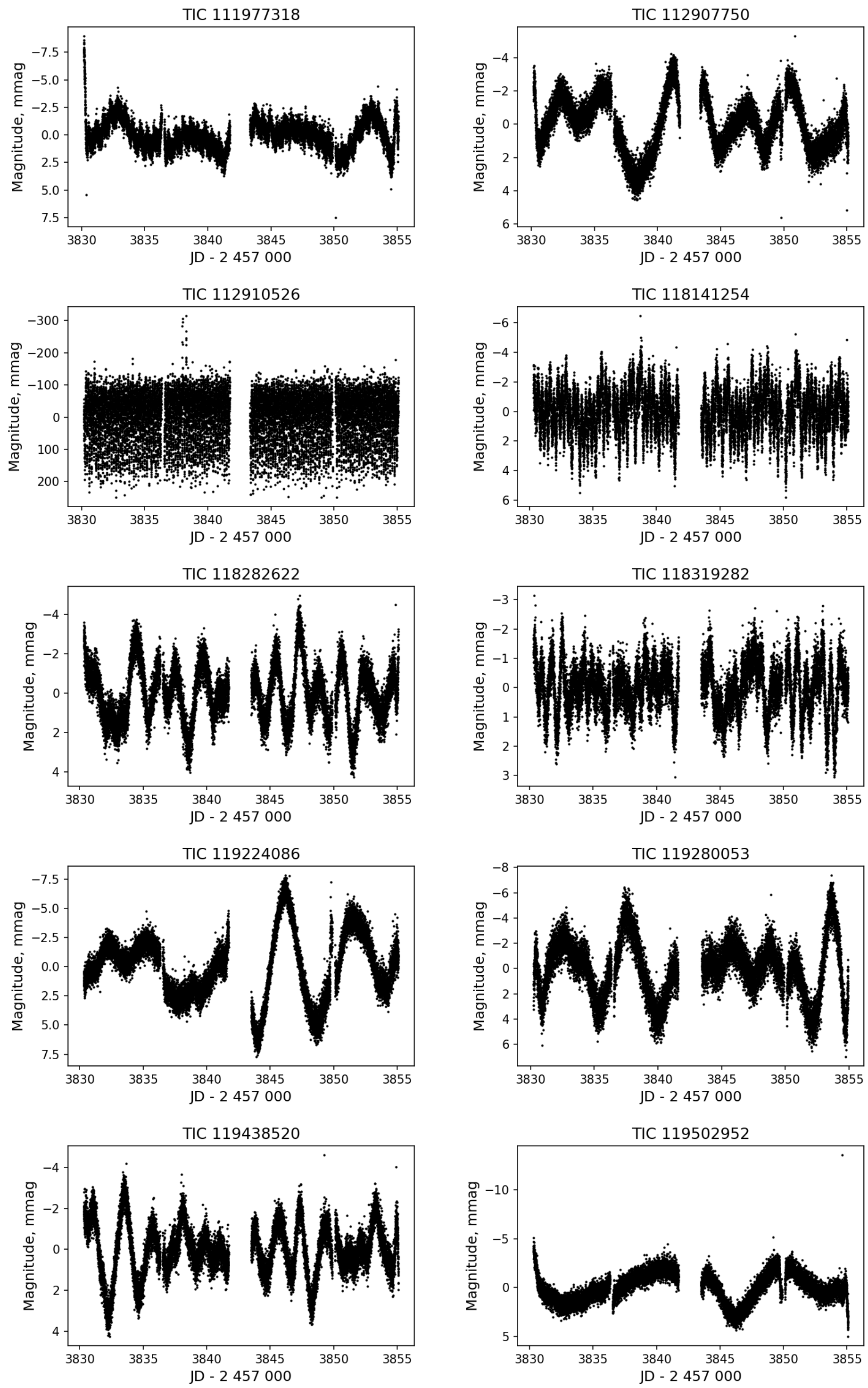

Figure 3: Grid of light curves for objects 11-20.

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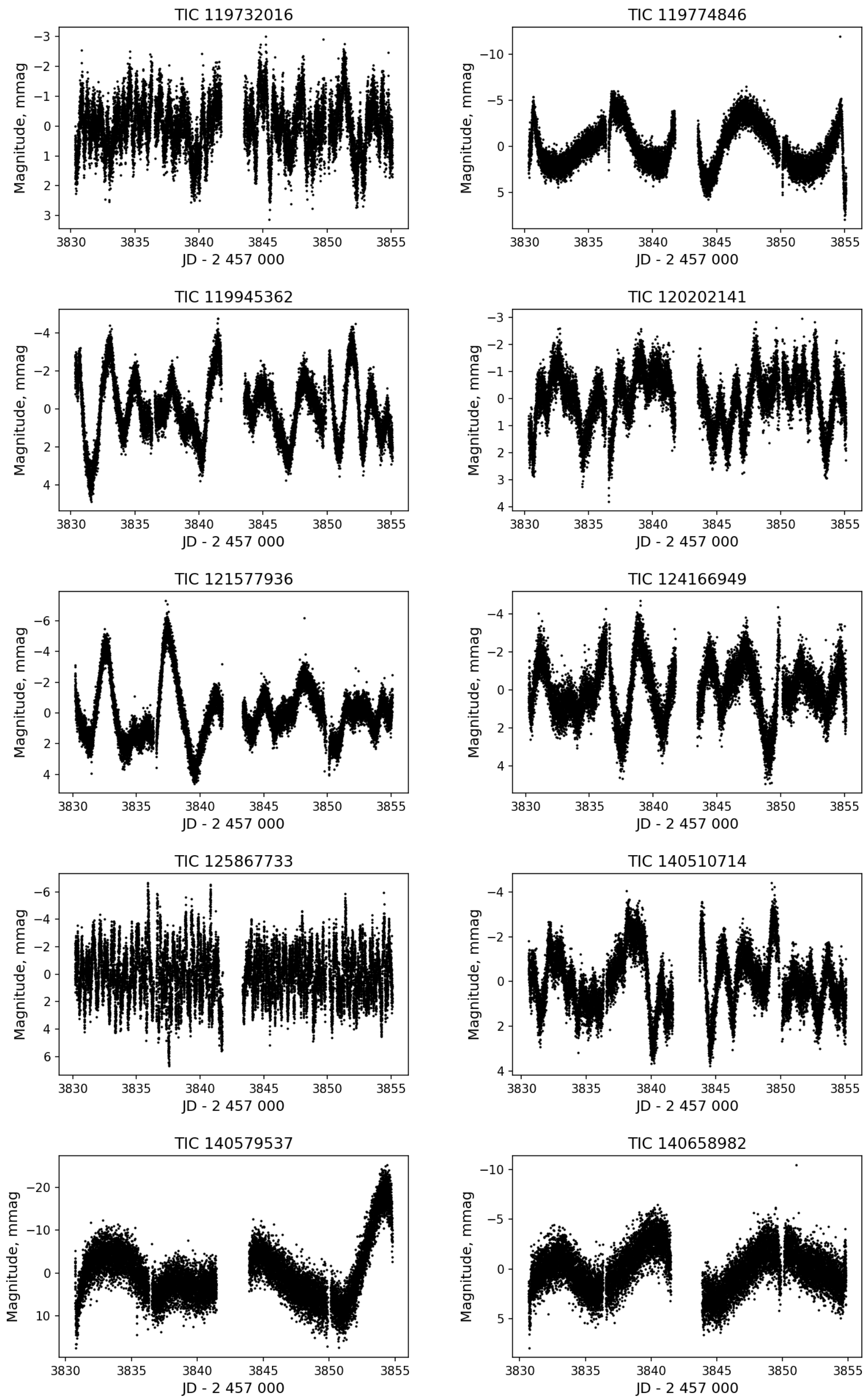

Figure 4: Grid of light curves for objects 21-30.

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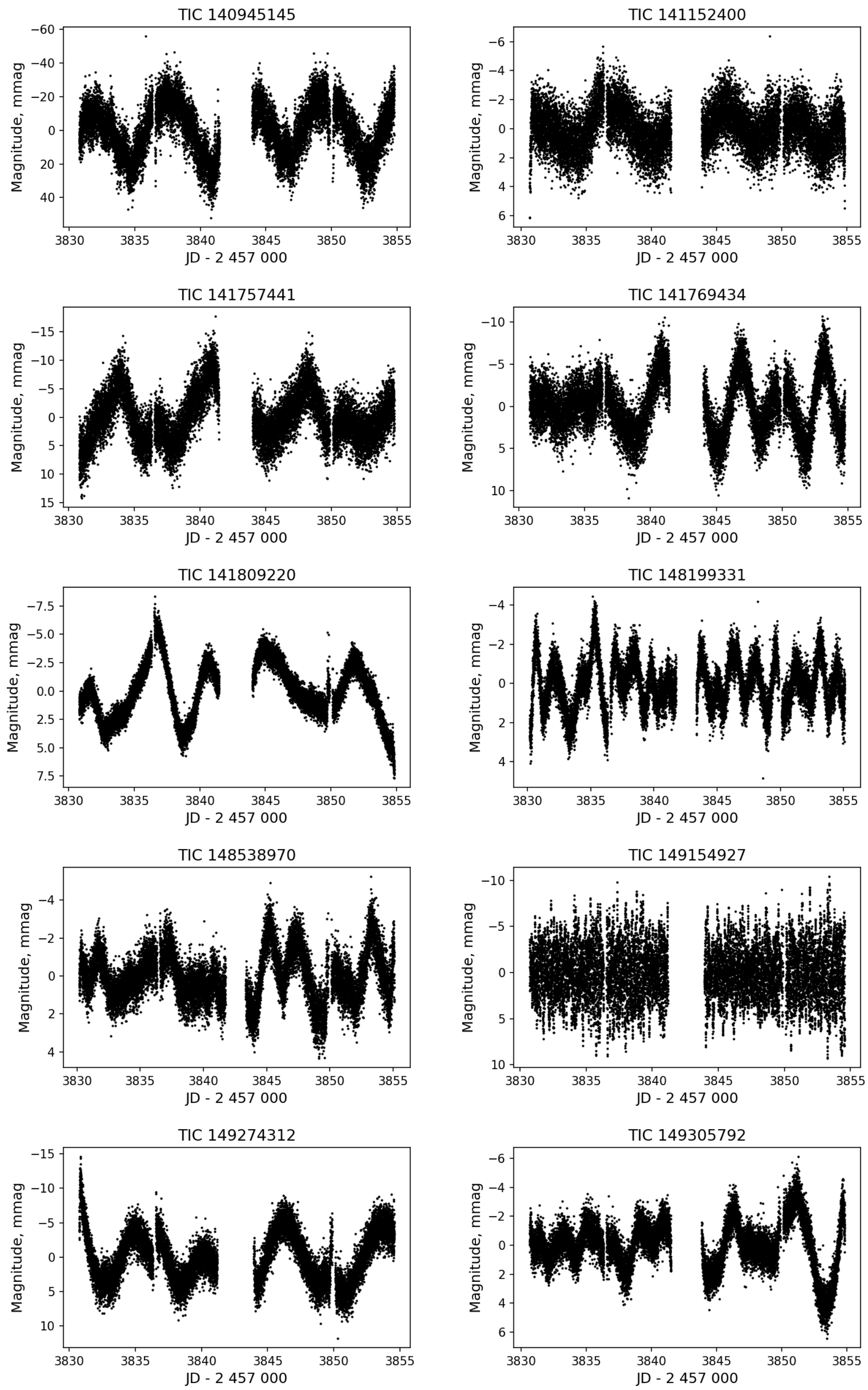

Figure 5: Grid of light curves for objects 31-40.

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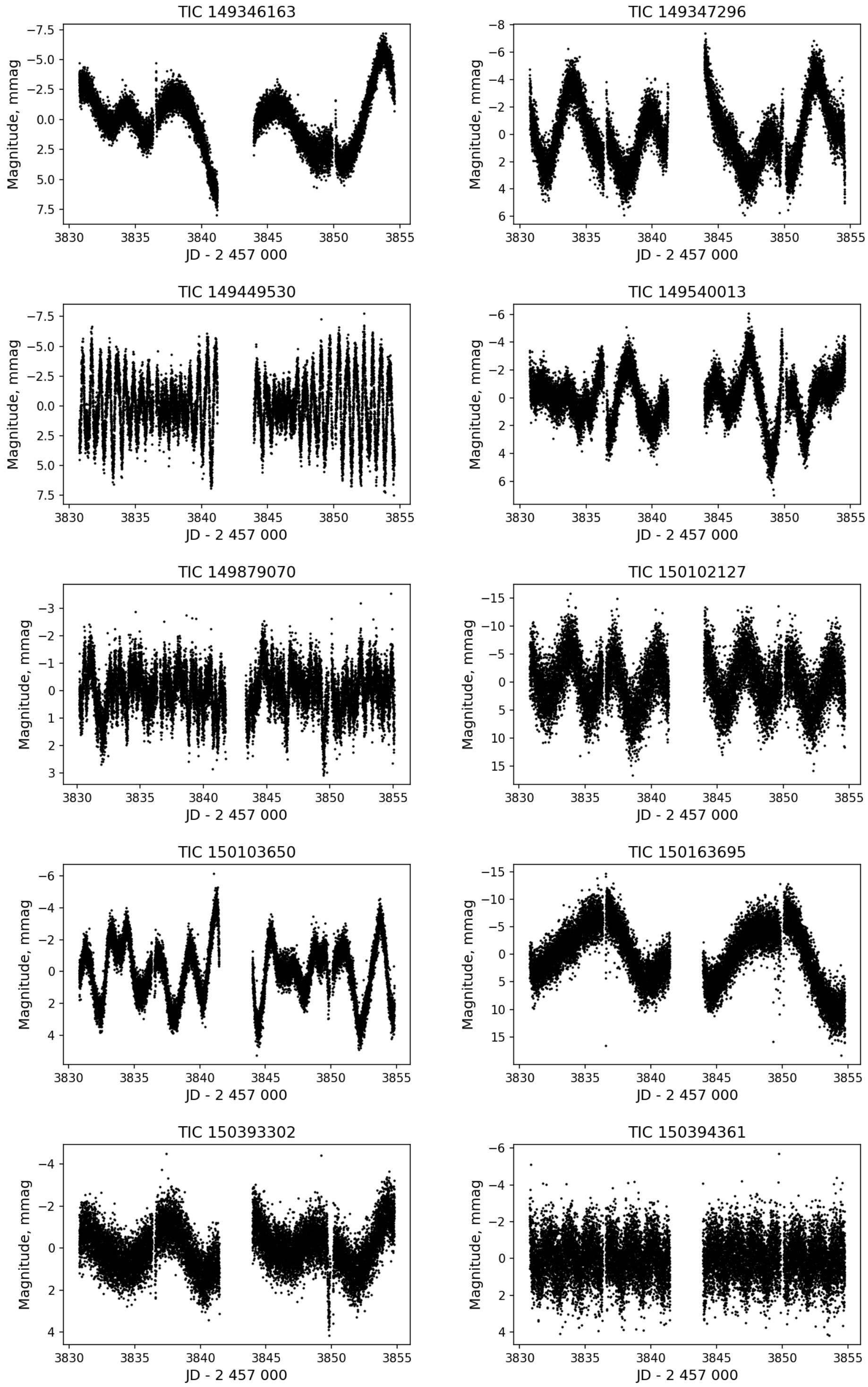

Figure 6: Grid of light curves for objects 41-50.

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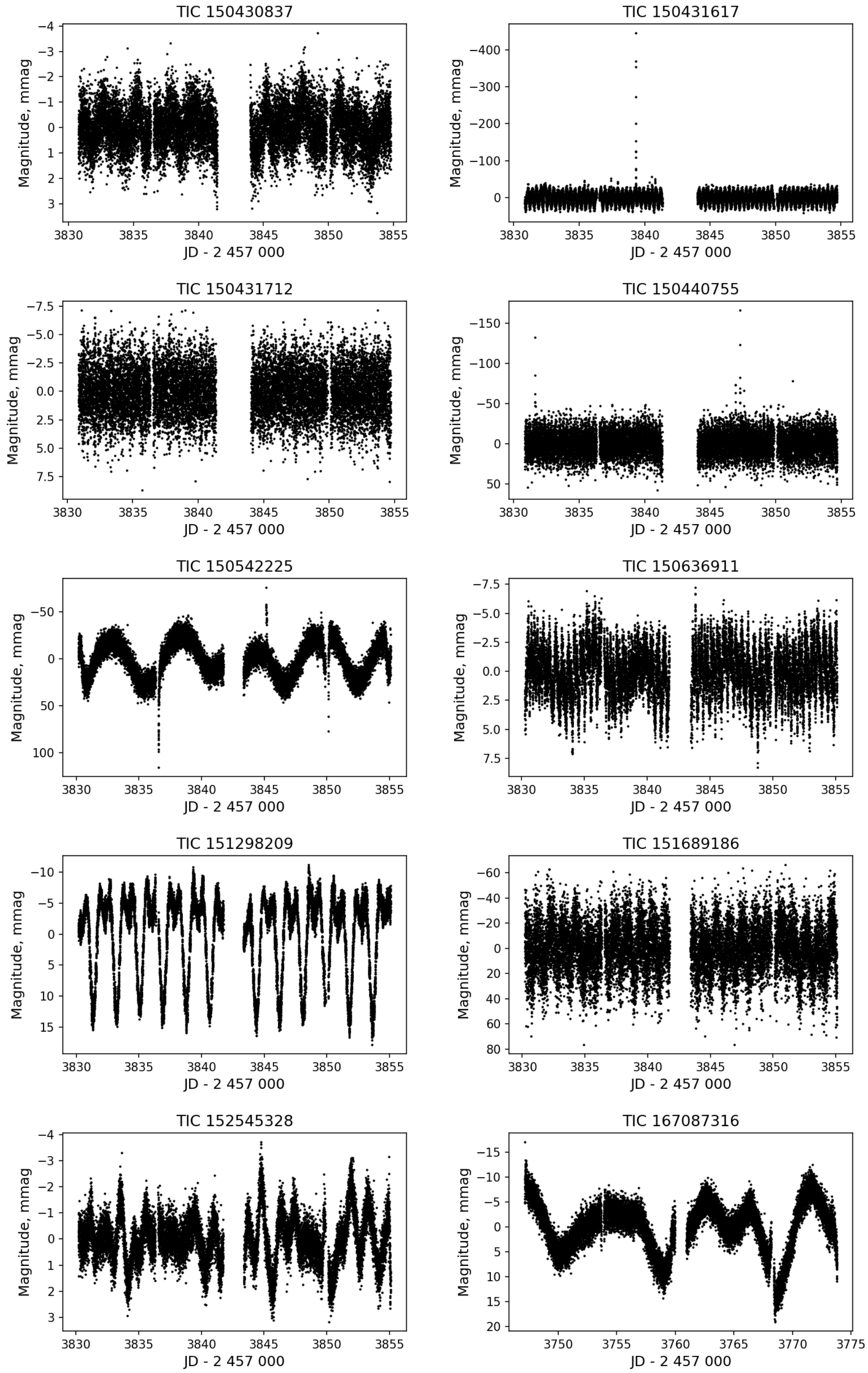

Figure 7: Grid of light curves for objects 51-60.

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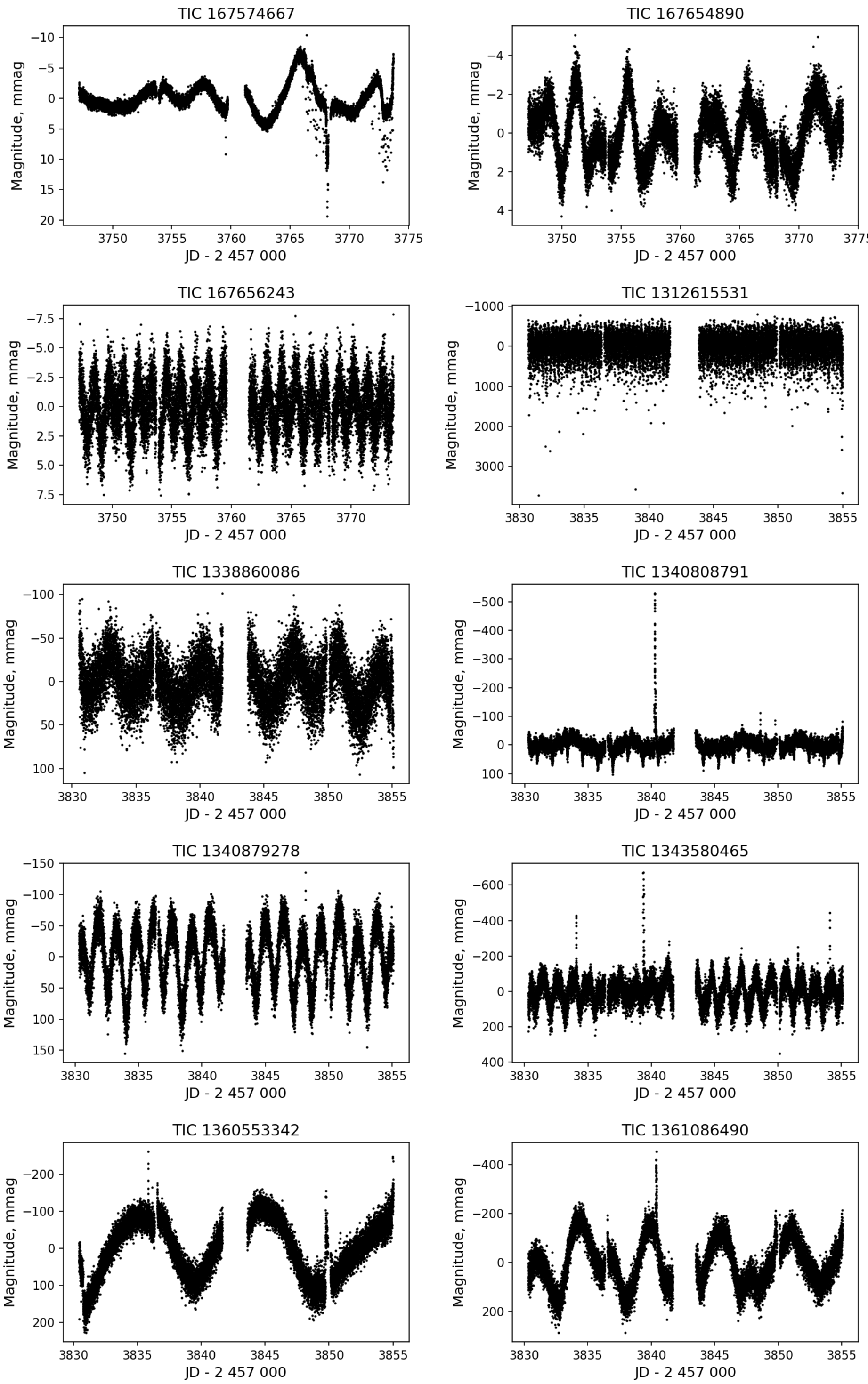

Figure 8: Grid of light curves for objects 61-70.

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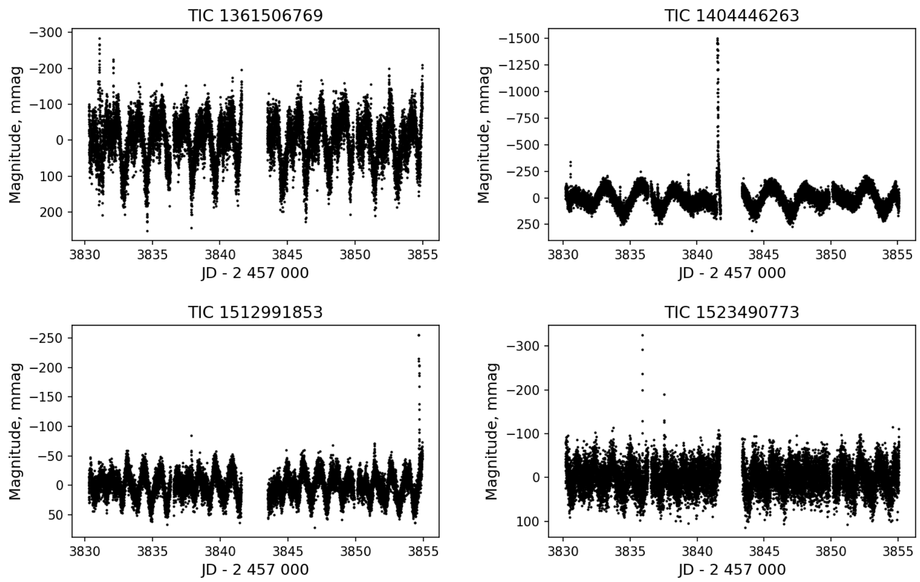

Figure 9: Grid of light curves for objects 71-74.