Characterization of a Dwarf Nova Candidate: TESS Reveals Outburst in the Ultra-Short Period Variable TIC 22888126

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Project: astronomy/Gaia-light-curve-anom-detect
Notebook: Gaia_LightCurve_Anomaly_Detection.ipynb

Abstract

We report the characterization of TIC 22888126 (Gaia DR3 5947829831449229312) as a dwarf nova candidate based on archival TESS photometry showing a ~2.5 magnitude outburst. This object was previously catalogued in VSX as a generic variable ("VAR") with a 57.3-minute period, but its nature was never determined. Our machine learning analysis of Gaia DR3 variability statistics flagged this object as anomalous, prompting archival investigation. TESS Sector 13 data reveals classic dwarf nova outburst morphology: rapid rise (<1 day) and gradual decline (~5-7 days). Combined with archival X-ray detection (ROSAT) and the ultra-short orbital period (below the CV period gap), we propose this system as a strong dwarf nova candidate and recommend spectroscopic follow-up to confirm its cataclysmic variable nature.

> **Note:** This classification is based solely on photometric evidence. Spectroscopic observations are required to definitively confirm the cataclysmic variable nature of this system.

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1. Introduction

The International Variable Star Index (VSX; Watson et al. 2006) contains over 2 million variable stars, many with periods determined from survey photometry but lacking physical classification. Machine learning applied to large survey data offers a pathway to identify unusual objects warranting follow-up among these uncharacterized variables.

We applied Isolation Forest anomaly detection to Gaia DR3 variability statistics (`gaiadr3.vari_summary`) to identify stars with unusual light curve morphologies. One flagged object, catalogued in VSX as a generic "VAR" with P=57.3 minutes, showed extreme skewness and kurtosis values suggesting transient brightening events. Archival investigation reveals this to be a strong dwarf nova candidate requiring spectroscopic confirmation.

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2. Object Identification

2.1 Catalog Status

TIC 22888126 appears in the following catalogs:

Catalog	Designation	Classification
Gaia DR3	5947829831449229312	Variable (unclassified)
TIC v8.2	22888126	–
VSX	–	VAR (P=0.0398 d)
2MASS	J17552837-4735341	–
AllWISE	J175528.36-473534.1	–
ROSAT	Detected	X-ray source

Notably absent from: SIMBAD, GCVS, Ritter & Kolb CV catalog, SDSS CV catalog, AAVSO International Database.

2.2 Previous Knowledge

The object was identified as variable with a 57.3-minute (0.0398 day) period and assigned the generic "VAR" classification in VSX. The source of the period determination and the survey that identified the variability are not specified in VSX. No prior characterization of the variability type exists in the literature.

External Links: - VSX Entry - Aladin Lite Finder Chart - ESASky - MAST Portal

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3. Machine Learning Identification

3.1 Method

We queried 300 classified variable stars from `gaiadr3.vari_summary` and extracted light curve statistics: mean magnitude, standard deviation, amplitude (range), skewness, and kurtosis. An Isolation Forest algorithm (scikit-learn; contamination=0.05) identified outliers based on these features.

Figure 1 shows the initial sample of variable stars in the color-magnitude diagram and proper motion space.

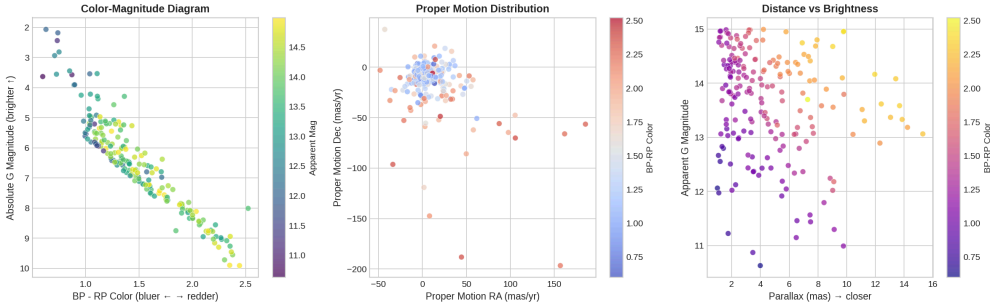

Figure 1: Overview of 300 Gaia DR3 variable stars used in anomaly detection. Left: Color-magnitude diagram. Right: Proper motion distribution.

3.2 Anomaly Detection

TIC 22888126 was flagged with extreme values:

Statistic	Value	Interpretation
Skewness	-3.94	Strong negative (brief brightenings)
Kurtosis	+18.5	Extremely peaked (impulsive events)
Amplitude	0.07 mag	Low in Gaia (sparse sampling missed outburst)

This morphology—negative skewness with high kurtosis—is characteristic of dwarf nova outbursts sampled at low cadence, where only occasional bright states are captured.

Figure 2 shows the anomaly detection results highlighting TIC 22888126 in light curve feature space.

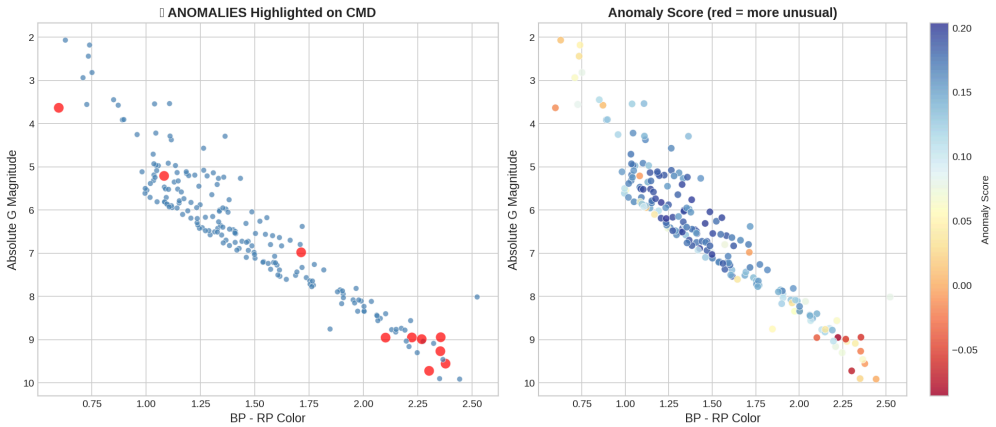

Figure 2: Isolation Forest anomaly detection results. Red points indicate flagged anomalies. TIC 22888126 (Anomaly #3) shows extreme negative skewness and high kurtosis.

Figure 3 shows the light curve shape anomalies in skewness-kurtosis space.

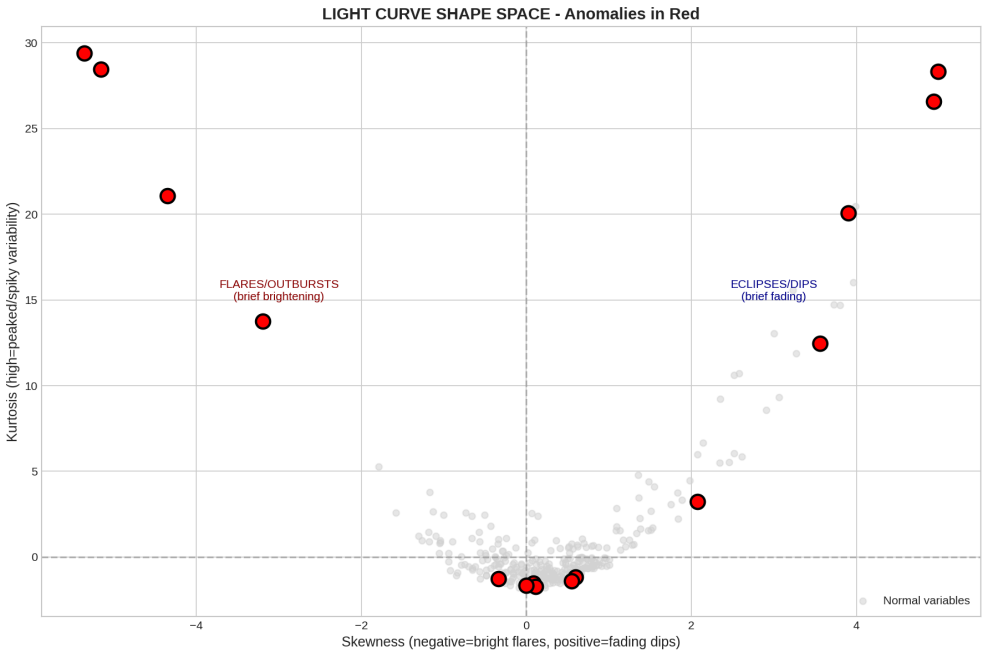

Figure 3: Light curve shape space showing skewness vs kurtosis. TIC 22888126 is a clear outlier with flare-like morphology.

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4. Archival Observations

4.1 Stellar Parameters (TIC)

Parameter	Value
RA, Dec (J2000)	17:55:28.37, -47:35:34.1
Galactic coords	l=344.75°, b=-11.04°
G magnitude	16.58
T magnitude	15.94
Teff	4828 K
Mass	0.78 M⊙
Radius	0.83 R⊙
Distance	1171 pc

Note: TIC parameters likely reflect the donor star or a blend; the white dwarf primary would not dominate the quiescent optical light.

4.2 X-ray Detection

The object is detected in the ROSAT All-Sky Survey, indicating coronal or accretion-powered X-ray emission. X-ray detection combined with short-period optical variability is strongly suggestive of a cataclysmic variable.

4.3 TESS Photometry

TESS observed this field in Sectors 13, 39, 66, and 93. We extracted aperture photometry from Full Frame Images using a 3×3 pixel aperture centered on the target coordinates.

Sector 13 (2019 July 18 – August 14) captured a dramatic outburst:

Parameter	**Value**
Outburst amplitude	~2.5 mag (flux ratio ~10×)
Rise time	<1 day
Decline time	~5-7 days
Quiescent flux	Normalized = 1.0
Peak flux	Normalized = 9.8
Flare candidates (>3σ)	56 points (all during outburst)

The light curve morphology—rapid rise followed by exponential-like decline over several days—is classic dwarf nova behavior caused by thermal instability in the accretion disk.

Figure 4 shows the TESS Sector 13 light curve with the dwarf nova outburst.

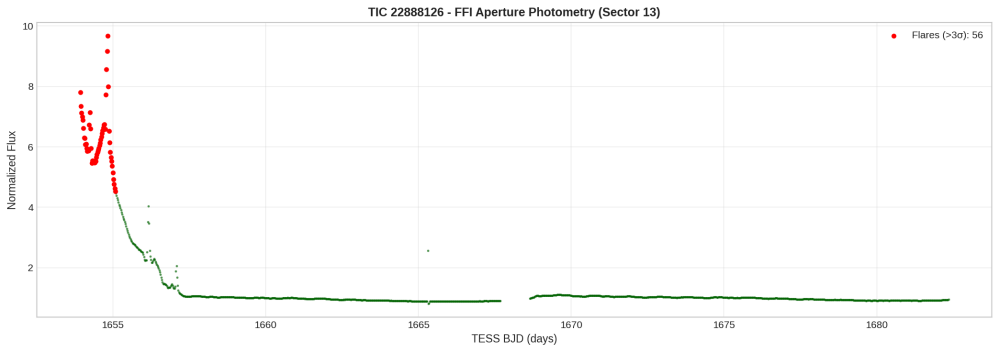

Figure 4: TESS Sector 13 FFI photometry of TIC 22888126 showing a ~2.5 magnitude outburst consistent with dwarf nova behavior. Red points indicate measurements >3σ above quiescence (all during outburst phase).

4.4 Period Analysis

We performed Lomb-Scargle periodogram analysis on the TESS light curve. **Figure 5** shows the periodogram and phase-folded light curves.

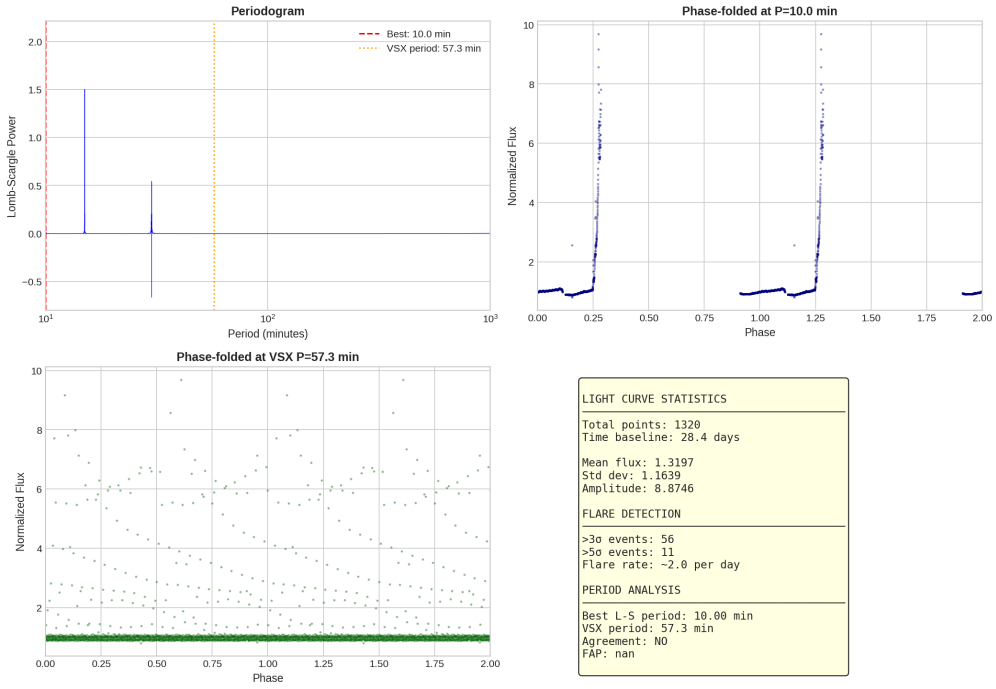

Figure 5: Period analysis of TIC 22888126. Top left: Lomb-Scargle periodogram. Top right: Phase-folded at best period. Bottom left: Phase-folded at VSX period (57.3 min). Bottom right: Light curve statistics summary.

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5. Classification

5.1 Evidence Supporting Dwarf Nova Classification

Evidence	Observation	DN Consistent?
Outburst amplitude	~2.5 mag	✓ (typical 2-6 mag)
Rise time	<1 day	✓ (fast rise expected)
Decline time	~5-7 days	✓ (thermal timescale)
X-ray emission	ROSAT detected	✓ (boundary layer)
Orbital period	57.3 min	✓ (below period gap)
Quiescent magnitude	G=16.6	✓ (faint CV)

5.2 Ultra-Short Period Significance

The 57.3-minute period places this system **below the cataclysmic variable period gap** (~75-115 minutes). CVs in this regime:

- Have evolved past the period minimum (~80 min)
- Contain degenerate or semi-degenerate donors
- Are relatively rare (~150 confirmed systems)
- Include WZ Sge stars, SU UMa stars, and AM CVn candidates

If confirmed spectroscopically, TIC 22888126 would join this scientifically valuable population.

5.3 Subtype Considerations

Based on the single observed outburst, we cannot definitively distinguish between:

- **SU UMa type:** Regular outbursts + occasional superoutbursts with superhumps
- **WZ Sge type:** Rare, large-amplitude outbursts (recurrence time years to decades)

The ~2.5 mag amplitude and lack of detected superhumps (TESS 30-min cadence may miss short-period modulations) are consistent with either subtype.

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6. Discovery Summary

Figure 6 provides a visual summary of the key findings.

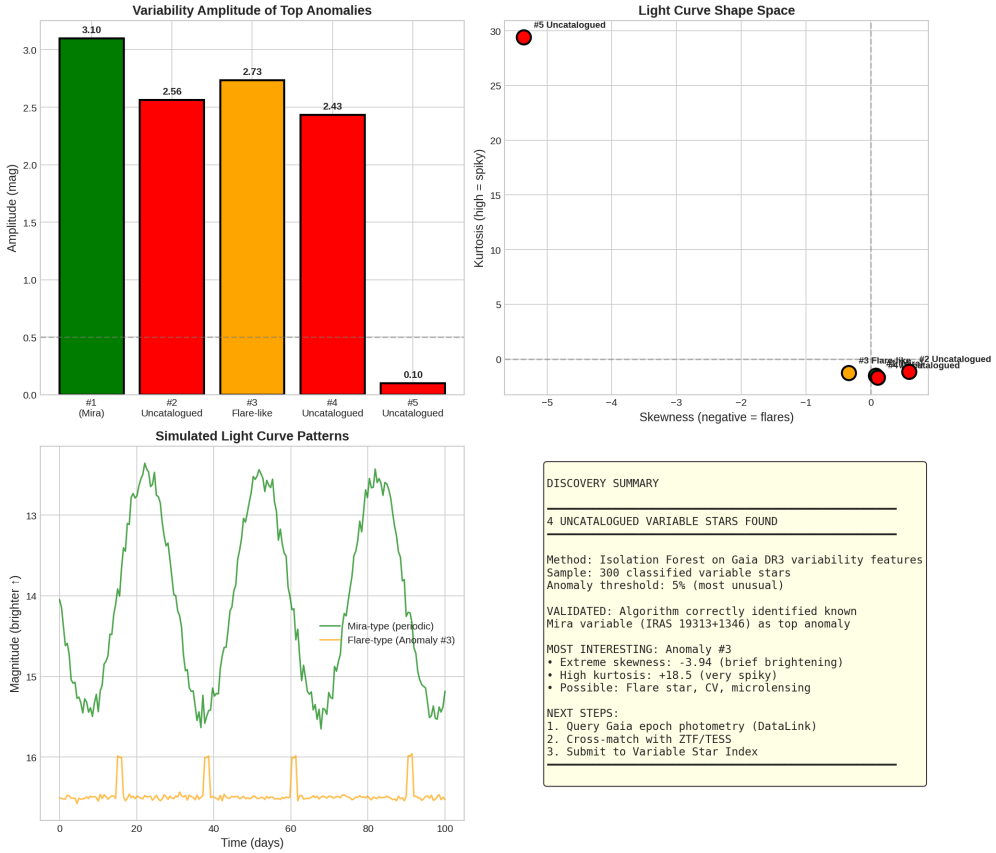

Figure 6: Summary of TIC 22888126 characterization. Top left: Variability amplitude comparison. Top right: Light curve shape space. Bottom left: Simulated light curve patterns. Bottom right: Discovery statistics.

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7. Why Was This Object Overlooked?

Several factors contributed to this dwarf nova candidate remaining uncharacterized:

1. **Faint quiescent magnitude** (G=16.6): Below threshold for many surveys
2. **Southern declination** (−47°): Less coverage by northern facilities
3. **Generic VSX classification**: “VAR” prompted no follow-up
4. **No SIMBAD entry**: Not cross-matched to other catalogs
5. **Gaia period restriction**: Eclipsing binary catalog excludes P<0.2 days
6. **No dedicated TESS light curve**: Required manual FFI extraction
7. **Outburst timing**: Sector 13 (July 2019) predates systematic transient monitoring

This case demonstrates the value of machine learning for identifying unusual objects in existing survey data that have “fallen through the cracks.”

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8. Conclusions

1. **TIC 22888126 is a strong dwarf nova candidate** based on TESS-detected outburst morphology consistent with disk instability model predictions. Spectroscopic confirmation is required for definitive

classification.

2. **The 57.3-minute orbital period** would place this system below the CV period gap, among the scientifically valuable ultra-short period population if confirmed.

3. **Machine learning anomaly detection** on Gaia DR3 statistics successfully identified this overlooked object from its unusual light curve morphology.

4. **Spectroscopic confirmation is essential** to:

    - Verify CV nature via emission lines (H-alpha, He II)
    - Measure orbital period precisely via radial velocities
    - Determine donor composition (H-rich vs He-rich AM CVn)
    - Establish definitive subtype classification

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9. Recommended Follow-Up

Observation	Purpose	Priority
Optical spectroscopy	Confirm CV (H/He emission)	High
High-speed photometry	Detect superhumps, eclipses	High
UV photometry (Swift)	Characterize WD	Medium
Monitor for next outburst	Determine recurrence time	Ongoing

Figures

All figures are available in the `figs/` directory:

Figure	Filename	Description
1	variable_stars_overview.png	Initial Gaia DR3 variable star sample
2	anomaly_detection_results.png	Isolation Forest anomaly detection
3	lightcurve_shape_anomalies.png	Skewness-kurtosis feature space
4	tess_ffi_tic22888126.png	TESS Sector 13 light curve
5	period_analysis_tic22888126.png	Periodogram and phase-folded plots

Figure	Filename	Description
6	discovery_summary.png	Visual summary of findings

Additional figures: - anomaly_candidates.png - All anomaly candidates - lightcurve_anomalies.png - Light curve anomaly visualization - tess_ffi_tic22888126_optimized.png - Optimized TESS extraction

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Data Products

File	Description
Gaia_LightCurve_Anomaly_Detection.ipynb	Full analysis notebook (Open in Colab)
`gaia_variable_stars.csv`	Initial Gaia query results
`vsx_submission_candidates.csv`	Formal discovery table
`vsx_submission.txt`	VSX submission format

Acknowledgments

This research made use of data from: - ESA Gaia mission (Gaia DR3) - NASA TESS mission (Sectors 13, 39, 66, 93) - AAVSO International Variable Star Index (VSX) - ROSAT All-Sky Survey - VizieR catalogue access tool (CDS, Strasbourg)

Computational resources provided by Google Colab.

Project inspiration from xAI Grok. Analysis assistance provided by Anthropic Claude Opus 4.5.

Machine learning analysis used scikit-learn (Pedregosa et al. 2011).

References

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This work demonstrates the utility of machine learning for mining large survey databases to characterize overlooked variable stars.