Chromatic pulsation signature of DY Herculis from time-series photometry over a full night

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Time-series photometry of the DY Herculis field — B, G, R over a full night (through a meridian flip)

1 Introduction

DY Herculis is a High-Amplitude Delta Scuti star (HADS): a radially pulsating A–F dwarf that behaves like a scaled-down Cepheid, with an asymmetric fast-rise / slow-decline light curve. From the varstar database it has a period of just 3.57 hours (0.148631 d) and a V amplitude of 0.51 mag (V ≈ 10.15–10.66), spectral type A7III–F4III, and a Gaia DR3 distance of ~690 pc. Its short period makes it one of the rare pulsators whose *entire* cycle fits inside a single night's observing.

This report is a single-night, three-color (B, G, R) run of ~4 hours — more than one full pulsation cycle in each band, so the complete, unfolded HADS light curve is recorded directly, not reconstructed by folding. The session crossed the meridian mid-run: the mount flipped, rotating the field 180° and pausing acquisition for 14 minutes. Because the pipeline matches stars in sky coordinates and refines each frame's WCS independently, the two orientations stitch into one continuous series; the flip gap is marked on the light-curve figure. (An earlier cloud-truncated Green-only run is analyzed separately and not combined here.)

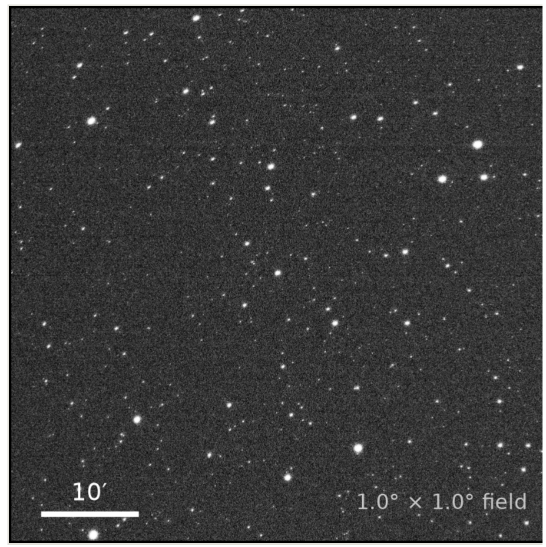

Figure 1. The DY Herculis field from a session G-band frame (author's own data; asinh stretch). DY Her sits near the centre of the frame.

2 Observations & Data Reduction

Equipment. Apertura 60 mm FPL-53 doublet APO refractor (371 mm focal length), ZWO ASI294MM Pro cooled monochrome camera (bin 1, 2.315 µm pixels, 1.28″/px), ZWO Premium 1.25″ LRGB filter set (B, G, R used here). Images acquired at the Lowell Observatory, Flagstaff, AZ (35.20° N, 111.67° W).

Data. 300 × 30 s frames of the DY Herculis field (2.96° × 2.01°), 100 each in B, G and R, on 2026-07-08 over ~4 hours (> one 3.57 h pulsation cycle per band). A German-equatorial meridian flip 53 minutes in rotated the field 180° with a 14-minute acquisition gap; frames on both sides carry their own plate solution and are co-registered in sky coordinates. Calibrated with a master dark, with the caveat that the sensor ran warm (−14.8 to −15.4 °C) relative to the −19.8 °C dark library — a modest systematic at 30 s, not a matched-temperature subtraction. No flats were available.

Reduction. Source detection (DAOStarFinder) and aperture photometry with sigma-clipped annulus sky subtraction (photutils[1]); per-frame astrometry refit against Gaia DR3[2] positions from the varstar database; per-frame zero points from an ensemble of bright unsaturated field stars present in ≥40% of frames, excluding catalogued variables, with iterative high-scatter rejection. Magnitudes are instrumental G anchored to a Gaia-G zero point (not transformed to a standard system). Variables were identified by cross-match against the AAVSO VSX catalog[3] (10.3 M objects, accessed via VizieR[4] and enriched with Gaia DR3); coordinate, WCS and time handling use Astropy[5]. Nearby high-proper-motion targets whose J2000 catalog position has drifted required a widened labeling tolerance to recover.

3 Results

- **DY Her (HADS, P = 3.57 h): a complete pulsation cycle recorded in three colors.** The G series spans 4.2 h (≈1.2 cycles, 83 points), tracing the full asymmetric fast-rise / slow-decline curve directly. The observation crossed a meridian flip (marked on the light-curve figure); the two orientations stitch seamlessly, demonstrating sky-coordinate registration across the flip. The fold confirms the catalog period and shows the blue amplitude exceeding the red.
- **86 catalogued VSX variables measured** in 90 G frames; **35 unsaturated stars show statistically significant variation** (robust scatter > 2.5× measurement error).
- **Photometric precision floor ≈ 69 mmag** (ensemble stars); no flat-field calibration was available — the dominant systematic.
- **Database consistency: 68/84 unsaturated stars agree with their Gaia DR3 G magnitude to within ±0.30 mag**; disagreements are flagged Δ in the table and are dominated by stars observed at a different phase of their variation cycle.
- Single-night data, so this is a phase-fold against the catalog ephemeris rather than an independent period determination; the warm-sensor dark mismatch and absence of flats make absolute magnitudes preliminary. Differential shapes and amplitudes are robust.

Finder chart (reference G frame)

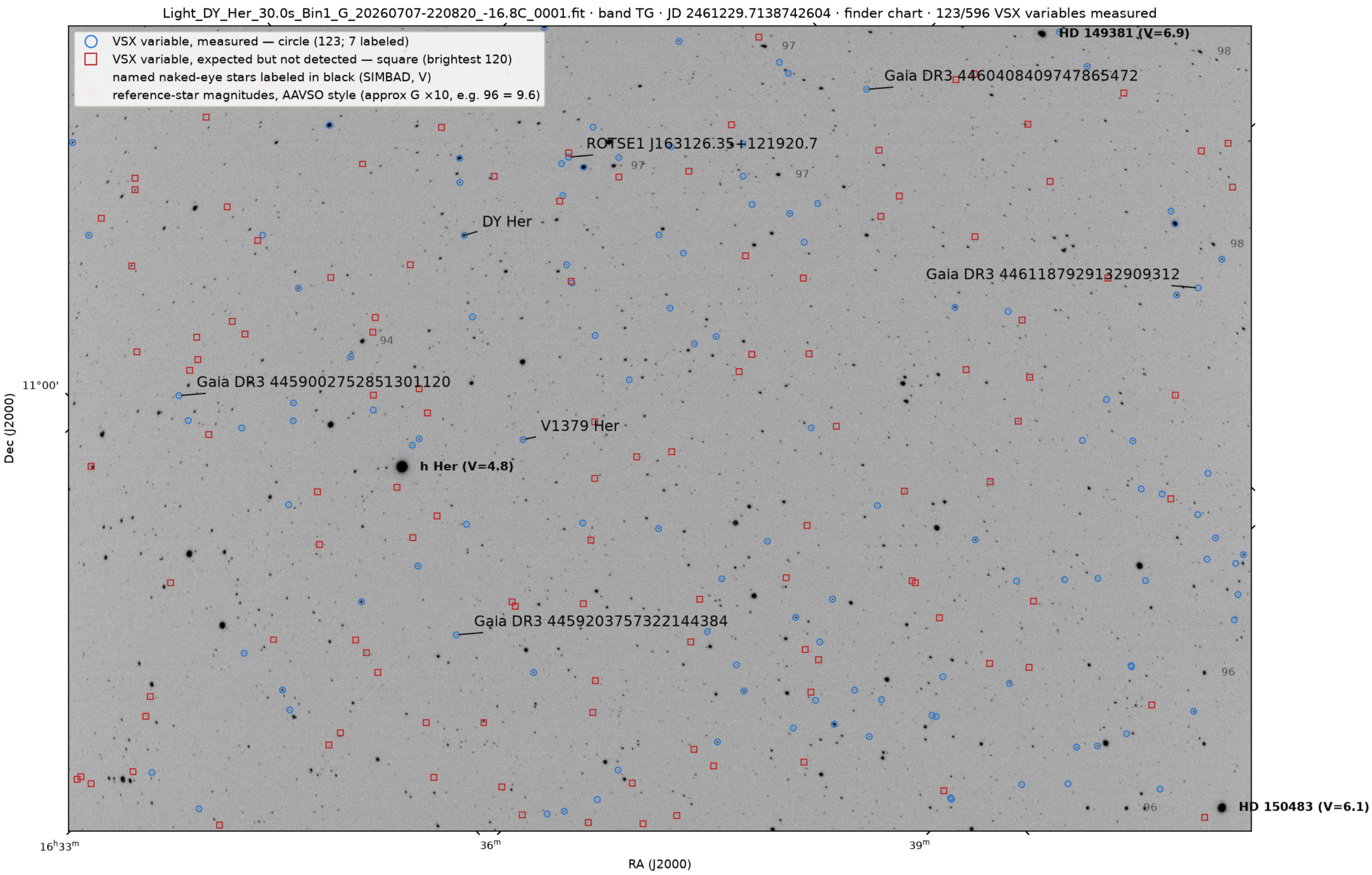

Figure 2. Reference G frame as a finder chart (dark stars on white, RA/Dec J2000 grid). Marker shape distinguishes categories in grayscale: open circles = VSX variables detected and measured (light-curve targets named); open squares = catalogued variables expected but not detected. Bright field stars carry AAVSO-style reference magnitudes (approx. G ×10, decimal dropped; e.g. 96 = 9.6); naked-eye stars named in black for orientation.

Light curves — most significant unsaturated variables (G)

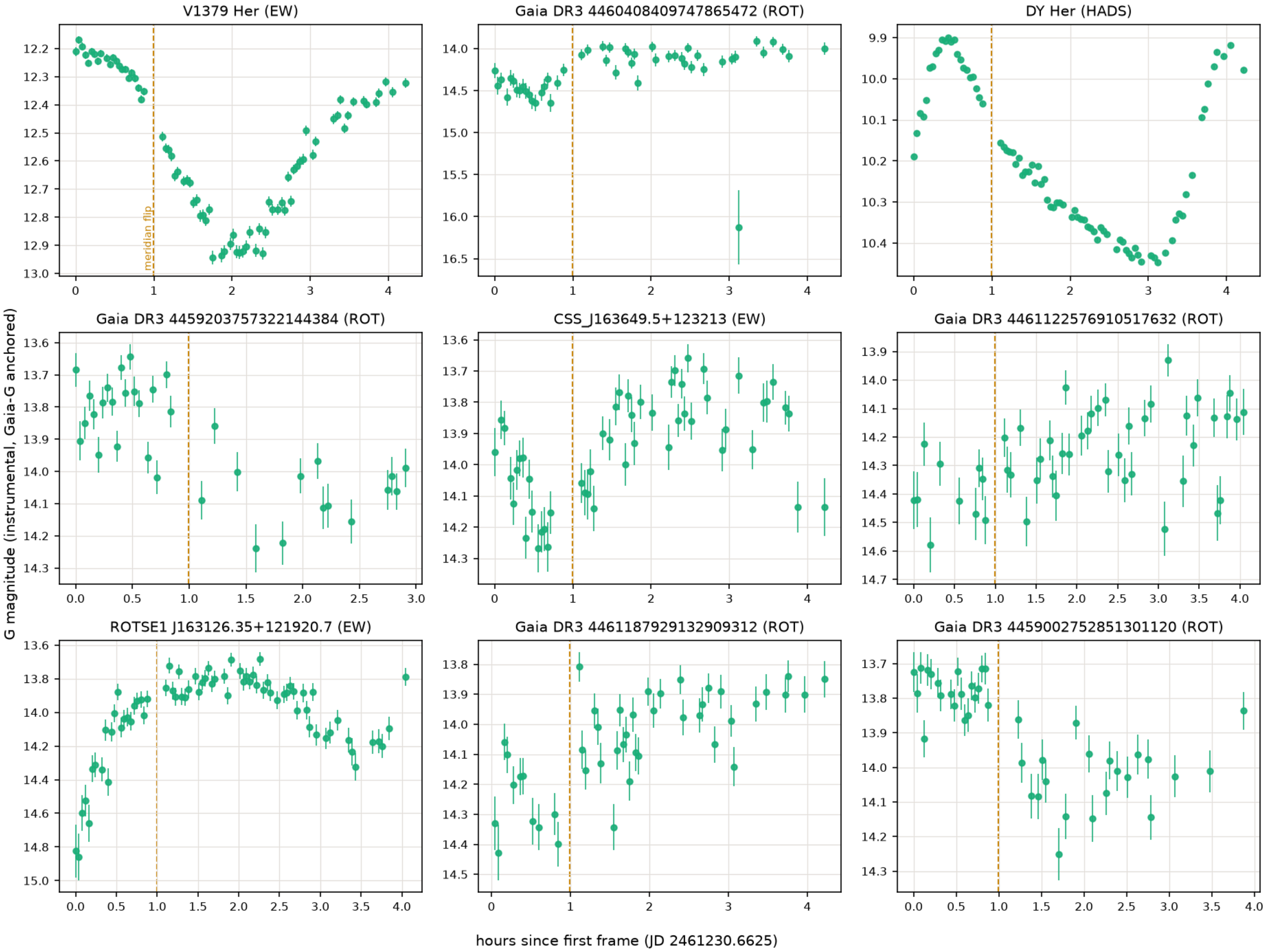

Figure 3. Ensemble differential light curves for the stars labeled on the annotated field: V1379 Her, Gaia DR3 4460408409747865472, DY Her, Gaia DR3 4459203757322144384, CSS_J163649.5+123213, Gaia DR3 4461122576910517632, ROTSE1 J163126.35+121920.7, Gaia DR3 4461187929132909312, Gaia DR3 4459002752851301120. A meridian flip mid-run (dashed line, where present) can introduce a small per-star magnitude step: the field rotates 180° onto different detector regions whose response is uncorrected without flats, so the per-frame ensemble removes the global shift but a position-dependent residual remains — the dominant systematic in this dataset.

Photometric precision (G)

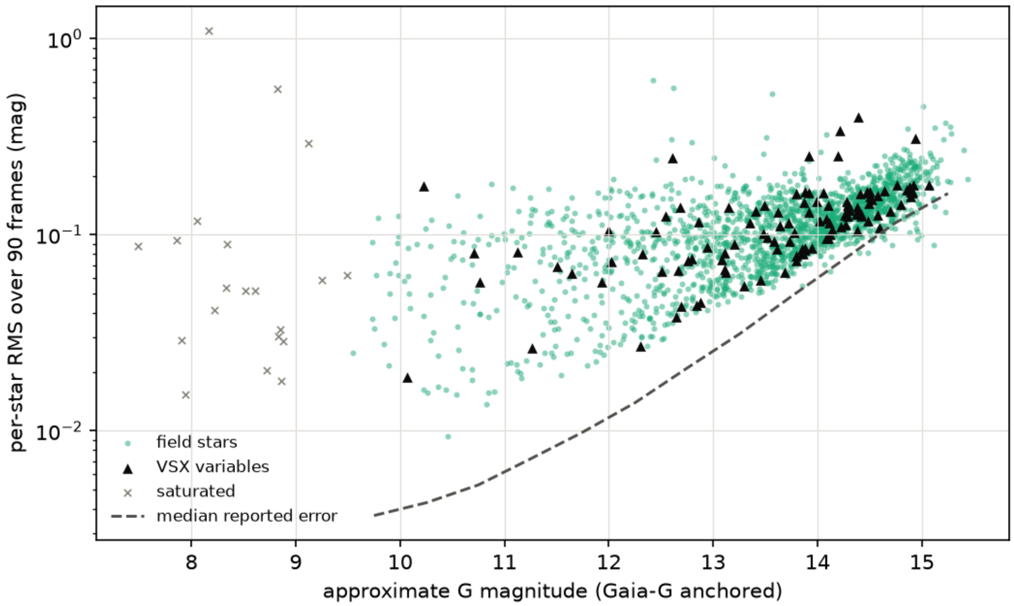

Figure 4. Repeat-measurement RMS vs magnitude for every measured star. The gap between the field-star cloud and the dashed reported-error line at the bright end is the flat-field systematics floor; triangles above the cloud are genuine variables.

Observing yield — measurements by category

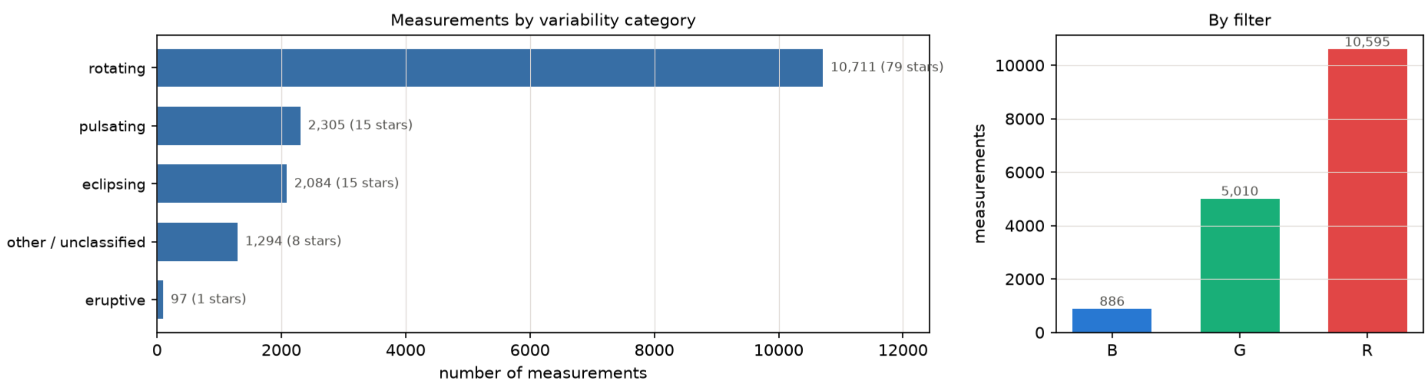

Figure 5. 16,491 ensemble-calibrated measurements across 118 variables. Left: measurements per variability class[6] (with the number of distinct stars); right: measurements per filter. The raw scientific yield of the run.

Chromatic pulsation signature (B / G / R)

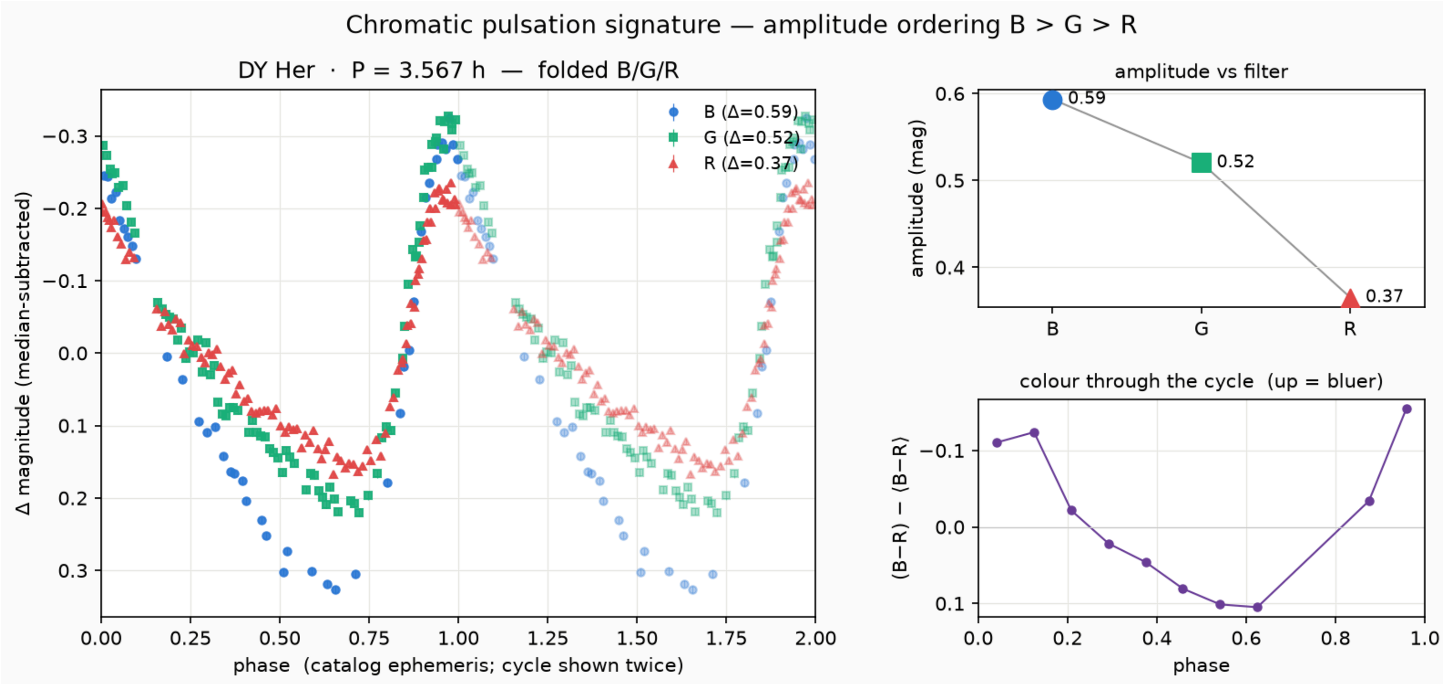

Figure 6. DY Her's three bands folded on the 3.57 h period and median-subtracted (left): the blue curve swings widest through the characteristic fast-rise / slow-decline HADS shape. The amplitude falls monotonically from blue to red (B ≈ 0.59, G ≈ 0.52, R ≈ 0.37 mag; center), and the (B−R) color (right) is bluest at maximum light — the hallmark of temperature-driven radial pulsation, where the star is hottest as it brightens. Recovering the blue band required rebuilding its calibration ensemble and retaining the partial arc obtained while the field was still high, before it set into heavy blue extinction.

Phase-folded light curves, all filters

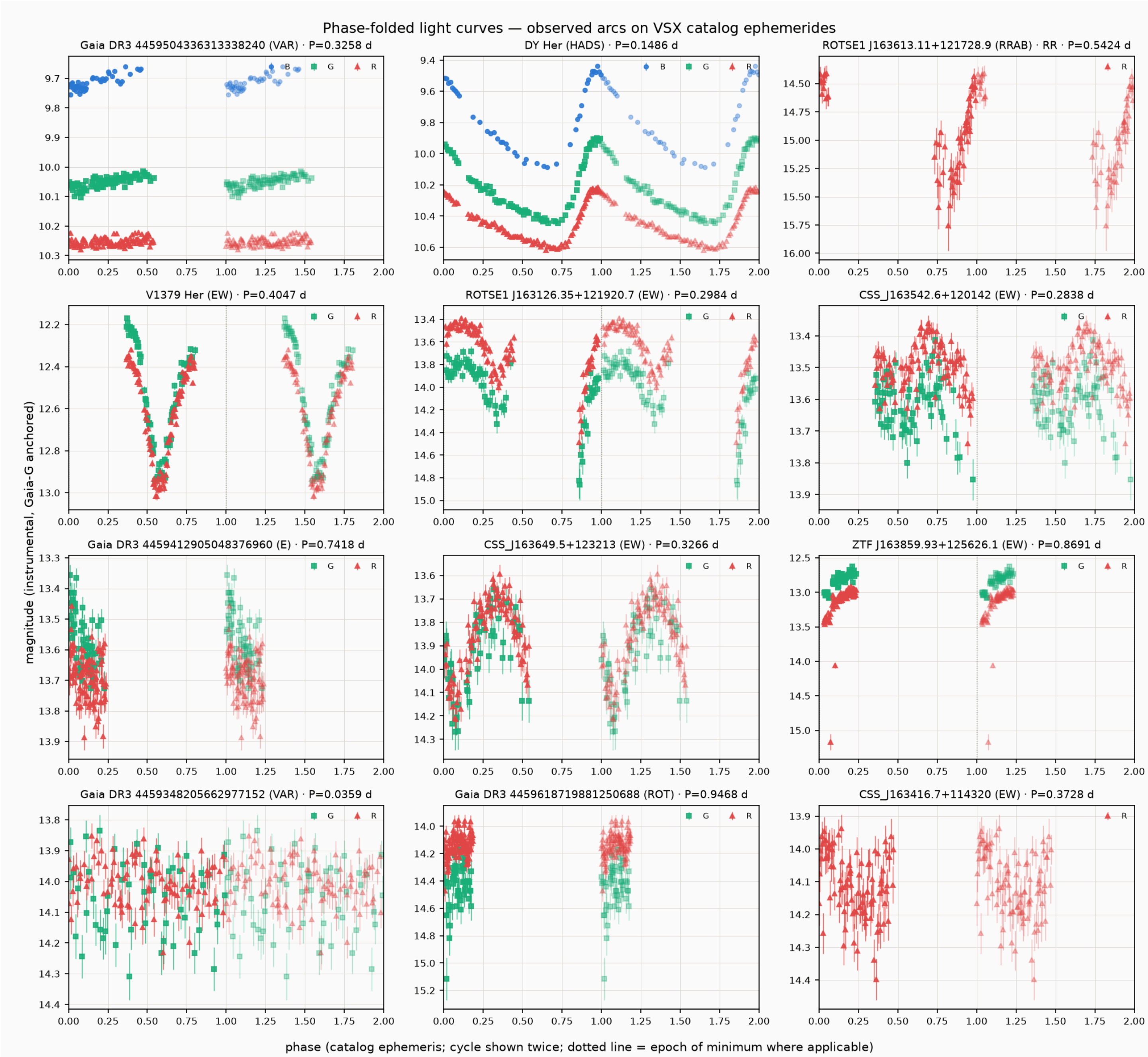

Figure 7. The full-cycle B/G/R series folded onto DY Her's VSX catalog ephemeris (phase = ((JD − epoch)/P) mod 1). With the 2003 epoch ~57,000 cycles in the past, a coherent fold confirms the catalogued 3.57 h period to high precision. For DY Her the blue amplitude exceeds the red — the chromatic signature of temperature-driven pulsation. Other periodic variables in the frame are shown alongside; full statistics in the observations database.

4 Discussion

Caveats. Single-night data, so this is a phase-fold against the catalog ephemeris rather than an independent period determination; the warm-sensor dark mismatch and absence of flats make absolute magnitudes preliminary. Differential shapes and amplitudes are robust.

References

1. Bradley, L., et al. 2024, photutils: photometry and related tools for Python (Zenodo, doi:10.5281/zenodo.596036).
2. Gaia Collaboration, Vallenari, A., et al. 2023, "Gaia Data Release 3: Summary of the content and survey properties," A&A, 674, A1.
3. Watson, C. L., Henden, A. A., & Price, A. 2006, "The AAVSO International Variable Star Index (VSX)," Society for Astronomical Sciences Symposium, 25, 47. Accessed as VizieR B/vsx, release 2026-06-28.

4. Ochsenbein, F., Bauer, P., & Marcout, J. 2000, "The VizieR database of astronomical catalogues," A&AS, 143, 23 (CDS, Strasbourg).
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7. Gaia Collaboration, Prusti, T., et al. 2016, "The Gaia mission," A&A, 595, A1.
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9. Breger, M. 2000, "δ Scuti stars (Review)," ASP Conf. Ser. 210, 3.

Acknowledgements. This work made use of the International Variable Star Index (VSX), operated at AAVSO, Cambridge, MA, USA, and of data from ESA's Gaia mission[7], processed by the Gaia DPAC. Observations were acquired at the Lowell Observatory, Flagstaff, AZ. Photometry was produced with the author's varstar pipeline (vphot / solve_wcs / lightcurve / fold_analysis), developed with Claude (Anthropic).

Appendix A — Per-star measurements

Column definitions

COLUMN	TYPE	UNIT	DEFINITION
name	text	—	Primary VSX identifier (object.name in the varstar database, VSX release 2026-06-28).
vartype	text	—	Variability type as catalogued in VSX (GCVS-style; trailing colon = uncertain classification).
n	integer	frames	Number of G frames in which the star was detected within 2.5″ of its catalog position with a valid flux measurement.
measured G	real	mag	Median of the ensemble-corrected instrumental G magnitudes over the series, zero point anchored to Gaia G (not transformed to a standard system).
Gaia G	real	mag	Gaia DR3 broadband G magnitude of the cross-matched source (catalog reference brightness).
Δ	real	mag	measured G − Gaia G. Nonzero values reflect the filter-bandpass difference, calibration systematics, and genuine variability phase.
db	flag	—	Database-consistency verdict: ✓ when $\lvert\Delta\rvert \le 0.30$ mag; Δ-flag when discrepant and worth review.
median_err	real	mag	Median propagated single-measurement uncertainty: $1.0857 \cdot \sigma_F / F$ (source photon noise + sky-annulus noise + aperture terms, gain-scaled).
robust_std	real	mag	Robust standard deviation across frames: 1.4826 × median absolute deviation about the series median; the primary variability statistic.
range	real	mag	Peak-to-peak spread (max − min) over the series; outlier-sensitive by construction.
sig	flag	—	Significant variation: robust_std > 2.5 × median_err and > 0.008 mag during the observation window.
sat	flag	—	Saturated: stellar peak exceeded 90% of detector saturation in ≥1 frame; magnitudes unreliable.

Variability summary — one row per star (G band)

Sorted: valid (unsaturated) rows first, significant variation first, then by robust scatter.

NAME	VARTYPE	N	MEASURED G	GAIA G	Δ	DB	MEDIAN_ERR	ROBUST_STD	RANGE	SIG	SAT
V1379 Her	EW	78	12.56	12.55	+0.00	✓	0.0177	0.3222	0.775	✓	
Gaia DR3 4460408409747865472	ROT	50	14.18	14.25	-0.08	✓	0.0748	0.2633	2.216	✓	
DY Her	HADS	83	10.23	10.42	-0.19	✓	0.0045	0.2253	0.548	✓	
Gaia DR3 4459203757322144384	ROT	34	13.91	13.93	-0.01	✓	0.0521	0.2026	0.596	✓	
CSS_J163649.5+123213	EW	52	13.93	13.87	+0.05	✓	0.0636	0.1866	0.610	✓	
Gaia DR3 4461122576910517632	ROT	48	14.26	14.33	-0.07	✓	0.0744	0.1865	0.648	✓	
ROTSE1 J163126.35+121920.7	EW	72	13.91	13.73	+0.19	✓	0.0531	0.1854	1.177	✓	
Gaia DR3 4461187929132909312	ROT	44	14.05	14.06	-0.01	✓	0.0603	0.1781	0.620	✓	
Gaia DR3 4459002752851301120	ROT	41	13.86	13.93	-0.06	✓	0.0542	0.1728	0.538	✓	
Gaia DR3 4459029759605660288	ROT	43	13.92	13.97	-0.05	✓	0.0536	0.1673	0.449	✓	
Gaia DR3 4459215886309345408	ROT	60	13.47	13.32	+0.15	✓	0.0368	0.1581	0.561	✓	
Gaia DR3 4459029416008259328	ROT	56	13.70	13.39	+0.30	Δ	0.0449	0.1295	0.444	✓	
ASASSN-V J163221.29+125203.7	EA	63	13.38	13.40	-0.02	✓	0.0344	0.1203	0.476	✓	
Gaia DR3 4459247394189660800	SR|M	70	13.46	13.01	+0.45	Δ	0.0364	0.1092	0.454	✓	
Gaia DR3 4461192945655073280	ROT	46	13.60	13.51	+0.09	✓	0.0421	0.1066	0.523	✓	
Gaia DR3 4459412905048376960	E	54	13.57	13.60	-0.04	✓	0.0396	0.1016	0.370	✓	
Gaia DR3 4459100540667943680	DSCT|GDOR|SXPHE	43	12.00	12.12	-0.12	✓	0.0114	0.0981	0.256	✓	
Gaia DR3 4459359406937978368	DSCT|GDOR|SXPHE	80	13.04	13.09	-0.05	✓	0.0257	0.0945	0.291	✓	
Gaia DR3 4459207571252850176	ROT	66	13.13	12.60	+0.53	Δ	0.0273	0.0945	0.427	✓	
ZTF J163859.93+125626.1	EW	62	12.80	13.08	-0.28	✓	0.0219	0.0940	0.461	✓	
Gaia DR3 4460315397935882112	ROT	66	12.93	12.68	+0.25	✓	0.0238	0.0872	0.341	✓	
ASASSN-V J163639.82+114343.2	ROT	77	12.41	12.24	+0.16	✓	0.0155	0.0859	0.365	✓	

NAME	VARTYPE	N	MEASURED G	GAIA G	Δ	DB	MEDIAN_ERR	ROBUST_STD	RANGE	SIG	SAT
Gaia DR3 4459413351724977152	ROT	70	13.16	13.00	+0.16	✓	0.0287	0.0843	0.352	✓	
Gaia DR3 4459054017580993152	ROT	61	12.76	12.65	+0.11	✓	0.0209	0.0813	0.290	✓	
ASASSN-V J163324.95+123752.3	L	70	12.74	11.86	+0.88	Δ	0.0198	0.0799	0.276	✓	
Gaia DR3 4460458609325439744	ROT	56	12.63	12.72	-0.08	✓	0.0185	0.0742	0.425	✓	
Gaia DR3 4459356142762328832	ROT	84	12.29	12.12	+0.17	✓	0.0143	0.0641	0.309	✓	
Gaia DR3 4460460980147404800	ROT	57	12.50	12.65	-0.16	✓	0.0167	0.0518	0.456	✓	
Gaia DR3 4461107355546466688	ROT	70	11.62	11.71	-0.09	✓	0.0089	0.0366	0.239	✓	
ASASSN-V J163647.26+132012.2	EA	33	11.97	12.27	-0.30	✓	0.0110	0.0330	0.331	✓	
ASAS J163018+1229.9	MISC	79	10.74	10.08	+0.66	Δ	0.0055	0.0325	0.166	✓	
ASAS J163733+1150.1	ESD	85	10.68	10.53	+0.15	✓	0.0053	0.0286	0.255	✓	
ASAS J162900+1211.8	MISC	80	11.25	10.11	+1.14	Δ	0.0073	0.0272	0.122	✓	
V1028 Her	EA	32	11.62	11.70	-0.08	✓	0.0081	0.0250	0.211	✓	
Gaia DR3 4459504336313338240	VAR	84	10.05	10.19	-0.15	✓	0.0043	0.0182	0.088	✓	
Gaia DR3 4460280385362669312	ROT	44	14.45	14.43	+0.03	✓	0.0860	0.1777	0.660		
Gaia DR3 4460411742642131712	DSCT|GDOR|SXPHE	49	14.33	14.53	-0.20	✓	0.0747	0.1464	0.607		
Gaia DR3 4460442700766542336	ROT	38	14.64	13.89	+0.75	Δ	0.1241	0.1449	0.809		
Gaia DR3 4459255365649030656	ROT	30	14.40	14.34	+0.05	✓	0.0851	0.1437	0.595		
Gaia DR3 4459348205662977152	VAR	54	14.04	14.01	+0.03	✓	0.0624	0.1385	0.474		
Gaia DR3 4459368065591831936	ROT	36	14.41	13.64	+0.77	Δ	0.0843	0.1377	0.494		
Gaia DR3 4459247772146759168	ROT	33	14.12	14.09	+0.03	✓	0.0622	0.1369	0.564		
Gaia DR3 4459345697402362112	DSCT|GDOR|SXPHE	32	14.22	14.42	-0.20	✓	0.0691	0.1369	0.549		
CSS_J163745.2+122451	EB	40	14.43	14.24	+0.19	✓	0.0854	0.1316	0.546		
Gaia DR3 4459354081178263296	ROT	30	14.54	13.66	+0.87	Δ	0.0919	0.1314	0.536		
Gaia DR3 4459661703914003200	ROT	39	14.58	14.47	+0.11	✓	0.0946	0.1312	0.720		
Gaia DR3 4459618719881250688	ROT	49	14.42	14.25	+0.17	✓	0.0883	0.1303	0.943		
Gaia DR3 4459841920741216512	ROT	41	14.16	14.21	-0.06	✓	0.0679	0.1281	0.581		
Gaia DR3 4460289318894390144	ROT	37	14.55	14.60	-0.05	✓	0.0911	0.1280	0.472		
Gaia DR3 4460300451449840128	RS	67	14.14	13.72	+0.42	Δ	0.0663	0.1263	0.423		
Gaia DR3 4459540173519572736	ROT	47	14.26	14.27	-0.01	✓	0.0715	0.1256	0.459		
Gaia DR3 4460838250078146048	RS	50	14.26	14.46	-0.20	✓	0.0736	0.1182	0.507		
Gaia DR3 4459299616692638080	ROT	55	13.80	13.71	+0.09	✓	0.0480	0.1162	0.449		
ASASSN-V J163540.89+125141.7	ROT	35	14.56	14.50	+0.06	✓	0.0972	0.1155	0.770		
Gaia DR3 4459641225509680128	ROT	65	14.12	14.19	-0.08	✓	0.0636	0.1154	0.553		
Gaia DR3 4460319246226596608	ROT	41	14.42	14.53	-0.11	✓	0.0850	0.1132	0.575		
Gaia DR3 4459643871209596032	ROT	59	14.26	13.87	+0.39	Δ	0.0718	0.1101	0.542		
Gaia DR3 4459481384007389568	ROT	41	14.18	14.24	-0.07	✓	0.0659	0.1100	0.429		
Gaia DR3 4459467537032546944	ROT	40	14.17	14.27	-0.10	✓	0.0676	0.1041	0.399		
Gaia DR3 4459258458025496704	ROT	40	13.63	13.92	-0.29	✓	0.0412	0.1014	0.406		
Gaia DR3 4459262203236941696	ROT	65	13.61	13.55	+0.06	✓	0.0404	0.1009	0.455		
Gaia DR3 4459349614412239616	ROT	58	14.11	13.94	+0.17	✓	0.0632	0.0952	0.531		
Gaia DR3 4459522993650308992	ROT	62	13.76	13.82	-0.06	✓	0.0477	0.0903	0.428		
Gaia DR3 4459349614412238208	ROT	69	13.84	13.22	+0.62	Δ	0.0487	0.0892	0.368		
Gaia DR3 4459534469803016320	RS	73	13.86	13.85	+0.01	✓	0.0520	0.0882	0.398		
CSS_J163542.6+120142	EW	68	13.60	13.49	+0.11	✓	0.0410	0.0872	0.440		

NAME	VARTYPE	N	MEASURED G	GAIA G	Δ	DB	MEDIAN_ERR	ROBUST_STD	RANGE	SIG	SAT
Gaia DR3 4459513269844503040	ROT	67	13.96	13.95	+0.01	✓	0.0549	0.0862	0.465		
Gaia DR3 4459512101613369344	DSCT|GDOR|SXPHE	65	13.81	13.97	-0.15	✓	0.0485	0.0826	0.396		
ASASSN-V J163147.74+122448.5	SR	70	13.85	13.12	+0.73	Δ	0.0514	0.0781	0.328		
Gaia DR3 4459568966979911424	ROT	67	13.69	13.72	-0.04	✓	0.0435	0.0760	0.338		
ROTSE1 J164001.79+124134.4	LPV	73	13.32	12.88	+0.44	Δ	0.0325	0.0739	0.544		
Gaia DR3 4459564500214022784	E	68	13.88	13.95	-0.07	✓	0.0512	0.0720	0.390		
CSS_J163257.8+120358	RS	58	13.85	14.04	-0.18	✓	0.0504	0.0709	0.419		
Gaia DR3 4459495643298630912	ROT	77	13.46	13.47	-0.01	✓	0.0362	0.0668	0.278		
Gaia DR3 4459523818284060800	ROT	71	13.82	13.71	+0.11	✓	0.0489	0.0639	0.407		
Gaia DR3 4459610336105101056	ROT	38	13.11	13.12	-0.01	✓	0.0266	0.0616	0.280		
Gaia DR3 4459608755557105280	ROT	54	13.10	12.48	+0.62	Δ	0.0268	0.0616	0.280		
Gaia DR3 4459524917795666432	ROT	76	13.29	13.31	-0.02	✓	0.0308	0.0521	0.300		
Gaia DR3 4459382359242886528	DSCT|GDOR|SXPHE	87	12.85	13.01	-0.16	✓	0.0217	0.0506	0.206		
Gaia DR3 4459503168081111552	ROT	80	12.83	12.60	+0.23	✓	0.0212	0.0467	0.232		
Gaia DR3 4461101205153540992	ROT	58	13.08	12.89	+0.19	✓	0.0266	0.0441	0.335		
Gaia DR3 4460258532568677120	ROT	80	12.69	12.72	-0.03	✓	0.0189	0.0431	0.205		
Gaia DR3 4459383905431114624	ROT	90	12.62	12.31	+0.31	Δ	0.0184	0.0382	0.190		
Gaia DR3 4459584836881207168	ROT	65	12.27	12.30	-0.03	✓	0.0137	0.0294	0.120		
NSV 7764		43	8.93	8.27	+0.66	Δ	0.0026	0.0219	3.708	✓	sat
NSV 20678		87	9.09	9.21	-0.12	✓	0.0033	0.0188	2.779	✓	sat