The Photometric Period of V606 Vulpeculae (Nova Vul 2021)

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Received October 4, 2021; revised October 16, 2021; accepted October 18, 2021

Abstract A photometric study of the galactic nova V606 Vulpeculae (Nova Vul 2021, TCP J20210770+2914093) was undertaken at the Burleith Observatory in Washington, DC. A total of 3,511 CCD observations were obtained over a time span of 57.1 days, yielding an observed period 0.133697 d ± 0.000064 d, of amplitude 0.012 magnitude I_c. The epoch (HJD) of minimum light was 2459432.6287 (0.0004). A new δ Scuti (DSCT) variable, GSC 02167-00712, of period 62.526 minutes, was discovered in the field of the nova.

1. Introduction

This is the sixth in a series of reports on the discovery of photometric periods of recent classical novae (Schmidt 2020a, 2020b, 2021a, 2021b; Schmidt *et al.* 2021). These *JAAVSO* reports serve a dual purpose: adding to the relatively few known orbital periods of novae, and hopefully inspiring urban astronomers to participate in nova research. The reddened color of galactic novae and their typically long period of outbursts lend them well to CCD observation—even in heavily light-polluted cities—when observing in the near infrared, as with the Cousins I_c filter and a monochromatic camera with sensitivity in the 700–900 nm region.

V606 Vulpeculae, (Nova Vulpeculae 2021, TCP J20210770+2914093), R.A. $20^h\,21^m\,07.70^s$, Dec. +29° 14' 09.1" (2000), was discovered by Koichi Itagaki, Yamagata, Japan, on 2021 July 16.475 UT (Itagaki 2021). Spectroscopy by Munari *et al.* on 2021 July 17, 18, and 28 confirmed its type as an Fe-II-type nova (Munari *et al.* 2021). Schmidt reported a preliminary photometric period of 3.096 h to the Central Bureau for Astronomical Telegrams on 8 August 2021 (Schmidt 2021c). The 15 arc-minute field of V606 Vul on 2021 September 24 is shown in Figure 1.

2. Observations

At Burleith Observatory a total of 3,511 CCD observations of V606 Vul were obtained between 2021 July 17.25 and October 2.05 UT with a 0.32-m PlaneWave CDK astrograph and SBIG STL-1001E CCD camera with an Astrodon Cousins I_c filter. Pixel size was 1.95 arc-seconds, yielding on average 2-pixel FWHM, and the field of view was 33 arc-minutes square. The observatory computer was synchronized to USNO NTP before each observing session. Images were de-darked and flat-fielded in real time. Exposure times ranged from 30 to 90 seconds.

3. Reductions

Cousins I-band differential ensemble photometry was performed using the comparison stars in Table 1, which are numbered as in Figure 1. Synthetic aperture photometry was performed using C-Munipack 2.1.29 (Motl 2021). Heliocentric corrections were applied to dates of observation. Data from poor nights and large outliers were filtered out, leaving 2,963 images for analysis.

Table 1. Photometry comparison stars from AAVSO chart sequence X26761AJ.

No.	AUID	R.A. (2000) h m s	Dec. (2000) ° ' "	Mag. I_c	Mag. Err.
1	000-BPB-795	20 20 52.08	+29 14 50.5	11.497	0.206
2	000-BPB-796	20 20 34.83	+29 14 10.1	12.029	0.156
3	000-BPB-797	20 21 02.11	+29 17 36.8	12.470	0.206
4	000-BPB-798	20 20 46.15	+29 20 26.5	12.845	0.222 (check star)

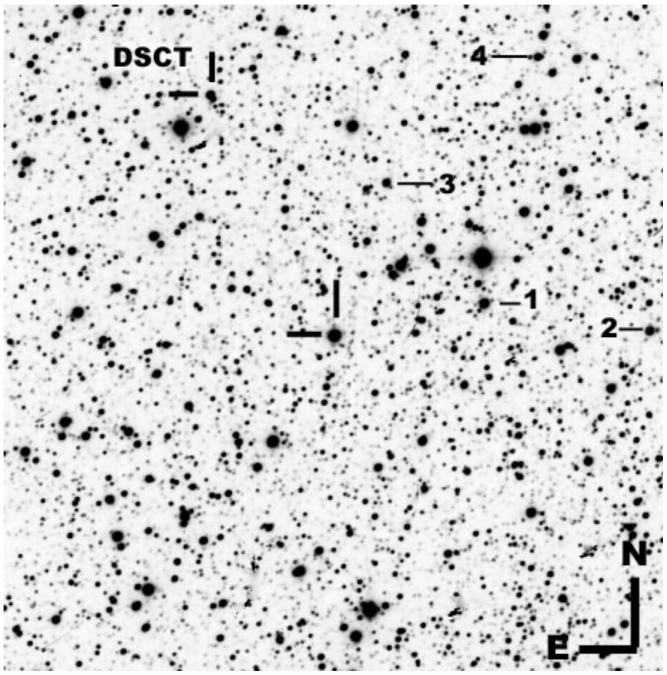

Figure 1. 15 × 15 arc-min field of V606 Vul (center) and DSCT GSC 02167-00712.

Table 2 and Figure 2 provide nightly mean times of observation (HJD-2400000), observed mean magnitudes I_c, mean error of the magnitudes, maximum airmass, and duration of nightly observing sessions.

Detrending nightly observations removes linear magnitude changes. For example, Figure 3 shows five hours of observations from 25 August 2021, during which the nova was brightening by 0.1 magnitude. Figure 4 shows the same observations after subtracting a linear solution, y = –0.356*x + 3564.5, from the observed magnitudes.

Table 2. Nightly mean magnitudes I_c.

HJD	*Mag. I_c*	*Error*	*Max. Airmass*	*Duration (hours)*
9412.7533	11.341	0.004	1.022	0.77
9419.6657	10.847	0.005	1.500	2.47
9421.6032	10.538	0.007	1.281	0.48
9423.6386	10.002	0.009	1.243	1.98
9429.5902	8.788	0.010	1.375	1.93
9432.6251	9.716	0.009	1.335	3.49
9435.6025	10.023	0.009	1.181	1.05
9439.6253	10.253	0.007	1.110	1.71
9451.6376	10.849	0.005	1.201	5.14
9456.7071	10.396	0.006	1.248	1.76
9460.6180	10.510	0.005	1.178	4.91
9461.5615	10.146	0.007	1.146	2.03
9462.5818	9.787	0.008	1.158	3.35
9464.5698	9.802	0.007	1.112	2.16
9465.5931	9.950	0.005	1.087	3.09
9466.5500	10.013	0.009	1.108	1.50
9467.6611	9.603	0.008	1.225	2.30
9468.5912	9.382	0.007	1.110	3.84
9469.5795	9.313	0.006	1.103	3.15
9471.5688	9.287	0.010	1.107	3.03
9476.5887	9.277	0.007	1.172	3.89
9477.5562	9.620	0.007	1.062	2.19
9482.5801	10.304	0.006	1.204	4.14
9487.5691	10.906	0.004	1.156	3.21
9489.5524	10.795	0.005	1.125	3.24

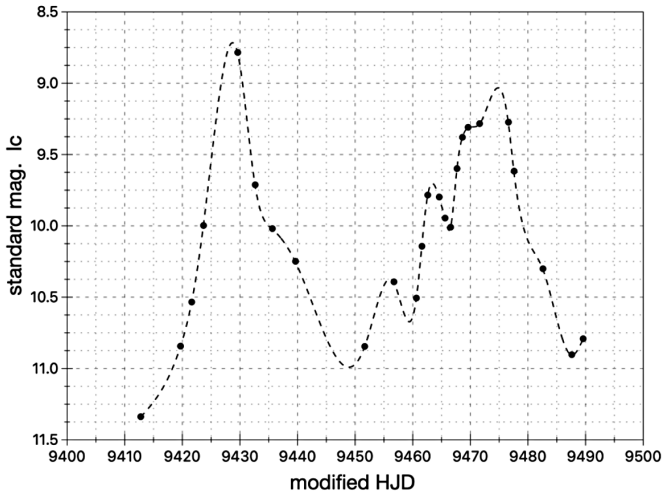

Figure 2. Nightly mean I_c magnitudes.

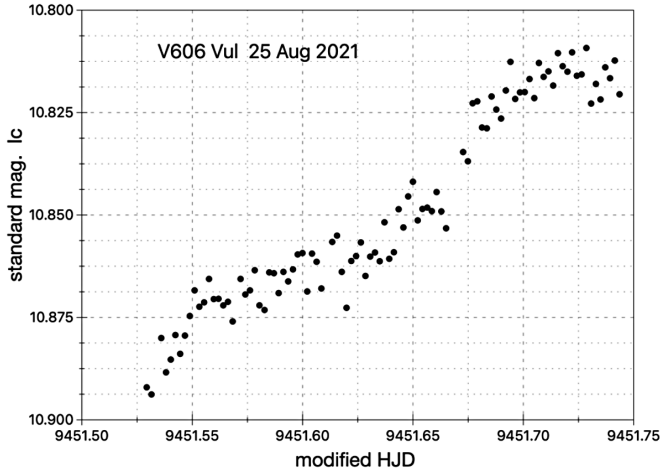

Figure 3. 25 Aug. 2021 as observed.

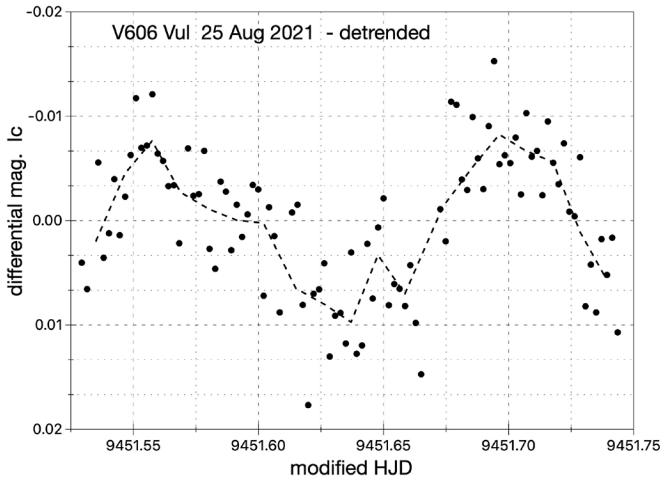

Figure 4. 25 Aug. 2021 detrended.

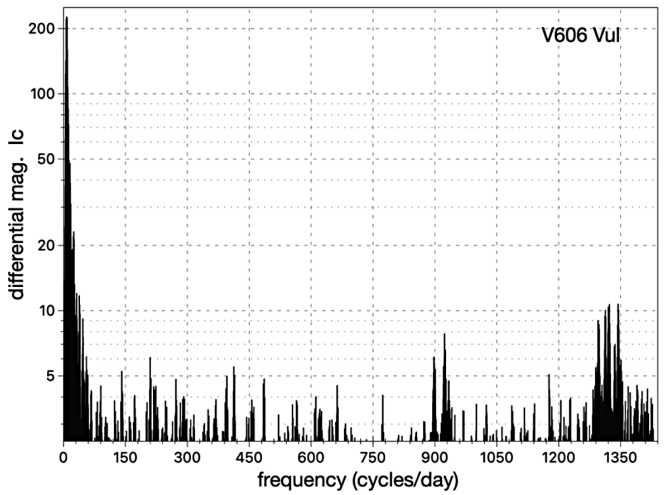

Figure 5. Wide Lomb-Scargle periodogram of V606 Vul.

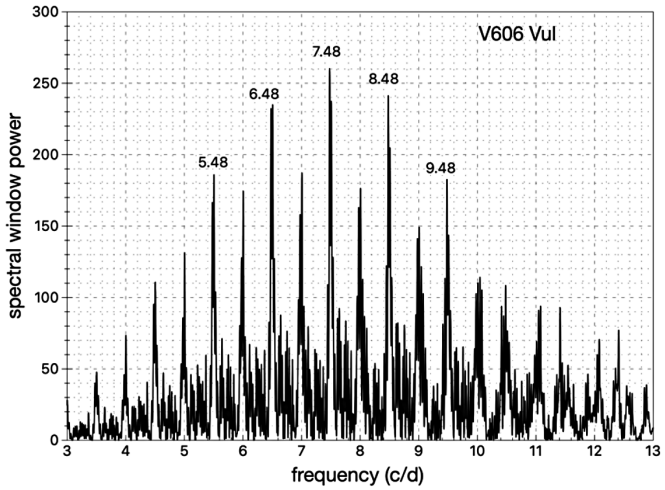

Figure 6. Lomb-Scargle periodogram of V606 Vul.

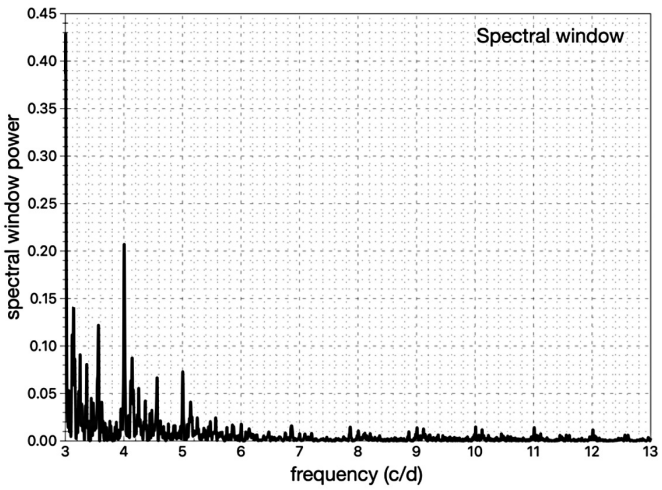

Figure 7. Spectral window of observations.

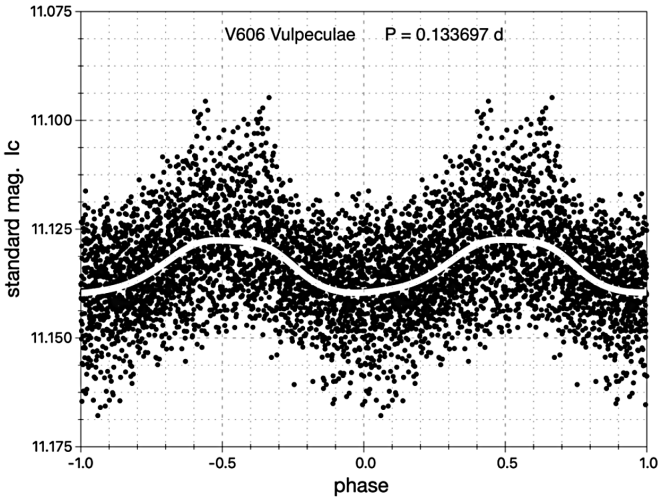

Figure 8. Double phased plot with spline interpolated smoothing (solid line).

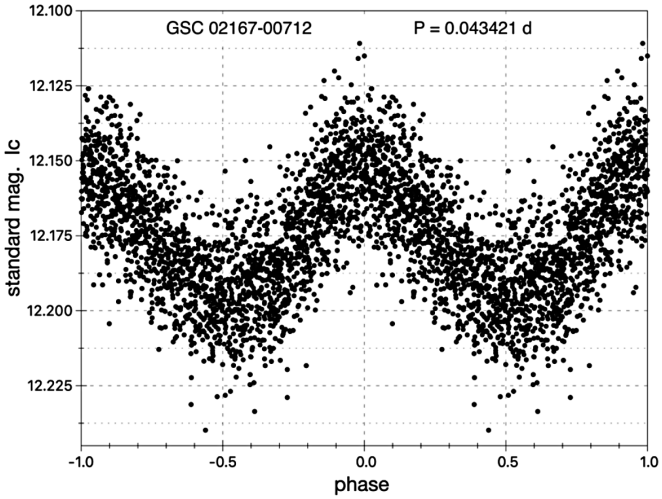

Figure 9. Phase plot of GSC 02167-00712.

Table 3. Observation summary V606 Vulpeculae.

Parameter	*Value*
Period (d)	0.133697 (0.000064)
Period (h)	3.2087 (0.0015)
Amplitude (mean curve) (mag. Ic)	0.012
Number of observations used	2963
Time span (d)	57.07
Epoch of minimum	2459432.6287 (0.0004)

4. Analysis

Prior to Fourier analysis, each nightly observation set was pre-processed by subtracting nightly average brightness and removing nightly linear trends. Period analysis was performed using Peranso 2.60 software (Paunzen and Vanmunster 2016), computing a Lomb-Scargle spectra of the observations. Because of the low signal-to-noise ratio of the nova light curve, a resolution of 100,000 steps was computed. Figure 5 shows a Lomb-Scargle periodogram over the range 0–1440 cycles/day (the range of possible photometric periods for novae). On the right of this logarithmic plot we see frequencies due to the observing cadences of 65 and 95 seconds.

Figure 6 shows a Lomb-Scargle periodogram over the frequency range 3–13 cycles/day, which peaks at 7.4796 cycles/day (3.2087 hours). Various aliases appear at ½-day and 1-day intervals due to the diurnal nature of night observing. Pre-whitening (removal of the main period) revealed no other significant periods that were not its aliases.

Figure 7 shows the spectral window for these observations, which displays artifacts caused by the cadence of observations. The absence of a peak at the observed frequency 7.47960 cycles/day shows that this frequency is not an artifact of the observing window.

A folded double-phase plot of the most prominent period is shown in Figure 8. The solid curve shown is a 512-point average with spline interpolation. The magnitude range (I_c) shown is from 01 October 2021.

Table 3 summarizes observed data for V606 Vul, with errors in parentheses. The period error estimate was computed by Peranso as the 1-σ confidence level on the period P which equals the line width of its Mean Noise Power Level, using the method in section 4.4 of (Schwarzenberg-Czerny 1991). The epoch of extremum is found from a 7-degree polynomial fit to the observations.

5. Discovery of a field δ Scuti variable

Tens of thousands of stars appear in each 33 × 33 arc-minute field taken with this telescope and CCD. Photometry reduction programs such as C-Muniwin can generate plots of magnitude vs. standard deviation for each field object. Each object with heightened magnitude standard deviation is checked for possible periodicity. Examination of the field of V606 Vul revealed a previously unknown variable, GSC 02167-00712, which has been assigned AAVSO AUID 000-BPC-988, of magnitude range 12.15–12.20 (I_c), at R.A. $20^h\ 21^m\ 20.38^s$, Dec. +29° 19' 39.8" (2000) ("DSCT" in Figure 1). ANOVA analysis of its light

curve yields the period 0.043421 d (0.000009) (62.526 min), with epoch of maximum JD 2459467.6147. The fast period and low amplitude is typical of δ Scuti variables. A double phase plot is shown below (Figure 9).

6. Conclusion

The photometric variability of V606 Vulpeculae, though of low amplitude (0.012 magnitude I_c), is readily detected with a Lomb-Scargle spectral analysis based on a large number of observations. The observed period is in agreement with the orbital periods of novae found in the catalogue of galactic novae of (Özdönmez *et al.* 2018). In spite of its location in a heavily light-polluted city, the small telescope of Burleith Observatory yields Cousins I-band photometric measurements with a mean error of 0.007 magnitude. Observations from dark sky sites would naturally yield much less noisy results. The serendipitous discovery of a δ Scuti variable adds to the enjoyment of CCD field photometry.

7. Acknowledgements

Schmidt wishes to thank Sebastián Otero, AAVSO; James A. DeYoung, NRL/USNO (ret.); and Sergei Yu. Shugarov, Sternberg Astronomical Institute, M. V. Lomonosov Moscow State University for helpful comments. Special thanks to the AAVSO for providing photometric standards from the AAVSO Comparison Star Database via its Variable Star Plotter utility. This work from the rooftop observatory of the author's house was enthusiastically supported by his wife, Margaret.

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