Early Sixty-Day Observations of V5668 Sgr using a DSLR Camera

Shishir Deshmukh
Akash Mitra Mandal (Amateur Astronomers' Organization, Mumbai, India; shishir.supernova@gmail.com

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Abstract Photometric observations of V5668 Sgr (Nova Sagittarii 2015 No.2) were carried out using a consumer-grade DSLR camera. Observations were made under urban sky conditions for 60 days after discovery. The brightness of the nova was monitored with reference to several nearby reference stars using a Canon EOS 600D with CMOS sensor. Estimates were then transformed using a "median" B–V value of 0.28 into standard magnitude. Preliminary plot shows large variations, especially gradual rise and rapid falls.

1. Introduction

A Possible nova in Sagittarius was reported by John Seach, Chatsworth Island, NSW, Australia, on March 15, 2015 (CBAT 2015). The photograph was taken using DSLR and 50-mm f/1.0 lens. The object's estimated magnitude was 6.0 at the time of initial report. There was no object visible down to magnitude 10.5 on the image taken on March 14, 2015.

Follow-up observations taken by John Seach showed a bright H-alpha source visible on six DSLR images taken using a 50-mm f/1.0 lens and H-alpha filter. Subsequent observations were carried out by K. Itagaki and T. Yusa. Further, Ernesto Guido and Nick Howes confirmed the optical counterpart with R-CCD magnitude 5.8 at coordinates R. A. = $18^h\ 36^m\ 56.85^s$, Dec. = –28º 55' 40.0" (equinox 2000.0; UCAC-4 catalogue reference stars (Zacharias *et al.* 2012)). They also compared their follow-up image taken remotely through a 0.61-m f/6.5 astrograph + CCD of the ITelescope network with the archive POSS2/UKSTU plate (R Filter-1996).

Nova Sgr 2015 No. 2 was subsequently assigned the name V5668 Sgr (Green 2015).

2. DSLR photometry: An overview

The application of consumer grade Digital Single Lens Reflex (DSLR) cameras for astronomical photometry was explored by Hoot (2007), Kloppenborg *et al.* (2012), and others. The variability measurement of variable stars is shown by Loughney (2010) and also by Collins and Prasai (2009).

3. Linearity check

An unmodified Canon EOS 600D camera was used throughout this project. A linearity check was performed so as to ensure that no measured star on the image was ever saturated.

In order to carry out the linearity test, images of an evenly illuminated surface were taken at different exposures, starting from 1/3 of a second to 60 seconds at the same speed at which the science images were taken. Using IRIS freeware (Buil 2015), mean green channel pixel counts were measured. The green channel pixel counts were then plotted against the exposure durations. The resultant plot (Figure 1) shows the response of the detector as a function of exposure duration in terms of pixel counts.

The mean count at which pixels became saturated was found to be a little less than 14,000. Care was taken that no comparison star, check star, or the target was ever saturated during any of the observation sessions of this project.

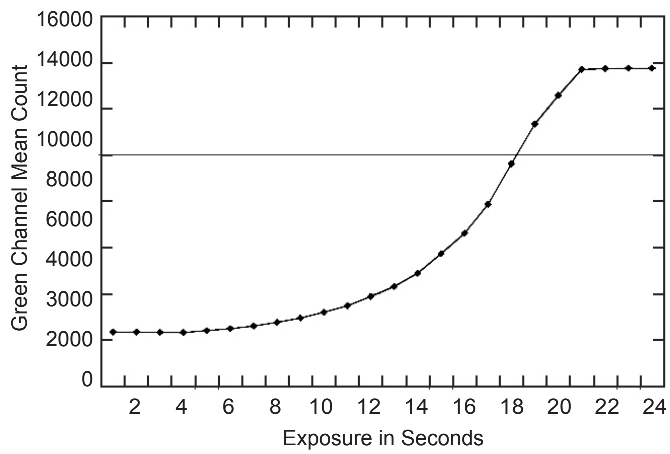

Figure 1. Linearity check plot.

4. Methodology

For photometric observations, a Canon EOS 600D camera was used with a 55- to 250-mm lens; no modifications were made to the camera. Since the images were taken from a light-polluted suburban sky, a suitable wide field focal length was selected to cover the nova and comparison stars in the same frame. Focusing was made manually by taking sample images prior to the science images. With no tracking device, short exposures of five seconds were taken for photometry to minimize the trails.

Exposures were taken at ISO 800 in order to compensate for short exposures. Weather permitting, a minimum of five exposures were taken in order to average out the measurements. Throughout this project, care was taken to have comparison stars, check star, and the target in the same frame. Immediately after the science images, a minimum of eight dark images were taken for each observing session. A minimum of sixteen flat frames taken at the same focal length were used to process the images. Similarly, a bias frame made at the same speed was used to process the images. For image processing, Christian Buil's IRIS software (Buil 2015) was used to de-bayer different channels, such as Red, Green, and Blue.

5. Choice of comparison stars

It has been categorically shown by Hoot (2007) that the DSLR dynamic range of magnitude can cover about 2.5 magnitudes. Outside of this range, errors increase rapidly, thereby reducing the utility of DSLR photometry with a wide magnitude range. Hence, a dynamic range of 2.5 magnitudes limits the choice of comparison stars. Care was taken to select comparison stars having a dynamic range of 2.5 in most cases. However, during the tenure of the observations, the nova remained hovering around magnitude 5.3, hence the selection of comparison stars was limited.

Although the nova was in one of the densest parts of the sky, with a modest limiting magnitude of the sky from the urban area along with a short exposure of five seconds with 154-mm focal length, the faintest star visible on an average image was around magnitude 8.5. Hence there were only a few comparison stars available around the nova. In most cases, a wide field finder chart (Figure 2) available on the American Association of Variable Star Observers website (AAVSO 2015) was used.

Another factor that governed the choice of comparison stars was the color of the stars. Very red stars and very blue stars were both avoided in order to increase the chances of picking up the truly non-variable star with a color (B–V) range of 0.3 and 1.0, and with a mean value of 0.7. Fortunately, the nova appeared in one of the richest parts of the sky; hence there were sufficient ideal comparison star candidates.

As a result, in most cases the comparison stars and check star were selected within the range of this color (B–V = 0.3 to 1.0). Table 1 contains the list of stars selected for photometry in most cases in this project. The adherence to the specified dynamic range of comparison star and the color cut ensures good quality of data. In these sixty days of observation, for almost 87% of the time at least six of the stars in Table 1 were used as comparison and check stars. At times when one or more stars were not visible due to poor seeing conditions, stars with a (B–V) value outside the range of 0.3 to +1.0 were chosen.

However, it should be noted that despite taking care, complete elimination of background starlight was not possible owing to the great density of stars in the region.

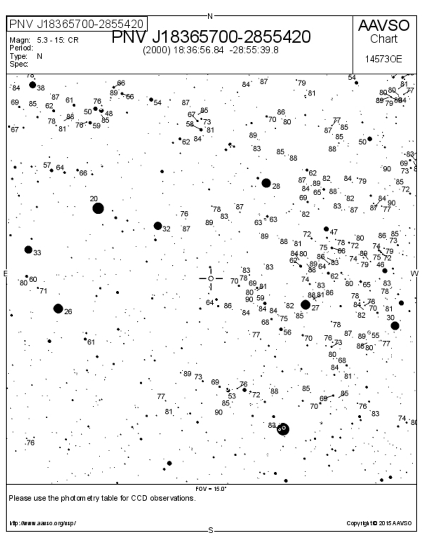

Figure 2. Wide field finder chart for V5668 Sgr (AAVSO 2015).

Table 1. Comparison stars and check star used.

Star (AAVSO Indentifier)	R. A. (2000) h m s	Dec. (2000) ° ' "	V Mag.	(B–V)
000–BCC–457	18 29 11.93	–29 15 34.3	6.888	0.451
000–BLP–686	18 37 17.21	–29 28 27.5	7.713	0.454
000–BCC–379	18 27 49.48	–29 49 00.7	5.920	0.520
000–BCC–337	18 26 40.81	–30 23 36.0	6.750	0.537
000–BCC–569	18 31 53.35	–28 30 40.4	8.308	0.592
000–BCC–587 = NSV 24489	18 32 14.01	–29 11 24.7	7.035	0.823
000–BLP–685	18 37 03.28	–28 30 47.0	6.782	0.964

6. Data reduction

Images saved in the camera's raw format were converted into "cfa format." After loading the cfa image, a master flat and master dark image were reduced from it apart from a master bias image in the preprocessing phase. The image was then aligned and RGB colors separated (de-bayered). Thus, for each image, there were now three individual images of different colors: red, green, and blue. From each image, the instrumental magnitudes of the objects could be derived. The software offers various display settings that do not alter the image data.

Using the software's "Aperture photometry" option, appropriate radii of different apertures were set depending upon the radii of the objects of interest in the image. Careful readings of the instrumental magnitudes were then taken and noted in a spreadsheet. In most cases, five science images were taken and an average of their instrumental magnitudes were used in the Citizen Sky Intermediate spreadsheet (CSIS; Citizen Sky 2015) for data reduction. The formulae embedded in CSIS accounted for airmass. This spreadsheet has some built-in checks like residuals versus airmass, quality of comparison star fit, and so on. In all cases, six comparison stars and a check star were used to derive DSLR Green magnitude. Since the target star was a nova, an accurate B–V value was not available beforehand; as a result, a B–V value of 0 was taken to keep the reduction effectively non-transformed.

7. Preliminary plot and transformations

A preliminary plot of the reduced Green observations (Figure 3) shows light variations as a function of time. Instrumental Green channel magnitudes were calibrated using nearby six comparison stars after accounting for atmospheric extinction and air mass. These observations are in good agreement with the similar observations submitted to the AAVSO by other observers. The preliminary plot shows large variations, especially a gradual rise and rapid fall. This is very unlike a classical slow nova with a rapid rise and gradual decline.

The transformation of DSLR Tri-G magnitude into standard V magnitude requires an exact color transformation coefficient (B–V value). However, as stated earlier, with the target object being a nova no B–V value was readily available. Non-transformed values can also be reported to the AAVSO using the "Tri-G" magnitude option. Table 2 shows estimated Tri-G values of the nova, along with standard errors that are a simple

Table 2. DSLR observations of V5668 Sgr.

Sl. Number	*Julian Day*	*DSLR Tri-G Magnitude*	*Average Errors*	*Standard V Mag. using (B–V) = 0.28*
1	2457098.53	6.1	0.028	6.0
2	2457099.51	7.1	0.083	7.1
3	2457100.52	5.3	0.037	5.3
4	2457101.52	4.4	0.089	4.4
5	2457102.52	4.9	0.049	4.7
6	2457103.52	4.6	0.181	4.6
7	2457104.51	4.9	0.086	4.8
8	2457105.51	5.5	0.055	5.5
9	2457106.50	5.9	0.033	5.9
10	2457107.52	5.3	0.609	5.7
11	2457112.50	5.0	0.053	5.0
12	2457113.51	4.5	0.023	4.5
13	2457114.52	4.6	0.049	4.6
14	2457115.50	4.2	0.035	4.2
15	2457116.50	4.3	0.026	4.4
16	2457117.50	4.2	0.126	4.2
17	2457119.50	5.0	0.029	4.9
18	2457120.51	5.6	0.041	5.6
19	2457121.50	5.5	0.054	5.5
20	2457122.50	5.8	0.026	5.8
21	2457123.50	5.6	0.037	5.6
22	2457124.49	4.8	0.066	4.8
23	2457125.51	5.1	0.049	5.0
24	2457126.50	4.8	0.083	4.8
25	2457127.50	5.1	0.035	5.1
26	2457128.50	5.0	0.050	5.0
27	2457129.51	5.4	0.068	5.3
28	2457130.50	5.2	0.050	5.2
29	2457131.50	5.1	0.073	5.1
30	2457132.50	6.0	0.203	5.7
31	2457133.49	5.1	0.068	5.2
32	2457135.50	4.9	0.084	4.8
33	2457136.50	4.8	0.030	4.8
34	2457137.50	5.0	0.022	5.0
35	2457138.48	4.9	0.053	4.9
36	2457139.50	5.0	0.025	5.0
37	2457140.49	4.9	0.023	4.9
38	2457141.49	5.9	0.074	5.9
39	2457142.49	5.7	0.016	5.7
40	2457143.49	6.1	0.025	6.0
41	2457144.49	5.8	0.060	5.7
42	2457145.49	6.2	0.019	6.2
43	2457146.49	6.2	0.072	6.2
44	2457147.49	5.4	0.044	5.4
45	2457149.50	5.2	0.038	5.1
46	2457150.46	5.2	0.027	5.1
47	2457151.47	5.0	0.083	5.0
48	2457152.48	4.8	0.029	4.8
49	2457153.47	5.3	0.012	5.3
50	2457154.48	5.0	0.055	5.0
51	2457155.47	5.3	0.014	5.4
52	2457157.46	6.1	0.014	6.1
53	2457158.47	5.5	0.045	5.6
54	2457159.48	6.3	0.065	6.3
55	2457160.45	6.8	0.023	6.7
56	2457161.45	6.6	0.034	6.6
57	2457162.45	6.5	0.027	6.5
58	2457164.46	6.2	0.035	6.1
59	2457165.46	6.1	0.036	6.1
60	2457166.45	6.1	0.037	6.1

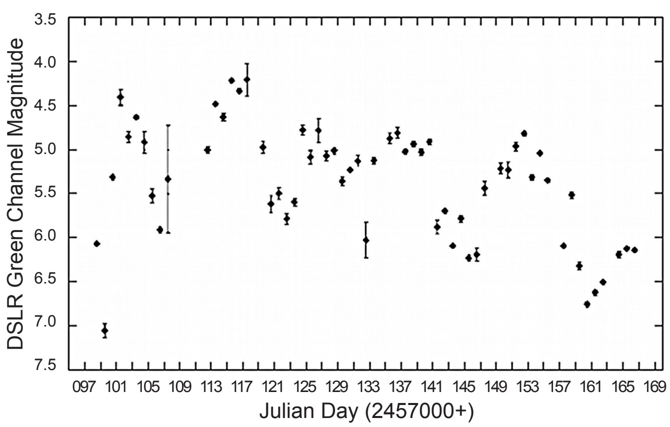

Figure 3. V5668 Sgr DSLR Green magnitude plot.

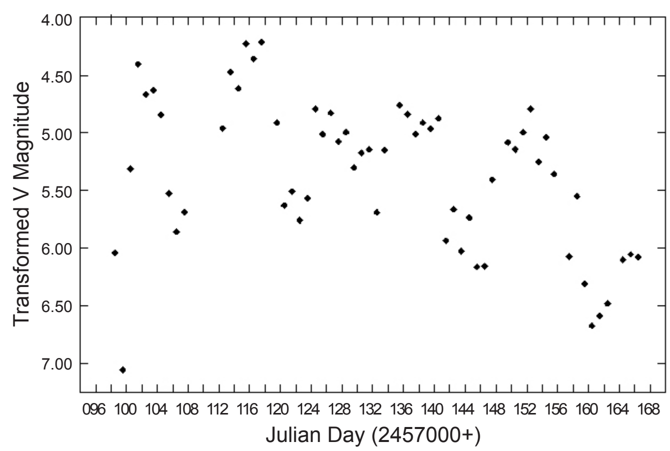

Figure 5. V5668 Sgr transformed V magnitudes.

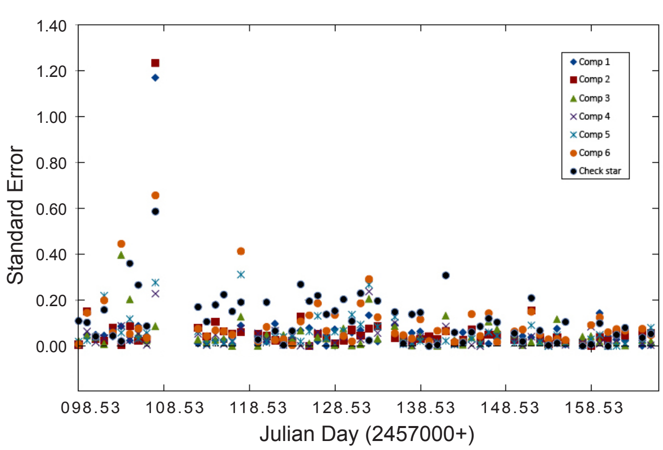

Figure 4. Standard errors of magnitude of comparison stars and check star.

average of standard errors of all comparison stars used.

A plot of the standard errors of magnitude of the comparison stars and the check star is shown in Figure 4.

The methodology of taking observations was to take five images of the same field with identical camera settings and then average them to reduce the errors in any particular image. However, on some occasions, sky conditions were not quite good and only one or two images were taken. Standard errors were large on such occasions. This is attributed mainly to two important aspects: low signal-to-noise ratio and reduced level of averaging to minimize errors. This is evident in the average of standard errors of all the comparison stars on a few occasions. For example, on March 26, 2015 (JD = 2457107.51736), only three images were taken and the average of standard errors of all the comparison stars was 0.6.

By the time the observations were compiled, it became evident that the actual color of the nova changed largely over the monitoring period, and the median value B–V = 0.28 was selected as a compromise. Since, CSIS has an in-built mechanism to transform DSLR Green magnitude into Standard V magnitude, all DSLR Green magnitudes were transformed into Standard V magnitude using a B–V value of 0.28. Formulae embedded in CSIS use a least squares fit to compute extinction coefficient, transformation coefficient, and the camera's zero point offset from instrumental magnitude and catalogued (B–V) values of comparison stars after taking atmospheric extinction into account. Then, on the basis of these coefficients, standard V magnitudes were computed. The values of standard magnitudes are also given in Table 2 and shown in Figure 5.

8. Acknowledgements

Image processing and aperture photometry was carried using IRIS (Buil 2015) which is freeware. Thanks to Christian Buil for making this available to the public. The author is also thankful to Mark Blackford and Brian Kloppenborg for their valued input. The author is grateful to members of the AAVSO for their input to the DSLR photometry forum. Members of Akash Mitra, an Amateur Astronomers' Organization, also made valuable suggestions during the course of this project, and the author is also thankful to them.

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