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V BAND PHOTOMETRY OF THE SN 2003gf SUPERNOVA UTILIZING THE 2MASS CATALOG

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RESUMEN

Hemos obtenido varias imágenes de la supernova SN 2003gf en el Observatorio de Maranganí (departamento de Cusco, Perú), en la noche del 3 al 4 de julio del 2003, a partir de lo cual hemos estimado su brillo en la banda V, obteniendo una magnitud de 15.10 ± 0.09. Esto fue conseguido con una calibración apropiada del campo de estrellas, considerando los datos fotométricos de las bandas infrarrojas del catálogo 2MASS. La precisión conseguida tiene un razonable concordancia con las mediciones realizadas por otros observadores.

ABSTRACT

We obtained several images of SN 2003gf at the Marangani Observatory (Peru) on the night 3–4 July 2003 from which we have estimated its brightness in the V band, as 15.10 ± 0.09 mag. This was obtained after a proper calibration of the starfield, considering the photometric data of the infrared bands of the 2MASS catalog. The precision achieved shows a reasonable agreement with measurements by other observers.

Key Words: supernovae: individual (SN 2003gf) — techniques: photometric — telescopes

1. INTRODUCTION

In 2003, IAU Circular No. 8156 notified the discovery made by J. Graham and W. Li of an apparent supernova. The researchers obtained images between 24 and 25 of June 2003 with the KAIT system (Katzman Automatic Imaging Telescope), within the framework of the LOTOSS (Lick Observatory and Tenegra Observatory Supernova Searches) program. The object called SN 2003gf was located 19.2″ east and 3.9″ south of the diffuse nucleus of the irregular galaxy MCG-04-52-26 (PGC 68328), in the Aquarius constellation, approximately 40′ south of the bright double star 41 Aqr. The coordinates established by the discoverers were RA=22h 13m 40.94s and Dec=−21° 44′ 03.3″. A KAIT image of the same zone taken on December 12, 2002, did not reveal any object with a magnitude fainter than 19.0 in that position. On the night following the first observation, Hamuy & Maza (2003) obtained a spectrum of the object which suggested a possible Type-Ic supernova. The overlapped emission of the host galaxy in the Hα line indicated a heliocentric recession velocity of 2520 km s^{-1}, in good accord with previous optical measurements, which reported a velocity of 2597.0 ± 31.6 km s^{-1} (HyperLEDA 2003).

In the next sections, we report our photometry of the object, obtained at the Marangani Astronomical Observatory 10 days after its discovery. This facility of the UNMSM is located in the Canchis Province, Cuzco Department, Peru; its geographic coordinates are: Lat. 14° 21′ 23″ S, Long. 71° 10′ 03″ W, and Altitude 3736 m above mean sea level. Our measurement is in agreement with the supernova light curve determined from measurements by other observers. In Table 1 we summarize a list of measurements carried out by different observers[4].

2. OBSERVATIONS

At the Marangani Observatory of the UNMSM, on the night of 3 to 4 July 2003, we secured 22 images of the object by using an LX200 telescope (of 200-mm aperture to $f/10$), and a ST-237 CCD

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[4]`www.astrosurf.com/snweb/2003/03gf/03gfMeas.htm`.

TABLE 1

A COMPILATION OF SEVERAL MEASUREMENTS FOR SN 2003gf[a]

Date	JD-2452800	Magn.	Band	Observer	Group
2003 06 24.500	15.0000	14.50	C	KAIT	1
2003 06 25.500	16.0000	14.60	C	KAIT	1
2003 06 30.080	20.5800	14.80	CR	Nicolas, J.	2
2003 07 12.144	32.6440	15.10	CR	Bosch, J. M.	2
2003 08 23.962	75.4620	15.50	CR	Roig, J. C.	2
2003 08 30.003	81.5030	15.70	CR	Roig, J. C.	2
2003 08 30.957	82.4570	15.70	CR	Roig, J. C.	2
2003 09 12.942	95.4420	15.90	CR	Roig, J. C.	2
2003 09 16.907	99.4070	16.10	CR	Llapasset, J. M.	2
2003 09 16.917	99.4170	16.30	Rc	Llapasset, J. M.	2
2003 09 19.933	102.4330	16.00	CR	Roig, J. C.	2
2003 09 20.444	102.9440	16.00	CR	Santallo, R.	2
2003 09 20.990	103.4900	15.90	CR	Bosch, J. M.	2
2003 09 24.896	107.3960	16.10	CR	Llapasset, J. M.	2
2003 09 24.949	107.4490	15.80	CR	Bosch, J. M.	2
2003 09 25.398	107.8980	16.10	CR	Santallo, R.	2
2003 10 09.910	122.4100	16.10	Rc	Bosch, J. M.	2
2003 10 10.867	123.3670	16.20	CR	Llapasset, J. M.	2
2003 10 19.860	132.3600	16.10	Rc	Bosch, J. M.	2
2003 10 25.807	138.3070	16.40	CR	Llapasset, J. M.	2

[a]Group 1 corresponds to IAUC (International Astronomical Union Circular); and Group 2, VSNET (Variable Star Network, Kato et al. 2004).

camera with 640 by 480 pixels (Genet, Johnson, & Wallen 2010; Howell 2006; Kennedy 2012). The images were taken without filter to reach a limiting magnitude fainter than that of the object. The exposure times varied between 7 and 70 seconds. The images were acquired as follows: individually; with the "track & accumulate" technique (Santa Barbara Instrument Group 1999); by binning the CCD; and, finally, by combining the binning and "track & accumulate" techniques.

We tried to acquire images with the V- and R-Johnson filters, but it prooved impossible to achieve an adequate signal to noise ratio.

3. PHOTOMETRIC DATA REDUCTION

On the evening of July 4th, 2003, we acquired several calibration images: bias, dark-frames and flat-fields. The correction for these images and the alignment were performed using `Astroart` software routines (Nicolini, Cavicchio, & Facchini 2003) in order to avoid transforming the original format of the camera (SBIG Type-3 format). Images having tracking problems were discarded and the other images were combined into three groups according to both utilized CCD binning and temporal continuity. In this way we obtained three final images called Gr1, Gr2 and Gr3; in Figure 1 we display the Gr1 final image showing the field of view. Further reductions were carried out with IRAF, and the instrumental magnitudes were obtained with tasks from the DAOPHOT package. For references about astronomical image processing, see Karthick (2012), van Altena (2013), and Berry & Burnell (2005). The seeing ranged between $2.4''$ and $4.8''$, possibly because of the presence of aerosols in the atmosphere. The stars detected on the images were identified from the following catalogs: 2MASS (Skrutskie et al. 2006); GSC; and USNO A2.0. All of them were used for photometric comparison. We set up a photometric system through calibration of the magnitudes of the 2MASS catalog as follows: using J, H, K 2MASS magnitudes, we calculated the $J - H$ and $H - K$ color indexes of each comparison star and with these indexes we estimated their $V - J$ color by means of the tables of Schmidt-Kaler and Peletier (see Binney & Merrifield 1998). Then, by knowing $V - J$ and

TABLE 2

LOCAL PHOTOMETRIC SEQUENCE[a]

Star	GSC name	2MASS Coordinates RA (hh mm ss)			2MASS Coordinates Dec (° ′ ″)			2MASS Magnitudes J	H	K	V_{2MASS}	V_{2MASS} error
1	6384-0374	22	13	38.69	−21	46	08.7	10.382	9.820	9.710	12.28	0.20
2	6384-0188	22	13	31.99	−21	43	17.5	11.545	11.047	10.848	13.98	0.38
3	6384-0098	22	13	39.23	−21	43	44.4	12.673	12.342	12.306	14.16	0.17
4	6384-0513	22	13	46.17	−21	44	6.5	13.489	13.067	13.023	14.98	0.17
5	6384-0531	22	13	40.79	−21	45	55.2	12.914	12.419	12.372	14.52	0.14
6#	supernova	22	13	41.01	−21	44	03.8	...	...	...	...	...
7	106§	22	13	41.64	−21	44	30.5	15.000	14.574	14.319	...	...
8	6384-0404	22	13	50.49	−21	48	49.0	10.628	9.956	9.817	13.44	0.04
9	6384-0198	22	13	49.39	−21	48	41.2	12.741	12.216	12.099	...	...

[a]#Supernova coordinates (star 6) were calculated relative to the remaining eight stars. The standard error of the astrometry was of 0.3″. §Number of source in the 2MASS H-band image.

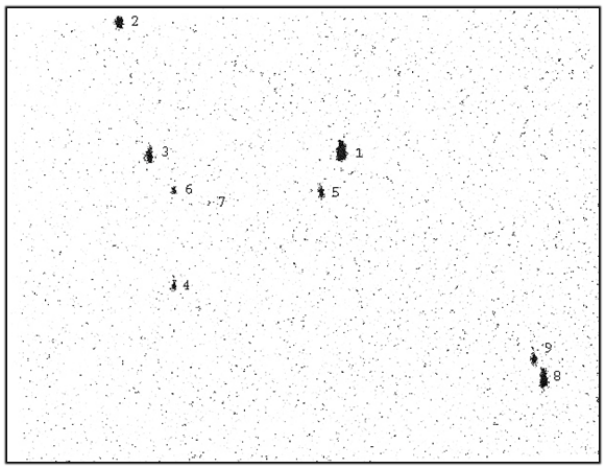

Fig. 1. Gr1 final image showing the field of view. The numbers correspond to the identification of the stars in Table 2.

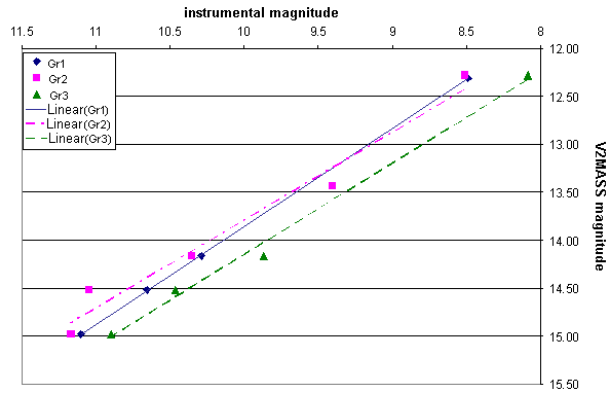

Fig. 2. Linear relations between instrumental magnitudes of comparison stars and their magnitudes in the V_{2MASS} system for each of the three final images.

by utilizing the J magnitude of the star according to 2MASS, we calculated the V magnitude of the star, which we denote as V_{2MASS}; see Table 2.

Next, using the V_{2MASS} magnitudes of the comparison stars, we established in each of the three final images a linear relation as $V_{2MASS} = \alpha c + \beta$, where c is the instrumental magnitude; α and β are constant of the linear regression (Figure 2). In Table 3 we summarize the photometric calibration for each Gr image.

By applying the linear relations to the instrumental magnitudes of the supernova, we obtained the V_{2MASS} magnitudes for each image. Then, we performed a weighted average with coefficients inversely proportional to the square of the estimated errors. In the Table 4 we report the magnitude for the supernova.

Previous reduction experiences in the Marangani Observatory (Aguilar, García, & Ferrero 2001), show that if the airmass X is less than 2, then the difference in the $k_V X$ product between stars in the same image is always much less than 0.01 mag; so, we neglected the atmospheric correction (k_V is the atmospheric-extinction coefficient in the V band). In each sky direction the following color-excesses was estimated: $E(J-K) \cong 0.005$ and $E(V-K) \cong 0.027$ (Fitzpatrick & Massa 2009; Martin & Whittet 1990); therefore, in the determination of the $V-J$ color index the interstellar extinction was not considered.

4. ANALYSIS

The correlation between the V_{2MASS} instrumental magnitudes of the comparison stars and their

TABLE 3

PHOTOMETRIC CALIBRATION OF THE Gr IMAGES[a]

Image	Stars	α	β	σ	R^2	SN V_{2MASS}	SN V_{2MASS} error
Gr1	1,3,4,5	1.02	3.6	0.01	0.9999	15.19	0.14
Gr2	1,3,4,5,8	0.92	4.6	0.21	0.9713	15.50	0.21
Gr3	1,3,4,5	0.96	4.6	0.12	0.9937	14.74	0.14

[a]The local standards used in each Gr image, the linear regression constants α and β, the standard error of the estimation σ, the R^2 correlation coefficient, and, finally, the V_{2MASS} magnitude for the supernova as well as the respective V_{2MASS} error.

TABLE 4

JULIAN DATE AND V_{2MASS} MAGNITUDE OBTAINED FOR SN 2003gf

JD	V_{2MASS}
2452824.53	15.10 ± 0.09

corresponding magnitudes in the USNO A2.0 catalog is high ($R^2 = 0.992$); however, we have utilized a calibration established by us, that is, we calibrated the image data (for the comparison stars) to 2MASS data, and from this correlation we obtained the V_{2MASS} magnitude of SN 2003gf. The reason for a proper calibration is that, for bright sources, the USNO photometric magnitudes are accurate to 0.5 mag whereas the ones of 2MASS are accurate to 0.02–0.03 mag. Besides, in as much as we consider neither atmospheric extinction nor interstellar extinction, the errors have to be more compatible with the 2MASS catalog than with the USNO catalog. The comparison between our results and the measurements carried out by other observers indicates that our results are within the expected behavior for the supernova light curve; this can be seen in Figures 3 and 4, which were plotted using data from Table 1. Figure 4 shows, additionally, a fit by means of piecewise square polynomials; in other words, we performed a square spline fitting. It is clear that our data (MAR V) are close to those obtained by other observers. So, our data give useful information to define the slope of the supernova light curve.

5. CONCLUSIONS

In this paper we employ the infrared photometric database of the 2MASS catalog to calculate the magnitude of SN 2003gf in the V band. We conclude that the techniques we used allow us to estimate that, with local atmospheric conditions, the

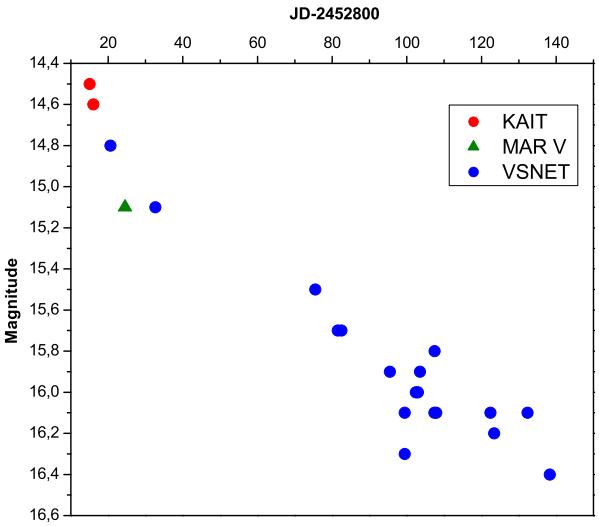

Fig. 3. V-band light curve of SN 2003gf. We have the following measurements: from KAIT telescope, from VSNET observers, and V_{2MASS} magnitude calculated in this work (MAR V).

error of our equipment is between 0.1 and 0.2 mag. These values are in agreement with the measured values for the supernova. The data of this paper are useful because they were obtained soon after detection of SN 2003gf; the point we obtained is very close to fitted light curve. Fainter objects would require longer exposure times; a larger telescope would be necessary to measure them.

Finally, the data collected through this work complement existing information about SN 2003gf, and contribute to the determination of the initial slope of its V-band light curve.

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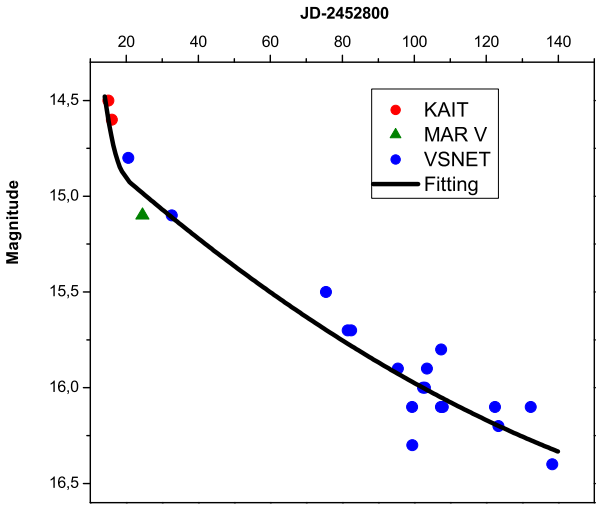

Fig. 4. Light curve fit of SN 2003gf using piecewise square polynomials. Data are from the Table 1.

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