COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 3906

Konkoly Observatory
Budapest
21 July 1993
HU ISSN 0324 - 0676

STRÖMGREN b, y PHOTOMETRY OF STARS IN THE FIELD OF MESSIER 81 (= NGC 3031)

Not long after the discovery of 1993J, it became apparent that observers were using a heterogeneous collection of magnitudes for comparison stars in the field of the galaxy to determine the brightness of the eruption. Some used magnitudes from the Space Telescope Guide Star Catalog (GSC), while others used values from the Thompson & Bryan (1990) "Supernova Search Charts and Handbook" chart of the region. Some of the latter were derived from published photoelectric data, but others were based only on eye estimates. Because of this mixture of systems, magnitudes published on the IAU Circulars in the first weeks after the event from CCD and photoelectric measures as well as visual estimates had unacceptably large scatter. This compromised astrophysical modelling of the eruption, which is constrained by the rise-time of the initial outburst and the date and magnitude of the peak brightness.

It was soon evident that the GSC magnitudes had a large zero-point error, amounting to about half a magnitude (the GSC values in this region are too bright). More photoelectric observations were clearly needed, nevertheless, to confirm the earlier photometry, and to get measures for several stars not previously observed accurately. Partly at the suggestion of Harold Corwin (IPAC/JPL), who observed many of the comparison stars some years ago, and at the specific requests of Daniel W. E. Green (Central Bureau for Astronomical Telegrams) and Gerard de Vaucouleurs (Univ. of Texas), I made observations of twelve stars in the field of the galaxy. They were most urgently required to calibrate visual and CCD observations made by amateurs at the time of the pre-maximum phase of the outburst. The earliest visual observations were made with respect to stars whose magnitudes turned out to be erroneous, and most of the CCD observations were made without using a filter in the light path, and so were not on a standard photometric system.

The photoelectric observations were made on 25 & 26 April and 8 & 9 July 1993 UT using the Lowell 53cm photometric telescope located on Mars Hill, in Flagstaff, Arizona. Strömgren y and b filters were used through a 19.″4 diaphragm for the April observations and a 29.″2 diaphragm for the July observations. On each night eight observations were made of five to eight uvby standard stars bracketing the measures of the M81 field.

The transformation from the instrumental values to the standard system was done by making a linear least-squares fit for both magnitude and color. The April observations were reduced using estimated values for extinction based on measurements taken on other nights near this time. The extinction was measured explicitly for the July observations, an important consideration given the high airmass (sec z$\sim$1.9) of this late-season data. The colors of the standard stars ranged over the interval $-0.07 < b-y < 0.87$ in April, and $0.02 < b-y < 1.09$ in July, extending well beyond the colors of the M81 field stars observed. The assumed values for the standards and the means from my observations are

Table 1. Standard Star Observations

Star	V (std)	b−y	V (obs)	b−y	n
HD 69994	5.817	0.688	5.811	0.685	2
HD 76151	6.008	0.410	6.012	0.403	2
HD 81524	6.574	0.868	6.577	0.871	1
HD 85217	6.236	0.306	6.239	0.308	4
HD 94180	6.374	0.045	6.374	0.058	2
HD100600	5.948	−0.066	5.945	−0.076	2
HD103095	6.429	0.483	6.429	0.485	2
HD122563	6.206	0.638	6.208	0.637	2
HD122866	6.163	0.020	6.160	0.023	2
HD134064	6.037	0.032	6.035	0.043	1
HD140850	8.806	1.089	8.801	1.094	3
HD143761	5.403	0.396	5.406	0.392	3
HD149845	7.964	0.815	7.964	0.821	1
BD−0°3353	9.332	0.967	9.340	0.958	1
HD161817	6.982	0.135	6.976	0.135	1
HD186427	6.230	0.417	6.238	0.410	1

shown in Table 1. The first set applies to the April series, and those in the second to the July series. "n" is the number of measurements.

My mean magnitudes and colors differ on average from the standard values by ±0.004 mag. in V and ±0.008 mag. in b−y for the April data, and 0.005 in V and 0.006 in b−y in July.

The results for the M81 field stars are shown in Table 2, listed in order of decreasing brightness. Four of the fainter stars were observed only on one night. Identification is made in the first column with the GSC in each case so that accurate positions can be found. On the second line of each entry is the rms uncertainty for each mean. For the stars observed on a single night, this is estimated from the uncertainty in the fit to the standard stars and the internal error of each measurement. For the remainder, the uncertainty is the standard deviation of the combined observations. The remarks include common star catalogue identifications and spectral types for the brighter objects.

I made four sets of differential measurements of the wide pair ADS 7565 = GSC 4383−1127 on two nights using a 12.″5 diaphragm and judiciously off-centering the components in order to isolate them (the separation is about 9 arcseconds). These yielded a mean Δy=0.647±0.013; the eastern component is the brighter, consistent with observations by double-star observers.

There is scant evidence in these data that GSC 4383−0384 is large-amplitude variable, as claimed recently by Hanzl et al. (1993).

Results from single observations of some of the brighter stars have already been published on an IAU Circular (Skiff 1993). Three of the stars included here have been previously observed in the UBVRI system by Harold Corwin, and his V magnitudes are listed in the remarks as published on the IAU Circulars (Corwin 1993). These agree within our mutual uncertainties, and indicate that previously published photoelectric V magnitudes for faint stars in the region are reliable (cf. Brandt et al. 1972, and Sandage 1984).

Table 2. Photometry of stars in the field of M81

GSC 4383−	V	b−y	n	Remarks
0848ab	8.538	0.310	2	=HD 85458(F5)=ADS 7566AB
	.000	.004		
0738	9.197	0.643	2	=HD 85743(K)
	.006	.001		
1127ab	9.852	0.454	2	=BD+69°0541=ADS 7565AB(G)
	.006	.011		
0150	10.456	0.766	2	=BD+69°0540(K0)
	.015	.029		
0698	10.821	0.646	3	
	.002	.015		
0384	11.018	0.315	3	
	.031	.016		
0565	11.422	0.362	1	
	.020	.020		
0928	11.933	0.306	3	Corwin: V=11.90
	.007	.030		
0434	12.427	0.438	1	Corwin: V=12.45
	.030	.030		
0863	12.885	0.555	1	
	.030	.030		
1123	13.644	0.440	1	Corwin: V=13.65
	.040	.040		
0574	14.440	0.600	5	differential with respect to GSC 4383−0928
	.022	.050		

Finally, in Table 3 are measures of the supernova itself on several nights. The first of these was included on the IAU Circular with the comparison stars (Skiff 1993). These were made differentially with respect to star GSC 4383−0928. Despite being corrected for the strong color difference between the two stars, because of the evolving nature of the emission-line spectrum in the supernova, they cannot be considered to be strictly on the Johnson V system, and so are given as Strömgren "y" magnitudes.

Table 3. Differential observations of Supernova 1993J

1993 UT	y	σ	
Apr 25.15	11.35	0.02	
May 7.16	11.95	0.03	
8.16	12.01	0.03	
9.18	12.01	0.04	
10.18	12.08	0.03	
11.18	12.11	0.03	
18.18	12.24	0.04	[poor night]
21.18	12.35	0.02	
24.16	12.37	0.04	

Acknowledgements.

I am grateful for the comments and encouragement of Harold Corwin and Gerard de Vaucouleurs. This work was facilitated by the use of SIMBAD, maintained by the Centre de Donnees astronomiques, Strasbourg, France.

BRIAN A. SKIFF
Lowell Observatory
1400 West Mars Hill Road
Flagstaff AZ 86001-4499
e-mail (Internet): bas@lowell.edu

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