LIGHT CURVES OF THE SUPERNOVAE OF 1954

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In the year 1954 three supernovae were found by the writer with the Palomar 18-inch Schmidt telescope. The photographic magnitudes given hereafter were determined not from one homogeneous set of observations, but with several widely different instruments and by different methods.

NGC 5668

The supernova in NGC 5668 ($\alpha = 14^h\ 30^m.9$, $\delta = +4°\ 40'$ [1950], type Sc) was estimated too faint at mag. 14 on the date of discovery, May 4, 1954. In reality it was then of $m_{pg} = 12.6$ and already on the decline. Photometry proved somewhat difficult and uncertain because of the supernova's position within the nebula, only 32″ south of the nucleus. On 18-inch films (103a-O) with direct (d) or schraffiert (s) images and on a few 48-inch Schmidt plates, the supernova was compared (Table I) with a

TABLE I

PHOTOGRAPHIC MAGNITUDES OF THE SUPERNOVA IN NGC 5668

Date 1954 (UT)	Exposure (minutes)	m_{pg}	Instrument	
May 2, $8^h\ 11^m$	33	12.44	18″, s	
3, 8 37	5	12.75	18″, d	
3, 8 46	5	12.88	18″, d	
4, 8 59	33	12.65	18″, s	
4, 9 37	33	12.57	18″, s	
5, 5 41	13	12.45	18″, s	
5, 6 11	33	12.67	18″, s	
5, 6 33	½	12.62	18″, d	
5, 6 36	1	12.78	18″, d	
5, 7 15	5	12.98	18″, d	
6, 9 44	5	13.02	18″, d	
7, 10 30	5	13.33	18″, d	
8, 6 53	3	13.07	48″, d	
9, 7 45		13.03	p.e.,	Hardie, Flagstaff
9, 8 25	1	13.30	18″, d	
9, 8 30	5	13.19	18″, d	

TABLE I (*Concluded*)

Date 1954 (UT)	Exposure (minutes)	m_{pg}	Instrument
9, 8 53	33	13.05	18″, s
9, 9 20	5	13.46	18″, d
10, 5 50		13.06	p.e., Hardie, Flagstaff
10, 8 00	1	12.95	18″, d
10, 9 53	5	13.52	18″, d
11, 5 50		13.20	p.e., Hardie, Flagstaff
12, 5 36		13.24	p.e., Hardie, Flagstaff
21, 5 16	1	14.22	18″, d
21, 5 32	5	14.36	18″, d
22, 5 23	1	14.43	18″, d
22, 5 28	2	14.63	18″, d
22, 6 05	33	13.71	18″, s
22, 6 35	5	14.54	18″, d
24, 6 54	2½	14.68	18″, d
24, 7 00	1	14.75	18″, d
24, 7 13	5	14.57	18″, d
26, 7 28	5	15.24	18″, d
28, 7 47	5	15.26	18″, d
30, 7 18		15.32	200″, p.e., Baum
31, 8 20	8	15.36	18″, d
June 2, 7 53	10	15.63	18″, d
11 5 04	2	15.65	48″, d
28, 8 02	5	15.79	18″, d
July 2, 7 58	6	15.97	18″, d
9, 4 45	1½	16.11	48″, d
31, 5 10	10	16.53	18″, d
Aug. 1, 5 30	10	16.17	18″, d
26, 3 48	8	16.96	48″, d

group of 16 comparison stars set up around NGC 5668 (see Fig. 1). Their magnitudes, in turn, were based on those in S.A. 106, reduced to Baum's new scale from 14th magnitude on: m_{pg} (new) $= 1.1\, m_{pg}$ (old) $- 1^{m}4$. The magnitudes obtained for some of these stars by Pietra through comparison with the North Polar Sequence were also made use of.[1]

It is uncertain whether the considerable changes in intensity within a few hours or even minutes (see, e.g., May 5) are real or only due to the uncertainty and inhomogeneity of the measures.

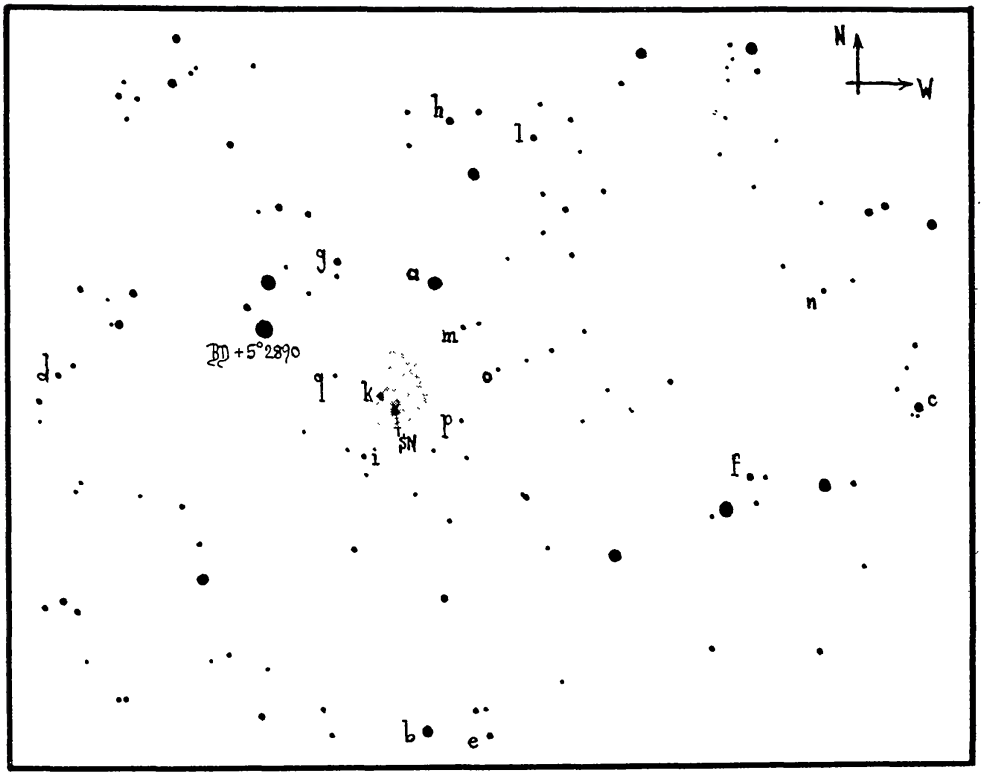

FIG. 1.—Comparison stars around NGC 5668. Scale: 1 mm = 22″.

In addition, the following color indices were measured photoelectrically:

Date 1954 (UT)	Days after maximum	$B-V$	$U-B$	
May 9.32	~12	+0^m.27	−0^m.02	Hardie
10.24	~13	+0.20	−0.06	Hardie
11.24	~14	+0.36	+0.06	Hardie
12.23	~15	+0.26	+0.09	Hardie
30.30	~33	+1.05		Baum

The photographic magnitudes adopted for the comparison stars were:

a 12.48	*e* 13.39	*i* 14.55	*n* 15.36
b 12.76	*f* 13.69	*k* 14.54	*o* 15.66
c 12.96	*g* 14.04	*l* 14.88	*p* 15.78
d 12.97	*h* 14.30	*m* 15.41	*q* 16.27

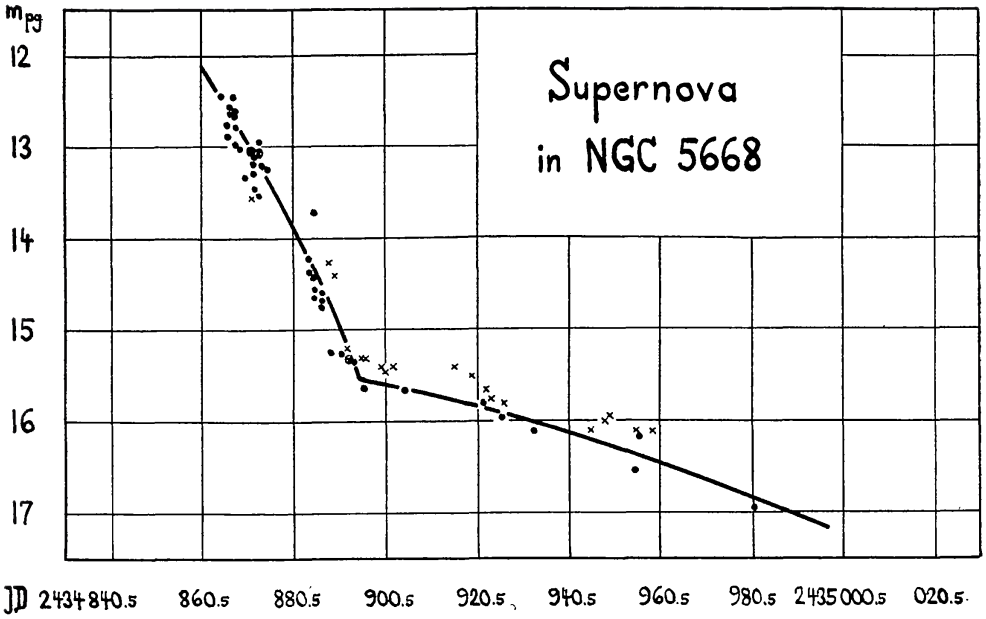

FIG. 2.—Light curve of the supernova in NGC 5668.

The spectrum of the supernova was first secured by Humason at the prime focus of the 200-inch on the night after the discovery. It was a typical type I spectrum. From its aspect and subsequent development, as well as from the light curve, the maximum might be surmised to have occurred around April 27 and at about $m_{pg} = 12.2$. It must however be mentioned that G. Gauthier, an able observer of the Société Astronomique de France, has stated that he saw this star as of 11th magnitude on April 4 ($\pm$ 2 days), during a survey of the nebulae in Virgo.[2]

A spectrogram obtained by Deutsch with the 200-inch coudé shows clearly two sets of interstellar H and K lines, one from our own galaxy and the other from NGC 5668, separated by 1570 km/sec.[3]

NGC 4214

On the outskirts—1'.4 east and 3'.6 south of the center—of NGC 4214 ($\alpha = 12^h\ 13^m.1$, $\delta = +36°\ 36'$ [1950], type Irr) a supernova of magnitude 12.5 was found on May 30, 1954. With the help of the sky patrol plates of the Sonneberg Observatory, it was possible to reconstruct the prediscovery light curve, right over the maximum. Dr. C. Hoffmeister was kind enough to reestimate

the early magnitudes against my comparison stars. These were measured, up to about mag. 13, with 18-inch Schmidt schraffier-transfers from S.A. 56 (*Bergedorfer Spektral-Durchmusterung,* magnitudes from Groningen). From mag. 12.5 to the faint end, the photometry of the comparison stars and the supernova (Table II) was carried out on an Eichner Astrophotometer, and

TABLE II

PHOTOGRAPHIC MAGNITUDES OF THE SUPERNOVA IN NGC 4214

Date 1954 (UT)	Exposure (minutes)	m_{pg}	Instrument
May 30, 7^h 09^m	6	12.43	18″, d
31, 9 35	6	12.32	18″, d
June 1, 5 15		12.66	200″, p.e., Baum
1, 7 11	12	12.59	48″, d
2, 5 03		12.57	100″, d
2, 6 08		12.65	100″, d
2, 6 51	8	12.56	18″, d
2, 7 25	35	12.66	18″, s
4, 5 20		12.67	60″, d
4, 6 00	10	12.68	60″, d
4, 6 11	2	12.67	60″, d
4, 6 27		12.69	60″, d
9, 6 00		12.76	p.e., Hardie, Flagstaff
10, 7 55		12.75	p.e., Hardie, Flagstaff
11, 4 42	3	12.72	48″, d
12, 7 55		12.69	p.e., Hardie, Flagstaff
17, 7 12		12.82	p.e., Hardie, Flagstaff
30, 5 56	5	13.01	18″, d
July 9, 4 36	2	13.19	48″, d
31, 4 45	10	13.42	18″, d
Aug. 5, 4		13.48	60″, p.e., Arp
29, 3 35	5	14.03	48″, d
29, 4 20	10	14.39	18″, d
Oct. 25, 12 34	11	15.11	18″, d
Jan. 28,* 9 39	30	16.88	200″, d
Feb. 14,* 9 21	10	17.08	200″, d
Mar. 2,* 10 34	7	17.58	48″, d
27,* 8 12	30	17.66	200″, d

* 1955.

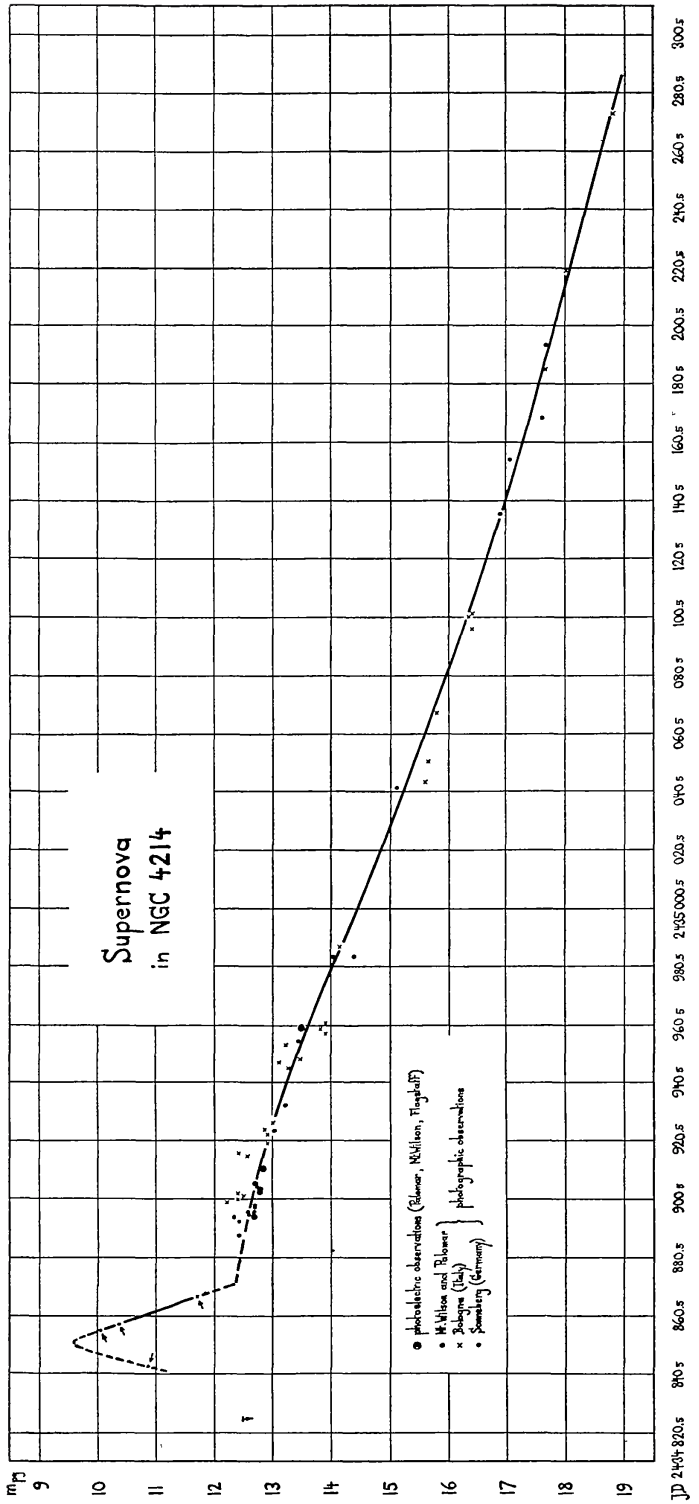

FIG. 3.—Light curve of the supernova in NGC 4214.

relies on 12 stars measured photoelectrically by Drs. A. R. Sandage and H. C. Arp.

The light decline (Fig. 3) after the discovery can be considered as exponential, the brightness declining by 50% each 43 days. The actual measurements lie on a somewhat bumpy curve around this approximation. Included are several points first determined by Pietra[1] and later remeasured by Rosino with our set of comparison stars. Exactly how bright the maximum was, is hard to tell. Probably it lay between photographic magnitudes 9.1 and 9.9 and occurred between April 16 and 21. The spectrum, obtained by Wellmann and Minkowski, was of type I, though apparently with some slight variations from "normal."[4]

Photoelectric color indices:

Date 1954 (UT)	Days after maximum	$B-V$	$U-B$	
June 1.22	~ 43	$+1^m.02$		Baum
9.25	~ 51	+1.00	$+0^m.45$	Hardie
10.33	~ 52		+0.4	Hardie
12.33	~ 54	+0.93	+0.43	Hardie
17.30	~ 59	+0.85	+0.61	Hardie
Aug. 5.17	~108	+0.52	+0.33	Arp

The following list gives the adopted photographic magnitudes of the 59 comparison stars around NGC 4214 (see Plate I).

No.	Identification	m_{pg}	No.	Identification	m_{pg}
1	BD +38°2324	7.98	15	BD +38°2320	10.64
2	BD +38°2326	8.51	16	BD +37°2255	10.80
3	BD +36°2248	8.75	17	BD +37°2265	10.92
4	BD +37°2257	9.24	18	BD +36°2255	10.93
5	BD +36°2254	9.61	19	BD +36°2259	10.90
6	BD +36°2256	9.77	20	BD +38°2317	11.02
7	BD +37°2254	10.02	21	BD +37°2258	11.11
8	BD +36°2250	10.14	22	BD +37°2256	11.28
9	BD +36°2258	10.23	23	BD +36°2261	11.33
10	BD +38°2316	10.23	24	BD +37°2263	11.43
11	BD +38°2321	10.42	25	BD +37°2260	11.50
12	BD +36°2257	10.36	26	$\alpha = 12^h\,16^m\,28^s$	11.51
13	BD +37°2266	10.58		$\delta = +36°\,02'.1$	
14	BD +37°2264	10.59	27	BD +37°2261	11.33?

PLATE I

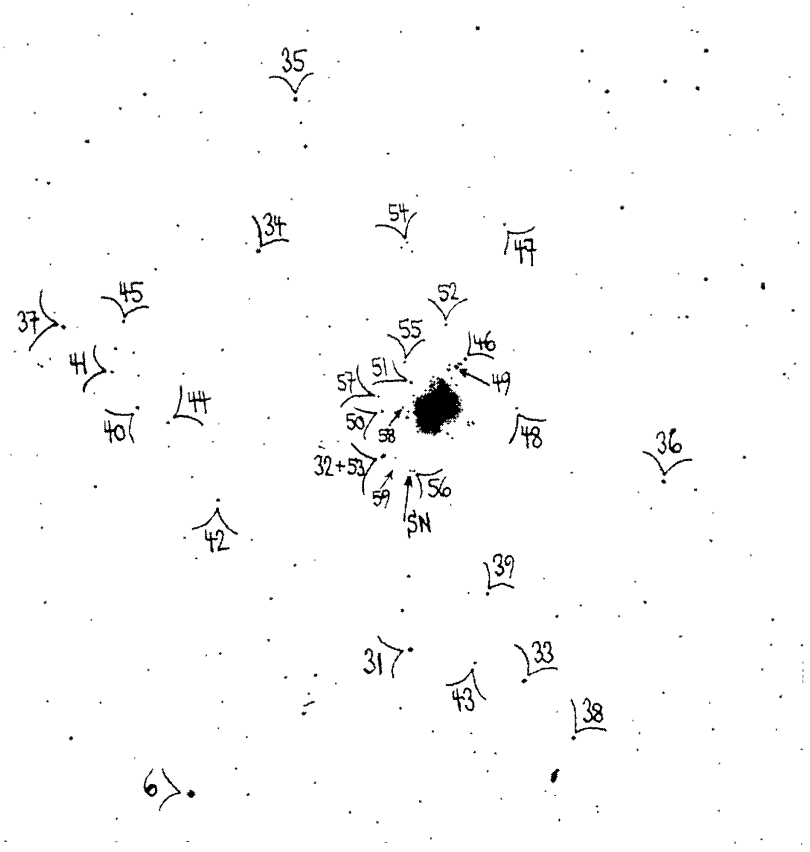

CHART OF FAINT COMPARISON STARS AROUND NGC 4214

No.	Identification	m_{pg}	No.	Identification	m_{pg}
28	$\alpha = 12^h\,17^m\,54^s$	11.57	43		14.26
	$\delta = +35°\,48'.6$		44		14.27*
29	BD +36°2252	11.80	45		14.44
30	$\alpha = 12^h\,12^m\,40^s$	12.06	46		14.56*
	$\delta = +37°\,08'.0$		47		14.73*
31		12.10	48		15.10*
32	BD +37°2262	12.35*	49		15.11
33		12.44	50		15.19
34		12.47*	51		15.35*
35		12.42	52		15.57*
36		12.72	53		15.67
37		12.93*	54		16.45
38		12.99	55		16.53*
39		13.47	56		16.52
40		13.62*	57		17.21*
41		13.88	58		18.06
42		13.97 var.?	59		18.51

* Magnitudes measured photoelectrically, changed not more than $\pm 0^m.03$ by combination with other determinations.

NGC 5879

Little is known about the third supernova. It flared up in NGC 5879 ($\alpha = 15^h\,08^m.5$, $\delta = +57°\,11'$ [1950], type Sb) and was found on September 27, 1954. Its position low in the evening sky was very unfavorable, and neither a spectrum nor a real light curve could be obtained. That it was of type II was, however, rather certain, from a series of 200-inch plates taken in different colors by Dr. F. Zwicky. The ratio of ultraviolet to blue light was similar to that observed only in type II supernovae. For several days after discovery the photographic magnitude remained roughly constant at 15 (maximum of measurements: 14.88, on Oct. 4); later it dropped out of sight, falling more than 5 magnitudes in 150 days.

All three supernovae of 1954 occurred in galaxies whose redshifts have been determined.[5] If we assume a Hubble redshift parameter of 100 km/sec per million parsecs, we find the following approximate maximum photographic absolute magnitudes for these three supernovae: NGC 5668: −19; NGC 4214: −18; NGC 5879: −15 (if at maximum at time of observation).

I am indebted to several astronomers from various observatories for letting me use their observations, but I especially wish to thank Drs. Sandage and Arp for their great help in establishing the necessary calibration sequences, Dr. Zwicky for the opportunity to work with him in Pasadena and on Palomar Mountain, and Dr. Humason for much friendly encouragement.

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[1] S. Pietra, *Mem. Soc. Astr. Italiana,* New Series, **26,** 185, 1955.

[2] See C. Bertaud, *l'Astr.,* **69,** 297, 1955.

[3] A. J. Deutsch, reported by I. S. Bowen, *Carnegie Inst. Washington Yearbook,* **53,** 11, 1954.

[4] P. Wellmann, *Zs. f. Ap.,* **35,** 205, 1955.

[5] M. L. Humason, N. U. Mayall, and A. R. Sandage, *A.J.,* **61,** 97, 1956.